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PREGLEDNI RAD – REVIEW SCIENTIFIC ARTICLE

NERALY ZERO ENERGY BUILDINGS - THE ROAD TO LOW- CARBON CITIES

Ana Radojević[1], Danijela Nikolić[1], Jasmina Skerlić[2], Jasna Radulović[1],

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ABSTRACT

Buildings consume 40% of primary energy and are responsible for 36% of greenhouse gas (GHG) emissions. Therefore, reducing energy consumption in buildings can lead to large energy savings, and thus to a reduction in GHG emissions and environmental protection. Nearly zero energy buildings have great potential for a significant reduction in energy consumption, while increasing the use of renewable energy sources and environmental protection. Some countries have adopted or are considering adopting near-zero energy buildings as a future standard for the building sector. European energy policies through the Directives on energy efficiency of buildings (Directive, 2010/31/EU and 2018/844/EU) stimulate the energy transition to Nearly Zero Energy Building (NZEB) and the Positive Energy Building (PEB) model. There is still no exact definition of Nearly Zero Energy Building (NZEB), but the Energy Performance of Buildings Directive states that "a near-zero energy building means a building with very high energy efficiency", and that "Approximately zero energy or very low amount of energy should be supplied to a very significant extent from renewable sources, including energy from renewable sources produced in or near the building". The paper gives an overview of the criteria of energy efficiency and energy supply from renewable sources in different countries that need to be met in order for facilities to reach the Nearly Zero Energy Building (NZEB) standard.

Keywords: Energy efficiency policy, nearly zero energy buildings (NZEBs) - definitions and implementation.

INTRODUCTION

Energy consumption in buildings is a huge concern at European level. Buildings are estimated to account for approximately 40% of primary energy and 36% of greenhouse emissions (Eurostat, 2014). In some Member States this share even exceeds 45%, making the building sector the largest end-use sector in Europe.

After the 2007 Climate and Energy package of 20% reduction of buildings primary energy consumption by 2020, 20% increase of renewable energy production and 20% decrease of greenhouse gas emissions from 1990 levels, new targets have been introduced by the 2030 Climate & Energy framework (European Commission, 2014). This package fixes the reduction of greenhouse gas emissions at 40% from 1990 levels, the share for renewable energy at 27% and the improvement in energy efficiency at 27%. Finally, the European Roadmap 2050 aims at reducing greenhouse gas emissions by at least 80% by 2050 compared to 1990 levels (Odyssee-Mure, 2021).

Thus, the reduction of energy consumption in buildings is an important pillar of the European strategy to ensure that future climate and energy targets are reached. Nearly zero energy buildings (NZEBs) represent one of the greatest opportunities to increase energy savings in Europe. Renovating existing buildings to the state of NZEBs can be a good way to low-carbon cities.

The term "renovation" has been used to describe a wide variety of improvements to an existing building or group of buildings. Different levels of renovation can be distinguished depending on the type of intervention and savings obtained. Renovation can involve the installation of renewable energy sources (RES), as well as the replacement or upgrade of all building elements to reduce energy consumption towards zero levels. The refurbishment of a building façade (i.e. walls and windows) provides a different energy saving level compared to the retrofit of the overall building envelope and systems (heating, ventilation and air conditioning - HVAC, lighting, etc) (D'Agostino, Cuniberti, & Maschio, 2017).

Examples of low-carbon cities that have, among other things, used NZEBs as a way to minimize CO_2 emissions in their urban areas are described in detail in the book (Rauland, & Newman, 2015).

METHODOLOGY

The EU set up a policy framework focused on reducing energy consumption and obtaining important savings from buildings. One important policy action is the Energy Performance of Buildings Directive recast (EPBD recast, Directive 2010/31/EC) (European Parliament and of the Council, 2012). Other Directives aimed at the improvement of buildings energy performance are the Energy Efficiency Directive (EED) (EU, 2012/27/EU) and the Renewable Energy Directive (RED) (EU, 2009/28/EU) (Official Journal of the European Union, 2012; D'Agostino, Zangheri, Cuniberti, Paci, & Bertoldi, 2016).

