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ISSUES RELATED TO INCREASING THE ENERGY EFFICIENCY OF BUILDINGS. FROM THERMAL RETROFIT TO DEEP ENERGY RENOVATION AT NZEB LEVEL

BY

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Abstract. In the conditions of the ever-increasing demands of the users and the continuously rising price of fossil fuels, today, the operational energy demand of buildings has become hardly bearable. In the context of global sustainability requirements, it is proposed to build constructions whose energy consumption is as low as possible or almost equal to zero, both new and existing buildings. This fact is of particular importance because buildings consume 40% of total energy and are responsible for 36% of greenhouse gas emissions. In the European Union, 80% of the energy used by households represents heating, cooling and domestic hot water. Achieving climate neutrality by 2050 requires deep renovation of existing buildings to enhance energy efficiency, reduce fossil fuel dependence, and increase renewable resource use.

The paper presents the current state of Romania's buildings, as well as the arguments for accelerating thermal rehabilitation works, from the perspective of obtaining an energy efficient and decarbonized building stock by the year 2050. Examples of good practices, initiatives, and representative pilot projects are

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presented, as well as an analysis of the new criteria existing buildings must meet in case of undertaking deep and major renovations to meet the nZEB principles.

Keywords: sustainability, energy efficiency, deep renovation, renewable resources, nZEB principles.

1. Introduction

Standards for nearly zero-energy buildings (nZEBs) are defined at national level, but the introduction and development of the concept is closely linked to regulatory developments at EU level.

The first version of the Energy Performance of Buildings Directive (EPBD), the cornerstone of EU construction legislation, from 2002 (Directive 2002/91/EC) included a requirement (Article 5) that Member States had to ensure that new buildings meet minimum energy performance requirements to achieve cost-optimal levels. In 2012, Regulation (EU) no. 244/2012 established a comparative methodology for calculating the cost-optimal levels of the minimum energy performance requirements.

The nZEB concept itself was introduced at the EU level with the 2010 recast of the EPBD (Directive 2010/31/EU). Article 2(2) of the Directive provides a definition of nZEB, while Article 9 sets out the provisions that Member States must fulfil in this regard. The EC supplemented the legal provisions in 2016 through Recommendation (EU) 2016/1318, with the aim of guiding Member States in nZEBs promotion and implementation and establishing some numerical benchmarks differentiated by climate regions.

An amendment to the 2018 EPBD (Directive (EU) 2018/844) did not change either the nZEB definition or the related provisions. However, according to the new Article 2a, Member States were obliged to establish a long-term renovation strategy to support the transformation of the national stock into a building stock with a high degree of energy efficiency and decarbonized by 2050, facilitating the cost-effective transformation of existing buildings into nearly zero-energy buildings.

Within the long-term renovation strategy, a direct link was therefore established between the nZEB standards and the overall objective for the existing building stock. In addition, the 2018 EPBD amendment placed some emphasis on aspects related to the modernization of the building stock to improve the interactions between the building and its occupants, as well as the energy network.

A notable result of this effort was the introduction of an optional smart readiness indicator. Legislation developed since then has attempted to recognize and consider the implications of the fact that buildings, far from being static elements, are an integral part of the energy system, as buildings not only consume but can also produce and store energy.

This means that the definition of nZEB as formulated in the EPBD has not evolved for more than 10 years (since the 2010 revision of the EPBD), which is quite striking in the current context.

In 2010, when the nZEB definition was introduced, the EU institutions had just adopted the energy and climate targets for 2020 (20% reduction of greenhouse gases (GHG) emissions compared to 1990, 20% of EU energy coming from renewable sources and 20% increase in energy efficiency). Since then, the EU's energy and climate architecture has evolved considerably.

The Clean Energy for All Europeans package, proposed in 2016 and agreed in 2018, set new targets for 2030 (40% reduction of GHG emissions compared to 1990, 32% of EU energy from renewable sources and increasing energy efficiency by at least 32.5%).

