

New qualitative approach based on data analysis of European building stock and retrofit market.

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Abstract:

The huge amount of energy consumed by the residential buildings makes the sector one of the principal sources affecting the energy use in the European countries. To face it, the renovation of the building stock is considered one of the key strategies to improve the energy performance of buildings and meet the energy efficiency targets. Thus, a full understanding of the building stock and renovation market is crucial to meet the objectives of energy efficiency strategies. This research presents the findings of an extensive research on the residential building stock and retrofit market in France, Italy, Spain, Slovenia and Austria and a detailed comparative analysis is developed to assess the quality and the level of the data sources. The weighting method is adopted in this paper as an analytic approach in order to evaluate the main indicators of the data collected and to highlight the commonalities and the differences of building data among European countries. The results of this analysis are considered as valuable vademecum aims to support the experts and the different stakeholders in the data collection process and initiates the opportunities for standardizing data collected from European countries. This research is a part of a European project H2020 (heartproject.eu).

Keywords: Building stock, Data collection and analysis, retrofit market, Heart project.

1.Introduction

The building sector in Europe is responsible for almost 41% of final energy consumption, which 27% is attributable to the residential sector[1]. Furthermore, the entire European building stock is estimated to 24 billion m² and almost 75 % of them are residential

buildings[1].For this reason, the principle key to reduce the energy consumption and to promote energy efficiency in Europe is to increase the interest in the existing building stock and to foster Zero-Energy Building renovations.

- *Literature overview*

At European level, several analyzes on building energy performance and on building stock were carried out in order to define the most significant measures for reducing the energy use in buildings. The main European directives related to energy are the energy performance of building directive (EPBD, 2010/31/EU) and the Energy Efficiency Directive (EED, 2012/27/EU). These latter represent the legislative framework that supports the improvement of building energy by obliging the member states to implement long term strategies for renovating the building stock and by providing support for a complete interactivity between the technologies, occupants and environment. The European initiatives are demonstrated also on the EU-funded projects that boost the building renovation process in the European countries. Simona et.al [2] have listed in her research the EU-funded projects that consist on deep renovation in the period from 2008 to 2020. The review includes the projects that address the development of smart devices, systematic renovation strategies, prefabricated systems, advanced technologies and monitoring and control operation such as : A2PBEER, E2ReBuild, INSPiRe, REFURB, ZEBRA 2020, smartTES, OptEEmal, TransitionZero and other projects that support the renovation strategies in Europe.

At the national level, the EPBD recast introduces specific requirements for each country depending on various factors. The member states should deliver a national plan which contains the principal policy measures and the energy efficiency obligation scheme. In this context, the national energy efficiency action (NEEA) was designed with the objective to report the progress achieved by the EU individual countries. The plans are delivered each three years and annual report is required.

Parallel to the various national and European directives, regulations and EU-funded projects developed for responding to the energy savings requirements, several researches were identified in this context with valuable results and outputs. The renovation of the building stock necessitates in the first phase a complete analysis of the building stock and its main energy characteristics and needs to better define the appropriate energy renovation approaches. In this context, multiples researches were performed in order to analyze the building stock. At European level, Csoknyai et.al [3] presented in his research a comparative analysis of the buildings' structures and systems in four countries of the Eastern Europe with an assessment of the data sources between countries. In the same respect, Hellenic buildings were investigated quantitatively and qualitatively by Constantinos et.al [4] with highlighting the main Energy conservation measures. In addition, the building typology identification was a key for Pohoryles et.al [5] for investigating the energy and structural characteristics of the building stock , and for exploring the effects of combined energy and seismic renovation on building energy performance. Others analysis of the building stock at national level were presented with specific consideration such as: *(a)* investigation of Greek building stock regarding the urban built environment [6], *(b)* presentation of the building age, built-up area, heating systems, envelope insulation and energy consumption of Liege, Belgium with a focus on the parameters affecting the growth of the building sector and renovation needs[7], *(c)* the typology , construction periods and buildings size were identified by Ballarini et.al[8] with an investigation of the effects of different measures applied to the Italian building stock, *(d)* the analysis of building performance, structural and thermal features of the building stock in social housing of Cyprus was carried out in order to evaluate the impact of EU directives with considering the life style of the habitants[9] , *(e)* and the assessment of buildings typologies, constructive aspects of the envelope, geographical location was presented to

investigate the social housing in southern Spain with a deep investigation on energy aspects [10].

The researches presented in this paragraph and this paper contribute to the elaboration of European and national data bases about the building stock and its characteristic to support the authorities and experts to better understand the actual performance of buildings. The comparative analysis of the data sources was the main challenge of our paper, this challenge was initiated by G.Dascalaki et.al [10] in order to provide an evaluated data base with exploiting a software developed in the frame of a European project. Furthermore, the building stock modelling approach was identified in the literature review performed and multiples objectives were identified such as : (i) simulation of the dwelling stock development, long term changes and retrofits actions [11], (ii) and the assessment of the current energy performance of the building stock [12]. In this regard, the stock dynamic modelling was identified as principal approach to monitor the stock development. One of the important methods, is the agent-based building stock modelling that shows a significant results in producing the historic development of the stock, and in considering the policies impact on energy use and GHG emissions [13].

The need of renovating the building stock become indispensable. The ageing stock, the huge amount of energy consumed and GHG emitted confirm the need of developing environmentally sustainable buildings[14]. For this purpose, various researches and instruments were developed in the literature to increase the implementation of retrofit actions. The analysis of the renovation passport [15], the use of BIM in renovation works[16], the adoption of the life cycle cost approach,[17] cost-optimal analysis[18] and Decision Support System [19] are considered as major approaches to support the increase of renovation rate. In addition, the existing of platforms collecting the data about the retrofit projects are important tools to establish a guideline and an overview about the European or national status of retrofit

works. Moreover, the energy efficiency technologies diffusion become a necessity to overcome the energy gap in the European residential building stock and to ensure the efficiency of policy and technologies measures in the European retrofit market[20]. In this respect, D'Agostino et.al [18] presents a European Efficiency Platform (E3P) that aims to provide information about building energy performance, the NZEBs retrofit practices and interventions with an open assess tool. This latter allows a better comprehension of the retrofit market dynamic and support the different stakeholders to adopt the best practices and strategies.

The renovation potentialities and barriers were investigated by different researchers. The economic and financial potential was investigated by Streicher et.al[21] to assess the investment cost, energy savings and the energy efficiency improvement for national building stock,

and by Brown et.al [22] who explores the factors influencing the success of finance mechanisms in different contexts. Other studies focused on providing an overview on technologies and policies measures implementation. As example, a review on modular facade retrofit implementation in Europe was investigated by Hu Du et.al [23], a study exploring the implementation of active and passive building retrofitting measures was presented by Bernadette et.al [24] and the assessment of the implementation of the EPBD in Spain regarding the energy rehabilitation potentialities was studied by M. López-Ochoa et.al [23].

This research completes the gaps identified by the researchers and the need for producing a database about the actual performance of the building stock, the renovation practices and interventions and mainly a guideline about the most efficient sources in term of quality and detail level.

This study is a part of a EU-funded project that support the building renovation of the building stock in Europe for residential buildings.

- **Heart project:**

The H2020 European project HEART (Holistic Energy and Architectural Retrofit Toolkit, <https://heartproject.eu/>) holds the strategy of Zero Energy Building (ZEB) and represent five main objectives (1)Development of a systemic and cost-optimal solutions for energy retrofit,(2) To develop, update and adapt innovative technologies for their systemic integration, (3) To foster building’s smart upgrade, (4) To support and improve the decision-making process and (5) To promote energy efficient financing. The outline of the project is an innovative approach for the rehabilitation of residential buildings by introducing a multifunctional retrofit toolkit (figure1) with different subcomponents (ICT, BEMS, HVAC, BIPV and envelope technologies). The toolkit coordinates to transform an existing building into a smart building and to enhance the energy efficiency in the existing residential building stock.

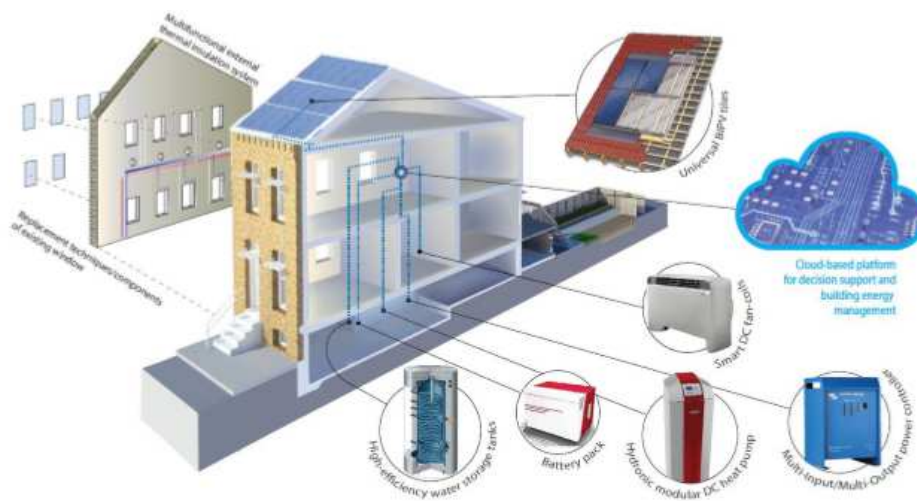


Figure 1: The Heart project toolkit.

In the context of the HEART project, the analysis of the building stock is necessary to study the existing residential stock in the countries implicated on the project, mainly Italy and

France where the renovation and the toolkit will be developed. In addition, the same interest will be consecrated to the retrofit market in the target countries in order to maintain an updated context of the development and the application of the project.

This research represents a summary of the work performed for the data collection of the residential building stock and retrofit market in France, Italy, Spain, Slovenia and Austria. This process is based on different categories of sources from the international and the national perspective. In particular, the purpose is to highlight with a detailed analysis the difference between the level sources, facilities and barriers to collect data in the targeted countries. This exploratory analyze will be based on a qualitative approach present in the section 6.

2.Objectives, research framework and methodology:

2.1 objectives and research framework

The aim of this research is to assess the process of the data collection for two main dimensions of HEART project: Building stock and Retrofit market in France, Italy, Spain, Slovenia and Austria. The main objectives of the present work can be summarized as:

- (1) Presentation of the climatic characteristic in the countries studied (section 3),
- (2) Synthetic review about the building stock and retrofit market in the targeted countries (section 4 & 5),
- (3) Contribution to the development of a new qualitative approach to better understanding and analyzing the data sources across the European countries (section 6).

To reach those objectives, an extensive research was developed for mining the most relevant information required for each section and each country of the study. The methodological approach used in this work comprises three main phases:

1. The first phase is the collection of available data related to the building stock and the renovation market in the five selected countries. This phase requires the identification

of the Key Indicators. For this reason, the mains aspects to collect for each section were identified.

2. The presentation of the relevant data collected for climatic characteristics, building stock and retrofit market. The residential buildings stock is classified in terms of their typology, year of construction and type of tenure and ownership. Otherwise, the renovation market is analyzed by means of renovation potential, rate and depth of retrofit actions in the studied countries, the cost of building renovations.
3. The final part covers the comparative analysis in order to identify the differences and similarities between data collected, and provide a synthetic comparison about the quality and level of data sources analyzed for the five studied countries.

Figure 2 describes the research framework with the main indicators of the sections covered in this work.

