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Overview on Direct Applications of Geothermal Energy

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Abstract: With restricted resource of fossil fuels the modern society is leading towards various other natural resources. Geothermal energy is the form of energy which is derived from internal heat of the earth. It is one of cleanest form of energy. People of Rome, China, and Japan are utilising geothermal energy from ancient times where it is manifestated on the earth surface basically for bathing and therapeutic purpose. Depending upon the depth of geothermal source and its temperature it is been utilised for various purposes like for bathing and swimming, agriculture, aquaculture, honey processing etc. This form of energy is used mainly in two ways one as direct utilisation and other as indirect utilisation. This paper elaborates various direct applications of geothermal energy. This paper also includes the worldwide status of direct application for geothermal energy from year 1995 to 2015.

Key words: Geothermal Energy, Direct application, Ground source heat pump, Aquaculture, Agriculture.

1. INTRODUCTION

The demand for the energy has been increased in the modern society. Heat is one of the most useful forms of energy and it is omnipresent in everyday life. It can not only be generated by the conversion of electrical energy and the combustion of fossil fuels, but it can also be found from internal heat of the earth in the form of natural resources.

There is enormous amount of heat which is present within the earth and is evidenced by its surface manifestation in various forms like hot springs, fumaroles and geysers etc. One of the most important examples of low grade heat source is the geothermal energy (thermal energy under the earth's crust), whose temperature varies from 60^{o}C to 200^{o}C (Yamamoto et al., 2001). The geothermal heat derives from the time of origin of earth 4.6 billion years ago due to the continuous radioactive decay of radioactive elements like uranium, thorium etc.

The three essential characteristics of geothermal reservoirs are an aquifer, an impermeable cap rock and a heat source i.e. the internal heat of the earth. Steam and hot water escape naturally through faults in the cap rocks forming fumaroles, geysers etc. This type of energy could be used for direct heating power generation and for many other purposes (Basaran and Ozegener, 2013).

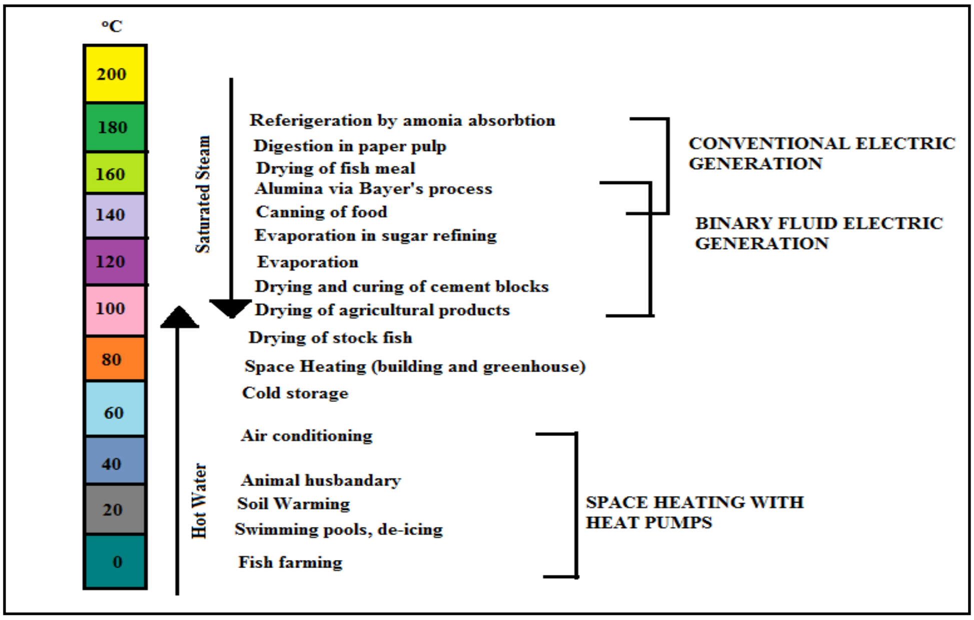

Figure 1: Geothermal Utilization at different temperatures
(Modified after Lindal, 1973)

The present researchers have studied in detail about the geothermal energy exploration and exploitation status in India and worldwide (Sircar et al., 2015). In India the exploration activities for geothermal sources has been carried out in various states like Gujarat, Chhattisgarh, Andhra Pradesh and West Bengal.

A total of four springs were demarcated in a radius of 4 km Dholera, Uthan, Swaminarayan temple and Bhadiyad. Dholera springs have the highest geothermal flow rate in Gujarat (Vaidya et al. 2015, Shah et al., 2015).

In these fields the activities like gravity, seismic, and Magnetotelluric surveys have been carried out for geothermal exploration. 3D Magnetotelluric survey is also done in the geothermal field of Unai. It was also first time in India when a 3D MT survey has been done for geothermal exploration (Shreya et al., 2015).

