Geothermal Energy: An Alternative Solution to Sustainable Cooling and Heating System in Brunei Darussalam.

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Abstract. Geothermal energy is the energy contained as heat in the Earth’s interior and can be utilized through horizontal or vertical tunnels to control temperature of home to earth’s level. This is known as ground-source heating and cooling. This paper emphasizes on the use of geothermal technologies on cooling and heating systems and describes the principle behind cooling and heating systems and also the current geothermal technologies and systems. One of the technologies is Shallow Geothermal Energy which makes use of the heat energy in the first 100 to 150 meters below the surface. In order to show the potential use for Brunei Darussalam, measurement on the soil temperature is conducted to determine the temperature difference at each depth and also temperature of non-moving air in a room to determine temperature increase during the day and night. This will allow us to identify the potential future use of geothermal energy for a sustainable cooling and heating system in Brunei. Finally a brief discussion on comparing conventional system with geothermal system based on its efficiency, reliability, cost and its sustainability.

Keywords: Geothermal Energy, Sustainable Cooling and Heating, Brunei Darussalam

1. Aims, Purposes and Method of Investigation

The aim of this paper is to identify the potential future use of geothermal energy for a sustainable cooling and heating systems in Brunei Darussalam and use the findings to propose a geothermal energy based solution reducing the current domestic energy demand.

Brunei Darussalam, a country with an area of 5,765 square km and a population of about 408,000 in 2010. Brunei Darussalam is endowed with rich resources of fossil fuels. Brunei Darussalam is currently embarking on its long term development plan called Wawasan 2035 to achieve its industrialization and economic diversification aspirations. Energy, a crucial necessity in the sustainable development of Brunei Darussalam, must meet the needs of today and the future without adverse effects to the environment [1].

In the path of investigating the potential, there are several factors that need to be satisfied for efficient usage of geothermal. One is main factor is the soil temperature. It is very crucial to measure the soil temperature at different depths and understand it variations. These findings will help us to determine the optimum depth for geothermal systems and to obtain a rough guide for sizing the system based on amount of volume involved for cooling or heating. In our study measurements were recorded at different depths of 0.2m, 0.4m, 0.6m and 1.0m using PICO Technology temperature sensor and data logger [4]. The second most important factor needed to be determined is the estimated thermal loads of the house or the building for...
geothermal system to be used to remove the heat trapped in the building. It is calculated based on the heat transfer through building’s materials such as brick, concrete, wood and glass.

2. Literature Review

Direct use of geothermal energy has been reviewed for over 25 countries and documented geothermal use for over 2000 years[6]. It has been widely used for generating electricity. In 2007, geothermal electrical installed capacity in the world is 9.7GW and it reached 11GW, producing up to 8.3% of world electricity for 17% of world population. The long-term sustainability of geothermal energy has been demonstrated at the Lardarello field in Italy since 1913, at the Wairakei field in New Zealand since 1958. Since then, many researches have been carried out in improving its performance and also combining it with existing systems. L. Kairouani and E. Nehdi [7] implemented geothermal principle in a refrigeration system in order to provide better cooling performance and energy saving. The aim of this work was to study the possibility of using geothermal energy to supply vapor absorption system cascaded with conventional compression system. Results showed that the COP of a combined system is significantly higher than that of a single stage refrigeration system. It is found that the COP can be improved by 37–54%, compared with the conventional cycle, under the same operating conditions.

Michaelis, Dimitrios and Constantine implement geothermal heating and cooling in existing buildings in Greece. Monitoring of the energy system showed excellent energy efficiency and performance [8].

3. Principles and Types of Geothermal Heat Pumps

Figure 1 shows a typical geothermal cooling and heating mechanism. Geothermal energy is the energy contained as heat in the Earth’s interior. This energy has been widely used for generating electricity. However it can be utilized for cooling and heating purposes [9]. During the day, the temperature above the ground will increase due to sun radiation. While in the ground, temperature remains constant and this can be used to cool down structures above the ground. This can be done by pumping a heat transferring medium through pipe which connects the structures and the ground. So the heat accumulated in buildings can be absorbed and send into the ground to disperse. In short, the ground will act as a heat sink for buildings and homes. While during the night, the process will be reversed [10].

There are two types of geothermal looping system which depends on the geographical site of the buildings and homes. Open loop systems involve ground water being drawn from an aquifer through one well, passes through the heat pump’s heat exchanger, and is discharged to the same aquifer through a second well at a distance from the first [12]. This looping system can only be applied if there is external water source available which can be utilized as heat transfer medium.

