HEART D2.1 Application Context Periodic Update -I

March 2018

HEART

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0.4	30/03/2018	Quality review	M. Buzzetti (ZH) F. Leonforte (POLIMI)
1.0	31/03/2018	Final version addressing all further comments	M. El Mankibi (ENTPE) M. Bahrar (ENTPE)

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1. INTRODUCTION AND OVERVIEW

1.1 PROJECT OVERVIEW

HEART «Holistic Energy and Architectural Retrofit Toolkit» focuses on improving energy efficiency in the building sector and aims to develop, test and validate a holistic and multi-technological integrated and interconnected system for the deep rehabilitation of residential buildings.

Based on a whole-building performance approach, the toolkit is conceived to achieve extremely high levels of energy efficiency in the existing residential building stock, with particular reference to Central and Southern Europe, where climate change and energy transition have boosted electricity consumption peaks both during summer and winter seasons. However, it may be extended equally well to new residential and commercial buildings.

The system's central core consists of a cloud-based computing platform which concentrates managing and operational logic to support decision-making in planning and construction as well as energy performance enhancement and monitoring during operation. The Toolkit provide energy saving, energy fluxes optimization, data exchange, stakeholders' active involvement and Smart Grid interactivity.

Interoperable building technologies and installations are also integrated in the toolkit: envelope solutions (thermal insulation and windows) ensure a reduction of thermal loads, while technical systems (BEMS, BIPV, heat pump, fan coils, power controller, storage systems) ensure energy efficiency and RES exploitation.
All technical systems and building components are structured as a function of their affordability, interactivity, practicality, reduced installation time and non-invasiveness.

1.2 PURPOSE AND SCOPE OF THIS DELIVERABLE

The objective of this first deliverable is to describe the different tasks related to the WorkPackage2. This first deliverable intend to define the baseline, the work done and further work envisaged.

The WP2 focuses on the several features of the HEART geographic, energy, regulatory and technological application context and of all its boundary conditions, including the economic and regulatory issues.

This deliverable will be updated throughout the project to ensure that along the development of the whole project, possible changes/evolutions of the framework due to new policies, new standards, technology advancement, will be immediately taken into account in the development of the project.

1.3 Work Package approach: roadmaps

The WorkPackage is divided in to five tasks as follows: Buildings retrofit market (**T2.1**), Economic and regulatory context (**T2.2**), Interactions between buildings and the Smart Grids (**T2.3**), Technological benchmarking process (**T2.4**) and Users' needs and communication techniques (**T2.5**).

Each of these tasks is then further divided into 2 to 5 sub-tasks according to the roadmaps defined as follows:

1.3.1 Buildings retrofit market (T2.1)

Participants: ENTPE Lyon (ENTPE), University of Ljubljana (UL), Housing Europe (HE).
Duration: (M1-M48), from 1/10/2017 to 30/09/2021.

Objectives of the task:

The objective of this task is to provide a tool that groups all the residential buildings energy retrofit market in the target Countries. This tool should be able to actively support the project decision-making by providing several buildings' data added by all the HEART partners.
The fast and easy access to the real estate market's information will allow an easier choice of the retrofit approach. A particular attention should be given to the unpredictable application target changes that could occur during the course of the project: for this reason, the developed tool should be easily alterable and updateable.

Aspects to be considered:

- Cultural and technical differences in construction between the HEART project countries
- Difficult access to building data in several case studies
- To develop a tool that should be simple and rapid

T2.1A - Targeted building characteristics data collection

Objectives: The aim of this activity is collect information about the residential buildings energy retrofit market in the HEART project Countries. For this reason, a datasheet will be created and diffused to all the project partners, in order to facilitate the case studies' data input.

Actions: All the HEART participants are invited to furnish to ENTPE all the buildings energy retrofit market data. ENTPE, University of Ljubljana (UL) and Housing Europe (HE) will define the format of the detailed product datasheet of each case study, containing the list of all the parameters needed to completely describe the buildings.

1) Definition of the detailed product datasheet and diffusion to all the HEART partners
2) Collection of the buildings energy retrofit market data

T2.1B -Development of a database collecting the residential buildings energy retrofit market

Objectives: The aim of this activity is to define a database collecting all the targeted building chosen for the project HEART. Their characteristics, such as climate zone, age, size, building performance, materials and technologies adopted, occupancy, etc. will be highlighted.

Actions: Once the data collected during the T2.1A will be obtained, ENTPE, University of Ljubljana (UL) and Housing Europe (HE) will create a database containing all the adopted solution. Once created, the access to the database should be facilitated in order to allow all the partners to update and modify the data.

1) Definition of the type of buildings energy retrofit market database
2) Elaboration of the database

1.3.2 Economic and regulatory context (T2.2)

Participants : ENTPE Lyon (ENTPE), Politecnico di Milano (POLIMI).
Duration: 48 months (M1-M48), from 1/10/2017 to 30/09/2021.

Objectives of the task:

The purpose of T2.2 consists in monitoring the relevant regulatory environments during the whole project in the target Countries. Regulation changes could in fact significantly affect the economics of the investment under the form of incentives, tariffs and tradable permits that must be considered in both the evaluation of the profitability of the investment and the future development of the technology under consideration.

