# HEART D2.2 Application context Periodic Update II

## March 2019

HEART

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## HISTORY OF CHANGES

| Version | Date | Comments | Main Authors |
|---|---|---|---|
| 0.1 | 07/02/2019 | First draft, establishing document structure | ENTPE |
| 0.2 | 27/02/2019 | First version, incorporating input from all participant | ENTPE, POLIMI, HE, EURAC, UL |
| 0.4 | 13/03/2019 | Revision of the first version | ENTPE |
| 0.5 | 27/03/2019 | Quality review | POLIMI, ZH |
| 1.0 | 31/03/2019 | Final version addressing all further comments | ENTPE |

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## DISCLAIMER



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# 1 EXECUTIVE SUMMARY

The objective of this second deliverable of WP2 is to update the D2.1 and to ensure the continuation of the different tasks included in the WP.
The main scope of WP2 is to assure the update of the HEART context and its different features (energy, regulatory and economic issues, technological application etc.) during the development and realization of the whole project. In this respect, possible changes of the context will be identified and detected and will be taken in consideration for the progress and improvement of the project.
The WP2 is divided in to five tasks as follows. For more details about the description of the tasks, please check the roadmaps of D2.1.

- **T2.1 Building retrofit market**
- **T2.2 Economic and regulatory context**
- **T2.3 Interactions between buildings and Smart Grids**
- **T2.4 Compatibilty continuous review**
- **T2.5 Technological benchmarking process**
- **T2.6 User's needs and communication techniques**

In D2.1, an initial assessment was performed about the countries where the case studies of the Project are located: Italy and France. In this second Deliverable, the objective was to continue with the same methodology of work while integrating Spain and Slovenia. This information will be updated within the framework of the 3rd report. Thus, other countries will be included in order to cover all the targeted countries.
Concerning the T2.3 and T2.4, the methodology and conception of the work was defined in collaboration with EURAC. For the T2.5, the D2.1 has been updated with more details in order to stay up to date with best practices related to the solutions proposed in the HEART.
Finally, a description of the work realized in collaboration with EURAC is provided with the purpose to present the strategy adopted for the identification of the stakeholders and their needs.

# 2 BUILDING RETROFIT MARKET

The building retrofit market focuses on the building stock and market renovation in the targeted countries of the HEART Project. For this report, we added Spain and Slovenia with an update of the Italian and French context. This information will be updated throughout the project and other countries will be integrated for the next report.

## 2.1 STATE OF THE ART OF ENERGY AND RENOVATION CONTEXT IN EUROPE

### 2.1.1 The building stock

#### *2.1.1.1 Building typology*

The European building is responsible for approximately 40% of the energy consumption, 36% of the $CO_2$ emissions and 55% of the electricity consumption.
Residential buildings account for 75% of the total stock in Europe. Non-residential buildings represent 25% of the building stock and comprise more heterogeneous sector compared to the residential sector.

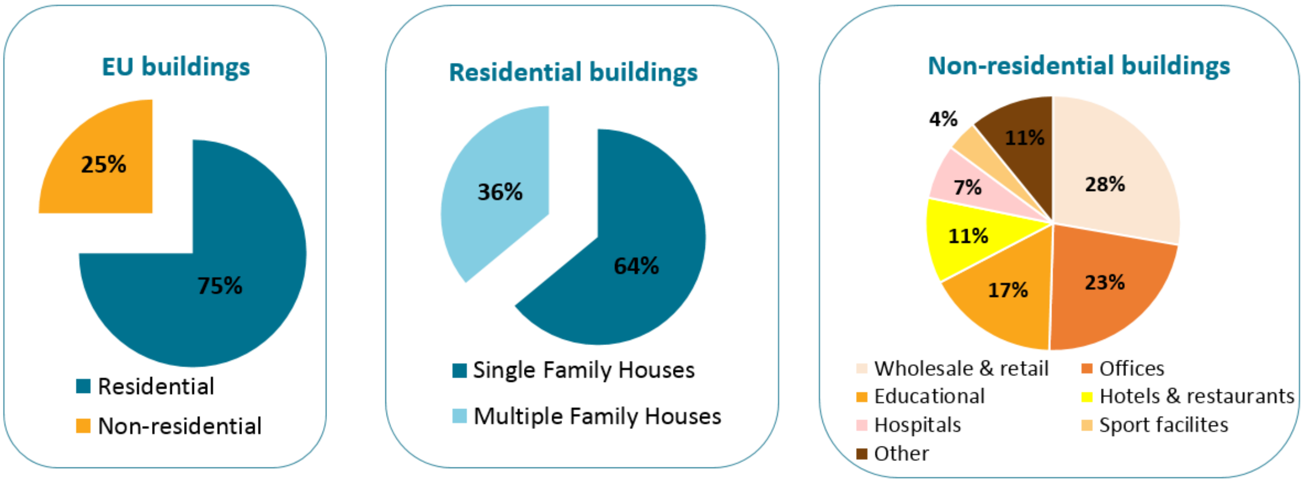



Figure 1: Overview of Europe's Building Stock

#### *2.1.1.2 Building characteristics*

The statistics confirm that a large part of the building stock in EU is relatively old « before 1960 » and 90 % before 1990. Each year, new constructions in Europe represent about 1% of the building stock. In this context, several analyses on building stock and energy performance of buildings by age were included by the Buildings Performance Institute Europe (BPIE). Older buildings are responsible of a significant amount of energy; hence, they have significant potential for energy efficiency improvements.

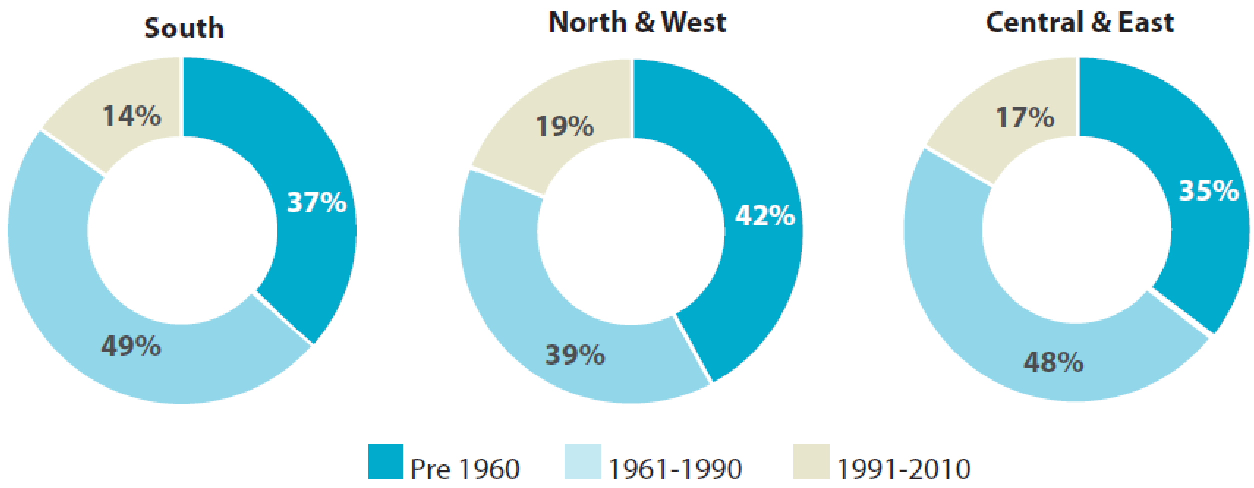



Figure 2: Age distribution of building stock in Europe [1]

The structure of ownership and occupancy is a key parameter to estimate renovation potential. A large part of the residential stock is held in private ownership while 20% is allocated to 'pure' public ownership [1]. Social housing is typically fully owned by the public sector but there is an increasing trend towards non-public involvement as is the case in Ireland, England, Austria, France and Denmark while in the Netherlands social housing is fully owned by private sector.
Moreover, at least 50% of residential buildings are occupied by the owner in all countries. Countries with the biggest share of private tenants are Switzerland, Greece and Czech Republic and countries with significant portions of public rented dwellings are Austria, the UK, Czech Republic, The Netherlands and France.
The ownership profile in the non-residential sector is more heterogeneous and private ownership can span from as low as 20% to 90% from country to country.

### 2.1.2 Renovation market

#### *2.1.2.1 Rates and depth of renovation*

In case of residential buildings, the rate of new construction is 1-1.5% and 0.1% for demolition activity. The annual energy consumption for all purposes in the EU is 17.793 kWh per active dwelling and 0.24€/kWh is the median cost per unit of energy. The non-residential buildings represent 25% of the total floor area of the EU's building stock and the average energy consumption is about 280 kWh/m$^2$.

The Energy Efficiency Directive EED considered that renovation is a key and main solution for reducing energy consumption; ensure building energy efficiency and another important way to tackle fuel poverty. The strategy of EED aims at a 20% improvement in energy efficiency by 2020 and 27% by 2030. Nevertheless, the renovation rate in EU is still low, and is about 1% - 2% per year of the building stock. Moreover, the solutions used for the process of renovation do not allow to achieve the maximum energy saving.
The following graph represents the different rates of renovation in the European countries.

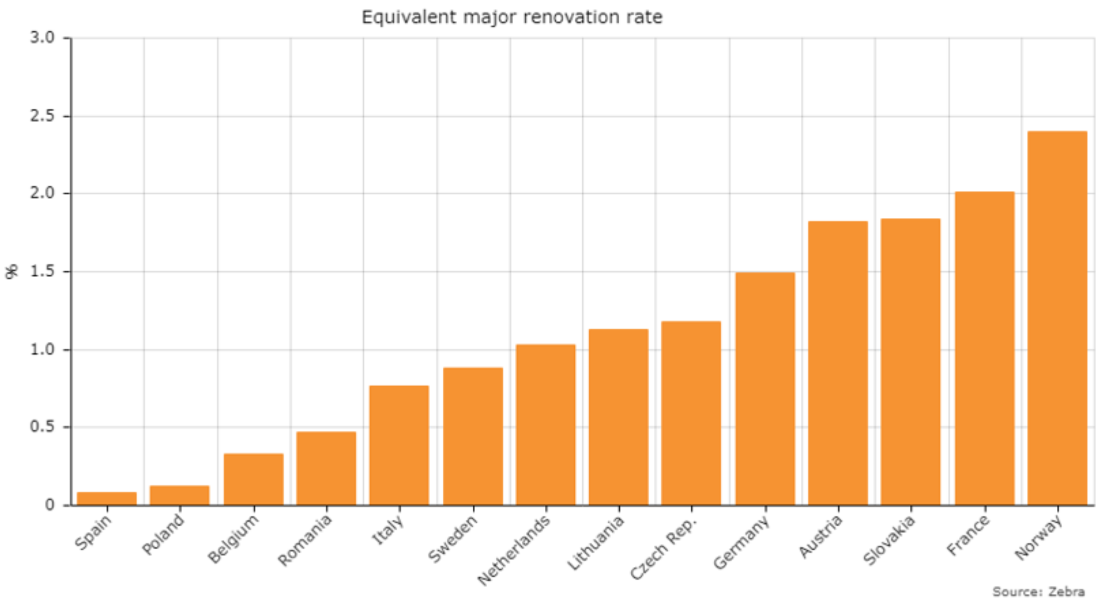



Figure 3: Major renovation rates of residential buildings

To support the European strategies for building renovation, amongst others, two projects was developed to contribute to achieving the EU energy goals:

- The BUILD2LC project based on improving energy efficiency of public buildings by adapting a renovation approach.
- The ZEROCO2 project focuses on the energy performance of buildings by the Promotion of near zero CO2 emission.

The definition of energy efficient renovation varies across EU legislation and in practice, with a variety of 'depths' of renovation and less extensive renovation. According to the BPIE, there is several levels of renovation:

- Minor renovations: the implementation of 1 or 2 measures with average costs of 60€/m$^2$ and the reduction of energy is between 0-30%.
- Moderate renovations: utilization of 3-5 improvement with average costs of 140€/m$^2$ and the reduction of energy is between 30-60%.
- Extensive renovations: represents a package of measures working together with average costs of 330€/m$^2$ and the reduction of energy is between 60-90%
- Almost Zero-Energy Building renovations: the aim is to reduce energy consumption and carbon mission levels to close to zero by replacement of all elements and installation of renewable energy technologies with average costs of 580€/m$^2$.

The following figure illustrates the market share renovation in the EU.

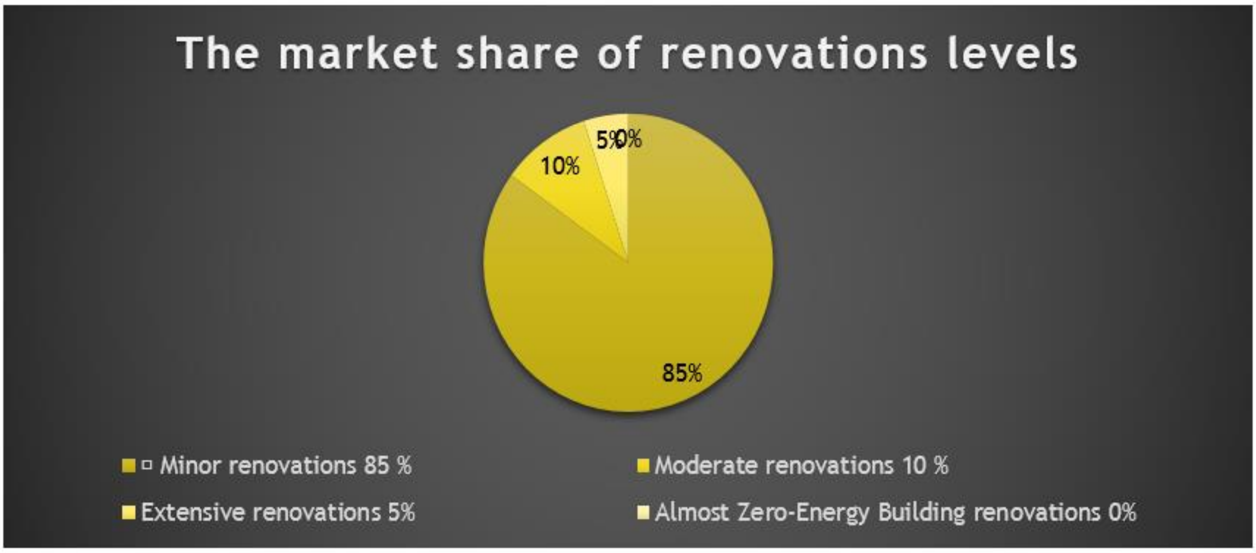



Figure 4: Market renovation levels

A recent study estimated that the EU energy renovation market was worth approximately EUR 109 billion in 2015, consisting of 882,900 jobs. The French, German and Italian energy renovation markets account for almost half of the total. The German market is by far the largest, accounting for 22% of the total.
Renovation accounts for 57% of the total construction market. Residential buildings account for 65% of the renovation market in 2015.
It has been estimated that the annual investment in the energy renovation of the building stock will need to grow from EUR 12 billion (~30 € per capita) (in 2014) to EUR 60 billion (~150 € per capita) in order to meet the EU target of a 20% energy efficiency improvement by 2020.

#### 2.1.2.2 Benefits of renovation

The studies confirmed that the renovations can affect in a good way different part in our lives. By 2050, it will reduce the final energy consumption by 75% and also lead to a 95% reduction in gas consumption. Furthermore, the construction sector utilizes a high percentage of material (65% of total aggregates and 20% of total metals).
In this context, less material is required per square meter than for new constructions.
In addition, some studies estimate that for each million euro invested, 12-17 jobs are generated. Also, the improvement in energy efficiency lead to improved indoor quality and thermal comfort which implies a better productivity which varies between 8-11%. The health benefits due to the reduction of fossil fuels are considered for the renovation.

#### 2.1.2.3 Barriers and challenges to renovation

The European building stock has a urgent need of renovation, as we can conclude. The renovation approach represents a lot of benefits and is considered as a key solution to solve many problems and achieve the EU goals. In contrast, the application of this approach is limited by different barriers. We can mention the following barriers:

- Financial barriers (renovation costs- Access to finance – Low energy prices)

- Technical barriers (Lack of technical solutions- Cost of technical solutions- lack of knowledge of construction professionals)
- Process barriers (Fragmentation of the supply chain- Burdening of home owners)
- Regulatory barriers (varying ambition of performance requirements – multiple definitions for renovation).

## 2.2 STATE OF THE ART OF ENERGY AND RENOVATION CONTEXT IN FRANCE

The building sector in France is one of the key consumers of energy and causes a significant amount of greenhouse gas emissions as show in in the following figure:

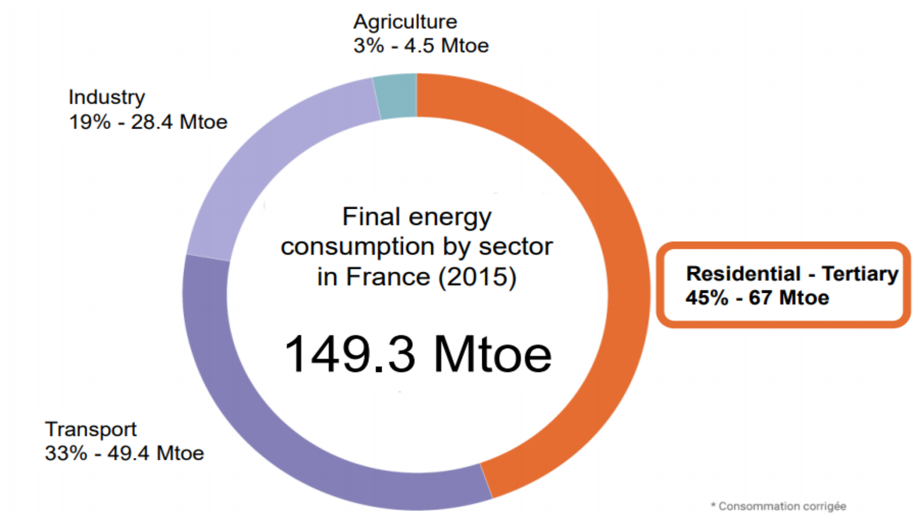



Figure 5: Final energy consumption by sector in France (2015)

Source : Ministère de l'environnement, de l'énergie et de la mer.

### 2.2.1 The building stock

#### *2.2.1.1 Building typology*

Buildings can be classified according to their geometric characteristics, which affect heating consumption. The TABULA project has defined four classes of buildings: Single-Family house (SFH), Terraced house (TH), Multi-Family House (MFH) and Apartment Block (AB).

| | SFH | TH | MFH | AB |
|---|---|---|---|---|
| Number of dwellings | 13 174 855 | 3 372 455 | 4 393 721 | 8 337 434 |
| Area of dwellings / m² | 1 376 440 928 | 330 182 300 | 275 194 440 | 548 731 884 |

Figure 6: Number of buildings according to typology [4]

### 2.2.1.2 Building characteristics

The residential building stock can be classified according to four main periods:

- Old buildings built before 1850: characterized by a great disparity of the building materials and methods used according to regions.
- Old buildings built between 1850 and 1948: industrialization in building construction and generalization of construction methods all over France
- buildings built between 1949 and 1974
- Isolated buildings: In 1974, the first thermal regulation (RT 1974) was introduced forcing buildings to have thermal insulation

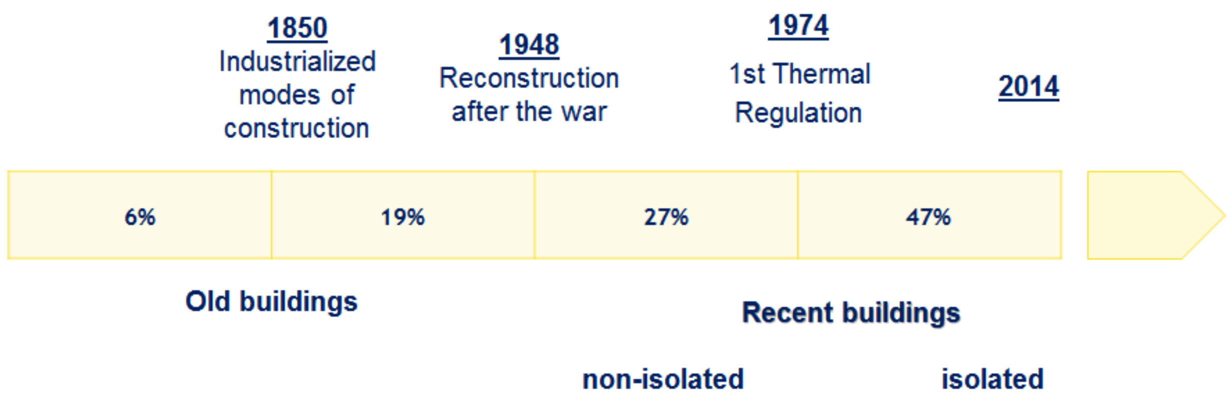



Figure 7: Classification of buildings according to age construction [4]

According to CEREN values for year 2016, the 51% of buildings stock in France were built before 1975, 29 % between 1975 and 1998 and 20% after 1999 0.

Therefore, the energy consumption depends on the period of construction. The buildings built before 1975 consumes between 400 to 900 kWh/m²/year, and the buildings built after 1975 need around 150 kWh/m²/year. The statistics show that 50% of energy consumption in buildings in France is mainly caused by heating that generally based on gas, electricity and oil.

## 2.2.2 Renovation market

To reduce consumption in this key sector, two scenarios were proposed and implemented by 2030 and then by 2050 based on the renovation of existing building stock and the design of high-energy performance new constructions.

- Ambitious targets to reduce energy consumption by 2030: 350,000 new dwellings are built each year and 500,000 dwellings per year would be retrofitted to be more energy efficient.
- Reduction of average consumption per square meter in housing by over 60% between 2010 and 2050, dropping from 191 kWh/m² of final energy per year to 75 kWh/m² per year, all uses included. By 2050, the housing stock consists of two main types of buildings: low-energy buildings and positive-

energy buildings (LEB/PEB), and renovated buildings. Energy consumption for the entire stock of 36,000,000 dwellings is thus divided into two main categories:

- Renovated buildings, a stock of 27,000,000 dwellings built before 2020.
- New buildings, comprising 9,000,000 dwellings.

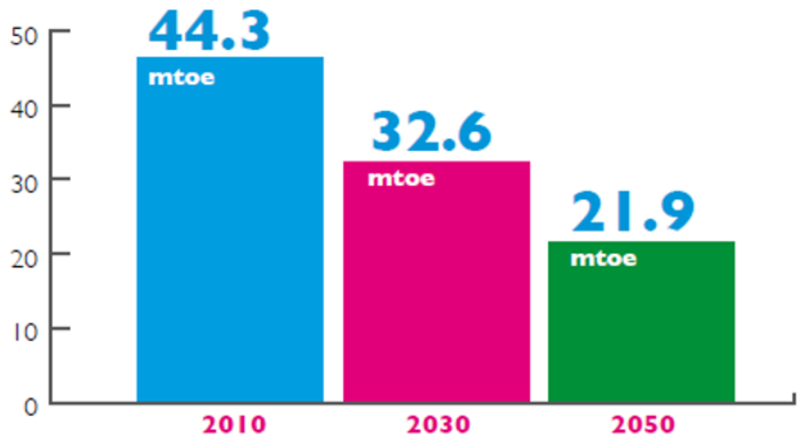



Figure 8: Energy consumption in the residential sector in 2010,2030 and 2050 (final Mtoe) (Source:ADEME)

For the building stock in France, the French government adopted "The Habitat energy renovation plan "in 2013 setting several goals:

- 400 000 housing must be renovated per year from 2013 and 500 000 per year from 2017.
- Obliges renovations for the buildings that consume more than 330 kWh /m²/year before 2025.
- Envisage – 38% of energy consumption for buildings and -50% of greenhouse gas emissions.
- 800 000 of social housing will be renovated by 2020 to minimize their energy consumption from 230 kWhep/m²/year to 150 kWhep/m²/year.

In this context, different activities for supporting the renovation approach were also proposed:

- OPEN is « Observatoire Permanent de l'amélioration Energétique du logement» was created in 2006 to describe the quantity and the quality of the energy renovation in the residential private buildings.
- A Guidelines and norms for quality of thermal renovation of old buildings was established.
- A Website for general public about renovation information "Renovation Info Service".
- A national number to access to the renovation service (0810 140 240).
- More than 150 « points renovation info service » (PRIS) were created and spread throughout France.

## 2.3 STATE OF THE ART OF ENERGY AND RENOVATION CONTEXT IN ITALY

### 2.3.1 The building stock

#### *2.3.1.1 Building typology*

The TABULA project has defined four classes of buildings for Italy: Single-Family house (SFH), Terraced house (TH), Multi-Family House (MFH) and Apartment Block (AB).

Three climate zone were considered for building classification according to TABULA project: middle climate zone, alpine zone and Mediterranean zone.
The table below shows the number of buildings classified by climate zones.

Table 1: Number of buildings classified by climate zones

| | Mediterranean zone | | Middle zone | | Alpine zone | |
|---|---|---|---|---|---|---|
| | SFH 1 apartment | MFH ≥ 2 apartments | SFH 1 apartment | MFH ≥ 2 apartments | SFH 1 apartment | MFH ≥ 2 apartments |
| Number of buildings | 3,746,505 | 2,953,382 | 2,673,446 | 2,560,209 | 121,795 | 132,361 |

### 2.3.1.2 Building characteristics

Eight construction age are defined 0:

- class I, up to 1900—the 19th Century.
- class II, from 1901 to 1920—the beginning of the 20th century.
- class III, from 1921 to 1945—the period between the two world wars.
- class IV, from 1946 to 1960—the post-war period and the reconstruction.
- class V, from 1961 to 1975—towards the oil crisis.
- class VI, from 1976 to 1990—first Italian regulations on energy efficiency.
- class VII, from 1991 to 2005—recent regulations on the energy performance of buildings in Italy (from Law No. 10/1991 to the Legislative Decree No.192/2005).
- class VIII, after 2005—more restrictive energy performance requirements (implementation decrees of Legislative Decree no. 192/2005 and regional laws).

Table 2: Repartition of the building stock according to age of construction and typology 0

| Age of Construction | Single Family House | House Terraced | Multi-Family House | Apartment Block |
|---|---|---|---|---|
| Before 1919 | 10% | 27% | 56% | 7% |
| From 1919 to 1945 | 12% | 23% | 51% | 14% |
| From 1946 to 1961 | 12% | 11% | 52% | 25% |
| From 1962 to 1971 | 12% | 7% | 51% | 30% |
| From 1972 to 1981 | 15% | 7% | 54% | 24% |
| From 1982 to 1991 | 17% | 7% | 52% | 24% |
| From 1991 to 2000 | 16% | 6% | 56% | 22% |
| After 2001 | 16% | 6% | 56% | 22% |

## 2.3.2 Renovation market

We can define two levels of renovation actions: standard and advanced.
For building envelope, standard renovation consists on the application of insulation materials in order to reach an U-value of 0.33 W/($m^2$K) for walls, 0.3 W/($m^2$K) for floors and roofs and the replacement of windows and doors to reach an U value of 2 W/($m^2$K). Advanced renovation improves the insulation of the building envelope by considering an U value of 0.25 for walls.

For heating system, the standard and advanced renovation includes, among others, the replacement of radiators with radiant heating panels and the insulation of the distribution subsystem.
The condensing boiler and air-to-water heat pump are considered for standard renovation actions. Regarding the advanced renovation, the following heat generators are considered:

- Geothermal heat pump
- Geothermal heat pump coupled with thermal solar plant
- Condensing boiler coupled with thermal solar plant
- Air-to-water heat pump coupled with thermal solar plant

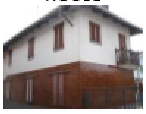
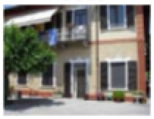
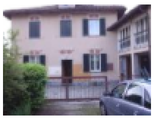
| Building-type | *"Standard" refurbishment* | | *"Advanced" refurbishment* | |
|---|---|---|---|---|
| | HEATING SYSTEM | DHW SYSTEM | HEATING SYSTEM | DHW SYSTEM |
| SINGLE-FAMILY HOUSE  up to 1900 | gas central heating, condensing boiler, insulated pipes (after 2005, horizontal strings in heated rooms) | gas condensing boiler - dhw distribution with circulation, pipeline inside of thermal envelope | central heating, condensing boiler + thermal solar plant, insulated pipes (after 2005, horizontal strings in heated rooms) | thermal solar plant + condensing boiler - dhw distribution with circulation, pipeline inside of thermal envelope |
| SINGLE-FAMILY HOUSE  1901-1920 | gas central heating, condensing boiler, insulated pipes (after 2005, horizontal strings in heated rooms) | gas-fired instantaneous water heater, condensing - dhw distribution without circulation | central heating, ground source heat pump, insulated pipes (after 2005, horizontal strings in heated rooms) | ground source heat pump - dhw distribution with circulation, pipeline inside of thermal envelope |
| SINGLE-FAMILY HOUSE  1921-1945 | central heating, air source heat pump, insulated pipes (after 2005, horizontal strings in unheated rooms) | gas-fired instantaneous water heater, condensing - dhw distribution without circulation | central heating, ground source heat pump + thermal solar plant, insulated pipes (after 2005, horizontal strings in unheated rooms) | thermal solar plant + ground source heat pump - dhw distribution with circulation, fraction of pipeline outside of thermal envelope |
| SINGLE-FAMILY HOUSE  1946-1960 | gas central heating, condensing boiler, insulated pipes (after 2005, horizontal strings in unheated rooms) | gas condensing boiler - dhw distribution with circulation, fraction of pipeline outside of thermal envelope | central heating, condensing boiler + thermal solar plant, insulated pipes (after 2005, horizontal strings in unheated rooms) | thermal solar plant + condensing boiler - dhw distribution with circulation, fraction of pipeline outside of thermal envelope |
| SINGLE-FAMILY HOUSE  1961-1975 | central heating, air source heat pump, insulated pipes (after 2005, horizontal strings in heated rooms) | air source heat pump - dhw distribution with circulation, pipeline inside of thermal envelope | central heating, air source heat pump + thermal solar plant, insulated pipes (after 2005, horizontal strings in heated rooms) | thermal solar plant + condensing boiler - dhw distribution with circulation, pipeline inside of thermal envelope |
| SINGLE-FAMILY HOUSE  1976-1990 | central heating, air source heat pump, insulated pipes (after 2005, horizontal strings in unheated rooms) | air source heat pump - dhw distribution with circulation, fraction of pipeline outside of thermal envelope | central heating, air source heat pump + thermal solar plant, insulated pipes (after 2005, horizontal strings in unheated rooms) | thermal solar plant + condensing boiler - dhw distribution with circulation, fraction of pipeline outside of thermal envelope |

Figure 9: Market renovation actions [4]

## 2.4 STATE OF THE ART OF ENERGY AND RENOVATION CONTEXT IN SPAIN

Spain enjoyed economic stability from the 1990s up to 2008, year in which the country experienced a recession, which lasted for approximately 5 years. In this timespan, Spain has gradually decreased its dependence on energy imports by 10%, lowering to 70% thanks to the boost of renewable energy supply.

According to the International Energy Agency (IEA) report from 2016 0, Spain has built a large, well-diversified power generation fleet and a very reliable power system. The country has managed to successfully integrate a large share of wind and solar power while limiting renewable decrease. As the country has relatively low cross border capacity, variations in power generation have to be dealt with largely within the Iberian system. This situation has recently improved, however, and more interconnections with France are being planned.

The cost of electricity had been accumulating since 2001 and increased to unprecedented levels due to the economic recession. In 2013, the cost of electricity had increased by 221% compared to 2005, while revenues only experienced a 100% raise. This increase was mainly due to the government's efforts to subside renewable energies. In order to try to halt this increase and regulate costs, the government temporarily stopped subsides for new installations. Furthermore, it reduced payments for transmission and distribution network activities, increased access tariffs and introduced a 7% tax on electricity generation (22% for hydropower). Nevertheless, the deficit grew to EUR 26 billion by the end of 2012.

In July 2013, the government introduced a broader electricity market reform package. The reform reduced the remuneration and compensation for the activities in the electricity system by several billion euros per year. It also introduced the principle of "no new cost without a revenue increase". Importantly, the reform introduced a new way of calculating compensation for renewable energy, waste, and co-generation (combined production of heat and power). With some exceptions, by mid-2015 the comprehensive reform had been implemented. The reform has reached its aim: the sector's costs and revenues are back in balance, and the accumulated deficit, which peaked at the end of 2013 at EUR 29 billion or 3% of GDP, should gradually disappear over the next 15 years.

As a consequence of the high level of costs in the electricity system, end-user prices in Spain are among the highest in IEA member countries. The government could reform end-user prices by eliminating any cost components that are unrelated to the supply of electricity to final users, recovering them via more appropriate mechanisms. Spain should revisit its renewable energy goals: the burden could be shared more evenly across sectors, which primarily implies a stronger focus on limiting oil use in the transport sector.

Creating single markets in electricity and natural gas has long been a priority for the European Union. For obvious reasons, physical cross-border capacity in electricity is essential not only for market integration but also for renewable energy integration and security of supply. Spain's electricity interconnection capacity remains very low at around 4% of installed capacity in 2014. Until very recently, efforts to increase interconnection capacity with France have had few results. In a welcome development, the 1.4 gigawatts (GW) Santa Logaia–Baixas interconnection was inaugurated in February 2015 – the first new interconnection in almost three decades. New momentum for additional interconnections is evident: the October 2014 European Council agreed on a target of a 10% share of interconnection capacity in total installed generation capacity in every member country by 2020.

Spain´s current measures to reduce energy-related CO2 emissions focus on energy efficiency and renewable energy. Spain is set to meet the 2016 target for 9% final energy savings in the non-emissions trading scheme (ETS) sector from the early 2000s levels. In 2013, it had already reached savings of 10.1%, and the government expects an increase to 15.5% in 2016. Nonetheless, current policies and measures are not enough to meet the target of reducing GHG emissions by 10% from 2005 to 2020 in the non-ETS sector. Furthermore, Spain set the objective of reaching 20% of final energy consumption derived from renewables and to improve energetic efficiency by 20%. This is evident from the scenarios laid out in Roadmap 2020, which was adopted in October 2014.

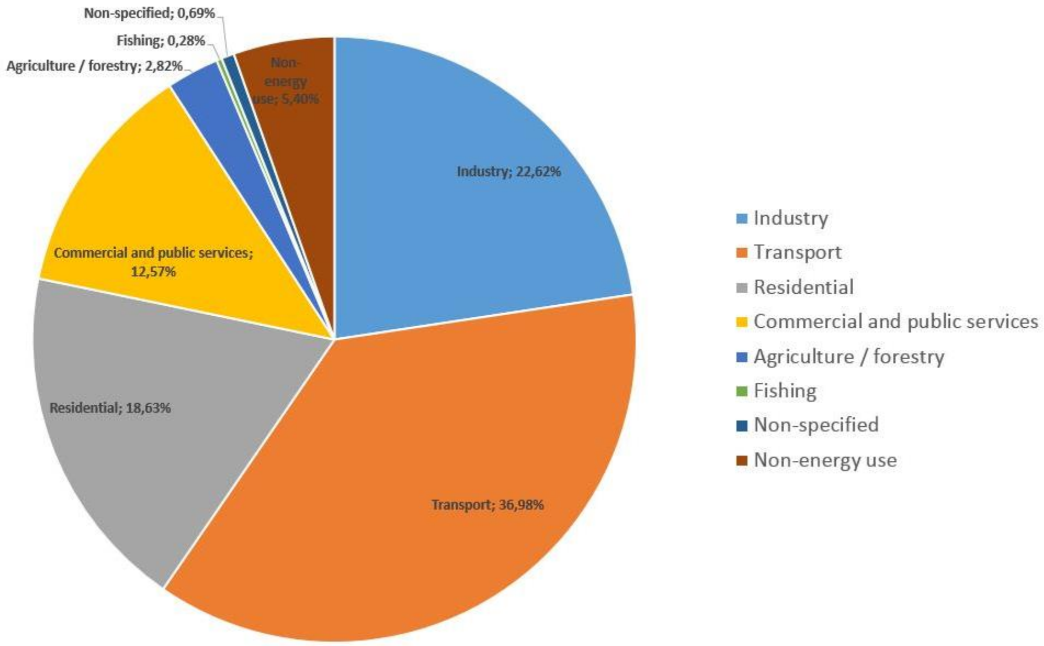



Figure 10: Spanish Total Final Energy Consumption (TFEC) by sector. [8]

### 2.4.1 The building stock

#### *2.4.1.1 Building typology*

The results presented in Table 3 and 4 show the information published by the Spanish Ministry of Development in the Building Construction Statistics report of 2018 0. The information was obtained from the data collected from the Major Works Permits granted by each Town Council. These tables present the number of building permits granted by the Spanish government from 2013 to 2017, although information for previous years is also available. This information shows that for 2017, out of the total number of permits granted by the Spanish government, renovation accounted for 41% of all buildings and 15% of households.

