The nZEBs in the near Future
Overview of definitions and guidelines towards existing plans for increasing nZEBs

Laura Aelenei
Laboratório Nacional de Energia e Geologia, Lisboa, Portugal

Helder Gonçalves
Laboratório Nacional de Energia e Geologia, Lisboa, Portugal

Daniel Aelenei
Universidade Nova de Lisboa, Faculdade de Ciência e Tecnologia, Caparica, Portugal

ABSTRACT: Zero-energy performance buildings have gained significant attention since the publication in 2010 of the recast of the EPBD recast which requires all new buildings to become nearly zero-energy by 2020. Buildings are requested to meet higher levels of energy performance and to explore more the alternative energy supply systems available locally on a cost-efficiency basis. Since the directive does not specify minimum or maximum harmonized requirements as well as details of energy performance calculation framework, it is up to the member states to define the exact meaning of “high energy performance” and “amount of energy from renewable sources” according to their own local conditions and strategic interests. Nearly zero-energy building (nZEB) performance derives from net zero-energy concept (Net ZEB) which in case of buildings is usually defined as a high energy performance building that over a year is energy neutral. The successful implementation of such an ambitious target, however, needs to be planned out diligently. The critical steps are a) a correct picture about the existing state and trends, b) clear definitions and targets, c) dynamic building codes and energy efficient technologies and d) rules for testing and verification. The nZEBs or NetZEBs built in the near future therefore may play a critical role in implementing any ambitious plan as its success on long-term relies on setting best practice examples, in addition of the supporting policies and initiatives. The purpose of this paper is to review existing definitions, terms and policies on strategic planning of nZEBs at national and international level.

1 INTRODUCTION

Zero-energy performance buildings have gained more attention since the publication in 2010 of the EPBD recast (EPBD, 2010). EPBD recast requests all new buildings to meet higher levels of performance than before, by exploring more the alternative energy supply systems available locally on a cost-efficiency basis and without prejudicing the comfort. To this end, beginning in 2020, all new buildings should become “nearly zero-energy”. A “nearly zero-energy building” refers to a high energy performance building of which annual primary energy consumption is covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby. The directive requires nearly zero energy buildings, but it does not give minimum or maximum harmonized requirements as well as details of energy performance calculation framework. In such case, it is up to the Member States to define the exact meaning of energy performance requirements and percentage of energy from renewable sources according to local and regional climate and economic conditions. Recent studies on implementation on EPBD 2002 (Seppänen & Goeders 2010, Kurntsky et al. 2011) have shown a large variation in the building regulations of the different countries, a fact which has a significant impact on the building industry. Regarding existing concepts for nearly zero energy buildings, another study performed across 17 countries has revealed as much as 75 definition approaches and a single country with a definition included in national legislation (Hermelink et al. 2013). In the light of this, the need of a common approach on the concept for net and nearly zero energy is requested by the strategic importance of the building industry and by the need of MS to adapt their national plans in time in order to guarantee the implementation of the EPBD requirements by 2020 (…). Hence, on the basis of the above considerations, two important issues arise: nZEBs definition (article 2 of EPBD) and implementation of national plans for increasing nZEBS (article 9 of EPBD). This paper intends to unveil some of the key aspects related to the above issues, with a particular focus on the national policy context.

2 REVIEW OF EXISTING DEFINITIONS AND UNDERLYING PARAMETERS

Various experts have called attention on the problem various definition of nearly zero energy building may cause in Europe (Kurntsky et al. 2011). There is urgent need to answer questions such as: what are net / nearly zero-energy buildings and how are established the energy boundaries on the building, what energy flows should be considered in the balance calculation, what balance metric and weighting factors should be used in the calculation, what period of time should be considered to calculate the performance and how the energy generated and consumed should be accounted?

2.1 *Energy balance and Boundary*

If one draws an imaginary boundary in the nearby of a building (to account for renewable energy produced on-site and/or nearby), the energy balance may be schematically represented as in Figure 1. According to Figure 1, zero-energy buildings exchange energy with the grids (electricity, heating or cooling, gas or biomass) in the form of energy carriers that is converted from or on to primary sources using credits. Accordingly, the energy balance, *EB*, for different energy carrier, *i*, between the energy delivered to building, *ED*, and the energy exported into the public grids, *EE*, writes:

$$EB = \sum_i EE_i \times f_{e,i} - ED_i \times f_{d,i} \tag{1}$$

where *f* are factors which are used to convert the physical units into other metrics, such as primary energy or equivalent carbon emission.

