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EFFICIENT WAYS OF PROVIDING THERMAL ENERGY TO PASSIVE HOUSES

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Abstract: *Under the circumstances heat energy covers most of the energetic balance of a building, in view of limiting energetic and ecological consumptions in passive houses, an essential role will be incumbent on finding the most efficient methods of providing heat. In this respect, the paper develops, in dynamic regime, some energy supply systems, using solar and geothermal sources of energy.*

Key words: *passive house, thermal energy, heat pump, double flow controlled mechanical ventilation.*

1. Introduction

Within the present energetic and ecological context, the energy efficiency represents one of the most remarkable energy resources of Europe, being an essential element for securing an economy based on low energy consumption and low greenhouse effect emissions and at the same time, efficient from the point of view of employing energy resources [4].

Considering that buildings have got the greatest potential of energy savings, measures have been taken for improving energetic performances of buildings at both enveloping levels and energy supply systems.

The highest contribution to the energetic balance of a building comes with thermal energy, consequently, the greatest energy savings will be obtained by improving the performance of enveloping, of heat energy production and turning to better account the renewable sources of energy in view of covering energy consumptions at a percentage as high as possible, even 100% in some cases.

Within these measures, a most remarkable role comes with the passive houses, with most restrictive standards concerning [7]:

- limitation of energy consumption:
  - heating/cooling: 15 kWh/m^{2}year;
  - primary energy: 120 kWh/m^{2}year;
- providing quality requirements and internal comfort – maximum tightness 0.6h^{-1},

and which, due to optimization of their components, minimizing losses and turning to value the renewable sources of energy decisively contribute to diminishing energy consumption and protection of environment.

2. Efficient systems of producing and supplying heat energy to passive houses

In the case of passive houses, characterized by high standards of thermal insulation and tightness, to provide comfortable conditions and air quality (a

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minimum rate of 36 m^3/h per person) is required to some mechanical ventilation systems.

These secure both evacuation of exhaust air (toxic substances, humidity, dust, odours) and admission of fresh air and reduction of CO_2 concentration.

In order to reduce energy losses through ventilation with provision of air quality and internal comfort, one recommends the use of some double flow controlled mechanical ventilation systems with heat recovery which would meet the following requirements [1]:

- provision of two air filters;
- electricity consumption for ventilators ≤ 0.45 Wh/m^3;
- efficiency of heat exchanger ≥75%;
- balancing input output air flow;
- noise level<35 dB.

As a result of heat recovery from the evacuated exhaust air and from the transfer to the fresh air input preheating air is provided which contributes to heating the passive houses. Consequently, these systems will be connected to heating/ cooling and domestic hot water (DHW) preparation systems.

The first version consists in associating ventilation systems with Canadian wells systems. These represent earth-to-air heat exchangers serving the preheating/cooling of air before entering the house [2], leading this way to energy savings. Figure 1 schematically represents a passive house equipped with double flow controlled mechanical ventilation system and Canadian well.

As domestic hot water preparation is concerned a solar heating system in combination with electric resistance is employed.

A second variant of turning into account the earth energy is given by brine/water heat pumps. These can be used for preparing domestic hot water and heating passive houses, coupled with mechanical

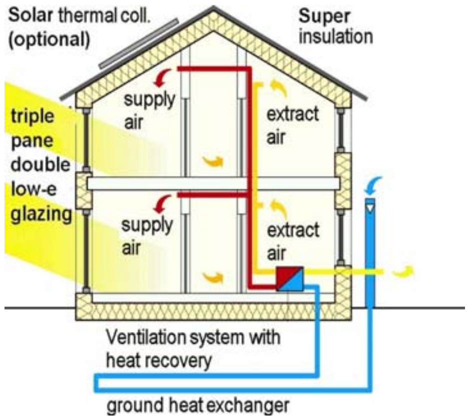

Fig. 1. *Mechanical ventilation system in a passive house, with Canadian well [7]*

ventilation systems; the hot water obtained serves for heating the air through the agency of a heating battery. The brine/water heat pumps can also provide the cooling of the house, either by an active system, by reversing the operational cycle, or by a passive system. In the case of passive cooling, the thermal agent gives up a heat flux through a heat exchanger to the soil thus, causing both to cooling the house and significant diminishing of energy consumption for cooling. In Figure 2, the scheme of a brine/water heat pump is presented, having the function of heating, domestic hot water preparation and passive cooling.

