H2020 Work Programme

D2.6- SCENARIO DEFINITION

Lead Partner: Fundación CARTIF (CAR)

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Abbreviations

°C: Celsius degrees
CAPEX: Capital Expenditure
CO2: Carbon Dioxide
COP: Coefficient Of Performance
DCN: District Cooling Network
DH: District Heating
DHN: District Heating Network
DHCN: District Heating and Cooling Network
DHW: Domestic Hot Water
EER: Energy Efficiency Ratio
ESCO: Energy Service Company
EU: European Union
GHG: Greenhouse Gas
GIS: Geographic Information System
HP: Heat Pump
H&C: Heat and Cold
IT: Information Technologies
LHTES: Latent Heat Thermal Energy Storage
LPG: Liquefied Petroleum Gases
KPI: Key Performance Indicator
kW: kilowatt
kWh: kilowatt-hour
kWh/y: kilowatt-hour per year
m²: square metre
m²: square metre
NPV: Net Present Value
OPEX: Operational Expenditure
ORC: Organic Rankine Cycle
O&M: Operation and Maintenance
PV: PhotoVoltaic
RES: Renewable Energy Sources
PBP: PayBack Period
PCM: Phase Change Material
TCS: Thermochemical Energy Storage
TDS: Total Dissolved Solids
WH: Waste Heat
WH/C: Waste Heat/Cold
WHR: Waste Heat Recovery

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Executive summary

This document represents the Deliverable 2.6 "Scenario Definition", developed within T2.4 (WP2). It provides not only a description of the identified scenarios, but also a description of the methodology followed to obtain these scenarios. Besides, a methodology for the selection of scenarios is included in order to guide the users of the SO WHAT tool to view and choose the most appropriate technologies and combinations that best suit their context and requirements. This methodology is based on the principles of reducing waste as much as possible and it is a six stage process.

All the partners involved in the scenario generation and description have put all their knowledge in support of the project to try to cover as much scenarios as possible, describing most of the different situations that the SO WHAT tool should take into account. Besides, information coming from multiple work packages of the project has been taken into account: tool's workflow and user needs coming from WP2, KPIs coming from WP3 and WP4 and technical solutions from WP1.

To provide the reader with all the information needed to perfectly understand this document, a first section including a summary of the SO WHAT tool and its main requirements is included. After this general overview of the SO WHAT tool, the process followed to obtain the list of scenarios and the hierarchy methodology is presented in section 3 (this section also describes the template used to describe each scenario). Section 4 contains the description of all the identified scenarios (using the aforementioned template) fitting them into each stage of the methodology for the selection of scenarios. Finally, the main conclusions are described in section 5.

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1 Introduction

1.1 Purpose and target group

The main aim of the task liked to this deliverable (T2.4) is to list and define a list of the most important scenarios that are envisaged to be covered by the SO WHAT tool.

As stated in D2.1, three roles have been considered as the main roles to be covered by the SO WHAT tool: industry, ESCO and municipality/energy agency, so the scenarios described in this deliverable are focused on these three roles.

1.2 Relation with other activities in the project

Most of the activities within WP2 are focused on the specification of the SO WHAT tool and its IT framework, therefore connections with the activities here developed are straightforward.

As stated in Figure 1, T2.4 will use information gathered from different work packages to define and describe the scenarios envisaged to be covered by the SO WHAT tool.

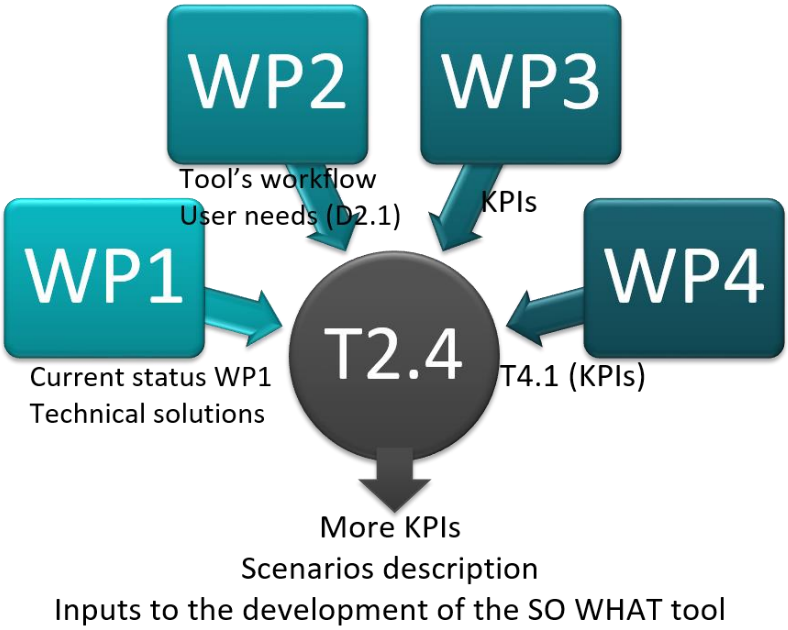

Figure 1 Inputs for T2.4

As shown in Figure 1, there are a lot of information (coming from other tasks and work packages among the SO WHAT project) to be considered and taken as an input to the scenario definition. WP1 will provide a lot of data about the available technical solutions concerning waste heat/cold recovery; WP2 main inputs will be concerning tool's workflow, user needs and use cases; WP3 will provide with information about KPIs, and WP4 inputs will be very important regarding KPIs. The work performed within this task 2.4, as well as the information generated within WP2 will flow into WP4, which is devoted to the actual tool development.

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2 SO WHAT tool description and main requirements summary

This chapter contains brief description of the main functionalities that the SO WHAT tool is envisaged to cover based on the information gathered in previous tasks and as described in detail in Deliverable 2.3 Common IT framework specifications.

The SO WHAT Tools, both free and commercial[2], will perform similar functions but to a different degree of complexity and accuracy. If the user wishes to conduct a quick analysis of the potential for waste heat/cooling and uses, then the outputs from the software will be fairly basic, but adequate enough to enable guidance and allow high level decision making. Whereas if the user wishes to do a detailed study requiring more time and resources, they will receive a highly accurate analysis of how best to utilise waste heat/cooling in their facility or community. The SO WHAT tool is expected to run on a mix of online and desktop software, and irrespective of whether the user is in a Free or Commercial version of the software, the following functions will be performed:

- **User management** – To enable secure log in and sharing of results
- **Data Collection** – Guiding the user to only collect the data necessary for their required analysis. Where data is missing, it should be possible for the various databases contained with the tool to use default data.
- **Baseline Analysis results**: In both the free and commercial versions, and at both Manufacturing and Community scales, the user will be able to view Baseline results regarding waste heat/cooling recovery potential and the existing energy network (supply and demand) for their areas of interest.
- **Scenario and KPI selections**: This is the focus of this deliverable. The user will be able to select from a list of set Scenarios and KPIs that they are interested in. Deliverable 2.3 showed that this will be done with a section of the 'online portal', and for both free and commercial tools it will be called 'Manufacturing/Community Scenario/KPI Setting.' Within D2.3, Use Cases were detailed, and the info in this document either fits into Use Cases for the Free tool – F9 Set KPI targets and scenarios – or into Use Cases for the Commercial tool – C15 Set KPI targets and scenarios.
- **Cost Calculator**: As well as energy KPIs, the user will also be able to view cost-related KPIs in order to see financial information on potential solutions. The cost calculator will take the different cost related algorithms and outputs from WP3, and apply these to the scenarios selected by the user.
- **KPI Panel and Dashboard**: This is the function where the end user will view the results of their simulations. There will be a KPI panel where the results can be viewed and also a

[2] "Free" and "Commercial" versions are two naming currently under discussion, given that this is a first exploitation pathway and both version will be free for the duration of the project: this aspect will be clarified and presented in D2.4 "Report and presentation on SO WHAT integrated tool functionalities". Nevertheless, it is worth highlighting that one version will be lighter and internet based (Free) and the other will be (partially) desktop based and more detailed (Commercial).

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dashboard format where the user can see the 3D & 2D map view of their building/local area and also see the KPI results visualised around this.

- **Value Choice Tool**: This allow the user to view multiple scenario results side by side so that they may rank KPIs and choose the most suitable solution according to their needs.
- **Business Model Guide**: This function will use the outputs from WP3 and the Value Choice Tool to allow the user to view select the most appropriate business model for their needs. Where suitable, Energy Performance Contracting will be recommended and explained.

3 Scenario identification and Hierarchy Methodology

3.1 Scenario identification

This chapter describes how the different scenarios were identified and filtered to become the final ones to be used in the SO WHAT tool, the process used to add details to each scenario, as well as the methodology for the hierarchy of the scenarios that will also be used in the software to guide the user towards the most appropriate selections.

A 'scenario' is defined as a potential future state that a user of the software may wish to simulate in order to understand how to recover waste heat/cooling and how best to use this either in their own facility or in the wider community. Figure 2 summarises the process used to identify the list of scenarios to be considered concerning the SO WHAT tool.

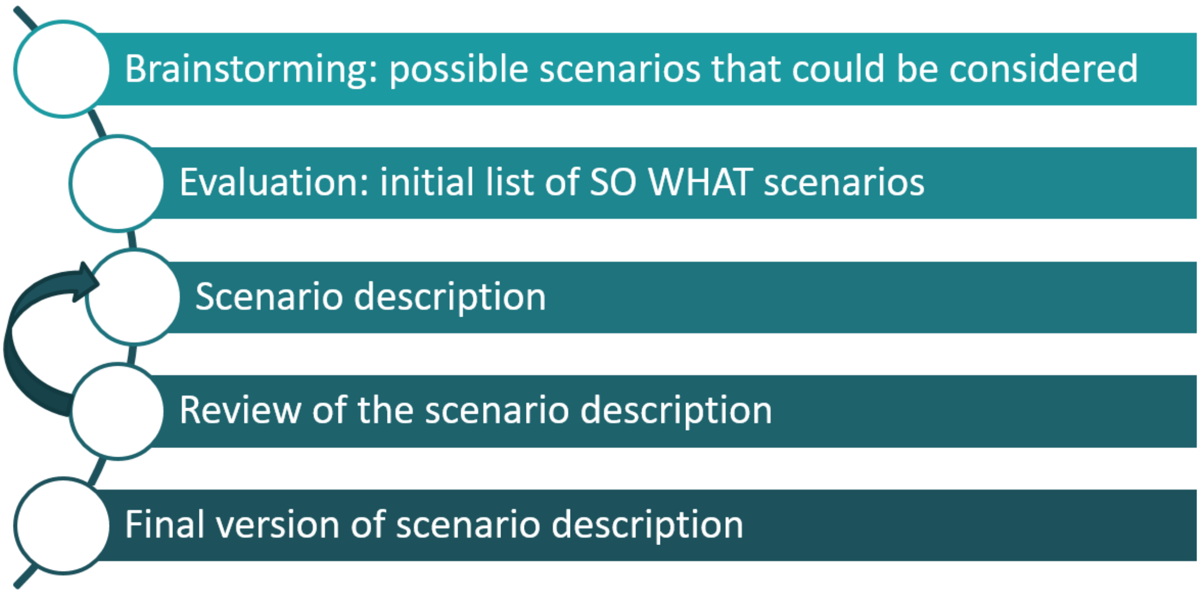

Figure 2 Scenario identification and description methodology

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Once all the information to be taken into account to define the scenarios was gathered by the involved partners, a brainstorming period was started to give as much ideas as possible of scenarios to be considered. IESRD, RINA-C, UoB and CAR gave their ideas of scenarios to be taken into account and, as task leader, CAR gather all the proposed scenarios and put them all together in a single document. Then, this list of scenarios was sent to all the partners involved in the task to let them give their opinion about scenarios to be included and scenarios not applicable or not needed in the scope of the SO WHAT project. Once the list of scenarios was agreed among all the involved partners, these scenarios were split in four groups (to be assigned to IESRD , RINA-C, UoB and CAR), and the partners started filling in the template of scenario description (see Table 1) that was defined in the scope of the task. All the scenario descriptions were sent to CAR to be reviewed, and this started a process of reviewing-modifying until each scenario description was finalized, and its final version was accepted.

