H2020 Work Programme

D6.8_LESSONS LEARNT FROM CLUSTERS

Lead Contractor: ENVI

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Executive summary

The deliverable is developed under the WP6 work. The main objective of WP6 is to conduct the impact analysis of the industrial WH/C recovery and RES integration solutions promoted by the SO WHAT tool and project, as well as to compile the derived conclusions into a set of lessons learnt and useful recommendations. Specific objectives will be linked to the different dimensions of the targeted WH/C recovery evaluation, including: i) assessment of environmental and technical benefits of each demo case, ii) analysis of relevant regulatory issues and certification/standardization procedures and requirements, iii) proposition of policy instruments for industrial WH/C recovery promotion, (iv) analysis of the public and industrial perspective of SO WHAT benefits for competitiveness.

The objective of this report is to summarize the different perspective and main differences within the various clusters of SO WHAT that tested and validate the tool: difficulties, issues, strengths and suggestions to implement in the commercial SOWHAT tool version.

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Abbreviations

BHKP: Bleached Hardwood Kraft Pulp

DAF: Dissolved Air Flotation

DHN: District Heating Network

ECF: Elementary Chlorine Free

GDPR: General Data Protection Regulation

KPI: Key Performance Indicator

PFC: Pipe flow calculation

RES: Renewable Energy Sources

TES: Thermal Energy Storage

TRL: Technology Readiness Level

WH/C: Waste Heat/Cold

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TABLE OF CONTENTS

Horizon 2020
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1 Introduction

The main objective of SO WHAT is to develop and demonstrate an integrated software at TRL8 which will support industries and energy utilities in selecting, simulating and comparing alternative Waste Heat and Waste Cold (WH/C) exploitation technologies that could cost-effectively balance the local forecasted H&C demand also via RES integration. The SO WHAT integrated tool is designed to support industries, and energy utilities in 1) auditing the industrial process to understand where WH/WC could be valorised 2) mapping the potential of locally available RES sources to be integrated with WH/WC potential 3) mapping the local forecasted demand for heating and cooling 4) define and simulate alternative cost-effective scenarios based on WH/WC technologies also leveraging TES introduction 5) evaluate the impacts (in terms of energetic, economic and environmental KPIs) that the adoption of the new scenarios will generate against the current situation (i.e., baseline) both at industrial and local level 6) promoting innovative contractual arrangements and financing models to guarantee economically viable solutions and less risky investments.

The SOWHAT tool developed by IES was tested by all the Clusters. The deliverable reports a brief description of the scenarios identified by the various Clusters and the final scenario identified for the SOWHAT tool trial. It also reports the main steps followed for each Cluster in the installation and the interactions with IES and the results for each trial in terms of: barriers faced, main problem encountered, Clusters tool expectations, tool platform functionality and user-friendly visualization, general results obtained by the trials.

2 Results from the Clusters

2.1 Italian Cluster

2.1.1 General description

The Italian Cluster is coordinated by ENVI and RINA-C with the involvement of the demosite Martini & Rossi's (M&R). At Martini & Rossi's (M&R) Pessione industrial site all the products of the company are produced: Martini and sparkling wines and liquors following their recipes. M&R demosite has been identified as particularly relevant for the SO WHAT project as the stabilization of sparkling wines requires low temperatures achieved via glycol-based refrigerators.

The overall cooling production is about 10GWh/year employed in different areas of the plant. Considering the remarkable amount of low temperature fluids related to this production, M&R is interested in analysing the possibility and potential benefits related to waste cold recovery. As a consequence of the refrigerating power, a large amount of low temperature waste heat is produced in the plant. Today it is cooled away in evaporative condensers and it accounts for about 15GWh/year and the potential has already been identified as

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interesting. Moreover, another waste heat stream of about 170MWh/year, currently cooled away in an evaporative tower, has been identified in the cooling circuit of the air compressors. Finally, M&R is committed to employing Renewable Energy Sources (RES) and the installation of solar thermal panels for process purposes is planned in the framework of SHIP2FAIR H2020 project: for the present reason, M&R is an optimal test case for the analysis of RES integration and its direct impact on the production.

2.1.2 Scenarios identified to use in the tool trial

Three scenarios are identified as possible for trials of the SOWHAT tool (TO6 below).

2.1.2.1 Scenario 1: Sparkling wine process optimization: "ASTI"

The process, see Figure 1, consists of :

- Must be kept at 0°C from harvesting (September) to the bottling time during all the year in the M&R plant and other suppliers.
- Must be heated to 20°C for the fermentation step, to allow for the fermentation process.
- Sparkling wine refrigerated to 0°C to control the fermentation (ABV of 7%).
- Sparkling wine bottled at 0°C.
- Bottle heated to 20°C for labelling and packaging purposes.

The volume is 28 Ml/year. The potential technology used to recover the heat is heat exchangers.

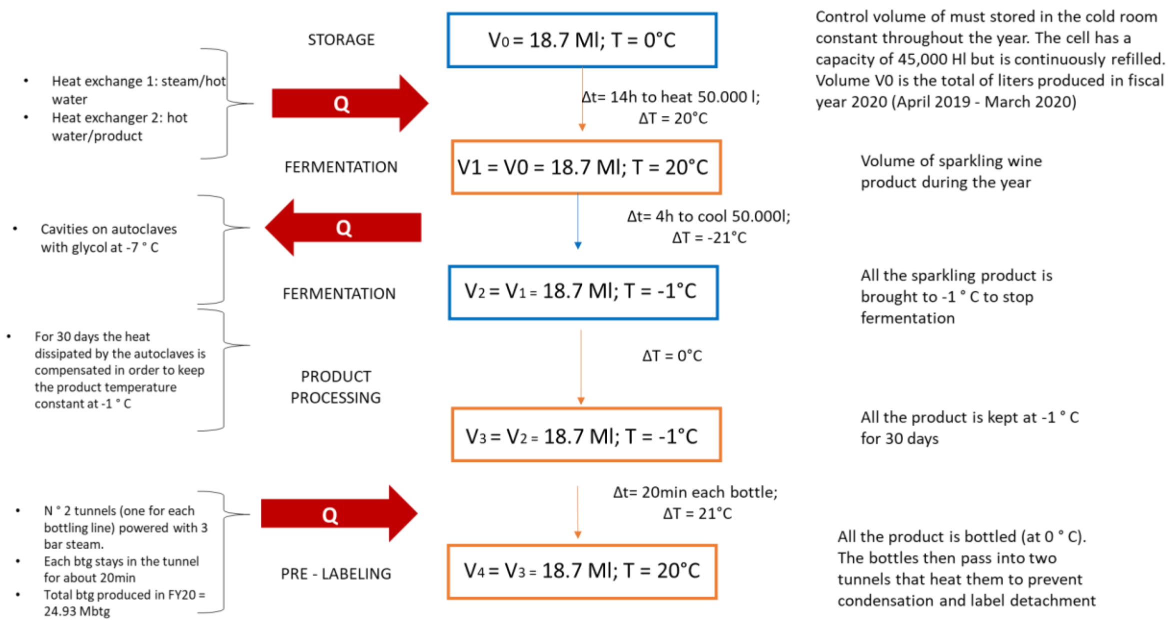

Figure 1 Sparkling wine process

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2.1.2.2 Scenario 2: Heat recovery from rooftop condenser of cooling plants for process

The process consists of:

- Heat recovery from rooftop condenser of cooling plants for process, see Figure 2.
- Cooling plant using R507 gas, typical Kelvin cycle process.
- Temperature of condensation: 35°C.
- 10 condenser, Condenser model: Baltimore VXC (185-576).

The technology used to recover heat are heat exchangers for the sparkling wine process. Heat exchangers will be used as water-cooled organic fluid condensers. The potential for recoverable heat is 1,848 MWh only from the "sparkling wine" line. The project will produce hot water, consequently reducing natural gas consumption of boilers and the CHP plant for the production of the same amount of hot water. The installation size is 1450 kWt and the investment cost is about 50-100 €/kWt.

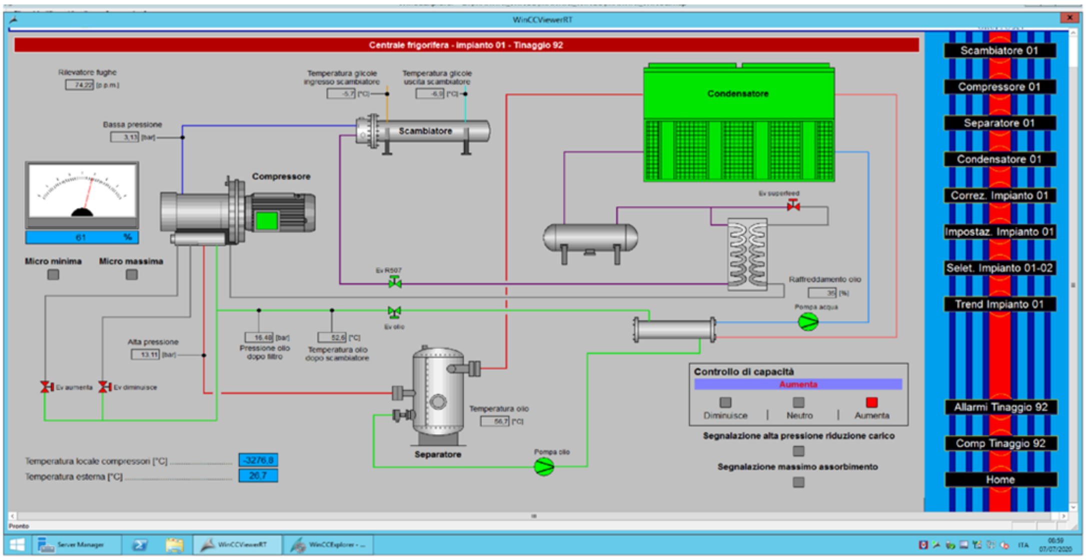

Figure 2 Heat recovery from rooftop condenser process

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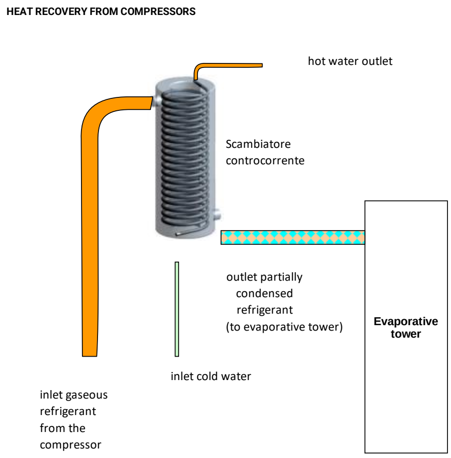
Compressor electrical power	128	kWe
Compressor cooling capacity	350	kWfr
COP cold production	2,73	
COP hot production	3,73	
Compressor thermal power	**478**	kWth
Compressor outlet refrigerant temperature	70	°C
Cooling tower outlet refrigerant temperature	25	°C
Coolant temperature after heat recovery	35	°C
ΔT useful coolant	35	°C
Useful percentage of usable heat refrigerant	78%	
Useful percentage of usable heat refrigerant	**372**	kW



2.1.2.3 Scenario 3: Solar field installed in SHIP2FAIR project

During the weekends in summer period, not much steam is needed in the M&R processes. It is possible to use the thermal energy produced by solar field to heat two existing warm water tanks (70°C), see Figure 3 and Figure 4. In this way it could be easier to bring the water inside the tanks at this temperature level at the beginning of the processes on the following Monday.

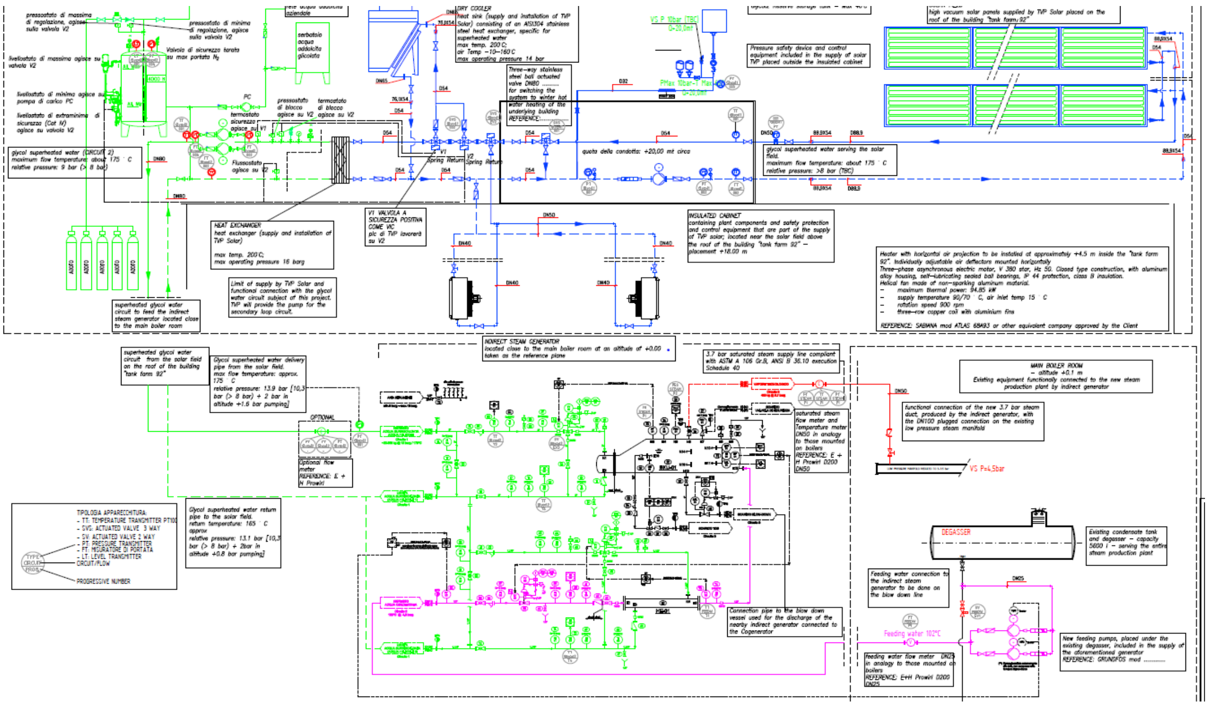


Figure 3 Solar field scheme

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Figure 4 Solar field process

2.1.3 M&R tool trial steps performed

The main activities done are:

- ✓ investigated with internal IT department about the possible constraints for software installation and given feedback to IES;
- ✓ identified and provide IES with an unique point of contact in charge of testing;
- ✓ downloaded the tool

There were three testing objectives for M&R. Table 1 below gives an overview of the testing objectives TO6, TO7 and TO11 and sub-objectives (or test steps).

