Towards Nearly Zero Energy Buildings in Europe: A Focus on Retrofit in Non-Residential Buildings

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Towards Nearly Zero Energy Buildings in Europe: A Focus on Retrofit in Non-Residential Buildings

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Abstract: Buildings are the focus of European (EU) policies aimed at a sustainable and competitive low-carbon economy by 2020. Reducing energy consumption of existing buildings and achieving nearly zero energy buildings (NZEBs) are the core of the Energy Efficiency Directive (EED) and the recast of the Energy Performance of Building Directive (EPBD). To comply with these requirements, Member States have to adopt actions to exploit energy savings from the building sector. This paper describes the differences between deep, major and NZEB renovation and then it provides an overview of best practice policies and measures to target retrofit and investment related to non-residential buildings. Energy requirements defined by Member States for NZEB levels are reported comparing both new and existing residential and non-residential buildings. The paper shows how the attention given to refurbishment of NZEBs increased over the last decade, but the achievement of a comprehensive implementation of retrofit remains one of main challenges that Europe is facing.

Keywords: nearly zero energy buildings (NZEBs); retrofit; energy policy; non-residential buildings; energy requirements

1. Introduction

Buildings are a strategic focus of European (EU) policies aiming to achieve a sustainable and competitive low-carbon economy by 2020. The European Commission encourages Member States to decrease energy consumption in buildings and convert national building stocks from energy consumers to energy producers through retrofit measures and renewable energy sources (RES).

The key policy instrument towards this goal is the Energy Efficiency Directive (EED), which includes provisions to increase energy efficiency at EU level [1]. In accordance with Article 24(2) of the EED, Member States are required from 2014 (and then every three years) to submit National Energy Efficiency Action Plans (NEEAPs), and Article 4 requires Member States to establish (by 30 April 2014 and update every three years) a long-term strategy beyond 2020 for mobilising investment in the renovation of residential and commercial buildings, with a view to improving the energy performance of the building stock. The exemplary engagement of public authorities is required to satisfy Article 5 of the EED, asking Member States to ensure that, as from January 2014, 3% of the total floor area of heated and/or cooled buildings owned and occupied by its central government is renovated each year.

Another central policy document is represented by the recast of the Energy Performance of Building Directive (EPBD) [2], which introduces Nearly Zero Energy Buildings (NZEBs) and establishes that all new buildings have to be NZEBs by 31 December 2020 (Article 9). Moreover, Articles 4 and 5 require the definition of new minimum energy performance requirements (for new buildings and major renovations) applying a cost-optimal calculation.

Besides efforts to design new buildings with low energy demand and availability of RES [3–5], it is essential to tackle the high energy consumption in existing buildings, characterized by an average

age of about 55 years. The contribution of buildings to the total final energy consumption in the EU was 40% in 2012, making the building stock responsible for 36% of the EU total CO_2 emissions. While more stringent building codes and policies caused this value to decrease slightly in residential buildings since 2007, the final energy consumption in non-residential buildings remained quite stable over the last decade. This is mainly because of the increasing cooling needs, leading to a six percent rise of primary energy use per m^2 in the period 13 February 2002.

It is undeniable that the economic crisis since 2007 has also influenced the energy trends of recent years [6]. On the one hand, it led to a reduction in energy consumption due to an increase in the poverty levels of households, and on the other hand, it curbed building renovation activity [7]. The recent evaluation of the Europe 2020 strategy [8] reveals that, due to the economic crisis, the number of people at risk of poverty increased from 80 million prior to the crisis to 124 million in 2012. This is quite evident from the evolution of building permits (Figure 1) and the trend of sales of material and equipment related to low-energy buildings (Figure 2).

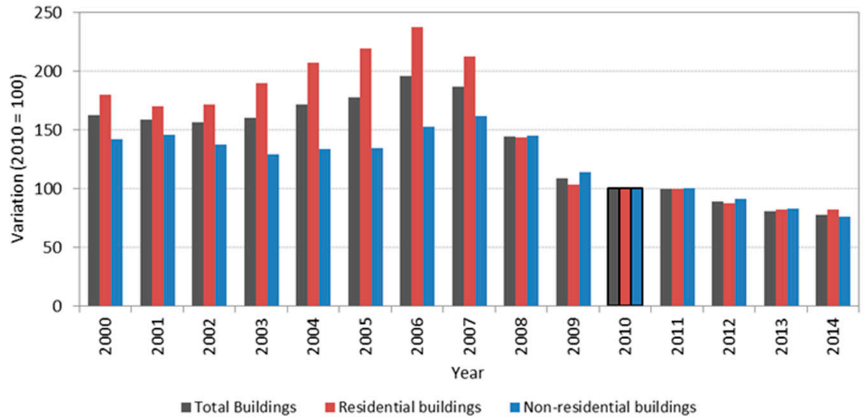

Figure 1. Trend of building permits in European (EU) 28 (2010 = 100). Source: elaboration from EUROSTAT [9].

