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Definition of nearly zero-energy building requirements based on a large building sample

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HIGHLIGHTS

- We analyse the European nearly zero-energy building definition.
- We present a method for setting requirements based on a large building sample.
- We demonstrate the method for residential buildings in Hungary.
- We compare the results with the European targets.

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ABSTRACT

According to the recast of the Energy Performance Building Directive, Member States must give an exact definition for nearly zero-energy buildings to be introduced from 2018/2020. The requirement system stipulating the sustainable development of the building sector is usually based on the analysis of a few reference buildings, combining energy efficiency measures and HVAC systems. The risk of this method is that depending on the assumptions either the requirements do not provide sufficient incentives for energy saving measures and renewables or the requirements cannot be fulfilled with rational solutions in many cases.

Our method is based on the artificial generation of a large building sample, where the buildings are defined by geometric and other parameters. Due to the large number of combinations, the effect of many variables appear in the results, with the deviations reflecting the sensitivity of the energy balance. The requirements are set based on some fundamental considerations and the statistical analysis of the sample.

The method is demonstrated on the example of setting the requirements for residential buildings in Hungary. The proposed requirements are validated against the common European targets. The suggested method is suitable for developing building energy regulation threshold values, certification schemes or benchmarking values.

1. Introduction

The goal of the European Union is to drastically cut its domestic greenhouse gas emissions by 80% by 2050 compared to 1990 levels (BPIE, 2011a). Since the building sector has been identified as one of the key sectors for cost-efficient savings, at least 88–91% reduction is necessary in this field to reach these ambitious targets (BPIE, 2011a). This can only be achieved if the energy consumption of both the existing building stock and new buildings is reduced, and the share of renewable energy sources is increased in the energy supply. The 88–91% reduction cannot be guaranteed in the existing building stock, which means that new buildings still to be built by 2050 must compensate with even larger reductions.

In line with these goals, the Energy Performance Building Directive has been revised in 2010 (EPBD recast, 2010). According to Article 9 of the EPBD recast, by 31 December 2020 all new buildings must be nearly zero-energy buildings (nZEB) in the Member States. Public authorities are supposed to take an exemplary role, and new buildings occupied and owned by public authorities must be nearly zero-energy buildings already after 31 December 2018 (EPBD recast, 2010). According to the definition of

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the recast, a nearly zero-energy building is "a building that has 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, including energy from renewable sources produced on-site or nearby" (EPBD recast, 2010). However, the exact definition, reflecting their national, regional or local conditions is the responsibility of the Member States, including a numerical indicator of primary energy use expressed in kW h/m^2 yr.

Another important directive is the Renewable Energy Directive that orders Member States to require minimum levels of energy from renewable sources in new buildings and in existing buildings subject to major renovation in building regulations and codes by 31 December 2014 (Renewable Energy Directive, 2009). District heating and cooling with a large renewable share will be also accepted.

A benchmarking mechanism for buildings is the principle of cost-optimality. The EPBD recast prescribes that Member States shall determine the cost-optimal levels of minimum energy performance requirements based on a comparative methodology framework established by the Commission (EU, 244/2012, 2012). If the gap between the calculated cost-optimal levels and the current requirements exceeds 15%, the Member States should plan steps to approach the cost-optimal levels. The cost-optimal methodology can also assist Member States in determining the nearly zero-energy requirements. *BPIE* recommends setting the nZEB requirements in a corridor, where the upper limit is the cost-optimal and the lower limit is the best available technology (BPIE, 2011a). MS can decide their individual position within the corridor depending on the national circumstances. It is expected that currently there is a gap between cost-optimal and nZEB levels, but by 2021 this gap will narrow due to the increase in energy prices and decrease in technology costs.

