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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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ABSTRACT

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

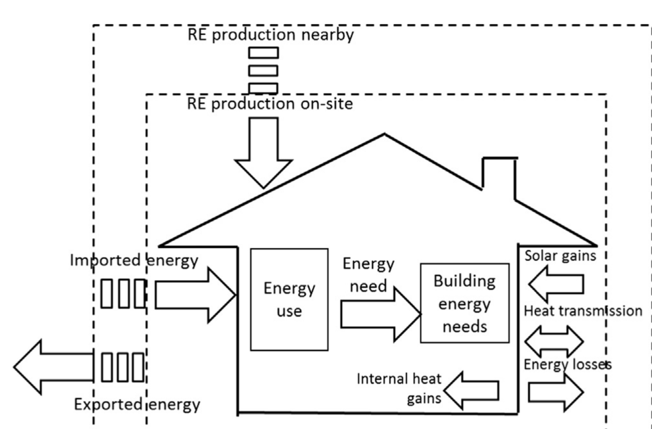

Fig. 1. A schematized nZEB with possible system boundaries.

primary energy produced from RES (EP_{RE}). Thus, off-site RE is allowed, but it has to be certified and is limited to a defined value.

Sartori et al. suggest three possible balances that differ by the amount of on-site energy generation which is self-consumed or "virtually" assumed as self-consumed: import/export balance, load/generation balance, and monthly net balance [19]. The first is made between weighted exported and delivered energy, the second between weighted generation and load, and the third between weighted monthly net values of generation and load. A balance can be calculated as according to formula (3):

$$|\text{weighted supply}| - |\text{weighted demand}| = 0 \tag{3}$$

where absolute values are used to avoid confusion on whether supply or demand is consider as positive. A complete set of equations and graphical representation of the different balances is proposed by the authors. The balance is achieved by a reduction of energy demand by means of energy efficiency measures and generation of electricity as well as thermal energy carriers by means of energy supply options. In most circumstances major energy efficiency measures to reduce demand are needed as on-site energy generation options are limited, e.g. by suitable surface areas for solar systems, especially in high-rise buildings.

2.2. nZEBs issues

The discussion around nZEBs has become more focused in the last decade especially on some aspects that still need to be properly defined [20].

The main arguments are schematised in Fig. 2 and are related to: physical boundary, period and type of balance, type of energy use, metric, renewable supply options and connection to energy infrastructure.

The boundary is one of the most discussed arguments as it is linked to RE inputs that can be included or not in the balance. The boundary of a system may include a single building or groups of buildings, in this last case it is not important that every building is nearly zero, but the overall sum of the buildings has to be. The renewable integration into district heating system is at neighborhood or infrastructural level, while a PV system is mostly taken into account at building or building complex level. If there is a PV plant in an area close to a building and the boundary is restricted to the building, this source is considered off-site, otherwise it is on-site.

Another main point of discussion is the metric of balance. More than one unit can be used in the definition or in the calculation methodology. The most frequently applied unit is primary energy while the easiest unit to implement is final or delivered energy. Among other options there are: end use energy, CO_2 equivalent emissions, exergy, delivered/site energy, and cost of energy. Conversion factors have also to be specified in definitions.

The period of the balance over which the calculation is performed can vary very much. It can be hourly, daily, monthly, seasonal or annual, or the full life cycle of a building or its operating time.

The type of energy use is also subject to debate. The methods for computing the energy use of a building can be diverse and include many options. Many definitions only cover operational energy (heating, cooling, lighting, ventilation, hot water) and omit auxiliary systems or embodied energy from the calculation. However, the energy required for building material manufacture, maintenance and demolition can be considerable. According to the Standard EN 15603: 2008 [17], energy rating calculations should include energy use that does not "depend on the occupant behavior, actual weather conditions and other (indoor and environment) conditions", such as heating, cooling, ventilation, hot water and lighting (for non-residential buildings). Other options include appliances, central services, and electric vehicles.

With regard to the type of balance, the energy use has to be offset by RES generation in off-grid ZEBs, while two possible options are possible in grid-connected ZEBs. The first is preferred during the design phase of a building and it balances energy demand with RE generation. The second is applicable during the monitoring phase as it balances energy delivered with energy feed into the grid.

The RE supply can be on-site, nearby, or off-site depending on the availability on site (sun, wind) or to be transported to the site (biomass). A ranking of preferred application of different renewable supply side options is proposed in [12]. As a starting point there is a reduction of site energy use through low-energy technologies (daylighting, high-efficiency HVAC—heating, ventilation, air conditioning, natural ventilation, evaporative cooling). On-site supply options use RES available within the building

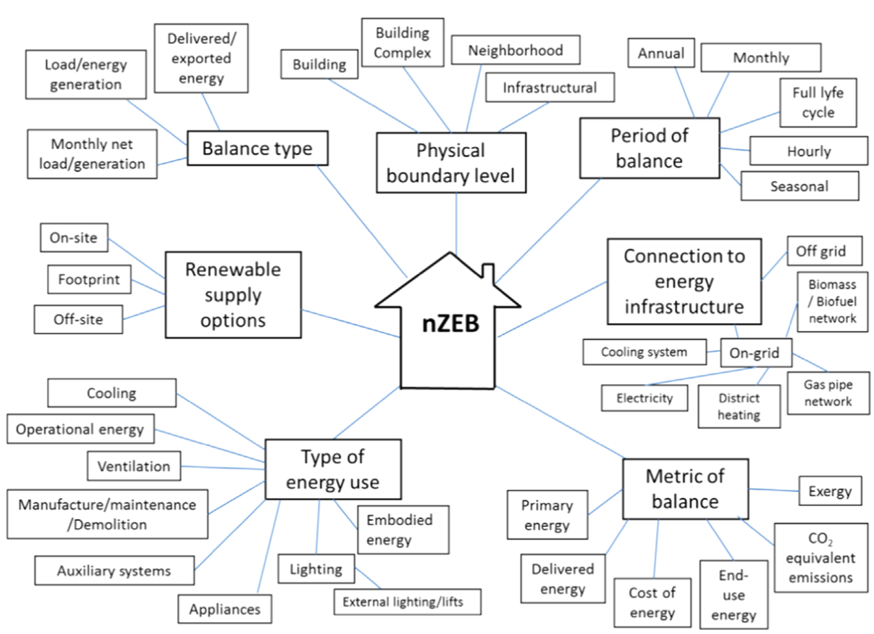

Fig. 2. Main arguments around nZEBs to be established in definitions.

footprint (such as PV, solar hot water, wind, heat pumps), or within the building site (such as PV, solar hot water, low impact hydro, wind). Off-site supply options use RES available off-site to generate energy on-site (such as biomass, wood pellets, ethanol, biodiesel that can be imported, or wasted streams used on-site to generate electricity and heat), or purchase off-site RES (such as utility-based wind, PV, emissions credits, or other "green" purchasing options and hydroelectric). The different RES options and the fraction of RE production to be included have to be also defined.

Another argument is the possible connection to the energy infrastructure. Most nZEBs definitions implicitly assume connection to one or more utility grids. These can be electricity grid, district heating and cooling systems, gas pipe network, or biomass and biofuels distribution network. Therefore, buildings have the opportunity to both import and export energy from these grids and thus avoid on-site electricity storage. While on-grid nZEBs are connected to one or more energy infrastructures using the grid both as a source and a sink of electricity, off-grid nZEBs require an electricity storage system in peak load periods or when RES are not available. Requirements related to energy performance, indoor air quality, comfort level, and monitoring are also important in nZEBs definitions.

