D2.1 Definition of stakeholder requirements, market demands and application challenges

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D2.1- Definition of Stakeholder requirements, market demands ans application challenges

Summary

Deliverable D2.1 identifies the potential market size and geographical location where MiniStor could have more opportunities for success in terms of market introduction based on maximized efficiency, output and constraints such as existing fuels used for heating. It was found that MiniStor is better placed in countries without heat networks (such as district heating). Available levels of solar radiation came as a second consideration for placement. However, system physical characteristics and regulations concerning ammonia pose further limits to system location. Nevertheless, the number of potential dwellings where this can happen is still counted in several millions.
Competing technologies were analysed. It was found that amalgamation of electrical and thermal storage is not met by current energy storage options. However, direct competitors for MiniStor are domestic hot water (DHW) storage tanks due to lower levels of design complexity and specialization for maintenance. However, primary fuel sources to heat DHW tanks are major contributors to greenhouse gas emissions due to low efficiency and output compared to thermochemical materials.
An initial group of external stakeholders was identified through consortium contacts, and were sent a short introduction to the system and a questionnaire to identify their current expectations regarding a thermal storage system. Results of the questionnaire reveal considerable interest in a standalone thermal storage system with higher capacity than water. The final part of the deliverable provides an overview of obstacles and barriers through a SWOT (Strenghts, Weaknesses, Opportunities, Threats) analysis, which reveals advantages and weaknesses of the MiniStor system in respect to competitor solutions.

Deliverable Number	Work Package
D2.1	WP2
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	PU	Public	X

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List of Abbreviations

Abbreviation	Definition
BEMS	Building Energy Management System
CAES	Compressed air energy storage
COP	Coefficient of Performance
DER	Distributed Energy Resources
DHW	Domestic Hot Water
D&R	Demand and Response
DSO	Distribution System Operator
EED	Energy Efficiency Directive
EMS	Energy Management System
EPBD	Energy Performance of Buildings Directive
EU	European Union
EV	Electric Vehicle
GDPR	General Data Protection Regulation
HEMS	Home Energy Management System
HP	Heat Pump
ICT	Information and Communications Technology
IoT	Internet of Things
LCA	Life cycle assessment
LE	Large Enterprise
LEED	Leadership in Energy and Environmental Design
NZEB	Nearly zero-energy building
PCM	Phase Change Material
PSH	Pumped storage hydroelectricity
PV	Photovoltaic
PVT	Photovoltaic-thermal
RES	Renewable Energy Sources
RTO	Research and Technology Organisation
S-LCA	Social Life Cycle Assessment
SME	Small and Medium-sized Enterprise
STP	Solar Thermal Panels
SWOT	Strengths, Weaknesses, Opportunities, Threats
T	Task
TCM	Thermo-chemical Materials
TES	Thermal Energy Storage
TRL	Technology Readiness Level
TTES	Tank Thermal Energy Storage
WP	Work Package

1. Introduction

1.1 Scope and objective of the deliverable

The scope of this deliverable is to identify stakeholders related to residential energy storage, their needs and requirements in relation to the demands of the market and other parameters (technological, economic, environmental). It is very important to understand the residential energy storage market needs, as well as expectations of MiniStor stakeholders, as it can contribute in addressing the goals and objectives set in the project.

A need can be considered as a problem that can be solved [1] or as a gap between current outcomes and desired outcomes [2]. It is the difference between the current state and the potential state which is targeted to be achieved. A needs assessment is a preliminary examination of a situation in support of planning and decision-making, in order to determine the potential for an action as a solution to a problem or a response to a new end-user's requirement in the market. It serves as a form of purposeful research for analyzing discrepancies or gaps, identifying problems, and ranking the needs hierarchically in order to determine the priority in which they should be addressed [3].

A needs assessment can serve several general purposes or functions and, as a planning tool in particular, it is of major importance for reducing uncertainty in decision making [1]. It is usually performed at the initial stage of project investigation. The needs assessment should examine and evaluate discrepancies and also facilitate the establishment of priorities of responses to the needs. McKillip [1] identifies three main types of needs assessment:

(a) discrepancy model;
(b) marketing model; and,
(c) decision-making model.

The most commonly used is the discrepancy model, which focuses on assessing the gap between the current and the desired state. The marketing model is based on selecting a target population and developing an effective marketing strategy that covers the needs of that selected target population, improving the market competitiveness. Finally, the decision-making model involves three stages: problem modelling, quantification and final synthesis for decision-making [3].

This deliverable follows the discrepancy model and focuses on determining the needs and expectations of selected representative members within an identified target group, the MiniStor stakeholder database. The database collects people from different sectors, researchers, academics, and managers from private and public companies, with the same interest in energy saving and energy management through energy storage.

1.2 Structure of the deliverable

This Deliverable aims to provide general indications from the residential energy storage market trend, the needs, and the expectations of beneficiaries involved in the MiniStor development but also of potential interested parties not directly involved in the project and which were contacted during the middle of year 2020. It also takes into account data from D2.2 "Definition of system context and limits for use".

This Deliverable is divided in three main parts:

1. The first part (chapter 2) presents the market trend with a brief overview of the competing technologies
2. The second part of the document describes the stakeholders' group, the tools used to collect information and lists the needs and the expectations from them.
3. The third and final part of this document focusses on the obstacles and barriers for the technology deployment.

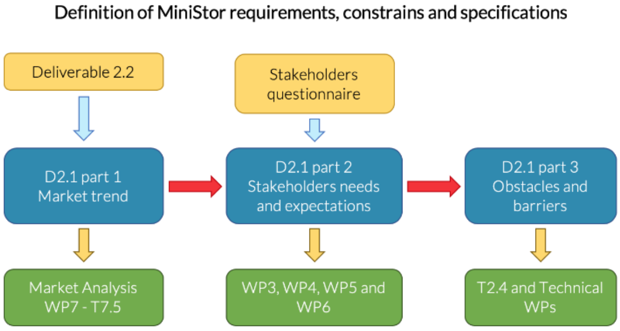

Figure 1 - Deliverable Structure and connections

Figure 1 shows the connections of these three parts, the main inputs, and the next tasks that will be fed from this deliverable. Some of the content described here will be analyzed in depth in WP7 in T7.3, Identification and management of the exploitable results, and in T7.4 Business Models, market introduction and IP management.

2. Expected European Market trends for energy storage systems

The energy policy of the European Union has a clear orientation towards improving energy efficiency and gives prominence to the participation of renewable energy in its different vectors (solar thermal, solar photovoltaic, wind, biomass, etc.). This is indicated by the Key targets of the European Commission for 2030 [4]: At least 40% cuts in greenhouse gas emissions (from 1990 levels), at least 32% share for renewable energy and finally at least 32.5% improvement in energy efficiency.

These objectives define in the medium and long term the need to develop and improve the different energy technologies applicable to the different sectors: industrial, transport and buildings. For energy storage technologies, it is expected that their development and optimization will contribute to a more efficient use of renewable energy, by managing the mismatch between the production and the demand [5],[6], very common when in renewable production technologies, such as the wind and solar (thermal and photovoltaic). Under this framework, the main trends and guidelines set by the policy of the European Union for the energy storage technologies are:

1. The development of **electric energy storage technologies**, especially those integrated into the **transmission and distribution networks at high and medium voltage electricity** [7]. Within these electrical storage technologies, there are options with high technological maturity such as pumped-storage hydroelectricity (PSH), compressed air energy storage (CAES) and flywheels. Other technologies for which further development is expected in the coming years are super-capacitors, with very short charge and discharge times, and solar fuels such as hydrogen.
2. The development of **thermal storage technologies**, integrated into centralized heating and cooling networks (**district networks**), integrating different renewable sources such as biomass, solar thermal energy and heat recovery from industrial clusters [8]. In this line, seasonal thermal storage should be specially developed.
3. The development and promotion of **efficient energy technologies and renewable energy technologies applicable in the building sector**. In this line, energy storage technologies must be designed according to the different energy demand profiles of

buildings (residential, commercial), and according to the production profile of the renewable energy source used (solar thermal, photovoltaic, etc.).

Considering that the building sector is responsible for 40% of energy consumption and 36% of greenhouse effect gas emissions in the EU [9], increasing the energy efficiency in this sector is crucial to achieve the aims of European Green Deal. The EU is aware of the importance of this sector, and has put a lot of effort to improve energy efficiency in buildings e.g. by introducing a series of directives - The Energy Performance of Buildings Directive (EPBD) 2010/31/EU and the Energy Efficiency Directive (EED) 2012/27/EU. They were revised in 2018, as part of the Clean energy for all Europeans package, to better reflect the EU's aim of driving the clean energy transition.

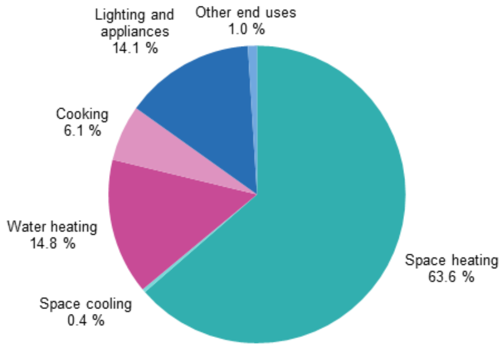

Figure 2 - Final energy consumption in the residential sector by use, EU-27, 2018

Residential buildings are responsible for most of the energy consumption in the building sector. Data collected by Eurostat show that thermal energy accounts for nearly 80% of the total energy used by households. It is used for space heating, water heating and space cooling. This information leads us to the conclusion that increasing thermal efficiency of buildings provides the best opportunity to decrease the absolute amount of energy used in buildings. This conclusion gave rise to the following market analysis which is oriented towards thermal energy storage.

