Deliverable Report

Project Title:

Solar-Biomass Reversible energy system for covering a large share of energy needs in buildings

Project Acronym:

SolBio-Rev

Work Package 8

Deliverable 8.4

"Local and EU key technical & market codes and framework conditions relevant to the SolBio-Rev system"

Responsible for Deliverable:

DBC Europe (DBC)

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Contents

Executive summary

The SolBio-Rev project is a H2020 funded project that aims at developing an innovative renewable energy system based on a novel and creative heat pump-based configuration, for the production of heating (space heating and domestic hot water – DHW), space cooling and electricity according to the daily and seasonal energy demand of buildings.

Information included in this Deliverable 8.4 provides a summary of existing regulatory framework conditions on the national and European level and insights into possible future directions.

The first part of the document consists of a comprehensive description of the SolBio-Rev solution to allow better understanding of the context of further chapters. Since this document focuses on describing the regulations in force at EU level and on national regulations in target countries, the first section contains also the reasoning and criteria for the selection of countries to be analysed. The criteria have been carefully chosen to ensure an optimal selection of the target countries. Firstly, the characteristics of the project have been taken into account, and such factors as location of prototype tests and origin of the consortium partners have been considered as well. The final choice has been confirmed by checking the availability and showing the potential for use of the SolBio-Rev system, according to D2.2. Due tot he availability of data for Sweden instead of Finland that was mentioned in D2.2 the analysis on the national level has been carried out for Greece, Spain, Germany and Sweden.

The next section is devoted to the overview of the regulations at European level.The main legislative instruments of the European Union to promote the improvement of the energy performance of buildings and to provide a comprehensive framework to support investment decisions are the Energy Performance of Buildings Directive (EPBD), the Energy Efficiency Directive (EED), and secondarily the Renewable Energy Directive (RED) as listed in Table 1.

Table 1. Legal documents on the European level relevant to the SolBio-Rev project.

Directive	Short info
Energy Performance of Buildings Directive (EPBD)	Aims at the decarbonisation of the building stock by 2050; introduces an obligation for energy performance certificates; by the end of 2020 all new buildings have to be NZEB.
Energy Efficiency Directive (EED)	Sets targets for energy efficiency (20% energy savings target by 2020 and 32,5% by 2030)
Renewable Energy Directive (RED)	Sets targets for final energy consumption from renewable sources (20% by 2020, 27% by 2030)

The EPBD includes both 'passive' measures for the building design and envelope, as well as 'active systems', such as for heating, cooling and electricity. In addition, the EPBD introduced certificates, which indicate the Energy Performance of the building as a numeric value, allowing for benchmarking. These certificates include also a list of cost-effective recommendations to increase energy saving. The Energy Efficiency Directive establishes a set of binding measures to help the EU reach its energy efficiency targets. Under the Directive, all EU countries are required to use energy more efficiently at all stages of the energy chain, from production to final consumption. The Renewable Energy Directive establishes an overall policy for the production and promotion of energy from renewable sources in the EU and can as well have a positive impact on the exploitation of the SolBio-Rev project results.

The above mentioned European directives are differently implemented in the target countries. Regulations related to energy performance for new and retrofitted buildings at country level have been identified and the relevant legal documents for each country are summarized in Table 2.

Table 2. Relevant legal documents on the national level in the target countries.

Country	Significant Regulation
Germany	German Energy Saving Ordinance (EnEV)
	Renewable Energies Heat Act (EEWärmeG)
	Energy Conservation Law (EnEG)
Sweden	Planning and Building Act (2010:900)
	Planning and Building Ordinance (2011:338)
	Boverket's Building Regulations (BBR 27 BFS 2018:15)
Spain	Technical Building Code 2006 (TBC)
	Regulation of thermal installations in buildings (RITE -Royal Decree 1027/2007)
	Regulation of energy efficiency certification (Royal Decree 235/2013)
Greece	Ministerial Decision No. 4003/2017 on Buildings Energy Performance Regulation
	Law No. 4342/2015 on energy efficiency.
	Law No. 4414/2016, Ministerial Decision ΥΠΕΝ/ΔΑΠΕΕΚ/30971/1190 and Law No. 4643/2019 on the Support of Power Production Plants with

Renewable Energy Sources and High Efficiency Combined Heat and Power Generation

It became apparent, that current legislation both at European and national level is conducive to the SolBio-Rev project and incentives the use of energy efficient, renewables-based solutions for heating and cooling.

Finally, an analysis of the constraints and barriers possibly limiting the wide deployment of SolBio-Rev technologies is presented in order to understand and identify further effort required in the project aiming at reducing the impact of their impact. The identified constraints and barriers are summarized in Table 3.

Table 3. PESTEL matrix of the identified constraints and barriers.

Political	Economic	Social
Lobbying in favour of conventional energy sources. Introduction of new or amended tax regulations. Changes in the economic incentives schemes.	Cost barrier. High upfront expense and long payback period. Lack of adequate financing opportunities and/or unattractive interest rates. Low initial investment and exploitation cost of competitive systems (e.g. gas boilers for heating). High prices for the installers and low margin for the technology suppliers	The reluctance of residential building owners to invest in new technologies. Lack of knowledge, information and qualified installers. Reluctance of the construction industry (installers) towards innovative solutions.
Technological	**Environmental**	**Legal**
Unknown possible exploitation problems. Unknown possible problems in serial production. Hard accessibility to providers. Hard to estimate expected life (durability) of the system.	Proper siting and availability of resources (solar radiation, biomass availability).	Restrictions over ambient noise. City planning and restrictions for historical buildings. Building codes.

Some of the listed barriers are purely external and cannot be influenced. Nevertheless, in relation to the majority of them, remedial actions can be applied as part of the project. For example, the social constraints can be addressed by communication and dissemination activities. The exploitation activities, on the other hand, can help to overcome the technological as well as some of the economic barriers.

1 Introduction

1.1 *Aims and objectives*

The purpose of this deliverable is to provide a review of the regulations, energy standards, and building codes at national and EU level, relevant to residential, new and renovated/existing buildings on various markets.

This information will assist identifying needs, chances and constraints for the technologies developed within the SolBio-Rev project and will be used to guide the business development and the definition of realistic market applications.

The second aim of this report is to ensure that all components as well as the system as a whole, meet basic requirements in compliance with the local regulations. A summary of existing regulatory framework conditions on the national and European level is developed and insights on possible future directions is gained.

1.2 *Relation with other activities in the project*

This deliverable collects outputs from Task 2.1 and Task 2.2, which have helped to define the scope of this report. Within this task, it was agreed that the project will focus on residential and office buildings, and in particular multi-family houses.

The results will feed into multiple tasks within work packages 6 and 7. Ensuring compliance with standards and regulations at the European and national level, and understanding the barriers, limitations, and chances that these provisions imply, is necessary before the introduction of new technology to the market.

This report will be extended by further contents developed in work packages 6 and 7, which will present a full view into legal and social environment of the project. An insight into user acceptance and policy mechanisms to promote open innovation will be delivered in WP6 Further market analysis assessing the market potential and impact of project results will be carried in WP8 (Task 8.4 *Market analysis and business model generation*). In this work package also the standardisation activities (Task 8.7 *Standardisation activities*) will be performed to ensure compatibility and interoperability with market available systems through standards and regulations.

1.3 *Report structure*

The report begins by outlining its purposes, role within the project, and layout. Section 2 specifies the scope of the document and contains the description of the overall concept and system components as well as the reasoning for the selection of countries considered in section 4. Section 3*Technical and market codes at EU-level* is devoted to the overview of the three most significant regulations at European level the “Energy Performance of Buildings Directive”, the “Energy Efficiency Directive”, and the “Renewable Energy Directive”.The national regulations for Germany, Sweden, Greece, and Spain with special consideration of the relevant building codes have been described in section 4. Finally, section 5 contains the analysis of constraints and barriers imposed on the project by the aforementioned regulations and the last chapter concludes collected information.

1.4 Contribution of partners

The consortium partners involved in Task 8.4 and contributing to this Deliverable are: DBC, NTUA, DAIKIN, AKOTEC and FAU and UOS,.

- **DBC** (Mr. George Sidiras)– Introduction, Scope, Technical and market codes in Sweden, Analysis of constraints and barriers, Conclusion, Executive Summary.
- **NTUA** (Prof. Sotirios Karellas, Mr. Antonios Charalampidis) –Scope, Technical and market codes in Greece, Spain
- **DAIKIN** (Mr. Nikolas Barmparitsas) –Technical and market codes at EU-level.
- **AKOTEC** (Mr. Uwe Sonnenfeld) – Technical and market codes in Germany.
- **FAU** (Mr. Maximilian Weitzer) – Technical and market codes in Germany
- **UOS** (Prof. Mari Martiskainen) – Social aspects and barriers and constraints.

2 Scope

2.1 *SolBio-Rev overall concept*

In this section, a comprehensive description of the SolBio-Rev system is provided in order to allow better understanding of the context of further chapters in the document. The overall SolBio-Rev system relies on a heat pump-based configuration hosting a reversible heat pump/ORC and an adsorption chiller, as well as a dual-temperature biomass boiler and solar collectors equipped with TEGs and is able to provide a large share of space heating, cooling and DHW demand and part of electricity needs using solar, biomass and ambient energy. Thanks to its flexibility, SolBio-Rev is suitable for a wide variety of buildings in different climatic conditions. According to D2.1, focus is given on multi-family houses and office buildings.

2.1.1 Project objectives

The main objective of the Solbio-Re project is to develop a multi-vector energy system combining promising renewable energy technologies based on solar, ambient and bioenergy, having at the core an innovative heat pump-based configuration and to allow the efficient application of this solution, without any geographical restriction. Apart from the global system, the SolBio-Rev system aims to develop innovative subsystems, integrated together under the supervision of an advanced control system.

2.1.2 System layout and its operation modes

The overall concept is presented in Figure 1, based on its two main operating modes (summer/winter).

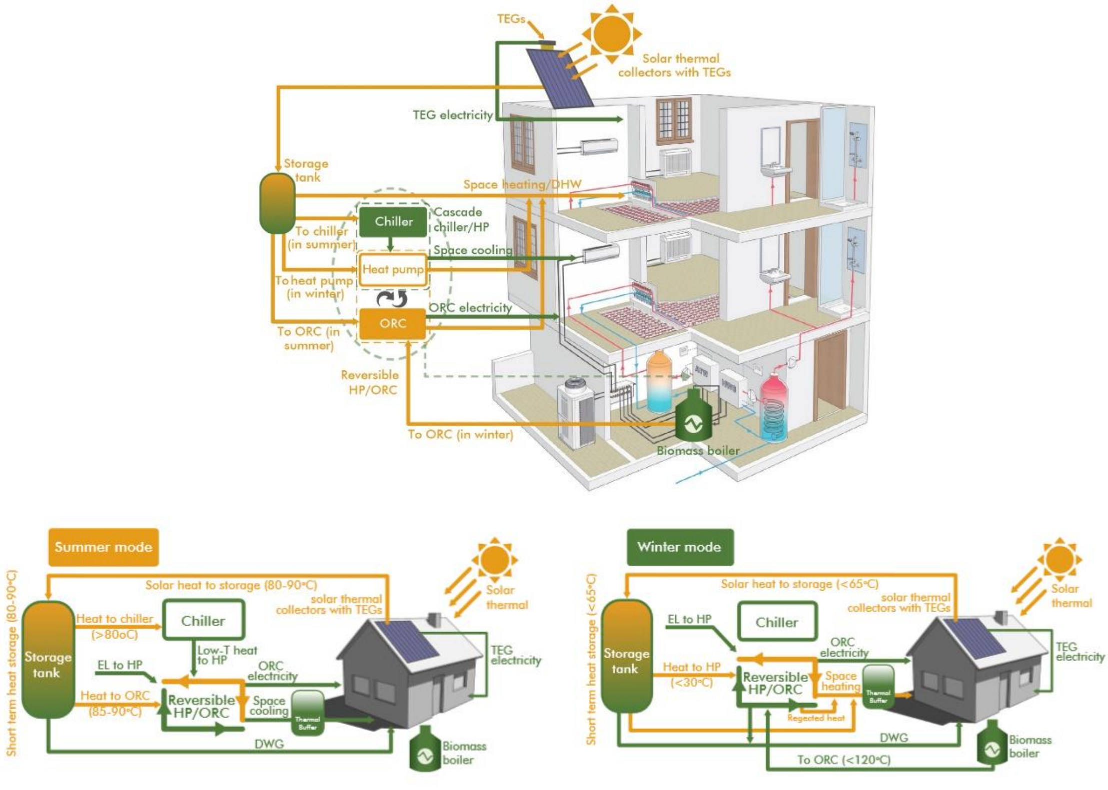

Figure 1. SolBio-Rev concept and main operating modes (summer and winter).