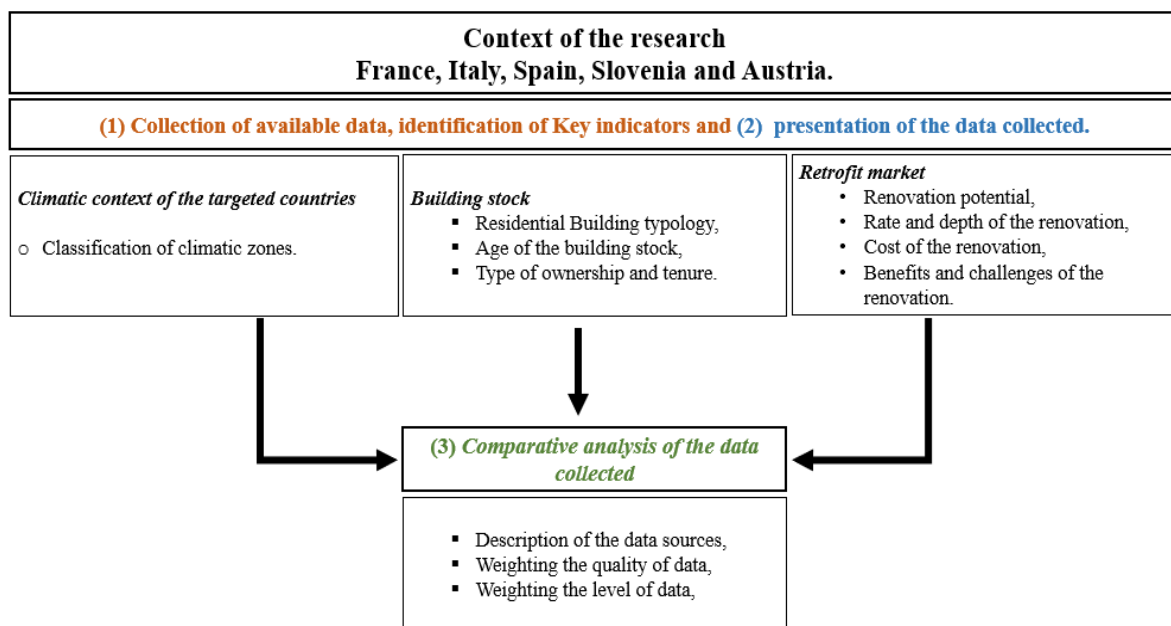


Figure 2: Research Framework.

2.2 description of the analytics approach:

The data collection process in this work was the key element to achieve a complete review on the sections presented above, and in the same time an important purpose to analyze and discuss. The collection of data it's a critical task and necessary for all the research topics and one of the initial steps for all the studies. In this respect, this section will aim to evaluate the data collected in this work and provide the important gaps identified during the data collection process.

The major focus and major barriers in this research were to identify the appropriate strategy in order to respond to two principal questions:

- What are the data sources the most reliable for each country?
- What is the amount of the information available for each country?

The data presented in the earlier sections are not all the data found, but the most pertinent data according to our research focus. To perform the best filter of the data, it was necessary to develop a technical map within the group with a view of standardizing the information collected as best as possible. The following figure 3 describes the approach adopted for the collection and analysis of data.

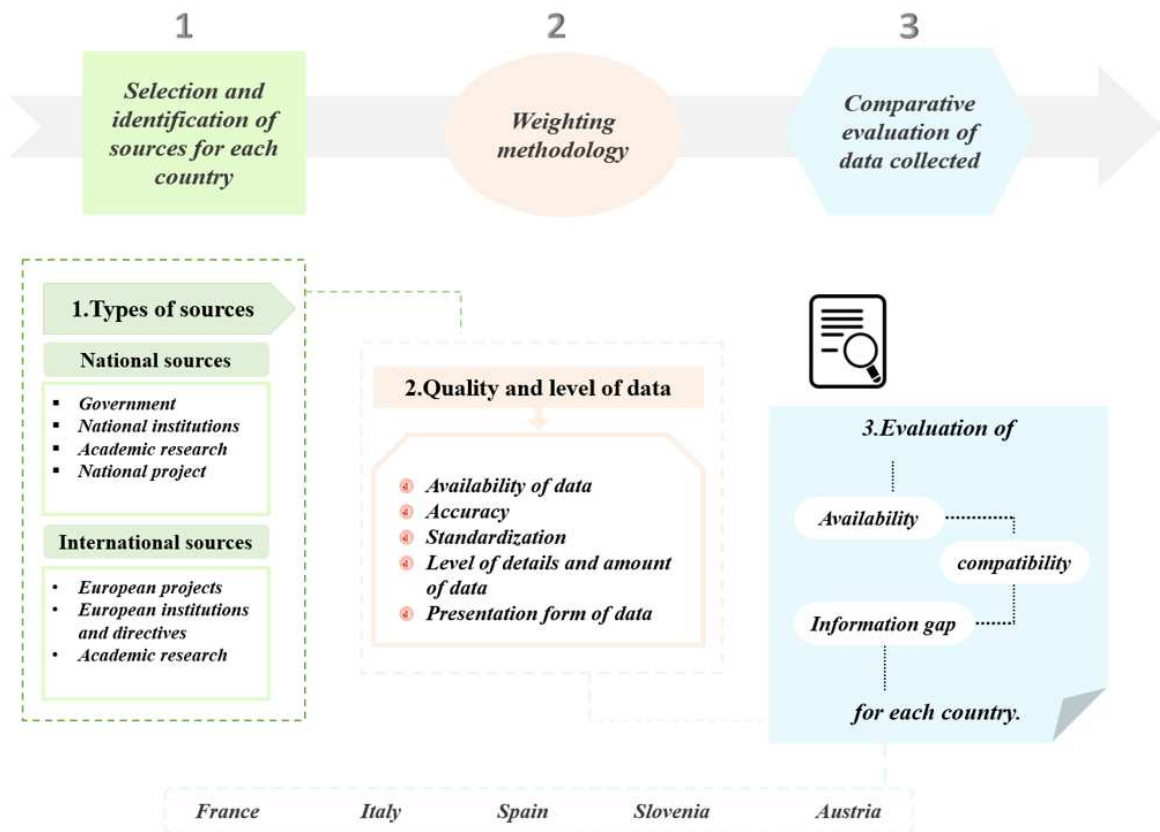


Figure 3: Technical map of data collection and analysis process.

Firstly, the identification of which type source should be considered for the research is one of the important challenges considering the variety of types of sources, documents and projects. The priority is to be based on official sources, on information from the ministries of development and energetic transition, energy agencies, national institutions, European projects, European directives and institutions, and the academic research. Sub consequently, the focus is to assess the information gathered from the multiple sources. In this respect, the weighting method was proposed and analyzed within the team, and two main indicators were suggested: (1) quality and (2) level of data collected. Each indicator is evaluated by scale numbers from **0** to **5**. The indicator of quality measures mainly the criteria of reliability of sources, accuracy and accessibility. Concerning the level indicator, is based on the quantification of data collected, in particular the update level and details, also the presentation form [25]. The following tables 1 & 2 presents the indicators and the detailed criteria.

Eventually, the team member of this research has completed the table of the weighting method, and answered a questionnaire for more details about the different types of sources exploited and about their consideration and recommendations concerning the improvement of the indicator of the data for the different countries.

Table 1: Weighting method: Quality criteria.

Weighting the quality of data collected	
5	Data source accurate and fully reliable - official document or more than one independent source giving same information
4	Good, trusted data source: an official document
3	Data generally available, but from mixed sources
2	Data available not very accurate
1	Weak data / not accurate
0	No evidence

Table 2: Weighting method: Level criteria.

Weighting the level of data collected	
5	Consistent, detailed and updated information
4	Good quantity
3	Data provided in a synthetic way
2	Partial data
1	Little available data
0	No evidence

The collection of data with a high quality and good level is a challenge, because it varies significantly and depends on several parameters. The biggest challenge in this research was to collect data from five countries and provide reliable data with similar quality and level. The first indicators defined by the weighting method is the quality, and it consists of four principal parameters: reliability, data trust, availability and accuracy. The trust is generally a subjective parameter, for this reason users consider that reliable data are usually trusted. However, untrusted data does not automatically lead to unreliable data[26]. Concerning the level of data indicator, it deals mainly with the details, quantity and consistency that depend on the objective of the research and what is the level necessary for the institution of the data base. In addition, the updated sources and information increase the level of trust and vulnerability as it represents the regular monitoring of the targeted data.

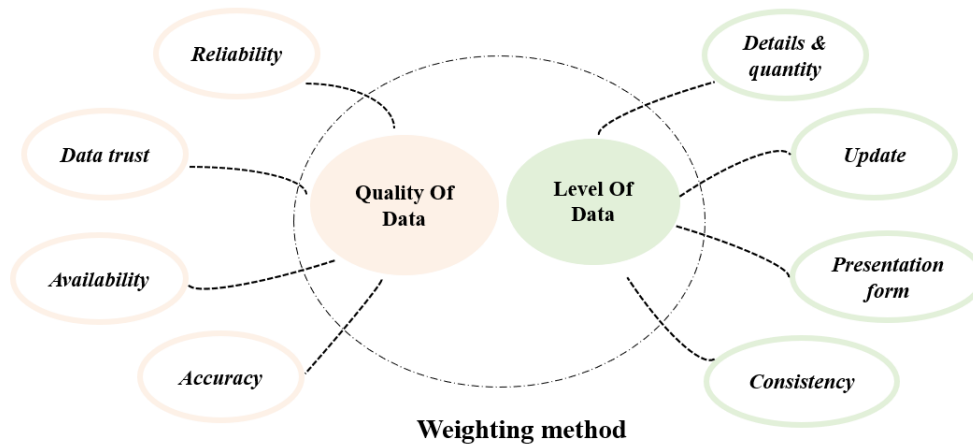


Figure 4: Principal parameters for weighting method.

Besides, the presentation form is reflecting the level of details of information if it presented in a: synthetic way, tables with precise number, graph that demonstrates the evolution of an aspect, etc... this latter parameter affect also the standardization of the data between the five countries, especially if we detect a huge gap level of details on the information between countries.

3. Description of the climatic characteristics of the targeted countries:

The objective of this section is to present: (a) a general classification of the climate zones of the targeted countries the application context of HEART project, and (b) synthesis about the data collection process. In the figures below, we adopted the Köppen classification as an international climate classification system for providing homogeneous presentation. This classification divides the climate into groups based on seasonal precipitation and temperature patterns. Concerning France (figure 5), the dominant climate is temperate with high level of humidity and warm summer. The French building standard developed a classification based on the energy need and the heating period required. The Zone H1 (north-east) requires a longer heating period. The zone H2 (south-west and north-west) has lower heating requirement than Zone H1, but higher than Zone H3 (south-east) which is characterized by

higher temperatures. Regarding Italy, the climate dominant is the Mediterranean climate presented by *Csa* in figure 6. A map analyzing the heating degree days was identified in the literature [27]. Based on this map, it was detected that the higher demand of heating on the northern of Italy where the winter is long, rainy and cold contrary to the southern of the country which is more characterized by mild and rainy winter and dry summer. In Spain (figure 7), there's a large variety in the climate zones. The southwestern and southern regions are characterized by warm summers and moderate winters. The temperate Mediterranean climate is more present in the western and northwestern areas of the country. The continental and the mountain areas are characterized by very cold winters [28]. In Slovenia (figure 8), the climate is warm, humid and temperate and referred as oceanic climate *Cfb*. For the northern coastal of the country, the climate is more continental with a warm summer. For Austria, (figure 9) the climate is predominated by Mountains climate which is characterized by long winter, short summer and high precipitation.

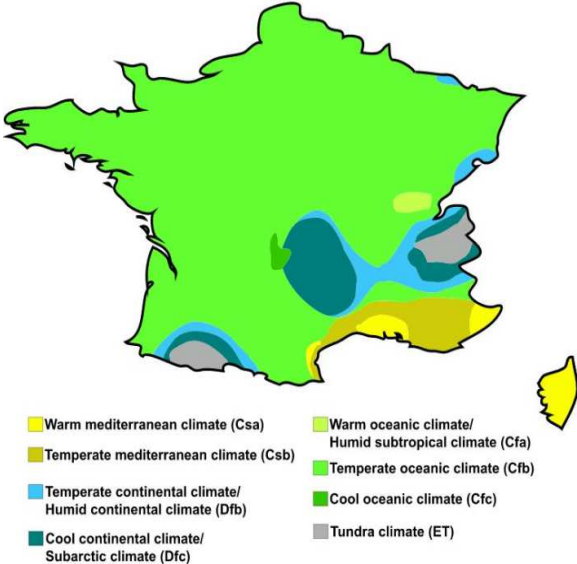


Figure 5: France map of Köppen climate classification.