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TASK - TESTING OBJECTIVE	ASSIGNED TO
TO6 - Identification of 3 to 5 relevant WH/C exploitation technologies	**Demo-site**
TO6.1 Review and share list of WH/C recovery/exploitation technologies (D1.6 report) with relevant stakeholders	**Demo-site**
TO6.2 Meet with stakeholders to select relevant WH/C recovery/exploitation technologies	**Demo-site**
TO11 - Detailed modelling of demo-site building(s)	**IES / Demo-site**
TO11.1 Review building data checklist and request relevant data available and shareable through building data checklist	**IES**
TO11.2 Review and/or complete building data checklist, and provide relevant data available and shareable	**Demo-site**
TO11.3 Collect, review and pre-process relevant data available and shareable through building data checklist	**IES**
TO11.4 Collect, review and pre-process relevant data available and shareable through building data checklist	**IES**
TO11.5 Develop and calibrate detailed VE/iCD building model (demo-site buildings)	**IES**
TO7 - Setup of virtual network baseline model for exploitation of WH/C resource and integration of RESs (baseline and scenarios)	**Demo-site**
TO7.1 Export data from VE to iSCAN for calibrated detailed VE model of demo-site buildings	**Demo-site**
TO7.2 Export data from iSCAN to iCD	**Demo-site**
TO7.3 Synchronisation of iCD data with iCIM model	**Demo-site**
TO7.4 Export data from iCIM model to iVN project	**Demo-site**
TO7.5 Setup iVN project parameters	**Demo-site**
TO7.6 iVN baseline network model (inc. virtual network, simulation and export of results)	**Demo-site**
TO7.7 iVN network model scenario #1 (inc. virtual network, setup of custom installation script, simulation and results visualisation)	**Demo-site**
TO7.8 iVN network model scenario #2 (inc. virtual network, setup of custom installation script, simulation and results visualisation)	**Demo-site**
TO7.9 iVN network model scenario #3 (inc. virtual network, setup of custom installation script, simulation and results visualisation)	**Demo-site**
TO7.10 iVN network model scenario #4 (inc. virtual network, setup of custom installation script, simulation and results visualisation)	**Demo-site**
TO7.10 Comparison against baseline results (inc. export of simulated results for baseline and scenario network models)	**Demo-site**

Table 1 Testing objectives for M&R demo site tool trials

TO6 - Identification of 3 to 5 relevant WH/C exploitation technologies is linked to chapter 2.1.2. The activity is 100% completed. Each scenario reports the technologies identified (heat exchangers identified as relevant WH/C exploitation technology, in particular for heat recovery from rooftop

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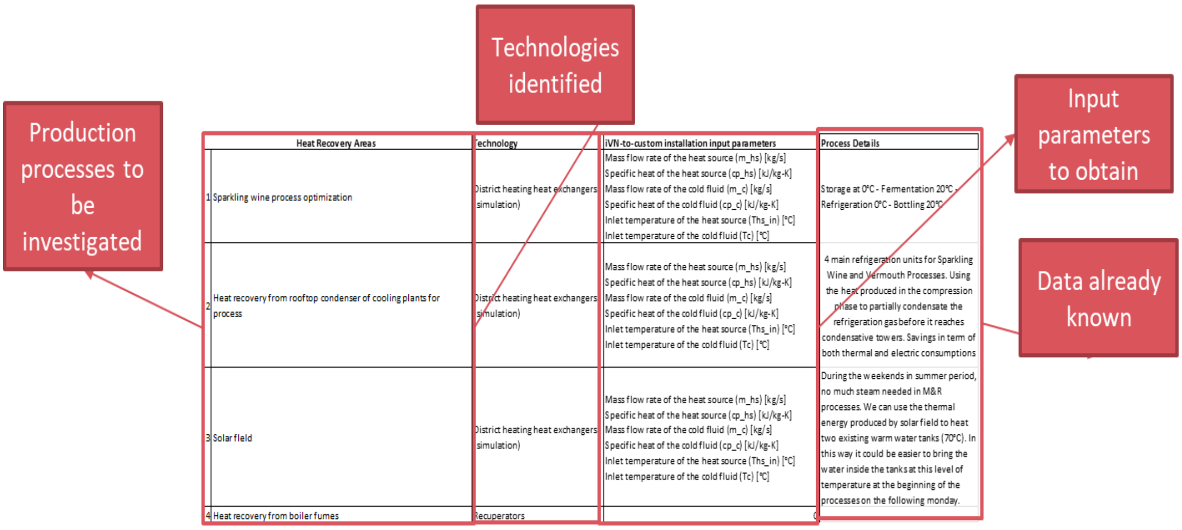
condenser of cooling plants), the input parameters useful to charge on SOWHAT tool (mass flow rate for heat and cold, temperatures, specific heat of the heat/cold source…) and the main process details. See Figure 5 for an overview.



	Heat Recovery Areas	Technology	iVN-to-custom installation input parameters	Process Details
1	Sparkling wine process optimization	District heating heat exchangers (simulation)	Mass flow rate of the heat source (m_hs) [kg/s] Specific heat of the heat source (cp_hs) [kJ/kg-K] Mass flow rate of the cold fluid (m_c) [kg/s] Specific heat of the cold fluid (cp_c) [kJ/kg-K] Inlet temperature of the heat source (Ths_in) [°C] Inlet temperature of the cold fluid (Tc) [°C]	Storage at 0°C - Fermentation 20°C - Refrigeration 0°C - Bottling 20°C
2	Heat recovery from rooftop condenser of cooling plants for process	District heating heat exchangers (simulation)	Mass flow rate of the heat source (m_hs) [kg/s] Specific heat of the heat source (cp_hs) [kJ/kg-K] Mass flow rate of the cold fluid (m_c) [kg/s] Specific heat of the cold fluid (cp_c) [kJ/kg-K] Inlet temperature of the heat source (Ths_in) [°C] Inlet temperature of the cold fluid (Tc) [°C]	4 main refrigeration units for Sparkling Wine and Vermouth Processes. Using the heat produced in the compression phase to partially condensate the refrigeration gas before it reaches condensative towers. Savings in term of both thermal and electric consumptions
3	Solar field	District heating heat exchangers (simulation)	Mass flow rate of the heat source (m_hs) [kg/s] Specific heat of the heat source (cp_hs) [kJ/kg-K] Mass flow rate of the cold fluid (m_c) [kg/s] Specific heat of the cold fluid (cp_c) [kJ/kg-K] Inlet temperature of the heat source (Ths_in) [°C] Inlet temperature of the cold fluid (Tc) [°C]	During the weekends in summer period, no much steam needed in M&R processes. We can use the thermal energy produced by solar field to heat two existing warm water tanks (70°C). In this way it could be easier to bring the water inside the tanks at this level of temperature at the beginning of the processes on the following monday.
4	Heat recovery from boiler fumes	Recuperators		

Figure 5 Scenarios identified

In particular, the evaporative condenser was chosen as case study useful for the trial. The aim of this scenario is to use the heat produced in the compression phase to partially condensate the refrigeration gas before it reaches the cooling towers. In this way it is possible to obtain savings in term of both thermal and electric consumptions. Figure 6 reports the simplified scheme: hot gas from the compressors recovered by the exchanger before it flows into the tower. The heat is used to warm up the environment. The recovery takes place during winter season.

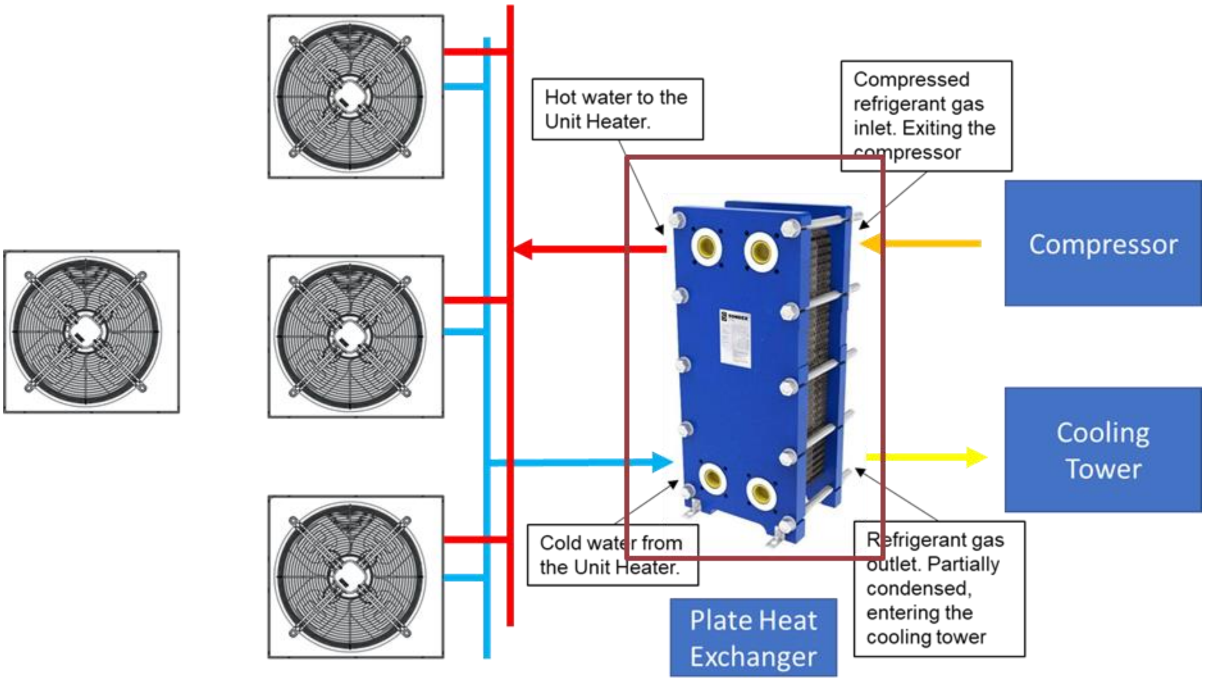


Figure 6 Scenario identified: evaporative condenser

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TO7 - Setup of virtual network baseline model: **100% completed**, on the basis of data gathered as part of T1.1 activities. There were some issues with measurement and collection of granular system data, due to the complexity of the cooling systems used.

TO11 - Detailed modelling of demo-site building(s): **100% completed**, on the basis of data gathered as part of T1.1 activities. Detailed building model may not be necessary, thanks to data available from installed energy metering network.

2.1.4 Validation of the tool (Scenario 2)

Finally, it was performed a feasibility study using the SO WHAT tool (see deliverable 5.3 for more information). The tool was used to calculate heat that will be recovered internally in the same process to obtain savings in term of both thermal energy and electricity consumption. It was assumed that the technical lifetime was 20 years. Considering an investment of 180k€, it results in a net present value (NPV) of 314 k€, an internal return of investment (IRR) of 26,71% and a payback time (PBT) of 4,5 years.

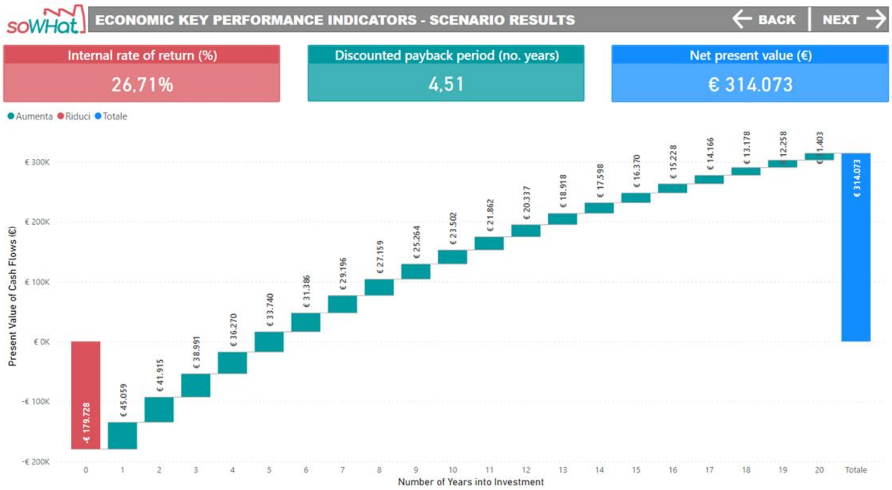

Figure 7. SOWHAT tool and Payback period.

2.1.5 Results and lessons learnt

The **main technical steps** that have been followed in the Italian Cluster are mostly related to the selection of the relevant data to use in the tool: definition of the hot gas temperature and pressure, of annual compressor use rate and recoverable energy, the definition of technology and scope. Typical production plant data was easily found, as this was already entered into a remote supervision system. It was more difficult to define data on potential energy use, such as the heat requirements of a department. The data upload process was carried out in a well independent manner, the help of IES was required to check that some fields had been filled in correctly. In order to work properly, the tool needs a lot of energy and economic data from both the baseline and the scenario to be analysed. However, with the help of the guidelines provided, it was easy to enter everything correctly.

The **main problem encountered** was related to the definition of a specific parameter. It was not immediately clear what it referred to. Issues have been reported related to the data collection and in particular it was difficult to define data about the potential energy use.

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Tool expectations: the main expectations were for a tool that, by receiving as input real plant data, potential wasted energy and real energy price data, would be able to assess the amount of recoverable energy and economically evaluate its areas of use and economic aspects. Expectations regarding the economic evaluation of the investment, according to the main financial parameters has been met. However, it is still the responsibility of the user to carry out the energy evaluation of the scenario.

A user-friendly tool: this is the most important aspect to take into consideration for IT Cluster members, mainly useful for industrial sectors analysis. The SOWHAT tool is very user-friendly, despite being a very technical tool.

Results obtained during the trial: the results obtained on the economic-financial and risk assessment part very interesting. I would also have expected some energy outputs. They show that the scenario initially assumed has potential energy savings, however the low temperatures involved make the application range limited and consequently the payback time longer than the accepted standards as well as the other financial rates

2.2 Spanish Cluster

2.2.1 General description

The Spanish cluster of the SO WHAT Project is made up of the following five companies (see Figure 8 below):

- **CARTIF:** Applied research centre. Legally it is a private non-profit foundation, emerged from the University of Valladolid, whose mission is to offer innovative solutions to companies to improve their processes, systems and products, improving their competitiveness and creating new opportunities of business.
- **ELEUKON:** Engineering company focused on energy efficiency services, industrial engineering, energy production and industrial digitization.
- **ENCE:** The business model of ENCE is based on the sustainable use of natural resources (wood and biomass) for the eco-efficient production of pulp and renewable energy.
- **SUSTAINABLE INNOVATIONS:** Communication company focused on innovation management services, business development and capacity building.
- **FAEN:** FAEN ("Fundación Asturiana de la Energía"), as the Principality of Asturias Energy Management Agency, studies the energy needs of the region (Asturias) in order to try to satisfy them in the most efficient way possible. To achieve this, it works in accordance with the proposed objectives and the international commitments that Spain must comply with.

Figure 8 The Spanish Cluster

ENCE, with an installed capacity of 1.2 million tons distributed in its two bio-factories in north-western Spain, Navia (Asturias) and Pontevedra (Galicia), is one of the largest European producers of short fibre pulp (BHKP) based on eucalyptus wood purchased in the environment of its bio-factories and from certified responsible sources, which guarantee sustainable forest management.

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Through its 51% stake in MAGNON GREEN ENERGY, ENCE is also the largest generator of renewable energy with agroforestry biomass in Spain, with an installed capacity of 266 MW distributed in eight independent plants located in southern Spain.

Navia pulp mill (Spanish SO WHAT demo-site), see Figure 9, is the centre of ENCE with the largest production capacity. After the recent expansion and improvement of its facilities, it has positioned itself among the leaders in the European eucalyptus market. The current production capacity of the bio-factory is 685,000 tons/year of high-quality ECF (Elementary Chlorine Free) eucalyptus cellulose. This capacity has been increased in 2019 after the execution of the "Navia 80" Project, which entails an expansion of capacity of 80,000 tons in the factory.

Figure 9 ENCE Navia pulp mill (Spanish SO WHAT demo-site)

2.2.2 Scenarios identified to use in the tool trial

Three scenarios were identified as possible trials for the SO WHAT tool.

2.2.2.1 Biomass Dryer

ENCE Navia installed a biomass dryer in 2019 in order to increase the calorific power of the biomass burnt into the biomass boiler (biomass savings), see Figure 10.

Figure 10: ENCE Navia biomass dryer facility

In this scenario the waste heat is recovered from the process flow of the bleaching stage through a water/water plate heat exchanger ("BIOMASS DRYER HEAT EXCHANGER" in Figure 11) installed in parallel of the **main** line. The heat recovered at this point does not affect the process, because the

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recovery point is located at the end of the process line before the flow is sent to the effluent treatment. The heat is recovered from the dilution fluid (inlet temperature of round 80ºC) of the bleaching stage and send to a water (outlet temperature of round 70ºC) closed circuit which is connected directly to the biomass dryer, in where through water/air heat exchangers and fans the recovered heat is used to generate a hot air stream used to dry the biomass which flows through a conveyor belt.

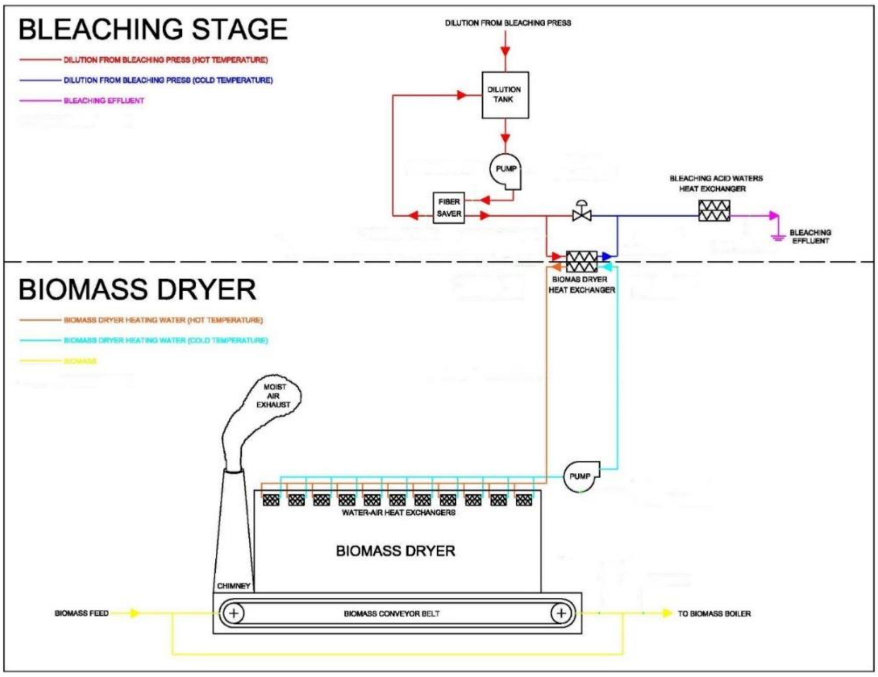

Figure 11: Biomass Dryer waste heat recovery flow diagram

2.2.2.2 Lime Kilns

In this scenario, the waste heat would be recovered from the exhaust gases of the lime kilns (causticizing stage), which are at a temperature greater than 300ºC, through a gas-water heat exchanger. The recovered heat would be used to further increase the temperature of the water (working fluid) used in the biomass dryer, thus increasing the drying capacity of the facility. See the heat recovery diagram in Figure 12.

