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### ► **To cite this version:**

Mamdouh El Haj Assad, Laveet Kumar, Maryam Almallahi, Oussama Rejeb, Mahmoud Elgendi, et al.. DIRECT AND INDIRECT USES OF GEOTHERMAL ENERGY. 50th International Conference on Computers & Industrial Engineering (CIE50), Computers and Industrial Engineering, Oct 2023, Sharjah, United Arab Emirates. pp.1595-1604. <hal-04632950>

**HAL Id: hal-04632950**

**<https://hal.science/hal-04632950v1>**

Submitted on 3 Jul 2024

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## DIRECT AND INDIRECT USES OF GEOTHERMAL ENERGY

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### ABSTRACT

Today, the world depends mainly on fossil fuels and actively promotes them. Unfortunately, pollution from fossil fuels as a primary power source and electricity has reached new peaks, ranging from climate-damaging greenhouse gases to health-threatening particles. As a result, different energy sources must be implemented. Since 2011, renewable energy has grown faster than all other electricity resources. Renewable energy efficiency is determined by the resource utilized. Some green energy options, such as geothermal energy, are more available and effective than others and are beneficial in some regions but not in others due to accessibility. The heat from the earth's subsurface is known as geothermal energy. It's present in rocks and fluids underneath the earth's shell, down to the heated molten rock below the surface. Drilling a well into a subterranean reservoir up to a mile or deeper is the first step in gaining access to geothermal resources. This paper introduces two primary utilization of geothermal energy: the direct use of geothermal energy for heating and cooling applications via a geothermal heat pump and indirect geothermal energy that is employed to generate power and electricity, such as in dry steam, single and double flash, and binary cycle power plants.

Keywords: Geothermal energy, heat pump, indirect geothermal, binary cycle power plant.

### 1 INTRODUCTION

The globe remains significantly dependent on fossil fuels and other sources that can be depleted. Nevertheless, the contamination produced by fossil fuel as the primary power source and electricity has hit new highs, ranging from climate-damaging greenhouse gases [1-3]. Renewable energy sources are considered clean because they produce minimal to zero greenhouse gas emissions and other harmful pollutants, unlike non-renewable energy sources that release high levels of carbon dioxide and other pollutants into the atmosphere. Adopting



renewable energy sources is crucial for reducing greenhouse gas emissions, mitigating climate change, and promoting energy security [4-6]. Renewable energy resources have the advantage of being readily accessible in some sort or another almost anywhere, unlike conventional energy sources, for instance, fossil fuels, including natural gases, coal, and oil, which are available and accessible in limited portions and will eventually finish as we continue extracting energy from them. Renewable energy sources involve solar, wind, geothermal, hydroelectric, etc. [7-10,45-53].

Some green energy resources are more accessible and efficient than others, such as geothermal energy, which is helpful in some places but not in others related to availability [11-13,42,44]. It is produced from the energy produced during the planet's creation and the radioactive decay of elements. Such thermal power is retained in rocks and fluids in the planet's core [14]. Moreover, some of the rock in the earth's core melts at temperatures above 4000 °C, yielding hot molten rocks known as magma [15].

Although previously, geothermal energy was used for cooking and heating in various places, other applications of geothermal energy are to generate power as well as for heating and cooling, which is done by using an underground geothermal reservoir of steam and hot water [16]. In addition, there are several techniques for heating and drying which includes the use of solar stills [17,18]. However, a geothermal heat pump is placed around 10 feet below the surface, where most water or coolant solution is injected into these pipelines as an instance of cooling and heating utilization. The water is pushed around the tubes in a closed loop [19]. The water captures the planet's energy as it returns to the house. In addition, geothermal water has been utilized to help grow crops in greenhouses and to heat homes and businesses through district heating [20]. Access to geothermal resources begins by drilling a well into a subsurface reservoir up to a mile deep [21]. Finally, natural and enhanced geothermal sources will derive the turbines that will power the electricity generators. To generate electricity, geothermal power plants will be employed, and they are available in three various models: dry steam, single and double flash, and binary [21,22].

Geothermal energy's advantages over other renewable energy resources are that geothermal energy is considered less harmful to the environment than traditional fuels like coal and other fossil fuels. Moreover, geothermal energy can effectively generate electricity with a 150 °C water temperature requirement for turbine operation. In addition, because it does not fluctuate with weather and surrounding conditions as much as other energy sources like solar and wind, the power produced from this source is simple to calculate. On the other hand, one of the main drawbacks of geothermal energy is that it is exclusive to a specific region. As a result, geothermal facilities must be constructed where power is available. Hence some areas will be unable to benefit from this resource. In addition, geothermal energy typically does not emit greenhouse gases, but some of these gases are trapped beneath the Earth's surface and discharged into the atmosphere during excavation. These emissions, however, are still significantly lower than those related to fossil fuels [23-25,41]. This paper addresses the direct uses, including heating and cooling and heat pump applications. Then, we will examine the indirect benefits of how a geothermal power plant can be used to generate electricity. Afterward, discuss the geothermal energy potential in the UAE to harvest geothermal energy.