Table 3: Number of households according to type of construction.

| Year | New Buildings | | | | | Total Building Renovation works (2) | Total Demolition works (3) | Total Households (1+2+3) |
|---|---|---|---|---|---|---|---|---|
| | TOTAL (1) | Residential Buildings | | | Collective and Non Residential | | | |
| | | Total | Single Family | Multifamily | | | | |
| **2013** | 31,236 | 31,213 | 14,231 | 16,982 | 23 | 5,286 | 6,424 | 30,098 |
| **2014** | 33,643 | 33,643 | 13,352 | 20,291 | -- | 6,065 | 5,758 | 33,95 |
| **2015** | 36,065 | 36,059 | 15,338 | 20,721 | 6 | 6,137 | 5,593 | 36,609 |
| **2016** | 57,209 | 57,182 | 19,502 | 37,68 | 27 | 7,942 | 6,634 | 58,517 |
| **2017** | 63,063 | 63,056 | 21,909 | 41,147 | 7 | 9,501 | 7,205 | 65,359 |

Table 4: Number of buildings according to type of construction.

| Year | New Buildings | | | | | | Buildings for Renovation | Buildings to Demolish |
|---|---|---|---|---|---|---|---|---|
| | TOTAL | Residential Buildings | | | | Non Residential Buildings | | |
| | | Total | Family Household | Permanent Collective Residence | Temporal Collective Residence | | | |
| **2013** | 24,052 | 16,267 | 16,012 | 55 | 200 | 7,785 | 25,227 | 5,725 |
| **2014** | 22,594 | 15,009 | 14,901 | 19 | 89 | 7,585 | 26,136 | 5,279 |
| **2015** | 24,823 | 17,077 | 16,971 | 25 | 81 | 7,746 | 25,825 | 5,1 |
| **2016** | 29,959 | 22,105 | 21,967 | 29 | 109 | 7,854 | 28,156 | 6,448 |
| **2017** | 33,095 | 24,946 | 24,778 | 19 | 149 | 8,149 | 28,581 | 6,989 |

#### *2.4.1.2 Building characteristics*

Until recently, Spain lacked detailed studies concerning the building typology of the country. Several regional studies existed, however a broader study was presented by the "Instituto Valenciano de la Edificacion", as a typological classification of residential buildings elaborated during the European project called TABULA (predecessor of EPISCOPE). The general typology of buildings in the Spanish territory is presented in this project.

Furthermore, an approximation of the number of buildings under each typology was carried out during the projects "Proyecto Rehenergía (Ministerio de Vivienda)" and "Proyecto Retrofit (Energía Inteligente Europa)", in 2005 and 2006 respectively. Both projects had the common goal of studying the potential of energetic building rehabilitation. Finally, the "Proyecto SPAHOUSEC" (Analysis of the Energy Consumption in the Spanish Households) focused on the energetic consumption of the more than 17 million Spanish households under the major climactic zones: North Atlantic, Continental and Mediterranean. The results were coupled with the TABULA project.
According to the Spanish National Institute of Statistics 0, which carried out the population and housing census on 2011, the building stock can be divided into the following periods:

Table 5: Dwelling stock by construction period.

| Construction period | Proportion of dwelling stock, % |
|---|---|
| Before 1950 | 12% |
| 1951 - 1960 | 8% |
| 1961 - 1970 | 15% |
| 1971 - 1980 | 21% |
| 1981 - 1990 | 13% |
| 1991 - 2000 | 14% |
| After 2000 | 17% |

Furthermore, the European *Inspire* Project, which used the aforementioned statistics as a reference, defined the following division for the building stock ownership:

Table 6: Ownership of buildings in Spain.

| Building age | Rented | Owned | Other |
|---|---|---|---|
| 1950s | 51% | 46% | 3% |

| | | | |
|---|---|---|---|
| 1960s | 41% | 52% | 7% |
| 1970s | 30% | 63% | 7% |
| 1980s | 21% | 73% | 6% |
| 1990s | 12% | 82% | 7% |

According to the EPISCOPE project, last updated in 2014, the distribution of households according to climate is shown in Table 7.

Table 7: Distribution of households according to climatic zone

| | Atlantic climatic zone | Continental climatic zone | Mediterranean climatic zone | Building stock total |
|---|---|---|---|---|
| No. of households | 2,253,421 | 5,782,834 | 9,163,375 | 17,199,630 |

The Ministry of development provides the number of households up to 2017, however the information is not divided according to climatic zone. The Spanish building stock can be observed in the following table. Previous and more detailed information can be found in the Ministry's website.

Table 8: Estimated total households by provinces.

| | 2013 | 2014 | 2015 | 2016 | 2017 | % of total building stock (2017) |
|---|---|---|---|---|---|---|
| NATIONAL TOTAL | 25 441 306 | 25 492 335 | 25 541 915 | 25 586 279 | 25 645 100 | 100,00% |
| Andalucía | 4 394 515 | 4 401 817 | 4 407 793 | 4 413 250 | 4 422 047 | 17,24% |
| Aragón | 787 938 | 790 341 | 792 179 | 794 012 | 795 925 | 3,10% |
| Asturias (Principado de ) | 621 278 | 621 859 | 622 383 | 622 769 | 624 001 | 2,43% |
| Balears (Illes) | 591 709 | 592 963 | 594 469 | 595 630 | 597 501 | 2,33% |
| Canarias | 1 045 619 | 1 046 356 | 1 047 307 | 1 047 838 | 1 049 945 | 4,09% |
| Cantabria | 361 673 | 362 356 | 363 195 | 363 852 | 364 468 | 1,42% |
| Castilla y León | 1 735 314 | 1 739 251 | 1 742 855 | 1 745 015 | 1 747 011 | 6,81% |
| Castilla-La Mancha | 1 260 106 | 1 262 964 | 1 265 793 | 1 267 805 | 1 270 032 | 4,95% |
| Cataluña | 3 888 233 | 3 893 959 | 3 899 624 | 3 905 544 | 3 915 370 | 15,27% |
| Comunitat Valenciana | 3 161 095 | 3 164 586 | 3 170 272 | 3 176 853 | 3 182 158 | 12,41% |
| Extremadura | 656 783 | 658 494 | 660 012 | 661 140 | 662 378 | 2,58% |
| Galicia | 1 616 838 | 1 619 573 | 1 620 454 | 1 621 564 | 1 623 679 | 6,33% |
| Madrid (Comunidad de) | 2 932 915 | 2 941 996 | 2 951 813 | 2 962 048 | 2 974 747 | 11,60% |
| Murcia (Región de) | 783 875 | 784 981 | 785 723 | 786 139 | 786 733 | 3,07% |
| Navarra (Comunidad Foral de) | 314 691 | 316 444 | 317 420 | 318 158 | 319 331 | 1,25% |
| País Vasco | 1 033 938 | 1 038 954 | 1 044 572 | 1 048 157 | 1 052 012 | 4,10% |
| Rioja (La) | 200 805 | 201 216 | 201 553 | 201 969 | 202 403 | 0,79% |
| Ceuta y Melilla | 53 981 | 54 225 | 54 498 | 54 536 | 55 359 | 0,22% |

## 2.4.2 Renovation market

### *2.4.2.1 Renovation potential*

Table 9: Number of permits according to type of works (information concerning demolition excluded)

| Year | TOTAL | New Buildings | | | Renovation | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | In buildings | | | In locals |
| | | Total | With previous demolition | Without demolition | Total | Previous partial demolition | Without Demolition | |
| **2013** | 51,726 | 19,889 | 2,505 | 17,384 | 24,395 | 10,040 | 14,355 | 4,852 |
| **2014** | 52,255 | 19,457 | 1,866 | 17,591 | 24,960 | 10,740 | 14,220 | 5,143 |
| **2015** | 53,099 | 20,606 | 1,885 | 18,721 | 25,091 | 10,893 | 14,198 | 4,804 |
| **2016** | 58,207 | 23,765 | 2,487 | 21,278 | 27,093 | 11,561 | 15,532 | 4,185 |
| **2017** | 60,259 | 25,392 | 2,540 | 22,852 | 27,731 | 12,128 | 15,603 | 3,728 |

According to data from the National Institute of Statistics, and consistent with the data presented by the European *Inspire* project in Table 9, 57% of homes in Spain are prior to 1980. Taking into account that the first Spanish legislation that required thermal insulation in buildings dates from 1979 (NBE-CT 79), a great number of households lack thermal insulation, except for those that have been renovated. From then on, thermal insulation became a construction requirement (39% of homes), but with much lower standards than the ones currently employed (only 4% of homes).

#### 2.4.2.2 Rates and depth of renovation

The Spanish government determines the depth of renovation according to the type of work carried out. The Ministry of Development determines six major categories. A brief example of recent years concerning the historical information provided by the Spanish government is presented in Table 10.

Table 10: Renovation works: N° of buildings according to type of work.

| Year | TOTAL | | EXTENSION | | REMOVALS | | Building Foundation | Building Envelope | Building Façades | N° of renovated or conditioned premises |
|---|---|---|---|---|---|---|---|---|---|---|
| | N° of Buildings | Area (thous. m2) | N° of Buildings | Area (thous. m2) | N° of Buildings | Area (thous. | | | | |
| **2014** | 26 136 | 1 183 | 6 029 | 927 | 1 367 | 255 | 4 167 | 9 955 | 8 797 | 5 143 |
| **2015** | 25 825 | 1 222 | 5 970 | 783 | 1 569 | 440 | 4 195 | 9 527 | 9 318 | 4 804 |
| **2016** | 28 156 | 1 358 | 6 851 | 1 024 | 1 412 | 333 | 4 299 | 9 673 | 9 182 | 4 185 |
| **2017** | 28 581 | 1 817 | 6 523 | 1 027 | 1 765 | 792 | 4 352 | 9 641 | 9 770 | 3 728 |

#### 2.4.2.3 Benefits of renovation

According to the report *Estimates on the sustainable rehabilitation of residential buildings in Spain*, led by Margarita de Luxán, in Spain, in 2005, 440,640,000 thousand tons of CO2 were produced, of which it is estimated that 6% corresponds to the residential sector (26,438,400 thousand tons of CO2). The reduction of emissions that would occur with a rehabilitation program in four years of 500,000 homes would imply an annual reduction of 4.45% and in 10 years of close to 50% 0.

Furthermore, renovation of household buildings under sustainable criteria, maintaining the walls and slabs, even if the interior partitioning is changed, all the carpentry works are replaced, insulation is provided and the facilities are changed, accounts for approximately 60 % of energy and pollution savings compared to new constructions. The possibilities of energy savings in the consumption for air conditioning, in rehabilitated buildings, is 60% of the current consumption, with the consequent decrease in derived pollution. Renovation minimizes the problems of uprooting and social unsustainability of populations with economic deficiencies particularly in cases such as Spain where the economic crisis had an important impact. Spain is the country of the European Union with the highest number of dwellings per inhabitant, 538 for every thousand citizens compared to the 432 on average registered by all European countries. In Spain, banks, construction companies and individuals own more than 3 million empty homes. Renovation involves acting on 24,000,000 homes in Spain, which is today one of the largest sustainable building proposals.

## 2.5 STATE OF THE ART OF ENERGY AND RENOVATION CONTEXT IN SLOVENIA

### 2.5.1 The building stock

The climate zones in Slovenia can roughly be divided in 3 main climate types, mild continental, sub-Mediterranean and Alpine. Most of the west and the entire east region (green) has a mild continental climate type (greatest difference between winter and summer temperatures). Coastal region has a sub-Mediterranean climate (yellow) where there is the effect of the sea on the temperature rates is visible – Soča Valley) and Alpine (violet) is present at the high mountains region mainly on the north of the count, region has a severe Alpine climate.

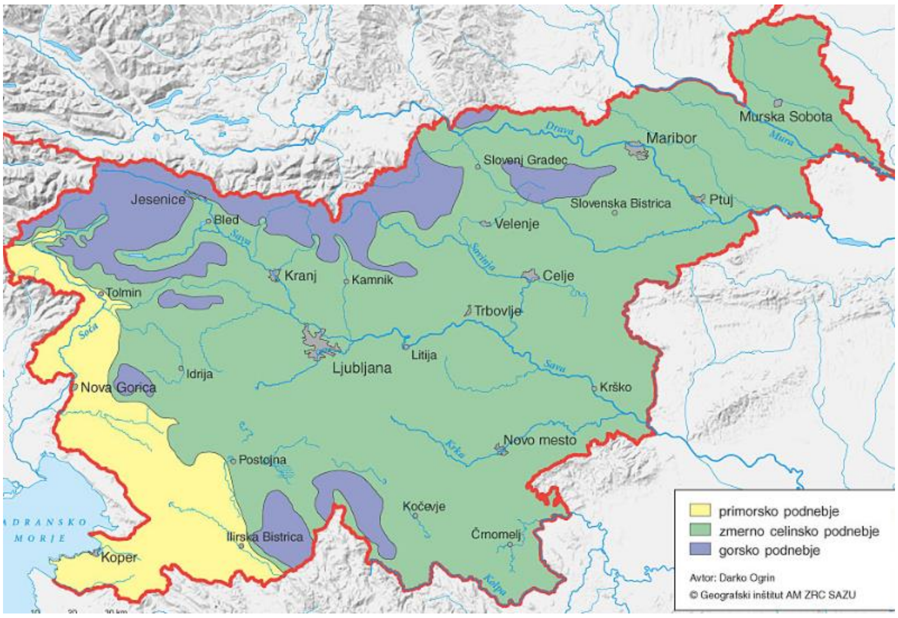
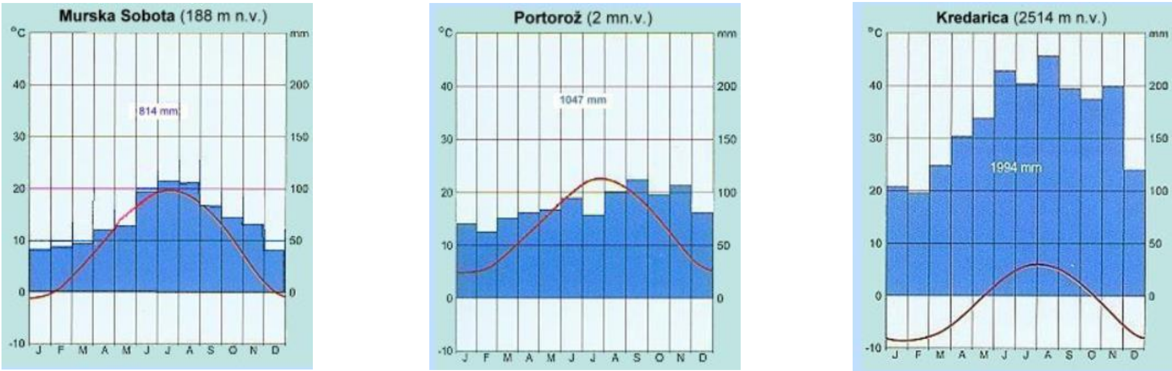



Figure 11: The climate zones in Slovenia [12]

Slovenia has a little over 2 million inhabitants, which presents 0.4% of the population in the European Union. Figure 12 shows regular annual air temperatures and precipitation measured at three different measuring points in the Slovenia. Each of them represents one of the climate types, Murska Sobota, Portorož and Kredarica, mild continental, sub-Mediterranean and Alpine, respectively.




Mild continental climate | Sub-Mediterranean climate | Alpine climate

Figure 12: Air temperatures and precipitation measured at Murska Sobota (left), Portorož (middle) and Kredarica (right) [14]

#### 2.5.1.1 Building typology

In Slovenia, nearly 40% of building area is residential. The number of dwellings in the country is 865572 and the number of buildings ~ 523983 0. Due to its small size and one prevailing climate type, in this project Slovenia has building typology determined only for this climate type - mild continental climate type. There are some slightly more specific building types in sub-Mediterranean (straight roof, because of the strong wind) and Alpine (larger roof inclination and higher roof, because of the large amounts of snow) climate. Type of ownership and tenure shows that, most of Slovenians own their dwellings 75.6%. However, the number started dropping over the last 10 years (10%).
Table 11 shows the assessment of the housing stock by the Statistical Office of the Republic of Slovenia.

Table 11: The general assessment of the housing stock

| Unit of measurement | Total | Urban settlements | Non-urban settlements |
|---|---|---|---|
| Number of dwellings | 865 572 | 451 878 | 413 694 |
| Average area of the dwelling [m$^2$] | 80.2 | 71 | 90.2 |
| Average area of the dwelling per person [m$^2$] | 33.3 | 30.6 | 36 |
| Average number of persons per dwelling | 2.4 | 2.3 | 2.5 |

Table 12 shows the number of the entire surface of dwellings in Single and double family houses and multifamily houses and apartment blocks in Slovenia.

Table 12: Surface area of dwellings in Slovenia

| Type of the summarised surface [1000 m$^2$] | 2018 | 2017 | 2016 | 2015 |
|---|---|---|---|---|
| Single and double family houses | 91.816 | 90.812 | 89.093 | 88.387 |
| Dwellings in multifamily houses and apartment blocks | 24.591 | 24.513 | 24.371 | 24.201 |

The tables below (Table 13 and Table 14) show the number of buildings in Slovenia. Obtained from the project EPISCOPE divided into categories by the age of construction.

Table 13: Age of building stock – number of buildings

| **number of buildings** | Single Family House | Terrace House | Multi Family House | Apartment Block | **Total** |
|---|---|---|---|---|---|
| -1945 | 140 605 | 91 163 | 82 684 | 114 561 | **429 013** |
| 1946-1970 | 21 567 | 99 | 12 974 | 11 383 | **46 023** |
| 1971-1980 | 7 505 | 8 301 | 2 394 | 47 | **18 247** |
| 1981-2000 | 10 693 | 5 142 | 2 105 | 2 248 | **20 188** |
| 2001-2008 | 1 152 | 14 | 930 | 885 | **2 981** |
| 2009-2014 | 1 060 | 826 | 256 | 4 | **2 146** |

Table 14: Age of building stock – number of apartments

| **number of apartments** | Single Family House | Terrace House | Multi Family House | Apartment Block | **Total** |
|---|---|---|---|---|---|
| -1945 | 150 283 | 99 013 | 88 604 | 118 970 | **456 870** |
| 1946-1970 | 22 093 | 102 | 14 897 | 12 800 | **49 892** |
| 1971-1980 | 8 354 | 9 078 | 2 575 | 56 | **20 063** |
| 1981-2000 | 60 531 | 39 591 | 16 238 | 18 320 | **134 680** |
| 2001-2008 | 9 233 | 84 | 43 683 | 35 085 | **88 085** |
| 2009-2014 | 50 667 | 38 962 | 12 397 | 1 077 | **103 103** |

Forecast model (until 2030) shows the predicted number of the households/dwellings and the number of persons in the average household Figure 13.

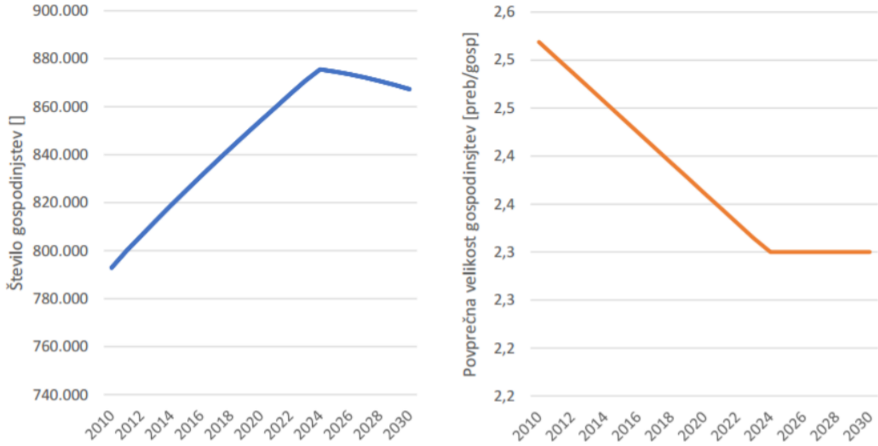



Figure 13: The predicted number of the households/dwellings and the number of persons in the average household [15]

### 2.5.1.2 Building characteristics

The building characteristics were determined based on the research performed by TABULA Web Tool. updated during the period of EPISCOPE 0. The typology and characteristics remain applicable.

TABULA project averaged the large building characteristics content and narrowed the data into 6 groups of buildings. that share a similar building type (single-family house (SFH) and terrace house (TH) or multifamily house (MFH) and apartment block (AB)) and neighbouring age groups ((1:-1945) and (2: 1946-1970) or (3: 1971-1980) and (4: 1981-2000) or (5: 2001-2008) and (6: 2009-)).

The chosen national representatives are shown in the joined figure below (Figure 14).

SFH 01

TH 01

MFH 01

AB 01

SFH 02

TH 02

MFH 02

AB 02

SFH 03

TH 03

MFH 03

AB 03

SFH 04

TH 04

MFH 04

AB 04


Figure 14: The typical representatives for Slovenia [15]

- **Building envelope**

The transparent surface to lateral surface area ratio of the building (T/W ratio) is shown in Table 15 below. The ratio is calculated based on the transparent wall area and external wall area.

Table 15: The ratio calculated based on the transparent wall area and external wall area

| Group | SFH-TH.01-2 | SFH-TH.03-4 | SFH-TH.05-6 | MFH-AB.01-2 | MFH-AB.03-4 | MFH-AB.05-6 |
|---|---|---|---|---|---|---|
| T/W ratio | 0.35 | 0.29 | 0.18 | 0.26 | 0.44 | 0.45 |

The envelope structure of the typical representatives of the typology and age groups is presented. The description includes the construction of the roof, external wall, floor, windows and door.
The roof of the single-family house (SFH) built until 1945 has wooden roof, wall out of stone and concrete floor without insulation and regular wooden window box. Typical SFH from period 1946-1970, has the roof out of concrete ceiling with thin insulation (2 cm), honeycomb thin brick wall, concrete floor on the ground with wooden floor and two pain wooden window. The buildings in 1971-1980 acquires a thin insulation (3 cm) on the external wall and on the ground floor. The next period to 2000, changes the roof material to pourus concrete ceiling with insulation (10 cm). The external wall has two leaves brickwork with medium insulation (5 cm) in-between. The floor insulation also increased to 5 cm. From year 2001 on, the buildings' structure started to expand according to the regulations from the national minimum requirement. The roof insulation has 20 cm. the wall and floor insulation 15 cm.

Up to 1945, the structure of terrace house (TH) is identical to the SFH. During the next period (1946-1970) the wooden roof is insulted with 8 cm and the concrete floor with 2 cm insulation. Until 1980, the insulation thickness of roof and floor increases to 12 cm and 5 cm, respectively. The wall type changes to the two leaves brickwork with medium insulation of 8 cm. In period 1981-2000, the roof with thick insulation (30 cm) is introduced. The honeycomb brick wall has thick insulation of 12 cm and the floor on the ground 10 cm insulation.

Similar as SFH and TH, multifamily house (MFH) constructed up to 1945 has wooden ceiling/roof and concrete floor. but the wall is out of brick. on the ground. The brick wall is added concrete up to 1970. From 1971 to 1980 the insulation is added on the floor (3 cm). From 1981 to 2000 the concrete ceiling and wall are added thin insulation (2 cm and 5 cm respectively). The insulation on the ground thickens to 5 cm.

Compared to SFH, TH and MFH, apartment blocks (AB) built until 1980 have a concrete ceiling/roof and wall without insulation. However, thin insulation (2 cm) was added between the apartment floor/ceilings. From 1981 to 2000. the concrete ceiling/roof and walls have increased insulation thickness (5 cm).

Up until 2000, the widows have either the wooden box or in some cases 2 panes and from 2001 on they have double glazing filled with argon and added low E coating. In some cases studied (SFH and MFH). the aluminium window with 2 panes and low e or PVC window with 2 panes and low E coating already occurred in period (1981-2000).

All of the building types (SFH, TH, MFH and AB) from 2009 have to insulate wooden cavities between rafters (cca. 12 cm) with additional 4 cm insulation layer on top. There has to be 15 cm of insulation (external insulated render system) on the wall and 6 cm of insulation below / alternatively: on top of the ceiling (in case of floor renovation).

Finally, all of building types during all periods until 2009, have standard doors without insulation. However, in 2 building types (TH and MFH) it is possible to observe the insulted door. The average dimensions of the building envelopes are presented in Table 16.

Table 16: Average dimensions of the building envelopes [18]

| | SFH-TH.01-2 | SFH-TH.03-4 | SFH-TH.05-6 | MFH-AB.01-2 | MFH-AB.03-4 | MFH-AB.05-6 |
|---|---|---|---|---|---|---|
| Roof [$m^2$] | 129.1 | 121.7 | 115.6 | 279.5 | 357.6 | 1372 |
| Wall [$m^2$] | 143 | 115.8 | 230.5 | 1323.5 | 1522.9 | 2244.6 |
| Window [$m^2$] | 50.3 | 33.6 | 40.8 | 348.9 | 662.8 | 1018.8 |
| Floor [$m^2$] | 117.2 | 119.3 | 123.8 | 278 | 380.9 | 1187.1 |

Table 17 below shows the non-refurbished U values (the original state of the buildings in Slovenia).

Table 17: Average U-values of the building envelopes [18]

| | SFH-TH.01-2 | SFH-TH.03-4 | SFH-TH.05-6 | MFH-AB.01-2 | MFH-AB.03-4 | MFH-AB.05-6 |
|---|---|---|---|---|---|---|
| Roof [W/($m^2$K)] | 1.68 | 0.39 | 0.18 | 1.58 | 1.5 | 0.17 |
| Wall [W/($m^2$K)] | 1.5 | 0.48 | 0.27 | 2.53 | 1.65 | 0.29 |
| Window [W/($m^2$K)] | 2.45 | 2.2 | 1.2 | 2.65 | 2.75 | 1.34 |
| Floor [W/($m^2$K)] | 1.68 | 0.61 | 0.26 | 1.55 | 0.93 | 0.25 |

Table 18 below describes the building systems distribution in percentage of buildings per time band and building type.

Table 18: The building systems based on time band and building type

| | Single Unit Houses | | | | | | Multi Unit Houses | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| percentage of buildings per building class | SUH.01 | SUH.02 | SUH.03 | SUH.04 | SUH.05 | SUH.06 | MUH.01 | MUH.02 | MUH.03 | MUH.04 | MUH.05 | MUH.06 |
| old wood or coal boiler | 45% | 30% | 35% | 25% | 20% | 50% | 26% | 9% | 2% | 14% | 0% | 0% |
| old oil or gas boiler | 32% | 42% | 42% | 49% | 37% | 17% | 53% | 58% | 84% | 69% | 86% | 100% |
| low energy boiler | 1% | 0% | 2% | 2% | 3% | 0% | 0% | 3% | 2% | 0% | 0% | 0% |
| condensation boiler | 0% | 0% | 1% | 0% | 6% | 0% | 0% | 0% | 0% | 1% | 0% | 0% |
| new biomass boiler | 4% | 2% | 4% | 5% | 11% | 0% | 7% | 1% | 2% | 0% | 0% | 0% |
| electric heater | 0% | 2% | 0% | 0% | 3% | 17% | 0% | 3% | 4% | 2% | 0% | 0% |
| heat pump air-water | 2% | 2% | 1% | 1% | 3% | 0% | 0% | 0% | 2% | 0% | 0% | 0% |
| heat pump water-water | 0% | 0% | 1% | 1% | 3% | 0% | 3% | 0% | 0% | 7% | 0% | 0% |
| heat pump water-water | 0% | 0% | 0% | 1% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| combined wood oil boiler | 8% | 18% | 10% | 10% | 11% | 0% | 2% | 6% | 2% | 4% | 0% | 0% |
| solar panels | 1% | 1% | 1% | 2% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| other | 8% | 2% | 3% | 2% | 3% | 17% | 9% | 17% | 2% | 4% | 0% | 0% |
| no data | 1% | 0% | 0% | 0% | 0% | 0% | 0% | 3% | 1% | 0% | 14% | 0% |
| total | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| | Single Unit Houses | | | | | | Multi Unit Houses | | | | | |
| percentage of buildings per building class | SUH.01 | SUH.02 | SUH.03 | SUH.04 | SUH.05 | SUH.06 | MUH.01 | MUH.02 | MUH.03 | MUH.04 | MUH.05 | MUH.06 |
| local | 32% | 15% | 8% | 9% | 9% | 13% | 51% | 44% | 27% | 24% | 0% | 0% |
| floor central | 12% | 11% | 8% | 10% | 9% | 0% | 25% | 16% | 20% | 27% | 69% | 100% |
| central | 56% | 72% | 81% | 80% | 82% | 88% | 14% | 14% | 11% | 32% | 31% | 0% |
| district heating | 0% | 1% | 3% | 2% | 0% | 0% | 5% | 25% | 42% | 17% | 0% | 0% |
| no data | 0% | 0% | 0% | 0% | 0% | 0% | 5% | 0% | 0% | 0% | 0% | 0% |
| total | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| | Single Unit Houses | | | | | | Multi Unit Houses | | | | | |
| percentage of buildings per building class | SUH.01 | SUH.02 | SUH.03 | SUH.04 | SUH.05 | SUH.06 | MUH.01 | MUH.02 | MUH.03 | MUH.04 | MUH.05 | MUH.06 |
| heat pump air-water | 9% | 7% | 6% | 8% | 11% | 0% | 12% | 0% | 6% | 11% | 0% | 0% |
| solar panels | 5% | 2% | 5% | 2% | 6% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| electric heater | 7% | 6% | 10% | 8% | 6% | 33% | 8% | 27% | 16% | 4% | 0% | 0% |
| fow-through gas boiler | 11% | 5% | 9% | 8% | 6% | 0% | 16% | 7% | 23% | 28% | 19% | 0% |
| same as heating | 65% | 77% | 69% | 72% | 72% | 67% | 52% | 66% | 55% | 52% | 81% | 100% |
| other | 2% | 2% | 2% | 2% | 0% | 0% | 12% | 0% | 0% | 4% | 0% | 0% |
| no data | 2% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| total | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| | Single Unit Houses | | | | | | Multi Unit Houses | | | | | |
| percentage of buildings per building class | SUH.01 | SUH.02 | SUH.03 | SUH.04 | SUH.05 | SUH.06 | MUH.01 | MUH.02 | MUH.03 | MUH.04 | MUH.05 | MUH.06 |
| natural ventilation | 100% | 100% | 100% | 100% | 92% | 100% | 100% | 100% | 99% | 99% | 100% | 100% |
| mechanical ventilation (no heat recovery) | 0% | 0% | 0% | 0% | 3% | 0% | 0% | 0% | 1% | 1% | 0% | 0% |
| mechanical ventilation (with heat recovery) | 0% | 0% | 0% | 0% | 5% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| total | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |

- **Energy consumption**

The table below shows the energy indicators from years 2014-2017 [19]. The indicators holistically show the energy image of the country.

Table 19: The national energy indicators

| | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Produced energy (1000 toe) | 3681 | 3402 | 3585 | 3664 |
| Supplied energy (1000 toe) | 6572 | 6505 | 6728 | 6839 |
| Final energy consumption (1000 toe) | 4644 | 4748 | 4931 | 4922 |

| | | | | |
|---|---|---|---|---|
| Energy dependence (%) | 43.9 | 47.5 | 46.7 | 47.5 |
| Energy efficiency (%) | 70.7 | 73.0 | 73.3 | 72.0 |
| Energy intensity - Energy supply/GDP (toe/mio EUR 2010) | 181 | 176 | 176 | 171 |
| Energy intensity - Final consumption/GDP (toe/mio EUR 2010) | 128 | 128 | 129 | 123 |
| Electrical energy consumption / GDP (MWh/mio EUR 2010) | 347 | 349 | 344 | 328 |
| Energy supply per capita (toe/cap.) | 3.19 | 3.15 | 3.26 | 3.31 |
| Final energy consumption per capita (toe/cap.) | 2.25 | 2.30 | 2.39 | 2.38 |
| Electrical energy consumption per capita (kWh/cap.) | 6094 | 6250 | 6351 | 6348 |
| RES heating and cooling (%) | 32.42 | 33.93 | 34.02 | 33.25 |
| RES electrical energy (%) | 33.94 | 32.73 | 32.06 | 32.43 |
| RES transport (%) | 2.88 | 2.24 | 1.60 | 2.74 |
| RES total (%) | 21.54 | 21.89 | 21.29 | 21.55 |
| Carbon content in energy supply (t/toe) | 2.06 | 2.09 | 2.14 | - |

Slovenia in 2016 produced the following energy: nuclear energy (42%), coal (26%), renewable energy sources (including wood, wood residues, biogas and waste) (19%), hydro-energy (11%) and geothermal and solar energy (2%). The total amount of domestic resources available in 2016 is 3.585 ktoe or 150 PJ (= 42 TWh).
Slovenia does not hold enough primary energy sources to meet all the needs in Slovenia, so some less than half of them need to be imported. In 2016, Slovenia uses 53% of local energy sources, such as nuclear energy (22%), renewable energy sources (17%) and coal (14%). The country has 47% dependence on energy imports: the rest of the coal (3%), natural gas (10%) and oil products (34%).
In 2016, the total (local and imported) consumed primary energy in Slovenia results in 6 830 ktoe or 286 PJ (= 79 TWh). These are: oil products (34%), nuclear energy (22%), coal (17%), renewable energy sources (17%) and natural gas (10%). The structure of the 17% of renewable energy sources consists from: wood and the rest of biomass, hydro-energy (33%), geothermal energy (5%), bio-gasses (3%), solar energy (2%), bio-fuels (2%) and the rest (4%) of primary energy sources.
In 2016, electricity consumption per capita in Slovenia was 6 351 kWh. This means that each Slovenian resident spent on average 17 kWh of electricity per day. The amount of energy invested in electricity production was 3 194 ktoe or 134 PJ (= 37 TWh). The majority of electricity and heat is produced with nuclear power (47%), coal (34%) and hydro-energy (12%) (93% total). It should be borne in mind, that the energy consumed for the energy production (37 TWh) differs from the produced electricity (16 TWh), due to conversion rate characteristic of the individual energy sources.
In 2016, Slovenia produced 15 550 GWh or 56 PJ (= 1 337 ktoe) of electricity. By the type of energy power plant, the country produced energy with the nuclear power plant (35%), thermal power plants (33%), hydro power plants (30%), solar power plants (2%) and wind power plants (0%). Although in recent years, the number of solar power plants has been rising steadily, only 2% of electricity was produced using the sun.
The amount of energy for end-use in Slovenia in 2016 was 4 930 ktoe or 206 PJ (= 57 TWh). The largest energy consumption was in the transport sector (39%), particularly in road transport. The number of registered motor vehicles is increasing from year to year: at the end of 2016, 1,096,523 passenger cars were registered in Slovenia. The second largest consumer is industry (mainly manufacturing) with 25% of total end-use, followed by households with 23% and 13% with the rest of the consumption.
In 2016, the energy carriers in households are wood fuels (42%), electricity (24%), extra light fuel oil (10%), natural gas (10%), district heating (7%), liquefied petroleum gas (3%), heat from the environment (3%), solar

energy (1%) and coal (0%). Most of the energy in households is consumed by the space heating (65%) and domestic hot water (16%) consumption.
Table 20 shows the building stock divided based on the heating system.

