

Geothermal Energy: Concepts, Applications and Limitations

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Abstract: - The energy found in the Earth's interior as heat is known as geothermal energy. For many years, geothermal energy, which is made up of natural steam and hot water has been used to produce electricity as well as for industrial and space heating purposes. Every year, 83.3 million barrels of petroleum are saved from being consumed globally because to electricity produced by geothermal plants. By doing this, 40.2 million tons of CO₂ are kept out of the environment. Globally, the direct use of geothermal energy saves 103.6 million barrels of fuel annually from burning. As a result, 49.6 tons of CO₂ are prevented from entering the atmosphere. This paper focuses on the direct usage and electric energy production of geothermal energy while providing a brief outline of its concepts and limits.

Key-Words:- Geothermal energy, Direct use, Geothermal fluid, Power generation.

Received: April 13, 2025. Revised: July 8, 2025. Accepted: August 6, 2025. Published: October 14, 2025.

1 Introduction

The energy found in the Earth's interior as heat is known as geothermal energy. The internal structure of our planet and the physical processes that take place there are connected to the source of this heat. This heat is irregularly distributed, rarely concentrated, and frequently at depths too great to be used industrially, even though it exists in enormous, nearly limitless amounts in the Earth's crust and deeper regions. The decay of the long-lived radioactive isotopes of uranium, thorium, and potassium that are found in the Earth continuously produces heat inside the Earth's core. Plate movements can create zones of high heat flow, which can push heat from the Earth's hot interior closer to the surface. Convective circulation is a key factor in moving this heat closer to the surface [1]. A geothermal system can be described schematically as 'convecting water in the upper crust of the Earth, which, in a confined space, transfers heat from a heat source to a heat sink, usually the free surface'. A heat source, a reservoir, and a fluid—the medium through which the heat is transferred—are the three primary components of a geothermal system. The Earth's usual temperature, which rises with depth, or a very high temperature (> 600 °C) magmatic incursion that has reached relatively shallow depths (5–10 km) could be the source of the

heat. The circulating fluids draw heat from the reservoir, which is a volume of hot permeable rocks. A cover of impermeable rocks typically covers the reservoir, and it is connected to a surficial recharge area where meteoric waters can partially or completely replace the fluids that are removed by boreholes or escape from the reservoir by springs. Depending on its temperature and pressure, the geothermal fluid is either liquid or vaporized water, usually meteoric water. This water frequently contains gasses and compounds including CO₂, H₂S, and others. An ideal geothermal system is depicted in simplified form in Fig.1[2].

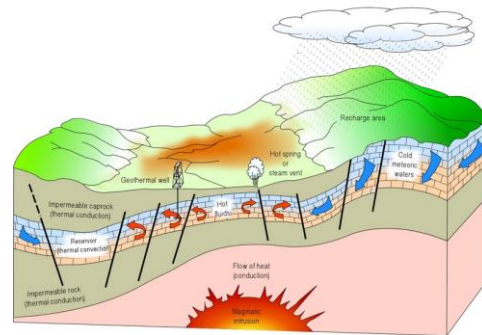


Fig.1 A schematic illustration of the ideal geothermal system .

Wells are dug into the reservoir to extract the hot fluids, and their usage is dependent on the fluids' temperature and pressure: either for space heating and industrial activities (low-temperature uses) or for the production of electricity (the most significant of the so-called high-temperature uses) [1]. Unlike hydrocarbon fields, geothermal fields typically have a constant flow of heat and fluid, with fluid entering

2 History of Utilization of Geothermal Energy

Geothermal energy has been used practically for cooking, cleaning, and bathing since prehistoric times. Evidence of the ancient use of hot waters, which were widely believed to have therapeutic qualities, may be found among the Etruscans, Romans, Greeks, Indians, Chinese, Mexicans, and Japanese. The first step in purifying the spirit is body purification, which the Japanese have been doing since the eighth century A.D. Many hot spring sites include temples devoted to the Buddha of Medicine. Thermal springs were also used recreationally by the Romans. They disseminated their understanding of the health benefits of thermal waters by constructing baths throughout the Mediterranean region and as far afield as possible within their empire, such as Bath, England. The traditional use of thermal baths, subsequently known as Turkish baths, was established and spread by Arabs and Turks throughout the Middle Ages. The French painter Ingres skillfully captures the rich and sensual ambiance of Turkish baths in his painting *The Turkish Bath*. These applications were supposed to pave the way for the current balneological sector. However, the use of geothermal waters for space heating was to be developed much later. According to Fridleifsson and Freeston's excellent paper on geothermal research and development [25], geothermal energy was used for space heating only after metal pipes and radiators became widely used, even though the Romans and Chinese had constructed crude pipelines to transport water and steam for baths. Geothermal space heating was first used in a home in 1909, even in Iceland, where