3. Methods

The progress made by MS towards the establishment of nZEBs definitions has been assessed through the analysis of the available literature, National Plans, information from the EPBD Concerted Action (CA), Energy Efficiency Action Plans (NEEAP) and National Codes. Results are also drawn from two reporting templates recently filled in by MS and submitted to the European Commission (EC) in the form of a questionnaire and a table.

An overview on the EPBD requirements related to nZEBs is given in Section 4.1. Overall results of MS compliance towards the EPBD are described in Section 4.2 as reported up to now to the EC. Results related to MS progress towards national definitions of nZEBs are in Section 4.3, considering the most important requirements to be established in nZEBs definitions.

4. Results

4.1. The European framework: the EPBD requirements towards nZEBs

MS are required to draw up National Plans for increasing the number of nZEBs, with targets that may be differentiated for different building categories. According to paragraph 3 of Article 9, these plans shall include a nZEBs definition reflecting national, regional or local conditions, and a numerical indicator of primary energy use.

The timeline for the implementation of nZEBs according to the EPBD recast is schematised in Fig. 3.

Intermediate targets for improving the energy performance of buildings have to be provided by 2015. Furthermore, paragraph 2 of Article 9 asks MS to show a leading example by developing particular policies and measures for refurbishing public buildings towards nearly zero-energy levels and to inform the EC about National Plans. Articles 6 and 7 of the EPBD recast, and Article 13 (4) of RED, state that MS have to give information on policies, financial or other measures adopted for the promotion of nZEBs, including details on the use of RES in new buildings and existing buildings undergoing major renovation.

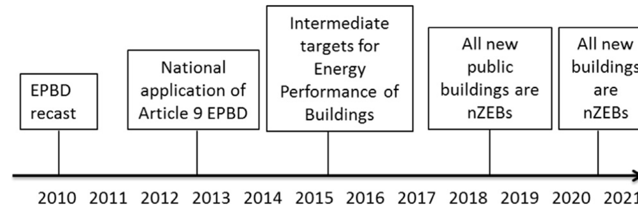

Fig. 3. Timeline for nZEBs implementation according to the EPBD recast.

Due to the general guidance given by the EPBD recast, other open issues are how to combine nZEBs implementation with cost optimal requirements between the investments involved and energy costs savings, and how to carry out performance level calculations in a harmonized way in each country [21].

In order to help MS to implement the nZEB concept, several projects have been developed. Furthermore, numerous simulation studies and pilot projects testify the interest of the international community in this topic [22–28]. The Entranze Project intends to support policy-making procedures by providing data, analysis and guidelines and by connecting building experts from European research institutions and academia to national decision makers and key stakeholders [29]. The ASIEPI (Assessment and Improvement of the EPBD Impact) project has been aimed at improving regulations effectiveness on energy performance of buildings [30,31].

The EPBD Concerted Action (CA) project has a regular survey on the implementation of the EPBD requirements in MS [32], and the Buildings Performance Institute Europe (BPIE) periodically analyse the differences among existing and best practices in MS [33].

Table 1 summarizes the main EPBD requirements that can be related to different nZEBs arguments to be defined, such as building category, balance type, physical boundary, system boundary demand and generation, balance period, normalization, metric, time dependent weighting, and renewables. These arguments are outlined in the next section of the paper as reported to the EC by MS.

4.2. MS status in compliance to the EPBD requirements

Sixteen MS have published a National Plan (12 in English) until March 2014 [34]. This indicates that many countries have problems to develop and implement suitable instruments and measures to reach the nZEB target. Another reason could be that the deadline for National Plans was too tight as European countries had to report nZEB plans two years after the EPBD recast.

Furthermore, those MS that did report have chosen very different forms of reporting, so National Plans are not easily comparable. Therefore, two reporting templates were recently developed as a result of a study undertaken by a consortium led by Ecofys to provide greater guidance on the EPBD recast requirements [35]. The first template has been designed as a questionnaire to report information on intermediate targets and policies to achieve the nZEB target while the second has the form of as a table. This template considers the most important aspects related to national applications of nZEBs definitions and it enables to evaluate and cross-analyse MS plans [36]. When any discrepancy has been found within the reported information, further material has been searched, considering the most updated source at the time of writing. This paper extrapolates data from the twenty-four filled-in templates reported until August 2014. The countries that have already submitted the template are: Austria (AT), Belgium (BE) (Brussels Capital region, Flemish region, Walloon region), Bulgaria (BG), Croatia (HR), Cyprus (CY), Czech Republic (CZ), Denmark (DK), Estonia (EE), Finland (FI), France (FR), Germany (DE), Hungary (HU), Ireland (IE), Italy (IT), Latvia (LV), Lithuania

Table 1
Summary of the EPBD requirements related to different nZEBs arguments.

EPBD requirements	EPBD reference	nZEBs arguments
MS shall ensure that by 31 December 2020, all new buildings are nZEBs and after 31 December 2018, new buildings occupied and owned by public authorities are nZEBs.	Article 9.1a/b	Private/public
New, and existing buildings that are subject to major renovation, should meet minimum energy performance requirements adapted to local climate.	Preamble recital 15	New/retrofit
MS shall […] stimulate the transformation of refurbished buildings into nZEBs.	Article 9.2	
[…] buildings should be adequately classified into […] categories.	Annex I	Category
[…] energy performance of a building means the calculated or measured amount of energy needed to meet the energy demand […]	Article 2.4	Balance type
The Directive lays down requirements as regards the common general framework for […] buildings and building units.	Article 1.2a	Physical boundary
[…] building' means a roofed construction having walls, for which energy is used to condition the indoor climate.	Article 2.1	
[…] energy performance of a building means the calculated or measured amount of energy needed to meet the energy demand associated with a typical use of the building, which includes, inter alia, energy used for heating, cooling, ventilation, hot water and lighting.	Article 2.4	System boundary demand
[…] energy from renewable sources means energy from renewable non-fossil sources, namely wind, solar, aerothermal, geothermal, hydrothermal and ocean energy, hydropower, biomass, landfill gas, sewage treatment plant gas and biogases.	Article 2.6	System boundary generation
[…] minimum levels of energy from renewable sources […] to be fulfilled through district heating and cooling […].	Article 13.4	
[…] The methodology for calculating energy performance should be based not only on the season in which heating is required, but should cover the annual energy performance […]	Preamble recital 9	Balance period
[…] including a numerical indicator of primary energy use expressed in kWh/m²/y.	Article 9.3a	Normalization
The energy performance of a building shall be expressed in a transparent manner and include an energy performance indicator and a numeric indicator of primary energy use, based on primary energy factors per energy carrier, which may be based on national or regional annual weighted averages or a specific value for on- site production.	Annex 1 9.3a	Primary metric
[…] primary energy means energy from renewable and non- renewable sources which has not undergone any conversion or transformation process […]	Article 2.5	
Primary energy factors […] may be based on national or regional yearly average values and may take into account […] European standards.	Article 9.3a	Time weighting
MS shall introduce […] appropriate measures […] to increase the share of all kinds of energy from renewable sources in the building sector […], require the use of minimum levels of energy from renewable sources in new buildings and in existing buildings […] The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources […]	Article 2.2 (RED Article 13.4)	Fraction of renewables
nZEB means a building that has a very high energy performance […].	Annex 1	Energy performance
The energy performance […] shall […] include an energy performance indicator and a numeric indicator of primary energy use [….]		
The methodology shall […] take into consideration: thermal characteristics […], heating installation, hot water supply, air-conditioning, natural, mechanical ventilation, built-in lighting, the design, positioning and orientation of the building, outdoor climate, passive solar systems and solar protection, […] internal loads.		
This Directive […] takes into account […] indoor climate requirements […]	Article 1.1	Comfort and IAQ
The methodology shall […] take into consideration […] indoor climatic conditions […] that includes […] indoor air-quality, adequate natural light [ ]	Annex 1 Preamble recital 9	
[…] energy performance of a building means the calculated or measured amount of energy needed […]	Article 2.4	Monitoring
MS shall encourage the introduction of intelligent metering systems […], the installation of automation, control and monitoring systems […]	Article 8.2	

