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Collaborative Project

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1 EXECUTIVE SUMMARY

1.1 Description of the deliverable content and purpose

This document provides a description of the installations at the three HYBUILD demonstration sites. It includes a short description of each system and the context of installation. It provides details on the commissioning actions carried out to reach results aligned with the objectives of the project, in order to provide reliable monitoring post-intervention data. Pictures of the installation are also provided to illustrate the description of the action.

The experience described in this deliverable shows the different steps needed to obtain quality demonstration results, in order to demonstrate the performance of the technology developed in HYBUILD. Moreover, it provides useful feedbacks for potential future demonstration initiatives for hybrid energy production systems in real environment, as described in the Conclusions section.

1.2 Relation with other activities in the project

The knowledge developed in task 6.2 constitutes the basis of the information available about the demonstrator buildings, especially all the data gathered during the pre-intervention monitoring period.

When deploying HYBUILD technologies at the demo sites, several commissioning tasks are developed to ensure a high level of performance. They are documented in this deliverable.

1.3 Acronyms and Abbreviations

DHW	Domestic Hot Water
GA	Grant Agreement
HDD	Heating Degree Days
IPMVP	International Performance Measurement and Verification Protocol
KPIs	Key Performance Indicators
MAE	Mean Average Error
M&V	Measurements and Verification
RH	Relative Humidity
ROI	Return on Investment
T	Temperature
DL	Data Logger
ACS	Adaptive Comfort Standard

2 General overview of the demonstration progress

The 3 demo sites in HYBUILD have been designed according to two different hybrid energy production and storage concepts:

- The Mediterranean concept, for the demo sites in Almatret and Aglantzia (Figure 1).
- The continental concept, for the demo site in Langenwang (Figure 2).

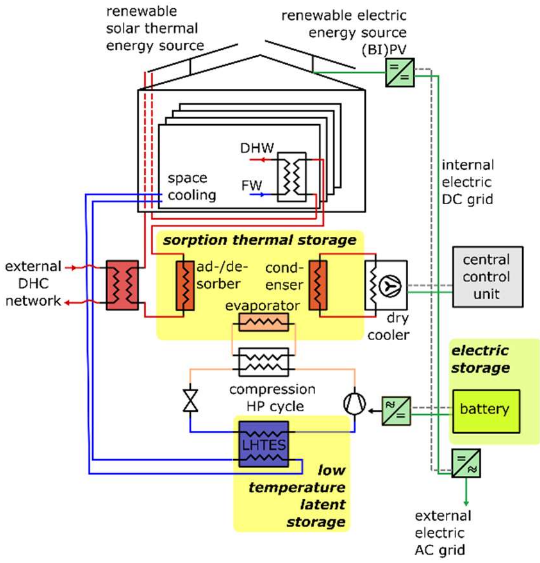


Figure 1. HYBUILD Mediterranean concept

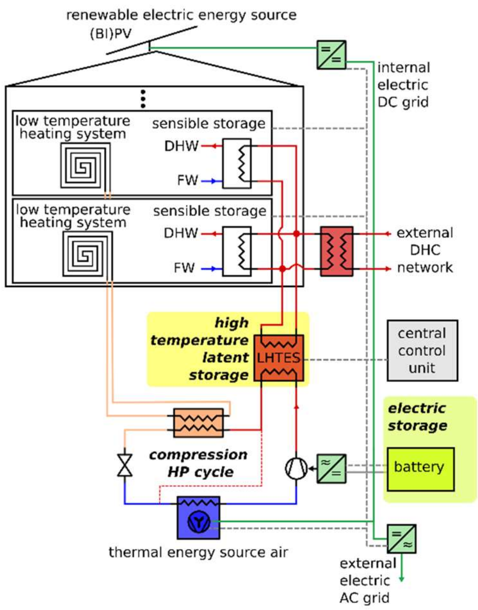


Figure 2. HYBUILD continental concept

- Almatret, Spain

Figure 3. Almatret demo site building

- **Climate:** Mediterranean
- **Site description**: Residential house in Almatret
- **Date of construction**: 1970
- **Current use of the building**: Residential
- **Area**: 107 m^2

At the Almatret demo site, the Mediterranean system is installed and tested. The system contains Fresnel solar collectors to capture the solar thermal energy, photovoltaic (PV) panels to produce electricity from solar radiation, a low temperature storage tank with phase change material (PCM) in thermal contact with the evaporator of the compression system (heat pump), and a sorption thermal storage system thermally connected with the solar thermal collectors and with the condenser of the compression system.

The installation and commissioning have been carried out during summer 2021.

- Aglantzia, Cyprus

Figure 4. Aglantzia demo site building

- **Climate:** Mediterranean – subtropical
- **Site description**: Kiriacou Karaoli Square (Aglantzia)
- **Date of construction**: 2005
- **Current use of the building**: Multifunctional center
- **Area**: 140 m^2

The Aglantzia case study is a listed building located in the city centre square. This pilot aims at converting the current building as a cornerstone of social interaction and creative activities. The building will become a benchmark for a permanent digital exhibition of renewable energy technologies and supportive equipment to serve as a space for informing the society about the use of smart technologies in our homes capable of offering the transition to a low carbon economy and high levels of energy savings. The hybrid compact storage system for Mediterranean climate is installed at this pilot site.

The installation and commissioning have been carried out during summer 2021.

- Langenwang, Austria

Figure 5. Langenwang demo site building

- **Climate:** Continental
- **Site description**: Office section of the Pink main building in Langenwang
- **Date of construction**: 1960s
- **Current use of the building**: Office with social room and toilets
- **Area**: 180 m^2

HYBUILD Austrian pilot site had a retrofit realized in 2020 to improve the comfort and to decrease the energy consumption. The office is split into four areas: single offices, plan office, meeting room and social room. The hybrid compact storage system for continental climate will be installed at this pilot site. The maximum heating power consumption expected after the foreseen retrofitting operations is 10 kW. The following technologies have been applied in the building: PV, PCM thermal latent storage, and heat pump.

The installation and commissioning occurred during late 2020. Fine tuning of the installation was carried out during the first semester of 2021, leading to a fully operative demo by summer 2021.

3 Installation and commissioning of demo-system: Mediterranean concept in Almatret (Spain)

This section provides a brief and illustrated report on the installation and commissioning works related to the demo of the Mediterranean system installed in Almatret, Spain.

3.1 Description of the installation works

Although the core part of the system installed at the Almatret demo site is identical with the general layout of the Mediterranean system, the actual system includes some particularities that resulted from the adaptation of the system to the local conditions. Specifically, since the building in Almatret to which the system was connected is the house where the doctor lives with his family, it was considered necessary to maintain the current gas-boiler as a back-up to assure uninterrupted supply of both DHW and heating during the period corresponding to the system installation and commissioning. For the same reason, the current heating system based on hot water radiators connected to the gas-boiler was also maintained to provide heating in winter, instead of installing an additional heating system connected to the HYBUILD heat pump. Therefore, the current heating system was connected to the buffer tank of the HYBUILD system through a heat exchanger, to reduce the gas consumption for heating by exploiting the heat produced by the Fresnel solar collectors. The detailed P&ID diagram of the Mediterranean system adaptation to Almatret demo is shown in Figure 6.

