International Journal of Civil and Structural Engineering– IJCSE
Volume 2 : Issue 2 *[ISSN : 2372-3971]*
Publication Date: 19 October, 2015

ANALYSIS OF BUILDING PERFORMANCE OF AN EFFICIENT HOUSE WORKING WITH GROUND SOURCE HEAT PUMP

[Cristian MARACINEANU, Smaranda Maria BICA]

Abstract— The present work analyze the efficiency of using ground source heat pump for inner space heating/cooling and hot water production in new energy-efficient buildings in Romania. Such analysis would be a way to answer to the problems resulting from the continuous increase of energy consumption. The present study describes the building performance of a 2010 construction from Timisoara, designed as an energy-efficient house. The energy consumption of this project was followed for 4 years and a new improvement is planned to be implemented.

***Keywords*—sustainable, energy efficiency, green technologies, pilot project.**

I. Introduction. The importance of the research field

The current paper aims to address an important problem: the continuously growing energy consumption in the maintenance of buildings. One way to address this issue is by implementing renewable energy solutions and newly released technologies. For a pertinent analysis the study was performed on a pilot project built back in 2010. This energy-efficient house has been created with the precise purpose of highlighting how renewable energy sources can help.

What does the concept of an energy-efficient building refer to?

Energy-efficient buildings (new constructions or refurbished existing buildings) can be defined as buildings that are designed to provide a significant reduction of the energy consumption by using the amount of energy provided by on-site renewable energy sources. [1]

Cristian Maracineanu
Politehnica Univeristy of Timisoara
Romania

Smaranda Maria Bica
Politehnica Univeristy of Timisoara
Romania

The cornerstone in the design of an energy-efficient building was to first minimize the energy demand for heating/cooling and electricity use, and to cover the rest of the needed energy by using building-integrated renewable energy production systems. The main unlimited heating sources that must be considered primary energy sources are the ground and the sun.

Considering the above concept there has been used a ground source heat pump for heating/cooling and hot water production for the entire house.

II. The pilot energy-efficient house configuration and description

The entire study has been conducted on a residential building in Timisoara, Romania, a city with a humid continental climate. The entire project is designed as a newly built single-family dwelling (2-3 people) that includes a fully equipped kitchen, a living room, two bedrooms and two bathrooms and a technical room. The house is separated in two independent regions with separate entries and separate bathrooms. This gives the house the possibility to have flexible utility. An important issue considered from the first stages of the design regarding the building energy consumption was represented by the shape of the building (Fig.1) and the orientation of the rooms. Incorrectly solved, these factors may cause heat loss when heat gain is required and also heat gain when cooling is required.

Fig.1 *Pilot Project Ground floor Plan (source: drawn picture)*

The rooms of the house are mostly South oriented with a "L" shape plan and a 7.2 sqm large glazing surface for the open space dedicated to the living room, dining place and kitchen. The Eastern and Western facades have much smaller glazed surfaces and the north façade is completely closed. L shape is not the most efficient shape, but it was chosen in order to leave as much as possible of the surface of the plot for further constructions.

Building parameters

Ground built surface:	125.0 m$^{2;}$
Internal volume:	265.0 m^3;
Height:	2.50 m;
Heated floor area:	100 m^2
Total windows surface:	20.4 m^2
South oriented double glazing	U=1.1 W/ m^{2}K 12.3 m^2
Opaque walls	U=0.20 / m^{2}K 227 m^2
Roof	U=1.1 W/ m^{2}K 134 m^2;

Structure: wood structure with Basaltic Mineral Wool Insulation and OSB enclosure.
The total surface of the envelope is of 480 m2 and a average value of 0.19 W/ m^{2}K [3].

Electrical components

- LED Television, Laptop;
- Refrigerator, Microwave, Toaster, Hood;
- Washing machine A+, Flatiron;
- LED Lighting, Heat Pump + components;
- Surround Home Studio System, Phone;

This gives for entire house a total consumption capacity of 4800 W.

