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Differences between the five climatic zones of Romania regarding the design and energy requirements of an energy efficient house

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Abstract

In Romania, the energy performance design of buildings and related facilities is made on the hypothesis of standardized conventional climate data determined based on statistical average values. The Romanian territory is divided in five different climate zones that have different exterior climate parameters. This paper evaluates to what extent the energy demand vary in case of a residential building already built in the climatic zone II if it transposed to each of the other four climatic zones of Romania. Thus, the study starts from a baseline case of an energy-efficient building, designed and built in compliance with the principles of the passive house standard, in Timis County. Also, another purpose of this study is to establish U-values for the envelope elements, necessary to achieve the passive house standard for each of the five climate zones, in the conditions of the architecture and building services chosen for the already built house in the climate zone II. The energy performance calculations indicate different energy requirements for each of the five climatic zones, except the results for the climatic zone III and IV which are very similar. This paper emphasizes de particularity of the energy efficient design related to the climatic zone and the need of a careful planning in order to obtain the desired energy efficiency at a cost optimal level.

Keywords: energy efficient house, energy requirements, climate zones

1. Introduction

One of the current global problems is the need to reduce the energy consumption in order to prevent conventional natural resources depletion and environmental pollution. According to the statistics of the International Energy Agency (IEA) for energy balance for 2004-2005, the major part of the total final energy use globally is in the building sector (residential and commercial) (IEA, 2008). Thus, the energy consumption in the building sector represents an important category of the total energy consumption at a global level. At the level of the EU, the residential sector accounts for about a quarter of the final energy consumption, according to another important document issued by the European Commission (EC, 2014). The gradual reduction of the energy need in the European Union represents a necessary strategy in order to reduce the greenhouse gas emissions and also European Union dependency on the imported energy. The building sector is identified as the one with the highest potential for reducing the energy consumption. In 2006, the estimated potential for energy saving was 27% for residential and 30% for commercial buildings (EC, 2006). The European Union published the Energy Performance of Buildings Directive EPBD as a legislation regarding the energy performance of the buildings for the European member states and aims to promote improvements in the energy efficiency of a building (EBPD, 2010).

In Romania, the highest percent of the total energy consumption of a building is registered for heating. This fact proves the high potential for the implementation of energy efficient solutions in the rehabilitation of existing buildings and also the importance of developing more accurate standards and energy efficiency solutions for the design and construction of the new buildings.

Throughout the world, different approaches of energy efficient buildings exist with the attempt of providing validation for low energy buildings (Dequaire, 2012). Were developed several energy efficient buildings standards and requirements on energy and energy efficiency. These standards and requirements have the purpose to guide building norms and standards in each country and contribute to the implementation of the necessary actions. Due to the diversity of climatic conditions, available technologies and practices among European Union countries, the manner and extent of implementation of energy efficiency in buildings are regulated in each country.

An already well known energy efficient design standard is the passive house concept. In order to achieve the passive house standard, a house must have an annual heating/cooling requirement for at most 15kWh/m2/year and a total energy footprint of less than 120kWh/m2/year (Feist, 2007). A passive house combines high-level comfort with low energy consumption. Passive components like insulation, advantageous orientation, heat recovery, air tight envelope are the key elements. The high level of thermal insulation, heat recovery system and solar gains provide a comfortable indoor environment without the need of a conventional heating system. Thus, a passive house doesn't need to be heated actively to a large extent and the additional necessary heat is frequently supplied by heat pumps (Ochs 2012).

This paper presents aspects related to the design using passive house design procedure of an energy efficient building in Romania, focusing on the particularity of the Romanian climatic conditions.

2. Method

2.1. Details for the residential building subjected to energy demand evaluation

2.1.1. Architectural aspects and energy efficient design

The residential building subjected to study was designed and built applying passive house measures and is situated near the city of Timisoara. The construction of the house was finalised in 2011 and ever since is continuously monitored through a complex monitoring system that registers data related to energy consumption and comfort parameters. The studied residential building is a semidetached house with a treated floor area of approximately 140 m^2. Fig. 1 shows the geometry of the studied house.