(LT), Luxembourg (LU), Malta (MT), Netherlands (NL), Poland (PL), Portugal (PT), Slovakia (SK), Sweden (SE), and the United Kingdom (UK). Greece (EL), Romania (RO), Slovenia (SI), and Spain (ES) have not yet finalized their template.

General information provided by MS on Regulations, Directives, or Certification schemes are summarized in Table 2.

Fig. 4(a) reports an overview of the status of nZEBs implementation in European MS as assessed by the EC in 2013 [37].

According to the analysis, only four MS (BE, CY, DK, and LT) have provided a definition that comprises both a numerical target (between 0 and 220 $\mathrm{KWh/m^2/y}$) and a share of RES. Many countries have reported almost ready nZEBs definitions and plans, ongoing preparatory studies, or the intention to undertake future actions [38]. Other MS have only made qualitative statements (BE, DK, EL, IE, LT, NL, SE, UK).

Fifteen MS (BE, CZ, DE, DK, EE, FI, EL, HU, IE, LV, LT, NL, SE, SI, UK) have set intermediate targets but, as the Directive does not define these targets, different approaches have been followed. Many countries have chosen minimum energy performance requirements (e.g. 50 $\mathrm{kWh/m^2/y}$ in 2015), or a required energy performance certificate level (e.g. class B by 2015). Other MS have defined qualitative targets (e.g. “all new buildings” or “all new public buildings” will be nZEBs by 2015). Intermediate targets for refurbishment of existing buildings have been set by a few MS (BE, DK, IE), while many countries (BE, CZ, DE, DK, EE, IE, NL, UK) have established intermediate targets for public buildings.

A few countries have mentioned objectives that go beyond nZEB requirements (such as positive energy buildings in DK and FR, climate neutral new buildings in DE and zero carbon standards in the UK), while others (DE, FI, IE, IT, SE, UK) refer to efficient buildings in their regulation rather then nZEBs.

As regards policies and measures in support of nZEBs implementation, Fig. 4(b) shows that several countries have adopted financial instruments and supporting measures, such as tax credits for notary fees, subsidized mortgage interest rates for energy efficient homes and low-interest loans for retrofitting. Other measures are: strengthening of building regulations, awareness raising, education and training activities, pilot or demonstration projects for high efficient buildings.

4.3. Progress of MS towards nZEBs definitions

In this section different arguments related to the EU progress towards the achievement of nZEBs definitions are reported.

MS state their interest in implementing nZEBs for both residential and non-residential buildings. Furthermore, they provide the inclusion of specific subcategories in their national definition,

Table 2
General information on MS regulations, directive, or certification scheme.

Country	Regulation/directive/certification scheme	Editor	Year of introduction
AT	OIB-Dokument zur Definition des Niedrigstenergiegebäudes und	OIB/Länder	2012
BE	Brussels Capital: The Brussels Air, Climate and Energy Code (COBRACE), Flemish region: Flemish Action Plan nZEB—Energy Decree, Walloon region: Co-ZEB study – Regional Policy Statement.	Flemish Energy Agency in Flemish region	2013
BG	National Plan for Nearly zero-energy buildings	Ministry of Investment	2014
CY	The Energy Performance of Buildings. NZEB Action plan	Government	2009
CZ	The Energy Management Act n. 406/2000 Coll.	Ministry of Industry and Trade	2012
DE	EnEG, EnEV, EEWärmeG	Government	EnEG 2013, EEWärmeG 2011
DK	Building Regulation (BR10)	Ministry of Economic and Business	2010
EE	Minimum requirements for energy performance-VV n. 68: 2012	Ministry of Economic Affairs and Communications	2012
FI	National Building Code of Finland	Ministry of the Environment	2012
FR	Réglementation Thermique 2012 (RT 2012)	Government	2013
HU	7/2006 (V. 24.) TNM degree	Ministry of Interior	2012
IE	Building regulation Part L amendement-Buildings other than Dwellings SI	DECLG	2008
IT	Decreto Legge 4 giugno 2013, n. 63	Government	2013
LT	Building technical regulation STR 2.01.09:2012. Law on Renewable Energy, on Construction, Construction Technical Regulation STR 2.01.09:2012 "Energy Performance of Buildings. Certification of Energy Performance", STR 2.05.01:2003 "Design of Energy Performance of Buildings"	Government	2012
LU	RGD 2007 /RGD 2010: Règlement grand-ducal modifié du 30	Ministry of Economy	2008
LV	Cabinet Regulation n.383 from 09.07.2013.	Government	2013
MT	LN 376/2012, transposing Directive 2010/31	Ministry for Transport and Infrastructure	2012
NL	EPG 2012—National Plan to promote nearly zero-energy buildings Bouwbesluit	Government	2011
PT	Decree-Law 118/2013, August 20th	Government	2013
SE	Building regulations BBR 2012	The Swedish Board of Housing, Building and Planning	2013
SK	Act No. 555/2005 Coll. as amended by the act No. 300/2012 Coll.	Ministry of Transport, Construction and Regional Development	2013
UK	Building Regulations Energy Efficiency Requirements: England (Part L); Wales (Part L); Scotland (Section 6); Northern Ireland (Technical Booklet F)	HM Government; Welsh Government; Scottish Government; Northern Ireland Assembly	2013

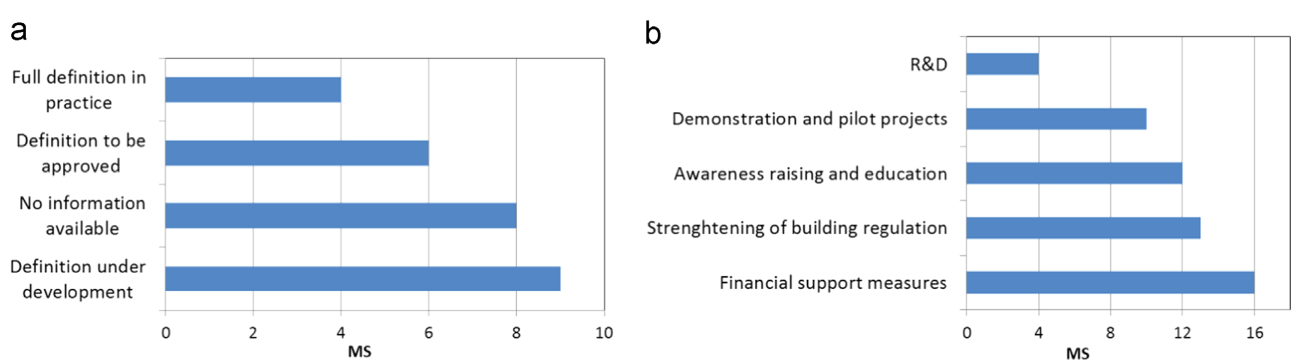

Fig. 4. Overview of the status of nZBEs implementation in MS.

such as apartment blocks, offices, educational buildings, hospitals, hotels, wholesale and retail buildings (Table 3).

