PASSIVE HOUSE DESIGN IN ROMANIA AS AN INFLUENCE OF WEATHER DATA ANALYSES

Eng. **Marcel Mugurel Iancău,** Ph.D. candidate[1], Ph.D.Prof.Eng. **Gheorghe – Constantin Ionescu** [2], Eng. **Raul Stelian Balota,** Ph.D. candidate[1]

[1]University of Oradea, Faculty of Energy Engineering
[2]University of Oradea, Faculty of Constructions and Architecture

REZUMAT. Reducerea consumului energetic în sectorul construcţiilor este o problematică esenţială pe întreg mapamondul. În această lucrare sunt discutate posibile soluţii de proiectare a caselor în standard pasiv din România. Totodată, în studiul de faţă sunt folosite programe de simulare statice, fiind aplicate simulări cu programul de calcul al caselor pasive PHPP pentru a furniza studii cu privire la proiectarea anvelopei clădirii în corelaţie cu materialele de construcţii, mărimea ferestrelor, zona climatică şi orientarea.

Cuvinte cheie: sarcină termică, eficienţă energetică, proiectarea clădirii, PHPP, consum energetic.

ABSTRACT. The decrease of energy consumption in building sector is a major train worldwide. In addition, practical applications using building simulation programs, plant simulations tools are becoming highly accepted as a design tool, for carrying out or confirming the performance of proposed building design or to evaluate the effects of varying design parameters. Possible sollutions for passive house design in Romania are discussed in this paper. Simulation software are conducted in this study, where PHPP simulations are applied to supply facade design studies considering building materials, window sizes and orientation.

Keywords: heating load, energy efficiency, building design, PHPP, insulation

1. INTRODUCTION

Building sector is a major consumer in a society and the implications to economic, social and environmental issues regarding the energy consumption are very important. Facing high prices for heating the housing sector, a challenging task is to change the way of today building by designing and promoting energy efficient constructions in a cost effective and environmentally responsive direction. Almost half of the national energy consumption is in buildings, reason why the importance of passive design is strongly needed. Minimizing the energy consumption is possible with strong passive sustainable design, using local materials and specific climate data. When judging the costs of a new settlement, some 30% up to 50% is related to HVAC systems in case of commercial buildings, and 5% up to 10% in case of domestic buildings [1]. The potential for energy savings in the building sector is large: the primary potential is in the reduction in the use of HVAC systems since more than 60% of the building energy consumption is used to condition the indoor environment [1]. It is generally accepted that buildings can be designed to be energy effective if their thermal insulation is increased, window size and lighting level decreased, shading devices properly installed and heating and cooling systems adequately designed, installed and maintained [1]. These energy savings features must be considered with reference to numerous constrains, such as added costs for materials, construction and maintenance, conformance to local building codes, occupancy life styles, aesthetics, construction practices and availability of equipment [2], [3]. Passive Houses are buildings with a very low service energy demand [4]. The total primary energy demand of certified domestic European Passive Houses may not exceed 120kWh/m^2 per year (103,200 Kcal/m^2 per year) for heating and cooling, hot water production and household energy consumption [4]. Furthermore the maximum heating and cooling load is minimized to a value of 10W/m^2 which allows the passive tempering of such buildings (hence the term passive is used) [4]. The average energy demand for the tempering of Passive House is approximately only 10 percent of the existing building stock in Germany and Romania. Hence they contribute significantly to the reduction of fossil energy consumption and the related green house gas emissions [4]. Passive building design can be described as the utilization of the sun's energy together with the characteristics of a local climate and materials of the building, to directly maintain thermally comfortable conditions within built-environment, while minimizing the energy consumption[5]. This should include sufficient 'tuned' thermal mass corresponding to the insulation and window design [5]. Further, analysis of whole building permits 'right' sizing of building features, which can be implemented by placements of highest efficient external systems like windows and doors for effective utilization of natural day-lighting and ventilation. [5], [6], [7]

2. SIMULATIONS

Energy simulation software are useful tools for designing buildings in this century. They provide significant contribution dealing with climate mitigation and adaptation in regard to energy responsible planning. Architects should use energy simulation tools for dealing with better support by decision-making and energetically optimization in building design [8].