In December 2019, the EC committed, in its communication on the launch of the European Green Deal, to increase the EU's climate ambition for both 2030 and 2050.

With the adoption of the Climate Act in 2021, the EU has now enshrined in law the dual objective of achieving carbon neutrality by 2050 and reducing GHG emissions by at least 55% by 2030 compared to 1990.

In July 2021, the EC also proposed increasing the 2030 energy efficiency target to 39% for primary energy and 36% for final energy, with a target of 40% renewable energy in the EU's energy mix, together with a benchmark of 49% renewable energy in buildings.

Overall, the EU's climate and energy ambitions between 2010 (for 2020) and now (for 2030 and 2050) are significantly different.

The EU Green Deal (2019) also included the announcement of a "renovation wave" of public and private buildings, which the EC later published in a communication in October 2020. The objectives of the renovation wave are to at least double the annual energy renovation rate by 2030 and to encourage deep energy renovations, which should lead to the renovation of 35 million buildings by 2030 (strategy clearly focuses on renovating the existing building stock, nothing is mentioned about current standards for new buildings).

The renovation wave also provided more details about the New European Bauhaus, an initiative that should, as the EC president announced, act as "an accelerator for socially and aesthetically promising green and digital solutions, technologies and products. It will foster innovative solutions in terms of architecture and materials".

2. Implementation of nearly zero-energy buildings (nZEBs) in Romania

2.1 National context

Romania was the second largest producer of oil and methane gas in Europe. Now its reserves are decreasing and there are disputes with Ukraine over the exploitation of resources in the Black Sea. Thus, the energy independence of

the country based on fossil fuels is not ensured and the construction of the nuclear units at Cernavodă is developing. After the Second World War, the thermal protection of buildings was not improved, not even after the oil shock of the '70s, which alarmed Western governments. The use of efficient materials (expanded polystyrene and mineral wool) was drastically limited. Thus, the existing built stock requires almost double the amount of energy per square meter of useful surface compared to those in the EU, although the technical regulations have now been modified in accordance with those in the West. Carrying out energy audits must contribute to changing this situation, especially since the general public, as well as architects and engineers, have not fully embraced the principles and knowledge necessary for energy efficiency. To achieve this goal, what matters most is not just the accuracy of the calculations, but also identifying effective solutions and persuading beneficiaries to implement them.

Renewable sources, aside from hydropower, hold great potential but remain underutilized and not widely known. The negative psychological effect of solar collectors mounted on roofs and left unused still persists. Funds, a lot of power of persuasion, economic incentives and the training of many qualified personnel are needed.

The secondary energy (electricity and heat) is mostly produced by rather old Combined Heat and Power plants, and the heat is transmitted through urban networks where significant losses occur. Overall, the efficiency of using primary energy for heating buildings is about quite low. A series of contradictions between the owners of apartments or commercial spaces in a condominium limits the rehabilitation works, although the state and the municipalities now bear a large part of the necessary expenses for housing.

The technical books often do not exist in the case of old buildings, and the technical expertise report regarding resistance and stability, respectively the consolidation project, as well. Or the realization of thermal protection requires the existence of these basic documents. There are difficulties that must be overcome and this requires time.

Romania must be in solidarity with the rest of the EU member states in efforts to reduce GHG emissions. But its contribution on a world scale is obviously small. The climate will evolve decisively depending on what the great powers and groups of industrialized states will be able to do, as well as possible new solutions that the scientific research mobilized in this direction could discover. In either case, we face decades of worsening climate conditions ahead. The measures to reduce energy consumption and the use of existing renewable resources at the local level are very important. In this way, it will be possible to reduce the dependence on imports and the situation of family budgets will improve.

