Architectural and Energy Performance Analysis: a Case Study on a New Building in Timisoara

Cristian Mărăcineanu, Smaranda Maria Bica

Faculty of Architecture, Politehnica University Timisoara, Romania

Abstract - The present work researches the possibilities of solving in a realistic and economically-sound way the design of new energy-efficient buildings in Romania. Such solutions would be a way to answer to the problems resulting from the continuous increase of energy consumption, from the continuous rising of energy production costs and decrease of the respective natural resources at a global level. Although the concept of energy-efficient houses is a well-known subject in the international scientific and political community, unfortunately in Romania this concept, though frequently discussed at the theoretical level, is rarely applied to the building process of new constructions. The approach undertaken in this study is based on the mixing of efficient technological and architectural solutions. The present study describes the phases of a pilot project built in Timisoara since 2010, a new construction using new energy efficient technologies available on the Romanian market. 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. The purpose is to reduce the energy cost by installing photovoltaic systems and using the available solar energy even more.

Keywords—sustainable building, energy efficiency, pilor project research, green technologies

1. INTRODUCTION

The current paper aims to address several different problems, the most important one being the continuously growing energy consumption and how this issue can be addressed by implementing renewable energy solutions and newly released technologies. The current paper will thoroughly analyze all the problems related to the energy consumption of the house, and how the consumption can be reduced by implementing cost-effective and energy-efficient solutions for minimizing the overall use of energy.

The most important key role in the design and operation of efficient energy buildings is played by mix of the architectural sustainable desiderates with the highly efficient HVAC systems able to integrate different energy sources to cover the maximum efficiency the building energy demand. This implies the use of systems that exploit renewable sources, with thermal or electrical storages and heat recovery capacity. It is known in fact that the combination of two or more energy conversion devices and two or more energy sources for the same device, when integrated, overcomes the limitation that may be inherent in either source or device [4].

The efficiency of the systems can be massively improved by the architectural building design. Energy losses can be minimized and energy gains maximizes through the design of the building itself by using sensible window areas in order to achieve solar gains and lighting requirements and microclimate factors in conjunctions with usage requirements can help to structure the building in diverse ways.[5]

2. WHAT DOES THE CONCEPT OF AN ENERGY-EFFICIENT BULDING REFER TO?

Energy-efficient buildings (new constructions or renovated 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.

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.

Three aspects can characterize an energy efficient building system:

- the first aspect is the capacity of producing on-site a part of the energy demand from renewable sources;

- the second aspect refers to the building design that must reduce the energy demand to a limit that is a compromise between energy efficiency and financial feasibility;

- third aspect involves efficient thermal and electrical storages and the heat recovery concept;

3. BUILDING CHARACTERISTIC

The entire study has been conducted on a residential building in Timisoara, Romania, a city with a humid continental climate. An important issue that has been considered since the design phase regarding the building energy consumption is represented by the shape and the orientation. These factors may cause heat loss when heat gain is required and also heat gain when cooling is required.

Fig. 1. Location of the EEH Project (source: apmtm.anpm.ro)

Building architecture and design performance

A very important role in governing the energy consumption of any building is represented by the shape and the architectural characteristic of the envelope. These factors may cause heat loss when heat gain is required and also heat gain when cooling is required.[1]

For any given enclosed building volume, there are numerous ways in which actual dimensions of height, length and breadth can vary resulting in different total surface areas. Two buildings may have quite different surface areas and hence different rates of heat loss and heat gain and both having the same volume and built of the same materials. [2] Orientation of the volume and surfaces of the building severely affect the heat gain or loss from a building. The house is South oriented with a “L” shape planimetry with large glazing area that close the open space living, dining and kitchen on this south side. The Estern and Western facades are much less open to sunshine and the north façade is completely closed.

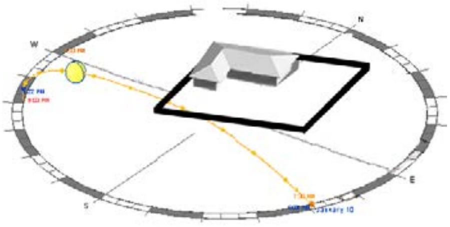

Fig. 2. EEH Project Solar Orientation Plan (source: drawn picture)

EEH Project characteristics:

- Ground built surface: 125.0 sqm
- Internal volume: 265 m3
- Heated floor area: 100 sqm
- Windows: 20.4 sqm with 12.3 sqm south oriented double glazing U=1,1 w/m2K
- Opaque walls: 227 sqm U=0,20 W/m2K
- Roof: 134 sqm U=1,1 W/m2K
-Structure: wood structure with Bazaltic Mineral Wool Insulation and OSB enclosure.

This gives for the envelope a total area of 480 m2 and a average value of 0.19 W/m2K. [3]

Since the project started an important concept was the south orientation of the house with a large 7.2 sqm glazing area for the living room to increase the passive solar heat gain during the year. The 7.2 sqm of window glazing from the living room rise the passive solar heat gain and helps to reduce the heat energy consumption in the following months: March, April, May and September, October, November with 20% a month if there are sunny days.