A core element of the cost-optimal methodology is the definition of reference buildings (EU, 244/2012, 2012). The effect of different energy saving measures is assessed for these buildings, and the associated primary energy demand and global costs are calculated. According to the Directive (EU, 244/2012, 2012) reference buildings shall be established for single-family buildings, apartment blocks and multifamily buildings, office buildings, and for other non-residential building categories for which specific energy performance requirements exist. Usually only a few reference buildings per building category are analysed, and these reference buildings are used for validating the pre-set requirements. However, this approach does not consider some special features of real buildings, such as the effect of geometry, orientation, shading etc.

The nZEB requirements should be demanding, but at the same time they should be realistic. Defining the requirement system stipulating the sustainable development of the building sector based only on a few reference buildings is highly risky: if the requirements are too 'soft', it will not stimulate energy saving and the European targets will not be met, but if the requirements are too strict, the effectiveness of the regulation will be compromised if many buildings cannot comply using rational solutions.

This paper shows a methodology for defining the requirements for nZEB with a bottom-up approach, based on the analysis of a large, artificially generated sample of buildings. As a consequence of the large number of combinations, the effect of many parameters can be studied on the energy balance. The use of a building sample instead of a few reference buildings may be very helpful, for example, for defining energetic requirements, benchmark values or labelling categories. The methodology was applied in Hungary when proposing the requirements.

The structure of the paper is the following: first, approaches for setting the nZEB requirements in the European Union, and methods for selecting reference buildings are summarised. In the second part, our fundamental considerations for setting the requirements are established. Then the methodology is presented in detail, and finally the usability of the method is demonstrated on the example of the proposed Hungarian requirements. In this paper only residential buildings are shown, but the method was also applied for offices and educational buildings.

It has to be mentioned that the methodology presented here was applied in a background study for setting the requirements prepared for the Ministry, but the requirements have not been officially approved (Zöld et al., 2012, 2013).

2. Background

2.1. nZEB principles in the European Union

In existing highly efficient building concepts, the high level of insulation, efficient windows, high level of airtightness and balanced mechanical ventilation are typically combined with passive and active solar measures and other renewable energy sources.

The advantage of the qualitative definition for nearly zero-energy buildings in the EPBD recast is that it leaves room for the Member States (MS) to adapt the definition to their specific conditions and climate. However, the level of ambition, the emission thresholds and renewable share remain vague and there is a risk that MS will defy common understanding. To assist the Member States in developing a uniform approach for implementing nZEB, BPIE has identified 10 main challenges (for example the consideration of both energy and CO_2 targets, the time and local disparities of energy consumption and production, the inclusion of household electricity, the balance of energy efficiency and renewable energy, etc.) and has defined some common principles for sustainable and realistic nZEBs (BPIE, 2011a):

- a threshold for the maximum allowable energy need should be defined;
- a threshold for the minimum share of renewable energy demand should be defined;
- a threshold for the overarching primary energy demand and CO_2 emissions should be defined.

BPIE has derived that the maximum CO_2 emission of a new nZEB should not exceed 3 kg/m^2 a to reach the long term EU targets, and suggested a corridor between 50% and 90% (or 100%) for the share of renewable energy in the total energy demand. This is the result of a top-down analysis (BPIE, 2011a). Simulations were carried out on two reference buildings for three European climates to validate the proposed principles (BPIE, 2011a). The thermal characteristics of the building envelope were chosen to be significantly better than actual standards but above the best available technology and close to the economic feasibility. Combinations of a number of HVAC options were evaluated.

BPIE also proposed nZEB definitions for Bulgaria, Romania and Poland (BPIE, 2012a, 2012b, 2012c). For every country, many combinations of measures were analysed for three reference buildings from a technical and financial point of view. The conclusion was that it is possible to achieve the nZEB levels even without changing the most common building shapes. The proposed requirements are, however, less ambitious than the requirements proposed for Western Europe, because affordability was considered with a larger weight.

In Hermelink et al. (2013) dynamic simulations were carried out for a single-family house and an office building for four representative European climates, and meteorological data based