Technical Report on relevant public support actions in relation to EEM

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Table of Contents

Executive Summary

The present report aims at presenting and discussing the existing EE legislation among EU Member States (MS). This deliverable is developed as the first of a series of three reports dedicated to EU EE policies coverage, their perception by the banking sector and its respective awareness (D7.2), and their critical impact evaluation (D7.3). Indeed, D7.1 describes the current EE legislative landscape and its particularities among a selection of EE Mortgage markets (EEMM). While D7.2, based on a survey completed by 65 Financial Institutions (FIs)1, proposes an overview of their opinion on the existing EE policy framework and its suitability, but also of their capacities and readiness to propose financial products related to EE and integrating EE evaluations such as Energy performance Certificates (EPCs). And D7.3 focuses on several case studies in order to draw a critical analysis of public support schemes, their limits, impacts and replicability.

Thus, in the context of efforts to stimulate and sustain market development in relation to energy efficient mortgages (EEM) by way of the design and deployment of an EEM ecosystem, this series of Reports is intended to coordinate and integrate institutional support and public policy alignment into the EEM 'ecosystem' and ensure coherence between the Initiative's actions to mobilise private finance through mortgage credit and public sector actions. Indeed, while EEM are primarily intended as a stand-alone, private financing mechanism, independent of public funding, there is significant potential to accelerate market development and reinforce the mechanism through institutional support and public policy alignments, whether this be at international, European, national, or local levels.

We have extracted from the Mure database 1048 EE policies covering 17 EU members presenting a considerable potential or already developed EE Mortgage markets (EEMM). Our dataset concerns EE policies relative to residential and commercial buildings, while industry and transport related legislation are totally excluded. We use a keyword extraction method for the policies selection, and in order to overcome any potential shortcomings we expand the provided analysis through the inclusion of several relevant additional reports and publications. In result, we propose the description of a large span of EE policies and propose a critical analysis of their implementation and effectiveness in terms of EE potential.

Based on a comprehensive analysis of the database we observe that 38% of the adopted legislation concerns mandatory standards and information regulations, while the economic tools (fiscal, financial, and market-based instruments) account for 35%. The predominance of standards and mandatory regulation resides in their capacity to provide a clear message to the concerned counterparties (households, firms, investors). Indeed, besides their relative stability over time, they benefit from a relative ease of implementation and compliance, since they require fewer personal efforts, knowhow, and involvement comparatively to economic tools. The relatively low share of fiscal incentives (3%)

[1] The analyzed sample consists of 65 Financial Institutions from 18 countries located in the European area, operating at the European and global level reaching 30 countries where their products are delivered.

precisely indicates the complexity of these tools and an important potential for development if more simplified methods are applied.

Furthermore, a large majority of the EE policies have been recently put in place and are ongoing, which suggests an important room of improvement and further development.

Concerning the sectoral repartition, residential buildings capture a larger majority of EE policies since they represent a large majority of the available building floor area (from the lowest 60% in Slovakia to the highest 89% in Italy) (EC, EU Buildings Factsheets, 2022[2]), and also given the age structure of the residential building stock since most of the buildings date before the introduction of thermal standards in the 1970s (EC, EU Buildings Factsheets, 2022). Indeed, more than 60% of residential buildings have been constructed before 1981 (Hypostat 2021)). Also, residential buildings are responsible for around 26% of the final energy consumption, while commercial buildings (non-residential) account for twice less (Odyssee Mure, Sectoral profile, 2021).

Also, even though the EU is playing a key role in the promotion of EE, through the adoption of strategic EE related directives, most of the policies are country specific. This feature stresses the predominance of public country specific awareness as a trigger for EE policies.

In a second step we proceed to a more detailed outlook of several specific policies targeting Energy Performance Certificates (EPC), nearly Zero Energy Buildings (nZEB), smart metering installations, electrical appliances, renewables, insulation solutions. We also consider energy savings and energy auditing measures, the latter being of particular relevance for the EEM 'ecosystem'. We also include rental oriented policies given the existing difficulty between costly EE investments provided by the owners but benefiting to tenants.

In brief, among the above-mentioned policies the most predominant concern the development of EPC, electrical appliances EE, and renewables adapted to buildings. Even though most of the EU Member States have adopted EPC legislation, there is an important heterogeneity among them, with regards to the different categories and the inherent energy consumption levels. There is also heterogeneity concerning the calculation methodology, the qualification and accreditation of certifiers, the software validation procedure, and the penalty systems, which makes national systems difficultly comparable. Nevertheless, their utility for evaluating and promoting buildings' EE is undeniable.

Given the rising recent attention on NZEB policies, we also include a specific section using several relevant recent reports and publications

The spread of EE legislation relative to electrical appliances has proven its efficiency given the EE improvement levels described by the Odyssee Mure database. Renewables adapted to buildings such as solar rooftop photovoltaic (PV) systems and heat pumps (or geothermal heat pumps) have proven their efficiency under certain climate and architectural conditions and especially when they are combined with other sustainable solutions such as green roofs.

[2] The last available data for all EU countries is from 2013.

However, besides these three topics concentrating the majority of EE measures, there is a considerable potential for developing insulation measures and smart metering infrastructure. Both types of policies have proven their potential for reducing energy consumption and thus improving EE (BPIE (2022), IEA (2020) and EC (2020)). NZEB however present quite controversial effects in terms of achieved EE levels, according to the relevant literature, since they are considered as a very demanding solution in terms of high installation costs, specific know-how necessary for appliances use, and the difficult matching of all the technologies which might need adjustments in accordance with changing weather conditions or different installation and functioning difficulties or errors.

Thus, despite the important set of regulatory and economic instruments implemented in EU members, EE levels in buildings present an important degree for further improvements, as it was mentioned by the IEA (2020) which was observing a slower progress in buildings' energy transition (EE and renewables spread) by the end of 2019. While the EU Green Deal was expected to boost this trend through a greater promotion of smart metering and renewables systems, the phasing out of fossil fuel subsidies and the promotion of Research Development and Demonstration (RD&D) as well as more efficient electrical appliances (IEA, 2020), the Covid-19 pandemic and the current energy crisis are already affecting some of the enumerated solutions. Indeed, the phase out of polluting fossil energies will be probably delayed, but as indicated by the EBF and Enerdata report (2022) the measures promoting buildings' EE and the spread of regular or geothermal heat pumps (the latter being a costlier solution but are adapted to colder climates) will represent key solutions for addressing energy consumption.

1. Introduction

According to the recent Global Alliance for Buildings and Construction report (IEA and UNEP 2021) the construction and operation of buildings are responsible for 36% of the energy consumption and 37 % of CO_2 emissions worldwide (United Nations Environment Programme, 2021).

In general, the buildings' contribution of Greenhouse gas (GHG) emissions can be split among three types of sources. The first one encompasses all direct emissions, i.e., all emissions resulting from on-site combustion (i.e., natural gas used for space and water heating, cooking, and refrigerant use). The second, which is also the most predominant, concerns indirect emissions or all emissions related to purchased electricity from the grid (for space heating and cooling, lightning, cooking, electrical appliances use, water heating) or other centralized energy sources (steam, hot water). All gas emissions related to raw material extraction and production, but also to waste and water disposal are included in the same category of indirect emissions. At last, the third source of buildings' GHG emissions is inherent to the buildings' construction industry (raw materials extraction, manufacturing, and transportation).

According to the IEA and UNEP report (2021), the buildings' increasing emissions footprint is due to the significant population growth, observed in the last decades, and the ongoing need to create new living spaces. The same reasons can explain the growing buildings 'contribution to energy use.

In consequence, a large majority of countries and international organizations consider energy efficiency (EE) initiatives as crucial for reducing GHG emissions and achieving associated side effects, especially as a short-term strategy (COM 0769 final, 2000). Compared to other decarbonization options, efficiency measures present the advantage of a relative ease of implementation, considerable cost-effectiveness, and immediate technological availability (IEA, 2014).

More specifically, the European Union recognized energy efficiency improvements as essential for GHG emissions reductions, but also for air quality ameliorations and employment growth. In consequence, during the last two decades, the EU established a set of policies and legislation on energy efficiency, in order to accomplish a wider implementation and take advantage of the different benefits resulting from energy efficiency improvements (COM 545 final, 2006). Thus, several directives targeting EE have been adopted since 2006.

Indeed, the first directive, setting an indicative end-use efficiency target of at least 9% by 2016 for EU Member States (MS), was the Energy Service Directives (Directive 2006/32/EC). Starting in 2008, MSs were required to create National Energy Efficiency Plans (NEEAPs) every three years in accordance with the Effort Sharing Decision (ESD). The NEEAPs provided an overview of energy efficiency activities in each MS, including descriptions of national energy efficiency measures and quantification of achieved and forecast energy savings (Bertoldi and Mosconi, 2020).

The EU EE efforts have been further fostered by the Energy Efficiency Directive (EED, 2012/27/EU), implemented in 2012. All Member States were committed to reduce their final energy consumption by at least 1.5% annually from 2014 to 2020. Also, they had to indicate their national energy efficiency objectives for 2020 allowing to meet the global 2020 EU's 20% energy savings target. Measures concerning Energy Performance certificates, electrical appliances, smart metering and energy auditing were also included. In October 2014, the European Council established energy and climate goals for 2030. An indicative target of at least 27% improvement in energy efficiency in the EU in comparison to baseline forecasts for future energy consumption was included in the decision. Individual Member States were urged to adopt higher national objectives, even though the European Council was not planning to translate the target into legally binding targets at the national level (Directive 2012/27/EU) (COM 520 final, 2014).

More recently, the amended in 2018 Energy Efficiency Directive ((EU) 2018/2002) has increased the EU EE target for 2030 up to at least 32.5% (compared to the expected energy use projections for 2030). Given the clause for possible upward revision by 2023, in 2021, the EU Commission adopted, within the framework of the European Green Deal, a proposal for recasting the EED, with more ambitious targets (9% in 2030 compared to the projections of the 2020 Reference Scenario). Given the current energy markets context, the REPowerEU plan, considers the possibility to increase the 9% target up to the level of 13%. The negotiations on these aspects are currently ongoing following the ordinary legislative procedure.

In result of all this legislative effort, as mentioned by the EEA (2021), the EU's building sector has improved its emissions footprint. Indeed, the implementation of strong standards for new buildings, the development of multiple tools improving the energy characteristics of existing buildings (heating systems and thermal insulation performances), the considerable efforts for decarbonizing power production but also warmer temperatures have allowed the EU buildings sector to reduce its GHG emissions since 2005. Nevertheless, the previously mentioned growing population and dwellings construction processes, but also larger built-up areas have partly compensated the observed achievements. Thus, according to the EEA (2021), despite the expected trend of emissions reductions, further efforts in renovations would be necessary to meet the defined EU2030 targets.

Moreover, there are still several obstacles to achieving full energy efficiency. Some of these hurdles have been thoroughly examined by the literature. Namely, Economidou et al. (2020) identify how perceived uncertainty and potential risks, in the EU, inhibit the widespread application of energy efficiency measures in buildings. According to Wilson et al. (2015) and Pelenur and Cruickshank (2012), lack of information, split incentives, complex decision-making processes and difficulties in accessing capital have hindered a proper implementation of EE policies in the US and in the UK.