There are two major ways of utilisation for this energy one is direct utilisation like for aquaculture(mainly fish farming and raceway heating), agriculture(mainly greenhouse heating, crop drying and some heating of buildings housing livestock in order to increase growth rates), balneology, pasteurisation of milk, crop drying etc. and indirect application like space heating and cooling including district systems (the heating and cooling of several buildings from a single system), electricity generation, industrial purposes (such as mineral extraction and refining, drying or curing of building products such as lumber and concrete, and dehydration of food products).

Generally the geothermal fluid temperatures required for direct utilisation are lower than those for economic electric power generation (Gudmundsson and Lund, 1985; Lund, 2005a). The minimum range for temperature productions in geothermal field for different utilisation purposes are shown in Figure 1 (Lindal, 1973).

The direct use of geothermal energy is confined to low-temperature resources as well as the high- temperature resources for heating and drying purposes even if the process is at a very low temperature. The process of refrigeration is possible with temperature above 120^{o}C.

2. VARIOUS DIRECT APPLICATIONS OF GEOTHERMAL ENERGY-

2.1 Balneology

From centuries bathing is one of major known uses of geothermal energy. In countries like China, Iceland, Japan, New Zealand, North America, Turks and other areas geothermal water has been used for bathing and cooking purpose for over 1000 of years.

The Romans believed that geothermal water has therapeutic effect on human body. They have used geothermal water for treatment of high blood pressure, skin diseases, and diseases of the nervous system and for rheumatism symptoms relieving.
In cold countries like Iceland and Kenya uses geothermal water to heat swimming pools. In these countries almost all the outdoor swimming pools are heated by geothermal water from there nearby hot springs.

The systems like steam bathing and spas are also utilising the geothermal energy for providing heat and steam. These types of system also lead to some of the health benefits like improvement in blood circulation, in cleaning and skin rejuvenation, relief in muscle tension and enhancing detoxification processes (Kiruja, 2011).

2.2 Heating of Greenhouses:

Heating of greenhouses is one of the most common direct applications of geothermal energy which also controls the climate, predominantly relative humidity and temperature. The optimum temperature needed for growing different vegetables (Figure 2) and plants are different. Therefore depending upon the heating demand of green houses the temperature of water supplied ranges from 40- 100^{0}C (Vasilevska, 2007).

The water is spread by the means of steel pipes which are placed under the soil, on the soil or on benches, between the plant rows or suspended in the greenhouse space (Panagiotou, 1996). All over the world more than 1.000 glasshouses and soft plastic covered greenhouses use geothermal energy as the heat source.

According to the particular characteristics and requests of greenhouse interior, the elements and system of normal space heating cannot be used. There are various types of heating systems which have been used depending upon the nature of the greenhouse interior and local climate.

The most known classification of Von Zabeltits (Figure 3) accommodated by Popovski for geothermal energy use (Popovski, 2002), which are as follow:

1) Aerial Pipe Heating: These are made of steel pipes due to which they are easy in maintenance and can be allocated with different possibilities, depending upon the chosen temperature regime and requests of concrete culture. These are widely used in combination with the “vegetative” heatings.

2) Bench Heating: For growing the different types of flowers the technology accommodated to this system is known as bench heating. In this type of technology the benches are heated with the plastic pipes or metallic systems fitted below the bench, without or in combination with the vegetative or aerial heating system.

3) Vegetative Heating: These types of systems are made of either plastic or metallic pipes fitted on the the growing surface along with the plants in rows.

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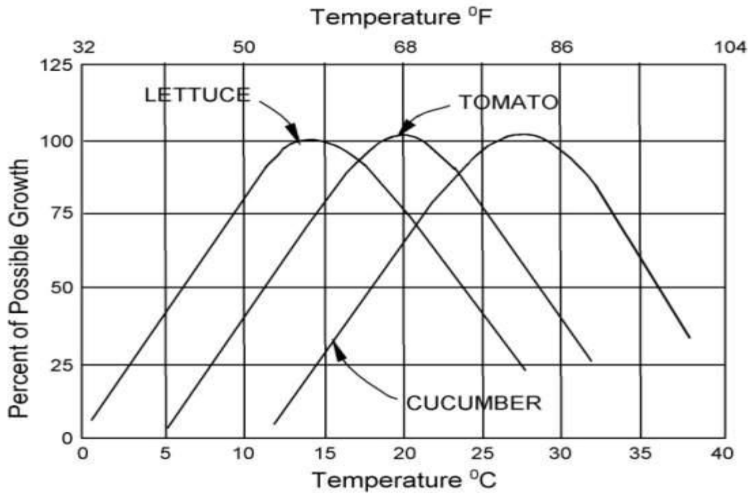

