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ECONOMIC EFFICIENCY OF HOUSE HEATING ECO-SYSTEMS

Stefan DRAGOMIR, Nicolae DIACONU

"Dunarea de Jos" University, Galati, Romania

stefan.dragomir@ugal.ro

ABSTRACT

Over the past decades, energy consumption per capita in the world has not only increased, but also the number of inhabitants who use energy in various forms. In this context, it still must be done efforts for energy conservation. This is necessary in order to have time to develop new sources of energy such as energy: geothermic energy, wind energy, tidal energy, etc. It also required the development of new energy technologies, which refer to unconventional technical solutions for conversion, storage, transport, use and recovery of energy. From the economic point of view, even if the implementation of renewable and clean energy sources seems expensive at first sight, these types of alternative energies will prove their durability and efficiency, their costs being amortized within 5-8 years.

Keywords: renewable energy, ecological habitat, passive house.

1. INTRODUCTION

The increase of energy consumption in industry, services and domestic fields will lead in the next 40 years to the situation of exhausting classical main sources of energy. In the vision of sustainability, research is aimed at the reduction of CO_2 emissions by up to 80 %, as compared to standard buildings and the reduction of costs for heating by about 40% as compared to conventional habitats. It is, therefore, necessary to find alternative systems for generating electricity, heat, water purification, waste water heating and waste recycling industrial, commercial and domestic products.

In the case of heating systems, which are the subject of this research, the authors tried to develop an application aimed at heating systems that use heat pumps in spaces for offices, services and mono dwellings, hotels and motels, shops, shopping centers.

2. RESEARCH AT THE LOCATION AND HABITAT CONSTRUCTION

Building for which it is considered the heating system and preparation of domestic hot water is composed of 6 rooms + hall, taking along a surface of 80 m^2. Outer walls are made of cement (BCA with a thickness of 10 cm plus a layer of expanded polystyrene thermos 10 cm. The internal walls are made of cement (BCA) and have a thickness of 20 cm. Between the two walls, it will be allowed a gap of 5 cm, which will be filled with mineral wool. The floor is made of a layer with a thickness of 25 cm. The concrete wil be cover with termoinsulating extruded polystyrene, with a thickness of 15 cm. The insulation shall be applied over a wooden parquet of fir, with a thickness of 5 cm. The ceiling made of reinforced concrete has a thickness of 20 cm and it is insulated with extruded polystyrene with a thickness of 15 cm. Windows and doors that communicate with the outside are made of PVC triple-laminated glass.

Since in the area there, there is no gas network, there are a few alternatives for building heating and domestic hot water preparation:

•center with liquefied gas,

•central solid fuel (wood or coal),

•electrical heating,

•ability to capture the source of groundwater.

In the design building, local distribution of the wind and relative humidity of the intake air, maximum exposure to direct sunlight, shape and climate specific for lowlands, as well as hills in Galati County, where we can use diverses systems of renewable energy [1], must be taken into account.

From the data obtained from the meteorological Galati station, a relatively large variation in temperature and annual average monthly was recorded. The highest temperature has been of 40.56 °C (Figures 1 and 2), and the lowest – 20.56 °C. It is to be noted that the average daily temperatures above 22 °C shall be carried out in the summer months and in a smaller number of days in the months may to September.

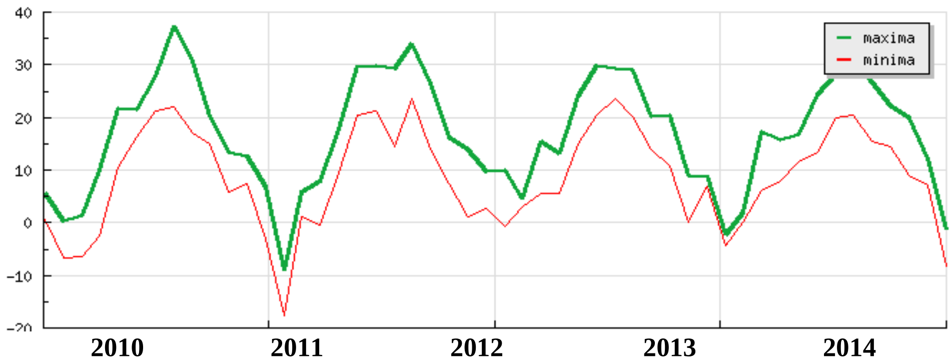

Fig. 1. Temperatures recorded in Galati County
(source: weatherundegroung.com, 2010-2014 years)

