D6.3 Results from pre-pilot implementation and stakeholder training

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Summary

The main scope of this first version of Deliverable 6.3 is to provide useful insights for preparatory works performed until the submission date of this document in the MiniStor pre-pilot and demo sites, in order to enable system installation and operation. A brief description of the MiniStor system is given, focusing on the main characteristics of the various sub-systems and on the way the system connection to the building is realized. It is followed by a description of the pre-installation state of Thessaloniki pre-pilot and of Cork, Kimmeria, Sopron and Santiago de Compostela demo sites. Information about the existing HVAC infrastructure is also given, as the specifications of these systems should be taken into account to achieve a smooth and safe integration of MiniStor.

The main part of the document regards the so-far performed activities in the pre-pilot and demo-sites. Necessary licencing and permissions are analysed in each case, giving particular attention to the identification of national and local regulations and standards that determine the installation and operation of ammonia containing systems. It has been revealed so far, that in most cases no particular restrictions are imposed for systems with low ammonia charges, such as MiniStor. Nevertheless, compliance to provisions of EN-378 Standard and acquirement of required permits are necessary. The performed activities are divided into three main categories that concern the installation of the solar field, the placement of the MiniStor container that incorporates the core sub-systems and the integration of MiniStor to the current infrastructure of the building. In general, preferred solutions about all activities have been defined and relevant drawings have been elaborated. However, the implementation of activities and the purchase of necessary equipment is still pending, as they depend on finalization of MiniStor specifications.

As the system has not been manufactured yet, no information about its pre-pilot implementation and testing could be provided. This also hinders the stakeholders training, but in this case the operation of the monitoring and control IoT platform is used as case study to verify the developed methodology. Therefore, both Chapters describing these topics (namely Chapters 5 and 6) will be completed in the final version of D6.3, which will be prepared after the system installation and testing operation in Thessaloniki pre-pilot.

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D6.3	WP. 6
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	PU	Public	X

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1. Introduction

1.1.Scope and objective

This deliverable summarizes the so-far activities implemented in the framework of Task 6.3 “Pre-pilot implementation, pilot planning, setup and training of stakeholders”. Its main objective is to present the preparatory activities of the MiniStor pre-pilot and demo sites, towards a successful deployment and installation of the system. It should be noted that this is the first version of the deliverable which deals only with the preparatory works and not with the pre-pilot implementation and actual stakeholder training as the prototypes have not been manufactured yet. The second final version of the document will be prepared in the future and its due date will be specified in the forthcoming project amendment.

More specifically, this first version of D6.3 includes a description of the pre-installation state of the demos. General building characteristics along with details of the current heating and cooling system are presented. This information is of high importance, as it highlights the ability of the system to adapt to buildings of various dates of construction, with different HVAC infrastructure and located in different climatic regions that correspond to distinct heating and cooling needs. Estimations of the heating and cooling needs of the demo sites are presented, which had also been used as input to other Tasks and particularly to T3.1 “Initial dimensioning of the whole system according to general use typologies”. A brief description of the system is also provided so that all necessary information about the MiniStor – building integration can be found in a single, comprehensive document.

The main part of this document concerns the up to present preparatory works of the pre-pilot and the demos. Because of the delays in the manufacturing of the prototypes these works could not be finalized yet, as many important technical details about the MiniStor integration could not be considered certain. Nevertheless, activities such as notification of interested parties (building occupants, facility managers, responsible technical services etc.) about the system technical characteristics and corresponding agreement between these persons or entities and project partners are described in detail. Additionally, actions towards the identification of regulation barriers about the installation and operation of ammonia-containing systems, such as MiniStor, are presented along with permissions necessary for the connection of the system to the grid. All the aforementioned actions aim to ensure that the demonstration activities, and particularly the use of ammonia, will be carried out safely, respecting all relevant regulations and with the consent of all involved persons.

Activities relevant to the system installation and integration are classified into three main categories: i) works for the positioning of the MiniStor solar field, ii) placement of the MiniStor system and iii) integration with the existing HVAC infrastructure. The first two branches of activities are quite challenging, as there are space limitations that may affect the compliance with safety rules and legislation as well as the efficient system operation. Providing sufficient thermal energy input to the system requires a collectors’ surface larger than 14 m^2 in all cases, but achieving optimum orientation and avoiding of shading of the collectors’ surface put additional constraints that are analysed. On the other hand, the provisions of EN-378 Standard for a 2 m distance between machinery rooms enclosing ammonia-containing systems and the openings of nearby buildings, along with actual building layout and the desired ease of access by trucks, set strict criteria for selecting the appropriate location of MiniStor system. Moreover, technical requirements that have to be met for achieving proper and efficient coverage of the demo sites needs in terms of heating, cooling and Domestic Hot Water (DHW) are identified. So far performed adaptations, as well as selection and installation of necessary technical equipment are also described in the document.

Finally, due to the small progress in system manufacture, no details about the pre-pilot implementation and testing could be provided. This information is to be included in the final version of the deliverable, which will be prepared upon system installation and testing operation in Thessaloniki pre-pilot. Nevertheless, progress regarding the definition of stakeholders’ training methodology has been achieved, using the operation of the monitoring and control IoT platform as a case study. Relevant material in the form of a demonstration video and a questionnaire was prepared and distributed to the team members of the demo sites and results of the evaluation process are presented.

1.2. Structure and connections

This document is divided in five main sections. Each section corresponds to a specific chapter and regards one of the main issues addressed by the deliverable:

- Chapter 2 includes a brief description of MiniStor system, paying particular attention to its connection with the building infrastructure.
- Chapter 3 presents the pre-installation state of the pre-pilot and the four demo sites. Necessary details about the building characteristics and infrastructure are given in separate paragraphs for each case.
- Chapter 4 describes the preparatory works performed so-far in each case. These include the acquirement of necessary licencing and permissions, the selection of solar field and MiniStor system location and the identification of the most advantageous methods and equipment for the proper system installation and operation.
- Chapter 5 will be compiled in the final version of this deliverable, as it concerns the installation and testing of MiniStor in Thessaloniki pre-pilot.
- Chapter 6 currently includes the description of the stakeholders' training methodology and its implementation in the case of the system monitoring and control IoT platform. The report on stakeholders' training in the prototype installation and operation will be included in the final version of this document, as it is closely related to the MiniStor operation and testing in the pre-pilot.

Deliverable 6.3 receives useful input from Tasks 2.3, 2.4 and 2.5 of WP2 and Task 4.5 of WP4, regarding the analysis of European legislation and standards for the use of ammonia (T2.3), the operational modes and specifications of MiniStor (T2.4) and safety and maintenance requirements (T2.5 and T4.5). Additional input for determining the location of MiniStor components and their integration with the current building equipment is provided by the Tasks of WPs 3, 4 and 5. The definition of KPIs in Task 6.1 also sets some boundaries for the MiniStor integration to the building infrastructure and the installation of necessary sensors. As previously described, a mutual data exchange between T6.3 and T3.1 was realized, through the provision by T6.3 of information about the demos heating and cooling needs for the conduction of thermodynamic simulations. This is also foreseen for the other technical tasks of WP3 (T3.2, T3.3, T3.4 and T3.5), as T6.3 when finalized, will provide useful input to their second phase facilitating the definition of installation strategies of the various MiniStor components. Additionally, T6.3 is a prerequisite and provides useful feedback for the successful implementation of T6.4, T6.5 and T6.6 of WP6, while it also feeds the activities of WP7. Figure 1 presents the aforementioned connections of D6.3 with the other activities of the project.

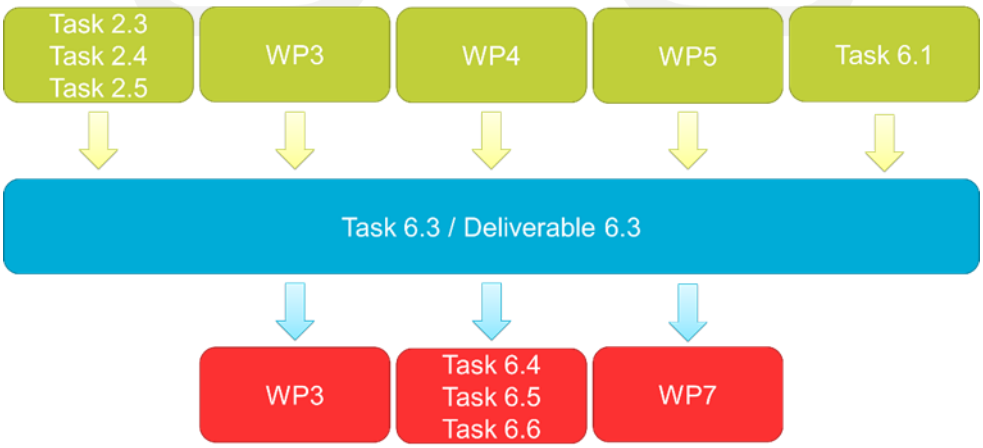

Figure 1. Deliverable connections with other tasks and WPs

2. Brief description of MiniStor system

MiniStor is an innovative system for generation and storage of heating, cooling and electricity. The required energy input can be provided by various RES-based systems and in the current configuration is given by a solar field. MiniStor is characterized by high thermal energy storage density, over 180 kWh/m^3 and almost 10.6 times higher than the energy storage density of water, which is achieved by a combination of Thermochemical and Phase Change Materials (TCMs and PCMs). Optimized system operation is ensured by the integration of an intelligent energy management system. The main hardware-based sub-systems of MiniStor are the following:

- A RES-based system that delivers the necessary heat input. Its basic configuration consists of a combination of PVTs and solar thermal collectors, whereas an arrangement combining PVTs with an air-to-water heat pump will also be tested. Relevant existing infrastructure with other RES resources can also be utilized, as is the case in Kimmeria demo site. Therefore, the energy supply sub-system could be considered as an external component of MiniStor and not as a core one.
- Thermochemical unit (TCM unit), which in turn includes two main components: a reactor containing thermochemical reactive medium and an ammonia refrigeration cycle. In the current case, the reactor contains a mixture of dehydrated calcium chloride salt (CaCl2) and expanded natural graphite (ENG). Its operating principle is based on the solid/gas thermochemical sorption process, according to which the reactive solid salts react with a reactive gas. In MiniStor the chosen reactive gas is ammonia (NH3) and after the initial charging of the reactor with this substance, ammoniated salts are formed (i.e. CaCl2·8NH3, CaCl2·2NH3). Thus, the reversible reactions taking place inside the reactor during its charging and discharging phases and enabling the storage of heat in the form of chemical energy are the following:

  $$CaCl_2 \cdot 8NH_3 + Heat \leftrightarrow CaCl_2 \cdot 4NH_3 + 4NH_3$$

  $$CaCl_2 \cdot 4NH_3 + Heat \leftrightarrow CaCl_2 \cdot 2NH_3 + 2NH_3$$

  In normal operation, the conversion rates of CaCl2·8NH3 into CaCl2·4NH3 and of CaCl2·4NH3 into CaCl2·2NH3 are expected to be 95% and 32% respectively, resulting in an energy storage density of 200 kWh/m^3 of reactive material for the TCM unit only. Therefore, the TCM reactor is the main thermal energy storage vessel and a key component of the system.

  The ammonia refrigeration cycle is essential to the function of the TCM reactor, as after its desorption (during reactor charging) gaseous ammonia is compressed, condensed and stored in a liquid ammonia reservoir. Moreover, ammonia evaporation takes place before its entrance to the reactor to realize the sorption process (during reactor discharging). Thus, the cycle includes an ammonia compressor, ammonia condenser, liquid ammonia reservoir, ammonia evaporator as well as valves and pipes.

- Heat Pump of water-to-water type, which is used to upgrade the condensation heat of ammonia (at around 22/26°C) and turn it into thermal energy at higher temperature (at around 63°C or higher) that can be used to cover the building needs. Its addition to the system enables the achievement of overall system COP for heating close to 1.80.
- PCM vessels that are used to store additional amounts of thermal energy in the form of latent heat of the contained Phase Change Materials. In the basic configuration of MiniStor the usage of three such vessels is foreseen: two of them are connected to both the TCM reactor and the heat pump condenser and are used to store excess of generated heat and provide heating and domestic hot water (DHW) to the dwelling respectively, whereas the third PCM vessel is connected to the ammonia evaporator and mainly used for storing and supplying cold. An additional functionality of the cold PCM vessel is to provide the necessary heat for the ammonia evaporation in cases of very low ambient temperature. However, due to their lower energy storage density than the TCM unit, the capacity of the PCM vessels is quite low and thus their role is supportive to the system thermal energy storage functionality.
- Electrical Energy Storage System (EESS), which is used to store amounts of electricity produced by the RES-based energy supply system. Its function is depended on the configuration of the

later, as it should include solutions (such as PVTs) capable of producing not only thermal but also electrical energy. The EESS comprises a Li-Ion battery and its addition to the system makes necessary the incorporation of other components too, such as a smart hybrid inverter for managing the electricity flows between generation, storage, MiniStor self-consumption and consumption of the dwelling.

The final layout of MiniStor thermal components, as defined in D3.2, is depicted in Figure 2. The TCM unit is in purple, the heat pump is in teal and the PCM vessels are depicted as grey boxes of rectangular shape. The orange line denotes the boundaries of the system, which includes additional auxiliary components listed below:

- Five pumps, illustrated in red colour, which circulate heat transfer medium in the circuits that connect the various sub-systems of MiniStor.
- An inertia tank that acts as a buffer between the RES-based energy supply system and the TCM reactor and facilitates the control of heat provision to the latter.
- Two (2) fan coils, depicted in orange colour that are used for heat exchange with the environment (i.e. rejection of excess heat or absorption of heat to enable ammonia evaporation).
- Valves and pipes that comprise the connecting circuits of the various sub-systems.

It should be pointed out, that the MiniStor connection with the building is realized through the PCM vessels, as is also shown in Figure 2. The latter act as heat exchangers, transferring heat or cold to the corresponding circuits of the building either directly or indirectly (i.e. through circuits connecting the vessels with other heat exchangers of the building). Thus, the specifications of the PCM vessels are important parameters that determine the rate and the temperature at which the heat and cold supply to the dwelling is made. More specifically, the melting temperature of the material contained in the hot and DHW PCM vessels is 58 °C, whereas that of the cold PCM is 11 °C. This means that the forward / return temperatures of the discharge circuit will be approximately 56 °C / 53 °C respectively for the hot and DHW PCM vessels and 13 °C / 16 °C for the cold one. Recommended flow rates are in the range of 6 – 25 L/min, nevertheless higher values could be applied at the expense of higher-pressure losses.

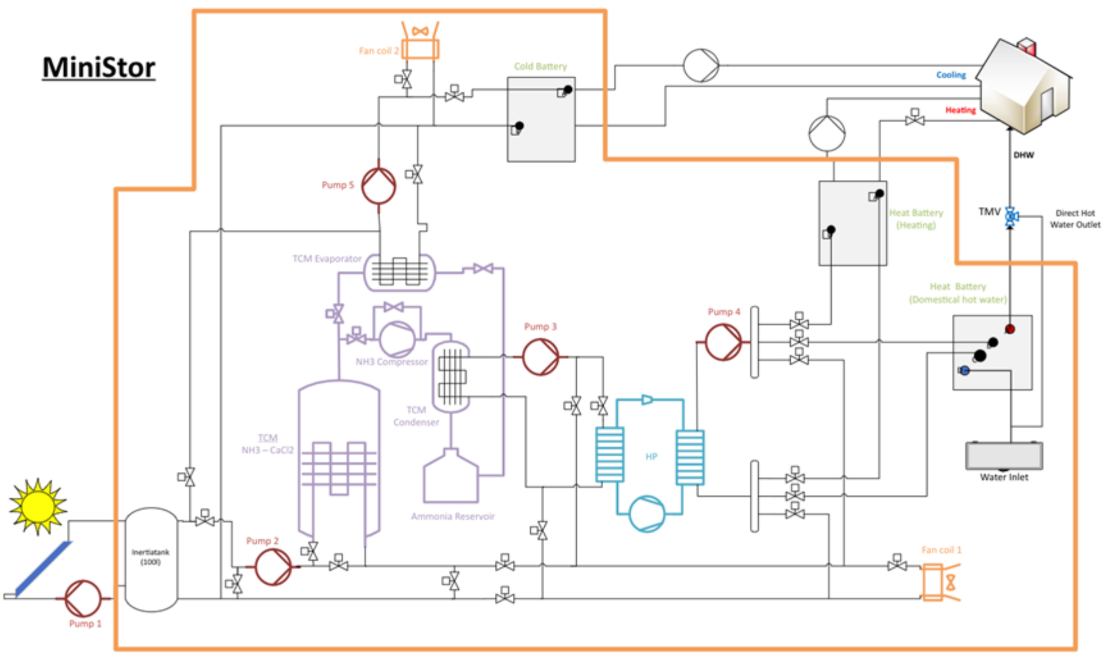

Figure 2. Final thermal layout of MiniStor (source: D3.2 "Design of peripheral thermal equipment")

Complying with the provisions of EN-378 Standard (described in detail in D2.3), the system will be containerized and placed outside the building of each demo. Thus, almost all components within system boundaries, along with some external ones such as Pump 1, will be appropriately installed inside a container, equipped with all necessary sensors and safety equipment. The only exceptions are the power supply modules of the TCM and PCM units, as these are to be installed into a separate cabin of the container or inside a room of the demo site, in order to comply with fire-safety regulations. Moreover, EN-378 refers to a minimum distance of 2 m between exterior openings of ammonia-containing machinery rooms (the MiniStor container in this case) and nearby buildings' emergency exit staircases or other openings, e.g. windows, doors, ventilation inlets. This is a very important provision that should be taken into account when planning and implementing the preparatory works in the demo sites, along with any additional restrictions imposed by national legislation and standards.

3. Description of MiniStor demo sites

3.1. Thessaloniki pre-pilot

3.1.1. Location and building characteristics

MiniStor will be first tested in the premises of CERTH in Thessaloniki, Greece and more specifically in Smart Home of CERTH / ITI (Latitude 40.57° N, Longitude 22.99° E). The latter is a demonstration platform for novel technologies, shaped like a real domestic building and constructed in 2017. It comprises two floors with a total habitable are of 317.7 m^2, of which 182.7 m^2 are on ground floor and 135 m^2 are on first floor. It has a rectangle shape and its longest dimension faces SW-NE. A machinery room (area 9.9 m^2) is attached to the western side of Smart Home, housing hydraulic and electrical connections. The building is currently used as offices for CERTH's personnel, thereby its occupancy is limited to usual working hours of the week. Nevertheless, it presents the architectural design along with the devices of a normal residential building.