As stated before, Table 1 presents the template designed to describe each scenario, containing the following information:

- Stage No, Scenario No. and Sub Scenario Title.
- Relevant User type: As stated in D2.1 (Definition of End User Requirements), the main roles considered in the scope of the SO WHAT tool were Industry, ESCO and Municipality/Energy Agency.
- Main Objectives: General objectives mapping: this field is focused on giving a detailed overview of the main objectives of the scenario that is being described.
- Relevant KPIs used for evaluation: KPIs that have to be used to evaluate each solution proposed.
- Example Baseline case: description of the current situation of the facilities/municipality.
- Intervention/Technologies: description of the intervention/s and/or technologies that are being considered in the scope of this scenario, and a brief description of them.
- Requested inputs: list of inputs to be provided by the user to let the SO WHAT tool develop its functionalities and returning the expected results.
- Output: expected output to be given by the SO WHAT tool.
- Main benefits: list (and description, if possible) of the main benefits foreseen by the SO WHAT tool.
- Main "disadvantages": main drawbacks foreseen by the SO WHAT.
- Exceptions: situations that could prevent this scenario from a normal execution, and a description of what could be done if each exception occurs.

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Table 1 Scenario description template

Scenario <X>: <Scenario Title> <Sub Scenario Title>		
Relevant User Type	Industry/ESCO/Municipality	
Main Objectives	**Energetic Domain**	
	☐Reduction of primary energy consumption	☐Reduction of final energy consumption
	☐Reduction of useful energy demand	☐Increase share of RES
	☐Increase utilization of energy from waste heat sources	☐Reduction of energy consumption from conventional fuels
	☐Reduction of energy consumption from imported sources	☐DHCN thermal losses reduction
	☐DHCN heat density reduction	☐Operating hours increase
	Environmental Domain	
	☐CO_2 reduction	☐Pollutants emission reduction
	☐Noise production reduction	☐Increase share of RES
	☐Increase utilization of energy from waste heat sources	
	Economic Domain	
	☐Creation of economically feasible H&C scenarios	☐Operational costs reduction
	☐Levelized cost of heat	☐CO_2 reduction cost
	Social Domain	
	☐Energy poverty reduction	☐Job increase
	☐Security of supply increase	
Relevant KPIs for evaluation	List of KPIs used to evaluate the benefits of the intervention	
Example Baseline case	Description of the current situation in the facilities/municipality	
Intervention / Technologies	Type/s of intervention/s that are being considered, and a brief description of each of them	
Requested inputs	Inputs to be provided to the SO WHAT tool (if possible, please provide: description, type of data, desired gathering frequency …)	
Output	Description of the output that would be offered by the SO WHAT tool (if needed, please include graphics…)	
Main benefits	Main benefits envisaged by the SO WHAT tool concerning the information given as an output.	
Main “disadvantages”	Main disadvantages envisaged by the SO WHAT tool concerning the information provided to the user as an output…	
Exceptions	What happens if the user does not provide all the information? Other exceptions (please, describe the exception and give a detailed explanation about what to do if it occurs)	

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3.2 Scenarios and Hierarchy Methodology

The methodology for the hierarchy of scenarios was designed in order to guide the different users to view and choose the most appropriate technologies and combinations that suite their context and requirements. It will be used in the development of the SO WHAT tool whereby the scenarios available to choose from will be dependent on the type of user and the version (Free or Commercial) they are using. The methodology is numbered sequentially, however there are many different sub scenarios grouped under one main theme and a number of them will only apply to specific user types.

The methodology is based on the principles of reducing waste as much as possible, before recovering waste and reusing in the most efficient ways. It is summarized in the followings 6 stages, and then described in further detail below.

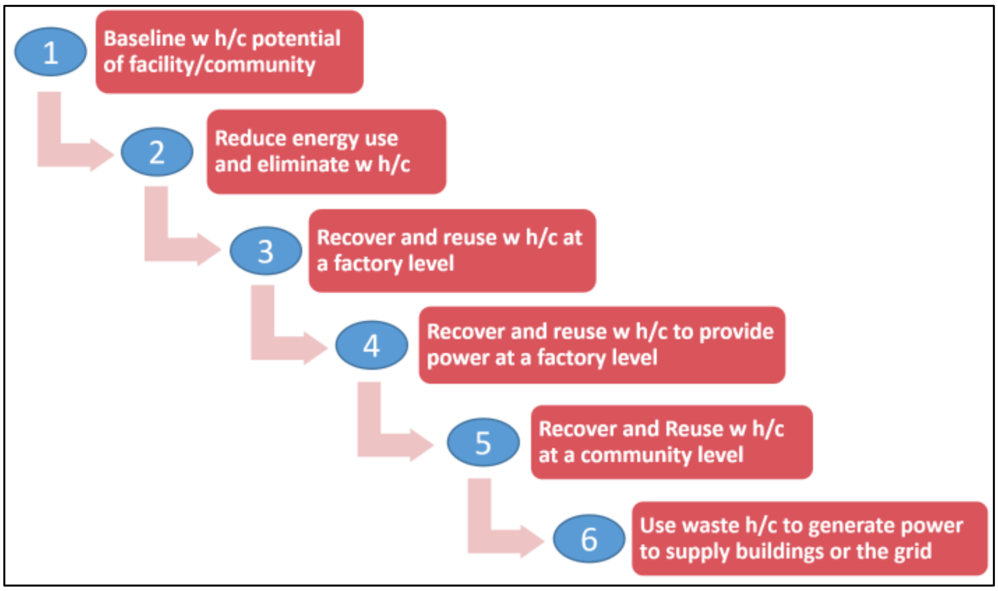

Figure 3 Scenario Selection Hierarchy

3.2.1 Stage 1: Baseline waste heat/cooling potential of facility/community

Although a 'scenario' is defined as a potential future state, the user must first have conducted a baseline simulation of the current state of waste heat/cooling potential and so this is considered as the top in the hierarchy and first scenario to consider. In both the free and commercial versions of the SO WHAT tool, this step will be done before the user is able to go through the other future scenarios. There are 3 Scenarios associated with this stage.

3.2.2 Stage 2: Reduce energy use and eliminate waste heat/cooling

This stage of the scenario hierarchy is not directly the focus of SO WHAT, nonetheless it is a logical and necessary steps that the user should consider and decide whether to conduct before moving to explore waste heat/cooling recovery and distribution. As the overall aim of reusing waste heat or cooling is to reduce the amount of resources utilised and cut down on carbon emissions, the industrial user of one facility should therefore try to improve the overall energy efficiency of their building before looking specifically at waste heat/cooling. In the software (as explained in D2.3), there will be

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a link in the commercial tool into IES VE to enable the user to conduct detailed energy performance simulations of their facility and analyse the best energy efficiency strategies for the whole building.

Similarly, the user of that facility should also look to completely eliminate waste heat/cooling from their process before trying to understand recovery potential. This is explained using Kaizen techniques. It should be noted this analysis is not part of SO WHAT, but was a key focus of a prior EU H2020 funded project REEMAIN.

3.2.3 Stage 3: Recover and reuse waste heat/cooling at a factory level

This relates to the recovery of waste heat/cooling to be re-used in the factory. Firstly, the user should look at whether they can re-use the waste within the same process as this will be the most efficient way to initially utilise resources, before analysing further on how utilise it in a different process in the facility. There are 16 Scenarios associated to this stage which describe the different technologies to recover waste heat, and how it can be reused as heat in the factory processes.

3.2.4 Stage 4: Recover and Reuse waste heat/cooling to provide power at a factory level

Stage 4 continues within the factory, albeit this time to generate power rather than solely thermal energy. There are a further 4 Scenarios associated with this Stage relating to general guidance on how to generate power and how to add solar panels/solar collectors, as well as more specific guidance on maximising the use of renewable energy and the optimal mix of different installations.

3.2.5 Stage 5: Recover and Reuse waste heat/cooling at a community level

Stage 5 moves to the scenarios at a community level in terms of the recovery of waste heat/cooling from industry. The first scenario concerns the overall matching of supply and demand, and then other scenarios look at how either a district heating network, or another means of transport, could be used to distribute the waste heat to the consumer. There is also a scenario related to the storage of waste heat so that it can be used at a later date, as well as two other scenarios that allow the user to conduct a cost benefit analysis of expanding a district h/c network, or constructing a new one, to connect to newly identified waste heat sources and users.

3.2.6 Stage 6: Recover and Reuse waste heat/cooling to provide power at a community level.

The final Stage relates to recovering waste heat/cooling from an industry and then converting this to produce electricity to be used either by other local buildings as part of a micro grid, or to be sold and used by the national grid.

3.3 Scenarios, Hierarchy and applicability to the user

Overall, there were 34 Scenarios developed that could be applicable to SO WHAT that fit within the 6-Stage methodology as described in the previous section. For each of these scenarios the hierarchy and their applicability to the user is shown in the table below:

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Table 2 List of scenarios , their hierarchy and applicability to the user

Stage	Stage Description	Scen. No.	Scenario Title	Sub Scen. No.	Sub Scenario Title	Industry	ESCO	Municipality
1	Baseline w h/c potential of facility/community	1.1	Baseline w h/c potential of individual facility			X	X	
		1.2	Baseline - Identify potential w h/c users in my community			X	X	X
		1.3	Baseline - Identify potential w h/c sources in my community			X	X	X
2	Reduce energy use and eliminate w h/c	2.1	Improve the energy efficiency of my building			X		
		2.2	Eliminate w h/c from my processes/services where possible			X		
3	Recover and reuse w h/c at a factory level	3.1	Recover w h/c to be re-used in the same process in my facility	3.1.1	WHR in Steam boilers by installation of economizers	X	X	
				3.1.2	WHR in the Steam boilers purge (Total Dissolved Solids, TDS, control)	X	X	
				3.1.3	Recovery from ovens for preheating of the burners input air (Option 1)	X	X	
		3.2	Recover w h/c to be re-used in a different process in my facility	3.2.1	WHR from Air Compressors for DHW or Space Heating (Preheating of water)	X	X	

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				3.2.2	WHR in the Steam boilers purge (Total Dissolved Solids, TDS, control)	X	X	
				3.2.3	Recovery from ovens for generating external hot water (Option 2)	X	X	
				3.2.4	Valorisation of effluent stream with HPs to produce hot water	X		
				3.2.5	Use of absorption chillers to produce refrigeration cold water from WHR	X	X	
				3.2.6	Waste Heat Recovery in the condensate collecting receiver	X	X	
				3.2.7	Cold recovery in the gas expansion systems (gasification plants)	X	X	
				3.2.8	Upgrade of low-grade waste heat by using heat pump in order to meet process heat demand	X	X	
				3.2.9	Waste heat recovery from existing	X		

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					refrigeration system			
				3.2.10	Recovery from Electric Chillers to produce medium-low temperature hot water (Preheating systems)	X		
				3.2.11	Cold Thermal Energy Storage integration for WHR inside a factory	X		
				3.2.12	Optimize waste heat/cold energy use	X	X	
4	Recover and reuse w h/c to provide power at a factory level	4.1	Recover w h/c to generate power for my facility			X	X	
		4.2	Add solar panels/solar thermal collectors on my site.			X	X	X
		4.3	Maximise the use of renewable energy I have installed.			X	X	
		4.4	Optimise the mix of renewable energy installations at my site			X	X	X
5	Recover and Reuse w h/c at a community level	5.1	Match local potential supply of waste heat with local demand			X	X	X
		5.2	Thermal Storage evaluation for WH integration into DH networks			X	X	
		5.3	WHR from Air Compressors for heat into District Heating Network			X	X	

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		5.4	Preliminary analysis of the cost related to DHN link			X	X	X
		5.5	Recover waste heat from a site and transport it for use in other buildings without the need of a DH network or pipes.			X	X	
		5.6	Use of absorption chillers in a district heating network				X	
		5.7	Heat Pumps with PV panels into DH network					
		5.6	Conduct a cost benefit analysis of expanding a district h/c network or constructing a new one, to connect to newly identified waste heat sources and users				X	X
6	How can I use w h/c to generate power to supply buildings or the grid	6.1	Recovery of industrial WH for electricity production (to be sold to the grid or local community)			X	X	X
		6.2	RES evaluation				X	X

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4 Full Description of Scenarios

This section contains the description of each scenario as its fits into each Stage of the methodology and using the aforementioned template.