Summer:

Main operating mode → Using solar heat for either cooling or electricity production

At moments with solar energy availability, solar heat at 90 °C is stored in the short-term heat storage tank for supplying the DHW demand at 60 °C (if required) and for either cooling or electricity production as follows:

- Cooling production: The stored heat supplies *in priority* the cascade chiller for space cooling, which requires heat at over 80 °C to reach a high thermal COP.
- Electricity production: When cooling is not required or the forecasted daily cooling needs are covered by charging the thermal buffer tank, the stored heat supplies the ORC for electricity production. Its operation is preferred over TEGs, having 30% higher efficiency for the same heat input temperature. At all moments, the TEGs operate to dissipate the excess solar heat in case of collector overheating, extending their lifetime.

At moments with no solar energy availability:

- The remaining stored heat is primarily used for DHW and then for cooling production, if required.
- At night time and if all daily or forecasted heating/cooling needs are covered (or buffer tank charged), a fraction of the stored heat at temperature < 75-80 °C supplies the TEGs for electricity production

Winter:

Main operating modes → Using either the heat pump for heating at solar-assisted mode or the biomass boiler for CHP.

At moments with solar energy availability, the pump of the solar field is controlled to reduce the temperature of the solar heat at up to 65 °C, and thus increase the collector efficiency at cold conditions. This heat is stored and is used as follows, according to its temperature:

- Heat at 65 °C is used for (1) DHW, and (2) space heating at up to 45 °C. In buildings with no DHW needs, the solar heat temperature is reduced to 50 °C for space heating only, further enhancing the collector efficiency.
- Heat at very low temperature (5 < T < 30 °C) supplies the evaporator of the electric HP for assisting the heating production and increasing its COP to over 4.5, reaching 5 in south Europe.

At moments with no solar energy availability or higher heating needs than the heat pump production, the biomass boiler operates to cover the excess of heating demand, by operating at CHP mode.

Intermediate Seasons:

- **Spring**: The moderate solar heat production covers all the heat demand (if any). No cooling is required, allowing the operation of either the TEGs or the ORC, according to the solar heat temperature (ORC for T > 80 °C).

- **Autumn**: In case that it is not possible to fully cover the heating demand by the direct solar heat gain, the heat pump operates at solar-assisted mode, leaving as the last resort the biomass boiler

The optimum decision and exact operating mode during each season (e.g. TEGs vs. ORC, heat pump vs. biomass boiler) depend mostly on the available solar irradiation, and energy needs and prices (e.g. gas, electricity or district heating). Therefore, the SolBio-Rev system relies on an advanced control strategy, with several optimisation parameters for maximising the renewable energy share and/or minimising energy costs. Finally, at all moments and seasons, TEGs offer the option to exploit all heat that is not utilised or otherwise wasted, not competing with the ORC, and especially in intermediate seasons, when their production potential is the highest.

2.1.3 The core technologies of the SolBio-Rev configuration

The core technologies on which the SolBio-Rev system is based are summarized in Table 4 and the main components are depicted in Figure 1. The majority of the core components and technologies are new and innovative and will be specifically developed in the framework of the project, apart from the storage tanks that constitute a mature technology.

Table 4. List of the main technologies of the SolBio-Rev system

No.	Technology (component)	Level
1	Cascade adsorption chiller/heat pump	Component
2	Reversible heat pump/ORC	Component
3	Creative heat pump-based configuration	Configuration
4	Solar collectors with TEGs	Configuration
5	Biomass boiler for cogeneration	Component
6	Advanced system control	Control
7	Thermal storage tanks	Component

2.1.3.1 Cascade adsorption chiller/heat pump

A cascade adsorption/compression component consists of an adsorption chiller, whose cold output is used by the directly coupled vapour compression HP for rejecting heat at its condenser. In this way, tThe cascade chiller/heat pump performance is greatly enhanced, by hostind an enhanced coated adsorber HEX and an integrated evaporator/condenser.

2.1.3.2 Reversible heat pump/ORC

A reversible heat pump/ORC is based on a vapour compression heat pump (the same heat pump of the cascade chiller) that its operation is reversed, leading to a heat-to-power unit , an ORC. Accordingly, this component produces either heating and cooling (*heat pump mode*) or electricity (*ORC mode*), using the same equipment[4] (e.g. HEXs, reversible compressor/expander).

2.1.3.3 Creative heat pump-based configuration

The two previous components are coupled and integrated into the heat pump-based configuration, shown in Fig. 5. The chiller operates only when cooling is required and shares the new dedicated HEX with the heat pump, while the space cooling is supplied by the HP evaporator. An additional condenser is included that provides heating during winter, when solar heat of very low temperature (< 30 °C) is supplied to the HP evaporator.

At ORC mode, the chiller does not operate and the HP cycle is reversed. Solar or biomass heat supplies the evaporator for power production by the expander. Heat rejected at the condenser is used for space heating when needed, otherwise rejected to the ambient.

2.1.3.4 Solar collectors with TEGs

The TEGs are externally connected to the collectors. They are optionally operated (on/off) according to the availability of surplus solar heat with the use of by-pass piping, actuated with a valve. This approach offers high flexibility by exploiting all solar heat that would be otherwise wasted. The TEGs are spatially separated from the heat flow (by-passed), when either the ORC or chiller operate, without affecting their performance.

2.1.3.5 Biomass boiler for cogeneration

The main features of this innovative biomass boiler concern the supply of heat at two different temperature levels; for space heating (up to 80 °C) and for CHP. More specifically, it includes the use of Exhaust Gas Recirculation (EGR) with advanced control strategy for emissions reduction (NOx, PM, etc.) and an internal heat exchanger for the production of heat at an increased temperature level (up to 120 °C) for CHP operation, supplying the ORC..

2.1.3.6 Advanced system control

A smart and predictive system and self-learning control with extended features is foreseen to provide efficient operation and monitoring of all components. According to real-time and forecasted energy needs and solar availability, this controller will manage: (1) the solar heat temperature and the operation of the TEGs, (2) the heat pump-based configuration for covering the daily heating/cooling demand, by storing hot/chilled water for later use, (3) the operation of either the HP or the biomass boiler for heating in winter. The developed operational strategy of the SolBio-Rev system will be hosted in this controller by contributing to the maximisation of renewable energy share, while self-consuming all electricity generation, and ensuring thermal comfort of the users/occupants.

2.1.3.7 Thermal storage tanks

Two storage tanks are included, one for storing solar heat in order to supply heat to the sorption chiller, the reversible heat pump/ORC and DHW, and one for storing hot or cold water for space heating and coling.

2.2 Selection of target countries

The analysis of the legal situation for all 46 countries in Europe seems to be a very wide task requiring huge expenditure of work, and not bringing the expected value to the project. Even a review of regulations in force in all 28 countries associated in the European Union is laborious, time-consuming and will not contribute to the project's success in expected extent. For this reason, this document focuses on describing the regulations in force at EU level (EU directives are implemented in all EU-countries) and on national regulations in selected countries. This limitation will not affect the usefulness of this document, while at the same time allows the best use of resources in the project. The countries, for which the analysis will be carried out, have been carefully selected according to the criteria, which aim at ensuring the best use of the collected data for the purposes of the project.

The main criteria for selection of the target countries are:

- Location of building prototype tests: Greece and Germany.
- Available information in the project thanks to the participation of partners located in that country: Greece, Spain, Italy, UK, Sweden, Germany, Belgium and Austria.
- Potential of the SolBio-Rev system. These countries result from the analyses performed in D2.1 and D2.2. According to that, the identified countries have been Greece and Spain for southern Europe, Germany for Central Europe, and Finland for Northern Europe.

As a result, Greece, Spain, Germany and Finland have been defined as the countries meeting the above criteria. With respect to northern climate however, data was already available for Sweden and therefore, **Sweden was selected in place of Finland**.

3 Technical and market codes at EU-level

In the past few decades, climate change has been intensified mainly due to the high amount of greenhouse gas emissions. Therefore, the European Union (EU) is oriented towards energy saving measures, focusing on the building sector. This is associated with the high energy consumption of buildings. In particular, buildings are responsible for approximately 40% of the energy consumption and 36% of CO_2 emissions in the EU. Regarding their characteristics, about 35% of the EU's buildings are over 50 years old and almost 75% of the building stock is energy inefficient, while only 0.4 – 1.2% (depending on the country) of the building stock is renovated each year [1]. More specifically, the renovation of existing buildings has the potential to lead to significant energy savings – potentially reducing the EU's total energy consumption by 5 – 6% and CO_2 emissions by about 5%.

Thus, emphasis is placed on buildings renovation and energy efficiency of buildings as well, in order to get nearly zero-energy buildings (NZEBs) or even zero- (ZEBs) and positive-energy buildings (PEBs). Hence, a specific legislative framework has been established setting out requirements such as the constant inspection of air conditioning and heating systems. The main EU Directives of this framework are primarily the Energy Performance of Buildings Directive (EPBD), the Energy Efficiency Directive (EED) and secondarily the Renewable Energy Directive (RED), which are described below:

3.1 The Energy Performance of Buildings Directive (EPBD)

The **Energy Performance of Buildings Directive** was first established in 2002 with the 2002/91/EC Directive [2] which was amended in 2010 by the 2010/31/EU Directive [3]. On 30 November 2016, the Commission proposed a further update to the Energy Performance of Buildings Directive towards the direction of smart technology implementation in buildings, as well as the harmonization of national frameworks, and buildings renovation acceleration. Furthermore, the Commission published a new buildings database – the EU Building Stock Observatory – to monitor the energy performance of buildings across Europe.

On 19 June 2018 the 2018/844/EU Directive [4] was published amending the EPBD. This revision focuses on the acceleration of the cost-effective renovation of existing buildings, aiming at the decarbonisation of the building stock by 2050. In this context of the new and revised Directive, the following requirements are set [5]:

- EU countries will have to establish stronger long-term renovation strategies, which can be included in their ***National Energy Efficiency Action Plans***, aiming at the decarbonisation of the national building stocks by 2050, and with a solid financial component.
- Smart technologies will be further promoted, for instance through requirements on the installation of building automation and control systems and on devices that regulate temperature at room level.
- EU countries will have to express their national energy performance requirements in ways that allow cross-national comparisons.
- All new buildings must be nearly zero-energy buildings by 31 December 2020 (public buildings by 31 December 2018).