Solar radiation varies between 127.5 kcal/cm^2 in the south and 122.5 kcal/cm^2 in the north and is closely linked to the duration of sunlight, which, in Romania, has a total average of 2100 hours per year in the north and 2160 hours per year in the south.

Atmospheric precipitation total values are the lowest in the country and this is the result of eastern continental influences and a result of the movement of air masses flowing to the west and north-west.

Average annual precipitation total is 420-430 l, with fluctuations in some impressive years, from 41.5 l to 630 l. It is an area that contains a great variety of habitats. The land, where the house is located, lies in the vicinity of forests providing, in addition, aesthetic appearance, like in the area, freshening up the air at all times.

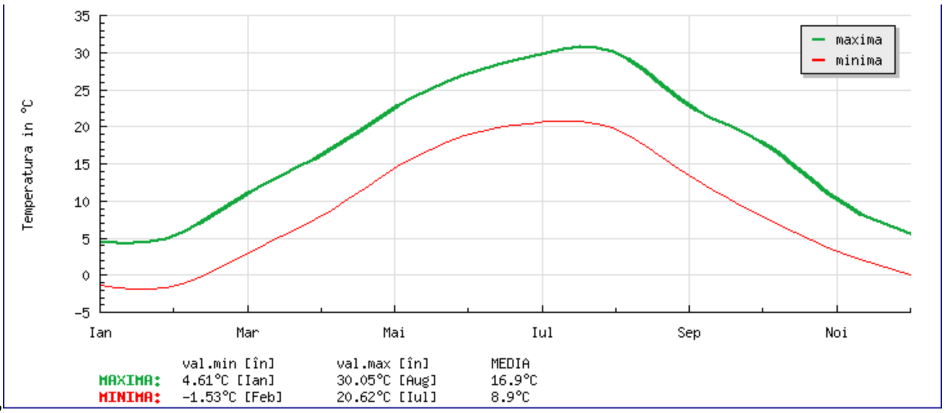

Fig. 2. Monthly average temperatures in Galati County.
(source: weatherundeground.com, 2014)

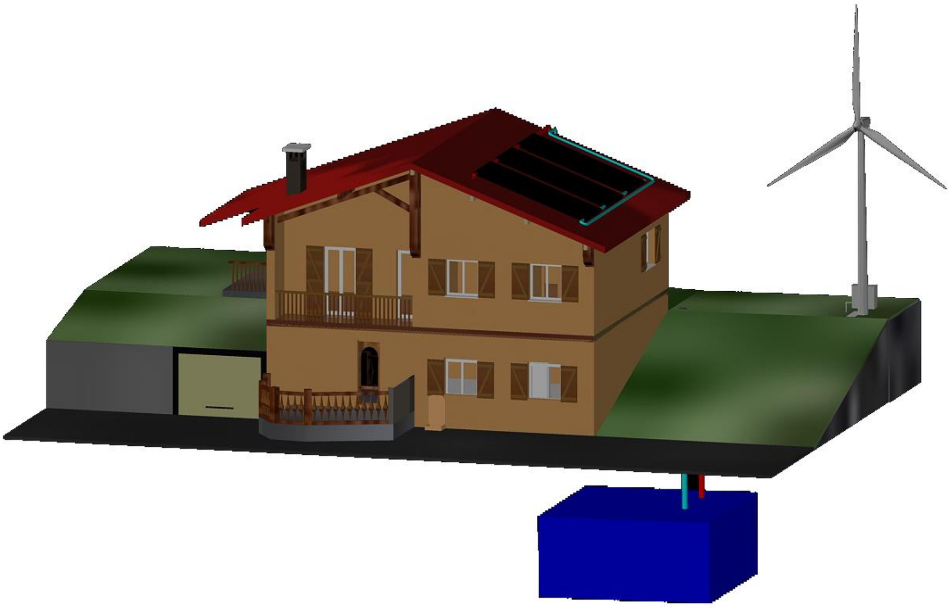

Fig**. 3.** View of the assembly in 3D

Building to be heated is drawn in the program AutoCAD. Figure 3 shows a front view of the assembly in 3D.