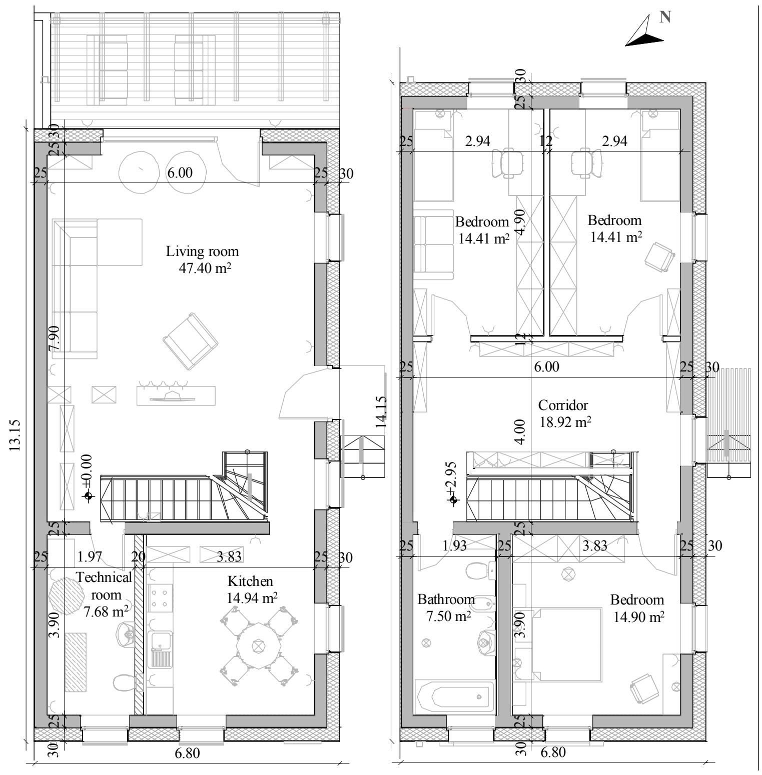

Fig. 1. Horizontal architectural plans for the studied house (ground floor, first floor)

From an architectural perspective, the house presents a compact form indicated by the thermal envelope surface area to volume (A/V) ratio of 0.89 m^2/m^3 and by the heat loss form factor of 2.77. The heat loss form factor is an alternative to the A/V ratio and describes the ratio of the thermal envelope surface area to the treated floor are. Achieving a heat loss form factor of ≤ 3 is a useful guideline when designing an energy efficient house such as the passive house (BRE Trust). Also, the building has considerable glazing surfaces for the south oriented facades in order to assure solar heat gains during the cold season.

The U-values of the enclosure elements are below the value of 0.15 W/(m^{2}K) recommended by the Passive House Institute. The use of external insulation provides a major advantage in reducing thermal bridges at geometric junctions. The vertical surfaces were complemented with general thermal insulation consisting of polystyrene plates of 300 mm thickness, while only 150 mm of thermal insulation was provided for the upper part of the parapet. The roof system is a non-traffic terrace with a slope of 2%, which incorporates 425 mm thick thermal insulation. Table 1 contains information related to the characteristics of the envelope elements of the house. The ground floor was insulated with polystyrene plates of 400 mm thickness. Polystyrene plates of 150 mm thickness were applied from the foundation beams upwards in order to reduce heat losses through ground.

Table 1. Characteristics of the envelope elements

Envelope element	*Surface area [m²]*	*Total thickness [m]*	*U-value [W/(m²K)]*
Exterior walls	158.55	0.588	0.10
Ground floor	86.70	0.887	0.09
Roof terrace	96.60	0.924	0.08
Floor over air	6.80	0.680	0.07
Windows	41.87	-	0.90

In the construction phase of the house, an airtightness test was performed using the Blower Door procedure obtaining an air change rate of 0.60 h^{-1}. The passive heating strategy of the house is based on the passive solar design and ventilation through a canadian well. The passive cooling strategy during summer is also based on the ventilation through the canadian well, solar protection and shading systems and night ventilation by opening windows.