T2.2A Implementation of the European directives EPDB and EPBD Recast into the national legislation of member states.

Objective: This chapter provides a summary of the national legislative framework regarding the implementation of the EPBD directives into national legislation of the target member states.

Actions: A summary of the laws transposing the EPBD directives into national legislation of the target member states (plus Swiss) will be provided by ENTPE and annually updated. The report will stress the attention on how the building regulations have changed because of the implementation of the European EPBD directives, how the energy certification of buildings have been implemented and finally, the definition of minimum energy performance requirements for both new residential building (nZEB) and the existing residential buildings subject to energy requalification.

Deadlines: ENTPE prepared the report and shared it with POLIMI by 16/03/2018. Further adjustment were made and the final document is delivered by 31/03/2018. ENTPE will annually update the report by 15 February of each year. The annual updates will be checked and revised with POLIMI before the delivery date.

T2.2B Implementation of the European Energy Efficiency Directive into the national legislation of member states.

Objective: 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.

Actions: A summary of the laws transposing the Energy Efficiency Directive into national legislation of the target member states (plus Swiss) will be provided by POLIMI and annually updated. The report will focus on the energy audit of buildings and energy redevelopment plans for public buildings (e.g. social housing).

Deadlines: POLIMI prepared the report and sent it to ENTPE by 16/03/2018. ENTPE checked and updated the report. The final document is delivered by 31/03/2018. POLIMI will annually update the report by 15 February of each year. The annual updates will be checked, revised and delivered by ENTPE.

T2.2C Definition of Standards according to CEN Standards and other Energy Planning tools

Objective: This chapter summarizes the regulatory transposition path consistent with the CEN standards and describes any other energy planning tools in the construction sector aimed at defining the minimum performance requirements for existing buildings (e.g. urban or regional energy plans, municipal building regulations, etc.).

Actions: POLIMI prepared a first report concerning the regulatory framework for the calculation of energy performance of buildings in target countries. The report focuses on how national legislation of target members 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.

Deadlines: POLIMI prepared the report and sent it to ENTPE by 16/03/2018. ENTPE checked and updated the report. The final document is delivered by 31/03/2018. POLIMI will annually update the report by 15 February of each year. The annual updates will be checked, revised and delivered by ENTPE.

T2.2D Strategies to promote the energy requalification of the existing building stock

Objective: 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. Moreover, the role of ESCo in the promotion of the energy requalification of the existing building stock is analysed.

Actions: ENTPE presented a detailed analysis of the state of art of Energy Performance Contract in target countries. The study describes 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. For example, it will be considered how to implement in EPC the energy consumption data in real time or the way in which the user manages the utilities that consume energy (heating, air conditioning, air conditioning, etc.)
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.

Deadlines: ENTPE prepared the report and sent it to POLIMI by 16/03/2018. Further adjustments were made and the final document is delivered by 31/03/2018. ENTPE will annually update the report by 15 February of each year. The annual updates will be checked and revised with POLIMI before the delivery date.

T2.2E Assessment of electricity and natural gas tariffs and Incentives for energy retrofit of buildings in EU target countries

Objective: The aim of this activity 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. Moreover, the state of the art of economic incentive policies for energy requalification adopted at national and / or local level is provided.

Actions: POLIMI will periodically collect data concerning electricity and gas prices in target states provided by Eurostat and present them in reports. In addition, POLIMI will outline the reference framework on national laws that incentivize energy retrofit actions on existing buildings, analyzing how those incentivizing mechanisms are implemented and diffused in the target markets.

Deadlines: POLIMI prepared the report and sent it to ENTPE by 16/03/2018. ENTPE checked and updated the report. The final document is delivered by 31/03/2018. POLIMI will annually update the report by 15 February of each year. The annual updates will be checked, revised and delivered by ENTPE.

1.3.3 Technological benchmarking process (T2.4)

Participants : ENTPE Lyon (ENTPE), Politecnico di Milano (POLIMI).
Duration: 48 months (M1-M48), from 1/10/2017 to 30/09/2021.

Objectives of the task

The purpose of T2.4 is to provide a framework and selected tools and guidelines to significantly facilitate the choice of energy effective solutions for retrofit in residential building undergoing renovation. Based on the study of residential buildings energy retrofit market in the target Countries (task T2.1) and a constant market monitoring, this task will provide a detailed list of innovative possible retrofit options for multi-storey residential buildings of the second half of the '900 located in the European areas with moderate climate.

Aspects to be considered

- The rapid development and release to market of new technologies.
- The climatic zone in which the building is located and its effect on the choice of solutions.
- The combined effect of different retrofit measures that can be lower or greater than each applied in isolation.
- Different occupant behavior and maintenance and their effects on retrofit approach.

T2.4A Definition of a database containing innovative energy retrofit solutions

Objective: The aim of the activity is to analyze all the energy-related refurbishment, renovation, or retrofit solutions present in the collection of case studies representing the targeted building types presented in task T2.1 (multi-storey residential buildings of the second half of the '900 located in the European areas with moderate climate) grouping the solutions according to their parameters (climatic zone, subcomponents concerned, etc.) and creating a “energy retrofit solutions” database. This database will take into account the potential improvement of these technologies.

