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Thermal Rehabilitation Technology and the Nearly Zero-Energy Buildings. Romanian Representative Education Buildings-Case Study

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Abstract

Improving energy efficiency of the existing buildings is essential, not only for the achievement of the national objectives of energy efficiency in the medium term, but also to meet long-term objectives of the strategy on climate change and the transition to a competitive economy based on low carbon dioxide emission by 2050. Recognizing the diversity of traditions and current practices in the building sector, the climatic conditions and different methodologies of approach across the EU, EPBD [1] does not establish an uniform methodology for implementing nearly zero energy buildings (nZEB), determining each EU Member State to develop its own definition of nZEB. In addition to the new buildings construction, nZEBs and important energy savings in building sector also can be obtained by retrofitting the existing building stock. Until now, the thermal rehabilitation activity was particularly aimed at collective housing sector for which there are appropriate regulations and technologies. Public buildings, in general, are characterized by certain constructive and functional diversity, requiring a specific approach for each case.
The aim of the paper is to study the potential of existing education buildings to become nZEBs, by applying current technologies based on improving the general level of thermal protection.

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Keywords: Energy efficiency; Thermal insulation; Nearly Zero Energy Building;

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1. The "Nearly Energy Zero Building" Concept

Today, due to population growth and a more advanced technology, the energy consumption is steadily increasing. At a time when environmental, economic and social concerns are becoming more important, being represented by the climatic changes or those who endanger energy security, resource depletion or the ability to pay the energy bills, reducing energy consumption in buildings is of strategic importance, both at national and international level. Reduced energy consumption and increased use of renewable energy also have an important role in promoting security of energy supply, technological developments and in providing opportunities for employment and regional development.

In addition to the efforts to build (design and construct) new buildings with low energy requirements from conventional sources of energy, it is essential to address the high levels of consumption of existing buildings. Buildings are a central element of EU Member States policy on energy efficiency, accounting for approximately 40% of final energy consumption (Figure 1) and 36% of emissions of greenhouse gases.

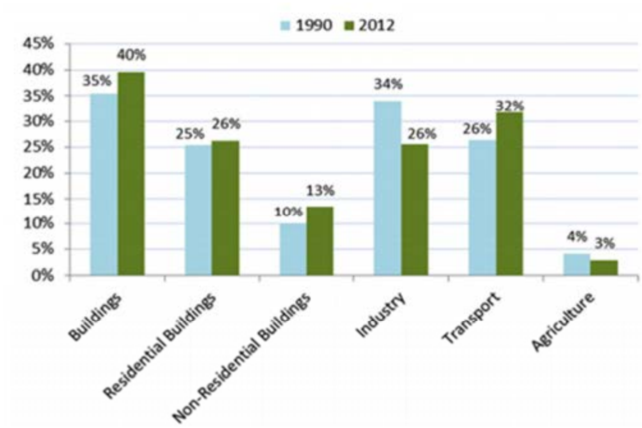

Fig. 1. Share of buildings in final energy consumption in EU-28 (Source: Eurostat)

Having a significant contribution to EU energy consumption, to the use of conventional energy resources and carbon dioxide emissions, the building sector is the subject of many policies, strategies and medium and long-term goals which seek reducing negative effects.

Wider objectives such as the protection of the environment were formulated in "20-20-20" target, which is a set of three key objectives for 2020:

- 20% reduction in emissions of greenhouse gases in the EU compared with 1999 levels;
- 20% increase in the share of energy produced from renewable sources in the EU;
- 20% improvement in energy efficiency in the EU.

In a longer perspective, the EU has set long-term targets for 2050.

Considering that more than a quarter of the building stock in 2050 to be built, much of these emissions are not considered at present. In order to achieve these ambitious EU objectives, energy consumption and associated CO_2 emissions of the buildings to be constructed will be nearly zero. This requires a definition or some guidelines into practice of "buildings with almost zero energy consumption" (nZEB).