4.1 Stage 1: Scenarios for Baseline waste heat/cooling potential of facility/community

Table 3 Scenario 1.1 description

Scenario 1.1: Baseline w h/c potential of individual facility		
Relevant User Type	Industry	
Main Objectives	**Energetic Domain**	
	☒Reduction of primary energy consumption	☒Reduction of final energy consumption
	☐Reduction of useful energy demand	☐Increase share of RES
	☒Increase utilization of energy from waste heat sources	☒Reduction of energy consumption from conventional fuels
	☒Reduction of energy consumption from imported sources	☐DHCN thermal losses reduction
	☐DHCN heat density reduction	☐Operating hours increase
	Environmental Domain	
	☒CO_2 reduction	☒Pollutants emission reduction
	☐Noise production reduction	☐Increase share of RES
	☒Increase utilization of energy from waste heat sources	
	Economic Domain	
	☒Creation of economically feasible H&C scenarios	☐Operational costs reduction
	☐Levelized cost of heat	☐CO_2 reduction cost
	Social Domain	
	☐Energy poverty reduction	☐Job increase
	☒Security of supply increase	
Relevant KPIs for evaluation	N/A	
Example Baseline case	Description of the current situation in the facilities/municipality	
Intervention / Technologies	N/A	

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Requested inputs	• Description of the production process of the industry (SO WHAT tool will ask for this information using checklist or different forms) • Description of the devices where waste heat is supposed to be produced (compressors, steam boilers, ovens, electric chillers…). Information to be asked for: brand, year of manufacture, power… • Data concerning thermal energy demand (both about heating and cooling)
Output	• List of the possible sources of waste heat/cold • Information about low-level scenarios linked to each source
Main benefits	The user has an understanding of the potential waste heat sources in the community and can begin to analyse how to best use them.
Main "disadvantages"	N/A
Exceptions	If the industry does not provide: • Description of the production process of the industry -> the SO WHAT tool would be able to gather information about it based on the type of industry that are being considered • Some data concerning the devices where waste heat is supposed to be produced -> some data could be obtained based on "key details" given by the user

Table 4 Scenario 1.2 description

Scenario 1.2: Baseline - Identify potential w h/c users in my community		
Relevant User Type	Industry/ESCO/Municipality	
Main Objectives	**Energetic Domain**	
	☐Reduction of primary energy consumption	☐Reduction of final energy consumption
	☐Reduction of useful energy demand	☒Increase share of RES
	☒Increase utilization of energy from waste heat sources	☒Reduction of energy consumption from conventional fuels
	☐Reduction of energy consumption from imported sources	☐DHCN thermal losses reduction
	☒DHCN heat density reduction	☐Operating hours increase
	Environmental Domain	
	☒CO_2 reduction	☒Pollutants emission reduction
	☐Noise production reduction	☐Increase share of RES
	☒Increase utilization of energy from waste heat sources	

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	Economic Domain ☒Creation of economically feasible H&C scenarios ☐Operational costs reduction ☐Levelized cost of heat ☐CO_2 reduction cost **Social Domain** ☒Energy poverty reduction ☐Job increase ☒Security of supply increase
Relevant KPIs for evaluation	List Energy demand per m2 Peak power demand Global/weekly/monthly energy demand CO_2 intensity Primary energy demand of KPIs used to evaluate the benefits of the intervention
Example Baseline case	Unknown distribution demand of city/district, Possible unbalanced energy demand, High-level knowledge of the overall consumption
Intervention / Technologies	N/A
Requested inputs	Annual global energy demand (fuel) Building characteristics Current energy mix (absolute values) Geographical information (maps) High-level information on the demand characteristics (e.g. peak, typical distribution)type of data, desired gathering frequency, ...)
Output	Visualisation of the energy demand over the map at annual level: superposition of the demand identified by different colours on the city/district map Increased granularity of the demand calculated up to hourly data: demand calculated is available on hourly basis (mainly for internal use by the Tool) Graphic of demand over time (possibly superposed to the map): possibility to plot the demand over a selected time
Main benefits	Additional info for local authority for energy planning Data available for any other use within the tool (coupling with other parts of the software for further analysis) Possibility to export data outside SO WHAT tool
Main "disadvantages"	Info not necessarily available, difficulty to retrieve complete one Basic knowledge of GIS base tool
Exceptions	If the user does not provide the necessary info, then the SO WHAT tool would try to gather this information based on industry waste heat profiles defaults in the database associated with this in the software.

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Table 5 Scenario 1.3 description

<table>
<tr><th colspan="3">Scenario 1.3: Baseline - Identify potential w h/c sources in my community</th></tr>
<tr><td>Relevant User Type</td><td colspan="2">Industry/ESCO/Municipality</td></tr>
<tr><td rowspan="18">Main Objectives</td><td colspan="2">Energetic Domain</td></tr>
<tr><td>☒Reduction of primary energy consumption</td><td>☒Reduction of final energy consumption</td></tr>
<tr><td>☐Reduction of useful energy demand</td><td>☒Increase share of RES</td></tr>
<tr><td>☐Increase utilization of energy from waste heat sources</td><td>☒Reduction of energy consumption from conventional fuels</td></tr>
<tr><td>☒Reduction of energy consumption from imported sources</td><td>☐DHCN thermal losses reduction</td></tr>
<tr><td>☒DHCN heat density reduction</td><td>☐Operating hours increase</td></tr>
<tr><td colspan="2">Environmental Domain</td></tr>
<tr><td>☒CO2 reduction</td><td>☒Pollutants emission reduction</td></tr>
<tr><td>☐Noise production reduction</td><td>☐Increase share of RES</td></tr>
<tr><td>☒Increase utilization of energy from waste heat sources</td><td></td></tr>
<tr><td colspan="2">Economic Domain</td></tr>
<tr><td>☒Creation of economically feasible H&C scenarios</td><td>☐Operational costs reduction</td></tr>
<tr><td>☐Levelized cost of heat</td><td>☐CO2 reduction cost</td></tr>
<tr><td colspan="2">Social Domain</td></tr>
<tr><td>☒Energy poverty reduction</td><td>☐Job increase</td></tr>
<tr><td>☒Security of supply increase</td><td></td></tr>
<tr><td colspan="2"></td></tr>
<tr><td colspan="2"></td></tr>
<tr><td>Relevant KPIs for evaluation</td><td colspan="2">N/A</td></tr>
<tr><td>Example Baseline case</td><td colspan="2">The entity wants to identify the WH/C sources available in its area</td></tr>
<tr><td>Intervention / Technologies</td><td colspan="2">N/A</td></tr>
<tr><td>Requested inputs</td><td colspan="2">In the case of a municipality/energy agency/ESCO:
Country/city/area where the study wants to be applied
Location
Nearby industries, DHN</td></tr>
<tr><td>Output</td><td colspan="2">List of the possible sources of waste heat/cold
Information about low-level scenarios linked to each source</td></tr>
<tr><td>Main benefits</td><td colspan="2">The user has an understanding of the potential waste heat sources in the community and can begin to analyse how to best use them.</td></tr>
<tr><td>Main “disadvantages”</td><td colspan="2">N/A</td></tr>
</table>

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Exceptions	If the municipality/energy agency/ESCO does not provide: • Nearby industries, DHN, ... and its location -> the SO WHAT tool would try to gather this information based on industry waste heat profiles defaults in the database associated with this in the software • If an ESCO is willing to make preliminary evaluation, the SO WHAT tool will use general information based on the type of industry

4.2 Stage 2: Scenarios for Reduce energy use and eliminate waste heat/cooling

Table 6 Scenario 2.1 description

Scenario 2.1: Improve the energy efficiency of my building		
Relevant User Type	Industry	
Main Objectives	**Energetic Domain**	
	☐Reduction of primary energy consumption	☐Reduction of final energy consumption
	☒Reduction of useful energy demand	☐Increase share of RES
	☐Increase utilization of energy from waste heat sources	☒Reduction of energy consumption from conventional fuels
	☒Reduction of energy consumption from imported sources	☐DHCN thermal losses reduction
	☐DHCN heat density reduction	☐Operating hours increase
	Environmental Domain	
	☒CO_2 reduction	☒Pollutants emission reduction
	☐Noise production reduction	☐Increase share of RES
	☐Increase utilization of energy from waste heat sources	
	Economic Domain	
	☒Creation of economically feasible H&C scenarios	☐Operational costs reduction
	☐Levelized cost of heat	☐CO_2 reduction cost
	Social Domain	
	☐Energy poverty reduction	☐Job increase
	☐Security of supply increase	
Relevant KPIs for evaluation	Energy saving per m2 Energy consumption per m2	
Example Baseline case	Energy demand is mapped and the evaluation of changes on it is to be performed. Basic knowledge of the thermal characteristics of the building stock is available.	

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Intervention / Technologies	The objective is to evaluate the effect of EE measures on the overall thermal demand and its impact, therefore the changes expected. The proposed intervention should be high-level and not on the specific (e.g.) apartments: • Introduction of insulation products of building façades, windows, roofs • Improve energy efficiency by other measures as change of thermal equipment
Requested inputs	Thermal characteristic of the building (after and before intervention) Energy demand evaluated at a previous step Technology for H/C if considered
Output	Multiple scenarios can be created by comparing a different number of retrofitted buildings and/or different retrofitting measures: they can be evaluated based on selected KPIs (energy demand, energy intensity)
Main benefits	Evaluation of energy efficiency measures for buildings and evaluation of changes in overall city landscape
Main "disadvantages"	Main disadvantages envisaged by the SO WHAT tool concerning the information provided to the user as an output.
Exceptions	What happens if the user does not provide all the information? Other exceptions (please, describe the exception and give a detailed explanation about what to do if it occurs)

Table 7 Scenario 2.2 description

Scenario 2.2: Eliminate w h/c from my processes/services where possible		
Relevant User Type	Industry	
Main Objectives	**Energetic Domain**	
	☒Reduction of primary energy consumption	☐Reduction of final energy consumption
	☐Reduction of useful energy demand	☐Increase share of RES
	☐Increase utilization of energy from waste heat sources	☒Reduction of energy consumption from conventional fuels
	☒Reduction of energy consumption from imported sources	☐DHCN thermal losses reduction
	☐DHCN heat density reduction	☐Operating hours increase
	Environmental Domain	
	☒CO_2 reduction	☒Pollutants emission reduction
	☐Noise production reduction	☐Increase share of RES
	☒Increase utilization of energy from waste heat sources	

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	Economic Domain ☐Creation of economically feasible H&C scenarios / ☒Operational costs reduction ☐Levelized cost of heat / ☐CO2 reduction cost **Social Domain** ☐Energy poverty reduction / ☐Job increase ☐Security of supply increase
Relevant KPIs for evaluation	Energy saving per m2 Energy consumption per m2
Example Baseline case	The facility wants know where it is potentially wasting heat/cooling and how this can be eliminate completely.
Intervention / Technologies	Kaizen approaches (summarised as): I. Enable – collect data, define KPIs, identify energy consumers, set targets II. Discovery – initial analysis and engagement of stakeholders III. Stop - Turn-off what is not required i.e. idling processes, lighting etc. IV. Eliminate – remove unnecessary energy consumers for alternative e.g. swap electric driven conveyor belt for gravity feed conveyor V. Repair - Linked to maintenance e.g. compressed air leaks etc. VI. Reduce - Challenge set-points of processes e.g. reduce oven temperature by 'x' °C if product is not compromised
Requested inputs	• Description of the production process of the industry (SO WHAT tool will ask for this information using checklist or different forms) • Description of the devices where waste heat is supposed to be produced (compressors, steam boilers, ovens, electric chillers…). Information to be asked for: brand, year of manufacture, power…
Output	Analysis of specific processes and machinery where waste heat could be reduced or eliminated completely.
Main benefits	Reduced energy demand, reduced costs and improved efficiency of operations.
Main "disadvantages"	The exercise is considered as time and resource intensive
Exceptions	N/A – as the SO WHAT software is not performing this scenario.