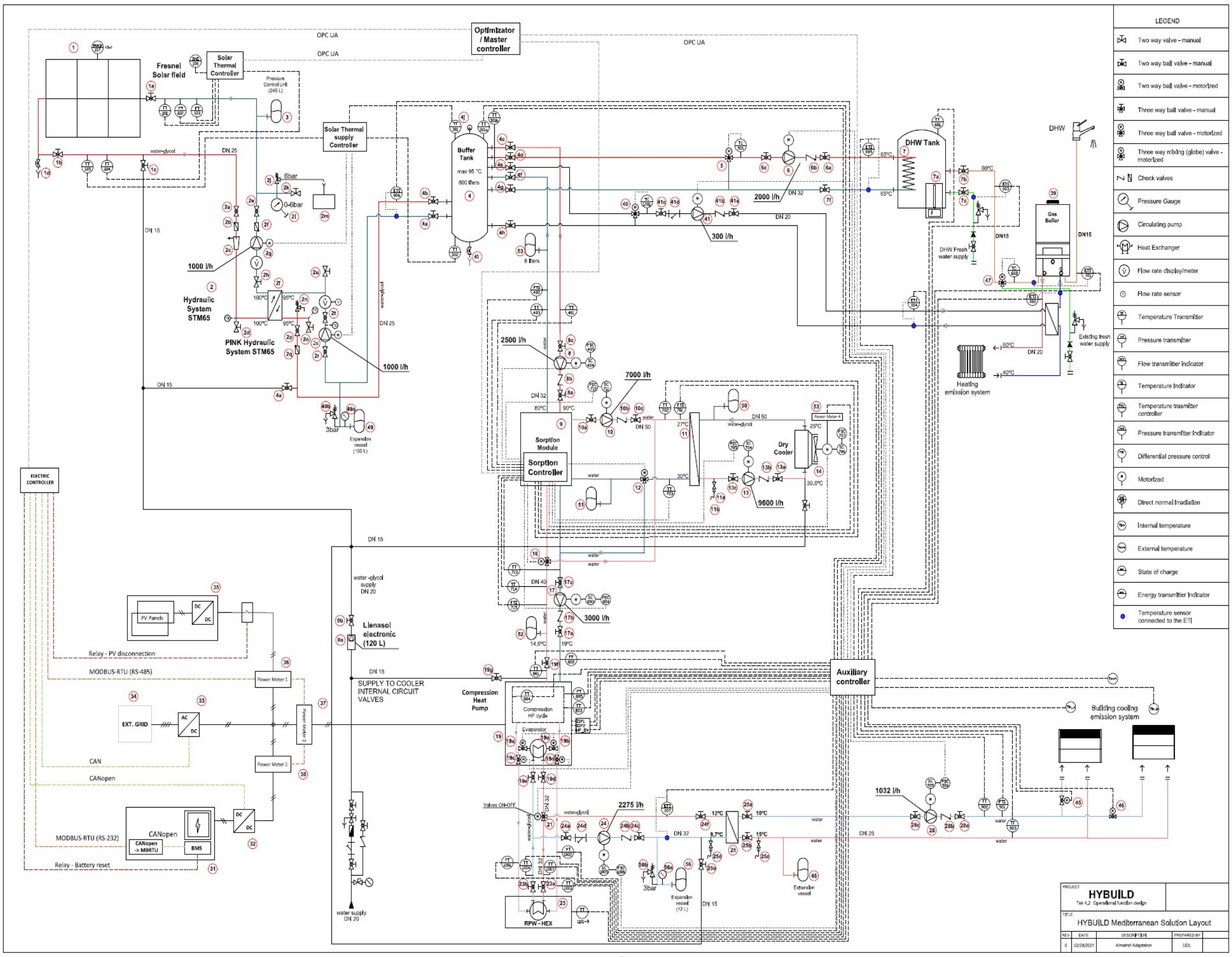
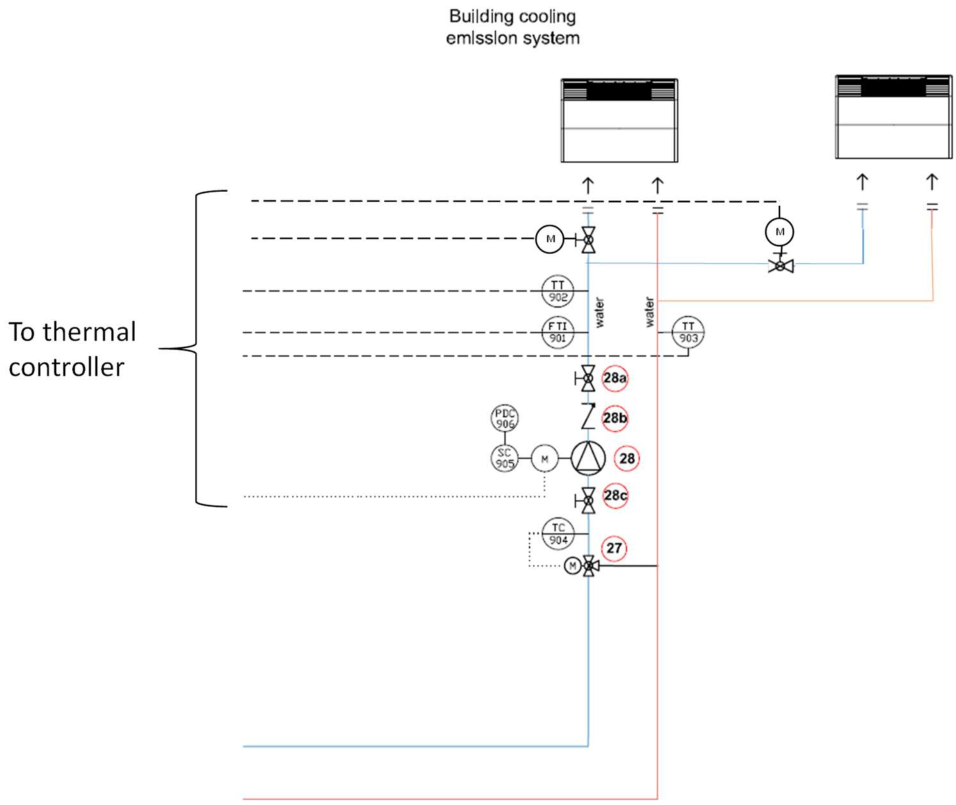


Figure 6. P&ID of the system installed at the Almatret demo site

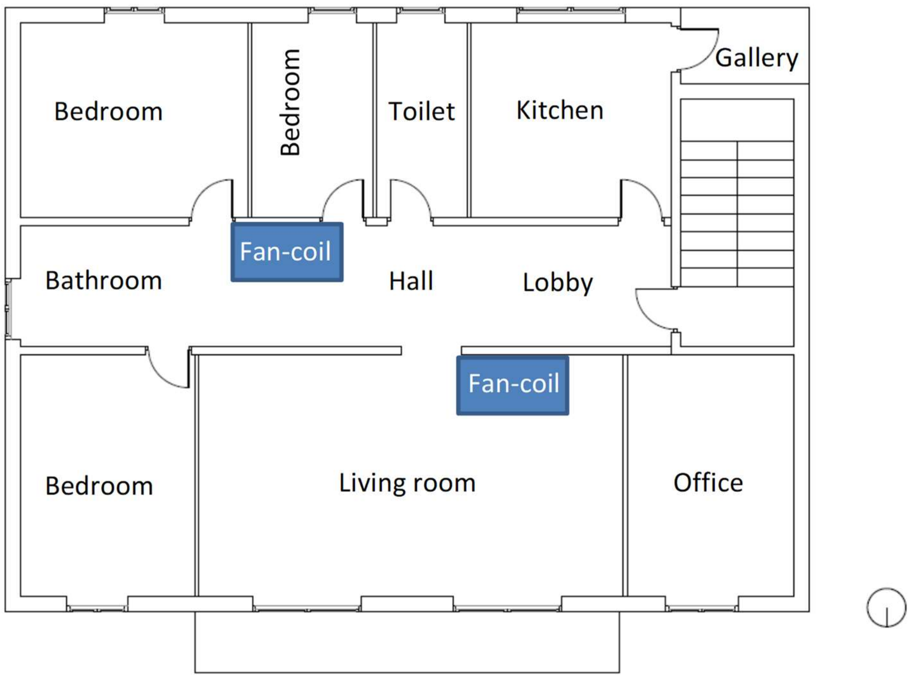
Installation works actually started well before the commissioning of the system. First of all, the municipality of Almatret built the HYBUILD equipment room, partially funded by HYBUILD and partially from their own funding. Since the building didn't have any cooling system installed prior to HYBUILD system installation, a cooling system using fan-coils was designed and installed during the first half of 2020. The cost of this installation was entirely covered by Almatret municipality from own funding. A schematic of the cooling system is shown in Figure 7.

Moreover, the Fresnel solar collectors, provided by the former project partner Fresnex, were shipped to Almatret and placed in the intended location in September 2019. A total of 6 modules were provided, with a total surface area of mirrors of 60 m^2 and with a receiver placed at the middle of the mirrors in the north-south direction.

A schematic view of the on-site location of the different equipment and components related to the Almatret demo installation and commissioning is shown in Figure 8. As seen in the figure, HYBUILD demo is located very close to the demo of another H2020 project, Innova MicroSolar (grant agreement N° 723596), which also have a field of Fresnel solar collectors that was already installed on-site when HYBUILD project started. This fact put some constraints on the location of the location of different components of the HYBUILD system, such as the Fresnel collectors, PV panels, and dry cooler.



(a)



(b)

Figure 7. Details on the cooling system: (a) schematic of the fan-coils connection and (b) location of the fan-coils

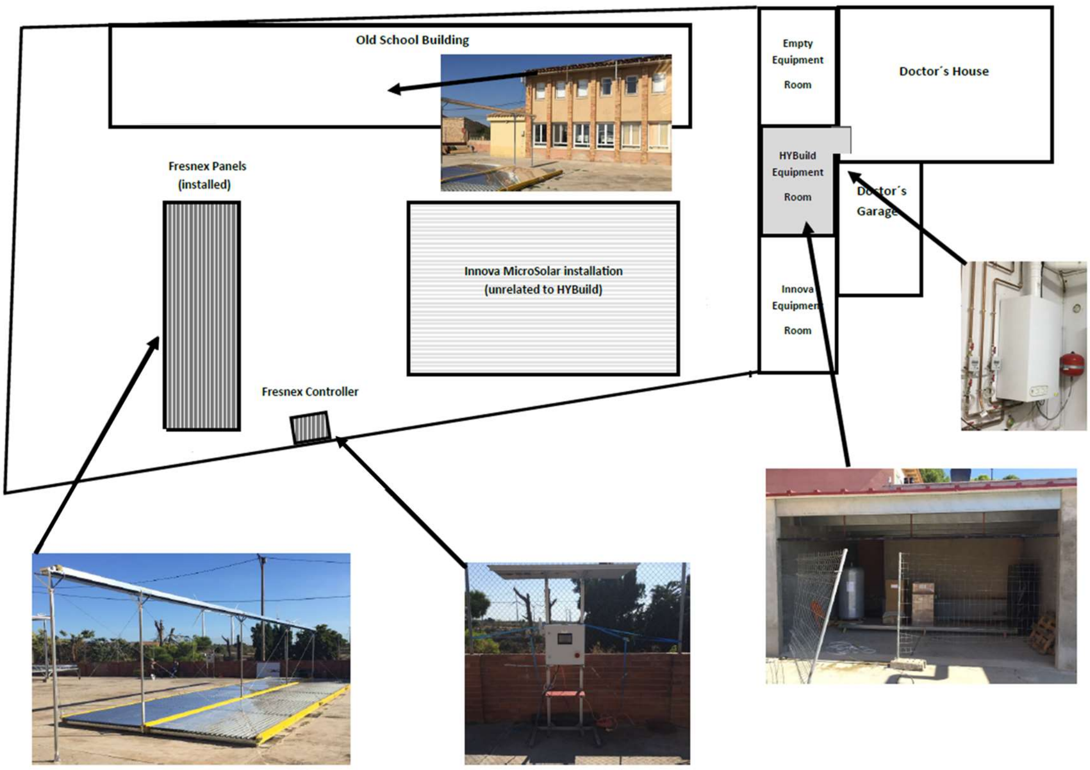


Figure 8. On-site location of the different equipment and components in Almatret

Other equipment that was also shipped to Almatret in September 2019 were the following system components provided by PINK: buffer tank (VarioStar - Vario 800), DHW tank (HDSW160), solar pump station (STM65) for the solar thermal field, pumping station (Grundfos ALPHA1 25-40 180) for the connection between the buffer tank and the DHW tank, two hydraulic pressure units (MADG250), and several auxiliary components such as temperature sensors and insulation material.

