Low valued energy sources UPgrading for buildings and industry uses

LowUP installation Plan for relevant environment 1

Deliverable D4.1

Lead Beneficiary: ACCIONA
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About LowUP

LowUp – Low valued energy sources UPgrading for buildings and industry uses – is developing efficient alternatives to supply heating and cooling for building and industries, based on the use of renewable free energy and heat recovery from non-valuated residual energy sources that are currently wasted. As a result, these technologies will contribute to reducing significantly CO_2 emissions and primary energy consumption, and increasing the energy efficiency in buildings.

Led by the Spanish firm ACCIONA, the LowUp project gathers 13 partners (3 large companies, 3 research and technology organisations and 7 SMEs) from 7 European countries. During 48 months, the consortium will develop efficient alternatives to supply heating and cooling for buildings and industries based on renewable free energy as well as non-valuated wasted thermal sources:

- 3 technologies will be developed and demonstrated: one heating and one cooling system for buildings, and one heat recovery system for industrial processes.
- The systems will be demonstrated at 4 demo sites: A Pilot Office building in Seville (Acciona Construction, Spain), a Waste Water Treatment plant in Madrid (Canal de Isabel II & Acciona Water), a Pulp and Paper mill in Setubal (Portugal, The Navigator Company) and a Student Hall in Badajoz (Spain, University of Extremadura)

For more information visit: www.lowup-h2020.eu

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Table of Content

Tables

Figures

Executive Summary

The aim of this deliverable is fulfilling all the activities necessary for executing the proper implementation of LowUP concepts at emulated test-site scale in relevant environment 1(building level), the thermal lab of ACCIONA in Seville and the students residence in Badajoz (Rucab), upgrading the already installed technologies and minimizing the investment for the execution.

Seville demo site is actually used for characterize novel & traditional thermal equipment (solar, boiler, chiller, cooling towers, etc…) and experimenting advanced integration concepts, in order to assess their viability before implementation in real market. Seville test site will be adapted in terms of space around the warehouse, for equipment installation, and in terms of building refurbishment, according to local laws and normative for energy efficiency with the objective of a fruitful installation of Heat and Cool-Low UP.

On other hand, the students residence (Rucab) in Badajoz will be modified according to integration with waste heat recovery system (Ecowec), developed by Wasenco; energy recovered will be monitored and transferred remotely to Seville pilot plant for emulated operation. Monitored data will be gathered and logged into a remote server for their use in Seville demo, where they will be emulated thank to existing heat generators.

This activity will allow defining the installation/integration procedures and activities for a proper integration the LowUP systems in the test sites

A detailed planning is here defined after the design phase, and just before the manufacturing process of WP4, identifying possible blank spots, delays, techno-economic constraints, risk analysis and contingency plans (in synergy with WP5).

Keywords

Installation Plan, space conditioning, building environment, residential demo building

List of acronyms and abbreviations

AHU	Air handling unit
RITE	Reglamento de Instalaciones Térmicas en los Edificios
CTE	Código Técnico de la Edificación
kW	kilowatt
PCM	Phase-Change Material

1 Introduction

In this second phase of the project, the goal is the design, installation, operation and validation in relevant environment of all 3 LowUP systems. This deliverable is focused on Heat-LowUP and Cool-LowUP systems, which will be validated in a real office (refurbished warehouse).

According to results from previous tasks (mainly within WP2), Heat-LowUP and Cool-LowUP prototypes, previously individually fully tested, will be shipped to the sites; most of them will be integrated with existing settings of ACCIONA pilot plat in Seville, while others will be integrated in Rucab (Badajoz), for remote emulation in Seville plant.

From now on, there are four partial objectives in the frame of this demonstration work package (WP4):

A - Design at component level: Engineering process for electromechanical adaptation of relevant test sites (Seville pilot plant and Rucab) to LowUP System/technologies. Engineering process for test site control system adaptation to operational necessities.

B - Installation at component level: Test sites conditioning for LowUP System implementation, from civil to electromechanical works.

C - Design at system level: Engineering process for integration of LowUP System with relevant test sites.

D - Installation at system level: Functional integration/implementation and commissioning of LowUP with real and simulated test facilities (relevant environment), from electrical, hydraulic and energetic point of view.

E - Control and operation: Characterization of LowUP System from limit to operational working conditions. Continuous operation and maintenance at nominal and modulating working conditions. Validation of predictive maintenance and continuous commissioning techniques. Calibration of simulation models and of control strategies.

This deliverable aims to fulfil the description of objectives A, B and C, dealing with the preparation of the sites where LowUP technologies will be deployed and giving an optimized installation plan. The objective of the related task in the project (Task 4.3) is fulfilling all engineering activities necessary for executing the proper implementation of LowUP concepts at emulated test-site scale, the thermal lab of ACCIONA in Seville, upgrading the already installed technologies and minimizing the investment for the execution.

Seville test site will be adapted in terms of space around the warehouse, for equipment installation, and in terms of building refurbishment, according to local laws and normative for energy efficiency. On other hand, the students residence located in Badajoz (Rucab) will be modified according to integration with the sewage energy recovery system developed by Wasenco (which energy recovered will be monitored and transferred remotely to Seville pilot plant for emulated operation of the system).

2 Installation plan for Seville demo building

The purpose of this section is to give a detailed overview of the LowUP demo site in Seville, describing the current state of the demo site, the systems that will be integrated and their main features and the necessary works to adapt the place and the installation plan.

2.1 Description of Seville demo before retrofitting

The demo building is located in an industrial area, next to another thermal lab where ACCIONA owns a research facility consisting of a tri-generation plant and an HVAC test site. This lab actually disposes of renewable based generation-transformation-dissipation systems, integrated with proprietary supervision system for real time monitoring and control, which are used for operation, simulation and emulation of heating & cooling technologies.

Figure 1: Aerial view Seville demo

There is plenty of space in the surroundings of the office demo building where the LowUP individual systems will be installed, as it is shown in the following illustration:

Figure 2: Aerial view Seville demo and available space

The demo building is going to be the result of the retrofitting of an existing establishment. The current state of this building is shown in the following figure:

Figure 3: Old warehouse in Seville before being retrofitted

The building, after the retrofitting, will have an administrative/office use, fulfilling the requirements of LowUP project.

2.2 Description of Heat-LowUP and Cool-LowUP to be installed in Seville demo

The demo site in Seville will accommodate all the systems that integrate the Heat/Cool LowUP installations. This subsection aims to give a brief description of the different systems and their main features. A more detailed description and analysis could be found in 2.1 and 2.2 deliverables.

2.2.1 Heat-LowUP systems and integration schema

Heat-LowUP starts from the principle that a more energy can be gathered from the sun, operating at lower temperatures (30-40°C) and recovered a lot of energy from residual waste water between 25-30°C, for their direct use in heating terminals without any upgrading. To make this result possible, specific developments to most of involved technologies have been challenged, in order to make them work at lower temperatures respect to current systems.

The system is composed by: Hybrid solar panels with PCM integrated, sewage energy recovery system (WASENCO), stratified heat storage (TISUN), radiant floor (RDZ), a heat pump installed as backup equipment and a drycooler, a dissipation system which belongs to the tri-generation plant. The first layout developed in the project is shown in next figure:

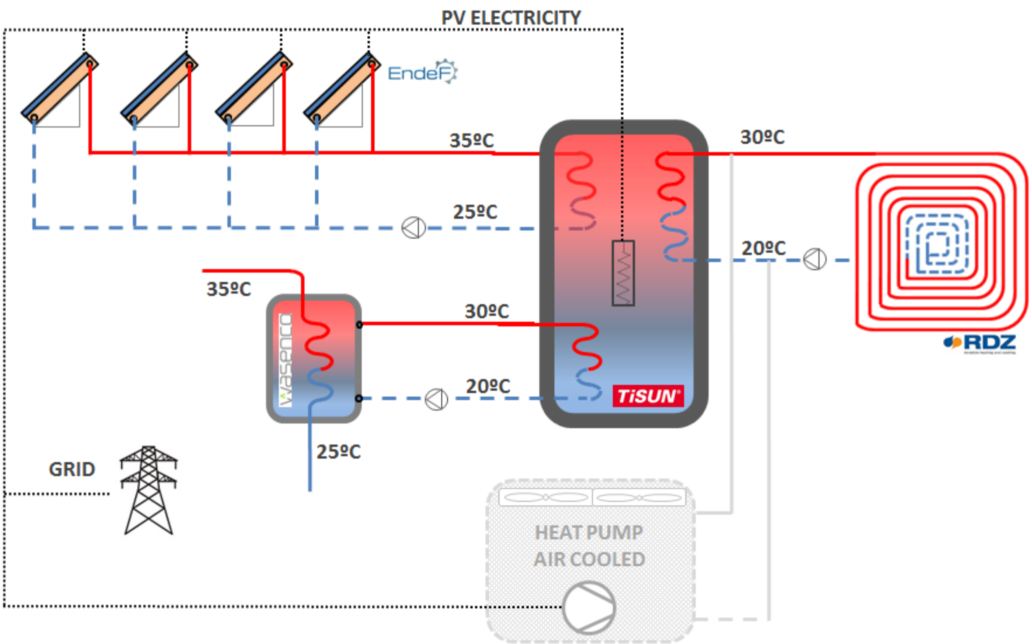


Figure 4: HEAT-LowUP layout at the beginning of the project.

Each element has been developed in the frame of the project, aiming to obtain the most suitable (and optimized) equipment for the project. After the first design step, some modifications were done to the original layout proposed. Some different configurations of the global system have been taken into account, and are available in Deliverables 2.1 and 2.2. The final configuration is defined as follows:

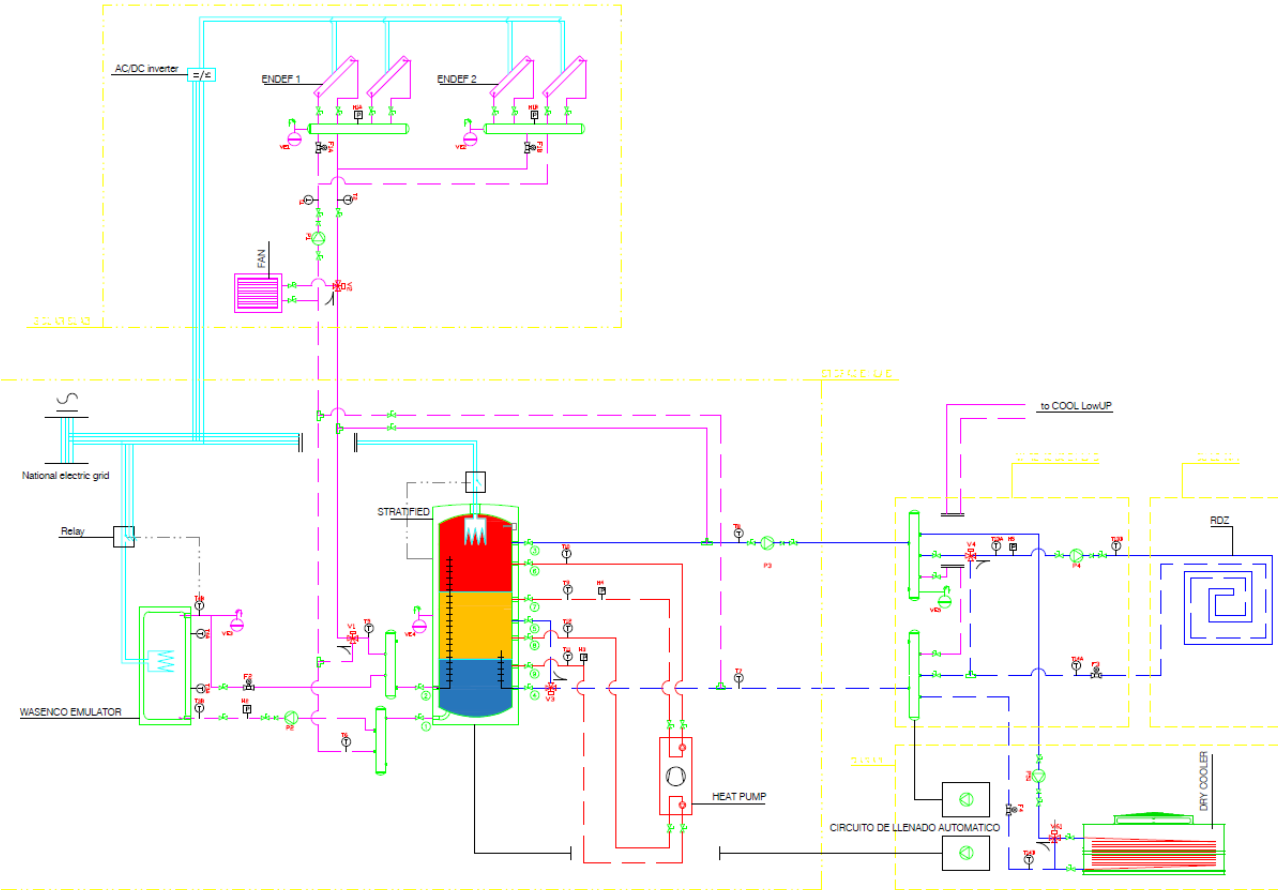


Figure 5: Final HEAT-LowUP layout and systems identification

This global system will act as follows: the stratified tank stores the waste and renewable energy produced in the sewage energy recovery system and the solar field respectively, and the radiant floor, using this stored energy, faces the thermal loads of the building. The sewage energy is produced in the student residents of Badajoz, and it is simulated in Seville through a thermal emulator, a water tank equipped with an electric resistance. The drycooler, an energy dissipation system, allows to test different energy productions and works at the same time as the radiant floor. In the chase that the energy stored is not enough to deal with the current thermal loads, a heat pump is used as a backup system.