Figure 3. Front view of CERTH/ITI Smart Home.

The large area and volume (1075.8 m^3) of the Smart Home result in considerable heating and cooling needs. Therefore, the testing of MiniStor will be limited to a large room (labelled as "Control Room West"), with a gross area of around 49 m^2 and located in the western side of Smart Home's ground floor. The main reason for selecting this specific space is its adjacency to the existing machinery room, facilitating the installation of MiniStor and its connection with the main hydraulic and electrical circuits of the building. Additionally, its large area, almost equivalent to that of a small apartment, renders it suitable for evaluating the performance of MiniStor and reaching useful conclusions and guidelines for the system deployment and operation in the other demo sites. Its peak heating and cooling needs were approximated in D3.1 to 3.6 kW and 8.1 kW respectively. Generally, Thessaloniki has a humid subtropical climate (Cfa).

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3.1.2. Current HVAC and electrical infrastructure

The building presents low heat losses considering its volume, as the heat transfer coefficient (U) of its opaque elements is lower than 0.35 W/m^{2}K. Its current heating and cooling needs are covered by two HVAC systems, with a total nominal thermal capacity of 56.7 kW for heating and 50.4 kW for cooling. Each HVAC system is a vapour compressor based-system that consists of one external unit (with compressor units) and several indoor units (of ceiling cassette type), mounted in the different rooms of the building. The cumulative nominal capacity of indoor units is equivalent to that of the outdoor units (i.e. 58.8 kW for heating and 52.4 kW for cooling). The connection between external and the corresponding indoor units is performed by refrigerant circuit (R-410A, gaseous or liquid) that uses a variable refrigerant flow (VRF) system. The MiniStor system will be operated in a demonstrative room, in which, two indoor units with a cumulative nominal thermal capacity of 8 kW for heating and 7.2 kW for cooling are installed for covering heating and cooling needs. Finally, the electricity demand of the building is partially covered by existing arrays of thin film CIS PV panels installed on the building roof with a total capacity of 9.57 kWp. In Thessaloniki pre-pilot, MiniStor will be used for providing heating, cooling and electricity and covering part of the corresponding energy needs.

Figure 4. View of existing Smart Home's machinery room (left) and currently rooftop installed PVs (right).

3.2. Cork demo site

3.2.1. Location and building characteristics

Location: This demo site will be located in Cork, Munster region, and specifically in the Bishopstown area which sits to the furthest extents of Cork city's urban area, southwest region. The property elevation is circa 24m above sea level. Cork has a temperate oceanic climate (Cfb according to Köppen climate classification). The corresponding location is shown in Figure 5 and Figure 6, and the corresponding latitude and longitude are 51.90° N and 8.47° W respectively.

Figure 5. Location Map: Ireland & Munster region

Figure 6: Location Map: Cork City area

Building characteristics: Constructed in the 1980's, Cork demo site, is a 3 Bedroomed Semi-detached two storey local authority owned property. The property contains a habitable area of circa 75.286m^2 (Volume 376.431 m^3) to which 5 occupants reside. A BER assessment (Irish **B**uilding **E**nergy **R**ating) of the building was completed in 2015 yielding a result of C**1**, rated energy consumption of 165.59 (kWh/m^2/yr) and CO_2 Emissions Indicator of 35.18 (kgCO_2/m^2/yr).

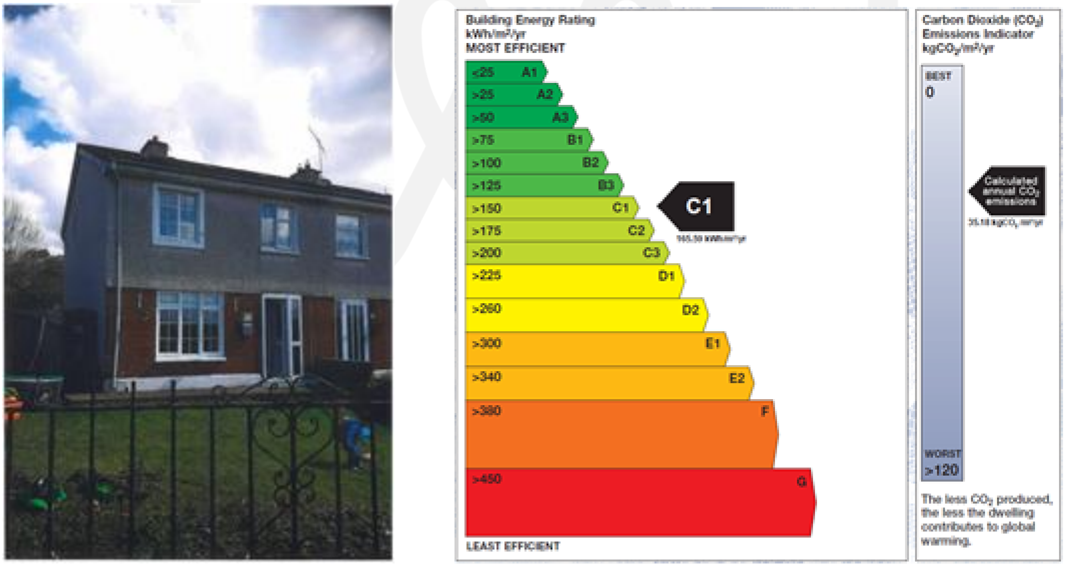

Figure 7: Property characteristics: Cork demo site

3.2.2. Current HVAC infrastructure

The property is heated by a Gas boiler based system, which is time and temperature controlled, with an output of 27kW. This is used to supply hot water to all associated taps and radiators. The System is segregated into 3 zones which can be manually turned on and off independently at one location. All 3 zones have independent thermostats which can be manually set to preferred temperatures depending on the season. The MiniStor system will be used to provide electricity, heating and domestic hot water in the Cork demo site, and thus partially cover the corresponding energy needs.

3.3. Kimmeria demo site

3.3.1. Location and building characteristics

The location of installation of the MiniStor system, in the case of DUTh demo site, will be inside the premises of Kimmeria student residencies, in northern Greece (warm-summer Mediterranean climate - Cfb) (Latitude: 41.15° N, Longitude: 24.91° E). The system will be placed at the southern side of G2 building (Figure 8) and it will be exploited to cover the heating and cooling needs of the students. The selection of the building was made upon consideration of distance constrains, as G2 building is the closest building to the premises' Energy Center.

The selected building (G2) has 3 floors (ground-floor, 1st and 2nd floor) and one machinery room (basement area), a total building height of 9 m. The total habitable area is 1188.01 m^2 and total heated volume is 4079.3 m^3, while the machinery room dimensions are 32.35m x 17.4m. The heated volume by the MiniStor system will be 226.95 m^3, of 5 rooms at the ground and 1st floor. These rooms have different orientations, in order to test both southern and northern heating and cooling demand/response of the MiniStor system and present a total area of 75.65 m^2. The heating and cooling needs of one room in worst case scenario (external temperature of -8 °C and northern room orientation in winter, 35.5 °C ambient temperature at 15:00 PM on 21st July regarding summer) were estimated using specialized numerical tools to 2 kW and 1.2 kW respectively. However, under typical conditions the daily heating demand of one room is around 10.5 kWh (considering 5 °C ambient temperature), whereas typical daily cooling demand is in the range of 15 kWh.

Figure 8: Birdview of the DUTh's demo site location for the MiniStor system.

3.3.2. Current HVAC and electrical infrastructure

The thermal energy demand of the DUTh's demo site residents, is covered via a district heating system which connects the buildings of the campus with the Energy Center (i.e. the main hub in which the thermal energy production of the whole community is produced). The Energy Center equipment for thermal energy production is a 1.18 MW_{th} installation of solar collectors, a 1.15 MW_{th} biomass boiler and 2 back-up oil boilers, operating only when the biomass boiler is under maintenance. As far as the electrical infrastructure, the Energy Center houses the transformers, which connect to the main medium voltage grid, and then it provides electricity to all 8 buildings of the campus. There is a 51 kW_p PV array installation on top of G2 building, which covers the loads of the common areas of the building (intermittent), as well as the resistance's load (8 kW_{el}) of the Domestic Hot Water (DHW) tank.

The HVAC infrastructure is currently an extensive pipework system of 3’’ insulated pipes, which, originating from the Energy Center’s hot water collector (Master), connects to all 8 buildings’ hot water collectors (Slaves). Then, a two-pipe hydraulic system, transfers the hot water to the rooms’ terminals (radiators). There is no cooling connection between the Energy Center and the buildings and so, the MiniStor system (apart from heating in winter) will cover an important load of the DUTh’s residencies, the cooling energy during summer.

3.4. Santiago de Compostela demo site

3.4.1. Location and building characteristics

Santiago de Compostela is the capital city of Galicia, a region located in the Northwest of Spain, Longitude, 42.88° N, Latitude: 8.60° West, bathed by the Atlantic Ocean, with an Atlantic, rainy and moderate climate (Cfb – temperate oceanic according to Köppen classification).

For the Santiago de Compostela demonstration centre, USC first selected the “Burgo de las Naciones” Hall (Figure 9a) for several reasons, including: having apartments for guests, in addition to rooms for resident students, and having one of them inhabited by a family. The building is U-shaped with wings of different sizes with approximate dimensions of 90m, 120m and 70m with a large interior patio at its rear with an approximate area of 20m * 90m. The building has 8 floors with a living area of about 14,687m^2 and its main use is as a university residence for national and international resident students and visiting professors and researchers. It has 400 individual rooms and 9 apartments. Of the 9 apartments, in one (Apartment “B”) a family of three members has lived for a long time and in the others, there is more mobility of invited professors and researchers, so the occupancy is uneven.

Due to the characteristics of the Project, the apartment with the continuous occupancy was chosen to serve as a demonstration centre. The chosen apartment has 80.47 m^2 of surface and it is located in the south-west wing of the building (Figure 9b). It has all the spaces on a single level, the mezzanine of the building, although it is accessed from the ground floor by means of an internal staircase. The selected apartment has as main spaces 3 bedrooms, kitchen, living room, bathroom, hall, stairs and entrance. It has hot water service in kitchen and bathroom and heating network with cast iron radiators. Using data taken from the database of one of the Spanish official tools for building energy rating assessment in existing buildings, called CE3X (IDAE - Instituto para la Diversificación y Ahorro de la Energía, 2012), its maximum heating load was estimated to 5.17 kW.

(a) (b)

Figure 9: (a) Burgo de las Naciones Hall and (b) apartment´s location

Currently the “Burgo de las Naciones” Hall has a centralized heating and DHW system, based on gas boilers, The hot water produced by the boilers, is distributed through central buffer tanks and several vertical hydraulic circuits to the different spaces in the building (entrance halls, corridors, apartments, etc.)

As a space of the overall building, the heating and hot water is supplied to the apartment through the hydraulic circuits fully integrated into the centralized system. Each room in the apartment has a radiator connected to the corresponding vertical distribution hydraulic circuit that runs through the building from the basement to the top floor and vice versa, connecting the spaces on each floor in parallel. Thus, each room in the apartment is connected to a different vertical distribution hydraulic circuit. The same configuration is used for DHW distribution network.

Due to the complexity of adapting any of the apartments to serve as a demonstration centre, for a few months the feasibility of adapting other buildings that function as university residences or are inhabited by families and are located in spaces owned by the USC was studied. The conclusion of this study was that, despite the cost of the necessary works to adapt the apartment, an apartment in the Burgo de las Naciones Hall was the best option due to size, being occupied by a young family with a representative number of members, with high permanence (except unexpected event) and being very cooperative.

3.4.2. Current HVAC infrastructure

The Burgo de las Naciones building was built in several phases starting in the 90s of the 20th century. Due to this, two boiler rooms were installed. One of them, Room BC, is next to the apartments in the south-western wing (Figure 11).

The heating and hot water systems of the Burgo de las Naciones building were recently renovated (September 2020), installing four (4) gas condensing boilers with a total power of 1899 kW and five (5) buffer tanks with a total capacity of 16,000 l of water. The distribution networks were not modified. The boilers and two (2) of the higher capacity tanks (5,000 l) were installed in boiler room A and in room BC three (3) 2,000 l buffer tanks were put in place (Figure 10), interconnecting the two rooms to form a single system.

Figure 10: BC boiler room. Inertia Tanks (USC demo site).

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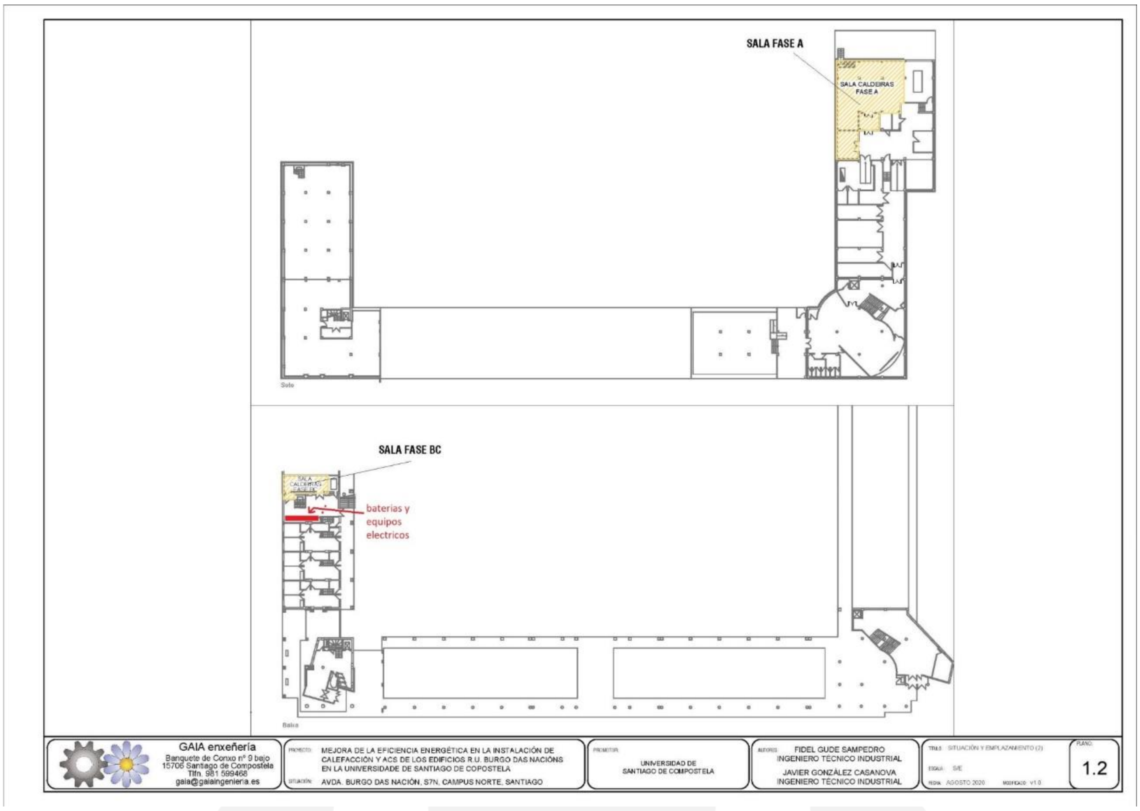

Figure 11: Boiler room locations (tagged as SALA FASE BC and A, USC demo site)

The heating and DHW distribution hydraulic circuits that start from the BC boiler room feed the apartments and rooms of that building construction phase. The distribution circuits are made through multiple branches of pipes that, starting from the ground floor, cross the building from bottom to top in an upward direction and vice versa.

Each room or space of the apartments is traversed by various distribution hydraulic circuits that connects these spaces in parallel with the corresponding residents' rooms on the upper floors. For the rest, it is necessary to isolate the apartment chosen to be the pilot of the MiniStor Project by making an individual hydraulic circuit for heating and hot water, while maintaining the heat input from the inertia tanks to guarantee service against possible failures or non-operational periods of the MiniStor System. The latter is expected to provide electricity, heating and domestic hot water to the dwelling.

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3.5. Sopron demo site

3.5.1. Location and building characteristics

Sopron is located in western Hungary at the foot of the Alps, consequently the climate is sub-Alpine (Latitude 47.67° N, Longitude 16.58°E). In the region there is a heating demand for 5 months and a cooling need for about one and a half month period, however the real cooling time is about three-four weeks.

There is double function of the Sopron Demonstration Site: 1) Family house on the upper store, 2) Woodspring research division office downstairs. The family part consumption dominates at the weekends, but the consumption in the office is quite high on the weekdays. By so the energy consumption is well balanced during the week.

This project has received funding from the European Union´s Horizon 2020 research and innovation programme under the grant agreement No 869821

Figure 12: Location of Sopron

The building was planned as nearly zero energy building with a high thermal resistance of the building envelope. The calculated heating energy demand of the family part, presenting an area of about 118 m^2, is slightly above 2 kW and that of the office part, which has an area of 58 m^2, is about 2 kW too. In case of very cold weather this heating demand of the building (including the flat and the office) can raise to 5 kW.

The building was at planning phase when MiniStor project started, which was a very beneficial situation to both the project and the building, because the aspects of the MiniStor could be taken into account during the building phase. That is why the heating system and the domestic hot water system were optimized for energy supplement by MiniStor.

Figure 13: View of the Sopron demo site

3.5.2. Current HVAC and electrical infrastructure

HVAC infrastructure was designed and built in as an integrated heating-cooling-airing system. The fresh air is heated up or cooled down and then directed to ventilation ducts providing the heating and cooling for the building. This is achieved through a 3 kW heat exchanger driven by a soil collector which acts as preheater in winter, and as cooler in summer period. Soil collector can work as preheater when the outside air is colder than the liquid gained from the soil collector dig into the soil about 4 meters deep. In summer the soil collector provides a 12–18 °C liquid which is used for cooling by means of built-in heat exchanger. In addition to the soil collector, the original heating system includes a heat recovery unit where heat is exchanged between the fresh and the exhaust air streams and 3 kW_{el} electric heating filaments built into the ventilation inlet pipe. Moreover, there are one-one 500 W towel dryers installed to the bathrooms. They can provide higher temperature in bathrooms than the normal heat supply temperature in the building. For the MiniStor project an additional (liquid-air) heat exchanger was built into the air duct system with about 3 kW capacity. MiniStor system can supply thermal energy, for heating, to the building via this heat exchanger. In parallel the same heat exchanger works as cooling heat exchanger in summer driven by the MiniStor.

