On the New Ground Source Heat Pump in Thailand: A case study at Chulalongkorn University, Bangkok, Thailand

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Abstract

We report the new result of the ground source heat pump (GSHP) which was installed at Chulalongkorn University in Bangkok. Our prime assumption is that if energy consumption can be reduced for operating the air conditioner, then electricity payment per month can be reduced as well. So we have selected the close loop of the vertical pipe system which involves circulating the underground cooling water in the high-density polyethylene (HDPE) pipes through the GSHP cooling system. With the constant flow rate of liquid through the GSHP system as well as the constant underground temperature, the electricity consumption can be essentially reduced. Our investigation commences with drilling of two bore holes to the depth of 50 meters. The 170 m - long HDPE pipes filled with anti-corrosion solution have been inserted into those boreholes and connected to the GSHP system without any leakage. Sensor system has been attached to the controlling unit in order to collect all measurement data including temperatures inside and outside experimental room (2 x 3 x4 m^3) as well as temperatures of flowing water inlet and outlet of the GSHP system. All data stored in a Data Logger have been used for calculating the electricity consumption reduction. The collected GSHP data have been compared with an air conditioner of the similar quality in the experimental room. Our result shows that with the application of vertical loop GSHP system, electricity consumption can be reduced for more than 30 %. The result also indicates that the consumption depends on room temperature control and outside air temperature in that day. Our result is very successful, but the operating cost of drilling is greatly high. This is mainly due to the fact that a cooling transfer system is from a vertical-loop arrangement of the HDPE pipes. It is therefore recommended that a horizontal pipe loop system be performed in order to reduce an operating cost.

Keywords: GSHP, Underground temperature, Surface temperature, Electricity saving, Bangkok

1. Introduction

Ground Source Heat Pump (GSHP), also known as GeoExchange, earth-coupled, ground-source, or water-source heat pump, has been in use since the late 1940s. The Ground Source Heat Pump or geothermal heat pump (GHP) system is the heating and/or cooling system that transfers heat to or from the ground. Therefore, it uses the earth as a heat source in the winter and a heat sink in the summer (Fridleifson, I.G., 2001, Curtis et al., 2005).

Ground source heat pumps (GSHP) is electrically powered system that taps the stored energy within the earth. The system uses the earth's relatively constant temperature as the exchange medium instead of the outside air temperature to provide heating, cooling, and hot water for homes and commercial buildings.

GSHP, which is one of the alternative energy system, replaces a heater in winter and a normal air conditioner in summer. So it can help to decrease the current energy shortage significantly because the underground temperature is stable more than the air temperature. This condition depends on many factors. The GSHP has been commonly used in many countries particularly in the cold regions. However; the GSHP cannot be applied in every area. It depends on the underground temperatures and geological background of the individual areas. In Thailand, GSHP can only be used for space cooling because the country is located near equator. (Takashima et al., 2011) This made subsurface temperatures to be similar to atmospheric temperatures. Based on this assumption, the subsurface temperatures need to be investigated in order to specify suitability of GSHP installation in Thailand. According to the preliminary worked by Yasukawa et al. (2009), many areas in central Thailand, including Bangkok, have a relatively stable underground temperatures, so it is possible to use the GSHP in this area. The objective of this study is to find out whether or not the GSHP system installed at Chulalongkorn University can be efficiently used.

2. GSHP Selection and Installation

Ground Source Heat Pump (GSHP) can be classified on the basis of system installation into closed loop and open loop systems (Fig. 1). The closed loop systems operated by circulating a water or water/antifreeze fluid through a sealed water-circulating pipe network. So the GSHP can exchange temperatures from underground to household building (Lund et al., 2004). The circulating fluid flows in a continuous loop, collecting or discharging heat as it circulates. The only interaction with the environment is the transfer of heat through pipe walls. (Fig. 1A) The open loop systems operated by extracting fluid directly from the environment, either as surface water or groundwater. The water is passed through a heat exchanger before being discharged. Theoretically, the water is not consumed, contaminated or modified in any way, except for a slight change in temperature. (Fig. 1B).

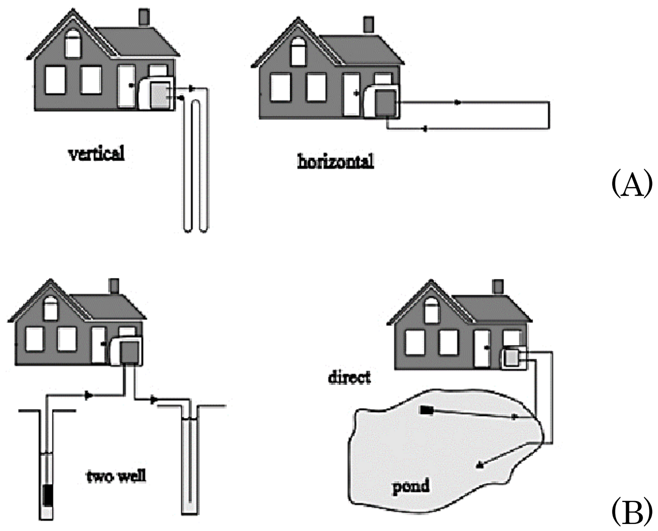

Fig. 1. Closed loop (A) and open loop (B) geothermal heat pump systems (Lund et al., 2004).

