Journal of International Scientific Publication:
Materials, Methods & Technologies, Volume 3

RENEWABLE ENERGY FOR SMART BUILDINGS IN CONDITIONS OF THE SLOVAK REPUBLIC

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Abstract

The renewable energy sources are domestic sources of energy that help to enhance the safety of energy supplies and the diversification of energy sources. An increased utilization of renewable energy sources in the heat and electricity generation is one of priority tasks of the Slovak Republic to boost the use of domestic energy potential and thus to decrease the Slovakia's dependence on imported fossil fuels. Heat pumps offer the most energy-efficient way to provide heating (central and water heating) and cooling in many applications, as they can use renewable heat sources in our surroundings. It is argued that heat pumps are very energy efficient, and therefore environmentally benign

Key words: *heat pump, electric energy, renewable energy, heating a cooling*

1. INTRODUCTION

The European Union and the world are at cross-roads concerning the future of energy. Climate change, increasing dependence on oil and other fossil fuels, growing imports, and rising energy costs are making our societies and economies vulnerable. These challenges call for a comprehensive and ambitious response. The heating and cooling sector accounts for approximately 50% of overall EU final energy consumption and offers a largely cost-effective potential for using renewable energies, notably biomass, solar and geothermal energy. However, with renewables today accounting for less than 10% of the energy consumed for heating and cooling purposes, this potential is far from being exploited [1].

Analyses show the fact that the process of climatic changes is closely tied to the increase of greenhouse emissions in the atmosphere. Depletion of planet's sources is exceeding 30% of its natural ability of recovery [2]. These facts support the motivation to decrease energetic costs of energy primary sources in combination with reduction of greenhouse gases emissions. It is the primary ecological debt of the planet in combination with climatic changes that creates the danger of generation of future costs ranging from 5 to 20 % GDP [3]. The report developed by commission administered by Lord Stern also shows the fact that yearly investments of 1% GDP during next 20 years will enable volume stabilization volume of emissions in atmosphere, and therefore also the increase of temperature and climatic changes to acceptable level. The aim is to reduce the greenhouse gas emissions by 80% by year 2050. From the point of view of all consumed energy, which is the main producer of emissions, the buildings contribute by 40%. One way of achieving this goal is reduction of energetic costs of primary energetic sources of buildings for delivery of heating and

cooling. Together with reduction we focus on the technique of production of energy and its consumption by intelligent systems of buildings.

It is argued that heat pumps are very energy efficient, and therefore environmentally-friendly. With good conditions the energy from low-potential heat, in other way unusable, is used as a source of energy for heat pump performance. The applicability of this system supports utilization of electric energy at low tariff rate, which is also valid for operation of other electrical appliances.

2. GENERAL DESRIPTION OF HEAT PUMP

The principle of the heat pump (HP) is known for more than 100 years. The usefulness of heat pump is clearly demonstrated by relatively low cost of the system and the competitive prices of other energy sources. Heat pumps can be thought of as a heat engine which is operating in reverse. For examples are food refrigerators and freezers and air conditioners and reversible-cycle heat pumps for providing thermal comfort. The sources of energy are in our surroundings (water, air, ground), which are huge natural resources at low temperature level. Their utilization is efficient when the energy at low temperature level is overdrawn by HP to higher temperature level. The useful heat consists of the energy extracted from the source (in this case the groundwater at 10 °C is cooled down) and the heat, which is equal to with delivered electrical energy. From these energies it is possible to define the coefficient of performance (E_1+E_2). The term coefficient of performance (COP) is used to describe the ratio of the output heat of the supplied work.

$$COP = \frac{E_1 + E_2}{E_2} \quad (1)$$

E_1 energy extracted from the source (water temperature from 10°C to 6°C)

