Low valued energy sources UPgrading for buildings and industry uses

LowUP relevant environment 1

Deliverable D4.9

Lead Beneficiary: ACCIONA
December/2019

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http://www.lowup-h2020.eu

The LowUP project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement n°723930.

Document Information

Grant Agreement:	723930
Project Title:	Low valued energy sources UPgrading for buildings and industry uses
Project Acronym:	LowUP
Project Start Date:	1 November 2016
Related work package:	WP 4: Installation, operation and validation in a relevant environment
Related task(s):	Task 4.3: Implementation at relevant environment
Lead Organisation:	Acciona
Submission date:	April 2020
Dissemination Level:	Public

History

Date	Submitted by	Reviewed by	Version (Notes)
25/03/2020	Carlos Ramos	Silvio Vitali	v0_First full draft
27/03/2020	Carlos Ramos	Silvio Vitali	v1_Revised version of contents
30/03/2020	Carlos Ramos	Silvio Vitali	v2_Final version

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 to give an overview of the results from the implementation process of HP-LowUP technologies at different demo sites, which compose the "relevant environment 2". Following the integration plan defined in the deliverable 4.2, integration activities have taken place down the supervision of the site owner and direction of the consortium, according to indications from LowUP technologies manufacturers.

HP-LowUP technologies have been installed in three test sites: one HReX at pulp and paper factory in Setubal (Portugal), another HReX at the wastewater treatment plant in Madrid (Spain), and the HP at the thermal lab of Tecnalia in Gipuzkoa (Spain). The target was the integration with already installed technologies and so minimizing the investment for the execution.

The test sites of Madrid and Setubal have hosted the technology developed by Pozzi, and the thermal lab of Tecnalia has hosted the technology developed by GEA. A summary of the integration process and all the modifications at electric, control and plumbing levels, carried out in these demo sites are presented in this document.

Minimizing the occupied surfaces and modifications of the existing settings has been the main purposes of this Task 4.3, which allows a minimal impact in the normal activities of the site owners.

Keywords

Installation procedure, space conditioning, highly efficient heat pump installation, heat recovery system, sludge

1 Introduction

The HP-LowUP concept is based on an effective and reliable heat pump-based system, 100% thermal powered by residual and rejected low-temperature energy sources (below 45ºC), for application at industrial processes with temperatures up to 80 ºC. This temperature upgrading solution is based on the combination of heat recovery technologies, from low valued energy sources like rejected and process waste heat (20-45ºC), with high efficiency-high temperature water-to-water heat pump for the production of process heat between 55-80ºC.

As shown from Figure 1, HP-LowUP system is composed of the following technologies:

- A sludge/wastewater-to-water (or alternatively a water-to-sludge/process water heat exchangers) that could be used as a heat recovery system (or as a heat delivery system).
- High efficiency electrically driven heat pump.

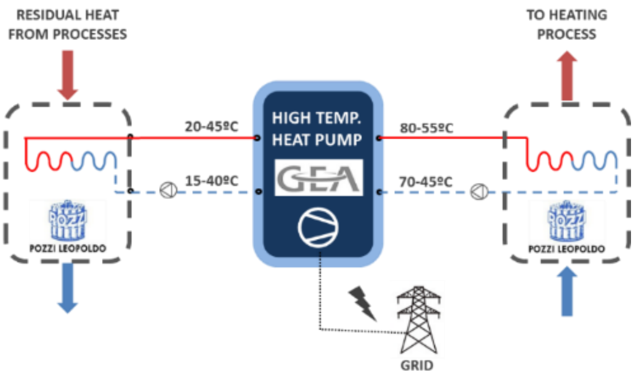

Figure 1. HP-LowUP concept

These systems will be characterized and operated independently. In a second step, they will be integrated into a virtual environment, based on simulation, in order to test them working jointly.

As demonstrator deliverable, this document aims to describe the installation process carried out in the test sites that have hosted the technologies: Madrid, Setubal and Gipuzkoa:

Figure 2: Test sites description

2 Madrid Demo Site

2.1 Description of the test site

The installation of part of HP-LowUP technologies has taken place in the EDAR Arroyo Culebro Cuenca Baja, located in Getafe (Madrid). The system selected is the Heat recovery and is integrated into the area of the biodigestion reactors, in order to recover the remaining low exergy heat contained in the sludge after the anaerobic digestion.

The following images show the water treatment plant and the digestion reactors area:

Figure 3: EDAR Arroyo Culebro Cuenca Baja and digestion reactors area

The sewage water produced in the wastewater treatment plant, products from the primary and secondary treatments, requires to be treated to reduce the organic suspended component. Anaerobic digestion is a proven technology for sewage sludge treatment because it allows a high reduction of the organic matter in the sludge.

The sewage water is continuously pumped into the anaerobic stirred tank reactors, where digestion takes place, usually at mesophilic temperature (35 – 39 °C).

After the anaerobic digestion, the digested sludge is released at a constant temperature around 35°C to be dewatered. At this point, the remaining low exergy heat contained in the sludge, which hasn't any application with actual technologies, can be recovered through the Heat Recovery System developed by Pozzi.

2.2 Integration concept

This section aims to describe in detail the system installed in Madrid, setting out the requirements necessary for proper integration at the wastewater treatment plant.

The main idea of the design was to develop a plug&play system able to be installed in the demo with minimum impact for the existing productive setting and reduced time of implementation. As a consequence, the system had to present characteristics of reduced space, reduced number of connections (piping, electricity, control), quick installation, and remote supervision.

On the other hand, the impact on physical components of the plant should not affect the regular activities of operation and maintenance; furthermore, the installation must return to original conditions after the end of the project.

The identified point of connection is eating the outlet of the digester, before the effluent arrives at another tank for separation, by gravity, of the water from activated sludge. At this point, the fluid still has the sludge component, to test the self-cleaning feature of the RHwX, and a useful (for HP LowUP concept) temperature for testing the efficiency in heat transmission.

A concept scheme of the installation is presented in the following drawing:

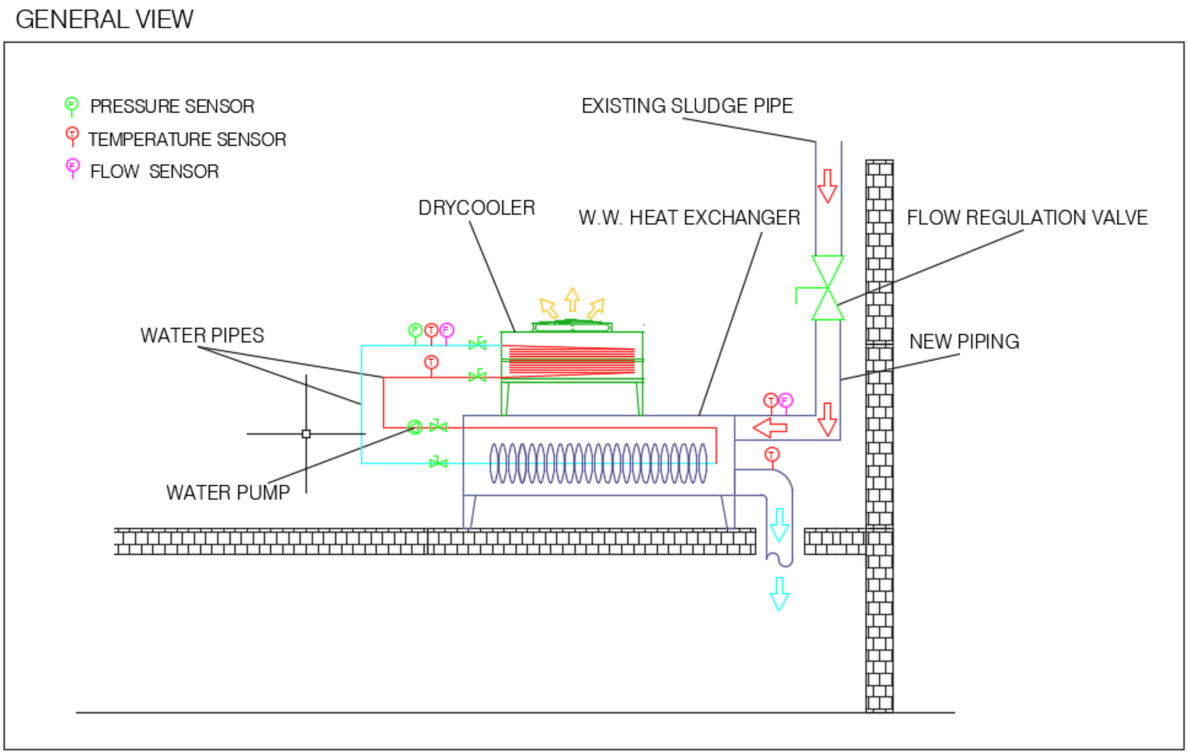

Figure 4. Madrid Demo Site P&ID diagram

The system is composed of five main devices (they can be identified in the images above):

- Heat recovery unit: RHeX (30 kW) manufactured by Pozzi
- Heat rejection unit: Dry cooler EA65 (35 kW) from Stulztecnivel
- Circulating device: Water pump Model EL 50-160 (0,75 kW) from Ebara
- Circulating piping: in stainless steel
- Electric cabinet: including power supply, local controller and remote communication devices

The technology specifically developed in the frame of the LowUP project, and installed in Madrid, is the RHeX heat recovery unit. The rest of the systems are auxiliaries necessary for the pug&play integration with the plant, considering the requirement of testing, whose function is the circulation of clean water and dissipation of recovered heat.