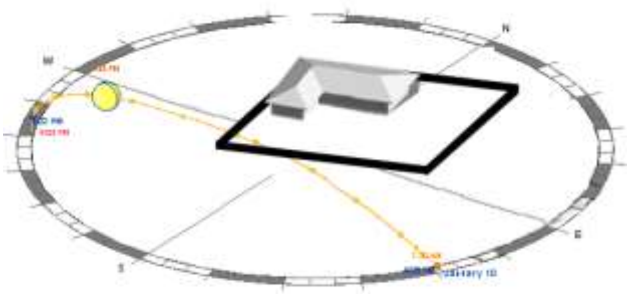

Fig.2 *Pilot Project Solar Orientation Plan (source: drawn picture)*

III. Ground Source Heat Pump and installation parameters

A geothermal heat pump or ground source heat pump (GSHP) is a central heating and/or cooling system that transfers heat to or from the ground. It uses the earth as a heat source in the winter and as heat sink in the summer.

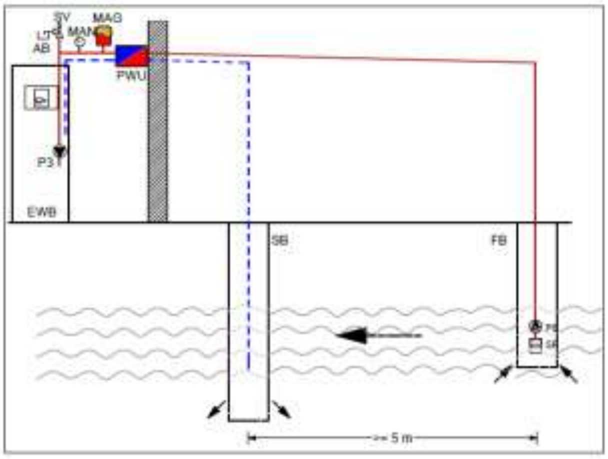

Fig.3 *Conceptual scheme of the entire geothermal installation (drawn picture)*

This device takes advantage of the moderate temperatures in the ground to boost efficiency and reduce the operational costs of heating and cooling systems, and may be combined with solar heating to form a geo-solar system with even greater efficiency.

The conceptual scheme of the entire geothermal installation is presented in figure 3 together with the two outside drills, one used to pull the necessary water for the system and the second one to send the used water back in the ground.

The house is equipped with Junkers TM 100-1 ground source heat pump (Fig. 5) with a built in hot water 163 l boiler and 300 l exterior water boiler for the floor heating system. In addition to these elements flow pumps, heat exchangers were installed, and a central control panel.

Each room has temperature sensor and adjustment mounted on the wall in a certain area, according to the drawing in Fig. 4.

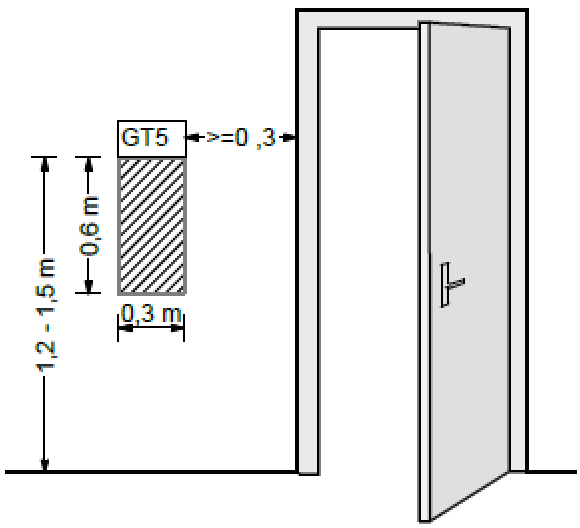

Fig.4 *Temperature sensor installation (drawn picture)*

Heat pump characteristics:

- Exterior temperature sensor;
- COP factor 5.0;
- Water boiler volume 163 l;
- Mitsubishi Scroll compressor
- Refrigerant R407c;
- Maximum flow temperature 65 **°C**;
- Auxiliary electric resistance 3-9 kW;
- Dimensions 1800x600x640;
- Functions: heating, cooling, hot water;

Fig.5 *Heat Pump scheme (source: processed picture)*

Installation parameters

The installation has been designed for a permanent use in the city of Timisoara, Romania. The city has a temperate continental climate with annual medium temperatures between 10.7 – 11.1 **°C**;

The heat pump system works with a floor heating/cooling system that has a working flow temperature of 45 C;

Flow pump is Grundfos Alpha 2, Energy Class A, auto adaptation, 5 – 45 W, 220V;

Number of permanent users 2;

Drilling depth: 20 m;

Number of drills: 2;

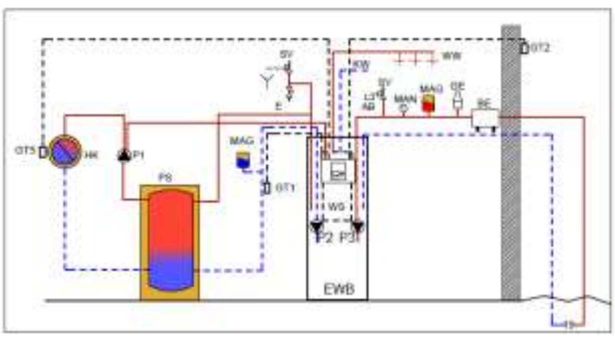

Fig.6 *Conceptual scheme of the interior installation (source: drawn picture)*

Heat system terminal characteristics

To extend the use of the GSHP and to increase the benefit of their energy efficiency, even to reach targets of 20-20-20, a floor radiating heating system was used as a terminal.

A floor radiating system requires a water input temperature between 35°C and 45°C compared to a radiator system working with input temperatures higher than 70°C.

Figure 7 presents a comparative analysis of the radiant floor heating system and a conventional radiators heating system in relation with the water input terminal temperatures and outdoor temperature. It is evident that the difference between the input water temperatures for the two systems is of 20°C to 25°C. This shows that it is possible to save energy by using radiant heat floor system and to increase the performance with 20%.

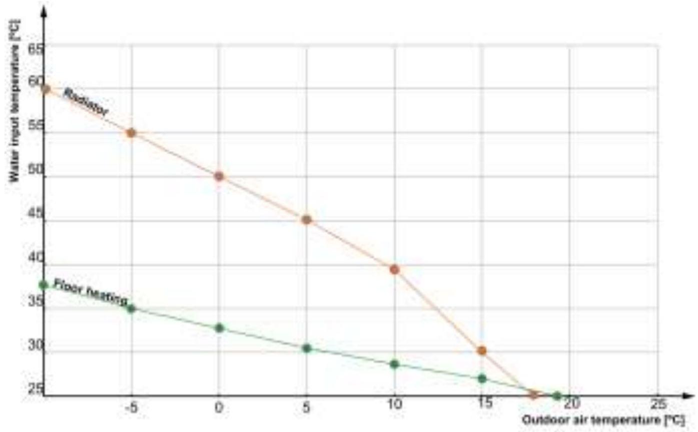

Fig.7 *Floor heating temperature versus radiator heating temperature(source: drawn picture)*

IV. Estimated consumption of the house

During the 4 years since the house has been build, the electrical consumption was manually recorded.

The electricity consumption of the house devoted to the heat pump, lighting, house equipments, heating, cooling and hot water are plotted in Fig. 8.

The diagram from Figure 8 shows that 54% of total energy consumption is used to heat the house. The length of time in which the heating system is in use is determined by the outside ambient temperature which was continuously monitored.