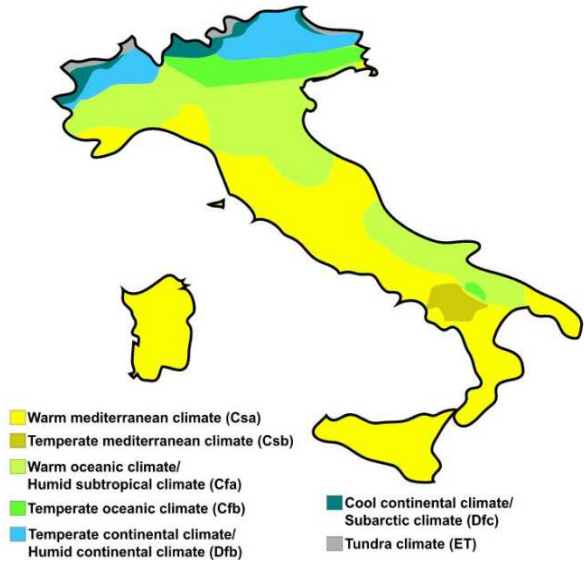


Figure 6: Italy map of Köppen climate classification.

The information collected for the climate characteristic is various and rich for each country, and the details and classification focus are not the same for all the countries. The technical information for France and Italy about the Heating demand was identified easily and

presented in the previous paragraph. For other countries, a map illustrating the HDD and CDD was not identified in the literature review. Alternatively, more than the Köppen description of climate presented, a table synthesize the HDD and CDD for the countries targeted is provided in table 3 for the year of 2019. The highest number of HDD is obtained in Austria due to the large amount of mountain area, followed by Slovenia, France, Italy and Spain. The highest number of CDD stand for Italy with the most area of temperate hot/warm dry summers, followed by Spain, France, Slovenia and Austria.

Table 3: heating and cooling degree days for each of the target countries in year 2019[29]

Country	HDD	CDD
France	2246.95	87.94
Italy	1813.91	305.83
Spain	1670.72	247.65
Slovenia	2600.72	72.66
Austria	3279.5	40.16

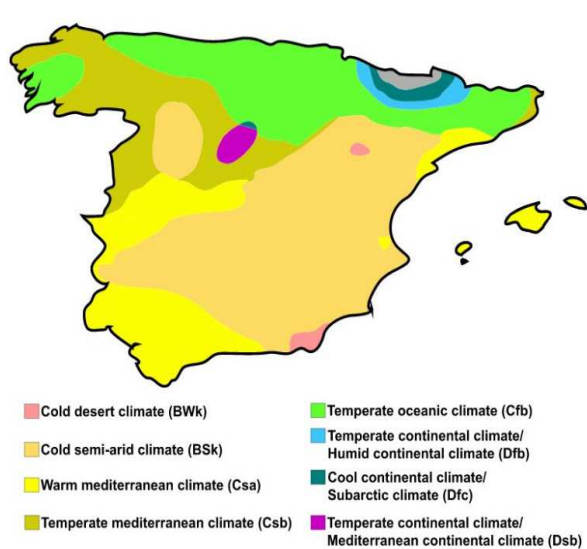


Figure 7: Spain map of Köppen climate classification.

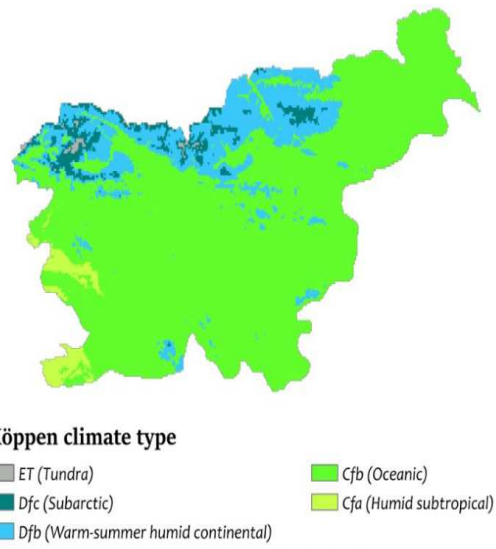


Figure 8: Slovenia map of Köppen climate classification.

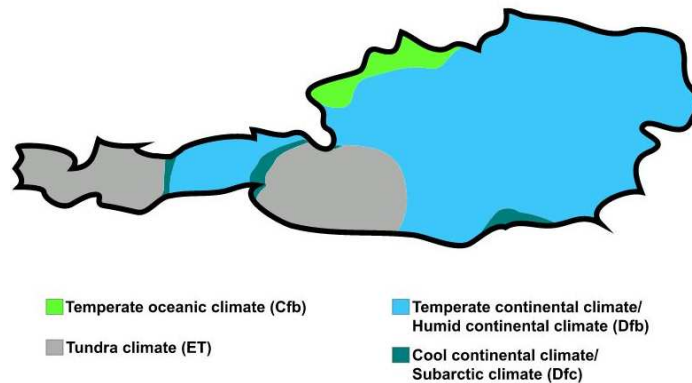


Figure 9: Austria map of Köppen climate classification.

To complete the data presented above, a synthesis table is presented to show the most relevant data for thermal zones based on different classifications where the countries and their primary classification are compared (table 4). French classification has 3 main climate types and 8 sub-types based on the heating requirement where the prevailing type is the type with lower heating requirement. Italy is classified with Mediterranean climate. Spain, Slovenia and Austria are presented through Köppen-Geiger classification. Various classifications reveal different information and thus, the countries are hard to compare. Therefore, for the purpose of easier comparison the next table with only Köppen-Geiger classification is prepared.

Furthermore, the table 5 is presented to indicate the thermal zones classified based on Köppen-Geiger classification with prevailing climate type and corresponding average high temperature, average low temperature and average annual relative humidity. The table shows that the sequence of countries based on min/max temperatures of the prevailing climate type corresponds to the sequence of countries of CDD/HDD. Austria and Slovenia are the coolest, France has a moderate climate and Spain and Italy are the warmest.

Table 4: The most relevant data for thermal zones based on different classifications.

	Number of relevant thermal zones	Classification type	Classification classes	Dominant
France	3 main/8 sub-classes	French building standard; according to the heating period required in winter.	The Zone H1 requires a longer heating period. The zone H2 has lower heating requirement than Zone H1, but higher than Zone H3 which is characterized by higher temperatures	H2
Italy	6	Köppen–Geiger climate classification	Zone A: HDD<600 Zone B: 601<HDD<900 Zone C: 901<HDD<1400 Zone D: 1401<HDD<2100 Zone E: 2101<HDD<3000 Zone F: HDD<3001	Italy is characterized mostly by its Mediterranean climate.
Spain	5	Köppen–Geiger climate classification	North Coast, Continental North, North Mediterranean, Continental South West, Continental South East, South Mediterranean	The dominant climate is continental because it affects a large surface of the country. The continental and the mountain areas are characterized by very cold winters.
Slovenia	3	Köppen–Geiger climate	Generally, is divided into three types of	The climate is warm, humid and

		classification	climate:(a) mountainous, (b) sub Mediterranean and (c) subcontinental climate.	temperate with mountains regions.
Austria	3	Köppen–Geiger climate classification	Alpine and Subalpine Climate, Transitional Climate and Continental Climate	Predominated by the alpine climate which is characterized by long winter, short summer and high precipitation

At the European level, an international study was developed in order to describe the general climate in Europe and its impact on the heating and cooling demand (figure 10)[30]. Currently the impact of the weather become a major issue for researchers especially with climate change that the world face at this century. A projection of the heating period and cooling period were developed to estimate the impact of climate change in the period 1981-2100 by the European environment agency. Hence, the total energy demand will decrease in cold countries and increase in warm countries. The electricity peak demand for cooling will increase in European and projected mainly for France, Italy and Spain[30]. For these reasons and more, it is crucial to identify the climatic conditions; a major technical factor affecting the building energy performance[31][32]. Thereby, it has a significant role on the conception of the building, construction pattern and mode and considered as a crucial factor affecting the energy renovation choice[33]. Concerning the retrofit approach, the climatic context provides indispensable elements in order to define the renovation actions and techniques adopted. On those grounds, the description of the climate of the targeted countries is vital. The European Köppen-Geiger classification is presented in the figure 11.

Table 5 :The most relevant data for thermal zones based on different classifications.

	Köppen-Geiger	Average high temperature [°C]	Average low temperature [°C]	Average annual relative humidity RH [%]

France [34]	Cfb	Temperate, no dry season, warm summer	24.8°C	0.7°C	78%
Italy [35][36][37]	Csa/Cfa	Temperate climate, dry summer, hot/warm summer	30.6°C	3.1 °C	75%
Spain [38][39]	Bsc/Bsk	Arid, steppe, cold/hot	32.4°C	3.12°C	55%
Slovenia [40]	Dfb	Cold, no dry season, warm summer	28°C	70%	
Austria [41][42]	Dfb	Cold, no dry season, warm summer	26°C	-3°C	70%

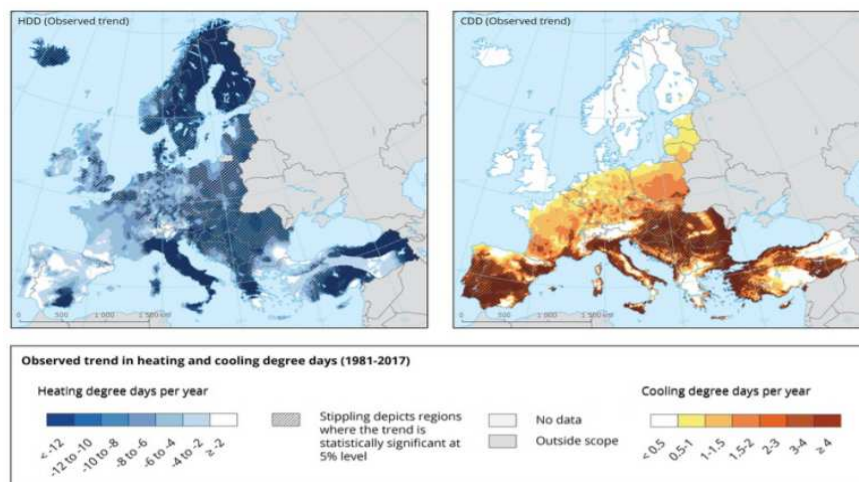


Figure 10: Description of heating and cooling degree days (1981-2017). www.eea.europa.eu

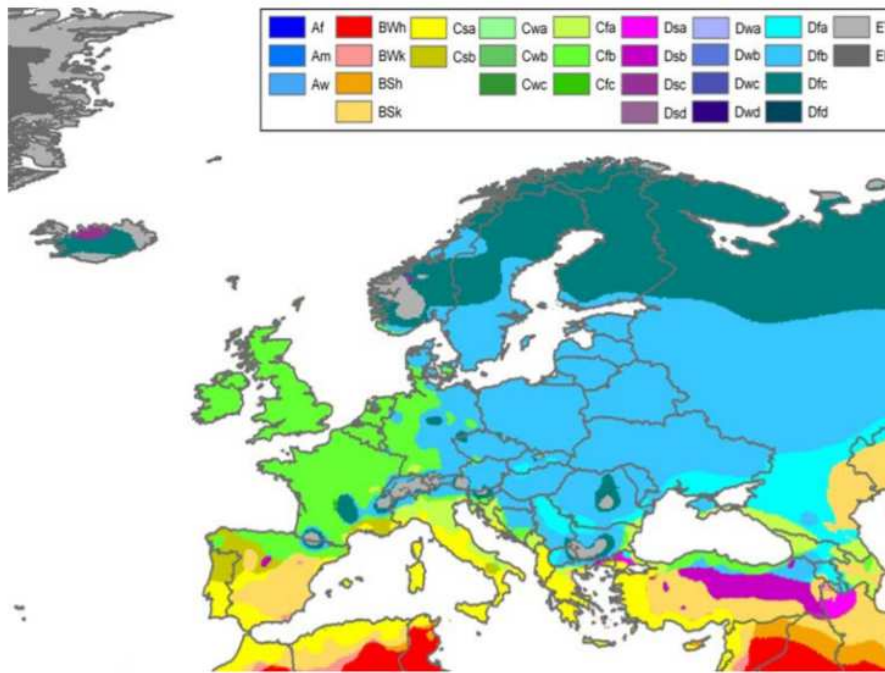


Figure 11: European Köppen-Geiger climate zones[43].

4. Building stock characteristics: typology, age, ownership and tenure:

4.1. Building age:

The five countries presented in this article present different age categorizations. For the four countries except France, data about the year construction were obtained through the TABULA project. Based on Tabula project, the building stock is generally divided into periods of 10 years after the Second World War. The post-War period led to the reconstruction of a great percentage of the building stock. In France, the building stock's period of construction is defined on the energy consumption after this point. The first energetic regulation and the further amendments or additions establish the most recent classifications. The last update of Tabula data is made in 2014.