For designing a low-energy buildings and passive houses in practice there is need for a tool that:

- is relatively easy to use and understand (for entire project team);
- is relatively and conservatively accurate concerning the annual heating demand and heating load despite the simplifications in methodology;
- has been proved to provide accuracy in comparison with real world buildings;
- takes into account all the details that are important when dealing with very low energy houses and passive houses (thermal bridges, window fragmentation, thermal mass etc.);

As an example, one possible simplified software package that addresses those issues has been compiled for passive houses and is called PHPP (Passive House Planning Package). PHPP2007 is primary validation and certification tool for Quality Approved Passive Houses. It utilizes ISO 13790 annual and monthly energy balance method and is calibrated for low-energy building requirements through comparison with detailed dynamic simulations and real life measurements. It relies heavily on other related European standards (ISO 13370, ISO 6946, ISO 13789, ISO 10077-1, ISO 10077-2, ISO 10211-2 etc). PHPP does not cover all the aspects of building modelling and optimization (especially in the case of non-residential buildings), for example daylight optimization, detailed HVAC scheduling, zoned cooling etc. Very important part of modelling quality is input data. If these involve a lot of uncertainty then the simulated results can deviate greatly from reality. So the input data has to be handled carefully and specified as accurately as possible. We have three large groups of input data: environmental conditions (weather data), geometric and physical properties of the building and involved material layers in very great detail and user behaviour data (free heat, equipment usage etc) along with scheduling info about HVAC system [9], [10], [11], [12].

3. WEATHER DATA ANALYSES

Weather data analyses should be the primary step for any energy efficient building or passive building design [13]. The analyses can provide important guides for building energy systems design and renewable energy system selections [13]. Usually weather datasets based on long-time measurements are used (representing average conditions). These can be directly measured yearly data (a real year statistically closest to average conditions) or constructed for example from different monthly measured datasets (statistically best matched months summed to form a typical year) [12].

In Europe on should rely on statistically proven national datasets or datasets which have been constructed following the methods described in European standard ISO 15927-4. If no measured data for certain location exists then there is a possibility to use interpolated data generated from multiple closest measured datasets.

Computer programs like Meteonorm (by Meteotest) can be used for that kind of interpolation purposes. Interpolated data has to be always used with caution. The simplified calculation use average monthly data derived from those hourly datasets [12].

In this study, simulations where done for the four different climatic regions in Romania (conventional temperatures used in computing the heating demand: -12°C, -15°C, -18°C, -21°C) for the city of Constanta, Oradea (Craiova), Cluj Napoca and Suceava.

