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Assessment of the progress towards the establishment of definitions of Nearly Zero Energy Buildings (nZEBs) in European Member States

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A B S T R A C T

The European Climate and Energy package foresees a substantial reduction of energy consumptions in buildings by 2020. The implementation of Nearly Zero Energy Buildings (nZEBs) as the building target from 2018 onwards represents one of the biggest challenges to increase energy savings and minimize greenhouse gas emissions.

The aim of this paper is to provide an overview of the European status towards the implementation of nZEBs. The main open issues are presented together with categories, definitions, and calculation methodologies.

The paper reports the progress made by Member States (MS) towards the adoption of nZEBs definitions through the analysis of the available literature, National Plans, templates submitted to the Commission, as well as information from the EPBD Concerted Action (CA) and Energy Efficiency Action Plans (NEEAP). Different aspects to be outlined, such as balance, boundary, energy uses, and renewables are taken into account in the study.

Results show that progress is evident in many MS compared to first attempts to launch a national definition, but coherency cannot yet be found. The current situation is discussed to contribute to the clarification and the establishment of agreed definitions. The paper underlines the effort to integrate the nZEBs notion into National Codes and International Standards. It also shows how this topic has gained a growing attention in the last decade, but the achievement of a common nZEBs concept is still far to be reached and implemented into construction practices and routines, especially at a refurbished level.

1. Introduction

Commercial and residential buildings are estimated to consume approximately 40% of primary energy and to be responsible for 24% of greenhouse emissions in Europe [1]. As a consequence, a reduction of energy demand in buildings can lead to a 20% potential reduction of their impact on the environment.

Specific measures to reduce energy consumptions in the building sector have been introduced by the European Union (EU) with the Energy Performance of Building Directive (EPBD) in 2002 [2] and its recast in 2010 [3].

The EPBD, together with the Energy Efficiency Directive (EED) [4] and the Renewable Energy Directive (RED) [5], set out a package of measures that create the conditions for significant and long term improvements in the energy performance of Europe's building stock.

Article 9 of the EPBD recast states that Member States (MS) shall ensure that new buildings occupied by public authorities and properties are Nearly Zero Energy Buildings (nZEBs) by December 31, 2018 and that new buildings are nZEBs by December 31, 2020. Furthermore, the Directive establishes the assessment of cost optimal levels related to minimum energy performance requirements in buildings [6].

The EU legislative framework for buildings led MS to adopt nZEBs definitions and national policies for their implementation. Therefore the importance to integrate the nZEBs concept into National Building Codes and International Standards is widely recognized [7].

A nZEB is a building that "has a very high energy performance with a low amount of energy required covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby" [3].

However, the EPBD recast does not give minimum or maximum harmonized requirements neither details of energy performance calculations. Consequently, it will be up to MS to define what "a very high energy performance" and "to a very significant extent by energy from renewable sources" exactly constitute for them.

What is still missing is a formal, comprehensive and reliable framework that considers all the relevant aspects characterizing nZEBs and allow each country to define a consistent definition in

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compliance with the country's policy targets and specific conditions [8]. Therefore, a common agreed definition can be seen as a first step towards the nZEB target laid down in the EPBD recast.

The aim of this paper is to give an overview on the Directive requirements related to nZEBs and the current MS situation in response to them. After a summary of nZEBs categories, calculation options and arguments, the progress made by MS towards the establishment of nZEBs definitions is evaluated based on the analysis of the collected material (literature, National Plans, templates submitted to the Commission, information from the EPBD Concerted Action (CA), Energy Efficiency Action Plans (NEEAP), and National Codes). Many aspects to be defined are taken into account, such as building category, typology, physical boundary, type and period of balance, included energy uses, renewable energy sources (RES), metric, normalization, and conversion factors.

2. Towards nZEBs definitions

2.1. nZEBs categories and balance

In recent years, the topic of nZEBs has been widely analyzed and discussed especially within the EU, but it is still subject to discussion at international level on possible nZEBs boundaries and calculation methodologies [9].

As the quantification of the word “nearly” is not specified in the EPBD recast, many definitions have been launched in the last decade generating debates around the meaning of nZEBs.

The term “ZEB” can be used in reference to a Zero Energy Building and Zero Emission Building. The first refers to the energy consumed by a structure in its day-to day operation, the second is referred to the carbon emissions that are released to the environment as a result of its operation.

In general terms, a ZEB can be described as a residential or commercial building with greatly reduced energy needs and/or carbon emissions, achieved through efficiency gains, such as the balance of energy needs supplied by renewable energy [10].