there are many hot springs and the average annual temperature is 4°C. At the moment, Reykjavik is the only capital city in the world that is heated exclusively by geothermal energy. Chaudes was the first place in the world where geothermal water was used for domestic heating [1]. Due to the quick development of thermodynamics, the use of thermal water for energy conversion did not begin until the second half of the 1800s. With the aid of turbines and generators, thermodynamics made it possible to effectively transform the energy from hot steam into mechanical energy and subsequently electrical energy. The Larderello region in northern Italy's Tuscany is unmistakably linked to the development of geothermal power generation. The boron and other materials dissolved in the thermal water were produced at the thermal springs close to Larderello until the early 1800s. In 1827, the first geothermal energy conversion plant was established by Francesco Larderel, who founded the boron industry. A cupola made of brick has been placed over one of the hot water pools. The structure functioned as the first low-pressure steam boiler heated by geothermal water to occur naturally. It produced the electricity needed for pumps and other equipment, as well as the heat needed to evaporate the boron-rich water for boron manufacturing. The installation prevented deforestation in the area and helped save a substantial amount of firewood. The first electrical power from a geothermal energy source was produced in 1904 by connecting a steam engine to a generator near Larderello (Fig. 2 [5-7]). The first Larderello power station had 250 kW of electrical output when it started up in 1913. The power plant was powered by saturated steam and had a 15 MW capacity in 1915. Beginning in 1931, superheated steam at a temperature of 200 °C was produced for the electrical power plant from new deep drillholes. Unlike saturated steam, superheated steam was free of substances that lead to corrosion and scale development. Thus, there was no need to install heat exchanger systems. The combined installed power of all Larderello power stations reached 66 MW in 1939. After World War II, the geothermal fields in Italy were rebuilt after being damaged. The Larderello plants currently have 545

MW of electricity installed, which accounts for 1.6% of Italy's total electrical energy production [5-7].



Fig. 2 Lardarello 1904: Principe Piero Ginori-Conti is shown here with his device that produced the first-ever electrical energy from geothermal energy.

the Shallow level igneous intrusions near the convergent plate boundary of the Apulian and Eurasian plates beneath Tuscany are the source of the Lardarello geothermal fields. The shallow magma chambers produce geothermal gradients that are exceptionally high. In Boise, Idaho, USA, a district heating system was completed in 1890, marking the beginning of systematic geothermal heat consumption. In 1900, Klamath Falls, Oregon, USA, imitated this approach. Later, in 1926, Klamath Falls began heating greenhouses with a geothermal well. In Klamath Falls, separate wells were used to geothermally heat the first private residences in 1930 [5]. The 1920s saw the widespread usage of thermal water for heating residences and greenhouses in Reykjavik, Iceland. The Vikings gave Reykjavik the name "steaming bay" in reference to the thermal springs that were clearly steaming. As early as the mid-19th century, the first wells were dug into hot water reservoirs to heat buildings. Public buildings and entire city districts were then heated by geothermal means [6]. In 1958, New Zealand built its first geothermal plant in Wairakei, following developments in Italy and Iceland. An experimental facility was established in Pathe, Mexico, in 1959, and the Geysers project was started in northern California in 1960. The Geysers currently have 21 power plants with 750 MW of installed electrical power capacity. It is the world's biggest geothermal installation. It is the largest geothermal installation in the world. The produced electricity is sufficient to supply a city of the size of San Francisco [6]. The heat pump, a vital piece of machinery for harnessing near-

surface geothermal energy, was created by Lord Kelvin in 1852. In 1912, Heinrich Zoelly submitted a patent application to extract heat from the earth using a heat pump. Before the 1940s, the first ground source heat pump system was successfully installed. Ground collectors were positioned near the surface of the first ground source heat pumps (GSHP) in Indianapolis, Philadelphia, and Toronto. The Union Electric Company's experimental installation in St. Louis included spiral pipes as heat exchangers in drill holes that were 5–7 meters deep. Other early systems, such as the Equitable Building in Portland in 1948 and an administrative building in Zurich in 1938, employed groundwater or rivers as a heat source, therefore they are not strictly speaking using geothermal energy [7].

3 Regional Geothermal Exploration in Egypt

Egypt's position in the northeastern corner of the African plate implies that it has geothermal resources, particularly along its eastern boundary, despite the fact that it does not have a lot of volcanic activity. Egypt has geothermal potential mostly in the Gulf of Suez's coastline regions and in a few isolated areas of the Western Desert. According to the statistics, the reservoir in the Red Coastal Zone and the Gulf of Suez, which is located at a depth of 4 km and beyond, may have temperatures of 150 oC or more. The Gulf of Suez region's high spring temperatures make it one of Egypt's most intriguing geothermal regions. As seen in Fig. 3, the hot springs in the eastern Gulf of Suez coast are Ayun Musa (37 oC), Ain Hammam Faraun (70 oC), Sudr (55 oC), and Hammam Musa (48 oC). About 55 kilometers south of Suez City, the Ain Sukhna springs directly ashore at 32.5°C [9]. In western Egypt, reservoir temperatures are estimated to be much lower at 53 oC. Although there is a modest regional temperature gradient (less than 20 oC/km) in the main Western Desert oases (Kharga, Dakhla, Farafra, and Bahariya), numerous wells draw water from deep artesian aquifers that generate huge amounts of water with temperatures between 35 and 43 oC. These wells are a type of geothermal resource that operates at low temperatures. Ain Elgabal (40°C and 5.2 l/s), Farafra

Oasis (28°C and 5.6 l/s), Baharya Oasis (Ain El Bishmou; 31.6°C and 4.4 l/s), Ain El Ris (28.3°C and 1.2 l/s), and Sinai (Ain Hammam Faroun; 70°C and 10.2 l/s) are other locations in the Western Desert [9–14]. The temperature, depth, and geothermal statistics for Egyptian springs and wells are displayed in Table 1 [15].

