Optimisation of the Use of Renewable Energy Sources in Near-zero Energy Building Standards in Poland and in the Czech Republic

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Abstract

European Union member states have, since 2020, introduced a model for the design and construction of buildings to a new energy standard for buildings with near-zero energy demand (nZEB standard). Following European models, many other countries are introducing the nZEB standard as a mandatory standard for building design and construction. Directive 2010/31/EU has left European countries free to adopt the parametric levels of the nZEB standard. The minimum parametric levels characterising the nZEB standard are based on the availability of materials and technology and on the economic calculation that each EU country had to make before adopting the minimum requirements for the nZEB standard. Directive 2010/31/EU only imposed the deadline for the introduction of the nZEB standard as 1.01.2021. A second requirement of the Directive is that renewable energy sources must be used to supply heat, cooling and electricity to buildings as far as possible. However, the percentage of RES sources used in the overall energy balance is not specified. It is not always possible to cover the total energy demand of buildings with renewable energy sources. Often, RES cover only part of a building's energy needs. In this article, the authors analysed the regulations for the nZEB standard in selected countries. Two European countries were selected for further analysis: Poland and the Czech Republic. Using a single-family residential building as an example, an analysis was carried out to determine what percentage of energy should be used from renewable energy sources in addition to other energy sources such as gas, district heating or coal to achieve the near-zero energy building standard defined for the two countries analysed. The analysis carried out by the authors can provide guidelines for the design of buildings to the nZEB standard in both Poland and the Czech Republic.

Keywords: *nZEB standard, barriers in nZeb Standard implementation, Polish requirements for nZEB buildings*

1. Introduction

The European Union's (EU) 2030 climate target entitled "Fit for 55" aims to achieve climate neutrality and reduce greenhouse gas (GHG) emissions by 55% by 2030 [1]. The 2018 recast version of the Energy Performance of Buildings Directive (EPBD) is an implementation tool to translate these targets and transform new and refurbished buildings in the 27 EU Member States. The revised Directive 2021/12/14UE (EPBD) indicates in Article 9 that EU Member States (MS) must achieve at least a 55% reduction in greenhouse gas (GHG) emissions by 2030 (compared to 1990 levels), thereby setting the EU on a path towards its ultimate goal of net zero GHG emissions (climate neutrality) by 2050 [2]. All 27 EU Member States need to develop decarbonisation plans and trajectories to phase out fossil fuels and set limits on carbon emissions. However, progress in implementing nZEB in Eastern Europe has been slow compared to Western countries and there are large differences in building energy efficiency between West and East.In urban areas, the housing stock in Eastern Europe consists mainly of multi-family buildings located in blocks of flats connected to district heating networks, in contrast to suburban and rural areas, where single-family houses predominate. While an increasing percentage of existing multifamily buildings are being renovated and their average energy efficiency is improving significantly year on year, single-family buildings, especially the oldest ones, are very energy-intensive and pose a major problem. According to the EU Building Stock Observatory (BSO), an online tool that monitors the energy performance of buildings across Europe, the average energy demand for heating single-family houses built before the Second World War is between 175 and 310 kWh/m^2.

2. nZEB Standard

The latest version of the 2021 version of the EPBD requires the use of two indicators for the calculation of nZEB, which are the pillars of the definition:

1) "Nearly zero energy building" means a building with very high energy performance. The near-zero energy required should be covered to a very large extent by renewable energy, including renewable energy generated on site or nearby.

2) 'Primary energy' means 'energy from renewable and non-renewable sources' that has not been converted or transformed.
Figure 1 shows the key elements that significantly affect the energy efficiency of buildings in the residential sector.

Fig. 1. Elements affecting the efficiency of buildings in the residential sector.

3. Poland and the Czech Republic

The construction sector in Poland and the Czech Republic shares similar characteristics due to a common historical and economic background. Much of the housing was built during the Soviet era, using uniform solutions and similar standards, but the similarities extend to other periods as well.