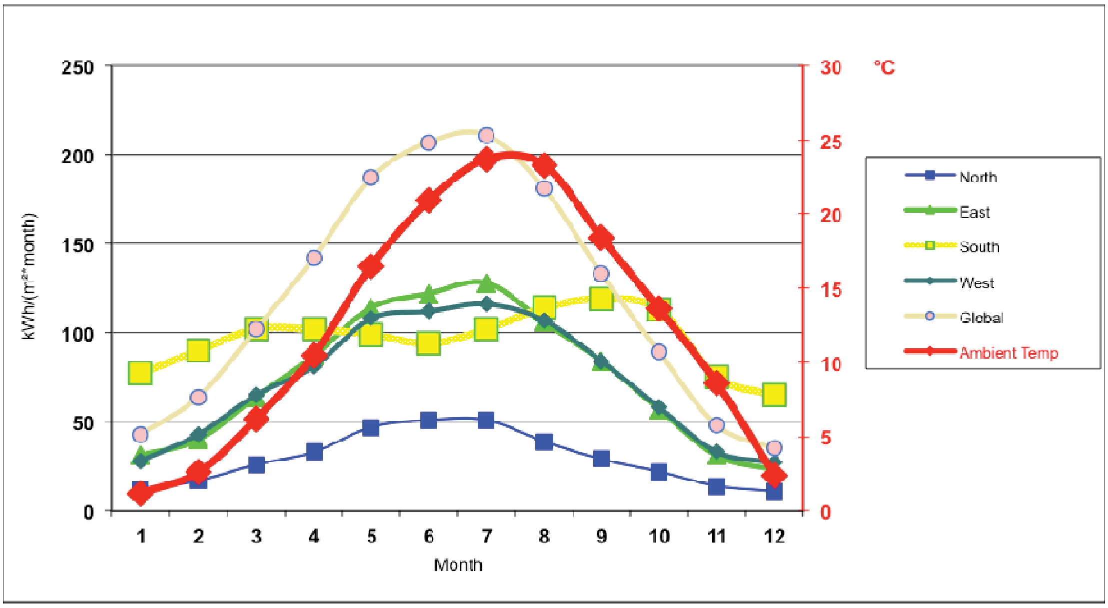

Fig.1 Climate data for Constanta- 1st climatic zone

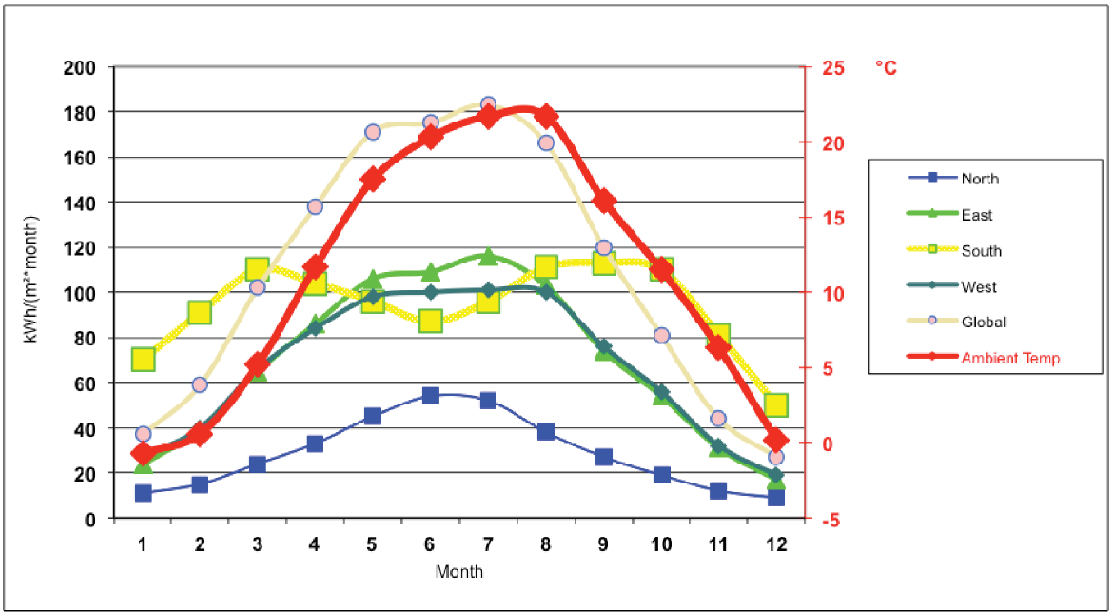

Fig.2 Climate data for Oradea- 2nd climatic zone

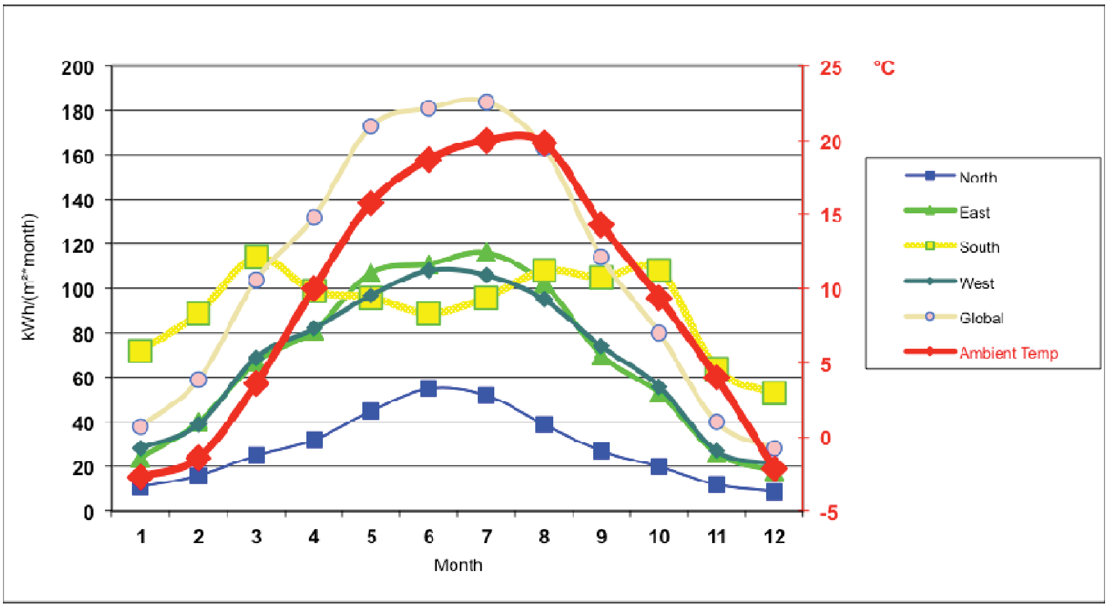

Fig.3 Climate data for Cluj Napoca- 3rd climatic zone

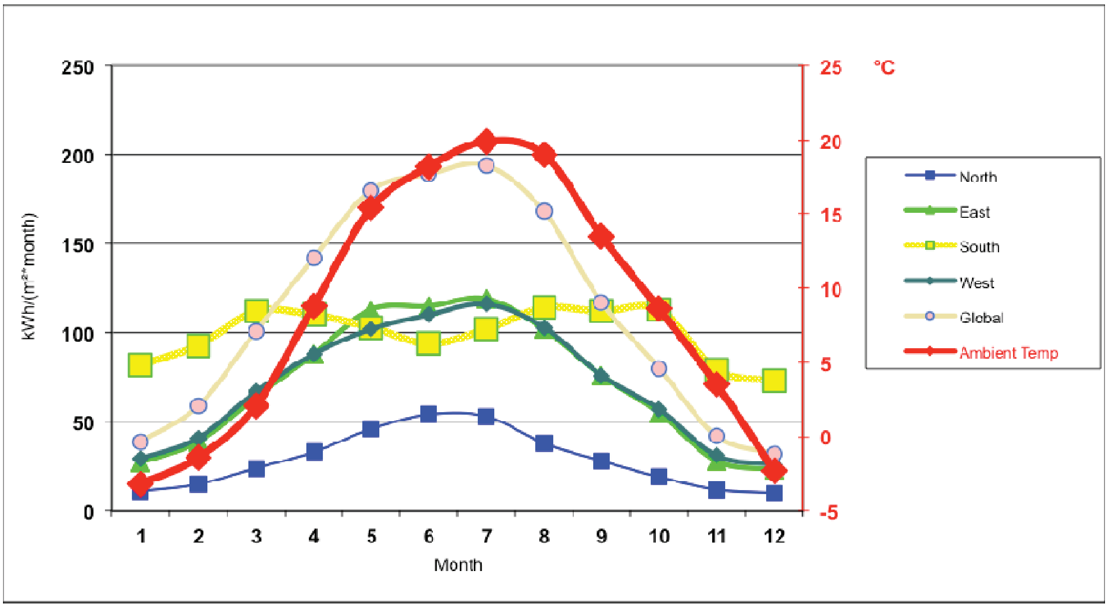

Fig.4 Climate data for Suceava- 4th climatic zone

4. PASSIVE BUILDING DESIGNS

Facade design studies, undertaking the manipulation of facade details, can be effective in determining their relationship with heating and cooling loads of a building as well as the associated indoor thermal environment [13]. In Fig. 5, the building model used for the facade design studies in PHPP, is shown, as well as the construction properties for the house are listed in Table 1. These reflect typical practice in Romanian domestic mass housing market.

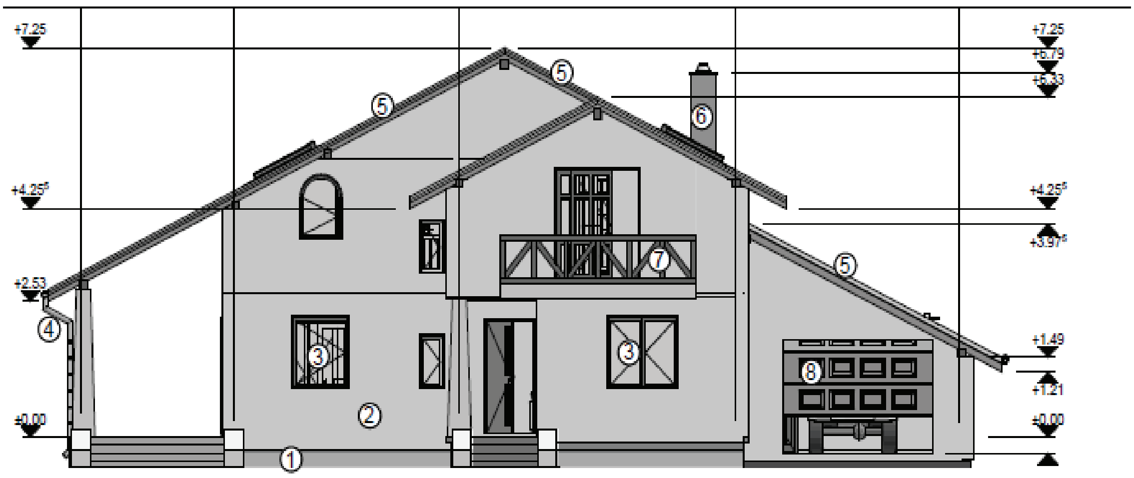

Fig.5. PHPP model for domestic house in Romania

