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ENERGETIC AND ECONOMIC ASPECTS RELATED TO THE USE OF HEAT PUMPS FOR HEATING AND COOLING ENERGY EFFICIENT BUILDINGS

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Abstract: *Within the context of providing a sustained development in conformity with the energetic and environmental strategies at European Union level, emphases will be laid on lowering energetic consumptions and environmental pollution by developing energy efficient buildings and utilization of renewable energy sources. In this respect, the paper approaches energetic and economic aspects in relation with the use of heat pumps for heating and cooling energy efficient buildings.*

Key words: *energy, heat pump, heating, cooling, renewable energy sources.*

1. Introduction

The economic development and the grows of living standards at European and world levels will bring about further increase of energy consumption along with ever severe consequences upon surrounding medium.

As fossil fuel reserves will run out, there is a need for energetic policies and those referring to diminution of environmental pollution should focus on energetic efficiency and reduction of greenhouse gas emissions.

Although the field of heating and cooling have begun and continues the transition to renewable energy sources, 75% of the fuel it uses still comes from fossil sources.

As 40% of the total energy at European Union level goes into the building sector, the energetic and environmental strategies should be applied at an accelerated rate, and scientific researches in the field of building energy should bring about results which answer the demands of the day. From technical and economic point of view, one will pursue the expected positive results both at the level of building structure and heating and cooling systems. Stress will be laid on developing energy efficient buildings and heat recovery from renewable energy sources. Among the efficient systems of energy recovering from renewable sources, geothermal especially, heat pumps are to be remarked.

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2. Heat Pumps

Within the energetical and ecological strategies based upon improving energetic efficiency, the growth of renewable energy sources and diminishing environmental pollution by reducing the greenhouse gas emissions, an essential role will be played by energy efficient buildings and performant systems of energy supply.

Within performant systems of thermal energy supply, heat pumps are to be remarked. Taking thermal energy from a lower temperature level medium (heat source – air, water, earth) transferring it to a higher temperature medium, using electric power, heat pumps could fulfil multiple functions, serving both for preparation of hot water, heating and cooling the building [1, 2].

Heat pumps represent an advantageous solution in energy efficient buildings characterized by:

- high level of interior comfort;
- low energetic consumption for heating/cooling as a result of:
  - optimizing building envelope by passive designing strategies [3]:
    - compact design,
    - a good orientation to turn to value solar energy,
    - a high degree of thermal insulation and tightness;
  - recovering heat by using some efficient systems .

In view of obtaining high performances by heat pumps, one will choose some renewable sources of heat, easily at hand, non-corrosive and with an annual temperature as constant as possible. In Table 1 the heat sources and their temperatures are presented.

Heat sources of heat pumps [1] Table 1

Type of heat source	**Temperature [^{0}C]**
Ambient air	-15...15
Exhaust air	15...25
Ground water	4...10
Surface water	0...10
Sea water	3...8
Ground soil	0...10
Ground rock	0...5
Waste water	>10

For choosing the type of heat pumps for various applications one should take into account the geographic location, climatic conditions and heat sources availability. Thus, for countries from southern Europe, air-air heat pumps of usual capacities of 3...5 kW are used for heating and cooling; for central European countries air-water heat pumps (4...40 kW) are used for heating; in Sweden, heat pumps with recovery from exhaust air (2...3 kW) are used for heating; for countries from the North and centre of Europe, heat pumps with ground soil recuperation (5...25 kW) are used for heating and heat pumps with ground rock recuperation (5...40 kW) are used for heating and free cooling [4].

3. Case Study. Implementing the Model and Simulation Results

In order to reveal the role of the solutions for achieving the building envelope, of energy supply systems and turning to account of renewable energy sources, a survey was effected, based on numerical simulations.

As a model, a dwelling house was chosen of ground floor, first floor and attic height regime, 0.76 area/volume proportion and a useful area of 160 m^2.

In view of reducing energy losses and turning to account the solar energy, the majority of window surfaces were oriented southward.

In view of reducing overheating, shading systems (60% shading degree) were provided.