Revision of the Directive on Energy Performance of Buildings (EPBD) introduced in Article 9, "Buildings with nearly zero energy consumption" (nZEB) as a future requirement to be implemented from 2019 to 2021 for public buildings and all new buildings. The directive defines buildings with nearly zero energy consumption as follows: "A building with nearly zero energy consumption is a high energy performance building with a reduced energy demand or nearly zero energy that should be covered largely from renewable sources, including energy produced on-site or nearby ".

Recognizing the diversity of traditions and current practices in the building sector, the climatic conditions and different procedures of approach across the EU, EPBD does not establish an uniform methodology for implementing the concept of buildings with nearly zero conventional energy (nZEB), determining each EU Member State to develop their own definition of nZEB. At the same time, EU Member States are required to develop national plans for implementing specific nZEB, plans that must take account of national, regional or local conditions. These plans aim the implementation of nZEB concept in practical measures, in order to increase the number of buildings with nearly zero energy consumption.

To improve energy efficiency of the existing buildings is essential, not only for achieving national objectives of energy efficiency in the medium term, but also to meet long-term objectives of the strategy on climate change and the transition to a competitive economy with a low carbon dioxide emission by 2050.

Given these strategic concerns, EU policy on energy consumption of buildings has been strengthened in recent years, primarily by reforming the Directive on Energy Performance of Buildings - EPBD (Directive 2010/31/EU) in 2010, and recently by the Energy Efficiency Directive - EED (Directive 2012/27/EU) [2] which repealed directives on energy services and promotion of cogeneration.

All these requirements, but also others such as the need to consider the use of renewable energy for new buildings or for those subjected to major renovation, laid down in Directive regarding the promotion energy from renewable sources (Directive 2009/28/EC) [3], provides a framework that can be implemented through policy measures designed to reduce energy consumption, particularly in buildings.

Romania has an important buildings patrimony, made mostly in the 1960-1990 period, with low thermal insulation, as a consequence of the energy crisis of 1973.These buildings have closing elements with a low thermal protection level, which is no longer adequate to the actual regulations. Besides the residential sector, the public buildings are also an important consumer of energy. The consumption distribution of final energy on different types of public buildings in Romania is shown in Figure 2. This is the reason why efforts are focused to reduce energy consumption in the non-residential sector by having in view the criteria associated to nZEB concept.

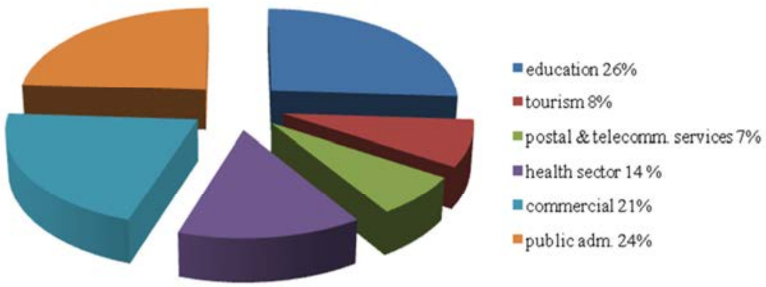

Fig. 2.Consumption distribution of final energy on different types of public buildings in Romania (source: INCD URBAN-INCERC)

Nomenclature

U'	adjusted thermal transmittance of each different building envelope element [W/ m^{2}K];
R'	adjusted thermal resistance of building element (thermal bridge effects are included) [m^{2}K/W];
R	specific unidirectional thermal resistance related to the element of area A [m^{2}K/W];
ψ	linear thermal bridge heat transfer coefficient [W/mK];
l	length of linear thermal bridges from the building element with area A [m];
A	area of the building envelope element with a specific thermal resistance [m^2];
V	heated volume [m^3];
τ	temperature correction factor [-];

G	global coefficient of thermal insulation [W/m^{3}K].

2. Energy performance of education buildings. Case study

2.1. Characteristics of the studied buildings

The analysed buildings belonging to the Technical University "Gheorghe Asachi" from Iași have different geometrical characteristics and different degrees of thermal insulation levels [4, 5, 6].