![Fig. 1: Principle of Geothermal for Cooling and Heating](image_url)

While closed loop systems, involve only heat exchanger which is a loop of piping filled with fluid, buried underground. The fluid circulates continuously inside the buried pipe, absorbing heat from houses[12]. This is commonly used since it is an independent system without external medium.
Over the years technologies for geothermal have been improved. Currently there are various types of technologies and methods to improve performance of geothermal systems such as energy pile, geothermal probes and heat collectors [13].

![Geothermal Technologies](image)

**Fig. 2: Geothermal Technologies, as of [14]**

### 4. Temperature Measurement and Analysis for Outdoor Air, Non-Air-Conditioner House and Soil at 0.4m

As mentioned above in our study measurements were recorded using a PICO Technology temperature sensor and a data logger. The graph in Figures 3& 4 below shows the daily temperature changes for outdoor air, indoor air of a house without air-conditioner and soil at a depth of 0.4m.

As observed, the soil temperature remains constant throughout the day and night. While for outdoor temperature and indoor temperature, it increased during sunrise and reached its peak around noon where the sun is directly above. Generally around 3pm when the sun starts to set, the temperature slowly decreases. And at night, the temperatures fall below the ground temperature. From this, as the temperature of the indoor air is greater than the temperature of the ground, the hot air from the indoor can be pumped into the ground for cooling and when it is reversed, the heat from the ground can be used for heating water. More importantly, this can help reduce the heat load for the buildings and homes and hence reduce the energy consumption of the air conditioner if used.

![Daily Temperatures](image)

**Fig. 3 and 4: Daily Temperatures on 10th and 11th October**

If the indoor temperature is reduced by geothermal cooling, which is from 36°C to 28°C, the air conditioner will require less power to cool down the hot air. For every 1°C difference reduced, the air conditioner will reduce the power used by 5% [16]. Therefore the amount of power reduced will be around 35%.
Fig. 5: Frequency Distribution of temperature of indoor air, outdoor air & soil temperature at 0.4m

The Figure 5 above shows that around 50% of the indoor air temperature is above the ground temperature and the soil temperature average at 28.9°C while the air temperature varies from 24°C to 35°C and the indoor air temperature varies from 38°C to 24°C.

5. Measurement of Soil Temperature of Different Depths

The temperature difference between the soil and indoor air can be utilized to bring down the indoor air temperature. Therefore in order to cover the range of temperature for the indoor air, a deeper loop can be built and hence soil temperature of different depths has to be measured.

Table 1: Average soil temperature at different depths

<table>
<thead>
<tr>
<th>Soil Depth</th>
<th>0.2m</th>
<th>0.4m</th>
<th>0.6m</th>
<th>1.0m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>28.50</td>
<td>28.50</td>
<td>28.37</td>
<td>28.35</td>
</tr>
</tbody>
</table>

The temperature decreases as the depth increases. As seen from the data, there is only a small change in the average soil temperature at different depths and hence it seems not viable to dig deeper into the ground. However in order to achieve 24°C which is optimum for geothermal, other cooling sources are needed such as using a river or a swimming pool.

6. Comparisons and Conclusions

The preliminaries studies show that geothermal technology can be applied during the day time as the ground temperature is lower than the indoor air and outdoor air temperature. In this case, the hot air from indoor can be pumped into the ground to disperse the heat away. Even though the geothermal system cannot be directly applied as the cooling system as the temperature is not low enough, it can be used to reduce the energy consumption of the air conditioner by lowering down the temperature of the building. As seen before it is not cost wise to dig into a deeper ground to obtain lower temperature values.

There are many types of geothermal heat pumps available in the current market. One of the dominating brands is Carrier [17]. In terms of efficiency, geothermal has a high efficiency coefficient compared to conventional air conditioners. However in terms of cost and reliability, conventional systems are higher than geothermal heat pumps. It is because geothermal systems require many types of equipment such as piping into the ground and it will be difficult for maintenance.

From view of economic aspects, geothermal heating may generate up to 3.1 times and geothermal absorption cooling is 2.9 times as high revenue as power generation alone. However cost and payback period comparisons appear to favor power generation. It is due to initial cost and also cheap electricity [18]. In terms of sustainability, geothermal heat pumps have the advantages over conventional air conditioner systems. This is because geothermal heat pumps run on a natural sources of energy which is renewable energy while conventional systems depends on electricity produced from burning of fossil fuels. At addition, geothermal system is environmentally friendly as it produces less greenhouse gases compared to air conditioners. Therefore, the only limitation for application the geothermal system is the initial high cost for installation of the equipment. Finally this paper has provided the stepping stone for our future research on geothermal systems for Brunei Darussalam.

7. References