The result of the integration of the above-presented equipment is the final skid showed in the following figure:

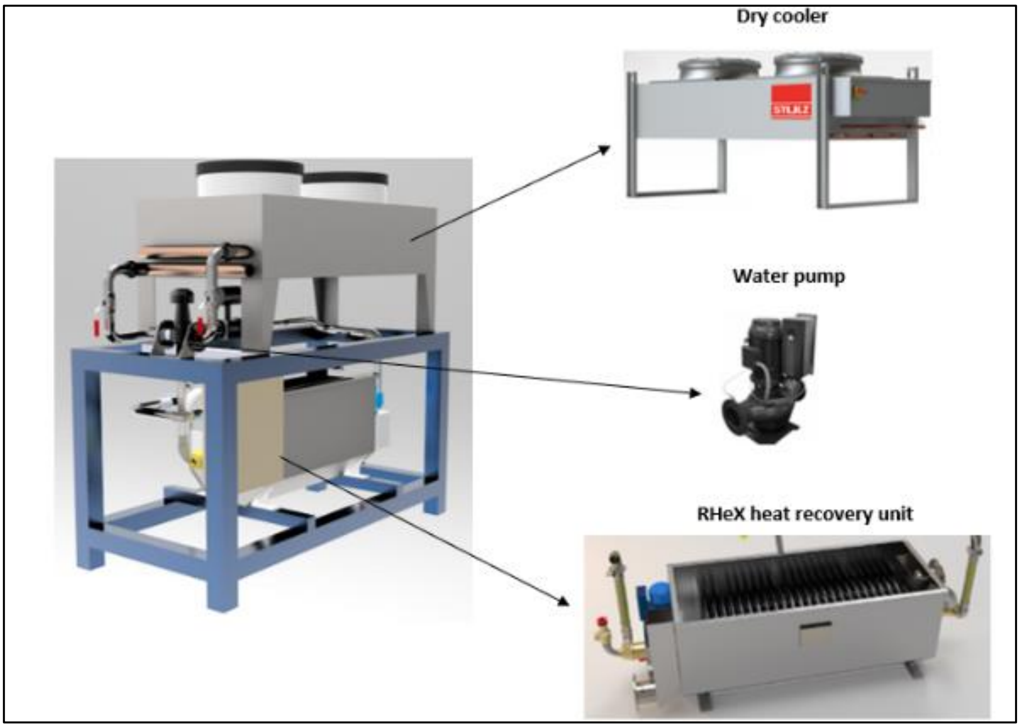

Figure 5: skid for heat recovery and rejection

The skid is able to operate autonomously from remote, thanks to the automation system developed in within the project, recovering heat from the effluent (water + sludge) and rejecting it into the air. Data from operation monitoring are gathered and stored locally for later transmission via the Internet to LowUP database. Remote and local control are both available.

2.3 Components of the plug&play heat recovery system (skid)

Because of the limited impact required for the demo, the main integration activity was focused on the skid, in order to limit piping and cables along with WTTP settings. In this section, all components are described.

2.3.1 Rotating Heater exchanger

The RHxE unit consists of:

- One rotating heat exchanging element made of AISI 316L stainless steel.
- One external tank with a protection lid with the overflow pipe and tank emptying valve.
- Two or more sealing groups and support assemblies to allow the rotation of the rotor
- Rotating joints for freshwater inlet and outlet connected to the rotor.
- One safety valve on the freshwater circuit.
- One motor group consisting of one or two moto-reducers with pulleys and toothed belts.
- One inverter for the rotational speed of the machine and of the start-stop ramps.

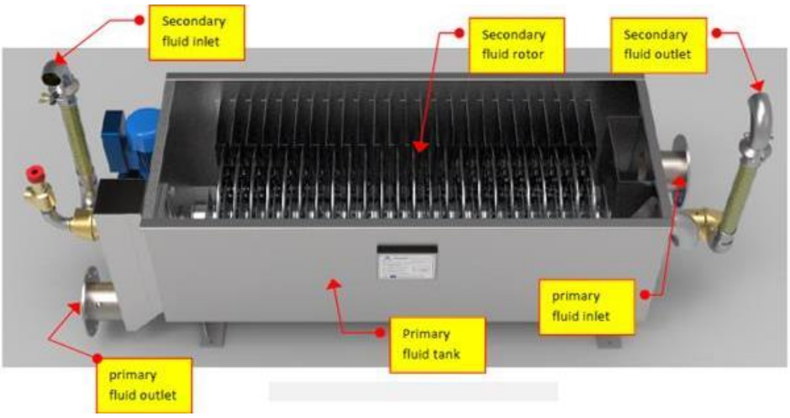

Figure 6. RHeX working principle

Next image shows the heater exchanger installed in the skid at Madrid installation.

Figure 7. Heater exchanger integrated into the skid

2.3.2 Dry cooler

Its main function is the dissipation of the heat recovered by the RHeX.

- Thermal capacity = 35 kW
- Electric consumption = 1.9 kW

Next images how dry cooler is integrated into the upper part of the skid:

Figure 8. Dry cooler at Madrid WWTP

2.3.3 Water pump

The water pump is in charge of the circulation of recovered heat working fluid. This pump flows the water between heater exchanger and dry cooler at regulable speed.

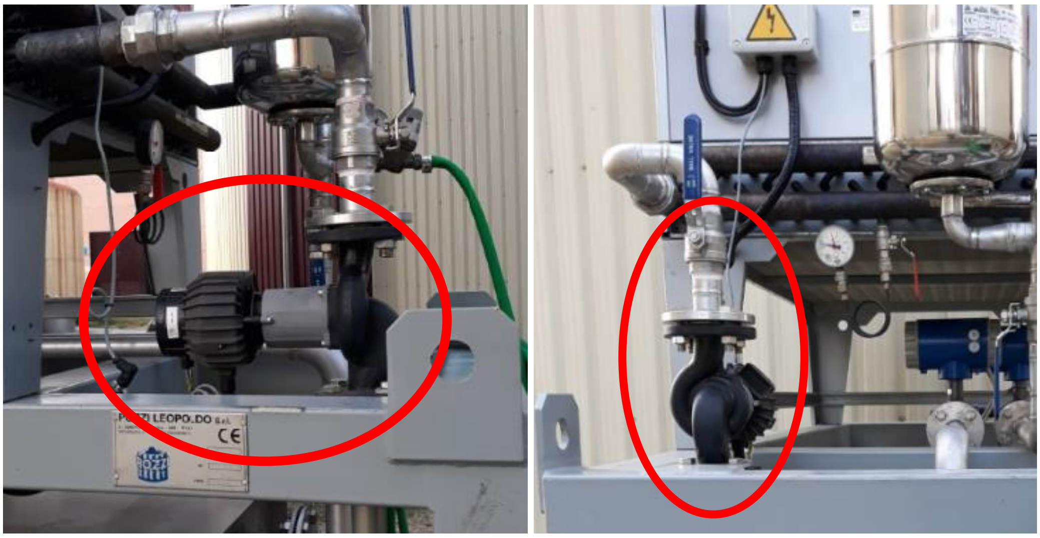

Figure 9. Inline Water pump

2.3.4 Monitoring components

Other important parts of the installation are the components for controlling and monitoring distributed over the skid. In the following image, the temperature sensors which are installed in water pipes.

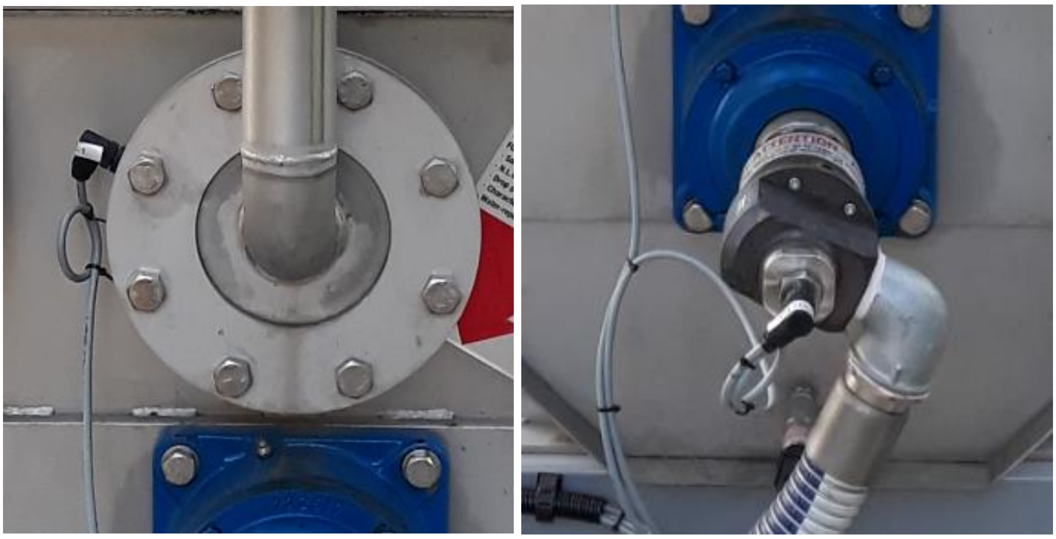

Figure 10. Temperature sensor

In the following image, the detail of flowmeter for detection of instant flow for sludge and clean water.