Figure 2: Optimum temperature for growing various vegetables (Smmuals, 1991)

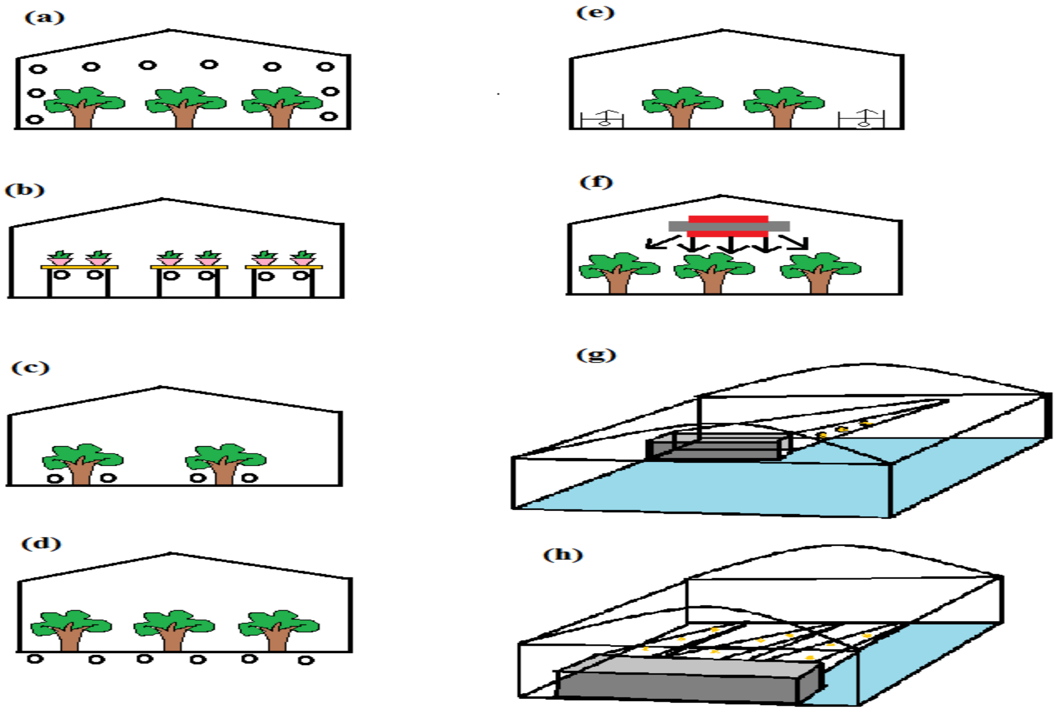

Figure 3: Classification of geothermal heating installations: a) Aerial pipe heating systems; b) Bench heatings; c) Vegetative heating; d) Soil heating; e) Convectors; f) Forced convection air heaters; g) Fan-jet air heating; h) Low positioned air heating
(Modified after Popovski, 1993)

In warmer countries like Kenya the greenhouse heating through geothermal energy is been used for humidity control as increase in humidity leads to the fungus affecting the crops. Heating through geothermal energy also enhances to growth and saves on fuel costs which save around 80% of the fossil fuel energy (Holes and Mills, 2003).

2.3 Honey Processing:

After the honey is removed from the honey comb the raw honey is immediately needed to process. Once the raw honey comes in contact with air it starts crystallising. To prevent it from crystallizing honey processing is needed immediately. One of the best methods for honey purification is through heating under the controlled and low temperature. After extraction, heat treatment reduces the moisture level and destroys all yeast cells present in it. The process of honey extraction cannot be done at higher temperature because the combs will become softer and may breaks therefore low temperature is kept for extraction.
At the time of heat treatment of honey, for purifying it, the honey is subjected to double heat treatment. The first heat

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treatment process is performed for the period of 24 hours the honey is heated up to a temperature of 50^{0}C so that the crystals formed in honey can melt. The second treatment process takes place at the temperature of 75^{0}C the undesirable substances like parts of bees and pollens are removed and after the filtration of such substances the temperature is suddenly cooled up to 50^{0}C. After the second process the wax capping are melted down and collected for sale. The conditional geothermal water is utilised for honey processing (Figure 4)