E_2 delivered electrical energy for HP

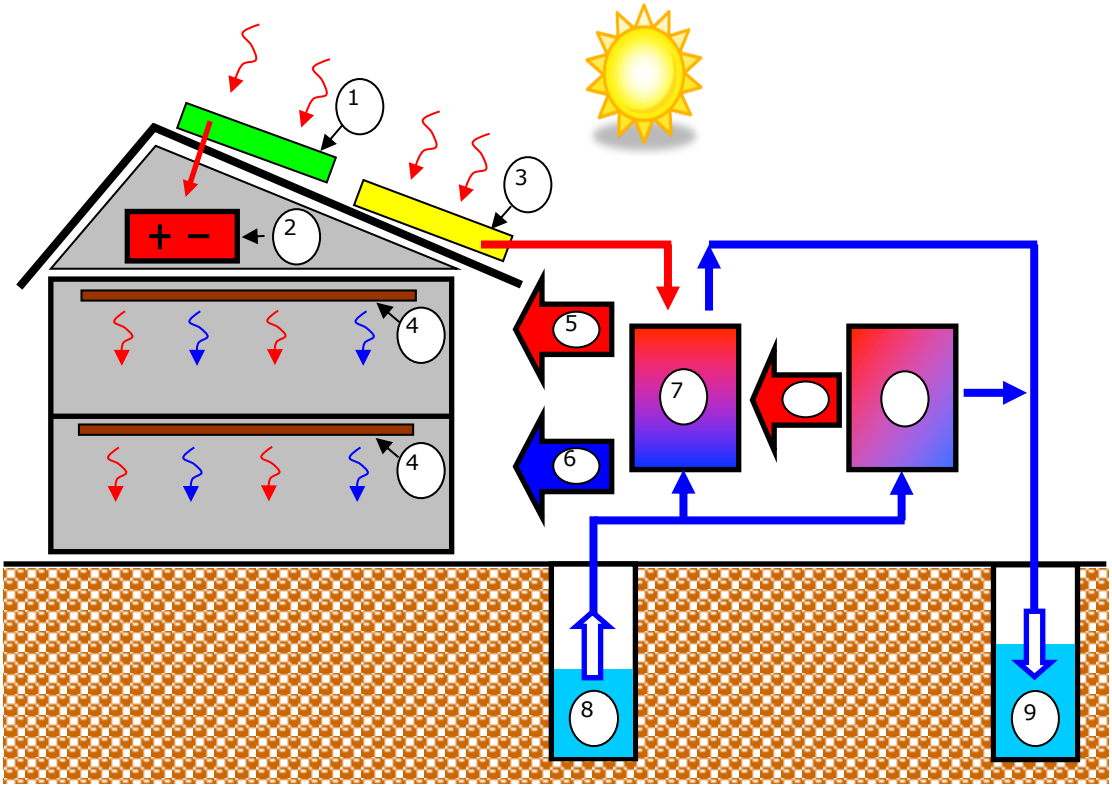
This number is spaceless and it is the main indicator of quality, or particularly appropriate of the source. The COP depends on work conditions. On the input side there is the temperature of the cooled down water, HP quality and working order and on the output side temperature of heated medium (water for heating or heated water). When the temperature difference between heated and cooled medium is smaller, the COP is higher. On the contrary, with the higher temperature difference COP goes down. For example: with COP = 5 the output energy is 5kWh and electrical energy input is 1 kWh. Therefore we want to use the low temperature heating systems.

3. ECONOMIC RESEARCH CENTRE FOR RENEWABLE ENERGY SOURCES AND DISTRIBUTION SYSTEMS

The experimental workplace: Economic Research Centre for Renewable Energy Sources and Distribution systems was founded with the purpose of investigating possibilities to reduce the energetic costs of buildings tied to economy. The Centre operates in the region of Slovakia, which is placed in Central Europe, in mild climatic area. Its founders are the most significant Slovak Universities. Two of them are of technical orientation and one of them is a university of economics orientation together with enterprising subject. The aim of this association is to create conditions for active solutions of economical and legal questions related to implementation of renewable resources and sources of energy with low level of emission production.

