Study Results and Achieving High Ventilation Air Quality in Architecture for a Public Utility Building – Shopping Centre in Mielec, Poland

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Abstract. The purpose of the current study is to utilise a novel technology that is expected to bring reductions in electrical and heat energy consumption and cut CO₂ emissions in the shopping centre public utility building in Mielec. The building is equipped with systems for obtaining heat and cold from groundwater and features the energy consumption level of a passive building with the lowest primary energy ratio (PER) in Poland. This state-of-the-art, innovative, energy-efficient and environment-friendly FCH system with BMS control was subjected to numerous tests and analyses, the details of which will be presented further in this paper. The design assumptions were confirmed and all work parameters were recorded for the system under extreme conditions, including the determination of final energy (FE) and primary energy (PE).

1. Introduction

The subject of this paper is the study of a public utility building, specifically a shopping centre in Mielec (Poland)[1], carried out as part of the programme of “Research for achieving high air quality in architecture and urban planning” by a team from the Institute of Architectural Design at the Department of Contemporary Architecture of the Faculty of Civil Engineering and Architecture, Lublin University of Technology since 2018 [2-4] (with two other studies published in 2019 [5], the “WICA” Academic teaching building at a hinger education institution, Lublin University of Technology, [6-8] the Historic Potocki Palace in Radzyń Podlaski).

The global climate change and mean temperature increase, melting glaciers, wildfires, hurricanes, droughts and other natural disasters are a sufficient sign to approach the current state of the natural environment seriously, as it is aggressively destroyed every day with the increasing CO₂ emissions and cannot be restored on its own. The efforts to mitigate climate change undertaken for several decades have so far completely failed, not just because of Europe, but mainly America and Asia. Similarly, the Polish energy sector, which is largely based on hard coal mining, as it stands today, does not contribute to reductions in CO₂ emissions. Although 2020 is not expected to introduce a radical shift towards reducing the carbon footprint, we must stay on the path of implementing the Paris Climate Agreement.

In the coming years, the continued failure to reduce CO₂ emissions and the increasing environmental degradation will lead to temperature increases, among other problems. This will necessitate the universal adoption of air conditioning systems in residential areas, which will only increase the consumption of...
energy, a commodity already in short supply. Higher energy consumption will automatically lead to higher CO\textsubscript{2} emissions. To prevent these phenomena, it is essential to take action leading to the reduction of CO\textsubscript{2} emissions as soon as possible. The technology described in this article, as the first such implementation in Poland and Europe, demonstrates how a modern public utility building, a 32,000 m\textsuperscript{2} shopping centre located in Mielec, Poland, featuring a HVAC system produced in 2016, can be heated and cooled by natural means. The presented solution is the best example of using RES for heating and cooling buildings with a minimum of 50\% final energy consumption reduction following the installation of a Free Cooling and Heating (FCH) technology. [9-11]

To determine the status of the described technology among the geothermal energy types and application examples of the Polish Geological Institute, National Research Institute, the Authors defined the area, as shown in Figure 1, and described examples of application of the Free Cooling and Heating technology. The figure shows the mean depth of the technology up to 50 m, which confirms the low investment costs, as well as the air cooling and heating capabilities of HVAC systems with reduced costs of primary energy consumption to a level compliant with the Polish Technical Conditions.

![Figure 1. Technology and geothermal energy – example applications. Source: Polish Geological Institute, National Research Institute](image)

2. Determining The Pe H+V (Partial Maximum Value of The Primary Energy Ratio for the Purposes of Heating, Ventilation and Domestic Water Heating, in Polish Regulations: Ep H+W) Value in Accordance with the Technical Conditions Applicable in Poland.

The PE H+V values were determined on the basis of comparing the systems involving:
- water loop heat pumps (WLHP)
- the suggested Free Cooling and Heating (FCH) technology.