Table 20: Building stock divided based on the heating system [19]

| | Number of dwellings (/) | Surface area ($m^2$) | (%) |
|---|---|---|---|
| Central heating system | 567825 | 44674988.77 | 65 |
| District heating system | 120918 | 9513539.86 | 14 |
| Local heating system | 134399 | 10574213.57 | 16 |
| | 823143 | 64762742.19 | The rest of the building stock (5%) is not heated |

Table 21 shows the building stock divided based on the centralization of the space heating in the building and periods of the construction in percentage within the entire construction period.

Table 21: Building stock divided based on the centralization of the space heating in the building and periods of the construction

| | Complete building stock | Old building stock (-1980) | New buildings (1980-) |
|---|---|---|---|
| local heating | 11% | 14% | 0% |
| floor central heating | 11% | 12% | 7% |
| central heating | 76% | 72% | 93% |
| district heating | 3% | 3% | 0% |

Table 22 reveals the main energy carriers within the single construction period.

Table 22: Main energy carrier for space heating divided by the periods of building construction

| | Complete building stock | Old building stock (-1980) | New buildings (1980-) |
|---|---|---|---|
| firewood | 50.57% | 53.05% | 36.59% |
| district heat | 2.17% | 2.59% | 0.00% |
| electricity | 1.57% | 1.38% | 9.86% |
| geothermal energy | 0.55% | 0.19% | 6.68% |
| fuel oil | 33.21% | 31.18% | 31.60% |
| wood briquettes | 0.13% | 0.08% | 0.00% |
| wood pellets | 0.54% | 0.43% | 0.00% |
| wood chips | 0.05% | 0.03% | 0.00% |
| petroleum | 0.06% | 0.08% | 0.00% |
| coal | 0.15% | 0.21% | 0.00% |
| solar energy | 0.32% | 0.34% | 0.00% |
| liquefied petroleum gas (LPG) | 1.29% | 1.07% | 3.75% |
| natural gas | 9.14% | 9.11% | 6.28% |

| | | | |
|---|---|---|---|
| wood residues | 0.06% | 0.09% | 0.00% |

Table 23 reports the national energy consumption of end use energy for building's space heating, space cooling and DHW in 2017.

Table 23: National energy consumption of end use energy for building's space heating, space cooling and DHW in 2017

| | Space heating | Space Cooling | DHW |
|---|---|---|---|
| Extra light fuel oil | 3757 | - | 526 |
| Natural gas | 3796 | - | 957 |
| Wood | 16790 | - | 2132 |
| Liquefied petroleum gas | 610 | - | 147 |
| Electrical Energy | 1210 | 218 | 2199 |
| Coal | 3 | - | 1 |
| District heating | 2752 | - | 556 |
| Solar energy | 11 | - | 447 |
| Heat from the surrounding area | 903 | - | 523 |
| Total | 29832 | 218 | 7488 |

The table 24 below contains the main heat generation system for space heating for the building stock.

Table 24: The main heat generation system for space heating for the building stock

| | Complete building stock | Old building stock (-1980) | New buildings (1980-) |
|---|---|---|---|
| conventional boiler for solid fuels (biomass and coal) | 35% | 38% | 37% |
| conventional oil boiler | 46% | 45% | 27% |
| low-temperature boiler | 1% | 1% | 0% |
| condensing boiler | 1% | 0% | 0% |
| special boiler biomass (firewood, wood pellet, wood chips) | 4% | 4% | 0% |
| electric boiler | 1% | 1% | 6% |
| heat pumps air - water | 2% | 1% | 11% |
| heat pump water - water | 1% | 0% | 0% |
| heat pump water - soil | 0% | 0% | 5% |
| heat pump air - air | 0% | 0% | 0% |
| Combination boiler for solid and liquid fuels | 10% | 10% | 5% |
| solar collectors - if they are used for heating | 1% | 1% | 0% |
| conventional gas boiler | 4% | 3% | 6% |
| other | 4% | 5% | 6% |

The typical values used values used for energy balance calculation of SFH and MFH in different time periods are shown in Table 25.

Table 25: Typical values used for energy balance calculation of SFH and MFH in different time periods 0

| | SFH-TH.01-2 | SFH-TH.03-4 | SFH-TH.05-6 | MFH-AB.01-2 | MFH-AB.03-4 | MFH-AB.05-6 |
|---|---|---|---|---|---|---|
| Utilisation dataset Internal temperature [°C] | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 |
| Reduction factor temp. | 0.83 | 0.88 | 0.89 | 0.92 | 0.94 | 1.00 |
| Air exchange rate (use) [1/h] | 0.40 | 0.40 | 0.40 | 0.4 | 0.5 | 0.6 |
| Internal heat sources [W/m²] | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 |
| Red. factor ext. shading | 0.60 | 0.60 | 0.60 | 0.60 | 0.60 | 0.60 |
| Energy need for DHW | 10.0 | 10.0 | 10.0 | 15.0 | 15.0 | 15.0 |
| Length of heating season [d/a] | 206 | 206 | 206 | 206 | 206 | 206 |
| External temp. during heating season | 4.3 | 4.3 | 4.3 | 4.3 | 4.3 | 4.3 |

The energy consumption for the entire national building stock characterised within the building types and construction periods are shown in the table below.

Table 26: Energy consumption for the entire national/Slovenian building stock

| Building type | Heating need ($Q_{nh}$) [GWh] | DHW final ($Q_{f.w}$) [GWh] | Lightning final (W.f) [GWh] | Final energy (Q.f) [GWh] | Primary energy [GWh] | $CO_2$ emissions [kt] |
|---|---|---|---|---|---|---|
| SUH.01 | 2.937 | 454 | 363 | 3722 | 4829 | 978 |
| SUH.02 | 2094 | 113 | 209 | 2538 | 3085 | 956 |
| SUH.03 | 1285 | 323 | 202 | 1534 | 2004 | 684 |
| SUH.04 | 154 | 57 | 36 | 199 | 264 | 71 |
| SUH.05 | 88 | 64 | 20 | 116 | 155 | 47 |
| MUH.01 | 1262 | 145 | 290 | 1767 | 2363 | 792 |
| MUH.02 | 356 | 64 | 40 | 410 | 517 | 151 |
| MUH.03 | 280 | 57 | 36 | 325 | 436 | 162 |
| MUH.04 | 95 | 28 | 16 | 133 | 181 | 68 |
| MUH.05 | 28 | 15 | 9 | 45 | 64 | 25 |
| Total | 8580 | 1320 | 1219 | 10791 | 13898 | 3934 |

## 2.5.2 Renovation Market

### *2.5.2.1 Renovation potential*

Within the following type groups, the building renovation potential (the energy inefficient buildings) is shown in percentage below:

- single-family houses 41%;
- multi-apartment buildings 40%;
- public sector buildings 38%;
- other non-residential buildings 34% and
- central government buildings (mandatory 3% renovation) 47%.

There are several different renovation strategies and projects for multifamily buildings.
The degree of renovation in the considered scenarios takes into account the renovation work on the components of the building's thermal envelope and the replacement of building systems. Considering the replacement of building systems, the study also takes into account the reduction in the use of fossil fuels and the increase in the share of renewable energy sources. It is envisaged to gradually reduce the use of heating systems with fossil fuels (ELKO boiler) and to increase the use of renewable energy technologies (heat pumps, biomass boilers), especially the use of biomass, as it is a very accessible resource.
The computational model of renovation rate in the national Long-term Strategy (hereinafter strategy) for the renovation of residential buildings is considered. The strategy envisages two scenarios. Scenarios for reference and intensive renovation rates for individual building classification (Figure 15). Left picture for single-family buildings and right for multi-family buildings. The different scenarios represent the share of renovated buildings according to the total useful floor area. The usable area of buildings subject to partial renovation is weighted by a factor of 0.5. The usable area of buildings subject to a complete or complete low-energy renovation is taken into account by a factor of [15], 0. The renovation rate for single-family buildings is 1.75% and for multi-family buildings 2.5%.

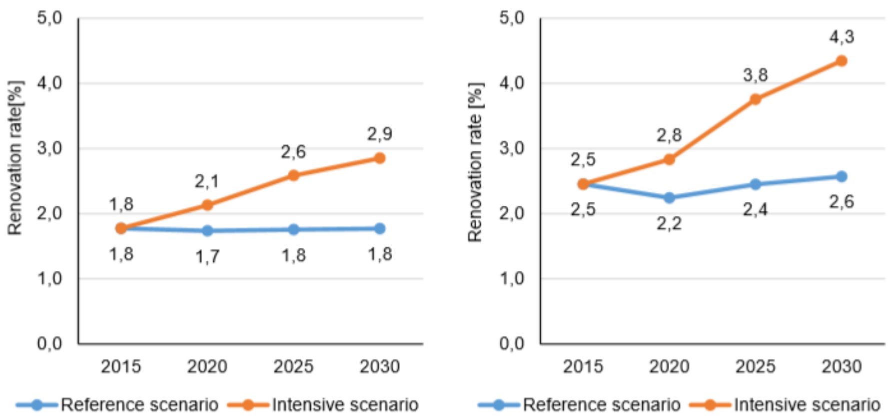



Figure 15: Renovation rate for single and multi-family buildings 2015-2030 [15]

Table 27 shows the number and level of renovated buildings within the Slovenian building stock based on the time bands.

Table 27: The level of renovation of the national building stock based on time period bands

| Time period | Level of renovation | SFH | MFH |
|---|---|---|---|
| up to 1945 | Not-renovated | 185 | 125 |
| | Renovated | 151 | 98 |
| | Improved Renovation | 77 | 75 |
| | NZEB Renovated | 35 | 25 |
| 1946 - 1970 | Not-renovated | 185 | 125 |
| | Renovated | 151 | 98 |
| | Improved Renovation | 77 | 75 |
| | NZEB Renovated | 35 | 25 |
| 1971 - 1980 | Not-renovated | 151 | 90 |
| | Renovated | 111 | 75 |

| | | | |
|---|---|---|---|
| | Improved Renovation | 77 | 58 |
| | NZEB Renovated | 35 | 25 |
| 1981 – 2002 | Not-renovated | 111 | 84 |
| | Renovated | 90 | 75 |
| | Improved Renovation | 77 | 58 |
| | NZEB Renovated | 35 | 25 |
| 2003 – 2008 | Not-renovated | 70 | 58 |
| | Improved/above standard (based on the legislation) | 55 | 49 |
| | NZEB Renovated | 35 | 25 |
| 2009 – today | Not-renovated | 30 | 30 |
| | NZEB Renovated | 15 | 15 |

In the table below the percentage of thermally refurbished segments of envelope areas is presented.

Table 28: Percentage of thermally refurbished envelope areas

| Building classes | walls | roofs | upper floor ceilings | basement/cellar ceiling | windows |
|---|---|---|---|---|---|
| Single Unit Houses | | | | | |
| SUH.01 | 38% | 74% | 38% | no data | 84% |
| SUH.02 | 45% | 74% | 48% | no data | 74% |
| SUH.03 | 38% | 58% | 49% | no data | 46% |
| SUH.04 | 35% | 34% | 31% | no data | 31% |
| SUH.05 | 20% | 7% | 9% | no data | 0% |
| SUH.06 | 0% | 0% | 0% | no data | 0% |
| Multi Unit Houses | | | | | |
| MUH.01 | 14% | 55% | 17% | no data | 77% |
| MUH.02 | 16% | 56% | 21% | no data | 52% |
| MUH.03 | 14% | 38% | 20% | no data | 49% |
| MUH.04 | 26% | 34% | 18% | no data | 27% |
| MUH.05 | 17% | 0% | 0% | no data | 0% |
| MUH.06 | 0% | 0% | 0% | no data | 0% |

Table 29 shows various thicknesses of thermal insulation and the percentage of buildings within the building types and time bands.

Table 29: Percentage of building stock with thermally refurbished envelope (wall and roof)

| Thickness of exterior wall insulation layer (eg. mineral wall. polystyrene) | | | | | |
|---|---|---|---|---|---|
| Building classes | no insulation | less than 5 cm | from 6 to 10 cm | more than 10 cm | no data |
| Single Unit Houses | | | | | |
| SUH.01 | 53% | 20% | 14% | 7% | 7% |
| SUH.02 | 45% | 16% | 29% | 7% | 3% |
| SUH.03 | 34% | 24% | 34% | 7% | 2% |
| SUH.04 | 19% | 24% | 40% | 13% | 4% |
| SUH.05 | 10% | 5% | 52% | 22% | 11% |

| | | | | | |
|---|---|---|---|---|---|
| SUH.06 | 46% | 17% | 37% | | |
| Multi-Unit Houses | | | | | |
| MUH.01 | 73% | 10% | 3% | 8% | 7% |
| MUH.02 | 51% | 17% | 6% | | 26% |
| MUH.03 | 48% | 15% | 16% | | 21% |
| MUH.04 | 12% | 28% | 28% | 5% | 27% |
| MUH.05 | | 34% | 52% | 14% | |
| MUH.06 | | | | 100% | |
| Single Unit Houses | | | | | |
| SUH.01 | 50.8 | 13 | 17 | 11 | 8 |
| SUH.02 | 44.6 | 9 | 29 | 11 | 6 |
| SUH.03 | 27.5 | 13 | 39 | 14 | 6 |
| SUH.04 | 34.5 | 9 | 31 | 16 | 7 |
| SUH.05 | 11.4 | 6 | 25 | 29 | 18 |
| SUH.06 | 45.7 | | 17 | 37 | |
| Multi Unit Houses | | | | | |
| MUH.01 | 74.0 | | 7 | 4 | 15 |
| MUH.02 | 42.4 | 4 | 11 | 5 | 34 |
| MUH.03 | 45.0 | 8 | 16 | 2 | 33 |
| MUH.04 | 8.3 | 22 | 26 | 9 | 34 |
| MUH.05 | 16.8 | 17 | 27 | 14 | 25 |
| MUH.06 | | | | 100 | |

Eco Fund is a Slovenian national public fund and it is co-financing the energy renovation measures. It has public calls for tenders and covers 1/3 of the renovations in Slovenia 0. Table 30 shows the number of registered subsidies granted by Eco Fund in 2018.

Table 30: Number of registered subsidies granted

| Type of measure | total | SFH | MFH |
|---|---|---|---|
| Central ventilation system with heat recovery | 400 | 400 | 0 |
| Local ventilation system with heat recovery | 745 | 745 | 0 |
| NZEB (construction or purchase) | 91 | 91 | 0 |
| Purchase of passive building | 20 | 20 | 0 |
| Holistic renovation | 7 | 0 | 7 |
| Insulation of roof with inclination | 457 | 295 | 162 |
| Insulation of roof without inclination | 14 | 1 | 13 |
| Insulation of the external wall | 1436 | 1081 | 355 |
| Insulation of the internal roof surface | 57 | 26 | 31 |
| Biomass boiler (spanners) | 500 | 500 | 0 |
| Biomass boiler (pellets) | 501 | 501 | 0 |
| Biomass fireplace (spanners) | 90 | 90 | 0 |
| Biomass (single zone boiler) | 6 | 6 | 0 |
| Biomass (spanner - pellets) | 9 | 9 | 0 |

| | | | |
|---|---|---|---|
| Biomass (wooden ships) | 21 | 0 | 21 |
| Replacement with new gas boiler | 605 | 595 | 10 |
| Warm air collector | 5 | 5 | 0 |
| Vacuum collector | 31 | 31 | 0 |
| Flat plate collector | 168 | 168 | 0 |
| Heat pump (Water-water) | 172 | 172 | 0 |
| Heat pump (Brine (salt water)-water) | 166 | 166 | 0 |
| Heat pump (Air-water) | 3716 | 3716 | 0 |
| District heating | 6 | 1 | 5 |
| Thermostatic valve | 30 | 0 | 30 |
| Photovoltaics self-supply | 1152 | 0 | 1152 |
| Photovoltaics heating | 1 | 1 | 0 |
| Windows ALU-PVC | 4 | 4 | 0 |
| Windows LES | 1083 | 1083 | 0 |
| Replacement or renovation of heat station | 2 | 0 | 2 |

### *2.5.2.2 Rates and depth of renovation*

The national Long-Term Strategy for Mobilising Investments in the ENERGY RENOVATION OF BUILDINGS describes the rates and depth of renovations, shown in Figure 16. For the preparation of the strategy, the calculation basis assumed an average annual renovation rate of 1.7% for residential buildings in period of 2016–2020 (1.8% in 2021–2030, 2.3% in 2013–2040 and 1.9% in 2041–2050). This was the weighted annual renovation rate. Energy savings from transitions between energy classes relative to the maximum reductions for an individual type of building were used for the weightings. The maximum reduction in energy use is achieved in the course of a transition from the lowest energy class to the low-energy level. This weighting was used for all transitions between energy classes. except for transitions to the low-energy level. A weighting of 1 was assumed for all transitions to the low-energy level from any energy class. Older residential buildings can move between four energy classes in the course of energy renovation. While newer buildings can move between three.

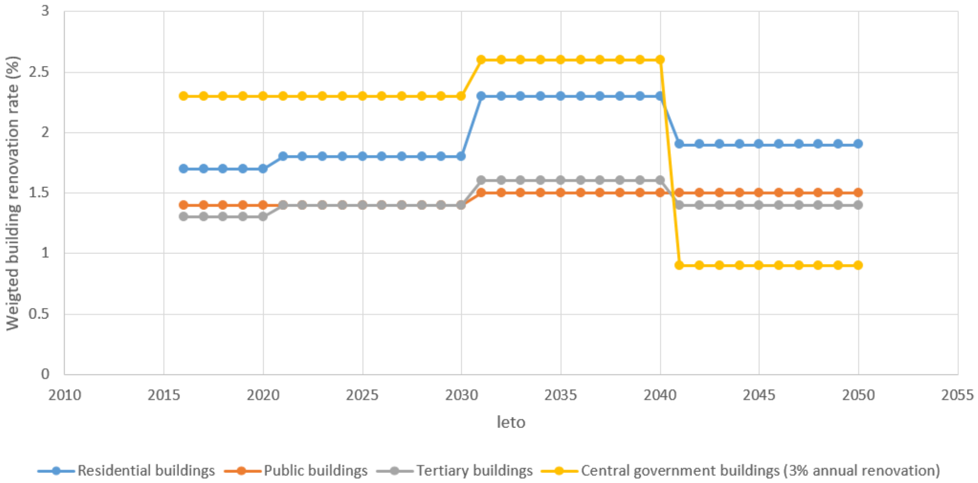



Figure 16: Renovation rate by IJS CEU [23]

The Long-term strategy has the amendment from 2018 where guidelines and suggestions for upgrading the existing measures for the renovation of residential buildings sector are proposed 0. Those are:

- financial incentives for energy efficient renewal and sustainable construction of residential buildings (return and grants, demonstration projects),
- aid scheme for energy renovation for vulnerable groups of the population,
- energy consulting network for citizens,
- instruments for financing of renovation in buildings with multiple owners,
- incentives between owners and tenants in multi-dwelling buildings and
- establishing a warranty schemes.

The figure below shows the floor area of the buildings to be renovated in 2016 and created by Jožef Štefan Institute – Centre for Energy Efficiency.

| | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2016-2030 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Single family buildings | | | | | | | | | | | | | | | | |
| Renovations | 1.393 | 1.363 | 1.323 | 1.282 | 1.241 | 1.248 | 1.256 | 1.224 | 993 | 978 | 985 | 992 | 999 | 1.005 | 1.012 | 17.295 |
| Complitly renovated | 229 | 338 | 439 | 533 | 620 | 637 | 653 | 735 | 550 | 608 | 659 | 734 | 764 | 794 | 824 | 9.117 |
| Partially renovated | 1.165 | 1.025 | 884 | 749 | 620 | 612 | 603 | 489 | 443 | 370 | 326 | 258 | 235 | 212 | 188 | 8.178 |
| Weighted partial renovations | 402 | 377 | 350 | 324 | 299 | 301 | 304 | 254 | 236 | 201 | 173 | 128 | 116 | 105 | 93 | 3.662 |
| Total equivalent of complete energy renovatio | 630 | 715 | 789 | 857 | 919 | 938 | 957 | 989 | 786 | 809 | 832 | 862 | 880 | 899 | 918 | 12.779 |
| Multi-family buildings | | | | | | | | | | | | | | | | |
| Renovations | 758 | 719 | 680 | 641 | 585 | 511 | 496 | 482 | 482 | 483 | 483 | 483 | 483 | 483 | 483 | 8.253 |
| Complitly renovated | 73 | 88 | 101 | 112 | 117 | 122 | 130 | 153 | 195 | 211 | 212 | 213 | 214 | 215 | 217 | 2.370 |
| Partially renovated | 685 | 631 | 580 | 530 | 468 | 389 | 366 | 329 | 288 | 272 | 271 | 270 | 269 | 268 | 267 | 5.883 |
| Weighted partial renovations | 203 | 191 | 180 | 169 | 152 | 126 | 123 | 99 | 77 | 74 | 75 | 76 | 76 | 77 | 77 | 1.774 |
| Total equivalent of complete energy renovatio | 275 | 279 | 280 | 280 | 269 | 248 | 253 | 252 | 272 | 285 | 287 | 288 | 290 | 292 | 294 | 4.144 |
| Single and Muliti-family buildings | | | | | | | | | | | | | | | | |
| Renovations | 2.151 | 2.083 | 2.003 | 1.924 | 1.825 | 1.759 | 1.752 | 1.706 | 1.475 | 1.461 | 1.468 | 1.475 | 1.482 | 1.489 | 1.496 | 25.548 |
| Complitly renovated | 301 | 426 | 540 | 645 | 737 | 758 | 783 | 888 | 744 | 819 | 871 | 947 | 978 | 1.009 | 1.041 | 11.487 |
| Partially renovated | 1.850 | 1.657 | 1.463 | 1.279 | 1.088 | 1.001 | 969 | 817 | 731 | 642 | 597 | 528 | 504 | 480 | 455 | 14.061 |
| Weighted partial renovations | 604 | 568 | 530 | 492 | 451 | 428 | 427 | 353 | 313 | 275 | 248 | 203 | 192 | 181 | 170 | 5.436 |
| Total equivalent of complete energy renovatio | 905 | 994 | 1.070 | 1.137 | 1.188 | 1.186 | 1.210 | 1.241 | 1.057 | 1.094 | 1.118 | 1.150 | 1.170 | 1.191 | 1.211 | 16.923 |

Figure 17: The floor are of renovated residential buildings in period between 2016-2030 by IJS CEU [23]

Figure 18 shows the floor area of the renovated buildings for private service sector, public sector and housing sector.

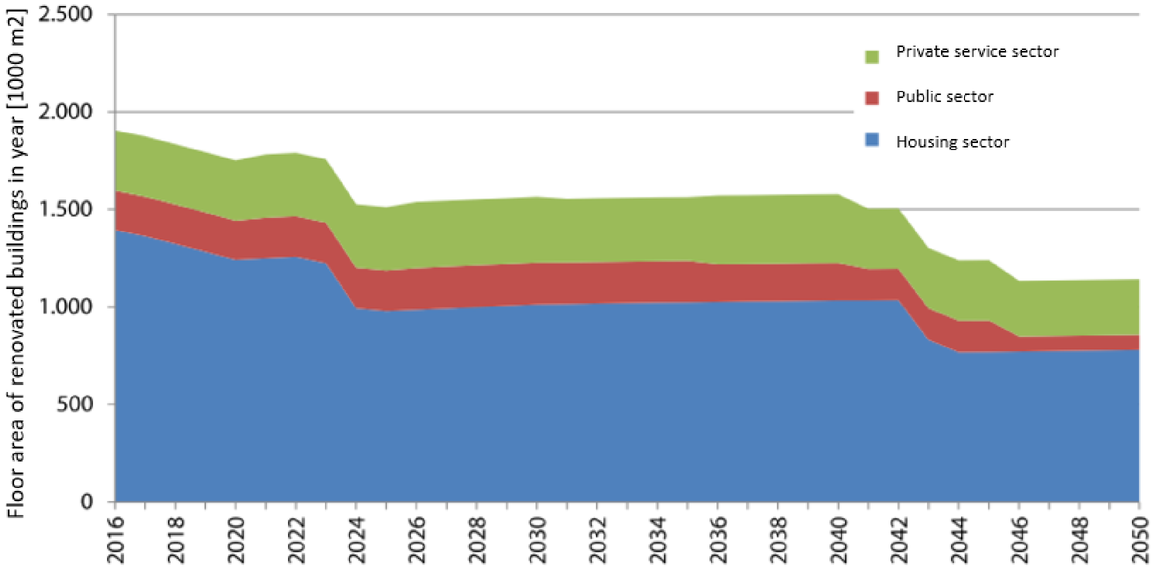



Figure 18: Floor are of renovated buildings in year 2016-2050 by IJS CEU [23]

Costs of building renovations depend on their level of renovation (minor or extensive):
Minor renovations: the implementation of 1 or 2 measures with average costs of 60 €/m² and the reduction of energy is between 0-30%. Moderate renovations: utilization of 3-5 improvement with average costs of 140 €/m² and the reduction of energy is between 30-60%.
Extensive renovations: represents a package of measures working together with average costs of 330 €/m² and the reduction of energy is between 60-90%. Almost Zero-Energy Building renovations: the aim is to reduce energy consumption and carbon mission levels to close to zero by replacement of all elements and installation of renewable energy technologies with average costs of 580 €/m².

### 2.5.2.3 Benefits of renovation

This chapter is summarised based on the Long-term Strategy.

Energy savings

- **Savings in end-use and primary energy** for heating and domestic hot water resulting from the implementation of measures for the energy renovation of existing buildings were estimated relative to 2015 (MZI and MZJU, 2015). Figure 19 shows end-use energy savings will amount to 1 509 GWh (5.4 PJ) in 2020. and will increase to 3 976 GWh (14.3 PJ) by 2030 and to 7 029 GWh (25.3 PJ) by 2050. Primary energy savings will be higher, as 1 kWh of electricity or district heating saved means over 2 kWh or 1.3 kWh of primary energy saved. Primary energy savings will amount to 1 624 GWh (5.8 PJ) in 2020, 4 323 GWh (15.6 PJ) in 2030 and 7 852 GWh (28.3 PJ) in 2050.

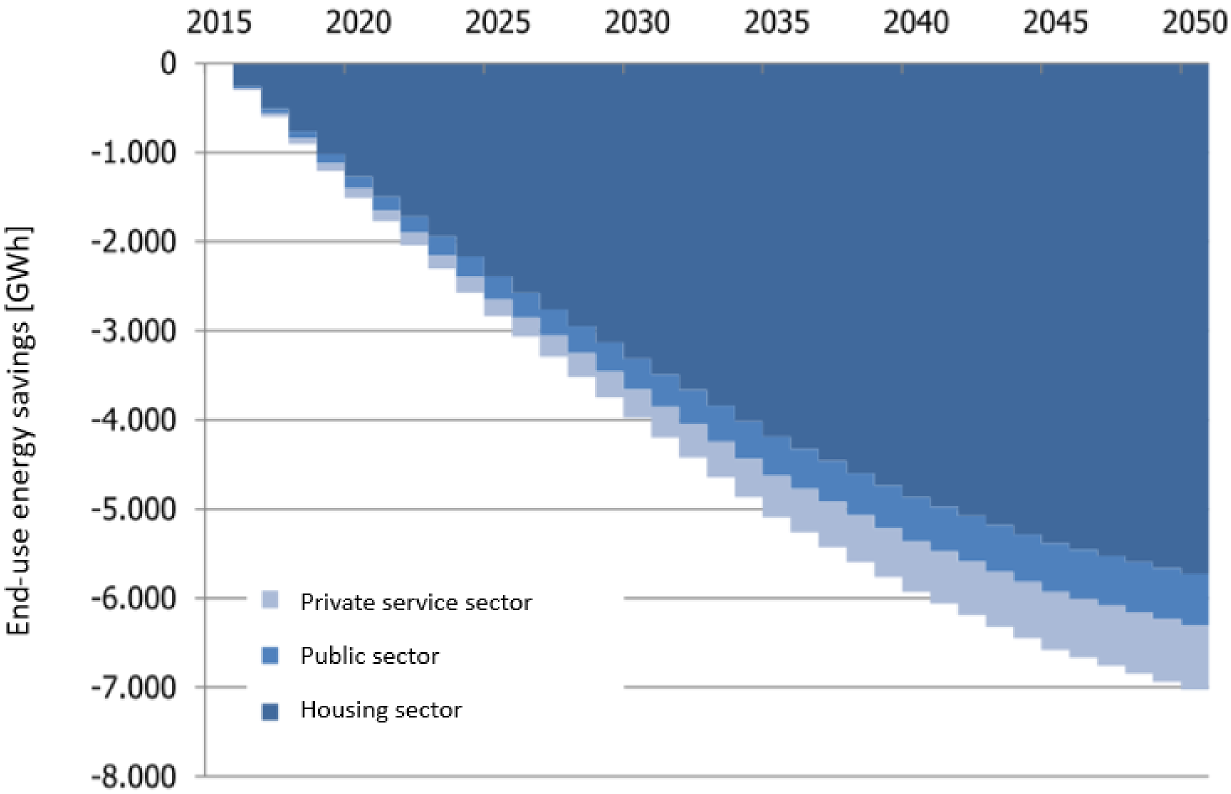



Figure 19: End-use energy savings for private service sectro, public sector and housing sector by IJS [23]

It is anticipated that the housing sector accounts for the highest share of end-use energy savings: in 2020 - 85% of all savings achieved as a result of building renovation measures (in 2030 – 83%). The energy savings achieved as a result of the implementation of the strategy will make a considerable contribution to achieving Slovenia's targets in the area of improving energy efficiency. The building renovation resulting from the implementation of the strategy will achieve a 12% reduction in primary energy use and a 16% reduction in end-use energy. Therefore, primary energy savings from building renovation account for 42% of total savings and end-use energy savings from building renovation account for 58% of total savings.

- **Additional investments**; increasing the energy performance of building stock entails a substantial volume of investments; between 2015-2030 the value of the required inputs is estimated to 6.71 billion € without taxes.
- **Additional employment**; the increased volume of investment in energy efficiency also means increased demand in sectors whose products and services lead to improvements in the energy performance of buildings.) Using the general equilibrium model, it was estimated, that additional investments in energy renovation will give rise to a direct growth in employment in Slovenia of between 0.36% and 0.58% annually (or the annual creation of between 3 000 and 4 600 new jobs).
- **Increased GDP**; GDP of 0.89% per year relative to the baseline scenario; an increase of 1.98% in domestic sales and 1% in domestic production. Private consumption should also increase by 0.93% and state consumption by up to 0.04%.
- **Public finance benefits**; Investing in the greater energy efficiency of buildings reduces government expenditure on energy and at the same time due to increase in investments and economic activity also strengthen the public finance revenues.
- **Increased property values**; numerous researches in the world show a positive impact of increased energy efficiency on value of a real estate.
- **Incentives for research and development, industry competitiveness and export growth**

## Social benefits

- **Reduced energy poverty**; one of the studies in 2012 showed that people normally spend 7% of their income for household related expenses (heating, lighting, DHW etc.) and more than 30% live in insufficient conditions (mouldy apartments, water leakage etc.).
- **Effect on health, improved living comfort and higher productivity;** improved parameters of indoor climate, such as thermal comfort and indoor air quality.

## Environmental benefits

**Reduced greenhouse gas emissions**; Emissions from existing buildings amounted to 1 208 kt $CO_2$ equivalent in 2015 (Figure 20). These will fall to 971 kt CO2 equivalent by 2020 and to 657 kt CO2 equivalent by 2030. This means that emissions will be 58% lower in 2020 and 72% lower in 2030 relative to the baseline year of 2005. Total emissions from existing and new buildings are slightly higher, they are estimated to be 681 kt in 2030 (a 71% reduction relative to emissions in 2005).

**Reduced air pollution;** An assessment has been made of the anticipated effects of the planned measures for the energy renovation of buildings on reducing air pollution levels in the period up to 2030 with reference to 2015. A reduction in emissions of the following is expected:

- sulphur dioxide – reduction of 572 t (59%);
- nitrogen oxides – reduction of 1 293 t (43%);
- all particles – reduction of 5 043 t. or 53 % (reduction of 4 745 t of primary particles smaller than 2.5 µm (P2.5) and of 4 766 t of primary particles smaller than 10 µm (PM10) and
- volatile organic substances – reduction of 3 995 t (39%).

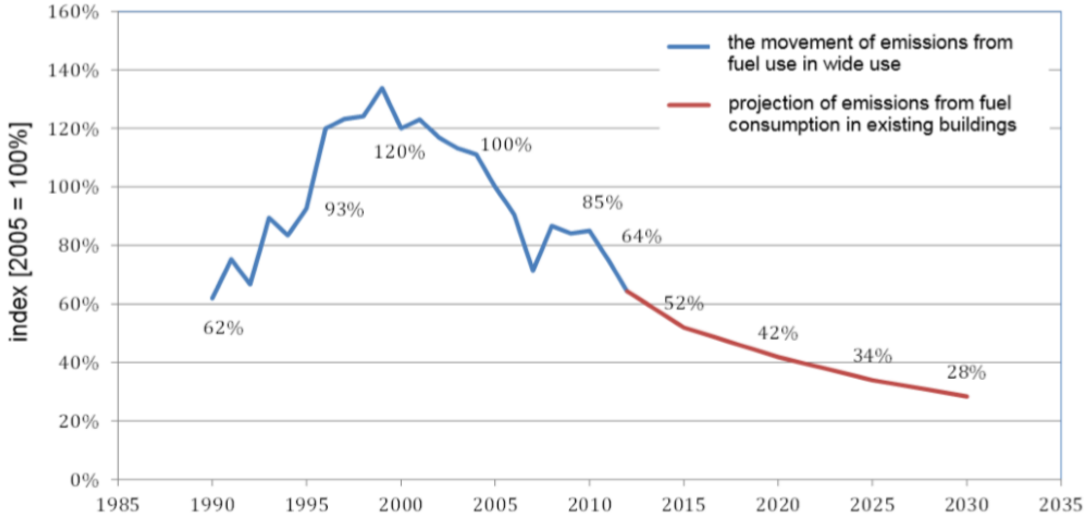



Figure 20: Emissions from fuel use [23]

## Benefits for the energy system

Energy efficiency measures and the replacement of fossil fuels with renewable energy sources will reduce dependence on imports.

**Impact on the electricity consumption diagram**; By promoting the installation of heat pumps the need for additional capacity of electricity supply will increase the demand for electricity in the winter months. Therefore, the relevance to simultaneously promote high-efficiency cogeneration of heat and power in district heating systems will improve.

### *Barriers and challenges to renovation*

This chapter is summarised based on the Long-term Strategy. The most relevant barriers and challenges of renovation are presented below:

- relatively poor level of awareness still present (chiefly of the organisational and implementation aspects of renovation);
- difficulties in reaching agreement in multi-family buildings;
- lack of confidence in the managers of multi-family buildings;
- lack of confidence in energy renovation providers;
- problem of low-income owners;
- lack of interest in energy renovation on the part of owners of rented flats;
- too many partial rather than complete energy renovations;
- implementation of the complete energy renovation of building envelopes without taking into account the changes to the requirement for users to behave in a certain way (e.g. deterioration in air quality in the absence of a ventilation system or no change in habits following the introduction of a recovery system);
- difficulties in acquiring funds for the renovation of multi-apartment buildings (no adequate loan instruments or the provision of loan instruments inhibited by legislation);
- inadequate training of energy renovation providers;
- extended period of relatively low fuel prices;

- uncertainty regarding future energy prices;
- instability of legislation and
- inadequate conditions for the introduction of innovative energy performance services/energy performance contracting in the housing sector (contractual provision of energy supply and contractual provision of energy savings).

