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Progress of the Member States in implementing the Energy Performance of Building Directive

Zangheri, P.
Castellazzi, L.
D'Agostino, D.
Economidou, M.
Ruggieri, G.
Tsemekidi-Tzeiranaki, S.
Maduta, C.
Bertoldi, P.

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Contents

Abstract

Overall, the EPBD policy framework laid down the foundation for: i) setting cost-optimal minimum energy performance standards in new buildings and existing buildings under major renovation; ii) ensuring that prospective buyers or renters are well informed through Energy Performance Certificates and thereby encouraged to choose higher than minimum standards in their decision making processes; iii) speeding up the rate at which investors engage in energy efficiency projects through national long-term renovation strategies and finance mechanisms.

In accordance with the policy assessment of 2017 it is expected that the EPBD is likely to deliver the expected impacts by 2020, with 48.9 Mtoe additional final energy savings and a reduction of 63 Mt of CO_2. However, the new Climate agenda set higher ambition targets and together with the Covid-19 crisis, the scenario has changed consistently and the next decade will be very challenging. The energy renovation of buildings can be a pillar of both the European decarbonisation process and the economic recovery after the pandemic.

This report provides a snap shot of the EPBD implementation progresses by Member States over the last years. In particular, the focus is mainly on: cost-optimal calculations to set minimum energy performance requirements, Energy Performance Certificates (EPC), Nearly Zero-Energy Buildings (NZEB), financial incentives and market barriers, Long-term Renovation Strategies (LTRS). In order to contextualize the European scenario, some general trends are presented and discussed in the introduction.

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Authors

Zangheri, Paolo conceived and designed the analysis and wrote Chapters 1, 2.1 and 2.3.

Castellazzi, Luca wrote Chapter 2.6.

D'Agostino, Delia and Maduta, Carmen wrote Chapter 2.4.

Economidou, Marina wrote Chapters 1.1.1 and 2.5.

Ruggieri, Gianluca wrote Chapter 2.2.

Tsemekidi-Tzeiranaki, Sofia wrote Chapter 1.1.2.

Bertoldi, Paolo reviewed the report.

Executive summary

Policy context

The building sector plays a key role in the long-term strategy on the reduction of greenhouse gas emissions for the European Union. The main pathways to an EU decarbonised building stock are designed under the Energy Performance of Building Directive 2010/31/EU (EPBD)[1] and focus on setting cost-optimal minimum energy performance requirements, promoting high energy efficient buildings, strengthening the Energy Performance Certificate scheme and developing long-term renovation strategies with the view of mobilising energy efficiency investments in residential and commercial buildings.

Main findings

The study indicates that during the period 2005-2018, the final energy consumption of the building sector decreased by 5%. In the residential sector, improvements in energy efficiency as well as warmer winters have led to a 10% reduction in the final energy consumption while in the services sector, the final energy consumption increased by 2% mainly due to economic growth. However, the renovation rate is still very low. For residential buildings, the annual weighted energy renovation rate[2] was estimated to 1.0% while the rate of deep renovation is much lower with values around 0.2%.

The review on the implementation of cost-optimal minimum energy performance requirements indicates that all Member States implemented the EPBD requirements. Normally as energy performance indicator each State referred to the one already used, to which over time it has added the primary energy consumption.

Moreover, the assessment of the Members States progress in implementing the cost optimal calculation reports a rather positive picture regarding the conformity with the requirements of the Delegated Regulation No. 244/2012[3]. The main gaps are registered for the calculations' scope, the derivation of cost-optimal levels, and the definition of a plan to reduce the gap.

The share of energy certified buildings across Member States is still very low. Only about 10% of the existing buildings have an Energy Performance Certificate. The main identified issues are related to lack of access to reliable information, quality and fair pricing of EPCs, diminishing the trust in this tool. Even though the use of EPCs generally improved after the EPBD recast, it is clear that further changes are needed to make EPCs a reliable information source.

The report reveals that currently 25 Member States have in force a complete Nearly Zero Energy Building definition. NZEB requirements are currently 70% lower than the national minimum energy performance requirements in 2006 showing a consistent trend in increasing building energy efficiency. Moreover, in comparison with cost-optimal levels the NZEB requirements are significant lower (about -50%) of cost-optimal references, implying that Member States may refer to the cost-optimal approach to define the NZEB requirements.

The assessment of the first 15 submitted LTRSs highlights that almost all the Member States provide a good overview of the building stock and policies to stimulate cost-effective deep renovation, to target worst performing buildings and public buildings and to alleviate energy poverty. However, less than half of the strategies provide a clear roadmap towards a decarbonised building stock by 2050 while the majority present a high level of ambition, not always supported by comprehensive policies.

The overview of the financial and fiscal instruments supporting energy renovation of buildings across the EU highlights that up until 2019, grants and subsidies were deployed in almost all Member States, representing the main type of public policy support. Soft loans were available in half of the EU countries supported by state guarantees or designed as revolving funds while several Member States offered incentives in the form of income tax incentives or VAT reduction schemes.

Related and future JRC work

While this report offers an overview of the mains aspects monitored in the implementation of the EPBD, each aspect has been closely examined by the JRC and the analyses are presented in related reports mentioned in this document.

Quick guide

Chapter 1 presents the general context and the key trend over the last years in the energy performance of buildings. Chapter 2 provides an overview on the progress of Member States in implementing the EPBD in the last years. It brings to the fore the cost-optimal calculations to set minimum energy performance requirements, the Energy Performance Certificates, the Nearly Zero Energy Buildings, financial incentives and market barriers and finally the Long-term Renovation Strategies. Chapter 3 draws general conclusions.

[1] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32010L0031

[2] For the calculation of the weighted energy renovation rate indicator, "below threshold" renovations rates have been also taken into account.

[3] European Parliament, 2012a, European Parliament (2012a). Commission Delegated Regulation (EU) No 244/2012 of 16 January 2012 supplementing Directive 2010/31/EU of the European Parliament and of the Council on the energy performance of buildings by establishing a comparative methodology framework for calculating cost-optimal levels of minimum energy performance requirements for buildings and building elements, Official Journal of the European Union.

1 Introduction

Buildings are responsible for approximately 40% of EU energy consumption and 36% of the energy related greenhouse gas emissions. Buildings are therefore the single largest energy consumer in Europe. At present, about 35% of the EU's buildings are over 50 years old and almost 75% of the building stock is energy inefficient. At the same time, only about 1% of the building stock is renovated each year.

The first cohesive European legal act on energy policy in buildings was the Energy Performance of Buildings Directive (EPBD, 2002/91/EC). Introduced in 2002, it aimed to tap into the large cost-effective saving potential of the sector (namely 22% in a 10-year period) underlined by several Commission Communications[4]. With this initiative, the European Union transposed a key article of its founding Treaty[5] (new Article 191 on environmental protection), based on the idea to, inter-alia, improve the security of energy supply, increase employment and eliminate large differences observed between Member States.

The EPBD introduced a joint energy performance calculation methodology for buildings. Among other, the following main areas of action were could be mentioned:

- national minimum requirements and specific energy performance measures for new buildings and large existing buildings undergoing major renovation;
- specific provisions for the set-up of mandatory national energy performance certificate (EPC) schemes for both new and some categories of existing buildings, including the need to display EPCs in large public buildings;
- conditions for the inspection of boilers and heating/cooling systems, made by qualified and accredited experts.

In accordance with the European subsidiarity principle and considering the local peculiarities and climatic differences, Member States were asked to transpose the EPBD provisions within a three year period. Given the novelty of the Directive, in particular in relation to building codes and certification schemes (Fokaides et al., 2017), the progress of the transposition in several Member States was rather slow (Dascalaki et al., 2012; Fokaides et al., 2017; Blumberga et al., 2018). Member States were therefore given the possibility to apply for an additional period of three years (until 2009) to comply with the provisions of the Directive.

After the official transposition by the Member States (due by 4th January 2006) and the first years of implementation, the Commission started to evaluate the Directive in light of the experience gained during its application.

In 2009 the European Commission presented the recast of the EPBD[6] (2010/31/EC, EPBD Recast) with the aim to strengthen some original EPBD provisions and capture additional energy savings as stated in the 2006 Action Plan[7]. The main purpose of the EPBD recast was to ensure that national Minimum Energy Performance Requirements adopted by Member States had similar ambition levels in terms of energy savings and greenhouse gas emissions reduction. This is because some national standards were not ambitious and cost-effective enough (Ó Broin et al., 2015). To this end, Article 5 of the EPBD recast introduced the cost-optimal methodology as the guiding principle for setting building energy requirements and Article 9 introduced the concept of "Nearly Zero-Energy Buildings" (NZEBs) according to which all new private buildings will have to comply with nationally defined NZEB standards by January 2021 (for public buildings the requirement applies as of January 2019).

The EPBD recast also eliminated the threshold of 1,000 m^2 for existing buildings under renovation to meet energy performance standards and installation requirements. In addition, energy performance requirements were introduced for technical building systems (heating, hot water, ventilation, cooling, air conditioning). The provisions related to the EPCs and inspection of heating and air-conditioning systems were reinforced to make them more effective. The EPBD recast aimed to raise the importance of financial incentives to promote energy renovations and required Member States to identify and submit to the Commission national financial measures to improve energy efficiency. From the Commission's side, support was made available in terms of structural funds, European Investment bank funds and other EU funds.

In order to implement the Energy Union Strategy[8], in November 2016 the Commission adopted a package of measures (the Clean Energy for all Europeans Package) to revise the EED and EPBD and align them to the new 2030 energy and climate targets. The EPBD amendment procedure started at the end of 2016 and ended on 30 May 2018 with the approval of the amending Directive 2018/844/EU. The evaluation of the EPBD concluded that the general objective, framework and boundary conditions of the EPBD remain relevant, and it was likely to deliver the expected impacts by 2020, with 48.9 Mtoe additional final energy savings and a reduction of 63 Mt of CO_2.

On 19th June 2018 the new Directive (2018/844/EU, EPBD) was published and the revised provisions entered into force on 9th July 2018. This revision introduces targeted amendments to the current EPBD aimed at accelerating the cost-effective

[4] COM (2001) 226, COM (2000) 769 of 29 November 2000 and COM (2000) 247 of 26 April 2000

[5] https://eur-lex.europa.eu/collection/eu-law/treaties/treaties-force.html

[6] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32010L0031

[7] Commission of the European Communities 2006. Communication from the Commission, Action Plan for Energy Efficiency:Realising the Potential, Brussels, 19.10.2006 COM(2006)545 final

[8] COM/2015/080 final

renovation of existing buildings, with the aim of a decarbonized building stock by 2050 and the mobilization of investments to reach this goal (Thonipara et al., 2019) through national long-term renovation strategies. The revision also supports electro-mobility diffusion by mandating electro-mobility infrastructure deployment in buildings' car parks. It also introduces new provisions to enhance smart technologies and technical building systems, including building automation and an optional scheme for rating the smartness of buildings.

The Commission also launched a new buildings database – the EU Building Stock Observatory[9] – to track the energy performance of buildings across Europe. In order to stimulate and increase the level of direct investment towards the renovation of the building stock, the Commission launched the 'Smart Finance for Smart Buildings' initiative, which aims to unlock an additional EUR 10 billion of public and private funds.

Member States had 20 months to transpose the Directive into national laws (namely by 10th March 2020). In particular, the 2018 EPBD includes the following provisions:

- Member States shall establish more effective long-term renovation strategies (LTRS), identifying indicative milestones for 2030, 2040 and 2050 and measurable progress indicators, an adequate set of financial measures and consulting stakeholders in the preparation and implementation of their strategies;
- Stimulate cost-effective deep renovation encouraging more holistic approaches in energy renovation projects. The possibility of using Building Renovation Passports (BRP) and trigger points in the life of the building is also given. Member States need to identify these trigger points as part of their LTRS and in accordance with national practices;
- The Commission introduced a common European scheme for rating the smart readiness of buildings, which will be optional for Member States;
- Smart technologies and ICT in buildings are promoted, for example through requirements on the installation of building automation and control systems and on devices that regulate the indoor temperature from the building level down to the room level ensuring that buildings operate efficiently;
- E-mobility is supported by introducing minimum requirements for electric recharge points over a certain size of the building and other minimum infrastructure are introduced for smaller buildings;
- Member States shall express their national energy performance requirements in ways that allow cross-national comparisons;
- Health and well-being of building users are promoted, for instance through an increased consideration of air quality and ventilation;
- Combatting energy poverty and reducing the household energy bill by renovating older buildings.

The European Green Deal took a step further by setting the vision for a fair and prosperous society and make Europe carbon free by 2050. It includes a series of initiatives that have a direct impact on the EU policy on energy efficiency and on renewable energy, in particular a plan to increase the EU greenhouse gas (GHG) emission reduction for 2030 towards 55% compared to 1990 in a responsible way.

In the Climate Target Plan 2030 presented on 17 September 2020, the Commission has proposed to cut net greenhouse gas emissions in the EU by at least 55% by 2030 compared to 1990. The ambitious climate agenda of the current Commission provides a clear role for energy efficiency. However, without a significant contribution from the buildings sector, the new energy and environmental goals will not be met. The building sector is one of the areas where efforts must be ramped up.

This is exactly why, among other initiatives, the Commission has announced a Renovation Wave[10] initiative as part of the European Green Deal with the objective to at least double the annual energy renovation rate of residential and non-residential buildings by 2030. The Renovation Wave was published on 14 October 2020 and endorses a holistic approach for the future built environment and lays a foundation (corner) stone of our recovery strategy through a wave of renovations of our homes, of our workplaces, schools, hospitals and public building in order to transform them into healthier, greener, smarter, more accessible, resilient and future-proof buildings.

1.1 General trends

This section describes and discusses some key trends over the last period, related to the energy performance of buildings: i) the final energy consumption of residential and service sector; ii) renovation rate, investment costs and specific primary energy savings.

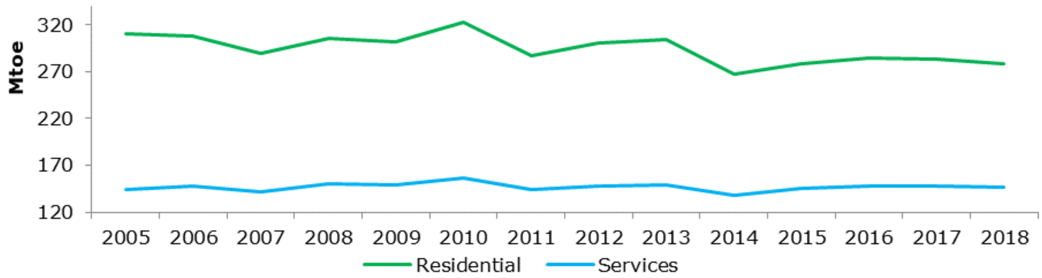
[9] https://ec.europa.eu/energy/topics/energy-efficiency/energy-efficient-buildings/eu-bso_en

[10] https://ec.europa.eu/energy/topics/energy-efficiency/energy-efficient-buildings/renovation-wave_en

1.1.1 Final energy consumption

In the period 2005-2018, the overall final energy consumption of the building sector as a whole has dropped by 5%. Figure 1 shows the individual consumption trends of households and services in the examined period (Tsemekidi-Tzeiranaki, 2020). Whilst the residential sector experienced a drop in consumption corresponding to 10%, services has had the opposite effect, with an increase of 2%.

Figure 1. Final energy consumption of households and services in the EU-28, 2005-2018.