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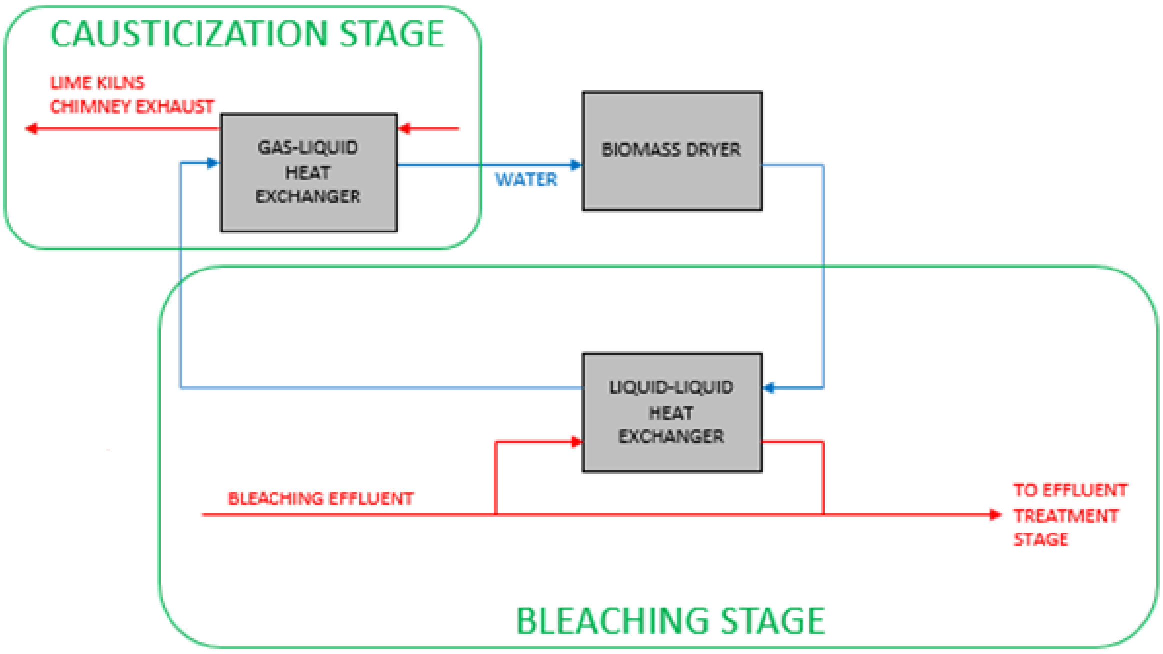

Figure 12: Lime Kilns waste heat recovery flow diagram

2.2.2.3 Effluent Treatment (DHN)

In this scenario, the waste heat would be recovered from the effluent during its treatment stage through plate heat exchangers (see Figure 13) and to be taken advantage of through a district heating network that would be connected to public buildings in the town of Navia (town hall, swimming pool, etc.), located less than 2km away from the factory. Currently there is a need for cooling in the effluent treatment process between the DAF (Dissolved Air Flotation) and the decanters, which is carried out through two cooling towers. The implementation of this measure would imply a reduction in the consumption of the cooling towers.

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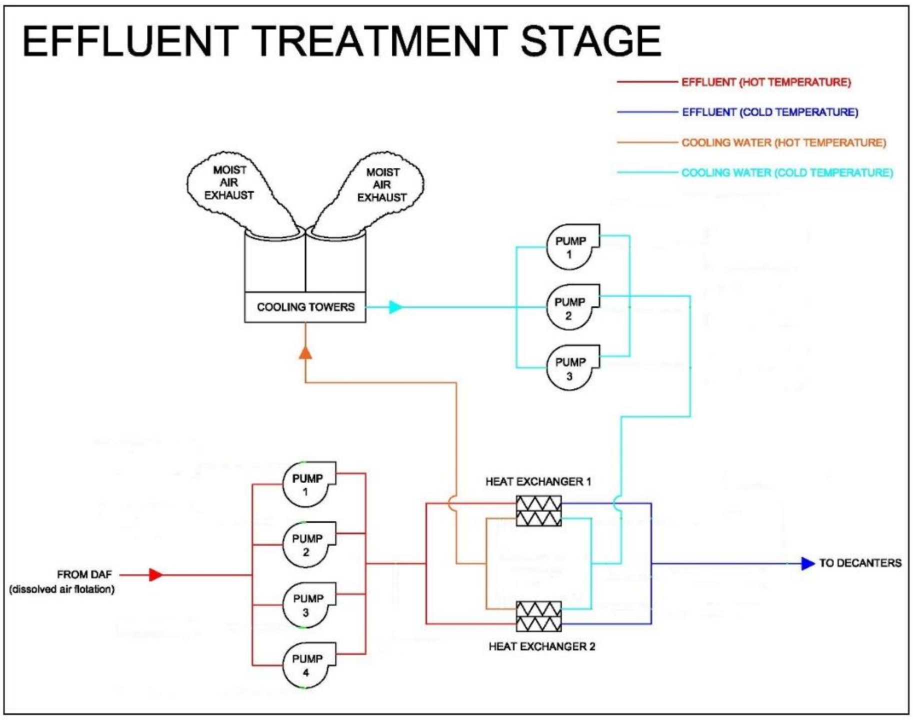

Figure 13: Effluent Treatment flow diagram (cooling between DAF and decanters)

2.2.3 ENCE tool trial steps performed

There were three testing objectives for ENCE. Table below gives an overview of the testing objectives TO1, TO6 and TO7 and sub-objectives (or test steps) and progress. TO6 and TO7 description is reported in table 1. Below in Table 2 the TO1.

Table 2 Testing objectives for TO1

TASK - TESTING OBJECTIVE	ASSIGNED TO
TO1 - Development/estimation of demo-site WH/C resource time series (annual, hourly resolution)	**Demo-site**
TO1.1 Request and collect relevant data available and shareable	**Demo-site**
TO1.2 Data formatting, upload to iSCAN, mapping and/or pre-processing	**Demo-site**
TO1.3 Rough-cut profiling and/or data processing and/or upload to iSCAN	**Demo-site**

Main work done for each task:

TO1: ELEUKON gathered the data of the three scenarios from the monitoring system of the plant (apart from data taken from documents and visits to the facilities). The sampling period was five months (between December 2019 and April 2020) and the temporal resolution chosen was one minute. ELEUKON cleaned the data of the three scenarios (removing periods of downtime or malfunction) and did the data formatting in order to upload the data to iSCAN platform (the format chosen was ".csv"). Taking into account the quality of the monitoring system of ENCE Navia plant, with temporal resolutions of less than one minute, this step was not necessary.

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TO6: Table 3 below summarizes the scenarios and the WH recovery technologies identified.

Table 3 Scenarios and technologies identified

Scenario	WH Recovery	Main Parameters
Biomass Dryer	Plate Heat Exchanger	- Flow rate of the hot working fluid (m3/h) - Inlet temperature of the hot working fluid (ºC) - Inlet pressure of the hot working fluid (bar) - Specific heat value of the hot working fluid (kJ/kg K) - Flow rate of the cold working fluid (m3/h) - Inlet temperature of the cold working fluid (ºC) - Inlet pressure of the cold working fluid (bar) - Specific heat value of the cold working fluid (kJ/kg K)
Lime Kilns	Gas-Liquid Heat Exchanger	- Flow rate of the hot working fluid (m3/min) - Inlet temperature of the hot working fluid (ºC) - Inlet pressure of the hot working fluid (hPa) - Specific heat value of the hot working fluid (kJ/kg K) - Flow rate of the cold working fluid (m3/h) - Inlet temperature of the cold working fluid (ºC) - Inlet pressure of the cold working fluid (bar) - Specific heat value of the cold working fluid (kJ/kg K)
Effluent Treatment (DHN)	Plate Heat Exchangers	- Flow rate of the hot working fluid (m3/h) - Inlet temperature of the hot working fluid (ºC) - Inlet pressure of the hot working fluid (bar) - Specific heat value of the hot working fluid (kJ/kg K)

ENCE held a meeting with representatives from the Navia town hall to present the Effluent Treatment scenario. Due to the fact that the surroundings of the factory are environmentally protected areas, the installation of a DHN (District Heating Network) posed many problems and hence the project was not evaluated further.

TO7: The following subtasks of TO7 were performed by ELEUKON for the Biomass Dryer scenario:

- Task 7.2: Export data from iSCAN to iCD.
- Task 7.3: Synchronisation of iCD data with iCIM model.
- Task 7.4: Export data from iCIM model to iVN project.
- Task 7.5: Setup iVN project parameters.
- Task 7.6: iVN baseline network model (include the virtual network).
- Task 7.7: iVN network model scenario #1 (included the virtual network and the setup of custom installation script).

Figure 14 summarizes the output of the SO WHAT tool for the simulation of the Biomass Dryer scenario. The Net Present Value obtained is 6,147,838€ with an Internal Rate of Return of 27.54% and a Discounted Payback Period of 3.89 years, for an annual biomass saving of 50,000 tons.

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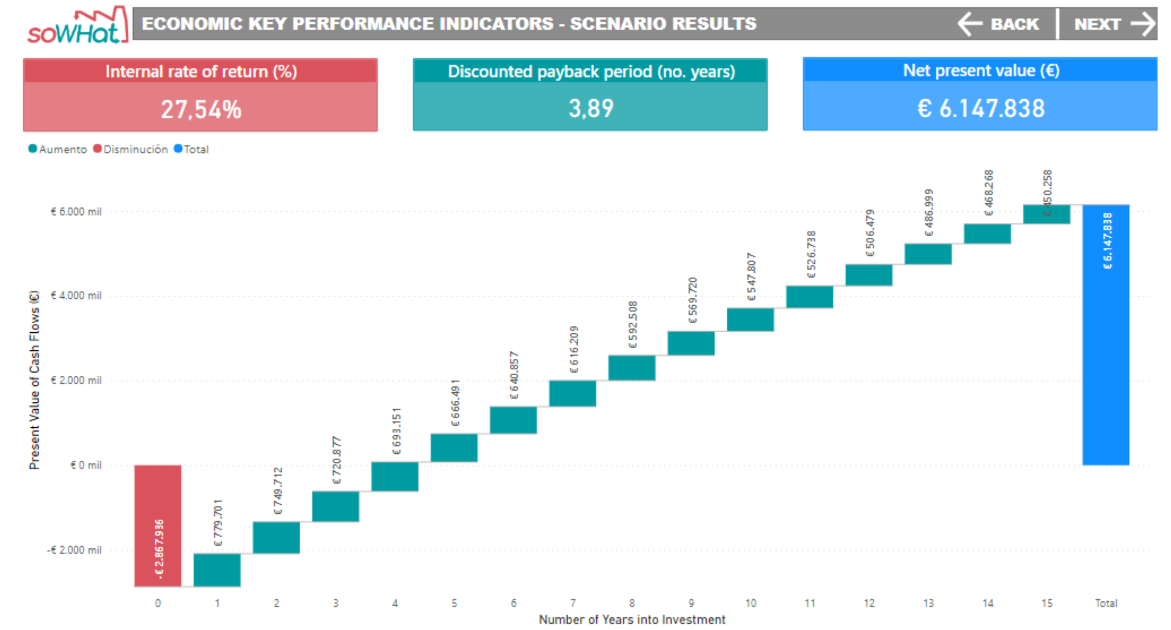

Figure 14: Output of the Biomass Dryer simulation (SO WHAT tool)

2.2.4 Results and lessons learnt

Finally, it was decided to prioritize the use the Biomass Dryer scenario for the Rask 7 of the testing plan of the SO WHAT tool due to the following main reasons:

- The facility was real and operational, providing the opportunity to collect data before and after its construction.
- The facility was fully monitored and integrated into the monitoring system of the plant.
- The plate heat exchanger had all the necessary sensors installed (flow, temperature and pressure).

Regarding the **installation of the SO WHAT tool**, ELEUKON did not suffer any problems during the process. However, it should be noted that the process, despite not being complicated (it is explained in detail step by step in the SO WHAT manual), becomes long and tedious due to the need to install different software and to navigate through different online platforms.

Regarding the **user experience**, the main aspects are summarized below:

- The interface is intuitive and clear, being easy to use.
- The menus are attractive to the user.
- Uploading data and navigating through the tool sometimes becomes complex, since, as during the installation process, it is necessary to move between different software and online platforms to establish connections between them.

As a main **conclusion**, a greater integration between the different software and online platforms would facilitate the user experience.

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2.3 Belgian Cluster

2.3.1 General description

Demosite 1: Umicore Olen

- Core process: Recycling of metals
- Reinforced sustainability objectives of the company (also due to geopolitical situation)
- Umicore requested studies to explore recuperation of waste heat via on site district heating network, and thus reducing the use of steam
  - Possible sources for waste heat
  - High temperature processes that could be transformed to low temperature processes
  - Connection of high temperature processes to low temperature waste heat, using heat pumps
  - Use of deep geothermal energy as extra source

Demosite 2: Isvag

- Core process: waste incineration plant
- Issues related to the permitting/licenses: not only for the construction of the new incineration facility, but also for the existing.
- However, willingness to continue to develop existing district heating net (Terbekehof) and to investigate new connections
- Democase of Isvag has been used to develop and test the tool to assess (financial/economical) feasibility

Demosite 3: Imerys Willebroek

- Core: production of graphite and carbon
- Increased production
- Decision taken to use waste heat for heat to power installation. Imerys found partner to dvelop heat to power.
- There might still be waste heat, but no certainty on amount and temperature.
- Discussions with POM Antwerp and Imerys on involvement in So What and outcome was to use existing information.

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2.3.2 Scenarios identified to use in the tool trial

Democase of Umicore has been used to develop and test the tool to assess (financial/economical) feasibility. Democase of Umicore has been used for testing So What tool.

Democase of Isvag has been used for testing So What tool: analysis based on existing plant. Scenario: provide waste heat to near located Atlas Copco plant.

Testing of the So What tool based on Imerys democase is on hold.

For both cases **(Umicore and Isvag)** the Waste Heat/Cooling recovery and Reuse Technologies are in the category/scenario of waste heat to heat. The technologies that are related or can be used are an economiser for the recovery and district heating heat exchangers to be able to transfer the heat to the heat net.

2.3.3 Tool trial steps performed for selected demos

There were six testing objectives for Umicore (TO1, TO2, TO3, TO4, TO5, TO6) and seven for ISVAG (TO1, TO2, TO3, TO4, TO5, TO6, TO7). Table 4 below gives an overview of the testing objectives and sub-objectives (or test steps): all completed.