The main characteristics of the equipment are shown as follows:

Hybrid PVT Solar panels:

- Unglazed Roll-bond prototype
- Type of PCM: C48
- Hydraulic connection based on Tichelmann loop: 40 PVT panels to be installed (2 circuits: 20 PVT panels with PCM integrated and 20 PVT panels without PCM.
- Electricity production: 270 Wp/panel
- Electricity consumption: 1.5 kW
- **Special requirements for installing activities:**
  - Available space without shadows.
  - Foundation able to support PVT weight.

Figure 6: Solar field

Stratified tank:

- Volume: 6500 liters
- Insulation: 120mm for heat
- Height: 3550mm
- Floor area: 2 m^2
- **Special requirements for installing activities:**
  - Available space
  - Horizontal foundation able to support tank weight.

Figure 7: Stratified tank

Radiant floor:

- Configuration: 2 manifolds with 8 circuits each.
- Material: PE-RT
- Height: 3cm
- Maximum weight supported:
- Floor material: ceramic
- Electricity consumption: <200 W
- **Special requirements for installing activities:**
  - Expansion joint between the 2 manifolds.
  - Radiant floor should be placed on uniform basement.

Figure 8: Radiant floor

Thermal Emulator:

- Volume: 1500 liters
- Static heat loss: 154 W
- Height: 1830 mm
- Weight (empty): 496 kg
- Floor area: 1.5 m^2
- **Special requirements for installing activities:**
  - Available space
  - Horizontal foundation able to support tank weight

Figure 9: Thermal emulator

Heat Pump:

- Length: 402 mm
- Width: 602 mm
- Height: 785 mm
- Weight: 90 kg
- Heat output: 12 kW
- COP: 5.26
- **Special requirements for installing activities:**
  - Available space

Figure 10: Heat Pump

Dry-cooler:

- Capacity: 114.40 kW
- Airflow: 42000 m3/h
- Power consumption: 3.75 kW
- Size: (3.7 x 1.26 x 0.76)
- **Special requirements for installing activities:**
  - **Already installed**

Figure 11: Drycooler

2.2.2 Cool-LowUP systems and integration schema

COOL-LowUP pretends to overcome current limitations in cooling systems, such as poor COPs, by the introduction of improvements in several fronts: by using cooling terminal devices operating at higher temperature respect to actual technology and recovering cooling from environment instead of producing it via compression cycle (18/16ºC instead of 7/12ºC); by using PCMs to store cool energy with melting temperatures close to the cooling operation; by charging the cool storage in periods when electricity is cheaper and the efficiency of the system is higher (night fare); by using the sensitive (and adiabatic evaporative) quality of atmospheric air, taking advantage that many times along the year, the outdoor atmospheric conditions are able to provide free cooling capacity.

Cool-LowUP system is composed by the following equipment: PCM storage (FAFCO), chilled beams (HALTON), a new system which integrated by a chiller and an Air Handling Unit (AHU) in a single system and an existing adiabatic cooling tower. The original layout of the global system is shown in the image below:

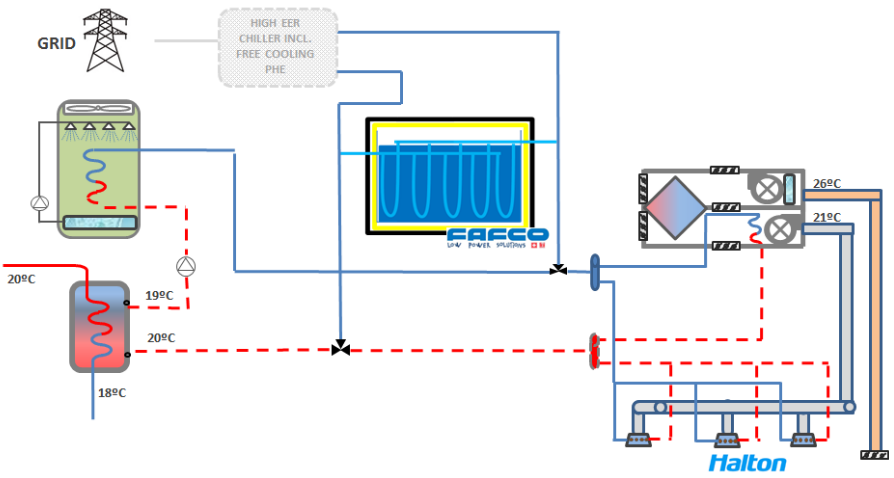


Figure 12: COOL-LowUP layout at the beginning of the project

Each element has been developed in the frame of the project, aiming to obtain the most suitable (and optimized) equipment for the project. After the first design step, some modifications were done to the original layout proposed. Some different configurations of the global system have been taken into account, and are available in Deliverables 2.1 and 2.2. The final layout is as follows:

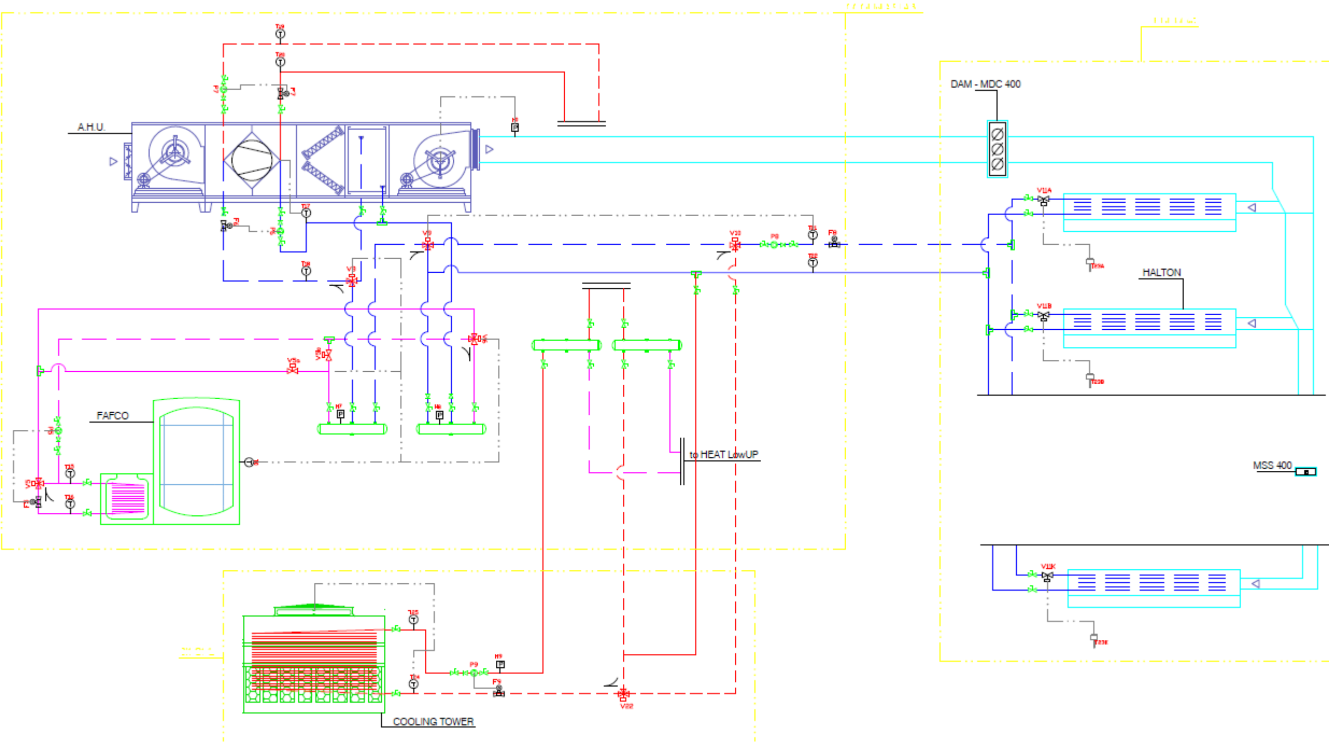


Figure 13: Final COOL-LowUP layout and systems identification

This global system will act as follows: the PCM tank is charged at night time, when the electricity consumed by the chiller has a lower cost and the COP of the chiller is higher. During the day (or during the occupancy time), the PCM tank is discharged, so that, the energy stored in it supplies the chilled beams, which are responsible for facing the thermal loads of the demo building. The cooling tower cools the water that is used as cold source in the refrigeration cycle of the chiller. Specific meteorological conditions could allow to used directly the cold water produced in the cooling tower to feed the chilled beams (water free cooling). The chiller could work as a backup system, when there is not available energy in the PCM tank to overcome the thermal loads. The ventilation air is produced by the AHU, whose cold source is also provided by the chiller. In some very specific meteorological conditions, the outside air, without any treatment, could be introduced in the building as ventilation air (air free cooling).

The main characteristics of the equipment are shown as follows:

PCM Cool Storage tank:

- Capacity: 96 kWh
- Type of PCM: PCP 10
- Weight: 3187 kg (operating conditions)
- Floor area: $3m^2$
- Dimensions: L1 (1.870 m), B (1.595 m), H3 (2.200 m)
- **Special requirements for installing activities:**
  - **Available space**

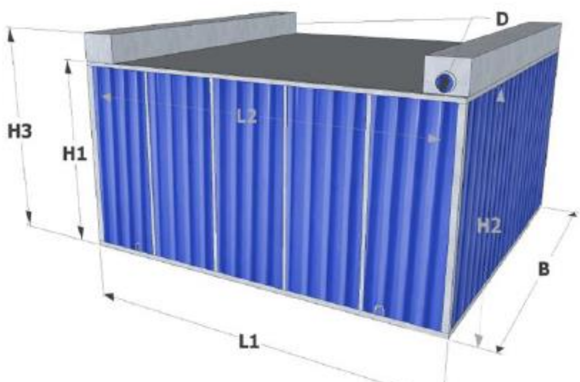


Figure 14: PCM Cool Storage tank

Chilled beams:

- Configuration: 8 chilled beams in Office Area (OA) and 3 Chilled beams in Warehouse Area (WA).
- Weight: 87.5 kg (WA); 95 kg (OA)
- Dimensions:
  - OA: width (0,432 m); height (0,309 m); length (3,636 m)
  - WA: width (0,414 m); height (0,281 m); length (3,336 m)
- LED lighting integrated
- **Special requirements for installing activities:**
  - First connection duct to chilled beam no closer than 2 m from MDC damper (green rectangle in the layout).
  - 1.2 m safety distance (straight duct) before MDC and MSS measurement unit (red rectangle).
  - After MSS straight duct 0.4 m distance minimum.
  - Building structure must support the beams weight.

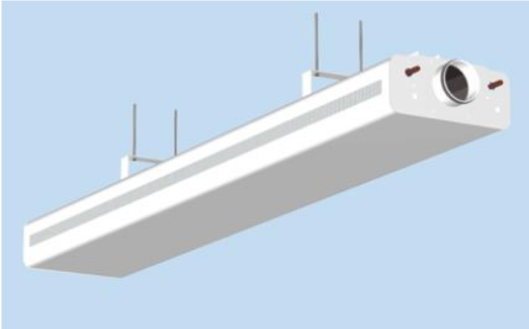


Figure 15: Chilled Beam

Chiller/AHU:

- Cooling capacity: 32.2 kW
- EER: 5.46
- Compressor consumption: 5.9 kW
- Dimensions:
  - Length: 3650 mm
  - Width: 1400 mm
  - Height: 1300 mm
  - Dimensions:
- **Special requirements for installing activities**
  - Available space

Figure 16: Chiller/AHU

Cooling Tower

- Air flow: 12.3 m^3/s
- Fan consumption: 11 kW
- Water flow: 9 l/s
- Water pump consumption: 0.75 kW
- Volume: 258 l
- **Special requirements for installing activities**
  - Already installed

Figure 17: Cooling tower

2.2.3 Auxiliary equipment

Some auxiliary devices (water pumps and 2 and 3-way valves) are necessary to carry out the systems integration. Both, Heat-LowUP and Cool-LowUP installations require a set of devices, which are presented in the global system layouts (Figure 5 and Figure 13), and are listed below:

Heat-LowUP system:

- Water pumps: P1, P2, P3, P4, P51
- 3-way valves: V1, V2, V3, V4, V61
- 2-ways valves: -

Cool-LowUP system:

- Water pumps: P5, P6, P7, P8, P8
- 3-way valves: V22, V5, V6, V8, V9, V10
- 2-way valves: V5a, V5b, V11 (one per chilled beam)

Some of these auxiliary devices are integrated in the main systems, and will be sized by the manufactures attending to their specific requirements, being the rest of them designed for a proper working of the global systems. All above elements compose the different systems:

Heat-LowUP:

- Solar field:
  - Pump (P1) + air rejecter (FAN) + solar panels (ENDEF) + 3-way valve (V2)
- Emulation:
  - Thermal emulator + electric resistance
- Storage:
  - Stratification tank + electric resistance
- Add-On:
  - Drycooler + pump (P51) + 3-way valve (V61)
- Load:
  - Radiant floor (RDZ) + pump (P4) + 3-way valve (V4)
- Back-up:
  - Heat pump
- Independent auxiliary devices:
  - Water pumps (P3 and P2) + 3-way valve (V1 and V3)

Cool-LowUP:

- AHU + Chiller:
  - AHU with integrated chiller + chilling water pump (P6) + condensation water pump (P7) + 3-way valve (V8)
- Chilled Beams:
  - Chilled beams + air damper (DAM)
- PCM tank (ICEBAT system):
  - Storage tank + water pump (P5) + 3-way valves (V5 and V6) + 2-way valves (V5a and V5b)
- Dissipation:
  - Cooling tower + water pump (P9) + diverting valve (V22)
- Independent auxiliary devices:
  - Water pump (P8) + 3-way valve (V9 and V10)

The sizing of the water pipes and ducts networks and water pumps will be done according to Spanish regulation: Reglamento de instalaciones térmicas en la edificación (RITE).