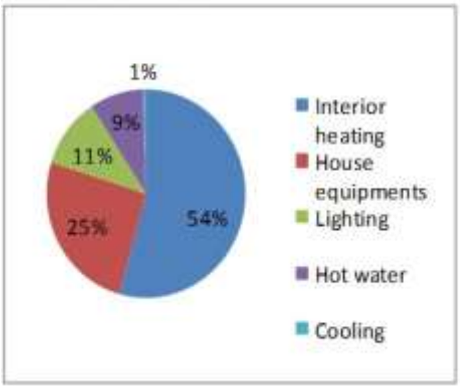

Fig.8 Pilot Project Electric energy consumption (source: drawn picture)

The heating works from the end of September or beginning of October until the end of February or beginning of March, in total approximately 5-6 months of operation in one year. During this period the heat pump operates without interruption. The recording of indoor and outdoor humidity and temperature offered by exterior and interior sensors every 24 hours helps to set the required parameters for the heat pump in order to maintain constant indoor temperature and humidity throughout the year.

The analysis of the measured electricity consumptions in the pilot house inhabited by occupants who are motivated for green energy consumption shows that the house can be considered an "energy efficient building": by installing a PV system and a thermo-solar system together with the heat pump can cover the whole yearly heating and hot water demand.

Switching from the conventional building system to a modern one that is based on advanced, energy-efficient principles and state of the art technologies is certainly a very challenging task that one needs to overcome, keeping in mind the following aspects:

- The continuous growth in energy consumption all around the world, as well as the constant increase in energy prices;
- The desire to save money and to lower the energy bills in the long term, while still maintaining the same standards of comfort;
- The increasing the quality of new buildings by relying on new, efficient and accessible construction techniques that are readily available on the market and that are especially designed to protect the surrounding environment and to make people's lives easier at the same time;

The building pattern is also important as it can increase, decrease and modify the air movement speed. The layout of the surrounding open space and vegetation can also influence the heat loss and gain. Deciduous trees reduce heat gain during the summer and will let the sun warm up the interior in winter time. [2]

V. Cost and consumption statistic analysis

The table from Fig.9 shows statistical data about the total electric consumption of the house during the last 3 years (2012, 2013, 2014) taking into consideration the medium temperature of each month. All the information is directly measured and compared with Enel (Electric supplier of Timisoara) measurements from My Enel account (www.enel.ro/crosweb/myenel).

The information about the climate and monthly medium temperature since 2012 has as source the website of the National Meteorology Agency of Romania. (www.meteoromania.ro/anm).

Statistically, in terms of annual data, one can see in the table from Fig. 10 that on a three years period the consumption was in total of 15751.74 kWh : 6663.71 in 2012, 5174.20 kWh in 2013 and only 3913.83 kWh in 2014. It shows a decrease in total energy consumption from 2012 to 2014. This is also influenced by the fact that the cold months of the year 2014 saw an increase of average temperature. In 2012 the average of the lower temperatures was of 2 °C. In addition in April 2014 the whole house lighting system has been changed to LED lighting. The result can be seen in Fig. 9: in 2014 the monthly energy consumption decreased by 65-80 kWh compared to 2013. This reduction in energy consumption represents a 12% to 18% economy from the total annual consumption. The reduction of energy consumption was constant from 2012 to 2014:

- A decrease in energy consumption of 22.36% in 2013 compared to 2012, although the average annual temperature was similar for both years.
- A decrease in energy consumption of 24.35% in 2014 compared to 2013

A decrease in energy consumption of 41.27% in 2014 compared to 2012, keeping in mind that in 2014 the average annual temperature was similar to that in previous years, but the average temperature in the cold months was slightly higher, when compared to 2012.