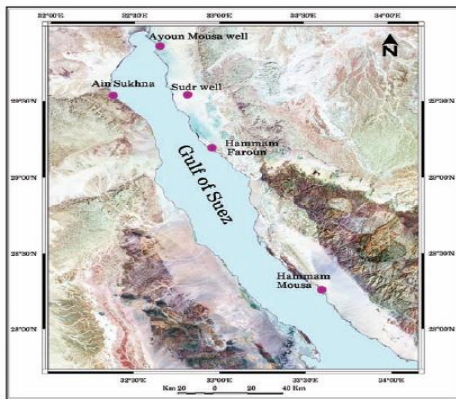


Fig. 3. Location map of the thermal groundwater's at the Gulf of Suez region

Table1: Temperature depth and geothermal data for springs and wells of Egypt.

Source	Sample no.	SS	D	T (°C)	T ₂₀₀ (°C)	T ₃₀₀ (°C)	Mg%
Eastern Desert							
Bir Asali	10	S	0	27.7	94	88	88
Ain Anbagi	60	S	0	29.4	75	83	77
Ain Anbagi	60	S	0	29.4	75	83	77
Bir Saigala (Dup.no.6-9)	112	-	15	23.0	89	84	84
El Ain	65	S	0	26.1	107	77	77
Bir Gahliya	66	DW	-	25.0	96	92	cold
Bir Qusi	67	DW	-	25.6	50	136	27
Umm Huweitat	68	DW	-	-	66	70	69
Umm Huweitat	69	M	150	29.4	63	187	19
Bir El Hammamas	E3	DW	65	25.0	81	86	86
El Laqaita	114	AW	450	33.0	57	89	65
Bir El Laqaita	E5	-	3	-	84	152	19
Bir Ambar	E6	DW	5	30.0	85	191	44
Bir Anas	E7	DW	4	24.0	78	76	76
Bir Faruqiya	E8	DW	18	26.0	76	51	61
Bir Abbad	E9	DW	2	34.0	89	159	Cold
Bir Kansiyia	E10	DW	57	32.0	46	91	34
Marea Tundaba	E11	DW	2	24.0	60	139	23
Bir Ohadir	E12	DW	3	26.0	77	88	66
Bir Wafi	E13	DW	28	28.0	74	58	68
Western Desert							
Kharga Oase							
Mahaziq	12	PW	160	29.0	45	196	33
Mahaziq	13	FW	650	37.5	50	237	68
Kharga	14	PW	642	38.0	52	245	59
Qinab Balad	15	FW	262	31.0	47	320	57
Qinab Balad	16	FW	504	33.2	50	300	76
Bulaq 5	17	AW	768	35.0	48	268	48
Bulaq Balad	18	AW	105	28.8	47	242	49
Qarmashin 5	19	AW	450	33.3	47	238	61
Qarmashin 5 "New"	20	AW	500	34.0	48	257	64

4 Geothermal Energy Utilization

Depending on the temperature and chemistry of the resources, geothermal energy can be used for both direct uses and electricity generation; medium-to-low resources are primarily used for direct application, while high-to-medium resources are used for electricity generation. Following World War II, geothermal energy attracted the attention of many nations because it was economically competitive with other energy sources, did not require importation, and in certain situations, was the only energy source available locally.

4.1 Direct Use of Geothermal Heat Applications

Geothermal heat has a wide range of uses that differ depending on location, resource properties, and temperature needs, among other things. This section aims to provide a fundamental understanding of both common direct use applications and ones that have not yet been tried but have the potential to be developed in the future. There is also discussion of cascaded consumption of geothermal heat, which involves setting up many applications to use the same resource at different temperatures. Applications are given more attention and information. The most concise overview of several direct use applications arranged by temperature requirements can be found in the Lindal diagram and its more recent iterations. Named for its proposer, the Icelandic engineer Baldur Lindal, the diagram is known as the Lindal diagram [19]. Certain temperatures that are appropriate for different direct-use activities are shown in Fig. 4.

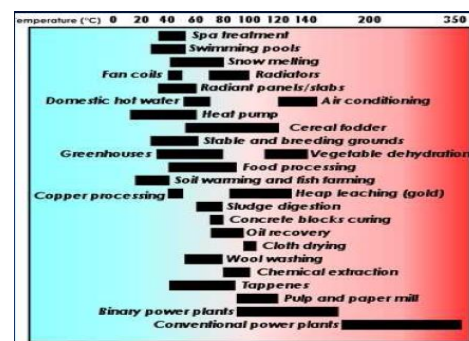


Fig.4 - Lindal Diagram

A. Agricultural Drying

Dehydration and drying are significant use of geothermal energy at moderate temperatures. Continuous belt conveyors or batch (truck) dryers with air temperatures ranging from 40° to 100°C can be used to dry a variety of fruit and vegetable products. Geothermal energy has been used to dry a variety of grain, vegetable, and fruit crops in thirteen different nations. Seaweed from Iceland, onions from the United States, wheat and other grains from Serbia, fruit from El Salvador, Guatemala, and Mexico, lucerne or alfalfa from New Zealand, coconut flesh from the Philippines, and lumber from Mexico and New Mexico are a few examples. In Mexico, a compact, portable geothermal fruit drier for apples and pears has been tried. This is an effort to preserve some local crops for export that would otherwise go bad because there isn't a local market. Another example of a small-scale food dehydrator is one in northeastern Greece that uses geothermal water at 59°C at a rate of 7 liters per second to dry 14 kilograms of tomatoes per hour on racks set inside a long tunnel drier. This facility dries four tonnes of tomatoes a year. After that, the tomatoes are dipped in olive oil before being shipped and sold. There are just three workers running the factory. The vast onion and garlic drying facilities in western Nevada, USA, which employ 75 people, are at the other extreme of the spectrum. After being fed 3,000 to 4,300 kg of onions per hour with an approximate moisture content of 85%, these continuous belt driers generate 500 to 700 kg of dried onions per hour with an approximate moisture content of 4% after a 24-hour period. Before being disposed of, the facility requires 50 to 75 l/s of geothermal water at 110°C that is cascaded down to about 70°C. These massive belt driers measure about 60 meters in length and 3.8 meters in width. A continuous belt dryer is depicted in simplified form in Fig. 5 [20].