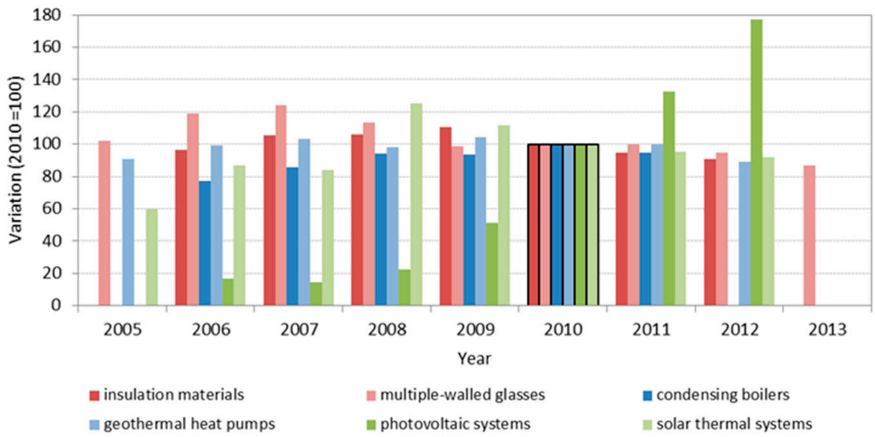

Figure 2. Trend of sales related to low-energy buildings in Europe (2010 = 100). Source: elaboration from Zebra 2020 database [10].

The stimulus resulting from the growth of the building sector on the entire economy, in terms of GDP (gross domestic product) and employment, is a further motivation for investing public funds in energy renovation of the EU building stock. Other important positive effects are the reduction of gas imports (as buildings are currently responsible for 35% of these imports) and the improvement of the indoor comfort and living conditions [11].

The aim of this paper is to provide an overview of the status of implementation of NZEBs in Europe with a focus on retrofit. This topic represents a challenge at EU level because the existing building stock is characterized by different uses, with buildings located in disparate climatic areas, and with many different construction traditions and system technologies. The paper analyses the definitions of deep, major and NZEB renovation that have been launched in recent years to clarify the principal differences between them. NZEBs energy requirements currently available are reported for new and existing residential and non-residential buildings. Common features within NZEBs' definitions implemented in Member States are highlighted together with varying levels of energy performance requirements. As energy policies are essential to target specific energy performance goals, an overview of best practices policies and measures for retrofit and investment are reported in particular for non-residential buildings. The paper shows that diversified approaches are in place for the improvement of existing buildings energy performance, involving technical, economic and financial aspects, but a comprehensive retrofit implementation is still distant at EU level.

2. Deep, Major and Nearly Zero Energy Buildings Renovations

It is essential to stimulate the construction sector to increase renovation rates in Europe. However, few data are available on numbers, depth, or trends in renovation rates.

In 2011, the Buildings Performance Institute Europe (BPIE) [12] noted that most estimates of renovation rates (other than those relating to single energy saving measures) are around between 0.5% and 2.5% of the building stock per year. The authors assumed a renovation rate of 1%, considering that higher rates had reflected the activity of the previous few years which in some cases had been linked to special circumstances (e.g., the existence of a renovation programme). This value was in line with the study carried out for the European Commission led by Fraunhofer Institute [13], where refurbishment rates of 1.2%, 0.9% and 0.5% per year were found for North-Western Europe, Southern Europe and new Member States respectively.

The term "renovation" has been used to describe a wide variety of improvements to an existing building or group of buildings. Different levels of renovation can be distinguished depending on the type of intervention and savings obtained. Renovation can involve the replacement or upgrade of all building elements which have a bearing on energy uses, as well as the installation of RES to reduce energy consumption towards zero levels or to less. Qualitatively, the refurbishment of a building façade (i.e., walls and windows) provides a different energy saving level compared to the retrofit of the overall building envelope and systems (heating, ventilation and air conditioning (HVAC), lighting, etc.).

Adopting BPIE parameters [14], the energy performance of a building can be improved by the implementation of a single measure, such as a new heating system or roof insulation. Such interventions are referred to "small retrofit" or "minor renovation". Typically, energy savings of up to 30% might be expected by the application of one to three implemented measures.

Many discussions have risen around the meaning of "major", "deep" and "NZEBs" renovations. A summary of the main definitions found in the literature is given in Table 1.

The EED defines deep renovation as able to: "lead to a refurbishment that reduces both the delivered and the final energy consumption of a building by a significant percentage compared with the pre-renovation levels leading to a very high energy performance". In the European Parliament report of July 2012 [15] (Amendment 28, Article 2, paragraph 1, point 27.a), the following definition has been launched: "deep renovation means a refurbishment that reduces both the delivered and the final energy consumption of a building by at least 80% compared with the pre-renovation levels". In the Commission Staff Working Document (SWD) (2013) 143 final [16], it is stated that Member States should aim to encourage deep renovation of buildings leading to significant efficiency improvements, typically more than 60%.

NZEB renovation combines high efficiency technologies with renewable production [17]. A reduction of primary energy demand is obtained through low-energy technologies (e.g., insulation, daylighting, high-efficiency HVAC, natural ventilation, evaporative cooling) while RES can be on-site or off-site depending on the availability on site (e.g., sun, wind) or to be transported to the site (e.g., biomass). A ranking of preferred application of different renewable supply side options is proposed by Torcellini et al. [18]. On-site supply options use RES available within the building footprint or within the site (e.g., photovoltaics (PV) solar hot water, low impact hydro, wind) while off-site options use RES available off-site to generate energy on-site (e.g., biomass, wood pellets, ethanol, biodiesel that can be imported, or waste streams used on-site to generate electricity and heat), or purchase off-site RES (e.g., utility-based wind, PV emissions credits).