In this study, we have selected the vertical closed-loop heat pump system located at Parot Racha building in Chulalongkorn University (Fig. 2). Two wells with the distance of 6 m apart have been drilled to the depth of 50 m. The HDPE (high-density polyethylene) pipes have been inserted into both wells to depth of 50 meters (Fig. 3). Unfortunately, well no.1 was collapsed after the insertion of 50 m-long pipes. The new set of pipes with the new 10 and 15 m-long HDPE pipes have been inserted as shown in Fig. 4. Moreover, insertion of pipes in well no. 2 has been made successfully. All the pipes have been connected without any leakage (Chokchai, 2016)

The inlet and outlet pipe filled with water and anti-corrosion liquid have been connected to the GHP outdoor unit (Fig. 5A). In this study, this unit has been connected to the GHP indoor unit similar to the normal air-conditioner (Fig. 5B). We selected "Corona" Geothermal Heat Pump air-conditioner (see http://www.corona.co.jp/en/index.html for more detail).

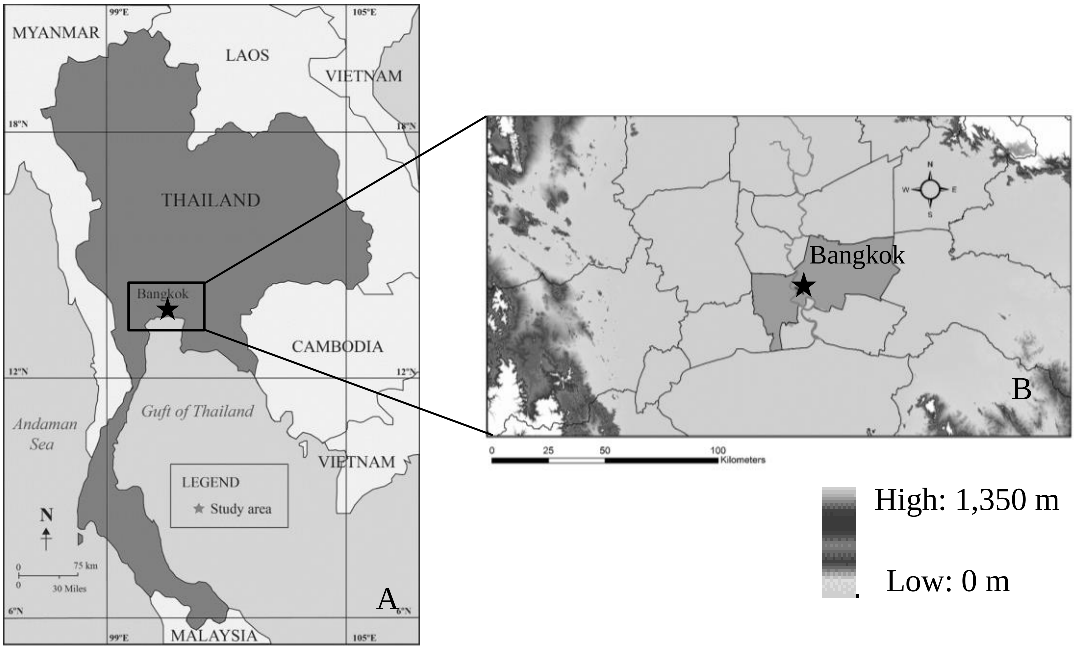

Fig. 2. Detail of GSHP system: Index map of Thailand (A) showing the location of Chulalongkorn University (star) in Bangkok (B).

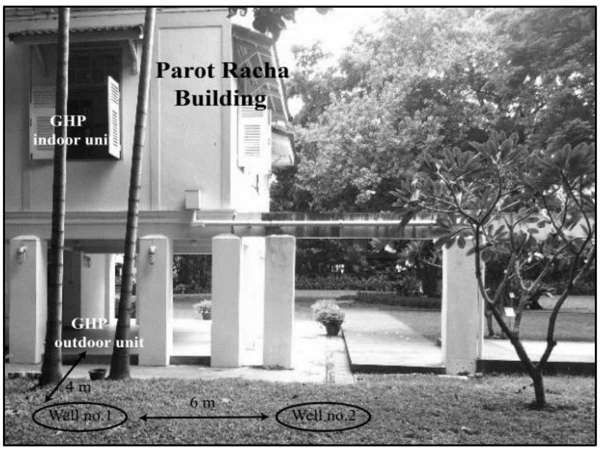

Fig. 3. GSHP experimental room located on the 2^{nd} floor of Parot Racha Building with locations of 2 drilled wells (nos. 1 & 2), which are approximately 6 meters apart, and about 4 meters at the backyard of the Parot Racha building.