## 2 METHODOLOGY

### 2.1 Indirect geothermal power plant

#### 2.1.1 Dry steam

To find enthalpies for each state:

- State 1 saturated vapor  $h_1 = h_g$  at  $T_1$  or  $P_1$ .

- State 2 is (2 phase)  $h_2 = h_f + x_2 h_{fg}$ ,  $h_f$  and  $h_{fg}$  obtained from steam table .
- State 3 saturated liquid  $h_3 = h_f$  at  $T_{Cond}$  or  $P_{Cond}$ .
- State 4 (neglecting the pump work)  $h_4 = h_3$ , then  $T_4 = T_{sat}(h_4 = h_f)$  if  $P_4 < 5MPa$ .

To Find turbine Power:

- $\dot{W}_T = \dot{m}(h_1 - h_2)$

To Find condenser heat rate:

- $Q_{Cond} = \dot{m}(h_2 - h_3)$

To find thermal efficiency:

$$\eta = \frac{\dot{W}_T}{\dot{m}_1(h_1 - h_{ref})}, \text{ Where } (h_{ref} = h_f \text{ at } 25^\circ\text{C})$$

To find turbine isentropic efficiency:

- $\eta_T = \frac{h_1 - h_2}{h_1 - h_{2s}}$

Mass flow rates:

- $\dot{m} = \dot{m}_1 = \dot{m}_2 = \dot{m}_3 = \dot{m}_4$

### 2.1.2 Single flash

To find enthalpies for each state:

- State 1 saturated liquid  $h_1 = h_f$  at  $T_1$  or  $P_1$ .
- State 2 is (2 phase)  $h_2 = h_1$ .
- State 3 saturated liquid  $h_3 = h_f$  at  $T_{sep}$  or  $P_{sep}$ .
- State 4 saturated vapor  $h_4 = h_g$  at  $T_{sep}$  or  $sep$ .
- State 5 is (2 phase)  $h_5 = h_f + x_5 h_{fg}$ ,  $h_f$  and  $h_{fg}$  obtained from steam table at  $T_{Cond}$  or  $P_{Cond}$ .
- State 6 saturated liquid  $h_6 = h_f$  at  $P_{Cond}$ .
- State 7 sub-cooled liquid (compressed)  $h_7 = h_6$ .
- State 8 compressed liquid  $h_8 = \frac{m_3 h_3 + m_7 h_7}{m_8}$ .
- State 9 compressed liquid  $h_9 = h_8$ , then  $T_9 = T_{sat}(h_9 = h_f)$

To Find turbine Power:

- $\dot{W}_T = \dot{m}_4(h_4 - h_5)$

To Find condenser heat rate:

- $Q_{Cond} = \dot{m}_5(h_5 - h_6)$

To find thermal efficiency:

- $\eta = \frac{\dot{W}_T}{\dot{m}_1(h_1 - h_{ref})}, \text{ Where } (h_{ref} = h_f \text{ at } 25^\circ\text{C})$

To find turbine efficiency:

- If turbine is isentropic  $\eta_T = 1$
- If turbine is not isentropic  $\eta_T = \frac{h_4 - h_5}{h_4 - h_{5s}}$

Mass flow rates:

- $\dot{m}_1 = \dot{m}_2$
- $\dot{m}_2 = \dot{m}_3 + \dot{m}_4$
- $\dot{m}_3 = (1 - x_2)\dot{m}_2$
- $\dot{m}_4 = x_2\dot{m}_2$
- $\dot{m}_4 = \dot{m}_5 = \dot{m}_6 = \dot{m}_7$
- $\dot{m}_9 = \dot{m}_1 = \dot{m}_2 = \dot{m}_8 = \dot{m}_3 + \dot{m}_7$

