IT-Based Feasibility Assessment of a Shallow Geothermal System in a Renovated Educational Building in Kragujevac

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Abstract

Within the framework of the Interreg Danube GeoHeCo project, pilot investments in selected countries tested innovative IT tools for planning heating and cooling shallow geothermal energy (SGE) systems. Based on these activities, a comprehensive transnational report was developed to identify lessons learned, assess the benefits, and assess the replication potential in countries without pilot investments. The paper presents the key findings of that report, focusing both on the practical results of the pilot implementations and on the broader strategic value of the developed tools and methodologies. Particular attention is paid to countries that did not host physical investments (such as Serbia) but contributed through technical documentation, feasibility insights, and preparatory knowledge for future implementation outside the project framework. The analysis shows how much non-investment participation can still generate significant value by strengthening institutional readiness, technical capacity, and strategic planning for future deployment of SGE. Finally, the paper makes policy recommendations aimed at facilitating wider adoption of SGE technologies and improving cross-border knowledge transfer.

Keywords: Renewable energy sources, Geothermal energy, Danube Region, UN SDG 7

1. Introduction

The Faculty of Engineering in Kragujevac was originally formed as the Faculty of Mechanical Engineering in Kragujevac on October 1, 1960. As a department of the Faculty of Mechanical Engineering in Belgrade, it started working on October 9, 1960, in the premises of the First Kragujevac Gymnasium. The first buildings were built next to the Upper Park in 1962 [1]. Today, the Faculty of Engineering includes 4 buildings marked as buildings A, B, C, and D (Figure 1).

Building D is the oldest building of the campus (built in 1962), in 2018 its renovation started, and it included replacing all windows with high-efficiency triple-glazed PVC windows and double-glazed aluminum doors, while the part of the facade was insulated with 10 cm of rock wool. Currently, all buildings of the faculty are connected to the district heating system, whose tariff system proved to be very unfavorable for the Faculty. In this regard, the faculty considered two scenarios: i) Two buildings switch to an alternative heating system, ii) all buildings switch to an alternative heating system. Which solution will be chosen depends on available investment funds.

Out of all renewable energy sources, only solar, geothermal, and biomass are usually converted into heat, while landfill gas, sewage treatment plant gas, and biogases are usually converted into electricity on-site or are still in the development stage [2]. Geothermal energy is a renewable energy source with significant potential to infiltrate the central heating system and decarbonize it [3]. Overall, geothermal energy can help us achieve fossil fuel dependency [4] and reduce carbon emissions significantly [5]. This paper analyzes the possibility of switching building D to shallow geothermal energy. This building was chosen due to the high performance of its envelope (after renovation) and its large area.

Figure 1. Faculty of Engineering Campus

2. Input parameters of the planned geothermal system with the conventional existing system

Input parameters are given in the table below (Table 1).

Table 1. Input parameters of the planned geothermal system

INPUT PARAMETERS	
Gross floor area	5344 m2
Specific heat consumption	163 kWh/m²/year
Nominal thermal capacity of ground-source HP system	300 kW
Number of boreholes	40
Deepness of boreholes	120 m
Diameter of the boreholes	40 mm

The IT Tool for this analysis is a web-based decision support tool (available at [6]) for assisting optimal usage of hybrid heating and cooling systems in the Danube region in order to avoid situations of over-sizing or under-sizing the number/depth of wells, i.e. in order to optimize the cost of system installation. Main features of the tool are: long-term simulation of all relevant phenomena, visualization of results in a form of timeseries, assistance in optimal choice for borehole heat exchanger length and bivalent temperature, calculation of

levelized cost of heat. It was developed during 2.5 year long Interreg Danube project called "Danube GeoHeCo", in which professors and researchers of the Faculty of Engineering participated actively. The IT tool was also fed with additional (but not presented) input data about working fluid, pipes, grout, ground, and groundwater.

3. Results

The results of the IT-Based feasibility assessment of a hybrid system combining a shallow geothermal system and a gas boiler for renovated building D are shown through Figure 2, depicting long-term borehole temperatures and power consumption, Figure 3 showing heat balances time-series and coefficient of performances, and Figure 4 illustrating annual energy balances.