In this study we analyzed various parameters including U values of external walls, window to wall ratios (WWR), and orientations (indicated by large area window facing orientation). Four different U values of external wall: 0.1 W/m^{2}K, 0.2 W/m^{2}K, 0.3 W/m^{2}K, 0.4 W/m^{2}K are employed to analyze heating loads for the residential house [13]. The orientation of the main facade is another important element to determine energy consumption of the building. Four orientations N, W, E, S have been examined in this study.

Table 1.

Building construction materials

Building Elements	**Material**	**U value**
External wall	Concrete block and brick	0.78 W/m^{2}K
Glazing	Double glazing	1.2 W/m^{2}K
Floor slab	Concrete slab and sound insulation	2.3 W/m^{2}K
Roof construction	Concrete tiles, mineral wool	0.6 W/m^{2}K

In the simulation, the heating setpoint is 20°C and cooling setpoint is 25°C. Single setpoint controls are used for heating and cooling. Heating is made available from November to March, and cooling from April to October. For the best facade design, the energy consumption of the house is taken as the criteria. In Fig. 2, the results of cooling and heating loads with the difference in U value for WWR = 0.1, south orientation are illustrated. The simulation results indicate that with the increase of U values of external wall, cooling loads decrease while heating loads increase [13]. The insulation double-edged effects on HVAC loads is the point of supply. Insulation, on the one hand, promotes the ability of a building to retain heat during the heating seasons; on the other hand it prevents the release of unwanted heat through the building envelope during the cooling seasons [13]. As shown in Fig. 6 the total energy consumption is reduced with the increase of thermal insulation. When the U value of the external wall is equal to 0.1 W/m^{2}K, the lowest heating loads and total energy consumption are predicted [13].

