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Innovative compact HYbrid electrical/thermal energy storage systems for low energy BUILDings

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CO	Confidential, restricted under conditions set out in Model Grant Agreement	
CI	Classified, information as referred to in Commission Decision 2001/844/EC.	

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Publishable executive summary

HYBUILD is an EU Horizon 2020-funded project, led by COMSA Corporación, which will develop two innovative compact hybrid electrical/thermal energy storage systems for stand-alone and district connected buildings.

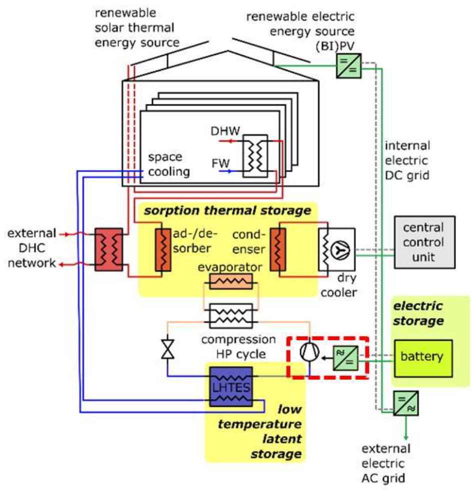
This report - D1.2 "Technical and market review codes studies, national and European certification frameworks" provides an analysis of the technical and economic framework in which the HYBUILD technologies will be implemented, in order to pave the way for the business development and the definition of realistic and achievable market applications.

The methodology followed consisted in analysing first the global HYBUILD solutions, and then the single components constituting them. The same approach was adopted also for what concern the analysis of regulations and directives: the European context was first analysed, and then the analysis was further developed for each target country and for each core HYBUILD components. The market analysis was performed mainly at European level and considering heating and cooling demand given the early stage of the project. A further detailed market analysis for each core HYBUILD technology will be carried out in the context of exploitation activities (WP7).

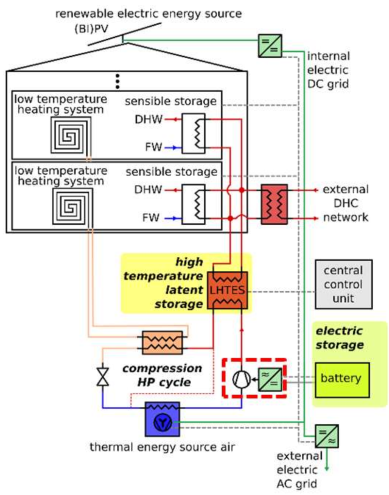
The overall objective of HYBUILD is presented in **Chapter two, "HYBUILD OVERALL CONCEPT AND PRODUCTS DESCRIPTION"**: it includes an introduction to the two innovative compact hybrid electrical/thermal energy storage systems for stand-alone and district connected buildings which will be specifically developed for ensuring comfort condition in residential buildings located in the **Mediterranean climate**, and **Continental climate**.

Both systems will be able to cover efficiently also heating and cooling demand respectively.

The technical functioning schemes of the two proposed concepts are illustrated below.



Mediterranean Concept



Continental Concept

The core components of the two systems are listed in the following table. Some of them are completely new, while others are already commercial but their use in combination with other subsystems represents a novelty.

Technology	Mediterranean Concept	Continental Concept	Innovative	Commercial
Sorption storage module (thermal)	✓		✓	
Latent storage module (thermal)	✓	✓	✓	
Water tank storage (thermal)	✓	✓		✓
Electrical battery coupled with a DC controller (electric storage)	✓	✓	✓	✓
Compression Heat Pump/Chiller	✓	✓		✓
PV panels	✓	✓		✓
Solar collectors	✓		✓	✓

For each of the components, a preliminary description of the technical functioning is provided in subchapters from 2.2 to 2.5.

In order to understand the market scenario in which HYBUILD results will be introduced, an analysis of energy usage in buildings at European level with a focus on the energy storage market is performed in **Chapter 3, "HYBUILD TARGET MARKET ANALYSIS".** Energy use in buildings represents a large part of global and regional energy demand. The energy consumption in the European residential sector is allocated mainly for **space heating**, accounting for 60%-80% of the total energy consumed in the sector, and it is in particular gathered in the northern and the continental countries (N. Pardo, 2012). In the maritime climates in Western Europe, there is a relatively long heating season with relatively low peaking demand. Countries such as Ireland, Belgium, Denmark and Germany have the highest space-heating share, higher than countries with colder winter seasons like Finland and Sweden. This stems from the use of less efficient technologies for insulation and heating systems than in the Nordic countries. Eastern Europe is characterized by a high heating demand and moderately high solar irradiation, leaving good opportunities there as well.

Mediterranean countries on the contrary have generally a low space heating demand due to warm temperatures during winter season, and consumption is mainly related to space cooling and Domestic Hot Water (DHW) production. The demand for **space cooling** is growing rapidly and it is predicted to continue growing with a rate of approximately 3.14% per year (Mindaugas Jakubcionis J. C., 2017). This growth is explained by the increase of the standards of living with the use of air conditioning systems together with the increase of the comfort requirements and the residential floor area.

DHW demand is the second largest heat demand in the residential sector after space heating, accounting for around 14% of the total energy consumed in the sector in the EU (Energy consumption in households, 2018).

Although HYBUILD won't immediately deliver marketable products (expected TRL6 by the end of the project for the overall solution, and TRL7 for some individual technological components), certification systems across Europe must be analyzed to prepare the future market introduction and uptake. Given the expected developments in the HYBUILD project, the study of certifications strategies covers both the HYBUILD global solution and its individual technological elements. Across the globe, countries are independently designing and implementing energy efficiency policies and programs for residential buildings stocks to increase their sustainability and meet EU common targets. In fact, energy efficiency in construction standards is universally recognized as a practical and cost-effective way to achieve energy savings. Since efforts to increase energy standards in building codes are relatively disparate between countries, it is useful to analyse not only which countries seem to be designing well-crafted and comprehensive energy codes, but also which are effectively implementing and enforcing those standards. At European level, two main pillars on this topic exist: The **Energy Performance of Buildings Directive (EPBD)** and the **Energy Efficiency Directive (EED)** (Buildings, 2018), which are the EU's main legislative instruments to promote the improvement of the energy performance of buildings and to provide a comprehensive framework to support investment decisions.

The EPBD regulates both 'passive' measures for the building design and envelope, as well as the 'active systems', such as building systems for heating, cooling and lighting. The EPBD introduced certificates, which indicate the Energy Performance of the building as a numeric value, which indicate the energy performance of buildings according to measurable indicators allowing a benchmarking. Certificates also include a list of suggested energy conservation measures.

The EED aims to help citizens, public authorities and businesses to better manage their energy consumption. The EED aims to bridge the gap between existing framework directives and national energy efficiency measures to help the EU achieve its 20% by 2020 reduction target. 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 (Energy Efficiency Directive , 2018). In order to understand how to make the HYBUILD solutions compliant with the aforementioned directives, a review of their national transposition in seven target countries has been performed in **Chapter 4 "EUROPEAN BUILDING CODES REVIEW".**

Building codes were collected and analysed at country level. A summary of the obtained findings is reported in the following table.

Country	Significant Regulation
Spain	Technical Building Code 2006 (TBC)
	Regulation for Buildings' Thermal Installations 2007
	Regulation for Energy Efficiency Certification 2007.
Cyprus	Energy Performance of Buildings" law introduced in 2009
Greece	Energy Performance Regulation for Buildings (KENAK), released in 2010.
France	2012 Thermal Regulation (RT)
Sweden	Boverket's Building Regulations
Germany	German Energy Saving Ordinance

Italy	Decree Law 311/2006
	Decree for energy efficiency requirements in buildings (2015)

The chapter concludes with a summary and comparison of the HYBUILD expected impacts with the European building codes, in order to evaluate the HYBUILD performances and benefits.

Energy certification of buildings is another key policy instrument that can assist governments in reducing energy consumption and improving the energy performance of new and existing buildings. It provides decision makers in the buildings industry and the property marketplace with objective information on a given building, either in relation to achieving a specified level of energy performance or in comparison to other similar buildings. **In Chapter 5 "NATIONAL AND REGIONAL CERTIFICATION SYSTEMS ANALYSIS"**, the main voluntary energy performance certification schemes for buildings which have a significant market share in Europe and that can be applied to residential buildings in the context of HYBUILD are reviewed. A summary is reported in the table below.

Building Rating or Certification system	Developer	Type of Standard or Certification	Areas of Focus
BREEAM	Building Research Establishment (BRE - UK)	International scheme that provides independent third party certification of the assessment of the sustainability performance of: • Individual buildings • Communities • Infrastructure projects	BREEAM measures sustainable value in a series of categories, ranging from energy to ecology: • Energy • Health & Wellbeing • Innovation • Land use • Materials • Management • Pollution • Transport • Waste • Water
LEED	U.S. Green Building Council (USGBC)	• Building Design and Construction • Interior Design and Construction • Building Operations and Maintenance • Neighbourhood Development • Homes • Cities and Communities	Each LEED rating system groups requirements that address the unique needs of different building and project types. For instance for Homes, LEED looks at : • Location and Transportation • Sustainable Sites • Water efficiency • Energy and atmosphere • Materials and resources • Indoor Environmental

Building Rating or Certification system	Developer	Type of Standard or Certification	Areas of Focus
			quality • Innovation • Regional priority
VERDE	Spain	• Sustainability certificate that measures the environmental, economic and social impact of buildings • Acknowledged in Europe	In the assessment of an office building to obtain the VERDE sustainability certificate are considered the following parameters • Site selection • Location and planning project • Indoor space quality • Energy & ambience • Quality of service • Natural resources • Socioeconomic impact
HQE	France	HQE certification covers the entire lifecycle of a building (construction, renovation and operation): non-residential buildings, residential buildings and detached houses as well as urban planning and development. It can be applied nationally or internationally.	• Assessment of the building's impact • Taking suitable measures to reduce the building's impact looking at: ○ Eco-construction ○ Eco-management ○ Comfort ○ Health
E+C-	France	The E+C- is composed by an Energy factor (evaluated via the "BEPOS" rating indicator) and a Carbon factor (evaluated via the "Carbon" indicator). In this way, property developers may select the two indicators that are best suited to their particular project in order to participate in the trial scheme and/or obtain the certification label.	• Energy performance focus: developing the use of renewable energy in buildings • Environmental performance focus: promoting buildings with low carbon footprints • Economic evaluation focus The current E+C- framework (Label E+C-, 2018) indicates that energy storage systems might be integrated to the calculation methodology in a next version.

Building Rating or Certification system	Developer	Type of Standard or Certification	Areas of Focus
DGNB	Germany	DGNB provides a full sustainability assessment scheme available for a wide range of buildings covering new, existing buildings, both publicly or privately owned. The DGNB Certification System can be applied internationally.	Due to its flexibility it can be tailored precisely to various uses of a building and even to meet country-specific requirements. It covers all of the key aspects of sustainable building: • Ecological quality • Economical quality • Socio-cultural quality • Technology • Process quality • Site use
PASSIVHAUS	Germany	The certifications system can be used for existing and new buildings covering non-residential and residential buildings	The certification system focuses only on the energy topic. Assessment areas include: • Health and living comfort ("comfort criteria") • Energy balance in practice ("energy criteria")
MINERGIE	Switzerland	Swiss construction standard for new and modernized buildings. The most important element is the comfort, housing and work of users made possible by a high quality building envelope and a systematic air renewal, guaranteed by a controlled ventilation system.	For new buildings, Minergie offers three construction standards that can be combined with the ECO complement, which stands for healthy and ecological construction
CASACLIMA	Italy	Energy label characterizing high insulation and compact constructions, also for existing and renovated buildings. CasaClima includes optimised construction methods, careful execution and a high level of comfort	Assessment criteria include: • Overall energy efficiency of the building • Environmental impact of the materials used in construction • Efficient use of water resources • High indoor air quality and low emission materials

Building Rating or Certification system	Developer	Type of Standard or Certification	Areas of Focus
			• Protection against radon gas • Optimal exploitation of the natural light • Acoustic comfort
ITACA	Italy	Energy-environmental certification tool including quality of the building and building components. The ITACA certification allows benefits as incentives for renovation and urbanization burden reduction, volumetric bonuses, controlled loans (for new buildings mainly)	• Definition and development of procedure for the management and/or award of contracts • Promotion and dissemination of good sustainability practices in services, supplies and public works • Using eco-friendly, certificated building materials
LIDERA	Portugal	Voluntary certification system applicable all residential, services, tourism and commercial buildings (and intervention areas) at any stage of its life cycle. It is adapted to the national context that attends to Portugal's intrinsic aspects, in environmental, social and economic level.	LiderA has 43 criteria distributed across different areas that, after an evaluation, are categorized into a performance scale from G to A (up to A ++). At the A ++ (most efficient) level, performance is about 90% higher than the least efficient level.

After having presented some of the main certification strategies at building level, the following paragraph is dedicated to the analysis of certification strategies covering the elements that compose the HYBUILD components, as reported in the table below.

Technology	Certification Strategy
Thermal energy storage	Pressure equipment directive (PED)
Electric storage	Low Voltage Directive (LVD) 2006/95/EU
	Electromagnetic Compatibility (EMC) 2014/30/EU
	Energy Regulator deliberation 574/2014/R/eel
	Italian standard CEI 0-21
Heat Pump/Chiller	CEN heat pump KEYMARK
	EHPA Quality Label
	F-Gases Regulation
Renewable Energy Sources PV	Low-Voltage Directive (LVD) 2014/35/EU
	EC-Machinery Directive 2006/42/EC
Renewable Energy Sources Solar Collectors	Machinery DIRECTIVE 2006/42/EC
	Pressure equipment DIRECTIVE 2014/68/EU
	Hazardous substances in electrical and electronic equipment DIRECTIVE 2011/65/EU
	Electromagnetic compatibility (EMC) DIRECTIVE 2014/30/EU

The possibility to apply the CE marking and the Energy Labelling to the HYBUILD solutions is investigated as well.

Technology	CE Marking to be affixed	Under which products?	Reference norm/directives	
Thermal energy storage	✗	-	-	
Electric storage	✓	• Low voltage electrical equipment	2006/66/EC	Batteries and accumulators and waste batteries and accumulators and repealing Directive 91/157/EEC ("Batteries and accumulators containing certain dangerous substances")
			BS EN 61429:1997 IEC 61429:1995	Marking of secondary cells and batteries with the international recycling symbol ISO 7000-1135
			IEC 61427	Secondary cells and batteries for renewable energy storage - General requirements and methods of test
			BS EN 60086-4:2000 IEC 60086-4:2000	Primary batteries. Safety standard for lithium batteries
			BS EN 61960-1:2001 IEC 61960-1:2000	Secondary lithium cells and batteries for portable applications. Secondary lithium cells
			BS EN 61960-2:2002 IEC 61960-2:2001	Secondary lithium cells and batteries for portable applications. Secondary lithium batteries
			02/209100 DC	IEC 62281. Ed.1. Safety of primary and secondary lithium cells and batteries during transport
			CEI EN 50438	Requirements for micro-generating plants to be connected in parallel with public low-voltage distribution networks
Heat Pump/Chiller	✓	• Low voltage (LVD) • Electromagnetic compatibility (EMC)	UNI EN 378-2:2017	Refrigerating systems and heat pumps - Safety and environmental requirements - Part 2: Design, construction, testing, marking and documentation
			UNI EN 12102-1:2018	Air conditioners, liquid chilling packages, heat pumps, process chillers and dehumidifiers with electrically driven compressors - Determination of the

Technology	CE Marking to be affixed	Under which products?	Reference norm/directives	
		• Pressure equipment • Eco-design and energy labelling		sound power level - Part 1: Air conditioners, liquid chilling packages, heat pumps for space heating and cooling, dehumidifiers and process chillers
			UNI EN 14511-2:2018	Air conditioners, liquid chilling packages and heat pumps for space heating and cooling and process chillers, with electrically driven compressors - Part 2: Test conditions
			UNI EN 14511-3:2018	Air conditioners, liquid chilling packages and heat pumps for space heating and cooling and process chillers, with electrically driven compressors - Part 3: Test methods
			UNI EN 14825:2016	Air conditioners, liquid chilling packages and heat pumps, with electrically driven compressors, for space heating and cooling - Testing and rating at part load conditions and calculation of seasonal performance
			EN 55014-1:2017	Electromagnetic compatibility - Requirements for household appliances, electric tools and similar apparatus - Part 1: Emission
			EN 55014-2:2015	Electromagnetic compatibility - Requirements for household appliances, electric tools and similar apparatus - Part 2: Immunity - product family standard
			EN 60335-1:2012/A12:2017	Household and similar electrical appliances - Safety - Part 1: General requirements
			IEC 60335-2-40:2018	Household and similar electrical appliances - Safety - Part 2-40: Particular requirements for electrical heat pumps, air-conditioners and dehumidifiers
			IEC 61000-3-11:2017	Electromagnetic compatibility (EMC) - Part 3-11: Limits - Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems - Equipment with rated current ≤ 75 A and subject to conditional connection
			IEC 61000-3-12:2011	Electromagnetic compatibility (EMC) - Part 3-12: Limits - Limits for harmonic currents produced by equipment connected to public low-voltage systems with input current >16 A and ≤ 75 A per phase
			EN 62233:2005	Measurement methods for electromagnetic fields of household appliances and similar apparatus with regard to human exposure

Technology	CE Marking to be affixed	Under which products?	Reference norm/directives	
RES	-	-	IEC 61215-1:2016	Terrestrial photovoltaic (PV) modules - Design qualification and type approval - Part 1: Test requirements
			BS EN IEC 61730-1:2018	Photovoltaic (PV) module safety qualification. Requirements for construction (British Standard)
			IEC 61730-2:2016	Photovoltaic (PV) module safety qualification - Part 2: Requirements for testing
			IEC 61727:2004	Photovoltaic (PV) systems - Characteristics of the utility interface
			BS EN 50524:2009	Data sheet and name plate for photovoltaic inverters
			BS EN 50530:2010+A1:2013	Overall efficiency of grid connected photovoltaic inverters
			UL 1741	Standard for inverters, converters, controllers and interconnection system equipment for use with distributed energy resources
			IEC 61683	Photovoltaic systems, Power conditioners and Procedure for measuring efficiency
			IEC 62109-1:2010	Safety of power converters for use in photovoltaic power systems Part 1: General requirements Part 2 - Particular requirements for inverters

The table above reports a summary of the main norms to be compliant with in order to provide each of the HYBUILD components with the CE marking, which is necessary to trade products on the EEA market.

In addition to CE marking, the **Eco-Design Directive** (**Directive 2009/125/EC)** (EUR-Lex, 2009) provides EU-wide rules for improving the environmental performance of products, such as household appliances, information and communication technologies or engineering, through eco-design. As with other CE marking directives, it applies to all products placed on the EU market and to imported products. The regulation in force about the **Energy Labelling** of energy consuming product is the Regulation **((EU) 2017/1369)** and complements the Eco-design requirements with mandatory labelling requirements, thus laying down a framework that applies to energy-related products placed on the market or put into service

The following table reports the references of harmonised standards for both eco-design and energy labelling regulations for applications interesting to the HYBUILD project.

Technology	Do the Eco Design Directive and Energy Labelling Regulation affect your product?	How?
Thermal energy storage	Eco Design Directive does not affect directly energy storage. No Energy Labelling Regulation has to be pursued	-
Electric storage	Eco Design Directive does not affect directly energy storage. No Energy Labelling Regulation has to be pursued	-
Heat Pump/Chiller	Yes	Ecodesign Directive 2009/125/EC (EUR-Lex, 2009)
Renewable Energy Sources	Yes	Ecodesign Directive 2009/125/EC

Acronyms and Abbreviations

AC	Alternating Current
BMU	Battery Management Unit
BREEAM	Building Research Establishment's Environmental Assessment Method
CAN	Controller Area Network
CDD	Cooling Degree Day
CEI	Italian Electro technical Committee
CMU	Cell-Monitoring Unit
COP	Coefficient of Performance
DC	Direct Current
DHW	Domestic Hot Water
EDD	Eco-design Directives
EEA	European Economic Area
EED	Energy Efficiency Directive
EFTA	European Free Trade Association
EHPA	European Heat Pump Association
ELD	Energy Labelling Directive
EMC	Electromagnetic Compatibility
EPBD	Energy Performance of Buildings Directive
EPC	Energy Performance Certificates
FPC	Factory Production Control
GBI	Green Building Initiative
HVAC	Heating, ventilation, and air conditioning
IDAE	Institute for Energy Diversification and Savings
IPCC	International Panel on Climate Change
LEED	Leadership in Energy and Environmental Design
LTO	Lithium Titanium Oxide
LVD	Low Voltage Directive
NZEB	Nearly zero-energy buildings
PCM	Phase Change Material
PST	Partial Support Transformation
PV	Photovoltaics
RES	Renewable Energy Sources
RT	Règlementation Thermique (French Thermal Regulation)
TBC	Technical Building Code
USGBC	U.S. Green Building Council

1 INTRODUCTION

1.1 Relations to other activities in the project

The work presented will constitute the background for the technology development to be carried out in WP2 and WP3. In fact, before to put on the market and even to use a new technology, it is important to ensure compliance with standard and regulations boundaries at European and National level.

The preliminary target market analysis will serve as a basis for the exploitation activities to be conducted in WP7.

1.2 Report structure

In section 2 **"HYBUILD Overall Concept And Products Description"**, the overall HYBUILD concept is presented, including a description of the functioning of the two systems, Mediterranean and Continental. The commercial products belonging to the two solutions are identified and a technical description is provided for each of them.

In chapter 3 **"HYBUILD Target Market Analysis"**, an overview of the current heating and cooling European market is presented. The analysis focusses in particular on the European heating and cooling energy demand in residential buildings, taking into account consumptions for both heating and cooling applications. The objective is to assess the HYBUILD project market potential on the seven identified target markets.

Section 4 **"European Building Codes Review"** is devoted to the review of country specific building codes on the seven identified target markets. The analysis starts with an overview of the two most significant regulations at European level "the Energy Performance of Buildings Directive" and the "Energy Efficiency Directive"; afterwards, the way in which these directives have been implemented at country level (with specific reference to the identified target markets) is illustrated.

Finally, section 5 **"National And Regional Certification Systems Analysis"** explores the energy performance certification systems across Europe, considering both the building level and the certification marking affecting each of the HYBUILD technologies, and to be taken into account in order to safely enter the market.

1.3 Contribution of partners

STRESS (RINA – C as third party) - Task 1.2 and 1.4 leader. Evaluation and review of building codes and certification systems. Identification of potential barriers for the HYBUILD solution.

DAIKIN – Provision of air conditioning systems target market and certification requirements.

FRESN – Contribution in the evaluation of regulation, codes and related laws in their target segment (pressurized systems, boiler regulations, solar systems, roof-top installations) and target market (EU in general with specific focus on Spain (=demo site)).

UCY - Contribution in the evaluation of technical codes.

R2M – Contribution in the identification of commercial products/component to be addressed by the European building codes review with particular focus on the thermal & electric storage markets for residential buildings.

NTUA - Contribution in the review of national and regional certification systems.

In addition, all **technology providers** were asked to issue a technical description of the innovation proposed, as well as to fill in a template about the certification strategies at European and national level relevant for their technologies.

1.4 Aims and objectives

Deliverable 1.2 “Technical and market review codes studies, national and European certification frameworks” collects the output of Task 1.2 and Task 1.4, respectively “Technical and market codes” and “Certifications strategies and requirements”. The aim of this report is to provide an analysis of the technical and economic framework in which the HYBUILD technologies will be implemented, in order to pave the way for the business development and the definition of realistic market applications.

2 HYBUILD OVERALL CONCEPT AND PRODUCTS DESCRIPTION

The overall objective of HYBUILD project is the development of **two innovative compact hybrid electrical/thermal energy storage systems** for stand-alone and district connected buildings.

The two concepts will be specifically developed for ensuring comfort condition in residential buildings located in two different climates:

- **Mediterranean climate**, where cooling season operation is particularly critical (e.g. Spain, Italy, Greece, Cyprus, and Portugal)
- **Continental climate**, where criticalities mainly concern the heating season operation (e.g. France, Germany, Switzerland, Denmark)

Both systems will be able to cover efficiently also heating and cooling demand respectively.

The proposed concepts are reported in Figure 2.1.