Figure 11. Flowmeter installed

The proprietary plc is in charge of: gathering data from distributed sensors, apply control strategies for the operation of the entire skid, regulation of individual devices.

The plc communicates via Ethernet with an embedded pc where monitored data can be stored, before transmission to a remote database. On the other hand, plc receive commands from the pc in case of remote manual operation, when the automatic operation is by-passed.

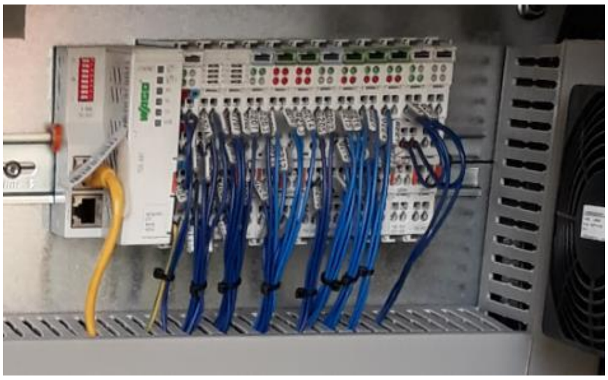

Figure 12. Plc with Inputs/Outputs signals modules

Remote communication and control are achieved with an embedded pc connected via 3G to remote LowUP control station (in Seville); a basic SCADA is present in the pc, for direct communication with plc.

Next image shows the embedded pc installed inside of the electrical cabinet with router 3G:

Figure 13. Embedded pc (left) and 3G router (right)

2.3.5 Control cabinet

The control cabinet is used to supply power to all components of the skid but is also used to control all equipment, to communicate with remote and to monitor operation variables. Components inside of the cabinet are listed below, presented and identified in the next figure:

1. Electrical protections
2. Plc + Inputs/Outputs modules
3. DC Power supply
4. Contactors for controlling
5. Frequency regulator for dry cooler fan
6. Router
7. Embedded pc

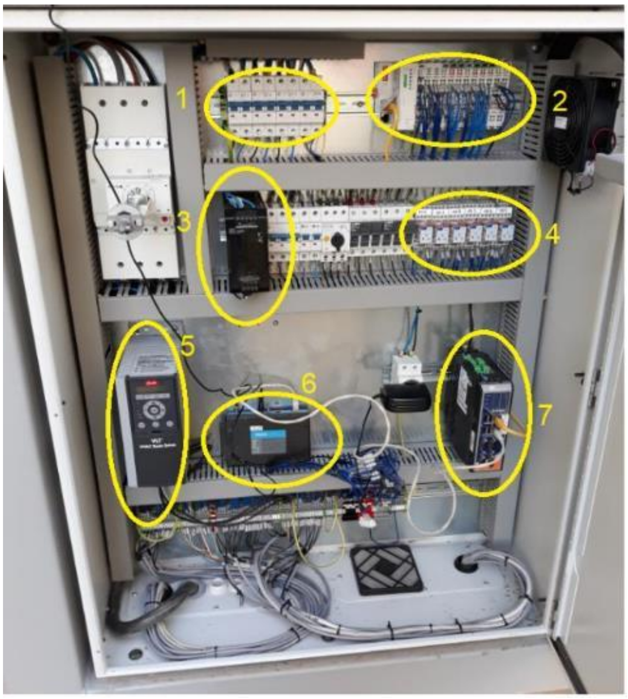

Figure 14. Electrical cabinet with all devices

2.4 Integration process

In this section, the system installation is described through a set of images, which define the main aspects of the integration of the LowUP system with the water treatment plant.

2.4.1 Bearing structure

It is important to place the skid in a stable flat surface, in order to guarantee circulation by the gravity of the sludge and complete submersion of rotating plates within sludge. To provide stable support, the ground was reinforced and levelled through a concrete foundation slab.

Figure 15: Foundation slab for skid levelling

The final unit, after its placement on the slab, is showed in the next image:

Figure 16: skid on slab and collecting channel

2.4.2 Piping integration

The industrial heat recovery system from Pozzi is installed next to one of the AD digesters, physically located near to the pipe, which is currently used for sample collection of sludge, which is directly connected with digester outlet, on the upper part of the digester.

To integrate the Heat recovery system with the reactor, one of the sludge pipes is adapted to allow the connection with HReX. So, the cut-off valve (see next figure), which is open only when a sample is required, keep open to feed the LowUP system with the sludge.

By this way, the circulation of the sludge will be produced by the gravity force, due to the high of the water column (almost same high of the digester) without the necessity of using a circulating pump. The adaptation of the pipe system is considered as a preparation work to integrate the system into the plant.

Note that depending on the sludge properties, this system could need an auxiliary sludge-grinding pump because the high sludge density could generate fouling problems in the pipes. Verification will be achieved during long time operation.

In the following pictures, the hydraulic connection point to the digester.

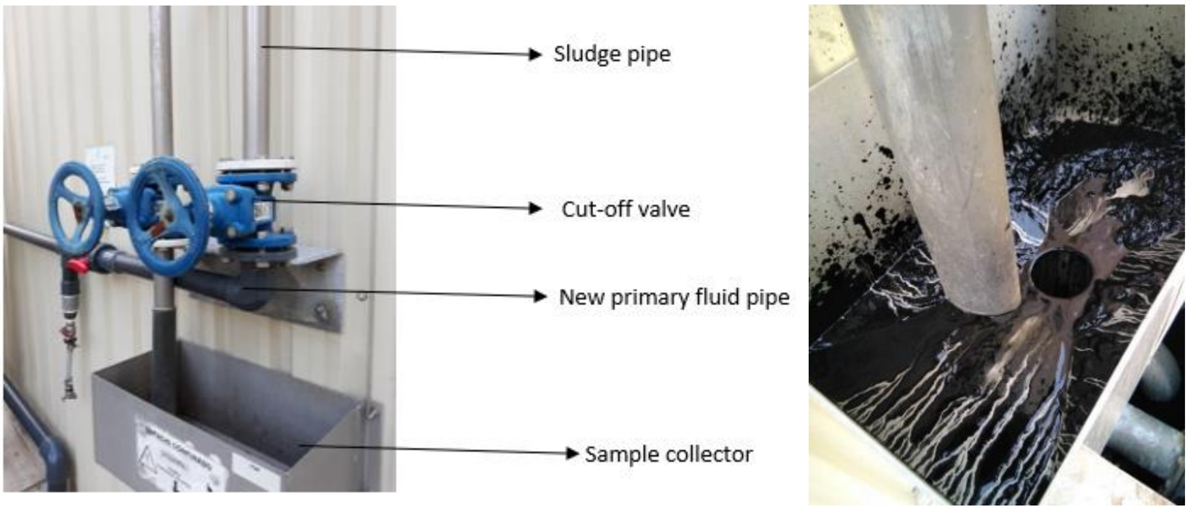

Figure 17. Detail of modification to sample piping and sample of digested fluid

According to recommendations of WWTP maintenance personnel, a water connection for piping cleaning has been added in case of fouling during colder periods; it can be seen as “T” junction with the manual valve between the cut-off valve and inlet of HReX.

Figure 18: Integration of modified sludge pipe with the RHeX unit

Finally, the sludge, outcoming from the skid, is returned by gravity to its normal stream with a pipe connected to one of existing collecting channels, as shown by the previous picture.

Thanks to plug&play solution of the skid, only these modifications were required for integration. Finally, a brief summary of the operation of the entire system is showed in the following pictures:

	Hot sludge		Cold sludge		Hot water		Coldwater

Figure 19. Operation scheme of LowUP system in Madrid demo site

3 Setubal Demo Site

3.1 Description of the test site

The installation of part of HP-LowUP concept has taken place in the pulp and paper factory of Navigator Company, and it is located in Setubal.

The pulp and paper (P&P) industry is one of the heaviest users of water within the industrial economy, requiring 54 m^3 on average of water per metric ton of finished product. Approximately 85% of the water used in the P&P industry is used as process water, resulting in relatively large quantities of contaminated water and necessitating the use of onsite wastewater treatment solutions.

Divided into different sections, the Navigator company facilities host a proprietary residual water treatment plant, where the treatment of the polluted water takes place.