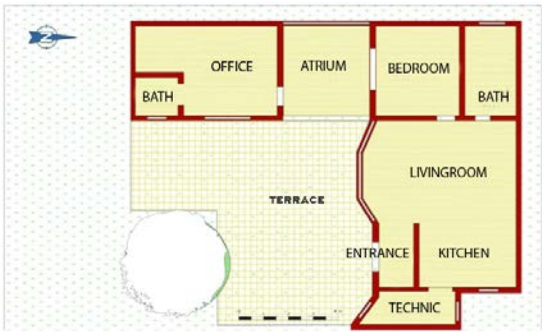

Fig. 3. EEH Project Ground floor Plan (source: drawn picture)

Open space and air movement

Open spaces have to be taken into consideration along with the form of the building, because together they can allow free air movement and increase heat loss or gain. [1]

The question is how should they be positioned and how much should there be? After all, any built mass modifies the microclimate. An open area as the one used in the building, especially a large one allows more of the "natural" climate of the place to prevail. Therefore, large open spaces allow free air movement.

The building pattern is also important as it can increase, decrease and modify air speeds. Open spaces gain heat during the day so in wintertime shading by surrounding (trees/vegetation) will reduce heat gain during the summer and will let the sun warmup the interior in winter time as long as the vegetation used for this purpose will be deciduous. [2]

4. ENERGY DEMAND AND ENERGY SOURCES

Heat pump

The building is a newly built single-family dwelling that includes a ground heat pump for the heating/cooling and domestic hot water production. The average heated area of the house is approximately 100 m². Statistically, the average heat demand for older buildings is 120 kWh/(m²/y), and for newly built buildings is 70 kWh/(m²/y). According to the energy consumption from the last 3 years the medium energy consumption for the entire house is 42.5 kWh/sqm/year.

Also from the entire yearly electric energy consumption of the house 64% is used for heating/cooling and domestic hot water production. To maximize the heat pump efficiency it was installed a ground floor heat system that need a lower working heat temperature.

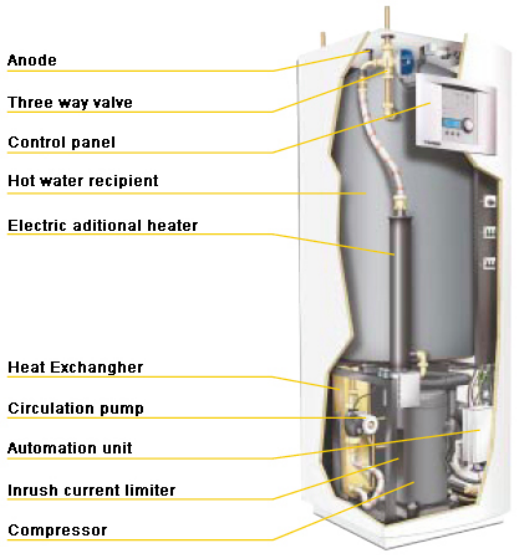

Fig. 4. EEH Project Heating Pump Junkers (source: junkers website. processed picture)

Improving the energy efficiency by coupling a 1.5kW off grid PV system.

The house was designed to have yearly overall consummation lower that 50kWh/m2 foar all users. In order to improve the energy efficiency of the building a 1,5 kW photovoltaic system will be installed on the 70 sqm south façade

As described in numerous studies, a photovoltaic collector produces electricity which supply a part of the energy demand of the building. This next step aims to increase the solar energy absorption and to decrease the electric consumption of the house.

According to the simulation made with PVGIS online software:

Percentage of days with fully charged batteries is 55.41% and. The average amount of energy that is not captured because the batteries are fully charged: 2283.39 Wh. Compared to the average consumption of 5 kWh/day, in all 1801 days taken into consideration for simulation, battery is fully discharged at 60% of their capacity since we have a cut-off limit of 40% (below this value inverter is commanded to stop and not start until the amount of battery power does not exceed 40%).

The facility oh this off-grid system with network compensation is that when the threshold of 40% of the batteries was reached, consumers are switched (automatically by a relay based automation) to the national network. Another benefit of this system is that the energy lost by the fact that the batteries are fully charged (in 55.41% of days) can be used directly by consumers in the home – energy produced is not lost but consumed.

Table 1. Monthly energy production, percentage o charged/discharged battery (simulation made with solargis software)

Month	Ed	Ff	Fe
Jan	1550.0	11	100
Feb	2230.0	24	100
Mar	3190.0	50	100
Apr	4060.0	76	100
May	4170.0	79	100
Jun	4330.0	80	100
Jul	4360.0	82	100
Aug	4400.0	90	100
Sep	3660.0	54	100
Oct	3020.0	54	100
Nov	2440.0	38	100
Dec	1050.0	0	100

Ed - Average daily energy produced (Wh/day)

Ff - Percentage of days when the batteries are fully charged (%)

Fe - Percentage of days when the batteries are fully discharged (%)

The PV system will be installed on the southern façade on the roof at a 35 degree angle from the ground and will consists of 5 monocrystalline PV modules, 1 x MPPT controller, 2 x 200 Ah solar gel battery, 1x pure sine inverter. Total electric energy produced by the 1,5 kW off grid PV system and consumed by the house is 1521.60 kWh/year this represents a 25-30% /year cost reduction for the electricity bill.