Table 1. Summary of definitions of minor, moderate, deep, major and NZEB renovation. NZEB: nearly zero energy building; BPIE: Buildings Performance Institute Europe; EED: Energy Efficiency Directive; SWD: Staff Working Document; GBPN: Global Buildings Performance Network; EPBD: Energy Performance of Building Directive; and RES: renewable energy sources.

Type of Renovation	Reference	Definition/Measures
Minor	BPIE [12]	It reduces final energy consumption up to 30% implementing from one to three improvement measures (e.g., new boiler plant, wall/roof insulation, windows), with an average total project cost of 60 €/m^2.
Moderate	BPIE [12]	It involves from three to five retrofit improvements resulting in energy reductions in the range 30%–60%, with an average total project cost of 140 €/m^2.
Deep	EED [1]	It reduces both the delivered and the final energy consumption by a significant percentage compared with the pre-renovation level leading to a very high energy performance.
	European Parliament report (July 2012) [15]	It reduces both the delivered and the final energy consumption of a building by at least 80% compared with the pre-renovation level.
	Commission SWD (2013) [16]	Significant efficiency improvements, typically more than 60%.
	GBPN [19]	Reduction in energy consumption for heating, cooling, ventilation and hot water of 75% or more.
	Entranze Consortium [14]	Renovation level implementing high-grade refurbishment packages (e.g., 30, 20 and 15 cm of insulation on roof, walls and basement; very efficient heating/cooling generators; heat recovery strategies).
	Zebra 2020 project [10]	Deep thermal renovation with more than two improved thermal solutions (e.g., efficient heating plus insulation of wall/roof, etc.).
	BPIE [12]	It adopts a holistic approach, viewing the renovation as a package of measures working together, resulting in energy reductions in the range 60%–90%, with an average total project cost of 330 €/m^2.
Major	EPBD [2]	Renovation of a building where: (a) the total cost of the renovation relating to the building envelope or the technical building systems is higher than 25% of the value of the building, excluding the value of the land upon which the building is situated; (b) more than 25% of the surface of the building envelope undergoes renovation.
NZEB	EPBD [2]	Renovation that leads to a building that has a very high energy performance [...]. The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from RES, including energy from RES produced on-site or nearby.
	BPIE [12]	It leads to more than 90% final energy saving, with an average total project cost of 580 €/m^2.

The reduction of primary energy demand towards very low levels, also including RES, can lead to the avoidance of a traditional heating/cooling system. This level can be termed nearly zero energy renovation, because in line with the EPBD recast definition: "'Nearly zero energy building' means a building that has a very high energy performance [. . .]. The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby" [2]. According to BPIE, between these two examples there are renovations involving a number of upgrades. These can be subdivided into: "moderate", involving improvements (typically more than three) resulting in an energy reduction in the range from 30% to 60%; "deep", related to the integration of high-grade improvements, able to reach energy savings from 60% to 90%, with an average total project cost of 140 €/m^2 and 330 €/m^2 respectively.

The term "deep renovation" has also been used by other references with similar, if not identical meanings:

- the Global Buildings Performance Network (GBPN) [19] equates a deep renovation to a reduction in energy consumption for heating, cooling, ventilation and hot water of 75% or more;
- the Entranze Consortium selected as "deep" the renovation level implementing high-grade refurbishment packages (e.g., 30, 20 and 15 cm of insulation on roof, walls and basement; very efficient heating/cooling generators; heat recovery strategies) [20];
- the Zebra 2020 project defines it as deep thermal renovation with more than two thermal solutions (e.g., heating plus insulation of wall/roof, etc.) [10].

Zebra 2020 is also collecting data and evidence for policy evaluation and optimization providing a strategy to boost the market uptake of NZEBs. As shown in Figure 3, deep renovation rates are available only for a few countries and, despite Member States efforts, they are lower than one percent of the whole building stock renovated each year.

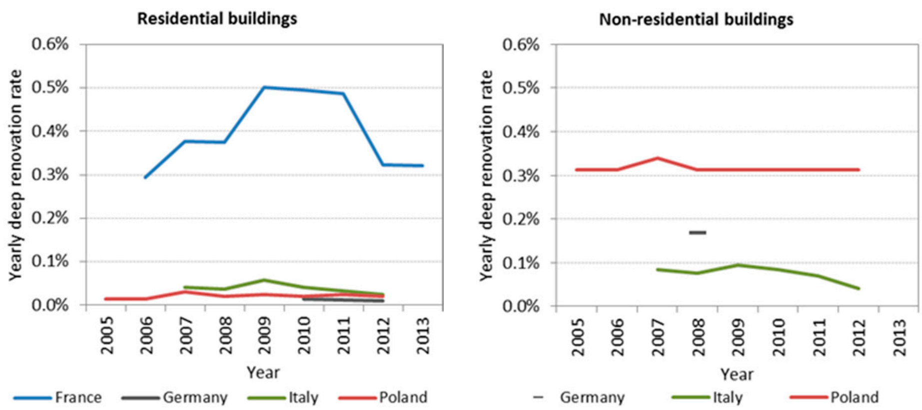

Figure 3. Evolution of deep renovation rates in some European Member States (in terms of % of the whole building stock renovated every year). Deep renovation means deep thermal renovation with more than two thermal solutions (e.g., heating plus insulation of wall/roof, etc.). Source: elaboration from [10].