The HP-LowUP concept pretends to benefit the P&P industry recovering the unused low exergy waste heat from polluted wastewaters, increasing the energy efficiency of the entire production process, and boosting it for other energetic purposes. The effluent has here temperatures around the 35-45°C.

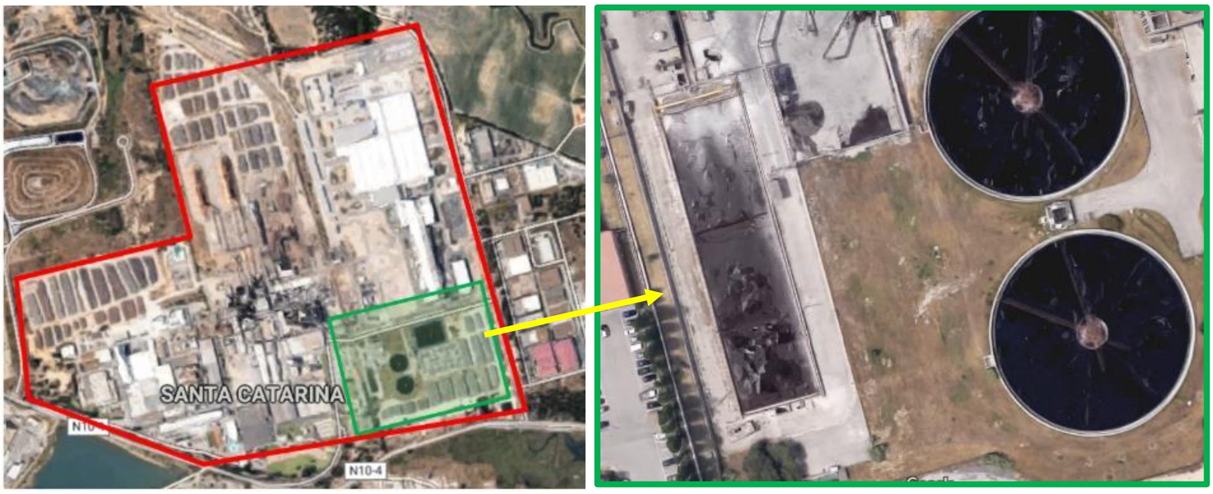

Figure 20. Pulp and paper plant (red area) and the wastewater treatment plant (green area)

The main requirement of the skid, in order to be integrated into the factory of Setubal, is the available space and the power and water supply. As it is observed in the image below, the space surrounding the sludge pool is wide, but there are some considerations to take into account:

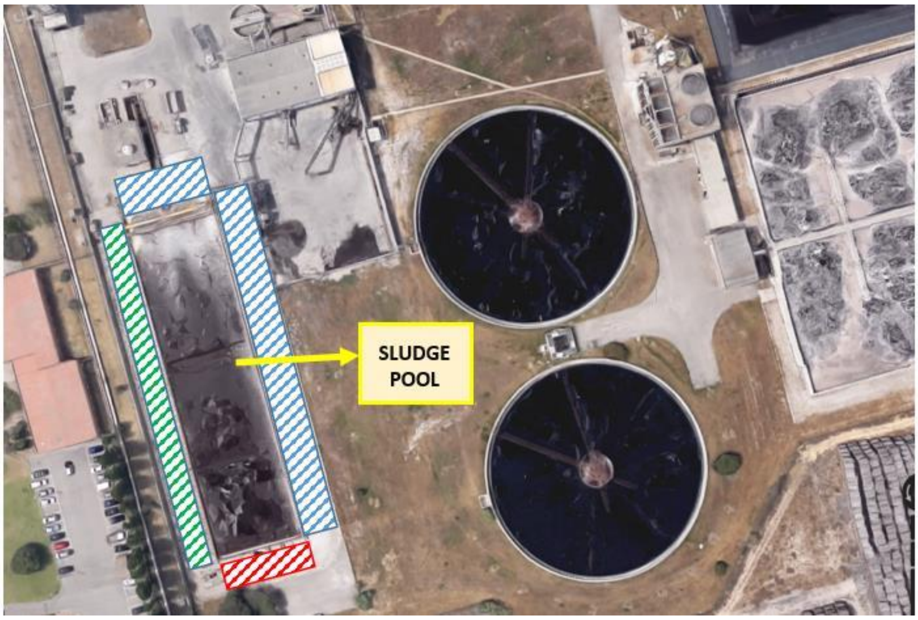

Figure 21. Available space around sludge pool

The blue area cannot be considered as available space, because it is a vehicles circulation zone. The green area could be considered as a suitable zone for system integration, but, as it is shown in the next image, the existence of some fences for bearing mechanic components of the pool hinders this.

Figure 22. Fences location and vehicle circulation zone

So, the system is installed in the red area of figure 21. The available space there is enough to host the system and is close to an electrical cabinet for power supply. The most important problem is the dealing against the aggressive environment that exists in this zone, represented by vapours of effluent.

3.2 Integration concept

This section aims to describe in detail the system installed in Setubal, setting out the requirements necessary for proper integration at P&P factory.

The main idea of the design was to develop a plug&play system able to be installed in the demo with minimum impact for the existing productive setting and reduced time of implementation. As a consequence, the system had to present characteristics of reduced space, reduced number of connections (piping, electricity, control), quick installation, and remote supervision.

On the other hand, the impact on physical components of the plant should not affect the regular activities of operation and maintenance; furthermore, the installation must return to original conditions after the end of the project.

The identified point of connection is at the outlet of the factory, when the effluent arrives at stabilization pool, before starting the cycle in the WWTP. At this point, the affluent has the maximum load for suspended particles, chemical contaminants to test the self-cleaning feature of the RHwX, and an interesting (for HP LowUP concept) temperature for testing the efficiency in heat transmission.

A concept scheme of the installation is presented in the following drawing:

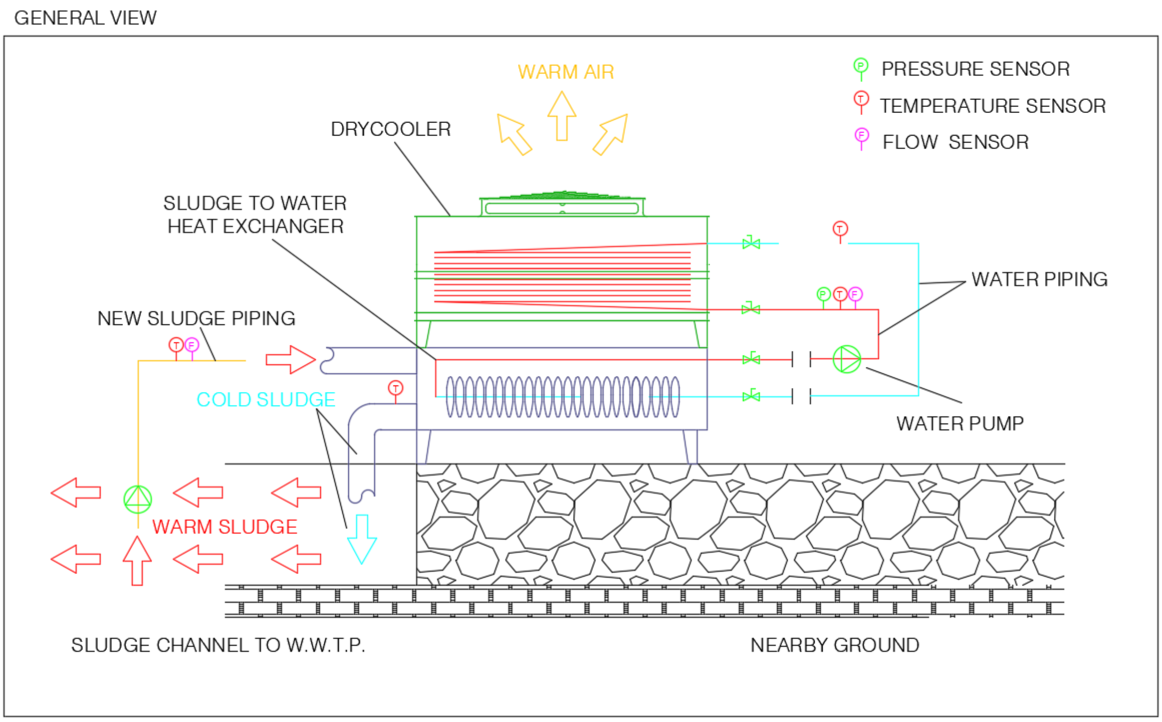

Figure 23. Setubal Demo Site P&ID diagram

The system is composed of five main devices (they can be identified in the images above):

- Heat recovery unit: RHeX (30 kW) manufactured by Pozzi
- Heat rejection unit: Dry cooler EA65 (35 kW) from Stulztecnivel
- Circulating device: Water pump Model EL 50-160 (0,75 kW) from Ebara
- Pumping device: Sludge pump Model DW VOX 75 from Ebara.
- Circulating piping: in stainless steel
- Electric cabinet: including power supply, local controller and remote communication devices

The technology specifically developed in the frame of the LowUP project, and installed in Madrid, is the RHeX heat recovery unit. The rest of the systems are auxiliaries necessary for the pug&play integration with the plant, considering the requirement of testing, whose function is the circulation of clean water and dissipation of recovered heat.