- Energy performance certificates must be issued when a building is sold or rented, and they must also be included in all advertisements for the sale or rental of buildings.
- EU countries must establish inspection schemes for heating and air conditioning systems or put in place measures with equivalent effect.
- EU countries must set cost-optimal minimum energy performance requirements for new buildings, for the major renovation of existing buildings, and for the replacement or retrofit of building elements (heating and cooling systems, roofs, walls and so on).
- EU countries must draw up lists of national financial measures to improve the energy efficiency of buildings.
- EU countries must make energy efficient renovations to at least 3% of the total floor area of buildings owned and occupied by central government.

In particular, the EPBD includes both 'passive' measures for the building design and envelope, as well as 'active systems', such as for heating, cooling and lighting. In addition, the EPBD introduced certificates, which indicate the Energy Performance of the building as a numeric value, allowing for benchmarking. These certificates include also a list of cost-effective recommendations to increase energy saving.

After the first version, the updated Directive introduced the concept of NZEBs, by including Renewable Energy systems. All new buildings after 2020 shall meet this requirement. The actual enforcement of the EPBD, as well as the responsibility for its implementation, is usually conferred to a national Ministry, which establishes relevant regulations and directives. Depending on the selected model, the local governments could engage private sector auditors, which are officially accredited, for the final enforcement [6].

In addition, the EPBD points out that the energy performance of buildings should be calculated based on a methodology, which may differ between EU countries. However, this methodology should take into account existing European standards. While no country has directly and fully applied them in their methodology procedures, many countries have adopted an approach, which is broadly compatible with the European standards.

Finally, despite being an EPBD requirement, only some of the countries have reported specific mandatory building codes associated with improving the energy performance of existing buildings. Regarding this, it shall be mentioned that EPBD only refers to buildings over 1000 m^2 and most Member States have introduced requirements for consequential improvements associated with buildings of this surface area. Nevertheless, these modifications might not be applied when they are not considered technically, functionally and economically feasible.

3.2 The Energy Efficiency Directive (EED)

The ***2012 Energy Efficiency Directive*** [7] establishes a set of binding measures to help the EU reach its 20% energy efficiency target by 2020. Under the Directive, all EU countries are required to use energy more efficiently at all stages of the energy chain, from production to final consumption.

On 30 November 2016 the Commission proposed an update to the Energy Efficiency Directive, including a new 30% energy efficiency target for 2030, and measures to update the Directive to make sure the new target is met [8].

Energy efficiency plays a vital role in reducing the impact of energy costs on business and domestic consumers. It lessens carbon emissions and decreases our dependence on fossil fuels, thereby improving our competitiveness and sustaining jobs. Achieving greater efficiency in resource inputs and minimising waste also improves productivity and reduces costs.
The aim of the EU's Energy Efficiency Directive is to help citizens, public authorities and businesses to better manage their energy consumption. If successful, the EED will bridge the gap between existing framework directives and national energy efficiency measures to help the EU achieve its 20% by 2020 reduction target [9].

3.2.1 The new EED (2018)

In order to review the EED with a 2030 perspective, the Directive was amended in 2018 (text not yet officially published).

The new regulatory framework includes an energy efficiency target for the EU for 2030 of 32.5% with an upwards revision clause by 2023. This new objective shows the EU's high level of ambition and demonstrates the remarkable pace of change of new technologies and reduced costs through economies of scale. Together with the recently agreed 32% renewable energy target for the EU for 2030 [10], Europe will be equipped to complete the clean energy transition and meet the goals set by the Paris Agreement.

The main points are:

- Sets a new energy efficiency target for the EU for 2030 of 32.5%, with an upwards revision clause by 2023;
- A strengthened Article 7 extended until 2050 with an effective energy savings rate at 0.8% of final energy consumption. Article 7 was originally conceived so that Member States secure new savings equivalent to 1.5% of energy sales each year. This is currently not achieved in the period 2014-2020 because Member States are allowed to use different options to reduce the savings to only half of this. The new deal focuses on ensuring a real annual savings rate of 0.8% after 2020.
- Will extend the annual energy saving obligation beyond 2020, which will attract private investments and support the emergence of new market actors;
- Will deliver real energy savings in the next period 2021-2030 and beyond, coming from new energy efficiency renovations or other measures undertaken in the next decade;
- Will strengthen rules on individual metering and billing of thermal energy by giving consumers - especially those in multi-apartment building with collective heating systems – clearer rights to receive more frequent and more useful information on their energy consumption, enabling them to better understand and control their heating bills.
- Will require Member States to have in place transparent, publicly available national rules on the allocation of the cost of heating, cooling and hot water consumption in multi-apartment and multi-purpose buildings with collective systems for such services.

- Will tackle existing market, behavioural and regulatory barriers in order to increase security of supply, competitiveness of EU industries, reduce energy bills of consumers and health costs for society, thereby also addressing energy poverty and exploiting the positive impacts on economic growth and employment.

3.3 The Renewable Energy Directive (RED)

The ***Renewable Energy Directive*** (2009/28/EC of 23 April 2009 [11]) establishes an overall policy for the production and promotion of energy from renewable sources in the EU. It requires the EU to fulfil at least 20% of its total energy needs with renewables by 2020 – to be achieved through the attainment of individual national targets.

In particular, Article 13 of the 2009/28/EC Directive requires minimum share of renewables for new buildings and major renovations. Given the current quite low construction rate for new residential buildings, refurbishment play a key role for addressing a large part of the building stock, thus contributing to a fruitful implementation of the Directive. However, building codes very often do not allow a wide use of renewables, because their scope just include only new buildings and not renovations. Supporting the implementation of Article 13 of the RES directive the developed technology within the project could significantly enhance the integration of Solar Thermal Power and thus the solar fraction in the residential sector.

As the Renewable Energy Directive (RED) 2009/28/EC will expire at the end of 2020, on November 30, 2016, the European Commission (EC) published a formal proposal to the EU Council and the European Parliament to recast a new directive, called RED II. This would succeed the existing regulation and enter into effect on January 1, 2021. RED II proposes a set of policy measures to achieve a 27% renewable energy share from energy consumed by the electricity, heating and cooling, and transportation sectors by 2030. The 27% target was endorsed by the EU Council in October 2014 and is binding at the EU level.

4 Technical and market codes at national levels

4.1 Germany

According to the Federal Ministry of Economics and Energy (BMWi), about 35 percent of final energy consumption in Germany and one third of greenhouse gas emissions are attributable to buildings. In order to achieve a reduction in these values, the Energy Saving Ordinance (EnEV) and the Renewable Energies Heat Act (EEWärmeG) have drafted texts that include requirements, procedures and promotion for new buildings and conversions. For these two texts, the EnEG (Energy Conservation Law) serves as the legal basis to enforce the energy transition in the building sector. The EnEV has been in force nationwide since 2002. The last update and the accompanying increase in requirements was an intermediate step on the way to the European Union's (EU) lowest energy building standard. In the future, the EnEV, the EnEG will be merged with the EEWärmeG to the EU valid Building Energy Act (GEG). Based on the EU Buildings Directive of 2010, this is to implement the lowest energy standard for new buildings: from 2019 for public and from 2021 for private-economical buildings. However, the bill has recently become stuck in the parliamentary process, which makes it unclear when the JIT will come into force. Before focusing on the legislation for different types of buildings, it is noted that First Ordinance Implementing the Federal Immission Control Act (German 1. BImSchV) [12] sets the efficiency and emission limits requirements for boilers. With regard to biomass boilers, a minimum 90% efficiency is mentioned.

4.1.1 New buildings

According to the EEWärmeG, every building owner in Germany today is obliged to plan and construct new residential buildings as energy-efficient houses. However, there is no clear definition of what makes such a house except that it should consume significantly less energy than a "traditional" house. However, the law obliges the owner of a new building to cover some of the heat demand with renewable energies. This obligation exists from a usable area of more than 50 square meters. At present, at least 15% of the energy required for heating and cooling via solar thermal systems must be met for the use of solar thermal radiation energies. According to §5 of the EEWärmeG the minimum requirements are fulfilled, if:

- For residential buildings with a maximum of two apartments, solar thermal systems with an area of at least 0.04 square meters of aperture area per square meter of floor space.
- For residential buildings with more than two apartments, solar thermal systems with an area of at least 0.03 square meters of aperture area per square meter of floor space be installed.

However, the additional use of other renewable energies can reduce this share. For its part, the EnEV describes the calculation according to which the energy requirement of a house is calculated. For this purpose, a building of identical design is simulated on the computer and drawn by means of specific specifications as a reference for the new building. It does not matter whether it is private or public buildings or single-family or apartment buildings. The used specifications are for all building types can be found in the facilities of the EnEV.

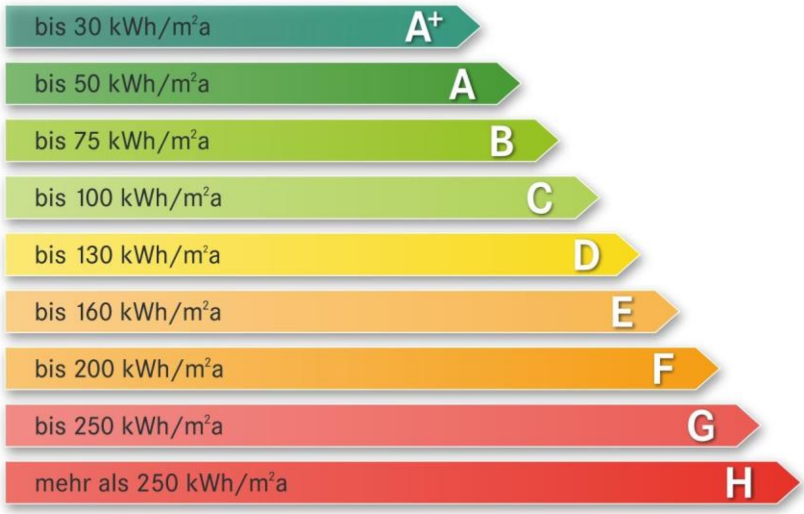

Figure 2. Energy efficiency classes according to EnEV.

The EnEV pretends that:

- Residential buildings to be constructed shall be designed so that the annual primary energy requirements for heating, water heating, ventilation and cooling do not exceed the annual primary energy requirement of a reference building of the same geometry, building area and orientation with the specified technical reference design.
- Residential buildings to be constructed shall be designed so that the maximum values of the specific transmission heat loss related to the heat-transferring enclosure surface are not exceeded.
- For the residential building to be constructed and the reference building, the annual primary energy demand must be calculated according to a specified procedure. The residential building to be constructed and the reference building should be calculated using the same procedure

From these calculations, the building receives an energy certificate, which is mandatory for all heated or refrigerated buildings that are to be rented or sold and prescribed by the EnEV. It is intended to give potential tenants and buyers an insight into the energy quality and thus also in the living comfort of the new property. It also helps to estimate future energy costs.

