NEARLY ZERO ENERGY BUILDING CONCEPT, ENERGY DESIGN PARADIGM FOR NEW BUILDINGS AND FOR RENOVATING EXISTING BUILDINGS

Dan CONSTANTINESCU[1], Gabriela CARACAŞ[2]

[1]Corresponding Member of the Academy of Technical Sciences of Romania
[2] SIGMA Publishing House

Abstract: The paper focuses on the new concept of Nearly Zero Energy Building – NZEB, which should lead, in time, to reducing the fossil energy consumption and to the protection of the natural and built environment. The NZEB concept, as defined by the European Directive 2010/31/EU, represents a new paradigm in the design and construction of new buildings, as well as in renovating existing buildings. In practice, starting with 01.01.2021 all new buildings will be NZEB buildings. The paper focuses on the energy configuration of NZEB buildings (new/existing buildings, as defined by Law 372/2005 and by Annex 1 of the European Directive 2010/31/EU) in terms of envelope, installations and energy profile. The definition of this type of building should include objective local particularities (climate parameters). The building is characterised by very high energy performance and the reference parameter is the primary energy indicator. The technical characteristics determined by using the cost-optimal method (Commission Delegated Regulation EU no. 244/2012), are introduced. By extrapolation, the maximum acceptable values of primary energy corresponding to the energy used by NZEB buildings in Romania are presented. The logical pattern of the original predictor-corrector method for the energy configuration of NZEB buildings, based on three calculation modules: dynamic modelling of the energy response of the building (M1), Primary Energy calculation module (M2) and estimation of cost-efficiency of the NZEB building technical solutions (M3) is presented. The results are presented as the technical and economic performance required by a NZEB building which will be designed in Romania.
Keywords: energy performance, dynamic simulation, cost-optimal, primary energy, energy configuration of buildings

1. GENERAL PRESENTATION

From the viewpoint of the methodology for defining the "Nearly Zero Energy Building" (NZEB) type of building, the paper aims at two targets which, through the evolution in time of the Energy Performance (as a result of replacing existing buildings with new buildings and of the expansion of urban settlements by constructing new NZEB buildings, as well as of the energy modernisation of existing buildings, both in terms of envelope and of installations, associated with the modernisation of central utility supply systems (heating and electricity)), may modify the Energy Profile of a settlement, not only of a building. The first target is to substantiate a new energy classification of buildings (to substantiate the development of new energy benchmarks) associated to the energy characteristics of both new buildings and of existing buildings. The second target is to define the energy configuration of buildings (new buildings / existing buildings undergoing major renovation works, as classified by Law 372 / 2005 [1] and in Annex 1 of the European Directive 2010/31/EU [2]), in terms of envelope, installations and energy profile. The European Directive 2010/31/EU mentions at Art. 9 the requirements for NZEB buildings implementation, but it does not provide harmonised requirements or indications on the methodological framework for the assessment of the Energy Performance of the Building. The definition of this type of building should include objective local particularities (climate parameters). Therefore, the ideal target is to establish a methodology for defining NZEB and not to define NZEB [3], [4], [5], [6], [7], and [8]. The building is characterised by very high energy performance, and the reference parameter is the primary energy indicator determined by calculation. An estimation of the economic efficiency should complete the requirements associated with the NZEB design.

2. ENERGY PERFORMANCE OF BUILDINGS IN ROMANIA

The promotion of European Directives with impact on reducing the toxic emissions release in the natural environment has the corollary of reducing the intensity of climate-related hazards, especially with regards to the anthropic component together with an increase in the buildings capacity to adapt to the impact of climate change, and to reduce the vulnerability of the built environment. Reaching the NZEB desideratum is possible by using the Renewable Energy Sources – RES [9]. The thermal dimension of buildings (construction and related systems) involves solutions whose indirect outcome is the minimisation of the urban heat island effect, a consequence of the forecast presented by the *European Environment Agency* (EEA) Report no 2 (2012), attesting that Romania is one of the most exposed countries to significant climate changes in the future, especially in terms of increased average outdoor temperature in summer days and longer summers (Fig. II.1).