Another category of ZEB was introduced by Laustsen who distinguished between Autonomous ZEB and Net ZEB [11]. An Autonomous ZEB does not require connection to the grid. According to the author, stand-alone buildings can supply their own energy needs, as they are able to store energy for night-time or winter-time use. A Net ZEB is a yearly energy neutral building that delivers as much energy to the supply grids as it draws back. This building does not need fossil fuel for heating, cooling, lighting or other energy uses although it can be supplied by the grid. Furthermore, an Energy Plus Building (+ZEB) produces more energy from RES than it imports over a year.

In Torricellini et al., four different concepts around Zero Energy Buildings are defined depending on boundaries and metrics [12]. Among these, a Net Zero Site Energy building is as a building that produces at its location at least the amount of energy that it uses. The authors proposes a hierarchy of renewable supply options, which encourages both the reduction of site energy use through low-energy technologies and the use of renewables available within the building footprint or at the site.

Lund et al. distinguish four types of ZEBs in reference to energy demand and installed renewable typology [9]. A PV-ZEB is a building with a relatively low electricity demand and a photovoltaic system (PV), while a Wind-ZEB has a relatively low electricity demand and a small on-site wind turbine. A PV-Solar thermal-heat pump ZEB is characterized by a low heat and electricity demand as well as by a PV installation in combination with a solar thermal collector, a heat pump and heat storage. A wind—solar thermal-heat pump ZEB has a low heat and electricity demand and a wind turbine in combination with a solar thermal collector, a heat pump and heat storage.

Another much debated topic is around possible calculation methodologies. Marszal et al. define various approaches towards energy performance calculations [13]. A recent review also considers life cycle assessment's role, energy storage, load match, and smart grid to evaluate energy performance [14].

The Rehva Task Force “Nearly Zero Energy Buildings” [15] has published a comprehensive definition of nZEBs based on energy flows to be taken into account in primary energy calculations [16]. Following the EPBD recast requirements, the system boundary is modified from the Standard EN 15603:2008 “Energy performance of buildings—overall energy use and definition of energy rating” and it is used with the inclusion of on-site renewable energy production [17].

Three system boundaries can be distinguished in reference to energy need, energy use, imported and exported energy (Fig. 1). Energy use considers the building technical system as well as losses and conversions. System boundary of energy use also applies for renewable energy (RE) ratio calculation with inclusion of energy from solar, geo-, aero- and hydrothermal energy sources for heat pumps and free cooling. Energy need is the total energy to satisfy building needs that mainly consist of heating, cooling, ventilation, domestic hot water (DHW), lighting, and appliances. Solar and internal heat gains have to be included in the balance. The RE production includes the generation of energy for heating, cooling and electricity that can be produced on site or by a nearby plant. The energy delivered on-site can be given by electricity, fuels, district heating and cooling.

Dall'O' et al. propose to calculate a zero energy balance over one year using the following eq. (1):

$$\sum_{m=1}^{12} (EP_G - EP_{RE} - EP_{GP})_m = 0 \tag{1}$$

where EP refers to specific primary energy (kWh/m^2/y), and the subscripts G, RE, and GP refer to global energy, energy linked to renewable sources, and green purchase, respectively [18]. Furthermore, global specific primary energy EP_G can be calculated as in Eq. (2):

$$EP_G = EP_H + EP_W + EP_C + EP_{EL} \tag{2}$$

where the subscripts H, W, C, EL refer to heating, water, cooling and electricity, respectively. Eq. (1) highlights how the energy needed could be compensated by primary energy from RES (EP_{RE}) as well as by certified purchased green energy (EP_{GP}), that is also energy produced from RES. The amount of primary energy offset by the purchase of green energy must be at most equivalent to the

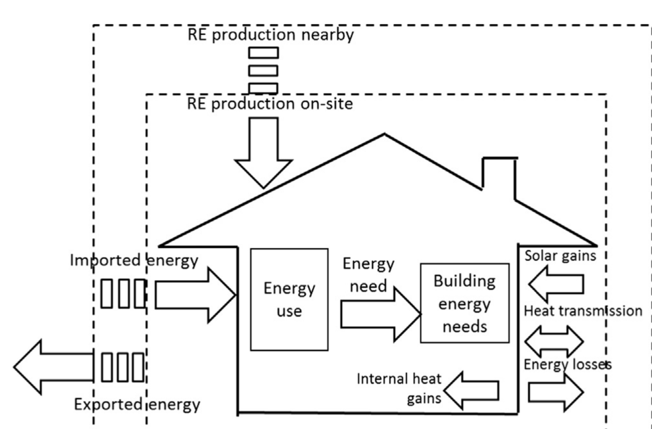

Fig. 1. A schematized nZEB with possible system boundaries.