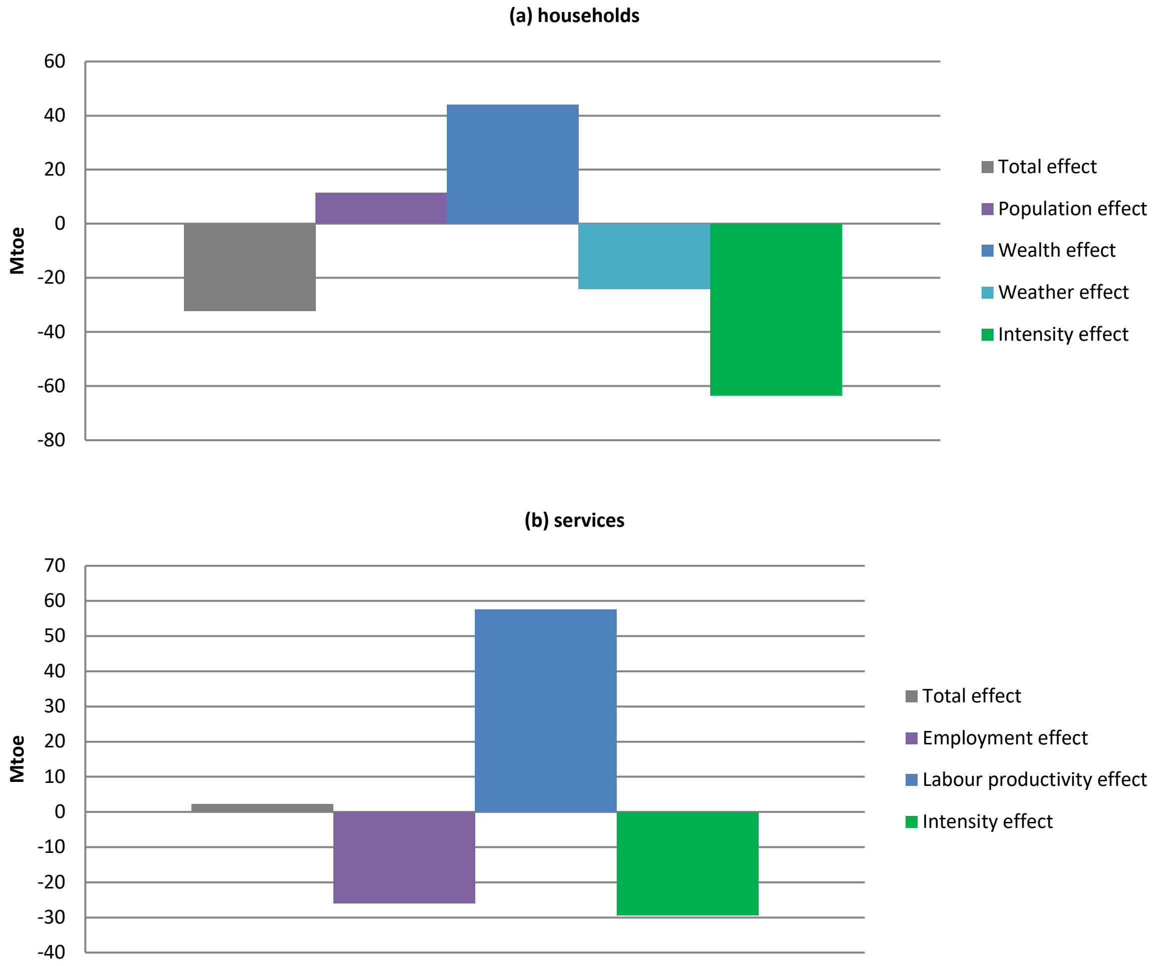


Source: JRC, 2020

The JRC carried out index decomposition analysis, with the aim to identify and quantify possible driving factors and their contributions to the latest energy consumption trends in the EU (Economidou, 2017, Economidou and Roman-Collado, 2019, Economidou, 2020). Index decomposition analysis (IDA) is a widely adopted analytical tool used by researchers (Ang, 2005; Ang, 2015). In particular, the Logarithmic-Mean Divisia Index method (LMDI) method, a widely-used IDA method, was applied to study both aggregated and sectoral energy consumption changes at EU and MS levels over the period 2005–2018. All applications were run using Eurostat data, with a few exceptions where data from other sources were considered. The methodological approach used herein is described by Economidou and Roman-Collado (2019).

In the period 2005-2018, energy consumption of the EU28 residential sector as a whole decreased by 32 Mtoe (Figure 2a). Improvements in energy efficiency (measured as consumption per m^2 for heating and consumption per disposable income for all other uses) contributed to a reduction of −63 Mtoe in this sector (−20% compared to 2005 consumption levels). Warmer winters over this period resulted in an energy consumption drop of −24 Mtoe. Both of these effects more than offset the driving forces behind residential consumption, namely the population and wealth effects which together accounted for an increase of 55 Mtoe in the same period. In particular, increase in population drove up consumption by 11 Mtoe (4% compared to 2005 consumption levels). A more pronounced effect was the one exerted by increase in wealth (expressed using the floor area and disposable income indicators) which was responsible for an increase of 44 Mtoe.

Figure 2. LMDI decomposition results in additive terms for the EU28 (a) households and (b) services in the period 2005-2018.



Source: JRC, 2020

The services sector, representing over three quarters of the EU28 gross value added, is the only productive sector of the economy whose energy consumption increased over the examined period, albeit in a very mild manner. In 2018, the energy consumption of services was above the 2005 consumption levels by 2 Mtoe (corresponding to a +2% increase). While services represent one of the least intensive productive sectors of the economy —responsible for just over three quarters of GVA and just one third of the consumption of industry, services and agriculture combined—, it is the fastest growing productive sector both in terms of energy and economic output. The decomposition results show that the economic growth in services in 2005-2018 (i.e. the combined effect of labour effect and labour productivity effect) was the main factor that led to the increase in total energy consumption. That is, if other effects would not have come into play, economic growth would have driven up the energy consumption of services by 32 Mtoe. However if activity effect is broken down into labour effect (hours worked) and labour productivity effect (GVA/hours worked) as shown in Figure 2b, opposite forces are revealed. At EU level, the labour effect is negative (-26 Mtoe) over the examined period due to lower global number of hours worked over time. On the other hand, the labour productivity effect indicates an increase in energy consumption due to an improvement in productivity (58 Mtoe). This may be attributed to more capital intensive processes, which means that the global increase of labour productivity contributes to lower number of hours worked per unit of output produced and, hence lower energy requirements to produce the same output. Intensity gains (measured as consumption per GVA) over this period drove down energy consumption by 29 Mtoe It should be noted that structural changes in the economy cannot be analysed at the current stage due to input data limitations. Having the possibility to include structural and/or weather effects, it would likely mean the intensity effect of the services sector would be of lower magnitude.

1.1.2 Renovation and investment

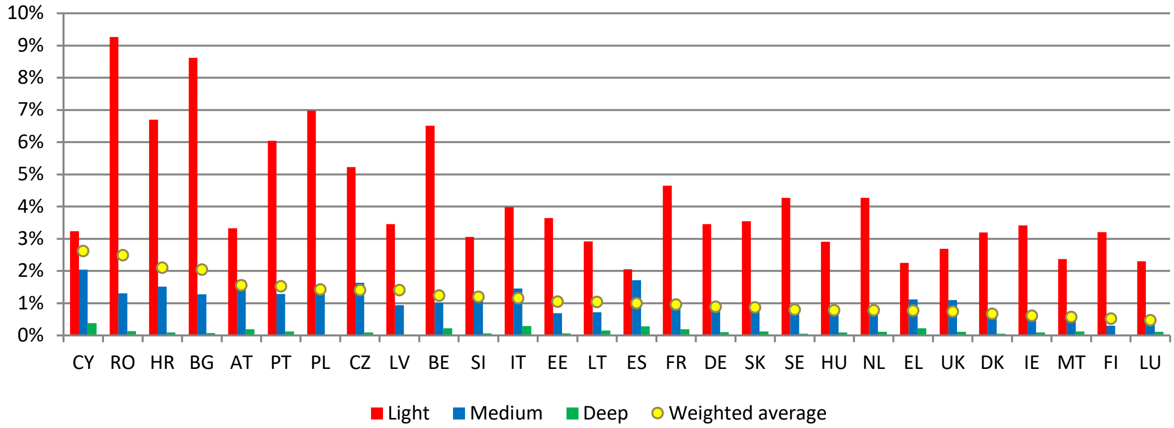
Renovation rate, investment costs and specific primary energy savings are the quantitative indicators analysed in this section, reflecting the energy-related building renovation activities in the EU-28, as found by a recent European study[11]. The results of the indicators are analysed for both residential and non-residential buildings. In addition, these indicators are analysed for different renovation levels (light, medium, deep), and a weighted average of the different renovation level range is provided. The results cover the period 2012-2016 and average annual values for this period are presented.

Renovation rates

Renovation rates for residential buildings in all the Member States decline from 'light", to 'medium" renovation level and from 'medium' to 'deep' renovation level. The renovation rate of deep renovations in the EU28 is only around 0.2%, with relatively small variation when looking at individual Member States. The highest renovation rates for deep renovations are identified in Cyprus (0.38%) and Spain (0.28%) (Figure 3).

For residential buildings, the annual weighted energy renovation rate[12] was estimated to 1.0%. Results show important variations between Member States. In general, values are higher in Eastern – European Member States, possibly as a result of the high renovation rates on light renovations. To note that Cyprus, Romania, Croatia and Bulgaria recorded weighted energy renovation rates higher than 2% (Figure 3).

Figure 3. Renovation rates in residential buildings in the EU28 Member States by renovation level, annual average 2012-2016.



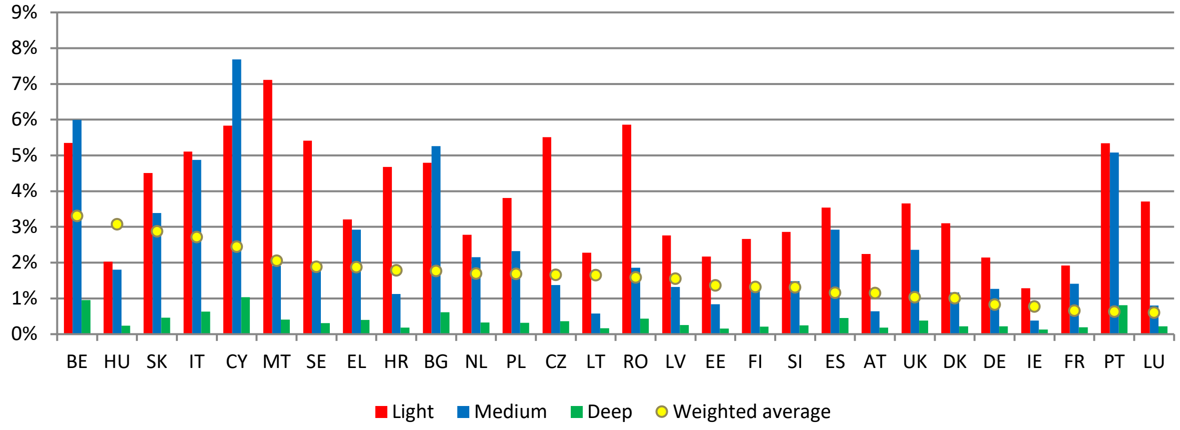
Source: JRC, 2020

Renovation rates for non-residential also decline from 'light", to 'medium" renovation level and from 'medium' to 'deep' renovation level in almost all the Member States. However this is not the case for Belgium, Bulgaria and Cyprus where 'medium' renovation rates are higher than 'light' ones. The renovation rate of deep renovations in non-residential buildings in the EU28 is 0.3%, while the 'deep' renovation rates in Member States range from 0.13% in Ireland to 1.04% in Cyprus (Figure 4). For non-residential buildings, the annual weighted energy renovation rate was estimated to 1.2%. Like for deep renovations, the weighted average also shows variations between Member States ranging from 0.6% in Luxembourg to 3.3% in Belgium (Figure 4).

[11] https://ec.europa.eu/energy/sites/ener/files/documents/1.final_report.pdf

[12] *For the calculation of the weighted energy renovation rate indicator, "below threshold" renovations rates have been also taken into account.*

Figure 4. Renovation rates in non-residential buildings in the EU28 Member States by renovation level, annual average 2012-2016.

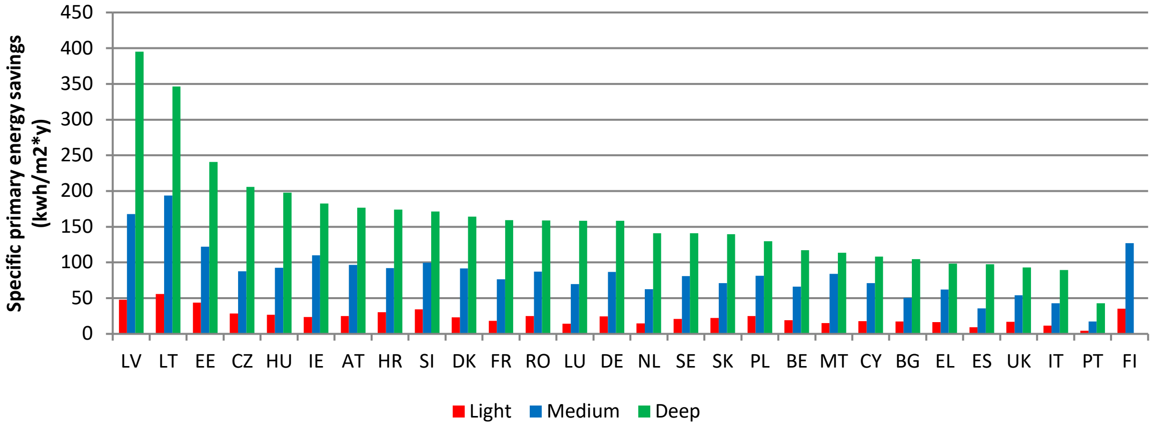


Source: JRC, 2020

Savings

The specific annual primary energy savings per residential, taking the average of the energy renovations across the EU28 that took place between 2012 and 2016, is estimated to be 19.4 kWh/m^{2}y for 'light' renovations, 64.1 kWh/m^{2}y for 'medium' renovations and 121.8 kWh/m^{2}y for 'deep' renovations. As expected, 'light' renovations result in less energy savings in all the Member States, followed by 'medium' renovations while 'deep' renovations produced the highest amount of savings in all the cases.

Figure 5. Specific primary energy savings in residential buildings in the EU28 Member States by renovation level, annual average 2012-2016.



Source: JRC, 2020

Differences can be observed between Member States (Figure 5). Latvia, Lithuania and Estonia recorded the highest values for specific primary energy savings from 'deep renovations' (395.2 kWh/m^{2}y, 346.2 kWh/m^{2}y, 340.9 kWh/m^{2}y respectively) while the same 3 countries registered values higher than 100 kWh/m^{2}y for savings from 'medium' renovations and higher than 40 kWh/m^{2}y for savings from 'light' renovations. On the other hand, Portugal recorded the lowest values for energy savings generated from all three levels of energy-related renovations[13].