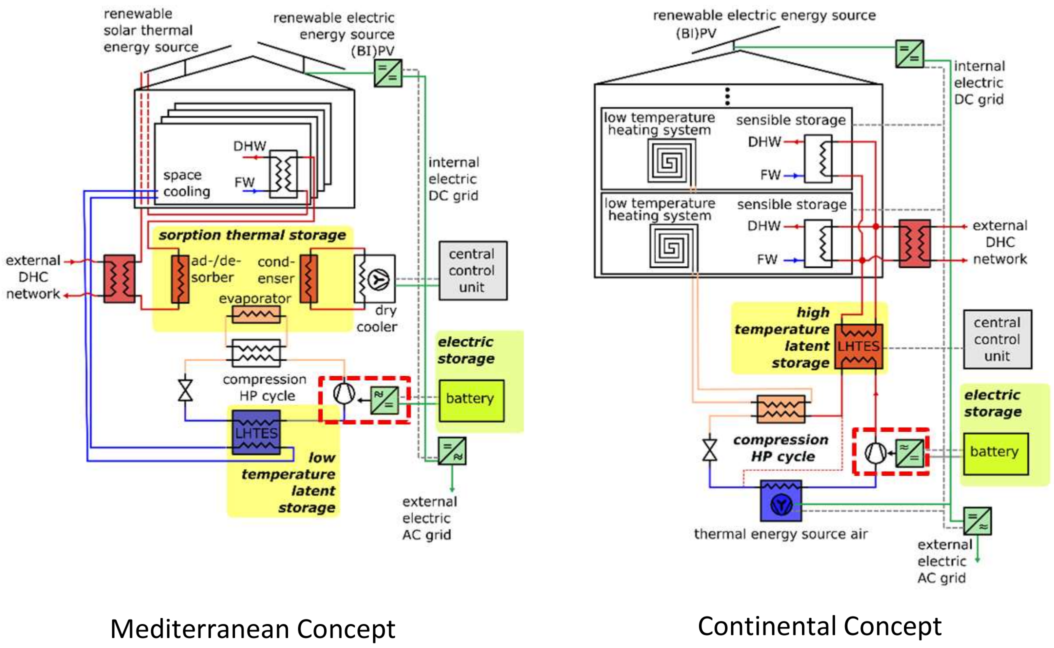


Figure 2.1: Scheme of the hybrid storage concept for Mediterranean climate during summer operation and Continental climate during winter operation

The primary operating condition of a heating/cooling system in the Mediterranean climate is to provide cooling energy during summer operation, which is usually accomplished, in the installed systems, by means of electrically driven vapour-compression refrigeration systems (vapour compression HPs). Nevertheless, to cover space heating and DHW demand, usually, gas boilers and solar thermal collectors are installed, since the common distribution systems are based on high temperature radiators, which restrict the applicability of compression HPs.

This leads to a high primary energy consumption during both cooling and heating seasons, due to the absence of a system integration as well as the limited efficiency of the components. The proposed hybrid storage concept for Mediterranean climate aims at the integration of an electrically powered compression HP with a thermally driven sorption storage module for domestic hot water (DHW) production, in order to increase the overall efficiency of the system, efficiently storing the surplus of electricity into heat when needed. Furthermore, an electric storage pack and a low temperature latent storage module are also integrated, in order to make the system able to store and reuse as much as possible the produced electrical and thermal energy from renewable source.

The working principle of the **Mediterranean concept** is based on the direct connection of a Direct Current (DC) powered vapour compression HP, which produces cooling energy for the building demand, with an advanced sorption storage (sorption heat pump) and a low-temperature latent thermal energy storage. In particular, during cooling season, when cooling energy is requested, the renewable electricity is employed to feed the compression HP, through a properly designed DC bus.

The inverter of the DC bus, featured in the red boxes in the above Figure 2.1, is an internal DC-AC inverter needed to run the compressor variation of speed. This equipment is a DC-driven heat pump from the final user point of view, as he/she will buy equipment that needs to be connected in a DC network. The use of a DC-driven heat pump fits very well the interaction with PV and DC-bus used in the concept.

The condenser of the compression HP is directly connected to the evaporator of the sorption storage that is driven either by solar thermal or district heating, thus increasing the electrical COP of the system. The produced cooling is stored in a high-density low temperature latent storage. In case of surplus renewable electricity, it can be either stored in an electrical storage (i.e. properly identified and sized battery) or efficiently converted in thermal energy or stored in the sorption storage. Domestic hot water and space heating, when needed, can be either produced directly by the thermal source or efficiently produced and stored by the hybrid compression/sorption storage. This will reflect in a reduced request of electrical energy to produce the cooling energy needed to cover the end user's demand.

When there is a surplus of electricity produced, renewable electricity (mostly from PV) can be effectively stored in two ways:

1. It can be efficiently converted into heat by using the HP, thus pumping energy from ambient temperature up to the evaporator temperature of the **sorption storage**
2. It can be stored in a properly sized battery pack (**electric storage**), to be reused afterwards to drive again the **compression HP** or to cover the electricity demand of the other appliances installed in the building.

In case of fully charged hybrid storage, a bidirectional inverter will then allow to feed the surplus of renewable electricity to the external electrical AC grid. Thanks to the reversibility of the operating mode of both **compression HP** and **sorption storage**, the system can operate also in heating mode, increasing the share of renewable, both thermal and electrical, thus reducing the primary energy demand by at least 20% compared to the state-of-the-art.

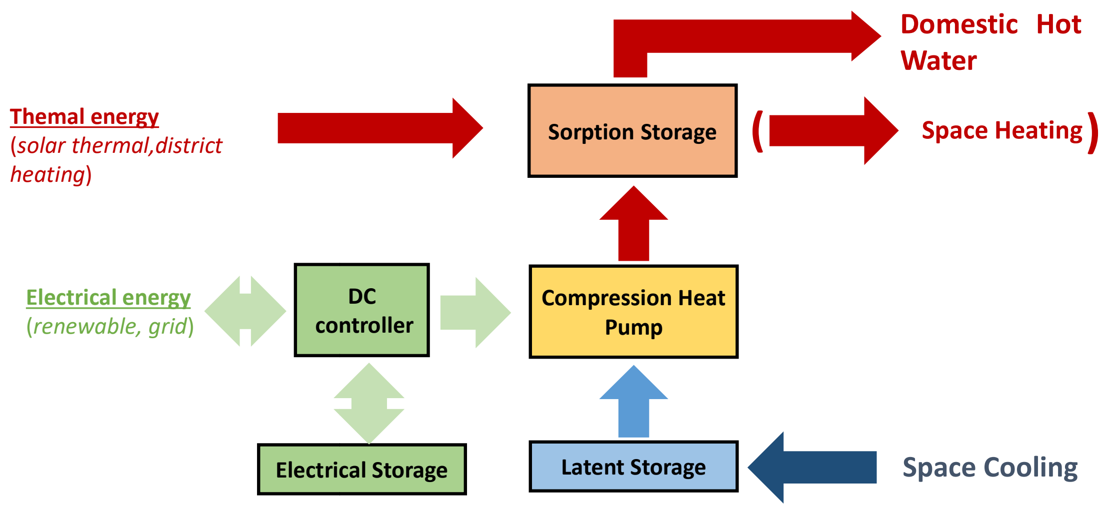


Figure 2.2: Simplified scheme of the hybrid storage Mediterranean concept

Contrary to the Mediterranean solution, the prioritized operation of the **hybrid storage concept for Continental Climate** is heating during winter and the production of domestic hot water (DHW), whereas cooling during summer plays a minor role compared to the other two.

This is based on a thermal PCM latent storage for DHW and an electrical storage.

The **Continental concept** focuses on the optimal use of available thermal and electrical surplus renewable energy sources. The balancing and control of energy flows is realized by an electrically powered **compression HP** that links thermal and electrical energy. The concept, in particular, is able to increase the system efficiency and renewable sources exploitation through the integration of a high-density high temperature latent storage employed to store the sensible energy of the hot gas exiting the compressor powered by a DC driven inverter and fed by renewable electricity. Indeed, the amount of sensible energy delivered by the gas is able to cover a large share of the DHW demand in northern countries. In such a way, the renewable electricity is efficiently converted, through the modulating compression HP, in thermal energy for heating and DHW and is then stored in the building and the high temperature latent storage for DHW, respectively. The system will also implement an electrical storage, which will allow to further increase the share of renewable energy both for buildings connected and non-connected to district heating networks.

Furthermore, an innovative sensible water storage with a high heat exchanger surface will be used inside the apartments to provide enough hot water within a short time.

Latent and sensible water storage complement each other perfectly in the proposed system. The high storage density of the PCM is used in the integrated latent storage directly at the heat pump, whereas the high tap-flow rates of needed for DHW are guaranteed by the sensible water storages in the apartment.

The operation mode of the air source heat pump can be reversed, to provide cooling energy and DHW during summer season. Depending on the ambient conditions, the high temperature latent storage can be charged with the hot gas during cooling operation or directly in the forward heat pump.

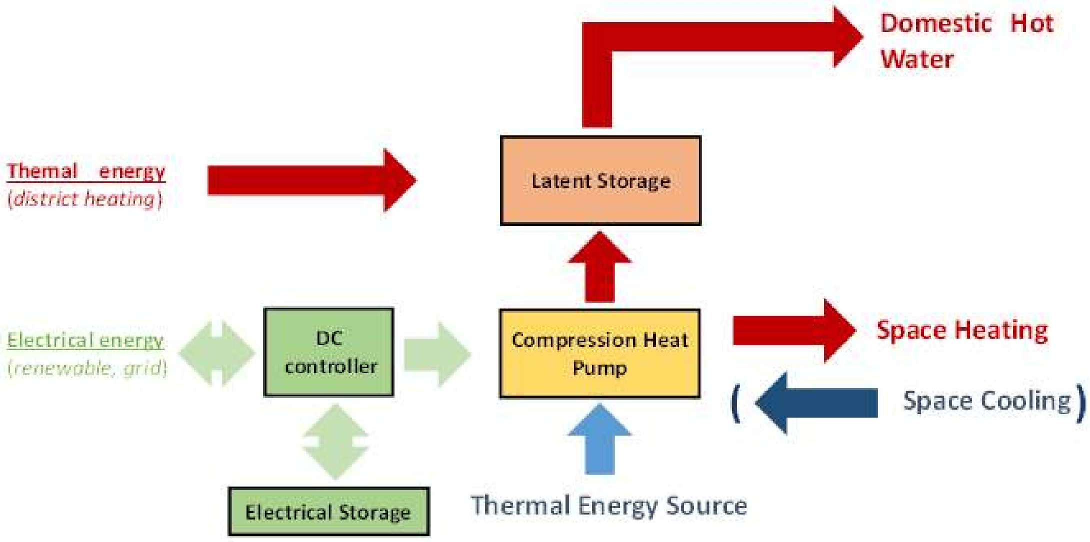


Figure 2.3: Simplified scheme of the hybrid storage Continental concept

Both systems will implement smart and predictive fully integrated control and management systems, which will optimize the operation of the system itself, through managing the energy flows and the storages operation.

An energetic analysis of the two concepts will be reported in D6.3 "Report of the energy performance" (due in M48).

The following Table 2.1 introduces the core components of the two systems that will be further explained in the next sections.

Table 2.1: List of the main technologies on which the HYBUILD solution is based

#	Products
1	Sorption storage module
2	Latent storage module
3	Water tank storage
4	Electrical battery coupled with a DC controller
5	Compression Heat Pump/Chiller
6	PV panels
7	Solar collectors

2.1 Identification and analysis of commercial products and components

The Mediterranean and Continental concepts are characterized by different sub-systems according to the different energy to be provided.

The Mediterranean concept, providing cooling energy and domestic hot water (DHW), contains the following technologies:

- Sorption storage (sorption module + evaporator condenser) integrated into a compression DC-driven Chiller
- Low temperature latent storage integrated on the evaporator side of the compression Chiller
- Electrical storage and DC system controller.

The Continental concept, providing heating during winter and the generation of DHW, contains the following technologies

- High temperature latent storage integrated on the compressor exit of the DC-driven compression HP
- Electrical storage and DC system controller

The table below summarises the main technologies on which the HYBUILD solution is based. For each of them, it is indicated in which of the two concept they are used and it is specified if they already exist, and the work to be performed is to integrate them in the HYBUILD solution, or if they will be specifically developed in the framework of the project.

The column "Innovative" means that the component/technology will be developed within the project; the column "commercial" means that the component/technology is already fully developed and needs only to be integrated in the overall HYBUILD system.

Table 2.2: HYBUILD Technologies per concept

Technology	Mediterranean Concept	Continental Concept	Innovative	Commercial
Sorption storage module (thermal)	✓		✓	
Latent storage module (thermal)	✓	✓	✓	
Water tank storage (thermal)	✓	✓		✓
Electrical battery coupled with a DC controller (electric storage)	✓	✓	✓	✓
Compression Heat Pump/Chiller	✓	✓		✓
PV panels	✓	✓		✓

Solar collectors	✓		✓	✓

Apart from the innovative components that will be developed within the project, the optimal usage, storage and distribution as well as the flexible thermal and electrical energy management will be realized by means of the adoption of an innovative approach for combining the above listed technologies. Particularly, the innovation of the process is given by the seamless integration of all electric components in a DC coupled system guaranteeing a maximum energy conversion and storage, and by the flexible integration with a **compression HP**, which simultaneously provides heat at high and intermediate temperatures, and uses the stored thermal energy for defrosting the evaporator.

2.2 Thermal energy storage

2.2.1 Sorption storage module

The sorption storage module consists of a Zeolite/aluminium heat exchanger, an integrated adsorption evaporator/ heat pump condenser and a condenser.

Zeolites are a class of non-toxic crystals, which are ideally suited for adsorption. In order to optimally apply zeolite to heat exchangers, there is a process called PST – Partial Support Transformation that, via sophisticated chemistry, makes zeolite crystals grow directly out of the surface of the heat exchangers. This alleviates the need for any kind of coating or glue and optimizes heat conductivity. Because zeolite can reach even the smallest cavities of porous or fibrous material, the surface-to-volume ratio and therefore power density can be maximized.

In order to show the potential of the developing Zeolith/aluminium heat exchanger, the following figures give an overview of specific performance for the adsorber.

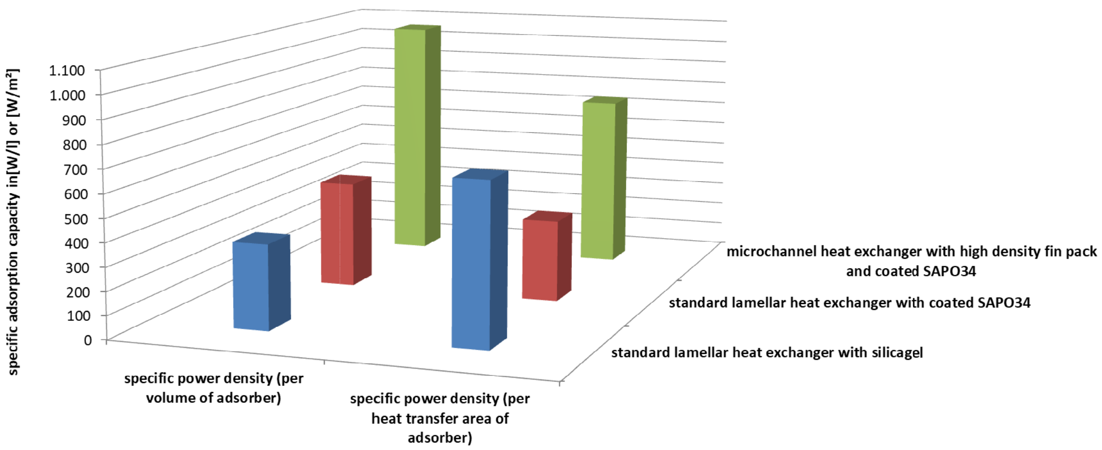


Figure 2.4: Comparison of specific power densities of different heat exchanger [volume, area]

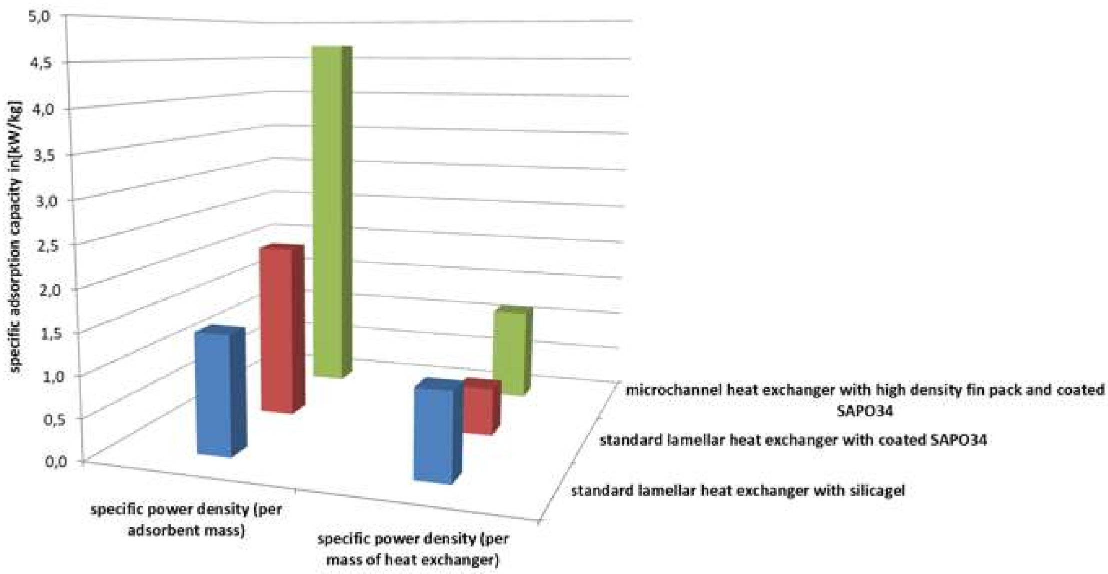


Figure 2.5: Comparison of specific power densities of different heat exchanger [mass]

The developing adsorber is comparable to the microchannel heat exchanger with high density fin pack. In combination with high porous aluminium structures like foams it will be possible to increase the surface-to-volume ratio up to 3 compared to standard lamellar heat exchanger. Another advantage is the great heat transfer coefficient of microchannel heat exchanger in general, showed in Figure 2.6 below.

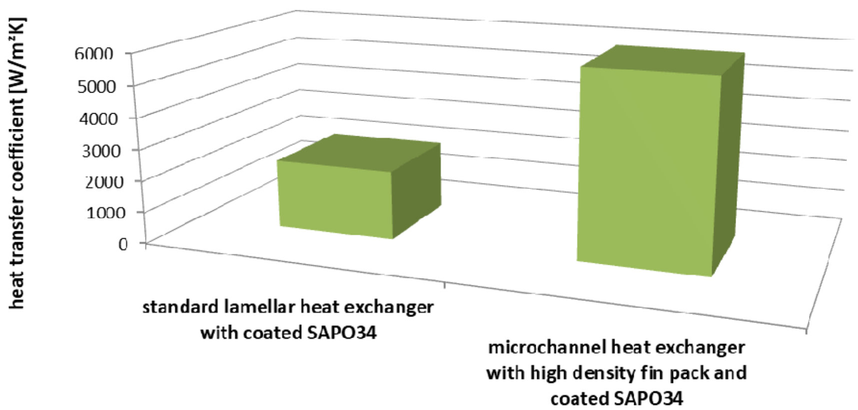


Figure 2.6: Heat transfer coefficient of standard lamellar-/microchannel- heat exchanger (same operating conditions, same specific zeolith layer)

Through high heat transfers no respectively low limitation in adsorption kinetic will be possible.

The following Table 2.3 shows and compares the specific power density, the heat transfer coefficient and the temperature range of different heat exchangers (adsorber).

Table 2.3: Comparison of different heat exchanger (adsorber)

Features	Standard lamellar heat exchanger with silica gel	Standard lamellar heat exchanger with coated SAPO34	Microchannel heat exchanger with high density fin pack and coated SAPO34
Specific power density:			
per volume of adsorber	365 W/l	462 W/l	1066 W/l
per heat transfer area of adsorber	689 W/m²	353 W/m²	750 W/m²
per adsorbent mass	1,45 kW/kg	2,14 kW/kg	4,67 kW/kg
per mass of heat exchanger	1,05 kW/kg	0,58 kW/kg	1,14 kW/kg
Heat transfer coefficient	-	2200 W/m²K	5900 W/m²K
Temperature range:			
Temperature level heat source	60-90°C	75-95°C	75-95°C
Temperature level precooling	20-37°C	20-45°C	20-45°C
Temperature level cooling	6-20°C	6-20°C	6-20°C

In addition, the zeolite layer is a very effective protection against corrosion. Without adhesives or glue in between the crystal and the heat exchanger, heat conductivity is maximized.

This innovation in material science and design allows a significant reduction in size of the adsorption modules, for a given cooling power. Therefore, weight, size, and cost can be improved simultaneously.

Figure 2.7: Crystallization process

The advanced heat exchanger concept from AKG, to be used in the evaporator/condenser section of the sorption module, will contain a very dense aluminium fin, which will be covered by the high-density coating of zeolite adsorbent material. The extremely high available heat transfer surface area will be easily reachable by the water vapour and will enable to noticeably increase the amount of adsorbent material deposited. This will reflect on the possibility to reach really high volumetric heat storage densities.

Also AKG will supply heat exchangers for the evaporator/condenser section of the sorption module. Also here a high fin density is needed to enable capillary forces to transport water inside the heat exchanger.

Concrete specifications of the components to be delivered by AKG are still under discussion as the sorption module will be connected to the refrigerant circuit of the compression chiller.

Figure 2.8: First sample of the sorption module developed by AKG

2.2.2 Latent storage module

High performance aluminium heat exchangers with additional PCM layers will be developed within the project to charge the thermal energy storage directly with the refrigerant from the heat pump or the chiller. The Refrigerant/PCM/Water HEX (RPW-HEX) is an aluminium heat exchanger which combines refrigerant, water and phase change material (PCM) in one heat exchanger. All components ae brazed together in one massive block to quickly charge and discharge the PCM storage.

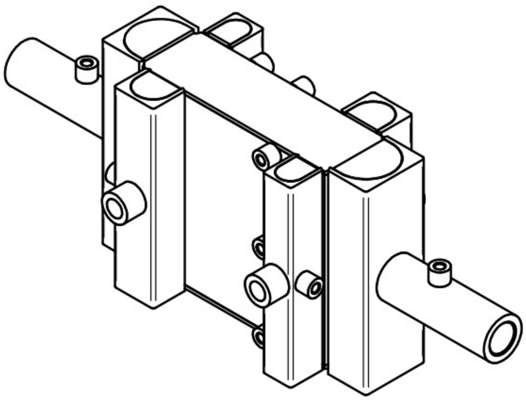


Figure 2.9: Drawing of small RPW - HEX

The latent storage module comprises a stack of RPW-HEX that will be connected in different ways depending on the concept (Mediterranean/Continental). Figure 2.10 shows an example for a possible connection of the RPW-HEXs.

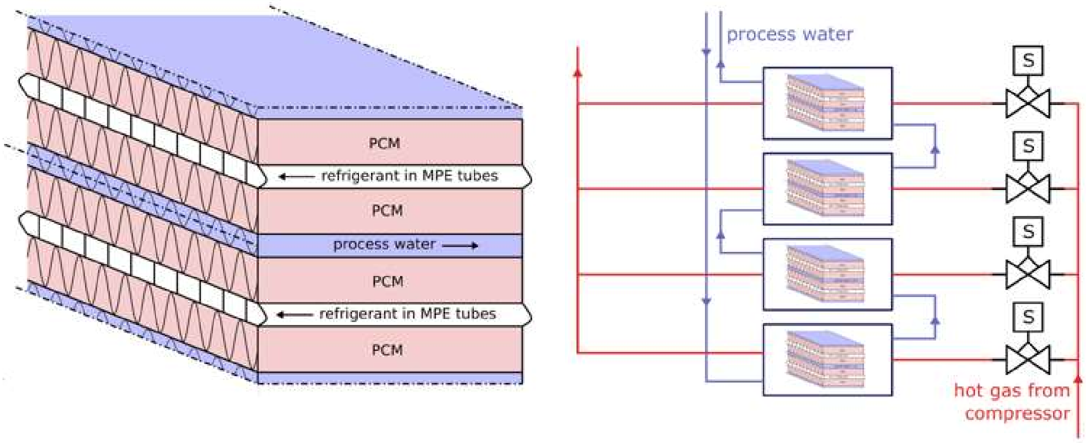


Figure 2.10: Concept of the RPW-HEX and the latent storage

2.2.3 Water Tank Storage

The result is a stainless-steel water storage with special, super-flat-shape to be able to being integrated into the wall of a dwelling including all features relevant for an optimized coupling with the hydraulics and control system being developed within the HYBUILD project. The tank will have an integrated electrical resistance-heating element used as a “booster”-device to cover temperature areas that is only inefficiently reachable by the heat pump and/or sorption storage.

Unique selling point: adapted configuration and control strategy in combination with the HYBUILD system approach.

The result can be included in multifamily houses proposing high-energy efficiency and low maintenance. The expected time for marketability is 3 years, when the result is expected to reach the level 7 in terms of TRL (Technology Readiness Level), starting from the level 4.

Figure 2.11: *Water tank storage*

2.3 Electric Storage module

The electric storage module combines the DC controller and the electrical battery. The core modules represent the next step after the core component design. Contrary to the core components, the core modules are already designed to interact with the other components (compression HP, pumps, heat exchangers, AC grid, etc.) on the hybrid sub-system level.

Battery module technology uses lithium titanium oxide (LTO) in its anode to achieve excellent characteristics, including safety, long life, low-temperature performance, rapid charging, high input/output power and large effective capacity. The technology is designed to prevent thermal runaway resulting from short-circuiting caused by physical stress. Furthermore, it shows long life exceeding 20,000 charge/discharge cycles, rapid charging time of 6 minutes, input/output current densities comparable with capacitors, and operation at temperatures as low as - 30°C. The technology related to the single 20 Ah LTO cell allows fast charging 0 to 80% SOC in 6 minutes. In particular, the battery module selected for the quasi-stationary application in the HYBUILD project can be recharged in 16 minutes (max charge continuous current 160A) keeping long life time and cycling.

Table 2.4: Electric Storage module – Battery module specifications

Battery module specifications	
Nominal capacity	45 Ah
Nominal voltage	27.6 V
Voltage range	18.0 to 32.4 V
Ambient temperature	-30 to 45°C
Ambient humidity	85%RH or less (no condensation)
Max. charge/discharge current	160 A (continuous), 350 A (rush current)
Dimensions	W190×D361×H125 mm (Protrusions excluded)
Weight	Approx. 15 kg
Major built-in functions	Cell voltage measurement, module temperature measurement, cell balancing, communication (CAN)

The module consists of 24 cells (2 in parallel 12 in series) combined to obtain the required capacity and voltage. A cell-monitoring unit (CMU) is mounted on top, and controller area network (CAN) communication provides transmission of the voltage data and temperature data. Series battery packs are equipped with a battery management unit (BMU).