The result of the integration of the above-presented equipment is the final skid showed in the following figure:

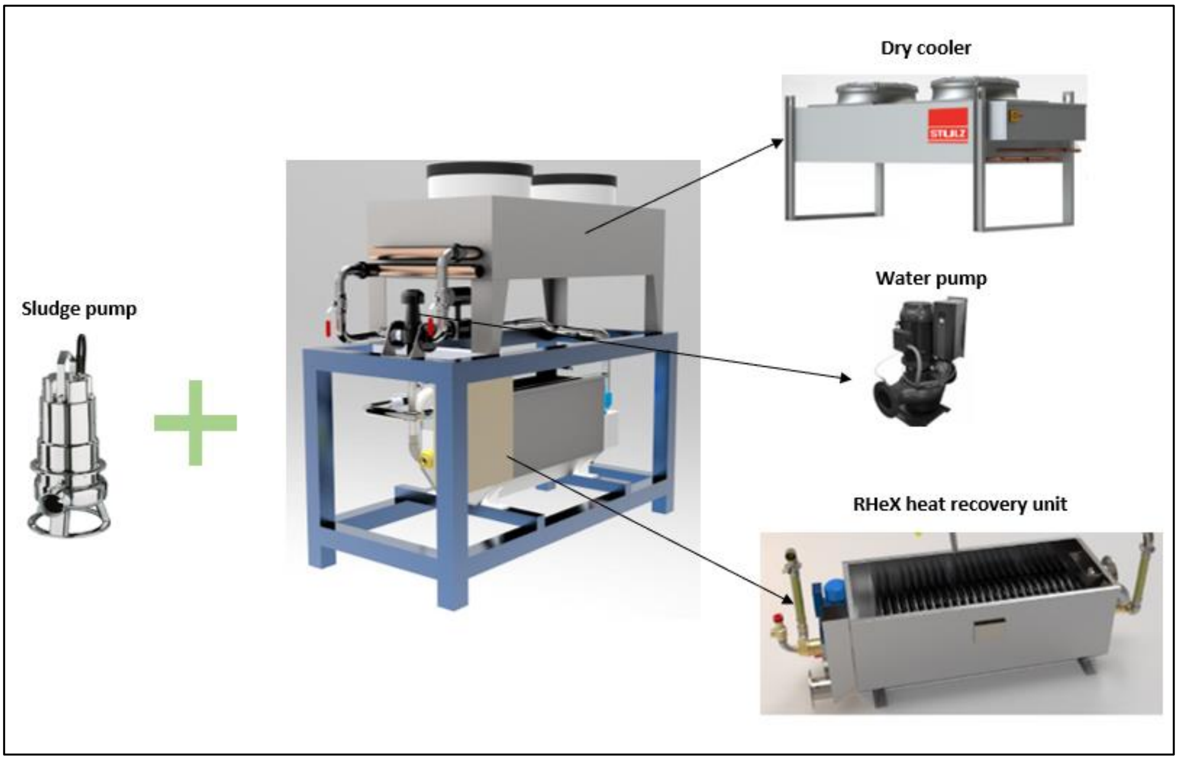

Figure 24. Systems installed in Setubal demo site

3.3 Components of the plug&play heat recovery system (skid)

Because of the limited impact required for the demo, the main integration activity was focused on the skid, in order to limit piping and cables along with P&P settings. In this section, all components are described.

3.3.1 Rotating Heater exchanger

The RHeX used for this kind of demo is exactly the same as the HReX of Madrid and so technical specifications; please refer to the previous demo for more details.

In the next figure, it shows the heat exchanger installed at Setubal Demo Site:

Figure 25. Heater exchanger installed

3.3.2 Dry cooler

Its main function is the dissipation of the heat recovered by the RHeX.

- Thermal capacity = 35 kW
- Electric consumption = 1.9 kW

Next images how dry cooler is integrated into the upper part of the skid:

Figure 26. Dry cooler installed over the skid

3.3.3 Water pump

The water pump is in charge of the circulation of recovered heat working fluid. This pump flows the water between heater exchanger and dry cooler at regulable speed.

Figure 27. Water pump installed

3.3.4 Monitoring components

Other essential parts of the installation are the components for controlling and monitoring distributed over the skid.

In the following image, the temperature sensors which are installed in water pipes.

Figure 28. Temperature sensors

In the following image, the detail of flowmeter for detection of instant flow for sludge and clean water.

Figure 29. Two flow meters installed

The proprietary plc is in charge of: gathering data from distributed sensors, apply control strategies for the operation of the entire skid, regulation of individual devices.

The plc communicates via Ethernet with an embedded pc where monitored data can be stored, before transmission to a remote database. On the other hand, plc receive commands from the pc in case of remote manual operation, when the automatic operation is by-passed.

Figure 30. Inputs/Outputs signal module

Remote communication and control are achieved with an embedded pc connected via 3G to remote LowUP control station (in Seville); a basic SCADA is present in the pc, for direct communication with plc.

Next image shows the embedded pc installed inside of the electrical cabinet with router 3G:

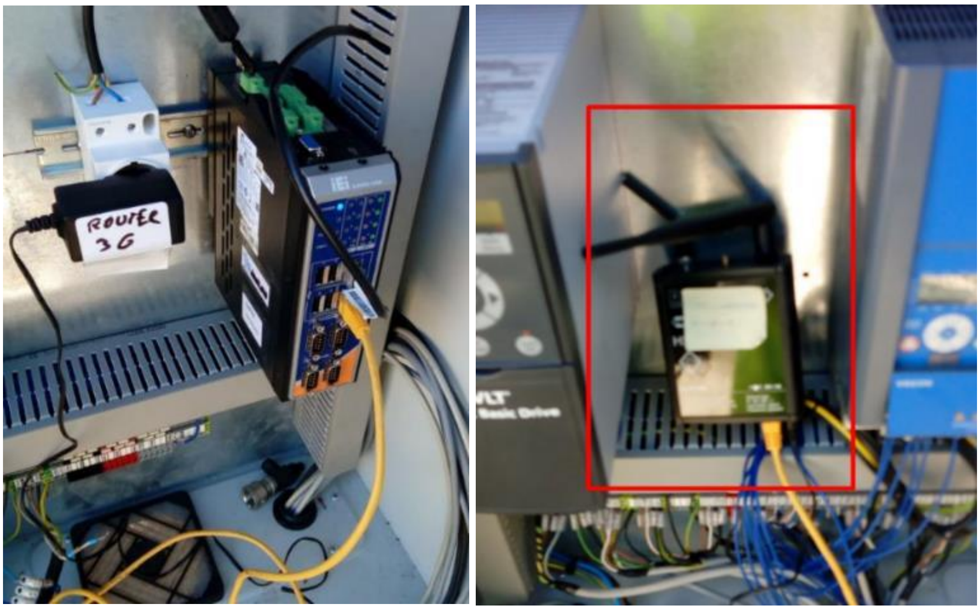

Figure 31. Embedded pc (left) and 3G router (right)

3.3.5 Control cabinet

The control cabinet is used to supply power to all components of the skid but is also used to control all equipment, to communicate with remote and to monitor operation variables. Outside of the cabinet has a light pilot for status information and a circuit breaker; Components inside of the cabinet are listed below, presented and identified in next figure;

1. Electrical protections
2. Plc + Inputs/Outputs modules
3. DC Power supply
4. Contactors for controlling
5. Frequency regulator for dry cooler fan
6. Embedded pc
7. Router

Figure 32. Inside components of the cabinet (left) and outside components (right); Status information lights (1) and Circuit breaker (2)

3.4 Integration process

In this section, the system installation is described through a set of images, which define the main aspects of the integration of the LowUP system with the water treatment plant.

3.4.1 Bearing structure

It is important to place the skid in a stable flat surface, in order to guarantee circulation by the gravity of the sludge and complete submersion of rotating plates within sludge. To provide firm support, the ground was reinforced and levelled through 2 concrete foundation blocks.

Next images show that structure made on the ground.

Figure 33. Blocks holding skid

3.4.2 Piping integration

The main difference with the installation carried out at Madrid demo site is the heat recovery system directly take fluid from a pool and return it to the same pool, without any physical modification of the existing settings.

The water of the pool is at a lower level with respect to skid, so gravity principle cannot be applied in this demo; a sludge pump is necessary for the circulation of the primary fluid (sludge) out and in the pool.

The sludge pump is connected through a flexible pipe with the RHex heat recovery unit, and it is totally submerged in the sludge:

Figure 34. Sludge pump before (left) and after being submerged in the sludge with piping

The next figure shows a system that has been used to keep the pump in an upright position; the pump is connected to a post with a metallic cable which holds the weight of the device:

Figure 35. The mechanism to keep the pump in an upright position and effluent return to the pool

In the same way, the return to the pool of the effluent has been achieved through an extension of the iron piping outcoming from HReX.