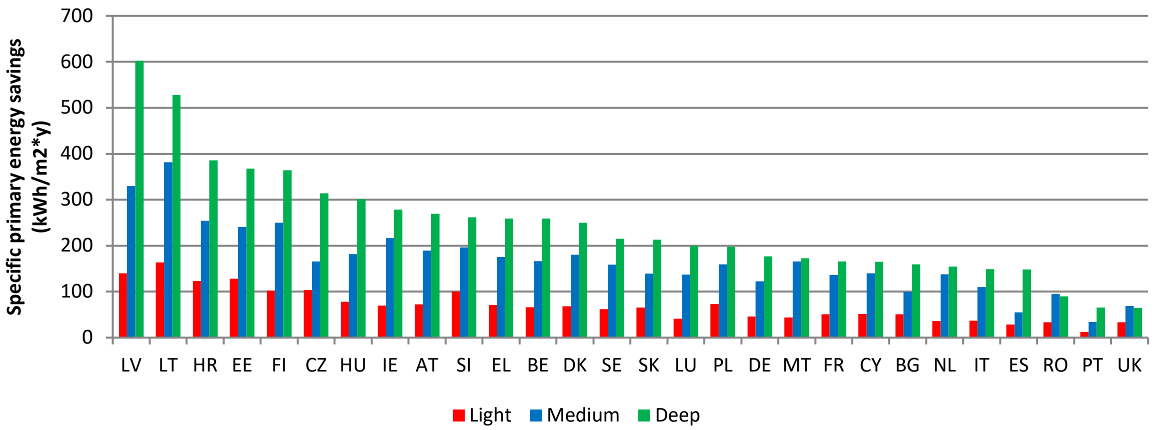
From energy renovations of 'light' renovation level in non-residential buildings, EU-28 generated 49.7 kWh/m^{2}y of specific primary energy savings. From energy renovations of 'medium' renovation level, it generated 116.3 kWh/m^{2}y while energy renovations of 'deep' renovation level resulted in 167.1 kWh/m^{2}y specific primary energy savings. As seen in Figure 6, some

[13] Not available data for savings from 'deep' renovations in Finland.

Member States (Romania, the United Kingdom), register slightly higher energy savings values from their 'medium' renovation than from 'deep' renovations while like in residential buildings, all the Member States produced the lowest amount of savings from 'light' renovations.

Comparing Figure 5 and Figure 6, it is observed that in general energy-related renovations in non-residential buildings produced more specific primary energy savings than in residential buildings. Regarding Member States, there are significant differences in generated energy savings. Like in residential buildings, Latvia and Lithuania recorded the highest values for savings from all levels of renovations. Portugal registered the lowest values for savings from 'light' and 'medium' renovation while the United Kingdom registered the lowest value for savings from 'deep' renovations.

Figure 6. Specific primary energy savings in non-residential buildings in the EU28 Member States by renovation level, annual average 2012-2016.

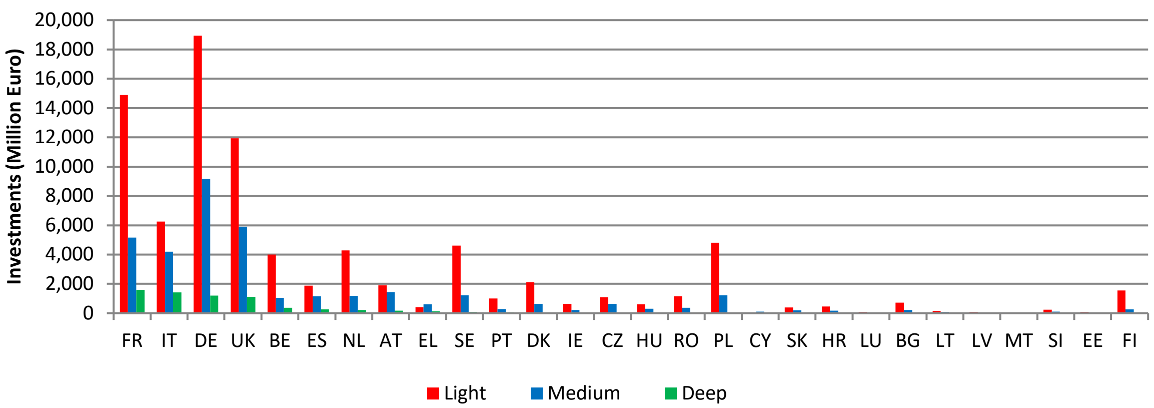


Source: JRC, 2020

Investments

Based on the Commission's study, for the period 2012-2016, it is estimated that more than 127 billion Euros for energy renovations on average per year for all renovation levels have been invested in the EU-28 (84.4 billion Euros for 'light' renovations, 36 billion Euros for 'medium' renovations and 6.9 billion Euros for 'deep' renovations. The largest amount of Euros has been invested in Germany (29298.8 million Euros for the sum of the renovation levels) followed by France (21650.2 million Euros) and the United Kingdom (18955.4 million Euros). On the other hand in Malta and Estonia, the lowest amounts of million Euros have been invested (75.8 and 111.4 million Euros respectively). In almost all the Member States, the amount invested for energy renovations in residential buildings is higher than the respective amount invested in non-residential buildings. Finally, in the case of residential buildings, almost all the Member States (except Cyprus and Greece) have invested the largest amount of Euro for 'light' level renovations (Figure 7).

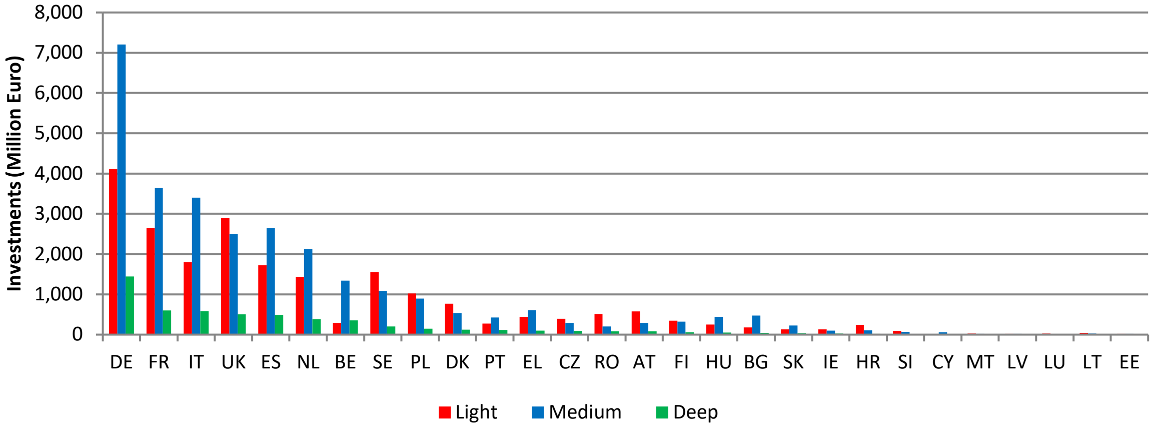
Figure 7. Investments costs in residential buildings in the EU28 Member States by renovation level, annual average 2012-2016.



Source: JRC, 2020

In the non-residential buildings, for the period 2012-2016, average annual investments in energy renovation are estimated to be about 22 billion Euros for 'light' renovations, 29.1 billion Euros for 'medium' renovation and 5.6 billion Euros for 'deep' renovations in EU-28. The largest amount of Euros has been invested in Germany (12579.4 million Euros for the sum of the renovation levels) followed by France (6896.1 million Euros) and the United Kingdom (5902.9 million Euros). On the contrary, in Estonia and Luxemburg, the lowest amounts of million Euros have been invested (38.9 and 30.8 million Euros respectively). As Figure 8 shows, for the half of the Member States, the highest amount of million Euros, has been invested for 'Medium' level renovations.

Figure 8. Investments costs in non-residential buildings in the EU28 Member States by renovation level, annual average 2012-2016.



Source: JRC, 2020

2 Progresses of Member States on key EPBD requirements

This section discusses some updates about the implementation of the main EPBD articles by the Member States. The information presented was mainly collected by analysing the progress reports provided by the national (or regional) governments to the Commission, accordingly with the EPBD timeline.

2.1 Cost-optimal minimum energy performance requirements

The adoption of the cost-optimal minimum energy performance requirements in buildings represented a major step forward (Papadopoulos, 2016) despite the existence of some prior experience in a small group of countries comprising Germany, France, UK, Denmark, Italy and the Netherlands. This early adopter group moved from the "first" generation of building codes in the 1970s-1980s (mainly consisting of thermal insulation requirements in the form of U-values) to the "second" generation of integrated building codes in the late 1990s. The second generation was developed with a view to regulate energy performance of buildings in a more holistic approach and give freedom to building designers to meet a targeted energy performance in function of building requirements, costs and other factors (Sorrell, 2015; IEA, 2017). The EPBD aimed to bring up to speed all Member States and set a common approach on the calculation of energy performance of buildings with a view to achieving cost-optimal levels. (Serrano et al., 2017). Under the EPBD provisions, the minimum energy performance requirements applied to both new and existing buildings under major renovation, where energy performance of a building was defined as the amount of consumed or 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; (typically measured in KWh/m^2 per year). This amount had to be reflected in one or more numeric indicators, taking into account:

- outdoor and indoor climatic conditions;
- position and orientation of the building ,including outdoor climate;
- thermal characteristics of the envelope (including thermal capacity, insulation, passive heating, cooling elements, thermal bridges and air-tightness);
- passive solar systems and solar protection;
- own-energy generation;
- heating installation and hot water supply, including their insulation characteristics;
- air-conditioning installations;
- natural and mechanical ventilation which may include air-tightness;
- built-in lighting installation (mainly in the non-residential sector);
- internal loads.

All Member States implemented the EPBD requirements, by introducing new legal acts or updating the existing ones. Normally as energy performance indicator each State referred to the one already used, to which over time it has added the primary energy consumption. Table 1 lists the indicator(s) used and the legal act introducing the last cost-optimal minimum energy performance requirements before the advent of NZEBs.

Table 1. Performance indicators used to set up the minimum energy performance requirements and last legal act approved by Member States.

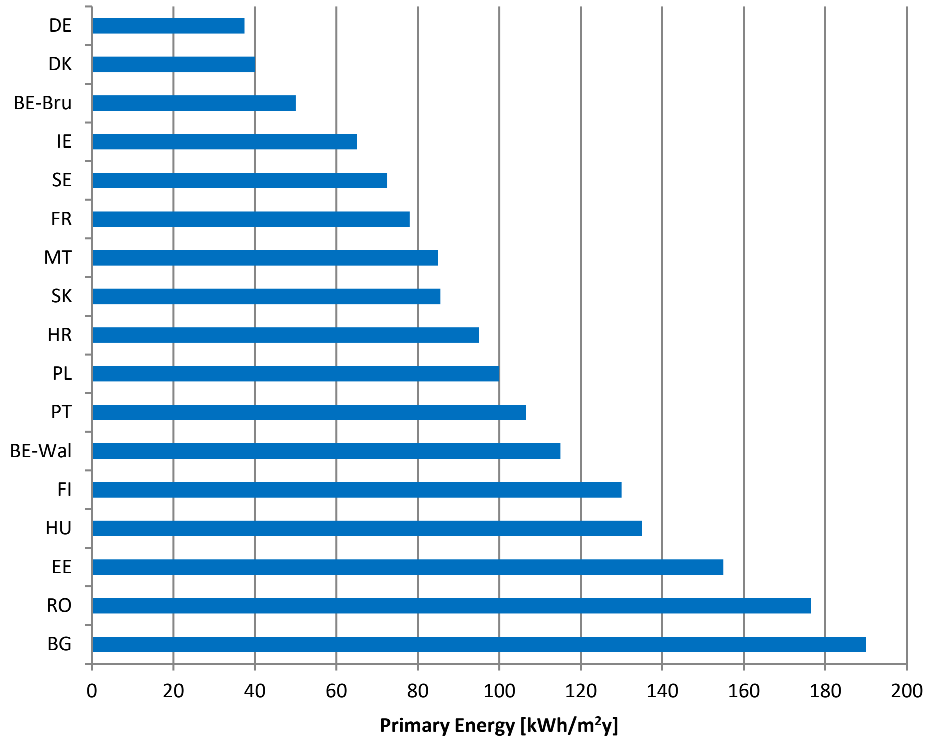
MS	Energy performance indicator	Legal act	Starting date
AT	Space heating demand [kWh/m^{2}y]	OIB Guideline 6 2015	01/01/2017
BE-Bru	energy need for heating, primary energy demand [kWh/m^{2}y]	Ordinance on the Brussels Air, Climate and Energy Code (COBRACE)	01/01/2015
BE-Wal	global energy performance level EW [-], specific energy consumption [kWh/m^{2}y]	Decree for the transposition of the EPBD and execution order of 28 January 2016	01/01/2017
BE-Fla	global energy performance level EW [-]	Energy Law	01/01/2017
BG	energy class primary energy demand [kWh/m^{2}y]	Decree No.35/2015 amended in 2016	15/07/2015
HR	heating energy need, final energy demand, primary energy demand [kWh/m^{2}y]	Technical regulation OG 128/2015	01/01/2014
CY	energy class	Ministerial Order of 2016 (Κ.Δ.Π. 119/2016)	01/01/2017
CZ	reduction of non-renewable primary energy sets for the reference building	Energy Management Act No. 406/2000 and Decree 78/2013	01/01/2015
DK	primary energy demand [kWh/m^{2}y]	Danish Building Regulation BR15	01/07/2016
EE	primary energy demand [kWh/m^{2}y]	Minimum Energy Performance Requirements Act	09/01/2013
FI	primary energy demand [kWh/m^{2}y]	National building Code 2017	01/01/2018
FR	primary energy demand, heating/cooling/DHW energy demand [kWh/m^{2}y]	Thermal Building Regulation RT2012	01/01/2013
DE	primary energy demand for heating [kWh/m^{2}y]	Energiewende, EnEV and 3nd amendment of the Energy Saving Ordinance (EnV)	01/01/2016
EL	energy class	Law 4122/2013 and “Regulation on the Energy Performance of Buildings”	01/02/2013
HU	primary energy demand [kWh/m^{2}y]	Decree of the Minister of Interior 20/2014 and rulebook 2016	01/01/2015
IE	energy performance coefficient, carbon performance coefficient [-] primary energy demand [kWh/m^{2}y]	Building Regulations (Part L) 2008 (S.I. No. 259) and 2011	01/01/2011
IT	Heating/cooling primary energy demand, primary energy demand [kWh/m^{2}y]	Decree N. 28/2011 and Law 63/2013 (enacted by Law 90/2013) and Decree of 26 June 2015	01/01/2017
LV	final energy demand for heating [kWh/m^{2}y]	Latvian Building code (LBN 002-15) and Cabinet Regulation Number 383	01/01/2019
LU	energy class	Reglement grand-ducal concernant la performance énergétique des batiments fonctionnels	01/01/2017 (residential) 01/01/2019 (public)
LT	energy class	Technical Regulation STR 2.01.02:2016 and update 2017	01/01/2018
MT	primary energy demand [kWh/m^{2}y]	Technical Guide F 2015	01/01/2016
NL	energy performance coefficient EPC [-]	Energy Performance Standard for Buildings (EPG) and amendments	01/01/2015
PL	H+W primary energy demand, cooling primary energy demand [kWh/m^{2}y]	Ordinance of Ministry of Infrastructure and Resolution No. 91 of the Council of Ministers	01/01/2017
PT	heating/cooling energy need, primary energy demand [kWh/m^{2}y]	Thermal Regulations and Decreee-Law 118/2013	01/01/2016
RO	primary energy demand [kWh/m^{2}y]	Law 372/2005 (recast 2013) and NZEB Plan and Governmental Decision no.122/2015	01/01/2016
SK	energy class primary energy demand, final energy demand, heating energy demand [kWh/m^{2}y]	Act 300/2012, Technical Standard STN 73 0540-2, Regulations 422/2012 and 282/2012	01/01/2016
SI	heating/cooling energy need [kWh/m^{2}y]	Regulation PURES 2010	01/01/2015
ES		Order 1635/2013 and Royal Decrees 238/2013 and 235/2013	01/01/2013
SE	primary energy demand [kWh/m^{2}y]	Building Code (BBR 25 BFS 2017:5)	01/01/2017

Source: JRC, 2020

Figure 9 shows the energy requirements in force for new residential buildings, actually available in terms of primary energy.