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TASK - TESTING OBJECTIVE	ASSIGNED TO
TO1 - Development/estimation of demo-site WH/C resource time series (annual, hourly resolution)	**Demo-site**
TO1.1 Request and collect relevant data available and shareable	**Demo-site**
TO1.2 Data formatting, upload to iSCAN, mapping and/or pre-processing	**Demo-site**
TO1.3 Rough-cut profiling and/or data processing and/or upload to iSCAN	**Demo-site**
TO4 - Identification of plan for exploitation of WH/C resource and for use of SO WHAT tool (including TO2)	**Demo-site**
TO4.1 Review and share list of WH/C recovery/exploitation technologies (D1.6 report), as well as overview on assessment of potential WH/C resource with relevant stakeholders	**Demo-site**
TO4.2 Meet with stakeholders to identify plan for exploitation of potential WH/C resource, and to select relevant WH/C recovery/exploitation technologies	**Demo-site**
TO7 - Setup of virtual network baseline model for exploitation of WH/C resource and integration of RESs (baseline and scenarios)	**Demo-site**
TO7.2 Export data from iSCAN to iCD	**Demo-site**
TO7.3 Synchronisation of iCD data with iCIM model	**Demo-site**
TO7.4 Export data from iCIM model to iVN project	**Demo-site**
TO7.5 Setup iVN project parameters	**Demo-site**
TO7.6 iVN baseline network model (inc. virtual network, simulation and export of results)	**Demo-site**
TO7.7 iVN network model scenario #1 (inc. virtual network, setup of custom installation script, simulation and results visualisation)	**Demo-site**
TO7.8 iVN network model scenario #2 (inc. virtual network, setup of custom installation script, simulation and results visualisation)	**Demo-site**
TO7.9 iVN network model scenario #3 (inc. virtual network, setup of custom installation script, simulation and results visualisation)	**Demo-site**
TO7.10 iVN network model scenario #4 (inc. virtual network, setup of custom installation script, simulation and results visualisation)	**Demo-site**
TO7.10 Comparison against baseline results (inc. export of simulated results for baseline and scenario network models)	**Demo-site**

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TASK - TESTING OBJECTIVE	ASSIGNED TO
TO1 - Development/estimation of demo-site WH/C resource time series (annual, hourly resolution)	**Demo-site**
TO1.1 Request and collect relevant data available and shareable	**Demo-site**
TO1.2 Data formatting, upload to iSCAN, mapping and/or pre-processing	**Demo-site**
TO1.3 Rough-cut profiling and/or data processing and/or upload to iSCAN	**Demo-site**
TO2 - Identification of 1 to 3 relevant WH/C recovery/exploitation technologies	**Demo-site**
TO2.1 Review and share list of WH/C recovery/exploitation technologies (D1.6 report) with relevant stakeholders	**Demo-site**
TO2.2 Meet with stakeholders to select relevant WH/C recovery/exploitation technologies	**Demo-site**
TO3 - Setup of possible future DHNs for exploitation of WH resource (baseline and scenarios)	**Demo-site**
TO3.1 Develop and calibrate iCD building model (demo-site buildings and relevant buildings located in DHN/DCN area of interest)	**Demo-site**
TO3.2 Export data from iSCAN to iCD	**Demo-site**
TO3.3 Synchronisation of iCD data with iCIM model	**Demo-site**
TO3.4 Export data from iCIM model to iVN project	**Demo-site**
TO3.5 Setup iVN project parameters	**Demo-site**
TO3.6 iVN baseline network model (inc. virtual and physical networks, simulation and export of results)	**Demo-site**
TO3.7 iVN network model scenario #1 (inc. virtual and physical networks, setup of custom installation script, simulation and results visualisation)	**Demo-site**
TO3.8 iVN network model scenario #2 (inc. virtual and physical networks, setup of custom installation script, simulation and results visualisation)	**Demo-site**
TO3.9 iVN network model scenario #3 (inc. virtual and physical networks, setup of custom installation script, simulation and results visualisation)	**Demo-site**
TO3.10 Comparison against baseline results (inc. export of simulated results for baseline and scenario network models)	**Demo-site**
TO6 - Identification of 3 to 5 relevant WH/C exploitation technologies	**Demo-site**
TO6.1 Review and share list of WH/C recovery/exploitation technologies (D1.6 report) with relevant stakeholders	**Demo-site**
TO6.2 Meet with stakeholders to select relevant WH/C recovery/exploitation technologies	**Demo-site**

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TO5 - Setup of existing DHN (baseline) for exploitation of WH resource and integration of RESs	Demo-site
TO5.1 Develop and calibrate iCD building model (demo-site buildings and relevant buildings located in DHN/DCN area of interest)	Demo-site
TO5.2 Export data from iSCAN to iCD	Demo-site
TO5.3 Synchronisation of iCD data with iCIM model	Demo-site
TO5.4 Export data from iCIM model to iVN project	Demo-site
TO5.5 Setup iVN project parameters	Demo-site
TO5.6 iVN baseline network model (inc. virtual and physical networks, simulation and setup of custom installation script)	Demo-site
TO5.7 Export and visualisation of simulated results for baseline model	Demo-site

Table 4 Testing objectives for Umicore&Isvag demo site tool trials

2.3.4 Results and lessons learnt

Both Umicore and Isvag demosites were approached with the tool slight differently because of the different context. For Umicore waste heat is recovered for re-use in their production processes. For Isvag waste heat coming from the CHP is used for building heating of industrial buildings nearby. For the ISVAG case the Belgian Cluster was able to simulate the buildings heating demand in the ICD module of the SoWhat tool. For the Umicore Belgian Cluster uploaded the waste heat and heat demand data in the ICM module using a CSV file. The tool was uploaded and used in autonomy, the help of IES was required to check that some fields had been filled in correctly and to clear out some issues.

Difficulties encountered during testing So What tool: heat demand in Umicore is mainly process heat, and no building heating. In the Isvag democase, it is difficult to analyses a large DHN with the current software as the radius is limited. Therefore, the Belgian Cluster limited the scenario to Isvag – Atlas Copco (otherwise the connection with Antwerp University could have been tested). It was time consuming to install the different modules of the So what tool and linking them together afterwards. A fully integrated tool with one install procedure could be a great improvement. For both the Umicore and ISVAG case it was hard to achieve relevant data. When Belgian Cluster received data, it was always data of high resolution which had to be modulated to make it useful to use in the tool. Most industries have no detailed data about the amount of waste heat that practically can be valorised.

General feedbacks: The simulation of heat demand of existing buildings was compared with the real heat consumption and was quite accurate; the visualisation of the economic KPI's is very clear and structured. Switching and linking between the different software modules was a hard process; modelling in the IVN module is not intuitive. Uncompleted steps are not cleared out by the tool. Most problems were related to the not intuitive nature of the tool and the many steps to follow before results are reached.

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Tool expectations: the Belgian Cluster's expectations at the beginning were to simulate the cases and have a full feasibility result at the end. Expectations have been satisfied; in fact we were able for both cases to reach the status of a fully feasible result.

Tool User Friendly: It is definitely important to have a user-friendly interface. On the integration side of the different modules big steps can be made which will improve the willingness to use the tool. In the tool itself error messages should more point out what the user has done wrong. That makes the tool much more intuitive, which saves time for both the end user and support functions.

2.4 Romanian Cluster

2.4.1 General description

The MEDGreen Cluster is a grouping of innovative companies, research organizations, universities, local authorities and other stakeholders from Romania associated with the promotion of eco-technologies and alternative sources of energy. At present, the membership of the Cluster includes 2 Universities, 3 Municipalities, 1 National Research Institute, 1 National Company, 11 SMEs and 2 Phisical Persons. The cluster is actively involved in eco-innovation projects dedicated to the enhancement of competitiveness by the promotion of the principles of green economy.

The MEDGreen Cluster is legally registered as Association "Cluster for promoting the specialized businesses in eco-technologies and alternative energy sources in South-East Region and Bucharest-Ilfov Region" according to the Romanian law for NGOs. The cluster is a member of the National Pole of Competitiveness in Promoting Modern Manufacturing Systems for the Implementation of the "Green economy" Principles.

In 2013 the MEDGreen Cluster founded the "Center of Engineering for Sustainable Development" in Constanta. Within this center there are carried out scientific research activities, innovation projects and evaluation studies with different aspects of sustainability including sustainable energy solutions and sustainable transport systems. The competencies of the center include modelling, analysis and optimization of energy systems with a lifecycle approach, comparative analysis of different transport modes, pollution and environmental impact, life cycle assessment, technical and economical complex analysis and optimization methods.

Cluster MEDGreen has expertise in developing and implementing projects funded by EU programs, national and/or third parties, with the aim to develop the cluster and achieve the progress of the members of the association. The research teams, which are involved in project developed under the framework of the Cluster, are in a national leading position in terms of scientific research and innovation. Between the partners there are collaborative relationships, both in commercial aspects, and in scientific research activities.

Association Cluster MEDGreen is part of the National Pole of Competitiveness in Promoting Modern Manufacturing Systems for the Implementation of the "Green economy" Principles. The organizations that are involved in the national pole are large enterprises, SMEs, universities, clusters, research institutes that aim to implement, in partnership, investment projects, research projects, research, development and innovation projects, projects for the national and international promotion of SMEs. The association is actively involved in facilitating and promoting cooperation between innovative enterprises, research institutions, education organizations and other stakeholders, that could contribute or support the activities for the development of innovative products and services for the sustainable development of the South-East Region of Romania.

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2.4.2 Scenarios identified to use in the tool trial

The interest for the use of the tool has been coming from the side of the SMEs and the municipalities that are members of the cluster. At the same time, the universities and the research groups from the National Institute have been also interested in evaluating the tool.

The Board of the Cluster took the decision to organize a task force within the umbrella of the MEDGreen Cluster in the Center of Engineering for Sustainable Development and Dr. Laurentiu Oancea has been appointed to coordinate the team of experts.

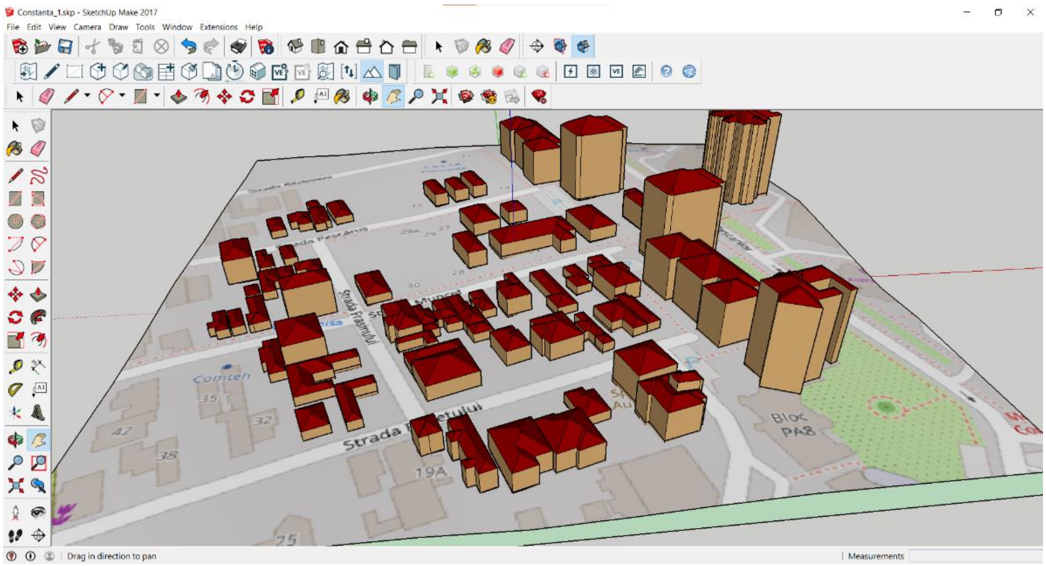
In a later stage, there will be dedicated workshops for all interested members of the Cluster to guide them to use the tool for their projects.

The tool has been also proposed for evaluation for the partner organization from Romania and from other countries like the Technical University of Varna and the INTRAVIS company from Slovakia that are collaborating with the Cluster.

2.4.3 Tool trial steps performed for selected demos

There were three testing objectives for the Petromida refinery (TO1, TO4, TO7) and three for Costanza (TO5, TO8, TO10).

The team coordinated by Dr. Laurentiu Oancea developed a trial of the tool for a project of great interest within the Cluster.



It consisted of the conversion of one of the re-heating stations located in the district "Faleza Nord" of Constanta to a thermal plant based on renewable energy. The plant will be suppling hot water for heating and warm water for daily use for an large secondary network of dwellings in apartments blocks.

The aim of the project was to define a pilot plant concept using solar energy by installing solar-thermal panels as an alternative thermal energy source on the roof-top of the building without additional structural changes. This would increase the sustainability, and a at the same time assuring the quantity and quality thermal energy for the end-user within the legal frame work for thermal

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energy distribution in Romania. The results are reported: Figure 15 and Figure 16 report investment analysis..

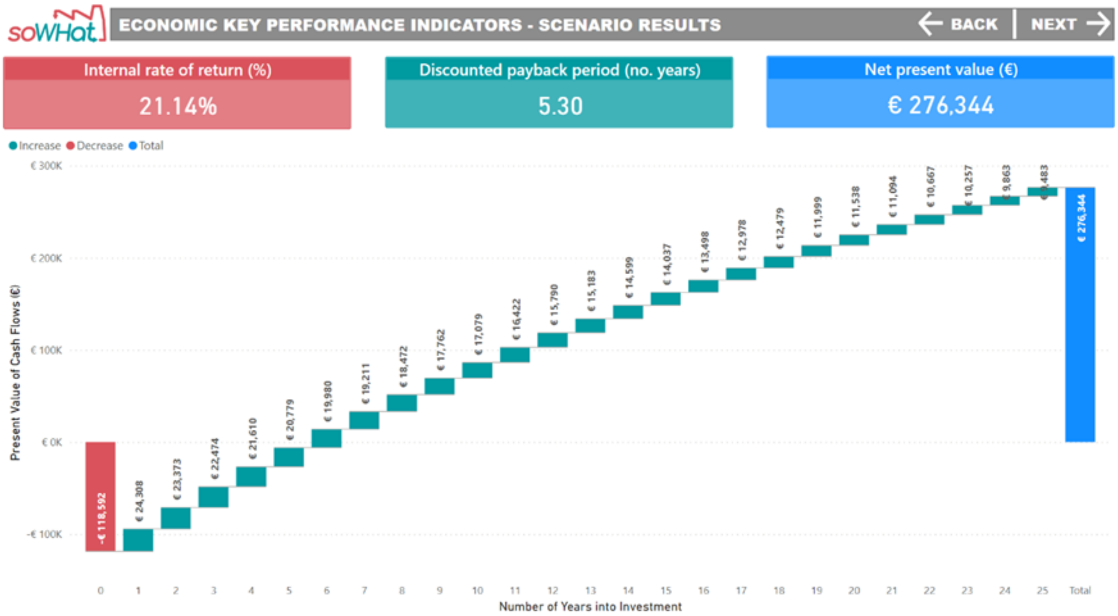

Figure 15 – Analysis for the investment in pellet boilers and the resulting payback period

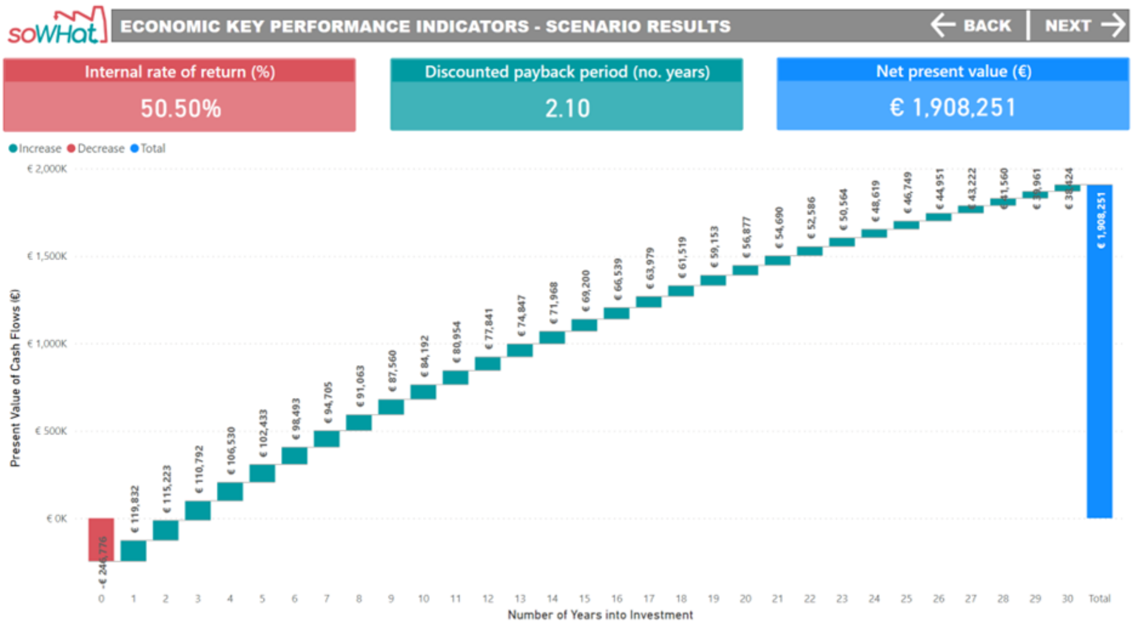

Figure 16 – Analysis for the investment in solar thermal system and the resulting payback period

2.4.4 Results and lessons learnt

Both the online and the advanced desktop tools were used and the result has been very positive. It has been possible to make intuitive development of the solutions by the graphical modelling and shaping the physical infrastructures.

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The obtained results were relevant and have been important for the preparation of the decision support activities.

The required time to get acquainted with the tool was reasonable. The **main technical steps** that have been followed in the team were related to the appropriate setting the input data and parameters to use in the tool.

The **main problem encountered** was related to the use of the advanced tool by integrating the licenses for Google Sketchup and IESVE. With the support of the call centre team from IES the problems have been solved.

Tool expectations: the expectation of the Cluster team was that the tool should have an appropriate populated database to offer suitable values for the different parameters used in different scenarios.

A user-friendly tool: the tool requires a period for familiarization and after this has been reached the further use of the tool is not that difficult.

Results obtained during the trial: the results obtained on the economic-financial and risk assessment part have been considered very interesting.

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2.5 SWEDISH Cluster

The Swedish lighthouse cluster comprises of two demo sites located in the cities of Gothenburg and Varberg on the Swedish west coast. IVL Swedish Environmental Research Institute (IVL) coordinates the work of the cluster. The tool trials were done for the Varberg demo site, as data was more easily accessible for this demo site and focused on testing the functionality of the tool.

