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Original Article

Considerations Regarding the Design of Energy Efficient Buildings

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Abstract

The limited time interval in which buildings were built during industrialisation period and the low degree of thermal insulation level of envelope members or inefficient cooperation of experts had as a consequence the defective design of a large number of buildings that today have to face issues such as inefficiency from energetically point of view, low interior confort, moisture and structural damages. Nowadays, the energy efficiency in buildings has become a critical and essential aspect for sustainable development as well as for improving the dwellers' comfort, diminishing the maintenance and utilities costs, or their impact upon the environment. The paper analyses the thermal balance of a residential building considering three constructive scenarios for highlighting the benefits (save energy for heating, reduce CO_2 emission) resulting from designing the building envelope on the basis of sustainable reasons.

Keywords: environment, energy demand, CO_2 emission, heat losses.

1. Introduction

The building stock, is responsible of almost 40% of final energy consumption and 36% of greenhouse gas emissions (GHG), being one of the main energy consumer at European level [2, 3]. The excessive consumption of energy in residential sectors, is a result of inadequate design of the buildings built in the past, or because of their improper maintenance and/or exploitation.

According to 2011 census in Romania are 8.2 million residential dwellings placed in 5.1 million buildings [2, 3, 18]. Residential buildings account 98% from building stocks: individual buildings placed in rural area are about 75.48% and block of flats placed in urban area about 24.51 %.

The number of buildings built before 1990 is about 90 % from all buildings stock, and are characterized by low energy performance and high energy consumption for heating (150-400 kWh/m^2/year) most of them being classified energetically in classes "C" and "E" [2, 3, 4, 5].

Saving energy in existing buildings has been obtained by improving the standards requirements, and increasing the values for resistances to heat transfer of building envelopes members (external walls, roofs, floors, glazing surfaces) [4, 5, 6, 8]. Even so, the research carried out in Romania during the last years has shown that annual energy consumption for the retrofitted building based on the actual exigencies reached only the class B, with values between 125 and 201 kWh/m^2 [4, 5]. From here is clearly suggested that the implementation of energy efficiency measures in the Romanian residential sector become essentialy in order to save energy and to reduce the CO_2 emission. Saving energy demand in buildings become stringent, in

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order to meet climate change objectives and to reduce with 80% greenhouse gas emissions by 2050 compared to 1990 proposed by European Comission of part of its roadmap [2, 3]. The research upon energy saving in buildings has extended a lot lately, both at national and international level through the adoption of programs dedicated to the improvement of heat performance of buildings, new or old alike.

Directive 2002/91/CE [12] as part of the efforts of the EU to have a common legislation for the Member States, also provides for building energy performance certificate issuing. By revising the Energy Efficiency Directive for Buildings (EPBD) in 2010 [13] for the first time a new term was introduced, namely that of ”nearly Zero Energy Building” (nZEB) where the energy performance of the building should be very high and the source should be found mainly in renewable energy (produced either in situ or very close to it). The Directive requires the implementation of the specifications as early as 2019 for public buildings and 2021 for all the new buildings [2, 3, 13].

The actual Romanian standard is classifying the buildings from energetically point of view in Class A if the energy needed for heating, cooling, ventilation and hot water preparation is bellow 125kWh/m^2/year, requirement which is not compulsory for new building. This it means that the new buildings, evaluated to reach about 25% of the buildings stock in 2050 must be carefully design in order to satisfy the EPBD task and to avoid the needed to retrofit them in the next few years [3, 5].

The initiatives applied in developed countries in order to save energy in the residential sector have consisted in:

- improving thermal insulation level (by increasing the thermal insulation layer thickness for all envelope members) [4, 8];
- using new materials and new constructive solutions with high efficiency: vacuum thermal insulation [7, 10], transparent thermal insulation (TIM) [11], Nano Insulation (NIM) [9], gas insulation materials (GIM) [17], efficient glazing surfaces, double facades, ventilated facades or green roof or facades [11], etc.;
- designing direct or indirect solar systems that can contribute to the reduction of heat losses during winter or to avoiding overheating during summer;
- using heat recovery ventilation systems to compensate up to 80-90% for the heat losses occurring through ventilation;
- putting to work renewable sources of energy by mitigating greenhouse gas effects emission in the atmosphere and reducing costs with the heating of the construction, etc.

These measures were adopted for retrofitting existing buildings and for designing of new ones.

2. Material and Method

The building that made the object of the case study is a detached residential dwellings considered to be located in the city of Cluj-Napoca. The exterior loadbearing wall is of masonry work made of hollowed bricks 25 cm thick, thermal insulation and rendering. The geometrical characteristics of the component parts of the building envelope are the following: A_{wall} = 116m^2, $A_{glazing}$=20.36m^2, A_{floor} = 90m^2, $A_{attic\ floor}$ = 90m^2.