On the house roof, solar receptors for heating water in winter and summer were mounted, the solar plant for the water to heat up is engaged with the heating system with heat pumps. Figure 3 shows a view from the rear of the assembly in 3D.

The supply of electricity to the recirculation pump water shall be made at a central wind, located in the court house. The wind system is connected to national energy system and can be operated under a system of co-generation. The power station is provided with a system with batteries and inverter. Figure 4 shows a breakdown into the assembly rooms. The dimensions and the manner in which the rooms are apportioned are given in Table 2.

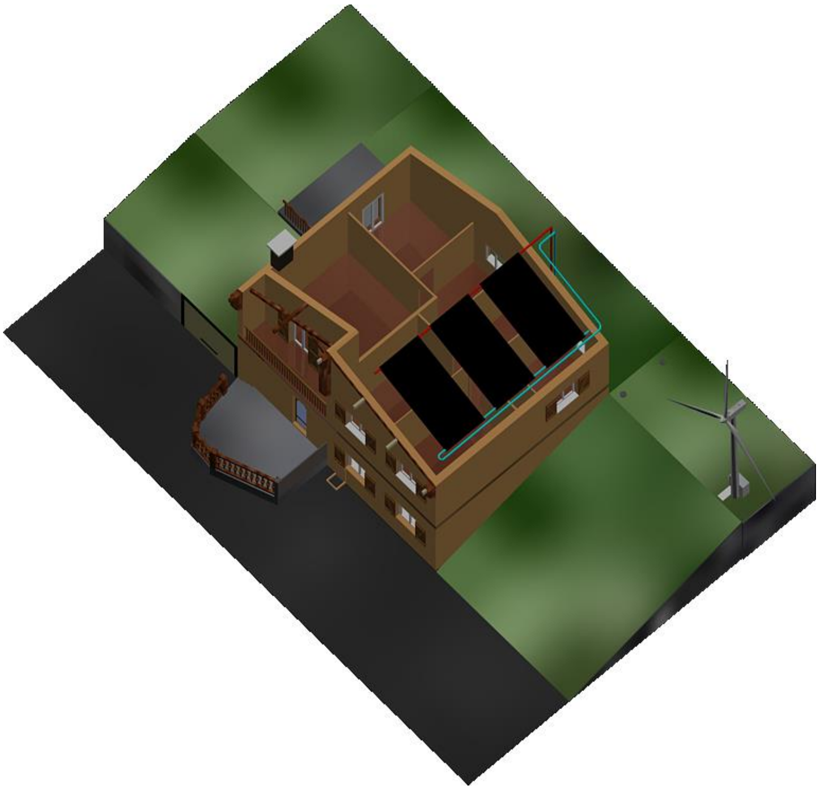

Fig. 4. Breakdown into the assembly rooms (up side).

Unconventional between the materials used for the construction of a house eco-friendly, wood is a matter of importance. Wooden houses do not have a tradition in our country, but it also represents a viable solution in the construction sector. These houses meet two basic requirements imposed by human society at present, namely, quality and environment protection [2].

Environment is protected by using eco-friendly, easily recyclable construction materials, by providing a very good thermal isolates greatly reduces charges for heating during the winter or summer air-conditioning. Through this system, the cost of heating in winter and cooling in summer, are reduced by 50-85 %.

Passive methods are actions that highly dependent on external conditions (solar radiation, cold weather, wind, humidity). For this reason, the use each system liabilities to be conceived for a specific location and orientation of the building on the front panel, otherwise system performance will not be satisfactory.

