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Energy transition and the buildings sector:

Analysis of the EU policy framework and its implementation on the national and regional level

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Résumé

La consommation d'énergie dans le secteur du bâtiment est responsable d'environ 28% des émissions mondiales de dioxyde de carbone (CO_2) liées à l'énergie en 2017 et représente un tiers des émissions de CO_2 dans l'Union Européenne (UE). Pour atteindre les objectifs climatiques, des efforts et des changements radicaux sont nécessaires dans tous les secteurs de l'économie et à tous les niveaux décisionnels. Dans ce cadre, les questions de recherche de ce mémoire sont les suivantes :

- Quelles sont les principales mesures législatives au niveau de l'UE afin de réduire les émissions de CO2 dans le secteur du bâtiment?
- Comment certaines mesures au niveau de l'UE ont-elles été mises en œuvre jusqu'à présent dans la Région de Bruxelles-Capitale et en Italie, y compris, le cas échéant, en Lombardie?

À la suite d'une analyse approfondie du cadre législatif de l'UE, trois mesures principales ont été identifiées et leur mise en œuvre aux niveaux national et régional a été évaluée. Premièrement, la mise en place d'exigences minimales de performance énergétique des bâtiments tenant compte des coûts pendant le cycle de vie économique; deuxièmement, des mécanismes d'obligations visant à stimuler un changement de comportement des consommateurs ainsi que la demande et l'offre de services et technologies visant à réaliser des économies d' énergie; et troisièmement, des niveaux minimaux d'énergie renouvelable dans les bâtiments pour favoriser le remplacement des combustibles fossiles.

L'intérêt de cette recherche est de déterminer si, dans les études de cas, les gouvernements ont atteint les objectifs et les principes énoncés dans la législation UE plutôt que sur des exigences techniques spécifiques, L'analyse montre que l'Italie, la Lombardie et Bruxelles ont tous adopté des exigences plus strictes en matière d'efficacité énergétique dans le secteur du bâtiment, en mettant l'accent sur l'optimisation des coûts. Il s'agissait d'un objectif majeur de la directive de l'UE sur la performance énergétique des bâtiments. En ce qui concerne les mécanismes d'obligations (article 7 de la directive sur l'efficacité énergétique), cette étude confirme la grande flexibilité offerte au niveau de l'UE ; dans ce cas, les gouvernements dans les études de cas ont choisi différents types d'instruments sur la base de préférences nationales afin de répondre aux objectifs spécifiques fixés au niveau de l'UE. Enfin, il est possible d'observer une approche divergente concernant l'obligation non contraignante d'établir un niveau minimal d'énergie renouvelable dans les bâtiments. Loin d'être exhaustive, cette recherche propose une piste de réflexion sur la valeur ajoutée des mesures européennes visant à atteindre l'objectif de décarbonisation du bâtiment d'ici 2050.

Abstract

Energy consumption in buildings accounted for around 28% of energy-related carbon dioxide (CO_2) emissions worldwide in 2017 and is responsible for more than one-third of CO_2 emissions in the European Union (EU). Meeting climate mitigation objectives requires efforts and radical changes in every sector of the economy and at all decision-making levels. In this context, the research questions of this thesis are the following:

- What are the main policy measures at EU level to reduce CO_2 emissions in the buildings sector?
- How selected EU policy measures have been implemented so far in the Brussels-Capital Region and Italy including, where applicable, in the Lombardy region?

Following an in-depth review of the EU policy framework, three main EU measures are identified for assessment of their implementation at national and regional levels. First, minimum energy performance requirements of buildings taking into account lifecycle costs; second, energy efficiency obligation schemes to stimulate behavioural changes and demand and supply of energy efficiency measures; and third, minimum levels of renewable energy in buildings to promote the switch from fossil fuels to renewables.

Rather than on the specific technical requirements, the interest of this research is to find out whether governments in the case studies have met the general objectives and principles set by EU law. The analysis shows that the Brussels-Capital Region, Italy, and the Lombardy region have adopted stricter energy efficiency requirements in buildings with an emphasis on cost optimisation. This was a major objective of the EU Energy Performance of Buildings Directive. As for the implementation of energy efficiency obligation schemes from Article 7 of the Energy Efficiency Directive, this research confirms the broad flexibility offered at EU level; in this instance, the governments in the case studies have selected different types of instruments based on national preferences to meet specific objectives set at EU level. Finally, it was possible to note the diverging approach regarding the non-binding requirement to establish a minimum level of renewable energy in buildings.

Far from being exhaustive, this research addresses and leaves open some questions about the added value of EU climate mitigation measures to decarbonise the buildings sector by 2050.

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Introduction

Background

Meeting the objectives set out in the Paris Agreement on climate change[1] will require extraordinary efforts in all sectors of the economy. As approximately two-thirds of global greenhouse gas (GHG) emissions originate from the energy sector (OECD/IEA, 2015; p.21), there is a need for a radical transformation in the way energy is used and generated. In 2017, energy services in buildings accounted for 30 % of global final energy consumption and 28% of energy-related carbon dioxide (CO_2) emissions worldwide, considering both on-site and indirect emissions and excluding embodied energy (OECD/IEA and UNEP, 2018). Similar trends are found in the European Union (EU), where buildings represent the largest end-use sector, responsible for more than one-third of CO_2 emissions (European Commission, 2018a).

Despite the current negative environmental footprint, analyses and strategic political documents stress the tremendous potential for cost-effective energy savings and low-carbon solutions in buildings. The call for action to fill what the literature defines as the "energy efficiency gap" (Hirst and Brown, 1990: 267; Jaffe and Stevins, 1994: 804) is reflected, among other things, in the EU objective to achieve a highly energy-efficient and decarbonised building stock by 2050.

To address barriers and market failures, governments may intervene in the private domain through policies and regulations. In this regard, Linares et al. (2013: 546) distinguish three types of instruments in environmental regulation: a) command and control instruments (e.g. standards); b) economic instruments, which can be further divided into price instruments (taxes) and quantity instruments (tradable quotas); and other instruments (information, voluntary agreements, etc.). The policy-making process is often simplified as a policy-cycle where more or less consecutive stages can be distinguished. Crabbé and Leroy (2008), for example, identify the following six phases: a) agenda setting, in which societal problems are placed on the political agenda; b) policy-making, when possible solutions are generated and selected; c) forming of opinions and political decisions; d) policy implementation, which implies a mobilisation of instruments

[1] Adopted in 2015 at the twenty-first session of the Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC), the Paris Agreement sets the objective of holding the increase in the global average temperatures to well below 2°C above pre-industrial levels and pursue efforts to limit such temperature increase to 1.5°C.

and organisational planning and that results in «policy outputs»; e) policy effects or policy outcomes, concerning intended changes in the behaviour of the target group and/or the environmental impact; and f) finally, the result of this process, together with autonomous developments, lead to new social problems and in turn to new agenda-setting. In this context, to facilitate learning and improve policies, each of the above phases deserves monitoring and evaluation (ibid.). With a focus on the EU legislation addressing energy in buildings, and considering the limitations in terms of access to data and time, this research will focus on phase (d) *policy implementation and policy outputs* of the above-described policy-cycle.

However, given the complex multi-level governance system of the EU, to fully appreciate the policy and regulatory framework in a specific domain, it is important to look at the interplay between all the levels of governance involved. Transposition and implementation[2] of EU law[3] at national and local levels have been studied since the 1980s. According to Löfgren (2015), the interest stems from the fact that «by studying the implementation of EU policies, we are endowed with a critical perspective into how, and to what extent, the European integration process affects and transforms the member-states of the EU». In this regard, also the field of energy in buildings has attracted the interest of scholars. Annunziata et al. (2013), for example, conducted a study covering 28 EU member states to better understand the difference and similarities between national regulatory frameworks towards nearly-zero energy buildings (nZEB) targets. Despite the common EU framework, this study shows that countries in Europe have adopted different approaches due to different traditions and maturity of the new EU measure in various contexts. Furthermore, in a comparative analysis of the implementation of the EU Energy Performance of Buildings Directive (EPBD), Abela et al. (2013) also observed a divergent approach taken in four Mediterranean countries. Moreover, a general assessment of the implementation of EU legislation in the EU-28 has been carried out by Renders et al. (2018), while a more detailed analysis of the impact of the EPBD was performed looking at specific sub-sectors, for example in the residential sector in Spain (López-Ochoa, 2017) and in the social housing sector in Cyprus (Fokaides, 2017). However, too often the impact of EU legislation on the national and regional regulatory frameworks has been assessed by looking only at one specific measure or directive or is limited to a short timeframe.

[2] *Implementation* is a general term covering both transposition and application of EU law. *Transposition* refers to the «procedure by which EU member states incorporate EU directives into their national law in order to meet their objectives, requirements and deadlines», while *application* is the «practical application of the national transposing provisions to a concrete situation or to a number of situations (Ballesteros, 2017; European Parliament Research Service, 2018).

[3] Or *Community law* prior to the entry into force of the Treaty of Lisbon in December 2009. The predecessor of the EU from 1993 to 2009 was the *European Community (EC)*, previously *European Economic Community (EEC)* since 1957. For simplicy, the terms ʻEU' and ʻEU law' will be used throughout this thesis.

Objective and research question (s)

Against this background, the overall objective of this thesis is two-fold. First, to deepen the knowledge on the subject by tracking the evolution, since the 1990s, of the EU policy and regulatory framework aiming to reduce energy consumption in buildings and promote its production from renewable sources. Second, to assess how selected measures have been implemented in two case studies. The focus will be on general principles, rather than on the specific technical requirements, to find out whether the national or regional governments analysed have met the objectives established at the EU level. To set the boundaries of the research, this work will be limited to the impact of three EU policy measures on the legislative framework in two case-studies only and will not address other very relevant aspects, for example, the quantification of the environmental impact (when not already available) and socio-economic aspects.

In detail, the **specific research questions** are:

a) What are the main policy measures at EU level to reduce CO_2 emissions in the buildings sector?
b) How selected EU policy measures have been implemented so far in the Brussels-Capital Region and Italy, including (where applicable) in the Lombardy region?

Methodology

This work applies a qualitative approach, although some parts contain an analysis of available data. Three main techniques are used to collect information, namely literature review, analysis of legislation and reports from government and intergovernmental institutions, and complementary semi-structured interviews with eight experts from public authorities and representatives of industry associations (see Annex 1). The first part of this research will be based on a literature review about the environmental problem considered, i.e. CO_2 emissions from energy use in buildings, to better understand opportunities, barriers, and role of policy-makers. This will be followed by a review, mostly based on legal documents and grey literature, to learn how the EU framework has developed over the last decades. This research aims to provide a response to the first research question and to identify and further study specific EU policy measures addressing the buildings sector. These measures will be classified according to the opportunities and options previously identified. One key EU policy measure per category will be selected based on the potential relevance in terms of CO_2 emissions reduction according to available literature, policy documents, and interviews with experts.

To address the second research question, a thorough analysis will be required to track and assess how the three selected EU measures have been implemented in the context of two case studies. This will be done to assess, *inter alia,* whether or not national and regional governments have complied with requirements from the EU; whether the requirements coming from the EU level were already somehow applied in the national/regional context; whether the national and regional levels have anticipated or just reacted to EU legislation; and whether EU policies have led to a certain degree of harmonisation between the two cases. The case study is a research method that can be applied for any phase of the public policy cycle, including policy implementation. According to Crabbe and Leroy (2008:59-60) an important criterion for determining whether a case study is desirable is the nature of the research question. Since the assessment of the implementation of EU legislation is an explanation (qualitative understanding), then a case study is a valid option. The selection of case studies in Belgium and Italy is motivated by the fact that both countries present energy consumption per dwelling higher than EU average and, in particular, Belgium has the highest consumption of all EU member states. The two countries are also among the few with increasing energy intensity trends in the tertiary sector (Odysee-Mure, 2015). Lastly, the knowledge by the author of the local languages in the two countries was expected to facilitate the research. That said, it is important to clarify that because the implementation of the EU legislation on energy in buildings in Belgium is a regional responsibility, the analysis will cover the Brussels-Capital Region (BCR). Finally, a specific comparison between the BCR and Italy (and Lombardy) is not found in the scientific literature, which may add value to this research.

Structure

This thesis is structured as follows: chapter 1 introduces concepts and trends related to energy consumption in buildings as well as possible solutions and barriers for emissions reduction; chapter 2 presents the policy framework established at the EU level with a focus on selected policy measures; chapter 3 and 4 look at the transposition and implementation of those selected EU policy measures in the BCR and in Italy, including a focus on Lombardy where applicable; chapter 5 features a discussion on the comparative results obtained; and, finally, the conclusions put forward a number of ideas for reflection.

1. BUILDINGS AND THE ENERGY TRANSITION: CURRENT TRENDS, OPPORTUNITIES AND CHALLENGES

The objective of this chapter is to provide the general context of the environmental problem addressed in the research. To this end, the main energy services in buildings will be presented, including global and European trends, followed by a brief overview of the opportunities and challenges for CO_2 emissions reduction in the sector.

1.1 Energy services and consumption in buildings

Energy consumption in buildings worldwide amounted to about 125 exajoules in 2017, representing 30% of final energy consumption (Figure 1), with residential buildings covering the largest portion (70% compared to 30% of non-residential buildings). This energy consumption caused the emission of 9.5 gigatonnes of CO_2, i.e. 28% of global energy-related emissions, including both direct on-site and indirect emissions from electricity and heat generated off-site (OECD/IEA and UNEP, 2018).

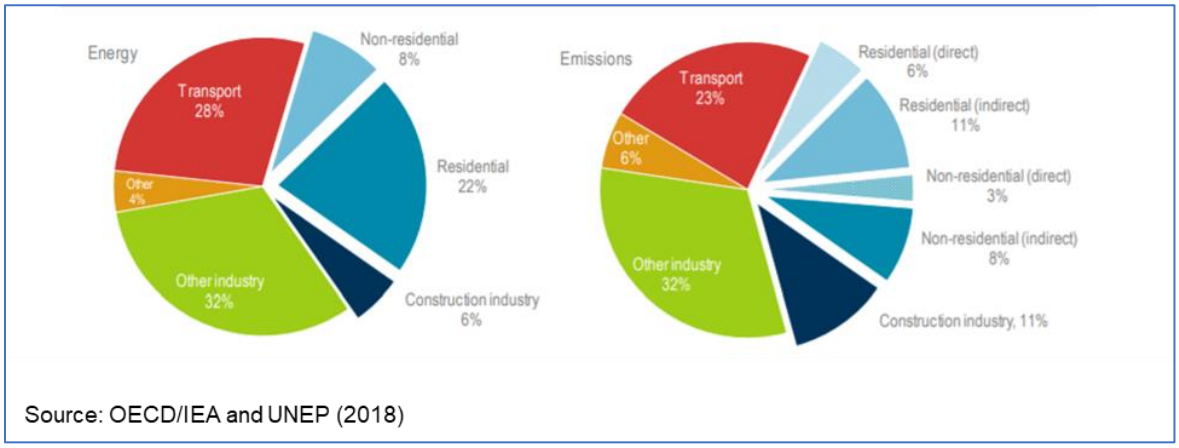

Figure 1 Global share of final energy consumption and CO_2 emissions by sector
Source: OECD/IEA and UNEP (2018) 2018 Global Status Report: Towards a zero-emission, efficient and resilient buildings and construction sector.

Energy consumption in buildings is very significant also in the European context. As depicted in Figure 2, residential (287 Million tonnes oil equivalent or Mtoe), commercial and public buildings (158 Mtoe) are responsible all together for over 40% of EU final energy consumption and represent the largest end-use sector in the EU-28 (Eurostat). In this regard, it is worth clarifying that energy use associated with the construction of buildings is reported under the industrial sector.

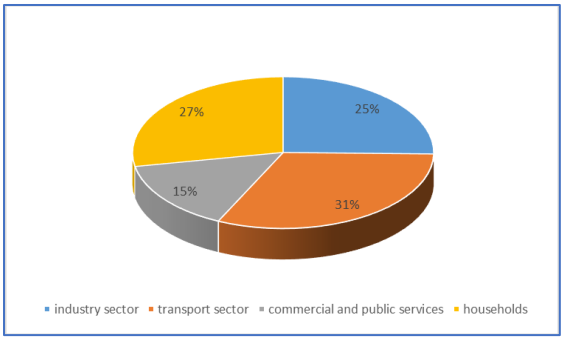

Figure 2 EU final energy consumption by sector, 2017; (%)
Source: Adapted from Eurostat (database) https://ec.europa.eu/eurostat/web/energy/data/database

This energy demand is still predominantly covered by burning natural gas and other fossil fuels as it is possible to note from Figure 3 for the residential sector[4]. CO_2 emissions from energy consumption in buildings have, therefore, been reducing quite slowly and currently amount to some 36% of total EU emissions (European Commission, 2018a).

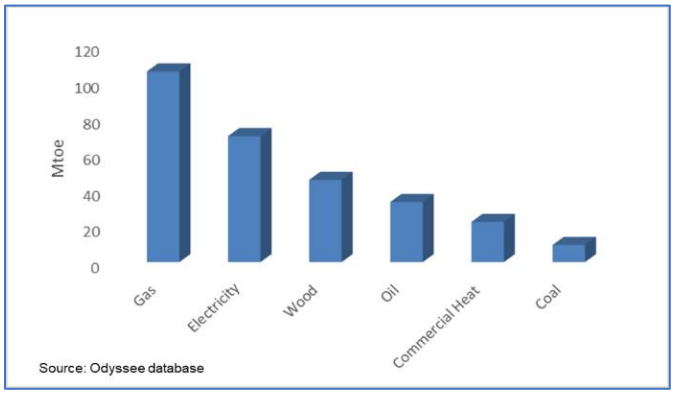

Figure 3 EU final energy consumption in residential buildings by fuel/vector, 2016 (Mtoe)
Source: Odyssee (database) https://www.indicators.odyssee-mure.eu/energy-efficiency-database.html

Energy use in buildings serves multiple purposes which can be grouped as follows:

a) Indoor thermal comfort through space heating and cooling (e.g. 20 °C in the winter and 24 °C in the summer);
b) water heating for washing;

[4] The figure, however, does not reveal the sources used to generate electricity and commercial heat (i.e. heat delivered from a third party through a district heating network).

c) lighting;
d) operation of appliances such as computers, televisions, fridges, washing machines, etc; and
e) cooking.

Overall energy demand depends on local weather and climatic conditions, income and number of occupants, type of buildings (e.g. single-family house, multi-apartment buildings) and other factors. Space and water heating demand represent almost 65% of final energy consumption in member states of the Organisation for Economic Co-operation and Development (OECD) and circa 50% in non-OECD countries. However, improved living standards in non-OECD countries are contributing to the growing demand for lighting, appliances and increasingly for space cooling, notably in countries with warm and hot climates (OECD/IEA 2017).

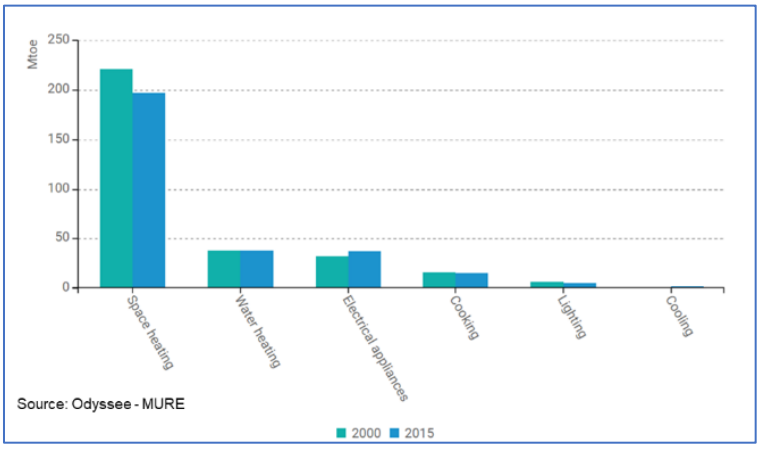

Figure 4 Final energy consumption in residential buildings by end-use in the EU (Mtoe), 2000-2015
Source: Odyssee-MURE (n.d.), Sectorial profile – Households (online) https://www.odyssee-mure.eu/publications/efficiency-by-sector/households/household-eu.pdf

In the EU's residential buildings, 71% of the energy is used to cover space heating demand (European Commission, 2018a). As reported by Odyssee-Mure project (see Figure 4), space heating consumption is slightly declining, while the share of water heating remains stable, and the use of electricity for appliances has increased from 10% in 2000 to 13% in the year 2015. Furthermore, lighting is around 2% and the contribution of cooling in residential buildings is growing but remains negligible (Odyssee-MURE, n.d.). The tertiary sector, on the other hand, presents different patterns depending on the subsector. It is estimated that 63% (96 Mtoe) of energy consumption in 2012 was used for heating and cooling (European

Commission, 2016:21). Compared to the residential sector, electricity used for lighting, air-conditioning, appliances and refrigeration is higher in the tertiary sector than in the residential sector.

The amount of primary energy to satisfy thermal comfort requirements depends on the behaviour of the occupants, the efficiency (coefficient of performance) of the heating or cooling system, and the insulating properties of the building envelope.

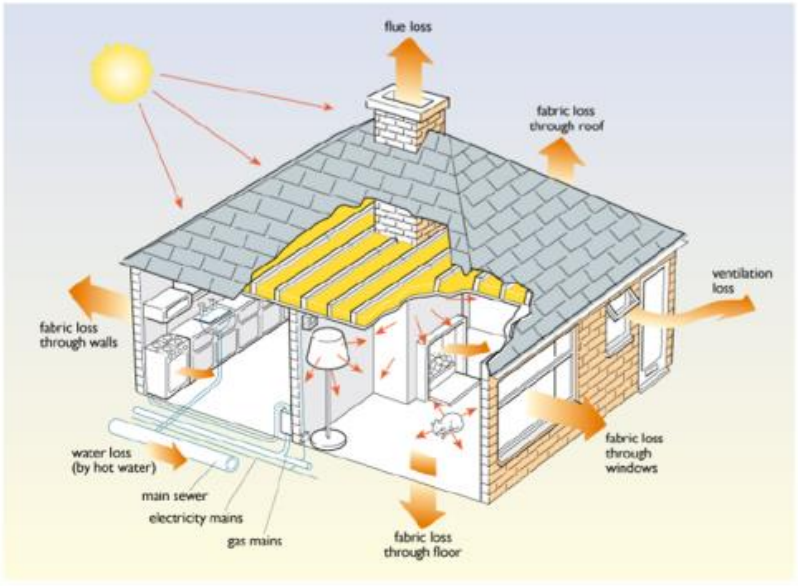

Figure 5 Illustration of heat flows through a building
Source: The Open University (2016:12), Energy in buildings, Open Learn.