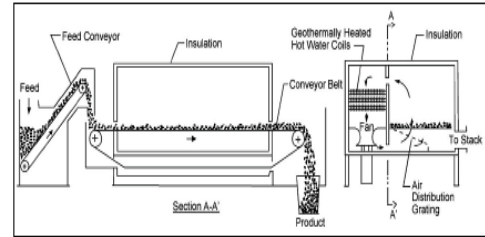


Fig. 5- Continuous belt dehydration plant, schematic

B. Space Conditioning

In isolated structures like houses and single buildings, distributed space conditioning encompasses both heating and cooling. Geothermal energy is widely used for space heating, particularly for individual use. In the United States, Klamath Falls, Oregon, and Reno, Nevada, as well as in Taupo and Rotorua, New Zealand, buildings heated by individual wells are common. Geothermal energy has not been widely used for absorption space cooling due to its low efficiency and high temperature requirements. Newer models that have just hit the market, however, claim to operate effectively at temperatures lower than 100°C. These devices can use a geothermal resource as low as 80°C and are made by Trane in Japan [21]. The Oregon Institute of Technology in Klamath Falls, Oregon, is an example of a room heating and cooling system that uses low-to-moderate temperature geothermal energy, as seen in Fig. 6. Here sixteen buildings covering 76,000 m² of floor space are heated with water from three wells at 89°C to 91°C. With an average heat utilization rate of over 0.53 MWt and a peak at 5.6 MWt, up to 62 l/s of fluid can be supplied to the campus. In order to meet the campus cooling base load, a 1,095 kW (312 tons) chiller that needed up to 38 l/s of geothermal fluid previously generated 23 l/s of chilled fluid at 7°C. Electric chillers took its place when it was retired due to an outdated, inefficient design that was only 50% efficient. The savings in heating costs on campus, compared to using diesel fuel, amount to over \$US 1 million per year. On campus, a 280 kWe geothermal binary electrical producing plant was recently erected. It uses well water first, extracting about 10 to 15

degrees Celsius from the geothermal water before releasing it to heat campus spaces [22].

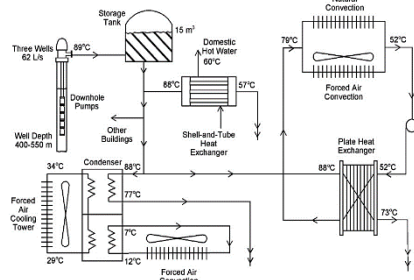


Fig. 6 Oregon Institute of Technology heating and cooling system

C. District Heating

From a central point, district heating distributes hot water or steam to individual homes or building blocks via a system of pipes. The heat is utilized for industrial process heating, home water heating, and space heating and cooling. The district's main source of heat is a geothermal well field, although depending on the temperature, it can be a hybrid system that uses fossil fuels and/or heat pump peaking. There are 17 nations with geothermal district heating systems in use, including the United States, Japan, China, Iceland, France, Poland, Hungary, and Turkey. The first official project in the United States was the Warm Springs Avenue project in Boise, Idaho, which began in 1892 and initially heated over 400 residences. The most well-known is most likely the district heating system in Reykjavik, Iceland, which is depicted in Fig. 7. The population of about 190,000 is heated by this method. Large storage tanks and an oil-fired booster station handle the higher load during colder months, but the installed capacity of 830 MWt is intended to fulfill the heating load down to roughly -10°C. One or two distribution systems are used by Reykjavik District Heating. The consumer's return flow returns to the pumping stations in the double system. Before being recirculated, it is combined with hotter geothermal water and used to chill it to the appropriate 80°C. The backflow in the single system goes straight into the sewer system. Customers require roughly 18,400

m³/hour at the coldest time of the year, and while field production is insufficient, the demand is typically met by the water in storage tanks because the cold spells are short. A primary pipeline transports the 54 million liters of geothermal water from the Reykir-Reyjahlid area to six tanks located just outside of Reykjavik. After there, the water travels to six 24-million-liter storage tanks on Oskjuhlid in the center of Reykjavik. Water is pumped to customers via nine pumping stations located throughout the servicing region. On the route to Reykjavik, the water from Nesjavellir pours into two 18 million-liter tanks. The hot water then travels to the southern portion of the servicing area via a main pipeline. Throughout the distribution system, the heated fresh water and the geothermal water are maintained apart until they reach the customer. The distribution system's pipelines are roughly 2700 km long overall. This covers every pipeline that connects the wells to the end user. Rock wool or foam is used to insulate the new pipes. The temperature in a building is between 25 and 40°C after the hot water has been utilized. Using this runoff water to melt snow off driveways and pavements has grown in popularity in recent years. Over the past 20 years, geothermal water has become more and more popular for melting snow. Around 835,000 m² of snow melting systems are built throughout Iceland, and they use about 360 GWh of electricity a year. Space heating systems' utilized return water accounts for half of this energy [23–25].