Another term used in the literature, often synonymously with "deep", is "major renovation". In 2010 it has been officially defined by the EPBD recast (where there is no mention of the term "deep renovation") as: "the renovation of a building where: (a) the total cost of the renovation relating to the building envelope or the technical building systems is higher than 25% of the value of the building, excluding the value of the land upon which the building is situated; or (b) more than 25% of the surface of the building envelope undergoes renovation; Member States may choose to apply option (a) or (b)".

As suggested by Shnapp et al. [21], this definition identifies a window of possibilities for "deep renovation", but probably it is inaccurate to compare these two terms, that were introduced by different legislative tools, i.e., EED and EPBD recast, and with different objectives. In line with the EPBD recast, it is necessary to set a reference to harmonize a certain level of renovation to the minimum energy requirement of new buildings. Therefore, an ex-ante measurable reference (economic or geometric) has been considered functional for the administrative management and legal implications (e.g., building permits, inspections, etc.). The EPBD asked for effective renovations, but the message has been emphasized in the EED: "Major renovations of existing buildings, regardless of their size, provide an opportunity to take cost-effective measures to enhance energy performance. For cost-effectiveness, it should be possible to limit minimum energy performance requirements to the renovated parts that are most relevant for the energy performance of a building [22]. The importance of having a long-term strategy for mobilizing investments in building renovation to improve energy performances, introduces the need for an ex-post reference: stimulate "deep renovations" able to reach significant energy savings.

The overlap between the meaning of "deep renovation" and "major renovation" should be avoided. Due to the lack of a clear definition for deep renovation, confusion is often raised between the terms. Consequently, future policy documents the term should be better defined or replaced by NZEB renovation which is linked to national NZEB definitions. According to the EPBD recast, "major renovation" has a legal implication in terms of building codes. On the other hand, a "deep renovation" does not carry legal requirements. It presents a more pragmatic approach that is focused on building envelope and systems to reduce energy consumption. The meaning of NZEB renovation is not yet consolidated but it implies a new concept of renovation, having a holistic approach, which considers the building lifecycle and its impact on the environment, which cannot exclude renewable production.

3. National Nearly Zero Energy Buildings Definitions

The progress made by the Member States towards the establishment of NZEB definitions is now summarized based on submitted National Plans [23]. Many aspects to be defined are taken into account, such as building category, typology, physical boundary, type and period of balance, included energy uses, RES, metric, normalization, and conversion factors. The analysis of NZEB definitions in relation to energy calculations reveals that [24]:

- included energy uses are heating, domestic hot water (DHW), ventilation, and cooling. Auxiliary energy and lighting are taken into account in almost all countries. Several Member States also include appliances and central services;
- the most common choice regarding the energy balance calculation is the difference between primary energy demand and energy generated, over a one year period, and considering annual constant weightings/factors (e.g., primary energy factors);
- single building or building unit are the most frequent indicated physical boundary for the calculation, but the overall impression is that the differences among building unit/site/zone/part need to be better addressed;
- as regards the normalization factors, conditioned area is the most agreed upon choice in Member States. Although other options, such as net floor area and treated floor are selected;
- the most common considered RES option is on-site generation, but many countries also consider external generation and nearby generation (but not always with the same meaning);
- almost all Member States prefer the application of low energy building technologies and available on-site RES. The used technologies are PV, solar thermal, air- and ground-source heat pumps, geothermal, passive solar, passive cooling, wind power, biomass, biofuel, micro combined heat and power (CHP), and heat recovery.

In relation to RES, both on-site and off-site generation have been selected by Member States that consider different options of RES generation, such as solar thermal, geothermal, passive solar and passive cooling, heat recovery, and PV. The proportion of renewable energy production has been defined in some Member States, with values expressed as a percentage, varying from 25% (Cyprus) up to 56% (Denmark) and 60% (Germany) or a number (e.g., more than10 kWh/m^{2}y).

The majority of EU Member States consider static conversion factors as time dependent weightings. Several studies have shown that weighting factors have a large impact on energy balance calculation [25]. The choice of different energy carrier weighting factors can also influence future energy market towards adopting specific energy technologies [26]. Mazzarella [27] points out that a conventional time profile for time variant primary energy conversion factor is acceptable applying conversion factors only to non-renewable energy carriers (i.e., produced by non-renewable energy sources) to account for non-renewable energy sources use.

The energy performance targets that Member States provided in their National Plans are shown in Table 2.

Table 2. Energy requirements defined by EU Member States for NZEB levels. PE: primary energy; and n/a: not available.