Beside the earth, another important source of heat is represented by the air that can contribute to both heating/cooling of passive houses and the preparation of domestic hot water through the agency of air/water heat pumps. Figure 3 presents a mechanical ventilation system to which an air/water heat pump is coupled (with recuperation from evacuated exhaust air) in view of heating and domestic hot water preparation, being accompanied by a solar system and electric resistance, while in Figure 4 an air/water heat pump is provided for heating, domestic hot water preparation and cooling.

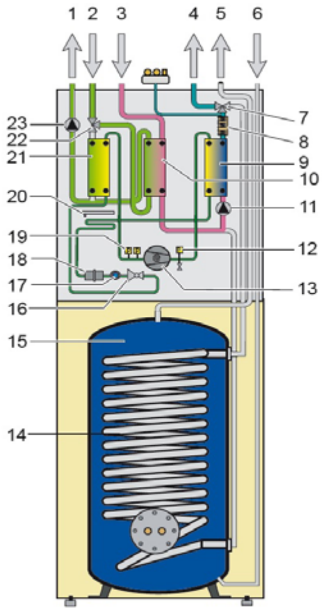

Fig. 2. *Brine/water heat pump for heating, DHW preparation and passive cooling [8] 1/2-brine outlet/inlet;3/4-return/flow heating;5/6-DHW/cold water;7,22-diverter valve;8-electric booster heater;9-condenser;10-heat exchanger;11,23-circulation pump;12,19-pressure limiter;13-compressor,14-indirect coils DHW;15-DHW cylinder;16-expansion valve;17-sight glass,18-filter dryer;20-condensate tray;21-evaporator*

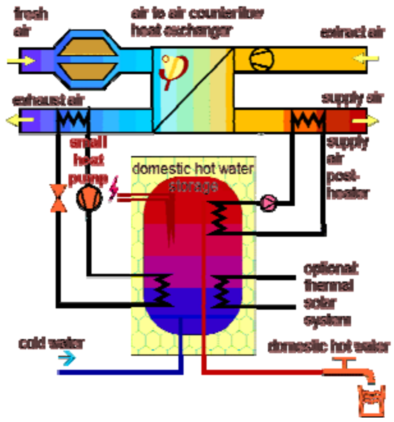

Fig. 3. *Thermal energy supply system for heating and DHW preparation [3]*

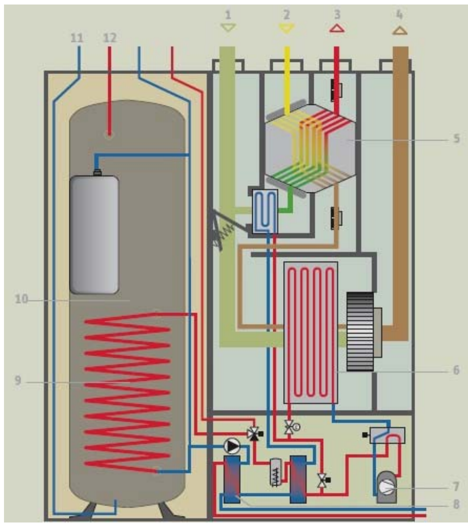

Fig. 4. *Thermal energy supply system for heating/cooling and DHW preparation [9] 1-outside air;2-extract air;3-fresh air;4-exhaust air;5-double-flow heat exchanger;6-evaporator;7-compresor;8-solar heat exchanger;9- indirect coils DHW;10- DHW cylinder;11-cold water;12-DHW*

3. Case study. Implementing the model and simulation results

Improving energetic performances of buildings is owed both to enveloping (shape, orientation, windows surface, shading, building materials) and energy supply systems.

In order to set into evidence the role of energy supply system in diminishing primary energy consumption and negative impact on environment, a survey, based on numerical simulations, was carried out, for analyzing various methods for devising a functional-structural system of energy supply.

A residential house in Cluj-Napoca was chosen as model, aiming, primarily the improvement of energetic and ecological performances, starting from strategies of passive designing. In this respect, a compact form was adopted with a height regime ground floor+first floor+platform roof, most of the windows south oriented, mobile external shading systems and a high degree of tightness and thermal insulation.

An energetic and ecological analysis was effected concerning thermal and electrical energy consumption, deciding upon efficient solutions of energy supply and the contribution of renewable sources in diminishing energy consumption and polluting emissions.

The house has a useful area of 170 m^2 and is made of concrete and porotherm bricks, rockwool insulation (30cm-walls, 40cm-platform roof, 40cm-floor slab), three layer glass windows of low emissivity, PVC frames, warm edge spacers and interspaces filled with Krypton. Consequently, the heat transfer coefficients at envelope level lay within limits imposed to passive houses:

- $U_{exterior\ wall}$=0.092 W/m^2K;
- U_{roof}=0.081 W/m^2K;
- $U_{floor\ slab}$=0.083 W/m^2K;
- U_{window}=0.7÷0.76 W/m^2K.