4.1.2 Restoration

In the case of a comprehensive modernization - comparable to a new building - an overall energy balance is carried out. Thereafter, the primary energy demand of the renovated building may remain up to 87 percent higher than that of a comparable new building. In addition, when installing heating, hot water, ventilation and air conditioning systems for the first time, the EnEV does not differentiate between installation in new buildings and installation in existing buildings. Various minimum requirements for the control technology and the insulation are placed on the installed system in such measures. For extensions of existing systems, the same applies to the new system components. In addition, in some cases of modernization (e.g. the renewal of central ventilation and air conditioning systems), certain requirements have been made. These requirements differ with regard to their scope and can be found in Sections 14 and 15 of the EnEV.If structural changes are made to an existing building that requires compliance with the EnEV, the builder must have the requirements confirmed by an expert for thermal insulation. For approval-free projects, the confirmation is issued by the respective specialist company.

4.1.3 Promotion

The KFW (credit administration for reconstruction) promotion provides an incentive for builders to build energy-efficient homes. The prescribed by the EnEV energy consumption calculation of the reference house, serves as a basis. So-called KFW60 houses require only 60% energy demand of the simulated reference house. KFW40 houses only 40%. At the same time, the amount of subsidies for the building owners increases as the demand for energydecreases.

The EEWärmeG also regulates the promotion of the use of renewable energies for the production of heat and cold in § 13. To this end, the Federal Government initiated the so-called Market Incentive Program (MAP) for the promotion of renewable energies in the heating market. Subsidies are administered and disbursed via the Federal Office for Materials and Economics (BMWi) and the Federal Office of Economics and Export Control (BAFA). It supports plants that use renewable energies for heating or cooling, in particular solar thermal systems. Innovative and highly efficient technologies are particularly eligible if they are used in new buildings. Further bonuses are available for the exchange of heating in existing buildings for the so-called "optimization bonus" and the "heating package" - for refurbishment or replacement of plants.

4.2 Sweden

With almost 70% of heat demand met by renewables, Sweden has the highest share of renewable heat in the European Union. The main drivers encouraging the shift towards renewable energy sources are the energy and carbon taxes. In 1985, Sweden introduced an energy tax on natural gas used for heating, followed in 1991 by a carbon tax on fuels. A tax on heating oil has been in place since the 1950s. Only biomass – as s local and renewable energy source – is free from this tax. Over time, the taxes have risen substantially. As a result, Sweden’s natural gas prices are the highest by far for domestic customers in the European Union, with taxes accounting for almost 50% of the price per kilowatt hour.

Electrical heating has been very popular in Sweden due to relatively cheap power supplies from hydropower and nuclear power. Currently, heat pumps are the preferred heating technology in single-family houses as well as in small multi-family houses.

The climate change law passed in June 2017 requires the country to become a net-zero carbon emitter by 2045, which means that Sweden still needs to make further progress in decarbonisation of heating sector

Energy efficiency requirements for buildings have a long history in Sweden. The first prescriptive requirements have been implemented in 1946 and gradually updated to reach its today's applicable form. In Sweden, the implementation of the Energy Performance of Buildings Directive (EPBD) is the responsibility of the Ministry of Enterprise and the Ministry of Environment. The managing body is **Boverket, the Swedish National Board of Housing Building and Planning**, which is involved in planning and urban development, building and housing activities. Boverket manages the building regulations as well as the EPC (Energy Performance Certificates) system.

The relevant Swedish legal documents specifying the energy efficiency requirements are:

- The Planning and Building Act (2010:900) with amendments up to SFS 2016:537 (Plan- ochbygglagen) [13],
- The Planning and Building Ordinance (2011:338) with amendments up to SFS 2016:773 (Plan- ochbyggförordning) [14],
- And often updated Boverket's Building Regulations BBR 27 BFS 2018:15 (Boverketsbyggregler) [15].

Regarding the energy performance certification, the following legal documents sets the applicable framework:

- Act on energy certification of buildings (2006:985) with amendments up to SFS 2018:314 (Lag omenergideklarationförbyggnader)which gives mandate to the government to write further explanations to the law on energy certification[16].
- Ordinance on the energy certification of buildings (2006:1592) with amendments up to SFS 2016:178 (Förordningom energideklarationförbyggnader) which contains the governments explanation to the law on energy certification of buildings and gives a special mandate to the National Board of Housing, Building and Planning [17].
- National regulations and general advice on energy certification of buildings (2007:4) with amendments up to BFS 2018:11 (Boverketsföreskrifterochallmännarådomenergideklarationförbyggnader) which sets the mandatory provisions and general recommendations on energy certification of buildings [18].

Article 4 of the Renewable Energy Directive (2009/28/EC) required Member States to submit national renewable energy action plans by 30 June 2010. These plans were prepared in accordance with the template published by the Commission and provide detailed roadmaps of how each Member State expects to reach its legally binding 2020 target for the share of renewable energy in their final energy consumption.In their national renewable energy action plans Member States set out the sectoral targets, the technology mix they expect to use, the trajectory they will follow and the measures and reforms they will undertake to overcome the barriers to developing renewable energy.In the National Renewable Energy Action Plan for Sweden the Federal Government estimates the share of renewable energies in gross final energy consumption to be 50.2% in 2020. The share of renewable energies in the electricity sector will thereby amount to 62.8%, the share in the heating/cooling sector will be 62%, while in the transport sector it will amount to 12.4% [19]. Moreover, under the Energy Efficiency Directive (2012/27/EU), the EU countries must draw up their National Energy Efficiency Action Plans (NEEAPs) every three years. These plans are expected to set out estimated energy consumption, planned energy efficiency measures, and the improvements individual EU countries expect to achieve. Sweden's energy objective for homes and premises set in Fourth National Energy Efficiency Action Planis that energy consumption in 2020 shall be 20 percent lower than it was in 1995 [20].

In order to promote the use of renewable energy sources, Swedish legislation introduces an obligation to investigate the alternative energy supply systems for new buildings. According to the §23 of the Act (2006:985) anyone who erects or constructs a building for his own account shall, before construction work commences, investigate alternative energy supply systems and report whether such systems are technically, environmentally and economically feasible for the building. The report must be submitted to the municipal council or committees that fulfil the municipality's tasks within the planning and construction system [16]. The mandatory provisions for the exemption from the statutory obligation to investigate alternative energy supply systems before constructing a building are indicated in Boverket's regulations (2013: 8) on investigation of alternative energy supply systems (Utredning om alternativaenergiförsörjningssystem). The exemptions are applicable to certain types of buildings including [21]:

- buildings whose total usable floor area amounts to a maximum of 100 m^2,
- buildings whose energy supply systems are wholly or predominantly based on energy from renewable non-fossil energy sources,
- buildings that have no heating system.

4.2.1 Boverket's Building Regulation

Boverket´s building regulations consists of mandatory provisions that have to be fulfilled and general recommendations that state how the mandatory provisions may be fulfilled [15]. This regulation sets mandatory overall performance demands for dwellings and non-residential buildings which depend on the location and type of primary energy source employed. The code outlines prescriptive requirements for the thermal envelope and encourages efficient and thoughtful design of the energy consuming systems including HVAC, hot water, lighting, auxiliary systems, as well as materials and products. Other solutions then the ones stated in the general recommendations can be chosen but the verification that needs to be done to make sure that the mandatory provisions are fulfilled will be more extensive. The building code is often updated, and the government is planning to tighten the code again in 2021 [22].

4.2.1.1 Regulations for new buildings

The energy management provisions are described in section 9 of the Boverket's Building Regulations. In general, all buildings shall be designed in such a way that energy use is limited by low heat losses, low cooling demands, efficient use of heat and cooling and efficient use of electricity. Heating and cooling installations in buildings shall provide adequate efficiency during normal operation. The installations should be also designed in such a way that calibration, testing, inspection, supervision, servicing and exchange can be easily performed without affecting the system's efficiency. HVAC installations and installations for domestic hot water heating have to be insulated to ensure that energy losses are limited. Moreover, the need for cooling shall be minimised through design and technical measures. To reduce the demand for cooling in the building, further measures should be considered such as the selection of window size, window location, sun-shading, sunlight protection glass, electrically efficient lighting and equipment to reduce internal heat loads, night cooling and accumulation of cold in the building structure. Strong emphasis is put on the efficient use of electricity. All of the electrically driven components shall be designed to ensure the power requirement is limited and energy is used efficiently. For example, circulation pumps, other than for hot tap water installations, should be designed to ensure they are normally shut off when no flow is required.

An additional important information regarding the heating systems is that for certain boilers, the provisions given in Boverket's mandatory provisions and general recommendations on efficiency requirements for new boilers heated by liquid or gaseous fuels (BFS 2011:11) apply [23].

In these regulations the building's energy performance is expressed in terms of primary energy. The primary energy consists of the total building's energy use, where the energyfor heating has been corrected with a geographical adjustment factor (F_{geo}), multiplied by the primary energy factor for energy carriers and distributed at area of temperature-controlled spaces (kWh/m^2*year). The primary energy factor is the primary energy divided by the energy delivered to the building for a given energy carrier. This factor is 1.6 for electrical energy and 1.0 for district heating, district cooling, biofuel, oil and gas. Geographic adjustment factors for every location in Sweden are specified in the regulation. The lowest value is 0.8 for Landskrona and the highest is 1.9 for Gällivare. The value for Stockholm is 1.0. It is worth to mention, that energy from the sun, wind, land, air or water generated in the building or on its site and used for the building's heating, comfort cooling, hot water and property energy is not included in the building's energy use.

For the new buildings the maximal values of primary energy of the building (in kWh/m^2*year), installed electric power for heating (in kW), and average thermal transmittance (in W/m^2*K), as well asthe building's envelope average air leakage (in l/s*m^2) are specified in the regulations. For example, the limit for the energy performance expressed as primary energy for a single-family house is 90 kWh/m^2*year, which corresponds to the energy efficiency class C. The average thermal transmittance of a single-family house may not be greater than 0.4 W/m^2*K, and if the house is located in Stockholm, the maximal installed electrical power for heating is 4.5 kW [24].

Table 5. Basic requirements for three standard types of buildings.

Type of building	Primary energy of the building in kWh/m²*year	Installed electric power for heating in kW	Average thermal transmittance in W/m²*K
Single-family house with area greater than 50 m²	90	$4.5+1.7x(F_{geo}-1)$	0.40
Multi-dwelling blocks	85	$4.5+1.7x(F_{geo}-1)$	0.40
Non-residential premises with area greater than 50 m²	80	$4.5+1.7x(F_{geo}-1)$	0.60

The regulations specify special cases in which the presented values may differ from the ones summarized in Table 5 (e.g. for the buildings with the area of temperature-controlled spaces greater than 130 m^2) [25].

Additional to the energy performance requirements mentioned above, the regulations specify also the maximum specific fan power for ventilation and air handling units, as well as the requirements towards controlling and monitoring of the HVAC systems. According to the Boverket's Building regulations, the building shall have a control and regulation system in order to maintain a high energy efficiency and thermal comfort. Heating, cooling and other HVAC systems shall be fitted with automatic control equipment to ensure that the supply of heating and cooling is controlled in accordance with the power demand in relation to the outdoor and indoor climate and the intended use of the building. It shall be also possible to continuously monitor the building's energy use by a measuring system. The system shall ensure that the energy use of the building can be read to enable calculation of the building's energy use for the desired time period.

The compliance of the building's energy characteristics (primary energy consumption, average thermal transmittance etc.) must be verified according to the Boverket's regulations and general advice (2016: 12) on the determination of the building's energy use during normal use and a normal year [26]. The verification can be performed as:

- Measurement during a continuous 12-month period, completed no later than 24 months after the building was put into use;
- Energy performance certificate of the building;
- Calculation.

The last important note on the regulations for the new buildings is that the requirement for electrical energy management does not apply to independent buildings with an area of less than 50 m^2 and premises intended for activities of a temporary nature.