More precisely, France is divided into four different periods: pre 1975, before the first thermal regulation (RT 1974) was introduced forcing buildings to have thermal insulation, from 1975 to 1981, from 1982 to 1989, from 1990 to 1998 and post 2000 [44]. Information about the French building stock is collected from national sources that were updated in 2019.

Italy divides the building stock into eight classes based on Tabula project : pre 1900, from 1901 to 1920, from 1921 to 1945, from 1946 to 1960, from 1961 to 1975, from 1976 to 1990, from 1990 to 2005 which marked the recent regulations on the energy performance of buildings in Italy (from Law No. 10/1991 to the Legislative Decree No.192/2005), and post 2005 when more restrictive energy performance requirements (implementation decrees of Legislative Decree no. 192/2005 and regional laws)[45]. Slovenia has seven different classifications pre 1945, from 1945 to 1969, from 1970 to 1979, from 1980 to 1989, from 1990 to 1999, from 2000 to 2010 and post 2010 [46]. Otherwise Austria has eight classes: pre 1919, from 1919 to 1944, from 1945 to 1960, from 1961 to 1970, from 1971 to 1980, from 1981 to 1990, from 1991 to 2000 and post 2001[47]. Finally, Spain divided the building stock into 7 categories: pre 1950, from 1951 to 1960, from 1961 to 1970, from 1971 to 1980, from 1981 to 1990, from 1991 to 2000 and post 2000 [48].

Figure 12 shows the classification of the residential stock based on the construction period where a large part of buildings is quite old, before the implementation of the first regulations including buildings insulation requirements.

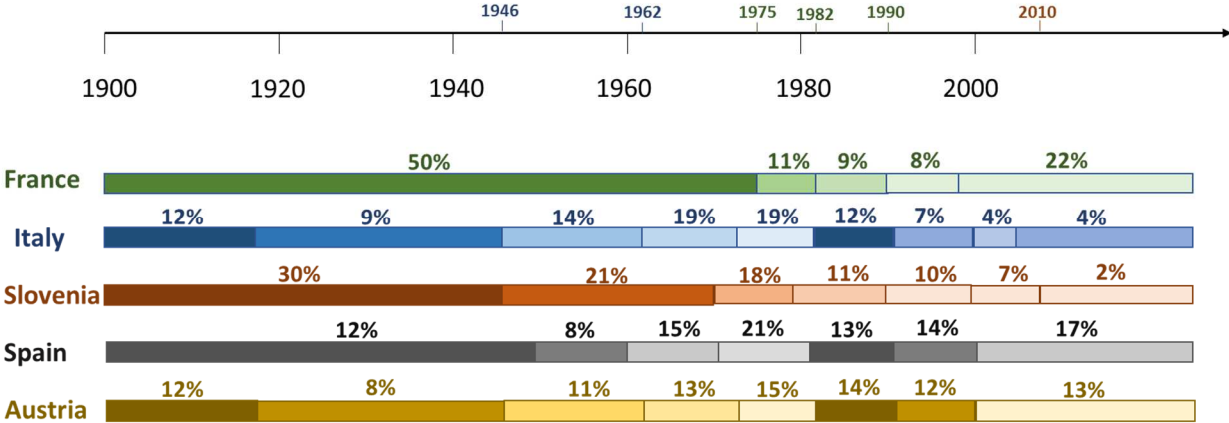


Figure 12: Classification of residential stock based on the construction period.

For building energy requirements, the similarity is that the five countries consider the different aspects influencing the performance of the building (thermal insulation, heating and hot water, Air conditioning systems, natural and mechanical ventilation, solar gains (G-

values), lighting efficiency, design, position and orientation, air-tightness, thermal bridging, renewables, indoor and outdoor climatic conditions, passive solar systems and solar protection)[49].

The energy efficiency measures in the selected countries pay great attention to building envelope insulation. For example, France and Austria have set minimum values for the thermal Resistance. These values vary between 2 m².K.W-1 and 4 m².K.W-1 depending on the climate zone and the type of element [50]. For Spain, the limit values of thermal resistance of envelope elements is established according to different climate zones varying between 1 m².K.W-1 and 2 m².K.W-1 [50]. For other measures, France and Slovenia give great importance to other measures such as sanitary hot water production and renewable energies. Moreover, Spain was the first European country to promote the use of renewable energies [51].

4.2. Building typology:

In France, the national sources (CEREN) [44] classify the residential stock into two types of building: Multi-family houses and single-family houses. These data were updated on 2018. 56% of the building are single-dwelling buildings, followed by multi-dwelling buildings at 44%. For heating, 60% of the multifamily dwelling have individual central heating system where electricity and gas are predominant, 38% collective central heating system, whilst 2% have independent devices. Otherwise, 92% of the single-family dwelling have individual central heating system.

For Austria, the national statistics [52] classify the residential stock into two types of building: multi-family houses and single-family houses as the case of France. However, these data were updated on 2011. Thus, the residential buildings with one conventional dwelling, i.e. single-

family houses, are predominant (72%), especially in Lower Austria, while we find a stronger presence of multi-family buildings for instance in Vienna.

Table 6: The description of building typology for the five countries.

	Type	Heating MFH	Heating SFH
France	SFH - 56%; MFH - 44%	60% of the multifamily dwelling have individual central heating system where electricity and gas are predominant, 38% collective central heating system, whilst 2% have independent devices	92% of the single-family dwelling have individual central heating system
Italy	SFH – 36%, MFH – 64%		In 2015, individual heating system for a single dwelling represents 60.4% and Central heating system for several dwellings. Otherwise, 68.7% of dwellings use natural gas for heating Generation.
Spain	SFH – 35%, MFH – 65%		42% of Single unit houses in Spain have room heating systems and 36% have apartment heating systems. In addition, 31% and 32% of Spanish single unit houses use respectively gas and electricity for heat generation.
Slovenia	SFH – 56%, MFH - 44%	Central heating system 65%, district 14% and local 16%.	
Austria	SFH – 72%; MFH – 28%		50% of MFH have central heating system. Half of them have central heating system, while the rest are mostly fuelled by gas.

**SFH – single-family house and *MFH – multi-family house*

For Spain, there is a lack of information in national sources concerning the building typology of the country. However, the general description of the building stock is given based on the

European project called TABULA (predecessor of EPISCOPE). This information dates from 2011. Residential typology and age depend on the communities: single family buildings are predominant in Andalucía and are older, while multi-family buildings are predominant in Madrid and represent the high average age compared to single family houses in this community [53]. In 2013 42% of Single unit houses in Spain have room heating systems and 36% have apartment heating systems. In addition, 31% and 32% of Spanish single unit houses use respectively gas and electricity for heat generation.

For Italy, the residential typology is given according to three climate zone based on TABULA project: middle climate zone, alpine zone and Mediterranean zone [45]. In middle climate, single family houses present 51% of building while multifamily houses represent 52% in alpine region. In 2015, individual heating system for a single dwelling represents 60.4% and Central heating system for several dwellings. Otherwise, 68.7% of dwellings use natural gas for heating generation [45]. For Slovenia, the residential typology is given according to TABULA project [54]. Single family houses represent 56% of building. The table 6 shows a description of a building typology distributed in types of SFH and MFH based on the data availability. In France, Slovenia and Austria, there is more than half SFH (56- 72% of all buildings). On contrary, in Italy and Spain the number of MFH (64-65%) is larger compared to SFH. SFH and MFH are mostly equipped with central heating system.

4.3. Building envelope

This section represents a summary description of building envelopes in target countries (table 7). The description is related to the time band of each country and include several different time gaps. The description is divided into several different time gaps. The type of house was selected based on the prevailing climate type.

The years listed below are related to either MFH or SFH, that introduced the technique first. Also, it has to be noted that the years are determined approximately as a result of the boundary of the time gap.

In roof structure, normally two main milestones were observed – the addition of thermal insulation and the incorporation of the new structural material different from the wood (normally the concrete). The first to incorporate the concrete in roof was Spain in 1937, followed by Slovenia (1946), Austria (1961), France (1968) and Italy (1980). The Slovenian buildings already from 1946 on had a small layer of thermal insulation which gradually increased through time. Afterwards, the main thermal insulation turning point appeared in French (1975), Italian (1991), Austrian (1991) and Spanish (2007) buildings.

Similarly, as with roof development, also in walls one of the main milestones is changing from stone to brick and then to concrete or reinforced concrete walls. Due to a wide usage of hollow brick in construction, it is decided to address the years when the countries introduced it to their structural culture. So, the usage began in France in 1915, Slovenia in 1945, Italy in 1960, Spain in 1960 and Austria in 1980. The next milestone is thermal insulation in walls which was presented in France in 1970, Italy in 1970, Slovenia in 1971, Spain in 1980 and Austria in 1981.

In all countries the floor is made mostly from concrete, wood combined with concrete fillings or reinforced concrete. This indicator depends highly on the terrain so it is not suitable for inter-country comparison. The exception are old Italian buildings from the period up to 1890, which have elevated brick cellars. The milestone worth consideration is the thermal insulation which appeared in 1975 in France, 1976 in Italy, 1971 in Slovenia and 1960 in Austria. The source has not mentioned any insulation in Spanish floor.

To reduce the heat losses through windows, double- or triple-glazing with addition of gasses or low-e coatings are introduced. According to the reference, double glazing was first introduced in Austria (1961), followed by France and Italy in 1975 with SFH and MFH, Spain and Slovenia in 1980.

Above presented results indicate both, country's level of development and the local climate conditions of a representative building. We may, see that in this part of Europe the target countries have relatively similar building envelope development. This means that new technologies were incorporated in buildings within the delay of a decade. Because MFHs are more demanding facilities than SFHs, their structural techniques are in all periods and target countries consequently more advanced compared to SFHs.

Table 7:A brief summary of the building envelopes in target countries.

	ROOF	WALL	FLOOR	WINDOW
France	The roof of SFH and MFH up to 1968 is made out of wooden slabs, when MFH got their concrete insulated roofs. From 1975 also, the roofs of SFH were insulated. From 1990 on the roof was insulated.	The walls to 1914 consisted out of stone. From 1915 on the walls are constructed from brick. MFH from 1949, consist out of concrete. From 1970 on the MFH walls are introduced thermal insulation which is applied to SFH in 1975. The insulation thickens from this point on.	Both, SFH and MFH from 1919 on have Concrete floor. The insulation was introduced from 1975 on and was by now gradually increased.	From 1914 on, the windows of SFH and MFH are equipped with single glazing. In 1975, both types received double glazing. From 1981 the windows receive low E coating option and from 2000 on the addition of gasses.
Italy	In case of SFH: Up to 1890 the roof is made out of wooden slabs. MFH had	The thick masonry walls with lists of stones and bricks walls	From 1900 on the floor was made out of concrete (SFH). MFH floor were vault and	SFH and MFH up to 1975 have single glass frame. In 1976, both types

	<p>solid bricks ceiling (up to 1900) which afterward became wooden beam roof. In 1921, the reinforced brick concrete was introduced in MFH, which was afterwards in 1946 used also in SFH. In 1991, thin thermal insulation was applied which was during the years increased.</p>	<p>were common from 1900 on in SFH and MFH., which were from 1920 to 1960 changed to pure brick walls. These brick walls became hollow after 1961. In 1970 these walls were couple with masonry layer and thin insulation which in following years increased.</p>	<p>out of bricks (cellar). In 1921, MFH floor consisted out of reinforced concrete and in 1946 out of reinforced brick-concrete slab. The last type was later in 1976 also brought to SFH and simultaneously thin insulation was added to MFH. From 1991 the insulation increased in its thickness. From 2006 on the SFH and MFH consist form insulated concrete floor.</p>	<p>received double glazing. SFH and MFH from 1991 have an addition of low-e coating. From 2006 on, there is also an addition of gasses.</p>
Spain	<p>In 1900, SFH roof consists out of the wooden frame where MFH has also the suspended ceiling which is in 1936 also incorporated in SFH. From 1937 the framework becomes concrete and ventilated. 1980 SFH flat roof: one-way framework with prestressed joint, where and MFH receives insulation. From 2007 on the insulation thickness.</p>	<p>From 1900 to 1936 the walls were made out of stone and brick. In 1960, the air cavity in brick appeared. In 1980 the insulation in the cavity is introduced which thickens through time.</p>	<p>In 1900 the floor is composed out of one-way framework - wooden (SFH) or metal (SFH) joints. Later on in 1960, the one-way framework was stabled with prestressed joints. The reference does not mention any floor insulation.</p>	<p>From 1900 on, SFH and MFH held wood frame single glazed windows. From 1901 on the metal frame was presented. In 1980 PVC or metal frame windows with double glazing become present. There is no gasses or low-e coating included in the reference cases.</p>