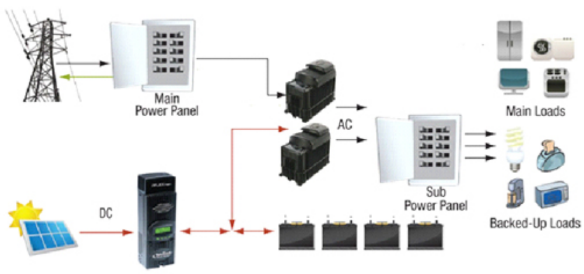

Fig.5. Off grid PV system (source: processed)

5. MEASURED AND ESTIMATED CONSUMPTIONS

The corresponding measured electricity consumption of the EEH Project devoted to the heat pump, lighting, house equipments, heating, cooling and hot water are plotted in Fig. 6:

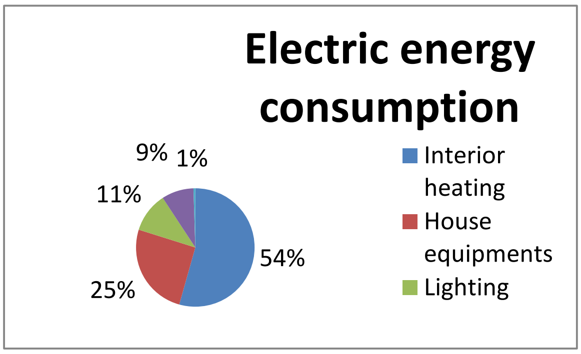

Fig. 6. EEH Project Electric energy consumption (source: drawn)

Also, electrical consumption was manually recorded on a three year period (Fig. 7) and it shows the total consumption of the building. The total electricity consumption is recorded from 1st January to 31st December.

kwh	month												Total
an	01	02	03	04	05	06	07	08	09	10	11	12	
2011				183,13	210,26	119,58	73,37	66,01	60,48	222,99	301,22	311,26	1.548,3
2012	311,26	785,35	1.162,34	1.124,84	708,38	143,39	104,18	153,36	174,59	515,63	677,42	802,97	6.663,71
2013	868	552,17	315,17	406,46	539,83	390,71	299,67	190,73	271,27	372	360	608,19	5.174,2
2014	738,1	285,71											1.023,81
Total	1.917,36	1.623,23	1.477,51	1.714,43	1.458,47	653,68	477,22	410,1	506,34	1.110,62	1.338,64	1.722,42	14.410,02

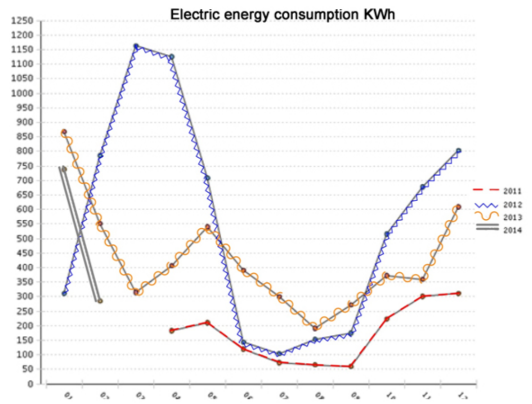

Fig. 7. 2011-2014 electrical energy consumption

6. CONCLUSION

The analysis of measured electricity consumptions in this house inhabited by occupants who are motivated for green energy consumption shows that the house can be considered a “energy efficient building”: the PV system and the heat pump can cover the whole (space and sanitary water) yearly heating demand with a good energy consumption

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 we will need 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;
- 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;

To sum it all up, through this pilot study - the energy-efficient house that was built four years ago, and whose energy consumption has been closely monitored – it was proven that significant cost and energy reductions can be made by simply relying on advanced technologies that are available on the market for highly affordable prices. [3]

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REFERENCES

1. A. Graf, “Passive House”, Oradea, 2013.
2. D. Pregizer, "Energy Passive House: Basics and Construction", Matrix Rom, Bucuresti, 2013.
3. Cristian Maracineanu, "Pilot Project - Energy Efficient House", Timisoara, 2013.
4. J. Manwell, “Hybrid systems, Enciclopedia of energy”, Elsevier.
5. M. Fuchs, T. Stark, M. Hegger, "Energy Manual:Sustainable Architecture” Darmstadt 2012.

Cristian Mărăcineanu
Faculty of Architecture, Politehnica University Timisoara, Romania
cristi.maracineanu@gmail.com

Smaranda Maria Bica
Faculty of Architecture, Politehnica University Timisoara, Romania
smaranda.bica@arh.upt.ro