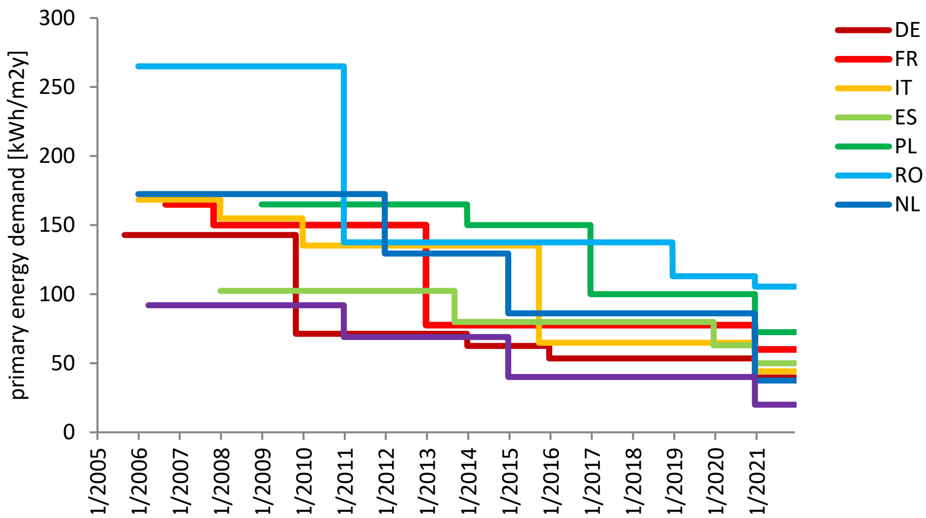
Figure 10 shows the main regulatory steps for the 8 most populated EU27 countries in terms of maximum primary energy demand for the average residential building (per type, dimension and climate). It can be derived that the NZEB requirements under EPBD (last level starting from the 1st January 2021) are on average 67% lower than the national requirements in 2006. This reflects a notable improvement for the countries, attained progressively over a relatively short period through reiterations of at least three legislative steps.

Figure 9. References of MEPR for new residential buildings in terms of primary energy.



Source: JRC, 2020

Figure 10. Improvement of residential minimum energy performance requirements in some key Member States, since the entry in force of the first EPBD.



Source: Economidou et al, 2020

2.2 Energy Performance Certificates (EPC)

Energy performance certification is an ambitious and mandatory information scheme set up by Member States in compliance with the EPBD Article 11. According to the EPBD provisions, EPCs with a 10-year validity must be made available to prospective buyers or tenants in real estate transactions. Using the integrated methodological approach adopted under Articles 4-5, EPCs are a concise document displaying the energy performance of a building or building unit —based on an energy class or continuous scale rating system— together with recommended actions on how to improve the existing energy performance. In accordance with the EPBD Annex 1, energy performance can be defined as either calculated or monitored energy consumption of a building. The primary scope of EPCs is to guide prospective buyers or renters in their decision making process, increase demand in buildings of high energy efficiency and act as a driver for more energy renovations (Bio Intelligence Service et al., 2013; de Ayala et al., 2016). Beyond their important awareness raising dimension, EPCs can also be used to monitor the overall energy performance of the building stock, thereby bringing more transparency in the property market (Arcipowska et al., 2014; Davis et al., 2015).

The scope and implementation details of the enacted EPC schemes varied greatly from country to country. Variations cover qualification systems for certifiers, dependent quality control systems, EPC registers, etc. (Arcipowska et al., 2014). While EPC registers and quality control measures were established in most Member States, a general underlying issue is the lack of access to trustworthy information which leads to reluctance in renovation decisions according to Hårsman et al. (2016). A survey carried out in eight European countries revealed low trust in EPCs among real estate agents, representing a key hurdle to their success (Pascuas et al., 2017). Even though the use of EPCs generally improved after the EPBD recast, further remaining changes to the design of EPCs have been identified by several researchers (Amecke, 2012; Bull et al., 2012). Li et al. (2019) stressed the need of upgrading the next generation of EPCs to a more comprehensive and reliable information source and Semple and Jenkins (2020), who studied EPC methodological differences between countries, pointed out the need of a more flexible approach.

The Renovation Wave also stated that the coverage of EPCs is still limited, with several Member States having less than 10% of their building stock with EPCs. In addition, the quality and fair pricing of EPCs remain an issue, eroding the trust in this tool, while EPCs do not reflect the interconnectivity and smart readiness of buildings. Given that solutions are increasingly available to measure and manage energy performance during the use of the buildings, the Commission will propose to update the EPC framework.

The relationship between energy performance and property value, which is generally studied in hedonic-price techniques, remains a complex and under-researched topic in part due to data limitations. Despite this, several studies have identified a positive correlation between energy performance and property value. These include studies on the Swedish, Irish, Italian, Spanish, UK and Dutch which all show that real estate markets value energy efficiency (Hyland et al., 2013; Högberg, 2013; Cerin et al., 2014; Fuerst et al., 2015; Chegut et al., 2016; de Ayala et al., 2016; Fregonara et al., 2017). Premiums for energy efficiency ranged from 1.8-5% for UK, 2.0-6.3% for Dutch, 6-8% for Italian and 5.4% and 9.8% for Spanish dwellings (Chegut et al. 2016; Fuerst et al., 2015; Fregonara et al., 2017, de Ayala et al., 2016). For commercial properties, an empirical analysis showed that inefficient buildings of EPC labels D or below were linked to rental price levels around 6.5% lower compared to energy efficient ones (Kok & Jennen, 2012). On the other hand, some studies identified a negligible or weak relationship between energy performance and property value (Fuerst & McAllister, 2011; Amecke, 2012; Murphy, 2014; Davis et al., 2015; Wahlström, 2016; Olaussen et al., 2017). In some cases, this weak relationship was found in markets which have been showed by other studies to value energy efficiency, pointing out to the need for further research.

Between October 2019 and February 2020 a survey has been conducted in order to understand how the EPC scheme were adopted in different Member States, including information on how the energy classes and the energy indicators were defined, what is the average energy consumption for each class, how the national registry of EPC is implemented and how many EPC where included. Data were collected from 24 Member States: the complete series in half of them, only general information in the other half.

Several different approaches can be adopted when defining energy classes for buildings. The most common approach includes in the calculation all final uses: space heating (including electric auxiliaries), domestic hot water, ventilation, air conditioning and (where relevant) lighting. In some cases air conditioning and lighting are not included, while in other the evaluation is restricted to heating and domestic hot water energy demand including only electric auxiliaries for these two services. Denmark and Slovenia don't include DHW in the calculation.

Table 2. Energy end-uses included in the EPC where absolute classes are adopted.

MS	End-uses
Austria	Heat., DHW, Aux.
Belgium - Brussels	Heat., DHW, Aux.
Belgium - Flanders	Heat., DHW, Aux.
Belgium - Wallonia	Heat., DHW, Aux.
Bulgaria	Heat., DHW, Aux.
Croatia	Heat., DHW, Vent., A/C
Denmark	Heating (depends on the floor area A)
Estonia*	Heat., DHW, Aux, Vent., A/C, light
Finland*	Heat., DHW, Aux, Vent., A/C, light
France	Heat., DHW, Vent., A/C
Germany	Heat., DHW, Vent., A/C
Ireland	Heat., DHW, Aux, Vent., light
Latvia	Heat., DHW, Aux, Vent., A/C, light
Luxembourg*	Heat., DHW, Aux.
Netherlands	Heat., DHW, Aux, Vent., light
Romania	Heat., DHW, Aux, Vent., A/C, light
Slovakia*	Heat., DHW, Aux, Vent., A/C, light
Slovenia	Heating
Spain	Heat., DHW, Aux, Vent., A/C, light

Source: JRC, 2020

Classes normally span between A and G, in some cases including an A+, A++ or an H and an I. Ireland has defined 15 different classes (compared to an average of 7-8).

In most cases an absolute reference is adopted, calculated in kWh/m^2 per year. The limits which define each class may be very different from country to country. For example the upper limit for class A may range between 15 and almost 300 kWh/m^{2}year, while lower limit for class G may range between 200 and 1150 kWh/(m^{2}year). This may depend on the climate and on the end uses included in the calculation.

Some member states (Cyprus, Czech Republic, Greece, Hungary, Italy, Portugal, Spain, Sweden) chose to compare the building with a reference case, normally with the same dimensions and put in the same climate condition. The UK adopted the Standard Assessment Procedure (or the reduced data version for existing dwellings) that runs from 1 to 100+ depending on the elements of structure, the heating and hot water system, the internal lighting and the renewable technologies used in the home. Dwellings that have SAP>100 being are considered net exporters of energy.

The EPC registry is normally adopted, developed and organized at national level, except in Austria (a registry in some federal states), Belgium (Flanders, Wallonia and Brussels region) and Spain (regions). The data are uploaded automatically in most Member States when the certifier obtains the EPC. The register data are normally partially accessible by the public. In some cases all data are open, in other cases they are available only for the building owner or the expert that was responsible for the EPC. Although data are available only for a limited number of countries, the number of EPC have increased dramatically between 2011 and 2018, especially in Bulgaria Greece and Lithuania.

Table 3. Number of cumulated EPC issued at the end of 2011 and 2018, and percentage variation.

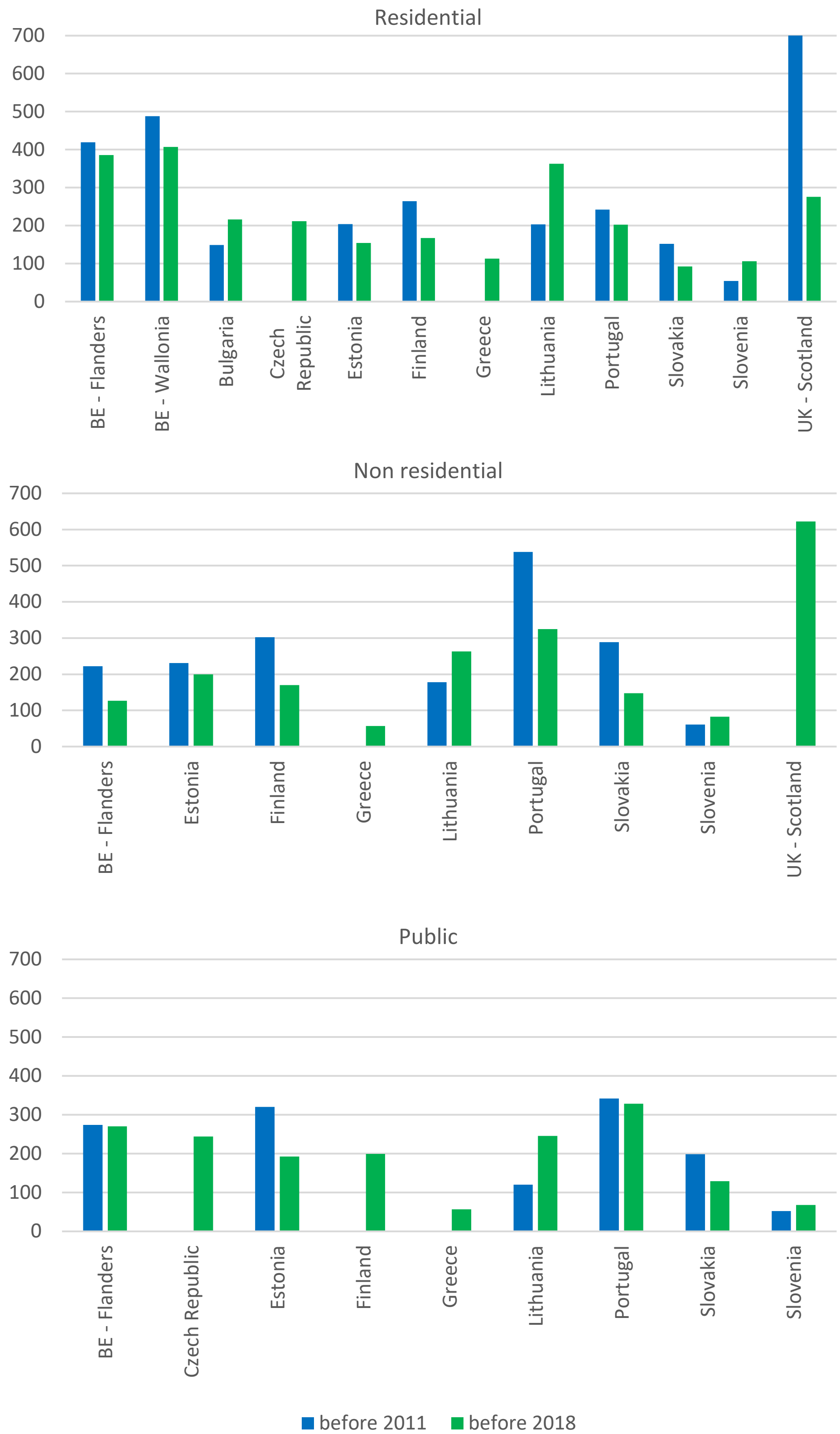
MS	Residential			Non-residential			Public		
	2011	2018	% var	2011	2018	% var	2011	2018	% var
BE - Brussels	21854	234899	975%	n/a	n/a		n/a	307	
BE - Flanders	555961	1509921	172%	5408	20671	282%	6247	10511	68%
BE - Wallonia	65410	538278	723%	n/a	n/a		n/a	n/a	
Bulgaria	13	2670	20438%	553	4997	804%	n/a	n/a	
Czech Rep.	n/a	74545		n/a	9450		n/a A	3446	
Denmark	270571*	670324*		22383	49094	119%	n/a	n/a	
Estonia	6381	22887	259%	654	4009	513%	41	438	968%
Finland	n/a	94366		n/a	11484		n/a	3693	
Germany	n/a	1231384		n/a	44398		n/a	n/a	
Greece	50958	1237100	2328%	2691	262523	9656%	394	4770	1111%
Ireland	271360	897797	231%	8023	54884	584%	n/a	n/a	
Italy	n/a	286744		n/a	54402		n/a	2916	
Lithuania	4091	206747	4954%	406**	2836**		2010	13198	557%
Portugal	431551	1401901	225%	21474	157299	633%	913	4376	379%
Slovakia	18229	111662	513%	224	1237	452%	1443	6686	363%
Slovenia	n/a	47016		n/a	2412		n/a	2662	
Spain	n/a	3332316		n/a	305372		n/a	n/a	
Scotland	n/a	223358		n/a	6355		n/a	n/a	

*including holiday homes
**industrial

Source: JRC, 2020

When comparing the average energy demand per building type it appears that in most cases the energy performance of buildings is improving over time (see Figure 11). In Bulgaria and Lithuania, the consumption is increasing only because the set of data before 2011 was limited to a very small number of buildings and is not statistically relevant).

Figure 11. Average Energy demand per building type in kWh/m^2 per year. Comparison data for Finland and Portugal are before 2014, for Slovenia before 2013 and for Lithuania before 2012.



Source: JRC, 2020

2.3 The cost-optimal approach

As indicated in the EPBD recast, in 2012 the Commission provided the delegated Regulation 244/2012 (accompanied by official Guidelines) related to the comparative methodology framework of cost-optimal levels to be used by Member States to benchmark their buildings standards (EC, 2012a and 2012b). Since 2013, the EPBD requires Member States to develop cost-optimal calculations every 5 years to verify and update the energy performance requirements in force.

The methodology is based on the principle of the cost-benefit analysis and can be calculated from two economic perspectives: the financial and the macroeconomic, which refer to different discount rates (lower in the macroeconomic one) and cost items. While the financial perspective includes taxes, the macroeconomic considers greenhouse gas emission costs.

