Study Results and Obtaining High Ventilation Air Quality in Architecture for an Old Shopping Centre Public Utility Building with Modernised EL. Heating in Warsaw, District, Poland

Jan Wrana¹, Wojciech Struzik²

¹Lublin University of Technology, Faculty of Civil Engineering and Architecture, Department of Contemporary Architecture, Poland
²WAKAD sp. z o. o., Daszyńskiego str.4, 20-250 Lublin, Poland

j.wrana@pollub.pl

Abstract. The subject of this paper is the study of a public utility building, a shopping centre in Warsaw/Targówek, carried out as part of the programme of “Research for obtaining high air quality in architecture”, with modernised electric heating system. by the team of. the Department of Contemporary Architecture, (architectural design) in new building [3, 4]” Wica ” Eastern Innovation Centre of Architecture.-Lublin University Of Technology, Faculty Of Civil Engineering And Architecture.

1. Introduction
The subject of this paper is the study of a public utility old Shopping Centre in Warsaw/Targówek, carried out as part of the programme of “Research for obtaining high air quality in architecture”, [1, 2] with modernised electric heating system. by the team of. the Department of Contemporary Architecture, (architectural design) in new building [3, 4]” Wica ” Eastern Innovation Centre of Architecture.-Lublin University Of Technology, Faculty Of Civil Engineering And Architecture.

In accordance with the applicable regulations, each building must follow the Technical Conditions and meet the maximum primary energy (PE) levels specified in the Regulation of the Minister of Infrastructure of 12 April 2002 on the technical conditions to be met by buildings and their location, Journal of Laws of the Republic of Poland. Warsaw, 7 June 2019, item 1065 Announcement By The Minister Of Investment And Economic Development 1) of 8 April 2019 on announcing the consolidate text of the Regulation of the Minister of Infrastructure on the technical conditions to be met by buildings and their location.

As the Technical Conditions clearly specify the partial maximum values of the PE H+V kWh/m²/year, it would be useful to analyse these values and attempt to answer the question why so
few places meet these requirements in Poland and Europe. In addition, since the entry into force of the Act designers and investors have expressed little understanding for heat and electrical energy consumption reductions, which often has the opposite effect to what was intended. In some cases, this situation leads to increases rather than reductions in CO2 emissions.

A good example are heat pumps and WLHP systems, as their installation significantly increases environmental pollution. This paper discusses what should be done and how designers could be persuaded to observe the law and design for lower-than-threshold-value heating, cooling and electrical primary energy consumption in HVAC systems.

The fundamental issue is the interpretation by multiple entities in the design and construction law verification process of the PER (primary energy ratio) in energy performance certificates for buildings and the frequent confusion of PE (primary energy) and FE (final energy) while forgetting that PE is the amount of energy obtained from source and required to meet the demand for heating and preparing domestic hot water, mechanical ventilation, and air-conditioning. Its value with considerable electrical energy consumption is three times higher than the final energy powering devices.

If the current methods of design and interpretation of the Technical Conditions continue to be used, then, as demonstrated below, we will only be producing and emitting higher amounts of CO2. It is true that in a large number of cases the Technical Conditions, and particularly the restrictions involving primary energy, make it impossible to carry out construction and redevelopment works. The values suggested by the Ministry are frequently unattainable without increased funding and a shift in the way of thinking, as well as the introduction of energy-saving and environment-friendly devices and systems.

Figure 1. Presents the realistic costs of a HVAC system installation, including operating costs. Traditional HVAC systems – 1, 2, 3, and the first Polish FCH technology – 4, 5. Source: The authors.

As shown, there are no technologies and devices in traditional HVAC systems in Poland that could meet the maximum primary energy values. As shown in the presented chart, Figure 1, traditional HVAC systems, items 1, 2, 3 are burdened by very high operating costs. 
By analysing the presented data and the average rate of **EUR 22**, we can draw an unmistakeable conclusion that the presented systems fail to meet the basic requirement described in the Technical Conditions and exceed the maximum values for primary energy consumption. A simplified analysis of operating costs / without accounting for the basis of obtaining FE obtained at source / for EUR 22/m2/year x 4.3 (PLN/EUR) x PLN 0.5/kW = **189.2 kW/m2/year** results in a much larger value than the maximum values for PE consumption specified in the Technical Conditions.

An analysis of the partial maximum value for an Office Building in Warsaw, price level 2009 / after calculating the conversion coefficient in accordance with PE H+V = **512 kWh/m2/year**. [5]

In conducting a similar analysis of the alternative and energy-saving Free Cooling and Heating (FCH) technology, we will determine the PER as in Figure 1 / after calculating the conversion coefficient in accordance with the Technical Conditions / as shown, its value is PE = 57 kWh/m2/year and does not exceed the maximum primary energy ratios in item 4.5. Where the operating costs of the HVAC system is EUR 3.35/m2/year x 4.3 (PLN/EUR) x PLN 0.4/KW = **28.81 KW/m2/year**.