3.1 Czech Republic

The Czech Republic is divided into four climatic regions with rated outdoor temperatures of -12°C, -15°C, -18°C and -20°C (ČSN 730540, Annex H1). The Czech Republic has a temperate continental climate, typically with warm summers and cold winters. The temperature differences between the two seasons are relatively large. Only one climate zone is used to calculate the energy efficiency of buildings. A detailed national plan for the implementation of the nZEB standard is available. The minimum thresholds for heating demand and cooling demand are compared with a reference building. The reference building is a hypothetical copy of the designed building, with parameters reflecting the limit values set out in ČSN 730540-2 Thermal protection of buildings - Part 2: Requirements.

In the Czech Republic, the average U-value of the building envelope must be below 70% of the U-value of the reference building. Primary energy demand is estimated at 30-90 kWh/(m2year). Mechanical ventilation requirements are not mandatory. Seasonal variations in energy demand for heating and cooling are significant in single-family houses nZEB [3].

In terms of the number of dwellings, almost half (45%) are located in single-family houses. Dwellings in high-rise buildings are less significant (26.9%), but noteworthy. A significant part of the building stock was built before the end of the Second World War (22%). More than 50% of the Czech housing stock was built after 1970; the average age of buildings is 49.3 years for single-family houses and 52.4 years for other residential buildings [4]. In the Czech Republic only 83.4% of dwellings are occupied, the rest (16.6%) are empty, unusable or abandoned [5]. In the Czech Republic, 9% of housing is owned by the state and municipalities. The remainder (91%) is owned by individuals (46%), housing cooperatives (11%) or other forms of ownership (34%) [6].

In the Czech Republic, 21.9% of dwellings have space heating, 43.2% have central or flat heating and 34.9% have district or collective heating. Since 2009. Natural gas was the most important energy source for heating (39%), followed by district heating (36.84%), solid fuels (17.62% - mainly wood), electricity (6.25%) and other sources (0.2%). For gas-fired heating, 82.2% of dwellings have boilers and the rest (17.2%) individual heating appliances (e.g. gas convectors). In the case of wood-fired heating systems, central systems are more common (59.8%) than individual cookers (40.2%) [7].

District heating networks were built in the 1970s and 1980s to supply heat to large blocks of flats. In the Czech Republic, district heating still plays an important role, with a slight downward trend over the past few years. The country's energy strategies foresee that, despite the current trend towards decentralisation, district heating will remain an important district heating technology in the future, as evidenced by scenarios and projections in key strategic documents. In the Czech Republic, distribution networks have been modernised and are thus in a better condition: losses range from 6 to 14% of the [8]. Nowadays, most buildings in the Czech Republic have heat exchanger heat centres for heating and hot water with modernised controllers and valves. Apartment blocks are usually heated in the Czech Republic up to 22-24°C. In the Czech Republic, both heat cost allocators and temperature control valves are required by law in flats served by district heating [9], [10].

In the Czech Republic, the most common ways to save energy are additional insulation of external walls (polystyrene or occasionally mineral wool), replacement of windows and entrance doors, additional insulation of the roof and insulation of the ceiling above the basement, hydraulic balancing of the heating system and controlled heating with heat cost sharing. In blocks of flats, it is quite common to switch from external heat substations to heat substations inside the buildings. Heat metering at building level is common. Replacement of heating and hot water sources with more efficient technologies can be observed especially in single-family houses [11], [12].

Recent renovations have mainly focused on large-plate buildings, partly due to available subsidies and also for practical reasons, as these standardised buildings offer good opportunities for optimised solutions that can be applied repeatedly. In the

Czech Republic, renovations of apartment blocks and multi-family buildings were analysed in a study of PanelScan [13] 2009 and in two more recent but less comprehensive studies, The surveys showed that many buildings have only been partially renovated (e.g. window replacements) and the quality of the work is quite variable.