2.1 Market Segmentation: competing technologies

Thermal energy storage (TES) technologies can be divided into three categories: sensible, latent and thermochemical heat storage. Sensible heat storage includes typically TES Tanks (TTES). Latent heat storage uses different types of phase change materials (PCM), while thermochemical storage (TCM) uses reversible chemical reactions to store large quantities of heat in a compact volume [4],[5]. The MiniStor system combines two different TES technologies: i) TCM, and ii) hot PCM and cold PCM in order to provide greater flexibility and control for the dispatch of the stored energy. Table 1 shows the typical parameters for these different thermal storage technologies [10].

TES technology	Energy density [kWh/t]	Typical storage period [d, h, m, y]	Efficiency [%]	Reference cost [€ /kwh]
TES Tank	10-50	h, d, m	50-90	0.1-10
PCM	50-150	h, d	75-90	10-50
TCM	120-250	h, d, m, y	75-100	8-100

Table 1 - Typical parameter values for the different TES technologies (h=hours, d= days, m=months, y=year)

The development of these thermal storage technologies is being carried out in different sectors, such as electricity generation, through thermo-solar generation plants; and the heating and cooling sector to meet the thermal demands of the building sector ([6]-[8]). Specifically, the MiniStor system is focused on applications in the building sector.

Within the building sector, there are two main applications according to the storage period: daily storage TES and Seasonal storage TES [7]. Seasonal TES is mainly oriented to large-scale systems, such as district heating/cooling systems and large residential complexes with centralized heating and cooling systems. In contrast, the MiniStor system is aimed at smaller buildings, such as individual houses and small/medium-sized multi-dwelling buildings.

Considering the characteristics that the MiniStor system incorporates, as well as the size of buildings, for which it has been designed, the following technologies can be identified as the main market options that will compete directly with the MiniStor system ([6]-[8]):

- Basic electric storage heaters [7];
- Tank TES based systems in combination with standard heat pumps;
- PCM based systems in combination with standard heat pumps;

The main characteristics and application market of each of these options are presented below.

2.1.1 Basic electric storage heaters

Basic electric storage heaters are not TES-Tanks, however, this technology is very common and has a high penetration in the current market, especially in existing old buildings. Its main advantage is the very low investment cost, but this technology has a lower COP efficiency compared to other systems, such as heat pumps and the MiniStor system. Furthermore, this technology can be enabled to use the electricity produced by renewable energy sources, such as photovoltaic (PV) modules, whose cost has been decreasing quickly during the last two decades. This could impact on the carbon footprint of the technology.

2.1.2 Tank TES water-based systems

The use of hot water tanks is a well-known technology for thermal energy storage. TES Tanks can be used as buffer tanks in heating and cooling installations for daily energy storage in hot water applications, and even in seasonal heating energy storage applications. This technology is a cost-effective option and its efficiency can be improved by using stratification elements and installing better thermal insulation. The main drawbacks are its low energy density in comparison with PCMs and TCM technologies and its variable discharging temperature [5],[10].

Currently, TES Tanks are being used in combination with heat pumps (air-to-water, water-to-water and brine-to-water) and low-temperature emitters in new and retrofitted buildings. Some of these emitters are fan-coil units, radiant floor and refrigerant ceiling or conventional radiators. These systems are promoted as a more efficient option than the usual systems based on gas-boilers combined with normal radiators and electrical storage heaters. Because this technology is consolidated and readily available, it can be classified as the main competitor of MiniStor system.

2.1.3 PCM based systems

In general, PCMs are more expensive than TES Tanks, but they could be economically viable in applications in which there are space limitations, thanks to the higher PCM energy density compared to traditional TES Tanks. Another important advantage of PCMs against the TES option is the capacity to provide more stable discharging temperatures. The viability of the PCMs' application depends highly on the number of cycles required by the application, versus the number of cycles supported by the PCM. For the MiniStor system, novel PCMs that can support more cycles than common PCMs currently available in the market will be used.

The combination of PCMs with market-available reversible air-to-water and water-to-water heat pumps, is a system that could pose competition to the MiniStor system. This option could benefit from activation using different renewable energy resources and also produce heating and cooling for residential usage. On the other hand, PCM slurries is another promising technology that can be applied in active heating and cooling systems as heat transfer fluid, with high possibilities to compete with MiniStor system. These technologies, however, have not found market implementation due to their still limited thermal capacity and the degradation over time that the materials can have due to interaction with water present as air vapour, requiring specific packaging processes to minimize this effect. PCM materials can also corrode their metallic containers and can be highly flammable.

2.1.4 Main advantages and disadvantages for each competing technology

Table 2 summarizes the main advantages and disadvantages identified for each of the above-mentioned competing technologies. The relevant characteristics of the MiniStor system are also presented.

Technology	Main advantages	Main disadvantages
Electrical storage heaters	- Low cost [8] - Mature technology - Possibility to use PV technology as (seasonal) energy source reducing CO2 footprint	- Low system efficiency - Low energy storage capacity - Small domestic application only
Tank TES based systems	- Low-cost TES material (water) - Mature technology - No toxic TES material - Easy integration to existing systems with water-based emitters units	- Low-temperature stability during the discharge process - Low energy density and high volume
PCM TES based systems	- High energy density (between 5 to 10 times higher than Sensible Tank TES). - Compact system. [11] - Stable temperature during the discharging process - Low toxicity - Easy integration to existing systems with water-based emitters units	- High cost. The total cost should include the material, the container, and the overhead cost. - Low thermal conductivity of PCMs - Inorganic PCMs are normally corrosive to metal containers - Organic PCMs are flammable
MiniStor system (initial analysis- see Section 5 for more details)	- Very high energy density - Low mass and volume of storage materials. - High exergetic efficiency ([10]-[13]) - High operating temperature ([10]-[13]) - Relatively easy integration to existing heating and cooling systems with water-based emitters units. - Combination of different storage technologies with internal heat pump. - Can provide both heating and cooling.	- Low technological maturity - More complex and expensive than TES-based tanks. [4] - Risk of degradation of the TCM material properties during charging and discharging processes if using water. - Regulation limiting use of ammonia in refrigeration systems for residential sector when avoiding water.

Table 2 - Main strengths and weaknesses of each competing technology, including also the MiniStor-System.[4], [8],[10]-[13]

2.2 European Market Size

a) Size of market by dwelling type

An initial analysis of the European housing market was carried out in D2.2, and this section includes some of the main findings of that Deliverable. The housing stock in the EU is diverse and has been analysed through different perspectives, with detailed analysis mostly done for research projects related to building refurbishment. However, reliable and updated data for the whole region can be found with limited availability.

Databases consulted in D2.2 included the EU Building Observatory (BSO) which directly collected data in the frame of the EU projects results such as Hotmaps[1], ODYSSEE-MURE[2], and in Switzerland the Swiss Statistics Office[3].-When considering the potential European Market size for the application of an energy storage solution designed for residential buildings it is necessary to begin with realising the size of the whole residential buildings sector. According to Eurostat data [16] from 2018 there are over 300 million residential structures in the EU, Switzerland and UK.

Residential structures can be classified according to their volume type and how many units are contained within this volume. By this classification it is possible to distinguish three main types of residential buildings:

• A single detached house: It is a house not attached to any other dwelling or structure – One dwelling building.

• A semi-detached house: It has attached another dwelling side by side (or back-to-back) but no dwellings either above it or below it – Two dwelling building.

• A flat: It is a dwelling unit in an apartment building which has fewer or more (High –rise) than five storeys, or in general in a building with more than 3 dwellings.

As shown in Figure 3, key markets of residential households are Germany, France, Italy, Spain and UK, which account for almost 65% of the total. In terms of type of dwelling, the distribution per country is shown in the following figure, which shows conventional dwellings (dwellings built and used purposely for residential use):

Even though MiniStor can be used in any of the mentioned types of buildings, it is expected to cover the energy needs of each type in a different way. In the case of detached houses, MiniStor will not be shared with other buildings, so it will be a standalone system. As for flats, MiniStor can be intended for simultaneous use by several flats, which will decrease the number of potentially installed units. The number of apartments that MiniStor will be able to supply will vary depending on their size, location, and overall energy needs.