As shown below, the maximum value for the FCH technology installed in a 30,000 m2 shopping centre (2016) presented in Figure 2 is PE H+V = **57.00 kWh/m2/year (5)**.

2. The Technology of Obtaining Energy from Groundwater

Shopping centres feature a considerable variability of heat loads and a large occupancy density, depending on the time of day and season. The primary determinant of the microclimate and air quality indoors is 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.

In every building, an operating ventilation and air-conditioning system is a major component in operating costs. The high operating costs include high values of final and primary energies, which involve considerable consumption of heating and cooling and electrical energy. The innovative, energy-efficient FCH technology is a way to minimise these costs while reducing CO₂ emissions. This interesting solution, which combines efficiency with low CO₂ emissions, involves a very simple method to obtain heating and cooling energy from groundwater.

By introducing this technology, every investor can gain access to environment-friendly heating and cooling energy for their HVAC system. This article is based on the studies and test results were obtained over 17 months of operation of a HVAC system. It should be mentioned that the presented building is located in central 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.
Figure 2. Groundwater temperature distribution Source: The authors.

Results of ground and water temperature measurements in boreholes up to 50 m, Eastern Poland Region 2013 (Figure 3).

Figure 3. Temperature distribution, depth up to 50 m, Eastern Poland Region. Source: The authors.
An analysis of the presented charts for measurements performed in 2013 leads to several basic conclusions.
- The studies demonstrated a considerable dependence of the feed temperature on return temperature.
- In a return temperature range from 11.0 °C to 32 °C (Δ 21 °C) and feed temperature increase from 11.0 °C to 21 °C (Δ 10 °C); there is a significant opportunity of sourcing natural energy from groundwater.
- Another interesting conclusion is that the higher the return temperature, in this case 32 °C, the higher the difference and energy recovery.
- Analysis Figure 7 indicates similarly large reserves of energy found in groundwater and considerable opportunity to use this energy in FCH HVAC systems.

The studied systems also show a possibility of HVAC device replacement from energy-intensive water chillers, where the production of 1 kilowatt of cold requires a minimum of 0.3 kW of electrical energy, into FCH systems, where, as demonstrated in the chart, one kilowatt of produced cold uses less than 0.1 kW of electrical energy.

**Figure 4.** Presentation of results, System performance studies Eastern Poland Region, Source: The authors.

Similar results are recorded for efficiency measurements of the borehole by calculating the direct efficiency $P_{\text{FCH HVAC}}$, where the model air handling unit at full heat load sources energy from groundwater over a specific period in the studied location. Figure 4 presents the partial results of measurement, as shown for outdoor temperature above 35 °C. The temperature of incoming air is about 22 °C. The stability revealed in this study confirms the high power of the FCH ground heat exchanger; as shown in the figure, a slight increase in feed temperature from 36 °C to 37 °C from 3.55 p.m. to 4.08 p.m. causes an increase in feed temperature of 0.3 °C. After 4.10 p.m., a further part of the chart shows the return of outdoor temperature to 36 °C and the automatic return of feed temperature to the previous level. By determining the borehole capacity using the simplified method on the basis of the temperature difference we obtained $1,500 \text{ m}^3/\text{h}$ of incoming air x 0.34 x 13 / delta 35 °C. – 22 °C / = 6.63 KW. [1]

### 3. Technology Use Case in the Shopping Centre In Warsaw

Figure 5 presents a schematic drawing of the FCH technology. A HVAC FCH air handling unit (1) with heater (3) and cooler (4) powered by glycol 35% from the ground exchanger heats or cools the air supplied to the air-conditioned room. Fresh air from intake vents (2) to ventilators (5) and the discharge system (6) with an exhaust vent (7) ensure the appropriate indoor conditions and ventilation. From head (13) via the feed and return system (11), (12), through the distribution manifold in the well (10), glycol is directed to node (9), where the circulator pump presses it further to the air handling unit (1) – to the heater (3) or cooler (4), depending on the demand. [6-8]
4. Study Results for the FCH HVAC System, Location: Shopping Centre in Warsaw

The studied building is a shopping centre located in central Poland. It features a compact shape and heating and cooling systems. Its area is 15,000 m² and contains eateries, shops, back facilities and storage areas. The first floor’s back facilities include offices and social areas. The building has no access to gas and district heating, which influenced the decision to introduce two additional FCH assisting systems to the HVAC system.

- The first system features an assisting heat pump for heating and cooling.
- The second system is an electric heating system. [6, 7, 9]

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, are not only workplaces for their employees, but also major hubs for the social life and shopping needs of nearby residents. 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 17 months of HVAC operation. 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 obtained from groundwater, while reducing electrical energy consumption in accordance with the applicable Technical Conditions and using the minimum amount of primary energy.