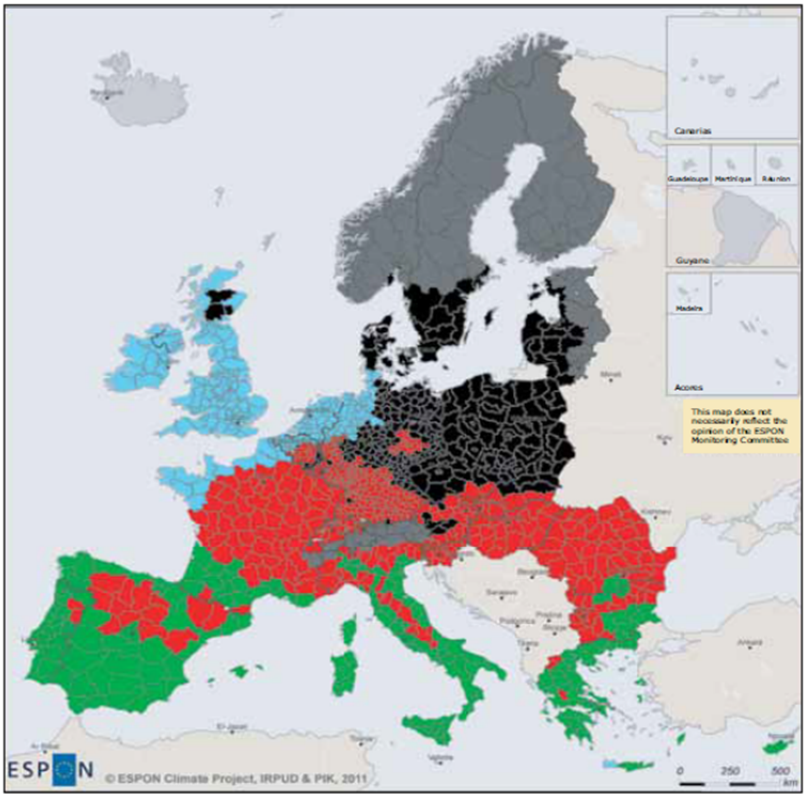

Fig. 2.1. Climate change in Europe –*European Environment Agency* (EEA) Report no 2 (2012).

Unfortunately, the energy design of buildings through the configuration/reconfiguration of the energy characteristics is currently in Romania just a wish, limited to the system of energy certification of buildings whose only practical result is the thermal insulation of condominiums. The energy benchmarks related to thermal processes (heating and air conditioning) presented in Fig. II.2 and Fig. II.3 provide clear information on the Energy Performance of Buildings (EPB) in Romania. The energy performance related to heating was determined based on the configuration of reference buildings, by types of buildings, according to their function. The energy consumption for heating was determined for 8 representative structures. The resulting values for each type of building and for each representative climate area were adjusted taking into account the number of buildings, by type, in each county. The energy classification scale [kWh/m^{2}year] for heating resulted by applying the nonlinear system of energy notation according to the methodology for the calculation of energy performance of buildings, Mc 001-3/2006. The dynamic method was applied to calculate the heating/sensitive cooling demand – empirically and numerically validated [10], [11], [12] – in order to determine the benchmarks for air conditioning. It is significant that most existing buildings fall under the energy class C-D for both utilities, except single-family buildings which are part of the energy class E-G. Summing up, we see that EPB is placed between approximately 160 kWh/m^{2}year and 520 kWh/m^{2}year, values which are quite far

from the NZEB standard. With regards to the chart in Fig. II.3 we note four categories of climate-vulnerable buildings, namely hospitals, office buildings, public buildings and residential buildings which are potentially the types of buildings which may produce the largest number of victims, in case of summer heat waves, such as type EHW03 from the summer of 2003 which caused more than 50,000 victims in the Western Europe [13]. The focused technical solutions (envelope, systems, energy management etc.) analysed to identify the NZEB characteristics, generate *solution packages*.

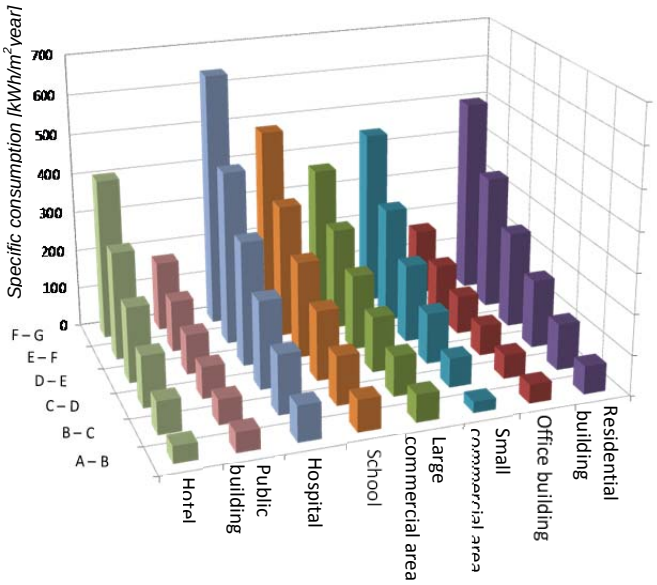

Fig. 2.2. Energy classes for heating.