Buildings lose heat in the winter or gain heat in the summer through walls, windows, ceiling, etc. due to conduction and air leakage or ventilation (MacKay, 2009). Conduction losses depend on a) the total area available for the flow; b) thermal transmittance of the envelope, also known as U-value[5]; and c) the temperature difference between the indoor and outdoor environments. Another aspect to consider is that, on top of the heating system, the temperature of a building is also influenced by passive solar gains from solar energy and by free heat gains from lights, occupants, hot water use, etc. (The Open University, 2016). Figure 5 illustrates the overall heat flow system through a building.

[5] U values are measured in W/m²/K. Lower U-values indicate lower heat losses and high levels of insulation.

1.2 Overview of opportunities for CO_2 emission reductions

As described in the previous section, energy consumption in buildings is currently a major contributor to climate change. However, there are considerable opportunities to reduce demand and associated emissions using existing and mature technologies, together with design approaches (Mlecnik et al., 2010; Powell et al., 2015). A popular hierarchical approach to achieve energy sustainability, known as «Trias Energetica», is by a) preventing the use of energy by reconsidering the energy use; b) using sustainable energy sources as widely as possible; c) using fossil fuels as efficiently as possible (Hestnes, 2001; Lysen, 2002; Entrop and Brouwers, 2010). In the context of the decarbonisation of the buildings sector, the opportunities for CO_2 emission reductions can be classified under the following four categories: a) technical improvements to the envelope to reduce the load; b) use of more efficient equipment; c) energy conservation behaviours; and d) switch to renewable energy or low carbon-intensive fuels.

a) Technical improvements to the envelope reducing demand for heating, cooling, and lighting

Several design techniques are available to reduce energy demand in buildings. In colder climates, thermal insulation is crucial to reduce heat losses, while in warmer climates it is important to minimise solar gains. Architectural details of individual buildings, such as orientation and shape, can also have an important role, including through the provision of daylight to reduce artificial lighting needs (Liu et al., 2010).

It is estimated that the energy demand in buildings can be reduced by 70–80 %, with the potential in new buildings larger than for existing buildings (Powell, 2015). However, new buildings will only represent less than 25% of the building stock in 2050. On the other hand, 35% of existing buildings in Europe are over 50 years old, and almost 75% were built at a time when no energy performance requirement was in place. More energy-efficient buildings also increase the health and well-being of occupants. Therefore, understanding and increasing awareness of these benefits can be an incentive for the implementation of energy-efficient buildings (OECD/IEA and UNEP, 2018). However, energy renovation rates in the EU remain as low as 1%-1.5% per year, and the objective for the next years is to accelerate these trends dramatically (European Commission, 2018a).

b) Use of more efficient equipment and control systems to cover demand

Increasing the efficiency of the equipment used to satisfy energy services can reduce energy consumption or at least contribute to offset increased number of energy-consuming appliances in residential and non-

residential buildings. Technology innovation and regulations have already contributed to reduced unit consumption, especially of light bulbs (e.g. by phasing-out inefficient incandescent light bulbs from the market) and large appliances.

Building automation and control systems can also contribute to optimising the technical building systems' operation, collect and assess data and present the information to decision-makers, including system operators, to allow for informed decisions about energy-saving potential. In this context, information and communication technology can enable demand-side management to shift loads and reduce the need for polluting peak plants.

As for space and water heaters, Pezzutto et al. (2019) report that conventional non-condensing boilers operated on natural gas, oil, coal and bioenergy are currently the most used technology in the EU (about 80 million units installed), followed by stoves (60 million units) and electric radiators (approximately 30 million units). Energy consumption of heating systems can be reduced with the replacement of conventional systems, whose efficiency ranges from 40 to 80%, with modern condensing boilers, which extract heat from their waste gases and can reach 90% efficiency (Powell, 2015 17).

c) Energy conservation behaviours

As pointed out by Powell et al. (2015:33), «the reduction of energy is nearly always considered from an engineering or technical perspective in which technology is used to improve the energy efficiency of supplying the required building services». On this point, Zaccai (2019: 96) stresses that searching in technology a solution to pollution problems is consistent with the technophile nature of our societies. However, both authors stress that while technologies are «essential ingredients», a technical approach only can exclude broader factors, such as how society is organised (Powell, 2015:33). Overall, reducing CO_2 emissions in buildings, like in other sectors of the economy, is a complex task and may require structural societal changes including urban planning, energy conservation behaviours, and a greater reliance on the sharing economy principles. In this context, it is important to shed light on the difference between energy conservation and energy efficiency. The former involves using less or going without a service to reduce energy consumption, for example, by turning off the heating system in unused rooms. On the other hand, energy efficiency is about using less energy to obtain the same service levels. Powell et al. (Ibid:) also underline that «energy conservation and energy efficiency are linked but neither automatically guarantees energy reduction, due to the rebound effect». The rebound effect is a paradox, whereby energy efficiency

measures result in lower energy savings than expected. This is because the money saved from energy efficiency measures may be used to pay for more of the same energy service or another service requiring energy. The rebound effect can also mean that, after the implementation of energy efficiency measures in buildings, the expected energy performance of a building may not be achieved, leading to what is known «energy performance gap» (Ibid.).

d) Fuel switch to renewable energy sources and low-carbon vectors

As noted above, due to the rebound effect and other factors, energy efficiency and conservation measures alone cannot guarantee the achievement of decarbonisation in the buildings sector. From the technology point of view, therefore, it will be key in the next years to phase-out fossil-based heating systems to avoid lock-in effects in the buildings sector.

On top of fossil fuels and biomass stoves, heating and cooling needs in buildings can be covered with on-site solar thermal collectors and both absorption and electric heat pumps. The latter can provide space heating, cooling and hot water by converting ambient energy (air and water) and energy stored in the ground to useful heat. This conversion is made possible thanks to the use of a refrigerant liquid boiling at a very low temperature, typically about –15 ºC (The Open University, 2016: 54).

Biomass, solar thermal, geothermal energy and heat pumps can also supply thermal energy through a district heating and cooling network of pipes connecting the buildings in a neighbourhood or the whole city. Lund et al. (2014) highlight that new and refurbished buildings can use supply temperatures of 40 °C and cool down the hot water to near room temperature (20–22 °C). District heating systems can therefore evolve and, unlike conventional systems, operate with low temperatures. This change can facilitate the use of low-temperature renewable heat sources such as solar and geothermal heat and excess heat (e.g. from data centres) and reduce grid losses. The new generation of low-temperature district heating can be an integrated part of energy systems and make use of excess electricity from variable renewable energy sources to supply thermal storage and/or operate large heat pumps. Furthermore, Buffa et al. (2019) report of very low-temperature thermal networks in operation in Europe able to cover both the heating and cooling demands of buildings by means of distributed heat pumps installed at the customer substations.

Additionally, the European Commission Communication “A Clean Planet for all: A European long-term strategic vision for a prosperous, modern, competitive and climate neutral economy” argues that emerging low carbon vectors such as hydrogen (e.g. fuel cell micro-cogeneration and power-to-gas) need to play a

bigger role to complement the above solutions and help the EU meet long-term climate objectives in the buildings sector.

To conclude, it is worth highlighting that the conception of buildings solely as a source of energy consumption and pollution is rapidly changing, at least in theory. According to certain visions, buildings hold significant potential as "micro-energy hub", flexibly connected and synchronised with an energy system and able to produce, store and consume energy efficiently (BPIE, 2016). Buildings can be used to generate on-site electricity, such as through rooftop solar photovoltaic (PV) systems or building-integrated PV[6] and to support the roll-out of charging infrastructure for electric vehicles. As already underlined, the dynamic interaction between the building and system operators enables demand-side management. This additional demand flexibility is considered as one of the key options enabling the integration into the energy system of a larger share of variable renewable energy sources such as solar PV and wind.

1.3 Main barriers and challenges

Despite the enormous opportunities, various barriers and challenges hamper the deployment of efficient and low-carbon technologies in buildings. This topic has been widely covered in the literature. For example, Paiho and Ahvenniemi (2017) group non-technical barriers under three categories to building renovation: a) social; b) economic; and c) regulatory. Social barriers are related to information and knowledge gaps for which literature suggests, as a solution, increased government support for communication and information targeting consumers, investors and financial institutions. To address economic barriers, especially the higher investment costs, the authors underline that governments very often rely on financial incentives to encourage behaviour change and increase the viability of energy efficiency and low-carbon technologies. Regulatory barriers suggested by the literature vary largely depending on the geographic location. In Europe, for instance, Tuominen et al. (2012) stress that these are often related to ineffective incentives and unclear and unstable regulatory frameworks.

Furthermore, Angell (2009) distinguishes between market and financial failures. Market failures result in lack of demand and include information failures, low energy prices that do not reflect negative externalities, split incentives between those making investment decisions and the users paying the energy bills, and lack of capacity of stakeholders involved in the value chain (financiers, developers, architects, designers,

[6]BIPV refers to the integration of PV modules into the building envelope, including to replace traditional building materials (Zhang and Yang, 2018).

contractors and suppliers, owners, equipment installers, and occupants). On the other hand, financial failures result in a lack of access to finance and include high upfront costs of energy savings measures and new technologies, conservative approaches by local banks due to lack of experience and high perceived risks, internal budget restrictions for public authorities or companies so that on-balance sheet financing is not always possible even if a project is economically viable, and regulatory barriers hampering the uptake of third-parties financing structures, i.e. energy services companies (ESCOs).

1.4 Summary

This first chapter has investigated global and European trends, as well as at opportunities and barriers for emissions reduction. A first element to retain for this research is that at the European level space heating represents most of the energy consumption in buildings and therefore deserves specific attention from policy-makers.

CO_2 emission reductions can be obtained through energy efficiency improvements such as thermal insulation of walls and building components and more efficient equipment. But technology alone is not sufficient to meet the complex challenge of decarbonisation the buildings sector. Structural societal changes and conservation actions by users, together with the switch to renewable energy and low carbon-intensive fuels, are other options.

Furthermore, we have also briefly reviewed how the scientific literature distinguishes the main categories of non-technical barriers (social, economic and regulatory). Given the urgency and the size of the challenge, a holistic and long-term approach is required to both reduce energy consumption and replace fossil fuel-based technology. The next chapter will look at what policy and regulatory measures have been put in place at EU level to reduce the carbon footprint of energy use in buildings.

2. ANALYSIS OF THE EU LEGISLATIVE FRAMEWORK FOR ENERGY IN BUILDINGS

To answer the first research question, this chapter aims to identify the main regulatory instruments put in place at EU level to trigger CO_2 emission reductions in the buildings sector. To this end, the following sections will clarify the principles governing the relation between the EU and its member states and present an overview of the main directives and regulations adopted over the last three decades. Following a thorough analysis of this legislation, the main policy instruments addressing the buildings sector will be analysed and classified under distinct categories. Finally, for each category, one key policy measure will be selected. Learning how the three selected EU measures have been implemented in two case studies will be the objective of chapters 3 and 4.

2.1 Principles governing EU actions on energy and climate action

The areas and limits of competence between the EU and its member states are laid down in intergovernmental treaties adopted by all EU member states. For the objective of this research, it is worth highlighting that Article 4 of the Treaty on the Functioning of the EU (TFEU) provides that both energy and the environment are shared competences. In this case, and in compliance with Article 5 of the Treaty on European Union (TEU), the EU can legislate when the objectives of an action cannot be achieved at the national, regional or local level (principle of subsidiarity). The action of the EU cannot exceed what is necessary to achieve the objectives of the EU treaties (principle of proportionality).

Both the areas of energy and the environment are relatively recent competences as neither of them was originally part of the 1957 Treaty of Rome (Treaty establishing the European Economic Community).[7] Nevertheless, until 1986, policy-makers adopted measures in the area of energy and the environment based on principles related to the harmonisation of national legislation or the implementation of the internal market (Thieffry, 2015 p.1235). With the adoption of the Single European Act in 1986, the environment becomes officially a new policy area and, as we shall see in the next sections, legislation on energy efficiency and renewable energy was justified on the basis of the provisions related to environmental protection (ex-Article 175 of the Treaty establishing the European Community, now article 192 TFEU). This was the case until 2009 when the Lisbon Treaty «operated a translation of the main power of the [EU]

[7] Energy was anyway a critical component at the very origin of the European integration process as two of the three originally treaties were focusing on energy, such as the 1951 Treaty of Paris (Treaty establishing the European Coal and Steel Community – expired in 2002) and the 1957 Euratom Treaty (Treaty establishing the European Atomic Energy Community).

in terms of [energy] from the European environmental, fiscal and free-trade domains» to a new specific title in the TFEU dedicated to energy (Ibid.:1249).

According to Article 194 of the TFEU, EU policy on energy aims to a) ensure the functioning of the energy market; b) ensure security of energy supply; c) promote energy efficiency and energy saving and the development of new and renewable forms of energy; and d) promote the interconnection of energy networks. The same article affirms the right of each member state to «determine the conditions for exploiting its energy resources, the choice between different energy sources and the general structure of its energy supply» (EU, 2016: C 202/134). At the same time, it reiterates the obligation to integrate environmental considerations into energy policy[8].

Understanding the legal basis of the EU action is essential as it determines the margin for manoeuvre of governments at the national level. In fact, to remove obstacles to trade within the internal market the EU often makes use of regulations which are simultaneously, automatically, and uniformly binding in all national legal systems. On the other hand, if the legal basis is related to environmental protection or the promotion of energy efficiency, the EU tends to adopt directives setting some goals that member states must achieve. In the case of directives, governments have the flexibility to choose the most appropriate means based on national preferences or traditions. In this context, it is worth stressing that under no circumstances national rules cannot contradict EU legislation; if that happens EU law always prevails according to the principle of supremacy.

Following the above clarifications, it is also important to remind that member states further share powers with regional and local authorities depending on the constitutional division in each jurisdiction. Hence, the role of different levels of the regional and local governments in areas such as energy and the environment may vary significantly. This may have a significant impact on the way the EU legislation, including buildings-related legislation, is implemented at a regional and local level.

2.2 The four waves of buildings-related EU legislation (1992-2018)

Early EU actions in the field of energy stem from the security of energy supply concerns due to the 1973 and 1979 oil crises. Among the various measures adopted in that period, the Council (i.e. the institution representing the governments of the member states) adopted in 1978 a first directive on the performance of

[8] In line with Article 11 of the TFEU, which provides that «environmental protection requirements must be integrated into the definition and implementation of the Union's policies and activities, in particular with a view to promoting sustainable development».

heat generators for space heating and the production of hot water (78/170/EEC) and in 1986 set an indicative target of 20% energy efficiency improvements by 1995 compared to 1985. The rationale for such an objective was the opportunity to reduce oil consumption through energy efficiency and thereby improve the security of supply. Following the dramatic reduction of oil prices in the subsequent years, national governments became rather reluctant to the arguments around energy efficiency and failed to make significant progress.

During the 1990s, EU initiatives on energy were recalibrated to address two major challenges: a) competitiveness through the liberalisation and establishment, still on-going, of an internal electricity and gas markets; and b) sustainability and GHG emissions from energy consumption. Growing scientific evidence about anthropogenic climate change followed by international and domestic commitments to reduce GHG emissions were the main drivers of four different waves of legislation adopted at EU level until the year 2018. EU legislative acts relevant to the buildings sector are presented below (and summarised in Table1), while specific measures impacting energy consumption and emissions in buildings will be detailed in Section 2.3.

The first policy initiatives linked to the need of combating climate change followed the first Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) in 1990 and the establishment of the United Nations Framework Convention on Climate Change (UNFCCC) in 1992 (Dupont, 2016:98; Bertoldi, 2018: 9). As a result, the Council adopted in 1992 a framework directive introducing mandatory energy labelling for domestic appliances (92/75/EEC) and a directive imposing efficiency requirements for new hot-water boilers fired with liquid or gaseous fuels (92/42/EEC) and the SAVE directive (93/76/EEC) in 1993. The SAVE directive was the first piece of EU legislation aimed to limit CO_2 emissions specifically by improving energy efficiency in buildings.

The adoption of the Kyoto Protocol, signed in 1997 and effective since 2005, imposed on the EU a binding 8% GHG emissions target. This, in turn, led policy-makers to enhance the framework for climate action. Part of this second wave of EU energy and climate legislation were the new directives on the energy performance of buildings (EPBD) (2002/91/EC), on eco-design for energy-using products (2005/32/EC), and energy end-use efficiency and energy services (ESD) (2006/32/EC). The new EPBD and ESD replaced the 1993 SAVE directive and reinforced some of its non-binding provisions. Among other things, the EPBD extended the scope of its predecessor to incentivise interventions in existing buildings, on top of new

buildings, while the ESD introduced for each member state an indicative target of at least 9% for end-use efficiency, excluding sectors covered by the so-called EU Emissions Trading System (EU ETS)[9].

Soon after, in 2007, EU leaders agreed on more ambitious targets for the year 2020: a) Reduction of at least 20% in GHG emissions compared to 1990 levels; b) 20% of the final energy consumption to come from renewable sources; and c) improvement of energy efficiency by 20% compared to 2007 projections. The above goals are headline targets of the European 2020 strategy for growth and were in line with the EU target under the second commitment period of the Kyoto Protocol (2013-2020).

To meet the so-called 20-20-20 targets, a set of binding legislation was put in place, together with new national targets for GHG emission reductions in non-ETS sectors[10] (Decision 406/2009/EC). The following sectorial directives, presented here in chronological order, were the most important for the buildings sector:

a) Directive on the promotion of the use of energy from renewable sources (RED) (2009/28/EC), setting national binding targets until 2020 and measures to facilitate the uptake of renewables, including for heating and cooling in buildings.

b) New directives on eco-design requirements (2009/125/EC) and energy labelling (2010/30/EU) extending the scope of the predecessors to all energy-related products. These framework directives were followed by implementing regulations for each product immediately applicable in all EU member states without intermediary interventions of national policy-makers.

c) Recast of the Directive on the energy performance of buildings (2010/31/EU), the main purpose of which was to ensure that member states maintained comparable levels of ambition, notably in terms of the energy performance of buildings (Bertoldi, 2018: 15).

d) Directive on energy efficiency (EED) (2012/27/EU) replacing the ESD and imposing binding measures aimed to achieve the 20% energy efficiency target at EU level.

[9] The EU ETS is a cap and trade system aiming to cap the overall level of emissions allowed and, within that limit, allowing participants in the system to buy and sell allowances as required. It operates in 31 countries (all 28 EU countries plus Iceland, Liechtenstein and Norway) and limits emissions from more than 11,000 heavy energy-using installations (power stations and industrial plants above 20 MW) and airlines operating between these countries. It currently covers around 45% of the EU's greenhouse gas emissions.

[10] Not ETS include buildings, tertiary and small industries, and land use, land-use change and forestry sectors.

In parallel with the above legislative developments, EU Heads of State and Government affirmed in February 2011 «the EU objective, in the context of necessary reductions according to the IPCC by developed countries as a group, of reducing GHG emissions by 80-95% by 2050 compared to 1990» (European Council, 2011). The subsequent European Commission's roadmap for moving to a competitive low-carbon economy in 2050 proposed sectoral reductions until 2050 and indicated that buildings (under residential and tertiary sectors) would be required to reduce their GHG emissions between 37% and 53% by 2030 and by around 90% by 2050 compared to 1990 (European Commission, 2011). As a follow-up, and in preparation of the twenty-first United Nations (UN) Conference of Parties (COP 21) in December 2015, EU leaders proposed new sectorial targets for the year 2030. This was followed by a new package of legislative acts, proposed in 2016 and adopted in 2017-18, to meet the post-2020 commitments under the Paris Agreement on climate change[11]. This represented the fourth wave of energy and climate legislation since the early 1990s and resulted in the following targets for the year 2030: a) at least 40% cuts in GHG emissions from 1990 levels); b) at least 32% share of renewable energy; and c) at least 32.5% improvement in energy efficiency with an upwards revision clause by 2023.

This fourth and, so far, last wave of legislation comprised a revised EPBD (2018/844/EU), the recast of the EED (2018/2002/EU), and RED (2018/2001/EU) amending the previous versions with targeted amendments. Important to note in the framework of this research is that the 2018 version of the EPBD aims to accelerate the cost-effective renovation of existing buildings to decarbonise the whole EU building stock by 2050 (Bertoldi, 2018: 19). The four waves of EU legislation presented above are summarised in Table 1. At the time of writing (i.e. July 2019), member states are still transposing most of this recent legislation. This implies that the evaluation of how EU legislation has been transposed and implemented at national and regional levels in the next chapters will be limited to the first three waves.

To conclude, it is important to underline that in support of the achievement of targets and legislation, the EU has put in place several horizontal programmes and financial initiatives supporting national, regional and local stakeholders. Amongst those programmes, notable examples are the Covenant of Mayors, launched in 2008 with the ambition to gather local governments voluntarily committed to achieving and exceeding the EU climate and energy targets, the Intelligent Energy Europe and Horizon 2020 programmes aiming to spur innovation and the Smart Finance for Smart Buildings initiative, launched in 2018 to make investments in energy efficiency projects in residential buildings more attractive to private investors

[11] Signed in 2015 and effective since 2016, the Paris Agreement requires all Parties to put forward their best efforts through nationally determined contributions (NDCs) and to strengthen these efforts in the years ahead.

through the use of EU funds as a guarantee and for technical assistance (European Commission, 2018b). However, the above and other non-regulatory measures are out of the scope of this research.

Table 1 Main EU buildings-related legislative acts. *Source: Author's elaboration.*

Year	Legislative act	Main trigger
First wave		
1992	Energy labelling directive (92/75/EEC)	First IPCC assessment (1990) and creation of UNFCCC (1992)
1992	Efficiency requirements for hot-water boilers directive (92/42/EEC)	
1993	SAVE directive (93/76/EEC)	
Second wave		
2002	Energy performance of buildings directive - EPBD (2002/91/EC)	Kyoto Protocol (1997)
2005	Eco-design directive (2005/32/EC) for energy-using products	
2006	Energy services directive - ESD (2006/32/EC)	
Third wave		
2009	Renewable Energy Directive (2009/28/EC)	EU 20-20-20 targets (2007); second commitment period of the Kyoto Protocol (2013-2020)
2009	Eco-design directive (2009/125/EC) including for energy-related products (repealing Eco-design directive 2005/32/EC) followed by implementing regulations for specific products	
2010	Energy labelling directive - recast (2010/30/EU) followed by implementing regulations for specific products	
2010	Energy performance of buildings directive – recast (2010/31/EU)	
2012	Energy efficiency directive (2012/27/EU)	
Fourth wave		
2017	Framework regulation for energy labelling (2017/1369) repealing Energy labelling directive 2010/30/EU	EU commitment to 80-95% GHG emissions reduction by 2050 (2011); proposal for EU 2030 targets (2014); and Paris Agreement (2015)
2018	Revised Energy performance of buildings directive (2018/844/EU)	
2018	Revised Energy efficiency directive (2018/2002/EU)	
2018	Revised Renewable energy directive (2018/2001/EU)	

2.3 EU measures impacting energy and emissions in buildings

Following a thorough review of the main buildings-related legislation, in this chapter the main policy instruments are classified based on three categories: a) those measures promoting efficiency requirements for building components, equipment and appliances; b) those stimulating energy efficiency demand and supply as well as a more rational use of energy by consumers; and c) those promoting renewable energy and other low carbon vectors in buildings. These measures are reviewed in the following sections and classified in Table 2 at the end of this section.