Actions: All the HEART participants are invited to furnish to ENTPE all the case studies' data. ENTPE will define the format of the detailed product datasheet of each solution, containing the list of all the parameters needed to completely describe the technical features, assess the
products compatibility and the expected performances. After this first phase, ENTPE and POLIMI will create a first database containing all the adopted solution. Once created, the access to the database should be facilitated in order to allow all the partners to update and modify the data.

1) Definition of energy retrofit solutions database:

T2.4B Constant market and scientific monitoring

Objective: The aim of the activity is to carry out a continuous updating work about new energy-related refurbishment, renovation, or retrofit solutions present on the market. These solutions will integrate the data collected during the T2.4A and will be necessary for the continuous benchmarking process developed during the T2.4C.

Actions: ENTPE and POLIMI will effectuate a constant market and scientific monitoring, in order to find new energy and cost-effective retrofit solutions.

T2.4C Development of tools and guidelines for facilitating the choice of energy retrofit solutions

Objective: The aim of the activity is to develop a tool able to provide adapted energy retrofit solutions for each building, based on the feedback obtained through the case studies contained in the database created in task T2.4A.

Actions: ENTPE and POLIMI will make a continuous benchmarking process with the upcoming 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. The collection of such information will provide the basic framework for the detailed definition of the performance features of the proposed technological system.

1.3.4 User's needs and communication techniques (T2.5)

Participants : ENTPE Lyon (ENTPE), Politecnico di Milano (POLIMI).
Duration: 48 months (M1-M48), from 1/10/2017 to 30/09/2021.

Objectives of the task

The objective of the task is to achieve an intelligent building management platform addressed to the different HEART stakeholders (designers, installers building users, occupants etc.) to ensure the best adaptation of the technical features of the toolkit to the specific needs and to provide information on the overall system performance. This allow to make effective and efficient decisions in respect of energy utilization efficiency and retrofit analysis.

Aspects to be considered

- Integrate the data of residential buildings energy retrofit market in the target countries, established with the task T2.1
- Integrate the different types of technologies used established with the task T2.4.
- To provide technical, economic and environmental characteristics of the different technologies.
- To compare the historical energy consumption of the buildings with the current energy consumption
- Comparing the building's energy use to other similar buildings in the database, considering similar climates.
- Integration of simulation tools to provide and compare real data with simulated data
- To provide alerts if the building's parameters exceeds the parameters established depending on the energy performance requirements for example, and to identify energy waste, then to recommend solutions, allowing for effective and efficient decisions.
- To provide early warnings for any problems.
- To provide a clear and user friendly interface (for example using graphs to inform the user) facilitating precisely interpretation.
- The user should be able to submit a thermal comfort evaluation
- The access to the toolkit must be according to the user, for example as an occupant or designer, etc.
- Updating the toolkit according to unforeseeable changes in the HEART application
- Security of the platform (access control and the security of the database)

T2.5A - Identify the stakeholders and their needs

Objective: The aim of the activity is to identify all the users and stakeholders (designers, installers building users, occupants etc.) and their needs through careful investigation and research related to the HEART project, or feedback from other projects.

Actions: ENTPE and EURAC will define what kinds of methods are suitable for identifying users' needs including questionnaires, interviews, focus groups and workshops. This helps ensure that the needs of all those involved are taken into account.

1) Definition of the data acquisition method
2) Identified users' needs report:

T2.5B - Synthesis of existing information and selecting the most significant parameters

Objective: Based on the requirements gathered for the stakeholders, identified in the T2.5A, the aim of the activity is to classify and identify the major parameters that should be taken into account to meet the requirements and needs of the HEART project users.

Actions: ENTPE and EURAC will define the data collection forms that will be addressed to all the HEART partners. The historical energy performance of the targeted building and feedbacks to the building occupants should be considered. Thus, information about the targeted buildings types, available from the task T2.1 and the adapted energy retrofit solutions for each building available from the technological benchmarking process (Task T2.4) will provide important information about the characteristics of the targeted buildings and their historical energy performance, the technical, economic and environmental characteristics of the different technologies, etc.

1) Definition of the data collection forms:
2) Synthesis of existing information:

T2.5C – Identify the user's interaction approach

Objective: Once the user's requirements and the building parameters has been defined, it is important to develop and identify the suitable approach and tools allowing to take account all the parameters.

Actions: ENTPE and EURAC will define the data collection forms that will be addressed to all the HEART partners. After collecting all the relevant information, ENTPE and EURAC will prepare a synthesis of existing tools including energy monitoring equipment, and simulation tools.

1) Definition of the data collection forms:
2) Feedback from all the partners:

2. BUILDING RETROFIT MARKET

2.1 State of the art of energy and renovation context in EU's:

The European building is responsible for approximately 40% of the energy consumption, 36% of the CO_2 emissions and 55% of the electricity consumption.

The statistics confirm that 40% 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 analyzes on building stock, energy performance of buildings by age was 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.

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/m².