3.4.3 Electrical connection

A 3-phase electrical connection is required for proper operation of the system. This requirement is fulfilled in the red area:

Figure 36. Power supply point

Thanks to plug&play solution of the skid, only these modifications were required for integration. Finally, a brief summary of the operation of the entire system is showed in the following pictures:

	Hot sludge		Cold sludge		Hot water		Coldwater

Figure 37. Operation scheme of LowUP system in Setubal demo site

3.4.4 Control system

Last part of the installation, which is common to Madrid and Setubal demo (is the same skid) is SCADA managing the operation of the skid, component by component or with automated strategies.

The following figure shows two software windows, the right one is software which manages all the system parameters, and it shows temperatures, pressure, energy, water and sludge flows.

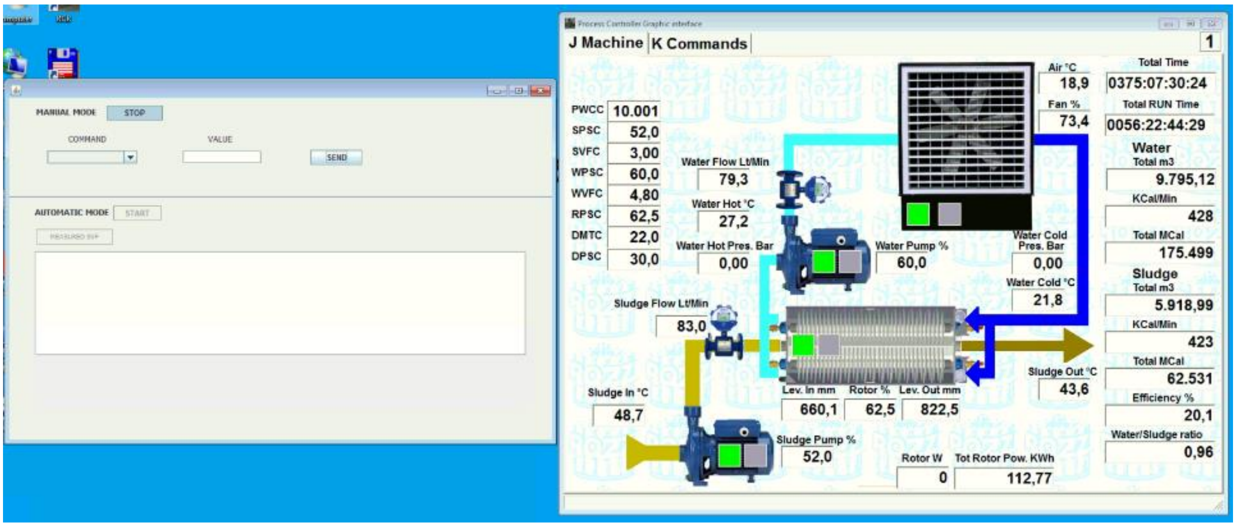

Figure 38. Screenshot of the Navigator PLC

In the below figure, the software window is divided in:

1. A parameter to manage Rotor speed, Water Cold temperature, Sludge and water pump flow.
2. Information parameter of the water loop
3. Sludge information about pump, exchanger rotor speed, temperature sensors.
4. General information about energy, power and efficiency of the system.

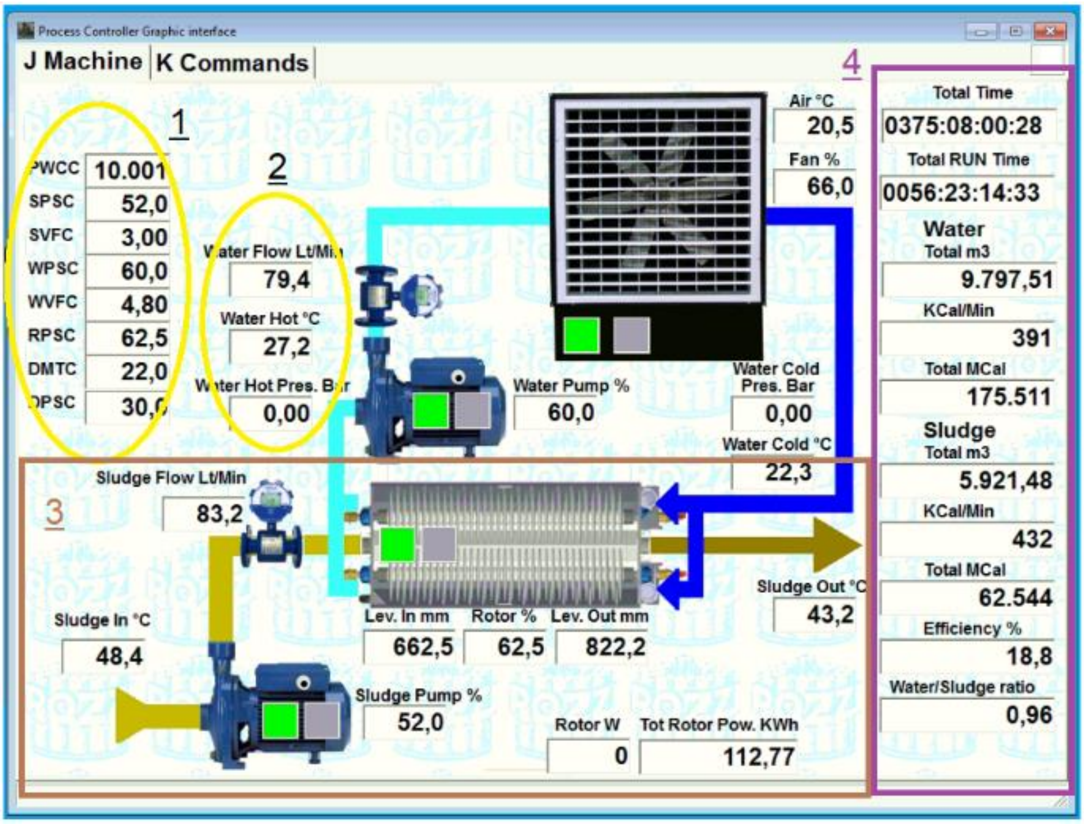

Figure 39. Navigator software

4 IMPLEMENTATION OF EQUIPMENT IN GIPUZKOA DEMO

4.1 Description of the test site

The test site of Tecnalia (Gipuzkoa) hosts the Heat Pump. This thermal lab bases its activity in the development, testing, evaluation and optimization of thermal systems. Next figure shows a satellite picture of the place and the location where the installation of the LowUP system has been carried out:

Figure 40: Place where the HP has been installed

Available area

Due to the usual activity of the Tecnalia thermal laboratory to test different technologies, the heat generation and the heat rejection systems are already present and can be used for characterizing the HP. For that, the main integration requirement is the hydraulic connection of the HP with existing water loops and the integration with lab main control system.

The decision of installing the HP outdoors, with respect to the lab, depended on weight & dimension of the containerized system, which allows reducing the integration process in terms of control, power supply and hydraulics, but requires a bearing ground able to resist to total load. The parking and truck loading space around one side of the lab fulfils with all these requirements, including proximity to the existing water loop.

In the next image, the reserved space for Heat Pump.

Figure 41. HP integration outdoor in Tecnalia facilities

4.2 Integration concept

The system is composed by three mainly devices whose role is to boosts efficiently the low thermal level of low-grade temperature source (like recovered heat from waste can be) into heat at medium temperature up to 80ºC (like low-temperature heat for industrial processes can be). The boiler provides heat for the cold sink of the HP, while the chiller rejects to air the heat boosted and produced by HP hot sink.

The devices are the following:

- Heat Pump: containerized water-water heat pump from GEA (45HP compressor);
- Boiler: model WA 250 (Heating capacity 291 kW) from YGNIS;
- Chiller: model EWAH290TZSSB1 (Cooling capacity 288,6 kW) from DAIKIN.

Furthermore, a water accumulator tank of 1000 litres is installed to premix the flows, avoiding in this way that dissipation of heat should only depend on the chiller, which runs at his limits during operation of HP at maximum capacity; it is connecting together return to the boiler and to the chiller. A more detailed description of the system is provided in deliverable D4.5.

Other auxiliary systems, like water pumps and three ways valves, are necessary for the correct operation of the system.