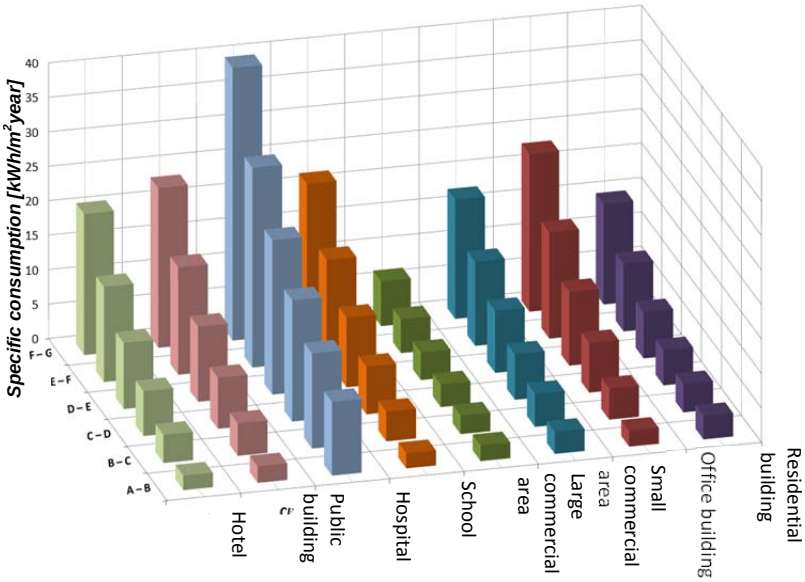

Fig. 2.3. Energy classes for air conditioning during summer.

They are virtually applied to existing/new buildings and simulated, based on the dynamic one-zone calculation model, the energy response of the building as EPB [kWh/m^{2}day, kWh/m^{2}month, kWh/m^{2}season, kWh/m^{2}year] and as natural thermal regime (free running temperatures) without air conditioning systems (thermal comfort indicators PMV and PPD). The second component is the economic component represented by determining the cost-optimal for the reference lifecycle of the building (according to the European Directive 2010/31/EU Art. 4 and 5) and by estimating the payback time through energy savings, in comparison with buildings designed in compliance with the current national regulations in force.

3. MINIMUM ACCEPTABLE ENERGY PERFORMANCE LEVELS FOR BUILDINGS UNDER THE NZEB CLASS – EVOLUTION BY 2021

The identification of NZEB technical characteristics involves a process with the following targets:

- To determine the technical characteristics for the cost-optimal interval according to the provisions of the European Directive 2010/31/EU;
- The energy impact of including renewable energy sources in the energy configuration of buildings;
- To assess the energy efficiency of technical solutions by determining the NZEB building cost recovery period as compared to the buildings developed in compliance with the current technical regulations (standard C107/2010).

The analysis to establish the minimum energy performance requirements is the cost-optimal analysis. The support for the cost-optimal analysis is the reference buildings for existing buildings and the architectural configuration solutions for new buildings. In both cases there is a correlation between the specific Total Cost (mainly investment and running costs) expressed in RON / m^2 and the Primary Energy for utilities provided to the end users (buildings) expressed in kWh / m^2, throughout the reference lifecycle, as set out by the European regulations (Delegated Regulation (EU)) [14] The minimum global cost is associated with EPB and, implicitly, it provides the minimum requirements for the building solutions and the utility supply system for each type of building. The charts in Fig. III.1, Fig. III.2 and Fig. III.3 show the representative variation curves of the Total Cost according to the Primary Energy for the types of reference buildings, with major impact on the energy resources consumption in Romania. The dark blue curves represent the Base Case and the other curves resulted after applying the sensitivity analysis to validate the cost-optimal interval for the Base Case. Table 3.1 presents a synthesis of results.