Figure 14: Central unit of airing system of Sopron Demo Site

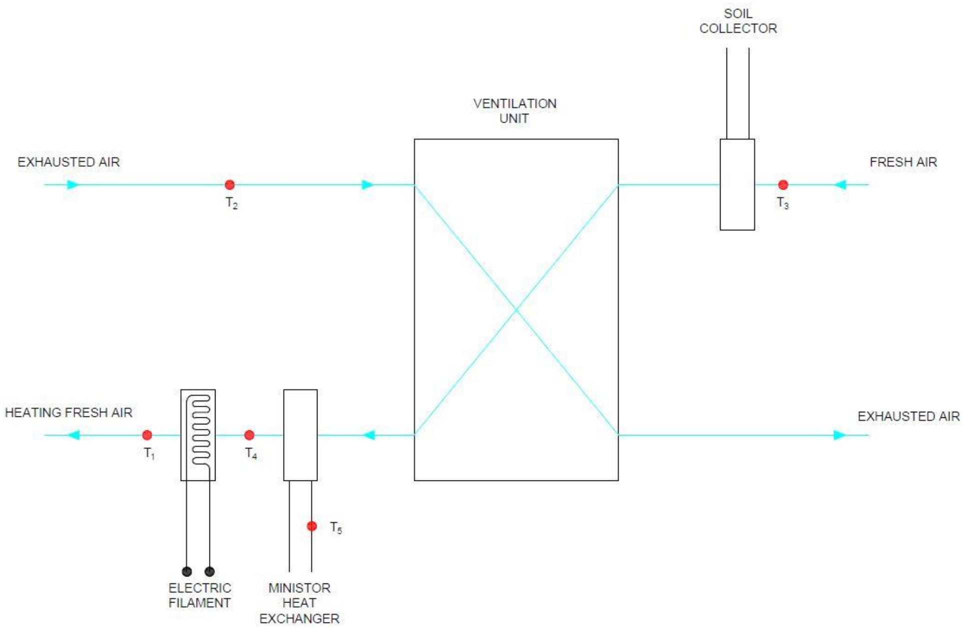


Figure 15: Drawing of HVAC system in Sopron Demonstration Site and its integration with MiniStor.

Figure 15 shows the schematic view of the HVAC system. The 3 kW heat exchanger, driven by the soil collector, was placed upstream the central airing unit and integrated into the pipe of fresh air. The additional heat exchanger built for the MiniStor system is placed right downstream the central unit. This component can provide heat and cold and it is the point where the MiniStor can connect to the heating-cooling system of the building.

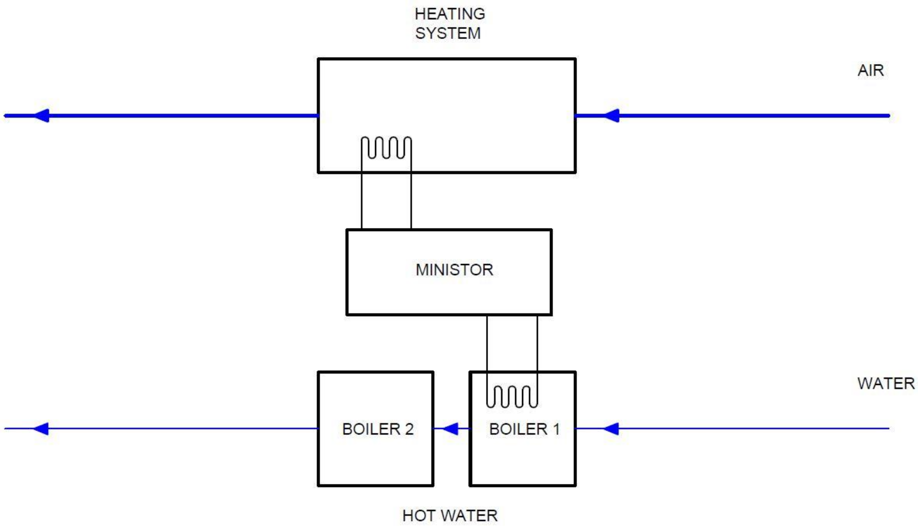


Figure 16: Drawing of MiniStor connection to the HVAC and DHW systems in Sopron Demo Site

Domestic hot water is provided by two electric boilers with power of 2.4 kW each, whereas an instantaneous water heater with electric capacity of 6 kW is built into the kitchen. Because of the MiniStor project, the first boiler was equipped with an extra heat exchanger in the water tank beside the electric heater. Thus, MiniStor can heat up the first boiler through this liquid-liquid heat exchanger built in the body of the boiler. The second boiler is supplied by the first boiler, i.e. they are connected in series. In case the MiniStor could heat up the water in the first tank up to the desired temperature, the second boiler should not use electricity from the grid. The electric heater would turn on only if the MiniStor cannot provide the sufficient amount of energy.

Figure 17: The two boilers providing DHW in Sopron demo site

The building acting as demo site in Sopron is equipped with a 3 phase (3 x 20 A) electrical system. A solar panel array with a nominal maximum power of 7.9 kW_el is already installed. This solar system belongs to the building and provides part of the electricity demand of the house. It is connected to the electrical grid through an electric meter, which measures the uploaded energy amount and the used electrical consumption. According to the Hungarian system the electricity supplier will bill only the difference if it is negative and pay back the surplus at a lower unit price.
MiniStor system will have its own electricity production system based on PVT panels, which will be connected to the grid, and will charge the battery installed next to the electric box of the building.

4. Preparation works for MiniStor installation

4.1. Preparation works in Thessaloniki pre-pilot

4.1.1. Licencing and permissions

MiniStor system is going to be installed in Smart Home, which is located inside CERTH premises. Responsible people will be the contractor that will undertake to install the relevant system along with CERTH internal technical services.

Licence is needed in order to be able to connect the system to the electricity network, and in more detail to the Hellenic Electricity Distribution Network Operator (HEDNO). A representative of CERTH Central Directorate signs a certificate of activation and parallel operation with the medium voltage grid of the electrical production system with storage capacity, and net-metering capability, for research purposes only (Responsible Engineer Declaration, Request for System Activation). In addition, a clause of the aforementioned contract is that CERTH will not receive any monetary reimbursement for the energy produced and injected to the grid, since the license is given only for research purposes. The procedure to acquire this licence is currently in progress.

Furthermore, in order to identify possible limitations and required licencing for the usage of ammonia containing systems, such as MiniStor system, the following steps have been subsequently taken:

- A first search in Greek Legislation was conducted through an online search engine (www.kodiko.gr) using the keyword “αμμωνία” (i.e. the Greek word for ammonia). No law or regulation prohibiting or limiting the use of ammonia as refrigerant was identified. However, two legislature acts were found that regard the safe use and disposal of ammonia in industrial facilities. The first one (Ministerial Decision 136860/1673/Φ15/2018) dictates that in case of usage of dangerous gases such as chlorine, hydrogen, ammonia etc., the facility should be equipped with detectors that will be able to automatically stop the gas flow in case of a leakage.

Additionally, at least one protective uniform satisfying the safety requirements that correspond to the used substance should be available for use. This decision also describes the necessary fire safety measures in such industrial facilities, without making any further specific reference to ammonia. The second relevant legislature act (Ministerial Decision Δ16γ/381/5/44/Γ/2012) imposes maximum limits of ammonia concentration in the liquid waste rejected in the sewage system by industrial facilities located in the region of Attica (i.e. in a different region than Thessaloniki). Nevertheless, the mentioned limit of 60 mg/L denotes that any rejection of undiluted ammonia to the sewage system should be avoided.

- As a next step, the Greek Cold Storage & Logistics Association (GCSLA) was contacted (first contact was made on 15th July 2021). The association preserves an online library (http://www.cold.org.gr/listlibrary.aspx?lang=gr) for its members (mainly Greek industries that manufacture refrigerating systems), where useful information about the use of refrigerants can be found. Documents of interest were identified and after the finalization of the necessary procedures, CERTH was given access to them on 23rd August 2021. Additional relevant documents were found during the same period on the online library of "Cryologic" (http://www.cryologic.gr/shoplist.aspx?CatId=40) a Greek consultancy in the field of cold chain logistics. The titles of the reviewed documents (all of them were in Greek) are the following: "Ammonia handling", "Refrigerant substances and their future", "Refrigeration using ammonia", "Ammonia detectors", "Low charge ammonia systems" and "Refrigeration using natural gaseous substances and small amounts of ammonia". All of them highlight the need to find alternatives to fluorinated greenhouse gases in accordance with current EU regulations (i.e. Regulation No 517/2014) and render ammonia as an excellent alternative due to its zero ODP and GWP. Of course, the potential dangers of using ammonia are mentioned as well, along with the corresponding regulations set by OSHA (Occupational Safety and Health Administration), ACGIH (American Conference of Governmental Industrial Hygienists), NIOSH (National Institute of Occupational Safety and Health), and recommendations of EPA (Environment Protection Agency) and IIAP (International Institute of Ammonia Refrigeration). However, only EU Standard EN-378 is identified as a regulation that dictates the installation and operation of ammonia containing systems. No reference to additional Greek regulations or legislature acts is made in these documents.
- Additionally, the Technical Services of CERTH have been asked about their possible knowledge of regulations that dictate the use of ammonia in Greece. However, they replied on 1st November 2021 that they could not provide a definite answer, due to their unfamiliarity with this topic.
- Finally, "Psyctotherm" a Greek company with experience in the manufacture of HVAC systems for industrial and marine applications was asked accordingly on 22nd October 2021. In their reply, provided on 25th October 2021, they indicated that the installation and operation of ammonia containing systems along with the corresponding safety measures, are defined by EN-378 standard. Moreover, in paragraph 5.12.2.1 of the aforementioned standard it is mentioned that the location of systems' installation should comply with local and national regulations. Regarding the latter, "Psyctotherm" indicated the existence of Ministerial Decision 172058/2016 that imposes regulations and restrictions for limiting the impact of large-scale accidents in facilities containing dangerous substances. Anhydrous ammonia is identified as one of them in the Decision Annex (this is the reason for not identifying this legislature act during the initially conducted search, as Annexes are sometimes not taken into account by the utilized search engine). The facilities for which the provisions of this Decision apply are classified into two categories: low grade and high grade facilities. Additionally, such facilities should be located at a distance from residential areas, which is decided at each case by urban planning authorities. Regarding ammonia content, as high grade facilities are defined those containing amounts higher than 200 tonnes, whereas for low grade facilities the limit is set to 50 tonnes. So, the conclusion of their answer was that for systems with smaller ammonia charges, such as MiniStor, there are no specific restrictions imposed by national regulations and only provisions of EU Standard EN-378 apply.

Thus, the outcome of this research is that for the installation and operation of systems with low ammonia charge, the provisions of EU Standard EN-378 should be followed. The installation of the container itself is not dictated by major restrictions, since this is a moveable structure (i.e. with a temporary foundation) that will be installed inside CERTH premises. The acquirement of the necessary licenses will be done by the contractor that will undertake all the installation works.

4.1.2. Installation of MiniStor system

As depicted in Figure 18, currently there is ample open space in the vicinity of Smart Home for installing the MiniStor containerized system, as well as the solar field providing renewable energy for the system charging. However, in an attempt to reduce as much as possible installation costs (e.g. piping length, necessary excavations etc.) along with the associated heat losses, the location of MiniStor system will be close to the W corner of Smart Home. Respecting the EN-378 Standard provisions (reported in detail in D2.3), for a necessary 2 m distance between exterior openings of ammonia-containing machinery rooms and nearby buildings' emergency exit staircases or other openings, e.g. windows, doors, ventilation inlets, two possible locations for the installation of MiniStor container were initially identified and depicted in Figure 19. Both locations present the advantage of limited visual disturbance, as they are located in the backyard of the building and especially close to one of its corners resulting in reduced overlap with its surface. Since location 1 is suitable for accommodating containers of variable size (even with an area of 12 m^2) it is preferred over location 2 for placing the container, despite the higher overlap with the Smart Home south-western wall. Additional advantage of location 1, is the longer distance between the outer walls of the container and the building (namely 4.7m).

Figure 18. Aerial view of Smart Home and vicinity, including approximate locations of future buildings.

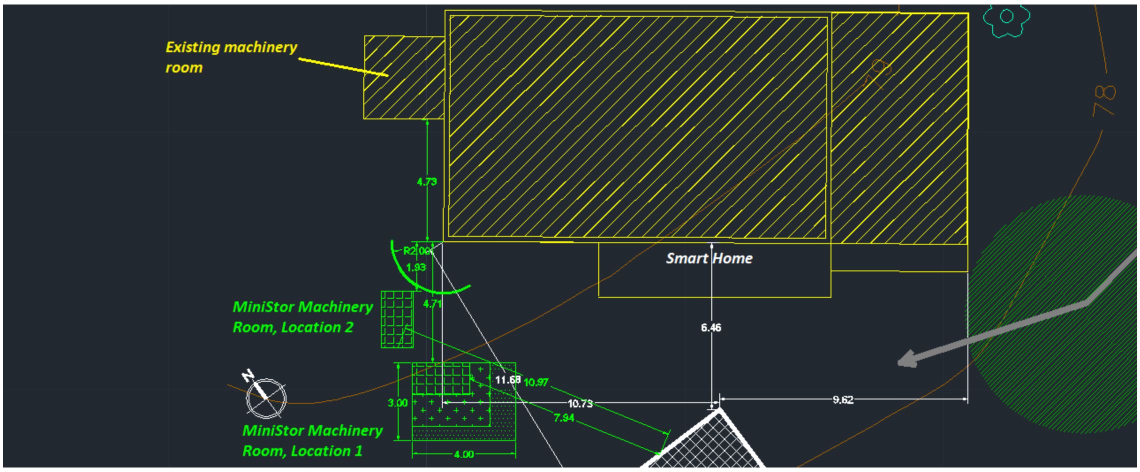


Figure 19. Drawing depicting the two possible locations for placing MiniStor machinery room in Thessaloniki pre-pilot.

4.1.3. Installation of solar field

As specified in D3.8, the solar field to be installed in Thessaloniki pre-pilot for harvesting solar energy and feeding MiniStor comprises 10 PVTs and 5 Flat Plate Collectors (FPCs) with gross collectors' area of 16.10 and 12.55 m^2 respectively. This results in a total gross area of 28.65 m^2 for the whole solar field, which as is explained in detail further below, leads to an even larger required open area for the collector's installation. This prerequisite combined with the fact that the largest part of the Smart Home roof is covered by PVs, excludes the rooftop installation of the MiniStor solar field. Two important parameters that affect both the solar field output and the required open area for installation are the collectors' orientation and slope. General rules of solar engineering indicate a southern orientation (i.e. azimuth angle equal to 0°) for achieving maximum incident solar radiation in applications in northern hemisphere (Duffie & Beckman, 2013). Regarding the slope, an angle value equal to the latitude ensures a maximum annual energy availability, whereas an angle 10-15° less or more than the latitude results in maximum summer or winter energy accordingly (Duffie & Beckman, 2013). In accordance with these guidelines, the collectors of Thessaloniki solar field are desired to have azimuth angle of 0° and a slope of 40°.

These specifications combined with the number of the collectors and their area, render the open area in the backyard of Smart Home as the most suitable area for the solar field installation. The selected location F1 (Figure 18) is also in the proximity of the selected location 1 for the placement of MiniStor container, decreasing the cost of the necessary connection works as well as the heat losses due to the hot water flow from the solar field to the TCM reactor. Moreover, the ground elevation in location F1 presents a gradual decrease towards south, which is also favourable for the deployment of multiple arrays of solar collectors. An alternative solar field location F2 at the northern side of Smart Home was disregarded as it is more remote from location 1, whereas the passage of several hydraulic and electrical underground lines in between of this location and Smart Home, would hinder the implementation of the necessary connections between the solar filed and the container.

In order to estimate the limits of the solar field installation, the necessary spaces between the collectors' columns and rows had to be defined. The solar filed will comprise three rows: the first and the second rows include 5 PVTs each, whereas the third one involves the 5 FPCs. The collectors of each row are connected in parallel with each other and the three rows are connected in series. Between the panels of each row, a space of 0.12m was considered, as indicated by ENDEF for implementing the required hydraulic connections. The estimation of the space between different rows is more complex as it is related to the possible shading from the first rows to the subsequent ones. In the current case, these spaces were selected so as to ensure that no shading occurs at 12 pm throughout the year. The minimum solar altitude angle (a_s) at this time of the day is 26°, occurring between 17th and 25th of December. This value, combined with the PVT panel height equal to 1.645 m and their slope of 40°, results in a minimum distance of 3.43 m as depicted in Figure 20. Thus, the resulting area covered by the collectors is around 51.7 m^2, while an additional circumferential strip approximately 0.3 – 0.4 m wide has to be considered for the installation of pipes, cables etc. A representation of the proposed solar field configuration is depicted in Figure 21.

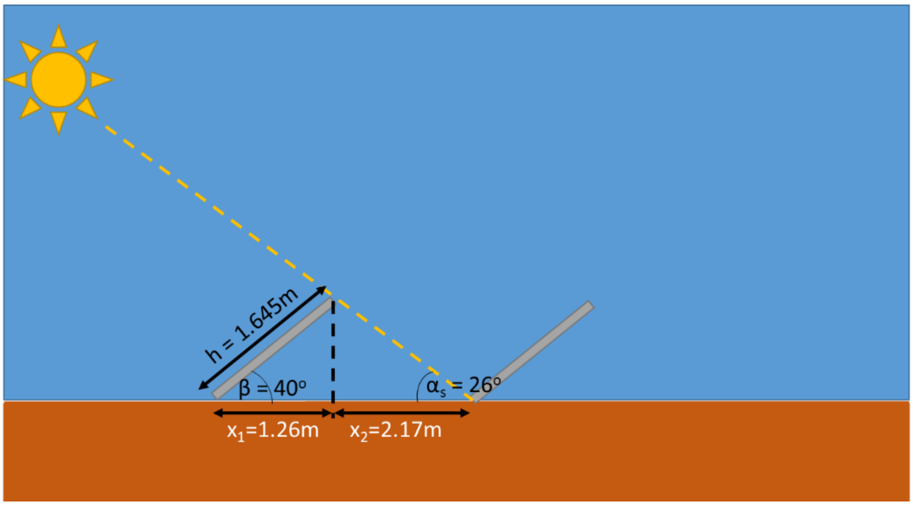


Figure 20. Estimation of the minimum distance between two rows of PVT panels in Thessaloniki pre-pilot.