# 3 ECONOMIC AND REGULATORY CONTEXT

## 3.1 EUROPEAN DIRECTIVES EPDB AND EPBD RECAST INTO THE NATIONAL LEGISLATION OF MEMBER STATES (ITALY, FRANCE, SPAIN AND SLOVENIA)

The document will be mainly focused on the differences between each target Country's buildings energy performance calculation methodology (Articles 3, 4 and 5), the requirements for application of minimum requirements on the energy performance of new buildings (Article 6) and for existing buildings that are subject to major renovation (Article 7), national definition of Nearly Zero Energy Buildings and plans for increasing their construction (Articles 8 and 9). Furthermore, an analysis of Swiss legislation in the field of energy efficiency and renovation plans of buildings will be made. The objective is to provide an accurate and easy-to-use tool able to highlight the differences between the implementations of each single Country that will be annually uploaded.

The so-called Clean Energy for All package provides for a series of revision of existing Directives in the field of energy. Those revised legislative text contains elements of direct relevance for the implementation of the HEART approach.

Regarding the revised Energy Performance of Building Directive, 3 elements are particularly important:

First of all, an article which obliges Member States to set out ambitious goals for the renovation of the building stock

**Renovation strategies**

Article 2a: It sets an obligation for Member States to formulate and implement a long term strategy to renovate the entire building stock with the view to decarbonize it.

"In its long-term renovation strategy, each Member State shall set out a roadmap with measures and domestically established measurable progress indicators, with a view to the long-term 2050 goal of reducing greenhouse gas emissions in the Union by 80-95 % compared to 1990, in order to ensure a highly energy efficient and decarbonized national building stock and in order to facilitate the cost-effective transformation of existing buildings into nearly zero-energy buildings. The roadmap shall include indicative milestones for 2030, 2040 and 2050, and specify how they contribute to achieving the Union's energy efficiency targets in accordance with Directive 2012/27/EU ".

"to support the development of its long-term renovation strategy, each Member State shall carry out a public consultation on its long-term renovation strategy prior to submitting it to the Commission. Each Member State shall annex a summary of the results of its public consultation to its long-term renovation strategy."

Secondly, a group of articles which promotes building automation and control (i.e the automatic centralized control of a building's heating, ventilation and air conditioning, lighting and other systems through a building management system or building automation system):

***Self-regulated devices:***

Article 8 paragraph 1: Member States shall require new buildings, where technically and economically feasible, to be equipped with self-regulating devices for the separate regulation of the temperature in each room or, where justified, in a designated heated zone of the building unit. In existing buildings, the installation of such self-regulating devices shall be required when heat generators are replaced, where technically and economically feasible.

Article 15 Alternatively to regular inspections, Member States may lay down requirements to ensure that residential buildings are equipped with:

- the functionality of continuous electronic monitoring that measures systems' efficiency and informs building owners or managers when it has fallen significantly and when system servicing is necessary.
- effective control functionalities to ensure optimum generation, distribution, storage and use of energy.

Thirdly, the revised EPBD aims to provide additional support by introducing a ‘Smart Readiness Indicator (SRI) for Buildings’ (article 8.6) to assess the technological readiness of buildings to interact with their occupants and the energy environment and, to operate more efficiently. Introducing such a SRI would raise awareness on the benefits of smarter building technologies and functionalities and their added value for building users, energy consumers and energy grids. It can support technology innovation in the building sector and become an incentive for the integration of cutting-edge smart technologies into buildings. The SRI is expected to become a cost-effective measure which can effectively assist in creating more healthy and comfortable buildings with a lower energy use and carbon impact, and can facilitate the integration of Renewable Energy Sources.

The Smart readiness indicator will look at 3 functionalities of buildings:

- The ability to maintain energy efficiency performance and operation of the building through the adaptation of energy consumption, for example, through use of energy from renewable sources;
- The ability to adapt its operation mode in response to the needs of the occupant paying due attention to the availability of user-friendliness, maintaining healthy indoor climate conditions and ability to report on energy use;
- The flexibility of a building's overall electricity demand, including its ability to enable participation in active and passive as well as implicit and explicit demand-response, in relation to the grid, for example through flexibility and load shifting capacities.

This indicator will allow for rating the smart readiness of buildings, i.e. the capability of buildings (or building units) to adapt their operation to the needs of the occupant, also optimizing energy efficiency and overall performance, and to adapt their operation in reaction to signals from the grid (energy flexibility).
Since HEART is meant to develop multifunctional retrofit toolkit including different components (ICT, BEMS, HVAC, BIPV and Envelope Technologies) that cooperate to transform an existing building into a smart building, the new legislative context of the revised EPBD will be favourable for this kind of approach and will incentivize housing providers to use the HEART toolkit. The combination between the long term renovation strategies carried out by Member States and the promotion of smart technologies at the project level is essential for the take-up of the HEART toolkit by housing providers and wider stakeholders.
This report contains a summary of the national legislative framework regarding the implementation of the European directives related to energy (in particular the Energy Performance of Buildings Directive) into national legislation of the target Countries.
Concerning the Italian, French, Spanish and Slovenian EPBD implementation laws, the most important can be found in the next paragraphs:

### 3.1.1 France

The Legislative Decree No 2010-1269 of 26 October 2010 transposed the EPBD Recast and it was modified for the last time on 30 January 2012 (Thermal regulation 2012).

In the RT 2012, the minimum energy performance requirements for new building are defined (Article 6 of EPBD Recast). All new buildings that obtained their building permit after 1 January 2013 must be NZEBs (Bâtiment à Basse Consommation (BBC) in French) and they must consume less than 50 kWhep/m²·year and must use 5-12 kWh/m²·year of renewable energy for single- and multi- family houses.
For existing buildings undergoing major renovation the maximum primary energy use is between 80 and 165 kWh/m². year. 'Major renovation' means the renovation of a building where the total cost of the renovation relating to the building envelope or the technical building systems is higher than 25 % of the value of the building, excluding the value of the land upon which the building is situated.

### 3.1.2 Italy

The Legislative Decree No 63 of 4 June 2013 transposed the EPBD Recast, amending Legislative Decree No 192/2005 transposing the EPBD.
To complete the transposition, the Interministerial Decree of 26 June 2015 was published, composed of three separate Decrees that involve Articles 3 and 4 of the EPBD Recast:

- "Application of energy performance calculation methods and the definition of the rules and minimum requirements for buildings";
- "Reference procedures and framework for compiling the project technical report for the application of rules and minimum energy performance requirements for buildings";
- "Adaptation of national guidelines for the energy certification of buildings".

Concerning the Article 5 of EPBD Recast, a working group coordinated by the Ministry of Economic Development and composed of ENEA, RSE and CTI presented, in July 2013, the Italian cost-optimal methodology (Application of the methodology for the calculation of cost-optimal levels of minimum energy performance Requirements).
Concerning Articles 8 and 9, a document called "National action plan for increasing the number of nearly zero-energy buildings" clarifies the Italian definition of NZEB and examines the energy performance of the various types of NZEB in different end-use sectors and climate zones. It estimates the additional costs – relative to current levels – necessary to construct new NZEB or transform existing buildings into NZEB.

### 3.1.3 Spain

In Spain, responsibility for the Energy Performance of Buildings Directive (EPBD) lies with the Ministry of Industry, Energy and Tourism, the Ministry of Public Works and Transport, and regional administrations. The rules and regulations governing energy efficiency requirements in Spain are contained in the Technical Code for Construction (CTE). This document contains all the information necessary to meet the minimum requirements for energy efficiency in new buildings, as well as energy rehabilitation of existing buildings.
The EPBD recast of articles 2 to 4 of the Directive 2010/31/EU is presented through the Basic Document of Energy Savings (HE) of the CTE first presented in 2006 and last updated in 2018 [73]. This document included requirements for the envelope, the systems of production of cold and heat (heating system regulations), ventilation, etc. Moreover, the Directive can also be appreciated in the Regulation of Technical Facilities in Buildings (RITE). All these documents are part of the plan of the Spanish Law of Sustainable Economy [72].
Furthermore, until 2018, Spain had not yet established a formal definition of NZEB in any of these documents, therefore it could not identify buildings that could comply with these requirements. In 2018, the CTE included the concept of nZEB, which must adhere to the requirements of the previous versions.
Some of the requirements presented in this last document include the obligation to install solar thermal systems to cover between 30 and 70% of the demand for hot water in new buildings and rehabilitations, and

cooling and heating energy demand must not surpass (depending on the region) a maximum of $20\ kW \cdot h/m^2$ and $40\ kW \cdot h/m^2$ respectively; complying with article 6, 7 and 8 of the Directive.
Concerning articles 8 and 9 of the directive, the CTE recognizes 6 different regions for the definition of NZEBs. The following tables present the limit values of different indicators towards this goal for private residential and tertiary use. This information can be retrieved from the 2018 Spanish CTE, and the later publication by the Ministry of development regarding the suggested values for NZEBs [73].
The methodology used for the preparation of these requirements included an analysis of the best solutions per type of construction in Spain, and simulated different scenarios of climates, types of construction and production systems using the LIDER/CALENER tool, the official tool created to simulate and evaluate energy efficiency in Spanish buildings.
The tool results were then used to determine which limit values should be used in the normative documents CTE and RITE. LIDER/CALENER is consistent with the established methodology and it is based on the European standards in force at the time of the creation of the programs. It includes in its calculations the building envelope, thermal bridges, infiltrations, solar shading, thermal inertia, and hours of operation, as well as the technical characteristics of the heating and cooling systems. The requirements are set in terms of both (non-renewable) primary energy consumption and CO2 emissions. These values are calculated through the LIDER/CALENER tool and are based on the final energy consumption and the application of specific factors that are published officially by the Ministry of Industry.
Spain has applied the inspection option in response to Articles 14 and 15 of the EPBD. This was initially done in 2007 (for Article 8 of Directive 2002/91/EC) and updated in 2013 by the Regulation of the Thermal Systems of Buildings (Royal Decree 238/2013). This document contains the implementation of a schedule of inspections to verify the correct operation of the facilities and to produce a report with advice on ways to improve energy performance. The responsibility to undertake the inspections lies with the regions.

### 3.1.4 Slovenia

The transposition of the Energy Performance of Buildings Directive (2010/31/EU) EPBD Recast (and EPBD from 2002) in Slovenia is the overall responsibility of the Ministry of Infrastructure and is primarily transposed by the Energy Act (EZ-1. published in Official Gazette. No. 17/14 and amended in 81/15). The Energy Act covers the following topics: nearly zero-energy building (NZEB), energy performance certification, inspection of heating and AC systems and energy efficiency information programmes. In addition, the Construction Act (ZGO-1. Official Gazette. No. 102/04 – UPB 2017), recently replaced by the Building Act (Official Gazette. No. 61/17 in 72/17) gives the legal basis for building codes (with minimum requirements for building energy performance. Technical building systems and the calculation methodology), while the Environmental Protection Act (ZVO-1 Official Gazette 2006-UPB 2018) addresses the inspection of boilers [78].

A proposal for the amendment of the Energy Act was put to public consultation in January 2019. The proposed changes establish the obligation for public display of the EPC for all buildings (not only public) frequently visited by the public.

Technical definition of nearly zero-energy buildings is given in the Slovenian national plan for nearly zero-energy buildings (NZEB) (AN sNES, 2015); based on the cost-optimal study (2014) for reference buildings. The primary energy as a core performance indicator of NZEB is limited to 75 / 80 / 55 kWh/m$^2$.year for new single- and multi-family houses and for non-residential buildings, respectively, and complemented by the requirement of a 50% share of RES in the final energy use. RES may be selected in consideration of their availability and acceptable NZEB technologies. In the future, the use of RES will be increased due to the growing share of RES in district heating systems which are subject to comply with the 2020 energy efficiency targets set in the Energy Act. The nearly zero or very low amount of energy required is achieved by the limitation of energy needs for heating to a maximum value between 25 kWh/m$^2$.K and 15 kWh/m$^2$.K (EPC class A1. A2 or B1), depending on the shape factor (envelope area to buildings volume ratio) and the local climate.

In the secondary regulation related to the transposition of EPBD is as follows [79,80,81]:
•Rules on efficient use of energy in buildings with a technical guideline (PURES-2010. Official Gazette. No. 52/10 in 61/17 – GZ) –minimum requirements for buildings and calculation methodology based on EPB-standards
•Rules on the methodology for the production and issuance of energy performance certificates for buildings (Official Gazette. No. 92/14)
•Rules on the training. accreditation and register of accredited independent experts for energy performance certificate production (Official Gazette. No. 30/18)
•Rules on the training. accreditation and register of accredited independent experts for regular inspection of air conditioning systems (Official Gazette. No. 18/16)
•Rules on regular inspection of air conditioning systems (Official Gazette. No. 26/08 in 17/14 – EZ-1)
The current revision of the building codes (PURES) is in progress (in 2018); it is focused on the technical details concerning NZEB requirements and on the revision of the calculation methodology according to a new - 2017 set of CEN EPB standards.

## 3.2 IMPLEMENTATION OF THE EUROPEAN ENERGY EFFICIENCY DIRECTIVE INTO THE NATIONAL LEGISLATION OF MEMBER STATES

This chapter provides a summary of the national legislative framework regarding the implementation of the Energy Efficiency Directive into national legislation of the target member states, mainly focusing on energy redevelopment plans for public buildings (articles 4 and 5) and on the energy audit of buildings (article 8). A summary of the laws transposing the EED into national legislation of the target European Countries will be provided and annually updated, together with an analysis of Swiss legislation in the field of energy efficiency and renovation plans of buildings.

The mandatory reports imposed by the Directive and published by Member states are considered the main source for the update of the EED implementation, they are the Annual Reports and the National Energy Efficiency Action Plans (NEEAPs) [25]. The first contain updates on major legislative and non-legislative measures implemented contributing to reach the overall national energy efficiency targets for 2020. The second are national plans, published every three years, containing significant energy efficiency improvement measures and expected and/or achieved energy savings; in particular these strategies must show how they plan to promote investment in the buildings renovation.
These are several other institutions, databases, EU projects that contributes to define progresses and implementation in national laws and will be monitored during the entire duration of the project, as the Directorate-General for Energy (DG Ener) which is the Commission department responsible for the EU's energy policy and order several studies and researches. The most important and complete database is the NIM database [26] which contains the national transposition measures communicated by the Member States. An example of European initiative is the *Concerted Action for the Energy Efficiency Directive* [27], a project financed under the European Union's Horizon 2020 research and innovation programme, which provide very precise reports on EED implementation. The *European Environmental Agency* [33] publishes each year

trends and projections towards Europe's climate and energy targets. The ODYSSE-MURE database [34] continuously offer summaries of energy efficiency trends and policy measures. Other European platforms to take into consideration are the *BUILD UP Portal* [35], established by European Commission and *E3P*, the *European Energy Efficiency Platform* [36] promoted by the Joint Research Centre. Both of them publish several reports and detailed analysis of regulatory framework updates and EED implementation. Important source of information, that will be periodically monitored, are national agencies and institutions, as ENEA (National Agency for New Technologies, Energy and Sustainable Economic Development) in Italy, BfEE (Federal Energy Efficiency Centre) in Germany, AEA (Austrian Energy Agency) in Austria and so on.
Hereafter the main Italian, French, Spanish and Slovenian national laws implementing the EED are reported, as the two case studies for retrofit intervention will take place in those countries.

### 3.2.1 France

In France the Ministry of Environment, Energy and the Sea has been responsible for establishing and implementing energy efficiency policies and measures. The list of measures adopted in compliance with the EED are available on the NIM database. The EED provisions have been principally transposed into national laws through the National Energy Code, Law n° 2013-619 [44] and the Law on energy transition n° 2015-992.

Article 4: The housing energy efficiency improvement plan (plan de rénovation énergétique de l’habitat – PREH), introduced in 2013, sets out a range of measures designed to increase the rate of residential energy refurbishment which focused on: decision-making, funding and development of a network capable of correctly and efficiently responding to enquiries [44]. A new long-term strategy for mobilising investment in building renovation has been presented with the 2017 NEEAP, which provided a national stock analysis, the list of profitable renovation approaches and funding, a description of implemented measures [46].

Article 5: For public buildings, France has opted to adopt an alternative approach in order to reduce the energy consumption of public buildings. It is based on a reduction of 40% by 2020 of the energy consumption of State buildings and relative public institutions. Several types of measures have been implemented to achieve this objective, as the renovation of buildings envelop and equipment, changes in management of equipment and behaviour of occupants, reduction of the surface area occupied by State services [44].

Article 8: The Law n° 2013-619 has been designed specifically to implement Article 8 of the EED in national legislation. It establishes that energy audits are mandatory for large enterprises with more than 250 employers, or for enterprises with revenues higher than 50 M€ or a total balance sheet of more than 43 M€. The 5$^{th}$ December 2015 deadline for enterprises which has to comply with the audit obligation has been transposed.
French legislation considers only operations that are based in France. No audit is required for extra-national operations of French companies. For multi-sites companies, all sites based in France are subject to the regulations and there is no lower limit on the size of the site or its energy use, only for comparable sites is possible to apply a sampling approach. The minimum mandatory coverage was 65% of total energy consumption for Audits undertaken till 2015 while thereafter, 80% of total energy consumption must be included within the audit. There are no additional specific provisions for buildings as the energy consumption to be included within the scope of an audit is defined by the energy expenditure of an enterprise.

SMEs can apply for funding of up to the 70% (maximum 50,000 €) of undertaking an energy audit. Additional funds of up to 100,000 € can be provided to support the implementation of energy efficiency measures.

### 3.2.2 Italy

In Italy the Ministry for Economic Development (MiSE) has established and implemented energy efficiency policies and measures, with the support of the Ministry of Environment, Energy and the Sea (MATTM), the Ministry for Economy and Finance (MEF) and other national institutions entities and agencies. The list of measures adopted in compliance with the EED are available on the NIM database. The EED provisions have been transposed into national laws through the *Legislative Decree (Dlgs) n. 102* approved on 4th July 2014 [37] and entered into force on 17th July 2014.

Article 4: The main redevelopment plans for public building are the *STREPIN* (National strategy for Energy Requalification for either Private and Public real estate) [38] and the *PANZEB* (National Action Plan to increase the number of NZEB buildings) [39]. Moreover, very important is "Conto Termico", the incentives scheme for Public Buildings which will be described in the proper section.

Article 5: Italy has chosen the Default Approach [40]. The inventory of all relevant central government buildings has been done by the Italian Public Property Agency charged by the Minister of Economic Development [42]. Italy has set up an ambitious program for public buildings refurbishment, the so called Set UP of PREPAC (Program for the renovation of the central public administration buildings) [41]. Several legislative actions have been implemented over the years, mainly concentrated energy efficiency interventions in Social Houses, construction of innovative schools from the architectural point of view, retrofit of school and university buildings [37].

Article 8: Energy audits in industry are carried on by ESCOs, experts in energy management or energy auditors. According to the Dlgs n° 102/2014, energy audits are mandatory for every energy-intensive companies and for large enterprises with 250 or more employers and for enterprises with revenues higher than 50 M€ and a total balance sheet of more than 43 M€. The deadline for application of energy audit or fully implement an energy management system was on 5th December 2015, as established by the Directive. Afterwards, energy audits have to be carried periodically, with intervals lower than four years [42]. The obligation does not apply to public administration offices.
About multi-national companies, the law establishes that for thresholds calculations, subsidiaries and other enterprises operating in Italy have to be considered, but sites abroad are not included in the requirement to undertake an audit. However, there is not a precise minimum coverage, but energy audit has to be proportionate and sufficiently representative of every companies' sites. If a company group has a large number of different sites, the exclusion of several sites is possible if they are similar in characteristics to other sites that are audited [41]. Buildings owned by the company must be covered by the energy audit and the owner is required to submit the results to ENEA [42].
Among most important legislative intervention, there is the development of a programme to implement audits in Small-Medium Enterprises in 2014-2020 that has been launched on May 12th, 2015 [43] and financed with 30 M€.

### 3.2.3 Spain

To implement the EED, changes have been made to different regulations and legal provisions and a new decree and a national law have been approved to transpose the Directive. These legal provisions are mentioned in the following tables. The most important legislations regarding EED is the Royal Decree 56/2016, February 12th [77], which transposes the EED regarding energy audits, accreditation of service providers and energy auditors and promoting efficiency of energy supply, and Law 18/2014 for everything related to the energy efficiency obligations scheme (art. 7, EED) and Energy Efficiency National Fund (art. 20, EED).

The Ministry of Development also intends to amend the legislation of public sector contracts to apply Article 6 of the EED in such a way that the central administration only purchases products, services and buildings that have high energy efficiency. This would also depend on profitability, economic viability, sustainability in a broader sense, and technical considerations, as well as sufficient competition, ensuring the multiple options that consider the best technologies.

**Article 4:** the Ministry of Development has presented, within the framework of this 2014–2020 National Energy Efficiency Action Plan, a 'Spanish Strategy for Energy Renovation in the Building Sector'. This is a long-term strategy (including forecasts for 2020, 2030 and 2050) which will be updated every three years, the aim of which is to stimulate investments in the renovation of residential and commercial buildings with a view to improving the energy performance of the national stock of buildings. With this in mind, it gives an in-depth analysis of how to take on exhaustive and cost-effective renovations which could potentially reduce consumption in terms of both the energy supplied to buildings and their final energy level.

According to the Directive, this strategy shall encompass: (a) an overview of the national building stock based, as appropriate, on statistical sampling. (b) Identification of cost-effective approaches to renovations relevant to the building type and climatic zone. (c) Policies and measures to stimulate cost-effective deep renovations of buildings, including staged deep renovations. (d) A forward-looking perspective to guide investment decisions of individuals, the construction industry and financial institutions. (e) An evidence-based estimate of expected energy savings and wider benefits.

**Article 5:** The inventory of heated and/or cooled central government buildings has been elaborated and published as it is stated in article 5 (firstly including those with a total useful floor area over 500 m2 and secondly including also those over 250 m2) and is available in the Ministry of Industry, Energy and Tourism’s website

**Article 8:** In regard to Energy Audits, the aforementioned Royal Decree establishes the obligation for companies not SMEs, to do an energy audit at least every four years from the date of previous energy audit. Requirements to be met by the audit as well as the energetic auditors are also established. An Administrative Registry of Energy Audits is created in the Ministry of Industry, Energy and Tourism and an inspection system is established. Furthermore, the conditions and requirements to be applied in the accreditation of suppliers and auditors is also fixed.

The royal decree also introduces the "Promotion of energy efficiency in the production and use of heat and cold", which regulates the assessment of high-efficiency cogeneration potential and district heating and cooling to be performed in order to provide information to investors regarding the national development plans and contribute to a stable and supportive environment for investment. Every 5 years, the Ministry of Industry, Energy and Tourism will carry out a complete evaluation of the potential for the use of high efficiency cogeneration and efficient urban heating and cooling systems, which must be transmitted to the European Commission. This Ministry must carry out as well an analysis of costs and benefits covering the Spanish territory, taking into account the climatic conditions, the economic viability and the technical suitability.

### 3.2.4 Slovenia

The official National implementation report states, that: *''The implementation of the Directive on Energy Efficiency (EED) (2012/27/EU) is the responsibility of the Ministry of Infrastructure. Also the Ministry for Environment and Spatial Planning and Energy Agency are involved in the implementation of the EED. Eco fund, public fund implements several instruments and programmes related to energy efficiency in assignment of the Ministries.''* and *''To implement the EED. changes have been made to several national laws. These have been among others effectuated by the new Energy law (Official Gazette. No. 17/14 in 81/15) coming into force March 2014. For the full transposition of EED Decree on physical assets of the state. regions and municipalities must be changed for transposition of Article 6 regarding buying and renting houses by public sector.''* [82].

Article 4 of EED:

Article 348 of Slovenian Energy Act (Z-1) required the elaboration of the long term strategy for mobilising investments in the energy renovation of buildings and its revision every three years. The strategy covers all building sectors. with a special focus on heritage buildings and public buildings in particular the ones in use and ownership of central government that are subject of 3% annual renovation rate. The focus is on deep / holistic renovation with a priority on building with the worst efficiency / the biggest energy saving potential. (The buildings for the national defence and the worship buildings are excluded from the strategy.)

The Slovenian "Long-Term Strategy for Mobilising Investments in the Energy Renovation of Buildings" was adopted in October 2015. According to the long-term strategy, the renovation rate of residential buildings is planned to be 1.7% in the 2016-2030 period, 1.8% in the period of 2021-2030, 2.3% in the 2031-2040 period and 1.9% in the 2041-2050 period. One third of renovations are expected to be in NZEB standards (as defined for NZEB renovation. i.e. with a focus on renewables).

The revision of the Long-Term Strategy was accepted in February 2018.

It elaborated in detail the critical fields in the ongoing energy renovation of 3existing buildings: quality management in renovation. further development of financial instruments. compensation rules allowing incentives also for energy renovation of heritage buildings in private ownerships – similar to the rules in place for public buildings and the problem of a moderate development of energy contracting market.

Article 5 of EED:

The article 5 of EED about the Exemplary role of public bodies' buildings was transposed with Articles 29. 324.346. 347. 348 of the Energy Act.

To meet the targeted annual renovation of 3% of the total floor area of central government-owned and – occupied buildings (in line with the minimum energy performance requirements of the national building code) the Ministry of infrastructure published the list of buildings for renovation [83].

Decree on energy management in public sector was adopted in June 2016. The official National implementation report of EED states, that: ''The Decree is bringing obligation for all public bodies to perform energy bookkeeping report to the central database and achieve EE and RES goals in the building owned and used by them. Regarding transposition of EED decree is defining minimum energy performance requirements for buildings which central government will purchase or rent.''

•Decree on energy management in the public sector (Official Gazette. No. 52/16)

Energy performance contracting to finance renovations is strongly supported and a share of financing the renovation with public vs. private money is limited to at least to 1:3. A number of mechanisms are put in place to encourage the development of energy performance contracting: i.e. up to 40% subsidy for investment in energy renovation of public building is available from EU cohesion funding. ELENA TA for governmental buildings (EU pre-investment technical support) and the governmental Project Office for Building Energy Renovation intended for facilitating the renovation investments [84].

Article 8:
Article 8 of EED on Energy audits and energy management systems was transposed by the Energy Act - Articles 350. 351. 352. 353. 354. The provision refers to the high quality of energy audits, promoting energy audits to SMEs, obligatory energy audits in large companies every four years, as well as the conditions for the implementation of audits (by implementing adequate training for the qualification of the auditors) and the necessary awareness raising about the benefits of audits among households through the energy advisory services.

The regulation on the methodology for compiling energy audits and the content of those audits was adopted in 2016.

•Regulation on energy audits (Official Gazette. No. 41/16)
It defined the standards for implementation of energy audits: i.e. SIST ISO 50002 or a series of SIST EN 16 247 and alternatively if energy management system in line with SIST EN ISO 50001 or environmental management system - SIST EN ISO 14001 is imposed. It defined also the criteria regarding the knowledge. Experience and personal features of the energy auditor performing the audit (as per SIST EN 16247-5) [80] ,[85].

## 3.3 DEFINITION OF STANDARDS ACCORDING TO CEN STANDARDS AND OTHER ENERGY PLANNING TOOLS

This report summarizes the regulatory transposition path consistent with the CEN-EPB standards and describes other energy planning tools in the construction sector (e.g. urban or regional energy plans, municipal building regulations, etc.). The report will focus on how national legislation of target Countries is consistent with CEN standards. Moreover, it will analyse national legislation on energy planning regarding the energy efficiency of buildings and municipal building regulations oriented to the energy sustainability of buildings. The report will be annually updated to provide any change in the regulatory framework.
When the EPBD Recast was established, it was decided to reformulate the content of CEN-EPB standards so that they become unambiguous (the actual harmonized procedures), with a clear and explicit overview of the choices, boundary conditions and input data that can or need to be defined at national or regional level. In fact, as solid and realistic energy plans can only be developed taking into account local problems, differences in climate, culture & building tradition and building typologies, the standards shall be flexible enough to allow for necessary national and regional differentiation to facilitate Member States implementation. All the CEN-EPB standards definitions contained in the annual report will be updated consulting the European Committee for Standardization page (CEN). Another important source consulted for the constant update of this report will be the European Portal for Energy Efficiency in Buildings portal (BUILD UP) that contains a special section dedicated to Energy performance calculation procedures and CEN standards. Regarding the implementation of these standards at national and regional level, the EPB-Centre (EPBC) was created by the Federation of European Heating, Ventilation and Air Conditioning Associations (REHVA) and the Dutch Building Services Knowledge Centre (ISSO).
The Center is dedicated to provide stakeholders and interested parties with technical support for the implementation and dissemination of information on the set of EPB standards at national and regional level.

Concerning regional and municipal level, many information can be found by monitoring national energy agencies and institutions reports and in Global Buildings Performance Network page (GBPN).
Concerning Italy, France, Spain and Slovenia some information about energy planning tools are given hereafter:

### 3.3.1 France

France has prescriptive building energy efficiency requirements since 1955. The first performance based standard was implemented in 2005 following the release of the EPBD requirements in 2002. The RT2012 reflect the demands of the EPBD recast, with compliant buildings aiming to be approximately 40% more efficient than buildings built according to the 2005 regulations. The energy regulations for new buildings or restructurings are defined at national level and they are modified at periodic time intervals.

### 3.3.2 Italy

In Italy, in the last years, a number of regional laws centred on energy efficiency have been issued in the aim of filling the regulatory gap that for years has characterised the Italian national legislation in the field of energy efficiency. Many regions have indeed autonomously defined methodologies, limits, energy efficiency criteria to be applied to new buildings or restructurings.
The Regions are subdivided into Provinces, and these into municipalities. Each of these municipalities implements its own building regulations, with their own sustainable building codes (Norme per l'edilizia sostenibile) but based on Regional guidelines. Certain elements are integrated from national laws and decrees, but in principle, there is no national system of building regulations.
These guidelines cover 4 areas:

- Environmental sustainability and enhancement of the context
- Energy performance of building envelope
- Energy performance of technical systems
- Renewable energy sources.

### 3.3.3 Spain

The Spanish Technical Building Code (CTE) was established in 2006 however, the EPB standards were not included until the latest update in 2018. The latest version incorporates the definition of NZEBs as well as the minimum requirements for this building classification. Before the Royal Decree 314/2006 of March 17, which established the CTE, the regulation had been scattered and unclear, mainly focusing on the basic requirements of safety and habitability. In 2006, the CTE included a new *Basic Document* regarding energy savings (DB-HE), which has been updated over the years to comply with EPB standards and the EU Directive.

### 3.3.4 Slovenia

The Slovenian national methodology for calculation of energy performance of buildings has already been based on the CEN-EPB standards (SIST EN ISO 13790. SIST EN 15603 and other) as described in the Technical guidelines (TSG-004-01) that are the obligatory part of the Building code (PURES-2010).
In 2016 the Ministry for the Environment and spatial planning, responsible also for the building codes, initiated the integration of new set of EPB-standards (published in the beginning of 2017 and adopted also as Slovenian standards SIST EN during the year 2017) into the calculation methodology.
As part of the revision of the national building code PURES, in the year 2018 the effort was put in the integration of new EPB standards. In particular starting from the ones related to the presentation of building

energy performance indicators and NZEB criteria (EN ISO 52000-1. -2). In line with that, Slovenia is also revising the primary energy factors.

## 3.4 STRATEGIES TO PROMOTE THE ENERGY REQUALIFICATION OF THE EXISTING BUILDING STOCK

This chapter describes the tools that at national level are made available in target countries to promote energy efficiency in construction (building technologies, plant technologies, EPC contracts, ESCo, etc.). The state of the art of the EPC (Energy Performance Contract) implementation, as well as legislation about Energy Service Company (ESCo) in target member states is provided. The study will describe how to implement in those kinds of contracts one of the innovative aspects which characterize the management model presented by HEART project: the user behaviour analysis.

The report will also focus on the role of the ESCo in the promotion of the energy requalification of the existing building stock, as well as the possibility to activate them in order to support the management of energy retrofit of buildings in a perspective of EPC (Energy Performance Contract) contracts.

There are several public and private institutions, databases, EU projects that analyse energy efficiency markets and the regulatory framework concerning EPC and ESCo that will be constantly monitored. An important Horizon2020 project is the “guarantee project” which is dedicated to foster the use of Energy Performance Contracting in the public and private sector across Europe. The Energy Efficiency Financial Institutions Group (EEFIG), established in 2013 by the DG Energy and United Nations, provides frequent reports, analysis and evidence on energy efficiency policies, investments, financing strategies, etc. Other source of information that will be monitored are the European Environmental Agency, the ODYSSE-MURE database, the BUILD UP Portal, the Building Performance Institution Europe, the European Energy Efficiency Platform, promoted by the Joint Research Centre, as well the JRC itself. All of them publish several reports and detailed analysis of energy efficiency policies updates and investment in energy efficiency across Europe. Important source of information, that will be periodically monitored, are national and international agencies and institutions, as the European Association of Energy Service Companies (EAESC) and the European Federation of Intelligent Energy Efficiency Services (EFIEES) .

An introduction of ESCO and EPC regulatory context in Italy, France, Spain and Slovenia is given, as the two case studies for retrofit intervention will take place in those countries. A deeper description of national legislation in target countries and further analyses on the role of ESCO and EPC in foster building retrofit market will be provided in next deliverables

### 3.4.1 France

The French ESCO market is known to be large and growing at a considerable rate, featuring great diversity and heterogeneity. The total number of ESCO-type companies in France is around 350, with only around 10 EPC providers offering guaranteed agreements.

It is important to note that EPC has a different definition in France than in other EU member states, as French regulation forbids the payment for the investments from the savings when the customer is a public customer. The only way to use savings to pay investments is a PFI project (PPP in France) but there are only few projects each year.

In 2009, the quality seal “High Performance Energy” (HPE 2009) was established by the French government in order to encourage owners to go beyond the European energy requirements, demanding a level of 150 kWh/m$^2$·year.

In 2013, the National Plan for Housing Thermal Renovation was launched. It is based on 3 pillars:

- Assisting private individuals with free independent advice;

Improving financing thanks to optimized grants based on households incomes;
Raising the skills of the construction sector to handle the cost and quality of the renovation.
Local authorities made, at the same time, more than 80 project proposals in order to work closer with both private and public landlords and promoted the best ones nationally as good examples of local work.
To encourage professionals to build-up their skills, they planned financial support to owners whose renovations are made by workers certified by the French Environment & Energy Management Agency (ADEME).
In Decree No 2017-919 of 9 May 2017 it was made compulsory for owners to undertake complete insulation of the external wall and roof as part of any major building works, including the conversion of attics and garages into habitable space.

### 3.4.2 Italy

In Italy the legislation concerning ESCo and EPC contracts has been introduced for the first time with the Legislative Decree 2008/115.and then completed and updated with the implementation of the Energy Efficiency Directive and consequent legislation. The ESCo market in Italy is still considered to be among the biggest and most developed ones in Europe, a growth in the number of EPC projects and volume of EPC market between 2010 and 2016 has been registered .Nevertheless revenues has decreased by 10% in the same period The total number of ESCo certificated according to UNI CEI 11352  has more than doubled in last years; in particular in 2016 the number of ESCo has increased by 90% reaching the total of 272 companies at the end of the year, even if the dimension of those companies is generally small.

### 3.4.3 Spain

Along with the different EU programs, which promote the renovation market, the Spanish government is constantly funding renovation programs that focus on different renewable solutions through different European and Spanish programs. The Spanish government agency in charge of the actions, strategies, and funding for the renovation market is called the IDEA ("Instituto para la Diversificación y el Ahorro de la Energía"). The IDEA was designated, by the Spanish Ministry of Finance and Public Function (MINHAFP), as the intermediary agency for the management of the funds stated in the Sustainable Growth Operational Program, specifically the thematic objective 4 (OT4), of the European Regional Development Fund (FEDER). This program centres in four priority axes (Low carbon economy, integrated and sustainable urban development, water quality and sustainable transportation) and an additional one dedicated to technical assistance.
Other successful renovation programs include PAREER, which is a grant-financing scheme for building renovation in Spain. The programme concentrated on the areas that required substantial effort from the public administration in order to save energy, and focused on residential buildings, thus promoting the rehabilitation of the Spanish building stock, based on the EPBD calculation methodology and the application of cost-optimal criteria.
Additionally, the IDEA has three major programs, which promote the installation of green technologies. The programs are noted below:

- GEOCASA: Pilot program for the promotion of geothermal energy as a power source in thermal installations in buildings.
- BIOMCASA: Program dedicated to the promotion of biomass projects to cover needs such as hot water and air conditioning in buildings through biomass fuel.