4.2.1.2 Regulations for renovations of buildings

According to the EU Building Stock Observatory, 86% of buildings in Sweden were built before 1990. The average energy consumption in residential sector is 188 kWh/m^2, and the average thermal transmittance of a residential building's envelope is 0.80 W/m^2*K. Therefore, the measures focusing on the renovation of the existing buildings are of great importance for Swedish market [22].

Boverket's Building Regulation clearly states, that the alterations to buildings must not result in reduced energy efficiency, unless there are exceptional reasons. However, energy efficiency may be reduced if after the alteration, the building still meets the requirements set for new buildings in the current building code.

Before the planned renovation, in order to verify the requirements for energy conservation, a review of possible measures toreduce the building's energy use should be performed. If the building has an energy performance certificate, the proposals onmeasures to improve the building's energy performance may be found in the said certificate.

If the building, after an alteration, does not meet the requirements set in the regulations forthe new buildings, the following U-values summarized in Table 6shall be pursued as part of the alteration [24].

Table 6. Maximum values of thermal transmittance for renovated buildings in Sweden.

Part of the building	Thermal transmittance (W/m^2*K)
Roof	**0.13**
Wall	0.18
Floor	0.15
Window	1.2
Exterior door	1.2

During the renovation process, the opportunities to achieve higher energy efficiency through change or tuning of the heating system should always be investigated. The heating installation shall be selected, designed, insulated, adjusted and calibrated to ensure the other technical characteristics requirements can be met in an energy efficient manner. The building's need for comfort cooling shall be minimised. Instead of installing cooling systems other measures such as sun-shading and reduce internal heat loads through electrically efficient lighting and equipment should be chosen if possible.

Similarly like in the case of new buildings, the regulations are encouraging the use of control and monitoring systems. Such systems should, when needed, be supplemented to ensure that regulation of the heat output can be selected according to particular applications and any additional heat source. It shall be possible to continuously monitor the building's energy using a measuring system. Thesystem shall ensure that the energy use of the building can be read to enable calculation of thebuilding's energy use for the desired time period.

4.2.1.3 NZEB definition

The new nearly Zero-Energy Building (NZEB) regulation had a real effect on the building code. The NZEB definition in Sweden corresponds to the energy management requirements for new buildings set in the current building code, which is implied by the fact that since July 2017, all new building permits should comply with the (NZEB) standard. In the new regulations, the energy consumption limit is expressed as primary energy consumption instead of being indicated in the final energy consumption [22].

4.2.2 Energy Performance Certificates

Energy Performance Certificates (EPC) were introduced in Sweden in 2006 through the Energy Declaration Act and the first certificate was issued in September 2010. The energy performance certification system is run by Boverket, which is responsible for the supervision, control and management of the national EPC database.

The purpose of the energy performance certificates is to facilitate an effective energy use and a good indoor environment of the buildings. The EPC should also work as an informative instrument, acting as a useful tool for the building owner.

Since 2007 building owners are required to provide an energy performance certificate for their buildings. The certificate must be presented whenever a building is sold or leased and can only be obtained after on-premises inspection by an authorized expert. Since the energy performance certificates are primarily requested when a building is changing owner, they constitute a common trigger for renovation activities. The EPC includes a list of potential measures to increase the energy efficiency of the certified building. Even if recommendations for improving the building's energy performance are added to the certificate, there is no obligation for the owner to carry out the suggested measures. The energy performance certificates are valid for ten years.

The EPC must be displayed in relevant advertisements, shown to the buyer before a transaction and handed over to the new owner or tenant after the deal is completed. In buildings frequented by the public, the certificate has to be disposed in a visible place [26]. The layout of the certificates were changed as of January 2014, when a system of grading from A to G was introduced. Energy class A stands for low energy consumption, and G stands for high. Energy class A of the EPC means that the building's energy performance required is half the requirement of the Swedish building code. A building that has an energy consumption corresponding to the requirement imposed on a newly built building is placed in class C [27].

The Swedish law requires all newly constructed buildings and buildings that are sold to have an EPC and the compliance rate is high with 90-95% of sold buildings getting an EPC.Due to this high compliance rate, over 700,000 energy performance certificates have been issued in Sweden up to 31st August 2018 [28]. All energy performance certificates are accessible by address on the Boverket's website [22]. The information that can be obtained online include:

- the ID-number of the EPC,
- the date of issuance,
- the energy performance rating (given as a single value of specific energy in kWh/m²/year and energy class),
- confirmationif a radon check and ventilation controls have been completed.

4.3 Spain

In the following section, specific building codes of Spain corresponding to the identified target markets of the project are presented in order to guide the business development and the definition of realistic market application. Building codes were collected at National level to provide an overall picture of what is happening in Europe in the area of building codes.

The main strategy developed for the improvement of the energy efficiency of the building stock in Spain was drafted by the Ministry of Industry, Tourism and Commerce, along with the IDAE (Institute for Energy Diversification and Savings). The resulting ***Energy Saving and Efficiency Action Plan 2017-2020*** [29] includes, among others, measures to boost the ESCOs market (Plan to Promote Energy Service Contracts, known as Plan 2000 ESCO) and the proposal of actions to guarantee the necessary exemplary role of the public sector (Energy Saving & Efficiency Activation Plan in the buildings of the State General Administration) which will also support meeting EED requirement on achieving 3% renovation rate for central Government buildings. This plan directed to public buildings has the objective of achieving energy savings up to 20% in 330 of energy consumer centres of the State General Administration, by carrying out saving and energy efficiency measures implemented by ESCOs. The Plan to Promote Energy Service Contract, involves the extension to the rest of the Regional Public Administrations of the former plan, affecting 1000 energy-consuming centres belonging to the Regional and Local Administration and other 1000 ones belonging to the state general administration.

The 2017-2020 National Energy Efficiency Action Plan fulfils the requirement laid down in Article 24(2) of Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, whereby all Member States of the European Union must submit such plans, doing so by 30 April 2014 in the first instance, and then every three years thereafter. In this new 2017-2020 National Energy Efficiency Action Plan, and based on the most recent macroeconomic forecasts, Spain has recovered the target set out in the 2013 annual progress report sent to the European Commission on 17 May of that year. Under this scenario, primary energy consumption in 2020 is envisaged to stand at 122.6 Mtoe, representing a 24.7 % reduction compared to the baseline or reference scenario.

The Action Plan defines different strategies for implementing the energy efficiency directive:

- Horizontal measures (i.e., energy audits and management systems, consumer information programmes,).
- Energy efficiency in buildings.
- Energy efficiency in public bodies.
- Energy efficiency in industry.
- Energy efficiency in transport.
- Energy efficiency in agriculture and fisheries.
- Promotion of high-efficiency cogeneration and district heating and cooling.
- Energy efficiency in transformation, transmission, distribution and demand response.

The specific measures to intensify energy savings in the building sector, which have been taken place in last Action Plans, are:

- As regards the energy saving measures affecting buildings, one key measure is the restriction on indoor temperatures in climate-controlled non-residential buildings and other public spaces, with the exception of hospitals and other centres requiring special indoor environments.
- Amendment of the Royal Decree on Energy Efficiency in New Buildings to make it obligatory for new national administration buildings to achieve a high energy rating.

The specific measures to intensify energy savings in the building sector, which are detailed in Energy Saving and Efficiency Action Plan 2011-2020, are:

- Energy refurbishment of thermal envelope of existing buildings.
- Energy efficiency improvement of thermal installations for existing buildings.
- Energy efficiency improvement of lighting indoor systems for existing buildings.
- Promoting of high EPC for new and existing buildings (at refurbishment context).
- Promoting of nZEB buildings (new buildings or refurbishment of existing buildings).
- Energy efficiency improvement of cooling systems for tertiary sector.
- Energy efficiency improvement of appliances stock.

Regarding meeting the EED article 4 requirement for developing a long-term strategy for mobilising investment in the renovation of the national building stocks, there is, so far in place, the National Housing and Refurbishment Plan 2009-2012 which promotes the refurbishment of the residential building sector. This plan grants subsidies in order to improve the energy performance of dwellings. Within the Energy Savings and Efficiency Action Plan 2011-2020, there are other plans like this planned to be developed until 2020.

The main legislation referred to energy performance of buildings for Spain are the Technical Building Code 2006 (CTE), the Regulation for Buildings Thermal Installations 2007, and the Regulation for Energy Efficiency Certification 2007.

4.3.1 Technical Building Code

The Technical Building Code (CodigoTecnico CTE [30]) is the regulatory framework that establishes and develops the basic requirements for the quality of buildings and their facilities, and that allow demonstrating that the basic requirements of the building are met.

The CTE gives access to other documents that complete the regulatory framework. The CTE is divided into two parts. The first detail all the requirements in terms of safety and habitability that are mandatory when building a building, according to the Law of Building Management and the second is made up of the different Basic Documents.

The first part is subdivided in several sections, each one referring to the different areas that must be regulated. In the field of security, we find the provisions related to structural safety, safety in case of fire and safety of use. Meanwhile, in the area of habitability, the requirements related to health, protection against noise and energy saving are included.

The second part consists of the Basic Documents (DB), which are technical texts that are responsible for transferring to the practical field the requirements detailed in the first part of the CTE. Each of the documents includes the limits and quantification of the basic requirements and a list of procedures that allow compliance with the requirements. However, the designer or project manager may, under their responsibility, opt for alternative solutions proving that the building meets the basic requirements of the CTE.

The BD are the following:

- DB SE: Structural safety. It constitutes the basis for whose correct application the following five documents are equally necessary:
- DB SE-AE: Actions in the building
- DB SE-A: Steel structures
- DB SE-F: Factory structures
- DB SE-M: Wood structures
- DB SE-C: Foundations
- DB SI: Security in case of fire
- DB SUA: Safety of use and accessibility
- DB HE: Energy saving
- DB HR: Protection against noise
- DB HS: Healthiness

In case of installing the solar field on the flat roof of a building, the possible overload of the roof due to the weight of the Linear Fresnel Reflector (LFR) collectors and engine room must be studied to satisfy corresponding structural requirements. Thus, it will be needed to evaluate the DB SE: Structural safety.

Within the DB HE: Energy saving there are six different documents. Some of them are of interest of SWS-Heating project, which are shown below:

- HE 2 – Performance of thermal installations. The buildings will have appropriate thermal facilities designed to provide the thermal well-being of their occupants. This requirement is currently developed in the current *Regulation of Thermal Installations in Buildings (RITE)*.

- HE 4 – Minimum solar contribution of domestic hot water (DHW). In buildings mentioned in the CTE[1], with DHW and indoor swimming pool energy demand, a part of the thermal energy needs will be covered by incorporating solar collectors, storage and use of solar energy at low temperature, appropriate to the global solar radiation of its location and to the DHW demand of the building and swimming pool. The values derived from this requirement will be considered as minimums. However, the consideration of heat pumps as renewable energy through the publication of the Directive 2009/28/CE of the European Parliament, the use of solar thermal collectors for DHW demand can be avoided if proper heat pump is installed. The requirements are:
    - The value of seasonal performance factor (SPF) must be greater than 2.5 (SCOPnet) for electric heat pumps and greater than 1.15 (SPER) for thermal heat pumps.
    - The annual renewable primary energy used by the heat pumps must be greater than the DHW demand + heat losses.
    - The annual non-renewable primary energy consumed by the heat pump must be lower or equal than the reference case (solar collector + boiler)
    - The CO2 emissions must be lower or equal than the reference case (solar collector + boiler).