The overall system uses some major components in conjunction with modules. They include BMU, contactors, current sensors, cables. Specifications of them are listed in Table 2.5 below.

An interface/controller developed by CNR will be included in order to provide to the supervisor controller the necessary registers for energy storage management. The CNR device can communicate in MODBUS/CAN protocol.

Table 2.5: Specifications of overall system components

Product name	Specification	Dimensions (mm)	Weight (g)	Remarks
BMU Battery Managent System	Upper communication: Select from Ethernet/CAN Maximum number of BMU connection: 22 *For BMU-2G, up to 56 modules can be connected	W95.0×D88.0×H32.0 (Protrusions excluded)	115	Standard type
CNR communication interface/controller	MODBUS/CAN	Aprrox 400X250X200mm	400	–
Contactor (MC)	Contact rated capacity: 800 VDC-100 A Coil rating: 12 VDC-583 mA ± 10%	W98.0×D44.0×H86.2	650	–
Current sensor (HCT)	Measurement range: -350 to 350 A High resolution	W51.4×D21.2×H71.5	67	Only for BMU-2G The CAN communication connector is to be prepared by customers
Service disconnect (SDC)	Rated voltage: 750 VDC Rated current: 120 A or lower Fuse: 750 VDC - 125 A (built-in)	W149.5×D43.9×H97.0	585	Fast acting fuse
Current leak sensor (ELS)	Ground pressure resistance range: DC ± 800 V Electric leakage detection resistance value: 500 ± 100 kΩ	W73.0×D62.0×H30.0 (Protrusions excluded)	90	–
Termination plug (TP)	125Ω ± 5% or less (Allowable loss: 1/4W or more)	Overall length: 52.5	10	Termination resistor for CAN communication

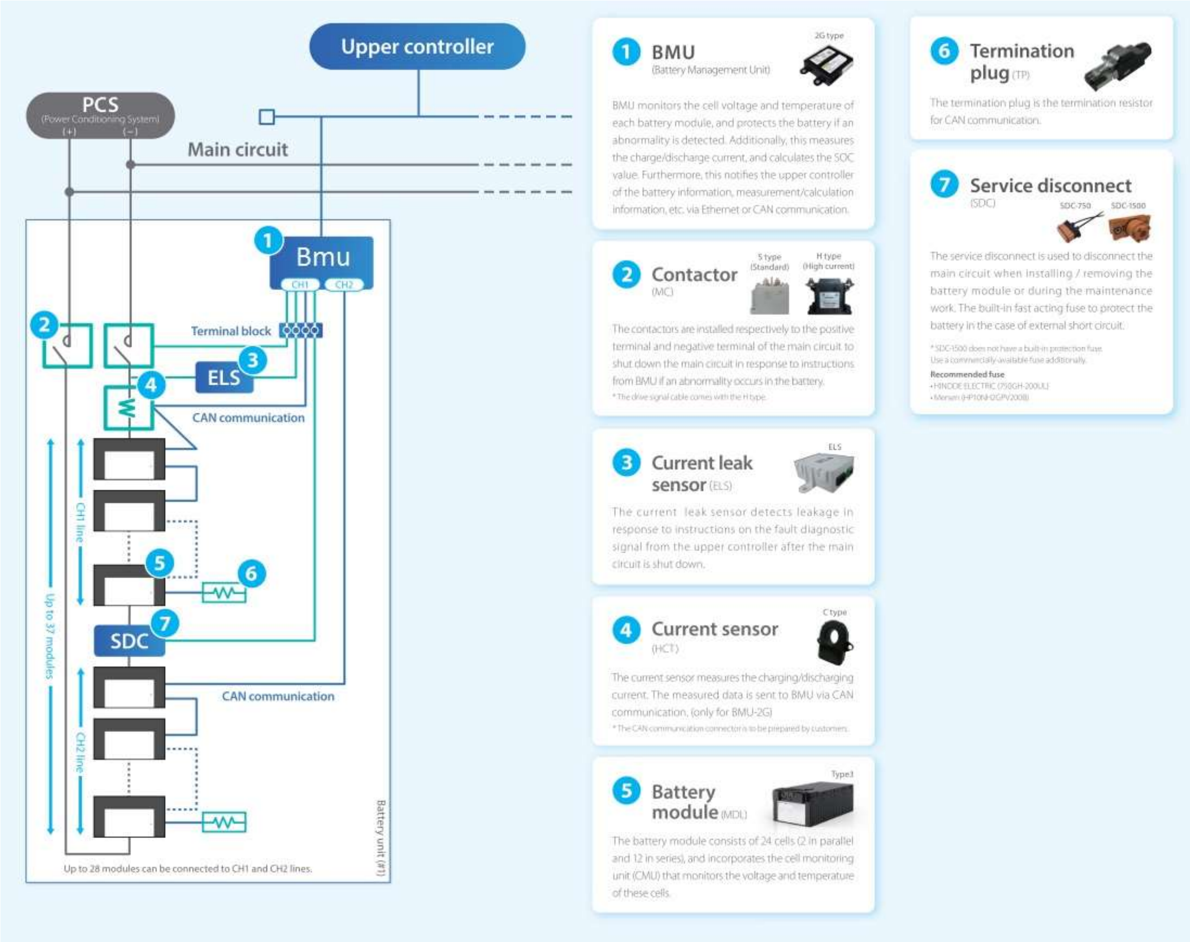


Figure 2.12: System Components

2.4 Heat pump /Chiller

2.4.1 Heat pump for the Mediterranean solution

The appliance is a water/water heat pump with water reversibility. Essentially it is a simple chiller that is also capable of heating production by the hydraulic exchange of its circuits. It can be used for remote cooling or heating, while it includes a controller for direct connection to a Modbus based BMS or to a remote server interface. Furthermore, it includes an advanced pCO^3 controller for assembly of 2 or 3 modules.

The heat pump includes a scroll compressor. Scroll compressors consist of two scrolls, one is fixed while the other orbits eccentrically without rotating. These compressors are designed for small and medium capacities and provide constant reliability and high efficiency throughout their service life.

Figure 2.13: Heat pump/Chiller for Mediterranean solution

The technical specifications of the heat pump are summarized in the following Table 2.6.

Table 2.6: Heat pump technical specifications

Hydrocube-EWWP014KBW1N	
Heating capacity [kW] @ A12/W24	16.7
Heating capacity [kW] @ A10/W35	12.9
Power input [kW]	Cooling: 3.8 Heating 3.8
COP	4.45
EER	3.44
Dimensions (unit) (mm)	600 x 600 x 600
Weight (unit) (kg)	118
Water heat exchanger-evaporator	Brazed plate
Minimum water volume in the system (l)	62
Water flow rate (min, nom, max) (l/min)	31.0, 37.0, 74.0
Water heat exchanger-condenser	Brazed plate
Water flow rate (min, nom, max) (l/min)	24, 48, 95
Compressor	Hermetically sealed scroll compressor (x 1)
Sound power level (dBA)	Cooling: 64.0
Operation range	Evaporator/Cooling: min: -10 °CDB, max: 20 °CDB

	Condenser/Cooling min: 20°CDB, max: 55 °CDB
Refrigerant	R407C (1 circuit)
Control	Thermostatic expansion valve
GWP	1773.9
Charge per circuit (kg)	1.20
Piping connections	Evaporator and condenser water drain: field installation
Space heating	average climate water outlet 55 °C SCOP: 2.88 Seasonal space heating eff. class: A+ average climate water outlet 35 °C SCOP: 3.49 Seasonal space heating eff. class: A+
Power supply	W1, Phase: 3N-, Frequency: 50 Hz, Voltage: 400 V

The main components and their interconnections are depicted in Figure 2.14.

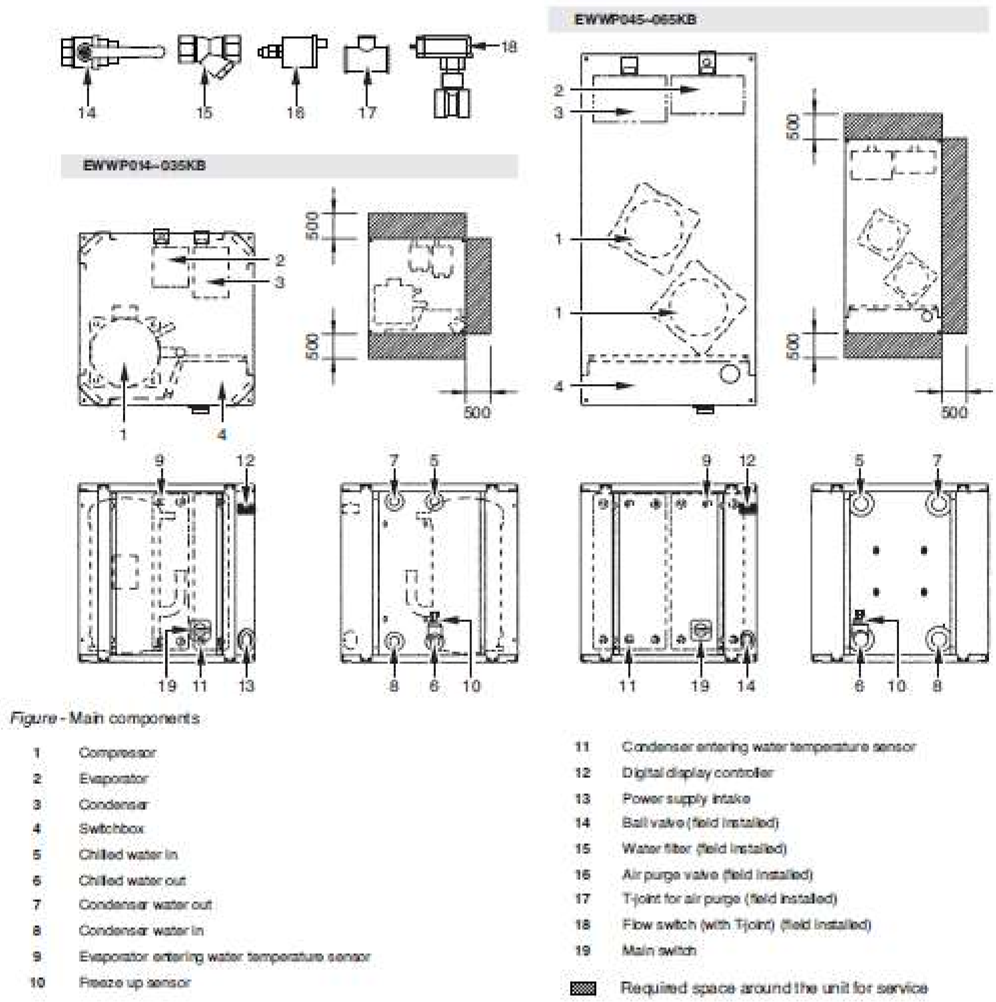


Figure 2.14: Main components of heat pump/Chiller for Mediterranean solution

As the refrigerant circulates through the unit, changes in its state or condition occur. These changes are caused by the following main components:

- **Compressor**

  The compressor (M*C) acts as a pump and circulates the refrigerant in the refrigeration circuit. It compresses the refrigerant vapour coming from the evaporator to a pressure at which it can easily be liquefied in the condenser.

- **Condenser**

The function of the condenser is to change the state of the refrigerant from gaseous to liquid. The heat gained by the gas in the evaporator is discharged through the condenser and the vapour condenses to liquid.

- **Filter**

The filter installed behind the condenser removes small particles from the refrigerant to prevent blockage of the tubes.

- **Expansion valve**

The liquid refrigerant coming from the condenser enters the evaporator via an expansion valve. The expansion valve brings the liquid refrigerant to a pressure at which it can easily be evaporated in the evaporator.

- **Evaporator**

The main function of the evaporator is to take heat from the water that flows through it. This is done by turning the liquid refrigerant, coming from the condenser, into gaseous refrigerant.

- **Water in/outlet connections**

The water inlet and outlet connection allow an easy connection of the unit to the water circuit of the air handling unit or industrial equipment.

2.4.2 Heat pump for the Continental solution

The appliance is an air/water heat pump consisting of an indoor unit and an outdoor unit. It can be used to heat a building and provide domestic hot water (DHW).

An air/water pump extracts thermal energy from the ambient air (low temperature) and transmits it together with electrical drive energy in the form of useful heat (higher temperature) to a heating and/or DHW circuit.

The heat pump consists of separated circuits linked together via heat exchangers:

- Heat source circuit (extracting heat)
- Refrigerant circuit
- Heat sink circuit (supply of heat to the central heating and/or DHW)

The operating principle of an air/water heat pump is shown in the following Figure 2.15, where the main components are presented with the following numbers:

1. Evaporator (fin heat exchanger)
2. Compressor
3. Condenser (plate heat exchanger)
4. Expansion valve
5. Heat sink (heating, DHW)
6. Air as heat source

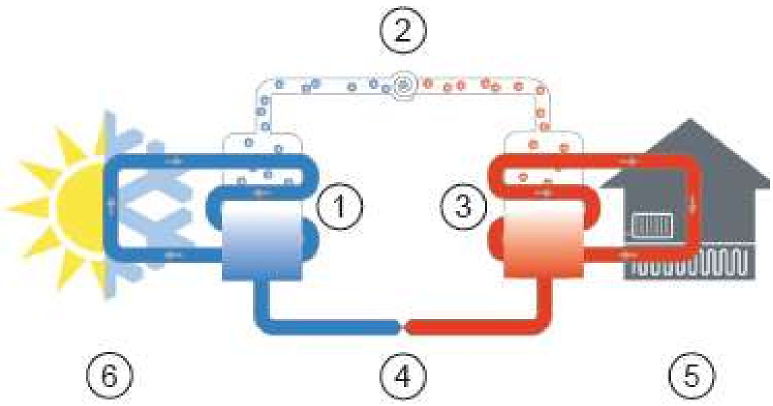


Figure 2.15: Operating principle of an air/water pump

In the following Figure 2.16 and Table 2.7, the preliminary features and specifications are reported.

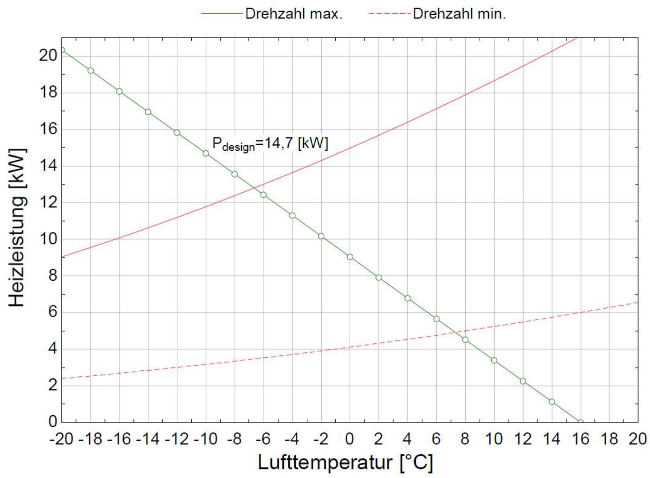


Figure 2.16: Preliminary power curve

Table 2.7: Preliminary specifications

AIR HAWK 5-18 C11A/B	
Heating capacity [kW] @ A12/W24	5
Heating capacity [kW] @ A10/W35	12
Electrical heater capacity [kW]	6
SCOP 35°C average	4,8
Refrigerant	R32
Compressor voltage supply	400V/3 ≈/50Hz or DC
Operating limits 1	A30 W62
Operating limits 2	A30 W25
Operating limits 3	A-10 W62
Operating limits 4	A-10 W25
Operating limits 5	A-25 W50
Operating limits 6	A-25 W30
Sound power level [dBA] @A7/W55 outside	49
Sound power level [dBA] @A7/W55 inside	40
Refrigerant pipe max. height [m]	15
Refrigerant pipe max. length [m]	25
Included components:	
Electrical heater	integrated
Water flow sensor	integrated

AIR HAWK 5-18 C11A/B	
Expansion vessel	24l internal
Flow valve heating/DHW	integrated
Water safety valve	integrated
Water circulation pump	integrated
Dimensions HxWxD [mm]:	
Indoor unit	1286x600x680
Outdoor unit	1080x1290x960
Weight:	
Indoor unit	approx. 135 kg
Outdoor unit	approx. 95 kg

In the following, the list of the major components is reported, specifying features and main characteristics, technical data and properties as well as performances using graphics and pictures, when available. Figure 2.17 shows the basic set-up of the system.

Figure 2.17: Basic set-up

2.4.2.1 Indoor unit

The indoor unit is intended to be installed only inside the building. It contains the compressor, which in terms of sound technology is acoustically decoupled a number of times from the casing. The casing is acoustically optimized and allows particularly quiet operation.

Figure 2.18: Indoor Unit

2.4.2.2 Compressor

The fully hermetically sealed compressor is designed for high efficiency heat pump applications. A suitable starting current limiter for the compressor is installed in the indoor unit.

2.4.2.3 Electrical booster heater

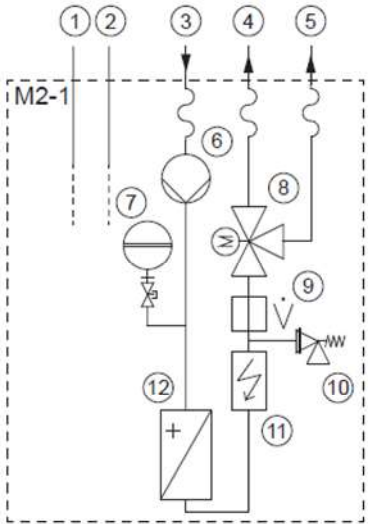
The appliance is fitted with an electric booster heater (immersion heater). At low outdoor temperatures, the appliance operates in bivalent-parallel mode. Furthermore, it can also be combined with an additional heat generator.

2.4.2.4 Condenser

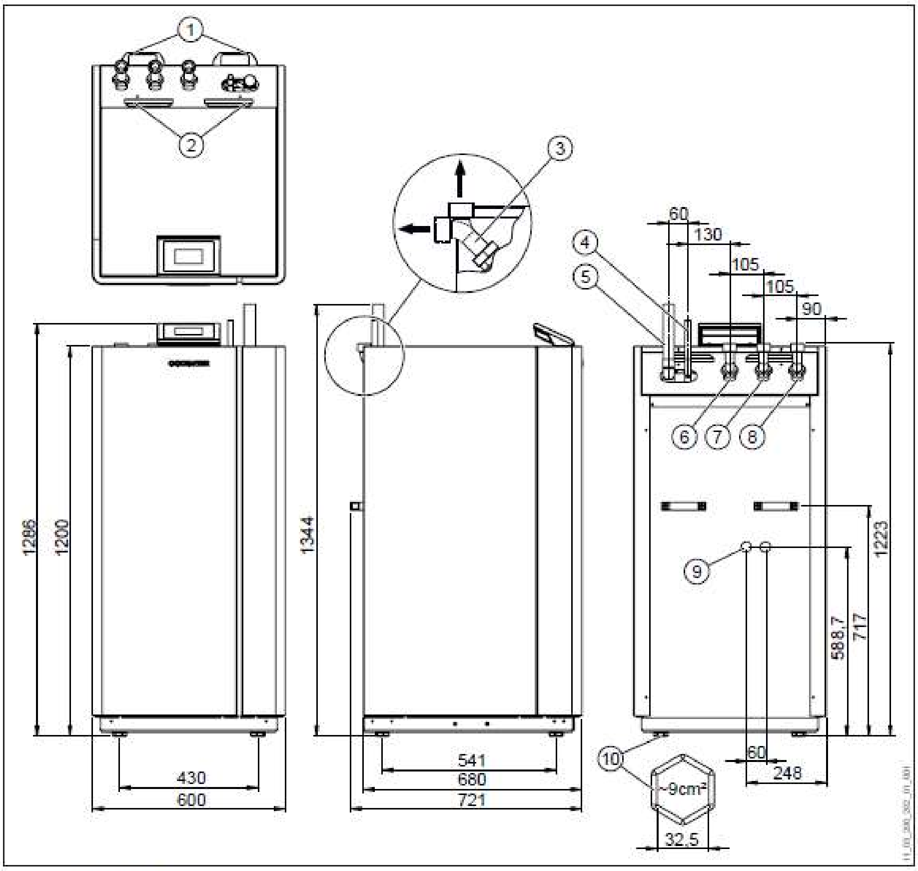
The condenser takes the form of a plate heat exchanger, which is built of stainless steel and insulated on all slides against condensation and heat loss.

2.4.2.5 Water circuit

In the following, the water circuit is shown.



1 Suction gas line
2 Liquid line
3 Heating water/DHW return
4 DHW flow
5 Heating water flow
6 Heat generator pump
7 Diaphragm expansion vessel
8 3-way switching module
9 Flow meter
10 Safety valve
11 Electric booster heater
12 Heat exchanger (heat sink side)



1 Carrying handles (removable)
2 Cable entries
3 Connections (optionally vertical with exit at top or horizontal with exit at rear)
4 Liquid line (refrigerant)
5 Suction gas line (refrigerant)
6 Heating water/DHW return
7 DHW flow
8 Heating water flow
9 Safety valve drain
10 Plastic glide (height-adjustable, 4 pcs)

2.4.2.6 Outdoor unit

The outdoor unit is intended to be installed outside. It is designed, in particular, as a horizontal split evaporator. The indoor unit is connected to the outdoor unit with refrigerant lines, along with electrical control and power supply cables.

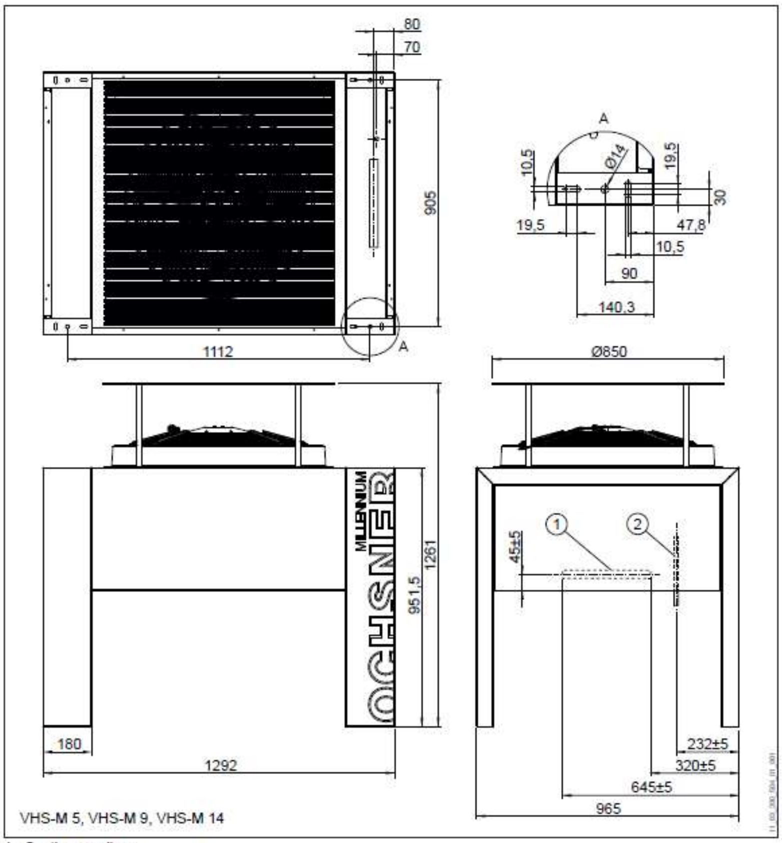
Figure 2.19: Outdoor unit

2.4.2.7 Evaporator

The evaporator is a part of the outdoor unit and consists of copper pipes in a set of aluminum fins. With an air/water heat pump, frost may form depending on the air temperature (below approx. +7 °C), air humidity and the operating point. The evaporator fins are automatically de-iced again in the cyclical defrosting mode of the heat pump.

2.4.2.8 Fan

The outdoor air is blown across the evaporator by a quiet fan.



1 Suction gas line
2 Liquid line

2.5 Renewable energy sources (RES)

2.5.1 Photovoltaic Systems (PV)

PV production is needed to provide electricity to the HYBUILD system. Main goal is to self-consume as much as possible this electricity for heat and cold usages and to improve self-production of the building. For this reason, HYBUILD system will be able to choose the best strategy between directly consume the electricity through the heat pump to heat, cool the building or to store heat into PCM storage for further usage or to directly store the electricity into a battery system. The connection to the grid could be seen as a backup system.

The following Figure 2.20 shows the electrical scheme at the base of the functioning of the PV panels.