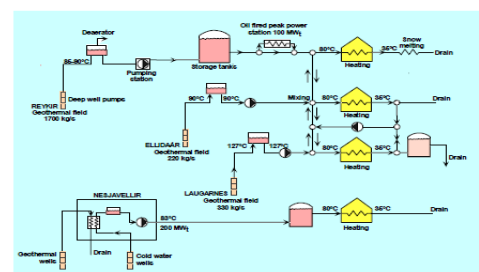


Fig. 7: Simplified diagram of the district heating system in Reykjavik, Iceland

D. Aquaculture

The production and commercialization of aquatic plants and animals in enclosed ponds or raceways is known as aquaculture. Geothermal aquaculture is a method of growing fish, shellfish, amphibians, reptiles, and aquatic plants more quickly by using naturally existing heated water. One highly promising application for low-temperature geothermal resources is aquaculture. The temperature and chemistry of the water determine whether geothermal water is used for aquaculture. Minerals in some Montana geothermal water, such as the extremely salty hot brines that come from the oil wells in the state's east, render it unfit for direct use in aquaculture. Geothermal water that is too poisonous to use directly in aquaculture, however, can be passed through a heat exchanger, which converts the hot water's heat into drinkable water that aquaculture operations can use. Depending on the species, aquaculture typically requires water that is between 60 and 90 degrees Fahrenheit. A summary of the ideal temperatures for particular species is given in Table 2 Furthermore, the final column displays the development times for cultures at ideal conditions. geothermal aquaculture operations in Klamath Falls is shown

Fig.8 [26,27].

Table 2 temperatures Requirements and Growth Periods for Selected Aquaculture Species.

Species	Tolerable Extremes (°F)	Optimum Growth (°F)	Growth Period to Market Size (mos)
Oysters	32 to 97 typ	76 to 78 typ	24
Lobsters	32 to 88	72 to 75	24
Penaeid Shrimp			
Kuruma	40 to ?	77 to 87	6 to 8 typ
Pink	52 to 104	75 to 85	6 to 8
Salmon (Pacific)	40 to 77	59	6 to 12
Freshwater Prawns	75 to 90	83 to 87	6 to 12
Catfish	35 to 95	82 to 87	6
Eels	32 to 97	73 to 86	12 to 24
Tilapia	47 to 106	72 to 86	--
Carp	40 to 100	68 to 90	--
Trout	32 to 89	63	6 to 8
Yellow Perch	32 to 86	72 to 82	10
Striped Bass	? to 86	61 to 66	6 to 8



Fig. 8 "Gone fishing" aquaculture project in Klamath Falls, Oregon.

E. Greenhouse Heating

One of the most popular applications for geothermal resources is greenhouse heating. Due to greenhouses' high heating needs and their capacity to use fluids with low temperatures. Geothermal greenhouses are used to grow a wide range of plants, such as bedding plants, poinsettias, tree seedlings, roses, tomatoes, lettuce, cucumbers, and other crops. Table 3 displays the Temperature Requirements for Common Greenhouse Crops. Table 3 Although most greenhouse operators believe that employing geothermal resources rather than conventional energy sources reduces fuel costs by roughly 80%, it should be noted that this only accounts for 5 to 8% of a greenhouse business's overall operating expenses [27].

Table 3 Temperature Requirements for Typical Greenhouse Crops

Vegetables	Day	Night
Peppers	65-85	60-65
Tomato	70-75	62-65
Cucumber	75-77	70
Lettuce (hydroponic)	75	65
(Reduce temp. 2° when picking)		
(During germination, humidity 30-70%)		
Flowers		
Roses	60-62	62
Poinsettias	70-80	64-72
Easter Lilies	60	
Carnations	75	50
Geraniums	70-80 (max)	
Fuchsia (min)	70 (min)	65

Figure9 [18] depict a typical commercial greenhouse arrangement, with a total area of 6.0 ha divided into

several units of 0.4 ha each. For peak use in northern climates, such as the northern United States and southern Canada (temperate environment with an average summer maximum of about 23°C and an average winter minimum of around -15°C), three production wells are depicted, each generating about 30 l/s.

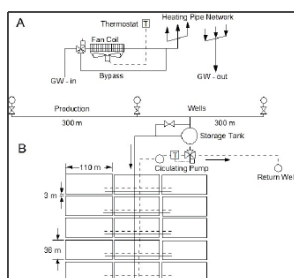


Fig.9 Typical large greenhouse layout consisting of 0.4 ha individual houses for a total of 6.0 ha.

Due to possible scaling and corrosion issues, Figure A depicts the interior greenhouse heating system, while Figure B shows the external system that uses geothermal fluid to supply the greenhouse heating equipment. Because they are the most effective and take up the least amount of space, plate heat exchangers are typically utilized. Shell-and-tube heat exchangers will lose 8 to 11 degrees Celsius, while these will lose 3 to 6 degrees. Fig. 10 shows a typical installation in a greenhouse.