<p>Slovenia</p>	<p>The MFH roofs up to 1945 had no insulation and were made out of wood. However, from 1946 on the concrete roof was introduced and the insulation thickness is increasing (cca. +3 cm per period) and has to eventually reach the value of 15 cm.</p>	<p>Up to 1945 the walls of SFH were made out of stone or brick in case of MFH. In the period after 1946 Honeycomb thin brick wall was introduced or in MFH concrete brick wall. From 1971, in SFH the brick wall is enriched for 2 cm thermal insulation. The insulation is gradually enriched (cca. +3 cm per period) and reached 15 cm in year 2000.</p>	<p>Floor up to 1945 is concrete with wooden elements under beneath when serving also as a ceiling. The thermal insulation of 3 cm in the ground floor is introduced in 1971 and is slightly increasing until it reaches 15 cm in 2000.</p>	<p>Up to 1980, the window had wooden frames with two pain wooden window. From 1981 on, the widow frames are made out of aluminium and some already have low E option. From 2000 on, the windows also have gasses incorporated.</p>
<p>Austria</p>	<p>Up to 1981 the roofs in SFH were wooden. In MFH the wooden roofs had filling and in 1961 the reinforced concrete was introduced. In 1981, SFH and MFH was introduced ventilated wooden flat roof. In 1991, MFH received some basic roof insulation. From 2000 on, SFH and MSH own at least 20 cm insulation.</p>	<p>SFH and MFH up to 1980 owned brick walls. From 1981 on, the walls upgraded to masonry honeycomb brick walls with some light insulation. The walls of SFH could become light, hollow and wooden with thermal insulation. From 2000 on SFH and MFH own 20 cm of thermal insulation on primary</p>	<p>Floor is normally made out of concrete. In 1960, MFH floor receive some thin insulation. In 1970 also SFH. From 1990 on, in both cases (SFH and MFH) the floor receives 10 cm insulation.</p>	<p>SFH buildings owned a single glazing box-type windows up until 1961, when double glazing became popular. While you may find 3x single glazing box incorporated in MFH buildings even in the period 1919-1945. Older periods ha double or triple glazing filled with gasses to enhance their performance and combined with low E coatings.</p>

		concrete or brick wall.		
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**SFH – single-family house and *MFH – multi-family house*

4.4. Type of tenure and ownership:

Type of tenure and ownership is a key parameter of retrofit market investigation. Table 8 presents the type of tenure and ownership in residential stock in terms of percentage based on Housing Europe statistics [7].

According to these data, more than 50 % of all households in the five countries were owner-occupied in 2017. The highest ownership percentages were recorded in Italy, Slovenia and Spain. For example, almost 77 % of the housing in Slovenia, Italy and Spain were owner-occupied. By contrast, the highest proportions of social/public rental were in France (17 %) and Austria (24%). while 23 % and 18% respectively were correspond to private rental in France and Austria. The Statistical Office of the Republic of Slovenia notice that the number has been dropping by 10 % over the last 10 years. For France, there is no differences between occupancy data updated on 2018 and available on national statistical sources [55] and information presented in Table 1.

Table 8: Type of tenure and ownership [56]

Country	Owner-occupied	Social/public rental	Private rental	Cooperative	Other
<i>France</i>	58%	17%	23%	0%	2%
<i>Italy</i>	72%	4%	15%	0%	10%
<i>Slovenia</i>	77%	6%	3%	0%	14%
<i>Spain</i>	77%	3%	14%	0%	7%
<i>Austria</i>	54%	24%	18%	0%	4%

5. Renovation market: potential, rate, depth and cost.

As presented above, the building stock in Europe and in the countries presented is huge and is growing continuously. Moreover, the rate of demolition is low contrary to the rate of new construction in the majority of the European countries[57]. For this reason, the renovation is

considered as a key to accomplish the energy efficiency strategies in Europe, especially that the building stock is old and in a deep need of renovation.

According to the Energy Efficiency Directive (EED), 20% of energy savings should be achieved along this year 2020. The last update in December 2018 declare the necessity to increase the 20% into 32,5% by 2030. In this regard, the EED recommend to the European countries to reconsider the strategies in order to reduce the annual energy consumption, as well as acting at European level and share the best practices which is very convenient for sustainability[58]. Thereby, HEART project supports these recommendations by highlighting the need of considering the renovation one of the major actions to achieve energy efficiency goals.

Various European projects were developed in the context of building renovation with different perspective. One of the pertinent projects is ZEBRA 2020, that determine the four levels of renovation :Low, medium, deep and deep plus[59]. In another way, the four categorization can be indicate as: Minor, moderate, extensive and Almost Zero-Energy Building renovation[57]. The deep and extensive renovations lead to a maximum energy reduction. Regarding the medium or the moderate renovations are generally applying the buildings code and regulations for each country. The minor and the light renovations measures are generally not satisfying and not achieving the minimum of the reduction required by the regulation.

At the European level, the greatest barrier to promote the retrofit strategies is the financial barrier, especially that deep and deep plus renovation are costly. Accordingly, different mechanisms have been identified in this context as: energy performance contracting (EPC), energy services agreements, national/municipal loan programs, subsidies and grants, mortgage-backed financing, utility on-bill financing, such as PAYS (pay as you save), preferential taxes or mortgage rates, energy utility obligations, green banks and climate funds

and revolving guarantee funds[60]. In this matter, to get access to finance it's important to assure a high level of confidence in the impact of the deep and deep plus renovation by developing new innovative ideas and initiative.

For more details about the different aspect mentioned in the introduction below about the EU retrofit market, the next sections will complete the focus of our papers by describing the renovation market in France, Italy, Spain, Slovenia and Austria.

5.1 Renovation Market in France:

5.1.1 Renovation potential in France:

The final energy consumption of residential buildings in France is about 26% [61]. The statistics shows that in 2014 the energy consumption in residential sector in France has been decreased by 1% per year since 2010 and the retrofit operations are the significant reasons for this diminution: 28 8000 of retrofit operations have been achieved for the private housing and 50 000 renovations by social landlords (benefiting from the Social Housing eco-loan)[62]. According to l'ADEME(Agence de l'environnement et de la maîtrise de l'énergie) [63], and based on Energy Transition for Green Growth and Grenelle regulations several strategies were developed for reducing the energy consumption in France.

- By 2020, Grenelle objective was to reduce energy consumption by 38% compared to 2008[64].
- By 2030, 500 000 of housing will be renovated by year and more than 50% of energy consumption will be decreased by. In addition, the renewable energies will present 35% of the energy mix and the renovation of the social housing stock built before 2005 is required. Concerning the single-family houses, 70% of those houses are built before 1975 and 5 million will be renovated.
- By 2050, (1) the building and transport sector each contribute to reduce energy consumption by 40%, (b) the renewable energies will constitute 55% of the energy

mix in France and (c) the energy consumption of new buildings is limited to 50 kWh/m²/year.

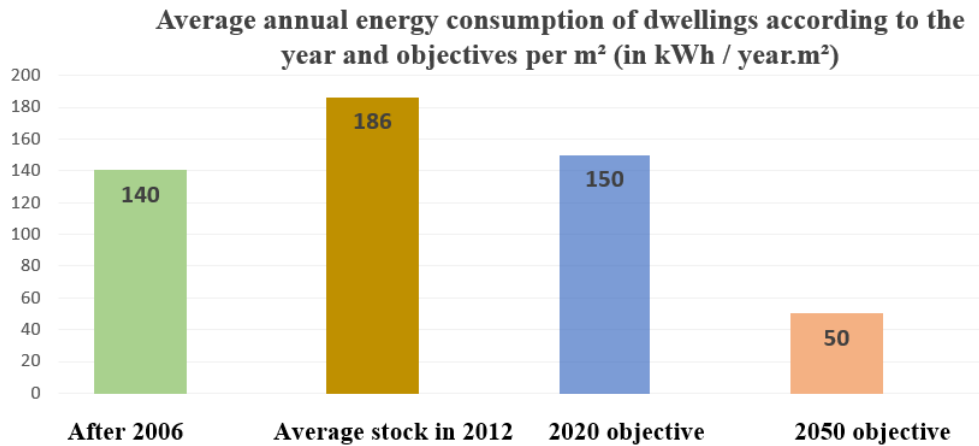


Figure 13: Average annual energy consumption of dwellings on 2006 and 2016, and the 2020&2050 energy projection.

5.1.2 Rates and depth of renovation in France:

In Zebra project [59], the major rate of renovation in France is around 2% (estimated in 2014) and considered one of the important rate in EU. The rate is defined by different levels of thermal improvement and by its impact on the energy performance.

In France, the principal approach to assess the energy performance is the Energy Performance Diagnosis (DPE). L'ADEME represent the impact into three main renovation categories[64]:

1. The renovation has no impact on DPE,
2. The renovation allows to improve the energy performance by one class on DPE,
3. The renovation allows an improvement of energy performance by at least two classes on DPE.

In this context, the statistics shows that between 2014 and 2016, 25% of renovations works had an improvement on at least on two classes on the Energy Performance Diagnosis [64].

Generally in France, 70 % of the retrofit actions on residential buildings focused on the insulation, double-glazing, shutters installation and the others 30% of activities is consecrated

to the HVAC systems[65]. More specifically, we can identify in France two types of renovations projects:(1) partial retrofit projects and (2) comprehensive retrofit projects. The first type is the most frequent type, especially that 90% of renovation works are made by the owner households[62], and is consist on the crucial need to fix a problem on the roof, on system or on the wall. In the partial refurbishment projects, the principal measures implemented is about the Heating system, ventilation system and windows replacement. The second type depends on the surface area of the building. In large building, more interest is dedicated to the wall (outer) and windows replacement[66].

5.1.3 Cost of building renovation in France:

The strategies, regulations and aspects discussed above, implicate the relevance of adopting the concept of financing the energy efficiency industry[66]. In this context, various financial incentives were develop to support the energy financing as: Energy transition tax credit (CITE), interest-free loan (PTZ),The Habiter Mieux (better housing) program, etc...

The average cost for renovating one dwelling is about 10,000€ and the financial aid could reduce this amount by 17% [64]. A National statistical analysis present a price scope for the classic actions of renovation and for different levels[67]. The following table 9 presents the cost of retrofit actions in France.

Table 9: Median cost of retrofit actions in France.

Insulation	Median price	Heating system	Median price	Carpentry	Median price	Ventilation	Median price	Domestic Hot Water system	Median price
Low Floor	49 €	Wood	5 041 €	Window	563 €	Single flow	876 €	Classical	1 224 €
Attic Lost	40 €	Gas	5 286 €	Roof window	962 €	HYGRO B	1 155 €	Individual thermodynamic water heater	2 874 €
		Fuel oil	8 345 €						
Rampant	65 €	Air-water	12 668 €	Door window	928 €	HYGRO A	999 €	Individual solar water heater	7 142 €
		Air-Air	6 629 €						
ETI	148 €	Poele	4 771 €	Door	1 961 €	Double flow	4 493 €	Combined solar system	16 884 €
ITI	55 €	Insert	4 438 €						

5.2 Renovation Market in Italy:

5.2.1 Renovation potential in Italy:

The residential sector in Italy is responsible for 27.8% of the final energy consumption. The consumption had increased by 5,7 % in the period between 2000-2016 [68]. Based on 2016 statistics, the space heating and air cooling represent almost 70% of the total energy consumption for the households. The final annual consumption of energy in Italian households in TWh is presented in figure 14.