2.3 Preparatory works in Seville

This section aims to describe all the preparatory works which are needed to be executed in the demo site of Seville to allow a proper systems integration, minimizing the impact and the investment. Seville site will be adapted in terms of space around the warehouse, for equipment installation, and in terms of building refurbishment. A preparatory works plan will be presented at the end of this section.

2.3.1 Office building

The current state of the building is showed in the images below:


Figure 18: Current state of demo building before refurbishment

The Spanish regulation to be followed in a building refurbishment, is the technical code, called “Código Técnico de la Edificación” (CTE). The CTE is the regulatory framework, that establishes the requirements that buildings must meet, regarding the basic requirements of safety and habitability.

The preparatory works to be executed in Seville demo, are listed below:

Office/Warehouse retrofitting

- Remove the old roof and installation of a new roof, composed by sandwich panels, in order to fulfil the CTE specifications. Three skylight panels, made by cellular polycarbonate, will allow a further luminosity.
- Floor conditioning: reparation of old pavement and adaptation to the radiant floor installation.
- Building envelope: Improve isolation in order to fulfil the CTE specifications. Holes opening for windows placement.
- New windows in order to fulfil the CTE requirements.
- Internal partition: new internal wall to divide the office and the warehouse.
- Toilets removed.
- Installation of a fire door.

The floor plan drawing, side cross-section drawing and the location of the metal structure and skylights on the roof are presented in the image below:

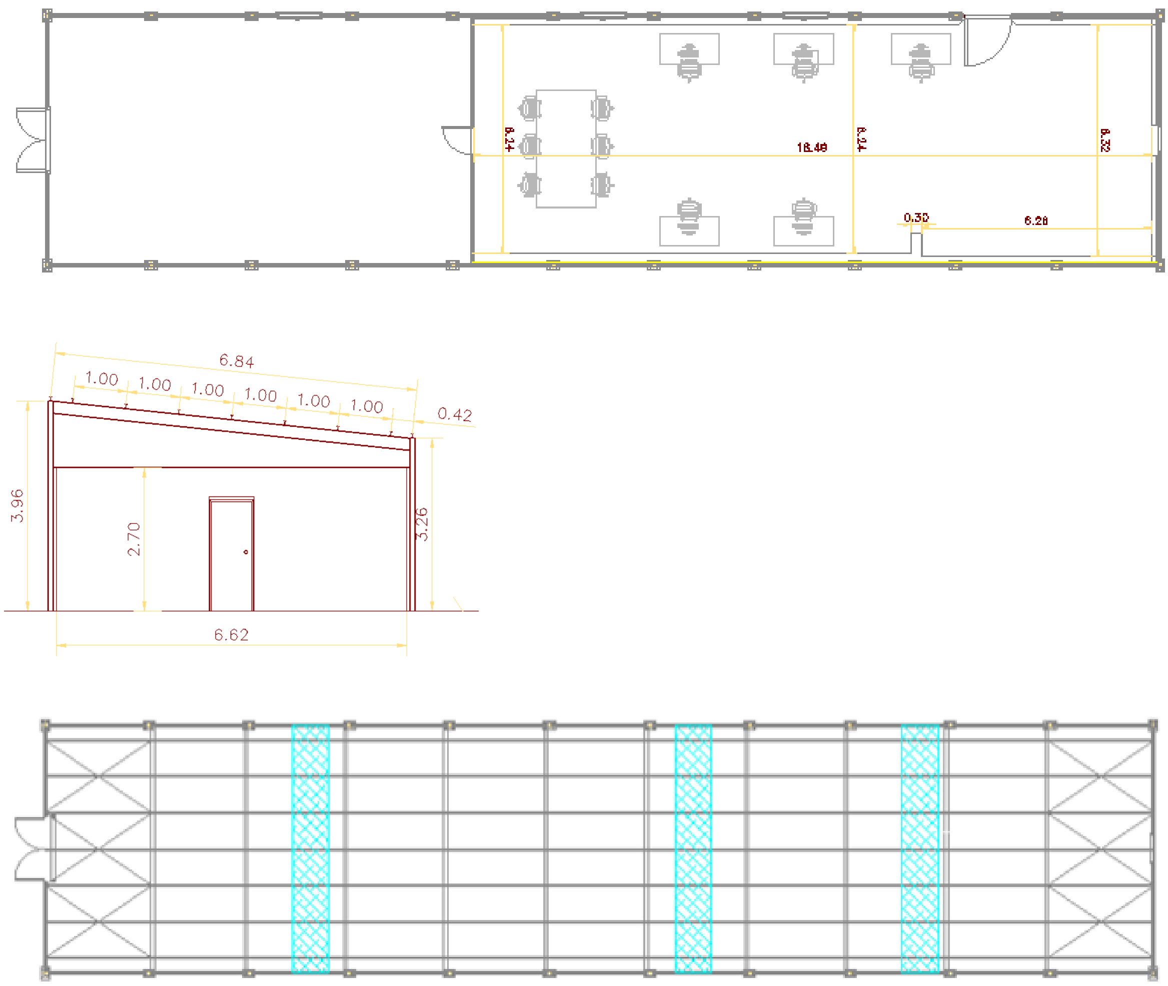


Figure 19: Floor plan drawing (on top), side cross-section drawing (middle) and location of the metal structure and skylights on the roof (on bottom)

Considering the available budget, compliance of regulation and technical optimization, main characteristics of the LowUP demo building after refurbishment are described in Table 1 and Table 2:

Table 1: Main characteristics and dimensions of the LowUP demo building in Seville (Spain)

<table>
<tr><th>Characteristic</th><th colspan="3">Description</th></tr>
<tr><td>Floor area</td><td colspan="3">~200 m²</td></tr>
<tr><td>Building plant/height</td><td colspan="3">Rectangular (30.2m x 6.6m) / 3.6 m high (average value)</td></tr>
<tr><td>Floor distribution</td><td colspan="3">- 66%: open office space
- 33%: warehouse</td></tr>
<tr><td>Windows</td><td colspan="3">• 3 windows (1m x 2.2m) located on the East façade; office zone
• 3 translucent polycarbonate sheets (1m x 6.5m; 30mm-thick) located on the roof; 2 for the office zone, 1 for the warehouse</td></tr>
<tr><td>External walls</td><td colspan="3">2 different wall constructions (see Table 2 for further details)
• Wall 1: on walls facing N and S, and 36% of W and E façades
• Wall 2: on 64% of W and E façades</td></tr>
<tr><td>Surrounding shade elements</td><td>Shade location:
South
West
East</td><td>Kind of element:
Industrial building
Industrial building
Fence</td><td>Height / Distance from demo:
10m / 3.20m
6m / 1.50m
1.5m / 11m</td></tr>
</table>

Table 2: Constructive details of LowUP building wall constructions

Wall 1	k ($W \cdot m^{-1} \cdot K^{-1}$)	c_p ($J \cdot kg^{-1} \cdot K^{-1}$)	ρ ($kg \cdot m^{-3}$)	Thickness (m)	R ($m^2 K \cdot W^{-1}$)
Ext. conv. R					0.0400
Mortar rendering	1.2	1100	1600	0.008	0.0067
Solid brick	0.87	1400	1800	0.115	0.1322
Insulation	0.040	1000	50	0.036	0.9000
Mortar rendering	1.2	1100	1600	0.008	0.0067
Int. conv. R					0.1300
				U-value ($Wm^{-1}K^{-1}$)	**0.823**
Wall 2	**k ($W \cdot m^{-1} \cdot K^{-1}$)**	**c_p ($kJ \cdot kg^{-1} \cdot K^{-1}$)**	**ρ ($kg \cdot m^{-3}$)**	**Thickness (m)**	**R ($m^2 K \cdot W^{-1}$)**
Ext. conv. R					0.0400
Mortar rendering	1.2	1100	1600	0.010	0.0008
Solid brick	0.87	1400	1800	0.115	0.1322
Insulation	0.040	1000	50	0.040	1.0000
Air gap (1cm)				0.010	0.3850
Perforated brick	0.76	1000	1600	0.050	0.0066
Mortar rendering	1.2	1100	1600	0.010	0.0008
Int. conv. R					0.1300
				U-value ($Wm^{-1}K^{-1}$)	**0.565**
Roof	**k ($W \cdot m^{-1} \cdot K^{-1}$)**	**c_p ($kJ \cdot kg^{-1} \cdot K^{-1}$)**	**ρ ($kg \cdot m^{-3}$)**	**Thickness (m)**	**R ($m^2 K \cdot W^{-1}$)**
Ext. conv. R					0.0400
Polyurethane	0.036	1800	50	0.080	2.2222
Int. conv. R					0.1300
				U-value ($Wm^{-1}K^{-1}$)	**0.418**

2.3.2 Open spaces

Considering systems requirements, which has been presented in sections 2.2.1 and 2.2.2, the main purpose of this section is to describe the preparatory works necessaries to fulfil these requirements: the distribution of the systems in the limited available space, attending to system dimensions or global system configuration and the adaptation of the ground in order to allow a proper installation of the different systems.

Available spaces can be observed in the following drawing:

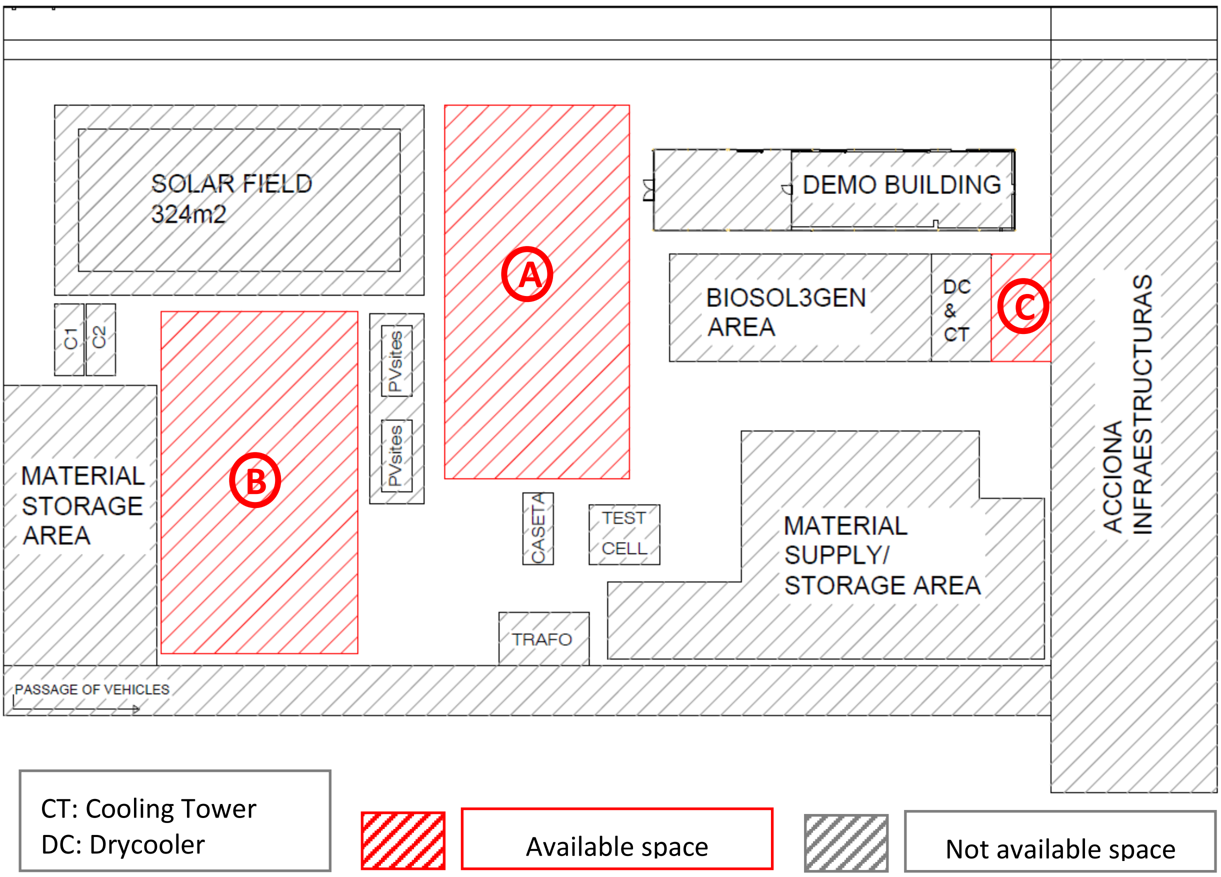


Figure 20: Analysis of available space for equipment placement

The current state of the ground in these spaces are shown in the following pictures:

Figure 21: Current state of space around the warehouse

The distribution chosen and the preparation work for each of the equipment that form both systems (that are placed outside) will be presented:

PVT System:

Location: The most suitable location to be placed, **without any shadows,** is showed in the next drawing (in red):

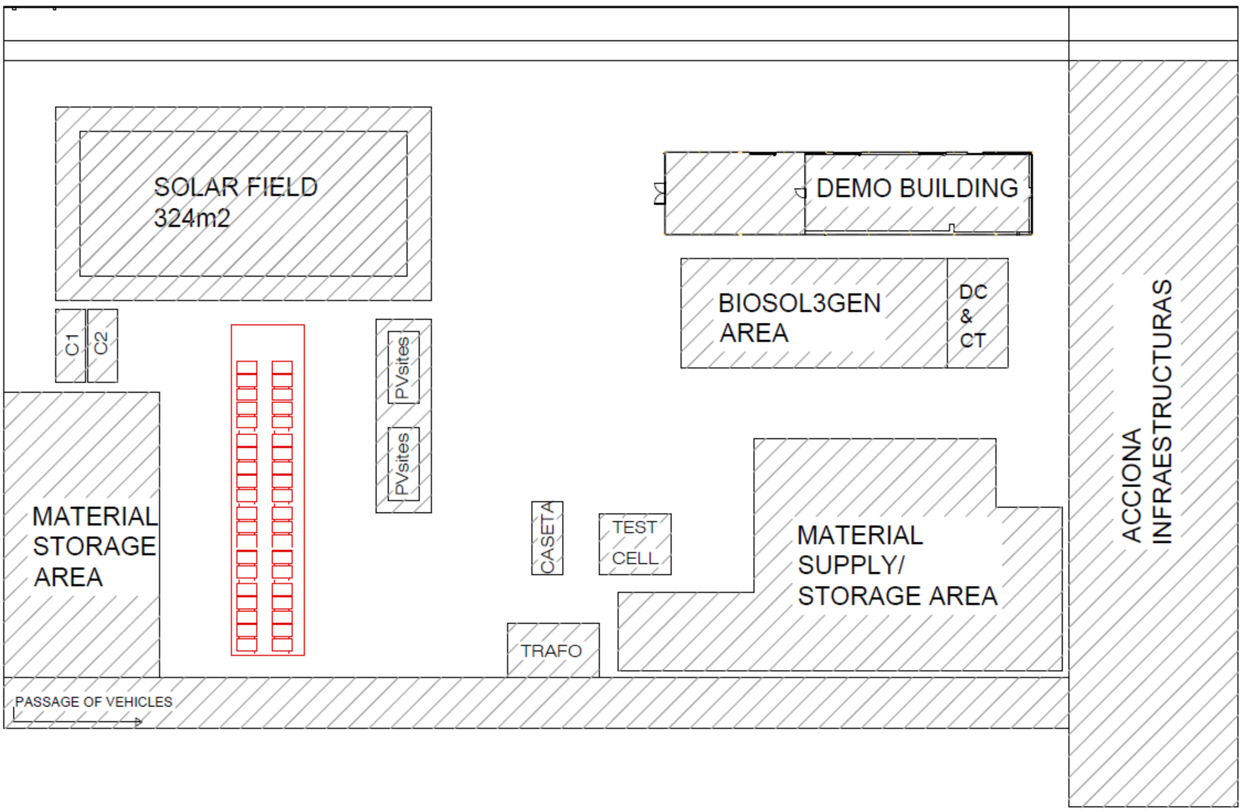


Figure 22: Solar filed location

Foundation for PVT installation: Due to the current state of the ground, and specifics necessities regarding land levelling and structure anchoring, a foundation slab will be built.

Stratified Tank:

Foundation for stratified thermal storage installation: This installation, due to the weight of the system, required a solid and level ground, to prevent from collapsing. So, a foundation slab is also proposed. The dimensions will be 5x7m^2, enabling to place the rest of the systems that integrate the Heat-LowUP installation. This foundation lab will be referred to as "isla".

Location: Due to the available space, the size of this slab and the proximity with the solar field, the most suitable location is showed as follows:

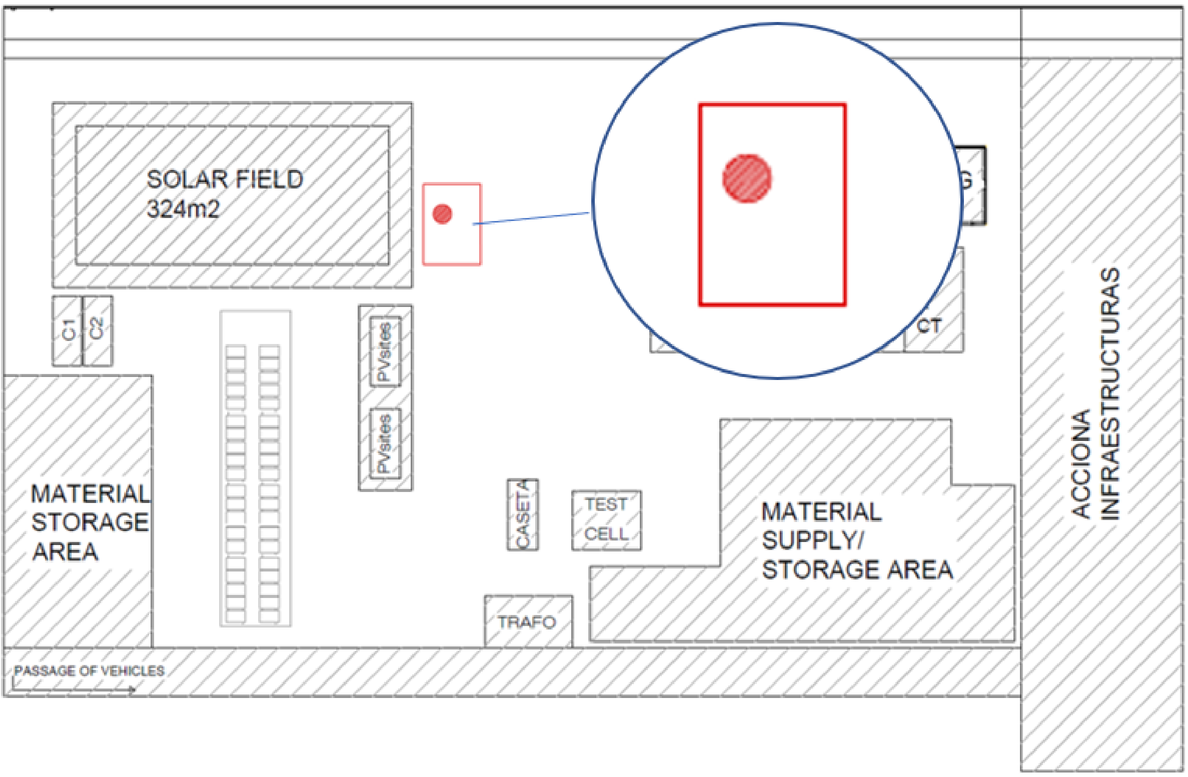


Figure 23: Stratified tank location

Thermal emulator:

Location: Located in the ISLA, its placement is showed in the following image:

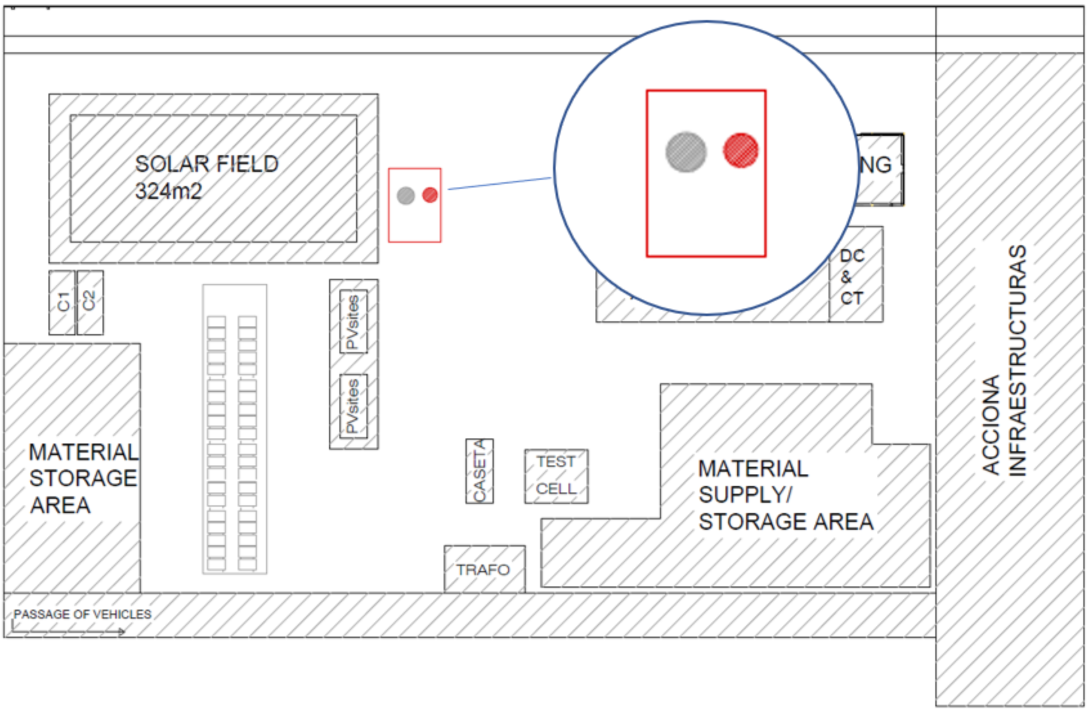


Figure 24: Thermal emulator location

Heat pump:

Location: Located in the ISLA, its placement is showed in the following image:

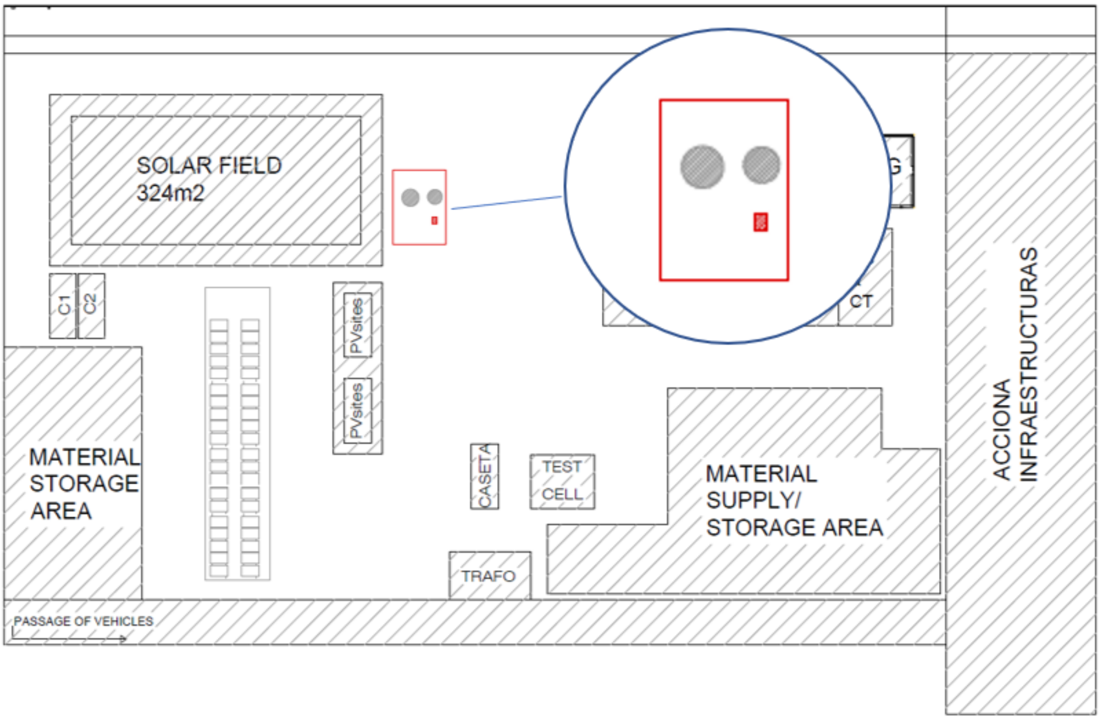


Figure 25: Heat pump location

AHU/Chiller:

Location: The mainly requirements are available space and proximity with the demo building and the already installed cooling tower. The most suitable place is showed in the following drawing:

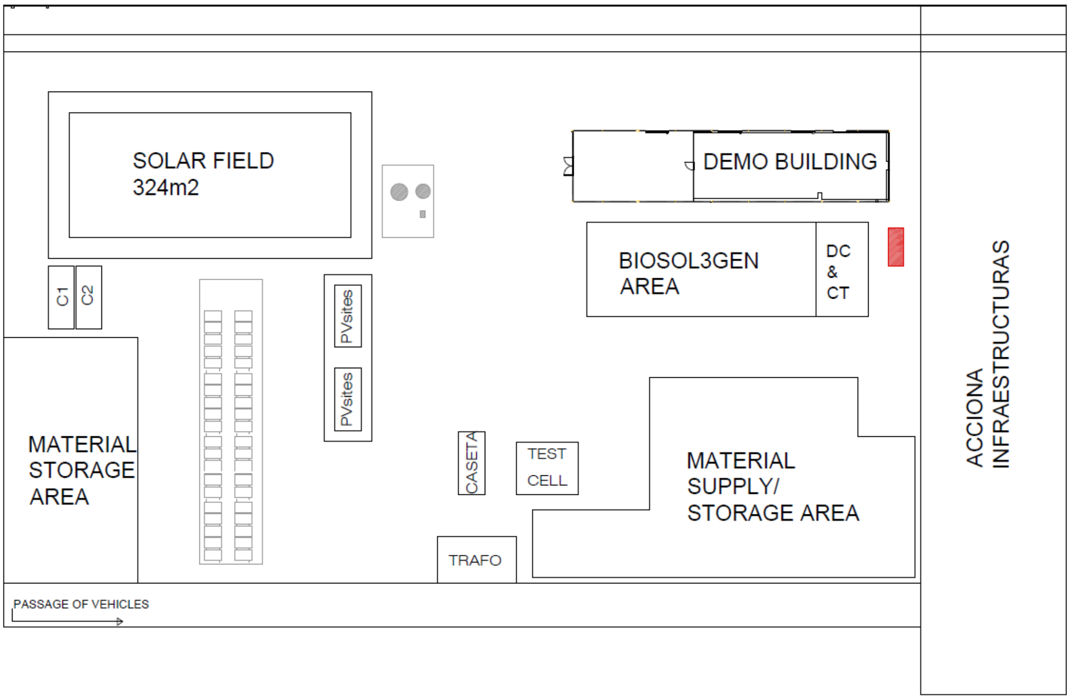


Figure 26: AHU/Chiller location

PCM Cool Storage Tank:

Location: The mainly requirements are available space and proximity with the chiller. The most suitable place is showed in the following drawing:

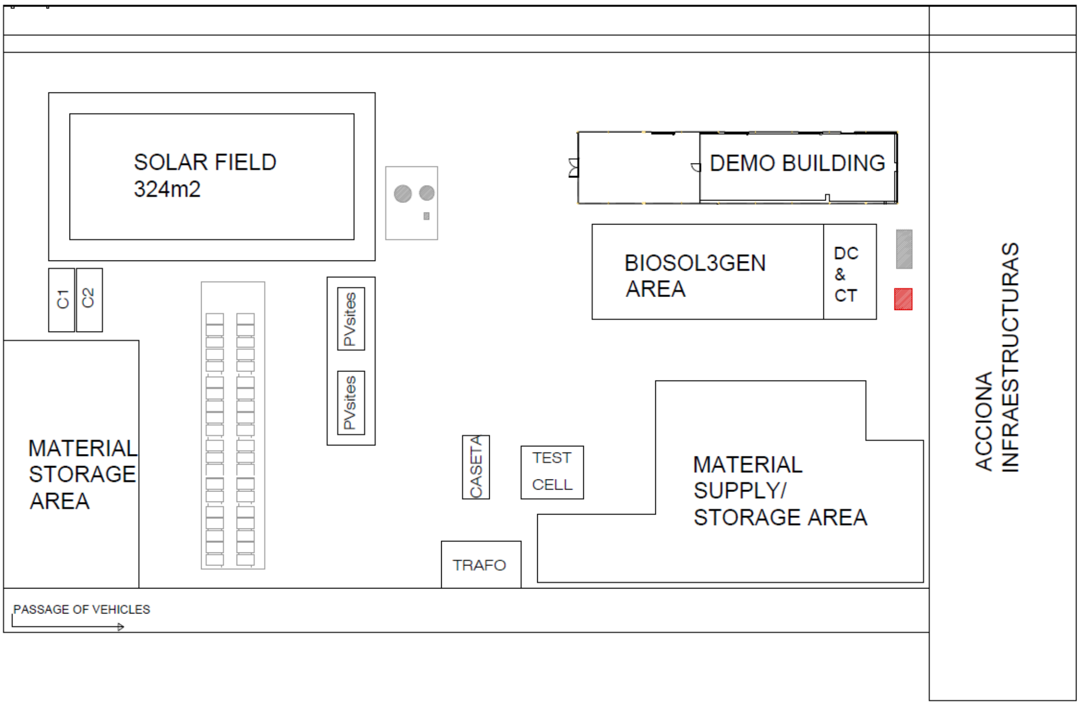


Figure 27: PCM Storage Tank location

<u>Foundation for AHU/Chiller and PCM Storage Tank installation</u>: In order to level the ground and enable an stable and sure support, a layer of gravel is proposed.

2.3.3 Monitoring/Control systems and electric panels location

This section does neither aim to describe in detail the control and monitoring systems or control strategy, nor give a detailed calculation of the different electrical protections and cable sections. This information is available in the deliverables 4.3 and 4.4. All the electrical calculations have been done according to Spanish regulation "Reglamento electrotécnio de baja tension (REBT)". A brief explanation of the system and its integration with the demo site of Seville will be described in this section.

A schema of the global control system is showed in the image below:

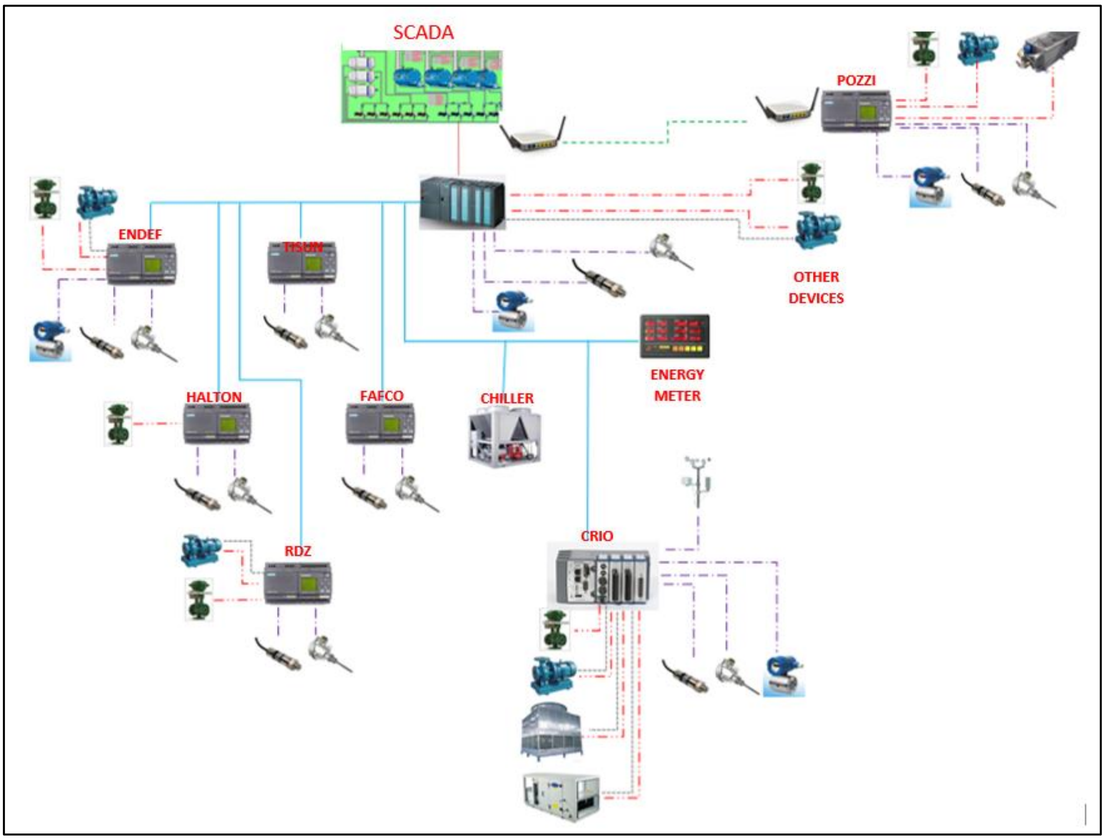


Figure 28: LowUP control system schematic diagram

As can be observed in the image, some systems (Endef, Fafco…) are controlled by a proprietary PLC. These PLCs send and receive information from the main PLC. This main PLC is known as Front-End PLC, and is directly connected with the SCADA software. The SCADA is the graphical interface, that allows the user to interact with the installation. Through the SCADA, the user is able to take some decisions as vary some comfort parameters, or visualize the current state or trends of some variables.

The PLCs will be located, together with the electrical protections, in some electric panels. More specifically, the LowUP installation in the demo site of Seville, will be composed by two main electric panels, both of them feeding by an electric panel already installed in Acciona I+D facilities. The PLCs will be distributed in these electric panels. However, some of the systems (Fafco, Borealis and Endef systems), have their own electric panel, and will integrate their own PLC in them. It is similar for the already installed systems -cooling tower (CT) and drycooler (DC)-. In these cases, these proprietary electric panels, only need to be energy supplied from the main electric panels.

The control installation will be completed with two PCs that host the SCADA software and the database.

All these components (electric panels and hosts) will be located in the following drawing:

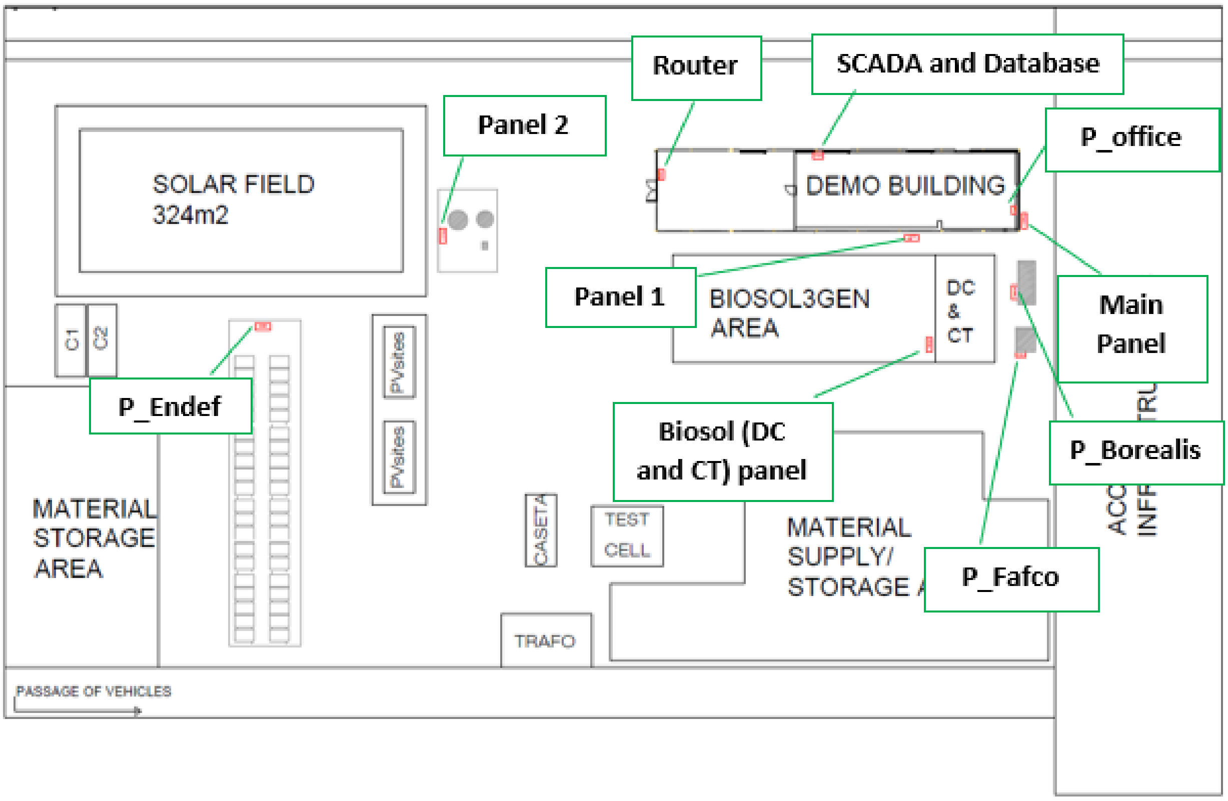


Figure 29: Electric panels distribution

Attending to the naming of the picture, "Main Panel" is the electric panel already installed, which supplies energy to the two main panels (which will be installed for LowUP project) Panel 1 and Panel 2 and to the panel located in the office, P_office. These three electric panels, will provide energy to the set of systems and to the demo building. On the other hand, the PLCs will be distributed in the following way:

Panel 1: $PLC_{FRONT-END}$, PLC_{HALTON}, PLC_{RDZ}

Panel 2: PLC_{TISUN}

P_Borealis: $PLC_{BOREALIS}$

P_Fafco: PLC_{FAFCO}

P_Endef: PLC_{ENDEF}

Biosol: PLC_{DC}, PLC_{CT}

2.4 Engineering works to fulfil systems requirements

This section aims to analyse the previous engineering works before the systems installation. The sizing of the equipment is already done by manufacturer in collaboration with Acciona and Cartif, taking into account the project requirements and the energy baseline studies performed in deliverables 2.1 and 2.2.