The core part of the system, consisting of the Daikin heat pump connected to the latent energy storage tank, the sorption chiller, and the electric rack, was shipped by ITAE-CNR at the end of April 2021 after a complete and successful testing in their laboratory. The dry cooler was shipped by Fahrenheit and arrived to Almatret in June 2021. The size and weight of the dry cooler, combined with the space limitations mentioned above, led to the decision to locate it in a room next to the HYBUILD equipment room. For that, additional work was necessary to improve the conditions of the floor of the room to make it suitable for hosting the dry cooler.

After most of the key system components were already at the demo site, UDL contacted the installer company to start the installation and to make all hydraulic and electrical connections between components. Several meetings were held in April and May 2021 between UDL and the installer company to provide them all the information regarding the system components and to make a full inventory of all material and components of the system. Likewise, the details related to the operating conditions of the system were discussed as well as the schedule for the installation and commissioning of the system.

The installation of the system started with the placement of all the components in their location in the HYBUILD equipment room, according to the schematic shown in Figure 9, prepared by COMSA along with other 3D schematics. At the same time, the order of all the necessary material for the hydraulic and electrical connections was made.

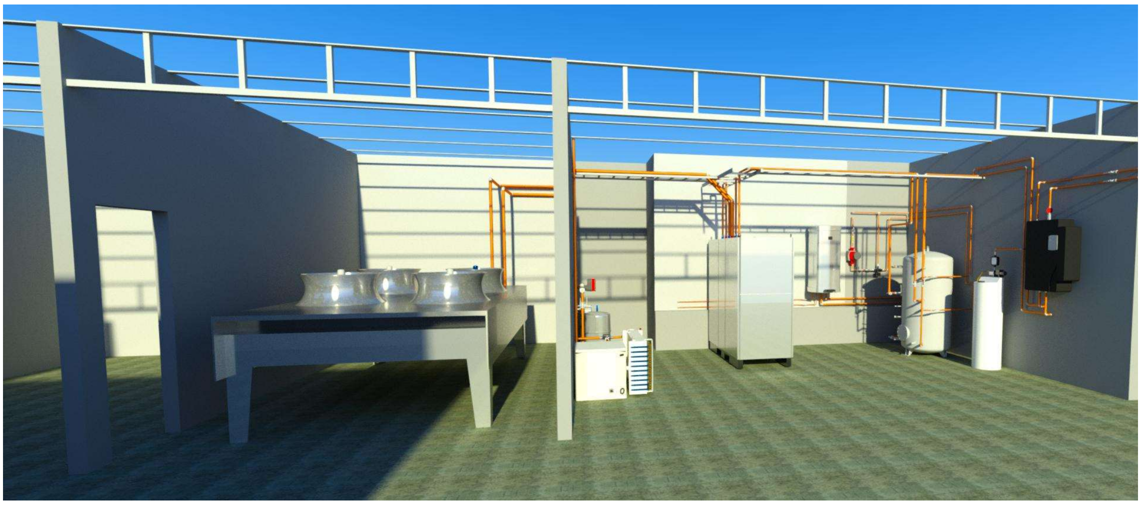


Figure 9. Drawing of the location of the different components in the HYUILD equipment room in Almatret

After all components were placed in their location, the following hydraulic connections between the main system components were realized:

- The solar pump station and the solar field of Fresnel collectors.
- The buffer tank and the sorption chiller, the DHW tank, the solar pump station, and the building heating system.
- The heat pump + latent storage and the building cooling system and the sorption chiller.
- The sorption chiller and the dry cooler.
- The DHW tank and the gas boiler.
- The filling unit and all hydraulic circuits.

Moreover, a dedicated connection between the HYBUILD system with the tap water was done to provide fresh water to the filling unit, as well as to an emergency shower that was also installed near the equipment room for safety reasons.

Since the HYBUILD equipment room is in direct contact with the outdoor air, a mixture of water and glycol was filled in the hydraulic circuits to avoid freezing of the water inside the pipes during the cold periods in winter, when the outdoor temperature can drop down to -5 ºC or even less. The circuits connected with the sorption chiller were also filled with a corrosion inhibitor material to protect the heat exchangers from corrosion. When all hydraulic connections were completed and it was checked that there is no leakage in the system, the pipes were insulated to avoid thermal losses to the ambient.

From the electric connection point of view, several electric connections of the components were also realized. A new PV system was installed by the local company Solenver, whose cost was paid by the Almatret municipality with own funding. The PV system consists of 12 panels of monocrystalline Jinko Solar Cheetah type having a power of 410 Wp each panel. The panels were connected in two strings and connected to the string optimizer Ampt String Optimizer V600 Series. Moreover, electric connections between the electric rack, the string optimizer, the heat pump, and the power grid were performed.

Different electric panels were installed, for individual components or subsystems, and also one for the main distribution circuit and one corresponding to the main protection circuit. A lighting system was also installed in the equipment room.

Furthermore, several devices that will be used for system monitoring and control were also installed. For the monitoring of the system, five thermal energy meters, three power meters, temperature sensors to measure the temperature in the different parts of the system as well as the indoor and ambient temperature, one flow meter in the primary circuit of the solar field, pressure sensors, and one pyranometer were installed. Most of these sensors were provided by UDL from own funding.

The above-mentioned components, along with the sensors and auxiliary elements such as motorized valves, pumps, temperature and pressure sensors, etc. already installed in the different components, were also used for control purposes of the thermal part of the system. Therefore, these components were connected to the auxiliary PLC built and programmed by UDL, and installed in the control room next to the main distribution circuit panel.

3.2 Commissioning process of the demo-system

The installer company that won the tender launched by UDL performed most of the hydraulic and electric connections of the system. According to their estimations, it would take around six weeks to complete the installation of the system. Since the installation started on 20 May 2021, the initial date for the commissioning of the system was the week of July 5.

Therefore, relevant partners for the commissioning were informed and invited to travel to Almatret to assist in the commissioning of the system. Those partners that couldn't participate on-site, were asked to be full-time available online in case their support was needed. However, due to delays in the installation because of material shortage, the commissioning had to be delayed and rescheduled for 23 July 2021.

Other than the installer company, the following HYBUILD partners were present in Almatret for the commissioning: UDL, ALM, ITAE-CNR, FAHR, ENG, COMSA. Other partners such as NTUA, CSEM, PINK, and AKG confirmed their availability online, either in July or September 2021. Moreover, the installer who did the installation of the fan-coil system inside the house also participated to finalise the connections with the HYBUILD system and to fill the hydraulic circuit. Although Fresnex was not a project partner at the time of the installation and commissioning, Antoni Castells, who worked at Fresnex during the time when they were a project partner, also provided support on-site several times.

During the installation and commissioning of the system, UDL provided the required support to the installer and acted as the link between project partners and the installer company. Moreover, UDL supervised the correct connections of the components with the auxiliary PLC and checked that the low-level control worked properly. ALM assisted in providing logistical support and did a great effort to respond to any need of the installer company or any other project partner. Due to the fact that ITAE-CNR were very familiarized with the core part of the system that was tested in their laboratory, their presence in Almatret was very helpful in providing support to the commissioning of the heat pump and sorption chiller, as well as to solve possible issues related to these components. The presence of one representative from FAHR on 22 and 23 July helped in completing the electric connections between the dry cooler and the sorption chiller, as well as to fill the corrosion inhibitor in the hydraulic circuits connected with the sorption chiller. From the control point of view, ENG provided the computer that contained the Master controller and helped in the realization of communication between the high-level and the low-level control. COMSA was present in Almatret on 23 July to supervise the installation and to check the current status and issues encountered before the commissioning. Antoni Castells went to Almatret to check that the main components of the solar collectors were still working after almost two years in Almatret without being used.

Prior to the commissioning, the key components and actions required for the different subsystems or components were checked. For that, a check-list was prepared by UDL as shown in Table 1.

Table 1. Check-list for supervision of the installation in Almatret

Component or item	No.	Description	Responsible partner	Current state				Depends on	Comments
				Date 1	Date 2	Date 3	Date 4		
1	1.1								
	…								
	1.n								
2	2.1								
	…								
	2.x								
⋮									
n	n.1								
	…								
	n.x								

For the solar field of Fresnel collectors, the correct installation of the sensors and connections to the controller was checked, as well as the installation of a safety valve of 1.5 bar needed for safety reasons. A test was done in June 2021 to check engines performance, which were operating satisfactorily. During July 2021, the mirrors were cleaned, and another test was done to check whether the controller was able to automatically concentrate the solar radiation on the receiver.

For the solar pump station, the correct connection operation was checked to confirm that the pumps work properly and that there is no air in the system. The correct reading of all temperature sensors connected to the controller of the pump station was also checked.

For the buffer tank, the correct installation of all temperature sensors and insulation material was checked, as well as all valves and other sensors in the connections with the other equipment.

For the DHW, the correct installation of sensors, as well as the correct control of the circulation pumps, mixing valve, and gas boiler from the auxiliary PLC was checked.

For the heating system, the correct operation of the circulation pumps and of the gas boiler in the heating mode was checked. The control of the pumps and building thermostat from the auxiliary PLC was checked.

For the sorption module, the correct installation of auxiliary components such as vent valves and of the ethernet cable for the connection with the Master controller was checked. The vacuum in the adsorber circuit was also checked. Moreover, the hydraulic and electric connection of the dry cooler with the sorption module was checked, as well as the installation of the expansion vessel in that circuit.

For the heat pump, an additional amount of refrigerant was filled in the system to reach the correct charge level. The correct connection of all sensors and auxiliary equipment installed in the heat pump and the latent storage with the auxiliary PLC was checked.

For the cooling system connected with the heat pump, the correct operation of the circulation pumps and of the fan-coils was checked, as well as the correct control of this subsystem from the auxiliary PLC.

For the electric rack, a firmware update was necessary, which was done according to indications received from CSEM.

The Master controller was installed in the control room and connected with the system through a local network.

3.3 Installation issues / adjustments

This section presents the different problems that were encountered during the installation and commissioning of the system and how they were tackled.