Bearing in mind the EU targets and the main economic barriers mentioned above, the present study aims to provide a comprehensive and detailed overview of Europe's current energy efficiency legislative instruments. For this purpose, 17 European countries were first selected, and all their policies targeting energy efficiency were grouped in a database, encompassing a total of, 1048 policies. Section 2.1 analyses policies in general according to their type, status, sectors and origin (local/national or EU-related). Section 2.2 explores some more specific EE policies, such as those concerning Energy Efficiency Certificates (EPC), Nearly Zero Energy Buildings (NZEB), policies targeting appliances, renewable energy use and insulation, smart metering infrastructure, energy savings and energy audit policies. Ultimately, the rental-oriented EE policies are discussed. Conclusions are drawn in Section 3. An Appendix provides details on the compiled database.

2. Database description

Energy efficiency is one of the EU's Energy Union strategic pillars. It has been proposed as a favorably adequate pathway to improve economic competitiveness and sustainability of the European economy, lower emissions, reduce energy dependency and increase the security of supply and job creation. With the appropriate set of policy tools, governments can promote energy efficiency and leverage more investments in the property sector, especially in the existing buildings. Indeed, there is a wide range of policies at EU level which require Member States to set many regulatory, informative and economic measures to improve the energy performance of buildings. Hence, energy efficiency policies play a critical role in supervising and molding long-term energy planning for new and existing buildings.

Public policy support is a vital issue for the development of EEMs. To achieve market development, it is necessary to know the mechanisms behind them, and thus the legislative framework on which they are based. An exhaustive investigation was conducted to list all the active energy efficiency policies in the 17 countries to outline the different local enforcements and the possible gaps in legislation. The examination was exploratory and interpretative and considered 1048 policies, currently in force, or already completed (the former being predominant).

Public policies can be mainly divided into two major groups: supportive actions or regulatory tools.

The main characteristic of a regulatory instrument policy is the setting of binding requirements, which in cases of non-compliance are followed by sanctions to shape actors' behavior. In case of high non-compliance, the cost of enforcement increases sharply. It has limited ability to cope with complex dynamic situations and stimulates stakeholders to commit themselves to policy objectives. Recently, there has been more reluctance towards selecting these instruments on the side of the actors involved.

On the other hand, support action is defined as economic and fiscal instruments based on a government that influences market mechanisms through subsidies, loans, taxes, and rights concessions. They have a voluntary nature as they stimulate the involved actor to act in a certain way by rewarding or financially discouraging specific behaviors. The usage of economic and fiscal instruments in principle can create the economic conditions to establish functioning markets. The advantage of these instruments is that they can improve market failure, particularly for common goods for which markets do not exist. However, the possibilities to develop and manage these market failures with financial instruments is complex. Disadvantages are the costs associated with the subsidies. Loans or taxes themselves require coordination programs to distribute or collect the money. Also, financial incentives can prevent compliance for other reasons, such as intrinsic motivations. Also, the competition for the funds between stakeholders can lead to high transactions costs and much frustration on their side.

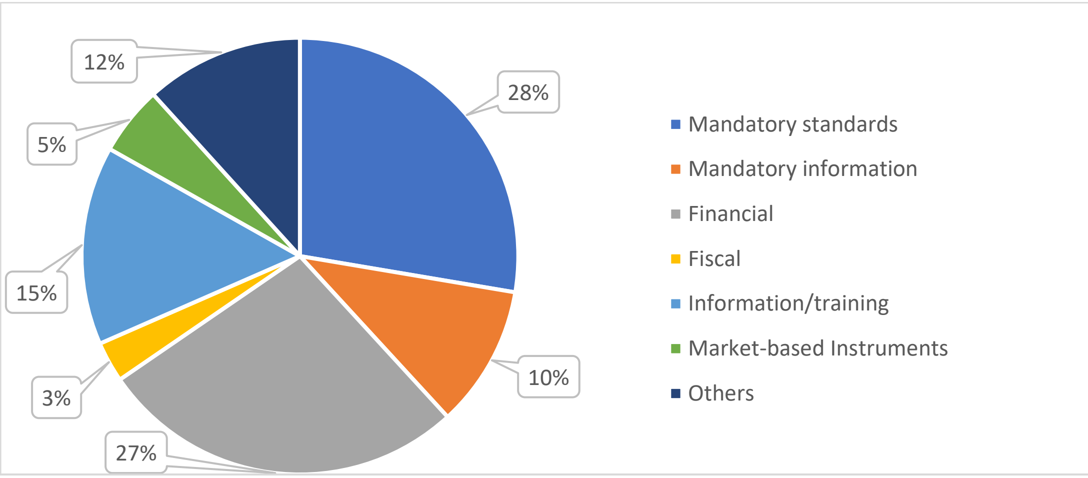
In the next subsection we will first describe briefly the general characteristic of the implemented EE policies and namely the different types of legislative tools.

2.1 General stylized facts: General trends in selected EEM Markets (EEMM)

2.1.1 Types of EE policies

As defined within the Mure database, the EE policies can be split into 7 major groups: mandatory information, mandatory standards, financial, fiscal tools, market-based instruments and information/training activities. The first two correspond to the regulatory tools, while the financial, fiscal and market-based instruments can be considered as supportive actions. The regulatory tools correspond to 38% of the EE legislation, while supportive actions account for 35% in the EU member countries (Figure 1).

Figure 1. Types of EE policies



Source: Authors' compilation, (Mure Database, 2022)

The EE policies are predominantly concerning mandatory standards and financial categories (55%). Given the encompassed EE policies in the Mure database, Fiscal and Market-based Instruments are less represented and account for less than one-fifth of all the policies.

Even though Information /training, Mandatory standards, and Mandatory information follow command and control approaches[3], the distributions look very different, with a clear predominance

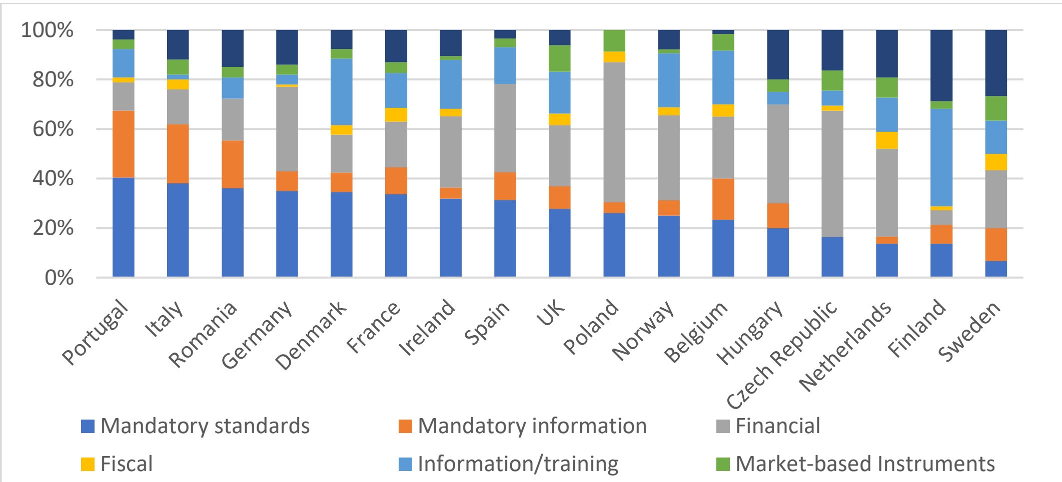
[3] According to the OECD, command and control policies encompass all environmental policies relying on regulation (permission, prohibition, standard setting and enforcement) as opposed to financial incentives, corresponding to economic instruments allowing to internalize externality costs or benefits. In our case, command and control approaches allow governments to define certain levels of standards relative to the technical characteristics of electric appliances or a minimum level of energy performance to be respected, such as the EE targets to be achieved.

of mandatory standards. Indeed, this highlights the recent development of mandatory information requirements and the room for improvement concerning EE disclosures.

At the same time, economic instruments such as Financial, Fiscal and Marked-based instruments aim to encourage or discourage certain economic decisions by indirectly influencing prices. This category is predominantly represented by financial policies counting for more than a quarter of the sample, Fiscal and Marked-based instruments, accumulating respectively 3% and 5%.

When considering the country repartition, the specificity of each EU member is evident. However, some common patterns can be observed. For this purpose, we will first discuss the observations based on the proportional national repartition (Figure 2) .

Figure.2. Energy Efficiency policies repartition by types in selected EEMM



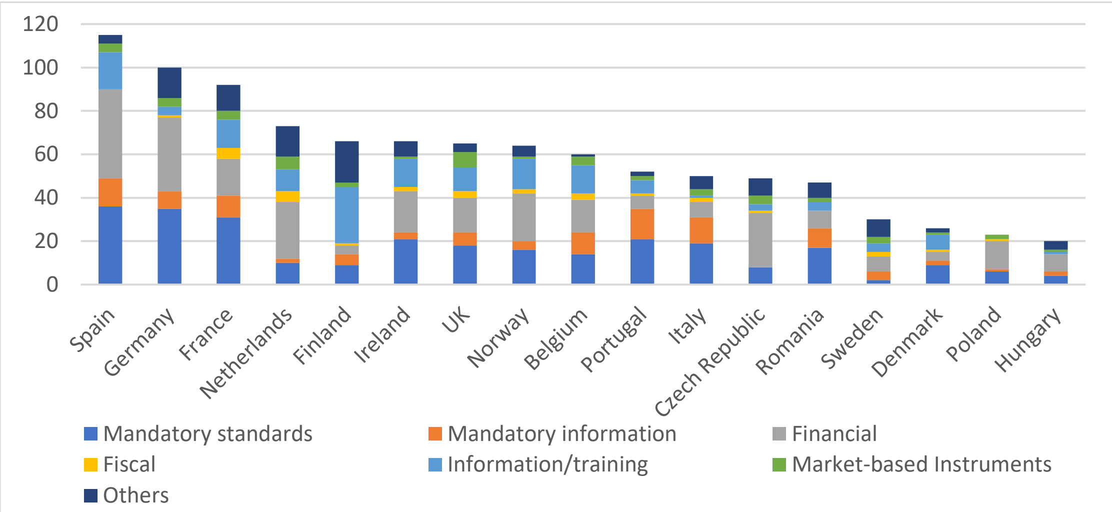
Source: Authors' compilation, (Mure Database, 2022)

Thus, three major country groups can be identified: i) those that have adopted a legislation predominantly represented through command and control approaches (Mandatory information and standards requirements): Italy, Portugal, Romania; ii) others such as France, Germany, Denmark, Spain, UK, Belgium have chosen a more equilibrated repartition of EE policies despite the predominance of standards; and at last, iii) countries like Poland, Czech republic, Hungary and the Netherlands that have opted for a larger deployment of economic incentives. Additionally, Finland, Denmark, Norway, Belgium, Ireland have considerably developed information and training EE policies

As highlighted by Figure 1, the most frequent type of EE policy are **mandatory standards**, which are present in high percentages across all nations, with the lowest shares in Sweden, Finland, Netherlands, Czech Republic (with respectively 7%, 14%, 14% and 16%). However, financial tools follow closely this trend and only in few members the dedicated EE policies represent less than 20% of all national EE policies (Finland, Denmark, Portugal, Romania, France). Even though **market-based instruments** policies (in green) are less developed they seem to be adopted by all of the considered EEMM.

Nevertheless, the relevance of these different types of EE policies has to be considered not only proportionally at the national level, but also globally among the EU members. Thus, as presented in Figure 3, France, Germany and Spain are the countries regrouping the highest level of adopted EE policies, with respectively: 9.2%, 10% and 11.5% among the 17 countries.