The building made in 1973 and named "R" has four floors, and at the upper level it is constructed an amphitheatre. The bearing structure is made of reinforced concrete diaphragm walls with pillars in the façades plans and reinforced concrete slabs. The external walls are protected on the exterior side with masonry units with vertical holes. The building has a useful area of 2931 m^2, a heated volume of 12185 m^3, and a floor area on the ground of 826 m^2 (Figure 3). The building envelope area is 4316 m^2 and the ratio between glazed area and walls area is 0.44.

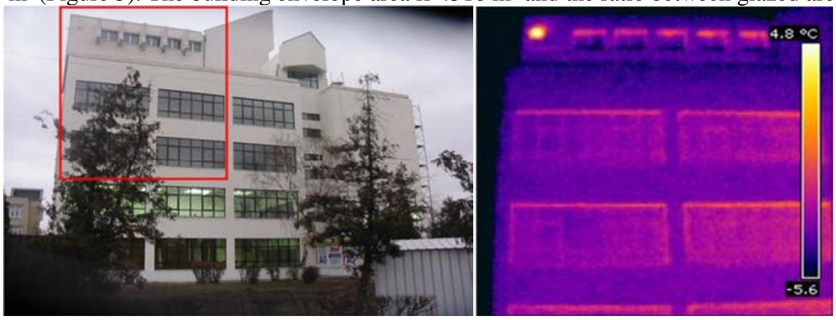

Fig. 3. The "R" building: photo and IR image

Another one, which belongs to the Building Services Department was made in 1990, has five levels and a constructive structure made of reinforced concrete frames. The frames from the facade walls are in-filled with masonry elements made of autoclaved aerated concrete of 30 cm thick. The useful area is 5328 m^2, the interior volume is 30987 m^3 and the floor area on the ground is 1744 m^2 (Figure 4). The building envelope area is 6986 m^2 and the ratio between glazed area and walls area is 0.76.

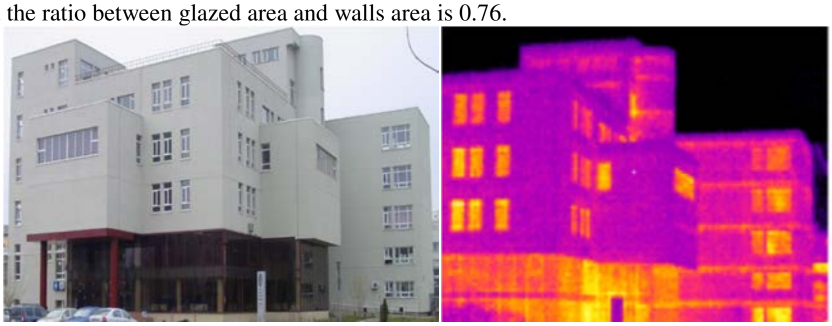

Fig. 4. The Building Services Department: photo and IR image

The third analysed building belongs to the Energetics Department. It was built in 1980, has four levels and a constructive structure made of reinforced concrete frames and closing elements made of autoclaved aerated concrete of 25 cm and reinforced concrete slabs. The useful area is 4524 m^2, the interior volume is 18760 m^3 and the floor area on the ground is 1773 m^2 (Figure 5). The building envelope area is 6076 m^2 and the ratio between glazed area and walls area is 0.56.