Table 3 shows that the countries that have already defined their subcategories (BE, BG, DK, EE, FI, HU, IT, LT, LU, MT, NL, PL, SE, UK) tend to include all of them in their definition.

Fig. 5 reports building typology (new/retrofit), building classification (public/private), balance type, and physical boundary chosen by MS in their nZEBs definitions.

According to Fig. 5(a), CY, CZ, DE, HU, and IE take into account new buildings while all the other MS include both new and retrofit. All European countries consider both private and public buildings, with the exception of FR and HR that refer to private buildings, even if audits are being made to investigate public buildings (Fig. 5(b)). The graph in Fig. 5(c) shows that, even if energy demand against energy generation is the most selected option for balance calculation (AT, BE, DE, DK, HU, LU, UK), most MS (BG, CY, CZ, FI, FR, IE, LV, NL, PL, PT, SE) have not yet established a methodology. Fig. 5(d) highlights that the physical boundary adopted by MS in the implementation of their nZEB definition is very variable among European countries. Most of them (CY, DE, HU, IE, LT, LU, NL, SE, SK) retain single building or building unit (BE, BG, DK, FI, IT, PL, UK) as boundary. A few MS (HR, EE, LV) consider building site and only one (CZ) takes into account part of building/zone building site. The Walloon region of Belgium differs from Brussels Capital as it indicates building site as the preferred physical boundary.

Table 4 refers to different energy uses as considered or not in the definition provided by MS. All countries include heating, DHW, ventilation, cooling, and air conditioning within energy uses, both for residential and non-residential buildings. With the exception of one country (PL), lighting has always been considered (for residential buildings in FI, FR, LT, SE, UK). Plug loads have been considered in seven MS (AT, BG, EE, FI, LV, LT, NL). Auxiliary energy has almost always been included while central services have been

Table 3
Building subcategory as accounted in nZEBs MS definitions (✓ = included in national definition, – = not defined).

Country	Single family houses	Apartment blocks	Offices	Educational buildings	Hospitals	Hotels/ restaurants	Sport facilities	Wholesale and retail trade service buildings
AT	✓	✓	–	–	–	–	–	–
BE	✓	✓	✓	✓	✓[a]	✓[a]	✓[a]	✓[a]
BG	✓	✓	✓	✓	✓	✓	✓	✓
CY	–	–	–	–	–	–	–	–
CZ	–	–	–	–	–	–	–	–
DK	✓	✓	✓	✓	✓	✓	–	–
EE	✓	✓	✓	✓	✓	✓	✓	✓
FI	✓	✓	✓	✓	✓	✓	✓	✓
FR	–	–	–	–	–	–	–	–
HR	–	–	–	–	–	–	–	–
HU	✓	✓	✓	✓	✓	✓	✓	✓
IT	✓	✓	✓	✓	✓	✓	✓	✓
LV	–	–	–	–	–	–	–	–
LT	✓	✓	✓	✓	✓	✓	✓	✓
LU	✓	✓	✓	✓	✓	✓	✓	✓
MT	✓	✓	✓	✓	✓	✓	✓	✓
NL	✓	✓	✓	✓	✓	✓	✓	✓
PL	✓	✓	✓	✓	✓	✓	✓	✓
PT	–	–	–	–	–	–	–	–
SK	–	–	–	–	–	–	–	–
SE	✓	✓	✓	✓	✓	✓	✓	✓
UK	✓	✓	✓	✓	✓	✓	✓	✓

[a] not defined in Brussels Capital region.

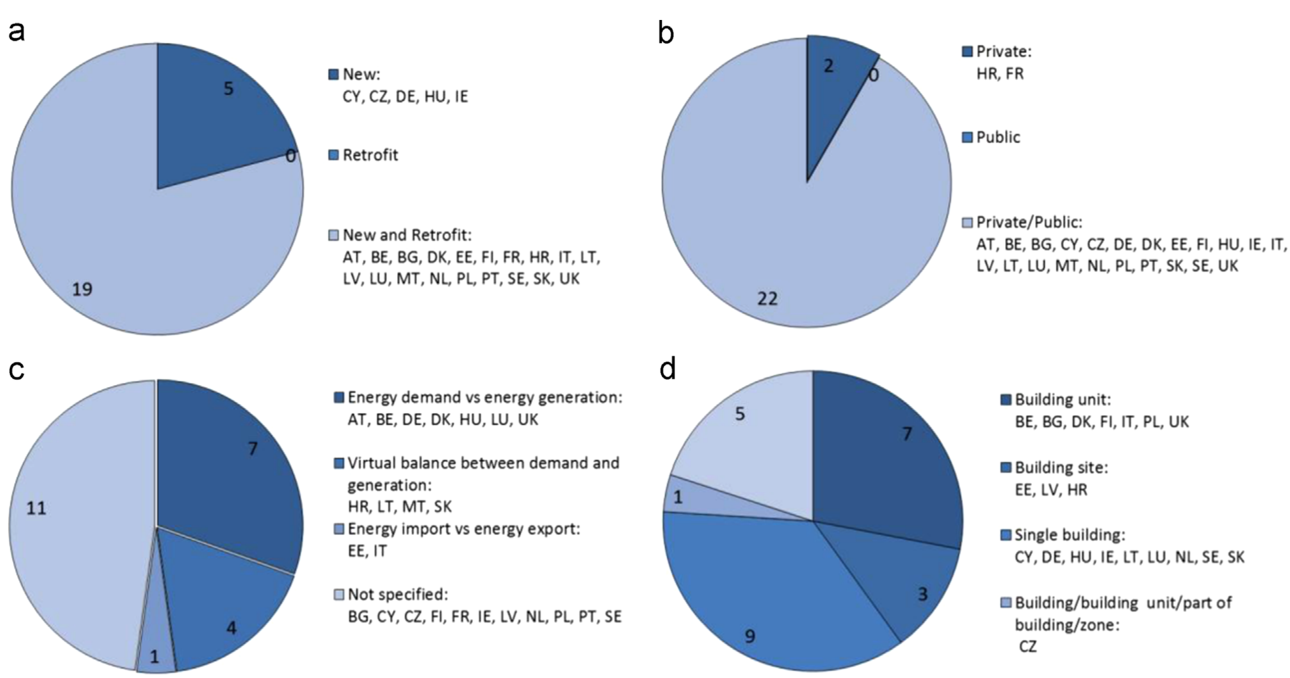

Fig. 5. (a) building typology, (b) building classification, (c) balance, and (d) physical boundary in nZEBs MS definitions.

included in nine countries (BG, HR, EE, IT, LT, LU, MT, NL, SK). Electrical vehicle have been considered in three MS (LT, NL, UK), and embodied energy has been only considered in one country (LT).