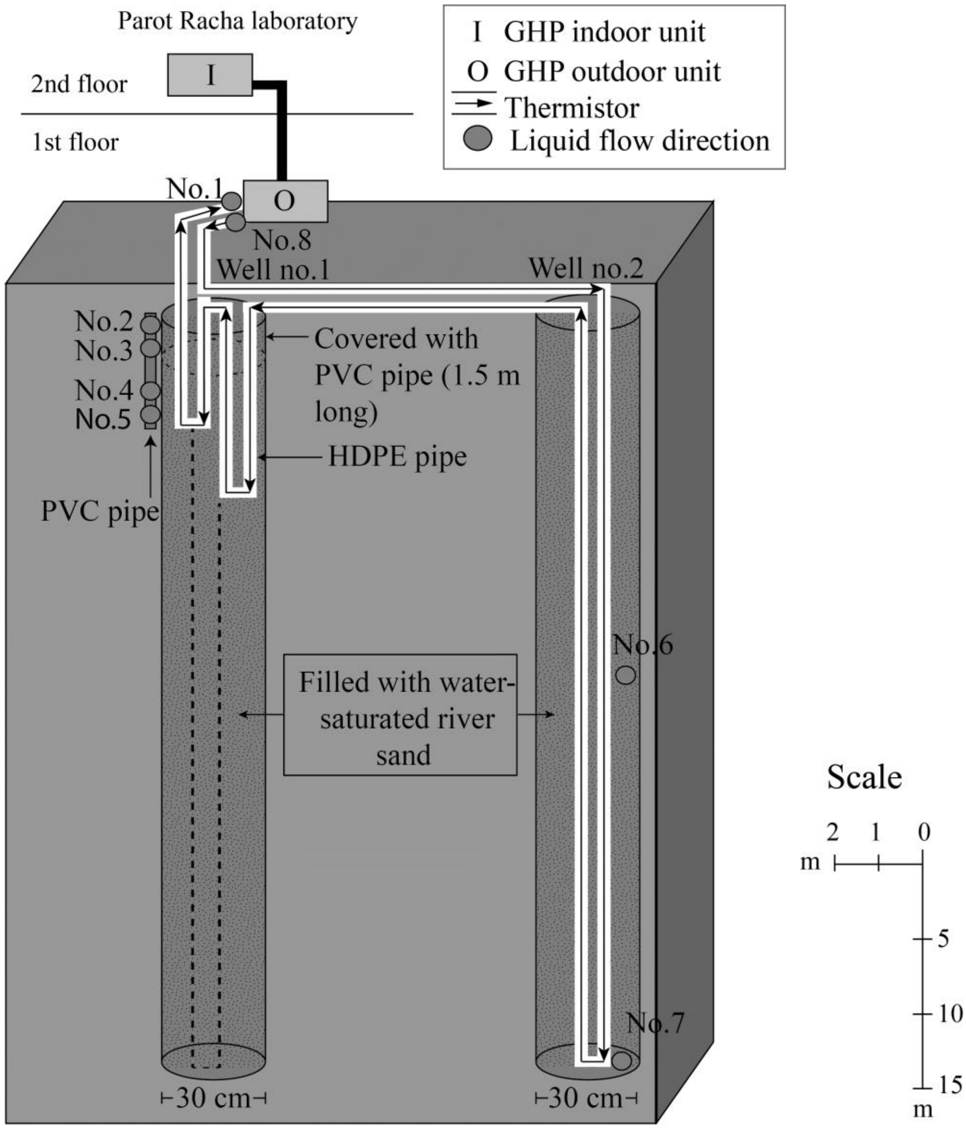

Fig. 4. Schematic installation of geothermal heat pump system at Parot Racha laboratory room. Note: HDPE pipe in well no.1 was broken. Therefore two new HDPE pipes with the lengths of 10 and 15 meters were inserted and connected to the well no. 2.

3. Measurements

Output thermistors have been connected to the pipes of both wells at several depths as shown in Fig. 4. The thermistors for measuring subsurface temperatures in well no. 1 have been set-up into the 10-m long PVC pipe at depths of 1.5, 3, 8 and 10 m. In well no. 2 without any PVC casing pipe, the thermistors have been set-up at depth of 25 and 50 m attached to the 50-m long HDPE pipe. Inlet and outlet liquid temperatures have been recorded using thermistors. Data on these temperatures have been recorded using “Graphtec” data logger. Additionally, atmospheric temperatures and room temperatures have been measured and recorded using the same data logger. Flow rates of liquid in pipes have also been recorded in volt unit. In order to understand the efficiency of the installed GSHP, the normal air-conditioner with almost the same specification has been established. Electricity consumption has been recorded in kilowatt using standard electricity meter as shown in Fig. 5B.