Country	Residential Buildings (kWh/m^2/y or Energy Class)		Non-Residential Buildings (kWh/m^2/y or Energy Class)	
	New	**Existing**	**New**	**Existing**
Austria	160	200	170	250
Belgium	45 (Brussels region) 30 (Flemish region) 60 (Walloon region)	~54	(95–2.5) *(V/S) (Brussels region) 40 (Flemish region) 60 (Walloon region)	~108
Bulgaria	~30–50	~40–60	~30–50	~40–60
Cyprus	100	100	125	125
Czech Republic	75%–80% PE	75%–80% PE	90% PE	90% PE
Germany	40% PE	55% PE	n/a	n/a
Denmark	20	20	25	25
Estonia	50 (detached house)	n/a n/a n/a n/a	100 (office buildings) 130 (hotels, restaurants) 120 (public buildings) 130 (shopping malls)	n/a n/a n/a n/a
	100 (apartment blocks)	n/a n/a n/a	90 (schools) 100 (day care centres) 270 (hospitals)	n/a n/a n/a
France	40–65	80 n/a	70 (offices without AC) 110 (offices with AC)	60% PE n/a
Croatia	33–41	n/a	n/a	n/a
Hungary	50–72	n/a	60–115	n/a
Ireland	45 (Energy load)	75–150	~60% PE	n/a
Italy	Class A1	Class A1	Class A1	Class A1
Latvia	95	95	95	95
Lithuania	Class A++	Class A++	Class A++	Class A++
Luxemburg	Class AAA	n/a	Class AAA	n/a
Malta	40	n/a	60	n/a
Netherlands	0	n/a	0	n/a
Poland	60–75	n/a	45–70–190	n/a
Romania	93–217	n/a	50–192	n/a
Spain	Class A	n/a	Class A	n/a
Sweden	30–75	n/a	30–105	n/a
Slovenia	45–50	70–90	70	100
Slovakia	32 (apartment buildings) 54 (family houses)	n/a n/a	60–96 (offices) 34 (schools)	n/a n/a
UK	~44	n/a	n/a	n/a

Maximum primary energy consumption is defined as a percentage of the primary energy consumption (PE) of a reference building. In the Czech Republic, non-renewable primary energy is considered instead of the primary energy. In Belgium Brussels region, the primary energy consumption has to be below (95–2.5) multiplied (*) per (Volume/Surface), that is the compactness, the ratio between the volume enclosed and the loss area. Looking at Table 2, it is evident that the Member States mainly focused on the requirements for new buildings and rarely introduced different limits for existing ones. "Member States shall take the necessary measures to ensure that when buildings undergo major renovation, the energy performance of the building or the renovated part thereof is upgraded in order to meet minimum energy performance requirements set in accordance with Article 4 in so far as this is technically, functionally and economically feasible" [2]. As discussed above, the EPBD recast requires conforming major renovations to new constructions, but some Member States decided to introduce less stringent (and probably more realistic) requirements. This is the case of Bulgaria, Germany, France, Ireland and Slovenia.

Moreover, the majority of Member States consider higher energy requirements for non-residential buildings (which typically consume more energy for cooling and lighting), but in a few cases different energy limits for different non-residential categories have been defined (Table 2). According to a BPIE survey [12], European non-residential buildings can be divided in the following categories: wholesale & retail (28%), offices (23%), educational (17%), hotels and restaurants (11%), hospitals (7%), sport facilities (4%), other (11%). Considering non-residential buildings a single category means that there is no difference in energy consumption among building typologies that significantly differ for occupancy, ventilation rate, lighting, appliances and operation. A variation in energy use by a factor of three can be easily found among offices, hospitals, schools, and retail buildings because of different usage. Considering the great variety of the non-residential buildings typologies stock, this approach (applied by Estonia, France and Slovakia) should be followed by all countries [28]. For example, Estonian values show energy requirement variation between 100 and 270 kWh/m^{2}y for seven non-residential building types.

4. Policies Designed to Target Building Renovations

In accordance with the analysis carried out by Entranze [14], policy measures already in place (business as usual (BAU) scenario) should result in a deep renovation of approximately 2.5% of the EU 28 building stock by 2020 and of around 5%–5.5% by 2030. Effort in more innovative and consistent policy packages should be encouraged with a moderate or strong ambition level. Information, qualification and training are being intensified. Regulatory instruments (RES-H) obligation, obliging new or retrofit building owners having a hot water consumption of more than 2000 L per day to install solar heating panels to cover this energy demand) and enforcement of building renovation are increasingly implemented [29]. A moderate energy tax has been introduced. Budgets for subsidies for building renovation and RES-H are also increasing.

As shown in Figure 4, a moderate additional effort could increase these shares to 3.7% (by 2020) and 8.7% (by 2030) and an ambitious improvement to 5.4% and 14.4%. Strong effort is seen in more innovative and consistent policy packages, with a high policy impact. Information, qualification and training are spreading, leading to a comprehensive coaching and support of building owners. Split incentive is addressed in the legal framework leading to a reduction of this barrier towards NZEBs. An energy tax is introduced and accompanied with social measures to support in particular low-income households. Budgets for subsidies for building renovation and RES-H are also increasing.