Figure 3. Energy Efficiency policies in selected EEMM, by type



Source: Authors' compilation, (Mure Database, 2022)

The two most frequent policies are mandatory standards and financial policies. The first one is present in high percentages across all nations, with the lowest shares appearing in Sweden (0.7%) and Hungary (1.4 %). The nations with the highest use of are France, Germany, and Spain (respectively with 11.2%, 12.7%, 13%). The distribution is different in the case of **financial** policies. Ten are the nations that account for less than 6% of all the financial policies, while the Netherlands (9.6%), Germany (12.5%), and Spain (15.1%) have high percentages. Thus, unlike mandatory standards policies, if absolute values are considered, a concentration of most financial policies is observed. Nevertheless, in relative terms, as presented above, (Figure 1.2) only five countries use financial tools in a limited manner (Finland, Denmark, Portugal, Romania, France).

There are 147 **information/training** policies in use overall throughout the nations studied, which represents an average level of usage. However, of them, Finland and Spain each issue 17,7% and 11,6% respectively. Seven nations, however, have less than 2.7% of these policies.

The sample's usage of **fiscal** policy is comparatively lower. Less than two policies are in place in more than half of the countries, compared to five in France and the Netherlands.

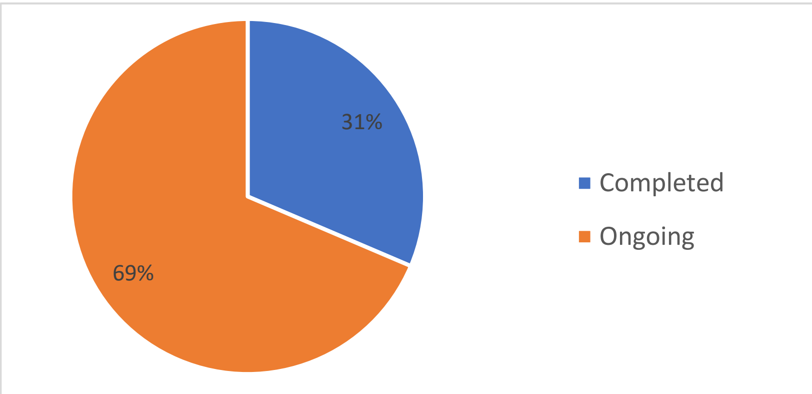
The states that concentrate the majority of **mandatory information** type policies, are Italy (12), Spain (13) and Portugal (14). In contrast, the countries that use them the least are Poland, with one example, and the Czech Republic, which has never adopted one.

In brief, regulatory tools are predominant with almost 38% of all implemented EE policies, closely followed by support actions representing 35%. Information and training topics concentrate 15% and the remaining 12% are classified as miscellaneous. In both predominant groups, mandatory standards and financial tools have been mostly favored up to the present moment.

2.1.2 Ongoing vs completed EE policies

Additionally, we have chosen to study the repartition of EE policies according to their status: ongoing and completed. An ongoing policy is one that is still in effect, while a completed policy is one that has come to an end. Figure 4 clearly reveals that energy efficiency ongoing policies account for a net majority (almost 70%), with 712 over 1038 policies in the database.

Figure 4 General repartition of completed and ongoing EE policies

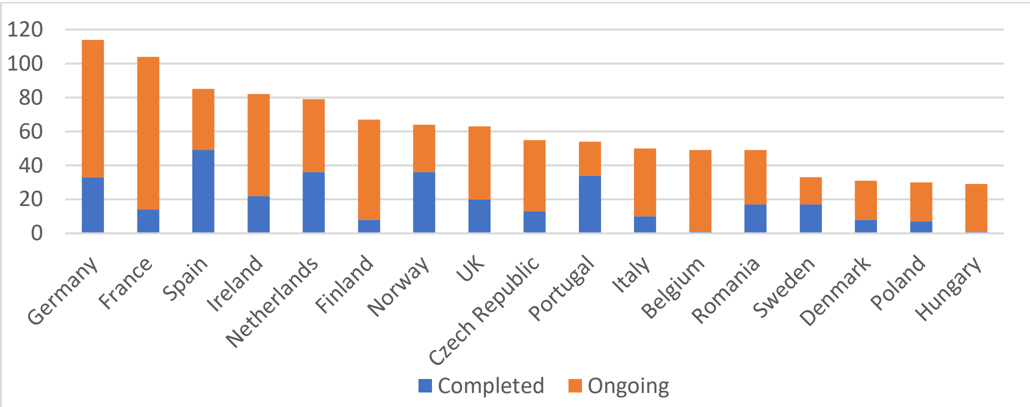


Source: Authors' compilation, (Mure Database, 2022)

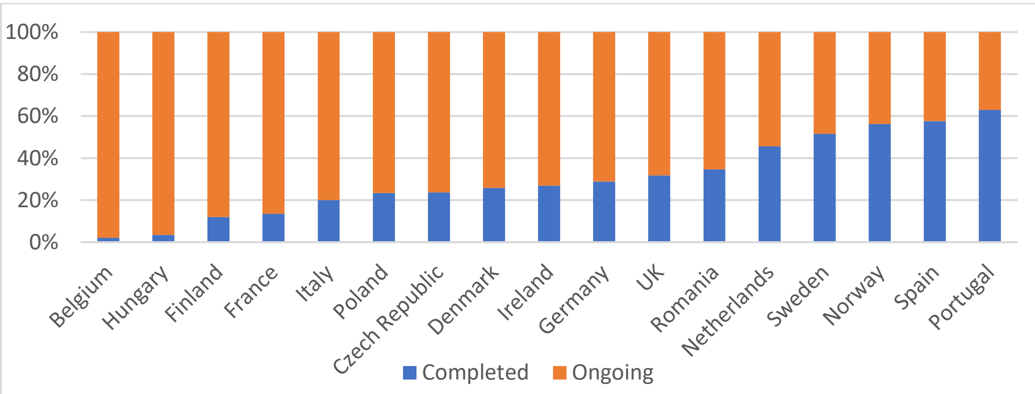
As highlighted previously, in absolute values Germany, France and Spain have adopted the highest levels of EE targeting legislative tools and while the first two concentrate a greater proportion of ongoing policies demonstrating their strong current political will, Spain predominantly accounts for completed policies (Figure 5a). Norway, Sweden and Portugal present the same pattern which is confirmed by the relative distribution (Figure 5b).

Figure 5 Completed and ongoing EE policies repartition in selected EEMM

5a.



5b.



Source: Authors' compilation, (Mure Database, 2022)

Indeed, Portugal, Spain, Norway and Sweden account for more than 50% of completed EE policies (right side of the graph), which highlights their long-term involvement, while countries like Belgium, Hungary, Finland, France and Italy (left side of the graph) seem to be rather on a catch-up trend concerning EE legislation with less than 20% completed policies.

Nevertheless, this repartition has to be considered parallelly with the previous graph describing the absolute values, which allows to distinguish the situation of Belgium, Hungary and Italy which are below the median level in terms of number of adopted EE policies. However, the highest number of adopted policies cannot for certain predict their efficiency but can be rather related to a more complex administrative process, or a more target-specific approach.

Thus, the studied sample highlights the large predominance of ongoing policies (69%) and the long-term involvement in EE (more than 50% of completed policies) of Portugal, Spain, Norway, Sweden

and the catch- up trend observed in Belgium, Hungary, Finland, France and Italy (more than 80% of ongoing policies).

2.1.3 Sectoral repartition

For the purpose of our study, we are focusing only on those policies that can affect the EE levels of residential and non-residential buildings. Thus, we have excluded all the policies related to transports and industries and have focused on those concerning households and services as well as on EE policies defined as general cross-cutting since they correspond to general measures encompassing all sectors (some examples of such policies are: the Renewable Energy Directive (Directive 2009/28/EC); the Energy Taxation Directive (Directive 2003/96/EC); the Energy Efficiency Directive (Directive 2012/27/EU), several national specific policies and etc.).

In general, a building is defined as residential when more than half of the floor area is used for this type of purposes, below that level buildings are considered as non-residential or dedicated to service purposes. The definitions of various building categories, however, might vary from one country to another making the cross-country comparison more challenging.

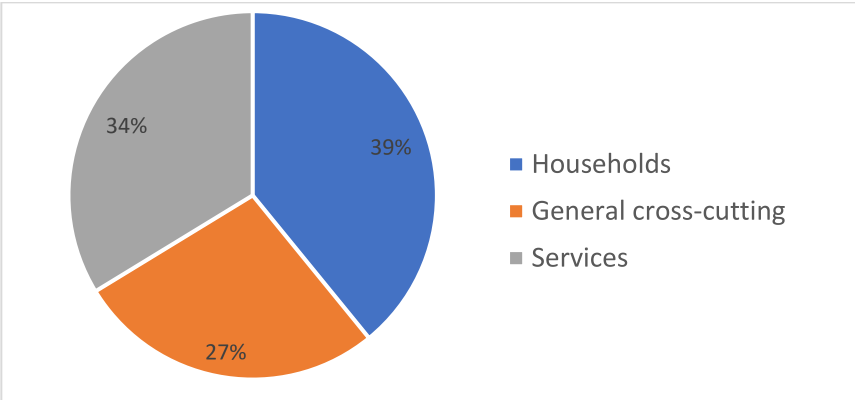
The non-residential sector includes an extremely vast typology diversity. The service sector is more complex and heterogeneous than the household sector. It includes offices, shops, hospitals, hotels, restaurants, supermarkets, schools, universities, and sports centers, while multiple functions exist in the same building.

Nevertheless, the residential building stock presents the largest segment, with an EU floor space of 75% of the building stock (COM 558 final, 2021) but the consumption patterns of the non-residential sector are more prone to improvements.

Indeed, consumption related to lighting, ventilation, heating, cooling, refrigeration, IT equipment and appliances differs among the categories. Commercial (non-residential) buildings require, on average, 55% more electrical energy than residential buildings (286 kWh/m2 compared to 185 kWh/m2) (Khan et al., 2017). Moreover, over the last two decades, electricity consumption has increased by 24.3% for the services sector and by 17.8% for households (Eurostat, 2022). These trends are mainly due to the use of many new appliances, IT devices, new telecommunication types, and air conditioning, even though for the last ten years a drop of 2.3% of households' electricity consumption is observed in the EU (Eurostat, 2022).

Given the structure of the Mure database, the EE policies in our sample are divided into three subgroups according to their target sector: residential buildings, non-residential buildings, and finally, policies that simultaneously address residential and non-residential buildings. As represented by Figure 6, the adopted policies are quite evenly distributed with a slight predominance of the residential buildings' sector (almost 40%).