The first problem that affected the entire installation and led to a long delay in the installation of the system was the shortage of material necessary for the installation, as an indirect consequence of the COVID-19 crisis. While some materials such as expansion vessels, pipes, or insulation could be purchased on time, other materials or equipment such as pumps, heat exchangers, filling unit, or electric wires were much more difficult to get than expected.

The second problem that arose before system commissioning was a leakage found in the Fresnel solar collectors after the primary circuit was filled with water and pressurized, and the receiver was heated up to the maximum operating temperature. The leakage occurred at one of the junctions between two modules of the central receiver, and especially when the temperature of the receiver was variating. Antoni Castells (former Fresnex partner) was contacted several times to determine the possible cause of and solution for the leakage in the solar field. Initially, the original gaskets were replaced by new ones provided by Antoni Castells, but the problem was not solved. After that, the original nuts were replaced by self-locking nuts and the problem with that junction was solved. In spite of it, other leakages occurred in two other junctions, so that the original nuts were replaced by self-locking nuts in all the junctions, and the leakage problem seemed to be solved.

Also related to the solar field, some issues were encountered with the controller of this component. Specifically, the controller of the solar field was not able to prevent the temperature of the water inside the receiver from exceeding the boiling point. Likewise, the controller was not able to make the mirrors correctly concentrate solar radiation on the receiver. Therefore, the required changes were implemented in the controller of the solar field with the on-site support of Antoni Castells and remotely by an Austrian control company linked to the current company of Antoni Castells (Ecotherm).

Another issue faced during the commissioning was the fact that the electric system was not working properly, which made it impossible to test the correct operation of the heat pump and sorption system. Despite the presence on-site of one representative from ITAE-CNR, who was familiar with the electric rack that had already been used for testing of the system in their laboratory prior to the shipment to Almatret, it was not possible to realize the full system commissioning at the planned date.

After consulting it with CSEM, different possible explanation for the incorrect operation of the electric system were explored. In a first step, CSEM solved the issue with the remote connection to the PLC of the DC bus. After that, it was detected that the string optimizer didn’t reach the voltage required by the DC bus and a reverse current was even observed. Following CSEM suggestion, the connection between the PV system and the string optimizer was double-checked, and it was found that the type of connectors used was not the one specified by the manufacturer. Moreover, the required blocking diode needed to prevent reverse current was not installed. Therefore, the connectors were replaced with the correct ones and the blocking diode was installed at the correct location.

During the presence in Almatret of the technician from FAHR, he realized that the location of the sorption chiller was not correct because there was not enough space between the back part of the sorption chiller and the wall next to which it was located. Therefore, since all hydraulic connections were already completed, the installer company was contacted again to move the sorption chiller 1 m away from the wall.

After the calibration of the flow meter in the primary circuit of the solar field, it could be noticed that the value of the flow rate in that circuit was far below the expected value. A value of the flow rate much lower than the nominal one makes it difficult or even impossible to properly charge the buffer tank. UDL and PINK worked then together during several weeks to solve the problem.

3.4 Pictures and schemes

Figure 10. Outdoor system components in Almatret: solar thermal (top picture) and PV collectors (down-right), and details on hydraulic connection with the solar thermal collectors (down-left)

Figure 11. HYBUILD equipment room in Almatret: solar pumping station (top-left), buffer tank (top-right), DHW tank (bottom-left), and sorption chiller (bottom-right)

Figure 12. Equipment and control room in Almatret: heat pump hydraulic connections (top picture), control room (bottom-left), and PLC components (bottom-right)

Figure 13. Connections to the gas boiler (left) and emergency shower (right) installed in Almatret

4 Installation and commissioning of demo-system: Mediterranean concept in Aglantzia (Cyprus)

4.1 Description of the installation works

The case study is a listed building located in the city center square of Aglantzia. This pilot aims at converting the current building as a destination that will be a cornerstone of social interaction and creative activities.

The building will become a benchmark for a permanent digital exhibition of renewable energy technologies and supportive equipment to serve as a space for informing the society about the use of smart technologies in our homes capable of offering the transition to a low carbon economy and high levels of energy savings.

In this context, the proposal aims at creating a multifunctional space which, apart from the promotion of smart technologies, will have the possibility of hosting events, seminars, artistic performances, etc. and at the same time it will function as a reading hall with a digital library for young citizens and students.

The area of building including external walls is 141 m^2 and excluding external walls is 114 m^2.

For the energy performance classification of the selected building, an Energy Performance Certificate (EPC) has been carried out, in alignment with the 2002/91/EC European Union Directive. Additionally, an Energy Efficiency Study, which includes more details in terms of use, systems and construction characteristics, has been performed to collect more accurate results in order to facilitate the sizing of the new system.

The building is connected to the distribution grid of the Electricity Authority of Cyprus. The electrical installation of the building has been upgraded from single phase (230 V) to three phase system (400 V line - line).

A photovoltaic system with 5 kWp capacity (16 panel of 310 Wp each) has been installed and connected to the DC bus of the electric rack provided by CSEM. The cost for the purchase and the installation of the photovoltaic system was covered by the Municipality.

In addition, a battery energy storage unit is connected to the DC bus through a DC/DC bidirectional charge controller, and a bidirectional DC/AC converter has been installed for the connection with the main distribution grid. Furthermore, the DC driven heat pump is connected directly to the DC busbar and provides heating and cooling to cover the building thermal energy demand. The AC loads will be supplied from the AC side of the DC/AC inverter.

There is no district heating system in the area. The domestic hot water is provided from the electric water heater. A 1.5 kW AC electric water heater is already installed in the building in order to cover the needs for domestic hot water.

Hereafter, a brief description of the installation and commissioning works is provided related to the demo site of Aglantzia, Cyprus.

Although in the case of the Cyprus demo site the Mediterranean system was installed as in the case of Almatret, the system of Aglantzia presents several modifications to cover the needs of the building always in accordance with local laws and regulations.

More specifically, the Aglantzia system does not include solar thermal, unlike the Almatret system. The building of Aglantzia due to its use as a multifunctional and exhibition center, does not have high demands on domestic hot water, so the system was adapted according to the real needs of the building.

The existing cooling-heating system of the building was replaced with a new system with fan coil units, which were connected to the heat pump and the dry cooler and to the rest of the system components to provide cooling-heating to the building. The detailed P&ID diagram of the Mediterranean system adaptation to Aglantzia demo is shown in Figure 14.

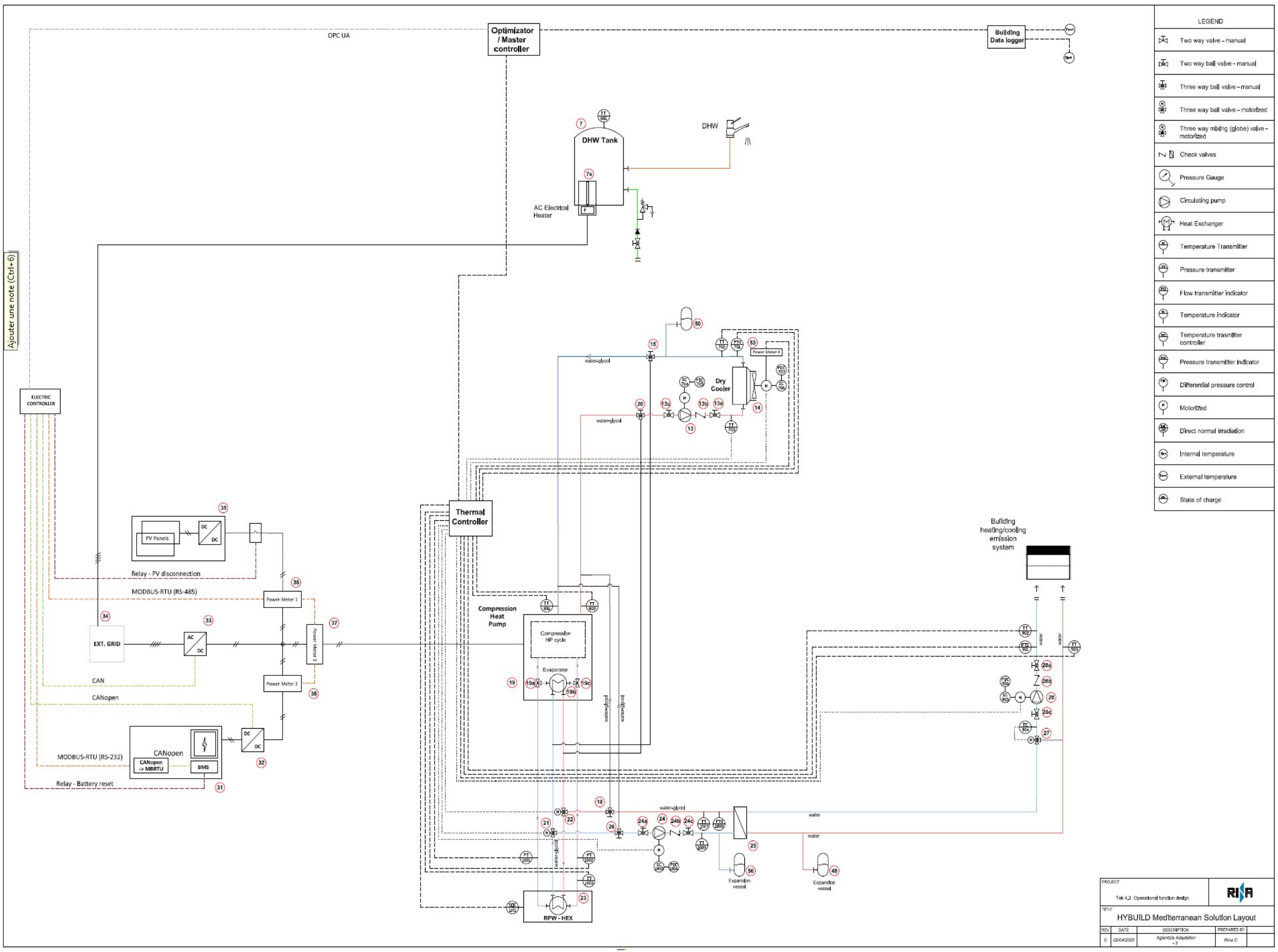


Figure 14: P&ID diagram for the HYBUILD system of Aglantzia demo site.