The building is equipped with an efficient system providing ventilation, heating, cooling and domestic hot water. The system consists in a heat recovery ventilation unit that features an underground heat exchanger for fresh air input, an air-water heat pump, a 2.5 square meter solar collector. The heat is distributed in the living areas through fan convectors mounted in the ceiling. All equipment installed in the building uses electricity thus facilitating an accurate and clear evaluation of the building's total energy consumption.

The monitoring process was initiated in 2012. Figure 2 shows a recent diagram obtained from the measurements of the passive house monitoring system during a year. This graph shows the daily mean temperature inside the house and the daily mean exterior temperature for a year of monitoring.

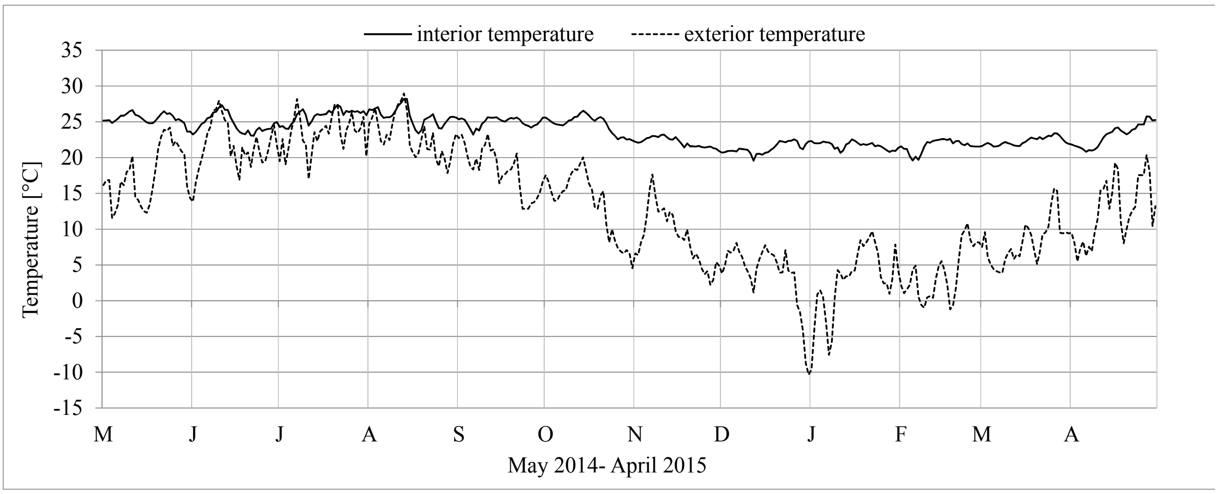

Fig. 2. Temperature measurement for the passive house

Analysis of the graph in Figure 2 shows that the interior air temperature is maintained at values between 20°C and 22°C for the winter months, indicating adequate thermal comfort. Yet for the summer months, there were days when the daily mean temperature was higher than recommended, meaning the house slightly overheated during the sunny summer days. The causes of the overheating are the lack of shading systems for the windows and of an active cooling system, the house being cooled during the night through windows opening and during the day through the Canadian well. Despite the overheating of the house during the summer days, the users of the house did not claim any major discomfort.

2.1.2. Structural characteristics of the house

As Romania is a highly active seismic country special structural requirements and detailing are imposed by codes. The structural system of the house was designed in conformity of P100/2006 (P100, 2006) Romanian standard, which is a more severe as equivalent European code EN 1998-1. Based on these requirements the structure was designed for a peak ground acceleration of ag = 0.16g, corresponding to the location of the house. The structural system of the house is a commonly used system in Romania and is composed of masonry structural walls of 250-mm-think ceramic hollow bricks, confined with reinforced concrete horizontal and vertical ties to meet seismic regulations.

Fig. 3. Pictures from the construction site of the residential house

The infrastructure consists of isolated concrete blocks connected with foundation beams that facilitated the thermal insulation of the entire ground floor. The roof of the house is a non-traffic terrace with structure of wooden beams. Figure 3 shows pictures taken during the construction of the structural system of the house.