The following conclusions can be drawn from an analysis of the results; The geothermal installations presented by the Polish Geological Institute fail to meet the Statutory requirements specified in the maximum values of PE\textsubscript{H+V} contained in the applicable
A comparison of the presented technology and heat pump systems leads to the following conclusions:

- The capital cost of heat pump systems is 270% higher than that of the presented technology.
- The operating cost of heat pump systems is 800% higher than that of the presented technology.

3. The Technology of Obtaining Energy from Groundwater

The Free Cooling and Heating technology is capable of obtaining renewable energy from groundwater for heating and cooling air in HVAC systems in civil engineering structures. Figure 2 [9-12] presents the detailed information and a diagram of the system.

Currently, with the traditional system, the heating and cooling energy is produced e.g. in water chillers. Chilled water is produced using electrical energy, 7 °C feed and 12 °C return in freon-based systems, e.g. in heat pumps.

The basis for the described technology is the groundwater temperature, which at a depth of 10 m (Figure 2) [9-12] is ca. 10 °C. The natural environment provides us with free energy having identical parameters as that produced using electrical energy in freon-based systems. These parameters made groundwater the perfect choice for using in HVAC systems to replace water chillers, which also drastically reduces operating costs while maintaining the required indoor parameters.

The diagram presented in Figure 2 shows the structure of the overground system, air handling unit and air distribution manifold and the underground system from the distribution manifold well to the vertical exchanger system finished with a head. [9] [10-12]
Figure 2. Diagram of the basic system featuring a technology of obtaining energy from groundwater
Source: The authors.

The energy is exchanged in several stages: horizontal and vertical PE tubing and vertical tubing made of acid-resistant steel. The power of a system can be easily determined by only using the heat transfer coefficient of PE tubing and steel tubing. Vertical exchangers made of steel tubes in the borehole transfer or obtain multiple times more energy from groundwater than PE tubes. The collected energy covers the demand for heating and cooling of the HVAC system, reducing the operating costs several times.

Another stage of obtaining the heating and cooling energy is the conversion of energy in special energy-efficient air handling units, which feature by-pass systems allowing them to further reduce electrical energy consumption. The schematic drawing of an air handling unit shows the highest resistance values and the location of highest losses (Pa) (Figure 3) [13].
Figure 3. Economical air handling unit, schematic drawing Source: The authors.

Every unit of this technology features a ground heat exchanger with vertical boreholes to a depth of ca. 20 m, in which heat/cold is recovered from groundwater. The individual boreholes are connected into systems which feed the multi-section distribution manifolds (depending on the system there are distribution manifolds located in external wells or wall distribution manifolds in the building’s rooms). The drilled wells feature a head, polyethylene PEHD 100 PN10 SDR17 tubes and steel inserts made of thin-wall acid-resistant tubes which facilitate cold/heat exchange. Multi-section distribution manifolds are mounted at the junction of the lower source with the internal system. In external arrangements, these devices (e.g. SPIDER manufactured by Energeo) are located in external wells (i.e. wells equipped with D400 manhole covers), while for internal arrangement internal multi-section distribution manifolds are used. The internal system was constructed as a forced-circulation double-pipe closed-circuit system. The elements that ensure the desirable flow parameters of the agent in the system are circulator pumps installed at the supply duct and the air handling units. The authors would like to draw attention to the described pumps, which are often confused with heat pumps. This comparison is not fair, because the whole system is based on circulator pumps and has nothing in common with the described heat pumps; the heating/cooling agent is a 35% solution of ethylene glycol, which protects the system against extreme temperatures. The presented technology is described in detail in the patent documents: in the Republic of Poland and Europe (Biuro, 2012, 2015, 2016, European 2016).