Determining both heat transfer coefficients and the energy consumption along with polluting emissions have been effected by means of Lesosai soft, on the basis of the Meteonorm climatic data for Cluj-Napoca.

Starting from considerations related to internal comfort and air quality in passive houses, the heat energy supply is provided with a double flow controlled mechanical ventilation system with heat recovery (88% efficiency) and a supplementary source.

In order to counteract the negative effects of a very good tightness and insulation – overheating and need for cooling – both external shading mobile systems were mounted at windows and natural ventilation during nights (an open window in each room for ventilation).

For energetic analysis, limit temperatures 20 ^{0}C were imposed for heating and 26 ^{0}C for cooling.

The calculation of energy needs for heating and cooling was effected in conformity with EN 13790 standards (hourly calculation), by determining the heat losses through transmission and ventilation and solar heat contribution.

The air flow rates were determined in conformity with Norms I5/2010, observing the rates extracted from bathrooms and kitchen (Table 1) and of minimum flow rates (Table 2). A flow rate of 75 m^3/h was chosen for the kitchen and 30 m^3/h for bathrooms, a total flow rate of 165 m^3/h resulted for 4 persons.

Determining the energetic needs for domestic hot water preparation was effected in conformity with SIA 380/1 standards (considering a specific medium consumption of 50 l/person/day at 55^{0}C), and the needs for illumination, ventilation and electric appliances, in conformity with SIA 380/4 standards.

For limiting electric energy consumption, led type illumination devices and efficient electric appliances have been provided.

The survey started with a reference case (case 1): double flow controlled mechanical ventilation system with air/air heat exchanger (η =88%), analyzing different variants of energy supply systems of model house:

- case 2: solar and photovoltaic panels;
- case 3: solar panels and brine/water heat pump;
- case 4: solar panels, brine/water heat pump and photovoltaic panels.

For covering the electric energy needs for preparing domestic hot water, two solar panels (S=4.26 m^2) were provided

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For covering the needs of electric energy,

Air flow rate for ventilation [5] Table 1

Number of main rooms	Extracted flow rates [m^3/h]				
	Kitchen	Bathrooms or communal shower and toilets	Another shower room	Toilets	
				unitary	multiple
1	75	15	-	-	-
2	90	15	15	15	15
3	105	30	15	15	15
4	120	30	15	30	15
>5	135	30	15	30	15

Minimum air flow rates for ventilation [5] Table 2

	Number of main rooms						
	1	2	3	4	5	6	7
Total [m^3/h]	35	60	75	90	105	120	135
In kitchen [m^3/h]	20	30	45	45	45	45	45

10 polycrystalline photovoltaic panels were provided (dimensions: 1.65x0.986 m).

For preparing heating agent, cooling and DHW preparation, a brine/water heat pump was provided with depth collectors and high coefficients of performance: 3.8 for heating and 3 for DHW preparation.

Cooling was passively achieved by a heat exchanger connected to the water-air cooling battery.

After simulations the annual energy consumptions were determined alongside with polluting emissions.

The monthly variation of heating and cooling energy needs is given in Figure 5, specifying the duration of heating and cooling periods. In the months of January-April and November-December the heating of the house will be needed, the highest values will be recorded in December (743.02 kWh) and January (594.62 kWh), and the lowest values in April (29.46 kWh). As concerning the need for cooling, the months with highest values will be June-September (in June 335.66 kWh), but cooling will also be needed in May (38.9 kWh) and October (46.32 kWh).

The annual energy consumptions and polluting emissions for the reference case are given in Figure 6.

Due to the application of passive designing principles for the house under consideration a specific annual need for heating was obtained of 11.9 kWh/m^2year and a specific annual need for cooling of 6.6 kWh/m^2year, thus observing one of the principal limit conditions imposed to passive houses (maximum 15kWh/ m^2year).