Figure 6 General sectoral repartition of EE policies concerning buildings in selected EEMM

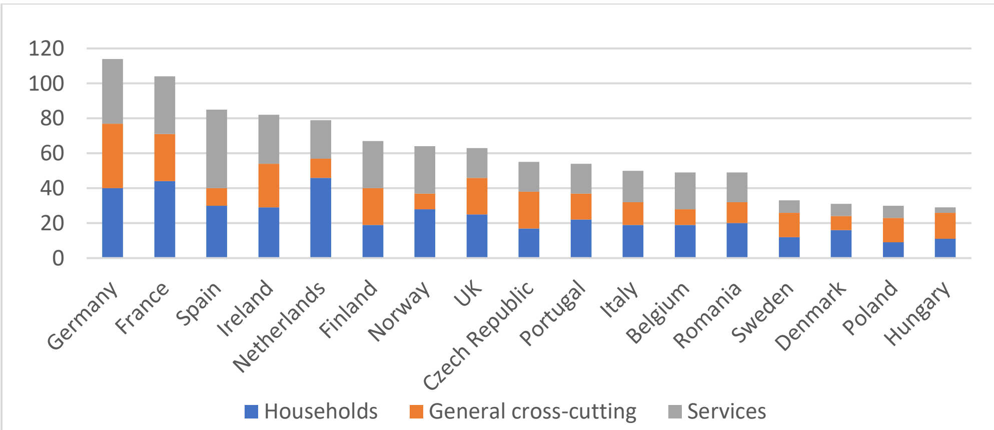


Source: Authors' compilation, (Mure Database, 2022)

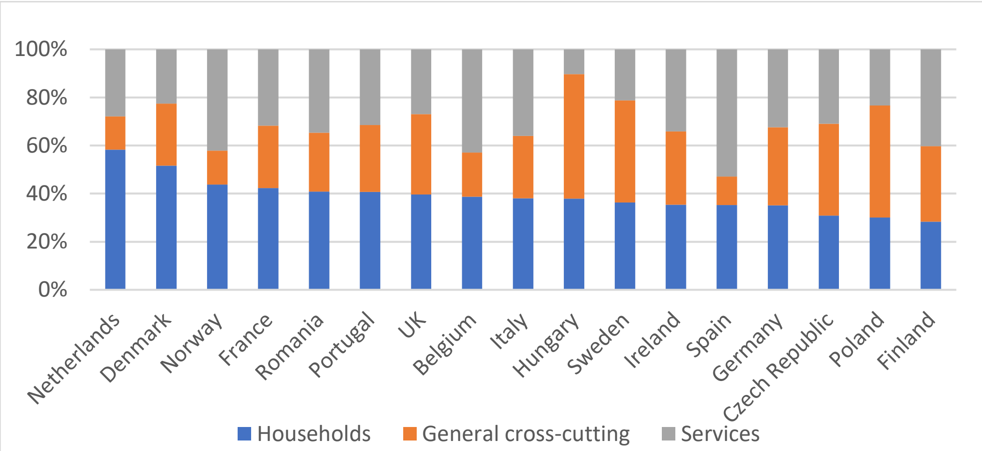
When considering the country repartition (Figures 7a and 7b) four major profiles can be identified: i) EU members adopting a greater proportion of measures concerning households (Netherlands, Denmark, France, Romania, Portugal, UK); ii) EU members focusing rather on the services sector (Spain, Belgium, Finland); iii) EU members adopting rather a more general approach through the preference of cross-cutting measures (Hungary, Sweden, Poland) and iv) more equilibrated repartition between residential and non-residential buildings' EE measures (Italy, Ireland, Czech Republic and Norway).

Figure 7. Sectoral repartition of EE policies concerning buildings in selected EEMM

7a



7b.



Source: Authors' compilation, (Mure Database, 2022)

The adopted EE policies are quite evenly distributed with a slight predominance of the residential buildings' sector (39% against 34 % for the non-residential sector). Several factors can explain such situation. Namely, while the residential building stock is characterized by an older age structure and represents 75% of the EU floor space, non-residential buildings require 55% more electricity than residential buildings, and their consumption patterns are more prone to marginal improvements.

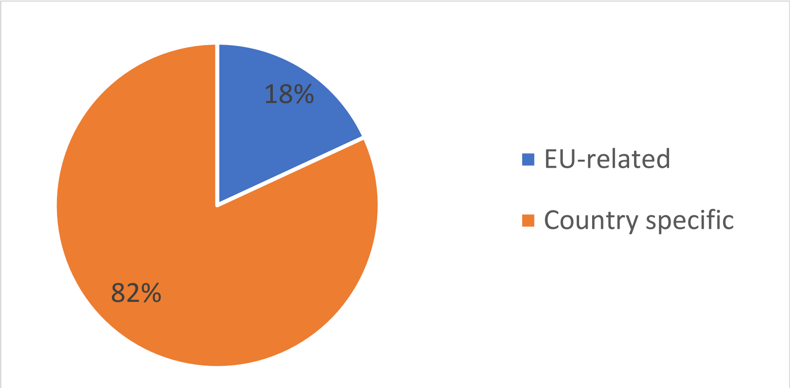
2.1.4 EU-related policies and country specific policies

The observed EE policies collected by the MURE database, can be also split into two categories according to their origin. Namely, policies can be either country specific or EU- related. EU policy measures are transposed into national legislation and as such are integrated to the rest of the country policy measures discussed in the previous sections.

The EU is placing more and more emphasis on the importance of reducing energy use and waste production. In 2007, the EU adopted the 20-20-20 targets including the reduction of GHG (by 20%), the promotion of renewable energies (20% being their share in total energy use) and energy efficiency (improvement by 20%). The "Clean Energy for all Europeans" package, set in 2018, increased the target to an improvement of EE of at least 32.5% by 2030. The advantages of EE measures encompass not only a fostered competitiveness but also a reduction of the GHG emissions and increased reliability, sustainability and security of energy supply. Energy efficiency is therefore a strategic priority for the Energy Union, and the EU promotes the principle of 'energy efficiency first' (Ciucci M., 2022). Namely, the Energy Efficiency Directive recognizes energy efficiency as a guiding factor that should be considered in all sectors, especially for the financial system (COM 558 final, 2021). Most importantly, it has been acknowledged that when new policies are developed, energy efficiency solutions should be considered as the first option in planning and investment decisions. Furthermore, any solutions increasing energy efficiency should be with a priority status in planning and investment decisions.

According to our sample country specific policies compose the great majority of energy efficiency policies (82%) (Figure 8).

Figure 8. EU-related and country specific EE policies general repartition in selected EEMM



Source: Authors' compilation, (Mure Database, 2022)

Despite the rather small proportion of EU-related policies, as shown in Figure 9, the EU has progressively increased the scope and intensity of its climate policy actions since the adoption of the 2020 framework in 2007. This has resulted in a stronger interaction between energy and climate policies when taking decisions in the EU (IEA, 2020).

The distribution of national and EU-related policies in both absolute and relative terms is shown in Figure 9.

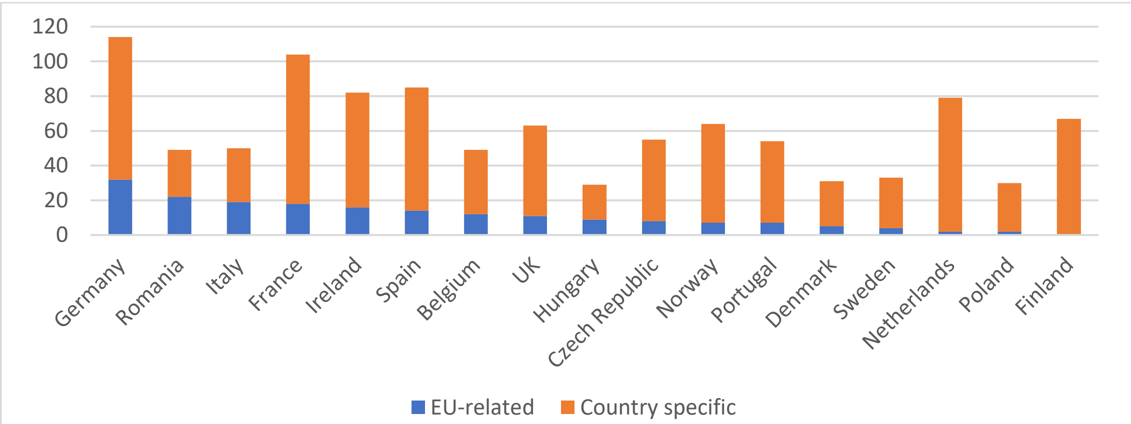
The bar charts in 9a. show that most of the policies in our sample are nation specific. Particularly noteworthy are the cases of the Netherlands and Poland, each of which has only one EU directive adopted, and Finland, which has none.

Additionally, the countries are ranked in Figure 9b based on how much of their national policies are influenced by European policy. In this instance, we can see that the nations having the most adopted EU-related policies are Romania, Italy, and Hungary.

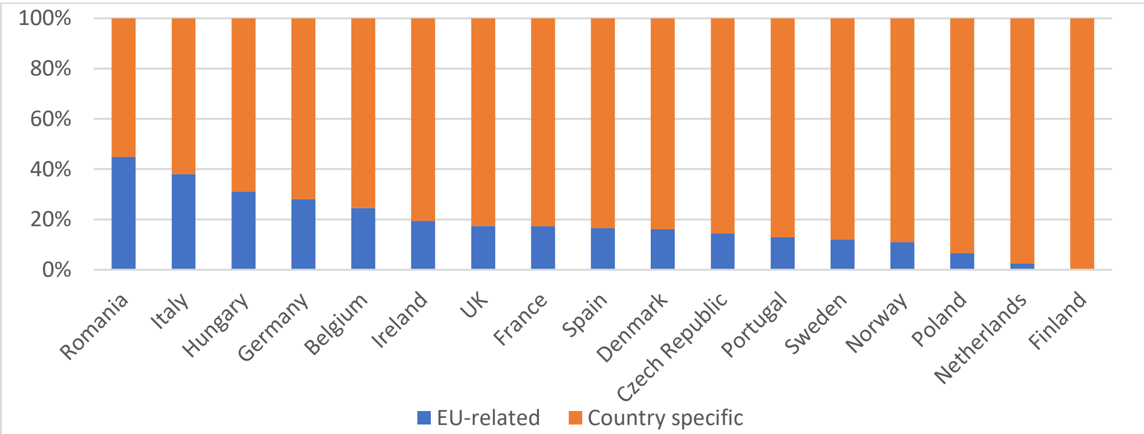
These observations have to be considered with caution since the selection of the data is based on a keyword extraction method. Indeed, if the targeted legislation does not include the considered keyword (in our case "EU-related" or "EU") in its description or title, it might not be selected. More specifically, even though in the Mure database, no Finnish policy is registered as being EU-related, the implemented national EPC policies seem to be connected to EU requirements and have been adopted consecutively (in 2002 and 2013) to the specific EU directives. Thus, probably the obtained figures above might indirectly underestimate the impact of EU legislation.

Figure 9. EU-related and country specific EE policies repartition in selected EEMM

9a.



9b.



Source: Authors' compilation, (Mure Database, 2022)

Most of the adopted EE policies in the 17 considered countries are country specific (82%), which stresses the relevance of the local will and engagement into EE policies.

In short, the implemented EE policies are mainly mandatory standards or financial tools. Most of these legislative measures are quite recent (currently ongoing), country specific (and not EU-related), and concern mainly the residential sector.

2.2 Special focus on several specific EE policies

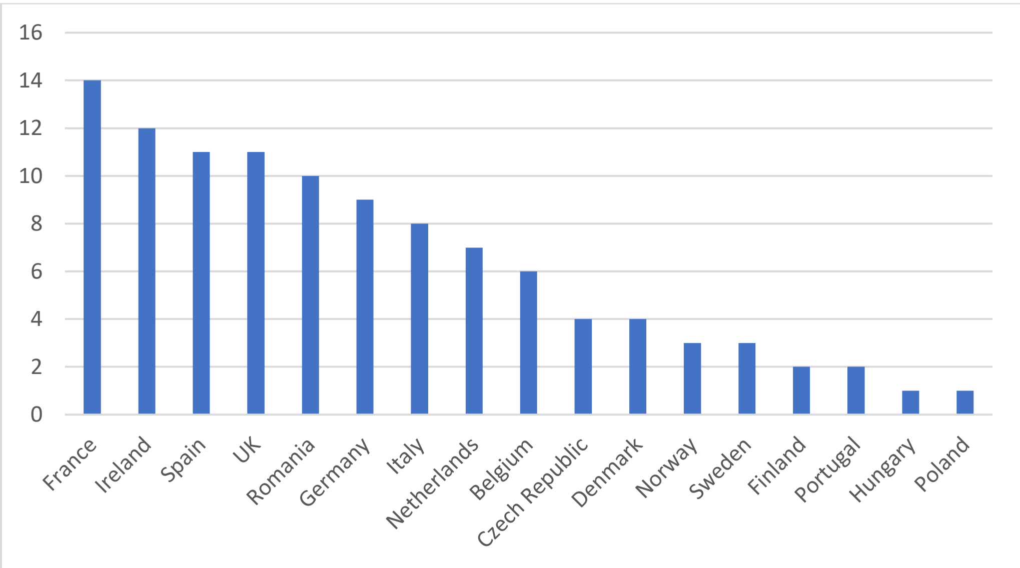
2.2.1 Energy Performance Certificates

2.2.1.1 General aspects

The Energy Performance Certificates (EPCs) were introduced in 2002 by the Energy Performance of Buildings Directive (EPBD) 2002/91/EC as a mandatory requirement for the EU MS[4]. EPCs label buildings on a scale from A to G and provide recommendations for cost-effective improvements. The EU energy performance label must be included in all advertisements in commercial media when a building is for sale or rent. The recast EPBD (2010/31/EU) reinforced the EPC obligation, recognizing the importance of independent quality control (Art. 18) in the residential sector. The EPC rate, assessing buildings' energy performances, is essential for improving the truthfulness and reliability of the provided information and for fostering market confidence.