[1] Hotmaps: https://www.hotmaps-project.eu/

[2] ODYSSEE-MURE: https://www.odyssee-mure.eu/

[3] Switzerland Source online: www.statista.com/statistics/918580/number-of-households-switzerland

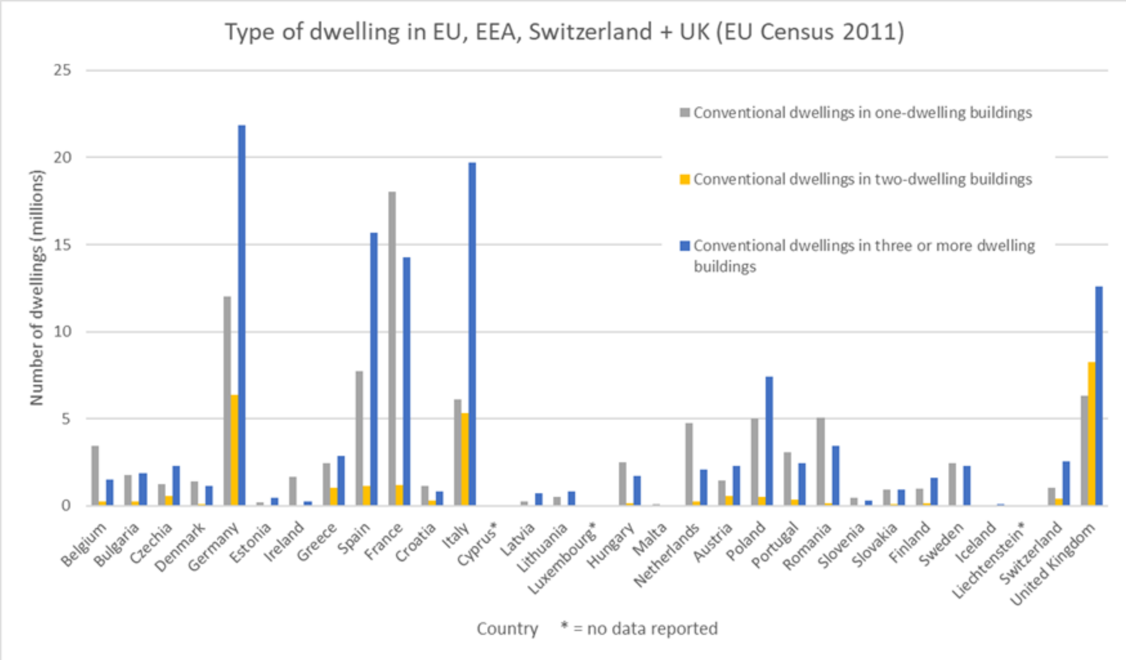

Figure 3 - Classification of the housing stock in the EU, EEA, Switzerland and UK through type of dwelling (conventional dwellings only). Source: European Statistical System, European Census 2011

b) Size of market by heating storage technology

Currently, the most common solution for thermal storage in the European residential sector is by use of Domestic Hot Water (DHW) tanks, which are connected to baseboard heaters in different spaces of the dwelling. The heat source for the water is in most cases electric or gas, which makes them incur in high costs to the end user, and become one of the sources for energy peak demand for national energy providers. There is no accurate data for the number of DHW tanks installed in each country, but some estimations state around 11 million installations in UK [11] and 24 million in France [14]. These means that DHW tanks are installed in nearly 35% of dwellings in UK and 80% of dwellings in France when considering all dwelling types [15].

However, the MiniStor solution, as an integrated system with electricity and thermal energy storage powered by photovoltaic-thermal (PVT) panels, is much more complex than DHW storage tanks. Therefore, a one-to-one comparison cannot be made. If European countries, especially EU member states, strengthen the adoption of renewable energy storage in all sectors, the need for solutions like MiniStor will grow. This section will analyse the potential European market size, as presented in the following paragraphs.

Due to being powered by renewable energy sources, an important factor that needs to be analysed when trying to estimate the potential market for MiniStor system is the climatic conditions of the site, such as potential for solar energy generation. MiniStor, as a solar energy-based system, will perform best in regions where solar radiation is the highest. This solar potential has already been analysed in Deliverable 2.2, and the geographic distribution is shown in Figure 4.

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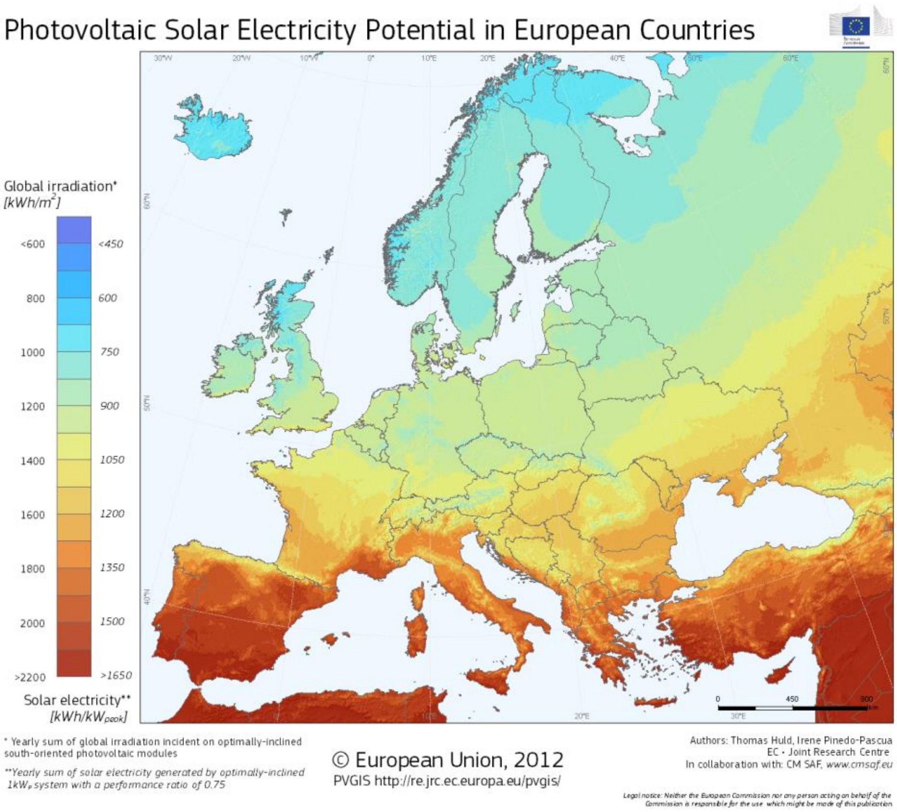


Figure 4 Photovoltaic solar electricity potential in the European continent for 2012. Source: PVGIS

From this information it can be determined that the highest potential of electricity and heat generation from solar sources can be found around the Mediterranean basin. However, viable solar installations for combined heat and power are still possible with suitable adaptations in farther northern latitudes such as Ireland, Sweden and Baltic countries.

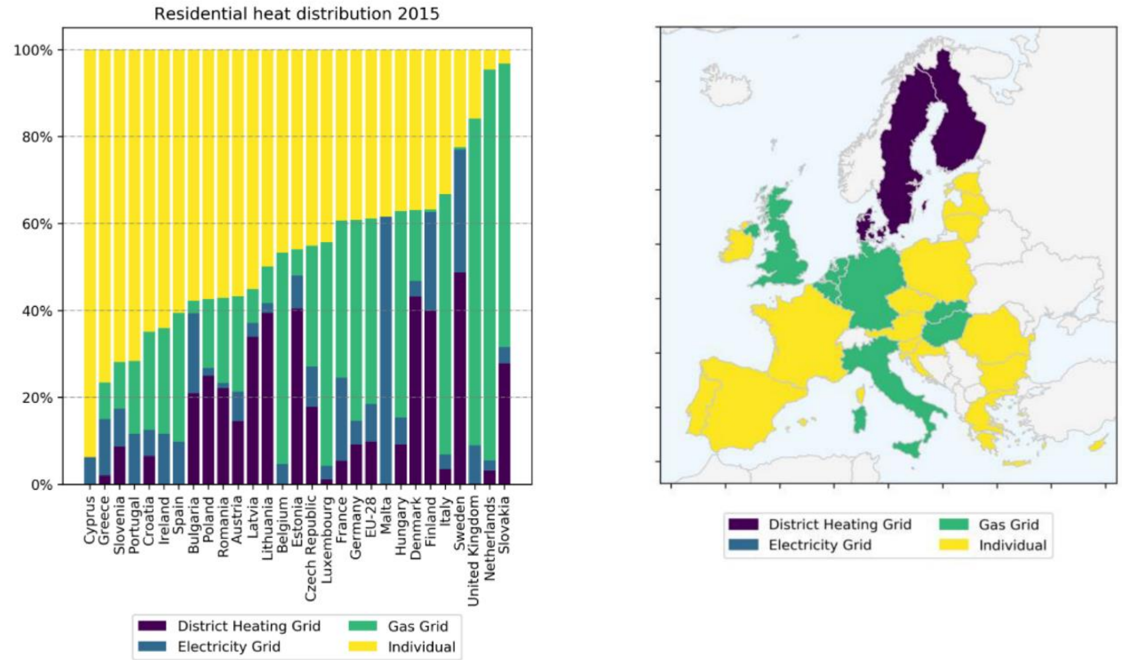
Another aspect of importance to define the European market size and potential MiniStor users' number is the type of heat delivery system, as seen in Figure 5. Four main types of heat energy sources can be found in European households, namely district heating, natural gas, electric heating and individual solid fossil fuel systems. The first three systems are delivered through connection to a grid, while the fourth can be found in urban centres and off-grid locations.

MiniStor offers itself as an alternative to supplement heat generated through electricity, natural gas and individual off-grid heat sources, such as biomass or oil burning. This will result in reduction of the carbon footprint of these heating networks and systems. Heat delivered through district heating have high efficiency when installed (but present a high upfront cost in new markets), which make MiniStor a less attractive option where those networks are already present. Figure 5 presents the share of residential heat systems present in each country, while the map represents the dominating heat delivery carrier.

Presented data show that in most EU countries and UK individual heat sources are dominant (gas, electricity and off-grid), while District Heating Grids dominate in Scandinavian countries. This aspect combined with reduced solar conditions for energy generation makes those markets not attractive for the MiniStor system.

An additional interesting factor to analyze is the actual source fuel used for space heating, as shown in Figure 6. It has been a goal of the EU to decarbonize its heat sources and increase the use of renewables. The introduction of MiniStor in those countries with the highest use of fossil fuels and gas for space heating can help to achieve those goals. This can be true for almost all the

EU27 countries and the UK, where despite efforts of recent years, the use of fossil fuels and gas is still very high.