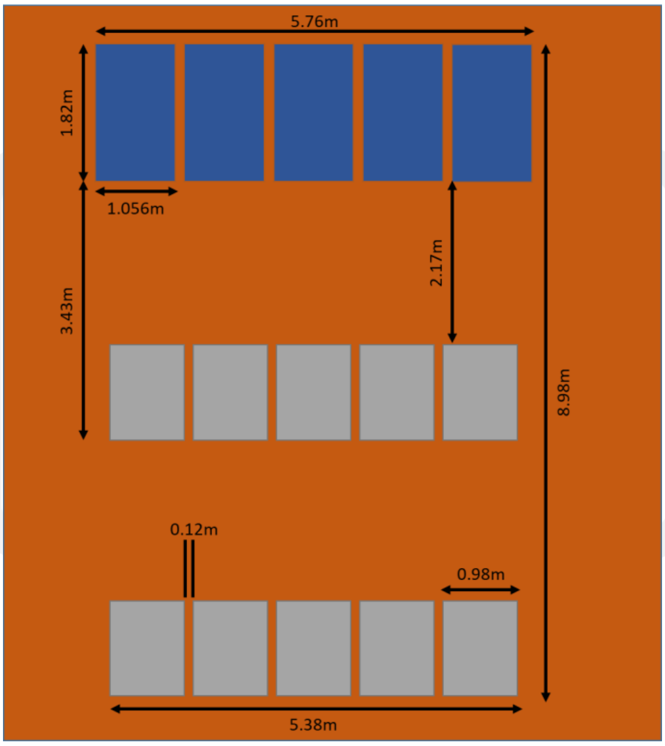


Figure 21. Representation of the solar field arrangement in Thessaloniki pre-pilot.

For estimating the exact spatial placement of the solar field, the effect of panel shading had to be investigated. Panel shading can be caused by neighboring buildings, as well as other obstacles such as adjacent trees. Underestimation of the shading effect may result in a significant underperformance of the solar field in specific hours of the day and / or periods of the year. In Figure 23 the solar position in the area of Thessaloniki can be observed for the average day of each month of the year. The lower solar altitude angles in winter, combined with the limited duration of intervals with significant solar radiation renders this period of the year more prone to reduced panels performance due to shading.

It should be noted that in solar applications, the azimuth angle is considered positive for displacements west of south and negative for displacements east of south. According to this convention, the orientation of the Smart Home's longest dimension is +37° / -143° (SW / NE orientation). Therefore, any potential shading of the area below the Smart Home (i.e. S / SW of it) and caused by the latter will occur during the sunrise and its extent is a function of the solar position at each hour of the day (solar azimuth and altitude angle) and of the building height. The latter is estimated to 6.75 m for the two floors main structure and 3.45 m for the SE facing section, which comprises only the ground floor. By placing the upper right (NE) corner of the solar field approximately 6.5 m (in the NE-SW direction +37^o / -143^o) from the Smart Home SW facing wall and 10.7 m from the Smart Home low left (W) corner and by implementing a solar field southern orientation (Figure 22), it is possible to ensure that no panel shading caused by the building occurs after 07:00 AM (solar time) throughout the year. This is depicted in Figure 23, where the solar position along with the shades of current obstacles (buildings and trees) are plotted in the same diagram as a function of the solar azimuth angle. In general shading of a specific point for a specific solar azimuth angle occurs when the altitude angle formed by the obstacle height and the obstacle - point distance is larger than the solar altitude angle (which is mainly caused by the fact that the sun is at a quite low position in the horizon). Thus, for the case of Smart Home two curves are depicted: one for the main two-floor building (line “SHM”) and one for one-floor eastern section (line “SHE”).

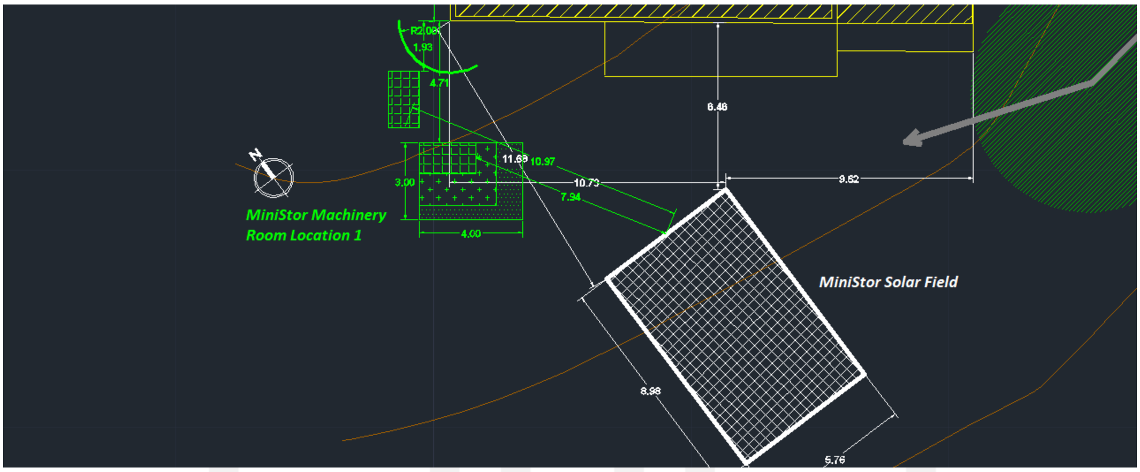


Figure 22. Drawing depicting the proposed location of MiniStor solar field in Thessaloniki pre-pilot.

Moreover, the proposed position also ensures a limited shading of the Smart Home by the solar field. As presented in the figure below (line “SH shading”), the shadow of the panels affects the building after 15:00 PM in the period November - January and after 16:00 PM in February and October. No shading occurs in the period April - August. It should be noted that no potential soil slope is taken into account in these calculations, which means that in reality the panels’ effect on the building is expected to be further reduced.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the grant agreement No 869821

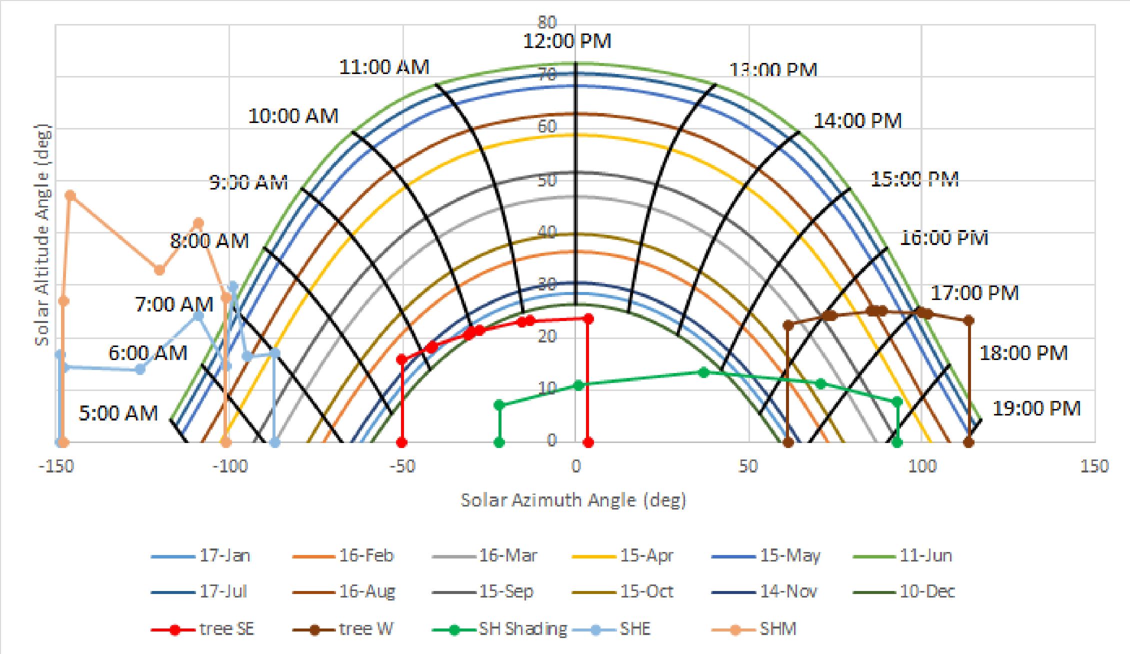


Figure 23. Solar position in the area of Thessaloniki and shading of the solar field by current obstacles.

Apart from Smart Home itself, two trees are identified as additional causes of potential panel shading: one is located S-SE and another almost west of the proposed PVT installation area (Figure 24). Trees' height and width were estimated as following: SE tree height 5m - width 5m, W tree height 9m - width 10m. However, the effect of the SE tree shading on the panels is limited by the soil slope which is estimated to 8.5°. The actual potential shading of the solar field southern edge caused by the S-SE tree is presented in Figure 23 as a function of the solar azimuth angle (line "tree SE"). It is obvious that the shading caused by the S-SE tree is limited, mainly because of the soil slope, and occurs in the period November - January and in the timeframe 8:30-9:30 AM. Its effect on the panels' power generation is weak, as the solar radiation levels before 10:00 AM in winter are rather low. However, it is important not to move the solar installation area further south as this will increase the shadow effect of the aforementioned obstacle.

Figure 24. Aerial view of Smart Home vicinity, depicting the original size of the adjacent trees.

The effect of the tree located W of the proposed PVT area is far more important, because of its position, its dimensions, its original dense foliage and the almost negligible soil slope in respect to the solar field. As depicted in Figure 23 (line "tree W"), the shading of the field western edge caused by this obstacle would occur after 16:00 PM throughout the year, except for May, June and July when it would be spotted after 17:00 PM (solar time). Therefore, the potential effect of the W tree shadow on the panels power output would be significant, especially during summer. However, as depicted in Figure 25, the aforementioned tree has been recently significantly cropped. Therefore, it is not expected to impose any serious limitations on the panels' performance.

Figure 25. View of Smart Home from SW, depicting also the current shape of tree W.

Finally, the analysis of solar field shading took also into account future obstacles that may affect the smooth harvesting of solar energy. Three of them were identified:

- A building of rectangular shape to be erected at the SE of Smart Home (denoted as "NB SE" in Figure 18)
- A building of hexagonal shape to be constructed at the S-SW of Smart Home (depicted as "HEX" in Figure 18)
- A greenhouse of rectangular shape that is to be created at the SW of Smart Home (denoted as "GH" in Figure 18)

The longest dimension of the SE new building will be almost vertical to the longest dimension of Smart Home, whereas its height is expected to be equal to the height of the Smart Home ground floor (approximately 3.5 m). Because of its orientation and its proximity to the solar field area, any potential shading of the latter is expected to occur in the morning hours. As shown in Figure 26 (line "NB SE"), no shading is expected to occur after 09:10 AM (solar time) throughout the year. This does not have any serious impact on the panels' power output during winter, as solar radiation levels before 10:00 AM are relatively low. In summer the solar radiation levels are quite high in the morning hours, however there is no shading of the collectors after 08:00 AM (solar time) in the period April - September. In May, June and July the shading is avoided even before 07:00 AM. Therefore, the potential impact of the new SE building on the yearly solar field power output is expected to be low.

On the other hand, the hexagonal future building is foreseen to be higher than the SE new building, its expected height being close to 4.5 m. This fact, combined with the structure location, result in a potential shading of the solar field right after midday. As shown in Figure 26 (line "HEX B"), no shading is probable to occur before 12:30 (solar time) throughout the year. Between 13:00 and 14:00, shading is spotted in the period November – January, whereas at about 15:00 it will be observed also in February and at the end of October. No shading occurs later than 16:00 throughout the year. In general, the effect of the hexagonal building is moderate and more intense in winter, as it coincides with periods of high solar radiation.

Similarly to the SE new building, the longest dimension of the greenhouse will be almost vertical to the longest dimension of Smart Home. Due to its considerable height (approximately 6 m) and location, it is expected to cause significant shading during the afternoon hours throughout the year. In winter months this effect will occur after 15:30, whereas in summer months after 16:30 (Figure 26, line "GH"). The resulting impact on solar field output is low in winter but severe in summer, as solar radiation levels are significant even at 18:00. To conclude, the combined effect of the three future buildings (SE, SW and Greenhouse and especially of the last two) is expected to be significant both in winter and summer. Nevertheless, the possible moving of the selected location towards any direction would result in equivalent or even more intense power output deterioration due to shading in winter.

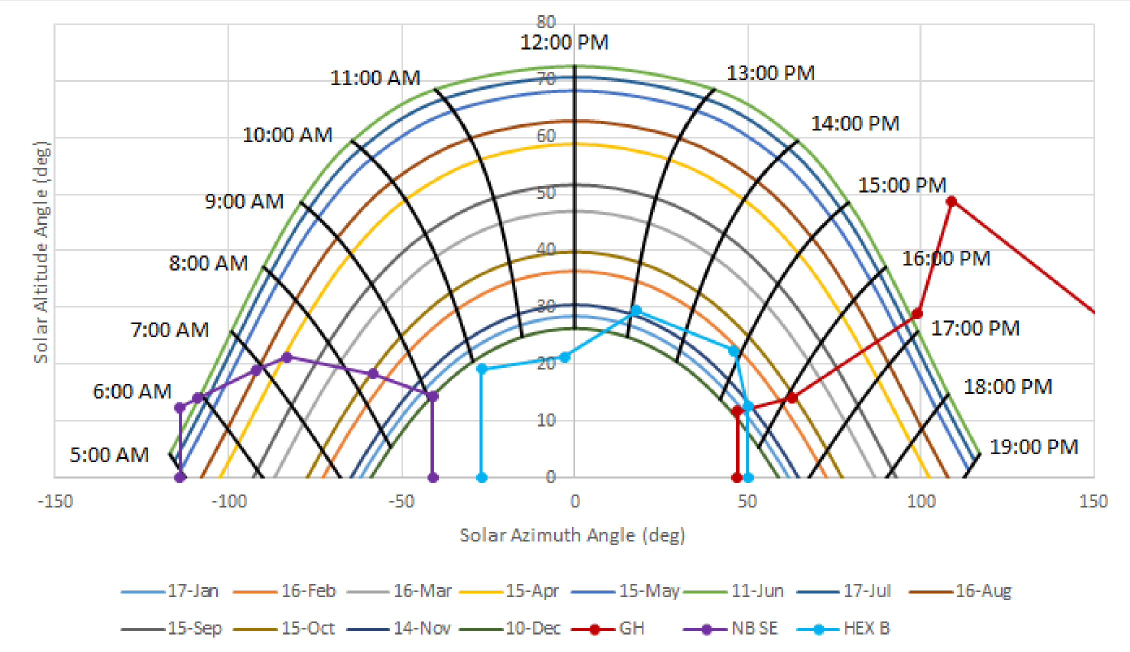


Figure 26. Solar position in the area of Thessaloniki and shading of the solar field by future obstacles.

Another issue related to the solar field installation is the associated pipework. In order to ensure the functionality of the solar collectors, the following networks should be constructed: i) pipes that connect the PVTs and the solar thermal panels of the field, ii) pipes that collect the heat transfer fluid from the solar field and directs it to the MiniStor system and more particularly to the water buffer tank and vice versa. According to the technical guide of the solar thermal collectors that have been selected for installation, their connecting pipes should be made of copper or stainless steel, thus defining the material of the whole pipework. Between these two options copper is more preferred due to its high usage in thermo-hydraulic applications in Greece. Additionally, the water velocity in these pipes is recommended to be lower than 0.7m/s, as higher velocities result in considerable pressure losses. On the other hand, very low velocities should be avoided too, as this makes the air ventilation (i.e. the removal of the air that collects at the solar collectors) difficult. Considering that: i) each PVT row will include 5 panels connected in parallel and ii) typical mass flow rate for such type of panels is about 50 kg/ (m^2h), then the resulting mass flow rate in the connecting pipes (between the three rows and between the solar field and MiniStor) will be about 402.5 kg/h, whereas in D3.1 a bit lower mass flow of 360 kg/h for connecting pipes is suggested due to the combination of PVT collectors with FPC collectors. Therefore, DN20 pipes (Φ22x1) result in flow velocities of 0.36 and 0.325 m/s respectively that satisfy the aforementioned criteria.

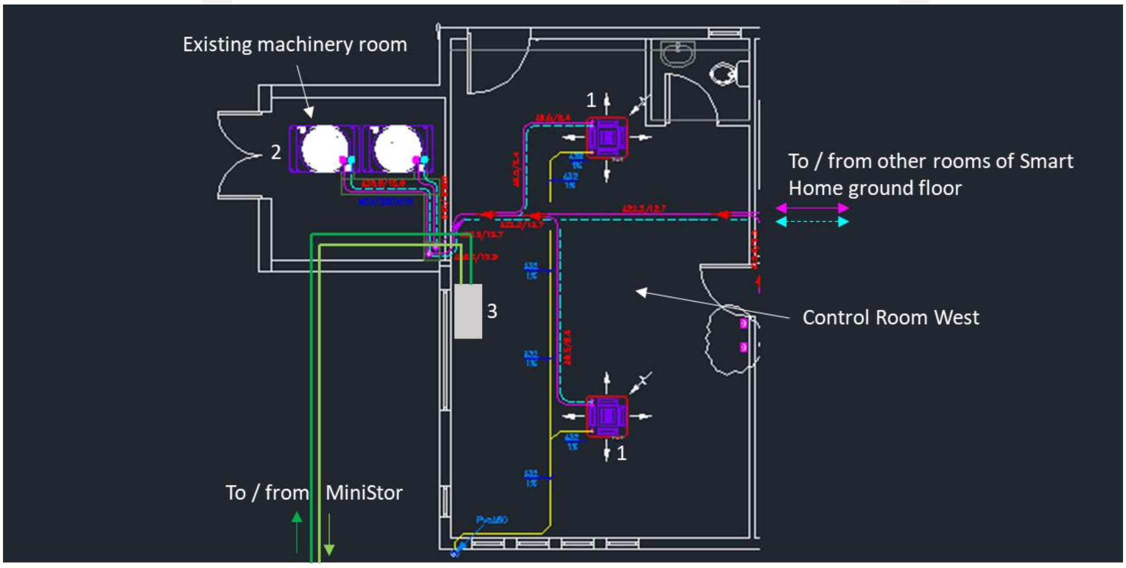
Moreover, a research to identify available piping products in Greek market has been conducted. Bare copper pipes are the most common type used. However, despite their low cost, their implementation in the current application should be excluded because of their significant thermal losses during winter.