Current situation is focused on sustaining emissions on limited figures by allocating quotas by the European Union Commission with exact assignment to the producer. Emissions which are within quota limits are funded by the state. The costs related to elimination of damage caused by emissions are not included in the price of energy. In this aspect, the renewable resources are economically handicapped in comparison to fossil fuels. The level of handicap is created by the value of emissions produced by particular type of energy source to energy unit. The aim of the Research Centre is (see figure 1):

- To define unified market of renewable energy sources (RSE) and energy produced by fossil fuel
- To handle the priority of RSE input into energy distribution system
- To define legal conditions for investments and investors‘ investments protection
- The review of individual types of RSE based on geographical and other characteristics and set their mutual priorities.
- To ascertain principles for review of influence of forced character of energy source in a particular distribution system.
- To solve elimination of RSE implementation legal barriers
- To consider the lack of European Union’s own energy resources
- To understand the coherence of solutions and implementation of projects in practice and legislation.



4. OBJECTIVES OF EXPERIMENTAL WORKSTATION

By founding experimental workstation we conduct applied research and development of RSE – heat pump and indoor technologies

4.1 Project aims

- To cut down CO2 emissions to less than 90% of current level
- To ensure that the building is supplied by at most 20% of fossil fuel energies and that at least 80% energies have come from renewable sources
- To minimalize operation costs
- To secure standard working environment with the aim of increasing the standard by use of summer cooling
- To ensure economic return on investments
- To provide economic justification for symbiosis use of sophisticated fossil fuel – natural gas with RSE energy carriers
- To propose legislative outputs
- To ensure the connection between the pedagogical practice with applied research and implementation of outputs