Table 5 reports possible system boundaries for RES generation as considered by MS. This table shows that on-site generation has been always considered, but not yet defined in CY, EE, FR, IE, PL, PT. Generation nearby has not been considered only in HR, IE, LT, and not defined in CY, EE, FR, PL, PT, UK. External generation has been considered in eleven countries (BE, BG, CZ, DE, DK, HU, IT, LT, LU, MT, NL) and not defined in nine countries (CY, EE, FI, FR, IE, PL, PT, SE, UK). Crediting has been never considered or defined.

As regards the different options included by RES generation, all countries consider solar thermal, geothermal, passive solar, passive cooling and, with the exception of SE, heat recovery, and PV. Wind power has not been considered by BE and FR, while micro-combined heat and power units (CHP) have not been considered by DK and LT. DK has been the only country not to consider biomass, biogas and biofuel, while SE has been the only MS not to consider daylighting. DK, FR, LT have not considered solar cooling. Waste heat has only been considered by BE, DE, HU, NL, SE, UK, and sewage water by BE, FI, FR, LT, NL.

The fraction of RE production has been defined in some MS, among these: BE (Brussels and Flemish region), BG, CY, CZ, DE, DK,

Table 4
Energy uses included in nZEBs MS definitions (✓=considered, not considered=X, not defined=–, /=possible to add).

Country	Heating DHW	Ventilation, cooling, air conditioning	Auxiliary energy	Lighting	Plug loads, appliances, IT	Central services	Electric vehicles	Embodied energy
AT	✓	✓	✓	✓	✓	X	X	X
BE[a]	✓	✓	✓	✓	X	–	X	X
BG	✓	✓	✓	✓	✓	✓	X	X
CY	✓	✓	X	✓	X	X	X	X
CZ	✓	✓	✓	✓	X	X	X	X
DE	✓	✓	✓	✓	X	X	X	X
DK	✓	✓	✓	✓	–	–	–	–
EE	✓	✓	✓	✓	✓	✓	–	–
FI	✓	✓	✓	✓	✓	/	–	–
FR	✓	✓	✓	✓	X	X	X	X
HR	✓	✓	✓	✓	X	✓	X	X
HU	✓	✓	✓	✓	/			
IE	✓	✓	✓	✓	X	X	X	X
IT	✓	✓	✓	✓	X	✓	X	X
LT	✓	✓	✓	✓	✓	✓	✓	✓
LU	✓	✓	✓	✓	X	✓	X	X
LV	✓	✓	✓	✓	✓	X	X	X
MT	✓	✓	✓	✓	X	✓	X	X
NL	✓	✓	✓	✓	✓	✓	✓	–
PL	✓	✓	✓	X	–	–	–	–
PT	✓	✓	–	✓	–	–	–	–
SE	✓	✓	✓	✓	–	–	–	X
SK	✓	✓	✓	✓	X	✓	X	X
UK	✓	✓	✓	✓	X	X	✓	X

[a] Plug loads, appliances, IT, central services possible to add in the Belgium Flemish region, central services not considered in the Belgium Walloon region.

Table 5
System boundary generation for RES in nZEBs MS definitions (✓=considered, X=not considered, –=not defined).

Country	Generation on site	Generation nearby	External generation	Crediting
AT	✓	✓	X	X
BE	✓	✓	✓	–
BG	✓	✓	✓	X
HR	✓	X	X	X
CY	–	–	–	–
CZ	✓	✓	✓	X
DK	✓	✓	✓	X
EE	–	–	–	–
FI	✓	✓	–	X
FR	–	–	–	–
DE	✓	✓	✓	X
HU	✓	✓	✓	X
IE	–	X	–	–
IT	✓	✓	✓	X
LV	✓	✓	X	X
LT	✓	X	✓	X
LU	✓	✓	✓	–
MT	✓	✓	✓	–
NL	✓	✓	✓	–
PL	–	–	–	–
PT	–	–	–	–
SK	✓	✓	X	X
SE	✓	✓	–	–
UK	✓	–	–	–

IT, LV, LT, LU, SK. The provided values are expressed as a percentage with the exception the Flemish region of Belgium who expresses it as a number (> 10 kWh/m^2/y). Percentages vary from 25% (CY) up to 56% (DK) and 60% (DE).

Fig. 6 reports balance periods, normalization, metric and time dependent weighting as chosen up to now by MS in their definitions.

Most MS take a year as balance period; only one considers a monthly balance (IE, plus the Flemish region of BE), and two life cycle balance (HR, PL) (Fig. 6a).

According to Fig. 6(b), eight MS (BE, CY, FR, HU, IT, LT, MT, SK) consider primary/source energy (renewable part not included), and four delivered/site energy (CZ, DK, FI, SE). Three countries refer to energy need (DE, LU, HR) or energy use (EE, LV, PL), and only one equivalent carbon emissions (UK).

Fig. 6(c) highlights that normalization can vary a lot among MS. The majority of MS consider conditioned area (DK, FI, HU, LT, LV, LU, MT, UK), while the other options are equally distributed among the possible alternatives, with AT, CZ, SK preferring gross floor area, BG, IE, SE treated floor area, and BE, DE, IT, PT net floor area. Twenty MS consider static conversion factors as time dependent weightings. Only CZ and the Flemish region of BE prefer quasi static conversion factors (Fig. 6d).

A numeric indicator of energy performance expressed as primary energy in kWh/m^2/y use has been defined in some MS as reported in Table 6.

Requirements for comfort level and indoor air quality have been defined in almost all MS and many countries have these requirements in their own national regulation. Monitoring procedures have been established in thirteen MS:BE (Brussels Capital and Walloon), DE, EE, FI, HR, HU, IT, LT, LU, MT, PL, SK, UK.

5. Discussion

5.1. Evaluation of the consistency of nZEBs definitions in MS

The analysis of National Plans and templates submitted by MS until August 2014 reveal a positive development towards the adoption of nZEBs definitions. Almost all countries, with the exception of EL, RO, SI, ES, have submitted consolidated information through the templates. According to the EPBD recast, each MS should develop its own nZEBs definition according to its unique context. One of the main issues highlighted in the Commission report of 2013 [34] is that a consistent and detailed evaluation of the European status in compliance to the EPBD requirements was not possible as the provided information was vague, sometimes