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:

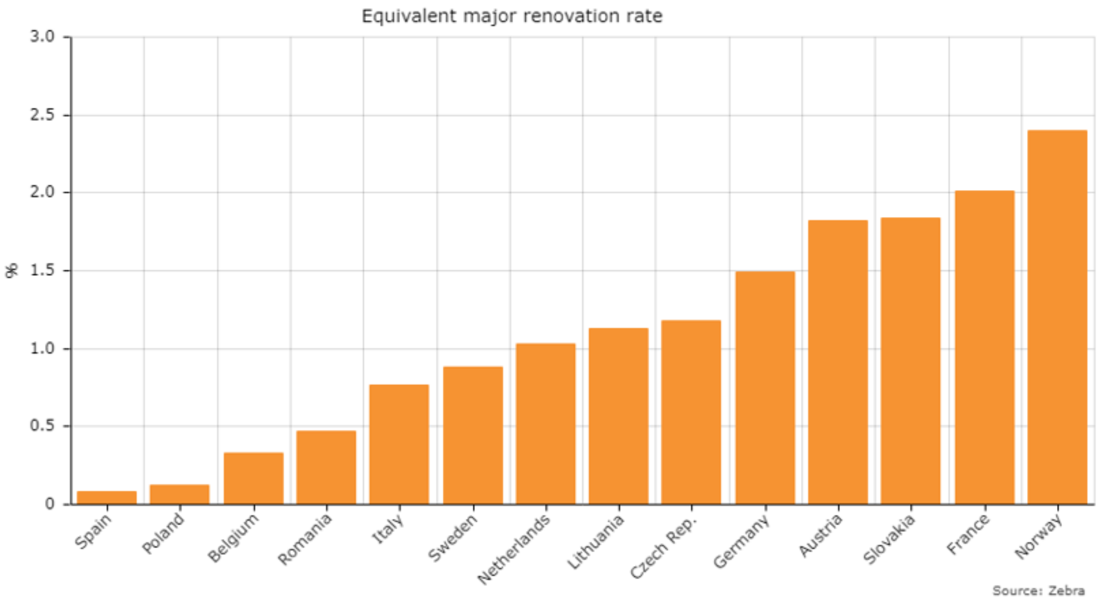

Figure 2-1 Major renovation rates of residential buildings (ZEBRA2020 Data tool)

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.

Renovation Market in EU's:

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 [1]:

- 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.

The following figure illustrate the market share renovation in the EU's.

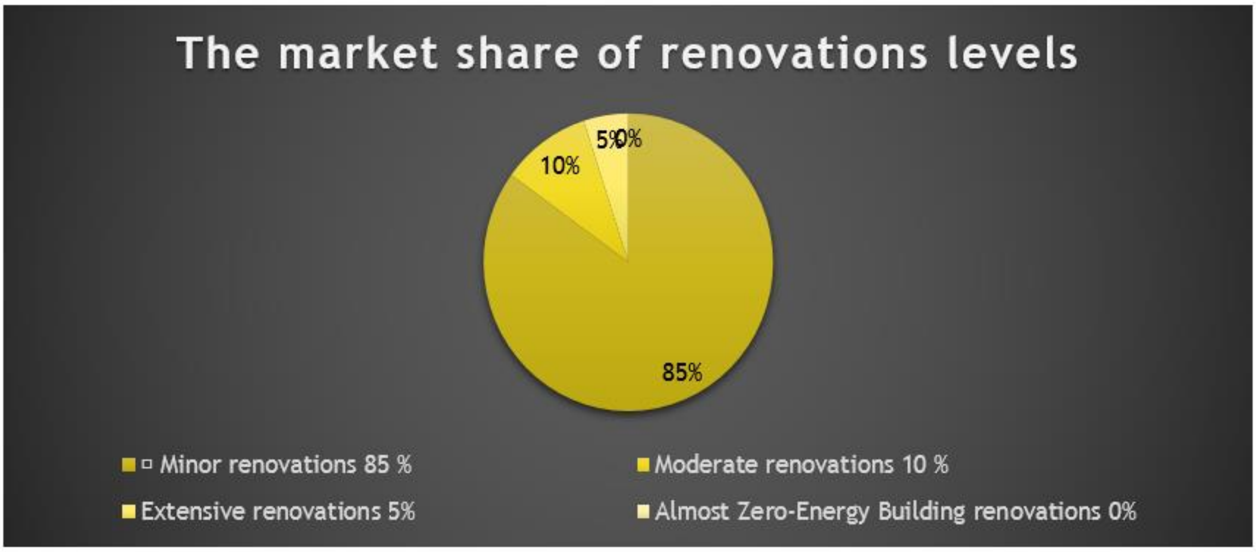

Figure 2-2 Market renovation levels

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.

Benefits of renovations:

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.