At the same time, measures to adapt the existing constructive compositions and load-bearing structures are also necessary. In addition to the very high probability of a major earthquake, after more than 40 years have passed

since the last one, floods and storms are added. Thermal comfort problems during the summer will increase and solutions must be found, without resorting to high consumption of electricity taken from the public network. Adaptation is also necessary in all other fields of human activities because they are correlated with energy efficiency. It is a significant issue that everyone in the population needs to be aware of, as it impacts us all.

2.1 National regulations on energy efficiency

The concept of a nearly zero-energy building is defined by Law no. 372/2005 (republished) as a building with a very high energy performance, while the nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby. This law also defines the terms of major renovation (work designed and carried out on the building envelope and/or its technical systems, the costs of which exceed 25% of the taxable value of the building, excluding the value of the land upon which the building is situated) and deep renovation (renovation leading to more than 60% improvement in the energy performance of a building, estimated by calculation according to the Mc 001-2022 methodology).

Among the most important measures of the Romanian authorities in the direction of the implementation of energy efficiency measures can be mentioned:

- Government Decision no. 462/2006 regulating the Program "District heating 2006-2020 - heat and comfort", the rehabilitation of centralized heat energy supply systems;
- Emergency Ordinance no. 18/2009 regarding the increase in the energy performance of the apartment blocks that regulates the National Program regarding the increase in the energy performance of the blocks of flats and the Thermal Rehabilitation Program with European funding from the Regional Operational Program;
- Order no. 163/2009 regarding the approval of the Methodological Norms for the application of the Ordinance no. 18/2009;
- Emergency Ordinance no. 69/2010 regarding the thermal rehabilitation of residential buildings with financing through bank loans with government guarantee;
- Emergency Ordinance no. 63/2012 for the amendment and completion of the Ordinance no. 18/2009, which introduces the thermal rehabilitation tax for the recovery of the contributions of owners' associations covered from the local budget and regulates the coverage from the local budget of the contribution of certain social categories, which are no longer recovered etc.

3. Examples regarding the evolution of the renovation process in Romania

3.1 Pilot projects

From the point of view of studying the energy efficiency of buildings, pilot projects are important to accelerate progress towards achieving nZEBs. They provide relevant and practical examples not only to specialists, but also to people wanting to know that these types of buildings are already possible, as well as information about cost implications, technologies used, user experiences etc. Also, in these pilot projects, innovative organizations in the industry can present their products, while designers share their experiences.

A. Pilot program coordinated by the Ministry of Transport, Construction and Technologies regarding the thermal rehabilitation of social housing owned by local authorities.

Within this pilot program, carried out with the support of the Swiss Confederation, between October 2003 and June 2004, a number of 12 residential buildings in Romania were thermally rehabilitated (Fig. 1).



Fig. 1 – The blocks in Iași, Tabacului street and in Piatra Neamț, Progresului street, before and after the execution of thermal rehabilitation works.

Investigating the results of the thermal rehabilitation under operating conditions (social surveys, IR thermography, measurements on the indoor microclimate, as well as determinations regarding the presence of harmful factors, such as carbon dioxide, microbial load etc.), have demonstrated the efficiency of the executed works, the reduction of energy consumption and tenants' expenses, an extremely important aspect in the case of social housing (Table 1 – Ungureanu, 2006).

Table 1

Energy consumption for heating (Q_h) and hot water preparation (Q_{HW}), in kWh/m²·a

Block in Iași		Block in Piatra Neamț	
Before rehabilitation	After rehabilitation	Before rehabilitation	After rehabilitation
$Q_h = 109.04$	$Q_h = 60.00$	$Q_h = 189.70$	$Q_h = 101.20$
$Q_{h+HW} = 188.00$	$Q_{h+HW} = 70.50$	$Q_{h+HW} = 243.10$	$Q_{h+HW} = 129.90$

B. Rehabilitation and modernization of the Tudor Vladimirescu Campus in Iași.

The series of experimental-demonstration rehabilitations carried out in the Tudor Vladimirescu Campus belonging to the "Gheorghe Asachi" Technical University of Iași began at the student dormitories T14 and T15, with the support of the Iași City Hall and the Romanian Association for Energy Conservation, being carried out with projects of the Faculty of Construction and Building Services and the Faculty of Architecture "G.M. Cantacuzino" (Fig. 2).