(a) (b)

Figure 5 - (a) Share of residential heat consumption from individual heating or delivered via district heat networks, gas network or electricity grids. (b) Geographical representation of the most usual type of energy carrier delivery [16]

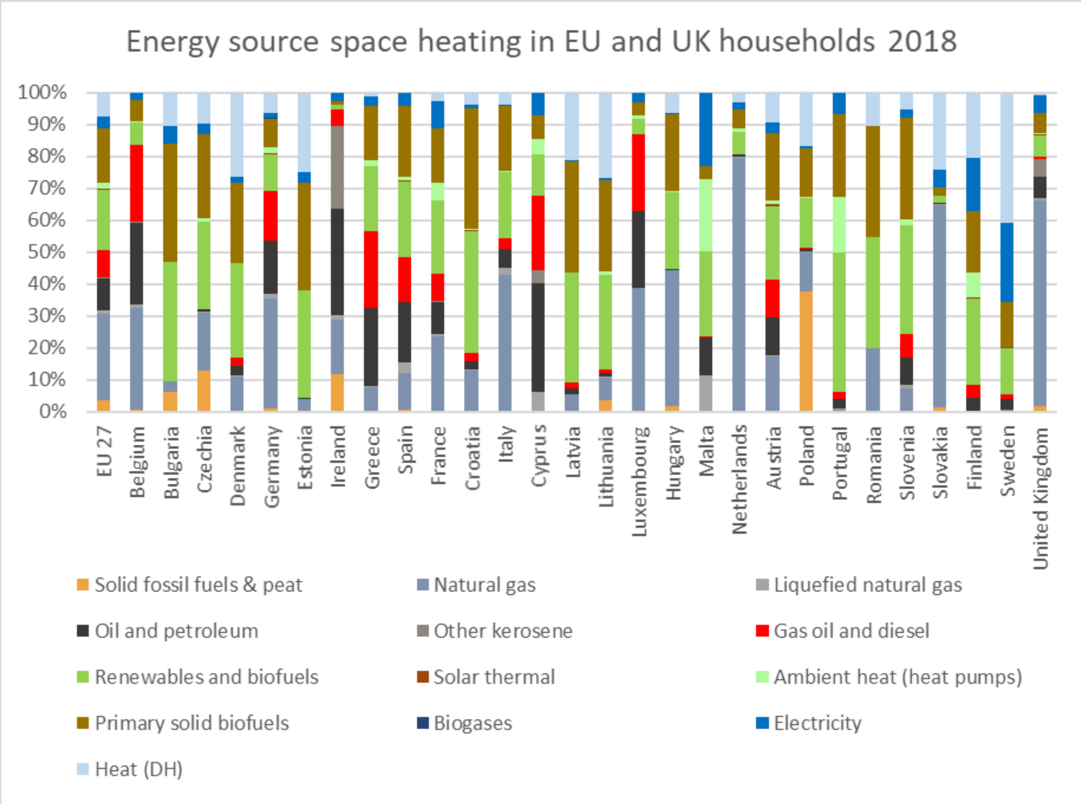


Figure 6 - Thermal energy source for space heating in EU 27 and the UK [18]

Another factor for the estimated location of potential markets is the analysis of future heating and cooling loads as analyzed for the demo sites in Deliverable 2.2. Using projected models for global warming, the general trend is an increase of cooling and reduction of heating demands throughout Europe. As an adaptable system, MiniStor can address these future needs of dwellings by transforming some of the stored energy into cooling while also allowing flexibility for the use of heating.

Based on all the considerations mentioned previously, the broad potential market size for MiniStor stands at about 128 million residential structures. This figure is based on the 2011 census, and takes into account a percentage of about 80% eligible single and semi-detached houses, and 30% of apartment buildings. This estimation also discounts most of the housing stock in Nordic countries connected to district heating. Further refinements to these calculations and assumptions will be done in the context of WP7 to determine a more accurate market size including possible number of early adopters.

In conclusion of this chapter, it is useful to remember the missing market analysis for cooling mode. The MiniStor system, unlike the competitor storage systems, can work both in heating and in cooling mode and this aspect is not present in the market. This is the reason why it is not included here. This aspect will be analyzed in the market analysis in the framework of WP7.

3. Identification of MiniStor stakeholders' group and requirements

A first effort is made in this chapter to identify the stakeholders with an interest in the MiniStor project. The main stakeholders are generally from the thermal or electric energy sector, as well as from providers of energy efficiency and energy flexibility management.

The target groups of the residential thermal energy sector can span in a wide range of stakeholders which can be classified in several categories:

- Producers/Manufacturers
- Installers
- End-Users (dwelling inhabitants, as well as owners and administrators)
- Public bodies for policy and regulation
- Innovation and Research
- External Services and consultancy

Similarly, the target groups for the electric energy sector can be classified in the following categories:

- Transmission/Distribution Operators
- Trading/Selling Players/Producers
- End-Users/Prosumers
- Public bodies for policy and regulation
- Innovation and Research
- External Services and consultancy

Those categories are related and interact with each other according to the following supply chains as shown in Figure 7 for the electric energy sector and Figure 8 for the thermal energy sector correspondingly.

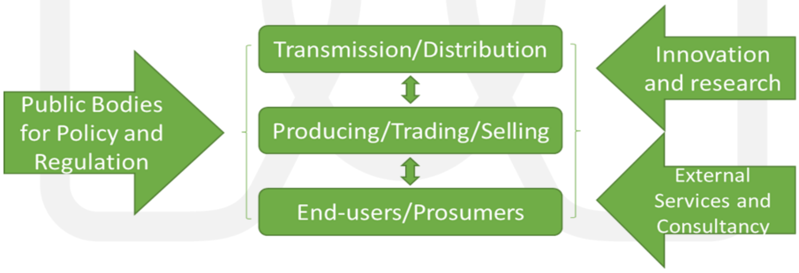


Figure 7- Supply chain of the electrical energy sector

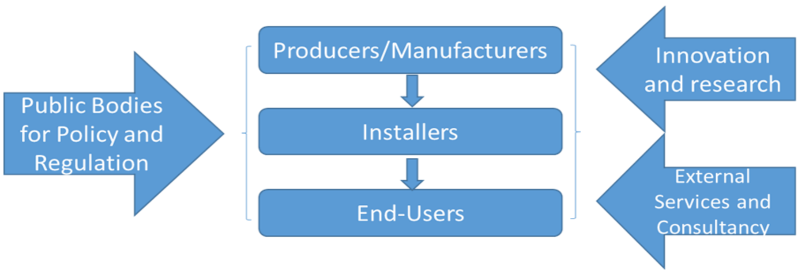


Figure 8 - Supply chain of the thermal energy sector

Interested parties were identified to provide inputs that could be used to gauge market expectations and that could have a role in future product introduction. For this reason, the MiniStor stakeholder group was divided in two parts:

1. The developers' stakeholder group, represented by the MiniStor consortium partners;

2. The external stakeholder group represents institutions that could show interest in the project after its conclusion. The initial list was provided by MiniStor partners.

3.1 Developers' Stakeholder Group

Since there are a large number of partners and demo sites are involved in this project, an advantage exists for the sharing of information from multiple stakeholder sources at a very early stage. Besides the useful results and the final outcome expected at the end of the project, this also offers the major advantage that a wide range of information from multiple sources is available from an initial stage of the project. The consortium formed consists of different key players and organizations, which bring together expertise and know-how from different aspects of the energy market. Their positioning also helps to identify external stakeholders and therefore start surveys that can direct to further interested parties. The MiniStor consortium is composed of 17 partners with a variety of roles (see Table 3).

Manufacturers/ Installers	Public bodies	Innovation & Research	External Services and Consultancy
Woodspring	Cork City Council	IERC (Tyndall)	FEUGA
EndeF		CERTH	R2M
Sunamp Ltd		CNRS	SGS
Sunamp GmbH		HSLU	
Enetech		Cardiff	
		University of Edinburg	
		EMI	
		DUTH	

Table 3 - Classification of the participants in the MiniStor consortium, according to the defined supply-chain categories

3.2 External Stakeholder Group

The initial MiniStor external stakeholder group database has been created by the contribution of the whole consortium by providing contacts who have a relevant interest in the development of thermal storage systems, nearly Zero Energy Buildings and RES technologies.

At an early stage, up to 35 contacts were made as listed in annex I. This initial group will continue to grow during the next years of the project, representing a fundamental tool for active dissemination for MiniStor to receive feedback. The list complies with GDPR and all the contacts included have given their consent to the processing of the provided data.

Figure 9 **- External stakeholder group by country** and Figure 10 show the classification of collected contacts by country of origin and by type of organizations.

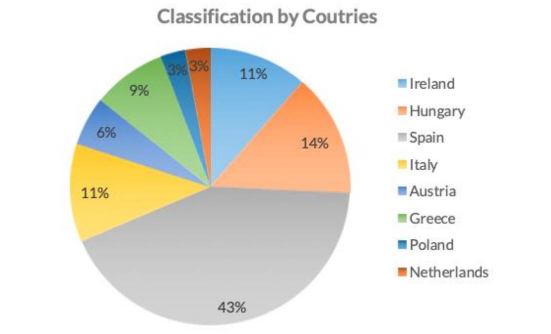


Figure 9 - External stakeholder group by country

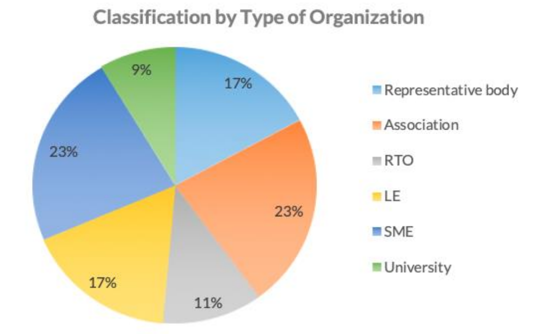


Figure 10 - External stakeholder group by type of organization

3.3 Identification of external stakeholder's requirements

Participants in the survey were presented with a brief project presentation and a questionnaire, in order to identify expectations and requirements for a thermal storage system, helping to gauge the distance between its current and targeted state. This will lead to the development of an Action Plan, that will address the needs or close the gaps and bring each stakeholder closer to its targets and objectives for the post project phase of MiniStor but that can also affect the development of the system during project lifetime. A needs assessment is most commonly conducted to determine which features should be included while still respecting the objectives set in the Grant Agreement.