Barriers to renovation in the EU:

The European building stock is in 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:

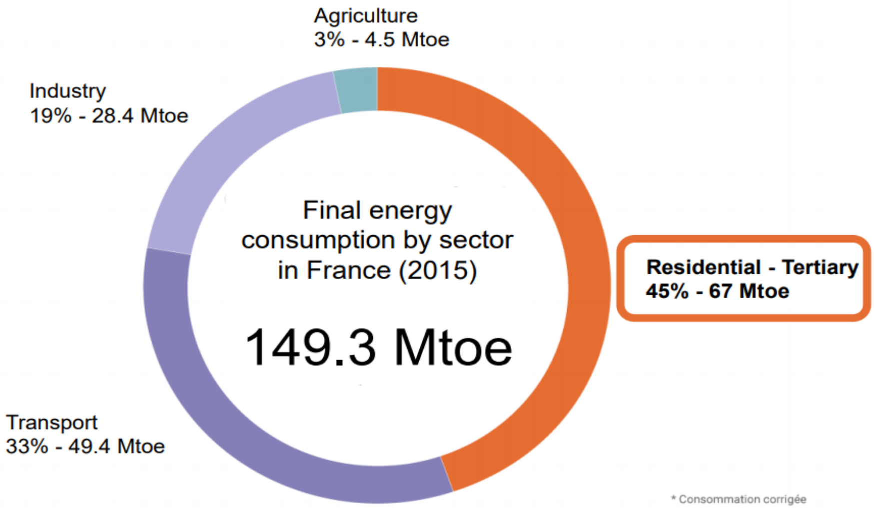

Figure 2-3 Final energy consumption by sector in France (2015)
Source : Ministère de l’environnement, de l’énergie et de la mer.

The 55% of buildings stock in France were built before 1975, 30 % between 1975 and 1998 and 16% after 1999 (source Ceren).
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.

To reduce consumption in this key sector, two scenarios was 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.

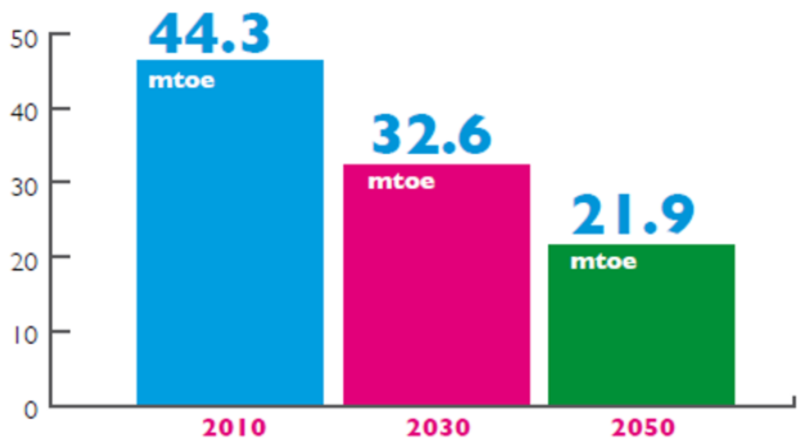

Figure 2-4 Energy consumption in the residential sector in 2010,2030 and 2050 (final Mtoe) [2]

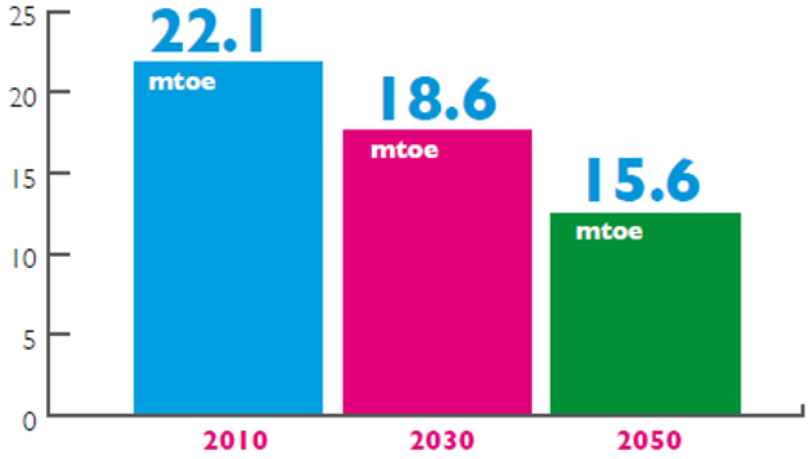

Figure 2-5 Energy consumption in the tertiary sector in 2010,2030 and 2050 (final Mtoe)) (Source:ADEME)

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.

3. Economic and regulatory context

3.1 European directives EPDB and EPBD Recast into the national legislation of member states.

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. 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 main source consulted for the constant update of this report will be National Energy Efficiency Action Plans and Annual Reports and Annual Reports [3], in which EU countries must report the progress achieved towards their national energy efficiency targets.

The first are national plans, published every three years, containing energy efficiency obligation schemes and policy measures, in addiction to expected and/or achieved energy savings, while the second contain annual updates on major legislative and non-legislative measures implemented in each national system. The most complete list of transposition of EU law into national laws can be found in the NIM database [4], in which the national transposition measures are updated weekly. Another important instrument are the extensive reports furnished by the Concerted Action (CA) EPBD [5]. This initiative, launched by the European Commission and the EU Member States in order to promote dialogue and exchange of best practice between the EU countries discusses in detail issues relating to setting up national requirements, designing, calculating, monitoring, financing and disseminating NZEBs. One of the key working areas is the exchange of information and discussion of national approaches of the application of the NZEB definition. Another important source for finding information about each EU member state implementation are the European Portal for Energy Efficiency in Buildings (BUILD UP) [6], that is the environment for building professionals, local authorities and building occupants willing to share their experience on how to cut energy consumption in buildings and the European Energy Efficiency Platform [7], the online community of energy efficiency experts. Important source of information, that will be periodically monitored, are national energy agencies and institutions.