Initially, the building was renovated by increasing the insulation of the roof (i.e. 12 cm of extruded polystyrene) to save energy by reducing losses. The cost for the purchase and the installation of the roof insulation was covered by the Municipality. In addition, some interior renovations were made to better serve the public that will use the building. Figure 15 and Figure 16 show an overview of the renovation process.

Figure 15: Photo from the installation of roof insulation

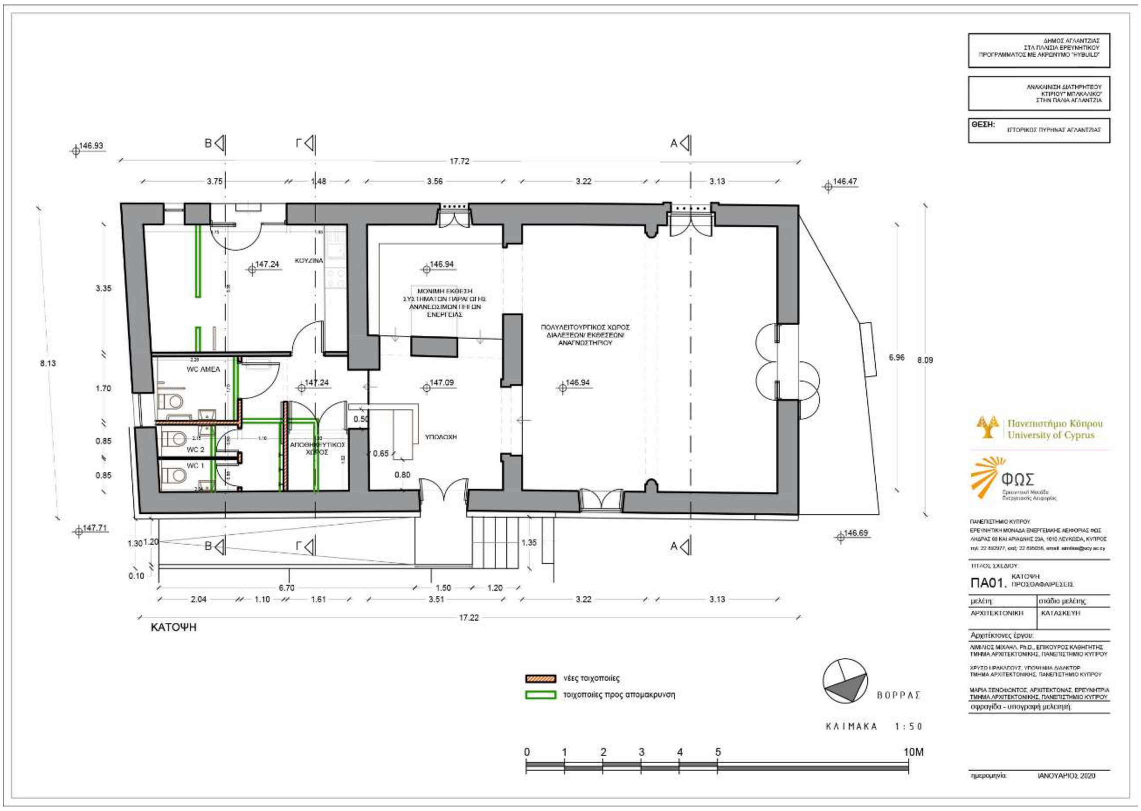
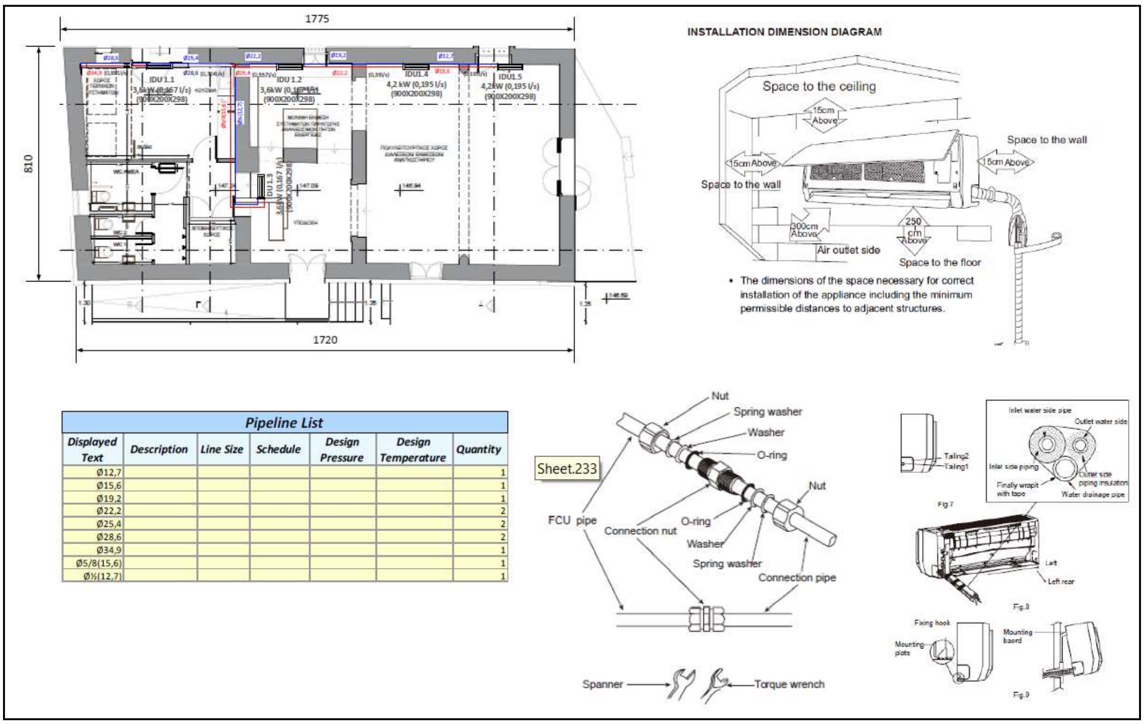


Figure 16: Layout plan of the building with the interior renovations.

The electrical installation of the building was then modified according to the requirements of the project and the electrical distribution system of the building was upgraded from single phase to three phases.

Then we proceeded to the study and installation of the photovoltaic system on the roof. Initially, the installed capacity of the photovoltaic was 3 kWp but then another 2 kW were added to the already installed system increasing the installed power capacity of the system to 5 kWp to meet the requirements of the DC/DC string optimizer. The 16 photovoltaic panels are connected in 2 strings of 8 panels each. The two strings end in the AMPT string optimizer where they become one which ends in the DC bus of the electric rack.

At the same time, the Municipality of Aglantzia announced a tender to select the companies that would proceed with the installation of HYBUILD systems (electrical and mechanical installation). After receiving the various systems from the technology providers, the companies that won the tender were invited to proceed with the installation of the components. Figure 17 and Figure 18 show the floor plan of the building with the placement of the various machines and some details of the installation components and pipelines.



Pipeline List						
Displayed Text	Description	Line Size	Schedule	Design Pressure	Design Temperature	Quantity
Ø12,7						1
Ø15,6						1
Ø19,2						1
Ø22,2						2
Ø25,4						2
Ø28,6						2
Ø34,9						1
Ø5/8(15,6)						1
Ø½(12,7)						1

Figure 17: Plan of the building with heating / cooling distribution system.

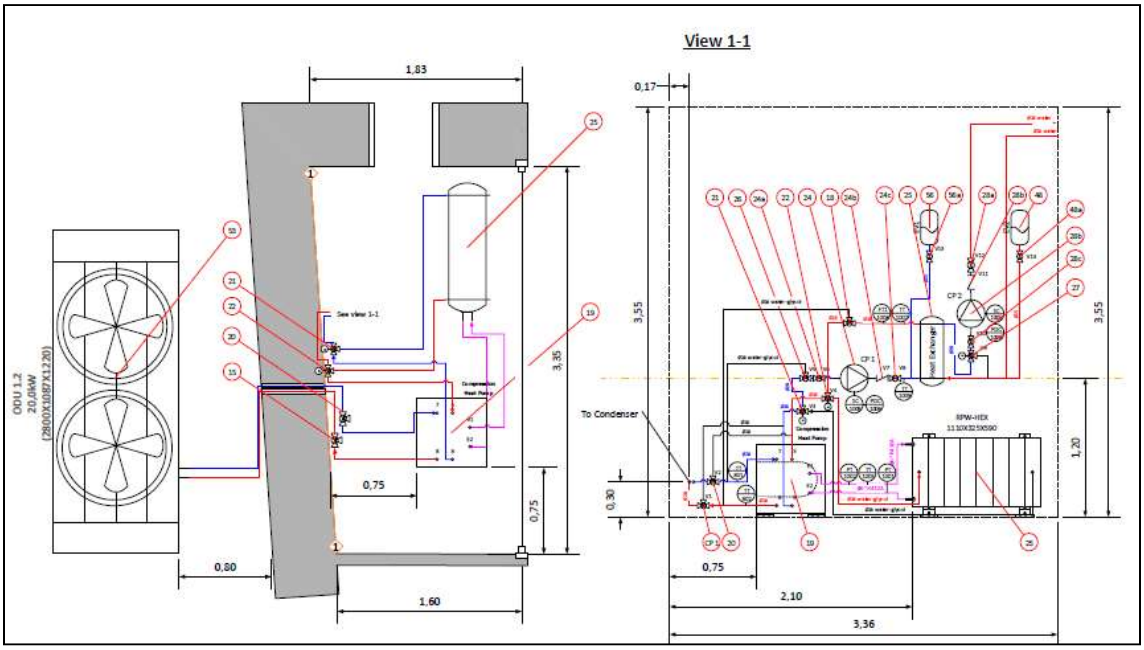


Figure 18. Plan of the mechanical room where indoor and outdoor components are placed

In the meantime, the companies that won the tender proceeded to order all the necessary equipment for the interconnection of the systems.