2.4.1 Heat LowUP systems.

<u>Hybrid PVT Solar field:</u>

The solar field is composed by a set of solar panels. All these panels are connected through a piping system, with its respective water pump and monitoring systems. The final layout proposed by the manufacturer is showed as follows:

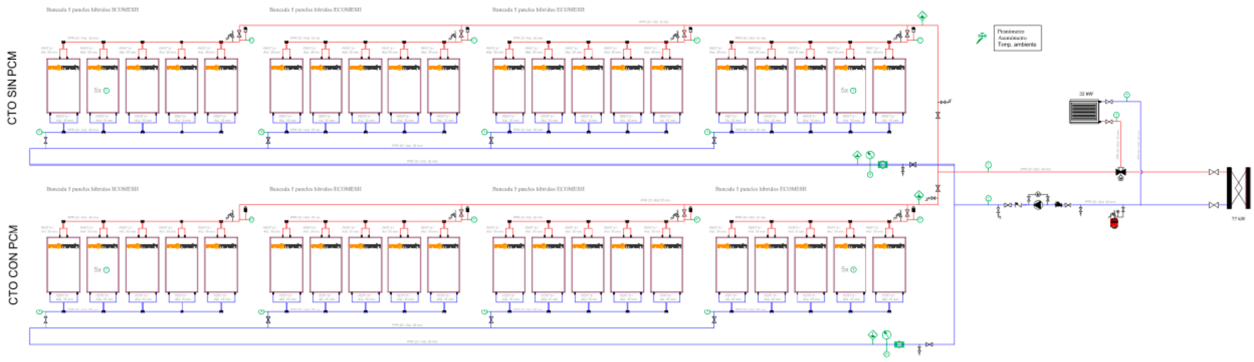


Figure 30: PV system layout

Engineering works: The pipe diameter selection and the sizing of the auxiliary devices.

<u>Radiant floor:</u>

The radiant floor consists of a pipeline system, which distributes the hot water through all the building floor. The heat transfer between the room and the water is produced by radiant heat transfer mechanism. So, the layout of this system must be adapted to floor dimensions. The final layout proposed by the manufacturer could be observed in the image below:

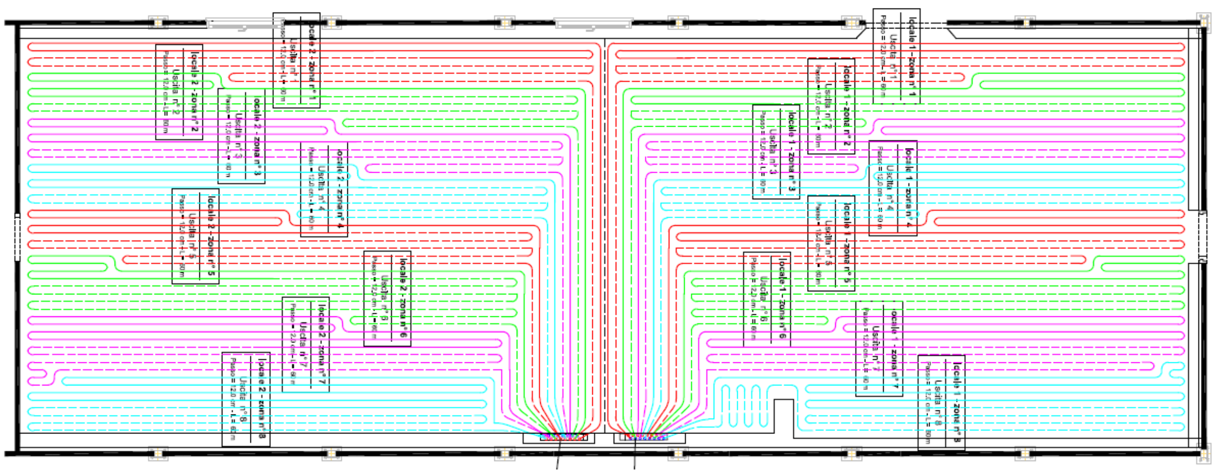


Figure 31: Radiant floor layout

Engineering works: The pipe diameter selection and the sizing of the auxiliary devices.

Hydraulic connections between systems and auxiliary devices selection:

All the systems that form the Heat-LowUP installation must be properly connected, attending the specific requirements of the layout, following the local regulations.

Engineering works: The pipe diameter selection and the sizing of the auxiliary devices. All the calculations can be consulted in deliverables 4.3.

2.4.2 Cool LowUP systems.

Chilled beams:

The chilled beams are the systems whose purpose is the distribution of the cold air around the building in order to reach the comfort humidity and temperature. The Cool-LowUP system is composed by 11 chilled beams, distributed as follows: 8 chilled beams in the office area and 3 chilled beams in the warehouse area.

Each chilled beam has two u-shaped anchoring points, as it is showed in the image below:

Figure 32: Chilled beam anchoring points detail

Some previous requirements must be taking into consideration before deciding the chilled beams final placement:

- Optimal air flow distribution.
- Spaces requirements to ducts and pipes installation.
- The beams position respect to roof girders.

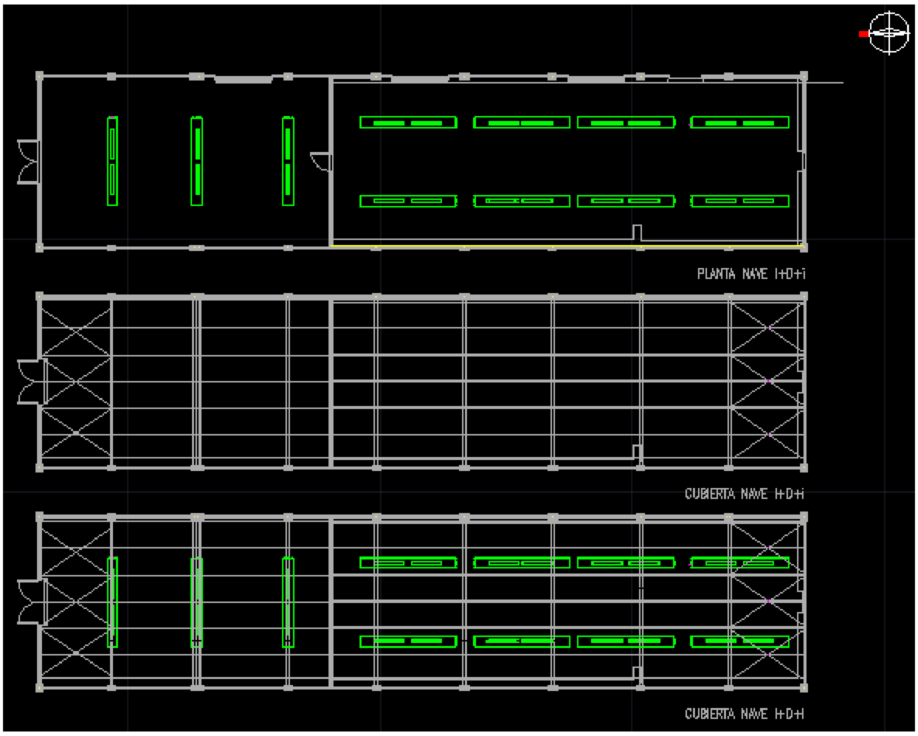


Figure 33: Chilled beams final placement

Engineering works: Analysis of loads involved to ensure that the structure can support the weight of the chilled beams.

Hydraulic connections between systems and auxiliary devices selection:

All the systems that form the Cool-LowUP installation must be properly connected, attending the specific requirements of the layout. The Figure 12 shows the layout of the Cool-LowUP system, with the pipeline network and auxiliary devices configuration.

Engineering works: The pipe diameter selection and the sizing of the auxiliary devices, following local regulation. All the calculations can be consulted in deliverables 4.4.

Ventilation air ducts connections between systems:

To distribute the air from the AHU to the chilled beams, it is necessary a duct connection between these systems. Because the chilled beams and the AHU/chiller are placed inside and outside the building respectively, it arises the requirements of opening several holes in the building wall, so that, the supply duct and the return duct can pass through these. The Figure 12 shows the layout of the Cool-LowUP system, with the duct network configuration.

Engineering works: Duct diameter selection, according to local regulation. All the calculations can be consulted in deliverable 4.4.

2.5 Systems adaptation

This section aims to describe the integration of the already installed systems: Cooling Tower and Drycooler. These systems were installed as a result of previous projects in which Acciona was involved.

2.5.1 Cooling Tower

The Cooling Tower is the system whose main objective is to cool the water, that has previously used to dissipate the heat of the refrigerant in the chiller condenser. In some specific meteorological conditions, the cool water produced by the cooling tower could be used to supply directly the chilled beams.

Some pictures of this system are showed as follows:

Figure 34: Cooling Tower

The cooling tower has a pipeline system already installed in the BIOSOL3GEN building (it could be located in Figure 21, as BIOSOL3GEN area). To integrate this system to the Cool-LowUP system, some adaptations must be done in pipeline network. Next images show the pipeline network already installed and the points of this system, where the new connections will have to be done:

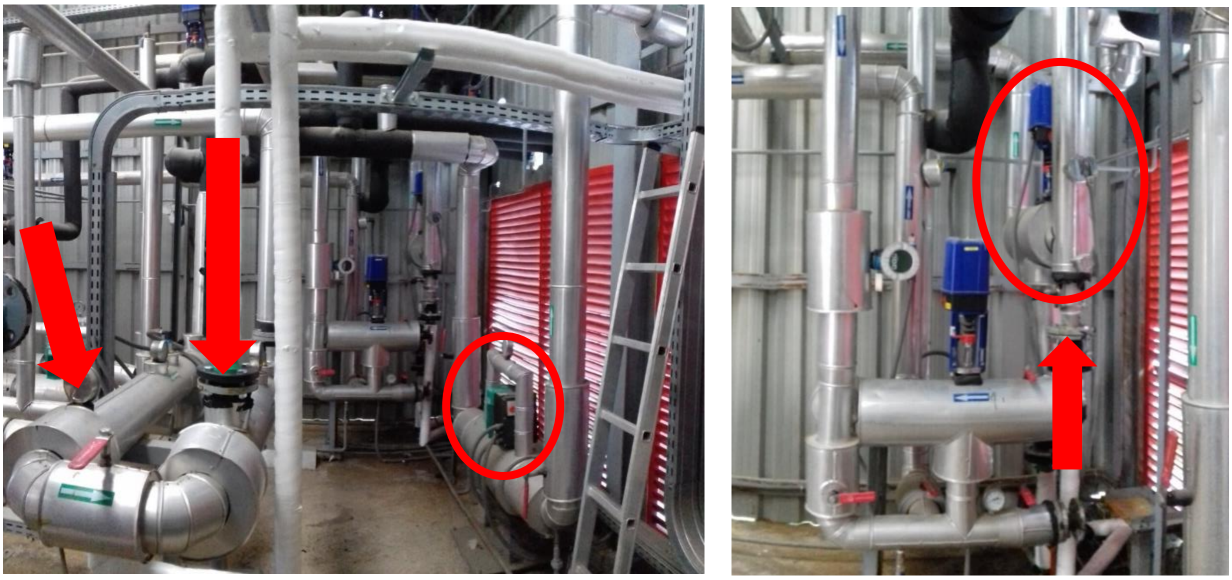


Figure 35: Cooling Tower pipeline network

In the same way, a control system is already installed, and only have to be reprogrammed to fulfil the requirements of the new global system control strategy. The Drycooler, whose images and state will be revised in next section, shares this control system with the Cooling Tower:

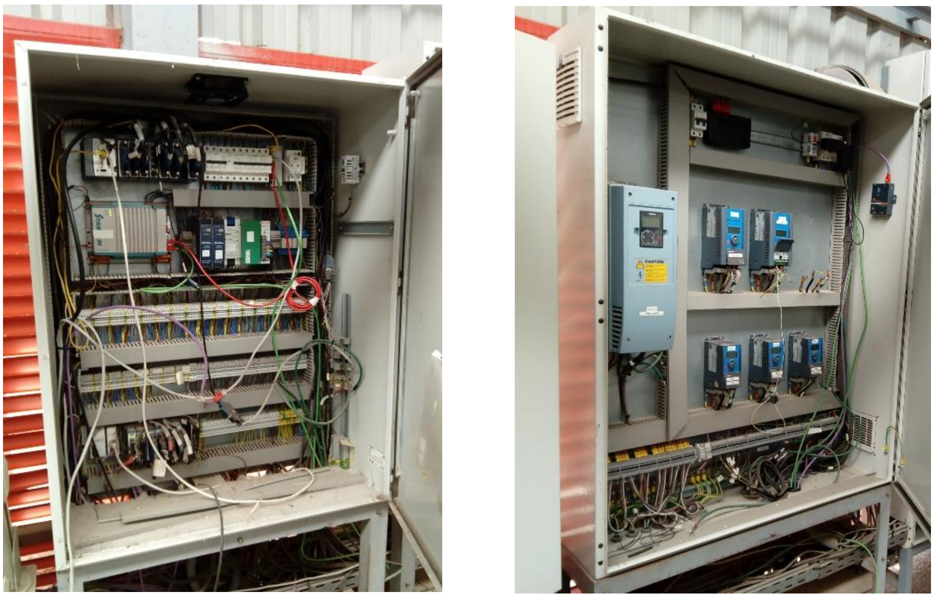


Figure 36: Old control system of Cooling Tower and Drycooler

2.5.2 Drycooler

The Cooling Tower is the system whose main objective is to dissipate the energy produced in excess through the solar field and the thermal emulator.

Some pictures of this system are showed as follows:

Figure 37: Drycooler

The Drycooler, similar to Cooling Tower, has a pipeline system already installed in BIOSOL3GEN building. To integrate this system to the Heat-LowUP system, some adaptations must be done in pipeline network. Next images show the pipeline network already installed:

Figure 38: Drycooler pipeline network

2.6 Installation plan for Seville demo site

This section aims to propose a timetable, collecting all the activities related to engineering and preparatory works, analysed in previous sections, and the installation and the commissioning of the systems.

Table 3: Installation plan – Seville demo

Act.	Work to be executed	Description of activities	Partners involved
1	Office/Warehouse retrofitting	- Remove old roof and installation of new roof with 3 skylights panels - Floor conditioning - New windows - Building envelope adaptation - New wall to divide office and warehouse - Toilets removed - Painting	- Acciona - Local installers - RDZ - Halton
2	Foundation for PVT installation	- Conditioning of current floor - Foundation installation	- Acciona - Local installers
3	Foundation for stratified thermal storage installation	- Conditioning of current floor - Foundation installation	- Acciona - Local installers
4	Open spaces conditioning: Layer of gravel	- Conditioning of current floor	- Acciona - Local installers
5	Engineering works	- Sizing duct and pipe networks - Auxiliary devices selection - Load analysis - Layouts	- Acciona - Cartif - Endef - Halton - RDZ
6	Manufacturing and delivery of products	- Sizing of equipment - Manufacturing - Delivery	- Endef - RDZ - Clivet - Fafco - Borealis - Halton
7	Systems installation	- Installation of each system, following the manufacturer instructions	- Acciona - Local installers - Endef
8	Systems connections	- Installation of airduct and water pipe network, auxiliary devices, electrical connections and monitoring systems.	- Acciona - Local installers
9	System commissioning	- Startup of each system (Cool LowUP and Heat LowUP).	- Acciona - Endef - RDZ - Clivet - Fafco - Borealis - Halton

Table 4: Installation plan – Seville demo – Timetable

Pilot Office Building	jun-17	jul-17	ago-17	sep-17	oct-17	nov-17	dic-17	ene-18	feb-18	mar-18	abr-18	may-18	jun-18	jul-18	ago-18	sep-18
Civil Works for retrofitting of former warehouse	X	X	X	X												
Open Spaces adaptation						X	X									
Engineering and Pre-Installation of products							X	X	X							
Integration Engineering of LowUP systems in Demo Sites									X	X	X	X	X	X	X	X
Manufacturing and delivery of products																
Chilled Beams (Halton)											X					
Chiller/AHU											X	X	X			
PCM Tank (Fafco)													X			
Radiant floor (Rdz)												X				
Solar filed (Endef)																X
Heat Pump																
Thermal Emulator																
Stratified Tank																
Implementation of equipment																
Cool System										X	X	X	X	X	X	X
Heat System																
Commissioning of equipment																
Cool System																
Heat System																

Pilot Office Building	oct-18	nov-18	dic-18	ene-19	feb-19	mar-19	abr-19	may-19	jun-19	jul-19	ago-19	sep-19	oct-19	nov-19	dic-19	ene-20
Civil Works for retrofitting of former warehouse																
Open Spaces adaptation																
Engineering and Pre-Installation of products																
Integration Engineering of LowUP systems in Demo Sites																
Manufacturing and delivery of products																
Chilled Beams (Halton)																
Chiller/AHU																
PCM Tank (Fafco)																
Radiant floor (Rdz)																
Solar filed (Endef)																
Heat Pump	X															
Thermal Emulator														X		
Stratified Tank	X															
Implementation of equipment																
Cool System	X	X	X	X	X	X										
Heat System	X	X												X	X	X
Commissioning of equipment																
Cool System												X	X	X	X	
Heat System															X	X

2.7 Risk and contingency plan

In next table, the main risks of the Heat and Cool LowUP systems integration and operation will be defined and characterized, as well as the contingency plan considered to solve each of them.

Table 5: Risk and contingency plan – Seville Demo Site

Risk	Probability	Impact	Contingency Plan
Power cuts or failure	Medium	Medium	Acceptable as long as the power cut is short and not repeated in moderated time
Repetitive power cuts in a short time	Medium	Medium	It could affect the proper operation of the data base and Scada PCs. An uninterruptible power supply (UPS) should be considered.
Network connectivity failures	Medium	Low	Acceptable. All LowUP systems are connected through a local network in Seville demo site.
Local network failures	Low	High	In case of supervisory PLC cannot connect with proprietary PLCs, safety rules shall be implemented in them in order to protect the individual equipment.
Auxiliary systems breakdown	Medium	High	Repairing or replacing the equipment.
Main systems deterioration or damage	Low	High	Preventive maintenance, according to maintenance manual provided by manufacturers.
Failure in monitoring systems	Low	High	Data collected must be reliable. In case of a failure in a monitoring device, it has to be recalibrated or replaced
Water leakages	Medium	Medium	Leakage detection and correction
Drop in water pressure due to water leakages	Medium	Medium	Pressure control through supervisory PLC will lead to emergency stops, in order to avoid systems damage.
Water flows target not reached	Low	Medium	Purge air from water pipes network
Chilled beams. Lack of structural stability	Low	Low	Reinforce the chilled beams structural support
Delay in integration process	High	Medium	Adaptation of test plan

3 Installation plan for Rucab demo building

The Hybrid Waste Heat Recovery (HWHR) system planned in the scope of the LowUP project, is aimed for recovering the heat of liquid or semiliquid effluents, with the special feature of not presenting the disadvantage of clogging or dirtiness such as other convectional heat exchangers.

Within this scenario, the aim was to find a facility with certain heat energy consumption and mainly with a high number of working hours. The potential candidates were the tertiary sector, due to the energy demand and also the frequency of the exploitation of the energy recovery system.

Two candidates were an indoor swimming pool, and a student residence. The swimming pool presented the weakness of not having enough number of hours for getting an energy source for recovering it. Dissimilarly, the residence resulted to have different installations which offer more versatility for adapting the equipment.

3.1 Description of Rucab building before system integration

The residence selected is located in Badajoz, RUCAB, and it has accommodation for 204 students offering service such as canteen, laundry service, and heating system.

Figure 39: Aerial view Rucab demo (Badajoz)

Figure 40: Students residence located in Badajoz (Spain)

Between the different possibilities that the residence offers for hosting the HWHR, the most interesting were the heating system, the kitchen, the waste water from the rooms, the hot water system, and the clothes washing service. The advantages and disadvantages of each possibility are presented below:

- Heating system: The heating system resulted interesting; however, the idea of preheating the inlet water entering in the boiler resulted to be a negligible heat recovery for the amount of power consumed by the boiler. Moreover, the price of the fuel for this system indicated that this system would not offer an affordable change.

- The kitchen: The residence has a big kitchen offering an everyday fresh cooked service, and they are involved in this activity in two shifts. The potential uses could be using the waster warm water (washing a dispatching pots and dishwashers), and recovering the energy as the inlet water in the dishwasher machines.

- The waste warm water from the rooms: this could be obtained mainly from the showers, however the water is collected with the cold water coming from the washbasin and even also with the rain water collected in the roof. Thus, this possibility leaded to a low temperature level, and therefore advising against this choice.

- The laundry service: despite there was specific machines running under electricity, which could deal to a realistic exploitation, the use of this equipment was not presented as frequent. The students can use this service however it was not used often. And this dubiety was undesirable for this demonstrator.

Finally, the actuation was decided to be placed in the kitchen installations, following the scheme in the next figure:

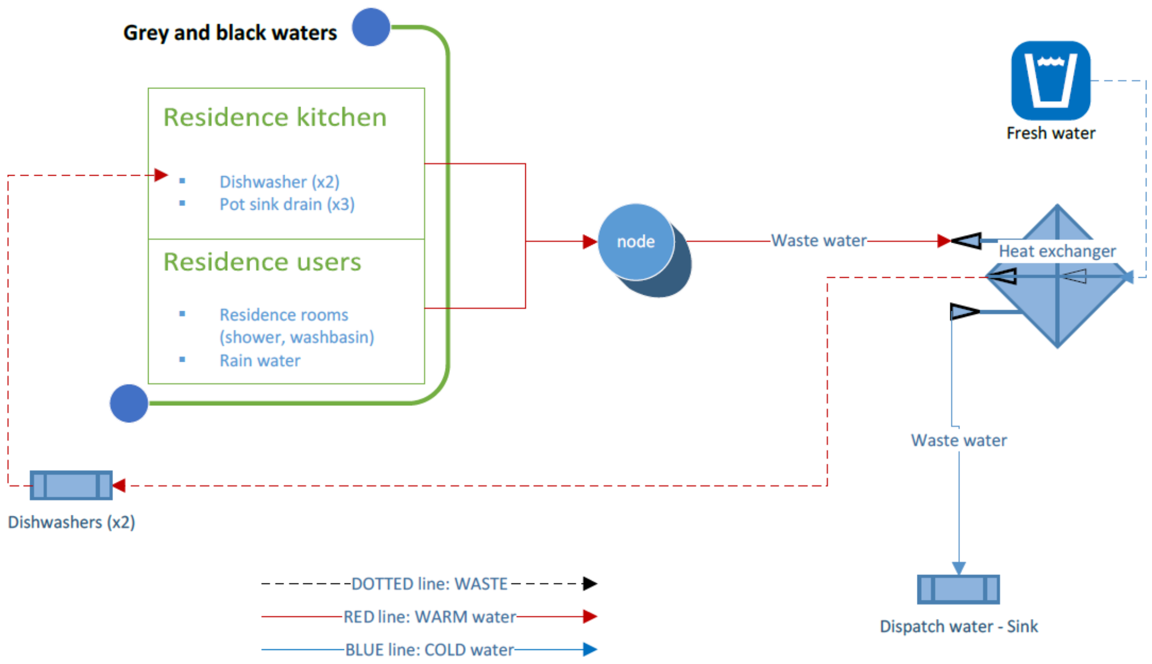


Figure 41: Students Conceptual scheme of the system planned

The kitchen is located in the ground floor, in two separates zones or rooms, while the cooking room is the main room where the sinks are placed, in the annexed room the dishwashers are separated.

In the basement floor are located the drains and the wastepipes, and also there was space enough available for placing the heat recovery tank and the additional accessories.

The actuation will affect some of the devices in the kitchen, the hot water sink, and the dishwasher. In the case of the dishwasher, both the inlet and outlet piping would be modified in the purposed actuation.

In the next figures could be shown the potential approach of the exhaust water from the dishwasher machines, showing a thermal level around 50 ºC.