Thermal insulation of a building envelope offers a major contribution toward enhanced energy efficiency. *Placement, type, and thickness* of the insulation material are three major factors with respect to insulating the building envelope. Simulations are run with many variations of thickness, the type and placement of the insulation material.

External wall: There are thermal and practical considerations for insulation: For instance, insulation placement on the outside of the external walls. Furthermore, polystyrene boards have been chosen as material according their wide usage in Romania. According to the simulation results, EPS boards with 0.38 W/mK have good energetic performance in the region as well. Different combinations of the placement and thickness (between 10-30 cm) have been simulated.

Roof insulation: Roof insulation is one of the most important criteria in regard to energy consumption of a building, because this surface is exposed through greatest direct solar radiation.

Mineral wool as insulating material, installed in different layers of the roof has been simulated with 20 to 40 cm thickness. According to the simulation results, 40 cm mineral wool installed under the accessible surface of the roof has the best performance on heating load [8].

Floor slab insulation: Floor slab insulation is also a very important criterion in regard to energy consumption of a building in Romanian climate. XPS boards have been chosen as material. Different combinations of thickness (between 8-30 cm) have been simulated.

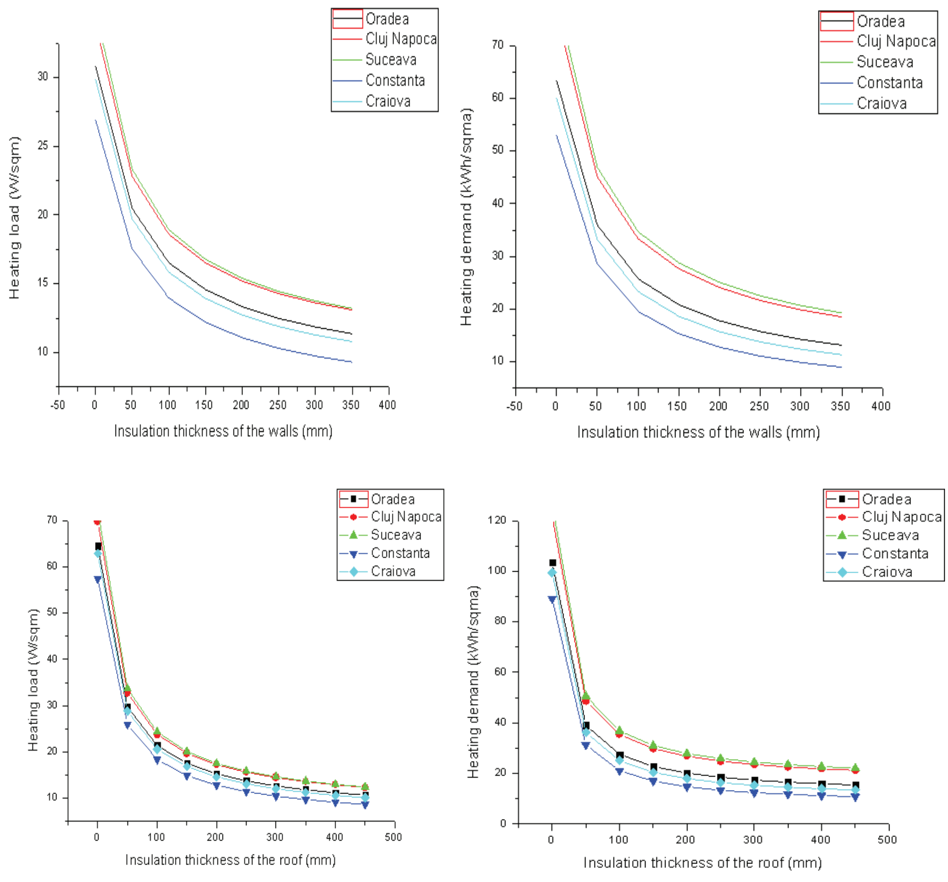

Fig.6. Insulation thickness for domestic house in Romania

Windows quality and energy performance. The heat losses and gains of the windows have got a great impact on the energy balance of a low-energy and passive house. Therefore they have to be calculated very carefully. The U-value of the window is calculated using the quality of the glazing, the frame, the spacer and the installation. Basic characteristics of highly efficient (or super-insulated) windows are: triple glazing with two low-e-coatings (or another combination of panes giving a comparable low heat loss), “warm edge”- spacers in glazing units (e.g. swisspacer etc.) and super-insulated frames with U_f-values between 0,7 to 1,0 W/(m^{2}K). The thermal loss coefficients, U_w, of the whole window (including losses from glazing, frame and spacer effects) suitable for a standard like passive house is typically approx. 0,8 W/(m^{2}K) or lower. For achieving this kind of thermal quality the inner and outer sides of window frames have to be thermally separated and the thermal properties have to be optimized through finite- element calculations (according to European standards EN ISO 10077-1 and EN ISO 10077-2). This enables accurate product description and therefore coupling with building energy modelling allowing precise variant calculations.