Despite their cost, the selection of pipes with advanced insulation is ideal, given that their thermal losses should be confined as much as possible. At present, preparation of tendering documentation is underway so as to identify the contractor that will undertake the implementation of all necessary earthworks, piping and wiring related to the solar field and the MiniStor container. PVTs and supporting structures have been received on November 26th, 2021 and stored to avoid any damage.

4.1.4. Connection to current infrastructure

The integration of MiniStor with the current heating and cooling system of Smart Home is a challenging task, since the first one involves the utilization of water-propylene glycol mixture as heat transfer medium, whereas the second one is based on refrigerant circulation in its connecting pipes. At first, a possible integration of both systems was examined through the utilization of an R-410a-to-water heat exchanger and the installation of refrigerant piping which had to be connected to the existing branch feeding the two indoor units of the "Control Room West". The manufacturer of the HVAC units was consulted about the ease and the reliability of the proposed integration. The need for a thorough monitoring of the whole system to ensure its proper operation was highlighted in their answer along with the necessity to achieve a perfect match in terms of pressure, temperature and R-410a state (liquid or vapour) between the current and the new refrigerant circuits. A possible inability to achieve the latter, would possibly result in a poor performance or even malfunction of the HVAC system of the whole ground floor, which was a crucial factor for disregarding the integration of MiniStor with the existing HVAC network.

Thus, a parallel operation of the two systems is foreseen (Figure 27). This involves the addition of a new indoor unit (most probably of floor standing type) in the "Control Room West", which will be directly connected to the hot and cold PCM vessels, utilizing water-propylene glycol mixture as heat transfer medium. The selection between the operation of the new and the existing indoor units will be realized manually, giving always priority to the new unit fed by MiniStor. The selected approach involves the installation of connecting water pipes between MiniStor container and the new indoor unit along with the necessary recirculating pump. Regarding the latter, a preliminary assessment of its required specifications has been carried out resulting in an estimated maximum desired mass flow rate of around 900 kg/h and a head of 10.4 m. The model Varios PICO-STG 15/1-13 produced by Wilo is one of the pumps available in Greek market that can meet these operating conditions. In any case, the choice of the desired indoor unit model as well as of the circulating pump will be based on the final specifications of MiniStor and particularly of the PCM vessels.



Legend: 1. Indoor units of existing HVAC, 2. Outdoor units of existing HVAC, 3. New indoor unit, water pipes to / from MiniStor, pipes of gaseous refrigerant, pipes of liquid refrigerant

Figure 27: Drawing of current HVAC infrastructure in "Control Room West" of Smart Home and proposed thermal energy supply by MiniStor

Regarding the electrical subsystem of MiniStor, the battery along with the inverter, the electrical panel, and the rest of the electrical components needed, are going to be installed in a separate machinery room. It will cover all necessary rules for placing electrical equipment, and will be installed close to the existing machinery room of Smart Home. The installation will be carried out by expertized personnel that CERTH will assign.

The ammonia container will be connected to the electrical system, in parallel with the rest of the loads, so that continuous power supply is ensured. Previously, the electrical profile of the container was made, and it was compared to the electrical production and consumption of the system for four different weather conditions; extreme winter, average winter, extreme summer and average summer conditions. The outcome was the fact that the system cannot support islanded mode operation, and connection to the electrical grid is required. The power line from container's electrical panel to the electrical panel of the MiniStor system, the necessary protection circuit and in general the electrical diagram will be studied by the company CERTH will contract as responsible for the system's installation.

The connection to the electrical network involves various requirements, as mentioned in section 4.1.1. Thus, in order to be aligned with the current legislation in Greece, a smart meter from HEDNO will be installed right after the inverter. The purpose is to give the ability to the network operator to monitor whether the system's operation follows the contract signed. This means that the regulations declared based on the requirements of the relevant Responsible Engineer Declaration submitted, alongside the Request for System Activation, will not be modified. A responsible person from HEDNO will carry out this work.

4.2. Preparation works in Cork demo site

4.2.1. Licencing and permissions

Cork City Council (CCC) have engaged with the city councils' planning department. As the monetary cost of the project is under €126,000 and as the project is being engaged on a local authority property and within the confines of a local authority boundary planning permission is not needed (as of 04/02/2022).

The MiniStor unit is a 'structure'. A 'structure' covers a wide range and is defined in Irish Planning and Development Act, 2000 as following: *"structure" means any building, structure, excavation, or other thing constructed or made on, in or under any land, or any part of a structure so defined, and—*

(a) where the context so admits, includes the land on, in or under which the structure is situate, and..... As such, for the general public planning permission will need to be sought.

Restrictions and exemptions apply regarding the solar array on the roof and for a standalone structure. These can be found under Schedule 2 Part 1 "Exempted Development" Class 2c of the "*PLANNING AND DEVELOPMENT REGULATIONS 2001 – 2021 (Unofficial Consolidation)".*

Relating to ammonia, CCC has not determined that there is any requirement for planning as the volume of materials fall under that referenced. Other permissions to use ammonia in the proposed setting are being sought. Investigations are ongoing. The HSA (Health and Safety authority of Ireland) have been consulted and the information and guidance's are being evaluated (04/02/2022).

Moreover, CCC have engaged with ESB (Electricity Supply Board; Irelands electrical network manager), in order to accommodate bidirectional flow. In addition, it is expected that legislation will come into being in 2022 enabling micro energy prosumers to export electricity to the grid for a fee.

4.2.2. Installation of MiniStor system

MiniStor system will be placed at the back of the rear garden of Cork demo site. The minimum distance between the MiniStor container and the house (labelled with number 22 in Figure 28) is 12.2 metres.

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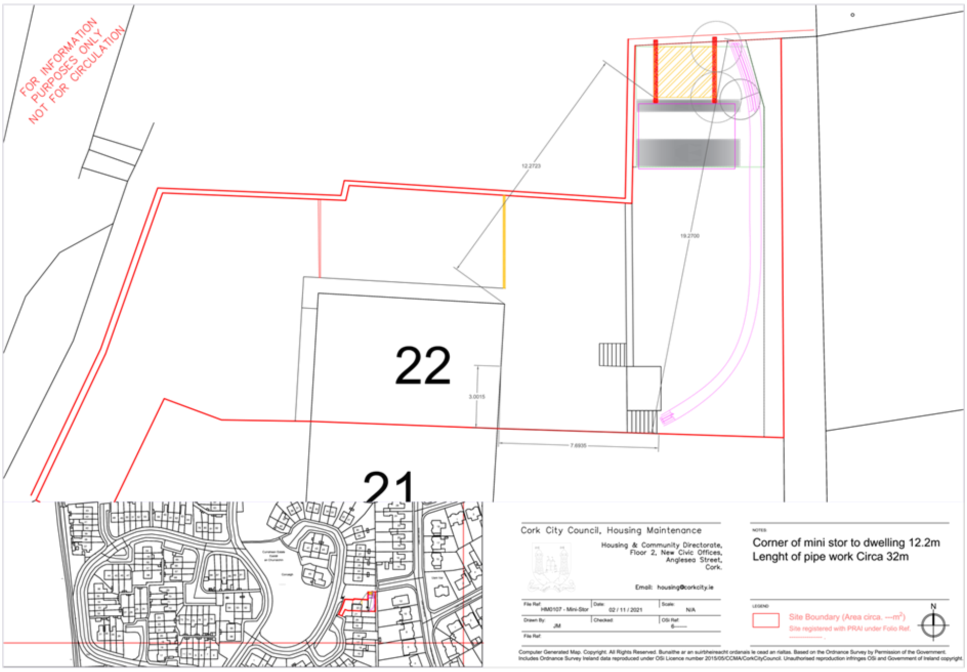

Figure 28: Drawing displaying the positioning of MiniStor system and its distances from the house in Cork demo site.

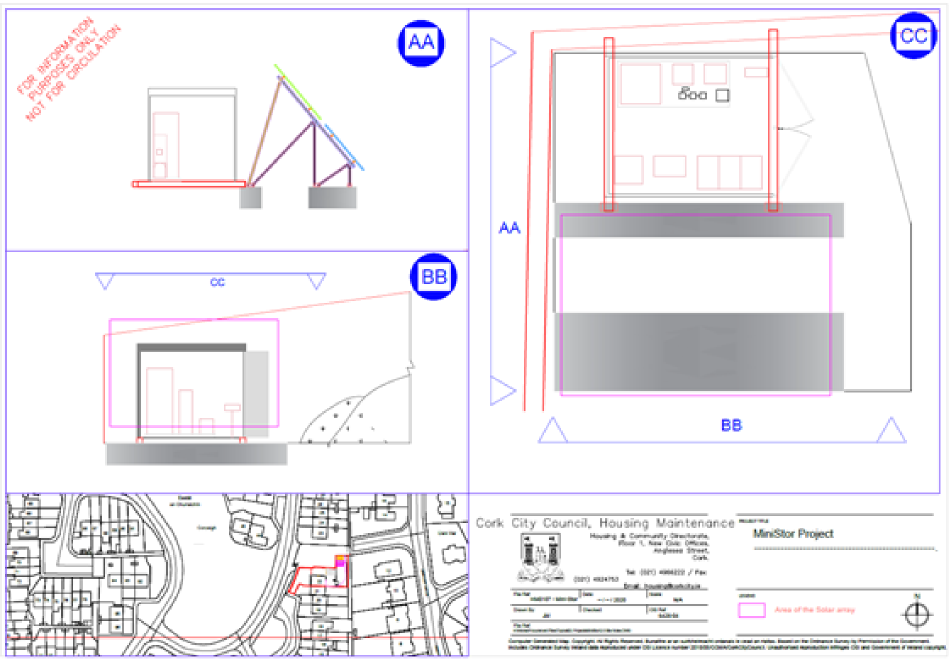

Figure 29: Depiction of the Plan (CC), Front Elevation (BB) and Open End-view (AA) of the MiniStor structures (Cork demo site).

Cork city council have progressed to install the solar supports and beams onto which the prefabricated MiniStor unit sit. Underground ducting and services have been installed to connect utilities from the residential property to the MiniStor container and solar array (Figure 29). In mid-2021 Cork city council procured and installed the foundations for the MiniStor container and solar array. Figure 30 shows the foundations for the MiniStor container (the steel beams) and the solar panel frame (concrete slabs)

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Figure 30: Installed foundations for the MiniStor container and the solar panel frame (Cork demo site)

4.2.3. Installation of solar field in Cork demo site

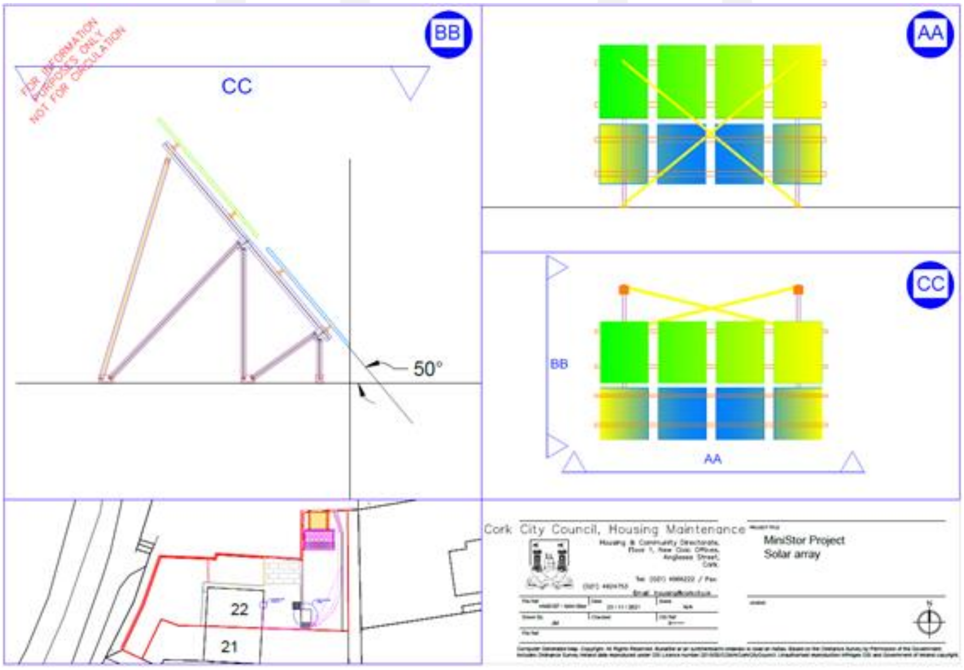

Figure 31: The solar array structure (Frame), mounted panels and their location within the property and installation location (Cork demo site)

To ensure that the solar PVT collectors could maximise the energy from the sun on a yearly basis it was decided to locate the panels in the raised rear garden facing due south. It was necessary to remove some of trees located in the rear garden (Figure 32). Solar array will be next to MiniStor container minimizing heat losses in the connecting pipes.

Figure 32: Trees to be removed to facilitate location of the solar panels (Cork demo site).

CCC received 4 PVT panels with total gross area of 6.44 m^2 (15/10/2021) and the solar frame (16/11/2021). As uncertainty looms over a suspension period coupled with current seasonal poor weather conditions CCC have decided to store the delivered items and progress with the erection at a later date.

As referred to in 4.2.2 Cork City Council have installed the footings for the solar frame and MiniStor unit. Utilities and utility ducting have been installed to accommodate communication from the MiniStor unit to the dwelling.

As referenced in 4.2.1 CCC are in communication with ESB to convert the existing system to bidirectional flow. Currently the electrical system is set to receive electricity and not produce and return surplus to the network. CCC have engaged with councils' fire marshal who provided guidance in re-locating the Battery and Inverter to an outside concrete shed present on the property grounds.

4.2.4. Connection to current infrastructure

CCC intend to connect the MiniStor unit to the existing heating system by means of a heat exchange unit affixed to either the internal or external leaf of the eastern external wall of the house (Figure 33). The two pipes supplying heat to the house are partially underground to reduce heat loss and to reduce the risk of an accident. The section of pipework above ground is mounted on the boundary fence and on the external wall of the house so as to reduce the risk of accident. The exposed pipework is enclosed in insulating material with very good insulating properties. The heat supply pipe terminates at the heat exchanger inside the house. The heat exchanger will be located close to the domestic boiler and operate in parallel with the boiler to deliver heat on demand to the house when available.

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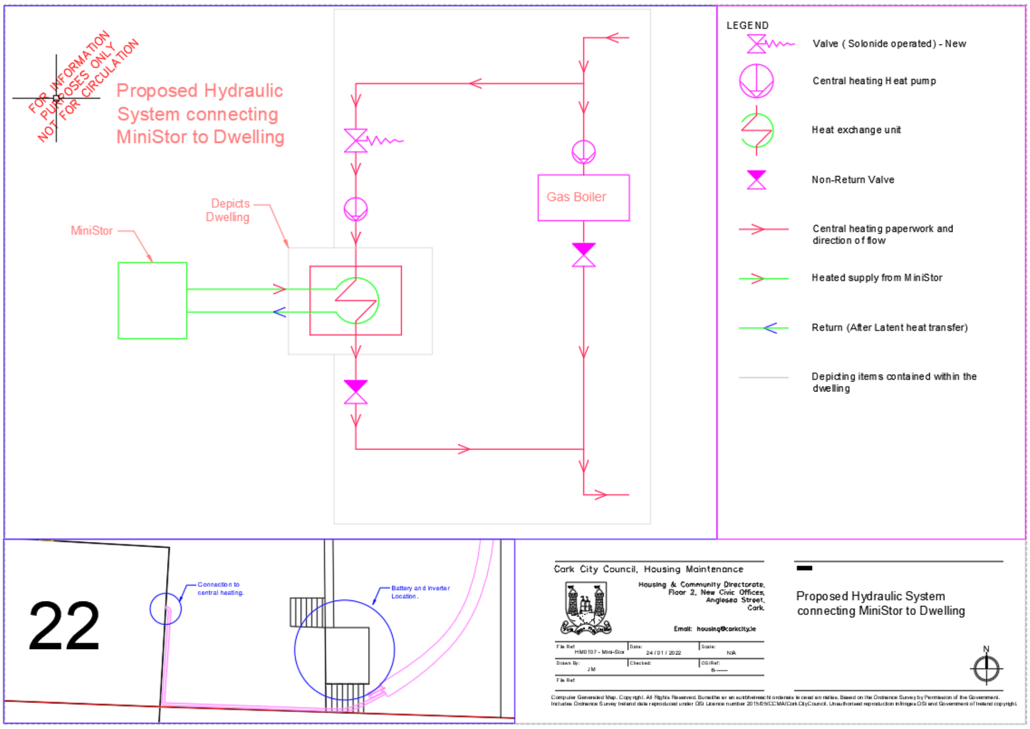


Figure 33: A draft of the proposed connection where stored heat will transfer between the MiniStor Unit and dwelling (Cork demo site).

When parameters are met by both the dwelling and MiniStor unit a signal will be sent to the MiniStor switch to engage. This will order the MiniStor glycol circuit pump to begin cycling the glycol fluid which will begin to transfer stored heat from the MiniStor to the dwelling's heat transfer unit. On reaching a desirable temperature another communication sequence will initiate requesting the solenoid operated valve depicted in Figure 33 to open and in tandem reduce the flow and heating demand from the existing central heating boiler and pump.

It is proposed to install the electrical battery and the hybrid inverter in an existing concrete shed (formerly a coal shed). Correctly sized cables will connect the inverter and battery to the PVT solar array, the mains power supply and the domestic distribution system within the property (Figure 34). The electrical line to feed the MiniStor container is depicted in Figure 35.

