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Experimental Analysis of Solar-Assisted Heat Pump System for School Building in North-Eastern Part of Poland †

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Abstract: The performance of a solar-assisted ground-source heat pump (SAGSHP)system is discussed. The results of observations of ground-temperature profiles in a compressor heat pump installation for the central heating of selected rooms of a school building have been presented.

Keywords: solar radiation; heat pump; vertical ground heat exchanger

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1. Introduction

Ground-source heat pump systems are very well known and popular for heating and cooling buildings. These systems often are expanded by solar collectors andphotovoltaic systems [1]. Many systems work with vertical ground heat exchangers(VGHE) as lower heat sources for the heat pump. The conversion of geothermal energy by heat pump systems is more expensive due to the excavation of geothermal heat exchangers. Research and developments areobserved with a solar-assisted compression heat pump. The performance of a solar-assisted ground-source heat pump (SAGSHP) system is a new type of high efficiency. It can improve heat conversion rates in the system. A review of models and applications of the vertical borehole ground-coupled heat pumps are presented in [1]. A detailed review on the research and development of solar-assisted compression heat pump systems are reported in [2,3]. According to article the integration of solar energy with heat pump systems have a vital role in reducing both the consumption of conventional energy sources and its environmental impacts.

Poland is located in the temperate warm transitional climate zone, with the temperatures during winter dropping to under minus 20 degrees. The performance often decreases due to an unbalanced ground load. Solar thermal collectors can help to ensure that systems are installed in zones such as Poland [4]. SAGHP simulation in a cold climate was investigated in [5,6]. Experimental investigation of SAGSHP has been carried outin [7,8]. The experimental results indicate that the system operation efficiency can be improved by the assistance of solar energy.

2. System Description

The results of observations of ground-temperature profiles in a compressor heat pump installation for the central heating of selected rooms of a school building have been presented. The experimental platform was installed in the building "*INNO–EKO–TECH Innovative Research and Didactic Centre for Alternative Energy Sources, Energy Efficient Construction and Environmental Protection*" at the Bialystok University of Technology, north-eastern Poland.

The SAGSHP operates as two independent systems. The first system works as a ground thermal storage system with solar collectors in the summer season, while the second system is a heating system based on a compressor heat pump. Both systems use as main component vertical ground heat exchanger (VGHE). There are three ground heat exchangers (GHE) at about 70 m, 85 m, and 100 m of depth, and three control probes for verification of the ground-temperature profiles. The measurement sensors are positioned at up to 100 m of depth. The brine volumetric flow and temperatures at the inlet and outlet of the all boreholes were measured. Depending on the season time, the heat flow is directed to the ground–summer or from the ground–winter season.

During the heating season, the temperature of the heat source drops. The boreholes were regenerated during warm seasons by heat from the solar collectors. The temperatures of the regenerated boreholes by the solar collectors are higher after the warm season. Solar collectors work together with the vertical ground heat exchanger (VGHE) through a water tank. The exact description of the system is presented by the author in [9,10].

3. The Results of the Experiment

The ground structure profile for all the boreholes was similar. Figure 1 presents the temperature fluctuations for VGHE no. 1 in the vicinity of the heat exchanger in the selected months of the year. The length of the heat exchanger no 1 was 70 m.

