DIRECT UTILIZATION OF GEOTHERMAL ENERGY

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Abstract
Geothermal energy is the ground source thermal energy used by the mankind for the past 2000 years as depicted from our geothermal heritage. Since it is a ground source reservoir so depth of penetration depects the intensity of energy available for use. Data presented in this paper is based on update papers presented by various countries in WGC 2010. WGC 2010 represented six new countries mainly (Bosnia & Herzegovina, El Salvador, Estonia, Morocco, South Africa)which were not present in WGC 2005. Earlier data of WGC 95, WGC 2000,WGC2005 has also been compared with data of WGC 2010. The comparison depects the worldwide use and availability of this energy and also highlights the countries reliability on this energy source.

Selection and Peer-review under responsibility of Advanced Materials, Manufacturing, Management and Thermal Science (AMMMT 2016).
Keywords: *space heating; district heating; aquaculture;Green houses; ground-source heat pumps; agricultural drying; energy savings*

Introduction

From decades, geothermal energy is the resource of energy which has been utilized in very less proficient way on small scale. Now recent development has lead to involvement of large scale project mainly in New Zealand with wide applications in space heating, crop drying, covered ground heating (Hungary and Russia). Success of various equipment such as heat exchangers and heat pumps lead to the establishment of platform for geothermal developments in non-geothermal countries such as Sweden, Canada, Switzerland, France, U.S.Space heating is convenient to develop and make project as it requires temperature ranging from 55°C to 102°C with 43°C useful in marginal cases.

Ground based heat pump ranges from 5°C onwards. Iceland is one of those countries whose 90% population uses geothermal energy and also it is the leading user of geothermal energy mainly in terms of market share. Direct heat utilization is supported by the total country use is supportedby the government agencies mainly 54% of the total country's use is supported.

1.1 Geothermal Heat Pumps

Geothermal (ground-source) heat pumps have the largest energy use and installed capacity, accounting for 68.3% and 47.2% of the worldwide capacity and use. The installed capacity is 33,134 MWt and the annual energy use of 200,149 TJ/yr, with a capacity factor of 0.19 (in the heating mode). Almost all of the installations occur in North American, Europe and China, increasing from 26 countries in 2000, to 33 countries in 2005, to the present 43 countries. The equivalent number of installed 12 kW units (typical of US and Western European homes) is approximately 2.76 million,over double the number of units report for 2005, and four times the number for 2000.

1.2 Space Heating

Space conditioning includes both heating and cooling. Space heating with geothermal energy has widespread application, especially on an individual basis. Buildings heated from individual wells are popular in Klamath Falls, Oregon; Reno, Nevada, USA, and Taupo and Rotorua, New Zealand. Absorption space cooling with geothermal energy has not been popular because of the high temperature requirements and low efficiency. However, newer units recently placed on the market report to use temperatures below 100 °C efficiently. Geothermal heat pumps (groundwater and ground-coupled) have become popular in the U.S., Canada and Europe, used for both heating and cooling. Down hole heat exchangers have been used for heating individual buildings using a closed loop of pipe in a well extracting only heat in Klamath Falls, Oregon, Reno, Nevada, Rotorua, New Zealand and Ismir, Turkey (see the Heat Exchanger section for more details). An example of space heating and cooling with low-to-moderate temperature geothermal energy is the Oregon Institute of Technology in Klamath Falls, Oregon. Here, twelve buildings (approximately 70,000 sq. m of floor space) are heated with water from three wells at 89 °C. Up to 62 L/s of fluid can be provided to the campus, with the average heat utilization rate over 0.53 MWt and the peak at 5.6 MWt. In addition, a 541 kW (154 tons) chiller requiring up to 38 L/s of geothermal fluid produces 23 L/s of chilled fluid at 7oC to meet the campus cooling base load (recently decommissioned). District heating involves the distribution of heat (hot water or steam) from a central location, through a network of pipes to individual houses or blocks of buildings. The distinction between a district heating and space heating system is that space heating usually involves one geothermal well per structure. The heat is used for space heating and cooling, domestic water heating and industrial process heat. A geothermal well field is the primary source of heat; however, depending on the temperature, the district may be a hybrid system, which would include fossil fuel and/or heat pump peaking. An important consideration in district heating projects is the thermal load density, or the heat demand divided by the ground area of the district. A high heat density, generally above 1.2 GJ/hr/ha (33.3 W/m2) or a favorability ratio of 2.5 GJ/ha/yr (0.0079 W/m2) is recommended. Often fossil fuel peaking is used to meet the coldest period, rather than drilling additional wells or pumping more fluids, as geothermal can usually meet 50% of the load 80 to 90% of the time, thus improving the efficiency and economics of the system. Geothermal district heating systems are capital intensive.