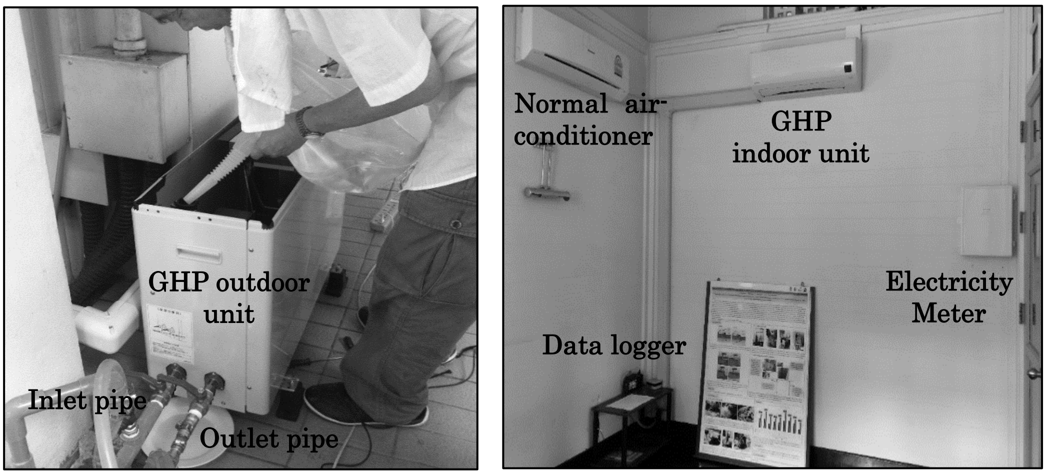

Fig. 5. (A) Inlet and outlet HDPE pipes that are connected to the HDPE pipes in both wells and to the GHP outdoor unit without any leakage (B) The GHP outdoor unit is connected to the GHP indoor unit with the data logger. Electricity meter is also shown (B).

4. Results of subsurface temperature

At depicted in Fig. 4, subsurface temperature data have been recorded at depth of 1.5 m (thermistor no. 2), 3 m (thermistor no. 3), 8 m (thermistor no. 4), 10 m (thermistor no. 5), 25 m (thermistor no. 6), and 50 m (thermistor no. 7). An example of data output for underground temperature measurement is illustrated in Fig. 6. The data was recorded on 15th May, 4th June, 10th June, 19th June, 24th June and 27th June 2014. The results shows that the ranges of subsurface temperatures are 29.6 - 29.8 °C, 29.6 - 29.8 °C, 29.8 - 30 °C and 30.5- 30.7 °C at depths of 8, 10, 25 and 50 m, respectively. The graph also indicates that the temperatures are almost constant at the same depth for 45 days (see Fig. 6). It is quite likely that subsurface temperatures tend to increase very slightly at deeper depth and with smooth curves as shown in Fig. 6.

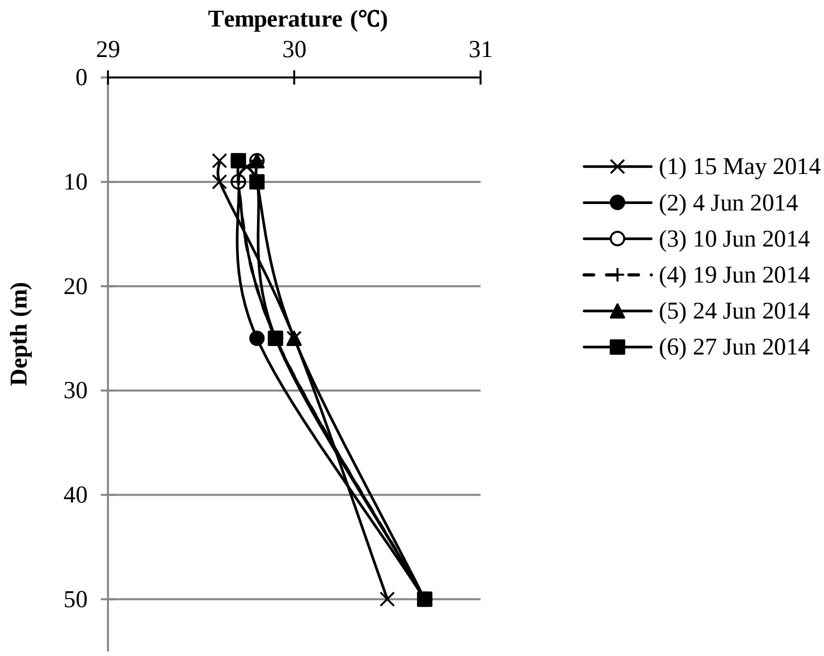

Fig. 6. Temperature profiles of observation well nos.1 and 2 at depths of 8, 10, 25 and 50 m. Note that data logger was installed in August 2014 together with thermistor at depth of 1.5 m (thermistor no. 2) and 3 m (thermistor no. 3), but thermistors at depths of 10, 25 and 50 m were broken before that.