- SOLCASA: Financing system that promotes quality and adapted supply to the needs of users in terms of hot water and air conditioning in buildings, through solar thermal energy.
- GIT [68]: Program dedicated to the funding of big installation projects of the three aforementioned programs.

### 3.4.4 Slovenia

The official National implementation report of EED states, that: ''Slovenian Environmental Public Fund Eco Fund (Eko sklad) is a public fund (owned by the state). Eco-Fund aims at improving energy efficiency through financing investments in energy efficiency, mostly in households. The funds for subsidies are collected from the contributions-fee for improving energy efficiency; from charges from district heating, electricity and solid, liquid and gaseous fuels, paid by final consumers on top of the price of energy or fuel to the operator or supplier of energy or fuels, which pays the funds collected to Eco-Fund.''

It also states, that: ''Non-repayable subsidies (grants) (higher for investments in at least three eligible measures and total retrofits vis-à-vis singular investments; up to 50 % of the eligible cost for investments on areas with high PM10 pollution; up to 100 % of the eligible costs for socially deprived households) are offered to:

• households for energy efficiency in residential buildings:
• solar heating systems
• biomass boilers
•heat pumps
•connection to district heating on renewable energy sources
•energy efficient wooden windows
•facade insulations
•roof insulations
•mechanical ventilation with heat recovery
•new nearly-zero-energy buildings (NZEBs)
•deep renovation of existing buildings
•purchases of apartments in NZEBs multi-family buildings (full retrofits)
•individuals (households) for energy efficiency and use of renewable energy sources investment projects in in multi-family buildings:

  - facade insulations.
  - roof insulations.

•households. legal entities and municipalities for electric cars
•municipalities for nearly-zero energy public buildings.

In 2016 for grants there was around 50 mio EUR available.

Eco Fund's is supporting also Energy Advisory Network which offers free advises regarding EE investments for households.'' [85].

Grants and support to energy performance contracting for public buildings and in particular for governmental buildings obtain under "3% renovation rule":

Project Office for Building Energy Renovation was established in October 2015 by the Ministry of infrastructure to set public bodies' buildings as exemplary role. The Project Office is a coordinating body concentrating knowledge and experience for the implementation of investments in the energy renovation of state-owned buildings. with special emphasis on the energy performance contracting.

An expert team assists in designing invitations to tender, conducting public-private partnership procedures, evaluating tenders, checking the implementation of measures, the implementation of the contract on the

provision of energy savings and transferring knowledge and good practice to the entire public and other sectors.
The main tasks of the Office id managing of the systematic preparation of a set of projects to meet the targets of renovation of state-owned buildings; to support the implementation of energy performance contracting projects: actively support financing by energy performance contracting (including the preparation of procedures and documents for the standardised implementation of projects) and removing administrative barriers, facilitation the preparation of projects, analysis of the quality of projects already carried out; to provide information and participate in the training of all important entities in these fields; to transfer knowledge and experiences relating to investments in the renovation of buildings between different segments of public administration (with entities such as local energy agencies. etc.), and transfer international knowledge and experiences to other sectors (e.g. SMEs. housing sector); to support the transfer of knowledge and experiences in the field of the energy renovation of cultural heritage buildings; to manage demonstration projects; to keep the records of central government buildings for energy renovation requirements.
The Project Office supports the use of Cohesion Funding for building renovation by preparing the instructions for the work of intermediary bodies and beneficiaries, the manual of eligible costs and instructions and technical guidelines for all participants in the energy renovation of buildings [84] [85].
Commercial banks – factoring in multi-family buildings
Commercial banks are also offering financial products to enable the energy renovation of multi-family buildings. Apart from standard loans it is frequently the case that the in residential buildings the financing is done by factoring. The contractor that renovated the multi-family building with several private owners' flats, sells the (remaining) debt of multiple flat-owners to the bank. The monthly payment of instalments is guaranteed by the legally obligatory monthly payments into the "reserve fund" (the agreement between the flat-owners. contractor and the bank is done in advance).
Training of facilitators in multi-family buildings
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. 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)) [85].

## 3.5 ASSESSMENT OF ELECTRICITY AND NATURAL GAS TARIFFS AND INCENTIVES FOR ENERGY RETROFIT OF BUILDINGS IN EU TARGET COUNTRIES

### 3.5.1 Assessment of electricity and natural gas tariffs

The aim of this part is to provide electricity and gas tariffs per countries, as well as their evolution in time, to outline the different scenarios of target country markets. Electricity and gas prices in target states are published by Eurostat [55] [56] every semester on its website. Data are collected by European states according to the new European Regulation 2016/1952 on "European statistics on natural gas and electricity prices" [57] which introduces a unique methodology for all reporting countries. The trimestral reports on gas and electricity markets published by European Commission on its website are another important source of information that will be monitored during the whole project duration.

According to the Regulation, household consumers shall be reported considering three different bands for Annual natural gas consumption (GJ): D1 < 20; 20 ≤ D2 < 200; D3 ≥ 200 and five different annual consumption bands for Annual electricity consumption (kWh): DA < 1000; 1000 ≤ DB ≤ 2500; 2500 ≤ DC ≤ 5000; 5000 ≤ DD ≤ 15000; DE ≥ 15000.
In addition to average values electricity and natural gas prices, the different kind of tariffs available in each of target countries will be monitored and annually reported. In fact, for household consumers there is not a single price for electricity and natural gas, as tariffs are generally set according to the amount of electricity consumed along with several other characteristics as hourly-basis or daily-basis ones, most tariffs also include some form of fixed charge.

### ✓ Spain

The price and volume of electric energy at a given time are established by the cross between supply and demand, following the marginal model adopted by the EU in compliance with Commission Regulation (EU) 2015/1222 of July 24, 2015 [66] establishing a guideline on capacity allocation and congestion management.
In Spain, the price of the kWh in 2019 depends on the market in which the client has contracted the supply of electricity or natural gas. Since 2014, the price of kWh of the regulated electricity market is established through the wholesale market (pool). Previously, it was done through electric auctions. During this year, the new regulation introduced the PVPC modality (Voluntary Price to the Small Consumer), which entered to fight more effectively the constant increase in the electricity bill in Spanish households, while also starting to bill their customers the price of electricity by the hour. Nonetheless, this type of pricing per hour is only adapted to digital counters, unfortunately approximately 10 of Spanish households are still analogue. These households have two PVPC pricing options: Weighted Average Price (PMP) or rate with time discrimination.
The price of the kWh in the free market is established by each company, which acquire energy at the same cost. The client can then decide with which marketer to contract their supply. Some of the prices available in the market are presented in the following table:

Table 31 – Electricity price comparison of the hour-to-hour rate of the PVPC with fixed-price in 2019.

| | TARIF | MONTHLY PRICE | ENERGY | POWER |
|---|---|---|---|---|
| **MINISTRY OF INDUSTRY** | PVPC electricity rate per hour | 48,8955 € | 0,1299 €/kWh | 3,1703 €/kW/month |
| **IBERDROLA** | IBERDROLA's stable plan | 56,7394 € | 0,1392 €/kWh | 3,5036 €/kW/month |
| **ENDESA** | One Luz of ENDESA | 50,7454 € | 0,1199 €/kWh | 3,4297 €/kW/month |
| **NATURGY** | Mean electricity of Naturgy | 60,9373 € | 0,1504 €/kWh | 3,7078 €/kW/month |
| **REPSOL** | Online tariff of REPSOL | 51,4232 € | 0,1199 €/kWh | 3,5766 €/kW/month |
| **EDP** | Electricity pricing EDP 1 | 59,9920 € | 0,15043 €/kWh | 3,5036 €/kW/month |

Table 32 - Comparison of the PVPC time discrimination rate with other time discrimination rates in 2019.

| | TARIF | MONTHLY PRICE | PEAK HOURS | OFF-PEAK HOURS | POWER |
|---|---|---|---|---|---|
| **MINISTRY OF INDUSTRY** | PVPC electricity rate per hour | 48,8955 | 0,1507 €/kWh | 0,0771 €/kWh | 3,1703 €/kW/month |
| **IBERDROLA** | IBERDROLA's night plan | 353,9989 € | 0,1653 €/kWh | 0,0865 €/kWh | 3,5036 €/kW/month |
| **ENDESA** | One Luz nocturnal of ENDESA | 351,6448 € | 0,1586 €/kWh | 0,0794 €/kWh | 3,4297 €/kW/month |
| **NATURGY** | Nocturnal electricity of Naturgy | 57,3775 € | 0,1702 €/kWh | 0,0945 €/kWh | 3,8411 €/kW/month |
| **REPSOL** | Nocturnal online tariff of REPSOL | 50,3294 € | 0,1499 €/kWh | 0,0749 €/kWh | 3,5766 €/kW/month |
| **EDP** | Electricity pricing EDP 2 | 61,9906 € | 0,1999 €/kWh | 0,0982 €/kWh | 3,7037 €/kW/month |

On the other hand, the Organized Gas Market in the Iberian Peninsula began operating in December 2015, once the regulatory framework was set by Law 8/2015, of May 21, which amends Law 34/1998, of October 7, of the Hydrocarbons Sector (and its subsequent developments). It is a culmination to the works previously developed (April 2012) by OMEL and OMIP SGPS for the design and implementation of a functioning model of the Iberian gas market, which, respecting the guidelines included in the European Gas Target Model, adapted to the particular needs of the Iberian gas system. Law 8/2015, of May 21, establishes the creation of an Organized Gas Market in the Iberian Peninsula, and designates MIBGAS S.A. as its operator.
The price of the kWh of gas in the market is not the same for all companies; instead, each supplier offers a different price to its customers based on the access rate contracted by them. While the price of electricity in the regulated market is different every day, the price of the regulated gas tariff, the Last Resort Rate (TUR by its acronym in Spanish), is fixed every 3 months by auction.

Table 33: Gas price rates for different suppliers in 2019.

| | TARIF | PRICE |
|---|---|---|
| **IBERDROLA** | IBERDROLA's Home Gas Plan Rate | 0,1392 €/kWh |
| **ENDESA** | One Gas of ENDESA | 0,1199 €/kWh |
| **NATURGY** | Mean gas of Naturgy | 0,1504 €/kWh |
| **REPSOL** | Gas & More 3.1 of REPSOL | 0,1199 €/kWh |
| | | |

## ✓ Slovenia

### -*Electricity tariffs*

Since 1 July 2004, the tariff periods changed by the Regulation on the Tariff System for the Sale of Electricity (Official Gazette of the Republic of Slovenia No. 36/04) and the Act on the Establishment of the Methodology for charging the network charge and the methodology for determining the network charge and the criteria for determining of eligible costs for electricity networks (Official Gazette of the Republic of Slovenia. No. 121/2005) [86].

The provisions of this Regulation apply to household customers and customers with guaranteed supply of electricity.

The essential change of the tariff system from 1 July 2004 is the end of the afternoon lower tariff (between 13.00 and 16.00 hours) and its introduction on Saturday and on a day off work. Tariff Settings

- For final customers at low voltage, it is possible to distinguish three tariff times, namely: lower daily tariff (LT). higher daily tariff (HT) and single tariff (ST).
- For medium and high voltage terminals, three tariff times are distinguished: lower daily tariff (LT), higher daily tariff (HT) and pick daily tariff (PT).

  Distribution of daily tariff times

  According to the Regulation on Tariff System for the Sale of Electricity (Official Gazette of the RS. No. 36/2004), the distribution of daily tariff times is as follows:
- HT - a higher daily tariff. which is recorded by the two-tariff meter every working day from 6 am to 10 pm.
- LT - a lower tariff is a tariff that a two-tariff meter records every working day from 22.00 to 6.00 on the following day and every Saturday. Sunday and free day from 0.00 to 24.00.
- ST - is a single tariff recorded by a single-tariff counter every day from 0.00 to 24.00.
- For end-to-end high-voltage customers and mid-voltage end-users, using measuring devices for recording a 15-minute peak load, the peak tariff rates (PT) apply for the time when the peak daily tariff lines for the use of electricity networks apply. PT hours are valid only on weekdays from Monday to Friday.

You can find the tariff rates (PT) at the following link (http://www.eles.si/ure-kt.aspx).

Final electricity prices are published on the website of the Statistical Office of the Republic of Slovenia and the European Statistical Office.

In 3$^{rd}$ quartile 2018, Slovenian private and industry prices for the electrical energy were 0.17 €/kWh and 0.08 €/kWh.

***-Gas tariffs***

If Slovenia would opt for a tariff system for gas as for electricity, we would need to establish an advanced measurement of gas consumption (i.e., smart meters for gas) [87].

In the beginning of 2014, the Energy Agency of Rep. of Slovenia published the results of the study "Cost and benefit analysis of the introduction of advanced measurement in Slovenia".

The Energy Agency of RS concluded:

"The analysis assessed the economic benefits, the potential scope and the framework of the introduction, as well as the qualitative estimates of the models, functionality and services of the Advanced Measurement System and the additional costs and benefits that are difficult or impossible to directly monetarily evaluate. The analysis showed that an organized, mandatory introduction of advanced measurement of electricity in Slovenia can generate significant net benefits for both customers and the entire company, with the introduction costs being particularly high at the start of the introduction, while the benefits will appear in the long run, somehow at the end of the first investment cycle switching of meters.

The combined mandatory introduction of advanced measurement in the field of electricity and natural gas is not recommended due to the long period of return on investment costs. In addition, total net benefits that become positive only after 25 years are the result of much greater benefits in the area of electricity

than in the natural gas sector. Therefore, the joint mandatory introduction of advanced measurement could result in the cross-subsidization of natural gas users by electricity users."
In 3rd quartile 2018. Slovenian private and industry prices for the natural gas were 0.05 €/kWh and 0.03 €/kWh. Respectively [87].

### 3.5.2 Incentives for energy retrofit of buildings

The state of the art of economic incentive policies for energy requalification adopted at national level will be provided. The reference framework on national laws that incentivize energy retrofit actions on existing buildings is fundamental to better outline the regulatory context of the project, as well as analyzing how those incentivizing mechanisms are implemented and diffused in the target markets. Several databases are available, as the "Policies and Measures Database" on energy efficiency by IEA [58], as well as many institutions and agencies provide annual reports, as the European Commission DG Energy [59], the Odyssee-Mure database [60], Buildings Performance Institute Europe [61], etc.
Hereafter the main Italian, French, Spanish and Slovenian incentivizing systems are presented.

✓ **France**

The principal incentivizing systems currently available in French legislation, updated to 2018 budget law, are:

- Energy transition tax credit: addressed to all kinds of dwelling' occupant (owner or tenants), this tax credit reimburses 30% of all energy retrofit actions performed (up to 8 000€). All the energy retrofit works must be realized by selected enterprises certified as "Recognized Responsible for the Environment" (RGE) by the French Environment & Energy Management Agency (ADEME) and must meet "High Energy Performance" criteria.
- Eco-prêt à taux zero (ECO-PTZ): zero-interest loan of up to 30 000€ for financing energy retrofit "simultaneous" actions. It is addressed to private dwellings' owners whose apartment was built before 1 January 1990. The retrofit actions can only be accepted if they involve at least two of these categories:
  - High performance roof insulation
  - High performance external walls insulation
  - High performance windows and external doors insulation
  - Installation or replacement of a heating or a DHW production system
  - Installation of a heating system using renewable energies
  - Installation of a DHW production system using renewable energies.

Energy retrofit works must be realized by selected enterprises certified as "Recognized Responsible for the Environment" (RGE) by the French Environment & Energy Management Agency (ADEME).

✓ **Italy**

The Italian Budget law for 2019 [95] confirmed the overall scheme of incentives for energy retrofit of building and renovation of HVAC systems. Some adjustments have been introduced on percentage of fiscal deduction and on the typology of HVAC system included in the incentives.
Beneficiaries of "Ecobonus 2019" are the same: single/family house which benefit of 65% fiscal deduction and multi/family buildings with 75% fiscal deduction. The incentivization of HVAC systems is changed: micro-cogenerator are no more included, while the fiscal deduction at 65% regards only "Class A" condensing boiler installed with advanced thermo-regulation systems, while "Class B" or lower condensing boilers can benefit only of 50% bonus, as well as biomass boilers, solar shading systems and windows insulation.

About the “Conto Termico 2019” there are no main differences with previous year. Some simplified procedures have been introduced to automatize the process of incentivization while the environmental certification for biomass and gas boilers became mandatory.

- ✓ **Spain**

The new Spanish State Housing Plan 2018-2021, approved by the Council of Ministers on March 9, 2018 increased the economic aid for works related to conservation, security, accessibility, improvement of energy efficiency and sustainability. In addition, it extends them to a greater number of beneficiaries. Since 2018, single-family households (isolated or grouped, in urban and rural areas) and individual apartments can request a subsidy to be renovated. In addition, the requirements were toned down: properties built before 1996, instead of 1981 as in the previous plan, can apply to this economic aid.

To profit from the economic aid, 50% of the dwellings must be the habitual residence of the owners or tenants in the building. In the previous plan this requirement was 70%, which meant that many buildings in small cities and tourist destinations, could not profit from the subsidy. According to the general secretary of the National Association of Ceramic and Construction Materials Distributors (ANDIMAC) Some 17.5 million homes could benefit from these subsidies.

Renovation works include the installation of new heating, cooling, sanitary hot water and ventilation systems; more efficient windows that prevent leaks and noise; improvement of the building envelope with thermal and acoustic insulation; facilities to separate household waste inside the houses and electric vehicle charging points in the car parks. In energy reforms, the maximum amount may not exceed 12,000 euros if it is a single family and 8,000 euros for apartments (up to 40% of the investment). After the renovation works, the owners can benefit from an annual saving on their bill of up to 1,700 euros. In addition, the improvement of the envelope and solar protection can revalue the house price.

## 3.6 ASSESSMENT OF NATIONAL REGULATION CONCERNING THE CONNECTION OF DISTRIBUTED GENERATION TO LOW VOLTAGE NETWORKS.

This report analyses the regulatory framework, showing the differences between the standards in force in European Countries for what concerns the connection of distributed generation to low voltage networks. Moreover, each Country (and each distribution system operator within each Country) may have specific connection procedures which do not conflict with the standards, but which may impose some additional operational constraints.

In particular, standard EN 50438:2013 collects the vast majority of the prescriptions in force in each European Country. However, even if the scope is to specify «technical requirements for the protection functions and the operational capabilities of micro-generation plants, designed for operation in parallel with public low-voltage distribution networks», for what concerns protection it mainly refers to relevant national standards and local regulation. This standard is, therefore, mainly focused on the operational capabilities and on the dynamic behaviour of the generators in case of voltage and frequency variations.

The standard VDE-AR-N 4105:2011-08 is more complete, as also includes typical connection schemes. However, it does not take into account the presence of energy storage devices.

Hereafter Italian, French, Spanish and Slovenian national regulatory framework has been analysed:

### 3.6.1 Italy

Italian standard CEI 0-21 is the most complete standard currently in force, but it is valid only in Italy. It has been analysed and the connection schemes of the MIMO will be designed in order to comply with this standard. Moreover, the MIMO and the whole connection scheme (including interface protection) shall be certified as CEI 0-21 compliant by a certification laboratory.
Specific e-distribuzione (the Italian DSO which manages the distribution network of the Italian test case) requirements and procedures have been identified. The requirements and procedures were sent to the relevant Partners and have been considered in the configuration of the prototype for Italy.
The Italian regulatory framework is managed by the Italian regulating authority (Autorità di Regolazione per Energia Reti e Ambiente – ARERA, www.arera.it).

### 3.6.2 France

French regulatory framework has been identified. It is made up of national decrees, technical guides and documents:
• « Décret n° 2008-386 du 23 avril 2008 relatif aux prescriptions techniques générales de conception et de fonctionnement pour le raccordement d'installations de production aux réseaux publics d'électricité » ;
• « Arrêté du 23 avril 2008 relatif aux prescriptions techniques de conception et de fonctionnement pour le raccordement à un réseau public de distribution d'électricité en basse tension ou en moyenne tension d'une installation de production d'énergie électrique » ;
• « Guide Pratique UTE C 15-400, Raccordement des générateurs d'énergie électrique dans les installations alimentées par un réseau public de distribution » ;
• « Guide Pratique UTE C 15-712-1, Installations photovoltaïques raccordées au réseau public de distribution » ;
• « Documentation Technique de Référence d'ERDF », in particular « ERDF-NOI-RES_13E - Protections des installations de production raccordées au réseau public de distribution ».
The French regulatory framework is managed by "Commision de Régulation de l'Énergie" (CRE, www.cre.fr).

The detailed requirements and procedures will be sent to the relevant Partners and will be thoroughly analysed in the next month. These requirements will be integrated in the next deliverable.

### 3.6.3 Spain

The electricity bulletin or Low Voltage Electrical Installation Certificate (CIBT) is the document which certifies if an installation is in compliance with the Regulations of the Low Voltage Regulation (REBT 2004) [71], abiding with all the necessary requirements for electricity supply. This document reflects the main characteristics of the installation, such as the installed power and the maximum admissible power and a plan of the electrical installation with all the basic elements.
In Spain the current regulations for electrical installations are developed in the electro technical regulation for low voltage (REBT), approved by Royal Decree 842/2002 of August 2. The document expresses the complementary technical instructions or ITCs (50 in total). Moreover, the Royal Decree 337/2014 of May 9, defines the technical conditions and safety guarantees in high voltage electrical installations and its Technical Complementary Instructions ITC-RAT 01 to 23 [76].
Each Autonomous Community elaborates its own model of certificate, and there are basically two variants: the white electric bulletin, with the technical memory, and the blue electric bulletin, which serves to change the ownership of an installation or increase the contracted power.

Concerning photovoltaic installation, Royal Decree Law 15/2018 of October 5 [70] allows photovoltaic self-consumption facilities to play an important role in the Spanish electricity system. This Law establishes that for installations of self-consumption without surpluses and with a power of less than 100 kW and those that have surpluses, but with an output of less than 15 kW, they will not need the permits for access and connection to the network by the distributor.

### 3.6.4 Slovenia

Slovenian Energy Act supports two national documents. Decree on self-supply of electricity from the renewable energy sources (Official journal RS, no. 97/15 in 32/18) and Rules on the technical requirements of installations for the self-supply of electricity from renewable energy sources (Official journal RS, no. 1/16 in 46/18).

The distributer should determine whether the electricity production facilities (micro-generating plants) can be connected to the grid with the 'Approval for connection to the distribution network' (SZP) and the designer should determine, whether the coupling power is strong enough for the electricity production facilities [89] [90].

Self-supply devices can be connected either by the household customer or by the small business customers in the groups of final consumers;

- the self-supplying products can be connected according to connection scheme of the SZP Approval (P.1 and P.2 measuring station), where the conditions for 'LO' and 'LR' are combined in the 'Approval for connection to the distribution network' (SZP) - hereinafter 'the SZP approval', where the conditions for electricity withdrawal are specified;
- the maximum total connecting power of one or more generating sets may be from 2018 on higher than 11 kVA. However, the power submitted into the network may not be higher than 11 kVA;
- an existing electricity production device, which is included in the support system by article no. 372. of Energy Act, may be connected by the principle of micro-generating plants, if the system exits the support system and the device itself meets the provisions of the formerly mentioned Decree and Rules.
- If the SZP approval already exists, the terms of existing system and the terms of micro-generating plant must be defined with the possibility of electricity meter replacement. If the SZP approval does not exist in the case of a new measuring point, the terms of the new system and the terms of micro-generating plant must be defined.
- After the self-supply device is assembled, the owner has to apply for the self-supply device connection to the network (''SZP Approval'') and submit the following documentation to the distributer. The owner has to:
  - declare (declaration), that the installation station for the of micro-generating plant connection is prepared and that the of micro-generating plant is in accordance with the Decree and Rules;
  - add Annex 2 of the Regulation supplementing the Energy Infrastructure Regulation (O.J. 75/2010) for the first time connected equipment for micro-generating plant;
  - add certificate from the Energy Agency for an existing production facility, that the device is not included in the support scheme according to Article 372 of the Energy Act;
  - add the manufacturer's declaration of the self-supplying production plant that the protection settings are set in accordance with SIST EN 50438, the standard for the first time connected self-supply device;
  - instructions for the usage of the usage of the self-supply device in Slovenian language;

- a self-handling contract for the existing (or new) measuring station concluded with the supplier (listed in the list of suppliers which is published on the distributor's website);
- in the case of the first time connection of the measuring station, the remaining required documentation stated in the Application form.

Another important document in relation to the installation of the micro-generating plants is the Technical Guideline for the fire safety of solar power plants [91]. The guideline has systematically presented requirements for achieving the following objectives of fire protection: prevention of the occurrence of fire, prevention of the spread of fire across the building and adjacent buildings, enabling people and animals to be saved and facilitating safe firefighting.

In January 2019, the new Regulation on self-handling from renewable energy sources has been proposed [201]. The regulation promotes the usage of renewable energy sources and addresses three main points.

Firstly, the regulation continues the net-metering approach for determination of the electricity emitted into the network. The customer with self-handling at the end of the billing period pays only the difference if he has taken over from the network more than he has given to the network. However, if he has taken less than he has paid, he does not pay anything (except for those charges which are not related to the amount of electricity but on power and are paid in any case).

Secondly, the self-care will be enabled not only for the owners of single-family houses or business facilities (individual self-sufficiency) but also for different types of community, eg. residents in multi-family buildings (group self-supply) and to customers in close proximity (connected to the same transformer station) and connecting to communities in the field of energy from renewable sources (referred to in the regulation as "RES communities").

Thirdly, after the building with self-care unit is defined, the connected individuals have to agree on the share of the energy they are belonged. Afterwards, the unit can start operating and the renewable energy sources concept on the national level is improved.

## 3.7 THERMAL REGULATION FOR EXISTING BUILDINGS (ITALY AND FRANCE).

### 3.7.1 French thermal regulation for existing building

The building sector is considered as the biggest contributor to France's energy consumption and overall greenhouse gas emissions. Therefore, there is a significant potential to reduce emissions and reduce costs in the building sector. In France, more than half of the buildings are constructed before 1975 (when the first thermal regulation took place). Thus, the improvement of the energy performance and the renovation of the existing building stock are considered to play a key role in the increasing of energy efficiency. In this context, several regulations (RT 1976, RT 1982, RT 1988, RT 2000, RT 2005, RT 2012) have been established and evolved over time in order to optimize energy use in buildings.

There are two distinct sets of regulations for buildings:

The thermal regulation RT2012 is part of the set of regulations concerning new building construction. The new thermal regulation RT 2020 will become mandatory for all new buildings by the end of 2020. The RT 2007/2008 is applied for the existing buildings.

#### *3.7.1.1 New buildings (RT 2012)*

The RT 2012 Thermal Regulations are applied for all new constructions. The RT 2012 imposes three performance requirements:

1. Bioclimatic design (Bbio) : this indicator characterize the impact of bioclimatic design and is independent from the HVAC and other system performance.
2. Cep: this indicator characterizes primary energy consumption taking into account heating, cooling, domestic hot water, lighting, and auxiliaries. It must not exceed the maximum conventional primary energy consumption Cepmax= 50kWh/ $m^2$/year. This indicator is calculated as a sum of the previews elements minus photovoltaic production (limited to 12 kWhEP/($m^2$a))
3. Tic: this indicator sets the requirement of the conventional indoor temperature for summer comfort, calculated with the coefficient Ticref that represents the interior temperature not to be exceeded.

The new thermal regulation RT 2020 will become mandatory for all new buildings by the end of 2020. Table 34 summarizes the differences between the two thermal regulations.

Table 34: Comparison between RT2012 and RT2020

| RT2012 | RT2020 |
|---|---|
| BBC buildings (aim to limit the consumption of primary energy housing per year 50 kWh/$m^2$ per year) | BEPOS buildings (produces more energy than it consumes) |
| Cooling<br>Heating<br>Domestic hot water production<br>Lighting<br>auxiliary | The same as RT 2012<br>Household appliances<br>Appliances<br>carbon impact of the construction |
| Thermal insulation of buildings | Thermal insulation of buildings<br>Energy production<br>Environmental footprint |

### 3.7.1.2 Existing buildings (RT 2007/2008)

The regulatory requirements depend on the building and the renovation level:

- The thermal regulation defines an overall performance objective for big scale/major renovation of buildings over 1,000 $m^2$, built after 1948, (cost of renovation is higher than 25% of the non-land value of the building).
- For all other renovation cases, the regulation defines a minimum performance for the replaced or installed element. This second part is called "RT element by element" and has been applied since 1 November 2007.

The figure below shows the different cases encountered in a renovation project:

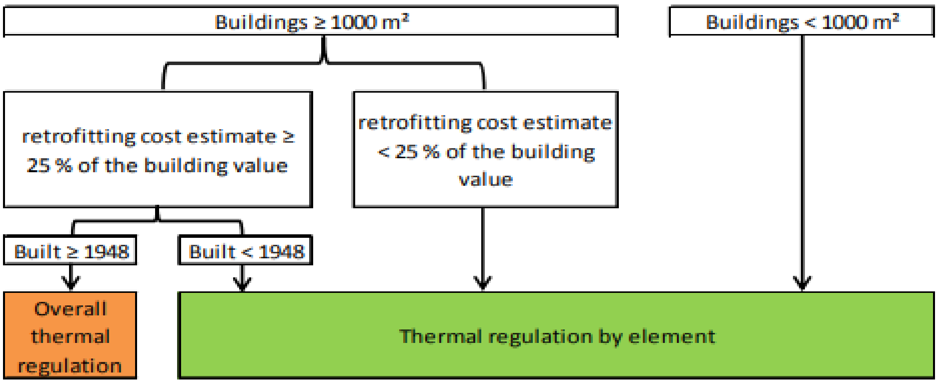



Figure 21: Thermal regulations according to size of building and type of work [197]

- ***Overall thermal regulation***

For big scale/major renovation of buildings over 1,000 m², built after 1948 , when the cost of renovation is higner than 25% of the non-land value of the building) , which corresponds to € 382.5 / m² for housing and € 326.25 / m² / m² for non-residential buildings. A thermal study of the initial performance of the building shall be carried out so that the limits of consumption required are not exceeded. This allows to evaluate the initial performance of the building, to guide the renovation choices and to estimate the potential energy saving.

In addition, retrofitting shall reduce the energy consumption by 30% for buildings other than housing. It is also mentioned in this case that "the renovation works shall not deteriorate the existing summer comfort". Such provisions have been in place since 1st April 2008 [197].

For residential buildings, the thermal regulation imposes a maximum consumption value. The energy consumption of the renovated building for heating, cooling and domestic hot water must be lower than a limit value depending on the type of heating and the climate. This maximum consumption is between 80 and 165 kWh / m².year depending on the case.

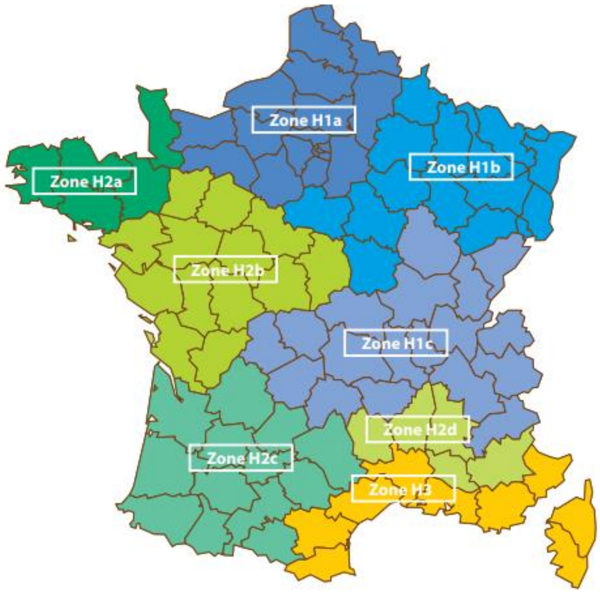



Figure 22 - Climate zones of France [199]

The table below shows the maximum conventional primary energy consumption Cepmax of the renovated building based on climate and type of heating [199].

Table 35: the maximum conventional primary energy consumption Cepmax of the renovated building based on climate and type of heating

| Type of heating system | Climate zone | Cepmax [kWh/(year.$m^2$)] |
|---|---|---|
| Wood and Fossil Fuels | H1 | 130 |
| | H2 | 110 |
| | H3 | 80 |
| Heat pumps / electric district | H1 | 165 |
| | H2 | 145 |
| | H3 | 115 |

In order to limit occupant discomfort and the use of air conditioning, the renovated building must provide acceptable summer comfort.
The conventional indoor temperature reached in summer must therefore be lower than a reference temperature.
In addition, minimum performance is required for a series of components (insulation, ventilation, heating system ...), when these are modified by the renovation work.
The table below shows the transmission coefficient (W/($m^2$.K)) of the reference building based on climate zone.

Table 36: the transmission coefficient (W/($m^2$.K)) of the reference building based on climate zone.

| Element | Climate zone H1, H2 | Climate zone H3 |
|---|---|---|
| Opaque Vertical Walls | 0,36 | 0,40 |
| Roofs | 0,20 | 0,25 |
| Ground floor | 0,27 | 0,36 |
| Windows, fully glazed doors | 1,80 | 2,10 |

The calculation according to the global regulation includes three categories:

| | |
|---|---|
| Calculation of the primary energy consumption<br><br>The calculation rules are defined by the order (calculation methods Th-CEex) | There's three types of coefficient of primary energy expressed in kWhep / $m^2$:<br><br>▪ Initial coefficient of primary energy before renovation<br>▪ Project coefficient of primary energy after renovation<br>▪ Reference coefficient of primary energy, according to a reference building. |

| | |
|---|---|
| | The coefficient of primary energy concerns the heating, cooling, hot water production, lighting, ventilation, and any auxiliary systems used.<br><br>Coefficients of conversion to primary energy (by convention):<br><br>- 2.58 for electricity consumption and production,<br>- 0.6 for wood consumption,<br>- 1 for other consumptions. |
| Calculation of the summer comfort | Calculation of the conventional indoor temperature Tic<br>▪ Tic after renovation<br>▪ Tic for the reference building. |
| Calculation of the Minimum thermal characteristics | Minimum requirements according to a reference building |

➢ ***The element by element thermal regulation***

The thermal regulation called element by element defines minimum requirements for eight individual components if included in the retrofitting project:

- Building envelope
- Windows and openings
- Heating
- Domestic hot water
- Chillers
- Ventilation
- Lighting
- Renewable energy

These requirements are defined in the Decree of March 22, 2017, became effective since January 1, 2018. The regulation concerns the thermal characteristics and energy performance requirements of installed or replaced equipment and systems.

The regulation includes eight major requirements, which must be respected. More information can be found in the legal decision dated March 22, 2017 [200].

***Insulation of the opaque walls***

These requirements concern the walls, low floor and the roof. The thermal regulation defines a minimal value of the thermal resistance ($m^2.K/W$) depending on the position of the insulation. The values can be found in the legal decision dated March 22, 2017.

***Insulation of the glass walls***

- The main requirement is to ensure a minimal thermal performance of the glass and windows (carpentry + glass).For the sliding windows: The surface coefficient of transmission must be less than or equal to 2.6 $W/m^2K$.
- For other type of windows: The transmission coefficient (Uw) must be less than or equal to 2.3 $W/m^2K$.
- Other requirements:
  - Housing ventilation ( art.13)
  - Summer comfort (art.11 – art.12)

- Thermal insulation of the shutter boxes: The transmission coefficient must be less
- than 3 W/m²K (art.14).

***Heating***
Heat pumps must satisfy a minimal coefficient of performance (COP) ranging between 2.7 and 3.2 depending on the type of system.

