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## HEAT PUMPS AS A RENEWABLE ENERGY SOURCE FOR ADMINISTRATIVE BUILDINGS

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### POMPY CIEPŁA JAKO ODNAWIALNE ŹRÓDŁO ENERGII DLA BUDYNKÓW ADMINISTRACYJNYCH

#### Abstract

The Economic Research Centre for Renewable Energy Sources and Distribution Systems was founded with the purpose to investigate the possibilities of reducing the energetic costs of buildings. The Centre creates a real environment for research on progressive technologies. We evaluate the operational behaviour of a zero-energy balance building, an interaction with its constructions, a study of the inner climate parameters and the overall results for a central heat supply system.

*Keywords: renewable energy sources, sustainable architecture, HVAC*

#### Streszczenie

Ośrodek Badań Gospodarczych w zakresie Odnawialnych Źródeł Energii i Systemów Dystrybucji został założony w celu badania możliwości ograniczania energetycznych kosztów utrzymania budynków. Ośrodek ten tworzy prawdziwe środowisko do badań technologii progresywnych, zajmuje się oceną operacyjnego zachowania budynku zero-energetycznego, wzajemnego oddziaływania pomiędzy konstrukcjami budynku, parametrów klimatu wewnętrznego oraz ogólnych wyników w odniesieniu do centralnego systemu grzewczego.

*Słowa kluczowe: odnawialne źródła energii, architektura zrównoważona, HVAC*

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## 1. Introduction

Large-scale radiant heating technology (capillary mats) achieves a more efficient energy source to expand opportunities in building cool supply services. The production and delivery of cool, significantly more effective in a higher standard of the internal microclimate, is compared with refrigerant systems (SPLIT). Physical nature lies in the change of convective energy transport in radiance with a significant reduction of the heating medium temperature. When using a heat pump SPF, the energy source in the heating mode increases from the value of 3.04 in the supply of convective energy transport on SPF value = 4.71 for radiant systems. The ratio of consumed primary energy and delivered useful energy is in the range of 1:2.

### 1.1. A description of the studied building

The presented results were obtained in an administrative building which has undergone successive targeted measures.

The condition of the building before project implementation:

- in 1996, primary energy consumption for heating GJ 3200;
- CO<sub>2</sub> production from the supplier of heat 419.2 tons (heating plant city coal and gas fired 50%: 50%).

The condition of the building after project implementation:

- Intended to ensure the production of emissions of heat and cool in the house falls by 80% or more compared to the state in 1996;
- Actually achieved decrease of 95%, the parameter to be met 118%;
- The planned consumption of primary energy sources to provide heating and cooling in buildings decreased by 80% or more compared to the reference state;
- Actually achieved 83% reduction, parameter met 104%;
- The expected proportion of energy from fossil fuels to renewable energy sources will be 20%: 80% or more in favour of renewable energy;
- The state actually achieved 17.3: 82.6, parameter filled.

## 2. A building with zero-energy balance

In 2006, the European Commission's Innovation Strategy defined the objective – to implement the concept of a building with zero-energy balance. An example highlighted in the document entitled Putting knowledge into practice: A broad-based innovation strategy for the EU [1].

In the course of further development, the concept of zero-energy balance was successively analyzed, and the specified criteria for assessing the stage were reached [2, 3]. As a principle, two basic concepts are discussed in expert groups:

1. Energy associated with the operation of a building itself is included in energy balance;
2. Energy associated with the operation of a building as well as its use is included in energy balance;

Fig. 1 shows a situation where part of a building has its own type of renewable energy source (heat pump). The building is connected to distribution networks to ensure the supply of energy from external sources. The basis for the definition of zero-energy represents

balance between the energy produced in a local power source and supplied by distribution networks and the energy supplied by the distribution networks in the building. The point where the energy supplied to the network of local sources and the primary energy consumed in the building settle is zero-point energy balance (Fig. 2).

The precondition for achieving a balanced state of energy depends on:

- Total renewable energy power source(s) in relation to natural conditions;
- Potential energy generation;
- Possibility of supplying a power distribution network put equal to total energy needs and the consumption of energy distribution networks [4–6].

There are several criteria for assessing the energy balance of buildings in terms of consumption:

- In terms of the consumption of primary energy sources;
- From the perspective of zero economic balance;
- Balance in terms of CO<sub>2</sub> emissions.