Low heat losses through the window will cause a further benefit that the interior surface temperature of a window, even in cold winter nights, will be only few degrees lower than indoor air temperature. This results in good thermal comfort even near the window [12]

Up to this point, the requirements of minimizing the energy consumption has been identified through the optimum passive design.
The ameliorate construction properties for the building are listed in Table 2.

Table 2.

Optimum passive house design

Building Elements	Material	U value
External wall	Concrete block and brick	0.1 W/m^{2}K
Glazing	Triple glazing	0.7 W/m^{2}K
Floor slab	Concrete slab, thermal insulation, thermal bridge free	0.13 W/m^{2}K
Roof construction	Concrete tiles, mineral wool, thermal bridge free construction	0.1 W/m^{2}K

5. CONCLUSIONS

To design an energy efficient building, previously mentioned aspects have to be taken into account throughout entire project and building process. Just a simple adapting to those aspects do not assure reaching the passive house or low-energy standard – the heat losses, energy use and indoor climate has to be calculated/simulated (predicted) from the start to enable the optimization and therefore economically feasible solutions to increase energy efficiency [12]. The whole design process can be summarized into two steps. Firstly, an analysis of local climate data is of primary importance in order to make use of the local climate condition for promoting passive homes [13]. Secondly, the application of passive design methods and advanced facade designs to minimize the load requirement from heating and cooling through building energy simulations [13].

6. ACKNOLEDGMENTS

This work was partially supported by the strategic grant POSDRU/88/1.5/S/50783, Project ID 50783(2009), co-financed by the European Social Fund-Investing in People, within the Sectorial Operational Programme Human Resources Development 2007-2013.

BIBLIOGRAPHY

[1]. HENSEN, J.L.M. (1995), *On System Simulation for Building Performance Evaluation*, 4thIBPSA World Congress on Building Simulation '95, Int. Building Performance Simulation Association, Madison, WI Aug,, pp.259-267.

[2]. *** www.esru.strath.ac.uk/Courseware/Casestudy/blagoevgrad_swu/swu.ht, accesed at 10/01/2012.

[3]. *** **KRNETA R., BJEKIC M., DRAGICEVI S.,** *Review of building energy simulation process*, http://www.et.upt.ro/cee/ro/psc/works03/psc47.pdf, accesed at 10/12/2011

[4]. THORSTEN S., PIL-RYUL L. (2008), *Passive House in Korea*, in: proceedings 12th International Passive House Conference, Nuernberg, Germany, 11th – 12th April.