5. Results of temperature monitoring

The data logger (see Fig. 5B) has been set-up to record all the input data in every 20 minutes. The data which have been input include room temperatures, outside air temperatures, inlet-outlet liquid temperatures, flow rates of liquid, subsurface temperatures at depths of 1.5 and 8 m. In this paper, only some selected data taken in the month of August 2015 have been reported. As displayed in Fig. 7, it is likely that subsurface temperatures show smooth curves in comparison with outside air temperature. The result shows that outside air temperatures aren't stable, it is relatively high during daytime and low during the nighttime while subsurface temperatures at depths of 1.5 and 8 m are more stable before increasing rapidly in operation days (4th, 6th, 10th, 13th, 20th and 25th August). However, in normal situation (not operate) underground temperature at depth of 1.5 m is lower than that of 8 m as shown in Fig. 8. In addition, recorded temperature data for the one-day operation has been shown (Fig. 7). The graphs indicate that apart from the outside air temperature curves, the other curves including those showing inlet and outlet temperatures as well as the subsurface temperatures are relatively smooth and shows slightly positive slope. However, after the GSHP started to operate, all temperature curves became increase and the outlet temperature curve is more fluctuated than that of the inlet liquid temperature. Similarly, the subsurface temperature curves shows very smooth curves. For the 8-m depth, the curve shows relatively stable after the GSHP stopped, the subsurface temperature curve at 1.5-m depth is smooth but with a slightly negative slope after operation stopped. We interpret that the effect of solar energy at shallow depth is stronger than that of the deeper depth.

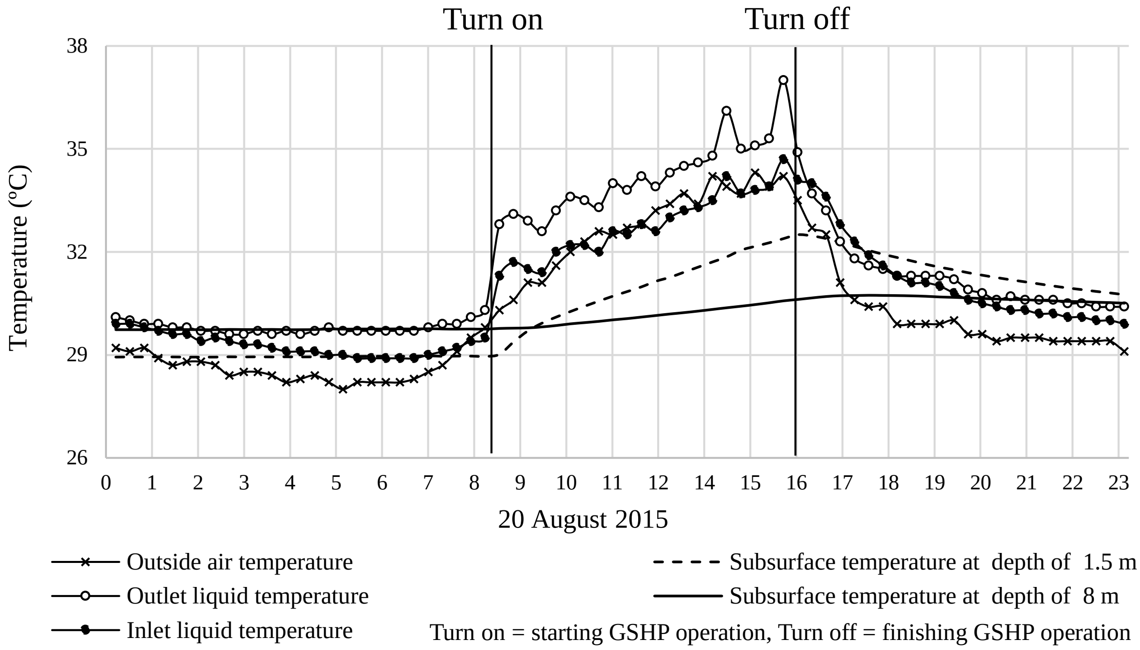

Fig. 7. Ranges of inlet-, outlet-, subsurface- and outside-air temperatures from 0 (12AM) to 23 (11 PM) of 20 August 2015 showing different styles of temperature excursion.