According to the EPBD recast, new buildings occupied by public authorities and properties have to be NZEBs by December 31, 2018 and all new buildings by December 31, 2020 (European Parliament and Council, 2010).

Another important EPBD recast provision relates the introduction of cost-optimality. A comparative methodology framework to derive cost-optimal levels of minimum energy performance requirements for buildings and building elements is given in the Delegated Regulation No 244/2012 supplementing the EPBD recast. The cost-optimal level is defined as "the energy performance level which leads to the lowest cost during the estimated economic lifecycle". The methodology involves the definition of reference buildings and the application of energy efficiency measures to reduce primary energy consumption and address the choice of the most economically advantageous solutions.

Several studies have shown how a heterogeneous situation characterizes Europe in relation to building and climate types. As a consequence, different cost-optimal levels and packages of energy efficient measures can be found.

The cost-optimal concept is strictly connected to NZEBs as cost-optimality sets the minimum level of ambition for both building renovation and new buildings. The European Commission Recommendation on Guidelines for the promotion of NZEBs states that there cannot be a single performance level for NZEBs across Europe. Flexibility is needed to account for the impact of climatic conditions on heating and cooling needs and on the cost-effectiveness of packages of energy efficiency and renewable energy sources (D'Agostino, & Mazzarella, 2019).

A NZEBs is defined as a building with a very high energy performance. The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources produced on-site or nearby. The EPBD states that Member States shall detail NZEB definitions, reflecting national, regional or local conditions, and including a numerical indicator of primary energy use expressed in kWh/m^2 per year. Primary energy factors used for the determination of the primary energy use may be based on national or regional yearly average values taking into account relevant European standards.

Quantitative definitions of "very high energy performance" and "a very significant extent by energy from renewable sources" have to be given by Member States. Furthermore, the primary energy to be used in the numerical performance indicator (total, non-renewable or renewable) and the meaning of "nearby" are also subject to definition in each country.

RESULTS

At EU level, according to the review “Nearly zero energy buildings definitions across Europe” (Buildings Performance Institute Europe [BPIE], 2015) and (Nearly Zero-Energy Building Strategy, 2020), by early 2015, in almost 50% of Member States the definition of nZEB was not adopted, ie, it was at different levels of development. An active approach to increasing the number of near-zero energy buildings is visible through a predetermined gradual increase in demand for buildings (Denmark, Slovakia); application of the nZEB definition only for some types of buildings (Czech Republic, UK), or a complete definition of almost zero energy buildings in the initial step, as in the example of Brussels, where the definition for nZEB was adopted in 2011 and in mandatory application since 2015.

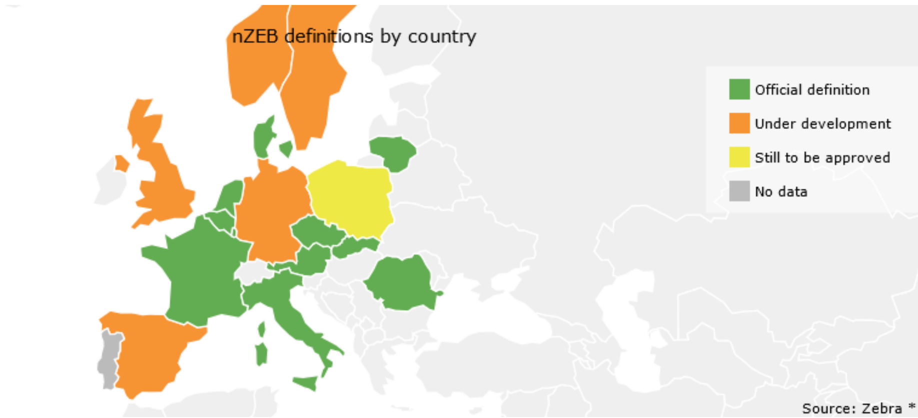

Figure 1. nZEB definitions across Europe.

Belgium

The definition of nZEB is different for the administrative regions - Brussels, Flanders and Wallonia, with primary energy for residential buildings up to 45 kWh/m²a, and 85-95 kWh/m²a for non-residential buildings.