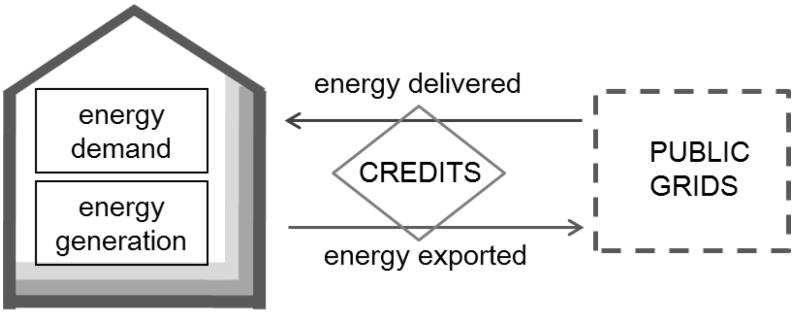

Figure 1. Schematic representation of energy balance of zero energy buildings.

Analyzing Equation 1, one can draw the conclusion that three different scenarios are possible, depending on the value of the energy balance. In the case of a neutral annual energy balance (i.e. the building use no more energy than it produce), the building is commonly referred as a Net Zero-Energy Building. If the building falls short of the neutral balance then it can be referred to as a “nearly Zero Energy Building”. In the scenario where the balance is positive (when the building produces more energy than it consumes) the building is referred as a plus-energy building. The simple balance approach described so far becomes rapidly complex if one considers other features. For instance, if the boundary is drawn around a group of buildings instead (zero energy community), additional concerns regarding grids and conversion factors together with community-based infrastructure and industry need to be considered as well. In such case, it is possible that plus-energy buildings may provide the additional amount of energy to nearly zero energy buildings from the same community and contribute in this way to the zero balance target of the entire community.

2.2 *Energy flows*

The boundary determines which energy flows are considered in the energy balance. While most of the building codes include energy use for heating, cooling, ventilation, hot water and lighting, recent proposals on definitions also include the plug loads and central services (e.g. appliances, elevators, fire protection systems) (Kurnitski et al. 2011, Atanasiu et al. 2011). Furthermore, some research projects also include the energy flows due to electric vehicles charging although these loads are not directly related to the building performance [B.u.S., 2011]. Additional critical analyses on the energy balance reveal that in the above approach the energy inputs to deliver the building and its materials and components is not considered. Accounting for embodied energy (within its constituent materials and systems), can effectively serve as a form of 'net energy' analysis when compared to the energy used by the building in operation over the life cycle (Hernandez & Kenny, 2010). Studies on the life-cycle energy balance of low-energy and net zero-energy buildings indicate that the embodied energy of a typical building accounts for not more than 20 % of the total primary energy expenditure [Kugel, 2007].

2.3 *Weighting system*

Primary energy indicator sums up all delivered and exported energy into a single indicator using primary energy factors. Therefore, the metric of the energy balance should allow comparison of different forms of energy (electricity, natural gas, biomass and solid fuels). Using primary energy as an indicator raises a question concerning the conversion factors that should be applied (Voss et al. 2011). The averaged conversion factors may be either derived from actual national statistics or from European similar figures and they are usually strategically determined in order to give priority to a particular category of energy fuel. A good example is the case of the asymmetrical weighting factors where the primary energy conversion factor for energy delivered by the grid is different from the factor for energy exported into the grid to encourage on-site generation. In cases where carbon dioxide is considered appropriate, conversion factors from primary energy to carbon dioxide can also be considered. This approach provides additional information about the consequences of energy use, in the terms of CO_2 emitted to the atmosphere. However, due to the fact that carbon cycle has a strong dynamic character, accounting for emissions in the same context can be a tricky business (Black et al. 2010).