2.5.1 General description

The demosite in Varberg is represented by Varberg Energi (VEAB), a municipality owned energy company providing district heating and other services to the area. VEAB is acting as one of the lighthouse partners for the SO WHAT project. As a municipality owned company, they have been given the directive to invest in sustainable, local energy resources. Incentivized by this directive they identified waste heat from a pulp mill (Södra Cell Värö, SCV), situated about 20 km from the city, as a promising source of waste heat to be fed into the district heating network. Prior to the construction of the Varberg district heating network, the pulp mill was forced to cool away heat and release it to the surroundings. Today, waste heat is the main source for the district heating network (85%), but conventional district heating sources such as wood chips, biogas and bio-oil are also available to diversify and increase the reliability of the network.

2.5.2 Scenarios identified to use in the tool trials

Two different scenarios were used to test the functionality of different parts of the SO WHAT tool. These scenarios are presented briefly in this section.

2.5.2.1 Scenario 1: Increased use of waste heat

VEAB and the pulp mill SCV are currently investigating the possibility to increase the amount of waste heat injected in the network through action both at heat exchanger level and at customer level, i.e. lowering the return temperature. The tool (meaning the iCD, iVN, iSCAN, iCIM softwares) was tested for the Varberg demo site using input data for hourly average power demand for the city of Varberg (MW), see Figure 17. The idea was to test how district heating demand could be matched by the excess heat from the pulp mill Södra Cell Värö (SCV) to make use of more of the excess heat.

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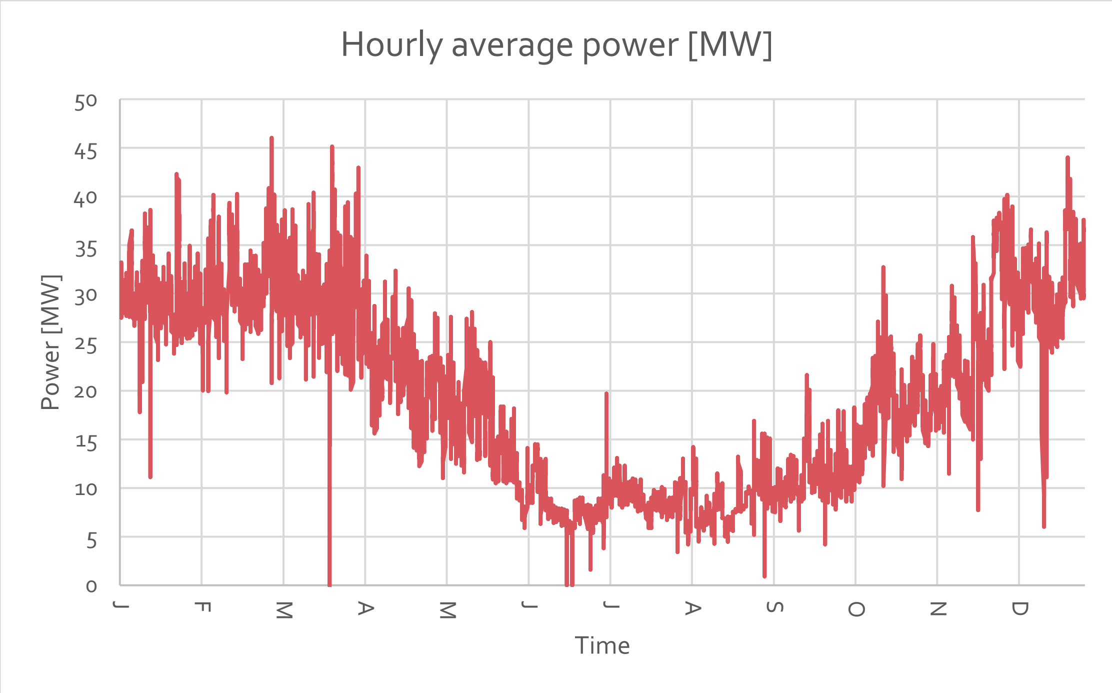

Figure 17 The input data for hourly average power used in the tool trials for Varberg demo site

2.5.2.2 Scenario 2: Provision of district cooling

VEAB is currently investigating the possibility to provide district cooling during the summer via absorption chillers exploiting local waste heat. VEAB has investigated the possibility of expanding their supply to the city of Varberg with district cooling. IVL used this scenario to compare VEAB:s own study with the results of the Power BI tool developed within SO WHAT.

Today, the potential district cooling customers have their own cooling installations (mainly electric chillers) that use environmentally harmful refrigerants and electricity. The aim is to minimize the use of refrigerants and free up electricity in the power grid for more appropriate purposes. A positive side effect is that the number of existing cooling units and coolants in the city centre can be reduced, which in this way reduces noise.

The production plant for the district cooling is planned to be taken into operation in 2026. The plan is to utilize free cooling from the cold seawater during the winter half-year, while excess heat from Södra Cell Värö produces district cooling during the summer when the temperature of the seawater is too warm. The total capacity of the district cooling network will be 13 MW and approximately 13,000 MWh of district cooling will be distributed every year. This will replace individual electric chillers and thereby reduce the annual electricity demand by 2,300 MWh. District cooling is mainly applicable for larger buildings such as shopping malls, industries, grocery stores, restaurants, hotels and hospitals.

The district cooling network will be built in two main pipelines: 1) a northbound line connecting properties in Lassabacka, Susvind, Kvarnagården and Holmagärde and 2) a southbound line that runs via Västerport, the city center and finally connects to the central hospital. The network is illustrated in Figure 18.

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Figure 18. Map over Varberg City. Red line is the pipeline for district cooling.

2.5.3 Tool trial steps performed for Scenario 1 in iCD, iVN, iSCAN, iCIM softwares

There were three testing objectives for Varberg. Table 5 gives an overview of the testing objectives TO8, TO5 and TO9 and sub-objectives (or test steps) and progress. TO8 was accomplished, TO5 was partly accomplished and TO9 was not initiated because of the dependencies on the final steps of TO5. Some of the issues are described more in detail in the section about results and lessons learned.

Table 5 Testing objectives and progress for Varberg demo site tool trials

Testing objective	Progress	Comment
TO8 - Development/ estimation of (W)H/C resource time series on DHN supply/demand sides	100%	
TO8.1 Request and collect relevant data available and shareable	100%	Data from Varberg Energi was used. The data represented hourly average heat demand [MW]
TO8.2 Data formatting, upload to	100%	The .xls-file was converted to .csv. The file was uploaded on PVV demo site iSCAN Research: https://iscan-research.iesve.com/building-details/SOWHAT/PVV

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iSCAN, mapping and/or pre-processing		
TO8.3 Rough-cut profiling and/or data processing and/or upload to iSCAN	100%	
TO5 - Setup of existing DHN (baseline) for exploitation of WH resource and integration of RESs		
TO5.1 Develop and calibrate iCD building model (demo-site buildings and relevant buildings located in DHN/DCN area of interest)	100%	The DHN was limited in the map by using the attribute function of the tool.
TO5.2 Export data from iSCAN to iCD	100%	Followed the steps on how to associate channels from iSCAN to iCD.
TO5.3 Synchronisation of iCD data with iCIM model	100%	iCD and iCIM has some function but iCIM is a cloud-based version that could be used to export data and map to iVN. The connection is online and no download or installation is needed.
TO5.4 Export data from iCIM model to iVN project	100%	
TO5.5 Setup iVN project parameters	100%	The different boilers were added to iVN. Heating generators were used in the cases were no boiler options were available. The nodes (heater, cooler, etc.) were added in 2D view. Piping was added in infrastructure view. A weather map was added: https://energyplus.net/weather-location/europe_wmo_region_6/SWE/SWE_Goteborg.Landvetter.025260_IWEC
TO5.6 iVN baseline network model (inc. virtual and physical networks, simulation, and setup of custom	-	Issues were encountered: To building a baseline network with the assets was quite easy, but I was missing an asset for the heat injection for the waste heat from the Pulp mill. Tried to build one, were we connected the generic asset with a waste heat node linked to a costume installation asset that worked as a heat exchanger (HEX), further connected to the heat node, but it didn't work well. The simulation of the heat generators (Biogas-, Bio oil- and biomass boiler) went fine, but I did not get any results for the heat exchanger even if I tried to change the parameters in the scripts.

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installation script)		
TO5.7 Export and visualisation of simulated results for baseline model	-	Was unavailable.
TO9 - Validation/calibration of WH/C recovery/exploitation technology model against currently installed technologies in DHN	-	
TO9.1 Comparison and gap analysis between simulated results for WH/C recovery/exploitation technology models against real-life measured data	-	
TO9.2 Iterations with adjustment of user input parameters for WH/C technology models, re-simulation, results comparison, and gap analysis	-	
TO9.3 Export and visualisation of simulated results for calibrated baseline model	-	

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2.5.4 Results and lessons learnt

The results and lessons learnt from the trials are presented in the subsequent sections.

2.5.4.1 Installing and using the iCD/iVN/iSCAN/iCIM softwares (Scenario 1)

For the Varberg demo site the following softwares were needed: iCD, iVN, iSCAN, iCIM (including the VE licence). Some of the problems encountered during the installation and use of these softwares are presented here. A general comment is that too many platforms (VE, iSCAN, iCD, iCIM, iVN) makes the user confused. It's difficult to keep the track of which platform does what and where to find them.

VE licence

To activate the VE licence the test person tried to follow the steps in the instructions but when reaching the highlighted step in Figure 19 there were some issues. **In VE, select Help >> Troubleshooting >> Set License Folder,** the test person tried to delete the keys.txt file but nothing happened. The test person had to find another way to activate the licence key.

VE

To activate your keys through our new license management system, you will need to be on a machine that has VE (download here) and pointing to the current keys folder location. Then follow the below steps:

- In VE, select Help>>Troubleshooting>>Set License Folder
- The file path will be displayed. Navigate to that folder and please delete the keys.txt file therein.
- Once deleted, go back to VE 2019 and select Help>Request License
- Complete the form with the Activation Code: **0011T00002ZIFkj5**
- Select 'Activate'
- Click 'Send Request' and license will be updated within the hour

Once a code has been used it cannot be used again.

If you get an error upon completing the above please follow these instructions :

- Open VE >>Help >>request license key
- In tab Action, select "Request free trial" don't send the request
- in the same tab action, Select "Activate/Refresh software again
- Send request

Once you have successfully installed VE, please then follow the iCD steps below.

Figure 19 Instructions for activating the licence key. The step text highlighted in yellow did not work properly.

iVN

The getting started video link (https://www.iesve.com/icl/ivn/getting-started) in the installations trial did not work.

It went well with the import of the iCIM-model and also the input-data from iSCAN (Project URL + Project token) to iVN. Compared to the other platforms, it was more logical to work with the iVN-platform and the test person would have preferred to work with this tool if it was all gathered on one platform.

It was also quite straight-forward to build a baseline network with the assets. However, the test person was missing an asset for the heat injection for the waste heat from the pulp mill. Connecting the generic asset with a waste heat node linked to a costumer installation asset that worked as a heat exchanger (HEX), and further connected to the heat node, did not work well. The simulation of the heat generators (biogas-, bio-, oil- and biomass boiler) went fine, but there were no results for the heat exchanger even if the parameters in the script were changed. An asset implemented in the tool for waste heat injection to the heat node would solve the problem encountered.

iCIM

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There were issues with synchronizing iCD with iCIM: "*Import error. An error occurred while opening project SOWHAT PVV: Unable to import entities. Failed when moving old model file*".

iCD

During the installation of the iCD software there were several issues. The SketchUp plugin could not be downloaded without the correct version of SketchUp being installed. To solve this, a suggestion is to put a link SketchUp with specific version in the description. The latest version (2022) did not work for the test person, which instead had to download the 2019 version. In addition to the issue with SketchUp, this link did not work: https://www.iesve.com/icl/icd/getting-started.

When using the iCD there were issued to import from open street map. An error message from SketchUp was displayed: "*An error has occurred: Failed when moving old model file*".

iSCAN

After creating access to the projects, the test person could not create a data source in the project PVV. Another access solved the problem.

2.5.5 Validation of the tool (Scenario 2)

Finally, a feasibility study using the SO WHAT tool (see deliverable 5.3 for more information) was performed.

The delivered data from VEAB consisted of internal decision document regarding district cooling in Varberg as well as a profitability calculation in Excel format. It was assumed that the technical life was 30 years and that reinvestments will have to be made after 15 years. Otherwise, the conditions are equivalent. The profitability calculation was compared with the SO WHAT Power BI tool.

The results match when it is considered that certain assumptions differ, which the tool cannot accommodate. The results in the Power BI tool and VEABs profitability calculation is showed below in Figure 20 and Figure 21.

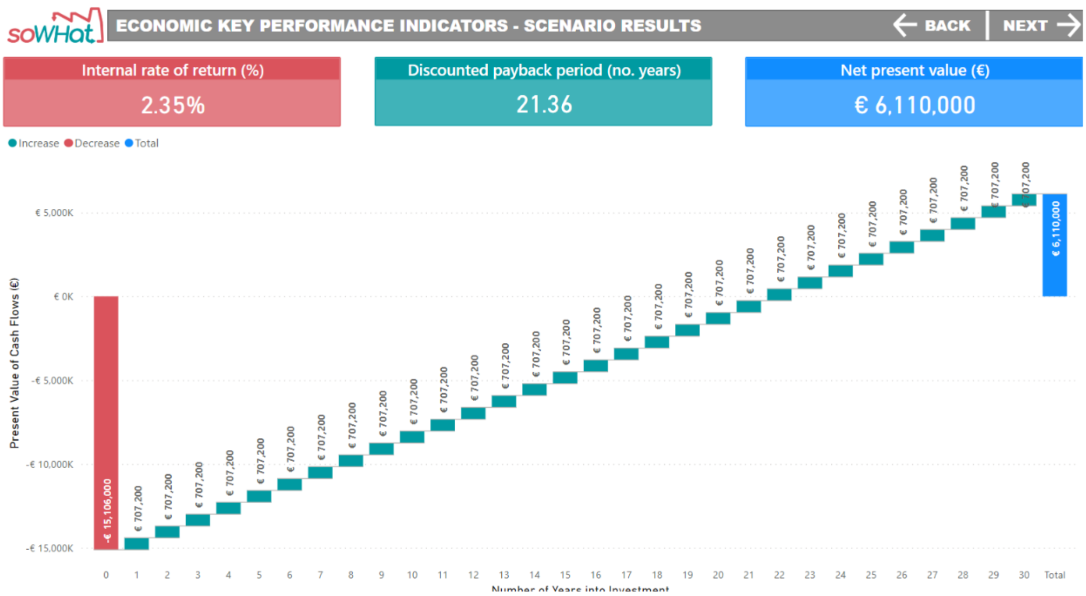

Figure 20. Power BI tool and Pay back period.

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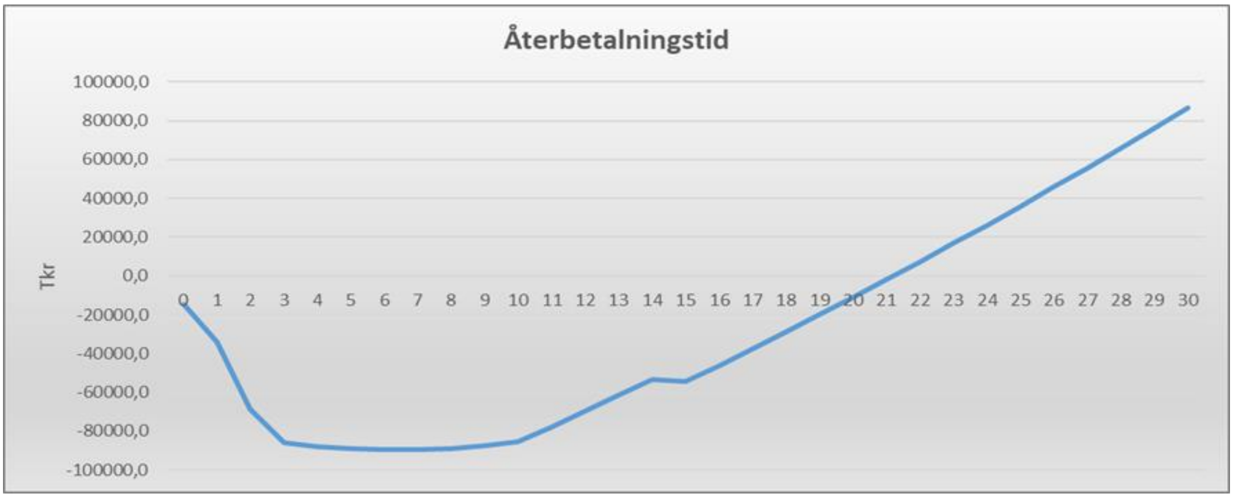

Figure 21. Varberg Energys Profitability Pay back calculation result.