2.3.1 Minimum efficiency requirements for buildings, equipment and appliances

2.3.1.1 Minimum energy performance requirements of buildings

The first concrete measure promoting energy efficiency of buildings at European level dates back to the 1993 SAVE Directive and its Article 5, which required member states to draw up and implement programmes so that new buildings receive effective thermal insulation. However, the first mandatory provision was only set a few years later with the 2002 EPBD. Taking into consideration local climates and circumstances, Articles 4-6 of this directive required member states to set own minimum requirements for the energy performance of new and certain categories of existing buildings with a total useful floor area over 1,000 m^2 undertaking major renovation[12] The 1,000 m^2 threshold was eliminated in 2010.

The 2002 EPBD moved away from energy efficiency requirements based solely on thermal insulation (U values) of walls and windows. The new approach followed a methodology, firstly developed and applied in the 1990s especially in the United States, Australia, Canada, and New Zealand, able to take into account also other important factors such as the efficiency of heating and air-conditioning installations, the use of renewable energy sources and the design of the building. This new integrated method gave an annual energy budget per square meter per typology and location of the building (Bertoldi, 2018: 12).

According to Annex I of the EPBD (2010 version), the methodology for calculating the energy performance of buildings should take into account European standards and must take into account a number of aspects, including thermal capacity, insulation, passive heating, cooling elements, and thermal bridges, heating

[12] Recital 13, Directive 2002/91/EC provided that member states could choose between two possible definitions of «major renovations»: a) those where the total cost of the renovation related to the building shell and/or energy installations such as heating, hot water supply, air-conditioning, ventilation and lighting is higher than 25 % of the value of the building […] or those where more than 25 % of the building shell undergoes renovation.

installation and hot water supply, air-conditioning installations, natural and mechanical ventilation lighting (mainly in the non-residential sector), the design, positioning and orientation of the building, passive solar systems and solar protection, etc. (Annex 1 para 3, 2010 EPBD). Furthermore, the positive influence of RES systems, cogeneration; district heating and cooling systems, and natural lighting should also be considered (Annex 1 para 3, 2010 EPBD).

Because of the striking difference in ambition across the EU, the EPBD was revised and reinforced in 2010. In particular, in setting minimum requirements for buildings and building elements member states need to take into account « cost-optimal levels» estimated during the whole life-cycle and not only the initial investment cost (Article 5, Directive 2010/31/EU). Cost-optimal levels are to be calculated based on a comparative methodology which takes into consideration the financial and the macroeconomic perspectives (the latter including CO^2 emissions costs, excluding VAT and presenting lower discount rates) and is set out in Annex III of the 2010 EPBD and detailed in Annex I of Commission Delegated Regulation (EU) No 244/2012 and accompanying Commission guidelines 2012/C 115/01. A summary of the cost-optimal methodology is provided in Annex 3 at the end of this thesis.

A key element in this respect is that, if the result of the comparison shows that the minimum energy performance requirements in force are significantly less energy-efficient than cost-optimal levels, Article 5 of the 2010 EPBD provides that members states must justify the difference or plan measures to significantly reduce the gap. The deadline for the introduction of the cost-optimal methodology was by the year 2013. To reflect technological progress and evolution of costs in the buildings sector, member states are required to review minimum energy performance requirements at least every five years.

2.3.1.2 Nearly zero-energy buildings (nZEB)

The 2010 EPBD also gives a clear signal about the progressive tightening of the energy performance of buildings by introducing what for Dall'O et al. (2013:6) is a «fairly vague» concept of nZEB'. Article 2 defines an nZEB as «a building that has a very high energy performance, whose very low amount of energy required should be covered to a very significant extent from energy from renewable sources produced on-site or nearby». Article 9 of the 2010 EPBD required member states to come up their own detailed nZEB definition, including in terms of kWh/m^2year, to draw up national plans for increasing the number of nZEBs, and to ensure that all public buildings after 31 December 2018 and all other types of buildings after 31 December 2020 will comply with the new nZEB requirements. Furthermore, member states are asked to set intermediate targets for improving the energy performance of new buildings by 2015.

Regarding renewable energy in nZEB, most member states require a renewable energy share of the primary energy or a minimum renewable energy contribution in line with the requirements of the 2009 RED (see section 2.3.3.1), whilst others use indirect requirements, such as a low non-renewable primary energy use that could only be met with the use of renewables (Erhorn and Erhorn-Kluttig, 2016).

2.3.1.3 Requirements for the energy performance of technical building systems

To optimise the energy use of technical building systems, Article 8 of the 2010 EPBD requires member states to set system requirements. This concerns the overall energy performance, installation, and the appropriate dimensioning in case of new, replacement and upgrading of technical building systems such as heating systems, hot water systems, air-conditioning systems, large ventilation systems, or a combination of two or more of the above systems. In the same framework, the EU legislator requires member states to encourage the introduction of intelligent metering systems and the installation of active control systems such as automation, control and monitoring systems.

2.3.1.4 Minimum requirements regulating the energy use of equipment and appliances

An area where EU intervention is believed to be especially relevant is the regulation of the energy use and other environmental criteria of products, including heating equipment. As highlighted by Delbeke et al. (2015: 76), «the purpose of [this] legislation is the prevision of coherent rules for the *eco-design* within the European Union, so that differences in national laws pose no obstacles to intra-EU trade.»

As presented in the previous chapter (2.2), the eco-design directive 2009/125/EC has repealed the previous directive 2005/32/EC and represents the current framework directive. Implementing regulations define the eco-design of specific products and can contribute to the removal of the least efficient products from the market. Considering the significant energy consumption dedicated to cover heating demand, the following regulations are of particular importance in the framework of this chapter: Commission Regulation 813/2013 for space and combination heaters; Commission Regulation 814/2013 for water heaters and hot water storage tanks; Commission Regulation 2015/1188 for local space heaters; Commission Regulation 2015/1189 for solid fuel boilers; and Commission Regulation 2016/2281 for air heating and cooling products.

The impact of these regulations at EU-level is significant. A study prepared for the European Commission in 2010 estimated that the energy efficiency requirements for space and combination heaters could allow

saving 109 million tonnes of carbon dioxide ($MtCO_2$,) 1,884 petajoules in terms of energy and EUR 25.4 billion/year and energy efficiency requirements for water heaters and hot water storage tanks would save 26 $MtCO_2$, 453 petajoules of energy and EUR 4.4 billion/year (ibid.: 77). These regulations are applicable in member states without the direct intervention of national or sub-national legislators and therefore will not be part of the assessment of the transposition and implementation in BCR and Italy in the next chapters.

2.3.2 Measures stimulating energy efficiency demand and supply

2.3.2.1 Regular inspection of heating and air conditioning systems

A heating and cooling system receiving regular controls is supposed to consume less energy, generates fewer GHG and pollutants, and to have a longer lifetime. In this context, already in the 1993 SAVE Directive, EU policy-makers required member states to draw up and implement programmes for the regular inspection of heating installations of an effective rated output of more than 15 kilowatts (kW) to improve operating conditions (Article 6 SAVE Directive). Article 8 of the 2002 EPBD raised the minimum rated output for heating boilers to be inspected to 20 kW and imposed regular inspections every two years for boilers above 100 kW, which may be extended to four years for gas boilers. Additionally, for boilers older than 15 years, independent experts were to advise consumers about the status and options for replacement. Furthermore, Article 9 of the 2010 EPBD extended the obligation to air-conditioning systems of an effective rated output of more than 12 kW. With the latest revision of the EPBD in 2018, the focus is placed on central systems and the threshold for regular inspections is raised to 70 kW for both heating and air conditioning (Articles 15-16 of the EPBD 2018).

2.3.2.2 Energy performance certificates

An energy performance certificate (EPC) aims to inform both landlords and tenants about the efficiency levels and performance of buildings and specific systems and to provide recommendations for improvements. Following a first attempt to incentivise the use of this tool at EU level with the SAVE Directive (Article 2), the EPBD 2002 required member states the introduction of a national certification scheme for both new and certain categories of existing buildings (including apartments) when these are constructed, sold or rented out. (Article 7). Certificates are to be based on the methodology for calculating the energy performance of buildings (see previous section 2.3.1). Besides, Article 10 of the 2010 EPBD required that EPCs are displayed in buildings with a total useful floor area over 500 m^2 (and 250m^2 after July 2015) occupied by a public authority and frequently visited by the public.

As pointed out by Bertoldi (2018:13), the EPC is an instrument intended to help remove the "split incentive" barrier between landlord and tenant. This is because neither the owner, who do not bear the costs of energy nor occupants may have an interest in investing in energy efficiency or cleaner sources of heating. However, the building's energy performance or the impact on CO_2 emissions may become a selection criterion and can incentivise owners to invest, for example, against a higher rental fee.

2.3.2.3 Energy labels for heating and cooling equipment and electric appliances

Based on the same rationale as the EPC, since 1992 energy labels aim to provide the consumer with information about the environmental performance of products with the objective of influencing purchase decision-making as well as innovation among manufacturers. EU Regulation 2017/1369 repealed Directive 2010/30/EU and is the current framework directive in this field. Specific energy labelling systems for heating equipment have been made available in the market since 2015. For the purpose of this research, regulations complementing those for the minimum requirements regulating the energy use of equipment and appliances (see section 2.3.1) are: Commission Regulation 811/2013 for space and combination heaters; Commission Regulation 812/2013 for water heaters and hot water storage tanks; Commission Regulation 2015/1186 for local space heaters for solid fuel boilers; Commission Regulation 2015/1187 for solid fuel boilers and packages of a solid fuel boiler, supplementary heaters, temperature controls and solar devices; and Commission Regulation 2016/2281 for air heating and cooling products.

2.3.2.4 Metering and billing measures

To break with the past and thereby incentivise a more rational use of energy, EU legislation since the SAVE directive in 1993 (Article 3) provided that billing of heating, air conditioning, and hot water is to be based on actual consumption and that occupants should be enabled to regulate their own consumption. Article 13 of the ESD in 2006, reinforced this provision and required that, «when technically possible, financially reasonable and proportionate in relation to the potential energy savings, final customers for electricity, natural gas, district heating and/or cooling and domestic hot water are provided with competitively priced individual meters that accurately reflect the final customer's actual energy consumption and that provide information on actual time of use». Articles 9 and 10 of the 2012 EED, and their updated version of 2018, contain clarifications and the requirement, by 2016, for individual meters for heating and cooling in all multi-apartment/multi-purpose buildings, if technically feasible and cost-efficient. Furthermore, Article 11 specifies that final customers must receive all their bills and billing information for energy consumption free of charge.

2.3.2.5 Mandatory renovation for public buildings owned or occupied by central governments

One of the principles of EU energy efficiency legislation is that public authorities at a national, regional and local level should play an exemplary role. In line with this principle, and in compliance with Article 5 of the 2012 EED, every year 3% of the total floor of buildings owned and occupied by the central government is renovated each year to meet at least the national minimum energy performance requirements. The 3 % rate shall be calculated considering the useful floor area over 500 m^2 (lowered to 250 m^2 since July 2015) of buildings which do not meet minimum energy performance requirements.

2.3.2.6 Building renovation strategies

Data and long-term thinking will be key to meeting long-term EU objectives, including for the buildings sector. In this regard, Article 4 of 2012 EED required national governments to develop, by 2014, a long-term strategy beyond 2020 for mobilising investment in the renovation of residential and commercial buildings. Integrated into the EPBD 2018 (Article 2a), this provision currently requires an update of the first plans with a view «to support the renovation of the national stock of residential and non-residential buildings, both public and private, into a highly energy-efficient and decarbonised building stock by 2050, facilitating the cost-effective transformation of existing buildings into nearly zero-energy buildings».

2.3.2.7 Energy efficiency obligation schemes

A key horizontal measure to achieve the EU energy efficiency targets for the year 2020 is no doubt the «energy efficiency obligations» under Article 7 of the EED. This article, which has a strong impact on buildings as well, requires member states to mandate energy retail companies or distributors to contribute to reach the national energy savings targets or to adopt alternative policy measures, including a CO_2 tax, to deliver the targeted amount of energy savings among final energy consumers. A combination of the two options is also allowed. The provision provides broad flexibility to national governments as it regulates the outcome but leaves it to the market operators to determine the most cost-effective path for achieving that outcome.

The energy savings considered in the framework of Article 7 EED are to be additional to those generated by other EU requirements. The total to be achieved must be at least equivalent to 1.5% of the annual energy sales to final consumers of all energy distributors or all retail energy sales companies by volume averaged over the previous three consecutive years. To that end, member states can exclude all sales from transport

from the baseline and use exemptions up to a maximum of 25% of their target. The 25% exemptions include four specific elements: a) progressive phase-in of the target; b) exclusion of energy sales in the ETS sector; c) energy savings from early actions; and d) energy savings achieved in the energy transformation, distribution, and transmission sectors (Article 7 and Annex V, 2012 EED).

Furthermore, it is noteworthy that the EED 2018 extends the energy savings obligation in end-use sectors after 2020. Under the amending directive, EU member states will have to achieve new energy savings of 0.8% each year of final energy consumption for the 2021-2030 period.

2.3.2.8 Training and information on energy efficiency

To ensure quality in the implementation of energy efficiency measures, Article 16 of the 2012 EED provided that, by 2014, certification and accreditation schemes or equivalent qualification schemes, including suitable training programmes are available for energy services providers and installers of energy-related building elements. Relevant as a horizontal measure, it is worth reporting the provision of Article 17, requiring member states to promote awareness-raising and training initiatives to inform citizens of the benefits energy efficiency measures and to ensure that information on energy efficiency mechanisms and financial and legal frameworks is disseminated to all relevant market actors transparently.

2.3.3 Measures promoting fuel switch to renewable energy and other low carbon vectors

According to experts from the EU renewable energy industry associations and policy-makers interviewed in the framework of this research (interviews n. 1 and 3), overarching national targets for renewable energy in each EU member states set out in the 2009 RED played a key role in the promotion of renewable energy, including in buildings. This is true, especially considering that many countries had a very low share of RES in heating and cooling and that key stakeholders were not very familiar with some emerging technologies, e.g. heat pumps. On top of national targets, the 2009 RED proposed the very first measures at EU level promoting the switch to renewable energy in buildings, notably for heating - which represents the largest end-use in buildings in the EU as seen in chapter 1. Specific EU measures in place are presented in the following sub-sections.

2.3.3.1 Minimum levels of renewable energy in buildings

Article 13 (4) of the 2009 RED required member states to introduce in their building regulations and codes appropriate measures to increase the share of all kinds of energy from renewable sources in the building sector. Since 2015 this provision attempts to become more stringent and requires, where appropriate, to set minimum levels of RES which should be used in buildings or equivalent supporting measures. This provision may be fulfilled through renewable energy generated on-site as well as through district heating and cooling using a significant proportion of renewable energy. In this context, paragraph 5 of Article 13 2009 RED specified that, as of January 2012, new and existing public buildings subject to a major renovation, at national, regional and local level fulfil an exemplary role. These provisions should be seen in combination with the nZEB requirement in the EPBD to cover the very low amount of energy required by these buildings to a very significant extent from RES.

2.3.3.2 Streamlining of administrative procedures

Article 13 of the 2009 RED (now Article 15 of the recast 2018 RED) provides that member states streamline and rationalise the administrative procedures and define and coordinate the respective responsibilities of national, regional and local administrative bodies. Furthermore, it specifically encourages the adoption of 'simple notification' for small-scale installations. This provision is complemented by Article 16 of the 2018 RED, which requires national governments to set up a one-stop-shop procedure with one single focal point to guide through and facilitate the entire administrative permit application and granting process.

2.3.3.3 Training and information on small-scale renewable energy technologies

Installers are often the main source of information for consumers. Therefore, especially for newer technologies, lack of knowledge by the installers a hamper their market uptake. Furthermore, poor performance of installations can undermine the reputation and limit further growth (Heiskanen and Matschoss, 2017: 585). For example, Jackson et al. (2009) found that poor service by installers was an important factor of dissatisfaction for small-scale renewable energy technologies in the UK.

In this regard, Article 14 of the 2009 RED (now Article 18 of the recast 2018 RED) specifies that, since 2013, member states ensure that certification or equivalent qualification schemes are available for installers of small-scale biomass boilers and stoves, solar thermal systems, shallow geothermal systems and heat pumps. Additionally, it encourages the publication of a list of installers who are qualified or certified and requires that a system of mutual recognition between countries be put in place. Furthermore, the same article provides that information on support measures is made available to all relevant actors, such as consumers,

builders, installers, architects, and suppliers of heating, cooling and electricity equipment and systems.

2.3.3.4 Encouraging integration of RES heating and cooling in regional and local planning

To facilitate fuel switch, Article 13 (3) of the 2009 RED recommends member states to encourage local and regional administrative bodies to include heating and cooling from RES in the planning of city infrastructure (Article 13). This provision is rather weak and should be considered in combination with Article 14 of the 2012 version of the EED requiring member states to carry out comprehensive assessments and a cost-benefit analysis for the deployment of efficient district heating and cooling[13] and high-efficiency cogeneration systems. If the cost-benefit analysis produces positive results, then member states should establish adequate measures to accommodate its realisation in case of positive results.

2.3.3.5 Post-2020 national quota schemes to mainstream renewable heating and cooling

With no binding targets for the post-2020 period, EU policy-makers somehow propose member states to replicate the experience of national energy efficiency obligation schemes to also promote RES heating and cooling. According to Article 23 of the 2018 recast version of the RED, member states may establish measures, including a quota system for implementing entities, such as fuel suppliers, public or professional bodies, which are to contribute to increase the share of renewable energy in the sector by an indicative 1,3 percentage points as an annual average calculated for the periods 2021 to 2025 and 2026 to 2030, starting from the share of RES in the heating and cooling sector in 2020. To this end, member states may use the structures established under the national energy savings obligations set out in Article 7 of the EED. Furthermore, EU countries may count waste heat and cold up to 40 % of the obligation and above 40% if the share of RES in the heating and cooling sector is above 50 %. The overall obligation is reduced to 1.1 percentage points in those countries where waste heat and cold is not used.

2.3.3.6 The right of self-consumption of renewable power

With the growing importance of self-consumption of renewable electricity, and to avoid discriminatory costs, Article 21 of the 2018 RED establishes at EU level the right for consumers to generate renewable energy, including for their own consumption, store and sell either individually or through aggregators their excess production of renewable electricity and to retain their rights as final consumers. Furthermore, the

[13] Article 2 of the EED defines efficient district heating and cooling a system using at least 50 % renewable energy, 50 % waste heat, 75 % cogenerated heat or 50 % of a combination of such energy and heat.

article underlines that self-consumers located in the same building, including multi-apartment blocks, have the same rights as individual self-consumers as well as the right of sharing renewable energy that is produced on their site or sites between themselves.

2.4 Selection of EU measures for the case studies

Building on the above comprehensive review of EU measures, in this section, one instrument per category which will be selected and then analysed in the case studies. To this end, the selection criteria applied are a) the measures should address, at least partly, space heating consumption, which represents the largest end-use in the EU both in residential and non-residential buildings; b) the measure should stem from a directive; in this case member states can choose according to national circumstances and preferences the most appropriate means to achieve the objective set at EU level; c) the selected measure should be the most or one of the most relevant for reducing CO_2 emissions in buildings among those in the same category based on interviews from policy-makers and stakeholders,; and d) the selected measures should be in force by 2014 to enable a proper assessment of its transposition; therefore, the newest EU measures adopted with the fourth wave of legislation in 2018 are excluded from the analysis at national and regional levels.

The application of the above criteria, as well as a certain degree of subjective evaluation of the author, have led to the selection of the following three EU measures addressing the buildings sector selected for the case studies:

a) *Minimum energy performance requirements* (among those EU measures promoting load reduction of buildings and building components, equipment and appliances).

b) *Energy efficiency obligation schemes* (among those EU measures stimulating energy conservation behaviours and energy efficiency demand and supply).

c) *Minimum levels of RES in new buildings and buildings undertaking major renovations, where applicable* (among the measures promoting fuel switch to RES and other low carbon vectors).

Table 2 Classification of EU measures for buildings by category *Source: Author's elaboration.*

Category	Type	Legal reference
Category 1: Measures on minimum efficiency requirements of buildings, building components, technical systems, equipment and appliances	Energy performance requirements of buildings and building components	*SAVE Directive: programmes for thermal insulation (Art.5)* *EPBD (2002): replaced minimum thermal insulation with minimum energy performance requirements including methodology (Art. 4-6)* *EPBD (2010): introduced cost-optimal methodology (Art.5, Annex III + Commission Delegated Regulation (EU) No 244/2012)*
	nearly Zero Energy Buildings	*EPBD (2010) (Art. 2 and 9) intermediate targets for improving the energy performance of new buildings by 2015, definition and timeline for nZEBs*
	Energy performance of technical building systems	*EPBD (2010) (Art. 8)* *EPBD (2018): including electromobility and smart readiness indicator (Art. 8)*
	Minimum energy efficiency requirements of products	*Directive on the performance of heat generators for space heating and the production of hot water (78/170/EEC)* *Eco-design Directive 2005/32/EC replaced by 2009/125/EC; complemented by Commission regulations*
Category 2: Measures stimulating energy conservation behaviours and energy efficiency demand and supply	Regular inspection of heating and air conditioning systems	*SAVE Directive: non-binding for heating only (article 6)* *EPBD (2002): mandatory inspections and extended scope to air conditioning (Art. 8-10)* *EPBD (2010) (Art. 14-16)* *EPBD (2018): decrease the min. threshold for inspections (Art. 14-16)*
	Energy performance certificates	*SAVE Directive: (Art. 2)* *EPBD (2002): (Art. 7)* *EPBD (2010) (Art. 11-13)*
	Energy labels	*Directive 2010/30/EU replaced by EU Regulation 2017/1369;* *complemented by Commission regulations*
	Billing measures	*SAVE Directive: (Art.3)* *EED (2012): (Art. 9-10-11)* *EED (2018): (Art. 9-10-11)*
	Mandatory renovation for public buildings owned or occupied by central	*EED (2012) (Art. 5)*

	governments	
	Energy efficiency obligation scheme	*Art. 7 EED (2012); updated with EED 2018*
	Building renovation strategy	*EED (2012): (Art. 4)* *EPBD (2018) (Art. 2a)*
	Training and information on energy efficiency	*EED (2012) (Art.16-17)*
Category 3: Measures promoting fuel switch to RES and other low carbon vectors	Minimum levels of renewable energy in buildings	*RED (2009) (Art. 13.4)* *RED (2018): introduced reference to the cost-optimal calculation of the EPBD (Art. 15.4)* *EPBD (2010): introduced the concept of nZEB*
	Streamlining of administrative procedures	*RED (2009) (Art. 13)* *RED (2018) (Art. 15)*
	Training and information on small-scale renewables technologies	*RED (2009) (Art. 14)* *RED (2018) (Art. 16)*
	Integration of RES heating and cooling in regional and local planning	*RED (2009) (Art. 13.3 and 14.5)* *EED (2012) (Art. 14)* *RED (2018) (Art. 15.7)*
	National quota schemes to mainstream renewable heating and cooling (post-2020)	*RED (2018) (Art. 23-24)*
	Right of self-consumption of renewable electricity	*RED (2018) (Art. 21)*

Regarding the first selected instrument, i.e. the use of minimum energy performance of buildings, this is by far the most widely adopted instrument to enhance building energy efficiency across the globe and both the scientific and grey literature highlight its fundamental importance in the context of climate and energy policies (Lee et al., 2004; Salvalai et al. 2015, European Commission, 2018; OECD/IEA and UNEP, 2018). Salvalai et al. (2015:1246), for example, stress that «increasing the energy performance of buildings is the key to secure the transition to a low-carbon economy and to achieve the EU Climate and Energy objectives».