For thermal analysis was considered 3 constructive scenarios where the difference lies in the quality of the glazing system and thickness of thermal insulation layers as follows:

- *1st scenario*: external walls- thermal insulation of 10 cm; attic floor- thermal insulation of 25 cm; floor above basement-15 cm thermal insulation and triple glazing;
- *2nd scenario*: external walls- thermal insulation of 20 cm; attic floor - thermal insulation 25 cm; floor above basement- 15cm thermal insulation and double glazing + low E + Ar.;
- *3rd scenario:* external walls- thermal insulation of 30 cm; attic floor- thermal insulation 30 cm; floor above basement- 25 cm thermal insulation and triple glazing + low E + Ar.

3. Results and Discussions

The characteristic values illustrating the building energy efficiency (Table 1) and the evaluation of the building overall energy performance was determined by using the ENEFControl software, a tool based on calculation Methodology Mc 001/1,2,3-2006 [14, 15, 16]. The thermal analysis (table 1) shows that:

- the average thermall resistance of the building envelope R'_M increases with 28% in case of scenario 2 respectively with 53% in case of scenario 3 compared with the first one;
- the effective global thermal insulation coefficient G_{ef} (heat losses) decreases with 19% in case of scenario 2 respectively with 33% in case 3 compared with the first case study;
- the annual space heat requirements, Q_N decreases with 24% in case of scenario 2 respectivelly with 45% in case 3 compared with the first solution.

Table 1. Thermal characteristics of the analysed building

Thermal characteristics		
1st scenario	2nd scenario	3rd scenario
External walls: $U=0.398$ W/(m^{2}K)	External walls: $U=0.23$ W/(m^{2}K)	External walls: $U=0.16$ W/(m^{2}K)
Triple glazing $U=1.43$ W/(m^{2}K)	Double glazing+low E, Ar. $U=1.20$ W/(m^{2}K)	Triple glazing +low E, Ar $U=0.65$ W/(m^{2}K)
Attic floor: $U=0.20$ W/(m^{2}K)	Attic floor: $U=0.20$ W/(m^{2}K)	Attic floor: $U=0.16$ W/(m^{2}K)
Floor above basement: $U=0.313$ W/(m^{2}K)	Floor above basement: $U=0.313$W/(m^{2}K)	Floor above basement: $U=0.18$ W/(m^{2}K)
Average thermall resistance of the bldg. env. $R'_M=2.76$m^{2}K/W	Average thermall resistance of the bldg. env. $R'_M=3.86$m^{2}K/W	Average thermall resistance of the bldg. env. $R'_M=5.87$m^{2}K/W
Heat losses coeff. $G_{ef}= 0.48$[W/m^{3}K]	Heat losses coeff. $G_{ef}= 0.39$[W/m^{3}K]	Heat losses coeff. $G_{ef}= 0.32$[W/m^{3}K]
Annual space heat req. $Q_N=55.99$[kWh/(m^{2}yr)]	Annual space heat req. $Q_N=42.81$[kWh/(m^{2}yr)]	Annual space heat req. $Q_N=30.76$[kWh/(m^{2}yr)]

Obviously it can be noticed that annual space heat requirement (table 1) can be reduced by increasing the thickness of the thermal insulation of the opaque building envelope member. In case of energy efficient buildings the energy demand for heating the buildings is reduced while embodied energy may play a significant role [1].

The thickness of the building envelope member may be reduced by using thermal efficient material (vacuum insulation material, transparent thermal insulation) instead of conventional thermal insulation materials (mineral wool or expanded polystyrene (EPS), extruded polystyrene (EXS)).

Pär Johansson in his study [7] shows that vacuum insulation material (VIP) has the thickness lower with 4.5 times than conventional ones. The embodied energy of the VIP material is about 999 MJ/m^2 compared with expanded polystyrene which has 890 MJ/m^2.

The impact on the human health and the effects on the environment during production stage are with 42% greater in case of EPS compared with VIP [7].

The energy balance of the building under investigation shows that an efficient thermal insulation diminishes the heat losses through the envelope members while heat losses through ventilation increases (Table 2), which suggests that the introduction of heat recovery systems will become an obvious necessity.

Table 2. Heat losses and their weight before and after retrofitting

Elements	1st scenario	2nd scenario	3rd scenario
External walls [kWh]	3591.5	1910.6	1192.1
Attic floor [kWh]	679.9	636.5	478.8
Floor above basement [kWh]	349.5	327.4	170.9
Glazing [kWh]	1916.7	1514.3	734
Ventilation [kWh]	3541.6	3317.6	2964.5
Heat requirement[kWh]	10079.3	7706.4	5540.3

By using heat recovery ventilation systems can be saved up to 90 % of energy necessary for ventilation which it means that energy demand may be reduced by 32% in first case, with 38% in second case, respectively 48% in third one.

The space heat requirement, heating energy demand, the cost of energy for heating, and the CO_2 emission was determined for all three scenarios (Fig. 1).

The reduction of CO_2 emission by improving the energy performance of buildings is significant in case of scenarios 2 and 3 compared with scenario 1, but even so the values are still high resulting in this way the importance of using the renewable energy (biomass, biofuels, and geothermal energy). High energy efficient or nZEB buildings are buildings which generate or produce necessary energy for a whole year.