Fig. 2 – Thermally rehabilitated student dormitories in the Tudor Vladimirescu campus: the T14 building covered with POLYALPAN strips, triple glazing and bow-windows for greenhouse effect; the T15 building covered with OLTPAN strips.

The modernization of the T14 dormitory, carried out with the support of the PHARE Energy program, was completed in 1997 and represent one of the first demonstrative action to promote the thermal rehabilitation of existent civil buildings and to select suitable technical systems. It aimed at strengthening the structure, increasing the degree of thermal protection and passive utilization of solar energy, optimizing the sanitary and heating installations, restoring the interior finishes and changing the architectural expression. Following the thermal rehabilitation measures, the calculated specific consumption of thermal energy decreased from $271.83\text{kWh/m}^2\text{a}$ to $143.55\text{kWh/m}^2\text{a}$, thus resulting in an economy of 47.2% (Baran, 1999).

Then followed the "Rehabilitation and Modernization of the Tudor Vladimirescu Campus" project, run through the Regional Operational Program 2007-2013. The main objective of the project was satisfaction of the real needs for energy rehabilitation and modernization of services complementary to accommodation in the student campus, generated by a series of physical and moral degradations over time of buildings and electricity and thermal energy distribution networks, of increasing expectations, changing the lifestyle and consumption behavior of students, as well as the European standards for the provision of services related to accommodation (public catering, spending free time etc.). In order to fulfill them, the project assumed several main directions of investment, including the thermal rehabilitation of 12 dormitories and 2 thermal points in the campus, the modernization of external thermal and electrical networks, the establishment of cogeneration modules for electrical and thermal energy, the modernization of sports fields and of the canteen and others.

The 12 student dormitories were thermally rehabilitated at the level of the facades, the roof and the floor in direct contact with the ground and/or the basement, achieving a decrease in heat loss through the building envelope elements. The rehabilitation works, carried out with high-performance technical solutions, ensured a reduced consumption of fuel in the production of thermal energy, but also an increased thermal comfort for students. These, together with the other measures, obviously led to the optimization of the energy consumption of the campus (Fig. 3).



Fig. 3 – Thermally rehabilitated student dormitories in the Tudor Vladimirescu campus: the T9, T10 and T11 buildings rehabilitated at the level of the facades using ventilated façade system.

The rehabilitation and modernization works (pilot projects) were carried out in compliance with the existing regulations and legislation during the period in which they were done. Today, however, they are increasingly moving away from the current requirements regarding thermal insulation, primary and final energy consumption, as well as the nZEB concept.

In general, the implementation of energy efficiency works cannot be limited only to interventions on the envelope and building services. In fact, the complex and integral modernization of the building is necessary in order to satisfy all the essential requirements in constructions as well as an appropriate adaptation of their operating mode

3.2 Renovation at Passive House level

Concept whose principles served as a source of inspiration in the nZEB regulation, the Passive House standard developed by the Passive House Institute from Germany in the early 90s, entered Romania after the 2000s. This standard is among the most rigorous energy efficiency standards in the world, promoting at the same time the production and use of energy from renewable sources (Passive House Plus and Passive House Premium classes). In addition to the realization and certification of new constructions, the standard also covers the renovation of existing buildings (EnerPHit standard). The first certified renovated building in Romania is in Sfântu Gheorghe, Covasna and is a single-family house with basement and first-floor dating from 1959. According to the information

from the Passive House database (Passivhaus Institut GmbH, 2023), the renovation was done in six steps, namely: replacement of windows, installation of a heat recovery ventilation system in the basement, completion of the airtight layer, thermal insulation of the roof slab, thermal insulation of the slab above the basement and, finally, external thermal insulation of the facades. Following these measures, heating energy savings were 85%.