### 3.7.2 Italian thermal regulation for existing buildings

Several Law Decrees (L. 373/76, L. 10/91, D.Lgs. 192/2005, D.Lgs. 311/2006, D.Lgs. 115/2008, D.L. 63/2013, D.M. 26/6/2015) have been promulgated since 70s, according to country increasing sensibility and following European Directive on energy efficiency in buildings.
The most important laws concerning energy efficiency in existing building incurring in renovations is the D.M. 26/6/2015 [92] which provides guidelines on the application of methodologies for calculating the energy performance and the definition of minimum requirements of the buildings. Other relevant legislative acts are the D.Lgs. 28/2011 [93] which introduce renewable energy requirements for new buildings or buildings undergoing major renovation; the D.L. 63/2013 [94] which transpose the measures of the EPBD directive.

D.M. 26/06/2015 “Minimum requirements”
The D.M. 26/06/2015 “Requisiti minimi” (Minimum Requirements) provide a guidance on the application of methodologies for calculating the energy performance and the definition of the minimum requirements of the buildings. The Decree constitutes, with D.Lgs. 28/2011 on the exploitation of renewable energy source in buildings, the transitional rule to achieve the NZEB standard.
The energy performance of buildings is based on the amount of energy needed annually to meet the requirements related to a standard use of the building corresponds to the annual energy needs in the global primary energy for each energy service, with a monthly time step:

- Heating
- Cooling
- Ventilation
- Production of domestic hot water
- Lighting, lifts and escalators (in the non-residential sector)

It is allowed to take into account the energy from renewable sources or cogeneration produced in situ, only to contribute to the needs of the same energy source, to cover the total corresponding demand. The excess of the monthly requirement, produced in situ and exported to the grid, does not contribute to the energy performance of the building. The electrical energy produced from renewable sources cannot be considered if it’s used for the production of heat by Joule effect.
For the purposes of the design checks of compliance with the minimum requirements, the calculation is carried out in terms of total primary energy and of non-renewable primary energy, obtained by applying the conversion factors in total primary energy fP,totand non-renewable primary energy fP,nren.

### 3.7.2.1 Italian climatic zones

Italian territory is divided in 6 different climatic zones as represented in Figure 23 according to the amount of annual degree days. On the basis of which, main thermal constraints are established.

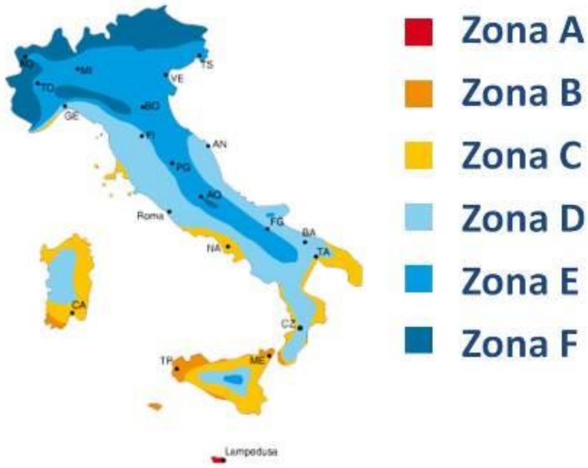



Figure 23: Map of Italian climatic zones.

Table 37: Italian climatic zones and corresponding degree days.

| Climatic Zone | Degree Days |
|---|---|
| A | <600 |
| B | 600 - 900 |
| C | 901 - 1400 |
| D | 1401 - 2100 |
| E | 2101 - 3000 |
| F | >3000 |

### 3.7.2.2 Thermal regulation of Existing buildings

The D.M. 26/06/2015 "Requisiti minimi" (Minimum Requirements) defines 4 different kind/levels of intervention:

• **New constructions**: the buildings whose qualifying title was requested after the entry into force of this regulation. Are assimilated to this category also buildings undergoing demolition-rebuilding and buildings subjected to extension with a new heated volume greater than 15% of the existing one (or in any case greater than 500 m2); [202]

• **Major renovations (first level)**: the interventions which, in addition to affect the building envelope with an incidence greater than 50% of the total gross external surface of the building, also include the restructuring of the HVAC systems;

• **Major renovations (second level)**: the projects which involve the intervention on the building envelope with an incidence greater than 25% of the total gross external surface and may affect the building HVAC systems;

• **Energy retrofit**: interventions involving an area less than or equal to 25% of the total gross external building surface and/or consist of the new installation, Principal regulations common to all buildings:

- Ensure the maximum reduction of the energy consumption considering the effectiveness in terms of costs;
- Include calculations and checks in a specific technical report;
- Verification of the effectiveness of technical solutions to limit consumption related to air conditioning in summer → use of materials with high solar.

## *Main requirements for new buildings and first level renovations*

1. Predisposition for the connection to district heating networks (if the building is less than 1 km from the network);
2. Installation of automatic control systems for the air temperature in individual rooms or in individual heating zones;
3. In non-residential buildings is mandatory a minimum level of automation
4. Calculate the parameters, performance levels and efficiencies and ensure compliance through the use of the reference building (a building identical in terms of geometry, orientation, location and boundary conditions to that one being analysed, but having the parameters defined in *Appendix A* of the Decree of 26/06/2015):
    a. Check the average overall heat transfer coefficient (average thermal transmittance of the envelope);

$$H'_T = H_{tr,adj} / \Sigma_k A_k \text{ [W/m}^2\text{K]}$$

| RAPPORTO DI FORMA (S/V) | Zona climatica | | | | |
|---|---|---|---|---|---|
| | A e B | C | D | E | F |
| S/V ≥ 0,7 | 0,58 | 0,55 | 0,53 | 0,50 | 0,48 |
| 0,7 > S/V ≥ 0,4 | 0,63 | 0,60 | 0,58 | 0,55 | 0,53 |
| 0,4 > S/V | 0,80 | 0,80 | 0,80 | 0,75 | 0,70 |
| | | | | | |
| TIPOLOGIA DI INTERVENTO | Zona climatica | | | | |
| | A e B | C | D | E | F |
| Ampliamenti e Ristrutturazioni importanti di secondo livello per tutte le tipologie edilizie | 0,73 | 0,70 | 0,68 | 0,65 | 0,62 |

    b. Check the “equivalent solar summer area” (Asol, east / Asupuseful). The values must be lower than those set out in *Appendix A*;
    c. Check of the primary energy indexes EP (heating, cooling and overall energy performance). The values must be lower than those related to the reference building.
    d. Check of the seasonal average efficiencies for heating, cooling and DHW. Values must be greater than those set out in *Appendix A*.
    e. Verification of the effectiveness of solar shading systems for glazed surfaces;
    f. Check the mass and the periodic thermal transmittance (Ms>230 kg/m2, YIE<0,10 W/m2K for opaque walls and 0,18 W/m2K for the horizontal and tilted opaque surfaces).
5. Ensure the compliance with D.Lgs. 28/2011.

The following tables show the maximum values of characteristics parameters, as transmission coefficient (W/(m².K)) and solar factor, of the reference building, according to climatic zones, as reported in, as reported in *Appendix A*.

Table 38: maximum transmission coefficient U for opaque vertical structures which border with environment, unheated spaces or ground.

| Climatic zone | U (W/m²K) | |
|---|---|---|
| | 2015 | 2019/2021 |
| A e B | 0,45 | 0,43 |
| C | 0,38 | 0,34 |
| D | 0,34 | 0,29 |
| E | 0,30 | 0,26 |
| F | 0,28 | 0,24 |

Table 39: maximum transmission coefficient U for opaque horizontal or tilted covering structures which border with environment and unheated spaces.

| Climatic zone | U (W/m²K) | |
|---|---|---|
| | 2015 | 2019/2021 |
| A e B | 0,38 | 0,35 |
| C | 0,36 | 0,33 |
| D | 0,30 | 0,26 |
| E | 0,25 | 0,22 |
| F | 0,23 | 0,20 |

Table 40: maximum transmission coefficient U for opaque horizontal flooring structures which border with environment, unheated spaces or ground.

| Climatic zone | U (W/m²K) | |
|---|---|---|
| | 2015 | 2019/2021 |
| A e B | 0,46 | 0,44 |
| C | 0,40 | 0,38 |
| D | 0,32 | 0,29 |
| E | 0,30 | 0,26 |
| F | 0,28 | 0,24 |

Table 41: maximum transmission coefficient U for technical transparent and opaque surfaces, garbage bin closures, including framework, which border with environment or unheated spaces.

| Climatic zone | U (W/m²K) | |
|---|---|---|
| | 2015 | 2019/2021 |
| A e B | 3,20 | 3,00 |
| C | 2,40 | 2,20 |
| D | 2,00 | 1,80 |

| | | |
|---|---|---|
| E | 1,80 | 1,40 |
| F | 1,50 | 1,10 |
| | | |

Table 42: maximum transmission coefficient U for opaque vertical and horizontal structures which borders with other buildings or dwellings.

| Climatic zone | U (W/m²K) | |
|---|---|---|
| | 2015 | 2019/2021 |
| all | 0,8 | 0,8 |

Table 43: Maximum value of overall solar factor for transparent surfaces on east, south or west.

| Climatic zone | $G_{gl+sh}$ | |
|---|---|---|
| | 2015 | 2021 |
| all | 0.35 | 0.35 |

## Main requirements for second level renovations

1. Check the average overall heat transfer coefficient (average thermal transmittance) of the entire portion subjected to intervention. The values must be lower than those set out in *Appendix A*.
2. Verification of compliance with the requirements and specifications defined for existing buildings undergoing energy retrofitting.

## Main requirements for buildings undergoing energy retrofitting:

1. The thermal transmittance of opaque/transparent vertical and horizontal structures. The values must be lower than those set out in *Appendix B*.
2. Check the solar transmission factor of the glazed components. The values must be lower than those set out in *Appendix B*.
3. Installation of thermostatic valves or other system of thermoregulation for individual room or single unit (in the case of centralized systems);

The following tables show the maximum values of characteristics parameters, as transmission coefficient (W/(m².K)) and solar factor, of the building element which are subject of the retrofit intervention, according to the climatic zone, as reported in *Appendix B*.

Table 44: maximum transmission coefficient U for opaque vertical structures which border with environment and are subject to retrofit.

| Climatic zone | U (W/m²K) | |
|---|---|---|
| | 2015 | 2021 |
| A e B | 0,45 | 0,40 |
| C | 0,40 | 0,36 |
| D | 0,36 | 0,32 |
| E | 0,30 | 0,28 |
| F | 0,28 | 0,26 |

Table 45: maximum transmission coefficient U for opaque horizontal or tilted covering structures which border with environment and are subject to retrofit.

| Climatic zone | U (W/m²K) |
|---|---|

| | 2015 | 2021 |
|---|---|---|
| A e B | 0,34 | 0,32 |
| C | 0,34 | 0,32 |
| D | 0,28 | 0,26 |
| E | 0,26 | 0,24 |
| F | 0,24 | 0,22 |

Table 46: maximum transmission coefficient U for opaque horizontal flooring structures which border with environment and are subject to retrofit.

| Climatic zone | U (W/m²K) | |
|---|---|---|
| | 2015 | 2021 |
| A e B | 0,48 | 0,42 |
| C | 0,42 | 0,38 |
| D | 0,36 | 0,32 |
| E | 0,31 | 0,29 |
| F | 0,30 | 0,28 |

Table 47: maximum transmission coefficient U for technical transparent and opaque surfaces, garbage bin closures, including framework, which border with environment or unheated spaces and are subject of retrofit.

| Climatic zone | U (W/m²K) | |
|---|---|---|
| | 2015 | 2021 |
| A e B | 3,20 | 3,00 |
| C | 2,40 | 2,00 |
| D | 2,10 | 1,80 |
| E | 1,90 | 1,40 |
| F | 1,70 | 1,00 |

Table 48: Maximum value of overall solar factor for transparent surfaces on east, south or west, in presence of a movable solar shading.

| Climatic zone | $G_{gl+sh}$ | |
|---|---|---|
| | 2015 | 2021 |
| all | 0.35 | 0.35 |

***Main requirements for the rehabilitation of thermal plants:***

1. Obligation of energy audits for refurbishing works on plants with thermal power higher than 100 kW.
2. Check of the average seasonal efficiencies for heating, cooling and DHW production. Values must be greater than those set out in *Appendix A*.
3. Installation of control systems for single room or single unit.
4. Installation of the heat meters in each unit (centralized systems);
5. Compliance with all the rules in force concerning energy efficiency of generators.

Detailed requirements for the rehabilitation of thermal plants are available in *Appendix A*.

***Other legislative references***

The D.Lgs. 28/2011 is another legislative reference that must be considered as it concerns the exploitation of renewable energy sources in buildings and contains in Annex 3, requirements for new buildings or buildings undergoing major renovation.

In particular, the Law states that a fraction equal to 50% of the sum of the consumption for heating, cooling and domestic hot water production must be supplied through renewable energy for building licensed after 1/01/2017.

In addition, the minimum electrical power from renewable sources, that must be installed on the building, measured in kW, is calculated using the following formula:

$$P = S/K;$$

Where S is the floor area of the building at ground level, measured in m2, and K is a coefficient (m2/kW) which is equal to 50 for building licensed after 1/01/2017.

# 4 INTERACTION BETWEEN BUILDINGS AND THE SMART GRIDS

## 4.1 INTRODUCTION

Regarding the application of Smart Grid-oriented technologies to the residential building stock and the evolution of issues related to IT security, vulnerability and privacy protection, it has to be stressed that Smart grids are enabled by ICT components so that security issues are given. In particular, the smart grid concept can be referenced as a branch of the Internet of Things - IoT (things in this case are e.g. grid components like circuit breakers or home meters). Smart Grid inherits similar problematics as IoT, like physical manumission of devices or tampering exploiting protocol weaknesses remotely. In contrast to IoT issues, Smart Grids adds another grade of possible compromising: pervasiveness of connection of the grid can expose systems that aren´t supposed or developed to be connected, like the supervisory control and data acquisition (SCADA) systems in power plants. Power plants are already a target of cyberattacks (e.g. Stuxnet in 2010 and the attacks on the Ukrainian grid in 2015). The consequences of massive attacks on the grid can be dangerous on human life scale. To carry this part of Task 2.3, we will begin by analysing literature, such as ENISA publications.

Moreover, Smart Grid solutions are going to enable new opportunities. They do not only bring threats. The digitalization of the grid through the implementation of ICTs allows for better connectivity between buyers and sellers, and real time data concerning production and consumption behaviors to be shared and exploited [96].

Furthermore, the penetration of clean distributed generation in the distribution grid is growing at a fast pace (IRENA). In addition to distributed generation (e.g. Building Integrated Photovoltaic), also commercial and residential demand response measures, and storage batteries are expected to witness a high rate of diffusion in the coming years.

This creates the need for new approaches that could integrate distributed generation and demand flexibility in electricity markets to have more efficient and transparent market prices and more stable and reliable energy systems [98].

These developments are changing how markets and the grid operate. The energy value chain is being reshaped, and new market entrants are challenging the incumbents.

At the current stage, there are several obstacles in the EU markets to unleash the full potential of Smart Grids. One reason is that new entrants (e.g. aggregators) are going to affect the positions of the incumbents (e.g. utilities), causing contractual issues and financial risks to arise [97]. These issues will have to be solved at either the EU level or national level. To understand how these issues will be addressed, we will analyse present and future EU Directives (e.g. [99]) and national regulatory frameworks.

Moreover, the growing penetration of non-dispatchable assets (i.e. intermittent generation) at the distribution grid level (e.g. PV, Wind) is increasing intermittency and therefore price volatility in the system. Therefore, in order to achieve cleaner, more secure and economical power systems, it is paramount to make electricity consumption more flexible.

An effective way to take advantage of the flexibility already embedded in the system is to adopt variable tariffs (e.g. Time of Use Rates) and indirectly influence prosumers through price signals (i.e. Implicit flexibility). During the project, we will analyse present and future EU Directives to assess EU provisions in terms of tariffs' features and we will conduct a market analysis so as to find out how retailers are charging their customers.

Moreover, a game-changing technology in Smart Grids and buildings that can improve grid stability and efficiency, adding flexibility into the system, is battery storage. For what concerns urban areas in the EU, small and medium size battery storage solutions are not yet very interesting nor cost-competitive solutions. Net metering measures give prosumers the opportunity to “store” their energy in the grid, without even paying grid charges for it. However, inefficient measures such as net metering are most likely to be replaced and prices for storage technologies are decreasing rapidly. It is therefore very relevant to closely follow the evolution of the energy storage market, and how policies and regulations will affect the integration of these technologies in our energy systems and markets.
The outcome of Task 2.3 activities will be presented in form of a report and delivered within month 32 (M32) – June 2020.

## 4.2 SMART GRID SECURITY ISSUES

Smart grid, being empowered by IT devices interconnected, has cyber security issues like all the devices that can be connected and accessed remotely.
Firstly, the smart grid devices can be tampered physically by an adversary: so is a fundamental and general task to make these devices difficult to access, as the devices can be deployed in public areas and not only in private ones.
Also, a user can tamper the home meter to show lower consumptions or increase the furniture levels of power to the building without having to pay for that. [100]
The smart grid poses another problem not related to technical issues: monitoring of power consumption can be a useful tool to retrieve information on the activities of people in their homes: thinking of a power consumption monitoring system developed by a national energy distribution society, in fact the society can potentially have in their hands a nationwide tool for in-home monitoring activities. Usage of monitoring data for espionage has in general ethical considerations and in a nationwide metering control in fact only the government and specific laws can assure the correct usage of data. Technically speaking, the data retrieved from the smart meters can be analysed by the so called NILM (Non-Intrusive Load Monitoring) [101] with the objective of retrieving from aggregated data profiles of usage of specific load (like the television or the washing machine), thus leading to knowing when a user is outside his home.
The general problem with smart grid isn’t to find a newer solution for security, but how to apply the existing ones: devices used on smart grid are completely equivalent to the classical connected ones, the difficulty is only to adapt already developed solution for devices that are constrained in computational power but used in critical infrastructure: cryptography to secure the connection and transmission of data, authentication of devices and so on. [102] [103]
The ENISA (European Network and Information Security Agency) has proposed a taxonomy of the possible threats on the smart grid, including also the accidental ones and the ones that are originated from social or human behaviour or motivated by economic or political reason; the ENISA’s threat taxonomy on smart grid are visualized in the table below.
Also, is worth noticing that addressing the technical threats, differently from the classic IT technologies, have to be done prioritizing the functionality of the grid itself: so, for the Automation and Industrial devices, referring to the CIA security triad (Confidentiality, Integrity and Availability) the triad itself has to be rewritten as AIC, in order of priority. For the meters and the items that retrieve data the CIA order of priority is good: if a meter is disabled the grid itself isn’t damaged. [104]

| Threat classification | |
|---|---|
| **Type** | **Threat** |
| Technical | Malware |
| | Non-optimized processes |
| | Weak innovation |
| | Manipulation of device's internal electronics |
| | Physical manipulation of devices' subcomponents |
| | Removable component replacement |
| | Manipulation of home devices |
| | Unauthorized firmware replacement |
| | Compromised firmware update |
| | Escalation of privileges |
| | Sensible information interception |
| | Alteration of information in transit |
| | Traffic injection |
| | Sensible information theft |
| | Credentials discovery |
| | Partial denial of service |
| | General denial of service |
| | Breakdown |
| | Propaganda |
| | Disclosure of information |
| | Disinformation |
| Corporate Image and Information management | Low quality information for decision making |
| | Damage to Brand Image/reputation |
| | Rumor |
| | Bad patenting policies and procedures |
| | Weak knowledge of regulations |
| | Lack of comprehensive insurance coverage |
| | Unfavorable contractual agreements |
| Legal, social aspects and human ethics | Noncompliance with national and international regulations |

| | |
|---|---|
| | Strike |
| | Sabotage |
| | Retention |
| | Faked sickness |
| | Incompetence |
| | Bribery |
| | Dishonest behavior |
| | Employee unreliability |
| | Error |
| | Panic |
| | Epidemics |
| | Penuries |
| Environment | Weak relations between management staff |
| | Weak internal controls |

| | |
|---|---|
| | Not respected management |
| | Procedures are not followed |
| | Illness |
| | Badly controlled outsourcing |
| | Low morals |
| Organizational | Weak relations between management staff |
| | Weak internal controls |
| | Not respected management |
| | Procedures are not followed |
| | Illness |
| | Badly controlled outsourcing |
| | Low morals |
| | Labor accidents |
| International Relations/Politics | War |
| | Terrorism |
| | Regional conflict |
| | Organized crime |
| | Kidnapping |
| | Government corruption |
| | Mass psychoses |

| | |
|---|---|
| | Group anarchy |
| | Riots |
| Marketing/Economical/ Financial | Volatile market |
| | Product/service boycott |
| | Unsuccessful merger/acquisition |
| | Bad product/service performance |
| | Non-adapted product |
| | Unsatisfied client |
| | Bad strategic decisions |
| | Client dependence |
| | High competition |
| | Interrupted production |
| | Negative Return on Investment (ROI) |
| | Debt |
| | Low capital |

| | |
|---|---|
| | Demands of shareholders |
| | Untrustworthy financial sources |
| | Slowdown in economic growth |
| | Fraud |
| | Insufficient resources |
| Environment | Natural catastrophe |
| | Pollution |
| | Nuclear catastrophe |
| | Biological disaster |
| | Chemical disaster |
| | Radio-electric incident |

A parallel and complementary problem of smart grid is the security of the power plants, a major concern is the possible tampering or sabotage of the components of the so-called Supervisory Control And Data Acquisition (SCADA) systems: an adversary in this case can potentially do extremely powerful damage to the end users, as an act of sabotage, terrorism or even war (so called cyberwarfare).

First known attack on a SCADA component, specifically the PLC (Programmable Logic Controller), was Stuxnet malware in 2010 that was intended to infect PLC components of SCADA systems as a major attempt of sabotage on Iran’s nuclear power plants. The attack was conducted through really standard ways (infected pen drive and weak security policy adopted by personnel), the malware itself searched a specific PLC model and acts silently to spread attempting to reach it, leaving unscattered the devices that propagated the infection. When founded a target, the malware leverage over zero-day vulnerabilities (in technical language that term refers to a vulnerability that is unknown to the public) to perform malicious operations. [105]

The SCADA systems in the Iranian case (and mostly normally) were “air gapped”: in the network security literature that term refers to a network that has any ports that can be used to make a connection to another external system.

SCADA systems, being developed to work in an isolated environment, are systems that in most cases don't have any basic cybersecurity related hardware or software and thus are extremely weak if connected to the Internet.

A recent (October 2018) malware that has attacked SCADA system is VPNFilter malware, this malware infects mostly older home routers and network hardware at the first stage and then listens for SCADA-related traffic; if a SCADA system is online the malware can interact with it (Ukrainian secret services claimed to have stopped a VPNFilter attack to a chlorine production plant). [106] [107]

Three years before VPNFilter attack, in 2015, Ukrainian electric grid itself was sabotaged through a similar cyberattack, the first ever that attacks directly power grids, with the BlackEnergy malware: the malware was spread via mail phishing on IT workers PC of energy supply societies as a first stage, using Microsoft documents as vectors attached in the mail and running the malware using Visual Basic Macro on the document.

At this stage, the attackers had a foot on IT network of the energy society, but (wisely) the SCADA systems were isolated through a VPN from the network, so the attackers must find vulnerabilities on the firewall or try to steal any worker's credentials. In some months of analysis (the attack was clever enough to inject a backdoor within the malware) the attackers were able to get the VPN credentials used to access the SCADA network. Hereafter, the attackers were able to switch off the 30 substations, with consequent 1-6 hours of blackout. [108]


*Figure 244: ENISA´s overview of ICS/SCADA threats (Source: [106])*

The 2015 Ukrainian grid attack was made up completely made up with a classic technique (Macros as a vector to inject malware) and usage of basic mail phishing, also is interesting to note that the Ukrainians in this case have some kind of security assessment as the SCADA network was protected through a VPN; that isn't always the reality, there are some SCADA devices open and public access through the Internet. [109]

Another thing to note is the different approach to the infection spread: the Stuxnet malware required a human intervention at some point to act maliciously, as the specific devices that targeted was at the time air gapped; VPNFilter is a malware that uses a more sophisticated approach: first creates a botnet of infected hardware (and don't is generic hardware, but older home routers mostly, which means hardware that is always online) and secondary searches for SCADA-related traffic in a completely automated fashion. That is mostly related to the widespread of the IoT technology concept and the SCADA connection to the Internet.

ENISA in the document [110] have done a study about communication networks and the ICS/SCADA systems connected to those, in this dissertation we are going to enunciate the recommendations suggested for manufacturers, operators and security experts:

1. **Include security as a main consideration during the design phase of ICS/SCADA systems.** Traditionally the ICS/SCADA systems were designed to be safe, not secure; although IT is now one of the main risk sources that should be covered to prevent future attacks and incidents. SCADA have to be designed as proper IT networks, so during the design phase there is the need to establish access controls (logical and physical) on all SCADA network communication access points, define security measures to protect and validate communications between SCADA devices, include security-specific devices (e.g. firewalls, IDS/IPS, gateways) on the main system design (instead of being an add-on later on), establish data validation processes among devices, excluding any unknown systems from the network (e.g. source node origin validation, MAC address filtering, etc.) and request the implementation of required basic security features to vendors (e.g. authentication or data validation);

2. **Identify and establish roles of people operating in ICS/SCADA systems.** Role management is crucial on the ICS/SCADA systems, also there is the need to make proper authorization for all the different areas of the system, is needed to check on the operation of the employees to limit privileges of those on a need-to-know basis, revoke unneeded privileges as soon as possible is needed to limit the access to only the minimum possible entities, making specific accesses to external contractors and maintenance personnel which must only be active during their intervention and remain disabled the rest of the time can be useful in the case of needed shared accounts (e.g. limited system capabilities) also the controls must be put in place to register and control the accesses made to these systems, a verification of new employees via background checks during the incorporation process and as well as defining exit interviews when leaving the organization is a good idea;

3. **Define network communication technologies and architecture with interoperability in mind.** ICS/SCADA systems as already said have to be developed as a proper IT network, so there is the need to identify in design phase the infrastructures and environments that require intercommunication with other systems (internal or external) or that may require this intercommunication within the near future (considering the lifecycle of the devices involved), also there is the need to select protocols that are compatible with the systems identified and the systems from the other organizations or environments. These can be proprietary or open-source protocols, as long as they are compatible with all devices involved although it is preferred if their internal workings are available to define security measures and ensure the compatibility;

4. **Establish brainstorming and communication channels for the different participants on the lifecycle of the devices to exchange needs and solutions.** This could be achieved through collaborative environments that allow the exchange of information between different parties and identification and exchange in a common platform of the main attack vectors;

5. **Include the periodic ICS/SCADA device update process as part of the main operations of the systems.** Helping to fulfil this recommendation can be possible to identify the different devices that make up the ICS/SCADA network determining their hardware version and their current software and firmware versions, is also possible to establish a communication channel with the manufacturers (if possible) to stay up-to-date on any new updates and patches released for the devices owned, to define the time periods when the updates are going to be implemented (e.g. periods of lower operations,

maintenance times, etc.), to make use of redundant systems with the purpose of maintaining operations while main devices are being updated, to progressively deploy updates/patches in order to detect any issues early without affecting multiple devices, to establish a testing period to verify the correct implementation of the update and ensure that operations continue to run smoothly with the new updates applied;

6. **Establish periodic ICS/SCADA security training and awareness campaign within the organization.** There is also a need of awareness on security within organizations and security training of the employees. So to establish those awareness campaigns can be done to inform users of the security concepts specific to both ICS/SCADA and traditional IT systems, also specific security training to teach how to apply security measures and behaviours on the daily processes with the least impact possible can be done, infographics that warn about new threats and risks and as well acting as a reminder of the common security practices and function scan be done and place in the workplaces;

7. **Promote increased collaboration amongst policy decision makers, manufacturers and operators at an EU Level.** Interconnection between industrial devices requires collaboration of policy makers, manufacturers and operators in order to ensure the safeness of the processes and security objectives. Promote the creation of an industrial control system professional community to help make the needs of operators more visible, serving as an invaluable aid for policy makers to ensure that they are aligned with other involved parties and that the measures provided are adequate and increase safety and reliability;

8. **Define guidelines for the establishment of reliable and appropriate cybersecurity insurance requirements.** Interconnection and the use of Internet for SCADA communications opens a new scenario where insurance also appears to cover these risks, but it is not clear to what extent this can be helpful and what would be covered. So, good purposes can be to identify the ICS/SCADA devices, assets, and network systems within the organizations' infrastructure, to carry out a risk analysis considering all these system devices and assets identified to determine the threats they are exposed to their likelihood and impact, to determine the security measures that are implemented to mitigate these threats (directly or indirectly), to list the security measures that are to be implemented in the following months/years with the objective of improve the security of these devices, to obtain the overall risk to these devices considering the initial risk analysis and the mitigation factor of the security measures in place or to be implemented, after a risk analysis with the direct participation of the top management can be possible to determine which risks are acceptable (i.e. the risk is minimum or the security implementation cost more than receive the damage) and the ones that need to be covered.

### 4.2.1 ENISA's framework on Smart Grid security

In document [111] ENISA has published a framework to address security on smart grids. The model proposed by ENISA consists of a set of domains (i.e. set of security measures) and a level of sophistication required to address those (this mainly with the purpose to distinguish different stakeholders and different in-place systems), the level of sophistication is chosen also considering a Risk Assessment value (RA) as higher risk related to a security measure requires higher sophistication; all the domains proposed by ENISA are illustrated below, in table 49 are recapped the domains and the associated practices founded by ENISA for smart grids.

1. **Security governance & risk management:** this domain covers the security measures that should been taken into consideration to facilitate a proper implementation and/or alignment with the security culture on smart grid stakeholders;
2. **Management of third parties:** this domain covers the security measures related to the interaction with third parties, so that the smart grid operator can reach a true and sustainable integration to the smart grid as a whole;
3. **Secure lifecycle process for smart grid components/systems and operating procedures:** this domain covers activities and procedures related to the secure operation, configuration, maintenance, and disposal of the smart grid components and systems. Therefore, the security measures included in this domain take into consideration among other things the proper configuration of the smart grid information systems and components or its change management procedures;
4. **Personnel security, awareness and training:** this domain ensures that employees of an organization running a smart grid receive adequate training to perform reliable operations on the smart grid;
5. **Incident response & information knowledge sharing:** this domain covers the possible security threats, vulnerabilities, and incidents affecting smart grids to provide an effective response in case of a potential disruption or incident;
6. **Audit and accountability:** this domain cover the implementation of an audit and accountability policy and associated controls to verify compliance with energy and smart grid specific legal requirements and organization policies;
7. **Continuity of operations:** this domain ensures the basic functions of the smart grid under a wide range of circumstances including hazards, threats and unexpected events;
8. **Physical security:** this domain covers the physical protection requirements for the smart grid assets;
9. **Information systems security:** this domain covers the definition of requirements to protect the information managed by the smart grid information systems using different technologies like firewalls, antivirus, intrusion detection etc.;
10. **Network security:** this domain covers the design and implementation of requirements that protect the established communication channels among the smart grid information system and the segmentation between business and industrial networks.

Table 49: Maximum Domains and security measures

| Smart Grid Domains Taxonomy | |
|---|---|
| **Security governance & risk management** | Information security policy |
| | Organization of information security |
| | Information security procedures |
| | Risk management framework |
| | Risk assessment |
| | Risk treatment plan |
| **Third parties management** | Third party agreements |
| | Monitoring third parties services and validating solutions against predefined acceptance criteria |
| **Secure lifecycle process for smart grid components and operating procedures** | Security requirements analysis and specification |
| | Inventory of smart grid components/systems |
| | Secure configuration management of smart grid components/systems |
| | Maintenance of smart grid components/systems |
| | Software/firmware upgrade of smart grid components/systems |
| | Disposal of smart grid components/systems |
| | Security testing of smart grid components/systems |
| **Personnel security, awareness and training** | Personnel screening |
| | Personnel changes |
| | Security and awareness program |
| | Security training and certification of personnel |
| **Incident response & information knowledge sharing** | Incident response capabilities |
| | Vulnerability assessment |
| | Vulnerability treatment |
| | Contact with authorities and security interest groups |
| **Audit and accountability capability** | Auditing capabilities |
| | Monitoring of smart grid information systems |
| | Protection of audit information |
| **Continuity of operations capability** | Continuity of operations capabilities |
| | Essential communication services |
| **Physical security** | Physical security |
| | Logging and monitoring physical access |
| | Physical security on third party premises |
| **Information systems security** | Data Security |
| | Account management |
| | Logical access control |
| | Secure remote access |
| | Information security on information systems |
| | Media handling |
| **Network security** | Secure network segregation |
| | Secure network communications |

Is worth noticing that many of the security measures cited in table 49 are the same cited discussing ICS/SCADA recommendations to stakeholders, smart grid and industrial devices security share some threats (in fact, ICS/SCADA are connected to a smart grid directly or indirectly as already said, smart grid itself can be the ”cause” of the ICS/SCADA threats due to the interconnections needed) for direct connection or for the fact that smart grid distribution devices are industrial devices with ”computational power”, so the similarities are clearly understandable.

### *Level of sophistication*

Reading the measures proposed by ENISA in table 49 just as an example the “Personnel screening” and “Security training and certification of personnel” voices reminds on the examples proposed at the beginning of this dissertation. The Stuxnet attack on Iran power plants and the attack against Ukraine’s grid have required at certain point some human intervention: an improper screening on personnel activity in the first case and an improper training of workers in second case were one of the main causes of the good work of these attacks.

Keeping using these voices as examples, we are going now to analyse the level of sophistication proposed by ENISA. Suppose to implement the screen of the personnel, the required in-depth analysis of the background and history of the workers relates to an estimate of how much dangerous the consequences are if that measure is implemented in a certain way.

ENISA proposes to use three levels from 1 to 3, ordered as levels of risk: first level of sophistication for low risk, level 2 of sophistication for normal risk and level 3 for high risk issues. For the security personnel screening case ENISA proposes these levels of sophistication:

- *LEVEL 1*. Standard requirements of public workers, individual screening criteria are established and reviewed for the organization’s position and screening of individuals before access to the smart grid information systems is authorized. In this case, the evidence of these practices is residency, personal information, degrees or law enforcement records.
- *LEVEL 2*. Standard screening and extra policies and regulation are applied on individuals to choose them, rescreening of personnel is applied periodically. As evidences, the organization maintains documented screening requirements and the records of rescreening process.
- *LEVEL 3*. Specific security clearance provided by government to personnel, evidences are databases of the clearance associated to each person and databases of the persons that have access to any critical data or resource of the organization.

This approach is maintained of each security practice founded in the domains illustrated in table 49 and for each the professionals in charge of security must choose the proper level of sophistication required to apply the practice reducing the estimated risk, all the other proposed levels of sophistication are illustrated in document [111].

## 4.3 CONCLUSIONS

Concluding this discussion on the smart grid security issues, the future objectives will be to enforce usage of security framework related to smart grid if already developed in order to find, to apply best practices founded (like the one proposed by ENISA) and trying to develop a security assessment even in the design phase, although in the smart grid case this isn't so simple.
For the industrial devices, there is still a lack of government enforced cyber security certificates of industrial devices in general and smart grid devices; a certification in cybersecurity lacks also for professionals that are employed in the energy distribution and generation sector or are working to analyse vulnerabilities on the industrial devices, although there is some work in progress on both in Europe. [112] [113].