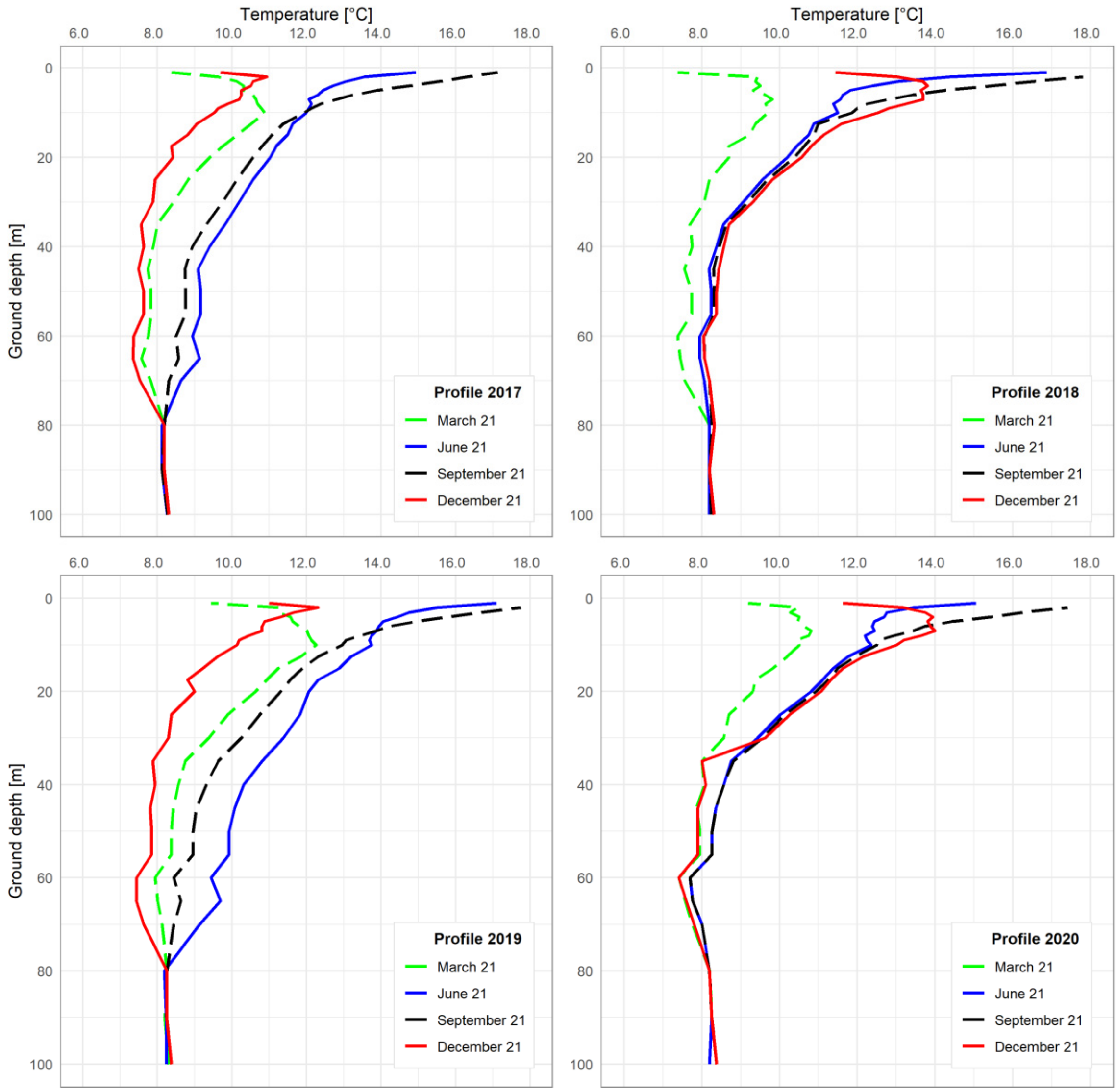

Figure 1. The temperature fluctuations for VGHE no. 1 in the system during four years ofthe selected months of the year.

The heating season ends in early May. Since that time, there was a return process to the thermal balance. Additionally, the heat flux from the solar radiation was directed to the ground. By the end of the summer season, the temperature of the ground was rising, as visible in Figure 1. The average temperature rise was at about 2K, above the undisturbed, steady-state temperature. During the heating season, the temperature dropped from mid-September and the heat was drawn back from the ground.

Despite temperature fluctuations, there was a significant increase in the temperature visible after the summer season. It is worthy to note the shape of the curves between about 10 m and up to about 50 m of depth. The literature describes that on this level, the temperature remains constant. It may be explained by the natural undisturbed ground temperature or by the impact external conditions after earthworks. It may also be a reason to pay more attention to oblique wells due to the higher ground temperatures at this point for the analyzed area.