General background about the EPBD

The Energy Performance of Buildings Directive provides for minimum requirements for energy performance of all buildings, be they new buildings or existing buildings.

- For the new buildings, the Directive requires all new buildings to be nearly zero-energy by the end of 2020. All new public buildings must be nearly zero-energy by 2018. Although there is no EU benchmark for the energy performance of NZEB, for residential buildings, most Member States aim to have a primary energy use not higher than 50 kWh/ (m^2.y). The maximal primary energy use ranges between 20 kWh/ (m^2. y) in Denmark or 33 kWh/ (m^2. y) in Croatia (Littoral) and 95 kWh/(m^2. y) in Latvia. Several countries (Belgium (Brussels), Estonia, France, Ireland, Slovakia, United Kingdom, Bulgaria, Denmark, Croatia (Continental), Malta, Slovenia) aim at 45 or 50 kWh/(m2.y)

- For existing buildings, Member States shall take the necessary measures to ensure that when buildings undergo major renovation, the energy performance of the building or the renovated part thereof is upgraded in order to meet minimum energy performance requirements. There is no common benchmark for the minimum requirements of the energy performance. For instance in

France the maximum primary energy use for existing buildings undergoing major renovation is between 80 and 165 kWh/m^2.year.

A slightly revised EPBD will be publish in 2018 with a new article 2a which provides that Member States shall establish a long-term strategy to support the renovation of the national stock of residential and non-residential buildings, both public and private, into a highly energy efficient and decarbonised building stock by 2050, facilitating the cost-effective transformation of existing buildings into nearly-zero energy buildings.

Concerning the Italian and French EPBD implementation laws, the most important can be found in the next paragraphs:

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.

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 (Règlementation Thermique 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 (Bâtiments Basse Consommation (BBC) in French) and they must consume less than 50 kWhep/m^2·year and must use 5-12 kWh/m^2·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/m^2. 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.

3.2 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) [8]. 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 [9] 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* [10], 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* [11] publishes each year trends and projections towards Europe's climate and energy targets. The ODYSSE-MURE database [12] continuously offer summaries of energy efficiency trends and policy measures. Other European platforms to take into consideration are the *BUILD UP Portal* [13], established by European Commission and *E3P*, the *European Energy Efficiency Platform* [14] 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 and French national laws implementing the EED are reported, as the two case studies for retrofit intervention will take place in those countries.

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 [15] 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) [16] and the *PANZEB* (National Action Plan to increase the number of NZEB buildings) [17]. 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 [18]. The inventory of all relevant central government buildings has been done by the Italian Public Property Agency charged by the Minister of Economic Development [20]. 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) [12]. 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 [15].

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 [20]. 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 [19]. Buildings owned by the company must be covered by the energy audit and the owner is required to submit the results to ENEA [20].
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 [21] and financed with 30 M€.

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 [22] and the Law on energy transition n° 2015-992 [23].

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 [22]. 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 [24].

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 [22].

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 5th 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 [21].
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 [21].

3.3 Definition of standards according to CEN standards and other energy planning tools (ENTPE, POLIMI)

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 and France, some information about energy planning tools are given hereafter:

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

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.

3.4 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 and France 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.

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. **Errore. L'origine riferimento non è stata trovata.** 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.

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.

3.5 Assessment of electricity and natural gas tariffs and incentives for energy retrofit of buildings in EU target countries

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 [33][34] 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" [35] 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.

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 [36], as well as many institutions and agencies provide annual reports, as the European Commission DG Energy [37], the Odyssee-Mure database [38], Buildings Performance Institute Europe [39], etc.

Hereafter the main Italian and French incentivizing systems are presented.

Italy

The principal incentivising systems currently available in Italian legislation, updated to 2018 budget law [40], are: - Ecobonus [41]: Fiscal deductions between 50% and 65% of total investment for single-house private building refurbishment and up to 75% for multi-house buildings, namely related to reduction of 20% of building energy demand, transparent and opaque envelopes, thermal solar collectors for domestic hot water production; installation of micro-cogeneration systems; high efficiency boilers and heat pumps in heating and cooling systems. - Conto Termico [42]: incentive scheme mainly addressed to public buildings for energy efficiency interventions as improving envelop insulation, installation high efficiency heating systems and shading systems, thermal energy production from renewable sources (available also for private buildings).

France

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

- Crédit d'impôt transition énergétique: 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).

3.6 Assessment of national regulation concerning certification of electrical devices.

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 and French national regulatory framework has been analysed:

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. They will be sent to the relevant Partners and will be thoroughly analysed.

The Italian regulatory framework is managed by the Italian regulating authority (Autorità di Regolazione per Energia Reti e Ambiente – ARERA, www.arera.it)

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).

4. Technological benchmarking process

This section describes the results of the technological benchmarking process carried out in the first 6 months of the project, related both to the general retrofit approach and to the specific technologies proposed. In detail, 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.