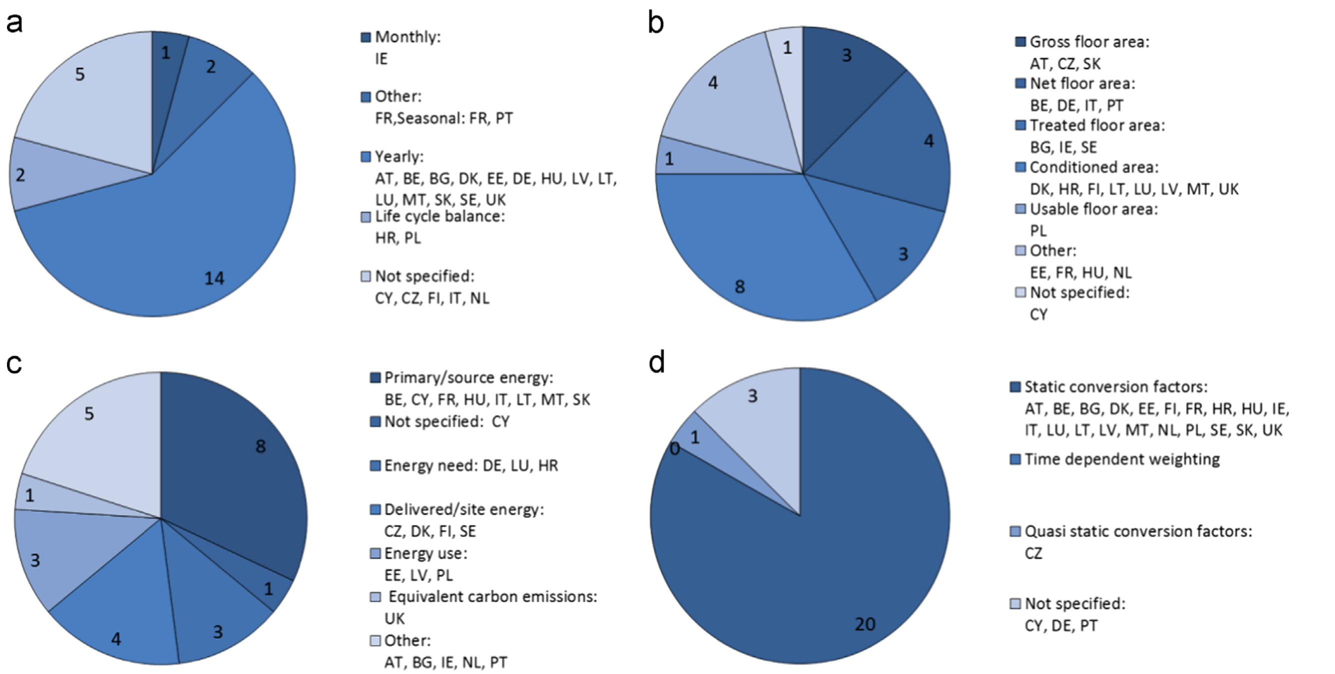

Fig. 6. (a) balance period, (b) normalization, (c) metric, and (d) time dependent weighting in nZEBs MS definitions.

Table 6
Energy performance expressed by MS as primary energy (kWh/m^2/y).

Country	Residential buildings (kWh/m^2/y)	Non-residential buildings (kWh/m^2/y)	Included energy use
BE	30—Flemish region, 45—Brussels region, 60 —Walloon region	40—Flemish region, 60—Walloon region	Heating, DHW, appliances in Brussels and Walloon regions. Heating, cooling, ventilation, DHW, auxiliary systems.
CY	180	210	Heating, cooling, DHW, lighting.
DK	20	25	Heating, cooling, DHW, ventilation. Heating, cooling, ventilation, DHW, lighting.
EE	50 (detached houses) 100 (apartment buildings)	100 (office buildings) 130 (hotels, restaurants) 120 (public buildings) 130 (shopping malls) 90 (schools) 100 (day care centers) 270 (hospitals)	Heating, cooling, ventilation, DHW, lighting, HVAC auxiliary appliances.
FR	50	70 (office buildings without air conditioning) 110 (office buildings with air conditioning)	Heating, cooling, ventilation, DHW, lighting, auxiliary systems.
IE	45—defined as Energy load	–	Heating, ventilation, DHW, lighting.
LV	95	95	Heating, cooling, ventilation, DHW, lighting.
SK	32 (apartment buildings) 54 (family houses)	60 (office buildings) 34 (schools)	Heating, DHW for residential buildings. Heating, cooling, ventilation, DHW, lighting for non-residential buildings

missing, and not harmonized among MS. According to that report, only four MS had a definition in place including both a numerical target of primary energy use and a share of RES.

This paper shows that thirteen countries (AT, BE, CZ, HR, DK, EE, FR, IE, LU, LV, LT, NL, and SK) currently have a nZEBs definition which includes a numerical target of primary energy use and eight MS give both a numerical target of primary energy use and a share of RES (Table 6). Other countries have a definition under development and a few have not yet adopted an official definition. Different approaches have been followed in national energy building regulations to address the EPBD requirements (Table 1). The new templates have considerably helped MS to provide the correct information and allows it to be made more assessable and comparable.

Not only can progress be seen in the quantity of the collected data, but also in quality. Among the agreed aspects within nZEBs definitions is building typology. Nineteen countries (AT, BE, BG, DK, EE, FI, FR, HR, IT, LT, LV, LU, MT, NL, PL, PT, SE, SK, UK) refer to new and retrofit buildings, and twenty-two (AT, BE, BG, CY, CZ, DE, DK, EE, FI, HU, IE, IT, LV, LT, LU, MT, NL, PL, PT, SK, SE, UK) both to private and public buildings (Fig. 5(a) and (b)).

MS that have submitted a plan, refer both to residential and non-residential buildings in their definitions, including different subcategories (e.g. apartment blocks, offices, hospitals, hotels, educational buildings) (Table 3). Results also illustrate that the most common choice regarding energy balance is energy demand against energy generation. However, more guidance has to be provided as many countries (eleven MS: BG, CY, CZ, FI, FR, IE, LV, NL, PL, PT, SE) have not yet specified the selected type of balance (Fig. 5(c)).

Some other agreed aspects are related to the period of balance, that should be performed over a year (fourteen MS: AT, BE, BG, DK, EE, DE, HU, LV, LT, LU, MT, SK, SE, UK), and static conversion factors as time dependant weightings (twenty MS: AT, BE, BG, DK, EE, FI, FR, HR, HU, IE, IT, LU, LT, LV, MT, NL, PL, SE, SK, UK) (Fig. 6(a) and (d)). Single building or building unit are the most frequent indicated physical boundaries (respectively nine MS: CY, DE, HU, IE, LT, LU, NL, SE, SK, and seven MS: BE, BG, DK, FI, IT, PL, UK), but the overall impression is that the differences among building unit/site/zone/part need to be better addressed (Fig. 5(d)). As regards normalization factors, conditioned area is the most agreed upon choice in MS (eight MS: DK, HR, FI, LT, LU, LV, MT, UK). Although other options, such as net floor area (four MS: BE, DE, IT, PT) and treated floor area (three MS: BG, IE, SE), are selected, this aspect should also be better addressed in future policies (Fig. 6(b)).

The renewables to be implemented still seem to be under discussion. The most common considered RES options include on-site generation (eighteen MS: AT, BE, BG, HR, CZ, DK, FI, DE, HU, IT, LV, LT, LU, MT, NL, SK, SE, UK). However, many countries also consider external generation (eleven MS: BE, BG, CZ, DK, DE, HU, IT, LT, LU, MT, NL) and nearby generation (fifteen MS: AT, BE, BG, CZ, DK, FI, DE, HU, IT, LV, LU, MT, NL, SK, SE) (Table 5). The exact meaning of these choices needs to be better defined. Almost all MS prefer the application of low energy building technologies and available RES. The most used technologies are PV, solar thermal, air- and ground-source heat pumps, geothermal, passive solar, passive cooling, wind power, biomass, biofuel, micro CHP, and heat recovery.