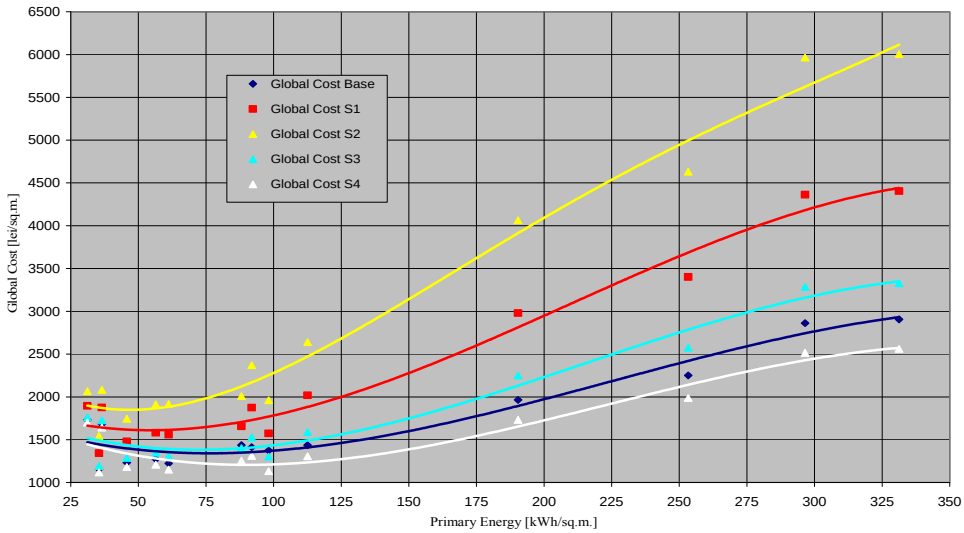

Fig. 3.1. Sensitivity analysis – office building, climate zone II.

With reference to the zone where one may agree is the starting point for NZEB buildings (lower values of the cost-optimal zone emphasized in **bold** in Table III.1) the deviations in the energy performance of buildings configured in compliance with the current technical regulations present a deviation of plus 78%, 9%, and 12% respectively, with reference to the buildings analysed. Therefore, the actual configuration of NZEB buildings, according to the requirements provided by Art.9 of the European Directive 31/2010/EU, requires the use of the Integrated Design method, based on a solution analysis using the dynamic thermal calculation method associated with the method of economic efficiency analysis by using the method of the dynamic function analysis Net Present Value (NPV). The adoption of the Integrated Design method would allow for achieving the objectives of Europe 2020 (A strategy for a smart, sustainable and inclusive growth). The statement also covers the renovation of the existing buildings. Reaching the energy performance specific to NZEB buildings

involves both works on the building envelope and the adoption of high performance systems associated with smart energy management.

Table 3.1

Type of building	Existing building	Cost-optimal solution	Current new building
Units of measurement	kWh/m^{2}year	kWh/m^{2}year	kWh/m^{2}year
Office buildings	296.50	**52**-100	92.55
Block of flats	271.07	**95**-130	103.06
Single-family houses	701.55	**115**-230	127.94

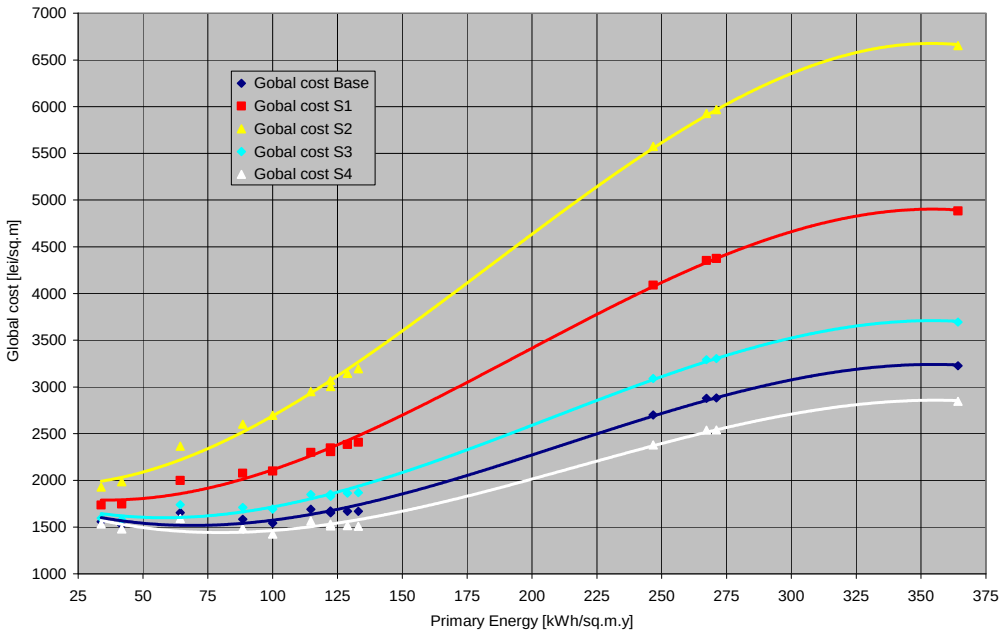

Fig. 3.2. Sensitivity analysis – office building, climate zone II.