EPCs represent one of the key tools for reaching EE targets in the European community. They are also the most spread measure among EU members, as it is described by Figure 10. Despite the significant discrepancies relative to their specifications (discussed further), all the countries in our sample have adopted at least one legislative decision dedicated to them.

Figure 10. EPC in selected EEMM



Source: Authors' compilation, (Mure Database, 2022)

Notably, a significant portion of policies comes from France, Ireland, Spain, and the UK. Whereas Poland and Hungary dedicate just a single policy measure.

[4] Buildings Performance Institute Europe (2010).

Even though the European directive sets a general framework and provides indications for the implementation, the transposition of the EU legislation to national laws is under each MS responsibility. Thus, each state should adopt independent implementation programs by defining the most appropriate: methodology, qualification and accreditation of certifiers, independent monitoring of EPCs, and penalty system.

2.2.1.2 Methodology, tools/software and input data

The first step for creating an energy certification scheme is defining the calculation methodology. According to Article 3 of the EPBD Recast, it can evaluate the energy performance of buildings by the calculated energy consumption (asset rating) or it can be based on the actual energy consumption (operational rating).

Choosing the methodology depends mainly on the further use of the EPC. The asset rating provides more information about the characteristics of the building envelope and technical systems, and it is usually adopted for new buildings. While the operational rating emphasizes the occupants' behavior and may be more appropriate for existing buildings (public and commercial buildings in particular). All MS have chosen asset rating at least for new buildings. At the same time, in many countries, the operational rating has been also adopted, especially in non-residential or existing structures. Thus, some countries combine both approaches, as indicated in Figure 11.

In orange appear the countries that have favored the asset rating methodology, while the blue color is dedicated to those EU members that apply both methodologies according to the type of concerned building. Furthermore, simplified procedures for calculating an EPC are allowed in some cases.

Figure 11. Type of rating used in selected EEMM

Source: Authors' compilation, (BPIE Database, 2020)

Usually, the assessment of a building's energy performance is carried out through the support of a software tool. Software validation is a crucial element to ensure the comparability of results. The national authorities usually validate the national methodology, and check if the output values calculated by the software are within a specific acceptable limit when applied to a reference building. Due to the different national contexts, it is essential to know whether they are officially validated.

In our sample, only Belgium is using a public software for the calculation of energy indicators. Private softwares are used in France, Germany, Sweden, the Netherlands, Poland, Czech Republic, Romania, Hungary, while Denmark, the UK, Ireland, Norway, Italy, Spain and Portugal are using both private and public softwares (Arcipowska, et al., 2014). The same report points out that among the private or commercial software users, in Sweden, Hungary, and the Czech Republic validation is not required.

As described by Arcipowska et al. (2014), another aspect related to the calculation process concerns the input data. The asset rating methodology is based on the computation of the energy performance levels, and thus requires an important set of documentation and information that a qualified expert can obtain either through the full-project documentation or through an on-site inspection of the building.

According to the same report, in 19 of the 28 EU member states, national legislation explicitly requires the certifier to perform a site visit of an existing building if sufficient data is not available. The concerned countries in our sample are: France, Spain, Portugal, the UK, Ireland, the Netherlands, Belgium, Denmark, Sweden, Finland, Hungary, Romania. However, this is not the case for the Czech Republic, Italy, Poland and Germany. The on-site visit can provide a more reliable assessment and can lead to more specific and tailored recommendations, but it is time consuming and cost intensive.

2.2.1.3 Qualification and accreditation of certifiers

According to Articles 18 and 27 of the EPBD recast (2010/31/EU), MS are required to, respectively, establish rules on penalties that are effective, proportionate, and dissuasive for compliance, as well as to monitor the quality of EPCs and, consequently, the work of certifiers, through an independent control system.

There is significant heterogeneity among the training requirements for certifiers. Among the countries studied, all except Denmark, the Netherlands and the United Kingdom require a minimum preparation of the certifier. In the case of Czech Republic, Germany, Ireland, and Italy, technical education is required; Poland and France differ in demanding specific higher education.

Certifiers must have an engineering degree in Belgium, Spain, Finland, Hungary, Portugal and Romania (BPIE EPCsFactsheet 2015).

Previous experience is not required in several countries such as: Spain, Italy, Ireland, Netherlands, UK, Poland. But most of the countries require a verification of experts' competence through an exam, except for Spain, where experts need to hold an engineering degree. Thus, only in the Netherlands and the UK, experts do not need specific education, nor previous experience, nor training (or 3 to 5 days training for Scotland) but have to pass a specific exam (BPIE EPCsFactsheet 2015).

2.2.1.4 Independent monitoring of EPCs

Article 18 from EPBD recast (2010/31/EU) implements the future new control methodologies through a casual verification of a statistically significant percentage of all energy performance certificates issued annually. Verification can take place regionally or nationally, by experienced certifiers or not. The latest 2014 data in the (BPIE, 2015) report shows that most countries (the Czech Republic, Denmark, Hungary, Ireland, the Netherlands, Norway, Poland, Portugal, and Sweden) have a national quality control system. France, Ireland, Belgium, the Netherlands, and Romania, however, require a certifier with specific experience. Germany is the only country in the sample that implements national and regional monitoring. The remaining four countries (Belgium, Italy, Spain, UK), implement regional-level tracking except for Finland, for which there is no data.

2.2.1.5 Penalty systems

In some countries, the sanctioning system is defined by national legislation, but the implementation process is regional (Italy and Belgium). In Italy, for example, some regional bodies refer directly to the national approach; others have defined their own rules, more restrictive than the national ones. Fifteen are the MS out of 28, where administrative sanctions are legally qualified in case of non-compliance with the EPBD (Volt et al., 2020). To date, the most common administrative sanction in member states is an official warning to qualified experts and recertification. It may include: a warning procedure (Finland), mandatory training (e.g., Belgium-Wallonia), periodic suspension of the license (e.g., Hungary up to 3 years, Portugal up to 2 years), and loss of accreditation (e.g., France, Czech Republic, Poland). In 12 countries, financial penalties may be imposed on qualified experts for non-compliance with the EPBD (Arcipowska et al., 2014). The maximum penalty varies between countries, for natural and legal persons.

In 2012 were introduced penalties for qualified experts in most member states. So far, there are only few countries, in our sample, where fines were imposed up to 2014, e.g., Flanders, Portugal and Romania (Arcipowska, et al., 2014). Most recent studies (Volt et al., 2020) precise that Belgium (Flanders), Italy, Portugal and Romania are the countries from our sample that are exposed to expert fines.

Table 1 Penalty systems for qualified experts defined by the EPBD recast (Article 27)

Regional approach	Administrative penalty	Monetary penalty	Administrative and monetary penalty
Belgium	Finland	Denmark	Netherlands
Italy	France	Germany	Romania
	Hungary	Sweden	Czech Republic
	Ireland	Spain	
	Poland	Portugal	
	UK		

Source: Arcipowska et al. (2014)

2.2.1.6 National EPC classification

At last, the national EPC classification and the inherent to each EPC class label level of energy consumption (primary or final) also present several discrepancies among the considered countries. As summarized by Tables 2 and 3, each country has defined its own classification of EPC labels based on different energy consumption levels, which makes their comparability more than complex.

Table 2 Corresponding primary energy (kWh/m²/year)

PC class	France	Austria	Sweden	Germany	Netherlands	Denmark	Portugal	Belgium
Label A	<50	<80	< 50	<50	A++ / (EI: <= 0,5)	< 20	≤25	45
Label B	51-90	81-120	100	51-100	A+ / (EI: 0,51 < 0,7)	< 30.0 + 1000 / A	26-50	95
Label C	91-150	121-160	150	101-150	A / (EI: 0,71 < 1,05)	< 52.5 + 1650 / A	51-75	150
Label D	151-230	161-280	200	151-250	B / (EI: 1,06 < 1,3)	< 70.0 + 2200 / A	76-100	210
Label E	231-330	281-340	300	251-350	C / (EI: 1,31 < 1,6)	< 110 + 3200 / A	101-150	275
Label F	331-450	341-400	400	351-400	D / (EI: 1,61 < 2)	< 150 + 4200 / A	151-200	345
Label G	>451	>400		>401	E / (EI: 2,01 < 2,4)	< 190 + 5200 / A	201-250	

Source: Zebra2020 Data Tool (2022)

Table 3 Corresponding final energy (kWh/m²/year)

EPC class	Czech Rep.	Romania	Norway	UK
Label A	<43	< 150	90,33	32
Label B	43-82	150 - 259	125,67	33-65
Label C	83-120	259 - 389	161,67	66-100
Label D	121-162	389 - 557	202,33	101-135
Label E	163-205	557 - 785	243,67	163-170
Label F	206-245	785 - 1150	303,33	171-200
Label G	>245	>1150	<303	>200

Source: Zebra2020 Data Tool (2022)

Thus, all the countries in our sample have adopted EPC related policies, which indicates the relative importance of this legislative tool in promoting EE. Nevertheless, the important heterogeneity that

can be observed in the definition of the different class labels, but also in terms of the methodology specificities, the qualification and accreditation of certifiers, the software validation procedure, and the penalty systems, makes national systems difficultly comparable. Despite the observed discrepancies among the different countries in our sample, EPCs have proven their effectiveness and utility for evaluating and promoting buildings' EE.

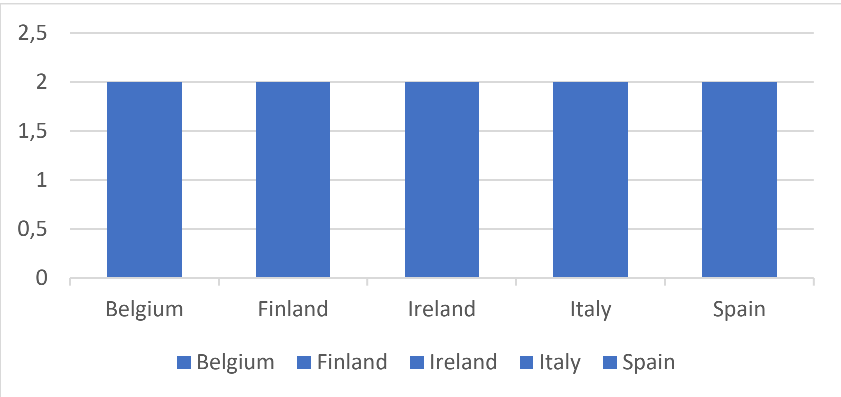
2.2.2 Nearly zero energy buildings

Among initiatives aimed at reducing greenhouse gas emissions and combining energy efficiency with the deployment of renewable energy, NZEBs play a crucial role. An NZEB is defined as a building with very high energy performance. The high energy consumption that characterizes the building sector, is estimated at around 40%, is a global concern (BPIE, 2016). The near-zero or low energy demand must be covered as much as possible by renewable energy sources produced on-site or nearby. The Energy Performance of Buildings Directive recast stipulates that new buildings occupied by government agencies and properties must be NZEBs by December 31, 2018, and all new buildings by December 31, 2020 (European commission, 2019).