2.4 *Balance period*

The standard energy calculation procedure is annual due to need of accounting the whole range of operating energy of a building typical for a complete meteorological cycle. Climate plays a dual role in zero energy buildings (residential mainly) as it is a driver for space heating and cooling and a driver for supplying renewable energy resources at the same time. Using time intervals shorter than one year for calculus of the energy balance (seasonally, monthly or daily) is useful for the analysis of the interaction of the building with the electricity grid and other energy grids (Hermelink, 2013). According to recent studies (Hermelink, 2013) a yearly energy balance is not capable to provide the complete interaction with the grid as this procedure assumes the grid as an infinite storage. Buildings incorporating renewable energy systems are often characterized by a mismatch between the energy need and the energy generated on site. For instance, a seasonal calculus of the energy balance may result positive in summer (due to higher solar potential and lower energy needs) and negative in winter. As the consequences of mismatch are a matter under investigation perhaps the best strategy to adopt in this respect is to reduce the absolute value of the potential mismatch between demand and local generation (Voss et al., 2011). An effective way to reduce the mismatch is to reduce energy needs, a strategy which also provides advantages in terms of economic benefits (low energy buildings are significantly less prone to risks connected to volatility of costs/prices of conventional and renewable energy during their lifetime) and benefits associated to higher thermal comfort and user satisfaction (Hermelink, 2013).

Table 1. Definitions - renewable energy supply option [Marszal et al. 2011]

RES-footprint	RES-on site	RES-off site	RES-purchase green
Use renewable energy sources available within the building's footprint.	Use renewable energy sources available at the building site.	Use renewable energy sources available off site to generate energy on site.	Purchase off-site renewable energy sources.

Table 2. Definitions [IEA, 2012].

Net ZEB limited	Net ZEB primary	Net ZEB strategic	Net ZEB emission
Weighted energy use for heating, DHW, cooling, ventilation, auxiliaries and built-in lighting (for non-residential buildings only) vs. weighted energy supplied by on-site generation driven by on- or off-site sources. Static and symmetric primary energy factors are possible.	Weighted energy use for heating, DHW, cooling, ventila-tion, auxiliaries and lighting and every kind of plug loads (electri-cal car possibly included), vs. weighted energy supplied by on-site generation driven by on- or off site sources. Static and symmetric primary energy factors.	Weighted energy use for heating, DHW, cooling, ventilation, auxiliaries, built-in lighting and every kind of plug loads vs. weighted energy supplied by on- and off-site generation systems driven by on- or off-site sources. Weighting factors could be static and asymmetric, varying on the basis of the energy carrier, the technology used as energy supply system and its location.	Balance between building CO2 equivalent emissions due to energy use for heating, DHW, cooling, ventilation, auxiliaries, built-in lighting, every kind of plug loads and the weighted energy supplied by on-site generation systems driven by on- or off-site sources. Static emission factors are used. They can be symmetric or asymmetric, depending on the energy carrier, technologies used as energy supply systems and their location.

Table 3. Related terms for definitions [Kurnitski et al. 2011].

energy performance of the building (EN 15316-1:2007)	delivered energy (EN 15603:2008)	exported energy (EN 15603:2008)	net delivered energy (EN 15603:2008)	system boundary (EN 15603:2008)
Calculated or measured amount of energy delivered and exported actually used or estimated to meet the different needs associated with a standardized use of the building, which may include, inter alia, energy used for heating, cooling, ventilation, domestic hot water, lighting and appliances.	Energy, expressed per energy carrier, supplied to the technical building systems through the system boundary, to satisfy the uses taken into account (e.g. heating, cooling, ventilation, domestic hot water, lighting, appliances etc.) or to produce electricity.	Energy, expressed per energy carrier, delivered by the technical building systems through the system boundary and used outside the system boundary.	Delivered minus exported energy, both expressed per energy carrier. Net delivered energy values are expressed separately for each energy carrier, i.e. for electricity, fuels, district heat, etc.	Boundary that includes within it all areas associated with the building (both inside and outside of the building) where energy is used or produced. All areas associated with the building typically refers to footprint of the building site.