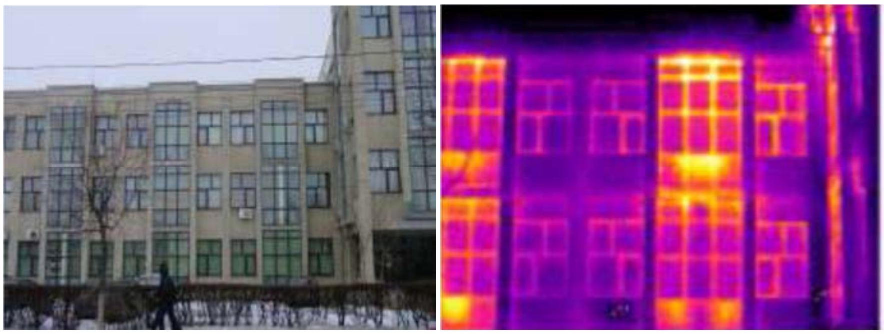

Fig. 5. Building of Energetics Department: photo and IR image

2.2. Impact of different thermal insulation levels on the energy performance indicators

The estimated energy performance indicators were the global coefficient of thermal insulation and the mean adjusted thermal resistance. The calculus follows the steps, according to methodology Mc 001/1, 2, 3-2006 and Mc 001/4-2009 [7]:

- Calculation of the unidirectional thermal resistance (*R*) for each of the enclosing element of the building;
- Identification of thermal bridges and evaluation of linear coefficients of thermal transfer, ψ, by means of numerical simulation, for the initial state and the rehabilitated one;
- The assessment of the adjusted thermal resistance for each element, R', was made with the relation [1]:

$$U' = \frac{1}{R'} = \frac{1}{R} + \frac{\sum(\psi l)}{A} \tag{1}$$

- Estimation of the global coefficient of thermal insulation, G_1, was made using the relation [2]:

$$G_1 = \frac{1}{V}\sum \frac{A_j}{R'_j}\tau_j = \frac{1}{V}\left(\frac{A_w}{R'_w}\tau_w + \frac{A_g}{R'_g}\tau_g + \frac{A_{uf}}{R'_{uf}}\tau_{uf} + \frac{A_{lf}}{R'_{lf}}\tau_{lf} \right) \tag{2}$$

where the indices *'w', 'g', 'uf'* and *'lf'* are corresponding, respectively, to the following building elements: exterior walls, glazing, upper floor, and lower floor.

- The mean adjusted thermal resistance is calculated with the following relation [3]:

$$R'_{med} = \frac{\sum A_i}{\sum \frac{A_i \cdot \tau_i}{R'_i}} \tag{3}$$

The energy performance indicators related to each of the three buildings are assessed in three different scenarios of thermal insulation solutions. The first case is the actual one, meaning that the external walls and the slab over the ground have no thermal insulation, the terrace having an insulation of 10 cm thickness (same as the buildings were constructed from the beginning). The second case is the most often used nowadays in practice, i.e. the external walls are insulated with a 10 cm thickness thermal insulation, the terrace with 20 cm and the slab over the ground has a 5cm thickness thermal insulation. For the third case, there are proposed the greatest possible thickness from technological point of view: 30 cm for external walls, 40 cm for terrace and 15 cm for the slab over the ground. In all the studied cases, the windows are considered to be triple glass window panes (with R' = 0.77 m^2K/W).

The calculus results are given in Table 1. As it was expected, for the second case of insulation, recommended by the code C107/2005 [8], the global coefficient of thermal insulation is greater than the global coefficient for the reference building (G_{ref}), with the exception of the Building Services Department because of the glazing degree, which is important in this case, and also because of particular volumetry of the whole ensemble.

Table 1. Energy performance indicators for the studied buildings

Building	Scenario	G_1[W/m^{3}K]	R'_{med} [m^{2}K/W]	G_{ref}[W/m^{3}K]
Building Services Department	I	0.373	1.112	0.150
	II	0.271	2.223	
	III	0.254	2.692	
"R" Building	I	0.404	0.877	0.246
	II	0.170	2.080	
	III	0.128	2.756	
Energetics Department	I	0.462	1.256	0.470
	II	0.289	2.725	
	III	0.264	3.433	

2.3. The potential of education buildings to be transformed into nZEB by means of thermal rehabilitation measures

In July 2014, the Ministry of Regional Development and Public Administration - MDRAP sent to the EC values that define nZEB for Romania [9]. In this document, the limit value recommended for the third climatic area and for education building is 136 kWh/(m^{2}a). In Table 2 are given the values of primary energy related to the three studied education buildings, calculated according to methodology Mc 001/2006for the three cases of thermal insulation degree. The heating energy demand considering the intermittent heating regime was determined for each case and the energy demand for artificial lighting was also added. These values were taken from the Energy Performance Certificate drawn up for each building. National conversion factors for natural gas and electricity were used to calculate the primary energy demand. The conversion factor for heating energy is 1.1, and for lightening the value is 2.8.