The calculation approach can be summarized in six steps:

- Establishment of reference buildings by selecting real or virtual buildings representing the building stock. Member States shall define them for at least four building categories, both for new and existing buildings (residential single-family, residential multi-family, offices, and another non-residential type). For new buildings, the energy performance standard in force can be assumed as base case, while for the existing stock at least two construction periods have to be considered as reference;
- Identification of energy efficiency and renewable measures to be implemented in new or existing buildings, including different packages of measures or measures of different levels (e.g. different insulation levels), which must respect the EU and national legislation on construction products, comfort indoor and indoor air quality;
- Calculation of the (net) primary energy consumption based on the current National (or CEN standards) methodology for each selected building variant;
- Calculation of the global cost at each step using the Net Present Value based on 30 years for residential and 20 years for non-residential buildings. The included cost categories are: initial investment costs, running costs (i.e. energy, operational, maintenance, replacement costs), disposal costs, final value and the cost associated to CO2 emissions (only for the macroeconomic perspective);
- Identification of cost-optimal levels for each reference building expressed in primary energy consumption (kWh/m^2/year or in the relevant unit). Cost-optimal levels can be calculated for both macroeconomic and financial perspectives, but normally derived with the second one;
- Evaluation of the gap with current minimum energy performance requirements. If the difference is more than 15%, Member States are asked to justify the gap or define a plan to reduce the gap.

Key calculation parameters in the cost-optimal calculation are: the discount/interest rate, the annual increase of energy prices, as well as primary energy factors associated to different fuels. The EPBD delegated Regulation required Member States to develop sensitivity analysis to evaluate the robustness of these parameters, and possibly also future technology price development.

A number of recent researchers tested the cost-optimal methodology applied in different EU countries (Kurnitski et al., 2011; Hamdy et al., 2013; Corgnati et al., 2013; Corrado et al., 2014; Congedo et al., 2015; Sağlam & Yılmaz, 2015; Becchio et al., 2015; Ashrafian et al., 2016; Brandão de Vasconcelos et al., 2016; Ortiz et al., 2016; Zangheri et al., 2017; Karásek et al., 2018). Member States sent their calculation reports to the Commission in 2013 and 2018.

The analysis of the first reports (2013) revealed an overall rather positive picture regarding both the conformity to the official requirements and the plausibility of the final outputs (ECOFYS, 2015).

For the second round of cost-optimal calculations, the Member States notified their reports to the Commission from March 2018 to October 2019 and the Joint Research Centre (JRC) assumed the role to analyse and assess these documents, in order to verify the conformity to the common methodology and the plausibility of results obtained.

The overall picture about the conformity with the requirements of the Delegated Regulation is less positive than the previous one (referred to the 2013 reports). This was also because very few Member States provided a reply to the requests of clarification of the Commission and this did not allow obtaining the same level of detail as with the previous assessment. The main gaps were registered for the calculations' scope, the derivation of cost-optimal levels, and the definition of a plan to reduce the gap. However, regarding the plausibility of input parameters and results, the picture looks quite positive, since no report has been assessed as not plausible. Also in this case the most critical categories are the last ones (derivation of cost-optimal levels and plan to reduce the gap), but also in the selection of energy efficiency measures some Member States missed to cover all significant technological options.

Unfortunately, it was not possible to extract the cost-optimal levels from all Member States' 2018 reports, since about half of them did not derive these energy levels in clear and complete way. However, based on data available, we observe that the average cost-optimal level is 80 kWh/m^2/year for new residential sector, 140 kWh/m^2/year for the new non-residential, 130 kWh/m^2/year for existing residential and 180 kWh/m^2/year for existing non-residential.

Table 4. Average cost-optimal levels (Primary Energy and Global Cost) for new buildings per climatic condition[14].

Climate	new Single Family House		new Multi Family House		new Office		new Other non-Residential	
	Primary Energy [kWh/m²y]	Global Cost [EUR/m²]	Primary Energy [kWh/m²y]	Global Cost [EUR/m²]	Primary Energy [kWh/m²y]	Global Cost [EUR/m²]	Primary Energy [kWh/m²y]	Global Cost [EUR/m²]
Mediter.	81	887	105	698	221	648	423	607
Oceanic	80	771	61	689	82	1002	140	992
Continental	93	394	96	381	89	142	77	137
Nordic	74	1776	77	2016	68	1626	78	1381

Source: JRC, 2020

Table 5. Average cost-optimal levels (Primary Energy and Global Cost) for existing buildings per climatic condition.

Climate	existing Single Family House		existing Multi Family House		existing Office		existing Other non-Residential	
	Primary Energy [kWh/m²y]	Global Cost [EUR/m²]	Primary Energy [kWh/m²y]	Global Cost [EUR/m²]	Primary Energy [kWh/m²y]	Global Cost [EUR/m²]	Primary Energy [kWh/m²y]	Global Cost [EUR/m²]
Mediter.	161	500	148	467	175	396	775*	808*
Oceanic	124	709	125	567	136	605	264	522
Continental	119	258	103	212	139	109	131	117
Nordic	148	446	94	285	75	254	82	251

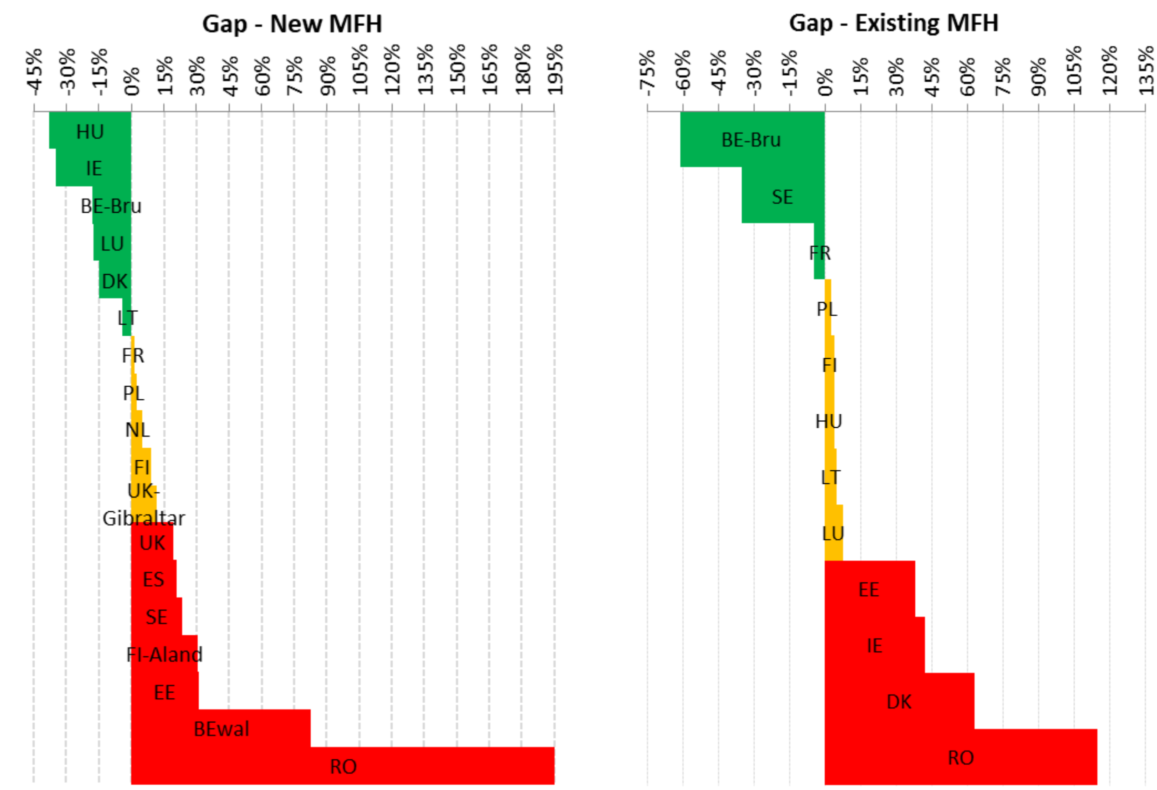
*Available only for Malta (average of values obtained for schools, hotels, restaurants, shops, elderly centres and sport complex).

Source: JRC, 2020

About the gaps with current energy performance requirements, depending on the building type 3 or 4 Member States provided gaps greater than 15%, which is the maximum deviation tolerated by EPBD. The picture is more critical for new multi-family buildings.

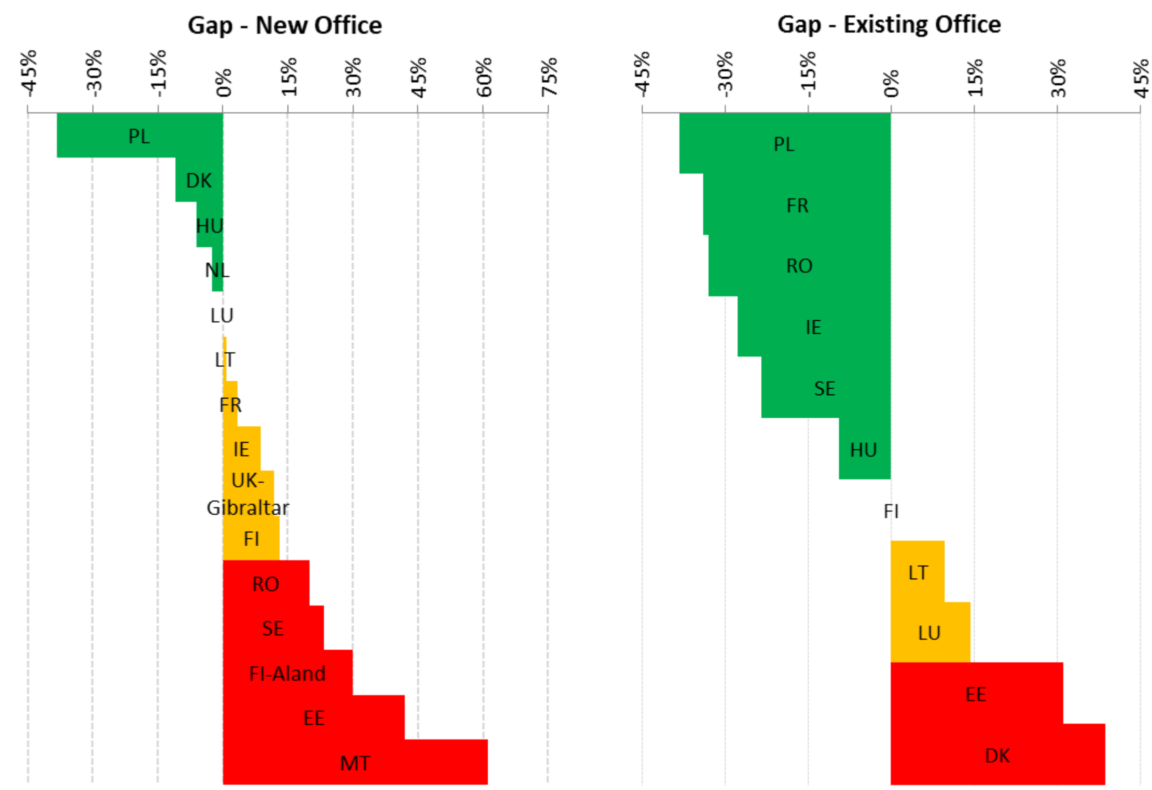
[14] We applied the approach already considered by the Commission Recommendation (EU) 2016/1318, by including: Cyprus, Greece, Spain, Italy, Malta and Portugal in the Mediterranean zone; Belgium, Denmark, France, Germany, Ireland, Luxembourg, the Netherlands and UK in the Oceanic zone; Austria, Czech Republic, Hungary, Poland, Romania, Slovenia and Slovakia in the Continental zone; Estonia, Finland, Lithuania, Latvia and Sweden in the Nordic zone.

Figure 12. Gaps between current requirements and cost-optimal levels for office buildings (new and existing).



Source: JRC, 2020

Figure 13. Gaps between current requirements and cost-optimal levels for multi-family buildings (new and existing).



Source: JRC, 2021

The comparison between the cost-optimal levels obtained with the two calculation rounds shows that for almost all building types lower values were obtained in 2018 respect the 2013 values. Looking at the consolidated version of cost-optimal levels (which includes the 2013 levels if the 2018 ones are missing) we point out that there are still two Member States (Bulgaria and the Netherlands) which did not clearly provide even one cost-optimal requirement.

Overall, these conclusions leave one thinking that the majority of Member States adopted the cost-optimal approach in appropriate way. This approach can provide useful references, which can support the development of incentive mechanisms for building renovation. These elements will assume a crucial relevance during next decade, on the road to the 2030 European energy efficiency target. However, there is still room for improvement, and a good starting point could be the revision of official guidelines. Also the introduction of a common template for collecting input data and outputs would be useful to support more the Member States, as well as the verification task done by the Commission.

2.4 Nearly Zero-Energy Buildings (NZEB)

The concept of nearly Zero-Energy Building (NZEB) was introduced in the EPBD recast. Article 2 establishes what a NZEB is: a building with "a very high energy performance with the nearly zero or very 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". The deadline to have mandatory NZEBs came into force: all new buildings have to be NZEBs by December 31st 2020, if occupied by public authorities already by December 31st 2018.

Member States are required to provide NZEBs definitions and increasing the number of NZEBs with targets differentiated per building types. The NZEBs implementation represents a huge opportunity to increase energy savings and reduce greenhouse gas emissions to accomplish EU ambitious goals of decarbonising the energy sector in next decades (EC, 2018).

After an assessment in 2016 (D'Agostino et al, 2016), the JRC assessed the progress towards the NZEBs implementation in Member States based on different sources: the documents prepared by Member States within the EPBD Concerted Action and complementary analyses (CA, 2018), NZEB National Plans, information collected by DG ENER from Member States, the Long-Term Renovation Strategies, the National Energy and Climate Plans submitted in 2020, scientific literature, and EU projects outputs.

Based on the latest information available, 25 Member States have in force a completed NZEB definition. For 4 Members States (Czechia, Hungary, Belgium - Brussels and UK) a previously adopted definition is currently under review. In Luxemburg the NZEB definition for residential buildings has been in force since 2017, while for non-residential buildings was to enter in force in 2019. Most of the provided definitions include an energy indicator of primary energy use, and 13 of them include the obligation to cover a minimum share of energy demand from renewable sources. For 18 of the Member States, an Energy Class or Energy label equivalent to NZEB requirements is defined. For the half of the Member States, the required U-Values for walls, roofs, floors, windows and doors are also provided.

Member States are requested to report NZEB definitions, reflecting on national, regional or local conditions. They have to include quantified information on the energy performance and renewable sources levels. The primary energy indicator (expressed in kWh/m^2) can be referred to total non-renewable or renewable energy use (Asdrubali et al., 2019).

Most agreed points in NZEBs definitions are:

- Heating, domestic hot water (DHW), ventilation, and cooling are the main included energy uses. Auxiliary energy and lighting are taken into account in the majority of Member States, while several also include appliances and central services;
- Energy balance calculations are derived as the difference between primary energy demand and generated energy over a one-year period;
- Single building or building unit are the most frequent physical boundaries in energy performance calculations;
- Conditioned area is the most agreed upon choice in relation to normalization factors.
- On-site generation is the most common RES option, but some Member States also consider external and nearby generation;

Different system boundaries and calculation methodologies cause a high variation within the described definitions. The level of energy efficiency, the inclusion of lighting and appliances, as well as the recommended renewables to be implemented vary across Member States.

Table 6 reports the benchmarks for the energy performance of NZEBs in different climatic zones per building type (single family houses and offices) published in the 2016 EU Commission Recommendation (EU, 2016). Based on the climatic zones defined in the Commission Recommendation and on the REHVA journal (REHVA, 2015), Member States are grouped under one representative climatic zones.