Barriers to nZEB implementation include a lack of sophisticated organisational certification mechanisms and a shortage of skilled labour due to mass migration to the West [14]. The proliferation of single-family nZEB houses in rural areas is slow. The newly built ones rely on HP and PV. However, old buildings are old and rely on solid fuel heating systems that emit pollutants.

The Czech Republic developed a national cost-optimal calculation, completed in June 2017, based on the cost-optimal approach set out in the Energy Performance of Buildings Directive [15].

The Czech Republic is the only country in the region that requires the calculation of nZEB energy efficiency based on a comparison with a reference building. Other countries have established prescriptive requirements for primary energy consumption or final energy consumption [16].

The total primary energy demand for heating and hot water of the residential building stock is relatively high in the Czech Republic, at 448.3 PJ/year [17].

3.2 Poland

Poland has a cold climate with maritime and continental elements. The non-renewable primary energy requirement for new residential buildings in Poland is 70 kWh/(m^2-yr), which is at the upper end of the range of 50-70 kWh/(m^2-yr) recommended by the European Commission for a continental climate. On the other hand, the requirements for non-residential buildings are 45 kWh/(m^2-year), making them much more ambitious than the EC's recommended range of 85-100 kWh/(m^2-year) and among the most ambitious in the EU.As far as the share of renewable energy in primary energy supply is concerned, the new building law in Poland does not specify such a requirement, making Poland one of the worst performing EU countries in this respect.

Poland's building stock is generally characterised by low levels of thermal insulation. Coal and gas are the main sources of heating, whether through individual heating units or district heating, which generates an excessively large carbon footprint.

The widespread use of coal and associated air pollution is also a major health problem, especially in cities. In light of these challenges, energy efficiency in buildings is becoming increasingly important in this country.

The Council of Ministers on 9 February 2022 adopted the Long-term Strategy for Renovation of Buildings (DSRB). The DSRB sets out a kind of roadmap for the renovation of Poland's building stock in the short and long term. The strategy (DSRB) aims to "cost-effectively transform the national building stock into near-zero energy buildings". For the purpose of developing the strategy, a review of all buildings in Poland, both public and private, was carried out, which showed that there are 14.2 million buildings in Poland, of which almost 40% (5.7 million) are single-family residential buildings, which are inhabited by more than half of the country's citizens [18]. A significant proportion of the buildings are characterised by low energy efficiency and will require thermomodernisation in the coming years. The data show a wide variation in the energy efficiency of buildings both in terms of their purpose and the year they were put into use. Buildings put into use in the 21st century are characterised by relatively high energy efficiency, but older buildings have high energy demand and require thermomodernisation. This applies in particular to single-family buildings, for which solid fuel boilers remain the primary source of heat. Only 1 % of existing single-family houses can be described as energy-efficient, and more than 70 % are either completely uninsulated or insulated too thinly. The high energy intensity of single-family houses causes their owners to use the cheapest and least ecological heating methods - around 3.5 million single-family houses in Poland are heated with the worst quality coal, burned in primitive, outdated appliances with low efficiency and high air pollutant emissions. Investors are also keen to install coal-fired boilers in newly constructed buildings, in which, in addition to coal, various types of rubbish and waste can be burnt. Emissions from the single-family residential sector are the main source of air pollution, including the most harmful substances: particulate matter, polycyclic aromatic hydrocarbons, heavy metals and dioxins. On the other hand, this sector contains the greatest potential for opportunities to reduce energy consumption and protect the environment.The Polish NZEB standard has been developed in accordance with the cost optimisation methodology set out by the EC. However, it is not clear whether the NZEB standard would be cost-optimal if introduced at current energy and building material prices. As is known, the level of the NZEB standard was set before Poland, along with the rest of the EU, agreed to achieve carbon neutrality by 2050. For this reason, there is an urgent need to revise the NZEB standard, especially in countries such as Poland that are heavily dependent on fossil fuels for heating.

Renewable energy systems compete with nZEB energy efficiency in residential buildings and the degree of readiness to provide nZEB and NZEB is currently low EPC requirements and implementation process are inaccurate and inconsistently applied. EPCs in Poland for nZEB do not represent the expected energy efficiency results [19].