A key issue is the development and the adoption of new national policies, but no less important is the guidance of the European Commission. Stakeholders are asking for a clear guidance for NZEBs renovation, to be possibly followed up in the coming EPBD review. Moreover, several experts point out that the net yearly primary energy indicator is insufficient to characterize NZEBs. Hermelink et al. [30] proposed to implement several indices for a more complete and correct description and ranking of NZEBs.

Most Member States did not describe in a detailed way the policies and measures that would lead to the NZEB level in refurbishments. Reported policies appear in line with the EPBD recast requirements, but these legislative and normative measures rarely explicitly refer to a clear definition of an NZEB renovation.

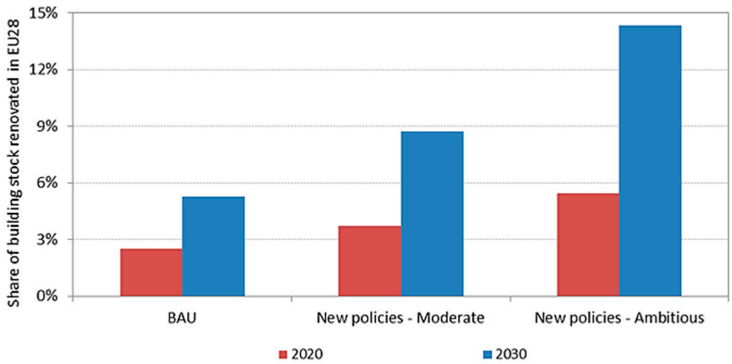

Figure 4. Share of EU 28 building stock renovated deeply (or to an NZEBs level) by 2020 and 2030, varying the policy scenario. Source: elaboration from Entranze [20].

Non-residential buildings account on average for 25% of the total EU stock, representing a heterogeneous sector compared with the residential. Due to fragmentary data on this sector, the development of effective policies to reduce energy consumption in non-residential buildings is more challenging. Legislative measures have a considerable role also in this sector, but unlike the residential sector, their role is not quite as dominant [31].

This sector is responsible for a large percentage of total EU final energy consumption (Figure 5), being a growing energy consuming sector, especially in relation to commercial and hospitals buildings.

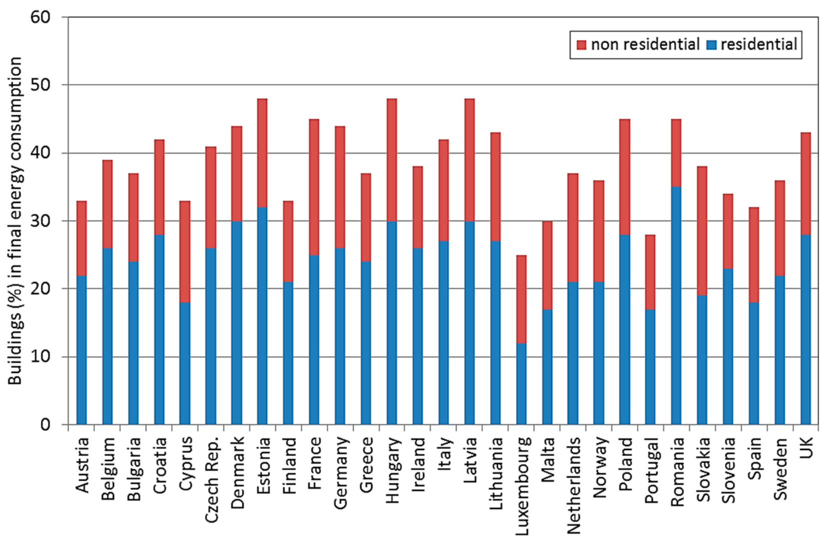

Figure 5. Share of buildings in final energy consumption in Europe. Source [32].

In the non-residential sector, energy consumption related to lighting, ventilation, heating, cooling, refrigeration, IT equipment and appliances vary greatly from one category to another [33]. Over the last decades, electricity consumption in non-residential buildings has increased in average by 74%. This is mainly due to technological advances, which saw a growing penetration of IT equipment and air conditioning systems [34].

In order to summarize recent improvements towards the effective support of deep and NZEB renovation with a special focus on non-residential buildings, several data sources have to be considered. For this analysis we refer to: (i) the Odysee-Mure database including around 2000 energy efficiency policy measures (including their impact); (ii) the third NEEAPs provided by Member States in mid-2014 including descriptions of the new measures adopted; and (iii) the first renovation strategies in line with Article 4 of the EED that Member States had to provide by April 2014.

Successful policy measures have been selected from Odysee-Mure, considering 225 measures explicitly related to the renovation of existing buildings. The most recent ones, adopted in the last 10 years have been selected focusing on those with a medium or high impact. The most interesting ongoing or proposed measures are selected and an overview of policies explicitly referred to non-residential stock (i.e., tertiary) is shown in Table 3.

Table 3. Ongoing and proposed policy measures on non-residential building renovation with medium or high impact, extracted from the Odysee-Mure database [31].