The EPBD does not establish a uniform approach for implementing NZEBs. Member states must develop definitions of NZEB in line with national, regional or local conditions, including a numerical indicator of primary energy consumption (in kWh/m^2/y). In addition, they must implement targeted policies and provide funding to facilitate the transition to NZEBs, gradually increasing the number of NZEBs with targets differentiated by building categories (Zacà et al. 2015; BPIE, 2022).

In our sample, according to the Mure database, only five nations with equally frequent active policies on NZEBs are identified.

Figure 12. Nearly zero energy buildings in selected EEMM



Source: Authors' compilation, (Mure Database (2022))

Basing our analysis on several reports, the most recent one being from the BPIE (BPIE, 2022), we choose to also include the cases of Germany, France, Spain, Poland and Denmark, which have adopted nZEB legislation very recently. The appearing differences with our data sample extracted from the Mure database can be explained by the keywords' extraction method that we have used. If the adopted legislation does not include the considered keyword (in our case nZEB) in its description or title, it might not be selected. In order to correct this discrepancy, we have adjusted the findings in accordance with the relevant literature. A more detailed description of the selected national NZEB frameworks is proposed below.

2.2.2.1 Belgium

In Belgium, the definition of NZEB differs according to the regions of responsibility.

In the **Brussels-Capital Region**, the Brussels Air, Climate and Energy Code (COBRACE) making the nearly zero energy buildings obligatory by 2021 (by 2019 for public buildings), came into force in 2015 (Danlois et al. 2020).

The definition written in the COBRACE uses the definition given by the Recast of the Energy Performance of Buildings Directive (2010/31/EU). The study "Cost Optimum" results is used to make this definition more specific.

Individual Housing EPB units[5] (Danlois et al. 2020).

- a primary energy consumption for heating, domestic hot water and electrical appliances below 45 + max(0 ; 30-7.5 * C)+15*max(0 ; 192/V_{EPR}-1) kWh/m^2/ year[6];
- a net heating need below 15 kWh per m² per year;
- an overheating temperature that can only exceed 25°C for 5% of the time throughout the year; by 2018, airtightness around 1.5 m³/h.m².

Offices and Services EPB units and Educational EPB units

- a total primary energy consumption below the obtained value through the formula:

$$\frac{\sum_f A_{gross\ fct\ f} \cdot PEC_{max\ fct\ f,Uref}}{A_{gross}} \quad \text{kWh/m}^2\text{/ year,}$$

where $PEC_{max\ fct\ f,Uref} = Y \cdot E_{spec\ ann\ prim\ en\ cons,ref}$ and $E_{spec\ ann\ prim\ en\ cons,ref}$ represents the primary energy consumption of the reference building/unit

[5] EPB units represent "a set of rooms in the same protected volume, which is designed or altered to be used separately" (Danlois et al. 2020).

[6] Where C stands for compacity and V_{EPR} corresponds to total unit volume.

For the **Walloon region**, a NZEB is characterized at the design stage by energy performances that are close or equivalent to those of the passive standard in terms of the building envelope and by the renewable energy coverage of part of the consumption.

The maximum energy usage is specified by an E-level requirement, that compares the project's primary energy consumption to the primary energy demand of a benchmark building.

According to Fourez et al. (2017), for residential buildings, the global energy performance level should be below 45 kWh/m^2/ year, while for non-residential buildings it should be between 45 -90 kWh/m^2/ year, following the formula:

$$E_{W,PEN,max} = \frac{\sum_f A_{ch,fct\,f} \cdot E_{W,max,fct\,f}}{A_{ch}}$$

where:
$E_{W,PEN,max}$ represents the threshold for the global energy performance level of the studied PEN unit (non- residential types of building unit)
$A_{ch,\,fct\,f}$ corresponds to the total heated floor area of each function f (type of use) of the PEN unit
$E_{W,\,fcf\,f}$ is the assumed requirement level per function (type of use), for each function f (type of use) of the PEN unit
A_{ch} the total heated floor area of the studied PEN unit.

On 29 Nov 2013, the **Flemish Government** imposed the requirements for NZEB residential buildings, such as schools and offices. On 28 Jan 2014, the legislation on the NZEB definition was published. To establish the minimum level of renewable energy, a proposal was agreed upon by the Government of Flanders on 28 Sept 2012 for integration into the EPB method. The essential requirement concerns the E-level, the annual primary energy consumption divided by a reference consumption. On 20 May 2011, the Government of Flanders approved the proposal to tighten the E-level requirement for residential, office and school buildings to E70 in 2012 and E60 in 2014.

In 2014 and 2015, were finalised consecutivly the legislation revision relative to existing buildings certification and the requirements for new or renovated buildings. In 2016, a new calculation method was adopted for new and renovated commercial buildings (De Meulenaer and Triest, 2016).

Currently, according to BPIE (2022), the mentioned above E-level is E30 which corresponds to a primary energy consumption equivalent to 20 kWh/m^2/year for residential buildings, and 30 kWh/m^2/year for non-residential buildings. Thus, the E-level has progressively evolved from E100 (in 2010) to E60 (in 2014) and at last to E30 (2021). Concerning renewables, the requirements are 15 kWh/m^2/year and 20 kWh/m^2/year respectively for residential and non-residential buildings.

Furthermore, thanks to the significant efforts of the Flemish government, through the gradual tightening of standards and the generous fiscal schemes, 90% of newly constructed Flemish buildings since 2018 respect the E30 standard. Namely, before 2021, all new buildings respecting the E30 standards were allowing the owners to benefit from a 50% rebate of their annual property tax over a

5-year period. For those buildings reaching the E20 level the rebate was 100% for the same period of time. Since 2021, an E20 level is allowing for a 50% rebate while an E10 performance is required for a 100% reduction in property tax.

2.2.2.2 Denmark

As described by Simson and Kurnitski (2021), the Danish NZEB regulation is based on the Danish Building Regulations 2018 (BR18). The latter defines the same standards' formula for residential and non-residential buildings primary energy use, taking into account, similarly to the Finnish case, the buildings' heated area. According to BPIE (2021) and Simson and Kurnitski (2021), the obtained primary energy values for Low energy classes residential and non-residential buildings are equivalent to 27 and 33 kWh/m²/year respectively.

Renewable energy can be included in the energy framework calculation with a maximum level of 25kWh/m²/year.

2.2.2.3 Finland

As described by Haakana et al. (2020), the preparation of the Finnish regulation concerning NZEB started in 2012 and after the definition of the technical recommendations in 2015 and the 2016 revision of the Land Use and Building Act, the new National Building Code enterred into force in 2017, with an application to new buildings starting from 2018.

Thus, the primary energy (PE) standards vary significantly according to the type of concerned building. As documented by Haakana et al. (2020), for single-family houses, three different levels are defined, depending on the heated net area (below 150m², between 150 and 600 m² and above 600m²) and the set maximum values are in the form of formulas integrating the area of the building (A_{net}):

- For a surface such as : $A_{net} < 150m^2$, PE : 200-0.6 A_{net} kWh/m²/year
- For a surface such as : $150\ m^2 < A_{net} < 600m^2$, PE: 116-0.04 A_{net} kWh/m²/year
- For a surface such as : $A_{net} > 600m2$, PE : 92 kWh/m²/year.

The standards for multi-family buildings are 90 kWh/m²/year, while those for non- residential buildings are split among 7 categories (offices, sport halls, schools, shops, hotels, hospitals, and other buildings). The first three categories have to fulfil the requirement of 100 kWh/m²/year, shops are allowed to reach a higher maximum level of 135 kWh/m²/year, hotels: 160 kWh/m²/year and hospitals 320 kWh/m²/year.

There are no specific requirements in NZEB regulation concerning renewable energy use, but the authorities encourage their use as well as district heating given their competitive primary energy factors.

2.2.2.4 France

The updates of the French regulation defining residential and non-residential buildings efficiency standards are provided by the new Environmental Regulation RE2020, published in 2021 and implemented in 2022 (BPIE, 2022). While there are no updates concerning the indicated precise values for commercial buildings, residential buildings have to comply with the quite permissive energy consumption use limit of 75 kWh/m^2/year. Nevertheless, the already existing ambitious standards for non-residential buildings (50 kWh/m^2/year) are among the strongest requirements in the EU.

According to BPIE (2022), the previously existing regulation was not providing any specific recommendations for non-residential buildings concerning renewable energies' use. The requirements for single-family and multi-family buildings were defining respectively a 30 and 20% share of renewable energy in primary energy demand. The RE2020 increases this share for residential buildings up to 75%.

However, the BPIE report mentions that a certain misalignment can be observed among the different French counterparties (officials, architects, and representatives of the construction industry) especially with regards to the potential costs. While the National Council of the Order of Architects regrets the insufficient consideration of bioclimatic design and its potential solutions, the construction industry reveals important preoccupations concerning the construction costs, especially in the case of more performant building envelopes and the integration of the whole life cycle performance of buildings.

2.2.2.5 Germany

In Germany, the EE of buildings is regulated by the Building Energy Law or the Gebäudeenergiegesetz (GEG), entered into force in 2020, and combining the previous two legislations on EE and renewables (BPIE, 2022). The report stresses, that similarly to the Italian case, Germany is not providing specific primary energy use requirements, but they are obtained from the calculation methodology based on reference buildings, i.e. as a percentage improvement of the performances. Thus, the obtained requirements can be equivalent to a primary energy use of 40 kWh/ m^2/year for residential buildings and of 75 kWh/ m^2/year for non-residential buildings.

Concerning renewable energy use requirements, several equivalent solutions can be considered in line with NZEB requirements, for instance: 15% of energy demand provided by solar collectors, or 50% of energy demand derived from geothermal heat pumps.

Despite the considerable levels of set standards, they are below those defined within the 2015 Strategic Roadmap. According to the study led by the BPIE team (BPIE, 2022) such situation is resulting from the confrontation of several actors' interests and the potential important construction costs increases. The authors also point out the considerable importance of the state-owned investment and development bank, KfW, in the spread of new energy standards in the residential sector, through their preferential loans. Namely, these financial incentives have fostered the development of the KfW EH 55 standards for new buildings, corresponding to an equivalent of 55% of the reference building primary energy consumption, or to a primary energy use of 35 kWh/m^2/ year. Nevertheless, in 2022, this standard has been phased out by the government given the predominance of buildings reaching the KfW 55 level, in which case the loan incentives transform themselves into a profit windfall. However, according to the auditioned experts the local political will, with regards to NZEB, is quite instable.