2.5.6 General comments on using the SO WHAT tools

When testing the tool during February-March, 2022 we understood that not all parts were developed yet. For the continued development we would like to stress what we think are most important to prioritise.

Expectations of the tool – platform for discussion between partners: Based on our experience, we think that in order for an it tool to facilitate industrial waste heat exploitation it should function as a platform for discussions between potential partners in a waste heat collaboration. As stressed in the deliveries of WP3, a major challenge for realising the waste heat potential in Europe is for the partners to understand each other's prerequisites, in terms of technical systems and business models, and to trust each other. Hence, important features of the tool are to take into account the heat and cold demands and excess energy potential of the partners and illustrate of how the respective demand and excess of energy can be matched over the hours of the year.

When the matching is illustrated, it should be possible to use the tool for testing main technical options. For example, if the temperatures do not match, a heat pump could be introduced. Or if the supply and demand do not match in time, an energy storage could be introduced. For the options that are tested, the advantages and disadvantages of exploiting the waste heat should be compared to business as usual, for example in terms of cost reduction or environmental impact reduction.

Starting point – auditing has shown there is energy in excess: Often, large industries have performed energy audits and are aware of the amounts, temperatures and fluctuations of their excess heat from major processes. Hence, this could be the starting point for using the SOWHAT tool. In these cases, the purpose of the tool will be to explore alternatives to make use of the excess heat. If internal heat integration within the industry has not already been implemented, such alternatives could be considered first. But then focus should be to match with external demand for heat, e.g. for district heating or cooling.

Existing decision support tools for the energy sector: Existing tools for planning new district heating or cooling networks are advanced and the use of them is well established in the energy sector. One exemple is PFC (Pipe Flow Calculation) from Hydroram which is used by GEAB. Because of this,

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we do not see the benefit of putting too much effort into developing detailed features for energy networks in the SOWHAT tool.

Furthermore, since the energy sector has critical infrastructure, there are high security requirements when it comes to installation of new software. Normally, it takes months to get approval for software installations. Most useful would be to have an online tool, that do not need desktop installation of softwares.

A user-friendly interface is essential: Users of the SOWHAT tool will probably have varying professional background, e.g. engineers and economists. High level of computer skills cannot be taken for granted. Therefore, we think the tool needs to be as self-explaining as possible. If possible, a solution with just **one platform** in which all the applications can be used would be preferable.

Outcome of the tool – basis for taking the decision to start a new collaboration: In summary, our vision for the SOWHAT tool is that it should be a facilitator for heat collaboration. In addition to the features mentioned above (matching supply and demand, testing of technical option, and presenting the economic and environmental consequences), the tool should also be a toolbox containing common business models in terms of ownership, sharing of risk, costs and revenues, and contractual arrangements. The ultimate outcome would be that partners get sufficient knowledge and understanding to be able to sign a letter of intent for a future collaboration.

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2.6 PORTUGUESE Cluster

2.6.1 General description

The Portuguese Cluster is coordinated by 2GO OUT Consulting with the involvement of the demosite LIPOR and AdEPorto – Energy Agency of Porto.

LIPOR is responsible for the management, recovery, and treatment of 380.000 tons of municipal waste in eight associated municipalities.

In 2021, 74% of the municipal waste sent to LIPOR's waste-to-energy (WtE) plant was used for energy recovery generating approximately 182,8 GWh of electricity. Nearly 88% of the electricity produced is sent to the grid, while the rest is consumed internally.

LIPOR waste-to-energy plant produces steam for electricity production and the excess heat is released at the condenser (55 – 60ºC) and is not yet exploited.

2.6.2 Scenarios identified to use in the tool trial

The LIPOR democase scenario considers the recovery of excess heat from the WtE to be delivered at the Porto Airport (2 km away from LIPOR's WtE), where it will be used for space heating and cooling, and to create a new district heating network. Nowadays gas boilers for heating and electrical chillers for cooling are used at the airport.

In this scenario 40,8 GWh of waste heat will be recovered from the WtE plant and shared with Porto Airport. The heat will be used for space heating and space cooling at the airport (26,8 GWh of thermal energy needs).

For this purpose, the investment planned considers: 1 heat pump (in WtE, COP 4.6) to increase the temperature of the supplied heat in the network, absorption chillers at Porto Airport for cooling purposes, heat exchangers, circulation pumps and 4 km of a new district heating network piping.

The total initial investment cost is estimated to be of 6,9 M€.

An additional scenario was considered for replication purpose, including two new potential users: a brewery and a business hub with more than 100 companies and more than 5,000 employees. Both new end-users are located at less than 4 km away from LIPOR's WtE.

2.6.3 Tool trial steps performed for selected demos

There were eight testing objectives (TO1, TO2, TO3, TO4, TO6, TO7, TO8, TO10). Table 6 below gives an overview of the testing objectives (TO8 and TO10, the others are reported in the sessions above) and sub-objectives (or test steps): all completed.

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TASK - TESTING OBJECTIVE	ASSIGNED TO
TO8 - Development/estimation of (W)H/C resource time series on DHN supply/demand sides	**Demo-site**
TO8.1 Request and collect relevant data available and shareable	**Demo-site**
TO8.2 Data formatting, upload to iSCAN, mapping and/or pre-processing	**Demo-site**
TO8.3 Rough-cut profiling and/or data processing and/or upload to iSCAN	**Demo-site**
TO10 - Validation of recommended use case	**Demo-site**
TO10.1 Comparison and gap analysis between simulated results for network baseline model against real-life measured data	**Demo-site**
TO10.2 Iterations with adjustment of input parameters (data-related) for network model, re-simulation, results comparison and gap analysis	**Demo-site**
TO10.3 Export and visualisation of simulated results for calibrated baseline model	**Demo-site**

Table 6 Testing objectives for LIPOR demo site tool trials

For the SO WHAT tool tests, the Portuguese Cluster tried to follow a step-by-step logic for the characterization and validation of the existing situation, so that later it was possible to simulate energy efficiency and emission reduction solutions.

Having overcome the whole issue of installing and acquiring a license for the various components of the software, the process began by gathering and analyzing existing information.

iSCAN

The first component of the tool used was iSCAN, which allowed to compile, postprocess, import and export data regarding the demosite and also the potential waste heat users.

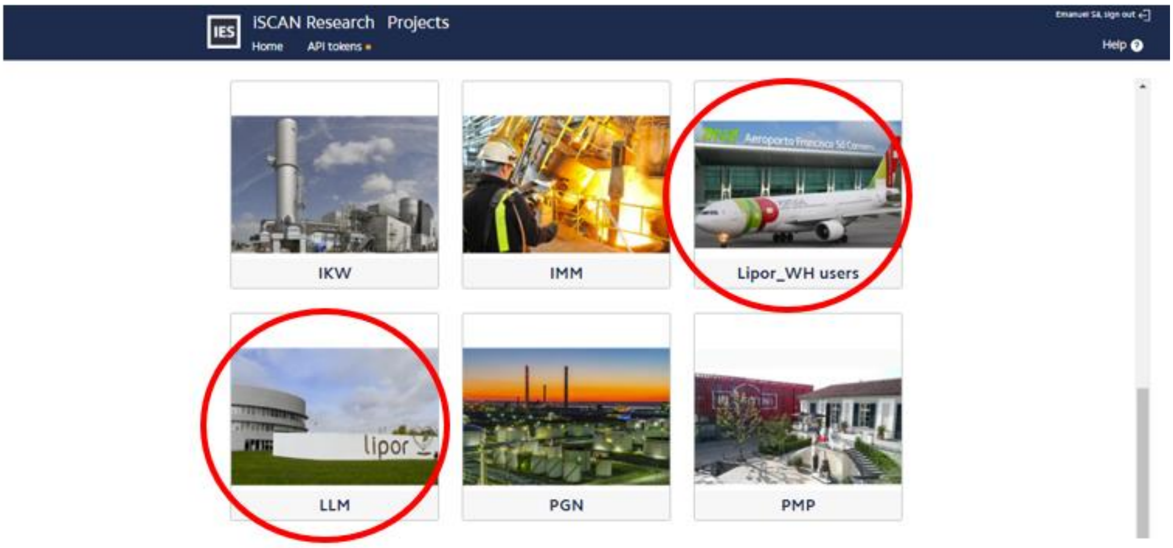

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Figure 22 – iSCAN different sets of data for different buildings (LLM – Lipor demosite data; Lipor_WH users – data from simulations in iCD and other external softwares)

Using iSCAN's capabilities of post processing data, it was possible to estimate de total waste heat available at the plant and its profile, see Figure 23.

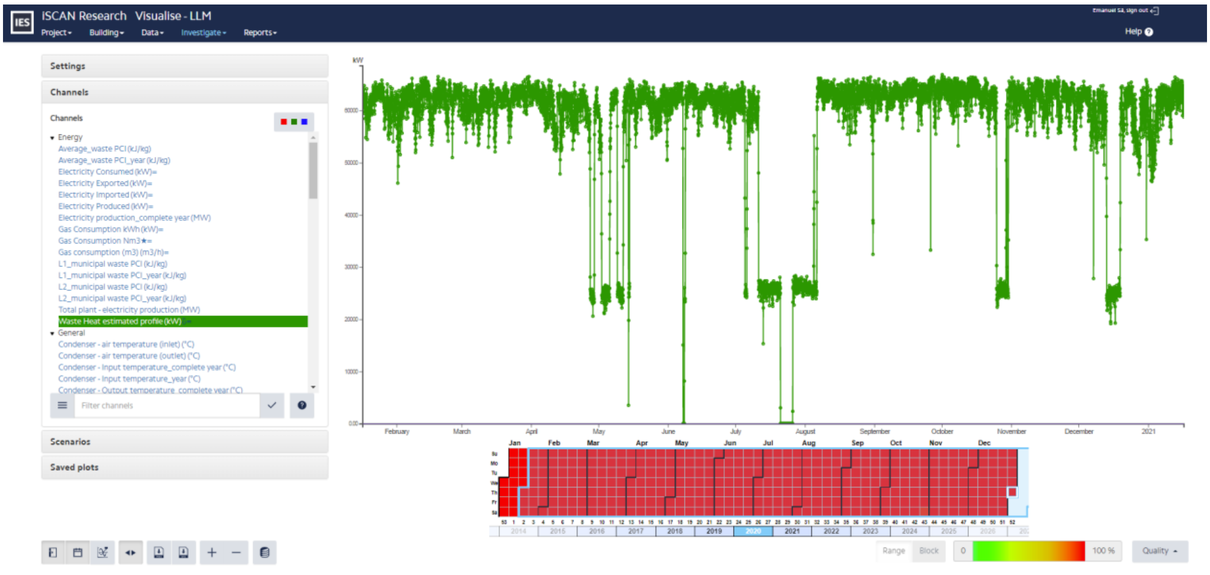

Figure 23 – iSCAN information regarding Lipor's data. Estimation of the waste heat profile

iCD

For the estimation of the waste heat demand for potential user, the Portuguese cluster used the iCD tool. This allows to select the area of interest from an *Open Street Map* and then proceed with the characterization and energy demand estimation for the desired buildings of interest in the area, see Figure 24.

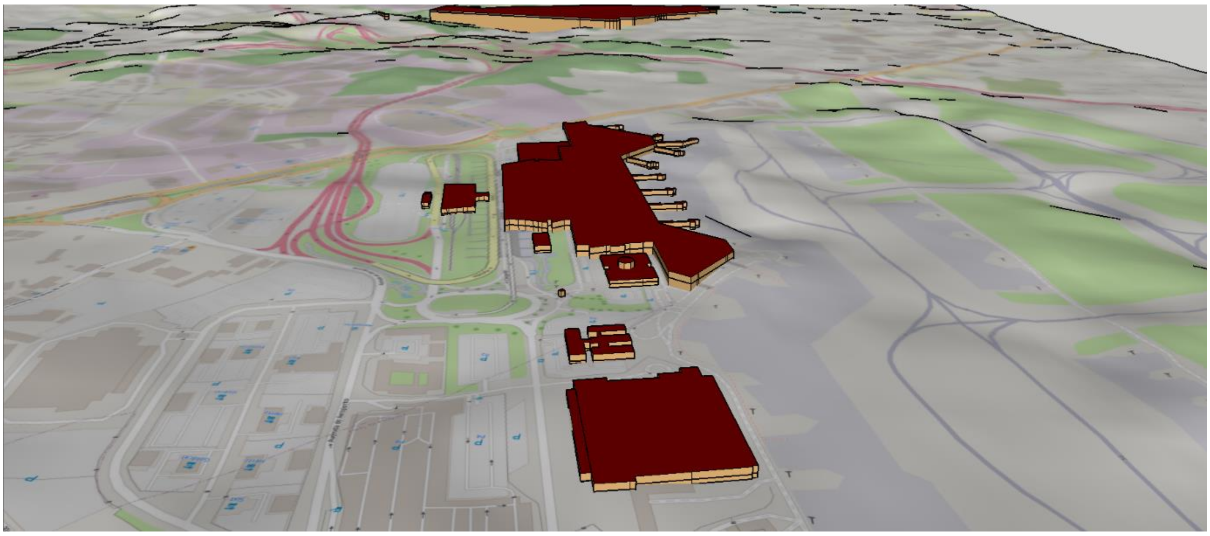

Figure 24 – iCD tool showing Porto airport and its premises.

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The tool for importing information on buildings and facilities from the "open street maps" immediately allowed a significant advance in the initiation of mapping the energy needs. In the specific case of the Portuguese study, and since it was of interest to know as many potential customers of the heat network as possible, an area of about 15 km^2 around the demosite was imported, see Figure 25. This area resulted in the survey of hundreds of buildings, proving to be impractical to maintain the model in such detail, both in terms of necessary information and in terms of graphic and computing resources. For this reason, the number of existing buildings in the model was reduced to those that were identified as being strictly necessary.

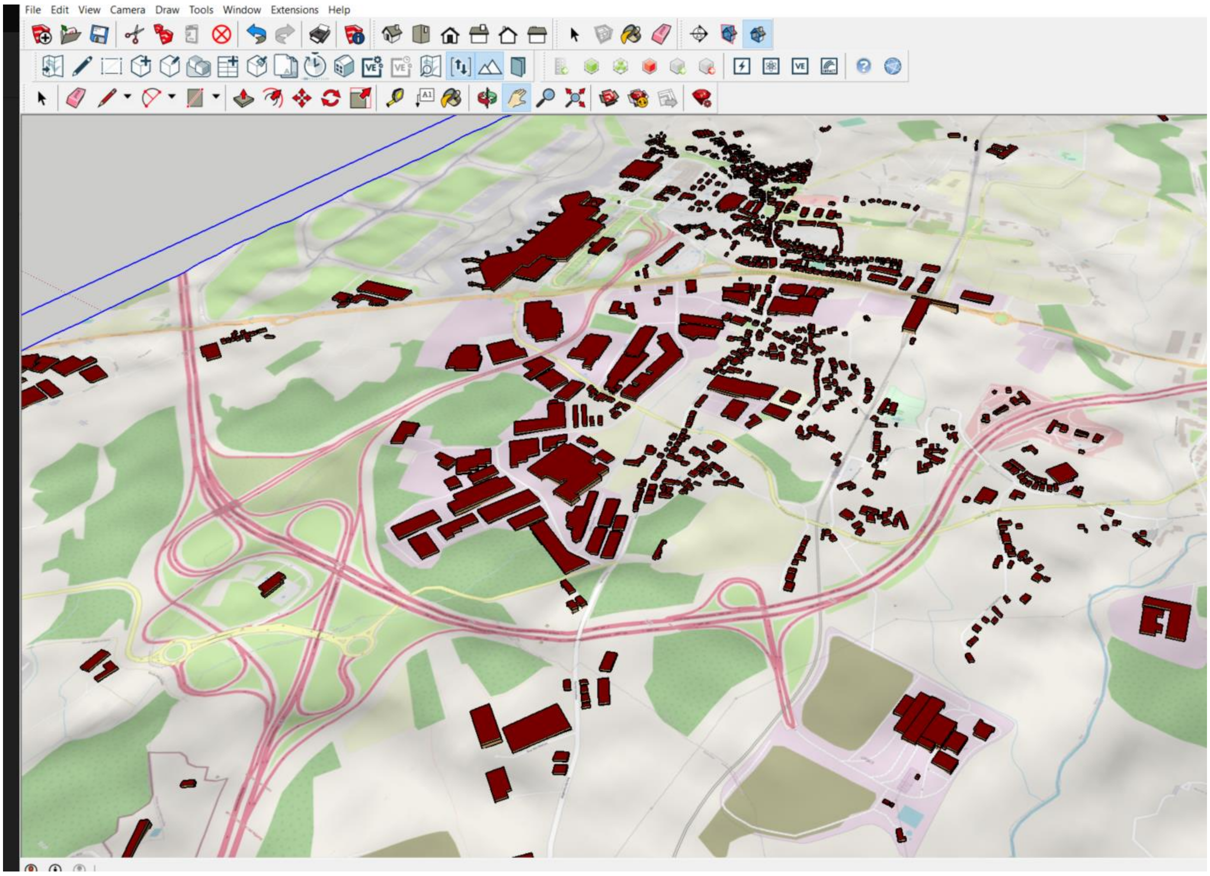

Figure 25 – Image of the initial model that was discarded

Figure 26 shows the image of the model with only information on the buildings identified as having relevant interest for this phase of the work.