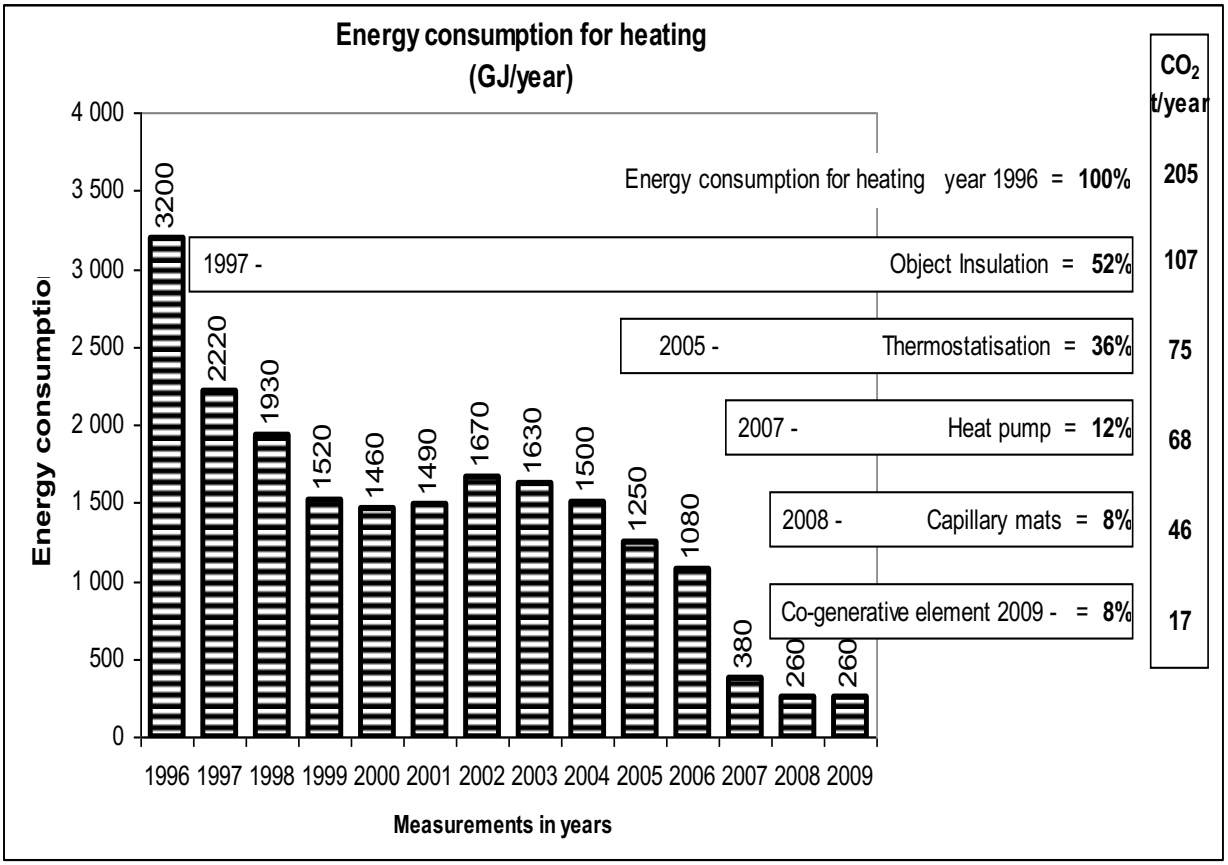


Figure 2 - Process of primary energy consumption for heating the experimental laboratory and the amount of CO2 emissions per year.

The experimental laboratory is an administrative building with space for laboratory and training (lectures). It was built in 1975 according to then valid standards and principles. The characteristics of constructions and heating system were influenced by the need for energy and heat supply. This object did not contain air condition or cooling system. This building was modified by long-running premeditated process to reduce energy supplied for operation of the object. These can be divided into two phases:

1. Constructional and technical modifications of the object effecting the reduction of heating consumption
2. Change of energy and fuel source, to secure increase in efficiency of primary energy use and minimalization of CO2 emissions.

Fallout of these modifications in both phases 1 and 2 in years 1996-2006 can be seen in Figure 2.

5. DESCRIPTION OF MEASURES, PHASE NO. 1

5.3 Original condition

The object was without changes to circuit constructions and the heating system since its construction until 1996. The supply of energy came from central distribution system. Heating plant - transmission station - object. The source was the city's heating plant burning up coal and natural gas in combination with electrical energy production. Heat consumption as measured at its entry to the object of heating was 3200 GJ (=100%). These initial data will be used to compare the effects of taken subsequent measures.

5.2 Object insulation and change of windows

In 1997 change of windows and insulation of circuit constructions of the object took place. The average consumption of heat in years 1997 – 2004 was 1678 GJ (=52% of original consumption)

5.3 Thermostatisation

In 2005, the average consumption was reduced to 1165GJ (=36%) by hydraulic regulation and installation of thermostatic valves. Installation of thermostatic valves on heating bodies enabled local regulation of each heating body. There is also the possibility to consider heat gain in each room by reduction of necessary heating output.

6. DESCRIPTION OF MEASURES PHASE NO. 2

6.1 Heat pump

The main change in the system of heat supply happened after installation of RSE – Heat pump- in the object in 2007. The original source works as peak and backup source. Heat energy is taken from groundwater. The energy gained by its cooling transforms heat pump to more efficient mode. It is driven by electric energy. By using heat pump, coefficient of performance (COP) 1:3 was reached. In numbers, this means that the amount of electric energy is 380 GJ (decrease to 12 %) If we compare years 2007 and 2006 (to find out the effect of renewable resource only), the result of the source change is the decrease to (380/1080=35%), which stands for 65% saving.

6.2 Capillary mats

Installation of capillary mats to the ceilings anticipates reduction of necessary primary energy needed to supply the heat pump to 260 GJ. The reason of heating system change from conventional heat conducting heating units (bodies) to emanating low temperature way is the increase of heat production effectiveness. COP of heat pump production is expected to be COP 1:4.3 instead of 1:3. However, if we compare original levels in year 1996, the consumption of primary energy is at the level of just (8%). The expected consumption of primary energy when compared with year 2006 means reduction to (260/1080 = 26%).

The change of system brings on new quality in form of the possibility to conduct summer cooling in this object. It is enabled by parameters of water in the well in summer (15 degrees) and the demand for cooling water of 18 degrees. The heat pump is completely excluded from the process of cooling and we only need pumping labor for circulation of cooling water. The proportion of pumping labor will be determined by COP of coolness production on level 1:2, which means 7 times increase in effectiveness.