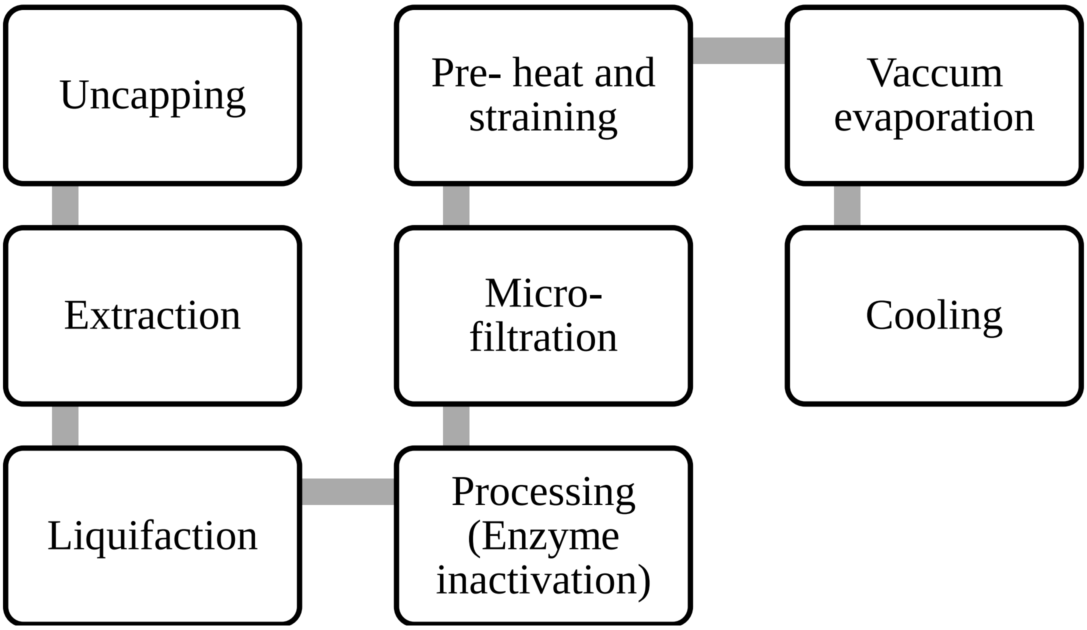

Figure 4: Honey Processing (Kiruja, 2001)

Figure 5: Eburru community bee keeping project (Mburu, 2012)

Bee keeping project next to the tree nursery (Figure 5) is benefited by nearby geothermal resources. Honey is purified by using these geothermal fluids.

For destruction of yeast from raw honey there is one another well known method which is based on pasteurization. In the method of pasteurization the yeasts named osmophilic start destructing as the temperature of honey riches up to 60- 65^{0}C. This process is only feasible at industrial scale using geothermal fluid.

2.4Aquaculture

Different species of fish have different rate of growing production with a quite small difference in water temperature. The geothermal water can be used rather than the water depended on sun for heat either for growing and production or to abbreviate the time needed for growing fish, shrimp, abalone and alligators to stage of maturity, depending upon the surrounding local climate. As the water temperature reaches to the optimal temperature, the fish's starts losing their ability of feeding because of sudden change in their metabolism (Johnson, 1981).

In the time of winter the geothermal water can be used for controlling pond temperature to enhance productivity and hence faster growing fish. Growing them with the warm geothermal fluid (convenient to chemical composition) or in the geothermally heated pools by the means of sinked

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heat exchangers, it is possible to create favourable conditions for their rate of growing and production during the months of winter. In warm- than- ambient water environment many of the species grows faster and larger.