# 5 COMPATIBILITY CONTINUOUS REVIEW

In order to ensure and to maintain HEART's open connotation throughout the duration of the project (2017 - 2021), market technological solutions with potential compatibility with the HEART toolkit will be reviewed on a regular base. Commercial products will be analyzed and selected for their potential integration in the HEART Toolkit. Compatible technologies with HEART's Toolkit, available on the market and including the most relevant innovations, will be listed along the project. Compatible technologies will include near to market technologies and innovative technologies that can improve the HEART Toolkit or that can substitute one or more utilized/investigated technologies. The reviewed technologies have potential compatibility with the HEART system and it will be an important information supporting the HEART development and uptake. It will be useful to widespread HEART to other potential partners and it will increase the desirability of the Toolkit. This activity will be done through several steps:

1) A screening of the revised Grant Agreement is ongoing, listing the most relevant technologies included in the project
2) So far, accessible deliverables (e.g. Ayoub et al. 2018, Scudo et al. 2018, etc.) are analyzed in order to further complete step 1
3) By means of web investigation, the market availability of the technologies identified will be checked and the near to market technologies will be investigated

During the second part of the project, new emerging technologies and their market availability which might be helpful for the integration and the desirability of the HEART Toolkit will be listed. The output of this activity will be an online Excel file (shared between partners) including available technologies, new innovative technologies and near to market technologies. The Excel file will include a list of technologies compatible with those included in HEART Toolkit, a description, and a subdivision per technology group, plus their costs. Costs indication of technologies replacing already utilized/investigated technologies are crucial for their potential application within the HEART Toolkit. Sources of information will be included as well in order to allow the process of continuous updating the database (as in Pezzutto et al. 2015). [114,115,116]

# 6 TECHNOLOGICAL BENCHMARKING PROCESS

This section represents an update of the technological benchmarking process related to T2.5. The expected technological features and performance parameters of the proposed in the project are being subjected to a continuous benchmarking process with the current best practices related to solutions for energy retrofit of residential buildings, in order to ensure the improvement potential of each subcomponent and of the whole system.

## 6.1 NZEB RETROFIT APPROACH IN TEMPERATE EU

The 2016 European Energy Efficiency Directive requires that EU member states draw up national plans for increasing the number of NZEB and develop policies and take measures to stimulate the transformation of buildings that are refurbished into NZEB [117].The recast of the Energy Performance of Buildings Directive (EPBD) [118] establishes the assessment of cost-optimal levels related to minimum energy performance requirements leading to the lowest building costs. In addition, the last EPBD recast [119] introduces a "smartness indicator" which will measure the buildings' capacity to use new technologies and electronic systems to optimize its operation and interact with the grid. EPBD requires EU member states to first reducing energy needs for heating and cooling and in a second step to cover a significant fraction of those needs by energy from renewable sources on-site or nearby. Combining cost-optimal solutions to reach NZEBs is an ongoing challenge. Energy consumption can be reduced evaluating different configurations at the design stage or refurbishment and implementing the most appropriate solutions according to the building and the location. Results of recent study [120] highlight how the cost-optimal measures vary with climate and how in each location final selected options differ. A key finding of the research is that a source energy reduction of 90% and beyond is feasible for new constructions in all locations. However, this is also true in case of energy refurbishment of existing building as the objective of HEART project. Next to the economic challenges, there are equally important factors like societal and technical barriers that hinder renovating the existing residential building stock and adding newly constructed high-performance buildings [121]. The importance of integrating renewables and energy efficiency measures is confirmed as crucial to reach the NZEBs target. Moreover, the central role of occupants is well recognized to achieve the NZEB goals [117].

Simulation-based optimization methods have increasingly revealed their effectiveness in decreasing energy consumption in buildings at the design stage [122] [123]. To derive the cost-optimal solution exploring several design options in more locations within a reduced computational time [124]. Recent research developments include the integration of optimization tools within the NZEBs design [125]. Furthermore, recently LCC based methodologies have also been developed for the evaluation of NZEBs [126].

Different design variables can be analysed with the purpose of reducing energy consumption in buildings [127] [128]. Applications deal with exploiting the efficiency of HVAC systems, ventilation, and photovoltaic (PV) systems [129] [130], and on optimizing a single building component, such as windows or envelope [131] [132].

Control automation and smart metering devices are among the most rapidly developing smart technologies. These devices allow the control of the energy demand/supply through ICT technologies considerably decreasing energy consumptions. Furthermore, they allow data collection for performance calculations and dynamic simulation modelling [133].

On-site renewables, such as PV systems, are more cost-effective in Mediterranean climates characterized by higher solar radiation and are becoming ubiquitous and efficient throughout Europe for building integration. PV can produce electricity to cover direct consumption or delivery to the grid or local storage for a later consumption [134].

The most common optimized NZEB configuration foresees a combination of good insulation, building airtightness as well as efficient heating and cooling system such as heat pumps, storage and home energy management systems along with PV.

In this scenario, HEART's multifunctional retrofit toolkit within which different subcomponents cooperate synergistically to transform an existing building into a Smart Building competes very well with technological benchmark in context of NZEB retrofit approach in temperate EU climates. In addition, the effort to innovates retrofit allowing to preserve some of the original elements of the windows and integrating –when feasible- new high-performance components, saving labour and material cost, is also an additional innovative element of the project.

## 6.2 MIMO (MULTI-INPUT MULTI-OUTPUT POWER CONTROLLER)

The choice of using a multi-input-multi-output power converter (MIMO) arose from the analysis of the characteristics of the devices to be connected to the plant. In particular, in the plant there are 5 electrical ports to be connected. Two ports are represented by loads that are fan coils and central heat pump. Both the load types have electric drives supplied in DC. The other three ports are for PV source, batteries and grid connections. The first two are DC devices. As a consequence, in order to improve the overall efficiency of the systems and, at the same time to simplify the regulation of the loads, a common DC bus has been selected as the best opportunity. The only DC/AC conversion required is for the grid connection. Also, in this case, anyway, a two-level inverter can ensure high efficiency, management of both active and reactive power and full compliance with the grid codes of European countries.

The analysis of very recent literature shows that great interest is still present for multiport power converters and for their advantages in connecting different electric power sources and loads. In particular, in [135] a resonant configuration for a MIMO is proposed while in [136] optimization of size and weight for a 2-outputs power converter is studied. An innovative configuration for a single input double output converter has been proposed in [137].

Recent literature is investigating stability properties and different control techniques for MIMO. For instance, in [138] a small signal stability analysis of an MV MIMO is shown, examining the impact of multivariable AC/DC dynamic interactions between the MTDC and AC power systems. In [139] a nonlinear current control strategy for the control of modal multilevel converters is proposed and experimentally validated.

As can be seen from the literature MIMO is a very good solution to integrate the different sources and, at the same time, if traditional configurations for single-stage realization are used, the technology is mature to be installed in reliable power plants for innovative and high efficiency buildings.

In order to achieve higher efficiencies, a new generation of switching components will be used in the realisation of the MIMO. Indeed, some of the conversion stages will be realized using wide band gap devices (in particular those based on Silicon Carbide technology) allowing the use of components with very low losses. Moreover, these components are very fast allowing to work at high switching frequency with a consequent reduction in size and weight for the low voltage DC ports [137] [140].

## 6.3 DC HEAT PUMP

The vapour compression heat pumps market in Europe reached in 2015 a size of 900,000 units, of which about one third is made of air-to-water heat pumps for space heating purposes [141].

The innovative DC heat pump under development within HEART has a packaged architecture and a modular structure with a nominal thermal power of 20 kWt that can be easily connected to other modules by means of plug-and-play hydraulic/electric connections. The PV system is DC-coupled to the HP, avoiding AC conversion and thus increasing the system's efficiency and eliminating the internal inverter. The unit also allows a total heat recovery when producing DHW, providing free cooling energy. The targeted COP for heating are at least 4.5 (A2/W35) and 5.5 (A7/W35), overcoming by 15% the efficiency claimed for the A+++ degree in 2019 in energy labelling regulation.

The results of a recent study [142] on the heat pump systems in European residential building, shows that the estimated efficiencies of an air-to-water heat pump for residential application, with an inverter driven compressor and with a nominal heating capacity of 15 kW are about 3 (A2/W35) and slightly over than 4 (A7/W35) air 7 °C. It has been verified that this HP model is representative of the units available on the market by comparing its efficiency with the efficiency of appliances from the Eurovent database [143]. Additionally, analyzing the models available in the Eurovent database, it was observed that the COP (A7/W40-45) is independent on the appliance capacity in the range between 4 and 16 kW.

On the other hand, in the prospective of space cooling, a detailed analysis of the projected performance of the main residential and commercial end uses air conditioning equipment up to 2040, is given in Ref. [144] and summarised in the literature [144]. For the residential air source heat pump systems the expected improvements is considerable. In particular, the typical seasonal EER in 2040 is expected to be close to 4.7 compared to 4.1 in 2013. Further a recent study [145] on 'Status Quo of the Air-Conditioning Market in Europe' stated that the average SEER for chillers in European building stock is about 3.2. The proposed DC heat pump is expected to perform much higher with the SEER for cooling > 5. This confirms that the DC heat pump proposed in HEART fits very well with respect to technological benchmarks.

## 6.4 THERMAL ENERGY STORAGE

The retrofit of heating and cooling system in HEART project represents the heat pump as main thermal energy source and excess electrical energy from PV as additional thermal energy source. Both sources are highly dependent from weather conditions, which is the reason that thermal energy storage (TES) is implemented into considered system, because it balances the mismatch between supply and demand of thermal energy. The proposed system for thermal energy storage in HEART project represents commercially available sensible TES tank manufactured by Heliotherm and modified with phase change materials (PCMs) to increase thermal energy density per unit volume.

In the research of Bourne et al [147] the latent heat thermal energy storage (LHTES) system compared to a similar-performing chilled water tank was investigated for improved energy efficiency of a chiller by shifting cooling load to non-peak electric energy loads. It was found that encapsulated tetradecane phase change material in tubes submerged in water-glycol tank can reduce size of a chilled water tank by more than a factor 2. Experimental research of an air-source heat pump water heater using water-PCM for heat storage has been done by Zou et al. [148] where the heat storage is increased by 14% compared to the standalone sensible thermal energy storage just by adding PCMs around condenser coil. According to the Abdelsalam et al. [149] the energy density of thermal energy storage containing water with submerged PCMs can increase energy density of storage from two to five times. In research of Fang et al. [150] a tube-in-tank LHTS system was investigated, where PCM is surrounded around several tubes in tank through which heat transfer fluid flows in charging or discharging period. The effective energy storage capacity of mentioned LHTES system can reach 4.4 times of that of an ideal stratified water storage system. Lu et al. proposed the improvement of buffer storage with multi-melting point PCMs. Investigated LHTES where compared with the conventional sensible storage, where the PCM accounting for 19% of the tank volume would extend time of heat release by 34%. In research of de Cunha et al. [151] comparison between performance of conventional gas boiler and air source heat pump with LHTS has been performed for a domestic space and hot water heating system with thermal solar collectors in a semi-detached dwelling. The LHTS system with paraffin provided 53% extra thermal storage capacity compared to a sensible thermal energy storage. According to simulation, yearly $CO_2$ reduction potential is 56% and yearly energy reduction potential is 76%.

In conclusion it is possible to state that the outlined analysis fully supports the technological path chosen within HEART project.

## 6.5 DECISION-MAKING AND ENERGY MANAGEMENT STRATEGIES BASED ON CLOUD COMPUTING

The identification of techno-economically feasible refurbishment paths for existing residential buildings is an important research task today and renovation processes can act in synergy with innovative economic and technological development paradigms to achieve different types of benefits. However, the potential gap between simulated and measured performance can be very relevant [152], considering in particular the impact on performance of occupants' comfort preferences and behavior [153] [154].

The research pursued within the H2020 project HEART (Holistic Energy and Architectural Retrofit Toolkit) aims at selecting the most relevant data analysis processes and techniques to respond to practical technical issues and to support decision-making in renovations, at multiple scales of analysis, from individual technologies, to single buildings, and to reference building stock.

Rigorous normative standards for new and existing buildings are fundamental components of sustainability and energy transitions strategies today. However, optimistic assumptions and simplifications are often considered in the design phase and, even when detailed simulation tools are used, the validation of simulation results remains an issue. At the same time, the calibration of energy simulation models on measured data during building operation is still not a common practice. The combined use of modelling techniques with data acquisition and processing can guarantee multiple feed-backs from measured data, useful for the evolution of design and operation practices in buildings.

The research concentrates on the analysis of these technical aspects for the creation of the DSS-BEMS platform, to be tested and refined by means of case studies, showing an efficient and transparent way to link design and operation performance analysis, thereby reducing effort in modelling and monitoring. In order to overcome the relevant technical issues encountered, a methodological continuity between performance analysis practices across life cycle phases is established, using parametric simulation (design phase) and progressively calibrating building model to real data, up to the statistical process control level (operation phase). Meta-models [155] (i.e. surrogate models, reduced-order models) can be successfully used for this purpose, e.g. in design optimization [155] [156], calibration and control [157]. The models used in the research are reduced-order grey-box models [158], i.e. physical-statistical models, and are defined in order to approximate the results of detailed dynamic building energy models employed during project development. The modelling approach proposed aims to synthesize the state-of-the-art of simulation, validation and M&V standards for building energy models. In order to render applications of reduced-order models more transparent and automated, the research is oriented towards the definition of multi-level performance metrics [159] [160], which corresponds to the consolidation of sensor data in the IoT platform, to be displayed through appropriate visualization techniques.

The methodology for information modelling used within the DSS-BEMS platform (i.e. integrated modelling workflow) is conceived to confront the plurality of models which are relevant to IOT applications [161]and to overcome the most relevant barriers to the deployment of integrated data analysis workflows and advanced control for energy management in the building sector [162] [163], i.e. the uniqueness of every building, which complicates the customization process. In order to overcome the relevant barriers, the modelling approaches proposed in the DSS-BEMS platform account for relevant capabilities such as incremental model construction (from simple to detailed), representation across scales (from single technologies, to individual buildings, and to reference building stock), accommodation of multiple formalisms (engineering systems, control, statistics, etc.), addressing domain-specific concerns, integration and aggregation across models (integrated data analysis workflow), flexibility and modularity (multiple models can run in parallel, using interoperable and scalable standards for IoT applications) and scalability (spatial and temporal analysis).

## 6.6 PV TILES

Currently the BIPV market holds a market share of around 2% of the overall PV market. The "BIPV Technologies and Markets: 2015-2022" report from n-tech Research [164] forecasts there will be about 13% BIPV penetration by 2022.

Although several products already exist (an overall database is shown in the "BIPV Status Report 2017" [165], the integration issue in terms of installation process, aesthetics long term maintenance and, above all, capital cost have been addressed. Capital cost, in fact, can be considered the major issue to consider, since it impacts most directly on the size of a PV roof tile. In order to achieve the overall integration, a PV roof tile should be identical in size and weight to a normal (traditional) tile.  However, such dimension is generally too small to make the manufacture of custom laminates economic. Increasing the width improves the economics significantly both in terms of capital and installation cost. However, as the size increases the product becomes less like a tile in terms of its behaviour and more susceptible to the quality of the roof construction [166]. Moreover, according to the BIPV market and stakeholder analysis and needs [164] the cost of conventional roofing products varies from 45€/m$^2$ (concrete tiles) to 150 €/m$^2$ (slates), while the PV products were all priced in the range between 200 and 650 €/m$^2$. In such respect, considering that the cost of the BIPV tiles, available in the market, vary between 375 and 475 €/m$^2$, it is possible to conclude that existing system cost 200 €/m$^2$ more than the conventional roofing materials [168].

Future growth prospects in the global BIPV market are significantly dependent on the extent of efforts by key members of the BIPV supply chain to enhance design and integration of PV into building structures, as well as to ensure cost-effectiveness of BIPV products. In such respect, recently, several European project have been funded; in detail, the BIPVBOOST project [169] defined a cost reduction roadmaps along the BIPV value chain. It aims to achieve a 50% reduction of additional cost of BIPV modules by 2020 and 75% reduction in 2030, and thus a substantial increase of market deployment of BIPV technology. Similarly, in 2017 the Energy Matching project [170] was funded with the aim to develop and demonstrate the cost-effectiveness of active building skin solutions as part of an optimised building energy system. At the same time, also the project PVSITES [171] has the aim to drive BIPV technology to a large market deployment by demonstrating an ambitious portfolio of building-integrated solar technologies and systems. More in general, other projects such as GRECO [172] and SUPER PV [173] which aim to reduce respectively costs of the photovoltaics (PV) system (in order to achieve a cost lower than 0.3€/W) and the LCOE in the range between 26%-37%) by combining technological innovations and data management methods along the PV value chain.

In such framework, it is possible to state that the main features of the new tiles developed in HEART can be considered ground-breaking. More in detail, the choice to use as a base product a PV panel in the range of standard commercial PV laminates ensures a low cost (lower than 150 €/m$^2$). The product will be suited to be integrated with both the structural supports of a roof and with the roof cover. The main feature of the anchoring system connecting the support system to the roof structure is planned to be that of being capable of sliding relatively to the roof structure and/or the support system so as to make possible to adjust the position of the support system in the three directions in space. A candidate solution (the validity of which should be assessed) for making this sliding action possible is that of suitably combining elongated bolt holes and sliding grooves and tongues obtained by extrusion or similar process. Furthermore, the selected material for the production of the anchoring system in HEART (as specified in the deliverable 7.4) is recycled plastic – extruded, cast or formed (pressed). This choice allows to contain cost, embodied energy and weight of the final product compared to existing solutions.

The general purpose underlying the design of the integrated system in question is that of embodying as many functions as possible in the conception (mostly, thanks the shape) of the recycled plastic profiles, so as to minimize the complexity and uncertainty of the installation operations without reducing the adaptability and robustness of the obtained solution.

## 6.7 SMART FAN-COILS

In the literature, a recent study on European air-conditioning (AC) market [167] shows that split systems account for the majority of AC units per type with more than 30 million (37.89% of total). The residential building sector in EU 15 has highest share in terms of cooled floor area (1567 Mm$^2$) in comparison to other sectors and is dominated exclusively by RAC (Room air-conditioning) application. Recent market research estimated that the traditional RAC segment will cover more than 70% of the total market share by the end of 2020 [174], confirming the lack of alternative easy-to-install solutions for retrofit interventions in existing buildings. In parallel, the World Air Conditioner Demand had an increase in 2017 approximately equal to 8% compared to the previous year and such trend is expected in the next years [175].

This current scenario (March 2019) still confirms that HEART's smart-fan coil, based on STILLE's commercial solution, represents a ground-breaking technology because it appears to be the only available solution that represent a realistic alternative to the installation of a traditional split system (indoor + outdoor units for each dwelling) to provide AC in existing residential buildings. The smart fan-coil allows to avoid the installation of an additional indoor component to the existing radiator and also of a new outdoor element (air condenser) to be placed outside each dwelling. Regarding the latter advantage, it has to be mentioned that Olimpia Splendid company recently launched on the market an AC system (similar to a fan coil) without outdoor unit [176], which however requires holes in the external wall for air exchange and a drain for condensation water. Such elements have a non-negligible impact when units are installed in existing buildings.

For such reasons the smart fan-coil developed within HEART has still a high potential to substitute the split systems, providing high-efficiency AC in existing buildings with a minimal impact.

## 6.8 FAÇADE THERMAL INSULATION

The technology benchmarking process has shown that the major researches on the development of building envelope are aimed to change the traditional renovation process as a time and cost consuming tailor-made process on site to a process with an extreme high grade of prefabrication [177]. The application of prefabricated renovation elements has the potential to reduce costs, reduce the renovation time and disturbance for occupants and, at the same time, enhance quality and performances of the building. The potential of prefabricated deep renovation solutions has been investigated for the first time on large scale within IEA EBC Annex 50 [178]. Within EASEE, an European project [179] [180] [181], modular external insulation prefabricated panels were developed for new scaffolding-free installation in building energy retrofit. Recently, MORE-CONNECT, a project developed in the framework of H2020, is demonstrating the feasibility and the advantage due to the application of prefabricated modular renovation components [167].

In such respect, HEART's modular facade elements are under design process in order to reduce time and installation cost as well as to guarantee the following features: thermal insulation, acoustical insulation, moisture safety, water and air tightness, fire safety, burglary protection, architectural quality and visual upgrading. Furthermore, in general, the installation process of envelope components needs specific connection which require space, specialised tools and extra time to install it on the building site. Moreover, such connections are often a weak point and increase the chance of failures.

According to the above-mentioned weaknesses, in HEART project the façade panels under development will be attached to the building by means of easy connections to speed up the installation process. The modular façade is at present in testing and will be deployed at the end of 2019 on the demo Italian case study.

## 6.9 BATTERIES

Generally speaking, the MIMO can be connected with every kind of commercial electrochemical batteries. In this sense, most recent analyses on energy storages for stationary application [182] demonstrate that:

a) the electrochemical storage industry is still in its early stage of development, and several dominant technological designs are available;

b) the ESS market remains very sensitive to storage costs, since ESSs are not yet competitive with other technologies providing the same services. A further reduction of ESS costs is still required, not only centred on the purchase price but also integrating operating and maintenance costs, installation and interconnection costs, battery replacements, etc.

This confirms the role of the battery in the HEART toolkit, which is not that to store – at low cost - large amount of energy (this purpose will be covered by the advanced thermal storage) but rather to allow the management of peaks of electrical power. However, to face future cost-reductions of electrochemical storages, an open configuration has been chosen in the development of the MIMO, allowing in the future the connection with batteries with a large range of capacity, and powers up to 10 kW.

With regard to the specific technology, on the basis of the current market scenario, Li-Ion batteries were currently selected as the best option, since it is demonstrated that – to date – such technology is well positioned to be the predominant one with the most increased installed capacity in the future [182] [183] [184] [185].

From a commercial viewpoint, Li-ion batteries designed for higher voltages (or modular, so that higher voltages can be reached by installing modules in series without the need of a specifically-designed device) are being offered by manufacturers. This contributes to confirm the choice of selecting for this project Li-ion batteries to be installed on a 400V-rated port.

# 7 USER'S NEEDS AND COMMUNICATION TECHNIQUES

## 7.1 INTRODUCTION

HEART aims to develop an innovative toolkit composed by several technologies and subcomponents.
These subcomponents cooperate synergistically to transform an existing building into a Smart Building, simplifying decision-making and enhancing energy performance. The toolkit HEART will constitute a support to the optimization of the refurbishment of residential buildings in all its phases: the design and the implementation of the refurbishment, the monitoring of the refurbished buildings, and the correct use of the refurbished buildings by tenants. This toolkit could be useful to architects, managers, investors, data users, energy utilities, and households. Looking at the network among technological and human components, this toolkit can be seen as a sociotechnical system.

This report analyses the opportunities of emergence and diffusion of the HEART system as an energy retrofit toolkit, using sociotechnical theories. This research underlines the importance to investigate both design and diffusion of an innovative system [186], in order to include the relevant elements of an effective uptake in the design process of the innovation. This has the potential to increase the effectiveness of future uptake of HEART [186, p. 143].

"The sociotechnical analysis is an approach that considers the transition process as involving multiple processes resulting in social, technical, and institutional reconfiguration and alignment" [187 p. 61]. The sociotechnical approaches have focused on single technologies by now and they rarely investigate the uptake of an entire system [186]. This research is an opportunity to focus on the uptake of an innovative and low carbon system to be used for retrofitting residential buildings, including technological and human components.
Definition of social technical system and its transition
HEART, integrating several innovative technologies, is a system and system "differs from discrete technologies in terms of scale, complexity, materiality, asset durability, capital intensity, spatiality, and socio-political dimensions" [186, p. 140].
HEART, as system, touches several actors, co-evolutionary learning and interaction, and multiple diffusion processes [186]. In this system, technologies and infrastructures, institutions, skills, knowledge, human behaviours co-evolve in a broad system, which does not include only technological components [186]

. In this research, the main question is how should the society and technology co-evolve and support one another in order to increase the success of HEART's uptake? The sociotechnical approaches permit to consider that the system continues to develop during the diffusion phase giving a processual view and involving several kind of stakeholders [186]. The transition processes are one per each context.
The existence of different transition processes depend on the assumption that a system is good for a context, but it can be not good for other contexts [188]. According to this assumption, we should investigate what is

innovative for the case study and what is innovative for a wider context and, therefore, transform the characteristics of the innovation in a more abstracted way [186].
How could the new system HEART enter in a new context, spreading at different places and time? The 'circulation and replication' for the spreading of innovations across space, and the alignments with existing political, cultural or economic structures in a societal embedding process of innovations are two fundamental processes for an effective uptake [186]. Based on the relationships between the "technical network, the user, the environment, the institutions responsible, and society at large" [189], this report investigates - a priori and based on the "discourses" and the practices of affected stakeholders - the conditions for an effective uptake of a technological system innovation. Considering the discourses, the practices, and the needs of stakeholders, the opportunities of uptake are increased because the stakeholders accept more the innovation [190].
This report aims to investigate if the elements for an innovation system uptake exist in the design phase of HEART, based on the experts' experience, knowledge, and discourses.
In particular, this research has two objectives:

- To analyse the stakeholder's discourses in order to understand if the elements for a transition (and uptake) of a sociotechnical system are considered in the design of HEART
- To analyse in detail the evolution of the stakeholder's needs, testing the interfaces with a wider and wider public of professionals, investors, etc.

## 7.2 IDENTIFICATION OF THE STAKEHOLDERS

### Methods to identify stakeholders

In order to answer the research objectives, several research steps are carried out: stakeholder's map, stakeholder's interviews, and workshops with stakeholders. First, a stakeholder's map has been filled with the support of project's partners and with the contribution of the interviewees. Second, in-depth interviews are administered to stakeholders and workshops will be organized (D10.13).
The approach adopted to identify the stakeholders uses the snowball method and the saturation mechanism, in order to collect the points of view of each stakeholder's group. The snowball sampling permits to achieve the representativeness of the stakes linked to HEART through the collection of points of view of key informants. This typology of sampling derives important information from the interviewee that could not be derived with other sampling [191]. The chosen sampling is also sequential and the sample evolves according the collected data and with the new interviews [192]. Furthermore, the list of interviewees finishes when saturation will be achieved: "*Saturation* is a term used to describe the point when you have heard the range of ideas and aren't getting new information" [193, p. 26].

### The list of the identified stakeholders

The list of identified stakeholders has been filled in different steps. In the first step, the partners of the project have been asked to fill an excel file with the name of the contact-person that belongs to an enterprise, a group, an institute, or an association. For structuring the filling of the excel file, it has been divided into different groups of stakeholders derived from the communication strategy document of HEART: (i) building social-housing owners and managers, (ii) building sector constructors and operators, (iii) energy efficiency and saving associations, (iv) installers associations, (v) designers of refurbishment (i.e., architects, engineers), (v) entrepreneurs-business organizations-investors, and (vi) technology platform. When filling the list, the partners aimed to list all the stakeholders that can be interested in using and buying the HEART toolkit when it will be ready (Table 50). The stakeholder mapping is ongoing and the filling of this list is asked to all the people who is interviewed.

Table 50: Number of collected contacts per each group of stakeholders, proposed by partners of the project.

| Group of stakeholders | Number of collected contacts |
|---|---|
| **Building social-housing owners and managers** | 17 |
| **Building sector constructors and operators** | 9 |
| **Energy efficiency and saving associations** | 8 |
| **Installers associations** | 5 |
| **Designers of refurbishment (i.e., architects, engineers)** | 4 |
| **Enterpreneurs - Business organizations - Investors** | 6 |
| **Technology platform** | 1 |

After the analysis of the interviews, the more appropriate subdivision of the stakeholders has been changed and is the following ones: designers of refurbishment, investors, energy managers and facilities, and tenants. Therefore, the previous contacts have been included in the new list.

## 7.3 IDENTIFICATION OF THE STAKEHOLDER'S NEEDS

### Methods to identify the stakeholder's needs

In order to identify the stakeholder's needs, qualitative interviews to the stakeholders have been administered. The interviews are designed based on the analytical framework included in the Introduction of this chapter. The interviews are analysed based on a content analysis through the software NVIVO11plus.

This chapter analyses the first 14 stakeholder-partner's interviews (13 partners and one external stakeholder), while further interviews are ongoing and will be analysed in future. The interviewees will be cited with the letter 'I' plus a number between one and 14.

### Example of stakeholder's needs

This report includes some findings that could be useful for the activities of other tasks of the project (i.e., T4.3, T4.4, T8.1). The findings include some stakeholder's needs and linked services.

1. **Need: to access knowledge for professionals-enterprises i.e., on how to behave and interact with tenants**
   - Service or element: create intermediaries - paper works to use in the diffusion process, especially in the adjustment of the toolkit for the contextualization
2. **Need: to have a replicable toolkit that can be spread**
   - Service or element: to identify a system and a common vision of the toolkit and its innovation for all partners
   - Service or element: to identify a common way to communicate and promote the toolkit for all partners (not each one decides to promote its own technology), like a brand
3. **Need: to ensure effectiveness of relationships between stakeholders (i.e., professionals, professionals-tenants)**

- Service or element: i.e., to promote a figure-mediator between professionals or to organize a support office behind the web-interface

## 7.4 CONSIDERATIONS ON THE HEART SYSTEM FOR AN EFFECTIVE UPTAKE

HEART is a system of technical, human, and procedural elements included in the design and uptake processes. According to the results of the analysis of 14 interviews, HEART toolkit increases its strength and its innovative component if it is flexible, adaptable to further contexts, open to an exhaustive offer of technologies and procedures, and secure to have the availability of an effective toolkit. All these features should be included in the communication strategy, which promotes a unique system. However, not all the stakeholders-partners interpret HEART as a unique system. For example, [110] says:

> *"What make it [HEART] desirable in my opinion is that the user is convinced that the tool options are as exhaustive as possible. So for instance if you are, in a typical example, considering a limited number of technologies in platform, but there are many many more relevant technologies around the market ... So that could be, you know, a kind of weakness of the tool. This is something to consider and we are thinking in a giving possibility to the users to add more technologies from the market."*

This vision is not coherent with the sociotechnical system framework that attributes the uptake of a system to the integration between all the components. The system should be treated and communicated as a system and not just a group of individual elements and technologies [186]. This vision can weaken the opportunities to uptake HEART. Information about new technologies can be an added service (i.e., [108]), but it cannot be included as disturbing element in the uptake of the system HEART.

HEART is a system, which integrates technologies, stakeholders, and procedures of building refurbishment. In order to propose a replicable toolkit, an effective circulation of knowledge about these procedures is fundamental. Of course, these procedures must be actively adjusted to other implementation sites. The knowledge about the procedures, structured during the European project, is an element that saves time and reduces the risks related to the implementation of HEART. The communication and transfer knowledge strategy should include the presentation of the entire system and not single technologies.

In the circulation of knowledge and adjustment processes, stakeholders have or should have relationships one another. These relationships permit to acquire and adopt the most effective refurbishment procedures. However, the relationships among stakeholders (i.e., professionals-enterprises and tenants) could be challenging. In order to decrease challenges, the creation of 'intermediaries' is important. The procedures can be communicated to the stakeholders (the human element of the system) through intermediaries [186] such as reports, patents, contracts, prototypes, products. The intermediaries are things and documents that are able to circulate knowledge, design rules, people, finance, paper-works. According to the 14 interviewees, intermediaries to be included in HEART can be of three different typologies:

- Written documents which circulate knowledge, best practices, and procedures such as handbooks, reports i.e., [105, 96]
- Automatic exchanges through Web-platform and algorithms for exchanging and updating information. The automatic update of the refurbishment work schedules is an example of relevant information according to i.e., [107]
- People or direct contact with an office which instantly solves problems i.e., [109]

All of the three typologies of intermediaries should be included in the Web-platform. The intermediaries should be adapted to the different groups of stakeholders, their competences, and their technical (or non-technical) languages, i.e., [96, 100, 108]. This means that HEART should also include a part of individualization, at least for the used language, according to the belonging of the stakeholder's group. The intermediaries, procedures, and the general HEART system should not only be adapted to the stakeholder's needs, but also to the new implementation contexts.

Stakeholders are aware that the adjustment to different physical, economic, social, cultural contexts, times can be approached using artificial intelligence i.e., [97, 102]. HEART aims to be a replicable toolkit, but it is needed a little bit of adjustment which could be based on machine learning. Other stakeholders underline that machine learning can be effective, but each problem (also those ones that builders and designers do not consider) must be instantly solved in the refurbishment building sector. For this reason, the third typology of intermediaries is needed: a human contact quickly available. In this case, the Web-platform should include a contact to an office or a person. If the contact is linked to an office or a person is a decision of the project's consortium. However, interviewees prefer an office i.e., [108].

The uptake of a system (i.e., HEART) is a complex process. This research emphasizes a self-sustaining diffusion of HEART for the future, which starts from a builders-based early-stage diffusion [186]. From a previous research study [186], the spread of information via word-of-mouth is important in the early period of diffusion. The later period should be characterized by a centrally organized information dissemination, based on abstracted communication about characteristics and elements of innovation and based on positive applications. "Innovation's diffusion also benefitted from cultural embedding and the development of positive discourses" [186, p. 149]. The communication strategy should include the experienced positive aspects of HEART. However, these positive aspects change along the time. The project needs to define a communication strategy considering the evolution and the change of the positive elements.

Investors and social-housing owners would invest only if this system is innovative and not already available in the market, i.e., [96, 108, 109]. For the stakeholders, the innovative aspect of HEART is its systemic approach, which integrates all the technological components for the energy refurbishment in an effective way. The effective integration is able to save time and money of the investors, energy managers, and energy facilities.

Another important element for the future uptake of HEART is the definition of costs. The definition of costs is very important for the beginning of the diffusion (i.e., building managers, users) and for some investors:

> *"When you make this such of decisions, you do not only look at the price today. You also want to know how much is going to cost me in the following years, right? For a typical investment, I guess such a big renovation, you take a big investment for 15 years. [...] So, if we can show that it is a very good system because all the components are linked one each other, so we can guarantee that it works very well, because it is one of the problems you see often in energy renovation." [99]*

The definition of costs is strictly related to the precise integration between all the technologies that compose the system, and the effective circulation of procedures (i.e., intermediaries). A reliable definition of the costs is only possible when all the technologies are clearly integrated in the system and the unforeseen situations in the installation are considered [105]. However, the definition of costs is less important in future uptake phases. Cultural embedding of HEART in the new contexts can be more effective than the mere costs definition [186].

## Conclusions

In the discourses of the interviewees, the toolkit Heart is dedicated to four stakeholder's groups (designer; energy manager and energy facility; energy investor; and inhabitant or tenant) even if the design process of the toolkit and the Web-platform should be addressed to one (the most relevant) stakeholder for having a higher quality. Focusing on one group of stakeholders (i.e., investors), the entire system and the Web-interface could achieve higher effectiveness. The following features for the Web-platform are relevant in order to ensure an effective uptake of the Heart system:

a. **Deepen integration between** the components and the interfaces (one system!)
b. Included in a **process**: Adaptable and updated according to new circumstances (i.e., knowledge, competences, and preferences of more and more stakeholders).
c. Open to changes along all the life of European project
d. Open to changes and further components after the project (**adaptable and flexible**)
e. **Individualization** for each stakeholder, its preferences, and its (not) technical language
f. On two levels: **the basic and the upper** ones (which should include also reports)
g. The balance between human intervention and automation of the Web-interface must be a decision of the project's consortium (see the following paragraphs)
h. In a very well-integrated work within the project, the activities of all the partners should find space in the Web-platform, if this is the shared decision. I.e., the LCA and the LCC should be integrated in the platform (collected data and elaborations)

The uptake is a process that includes a system working in an effective way in one location (A) and successively getting the system work in another location (B) [186]. The circulation of knowledge, design rules, people, paper works between locations A and B could give a start to the diffusion process. This kind of circulation of 'intermediaries' can be done through workshops, newsletters, and a testing process of the Web-interface. **Workshops with stakeholders testing the Web-interface can enhance the effectiveness and functionalities of the Web-interface.**

The network between technologies, the intermediaries, and people is a sociotechnical system and it is also the network through which the uptake can be enhanced. This network is not an exclusive matter of the Web-interface. At the opposite, the uptake of HEART will be the result of a correct and deep synergy between the entire toolkit and the Web-interface.