6.3 Co-generative element (CGE)

In the process of production we monitor the CO2 emissions parameter. The source of energy for the drive of heat pump is electrical energy. The CO2 emission coefficient for production of electrical energy in Slovakia is declared to be 0.640 Kg/kWh. The CGE will be installed to the heat pump system. It will produce the electrical energy to drive heat pump by burning up the gas and it will replace supply of electricity from distribution net. Simultaneously, heat produced by burning will be used to increase the temperature of heating body emerging from heat pump.

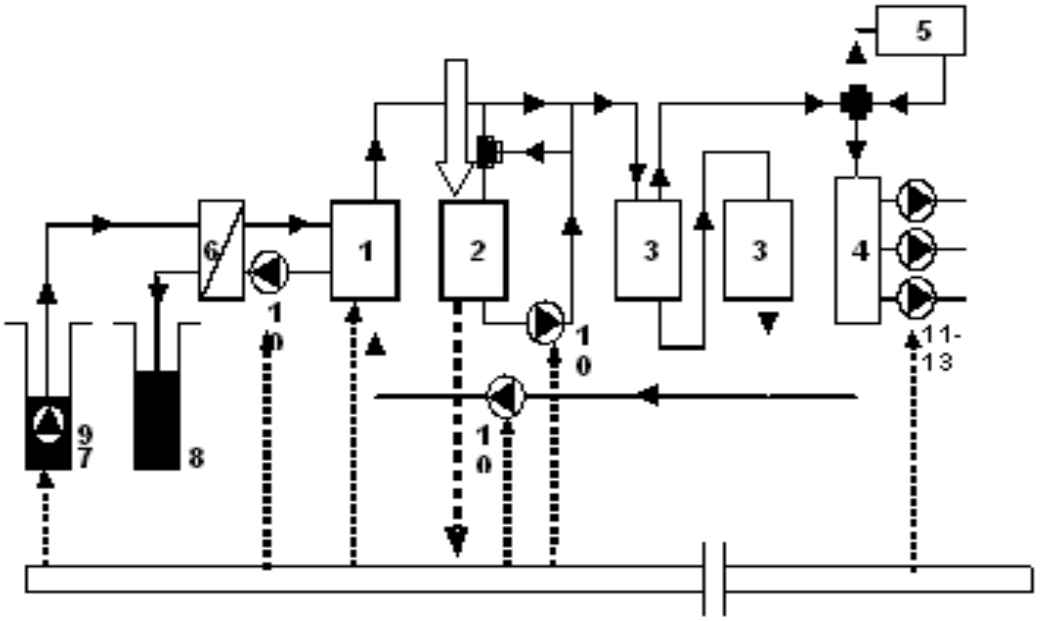


Figure 3 - Heat pump (HP), 2 Co-generative element (CGE), 3 Accumulation tank, 4 Heated object, 5 Supporting and top source, 6 Heat exchanger, 7 absorbing well, 8 suction well, 9 well pump,10 circulatory pumps- engine room, 11-13 circulatory pumps – object

The CO2 emission coefficient for combined production of heat-electricity in co-generative element is 0.23 kg/kWh. The benefit of CGE is cheaper electrical energy produced directly at the place of consumption and also significant decrease in produced CO2 emissions. It has no significant effect on the amount of supplied heat (=8%). The produced CO2 emissions calculated in tones per year can be seen in Figure 3.

7. THE DESCRIPTION OF HEAT AND COOLNESS SOURCE AFTER IMPLEMENTED AND PROJECTED CHANGES

The system enables production and supply of heat for heating and cooling to ensure the desired climate in summer. It is made of wells (suction and absorbing types), heat pump, co-generative element and heating-cooling system with help of capillary mats.

The energetic potential is contained in ground water. After pumping, this water is cooled by approx 4 degrees. Gained energy is transformed by heat pump to higher level (the demand of capillary mats is approx 35 degrees). Water is then heated by energy produced by burning the gas in the co-generative element and will be transferred via accumulation and regulation system into heating system. Heating system is made of ceiling capillary mats (so there is no heat wasted). Electrical energy produced in CGE will be used as fuel for heat pump and other supporting electrical devices.

In the cycle of production and consumption, the interesting part is geothermal energy gained from primary energy in the form of gas, which makes substantial part of operating costs.