Concerning the second instrument, EEO scheme and/or alternative measures in the context of Art. 7 EED, the stakeholders interviewed in the context of this research widely agree regarding the key importance of

this measure. This is particularly due to the incentive for the public sector to educate final consumers, the transformative potential in the business models of obligated market players, and the significant amount of energy savings involved. In this regard, it is worth reporting that the European Commission's impact assessment accompanying the proposal for the revision of the EED in 2016, highlighted that: «at the time of adoption of the EED in 2012, [it was estimated] that Article 7 and the related Annex V would be responsible for more than half of the energy savings the member states should achieve under the EED (European Commission, 2016: 18)».

Finally, mandatory minimum levels of RES in new buildings and buildings undertaking major renovations were considered important/ very important by 67% of respondents to the public consultation for the review of the EU RED in 2016 and a renewable heating and cooling obligation by 61% of respondents (European Commission, 2016). This measure is considered as an effective practice to incentivise the market uptake of renewable energy sources, especially for heating and cooling in buildings. One of the first examples in this regard is found in Spain with "Barcelona Ordinance on Application of Solar Thermal Energy Systems into the Buildings" in 1999 , This regulation required all new buildings to be built in Barcelona to have solar thermal water systems installed to cover at least 60% of domestic hot water needs (Puig, 2008). This example was expanded to the whole country and replicated elsewhere. According to four renewables energy experts interviewed in the context of this research, ensuring a minimum level of market share for alternative renewable energy systems is essential to attract the interest of installers and manufacturers alike as well as to increase knowledge among the consumer about less diffused technologies (interviews n. 1, 2, 5, and 7).

2.5 Summary

To respond to the first research question, this chapter has clarified some principles governing the relations between the EU and its member states and explored the implications of the fact that energy and the environment are shared competences. Furthermore, it was possible to note that the international climate policy and the domestic commitments have played a crucial role in shaping an EU energy policy in the development of four waves of EU climate and energy legislation. Various directives and regulations put in place in this context address directly or indirectly the buildings sector; in particular those promoting and regulating energy performance of buildings, energy efficiency, eco-design and energy labelling and renewable energy sources (see Table 1).

Following this overview, the main policy measures stemming from this legislation have been classified under three categories: a) measures promoting lower energy requirements for buildings, equipment and

appliances; b) measures stimulating energy efficiency demand and supply as well as a more rational use of energy by consumers; and c) measures promoting renewable energy and other low carbon vectors in buildings (see Table 2).

Building on the above review and based on four selection criteria, one measure per category has been selected: a) minimum energy performance requirements (among the measures promoting efficiency of building components, equipment and appliances); b) energy efficiency obligation schemes (among the measures stimulating conservation behaviours and energy efficiency demand and supply); c) minimum levels of RES in new buildings and buildings undertaking major renovations, where applicable (among the measures promoting fuel switch to RES and other low carbon vectors). The transposition and implementation of the above measures will be assessed in the BCR and Italy in the next chapters.

3. Implementation of selected EU policy measures in Brussels-Capital Region (Belgium)

This chapter analyses how the three selected EU measures from chapter 2, i.e. a) minimum energy performance requirements; b) energy efficiency obligation schemes; and c) minimum levels of RES in new buildings and buildings subject to major renovation) have been implemented in a first case-study. As highlighted in the introduction, in Belgium, the promotion of rational use of energy and new and renewable energy sources in buildings falls within the competence of the regional governments. Therefore, this analysis will focus on one region, namely Brussels-Capital Region (BCR).

3.1 Context

As illustrated in Figure 6, residential, commercial, and public buildings accounted for nearly 40% of Belgium's primary energy consumption in 2017. More impressing is the situation in the BCR, where buildings covered more than 70% of final energy consumption in 2017 and the residential sector represents the largest economic sector with 38 % of final energy consumption (Brussels Environment, 2019: 3).

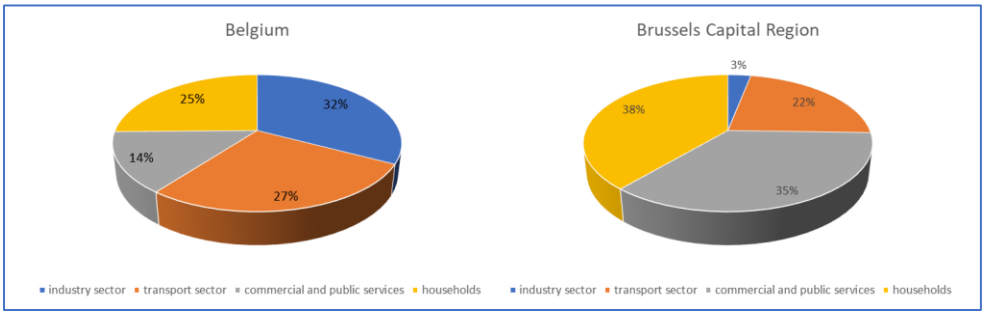

Figure 6 Share of final energy consumption by sector in Belgium and Brussels-Capital region, 2017; (%)
Source: Adapted from Eurostat (database) https://ec.europa.eu/eurostat/web/energy/data/database and Brussels Environment (2019a): Bilan énergetique 2017 de la Règion de Bruxelles Capitale : Résumé

From the energy balance provided by Brussels Environment, the regional environmental and energy agency, it is possible to observe that the main fuel/vector in the region in 2017 was natural gas (43%) followed by electricity (27%), solid fuels (20%) and heating oil (6%) (Ibid). It is therefore not a surprise that the buildings sector is also responsible for a significant share of emissions in Brussels, namely 56% of GHG

emissions in 2015 (Government of BCR, 2019: 5) and 24% of NO_x emissions and nearly 58% of PM_{10} emissions in 2013 (Government of BCR, 2016:25). In the residential sector, heating is by far the largest end-use accounting for 71% of final energy consumption in 2016 (Brussels Environment, 2018: 17).

As part of the "Burden Sharing" agreement[14], the BCR has the objective to reduce GHG emissions in non-ETS sectors (domestic transport, buildings, agriculture, and waste) by 8.8% by 2020 compared to 2005. In addition, through the Covenant of Mayors, the Region committed to reducing by 30% its GHG emissions by the year 2025 compared to 1990. Despite the ambitious targets, decarbonising the buildings sector will be a difficult task. According to several programmatic documents and interviews conducted in the framework of this research (Government of the BCR 2016 and 2017; interviews n. 1, 3, and 7), Brussels it is possible to identify at least the following five technical and socio-economic challenges. Firstly, Brussels is a city-region in a federal state, which is directly responsible for meeting EU objectives. Secondly, the Region has a limited renewable energy potential, due to lack of hydro and land for biomass and wind. Thirdly, the population has a lower income than the national average (BCR, 2010; interview n. 3). Fourthly, more than 40% of Brussels's residents are not owners of their house (Government of BCR, 2016:25), which hampers energy efficiency investments due to split incentive. Lastly, the building stock is very old. Only 6% of buildings were built after 1981 (compared to 29% in Flanders and 19% in Wallonia) and nine out of ten dwellings were more than 20 years old in 2001 and are therefore poorly insulated (Ibid.:51).

3.2 Evolution of the implementation of EU measures on building minimum energy performance

3.2.1 Early regulation

As highlighted by the Government of BCR, until the early 2000s «Belgium did not pursue a genuine energy policy, particularly as regards end-use [since] it was widely thought at that time that rational energy use [was] expensive and not worthwhile» (BCR, 2011:7). This was also due to «many misconceptions about possible technical solutions» (Ibid.). As a result, building insulation in Brussels was extremely poor; the energy loss through walls in the Region amounted to 250 MJ/m_2/year in 2001, which was the worst performance in Western Europe (Daoud, 2012). Despite the first explicit requests at European level in the 1993 SAVE directive, the first mandatory requirements for thermal insulation of buildings in the BCR were imposed only in the year 2000. Section V of the Regional Planning Regulation, applicable to new and

[14] Based on the Effort Sharing Decision at EU level (406/2009/EC), Belgium is legally obliged to reduce by 15% by 2020 GHG emissions in the non-ETS sectors compared to 2005. Following the national burden sharing agreement in 2015, the target was broken down at regional level as follows: Flemish Region: -15.7%; Walloon Region: -14.7%; BCR: -8.8%.

renovated residential buildings, office buildings, and schools subject to building permit, included a requirement for the overall level of insulation of the building, calculated according to Belgian standard NBN 62-301 (BCR, 2007:20).

3.2.2 Implementation of the 2002 EPBD

A critical moment for the evolution of energy efficiency in buildings was when a new Regional government took office in 2004 and adopted a new regional policy framework integrating energy and the environment into the building sector. This included the legal framework for energy performance of buildings, the integration of eco-construction elements, financial incentives including grants (primes énergie), free technical advice, and a reference centre for technical training and professional development.

To transpose the EU 2002 EPBD, in June 2007 the Government of BCR adopted the Energy Performance and Indoor Climate of Buildings Ordinance (EPB Ordinance), which repealed the provisions contained in Section V of the 2000 Regional Planning Regulation. In line with the main pillars of the EPBD, the EPB Ordinance established, among other things, a methodology to calculate the energy performance of buildings and set minimum performance requirements which entered into force on 2 July 2008 for new buildings and for renovations in which a building permit was requested. At the time, the applicable requirements were set for the energy performance of the building or global primary energy consumption over one year (E level); for global thermal insulation level (K levels); for maximum thermal transmittance (U_{max}) and/or minimum thermal resistance levels (R_{min}) of individual walls;[15]and ventilation requirements (Henrotte et al., 2015: 61-62). Yet, in the context of this research, it is important to underline that the PEB Ordinance went beyond the requirements of the 2002 EPBD. As we have seen in chapter 2, the EPBD imposed energy performance requirements for renovations and new buildings over 1,000 m² thresholds, while the regional EPB Ordinance incorporated the following two conditions applying to buildings of less than 1,000 m²:

a) the feasibility study imposed for new buildings was extended to the study of overheating and passive cooling, which were not requited by the 2002 EPBD and was made mandatory also for existing buildings over 5 000 m² subject to major renovations;
b) basic renovations, i.e. renovations below major renovation levels, were subject to the thermal insulation of the envelope and ventilation requirements (Government of BCR, 2011:20).

[15] Calculated as follows: E=Eprim / E ref) x 100

3.2.3 Implementation of the 2010 EPBD

A few years later, with the 2010 recast of the EPBD, the EU required that the minimum requirements in place at national and regional levels for the energy performance of buildings were measured against cost-optimal levels calculated according to a common methodology and that all new buildings and buildings undergoing major renovations comply with the national definition of nZEB (see previous chapter, sections 2.3.1.1 2.3.1.2). In the meantime, before the revision of the EPBD, the regional government had already adopted in July 2009 an ordinance imposing passive standards to all regional new public buildings already by 2010. This was followed in 2011 by the adoption of new maximum energy performance level for heating of 15 kWh per m² per year for all new residential buildings, offices and schools by 2015. This means that Brussels was effectively several years ahead of EU legislation on nZEB requirements. The new regional requirements, known as "EPB Passive 2015" were eventually adopted, after consultation with the construction sector, by a Decree of 21 February 2013 of the Government of the BCR.

As reported by Brussels Environment (2017) and Govaert et. al (2018), following Decree of 26 January 2017, the energy performance requirements of buildings in the BCR can be summarised following four categories of building units/renovations: a) new residential units, b) new non-residential units; c) units assimilated as new; d) all other types of renovations.

a) For new residential building-units in BCRstricter requirements have been set over the years[16]. Currently, these unit types need to meet the requirement of 15 kWh per m² per year for heating[17] and a specific primary energy requirement expressed in kWh/m²/year and replacing previous E level requirements.
b) New non-residential buildings and units were also imposed stricter requirements over the years[18]. The primary requirements for this category are specified by means of a virtual reference building or unit, representing the actual unit in terms of geometry, floor area, orientation and functionality. Due to this reference building approach, each new building or unit has an individual energy performance requirement that takes its specific details into account. According to Article 2.2.3 COBRACE, these requirements take now into account cost-optimal levels (Henrotte, 2015:60). In

[16] Energy performance requirements for residential buildings passed from E90 in 2008 to E70 in 2011 and the global thermal insulation requirement for the envelope (K-level3) K40 in 2014 (Govaert at al., 2018).
[17] With the exception of units with poor orientation or compactness makes it unfeasible to enforce compliance with a net heating energy requirement of 15 kWh/m².year.
[18] Energy performance requirement for office buildings and schools became E75 in 2011 from E90 in 2008 and the global thermal insulation requirement of the envelope K45 in 2014 (source: Govaert at al., 2018).

addition, the current passive standards are already considered to comply with nZEB requirements (Article 9 of the 2010 EPBD) «as energy losses are reduced to their minimum from a cost-optimal perspective and the need for compensation by renewable energy is implied by the requirement to fulfil the maximum primary energy consumption requirement (45 kWh/m2.year)» (Govaert et al., 2018:4)[19].

c) For units assimilated as new, i.e. over 75% change in the envelope and replacement of all the technical installations, there is a requirement to comply with the same energy performance levels as new units, with an extra 20% loss allowed to consider the net energy use for the heating requirement.

d) For all types of building units (residential, commercial and public buildings) undergoing simple renovations, there is a need to meet the same U-value requirement levels as a new building unit as well as ventilation standards. However, simple renovations do not need to comply with requirements in terms of global heating or primary energy consumption.

To sum up, as illustrated in Figure 7, the BCR did not react swiftly to the first calls from the EU in the 1990s. However, in only a few years the Region «has transformed from the worst student in Europe to a laudable front-runner in matters of energy policy and energy-efficient buildings» (En Effect, 2012:3). Supported by a strong commitment by the political level, the regulatory requirements imposed by the EPBD in 2002 and 2010 were fully implemented and contributed to the development of a robust legal framework. Furthermore, in some cases, the Region was even more ambitious than EU requirements, as was the case with the adoption of passive standards eight years ahead of the deadline set at the EU level for public buildings and six years for all other new buildings.

[19] For formal compliance, however, the same timelines required by the EU directive on nZEB obligations were formally integrated into the COBRACE (Articles 2.2.3 and 2.4.2 COBRACE).

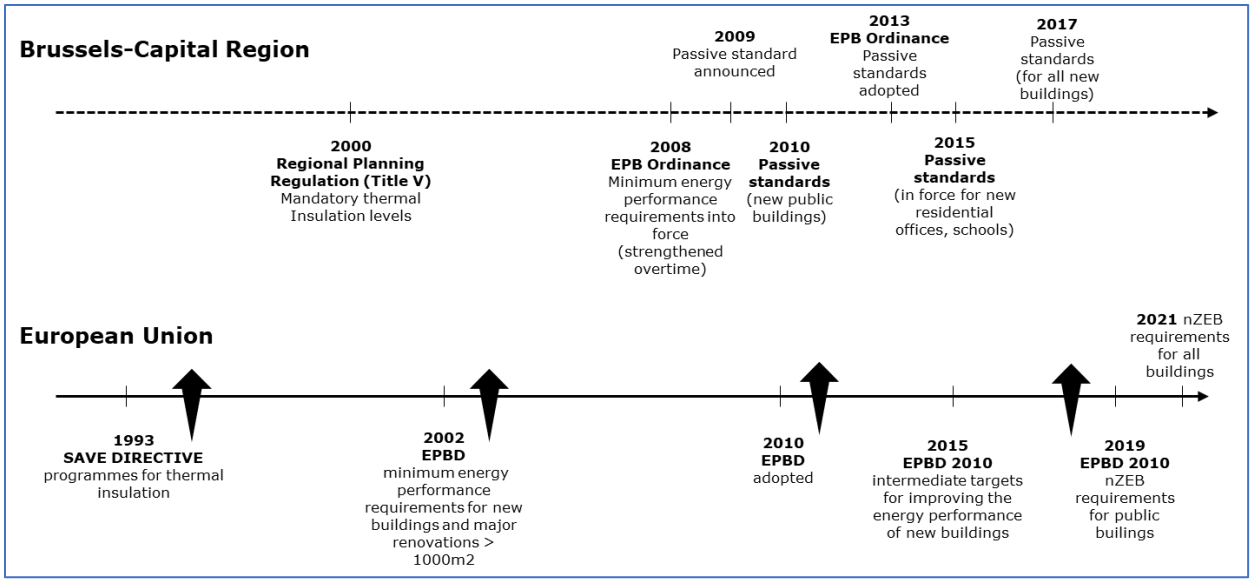

Figure 7 Evolution of regulatory framework on minimum energy performance requirements in buildings in Brussels-Capital Region vs EU level. *Source: Author's elaboration.*

One of the key factors in the government's decision to anticipate EU requirements for new buildings was the positive results from the Exemplary Buildings programme. Indeed, the first three rounds (2007, 2008 and 2009) of this initiative, which supported the construction of pilot passive buildings in Brussels, showed that the cost of a passive house was not much higher than normal constructions and was instrumental in convincing professionals that the regional policy was not moving too fast (En Effect, 2012; interview 4)[20].

3.3 Implementation of Energy efficiency obligation scheme (Art. 7 EED)

The second EU measures to be analysed in the context of the BCR is the energy efficiency obligation scheme under Article 7 of the EED (see Section 2.3.2.7) to achieve a specific amount of energy savings for end-users. In this regard, it is important to highlight since the beginning that the Government of BCR decided not to establish such a scheme. Instead, the Region opted to establish alternative public policy measures as allowed by paragraph 9 of Article 7.

Based on the calculation method set out in Article 7 and taking into account some flexibility allowed by the directive, the total energy savings to be achieved by the BCR over the 2014-2020 period amount to 5,178 gigawatt hours (GWh) (Government of BCR, 2017: Annex D 5). To meet this objective, the Government

[20] In fact, the construction sector feared about certain aspects of the new standards and, for instance, real estate companies were very worried about airtightness tests. But in the end, all buildings submitted and successfully passed the airtightness tests (En Effect, 2012).

of BCR relies on six main measures addressing specifically buildings[21]. These may be grouped in four sub-categories: a) stricter requirements than EU; b) financial incentives in the form of energy grants; c) advice programme for households; and d) technical and financial support to local authorities.

3.3.1 Stricter rules on the energy performance of buildings and inspections of heating boilers

As we have seen in the previous section, the BCR has anticipated EU requirements on nZEB (EPB Passive 2015) since July 2017 for all new buildings. In the framework of Art. 7 of the EED, the Region takes advantage of these stricter rules and counts the energy savings forecasted to be generated by this measure towards the target under Art. 7, but this only until the entry into force of European legislation, i.e. by the end of 2018 for public buildings and 2021 for other buildings.

Brussels took a similar approach with the stricter requirements in terms of heating systems inspection. In the territory of the region, boilers must be inspected every year, while natural gas boilers must be inspected at least every three years (Articles 2.2.15 to 2.2.17 and 2.5.1 to 2.5.5 of COBRACE and ordonnance of the Government of the BCR of 3 June 2010). On the other hand, Article 14 of the 2010 EPBD requires inspections only every two years, extended to 4 years for gas boilers. Even in this case, the BCR takes into account the energy savings resulting from the difference between the stricter rules on boilers inspections in Brussels and the minimum EU provisions to meet the 5,178 GWh energy saving target.

3.3.2 Grant scheme (Primes énergie)

Energy grants (*primes énergie*) is an investment aid instrument for works related to the improvement of energy efficiency or the use of RES in buildings. Based on the estimation provided in the Fourth Energy Efficiency Action Plan, it will contribute to more than 40% of the energy savings required. Taking advantage of the flexibility provided by the EED, the Region also considers energy savings generated through energy premiums disbursed since 2010, which fill the 25% flexibility limit permitted according to paragraphs 2 and 3 of Article 7 EED.

[21] Energy efficiency obligation schemes or alternative measures to comply with Article 7 of the EED may touch upon multiple end-use sectors. The other four measures considered by the BCR target industry (energy audits to accompany environmental permit requests) and transportation (companies' commuting plans; car sharing; voluntary agreement to improve energy efficiency of public transportation). In addition, in its Notification to the European Commission, Brussels indicated one more measure, since 2018, related to obligation for heating oil suppliers to contribute to the budget for the Energy Premiums (Government of BCR, 2017: 18-19).

The Energy grants, however, were established in 2004, way earlier the obligations imposed by the EED and has been one of the instruments applied in Brussels to comply with the 9% indicative target set by the ESD, the predecessor of the EED, in 2006. Looking at the evolution of the scheme, it is possible to observe the growing budget allocated, which started from EUR 1 million in 2004 and is currently stable for the period 2017-2018 at an average of EUR 22 million (following a peak in 2009, when 34 EUR million were disbursed (Government of BCR, 2017; Brussels Environment, 2019b). Ninety-five per cent of the budget for scheme originates from fees imposed on gas and electricity suppliers. However, new mandatory financial contributions were imposed on heating oil suppliers as well, which is expected to increase the budget of the scheme in the next years. The growing budget allocated to this mechanism may reflect the ambitious energy savings commitment of the Region as well as the mandatory nature of more recent obligations from the EU.

That said, it should be noted that the overall objective of the mechanism goes beyond compliance with Article 7 EED. This point emerges clearly from the technical report produced annually by Brussels Environment, which emphasises that the energy grants play a key role in complying with the overall obligations in terms of CO_2 emission reduction of the Region (Brussels Environment, 2019:7). Besides, Brussels Environment stresses other objectives of the scheme such as supporting the compliance with the implementation of EU energy efficiency requirements, boosting innovation and adoption of the most performing technologies in the market as well as stimulating the economy and creating jobs.