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4.3 Stage 3: Scenarios for Recover and reuse waste heat/cooling at a factory level

4.3.1 Recover WH/C to be re-used in the same process in my facility

Table 8 Scenario 3.1.1 description

<table>
<tr><th colspan="3">Scenario 3.1.1- WHR in Steam boilers by installation of economizers</th></tr>
<tr><td>Relevant User Type</td><td colspan="2">Industry/ESCO</td></tr>
<tr><td rowspan="18">Main Objectives</td><td colspan="2">Energetic Domain</td></tr>
<tr><td>☒Reduction of primary energy consumption</td><td>☐Reduction of final energy consumption</td></tr>
<tr><td>☐Reduction of useful energy demand</td><td>☐Increase share of RES</td></tr>
<tr><td>☒Increase utilization of energy from waste heat sources</td><td>☐Reduction of energy consumption from conventional fuels</td></tr>
<tr><td>☐Reduction of energy consumption from imported sources</td><td>☐DHCN thermal losses reduction</td></tr>
<tr><td>☐DHCN heat density reduction</td><td>☐Operating hours increase</td></tr>
<tr><td colspan="2">Environmental Domain</td></tr>
<tr><td>☐CO2 reduction</td><td>☐Pollutants emission reduction</td></tr>
<tr><td>☐Noise production reduction</td><td>☐Increase share of RES</td></tr>
<tr><td>☒Increase utilization of energy from waste heat sources</td><td></td></tr>
<tr><td colspan="2">Economic Domain</td></tr>
<tr><td>☐Creation of economically feasible H&C scenarios</td><td>☒Operational costs reduction</td></tr>
<tr><td>☐Levelized cost of heat</td><td>☐CO2 reduction cost</td></tr>
<tr><td colspan="2">Social Domain</td></tr>
<tr><td>☐Energy poverty reduction</td><td>☐Job increase</td></tr>
<tr><td>☐Security of supply increase</td><td></td></tr>
<tr><td colspan="2" style="display:none"></td></tr>
<tr><td colspan="2" style="display:none"></td></tr>
<tr><td>Relevant KPIs for evaluation</td><td colspan="2">Boiler performance improvement.
Energy saving compared to baseline.
CO2 emission abatement compared to baseline
Payback period</td></tr>
<tr><td>Example Baseline case</td><td colspan="2">Industry with a high consumption of steam produced by not very old steam boilers not equipped with economizer. (Investing money in a very old boiler that will be probably replaced in the next years makes not much sense)</td></tr>
<tr><td>Intervention / Technologies</td><td colspan="2">The action requires the installation of an air-water exchanger in the combustion gases boiler chimney to preheat the feed water of the boiler itself. There are two possible types of economizers: conventional or condensation economizers. The boiler feed water system must be converted to continuous operation mode if it was a start-stop operation system (two-level control).</td></tr>
</table>

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Requested inputs	Burner and Boiler models, powers and age. Time series of steam needs (pressure, temperature, and flow). Price of steam (current cost for the industry of producing the required steam) Exhaust gas stack temperature and flow Temperature of feed water Price of fuel.
Output	Economizer power [kW] Annual energy saved. [kWh/y] Approximate cost of investment. [€] Payback period [years]
Main benefits	Reduction of the consumption of fossil fuels Improvement in the operation of the boiler by feeding with water at a higher temperature. Reduction of the pollutants and CO_2 emissions Economic revenues (the most important for an ESCO)
Main "disadvantages"	Investment costs. Required space. If not calculated correctly, there may be overheating in the feed tank Reduction of the useful file of the boiler's pumps Additional minor increase in electricity consumption
Exceptions	I. There is lack of detailed time-series, but there are available fragments of time-series or there are available some instantaneous power values → The tool might allow to fill the missing values or directly "built" some simulated thermal demand curves II. The current cost of producing steam is not known. The tool might have an auxiliary calculator to provide a rough estimation based on providing data like the gas prices, the type of boiler, steam characteristics and other technical data. III. There is no information about the stack exhaust gas temperature and flow. The tool might be able to do a rough estimation based on the values of temperature, pressure and flow of produced steam.

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Table 9 Scenario 3.1.2 Description

<table>
<tr><th colspan="3">Scenario 3.1.2: WHR in the Steam boilers purge (Total Dissolved Solids, TDS, control)</th></tr>
<tr><td>Relevant User Type</td><td colspan="2">Industry/ESCO/Municipality</td></tr>
<tr><td rowspan="15">Main Objectives</td><td colspan="2">Energetic Domain</td></tr>
<tr><td>☒Reduction of primary energy consumption</td><td>☐Reduction of final energy consumption</td></tr>
<tr><td>☐Reduction of useful energy demand</td><td>☐Increase share of RES</td></tr>
<tr><td>☒Increase utilization of energy from waste heat sources</td><td>☐Reduction of energy consumption from conventional fuels</td></tr>
<tr><td>☐Reduction of energy consumption from imported sources</td><td>☐DHCN thermal losses reduction</td></tr>
<tr><td>☐DHCN heat density reduction</td><td>☐Operating hours increase</td></tr>
<tr><td colspan="2">Environmental Domain</td></tr>
<tr><td>☐CO_2 reduction</td><td>☐Pollutants emission reduction</td></tr>
<tr><td>☐Noise production reduction</td><td>☐Increase share of RES</td></tr>
<tr><td>☒Increase utilization of energy from waste heat sources</td><td></td></tr>
<tr><td colspan="2">Economic Domain</td></tr>
<tr><td>☐Creation of economically feasible H&C scenarios</td><td>☒Operational costs reduction</td></tr>
<tr><td>☐Levelized cost of heat</td><td>☐CO_2 reduction cost</td></tr>
<tr><td colspan="2">Social Domain</td></tr>
<tr><td>☐Energy poverty reduction
☐Security of supply increase</td><td>☐Job increase</td></tr>
<tr><td>Relevant KPIs for evaluation</td><td colspan="2">Boiler performance improvement.
Energy saving compared to baseline.
CO_2 emission abatement compared to baseline
Payback period.</td></tr>
<tr><td>Example Baseline case</td><td colspan="2">Industry with a high consumption of live steam. Industrial processes with low condensate return have higher blowdown rates and therefore are more suitable for this measure.</td></tr>
<tr><td>Intervention / Technologies</td><td colspan="2">Installation of a system to recover heat from the blowdown purges of a boiler by installing a flash vessel and a water-water exchanger. The flash vessel lowers the high-pressure blowdown stream to atmospheric pressure, generating flash steam and a flow of 100°C water. The flash steam is collected and used to provide heating elsewhere or injected back to the boiler's condensate receiver. The hot water (high TDS content) is discharged to the heat exchanger used to preheat the makeup water.
In case of non-continuous blowdown systems, it will be required to convert them into continuous systems.</td></tr>
</table>

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Requested inputs	Boiler model and operation pressure Time series of steam needs (pressure, temperature, and flow). Maximum allowed TDS content in the boiler Feed water TDS content Average temperature of feed water. Price of steam (industry cost of producing the required steam)
Output	Flow of TDS purge (blowdown rate) Water supply saved [m^3/y] Annual energy saved. [kWh/y] Approximate cost of investment. [€] Payback period [years]
Main benefits	Reduction of the consumption of fossil fuels Reduction of the consumption of water Improvement in the operation of the boiler by feeding with water at a higher temperature. Reduction of the pollutants and CO_2 emissions Economic revenues (the most important for an ESCO)
Main "disadvantages"	Investment costs. Required space. More complex facilities
Exceptions	I. There is lack of detailed time-series, but there are available fragments of time-series or there are available some instantaneous power values → The tool might allow to fill the missing values or directly "built" some simulated thermal demand curves II. The current cost of producing steam is not known. The tool might have an auxiliary calculator to provide a rough estimation based on providing data like the gas prices, the type of boiler, steam characteristics and other technical data.

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Table 10 Scenario 3.1.4 description

<table>
<tr><th colspan="3">Scenario 3.1.3: Recovery from ovens for preheating of the burners input air (Option 1)</th></tr>
<tr><td>Relevant User Type</td><td colspan="2">Industry/ESCO</td></tr>
<tr><td rowspan="15">Main Objectives</td><td colspan="2">Energetic Domain</td></tr>
<tr><td>☒Reduction of primary energy consumption</td><td>☐Reduction of final energy consumption</td></tr>
<tr><td>☐Reduction of useful energy demand</td><td>☐Increase share of RES</td></tr>
<tr><td>☒Increase utilization of energy from waste heat sources</td><td>☐Reduction of energy consumption from conventional fuels</td></tr>
<tr><td>☐Reduction of energy consumption from imported sources</td><td>☐DHCN thermal losses reduction</td></tr>
<tr><td>☐DHCN heat density reduction</td><td>☐Operating hours increase</td></tr>
<tr><td colspan="2">Environmental Domain</td></tr>
<tr><td>☒CO_2 reduction</td><td>☐Pollutants emission reduction</td></tr>
<tr><td>☐Noise production reduction</td><td>☐Increase share of RES</td></tr>
<tr><td>☒Increase utilization of energy from waste heat sources</td><td></td></tr>
<tr><td colspan="2">Economic Domain</td></tr>
<tr><td>☐Creation of economically feasible H&C scenarios</td><td>☒Operational costs reduction</td></tr>
<tr><td>☐Levelized cost of heat</td><td>☐CO_2 reduction cost</td></tr>
<tr><td colspan="2">Social Domain</td></tr>
<tr><td>☐Energy poverty reduction
☐Security of supply increase</td><td>☐Job increase</td></tr>
<tr><td>Relevant KPIs for evaluation</td><td colspan="2">Power of recovery vs burner power
Energy saving compared to baseline.
CO_2 emission abatement compared to baseline
Payback period</td></tr>
<tr><td>Example Baseline case</td><td colspan="2">Existing industry with ovens that emit high/medium temperature fumes and whose burners receive the input fresh air at ambient temperature. Old ovens might be the best candidates if the oven replacement is foreseen in the next years.</td></tr>
<tr><td>Intervention / Technologies</td><td colspan="2">The exhaust chimney output stream is diverted through an air-air heat exchanger in order to recover a portion of its thermal energy and transfer it to the clean air that enters the boiler's burners. Both air streams are forced to pass through the heat exchanger by the action of additional fans. The burners must be capable of operating with preheated inlet air instead of ambient temperature inlet air.</td></tr>
</table>

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Requested inputs	Type and power of the burners and number of them. Oven chimney fumes production time-series. (flow and temperature vs Time). Description of the physico-chemical properties of the fumes (humidity content, dust presence…). Price of thermal energy (gas or diesel) Oven temperature Electricity price
Output	Exchanger power [kW]. Annual energy saved. [kWh/y] Approximate cost of investment. [€] Payback period [years]
Main benefits	Reduction of the consumption of fossil fuels Reduction of the pollutants and CO_2 emissions Economic revenues (the most important for an ESCO)
Main "disadvantages"	Investment costs (at least it would be required the new heat exchangers and pipes and the replacement of the oven burners. In the worst case, the complete replacement of the oven) Required space. (or additional weight if the heat exchanger is placed on top of the oven) Formation of condensates in the chimney that can reduce its useful life. Additional extra electric consumption due to the required fans associated to the heat exchangers
Exceptions	There is lack of detailed time-series, but there are available fragments of time-series or there are available some instantaneous power values → The tool might allow to fill the missing values or directly "built" some simulated thermal demand curves.