2.2.2.6 Ireland

The transposition of the EPBD energy performance requirements into the Irish law was realized through the EC Energy Performance of Buildings Regulations 2006 – 2017 (Hugues, 2016), with an implementation starting from 2021 for all buildings, except for public administration for which the deadline was in 2019. Thus, for new residential buildings, according to the used regulation (Technical Guidance Document, Part L (Conservation of Fuel and Energy – Dwellings)), NZEB requirements correspond to a primary energy consumption of 45 kWh/m^2/year (European Commission, 2019) (including heating, ventilation, hot water and lighting). In terms of Building Energy Rating (BER) Certificates, all new dwellings will be rated as A3 or higher. For existing buildings, the cost-optimal level should be less than 125 kWh/m^2/y

Thus, the Sustainable Energy Authority of Ireland requires that NZEB present a 25% improvement of energy performance comparatively to the 2011 Buildings regulation and a renewable energies ratio of 20%. Concerning existing dwellings, major renovation works are defined such as any works concerning more than 25% of the built area and they include external wall renovation combined either to window, or roof, or floor renovation or to external or internal insulation (SEAI, 2022).

As for non-residential buildings, the SEAI expects a 60% improvement of the energy performance compared to the 2008 Building regulations levels. Renewables should provide 20% of the primary energy use or less if the building is more performant (SEAI, 2022; Hugues, 2016).

2.2.2.7 Italy

As described by Azzolini et al.(2020), the EPBD transposition to the Italian regulation has taken the form of several decrees. Thus, the first Decree 192/2005 (modified by the Decree 311/2006 from 29 December 2006) defined the basis for NZEB regulation. Consecutively, in 2009, additional provisions relative to buildings' technical, material and energy performance requirements were adopted, as well as the integration of cooling and lighting systems in the computation process and EPC guidelines. In 2013 were set the requirements concerning the technical inspection of buildings as well as those relative to accredited assessors. In 2015, three additional inter-ministerial decrees were adopted in order to tighten the minimum requirements for new buildings and major renovations, but also in order to define renewable energies' use levels and update EPC guidelines. At last, Decree n.48 from 10.06.2020, transposed Directive 2018/844/EU.

Thus, the minimum performance requirements were set starting from January 2021 for all buildings, apart from public buildings, for which the regulation was applied starting from 2019.

Similarly to the cases of Germany and Flanders, the Italian calculation methodology is based on reference buildings for the definition of the NZEB standards in terms of energy performances. It does also consider regional climatic specifities (BPIE, 2022). According to the same report, the Italian standards for primary energy consumption in residential buildings can be considered as equivalent to 35 kWh/ m²/year and those for non-residential buildings to 115 kWh/ m²/year, which stresses the greater expected effort from the first category. Furthermore, the chosen limitation of energy consumption for commercial buildings ranks Italy among the least involved among the EU MS.

However, concerning the engagement in terms of renewable energy use, Italy sets relatively ambitious targets. Namely, the standard for renewables energy use for domestic purposes (heating, cooling, ventilation, and domestic hot water). defines a share of at least 50%

At last, concerning the political will for the promotion of NZEB, Italian policy makers, SMEs, larger corporations and the Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA) are confident about the spread of NZEB through enhanced construction activity resulting from the Covid recovery measures, a fostered professional training and a high degree of technical preparation (BPIE, 2022).

2.2.2.8 Poland

BPIE (2022) identify that the first Polish legislation relative to new buildings dates from 2014. After a progressive tightnening of standards in 2017, the current levels have enterred into force in 2020. The adopted levels for primary energy use are inherently specific to the different types of residential and non-residential buildings (single-family houses, multi-family houses, healthcare buildings, warehouses and farm buildings, other non-residential buildings). Thus, for residential buildings, the standards limitation is 70 kWh/m²/year and for other non-residential buildings (especially offices) it is much more ambitious than the EC-recommended level , i.e. 45 kWh/m²/ year. The definition of such target aims probably to compensate the quite high allowed levels for healthcare buildings (190 kWh/m²/year). Concerning the renewable energy use, no specific requierements have been integrated in the new building code (BPIE, 2022).

2.2.2.9 Spain

The Spanish legislation targeting building's energy efficiency and decarbonization represents a package of laws, strategies and documents including the Climate Change and Energy Transition Law (Law 7/2021), and the Building Code (CTE, Código Técnico de la Edificación) from 2019, defining the standards for new buildings (BPIE, 2022). The BPIE report highlights that given the climatic differences among warmest and coldest zones, energy performance standards for residential buildings, vary from 40 kWh/m²/year (for warmer regions) to 86 kWh/m²/year (for colder regions). While the residential targets are close to the average EU levels, those for commercial buildings are ranking the country as the second-least ambitious EU member (120 to 165 kWh/m²/year).

Concerning the share of renewable energy use in NZEB, Spain does not define a specific minimum standard for residential buildings, even though 60 to 70% of the energy for domestic hot water should be provided by renewables. Non-residential buildings larger than 3000 m², are expected to dispose with an installed renewable electric capacity ranging from 30KW to 100KW.

According to the study led by BPIE, (2022), Spanish experts are confident with the realization and respect of the defined standards, even though further training and technological preparation of all concerned professionals such as architects, engineers and designers might be needed. Furthermore, some inconsistencies of the cost-optimality methodology have been identified by the Institute for Construction Science which might affect in turn the accuracy of the defined NZEB thresholds. Nevertheless, the long and progressive standard evolution for a period of almost ten years has allowed to the construction industry to be well prepared for the new and more ambitious requirements.

The current subsection briefly sketches the complexity and variety of adopted national solutions with regards to NZEBs. Even though the Energy Performance of Buildings Directive requires that all new buildings comply with NZEB targets, since 2021, the faced technical difficulties, the reluctances, or objections of some stakeholders' as well as the "reasonable cost issue" represent important burdens for this initiative.

Furthermore, according to several scientific publications (Ingeli and Cekon (2015), Zeiler et al. (2016), Elnagar and Köhler (2020)), NZEBs present quite controversial effects in terms of achieved EE levels, since they are considered as a very demanding solution (high installation costs, specific know-how necessary for appliances use, difficult matching of all the technologies requiring adjustments in accordance with changing weather conditions, installation and functioning difficulties or errors).

Nevertheless, other academic papers provide examples of particularly efficient tunning of the different technologies incorporated to existing NZEBs and leading not only to a total coverage of the energy consumption but even to a generated energy surplus (Magrini et al. (2020), Patel (2021)).

In both cases, however, the specificity, the considerable costs and the important technological intensity of NZEBs can represent an important hurdle for their deployment.

2.2.3 EE measures directly impacting residential energy consumption

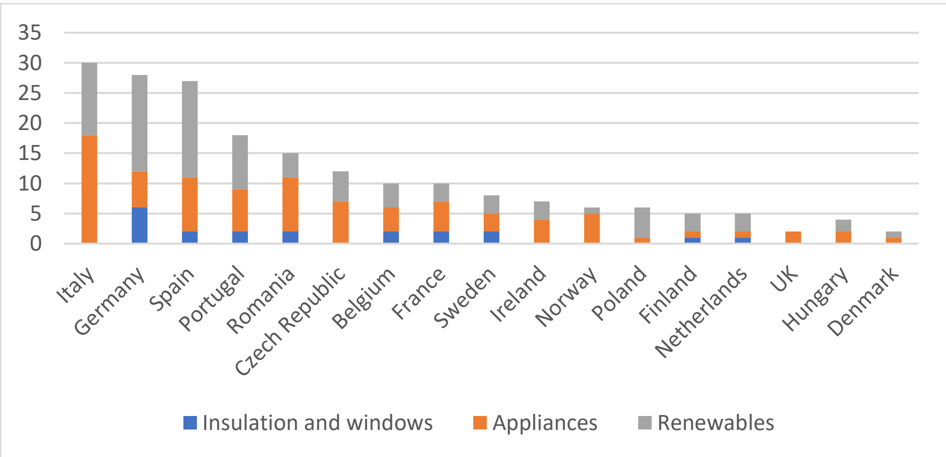
Among the large variety of EE regulatory measures, those focusing on electrical appliances, on residential renewables use and buildings' isolation have a direct impact on dwellings' energy consumption.

Of these three categories, most of the countries have adopted regulatory measures relative to electrical appliances. A smaller number of countries has chosen the implementation of policies fostering the development of residential renewables (solar rooftop photovoltaic (PV), heat pumps, and biomass use). Indeed, only the UK has chosen to abstain. As stressed by the IEA (2020) and the EBF and Enerdata report (2022) the relevance of all measures related to electrical appliances and residential renewables are crucial not only in the perspective of the European Green Deal but also given the current energy crisis. Several studies highlight the utility of rooftop PV, especially when they are combined with green roofs (Hui and Chan (2011), Movahhed et al. (2019), Martinopoulos (2020), Shafique et al. (2020)).

Concerning heat pumps, several advantages have been identified. Namely, they are considered as a highly efficient and mature technology, especially in well-insulated buildings (Thomassen et al., 2021). They present the advantage of a flexible solution to power systems with high shares of variable renewable electricity sources (Bloess et al., 2018). Also, they use less energy than furnaces and can be used for cooling purposes (Brecha, 2021), since they are more efficient than conventional air-conditionners (White te al., 2021). However, the high upfront investment represents a considerable burden for a more important use of small scale heat pumps in the EU (Barnes and Bhagavathy, 2020; Karytsas, 2018). As suggested by Bruckner and Kondziella, (2019) and Hannon, (2015) this could be overwhelmed by appropriate fiscal and financial incentives. Given the characteristics of regular heat pumps, their efficiency has been proven in the case of warmer climates (in our case Southern Europe), while for colder weather conditions geothermal heat pumps (requiering a higher degree of investment) are advised (Brecha, 2021). In consequence, the approrpiate fiscal and financial incenticves should be adapted accordingly.

At last, only 9 EU members out of the 17 studied, have policies promoting buildings' insulation (Figure 13).

Figure 13 : Specific EE measures targeting buildings



Source: Authors' compilation, (Mure Database, 2022)

Even though, several studies stress the positive impact of buildings' insulation on their energy efficiency namely through reduced energy consumption (Karlsson et al., (2006), Dombayci (2007), Gholizadeh (2014), Feng (2017), De Place Hansen (2018), Zilberberg (2021), BPIE (2022)) few efforts for a more widespread implementation of such policies can be noticed, up to now. Given the predominant buildings' age structure across EU members (the share of old buildings represents at least 60% of the building stock (Hypostat, 2021)) such type of policies can have a significant impact, even though it might vary due to weather, buildings' and isolation materials specifics[7].

According to BPIE (2022), improving the energy performance of the building envelope can lead to a 45% cut of final energy demand. Their study covers a sample of 8 EU members : France, Germany, Italy, Poland, Czechia, Slovakia, Slovenia, and Romania.

More specifically, Feng (2017) identifies that the heat loss relative to walls represents on average 60-70% of all heat losses. While windows and doors heat losses account for 20 to 30% and floor heat losses correspond to 10%. This finding stresses the relevance of wall insulation and its potential to reduce heat losses and thus energy consumption.

Furthermore, an Australian study Rahimpour (2022) evaluates the impact of using phase change materials in buildings' envelope and observes a reduction of annual electricity costs. Phase change materials can absorb and release heat energy when they change from solid to liquid stages (for instance when melting). The different materials have different properties in terms of melting, freezing temperatures and heat absorption capacities. Nevertheless, they might represent an interesting potential for improving the energy performance of the building envelope and thus improve its EE. However, as highlighted by Zilberberg (2021) all new technological solutions and materials (low-E coatings, electrochromic glazing, nanocoatings and etc) use should be considered in light of their overall environmental impact.

In short, insulation policies have historically less attracted the attention of policymakers, but they might represent an important potential for addressing buildings' EE capacities, especially given the current energy supply conjecture. On another hand, EE legislation relative to electrical appliances which is much more adopted by EU members has proven its efficiency given the EE improvement levels described by the Odyssee Mure database. At last, renewable energies adapted to buildings such as solar rooftop photovoltaic (PV) systems and heat pumps or geothermal heat pumps have proven their efficiency under certain climate and architectural conditions and especially when they are combined with other sustainable solutions such as green roofs.