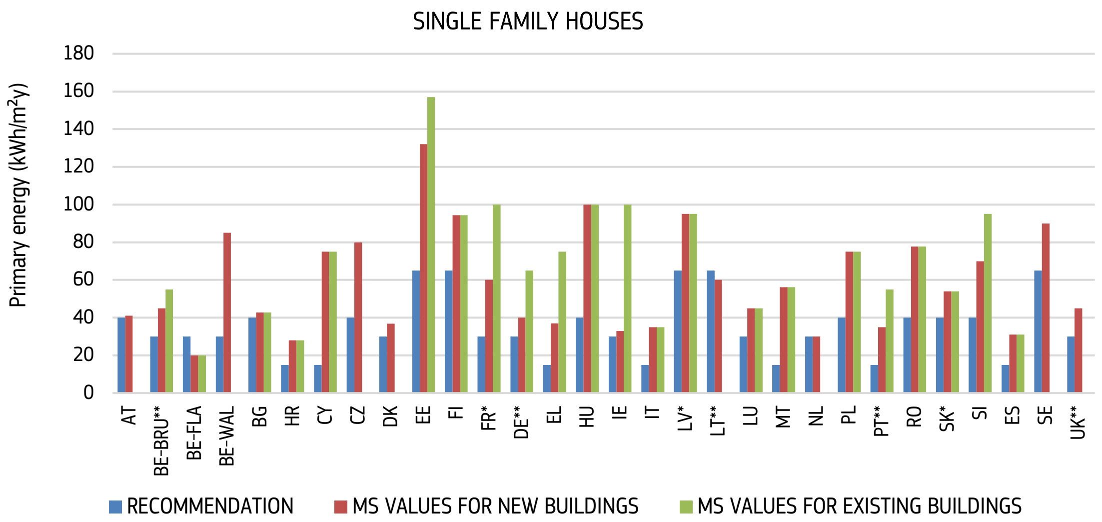
Table 6 EC NZEB Recommendation level of energy performance (kWh/m²/y) per building type and climatic zone

	NZEB RECOMMENDATION BENCHMARK	
Type of building	Net primary energy use (on-site RES excluded) kWh/(m²y)	Primary energy use kWh/(m²y)
MEDITERRANEAN (CY, HR, IT, GR, MT, PT ES)		
Single family houses	0-15	50-65
Offices	20-30	80-90
OCEANIC (BE, DK, IE, DE, FR, LU, NL, UK)		
Single family houses	15-30	50-65
Offices	40-55	85-100
CONTINENTAL (AT, BG, CZ, HU, PL, RO, SL, SK)		
Single family houses	20-40	50-70
Offices	40-55	85-100
NORDIC (EE, FI, LV, LT, SE)		
Single family houses	40-65	65-90
Offices	55-70	85-100

Source: JRC, 2020

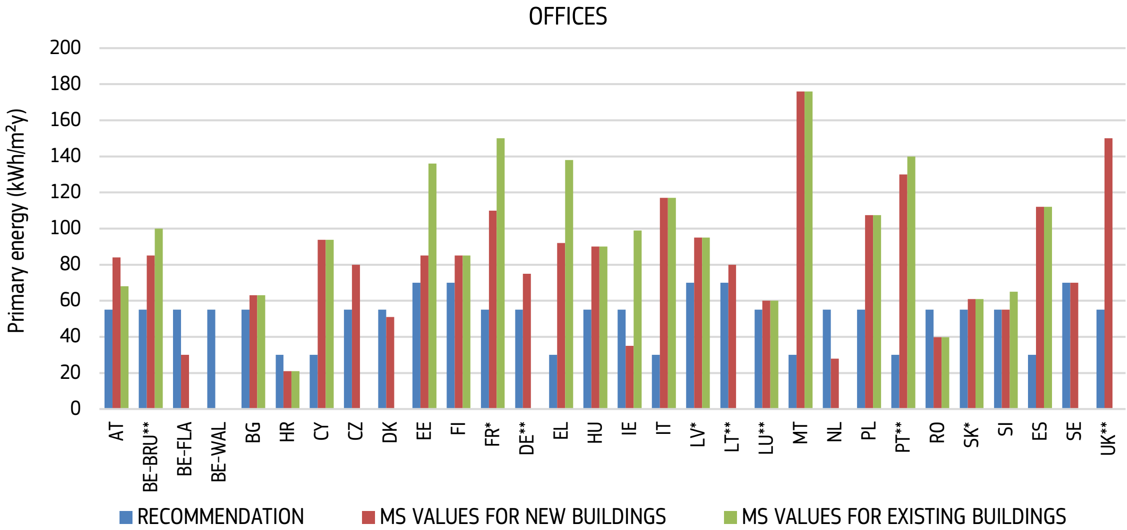
In relation to the ambition of the NZEBs levels, it can be pointed out that NZEBs primary energy values for most Member States exceed the benchmarks recommended by the Commission in both residential and non-residential buildings (Figure 14). On this point the front-runner are Belgium Flanders, and the Netherlands.

Figure 14. Comparison between recommended levels and MS levels of performance for single-family houses and offices[15].



Source: JRC, 2020

[15] **RES required but specific value not available*
***Value from Cost-optimal analysis or from EPBD report*
FR: values for existing building taken from EPBD report. The compared values are reported by the MS including the AC use.
HR, EL, ES, IT: the compared values correspond to the average climatic zones values reported by the MS
FI: values correspond to the average values for different types of detached houses reported by the MS
RO: values correspond to the most representative climatic zone of the country according to the MS report
DK: values have been calculated based on the following formula: Dwellings: (30 + 1000/A) kWh/m² per year. Other buildings than dwellings: (41 + 1000/A) kWh/m² per year. A is the floor area. Residential: A=145.72 m² (average floor area of single family dwellings in Denmark, 2018, source: Odyssee database, Non-residential: A=100 m²
HU: values for residential do not include lighting, values for non-residential include lighting
PL: The values have been calculated based on the following formula: EP = EPH+W + ΔEPC + ΔEPL
A share of 15% has been removed in the final graphs where appliances were included in the reported values.



Source: JRC, 2020

NZEB requirements are currently 70% lower than the national minimum energy performance requirements in 2006 showing a consistent trend in increasing building energy efficiency and a gradual move towards a zero energy consumption. This was obtained progressivity in all these Member States, where at least 3-4 legislative steps were introduced over the last 15 years.

The 2020 assessment shows that NZEBs energy performance levels vary from 20 kWh/(m^{2}y) (Belgium Flanders) to 132 kWh/(m^{2}y) (Estonia) in new residential buildings, and 30 kWh/(m^{2}y) (Belgium Flanders) and 176 kWh/(m^{2}y) (Malta) in new non-residential buildings. In relation to existing buildings, NZEBs levels vary from 20 kWh/(m^{2}y) (Belgium Flanders) to 157 kWh/(m^{2}y) (Estonia) in existing residential buildings, and 21 kWh/(m^{2}y) (Croatia) and 176 kWh/(m^{2}y) (Malta) in existing non-residential buildings. The reduction of energy demand through efficient measures and renewables to supply the remaining demand are a common agreement in the implementation of the NZEBs in Europe. However, a minimum share of energy demand from renewable sources is not always available (D'Agostino et al, 2019).

In comparison with cost-optimal levels, the NZEB requirements are significant lower (about -50%) of cost-optimal references, implying that Member States may refer to the cost-optimal approach to define the NZEB requirements. In more details, NZEB definitions for new buildings result significant higher of cost-optimal levels only in 4 and 3 cases, respectively for single family houses and office buildings. For existing buildings, for which unfortunately less data is available, this happens only for 3 and 1 Member States, respectively for single family houses and office buildings.

In relation to technologies, the NZEB target is reachable with a proper combination of high efficient solutions to minimise the energy demand for building operation and supply the remaining demand to a large extend with renewables produced onsite (PV, solar thermal, wind power, heat pumps). Most implemented technologies in NZEBs are passive (sunshade, natural ventilation and lighting, thermal mass, night cooling), and active (mechanical ventilation with heat recovery, heat pumps or district heating, solar and PV panels), in combination with efficient lighting and appliances. Most U-values are found between 0.15 – 0.20 W/m^{2}K (walls), 0.10 – 0.25 W/m^{2}K (roofs). Nonetheless, a critical role, not yet fully addressed, is played by occupant's behaviour (Hong et al, 2016). While predictive studies concerning energy performance investigated mainly NZEBs models that addressed the optimization of the building features themselves, different studies revealed the urgent need of reference models related to human behavioural issues (Barthelmes et al, 2016).

Looking at the market of key technologies, some good signals can be observed (CRAVEZERO, 2018; ZEROPLUS, 2016; NERO, 2019; CONZEB, 2019; AZEB, 2018). For instance, some Member States have set targets or have adopted financial or fiscal measures to favour the use of heat pumps. This may lead in increase in number of heat pump installation in the following years, and this will result in an important reduction (10-40%) of heat pumps costs in Europe until 2050. The European Heat Pump Association estimates that the number of sold heap pumps will be doubled in the coming years (EHPA, 2020). According to the NECPs, the total added final energy consumption from heat pumps is 7.7 Mtoe/ year between 2020 and 2030 (EC, 2020). Some Member States also implement policies to give incentives for the wider use of biomass boilers, which can potentially reduce their cost by 10-20% in the period by 2050. Also the cost of heat recovery systems is expected to decrease significantly (35-60%). PVs and solar thermal are most commonly implemented renewable technologies. Cost projections indicate that PV cost will decrease between 41% and 56% towards 2050, solar thermal between 22% and 51%. PV will probably be the pillar to decarbonise our power supply in next decade. In addition, IEA acknowledge solar as the most labour intensive technology. Specifically in the rooftop solar PV, 1 million dollars of capital is expected to generate 10 construction jobs (IEA 2020) Energy storage will be more and more important in NZEBs. The cost of stationary batteries will drop around 65% in next decades. Specific measures are needed towards this technology.

Member States are also requested to draw up national plans and adopt measures, policies and financial incentives for the promotion of NZEBs. Most of the Member States have also reported a number of measures to promote the increase of the number of NZEB. These measures are mainly regulatory (energy standards, definition of NZEB requirements, adoption of regulation and laws), financial (subsidies, renovation grants, operational programmes, fiscal incentives), informative (information campaigns, leaflets, websites) and educational (training courses for engineers and architects, publication of NZEB guidelines). Several Member States have also defined long-term milestones related to NZEB implementation.

After the introduction of EPBD recast, in EU the number of NZEB and highly performing buildings in Europe has increased significantly from 2012 to 2016 (EC, 2019). Previously NZEBs were diffused mainly at a demonstration project level, mostly for research purposes (D'Agostino 2015). Quantitative evidence about the NZEBs uptake in the EU show how currently the concept has been translated and spread in concrete examples, with the public sector as leading example. In summary, almost 1.25 million of buildings were built or renovated to NZEB (or similar) levels from 2012 to 2016, mostly residential. The share of NZEB in the total construction market has increased during the period 2012-2016 in EU (from 14% in 2012 to 20% in 2016, in average). Almost the 80% NZEB buildings added in 2016 were constructed or renovated in 7 Member States (France, Germany, UK, Italy, Austria, the Netherlands and Spain). Among the EU Member States, Luxemburg, Austria and Cyprus registered the largest shares in 2016 (around 40%) (EC, 2019).

However, while reaching the NZEBs target in new buildings appears to be feasible according to studies on energy performance optimization (D'Agostino & Parker, 2018) the challenge remains for existing buildings. A widespread NZEBs retrofit implementation is still a challenge to be overcome in the light of the Renovation Wave and the need of further boosting deep renovations (at least doubled). Different barriers persist towards NZEBs renovation. These are mainly technical, financial, social, political and institutional. It is frequent that existing structures limit the choice of the technical solutions that can be used, especially in buildings of architectural value. Furthermore, technical solutions may be expensive and request a high investment. The payback period for renovation may take between 15-30 years, and often residents do not benefit from it (Economidou et al, 2020). Recently, the importance of social barriers has risen (Dunlop, 2019). Communication of best practices and end-user behaviour are other aspects to be considered towards a wide NZEB retrofit implementation. Dedicated planning goals as well as mid- and long- term plans for upgrading to NZEBs levels are also useful instruments to be adopted. Building refurbishment to NZEBs levels requires specific innovative tools and incentive mechanisms able to make investment more attractive, beside an appropriate combination of efficient technologies, systems and envelope solutions depending on location, legislation and market conditions.

It appears clear that NZEBs will have also a stronger role in alleviating environmental, social or ethical issues. The future generations of NZEB could be scaled-up and integrated to a district level, shifting the focus from the single building to the district scale, creating Net Zero-Energy District (NZED). This concept includes a wider vision of urban sustainability that foresees innovative solutions for street lighting, urban mobility, waste, and public safety. The advantage of a widespread NZEBs implementation are massive. While decreasing greenhouse gas emissions, the EU dependence on energy supply, and energy poverty, NZEBs will increase jobs, energy security, and economic growth in Member States. This evolution appears strategic also in relation to the social and economy recovery after the Covid-19 pandemic.

2.5 Financial incentives and market barriers

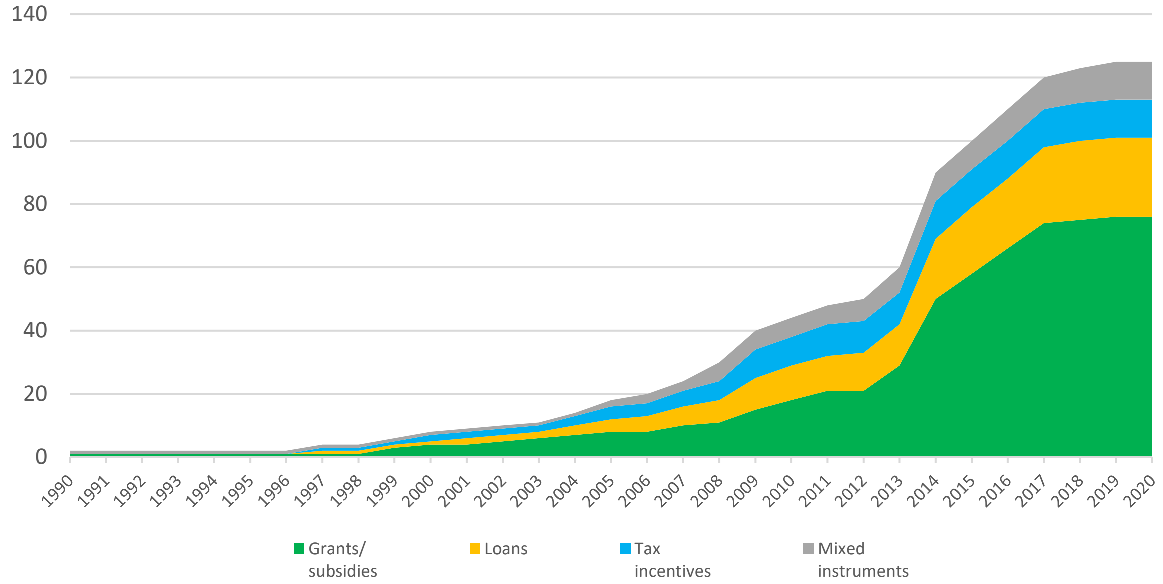
An extensive review of conventional and new financial mechanisms supporting energy renovations of buildings across the EU was undertaken by Economidou, Todeschi and Bertoldi (2019). The review provided a country-by-country overview and identified good practices and successful financial and fiscal instruments in residential, commercial and public buildings.

An overview of the identified financial and fiscal instruments by type of public policy and building is shown in Table 7. Of the 129 instruments examined, 78 were in the form of grants/subsidies, 25 loans/soft loans, 13 tax incentives and the remaining 13 a combination of the above. Up until 2019, grants and subsidies were deployed in almost all Member States, representing the main type of public policy support to-date for energy renovations in the EU. In particular, Croatia, Ireland, Cyprus, Malta and Greece relied exclusively on grants and subsidies as their main policy response to address underinvestment in energy efficiency in the building sector. Soft loans were available in half of the EU countries, some of which were supported by state guarantees such as in Bulgaria, Estonia, France, Italy and Romania or designed as revolving funds (e.g. Bulgaria, Estonia, in the Netherlands and the UK). Tax incentives in the form of income tax incentives or VAT reduction schemes were active in Belgium, Denmark, Finland, France, Italy, Sweden and the Netherlands. For most countries, the main focus was the residential sector, with some instruments also targetting commercial buildings and/or public buildings or a different combination of building types. Finland, Ireland, Estonia, and Romania provided public support for residential buildings only, while France, Belgium, Italy and Portugal enacted all types of instruments for all types of buildings.