### 2.1.3 Double flash

- State 1 saturated liquid,  $h_1 = h_f$  at  $T_1$  or  $P_1$
- State 2 is (2 phase)  $h_2 = h_1$ .
- State 3 saturated liquid  $h_3 = h_f$  at  $T_{sep1}$  or  $P_{sep1}$ .
- State 4 is (2 phase)  $h_4 = h_3$ .
- State 5 saturated vapor  $h_5 = h_g$  at  $T_{sep1}$  or  $P_{sep1}$ .
- State 6 is (2 phase)  $h_6 = h_f + x_6 h_{fg}$ ,  $h_f$  and  $h_{fg}$  obtained from the steam table at  $T_{Cond}$  or  $P_{Cond}$ .
- State 7 saturated vapor  $h_7 = h_g$  at  $T_{sep2}$  or  $P_{sep2}$ .
- State 8 saturated liquid,  $h_8 = h_f$  at  $T_{Cond}$  or  $P_{Cond}$
- State 9 saturated liquid  $h_9 = h_f$  at  $T_{sep2}$  or  $P_{sep2}$ .
- State 10 (neglecting the pump work)  $h_{10} = h_9$ .
- State 11 saturated liquid  $h_{11} = \frac{m_9 h_9 + m_{10} h_{10}}{m_{11}}$
- State 12 saturated liquid  $h_{12} = h_{11}$ .

To Find turbine Power:

- $\dot{W}_T = \dot{m}_5 h_5 + \dot{m}_7 h_7 - \dot{m}_6 h_6$

To Find condenser heat rate:

- $Q_{Cond} = \dot{m}_6 (h_6 - h_8)$

To find thermal efficiency:

- $\eta = \frac{\dot{W}_T}{\dot{m}_1 (h_1 - h_{ref})}$ , Where ( $h_{ref} = h_f$  at  $25^\circ\text{C}$ )

Mass flow rates:

- $\dot{m}_1 = \dot{m}_2 = \dot{m}_{11} = \dot{m}_{12}$
- $\dot{m}_5 = x_2 \dot{m}_2$
- $\dot{m}_3 = (1 - x_2) \dot{m}_2$
- $\dot{m}_7 = x_4 \dot{m}_4$
- $\dot{m}_9 = \dot{m}_4 (1 - x_4)$
- $\dot{m}_6 = \dot{m}_5 + \dot{m}_7$
- $\dot{m}_8 = \dot{m}_6 = \dot{m}_{10}$
- $\dot{m}_{11} = \dot{m}_9 + \dot{m}_{10} = \dot{m}_1 = \dot{m}_2$

## 2.2 Direct geothermal power plant

### 2.2.1 Direct geothermal power plant

- State 1 saturated vapor,  $h_1 = h_g$  .
- State 2 superheated.
- State 3 saturated liquid  $h_3 = h_f$  ,  $P_2 = P_3$  .
- State 4 saturated liquid  $h_4 = h_f$  at  $T_4$  .
- State 5 is (2 phase)  $h_5 = h_4$  .

To find mass flow rate use this equation:

- $W_{Comp} = \dot{m}(h_2 - h_1)$

Calculate the power absorbed by the hot water heater and the absorbed by the space heater:

- $Q = P_{WH} = \dot{m}(h_2 - h_3)$
- $Q = P_{SH} = \dot{m}(h_3 - h_4)$

Determine the coefficient of performance of the hot water heater:

- $COP = \frac{P_{WH}}{W_{Comp}}$

Determine the coefficient of performance of the heat pump:

- $COP = \frac{P_{WH} + P_{SH}}{W_{Comp}}$

Ground loop systems are divided into four main distinct types, three of these are closed-loop systems: horizontal, vertical, and pond/lake the fourth sort of system is the open-loop system. Climate, soil conditions, available acreage, and local installation prices all play a role in determining which is ideal for the job. Both residential and commercial constructions are suitable for these techniques [26]. A variety of applications that require heat can be assisted with geothermal heated fluid. Researchers are looking on ways to effectively employ geothermal fluid to generate electricity in some applications [27-29].

## 3 DIRECT AND INDIRECT USES

Geothermal energy has both direct and indirect uses. Geothermal power plants use steam from hot water reservoirs to generate electricity and pump heat to heat building water. It can also provide warmth for greenhouse crops, livestock, and fish farms. The heat is transferred directly to the desired application via a mechanical system consisting of piping, a heat exchanger, and controls once the water is pulled up through the well. The remaining liquid is subsequently delivered underground or dumped using a discharge facility on the surface. Various applications that require heat can assist with geothermally heated fluid [29].

### 3.1 Ground source heat pumps

A ground source heating pump uses the temperature differences between the above-ground air as well as the temperature of the underlying soil to convey heat for use in room warming, cooling, and water heating. In the geo-exchange system of underground pipes, the heat pump is connected in a series of subterranean [29]. The heat pump circulates a heat-conveying fluid, usually water, through the pipes to transport heat from one area to another. The heat pump can transport heat from the soil to the structure if the soil temperature is warmer than the surrounding air temperature. Users of geothermal heat pumps should be aware that even if



renewable electricity is not used to power the heating/cooling system (e.g., modes), geothermal heat pump devices might not be completely fossil-free (e.g., renewable-based) [23,24].