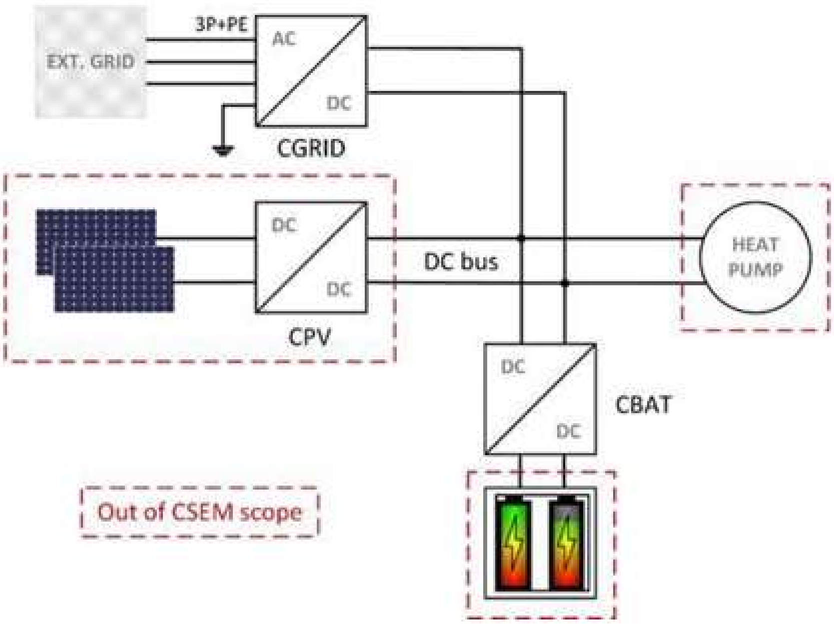


Figure 2.20: PV Electrical scheme

The particularity of the electrical system is that battery and heat pump are directly wired on a DC bus. This allow to remove one transformation stage between PV panels and the heat pump, improving efficiency of the main branch.

PV panels will be installed on a demo building in Bordeaux (demo site) characterized by a flat roof available for their installation. As no building around are higher, PV panels installed on the roof could not be seen from outside and so there are no particular aesthetic constraint.
PV panels will be mounted on a tilted self-standing system not to perforate the weather tightness layer of the building.

Figure 2.21: Example of tilted self-standing mounting system

An important component of PV panels is the PV DC/DC converter, also known as PV string optimizer that includes a MPPT function and a DC/DC inverter. Sometimes it can add management functions for direct plugging and often monitoring and connectivity functions.

Figure 2.22: Example of PV string optimizer that supply stabilized DC current for the DC bus

PV string optimizer used in the context of the project are V600 provided by Ampt (600-volt PV System Optimization, 2018), that are used to optimize new and existing 600-volt PV systems with models available up to 6.8kW maximum output power.

In addition to the PV string optimizer, the DC/AC inverter make the connection with the grid. It has to be bi-directional to supply heat pump or battery when needed or to inject excess electricity produces by PV panel on 230Vac circuits.

Finally, the DC/DC inverter for batteries will integrate all battery management functions.

The surface available to the installation of 5kWc of PV panels is 150m². Panels will be oriented to south +15° towards east and could be tilted from 5° to 45°.

The following Figure 2.23 shows the Google satellite view of the building. In red the available area for the installation of PV panels.

Figure 2.23: Satellite view of the installation building

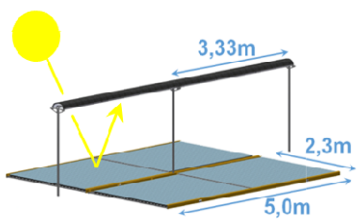
2.5.2 Concentrating Solar Collectors

The solar collector system bases its operation on a solar process heat up to 250 °C characterized by a direct steam generation, pressurized hot water and thermal oil/hot air.

Figure 2.24: Linear Fresnel Collector – Model FRX 2.1

Two different modules characterize the solar collector system: the collector unit and the mirror modules, in turn characterized by other components. The mirror module, in particular, consists of some mirrors link together with a mechanism for their joint movement.

Table 2.8: Technical data of solar collector modules

Drawing	Modules	Technical Data
	**Mirror module**	❑ Length 5.0 m ❑ Width 2.3 m ❑ Mirror surface 10 m² ❑ Total surface app. 13 m²
	Collector unit	❑ Total surface app. 26 m² ❑ Receiver height 2.5 m ❑ Total weight < 25 kg/m²

The **mirror modules** focus the sun onto a receiver pipe to generate steam. A steam drum at the end of the collector loop collects the steam and forwards the same via a pressure control unit to the steam header. The system is very well suited for upgrading an existing steam system in the industry as well as for new design concepts of production facilities.

The solar steam generation is characterized by the following properties:

- System pressure: 0-25 bar
- Steam generation 0.3-10 t/h
- 3-stage security concept
- Fully automated operation
- Remote monitoring
- Easy system integration
- No changes to existing system
- Clearly defined interfaces
- Design lifespan: 25 years

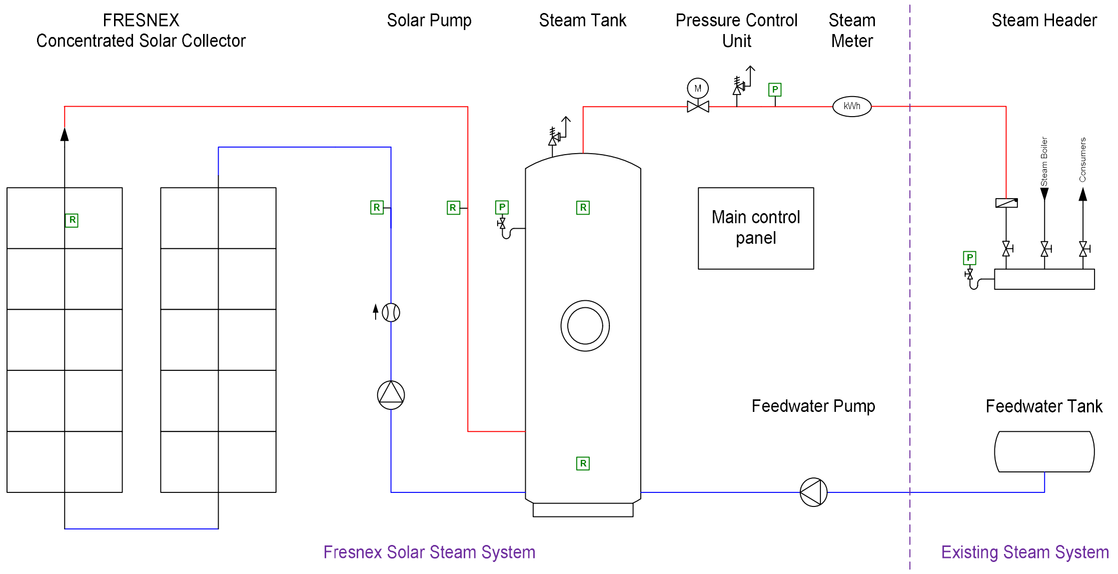


Figure 2.25: Solar steam generation

The module is also characterized by a superheated water (e.g. district heating) whose efficient application up to 150°C or more on request leads into excellent price performance ratios. The closed loop concept contains a high capacity stainless steel heat exchanger including small storage capacities to compensate solar fluctuations. In the following the main properties characterizing the superheated water:

- Highest space utilization ratio
- Simple collector piping due to
- 2.000m² per collector loop
- High temperature output
- Stagnation proof
- Patented heat exchanger
- Stainless steel components
- Remote monitoring
- Design lifespan: 25 years

Each solar mirror module includes:

- 1 Base plate characterized by a hot-dip galvanized carbon steel, including mirror support rails out of galvanized sheet metal (FVZDX51D+Z275MAC)
- 45 stripes of solar mirrors (93mm wide and 3,2mm thick) characterized by tempered, extra clear solar float-glass and silver layer for high solar reflection and solar protection coating

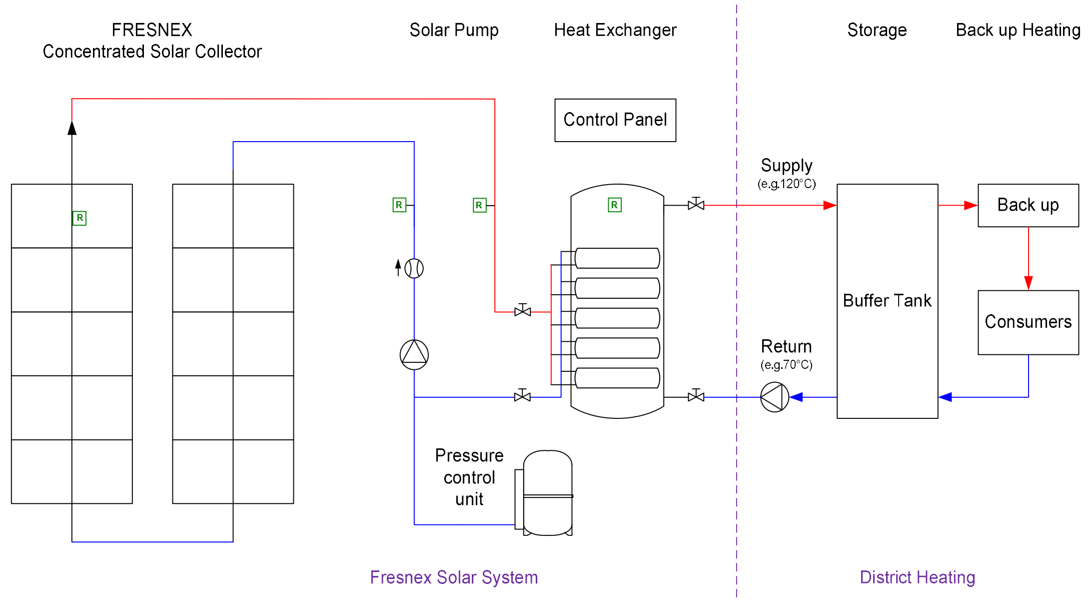


Figure 2.26: Superheated water process

The other components of the solar collector are:

- Electric drive units including mounting device
    - Electric motor (24V / 4A / 3.080 rpm) with integrated control and gear box
    - Protection class IP50 (DIN EN 60034)
    - Cable connection (signal, logic and power supply)
    - Open loop tracking based on geo-position
    - Electrical mirror positioning
    - Touch panel 5“- 23“
    - Best energy efficiency class of electrical components
    - Data monitoring and remote control (optional)
- Set of thermal receiver units (suitable for water)
- Set of thermal receiver supports

Equipment for supporting the thermal receiver to fit the above-mentioned number of solar mirror modules and thermal receiver units, with two modules focusing on one receiver line

- Control system for mirror tracking
- Control cabinet
    - For connections to electric motors (power supply and CAN bus)
    - External power supply to be provided by the customer for the control system
- Control system hardware
    - Industrial PC
    - Touch screen panel 7" (800x480 pixel)

- Software for mirror tracking
- Terminal boxes for connection of electric motors on one side and control cabinet on the other side (cable to cabinet itself is not included)
- Electric motor connection: electric cable and CAN bus connection between terminal boxes and electrical motors

The system has some key benefits: it saves costs thanks to the reduction of energy costs and easy installation (turnkey available); the space of installation can be gained from unused rooftop or land space and the use of space is modular and easily expandable; it is green in terms of reduction of CO_2 footprint and benefit from award winning image.

3 HYBUILD TARGET MARKET ANALYSIS

In the following sections, an overview of the current heating and cooling European market with a focus on the energy storage market is presented.

In particular, an analysis related to the European heating and cooling energy demand of buildings has been performed in order to assess the HYBUILD project potential.

The focus of this analysis is related to the energy demand of the residential building and energy consumption for both heating and cooling applications.

The market energy storage analysis concerns the residential electrical and thermal storage and will be further developed in the context of Task7.4 (Market Analysis & Business Model Generation).

Every year, over 40% of the total energy consumed in Europe is used for the heat generation for either domestic or industrial purposes. According to the use, the heat is supplied at different temperatures, ranging from 50 °C to more than 400 °C. The heat supplied in the residential and service sectors is mainly at low temperature and it is related to space heating, domestic hot water production and cooking.

3.1 Heating and cooling market in the European Union

Energy use in buildings represents a large part of global and regional energy demand. The importance of heating and cooling in total building energy use is very various with a share ranging between 18 % and 73 % (DianaÜrge-Vorsatz, Luisa F.Cabeza, SusanaSerrano, CamilaBarreneche, & Ksenia Petrichenko, 2015).

In 2016, the households or residential sector represented the 25.4 % of final energy consumption in the EU. Households use energy for various purposes: space and water heating, space cooling, cooking, lighting and electrical appliances and other end-uses, which mainly cover uses of energy by households outside the dwellings themselves.

In the EU, the main use of energy by households is for heating their homes (64.7 % of final energy consumption in the residential sector). Electricity used for lighting and other electrical appliances represents 13.8 % (this excludes the use of electricity for powering the main heating, cooling or cooking systems), while the proportion used for water heating is slightly higher, representing 14.5 %. Main cooking devices require 5.4 % of the energy used by households, while space cooling and other end-uses cover 0.3 % and 1.3 % respectively. Heating of space and water consequently represents 79.2 % of the final energy consumed by households.

The lowest proportions of energy used for space heating are observed in Malta (16.0 %), Portugal (21.1 %), Spain (43.3 %) and Bulgaria (54.0 %), and the highest in Luxembourg (79.9 %), Hungary (74.0 %), Belgium (73.3 %) and Lithuania (70.8 %).

	Space heating	Space cooling	Water heating	Cooking	Lighting and appliances	Other end uses
EU-28	**64.6**	**0.3**	**14.5**	**5.5**	**13.8**	**1.3**
Belgium	73.3	0.1	11.6	1.7	13.0	0.4
Bulgaria	54.0	0.4	17.4	8.5	19.6	0.1
Czech Republic	68.5	0.1	16.4	6.4	7.2	1.5
Denmark	62.5	0.0	20.8	1.8	14.7	0.2
Germany	69.9	0.2	14.3	5.7	6.6	3.3
Estonia	:	:	:	:	:	:
Ireland	61.1	0.0	18.7	2.3	17.0	0.9
Greece	56.9	4.1	12.4	6.5	20.1	0.0
Spain	43.3	0.9	19.0	7.8	29.0	0.0
France	66.3	0.2	10.6	5.5	17.4	0.0
Croatia	70.2	1.5	9.2	6.2	12.8	0.0
Italy	67.7	0.4	11.7	6.3	12.6	1.3
Cyprus	:	:	:	:	:	:
Latvia	64.2	0.0	18.8	7.2	9.1	0.6
Lithuania	70.8	0.0	9.1	6.3	13.7	0.0
Luxembourg	79.9	0.2	7.1	2.3	10.5	0.0
Hungary	74.0	0.1	12.3	4.4	9.2	0.0
Malta	16.0	6.7	24.6	12.6	39.1	1.1
Netherlands	64.3	0.2	16.3	2.2	17.1	0.0
Austria	70.2	0.0	14.6	2.7	10.1	2.3
Poland	66.4	0.0	15.8	8.1	9.7	0.0
Portugal	21.1	0.7	18.8	39.4	20.0	0.0
Romania	63.9	0.3	13.3	9.2	13.3	0.0
Slovenia	65.0	0.4	15.6	4.0	15.0	0.0
Slovakia	:	:	:	:	:	:
Finland	66.4	0.1	15.1	1.0	12.4	5.0
Sweden	55.3	0.0	15.2	1.4	17.0	11.2
United Kingdom	61.4	0.0	18.3	2.8	17.5	0.0
Norway	37.4	0.0	14.1	0.0	36.4	12.1
Serbia	61.4	0.5	13.8	7.3	17.0	0.0
Albania	32.2	5.4	21.2	29.5	11.6	0.0
Kosovo*	8.7	0.0	8.2	8.1	10.0	65.0
Moldova	69.3	0.1	10.1	11.9	8.5	0.0
Georgia	58.4	0.3	11.6	17.5	12.2	0.0

Figure 3.1: Share of final energy consumption in the residential sector by type of end-use (%) [Eurostat, 2016]

Most of the energy products are almost exclusively used for space and water heating (from 94.1 % of oil products to 100 % of derived heat); only electricity has a wider use (56.6 % for lighting, 26.3 % for heating space and water, 11.0 % for cooking and 1.1 % for cooling).

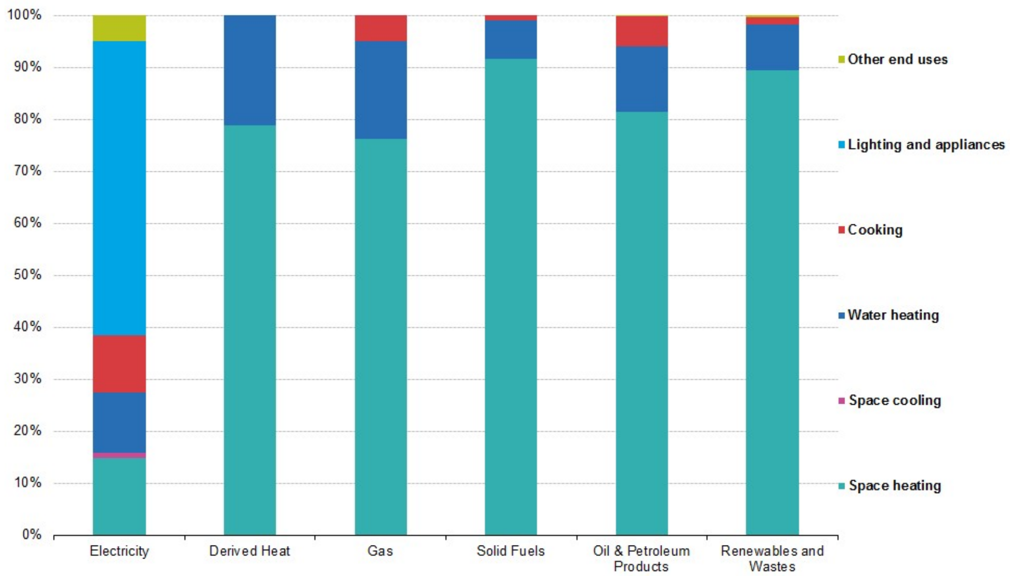


Figure 3.2: Final Energy consumption in the residential sector by type of end-uses for the main energy products [Eurostat, 2016]

Regarding space heating, eleven out of 28 EU Member States use mainly renewable energies for heating their homes; they are Portugal (72.2 %), Croatia (65.2 %) and Slovenia (59.8 %) having the largest proportion of their energy consumption for space heating covered by renewables. However, while the number of countries using principally gas for this purpose is smaller (7 Member States), most of them are among the largest energy consumers of Europe; they are the Netherlands (87.2 %), the United Kingdom (76 %) and Italy (60.6 %) being those where the proportion of gas used for space heating is the highest. Three Member states, instead, use mainly petroleum products for space heating: Malta (56.9 %), Greece (50.3 %) and Ireland (47.2 %) and two mostly rely on derived heat - Sweden (49 %) and Finland (34.5 %). Finally, one Member State (Poland) uses mainly solid fuels for space heating (45.2 %).

Space heating	Electricity	Derived Heat	Gas	Solid fuels	Oil & petroleum products	Renewables and Wastes
EU-28	**5.6**	**9.2**	**43.4**	**4.8**	**14.8**	**22.2**
Belgium	3.2	0.0	49.1	1.3	36.2	10.3
Bulgaria	8.6	15.9	3.8	12.6	0.1	58.9
Czech Republic	4.4	14.6	26.9	18.4	0.7	35.0
Denmark	3.0	37.5	15.8	0.0	4.4	39.3
Germany	1.9	10.5	46.2	1.3	25.8	14.3
Estonia	:	:	:	:	:	:
Ireland	4.0	0.0	24.5	21.0	47.2	3.2
Greece	7.5	2.0	12.7	0.0	50.3	27.6
Spain	6.7	0.0	24.4	1.0	30.8	37.1
France	13.0	3.7	38.5	0.1	18.2	26.5
Croatia	1.6	6.6	20.9	0.1	5.5	65.2
Italy	0.4	3.8	60.6	0.0	8.2	26.9
Cyprus	:	:	:	:	:	:
Latvia	0.9	36.7	7.6	1.4	2.9	50.6
Lithuania	1.2	38.8	9.2	5.0	1.3	44.4
Luxembourg	4.2	0.0	50.1	0.1	39.3	6.3
Hungary	0.8	8.2	51.0	2.6	0.2	37.3
Malta	34.5	0.0	0.0	0.0	56.9	8.7
Netherlands	1.8	3.3	87.2	0.0	0.6	7.1
Austria	6.8	14.9	22.5	0.4	20.4	35.1
Poland	0.9	20.8	14.3	45.2	0.7	18.2
Portugal	18.5	0.0	1.4	0.0	7.8	72.2
Romania	0.2	17.1	28.3	0.6	0.0	53.9
Slovenia	4.0	9.2	11.8	0.0	15.2	59.8
Slovakia	:	:	:	:	:	:
Finland	25.6	34.5	0.6	0.1	7.7	31.5
Sweden	31.1	49.0	0.6	0.0	0.5	18.9
United Kingdom	6.8	0.2	76.0	2.2	9.2	5.6
Norway	55.4	6.1	0.2	0.0	6.1	32.2
Serbia	7.9	21.2	8.4	16.3	2.7	43.4
Albania	42.5	0.0	0.0	0.0	16.5	41.0
Kosovo	100.0	0.0	0.0	0.0	0.0	0.0
Moldova	0.5	12.6	14.5	2.9	0.0	69.5
Georgia	1.7	0.0	52.6	0.1	0.0	45.6

Figure 3.3: Share of fuels in the final energy consumption in the residential sector for space heating (%) [Eurostat, 2016]

3.1.1 Focus on heating EU market

The energy consumption in the European residential sector is allocated mainly for **space heating**, accounting for 60%-80% of the total energy consumed in the sector. The Mediterranean countries in Europe have generally a low space heating demand due to the heating season with warm temperatures during winter season. The annual solar irradiation energy sum is high. In the maritime climates in Western Europe, there is a relatively long heating seasons with relatively low peaking demand. Countries such as Ireland, Belgium, Denmark and Germany have the highest space-heating share, higher than countries with colder winter seasons like Finland and Sweden. This stems from the use of less efficient technologies for insulation and heating systems than in the Nordic countries.

Eastern Europe is characterized by a high heating demand and moderately high solar irradiation, leaving good opportunities there as well. It is noted that integration with district heating in urban area can be considered here as well. Buildings in the Scandinavian countries are generally thermally well insulated, resulting in heating demands similar to those of Western European countries. However, solar irradiation is rather low.

Hot water demand is the second largest heat demand in the residential sector after space heating, accounting for around 14% of the total energy consumed in the sector in the EU. The average hot water consumption in the EU is estimated in 50 L/day per person but this number varies among the different EU countries according to the different standards of living and the number of people per household.

In addition, the activities related with domestic hot water often require higher temperatures than space heating with temperatures around 50 °C or higher compared to the 21 °C air temperature needed to heat a living space to make it comfortable.

In the heat market, most part of the useful energy comes from the direct burn of a fuel where natural gas is the major contributor for all the sectors. The contribution of the electricity in the heating market represents the 15% for the residential sector. The use of renewable energy sources, such as wind and photovoltaic, could reduce the use of primary energy avoiding the electricity generation losses of the conventional power station including biomass power station. The current contribution of the district heat is around 8% of the useful energy demand for the residential sector. The use of electric boilers and heat pumps in the district heating could allow to store, as heat, the surplus of energy generation from the intermittent energy sources such as the electricity coming from wind turbines. In addition, the importance of the recovering heat in the incineration process could imply in the middle term an increase of the use of the district heating, a decrease of the energy resources together with a better valorization of the waste in Europe.

In many Northern and Western countries, like Germany, United Kingdom, The Netherlands and Ireland, residential heating systems are operated as gas central heating systems due to the availability of natural gas sources in these countries. Commonly, these systems are integrated with supply of domestic hot water in combination with boilers or central heating systems and operate at a temperature of around 65 ºC. It is noted that, if the penetration of the seasonal thermal energy storage were to be significantly increased, it would be most advantageous if this sector were targeted.

In conclusion, since heating and cooling demand is increasing, there is a market potential for the innovative compact hybrid electrical/thermal energy storage systems. Furthermore, it is foreseen that given climate conditions, energy demand requirements and building integration characteristics, optimal hybrid electrical/thermal energy storage systems have to be developed for each application.

3.1.1.1 Energy demand for space heating and DHW

The energy demand for space heating may vary significantly from country to country, depending on the quality of the building stock and local climatic conditions. On the other hand, in the Scandinavian countries, most houses are thermally well insulated and consequently, the energy demand for space heating is not much higher than in West European countries like the UK and France. In general, however, energy demand decreases with increasing ambient temperatures, as illustrated in Figure 3.4 below.

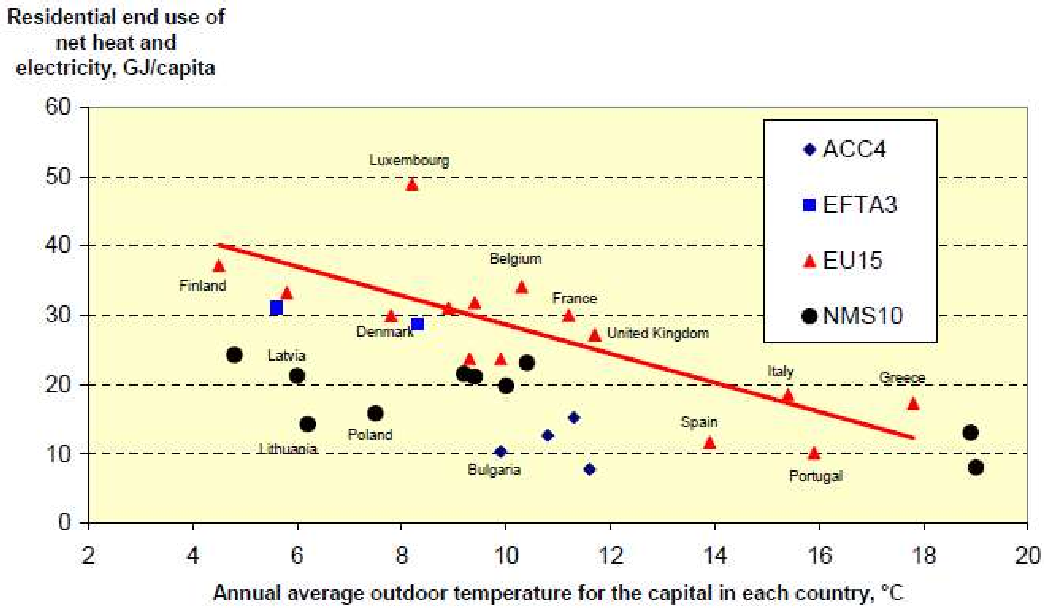


Figure 3.4: Residential energy demand vs. annual average outdoor temperature by country (Pär Dalin, 2006)

Each abbreviation shown in the above Figure 3.4 stands for a group of EU countries:

- ACC4 – Accession Countries: Bulgaria, Romania, Turkey, Croatia
- EFTA3 - European Free Trade Association: Iceland, Norway and Switzerland
- EU15 - Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, United Kingdom
- NMS 10 - New ten Member States since May 2004

All EU15 countries align well to the average line, except Luxembourg, having a high residential sector demand and a low service sector demand.