3. DETERMINATION OF THE HEAT REQUIREMENT FOR WARMING UP

For temperature requirements of the designed dwelling, for heating and preparation of domestic hot water, a program of calculation has drawn up on the basis of a mathematical model, in the C programming language PHP (preprocessed hypertext markup language), with a display in an HTML interface. There are applications which may calculate the heat demand (as in Table 2**).**

Table 2. Required heat after application usage (take account of insulation)

Tipe of room	Lengh (m)	Width (m)	Watt –Area (m^2)
Livingroom	4.28	5.06	1460 - 21.65
Bedroom 1	4.50	2.80	506 - 12.60
Bedroom 2	4.50	2.80	732 - 12.60
Bathroom 1	3.30	2.50	678 - 8.25
Bathroom 2	3.30	2.19	961 - 7.25
Kichen	3.38	3.58	876 - 2.10
Total			5213 – 64.45

4. MATHEMATICAL MODEL

To study the flow of heat requirement is needed to know possible losses of heat and how to use it. Overall equation heat balance is used in the calculation of the heat flux [3]:

$$\dot{Q} = \dot{Q}_1 + \dot{Q}_2 + \dot{Q}_3 \quad [W] \tag{4.1}$$

where

$\dot{Q}_1$ - heat flow lost through the transmission;

$\dot{Q}_2$ - heat flow necessary to heating venting air;

$\dot{Q}_3$ - heat flow used for heating domestic hot water.

Heat flow lost through the transmission [3] is divided among house components, like walls $\dot{Q}_{1.1}$, floor $\dot{Q}_{1.2}$, ceiling $\dot{Q}_{1.3}$ and windows $\dot{Q}_{1.4}$, thus:

$$\dot{Q}_1 = \dot{Q}_{1.1} + \dot{Q}_{1.2} + \dot{Q}_{1.3} + \dot{Q}_{1.4} \quad [W] \tag{4.2}$$

The formula shall be used for the calculation of the heat flow is common in four components [3]:

$$\dot{Q}_{1.i} = S_i \cdot k_i \left(t_{int} - t_{ext}\right) \quad [W] \tag{4.3}$$

where

S_i – the total area calculated for each of these components; only those elements of connection with the outside shall be taken into account, [m^2];

k_i – the coefficient of thermal transfer, specific to each type of element, in $W/(m^2 \cdot K)$;

t_{int} – inside temperature of the assembly, in [K];

t_{ext} – outside temperature of the assembly, in [K].

The coefficient of global heat transfer shall be calculated according to the formula [3]:

$$k_i = \frac{1}{\frac{1}{\alpha_i} + \sum_{i=1}^{n} \frac{\delta_i}{\lambda_i} + \frac{1}{\alpha_e}} \quad [W/(m^2 \cdot K)] \tag{4.4}$$

α_i – the convectiv heat transfer coefficient from the inside, $\alpha_i = 8\, W/(m^2 \cdot K)$

α_e – the convectiv heat transfer coefficient from the outside, $\alpha_e = 25\, W/(m^2 \cdot K)$;

λ_i – the thermal conductivity of „i" layer;

δ_i – „i" layer width, expressed in [m].

Heat-flow heating necessary to venting air shall be calculated on the basis of house category from the point of view of thermal insulation:

$$\dot{Q}_2 = n \cdot \dot{Q}_1 \quad (4.5)$$

where: n=0.7 for a house without thermal insulation; n=0.8 for a house with normal thermal insulation; n=1 for a house with low energy consumption or for a passive house.

The heat-flow necessary for heating domestic hot water depends on the following parameters [3]:

$$Q_2 = \rho \cdot V \cdot c_p \left(t_{hot} - t_{cold}\right) \cdot n / \tau \quad [W] \quad (4.6)$$

where:

τ – time necessary for having the domestic hot water, in [s];

ρ – water density, $\rho = 1000$ [Kg/m^3];

V – volume domestic hot water on person, [m^3];

c_p – specifically hot water coefficient, $c_p = 4.186\ kJ/(kg \cdot K)$;

t_{hot} – hot water temperature, [K];

t_{cold} – cold water temperature, [K];

n – number of persons.