Principal included energy uses are heating, DHW, ventilation, cooling, and air conditioning. Auxiliary energy and lighting are taken into account in almost all MS. Many countries also include appliances (seven MS: AT, BG, EE, FI, LT, LV, NL) and central services (nine MS: BG, EE, HR, IT, LT, LU, MT, NL, SK) (Table 4). Therefore also these points should be carefully considered in upcoming policies.

5.2. nZEBs roadmaps and demonstration projects

Among the EU countries that have already established more exhaustive strategies or aims around nZEBs, there are: BE, DE, DK, FR, UK [39].

DK is one of the first EU countries to set-up its national nZEBs definition and roadmap to 2020. Progressive performance classes will be established. Minimum energy performance requirements will gradually become stricter, starting from the current Standard, BR10, with an intermediate milestone in 2015 (class 2015, mandatory in 2015) and a final target in 2020 (class 2020) [40]. The energy scope includes energy need for heating, ventilation, cooling, DHW, and auxiliary equipment. The improvement of energy performance is done by increasing the requirements for buildings insulation. Lighting is also included within the regulated energy for non-residential buildings. A maximum demand is defined for total heating, ventilation, cooling and DHW.

BE amended in 2011 the Energy Performance of Buildings Ordinance stipulating that from January 2015 onwards, all new public and residential buildings have to fulfill a primary energy need at level of Passive House standard [41]. The requirement establishes that residential buildings will have a primary energy consumption for heating, DHW, and auxiliary energy below 45 kWh/m^2/y and heating below 15 kWh/m^2/y.

In FR low energy requirements are adopted in the recast of the French thermal regulation, RT 2012, which is applied to new residential buildings since January 2013. Requirements address a building's energy need for space heating, DHW, cooling, lighting, and auxiliary energy. RT 2012 set the minimum performance requirements to 50 kWh/m^2/y in primary energy. The minimum energy requirement is adjusted by climatic zone and altitude and varies between 40 kWh/m^2/y and 65 kWh/m^2/y. All new buildings will be energy positive in 2020.

The UK developed a roadmap for implementing zero carbon buildings by 2016/2019. Energy Performance Requirements of building regulations incrementally increase the energy performance. From 2016 all new homes and from 2019 all new non-domestic buildings will be built to zero carbon standards. The process of nZEBs definition has been built following the certification system "Code for Sustainable Homes (CSH)". From 2016 carbon compliance limits for building performance should be 10 kg CO_2(eq)/m^2/y for detached houses (or ~46 kWh/m^2/y) [29].

In DE, the government carried out the project "Analysis of the revised EPBD" to research possible nZEBs definitions and determine best solutions [42], [43]. The analysis identified that new buildings in 2020 will have an energy performance by 50% better than the current buildings performance, i.e. according to the EnEV2009 standard. In addition, the current legislation has to be changed including requirements for new buildings to comply with the nZEB target. The Energy Conservation Regulations envisages tightening the energy minimum standard in two phases (12.5% in 2014 and 12.5% in 2016).

A great variety of concepts, models and examples of highly energy-efficient or low energy buildings are available throughout Europe. Among these, the Passive House, 3-l house, and Energy Plus. In DE, more than 13,000 passive houses have been built since the 1990s [44]. The German building codes have been strengthened five times over the past 35 years and the energy demand for space heating and DHW has been reduced from 300 kWh/m^2 to approximately 52.5–60 kWh/m^2 primary energy [10].

European policies seem to have motivated the private construction sector to take initiatives and the construction sector appears to moving towards nZEBs. However, the majority of nZEBs are still demonstration projects, indicating that a full implementation of the concept is not yet present. Recently, the project Nearly Zero Energy Hotels (neZEH), supported by the Intelligent Energy Europe (IEE), aims at accelerating the refurbishment of existing buildings into nZEBs in the hospitality sector.

A database of ZEBs throughout Europe has been created by the International Energy Agency (IEA) [45]. The website testifies that built examples are diffusing in many countries, but a considerable number of projects are located in AT, DE, DK, and SE. However, energy data of available case studies reflect the uncertainty of calculation methodologies and accounted energy flows. Furthermore, measurements should be also required at a built nZEB level during its operation to verify the claimed performance and the effectiveness of the solutions after their implementation.

Several national approaches towards the nZEB implementation have been presented. They vary from zero carbon to explicit maximum primary energy values. Besides the primary energy indicator required by the EPBD recast, many countries also intend to include a list of additional indicators, dealing with building envelope and also with system efficiency as well as generated renewables. A gradual approach in form of a roadmap towards the 2020 goals is planned in most countries.

BG, PL, and RO have already developed roadmaps for moving towards nZEBs [46].

Starting from current construction practices, existing policy framework and economic conditions, simulations have been carried out on energy performance and economic implications in nZEBs reference buildings. The estimated macro-economic benefits of implementing nZEBs between 2020 and 2050 are remarkable. CO_2 savings are estimated as follows: around 5 million tons in BG, 31 million tons in PL, and 68 million tons in RO. Energy savings are estimated around 16 TWh in BG, 92 TWh in PL, and 40 TWh in RO. New full time jobs will be created: between 649 and 1180 in BG, between 4100 and 6200 in PL, between 1390 and 2203 in RO. Additional investments are expected between 38 and 69 million Euros in BG, between 240 and 365 million Euros in PL, between 82 and 130 million Euros in RO.

Minimum primary energy requirements are foreseen between 70 kWh/m^2/y (BG and PL) and 100 kWh/m^2/y (RO) in 2015, but they will become between 30 kWh/m^2/y and 50 kWh/m^2/y in 2020. The percentage of renewable share will pass from 20% in 2015 to 40% in 2010. CO_2 emissions will pass from 8–10 KgCO$_2$/m^2/y to 3–7 KgCO$_2$/m^2/y in 2020.

5.3. Further future policy challenges

The current situation towards the establishment of nZEBs definitions in European countries can be stated as improved in comparison with the 2013 Commission progress evaluation [36]. In the last year, many nZEBs definitions have been implemented at national level, intermediate targets set as well as policies and measures launched.

Even if progress can be assessed mainly due to the consolidated information submitted through the templates, as well as more guidance and clarifications given to MS, there is still space for improvement. Sometimes the provided information remains ambiguous and it is not always clear to what extent definitions are compulsory or conform to the EPBD requirements. As an example, a wide range of policies is selected in relation to adopted measures to increase the number of nZEBs. Among them there are: awareness raising and information, education and training, strengthening building regulations and energy performance certificates, chosen by: AT, BE, BG, HR, CY, CZ, DK, EE, FI, FR, DE, HU, IE, IT, LV, LT, MT, PL, PT, SE, SI, UK. However, policies sometimes seem rather general and addressed to "all buildings". Their specific support is not always sufficiently clear, nor is to what extent they practically contribute to achieving the nZEB target in a country. Therefore, a stronger connection between policies, measures and nZEBs needs to be established.