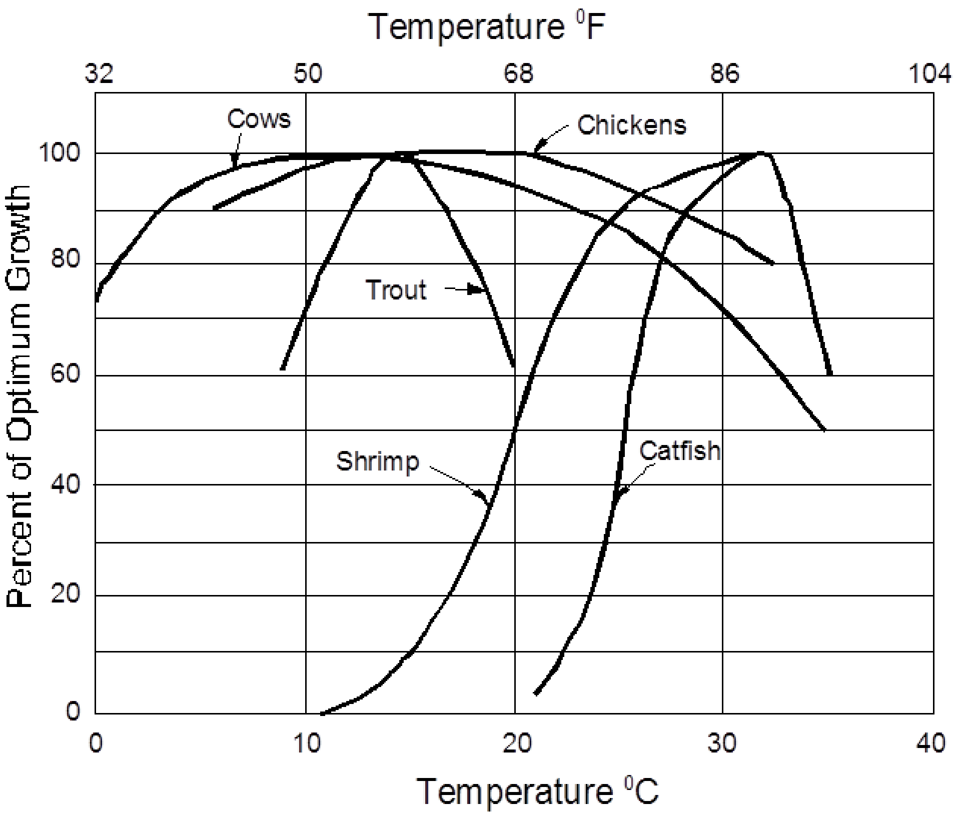

Figure: 6 Temperature requests of different animal and fish species (Beall and Sammuels, 1991)

The rate of production for freshwater organisms like crap, catfish, bass, tulapia, frogs, clams, mullet, eels, salmon, sturgeon, lobster, crayfish, crabs, oysters, scallops and mussels can also be maintained by using geothermal water (Johnson, 1981).

2.5 Ground Source Heat Pump (GSHP) System:

One of the world's fastest growing application of renewable energy is GHP or GSHP i.e. Ground Source Heat Pump (Lund and Freeston, 2000, Lund et. al, 2004). In countries like USA and Europe this systems have an annual increase of about 10%. The number of GSHP systems installed around the world has exceeded by one million. The advantage of GSHP is that it uses the ground temperature as a heat source. Extensive literature surveys have been found on the GSHP systems, mainly on the U-tube ground type system (Deerman and Kavanaugh, 1991, Yavuzturk et al, 1999) or on the general closed loop GSHP system.

The commercial production of GSHP has been started over 80 years on the scale of 100 of megawatts including both types of applications electricity generation as well as direct use. Rapid increase in GSHP system utilisation has been started during last three decades. A quantified record has been found in the world for direct utilisation of geothermal energy in 58 countries and in around 80 countries the geothermal resources are found (Fridleifsson, 2001). Millions of GSHP system with the thermal capacity of 12GW is installed all over the world.

A geothermal or "Ground Source Heat Pump" is an electrically powered device that uses the natural heat storage ability of the earth and/or the earth's groundwater for heating and cooling. GSHPs are the shallowest geothermal systems which are classified as conventional energy systems. It basically utilises the stable earth surface temperature up to shallow depths which can be maximum at the depth of 150m. The low enthalpy conditions up to this depth less than 30 °C is used for providing heating or cooling to the domestic and industrial sectors. In winter the cold working fluid is pumped to the underground pipes so that it can absorb the relatively warmer surrounding rock temperature. This warm water is then used to heat the buildings. This same basic principle acts during the summer when the liquid warmed by the surrounding atmospheric temperature is pumped into the underground pipes so that it transfers the heat to the relatively cooler rocks which returns to the surface and act as the air conditioning. GSHP system is categorized into two categories (Ayling, 2007b):

(1) Closed Loop System- It includes the horizontal, vertical and pond/ lake system.
(2) Open Loop System

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(1) Closed Loop Systems: Most of closed loop geothermal heat pumps circulate an antifreeze solution through a closed loop system usually made of plastic tubing that is buried in ground or inundated in water. A heat exchanger transfers heat between the refrigerant in the heat pump and the antifreeze solution in the closed loop. There are three types of closed loop system (a) Horizontal (b) Vertical (c) Pond/Lake.

(a) Horizontal Closed loop system: It requires trenches at least four feet deep. The most common layouts either use two pipes, one buried at six feet and the other at four feet or two pipes placed side- by- side at five feet in the ground in a two foot wide trench.

(b) Vertical Closed loop system: For a vertical system, holes are drilled about 20 feet apart and 100 to 400 feet deep. Into this holes go two pipes that are connected at the bottom with a U- bend to form loop.

(c) Pond/ Lake Closed loop system: If the site has an adequate water body, this may be the lowest cost option. A supply line pipe is run underground from the building to the water and coiled into circles at least 8 feet under the surface to prevent freezing.