Temperature changes for two different operating states of the VGHE are presentedin Figures 2 and 3. Figure 2 presents the temperature fluctuations for VGHE no. 1 with two years of operation in SAGHP, namely 2017 and 2019. The operation of VGHE no. 2 during 2017, 2018, and 2019 is presented in Figure 3. Despite the long operating time of the system, the soil regeneration process was effective. After each work cycle, the ground was regenerated. Moreover, at the beginning of the heating season, the temperature in the vicinity of the ground was two degrees higher above the undisturbed condition in the ground.

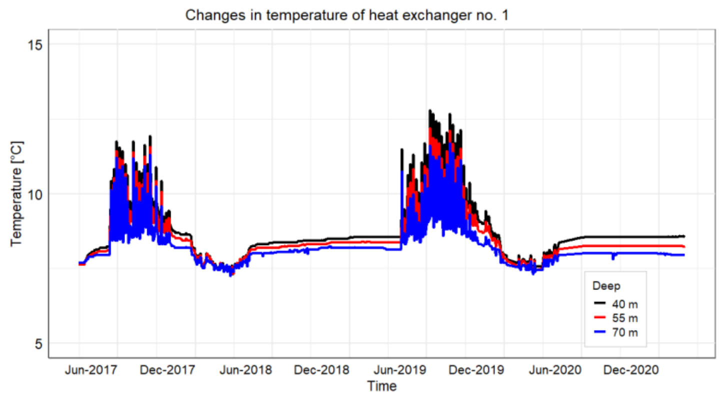

Figure 2. The temperature fluctuations for VGHE no. 1 at 40, 55, and 70 m of depth.

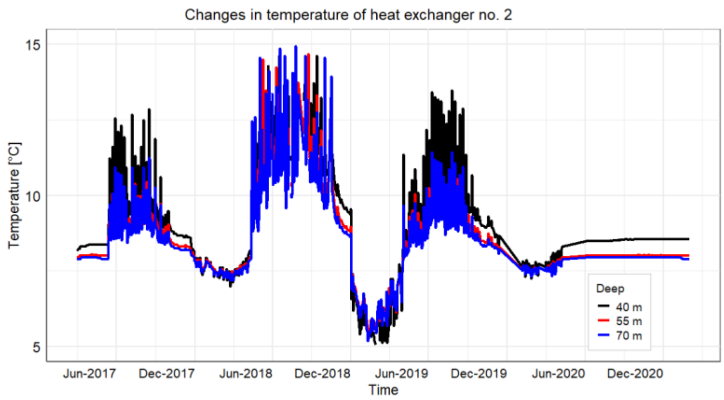

Figure 3. The temperature fluctuations for VGHE no. 2 at 40, 55, and 70 m of depth.

The objectives of this research study,, was to present the effectiveness of SAGHPS, the temperature changes in the vicinity of VGHE during the heating season, and the solar-assisted ground-source heat pump operation. Regardless of the research results, the boreholes regeneration process is a very important process in the optimal operation of the heating system based on compressor heat pumps in transitional climate zones, such as in Poland. SAGHPS seems to be an active regeneration process of a borehole and can be achieved with relatively simple methods. Solar-assisted ground-source heat pumps can stabilize the borehole temperature and ensure the increased effectiveness of the system.

4. Conclusions

The paper presents changes of ground temperature in three boreholes with similar geological structure and the same technology for heating system based on heat pump with the solar-assisted ground-source heat pump (SAGSHP) system. During the heating season the heating system operates like a classic heating system based on compressor heat pump. During the summer season the system works as ground thermal storage system with solar collectors. The results show the borehole temperature is variable and dependent on the amount of energy drawn by the heat pump and energy transfer to the ground by solar collectors in summer season. The biggest borehole temperature changes in the vicinity of the vertical ground heat exchangers (VGHE) occur in the first few days when the system starts operating. It can be seen, Figure 2 and 3, relatively large temperature fluctuations, from near 8 °C to more than 15 °C. It is related to the proximity of the location the measuring probe from VGHE. It is important that the ground temperature increases after the summer season. In this experiment, the temperature increased by an average near 2 °C over the summer season above the undisturbed, steady state temperature, Figure 1. Temperature differences are greater as the ground depth decreases. Changes in the three-year follow-up period seem to be stable.