In addition to the already identified points that require further definition in the view of an upcoming effective and uniform policy delivery, such as boundary, energy uses, balance, renewables, numerical indicators of energy performance widely differ across MS and are not always comparable. It would be useful to give more guidance on the reference metric to be provided by MS. Primary energy factors per energy carriers should be also reported in future templates to enlighten their variability among MS. Primary energy as a metric expressed in kWh/m^2/y and a percentage of minimum requirements given by National Building Codes are agreed choices in most countries. The range of values goes from targets beyond nZEB requirements, such as positive energy buildings, up to 270 kWh/m^2/y. Energy performance indicators can vary remarkably from to 20 kWh/m^2/y to 180 kWh/m^2/y in residential buildings, but usually targets aim at 45 kWh/m^2/y or 50 kWh/m^2/y. Values from 25 kWh/m^2/y to 270 kWh/m^2/y are reported for non-residential buildings with higher values given for hospitals.

Common percentages related to RE production are around 50%, but the share of renewable energy is not yet completely assessed. Only few countries give a minimum percentage, ranging from 25% (CY) to 60% (DE), and the others make qualitative statements (BE, BG, CZ, DK, FR, DE, IE, IT, LV, LT, NL, SK, SE, UK). Furthermore, some MS have included the share of renewables in the provided primary energy indicator (IE, LT, NL, SK).

Even if most MS have the common objective to achieve an equalized annual energy balance, many of them have a variety of definitions and schemes related to nZEBs. Since calculation procedures at country level differ significantly, there are still limits in a precise cross-comparison of energy performance indicators. Therefore, an open issue is related to the target expressed as a numeric indicator of primary energy use, as required by Annex 1 of the EPBD (Table 1). Moreover, the application of CEN standards leaves flexibility in determining this numeric indicator, for example in relation to different primary energy factors or time step used in calculations. This uncertainty is reflected in MS metric selection that seems to be variable among countries (Fig. 6(c)). The most selected choice is primary/source energy (eight MS: BE, CY, FR, HU, IT, LT, MT, SK), but also energy need (three MS: DE, LU, HR), delivered/site energy (four MS: CZ, DK, FI, SE), and energy use (three MS: EE, LV, PL) have been selected.

As already stated in [46], primary energy should not be considered as the only parameter to be used in the assessment of nZEBs. Energy need can be seen as a starting point in primary energy calculations, where additional steps can be currently represented by energy use and delivered energy. In each step additional parameters are included which make the result of the calculation more dependent on the chosen factors. Therefore, energy need seems to be a suitable benchmark for nZEBs energy performance assessment.

MS status in relation to intermediate targets (provided by: AT, BE, BG, HR, DK, EE, FI, FR, DE, HU, IE, IT, LT, LU, MT, NL, PL, PT, SK, UK, six more MS compared to 2013) seems to be currently more defined with information collected in one document. This facilitates the comparison and the evaluation of measures for increasing the number of nZEBs. Most MS have reported a variety of supporting measures to promote nZEBs, including financial incentives, strengthening building regulations, education and training, research and development, awareness raising activities, and demonstration or pilot projects. Nevertheless, it is not always defined to what extent these measures specifically target nZEBs. Many MS did not provide details on the proposed measures and policies (e.g. HU). The lack of information means that the evaluation of the effectiveness of these measures is still difficult.

An improvement can be seen in the number of MS that reported specific measures for refurbishing existing buildings (twenty-two MS: AT, BE, BG, HR, CZ, CY, DK, EE, FI, FR, DE, HU, IE, It, LV, LT, MT, NL, PL, SK, SE, UK, in 2013 only seven). This indicates that MS are more aware of the huge impact of the existing building stock on overall energy consumption. Financial support schemes remain the prevalent measure to support renovation.

However, also in this case, the submitted information could be better structured and described.

Existing sources of renovation funding as well overall investments and mechanisms are not always assessed for residential and non-residential buildings. The effectiveness of existing policies, as well as the need of new ones, should be better evaluated in many countries. Several barriers towards the improvement of energy performance of buildings can prevent the achievement of the European Climate and Energy package goals.

Most MS presented intermediate targets for improving the energy performance of new buildings by 2015 (e.g. strengthening building regulations, obtaining energy performance certificates by a certain year, establishing a number of nZEBs to be built). The targets appear very variable, ranging from qualitative to quantitative or from energy performance to the number or the percentage of nZEB buildings (e.g. NL foresees to build 60,000 new nZEBs dwellings by 2015). Therefore, when information remains dispersive, there is the need of further clarifications and improvements. This could be made through a more detailed description of what is required in each aspect, allowing MS to organize their information in a more structured way, for example reporting residential and non-residential buildings separately.

6. Conclusions

According to the recast of the EU Directive on Energy Performance of Buildings (EPBD), by the end of 2020 all new buildings should be Nearly Zero Energy Buildings (nZEBs). As a consequence, the attention given to nZEBs increased consistently over the last decade. It is widely recognized that ZEBs have a great potential to decrease energy consumption and to increase at the same time the use of renewables, alleviating energy resources depletion and environmental deterioration.

Progress, however slow, may be seen in many MS compared to the very first attempts of establishing nZEBs definitions. Such progress has been facilitated by greater guidance provided to EU countries in setting consistent nZEBs requirements.

The reduction of energy demand through energy efficient measures and the utilization of RES to supply the remaining demand appear agreed points towards the implementation of nZEBs definitions in Europe.

MS that have submitted a plan refer both to new and retrofit, private and public, residential and non-residential buildings in their definitions. Results illustrate that most common choices include demand/generation as balance, performed over a year using conditioned area as normalization factor, and static conversion factors as time dependent weighting. Nevertheless, many countries have not yet defined the selected type of balance. Single building or building unit are the most frequent indicated physical boundary, and on-site the most common considered RES options. However, zero energy districts can effectively overcoming physical boundary limitations that are common in the refurbishment of existing buildings at the nearly zero level, such as access to on-site renewable energy generation. Many countries prefer the application of low energy building technologies and available RES. The most used renewable technologies are PV, solar thermal, air- and ground-source heat pumps, geothermal, and heat recovery.

However, a consensus on various arguments to be defined seems still far off. Different system boundaries and energy uses are the cause of high variations within the described definitions. The level of energy efficiency, the inclusion of lighting and appliances, as well as the renewables to be implemented are difficult to be agreed upon. Therefore these aspects should be better addressed in the forthcoming EU policy framework.

In particular, primary energy values appear very variable and reflect different calculation methodologies and accounted energy flows. This paper has shown that national energy policies have evolved significantly with new legislation and methodologies introduced together with technical regulatory measures to promote a more reasonable use of energy and RES generation. However, MS need to further strengthen and evaluate their policies and measures in order to successfully stimulate cost-effective deep renovation of existing buildings towards nZEBs. Starting from a comprehensive overview of their national building stock, MS have to evaluate the cost-effectiveness of nZEBs renovation according to building types and climatic zones. To meaningful comparison of different MS definitions, input parameters need further alignment and consequently there is the necessity to further support MS.

The paper shows how many aspects still remain under discussion and open to interpretation, such as boundary, balance, energy uses, renewables options. It also underline the urgency of a harmonized definition framework and a robust calculation methodology. Finally, especially in the view of building refurbishment to the nZEBs target, MS should powerfully develop strategies able both to overcome barriers towards energy efficiency and to guide investment decisions in a forward-looking perspective.

It has to be stressed that the interdisciplinary nature of the nZEB concept requires further cooperation among all the actors involved in the nZEBs topic, from policy makers, to economists, researchers, environmental analysts, designers, up to the construction sector. The study finally enhances the importance of research projects in inspiring the nZEBs development in different European climates and regions as well as the implementation into construction practices and routines.

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