4. Technology Use Case in the Shopping Centre in Mielec
It should be remembered that indoor air, its humidity, temperature and cleanliness directly affect the health and well-being of every building’s residents and users. Public utility buildings, such as shopping centres (Figure 4-7), are not only workplaces for their employees, but also major hubs for the social life and shopping needs of nearby residents. Buildings of this type are characterised by a high variability of thermal loads, as well as a high density of people, depending on the time of day and season. The primary condition for achieving an appropriate microclimate and air quality is well-designed ventilation. The function of ventilation is the exchange of used-up air from closed rooms and the removal of gases, organic matter, bacteria and fungi. By introducing the described technology, the investor obtained environment-friendly heating and cooling energy for the HVAC system. This paper focuses on studies and results obtained over a period of 18 months of HVAC operation. It should be emphasised that the presented building is located in south-eastern Poland, has a traditional structure and reproducible function. Drawing on the results of measurements and analyses, the authors demonstrate how the air should be exchanged and how heating and cooling energy should be collected from groundwater, while reducing electrical energy and district heat consumption in accordance with the applicable Technical Conditions and using the minimum amount of primary energy (Project 2016). [14, 2]
The roof features the installed system components, including modern energy efficient air handling units. As shown, there are no ducts on the roof, which reduces unnecessary gains and losses from heating and cooling energy. The installation of air handling units also ensures a reduction of local losses and resistance, which brings down the operating costs and results in lower CO\textsubscript{2} emissions.

5. Results Analysis on The Basis of System Implementation in Mielec
To determine the correct value of final energy (FE), the BMS was additionally equipped with:
1. electric meters for air handling units CG1, CP4, CS1
2. electric meter for Node W4
3. heat meters for air handling units CG1, CP4, CS1.
5.1 Indoor air parameters
The values of indoor temperature and humidity, calculated for air-conditioned rooms, comply with the Polish standards and with the Investor’s guidelines.

Analysis of the Operation of a Model Air Handling Unit CS1 – Groceries at the Mielec Shopping Centre, Bms View.

![Diagram](image)

**Figure 8.** A schematic view of the operation of the BMS for the HVAC system for the period winter 2017. In extreme winter temperatures at $T_z = -18.5 \, ^\circ C$ the system maintains the indoor temperature of $T_w = 16.0 \, ^\circ C$ (6.40 a.m.) The facility is operated from 9.00 a.m. with the recovery temperature from groundwater of 6.8 °C feeding with glycol at 7.0 °C and temperature beyond the rotary heat exchanger of 17.1 °C (RES energy) and ventilation of 26.2 °C. Determining heat energy savings in a simplified layout of control station CS1. The control station provides the room with incoming air in the amount of $V_n = 9,000 \, m^3/h$ with the outdoor temperature $T_z = -18.5 \, ^\circ C$, which after flowing through the pre-heater, is heated with groundwater energy at glycol temperature $T_g = 7.2 \, ^\circ C$ to temperature $T_2 = 6.8 \, ^\circ C$. The value of renewable energy obtained from only this part of the system is $0.34 \times 9,000 \, m^3/h \times 25.3 \, ^\circ C = 77 \, KW$. Source: The authors.

![Graph](image)

**Figure 9.** The result for final energy (FE) consumption in the period December 2016 – July 2018. A comparison of a system fed by district heating and, as an alternative, electrical energy. The authors
6. Conclusion
The final energy consumption and HVAC system diagram presented in Figure 8 provides optimistic insights not only for Poland, but for the whole world. There is a technology, which in a matter of 10 years might significantly reduce air pollution and electrical energy consumption, cutting CO₂ emissions. Poland is still far from being at the forefront of the fight for clean air and recognising the dangers of air pollution, such as residents are dealing with e.g. in Kraków. Similarly, there are no measures to significantly cut energy consumption and fight CO₂ emissions, and no real reduction in energy consumption. On the contrary, consumption and emissions have been increasing in recent years. By analysing the chart (Figure 9) and the presented measurements, the authors determine the correct parameters for HVAC systems. The results of operating a HVAC system over a period of 18 months confirm the very low operating costs at the level of **EK=3.07 EUR/m²/year**. Such an excellent result for final energy provides an opportunity to popularise real green energy stored in the huge groundwater deposits, which may translate into a minimum 50% CO₂ emission reduction in the near future. Our papers, presented technology and other independent research demonstrate how this energy can be efficiently utilised.

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