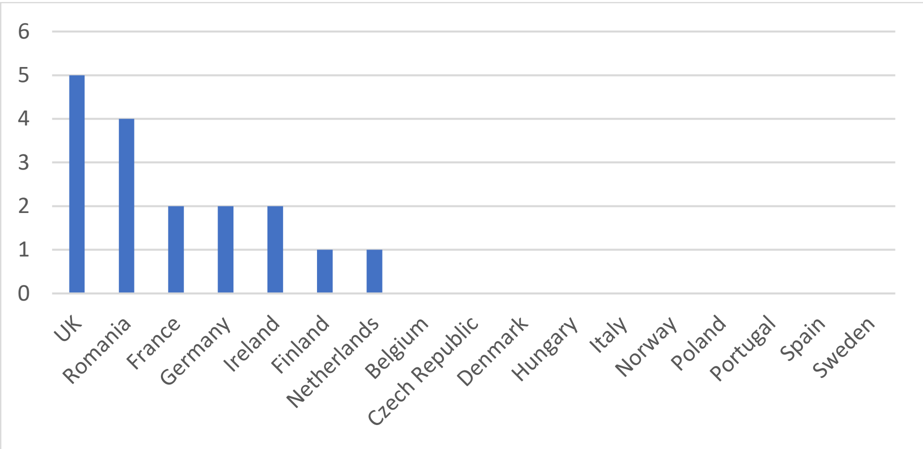
2.2.4 Smart metering policy measures

Even though smart metering is considered as an important tool in the management of personal electricity and gas consumption according to the dwellings' specific needs and the undergone weather conditions, its spread among EU members is quite limited. Thus despite its important potential for

[7] According to De Place Hansen (2018) the achieved final energy demand economies due to internal insulation of historic buildings can reach the range of 9 to 43 % and even 78 % when internal insulation is combined with other energy saving measures. BPIE (2022) identifies energy savings amounting from 39 to 56 % according to the concerned country, the lowest level corresponding to Poland and the highest to Romania. When comparing the EE of different isolating materials, Gholizadeh (2014) finds a reduction in energy consumption ranging from 35 to 47%. Dombayci (2007) obtains a reduction of almost 47% in energy consumption, in case of optimal insulation.

improving energy efficiency, only seven countries in our sample (out of 17) have adopted the adequate regulatory measures (Figure 14).

Figure 14: Regulatory measures related to smart metering



Source: Authors' compilation, (Mure Database, 2022)

According to the Final report on the technical support to the development of a smart readiness indicator for buildings (EC, 2020), buildings that have adopted an advanced package of smart metering technologies can reach a final energy saving of on average 30%. Besides the expected reductions in terms of primary energy consumption and its relative GHG emissions, a more widespread adoption of the Smart Readiness Index (SRI) can influence consumer energy costs, but also energy system costs while delivering important health and wellbeing benefits[8] (EC, 2020).

The International Energy Agency (IEA) also highlights the relevance of smart metering technologies in its European Union 2020 Energy Policy Review. Besides the policies targeting residential renewables (mainly PV and renewable heat) and appliances, the phasing out of fossil fuel subsidies and the promotion of RD&D[9], the agency stresses the importance of policies and investments targeting infrastructure and smart energy systems.

Thus, smart metring can represent an important potential for improving buildings' EE, through reduced energy costs and enhanced living conditions.

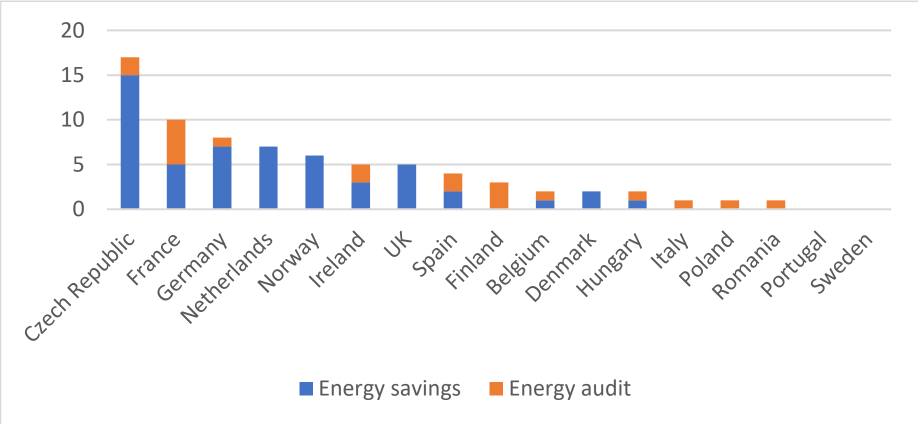
[8] "Depending on how it is implemented across the EU by 2040, the SRI has the potential to save annually up to: 160 TWh in primary energy consumption, 23 Mt of CO2 emissions, €12.5bn in consumer energy costs and €1.4bn in energy system costs. In addition, it could deliver annual health and wellbeing benefits valued at €6.5bn and help create 76 thousand jobs." (EC, 2020)

[9] Research, Development and Demonstration activities.

2.2.5 Energy savings and energy audit policies

Energy savings and energy auditing policies are almost equivalently spread among EU members. Nevertheless, Portugal and Sweden seem to not be concerned by both types of policies (Figure 15).

Figure 15: Energy savings and energy audit policies



Source: Authors' compilation, (Mure Database, 2022)

Even though these types of policies seem quite general they can influence directly the dwellings' energy consumption and therefore the buildings' EE. Nevertheless, according to the available literature, (Murphy (2014) and Kontokosta (2020)), the effects of energy auditing on induced EE levels are quite restricted. However, in the case of EE mortgages, energy auditing represents a particularly important stage of the entire procedure.

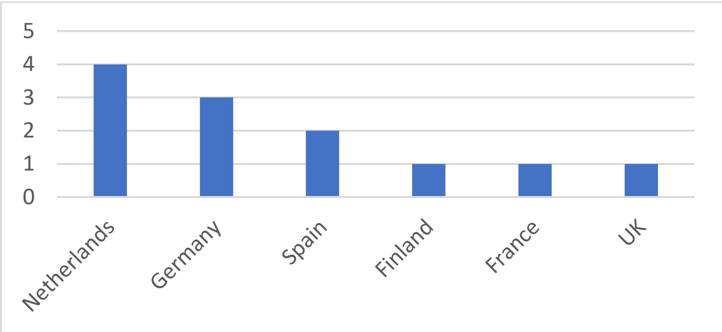
2.2.6 Rental oriented policies

The 2015 Paris Climate Agreement's climate targets can only be achieved with the help of the buildings sector. According to the IEA and UNEP report (2021), dwellings are responsible for 22% of total energy consumption. This consumption is related to the use of electrical appliances, lighting, water and space heating, cooling and cooking.

Therefore, in most of the cases the direct benefits from EE improvements concern the occupants of a dwelling, whether they are owners or tenants. The potential issue that could arise in the case of rented properties is that the realised investments by the owners would mainly benefit in a first step to the tenants. This separation between the effort providing counterparty and the benefitting one might reduce the incentives for improving the EE of rented buildings. Indeed, Burfurd et al. (2012) observe that rental properties often present lower levels of EE comparatively to owner-occupied buidlings. Thus, specific legislation for this case, seems necessary, especially givent that 30% of the total housing stock in the EU is dedicated to rental use as specfied by the Housing in Europe report (Eurostat, 2021).

Nevertheless, few countries in the considered sample have adopted appropriate measures dealing with rental oriented properties. As stressed by Figure 16, six of the 17 nations in the sample database have policies aimed at improving the energy efficiency of rental properties. The number of these is higher in the Netherlands and Germany in particular.

Figure 16 Rental oriented policies in selected EEMM



Source: Authors' compilation, (Mure Database, 2022)

For all of the six concerned MS, a combination of two major factors can explain the current situation: the proportion of tenants and the relative expenditure for electricity, gas and other fuels.

Indeed, according to the OECD Affordable Housing Database (AHD) (2021), the six EU members present levels of rental occupancy and energy/maintenance expenditures above the EU average (Table 2). More specifically, Germany and the Netherlands are among the countries with the highest proportion of tenants in the EU. Probably, the current energy crisis will impact further the energy factor, thus stressing the necessity for a greater spread of EE policies targeting rented properties.

Table 2: Housing tenure distribution and energy/mainatinance expenditures (2019 or latest year available)

	Rent (private)	Rent (subsidized)	Electricity, gas and other fuels costs	Maintenance and repair of the dwelling costs	Total - Housing, water, electricity, gas, and other fuels expenditure /final households consumption expenditure
Finland	18,2%	17,1%	4,4%	0,2%	28,8%
France	17,5%	18,5%	4,2%	1,6%	26,2%
Germany	47,3%	6,6%	4,0%	0,8%	23,9%
Netherlands	40,8%	..	3,3%	0,4%	24,3%
Spain	14,4%	3,3%	3,4%	0,8%	22,0%
United Kingdom	11,1%	20,0%	2,5%	0,2%	25,7
EU	13,0%	5,1%	4,3	0,8	22,0

Source: Authors' compilation (OECD Affordable Housing Database ,2021)

As mentioned by Wrigley, (2017), environmental and social factors are significantly impacted by the rental housing sector. In order to benefit more optimally from new measures aiming to reduce energy use, it is necessary to increase the number of measures targeting owners, tenants and agencies, but moreover strong political will and carefully designed policy packages are crucial.

Even though rented properties in the EU represent on average only 18% of the building stock, in some countries this share reaches the level of 30% and even beyond, like in Germany and the Netherlands where it ranges between 54 and 41% respectively. This important proportion stresses the necessity for adapted legislative tools allowing to override the existing barriers.

3. Conclusion

The present deliverable aims to describe the buildings EE policies' landscape in a selection of 17 EU member states proposing EE mortgages or presenting a potential for developing EEMM.

Based on the Odyssee Mure database, we extract information on policies targeting residential and commercial buildings and we identify several stylized facts. For this purpose, we use a keyword extraction method. Given the potential shortcomings that might reside in the selection process, we have expanded our analysis on the basis of several relevant additional reports and publications. In result, we describe a large span of EE policies and propose a critical analysis of their implementation and effectiveness in terms of EE potential.

While the large majority of legislative measures are quite recent (currently ongoing) and country specific (and not EU-related), the predominance of the residential sector is justified by its weight in terms of energy consumption, concerned floor area, and advanced age structure, comparatively to the non-residential sector. Furthermore, regulatory tools (mandatory standards and information) represent the majority of implemented policies, (38%), followed by economic or support actions tools (financial, fiscal, market based).

We also focus on several specific types of policies directly related to buildings' EE improvement, such as those relative to EPC, nZEB, smart metering installations, electrical appliances, renewables, insulation solutions. We also consider energy savings and energy auditing measures, the latter being relevant for EEM procedures. We do also include rental oriented policies given the existing difficulty between costly EE investments provided by the owners but benefiting to tenants.

In a nutshell, we find that an important share of the current EE policies concerns EPC, electrical appliances and renewables. On the contrary, policies relative to buildings insulation, smart metering infrastructure and the promotion of nZEB are significantly less adopted. While the lower interest for nZEB can be motivated by the important installation difficulties and costs, smart metering infrastructures and buildings' insulation present important potential capacities to reduce energy consumption and thus improve buildings' EE (EC (2020), IEA (2020) and BPIE (2022)).

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