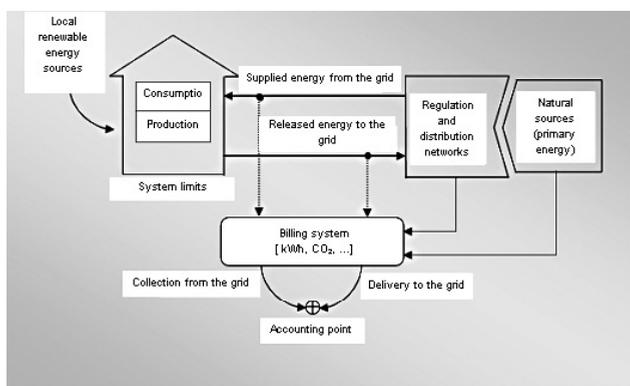


Fig. 1. Accounting system for energy in a building connected to power distribution networks

Rys. 1. System obliczania energii w budynku podłączonym do sieci dystrybucyjnej

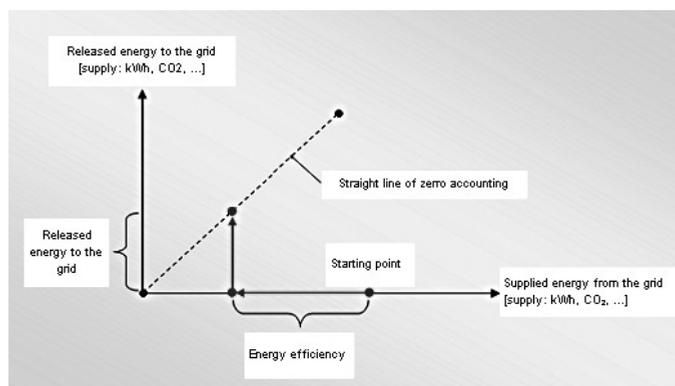


Fig. 2. Energy balance of local energy sources supplied and consumed in a building

Rys. 2. Bilans energetyczny lokalnych źródeł energii dostarczonej i używanej w budynku

### 3. The application of the principles of a zero-energy balance building

The application of the principles of zero-energy balance was performed within the reconstruction of an office building at 3 Murgasova Street, Kosice.

Figure 3 shows the concept of the studied office building targeted solutions. The building, raised in 1980, provides a zero-energy balance in accordance with the above definition. The systematic reconstruction of the building project was launched in 1996. Gradually, the techniques were applied allowing the first absolute consumption to reduce heat transfer through the replacement of windows, insulation and building thermal statization. This part of the project was completed in 2005.

Figure 4 presents the measured data of energy consumption in the building from 1996 to 2010 and the predicted energy consumption by 2015. An important part of this solution is the reduction of CO<sub>2</sub> emissions by more than 90% compared to 1996. A significant impact is the substitution of primary energy in electricity for a heat pump. (In Slovakia, the origin of generated electricity: nuclear energy 57%, hydro 15%, gas and fossil fuels 28%).

For heating and cooling solutions, we selected heat pump technology. Furthermore, there is a change in the shape of classic radiators for large radiant ceiling systems and capillary matting which make it possible to heat as well as cool a building.

Hence, different possible definitions of zero-energy balance; we are assessed in accordance with the EU Directive (10) in terms of primary energy sources.

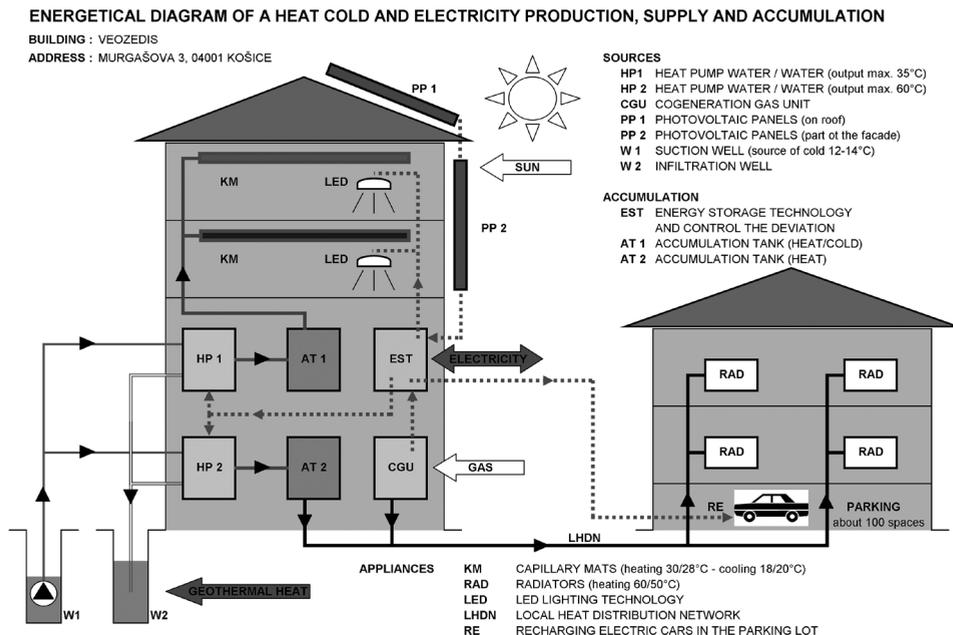


Fig. 3. Office Building, Murgasova str. No. 3, Kosice, equipped with local low-potential geothermal energy resources