Country	Sector	Measure Title	Status	Type	Starting Year
Belgium	Residential and Tertiary	Brussels—Develop and promote exemplary buildings—BATEX (with virtually zero consumption and of high environmental quality)	Ongoing	Financial	2007
Bulgaria	Tertiary	National Strategy for financing the building insulation for energy efficiency 2006–2020—services	Ongoing	Financial, Legislative, Informative	2006
Estonia	Tertiary	A programme for reconstruction of public sector buildings	Ongoing	Financial	2009
Spain	Residential and Tertiary	State Plan 2013–2016 for Rental Housing, Housing Rehabilitation, and Urban Regeneration and Renewal	Ongoing	Financial	2013
	Tertiary	Action Plan 2008–2012: Energy Saving and Efficiency Plans in Public Administrations	Ongoing	Information-Education-Training, Legislative-Informative	2008
Finland	Tertiary	Renovation of State Property Stock	Ongoing	Information-Education-Training	2009
France	Residential and Tertiary	Energy Savings Certificates (ESC)	Ongoing	Financial	2006
	Tertiary	"Moderning building and cities" programme	Ongoing	Financial, Legislative-Informative	2008
Croatia	Tertiary	Energy reconstruction of commercial non-residential buildings	Ongoing	Financial	2011
	Tertiary	Energy renovation of commercial non-residential buildings	Ongoing	Financial	2012
Lithuania	Tertiary	EU Structural Funds 2007–2013	Ongoing	Financial	2007
	Tertiary	Renovation of State institutions	Unknown	Financial	2014
Latvia	Tertiary	Increasing Energy Efficiency in State (Central Government) Public Buildings: EU Programming Period of 2014–2020	Proposed	Financial	2015
	Tertiary	Increasing Energy Efficiency in Municipal Buildings: EU Programming Period of 2014–2020	Proposed	Financial	2015
Slovenia	Tertiary	Financial incentives for energy-efficient renovation and sustainable construction of buildings in the public sector	Ongoing	Financial	2008

According to the EED, Member States are requested to provide within their renovation strategies an overview of policies and measures to stimulate cost effective deep renovations of buildings, in particular to: (a) give an appraisal of existing measures/policies in Member States; (b) provide an analysis of existing barriers to deep building renovation; (c) give an appraisal of relevance of policies used in other territories; and (d) provide a design of new policy landscape that addresses barriers and enables the delivery of the required ramp up in deep renovation activity, with a particular focus on those measures that need to be introduced within the next three years.

Member States addressed quite exhaustively Article 4 requirements, providing a comprehensive set of policy designed to address the identified barriers [35]. As shown in Figure 6, there is a great heterogeneity of policy packages in Europe, both in terms of absolute number and in terms of policy type, with a predominance of financial/fiscal and regulatory measures.

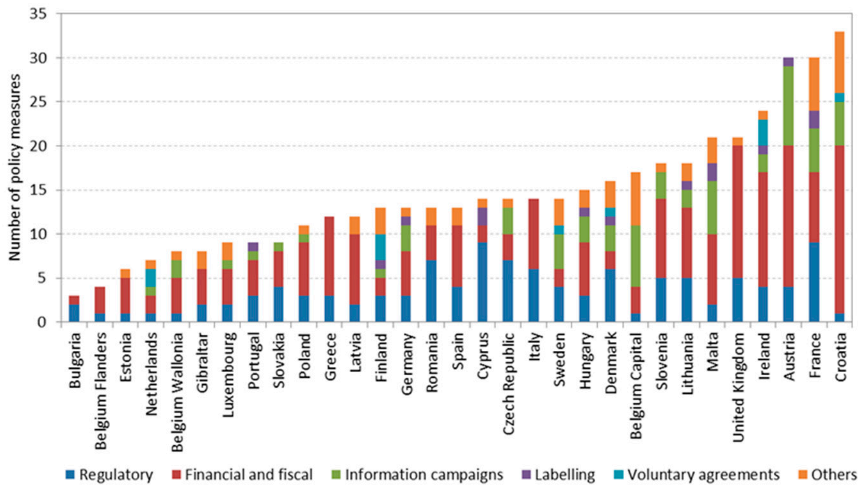

Figure 6. Number of all the measures in the building sector (implemented and planned) by country and type.

Regulatory measures are mostly composed of requirements related to the EPBD and more specifically on minimum energy performance requirements for new and existing buildings. Nearly all Member States include information on the most recent building regulations and very few of them referred to further improvements in their building codes, strengthening the energy standards to be met during building construction and renovation. As example, Denmark reports various upgrades in energy requirements for new buildings and specific requirements for envelope, windows and installations, while Austria states that on-going adjustments are in place for building regulations. Other examples of countries with measures tightening energy performance standards include Ireland and the Netherlands. Other building regulations mentioned in the strategies include inspections of water boilers and air conditioning systems (e.g., Bulgaria, Cyprus, Italy, Croatia and France).

Specific regulatory measures for the services sector include the Luxembourgish scheme which introduces specific energy efficiency requirements for lighting in new non-residential buildings. The Netherlands has an Environmental Management Act for non-residential buildings which places a legal obligation to take energy-saving measures with a payback time of less than five years. The obligation applies for large or medium-sized companies with an energy consumption of more than 50,000 kWh and 25,000 m^3 gas per year and also for non-residential buildings including offices, healthcare institutions and schools.