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4.3.2 Recover WH/C to be re-used in a different process in my facility

Table 11 Scenario 3.2.1 Description

Scenario 3.2.1: WHR from Air Compressors for Space Heating (Preheating of water)		
Relevant User Type	Industry/ESCO	
Main Objectives	**Energetic Domain**	
	☒Reduction of primary energy consumption	☐Reduction of final energy consumption
	☐Reduction of useful energy demand	☐Increase share of RES
	☒Increase utilization of energy from waste heat sources	☐Reduction of energy consumption from conventional fuels
	☐Reduction of energy consumption from imported sources	☐DHCN thermal losses reduction
	☐DHCN heat density reduction	☐Operating hours increase
	Environmental Domain	
	☒CO_2 reduction	☐Pollutants emission reduction
	☐Noise production reduction	☐Increase share of RES
	☒Increase utilization of energy from waste heat sources	
	Economic Domain	
	☐Creation of economically feasible H&C scenarios	☒Operational costs reduction
	☐Levelized cost of heat	☐CO_2 reduction cost
	Social Domain	
	☐Energy poverty reduction	☐Job increase
	☐Security of supply increase	
Relevant KPIs for evaluation	Power compressor vs power recovery (at the water use temperature) Recoverable energy vs distance compressors to hot water circuits. Energy saving compared to baseline. CO_2 emission abatement compared to baseline Payback period.	
Example Baseline case	Existing industry facility that is equipped with high-power air compressors and its processes require medium-temperature water or relatively important hot domestic water consumption. The same consideration applies for the refrigerant compressors of the split cooling machines.	
Intervention / Technologies	The installation of an oil-water heat exchanger in the compressor oil cooling circuit will be required. Most compressors manufacturers offer a kit to recover the rejected heat, but it is also possible to use generic kits in case of non-availability of the manufacturer's kit. The measure may also require storage in the water side depending on the hourly profile of the hot thermal demand and the type of compressors (modulated or start-stop).	

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Requested inputs	Compressor brand, model and power. Time series of compressed air demand (or compressor power energy consumption profile) Time series of hot water energy demand Distance between compressor and hot water production facility. Price of thermal energy or current cost for the industry of producing the required hot water
Output	Heat exchanger power Minimum size of tank accumulators (inertial tanks) [m3] Annual energy saved. [kWh/y] Approximate cost of investment [€] Payback period [years]
Main benefits	Reduction of the consumption of fossil fuels Reduction of the pollutants and CO_2 emissions Improvement in oil cooling, especially in summer Economic revenues (the most important for an ESCO)
Main "disadvantages"	Investment costs. Required space. Increased electricity consumption due to the additional water pumping.
Exceptions	I. There is lack of detailed time-series, but there are available fragments of time-series or there are available some instantaneous power values ➔ The tool might allow to fill the missing values or directly "built" some simulated thermal demand curves. II. Power compressor time series and water use time series have different sampling frequency ➔ The tool might allow to "harmonize" both time series III. The current cost of producing hot water is not known (for instance, hot water is produced from steam in a centralized system without specific energy meters) → The tool might have an auxiliary calculator to provide a rough estimation based on providing data like the gas prices, the type of boiler and other technical data.

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Table 12 Scenario 3.2.2 description

<table>
<tr><th colspan="3">Scenario 3.2.2: WHR in the Steam boilers purge (Total Dissolved Solids, TDS, control)</th></tr>
<tr><td>Relevant User Type</td><td colspan="2">Industry/ESCO/Municipality</td></tr>
<tr><td rowspan="17">Main Objectives</td><td colspan="2">Energetic Domain</td></tr>
<tr><td>☒Reduction of primary energy consumption</td><td>☐Reduction of final energy consumption</td></tr>
<tr><td>☐Reduction of useful energy demand</td><td>☐Increase share of RES</td></tr>
<tr><td>☒Increase utilization of energy from waste heat sources</td><td>☐Reduction of energy consumption from conventional fuels</td></tr>
<tr><td>☐Reduction of energy consumption from imported sources</td><td>☐DHCN thermal losses reduction</td></tr>
<tr><td>☐DHCN heat density reduction</td><td>☐Operating hours increase</td></tr>
<tr><td colspan="2">Environmental Domain</td></tr>
<tr><td>☐CO_2 reduction</td><td>☐Pollutants emission reduction</td></tr>
<tr><td>☐Noise production reduction</td><td>☐Increase share of RES</td></tr>
<tr><td>☒Increase utilization of energy from waste heat sources</td><td></td></tr>
<tr><td colspan="2">Economic Domain</td></tr>
<tr><td>☐Creation of economically feasible H&C scenarios</td><td>☒Operational costs reduction</td></tr>
<tr><td>☐Levelized cost of heat</td><td>☐CO_2 reduction cost</td></tr>
<tr><td colspan="2">Social Domain</td></tr>
<tr><td>☐Energy poverty reduction</td><td>☐Job increase</td></tr>
<tr><td>☐Security of supply increase</td><td></td></tr>
<tr><td colspan="2"></td></tr>
<tr><td>Relevant KPIs for evaluation</td><td colspan="2">Boiler performance improvement.
Energy saving compared to baseline.
CO_2 emission abatement compared to baseline
Payback period.</td></tr>
<tr><td>Example Baseline case</td><td colspan="2">Industry with a high consumption of live steam. Industrial processes with low condensate return have higher blowdown rates and therefore are more suitable for this measure.</td></tr>
<tr><td>Intervention / Technologies</td><td colspan="2">Installation of a system to recover heat from the blowdown purges of a boiler by installing a flash vessel and a water-water exchanger. The flash vessel lowers the high-pressure blowdown stream to atmospheric pressure, generating flash steam and a flow of 100°C water. The flash steam is collected and used to provide heating elsewhere or injected back to the boiler's condensate receiver. The hot water (high TDS content) is discharged to the heat exchanger used to preheat the makeup water.
In case of non-continuous blowdown systems, it will be required to convert them into continuous systems.</td></tr>
</table>

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Requested inputs	Boiler model and operation pressure Time series of steam needs (pressure, temperature, and flow). Maximum allowed TDS content in the boiler Feedwater TDS content Average temperature of feed water. Price of steam (industry cost of producing the required steam)
Output	Flow of TDS purge (blowdown rate) Water supply saved [m³/y] Annual energy saved. [kWh/y] Approximate cost of investment. [€] Payback period [years]
Main benefits	Reduction of the consumption of fossil fuels Reduction of the consumption of water Improvement in the operation of the boiler by feeding with water at a higher temperature. Reduction of the pollutants and CO_2 emissions Economic revenues (the most important for an ESCO)
Main "disadvantages"	Investment costs. Required space. More complex facilities
Exceptions	I. There is lack of detailed time-series, but there are available fragments of time-series or there are available some instantaneous power values ➔ The tool might allow to fill the missing values or directly "built" some simulated thermal demand curves II. The current cost of producing steam is not known. The tool might have an auxiliary calculator to provide a rough estimation based on providing data like the gas prices, the type of boiler, steam characteristics and other technical data.

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Table 13 Scenario 3.2.3 description

Scenario 3.2.3 Recovery from ovens for generating external hot water (Option 2)		
Relevant User Type	Industry/ESCO	
Main Objectives	**Energetic Domain**	
	☒Reduction of primary energy consumption	☐Reduction of final energy consumption
	☐Reduction of useful energy demand	☐Increase share of RES
	☐Increase utilization of energy from waste heat sources	☐Reduction of energy consumption from conventional fuels
	☒Reduction of energy consumption from imported sources	☐DHCN thermal losses reduction
	☐DHCN heat density reduction	☐Operating hours increase
	Environmental Domain	
	☒CO_2 reduction	☐Pollutants emission reduction
	☐Noise production reduction	☐Increase share of RES
	☒Increase utilization of energy from waste heat sources	
	Economic Domain	
	☐Creation of economically feasible H&C scenarios	☒Operational costs reduction
	☐Levelized cost of heat	☐CO_2 reduction cost
	Social Domain	
	☐Energy poverty reduction	☐Job increase
	☐Security of supply increase	
Relevant KPIs for evaluation	Power of recovery vs burner power Recoverable energy vs distance between them. Energy saving compared to baseline. CO_2 emission abatement compared to baseline Payback period	
Example Baseline case	Existing industry with furnaces that emit fumes at high/medium temperatures and has processes that feed on hot water at a reasonable distance from the ovens.	
Intervention / Technologies	The oven exhaust chimney is modified by the introduction of an air-water heat exchanger in order to recover a portion of the fumes thermal energy and transfer it to a hot water flow. The new heat exchanger introduces a restriction to the chimney airflow that typically requires to be compensated with an additional fan. The measure may also require storage tanks for the water.	

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Requested inputs	Power of the oven Oven chimney fumes production time-series. (flow and temperature vs Time) Description of the physico-chemical properties of the fumes (humidity content, dust presence…). Time series of end-use energy needs (flow and temperature vs time). Price of thermal energy or current cost for the industry of producing the required hot water. Distance between oven chimneys and the hot water circuits Electricity price
Output	Exchanger power [kW]. Size of tank accumulators (if necessary, its installation) [m^3] Annual energy saved. [kWh/y] Approximate cost of investment. [€] Payback period [years]
Main benefits	Reduction of the consumption of fossil fuels Reduction of the pollutants and CO_2 emissions Economic revenues (the most important for an ESCO)
Main "disadvantages"	Investment costs. Required space (tanks, pipes, pumps…) Formation of condensates in the chimney that can reduce its useful life. Additional extra electric consumption due to the required additional fan in the chimney and the water pumps.
Exceptions	I. There is lack of detailed time-series, but there are available fragments of time-series or there are available some instantaneous power values ➔ The tool might allow to fill the missing values or directly "built" some simulated thermal demand curves II. Gas combustion production time series and thermal use time series have different sampling frequency ➔ The tool might allow to "harmonize" both time series III. The current cost of producing hot water is not known (for instance, hot water is produced from steam in a centralized system without specific energy meters) → The tool might have an auxiliary calculator to provide a rough estimation based on providing data like the gas prices, the type of boiler and other technical data

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Table 14 Scenario 3.2.4 description

Scenario 3.2.4: Valorisation of effluent stream with Heat Pumps to produce hot water	
Relevant User Type	Industry/ESCO
Main Objectives	**Energetic Domain** ☐Reduction of primary energy consumption ☐Reduction of final energy consumption ☐Reduction of useful energy demand ☐Increase share of RES ☒Increase utilization of energy from waste heat sources ☐Reduction of energy consumption from conventional fuels ☐Reduction of energy consumption from imported sources ☐DHCN thermal losses reduction ☐DHCN heat density reduction ☐Operating hours increase **Environmental Domain** ☐CO2 reduction ☐Pollutants emission reduction ☐Noise production reduction ☐Increase share of RES ☒Increase utilization of energy from waste heat sources **Economic Domain** ☐Creation of economically feasible H&C scenarios ☒Operational costs reduction ☐Levelized cost of heat ☐CO2 reduction cost **Social Domain** ☐Energy poverty reduction ☐Job increase ☐Security of supply increase
Relevant KPIs for evaluation	Temperature ratio between end use and effluent. (T_{heat}/T_{eff}) Recoverable energy vs distance between them. Energy saving compared to baseline. CO2 emission abatement compared to baseline Payback period.
Example Baseline case	Existing industry with significant unused hot/warm liquid effluent stream with insufficient temperature to be directly used. Moreover, in the case of wastewater, the industry might be expending electricity on cooling the effluent before it enters the water treatment plant.
Intervention / Technologies	Depending on the physico-chemical properties of the effluent, it could be necessary to have specific heat exchangers and filtering systems. The required heat pumps must be adapted to the temperatures of both the cold focus (effluent) and the final focus (end use). The measure may also require storage tanks on one or both sides of the heat pump depending on the hourly profile of the flows.

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Requested inputs	Excess effluent liquid production time-series (flow and temperature vs Time). Time series of end-use energy needs (flow and temperature vs time). Distance between flows. Price of thermal energy (or current cost for the industry of producing the required hot water) Price of electrical energy. (average price or X-Period tariffs)
Output	Heat pump power [kW] Exchanger power (If necessary, its installation) [kW]. Recommended filters and/or heat exchangers based on the effluent physico-chemical properties Size of tank accumulators (if necessary, its installation) [m3] Electrical energy consumed by the heat pump per year. [kWh/y] Annual energy saved. [kWh/y] Approximate cost of investment. [€] Payback period [years]
Main benefits	Reduction of the consumption of fossil fuels Reduction of the pollutants and CO_2 emissions Economic revenues (the most important for an ESCO)
Main “disadvantages”	Investment costs. Required space. Increase of the electricity consumption (max power and energy)
Exceptions	I. There is lack of detailed time-series, but there are available fragments of time-series or there are available some instantaneous power values ➔ The tool might allow to fill the missing values or directly “built” some simulated thermal demand curves II. Effluent production time series and thermal use time series have different sampling frequency ➔ The tool might allow to “harmonize” both time series III. The current cost of producing hot water is not known (for instance, hot water is produced from steam in a centralized system without specific energy meters) → The tool might have an auxiliary calculator to provide a rough estimation based on providing data like the gas prices, the type of boiler and other technical data.