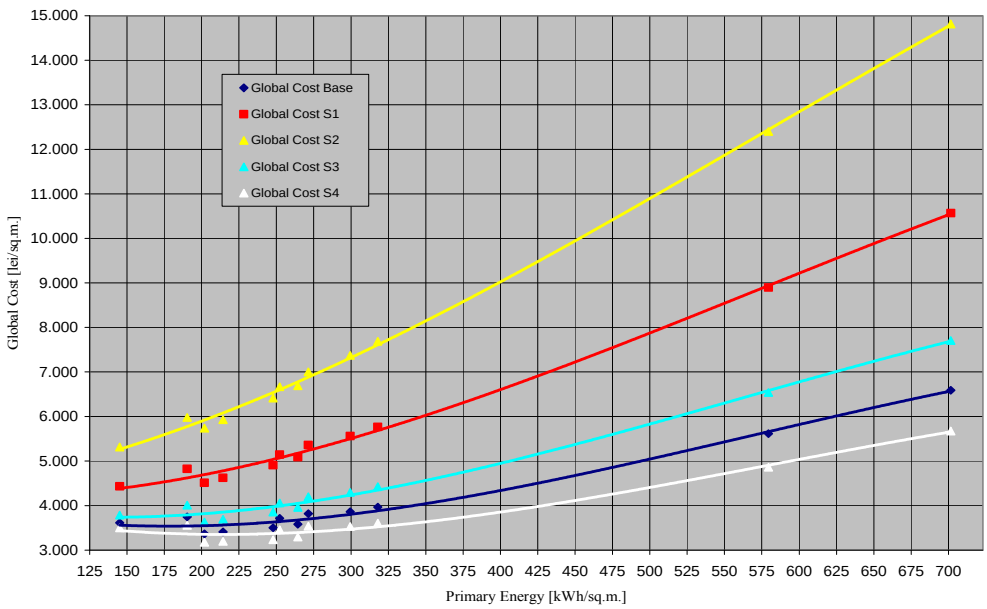

Fig. 3.3. Sensitivity analysis – single-family house, climate zone II.

4. LOGICAL SCHEMA FOR THE ENERGY CONFIGURATION OF A NEW NZEB BUILDING

The energy configuration method for a new NZEB building is presented as a modular logical schema (Fig. 4.1), and it is applicable to all types of buildings, as defined by Directive 31 / 2010 / EU, Annex I, point 5. The application of the calculation algorithm presented in the logical schema allowed for determining reference solutions. The first two targets presented in chapter II are included in Modules M1 and M2 of the logical schema for the configuration of NZEB buildings while the third target is presented in Module M3.

5. CONCLUSIONS ON THE ENERGY CONFIGURATION OF POTENTIAL NZEB BUILDINGS IN ROMANIA

The economic acceptability requirement for the analysed solutions is that the recovery period for the additional investment costs, as compared to the solution compliant with the current regulations on new buildings, should be lower than the maximum value, N_{max} =10 years. The results of the analysis on reference buildings – office buildings, blocks of flats and single-family houses are presented in the charts at Fig. V.1, Fig. V.2 and Fig. V.3 for the optimal variants whose performance is presented in Table V.1. In all cases, the best solution for the utility supply system is *high efficiency cogeneration* combined with *photovoltaic solar panels* on buildings. The main indicators of technical performance are the values of specific primary energy associated with the specific values of carbon dioxide emissions, associated with similar values of the new reference building without photovoltaic solar panels. The results are presented in Table V.1 for the three types of buildings. Therefore, by applying the Integrated Design method we may determine the correct energy configuration of highly energy efficient NZEB buildings. The logical schema presented by Fig. IV.1 indicates the steps to be taken.