Cost analyses were conducted on the basis of the operation and consumption of electrical energy by the measured CNW-8 and CNW-9 air handling units and included the costs of heat pumps installed for these units to meet the indoor conditions in accordance. The air handling units are installed on the roof and are included in a single BMS [4, 6-10] control system for HVAC. To calculate all operating costs, the total number of air handling units installed in the building, as disclosed by the investor was assumed, and the value of electrical energy consumption of the studied air handling units was multiplied by the number of air handling units in the sales and offices areas according to the schematic drawing and view of BMS presented in Figure 6.

![Figure 6. The operating screen of the CNW-8 BMS FCH HVAC air handling unit of the studied building. Source: The authors.](image)

A schematic view of the operation of the BMS for the HVAC system for the period winter 2017. In extreme winter temperatures at Tz = -3.5 °C the system maintains the indoor temperature of Tw pom. +22.0 °C. The facility is operated from 9.00 a.m. with the recovery temperature from groundwater of 7.7 °C with glycol fed through the FCH heater, the temperature of the incoming air is +5.6 °C, and behind the rotary exchanger +17.1 °C and 27.6 °C at ventilator. Determining heat energy savings in a simplified system. The air handling unit provides the room with Vn 15,000 m3/h of incoming air at an outdoor temperature of Tz = -3.5 °C, which after flowing through the pre-heater, is heated with groundwater energy at glycol temperature Tg = 7.7 °C to temperature T2 = 6.8 °C. The value of renewable energy obtained from only this part of the system is 0.34 x 15,000 m3/h x 9.1 °C = 46 KW. [5]

![Figure 7. Results of air handling unit operation over 2 winter months of 2018, BMS FCH HVAC](image)

Source: The authors. [5]
RESULTS FROM 1 Dec. 2016 to 2 Apr. 2018

Analysis period 1 Dec. 2016 to 1 Jan. 2017

| Date         | Centrala CNW-8 | Dni | Średnie zużycie | Dzienne kWh |
|--------------|----------------|-----|----------------|-------------|
| 2016-12-01   | 27 291 KWH     | 32  | 6753,4 zł/kWh   | 20 957 PLN/m2 |
| 2016-12-31   | 27 291 KWH     | 32  | 9885,2 zł/kWh   | 22 22,22 PLN/m2 |
| 2017-01-31   | 27 291 KWH     | 32  | 13 673 zł/kWh   | 34 99 581 PLN/m2 |
| 2017-02-28   | 27 291 KWH     | 32  | 43 667 zł/kWh   | 43 667 PLN/m2 |
| 2017-03-31   | 27 291 KWH     | 32  | 43 667 zł/kWh   | 43 667 PLN/m2 |
| 2017-04-30   | 27 291 KWH     | 32  | 43 667 zł/kWh   | 43 667 PLN/m2 |

Figure 8. Results of air handling unit operation over 3 days of 2018, BMS FCH HVAC, presenting the scale of recovery / shown in green / of groundwater energy in a period of low temperatures. Source: The authors. [5]
The results presented in the Figure 7-9 were achieved by installing an FCH HVAC system without district heating in a configuration with small heat pumps with direct evaporation in air handling units and an electric heating system section. The result for 2 winters does not exceed EUR 4.18/m²/year.

5. Conclusion
The presented final energy consumption charts of the FCH HVAC system are optimistic not just for Poland, but for the world as well. We are confident that the demonstrated results confirm the purposefulness of using such solutions in accordance with the applicable Technical Conditions. An analysis of the results and indoor parameters in rooms confirms all the system assumptions, including low 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 or Silesia. There is no real reduction in energy consumption. On the contrary, CO₂ consumption and emissions have been increasing in recent years. The presented analyses of charts conducted measurements and very low operating costs provide a basis for recommending this technology for use in HVAC systems. The results of operating a HVAC system over a period of 17 months confirm the very low operating costs at the level of \( \text{FE} = \text{EUR 4.18/m²/year} \). 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 significant CO₂ emission reductions in the near future. In addition, the studied project also shows savings made by switching from district heating to electric heating and small air heat pumps. The operating cost of the system in the configuration described in this paper compared to a system based on district heating is as follows.

The operating cost of the described system for 17 months, \( 2 \times \text{winter} / \text{FE} = \text{EUR 3.83/m²/year Targówek vs. EUR 3.07/m²/year Mielec; difference: EUR 0.76/m²/year} \).

A comparison of operating costs over a period of 12 months changes the proportions, leading to comparable values. The system described in this paper uses on average \( \text{FE} = \text{EUR 2.74/m²/year} / \) from
December 2016 to December 2017 / and the system utilising district heating over a similar period \( \text{FE} = \text{EUR 2.72/m2/year} \). With a difference in operating costs is \( \text{EUR 0.02/m2/year} \), it would not be worth investing in external networks/ installations, devices, service and maintenance costs in the studied case. The value of this difference in the studied facility is PLN 1,020.00 per year. Another conclusion that can be drawn from comparing these results is that in a system of electric heaters and air heat pumps it might be a good idea to install photovoltaic cells, which reduces CO2 emissions and significantly cuts operating costs.

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