The Technical Building Code 2006 defines 12 climatic zones in Spain, according to winter and summer severity indexes. The minimum energy requirements are coherent with each climatic zone (A4, A3, B4, B3, C4, C3, C2, C1, D3, D2, D1 and E1).

Existing buildings have to comply with the same minimum requirements as new ones, when building rehabilitation, enlargement or renovation are carried out, if the floor area exceeds 1000 m2, and more than 25% of the building envelope undergoes renovation.

Current Spanish regulations do not oblige to reach a certain energy performance for any kind of building. Those regulations only establish some minimum values for thermal transmittance to be reached within each climate area.

Energy performance requirements depend on each case (reference building) and climatic zone. The minimum energy performance requirement used to match with energy certification D.

4.3.2 Nearly zero-energy building criteria – Directive 2010/13/EU

Under ***Directive 2010/31/EU***, Member States must ensure that by 31 December 2020 all new buildings meet the nearly zero-energy building criteria. Likewise, by the end of 2018 all new buildings that are occupied and are the property of public authorities must qualify as nearly zero-energy buildings. The update to the core energy saving 106 document, (DB-HE) and the requirements laid down in it constitute the first step towards the goal of achieving buildings of this type.

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[1]New and reburbished buildings with a DHW demand higher than 50 litter per day. Extensions or interventions, not covered by the previous point with an initial DHW demand greater then 5000 l/day, which suppose an increment of more than 50% of the initial demand. Swimming pools

4.3.3 Regulation of thermal installations in buildings (RITE) - Royal Decree 1027/2007

Royal Decree 1027/2007 of 20 July 2007 approving the regulation on building heating systems (amended by Royal Decree 238/2013 of 5 April 2013 amending certain articles and technical instructions of the above regulation) regulates the minimum output requirements applicable to heating, cooling, ventilation and domestic hot water systems and periodic energy efficiency audits, as well as the design, size, assembly and maintenance of such systems. The code it's divided in 4 main parts or technical instructions (IT):

- IT 1. Design and sizing
- IT 2. Mounting
- IT 3. Maintenance and use
- IT 4. Inspection

4.3.4 Royal Decree 235/2013 – Energy efficiency certification

Royal Decree 235/2013 [31] of 5 April 2013 adopting the basic procedure for building energy efficiency certification lays down the obligation to provide the buyers or users of buildings with an energy efficiency certificate that must include objective information on the energy efficiency of the building and reference values, such as minimum energy-efficiency requirements, so that the owners or tenants of the building, or a unit of it, can compare and evaluate its energy efficiency.

4.4 Greece

Currently in Greece, the main regulatory framework for buildings include:

- **Ministerial Decision No. 4003/2017** on Buildings Energy Performance Regulation "Approval and Implementation of the Technical Directions of the Technical Chamber of Greece for the Buildings Energy Performance"
- **Law No. 4342/2015** on the Inclusion of Directive 2012/27/EU and amending **Law No. 4602/2019**, **Law No. 4685/2020** on the Inclusion of Directive 2018/844/EU and **Law No. 4843/2021** on the Inclusion of Directive 2018/2002/EU and the adjustment to Directives 2018/199/EU and 2019/826/EU.
- **Law No. 4414/2016, Ministerial Decision ΥΠΕΝ/ΔΑΠΕΕΚ/30971/1190** and **Law No. 4643/2019** on the Support of Power Production Plants with Renewable Energy Sources and High Efficiency Combined Heat and Power Generation

4.4.1 Ministerial Decision No. 4003/2017

The main framework of the Ministerial Decision No. 4003/2017 [32] consists of the following points:

- The energy performance of buildings is calculated based on a methodology defined in the Buildings Energy Performance Regulation (*Κανονισμός Ενεργειακής Απόδοσης Κτηρίων* – hereinafter referres to as KENAK) which includes, in addition to the thermal insulation characteristics of the structural elements of the exterior of the building (envelope) and other factors that play an important role, such as heating installations./air conditioning and domestic hot water production, the use of renewable energy sources, passive heating and cooling elements, shading, indoor air quality, adequate natural light and building design. The energy performance calculation methodology covers the annual energy efficiency of the building and has been prepared in accordance with the relevant European standards. The KENAK determines the minimum requirements for the energy performance of buildings and structural elements. These requirements have been set in order to achieve the optimal cost balance between the related investments and the energy costs saved throughout the life cycle of the building.

- Information on the standard energy performance of a building, as well as cost-effective tips on improving its efficiency, are given in the Energy Performance Certificate (EPC) which is useful to the owner, the prospective buyer and the tenant of a building or building unit. The owner assigns to an energy inspector the preparation of an energy inspection and the issuance of an EPC.
- The issuance of the EPC is mandatory for the sale and rental (long-term, short-term, subletting) of each building/building unit. Especially for the sale or lease of a building or building unit, the declaration of the energy efficiency index (energy category), as it results from the EPC, is required in all commercial advertisements and listings. In the electronic declaration to the State of the lease (long-term, short-term, sublease) to a new tenant of a building or building unit, the protocol number of the EPC is registered in it. In addition, the EPC is required after the completion of the construction work of a new building, addition, radical renovation, for the issuance of the Construction Control Certificate (CCC)

More specifically, the decision is divided into five parts (Technical Directives), namely:

- Technical Directive 20701-1/2017: Detailed national parameter specifications for the calculation of the energy performance of buildings and the issuance of the energy efficiency certificate
- Technical Directive 20701-2/2017: Thermophysical properties of building materials and control of the thermal insulation adequacy of buildings
- Technical Directive 20701-3/2017: Climatic data of Greek regions
- Technical Directive 20701-4/2017: Guidelines and report forms for energy inspections of buildings, heating systems and air conditioning systems
- Technical Directive 20701-5/2017: Cogeneration of Heat, Power and Cooling: Applications in Buildings

In the present deliverable, focus is given in Technical Directive 20701-1/2017 while the part of cogeneration which is the main feature of the SolBio-Rev system, is covered by the other regulations listed in the following sections.

The main target of the directive is the classification of the buildings into the energy performance categories, according to their total specific primary energy consumption *EP* (for heating, cooling and electricity) compared to the consumption R_R of the "reference building", i.e. a building of the same geometry and location, equipped with the reference envelope structure and the reference technical systems which are herein defined. The reference buildings is classified into category B. The performance categories are listed in the following table:

Table 7. Thermal transmittance of walls (outside boundary)

Category	Specific primary energy consumption range
A+	$EP < 0.33R_R$
A	$0.33R_R < EP < 0.50R_R$
B+	$0.50R_R < EP < 0.75R_R$
B	$0.75R_R < EP < 1.00R_R$
C	$1.00R_R < EP < 1.41R_R$
D	$1.41R_R < EP < 1.82R_R$
E	$1.82R_R < EP < 2.27R_R$
F	$2.27R_R < EP < 2.73R_R$
G	$2.73R_R < EP$

Next, a division of the country into four main climatic zones (A-D) is made, which is necessary to define the minimum requirements in terms of building envelope specifications. Namely, the colder regions (northern Greece) are classified into zone D while the regions of milder climate belong to zone A (Southern Greece and islands).

Table 8 to Table 13 report the reference parameters values (comprehensive of thermal bridges) for the main building envelope components. Distinction is made between new and renovated buildings.

Table 8. Thermal transmittance of walls (outside boundary)

Climate Zone	U [W/m²K]	
	New	Renovated
A	0.55	0.60
B	0.45	0.50
C	0.40	0.45
D	0.35	0.40

Table 9. Thermal transmittance of walls (inside boundary)

Climate Zone	U [W/m²K]	
	New	Renovated
A	1.30	1.50
B	0.90	1.00
C	0.70	0.80
D	0.65	0.70

Table 10. Thermal transmittance of floors (outside boundary)

Climate Zone	U [W/m²K]	
	New	Renovated
A	0.45	0.50
B	0.40	0.45
C	0.35	0.40

D	0.30	0.35

Table 11. Thermal transmittance of floors (inside boundary)

Climate Zone	U [W/m²K]	
	New	Renovated
A	1.10	1.20
B	0.80	0.90
C	0.65	0.75
D	0.60	0.70

Table 12. Thermal transmittance of roofs (outside boundary)

Climate Zone	U [W/m²K]	
	New	Renovated
A	0.45	0.50
B	0.40	0.45
C	0.35	0.40
D	0.30	0.35

Table 13. Thermal transmittance of fenestration (outside boundary)

Climate Zone	U [W/m²K]	
	New	Renovated
A	2.80	3.20
B	2.60	3.00
C	2.40	2.80
D	2.20	2.60

To evaluate building envelope, the Decision introduces the average total heat transmission coefficient U_m, which refers to the thermal properties of the building envelope components, i.e. both opaque and transparent. It must be lower than the values present in Table 14 and Table 15, which are based on the shape factor and climate zone of the building.

Table 14. Maximum values of U_m for new buildings

SHAPE RATIO (S/V)	Climate Zone			
	A	B	C	D
<0.2	1.25	1.13	1.04	0.95
0.3	1.17	1.05	0.96	0.88
0.4	1.10	0.99	0.91	0.83
0.5	1.04	0.93	0.86	0.78
0.6	0.98	0.89	0.81	0.73
0.7	0.92	0.83	0.76	0.68

0.8	0.86	0.77	0.71	0.63
0.9	0.80	0.73	0.65	0.59
>1.0	0.77	0.69	0.62	0.55

Table 15. Maximum values of U_m for renovated buildings

SHAPE RATIO (S/V)	Climate Zone			
	A	B	C	D
<0.2	1.26	1.14	1.05	0.96
0.3	1.20	1.03	1.00	0.92
0.4	1.15	1.03	0.95	0.87
0.5	1.09	0.98	0.90	0.83
0.6	1.03	0.93	0.86	0.78
0.7	0.98	0.88	0.81	0.73
0.8	0.92	0.83	0.76	0.69
0.9	0.86	0.78	0.71	0.64
>1.0	0.81	0.73	0.66	0.60

Finally, the key requirements for new and radically renovated buildings are reported below:

- The heating and DHW system must meet the requirements of Ecodesign regulation of space heaters and heaters combined operation, EC 813/2013 [33] (Table 16, Table 17).

Table 16. Heat pump minimum required seasonal COP (SCOP)

System type	SCOP
Low-temperature (35 °C) air-to-water, < 400 kW	3.20
Low-temperature (35 °C) water-to-water, < 400 kW	3.33
High-temperature (55 °C) air-to-water, <400 kW	2.83
High-temperature (55 °C) water-to-water, <400 kW	2.95

Table 17. Space and combi (heating + DHW) heaters-Boilers minimum seasonal efficiency

System type	Seasonal efficiency
Fuel boiler 10-70 kW & combi-heater, 30-70 kW	0.86
Fuel boiler < 10 kW & combi heater < 30 kW	0.75
Fuel boiler & combi-heater, 70-400 kW	0.86 at rated load, 0.94 at 30% load
Electric boiler & combi-heater	0.36
Cogeneration space heaters	1.00

- The cooling system must meet the requirements of the Ecodesign regulation of cooling products, EC 2281/2016 [34] or in the case of units with cooling power of less than or equal to 12 kW the requirements of the Ecodesign regulation of air conditioning units and cooling fans, EC 206/2012 [35] (Table 18, Table 19).