For providing a high degree of thermal insulation and air tightness the following schemes were suggested:

- external walls of BCA Ytong and mineral wool thermal insulation 30 cm thick; global heat transfer coefficient U=0.10 W/m^2K;
- the plate over the last level made of wood and mineral wool thermal insulation 30cm thick; global heat transfer coefficient U=0.13 W/m^2K;
- the plate over the ground made of concrete and mineral wool thermal insulation 25cm thick; global heat transfer coefficient U=0.11 W/m^2K;
- windows with three glass panes and two layers of low emissivity, the space between them filled with argon, wood frames and spacing profiles with warm edges; global heat transfer coefficient U=0.74 W/m^2K.

In view of turning to value the geothermal energy a soil-water heat pump was chosen as heating system (underfloor heating).

The simulations were effected with Casanova software, for Bucharest - Romania; characterized by maximum temperatures of 35.9 ^{0}C (in July) and minimum temperatures of -16.3 ^{0}C (in January). The following were determined:

- monthly and annual values of energy demand for heating and cooling (Figure 1);
- the number of heating and cooling hours, both month by month and annually (Figure 2);
- the energy flow diagram for heating and cooling and annual primary energy demand for heating and cooling.

In conformity with simulations, resulted in a heating energy demand of 59.2 kWh/m^2year and for cooling 2.4 kWh/m^2year. Cooling the building will be needed in the months of June, July and August, while the heating period will extend over more months; the highest energy consumption being recorded in January and December and the lowest in October and April.

The yearly number of cooling hours will be 822 hours, while those for heating will mount up to 5412 hours.

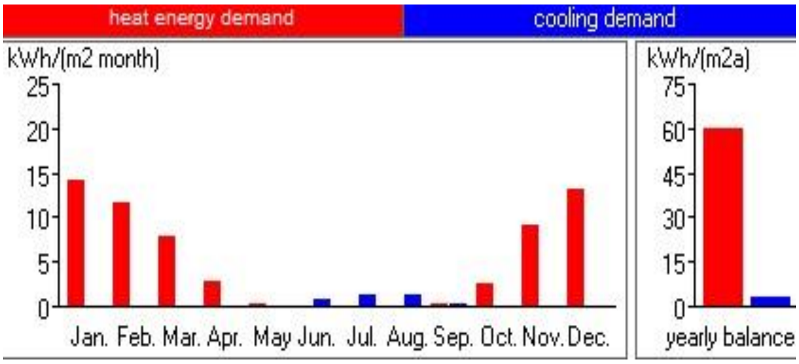

Fig. 1. *Heating and cooling energy demand. Monthly and yearly balance [5]*

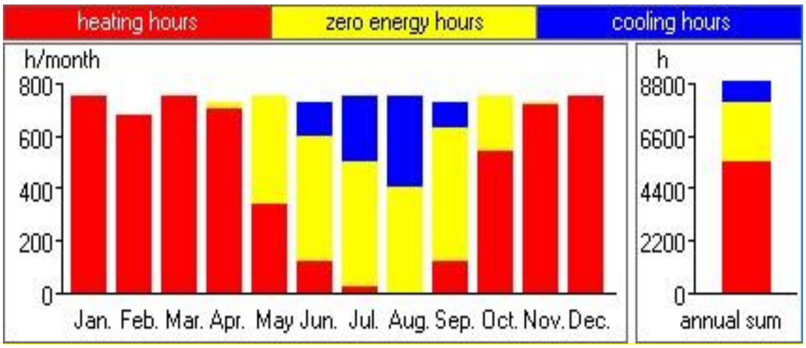

Fig. 2. *Heating, cooling and zero energy hours. Monthly and yearly values [5]*

In conformity with energy flow diagram, a primary energy demand of 53.7 kWh/m^{2}year have resulted and for cooling the demand was 14.2 kWh/m^{2}year.