Rys. 3. Budynek biurowy, ul. Murgasova 3, Koszyce, wyposażony w lokalne nisko-potencjalne zasoby energii geotermalnej

As the second parameter considering the balance of CO<sub>2</sub> emissions, energy efficiency is defined as the ratio between energy supplied to the distribution networks of a local energy source and building primary energy supplied from a distribution network in a building. A comparison of changes in selected parameters between the systems, when the building is heated by a heat pump and radiators, was to relate the heating and cooling system with capillary mats to the following positive changes:

1. Produced CO<sub>2</sub> emissions were reduced from 21.26 tons to 17.57 tons value, i.e. by 17.35%.
2. The SPF value increased from 3.14 to 4.71, i.e. by 50%.
3. The extended range of functions is to supply cooling in the summer months.
4. The amount of useful energy increased from 242,996 kWh to 313,158 kWh value, i.e. by 28.87%.
5. The consumption of primary fuels increased from 161,110 kWh to 135,612.5 kWh value, i.e. by 15.82%.
6. The ratio of fossil fuels decreased from 20.27% to 16.89%, i.e. by 3.38%.
7. The ratio of energy supplied from a renewable source to consumed primary energy increased by 53%.

The measured and calculated values are shown in Table 1.

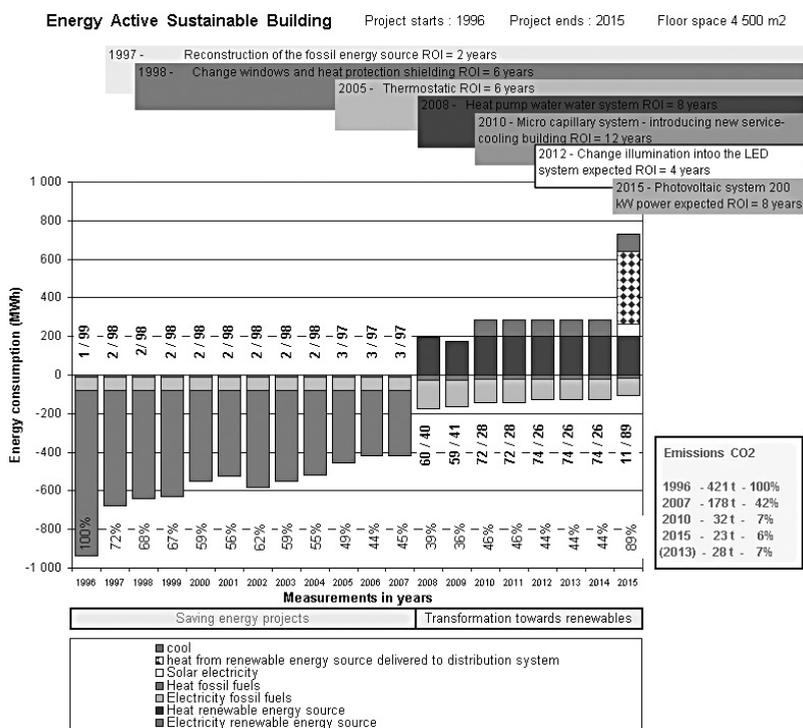


Fig. 4. Measured and predicted annual energy consumption in the administrative building, Murgasova 3, Kosice

Rys. 4. Mierzone i przewidywane roczne zużycie energii w budynku administracyjnym, Murgasova 3, Koszyce