A layout of the installation is presented as follow:

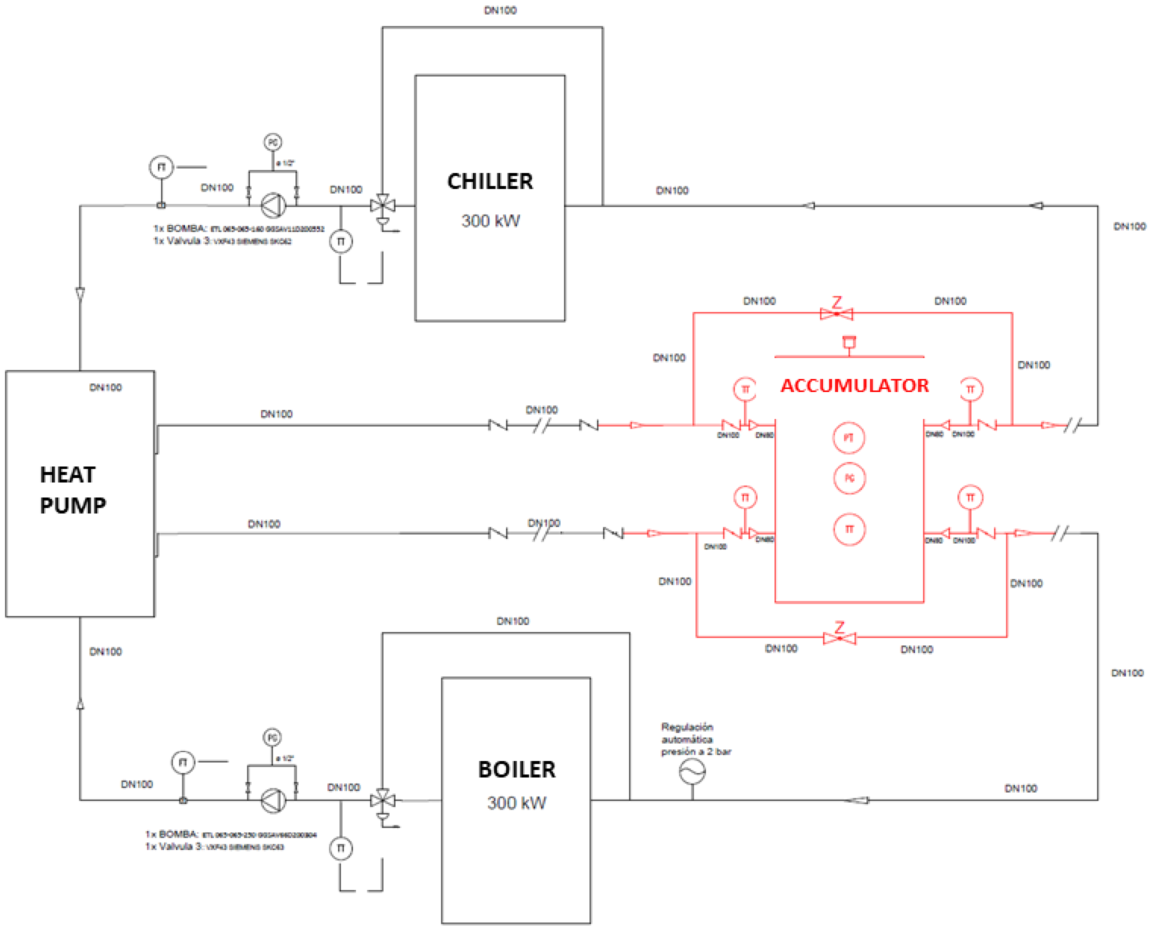

Figure 42. P&ID of HP integrated at the thermal lab

In the next figure, the main components of the installation are shown.

Boiler-Ygnis Accumulator Chiller Daikin

Figure 43. HP (top) and rest of main equipment (bottom)

4.3 Integration process

The transport of the containerized heat pump was by truck, and in the following images, it is shown how the discharge was made to be installed in its final position.

4.3.1 Bearing structure

To ensure stable support of the container, which can be an object of vibrations for the operation of the compressor, a robust structural steel base frame was built to level the HP and reduce undesired movements because of vibrations. This allows anchoring the structure to the ground.

Next figure, the built structure is placed in final position.

Figure 44. Bearing structure for the Heat Pump

In the following image, the discharge and installation process of the HP at freight arrival.

Figure 45. Discharge and placement of GEA Heat Pump

Once HP was placed, the next step was the connection with existing piping of the lab. In the next figure, the piping network existing inside the building, new "T" connections and passage through the wall.

Figure 46. Existing piping inside the building and connections to HP

The HP container has hydraulic connections (for evaporator and condenser) for the integration with boiler and chiller loops. This specific configuration makes the HP a plug&play solution.

In the next image, the connections of HP with steel pipes through anti-vibration joints.

Figure 47. Connection with containerized Heat Pump

On the following table, all the hydraulic connections required for the skid are specified.

	Chiller circuit	Boiler circuit	Accumulator circuit
Inlet pipe diameter	DN100	DN80	DN100
Outlet pipe diameter	DN100	DN80	DN100
Type of connection	Collar, Welded; AISI 304L (EN1092-1 TYPE33) PN10 /Lap joint flange, Al-Epoxy coated (EN1092-1 TYPE302)		

Table 1. Hydraulic connections required for Guipuzkoa demo site

And the connection of the pipes from the system inside the building it shows in the next figure

In the following image, a moment of installation of piping, from the HP to labs water loops.

Figure 48. Piping installation process outside the building

In the following image, the piping totally installed and insulated.

Figure 49. Pipes with final insulation

In the following image, the connection of the water loop with chiller and boiler

Figure 50. Pipes connection with the chiller (left) and pipes connection with boiler (right)

Inside the building, the piping network was isolated as well, and it was adapted to the existing connection with the boiler and the chiller. Next images, it shows the isolated piping network inside the building.

Figure 51. Distribution loops for heat generation and rejection

4.4 Components of the test bench

In this section, the main components of the test bench are detailed.

4.4.1 Hot sink – the chiller

The chiller is used to cool down the heat generated by the HP, feeding the dissipation water loop present in the lab. The chiller is connected with his primary loop to a storage tank of 2.000 litres able to absorb the thermal inertia of the cooler; the tank is connected to the load through the secondary loop and covers the spikes of thermal power from the load. The secondary loop is connected with the pre-mixing tank.

In the next figure, the DAIKIN chiller with the storage tank and its connections.

Figure 52. Daikin chiller (left) with primary loop and storage tank (right)

In the next figure, the secondary pump, three-way valve with its control cabinet and a flow meter.

Figure 53. Pump (1), three-way valve with its control cabinet (2) and a flow meter (3)

4.4.2 Cold sink - the boiler

The boiler is used to generate the heat necessary to feed the evaporator of the HP, in order to simulate recovered waste heat from RHeX. The boiler is connected to a pre-mixing tank of 1.000 litres before being directed to HP.

In the next image, the boiler with his loop and circulating devices.

Figure 54. Heat input system and primary pump to the evaporator

In the next image, the loop from the pre-mixing tank to the evaporator of HP.

Figure 55. Heat loop pump to HP (1), three-way control valve (2) and flowmeter (3)

4.4.3 The pre-mixing tank

The pre-mixing tank is the connection node between the boiler loop and chiller loop; it connects physically, with the transfer of heat and mass, the outlet from HP condenser and the outlet from HP evaporator. The tank works like a heat exchanger (with mass transfer) that heat up the cold sink loop and cool down the hot sink loop. By this way, the capacity of the chiller for cooling and of the boiler for heating is reduced during the point of operation at maximum capacity, like a sort of self-feeding of the HP.

In the next image, the view of the tank connected with cooling and heating loop.

Figure 56. Premixed storage tank (1.000l)

4.4.4 Electrical connections

The HP container needs to be power supplied with a 3-phase electrical connection. The main electrical supply and control cabinet needs a 220 A supply, while the NH_3 extraction system needs a 25 A supply. For the rest of the equipment of the laboratory, used for the tests, the maximum global intensity is 150A.

In the next image, the view of the electrical cabinet adapted to electric requirements.

Figure 57. Electrical cabinet

Figure 58. Electrical wiring distributed over the installation

4.4.5 Control and monitoring

Related to control aspects, each of the equipment counts with its proprietary control system so that they can operate autonomously for a given set-point of temperature. All the operating variables are controlled and monitored from remote by the SCADA of the laboratory.

The three-way valves and the pumps can also be operated from the SCADA through a PLC that controls the opening degree, in order to follow a set point for a given variable in the system.

The aforementioned Delphin system is the centralized control system of the laboratory. In the following figure, it is shown how the integration of HP with the lab from Dolphin interface point of view.