3.3.3 Advice programme for households

This measure is intended to reduce final energy consumption by directly influencing the behaviour and decisions of households through free advice for simple actions, the direct realisation of small interventions, identification of energy efficiency investments, and information to facilitate access to finance. The free advice is provided by a single non-profit public organisation established in 2017 and called HomeGrade, (Government of BCR, 2017: Annex D 14-16; 36). Brussels Environment estimates that from 2014 to 2020 this measure will contribute to 32,97 GWh of energy savings towards the 5,178 GWh energy saving target under Article 7 of the EED (Government of BCR, 2017: Annex D 36).

3.3.4 Technical and financial support to local authorities

To support regional and local public authorities and other public organisations, the Region has put in place a supporting framework. One of the measures considered in the framework of the implementation of Art.7

EED is the NRClick, which is a service to support energy management of public buildings. The system is based on three pillars: firstly, provision of a software to monitor energy consumption and verify the profitability of energy efficiency investments; secondly, a mechanism to facilitate the administrative procedures for the purchase of equipment or energy performance contracts; and thirdly, support to implement energy efficiency measures.

Another measure put in place in Brussels is the Action Plan for Energy Management (Plan d'Actions pour la Gestion Energétique – PLAGE) launched as a voluntary instrument in 2006 for municipalities, hospitals and schools. This system aims to ensure that property managers put in place better energy management of their assets through the establishment of an energy register of buildings owned or occupied by the organisation, the implementation of energy accounting and the development and the implementation of an action programme to achieve a specific energy consumption reduction target. This provision was made mandatory for public authorities owing or occupying a total building surface of at least 50.000m^2 (Articles 2.2.21 to 2.2.24 and 2.4.315 COBRACE) and extended to buildings owned and managed by other organisations. The Government supports financially and, since 2016, accounts the energy savings from the implementation of the PLAGE for public real estate companies managing social housing and the Brussels Regional Development Agency to comply with Article 7 EED.

3.3.5 New energy savings in 2014-2016 in the BCR from the implementation of Article 7 EED

The progress reports submitted at the national level in compliance with Article 24(1) and Annex V of the 2012 EED enables the analysis of the impact of the measures implementing Article 7 of the EED. As depicted in Figure 8, taking into consideration only the measures from 2014 to 2016 addressing buildings and excluding, therefore excluding early actions, the BCR saved a total of some 30 thousand tonnes oil equivalent (ktoe) (approx. 349 GWh or 7% of the total obligation under Article 7 EED). Most of the energy savings are generated through energy grants, followed by stricter rules on boiler inspections. Savings generated by advice to households are rather negligible. Finally, it should be noted that PLAGE and stricter rules on the energy performance of buildings are considered to generate savings only starting from 2017 and 2018 respectively.

In the calculation of the energy savings, the Region makes some estimations. For the stricter rules in terms of inspections, periodic controls of the boilers are estimated to save 4% of energy for heating oil boilers and 2% for natural gas boilers.

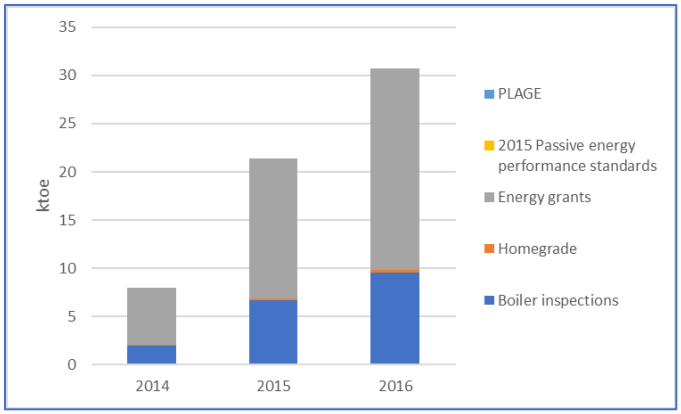

Figure 8 Cumulative new final energy savings in the buildings sector by implementing Article 7 EED (2014-16), ktoe. *Source: Own elaboration based on Belgium's annual reports 2015, 2016, 2017, and 2018. https://ec.europa.eu/energy/en/topics/energy-efficiency/energy-efficiency-directive/national-energy-efficiency-action-plans*

To avoid double-counting, only boilers replaced following an inspection and that do not benefit from energy grants are considered, i.e. 3.5% of the fleet every year. For those new boilers, it is estimated that energy savings amount to 20%. Furthermore, to comply with the principle of additionality, only savings resulting from the difference between the European and the regional regulations are accounted and only boilers above 20kW in the residential sector. (Government of BCR, 2017: Annex D 6-10; 36).

3.4 Implementation of minimum levels of renewable energy, where applicable

The third and last EU measures to be analysed in this first case study is, under Article 13 of the Renewable Energy Directive (RED), the non-mandatory requirement to establish a minimum level of renewable energy for new buildings and buildings subject to major renovations (see Section 2.3.3.1). In this regard, it is important to note that the choice of the Government of BCR to go for passive standards ahead of EU legislation requirements (see section 3.2) somehow limited the possibility to also mandate a minimum level of RES. In this respect, Govaert et al. (2018: 4) underline that « the 2015 […] requirements are very ambitious for an urban context and the need for compensation by renewable energy is implied by the requirement to fulfil the maximum primary energy consumption requirement […]; however, the specific RES share is not quantified».

For public buildings only, there is still a weak reference in the COBRACE about the possibility for the Government to require new public buildings and building subject to a major renovation, to «take into account the production possibilities of energy from renewable sources» (Art. 2.4.2. § 1 COBRACE). For

the future, however, the 2019 "Regional strategy for the reduction of the environmental impact of the existing building stock in BCR", indicates the possibility to require that 30% of the energy consumed in public buildings subject to major renovation will be covered through renewable energy or high-efficiency cogeneration in situ or nearby when the renovation involves the replacement of all technical installations (Government of the BCR, 2019: 47).

3.5 Summary

In this third chapter, to address the second research question of this thesis, we have tracked and analysed the evolution of the implementation of three EU measures in the BCR. Regarding minimum energy performance requirements of buildings, the Region passed from having no legal requirements and the worst energy performance of buildings in Western Europe in the late 1990s to being considered a front-runner in energy efficiency of buildings. Supported by a strong political commitment, the regulatory requirements imposed at EU level for new buildings and buildings subject to major renovations by the EPBD in 2002 and 2010 were swiftly implemented and contributed to the development of a robust legal framework and stringent energy efficiency requirements. In some cases, the EU framework has provided time to adapt, but the Region has in some cases even anticipated EU deadlines such as is the case on nZEB requirements, which are mandatory in Brussels for all new units and units assimilated to new since 2017, compared to EU requirements for public buildings in 2019 and all buildings in 2021.

As for the implementation of energy efficiency obligation schemes (Article 7 EED), the Government of BCR used the flexibility provided by EU legislation and decided not to establish such a scheme. Instead, to achieve an energy-saving obligation of 5,178 GWh in the period 2014-2020, the Region opted for alternative public policy measures. In particular, the energy savings generated by anticipating EU obligations on nZEB and stricter rules on boiler inspections are accounted towards this obligation. In addition, already existing financial instruments such energy grants and information, advice, and facilitation programmes to households and local authorities have been continued and adapted to support compliance with this EU obligation. Finally, in the case on the non-binding requirement to integrate minimum levels of RES in new buildings and buildings subject to a major renovation, we have learned of the choice of the Government of BCR not to apply this specific option. This is somehow justified by the passive standard requirements already in place and which, according to the Region, would require anyhow the installation of renewable energy to cover very restrictive non-renewable primary energy requirements.

4. IMPLEMENTATION OF SELECTED EU POLICY MEASURES IN ITALY

Following the first case-study of Brussels-Capital Region, this chapter will look into how the three selected EU instruments, i.e. a) minimum energy performance requirements; b) energy efficiency obligation schemes; and c) minimum levels of RES in new buildings and buildings subject to a major renovation, have been transposed and implemented in Italy. This assessment, when applicable, will also have to explore the implementation on the regional level, with a focus on the Lombardy region. Located in the northwest of the country, Lombardy is not only the most populous and richest in Italy[22], but was also the first region to develop a regional regulatory framework on energy efficiency in buildings.

4.1 Context

Since 2001, energy is in Italy an area of shared and often disputed competence between the central government, the Regions and the Autonomous Provinces (Buzzacchi, 2010). The EPBD and other EU buildings-related legislations are applied on three levels: the national level gives the general framework, the Regions provide technical guidelines, rules, and general inspections, the provinces and municipalities are in charge of inspections.

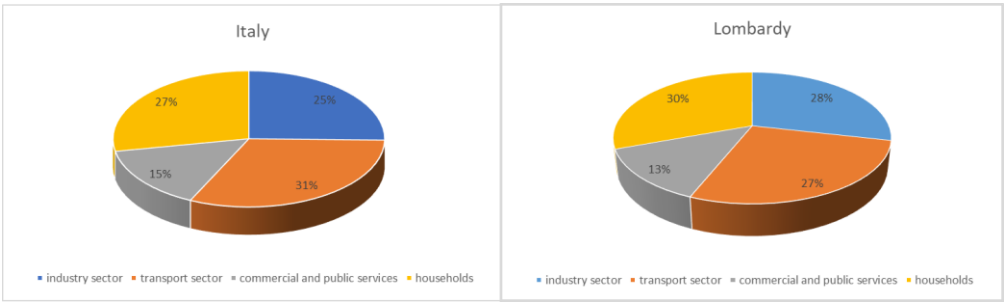

Figure 9 Share of final energy consumption by sector in Italy (2017) and Lombardy (2016); (%).
Source: Adapted from Eurostat (database) https://ec.europa.eu/eurostat/web/energy/data/database and Infrastrutture Lombarde (database) http://www.energialombardia.eu/efficienza_energetica

Compared to the case of Brussels analysed in the previous chapter, the structure of final energy consumption among different end-uses in Italy is more balanced. Figure 9 shows that, at the national level, transport was

[22] According to Eurostat (2019), the Lombardy region produced in 2017 about 22% of the Gross Domestic Product of the whole country.

the single largest end-use sector in 2017, covering nearly one-third of energy consumption, followed by residential buildings (29%) and industry (22%), while the tertiary and public buildings represented slightly more than 15%. Regarding Lombardy, according to the regional energy balance, in 2016 the residential sector was the largest sector accounting for30% of final energy consumption, followed by industry (28%) transport (about 27%) and the tertiary and public sectors (some 13%).

Italy presents a significant variety of climate zones, ranging from a continental temperate climate in the north to dry summer subtropical (Mediterranean) climate in the south. This variety impacts solar radiation, heating and cooling needs as well as solar energy potential. Italian legal framework sets the parameters for energy efficiency requirements in buildings according to six different climate zones based on the degree days. As it is possible to observe from Table 3, most of the population in the country is concentrated between climate zones C and E.

Table 3 Italian climate zones by degree days. *Source: Adapted from Government of Italy (2017a), Italian Energy Efficiency Action Plan*

Climate Zone	Degree day (DD)	Resident population (%)	Example of city
A	DD≤600	0.04	Lampedusa
B	600<DD≤900	5.33	Palermo
C	900<DD≤1,400	21.25	Naples
D	140<DD≤2,100	25.13	Rome
E	2,100<DD≤3,000	45.53	Milan
F	DD>3,000	2.72	Courmayeur

In line with the general trend in Europe, one of the main challenges for decarbonising the buildings sector in Italy is the very old building stock. Indeed, most of the existing buildings (over 60 %) are more than 45 years old and were built before the first energy efficiency requirements (Government of Italy, 2017a; 3 of Annex 1).

The national situation is also reflected in Lombardy. As reported in the 2015 regional energy strategy, most of the buildings (around 78%) were built before the entry into force of the first energy efficiency regulations in 1991 (see next section). The energy performance of certified public buildings is on average lower compared to private buildings, with a requirement value of 3% higher in the residential sector (equal to 208 kWh / m2 per year) and + 8% for the non-residential (equal to 76 kWh / m^3 year) (Lombardy Region, 2015).

4.2 Evolution of the implementation of EU measures on building minimum energy performance at the national level and in the Lombardy region

4.2.1 From early regulation to a general national framework in 2009

Law n. 373/ 1976 was the first piece of legislation in Italy related to the characteristics and size of the heating systems and the insulation levels of buildings. Adopted during the oil energy crises in the 1970s, it introduced modern concepts for the construction sector at that time such as the concept of degree-days and classification of buildings (Pianezze and Lucchi, 2013: 21). Fifteen years later, Law 10 of 9 January 1991 established rules for the implementation of the national energy plan on the rational use of energy, energy-saving and the development of renewable energy sources. Anticipating the 1993 SAVE Directive, Law 10 of 1991 highlighted that rational use of energy had to be also implemented through a reduction in consumption and greater use of renewables; furthermore, this law introduced the definition of new calculation methods and the introduction of the concept of energy certification. Since then, designers had an obligation to verify the efficiency of their projects from an energy point of view. However, Pianezze and Lucchi (2018: 20) underline that «despite the Italian regulation was at the forefront, the lack in the implementing decrees[23] made it ineffective in practice ».

Law 10 of 1991 represented the legal reference for energy efficiency in buildings for 15 years, until the transposition of 2002 EPBD through Legislative Decree 19/08/2005 n.192, soon after corrected with Legislative Decree 311/2006. In line with the EPBD, the new decrees distinguished between new and different types of existing buildings. Article 3 of Legislative Decree 19/08/2005 n.192 prescribed the compliance with minimum performance requirements for heating and minimum global seasonal efficiency of thermal transmittance (U values) for new buildings, extensions of more than 20% of the total volume, and existing buildings above 1,000 m^2 subject to a total renovation of the elements constituting the envelope. For existing buildings subject to renovation, but below 1,000 m^2, and for extensions of less than 20% of the total volume, the same article required compliance only with the thermal transmittance requirements of the building envelope and, in case of replacement, of the global seasonal average efficiency of the heating system (Ibid.: 21). For the purpose of this research, it is important to underline that the above requirements were not yet sufficient to fully align Italian legislation to the EPBD. In fact, while the decrees required compliance for single elements (walls, windows, heating system etc.) the national calculation procedures

[23] With the exception of Presidential Decree no. 412/1993 introducing rules for the design, installation, operation and maintenance of building heating systems.

and minimum requirements for energy performance of buildings were defined only in 2009, with Presidential Decree 59/2009 and the Ministerial Decree of 26 June 2009 defining the calculation methodology for the assessment of the energy performance of buildings in accordance with the national standard UNI/TS 11300 (Abela et al., 2013; Salvalai et.al, 2015). The delay in issuing implementing measures for the implementation of the 2002 EPBD was one of the reasons for the infringement procedure launched by the European Commission against the Italian government in 2006, together with other aspects such as the incorrect transposition of the energy certification system and the lack of regular inspections for air-conditioning systems.

4.2.2 Developments at the regional level: the example of the Lombardy region

In the meantime, with the reform of Title V of the Constitution in 2001, energy became a shared task between the State and the Regions. The above-mentioned Legislative decrees 192/2005 and 311/2006 established a general framework within which the Regions should have legislated according to the specificities of their local context (Article 17 of Legislative Decree 192/2005). This was a critical point, combined with the fact that the above decrees required the adoption of several implementing regulations. Only six regional/provincial authorities chose to independently transpose the EPBD: Liguria, Emilia Romagna, Tuscany, Val d'Aosta, Piedmont, Lombardy and the provinces of Trento and Bozen. (Costanzo et al., 2018:1). The following will briefly present the evolution of the legislation on minimum energy performance requirements in the Lombardy Region.

A few years after the Constitutional reform, the Lombardy Region adopted Regional Law 39 in December 2004 defining consumption limits more stringent than those provided by the national Law 10 of 1991. A few months later, Regional Law 12 of March 2005 introduced an incentive to provide a bonus of 15% on maximum volume for constructions meeting specific energy efficiency and environmental requirements. In this context, the definition of minimum performance levels was left to municipalities (Salvalai et al., 2015: 1253). Following Legislative Decree 192/2005 at the national level, Regional Committee Decree No. VIII/5018 of 26 June 2007 detailed the procedure to calculate performance indicators considering the use of energy for space heating, ventilation, domestic hot water, and air conditioning. This procedure was updated by Decree 5796 of 6 November 2009. In this context, Dall'O et al. (2013:6) suggest that

> «the new calculation procedure [was] more complete and complex, and closer to that used nationally (UNI/TS 11300) and to the European standards issued by the European Committee

for Standardization on the basis of Mandate 343 of the European Commission to support the implementation of EPBD in the member states».

In addition, with Regional Committee Decree VIII 8745 of December 2008 the Region set specific mandatory minimum requirements for the primary energy consumption of heating, U values for external walls, mandatory connection to district heating network if present within 1,000 meters etc. In the context of this research, it is important to report that mandatory minimum requirements in Lombardy were set stricter than the national level. As an example, by comparing Legislative Decree 311/2006 with Regional Committee Decree VIII 8745 of December 2008, it is possible to observe that values for external walls in climate zone E, where Milan is located, were set at 0.47 W/m^2 K at the national level against 0.36W/m^2 K in Lombardy. Furthermore, how highlighted by Salvalai et al. (2015: 1252 regional legislation «anticipat[ed] to 1st January 2008 the minimum energy requirements defined by the national law for 1 January 2010», thereby making Lombardy emerging, at the end of the 2010s, as a virtuous example in the Italian context.

4.2.3 Transposition of the 2010 EPBD: catching up with Europe through national harmonisation?

As we have seen with the example of the Lombardy Region, the application of the principle of subsidiarity in Italy has allowed the Regions to adapt the national rules for the energy performance of buildings to the specificities of their respective territories. However, as pointed out by Pianezze and Lucchi, (2013: 27), «this approach has also created a complexity that ma[de] comparison between similar buildings almost impossible, given the diversification in terms of minimum requirements, certification tools, etc.».

Aware of this problem, Italian policy-makers seem to have changed approach starting from Decree Law 63/2013 of 2013. The Decree, intended to transpose the 2010 EPBD, intervenes on Legislative Decree 192/2005 updating the text and providing a new methodology for calculating the energy performance of buildings. Regarding the application of the new national regulatory framework at the regional level, Article 13 bis of Decree Law 63/2013 of 2013 modifies Article 17 Legislative Decree 192/2005, requiring the Regions and the Autonomous Provinces to align to the national framework. Decree Law 63/2013 also allowed the government to close the infringement procedures initiated by the European Commission against Italy since 2006.

A new element of Decree Law 63/2013 of 2013 is the introduction into the Italian legal framework of the concept of nZEB. In line with Article 9 of the 2010 EPBD, new buildings must meet nZEB requirements

by 2021, with this obligation anticipated to 2019 for public buildings. Compliance implies a) meeting the minimum energy performance requirements set for the year 2021 (or 2019 for a transitionary period of two years for new public buildings), and b) meeting minimum levels of renewable energy set by law (see section 4.4). In this regard, it is interesting to compare the evolution of the national framework with that of the Lombardy Region, our regional example. Also in this case, the Lombardy Region decided to apply EU requirements ahead of both national and EU deadlines. As a matter of fact, Regional Law n. 7 of 2012, required to apply nZEB requirements to all new buildings, public or private, as of 31 December 2015. According to the 2015 Energy and Environmental Plan of the Region, anticipating the nZEB requirements will save between about 70 and 80 ktoe annually by 2020[24] (Lombardy Region, 2015: 95).

An important step towards the implementation of the 2010 EPBD as well as towards a more consistent national framework was taken in 2015 with the adoption of new decrees implementing certain provisions of Decree Law 63/2013. The three decrees, which entered into force on 1 October 2015, are the following:

a) Inter-ministerial decree of 26 June 2015 on "Minimum Requirements" related to the application of energy performance calculation methods and definition of the minimum building requirements,
b) Inter-ministerial of 26 June 2015 on "Technical report" providing a template for compiling the technical project report to apply minimum energy performance requirements in buildings;
c) Inter-ministerial decree of 26 June 2015 concerning the adaptation of national guidelines for the energy certification of buildings.

For the purpose of this section, it is relevant to report that the "Minimum requirements" decree requires Regions and Autonomous Provinces to adapt, among other things, their calculation methodologies for the energy performance of buildings and minimum requirements based on the provisions of the "Minimum Requirements" decree. The objective was to «promot[e] a homogeneous application of this decree throughout the national territory, in regulating the matter, in compliance with the constraints deriving from the EU regulation […] (Article 6, Inter-ministerial decree of 26 June 2015 on "Minimum Requirements".

Another important aspect to assess is how the "Minimum Requirements" decree adapted the national regulatory framework in response to the new requirements of the 2010 EPBD. To this end, first of all, it is possible to observe that the Decree updated the energy performance calculation methodology in line with Annex I of the 2010 EPBD. More in detail, the global annual energy use must be calculated for each energy

[24] The estimation is based on the hypothesis that new nZEB buildings replace new buildings with medium energy performance. A demolition/replacement rate of old buildings was estimated at between 0.8% and 1% per year (Lombardy Region, 2015:95)

service on a monthly basis and expressed in primary energy terms. Furthermore, the compensation between energy needs and renewable energy produced on-site is made possible only for the same energy carrier up to cover the total energy demand for that carrier. To this end, the renewable energy generated on-site but exported cannot be deducted to comply with minimum energy performance requirements.

Secondly, based on Article 5.2 of the 2010 EPBD, stricter minimum energy performance requirements for new buildings and major renovations are established based on the application of the cost-optimal methodology results and differentiated according to typology and climatic zone. As summarised from Costanzo et al. (2018:2-4) for new buildings, the calculation of the following energy performance indicators is required:

a) Energy performance indexes for heating, cooling, domestic hot water, ventilation, plus lighting and transport (lifts and escalators) for non-residential buildings, expressed in non-renewable and in total primary energy [kWh/m^2];
b) Global energy performance index expressed in non-renewable and in total primary energy [kWh/m^2] including lighting and transport services for non-residential buildings only.

A new building (or major renovated building) satisfies the minimum requirements if the specific energy needs for heating and cooling and the global energy performance EPgl are lower than those calculated values for the reference building. On the other hand, for existing buildings, minimum requirements are differentiated according to the extent of the renovation:

a) For major renovations- first level (renovations of at least 50% of the envelope and replacement of the heating and/or cooling system), standards for new buildings apply to the whole building but limited to the considered energy services.
b) For major renovations- second level (renovations of at least 25% of the external surfaces of the building with or without renovation of the heating and/or cooling system), the U-value of the concerned surfaces is lower than the limit values, while the average efficiencies of renovated technical building systems are higher than the reference values.
c) For minor renovations (renovations of less than 25% of the external surfaces of the building and/or modification of the heating and/or cooling systems), the performance of single components or the technical building systems needs to comply with mandatory limit values.