3.3 Renovation at nZEB level

A private project carried out by the Energy Policy Group (EPG) with the support of OMV Petrom started in the spring of 2022 with the nZEB level renovation of an educational building in Ploiești, the "Elie Radu" Energy Technology High School.

The investment of around one million euros consisted of extensive renovation works, both externally and internally, including: thermal insulation of the external walls, replacement of the existing carpentry with energy-efficient one, installation of sunshades on sunny windows and of solar thermal and photovoltaic panels, replacement of the lighting system with an intelligent one, replacement of pipes and radiators, installing heat recovery air filtration equipment, air disinfection equipment and others (Fig. 4).



Fig. 4 – The building of the "Elie Radu" Energy Technology High School from Ploiești, before and after renovation at nZEB level (NewsEnergy, 2022).

In addition to the significant energy savings, the benefits of this investment will also be reflected in greatly improved indoor conditions.

Carried out exclusively from private funding and in a relatively new legislative framework for Romania, this renovation project demonstrates the need for examples of good practices in what is intended to be the extensive program of modernization and energy efficiency of buildings in our country.

3.4 Step-by-step renovation and integrated interventions

Since the high levels of intervention required for the deep renovation of buildings involve efforts and costs that can discourage their owners, a possible option is the so-called "step-by-step" renovation, a renovation in stages during the life span of a building. In order to provide advice and support to owners, the European Commission will develop by the end of 2024 a common framework for

the implementation of Building Renovation Passports (BRPs), which promotes a long-term approach (15-20 years) in order to significantly improve the energy performance of buildings.

The BRP (integrated into the building's Technical Book) includes a roadmap that represents a personalized plan for energy renovation of the building (packages of measures, their order and terms, financing possibilities) established as a result of an energy audit and together with the owner of the building, as well as a logbook that includes all the information related to the energy efficiency of the building. Trigger points must be defined for each category of buildings, i.e. the opportune moments in the life cycle of the buildings to carry out energy efficiency renovations (e.g. transactions, planned renovations, disaster events).

Many times, especially in the case of old buildings, some of them with historical and architectural value, the energy efficiency works cannot be approached separately from the seismic consolidation ones. In this case, an integrated approach is necessary, aiming at multiple objectives: increasing energy performance and indoor comfort level, reducing seismic risk, extending the duration of use of the building, ensuring safety in operation and in case of fire, sustainable use of natural resources etc.

For buildings with special architectural and historical value, a non-invasive intervention methodology was recently adopted in Romania (Order no. 3568/2022), with measures leading to a 20-50% reduction in the energy consumption of the renovated building, under the conditions of good conservation and preservation of its cultural value.

4. Conclusions and perspectives

To achieve the ambitious objectives in the field of energy efficiency of buildings, both at the European and national level, efforts and measures are needed to aim at the construction of new buildings and especially at the renovation of existing ones. The buildings existing today will represent the vast majority of the built stock in 2050 (between 85-95% because the renewal rate of the real estate park is very slow).

The level of intervention required to improve energy performance is increasingly high. Compared to the simple thermal rehabilitation promoted in the past in our country, at present, there is a need for energy renovation at the nZEB level, and the EPBD revision proposal from December 2021 introduces the concept of zero-emission buildings, which will be the new standard for the renovation of existing buildings starting in 2030.

This development requires the mobilization of important financial resources, as well as sustained information campaigns for all the factors involved regarding the possibilities of accessing them. The realization of demonstrative pilot projects and the dissemination of information regarding the benefits

obtained in terms of energy savings in operation and the improvement of the indoor climate, can contribute to the decision to renovate buildings.

Building renovation has multiple beneficial implications. In addition to creating a highly energy efficient and decarbonized building stock, this ensures the improvement of the life quality for all building occupants, contributes to reducing the level of energy poverty and creates opportunities for new jobs and investments.