2.5 *Definitions*

In an effort to synthesize many of the issues covered in previous sections, and assess the advantages and disadvantages of different strategies and scenarios of NetZEB definitions, and excel-based tool (NetZEB evaluator tool) was developed by a group of experts from IEA SHC Task 40 - ECBCS Annex 52 (IEA, 2008). The tool allows checking annual energy or emission balances as well as characterizing the load match and the grid interaction profile of a building by simplified indicators on the basis of four energy balance approaches (Table 2). As it can be seen from Table 1, four possible definition sets are proposed to allow detailed recommendations for future building codes in terms of a minimum of harmonization. After testing the NetZEB tool on seven buildings and their specific technical solution sets available in Task 40 database according to the four definitions, the authors have determined large differences between energy balance performances. They concluded that although all four balance procedures are conceivable in the frame of the EPBD it is very difficult to compare the results between each category. In spite of this difficulty, however, an important recommendation emerges from the study: the adoption of a definition for nearly zero-energy buildings on the basis of "Net ZEB limited" approach, as this methodology follows the minimum requirements in compliance with EU´s EPBD. For the uniform definition methodology, a general system boundary definition (Marszal et al., 2011) can be adopted as the guidance for technical meaning of "nearby" in the directive, as presented in Table 1. According to EPBD Annex 1, *The methodology for calculation the energy performance of buildings should take into account European standards*. A framework for energy performance calculation, including references to the definition of system boundaries, share of renewable is identified in EN 15603 as can be observed in Table 2.

3 NATIONAL PLANS FOR NEARLY ZERO ENERGY BUILDINGS

3.1 International guidelines

According to EPBD Article 9 Paragraph 3(a) the MS are asked to provide national plans for increasing the number of nearly zero-energy buildings. These national plans should include the requirements presented by at Paragraph 3(a), (b) and (c), namely, "national plans the inclusion (…) of the detailed application in practice of a definition of nearly zero-energy buildings, which reflects the national, regional or local conditions, and including a numerical indicator of primary energy use expressed in kWh/m² per year", as well as intermediate targets and information about the policies and financial or other measures towards increasing the number of nZEB. In this respect, a recent work published by ECOFYS [Hermelink 2013] presents a set of guidelines for the implementation in the national plans the steps for increasing the number of nZEBs.

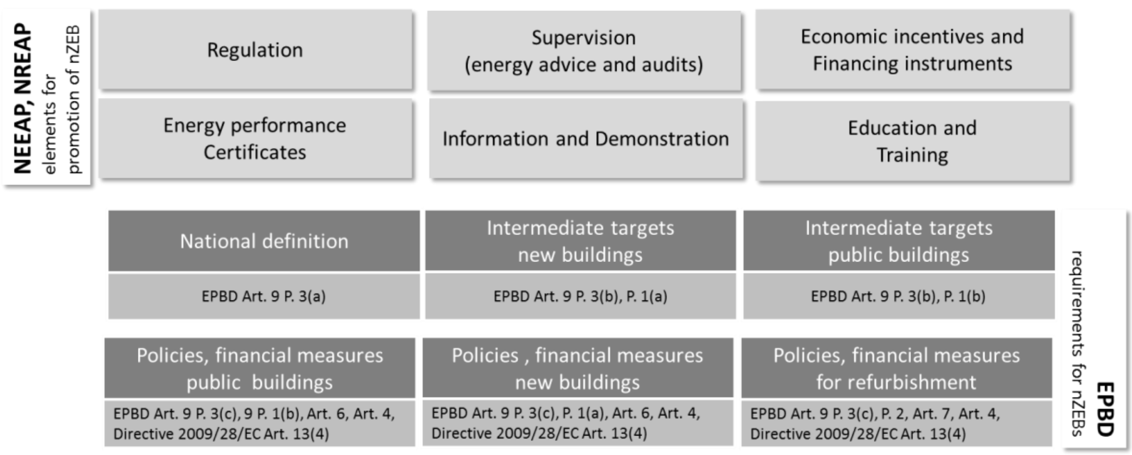

Figure 2. Key parameters of NEEAP/NEAPR together with EPBD requirements on plans for increasing the number of nearly zero-energy buildings

These strategic guidelines are drawn up on the basis of a consistent part of existing nZEB definitions, EPBD requirements and national energy strategic plans (National Energy Efficiency Action Plans or NEEAP and National Renewable Energy Action Plans, or NREAPs). Figure 2 summarizes the key parameters of NEAAPs and NREAPs together with the EPBD relevant requirements in the context of the nearly zero energy concept.