Hot water for domestic and other purposes is the second largest heat demand after space heating. While the heating demand for space heating occurs mostly in wintertime, the heating demand for DHW occurs all year round. Here, again, considerable differences in DHW consumption are found between countries in Europe. A consumption of 100 litres per day per capita corresponds to a heating demand for DHW of approx. 35 kWh/m^{2}a.

3.1.2 Focus on cooling EU market

The demand for **space cooling** is growing rapidly and it is predicted to continue growing with a rate of approximately 3.14% per year. The International Panel on Climate Change (IPCC) estimates that the demand for residential space cooling will rise from 300 TW h in 2000 to 4000 in 2050 and 10,000 in 2100.

The EU Heating and cooling strategy also foresees a strong increase in residential cooling consumption, i.e. from about 35 TW h in 2015 to 137 TW h in 2050 (Mindaugas Jakubcionis ,. J., 2017).

This growth is explained by the increase of the standards of living with the use of air conditioning systems together with the increase of the comfort requirements and the residential floor area. The electric power demand is a key indicator to estimate the increase of the cooling demand in the residential sector because the most popular technologies (the air-conditioning and chillers) operate with this energy source. Currently around 1% of the total electricity consumed by the residential sector of the EU is consumed for cooling space where the highest demand is located in the Mediterranean countries (Nicolas Pardo, 2013).

In order to analyze the potential cooling demand in European Union, it is important to know and study climatic conditions. The following figure presents the map of the EU with the mean CDD values (Cooling Degree Day) determined for each region. In the map, parts of Northern Scandinavia are omitted due to the low mean CCD values obtained and low population density.

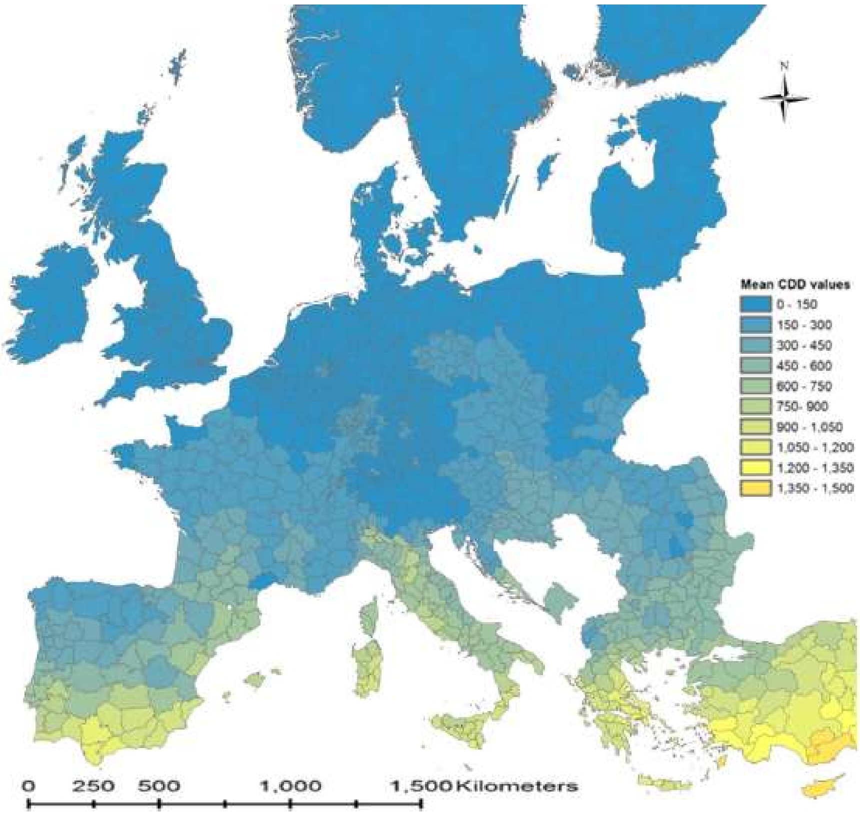


Figure 3.5: Distribution of mean CDD values in EU (Mindaugas Jakubcionis ,. J., 2017)

The highest mean CDD values were registered for Cyprus in Nicosia, but other weather stations in this region were significantly lower. This shows that climatic conditions can be local, but still have a large influence on the energy consumption.

High mean CDD values were also calculated for other stations located in Southern Europe, particularly in Malta, Southern Spain, Greece and Italy. The lowest mean CDD values were calculated for Northern and Northwestern Europe (e.g. Ireland) as well as mountainous localities in other regions.

Taking into account the CDD values, the potential cooling demand can be estimated. The lowest residential space cooling penetration is expected in Nordic (3.7% – 4.3%) and Baltic countries (4.9% – 7.3%) as well as portions of Central and Western Europe with maritime climates, such as Netherlands, Belgium and UK (4.7% – 6.9%). The highest penetration of cooling is expected in countries of Southern Europe such as Cyprus, Malta, Southern Spain, Southern Italy and Greece with 34% – 97% and Balkan region countries, such as Croatia, Bulgaria and Romania with 20% – 26% (Mindaugas Jakubcionis ,. J., 2017).

Based on the average temperatures during the last 20 years, the cooling demand potential in residential sector was estimated to be 292 TWh. The maximum and minimum number of CDDs will vary from year to year based on natural temperature variations. It was determined that the maximum cooling demand potential would be 404 TWh, whereas the minimum demand potential is 211 TWh.

3.2 The Energy Storage Market

Energy storage is a key component in providing flexibility and supporting renewable energy Integration in the energy system and can efficiently contribute to the decarbonization of buildings. The overall impact is to enhance energy savings, leading to reduced greenhouse gas emissions and fossil fuel utilization, thus contributing to the EU energy security (Energy storage , 2018).

3.2.1 Residential Electrical storage

Delta-ee and the European Association for Storage of Energy recently published their European Market Monitor on Energy Storage (EMMES) report (European Market Monitor on Energy Storage (EMMES), 2018) which indicates that in 2017 the annual electrical energy storage market grew by 49% to 589 MWh. The report analyses the energy storage installed base in the residential, commercial & industrial and front-of-meter sectors. EMMES is based upon primary research conducted in collaboration with leading companies and stakeholders, including EASE Members.

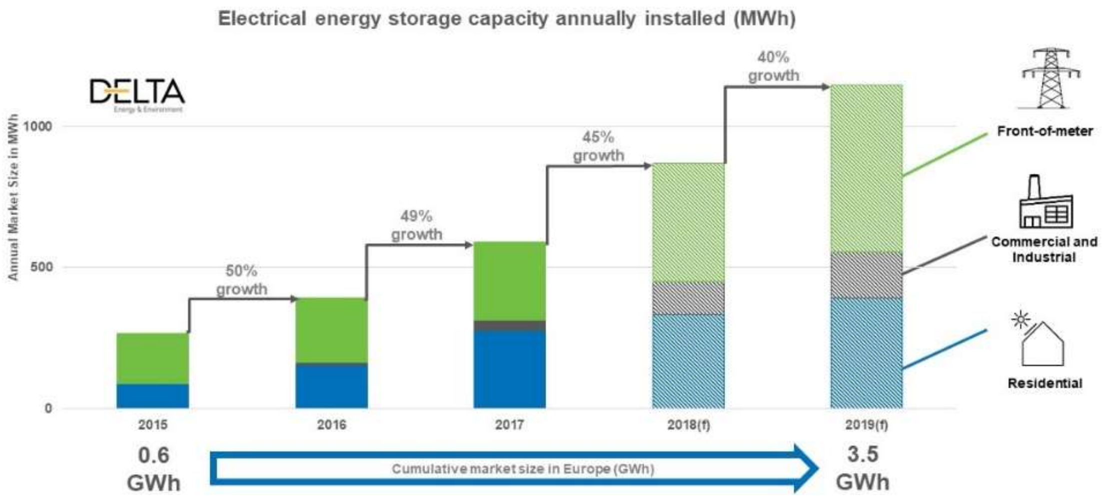


Figure 3.6: EMMES 2.0 Electrical energy storage market forecast (2015-2019)

The market analysis shows a booming market for storage technologies in key European regions, fueled by the growth in renewable energy and the attending cost reductions. Germany and the U.K. are the two most important markets for storage, which is dominated by lithium-ion batteries. Italy is also emerging as "a rapidly growing market" in the residential sector, according to the report.

It is also observed that the growth of electrical storage in the residential context can be correlated to falling costs of PV system and incremental deployment of smart meters, as well as several national incentive measures to boost PV self-consumption in the post feed-in tariff era (Jason Deign, 2017).

3.2.2 Residential Thermal storage

Thermal storage mainly exists in households through water storage tanks to provide domestic hot water on command for uses such as washing dishes, washing hands, and showers. These storage water heaters range in size from a few liters to more than a thousand, contain heating elements or burners to heat cold water and maintain its temperature before providing hot water on command to the faucet.

Less frequently, thermal storage can be used in space heating systems to store heat for a length of time. Some examples include the storage of solar energy from solar panels for overnight heating and the seasonal storage of heat for use in winter in a district heating system. In either case, thermal storage can be thought of as a “heat battery” because it stores heat energy to be released later.

While there are residential thermal storage systems in existence throughout the world, there is not a high level of commercialization. There is no industry support group and few educational materials in comparison to other heating and/or cooling systems, many of which have certification programs, training programs, and promotional materials from a centralized group (Vanessa Stevens, Colin Craven, & Bruno Grunau, 2013).

The lack of information on thermal storage, the lack of commercial options for installing a thermal storage system, the capital cost of systems and the infrastructure constraints (such as limited space in buildings being retrofitted) are some of the barriers to widespread adoption of thermal storage (Ibrahim Dinçer & Marc A. Rosen, 2011).

Although today’s thermal storage market is tiny, it is considered vital to decarbonization roadmaps, and a handful of companies are hoping to change that (Julian Spector, 2017): for instance ICE Energy with their home Ice Bear battery for cooling (Residential, 2018) or Sunamp heat batteries for heating (Residential, 2018).

3.2.3 HYBUILD Market watch

HYBUILD is focused on the promising research area of compact hybrid energy storage systems for covering space heating and/or cooling, Domestic Hot Water, and electricity demand. It will therefore conduct a market watch of the above residential energy storage markets, on one hand through the HYBUILD Flipboard (R2M Solution, 2018) (see Deliverable D7.3) being used by the Consortium to gather and share relevant articles and updates and, on the other hand, through a further developed business model and market analysis conducted in the context of Task 7.4 (Market Analysis & Business Model Generation).

4 EUROPEAN BUILDING CODES REVIEW

Energy efficiency in construction standards is universally recognized as a practical and cost-effective way to achieve energy savings in residential and commercial buildings. Across the globe, countries are independently designing and implementing energy efficiency policies and programs in residential and commercial buildings to decrease energy waste in the new building stock. Since efforts to increase energy standards in building codes are relatively disparate between countries, it is useful to analyse not only which countries seem to be designing well-crafted and comprehensive energy codes, but also which are effectively implementing and enforcing those standards (Rachel Young, 2014).

Seven target countries will be taken into account in the review, namely: Spain, Cyprus, Greece, France, Sweden, Germany, Italy. Countries have been chosen in accordance with T1.1 “Specific climate consideration and building typological classification”, in order to cover with the European building codes review, the same locations analysed in the climatic zones review.

Starting from the evaluation of building codes at European level reported in Chapter 4.1, the review moves to the seven target countries in order to understand in which way they have accepted the main European building codes.

4.1 Evaluation of building codes at European level

Buildings are responsible for approximately 40 % of energy consumption and 36 % of CO_2 emissions in the EU. Currently, 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. Therefore, more 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 lowering CO_2 emissions by about 5 %.

The **Energy Performance of Buildings Directive (EPBD)** (EUR-Lex, 2010) and the **Energy Efficiency Directive (EED)** (EUR-Lex, 2012) are the EU's main legislative instruments promoting the improvement of the energy performance of buildings within the EU and providing a stable environment for investment decisions to be taken.

On 30 November 2016, as part of the Clean Energy for All Europeans package, the Commission proposed an **update to the Energy Performance of Buildings Directive** to help promote the use of smart technology in buildings, to streamline existing rules and accelerate building renovation. The Commission also published a new buildings database – the EU Building Stock Observatory – to track the energy performance of buildings across Europe.

On 19 June 2018 Directive (2018/844/EU), amending the Energy Performance of Buildings Directive was published. Under the new and revised directive, the following requirements are established (Buildings , 2018).

- EU countries will have to establish stronger long-term renovation strategies, aiming at decarbonising 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.

4.1.1 The Energy Performance of Buildings Directive (EPBD)

The key legislative instrument to unlock the savings potential in the building sector is the Energy Performance of Buildings Directive (EPBD), accompanied by provisions for the building sector in other Directives (specifically the Energy Efficiency Directive, Renewables Directives and Eco-design and Labelling Directive) (Thomas Boermans, et al., 2015).

This is a directive on the overall energy efficiency of buildings. The European Union recognised the cost-effective energy saving potential in the building sector and thus developed the ambitious Energy Performance of Buildings Directive (EPBD).

The EPBD regulates both ‘passive’ measures for the building design and envelope, as well as the ‘active systems’, such as for heating/cooling and lighting.
The EPBD introduced certificates, which indicate the Energy Performance of the building as a numeric value, allowing for benchmarking. The certificates also include a list of cost-effective energy saving measures.

After the first version, the update Directive raised the bar to a higher level by introducing the ambitious concept of nearly-zero energy consuming buildings, by including Renewable Energy systems. After 2020, this will be mandatory for all new constructions.

The end responsibility of the implementation of the EPBD is usually with a national Ministry, like Housing, or Urban Development. The actual enforcement of the EPBD is delegated to local level through regulations and directives. Depending on the selected model, the local governments could engage private sector auditors, which are officially accredited, for the final enforcement (Adel Mourtada, 2016).

For many countries, the EPBD was the means of introducing new elements in their building codes prior to which there were no energy performance requirements concerning the building as whole or specific elements. Nearly all countries have now adopted a national methodology, which sets performance-based requirements for new buildings. For countries in which prescriptive requirements existed before 2002 (e.g. Czech Re-public, Belgium, Estonia, Bulgaria, Hungary, Ireland, Poland), there was a shift towards a holistic-based (i.e. whole building) approach whereby existing single element requirements in many cases were tightened. In some cases, the single element requirements are just supplementary demands to the energy performance requirements ensuring the efficiency of individual parts of a building is sufficient (e.g. Denmark). In others, they act as alternative methods where the two approaches exist in parallel (e.g. Spain, Poland); the first based on the performance of single elements and the second on the overall performance of a building.

The EPBD mentions specifically that the energy performance of buildings should be calculated based on a methodology, which may be differentiated at national and regional level. However, that methodology should take into account existing European standards5. 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.

Despite being an EPBD requirement, not all countries have reported specific mandatory building codes associated with improving the energy performance of existing buildings. It is important to recognise that EPBD only applies to buildings over 1000 m^2 and most Member States have introduced requirements for consequential improvements associated with buildings over 1000 m^2. It should be noted that these requirements might not be applied when they are not deemed “technically, functionally and economically feasible”.

4.1.2 The Energy Efficiency Directive (EED)

The **2012 Energy Efficiency Directive** 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 (Energy Efficiency Directive , 2018).

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 (The EU Energy Efficiency Directive , 2018).

4.2 Evaluation of building codes at country level

In the following paragraph, specific building codes of the seven countries corresponding o 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 was collected at country level to provide an overall picture of what is happening in Europe in the area of building codes.

4.2.1 Spain

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** (Plan Nacional de Acción de Eficiencia Energética 2017-2020 , 2018) 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’s 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 achieve energy savings of 20% in 330 of energy consumer’s centres of the State’s 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's general administration.

The specific measures to intensify energy savings in buildings 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 buildings 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 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 (TBC)** (Raffaele Piria, 2006), the **Regulation for Buildings' Thermal Installations 2007** (Reglamento de Instalaciones Térmicas de los Edificios, 2018) and the **Regulation for Energy Efficiency Certification 2007**.

4.2.1.1 The Technical Building Code

The Technical Building Code is organised in six sections; DB HE is the section referred to energy performance that is divided in the following sub-sections:

- HE1 (energy need limitation),
- HE2 (efficiency in HVAC)
- HE3 (efficiency in lighting)
- HE4 (minimum contribution of RES: solar thermal energy for DHW)
- HE5 (minimum contribution of RES: solar photovoltaic in tertiary buildings)

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 m^2, 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.

The following Table 4.1 provides a summary of the main information characterizing the Technical Building Code.

Table 4.1: The Technical Building Code - Spain

Original Title	Código Técnico de la Edificación
English Title	**Spanish Technical Building Code**
Publication Year	2006
Document Type	☒ Laws, regulations, codes with legal status ☐ Professional standards (mandatory) ☐ Good practice guidelines or recommendations
Status	☐ Draft ☐ Approved (but not yet in force) ☒ Approved and in force
Countries / regions of enforcement	Spain
Document Summary	The Spanish Technical Building Code (TBC) is the normative framework that establishes the safety and habitability requirements of buildings set out in the Building Act (LOE). To promote innovation and technological development, the TBC has adopted the most modern international approach to building norms: Performance-Based Codes or objectives. The use of these new regulations based on performance calls for the configuration of a more flexible environment, easily updated in accordance with the development of techniques and the demands of society, and based on the experience of traditional norms. Spanish society increasingly demands building quality, which means satisfying certain basic requirements both with respect to safety and aspects linked to human welfare. Other basic technical regulations, such as the EHE (concrete regulation), will coexist with the TBC and, in principle, will be external references to the code.

	The statutory regulations for industrial safety which are dependent on other ministerial departments and that affect installations which are incorporated into buildings, will be given specific consideration. European regulations will be regarded as basic documents whose consideration will be mandatory in drawing up the TBC. The TBC, as stipulated in the LOE, may include other norms as dictated by the competent authorities.
Comments	First law in Spain (and Europe) foreseeing the mandatory use of solar thermal installations in buildings (hot water demand).

4.2.2 Cyprus

The residential sector represents the 23% of the final energy consumption in Cyprus and 35% of the final electricity consumption.

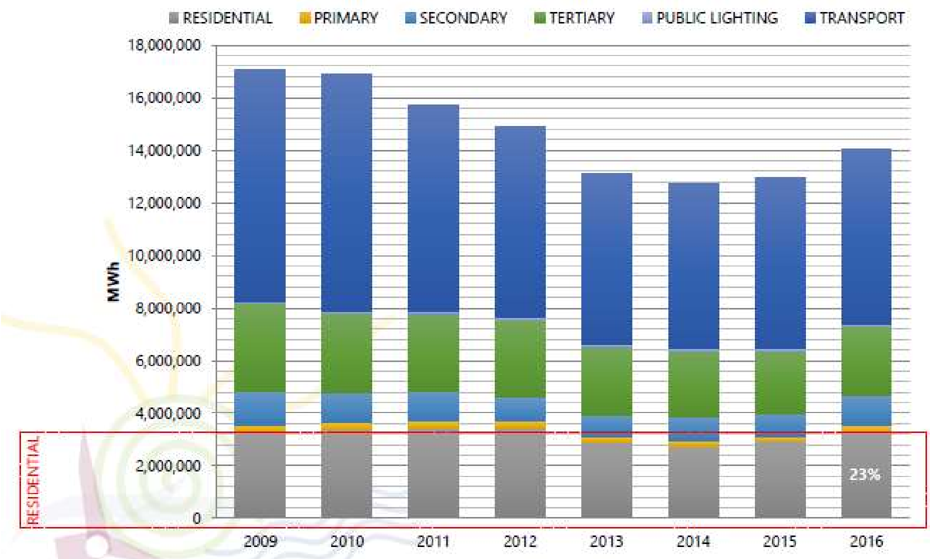


Figure 4.1: Final Energy consumption in Cyprus

Regulations for the energy performance of buildings are in compliance with the EPBD directive 2002/91/EC. Minimum energy efficiency requirements for new buildings have been set.

The Cyprus reference residential building includes all the minimum technical characteristics such as the building shell thermal code, energy efficiency of HVAC equipment, mandatory installation of solar thermal system for hot water, provisions for the installation of a photovoltaic system. A national calculation method named SBEMCY based on a reference building has been developed and is applied to prove and get a building permit that a new building passes the minimum requirements (B class building) and also for the issuance of the energy performance certificate.

New legislative regulations for the mandatory inspection of boilers and air conditioning systems have been enacted. Due to the hot climate conditions, the use of split air conditioning units is standard in Cyprus and therefore air conditioning constitutes a significant part of electricity consumption and maximum power demand during peak seasons.

Since the solar potential of Cyprus is one of the highest in the EU, the installation of solar energy technologies (solar thermal, PV, concentrated solar power) is a priority and the main way to comply with the overall RES targets (Kyriakos Kitsios & Dr. Theodoros Zachariadis , 2012).

All the national legislations on Energy Efficiency of Buildings are adoption of the following relevant European Directives (Savvas Vlachos, 2017):

- The first regulation for thermal insulation of buildings introduced from 2007
- The "Energy Performance of Buildings" law introduced in 2009, from which various regulations have been implemented
- From 2010 the Energy Performance Certificate (EPC) is obligatory for all new buildings and for all the buildings that are available for sale or rent
- The definition for the near Zero Energy Building (nZEB) was introduced in 2014
- All new buildings must be nZEB from the 01/01/2021

The most important legislative measures for the energy upgrading of existing buildings relate to the provisions of the Regulation on the Energy Performance of Buildings Laws of 2006 to 2017 and the regulatory and administrative acts adopted on the basis thereof. The minimum energy performance requirements include requirements for existing buildings.

The first decree on the minimum energy performance requirements, as adopted in 2007, provided for the mandatory energy upgrading only of buildings with a floor area of more than 1000 m^2 undergoing major renovation, as it required that the same level of thermal insulation should be installed on the building envelope elements as that required for a new building. The minimum requirements were amended in 2009, adding the requirement for issuing energy performance certificates with a minimum class B for buildings with a floor area of more than 1000 m^2 undergoing major renovation.

A new decree was adopted in December 2013, reducing the U-values by 15 % both for buildings with a floor area of more than 1000 m^2 undergoing major renovation and for the building elements that are installed subsequently or are replaced irrespective of the size of the building.

As of 1 January 2017, all buildings undergoing major renovation must be classified under energy efficiency class B (Aikaterini Piripitsi, et al., 2017).

4.2.3 Greece

There are several documents in Greece that regulate the Building Code. The main legal framework for buildings is defined in the Building Regulation (M.D. 3046/304/1989, ΦΕΚ 59/Δ/3.2.89) for the construction of buildings, and the Generic Building Regulation (Law 4067/4-2012) mainly for the terms of building (Jorge Escribano Troncoso, 2015).

Transposition of the European Directive on the energy performance of buildings (EPBD) in Greece was enacted in 2008 by a national law, the Greek Law 3661/2008 "Measures for decreasing the energy consumption of buildings".
A follow-up regulation on the energy performance in the building sector is represented by the **Energy Performance Regulation for Buildings (KENAK)**, released in 2010**.**

It refers to the energy performance of new buildings as well as existing buildings under specific conditions. In particular, the regulation defines the methodology for the calculation of the energy consumption of buildings, sets the minimum energy performance requirements and prescribes the issue of an energy performance certificate, the inspection of boilers and air-conditioning systems and the implementation of a national body of energy inspectors, in compliance with the European Directive 2002/91/EC.

According to the regulation KENAK, the reference building is naturally ventilated. The ventilation requirements for buildings set by KENAK are differentiating according to the use and type of building. For tertiary buildings, or buildings with mechanical ventilation, the ventilation system of the reference building should have the following prerequisites:

- ventilation according to the maximum expected number of people and the minimum quantity of air per person
- mechanical ventilation system is included by heat exchanger with a heat recovery coefficient (nR=0,6)
- for the reference building the absorption power is set at 1,0 kW(m^3/s)

The implementation of the EPBD (Energy Performance of Buildings) Directive 2002/91/EC was incorporated into the national legislation with the Law 3661/2008 in 2008 but officially was implemented in July 2010 with the publication of the new Energy Regulation (ΦΕΚ Β' 407 2010) and the respective Technical Guidelines formulated since January 2011 (Guidelines of Technical Chamber of Greece) (Marianna Papaglastra & Kyriaki Papadopoulou, 2009).