Thanks to the SAGSHP system regeneration of the ground is very fast. In the summer 2018, when VGHE no. 1 did not work, Figure 2, self-regeneration of the ground was very slow. In that case, the temperature rise has been limited to the sum the undisturbed ground temperature and influence of the adjacent exchangers. During this period 2018, for VGHE no. 2 the temperature has risen relatively quickly. The maximum temperature of the boreholes during the SAGHP system operation did not exceed 15 °C. There is no overheating of the ground.

At the beginning of the heating season, the heating system with SAGHP system starts to operate with the temperature difference, between the upper and lower heat source, of about 2 °C lower comparing to the traditional system without SAGHP. The outcome is not spectacular but it has a direct impact on the operating costs of the heating system. In countries with a cold climate, 2 °C is a big difference.

It is worth noting the shape of the profile that is not constant below the zone 10 m depth. The results may suggest that it is worth analyzing inclined heat exchangers for this type of the soil. The article presents the trends in the yearly temperature fluctuations with active regeneration.

Basing on the data from the experiment, it is planned to analyze the energy and economic efficiency of the SAGHP system based on the heat pump and to develop a model for SAGHP system analysis for different heat pump sizes and different energy balances.

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Ethical review and approval were waived for this study. No human or animal participation.

Data Availability Statement: Details data supporting reported results can be found at HVAC, Bialystok University of Technology.

References

1. Yang, H.; Cui, P.; Fang, Z. Vertical-borehole ground-coupled heat pumps: A review of models and systems. *Appl. Energy* **2010**, *87*, 16–27. [CrossRef]
2. Mohanraj, M.; Belyayev, Y.; Jayaraj, S.; Kaltayev, A. Research and developments on solar assisted compression heat pump systems—A comprehensive review (Part A: Modeling and modifications). *Renew. Sustain. Energy Rev.* **2018**, *83*, 90–123. [CrossRef]
3. Mohanraj, M.; Belyayev, Y.; Jayaraj, S.; Kaltayev, A. Research and developments on solar assisted compression heat pump systems—A comprehensive review (Part B: Applications). *Renew. Sustain. Energy Rev.* **2018**, *83*, 124–155. [CrossRef]

4. Badiei, A.; Golizadeh Akhlaghi, Y.; Zhao, X.; Shittu, S.; Xiao, X.; Li, J.; Fan, Y.; Li, G. Achronological review of advances in solar assisted heat pump technology in 21st century. *Renew. Sustain. Energy Rev.* **2020**, *132*, 110132. [CrossRef]
5. Wang, Q.; Huang, Q. Research on integrated solar and geothermal energy engineering design in hot summer and cold winter area. *Procedia Eng.* **2011**, *21*, 648–655. [CrossRef]
6. Emmi, G.; Zarrella, A.; De Carli, M.; Galgaro, A. An analysis of solar assisted ground source heat pumps in cold climates. *Energy Convers. Manag.* **2015**, *106*, 660–675. [CrossRef]
7. Yang, W.; Sun, L.; Chen, Y. Experimental investigations of the performance of a solar-ground source heat pump system operated in heating modes. *Energy Build.* **2015**, *89*, 97–111. [CrossRef]
8. Verma, V.; Murugesan, K. Experimental study of solar assisted ground source heat pump system during space heating operation from morning to evening. *J. Mech. Sci. Technol.* **2018**, *32*, 391–398. [CrossRef]
9. Rynkowski, P. The influence of the solar-ground heat pump system on the ground temperature in the boreholes and in their vicinity—Study based on experimental data. *E3S Web Conf.* **2019**, *116*, 00067. [CrossRef]
10. Rynkowski, P. The energy source for heat pumps with vertical heat exchangers. *E3S Web Conf.* **2018**, *44*, 00157. [CrossRef]