As a result of the decrees adopted at national level in 2015, the Lombardy Region adopted Regional Decree X/3868 of 17 July 2015 that, together with the subsequent decrees adopted in 2017 (n. 176 of 12 January

2017 and n.2456 of 8 March 2017) aim to "transpose" the main national principles and procedures into the regional framework, while preserving the obligation to apply nZEB requirements before the rest of the country. Figure 10 illustrates the evolution of the implementation of the EU requirements on the energy performance of buildings in Italy and Lombardy since the 1990s and highlights the interplay between the national and regional levels.

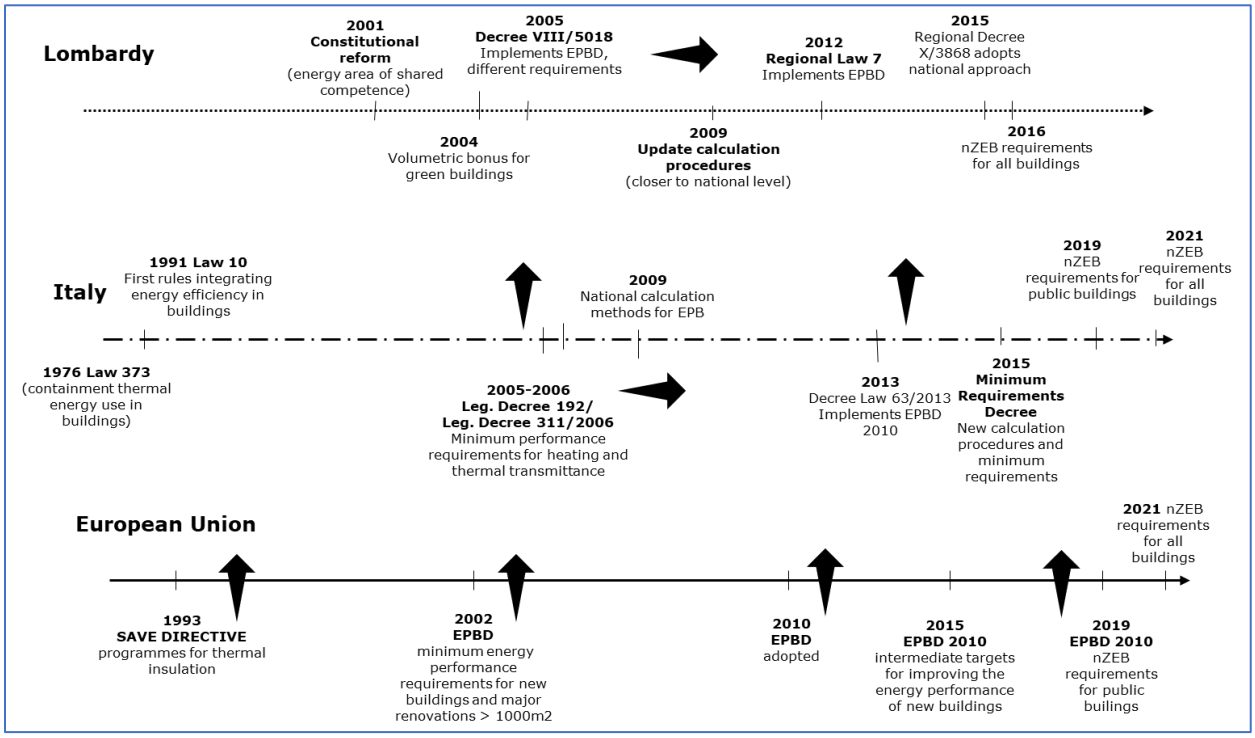

Figure 10 Evolution of regulatory framework on minimum energy performance requirements in buildings in Italy and Lombardy region vs EU level. *Source: Author's elaboration.*

For the purpose of this research, it is also important to underline that the new minimum requirements introduced at national level for the year 2016 were 15% stricter than their predecessors (Costanzo et al., 2018:2-4) and that further strengthening were included in the same "Minimum Requirements" decree starting from 2017, 2019, and 2021 respectively. In this context, the Italian Energy Efficiency Plan of 2014 (Government of Italy, 2014: 71-73), reported that the study applying the cost-optimal methodology required from the EU level played an important role. In comparison with the legal limit values in force at the time showed for new residential buildings significant room for improvement and «the need to adjust the minimum performance requirements». To justify this gap, then Italian authorities affirmed that «the national standards in 2006 could not at the time take into account the technology developments [occurred in the

market] » (Ibid: 72). As confirmed in written communication by an expert involved in the cost-optimal study, «for the [Italian] Ministry of Economic Development in charge of the process, [the cost-optimal study carried out in 2013] was a very useful tool for the preparation of the Ministerial Decree of June 2015. For the determination of the various parameters and limits, the findings were therefore taken into account, together with other evaluations» (interview n. 6).

4.3 Implementation of Energy efficiency obligation schemes and/or alternative measures under Art. 7 EED

The second EU measures to be analysed, also in the Italian context, is the energy efficiency obligation scheme and/or alternative measures under Article 7 of the EED (see Section 2.3.2.7). In this regard, the energy savings from end-users to be achieved in Italy for the period 2014-2020 amounts to 25.58 Mtoe (Government of Italy, 2017a: 10). This target is not formally shared with the Regions; therefore, in this section, the analysis will be limited to the national level only, which is the only level responsible for the implementation of this EU measure in Italy.

To meet this objective, Italy relies on five measures, of which four[25] are either exclusively or partly addressing the buildings sector. These four instruments are: a) an energy efficiency certification scheme; b) tax relief on renovations and to improve the energy efficiency of buildings; c) a grant scheme called "Thermal Account"; d) and a National Fund for Energy Efficiency (Ministry of Economic Development, 2018).

3.2.2 Energy efficiency certificates scheme

According to Legislative Decree 102 of 4 July 2014 transposing the 2012 EED, the energy efficiency certificates scheme is intended to deliver 60% of the final energy savings target set for Italy under Article 7 EED. This is a market-based mechanism grounded on the creation of an obligated market for these certificates. Also called white certificates, these negotiable securities certify the achievement of energy savings in energy end-use through measures and projects to improve energy efficiency. Each year, the obligated parties, i.e. electricity and gas distributors with more than 50 000 final customers, need to meet a

[25] The fifth instrument considered by the Italian government in the context of Art. 7 EED is addressing industry and is called National Industry 4.0 plan (Impresa 4.0).

mandatory quota and, to this end, may either generate certificates through own action or purchase the certificates from the market.

This instrument, however, was not created *ex novo* to comply with Article 7 of the EED 2007. It was instead established in 2004 in the context of the liberalisation of the electricity and gas markets and updated in the framework of the implementation of the ESD in 2008, 2011 and 2012. Legislative Decree No 102 of 2014, linked the scheme with Article 7 of the EED and, among other things, provided that only certified energy managers and ESCOs as of July 2016 were eligible to participate in the energy efficiency certificates' market Government of Italy, 2017b).

As the mechanism covers multiple end-use sectors, for the purpose of this research it is of interest to understand the impact on buildings. To this end, from the 2017 Italian Energy Efficiency Action Plan it is possible to extrapolate the number of certificates from various sectors, and thereby the energy savings. In particular, regarding interventions to replace space heating, space cooling, and domestic hot water systems, certified energy savings amounted to 0.34 ktoe in 2014, 0.19 ktoe in 2015, and 0.14 ktoe in 2016. On the other hand, certified energy savings through the improvement of the envelope amounted to 0.06 ktoe in 2014, 0.16 ktoe in 2015, and 0.051 ktoe in 2016. All in all, certified energy savings from buildings are negligible as they represented only 4% of the total certified savings in 2016. This factor in part justifies the choice of policy-makers in Italy, who decided to devise tailor-made instruments targeting specific categories of actors in the buildings sector as analysed in the following sub-sections.

4.3.2 Tax relief on renovations and to improve the energy efficiency of buildings

As in the case of energy efficiency certificates scheme, also the tax relief instrument was introduced before the requirements from the EED.

In force since 2007, this instrument address to both residential and tertiary sectors but excludes the public sector. It consists of reductions in personal and corporate income tax for the expenses incurred for interventions that increase the level of energy efficiency of existing buildings. Eligible measures are a) global energy requalification and transformation of the building to comply with nZEB requirements; b) the improvement of the thermal insulation through replacement of windows including fixtures and insulation of roofs, vertical walls and floors; c) the installation of solar thermal systems; d) replacement of existing heating systems with condensing boilers, heat pumps, hybrid systems, micro-cogeneration, biomass boilers; e) replacement of electric water heaters with heat pump water heaters; and f) since 2016, installation of

building automation devices and systems. The interventions related to the expansion works are not eligible for tax relief (Ministry of Economic Development, 2018: 10).

To facilitate the implementation of energy efficiency measures in multi-apartment buildings, the 2016 Stability Law established that for works carried out in common areas, the tax relief could be transferred to the companies doing the work in return for a discount. This may allow tenants to benefit from the tax relief, even if they would otherwise be unable to take advantage of it. The Law of 11 December 2016 increased the tax relief from 50% to 65 %, which is further raised to 70% for energy efficiency improvements to common areas of multi-apartment buildings carried out on at least 25 % of the envelope.

4.3.3 Grant scheme (Thermal Account)

This mechanism, launched in 2012 and operational since 2013, is the first investment aid scheme in Italy incentivising small-scale renewable heating and cooling systems for households and companies, as well as the first open to energy efficiency in public buildings. The budget available amounts to a maximum of EUR 200 million for the public sector and EUR 700 million for households and companies (Government of Italy, 2017a and 2017b; Ministry of Economic Development, 2018: 10-17).

Since the second phase of the scheme, launched in 2016, the Thermal Account provides grants for two categories of interventions. The first category concerns energy efficiency in buildings, open to the public sector only, and include: a) thermal insulation of opaque surfaces; b) replacement of windows; c) replacement of existing heating systems with condensing boilers; d) installation of screening and/or shading systems; e) conversion of buildings complying with nZEB requirements; f) replacement of existing internal lighting systems and external appurtenances with energy-efficient lighting systems; and g) installation of building automation systems. The second category of interventions, concerning small-scale renewable heating and cooling systems, are open to both the public and the private sectors and include: a) replacement of existing heating systems with heat pumps, hybrid condensing boilers and heat pump systems, and biomass boilers up to 2 000 kW; b) installation of thermal solar collectors, up to 2 500 m^2; and c) replacement of existing electric water heaters with heat-pump water heaters.

4.3.4 National Fund for Energy Efficiency

Originally established by Article 15 of Legislative Decree n. 102 of 2014, the National Fund for Energy Efficiency was operationalised in 2017 and the first call was open only in May 2019. This instrument has

a revolving nature and provides a) guarantees on individual financing operations, for 30% of the available budget; and b) concessional loans.

The Fund is open for energy renovation of buildings as well as for energy efficiency measures in industry, the construction and extension of district heating and cooling systems, and efficiency improvements of public services and infrastructures. To avoid double incentives and counting, it can cover exclusively the costs of additional investment needed to achieve the highest level of energy efficiency and cannot finance interventions already subsidised by other instruments, for instance, the Thermal Account.

The maximum budget provided in the until 2020 period according to Article 15 is EUR 490 million. Even though at the time of writing (July 2019) the fund did not generate any energy-saving yet, the Ministry of Economic Development reports that the estimated leverage factor of the fund is 5.5. This means that over EUR 800 million should be mobilised, from EUR 150 million of public finance (Ministry of Economic Development, 2018: 18).

4.3.5 New energy savings in 2014-2016 in Italy from the implementation of Article 7 EED

Based on the analysis of the progress reports submitted to the European Commission in compliance with Article 24 of the EED as well as from the methodology submitted to justify the selection of the measures under Article 7 (Ministry of Economic Development, 2018) it is possible to extrapolate the cumulative energy savings from interventions in buildings from the energy certificates scheme (4% of the total certified savings from the scheme over the last three years), the tax rebate mechanism and from the Thermal Account, while no energy savings have been generated s of 2017 from the National Fund for Energy Efficiency, Figure 11 illustrates the new cumulative energy savings obtained from end-users under Article 7 in Italy and highlights the important role of the tax rebate regime in the development of energy efficiency in the residential sector. As reported by the Ministry for Economic Development (2018: 9) regarding the tax rebate mechanism,

> «the total number of interventions performed (approximately 2.9 million at December 31, 2016) generated final energy savings approaching today at 1 Mtep / year, corresponding to an environmental benefit in terms of CO2 not emitted into the atmosphere of over 2 million tons per year».

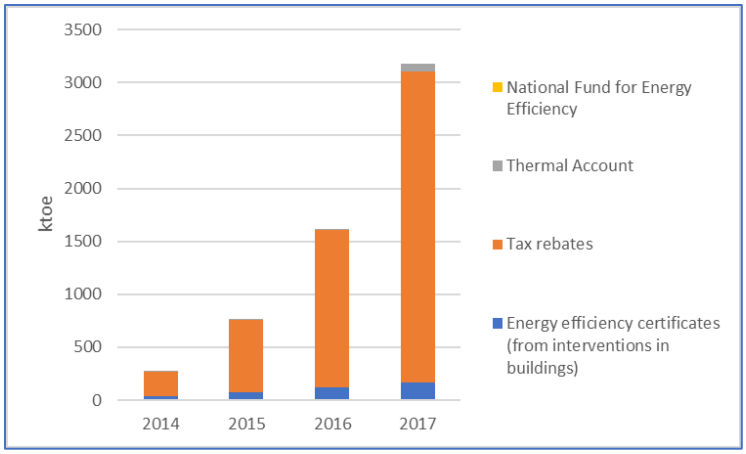

Figure 11 Cumulative new final energy savings in the buildings sector by implementing Article 7 EED (2014-16), ktoe. *Source: Own elaboration based on data from Italy's annual reports 2015, 2016, 2017, and 2018 and Ministry of Economic Development (2018), Application of Article 7 of Directive 2012/27/EU on the energy efficiency obligation scheme [in Italian].*

4.4 Implementation of minimum levels of renewable energy, where applicable

The last of the three EU measures to be analysed in the context of the Italian case study is the non-mandatory requirement, under Article 13.4 of the EU RED of 2009, to establish a minimum level of renewable energy in new buildings and buildings subject to major renovations (see Section 2.3.3.1).

Initially, Italy was ahead of the EU legislation. This is because, already in 2005, Legislative Decree 192/05 provided in Annex I the requirement to cover at least 50% of the energy for domestic hot water from RES in new buildings and, in case of replacement of the water heater system, in case of extensions of over 20% of the volume. Nonetheless, the necessary implementing measures were never issued and, therefore, the above provision remained in practice ineffective. At the regional level, as we have seen in section 4.2, Legislative Decree 192/05 gave the possibility for the regional governments to legislate on their territory. As in the case of minimum requirements for the energy performance of buildings, the Lombardy region seized the opportunity and applied the obligation to cover 50% of domestic how water demand with renewable energy through Regional Decree VIII/8745 of 2008.

Six years later, Legislative Decree 28/2011 of 3 March 2011 transposing into the Italian legal framework the 2009 RED, reinforced the previous provision in place in line with the (non-binding) requirements of Article 13 2009 RED. In detail, Article 11 para 1 required that new buildings and buildings subject to major renovations cover 50% of the demand for domestic hot water. In addition, the Italian legislation requires to

comply with the following share of the sum of the consumption for domestic hot water, space heating, and space cooling: a) 20% from June 2012 to December 2013; b) 35% from January 2014 to December 2016; and c) 50% from 1 January 2017[26]. (Annex 3, Legislative Decree 28/2011) A third requirement is the installation of a minimum capacity of solar PV depending on the size of the building and the date of construction of the plant. That said, an important a derogation from the above obligations may be provided for buildings of specific historical and artistic value (Article 11 para 2 Legislative Decree 28/2011).

Annex 3 of the decree clarifies that the obligation is to be considered fulfilled for buildings connected to district heating supplying the totality of space heating and domestic hot water (Annex 3 para 5 Legislative Decree 28/2011). Additionally, it specifies that the above obligations cannot be fulfilled through renewable energy systems generating exclusively electrical energy and which, in turn, supply power to devices or systems to produce domestic hot water, heating and cooling. Finally, it is also worth highlighting that access to government incentives allocated for the promotion of RES (e.g. the tax rebate) is limited only to the amount exceeding the level required for compliance with the minimum obligations.

Unlike Legislative Decree 192/05, Legislative Decree 28/2011 did not provide an opportunity for regional governments to apply different approaches compared to the national legislation. Therefore, the obligations for RES to cover thermal demand in new buildings and buildings subject to major renovation are applicable in the same way throughout the country, including in the Lombardy region.

4.5 Summary

In chapter 4, to continue the analysis in response to the second research question, we have tracked and analysed the evolution of the implementation of three EU instruments in Italy. When possible, the assessment has also looked at the regional level, and in particular at the developments in the Lombardy region.

Regarding minimum energy performance requirements of buildings and building components, we have observed that in the 1970s and in the early 1990s, Italy was at the forefront. Yet, the lack of implementing measures made the innovative Italian regulatory framework poorly impactful in practice. From our analysis, four main elements emerge. First, the reform of Title V of the Constitution in 2001 made energy a shared task between the State and the Regions. This paved the way to a very fragmented regulatory framework in which was nearly impossible to compare buildings from one region to another. Adopted to

[26] Postponed to 1 of January 2018.

implement the EU EPBD adopted in 2002, the Italian Legislative Decree 192 of 2005 required the Regions to legislate within a general national framework. However, only six out of the 20 Regions adopted regional regulations. Second, for some region, there was the opportunity to advance a more ambitious agenda in terms of energy efficiency in buildings. In our regional case study, Lombardy, we have seen the introduction in the 2000s of incentives in terms of a bonus of 15% on maximum volume for constructions meeting specific energy efficiency and environmental requirements and stricter energy performance requirements of buildings and building components.

Furthermore, following the 2010 recast of the EPBD, Lombardy also required the application of nZEB already in 2016, well ahead of EU and national requirements. The third element concerns the relatively longer time taken at the national level to adapt to the requirements from the EU. Only with Decree Law 63/2013 of 2013 and the implementing Inter-ministerial decree in 2015 eventually completed the regulatory framework on the energy performance of buildings. The two regulatory acts also required the regional authorities to harmonise their requirements in line with the EU and national frameworks. The fourth element emerged after two decades of implementation of EU law, is the adoption of more stringent requirements in Italy in terms of the energy performance of buildings. As we have seen, the latest requirements introduced to implement the 2010 EPBD are 15% stricter than their predecessors. In this framework, as highlighted by experts interviewed, the EU requirement to apply a cost-optimal methodology considering the life-time costs rather than only the investment costs played an important role in the realisation of the potential for stricter energy performance requirements.

As for the implementation of energy efficiency obligation schemes (Art.7 EED), the implementation was the exclusive responsibility of the national level, which adapted and reinforced existing instruments such as the energy efficiency certificate quota system and tax rebate and proposed new instruments. In particular, to incentivise the public sector and the uptake of renewable heating and cooling systems, the Italian government launched a grant scheme, while a new National Fund for Energy Efficiency was operationalised in 2019 to provide guarantees and concessional loans, including for building renovation. Among those instruments, the tax rebate generates most of the energy savings from end-users in buildings.

Finally, regarding the non-binding requirement to integrate minimum levels of RES in new buildings and buildings subject to a major renovation, we have seen that Italy provided this requirement before EU legislation. The reinforced requirements adopted in 2011, require a minimum growing share of RES for heating and cooling and a minimum of solar PV depending on the size of the building.

5. Comparative analysis of the two case-studies

This chapter briefly presents similarities, differences and other relevant elements emerged from the analysis of the implementation of the three selected EU measures carried out in chapters 3 and 4 in the two case-studies.

5.1 Context

The two selected cases studied, the Brussels-Capital Region (BCR) in Belgium and Italy, with focus (when applicable) on the Lombardy region present some common features and challenges in their on-going journey towards the decarbonisation of the buildings sector. Firstly, the residential sector represents the largest end-use sector in terms of energy consumption (38% in Brussels and around 30% both in Lombardy and Italy), within which demand for space heating is the dominant energy service; secondly, the climate zones of Brussels and Lombardy are roughly comparable: 2355 heating degree days in BCR and an average of 2381 degree days in Lombardy in 2018 (Eurostat). However, the rest of Italy presents a significant climate variety; thirdly, both cases present a relatively old building stock, most of which built before the entry into force of minimum energy efficiency requirements.

On the other hand, Brussels presents some unique features: it is a city-region, with limited industrial production, land availability and renewable energy potential, and lower than average income per capita compared with the rest of the country. As for the legislative competence in the area of energy in buildings, this falls within the responsibilities of the regional governments in Belgium, while it is a shared responsibility in Italy.

5.2 Implementation of EU measures on building minimum energy performance

In chapter 4, we have seen that the Italian regulatory framework on energy efficiency in buildings preceded regulatory intervention at EU level, but lack of implementation was the main reason for poor results in the 1990s. Contrarywise, no major regulation was in force in the Brussels region before the SAVE Directive of 1993. Reaction to the developments at the EU level was slow in Brussels (and Belgium in general) in the 1990s. However, the situation dramatically changed in 2004, when a new government launched an ambitious energy efficiency policy. In the context of the implementation of EPBD, the Government of the BCR appears to have found guidance and inspiration to set more stringent energy performance requirements in buildings. The Region has even outpaced the EU ambition and, in 2013, adopted passive standards for

buildings. These ambitious requirements have been applied in residential buildings, offices, and schools since 2015 and all new buildings in the region since 2017.

Going back to Italy, Figure 12 shows the slower adaptation of the national level to the EPBD, compared to the swifter reaction of the Lombardy region as well as of the BCR in Belgium. The Lombardy region was one of the six Italian regions to adopt a regional framework to implement the EPBD. Following the reform of the Title V of the Constitution in 2001, which made energy a shared area of competence between the central and the regional levels, Lombardy introduced incentives for buildings meeting ambitious standards and, in the framework of the EPBD implementation, stricter energy performance requirements compared to the national level. Figure 12 also shows that both the BCR and the Lombardy region applied nZEB requirements well ahead of EU and national deadlines.