Slovenia

The definition of nZEB is given according to cost-optimal analyzes, and is limited through primary energy to 75 kWh/m²a for family houses, 80 kWh/m²a for apartment buildings and 55 kWh/m²a for non-residential buildings and the share of RES of at least 50% of total delivered energy.

Cypres

The nZEB definition includes primary energy for energy needs of buildings, ranging from 100 kWh/m²a for residential to 125 kWh/m²a for non-residential buildings, maximum required energy for heating of 15 kWh/m²a and 25% share of renewable energy sources in delivered energy for the building, and additional requirements regarding the maximum heat transfer coefficients of the outer shell and the energy required for lighting.

Danemark

The definition of nZEB is given as Building class of 2020 in the current regulations, through the total energy needs for residential buildings of up to 20kWh/m²a, or 25 kWh/m²a for non-residential buildings.

Germany

The definition of a near-zero energy building is given through primary energy, as a 25% stricter requirement than the minimum (cost-optimal) requirements for new buildings. At the same time, funding models through KfW programs are available for buildings that are at the level of KfW 55 and KfW 40 (55 and 40% of the minimum requirements, respectively), and it is expected that the requirements for nZEB will increase to KfW 55, ie 45% stricter than the minimum requirements in the current regulations.

Great Britain

The definition of very high energy efficiency buildings in the Great Britain is focused on zero CO_2 buildings, proposed from 2016 for new residential buildings and from 2019 for non-residential buildings, although primary energy is also an indicator of building energy performance and applicable to the nZEB building definition. The plan relies on measures included in the 2008 Climate Change Act, through reducing energy consumption in buildings and decarbonising heating and cooling supply.

Sweden

The Swedish plan to increase the number of buildings is from 2011, and does not provide a detailed definition of almost zero energy buildings, but predicts that the values will be below the maximum allowable values according to current regulations, which in 2012 ranged from 90 to 130 kWh/m^2a depending on the climate zone, ie 55 to 95 kWh/m^2a for buildings with electric heating. Promotional measures and research projects for the definition of nZEB buildings are envisaged.

Lithuania

The definition of a near-zero energy building in Lithuania is set in relation to the minimum building requirements, which depend on the geometric characteristics of the building. According to that definition, a near-zero energy building is a building that uses less than 25% of primary non-renewable energy for heating, cooling, ventilation, air conditioning and lighting and less than 70% of primary non-renewable energy for DHW preparation in relation to minimum requirements for new construction. The additional requirement regarding the share of renewable energy sources is equal to the requirements for the share of renewable for all buildings, as well as a stricter requirement regarding the air permeability of the outer envelope and the degree of action of the mechanical ventilation composition with heat recovery.

Hans Erhorn and Heide Erhorn-Kluttig in a report (Erhorn, & Erhorn-Kluttig, 2014) gave a set of examples of buildings in individual EU member states, whose level of energy performance in the range of buildings is approximately zero energy or at least close to that range. Examples of such buildings offer practical experience and the realization that such buildings or even buildings with higher energy efficiency are achievable.

Some of the examples are given below.

Austria – passive house Ebner

Passive house Ebner is a new single-family residential house with a small built-in office. The size of the house is 160 m^2 net area, 216 m^2 gross area. The house is built to meet the standards of a passive house, using solar thermal panels. The goal was to use ecological building materials such as straw, wood and clay, so the walls and roof are made of 70 cm bale of straw between the wooden structure, and the floor consists of 50 cm filling of glass foam and gravel under the concrete base plate. The windows are triple glazed.

For the application of renewable energy sources, solar thermal panels (8 m^2) are used for the production of domestic hot water and a wood pellet heating system. Demand for hot water is mainly covered by solar panels while the house is heated by a wood pellet stove. The house has a mechanical ventilation system with a heat recovery of 86%. The cost of the building was around EUR 300,000 (EUR 1,875/m^2 net area).

Figure 2. Passive house Ebner in Austria (Erhorn, & Erhorn-Kluttig, 2014).

Table 1. Achieved U-values of the building envelope per component; passive house Ebner, Austria.