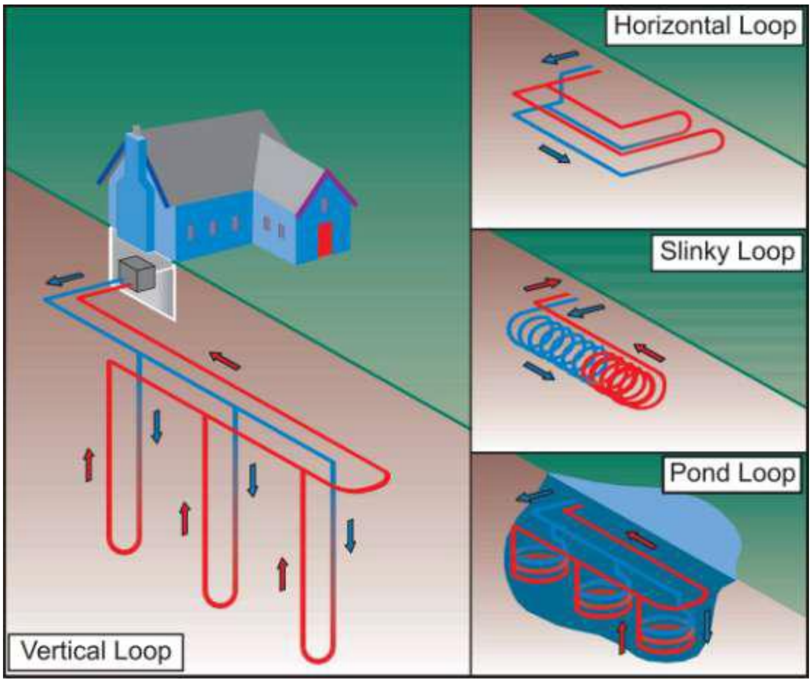

Figure 7: Closed-loop GSHP showing various orientations of pipe work (modified after Ayling, 2007b)

(2) Open Loop System: This type of system uses well or surface body water as the heat exchange fluid that circulates directly through the GSHP system. It means that this system physically extracts groundwater or utilise surface water for the purpose of stripping energy for heating and cooling. The water in this system is not recirculated or reinjected to its source or to another discharge point like it is in closed loop system.

2.6 Dairy Processing:

Once the milk is expressed from the cow it starts to go bad within some hours. Therefore it is important to start processing as soon as it is possible to preserve it longer. Depending up on the kind of treatment the processed milk can be preserved for days or even months. The processes like chilling, heat treatment and evaporation are most common treatments (Lund 1995). These are all thermal processes that entail the addition or removal of heat by using the geothermal energy.

1) Chilling: Before proceeding to the further processes chilling is the first stage of milk processing. To slowdown the action of the microorganisms and enzymes which are responsible for milk spoilage the temperature of the milk is reduced to around 2-40C. For securing the longer shelf life the milk is further cooled before the packaging. To provide cooling in the storage silos and in the cooling sections of the pasteurization the ice water is used.

2) Thermal Treatment: Heating of every particle of milk product to a specific temperature for a specific period of time without allowing any recontamination during the process is known as Thermal treatment process. There are two major purposes behind the thermal treatment of the milk. They are as follows:

- To reach total destruction of all pathogenic microorganisms this can cause diseases in human beings.
- In order to improve shelf life of the milk from a day to week a significant reduction in quantity of spoilage enzymes and microorganisms are needed to be maintained (DST, 1999).

2.7 Crop Drying:

The Geothermal energy has been also used to dry vegetables, fruits crops and other cereals (Lund et. al., 2005). For avoiding wastage and ensuring the availability

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of nutritious food all around the year the drying of agricultural products plays most important role. The highest potential of geothermal resources for the purpose of agricultural drying applications (Ogola, 2013) includes low- to – medium enthalpy geothermal resources having temperature less than 150 °C (Muffler and Cataldi, 1978). By recovering the waste heat from the geothermal power plant the heat required for drying can be obtained or it can also be obtained from the hot water or steam of geothermal wells (Vasquez, Bernardo and Cornelio, 1992). Rather than using the fossil fuel and electricity for food processing the geothermal energy is the most advantageous technique for agricultural processing including the far low costs of using hot water and steam (Arason, 2003). In the former Yugoslav Republic of Macedonia requires around 136 kilowatt hours (kWh)/tonne of wet weight for rice drying (Popovski et al., 1992), While in Greece the tomato drying requires about 1,450kWh/tonne (Andritsos et al., 2003). Similarly the wide range of agricultural products like rice, wheat, tomatoes. Onions, cotton, chillies and garlic can be dried and preserved for years by the means of geothermal energy.

A pilot scale drying plant for tomato is installed in Nea Kessani, Xanthi has been started operating in 2001 (as shown in figure 8). This drying power plant is an excellent example for liability of geothermal energy for different types of vegetables and fruits drying. By using the geothermal water of temperature 59^0C tomatoes are dried in 14-m long tunnel dryer (1m wide and 2m high). The tomatoes are placed in stainless steel trays (of $100cm^2$ x $50cm^2$ mesh) after they are cut into two equal halves. Each batch is consisting of 25 trays which are dried for around 45 minutes, in which each tray contains about 7kg of raw tomatoes. After drying the tomatoes are submerged into olive oil and then they are ready to sale and transport.