Figure 34: Connection of PVT Solar Array, Inverter and Battery to the house and the mains of Cork demo site

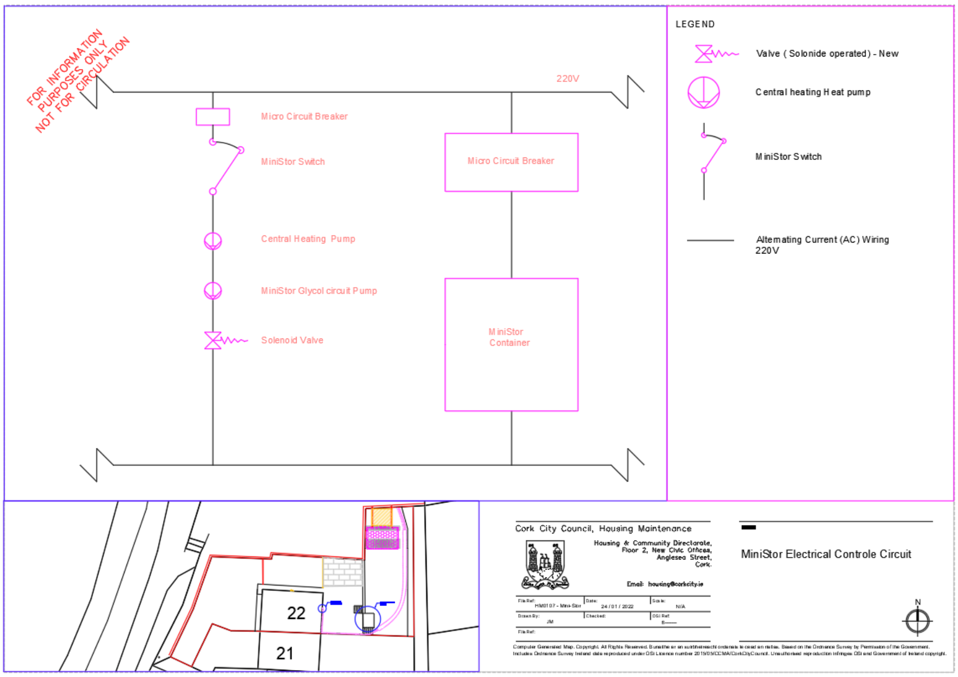


Figure 35: Depiction of the electrical line to feed the MiniStor container (Cork demo site).

4.3. Preparation works in Kimmeria demo site

4.3.1. Licencing and permissions

As a MiniStor partner and demo site owner, DUTh will test the operation of a novel experimental equipment that is the MiniStor box. The university campus, where the system is about to be installed, is occupied by students and thus, the participants and users of the system will be students (ages 19-25). In order to begin the preparations for the installation of the MiniStor system, the willing candidates had to be selected. The DUTh team prepared questionnaires which informed the students about the benefits as well as the dangers of the system and the ones willing to participate formed the subjects of the experimental operation of MiniStor. The National regulation regarding the ammonia usage in the urban environment was then thoroughly researched. The EU Standard EN-378 is the only applicable standard for the Greek case as there is no national directive regarding the urban use of ammonia. After extensive search, the staff of the university currently employs a cooling systems' expert whose previous experience with manufacturing ammonia containing equipment and with the usage of ammonia in general, can be exploited on-site. In order to ensure the safety of the students, a Greek company named "Psyctotherm" was consulted as DUTh had previously employed their services. The company specializes in various cooling mediums along with ammonia and ensured the DUTh team of the operability of the system.

The system will be installed in open-space, inside the university campus and thus permissions of installation are not required. However, a formal request for the place to be occupied as well as the details of the container regarding its size and enclosed equipment was addressed to the technical department of the university. A formal notification about the ammonia system use and placement was also part of the document. The document was shared with all the MiniStor partners after the final signing. The residents / students / maintenance staff of the demo site, however, will be informed again about the subject of ammonia usage and will be formally notified about the hazards of the ammonia-based system, which is the MiniStor system, as well as the precautions to be taken in situations of system failure.

4.3.2. Installation of MiniStor system

The installation of the MiniStor system at DUTh's demo site will be at the southern side of G2 building (as seen in Figure 8 and Figure 36). The placement of the system will be at rocky soil with no restrictions regarding weight, on a temporary foundation. The path towards the end-point of the placement is accessible by a crane, providing a favourable installation option. According to EN-378 regulation, the positioning of the system was chosen to be at over 12 m (in respect of the defined by the Standard 2m distance), from system to the first resident's window.

The option of the outdoors positioning of the system, ranks as a low risk position.

4.3.3. Renewable energy input

In Kimmeria demo site existing infrastructure, described in 3.3.2, will be used and no installation of equipment relevant to solar field is foreseen as part of MiniStor activities. More specifically, there will be no direct connection of the DUTh's solar field and the MiniStor system. The MiniStor system will receive, instead, unlimited heat (hot water at temperatures above 70°C) from the central district heating network of the demo site, which will provide the necessary thermal energy for the decomposition of the TCM. The connection between the central district heating network to the MiniStor system will be done by connecting the G2 building's hot water collector (Master) (connected to the overall DUTh's heating system) to the MiniStor box (via the red line– Figure 36).

4.3.4. Connection to current infrastructure

As described in 4.3.3., the necessary thermal energy will be provided to the MiniStor system by a hydraulic connection between the building's hot water collector and the MiniStor box (via the red line-Figure 36). There are two different options regarding the plumbing connections between the MiniStor box and the consumption level (student rooms). A temporary suspended pipework will connect the MiniStor System with the buildings shafts. The best option is the connection of the system via an available window at the southern side of the building, (Figure 36). The orientation of the container will be as shown in Figure 36. Terminal fan coil units will be installed in the selected rooms, which will be directly connected to MiniStor system's hot and cold PCM (via the orange line – Figure 36). The fan coils will be either suspended or placed on the position of the previous radiator. The proposed hydraulic connection of the MiniStor system to the G2 building's HVAC system is depicted in Figure 37.

DUTh's campus in Kimmeria, Xanthi is connected to the MV Grid through an MV/LV transformer located in the Energy Centre building. The G2 building is connected to the Energy Centre with an exclusive three-phase cable. The main electrical board (250A) of the G2 building is located in the basement. MiniStor will be connected directly to the main electrical board of the G2 building with an exclusive electrical line dimensioned according to ELOT 60364 (via the pink line-Figure 36). According to the existing electrical loads of the building there is available electrical power to cover the electrical load of MiniStor.

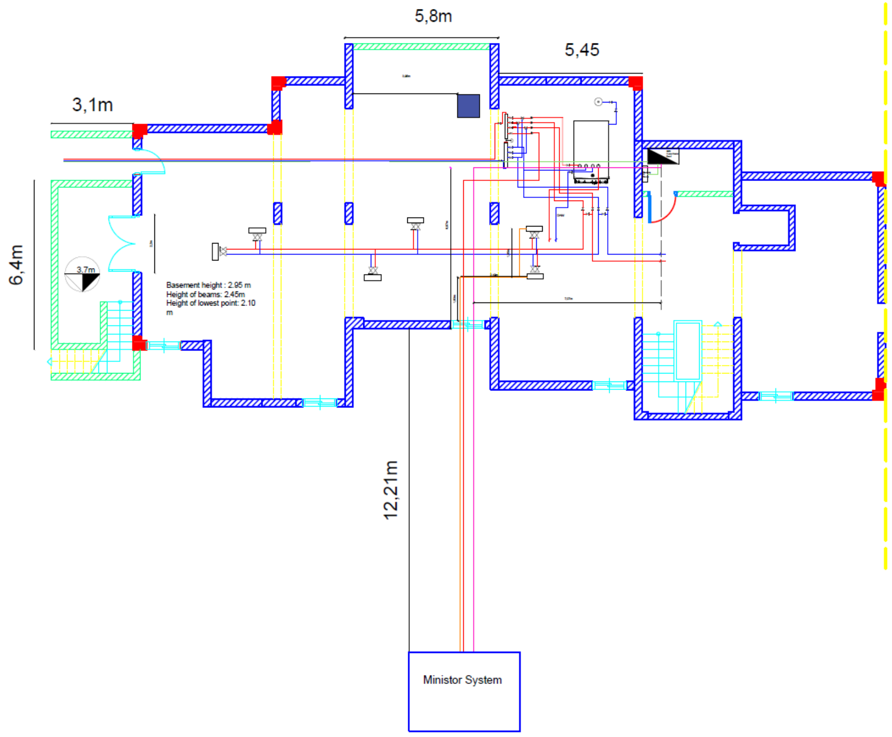


Figure 36: Position of installation of the MiniStor system at DUTh's demo site

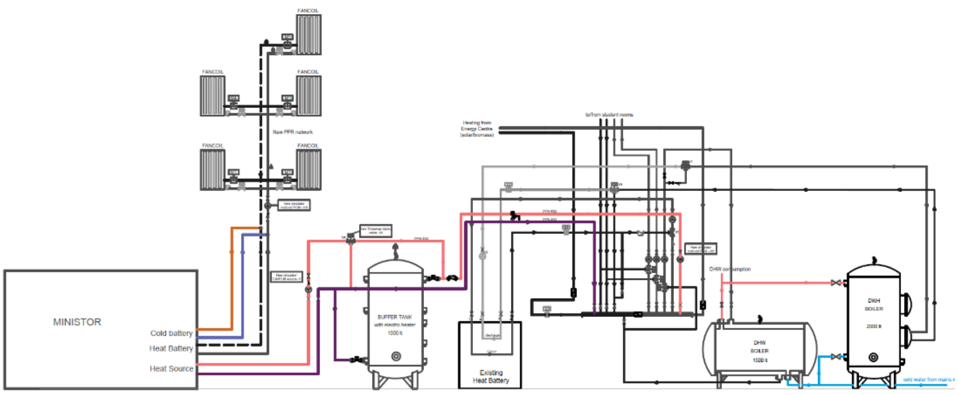


Figure 37: Hydraulic connection scheme for the MiniStor system to the G2 building's HVAC system.

4.4. Preparation works in Santiago de Compostela demo site

4.4.1. Licencing and permissions

Before the formal integration of the USC as a partner of the Project, its participation as a member of the Project team was negotiated with the energy and sustainability unit of the infrastructure service of the USC. This participation was vital for the technical viability of the Project. Once said participation was assured and an apartment of the Burgo de las Naciones Hall was identified as a demonstration centre, authorization was requested from the person in charge of special projects of the Office of the Rector, in addition to that of the Vice-Rector responsible for University Hall and the director of the "Burgo de las Naciones" Hall.

The apartment that serves as the demonstration centre is inhabited by a family of three. The father of the family was informed (during the application process for authorizations) and agreed to participate in the

Project. Since then, he has been providing valuable information when asked about the perception and behaviour of the heating and hot water systems and the estimated energy consumption of the family according to their habits and behaviour.

The Vice-Secretary General of the USC, responsible for the protection of data at USC, was consulted about the data capture in the apartment that will be done during the Project and the possible need for adaptation to the legal regulations. His opinion was that taking into account the type of data that is collected and how it is collected, no additional measures are necessary.

The collaborating company of the USC risk prevention service will be informed of the characteristics of the Project in order to follow its recommendations, guidelines and knowledge of the processes to follow before, during and after the installation of the Project equipment.

Regarding the processing of permits before the Municipality of Santiago de Compostela and other competent entities for the installation of the MiniStor System and the solar and thermal collectors, an engineering company has been hired to prepare the necessary technical documentation and direct the necessary work. It has also been agreed with the USC administrative service responsible for customs procedures to collaborate in carrying out such procedures if necessary.

Additionally, an investigation and a legislation analysis were carried out to evaluate the viability of the installation of an ammonia containing system, such as MiniStor, in the demonstration centre of Santiago de Compostela. The followed methodology involved:

a) Search for information on the Internet
b) Consultation with experts (i.e. people, services and organizations related to energy installation)

The search for information on the Internet was carried out using phrases in Spanish. The purpose of this search was to obtain data and information on legislation in various fields that are related to ammonia and from various approaches, i.e. as a refrigerant, as a gas, as part of a system, as a toxic compound, etc. Several search expressions were used in Spanish and the texts of the legislation found were analysed and saved for later reading and analysis.

The experts' consultation was carried out by sending an e-mail describing the use of ammonia in MiniStor system and its basic characteristics. Emails were sent to: i) an industrial engineer with experience in installations, ii) an engineering company with extensive experience in facilities and iii) the National Technological Center for Energy and Sustainability, whose acronym is ENERGYLAB.

The results of the search for legislation related to ammonia (including both findings of the internet research and contribution from the consulted experts) are shown in the following table.

Law / standard / norm	Acronym	Description (in Spanish and English)	Impact
R.D. 732/2019	CTE	Código Técnico de la Edificación / Technical Building Code	High
R.D. 178/2021	RITE	Reglamento de Instalaciones térmicas de edificios / Regulation of Thermal Installations in Buildings	High
R.D. 552/2019	RSIF	Reglamento de Seguridad para Instalaciones Frigoríficas y sus Instrucciones Técnicas Complementarias (ITC) / Safety regulation for refrigeration installations and complementary technical instructions (ITC) --ITC IF-05. Diseño, construcción, materiales y aislamiento empleados en los componentes frigoríficos --ITC IF-07. Sala de máquinas específica, diseño y construcción --ITC IF-09. Ensayos, pruebas y revisiones previas a la puesta en servicio --ITC IF-12. Instalaciones eléctricas	Very high

		--ITC IF-16. Medidas de prevención y de protección personal --ITC IF-17. Manipulación de refrigerantes y reducción de fugas	
R.D. 656/2017		Reglamento de Almacenamiento de Productos Químicos y sus Instrucciones Técnicas Complementarias (ITC) / Regulation for the storage of chemical products and complementary technical instructions (ITC) ---ITC MIE APQ 4 – almacenamiento de amoníaco anhídro.	High
R.D. 842/2002		Reglamento Electrotécnico de Baja Tensión / Electrical low voltage regulation	Medium
R.D. 2060/2008		Reglamento de equipos a presión y sus Instrucciones Técnicas Complementarias (ITC) / Regulation for pressure equipment and complementary technical instructions (ITC)	Low
UNE-EN 378-1:2017+A1:2021	UNE-EN 378	Sistemas de refrigeración y bombas de calor. Requisitos de seguridad y medioambientales. Parte 1: Requisitos básicos, definiciones, clasificación y criterios de elección. / Standard EN378, Part 1	Very high
R.D. 39/2017		Mejora de la calidad del aire(modificación del 102/2011) / Improved air quality	No impact
R.D. 102/2011		Mejora de la calidad del aire --Artículo 12.-mediciones de las concentraciones de amoníaco. / Improved air quality, article 12	No impact
R.D. 31/1995		Prevención de Riesgos Laborales / Prevention of occupational hazards	Medium
R.D. 485/1997		Disposiciones mínimas de señalización de seguridad y salud en el trabajo. / Minimum provisions for occupational health and safety	Low

Table 1: Spanish legislation & standards related to the use of ammonia as a refrigerant.

From the analysis of the information found and the contribution from the experts, the legislation acts were classified by their impact on the viability of the MiniStor system in six (6) levels: null, very low, low, medium, high, very high. This classification has been included in Table 1, in the column entitled “impact”. Thus, it can be seen that of highest importance are UNE-EN 378, i.e. the EU Standard EN-378, and R.D. 552/2019 (RSIF), i.e. the Safety Regulation of Refrigeration Installations and its Complementary Technical Instructions (ITC) that MiniStor system must comply with. As part of a home heating and cooling system, MiniStor system is also subject to the basic building legislation and its regulation of thermal installations, that is, R.D. 732/2019, called the Technical Building Code (CTE), and R.D. 178/2021 called Regulation of Thermal Installations of Buildings.

Royal Decree R.D. 656/2017 concerns the Regulations for the Storage of Chemical Products and one of its Complementary Technical Instructions (namely ITC MIE-APQ-4) is dedicated to the storage of anhydrous ammonia. Depending on the amount of ammonia in MiniStor system, the latter could be highly affected by this law. Moreover, Royal Decree R.D. 31/1995 is related to the prevention of occupational hazards and similar to all legislation acts in the area of safety, is very important for the viability of the implementation of MiniStor system, although from another approach.

Given the above analysis, the entities that are involved in the authorization of the installation of MiniStor system in USC demonstration centre are:

a) The autonomous government of Galicia regarding the legalization of the installation

b) The Municipality of Santiago de Compostela, with regard to emergency plans, fire defence and urban planning.

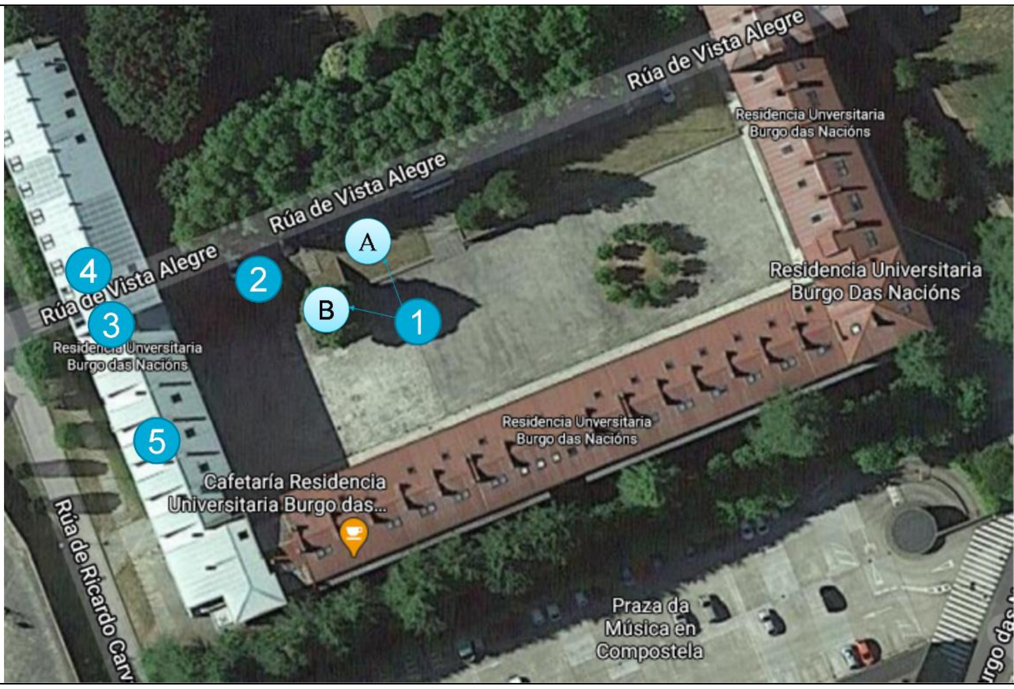
c) The USC through its infrastructure management and occupational health & safety services that will consult the academic authorities about the application or not of corresponding permits and other necessary actions.