**Evaluation of critical parameters in comparison with the situation in 1996**

Comparison table of key indicators, the reference year						
Entered parameters						
1	SPF split system	Conversion factor for primary energy in electrical system of SR			Emmission coefficient of electricity mix	
2	2.7	0.53			0.275	
3	Parameter	Entering the 1996 reference year	Reference year 1996 OST + split system	Heat pump radiators/split system	Heat pump capillar mats	Comparison of the radiator, split system / capillary mats [%]
4	CO <sub>2</sub> production in the supply of heat [t/year]		419.2	25.32	19.27	-24 [%]
5	CO <sub>2</sub> production in the supply of cold [t/year]		7.1	7.13	1.71	-76 [%]
6	CO <sub>2</sub> production [t/year]	reduced by 80 [%]	426.33	32.46	20.99	-35 [%]
7	Reducing CO <sub>2</sub> production compared to the reference year [%]	reduced by 80 [%]		92 [%]	95 [%]	-3 [%]
8	kWh heat supplied		888 889	289 156	289 156	0 [%]
9	kWh cold supplied		70 052	70 052	70 052	0 [%]
10	Total energy Qv [kWh]		958 841	359 208	359 208	0 [%]
11	Energy consumed for heat supply [kWh]	reduced by 30 [%]	888 889	92 088	70 087	-24 [%]
12	Energy consumed to supply cooling [kWh]	reduced by 80 [%]	25 945	25 945	6 235	-76 [%]
13	The total energy consumed		914 834	118 033	76 322	-35 [%]
14	Primary sources energy consumed for heating [kWh]			173 751	132 240	24 [%]
15	Primary sources energy consumed for cooling [kWh]			48 953	11 764	76 [%]
16	The total primary sources energy consumed [kWh]		937 842	222 704	144 004	-35 [%]
17	Reducing consumption of primary resources versus reference year 1996 [%]	reduced by 80 [%]		76.25 [%]	84.65 [%]	
18	Ratio of supplied energy from RES and consumed primary energy sources			1.6129	2	55 [%]
19	E RES = Q useable + (1-1/SPF) [kWh]			241 175	282 866	17 [%]
20	SPF to ensure heat			3.14	4.13	
21	SPF to ensure cold			2.70	11.24	
22	SPF total			3.04	4.71	55 [%]
23	The ratio of energy from fossil fuels and RES%	20 : 80		28.5 : 71.5	17.3 : 82.6	

#### 4. Outputs from the model situation of a building with zero-energy balance

1. Annual energy performance studies for the supply of heat in the heating season reaches 1,147,713 kWh of which buildings are to supply 243,106 kWh of the energy reserve, whereas the power source for supplying heat represents 904,607 kWh;
2. Annual energy input supply in the summer season is 430,392 kWh of which buildings are to supply 70,052 kWh, whereas the power reserve energy source represents 360,340 kWh;
3. Consumption of electricity in the building = 120,000 kWh;
4. Energy consumption for heating and cooling in the building = 65,094 kWh;
5. Total electricity consumption in the building = 185,094 kWh;
6. Consumption of primary energy sources in the building  $185,094 / 0.48 = 385,612$  kWh;
7. Delivered useful heat and cool from the local RES = 313,158 kWh;
8. For the supply of heat to the external environment in the heating season, we will consider the SPF = 3.0;
9. To achieve the state of zero-energy balance, it should be added to the distribution of energy from renewable sources amounting to  $385,612 * (1 + 1/3) = 514,149$  kWh which represents 1,850 GJ;
10. The abovementioned amount of heat in the distribution system allows for the heat of the substituted OST exchanging station 911 located in the building at 3 Murgasova, Kosice, which may develop into the provision of supportive services;
11. Energy supply in terminal heating units for the building capable of supplying cool.

#### 5. Discussion

Although the EU's intentions are very strict, the administrative building, which underwent successive modifications and measurements, confirmed that these plans can be achieved.

#### Denotations

*COP* – Coefficient Of Performance – indicates how much energy is exploited in relation to energy consumption,

*SPF* – Seasonal Performance Factor – the measurement of heat pump efficiency over a broad operational area which represents an “average COP” measured over the whole year

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## References

- [1] European Parliament, European Committee – Putting knowledge into practice, *A broad – based innovation strategy for the EU*. Brussels: European Committee, 2006.
- [2] Sartori I., Napolitano A., Marszal A.J., Shanti P., Torcellini P., Voss K., *Criteria for Definition of Net Zero Energy Buildings*, Aalborg, University of Aalborg, Denmark 2001.
- [3] EU, European Parliament and Council, Directive of the European parliament and of the council 2009/28/EC on the promotion of renewable energy sources, Official Journal of the European Union, Brussels 2009, L140/16.
- [4] Azariová, Horbaj, Jasmínská, *Zníženie energetickej náročnosti budov*, EKO – ekológia a spoločnosť, Vol. 21, no. 3, 2010, 27-28.
- [5] Selín, Jasmínská, Horbaj, *Niekoľko poznámok k ekonomickej efektívnosti využitia nízko-teplotného vykurovania v kombinácii so solárnymi kolektormi v bytovo-komunálnej sfére*, Plynár, Vodár, Kúrenár + Klimatizácia, Roč. 8, č. 2, 2010, 65-67.
- [6] Klenovčanová, Brestovič, *Možnosti využitia fotovoltických článkov na výrobu elektrickej energie v oblasti Košíc*, Acta Mechanica Slovaca, Roč. 11, č. 4-D, 2007, 511-516.