The above set of set of parameters are the basis of guidelines of a study performed among 12 European countries which were asked to provide information of the existing plans according to each parameter. This overview was useful in order to bridge the understanding between the existing national strategic plans (NEEAP and NREAP) and EPBD requirements based on the categories shown in Table 3.

Table 3. EPBD requirements on the national plans for increasing the number of nZEB

1) Definition	**2) New buildings**		**3) Public buildings**		**4)Refurbishment**
	2015 targets	**2021 measures**	**2015 targets**	**2019 measures**	**nZEB measures**
National definition of nearly zero-energy building, including a numerical indicator of primary energy use	Targets for new buildings on how to ensure that by December 2020, all new buildings are nZEB	Policies and financial or other measures to promote that by December 2020, all new buildings are nZEB	Targets for new buildings occupied and owned by public authorities to be nZEB by December 2018	Policies and financial or other measures to promote that by 2018, all buildings occupied and owned by public authorities to be nZEB	Policies and financial measures for the transformation of buildings that are refurbished into nZEB

According to the same study the intermediate targets should be explained in both qualitative and quantitative ways. The qualitative 2015 targets should be focused on energy related requirements for new buildings (including public buildings) and in this context specifically determine requirements on the fraction of renewable energies, the useful energy demand and the primary energy demand. The quantitative 2015 targets, on the other hand, should have a reference to the aimed share of new (and) public nearly zero-energy buildings according to official national nearly zero-energy building definition.

3.2 National situation point

The comprehensive overview of set of guidelines outlined in Table 3 provides valuable insights about the strategies to be considered in national plans. In the following, a general description of existing national plans is given, on the basis of the same strategic format proposed in Table 3.

3.2.1 National targets (Intermediate and 2020) for improved energy performance of new and existing buildings undergoing major renovation existing in PNAEE2016 and PNAER2020

The recently published National Energy Efficiency Action Plan (PNAEE2016, 2013) presents a list of programs and sub-programs that integrate targets and measures to improve the buildings energy performance including the new buildings, public buildings. These programs and the corresponding targets are listed in Table 4.

Table 4. PNAEE2016 targets

Program	Accumulated Energy savings (tep)		CO_2 emissions reduction (tCO_2)	
	2016	2020	2016	2020
Residential and service Buildings	320.932	582.727	1.400.941	2.543.735
Government Energy Efficiency in Public Buildings	112.170	253.988	489.647	1.108.715
Behaviour - Information and communication of energy efficiency	-	-	-	-

Regarding the National Renewable Energy Action Plan (PNAER2020, 2013), the program of the use of renewables for heating and cooling sets for 2020 an increasing of 9% compared with 2010 taken as reference; with the major contribute of solar thermal and biomass. The total renewable energy use for heating, cooling and transport predicted for 2016 and 2020 is 5.259ktep and 5.737ktep, respectively.

3.2.2 Elements of policy packages for the promotion of nearly zero-energy building (new and existing buildings undergoing major renovation)

a) Regulation

No definition of nearly zero-energy building performance standard available. The new regulation for building energy performance calculation will be available in 2013 (for residential and non-residential buildings). Beginning with 2006, the installation of solar thermal collectors is mandatory for all new buildings according with the building regulation. (RCCTE, 2006).

b) Economic incentives and financing instruments

According with PNAEE 2020 the following incentives and financial instruments will be offered: Energy Efficiency Fund (FEE), Innovation Support Fund (FAI), Strategic Energy Efficiency Plan for promoting energy efficiency in the industrial, retail, residential and services sectors (PPEC), Portuguese Carbon Fund (FPC), National Strategic Framework (QREN), Joint European Support for Sustainable Investment in City Areas (JESSICA)

c) Energy performance certificates

The certificates for nearly zero energy buildings are not yet available. According with the PNAEE 2016 and with the revision of former PNAEE, the program Building Energy Efficient System increase the buildings energy performance through energy certificates by applying the requirements of the building regulation. This program will be reviewed after publication of the new building regulation.

d) Supervision (energy advice and audits)

One of the objectives of the PNAEE 2016 for 2020 is to certificate a total of 2225 public buildings. 550 of these buildings will be covered by Eco-innovation Action Plan – EcoAP, that has as principal objective to improve of energy efficiency in public buildings by means of monitoring and audits and is expected an energy savings of these buildings in about 30%.

e) Information and Demonstration

The program EcoAP is assisted by the initiative Barometer of Energy Efficiency in Public Buildings (Barómetro da Eficiência Energética na Administração Pública) which has as objective a continuous divulgation of the energy efficiency and audits results. Later on will be promoted a Guide of Energy Efficiency of Public Buildings (Guia da Eficiência Energética na Administração Pública).

f) Education and training

Trainings on building energy performance regulation have been developed by various institutions (universities and research institutes) in order to prepare experts leading and performing energy certification of buildings residential and non-residential.