[5]. RABAH, K. (2005), *Development of energy-efficient passive solar building design in Nicosia Cyprus*, Renewable Energy 30, pp 937.

[6]. YAGLOU CP. (1927), *The comfort zone for man*. J Ind Hyg, pp.9-251.

[7]. GIVONI B. (1969), *Man, climate and architecture*. 2nd Ed. New York: Van Nostrand Reinhold.

[8]. KARASU, A. (2010), *Concepts for Energy Savings in the Housing Sector of Bodrum*, Turkey: Computer based analysis and development of future settlements using renewable energy, case study for Bodrum, Ph.D., Technische Universität Berlin, Berlin.

[9]. *** http://passiv.de/07_eng/phpp/Certification_Non-Residential.Pdf, accesed at 15/12/2011.

[10]. KOKOGIANNAKIS, G., STRACHAN, P.A., and CLARKE, J.A. (2008), *Comparison of the simplified methods of the ISO 13790 Standard and detailed modelling programs in a regulatory context*, Journal of Building Performance Simulation, 1 (4). pp. 209-219, ISSN 1940-1493.

[11]. JOKISALO, J. and KURNITSKI, J. (2007), *Performance of EN ISO 13790 Energy utilisation factor heat demand calculation method in a cold climate*, Energy and Buildings, 39(2), pp. 236-247.

[12]. *** Planning of Energy Efficient Buildings, http://www.activethroughpassive.eu/userfiles_/files/E-book-download.pdf, accesed at 14/01/2012.

[13]. WANG, L., GWILLIAM, J., JONES, P. (2009), *Case study of zero energy house design in UK*, Science Direct Energy and Buildings 41, pp. 1215–1222.

About the authors

Eng. **Marcel Mugurel Iancău,** PhD candidate,
University of Oradea, Faculty of Energy Engineering, 1st Universității street, Oradea, Romania
email:iancau.marcel@gmail.com

Graduated at the Technical University of Cluj Napoca, Romania, Civil Engineering Faculty, Master program in Thermal insulation of the buildings. After finishing of the university he started to work in the field of thermal insulation of the buildings. He attended a research stage at the University of Innsbruck, Austria, with Mr. Wolfgang Feist in the field of passive house planning. He started a Phd in the field of passive house design at the University of Oradea. The research topics: passive design planning, weather data analyses related to the building design, thermal insulation of the buildings.

Ph.D.Prof.Eng. **Gheorghe – Constantin Ionescu**,
University of Oradea, –1st Universității street, Oradea, Romania. I am a Ph.D. supervisor in the field of ENERGETIC ENGINEERING.
email:gheionescu@gmail.com

Graduated at the "Gheorghe Asachi" Politechnic Institute – IAŞI – România, Faculty of Constructions – Specialty Installations for Constructions – ***Engineer Diploma***. Right now, I am a **Professor** at the Construction Department of the Faculty of Constructions and Architecture, University of Oradea, –1st Universității street, Oradea, Romania.

Eng. **Raul Stelian Balota**, PhD. candidate,
University of Oradea, Faculty of Energy Engineering, 1st Universității street, Oradea, Romania
email:raulbalota@gmail.com

Graduated at the Technical University of Cluj Napoca, Romania, Civil Engineering Faculty, Master program in Thermal insulation of the buildings. After finishing of the university he started to work as a civil engineer consultant for the investment department of a multinational company. He attended a building energetic auditor course held at the Technical University of Cluj-Napoca in 2007. He was involved in multiple investment projects as a consultant engineer. In 2010, he started a Phd in the field of non residential building energy efficiency, at the University of Oradea. The research topics are: energy efficient design of non residential building, weather data analyses related to the building design, double skin facades, energy efficient systems for indoor microclimate of non residential buildings.