Table 4.2: The Regulations for Energy Performance of Buildings - Greece

Original Title	Κανονισμός Ενεργειακής Απόδοσης Κτιρίων (ΚΕΝΑΚ)
English Title	**Regulation for Energy Performance of Buildings (REPB)**
Publication Year	2017
Document Type	☒ Laws, regulations, codes with legal status ☐ Professional standards (mandatory) ☐ Good practice guidelines or recommendations
Status	☐ Draft ☐ Approved (but not yet in force) ☒ Approved and in force
Countries / regions of enforcement	Greece
Document Summary	The REPB introduces integrated energy planning in the building sector with the aim of improving the energy efficiency of buildings, saving energy and protecting the environment, with specific actions: • Elaboration of Energy Efficiency Study of Buildings • Adopt minimum energy performance requirements for buildings • Energy Classification of Buildings (Energy Performance Certificate) • Energy Inspections of buildings, boilers and heating and air-conditioning installations The Energy Performance Certificate includes, among others the results of the energy inspector's evaluation and recommendations for improving the energy performance

	of the building so that consumers can compare and assess their actual consumption and potential for improving energy efficiency. Energy Inspection is an important tool for diagnosing the energy status of existing buildings, their energy rating, and the potential for improving their energy status. Classification of the building in an energy class is based on the ratio of building consumption to the consumption of the reference building. The audit of the correct implementation of the institutional framework is carried out by the Energy Inspection Departments of the Special Secretariat of the Corps of Inspectors and Auditors.
Comments	Certain categories of buildings, such as monuments, sheltered buildings, worship centers, industrial sites, crafts, laboratories, temporary buildings and individual buildings with a total area of less than fifty square meters (50 square meters), are exempted from the requirement to issue an Energy Performance Certificate.

4.2.4 France

In France, there is a long-term objective established by the French energy law in 2005, known as "*Facteur 4*", to reduce greenhouse gas emissions by a factor of four by 2050, when compared with the emissions level of 1990. The latest French law is the "Energy transition for Green Growth Act" (La transition Energétique pour la croissance verte) – July 2016 (Loi de transition énergétique pour la croissance verte, 2016).

As the construction sector accounts for 44% of France's final energy consumption, the Environment Round Table has set very ambitious targets for new and existing buildings.

New buildings should be energy positive by 2020, whilst for existing building stock, a 38% reduction in primary energy consumption has been set with the objective to achieve an average specific energy consumption of 150 kWh_{ep}/m^2/year in primary energy terms by 2020, compared with a current average of 240 kWh_{ep}/m^2/year. To achieve this goal a massive programme of major renovation must be implemented and the target is to achieve 400 000 renovations per year over the period 2013-2020. Further, a range of diversified instruments is being mobilized such as regulations, financial incentives, training, information and awareness raising.

Regarding the EED requirement for the annual renovation rate of 3% in central Government buildings, the renovation should achieve a reduction of at least 40% in energy consumption and 50% in greenhouse gas emissions in the State building stock by 2020.

In France, the building code reference document is the **2012 Thermal Regulation (RT)** (Thermal Regulation 2012 (RT 2012), 2018), which replaces the RT 2005. The new document strengthens requirements concerning the thermal performance of new buildings. In particular, all new buildings with a building permit lodged after 1 January 2013 must have a specific energy consumption in primary terms below a threshold of 50 kWh_{ep}/m^2/year, including space heating, cooling, lighting, domestic hot water and auxiliary equipment (pumps and fans). This requirement applied earlier, from 28 October 2011, in the case of public and service buildings.

For major renovation of buildings more than 1000 m² that costs more than 25% of the value of the building, excluding land cost (e.g. 322 €/m² for dwellings and 275 €/m² for non-residential buildings (cost without taxes)), the global Thermal Regulation sets a global energy performance target for renovated buildings, built after 1948. The target is for dwellings to reach a consumption between 80 and 195 kWh/m²/year between 2005 and 2010 and a range of 80-165 kWh/m²/year since 2010 compared to an average of 240 kWh/m²/year for the existing stock. The range depends on the climatic zone and heating fuel. For non-residential buildings, the savings should be of 30%.

For major renovation of buildings less than 1000 m^2, or buildings more than 1000 m² undergoing minor renovation, the element-by-element Thermal Regulation sets a minimum performance level for elements replaced or installed: this concerns, in particular, insulation, heating, hot-water production, cooling and ventilation equipment.

In case of existing buildings, the Thermal Regulation aims to ensure significant improvement in the energy performance when a contracting authority undertakes work with potential for such an improvement. The applicable measures, the global Thermal Regulation and the element-by-element Thermal Regulation, differ according to the scale of the work undertaken.

4.2.5 Sweden

Sweden has a long history of energy efficiency requirements for buildings, with the first prescriptive requirements being implemented in 1946. Sweden started the implementation of the EPBD in October 2006 by taking the national law SFS 2006:985 into force. The certification of new buildings became mandatory in January 2009. All buildings over 1000 m^2 and rented buildings (both residential and non-residential) and public buildings have to be provided with energy certificate not older than 10 years (Antoni Broda, 2012).

The Swedish authority for building and planning is called Boverket, which is involved in planning and urban development, building and housing activities.

The **Boverket's Building Regulations – mandatory provisions and general recommendations, BBR** (BFS 2011:6 with amendments up to BFS 2016:6) (Boverket´s building regulations – mandatory provisions and general recommendations, BBR, 2016) sets mandatory overall performance demands for dwellings and non-residential buildings that depends on the location and type of heating system 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. Compliance is achieved through measuring the actual energy use of the (occupied) completed building and showing it to be less than or equal to the allowable energy frame.

The Building regulations aim to ensure that newly constructed buildings meeting essential technical requirements as well as environmental goals, such as that of a "Good built environment." Regarding energy use, building regulations require new construction to limit energy use through low heat losses, low cooling requirements and efficient heating, cooling and electricity usage.

4.2.6 Germany

The energy concept of the German government, decided and published in 2010, sets various targets in the field of rational energy use, energy savings and increasing the use of renewable energy. One of the main targets concerning the building stock is to have an almost climate neutral building stock by 2050, mainly by reducing heat demand and providing the remaining energy through renewable sources. To achieve such a reduction in energy demand the rate of building renovation shall be doubled and the heating demand shall be reduced by 20 % by 2020. In addition, by 2050 Germany aims to reduce overall primary energy demand by around 80 %.

The energy concept of the German Government has established that a renovation roadmap for existing buildings will be developed starting in 2020, built on the current renovation cycles for existing buildings and mapped out a systematic approach for the building stock to reach the target of an 80% reduction of primary energy demand by 2050.

In order to achieve a public buildings' renovation rate of 3 % as defined by the Energy Efficiency Directive (EED), the federal authority for real property administration (*Bundesanstalt für Immobilienaufgaben, BImA*) holding more than 4.700 civil and military properties, has decided to work with the German Energy Agency to establish a renovation roadmap for the federal properties. The roadmap comprises the order and the technical level of the renovations until 2050.

In terms of proposed or scheduled legislation affecting requirements for energy performance of buildings, the draft of the Energy Savings Ordinances (EnEV) recast comprises an average reduction of maximum primary energy demand by 12.5 % for new buildings compared to the previous standard. Requirement on existing buildings as well as on maximum heat transfer are not tightened. Distribution and control mechanisms around the energy certificate shall also be enhanced in the revised ordinance.

The minimum energy requirements for residential and non-residential buildings, both in terms of new buildings and rehabilitation of existing ones, are regulated by the **German Energy Saving Ordinance** (German Energy Saving Ordinance (EnEV), standards and laws, 2018) (*Energieeinsparverordnung*, hereafter EnEV), the German counterpart of EPBD.

For new buildings, the EnEV lays down maximum building-specific levels of primary energy demand and the required energy performance of the building envelope (expressed in maximum values of the specific transmission heat loss related to the heat transmitting surface area). The requirements (maximum levels) are defined by means of a reference building, which corresponds to the real building in terms of geometry, net floor area, orientation and utilisation.

For the renovation of buildings, the EnEV sets component-specific minimum efficiency requirements, which have to be complied with when it is necessary to change or modernize a building component (e.g. the roof, the windows or the exterior wall). However, there is no obligation to conduct upgrade measures. This means where no renovation takes place there is no requirement to fulfil any performance standard at all (with the exemption of some obligatory refurbishment measures such as the insulation of the heat distribution and hot water pipes as well as fittings or the insulation of top floor ceilings).

Major renovations meet the EnEV standard if the refurbished building (residential and non-residential) does not exceed the annual primary energy demand of the corresponding (new) reference building and the maximum value of the specific transmission heat loss related to the heat-transmitting surface area of the reference building by more than 40%. In case of single measures, modifications are to be designed in such a way that specific heat transfer coefficients of the exterior components are not exceeded.

4.2.7 Italy

With regard to energy efficiency, Italy aims to overcome the 20% European target with an expected savings of up to 24%.

In accordance with the current version of the New National Energy Strategy, the Italian Government aims to:

- reinforce the actions that can affect the high energy saving potential unexploited (building included) and to strengthen the control and sanction mechanisms, making them consistent across all regions
- introduce instruments for the direct stimulation of energy efficiency measures in public administration (which, by the well-known budget constraints and lack of access to tax deductions, it is not able to exploit the full potential of energy savings)
- stimulate actions on energy planning and sustainable urban development, with the aim to enable innovative models of urban planning and energy flows, grid efficiency , mobility and upgrading of the building stock
- adopt plans for sustainable development of renewable energy sources.

Regarding the development and implementation of renovation roadmaps (or long-term strategies), there has been, in recent years (Finance Act 2007 and following Finance Acts) a national incentive mechanism for the renovation of residential building (covering large part of the energy consumption of the Italian building stock). It allows building owners to recover 55% of the investment costs (with maximum limits) in 10 years within the income declaration procedure. This mechanism, positively judged by ENEA, the Italian National Agency for New Technologies, Energy and Sustainable Economic Development, has been renewed for 2013 but there are no guarantees about further renewals (Amalia Martelli, 2010).

Concerning the EED target to renovate 3% of public central building, no specific and well-defined measures are there. Given the historical value of many of these buildings, it will be complicate to implement effective renovation actions.

Regarding Italian building codes, the Decree law 192/2005 was updated by the **Decree Law 311/2006**, which proposes (for five Italian climatic zones):

- revised values for maximum U-values for the various opaque and transparent components of the building envelope
- minimum average seasonal thermal efficiency of the heat generation system
- maximum annual total primary energy consumption for space heating expressed as a function of S/V ratio and HDD and referred to heated net floor area for residential building (while to heated net volume for other building uses). These requirements are applied to new buildings and major renovation of buildings with a floor area greater than 1000 m^2.

With the D.P.R. of 24 February 2009, maximum annual total primary energy consumptions for space cooling have been introduced. Additional requirements for new buildings and major refurbishment:

- for new buildings and refurbishment is obligatory to install a solar thermal plant designed to cover at least 50% of the thermal energy consumed annually to produce DHW

- Since June 2012 (Dlgs n. 28/2011), it is mandatory to cover 20% of thermal energy uses with thermal RES systems and to install 1 kW of electric renewable systems for every 80 m^2 of floor area.

Another important national building code is the **Decree for energy efficiency requirements in buildings (2015)** (Decreto interministeriale 26 giugno 2015 - Applicazione delle metodologie di calcolo delle prestazioni energetiche e definizione delle prescrizioni e dei requisiti minimi degli edifici , 2018). The Ministerial Decree 26 June 2015 completes the transposition of the European Directive EPBD 2002/91/CE, and modifies the Decree 192/2005. This legislative measure comprises three different decrees. The first one ("Application of calculation methodologies for energy performance and definition of buildings minimum requirements") also defines the requirements of nearly zero energy buildings and set the new minimum EP and single component requirements. A new calculation methodology for the energy performance is introduced, based on the comparison with a reference building having the characteristics set in the decree. All energy use needed to comply with the standard use of the building is included in computation of the energy performance of the building, which is referred to different classes.

In the second decree ("Reference scheme for the technical project reports to apply buildings minimum requirements"), the format for technical project reports is defined, relative to new and nearly zero energy buildings, relevant retrofitting and technical installations.

The last decree ("Upgrade of national guidelines for energy certification of buildings") includes the national guidelines for Energy Performance Certificates (EPC). A unique information system harmonising Energy Performance Certification in the different regions was also set for all Italian regions, aimed at the management of a national registry of EPC and thermal installations, to be created by ENEA and the Regions by the end of 2015 (Codes, 2018).

4.3 HYBUILD results toward EU expectations

In response to the European building codes described above, the HYBUILD solution will contribute to generate substantial impacts. The following Table 4.3 summarizes and compares those expected impacts to the European expectations in terms of the main European building codes, in order to evaluate the HYBUILD performances and benefits.

Overall the HYBUILD solution will generate substantial impacts, more than those expected by the main European building codes. In particular, the target contributions to these expected impacts are:

- simple payback period of about 8 years for buildings non-connected to DHC and 15 years for building connected to DHC
- great potential for replication and market penetration leading to up to 167B€
- lifetime expectancy of the solution of at least 20 years
- easy installation and compact storage concepts with required volume less than 1,5 m^3 for non-connected and less than 1 m^3 for connected buildings
- expected energy reduction ranging from 20% to 40% depending on the configuration and contexts
- contribution to the electricity grid flexibility and ability to respond to diverging generation and consumption profiles
- total primary energy savings of 44.6% and CO_2 emissions reduction of 37.4% at EU building level.

Table 4.3: State of the art and HYBUILD targets in comparison

#	HYBUILD Impacts	HYBUILD Target	EU Expectations	
			EPBD	EED
1	Cost-effective overall energy storage solutions supported by advanced economic and business models for investors	Great technical performances	✓	✓
		Simplicity of integration	✓	
		Reduced investment and maintenance costs	✓	✓
		Energy savings guaranteed of 30-40%		✓
		Reduction of ROI		
2	Market penetration with high replicability potential of robust hybrid storage solutions	Technology and tools close to the market		
		Targeting different market sectors		✓
		Easy to install		✓
		Little space required		
3	Ensured extended solution life time	Extended lifetime expectancy of technologies and solutions		✓
4	Easy to integrate and compact solutions into existing buildings/systems	Increased material energy savings	✓	✓
		Sorption module size of about 0,25-0,3 m^3		
		The latent storage will not exceed the 0.20 m^3		
		Hybrid storage system would not exceed 1.5 m^3		
5	Superior energy performance contributing also to the energy system flexibility	Increase of the electrical COP of about 50% compared to a simple configuration		
		Increasing in electrical COP up to 70 - 80%		
6	Reduction of building energy consumption and greenhouse gases	Reduction of primary energy by 44.6% per year	✓	✓
		Reduction of CO_2 emissions by 37.4% per year	✓	✓

5 NATIONAL AND REGIONAL CERTIFICATION SYSTEMS ANALYSIS

The following paragraph explores energy performance certificates across Europe finding that the Energy Performance Certificates (EPC) is one of the most important drivers of energy performance of the European building stock.

5.1 Certification Strategies at Building level (Overall HYBUILD solution)

Buildings have extensive direct and indirect impacts on the environment. During their construction, occupancy, renovation, repurposing, and demolition, buildings use energy, water, and raw materials, generate waste, and emit potentially harmful atmospheric emissions. These facts have prompted the creation of green building standards, certifications, and rating systems aimed at mitigating the impact of buildings on the natural environment through sustainable design (Stephanie Vierra, 2016).

Certification is an independent confirmation by an expert third party that a product, system or service meets, and continues to meet, appropriate standards. Indeed, a certification distinguishes products and services from their competitors, and gives customers confidence about their performance.

Energy certification of buildings is a key policy instrument that can assist governments in reducing energy consumption and improving the energy performance of new and existing buildings. It provides decision makers in the buildings industry and the property marketplace with objective information on a given building, either in relation to achieving a specified level of energy performance or in comparison to other similar buildings. As such, certification can help governments achieve national energy targets and enhance environmental, social and economic sustainability in the building sector.

Direct benefits associated with building certification schemes include:

- Energy and CO_2 emissions reductions and broader environmental benefits
- Increased public awareness of energy and environmental issues
- Lower costs for users
- Improved data on buildings, which can be used for future policy development to further improve energy efficiency in the building stock.

Certification can be applied to both new and existing buildings. For new buildings, energy certification can demonstrate compliance with national building energy regulations and provide an incentive for achieving a better standard compared with buildings of the same type. For existing buildings, energy certification attests to the energy performance of the building, and provides information that may increase demand for more efficient buildings, thereby helping to improve the energy efficiency of the building stock in the country.

The **Energy Performance Certificate (EPC)** was introduced for the first time in the Energy Performance of Buildings Directive (EPBD) in 2002, and in 2010, the EPBD recast added a set of new requirements to improve the quality, usability and public acceptance of EPCs.

The main aim of the EPC is to serve as an information tool for building owners, occupiers and real estate actors. Therefore, EPCs can be a powerful market tool to create demand for energy efficiency in buildings by targeting such improvements as a decision-making criterion in real-estate transactions, and by providing recommendations for the cost-effective or cost-optimal upgrading of the energy performance (Aleksandra Arcipowska, Filippos Anagnostopoulos, Francesco Mariottini, & Sara Kunkel, 2014).

Energy performance certification provides a means of rating individual buildings – whether they be residential, commercial or public – on how efficient (or inefficient) they are in relation to the amount of energy needed to provide users with expected degrees of comfort and functionality. The degree of efficiency depends on many factors including:

- Local climate
- The design of the building
- Construction methods and materials
- Systems installed to provide heating, ventilation, air condition or hot sanitary water
- The appliances and equipment needed to support the functions of the building and its users.

Certification is a complex procedure, requiring in-depth knowledge of building components. It also reflects increasing recognition of the need to think of buildings as "integrated systems", rather than simply the sum of their parts.

Apart from EPC, from the analysis of the existing market for certification schemes for buildings in the EU, it can be concluded that the European countries can be divided into two blocks (Koen Rademaekers, 2014):

1. Countries where voluntary sustainable and energy certification schemes have been developed (some of which are used internationally) in addition to the Energy Performance Certification (national EPC) rating system required by the EPBD, and
2. Countries where voluntary certification schemes have not been developed, and which to a large extent utilise the mandatory EPC certification scheme system required by the EPBD and make limited use of additional voluntary sustainability certification schemes.

The following Table 5.1 shows countries which have developed voluntary building certification schemes.

Table 5.1: National certification systems developed by some European countries

Country		National certification system
	UK	BREEAM
	France	HQE, E+/C-
	Germany	DGNB, DE-BREEAM, Passivhaus
	Denmark	DK-DGNB
	Sweden	SE BREEAM

Country		National certification system
	Italy	Casa Clima, ITACA
	Portugal	LiderA
	The Netherlands	NL BREEAM
	Spain	ES-BREEAM, Verde
	Austria	AT-BREEAM
	Belgium	Valideo

There are over 20 schemes for voluntary building certification that are used across Europe. Of these, the most common are: BREEAM, LEED, DGNB, HQE, Minergie and PassivHaus.

The push toward sustainable building design increased in the 1990s with the creation of **Building Research Establishment's Environmental Assessment Method (BREEAM)** (BREEAM, 2018), the first green building rating system in the U.K., served as the basis for many of the green building certification systems. It was the first building rating system to be established and has been in use since 1990 throughout the UK, EU, EFTA member states, EU candidates, as well as the Persian Gulf. Due to its longevity, its use is widespread and its certification highly recognized. BREEAM ratings are required for many governmental organizations throughout these countries and there are currently over 100,000 BREEAM-rated buildings.

The BREEAM application and certification system is a multi-tiered process with pre-assessment, third-party consultant guidance through an assessment organization, of which there are over 1,000 in the UK alone, and the approval process. BREEAM has stipulated that projects must be certified within five years of registration.

In 2000, the U.S. Green Building Council (USGBC) followed suit and developed and released criteria also aimed at improving the environmental performance of buildings through its **Leadership in Energy and Environmental Design (LEED)** (LEED, 2018) rating system for new construction. It was created for rating design and construction practices that would define a green building in the United States. LEED is used throughout North America as well as in more than 30 countries with over 6,300 projects currently certified across the globe and over 21,000 projects registered. As of September 2010, over 35 state governments, 380 cities and towns, and 58 counties have enacted sustainable legislation, ordinances, or policies, many of which specifically call for LEED certification.

LEED consists of credits, which earn points in 7 categories: Site Selection, Water Efficiency, Energy and Atmosphere, Materials and Resources, Indoor Environmental Quality, Regional

Priority, and Innovation in Design. One hundred points are available across these categories with mandatory prerequisites such as minimum energy and water-use reduction, recycling collection, and tobacco smoke control. Within each category are credits that pertain to specific strategies for sustainability, such as the use of low-emitting products, reduced water consumption, energy efficiency, access to public transportation, recycled content, renewable energy, and daylighting. Since its inception, LEED standards have become more stringent as the market has changed and expanded to include distinct rating systems that address different building types: New Construction, Existing Buildings, Commercial Interiors, Core & Shell, Schools, Retail, Healthcare, Homes, and Neighbourhood Development.
Both LEED and BREEAM are voluntary systems providing comparative certifications that are widely applied and certified. The assessment methods are similar but differ in their measurement scales and some of the identified criteria. BREEAM criteria include energy, transport, pollution, materials, water, land use and ecology, health and well-being. LEED criteria include sustainable sites, water efficiency, energy, materials and resources, indoor environmental quality, and process and design innovation. Both assessment methods include some form of evaluation of energy consumption, indoor environmental quality, land use, water management and use of materials in their assessment. While there is ongoing discussion about the proper application of the systems, the certification is seen as a valuable marketing tool for building clients and a motivator for building occupants to conserve resources.

An adaptation of LEED to the Spanish context is the **VERDE sustainability certificate** standing for Valoración de Eficiencia de Referencia de Edificios (Building Reference Efficiency Evaluation). It is a sustainability certificate that measures the environmental, economic and social impact of buildings. VERDE was developed by Green Building Council Spain association to foster a more sustainable architecture (What is the VERDE sustainability certificate?, 2018).
The **HQE certification** (HQE Certification, 2018), from the other side, has been developed by the Association pour la Haute Qualité Environnementale (France) in 2005. With 1793 certificates issued by 2014, it accounts for 12% of all sustainable commercial building certifications in Europe. Over 90% of all HQE certificates are issued in France. This scheme follows also the provisions in the upcoming European standards EN 15804 and EN 15978 (under CEN TC350).

In France in 2016 the **E+C- certificate** has been proposed; since this certificate is more energy and carbon issues oriented, it is more adapted to the HYBUILD ambitions compared to the HQE certificate that is more holistic and targeted at environmental issues.

The **German Sustainable Building Council (DGNB certification)** (DGNB - German Sustainable Building Council, 2018) was founded in 2007 by 16 initiators from various subject areas within the construction and real-estate sectors. The aim was to promote sustainable and economically efficient building even more strongly in future. It is among the youngest voluntary certification schemes, popular mainly in Germany and Austria. By 2014, there were 487 DGNB certificates issued in Europe, which accounts for 3% of all sustainable commercial building certifications.
DGNB scheme follows the provisions in the upcoming European standards EN 15804 and EN 15978 (under CEN TC350) and it is therefore well suited to describe the material and building impacts during building lifetime.

In 2014 the **Passivhaus certification** (Advantages of certification, 2018) was established. It is a rigorous, voluntary standard for energy efficiency in a building, which reduces the building's ecological footprint. It results in ultra-low energy buildings that require little energy for space heating or cooling (Dr. Wolfgang Feist, 2006). It was present in the majority Member States and it is most popular in Germany and Austria.

A similar scheme is **Minergie** established in 1994 in Switzerland. Minergie is a Swiss construction standard for new and modernized buildings. It is a voluntary certification scheme primarily used in the residential sector. The core market for this scheme is France, where Minergie is also produced for non-residential buildings.
For new buildings, Minergie offers three construction standards that can be combined with the ECO complement, which stands for healthy and ecological construction. The three construction standards Minergie, Minergie-P and Minergie-A differ in the energy balance of the building.

- Minergie construction standard is aimed at builders and designers with higher demands on quality, comfort and energy.
- Minergie-P designates low-energy buildings that are distinguished by an exceptional building envelope and optimal comfort.
- Minergie-A buildings produce more energy than they consume and thus combine living comfort with maximum energy independence.

CasaClima (KlimaHaus, Klimahouse) (Certificazione edifici, 2018) was the first in Italy to introduce an energy rating for buildings and it is mandatory in the Province of Bolzano, while outside the province it is voluntary. Since 2002 this initiative has aimed to save energy and create a cultural change in the way people think – making KlimaHaus synonymous with health and wellbeing. Buildings designed according to the KlimaHaus standards can save up to 90% of the energy compared to traditionally built residences - thereby resulting in CO_2 reductions and financial savings. The Casaclima-Klimahaus is a combination of the LEED certification system and the standard energy efficiency certification in Middle and Northern Europe.

Another Italian scheme is the **ITACA Protocol** (Sostenibilita' Energetica e Ambientale, 2018)**,** an energy-environmental certification tool including quality of the building and building components. So far it has been integrated within the EPBD implementation system in some Italian region, while the others use it for assess the building at design stage (competitions, call for tenders for residential public building mainly). The ITACA certification allows benefits as incentives for renovation and urbanization burden reduction, volumetric bonuses, controlled loans (for new buildings mainly). Since 2007 the Conference of Regions and Autonomous Provinces has approved the draft regional law that refers to the protocol, as a common reference for regions to take up shared actions and initiatives in:

- defining and developing procedure for the management and/or award of contracts including quality systems inspired by EN ISO
- promoting and disseminating good sustainability practices in services, supplies and public works
- using eco-friendly, certificated building materials.

The final certification of sustainability also internationally recognized (iiSBE) established a written agreement with ITACA in order to support the Italian Regions to define and apply the assessment and certification system.

LiderA - Sustainability Assessment System (LiderA - Sustainable Assessment System, 2018) is the designation of a Portuguese voluntary system which aims an efficient and integrated support for the evaluation and certification process of the built environments that seek sustainability. Through its principles and criteria, LiderA supports the development of projects that wants to achieve sustainability and certify the demand for sustainable products in the built environment (buildings, urban areas, projects, materials and products) from the design phase to the operation phase.