Separate electrical panels were installed to power the systems. A central panel for the distribution of electricity in the building was installed, followed by a separate panel for the supply of mechanical systems and a separate panel for the PLC.

Several devices that will be used for system monitoring and control were also installed. For the monitoring of the system, power meters, temperature sensors to measure the temperature in the different parts of the system, pressure transmitters, flow meters, as well as a complete weather station including indoor and outdoor temperature sensors, wind velocity and direction sensor, and rain gauge were installed. Most of these sensors were provided by UCY.

The above-mentioned components, along with the sensors and auxiliary elements such as motorized valves, pumps, temperature and pressure sensors, etc. already installed in the different components, were also used for control purposes of the thermal part of the system. Therefore, these components were connected to the auxiliary PLC built and programmed by UCY, and installed in the control room next to the mechanical panel.

4.2 Commissioning process of the demo-system

Before the commissioning of the system, all the connections between the different components of the system were performed by the electrical and mechanical installers. According to the terms of the tender, the installation companies that won the tender had 2 months to complete the installation from the day of receipt of all the components. Despite the long delay that occurred in the shipment of the HYBUILD systems, the installation companies behaved with impeccable professionalism and completed the installation in a very short time. The coordination and the supervision of the installation of the system of HYBUILD was carried out by the Municipality of Aglantzia with the technical support of the design consultants of the Municipality and the cooperation of the UCY.

The University of Cyprus, throughout the design and installation of the systems, coordinated the work for the proper installation of the system and was the connecting link between the installers and the partners of the project.

Before the final commissioning of the system, all the components installed on the site, were checked for the correct installation and the right connection with the system. More particularly, the following checks were performed prior to the commissioning:

- **Photovoltaic system:** The correct installation of the 16 PV modules connected in two strings with 8 PV modules per string was checked, and the open circuit voltage of each string was measured to be sure that there weren´t any unexpected losses.
- **Heat Pump:** The correct installation of the heat pump was and the communication with other devices was checked. The pipes and the components between the heat pump and the Dry Cooler were also checked for any leakages, and the appropriate amount of water – glycol added to the circuit, according to the instructions from Fahrenheit.
- **Electric rack:** The right connection of the electric rack with the photovoltaic system and the utility distribution grid was checked according to the instructions of CSEM.
- **Monitoring devices:** Netatmo and Shelly devices were installed for the monitoring of the indoor and outdoor conditions and the energy consumption of different components of the system. The right connection and communication of these devices was performed and checked before the commissioning with the help of ENG.
- **PLC:** The connections of the various sensors, valves, and pumps with the auxiliary PLC were checked before the commissioning with the presence of the local PLC provider in order to avoid any connection faults that could cause errors on the operation of the system.
- **Heating/cooling distribution system:** the water distribution system for the heating/cooling system was checked by the mechanical installer for leaks, and the correct pressures were confirmed.
- **Master controller:** The master controller was installed in the control room and connected with the system through a local network.

In addition, the University of Cyprus has a very good cooperation with the Municipality of Aglantzia for the purchase of equipment that will be installed in the building (furniture, computers, projectors, etc.) as well as for the access of the users and citizens to platforms of the University of Cyprus (library, some courses, etc.).

In parallel with the work in the field, the University of Cyprus collaborated perfectly with ENG and CSEM for the installation of the control and monitoring software on the local PC and for the connection of the software with appropriate sensors and actuators.

4.3 Installation problems / adjustments

From the initial stages of the project, some problems arose, mainly with securing the necessary approvals from the competent state departments. Because the building chosen for the installation of the HYBUILD systems is a listed building, obtaining a permit to install the photovoltaic system on the roof of the building was quite difficult. Eventually, however, we managed to proceed with the installation of the photovoltaic system after a special agreement.

The initial design of the system for the demo site of Aglantzia included solar thermal collectors to be supplied by the company FRESNEX which was also a partner in the project. Eventually, however, due to the lack of space, the difficulty of securing approval from the local authorities, but also due to the departure of the company FRESNEX from the project, it was decided to modify the system to operate without the need to install solar thermal collectors. This decision was discussed with the entire consortium of the project and the new design of the system was approved by the project officer.

Furthermore, during the installation phase, the most important problem that we faced was the long delay on the delivery of the equipment and the materials necessary for the installation. Firstly, mainly due to the Covid 19 pandemic, there was a considerable delay in the purchase and supply of the PLC and the electrical panel of the PLC and its accessories. Secondly, some components such as some sensors and valves, which had to be supplied from the local market, were out of stock and their order from abroad was time consuming.

The second problem encountered during the installation process was the late receipt of the Dry cooler. The Dry cooler was sent by Fahrenheit by ship, but due to a ship's failure and due to Covid 19 pandemic, its arrival in Cyprus was delayed, with the result that its integration into the system took place at a later stage.

Due to the abovementioned delays, the finalization of the installation of the systems was delayed for a period of around 4 months.

4.4 Pictures and schemes

Figure 19. PV panels in Aglantzia

Figure 20. HYBUILD system components in Aglantzia

Figure 21. Logic control box with PLC in Aglantzia

5 Installation and commissioning of demo-system: continental concept in Langenwang (Austria)

5.1 Description of the installation works

The technical room to take all the continental system components has been prepared in the basement of the company Pink GmbH in Langenwang, Austria.

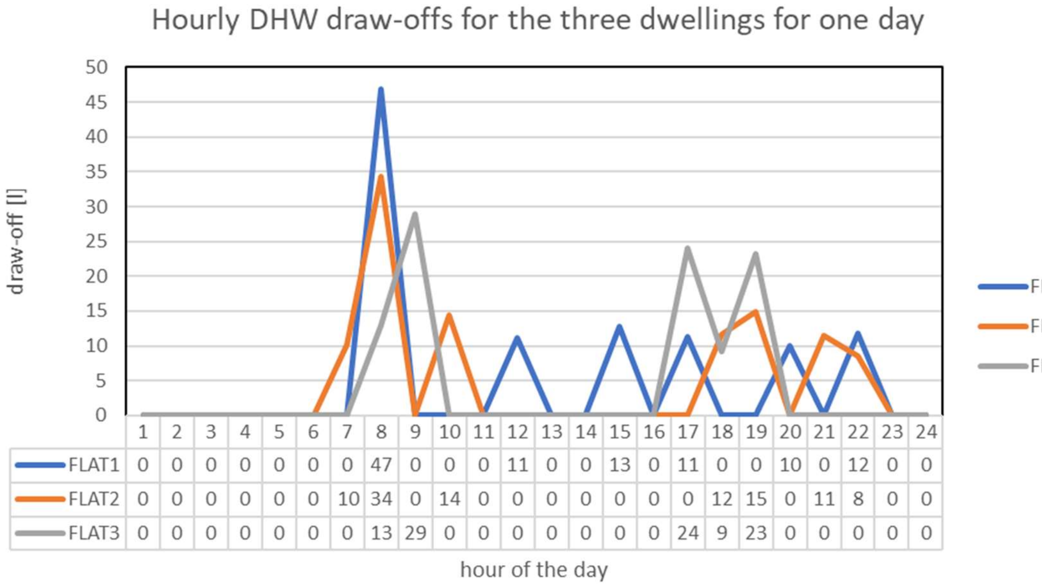
The real heating and cooling load are provided by the office section of the company in the eastern part of the building (marked in orange).

Figure 22. Plan of the installation area

The offices area has both heating and cooling systems. A low-temperature heating system has been installed to be connected to the HYBUILD system.

The hot water demand is basically at the shower rooms, as there was a risk not to cover all the DHW production, an artificial load has been applied.

The load profile has been defined by EURAC and implemented into the control system.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
FLAT1	0	0	0	0	0	0	0	47	0	0	0	11	0	0	13	0	11	0	0	10	0	12	0	0
FLAT2	0	0	0	0	0	0	10	34	0	14	0	0	0	0	0	0	0	12	15	0	11	8	0	0
FLAT3	0	0	0	0	0	0	0	13	29	0	0	0	0	0	0	0	24	9	23	0	0	0	0	0

Figure 23. DHW draw-offs on a one-day basis

The whole installation is described on the next figures (first a general figure, then a more detailed vision of each group of components).