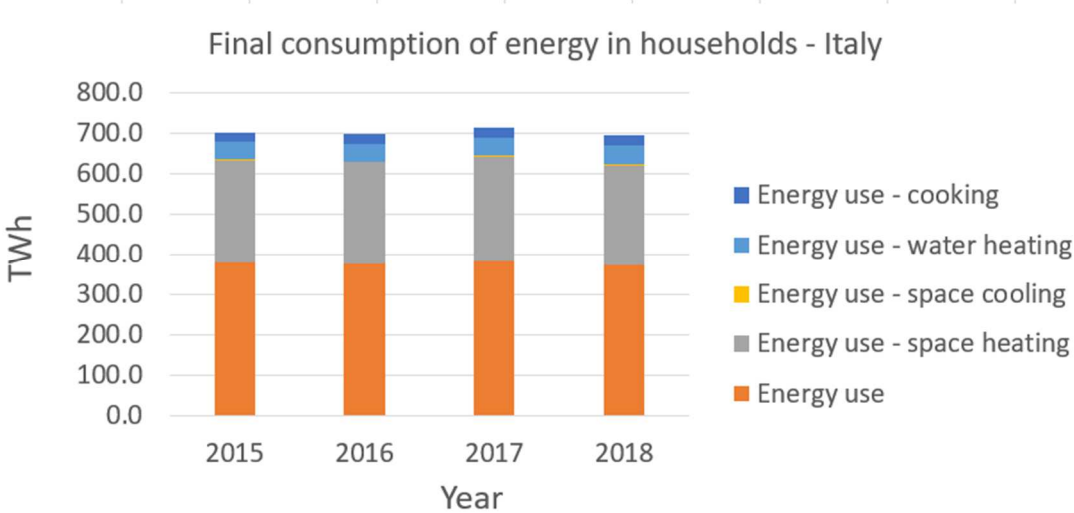


Figure 14: The final annual consumption of energy in Italian households in TWh.

In this context, several strategies and regulatory were developed in order to mobilizes the energy efficiency in the country. The ambition of the European commission and the Italian energy strategy is to reach 30% of energy savings by 2030, especially that new buildings consume already 50% of the energy consumed in the 1980s [69]. The average of annual savings envisaged in the period 2021-2030 is about 1 Mtoe with more focus on residential sector, services and transports[70].

The retrofit has been identified as one of the important approaches for reducing energy consumption of the existing building. For this reason, the Italian strategy envisage a total renovation of 3.5% of Single-Family Houses (SFH) and 3% of Multiple Family Houses (MFH), and a partial renovation of 4% of buildings constructed from 1946 to 2005. Various instruments were proposed in order to boost the action on residential sector and mainly renovations actions[70]:

- The Action Plan for the Energy Efficiency” (PAEE 2017): consists on increasing the new and existing building energy performance, mainly for the energy retrofit by an augmentation of the tax deduction system.
- The “Strategy for Energy Refurbishment of the National Building Stock” (STREPIN 2015) that supports the renovation strategies by identification of retrofit criteria and cost optimization to success the energy efficiency measures in buildings.
- The “Italian Action Plan for nZEBs” (PANZEB 2015) that represents an update of the nZEBs completed in 2015 and suggest an amelioration of the existing financial instruments.

5.2.2 Rates and depth of renovation in Italy:

In Italy, the rate of retrofit operations is specified according to the climate classification presented by Tabula [71]. As show the following table, the three main zone climates are: (a) Mediterranean zone, (b) Middle zone and (c) Alpine zone. We can identify that the percentages of refurbished apartments are higher in Middle and Alpine zone than the Mediterranean zone, and the retrofit operation in Italy focus mainly on technical systems.

Table 10: Rate of refurbished dwellings and renovation types by climate zones.

	Rate of refurbished dwellings	Retrofit on technical systems	Retrofit on structural elements	Retrofit on no-structural elements
Alpine zone	51,4%	45,7%	12,7%	41,6%
Mediterranean zone	42,8%	49%	8,6%	42,4%

Middle zone	52,5%	51,5%	9,9%	38,6%
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Furthermore, the standard and advanced renovation are considered the main two levels of retrofit operations in Italy. The principal two measures concern the building envelope (walls, windows, floors and roofs) and technical systems (space heating and domestic heat water) as shown in figure 15 that indicate the proposed values and applications for each level of renovation[72].

Standard renovation	Advanced renovation
Building envelope	
<p>Walls:</p> <ul style="list-style-type: none"> ▪ 0,33 W/(m²K) ▪ Insulation thickness (6 to 11 cm). <p>Windows: 2 W/(m²K).</p> <p>Floors and roofs:</p> <ul style="list-style-type: none"> ▪ 0,3 W/(m²K) ▪ Insulation thickness (7 to 12 cm). 	<p>Walls:</p> <ul style="list-style-type: none"> ▪ 0,25 W/(m²K) ▪ Insulation thickness (10 to 15 cm). <p>Windows: 1,7 W/(m²K).</p> <p>Floors and roofs:</p> <ul style="list-style-type: none"> ▪ 0,23 W/(m²K) ▪ Insulation thickness (11 to 16 cm).
Technical systems	
<ul style="list-style-type: none"> ▪ <i>Insulation of pipes</i> ▪ <i>Insulation of the heat storage</i> ▪ <i>Replacement of the heat generator (condensing boiler, district heating ...)</i> 	<ul style="list-style-type: none"> ▪ <i>Insulation of pipes</i> ▪ <i>Insulation of the heat storage</i> ▪ <i>Replacement of the heat generator (geothermal heat pump _ air source heat pump_ thermal solar plant ...)</i>

Figure 15: Specifications of renovation actions in Italy.

5.2.3 Cost of building renovation in Italy:

The financial aspect is a fundamental key for achieving the energy efficiency goals. Accordingly, several energy efficiency policies were developed to support the renovation of the existing building stock. As an example, the budget law 2018 validated the tax deduction to encourage the renovation and to establish new features for some specific cases and eligible action. This “Ecobonus” law propose 65% of deduction for the following interventions: (1) Reduction of heating energy demand of the whole building and (2) Installing solar panels to

produce domestic hot water[68]. In addition, it propose a complete retrofit package with the condition of minimizing the primary energy demand by 20%[73].

In terms of cost, the statistics presented by the Energy Efficiency trends and policies in ITALY for 2017, indicates that the principal energy savings are from the replacement of windows/shutters and actions on walls, slabs and roofs (figure 16). Otherwise, Italy expect to save 48,888 GWH/year by this year 2020 with an investments of 13,6€ for complete renovation and 10,5€ for partial renovation [70].

Investments (M€) and energy savings by technology in 2017		
Technology	M€	Percentage%
<i>Technology/action</i>	<i>384,6</i>	<i>10,3%</i>
<i>Walls</i>	<i>412,3</i>	<i>11,1%</i>
<i>Slabs and roofs</i>	<i>1736,4</i>	<i>46,6%</i>
<i>Windows and shutters</i>	<i>50,3</i>	<i>1,4%</i>
<i>Solar thermal</i>	<i>183,9</i>	<i>4,9%</i>
<i>Solar shading</i>	<i>633,5</i>	<i>17%</i>
<i>Condensing boilers</i>	<i>3,1</i>	<i>0,1%</i>
<i>Geothermal plants</i>	<i>234,8</i>	<i>6,3%</i>
<i>Heat pumps</i>	<i>20,3</i>	<i>0,5%</i>
<i>Building automation</i>	<i>64,4</i>	<i>1,7%</i>
<i>Other</i>	<i>3723,7</i>	<i>100,0%</i>
Total	3723,7	100,0%

Figure 16: Investments on renovation actions in 2017 in Italy.

5.3 Renovation Market in Spain:

5.3.1 Renovation potential in Spain:

During the last 20 years, Spain passed through different difficult economic and energy situations. As a consequence, Spain has the higher level of cost in electricity system and end-user price in IEA member countries[72]. The 2016 statistics shows that the energy consumption of building is around 31,2% of final energy demand and 60,9% of total electricity demand[74]. In this context, Spain engaged to adopt several measures in order to reduce the energy related CO2 emissions and to boot the energy efficiency and renewable

energy. By 2020, Spain declare the objective of reducing 20 % of primary energy use in the union[75].

The following figure illustrate the development of building energy demand in the period 2012-2050 presented by ZEBRA. Two different policies are presented in the figure, and in the both Spain will reconsider the use of coal, oil and gas which the use will decrease significantly by 2050, in addition the PV electricity generation and Solar thermal will be more considerable for the production of energy for the current and ambitious policies[59].

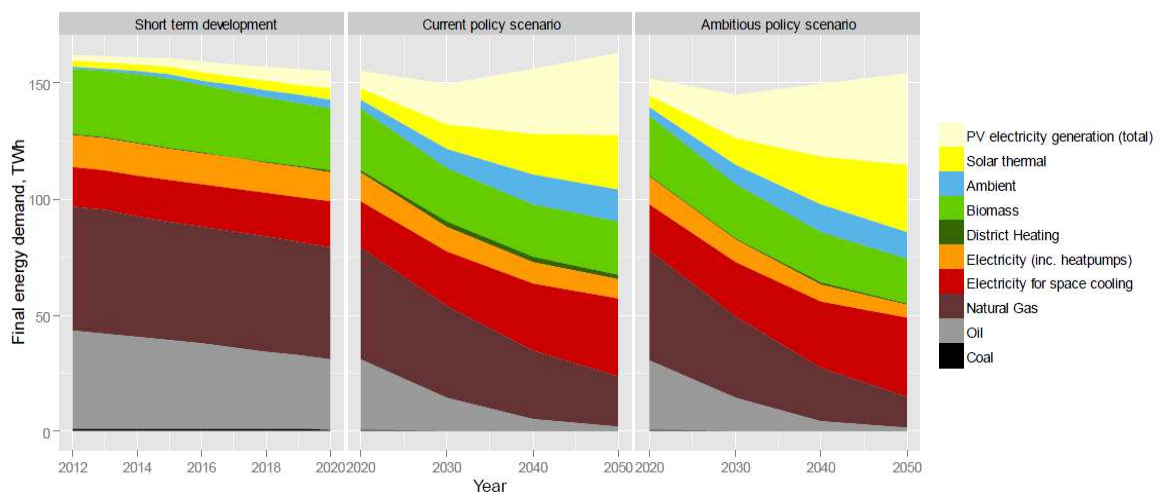


Figure 17: Final energy demand for space heating, hot water and cooling, 2012 to 2050, current policy scenario and ambitious policy scenario[59]

One of the important economic support programs for renovation measures: (a) The promotion of rental housing, building restoration and urban regeneration and renovation, 2013–2016 (Royal Decree 233/2013) of the Ministry of Development that consist on boosting renovation of residential buildings. The objective is to reduce 30% of total energy demand of buildings and, (b) the PAREER Aid Program for the Energy Renovation of Existing Residential Buildings (housing and hotel use) that implicate measures for energy efficiency and renewable energy use. The program was expanded to PAREER CRECE cover all the existing buildings[75].

5.3.2 Rates and depth of renovation in Spain:

According to the 2014 statistics, Spain has the minimum rate (around 0,08%) for the renovation of the building stock in union European countries[59]. In the period of 2003-2017, the renovation works become more and more present than the new construction. According to the “OBSERVATORIO DE VIVIENDA Y SUELO”, the rate of renovation had increased by almost 37% in the 16 years. The important augmentation was started in 2009. The higher percentage was identified in 2015, with a decrease of 7% in the period of 2015-2017[59].

In terms of number, we can identify the same evolution in figure 18 and the last update confirm that in 2018, 10,105 licenses were approved for rehabilitation[76].