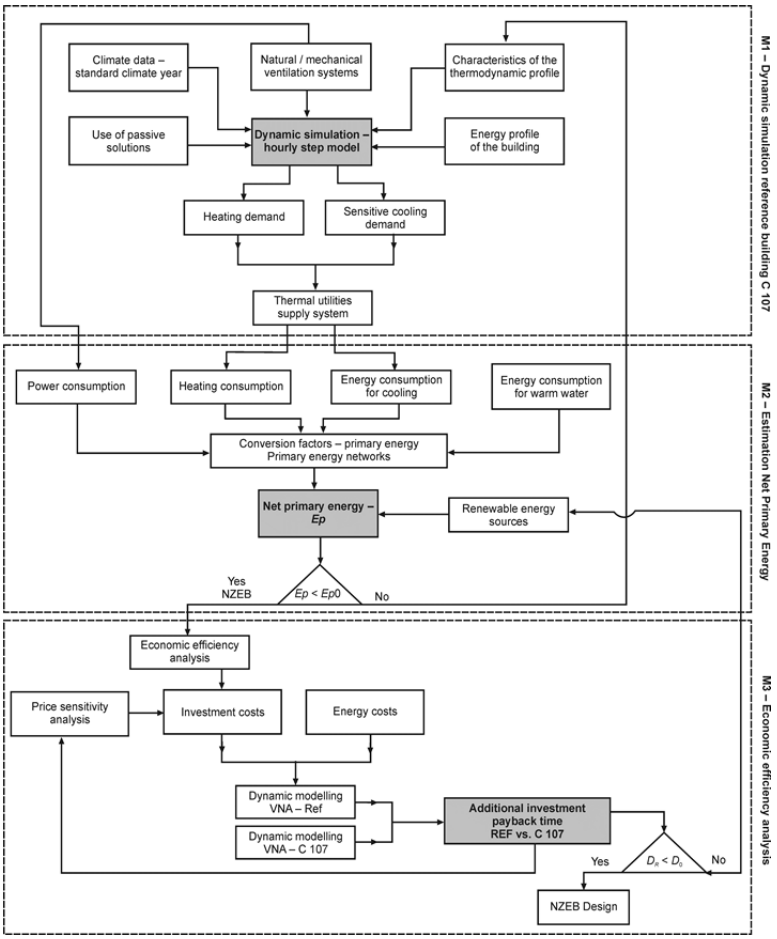

Fig. 4.1. Logical schema for a NZEB building configuration .

The empirical validation of the solution is achieved by monitoring during the significant time interval (minimum 5 years). The development of NZEB buildings is a real target, in line with the Sustainable Development strategy, provided that the energy configuration method presented in the paper is observed, in correlation with the criterion on the economic acceptability of the proposed solution (dynamic NPV analysis).