In the Portuguese case, and as a result of contact with several well-known stakeholders in the vicinity of the demosite, there were already some knowledge of energy consumption in buildings and their respective hourly profiles. In a particular case, there was a dynamic simulation executed in another software (EnergyPlus) and the results could be exported and integrated in the iSCAN tool for later use in the various components of the SO WHAT tool, thus making its use much more flexible.

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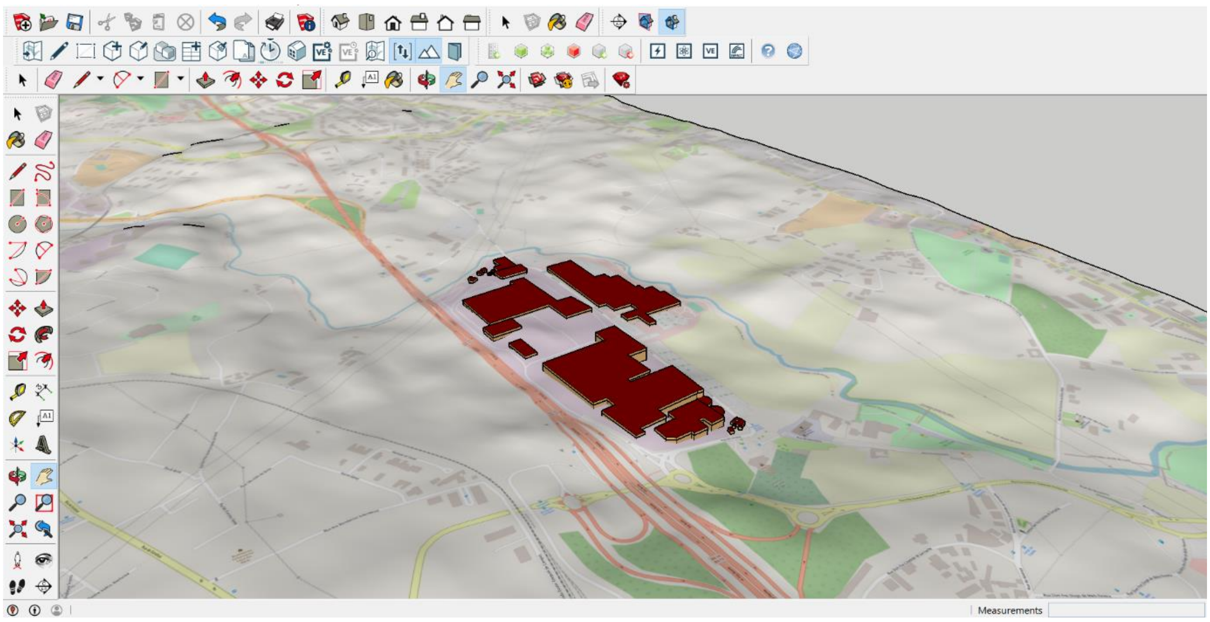

Figure 26 – iCD tool other buildings of interest in the area (used for replication studies D5.5)

iCIM

After this initial phase of surveying and characterizing the buildings around the demosite, the iCD tool was linked with the iSCAN tools for acquiring and processing information, and the iCIM tool for sharing and visualizing results and scenarios. See Figure 27 for a visual representation.

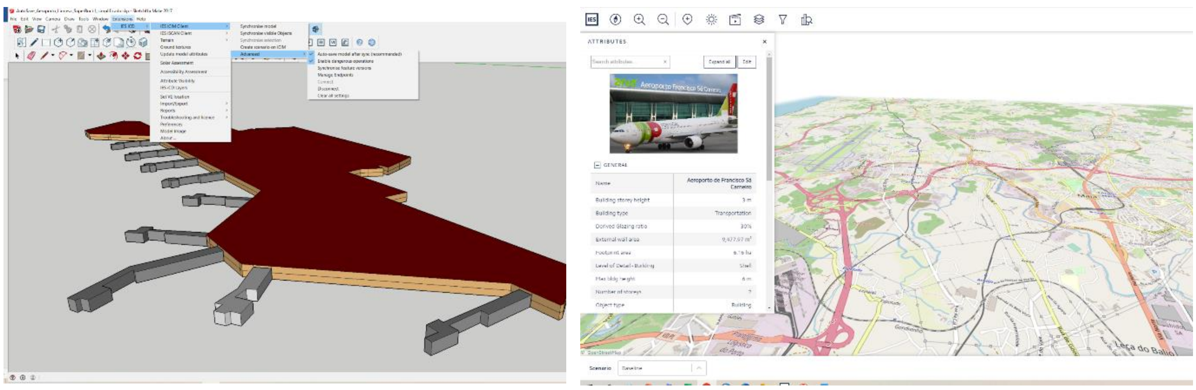

Figure 27 – Connection to iCIM and iSCAN (left). iCIM exported model (right).

After making this connection between the various modules of the So What tool, it was possible to import the 3D model previously developed in iCD to the network simulation tool, iVN. See figure Figure 28.

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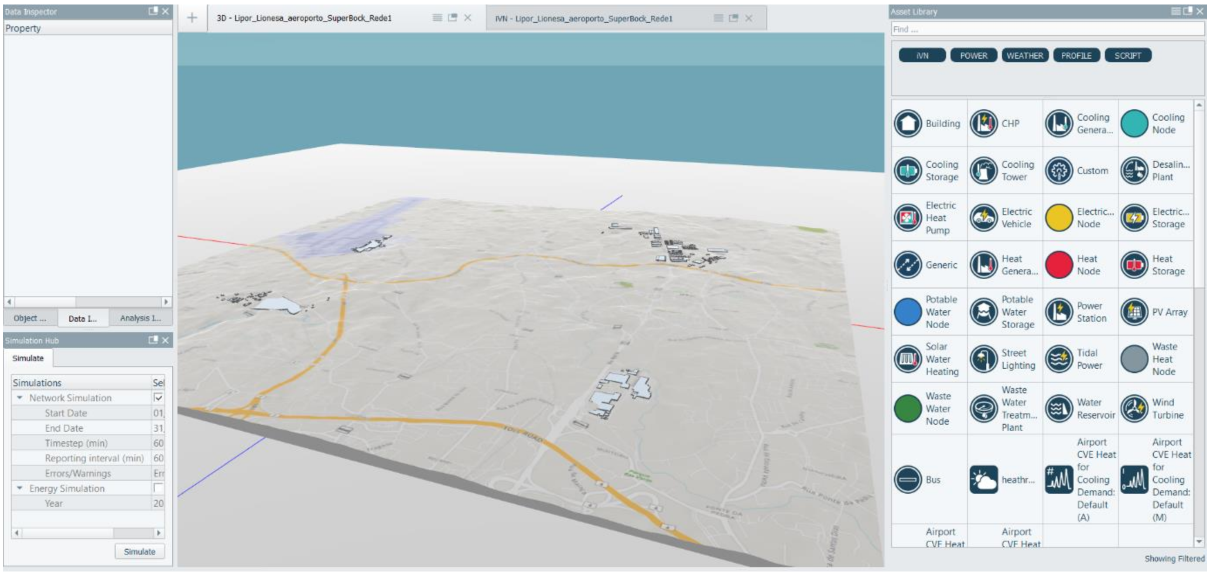

Figure 28 – iVN tool showing the imported 3D model from iCD

iVN

The iVN tool also allows for obtaining data from iSCAN, allowing to import hourly profiles of energy needs as well as supply and availability of resources, such as the residual heat profile.

The construction of the network model in iVN took several iterations, as it was necessary to use the different components of the network step-by-step in order to mitigate errors and inconsistencies. Figure 29 exemplifies one of the more than ten models tested with the iVN software using several scripts developed within the scope of this project, as well as pre-existing modules.

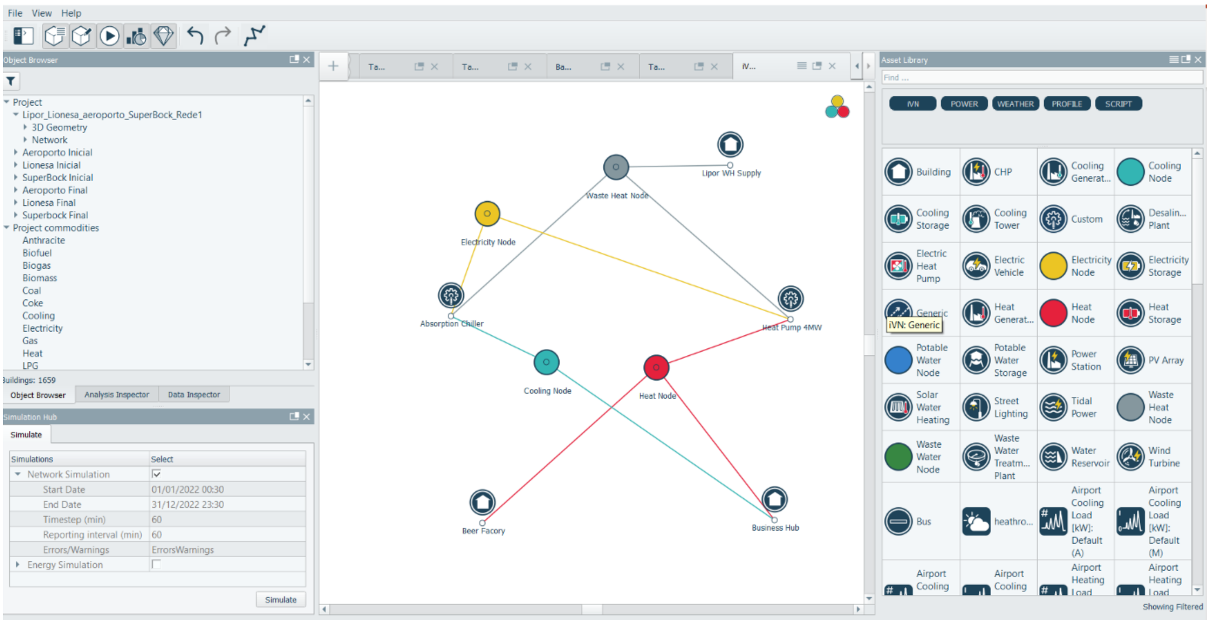

Figure 29 – Scenario modelling in iVN

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Given the characteristics of the Portuguese cluster case study, the iVN tool was the one that required the most effort, since the heat network modelling was in the center of this case. For this, more than 10 scenarios were created and simulated in this software and several different technologies were tested for modelling waste heat technologies for both heating and cooling purposes.

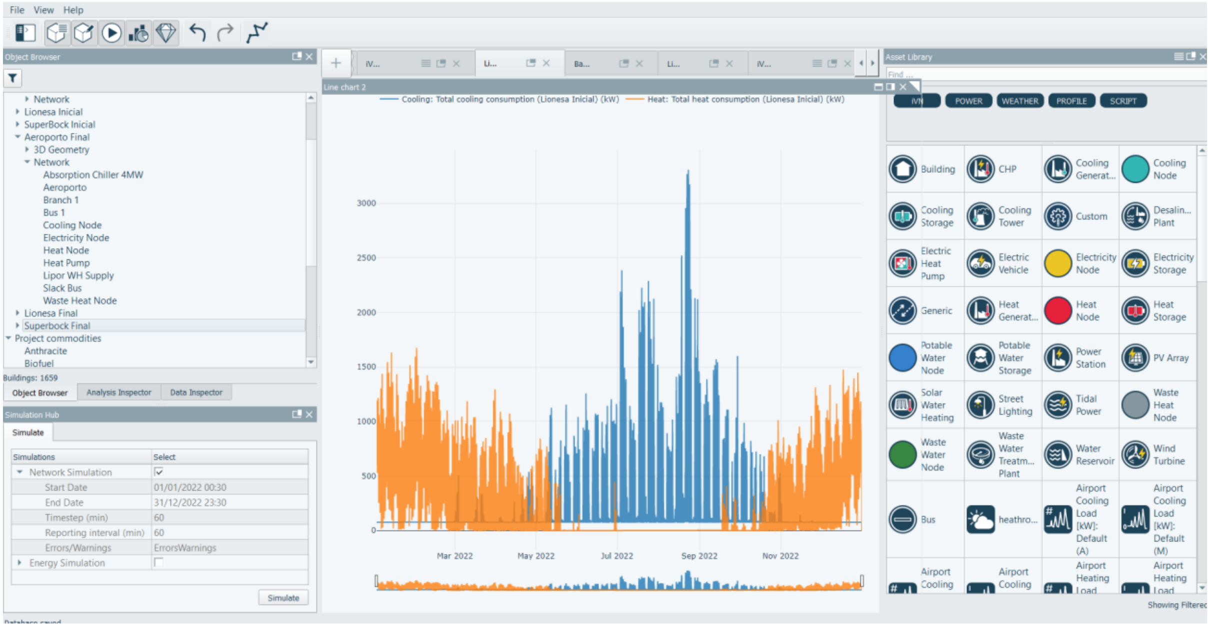

Figure 30 – Results from the simulation in iVN

The use of Python scripts (see Figure 31) was a challenge because it requires technical knowledge in terms of modelling the technology in question as well as the interpretation of the code developed for this modelling. The interaction with the partners involved in the development of these scripts proved to be fundamental to obtain results and be able to complete the modelling with an understanding of all the assumptions involved in the process.

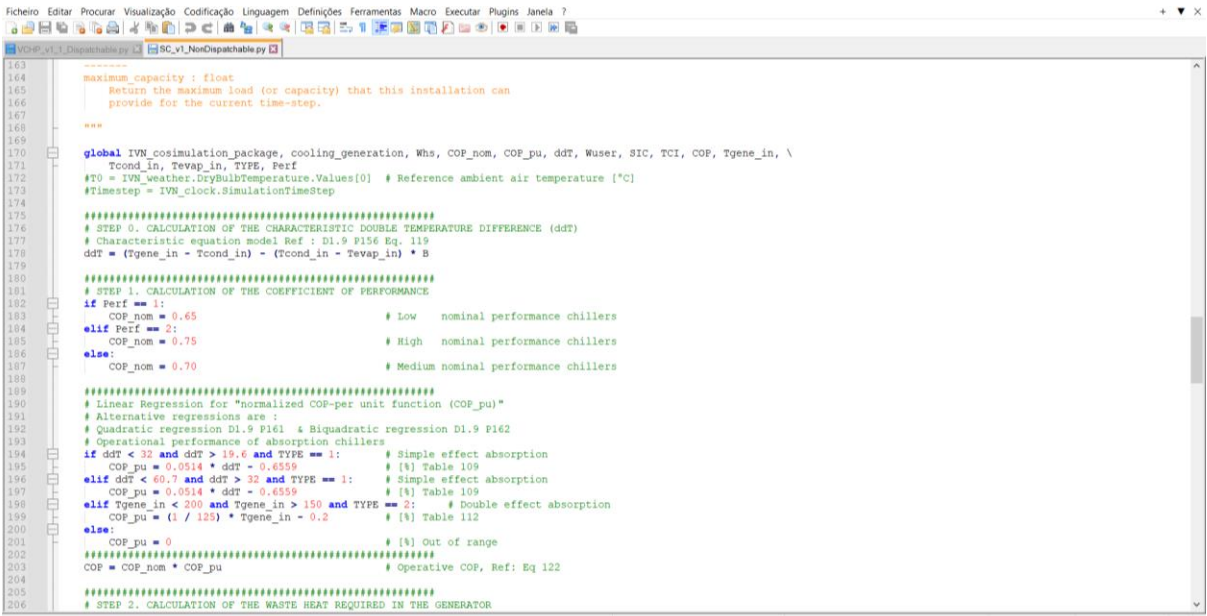

Figure 31 – Use of the Python Script for sorption chiller

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Finally, it was performed a feasibility study using the SO WHAT tool (see deliverable 5.3 for more information). Outcome of the feasibility study were the following: an Intern rate of return percentage of 19.53% is reached, a discounted payback period of 5.66 years and a net present value of 12 M€ is reached over 20 years taking in account an annual discount rate of 4%.