4.1 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 [43]. The recast of the Energy Performance of Buildings Directive (EPBD) [44] establishes the assessment of cost-optimal levels related to minimum energy performance requirements leading to the lowest building costs. 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 [45] 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. The importance of integrating renewables and energy efficiency measures is confirmed as crucial to reach the nZEBs target.

Simulation-based optimization methods have increasingly revealed their effectiveness in decreasing energy consumption in buildings at the design stage [46,47]. A simulation based optimization method can be used to derive the cost-optimal solution exploring several design options in more locations within a reduced computational time [48]. Recent research developments include the integration of optimization tools within the nZEBs design [49].

Different design variables can be analysed with the purpose of reducing energy consumption in buildings [50,51]. Applications deal with exploiting the efficiency of HVAC systems, ventilation, and photovoltaic (PV) systems [52,53], and on optimizing a single building component, such as windows or envelope [54,55].

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 [56].

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 [57].

The most common optimized nZEB configuration foresees a combination of good insulation, building airtightness as well as efficient heating and cooling system such as 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.

4.2 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 [58] a resonant configuration for a MIMO is proposed while in [59] optimization of size and weight for a 2 output power converter is studied. An innovative configuration for a single input double output converter has been proposed in [60].

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.

4.3 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 [61].

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 [62] 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 [63]. 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. [64] and summarised in the literature [65]. 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 [67] 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.

4.4 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. [67] 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. [68] 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. [69] 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. [70] 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. [71] 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.

4.5 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 [72], considering in particular the impact on performance of occupants' comfort preferences and behavior [73, 74]. 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 [75] (i.e. surrogate models, reduced-order models) can be successfully used for this purpose, e.g. in design optimization [76] [75], calibration and control [77]. The model used in the research is a reduced-order grey-box model [78]. In order to render these applications easier and more transparent and automated, the research is oriented towards the definition of multi-level performance metrics [79, 80] 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 [81] and to overcome the most relevant barrier to the deployment of integrated data analysis workflows and advanced control for energy management in the building sector [82,83], 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) and **scalability** (spatial and temporal analysis).

4.6 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 [84] forecasts there will be about 13% BIPV penetration by 2022. Although several products already exist, 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 [85]. Moreover, according to the BIPV market and stakeholder analysis and needs [86] 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.

In such framework, it is possible to state that the main features of the new tiles developed in HEART can be considered groundbreaking. 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. Furthermore, a candidate material for the production of the anchoring system 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.

4.7 Smart fan-coils

In the literature, a recent study on European air-conditioning (AC) market [87] 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.

This scenario confirms that HEART's smart-fan coil, based on STILLE's commercial solution, represents a ground-breaking technology. It includes a small-size DC compressor to increase the thermal power coming from the centralized DC heat pump, according to the energy demand of each room. This allows to minimize heat losses on the existing distributions pipes (water temp. < 30°C in winter and > 15° in summer), to avoid condensation in cooling mode and to increase the COP/EER of the centralized heat pump. The same compressor provides dehumidification when needed. It also allows to provide mechanical ventilation with heat recovery, by means of small vents to be realized on the external wall attached to the fan-coil and it enables smart functions, through a Narrowband IoT chipset.

For such reasons the smart fan-coil developed within HEART has a high potential to substitute the split system gradually. The study [87] also confirms that, at present, in the market no product for air-conditioning is present like HEART's smart fan-coil.

4.8 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 [88]. 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 [89]. 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 [88].
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 speedup the installation process.

4.9 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 [90] 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 centered 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 [90, 91].

5. User’s needs and communication techniques

Designing energy- efficient buildings depend not only on the architectural design and building technologies but also on the involvement and behaviour of different stakeholders that affect the building energy efficiency. There are numerous potential stakeholders who are directly or indirectly affected by the project and involved in the whole building life cycle including, design and construction, living, operating, managing, and regulating the built environments. These include building designers, operators, managers, engineers, occupants, industry, vendors, and policymakers.

The purpose of the task is to identify and analyse in detail the evolution of the needs of the different HEART users. This has several benefits, it allows to ensure the best adaptation of the technical features of the toolkit to the specific needs and also to identify the best targeted communication techniques to provide information on the overall system performance, to optimize the active participation and acceptance of provided technologies and maximize the impact.

5.1 Identification of stakeholders

The first step is to identify all the users and stakeholders and their needs. This helps ensure that the needs of all those involved are taken into account.

Figure 5-1 presents the methodology designed for identification and prioritization analysis of stakeholders at different building life cycle stages (. Due to the complexity of the building energy management, the first task consists on analyzing user’s involvement both on the time and space [92].

(Bourdic and Salat,2012) [93] indicate four intervention levels: urban morphology, building efficiency, system efficiency, and individual behaviour. Each level includes different intervention points that affect various aspects of the building energy performance. For example, different energy aspects are involved at the building and equipment level, such as building usage, energy use and cost, building comfort (indoor air quality, thermal comfort, lighting comfort).