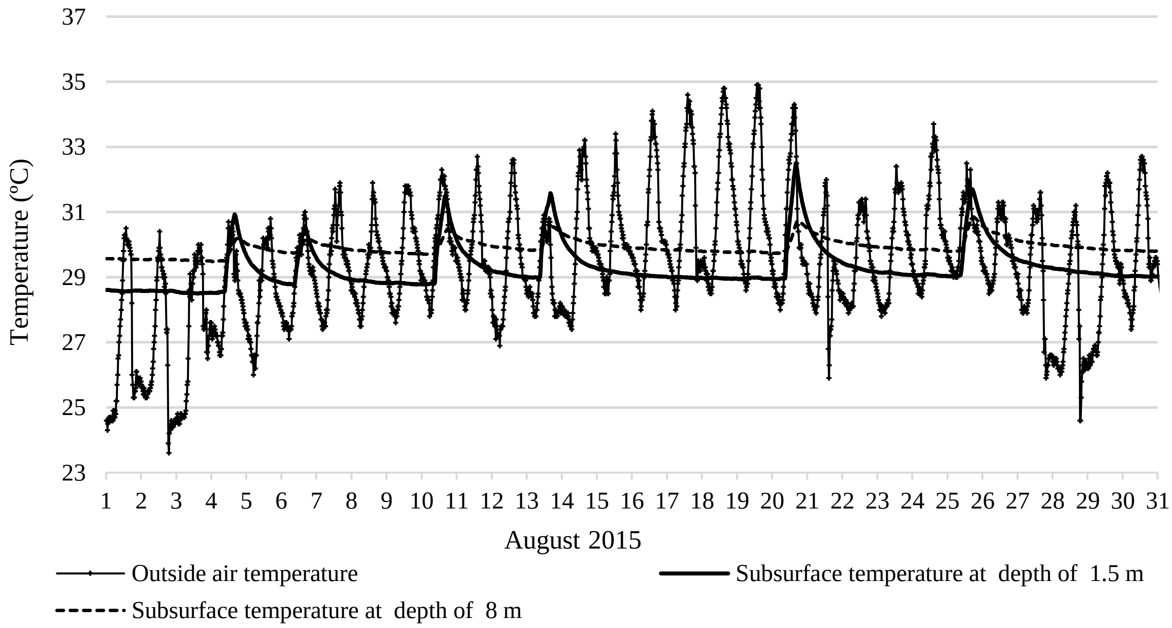

Fig. 8. Fluctuation of various kinds of temperatures that were recorded during the whole month of August, 2015.

6. Seasonal variation of subsurface and outside air temperatures

In the long-term comparison, such as the whole year in this study, outside-air and subsurface temperatures are reported. The outside-air temperatures were recorded during 9.00 to 16.00 whereas the subsurface temperatures were measured at depths of 1.5 to 8 m in each month as shown in Fig. 9. The subsurface temperatures were quite stable within the approximate range of 29 to 30 °C. Moreover, the subsurface temperatures are lower than monthly mean maximum outside air temperatures throughout the year. This scenario are essential in the GSHP installation.

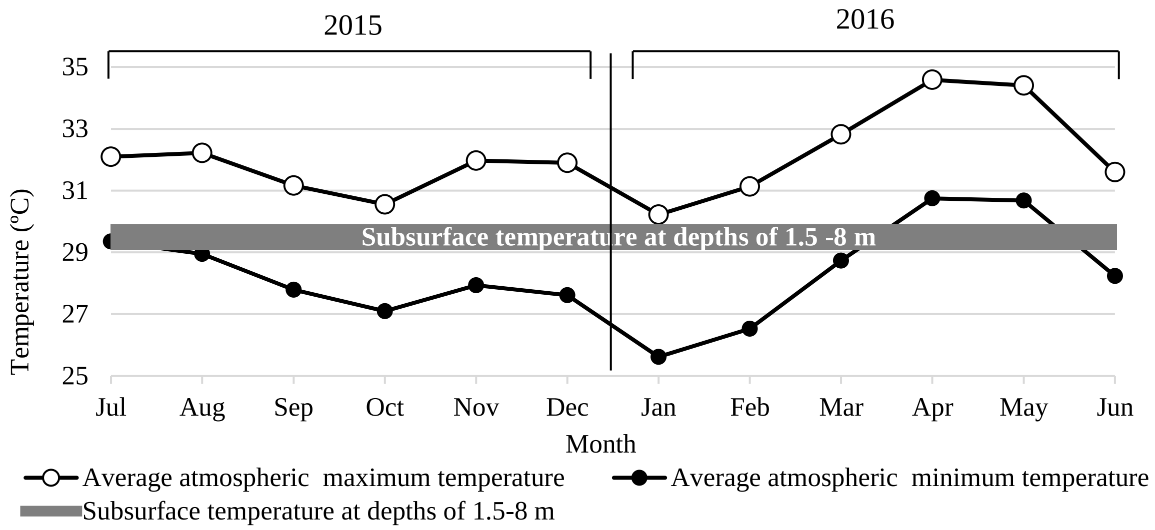

Fig. 9 Comparison of outside air temperatures and subsurface temperatures during July 2015 to June 2016.

7. Comparison with normal air-conditioner (AC)

A comparison has been made for the GSHP air-conditioner and the normal air-conditioner (AC). For convenience, we select to apply 25º C for the room temperature and 1-hour operation for both air-conditioners. The electricity consumption from both air-conditioners have been recorded manually. The result indicates that in one-day (i.e. 1 hours) operation during summer time, the GSHP and normal air-conditioners consumed the average electricity at about 0.4 and 0.6 kilowatts, respectively. According to Chokchai (2016), electricity can be saved at about 30 %. Since we installed GSHP system and normal air-conditioner (AC) in the same room, so electricity measurement has to be selected in almost the same weather and outside air temperature.

As shown in Fig. 10, the electric current unit per hour of both GSHP and normal air-conditioner were high in the hot day and become lower in the cool day. Furthermore, electricity uses of the GSHP system was lower than the normal air-conditioner but percentages of reduction depends on the outside air temperature (Fig. 9).