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Table 15 Scenario 3.2.5 Description

Scenario 3.2.5: Use of absorption chillers to produce refrigeration cold water from WHR		
Relevant User Type	Industry	
Main Objectives	**Energetic Domain**	
	☐Reduction of primary energy consumption	☐Reduction of final energy consumption
	☐Reduction of useful energy demand	☐Increase share of RES
	☒Increase utilization of energy from waste heat sources	☐Reduction of energy consumption from conventional fuels
	☐Reduction of energy consumption from imported sources	☐DHCN thermal losses reduction
	☐DHCN heat density reduction	☐Operating hours increase
	Environmental Domain	
	☒CO_2 reduction	☐Pollutants emission reduction
	☐Noise production reduction	☐Increase share of RES
	☒Increase utilization of energy from waste heat sources	
	Economic Domain	
	☐Creation of economically feasible H&C scenarios	☒Operational costs reduction
	☐Levelized cost of heat	☐CO_2 reduction cost
	Social Domain	
	☐Energy poverty reduction	☐Job increase
	☐Security of supply increase	
Relevant KPIs for evaluation	COP Coefficient of performance (Cold Energy/waste Energy) Energy saving compared to baseline. CO_2 emission abatement compared to baseline Payback period	
Example Baseline case	Existing industry with significant unused recovered waste heat potentials (>80 ºC) and existing cooling demand in their own factory processes and systems.	
Intervention / Technologies	It will be necessary to use an absorption machine and an intermediate temperature sink (25-20ºC) to be able to condense the machine. The optimal would be having such a sink inside the factory; otherwise, cooling towers would be necessary.	
Requested inputs	Excess waste heat production time-series (flow and Temperature vs time) Cooling demand time-series (temperature and flow vs time) Values of maximum peak power demand. Geographical location Price of cold thermal energy. Price of electrical energy.	

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Output	Absorption chiller Power [kW] Size of tank accumulators (if necessary, its installation) [m3] Waste Heat energy consumed by the absorption chiller per year. [kWh/y] Cold energy produced by absorption chiller (Annual energy saved) [kWh/y] Cooling energy to dissipate in the cooling tower [kWh/y] Electricity consumption of the system (cooling tower and pumps) [kWh/y] Water consumption in the cooling tower [m3/y] Approximate cost of investment. [€] Payback period [years]
Main benefits	Reduction of the consumption of electricity. Reduction of the pollutants and CO_2 emissions. Economic revenues (the most important for an ESCO)
Main "disadvantages"	Investment costs. Required space. Cooling tower (→Legionella treatment and other maintenance issues, water consumption)
Exceptions	I. There is lack of detailed time-series, but there are available fragments of time-series or there are available some instantaneous power values ➔ The tool might allow to fill the missing values or directly "built" some simulated thermal demand curves II. Waste heat production time series and cold use time series have different sampling frequency ➔ The tool might allow to "harmonize" both time series III. If the price of cold thermal energy is not available → The tool might do an approximated calculation based on the chiller model and the weather data.

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Table 16 Scenario 3.2.6 description

Scenario 3.2.6: Waste Heat Recovery in the condensate collecting receiver by the use of a vent condenser		
Relevant User Type	Industry/ESCO	
Main Objectives	**Energetic Domain**	
	☒Reduction of primary energy consumption	☐Reduction of final energy consumption
	☐Reduction of useful energy demand	☐Increase share of RES
	☒Increase utilization of energy from waste heat sources	☐Reduction of energy consumption from conventional fuels
	☐Reduction of energy consumption from imported sources	☐DHCN thermal losses reduction
	☐DHCN heat density reduction	☐Operating hours increase
	Environmental Domain	
	☒CO_2 reduction	☐Pollutants emission reduction
	☐Noise production reduction	☐Increase share of RES
	☐Increase utilization of energy from waste heat sources	
	Economic Domain	
	☒Creation of economically feasible H&C scenarios	☒Operational costs reduction
	☐Levelized cost of heat	☐CO_2 reduction cost
	Social Domain	
	☐Energy poverty reduction	☐Job increase
	☐Security of supply increase	
Relevant KPIs for evaluation	Pressure drop in condensate line. Recoverable energy vs distance between them. Energy saving compared to baseline. CO_2 emission abatement compared to baseline Payback period	
Example Baseline case	Existing industry with significant vents steam in the return condensate tank. When the pressure of saturated condensate is reduced, a portion of the liquid "flashes" to low-pressure steam and in most cases, the flashing steam is vented, and its energy content lost	
Intervention / Technologies	The feed tank must be vented to prevent any build-up of pressure, but a heat exchanger can be placed in the vent to recover this energy. It could condense the flashed steam, transfer its thermal energy to incoming makeup water, and then return it to the boiler. Energy is recovered in two forms: hotter makeup water and clean distilled condensate ready for its use.	

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Requested inputs	Time series of steam demand (pressure, temperature, and flow). Percentage of steam consumed and that returned to the feed tank. Condensed steam return pressure. Feed tank pressure. Time series of end-use energy needs (flow and temperature vs time). Distance between flows (water condensed and energy needs). Temperature supply water. Cost of producing distilled water at use temperature, Cost of producing steam. Price of thermal energy. Price of electrical energy.
Output	Exchanger power [kW]. Water saved [m3] Annual energy saved. [kWh/y] Approximate cost of investment. [€] Payback period [years]
Main benefits	Reduction of the consumption of fossil fuels Reduction of the pollutants and CO_2 emissions Economic revenues (the most important for an ESCO)
Main "disadvantages"	Investment costs. Required space.
Exceptions	I. There is lack of detailed time-series, but there are available fragments of time-series or there are available some instantaneous power values ➔ The tool might allow to fill the missing values or directly "built" some simulated thermal demand curves II. Steam vent production time series and thermal use time series have different sampling frequency ➔ The tool might allow to "harmonize" both time series

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Table 17 Scenario 3.2.7 description

<table>
<tr><th colspan="3">Scenario 3.2.7: Cold recovery in the gas expansion systems (gasification plants)</th></tr>
<tr><td>Relevant User Type</td><td colspan="2">Industry/ESCO</td></tr>
<tr><td rowspan="17">Main Objectives</td><td colspan="2">Energetic Domain</td></tr>
<tr><td>☐Reduction of primary energy consumption</td><td>☐Reduction of final energy consumption</td></tr>
<tr><td>☐Reduction of useful energy demand</td><td>☐Increase share of RES</td></tr>
<tr><td>☒Increase utilization of energy from waste heat sources</td><td>☐Reduction of energy consumption from conventional fuels</td></tr>
<tr><td>☐Reduction of energy consumption from imported sources</td><td>☐DHCN thermal losses reduction</td></tr>
<tr><td>☐DHCN heat density reduction</td><td>☐Operating hours increase</td></tr>
<tr><td colspan="2">Environmental Domain</td></tr>
<tr><td>☐CO2 reduction</td><td>☐Pollutants emission reduction</td></tr>
<tr><td>☐Noise production reduction</td><td>☐Increase share of RES</td></tr>
<tr><td>☒Increase utilization of energy from waste heat sources</td><td></td></tr>
<tr><td colspan="2">Economic Domain</td></tr>
<tr><td>☐Creation of economically feasible H&C scenarios</td><td>☒Operational costs reduction</td></tr>
<tr><td>☐Levelized cost of heat</td><td>☐CO2 reduction cost</td></tr>
<tr><td colspan="2">Social Domain</td></tr>
<tr><td>☐Energy poverty reduction</td><td>☐Job increase</td></tr>
<tr><td>☐Security of supply increase</td><td></td></tr>
<tr><td colspan="2"></td></tr>
<tr><td>Relevant KPIs for evaluation</td><td colspan="2">Pressure (supply or storage) / Pressure use
Payback period [years]</td></tr>
<tr><td>Example Baseline case</td><td colspan="2">The plant has an expansion/gasification facility from compressed or liquefied gases and the facility has cold supply needs. It can also be included factories where natural gas or LPG is supplied in liquid state.</td></tr>
<tr><td>Intervention / Technologies</td><td colspan="2">Normally, liquefied gases evaporate in an air evaporator absorbing heat from the environment. High-value cold is lost to atmosphere.
Using specific cold exchangers is possible to transfer rejected heat to the gas expansion device and therefore implement a free cooling system with almost cryogenic operation temperatures (typically between -50ºC and -30ºC). Due to this lower temperature values, thermal storage as well as the primary cooling circuits are usually filled with specific brines like Calcium Chloride brine.</td></tr>
</table>

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Requested inputs	Gas (name, composition). Supply/storage pressure. Operating pressure. Gas consumption (expansion) flow time series Cold demand usage and temperature time series. Distance between the gas plant and cold circuits. Average EER of chillers Price of electrical energy. Geographical location
Output	Recovered energy [kWh/y] Exchanger power [kW]. Size of tank accumulators (if necessary, its installation) [m^3] Approximate cost of investment. [€] Payback period [years]
Main benefits	Reduction of electrical consumption for cold production. Reduction of electricity costs Reduction of pollutants and CO_2 emissions.
Main "disadvantages"	Investment costs. It is an improvement measure that depends a lot on the gas and its conditions of use (pressures, flows, etc.) Not very mature technology with a limited number of suppliers
Exceptions	I. There is lack of detailed time-series, but there are available fragments of time-series or there are available some instantaneous power values → The tool might allow to fill the missing values or directly "built" some simulated thermal demand curves II. Gas flow production time series and cold use time series have different sampling frequency → The tool might allow to "harmonize" both time series

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Table 18 Scenario 3.2.8 description

Scenario 3.2.8: Upgrade of low-grade waste heat by using heat pump in order to meet process heat demand		
Relevant User Type	Industry/ESCO	
Main Objectives	**Energetic Domain**	
	☒Reduction of primary energy consumption	☒Reduction of final energy consumption
	☐Reduction of useful energy demand	☐Increase share of RES
	☒Increase utilization of energy from waste heat sources	☒Reduction of energy consumption from conventional fuels
	☐Reduction of energy consumption from imported sources	☐DHCN thermal losses reduction
	☐DHCN heat density reduction	☐Operating hours increase
	Environmental Domain	
	☒CO_2 reduction	☒Pollutants emission reduction
	☐Noise production reduction	☐Increase share of RES
	☒Increase utilization of energy from waste heat sources	
	Economic Domain	
	☒Creation of economically feasible H&C scenarios	☐Operational costs reduction
	☐Levelized cost of heat	☐CO_2 reduction cost
	Social Domain	
	☐Energy poverty reduction	☐Job increase
	☒Security of supply increase	
Relevant KPIs for evaluation	primary energy reduction share of imported sources CO_2 emissions reduction reduction of energy costs Economic KPIs (CAPEX/OPEX/PBP)	
Example Baseline case	low-grade waste heat is available in the plant and not used due to its temperature which is not suitable for any process	
Intervention / Technologies	Heat pumps (HPs) can be used to increase the temperature of WH if a suitable sink for it is available. A match among a source and a sink has been identified but temperature is not suitable for it. Therefore, a HP can be used to increase (technological limits) the temperature and the avoid fuel consumption should justify the electricity used by the HP to meet the demand.	
Requested inputs	Technical parameters of the WH as identified before Technical parameter of the thermal demand to be met Cost of the electricity Fuel/source currently used to meet the identified demand and its cost	

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Output	Amount of low-grade waste heat used Reduction of fuel consumption (based on the current source) CO_2/GHG emission reduction Reduction of primary energy consumption Characteristics of the HP required Economic evaluation of the intervention (CAPEX/OPEX/PBP)
Main benefits	Possibility to evaluate the proposed substitution from the technical and economic perspective
Main "disadvantages"	WH should be precisely characterised as well as the identified sink A fair knowledge of the energy fluxes is required
Exceptions	None