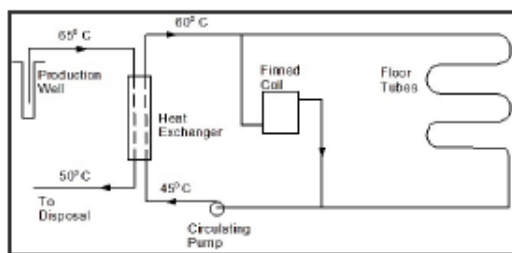


Fig.10 Typical geothermal heat exchanger system for a greenhouse

F. Bathing, Swimming, and Balneology

For thousands of years, people have used mineral and geothermal water for bathing and wellness. The use of

natural mineral water to treat and cure illnesses is known as balneology, and it has a long history. Mineral water has been utilized for bathing since the Bronze Age, about 5,000 years ago, according to Asian archeological discoveries. In Egypt, numerous hot springs have also been utilized in religious ceremonies. From Persia to England, the Greeks, Turks, and Romans were well-known for their spa development and use. The town of Liège in southern Belgium, close to the German border, is where the word "spa" first appeared. In 1326, an iron master here cured his illnesses by using a spring of water that contained iron. Espa, which translates to "fountain" in Walloon, is the name of the healing resort he established at the spring. Espa gained such widespread popularity that it became the standard term for comparable health resorts worldwide. First Nations and Native Americans view hot springs as holy sites and believe that the mineral waters and heat have therapeutic properties. The renowned Aztec leader Montezuma used Aqua Hedionda, a spa that the Spaniards eventually transformed into a chic spa, to rest after his demanding work. Native Americans have used every significant hot spring in the United States at some point, some for more than 10,000 years [18]. These springs were also known as neutral ground, to which warriors could travel to, rest undisturbed by other tribes, and recuperate from battle. The American Society of Heating and Air Conditioning Engineers (ASHRAE, 1999a) states that 27°C is the ideal temperature for swimming pools, although this can differ by up to 5°C depending on the culture. Some kind of mixing or cooling, either in a holding pond or by aeration, is necessary if the temperature of the geothermal water is higher. A flow-through procedure is required to regularly replace the "spent" water if the geothermal water is used directly in the pool. Since chlorine treatment is frequently required for pool water, it is more cost-effective to utilize a closed loop for the treated water and employ a heat exchanger to use the geothermal water to generate heat. The water heating system in this case, is installed on the return line to the pool. Acceptable circulation rates vary from six to eight hours for a complete change of water. Heat exchangers

must be designed to resist the corrosive effects of the chlorine in the pool water and scaling or corrosion from the geothermal water. This often requires, in the case of plate heat exchangers, using titanium plates. Approximately 10 to 15 percent of a pool's operating budget is spent on heating using geothermal energy. The percentages can double if fossil fuels or electricity are being used for heating [18]. For comfort, energy efficiency, and structure safety, spas and natatoriums need humidity levels between 40 and 50 percent throughout the year. The following factors must be taken into account in any design: air distribution, duct design, humidity control, ventilation needs for air quality (exhaust and exterior air), pool water chemistry, and evaporation rates. Figure 11 shows a typical Ouray hot springs pool in Ouray, Colorado. Through a pipeline, the pool receives around 120 gpm of water at 145°F from the The Box Canyon spring and roughly 134 gpm from well OX-2 at 124°F. Although the springs' water chemistry varies slightly, it is extremely hard (500–1,000 ppm CaCO_3), with a TDS of roughly 1,000–2,000, a pH of 7 (field) and 8 (lab), and 500–1,000 ppm sulfate. Most of the time, scaling is an issue. For the pool itself, a concrete tank on the west side of the building receives the combined flow from the spring and the well. At this point, the water is pumped to the filter room and chlorine is added. After passing through the primary filters, the geothermal water is combined with pool water after passing through two sand pre-filters to eliminate iron and manganese. The pool is kept in three different temperature zones: a tiny 104°F section, a bigger 98°F section, and the main pool area, which is permitted to "float" with whatever geothermal water remains once the warmer portions are satisfied. By manually regulating the valves that combine the filtered pool water and geothermal water, the temperature is maintained. The Uncompagre River, which is next to the plant, receives pool overflow [28].

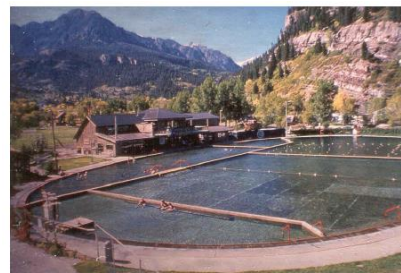


Fig.11 Typical Ouray hot springs pool Ouray Colorado.

G. Industrial and Process Heating Applications

Due to a lack of awareness about the advantages of geothermal energy and the fact that traditional heating systems based on fossil fuels are already well-established, there are currently very few uses of geothermal energy in industrial and process applications worldwide. These operations, which have been recorded for 14 countries, typically use a lot of energy and are rather huge. Boric acid and other borate chemicals have been produced from geothermal brines in Larderello, Italy, since 1790, making it the site of the earliest industrial use. The pulp, paper, and wood processing factory in Kawerau, New Zealand, and the diatomaceous earth drying plant in northern Iceland are currently the two biggest industrial uses. Additional examples include the following: the curing of concrete in Guatemala and Slovenia; the bottling of water and carbonated beverages in Bulgaria, Serbia, and the United States; the pasteurization of milk in Romania; the preparation of leather in Serbia and Slovenia; the chemical extraction of leather in Bulgaria, Poland, and Russia; the extraction of CO_2 in Iceland and Turkey; and the extraction of salt and iodine in Vietnam. In Klamath Falls, Oregon (USA), milk pasteurization was tried for several years before the company went out of business due to lack of proper management. The procedure made use of a 233-meter deep well with an artesian flow of 1.9 l/s at 82°C. Pumping up to 6.3 l/s of geothermal fluid into the building and through a short-term pasteurizer (a stainless steel Cherry Burrell plate heat exchanger) was part of the pasteurization process. As illustrated in Figure 15, the 87°C