Table 2. Values of primary energy related to the three education buildings.

Building	Scenario	Primary energy for heating [kWh/(m^{2}a)]	Primary energy for lightening [kWh/(m^{2}a)]	Total primary energy [kWh/(m^{2}a)]	nZEB primary energy [kWh/(m^{2}a)]
Building Services Department	I	112	92	204	136
	II	66	92	158	
	III	60	92	152	
"R" Building	I	92	87	179	
	II	48	87	135	
	III	32	87	119	
Energetics Department	I	166	90	256	
	II	92	90	182	
	III	82	90	172	

As it can be noticed, only in the case of the "R" building, the resulted primary energy is lower than the recommended value, for the second and the third scenarios. For the other two cases, this can lead to the conclusion that the primary energy related to the lightening system must be decreased by adopting a more economic one, and the energy necessary for heating can be reduced by using more efficiently the solar gains, or by using photovoltaic panels on terraces and blind external walls.

3. Conclusions

Education buildings, in general, are characterized by certain constructive and functional diversity, requiring a particular approach for each case. Each of these buildings are specific ones, through the architectural solutions, daily - weekly or yearly utilization program (they are not used during the night, etc.) and occupancy level.

To transform these buildings into nZEB means a difficult design and constructive target, because, as in many cases, adopting only a higher degree of thermal insulation for the envelope elements is not enough.

There are necessary many other measures to conserve or to gain green energy for the building, like the use of photovoltaic panels placed on terraces or on the opaque part of the southern façades. Also, education buildings can be equipped with heat recovery systems and, because of the high glazing degree, mobile insulated shutters that can be used during night time.

Any existing public building transformed into nZEB could be an example of good practice in urban settlements.

References

[1] Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the Energy Performance of Buildings (recast). Official Journal of the EUL 153, 18 June 2010, pp. 13–35;

[2] Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency. Official Journal of the EUL 315, 14 November 2012, pp. 1-56;

[3] Directive 2009/28/EC of the European Parliament and of the Council on the promotion of the use of energy from renewable sources. Official Journal of the EU L 140, 5 June 2009, pp. 16-47;

[4] Dumitrescu L., Bărbuţă M., Pescaru R.A. Sustainability Indicators for Education Buildings. Case Study.13th International Multidiciplinary Scientific Geoconference SGEM 2013, Nano, Bio and Green – Technologies for a Sustainable Future, Section Green Buildings Technologies and Materials, pp. 457-464;

[5] Pescaru R.A., Baran I., Dumitrescu L. Energy Efficiency of Public Buildings Toward NZEB. Possibilities and Constraints, Buletinul I.P.Iasi, Secţia "Construcţii şi Arhitectură", Tomme LX(LXIV) Fasc. 4, 2014, pp. 165-171;

[6] Baran I., Pescaru R., Dumitrescu L. Comparative Study Regarding the Efficiency of Thermal Rehabilitation Measures at Education Buildings, 14th International Multidiciplinary Scientific Geoconference SGEM 2014, Nano, Bio and Green–Technologies for a Sustainable Future, Section Green Design and Sustainable Architecture, pp. 487-494;

[7] Methodology for calculating energy performance of buildings Mc 001/2006 (in Romanian);

[8] Normative document concerning the thermo-technical calculation of construction elements for buildings, code C107/2005 (in Romanian);

[9] Ministry of Regional Development and Public Administration – MDRAP. Nearly Energy Zero Buildings (NEZB) Romania, Revised and Updated Plan, 2014.