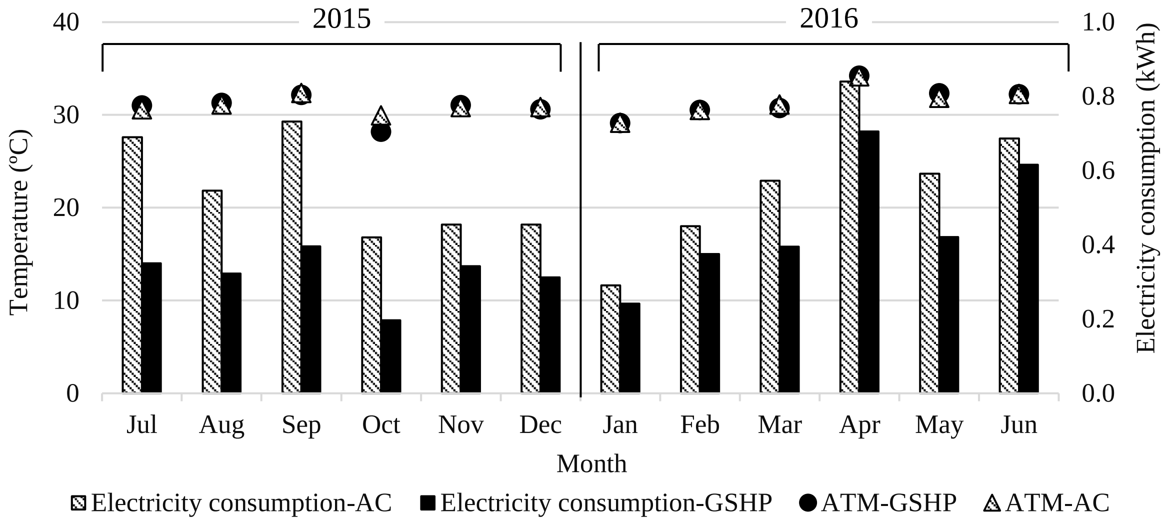

Fig. 10. Comparison of electric consumption between GSHP and normal air-conditioner (AC).

8. Discussion and Conclusions

As mentioned earlier, the GSHP cannot be applied to all the tropical areas. Chokchai (2016) noted that temperature-depth curves at Chulalongkorn University can be compared with those of the other parts of Bangkok reported earlier by Yasukawa et al. (2009). The result shows that our curves conform very well with their curves, suggesting that the GSHP system can be installed for the whole Bangkok region. Additionally, as also shown by Yasukawa et al. (2009), the temperature-depth curves derived from Sukhothai boreholes show quite fluctuation.

The other issue needed to be addressed herein is that shown in Fig. 11. In Bangkok region, the average maximum atmospheric temperatures seem to be almost higher than the subsurface temperatures. A comparison is also made for the subsurface and atmosphere air temperatures at Bangkok (Chulalongkorn University) area and Sukhothai area (see Fig. 11), It is shown that Sukhothai region is not good for GSHP installment. Our reconnaissance survey in Sukhothai area (see also Chokchai, 2016) reveals that bedrocks are much shallow. So this may be the case that thermal capacity deduced from textures of soil and rocks is one of the controlling factors for GSHP installation (Chokchai, 2016). Although quite expensive in the first stage, the GSHP system in the long run is quite a cheaper and cleaner energy technology than fossil fuels. Bangkok is therefore an ideal region to install GSHP with the vertical closed-loop system. However, in the much less populated area the closed-loop GSHP system with a horizontal arrangement is recommended.

Thus GSHP system can be used in many tropical countries, such as Bangkok region underlain by Bangkok clay which has the appropriate thermal conductivity (Chokchai, 2016). Our experiment is a guideline for GSHP installation in the other places having similar underground geology. It is quite likely in the near future that the GSHPs can be utilized in Thailand or at least in Bangkok not only for space cooling at a small scale (e.g. residential buildings) but also space cooling at a larger scale (e.g. commercial/governments buildings, multi-story office buildings, airport terminals, schools, shopping centers, sports facilities).