4. Polish Requirements for nZEB Buildings

The requirements for nZEB buildings in Poland are those contained in the Regulation on Technical Conditions in force from 31 December 2020 [20]. Buildings and their heating, ventilation, air-conditioning, hot water and, in the case of public utility, collective residence, production, utility and storage buildings, also built-in lighting, should be designed and constructed so as to meet the minimum requirements for both thermal insulation of partitions and technical equipment, window area and the EP indicator, which determines the annual calculated demand for non-renewable primary energy. Table 1 presents the most relevant requirements related to thermal insulation of partitions and energy savings for residential buildings in Poland, as well as other selected recommendations related to minimising heat loss.

Tab. 1. Requirements for thermal protection of residential buildings in Poland effective from 31 December 2020 and selected recommendations [20].

No.	Requirement/ recommendation	Single-family residential buildings	Multi-family residential buildings
1.	Required primary energy indicator value, [kWh/(m^{2}· rok)]	70	65
2.	Maximum values for the heat transmission coefficient of the building envelope at t_i≥16°C [W/m^{2}K]		
2a.	External walls	0,20	
2b.	Roofs, flat roofs, ceilings under unheated attics or over passageways	0,15	
2c.	Floors on the ground	0,30	
2d.	Ceilings over unheated spaces	0,25	
2e.	Windows, balcony doors, non-opening transparent surfaces	0,90	
2f.	Roof windows	1,10	
2g.	External doors	1,30	
3.	Minimum thickness of thermal insulation for distribution pipes and components in central heating systems, hot water systems (including circulation pipes), cold storage systems and air heating systems with thermal		
3a.	With an inside diameter of up to 22 mm	20	
3b.	With an inside diameter of 22 mm to 35 mm	30	
3c.	For inside diameters from 35 mm to 100 mm	Equal to the diameter of the inner pipe	
3d.	For inside diameters over 100 mm	100	
3e.	Air heating ducts (laid in the heated part of the building)	40	
3f.	Air heating ducts (laid in the unheated part of the building)	80	
4.	Other requirements to minimise energy consumption:		
4a.	Specific power of supply fans used in ventilation and air-conditioning systems with heat recovery, [kW/(m^3/s)]	1,60	
4b.	Moc właściwa wentylatorów nawiewnych stosowanych w instalacjach wentylacyjnych i klimatyzacyjnych bez odzysku ciepła,	1,25	
4a.	Specific power of exhaust fans used in heat recovery ventilation and air conditioning systems and in non-heat recovery supply and	1,00	
4b.	Specific power of exhaust fans in an extract system, [kW/(m^3/s)]	0,80	
5.	Recommended air tightness of the building n50 [1/h]		
5a.	in buildings with gravity or hybrid ventilation	< 3,0	
5b.	in buildings with mechanical ventilation or air conditioning	< 1,5	

5. Conclusion

To achieve high levels of efficiency, a combination of photovoltaics, heat pumps, sustainable ventilation with heat recovery and improved external insulation is required, and this in turn requires an optimised design process from both an architectural and economic perspective.

Since the introduction of the NZEB requirements, there have been no significant changes in the management and implementation of the new building standards. Those involved in the construction process, such as architects and engineers, are required to design and build to the specified requirements, including minimum energy efficiency requirements.

Given the updated EU climate targets for 2030 and 2050, there is a need to develop a new paradigm and standards for new buildings that will lead to the full decarbonisation of the current and future building stock. The need for such a paradigm is urgent: further tightening of energy performance standards is required, together with more ambitious regulations on maximum energy consumption levels and the use of renewable energy sources. The implementation of tools to measure operational and embedded carbon emissions prior to setting limits on these emissions is also strongly recommended, as are plans to phase out fossil fuels in construction. This is also crucial in the context of a wider transition towards a more integrated and decentralised energy system, with a high degree of intermittency of renewable energy supply and appropriate storage solutions.

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