In the absence of a more in-depth study, the conclusions drawn until the time of the current documentation are:

- The use of a machinery room outside the apartment facilitates installation by eliminating many restrictions.
- The limitation of the amount of ammonia in MiniStor to less than 80 kg makes its authorization more viable, although in the legislation there are some assumptions of installation limited to 25 kg of load.
- The interpretation of the regulations is confusing with several Royal Decrees imposing restrictions with somewhat ambiguous scopes of application for not very expert people.
- As an energy system charged with more than 10 kg of NH_3, the MiniStor system must comply with ITC IF-12 of the R.D. 552/2019, RSIF.
- The MiniStor system must comply with the provisions of the following ITCs: ITC IF-05, ITC IF-07, ITC IF-09, ITC IF-16, and ITC IF-017 (see Table 1).
- Gas ammonia sensors to detect leaks at various levels, electrical installations with automatic power switches and warning elements are mandatory.
- It is necessary to protect access to the MiniStor system, limit access to authorized personnel and signal it in accordance with the regulations.
- Periodic maintenance must be contracted to an authorized company.
- USC has to take out insurance for an amount of 500,000 euros.
- A study of the risks to the health of the residents in the demonstration centre and the building that contains it, is necessary. This has to be done by the USC risk prevention service.

4.4.2. Installation of MiniStor system

As a preliminary step to the use of apartment B of the “Burgo de las Naciones” Hall as a demonstration centre in the MiniStor Project, it was necessary to design and install a heating system and distribution of domestic hot water (DHW) only for said apartment, separating it from the hydraulic distribution circuit of the centralized system in the building. In addition, a local monitoring and control system is being installed for the new technical facilities.



Description:
1. Possible areas for PVT solar Field (A and B) ()
2. Selected location for the machinery container for the MiniStor system
3. Location for Li-ion batteries and inverter (Basement)
4. Location of BC boiler room (Basement and Ground floor)
5. Location of the Apartment

Figure 38. General location of main components of MiniStor project in USC demo site.

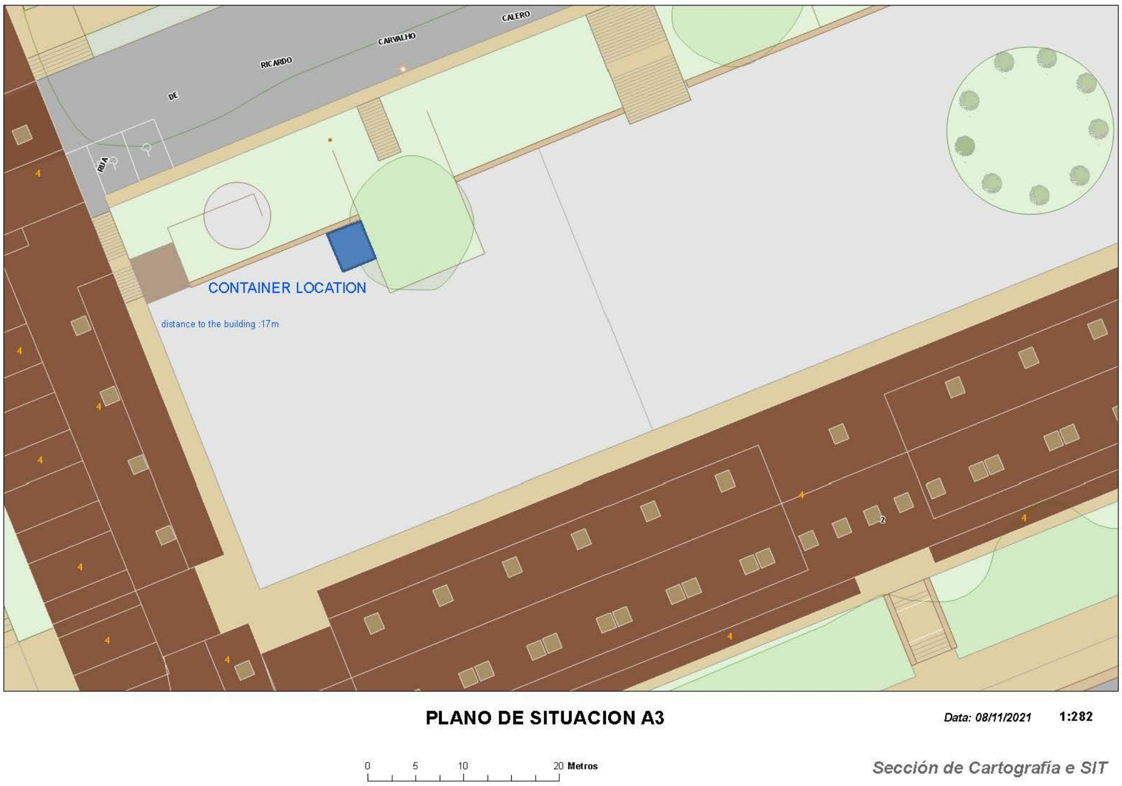


Figure 39: Container location in USC demo site (city council´s GIS).

Apartment B is located in the south-west wing of the U-shaped building that houses the Burgo de las Naciones Hall. Figure 38 shows, marked with the number 2, the planned place of installation of the container with the MiniStor System, close to the solar and thermal collectors and in front of the connection point with the new heating and hot water network of the apartment and the electrical and control panels located in the basement of the building. In Figure 39 the location of the container is shown in greater detail. Its distance from the building walls is at least 17 m.

The intended location of the container with the MiniStor System is in the building´s courtyard and its installation will be done without permanent fixing to the ground. Due to the fact that it is located on private land, surrounded by land owned by the same owner, it does not take away views of other properties, it is not permanently fixed to the ground and this location is in line with the legislation on technical installations of buildings, no difficulties are expected from the point of view of planning permission.

The canalization for the connection of pipes to the MiniStor System has not been carried out since it will be carried out when the system is received and its final location is definitely determined. The chosen location minimizes civil works and network connection work, reducing time and costs as much as possible.

Access to the inner courtyard has been found to be sufficient for the passage of medium-large tonnage trucks with an opening of approximately 4.7m x 5.6m. Two companies with cranes and adequate equipment for handling containers have been identified in the Municipality of Santiago de Compostela.

4.4.3. Installation of solar field

The possible locations for the solar and thermal collectors of the Project are shownFigure 38 in Figure 40 marked with two red squares. One of the two zones (area B) is a flat surface dedicated to a green area of more than 80 m^2 located 3 m above the level of the interior patio of the Burgo de las Naciones Hall. The other area is a sloping green area of about 84 m2. Both zones are suitable to contain the 20 panels selected for this demonstration centre, each one with about 2 m^2 of surface. A 1.5 m elevated support structure is proposed with a 20º inclination and an azimuth of 22º East (See, Deliverable 3.6). The surfaces have been prepared, freeing them from obstacles and making an underground passage from an area near the basement of the building to facilitate connections.

The definitive location of the batteries, inverter and other necessary elements will be in the basement of the building, under the apartment, next to the other equipment and heating networks, hot water, electricity and monitoring and control. It has been changed from the one initially planned and indicated in Deliverable D3.6. The characteristics of the collectors selected for the Santiago de Compostela demonstration centre, which differ from the PVT collectors to be installed in Thessaloniki, Cork and Sopron, can be found in the aforementioned deliverable. The delivery of the PVTs is expected to take place in autumn 2022.

This project has received funding from the European Union´s Horizon 2020 research and innovation programme under the grant agreement No 869821

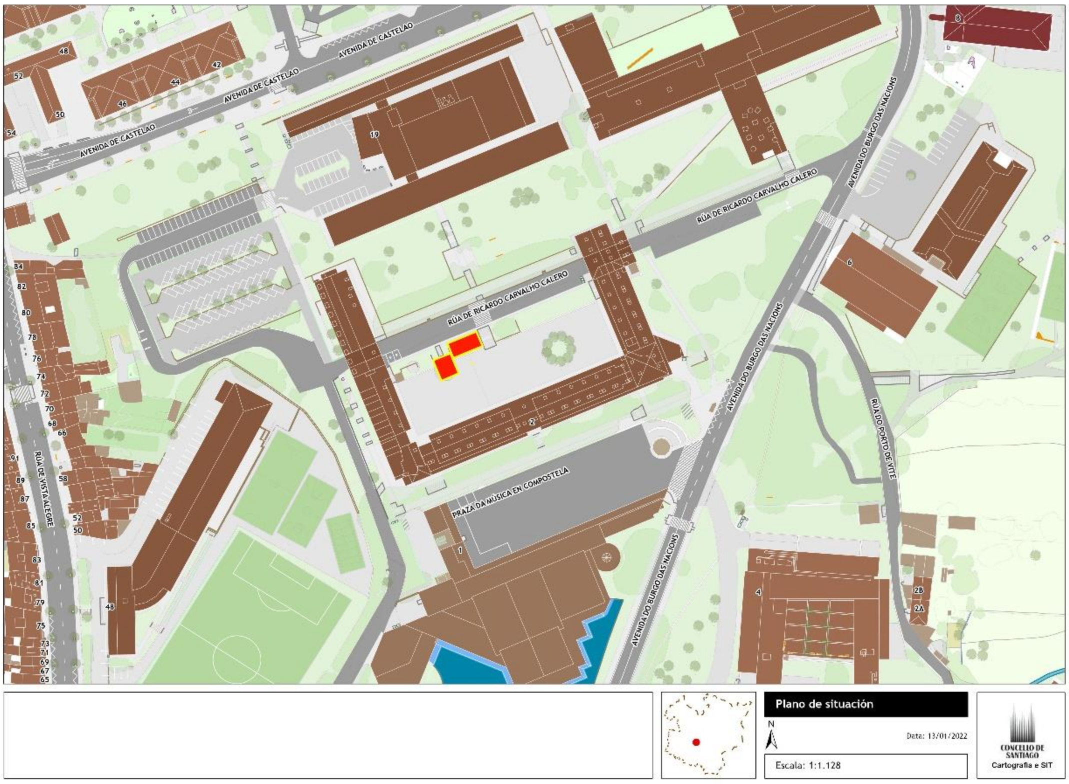


Figure 40: Possible locations of PVT field in USC demo site

4.4.4. Connection to current infrastructure

The connections of the elements of the MiniStor Project to the existing infrastructure will be made in the basement of the Burgo de las Naciones Hall, which is accessed through the BC boiler room, and where the new facilities necessary for apartment B are located (Figure 41). From the physical point of view, a canalization is needed to connect the PVT solar collectors with the container of the MiniStor System and this with the basement of the building.

The Burgo de las Naciones Hall is located on the North campus of USC, which has an electrical microgrid with an interconnection point to the public operator's network. Therefore, the connection of the photovoltaic and thermal collectors and the MiniStor System to the existing electrical infrastructure will be an internal connection to the USC Network. The engineering company hired for the preparation of the technical documentation necessary for the request for permits will evaluate this scenario.

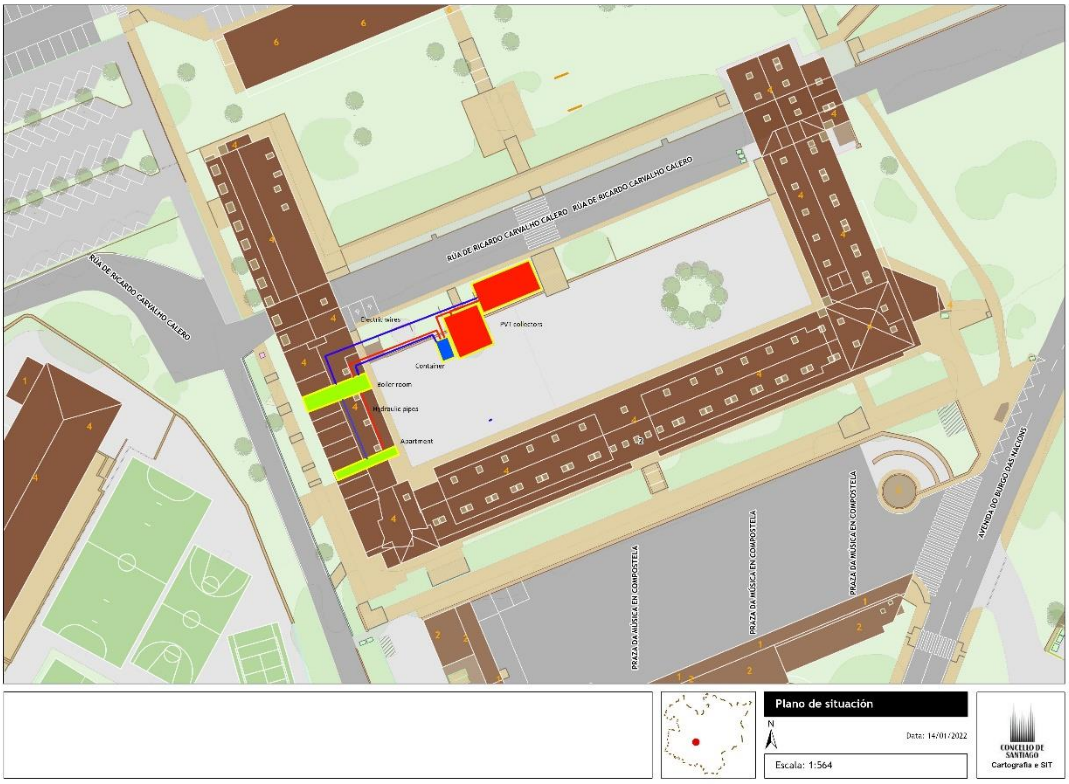


Figure 41: Connection to current infrastructure – USC demo site

Figure 42 shows the diagram of the integration of the PVT collectors and the MiniStor System in the existing heating system. The new heating installation in the apartment was designed to work at a low temperature. It uses an input from the building´s heating systems and integrates with MiniStor system through a heat exchanger.

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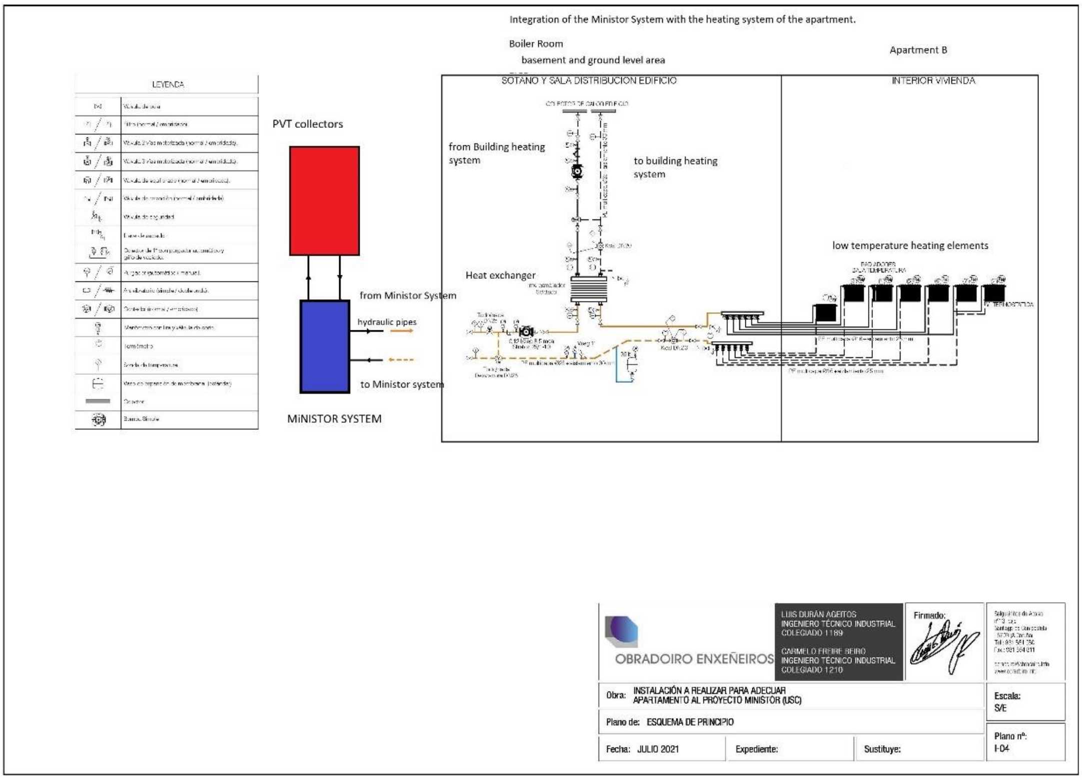

Figure 42: Hydraulic diagram of MiniStor integration in the heating system of USC demo site.

Figure 43 shows the electrical block diagram of the integration of the MiniStor System components with the existing electrical installation.

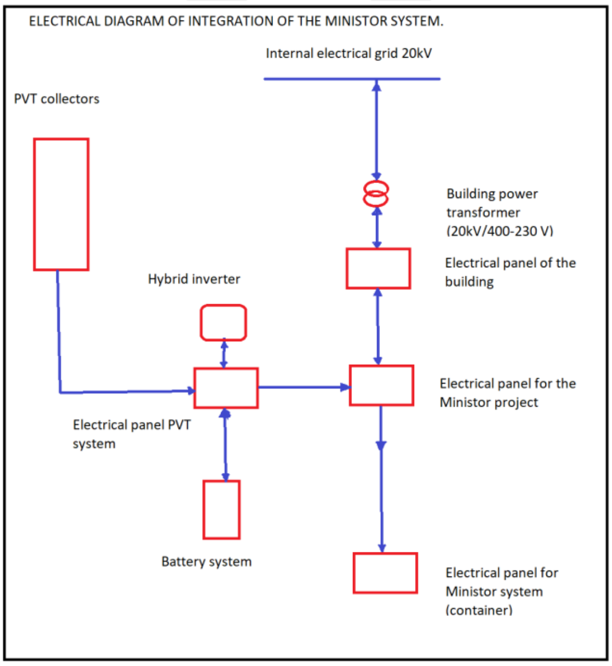

Figure 43: Electric block diagram of the integration of MiniStor components with the existing electrical installation of USC demo site.

4.5. Preparation works in Sopron demo site

4.5.1. Licencing and permissions

The owners of the Sopron Demo Site (i.e. the family that lives in the building) contributes to the measurement, and storage of energy consumption data of the building. They agreed that the building will participate in the MiniStor project and that measured data will be analysed for scientific purposes in the frame of the MiniStor project. A relevant GDPR consent was also signed. They also agreed to install the sensors and the elements of MiniStor system to the building or around the building. Finally, there is an acceptance from the representative owner for publication without mentioning the address and the name and data of the owner.