geothermal water was pumped from the well into the structure and passed through a three-section plate heat exchanger. In one part of the plate heat exchanger, milk from the homogenizer was used to pre-heat the entering cold milk at 3 °C. After that, the milk was sent to the second part of the plate heat exchanger, where the short-time pasteurizer's geothermal fluid heated it to a minimum temperature of 78 degrees Celsius for 15 seconds. The short-time pasteurizer automatically recirculated the milk until the necessary exposure was achieved if the temperature fell below 74 °C. Following its pasteurization, the milk was sent through a homogenizer before being pumped back through the opposite side of the plate heat exchange's first section, where the cold milk from the incoming source cooled it to 12 degrees Celsius. The milk entered the cartons without any possibility of further cooking after being chilled to 3°C by cold water in the third segment of the plate heat exchanger. Longer shelf life and flavor were guaranteed as a result. As a bonus, the entering cold milk pre-heated the outgoing heated milk, and the outgoing heated milk cooled it down a little by passing it by it. A monthly total of 225,000 kg of milk were processed at a rate of 0.84 l/s (Fig. 12) [29, 30].

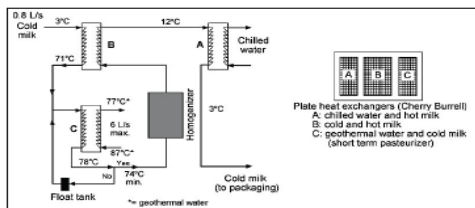


Fig.12 Klamath Falls milk pasteurization flow diagram.

H. Snow Melting

Although it might seem like a straightforward application, melting snow with geothermal heat is constrained by installation costs and a lack of nearby geothermal resources. Argentina, Iceland, Japan, Switzerland, and the US all have snow melting initiatives for pavement and bridge decks. Around two million square meters of pavement are heated globally, with Iceland accounting for the majority of this number. In order to keep a resort town open throughout

the winter, a project in Argentina uses geothermal steam to melt the snow on the Andes highway. The majority of pavement snow melting in the United States occurs in the City of Klamath Falls and on the campus of the Oregon Institute of Technology. Depending on the amount of snowfall, air temperature, relative humidity, and wind speed, the power needed ranges from 130 to 180 W/m² (in the US and Iceland). Although piping can be made of plastic or metal, cross-linked polyethylene pipe (PEX) is increasingly frequently utilized in place of iron due to external corrosion issues. Geothermal energy is supplied to systems through the use of heat pipes, directly from water circulating in pipes, through a heat exchanger or by allowing water to flow directly over the pavement [18].

I. Cascaded Uses & Combined Uses

Power generating, space heating, greenhouse and aquaculture pond heating, industrial processing, and bathing are just a few of the many uses for geothermal resources. However, some of the uses may not promise an attractive return on investment because of the high initial capital cost. To get the most out of the geothermal fluid, it is therefore advantageous to think about using it multiple times. Cascade or waste heat utilization is the term for this multistage usage, which uses progressively decreasing water temperatures. Figure 13[13] illustrates a basic type of cascading that uses surplus heat from a power plant for direct use projects known as a combined heat and power application.

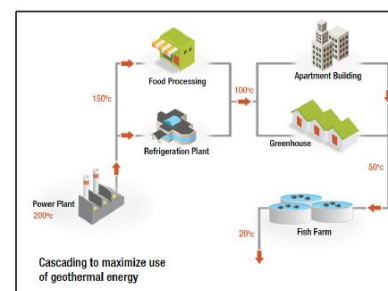


Fig.13 An example of cascading for combined heat and power

4.2 Egypt - Direct Uses

Although Egypt was not included in the country update report, Idris (2000a) cites one geothermal resource that is being used: the Helwan sulphur spa, which lies south of Cairo and east of the Nile River. This bath, which has been used to treat skin disorders since the 7th century, is fed by a large sulphur spring in the central part of Helwan district. The discharge rate is 2.9 L/s and the temperature is 31.6°C. Personal communications with the author have revealed that there are other bathing/spa uses of geothermal water in Egypt. Springs can also be found in the Western Desert of Dakhla Oasis (Ain Elgabal - 40°C and 5.2 L/s), Farafra Oasis (Ain Elbalad - 28°C and 5.6 L/s), Bahariya Oasis (Ain El Bishmou - 31.6°C and 4.4 L/s) (Ain El Ris - 28.3°C and 1.2 L/s), and Sinai (Ain Hammam Faroun - 70°C and 10.2 L/s). Based on this information, 1.0 MWt of capacity and 15 TJ/year of use are estimated for the country [13, 14].

4.3 Electricity from Geothermal Fluids

To generate energy, we use the earth's natural steam and hot water to turn turbine generators. No fuel is burned, in contrast to fossil fuel power plants. Water vapor is released by geothermal power facilities, but no smoke is released. There are numerous varieties of plants, including: Binary power plants, flashing steam plants, and dry steam plants. Binary cycle units and steam condensing turbines are the two main forms of geothermal power plants now in operation. Flash or dry-steam plants that operate at locations with intermediate and high-temperature resources ($\geq 150^\circ\text{C}$) can make use of steam condensing turbines. A step-up transformer for transmission into the electrical grid, vaporizers, de-misters, heat exchangers, turbine generators, cooling systems, pipelines, and water-steam separators are often found in a power plant. In order to optimize the energy extraction from the geothermal fluid, the power unit size typically falls between 20 and 110 MWe. It may also employ a multiple flash system, which flashes the fluid in a sequence of vessels at progressively lower pressures. The sole distinction between a flash plant and a dry-steam plant is that the latter can be designed more simply and affordably because it does not require brine separation. Usually constructed to extract heat from low- and intermediate-temperature geothermal fluids