7.1 Winter operation

Main source is the renewable low potential geothermal energy (groundwater of approx 12 degrees). Transformation of heat from low potential level into higher (approx 35 degrees for heating with capillary mats) is happening in heat pump, propulsion of which is done via electrical energy produced by burning up the gas in CGE. Production efficiency of electrical energy in CGE by burning up the gas is 30-35%. The rest of heating energy will be used for raising the temperature of heating water, which enables the efficiency of CGE of 85-90%. Produced electrical energy will be used for propulsion of heat pump and supporting electrical devices (circulatory pumps). Evaluation of electrical energy for production and delivery of heat is defined by heating factor COP, which has the value of 4.3 during heating season. This means 4.3 times higher amount of produced heat than that delivered in electrical energy. The overall energetic utilization of gas via production of heat, production of electricity and the labor of heat pump and delivery of geothermal energy at 200%.

7.2 Summer operation

The energy of water from the well is used for cooling during the summer. In case of cooling by capillary mats, the temperature of water in capillaries is 18 degrees. Groundwater sustains temperature of approx 15 degrees in summer. Its temperature is lower than the temperature demanded for cooling. It is not necessary to produce coolness; the necessary temperature of 18 degrees will be produced by mixing in the returned cooling water which is already heated. The demand for energy for production and distribution of coolness will consist of just pumping labor for circulation of cooling water via capillary mats. Heat pump doesn't have to be in operation during cooling. Electrical energy produced by CGE will be used as propulsion of circulatory pumps and the heat produced by burning the gas will be used for heating up the water. The production and delivery of coolness via COP is 14. If we use the gas burned in CGE together with heat to heat up the water to produce electrical energy, the utilization of gas is 480%. Energetic utilization of gas for heating, cooling and heating up the water, during the whole year is 270%

Yearly balance shows the proportion of production of heat and coolness 3/1. COP of heating is 4.3 and COP of cooling is 14, yearly balance of whole system is 6.7.

5. CONLUSIONS

The balance of measured and calculated figures of operation of the building confirms the correctness of assumptions and accuracy of projected balance. From the point of view of energetic balance, the consumption of primary energy (geothermal energy is not being considered) was decreased from original 3200GJ in year 1996 to 260GK. This means decrease by 92%.

The structure of resource and fuel base was changed. The coverage of consumption has significantly lower amount of CO2 emissions. The decrease from original 205 tones per year to 17 tones per year makes 92%.The structure of fuel for production of primary energies in year 1996 consists of 100% fossil fuel. After adjustments, it consists of geothermal energy and electrical energy produced by burning gas in year 2009. If eventual COP for yearly operation of heat pump is 6.7, then the proportion of energies is as follows:85% of energy is from geothermal source and 15% of energy is from electrical energy. Overall efficiency of co-generative element is 90%.Calculating primary energy 15%/0.9 = primary energy = 16.7%.

Proportion of geothermal energy will be decreased to 100% - 16.7 % = geothermal energy = 83.3%. The rest of produced heat from co-generative element will be used in distribution net for other consumers for heating and heating of hot water. The realized project creates real environment for effective implementation research of technologies in laboratory and operative conditions: technologies of co-generative elements, heat pumps, thermal capillaries, and technologies in field of measurement and regulation. The solution is the project with possibility to repeat it on other similar applications as well as the utilization of experience and determination of economical expedience of researched technologies implementation.

The quality of buildings' environment influences health, efficiency and comfort of building's users. Current studies show that the costs of internal environment quality improvement are often higher (for company, employer and building's owners) than costs of energy consumed in the building. Energetic declaration without declaration of relation to quality of inner environment therefore does not make sense and is not sufficient. Specification and consideration of design criteria for parameters of inner environment are needed for design of buildings, energetic calculations, operation and regulation of buildings. Next phase of the research will be evaluation of operative behavior of the building, interaction with building constructions and study of inner climate parameters.

ACKNOWLEDGEMENTS

This contribution was written as a solution of grant task VEGA 1/0620/09 and as contribution of EcoFund of company SPP.

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