**The findings of this preliminary analysis focus on some elements important for the effective uptake of the toolkit, considering HEART as a system that includes technological, human, and procedural components. These findings are used to make recommendations for other activities in the project i.e., interfaces of the Web-platform, communication strategy.**

**This chapter summarizes the preliminary findings of the research, while further individual and group interviews will be analyzed in future months, in order to define a wider research and deeper results.**

[194,195]

# REFERENCES


[1] Buildings Performance Institute Europe (BPIE), Europe' s Buildings Under the Microscope. 2011.
[2] Zebra2020, "ZEBRA 2020 – Nearly Zero-Energy Building strategy 2020. D6.2: Strategies for NZEB market transition on national level," no. October, p. 516, 2016.
[3] L. V. Divone, A. H. Rosenfeld, and F. E. Wood, "Improving Energy Efficiency in Buildings," no. August, pp. 23-45, 2013.
[4] U. Rochard, S. Shanthirablan, and C. Brejon, "Bâtiments résidentiels: Typologie du parc existant et solutions exemplaires pour la rénovation énergétique en France," pp. 1–119, 2015.
[5] "Donnees_CEREN_2016_MAJ_2018_10_01-Résidentiel-2." .
[6] E. Dascalaki, C. A. Balaras, P. Droutsa, and S. Kontoyannidis, TABULA: Typology Approach for Building Stock Energy Assessment D6.2: National Scientific Report - GREECE, no. May. 2012.
[7] F. Calise, M. D. D'Accadia, C. Barletta, V. Battaglia, A. Pfeifer, and N. Duic, "Detailed modelling of the deep decarbonisation scenarios with demand response technologies in the heating and cooling sector: A case study for Italy," Energies, vol. 10, no. 10, 2017.
[8] International Energy Agency (IEA), "Spain 2015 Review," Energy Policies IEA Ctries., p. 178, 2015.
[9] Ministerio de Fomento, "Construcción De Edificios 2013 - 2017," 2018.
[10] INE Spanish Statistical Office (Instituto Nacional de Estadistica), "Population and Housing Censuses 2011 Data," vol. 069, no. April, pp. 1–35, 2011.
[11] Fundación Biodiversidad and Observatorio de la Sostenibilidad en España, "Informe Empleo Verde en una economía sostenible," 2010.
[12] d. o. o. Modrijan založba, "Climate types," 2010. .
[13] Statistical office of the European Union EUROSTAT, "Eurostat," 2018. .
[14] Moskuber M., "Climate types in Slovenia," 2014. .
[15] "European Union H2020 Project TABULA and EPISCOPE.  SI - Slovenia," 2016. .
[16] Ministry of the Environment and Spatial Planning and Geodetic Administration of the Republic of Slovenia, "Real Estate Register," 2018. .
[17] Statistical Office of the Republic of Slovenia, "Assessment of building stock, 1999 – 2014," 2014. .
[18] European Union H2020, "Status Quo Report | Build Up Skills Slovenija," 2011. .
[19] Statistical Office of the Republic of Slovenia, "Environment/Energy," 2017. .
[20] EN-Lite Društvo za spodbujanje energetske učinkovitosti, "iEnergija," 2016. .
[21] Ministry of Infrastructure, "Action Plan for nearly Zero Energy Buildings (AN Snes).," 2015.
[22] Eco Fund, "Data on registered subsidies," 2018. .
[23] Ministry of Infrastructure and Ministry of Public Administration, "Long-Term Strategy for Mobilising Investments in the ENERGY RENOVATION OF BUILDINGS," 2015.
[24] Ministry of Infrastructure, "Amendment to Long-Term Strategy for Mobilising Investments in the ENERGY RENOVATION OF BUILDINGS," 2018.
[25] National Energy Efficiency Action Plans and Annual Reports: https://ec.europa.eu/energy/en/topics/energy-efficiency/energy-efficiency-directive/national-energyhttps://ec.europa.eu/energy/en/topics/energy-efficiency/energy-efficiency-directive/national-energy-efficiency-action-plansefficiency-action-plans
[26] NIM database: http://eur-lex.europa.eu/legal-content/EN/NIM/?uri=CELEX:32012L0027
[27] Concerted Action for the Energy Efficiency Directive: http://www.epbd-ca.org/
[28] BUILD UP portal: http://www.buildup.eu/en
[29] European Energy Efficiency Platform: https://e3p.jrc.ec.europa.eu/

[30] National Energy Efficiency Action Plans and Annual Reports database: https://ec.europa.eu/energy/en/topics/energy-efficiency/energy-efficiencydirective/national-energy-efficiency-action-plans
[31] NIM database http://eur-lex.europa.eu/legal-content/EN/NIM/?uri=CELEX:32012L0027
[32] Concerted Action for the Energy Efficiency Directive: http://www.esd-ca.eu/
[33] European Energy Agency: https://www.eea.europa.eu/it
[34] ODYSSE-MURE database: http://www.odyssee-mure.eu/
[35] BUILD UP portal: http://www.buildup.eu/en
[36] European Energy Efficiency Platform: https://e3p.jrc.ec.europa.eu/
[37] Decreto Legislativo 4 luglio 2014, n° 102. Attuazione della direttiva 2012/27/UE sull'efficienza energetica. Online: http://www.gazzettaufficiale.it/eli/id/2014/07/18/14G00113/sg
[38] Strategia per la Riqualificazione Energetica del Parco Immobiliare Nazionale plan. Online: http://www.sviluppoeconomico.gov.it/images/stories/documenti/STREPIN_13_11_2015.pdf
[39] Piano d'Azione Nazionale per incrementare gli edifici ad energia quasi zero. Online: http://www.sviluppoeconomico.gov.it/images/stories/documenti/PANZEB_13_11_2015.pdf
[40] 2014 Italian National Energy Efficiency Action Plan. Online: https://ec.europa.eu/energy/sites/ener/files/documents/ItalyNEEAP2014en.pdf
[41] PREPAC. Online: http://www.sviluppoeconomico.gov.it/images/stories/documenti/linee_guida_prepac_12_luglio_2017.pdf
[42] 2017 Italian National Energy Efficiency Action Plan. Online: https://ec.europa.eu/energy/sites/ener/files/documents/it_neeap_2017_en.pdf
[43] MiSE, Chiarimenti in materia di diagnosi energetica delle imprese. Online: http://www.sviluppoeconomico.gov.it/images/stories/documenti/Efficienza_energetica_CHIARIMENTI_DIAGNOSI_IMPRESE_19_05_15.pdf
[44] A Study on Energy Efficiency in Enterprises Energy Audits and Energy Management Systems: https://ec.europa.eu/energy/sites/ener/files/documents/eed-art8-implementationhttps://ec.europa.eu/energy/sites/ener/files/documents/eed-art8-implementation-study_task12_report_final-approved.pdfstudy_task12_report_final-approved.pdf
[45] Programma per il cofinanziamento di programmi presentati dalle Regioni e finalizzati a sostenere la r ealizzazione di diagnosi energetiche nelle piccole e medie imprese (PMI). Online: http://www.sviluppoeconomico.gov.it/images/stories/normativa/Bando_Cofinanziamento_AUDIT_PMI.pdf
[46] 2014 French National Energy Efficiency Action Plan. Online: https://ec.europa.eu/energy/sites/ener/files/documents/2014_neeap_en_france.pdf
[47] guarantEE project. Online: http://guarantee-project.eu/
[48] Energy Efficiency Financial Institutions Group (EEFIG). Online: http://www.eefig.com/
[49] European Association of Energy Service Companies. Online: http://euesco.org/
[50] European Federation of Intelligent Energy Efficiency Services. Online: www.efiees.eu/
[51] Decreto legislativo 30 maggio 2008, n° 115 sull'attuazione della direttiva 2006/32/CE relativa all'efficienza degli usi finali dell'energia e i servizi energetici. Online: http://www.gazzettaufficiale.it/eli/gu/2008/07/03/154/sg/pdf
[52] MiSE, Approvazione degli schemi di certificazione e accreditamento per la conformità alle norme tecniche in materia di esco, esperti in gestione dell'energia e sistemi di gestione dell'energia. Online: http://www.sviluppoeconomico.gov.it/images/stories/normativa/decreto_12maggio2015_schemi.pdf

[53] JRC, Practices and opportunities for EPC in the public sector in EU Member States (2017). http://publications.jrc.ec.europa.eu/repository/bitstream/JRC106625/kjna28602enn.pdf
[54] Energy & Strategy Group, Energy Efficiency Report 2017. Online: http://www.energystrategy.it/assets/files/EER_17_conCover_alta.pdf
[55] Eurostat - Electricity price statistics. Online: http://ec.europa.eu/eurostat/statisticshttp://ec.europa.eu/eurostat/statistics-explained/index.php/Electricity_price_statisticsexplained/index.php/Electricity_price_statistics
[56] Eurostat - Natural gas price statistics. Online: http://ec.europa.eu/eurostat/statisticshttp://ec.europa.eu/eurostat/statistics-explained/index.php/Natural_gas_price_statisticsexplained/index.php/Natural_gas_price_statistics
[57] Regulation (EU) 2016/1952 of the European Parliament and of the Council of 26 October 2016 on European statistics on natural gas and electricity prices and repealing Directive 2008/92/EC. Online: http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32016R1952
[58] IEA - Policies and measures database: Online: https://www.iea.org/policiesandmeasures/
[59] European Commission DG Energy https://ec.europa.eu/info/departments/energy_en
[60] Odyssee-Mure project. Online: http://www.odyssee-mure.eu/publications/policy-brief/
[61] Buildings Performance Institute Europe. Online: http://bpie.eu/publications/
[62] LEGGE 27 dicembre 2017, n. 205. Bilancio di previsione dello Stato per l'anno finanziario 2018 e bilancio pluriennale per il triennio 2018-2020. Online: http://www.gazzettaufficiale.it/eli/gu/2017/12/29/302/so/62/sg/pdf
[63] DECRETO-LEGGE 4 giugno 2013, n.63. Disposizioni urgenti per il recepimento della Direttiva 2010/31/UE del Parlamento europeo e del Consiglio del 19 maggio 2010, sulla prestazione energetica nell'edilizia per la definizione delle procedure d'infrazione avviate dalla Commissione europea, nonchè altre disposizioni i n materia di coesione sociale. Online: http://www.gazzettaufficiale.it/eli/gu/2013/06/05/130/sg/pdf
[64] DECRETO 28 dicembre 2012. Incentivazione della produzione di energia termica da fonti rinnovabili ed interventi di efficienza energetica di piccole dimensioni. Online: http://www.gazzettaufficiale.it/eli/gu/2013/01/02/1/so/1/sg/pdf
[65] S.Attiaa, et.al., Overview and future challenges of nearly zero energy buildings(nZEB) design in Southern Europe, Energy and Buildings 155 (2017) 439–458.
[66] European Comission. REGLAMENTO (UE) 2015/1222 DE LA COMISIÓN de 24 de julio de 2015.(2015).
[67] Instituto para la Diversificación y Ahorro de la Energía (IDAE). (2010). Programa GEOTCASA.
[68] Instituto para la Diversificación y Ahorro de la Energía (IDAE). (2011). Programas de IDAE para el Impulso de las EERR Térmicas en Edificación.
[69] Jefatura del Estado. Ley 18/2014, de 15 de octubre, de aprobación de medidas urgentes para el crecimiento, la competitividad y la eficiencia. , Boletín Oficial del Estado § (2014).
[70] Jefatura del Estado. Real Decreto-ley 15/2018. , Boletín Oficial del Estado § (2018).
[71] Ministerio de Ciencia y Tecnologia. (2004). Reglamento Electrotécnico Para Baja Tensión E Instrucciones Técnicas Complementarias.
[72] Ministerio de Fomento. (2013). Código Técnico de la Edificación.
[73] Ministerio de Fomento. (2018). Documento Básico HE - Ahorro de energía 2018.
[74] Ministerio de Industria Energía y Turismo. (2013). Resolución de BIOMCASA II, convocatoria y bases reguladoras para habilitación de empresas colaboradoras en el programa para ejecución de proyectos de biomasa térmica en edificios.

[75] Ministerio de Industria Energía y Turismo. (2014a). Convocatoria y bases correspondientes a la habilitación de empresas colaboradoras en el Programa SOLCASA con empresas del sector de la energía solar térmica en edificios. In Boletín Oficial del Estado (BOE). https://doi.org/BOE-A-2012-5403
[76] Ministerio de Industria Energía y Turismo. Real Decreto 337/2014, de 9 de mayo. , (2014).
[77] Ministerio de Industria Energía y Turismo. (2020). Directiva 2012/27/UE - Real Decreto 56/2016, relativa a la eficiencia energética, en lo referente a auditorías energéticas, acreditación de proveedores de servicios y auditores energéticos y promoción de la eficiencia del suministro de energía.
%%%%%%%%%%%%%%%%%%%%%%%
[78] Ministry of Infrastructure. Action Plan for nearly Zero Energy Buildings (AN Snes). 2015. Available from: http://www.energetika-portal.si/dokumenti/strateski-razvojni-dokumenti/akcijski-nacrt-za-skoraj-nic-energijske-stavbe/ [Accessed 20.1.2019]
[79] Concerted Action EPBD. 2015. Available from: www.epbd-ca.eu [Accessed 20.1.2019]
[80] Ministry of Infrastructure. Energy Renovation of Buildings Available from: Http://www.energetika-portal.si/ [Accessed 20.1.2019]
[81] Energy Act. 2014. Available from: http://pisrs.si/Pis.web/pregledPredpisa?id=ZAKO6665 [Accessed 20.1.2019]
[82] Concerted Action EED. 2015. Available from: https://www.ca-eed.eu/Countries/Slovenia [Accessed 20.1.2019]
[83] Ministry of Infrastructure. Energy Renovation of Buildings. Records of buildings owned and used by persons of the public sector. 2017. Available from: http://www.energetika-portal.si/podrocja/energetika/energetska-prenova-javnih-stavb/evidenca-stavb-v-lasti-in-uporabi-oseb-ozjega-javnega-sektorja/). [Accessed 20.1.2019]
[84] Ministry of Infrastructure. Project office for the energy renovation of buildings. 2015. Available from: http://www.energetika-portal.si/podrocja/energetika/energetska-prenova-javnih-stavb/projektna-pisarna/ [Accessed 20.1.2019]
[85] GI ZRMK. Training of managers of multi-dwelling buildings. 2015. Available from: http://energetskaizkaznica.si/upravniki/ [Accessed 20.1.2019]
[86] Elektro Gorenjska. Tarifni časi. 2004. Available from: https://www.elektro-gorenjska.si/storitve/merjenje-elektricne-energije/tarifni-casi [Accessed 20.1.2019]
[87] Statistical Office of the Republic of Slovenia. Prices of Energy Sources. 2018. Available from: https://www.stat.si/StatWeb/en/Field/Index/5/30 [Accessed 20.1.2019] SURS, 2018, TARIFE
[88] Energy Agency. Advanced Measuring Systems. 2014. Available from: https://www.agen-rs.si/izvajalci/plin/napredni-merilni-sistemi [Accessed 20.1.2019]
[89] Electricity Distribution System Operator (SODO). The instructions for connecting the electricity production facilities to the grid. 2015. Available from: https://www.sodo.si/_files/3371/Navodilo%20za%20prikljucevanje%20proizvodnih%20%20naprav.pdf [Accessed 20.1.2019]
[90] Elektro Ljubljana. Approval for connection to the distribution network SZP. 2015. Available from: https://www.elektro-ljubljana.si/Portals/0/Za-uporabnike-Dokumenti/Vloga_za_prikljucitev_in_dostop_na_distribucijsko_omrezje_OB_NA_SU_209_03.pdf [Accessed 20.1.2019]
[91] SLOVENIAN FOUNDATION FOR FIRE PROTECTION (SLOVENSKO ZDRUŽENJE ZA POŽARNO VARSTVO). Guidance SZPV 512. Guidance on the fire safety of solar power plants. 2016, IZDAJA 02/16 Available from: http://www.szpv.si/wp-content/uploads/SZPV-512_2016.pdf [Accessed 20.1.2019]
[92] D.M. 26/06/2015 “Requisiti Minimi” - http://www.gazzettaufficiale.it/eli/gu/2015/07/15/162/so/39/sg/pdf

[93] D.Lgs. 28/2011 - http://www.gazzettaufficiale.it/eli/gu/2011/03/28/71/so/81/sg/pdf
[94] www.gazzettaufficiale.it/eli/gu/2018/12/31/302/so/62/sg/pdf
[95] www.gazzettaufficiale.it/eli/gu/2018/12/31/302/so/62/sg/pdf
[96] D. J. Arent, A. Wise, R. Gelman The status and prospects of renewable energy for combating global warming. Energy Econ 33 (2011) 584-593
[97] H. De Heer, The Independent Aggregator. Position Paper. USEF (2015)
[98] European Commission. Improving State Aid for Energy and the Environment (2014)
[99] EU. DIRECTIVE (EU) 2018/2001 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 11 December 2018 on the promotion of the use of energy from renewable sources (recast) (Text with EEA relevance). 2018 https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018L2001&from=EN
[100] J. Liu, Y. Xiao, S. Li, W. Liang and C. L. P. Chen, "Cyber Security and Privacy Issues in Smart Grids", in IEEE Communications Surveys & Tutorials, vol. 14, no. 4, pp. 981-997, Fourth Quarter 2012.
[101] S. Finster and I. Baumgart, "Privacy-Aware Smart Metering: A Survey," in IEEE Communications Surveys & Tutorials, vol. 17, no. 2, pp. 1088-1101, Second quarter 2015.
[102] H. Khurana, M. Hadley, N. Lu and D. A. Frincke, "Smart-grid security issues," in IEEE Security & Privacy, vol. 8, no. 1, pp. 81-85, Jan.-Feb. 2010.
[103] A. R. Metke and R. L. Ekl, "Security Technology for Smart Grid Networks", in IEEE Transactions on Smart Grid, vol. 1, no. 1, pp. 99-107, June 2010.
[104] ENISA, "Smart Grid Security - Annex II. Security aspects of the smart grid", April 2012. [Online], Available: www.enisa.europa.eu/topics/critical-information-infrastructures-and-services/smart-grids/smart-grids-and-smart-metering/ENISA_Annex II - Security Aspects of Smart Grid.pdf, [Accessed February 22, 2019].
[105] D. Kushner, "The real story of stuxnet", in IEEE Spectrum, vol. 50, no. 3, pp. 48-53, March 2013.
[106] Bruce Schneier, "Why the FBI wants you to reboot your router — and why that won't be enough next time", June 2018. [Online], Available: www.www.schneier.com/essays/archives/2018/06/why_the_fbi_wants_yo.html, [Accessed February 22, 2019].
[107] Joe Slowik, "Questions and Considerations from Alleged Ukraine Chemical Plant Event", July 2018. [Online], Available: www.dragos.com/blog/industry-news/questions-and-considerations-from-alleged-ukraine-chemical-plant-event, [Accessed February 22, 2019].
[108] Kim Zetter, "Inside the Cunning, Unprecedented Hack of Ukraine's Power Grid", March 2016. [Online], Available: www.wired.com/2016/03/inside-cunning-unprecedented-hack-ukraines-power-grid/, [Accessed February 22, 2019].
[109] S. Samtani, S. Yu, H. Zhu, M. Patton, J. Matherly and H. Chen, "Identifying SCADA Systems and Their Vulnerabilities on the Internet of Things: A Text-Mining Approach", in IEEE Intelligent Systems, vol. 33, no. 2, pp. 63-73, Mar./Apr. 2018.
[110] ENISA, "Communication network dependencies for ICS/SCADA Systems", December 2016. [Online], Available: www.enisa.europa.eu/publications/ics-scada-dependencies, [Accessed February 22, 2019].
[111] ENISA, "Appropriate security measures for smart grids-Guidelines to assess the sophistication of security measures", December 2012. [Online], Available: www.enisa.europa.eu/publications/appropriate-security-measures-for-smart-grids, [Accessed February 22, 2019].
[112] ENISA, "Certification of Cyber Security skills of ICS/SCADA professionals - Good practices and recommendations for developing harmonised certification schemes", December 2014. [Online], Available: www.enisa.europa.eu/publications/certification-of-cyber-security-skills-of-ics-scada-professionals, [Accessed February 22, 2019].

[113] ENISA, Smart grid security certification in Europe-Challenges and recommendations", December 2014. [Online], Available: www.enisa.europa.eu/publications/smart-grid-security-certification-in-europe, [Accessed February 22, 2019].
[114] Ayoub H., Delpero C. (2018), HEART D10.5 Leaflets/Brochure - I, https://heartproject.eu/wp-content/uploads/2019/02/D10.5-Leaflets-Brochure-I.pdf, September 2018
[115] Scudo P., Cenuse S., Delpero C., Vallan A. (2018), HEART D10.19 – Knowledge Transfer Conferences I, https://heartproject.eu/wp-content/uploads/2019/02/D10.19-Knowledge-transfer-conferences-I.pdf, November 2018
[116] Pezzutto S., Vaccaro R., Zambelli P., Mosannenzadeh F., Bisello A., Vettorato D. (2015), Deliverable 2.1 SWOT analysis report of the refined concept/baseline, SINFONIA project, http://www.sinfonia-smartcities.eu/contents/knowledgecenterfiles/sinfonia_d21_swot-analysis-report-of-the-refined-concept-baseline_8164.pdf

[117] S.Attiaa, et.al., Overview and future challenges of nearly zero energy buildings(NZEB) design in Southern Europe, Energy and Buildings 155 (2017) 439–458.
[118] EPBD recast, Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings (recast), Off. J.Eur. Union (2010) (12/09/2016).
[119] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv%3AOJ.L_.2018.156.01.0075.01.ENG
[120] D. D'Agostino, D. Parker, A framework for the cost-optimal design of nearly zero energy buildings (NZEBs) in representative climates across Europe, Energy 149 (2018) 814-829.
[121] A. Santangelo, S. Tondelli, Occupant behaviour and building renovation of the social housing stock: Current and future challenges, Energy and Buildings 2017 ; 145 : 276-283.
[122] A.T. Nguyen et al., A review on simulation-based optimization methods applied to building performance analysis. Appl Energy 2014;113: 1043-58.
[123] B. Cristina, et al., Envelope design optimization by thermal modelling of a building in a warm climate. Energies 2017;10:1808. https://doi.org/ 10.3390/en10111808.
[124] S. Attia et al., Assessing gaps and needs for integrating building performance optimization tools in net zero energy buildings design. Energy Build 2013;60:110-24.
[125] B. Eisenhower et al., A methodology for meta model based optimization in building energy models. Energy Build 2012;47:292-301.
[126] E. De Guseppe et al., Probabilistic life cycle costing of existing buildings retrofit interventions towards NZEB target: Methodology and application example, Energy and Buildings 2017; 144: 416-432.
[127] L. Zhou, F. Haghighat, Optimization of ventilation system design and operation in office environment. PartI: Methodology. Build Environ 2009;44:651-6.
[128] S. Ferrari S, M. Beccali, Energy-environmental and cost assessment of a set of strategies for retrofitting a public building toward nearly zero-energy building target. Sustain Cities Soc 2017;32:226-34. https://doi.org/10.1016/ j.scs.2017.03.010.
[129] J.T. Vera et al., Multi-objective optimization of hybrid photovoltaice thermal collectors integrated in a DHW heating system. Energy Build 2014;74:78-90.
[130] G.M. Stavrakakis et al., Optimization of window-openings design for thermal comfort in naturally ventilated buildings. Appl Math Model 2012;36:193-211.
[131] G. Rapone, O. Saro, Optimisation of curtain wall facades for office buildings by means of PSO algorithm. Energy Build 2012;45:189-196.
[132] F. Pernodet Chantrelle et al., Development of a multicriteria tool for optimizing the renovation of buildings. Appl Energy 2011;88:1386-94.
[133] E. Annunziata et al., Towards nearly zero-energy buildings: the state-of-art of national regulations in Europe. Energy 2013;57:125-33.
[134] P. Ergo et al., Cost-benefit analysis of NZEB energy efficiency strategies with on-site photovoltaic generation. Energy 2017;128: 291-301.

[135] M. Jabbari and M. S. Dorcheh, "Resonant Multi-input/Multi-output/Bidirectional ZCS Step-Down DC--DC Converter With Systematic Synthesis for Point-to-Point Power Routing," in IEEE Transactions on Power Electronics, vol. 33, no. 7, pp. 6024-6032, July 2018.
[136] Y. Matsushita, T. Noguchi, O. Kimura and T. Sunayama, "Current-doubler based multiport DC/DC converter with galvanic isolation," 2017 IEEE 12th International Conference on Power Electronics and Drive Systems (PEDS), Honolulu, HI, 2017, pp. 1-6.
[137] F. Chen, R. Burgos, D. Boroyevich. "A Bidirectional High-Efficiency Transformerless Converter With Common-Mode Decoupling for the Interconnection of AC and DC Grids." IEEE Transactions on Power Electronics, vol. 34, no. 2, pp. 1317–1333, Feb. 2019.
[138] W. Du, Q. Fu, H. Wang. "Open-Loop Modal Coupling Analysis for a Multi-Input Multi-Output Interconnected MTDC/AC Power System." IEEE Transactions on Power Systems, vol. 34, no. 1, pp. 246–256, Jan. 2019.
[139] S. Yang, P. Wang, Y. Tang. "Feedback linearization-based current control strategy for modular multilevel converters." IEEE Transactions on Power Electronics, vol. 33, no. 1, pp. 161–174, Jan. 2018.
[140] Z. Huang, Z. Liu, F. Lee, and Q. Li. "Critical-Mode-Based Soft-Switching Modulation for High-Frequency Three-Phase Bi-Directional AC/DC Converters." IEEE Transactions on Power Electronics, vol. 34, no. 4, pp. 3888–3898, Apr. 2019.
[141] T. Novak, P. Westring, European Heat Pump Market and Statistics, Report, EHPA, 2016, http://www.ehpa.org/market-data/order-here/.
[142] R. Scoccia et al., Absorption and compression heat pump systems for space heating and DHW in European buildings: Energy, environmental and economic analysis, Journal of Building Engineering 16 (2018) 94–105.
[143] Certified Product for the Eurovent Certified Performance Website, Available at: http://www.eurovent-certification.com/index.php?lg = en
[144] Navigant Consulting, Inc, EIA – Technology Forecast Updates – Residential and Commercial Building Technologies – Reference Case, (2014). https://www.eia.gov/analysis/studies/buildings/equipcosts/pdf/appendix-a.pdf
[145] M. Santamouris, Cooling the buildings – past, present and future, Energy and Buildings 128 (2016) 617–638.
[146] S. Pezzutto, Status Quo of the Air-Conditioning Market in Europe: Assessment of the Building Stock, Energies (2017).
[147] Bourne, S., & Novoselac, A. (2015). PCM-based High-density Thermal Storage Systems for Residential and Small Commercial Retrofit Applications. Procedia Engineering, 121, 536–543. https://doi.org/10.1016/J.PROENG.2015.08.1025
[148] Zou, D., Ma, X., Liu, X., Zheng, P., Cai, B., Huang, J., … Liu, M. (2017). Experimental research of an air-source heat pump water heater using water-PCM for heat storage. Applied Energy, 206, 784–792. https://doi.org/10.1016/J.APENERGY.2017.08.209
[149] Abdelsalam, M. Y., Sarafraz, P., Cotton, J. S., & Lightstone, M. F. (2017). Heat transfer characteristics of a hybrid thermal energy storage tank with Phase Change Materials (PCMs) during indirect charging using isothermal coil heat exchanger. Solar Energy, 157, 462–476. https://doi.org/10.1016/J.SOLENER.2017.08.043
[150] Fang, Y., Niu, J., & Deng, S. (2018). Numerical analysis for maximizing effective energy storage capacity of thermal energy storage systems by enhancing heat transfer in PCM. Energy and Buildings, 160, 10–18. https://doi.org/10.1016/J.ENBUILD.2017.12.006
[151] da Cunha, J. P., & Eames, P. (2018). Compact latent heat storage decarbonisation potential for domestic hot water and space heating applications in the UK. Applied Thermal Engineering, 134, 396–406. https://doi.org/10.1016/J.APPLTHERMALENG.2018.01.120
[152] P. de Wilde, "The gap between predicted and measured energy performance of buildings: A framework for investigation," Automation in Construction, vol. 41, pp. 40-49, 5// 2014.
A. C. Menezes, A. Cripps, D. Bouchlaghem, and R. Buswell, "Predicted vs. actual energy performance of non-domestic buildings: Using post-occupancy evaluation data to reduce the performance gap," Applied Energy, vol. 97, pp. 355-364, 9// 2012.

[153] L. C. Tagliabue, M. Manfren, A. L. C. Ciribini, and E. De Angelis, "Probabilistic behavioural modeling in building performance simulation—The Brescia eLUX lab," Energy and Buildings, vol. 128, pp. 119-131, 9/15/ 2016.
[154] M. Manfren, N. Aste, and R. Moshksar, "Calibration and uncertainty analysis for computer models – A meta-model based approach for integrated building energy simulation," Applied Energy, vol. 103, pp. 627-641, 3// 2013.
[155] A.T. Nguyen, S. Reiter, and P. Rigo, "A review on simulation-based optimization methods applied to building performance analysis," Applied Energy, vol. 113, pp. 1043-1058, 1// 2014.
[156] N. Aste, M. Manfren, and G. Marenzi, "Building Automation and Control Systems and performance optimization: A framework for analysis," Renewable and Sustainable Energy Reviews.
[157] C. Koulamas, A. P. Kalogeras, R. Pacheco-Torres, J. Casillas, and L. Ferrarini, "Suitability analysis of modeling and assessment approaches in energy efficiency in buildings," Energy and Buildings, vol. 158, pp. 1662-1682, 2018/01/01/ 2018.
[158] Z. Yang and B. Becerik-Gerber, "A model calibration framework for simultaneous multi-level building energy simulation," Applied Energy, vol. 149, pp. 415-431, 7/1/ 2015.
[159] L. Tronchin, M. Manfren, and L. C. Tagliabue, "Optimization of building energy performance by means of multi-scale analysis – Lessons learned from case studies," Sustainable Cities and Society, vol. 27, pp. 296-306, 11// 2016.
[160] S. Breiner, E. Subrahmanian, and R. D. Sriram, "Modeling the Internet of Things: A Foundational Approach," in Proceedings of the Seventh International Workshop on the Web of Things, 2016, pp. 38-41.
[161] G. Serale, M. Fiorentini, A. Capozzoli, D. Bernardini, and A. Bemporad, "Model Predictive Control (MPC) for Enhancing Building and HVAC System Energy Efficiency: Problem Formulation, Applications and Opportunities," Energies, vol. 11, p. 631, 2018.
[162] N. Aste, M. Manfren, and G. Marenzi, "Building Automation and Control Systems and performance optimization: A framework for analysis, Renewable and Sustainable Energy Reviews, vol. 75, pp. 313-330, 8// 2017.
[163] n-tech Research, "BIPV Technologies and Markets: 2015-2022," 2015.
[164] Solar Roof Tiles: Integration into Buildings. http://www.energy.soton.ac.uk/projects-research-timeline/solar-roof-tiles-integration-into-buildings
[165] https://www.seac.cc/seac-presents-the-bipv-status-report-2017]
[166] PVsites. BIPV market and stakeholder analysis and needs, www.pvsites.eu
[167] S. Pezzutto, Status Quo of the Air-Conditioning Market in Europe: Assessment of the Building Stock, Energies (2017).
[168] https://www.seac.cc/seac-presents-the-bipv-status-report-2017 2017]
[169] https://bipvboost.eu/]
[170] https://www.energymatching.eu/project/
[171] https://www.pvsites.eu/project/
[172] https://www.greco-project.eu/the-project/
[173] https://isfh.de/en/forschung/photovoltaik/projekte/superpv/
[174] Global Split Air Conditioning Systems Market 2018: Industry Status, Sales Overview, Supply-demand 2017-2026.
[175] World air conditioner demand by year, Japan refrigeration association, 2018.
[176] http://www.olimpiasplendid.it/climatizzazione/senza-unita-esterna
[177] IEA EBC Annex 50, Prefabricated Systems for Low Energy Renovation of Residential Buildings, Building Renovation Guide and Guidelines for System Evaluation, 2012, AECOM Ltd, United Kingdom.
[178] Telaretti E, Dusonchet L. Stationary battery technologies in the US: Development trends and prospects. Renewable and Sustainable Energy Reviews. (2017)
[179] G. Iannaccone, G. Salvalai, M. M. Sesana, R. Paolini (2016), Integrated Approaches For Large Scale Energy Retrofitting Of Existing Residential Building Through Innovative External Insulation Prefabricated Panels, Proc. Sustainable Built Environment (SBE) Regional Conference, Zurich, June 15-17 2016.

[180] European Commission (2015), Envelope Approach to improve Sustainability and Energy efficiency in Existing multi-storey multi-owner residential buildings. https://cordis.europa.eu/project/rcn/102518/brief/en
[181] G. Salvalai, M. Sesana, G. Iannaccone, Deep renovation of multi-storey multi-owner existing residential buildings: A pilot case study in Italy, Energy and Buildings 2017; 148: 23–36.
[182] Hu X, Zou C, Zhang C, Li Y. Technological developments in batteries: a survey of principal roles, types, and management needs. IEEE Power and Energy Magazine. (2017)
[183] Hu X, Zou C, Zhang C, Li Y. Technological developments in batteries: a survey of principal roles, types, and management needs. IEEE Power and Energy Magazine. (2017)
[184] D. Di Lecce, R. Verrelli, and J. Hassoun, "Lithium-ion batteries for sustainable energy storage: recent advances towards new cell configurations." Green Chem., 2017, 19, pp. 3442–3467.
[185] G. Zubi, R. Dufo-Lopez, M. Carvalho, and G. Pasaoglu, "The lithium-ion battery: State of the art and future perspectives." Renewable and Sustainable Energy Reviews 89 (2018): 292–308
[186] F. W. Geels, V. Johnson, Towards a modular and temporal understanding of system diffusion: Adoption models and socio-technical theories applied to Austrian biomass district-heating (1979{2013), Energy Research & Social Science 38 (2018) 138-153.
[187] S. Selvakkumaran, E. O. Ahlgren, Understanding the local energy transitions process: a systematic review, International Journal of Sustainable Energy Planning and Management 14 (2017) 57-78.
[188] F. G. Li, E. Trutnevyte, N. Strachan, A review of socio-technical energy transition (STET) models, Technological Forecasting and Social Change 100 (2015) 290-305.
[189] F. Faller, A practice approach to study the spatial dimensions of the energy transition, Environmental Innovation and Societal Transitions 19 (2016) 85-95.
[190] J. Balest, E. Pisani, D. Vettorato, L. Secco Local reflections on low-carbon energy systems: A systematic review of actors, processes, and networks of local societies, Energy Research & Social Science, 42 (2018), 170-181
[191] J. A. Maxwell, Designing a qualitative study, The SAGE handbook of applied social research methods 2 (2008) 214-253.
[192] C. Teddlie, F. Yu, Mixed methods sampling: A typology with examples, Journal of mixed methods research 1 (2007) 77-100.
[193]R. A. Krueger, Focus groups: A practical guide for applied research, Sage publications, 2014.
[194] L. S. Dos Muchangos, A. Tokai, A. Hanashima, Stakeholder analysis and social network analysis to evaluate the stakeholders of a MSWM system: a pilot study of Maputo city, Environmental Development 24 (2017) 124-135.
[195] F. W. Geels, T. Schwanen, S. Sorrell, K. Jenkins, B. K. Sovacool, Reducing energy demand through low carbon innovation: A sociotechnical transitions perspective and thirteen research debates, Energy research & social science 40 (2018) 23-35.
[196] www.gazzettaufficiale.it/eli/gu/2018/12/31/302/so/62/sg/pdf
[197] Dra. Niki Gaitani, "Nearly Zero Energy Buildings ( NZEB ) Status Report in Mediterranean countries," no. June, 2014.
[198] "Cas général : RT existant par élément Cas particulier : RT existant globale Label HPE rénovation Textes de référence."
[199] "Arrêté_du_13_juin_2008_version_consolidee_au_20190301." .
[200] "Arrêté_du_22_mars_2017_version_initiale.".
[201] Ministry of Infrastructure, "Public hearing of the Regulation on self-handling of electricity from renewable energy sources," 2019. [Online]. Available: http://www.energetika-portal.si/nc/novica/n/javna-obravnava-uredbe-o-samooskrbi-z-elektricno-energijo-iz-obnovljivih-virov-energije-4128/. [Accessed: 26-Mar-2019].