REFERENCES

- ** *Clean Energy for all Europeans (2018)*, https://energy.ec.europa.eu/topics/energy-strategy/clean-energy-all-europeans-package_en.
 - ** *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions A Renovation Wave for Europe - greening our buildings, creating jobs, improving lives, COM/2020/662 final*.
 - ** *Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings (recast)*, OJ L 153, 18.6.2010, p. 13–35.
 - ** *Directive (EU) 2018/844 of the European Parliament and of the Council of 30 May 2018 amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency*, OJ L 156, 19.6.2018, p. 75–91.
 - ** *EU Green Deal (2019)*, https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en.
 - ** *Legea nr. 372 din 13 decembrie 2005 (*republicată*) privind performanța energetică a clădirilor*, MO nr. 868/23.09.2020.
 - ** *New European Bauhaus*, https://new-european-bauhaus.europa.eu/index_en.
 - ** *Ordinul nr. 3568/2022 pentru aprobarea Metodologiei de intervenție pentru abordarea noninvazivă a eficienței energetice în clădiri cu valoare istorică și arhitecturală*.
 - ** *Paris Agreement (2016)*, <https://www.un.org/en/climatechange/paris-agreement>.
 - ** *Programul România Eficientă*, <https://newsenergy.ro/?s=romania+eficienta>.
 - ** *The Climate Act (2021)*, https://climate.ec.europa.eu/eu-action/european-climate-law_en.
- Baran I., *Contribuții la studiul problemelor de interacțiune construcții – mediu*, Teză de doctorat, Iași, 1999.
- NewsEnergy, *Ghid de renovare la standard nZEB a școlilor din România*, 2022, <https://newsenergy.ro/ghid-de-renovare-la-standard-nzeb-a-scolilor-din-romania-galerie-foto-video/>.
- Passivhaus Institut GmbH, *Passive House Database*, 2023, https://passivehouse-database.org/index.php?lang=en#d_6203.
- Ungureanu C.C., *Contribuții la proiectarea construcțiilor civile în cadrul conceptului de dezvoltare durabilă*, Teza de doctorat, Iași, 2006.

ASPECTE PRIVIND CREȘTEREA EFICIENȚEI ENERGETICE A CLĂDIRILOR.
DE LA REABILITARE TERMICĂ LA RENOVARE ENERGETICĂ
APROFUNDATĂ LA NIVEL NZEB

În condițiile exigențelor tot mai ridicate ale utilizatorilor, precum și ale creșterii continue a prețului la combustibilii fosili, astăzi consumul de energie pentru exploatarea clădirilor a ajuns să fie tot mai mare și mai greu de suportat. În acest context, pe plan mondial se propune realizarea unor construcții ale căror consumuri să fie cât mai reduse sau aproape egale cu zero, cerințe devenite obligatorii atât la clădirile noi, cât și la cele existente. Acest fapt are o importanță deosebită deoarece clădirile consumă 40% din totalul de energie și sunt responsabile pentru 36% din emisiile de gaze cu efect de seră. În Uniunea Europeană, 80% din energia consumată de gospodării reprezintă încălzirea, răcirea și apa caldă menajeră. Pentru atingerea obiectivului de neutralitate climatică în 2050 este necesară renovarea aprofundată a clădirilor existente, cu scopul de a deveni mai eficiente din punct de vedere energetic și mai puțin dependente de combustibilii fosili.

Lucrarea prezintă contextul stadiului actual în care se găsesc majoritatea clădirilor din România, precum și argumentarea necesității accelerării lucrărilor de reabilitare termică, în perspectiva obținerii unui parc imobiliar cu un nivel ridicat de eficiență energetică și decarbonat până în anul 2050. Pentru atingerea acestor deziderate, sunt prezentate exemple de bună practică, inițiative, proiecte pilot reprezentative, precum și o analiză din punct de vedere al noilor criterii pe care trebuie să le îndeplinească clădirile existente în cazul unor renovări aprofundate la nivel nZEB.