The MiniStor Needs Assessment process is performed into three different steps:

- Exploration and identification;
- Data gathering and analysis;
- Utilization

3.3.1 Exploration and identification

In this first step of the external stakeholder needs assessment, the expertise and interest in the project was assessed. Figure 11 shows the expertise of the collected external contacts and Figure 12 the expressed interest in the MiniStor system:

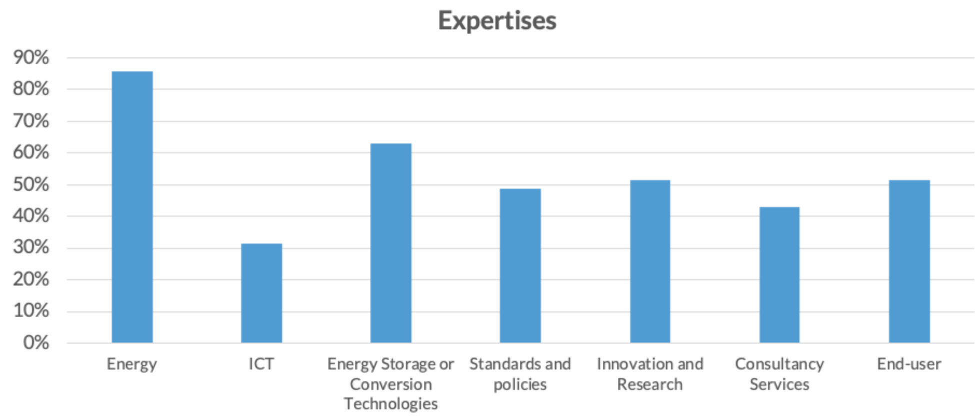


Figure 11 – Expertise of the external stakeholder contacts

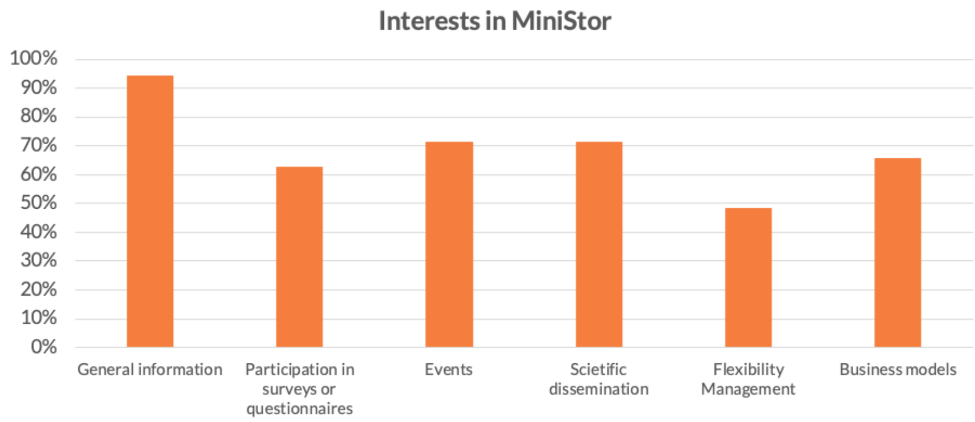


Figure 12 – Interests in the MiniStor project

The questionnaire also served to analyse their current experiences with renewable energy sources (RES). In the following graph, it can be seen that the installed RES capacity in their dwellings is low. Only 30% of the stakeholders have a photovoltaic system, 20% use solar thermal panels and an EMS, 15% have a heat pump and there is no energy storage system. However, interest is high in increasing their capacity in these systems and is dependent on particular conditions (e.g., availability at the rooftop for solar panels). These findings mean that focus on the MiniStor objectives is well-placed.

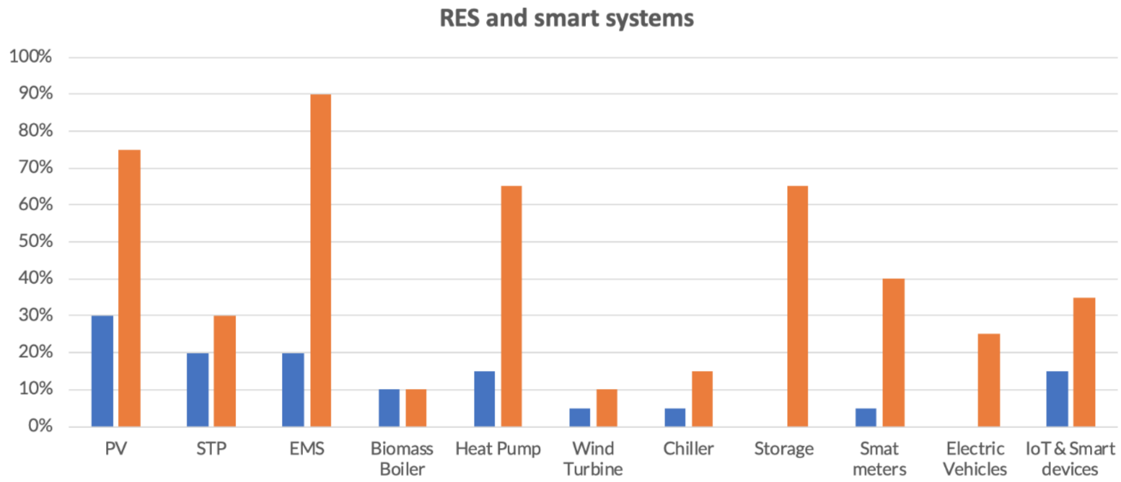


Figure 13 – Stakeholders' RES and smart system penetration (Blue: actual conditions; Orange: condition of future interest)

3.3.2 Information gathering and data analysis

The external stakeholder requirements and expectations were collected through a questionnaire divided into four sections with 22 questions in total. A synoptic summary is reported in Table 4 below.

The questions have been identified and expressed in such way as to understand if stakeholders have had personal experience with thermal storage systems, renewable energy systems and the application of energy flexibility. It also collects information on possible market dynamics such as future price and investment outlook. This will serve to provide a baseline for comparison with the project targets.

This questionnaire aims to collect stakeholder information related to energy needs, energy flexibility, demand & response strategies for residential applications which can contribute to the MiniStor storage development, characterizing the application context and making in evidence the main stakeholders needs and expectations. Please fill the template and define what are your main needs and indicate the main goals you expect to reach thanks to MiniStor outcomes
A - Technology Considering the technological context for the market available technologies in field of energy management, energy conversion and storage able to provide residential energy flexibility, provide the information requested: 1. Have you got systems able to generate renewable energy in your home, apartment, or building? (If yes, please list the systems in use) 2. Have you got systems able to manage energy flexibility or participate in demand & response programmes in your home, apartment, or building? (If yes, please list the systems in use) 3. Which systems do you think are necessary, in respect to your lifestyle, to manage the energy in residential sectors 4. Which systems, present in the market, do you think could improve your quality of life at home? 5. With reference to the previous response, please fill the box below making evident your technological needs and what you would like to improve regarding your needs.

Needs	**Expected improvements**
Please indicate the main technology needs you have	Here you can report the improvement you expect to reach during the project

B - Market

In respect to the energy market and the energy flexibility you get from the market or your DSO, (D&R programmes, energy prices scheduling, possibility to sell energy to the grid, etc, etc) reply to the following questions:

6. What are the forms of energy you mainly use in your residential activity? (electrical energy, thermal energy) and how do you get or generate those energy forms?
7. What are the average energy prices (electrical and thermal) are you paying for your residential needs?
8. Are you satisfied for the prices and the energy programmes you have for the energy supply?
9. If you have a PV system and you are selling energy to the grid, are you satisfied for your remuneration? (please indicate your remuneration price and programme)
10. Would you be willing to buy a residential energy storage system?
11. What limit price would you be willing to pay for a residential energy storage able to increase your energy flexibility?
12. Would you be available to sign an energy performance contract for your residential building?
13. With reference to the previous response, please fill the box below making evident your market needs and what you would like to improve in respect to your needs.

Needs	**Expected improvements**
What are your market needs?	Do you expect the innovation in MiniStor can contribute to improve your market?

C - Business/Economical/Financial

If you are a company or an energy market player, please fill the boxes below

14. With reference the MiniStor storage, do you need to test or implement new business or market models?
15. If you are on the energy market (energy provider or technological producer), do you need a specific investment framework to consolidate your market position?
16. Would you be available to share your know-how (patent of knowledge) to try to enter other sectors of the energy market? If yes which sectors are interesting for your business?
17. Do you think it is possible and interesting, for your current business, to improve a synergistic market approach for the MiniStor product, after the conclusion of the project? (MiniStor startup, collaboration contracts, exclusive resale agreement, etc.) If yes, which is your vision?
18. With reference to the previous response, please fill the box below making evident your needs and what you would like to improve in respect to your needs.