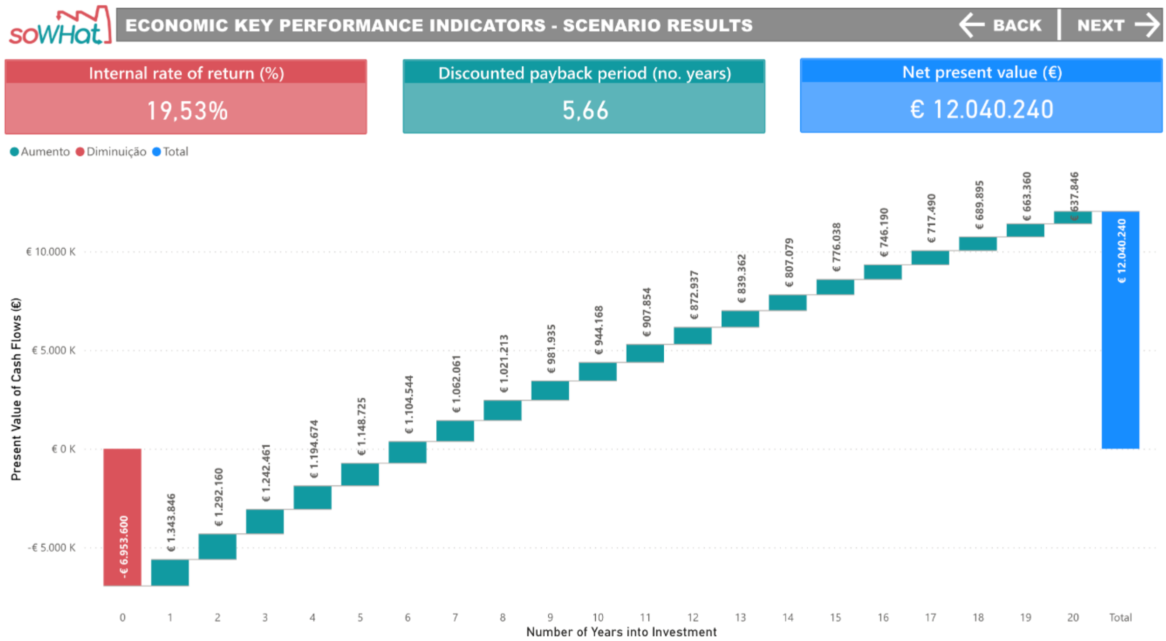

Figure 32 – SO WHAT Economic tool for feasibility studies

2.6.4 Results and lessons learnt

Recovery of excess heat at LIPOR's WtE with the creation of a new DH/C network connecting LIPOR's WtE to Porto Airport was completed. In addition, a replication study, considering another DH/C network connecting LIPOR's WtE to 2 new potential users (Superbock brewer factory and Lionesa Business Hub), was made. The tool trial was conducted with the help of IES.

Regarding the results, these were not always easy to interpret and sometimes it was necessary to resort to external tools to trace the way in which the calculations were being processed. In the end, it was possible to obtain understandable results in line with what would be expected.

Data collection: Most of the data charged was sufficient for proceeding with the model. This was mainly related to the initial difficulties to have access to data regarding LIPOR WtE operations. Another difficulty was related to the current and future energy uses and needs of both scenarios considered (1 – Porto Airport and 2 – Superbock + Lionesa Business Hub)

Difficulty encountered during installation of the So What tool: The main problems were related to the use of a Mac laptop.

Difficulty encountered during the use of the So What tool: There were some difficulties in seeing the big picture of all the modules working together. The Portuguese cluster started using the tool before the user manual was available. There were also technical problems like difficulties to install and activate the use of all modules and to upload all the required data in the proper format.

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General feedbacks: A complete tool with several functionalities would be very useful; however the installation process needs to be simplified, and if possible, through an integrated solution.

Tool expectations: The main expectations from Portuguese Cluster are linked to the possibility to develop the modelling of a new DH/C network connecting LIPOR WtE and Porto Airport, as well as to perform a detailed feasibility study of this investment. It is expected that the tool could design and develop a DH/C network, including the selection of the WH/C recovery technology and give an estimation of energy savings and GHG emissions reduction.

Tool User Friendly: some improvement can be done in order to make the use of the SOWHAT tool easier. The manual of SOWHAT tool (D4.8) is useful for the final users.

2.7 UK Cluster

2.7.1 General description

The Materials Processing Institute is an independent not for profit research and technology organisation located in the Northeast of England, UK. It is a centre for innovation, development and commercialisation of technology for advanced materials, industrial decarbonisation and the circular economy.

The Institute houses a number of pilot facilities; the largest of which are a 7 tonne electric arc furnace, ladle arc furnace and continuous casting machine. These facilities allow the development of new steel alloys, raw materials and steelmaking practice. The overall energy use of the site is approximately 1400 MWh of electricity and 400 MWh of gas per year. This includes energy used by site tenants. One of the biggest uses of gas at the Institute is natural gas used for domestic heating, i.e. heating of office and laboratory space.

2.7.2 Scenarios identified to use in the tool trial

The scenario identified for analysis at the Materials Processing Institute was to model the use of a heat pump to upgrade heat from the cooling water bulk tank on the site for use in domestic heating. A diagram of the proposed scenario is shown in Figure 33 below.

The SO WHAT tools were also be used to estimate the amount of energy required to heat the buildings to determine how the required amount of heat compares to that available from the cooling water.

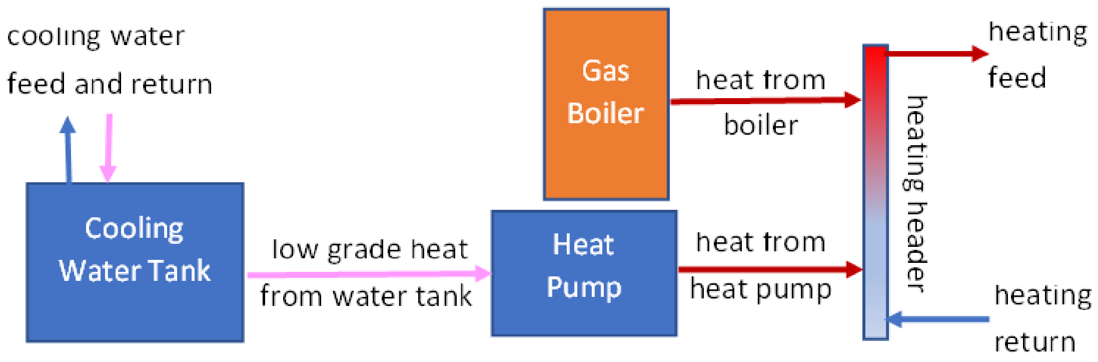

Figure 33 diagram of Materials Processing Institute heating system with proposed heat pump

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2.7.3 Tool trial steps performed for selected demos

The primary testing objectives for the Institute were TO6, identification of 3-5 relevant WH/C exploitation technologies, TO7, setup of virtual network baseline model for exploitation of WH/C resource and integration of RES (baseline and scenarios), TO 11, detailed modelling of demo site-buildings.

2.7.4 Results and lessons learnt

The software installation process worked well with few problems. It was noted that there are a number of steps to the installation with external software, Sketchup, required for building modelling. Some modules such as iScan and iCIM are cloud based whereas iCD, iVN and VE are desktop based. This spread setup of software modules, each of which needs logging into separately, can cause some confusion to the new user. Better integration of the installation and login to the array of packages would improve user buy in, particularly for new users.

The waste heat scenario described in 2.7.2 was identified and a water source and sink heat pump identified as the most appropriate technology for the scenario. The code for this technology developed earlier in the project was chosen for use in the iVN model.

Data including energy consumption data and the recorded temperatures of the cooling water tank that might be used as a waste heat store were loaded into the software using the online iScan module. Users found the interface to this software to not be always intuitive with multiple steps required to upload data. The interface for reviewing the data took time to understand in order to check that the data had uploaded correctly with all units and time resolutions correctly copied into iScan.

Improved instructions on operating this interface aided this process and its useability improved and less assistance in use was required in the later stages of testing.

The Institute buildings were modelled using the rapid modelling tools in the iCD module (Figure 34).

The software was found to be intuitive to use and create building models. Changing the building parameters was also found to be straightforward. Some limitations were experienced in describing the interfaces between buildings, particularly where one structure sits on to of another. These limitations are minor and the VE module is available if models with greater detail need to be created.

Figure 34 iCD model of buildings at the Materials Processing Institute

Connecting the iCD module back to the iScan data module and iCIM community module was not found to be straightforward. Some bug fixes and improved instructions later in the testing programme improved the process of making the connections.

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The modelled heat use of the buildings (Figure 35) was compared to the actual energy use of the buildings (Figure 36). This required exporting data from iScan to allow it to be analysed in a comparable manner. Export from iScan worked well.

Figure 35 Modelled heat load of buildings at Materials Processing Institute viewed in iScan

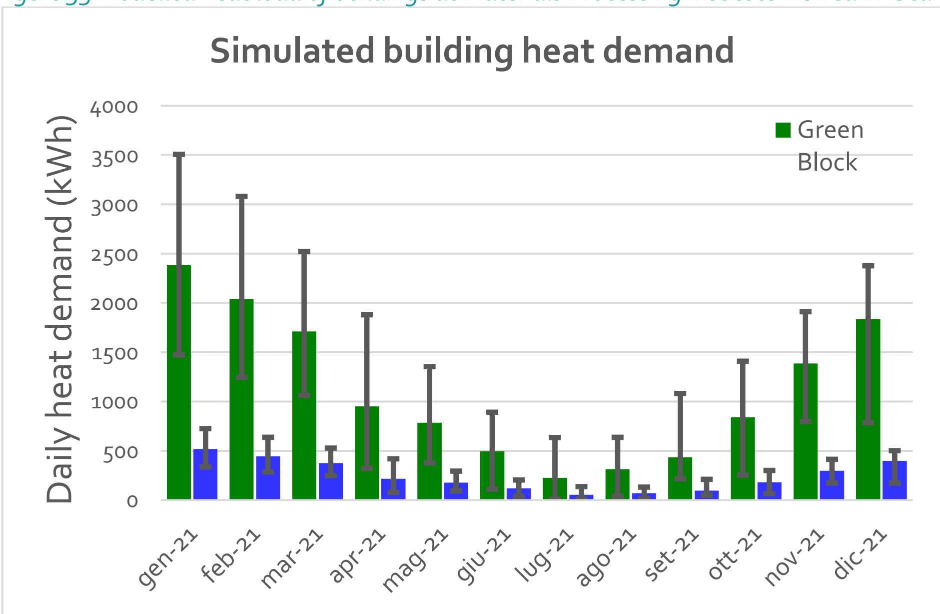

Figure 36 simulated daily heat demand of buildings at Materials Processing Institute by month

As reported in D5.4 and D6.1, the simulated heat load for the coldest month of the year is within 12% of the measured gas use of the Green building for the years 2018, 2019 and 2020. The measured gas use for the Blue building is 50 to 60% higher than that simulated. The heating boilers in the Blue building are known to be close to end of life and are not working at good efficiency. This may explain the discrepancy between measured gas use and modelled demand.

It is has been found that the iCD software is able to quickly produce good estimates of building heat use.

The iVN tool was used to create a network model describing the waste heat scenario described in 2.7.2, see Figure 37.

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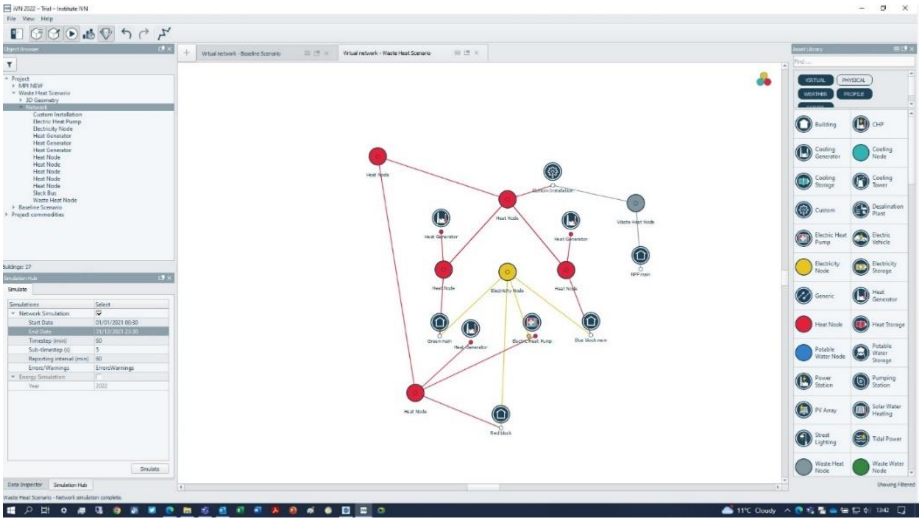

Figure 37 iVN network model of heat recovery system at Materials Processing Institute

The building of the iVN model of the heat network to model the heat recovery scenario at the Institute was intuitive and the user interface is clear.

A 'custom installation' node is used with a piece of code developed earlier in the project to describe the heat pump that will be used to upgrade the heat from the water tank for domestic heating. Unfortunately, the code as supplied is unable to work with the varying temperature of the heat from the water tank or that the temperature decreases as the heat pump removes the heat from this heat store. This resulted in being unable to run the model simulation to match the heat availability and demand.

In setting up the iVN model there were difficulties in connecting data, originally from iScan through the iCD model then iCIM into iVN and then simulation data back into iScan. The connectivity improved as some inconsistencies were fixed through the software testing phase but the process of connecting through different software modules is not clear and can cause the user some confusion and frustration. Establishing these connections was the most frequent reason for assistance being required in the use of the SO WHAT software tools.

The financial dashboard from the SO WHAT tool was used to estimate the potential payback from the waste heat use scenario. This estimated a payback period of approximately 33 years and a reduction in CO2 generated of 3.7 tonnes per year.

A scenario is envisaged that would double production, and hence waste heat, at the Institute. The process of updating the financial estimation to reflect this scenario was rapid and easy to understand. It was shown that increased production would reduce potential payback period to 14 years.

It was noted when using this dashboard that improved description of how the 'baseline' and 'scenario' inputs to this tool are used in the calculation would enable faster understanding and improved confidence in the calculations made by this tool.

General lessons learnt. The SO WHAT software enables good rapid estimation of building heat loads with the iCD module. The environment for building these models is user friendly and mainly intuitive to use.

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The iVN module allows rapid building of heat networks for heat availability and demand simulation. Unfortunately, the technical modules representing heat recovery equipment did not allow modelling of the scenario envisaged for the materials processing Institute.

The process of importing data into the SO WHAT software is not always straightforward. This is compounded by the need to connect data through different software modules, some online, some locally installed, in order to run simulations. Some of the bugs in this connectivity were fixed through the testing phase but it remains difficult for the user to understand how and why these connections through modules are made and are required. Making this process and the borders between modules more seamless would greatly enhance the user experience of the software.

3 Conclusions

The chapter summarizes general lessons learnt from Clusters, connected to each process step.

General feedbacks linked to the installation

1) Long process to get the permission to install the software due to high security requirements. This can be solved once a commercial SO WHAT tool is available. The company will have all information to make a risk assessment of the tool. A chapter under the SOWHAT tool manual (D4.8) dedicated to security process can facilitate the installation.
2) Very difficult to meet all internal IT requirements. Some improvement for the management of personal data, to comply with GDPR, must be performed based on the specific feedback from each IT department.
3) Incompatibility with Mac OS. This can be solved creating a virtual machine or by having an online version.
4) The installation is time consuming.

Technical feedbacks for installation and use

Data collection & processing

1) With reference to heat demand, it is very difficult to ask for detailed information and requires a different interaction. This is not relevant to the SO WHAT tool but from the process in general and it is difficult to model if you are not a professional.
2) The tool provides heat demand from buildings that it is very useful.
3) Data imports is a critical part, for example the format can be an issue (e.g. separator and comma).
4) Data collection could be easier if there is a monitoring of the main plant's measures. Not so easy to do so in an industrial site as adding measurements sometimes means stopping the installation and this cannot always be done.
5) With reference to heat demand for modelling district heating networks, the user can work with aggregated data or at building level. This can be an issue.
6) Getting data in iScan is very difficult.
7) Data collection can be difficult for some data, it was necessary a monitoring campaign (for example temperature of exhaust gas).
8) Aggregated data: SOWHAT can be used with different aggregated data, but it is more difficult to enter more in detail to each aggregated data.

Simulation of waste heat/cold recover technologies and res integration

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1) The integration of RES requires the experience of a professional user
2) The user must have an idea about the solutions that he or she would like to install. This can be an issue but it is linked to the difficulties of the process. If the user has a clear idea on the final technology to use, the use of SOWHAT tool can support on final costs and energy savings.
3) The tool did not provide a technical feasibility study of the technology, for this reason it would be necessary to have a professional user.
4) Software issues found connecting data from iScan through to iVN model

Results analysis and visualization

1) Visualization is clear and easy. There are clear diagrams and reading the result is very intuitive.
2) There is a need to improve the explanation in the financial tool about the outcomes. It is recommended to put units of measurement and introduce an explanation of different terms.

Online tool

1) Only the industrial part is included and the community will not be included. The community part could be relevant for the users.

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