The distribution of public financial and fiscal instruments by starting year is depicted in Figure 15. It can be noted that a number of countries have had a long tradition in promoting energy efficiency before action at the EU level was taken, with some measures starting well before the 2000s. Specifically, Austria and France have implemented energy efficiency policy measures since 1970s. A sharp increase of measures starting in the period 2009 and 2014 is observed. This can be largely attributed to the introduction of the implementation of key Directives and financial framework period.

Based on budget-related information collected for 85% of instruments, it can be deducted that around EUR 15 billion are roughly spent by public resources on an annual basis across the EU[16]. The largest schemes in terms of public resources are the Italian Eco-bonus tax rebate scheme, the French Energy Transition Tax Credit scheme, the German KfW Energy Efficient Refurbishment Programme and the Austrian Regional subsidies for energy efficiency in residential buildings.

Figure 15. Cumulative distribution of public financial and fiscal instruments by starting year.



Source: JRC, 2020

Table 7. Identified financial and fiscal instruments by type of public policy and building (residential, commercial and public) across the EU.

	Grants/Subsidies			**Loans/Soft Loans**			**Tax Exemption/Reduction**			**Mixed schemes**		
	RES	COM	PUB	RES	COM	PUB	RES	COM	PUB	RES	COM	PUB
AT	✔	✔	✔							✔		
BE	✔	✔	✔	✔	✔	✔	✔	✔	✔			
BG	✔	✔		✔	✔	✔						
CY	✔	✔										
CZ	✔	✔	✔	✔	✔							
DE	✔	✔	✔	✔	✔	✔						
DK	✔						✔	✔	✔			
EE				✔								
EL	✔		✔									
ES	✔	✔	✔	✔						✔		✔
FI	✔						✔					
FR				✔	✔	✔	✔	✔	✔	✔	✔	✔
HR	✔	✔	✔									

[16] It is important to note that these figures do not refer to any specific period, but rather represent a generic year during the duration of the given scheme. Depending on data availability for each scheme, this was taken as the average value over a specified period (preferred option) or the value given for a specific year or a typical year on average (alternative option).

	Grants/Subsidies			Loans/Soft Loans			Tax Exemption/Reduction			Mixed schemes		
	RES	COM	PUB	RES	COM	PUB	RES	COM	PUB	RES	COM	PUB
HU	✔	✔	✔	✔								
IE	✔											
IT	✔	✔	✔	✔	✔	✔	✔	✔	✔			
LT	✔	✔	✔							✔		
LU	✔			✔	✔	✔						
LV	✔	✔	✔							✔		
MT	✔											
NL	✔	✔		✔			✔	✔				
PL	✔		✔							✔		
PT	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔		
RO	✔			✔								
SE	✔						✔	✔	✔			
SI	✔		✔							✔	✔	
SK	✔	✔	✔	✔								
UK	✔	✔		✔		✔						

Source: JRC, 2020

Good practices of public schemes have been identified using the 6 criteria, ranging from impact to cost effectiveness and scalability. The global score computed for each of the pre-selected schemes enabled the identification and further investigation of 10 best practices. These included the French Energy Transition Tax Credit, Dutch Energy Investment Tax Deduction, Estonian Kredex Credit and Export Guarantee Fund and KfW Energy Efficient Refurbishment Programme among others. Since their inception, these programmes have collectively had a significant impact in terms of generated energy savings, supported ambitious energy upgrades and sustained relatively low pressure on public finances.

Whilst energy efficient lending is mostly integrated into mainstream products, private schemes offered as stand-alone energy efficiency loan products have also been identified. Examples include the Intesa San Paolo Condominium Loan Scheme in Italy, Zagrebank Green Housing loans in Croatia and Belfius housing retrofit programme in Belgium. Several banks have also tapped into energy efficiency mortgage sector in recent years, offering interest rate reductions based on the improved risk profile of energy efficient lending. Notable examples include Raiffeisen bank in Eastern Europe, Nordea bank in Scandinavian countries and Muenchener Hyp in Germany. The Energy Efficient Mortgages Initiative, which is supported by the participation of 40 EU banks, aims to standardise the way energy efficiency mortgage products are designed across the EU. Beyond traditional financing, crowdfunding has also gained some ground in recent years by offering support to sustainable energy projects through debt financing options. Even if crowdfunding platforms mainly focus on renewable energy investments, recent platforms such as CitizenEnergy, Bettervest, Econeers and Fundeen specialise on energy efficiency projects, too. This financing route however accounts only for a small share of the sector for now. Energy efficiency insurance, an innovative product which aims to shield from under-achievement and increase trust and awareness of energy efficiency projects, is currently used in Germany and the UK. Finally, specialised energy efficiency funds which third party participation have also been identified.

2.6 Long-term Renovation Strategies (LTRS)[17]

To tap into the large cost-effective energy saving potential of energy renovations across the EU, Member States were asked (EED, Article 4) to develop long-term renovation strategies with the view of mobilising energy efficiency investments in residential and commercial buildings. These strategies, which represented the first strategies of this kind, aimed to act as a guiding tool for Member States in the decarbonisation transition of their building stocks. The EED did not require setting up specific renovation targets. Instead, the strategies were drawn up to provide:

— an overview of the country's national building stock;
— identify key policies to stimulate renovations;
— provide an estimate of the expected energy savings and wider benefits;
— identify cost-effective approaches by building type and climatic zone;
— encompass a forward-looking perspective to guide investment decisions.

[17] https://ec.europa.eu/energy/topics/energy-efficiency/energy-efficient-buildings/long-term-renovation-strategies_en

While high compliance with the above 5 elements was in general achieved in both the originally submitted national strategies in 2014 and subsequent updates in 2017 (Castellazzi et al., 2016; Castellazzi et al., 2019), the ambition level, scope and depth of analysis varied significantly from country to country. In particular, data gaps in the non-residential sector were identified as well as lack of modelling and clear and ambitious targets. The updated strategies of 2017 provided a more in-depth analysis of national building stocks and more rigorous scenario analysis of possible intervention options. On the other hand, the evaluation and monitoring of implemented policies and the development of specific monitoring indicators remained weak points of the strategies (Castellazzi et al., 2019). While there is no yet evidence in the literature on the actual impact of these strategies in generating energy savings or indeed in mobilising investments, several new policy measures have been put in place as a result of the development of these strategies (Sebi et al., 2019; Sesana & Salvalai, 2018).

With the revision of the EED and EPBD in 2018, under the Clean Energy for All Europeans package, Article 4 of EED was moved to the amended EPBD Article 2a. To address some of the above shortcomings, the amended EPBD introduced a number of key changes with the view of enhancing the role of these strategies as 'roadmaps' with an action plan on how to transform their building stock to a highly energy efficient and decarbonized building stock by 2050 including specific milestones for the years 2030 and 2040. Even though the new strategies are not required to include quantifiable targets, they must be supported by measurable progress indicators and must explain how they contribute to the overall 32.5% energy efficiency target for 2030 (as part of the implementation of the Energy Efficiency Directive). It goes further by emphasizing that the strategies shall facilitate the cost-effective transformation of existing buildings into nearly zero-energy buildings (NZEBs), a provision already included in Article 9.2 pf the EPBD. Emphasis is also given for the worst-performing segments of the national building stock, actions to alleviate energy poverty, efforts to accelerate energy efficiency gains in public buildings, promotion of smart technologies including electro mobility and the use of innovative instruments and tools to mobilise investment into energy renovations. Member States are also now required to undertake a wide public consultation of all the stakeholders during the preparation of their LTRS.

It has to be noted that the LTRSs are part of the NECPs. The first LTRSs under the amended EPBD, by derogation to the official NECPs deadlines, had to be submitted by the Member states to the European Commission as a stand-alone document by the 10th of March 2020[18]. Nevertheless as of the end of 2020 only 15 LTRSs have been received by the EC (covering about 55% of the EU population): AT, Brussel Capital Region (BCR), Belgium Flanders (DE-FL), CY, CZ, DE, DK, EE, ES, FI, FR, LU, NL, RO, SE.

The following analysis and considerations are based on the evaluation of the available strategies and have to be considered as preliminary findings, to be complemented once all the LTRS will be assessed.[19]

Despite the important strengthening and increase of the 2020 LTRS requirements, all the submitted strategies, have been assessed as compliant with the EPBD Art.2a provisions: 11 strategies have been assessed as "fully compliant" (covering all the 6 basic requirements[20] – dark green in the table) and 4 as "partially compliant" (covering at least 4 requirements – light green in the table). The result of the compliance assessment are presented in Table 8 and Figure 16.

[18] Subsequently, it will be included as an Annex to the National Energy and Climate Plans (NECP) that are required by the Regulation on the Governance of the Energy Union every 10 years (with a progress report every two years).

[19] The Commission has published an analysis of the long-term renovation strategies that were submitted by 15 November 2020 (by 13 member states) in order to feed into the implementation of the Renovation Wave strategy and the analysis of the recovery plans. It contains an overall assessment of the different strategies, lists the planned measures and highlights best practice, and analyses each LTRS separately following a common template. The Commission will update this analysis later this year when the remaining strategies have been submitted.
https://ec.europa.eu/energy/sites/default/files/swd_commission_preliminary_analysis_of_member_state_ltrss.pdf

[20] For the compliance assessment, 6 evaluation different categories, in relation to the EPBD Art.2a requirements have been identified. Details on the assessment methodology can be found in the forthcoming report Castellazzi L. et al. (2020), Assessment of the long-term renovation strategies under the Energy Performance of Building Directive –EPBD Art.2a JRC Science for Policy report.

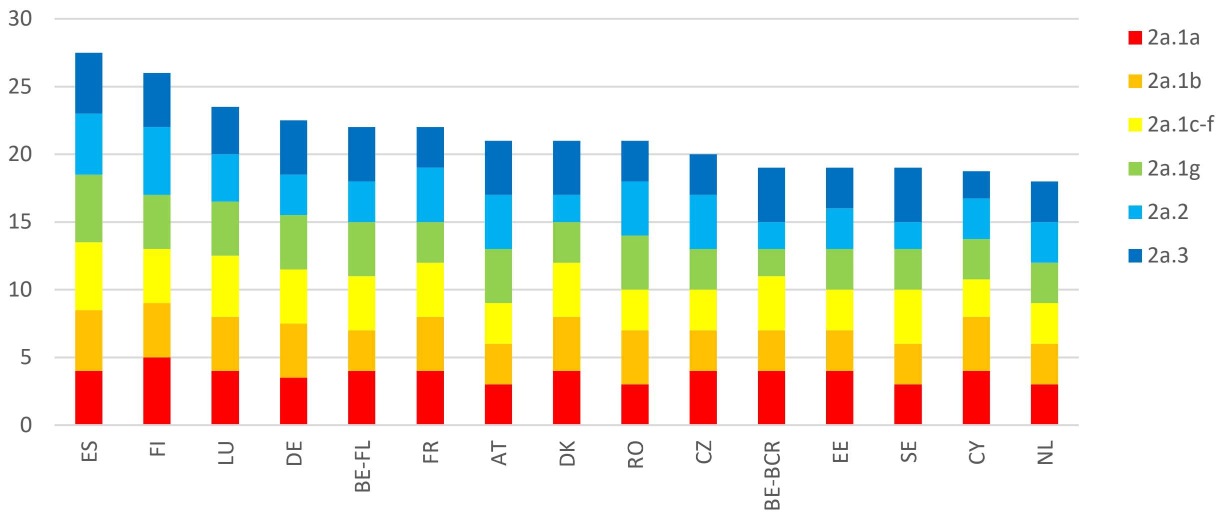
Table 8. Compliance with EPBD Art.2a requirements.

MS	Overview of building stock- Art 2a.1a	Identification of cost-effective approach to renovation - Art.2a.1b	Policies and Actions Art. 2a.1c-f	Expected energy savings and wider benefits - Art.2a.1g	Roadmap and milestones Art.2a.2	Mobilisation of investments; Art.2a.3
Austria	3	3	3	4	4	4
BE Brussels	4	3	4	2	2	4
BE Flanders	4	3	4	4	3	4
Cyprus	4	4	3	3	3	2
Czech Republic	4	3	3	3	4	3
Denmark	3.5	4	4	4	3	4
Estonia	4	4	4	3	2	4
Finland	5	4	4	4	5	4
France	4	4	4	3	4	3
Germany	3.5	4	4	4	3	4
Luxembourg	4	4	4.5	4	3.5	4
Netherlands	3	3	3	3	3	3
Romania	3	4	3	4	4	3
Spain	4	4.5	5	5	4.5	4.5
Sweden	3	3	4	3	2	4

Source: JRC, 2020

Overall, the highest-scored renovation strategy as regards the compliance assessment is the one from Spain (28/30 – 92% of total possible points) followed by Finland (26/30 – 87%) and Luxemburg (21/30 – 78%).

Figure 16. Comparison of the scores of the 15 evaluations of Member States 2020 LTRS.



Source: JRC, 2020

As in the previous LTRS submission rounds the structure of the received documents is quite heterogeneous, with some Member States that exactly followed the structure of EPBD Art.2a (e.g. AT, BE-FL and FI) and others using a different approach (e.g. BRC, DK), providing the requested information in a less systematic way, often spread in annexed documents.

None of the received strategies mentions the covid-19 crisis and the role of building renovation as a way to recover national economies. This is most likely due to the fact that the received strategies were drafted before March 2020 (deadline for submission was 10/03/2020). Nevertheless, also in the strategies received later (e.g. July and August) any reference to the possibility of using building renovation plans to kick-start post-COVID-19 economic recovery is completely missing.

In the submitted strategies, the Art.2a requirements have been covered with a different level of details; the overview of the building stock has been well covered by almost all the Member States (3.8 out of 5 average mark), with the exception of Sweden. Moreover almost all the strategies include a good overview of the current and planned measures to stimulate cost-effective deep renovations, to target worst performing segments of the national building stock, public buildings (3.7/5 average marks), describing also the relevant national actions contributing to the alleviation of energy poverty.

Only few strategies adequately reported the information of the implementation status of the 2017 LTRS (e.g. BE-FL and DK). This was an important new requirement for the 2020 LTRSs, because in the previous strategies the evaluation and monitoring of implemented policies, developing specific monitoring indicators, was quite weak. Also the information on the required public consultation were insufficiently reported by the majority of Member States with the exception of NL, DK, FR, RO, ES and SE.

Another relevant new requirement was the indication of a clear roadmap towards a decarbonised building stock by 2050, with indicative milestones and measurable progress indicators, but less than half of the submitted strategies addressed adequately this provision (i.e. AT, CZ, FI, FR, RO and ES).

Moreover, the majority of the strategies present a high level of ambition (see Table 9), but this is not always supported by a comprehensive set of measures that justify the challenging 2030 and 2050 renovation targets set (i.e. EE, NL, RO). Nevertheless, only few strategies have a low or moderate level of ambitions, i.e. CY and CZ.

Table 9. Ambition level of the analysed 2020 LTRS.