In particular, the LiderA system is intended to:

- support the development of plans and projects seeking sustainability
- evaluate its performance and position in the design, construction and operation phases, concerning the demand for sustainability
- support environmental management
- assign a certification by trademark through a verification by an independent evaluation
- be a distinctive brand for businesses and customers who value sustainability.

Since its creation in 2005, the LiderA system certified more than a thousand dwellings, more than five thousand hotel beds, as well as multiple Commercial projects and other Services.

In general, in the 21st century, when growing concerns over global warming and resource depletion became more prominent and supported by research, the number and type of green product standards and certifications grew. The focus also expanded to include a broader range of environmental issues and the impacts of products during their manufacture, use, and reuse. There is now a proliferation of standards, rating, and certification programs in the marketplace to help guide, demonstrate, and document efforts to deliver sustainable, high-performance buildings. It is estimated that there are nearly 600 green product certifications in the world with nearly 100 in use in the U.S. and the numbers continue to grow.

The following Table 5.2 provides an overview of the most commonly used and respected green building certification schemes in Europe. These schemes are mainly developed and used for commercial buildings. The majority of residential buildings in Europe are not certified. In fact, only a few European countries have developed sustainable certification schemes for residential buildings, including the UK and France.

Table 5.2: Summary of energy performance certification systems

Building Rating or Certification system	Developer	Type of Standard or Certification	Areas of Focus
BREEAM BREEAM	Building Research Establishment (BRE - UK)	International scheme that provides independent third party certification of the assessment of the sustainability performance of: • Individual buildings • Communities • Infrastructure projects	BREEAM measures sustainable value in a series of categories, ranging from energy to ecology: • Energy • Health and Wellbeing • Innovation • Land use • Materials • Management • Pollution • Transport • Waste • Water

Building Rating or Certification system	Developer	Type of Standard or Certification	Areas of Focus
LEED	U.S. Green Building Council (USGBC)	• Building Design and Construction • Interior Design and Construction • Building Operations and Maintenance • Neighbourhood Development • Homes • Cities and Communities	Each LEED rating system groups requirements that address the unique needs of different building and project types. For instance for Homes, LEED looks at : • Location and Transportation • Sustainable Sites • Water efficiency • Energy & atmosphere • Materials and resources • Indoor Environmental quality • Innovation • Regional priority
VERDE	Spain	• Sustainability certificate that measures the environmental, economic and social impact of buildings • Acknowledged in Europe	In the assessment of an office building to obtain the VERDE sustainability certificate are considered the following parameters • site selection • location and planning project • indoor space quality • energy and ambience • quality of service • natural resources • socioeconomic impact

HQE	France	HQE certification covers the entire lifecycle of a building (construction, renovation and operation): non-residential buildings, residential buildings and detached houses as well as urban planning and development. It can be applied nationally or internationally.	• Assessment of the building's impact
			• Taking suitable measures to reduce the building's impact looking at:
			  ○ Eco-construction
			  ○ Eco-management
			  ○ Comfort
			  ○ Health

Building Rating or Certification system	Developer	Type of Standard or Certification	Areas of Focus
E+C-	France	The E+C- is composed by an Energy factor (evaluated via the "BEPOS" rating indicator) and a Carbon factor (evaluated via the "Carbon" indicator). In this way, property developers may select the two indicators that are best suited to their particular project in order to participate in the trial scheme and/or obtain the certification label.	• Energy performance focus : developing the use of renewable energy in buildings • Environmental performance focus : promoting buildings with low carbon footprints • Economic evaluation focus The current E+C- framework (Label E+C-, 2018) indicates that energy storage systems might be integrated to the calculation methodology in a next version.
DGNB	Germany	DGNB provides a full sustainability assessment scheme available for a wide range of buildings covering new, existing buildings, both publicly or privately owned. The DGNB Certification System can be applied internationally.	Due to its flexibility it can be tailored precisely to various uses of a building and even to meet country-specific requirements. It covers all of the key aspects of sustainable building: • Ecological quality • Economical quality • Socio-cultural quality • Technology • Process quality • Site use
PASSIVHAUS	Germany	The certifications system can be used for existing and new buildings covering non-residential and residential buildings	The certification system focuses only on the energy topic. Assessment areas include: • health and living comfort ("comfort criteria") • energy balance in practice ("energy criteria")
MINERGIE	Switzerland	Swiss construction standard for new and modernized buildings. The most important element is the comfort, housing and work	For new buildings, Minergie offers three construction standards that can be combined with the ECO

Building Rating or Certification system	Developer	Type of Standard or Certification	Areas of Focus
		of users made possible by a high quality building envelope and a systematic air renewal, guaranteed by a controlled ventilation system.	complement, which stands for healthy and ecological construction
CASACLIMA	Italy	Energy label characterizing high insulation and compact constructions, also for existing and renovated buildings. CasaClima includes optimised construction methods, careful execution and a high level of comfort	Assessment criteria include: • Overall energy efficiency of the building • Environmental impact of the materials used in construction • Efficient use of water resources • High indoor air quality and low emission materials • Protection against radon gas • Optimal exploitation of the natural light • Acoustic comfort
ITACA	Italy	Energy-environmental certification tool including quality of the building and building components. The ITACA certification allows benefits as incentives for renovation and urbanization burden reduction, volumetric bonuses, controlled loans (for new buildings mainly)	• Definition and development of procedure for the management and/or award of contracts • Promotion and dissemination of good sustainability practices in services, supplies and public works • Using eco-friendly, certificated building materials
LIDERA	Portugal	Voluntary certification system applicable all residential, services, tourism and commercial buildings (and intervention areas) at any stage of its life cycle. It is adapted to the national context that attends to Portugal's intrinsic aspects, in environmental, social and	LiderA has 43 criteria distributed across different areas that, after an evaluation, are categorized into a performance scale from G to A (up to A ++). At the A ++ (most efficient) level, performance is about 90% higher than

Building Rating or Certification system	Developer	Type of Standard or Certification	Areas of Focus
		economic level.	the least efficient level.

From the analysis of the above certification schemes we can assume that in the middle/long-term, a building equipped with the HYBUILD solution will get additional credits allowing to get a better score on those schemes (and that makes a selling point for the HYBUILD solution and its business model).

5.2 Certification strategies on the HYBUILD components

After having presented some of the main certification strategies at building level, the following paragraph is dedicated to the analysis of certification strategies cover on the elements that compose the HYBUILD components.

5.2.1 Thermal energy storage

The integration of the unit into the refrigeration circuit of the chiller may require the application of refrigerant specific certifications. So far AKG is not active in such fields and not familiar with details of applicable national and international certifications. Ideally the certifications should be handled by the module provider (Fahrenheit).

At European level, the main relevant directive concerning the thermal energy storage technologies is the **Pressure equipment directive (PED)** (2014/68/EU) that applies to the design, manufacture and conformity assessment of stationary pressure equipment with a maximum allowable pressure greater than 0.5 bar (Pressure Equipment Directive, 2018). Typical examples of pressure equipment covered include:

- shell and water tube boilers,
- heat exchangers,
- plant vessels,
- pressurised storage containers, and
- industrial pipework.

According to this directive, all stationary pressure equipment must conform to strict specifications if it is to be sold in the EU. Manufacturers, importers and distributors are responsible for the compliance of their products with this law in order to ensure the health and safety of users and the safety of domestic animals and property, as well as to guarantee fair competition in the EU market.

The Directive defines a number of classifications for pressure equipment, depending on their hazard level which is determined based on the stored energy (pressure-volume product) and the nature of the contained fluid. Assessment and conformity procedures are different for each category, ranging from self-certification for the lowest (category I) hazard up to full ISO9001 quality management and/or notified body type examination for category IV equipment. Aspects of the design, production and testing of the equipment are the subject of a large number of harmonized standards to aid compliance with the essential requirements of the directive; the conformity assessment procedure is described in detail in Annex III of the legal text (Pressure Equipment directive, 2014). The manufacturer of pressure equipment must subject each item to this conformity assessment procedure before it is placed on the market. Once the manufacturer provides the Notified Body with the corresponding technical documentation he obtains the CE marking (CE 0035).

5.2.2 Electric Storage module

The electric storage module is mainly covered by two European regulations:

- The **Low Voltage Directive (LVD) 2014/35/EU** (The Low Voltage Directive (LVD), 2014): it is intended to remove all obstacles to the sale of low voltage electrical equipment within the EU, while at the same time ensuring that they offer the highest possible level of safety.
  Low voltage electrical equipment are defined as any equipment designed for use with a voltage rating between 50 and 1000 V for alternating current and between 75 and 1500 V for direct current. Annex II to the Directive contains a list of equipment not covered, including electrical components of lifts, electricity meters, plugs and socket outlets for domestic use.
  The Directive 2014/35/EU specifies that equipment must not endanger the safety of people, animals or property when properly installed and maintained and used in applications for which it was made. The key safety objectives for equipment covered are listed in Annex I.

  It applies to a wide range of electrical equipment for both consumer and professional usage, such as:

  - household appliances
  - cables
  - power supply units
  - laser equipment
  - certain components (e.g. fuses)

  EU legislation in the electrical sector is important to ensure that health and safety requirements are the same across Europe for products placed on the market.
  The General Product Safety Directive (2001/95/EC) covers consumer goods with a voltage below 50 V for alternating current, or below 75 V for direct current.

- The **Electromagnetic Compatibility (EMC) 2014/30/EU** (EMC Directive (2004/108/EC), 2018): it sets the essential protection requirements for electrical and electronic equipment. In particular, it limits electromagnetic emissions of equipment in order to ensure that, when used as intended, such equipment does not disturb radio and telecommunication as well as other equipment. The Directive also governs the immunity of such equipment to interference and seeks to ensure that this equipment is not disturbed by radio emissions when used as intended. In order to market your electrical device within the member states of the European Union, your product must comply with harmonized standards (such as EN 55022 and EN 55024 for Information Technology Equipment).

The following Figure 5.1 shows the applicable standards for energy storage systems and components in a hybrid system.

Others standards and regulations in addition to those already cited are:

- **Energy Regulator deliberation 574/2014/R/eel** (IEA - Italy, 2018): The Italian Regulator identified technical specifications to integrate storage systems into the national electricity. *Gestore dei Servizi Energetici* has defined the procedure of implementation specifying: requirements to keep the benefits (incentives) granted to production plants; the algorithms used for the quantification of electricity produced and fed into the grid from those installations as well as the payment method of the recognized benefits.

- **Italian standard CEI 0-21** (Reference technical rules for the connection of active and passive users to the LV electrical Utilities, 2016): it consists in a technical reference rule about the connection of active or passive users to the low voltage networks of distributors of electricity. CEI 0-21 provides the requirements about the correct connection of users' plants, considering the functional, electrical and managing characteristics of the most Italian LV networks. Moreover, this norm indicates the modalities of testing, in order to verify and certify PV inverters that will be installed in the Italian electricity network.

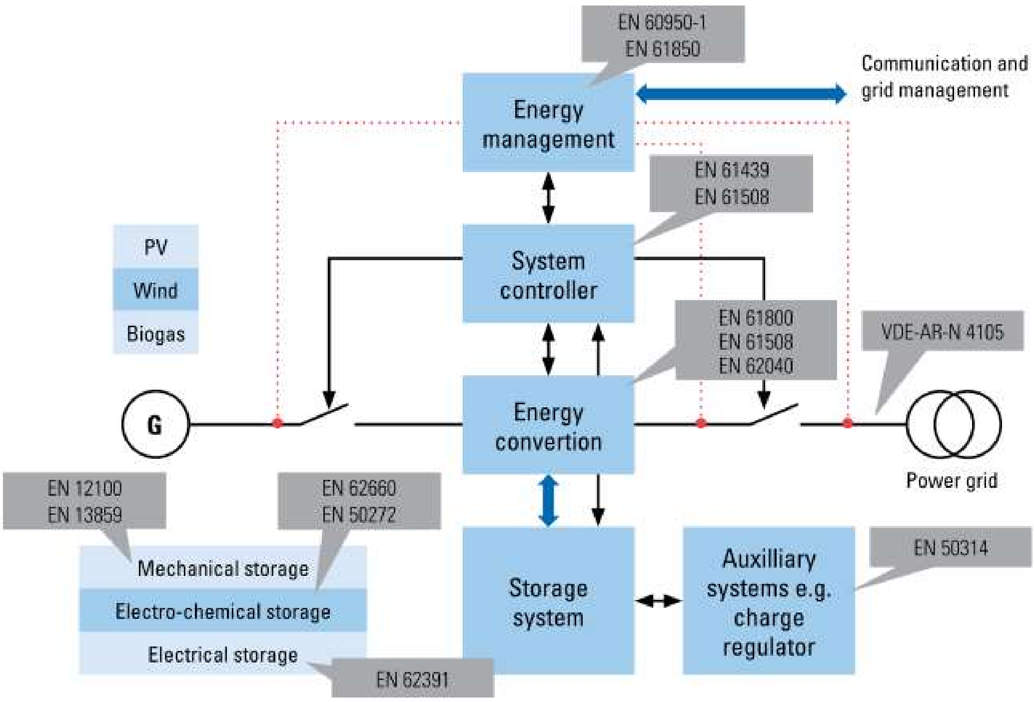


Figure 5.1: Examples of applicable standards for energy storage systems and components

5.2.3 Heat pump /Chiller

The European heat pump industry and European certification bodies cooperated to introduce a European heat-pump certificate based on the CEN KEYMARK scheme.

The Heat Pump KEYMARK is an independent European certification mark (ISO type 5 certification) for all heat pumps, combination heat pumps and hot water heaters (as covered by Eco-design, EU Regulation 813/2013 and 814/2013).

The **CEN heat pump KEYMARK** is a full certificate supporting the quality of heat pumps in the European market. It has been developed by the heat pump industry in 2015 but it is owned by CEN.

The key requirements of the new heat-pump KEYMARK include:

- a set of performance test requirements carried out by third party tests based on EN 14511, EN 15879 and EN 16147
- a robust model range approach
- a product related Factory Production Control (FPC)

- an initial inspection of the FPC
- Regularly surveillance of the certified products and FPC

The **EHPA Quality Label** (Quality Label, 2018) is a label that shows the end-consumer a quality heat pump unit or model range on the market.

The EHPA quality label for heat pumps originates in activities of the heat pump associations of Austria, Germany and Switzerland to create a common set of requirements to ensure product and service quality for heat pumps (named D-A-CH quality label after the countries international codes). The idea has been further developed in the European Heat Pump Association and the country scope has been extending. In order to reflect this development, the D-A-CH quality label has been gradually replaced by the EHPA Quality Label (EHPA-QL). In addition to the founding countries the EHPA Quality Label was introduced in Sweden (2007), Finland (2008), Belgium, France (2010) and the Netherlands (2012) which makes a total of 11 participating countries. Its use and development in more countries is under preparation. Except in France, the label is mutually accepted in all the participating countries.

The label can be granted to standardised space heating electrically-driven heat pumps, with or without domestic hot water heating capability, with a capacity up to 100 kW from air, geothermal or water heat sources. In order to qualify for the label, the heat pump in question must comply with EHPA heat pump test criteria and the distributor must provide a defined level of service.

The key requirements are (non-exhaustive list):

1. Conformity of all main components and compliance with the national rules and regulation (CE marking)
2. Minimum efficiency values defined as follows (operating points - required COP), tested in labs accredited to ISO 17025 to perform heat pump test according to standards needed for each method that is applied:

   - **EN 14511-1:2018** (EN 14511-1:2018, 2018) - Air conditioners, liquid chilling packages and heat pumps for space heating and cooling and process chillers, with electrically driven compressors - Part 1: Terms and definitions

     This European Standard specifies the terms and definitions for the rating and performance of air conditioners, liquid chilling packages and heat pumps using either air, water or brine as heat transfer media, with electrically driven compressors when used for space heating and/or cooling.
     It also specifies the terms and definitions for the rating and performance of process chillers.
     This European Standard does not apply to heat pumps for domestic hot water, although certain definitions can be applied to these. In particular, it applies to:

     - factory-made units that can be ducted,
     - factory-made liquid chilling packages with integral condensers or for use with remote condensers,
     - factory-made units of either fixed capacity or variable capacity by any means, and
     - air-to-air air conditioners which can also evaporate the condensate on the condenser side.

     In the case of units consisting of several parts, this European Standard applies only to those designed and supplied as a complete package, except for liquid chilling packages with remote condenser.

This European Standard is primarily intended for water and brine chilling packages but can be used for other liquid subject to agreement.

- **UNI EN 14825:2016** (UNI EN 14825:2016, 2016) - Air conditioners, liquid chilling packages and heat pumps, with electrically driven compressors, for space heating and cooling - Testing and rating at part load conditions and calculation of seasonal performance.

  This European Standard covers air conditioners, heat pumps and liquid chilling packages. It applies to factory made units defined in EN 14511-1, except single duct, double duct, control cabinet and close control units.

  This European Standard gives the temperatures and part load conditions and the calculation methods for the determination of seasonal energy efficiency SEER and SEERon, seasonal coefficient of performance SCOP, SCOPon and SCOPnet, and seasonal space heating energy efficiency.

  In case of measured values, this European Standard covers the test methods for determination of capacities, EER and COP values during active mode at part load conditions. It also covers test methods for electric power consumption during thermostat-off mode, standby mode, off-mode and crankcase heater mode.

- **UNI EN 15879-1:2011** (UNI EN 15879-1:2011, 2011) - Testing and rating of direct exchange ground coupled heat pumps with electrically driven compressors for space heating and/or cooling - Part 1: Direct exchange-to-water heat pumps

  This European Standard specifies the terms and definitions, test conditions, test procedures and requirements for the rating and performance of direct exchange-to-water ground coupled heat pumps with electrically driven compressors, used for space heating and/or cooling. Brine can be used instead of water. This European Standard applies to factory-made units with horizontal in-ground collectors.

- **UNI EN 16147:2017** (UNI EN 16147:2017, 2017) - Heat pumps with electrically driven compressors - Testing, performance rating and requirements for marking of domestic hot water units

  This European Standard specifies methods for testing, rating of performance and calculation of water heating energy efficiency of air/water, brine/water, water/water and direct exchange/water heat pump water heaters and heat pump combination heaters with electrically driven compressors and connected to or including a domestic hot water storage tank for domestic hot water production.
  It comprises only the testing procedure for the domestic hot water production of the heat pump system.

  - Testing procedures for simultaneous operation for domestic hot water production and space heating are not treated in this standard. Simultaneous means that domestic hot water production and space heating generation occur at the same time and may interact.
  - For heat pump combination heaters the seasonal efficiency of space heating is determined according to EN 14825.

  This European Standard does not specify requirements of the quality of the used water.

3. Declaration of sound power level according to EN 12102 (**UNI EN 12102-1:2018** (UNI EN 12102-1:2018, 2018) - Air conditioners, liquid chilling packages, heat pumps, process chillers and dehumidifiers with electrically driven compressors - Determination of the sound power level - Part 1: Air conditioners, liquid chilling packages, heat pumps for space heating and cooling, dehumidifiers and process chillers)
4. Existence of sales & distribution, planning, service and operating documents in the local language of the country where the heat pump is distributed.
5. Existence of a functioning customer service network in the sales area that allows for a 24h reaction time to consumer complaints.
6. A two-year full warranty which shall include a declaration stating that the heat pump spare parts inventory will be available for at least ten years.

At European level, another relevant directive concerning the heat pump technologies is the **F-Gases Regulation** (EUR-Lex, 2015) (EU) (No 517/2014) of the European Parliament and of the Council of 16 April 2014 on fluorinated greenhouse gases and repealing Regulation (EC) No 842/2006.
The regulation is designed to mitigate climate change and protect the environment by reducing emissions of fluorinated greenhouse gases (F-gases). Fluorinated gases are man-made gases comprising families of gases known as hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF6). They can be found in a multitude of applications, specifically:

- HFCs are used as refrigerants, cleaning solvents and foam-blowing agents (such as fire extinguishers).
- PFCs are used to manufacture semi-conductors, as cleaning solvents and as foam-blowing agents. These gases are created in particular during the production processes of aluminium and semiconductors.
- SF 6 are used in. extensively used in equipment for the transmission and distribution of electricity (e.g. high-voltage switch gear).

The regulation sets out the following prescriptions:

- Intentional release of F-gases is prohibited
- Operators of equipment containing F-gases must take every precaution to avoid any leakage. They must ensure the equipment is regularly checked for leaks. Requirements vary according to the potential climate impact or whether the equipment is hermetically sealed.
- National authorities are responsible for setting up certification and training programmes for businesses and people involved in installing, servicing, maintaining, repairing or decommissioning F-gases equipment and in recovering F-gases.
- It gradually introduces prohibitions on the sale of new items (such as certain categories of fridges and freezers, air-conditioning systems, foams and aerosols) where safer, more climate-friendly alternatives exist.
- It reduces the climate impact of the use of HFCs over time, introducing limits on the annual emission of HFCs. To ensure the limits are respected, the Commission allocates annual quotas to producers and importers that must not be exceeded.
- Producers, importers, exporters, users of feedstock and businesses that destroy F-gases must report annually to the Commission. Importers of F-gases equipment must do the same and from 2017 provide evidence that the quantities of HFCs in their imported equipment are accounted for.

5.2.4 Renewable energy sources (RES)

5.2.4.1 Photovoltaic Systems (PV)

Photovoltaic (PV) modules and photovoltaic installations represent electrical equipment and the fulfilment of test specifications, the conformity assessment and the CE-marking are obligatory for such components and equipment.

The **Low-Voltage Directive (LVD)** 2014/35/EU (The Low Voltage Directive (LVD), 2014), is mandatory for PV-modules with voltages above 75 V DC. However, the scope of the European directive relating Electromagnetic Compatibility (EMC) is not applicable in its present form for the modules acting as electromagnetic passive components.

This directive does not apply to equipment where the inherent nature of the physical characteristics is such that:

- it is incapable of generating or contributing to electromagnetic emissions which exceed a level allowing radio and telecommunication equipment and other equipment to operate as intended
- it will operate without unacceptable degradation in the presence of the electromagnetic disturbance normally consequent upon its intended use.

However, complete PV-Installations (modules, power converter etc.) need to take into account other directives. If movable parts are also present, the EC-Machinery Directive 2006/42/EC may also have to be taken into account.

The **Machinery Directive 2006/42/EC** (Machinery, 2006) covers machinery, interchangeable equipment, safety components, lifting accessories, chains, ropes and webbing for lifting purposes and removable mechanical transmission devices. It also includes requirements for partly completed machinery.

The first step a manufacturer should take to ensure that a machine will be compliant with the Directive is to carry out an assessment procedure, with regard to the essential requirements. This includes also to check which European Harmonised Standards are applicable, as a way to get presumption of conformity. A list of harmonised standards for machinery can be found on the European Commission's Directorate-General (DG) for Internal Market, Industry, Entrepreneurship and SMEs website.

Annex I to Directive 2006/42/EC sets out in detail the essential health and safety requirements for the products covered.

The product quality and the safety performance are particular important properties of PV modules. Requirements for such PV-products can be classified against the following requirements:

- Type requirements on PV-modules such as:
    - **IEC 61215-2:2016** (IEC 61215-2:2016 , 2016) - Terrestrial photovoltaic (PV) modules - Design qualification and type approval - Part 2: Test procedures
    - **IEC 61215-1-2:2016** (IEC 61215-1-2:2016 , 2016) - Terrestrial photovoltaic (PV) modules - Design qualification and type approval - Part 1-2: Special requirements for testing of thin-film Cadmium Telluride based photovoltaic (PV) modules
- Safety requirements such as:

  - **EN 61730:2007** (BS EN 61730-1:2007+A11:2014 , 2007) - Photovoltaic (PV) module safety qualification. Requirements for construction
- Additional Requirements such as
  - **EN 50380:2017** (BS EN 50380:2017 , 2017) - Marking and documentation requirements for Photovoltaic Modules

The Low Voltage Directive 2014/35/EU, is valid for electrical equipment with rated voltages between 50 V and 1000 V AC respectively 75 V and 1500 V DC. This directive is, along with the listed product standards dealing with safety, key to the CE-Marking of PV Modules.

A basic aspect for the safe operation of PV-modules and equipment is electric shock protection. Compliance with safety class II demands becomes of great importance particularly for modules destined for high system voltages up to 1000 V.

For large PV systems, standards that facilitate making a functional and safe grid connection exist. The **IEC 61727:2004 - Photovoltaic (PV) systems - Characteristics of the utility interface** (IEC 61727:2004 , 2004) is an international standard that specifies the main requirements of a grid interface which will ensure that it is both functional and safe for PV connections of 10kVA or less. In particular, the object of this standard is to lay down requirements for interconnection of PV systems to the utility distribution system. Most the required functionality to comply with the standard is implemented within the PV systems inverter. Inverter Output Power Quality - the output of any inverter should operate within the following limits:

- the inverter must limit the injection of any DC current into the utility to less than 1% of its rated output
- the total harmonic current distortion should be less than 5%
- harmonic current distortion for each individual harmonic should be less than those given in the standard
- when the inverters output is greater than 50%, the power factor must be greater than 0.9.