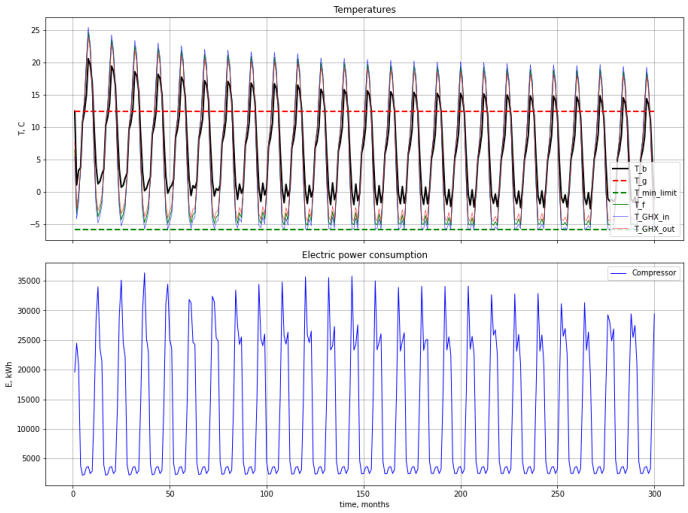

Figure 2. Results: Long-term borehole temperatures and power consumption

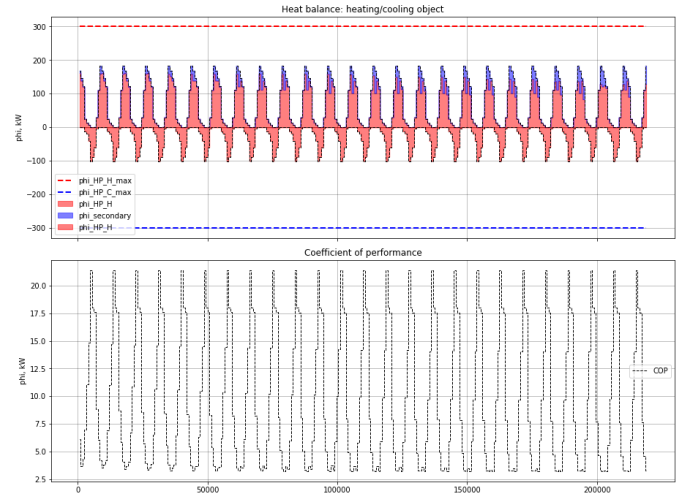

Figure 3. Results: Heat balances time-series and coefficient of performances

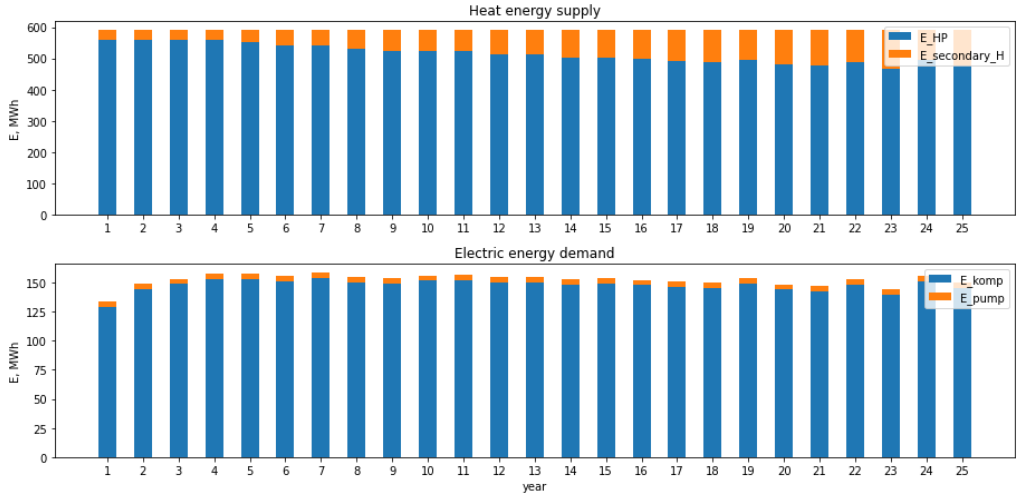

Figure 4. Results: Annual energy balances (heat and electric)

4. Conclusions

The IT-based assessment of the shallow geothermal system on the renovated (but oldest) building of the Faculty of Engineering campus gave positive results. Namely, the results show that a properly dimensioned ground-sourced geothermal heat pump system can meet the heating needs of the mentioned building while maintaining the long-term thermal stability of the ground. Overall, a shallow geothermal system can operate efficiently as a base load heating source, while the gas boiler could cover the peak loads during periods of extremely low temperatures. Such a hybrid configuration would ensure both reliability and resilience of the heating supply, why allowing for significant reductions in fossil fuel consumption and associated CO_2 emissions.

From a technical and environmental perspective, this study confirms that shallow geothermal energy represents a viable and renewable option for the decarbonization of the Faculty of Engineering campus heating system. Further detailed design and economic optimization studies are recommended to refine the system sizing and assess the return on investment.

Acknowledgements

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