#### 4 GEOTHERMAL ENERGY POTENTIAL IN THE UNITED ARAB EMIRATES

In the northeastern region, the Arabian Peninsula's United Arab Emirates (UAE) is situated. It is located in the Middle East, between Oman and Saudi Arabia, on the coast of Oman and the Arabian Gulf. Moreover, the UAE is located between 22 30' and 26 10' northern latitudes and 51 and 56 25' eastern longitude. However, several studies are being conducted to examine the possibility of establishing geothermal power plants in various locations throughout the UAE that meet standards [30]. In this paper, we will discuss the feasibility of constructing geothermal power plants in Dubai, Masdar city, and Al-Mubazzarah.

##### 4.1 Dubai

Dubai is actively looking at utilizing geothermal energy to power desalination plants, with preliminary studies on electric power yielding favorable outcomes. Moreover, the Dubai Electricity and Water Authority (Dewa) is seeking suggestions for an earlier stage of feasibility research on geothermal energy-generated electricity and its application in desalination. In addition, the project will also investigate the possibility of using tidal, wave, and ocean currents to generate electricity [31,43]. Meanwhile, experts say that because the UAE's temperatures are beneath 200°C, that is the minimum temperature needed for electricity production from geothermal; hence, geothermal is better suited to desalination rather than energy production [32].

##### 4.2 Abu Dhabi (Masdar City)

National Central Cooling Company PJSC (Tabreed), a UAE-based district cooling company, has stated that it is strengthening its cooperation with Masdar. The purpose is to connect and improve Masdar and Tabree's infrastructure in order to increase operating synergies even more [33]. Since Tabreed is expanding its attempts to deliver adequate cooling to sustainable places around the globe as a result of the agreement. Furthermore, Tabreed purchased Masdar City's local cooling firm in January 2020, a step which will offer adequate chilling facilities to far more than 2.7 million square meters in Masdar City, providing an overall power capacity of 69,000 Refrigerated Tonnes (RT) under the license [34].

Two huge geothermal wells were sunk in Masdar City in Abu Dhabi about ten years ago and see whether geothermal energy could be used for cooling applications. However, how could the underground heat be utilized to provide cooling? The refrigerator in your household, for example, employs a similar mechanism [35]. Tabreed would examine the two large geothermal wells to see if geothermal energy generation could be utilized for chilling and if it can significantly cut power usage. Where when temperatures ranging from roughly 50 °C to 100 °C and higher are possible, and this is where geothermal wells supplying fluids with the required temperature come into play [34].

##### 4.3 Al-Ain (AlMubazzarah Area)

The Al Mubazzarah region is located at the base of the Jabal Hafit mountain range. There is a wonderfully planned green spot in the middle of the desert [36]. The hot springs of Mubazzarah are widely recognized and are being explored to learn more about geothermal possibilities and potential implications. Hot springs can be found inside the research region and arise through fault systems that influence the research. It is found that the hot water geothermal fluids are primarily sodium chloride (NaCl) based, and the outflow surface temperature varies from 32.5°C to 49°C. Along with the reservoir temperatures for the Na-K

Cation, geothermometers varied from 119 to 128 degrees Celsius. In contrast, the reservoir temperatures for the Na-K Cation geothermometers spanned from 97 to 137 degrees Celsius. In addition, the elevation depth of the geothermal reservoir is approximately 2.3 km to 3.5 km by utilizing a geothermal gradient of 2.75 OC/100 m [36]. The isotopic and chemical data indicate that the Mubazarah hot springs are entirely composed of precipitation from high-elevation places. Finally, the substantial geothermal renewable energy capacity in the Mubazarah region is a promising alternative for food security and may be used to warm greenhouses and dry different crops [38].

## 5 CONCLUSIONS

To conclude, geothermal energy is considered renewable and sustainable and is currently under development energy resource. It has the potential to address future heating, cooling, and electrical needs because it is an environmentally friendly resource. Geothermal energy has many benefits but drawbacks that must be overcome to utilize this natural resource properly. Traditional fuels such as coal and other fossil fuels are more detrimental to the environment than geothermal energy. Moreover, it supplies a continuous supply of energy compared to other green power resources, for instance, wind and solar energy. This is because, unlike wind or solar energy, help is constantly available. The most significant drawback of geothermal energy is that it is site dependent. Because geothermal facilities must be built where power is available, some areas will need help to benefit from this resource.

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