MS	Ambition level	Level of ambition assessment: LTRS renovation targets, indicators, milestones
Austria	Unclear	80% reduction of GHG in the building stock by 2050. Underlying rate of renovation (across all building types): 1.5% p.a. (for the period 2020-2050) The overall level of ambition in terms of fossil fuels in heating and cooling differs across the reported scenarios, but is clearly high in terms of phasing out of coal, heating oil and gas. Data for other assessment indicators are not provided at national level (at regional level only).
Brussels Capital Region	high	At 2050 energy carbon neutrality for heating, domestic hot water, cooling and lighting in the tertiary sector and an average 100 kWh/m2/y primary energy consumption for residential. Although a total decarbonisation of the stock of the building stock is not foreseen at 2050, the level of the strategy ambition is deemed high. In fact, the planned target corresponds to a reduction of the 53% of the current average primary consumption in the residential sector for heating, DHW, cooling and lighting. This means to deep renovate about 80% of the existing residential buildings in the next 30 years. Moreover, according to the Energy Pact commitment, public buildings will be energy neutral by 2040.
Belgium Flanders	high	Reducing the emissions of the Flemish building stock by 74% by 2050 (from 8.9 Mt CO2eq to 2.3 Mt CO2eq) and by 22% by 2030. 2030: Public buildings: reduce CO2 emissions by 40% and reduce primary energy consumption by 27% compared to 2015; Healthcare sector: achieve annual energy savings of 2.09 % per year (per health institution) and 27% savings 2050: Carbon neutrality for the heating plant of non-residential buildings, sanitary hot water, cooling and lighting; existing residential buildings will have to reach the same energy performances of new buildings for which a construction permit was issued as of 2015 (correspond to an energy rating of 100 kWh/m2 per building) . It means on average an energy consumption reduction by 75%.
Cyprus	moderate	The majority of future renovations are modelled as minor or moderate, with only 1 of 6 dwellings expected to undergo a major renovation. While it is assumed that the non-residential stock will, on average, get renovated to deeper levels, the difference between the realistic scenario (i.e. scenario underpinning the Cypriot milestones) and the technical scenario (i.e. maximum potential) is considerably large. This may leave some room for increasing the overall ambition of the milestones set for the building stock. The overall ambition level of the milestones are assumed to be of moderate level.
Czech Republic	low	The optimal scenario is expected to bring only 9% energy savings in 2030 and 23.5% in 2050. The hypothetical scenario then leads to 17 % savings in 2030 and 44 % savings in 2050. The Optimal scenario is very close to BAU and therefore seems conservative, especially given the fact that CZ has a higher than average unitary heat consumption in the building sector (232 kWh/m2y).
Denmark	high	Reduction of the heating needs by 35% at 2050, meaning to pass from a consumption of 113 kWh/m2*y to 76 kWh/m2*y on average at 2050); The overall energy consumption target could appear moderate, however Denmark has already reduced significantly the building stock energy consumption in buildings during the last 30 years (The energy needs of new buildings are therefore currently very limited) and now it has less margins for further reduction compared to other countries.
Estonia	high* (non-supported by adequate policy package)	The main objective of the LTRS is to rebuild the entire existing building stock (built prior to 2000) cost-effectively into nearly zero-energy buildings by 2050. This target seems very ambitious given the current renovation rate and available National resources and takes into account the renovation of both residential and non-residential buildings as well as public sector and private non-residential buildings completed by 2000; nevertheless the current technologies involved in the buildings renovation, make it difficult to achieve a fivefold increase in the volume. Also there seems to be a shortage in labour both in the preparatory and reconstruction phase to cover a rapid increase in the building renovation volume
Finland	high	The Finnish LTRs goal to reduce the emissions from residential and non-residential buildings completed by 2020, by 90% to 0.7 MtCO2 and to decrease heating energy consumption for both residential and non-residential buildings by 55% compared to heating energy consumption in 2005. Although in the period 2020-2050 Finland foresee a steady decrease of his population, the building stock in 2020 will decrease 30% by 2050, the renovation strategy level of ambition is deemed high, also in relation of the already quite good energy performance of the 2020 building stock and the objective of having all buildings (residential and not residential) with an energy class C or above by 2050.
France	high	Overall the LTRS is presenting a high level of ambition in terms of planning, objectives (-49% GHG emission of the building sector at 2030 vs 2015; carbon neutrality at 2050) and policy measures. Especially the regulatory measures stand out by stipulating new refurbishment obligations for the worst part of the building stock and the tertiary sector. A comprehensive package of financial support scheme is in place and well-tailored to a number of different target groups. The sum of measures seems promising to lead to a decarbonisation of the building stock.
Germany	high	Overall aim is to reach a "nearly climate neutral" building stock in 2050. In the buildings sector, Germany has enacted a reduction of greenhouse gas emissions to 70 million tonnes of CO2 equivalents in 2030 in the Climate Protection Act, representing a reduction of 67 % compared to 1990 (210 million tonnes of CO2). This overall positive assessment is also founded on the comprehensive and refined set of measures that address systematically the renovation needs and barriers as well as the stepped-up mobilisation of financing measures.
Luxemburg	high	Overall high level of ambition with clear measures attributed to each segment (residential and non-residential buildings). Reduction of final energy demand: from 6438 GWh/a (2020) to 4611 GWh/a (2030), to 3551 GWh/a (2040) to 2715 GWh/a (2050), which represents a reduction of 28% (2030), 45% (2040) and 58% (2050) respectively compared to 2020. Renovation rate of the building envelope: 3% per annum of the number of housing units built before 1991, corresponding to approximately 4500 housing units per annum (full renovation equivalents). Renovation quality: Efficiency class A/A to B/B, with mean renovation depth of approx. 72 %.

MS	Ambition level	Level of ambition assessment: LTRS renovation targets, indicators, milestones
NL	high* (non-supported by adequate policy package)	The indicative milestone for Netherlands is to reduce 5.3 million tonnes of CO2 emissions by 2030 (-37%), compared to 1990. This equals to 4.4 million tonnes CO2 of extra reduction relative to existing and proposed policy that will be achieved by a range of measures aiming at reducing energy consumption and increasing the proportion of renewable energy in the built environment. However, according the forecasts reported in the document, estimated emissions in 2030 are higher than the indicative milestone. The scarcity of indicators or modelling results in the LTRs makes it difficult to assess whether the mix of low, medium and deep renovations actions supported by the large number of incentives available can be considered adequate for leading Netherlands to the decarbonisation of the building stock.
Romania	high* (non-supported by adequate policy package)	Based on the recommended scenario, the annual renovation rates will increase gradually from the current 0.5% to 3.39 % in 2021-2030, 3.79% in 2031-2040 and 4.33% in 2041-2050. This is expected to bring a 9% reduction of final consumption in 2030 (0.83 Mtoe) and cumulative -24% GHG emission reduction (2.34 Mton) in 2021-2030 and -65% reduction of final consumption in 2050 (-6.14Mtep) and -80% cumulative GHG emission reduction in 2021-2050. These are deemed quite ambitious targets, considering the current low renovation rate (0.5%), the current quite low pro-capita energy consumption (i.e. 0.375 toe in 2016, around 71.5 % of the EU-28 average) expected to increase considering the annual GDP grow. However, given that the full details on the measures are not provided in the LTRS, it is quite difficult to evaluate how the various PaMs will actually contribute towards these milestones, and hence review how realistic and achievable these milestones are.
Spain	high	Spanish LTRS is an ambitious strategy: the target of renovating 1.2 million dwellings over 2021-2030 (improving EE of the building envelope) would mean an expected substantial increase in the renovation rate from 30000 dwellings per year (2017, see. NECP) to 300000 per year in 2030 (x10 increase). Heating in the residential sector is expected to give a large contribution to the projected energy savings: as of 2050, the expected consumption from heating would be less than 55% of 2020 levels. Projections reported indicated that the targets are reachable and the implementation of adequate measures to foster PV installations and self-consumption, together with energy efficiency renovations are likely to lead to the expected decarbonisation of the building stock by 2050.
Sweden	low/unclear	Sweden has objectives that can be considered relatively ambitious (2030 target of 50% reduction of energy intensity compared to 2005, 100% renewable electricity production by 2040, and cut its net greenhouse gas emissions to zero by 2045 and then achieve negative emissions). Nevertheless, the same ambitions do not seem to be reflected in the targets for the building sector that in 2017 accounted for 39% of end-use energy consumption. In fact, the expected energy savings at 2050 are around 10-15%.On the other hand, according to a recent study (2019), the potential for energy saving in the building sector, is much higher than the energy savings of the reference scenario (i.e. 25% for the "Energy efficient renovation" scenario, and 38% "Major renovation" scenario). This issue/aspect should be better explained/investigated.

Source: JRC, 2020

3 Conclusions

Studying the key trends related to the energy performance of buildings during the period 2005-2018, it is observed that the final energy consumption of the building sector as a whole decreased by 5%. By means of index decomposition analysis, it has been found out that in the residential sector, improvements in energy efficiency as well as warmer winters have led to a 10% reduction in the final energy consumption while in the services sector, the final energy consumption increased by 2% mainly due to economic growth.

Renovation rates, investment costs and specific primary energy savings are important indicators helping to understand the progress of EU towards the target to reach a decarbonised building stock by 2050. Distinguishing by renovation level, it's observed that 'light' renovations succeed more commonly, and as a result the generated savings are relatively low. Regarding investments, it's observed also that the largest amounts have been invested for 'light' and 'medium' renovations instead of the 'deep' renovations. This is the main challenge on which the efforts undertaken within the EPBD framework has to focus in the coming years.

As Europe seeks to overcome the COVID-19 crisis, renovation offers a unique chance to rethink, redesign and modernise our buildings to make them fit for a greener and digital society and sustain economic recovery. The recent Renovation Wave initiative[21] provides a reinforced framework and a European budget to support a paradigmatic transition of the existing building stocks. The 2021-2027 Multiannual Financial Framework, the recovery instrument NextGenerationEU, the Recovery and Resilience Facility (RRF) and connected funds will provide a relevant support targeted to climate-related expenditure that can support renovation investment and energy efficiency-related reforms across Member States. This is an unprecedented opportunity to trigger a broad and deep energy renovation and capitalize the progresses of recent years. In fact, the funding should be addressed and defined on the basis of the references already available. In particular:

- The Energy Performance Certificates can be an appropriate tool also to promote deep renovation works by taking staged renovation into account. Moreover, as requested in the mended EPBD (Art.10.6), financial incentives can be based on the energy classes already defined at national or regional level.
- The national NZEBs definitions, especially if available for existing buildings, can be considered as the main reference to address incentive instruments for deep renovations.
- Also the energy levels derived from the cost-optimal calculations should be taken into account as one of best energy targets for deep renovation works, since they maximise the economic profit over the building life, from a financial and/or macro-economic perspective.
- Last but not least, the Long-Term Renovation Strategies already provide a robust framework, including a roadmaps with targets, milestones, progress indicators and a collection of financial mechanisms (in force and planned) that can be enhanced by the European funds.

Energy performance certification under EPBD is an information scheme set up by Member States that must be available to prospective buildings' buyers or tenants displaying buildings' energy performance based on an energy class or energy rating system. The implementation of EPC schemes varied significantly from country to country. Although the implementation of EPCs generally improved after the EPBD recast, there are still issues to be addressed.

According to the EPBD, Member States have to develop cost-optimal calculations every 5 years to verify and update the energy performance requirements in force. The calculation is done from two economic perspectives: the financial and the macroeconomic. Analysis shows that most of Member States adopted the cost-optimal approach in appropriate way. To note that there is still room for improvements that can be starting with the revision of official guidelines. The introduction of a common template for collecting data as well as verification tasks done by the Commission will provide significant support to the Member States.

According to Article 4 of EED, moved under Article 2a of the 2018 revised EPBD, Member States must develop long-term renovation strategies with the aim to mobilise energy efficiency investments to decarbonise the existing building stock by 2050 including specific milestones for 2030 and 2040. This report analyses 15 LTRSs received by the EC by the end of 2020. The submitted strategies are quite heterogeneous, almost all the Member States provide a good overview of the building stock and policies to stimulate cost-effective deep renovation, to target worst performing buildings and public buildings and to alleviate energy poverty. Only a few strategies provide a good reporting regarding the implementation of 2017 LTRS as well as the required public consultation. Less than half of the submitted strategies provide a clear roadmap towards a decarbonised building stock by 2050. The majority of the strategies present a high level of ambition, which is not always supported by comprehensive policies and measure. However, none of them mentions the impact of the COVID-19 crisis and the role of building renovation as a mean to recover national economies.

[21] *COM(2020) 662 final. A Renovation Wave for Europe - greening our buildings, creating jobs, improving lives.*

Looking forward, NZEBs are progressively spreading and involving new and smart technologies combined with environmental and social considerations. A broad scale shift towards NZEBs requires an additional effort to overcome the main barriers that persist especially at retrofit level (technical, financial, social, and political). For the next decade, new ambitious building energy performance targets need to be set which go beyond minimising the energy use and aim, as is the case with plus-energy houses, at (over)compensating the remaining low energy needs with renewable energy and even go beyond the building level reflecting district approaches. Moreover, its ability to manage the energy demand and generation according to local climate conditions, user needs and grid requirements (i.e. its energy flexibility), will be essential. Together with the implementation of the national Long-Term Renovation Strategies, this will be necessary for a highly energy efficient and decarbonised building stock by 2050 and for achieving the EU energy and climate goals.

While the ultimate goal is to streamline private financing into energy efficiency, the energy efficiency market still faces various obstacles which require further intervention. Together with an appropriate policy framework, successful energy efficiency financial instruments can incentivise the stakeholders involved, and balance the risks of implementing energy efficiency improvements with the resulting energy savings returns and benefits. Future research, however, must also look beyond innovative financial models. For example, the concept of one stop shops (OSS) has gained popularity in recent years as they offer a single entry to customers which can guide them through all aspects of the complex renovation value chain. Aggregation of small projects through the establishment of OSS or other means is also an issue that cannot be resolved through financing alone. The same applies to identification of ways to overcome uncertainties with regards to future energy savings, which must be investigated in more detail in order to shield customers and ESCOs from performance risks. Finally, additional research is also needed to quantify the financial impact of non-energy benefits, including increased property value. All these are prerequisites for turning innovative models such as energy efficient mortgages, PACE, feed-in tariffs and the other instruments into mainstream financial products that will have a pivotal role as the energy transition accelerates in the coming decades.

The Commission is reviewing the Energy Performance of Buildings Directive (planned for December 2021) focusing on aspects most relevant for supporting the renovation of buildings and delivering on the increased climate ambition. It will also ensure complementarity and continuity of the ongoing transposition and implementation of the recent revision of the Directive as part of the Clean Energy for all Europeans Package. The Renovation Wave already provided an indication of specific aspects and measures to be considered through the revision of the EPBD:

— Addressing worst performing stock through the phased introduction of Mandatory Minimum Energy Performance Standards for buildings for all types of buildings (public and private). This grows from experience in a number of Member States (e.g. NL, FR, BE-Flanders and the UK);

— Reviewing requirements for new buildings (NZEBs) and looking into the long-term vision towards a net-zero buildings stock in line with the Climate Target Plan and the increased climate ambition in the Climate Law;

— Improving information tools, particularly strengthening and digitalising Energy Performance Certificates (EPCs), and introducing building renovation passports (clear map to building renovation, including individual measures over time);

— Modernising buildings by addressing smartness, digitalisation and fostering e-mobility;

— Addressing the possible review of Long-Term Renovation Strategies framework, to improve their monitoring and governance and align with the Renovation Wave and the increased climate ambition;

— Supporting a more ambitious and effective deployment of EU funds through the introduction of a 'deep renovation' standard in the context of financing and building decarbonisation objectives. The revision will also examine synergies with ETS, including the use of revenues to support housing affordability, and building renovation, as indicated in the Renovation Wave.

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List of abbreviations and definitions

EPBD	Energy Performance of Building Directive
EED	Energy Efficiency Directive
EPC	Energy Performance Certificates
LTRS	Long Term Renovation Strategies
MEPR	Minimum Energy Performance Requirements
NZEB	Nearly Zero Energy Building
EE	Energy Efficiency
RES	Renewable Energy Systems

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