Needs	**Expected improvements**
Please specify what you need	Here indicate your expectations (i.e. a consolidated financial position, or savings generated thanks to the project, or sales improvements thanks to an increased visibility etc.)

D - Environmental improvements

19. Which are your energy systems which have the greatest environmental impact?
20. Would you be willing to spend a little more on your energy systems to reduce the environmental impact?
21. What environmental actions you need to address? In addition, what improvements you expect to deliver by the end of the MiniStor project?

Needs	**Expected improvements**

Please specify what you need	Please specify what you expected improvements
E- Other	
22. Please indicate any other implementation priorities (i.e. implementation actions considered strategic for you, for instance to get advantage with respect to competitors, to save money, to increase the quality of service etc.) 23. Please indicate any other needs relevant with the project activities (i.e. Policy, Regulatory, etc...)	

Table 4 - MiniStor stakeholder questionnaire

3.3.3 Utilization

Outcomes from the previous analysis will be used in future project activities as a guideline, in order to define effective strategies for successfully addressing pre-identified needs required for achieving the set targets and closing the gaps between the product's desired future state and its current state. This deliverable will be also an input for the market analysis that will be carried out in WP7 (T7.5). The process will be completed with a cost-benefit analysis, which will be necessary in order to assess possible actions to fill the identified gaps and to select the best possible strategies suitable for each organization or stakeholder in terms of costs and benefits.

3.4 Data collection analysis

During the analysis, it emerged that many of the needs are common to multiple external stakeholders, therefore, they were grouped into the main requirements and each of them has been matched with specific expectations presented in the middle columns of Table 5 to Table 8. Four levels of indicators, each identified by a different colour, were used to give a fast assessment of the relevance to the context of the project and the feasibility to reach the expectation:

- **Green**: It represents a condition where the stakeholders' needs and expectations are well aligned with project activities and will be easily reached
- **Yellow**: This colour represents a situation where stakeholders' needs and expectations are expressed, do not necessarily align with the stated aims of MiniStor but they can be explored without deviating from the MiniStor Grant Agreement.
- **Cyan**: Represents needs and expectations for which it is not possible to have more information yet.
- The fourth level characterizes a situation where the needs and expectations are not totally contextualized in MiniStor or where the target is hard to be reached. However, no stakeholders' need or expectation was assessed as belonging to this level.

3.5 Technological needs and expectations

From the collected data, technological needs can be grouped into 7 basic requirements to which the corresponding expectations of the external stakeholders are linked. However, it is important to keep in mind that tables 5 to 8 must be considered as a wish list and not as a set of requirements to be addressed during project implementation.

#	Technological needs	Expectations	Level
1	***Commercial energy storage***	*a. The MiniStor system has to become a commercial product able to store energy from different types of RES plants (PV,*	***Green***

	solution usable with multiple RES plants.	*Biomass Boiler, STP, etc.). The source of energy must not be a constraint on its use.*	
		b. The connection with the Heat Pump (HP) is fundamental to exploit the potential of the stored energy.	***Green***
		c. The system could integrate the function of energy recharging for electric vehicles (EV). In a certain way it is desirable to manage the EV as an alternative electrical storage module connected to the system.	***Yellow***
		d. The system has to be able to works as a backup and reduce the exposure to energy black out.	***Green***
2	***Energy storage combined with an Energy Management System (EMS)***	*a. Have a unique product for the energy storage and the energy management (Smart storage system). The combination of storage and EMS is a fundamental skill for a better applicability and an easy use of the stored energy.*	***Green***
		b. The electrical storage has to better manage the electrical or thermal self-consumption (optimize the production from solar radiation) and reduce the gap with the NZEB level.	***Green***
		c. From the energy management a reduction of the energy consumptions in general is expected.	***Yellow***
3	***High smartness and monitoring***	*a. High smartness level.*	***Green***
		b. User-friendliness of new technologies.	***Cyan***
4	***Interaction with demand and response***	*a. Possibility to have access to demand and response programmes. The BEMS has to permit the connection with a wider energy management considering the benefits (technical and economical) from the demand and response strategies. This is the most important aspect, noted by different stakeholders, as a great innovation with respect to the commercial solutions.*	***Yellow***
5	***Connectivity with home automation systems and appliances***	*a. It is expected that the MiniStor system will become able to connect with home automation systems (IoT systems and home devices). This ambitious expectation implies the extension of the storage system + BEMS to a high smart home controller.*	***Cyan***
		b. The system can leverage the development of high-tech development technologies.	***Cyan***
6	***High efficiency, affordability and durability of the system***	*a. A high conversion efficiency (in the thermal and electrical conversions) compared to commercial solutions is expected.*	***Yellow***
		b. The system has to reach a higher level of energy density compared to the commercial solutions.	***Green***
		c. The system has to be able to store energy for long time minimizing the energy loses.	***Cyan***
		d. The system has to be affordable in the utilization with new technologies.	***Cyan***
		e. The system has to be considered an opportunity for low-carbon heat and electricity consumption.	***Green***

7	***Easy installation and maintenance***	*a. Possibility to have a smart connection with most of the commercial RES systems, quickly and without relevant modification to the current plants*	***Green***
		b. The storage system has to be considered a modular system.	***Yellow***
		c. The system has to be compact and able to be located in a small space compatible with the residential sector (dwellings).	***Green***
		d. The MiniStor system has to be easy to maintain.	***Yellow***

Table 5 – Stakeholder technological needs and expectations

Technological needs: In most cases, the stakeholders (internal and external) reported their interest for innovative, compact, high-tech technologies of low-carbon thermal and electricity storage which would be affordable, cost-effective and would result in energy savings and reduction of energy consumption. The expected technological results from the MiniStor project involve development of an integrated system (storage system + BEMS) which could serve all these needs and ensure energy efficiency and independency (backup system) from the grid.

The efforts in the technological field focus on utilizing existing know-how regarding electricity and thermal storage and pushing forward towards achieving the expectations of the MiniStor project in order to fill the gap towards the desired results. Energy storage technologies will ensure energy efficiency and push the end-user's energy consumptions awareness. The combination of the PVT technology along with thermal and electricity storage will also contribute to the goal of reducing energy dependency from the grid (NZEB concept) by producing own electricity along with using less electricity for heating, cooling and DHW. Minimization of exposure in case of black out will also be achieved through this way, enhancing grid independency furthermore. Collateral but not insignificant technological goals of developing user-friendly systems which ensure user comfort and compactness through employing modular design are also the focus of the MiniStor project.

Some aspects are not yet well defined such as the energy performance in the energy conversions or the possibility to store energy for long time periods with very low energy losses. These might be verified during the demonstration phase.

The interest in demand and response participation is well evident from the stakeholders needs. The incorporation of such ability in MiniStor is one of the main challenges of the project. Demand response modes for the electrical storage, along with DER and load forecasting are going to be developed. However, better definition of market conditions for energy flexibility in residential facilities must be defined in order to meet this expectation.

3.6 Market needs and expectations

From the market box of the questionnaire 4 main categories of needs emerged.

#	Market needs	Expectations	Level
1	***Cost structure and competitiveness with the market***	*a. It is desirable for the MiniStor system to combine cost-competitiveness with the benefits produced and to guarantee a payback time no longer than 3-4 years.*	***Yellow***
		a. The system has to produce energy savings (and cost savings) as a result of energy management.	***Green***
		b. With respect to the production and the technology development, the structure of costs has to be clear and well comprehensible.	***Green***

		c. *The costs for installation and maintenance have to be comparable with the competitor technologies or compared with the market costs*	***Cyan***
2	***Comfort level and safety conditions***	a. *The system has to be able to provide an improved level of comfort, easy comprehensible for the end users, better than the competitors technologies.*	***Green***
		b. *The system has to guarantee a high level of safety for the applicability in the residential sector.*	***Green***
		c. *The system has to leverage the green aspects of the building/dwelling contributing to the increase of the energy labelling. It can be considered also in the labelling standards as WELL or LEED.*	***Cyan***
3	***Possibility to have access to incentives or energy efficiency programmes***	a. *The MiniStor system has to be able to participate in the energy efficiency economic support programs offering economic incentives or tax recovery programs.*	***Green***
		b. *It is desirable for the system to be able to participate in demand and response programmes in each country and give the opportunity to enjoy economic benefits for energy flexibility.*	***Yellow***
4	***Technology awareness and marketing***	a. *The system has to be supported by a well-structured informative program that increases the awareness of the benefits to the end users. A lot of end-users are not aware of the benefits that can be offered from smart and responsible energy management.*	***Cyan***
		b. *The MiniStor technology has to increase the responsible and green actions of the end-user by reports or messages related to the energy and costs saved.*	***Cyan***
		c. *The system has to be able to provide a real-time information about energy situation and history of the building*	***Green***

Table 6 - Market needs and expectations

Market need: Market needs are mostly focused on developing a product with added value to the consumer, ensuring mainly comfort, safety and convenience. Compatibility, easy maintenance, cost savings, lower energy prices and affordability are targeted for making the product more attractive to the buyer. Setting a clear cost structure and accessing incentives or energy efficiency support programmes are also considered important for meeting the reported expectations.

Other needs which concern the stakeholders and could be covered by the MiniStor project involve collection of up-to-date information on the energy usage on residential level and the corresponding available energy. The possibility to have access to Demand & Response programmes will be evaluated during the project as a plus for the system, and will depend on the amount of energy generated as well as minimal requirements set by the electricity operators in each demo site country. With the advanced system developed in the MiniStor project, real time information about the energy situation and history of the building where it is applied could be recorded and major improvements of energy management could be made, which could boost flexibility at residential level, increasing the possibility to auto-manage the energy consumption and allowing exchange with neighboring buildings with similar systems. Access to incentives and other support programmes for the stakeholders could also be achieved indirectly through the MiniStor project, as it will provide an open channel for communication and contact with the relevant public bodies and official entities through the dissemination campaign of the project.