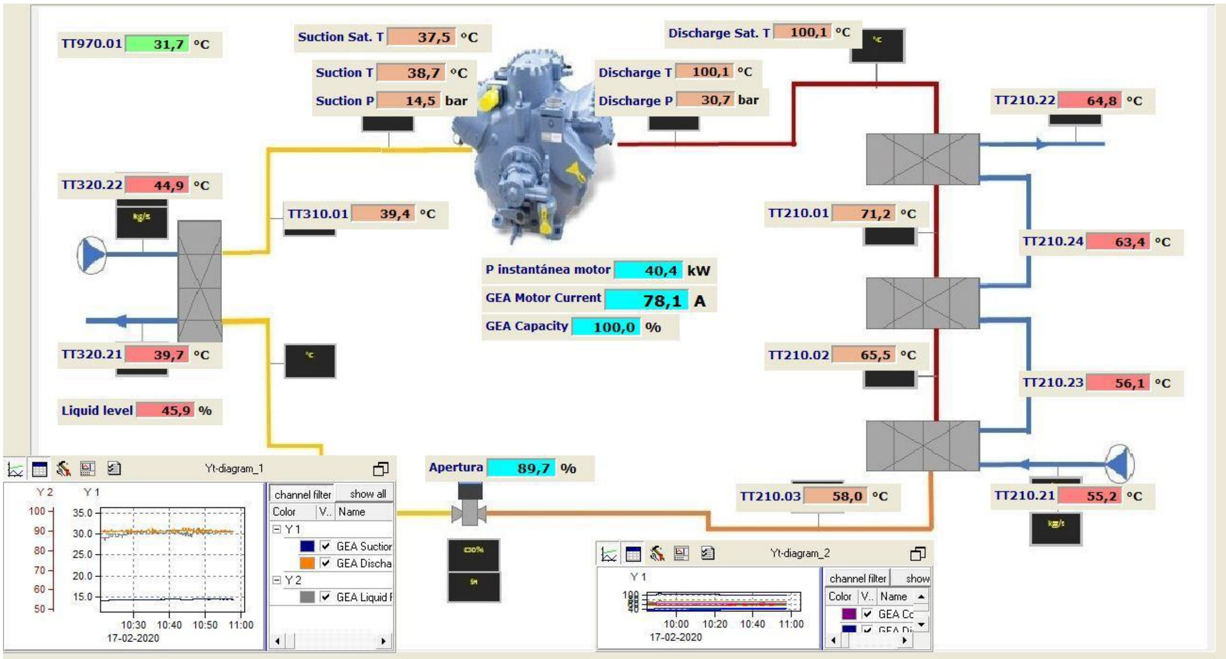

Figure 59. Scada of Delphin integrating the HP control system

Likewise, the rest of the laboratory is controlled by the Delphin system.
In next figure is depicted the SCADA screen of the whole setup for the LowUP project.

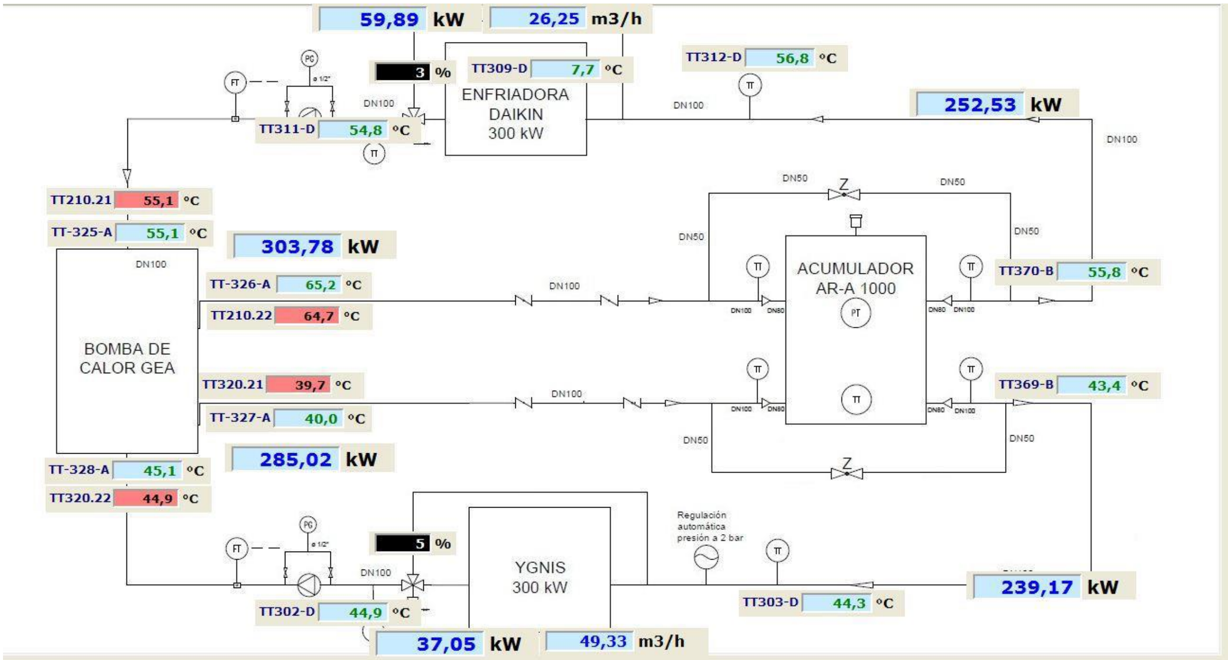

Figure 60. Scada of Delphin integrating all elements of the lab

The HP dispose of own plc, which can be connected, controlled and monitored from remote; actually, it's integrated into the distributed control system of the lab. The proprietary control system is called Omni system. There, the setpoints desired for each experiment of the test plant will be introduced. Together with GEA, some advanced control features will be accessed, such as to fix the working power load fraction. The system allows monitoring and registering all the variables needed for the characterisation.

In the next image, a screenshot of the Omni.

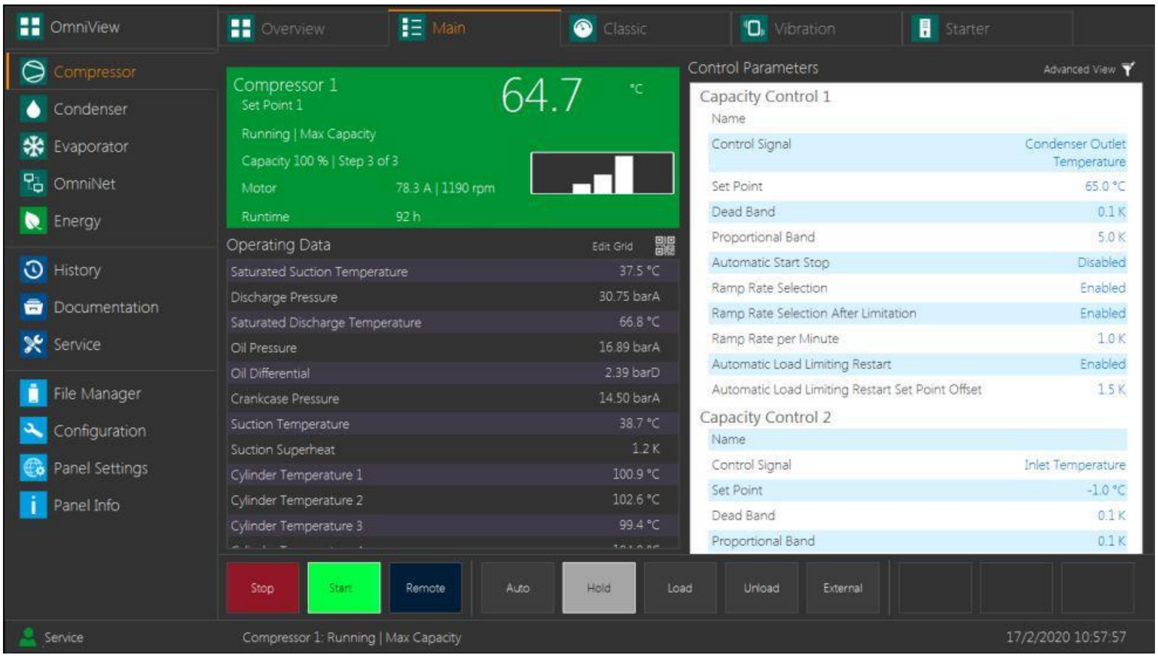

Figure 61. The screen of the HP GEA is the interface of the Omni system.

For the tests needed to be carried out in the LowUP project, it is required to fix constant the power load of the pump. For this project, the Omni system has been unlocked by its manufacturers in order to allow this feature at an advanced user level.

Conclusion

This deliverable gives a full description of the sites where Heat Pump and Rotating Heater exchanger technologies are installed: the wastewater treatment plant of Cuenca Baja del Arroyo Culebro (Madrid), the pulp and paper plant factory of Navigator (Setubal) and the thermal laboratory of Tecnalia in Gipuzkoa. The demo site in Madrid and Setubal host the Heat recovery systems integrated by Pozzi, while the demo site in Guipuzkoa hosts the highly efficient heat pump system integrated by GEA.

All the systems have been described in detail, explaining the main features and requirements of each one. In order to commission and start-up each installation, some previous works to adapt the demo sites have been made. These works are mainly: building refurbishment, ground improvement, already installed systems and equipment adaptation, available surface and power and hydraulic supplies.

All demos, composed of one or more concepts, can be controlled from remote thank to level of automation implemented at a different level: technology, sub-system, system and concept.

The monitoring system is completed, and all relevant parameters are correctly logged in the DBB for future analysis.

Basic control strategies are implemented in order to achieve specific targets for each system and so being able to realize future tests of characterization.

All technologies have been commissioned and partially started-up, waiting for the introduction of the intelligent algorithm for operation optimization.

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