Table 18. Chiller minimum required seasonal EER (SEER)

System type	SEER
Air-cooled, < 400 kW	3.80
Air-cooled, 400-2000 kW	4.10
Water-cooled, < 400 kW	5.10
Water-cooled, 400-1500 kW	5.88
Water-cooled, 1500-2000 kW	6.33

Table 19. Air-conditioning units minimum required seasonal EER (SEER)

System type	SEER
Refrigerant GWP >150, < 6 kW	4.60
Refrigerant GWP >150, 6-12 kW	4.30
Refrigerant GWP <150, < 6 kW	4.14
Refrigerant GWP <150, 6-12 kW	3.87

- All distribution networks (water or other means) heating, cooling and DHW must have thermal insulation of thermal conductivity below or equal to 0.040 W/(mK) and thickness for heating and cooling of of 9-19 mm and 19-25 mm for indoor and outdoor installation, respectively, and 9 or 13 mm for DHW in indoor and outdoor installation.

- All hot and cold media distribution networks must have a compensation system for handling partial loads or other equivalent reduction system energy consumption under part load.

- In buildings with DHW needs greater than 10 l/person/day, DHW needs must be covered by solar systems to a minimum 60% on an annual basis or with energy supply systems based on renewable energy sources, CHP, district heating systems and heat pumps of seasonal COP greater than 3.3.

- All buildings require independent automatic control of their operation terminals at the level of autonomous spaces (per functional space) using at least a thermostat and thermostatic valves.

4.4.2 Laws No. 4342/2015, 4602/2019 and 4685/2020

In general, Laws No. 4342/2015 [36] and No. 4602/2019 [37], deals with the Inclusion of the European Directive 2012/27/EU on energy efficiency, while Law No. 4685/2020 [38] is about the Inclusion of the updated Directive 2018/844/EU and Law No. 4843/2021 [39] refers to the Inclusion of Directive 2018/2002/EU and the adjustment to Directives 2018/199/EU and 2019/826/EU.

Considering the building sector, the Laws are summarized into four Sections, as follows:

- Section 1: It defines the overall objectives and the targets of energy efficiency in order to contribute to the target of the EU for an increase of energy efficiency up to 32.5% until 2030.
- Section 2: It deals with the energy efficiency in the use phase and focuses on the significance of building interventions and retrofits. As far as public buildings are concerned, a minimum of 3% renovation in terms of the total conditioned area of

public buildings with a total conditioned area exceeding 250 m^2. This target refers not only to the building envelope, but also to the technical equipment, the operation and the maintenance. Priority is given in buildings of poorer energy performance. In addition, restrictions are legislated for energy supply companies, claiming annual energy savings of at least 0.8% of their final energy consumption of the last 3 years. In this context, the framework of energy audits by independent energy inspectors is carved. Standard EN 16247 is applied for the conduction of the audits. These audits may be applied in all types of buildings, from residential ones and office buildings of area lower than 2000 m^2 (Category A), to larger office and commercial buildings (schools, hotels, etc.) and industrial spaces with installed capacity less than 1000 kW (Category B) and to large industrial sights, with installed capacity higher than 1000 kW (Category C). Although this is optional for the majority of the building sector, it is mandatory once every 4 years for the following companies:
    - Companies with personnel exceeding 250 people
    - Companies with personnel smaller than 250 people but with annual turnover higher than 50 million €.
- Section 3: It sets the framework for energy efficiency in the energy supply phase. This applies in local level prioritizing the use of efficient heating and cooling systems and especially cogeneration. In this framework, a cost-benefit analysis has to be implemented for power plants, waste heat-supplying industrial processes, and district heating and cooling networks of installed thermal capacity larger than 20 MW.
- Section 4: On the one hand, it provides insight into energy service companies by making widely available the list of such companies, the framework of their operation, the incentives and the best practices for energy services. Ultimately, financial incentives are mentioned for financing energy efficiency improvement measures, as well as the prioritization of interventions in households affected by energy poverty.

4.4.3 Law No. 4414/2016, Ministerial Decision ΥΠΕΝ/ΔΑΠΕΕΚ/30971/1190 and Law No. 4643/2019

Law No. 4414/2016 [40], Ministerial Decision ΥΠΕΝ/ΔΑΠΕΕΚ/30971/1190 [41] and Law No. 4643/2019 [42] define the framework of legal agreement between power suppliers based on Renewable Energy Sources and High Efficiency Combined Heat and Power Generation, and the Greek state. The reference prices for Feed-in-Tariff (FiT) and Feed-in-Premium (FiP) schemes are determined and the context of their amendment throughout the lifespan of the corresponding power plants. The main idenrtified technologies are listed below:

- Onshore wind turbine power plants (installed capacity lower than 60 kW, between 60 kW and 3 MW, above 3 MW and between 60 kW and 6 MW for energy communities)
- Hydro power plants (installed capacity below 3 MW and between 3 and 15 MW)
- Biomass or biogas thermal power plants (distinction is made based on both installed capacity and fuel derivation process)
- Geothermal power plants (below and above 5 MW)

- CHP plants based on natural gas (distinction between technology e.g. gas turbine, combined cycle or Rankine cycles and capacity classes of 5, 10 and 35 MW)
- Solar thermal power plants (distinction based on the existence of storage system sufficient to cover two-hour operation at rated capacity)
- Photovoltaic power plants (capacity classes of 6 kW for residential use, and 200, 500 and 1000 kW for commercial use and energy communities).

More specifically, using a typical project per RES technology in terms of construction and operation costs, as well as its capacity factor, the reference Price per category was determined based on a reasonable return on invested capital. Additionally, existing stations will be able to voluntarily switch to the new operating aid and market participation scheme. Moreover, the reference price for the mature technologies of wind and photovoltaic stations, results through a competitive process, with the aim of reducing costs for consumers. In this context, only those successful in the process receive operational support. Finally, it is noted that the the obligation for RES producers based on FiP for participating in the market mechanisms. Furthermore, Law 4643/2019 completed the operating framework of RES stations established by Law 4414/2016, enabling RES stations to participate directly in the wholesale electricity market and to be rewarded by its mechanisms without receiving operational support.

5 Analysis of constraints and barriers

Every business and non-business endeavour is pursued in an external environment with an extended net of dependencies, which can impose chances as well as threats to the project. A thorough understanding of the environment enables to fully take advantage of the opportunities and minimize the influence of barriers and constraints on the project's success. This deliverable was aimed at gathering information about the environment in which the SolBio-Rev project is implemented, mainly in terms of legal regulations such as technical and market codes.

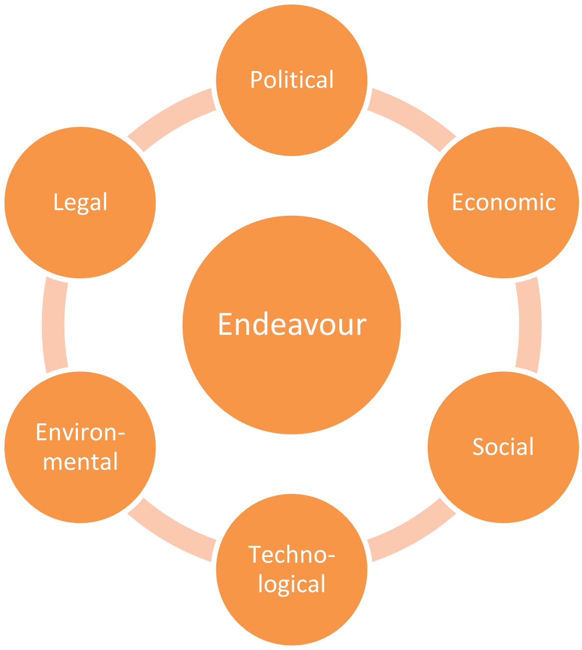

Figure 3. General PESTEL approach.

In this section, an analysis of the factors that may affect the project itself and its products will be presented. For this purpose, the well-known PESTEL methodology (Figure 3) has been used. The assessment of the main constraints and barriers, which are encountered for the implementation of the SolBio-Rev technologies are analysed from the Political, Economic, Social, Technological, Environmental, and Legal perspectives.

Some barriers presented in this chapter are generic and affect renewable energy solutions in general – such as high capital costs, low prices for fossil fuels or subsidies for fossil fuels. Some are more specific and relevant only for the solution developed by SolBio-Rev project. Identified constraints and policy approaches are often country- or even location-specific, hence the full and detailed analysis of all aspects seems difficult.

5.1 Political aspects

Nowadays, to protect the climate and environment, governments encourage the energy efficiency measures through incentives and stimulate the use of renewable energy sources through establishing limits for the primary energy consumption or the total CO2 emissions of buildings. These limits are being introduced through building codes, mandates and obligations, and binding targets for renewable heating. Furthermore, investors who would like to increase the energy efficiency and/or implement renewables in their systems can apply for government subsidies or co-funding. Policy makers can support the deployment of renewable technologies by using financial incentives such as grants, loans and tax incentives, as well as market instruments such as renewable energy certificates and guarantees of origin. Nevertheless, the said incentives and subsidies are strongly dependent on the politics of the government in power, therefore, the impact of the policy cannot be underestimated.

Renewables policies of many countries focus on electricity supply, although the heat consumption enormously contributes to final energy demand and emissions. Specific policies for heating and cooling appliances are still relatively rare.

5.1.1 Lobbying in favour of conventional energy sources.

The low price of fossil fuels and electrical energy from non-renewable sources has a great influence on the economic feasibility and spreading of the alternative technologies. The fossil fuels industry is big, profitable and gives employment to thousands of people in most countries. Hence, in order to secure its profits the industry may try to use its power of influence to convince the government to introduce fossil fuel and/or nuclear subsidies that inhibit the deployment of renewables. Politicians influenced by the aforementioned lobbies may pursue to change the trends on energy generation systems.

5.1.2 Introduction of new or amended tax regulations.

It is often difficult for renewable heat options to compete with cheap fossil fuels, hence carbon and energy taxation are very useful tools to address this issue. For example, energy and carbon taxes have made fossil fuels less competitive compared with biomass, which has been exempt from taxation.

Possible barrier for the SolBio-Rev project results are the new tax regulations for renewable energy generation systems or an amendment in existing taxation which could lead to lower prices of competitive technologies.

5.1.3 Changes in the economic incentives schemes.

Fiscal and financial incentives are a very effective tool to reduce the capital costs of renewable-based heating and cooling technologies, and can help to create a level playing field with fossil fuels. Therefore, variations on the amount of the economic incentives or amended eligibility criteria can constitute a barrier for commercialisation of the products developed during the project.

5.2 Economic aspects

The economic aspects of the project environment concern both the supply and the demand side. The final cost of the solution developed by the project and the availability of attractive financing opportunities will have a significant impact on users' willingness to invest in this product. However, a satisfactory margin for producers and distributors as well as an attractive commercial offer for installers are factors conditioning the maintaining of the developed product on the market.

5.2.1 Cost barrier. High upfront expense and long payback period.

The reason for this barrier is that the capital/investment costs of the proposed solution will be higher compared with competing technologies. Not every building's owner would assume such high initial investment, even if the return periods will be close to 10 years.

In the eyes of investors (private households, companies, and organisations) the long recovery periods of the investment constitute an important limiting factor. According to the results of German Federal Ministry of Transport and Digital Infrastructure's (BMVBS) survey, 47% of the households would decide to invest for a recovery period of five years maximum, while only 18% would be willing to invest when the recovery period is of eight years and this drops to 3% for a recoveryperiod of twelve years or more [43]. Lots of residential building owners fear to undertake major renovations as they expect to leave the house and are uncertain if the investment costs could be incorporated in the sales price.