More details on market demand analysis will be provided in WP7 in Task 7.5.

3.7 Business & economic needs and expectations

The business and economic needs provide a general indication for the main analysis that will be done in T7.4.

#	Business and economic needs	Expectations	Level
1	***Business models and market approach***	*a. It is desirable for the system has to be able to cover the gap between the research and development of new technologies and the market (achieve a TRL 9 instead of TRL 7 as stated in the original call).*	***Yellow***
		b. The system could contribute to the opening of energy markets in specific countries. For example, this solution can participate in the energy trading in Poland or Spain.	***Cyan***
		c. The MiniStor system can be an innovative product, leveraging mechanisms as energy performance contracting in the residential sector.	***Cyan***
		d. By innovative business models, the system can be considered in synergic offers with PV or STP plants for the residential sector.	***Green***
		e. The MiniStor system can be offered in a full-service programme within the energy supply in the residential sector.	***Green***
		f. Reduce the gap between real solutions and NZEB level.	***Green***
2	***Demand and response programmes***	*a. Possibility to have access to demand and response programme. This technology has to be considered as an opportunity to enter the energy flexibility market and create new opportunity for the prosumers.*	***Yellow***

Table 7 – Business and economic needs and expectations

Business needs: Main targets in the business and economical field mainly include adopting management models suitable for the specific cases investigated in MiniStor project and ensuring a competitive price for market penetration. Reaching Technology Readiness Level (TRL) of 9 is also a goal which is pursued in this project. The need of some of the internal stakeholders to extend their activities to the residential sector was also reported.

The MiniStor project offers the opportunity to cover the gap between research and market and provide a product with competitive price along with ensuring energy and cost savings at the same time. The expected result from the MiniStor project is the development of a high-efficiency, high-energy-density, low-cost storage system which would allow it to be provided in a low, competitive price.

Other skills such as the possibility to benefit from flexibility and possibility to exchange energy with neighbouring prosumers, avoiding administrative and other intermediate costs, depend not only on the MiniStor system but also on the context where it will be installed (local normative or restrictions). The latter remains an unclear point for the moment but it will provide interesting inputs for creating synergic opportunities with other H2020 projects focused more on this issue.

3.8 Environmental needs

#	Environmental needs	Expectations	Level
1	***Reduce the environmental impact exploiting the renewable resources***	*a. Exploit the renewable resources for the heating and the production of DHW*	***Green***
		b. Reducing the residential carbon footprint	***Green***
		c. Desirable for the system to help Improve the environmental (energy) label of the building or dwelling	***Yellow***
2	***Life Cycle assessment***	*a. Life cycle assessment and S-LCA for MiniStor Technology*	***Green***
		b. The system has to include environmentally friendly components.	***Cyan***
3	***Environmental normative***	*a. The MiniStor system has to respect the normative for the use of ammonia*	***Green***
		b. MiniStor has to be legal and according to the safety rules of each country.	***Green***
		c. The MiniStor has to be noiseless or to have very low noise emissions.	***Green***

Table 8 – Environmental needs and expectations

Environmental needs: The main need for environmental improvements is the development of a system with reduced emissions and low carbon footprint, high-efficiency and a long lifecycle. Therefore, the use of renewable energy sources and the improvement of self-consumption are a necessity in order to achieve the goal of low emissions and carbon footprint and to provide an environmentally friendly solution. High efficiency is also a target that contributes to optimal energy usage and thus motivates users to have better environmental behavior. The system which will be developed is expected to have long lifecycle, allowing for a high number of charge and discharge cycles without any major effect on the efficiency and deterioration of its operation. A life cycle assessment will be performed particularly for the MiniStor project cases, in order to investigate those aspects of the technology. Furthermore, since the heat storage system will be ammonia-based, it is also important to note that all the necessary safety measures and precautions will be taken and the relative legislation will be respected, in order to avoid any possible environmental pollution and dangerous emissions from leaks and mishandling of ammonia.

3.9 Other needs and expectations

Other issues have been also identified, which relate to:

- legislation and the institutional framework;
- operation and design;
- quality and strengths of the project.

Regarding the **legislative and standardization framework**, it is recognized that the MiniStor system must abide by existing safety and operative regulations and standards of each country. One issue already mentioned in the environmental needs section is that since the MiniStor system utilizes ammonia. Therefore, applicable safety standards regarding its handling and use must be applied such as EN norms. Other regulations such as local planning requirements in demo site countries must be considered before implementation and operation of the system. Most of the standards seem to be directed for application in industrial facilities. Therefore, there is the necessity for a clearer framework that can be applied in the EU residential sector. Other issues regarding the institutional framework involve the need for providing motivation for improving billing from the electricity providers and DSOs to make the electrical storage component more attractive by allowing better prices to sell of excess energy to the grid, which at the moment is not possible in every demo site country.

Operation and design characteristics which need to be taken into account include: adopting a modular design for easier customization, portability, compatibility with current heating and cooling systems, quiet operation and ease of installation and connection to both the existing heating systems and the electricity grid.

Quality issues that need to considered are:

i) the improvement that the system can bring to the current Building Energy Rating of each residence where the MiniStor technology is applied, while increasing quality and cost savings;

ii) establishment within a stable electricity grid that can support injection from many small suppliers;

iii) understanding advantages and other benefits that the MiniStor technology could provide, compared to other equivalent technologies existing in the market.

These operation and quality issues are specific for each building where MiniStor is intended to be applied. During the demonstration phase practical approaches to calculate improvement will be explored.

4. Obstacles, Barriers and SWOT Analysis

4.1 Obstacles & Barriers

One major issue which may appear as an obstacle for implementing the integrated energy storage system in the project is the use of ammonia involved in the TCM reaction and in the refrigerant cycle of the system. The achievement of project targets could be hindered due to current restrictions on the amount of ammonia that is safe for use in this type of configuration. Relevant implementation obstacles emerge from current standards and regulations, which determine system placement, either indoors or outdoors. Halide hydrates could be used as an alternative of ammoniated halide salts that would allow indoor placement utilizing current traditional technologies that comply with current indoor use standards. However, this would restrict system efficiency since there would be issues of corrosion and interaction of water with the TCM material, limiting the expected energy storage density as set in the original call text. However, novel manufacturing processes, especially for component welding and sealing, can allow for new standards to be set for ammonia containers. Valves and tubing that are safer and more reliable, with the proposed enclosures and systems which are being used in commercial applications for mobile refrigeration systems.

Ammonia regulations are based on the European Standard EN 378:2016 stating the load limits in refrigeration systems. This standard specifies that if the refrigeration system (the absorption loop in this case) has a double indirect system configuration, there is no load limit, since the ammonia will be stored in a different room, and not directly connected to any inhabited space. However, the room where the TCM reactor is placed must comply with requirements of EN 378: 2016 - Part 3 (machinery room). It is very likely that most of EU Member States have legislated certain load limits based on EN 378:2016. Local regulations (i.e. city planning codes) might restrict even more the placement of systems similar to the TCM reactor. These potential prohibitions could be a barrier for the placement of TCM in certain locations when the time comes to commercialize the product. An examination of standards and planning regulations in demo site countries is planned in the project to overcome any potential barrier in this aspect.

Other restrictions that could act as barriers in the project stem from regulations on renewable energy generation. Although European directives are tending towards development of positive energy buildings (Directive 2018/844/EU), national and regional regulations in all Member States need to be harmonized towards aperture of energy markets for individual consumers-generators. A mixture of participation models exists where selling is allowed [4], therefore energy selling to the system should adapt to them.

Regulations for IoT and smart HEMS such as standardization and protocols that regulate the rollout of IoT and ensure safety and security of data exchange could also be considered as obstacles that would arise in the future. It is expected that governments and standardization bodies might create and enforce future regulations governing those aspects.

Other barriers that should also be considered but fall out of scope of this research, is the availability and price of precursors and finished products that constitute the PCM and TCM materials. It can be expected that as demand rises for such materials, prices will also increase. Therefore, supply chains must be secured or somewhat regulated in order to keep final product price accessible for the residential user.

Furthermore, there are technical barriers of storage systems based on TCM and PCM which include addressing the issue of thermal losses, the significant size and area required for installation in domestic level, the controllability of the system and the need for improvement in the stability of storage performance, which is associated with material properties [10]. Finally, the fact that MiniStor requires a heat input at high temperature is another potential technical barrier that could affect the competitiveness and market penetration of the system, as the dwellings where it will be installed should have the necessary equipment or characteristics to provide this input.

4.2 SWOT analysis

The SWOT analysis is used to summarize the MiniStor offering with respect to the market competitors and to the stakeholder's expectations. The purpose is to convert be aware of potential weaknesses and threats, while minimizing or eliminating them.

The SWOT Analysis is the first step in order to explore paths for commercialization and market uptake and to set the basis for the "value map" by assessing the internal and external points of strength and weakness. It substantially helps to evaluate how a product or service would fit in the market. It is an essential model to be used to focus on the potentiality and weaknesses of a company's product that is meant to be suitable for the market. It helps, as output, to get a complete list of pros and cons compared to competing or substitute technologies.
According to the SWOT analysis, a project has four possible characteristics. The first two, strengths and weaknesses, are related to the internal potentiality of the object of the analysis; the other two, opportunities and threats, are more dependent on external factors.