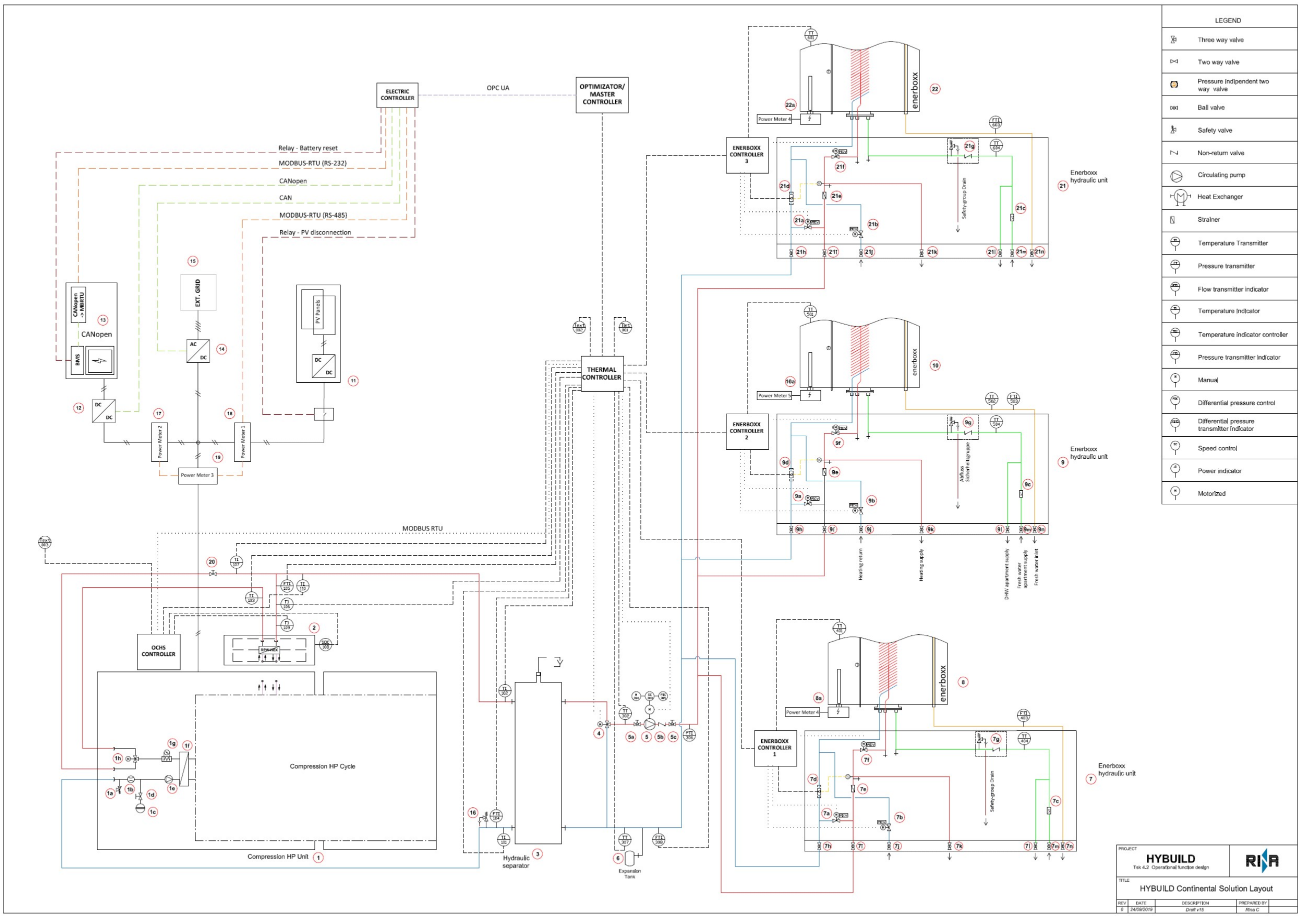


Figure 24. General scheme of installation in Langenwang

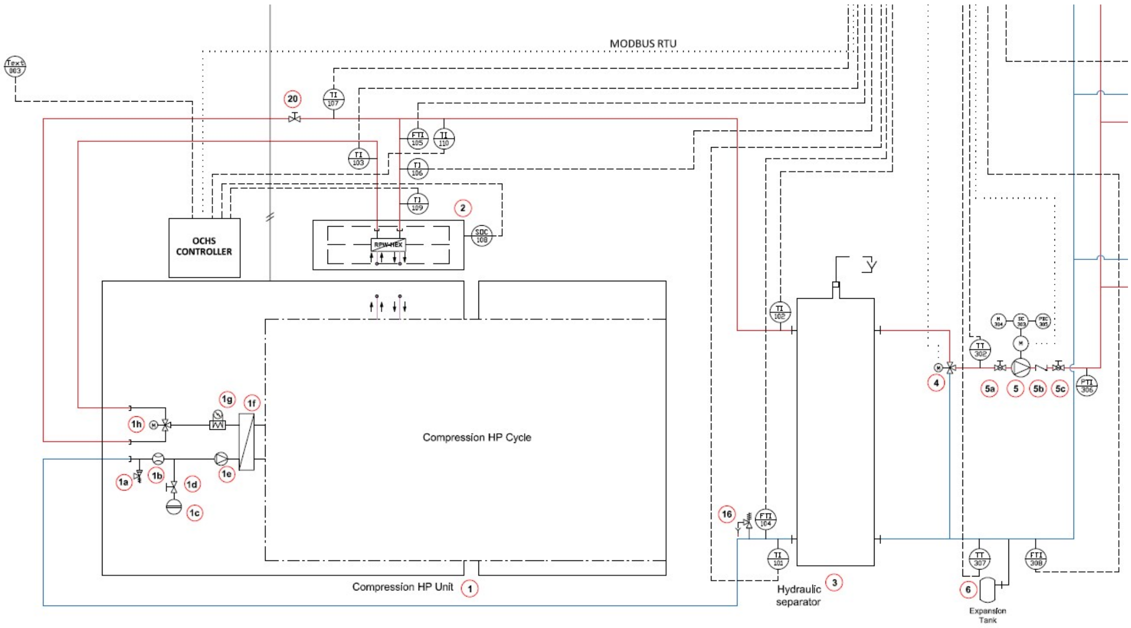


Figure 25: Thermodynamic components (linked to thermal controller)

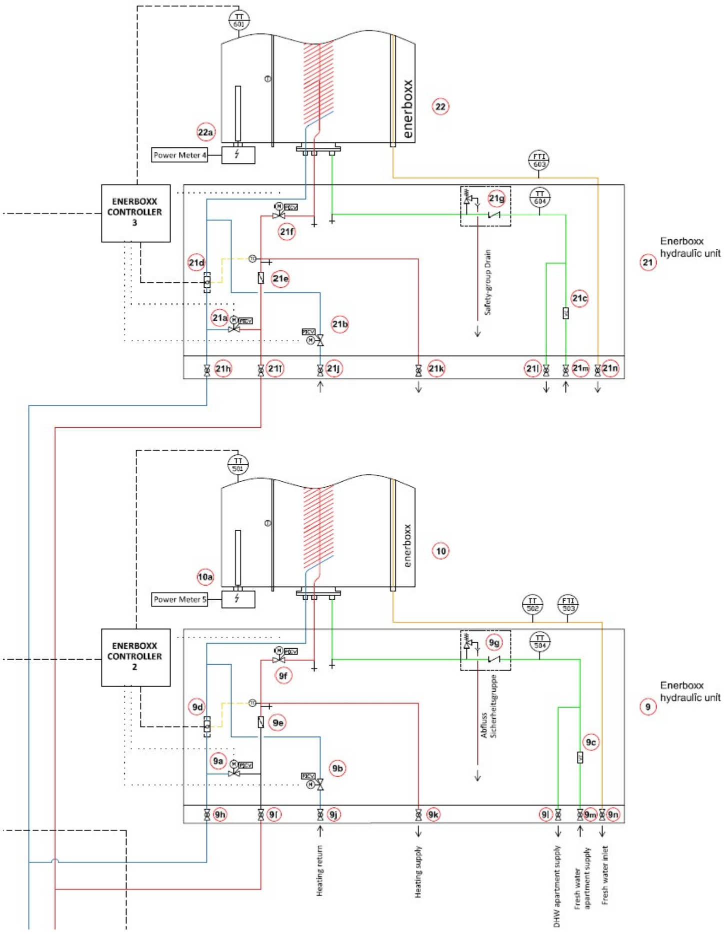


Figure 26: Enerboxx components (linked to thermal controller)

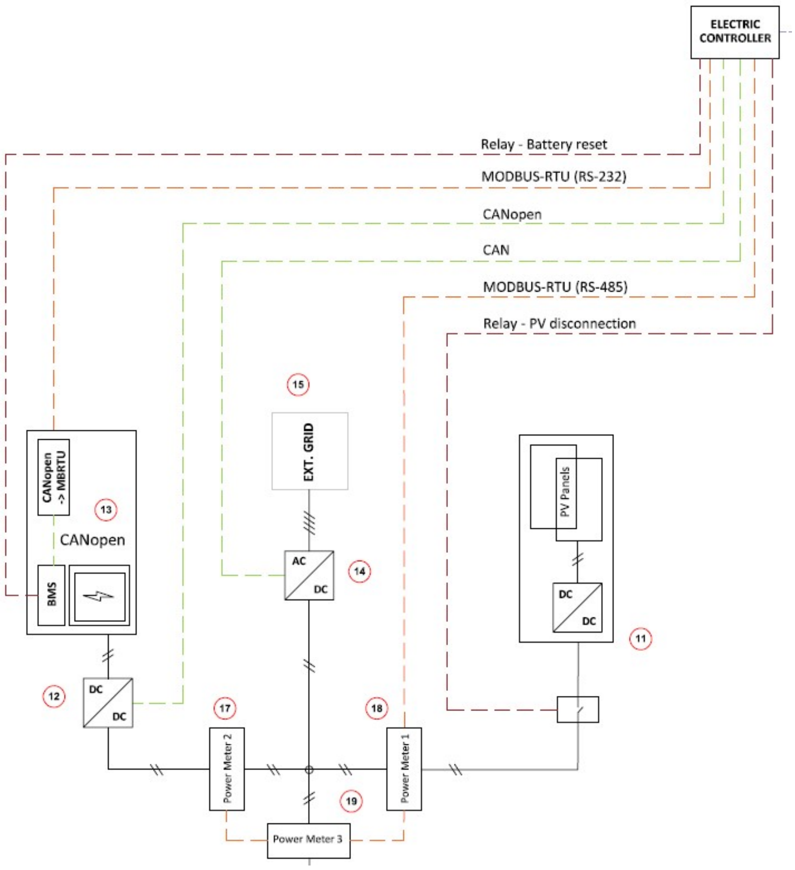


Figure 27: Electric components

5.2 Commissioning process of the demo-system

Works in the new demo started during November 2019 (M26). Within the period M26 to M38 (November 2019 to November 2020), the preparations and main works to install the continental demo at the new location in Langenwang (Austria) were performed:

1- Preparation of the technical room for the installation.
2- Installation and connection of a cooling/heating ceiling at the plan office.
3- Installation of a 6.2kWp PV-plant.
4- Proper wiring to integrate the DC rack and battery.
5- Placement and hydraulic installation of the RPW-HEX.
6- Positioning of the heat-pump outdoor unit.
7- Hydraulic installation of the decentralized sensible domestic hot water tanks with integrated hydraulic modules.
8- Hydraulic installation of the hydraulic switch and the district heating backup connection.

The installation has been performed by personnel of PINK and external local companies for special tasks.
The post-intervention strategy has been discussed with the help of all partners involved in HYBUILD demonstration work package. The installation of the heat pump and the commissioning of the new HYBUILD system was scheduled for November-December 2020. Therefore, a full year of post-intervention monitoring has been guaranteed in the continental demonstration.

EURAC is the responsible for the data collection and data quality control for the continental demonstrator, which has been collected from the installation until now.