In addition, there are several certifications that apply to solar inverters, including:

- **BS EN 50524:2009 - Data sheet and name plate for photovoltaic inverters** (BS EN 50524:2009, 2009): this European Standard describes data sheet and nameplate information for photovoltaic inverters in grid parallel operation. The intent of this document is to provide minimum information required to configure a safe and optimal system with photovoltaic inverters.
- **BS EN 50530:2010+A1:2013 - Overall efficiency of grid connected photovoltaic inverters** (BS EN 50530:2010+A1:2013, 2013): this European Standard provides a procedure for the measurement of the accuracy of the maximum power point tracking (MPPT) of inverters, which are used in grid-connected photovoltaic systems.
- **UL 1741 - Standard for inverters, converters, controllers and interconnection system equipment for use with distributed energy resources** (UL 1741, 2010): these requirements cover inverters, converters, charge controllers, and interconnection system equipment (ISE) intended for use in stand-alone or grid-connected power systems.
- **IEC 61683 - Photovoltaic systems, Power conditioners and Procedure for measuring efficiency** (IEC 61683, 1999): this standard describes guidelines for measuring the efficiency of power conditioners used in stand-alone and utility-interactive photovoltaic systems, where the output of the power conditioner is a stable AC voltage of constant frequency or a stable DC voltage. The efficiency is calculated from a direct measurement of

input and output power in the factory. An isolation transformer is included where it is applicable.

- **IEC 62109-1:2010 - Safety of power converters for use in photovoltaic power systems - Part 1: General requirements** (IEC 62109-1, 2010): this part of IEC 62109 applies to the power conversion equipment (PCE) for use in Photovoltaic (PV) systems where a uniform technical level with respect to safety is necessary. This standard defines the minimum requirements for the design and manufacture of PCE for protection against electric shock, energy, fire, mechanical and other hazards. It provides general requirements applicable to all types of PV PCE. There are additional parts of this standard that provide specific requirements for the different types of power converters, such as **Part 2 - Particular requirements for inverters.** This part covers the particular safety requirements relevant to DC to AC inverter products as well as products that have or perform inverter functions in addition to other functions, where the inverter is intended for use in photovoltaic power systems. Inverters covered by this standard may be grid-interactive, stand-alone, or multiple mode inverters, may be supplied by single or multiple photovoltaic modules grouped in various array configurations, and may be intended for use in conjunction with batteries or other forms of energy storage. This standard must be used jointly with IEC 62109-1.

5.2.4.2 Concentrating Solar Collectors (FRESNEX)

The use of solar technologies in buildings can be subject to different directives and regulations that must be taken under consideration, both EU-wide and nationally. The concept of installing equipment directly on rooftops of buildings and the use of solar thermal technologies that heat up water and can lead to a pressurized system and the two main critical points that can affect the solution proposed by the HYBUILD project.

In order to give a notion of the most applicable directives and regulations, the official EU norms have been checked and analysed. The main goal for this research work was to identify key aspects of the regulations at an early stage of the design process to provide guidelines and reduce the risk to cost relevant changes at a later stage.

Besides the product itself, the evaluation process for the demo site and the relation to the testing to applicable certifications have been identified. This way results can be compared to other products on the market based on harmonized testing procedures.

For each component/product of the solar collector, there is a dedicated norm, as indicated in the following Table 5.3.

Table 5.3: Norms corresponding to each component/product of the solar collector

Component/product	Norm
Machinery	DIRECTIVE 2006/42/EC (EUR-Lex, 2006)
Pressure Equipment Directive	**DIRECTIVE 2014/68/EU** (EUR-Lex, 2014)
Hazardous substances in electrical and electronic equipment	DIRECTIVE 2011/65/EU (EUR-Lex, 2011)
Electromagnetic compatibility (EMC)	DIRECTIVE 2014/30/EU (EUR-Lex, 2014)

The first two directives are important as they influence the design of the new system while the last two relate to the electric motor used in the product. Fresnex has especially focused on the second directive related to pressure/boiler regulations as this has a major influence on the practicability of the final product and its application.

In particular, Directive 2014/68/EU of the European parliament and of the council of 15 May 2014 on the harmonisation of the laws of the Member States relating to the making available on the **market of pressure equipment.**

According to the Directive 2014/68/EU of the European Parliament and of the Council, pressure equipment subject to a maximum allowable pressure PS greater than 0,5 bar is subject to the Directive. The Directive also states that pressure equipment subject to a pressure of not more than 0.5 bar does not pose a significant risk due to pressure. Therefore, there should not be any obstacle to its free movement within the Union.

The maximum allowable pressure PS means the maximum pressure for which the equipment is designed, as specified by the manufacturer, and defined at a location specified by him, being either the connection of protective and/or limiting devices, or the top of equipment or, if not appropriate, any point specified.

The initial technical approach of the HYBUILD project for thermal generation is to heat up water up to 95°C at atmospheric pressure (1 bar) using the Fresnel solar concentrators. Therefore, the Directive 2014/68/EU should apply for the solar thermal configuration of the HYBUILD project. However, under the specific technical requirements of the Directive, only fired or otherwise heated pressure equipment with the risk of overheating intended for generation of steam or super-heated water at temperatures higher than 110 °C having a volume greater than 2 L, and all pressure cookers, shall satisfy the essential safety requirements in terms of steam or super-heated water generation. This also refers to assemblies which include at least one item of pressure equipment and that are intended for generating steam or superheated water at a temperature higher than 110 °C comprising at least one item of fired or otherwise heated pressure equipment presenting a risk of overheating.

Therefore, the initial technical approach of the HYBUILD project for thermal generation is not subject to the safety requirements specified in this Directive, as long as the temperature of the water remains below 110°C. If temperature were to be between 100°C and 110°C, the system will generate super-heated water, needing a pressure value of around 1,5 bar to raise the boiling temperature and avoid the generation of steam. Consequently, for the initial HYBUILD configuration, pressure equipment and assemblies below or equal to the limits set out shall be designed and manufactured in accordance with the sound engineering practice of a Member State in order to ensure safe use. Pressure equipment and assemblies shall be accompanied by adequate instructions for use.

However, it has been discussed among the consortium during the initial technical meetings the possibility to test the performance of the global system with higher temperature and higher pressure. This temperature would be in the range of 120-130°C, and the maximum pressure would be 3 bar. In this case, the exclusion of the Directive seen before does no longer apply. Such event will initially only be considered as demonstration unless the performance and results obtained indicate that the technical approach of the HYBUILD project should indeed have a configuration working with superheated water at a temperature above 110°C.

In first place, note that for during demonstrations and other similar events, Member States shall not prevent the showing of pressure equipment or assemblies which do not comply with this Directive, provided that a visible sign clearly indicates that such pressure equipment or assemblies may not be made available on the market and/or put into service until they are brought into conformity. During demonstrations, appropriate safety measures shall be taken in accordance with any requirements laid down by the competent authority of the Member State concerned in order to ensure the safety of persons.

In second place, in order to better understand the implications of working with superheated water at a temperature higher that 110°C, the case has also been studied in the Directive. Pressure equipment shall be classified by category in accordance with Annex II of the Directive, according to an ascending level of hazard.

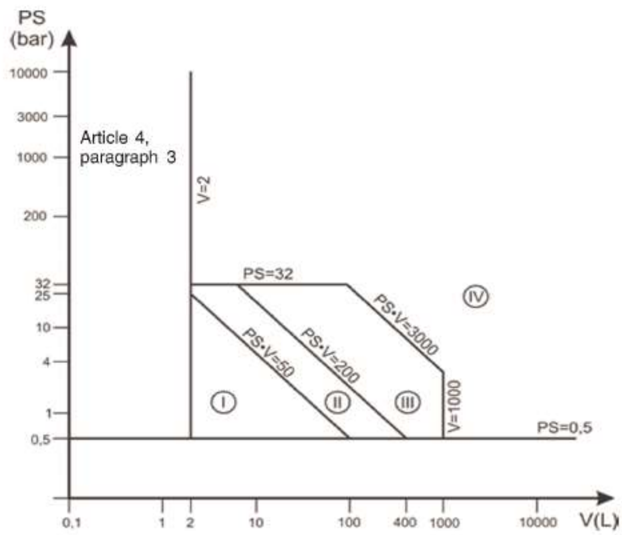


Figure 5.2: Pressure equipment to in Article 4 (EUR-Lex, 2014)

The conformity assessment procedures to be applied to an item of pressure equipment shall be determined by the category in which the equipment is classified.

Currently there are three labels available for solar products or solar assisted heating systems in Europe, so there is an increasing need to explain the differences to market players as well as customers. There are the two voluntary collector labels **Solergy** and **Solar Keymark** as well as the EU Energy Efficiency label (right) which is obligatory for water, space and combi heaters under the **Energy Labelling (ELD)** and the **Eco-design (EDD) Directives** since September 2015.

The main certification label available for solar collectors is the **Solar Keymark certificate**. It was created to certify solar thermal products of high quality at European level with the aim to reduce trade barriers and promote the use of high quality solar thermal products in the European market and beyond.

The Solar Keymark is a voluntary third-party certification mark for solar thermal products, demonstrating to end-users that a product conforms to the relevant European standards and fulfils additional requirements. It is used in Europe and increasingly recognized worldwide.

In particular, the Solar Keymark is a CEN/CENELEC European mark scheme, dedicated to solar thermal collectors and solar thermal systems, storages and controllers.

Relevant European standards related to the Solar Keymark are (Solar Keymark, 2018):

- **UNI EN ISO 9806:2014** (UNI EN ISO 9806:2014, 2014): Solar energy - Solar thermal collectors - Test methods

  This International Standard specifies test methods for assessing the durability, reliability and safety for fluid heating collectors. It includes test methods for the thermal performance characterization of fluid heating collectors, namely steady-state and quasi-dynamic thermal performance of glazed and unglazed liquid heating solar collectors and steady-state thermal performance of glazed and unglazed air heating solar collectors (open to ambient as well as closed loop).

  This International Standard is also applicable to hybrid collectors generating heat and electric power. However it does not cover electrical safety or other specific properties related to electric power generation.

  This International Standard is also applicable to collectors using external power sources for normal operation and/or safety purposes. However it is not applicable to those collectors in which the thermal energy storage unit is an integral part of the collector to such an extent that the collection process cannot be separated from the storage process for the purpose of making measurements of these two processes.

- **UNI EN 12976-1:2017** (UNI EN 12976-1:2017, 2017): Thermal solar systems and components - Factory made systems - Part 1: General requirements

  This European Standard specifies requirements on durability, reliability and safety for Factory Made solar heating systems. The standard also includes provisions for evaluation of conformity to these requirements. Concept of system families is included, as well.

  The installation of these systems including their integration with roofs or facades is not considered, but requirements are given for the documentation for the installer and the user to be delivered with the system.

  External auxiliary water heating devices that are placed in series with the Factory Made system are not considered to be part of the system.

  Piping between components of the Factory Made system is considered to be part of the system. Any integrated heat exchanger or piping for space heating option is not considered to be part of the system.

- **UNI EN 12977-1:2018** (UNI EN 12977-1:2018, 2018): Thermal solar systems and components - Custom built systems - Part 1: General requirements for solar water heaters and combi systems

  This European Standard specifies requirements on durability, reliability and safety of small and large custom built solar heating and cooling systems with liquid heat transfer medium in the collector loop for residential buildings and similar applications.
  This document also contains requirements on the design process of large custom built systems.

The Solar Keymark is not mandatory, but in order to receive funding form governmental organizations it is often required.

This certification system was mainly developed for flat-plate and vacuum-tube solar collectors.

The main pillar of the system and especially relevant for concentrated solar collectors is the performance testing according to EN ISO 9806. Fresnex had tested an earlier version of the collector (proof of concept) in 2014 using this standard.

The final solar Keymark certificate requires projects and a quality inspection system in the serial production of the collector. Hence the certificate can be obtained only at a later stage after the HYBUILD project. However important points of the performance testing (EN ISO 9806) should be considered already during the on-site installations and measurements to make use of this standard and be able to compare the results to already available products with solar Keymark in the market.

Solergy is a voluntary certificate while **Eco-design** directive is mandatory if the product fits in the scheme, which is unclear and depends on the actual application and market of the product (housing market or large scale, even industrial sized market).

5.3 Review of European certification systems: (CE MARKING)

The letters 'CE' appear on many products traded on the extended Single Market in the European Economic Area (EEA). They signify that products sold in the EEA have been assessed to meet high safety, health, and environmental protection requirements.

By affixing the CE marking to a product, a manufacturer declares that the product meets all the legal requirements for CE marking and can be sold throughout the EEA. This also applies to products made in other countries that are sold in the EEA.

CE marking is a part of the EU's harmonisation legislation, which is mainly managed by Directorate-General for Internal market, Industry, Entrepreneurship and SMEs. The CE marking for Restriction of Hazardous Substances is managed by Directorate-General for Environment. Comprehensive guidance on the implementation of EU product rules can be found in the so-called Blue Guide.

In this section, a review of the CE marking protocols for the product types that are related to the HYBUILD project is provided. The CE marking covers three main aspects: manufacturers, importers and distributors and consumers. Among these three aspects, the protocols regarding manufacturers are relevant to the HYBUILD project requirements.

Manufacturers play a crucial role in ensuring that products placed on the extended Single Market of the EEA are safe. They are responsible for checking that their products meet EU safety, health, and environmental protection requirements. It is the manufacturer's responsibility to carry out the conformity assessment, set up the technical file, issue the EU declaration of conformity, and affix the CE marking to a product. Only then this product can be traded on the EEA market.

If you are a manufacturer, you have to follow these six steps to affix a CE marking to your product:

1. Identify the applicable directive(s) and harmonised standards
2. Verify product specific requirements
3. Identify whether an independent conformity assessment (by a notified body) is necessary
4. Test the product and check its conformity
5. Draw up and keep available the required technical documentation
6. Affix the CE marking and draw up the EU Declaration of Conformity

The regulation in force about the energy labelling of energy consuming product is the **Regulation (EU) 2017/1369** (EUR-Lex, 2017) of 4 July 2017 that sets a framework for energy labelling and repeals the Directive 2010/30/EU.

This Regulation lays down a framework that applies to energy-related products placed on the market or put into service. It provides for the labelling of those products and the provision of standard product information regarding energy efficiency, the consumption of energy and of other resources by products during use and supplementary information concerning products, thereby enabling customers to choose more efficient products in order to reduce their energy consumption.

After the end of the project, the final product could be follow the Directive 2006/42/EC of the European parliament and of the Council of 17 May 2006 on machinery, and amended Directive 95/16/EC as a declaration of incorporation of partly completed machinery and of conformity to machine directive.

The following Table 5.4 summarizes the European certification system in terms of CE Marking for each of the core component of the HYBUILD systems. Each partner developing the components was asked to declare his intention to affix the CE Marking on his technology.

In addition to the partners' intention to affix the CE Marking on each technology, the Table 5.4 reports the products under which they intend to affix it and reference norms and directives.

Table 5.4: Review of European certification system (CE Marking) for each HYBUILD technology

Technology	CE Marking to be affixed	Under which products?	Reference norm/directives	
Thermal energy storage	✗	-	-	
Electric storage	✓	• Low voltage electrical equipment	2006/66/EC	Batteries and accumulators and waste batteries and accumulators and repealing Directive 91/157/EEC ("Batteries and accumulators containing certain dangerous substances")
			BS EN 61429:1997 IEC 61429:1995	Marking of secondary cells and batteries with the international recycling symbol ISO 7000-1135
			IEC 61427	Secondary cells and batteries for renewable energy storage - General requirements and methods of test
			BS EN 60086-4:2000 IEC 60086-4:2000	Primary batteries. Safety standard for lithium batteries
			BS EN 61960-1:2001 IEC 61960-1:2000	Secondary lithium cells and batteries for portable applications. Secondary lithium cells
			BS EN 61960-2:2002 IEC 61960-2:2001	Secondary lithium cells and batteries for portable applications. Secondary lithium batteries
			02/209100 DC	IEC 62281. Ed.1. Safety of primary and secondary lithium cells and batteries during transport
			CEI EN 50438	Requirements for micro-generating plants to be connected in parallel with public low-voltage distribution networks
Heat Pump/Chiller	✓	• Low voltage (LVD) • Electromagnetic	UNI EN 378-2:2017	Refrigerating systems and heat pumps - Safety and environmental requirements - Part 2: Design, construction, testing, marking and documentation

Technology	CE Marking to be affixed	Under which products?	Reference norm/directives	
		compatibility (EMC) • Pressure equipment • Eco-design and energy labelling	UNI EN 12102-1:2018	Air conditioners, liquid chilling packages, heat pumps, process chillers and dehumidifiers with electrically driven compressors - Determination of the sound power level - Part 1: Air conditioners, liquid chilling packages, heat pumps for space heating and cooling, dehumidifiers and process chillers
			UNI EN 14511-2:2018	Air conditioners, liquid chilling packages and heat pumps for space heating and cooling and process chillers, with electrically driven compressors - Part 2: Test conditions
			UNI EN 14511-3:2018	Air conditioners, liquid chilling packages and heat pumps for space heating and cooling and process chillers, with electrically driven compressors - Part 3: Test methods
			UNI EN 14825:2016	Air conditioners, liquid chilling packages and heat pumps, with electrically driven compressors, for space heating and cooling - Testing and rating at part load conditions and calculation of seasonal performance
			EN 55014-1:2017	Electromagnetic compatibility - Requirements for household appliances, electric tools and similar apparatus - Part 1: Emission
			EN 55014-2:2015	Electromagnetic compatibility - Requirements for household appliances, electric tools and similar apparatus - Part 2: Immunity - product family standard
			EN 60335-1:2012/A12:2017	Household and similar electrical appliances - Safety - Part 1: General requirements
			IEC 60335-2-40:2018	Household and similar electrical appliances - Safety - Part 2-40: Particular requirements for electrical heat pumps, air-conditioners and dehumidifiers
			IEC 61000-3-11:2017	Electromagnetic compatibility (EMC) - Part 3-11: Limits - Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems - Equipment with rated current ≤ 75 A and subject to conditional connection
			IEC 61000-3-12:2011	Electromagnetic compatibility (EMC) - Part 3-12: Limits - Limits for harmonic currents produced by equipment connected to public low-voltage systems with input current >16 A and ≤ 75 A per phase

Technology	CE Marking to be affixed	Under which products?	Reference norm/directives	
			EN 62233:2005	Measurement methods for electromagnetic fields of household appliances and similar apparatus with regard to human exposure
RES	-	-	IEC 61215-1:2016	Terrestrial photovoltaic (PV) modules - Design qualification and type approval - Part 1: Test requirements
			BS EN IEC 61730-1:2018	Photovoltaic (PV) module safety qualification. Requirements for construction (British Standard)
			IEC 61730-2:2016	Photovoltaic (PV) module safety qualification - Part 2: Requirements for testing
			IEC 61727:2004	Photovoltaic (PV) systems - Characteristics of the utility interface
			BS EN 50524:2009	Data sheet and name plate for photovoltaic inverters
			BS EN 50530:2010+A1:2013	Overall efficiency of grid connected photovoltaic inverters
			UL 1741	Standard for inverters, converters, controllers and interconnection system equipment for use with distributed energy resources
			IEC 61683	Photovoltaic systems, Power conditioners and Procedure for measuring efficiency
			IEC 62109-1:2010	Safety of power converters for use in photovoltaic power systems Part 1: General requirements Part 2 - Particular requirements for inverters

5.4 Eco-design and energy labelling for energy related products

There is world-wide demand for more efficient products to reduce energy and resource consumption. The **EU legislation** on **Eco-design** and **energy labelling** is an effective tool for improving the energy efficiency of products. It helps eliminate the least performing products from the market, significantly contributing to the EU's 2020 energy efficiency objective. It also supports industrial competitiveness and innovation by promoting the better environmental performance of products (Ecodesign, 2018).

In particular, the **Eco-Design Directive** (**Directive 2009/125/EC)** (EUR-Lex, 2009) provides EU-wide rules for improving the environmental performance of products, such as household appliances, information and communication technologies or engineering, through eco-design. In particular, it is an Eco-design directive according to which products like heat generators will have to be labelled in terms of their energy efficiency across Europe. The Directive sets out minimum mandatory requirements for the energy efficiency of these products, helping prevent creation of barriers to trade, improve product quality and environmental protection.

The Directive has the potential to apply to most energy using and energy related products (except vehicles for transport), and covers all energy sources. However, as the Directive is only a framework directive, there is nothing for products to actually be designed in accordance with until specific implementing measures are published for them. As with other CE marking directives, it applies to all products placed on the EU market and to imported products. In particular, the Eco-design Directive covers the following products (Conformance, 2012):

- Air conditioners
- Boilers
- Circulators
- Dishwashers
- Electric motors
- Fans
- Lamps (directional and LED, household and fluorescent)
- Power supplies
- Refrigerating appliances
- Set-top boxes
- Standby and off mode
- Television
- Tumble driers
- Vacuum cleaners
- Washer-driers (combined)
- Washing machines
- Water pumps

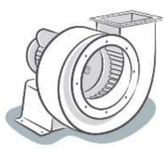
The regulation in force about the **Energy Labelling** of energy consuming product is the Regulation **(EU) 2017/1369** (EUR-Lex, 2017) of 4 July 2017 that sets a framework for energy labelling and repeals the Directive 2010/30/EU (EUR-Lex, 2017).

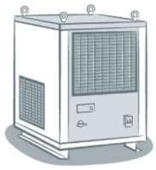
This Regulation, that complement Eco-design requirements with mandatory labelling requirements, lays down a framework that applies to energy-related products placed on the market or put into service. It provides for the labelling of those products and the provision of standard product information regarding energy efficiency, the consumption of energy and of other resources by products during use and supplementary information concerning products, thereby enabling customers to choose more efficient products in order to reduce their energy consumption.

The Eco-design Directive and energy labelling regulation are implemented through product-specific regulations, directly applicable in all EU countries. They are complemented by **harmonised European standards**, whose technical specifications indicate that a product complies with the mandatory requirements.

The following Table 5.5 reports the references of harmonised standards for both eco-design and energy labelling regulations for applications interesting to the HYBUILD project.

Table 5.5: Harmonised standards for eco-design and energy labelling regulations

Applications			Eco-design Regulations	Energy Labelling Regulations
Electric Motors		Electric motors	(EU) No 640/2009 (EUR-Lex, 2009)	-
			(EU) No 4/2014 (EUR-Lex, 2014)	-
Fans		Industrial fans driven by motors	(EU) No 327/2011 (EUR-Lex, 2011)	-
Heating and cooling appliances		Air conditioners and comfort fans	(EU) No 206/2012 (EUR-Lex, 2012)	(EU) No 626/2011 (EUR-Lex, 2014)
		Hot-water boilers	92/42/EEC (EUR-Lex, 1992)	-
		Water heaters and hot water storage tanks	(EU) No 814/2013 (EUR-Lex, 2013)	(EU) No 812/2013 (EUR-Lex, 2013)
		Space heaters	(EU) No 813/2013 (EUR-Lex, 2013)	(EU) No 811/2013 (EUR-Lex, 2013)
		Local space heaters, Solid fuel local space heaters	(EU) 2015/1188 (EUR-Lex, 2015)	(EU) 2015/1186 (EUR-Lex, 2015)
			(EU) 2015/1185 (EUR-Lex, 2015)	

		Solid fuel boilers	(EU) 2015/1189 (EUR-Lex, 2015)	(EU) 2015/1187 (EUR-Lex, 2015)
		Air heating products, cooling products, high temperature process chillers and fan coil units	(EU) No 2016/2281 (EUR-Lex, 2016)	-
Refrigerated storage cabinets		Professional refrigerated storage cabinets, blast cabinets, condensing units and process chillers	(EU) 2015/1095 (EU-Lex, 2015)	(EU) 2015/1094 (EUR-Lex, 2015)
Ventilation		Ventilation units	(EU) No 1253/2014 (EUR-Lex, 2014)	(EU) No 1254/2014 (EUR-Lex, 2014)

The following Table 5.6 reports if and how the Eco-Design Directive and Energy Labelling Regulation affect the core components of the HYBUILD system.

Table 5.6: Eco-Design and Energy Labelling Regulations in the HYBUILD systems

Technology	Do the Eco Design Directive and Energy Labelling Regulation affect your product?	How?
Thermal energy storage	Eco Design Directive does not affect directly energy storage. No Energy Labelling Regulation has to be pursued -	-
Electric storage	Eco Design Directive does not affect directly energy storage. No Energy Labelling Regulation has to be pursued	-
Heat Pump/Chiller	Yes	Ecodesign Directive 2009/125/EC (EUR-Lex, 2009)
Renewable Energy Sources	Yes	Ecodesign Directive 2009/125/EC (EUR-Lex, 2009)

In particular, the Eco-design Directive 2009/125/EC (or ErP Directive) requires that energy-related products fulfil eco-design minimum levels of energy efficiency and environmental performance. Furthermore, the Eco-design Directive requires that manufacturers keep and make available EC declarations of conformity, and affix CE markings.

6 CONCLUSION

The present report provides a preliminary market analysis of the European heating and cooling sector, as well as an overview of the technical codes and certification systems affecting the overall HYBUILD solutions and their specific components. The objective is to pave the way for the future commercialisation of HYBUILD results, ensuring their compliance with the highest European standards and market needs.

At first, a technical explanation of the two proposed HYBUILD systems is provided, identifying at the same time each commercial component constituting the two solutions. Then, a general overview of the European energy demand scenario is provided, highlighting the market potential for the innovative compact hybrid electrical/thermal energy storage systems to be developed in the project.

Since HYBUILD results are envisaged to be marketed in seven target markets according with the different commercial scopes of the participants, the future compliance with EU and country specific building codes must be ensured. The most relevant European directives concerning energy efficiency in buildings have therefore been analyzed, as well as their implementation in the regulations of the seven identified target markets, in order to guide the business development and the definition of realistic market applications.

Finally, given the expected developments in the HYBUILD project, a study of certifications strategies covering both on global system and on the elements that compose the HYBUILD components is performed. Certification mechanisms are reviewed both at building level and at each single component level. Considering that the HYBUILD solution will be commercialised after the end of the project, an outlook about CE marking and eco labelling is shown.

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