2.2. Climatic parameters used to determine the energy performance of the building

The climatic parameters represent essential values in order to assess the energy performance and efficiency of a building and its equipment. Thus, the values for specific climate parameters are needed to assess the energy performance of new and existing buildings and also sizing the energy efficient envelope and equipment of the building. Information related to the climate data used in the energy use for space heating and cooling computation in Romania is presented in the Romanian methodology Mc001 (Mc 001, 2006). The first classification on climate zones was made using the weather parameters specific to the years 1961-1988. The update of the climate data implied the analysis of the weather parameters for two representative climate intervals 1961-2008 and 1994-2008. Currently, the Romanian territory is divided in five climate zones characterised by conventional exterior temperatures used for the buildings heating load calculation. For the purpose of this paper five representative towns for each climate zone were chosen (Table 2).

Table 2. Representative locations for each climate zone

Climatic zone	***City***
I	Constanta
II	Timisoara
III	Iasi
IV	Targu Mures
V	Sfantu Gheorghe

The monthly average temperatures and intensity of global solar radiation for each location were used in the energy requirements calculations performed by quasi-steady-state method.

Figure 4 shows a graph with the variation of the monthly average exterior temperature during the year. We can observe the temperature differences between the five cities and also the close values for the temperatures in Iasi and Targu Mures.

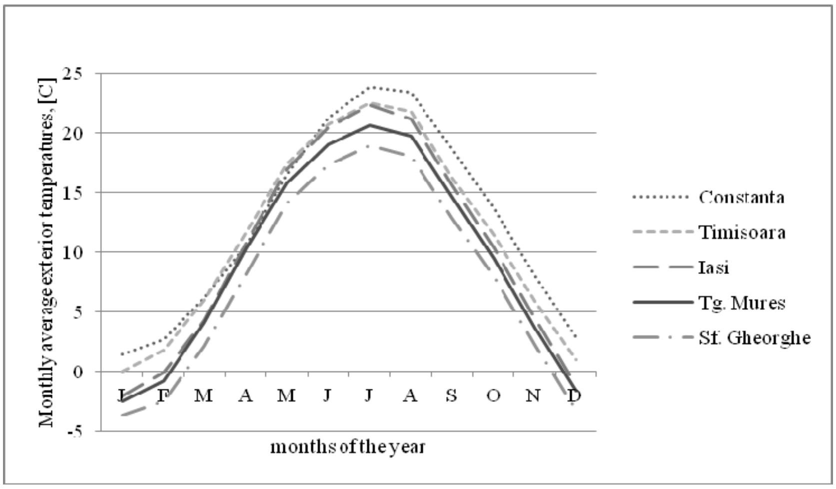

Fig. 4. Monthly average exterior temperature [°C]

Similar to Figure 4, Figure 5 presents the variation of the total solar radiation intensity during a year. The values for Constanta are the highest for almost the entire year.

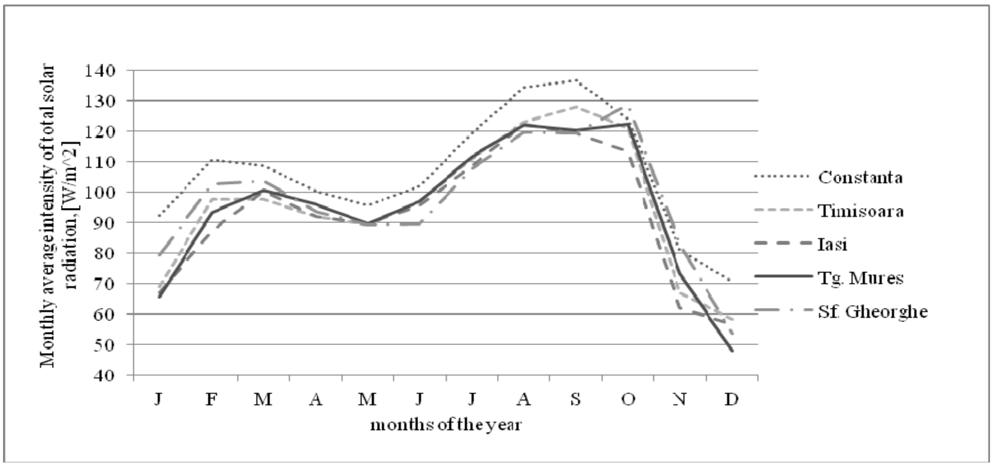

Fig. 5. Monthly average intensity of solar radiation [W/m^2]

A comparative presentation of the average annual temperature and the maximum and minimum values of the parameters used in the calculations, for each location for the five climatic zones, are presented in Table 3.