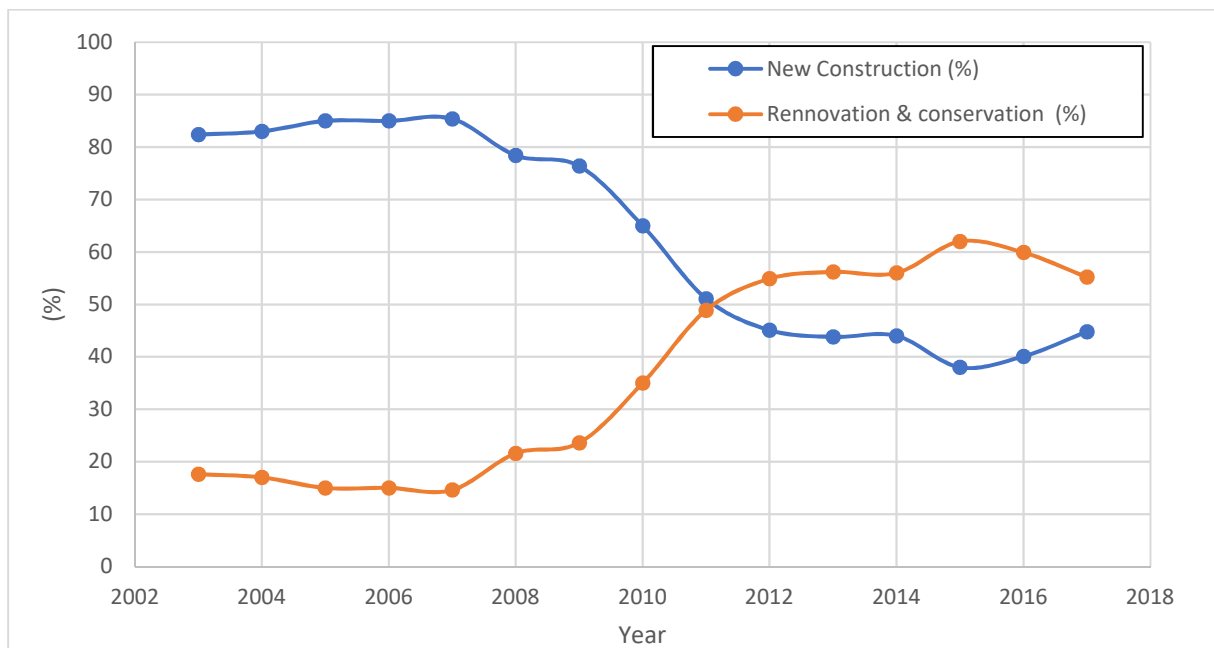


Figure 18: Evolution of renovation and new construction in Spain in the period 2003-2017.

According to zebra project, the levels of renovation actions identified in Spain are three: light, medium and deep and evaluated according to the energy savings estimation. The light renovation represents 17,5% of energy savings and is consist mainly on the implementation of energy efficiency actions plans and integration of solar thermal PV, the second level is the

medium renovation which 64,5% of energy savings is assured by several intervention on the building envelope. Finally, the deep renovation that achieve the 85% of energy savings and combines the different technical measures of the light and medium level. Furthermore, with the current policies regulations measures, the deep plus renovation level will be almost 25% by 2040 with higher energy savings [59].

5.3.3 Cost of building renovation in Spain:

The main key suppliers of resources according to the report of rehabilitation Working Group (GTR 201 are: (1) European funds, (2) Spanish Government, Central, Regional and Local administrations, (3) Energy Companies and ESCO and (4) Owners (savings and loans)[77].

Renovation of buildings in Spain would need almost EUR 16 billion in the period 2013-2020[75]. In this context, the banks in Spain should include the concept of energy efficiency in their economic offers by considering the benefits of renovation works. As consequence, the rate of renovation will be increased and end-users will be encouraged.

As an example of renovation funding, PAREER-CRECE cited above; a support program for the energy rehabilitation of existing buildings that proposes financial assistance complemented by a refundable loan. The owners, the energy services and the operating companies can benefit from this aid[78].

Monetary assistance for renovation in the building sector (PAREER-CRECE program)				
Type of action		Maximum money delivery without consideration (% according to eligible cost)		Maximum loan (% according to eligible cost)
		Base assistance	Additional help by social criteria, energy efficiency or integrated action.	
ENERGY EFFICIENCY	Type 1. Improvement of the energy efficiency of the thermal envelope.	30%	30%	60%
	Type 2. Improvement of the energy efficiency of thermal and lighting installations.	20%	Depending on the use of the building and according to what is established in Annex I, for the type of action. Up to the limits of the State aid regulations or FEDER co-financing rate in the Autonomous Community where the project is located, according to Annex V.	70%
	Type 3. Replacing conventional energy with biomass in thermal installations.	25%	25%	65%
RENEWABLE ENERGIES	Type 4. Replacing conventional energy with geothermal energy in thermal installations.	30%	30%	60%

Figure 19: Monetary assistance for renovation in the building sector (PAREER-CRECE program).

5.4 Renovation Market in Slovenia:

5.4.1 Renovation potential of Slovenia:

Slovenian Energy Balance states that the country imports 48% of primary energy, namely coal (3%), natural gas (11%) and fossil fuels (34%) [79], [80]. The rest of the primary energy consists of the coal (13%), renewables (16%) and nuclear energy (22%). In 2016, the traffic used 39% of the final energy, 25% to the industry, 23% to the households and 13 % was the rest of consuming [80]. In 2018, Statistical office of Slovenia reported that the total final energy use increased for 0.6% compared to year 2017 and that Slovenian households consumed slightly less of it than in 2016 - 21% of it 12392 GWh (= 44 610 TJ) [81], [82].

In residential buildings, most of the energy is consumed for space heating (65%) and domestic hot water (16%) [80]. According to the Directive 2012/27/EU Slovenia is bound to set an indicative goal of improving energy efficiency by 2020, so that primary energy consumption in 2020 will not exceed 7.125 million toe (82.86 TWh) [83].

Up to 2050, Slovenia estimated only the expected energy savings. The vision for 2050 is a near-carbon-free energy use of buildings, which will be achieved by significantly improving energy efficiency and increasing the use of renewable energy in buildings. One of the 2030 indicative targets that are the framework for the strategy in 2030 are reduction of final energy use in buildings by 30% compared to 2005 [83].

In addition to that, Slovenian Energy Act (2014) specifies that all newly built buildings need to meet nearly Zero Energy Buildings (nZEBs) criteria and Slovenian long-term strategy (2015) describes the renovation measures on the levels of building envelope, heating system, ventilation and climatic systems, sanitary water, electrical energy use and its production [83], [84]. The rest of the energy policy documentation of Republic of Slovenia is collected on the web portal ‘Energy Portal’ (Slovenian Portal Energetika) [85]. The technical renovation potential of existing buildings is shown in percentage relative to the overall baseline floor area of buildings within individual in Table 11 below [83].

Table 11: Technical renovation potential according to the floor area of buildings [39].

Category	Single-Family Houses (SFH)	Multi-Family Houses (MFH)	Public sector buildings	Other non-residential buildings	Central government buildings
Percentages of renovation potential /floor area of buildings	41%	40%	38%	34%	-mandatory 3% -renovation 47%.

5.4.2 Rates and depth of renovation in Slovenia:

In Slovenia, about 75% of the single- and 55% of multi-unit buildings constructed in years up to 1970 have renovated roofs [86]. Accordingly, a high percentage of 80% (single) and 64% (multi) have renovated windows. In addition, 40% of single- and 15% of multi-unit building refurbished walls and upper ceilings and 30% of single- or multi-unit buildings constructed between 1970-2002 refurbished their envelopes.

Slovenian Energy Action Plan from 2014 reports that buildings designed in accordance with national policy PURES have high thermal protection and energy efficient windows [87], [88]. So, that the total transmission heat losses of a building envelope (H_T) are below 0.4 W/(m².K). It is also required to use advanced technologies such as condensing gas boiler and solar collectors for hot water preparation or other systems such as heat pumps or biomass boilers, leading to the required share of renewable energy within the building (since 2010 at least 25%). The highest numbers of grants subsidized in 2018 by Eco Fund are presented in the following Table 12.

Table 12: The highest numbers of grants subsidized in 2018 by Eco Fund [35].

	Single-family houses	Multi-family houses
Heat pump (Air-water)	3716	-
Insulation of the external wall	1081	355
Wooden Windows	1083	-
Central ventilation system with heat recovery	400	-
Local ventilation system with heat recovery	745	-
Biomass boiler (spanner)	500	-
Biomass boiler (pellets)	501	-
Replacement with new gas boiler'	595	10
Photovoltaics self-supply	1152	

5.4.3 Cost of building renovation in Slovenia:

The values described below are the net present values of costs incurred in the chosen period of the calculation, considering residual values of equipment with a longer life-cycle calculated in the national strategy [83]. The costs of renovation measures are more expensive for a single-family building compared to multi-family building. Normally, the measures on the single-family house are in the price range of 400-550 €/m². The price range of cost optimal solution for multi-family buildings is 260-370 €/m².

Slovenia established its public fund called Slovenian Environmental Public Fund Eco Fund [89]. The fund works toward improving energy efficiency by financing its residents' investments as loans and grants and covers 1/3 of residential renovations [86]. The fund

approves financial subsidies to 90% of the applied projects. On average it covers 30% of the individual project's investments cost or up to 50% of the eligible cost for investments on areas with high PM₁₀ pollution and in cases socially disadvantaged applicants even up to 100%.

Renovation is enabled also by other investment mechanisms, for example : (a) commercial banks are offering financial solutions to enable the energy renovation of multi-family buildings (apart standard loans, factoring), (b) The Ministry for environment and spatial planning financed (from the Fund for mitigation of climate change) a series of trainings for building managers of multi-family buildings in Slovenia (over 300 persons trained) in order to facilitate the preparation of energy renovation projects in multi-family building sector. Especially that the sector is difficult to reach due to the multiple private owners of flats in Slovenia (90% of all flats in Slovenia are private and for renovation as well as for any financial commitment a consensus is needed (75% for legal issues by the Housing act and 100% for any kind of liability based on financing contract)[90].

5.5 Renovation Market in Austria:

5.5.1 Renovation potential in Austria:

The energy consumption of the residential sector in Austria had an annual average growth of 0,5 % in the last decade [37]. In the period 2000-2016, the amount of the energy demand in residential buildings by fuel type was increased by 4,6 %. Concerning the end-use, the principal final energy is consecrated to the space heating by almost 70% (2016), at the second place the electric appliances and water heating have an average of 12,5% of end-use [38]. This consumption varies and depends on the regions, types and numbers of dwellings. According to the union European, the country doesn't represent an adequate model and the most of households presents a higher value than the European average. As a result, the buildings in Austria need an improvement in service, quality of life and a social upgrading of the neighborhood [39].

Austria has several tools, incentives and policies in order to promote energy efficiency and encourage retrofit actions as building regulations, technological innovation, political support, refurbishment program and information campaigns [91]. The first building renovation program was implemented in 2009, focuses on thermal retrofit of residential and commercial buildings and includes the insulation of :outer walls, ceiling and roof and windows, the replacement of fossil heating systems for residential buildings [92].

By 2030, the energy reduction in building sector need to be achieved by the elimination of fossil fuels in new buildings, increasing the thermal renovation and highly efficient systems. In addition, the share of energy renewable will be boosted by 40-50% for the final energy consumption, mainly in buildings with a more consideration of energy renewable sources[92].

5.5.2 Rates and depth of renovation in Austria:

In 2007, Austria had set the objective to achieve 3% renovation rate for the residential stock and at least 80% of the buildings built before 1980 have been retrofitted in order to achieve at least minimum energy performance levels [93][94].The GBV (the Austrian Federation of Limited-Profit Housing Associations) estimates about 78,000 units will be retrofitted in the period 2015-2019 (Source: information provided by GBV for Housing Europe General Survey 2019 (unpublished).

In Austria, energetic retrofitting is always undertaken in the course of a substantial renovation project which usually takes place after 30 – 40 years after completion of the building. The measures taken are mainly insulation of the outer façade, the roof and cellar, partially together with the renewal or rather exchange of windows, prevention of thermal bridges, Requirements on quality of boilers and aeration systems and chillers. Other additional measures identified as: the renewal of the roofs, modernization of the elevator, the lightening system, the kitchen and bathroom[91][59]. The impact of retrofit operations is

measured by the energy savings achieved. The estimation for renovation potential in Austria is presented by Zebra (table5) [59].

Table 13: Energy savings according to the main retrofit actions in Austria.

Actions	Façade thermal renovation	Ceiling thermal renovation	Replacement of windows	Boiler replacement
Energy savings	34%	13%	14%	5%

5.5.3 Cost of renovation in Austria:

GBV assume an average unit cost of 15,000 euros. The cost of the retrofit works varies depending on the different factors mainly on the level of renovation. Severally per dwelling, the cost of the replacement of heating systems is about 4,000 € per dwelling, outer insulation of the façade about 14,000 € per dwelling, renewal of windows about 17,500 € per dwelling. For a major renovation, the cost of insulation of the façade and replacement of windows) is about 21,000 € per dwelling. In some cases when in addition elevators are installed and part of the vacant dwellings are modernized and balconies are added, costs can add up to 1,000 €/m². There is also variation depending on the size of the building: renewal operations in small buildings tend to be more expensive per m² than in larger buildings.