4 CONCLUSIONS

National roadmaps towards nZEBs are needed for all member states. Member States shall draw up national plans for increasing the number of nZEBs that shall include, inter alia, the following elements: (a) detailed application in practice of the definition of nZEB, (b) intermediate targets for improving the energy performance of new buildings by 2015, (c) information on the policies and financial or other measures adopted in the context of for the promotion of nZEBs. Rather than disseminating specific results of the ongoing research developed under various frameworks, the authors of the present paper intended to bring into focus some insights of the existing definition and terms as the basis of the implementing national roadmaps towards increasing the number of nZEBs together with the strategic guidelines drawn up on the basis of a consistent part of existing nZEB definitions. Regarding the national situation, the existing national strategic plans (PNAEE 2016 and PNAER 2020) are consistent with the strategic guidelines set out by EPBD for increasing the number of nZEBs. However, the successful of such an ambitious target depends greatly on definitions and energy performance calculation and demonstration methods which are not yet available.

5 REFERENCES

Atanasiu, B. 2010. Principles for nearly Zero- Energy Buildings Paving the way for effective implementationof policy requirement.

Black. C., Van Ooteghem, K. & Boake, T. M., 2010. Carbon neutral steel building systems research project: A Case Study Investigating the Relationship of Operating Energy and Embodied Energy in

European Parliament and of the Council, 2010. The Directive 2010/31/EU of the European Parliament on the energy performance of buildings (EPBD recast), Official Journal of the European Union, 53.

B. u. S. Bundesministerium für Verkehr, Wohnhäuser mit Plusenergie-Niveau - Definition und Berechnungsmethode, Anlage 1 zum BMVBS Förderprogramm, Berlin: Bundesministerium für Verkehr, Bau und Stadtentwicklung, 2011.

Hermelink, A. 2013. Towards nearly zero-energy buildings Definition of common principles under the EPBD

Hernandez, P., & Kenny, P., 2010. From net energy to zero energy buildings: Defining life cycle zero energy buildings (LC-ZEB), *Energy and Building,* (42): 815-821.

International Energy Agency Solar Heating and Cooling (IEA) Task 40 / ECBCS Annex 52, 2008. Towards Net Zero Energy Solar Buildings (NZEBs); http://www.iea-shc.org/task40/index.html.

Kugel, D. 2007. Lebenszyklusbetrachtungen als ökonomisches und ökologisches Einsparpotential in der Gebäudeplanung und Bewirtschaftung. Master Thesis, Wuppertal: Bauphysik und technische Gebäudeausrüstung, University of Wuppertal.

Marszal, A., J., Heiselberg, P., Bourelle, J., S., Musall, E., Voss, K., Sartori, I., & Napolitano A., 2011. Zero Energy Building – A review of definitions and calculation methodologies, *Energy and Building,* (43): 971-979.

PNAEE2016, 2013. Plano Nacional de Ação para a Eficiência Energética.

PNAER2020, 2013. Plano Nacional de Ação para as Energias Renováveis.

RCCTE, 2006. Regulamento das Características de Comportamento Térmico dos Edifícios.

Seppänen O, Goeders G. Benchmarking Regulations on Energy Efficiency of Buildings. Executive summary. Federation of European Heating, Ventilation and Air-conditioning Associations – REHVA, May 5, 2010.

Voss, K., Musall, E., & Lichtmeß, M., 2011. From low-energy to net zero-energy buildings: Status and perspectives, *Journal of Green Building*, (6) 1.

Voss, K., Musall, E. and Lichtmeß, M. 2011 "From Low Energy to Net Zero-Energy Buildings: Status and Perspectives," Journal of Green Building, vol. 6, p. 46–57.