(usually between 100 and 150°C), binary-cycle plants are organic Rankine cycle (ORC) units. Since the geothermal fluid (water, steam, or both) travels via a heat exchanger heating another working fluid, as seen in Fig. 14bottom, binary plants are more complicated than condensing ones. This working fluid, like low-boiling-point pentane or isobutene, vaporizes, powers a turbine, and is subsequently air-cooled or condensed with water. Binary plants are frequently built as interconnected modular modules with capacities of a few MWe. In combined heat and power plants (CHP), low to moderate temperature geothermal resources are now used. In CHP, hot waters as low as 100 °C are first passed through a binary (Organic Rankin Cycle) power plant, after which they cascade for heating spaces, swimming pools, greenhouses, and aquaculture ponds. The hot waters are then reinjected into the aquifer or disposed of at the surface, though the latter option is gradually being dropped for clear environmental reasons. CHP initiatives undoubtedly increase economics and make the most use of available resources [32–35].

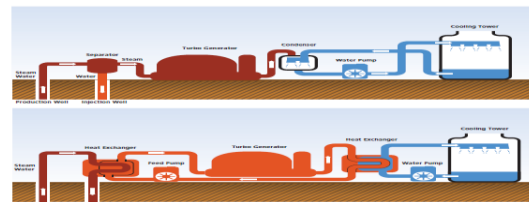


Fig.14 Schematic diagram of a geothermal condensing steam power plant (top) and a binary-cycle power plant (bottom)

5. Geothermal Energy Advantages

It is possible to extract useful minerals from subterranean water, including silica and zinc. The term "homegrown" refers to geothermal energy. This will improve international trade, reduce dependency on oil-producing nations, and generate jobs. Geothermal plants can be online 100%-90% of the time. Coal plants can only be online 75% of the time and nuclear plants can only be online 65% of the time. Geothermal energy doesn't contribute to the greenhouse effect or create any pollution.

Because the power plants are small, they have little effect on the environment. Geothermal plants save 83.3 million barrels of fuel from being used annually all around the world. By doing this, 40.2 million tons of CO₂ are kept out of the environment. Globally, 103.6 million barrels of fuel are avoided annually by the direct use of geothermal energy. As a result, 49.6 tons of CO₂ are prevented from entering the atmosphere. Fig. 15 [1] shows that the carbon dioxide emissions from geothermal energy systems are lower than those from other conventional energy systems used to generate power.

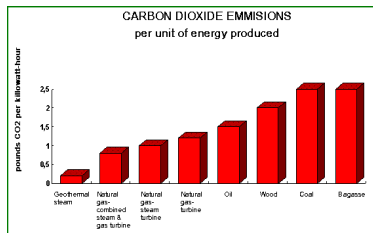


Fig.15 comparison of co2 emissions between conventional energy systems and geothermal plants to generate electricity.

6. Geothermal Energy Disadvantages

If the water is not reinjected into the reserve after the heat is removed, brine can cause the soil to become salinized. H₂S, or "rotten eggs," gas can be released by power plants that do not re-inject the cooled water into the ground. This gas can cause problems if large quantities escape because inhaling too much is fatal. When wells are being drilled, there is concern about noise pollution.

7. Conclusion

Geothermal energy is the energy derived from the heat of the earth's core. It is clean, abundant, and reliable. If properly developed, it can offer a renewable and sustainable energy source. Geothermal energy appears to be a logical solution to energy needs. Direct-use has

grown at an annual pace of more than 10% during the last several years. The development of this natural "heat from the earth" should accelerate in the future due to the instability of natural gas and oil prices, which has made geothermal energy more competitive, in addition to the environmental benefits of this renewable energy source. If current trends continue, direct geothermal energy use should more than double over the next decade. Where the climate demands it, direct use for space heating and cooling as well as for agricultural purposes is probably going to increase. For both visitors and residents, spa and balneology offer intriguing opportunities. Due to a lack of awareness about the advantages of geothermal energy and the established status of conventional heating systems based on fossil fuels, industrial use will continue to play modest role. Direct applications of geothermal fluid heat could aid industrial processes in reducing the amount of fuel burned to produce steam. In combined heat and power plants (CHP), low to moderate temperature geothermal resources are now used. In CHP, hot waters as low as 100 °C are first passed through a binary (Organic Rankin Cycle) power plant, after which they cascade for heating spaces, swimming pools, greenhouses, and aquaculture ponds. The hot waters are then reinjected into the aquifer or disposed of at the surface, though the latter option is gradually being dropped for clear environmental reasons. CHP initiatives undoubtedly increase economics and make the best use of available resources. In industry, steam is preferred. The generation of electricity from geothermal sources will likely continue to be the most important use. Electricity generated by geothermal plants saves 83.3 million barrels of fuel each year from being burned worldwide. This prevents 40.2 million tons of CO₂ from being emitted into the atmosphere. Direct use of geothermal energy prevents 103.6 million barrels of fuel each year from being burned worldwide. This stops 49.6 tons of CO₂ from being emitted into the atmosphere. Geothermal plants have no fuel costs, and minimal maintenance. Once a plant is operating, it can generate electricity for

30 years or longer if the field is engineered and maintained sustainable.

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