5.3 Installation problems / adjustments

By the end of December 2020, the HYBUILD system was running in Langenwang. At that time, some adjustments were still to be made.

During the following months several issues were observed, analyzed and solved continuously. In this section, we provide several examples of these issues to illustrate how the commissioning activity has been tackled over the months following the installation.

In January, these problems were observed and then solved:

- Data from the thermal controller is collected, but there was no access locally to the real-time electrical consumption. However, the electrical consumption data was fully registered from that moment to the end of the project.

- EURAC-CSEM-PINK-ENG discussed and confirmed the PV/battery charging management strategy. An issue was still to be solved with the string optimizer, there was an issue with the electrical storage data. Involved partners discussed this problem to solve it.

- ENG provided access to data of Pink demo to PINK, NBK, OSCHNER, AIT and CSEM via GRAFANA.

In February 2021, some problems were observed with different components:

- A pressure sensor in the HP was not working, thus impacting the performance of the heat pump. Ochsner is aiming at solving this problem.
- As a consequence, it was not possible to run an automatic mode.
- A DC rack was always shutting down after a few hours of operation, thus having issues to provide the energy to the HP. CSEM worked on a solution.
- Further data checking was necessary in order to ensure they were collected correctly.

In March 2021:

- Errors appeared on the DC/DC converter, during the battery charging phase. ITAE, CSEM, ENG, and PINK worked to solve the problem.
- An optimization of the hydraulic charging of the DHW-tanks (Enerboxes) was decided.

In April 2021:

- The external insulation of the RPW-HEX was done, in addition to the already existing one coming from AIT or AKG.
- From the hardware point of view, everything was completely finished.

5.4 Pictures and schemes

Figure 28. Langenwang demo building

Figure 29. Preparation of the technical room for installation

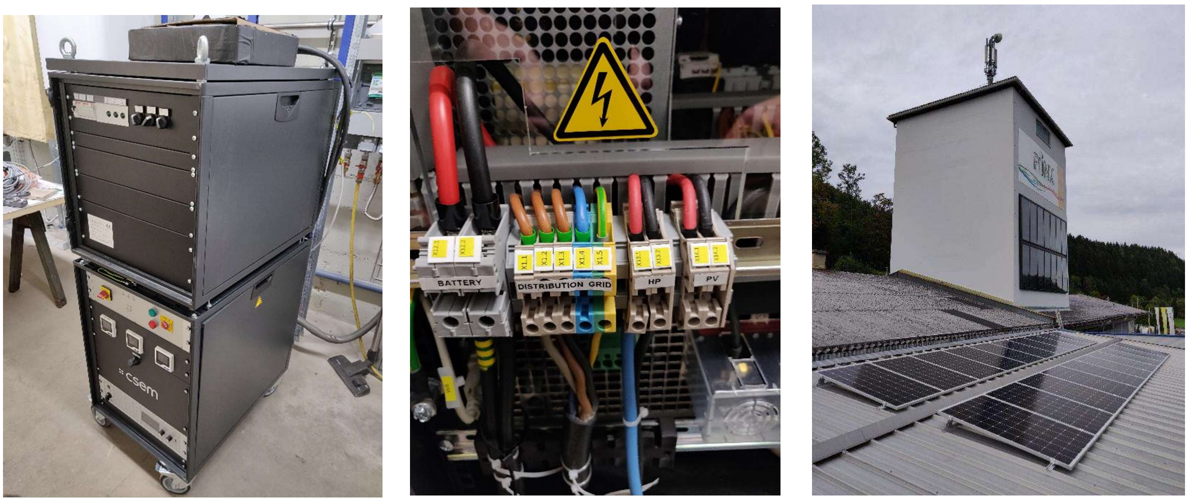


Figure 30. DC rack and battery are ready for implementation

Figure 31. PINK storage, hydraulic network and, Ochsner outdoor unit installation

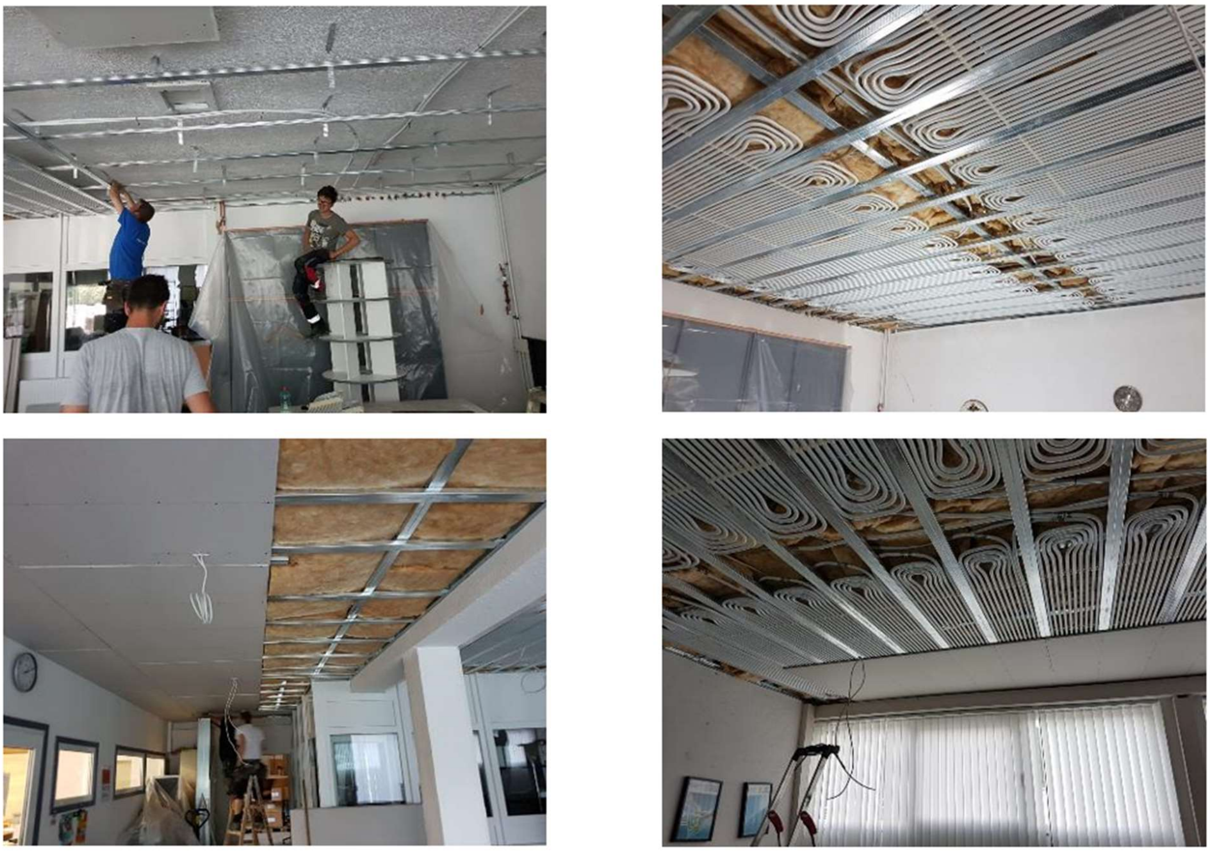


Figure 32. Cooling/heating ceiling installation

6 Conclusions

The installation of demonstration setups of **hybrid energy systems** is a complex activity. This deliverable provides feedback on the successful **installation and commissioning** of 2 different hybrid concepts (**Mediterranean** and **continental**) in 3 different demonstration sites: **Almatret** (Spain), **Aglantzia** (Cyprus), and **Langenwang** (Austria). Detailed comments are provided in sections 3, 4, and 5 for each demo site. The main lessons learnt from the commissioning activities are proposed as a conclusion, so that they can be useful for other hybrid energy demonstration initiatives.

Prior to the installation, it is essential to pay attention **not only to the technical** aspects but also to the **administrative** required steps: permit for installation, safety plan for the works, inspection office contracting. These are necessary to avoid any additional delay, but most of all to ensure the **quality** of the demonstrator and the **safety** of the people working on it as well as the one of the users of the buildings.

For HYBUILD demonstrators, the **risk linked to hardware and software malfunctions** has been mitigated as much as possible. However, some dysfunctions occurred that had to be resolved (e.g. leakage on hydraulic primary circuit). In this case, identifying the problem and solving it requires a series of actions: hypothesis on the origin of the problem, to order and install replacement components, to modify controller programming, to contract services, to repeat the previous steps based on another hypothesis, to check if the problem is only one-time or may be recurring, etc.

The installation of the hybrid systems demonstrators is the first opportunity to test some of the **dimensioning choices** and the **interdependent behaviours** of the integrated components (e.g. hydraulic connections). Time is needed to run the system and make all the required adjustments. Some of them can be anticipated (e.g. dimensioning), others can only be done during the commissioning process (e.g. setting up operating parameters). In some cases, modifications must be done on the main design and must be discussed with the consortium to ensure that the ambition of the project will still be reached.

In the case of prototype installations, to limit the impact of unforeseen issues, one crucial element is the **availability on site** of the designers and integrators of the solutions. In spite of having successfully tested the components under lab conditions, differences may occur at the demonstration site (e.g. electric rack issues). The presence on site of the experts allows to avoid weeks of iterative discussions and tests, thus speeding the overall commissioning process.

Apart from the design, fabrication, testing, and shipping of components, a precise **planning of all the interventions**, considering some margin due to risks and uncertainties, allows to control the duration of the installation and commissioning.

To avoid **spatial layout** issues (e.g. placing the components or connections), beyond the detailed design of the installation based on precise dimensions, it is useful to share previously to the design more contextual elements, such as preliminary visits, photos, videos, and 3D scanning coupled to virtual visits.

The **global material shortage** in summer 2021 had an impact on two HYBUILD's demo sites. Although only a limited number of components was involved in this shortage, it resulted in delays that affected the whole commissioning process.

Finally, the commissioning goes well beyond the few days required for the installation and initialization of the system. **During a longer period**, improvements can be done on the demonstrator based on the first analysis of the measurements.