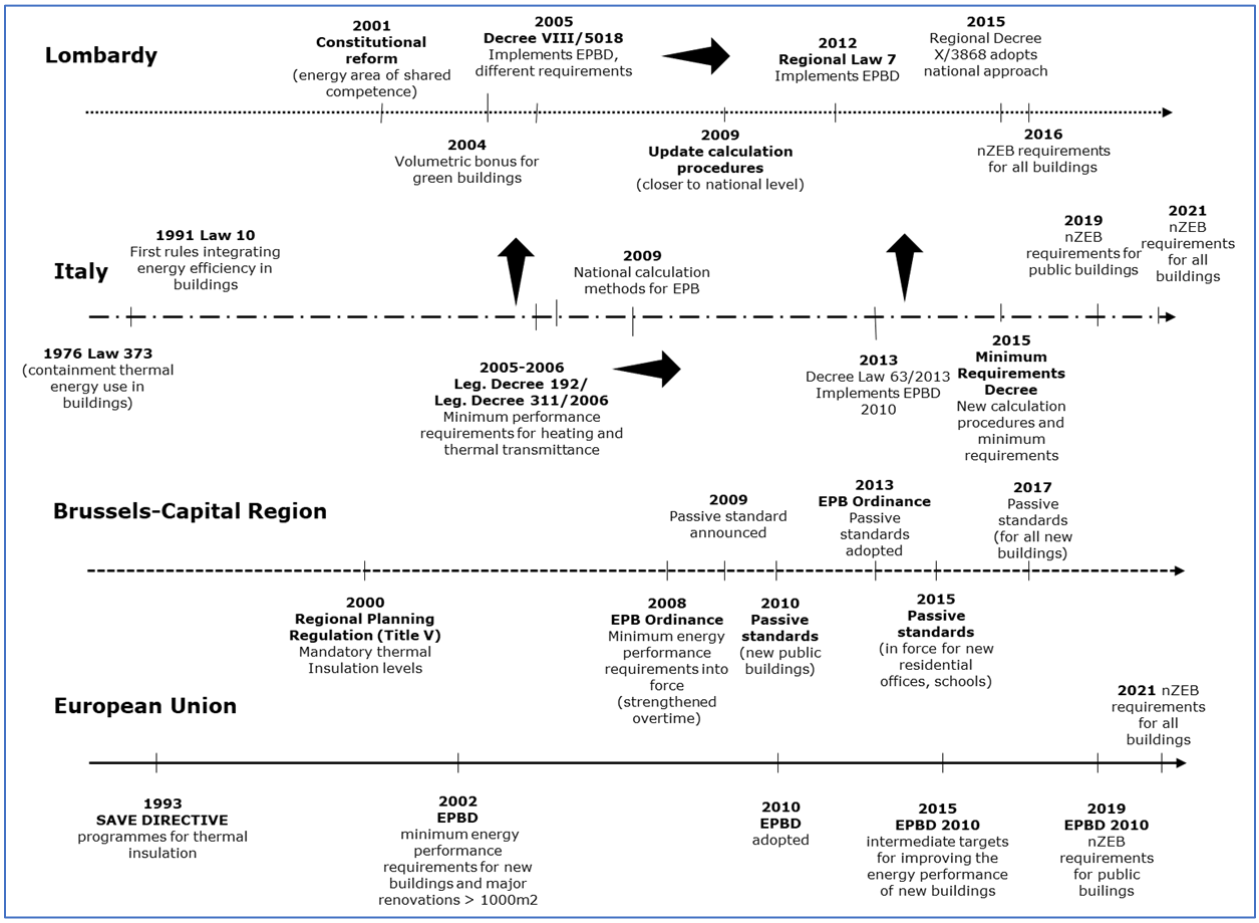

Figure 12 Evolution of regulatory framework on minimum energy performance requirements in buildings, in the EU, Brussels-Capital Region, Italy and Lombardy. *Source: Author's elaboration.*

The Italian national government, in the meantime, completed the national framework in compliance with EU requirements only in 2015 with the Inter-ministerial decree implementing Decree Law 63/2013 of 2013.

Regardless of the time required for transposition, one of the fundamental objectives of the EPBD was the adoption of more stringent requirements for the energy performance of buildings with an emphasis on the cost optimisation of energy-related regulations (Abela et al., 2013). As a matter of fact, in Brussels, energy performance requirements for residential buildings passed from E90 in 2008 to E70 in 2011 before the adoption of more stringent requirements in 2017 (Govaert at al., 2018). Similarly, in Italy, the requirements introduced to implement the 2010 EPBD are 15% stricter than their predecessors and the application of the cost-optimal methodology considering the life-time costs played a key role in the setting of stricter requirements in 2015. In Lombardy, a study carried by Dell'O at al. (2015), Figure 13 shows a significant reduction of the indicator for global energy performance of heating, both for residential and non-residential buildings over the last decades.

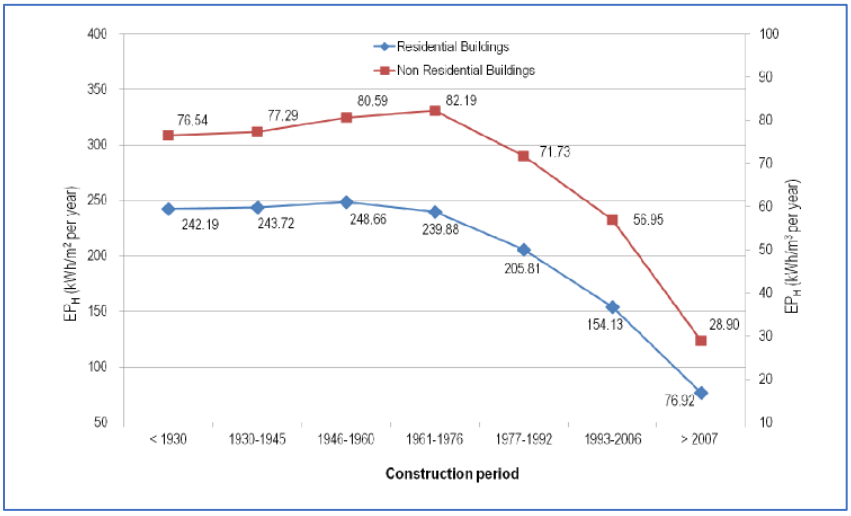

Figure 13 Variation of the energy performance of residential buildings and non-residential buildings in Lombardy region on the basis of the EPH indicator. *Source: Dell'O et al. (2015:3514), Nearly Zero-Energy Buildings of the Lombardy Region (Italy), a Case Study of High-Energy Performance Buildings.*

Based on data from EPCs available for the Lombardy region, the same authors report improvements also in terms of the energy performance of walls, roofs and floors in residential buildings. These values have generally decreased after 1991 and especially following the entry into force of Regional Council Decree No. VIII/5018 in 2007 (Dall' O et al., 2015). From the above analysis, therefore, it is possible to conclude

that the implementation of the EPBD brought about an effective enhancement of energy performance requirements in the case-studies assessed in this research.

5.3 Implementation of Energy efficiency obligation schemes and/or alternative measures under Art. 7 EED

Concerning the implementation of Article 7 of the EED, in chapter 2 we have seen that member states had the choice to establish a quota system in which obligated energy suppliers and distributors would be mandated to achieve a certain level of energy savings. To complement, or as an alternative to, the energy efficiency obligation scheme, EU countries could put in place several other public policy measures. Building on the classification of policy instruments proposed by Linares (2012), it is possible to observe the selection of instruments addressing the building sector in the two-case studies. Brussels did not put in place any quota system, which was the original intention of Article 7 EED. Instead, the Region relies on a mix between command and control instruments (early adoption of nZEB requirements and more frequent boilers inspections) a price instrument (grant scheme), and information and support to households and local authorities.

Table 4 Classification of policy instruments in the Brussels-Capital Region and Italy under Article 7 EED
Source: Author's elaboration.

	Command and control	**Economic instruments**		**Other (information, etc.)**
		Price instruments	Quantity instruments	
Brussels-Capital Region	Stricter energy performance requirements of buildings More frequent boiler inspections than EU rules	Grant scheme (prime énegie) Financial support to implement action plans for energy management (PLAGE) of social housing and Brussels Regional Development Agency		Advice and technical support for households and local authorities
Italy		Tax rebate Grant scheme (Thermal Account) National Fund for Energy Efficiency	Energy efficiency certificate system	

In Italy, where compliance with Article 7 EED is a responsibility of the national level, the Government relies only on economic instruments. As we have seen in chapter 4, the quota mechanism based on energy efficiency certificates is expected to play an important role; yet, the impact on buildings is rather limited (4%). On the other hand, the grant scheme for households, companies, and the public sector, as well as the

tax rebate mechanism, are expected to boost CO_2 emission reductions in buildings. Lastly, a National Fund for Energy Efficiency was launched in 2019 to provide complementing guarantees and concessional loans.

Following this analysis, it is evident how this EU instrument provides broad flexibility to EU countries to devise the most appropriate policy instruments according to national preference and traditions. In this context, an interesting aspect to consider is that neither the BCR (or Belgium) nor Italy relies on a carbon tax to comply with Article 7 of the EED.

5.4 Implementation of minimum levels of renewable energy, where applicable

As far as the minimum level of renewable energy is concerned, we have seen in chapter 3 that the Government of BCR decided not to impose this non-mandatory requirement from Article 13.4 of the EU RED of 2009. This decision is linked to the application of passive standards ahead of EU legislation requirements. The need for installing renewable energy would be somehow implied by the requirement to fulfil ambitious non-renewable primary energy consumption requirements in new buildings or renovated buildings assimilated to new buildings. An incentive to install small-scale renewable energy technology is also provided through the grant scheme (Prime énergie) assessed in the framework of the implementation of Article 7 EED. However, based on the data available, the contribution of RES heating and cooling remains negligible in the region. For example, the combined installed capacity of solar thermal and heat pumps amounted to only 20 MW and contributed to 15 GWh in 2016, representing only 0.2% of the regional energy consumption for space heating and domestic hot water in the residential sector (6834 GWh) (Brussels Environment, 2018:12, 17).

In Italy, on the other hand, chapter 4 has shown how this requirement was put into force through with Legislative Decree 28 of 2011 implementing the EU RED of 2009. At the regional level, the Lombardy region anticipated both EU and national legislation and imposed the obligation to cover 50% of domestic how water demand with renewable energy since Regional Decree VIII/8745 of 2008. With the adoption of nZEB requirements since 31 December 2015, the Region also anticipated the obligation to cover 50% of the sum of thermal demand (space heating, cooling and domestic hot water) with renewable energy compared to the rest of the country (35% before 1 January 2018 and 50% after 1 January 2018). Even though no data were found during this research to show the specific impact of this measure in Lombardy and in Italy, two stakeholders interviewed from the private sector highlighted that this obligation has created a niche market for small-scale renewable heating and cooling installations, and thereby contributed to a renewed interest for these technologies from installers and market operators (interviews 2 and 5).

5.5 Summary

To address the second research question and provide insights on how the three selected EU measures have been implemented in the two case studies, this chapter has highlighted relevant findings emerged from the comparison of the assessment in the BCR in chapter 3 and Italy, with focus (where applicable) on Lombardy in chapter 4.

Despite a different adaptation period, over the last decade the Brussels region, the Lombardy region, and Italy have all adopted stricter requirements with an emphasis on the cost optimisation of energy-related regulations. This was a major objective of the 2010 EPBD. Within this framework, both Brussels and Lombardy can be considered best practices as they both have anticipated the entry into force of nZEB requirements, which is another major element of the EU legislation on buildings.

Concerning the implementation of Article 7 of the EED, we have classified the policy instruments adopted in Italy and the BCR according to the framework proposed by Linares (2012). In this context, Brussels relies on a mix between command and control instruments, a price instrument (grant scheme), and advice and technical support. On the other hand, Italy relies exclusively on economic instruments. This analysis confirms that Article 7 is an instrument providing broad flexibility to EU countries to meet the objective set at the EU level based on national preferences.

As for the application of a minimum level of renewable energy in buildings, the two cases diverge. The Government of BCR decided not to impose such measure but lags behind in terms of market uptake of alternative renewable heating installations. Italy, instead, implemented minimum requirements since 2012. In this context, the Lombardy region adopted higher minimum levels of RES before the national level. Stakeholders interviewed in the context of this research argue that this obligation has created in Italy a niche market for small-scale renewable heating and cooling installations which is, to a certain extent, attracting more interest from installers and market operators towards renewables in the buildings sector.

Conclusions and perspectives

The objective of this thesis was to address the following research questions: a) «What are the main policy measures at EU level to reduce CO_2 emissions in the buildings sector?»; and b) «How selected EU policy measures have been implemented so far in the Brussels-Capital Region and Italy, including (where applicable) in the Lombardy region?»

In the first phase of the research, literature and data reviews were carried out to define the boundaries of the analysis and the context of the specific environmental problem addressed. In this regard, it was possible to note that space heating accounts for some 70% of final energy consumption in residential buildings in the EU and more than half of energy consumption in non-residential buildings. In the context of this research, this factor was later taken into account in the selection of the policy measures to be analysed at national and regional levels. Another element emerging from the literature review was the need for structural societal and behavioural changes to accompany existing technology options as fundamental ingredients to meet the decarbonisation objectives in the sector.

Building on the above, a thorough review of the evolution of the complex EU legal framework has revealed how multiple directives and regulations address, directly or indirectly, energy consumption in buildings. The first EU measures were due to the security of supply concerns following the oil crises in 1973 and 1979 and to the need for removing trade barriers on products within the internal market. Since the early 1990s, however, there is a clear link between the enhancement and expansion of the EU energy framework and the EU commitments to reduce domestic CO_2 emissions.

Within this framework, and to answer the first research question, the main EU measures specifically addressing energy in buildings can existing under the following three categories (see also Table 3 in chapter 2).

a) *Measures on minimum efficiency requirements of buildings, building components, technical systems, equipment and appliances*

In the case of buildings and technical systems, the EPBD imposed on member states to set their own minimum energy efficiency requirements based on national conditions and taking into account life-cycle costs. Furthermore, nZEB requirements are to be applied as of 2021 for all new buildings, anticipated to 2019 for new public buildings. For equipment and appliances, eco-design requirements are established at

the EU level through regulations directly applicable to the entire EU and in other countries the European Economic Area (Iceland, Liechtenstein, and Norway).

b) Measures aiming to stimulate energy efficiency demand and supply as well as the rational use of energy

This second category includes measures scattered in various EU directives and regulations, including obligations for the regular inspection of thermal systems (EPBD), the evolving requirements to empower the consumer with information through energy performance certificates of buildings (EPBD), energy labels for heating and cooling equipments and electric appliances (Energy Labelling legislation), and transparent bills from utilities (SAVE Directive, ESD, and EED). Also, we have seen that EU measures often require the public sector to play an exemplary role, as is the case with the mandatory minimum renovation of buildings owned or occupied by central governments (EED). Amongst other measures, the EU also requires member states to establish a certification or qualification scheme for installers to ensure the quality of energy efficiency works (ESD and EED) and boost the confidence of the market.

c) Measures promoting renewable energy and other low carbon vectors in buildings

Measures under this category include: the non-binding requirements for minimum levels of renewable energy in new buildings and buildings subject to major renovation; the requirement to streamline administrative procedures and to set up qualification schemes for small-scale renewable installers; the provision for member states to inform and provide guidance to local planners, market actors, and the consumer (RED). Besides, the nZEB standards (EPBD) are expected to incentivise the installation of more renewable energy in new buildings to comply with the very low non-renewable primary energy requirements. Furthermore, for the period post-2020, new measures have been adopted with the 2018 RED. These include a new national quota system, presenting similar principles as the energy efficiency obligation scheme of the EED, and which is intended to increase the share of RES in heating and cooling in the next decade.

From the above review, it is possible to draw a few considerations. First, EU measures address energy use in buildings in a very comprehensive manner, tackling all the main opportunity areas for energy and associated CO_2 emission reductions identified in chapter 1 (i.e technical improvements to the envelope to reduce demand; use of more efficient equipment and control systems; behavioural changes; and fuel switch to renewable energy and other low carbon vectors). Second, it is possible to observe a general transition from non-binding measures in the early phase of EU measures, e.g. in the 1993 SAVE Directive, to more

ambitious and binding measures such as those found in the 2012 EED; third, EU interventions seem to be more prescriptive concerning minimum energy performance requirements of buildings and appliances as well as in the obligations for the public sector; fouth, more flexibility is offered to member states in the way to harness energy savings potential from end-users, including households, as is the case with the energy efficiency obligation schemes under the EED; and lastly, regulatory incentives to accelerate the uptake of RES technologies in buildings appear to be the weakest among the EU requirements in the field. However, a new obligation scheme was adopted with the 2018 RED and is to be applied by member states after the year 2020.

To address the second research question, within the limits of a Master's thesis, the analysis was limited to three selected EU measures, one per each of the above categories (for the selection criteria, see section 2.4):

a) Minimum energy performance requirements of buildings from the 2002 and 2010 versions of the EPBD;
b) Energy efficiency obligation schemes under Article 7 of the 2012 EED; and
c) Minimum levels of RES in new buildings and buildings subject to major renovations, where applicable, from the 2009 RED.

Although limited, the findings from the analysis of the implementation of the above measures in the case studies are reported below.

As for *minimum energy performance requirements of buildings*, there is solid evidence that the implementation of the EPBD brought about an effective enhancement of energy performance requirements in the case-studies assessed in this research. Indeed the Brussels region, the Lombardy region, and Italy have all adopted stricter requirements over the last decade. Furthermore, the application of the cost-optimal approach to energy regulation in buildings required by Article 5 of the EPBD played an important role in the adoption of more stringent energy performance requirements as of 2016 in Italy. Second, when made possible by the constitutional arrangements at the national level, there is room for the regional levels to be more ambitious. In this regard, based on the analysis in Brussels and Lombardy, we can consider both the regional cases in this research as good examples. Indeed, both regions have not only adapted swiftly to EU requirements on minimum energy performance requirements of buildings but have also anticipated the entry into force of nZEB requirements compared to the deadline set at the EU level. However, it is desirable to verify that all regions are equally empowered and have the means to implement complex regulation to avoid the development of a fragmented framework as was the case in Italy in the 2000s.

Regarding the implementation of *energy efficiency obligation scheme under Article 7 EED*, it was possible to observe that the two case-studies have selected different types of policy instruments to achieve a pre-determined amount of energy savings from end-users. In particular, taking advantage of the flexibility offered by Article 7 of the EED, Brussels decided not to adopt an energy efficiency obligation scheme in the form of a quota system but to rely on a mix between command and control instruments, a price instrument (grant scheme), and advice and technical support. On the other hand, Italy exclusively adopted economic instruments. The analysis confirmed that Article 7 of the EED is an instrument providing broad flexibility to EU countries to meet the objective set at the EU level based on national preferences. Furthermore, it was noted that neither the BCR nor Italy have adopted a CO_2 tax as an alternative measure to comply with Article 7 EED. In the two case-studies, therefore, the «polluter pays» principle is not applied in the residential and tertiary sectors, as of 2019.

As far as the *minimum level of renewable energy in buildings* is concerned, the governments in two case-studies applied a different approach vis-à-vis this non-binding EU measure. In Italy, minimum levels of RES in new and existing buildings subject to major renovations are in force since 2012 and were raised in 2018 to reach 50% of the sum of space heating, space cooling, and domestic hot water consumption. According to some of the experts interviewed in the context of this research, such obligation has created in Italy a niche market, which has, in turn, increased the interest of installers and market operators towards small-scale renewable heating and cooling technologies. On the other hand, the Government of the BCR decided not to impose a specific requirement on renewable energy in buildings. While small-scale RES heating technologies are incentivised through energy grants and could benefit from nZEB requirements already in force, the Region lags very much behind in terms of market uptake of non-fossil based heating systems. This consideration may suggest the need for further incentives in the next years to increase, from the supply side, the technology portfolio available for the decarbonisation of the buildings sector in the BCR.

To answer the research questions, the author has taken as much as possible a multi-disciplinary approach and applied knowledge acquired in the courses of the Master's, in particular about energy and the environment, analysis of environmental policies, environmental law, and ecological economics. However, the main findings from this research are inevitably limited. The first limitation is due to the qualitative nature of the research, which had a focus on the impact of EU legislation on the policy and regulatory frameworks only. Despite an initial attempt to present available data on the specific impact in terms of CO_2 savings generated by each of the three selected EU measures, lack of widely available and comparable data

in the case-studies has suggested not to pursue with this complementary task. In this framework, it is worth noting that information on energy savings is available when explicitly requested by the EU, as in the case of the reporting obligation under Article 7 and Article 24 of the EED. Another limitation of this research is related to difficulties in having access to costly standards, which could provide further details. Moreover, it could be worth increasing the number of case studies and the EU policy measures analysed. In particular, the risk of isolating one specific measure from the others is to overestimate the impact of that measure under assessment and to neglect the impact of others.

The research could, therefore, be expanded to assess the interplay at national and regional levels between more complementary policy measures, including for instance those related to the energy performance certificates of buildings, regular inspection of thermal systems, or the link between the number of certified installers and quota systems for energy efficiency and renewable energy technologies. Furthermore, the scope of the analysis could also be enlarged by including an analysis of the acceptance of market actors and the consumers, on the socio-economic impacts, the abatement costs of the chosen measures, or the link between the implementation of the EU legislation and the position of the government during the negotiations process at EU level.

Finally, looking back at the evolution of the EU policy framework over the last decades, it is possible to appreciate the leading role of the EU in steering energy efficiency regulation in buildings and the transfer of innovative principles and concepts from front-runners to the rest of the EU. Looking at the 2050 horizon, and considering the enormous challenges ahead, policies and regulation are expected to evolve and to play a key role in the effort to minimise the carbon footprint of energy use in buildings.

List of abbreviations

BCR	Brussels-Capital Region
COBRACE	Brussels Air, Climate and Energy Control Code
CO_2	Carbon dioxide
COP	Conference of Parties
EC	European Commission
EED	Energy Efficiency Directive
EPB Ordinance	Energy Performance and Indoor Climate of Buildings
ESD	Energy Services Directive
EPBD	Energy Performance of Buildings Directive
EPCs	Energy Performance Certificates
ESCOs	Energy service companys
ETS	Emissions Trading System
EU	European Union
GHG	Greenhouse gas
GWh	Gigawatt hours
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
Ktoe	Thousand tonnes oil equivalent
kW	kilowatt
kWh	kilowatt hours
Mtoe	Million tonnes oil equivalent
MJ	Megajoule
$MtCO_2$	Million tonnes carbon dioxide
nZEB	nearly Zero-Energy Buildings
OECD	Organisation for Economic Co-operation and Development
PJ	Petajoules
PLAGE	Action Plan for Energy Management/ Plan d'Actions pour la Gestion Energétique
PV	Solar photovoltaic

RES	Renewable energy sources
RED	Renewable Energy Directive
TEU	Treaty on European Union
TFEU	Treaty on the Functioning of the EU
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change

Glossary

Building: According to Article 2 of Directive 2010/31/EU, means a roofed construction having walls, for which energy is used to condition the indoor climate

Energy performance of a building: According to Article 2 of Directive 201/31/EU, means the calculated or measured amount of energy needed to meet the energy demand associated with a typical use of the building, which includes, inter alia, energy used for heating, cooling, ventilation, hot water and lighting.

Embodied energy: Energy used in each lifecycle stage of a product.

Energy efficiency: According to Article 2 of Directive 2012/27/EU, means the ratio of output of performance, service, goods or energy, to input of energy.