Figure 8: Tomatoes loaded on drying racks in Greece (Van Nguyen et al., 2015)

2.8 Snow Melting:

All over the world in northern countries the footpath and street snow melting is a major issue. In several countries like Japan, United States and particularly in Ice land this technology is installed along sidewalks, roadways, bridges and runways for snow melting. Most commonly by the help of glycol solution the geothermal water or steam is pumped in the pipes within or below the footpaths. At some instances this hot water is sprinkled directly on the surface of footpaths. The major advantage of this technique is that it banishes the need of snow removal and provides safety to vehicles and pedestrians, and it also reduces the labour of slush removal.

Depending on the expected type of use and security majors. Chapman has classified the installation of snow melting into three classes i.e. Class I, II and III.
These classes are described as follows:
Class I (minimum): It generally includes residential walks or drive- ways; interplant ways or paths.
Class II (moderate): It includes commercial side- walks and drive ways; steps of hospitals.
Class III (maximum): It includes toll plaza along highways and bridges; apron and loading areas of airports.
In this system the piping materials are either of metal or plastic. The piping's of steel, iron and coopers are also used extensively, however the problem in steel and iron piping is of corrosion and they are need to be protected by coatings and cathodic protections.

3. WORLD WIDE STATUS OF DIRECT APPLICATION FOR GEOTHERMAL ENERGY

One of the most versatile and common utilising form of energy is direct use of geothermal energy (Dickson and

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Fanelli, 2003). The early history for direct use of geothermal energy has been reviewed over 25 countries in the stories from a Heated Earth- Our Geothermal Heritage (Cataldi et al., 1999) which documents geothermal use for over 2,000 years. Direct application of geothermal energy leads to the low enthalpy resources (<150^{0}C). It can also be related to the steam dominated resources when the heat is extracted by the means of heat exchanger and used for various other purposes. The expression of direct application basically indicates the difference between the electricity (indirect application) and other uses of geothermal energy (direct application). The major direct application of geothermal energy includes: (1) space heating and cooling, (2) agriculture application, (3) application to aquaculture (4) industrial processes (5) swimming, bathing and balneology (6) snow melting (7) heat pumps etc.

In about 65 countries the major direct application projects exploiting geothermal power plants are installed with estimated thermal power of 16,200 MWt utilising over 64,000 kg/s of fluid (Lund, 2005). The worldwide thermal energy used is estimated to be at least 162,000 TJ/yr (45,000 GWh/yr) - saving 11.4 million TOE/yr (Lund, 2005). Majority of the geothermal energy is used as direct application either for space heating and cooling or for swimming and bathing.

In India the direct application of this source is in practice at places like Manikaran, Vasist in Himachal Pradesh, Dholera in Gujarat where this geothermal water is used for day-to- day life activities and for therapeutic purposes (Chandrasekharam, 1999). Many foreign tourists visit to the thermal springs at Vasist (75^{o}C) near Manali, though the geothermal source at Puga is been used for the power generation practices. Rather than the power generation practices in Puga the practices like greenhouse and space heating facilities are also proposed for residential Tibetan schools. Other geothermal sources present in the areas like Godavari and Bakreswar are always been used for bathing and religious purposes since long time. Comparative to all this geothermal sources we also have some provinces in western India such as Dholera thermal spring in Gujarat where various exploration and exploitation activities has been carried out till date. Two parametric wells have been drilled in Dholera the water coming out from these wells have temperature of around 40- 45^{o}C with flow rate of 5-7 liter/sec. These thermal springs are also mainly used for bathing and religious purposes. A pilot scale GSHP system has been demonstrated in Dholera as a direct application of geothermal energy. Rather than

	2015	2010	2005	2000	1995
Geothermal Heat pumps	49,898	33,134	15,384	5,275	1,854
Space Heating	7,556	5,394	4,366	3,263	2,579
Greenhouse Heating	1,830	1,544	1,404	1,246	1,085
Aquaculture pond heating	695	653	616	605	1,097
Agriculture Drying	161	125	157	74	67
Industrial uses	610	533	484	474	544
Bathing and swimming	9,140	6,700	5,401	3,957	1,085
Cooling/ snow melting	360	368	371	114	115
Others	79	42	86	137	238
Total	70,329	48,493	28,269	15,145	8,664

Table 1: Summary of the various categories of direct-use worldwide for the period 1995-2015 (Lund and Boyd, 2015)