Table 19 Scenario 3.2.9 description

Scenario 3.2.9: Waste heat recovery from existing refrigeration systems		
Relevant User Type	Industry	
Main Objectives	**Energetic Domain**	
	☒Reduction of primary energy consumption	☐Reduction of final energy consumption
	☐Reduction of useful energy demand	☐Increase share of RES
	☒Increase utilization of energy from waste heat sources	☒Reduction of energy consumption from conventional fuels
	☐Reduction of energy consumption from imported sources	☐DHCN thermal losses reduction
	☐DHCN heat density reduction	☐Operating hours increase
	Environmental Domain	
	☒CO_2 reduction	☐Pollutants emission reduction
	☐Noise production reduction	☐Increase share of RES
	☒Increase utilization of energy from waste heat sources	
	Economic Domain	
	☒Creation of economically feasible H&C scenarios	☐Operational costs reduction
	☐Levelized cost of heat	☐CO_2 reduction cost
	Social Domain	
	☐Energy poverty reduction	☐Job increase
	☐Security of supply increase	
Relevant KPIs for evaluation	Payback time Net present value Internal rate of return	

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Example Baseline case	Significant amount of waste heat rejected by industrial refrigeration systems in the following locations: i) heat of the desuperheating vapour; ii) heat of the condensing vapour; iii) lubricating oil of screw compressors; iv) water cooling of the heads of reciprocating compressors; v) water cooling of the electrical motors. On the other hand, significant consumption of fossil fuels (natural gas) for water heating and space heating.
Intervention / Technologies	Installation of a heat exchanger between the compressor and the condenser and/or an oil cooling heat exchanger to deliver heated water at 40-60°C (domestic and service hot water). Installation of a condensing heat exchanger for delivery of lower temperature water (≈25°C) for underfloor heating or air heating for both temperature and humidity control (fan coils, air conditioning). Use of the condensing waste heat in a water loop to drive water-source heat pumps for space heating or high temperature heat pumps for sterilizing and cleaning processes.
Requested inputs	Desuperheating and condensation heat loads and temperatures. Heat loads and temperatures of the oil/water used for cooling of the compressors and motors. Time variations of demand for hot water and space heating.
Output	Mass flow rate and outlet temperature of the heated water. Cost of the heat exchangers. Fraction of the heat demand for space and water heating covered by waste heat recovery.
Main benefits	Reduction of the natural gas consumption (and costs) associated with space heating and water heating. Reduction of CO_2 emissions.
Main "disadvantages"	Heating and refrigeration are required at the same time (e.g. supermarkets, dairies, butcheries, etc.). Moreover, the heating supply must be coincident with the demand (otherwise, one or more storage tanks will be needed).
Exceptions	I. Lack of data for the temperatures of the waste heat rejected by industrial refrigeration systems → collection of data from the literature for different types of systems (screw, reciprocating); II. The user might want to use the waste heat from the refrigeration systems in adsorption or absorption dehumidification systems, which are not covered by the SO WHAT tool → extension of the technology database to include adsorption and absorption dehumidification systems.

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Table 20 Scenario 3.2.10 description

Scenario 3.2.10: Recovery from Electric Chillers to produce medium-low temperature hot water (Preheating systems)		
Relevant User Type	Industry	
Main Objectives	**Energetic Domain**	
	☒Reduction of primary energy consumption	☐Reduction of final energy consumption
	☐Reduction of useful energy demand	☐Increase share of RES
	☒Increase utilization of energy from waste heat sources	☐Reduction of energy consumption from conventional fuels
	☐Reduction of energy consumption from imported sources	☐DHCN thermal losses reduction
	☐DHCN heat density reduction	☐Operating hours increase
	Environmental Domain	
	☒CO2 reduction	☐Pollutants emission reduction
	☐Noise production reduction	☐Increase share of RES
	☐Increase utilization of energy from waste heat sources	
	Economic Domain	
	☒Creation of economically feasible H&C scenarios	☒Operational costs reduction
	☐Levelized cost of heat	☐CO2 reduction cost
	Social Domain	
	☐Energy poverty reduction	☐Job increase
	☐Security of supply increase	
Relevant KPIs for evaluation	Fuel savings Cost savings CO_2 emissions reduction Payback period	
Example Baseline case	The desuperheating and condensation heat of the vapour exiting the compressor of the electrical chiller is rejected to the surrounding environment	
Intervention / Technologies	A desuperheater/condensing heat exchanger is installed downstream of the chiller's compressor, where the desuperheating heat and part of the condensation heat of the refrigerant are recovered for water heating. The heated water is stored in a tank for later use in the manufacturing process, cleaning processes and for sanitary purposes.	
Requested inputs	Capacity and COP of the electrical chiller Temperature of the refrigerant at compressor outlet and condensation temperature Effectiveness of the desuperheater/condensing heat exchanger Specific investment cost of the desuperheater/condensing heat exchanger	

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Output	Heat recovered Temperature increase of water Cost of the desuperheater/condensing heat exchanger
Main benefits	Reduction of the energy required for domestic water heating Reduction of the parasitic loads (fans) of the chiller Reduction of the thermal pollution
Main "disadvantages"	Investment required due to the addition of the desuperheater/condensing heat exchanger. Limited temperature increases or limited heat load because the condensing heat is typically available at low temperatures and the higher quality desuperheating heat represents only a fraction of the condensing heat. The water preheat may hinder the utilization of the latent heat of the flue gases of a condensing natural gas boiler.
Exceptions	I. The user does not know the internal parameters (temperature, pressure, refrigerant) of the electrical chiller → typical parameters should be provided by the software depending on the application of the electric chiller (refrigeration, air conditioning); II. The user is not interested in the utilization of the heat of condensation but only in the desuperheating heat → the software must be able to separate the two processes.

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Table 21 Scenario 3.2.11 description

Scenario 3.2.11: Cold Thermal Energy Storage integration for WHR inside a factory		
Relevant User Type	Industry	
Main Objectives	**Energetic Domain**	
	☒Reduction of primary energy consumption	☐Reduction of final energy consumption
	☐Reduction of useful energy demand	☐Increase share of RES
	☒Increase utilization of energy from waste heat sources	☐Reduction of energy consumption from conventional fuels
	☒Reduction of energy consumption from imported sources	☐DHCN thermal losses reduction
	☐DHCN heat density reduction	☐Operating hours increase
	Environmental Domain	
	☒CO_2 reduction	☐Pollutants emission reduction
	☐Noise production reduction	☐Increase share of RES
	☒Increase utilization of energy from waste heat sources	
	Economic Domain	
	☒Creation of economically feasible H&C scenarios	☒Operational costs reduction
	☐Levelized cost of heat	☐CO_2 reduction cost
	Social Domain	
	☐Energy poverty reduction	☐Job increase
	☒Security of supply increase	
Relevant KPIs for evaluation	Payback time Internal Rate of Return Net Present Value	
Example Baseline case	Waste heat of flue gases discharged through the chimney or unrecovered from hot products cooled by ambient air	
Intervention / Technologies	Waste heat to cooling by installing an absorption chiller. The residual heat of the flue gases or the heat of the hot products is recovered in a (more or less conventional heat) recovery unit to generate hot water that drives the absorption chiller. The chilled water is supplied to the air conditioning system (fan coil) and to the manufacturing process. A chilled water storage tank or a latent heat storage (ice, paraffin, etc.) acts as a buffer and supplies the necessary cooling to the user.	

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Requested inputs	Thermal parameters of the exhaust heat Thermal parameters of the water loop Time variation of the cooling load required by the manufacturing process and for air conditioning Volume of the cold storage tank Investment and O&M costs of the absorption chiller Investment and O&M costs of the cold storage tank
Output	COP of the absorption chiller Cooling capacity (kW) Electricity savings Economic KPIs
Main benefits	Reduction of the electricity consumption for air conditioning and process cooling. Reduced size and investment of the absorption chiller due to the integration of cold storage.
Main "disadvantages"	Low utilization factor of the absorption chiller if the only load is the air conditioning load in the office (daily and seasonal pattern)
Exceptions	I. The volume of the cold storage tank is unknown → The user may carry out a sensitivity analysis to evaluate the impact of the cold storage size on the performance and cost of the system; + II. The substance to be used as phase change material (PCM) in the latent heat store is unknown → The software gives some suggestions about the most suitable substance based on temperature level, energy density and cost of storage.

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Table 22 Scenario 3.2.12 description

Scenario 3.2.12: Optimize waste heat/cold energy use		
Relevant User Type	Industry/ESCO	
Main Objectives	**Energetic Domain**	
	☒Reduction of primary energy consumption	☐Reduction of final energy consumption
	☐Reduction of useful energy demand	☐Increase share of RES
	☒Increase utilization of energy from waste heat sources	☒Reduction of energy consumption from conventional fuels
	☒Reduction of energy consumption from imported sources	☐DHCN thermal losses reduction
	☐DHCN heat density reduction	☐Operating hours increase
	Environmental Domain	
	☒CO2 reduction	☐Pollutants emission reduction
	☐Noise production reduction	☐Increase share of RES
	☒Increase utilization of energy from waste heat sources	
	Economic Domain	
	☐Creation of economically feasible H&C scenarios	☐Operational costs reduction
	☐Levelized cost of heat	☒CO2 reduction cost
	Social Domain	
	☐Energy poverty reduction	☐Job increase
	☐Security of supply increase	
Relevant KPIs for evaluation	Share of energy consumption met by recovered WH/C energy Shares of recovered WH/C energy used on-site and exported to district network Energy savings compared to baseline	
Example Baseline case	Main actor has already installed some WH/C recovery technologies which supply a share of its facilities energy demand, but wants to optimise their energy use	
Intervention / Technologies	- Shift of energy demand in order to better match WH/C energy recovery pattern with energy demand profile Scaling of WH/C energy source output in order to better match peak energy demand	
Requested inputs	- Energy demand time series - WH/C energy recovery time series - WH/C energy consumption time series - WH/C technology scaling constraints (maximum and minimum output capacity, ramping limits, time limits, other limiting factors) Energy demand shifting constraints (increase and reduction magnitude, duration and time limits)	

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Output	Line chart Share of energy consumption met by WH/C recovery technology Shares of recovered WH/C energy used on-site and exported to district network Energy savings
Main benefits	Increased match between WH/C energy recovery pattern with energy demand profile Increased share of energy consumption met by WH/C technology Increased share of recovered WH/C energy used on-site or exported to district network Increased energy savings
Main "disadvantages"	Possible reduced lifetime of installed WH/C recovery technology due to increased output Uncertainty with regards shift of energy demand due to required changes in human behaviour against usual patterns
Exceptions	If the user does not provide at all, or partially, information about: - Energy demand time series → the tool might be able to approximate energy demand time series, as based on utility bill data and other inputs provided (e.g. operational schedules), through rough-cut profiling approach - WH/C energy recovery time series → the tool might be able to simulate WH/C energy recovery patterns - WH/C energy consumption time series → the tool might be able to simulate WH/C energy consumption profiles, assuming no energy storage - WH/C technology scaling constraints (maximum and minimum output capacity, ramping limits, time limits, other limiting factors) → Standard constraints might be used as default inputs into SO WHAT tool

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4.4 Stage 4: Scenarios for Recover and Reuse waste heat/cooling to provide power at a factory level

Table 23 Scenario 4.1 description

Scenario 4.1: Recover w h/c to generate power for my facility		
Relevant User Type	Industry/ESCO	
Main Objectives	**Energetic Domain**	
	☒Reduction of primary energy consumption	☒Reduction of final energy consumption
	☐Reduction of useful energy demand	☐Increase share of RES
	☒Increase utilization of energy from waste heat sources	☒Reduction of energy consumption from conventional fuels
	☐Reduction of energy consumption from imported sources	☐DHCN thermal losses reduction
	☐DHCN heat density reduction	☐Operating hours increase
	Environmental Domain	
	☒CO_2 reduction	☒Pollutants emission reduction
	☐Noise production reduction	☒Increase share of RES
	☐Increase utilization of energy from waste heat sources	
	Economic Domain	
	☐Creation of economically feasible H&C scenarios	☒Operational costs reduction
	☐Levelized cost of heat	☒CO_2 reduction cost
	Social Domain	
	☐Energy poverty reduction	☐Job increase
	☐Security of supply increase	
Relevant KPIs for evaluation	Reduction of energy produced by traditional power plant Fossil fuels use Average Production Cost/MWh (el) CAPEX/OPEX PBP	
Example Baseline case	A WH source has been identified and characterised: temperature, profile, and intermittency. The evaluation of suitable technologies for its conversion into electricity is performed based on technical and economic parameters.	
Intervention / Technologies	Multiple technologies are considered and compared to identify the best fit for the utilisation of the WH.	
Requested inputs	Waste heat characteristics as previously mentioned Electricity demand to evaluate whenever a surplus could be generated Electricity cost/price Available space for installation	