1.3 Agribusiness Applications

Agribusiness applications (agriculture and aquaculture) are particularly attractive because they require heating at the lower end of the temperature range where there is an abundance of geothermal resources. Use of waste heat or the cascading of geothermal energy also has excellent possibilities. A number of agribusiness applications can be considered: greenhouse heating, aquaculture and animal husbandry facilities heating, soil warming and irrigation, mushroom culture heating and cooling, and bio-gas generation. Numerous commercially marketable crops have been raised in geo thermally heated greenhouses in Hungary, Russia, New Zealand, Japan, Iceland, China, Tunisia, and the U.S. These include vegetables, such as cucumbers, peppers, and tomatoes, flowers (both potted and bedded), house plants, tree seedlings, and cacti. Using geothermal energy for heating reduces operating costs (which can account for up to 35% of the product cost) and allows operation in colder climates where commercial greenhouses would not normally be economical. The use of geothermal energy for raising catfish, shrimp, tilapia, eels, and tropical fish has produced crops faster than by conventional solar heating. Using geothermal heat allows better control of pond temperatures, thus optimizing growth. Fish breeding has been successful in Japan, China and the U.S. Livestock raising facilities can encourage the growth of domestic animals by a controlled heating and cooling environment. An indoor facility can lower mortality rate of newborn, enhance growth rates, control diseases, increase litter size, make waste management and collection easier, and in most cases improved the quality of the product. Geothermal fluids can also be used for cleaning, sanitizing and drying of animal shelters and waste, as well as assisting in the production of bio-gas from the waste.

1.4 **Greenhouse and Covered Ground Heating**

Worldwide use of geothermal energy used for greenhouse heating increased by 10% in installed capacity and 13% in annual energy use. The installed capacity is 1,544 MWt and 23,264 TJ/yr in energy use. A total of 34 countries report geothermal greenhouse heating (compared to 30 for WGC2005), the leading countries being: Turkey, Hungary, Russia, China and Italy. Most countries did not distinguish between covered greenhouses *versus* uncovered ground heating, and only a few reported the actual area heated. The main crops grown in greenhouses are vegetables and flowers; however, tree seedlings (USA) and fruit such as bananas (Iceland) are also grown.

1.5 Aquaculture Pond and Raceway Heating

The increase over the past five years has been 6% for the installed capacity and 5% for annual energy use. The installed capacity is 653 MWt and the annual energy use is 11,521 TJ/yr. Twenty-two countries report this type of use, the main ones being China, USA, Italy, Iceland, and Israel. These facilities are labor intensive and require well-trained personnel, which are often hard to justified economically, thus the reason why the growth is slow. Tilapia, salmon and trout seem to be the most common species, but tropical fish, lobsters, shrimp, and prawns, as well as alligators also being farmed. Based on work in the United

1.6 Industrial Applications & Agricultural Drying

Using geothermal energy increases the efficiency of the process and extends the production into the winter months.

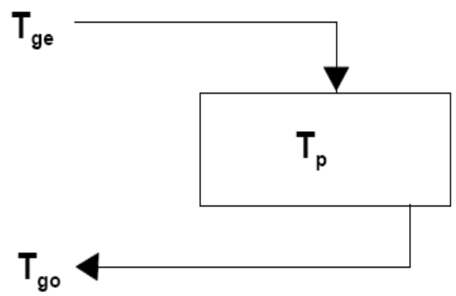
Drying and dehydration are important moderate-temperature uses of geothermal energy. Various vegetable and fruit products are feasible with continuous belt conveyors or batch (truck) dryers with air temperatures from 40 to 100 °C [16]. Geo-thermally drying alfalfa, onions, garlic, pears, apples and seaweed are examples of this type of direct-use. Industrial applications mostly need the higher temperature as compared to space heating, greenhouses and aquaculture projects A variety of vegetable and fruit products can be considered for dehydration at geothermal temperatures, such as onions, garlic, carrots, pears, apples and dates. Industrial processes also make more efficient use of the geothermal resources as they tend to have high capacity factors in the range of 0.4 to 0.7. Fourteen countries report the use of geothermal energy for drying various grains, vegetables and fruit crops compared to 15 for WGC2005. Examples include: seaweed (Iceland), onion (USA), wheat and other cereals (Serbia), fruit (El Salvador, Guatemala and Mexico), Lucerne or alfalfa (New Zealand), coconut meat (Philippines), and timber (Mexico, New Zealand and Romania. Industrial ProcessHeat has applications in 14 countries, down from 15 in 2005 and from 19 in 2000. These operations tend to be large and of high-energy consumptions. Examples include: concrete curing (Guatemala and Slovenia), bottling of water and carbonated drinks (Bulgaria, Serbia and the United States), milk pasteurization (Romania), leather industry (Serbia and Slovenia), chemical extraction (Bulgaria, Poland and Russia), CO2 extraction (Iceland and Turkey), pulp and paper processing (New Zealand), iodine and salt extraction (Vietnam), and borate and boric acid production (Italy).