Energy efficiency obligation scheme: Under Directive 2012/27/EU, a scheme requiring energy companies to achieve a given amount of yearly energy savings of annual sales to final consumers.

Renewable energy: Under Directive (EU) 2018/2001, means energy from renewable non-fossil sources, namely wind, solar (solar thermal and solar photovoltaic) and geothermal energy, ambient energy, tide, wave and other ocean energy, hydropower, biomass, landfill gas, sewage treatment plant gas, and biogas.

Energy savings: According to Article 2 of Directive 2012/27/EU, means an amount of saved energy determined by measuring and/or estimating consumption before and after implementation of an energy efficiency improvement measure, whilst ensuring normalisation for external conditions that affect energy consumption.

Final energy consumption: according to Eurostat, it is the total energy consumed by end-users, such as households, industry and agriculture. It is the energy which reaches the final consumer's door and excludes that which is used by the energy sector itself.

Heating degree days: the sum extended to all days in a conventional annual heating period, of positive differences between interior temperature (conventionally fixed at 20°C) and the mean daily external temperature.

k-value: or thermal conductivity is the ability of a material to conduct heat. Consequently, a high thermal conductivity means that heat transfer across a material will occur at a higher rate. The units of thermal conductivity are W/m·K.

Indirect emissions: From the buildings sector perspective, emissions occurring at a different geographic location from where the energy is used, e.g. from electricity produced in a power plant or from heat supplied through district heating.

Implementation (of EU law): is a general term covering both transposition and application of EU law and involves the «practical application of the national transposing provisions to a concrete situation or to a number of situations

nearly Zero-Energy Building: according to Article 2 of Directive 2010/31/EU, means a building that has a very high energy performance, as determined in accordance with Annex I. The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby.

Net present value: In finance, it is the present value of future cash flows discounted at a certain discount rate. The present value of a cash flow depends on the interval of time between now and the cash flow as well as on the discount rate.

Primary energy consumption: According to Eurostat, it measures the total energy demand of a country and covers consumption of the energy sector itself, losses during transformation and distribution of energy, and the final consumption by end-users.

Public policy: The system of laws, regulatory measures, courses of action, and funding priorities concerning a given topic promulgated by a governmental entity or its representatives in response to a societal problem of political relevance.

R-value: or thermal resistance, it is the converse of thermal transmittance (U values); in other words, the ability of a material to resist heat flow. The units of measurement are m^2K/W.

Transposition (of EU law): the procedure by which EU member states incorporate EU directives into their national law to make their objectives, requirements and deadlines directly applicable.

U value: Typically used for assessing the performance of building elements, U value or thermal transmittance is the rate of heat loss through a structure divided by the difference in temperature across that structure. The units of measurement are W/m^2K.

References

Abela, A. et al. (2013), "A comparative analysis of implementation of the Energy Performance of Buildings Directive in the Mediterranean", International Journal of Law in the Built Environment, Vol. 5 No. 3, 2013 pp. 222-240.

Angell, C. (2009), Addressing the Energy Efficiency Financing Challenge: The Role and Limitations of a Green Bank, Advanced Seminar In Climate Change Law – Fall 2009 December 31, 2009, http://wordpress.ei.columbia.edu/climate-change-law/files/2016/06/Angell-2009-12-Green-Banks-and-Energy-Efficiency-Financing.pdf [accessed on 8 June 2019].

Annunziata E., et al. (2013), "Towards nearly zero-energy buildings: the state-of-art of national regulations in Europe", Energy 2013; 57:125–33 (August).

Ballestreros, M. (2017), Monitoring the implementation of EU law: tools and challenges, Policy Department for Citizens' Rights and Constitutional Affairs, European Parliament http://www.statewatch.org/news/2017/nov/ep-study-implementation-eu-law.pdf [accessed on 10 May 2019].

Bertoldi, P. (2018), "European Union Energy Efficiency Policies for Buildings" in Desideri, U., Asdrubali, F., "Handbook of Energy Efficiency in Buildings: A Life Cycle Approach" pp.7-40, Butterworth-Heinemann.

BPIE (Building Performance Institute Europe) (2016) Smart buildings in a decarbonized energy system, Brussels http://bpie.eu/wp-content/uploads/2016/11/BPIE-10-principles-final.pdf [accessed on 8 February 2019].

Brussels Environment (2019a). Bilan énergétique de la Région Bruxelles-Capitale 2017, Resumé, Bruxelles.

Brussels Environment (2019b). Primes ènergie, Rapport technique 2018, Division Energie, air, climat et bâtiments durables, Bruxelles.

Brussels Environment (2018). Bilan énergétique de la Région Bruxelles-Capitale 2016. Bruxelles.

Buzzacchi C. (2010), "La materia energia nella giurisprudenza costituzionale" in Buzzacchi, C. (ed.), Il prisma energia. Integrazione di interessi e competenze, Milano.

Buffa, S. et al. (2019*)* 5th generation district heating and cooling systems: A review of existing cases in Europe, Renewable and Sustainable Energy Reviews 104 (2019) 504–522.

Costanzo, E., (2018), Implementation of the EPBD in Italy, Concerted Action Energy Performance of Buildings, Status in December 2016, https://epbd-ca.eu/wp-content/uploads/2019/06/CA-EPBD-IV-Italy-2018.pdf [accessed on 2 August 2019].

Crabbé, A., and Leroy P. (2008), The handbook of environmental policy evaluation. Earthscan, London, UK.

Dall'O, G. et al. (2013), Nearly Zero-Energy Buildings of the Lombardy Region (Italy), a Case Study of High-Energy Performance Buildings, Energies 2013, 6, 3506-3527.

Delbeke, J., et al. (2015), "Climate-related Energy Policies", in Delbeke J., and Vis, P., EU Climate Policy Explained. (pp. 61-91), United Kingdom: Routledge.

Daoud, Ismaël. 2012. "Brussels goes passive: Adoption of Passivhaus as the Brussels EPB standard in 2015." Presentation at the PassREg 2nd International Workshop, Brussels (October 5) cited in EnEffect (2012) The success model of Brussels: Case study. In: Passive House Regions with Renewable Energies, PassREg Projet, https://passreg.eu/index.php?page_id=374 [accessed on 30 June 2019].

Dupont, C., (2016), Climate Policy Integration into EU Energy Policy. London: Routledge

EnEffect (2012) The success model of Brussels: Case study. In: Passive House Regions with Renewable Energies, PassREg Projet, https://passreg.eu/index.php?page_id=374 [accessed on 30 June 2019].

Entrop, A.G. and Brouwers H, J. H (2010), Assessing the sustainability of buildings using a framework of triad approaches, Journal of Building Appraisal, March 2010, Volume 5, Issue 4, pp 293–310.

Erhorn, H. and Erhorn-Kluttig, H. (2016), "Nearly Zero Energy Buildings: Overview and Outcomes", in Concerted Action EPBD, 2016 – Implementing the Energy Performance of Buildings Directive (EPBD) (pp. 57-74), Adene, 978-972-8646-32-5.

European Commission (2019), 'Better regulation: why and how' http://ec.europa.eu/smart-regulation/index_en.htm [accessed on 8 April 2019].

European Commission (2018a), In depth analysis in support of the Commission Communication COM(2018) 773 A Clean Planet for all A European long-term strategic vision for a prosperous, modern, competitive and climate neutral economy, 28 November 2018. https://ec.europa.eu/clima/sites/clima/files/docs/pages/com_2018_733_analysis_in_support_en_0.pdf [accessed on 8 April 2019].

European Commission (2018b) 'Smart finance for smart buildings: investing in energy efficiency in buildings", News 7 February 2018' https://ec.europa.eu/info/news/smart-finance-smart-buildings-investing-energy-efficiency-buildings-2018-feb-07_en [accessed on 4 June 2019].

European Commission (2016), Review of available information, Commission Staff Working Document accompanying the document Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions on an EU Strategy for Heating and Cooling, COM(2016) 51 final https://ec.europa.eu/energy/sites/ener/files/documents/1_EN_autre_document_travail_service_part1_v6_0.pdf [accessed on 4 June 2019].

European Commission (2012), Guidelines accompanying 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 OJ C 115, 19.4.2012, p. 1–28

European Commission (2011), Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, A Roadmap for moving to a competitive low carbon economy in 2050, COM(2011) 112 final.

European Council (2011), *Presidency conclusions*, 4 February 2011.

European Environmental Agency (EEA) (2016) - European Environmental Agency: Environmental and Climate Policy Evaluation. http://www.eea.europa.eu/publications/environment-and-climate-policy-evaluation [accessed on 25 May 2019].

European Union (2016), Consolidated versions of the Treaty on European Union and the Treaty on the Functioning of the European Union (TFEU) [2016] OJ C202/1.

European Parliament Research Service (2018), Transposition, implementation and enforcement of Union law, http://www.europarl.europa.eu/RegData/etudes/ATAG/2018/627141/EPRS_ATA(2018)627141_EN.pdf [accessed on 30 June 2019].

Eurostat (2019), Regional GDP per capita ranged from 31% to 626% of the EU average in 2017, News release 34/2019, 26 February 2019, https://ec.europa.eu/eurostat/documents/2995521/9618249/1-26022019-AP-EN.pdf/f765d183-c3d2-4e2f-9256-cc6665909c80 [accessed 31 July 2019].

Fokaides, P.A. et al. (2017), The impact of the implementation of the European Energy Performance of Buildings Directive on the European building stock: The case of the Cyprus Land Development Corporation, Energy Policy Volume 111, December 2017, pp. 1-8.

Govaert, M. (2018), Implementation of the EPBD in Belgium – Brussels Capital Region, Concerted Action Energy Performance of Buildings, Status in December 2016, https://epbd-ca.eu/wp-content/uploads/2018/08/CA-EPBD-IV-Belgium-Brussels-Capital-Region-2018.pdf [accessed 31 July 2019].

Government of Italy (2017a), Italian Energy Efficiency Action Plan, June 2017 https://ec.europa.eu/energy/sites/ener/files/documents/it_neeap_2017_en.pdf [accessed 27 July 2019].

Government of Italy (2017b), Italy's Fourth Progress Report under Directive 2009/28/EC, December 2017.

Government of Italy (2014), Italian Energy Efficiency Action Plan, 2014.

Government of the Brussels-Capital Region (2019), Stratégie de réduction de l'impact environnemental du bâti existant en Région de Bruxelles-Capital aux horizons 2030-2050.

Government of the Brussels-Capital Region (2017), Quatrième Plan d'Action en Efficacité Energétique.

Government of the Brussels-Capital Region (2016), Plan Regional Air-Climat-Energie.

Government of the Brussels-Capital Region (2014), Troisième Plan d'Action en Efficacité Energétique.

Heiskanen, E., and Matschoss K., (2017), Understanding the uneven diffusion of building-scale renewable energy systems: A review of household, local and country level factors in diverse European countries, Renewable and Sustainable Energy Reviews 75 (2017) 580–591.

Henrotte, L. O. et al. (2015), Performance énergétique des bâtiments : Wallonie-Bruxelles-Flandre, Bruxelles.

Hestnes, A. G. (2001), "The New Solar Buildings" in van der Leun, K. and van der Ree B. (eds.), Proceedings of the 9th International Conference on Solar Energy in High Latitudes; 6 – 8 May, Leiden, the Netherlands: Ecofys.

Hirst E, Brown MA. Closing the efficiency gap: barriers to the efficient use of energy, Resources, Conservation, and Recycling 1990;3:267–81.

Jackson C, O'Flaherty F, Pinder J. (2009), "Managing change in domestic renewable energy schemes", in Sustainability in Energy and Buildings (pp. 175-186). Berlin/Heidelberg: Springer; 2009.

Jaffe, A. B, and Stavins R.N. (1994), The Energy-Efficiency Gap: What Does It Mean?, Energy Policy 22 (1994): 804–810.

Lee W. L, Regulatory and voluntary approaches for enhancing building energy efficiency. Prog Energy Combust Sci 2004; 30:477–99.

Linares, P., et al. (2013), "Environmental Regulation", in Perez-Arriaga, I. (eds.) Regulation of the Power Sector, Springer, London, pp. 539-580.

Liu F., et al. (2010), Mainstreaming Building Energy Efficiency Codes in Developing Countries: Global Experiences and Lessons from Early Adopters, World Bank Working Paper; No. 204. World Bank. https://openknowledge.worldbank.org/handle/10986/5915 License: CC BY 3.0 IGO [accessed 10 May 2019].

Löfgren, K. (2015), "Implementation Studies: Beyond a Legalistic Approach", in Lynggaard K., et al. (eds) Research Methods in European Union Studies. Palgrave Studies in European Union Politics. Palgrave Macmillan, London, pp 154-167.

Lombardy Region (2015), Programma Energetico Ambientale Regionale (PEAR) http://doc.servizi-regionali.it/pear/Programma_Energetico_Ambientale_Regionale.pdf [accessed 31 July 2019].

López-Ochoa, L.M., et al. (2017), Environmental and energy impact of the EPBD in residential buildings in cold Mediterranean zones: The case of Spain, Energy and Buildings 150 (2017) 567–582.

Lysen, E. H. (2002), Energy Financing for Sustainable Development. Project Number: 2001.04.148. Utrecht, the Netherlands: Utrecht Centre for Energy Research.

Lund H. et al. (2014), 4th Generation District Heating (4GDH): integrating smart thermal grids into future sustainable energy systems, Energy, 68 (2014), pp. 1-11.

MacKay, D. J.C. (2009), Sustainable Energy: Without the hot air, UIT Cambridge.

Ministry of Economic Development (2018), Application of Article 7 of Directive 2012/27/EU on the energy efficiency obligation scheme, April 2018. [in Italian] https://www.mise.gov.it/images/stories/documenti/IT-RELAZIONE-ART-7-DIRETTIVA-EFFICIENZA-ENERGETICA.pdf [accessed 24 July 2019].

Mlecnik, E., et.al. (2010), Barriers and opportunities for labels for highly energy-efficient houses, Energy Policy, Vol. 28, pp. 4592-4603.

Odyssee-MURE (2015), Energy Efficiency Trends and Policies in the Household and Tertiary Sectors: An Analysis Based on the ODYSSEE and MURE Databases, June 2015, https://www.odyssee-mure.eu/publications/br/energy-efficiency-trends-policies-buildings.pdf [accessed 5 June 2019].

Odyssee-MURE (n.d.), Sectorial profile – Households (online) https://www.odyssee-mure.eu/publications/efficiency-by-sector/households/household-eu.pdf [accessed 2 July 2019].

OECD/IEA and UNEP (International Energy Agency and United Nations Environment Programme) (2018): 2018 Global Status Report: towards a zero-emission, efficient and resilient buildings and construction sector, Paris.

OECD/IEA (2018), Energy Efficiency 2018, Analysis and outlooks to 2040, Paris.

OECD/IEA (2017), Energy Technology Perspectives 2017 · Tracking Clean Energy Progress 2017, Paris.

OECD/IEA (2016), Energy Policies of IEA Countries: Belgium 2016 Review, Paris.

OECD/IEA (2015) Energy and Climate Change - World Energy Outlook Special Report, Paris.

Paiho, S. and Ahvenniemi, H. (2017), Non-Technical Barriers to Energy Efficient Renovation of Residential Buildings and Potential Policy Instruments to overcome Them—Evidence from Young Russian Adults, Buildings 2017, 7(4), 101.

Pezzutto et. al., (2019), Assessment of the Space Heating and Domestic Hot Water Market in Europe-Open Data and Results, Energies 12(9):1760, May 2019.

Pianezze F., and Lucchi, E., (2013), "Quadro legislativo", in Lucchi, E. And Pracchi, V. (a cura di), Efficienza energetica e patrimonio costruito. La sfida del miglioramento delle prestazioni nell'edilizia storica, pp. 11-34, Segrate, Milano.

Powell, J. et al. (2015), Building Futures: Managing energy in the built environment, Routledge.

Puig, J. (2008), Barcelona and the Power of Solar Ordinances: Political Will, Capacity Building and People's Participation, Urban Energy Transition From Fossil Fuels to Renewable Power 2008, pp. 433-449.

Renders, N. et al. (2018), Ex post evaluation and policy implementation in the building sector, Eionet Report - ETC/ACM 2018/2, April 2018.

Salvalai, G. et al. (2015), Italian local codes for energy efficiency of buildings: Theoretical definition and experimental application to a residential case study, Renewable and Sustainable Energy Reviews 42 (2015)1245–1259.

Thieffry, P. (2015) Traité de droit européen de l'environnement, 3ème ed., Bruylant, Bruxelles.

Tuominen, P., et al. (2012), Energy savings potential in buildings and overcoming market barriers in member states of the European Union, Energy and Buildings 51, 48–55.

The Open University (2016), Energy in buildings, Open Learn.

Zaccai, E. (2019). Deux degrés, SciencePo Les Presses, Paris.

Annex 1: List of interviews

1. Representative of European bioenergy association, July 2019
2. Representative of Italian installers association, July 2019 (phone interview)
3. Representative of Brussels Environment, July 2019
4. Representative of Brussels Environment, July 2019 (phone interview)
5. Representative of Italian geothermal heat pump association, July 2019 (phone interview)
6. Representative of Italian standardization body, July 2019 (communication via email)
7. Representative of European heat pump association, July 2019 (phone interview)
8. Representative of Municipality of Milan, August 2019 (phone interview)

Annex 2: Bibliographic research

To carry out the research, the following databases and portals have been consulted:

- CIBLE+
- Google scholar
- Google books
- Google
- Eurostat
- Odyssee-MURE
- Infrastrutture Lombardia
- EU building stock observatory

The following libraries have been consulted:

- Bibliothèque de droit, Université Libre de Bruxelles
- Bibliothèque des Sciences Humaines, Université Libre de Bruxelles
- Bibliothèque des Sciences et Techniques
- National library of Potenza, Italy

The main, non-exhaustive, combination of key words used are (in English, French, and Italian):

- Energy, buildings, environmental impacts
- Implementation EPBD, impact
- Impact EU, legislation, buildings
- EU legislation, climate, buildings
- Thermal insulation, buildings
- Energy conservation, buildings
- Certification, energy efficiency
- Legislation, buildings, Brussels
- EU, implementation, buildings, Italy
- EU, implementation, buildings, regional level
- EU, buildings, regulation,
- Energy, buildings, Brussels, Belgium
- Renewable energy, energy efficiency, barriers, challenges, opportunities
- Energy efficiency, buildings
- Energy efficiency obligations
- Energy performance requirements, buildings
- Minimum renewable energy obligations, Italy, EU
- Buildings, Lombardy
- Buildings, Italy
- Primes énergie, Bruxelles
- PACE, Bruxelles,

- Energy efficiency action plan, Brussels
- Energy efficiency action plan, Italy
- Action plan, energy, Italy, Lombardy, Brussels
- Renewable energy progress reports
- Thermal account, Tax rebate, energy efficiency certificates, Italy
- Trends, energy, buildings
- Emissions, buildings
- Decarbonization, households
- CO_2 emissions factor
- Rebound effect, buildings
- Decarbomnisation, EU
- Implementation, transposition, EU law
- U values, buildings, evolution, Italy, Belgium, Lombardy

Annex 3: Summary of EU methodology to calculate cost-optimal levels of minimum energy performance for buildings

Following the recast EPBD in 2010, EU member states are required to set minimum requirements for buildings and building elements member states need to take into account « cost-optimal levels» estimated during the whole lifecycle (Article 5, Directive 2010/31/EU). To this end, a comparative methodology is set out in Annex III of the 2010 EPBD and detailed in Annex I of Commission Delegated Regulation (EU) No 244/2012 and accompanying Commission guidelines 2012/C 115/01.

This methodology involves the following six steps:

1. Defining reference buildings that are characterised by and representative of their functionality and geographic location, including indoor and outdoor climate conditions. The reference buildings shall cover at least three categories (residential single-family, residential multifamily), and office building, both for the new and the refurbished ones;
2. Defining energy efficiency measures or renewable energy measures to be assessed for the reference buildings. These may be measures for individual buildings as a whole, for individual building elements, or for a combination of building elements;
3. Calculating the primary energy consumption of the reference buildings and the reference buildings with the defined energy efficiency measures applied, based on the EPBD methodology (CEN standard) in accordance with the common general framework provided in Annex I to the 2010 EPBD; in this framework it should be noted that energy produced onsite shall be deducted from the primary energy demand and delivered energy;
4. Calculating the costs (i.e. the net present value) of the energy efficiency measures during the expected economic lifecycle applied to the reference buildings (as referred to in the first indent) by applying the comparative methodology framework principles;
5. Undertaking a sensitivity analysis on the discount rates and the energy prices for all energy carriers used to a significant extent in buildings in their national context and other crucial input data. The objective of the sensitivity analysis is to identify the most important parameters of a cost optimal calculation;
6. Deriving cost-optimal level of energy performance for each reference buildings based on the macroeconomic or the financial calculation. As reported in the Commission Guidelines (European

Commission, 2012).:

> «Based on the calculations of primary energy use (step 3) and global costs (step 4) associated with the different measures/packages/variants (step 2) assessed for the defined reference buildings (step 1), graphs can be drawn per reference building that describe primary energy use (x-axis: kWh primary energy/(m^2 useful floor area and year)) and global costs (y-axis: EURO/m2 useful floor area) of the different solutions. From the number of measures/ packages/variants assessed, a specific cost curve (lower border of the area marked by the data points of the different variants) can be developed. The combination of packages with the lowest cost is the lowest point of the curve (in the illustration below, package '3'). Its position on the x-axis automatically gives the cost-optimal level of minimum energy performance requirements».

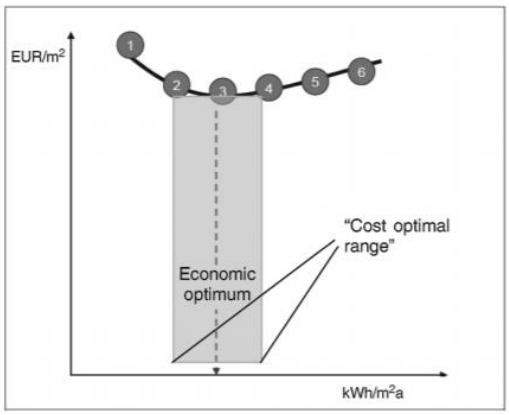

Figure 14 Illustration of cost-optimal levels for setting minimum energy performance requirements under the EPBD. *Source: European Commission guidelines 2012/C 115/01 (European Commission, 2012b)*

7. Calculating the gap between existing energy performance requirements and the calculated cost-optimal levels based on the difference between the averages of the calculated cost-optimal energy performance levels for all the reference buildings used and those of the existing energy performance requirements for the same reference buildings (European Commission, 2012a and 2012b).

If the result of the comparison shows that the minimum energy performance requirements in force are significantly less energy-efficient than cost-optimal levels, Article 5 of the 2010 EPBD provides that members states must justify the difference or plan measures to significantly reduce the gap.