WALL	0.065 W/m²K
WINDOW	0.86 W/m² K
ROOF/CEILING TOWARDS ATTIC	0.065 W/m²K
BASEMENT CEILING/FOUNDATION PANEL	0.11 W/m² K

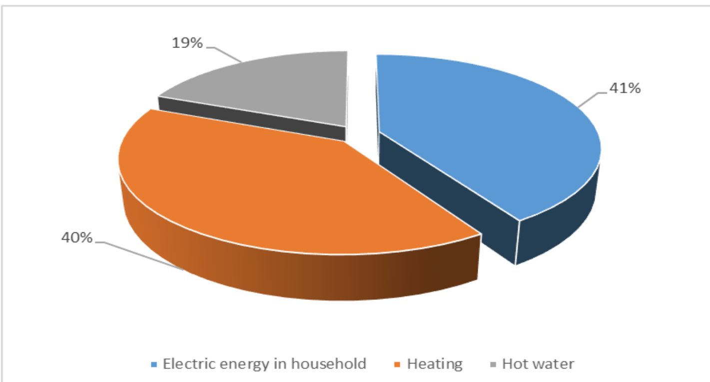

Figure 3. Final use of energy; passive house Ebner, Austria (Erhorn, & Erhorn-Kluttig, 2014).

Table 2. Final use of energy.

HEATING	16.0 kWh/m²year
HOT WATER	7.3 kWh/m²year
COOLING	0.0 kWh/m²year
VENTILATION	included in household electricity
LIGHTING	included in household electricity
ELECTRICAL APPLIANCES (ELECTRIC ENERGY IN HOUSEHOLD)	16.4 kWh/m²year
TOTAL	39.7 kWh/m²year

Table 3. Use of primary energy/CO_2 emission

TOTAL PRIMARY ENERGY	85.9 kWh/m².year
TOTAL CO2 EMISSION	10.4 kg/m².year

Croatia – residential building in Lenišće – "Šparna hiža"

Figure 4. Residential building "Šparna hiža" (Erhorn, & Erhorn-Kluttig, 2014).

"Šparna hiža" is a new, residential building designed as a low-energy building with a maximum energy consumption for heating of 15kWh/m^2 of apartment per year, which belongs to the A + energy class.

The size of the building is 1539 m^2 of net usable area. It consists of three floors of 612 m^2, 28 apartments, basement and ground floor.

The structural walls are made of reinforced concrete, 20 cm thick, or brick masonry blocks 25 cm thick. The envelope of the building is thermally insulated with 20 cm thick stone wool for concrete walls and 15 cm for brick walls. The roof is flat, made of 20 cm of concrete and thermally insulated with 30 cm of XPS. PVC windows are made with triple low-e glass, glazed filled with argon.

Heating and cooling are provided through a floor system that uses the same pipes for both heating and cooling. Heating is carried out using a compact heat pump with COP 2.8 (90%) or boilers using natural gas (10%). Each apartment has its own energy meters.

Hot water is primarily produced using solar thermal collectors on the roof of the building, which are connected to DHW tanks with a capacity of 4000 liters. The system is designed to primarily use solar energy to produce hot water, with gas boilers as a supplement.

The ventilation system works continuously to supply 0.5 air changes per hour for the entire volume of the apartment. Waste air heat is dissipated through a high-performance energy recovery system.

The costs of land, design, construction and supervision amount to 11,485,000.00 HRK (about 1,500,000.00 €) for 1,644 m^2 (28 apartments).

Table 4. Achieved U-values of the building envelope per component; residential building "Šparna hiža", Croatia.