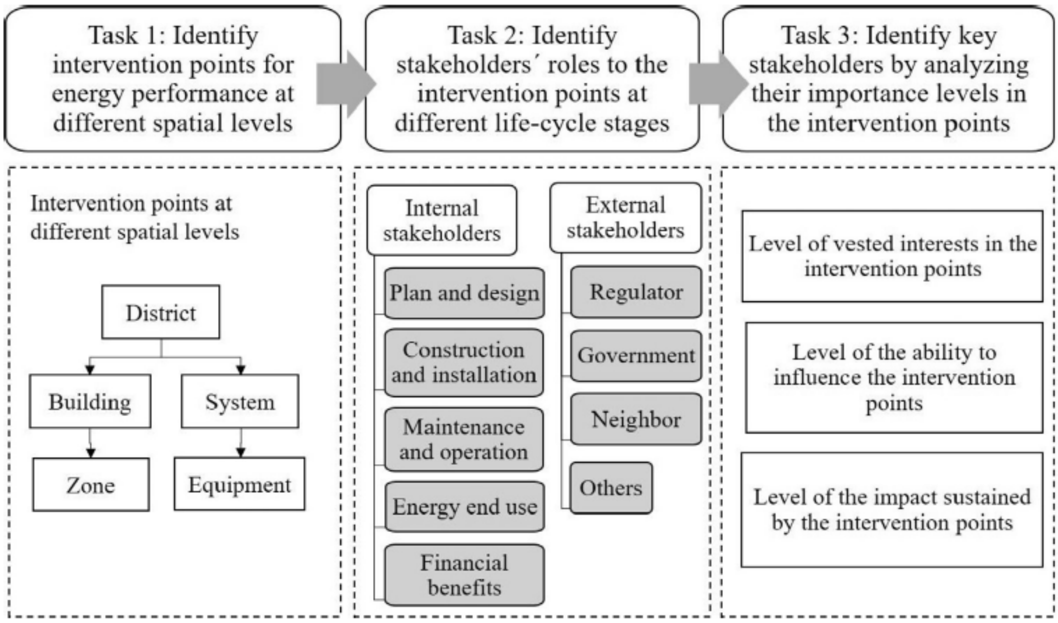

Figure 5-1 The three-task method to identify and prioritize stakeholders for enhanced multi-level energy management [92]

Type of stakeholders	Intervention point	stakeholder roles
Internal	Planning and design	Architect, electrical and mechanical engineer, energy engineer
	Construction and installation	Construction company, equipment manufacturer, system installation company
	Maintenance and operation	Building energy manager, facility manager, building solution provider, distribution energy manager, asset manager
	Energy and use	Occupant, building energy consumer/prosumer
	Financial benefits	Building owner/tenant, energy customer, organization owner
External	Central and local government, regulator, energy analyst, energy auditor Environmental advocacy organization, local non-profit and community-based organization (environment/public health), neighbor	

Table 5-1 A list of stakeholder roles involved in various intervention points [92].

A prioritization analysis for the identification of the key stakeholders can be performed based on Stakeholder Prioritization Index (SPI) varying from 0 to 5 [92,94].

5.2 Identifying stakeholder's needs

Once stakeholders have been identified, the next step is to identify and analyse their specific needs. For example, Architects, engineers, and energy modelers aim at maximizing building energy efficiency. Thus, several modelling approaches have been developed and monitoring techniques have been used to analyze and predict the whole building energy performance.

Utilities and policy makers address occupants, operators, and managers, energy savings impacts through codes and standard regulations [95]. Building technology manufacturers and vendors needs knowledge about the users' acceptance of technologies and the financial and regulatory context of the targeted buildings to develop technologies that are more adapted to the users and more effective. Otherwise, the occupants' behavior significantly influences the building energy performance. Occupants need to interact with their built environment, and to understand the design and operation of building systems, thus, they can adapt and give feedback about their comfort satisfaction and perceptions while minimizing energy use [95].

When an occupant feels discomfort with their environment (thermal discomfort, visual, air quality, acoustic). They tend to restore a desired indoor conditions by acting on personal variables such as clothing, change of activity and posture, or by acting on the control systems of the buildings (opening or closing windows, adjusting the thermostats, etc.). These adaptive behaviors impact the building energy performance. An effective building management require to provide the building users with informative data and Data Awareness, tools and technologies, to ensure a smarter control and interaction.

This is not necessarily an exhaustive list of all user's needs. Further investigation is needed including questionnaires, personal visit and performing indicators.

5.3 Identification and selection of key performance indicators

After identifying the stakeholders, It's important to identify and analyse the key performance parameters that define and meet their requirements.

(Xu et al. ,2012)[92] proposed a three-step method to define a list of key performance indicators (KPIs) that was used for the sustainability of building energy efficiency retrofit in hotel buildings[92] . The first step consists on a literature review and interviews with industry experts and academic researchers for the definition of performance indicators (PIs). Then, questionnaires surveys were performed with the different stakeholders to analyze the weight and significance of the selected KPIs.

The Stakeholder Vote Index (SVI) can be used to classify the PIs using a grade from 0 to 5 via interviews with stakeholders[92]. Considering 0 when the PIs are not related directly to the stakeholders, and 5 when the PIs are important to them.

6. Conclusion

This deliverable represents the initial work performed for the WP 2 in collaboration with ENTPE and POLIMI. The aim of this work was to collect the maximum of information about the different tasks in this WP (Retrofit market, Economic and regulatory context, technological systems and identification of stakeholder's) and It will be developed and actualized throughout the project.

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