Table 3. Climate parameters values for the studied climatic zones/cities

Climatic zone /city	***I Constanta***	***II Timisoara***	***III Iasi***	***IV Targu Mures***	***V Sfantu Gheorghe***
Annual average temperature [°C]	12.4	11.4	10.3	9.4	7.7
Maximum monthly average exterior temp. [°C]	23.8/July	22.5/July	19.8/July	20.6/July	18.9/July
Minimum monthly average exterior temp. [°C]	1.4/Jan.	0.0 /Jan.	-2.1/Jan.	-2.5/Jan.	-3.7/Jan.
Maximum monthly average intensity of total solar radiation [W/m^2]	136.6/Sept.	127.8/Sept.	122.1/Sept.	122.2/Sept.	128.7/Sept.
Minimum monthly average intensity of total solar radiation [W/m^2]	70.7/Dec.	58.2/Dec.	56.5/Dec.	48.1/Dec.	53.6/Dec.

Thus, for the calculations the monthly method was applied using the dedicated software tool Passive House Planning Package PHPP.

2.2. Evaluation of the energy requirements for the studied house using PHPP in case of the five climatic zones in Romania

The first prerequisite on the road of realising a passive house consists in a well-planned and documented design. Throughout time, the Passive House Institute has presented different passive house building techniques and specific details that are suitable for the Central European Climate. However, it is not enough to solely apply those solutions for buildings situated in other climatic conditions. A more detailed design is necessary by performing simulations using the specific climatic conditions. As presented earlier in this paper, in Romania can be identified five climatic zones, each one characterised different exterior parameters such as temperature and solar radiation. At the moment of the planning and design of the house discussed in this paper, the energy use evaluation was performed for the climatic zone II, using the specific climate data for exterior temperature and solar radiation for the city of Timisoara. To achieve the desired energy efficiency, the design was performed using the dedicated software tool Passive House Planning Package PHPP which is one of the most frequently used design tools for passive houses and was developed by W. Feist at the Passive House Institute in Germany. Passive House Planning Package PHPP is based on European standards related to thermal protection of buildings and energy performance calculations. PHPP is an Excel-based energy modelling tool that can be used to design a passive house or to verify whether a building meets the Passive House standard. The main advantage of the PHPP software is that all components for the thermal envelope and the building services can be optimized to achieve the entire maximum technical potential of the respective component (CEPH, 2011). The thermal properties of the building envelope were required for computational analysis. Along with the thermal properties and areas of the building components, parameters related to the activities of occupants, window and wall orientations, shading and ventilation are also necessary.

For the purpose of this study, the energy demand of the residential building was also evaluated in the situations of the other four locations corresponding to the climate zones of Romania. Therefore, for the same calculation model, different climate data was used in order to assess the energy requirements in each of the other four locations. Table 4 presents the results obtained from the PHPP simulations for each of the climate scenario. As expected, for the first location, Constanta, the energy requirements are the lowest due to the fact that the exterior temperature and solar radiation intensity are higher than for the second location, Timisoara, which represents the location for which the house was designed for in the first place. The results for the third location, Iasi, and forth location, Tg. Mures, show close values for the energy requirements. For the fifth location, Sf. Gheroghe, the energy requirement is the highest, bear in mind that the weather parameters for this town are the most disadvantageous.