WALL	0.19 W/m²K (concrete wall) – 0.22 W/m²K (brick wall); allowed Umax = 0.45 W/m²K
WINDOW	0.99 W/m²K; allowed Umax = 1.80 W/m²K
ROOF/CEILING TOWARDS ATTIC	0.10 W/m²K; allowed Umax = 0.30 W/m²K
BASEMENT CEILING	0.21 W/m²K; allowed Umax = 0.50 W/m²K
FOUNDATION PANEL	0.13 W/m²K; allowed Umax = 0.50 W/m²K

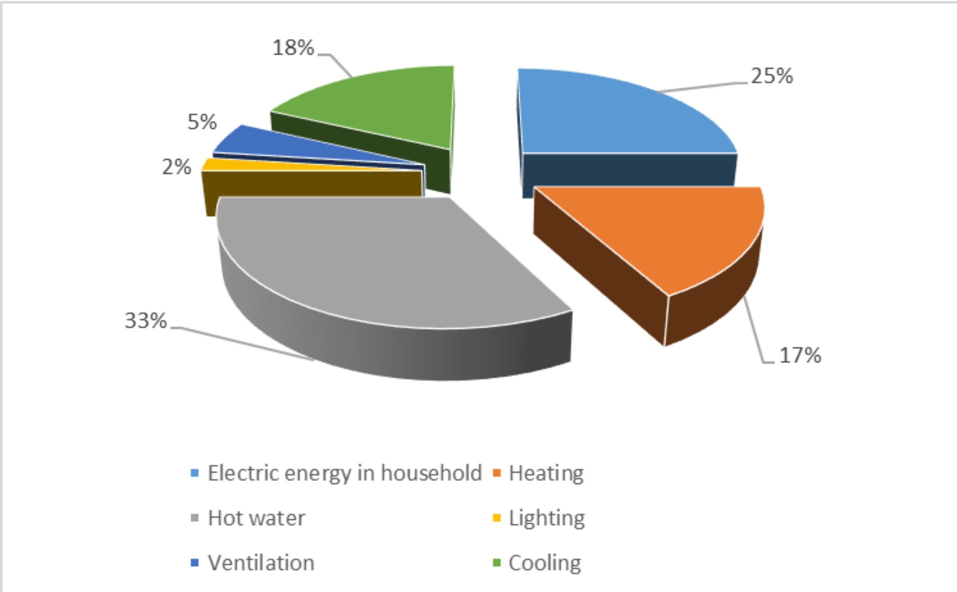

Figure 5. Final use of energy; residential building “Šparna hiža”, Croatia (Babić, 2016)

Table 5. Final use of energy; residential building “Šparna hiža”, Croatia.

HEATING	14.95 kWh/m²year(~ 10% gas boiler, 90% heat pump)
HOT WATER	29.10 kWh/m²year (50% solar energy)
COOLING	15.65 kWh/m²year
VENTILATION	4.17 kWh/m²year
LIGHTING	1.69 kWh/m²year
TOTAL	65.56 kWh/m²year
ELECTRICAL APPLIANCES (ELECTRIC ENERGY IN HOUSEHOLD)	21.54 kWh/m²year

Table 6. Primary use of energy; residential building “Šparna hiža”, Croatia.

ELEKTRIC ENERGY	78.95 kWh/m².year	primary energy factor: 3
NATURAL GAS	17.65 kWh/m².year	primary energy factor: 1.1
TOTAL	96.30 kWh/m².year	

CONCLUSIONS

The reduction of energy consumption in buildings is an important pillar of the European strategy to ensure that future climate and energy targets are reached. Nearly zero energy buildings (NZEBs) represent one of the greatest opportunities to increase energy savings in Europe. Renovating existing buildings to the state of NZEBs can be a good way to low-carbon cities.

A NZEBs is defined as a building with a very high energy performance. The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources produced on-site or nearby. The EPBD states that Member States shall detail NZEB definitions, reflecting national, regional or local conditions, and including a numerical indicator of primary energy use expressed in kWh/m^2 per year. Primary energy factors used for the determination of the primary energy use may be based on national or regional yearly average values taking into account relevant European standards.

Differences in national regulations on energy use and thermal protection, and differences in the very definition for near-zero energy buildings, make comparing buildings between countries quite difficult.

There is a visible difference in ambition in setting the definition of a near-zero energy building between EU member states. There is a difference in the share of renewable energy that should be realized in buildings of approximately zero energy, but also in the amount of maximum primary energy. The obtained results show that energy efficient measures on the building envelope are not sufficient to achieve approximately zero consumption, and that it is necessary to increase the share of renewable energy in order to achieve the set goal.

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