5.6 European barrier and benefits of renovation:

5.6.1 Barriers of renovation

The complexity of renovations operations is reflected by the different aspects that should be monitored and considered as an obstacle to achieve a successful renovation. Based on our research, at the European level and nation level of the countries analyzed; the renovation potential is limited by several barriers. Six principal barriers were identified : financial, Technical, Organizational, Informative, Awareness and regulatory barriers[2][73][95][57][96][65][95][96]. The figure 20 presents the details of each barrier signification. The financial/ economic is the important aspect to consider for the retrofit

actions in the most countries in Europe, especially that the alternatives had a long payback and expensive and the overall budget is limited. Otherwise, the energy bills is not a considerable charge for most of households, thereby is not a trivial task to convince the occupants of the terms of payback of the investments[70].

5.6.2 Benefits of renovation:

The implementation of sustainable policies and actions to increase the rate of energy operations in different European countries affect in a very positive way several aspects in the society notably at the environmental, economic and social level. In addition, the energy savings and GHG emissions reductions, are also main important benefits from renovation in Europe. Furthermore, the retrofit strategies have a significant contribution for increasing the employment, health and comfort benefits, energy security and tenant’s satisfaction [73].

Barriers of renovation approach	
<p>Financial barriers:</p> <ul style="list-style-type: none"> -Renovation costs, -Access to finance, -Energy prices. 	<p>Informative barriers:</p> <ul style="list-style-type: none"> -Lack of skills, Lack of training , -Lack of knowledge dissemination and convincing the stakeholders, -Lack of information.
<p>Technical barriers:</p> <ul style="list-style-type: none"> -Lack of technical solutions, -Cost of technical solutions, -lack of knowledge of construction professionals. 	<p>Regulatory Barriers:</p> <ul style="list-style-type: none"> -Varying ambition of performance requirements, -Multiple definitions for renovation.
<p>Organizational and Process barriers:</p> <ul style="list-style-type: none"> -Fragmentation of the supply chain, -Burdening of home owners. 	<p>Awareness barriers (Lack of awareness). Social barriers, Environmental barriers.</p>

Figure 20: Principal barriers of renovation approach.

In France, the higher motivation by renovation works is to improve the interior conditions comfort and minimizing the energy bills. Later, enhance the French heritage and also

environmental preservation one of the important focus at the moment. In some case, the benefits can be related to health and safety and improving the quality of life[60].

6. Comparative analysis of data collected for the five countries

The experience of data collection for the five countries was rich and diversified. The quality and level of the data varies from country to another and depend on the aspect researched. For example, it's possible to find information very reliable but not in good quantity or not accessible.

Some data presented in this article rely heavily on International sources, especially some aspects information provided by the TABULA and ZEBRA 2020 projects, which was last updated in 2016. Some information is available only on Episcopo/Tabula, and only on ZEBRA 2020 and no national effort was made to provide accurate data. The latest updates of TABULA project do not necessarily involve the latest information of the five countries, but rather the addition of other European member states. Other are based on the National sources that keep the more detailed record of the evolution of the building stock, national regulations, strategies and policies, depth of renovation and main retrofit focus actions for each country. Furthermore, when comparing the national sources against the international sources, some discrepancies can be encountered particularly for the French and Slovenian cases.

The French context sees great variations for the residential market between sources which leads to unreliable information. In this context, the French residential building data presented in this article are based on national census [CEREN], that were updated in December 2019. Nonetheless, the French have a clearly defined age division of the building stock, which is based on the national thermal regulations. Concerning the renovation market, the government has a clear strategy on the necessity of the implementation of retrofit solutions, and defined goals for minimizing energy consumption by 2030 and 2050. The national sources provide

good quantity and details about the retrofit measures in France and median price for each retrofit action. The information considered reliable since there's an update and also trusted for the level of details and the good quantity presented. No problem of accessibility and availability was identified for the renovation market.

The Italy data base is rich and presented in different sources: European projects, international and national energy agency, national institute of statistics and projects. The Building stock was presented in an organized form and according to the age and climatic zones in Italy. These data are considered trusted and accurate for the level of details and consistency provided. The presentation from between the national and international sources is different, so an effort to synchronize the data is necessary to ensure more reliability. Regarding the renovation market, a similarity between Italy and France in terms of the quantity, availability and accuracy was identified. Concerning the rate and depth information, the mainly source was TABULA, for this reason national sources should produce more details and information.

Table 14: Evaluation of the data collected by the weighting method.

Weighting of the quality & level of data collected.										
Targeted countries	France		Italy		Spain		Slovenia		Austria	
<i>Aspects of data collected</i>	<i>Q</i>	<i>L</i>	<i>Q</i>	<i>L</i>	<i>Q</i>	<i>L</i>	<i>Q</i>	<i>L</i>	<i>Q</i>	<i>L</i>
Climate context and description	5	5	5	5	3	4	3	4	3	4
Residential building typology	4	4	4	3	4	4	4	4	5	5
Age of residential buildings	5	4	4	3	4	3	4	4	5	5
Tenure and ownerships	4	3	3	3	3	3	3	3	3	4
Renovation potential	5	5	5	5	2	3	2	4	3	4
Rate of renovation	4	4	3	4	4	3	3	4	3	3
Depth of renovation	3	4	4	4	2	3	3	4	3	3
Cost of renovation	4	4	4	4	1	1	4	4	3	3

The Spanish context has the best control of the information and least discrepancies between different sources, but not the best quality and level. Accordingly, the criteria employed in order to gather the information consisted in analyzing only official sources, particularly information gathered by the ministries of development and energetic. The Spanish government has an update database, accessible to all public with the latest information regarding the number of households and buildings falling under different categories, per year. The information collected from Spanish government is considered to be very reliable since they represent the official figures of Spain. Otherwise, some of information are not clearly presented, even though available for the latest years, aren't updated for every type of information. The biggest lack of information concerns the renovation potential, cost of renovation and the depths of renovation. For example, there's not a national source that provide an estimation of cost for retrofit actions, the only information founded and presented was about a renovation funding of PAREER-CRECE project. Even if some information can be found on the international source, but to ensure the same level of reliability and quality it's recommended that the national sources provide more details and data concerning the renovation market.

For Slovenia, the data is accessible from various sources. The main sources were: National legislation (N), Eco Fund (N), National Statistical Office, SURS (N), European Statistical Office EUROSTAT (I) and TABULA/EPISCOPE (I). The lack of information is identified mainly for the renovation market especially in the residential sector and technical data as: deep of renovation and thermal properties required for the envelope. Accordingly, the mix of the national and international sources can generate differences and unreliability. Concerning the accessibility, some of the data was not accessible for the public, so private meetings were needed to obtain them (Eco Fund). The regular update is one of the important criteria to improve in data sources in Slovenia. For example, the statistical office SURS has data on

building stock (size and year of construction) but without regular update from the year 2014. In addition, the focus on the renovation aspect is necessary by updating the energy labels for buildings, providing a renovation portal, containing the technical information of individual buildings and the improvement of REN database for renovation. The objective is to synchronize and produce data frequently and not only for specific needs which is generally due to a European project.

The data collected for Austria concerning the energy efficiency was based mainly on the Austrian energy agency and the department of the environment and energy (Austrian government). The criteria of update are successfully validated with a last update in 2018 and 2019. However, not all of the detail's information were available. The main lack is identified for the and depth of renovation. For this reason, the information was completed by the international sources, in particular Housing Europe (HEART partner project) provided a very relevant information for both building stock and renovation market.

The core of this section is to evaluate the experience of the data collection for the building stock and renovation market concerning France, Italy, Spain, Slovenia and Austria. The evaluation is based on qualitative approach: (1) weighting method that analyze the quality and level of the data collected, and (2) questionnaires that reflects the main observations and remarks of the team worked on it. The idea is not to provide a very long list of references and all the sources available for the topic, but specifically the main reliable, available, accurate, trusted, updated, consistent data. In this respect, an extensive research was carried out with the guidance of people related to the energetic and a building sector. Specialist helped guide towards the correct information but the data mining took more time since the information is not clearly presented, and some of the databases, even though available for the latest years, aren't updated for every type of information. The results of the weighting method are presented in the table 14.

The proposed methodology has numerous advantages, such as:

- Define a specific criterion for the data collected. These criteria provide a better assimilation and evaluation of the sources identified.
- The results of this methods are very relevant and constructive to guide the researchers and the various stakeholders on their data analysis.
- The application of this method is very simple and depends on the proper experience of each researcher about the data collection process

7. Conclusion

Based on this review and deep research about the building stock and renovation market for the five countries targeted, we firstly can identify that the retrofit strategies and actions for the building stock are presented as a main approach for the reduction of energy consumption, and the weather conditions are one of the important factors affecting the renovation technics implemented for each climatic zone. The data collected for the building stock are obtained from mixed sources and references. The national sources were more vigorous for France and Austria. The information gathered for Italy, Spain and Slovenia was based mainly on International projects who suffers from a lack of update (last update 2016). In this context, it's essential to encourage the national institute and statistics office to work and improve their own data base. As an example, the effort made by France to provide pertinent and updated data for higher reliability and quality gives more latitudes of analysis and retrofit actions strategies.

Regarding the retrofit market, more relevant information was identified in France and Italy, and a remarkable progress is envisaged for Slovenia, Austria and Spain. The international and national sources are clear in terms of energy reduction goals. The details of renovation objectives were more clarified in France, Italy than other countries. The national sources are

more useful regarding the policies, incentives and depth of renovation for each country, contrary to the international sources provide more general information. As an example, the large gap to mention, is the absence of detailed information about the median price of each retrofit action for Spain and the main mechanism that encourage the renovation strategies in Austria. The following table presents an evaluation of the data sources identified with highlighting the strengths and weaknesses for the potential, cost, rate and depth of renovation in the targeted countries.

Table 15: retrofit market: assessment of the strengths and weaknesses of data sources.

		France	Italy	Spain	Slovenia	Austria
Renovation potential	Strengths	data are based on national sources good quantity and details about the retrofit measures	data are based on international sources good quantity and details about the retrofit measures	least discrepancies between different sources data are very reliable	Availability of data	data are based on national sources and updated frequently
	Weaknesses	monitoring and displaying of real time retrofit actions	need to synchronize between national and international data	need to provide more detailed data	need to synchronize between national and international data need to update data	need to provide more detailed data
Rates and depth of renovation	Strengths	clear long-term renovation strategies good quantity and details about the retrofit measures	Availability of data	least discrepancies between different sources data are very reliable	Availability of data	data are based on national sources and updated frequently
	Weaknesses	monitoring and displaying of real time retrofit actions	data are mainly based on TABULA project and data must	need to provide more detailed data	need to synchronize between national and international data	Lack of information

			be updated national sources should produce more details and information		need to update data	
Cost of building renovation	Strengths	good quantity and details about costs and financial aspect	good quantity and details about costs and financial aspect	no detailed data	Availability of data	data are based on national sources updated frequently
	Weaknesses	-	-	need to provide an estimation of cost for retrofit actions	need to synchronize between national and international data need to update data	

The evaluation of the data collected was performed through a qualitative approach, the aim is to share the point of view of the researchers involved in this study. The objective is to give more visibility about the actual situation of the data base available for the Building stock and retrofit market at national and international level, and to contribute to the ideal goal that consist on developing a standard data base for European countries which ensure the good level and quality of the data.

The main novelties of the present work can be summarized as:

- A first synthetic review about the building stock that combines these five countries: France, Italy, Spain, Slovenia and Austria,
- A first synthetic review about the retrofit market that combine these five countries: France, Italy, Spain, Slovenia and Austria,

- A proposition of key indicators that characterize the research of the building stock and retrofit market,
- A qualitative assessment of the data collection process for the targeted countries, this evaluation allows to the research to learn more about the quality of the data collected (availability, accuracy, data trust and reliability) and about the level of the data identified (details& quantity, update, presentation form and consistency).
- The international and national sources covering the building stock and retrofit market were analyzed. This analyze will contribute to assess a data base for research to simplify the data collection process.

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Note: A possibility of not including some references and sources is very probable. This lack may be generated because of accessibility and confidentiality issues, or other reasons.

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