1.7 Snow Melting and Space Cooling

There are very limited applications in this area, with pavement snow melting project in Argentina, Iceland, Japan, Switzerland and the United States. A total of about two million square meters of pavement are heated worldwide, the majority of which is in Iceland. A Heat pumps in the cooling mode are not included as they return heat to the subsurface, and thus do not use geothermal energy.

Direct-Use Temperature Requirements

The first is the difference between the geothermal temperature entering the system (Tge) and the process temperature (Tp). This difference determines whether of not the application will be feasible. For a direct-use project, the temperature of the geothermal entering the system must be above the temperature of the process in order to transfer heat out of the geothermal water and into the process (aquaculture pond, building, greenhouse, etc.). Beyond that, it must be sufficiently above the process to allow the system to be constructed with reasonably sized heat transfer equipment. The greater the temperature difference between the geothermal resource and the process, the lower the cost of heat exchange equipment. The key question is how much above the process temperature does the geothermal need to be for a given application.



Delta T	Influence
$T_{ge} - T_p$	Feasibility, equipment cost
$T_{ge} - T_{go}$	Geothermal flow rate

Figure 1. Fundamental direct-use temperature differences

The second temperature difference is the one between the geothermal entering the system and leaving the system (Tgo in Figure 1). This determines the geothermal flow rate necessary to meet the heat input requirement of the application. The greater the temperature difference between the entering and leaving temperatures, the lower the geothermal flow required. Obviously, the resource temperature is fixed. The process temperature plays a role as well since the leaving geothermal temperature cannot be lower than the process temperature to which it is providing heat. In addition, the specifics of the application and the heat transfer equipment associated with it also influence the temperature required. There are two broad groups of applications with similar characteristics in terms of heat transfer–aquaculture and pools, greenhouses and building space heating

Energy Savings

Geothermal, a domestic source of sustainable and renewable energy, replaces other forms of energy use, especially fossil fuels. For many countries, geothermal energy leads to a reduction in their dependence on imported fuel, and for all countries, it means the elimination of pollutants such as particulates and greenhouse gases. An attempt is made here to quantify the fossil fuel savings, using a 0.35 efficiency factor if the competing energy is used to generate electricity and 0.70 if it is used directly to produce heat, such as in a furnace.

If the oil were used directly to produce energy by burning for heating, then these savings would be 100.0 million barrels and 15.0 million tonnes respectively. The actual savings are most likely somewhere in between these two values. Note that 200.0 million barrels is almost three days of worldwide oil consumption.

Conclusion

This is not surprising as fossil fuels are a major competitor, and development has been curtained due to the recent downturn in the world economy, and the initial high investment costs. Many countries have; however, been doing the necessary groundwork, conducting inventories and quantifying their resources in preparation for development with the economic situation is better and governments and private investors see the benefits of developing a domestic renewable energy source. With the increased interest in geothermal heat pumps, geothermal energy can now be developed anywhere, for both heating and cooling. Low-to-moderate temperature geothermal resources are also being used in combined heat and power plants (CHP), where hot waters with temperatures below 100 °C are first run through a binary (Organic Rankine Cycle) power plant and then cascaded for space, swimming pool, greenhouse and aquaculture pond heating, before being injected back into the aquifer. CHP projects certainly maximize the use of the resources and improve the economics, as has been shown in Iceland, Austria and Germany.

Despite these discrepancies and the effort required to correct them, work on this review has proved useful, as it has allowed us to demonstrate that using low-to-moderate temperature geothermal resources in the direct-heat applications, given the right conditions, is an economically feasible business, and can make a significant contribution to a country's or region's energy mix. As oil and gas supplies dwindle and increase in price, geothermal energy will become an even more economically viable alternative source of energy geothermal energy becoming increasingly more competitive with fossil fuels and the environmental benefits associated with renewable energy resources better understood, development of this natural "heat from the earth" should accelerate in the future. An important task for all of us in the geothermal community is to spread the word on geothermal energy, its various applications, and the many environmental benefits that can accrue from its use.

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