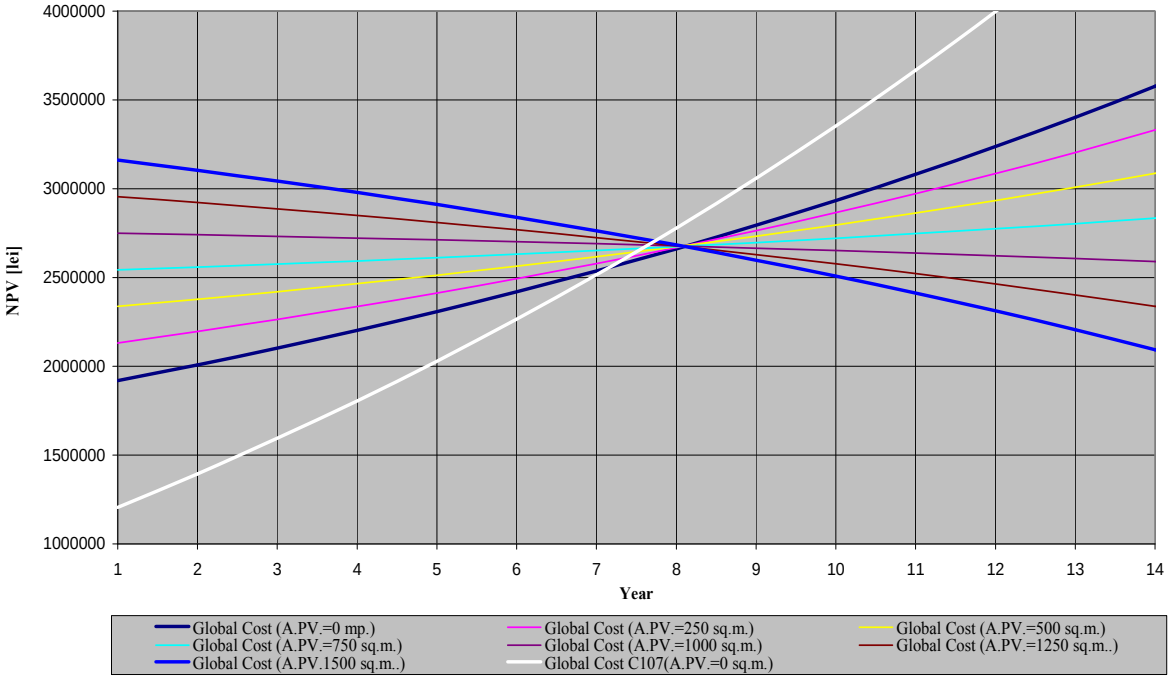

Fig. 5.1. Economic efficiency analysis for technical solutions for NZEB office buildings.

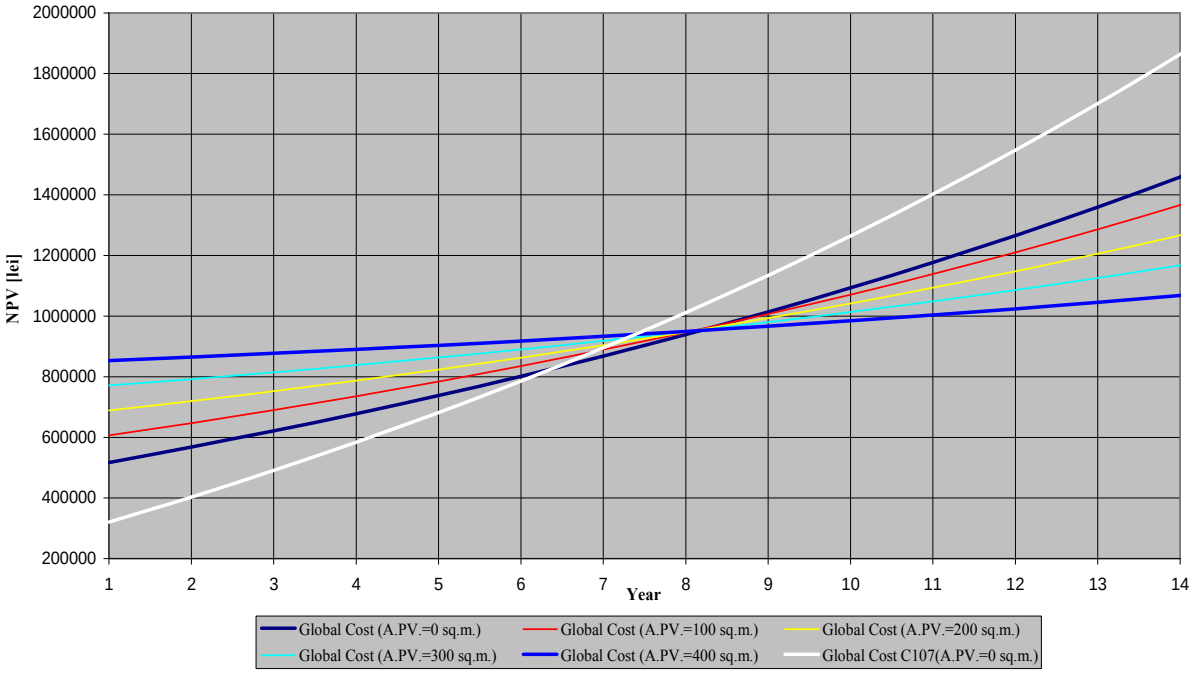

Fig. 5.2. Economic efficiency analysis for technical solutions for NZEB blocks of flats.

Table 5.1

Performance indicators	Office Buildings		Block of flats		Single - family Houses		U.M.
	NZEB	Actual regulations	NZEB	Actual regulations	NZEB	Actual regulations	
Primary Energy	– 89.90	88.30	– 22.30	101.92	– 63.66	117.17	[kWh/m^2.y]
CO_2 emissions	– 49.90	31.77	6.77	40.65	– 4.40	51.43	[kg/m^2.y]
EPB	– 27.80	105.34	32.01	137.34	– 2.60	176.49	[kWh/m^2.y]