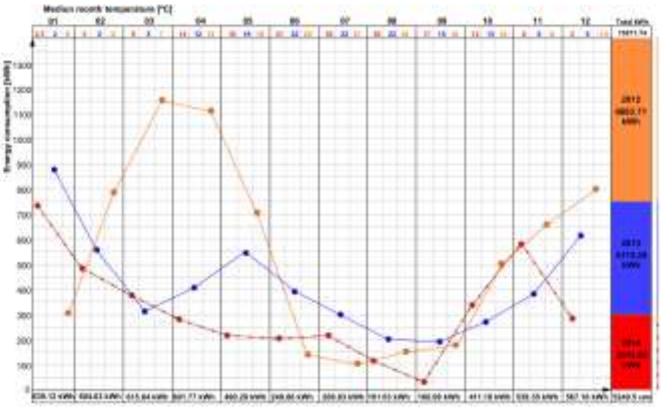

Fig.9 *Pilot Project Electric energy consumption analysis 2012 -2014*

Cost analysis

In addition to the statistics of the power consumption of the energy efficient pilot house shown in the diagram above in the table below, the annual and monthly maintenance costs should also be considered.

Month	2012 kWh	2013 kWh	2014 kWh
Jan	311.26	868	738.1
Feb	785.35	552.17	476.38
Mar	1162.34	315.17	369.42
Apr	1124.84	406.46	277.02
May	708.38	539.83	222.66
Jun	143.39	390.71	215.48
Jul	104.18	299.67	222.66
Aug	153.36	190.73	139
Sep	174.59	271.27	36.21
Oct	515.63	372	345.93
Nov	677.42	360	580.65
Dec	802.97	608.19	290.32
Total kWh	**6663.71**	**5174.20**	**3913.83**
Ron/kWh	0.54	0.55	0.56
Total RON	**3598.4**	**2845.81**	**2191.74**
Total EUR	**808.62**	**639.50**	**492.52**

Fig.10 *Yearly cost analysis table*

The considered conversion rate for the electrical energy cost was of 4.45 Ron for 1Euro. The average monthly expenses, as shown in Fig. 10, were:

- 67.37 Euro/month, VAT included, for 2012
- 53.30 Euro/month, VAT included, for 2013
- 41.00 euro/month, VAT included, for 2014

For the 110.00 m² usable build surface of the house, in 2014 the expenses were 0,372 euro/month/m².

VI. Conclusion

The indicators defining sustainability in buildings assessment vary slightly, depending on conditions that affect the entire environment of the house: outside temperatures and humidity, inside temperatures, energy efficiency of the electrical equipment, indoor temperature and humidity, indoor air quality etc. But the analysis results are show beyond doubt an important improvement of the energy efficiency: the electrical consumption has been reduced with 41.27% in 2014 comparing with 2012. And, just by replacing conventional light bulbs to LED systems the cost for electricity was reduced by 15%.

Future research

In the next period the research will be focused on the installation of a 1.5 kW PV System and a Thermo-solar system on the house roof. The aim is to reduce the annual energy costs to 150 - 250 Euro/year by using efficient technologies available on the market.

VII. Acknowledgements

This paper is supported by the Sector Operational Program Human Resources Development POSDRU/159/1.5/S/137516 financed from the European Social Fund and by the Romanian Government.

References

[1] Mărăcineanu C., Smaranda B., The energy Efficient Home – Timisoara EEH Pilot Project – 2nd International Conference for PhD Students in Civil Engineering, Cluj-Napoca, 2014.

[2] Presier, W. F. E., Robinowitz, H. Z. And White, E.T., Post-Occupancy Evaluation: how to make buildings work better, Facilities, vol.13, 1995.

[3] Boyle, G.: Renewable Energy. Glasgow, Oxford University Press, 2004.

About Author (s):

[The cornerstone in the design of an energy-efficient building was to first minimize the energy demand for heating/cooling and electricity use, and to cover the needed energy by using renewable energy production systems.]

[Energy-efficient buildings can be defined as buildings that are designed to provide a significant reduction of the energy consumption by using the amount of energy provided by on-site renewable energy sources.]