However, even if the upfront invest is high, taking into account the costs over the lifespan of the system, renewables can turn out be the least expensive energy sources for heating and cooling appliances, because the fuel costs are very small or none. Moreover, the capital costs of renewable heating systems (e.g. solar collectors) have fallen dramatically since the early 2000s and will likely continue to do so.

5.2.2 Lack of adequate financing opportunities and/or unattractive interest rates.

Most of the investors, including households usually require a loan to cover the initial investment in renovation of HVAC systems. Hence, the interest rateand the criteria set by the banks to grant a loan are also barriers for the deployment of renewables in this sector.

Investments in systems which are primarily based on electricity or fossil fuels such as natural gas, are perceived as less risky for the financial institution. The main reason for that is the lower initial cost of the system, and that the cost of fuel is passed onto the consumer. Due to the less risky investment, the interest rates can be potentially lower than for investments in renewables, in case of which the financial institution may tend to make it harder for utilities or developers to justify the investment.

Moreover, this barrier can also refer to difficulties in accessing suitable financial instruments (debt with long tenor, for example, or structured finance vehicles, including aggregation and securitization of assets) or lack of access to and affordability of effective risk mitigation instruments (such as guarantees, currency hedging instruments or liquidity reserve facilities).

5.2.3 Low initial investment and exploitation cost of competitive systems (e.g. gas boilers for heating).

Long payback times of the renewable systems are a direct result of the low exploitation costs (mainly fuel costs) of the conventional technologies. Of course, an increase of the gas or electricity price (e.g. through taxes as mentioned in subsection 5.1) would mean a more attractive payback period. Additionally, a decrease in the electricity demand due to the use of renewable HVAC solutions would result in lower electricity price (allowing to reduce the capacity availability charge).

5.2.4 High prices for the installers and low margin for the technology suppliers.

Because of the development cost and time, the newly developed products, in the early stages of their commercial exploitation, have high prices even though the technology supplier's margin is kept low. Therefore at the beginning, the discount offer on the new technology is less attractive for installers than what they can get from the well-established ones. At the same time, the low scale of production, as well as the newly developed, not-optimized production processes will not allow to obtain high benefits from sales for the technology suppliers.

5.3 Social aspects

The experience of other industries, such as electronics (smartphones, TVs) or automotive, suggest that consumers perceive new technologies well and are willing to invest in the latest innovations. Unlike electronics, which consumers often exchange for a new one, investments in renovating HVAC systems seem to be riskier because they require loans or other forms of financing and may have a visible impact on the value of the property. On the other hand, the social awareness of environmental and climate protection is growing, and therefore renewable energy sources will enjoy increasing interest among consumers aware of the problem.

5.3.1 The reluctance of residential building owners to invest in new technologies.

The use of renewable heating and cooling technologies have good acceptance within the residential building owners, but the risk that a new technology could not be sufficiently proved and could fail becomes a great barrier when a high investment has to be assumed. On the other hand, such investment is only considered when there is a need to replace the existing system. This need can be driven by a poorly working old system or arise from the political incentives or prohibitions (e.g. a ban on using solid fuels for heating residential buildings in Krakow). If the equipment in place is still working well, this could be perceived as a barrier to renew it without further incentives.

Further reasons for the reluctance is the lack of investor's confidence in the performance of the technology, its lifetime, or its ability to meet heating needs. Home owners might have concerns about the house's market value if a non-standard heating system would be installed. Additionally, the owners of single-family houses fear that they will not be able to properly lead the refurbishment project to the end, and therefore they avoidthe risk of starting the renovation which may be left uncompleted.

5.3.2 Lack of knowledge, information and qualified installers.

Installers are well trained in known solutions for the DHW and air conditioning and are still not so fluent in the design, integration and installation of less conventional systems. A new system implies a learning process in order to get to know it, buteven though the training possibilities are available, experiences reveal that engineers and other technicians in charge of installation work are often too busy to undergo such training.

Lack of sufficient information and knowledge about the system developed in the SolBio-Rev project and its performance as well as a lack of skilled personnel and training programmes can constitute a serious barrier for the exploitation of the project's results. Moreover, the potential inability of the staff to properly carry out operation and maintenance activities can cause a failure in the system after implementation. For the installation and utilization of such system, not only trained plumbers and heating system engineers are needed, but also all those involved in selling and evaluating of the system (e.g. energy advisors) need information about the new technology.

5.3.3 Reluctance of the construction industry (installers) towards innovative solutions.

A variety of well-known and widespread conventional heating and cooling appliances is available on the market. The construction industry is very traditional and reluctant to do things in a different manner. Firstly, because novelties require more time for training beforehand and more effort for the implementation. Secondly, because the suppliers of the widespread systems can offer more benefits for the constructors themselves (free spare parts, high discounts, attractive trainings) than the suppliers of the newly developed technologies. In order to overcome this barrier, the advantages in efficiency, operation costs and primary energy consumption offered by the new technology need to be significant and effectively communicated.

5.4 Technological aspects

Technological limitations are very important in innovative projects. At the early stages of product development, it is not possible to predict all the difficulties that may arise during mass production or product use. In order to learn about these limitations, prototypes and demonstration installations are created.

5.4.1 Unknown possible exploitation problems.

The global energy system developed in the scope of the SolBio-Rev project is far from being mature, and obviously no units have been yet installed. Therefore, it is impossible to already know all possible design and exploitation problems, thus their know-how is still under development.

5.4.2 Unknown possible problems in serial production.

After the development stage, to achieve satisfactory level of sales and bring financial benefits for the technology suppliers, the production processes for each individual sybsystem have to be optimized to meet the criteria of serial production. Similarly like in the case of exploitation problems, at this stage of the project it is impossible to correctly anticipate all of the possible problems with serial production.

5.4.3 Hard accessibility to providers.

For the sales and implementation processes of the new technology, the installers or investors often require an intensive assistance from the technology supplier. Therefore, the accessibility of supplier or its representatives can constitute a barrier for the deployment of the global system. Contacting with providers from other countries or with their local offices at a great distance could be a problem when referred to the maintenance of the installed systems.

5.4.4 Hard to estimate expected life (durability) of the system.

The expected durability of the system is one of the critical factors which the building owners would take into account while making their decisions about the investment. Unfortunately, since the developed system is a novelty, the expected life of these units is still far from being known and proved.

5.5 Environmental aspects

Since the solution proposed in the project is based on renewable energy sources and is in fact intended to help protect the environment, not many environmental constraints are presented in this section. Nevertheless, the natural environment has a large impact on the possibility of rational implementation of the discussed system, mainly due to the availability of solar energy.

5.5.1 Proper siting and availability of resources (solar radiation-biomass).

For the developed system the key climatological and geographical factors determining the exploitability of the system are solar radiation, ambient temperature and the availability of high-quality biomass. On the one hand, proper siting of the solar system is a major challenge, since the surroundings can offer advantages or disadvantages, such as the presence of shading elements which could restrict the solar exploitability. An ideal solar installation would be situated in an unshaded, south-facing location with an optimum tilt angle. In many countries the solar radiation maps are available (e.g. ADRASE in Spain [44]) and help to determine if a building site is located in an area with acceptable amounts of this renewable energy resource. On the other hand, the biomass demand of the system is significant thus necessitating the availability of this source. Moreover, the specifications of the biomass boiler require a pellet form of biomass which adds extra restrictions in terms of the environment's supply chain.

However, other factors such as the cost of alternative energy sources and available local incentives for renewable energy installations often make installing such systems cost effective even if the resources are not abundant.

5.6 Legal aspects

As mentioned in one of the previous subsections, governments trend to incentive the introduction of energy efficient systems. Nevertheless, very often there are other legal aspects which aim to avoid violation of rights or property of third parties, preserve the character of historical districts and buildings or protect global interest of the communities but may at the same time establish restrictions for the renewable heating & cooling systems.

5.6.1 Restrictions over ambient noise.

For facilities installed in urban zones, municipal regulations establish limits for the noise emission of the equipment, in order to avoid an excessive acoustic contamination that creates an annoying environment. The majority of the sybsystems involved in the SolBio-Rev system are characterised by few moving parts, with the exception of the reversible heat pump. As a result, attention hast o be paid to minimize the noise effect.

5.6.2 City planning and restrictions for historical buildings.

In many European countries the historic preservation entities are often responsible for designating historic properties, providing guidance and resources for historic preservation projects, and imposing regulatory restrictions with which historic projects must comply. In old towns with protected façades and aesthetics of the neighbourhood, the municipalities establish some regulations in order to control the view of historical quarters. Therefore, maintaining the architectural aspects of existing buildings, especially historic buildings, is often a priority in the retrofitting projects. If the installation of an innovative system could damage the historical aesthetics of the protected buildings or quarter, the municipality will refuse such retrofit. Therefore, it is important to understand what regulations apply to historic building projects before investigating the installation options.

It is worth to mention, that some technologies of the system can be hidden from view. Solar thermal systems can be integrated into the building's "skin", such as the roof or shading devices. It can also be installed out of the view of building visitors, such as on a roof, facing away from where visitors view the building, behind roof parapets, on other structures located on the site such as a parking structure, or ground-mounted away from the historic building.

However, local planning and zoning regulations and environmental features can further hinder the deployment of the SolBio-Rev system in certain areas.

5.6.3 Building codes.

Building codes can be considered as a driver and as well as a barrier for the wide spreading of the SolBio-Rev system. The building regulations implicitly support renewable heating and cooling and decentralised power generation by setting energy performance requirements. Although they apply mostly to new buildings, they encourage also renovations of the existing buildings. By stating the requirements for the new buildings, the building codes inform the tenants about the current energy performance standards, which are possible to obtain with the available technologies.

Some stakeholders point the imperfections of the building codes such as: the absence of clearly defined responsibilities, inadequate planning guidelines, and complex, slow, lengthy or opaque permitting processes.

6 Conclusion

Within the scope of this report a preliminary market analysis of the European heating and cooling sector, as well as an overview of the technical codes affecting the overall SolBio-Rev solution is presented. The objective is to pave the way for the future commercialisation and exploitation of SolBio-Rev project results, ensuring their compliance with the highest European standards and market needs.

A short technical explanation of the SolBio-Rev system is provided in order to allow better understanding of the context of further chapters. The components of the system are divided in two groups indicating whether they are innovative or commercial products. This division clearly indicates how innovative the overall solution is, and that only few of its components are already mature and market-available products.

To ensure the best use of the report for the purposes of the project, the analysis of the national regulations has been carried out for four carefully selected countries (Germany, Sweden, Spain and Greece). The criteria and reasoning for the selection of these countries are given in Section 2.2.

Regulations related to energy performance for new and retrofitted buildings have been identified. The info has been collected first at European Level and later for every selected country. The most relevant European directives concerning energy efficiency in buildings have therefore been analysed, as well as their implementation in the regulations of the four identified target markets, in order to guide the business development and the definition of realistic market applications. The current legislation both at European and national level is conducive to the SolBio-Rev project and incentives the use of energy efficient, renewables-based solutions.

The overall constraints and barriers are listed and analysed in Section 5 to understand the boundaries and potential limitations for the introduction of the technologies and systems considered for the SolBio-Rev project. Some barriers are purely external and cannot be influenced. However, in relation to the majority of them, remedial actions can be applied as part of the project. The social and partially also political constraints can be addressed by communication and dissemination activities, and the exploitation activities can help to overcome the technological as well as some of the economic barriers.

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