A survey was also carried out by WOODSPRING, regarding the usage of ammonia containing systems in residential settings in Hungary. In order to identify possible limitations and required licencing for the usage of systems such as MiniStor, the following steps have been subsequently taken:

1. Online search in Hungarian Legislation was done on the official codes which contains also the laws and the regulations. The search was done to the word ammonia. There were 77 documents mentioning the word ammonia in the Hungarian Legislations, with the more relevant to MiniStor listed below.
    - 219/2011 government decree (219/2011. (X. 20.) Korm. rendelet). There is a regulation within the code which gives important information for using ammonia. In 1. § part 3 C point it is determined the amount over which there is prescribed a safety plan. Under this amount it is not needed, but risk possibility has to be minimized. In case of damage of the storage tank a free distance from households has to be kept. The amount determined in the regulation is 1000 kg. The storage of over 1000 kg ammonia necessitates that the company/owner has to prepare a risk analysis and an activity plan to minimize the hazard in case of escaped ammonia.
    - 90/2007 government decree (90/2007. (IV. 26.) Korm. rendelet) prescribes the plan for minimizing the risk for the manufacturer of ammonia.
    - 35/2014 NGM decree (35/2014 (XI. 19.) determines the regulation for containers under high pressure in case the contained ammonia is in higher concentration than 35%. This decree regulates the method of checking the container before filling, and the handling in its usage. The decree is limited to the container and includes general rules about containers. No limitation is given to the amount of the filling substances.
    - 28/2004 decree (28/2004 (XII.25.) KvVm rendelet) defines the limitation of the threshold of ammonia concentration in wastewater in 10 mg/l in a 2 hours average sample. For shorter time it can be accepted the 25 mg/l amount.

2. Communication took place with an expert of Fire Department of Sopron on 11th of November 2021. The question was placed, regarding the restrictions in regulation for using ammonia in residential thermal storage systems. He answered that the regulation does not separate the residential and industrial utilization of hazardous materials. He referred in his answer the 219/2011 government decree and said if the amount is less than 1000 kg, then only the normal caution is necessary, but special measures are not needed. Over 1000 kg, it is mandatory to prepare a written methodology about how to minimize the environment damage and defining the provisions to protect human health. In case the amount is less, as happens in Sopron Demo Site, it is not prescribed any manual or activity plan. Especially since the MiniStor block is in free space the risk is minimized.

3. A third step was to have a contact with ÉMI as an authorized organization concerning all building materials (including thermal storage). They informed us that they do not know any law or decree which restricts the usage of ammonia for the purpose of energy storage in Hungary. However, it is used widely in refrigeration systems. Although they participate in the MiniStor project it was mentioned that no case has occurred till now about asking for permit for similar purpose as MiniStor.

In conclusion, the regulation determines the limit of ammonia at 1000 kg, but this limit is relevant just for the needed documentation and the preparation of plans for handling hazardous material. According to

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the information from MiniStor project, the TCM unit will certainly contain less than 80 kg of ammonia, thus it seems sure that the threshold of 1000 kg will not be reached. In this case it is compulsory to take the normal caution. In the unlikely case that MiniStor would contain more than 1000 kg of ammonia, then a special manual had to be prepared with the actions and precautions to minimize the risk in environment and human health.

4.5.2. Installation of MiniStor system

Originally two potential places were considered for MiniStor installation in the very early phase of the project, one in the machinery room very close to the airing machine; the other in the attic very close to the domestic hot water boiler. During the project the consortium decided to place the MiniStor out of the building for safety reasons. Thus, the system will be placed on the southern side of the building and at a distance of at least 5 m (Figure 44). This option was preferred, as the prevailing wind direction in Sopron is north, so the wind will blow from the building towards the MiniStor container. Additionally, the intake pipe of the building ventilation system is on the northern side of the building, preventing the inflow of ammonia in case of a leakage. After the arrival of MiniStor container, the building machinery room will be connected to it with electric and net cables and with pipes for heating and for domestic hot water supply. Ground works will be done also after the arrival of the MiniStor box, however for the sake of fast implementation they are prepared as much as it was possible.

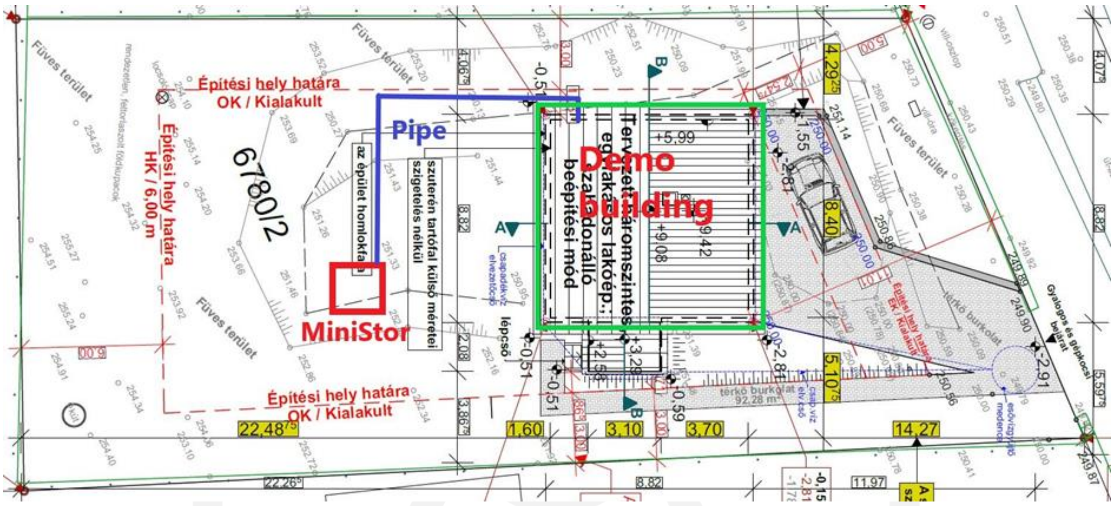

Figure 44: Drawing showing the position of the MiniStor system in Sopron demo site.

MiniStor core system will be installed and fixed into a standard container, which will incorporate the necessary connection plugs to the HVAC, DHW, electrical (including battery and inverter), and internet networks. Connecting piping and wiring will be implemented underground in protecting plastic pipes. For technical reasons the MiniStor system bottom part will be slightly under the ground, about 30-50 cm, with a protecting dig around it for providing the foundation and facilitating the safe hydraulic and electric connection. The piping route will be located next to the building and within the property limits. No official prescription exists which would have restricted these works or would have prescribed any licence obligation.

The MiniStor system will be placed next to the building as a temporary installation, and any part such as its foundation or pipe connections will not be permanent. The MiniStor container height does not exceed the limit of declaration obligation. That is why the installation of MiniStor including the necessary connections does not need any licence.

4.5.3. Installation of solar field

The solar field for feeding MiniStor system includes both PVTs (9 panels with total gross area of 14.49 m^2) and solar thermal collectors (6 collectors with total gross area of 15.06 m^2). They will be installed next to the MiniStor box, on the ground. In this way, the solar field will have the same efficiency as it would have if installed on the roof, but the energy transport heat losses will be significantly lower. PVT panels and supporting structures have already been received on 27 of October 2021.

4.5.4. Connection to current infrastructure

Connection to current infrastructure has two main parts. The first one is the thermal connection which can be completed right after the MiniStor is delivered to the Demo Site. As described in Section 3.5.2, preparations for the domestic hot water system and the heating and cooling system connection to the MiniStor box have been carried out. The heat exchangers are built into the pipeline of the DHW and HVAC systems (Figure 15 and Figure 16) and the connection elements are ready. Necessary pipe works are already prepared and the implementation of remaining connections needs quite short time. The second part is the electric connection to the grid. This work needs a planning process and the permission from the local electricity supply company. This process takes about 3-4 months.

5. Pre-pilot implementation and testing

5.1. MiniStor installation in Thessaloniki pre-pilot

Due to delays in the system manufacture, until the time of compiling this report the MiniStor system has not been installed in Thessaloniki pre-pilot. Reporting upon the relevant installation activities will be provided in a future complete version of the current document.

5.2. Results of testing operation

Due to delays in the system manufacture, until the time of compiling this report the MiniStor system has not been installed in Thessaloniki pre-pilot. Reporting upon the testing and performance of MiniStor prototype will be provided in a future complete version of the current document.

6. Stakeholders training

Initially, stakeholders' training aimed to facilitate learning of the installation process of the MiniStor system. Unfortunately, this was not feasible to accomplish, since the system hasn't been installed yet, thus herein we present the actions taken to train stakeholders on the operation of the monitoring and control IoT platform. This would be achieved through a usage demonstration video that goes through each tab of the platform, exploring the available monitoring and controlling capabilities. This is combined with a questionnaire to effectively assimilate the information to the users. The questionnaire was disseminated to each of the demonstration sites for their teams to complete and the questions can be found in the appendix at the end of this deliverable. Further training on the actual system will take place once the prototype will be installed in Thessaloniki pre-pilot. The plan is to keep track of all activities done, issues faced and organize interactive sessions for the stakeholders to get in touch with the system and train for its use.

The questions aim to familiarize the users with the functionalities and capabilities of the platform. Particularly, to assist them on learning how to operate and navigate through the platform and where they could find the information that they may be looking for. To evaluate the overall learning, we considered the average and minimum scoring achieved by the stakeholders. Given that, it seems that the aim was achieved as most of the stakeholders achieved a score equal or above the average one and the minimum scores are very close to the mean of the maximum score. A summarization of the results can be seen in the following figures (Figure 45 & Figure 46).

It is worth noting that the evaluation scores are not hard scores, meaning that even the lowest scoring stakeholders were successfully introduced to the platform and a certain level of learning and usage comfort of the platform was achieved. Also, to achieve a higher level of understanding, the questionnaire tackles some points that may not be obvious to the beginner level users. This is combined with proper feedback after completing the questionnaire that points out the wrong responses and their correct options.

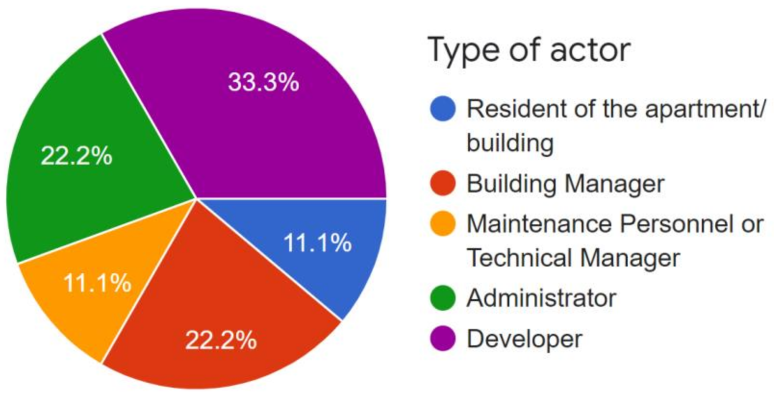

Figure 45: Type of actors that answered the questionnaire

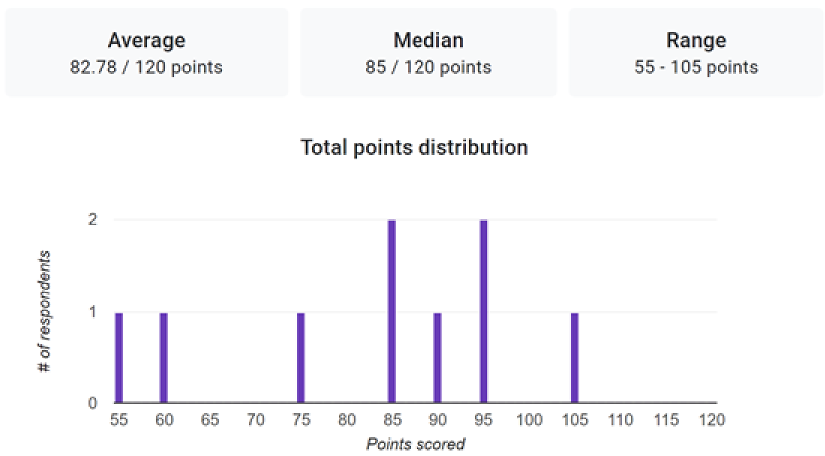

Figure 46: Aggregated results of the questionnaire

7. Conclusions

This first version of Deliverable 6.3 discusses the works implemented in Thessaloniki pre-pilot and in MiniStor demo sites (i.e. Cork, Kimmeria, Sopron and Santiago de Compostela), towards enabling the installation and operation of MiniStor system. The demonstration sites present different characteristics regarding floor area of the building (varying from 49 m^2 in Thessaloniki pre-pilot up to 176 m^2 in Sopron demo site), construction date (ranging from 1980 in the case of Cork demo up to 2019-20 in Sopron demo site) and current HVAC system (VRF units in Thessaloniki pre-pilot, heating and cooling system using ventilation ducts in Sopron demo, independent heating system with boiler and radiators in Cork demo, central heating system in USC demo, local district heating network in Kimmeria demo site). This reality on one hand will enable the evaluation of MiniStor in different building typologies, but on the other hand requires unique measures to be taken in each case in order to realize an appropriate system integration.

A significant part of the preparatory works, regards the acquirement of necessary permissions and licencing from local authorities, public services and / or facility managers and technical services for the installation and operation of the various system components. A thorough search of local legislation and standards is conducted in each case to identify such required permissions and its main findings are presented in the current document. It has been revealed so far, that national regulations mainly impose restrictions to systems with significant ammonia loadings (higher than 1 tonne). Thus, the installation and operation of MiniStor which will contain less than 80 kg of ammonia, does not require any special licencing in most of the demo sites. Regarding the placement of MiniStor, in all cases the provision of EN-378 Standard about a minimum distance of 2 m between ammonia containing machinery rooms (the MiniStor container in this case) and openings of nearby buildings is respected. More specifically, the defined distance between the foreseen locations of container and adjacent buildings ranges from 4.7 m in Thessaloniki pre-pilot up to 17 m in USC demo site. However, apart from the elaboration of drawings, there are no major activities regarding the system installation (i.e. earthworks, construction of necessary hydraulic and electrical connections etc.), as the MiniStor manufacture has not yet started.

Another important part of the preliminary works concerns the installation of the solar field that will supply the renewable energy input to MiniStor. Limited available space on buildings' roof and / or unfavourable orientation and slope, lead to the installation of panels on the ground in all cases. Nevertheless, this solution is not free from problems, since shading caused by nearby buildings or trees makes the selection of an appropriate location a difficult task as described in the case of Thessaloniki pre-pilot. In Cork demo site, the limited open space renders the utilization of special supporting structures necessary in order to install an appropriate number of panels and achieve optimum orientation. Although components of the solar field have already been delivered to the majority of demo sites by the time of this document preparation (i.e. PVT panels and supporting structures), no installation has taken place, as the connection of both thermal (i.e. the MiniStor system) and electrical loads (namely the MiniStor and building consumption) to the solar field is necessary to ensure a proper operation of such equipment and avoid malfunctions or even damages. Thus, the required works for the solar field installation (earthworks, hydraulic and electrical connection etc.) are still under way. This is also valid for Kimmeria, where the existing hybrid Energy Center will deliver the necessary heat to MiniStor.

A third category of preparatory works is related to the system integration with the current HVAC infrastructure of the building and the acquirement of any necessary equipment. Conceptual design and selection of preferred solutions have been completed in all cases, but in the majority of them works have not gone beyond the elaboration of drawings and preparation of tendering documents. In Sopron demo site, integration activities are at an advanced stage, which was facilitated by the coincidence of building erection with the start of project activities. The finalization of MiniStor specifications and the start of system manufacture is necessary in order to implement and finalize the integration activities.

Finally, although there are no results about the system pre-pilot testing operation, a stakeholders' training methodology has been developed. It is based on the preparation of a demonstration video and the distribution of a questionnaire to evaluate the training results. This procedure has been tested in the case of the monitoring and control IoT platform with very encouraging results.

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Annex

This section presents the questionnaire distributed to MiniStor demo sites, to evaluate the demonstration video for the monitoring and control IoT platform.

Demo Site *

Choose

Type of actor *

Choose

MiniStor IoT Platform Tutorial

Watch the video, and fill in the following questionnaire. Tip: Keep the video open through the procedure to help you :)

In which tab can I... * 40 points

Select the most fitting answer for each row

	Microgrid	DR Events	Data Analytics	Control Panel	Not possible through the platform
see what is the SoC of my battery?	○	○	○	○	○
see when the next DR Event will occur?	○	○	○	○	○
control the HVAC of a specific room?	○	○	○	○	○
see the current outdoor conditions?	○	○	○	○	○
check the weather forecast?	○	○	○	○	○
enable or disable the DR Events?	○	○	○	○	○
change the temperature of a specific room?	○	○	○	○	○
create temperature schedules that control the heating system?	○	○	○	○	○

In the "Data Analytics" tab, someone can see... * 15 points

Select all that apply

- [ ] real-time values of essential system parameters.
- [ ] historical values from previous days of essential system parameters.
- [ ] predictions of essential system parameters.

In the "Microgrid" tab, someone can see... * 15 points

Select all that apply

- [ ] predictions of essential system parameters.
- [ ] current values of essential system parameters.
- [ ] historical values from previous days of essential system parameters.

In the "DR Events" tabs, someone can see... * 15 points

Select all that apply

- [ ] the completed DR Events.
- [ ] the currently active DR Events.
- [ ] the upcoming DR Events.

The platform only allows the monitoring of essential system parameters. * 5 points

- ○ True
- ○ False

The "Energy Flow" widget in the "Microgrid" tab shows... * 15 points

Select all that apply

- [ ] the current flow and the daily imported Gas?
- [ ] today's thermal and hot water flow?
- [ ] if the system is importing/exporting from the Grid?

What is the functionality of the "Auto" button in the "Control Panel" tab? * 5 points

- ○ Control the temperature based only on the set temperature range.
- ○ Simplify the user interface to allow for a more intuitive and precise manual control over the temperature of my home system.
- ○ Control the temperature taking into consideration the set temperature range and other system parameters.

Where could I see the "Electrical Energy Consumption"? * 5 points

- ◯ This information does not exist in the platform
- ◯ In the "Current Household Conditions" widget in the Microgrid tab
- ◯ In the "DR Events" tab

What is the purpose of temperature schedules? * 5 points

- ◯ Control the heating system depending on the set temperatures
- ◯ Control the temperature, but only when I am at home.
- ◯ Get notified about the current temperature