In order to emphasize the role of heat pumps for reducing consumptions for heating the building, the following 3 systems for heating were analyzed:

- soil heat pump, buffer storage and distribution inside the thermal zone; underfloor heating; source of energy – electricity (case 1);
- electric direct heating; source of energy – electricity (case 1a);
- condensing boiler (high efficiency), boiler and distribution inside the thermal zone; underfloor heating; source of energy – natural gas (case 1b).

As a result of simulations it was observed that with the use of heat pumps with heat recuperation from the soil, the end energy demand for heating have decreased by 70% (Figure 3).

As primary energy demand is concerned, reductions of 70% compared with electric direct heating and of 25% as compared with natural gas heating were obtained (Figure 4).

In view of reducing energy consumption for heating, taking into account major losses by ventilation, the second analysis on the model house has also considered provision of a mechanical ventilation system with heat recovery (88% efficiency). After the simulations the following were noticed:

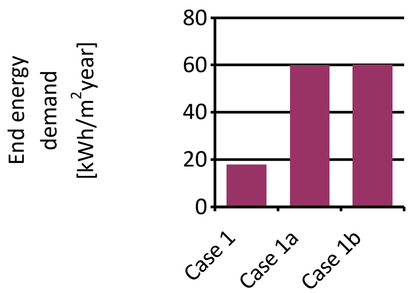

Fig. 3. *The influence of heating system upon the end energy demand (electricity and natural gas)*

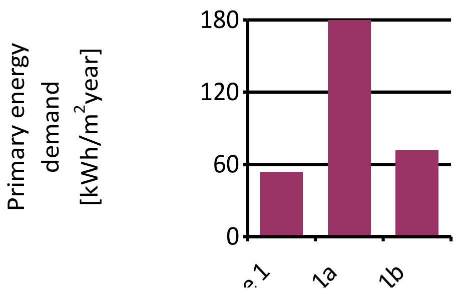

Fig. 4. *The influence of heating system upon the primary energy demand (electricity and natural gas)*

- diminution of energy demand for heating below 15 kWh/m^{2}year in conformity with passive standards (Figure 5) and the fall of annual number of hours for heating (Figure 6), respectively the heating period;
- increasing the energy demand for cooling without exceeding the value of 15 kWh/m^{2}year in conformity with passive standards (Figure 5) and the increase of annual number of hours for cooling (Figure 6), respectively the cooling period;
- the fall of annual primary energy demand electricity for heating and its rise for cooling (Figure 7), the diminution of annual end energy demand electricity for heating and its rise for cooling (Figure 8).

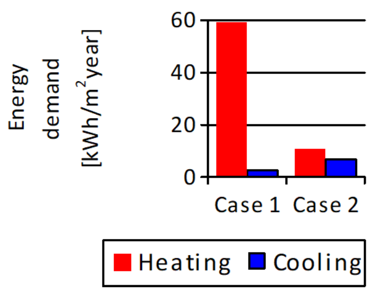

Fig. 5. *The influence of mechanical ventilation upon the energy needs for heating and cooling*

For the cases analyzed, by introducing the controlled mechanical ventilation with heat recovery, the annual energy consumption for heating and cooling the building has diminished by 71.4%, that for primary energy by 12.7% and final energy demand electricity by 12.4%.

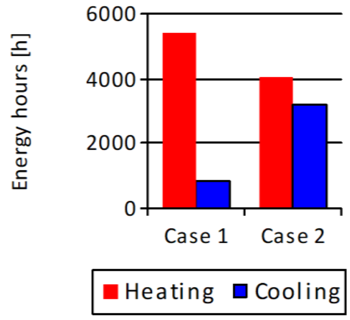

Fig. 6. *The influence of mechanical ventilation upon the heating and cooling energy hours*

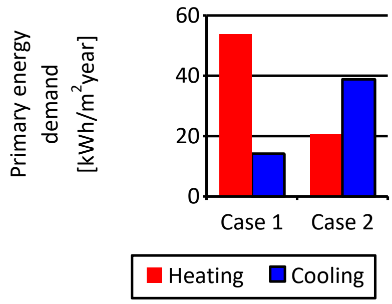

Fig. 7. *The influence of mechanical ventilation upon the primary energy demand electricity for heating and cooling*