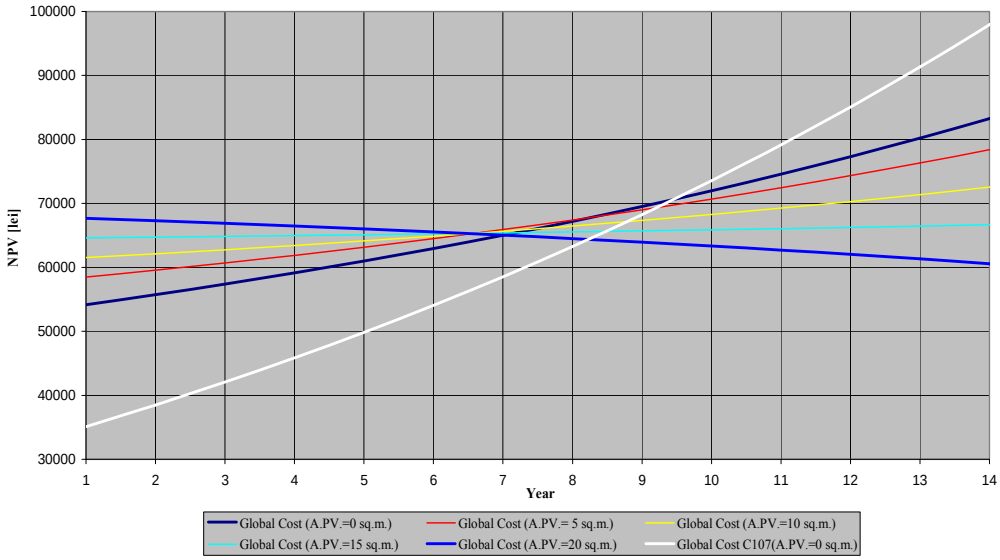

Fig. 5.3. Economic efficiency analysis for technical solutions for NZEB single-family houses.

Note: The negative values in Table V.1 indicate that during one year the building fully covers, due to RES sources, its energy consumption and provides electricity to the national network. The values are the results of a case study on reference buildings. The method is applicable to new buildings in the design stage.

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CONCEPTUL NZEB, PARADIGMĂ A PROIECTĂRII ENERGETICE A CLĂDIRILOR NOI ŞI A RENOVĂRII FONDULUI DE CLĂDIRI EXISTENTE

Dan CONSTANTINESCU [1], **Gabriela CARACAŞ**[2]

[1]Membru corespondent al Academiei de Ştiinţe Tehnice din România
[2]Editura SIGMA

Rezumat Lucrarea are în vedere un concept nou de clădire al cărei consum de energie este aproape de zero (Nearly Zero Energy Building - NZEB), şi care trebuie să conducă, în timp, la reducerea consumului de energie din surse fosile precum şi la protecţia mediului natural şi construit. Conceptul NZEB, aşa cum este definit în cadrul Directivei Europene 31/2010/UE, reprezintă o noua paradigmă în proiectarea şi realizarea noilor clădiri precum şi in renovarea celor existente. Practic începând cu data de 01.01.2021 toate clădirile noi vor fi clădiri de tip NZEB. Lucrarea vizează configurarea energetică a clădirilor de tip NZEB (noi / existente, după cum sunt clasificate în Legea 372 / 2005 şi în Anexa 1 a Directivei Europene 31 / 2010 / UE) cu referire la anvelopă, instalaţii şi profil energetic. Definirea acestui tip de clădire trebuie să includă particularităţi locale obiective (parametrii climatici). Clădirea este caracterizată de performanţă energetică foarte ridicată iar parametrul de referinţă îl reprezintă indicatorul de energie primară. Se prezintă caracteristicile tehnice determinate prin aplicarea metodei costului optim (Regulamentul delegat UE, nr. 244/2012). Prin extrapolare se fixează valorile maxim admisibile ale energiei primare corespunzătoare energiei utilizate la nivelul clădirilor NZEB din România. Se prezintă schema logică a metodei originale, de tip predictor-corector, de configurare energetică a clădirilor de tip NZEB, bazată pe trei module de calcul: modulul modelării dinamice a răspunsului energetic al clădirii (M1), modulul de calcul al Energiei Primare (M2) şi modulul estimării eficienţei economice a soluţiilor tehnice din dotarea clădirii NZEB (M3). Rezultatele sunt sintetizate sub forma performanţelor tehnice şi economice care conferă calificativul de NZEB unei clădiri care se va proiecta în România. Se prezintă rezultatele unui studiu de caz cu privire la clădirile de locuit de tip condominiu, prin raportare la reglementările tehnice naţionale în vigoare.