The energy saving and diminishing of CO_2 emission can be reached not only by improving the energy performance of the envelope members but also by an improved design, that takes into account the S/V ratio, the orientation of the building, or the uses of shadowing devices.

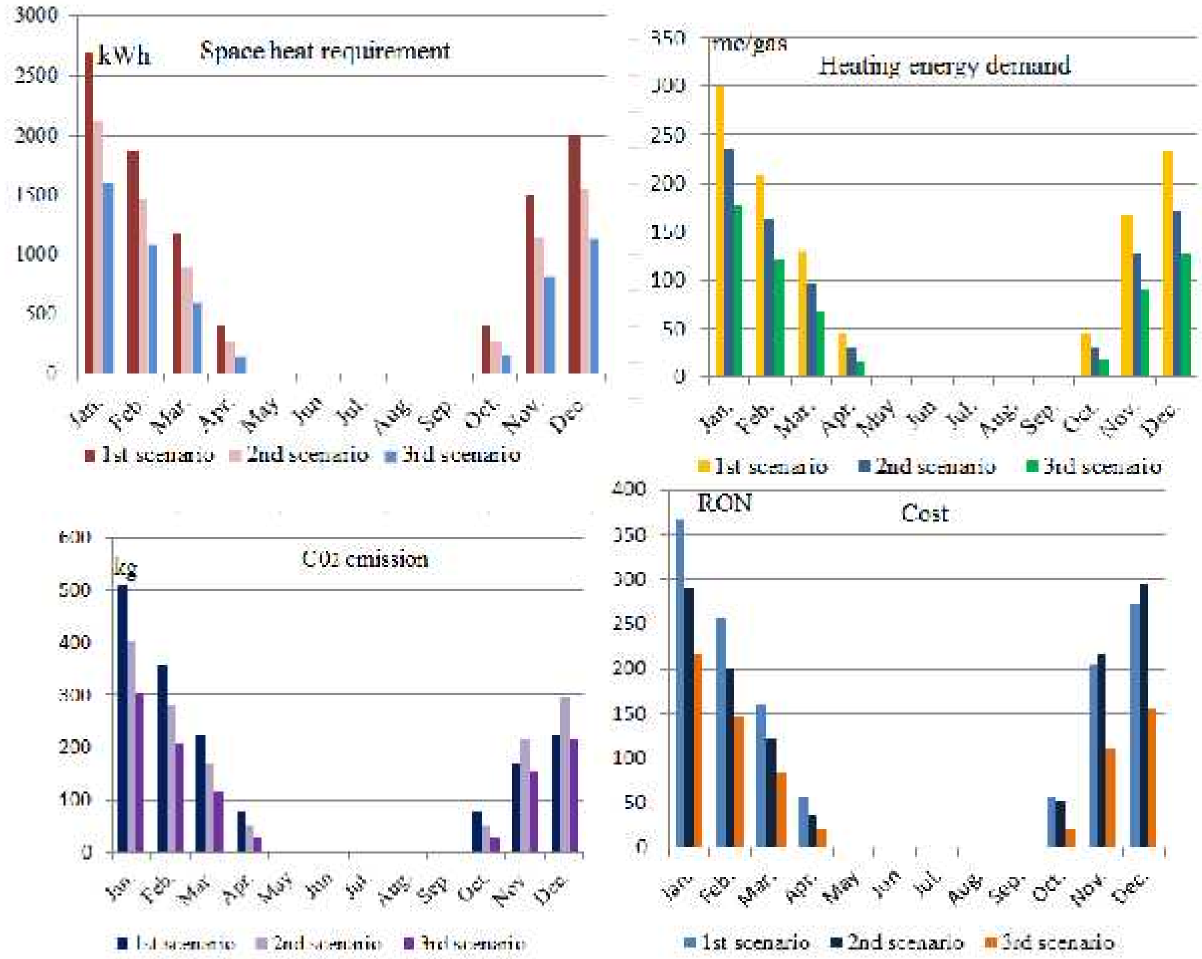

Figure 1. Results of the building energy performance for all analysed scenarios

4. Conclusion

Based on the results of the case study presented in this paper it is obviously that the changes to be made in the sector of constructions with the implementation of the low energy consumption house concept or nearly zero energy buildings involve not only modification in the design principles by improving the actual standards but even the implementation of renewable sources systems. Using alternative sources of energy to produce the energy necessary for operating should be extended to a larger and larger number of buildings as Romania has a high potential of natural resources.

By retrofitting all the existing building can be saved a considerable quantity of final energy consumption obtaining in this way a great contribution to the reduction of GHG emissions till 2020. A great attention must be paid in case of designing the new buildings due to their high increasing rate. Designing the new building respecting the EPBD task and sustainable principle may be avoided the needed to be retrofitted later. These buildings are technically higher quality buildings, with a longer life span as compared to buildings designed conventionally, comfortable, with a lower service and maintenance cost and low impact upon the environment.

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