- **Strengths**: In this category all the positive factors of the project are accurately sorted, highlighting the points which mark a positive distinction from the competitors, and any aspect which can potentially lead the product to have a powerful position in the market. In general, a new product must satisfy the needs of a specific target audience and combine it with a competitive selling price.
- **Weaknesses**: The weaknesses of a project can be even more important than the strengths, indeed sometimes they are well hidden and difficult to find out, and if they are not discovered in advance, they might come up unexpectedly leading to difficulties for organisations.

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Carefully assessing and reporting them is essential to develop an effective business and being able to face and fix them can lead to strong settlement in the market. Otherwise, if they are not assessed, project objectives will not be met and expected results will not be reached.

- **Opportunities**: They are related to the potentiality which might be discovered and exploited by the product. They are an important step as they can lead the product to new prospects. They are more variable than strengths and weaknesses and finding the best opportunities can be a very big advantage. Each product has some channels in which more potentialities exist and finding the best ways to exploit them can be a very useful point.
- **Threats**: They are all the obstacles and limits of the project which might break the launch of the business. They can include the launch of other competitors' projects, harsh policymaking, unexpected costs and other issues. Whenever a product is launched in the market, some responses from competitors are expected, therefore it is good to predict them in advance. It is important to assess threats in order to be able to manage them. The best way to fix a problem is to predict it.

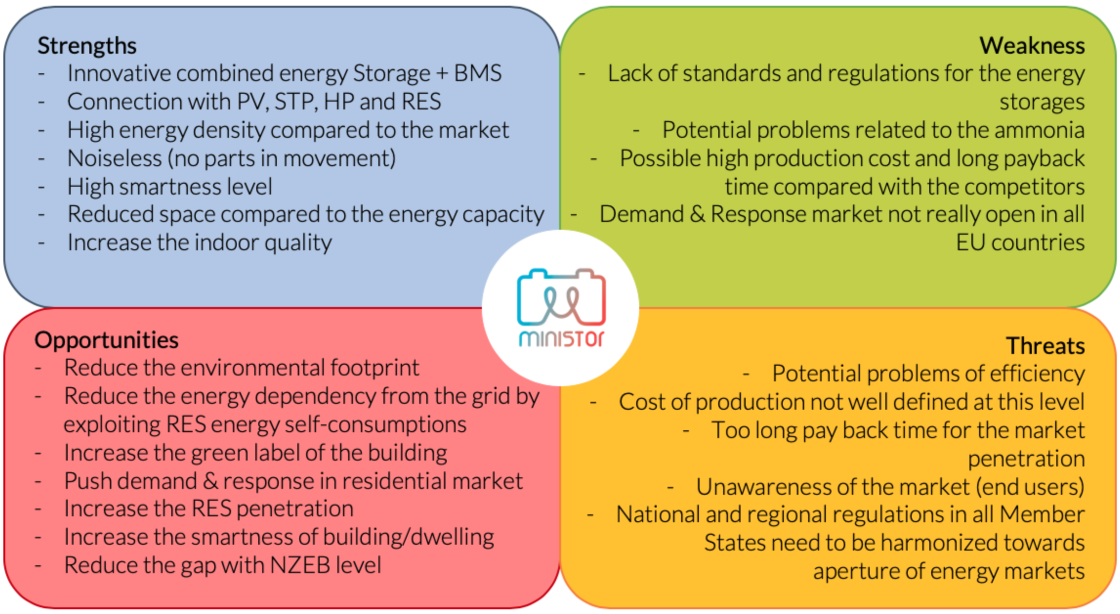

Figure 14 -MiniStor SWOT analysis

Figure 14 is a summary of the MiniStor SWOT analysis and shows the potential skills that can be brought in the energy storage market. The main strength can be considered to be the combination of different technologies that make it unique and innovative in the market. It can be considered not only a system but a combination of systems in a unique product. The TCM technology guarantees a high level of energy density compared to the market competitors as well as a reduced space necessary for its installation.

On the other hand, the ammonia regulation, not yet harmonized in the EU countries, could represent an uncertain point. The expectations around the market price are ambitious considering the high level of technology used and it can be a weakness if the production costs will not be well analyzed during the project. This aspect can generate long pay back periods without any incentives, but in line with the national legislations this system can benefit from green incentives or tax reductions (e.g. Italian context).

Market opportunities are very large and ambitious. The main challenge is the exploitation of the energy produced by RES – Photovoltaic (PV) and Solar Thermal Panels (STP) in combination with the MiniStor storage. The goal is to increase the self-consumption, reduce the electrical energy purchasing from the grid and the use of fossil fuels for the production of heat (Space heating, cooling and DHW production) until the final target represented by the NZEB limit. This concept is at the basis of the economical saving as well as the potential participation in flexibility energy schemes (flexibility sharing or energy sharing). An ambitious opportunity will be the inclusion of demand and response schemes.

A potential weakness is related to imposed normative limits in the use of ammonia in residential settings, and the lack of harmonized regulations across Europe. Considering the high level of technology used in the MiniStor storage, the application in the pilots will be fundamental to test the performances and the benefits.

Possible threats could come from the electricity trading market, which is not totally opened in some countries to small prosumers, and from the legislation around electrical and thermal storage systems, which is not well defined yet. The project also aims to bridge the regulatory gap evidencing the route for a technology penetration.

5. Conclusions

This document presents a preliminary overview of market demands, application challenges and stakeholder expectations. It provides information necessary to drive the MiniStor development toward fitting the best solution for the market penetration and reaching the higher level of stakeholder's satisfaction.

In terms of market size, it was seen that the potential market varies mostly with the type of energy carrier. As such, most individual and collective dwellings that have their own heating system have more potential for system installation than those that are connected to a heat network such as district heating. Solar radiation, which powers up the system, also has an influence. However, suitable technical adaptations make it possible to be used in higher latitudes although there is always a decrease in power output compared to Mediterranean locations.

Nevertheless, an important and determining factor for the entire market size definition is the location of the system. Given its projected dimensions and compliance with current regulations regarding use of ammonia as refrigerant, it can be mentioned that this can be accomplished in dwellings with sufficient ground open space, or with a rooftop horizontal surface that is well protected.

Regarding competing technologies, it was found that MiniStor is made of several technologies that make it not directly comparable to market-ready heat storage technologies. The reason lies in the innovative character of the MiniStor storage that can be considered not a simple system but a combination of systems: thermal storage, electrical storage and a home energy management system. However, the most developed system available in the market towards which MiniStor will have to compete is domestic hot water tanks. Their use is widespread and does not require high technical skills for maintenance. However, their energy storage density is much less than the potential offered by MiniStor.

The data collected by the external stakeholders' questionnaire outline a situation where the expectations on thermal and electrical storage are in the main part aligned with the project objectives. There is also a demonstrated high interest in a solution such as MiniStor.

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ANNEX I

List of external stakeholders by type of organization and country of origin

#	Contacts	Organization	Type of organization	Country
1	Kieran Lettice	Energy Cork	Representative body	Ireland
2	Pat Barry	Irish Green Building Council	Association	Ireland
3	Stevie Donnelly	Contract Research Unit, IT Sligo	RTO	Ireland
4	Aidan Mangan	Construction Industry Federation	Representative body	Ireland
5	Tibor Orbán	Budapest District Heating Co	LE	Hungary
6	Géza Matuz	Energy Consulting Kft	SME	Hungary
7	Tamás Király	AERECO	LE	Hungary
8	Norbert Harmathy PhD	Technical University of Budapest	University	Hungary
9	Sarolta Horváth PhD	HORBER Kft.	SME	Hungary
10	Isabel Guedea	EndeF	SME	Spain
11	Aldo Bischi	University of Pisa	University	Italy
12	Zauet Chritoph	Austrian Institute of Technology	University	Austria
13	Matteo Cavalletti	MIDAC	LE	Italy
14	Paolo Marchini	VESTA Energie	SME	Italy
15	Emilio Miguel Mitre	GBC Spain	Association	Spain
16	Raquel Diaz	GBC Spain	Association	Spain
17	Félix Rodríguez	Instituto Tecnológico de Galicia	RTO	Spain
18	Javier Torralba	Instituto Tecnológico de Galicia	RTO	Spain
19	Antonio López-Nava Gerente	La Asociación de Empresas de Eficiencia Energética	Association	Spain
20	Penélope López	La Asociación de Empresas de Eficiencia Energética	Association	Spain
21	Cristobal Jose G. Castillo	E.T.S.I. Aeronàutica y del Espacio	Association	Spain
22	Marta García Pellicer	INSTITUTO TECNOLÓGICO DE LA ENERGÍA	RTO	Spain
23	Ignacio Pérez del Pozo	ENERGETIA S.L	SME	Spain
24	Javier Martín	VEOLIA España	LE	Spain
25	Francesco Peccianti	RINA-C	LE	Italy
26	C. Ovadonga	VIVA	Representative body	Spain
27	Domingo González	VIVA	Representative body	Spain
28	David Grisaleña	VISESA	Representative body	Spain
29	Alberto Ortiz	VISESA	Representative body	Spain

30	Stefan Pallantzas	Hellenic Passive House Institute	Association	Greece
31	Dimitris Pallantzas	Hellenic Passive House Institute	Association	Greece
32	Eleftherios Filios	Greenstruct	SME	Greece
33	Katarzyna Rajkiewicz	NAPE	SME	Poland
34	Petra Bijvoet	InHolland	LE	Netherlands
35	Werner Pink	Neotec	SME	Austria

Table 9 – Initial external stakeholder database