But for limiting the primary energy consumption in conformity with the passive standards at 120 kWh/m^2year (calculated with a conversion factor of electric energy of 2.97) the implementation of renewable sources technologies will be required, with the cases under consideration they are:.

solar panels, photovoltaic panels and brine/water heat pump

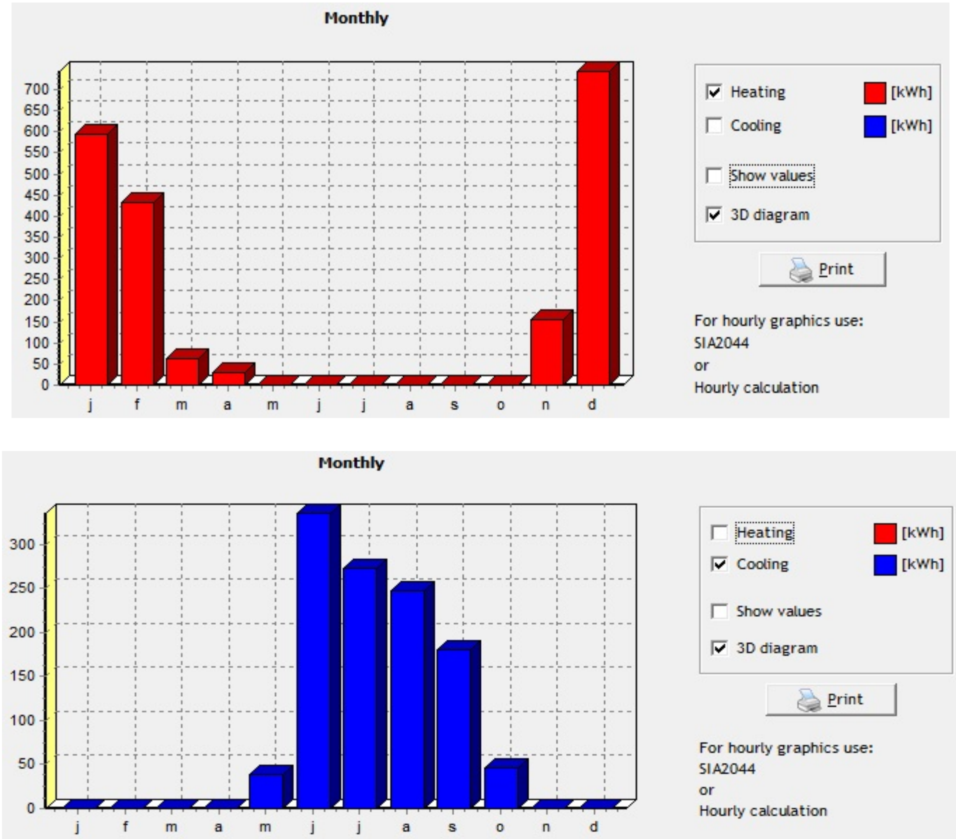
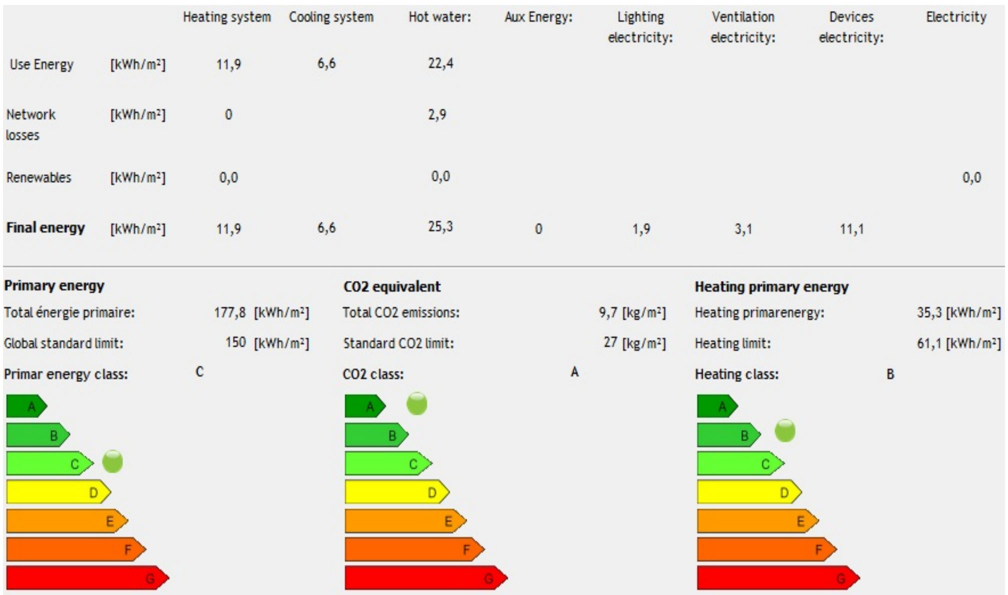