The coefficient of performance of a heat pump is defined as the ratio of the heating power and the power absorbed by the network, i.e. (COP):

COP = Heating Power / Electrical Absorbed Power

In the case of heat pumps type water - water, the coefficient of performance is COP = 5.4 - 5.5. This means that 1 kWh of absorbed electrical energy produces, via the pump type heat water-water, 5.4 - 5.5 kWh (thermal power).

The heat pump is powered by electricity produced by the photovoltaic cells on the roof. Hot water comes mostly from a solar panel on the roof. Also, the windows are equipped with automatic shutters that close when summer is too hot.

Nearly 50% of CO_2 emissions derive from the energy we use for heating, lighting and cool buildings, with an additional 10% generated by the production of the construction materials.

If we want to move quickly toward an economy based on low carbon, construction is the key. Another key would be the waste, so 35% of waste from this sector and almost 20% of construction waste are new materials used to build the construction.

This building energy consumption is less than three-fourths of a traditional building, with full exploitation of natural light. In addition, the energy comes from a combination of solar panels and heat pumps [1].

5. CONCLUSIONS

The conclusions of this study require an analysis of the strengths and weaknesses to find the economic efficiency of house heating eco-systems, as follows:

Strengths of passive houses are:

• absolute efficiency when electricity grid connections cannot be / too expensive;

• rural areas have a net advantage for alternative energies [1] as compared to towns;

• a house of 150 m², the price of a hybrid power system that uses wind power and solar energy is 12000-20000 euros;

• for days with no wind / light or special situations, a generator that runs on diesel or petrol power can take home;

• the energy cost of a wind system is 1-3 euro/W;

• The cost of photovoltaic panels is 6-9 euro/W;

• Heat pump price is 7,000...8,000 euros - for heating (can be used in combination with photovoltaic panels);

• a system of solar collectors / photovoltaic, heat pump and storage tank should not exceed 16,000 euros at current prices;

• the air conditioner can be supplied with a plastic pipe, buried about 2 feet into the ground, which helps a few low power fans that can provide 21°C to 22 °C in midsummer, in house [4];

• the possibility of combining multiple sources of alternative energy.

Weaknesses of passive houses are:

• consumers and providers have little incentive network (covering a percentage of the investment, exemption / tax cuts);

• no incentives for interconnection with the national energy system / local;

• change of countryside or urban areas (for small installations, visual and noise pollution is limited);

• an urban housing system based on alternative energy requires considerable time and finances;

• local government performance (efficiency of spending public money for taxpayers priorities, not for their own interests);

• issues in terms of bureaucratic obstacles in licensing or ownership by the authorities;

• district heating plant performances (dependent on the induced thermal energy from the neighbourhood centres that load heat bills, not only with the argument barrel price increase).

Careful planning of the position of a building - that is taking into account exposure to the sun and wind - can profoundly influence the heating and cooling systems, and those of artificial light. This can have a positive impact on housing prices during the operation habitat.

Water-water heat pumps extract energy from water (rivers, lakes, sea, aquifers, etc.) and supplies heat in the form of warm water. The range of these heat pumps is very large, being between installations for heating to households and individual installations intended for very large industrial sectors or tourism [5].

Water temperature of groundwater has a constant level, almost independently of weather conditions during the year. This is the main reason why a heat pump water-water is ideal for point-to-point operation. The water-water heat pump receives the accumulated energy in the water from the groundwater source and it runs, using electrical energy, through the heating circuit of the assembly. Large values of the coefficient of performance are achieved when warming your house with the system "in the floor".

REFERENCES

[1] Pah G., 2003, *Natural Home Heating: The Complete Guide to Renewable Energy Options,* Chelsea Green Publishing.

[2] Chen G., 2004, Electrochemical technologies in waste water treatment, Separation and Purification Technology, 38/8, pp. 11-41.

[3] Mădărăşan T., Bălan M., 1999, *Termodinamică tehnică* (in Romanian), Ed. Sincron Cluj-Napoca.

[4] Vidal G., Carvalho A., Mendez R, Lema J. M., 2000, Influence of the content in fats and proteins on the anaerobic biodegradability of waste waters, Bioresource technology, 74/5, pp. 231-239

[5]. *** http://www.westfalia-separator.com/applications/fluids-water/drinking-water-recovery-waste.