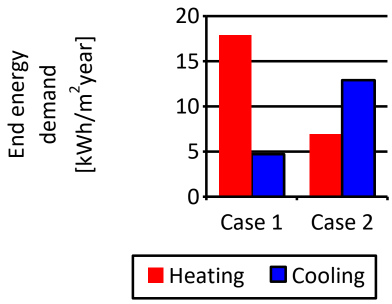

Fig. 8. *The influence of mechanical ventilation upon the end energy demand electricity for heating and cooling*

As compared with electric direct heating system or that with natural gas, by introducing the controlled mechanical ventilation with heat recovery and of a heat pump with soil recuperation, the end energy demand for heating have been reduced by 41%, respectively 54% and the primary energy demand has fallen by 42%, respectively

7%.

The last analysis meant to emphasize the economic impact of heat pumps. The simulations have been effected with the Heat Pump Navigator software of Stiebel Eltron Company [6].

Starting from the cases analyzed (case 1 and case 2) and taking into account three types of heat pumps (Air/Water, Water/Water and Brine/Water) and a conventional system of heating based on natural gas, the following results have been observed (Figure 9 and 10):

- as compared with a system based on natural gas, by using some performant heat pumps, the operating costs have been reduced by 83% (case 1), respectively 89% (case 2);
- as the annual energy costs of the system, both for case 1 and 2, the greatest economies were obtained by using a Brine/Water heat pump.

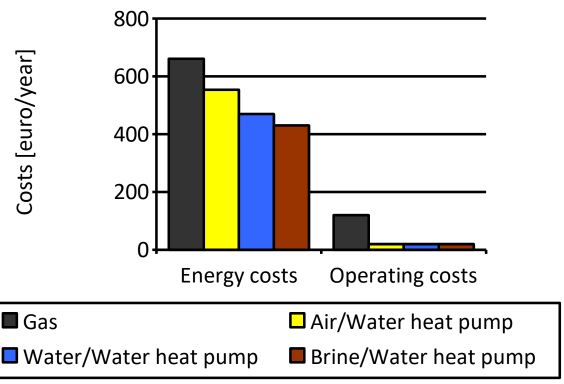

Fig. 9. *Annual costs for heating and cooling (case 1)*

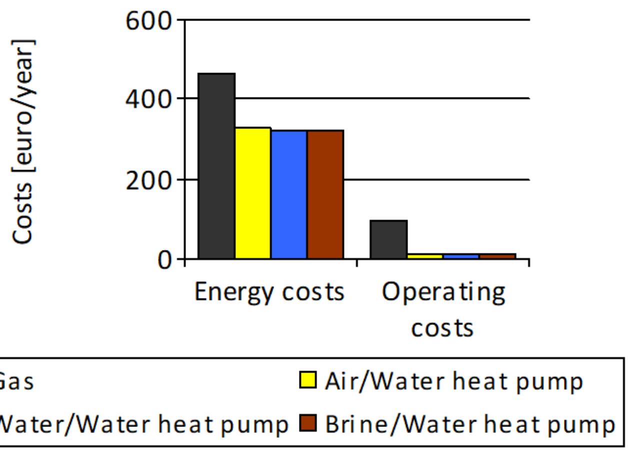

Fig. 10. *Annual costs for heating, cooling and ventilation (case 2)*

4. Conclusions

Turning to value the renewable energy sources, the heat pumps greatly contribute to significant reduction of final energy consumption meant for heating and cooling a building, as compared with conventional systems based on fossil fuels. The primary energy consumption has also been reduced.

Due to high performances and turning to value the available energy from the environment, especially the geothermal energy, the heat pumps contribute to diminish the negative impact upon surrounding medium by the reduction of greenhouse gas emissions and consequently to the reduction of energetic costs.

The combined utilization of heat pumps and controlled mechanical ventilation systems bring about both diminution of energy demand for heating and cooling a building and achieving energetic and financial savings.

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