Fig. 5. *Monthly values of heating and cooling energy demand [6]*



		Heating system	Cooling system	Hot water:	Aux Energy:	Lighting electricity:	Ventilation electricity:	Devices electricity:	Electricity
Use Energy	[kWh/m²]	11,9	6,6	22,4					
Network losses	[kWh/m²]	0		2,9					
Renewables	[kWh/m²]	0,0		0,0					0,0
Final energy	[kWh/m²]	11,9	6,6	25,3	0	1,9	3,1	11,1	

Fig. 6. *Energy consumptions and CO_2 emissions (case 1) [6]*

Comparatively analyzing the proposed cases with reference case (controlled mechanical ventilation with heat recovery), one observes the following:

- recuperating energy from earth and using high coefficients of performance, the heat pump contributes 74% to diminishing energy consumption for heating the house (Figure 7);

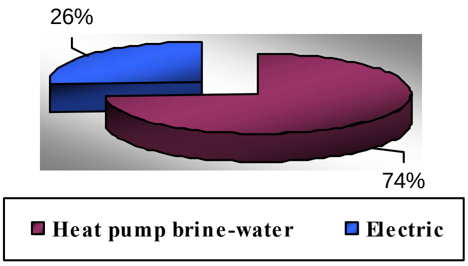


Fig. 7. *The contribution of renewable sources to covering the energy needs for heating the house*

- accomplishing the cooling in passive regime, the heat pump reduces energy consumption to a minimum for cooling, excepting the circulation pumps (Figure 8);
- turning to good account the solar energy through the agency of solar panels as well as well as the energy of the earth (geothermal energy) by means of heat pump, the need for covering the DHW preparation at a proportion of 84% is assured (Figure 9);
- using solar energy (solar and photovoltaic panels) and geothermal energy (brine/water heat pump) low annual primary energy consumptions of 120 kWh/m^{2}year were obtained, for all cases studied (Figure 10);
- through turning to account of solar energy by implementation of solar and geothermal systems, alongside with

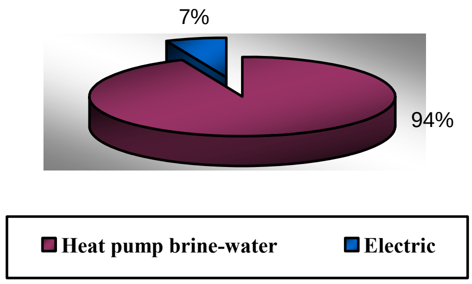


Fig. 8. *The contribution of renewable sources to covering the energy needs for cooling the house*

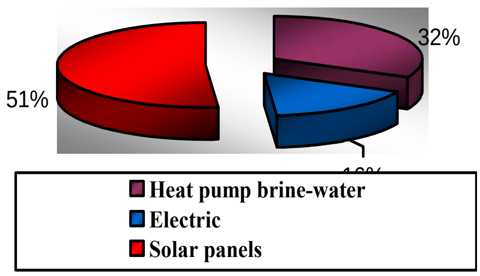


Fig. 9. *The contribution of renewable sources to accomplish the energy needed for DHW preparation*

- diminishing energy consumption emissions of polluting gases were also reduced (Figure 11).

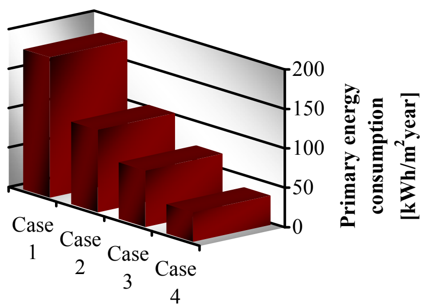


Fig. 10. *Total primary energy consumption for the house*

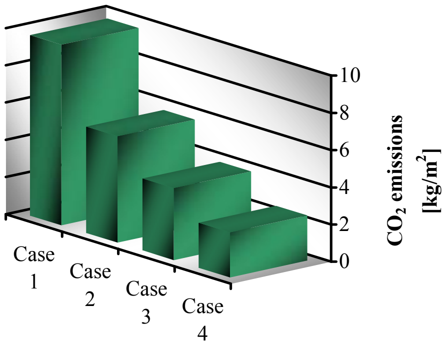


Fig. 11. *Total CO_2 emissions for the house*

4. Conclusions

As a result of high performances at envelope level to meet the quality needs and internal comfort in passive houses, the implementation of a controlled mechanical ventilation system with heat recovery is required.

Improving energetic and ecological performances of thermal energy supply systems may be achieved by connecting systems of turning to value of solar energy – solar panels (for DHW preparation) and geothermal energy – brine/water heat pump (for heating, cooling and DHW preparation) to mechanical ventilation system. For covering the electric energy needs in increasing energetic independence the provision of photovoltaic systems are recommended.

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