All Member States have reported financial and fiscal measures supporting energy efficiency improvements in the residential and non-residential sectors. Specific measures for services include the Greek financial incentive scheme for energy upgrading of commercial buildings. Ireland ran a grant scheme for exemplar projects in the public and business sectors, offering support for sustainable energy upgrades to buildings, services, facilities and processes. Ireland also provides on-going advice, mentoring and training in energy management to small and medium-sized enterprises (SMEs) in the commercial sector since 2008. The Energy Investment Allowance enables companies to deduct energy efficiency investments from their taxable profit. In Sweden, aid is provided to small and medium-sized enterprises in the form of energy audit checks. This aid may be granted to enterprises with energy consumption over 500 MWh per annum.

Market-based instruments in the residential and non-residential sectors are mainly in the form of Energy Efficiency Obligation Schemes. Austria, Flanders region of Belgium, Bulgaria, Denmark, France, Italy, Ireland, Latvia, Luxembourg, Malta and the United Kingdom have energy efficiency obligation schemes which target these sectors.

About the new policy measures that Member States are implementing to reduce the energy consumption of the existing building sector, information can be found in the third NEEAPs. Table 4 lists the main information referred to non-residential buildings and distinguished by country and typology.

Table 4. New measures on the building renovation of non-residential buildings included in the 3rd NEEAPs. NEEAPs: National Energy Efficiency Action Plans; ESCOs: Energy Savings Companies; PAREER: Aid Programme for the Energy Renovation of Existing Buildings; and NEEF: National Energy Efficiency Funds.

Country	Measure Type	Description
Germany	Financial	Additional funding for energy-related building renovation is secured from 2013 onwards with extra Development Bank KfW (Kreditanstalt für Wiederaufbau) grants of €300 million. To promote not only the energy-efficiency of residential buildings, but also of commercial and municipal buildings, the state-owned promotional bank KfW will increase support for energy-efficient renovations of commercial and municipal buildings.
Greece	Financial	Greece plans to carry out Energy performance improvements of services buildings through ESCOs in the period 2015–2020 where 3000 buildings should be renovated through ESCOs.
Spain	Financial	The PAREER approved in September 2013, aimed at buildings used for housing and in the hotel industry. With a budget of €125 million, it promotes integrated energy efficiency improvement and renewable energy measure in the stock of existing buildings by awarding grants and repayable loans to projects.
Ireland	Financial	A NEEF has been established in March 2014 (€35 million committed by government) with the objective of directly assisting energy efficiency upgrades in the commercial and public sectors.
Italy	Financial	An incentive scheme for the promotion of renewable thermal energy and energy efficient heating (also known as "Conto Termico") started in 2012. This measure partly overlaps with the existing tax credits scheme, meaning that a large series of measures implemented by private actors can be eligible both for tax credits and incentives available under the "Conto Termico".
Lithuania	Financial	An existing public building renovation scheme will be refinanced for a new period (2014–2020). Specifically, a grant scheme, financed through EU structural funds will target renovations of central government buildings and improvements in the energy performance of municipal buildings.

5. Conclusions

The existing EU building stock is old and inefficient and renovated at a slow pace. Building retrofit is one of the biggest challenges that Europe is facing also because different typologies, climates, construction materials and systems characterize its stock. In the framework of the EPBD and EED Directives, Member States have to develop and adopt specific actions with a view to achieving the great unrealized buildings energy saving potential. Several benefits are linked to this improvement, among them: energy security, job creation, fuel poverty alleviation, health and indoor comfort.

The attention given to NZEBs increased over the last decade due to the great potential to decrease energy consumption and increase renewable production. Different possible retrofit definitions (e.g., minor, deep, major and NZEB renovation) exist and are discussed in this paper to clarify their meaning and objectives.

The paper highlights how NZEB renovation implies a new holistic approach, which considers the building lifecycle and its impact on the environment, and includes renewable production, while deep renovation has a more pragmatic approach mainly focused on reducing energy consumption. Results show how only a few Member States are developing NZEB definitions specifically addressed to the retrofit of existing buildings, and it is not clear how the existing measures will be adapted to specific NZEB requirements. A huge variability can be found among European countries also in relation to energy performance requirements and calculation methodologies available around NZEBs.

In recent years, most Member States introduced measures addressed to the energy improvement of the existing building stock and new strategies have been defined, in compliance with the EED. As a result, Member States are more aware of the huge impact of the existing building stock, but they need to further strengthen the adopted measures to successfully stimulate cost-effective renovation.

Renovation strategies analysis reveals that only a few Member States have planned new measures for energy efficiency in buildings, while the vast majority refers to already existing policies. Member States should effectively develop new detailed measures both to overcome the existing barriers towards retrofit and to guide investment decisions in a forward-looking perspective. The effectiveness of existing policies, as well as new ones, should be better evaluated in most countries. Member States should provide more information and measures specifically targeted to NZEBs renovation and designed for the non-residential stock. Results demonstrate that this sector is characterized by fragmented data, several typologies and high energy consumptions, making the development of effective policies to reduce energy consumption more challenging.

Member States need to design consistent policy instruments (policy packages considering technical, economic and financial aspects) to provide the required long-term stability to investors in efficient buildings. There is also the need to adopt detailed roadmaps towards NZEBs, including quantitative targets, and implement monitor systems to obtain consistent data on policy impacts towards a comprehensive retrofit implementation.

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