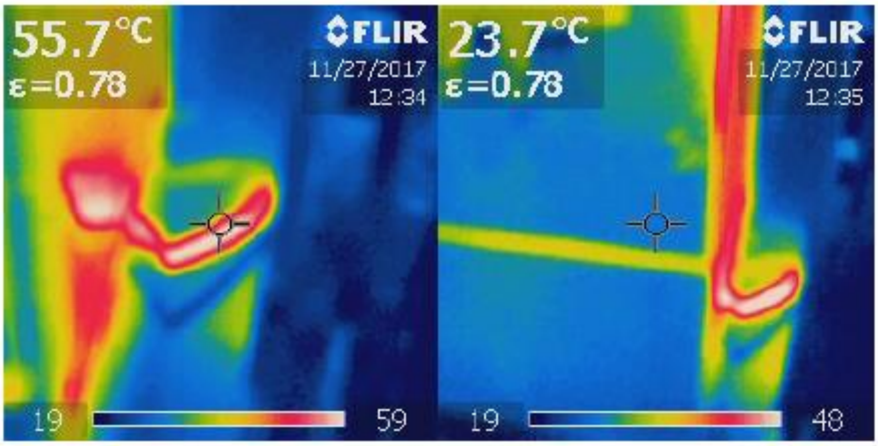


Figure 42: Thermography image of the dishwashers

3.2 Description of Ecowec equipment

The HWHR presents the next items:

- Pump system. Two pumps in cascade offering a backup system, those are suitable for admitting water with certain level of dirtiness, made with plastic parts for a better life cycle.

- Degrease tank. Offering a lower maintenance for the pump system and also the big HWHR tank.

- The HWHR tank, is system based in three circuit without mass transfer. Circuit of dirty water, the clean water, and the third is planned for clean water storage in the tank, not flowing, just filled during the starting-up process.

- The system will be monitored and controlled by a PLC with network setting offering the data storage of the data for further studies.

The main feature of the equipment to be installed is described as follows:

The HWHR Tank

- Electricity consumption: No needs
- Floor area: 0,23 m^2
- Height: 1600 mm
- Weigth: 200kg
- **Special requirements for installing activities:**
  - Available space
  - Additional pump in case that the wastewater is not directed gravitationally downward.

Figure 43: HWHR Tank

The following systems are considered as auxiliary systems. But, due to the lack of space in the Badajoz demo Building, the requirements to install these systems will be show as follows:

Auxiliary devices: Pump system

- Electricity consumption: 1.8 kW
- Weight: 119 kg
- Height:0,55 m
- Length: 0,72 m
- Width: 0,868 m
- **Special requirements for installing activities:**
  - Available space

Figure 44: Pump system

Auxiliary devices: Degrease Tank

- Electricity consumption: No needs
- Height:140
- Length: 110
- Width: 65
- **Special requirements for installing activities:**
  - Available space

Figure 45: Degrease Tank

The process design scheme is showed in the Figure 46, following the next concepts:

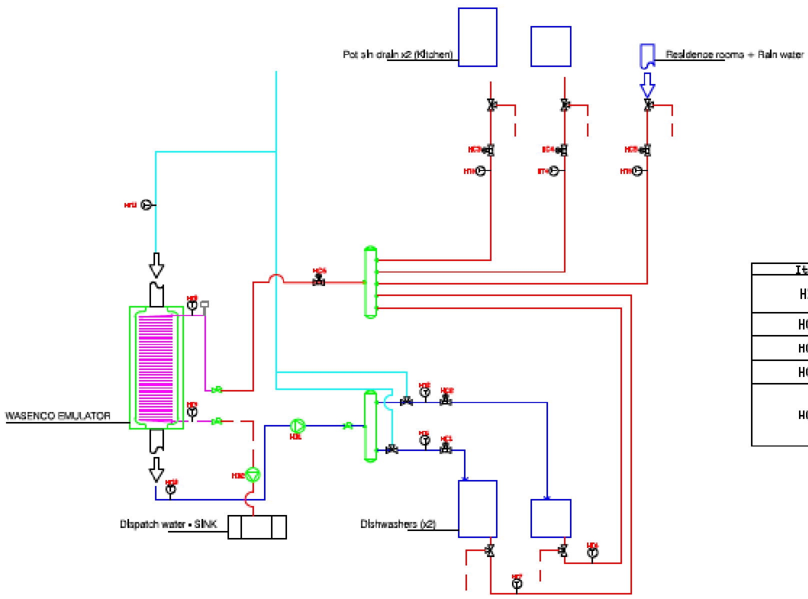
- The dispatched water was flowing through the sink drain, the residence rooms, and also the dishwasher, with the category of dirty water (red lines).

- The dirty water will flow to the HWHR system and there the heat could be recovered.

- The fresh cold water (light blue), is entering in the HWHR and also could feed the dishwasher, in case of a selected by-passing pipe setup.

- The fresh and clean water leaving the HWHR will be preheated and then will feed the dishwasher. (Dark blue)

- The dirty water, once exhausted was dispatched to the general sink (dashed red line).



Item	Optional Items; Reason
HB1	Only if pressure service pressure is nor enough
HC3	Potential problem, dirty water
HC4	Potential problem, dirty water
HC5	Potential problem, dirty water
HC6	Potential problem, dirty water. Reccomended for balance in the exchanger

Figure 46: P&ID Scheme design for a thermal recovery

3.3 Preparation works for ECOWEC demonstration

In this section all the preliminary works needed to implement the ECOWEC system in Badajoz demo site will be describe in detail.

3.3.1 Pre-assembling in Wasenco's facilities

Wasenco, as manufacturer, has carried out the pre-assembling of the system in its facilities of Finland, to test it and check that the integration of systems works in a proper way. The following images show the pre-assembling stage:

Figure 47: Pre-assembling stage in Finland

3.3.2 Rucab building

The objective was to act in the current installation according to the requirements of Wasenco, for having the piping connections ready to the final purpose. The main aim is to accomplish the invasive actuations during non-academic period, Christmas holydays, for avoiding possible interruption in the kitchen and cleaning service. Next drawing shows a kitchen plan, where appears the different sources of waste heat considered in this installation:

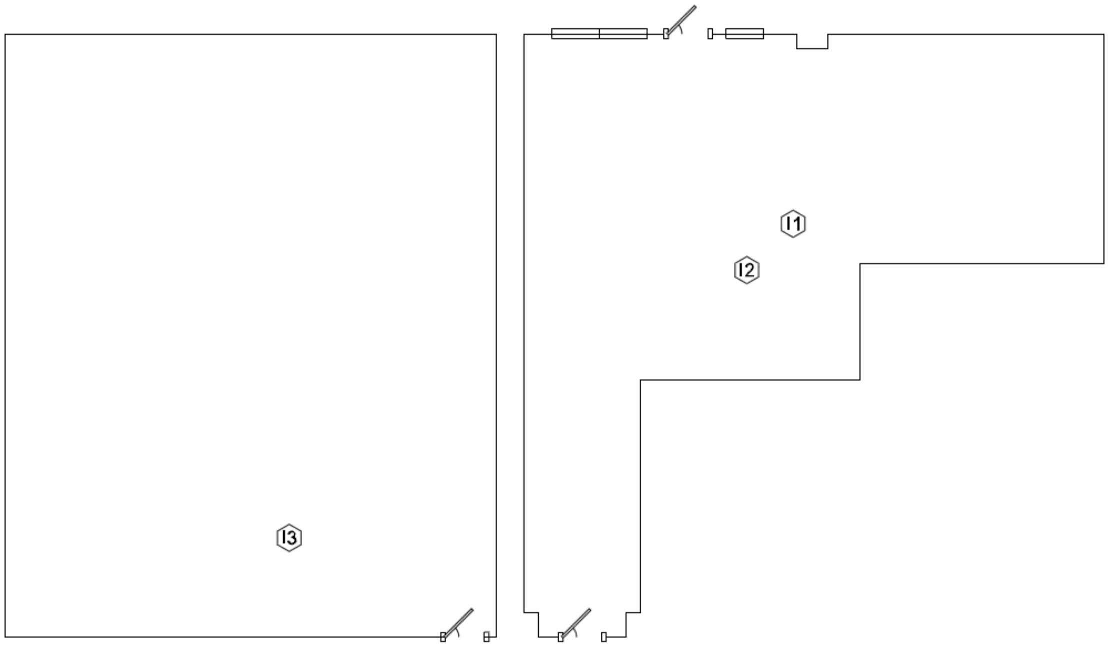


Figure 48: Kitchen plan and heat sources location

Item 1 and 2: Sink 1 and 2 from the kitchen.
Item 3: Dispatched water line from the dishwashers.


Figure 49: Dishwashers pictures

The system will be placed under the ground floor, at the same level of the kitchen, making some minor changes to the pipes to re-arrange the final positions of the flanges.

Figure 50: Current state of pipe system

3.3.3 Monitoring/Control systems

The control system will consist of: an embedded pc, a PLC, a router, all the required sensors and some electric consumption meters. These elements will be integrated in an electric panel, together with the electric protections. The energy supply will come from an already installed electric panel, located in the laundry room (see image).

Figure 51: Current electric panel, located in the laundry room

The PC will store all the data registered by the sensors. This data will be used as inputs to simulate the energy waste produced by the thermal emulator in the demo site of Seville.

3.3.4 Engineering previous works

In order to have a previous estimation of the potential impact of the installation, a monitoring process was accomplished in the receptors (dishwashers), measuring the energy demand.

These measures were carried out using a power Logger manufactured by Fluke, model 1736 equipped with Firmware Version: 2.1 and DSP Version: 2.6. with claps iFlex1500-12.

Figure 52: Power logger: Fluke model 1736

3.4 Installation plan for Rucab building

This section aims to propose a timetable, collecting all the activities related to engineering and preparatory works, analysed in previous sections, and the installation and the commissioning of the systems.

Table 6: Installation plan – Rucab demo

Act.	Work to be executed	Description of activities	Partners involved
1	Pre-monitoring Definition	- Analysis of most adequate waste energy sources in Rucab facilities.	- Acciona - Local installers
2	Engineering works	- Previous works to analyses the expected outcomes - System integration diagrams	- Acciona - Wasenco - Local installers
3	Manufacturing and delivery of products	- Manufacturing the different systems. - Pre-assembling and testing in Wasenco facilities	- Wasenco
4	Water pipe network adaptation	- Adaptation of current pipeline network to the requirements of the new system	- Acciona - Wasenco - Local installers
5	System installation	- System installation an integration in Rucab facilities.	- Acciona - Wasenco - Local installers
6	Commissioning	- Startup of the global system and monitoring system	- Acciona - Wasenco - Local installers

Table 7: Installation plan – Rucab demo – Timetable

2.Buiding Sewage heat recovery	jun-17	jul-17	ago-17	sep-17	oct-17	nov-17	dic-17	ene-18	feb-18	mar-18	abr-18	may-18	jun-18	jul-18	ago-18	sep-18	oct-18	nov-18
Pre-monitoring definition				X	X													
Engineering works					X	X	X											
Manufacturing and delivery of products							X	X	X	X	X							
Water pipe network adaptation										X	X							
System installation											X	X	X					
Commissioning													X	X	X			

3.4.1 Risks and contingency plans

In next table, the main risks of the Heat Recovery System integration and operation will be defined and characterized, as well as the contingency plan considered to solve each of them.

Table 8: Risk and contingency plan – Badajoz demo site

Risk	Probability	Impact	Contingency Plan
Power cuts or failure	Medium	Medium	Acceptable as long as the power cut is short and not repeated in moderated time. Maintenance staff will play a role in case of the general switch of the Heat Recovery System electrical cabinet keep down after power supply restoring.
Network connectivity failures	Medium	Medium	Acceptable. In case of a failure in the 3G connection, data will be collected in a local data base.
Auxiliary systems breakdown	Medium	High	Repairing or replacing the equipment.
Main systems deterioration or damage	Low	High	Preventive maintenance, according to maintenance manual provided by manufacturers.
Failure in monitoring systems	Low	High	Data collected must be reliable. In case of a failure in a monitoring device, it has to be recalibrated or replaced
Water leakages	Medium	Medium	Leakage detection and correction
Water flows target not reached	Low	Medium	Purge air from water pipes network
Delay in integration process	High	Medium	Adaptation of test plan
Degrease Tank overflowed	Medium	Low	Periodic maintenance in order to avoid the overflowing of the degrease tank.

Conclusion

This deliverable gives a full description of the sites where Cool and Heat LowUP technologies will be installed and tested: the thermal lab of ACCIONA in Seville and the students' residence of Badajoz (Rucab). The demo site in Seville will host the Cool-LowUP and Heat-LowUP installations, while the demo site in Badajoz will host the Waste Heat Recovery System, which are related to the Heat LowUP system.

All the equipment has been described in detail, explaining the main features and requirements of each one. Regarding these requirements, some previous works to adapt the demo sites have been proposed. These works are mainly: building refurbishment, ground conditioning, systems integration and previous engineering studies.

Finally, a detailed plan is presented, with a summary of all tasks involved in the demo sites adaptation and systems integration. A schedule is also proposed, in order to have a fully descripted plan to be accomplished in next months. A risk and contingency plan complement this information.

Bibliography

[I] Reglamento de Instalaciones Térmicas en los Edificios (RITE).

[II] Código Técnico de la Edificación (CTE).

[III] Reglamento Electrotécnico para Baja Tensión (REBT).