Table 4. Results of the energy performance simulation using Passive House Planning Package

Climatic zone	***Heating energy demand***	***Specific primary energy***	***Frequency of overheating at 25°C during summer***
	[kWh/m²/year]	*[kWh/m²/year]*	*[%]*
I Constanta	10.4	99	30.6
II Timisoara	15.0	106	15.4
III Iasi	19.6	114	11.7
IV Targu Mures	20.6	115	7
V Sfantu Gheorghe	23.4	119	2.4

The energy requirements of the building transposed in each of the five climate conditions vary from one location to the other. The highest difference is between the results for the first location and the results for the fifth location, which are the extremes in terms of weather parameters values. The lowest difference is between the results for Iasi and Targu Mures.

Regarding the frequency of overheating, for the climatic zones IV and V the risk reduced even though shading and systems were not considered in the calculation for neither of the scenarios. The Passive House Institute recommends a limit of less than 10% of the total number of occupied hours in a year for the frequency of overheating events when indoor temperature is higher than 25°C. For the other three climatic zone, the frequency of overheating exceeds the 10% limit, especially in the situation of the climatic zone I. In these cases, summer shading devices are required in order to maintain a comfortable climate inside the house during the summer sunny days.

2.3. Required U-values to achieve the passive house standard for each of the five climatic zones

The results of the PHPP evaluations show on one hand that the efficiency measures applied for the climatic zone II are not enough to achieve the passive house standard in the climatic zones III, IV and V for the studied house. On the other hand, it can be concluded that in the situation of climate zone I for the location Constanta, the energy efficiency measures might be less restrictive if the purpose is solely to achieve heating energy demand under 15 kWh/m^2. Thus, other series of PHPP simulations were performed with the purpose of achieving the passive house requirement for each climate scenario. For this purpose, the U-values of the envelope elements were improved or reduced until the heating energy demand was ≤15 kWh/(m^{2}year) for all situations. For each location, maximum U-values were defined that are necessary to achieve the passive house standard (Table 5).

Table 5. U-values necessary to fulfil the passive house requirements in the five climatic zones

Climatic zone/city	*Average U-value [W/(m^{2}K)]*
I Constanta	0.216
II Timisoara	0.178
III Iasi	0.155
IV Targu Mures	0.149
V Sfantu Gheorghe	0.139

The obtained U-values are relevent only for the situation of the studied residential building. The requirements might be more or less restrictive depending on the architecture/geometry of a building, orientation and also building equipment.

3. Conclusions

The purpose of this paper was to assess the influence of the climatic zone on the energy requirements of a residential building designed as a passive house. For this purpose, a case study was developed on the energy efficient residential house built in Timisoara. The house was subjected to simulations in PHPP using different climate scenarios corresponding to the five climate zones of Romania. The results indicated, as expected, the lowest energy demand for the climatic zone I scenario and the highest energy demand for the climate zone V scenario. The difference between the results for the climate zone I and climate zone II scenarios is noticeable, although in both cases the house fulfils the passive house requirement of heating demand less than 15 kWh/(m^2year). The scenarios for climate zone III and IV have close results for energy requirements but a significant growth is noticed compared to the baseline case scenario. For the climate zone V scenario the difference from the baseline case scenario is even more noticeable. These results of the PHPP simulations lead to the conclusion that the residential house, as designed to achieve the passive house standard for climate zone II, easily fulfils the criteria for climate zone I but for the climate zone III, IV and V requires additional energy efficiency measures. For the studied house, maximum U-values are defined necessary to achieve the passive house standard in each of the five climate conditions. Compared to the baseline case scenario, these U-values can be achieved through an increase in the thermal insulation thickness or use of more efficient materials, use of highly energy efficient windows. For the climate zone I scenario, the energy demand results indicate that it is possible to increase the U-value compared to the baseline case scenario and still fulfil the passive house heating demand criteria.

As a future development of this study, specific solutions and energy efficiency details will be developed and also economic calculations will be performed for each scenario in order to compare the initial investments and also the life cycle costs. Also, structural design aspects have to be considered taking in consideration the corresponding seismic load for each location. For the locations chosen for this study, only Iasi has a seismic load higher than Timisoara. For this situation it is likely that additional measures will be required to improve the seismic resistance of the building.

4. Acknowledgements

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