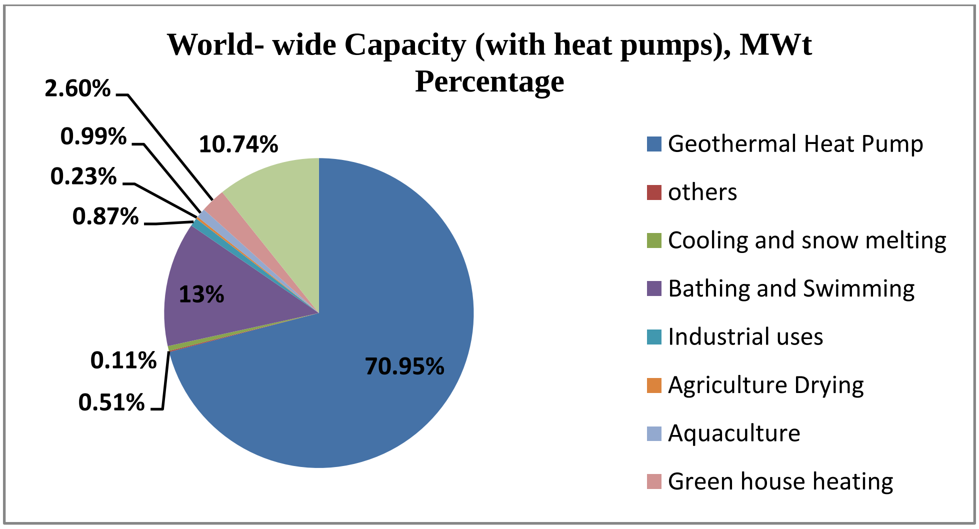

Figure 9: Geothermal direct applications worldwide in 2015, distributed by percentage of total installed capacity (MWt) (Modified after Lund and Boyd, 2015)

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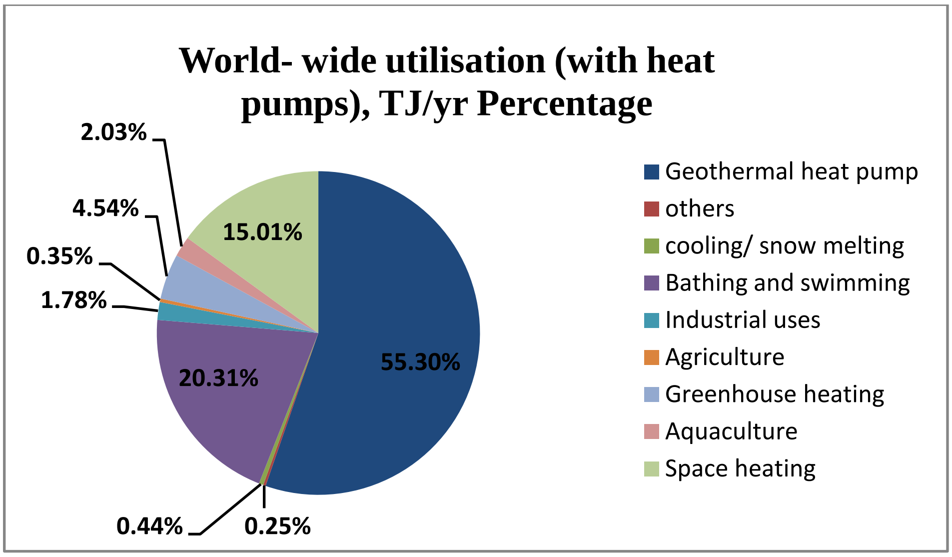

Figure 10: Geothermal direct applications worldwide in 2015, distributed by percentage of total energy used (TJ/yr) (Modified after Lund and Boyd, 2015)

4. CONCLUSION

Depending on the energy scenario in 2050, renewable energy sources will expect to provide 20-40 percent of world's energy demand. Geothermal energy is among the most important renewable resources which plays a vital role in various regions of countries. This energy can be used for commercial and domestic purposes both. Nowadays, it contributes for electricity production in various developing countries such as Central America, Asia and Africa. Based on the enthalpy of geothermal reservoir, geothermal energy can be used for direct or indirect applications. Low enthalpy geothermal resources can be used for space heating/cooling and water heating. Whereas, high enthalpy geothermal resources can be used for direct utilisations like aquaculture, agriculture and power generation. In industrialized countries, 35–40 per cent of total primary energy consumption is used in buildings. In most of the EU countries geothermal energy is been used for Space heating and cooling purpose. In India many exploration activities has been carried out for geothermal energy. Places like Tatapani in Chhattisgarh, Vasist etc. are zones where geothermal water has been used for purposes like bathing and therapeutic purposes. Apart from these places there are many other regions in western India where many low enthalpy geothermal provinces are present. In Dholera, Gujarat this low enthalpy resource is been used for bathing and religious purposes. Many other research activities are still going on in India to harness the low enthalpy geothermal resources.

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