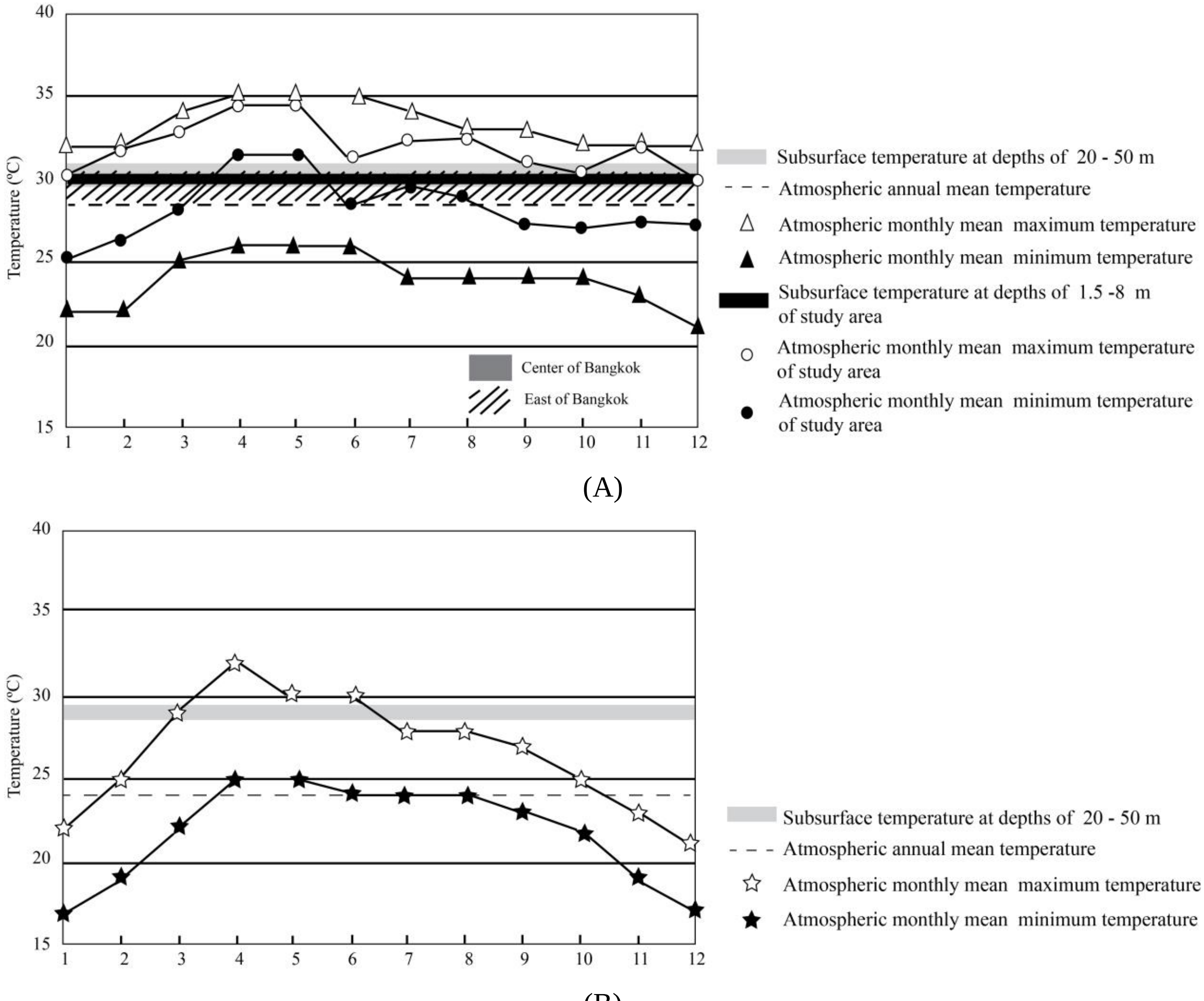

Fig. 11. Comparison of atmospheric and subsurface temperatures at Bangkok (A) and Sukhothai (B) areas.

9. Acknowledgments

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References

Chokchai, S., (2016), *Thermal Exchange from Bangkok Subsoil to Household Air conditioner.* Master's Thesis, Department of Geology, Faculty of Sciences, Chulalongkorn University (in prep.)

Curtis, R., Lund, J., Sanner, B., Rybach, L., and Hellstrom, G., (2005), Ground source heat pumps-Geothermal energy for anyone, anywhere: Current worldwide activity. In Proceeding of the World Geothermal Congress 2005: 3456-3464.

Fridlefson, I.G., (2001), Geothermal energy for the benefit of the people. *Renewable and Sustainable Energy Reviews* 5: 299-312.

Lund, J., Sanner, B., Rybach, L., Curtis, R., and Hellström, G., (2004), Geothermal (Ground-Source) Heat Pumps - a World Overview, *GHC Bulletin,* September.

Takashima, I., Yasukawa, K., Uchida, Y., Yoshioka, M., and Won-In, K., (2011), A Geothermal Heat Pump System in Bangkok, Thailand. In Proceedings of the 9th Asian Geothermal Symposium. Japan: Institute for Geo-Resources and Environment (GREEN), National Institute of Advanced Industrial Science and Institute of Geoscience and Mineral Resources (KIGAM), Geothermal Research Society of Japan (GRSJ) (7-9 November 2011): 96-101.

Uchida, Y., Yasukawa, K., Tenma, N., Taguchi, Y., Suwanlert, J. and Buapeng, S., (2009), Subsurface Thermal Regime in the Chao-Phraya Plain, Thailand. *Bulletin of the Geological Survey of Japan* 60, 9/10: 469-489.

Yasukawa, K., Takashima, I., Uchida, Y., Tenma, N., and Lorphensri, O., (2009), Geothermal heat pump application for space cooling in Kamphaengphet, Thailand. *Bulletin of the Geological Survey of Japan* 60, 9/10: 491-501.

Yasukawa, K., Uchida, Y., Tenma, N., Taguchi, Y., Muraoka, H., Ishii, T., Suwanlert, J., Buapeng, S. and Thi Ha, N., (2009), Groundwater Temperature Survey for Geothermal Heat Pump Application in Tropical Asia. *Bulletin of the Geological Survey of Japan* 60, 9/10: 459-467.