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Output	Selection among multiple suitable technologies by comparison Graphic of electricity produced based on the identified WH Economic parameters (CAPEX, OPEX, PBP, etc.) calculated Possible business model and opportunities to deploy the intervention
Main benefits	Improve cost-effectiveness Possibility to compare different options Reduce CO_2 emissions
Main "disadvantages"	Information on the WH stream must be known
Exceptions	I. Geometric info is optional II. Electricity cost/price is needed for the economic calculations, basic output on suitable technologies can be provided without taking them into consideration

Table 24 Scenario 4.2 description

Scenario 4.2: Add solar panels/solar thermal collectors on my site.		
Relevant User Type	Industry/ESCO/Municipality	
Main Objectives	**Energetic Domain**	
	☐Reduction of primary energy consumption	☐Reduction of final energy consumption
	☐Reduction of useful energy demand	☐Increase share of RES
	☐Increase utilization of energy from waste heat sources	☐Reduction of energy consumption from conventional fuels
	☐Reduction of energy consumption from imported sources	☐DHCN thermal losses reduction
	☐DHCN heat density reduction	☐Operating hours increase
	Environmental Domain	
	☐CO_2 reduction	☐Pollutants emission reduction
	☐Noise production reduction	☐Increase share of RES
	☐Increase utilization of energy from waste heat sources	
	Economic Domain	
	☐Creation of economically feasible H&C scenarios	☐Operational costs reduction
	☐Levelized cost of heat	☐CO_2 reduction cost
	Social Domain	
	☐Energy poverty reduction	☐Job increase
	☐Security of supply increase	

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Relevant KPIs for evaluation	Investment cost NPV CO_2 emission reduction Increase electrification
Example Baseline case	Industrial site with a good availability of solar radiation and plenty of space on the top of the roofs (flat or curved) for installation of PV panels.
Intervention / Technologies	Installation of photovoltaic panels on the factory roofs. The electricity produced could be used for self-consumption in the factory or could be totally sold to a third party (i.e. the national grid) or could be mixed business model (self-consumption and grid-injection). Alternatively, the electricity produced can be used to electrify thermal processes at the industrial site.
Requested inputs	Performance of PV panels (e.g. conversion efficiency) CAPEX of PV Heat and electricity demand profiles, possibly electricity prices profiles GIS mapping of the industrial site (e.g. roof area)
Output	Technical potential for PV installation as well as location Investment cost Electricity generation, including share of electricity from PV generation
Main benefits	Increased renewable generation from solar Reduce fuel consumption from fossil fuels Reduced import of electricity from electricity grid Reduced CO_2 emission
Main "disadvantages"	Additional complexity due to the need to mitigate fluctuation in solar irradiation and hence in electricity production. This is expected to be particularly relevant in industrial processes, which need uninterrupted supply of electricity.
Exceptions	I. The data on the tilt and azimuth angles of the planned PV installation are available → The software must be able to calculate the solar irradiation incident on the PV panels starting from the hourly data of global solar irradiation; II. The user might want to increase the percentage of self-consumption by installing an electrical energy storage → the software must embed a lumped model of electrical energy storage (e.g. batteries) which gives as output the roundtrip efficiency and the investment cost; III. The subsidy schemes for electricity production from PV generators are various and country-specific → the software user should be able to include them in the calculation of the economic performance metrics.

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Table 25 Scenario 4.3 description

Scenario 4.3: Maximise the use of renewable energy I have installed.			
Relevant User Type	Industry/ESCO/Municipality		
Main Objectives	**Energetic Domain**		
	☒Reduction of primary energy consumption	☐Reduction of final energy consumption	
	☐Reduction of useful energy demand	☒Increase share of RES	
	☐Increase utilization of energy from waste heat sources	☒Reduction of energy consumption from conventional fuels	
	☒Reduction of energy consumption from imported sources	☐DHCN thermal losses reduction	
	☐DHCN heat density reduction	☐Operating hours increase	
	Environmental Domain		
	☒CO_2 reduction	☒Pollutants emission reduction	
	☐Noise production reduction	☒Increase share of RES	
	☐Increase utilization of energy from waste heat sources		
	Economic Domain		
	☐Creation of economically feasible H&C scenarios	☐Operational costs reduction	
	☐Levelized cost of heat	☒CO_2 reduction cost	
	Social Domain		
	☐Energy poverty reduction	☐Job increase	
	☐Security of supply increase		
Relevant KPIs for evaluation	Share of energy consumption met by renewable energy source Shares of produced renewable energy used on-site and exported to grid Energy savings compared to baseline		
Example Baseline case	Main actor has already installed some renewable energy source technologies which supply a share of its facilities energy demand, but wants to optimise renewable energy use		
Intervention / Technologies	- Shift of energy demand in order to better match renewable energy production pattern with energy demand profile Scaling of renewable energy source output in order to better match peak energy demand		
Requested inputs	- Energy demand time series - Renewable energy supply time series - Renewable energy consumption time series - Renewable energy source technology scaling constraints (maximum and minimum output capacity, ramping limits, weather-dependence, time limits) - Energy demand shifting constraints (increase and reduction magnitude, duration and time limits)		

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Output	Line chart Share of energy consumption met by renewable energy source Shares of produced renewable energy used on-site and exported to grid Energy savings
Main benefits	Increased match between renewable energy production pattern with energy demand profile Increased share of energy consumption met by renewable energy source Increased share of produced renewable energy used on-site Reduced share of produced renewable energy exported to grid Increased energy savings
Main "disadvantages"	Possible reduced lifetime of installed renewable energy source technology due to increased production output Uncertainty with regards shift of energy demand due to required changes in human behaviour against usual patterns
Exceptions	If the user does not provide at all, or partially, information about: - Energy demand time series → the tool might be able to approximate energy demand time series, as based on utility bill data and other inputs provided (e.g. operational schedules), through rough-cut profiling approach - Renewable energy supply time series → the tool might be able to simulate renewable energy production - Renewable energy consumption time series → the tool might be able to simulate renewable energy consumption profiles, assuming no renewable energy storage - Renewable energy source technology scaling constraints (maximum and minimum output capacity, ramping limits, weather-dependence, time limits) → Standard constraints might be used as default inputs into SO WHAT tool

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Table 26 Scenario 4.4 description

Scenario 4.4: Optimise the mix of renewable energy installations at my site	
Relevant User Type	Industry/ESCO/Municipality
Main Objectives	**Energetic Domain** ☒Reduction of primary energy consumption ☐Reduction of final energy consumption ☐Reduction of useful energy demand ☒Increase share of RES ☐Increase utilization of energy from waste heat sources ☒Reduction of energy consumption from conventional fuels ☒Reduction of energy consumption from imported sources ☐DHCN thermal losses reduction ☐DHCN heat density reduction ☐Operating hours increase **Environmental Domain** ☒CO_2 reduction ☐Pollutants emission reduction ☐Noise production reduction ☒Increase share of RES ☐Increase utilization of energy from waste heat sources **Economic Domain** ☐Creation of economically feasible H&C scenarios ☐Operational costs reduction ☐Levelized cost of heat ☒CO_2 reduction cost **Social Domain** ☐Energy poverty reduction ☐Job increase ☒Security of supply increase
Relevant KPIs for evaluation	Fraction of electricity, heating or cooling demand covered by renewables. CO_2 emissions reductions compared to the baseline case. Payback time, net present value, internal rate of return.
Example Baseline case	Use of grid electricity to cover the electricity demand of the industry or the district. Use of fossil fuels (e.g. natural gas) to cover the heating demand and grid electricity to cover the cooling demand. Good availability of local renewable energy sources (solar, wind, geothermal and biomass energy) which are either not used or only partially used for energy production. Availability of space (e.g. roofs of buildings, warehouses) for installation of new bulky equipment.
Intervention / Technologies	Installation of PV panels and/or wind turbines for electricity production. Installation of flat plate or evacuated solar collectors for water/space heating. Concentrating solar collectors (Fresnel, parabolic trough) for production of process heat or cooling through sorption chillers. Ground source heat pumps for water/space heating. Biomass boilers for production of steam or hot water. Thermal and electrical storage to solve any mismatch between energy supply and demand.

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Requested inputs	Historical hourly data on ambient temperature. Hourly data of solar global irradiation (for PV panels and non-concentrating collectors) and direct irradiation (for concentrating collectors). Performance and cost data of PV panels and solar collectors. Hourly data on wind speed and characteristic curves and costs of wind turbines. Data on ground temperature at different depths for installation of geothermal probes. Data on type and amount of biomass locally available. Data on the space available for installation of renewable plants within the industrial site or district. Availability of any waste heat source. Data about the demand of electricity, heating and cooling.
Output	Electricity generated by the PV generator or wind turbines and time variation. Heating load and temperature produced by the geothermal heat pump, solar collector or biomass boiler. Cooling duty of the absorption chiller.
Main benefits	Use of renewable energy sources for production of electricity, heating and cooling in place of fossil fuels or grid electricity. Reduction of fossil fuels consumption and CO_2 emissions. Distributed generation of electricity. Possible positive synergies between waste heat and renewable energy sources (e.g. to increase the temperature of waste heat).
Main "disadvantages"	Intermittent availability of solar and wind energy. High costs of small renewable energy plant (e.g. wind turbines, concentrated solar) in comparison to centralized plants. Limited amount of resources in many sites (e.g. solar energy in northern countries) and/or limited space for installation of renewable plants. Difficult social acceptance for installation of wind turbines or biomass plants in districts. High costs of the electrical storage or reduced profitability when the generated electricity is fed to the grid. The integration between waste heat source and renewable energy source may complicate the design and operation of the plant.
Exceptions	I. Lack of availability of models for renewable technologies within SO WHAT → need to establish a link with the libraries of models already developed in other software; II. Electrical energy storage not covered by the SO WHAT technologies → add a lumped model for e.g. batteries; III. Some of the renewable energies (hydro, biogas, etc.) not covered by SO WHAT; IV. Some hybrid systems combining waste heat and renewables, or two/more renewables together may not be fully described by the set of SO WHAT technologies

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4.5 Stage 5: Scenarios for Recover and Reuse waste heat/cooling at a community level

Table 27 Scenario 5.1 description

Scenario 5.1: Match local potential supply of waste heat with local demand		
Relevant User Type	Industry/ESCO/Municipality	
Main Objectives	**Energetic Domain**	
	☐Reduction of primary energy consumption	☐Reduction of final energy consumption
	☐Reduction of useful energy demand	☐Increase share of RES
	☒Increase utilization of energy from waste heat sources	☐Reduction of energy consumption from conventional fuels
	☐Reduction of energy consumption from imported sources	☐DHCN thermal losses reduction
	☐DHCN heat density reduction	☐Operating hours increase
	Environmental Domain	
	☐CO2 reduction	☐Pollutants emission reduction
	☐Noise production reduction	☐Increase share of RES
	☒Increase utilization of energy from waste heat sources	
	Economic Domain	
	☒Creation of economically feasible H&C scenarios	☐Operational costs reduction
	☐Levelized cost of heat	☐CO2 reduction cost
	Social Domain	
	☐Energy poverty reduction	☐Job increase
	☒Security of supply increase	
Relevant KPIs for evaluation	Share of heat met by WH/C resource Shares of WH/C resource exported to DHN/DCN Energy savings compared to baseline Additional revenues compared to baseline Payback period [years]	
Example Baseline case	Main actors want to know the share of heat demand from a group of nearby buildings, or from a district heating network (DHN), that can be met through the reuse of the excess waste heat/cold (WH/C) resource available from an industrial site that is located in the neighbourhood.	
Intervention / Technologies	Connection to an existing district heating or cooling network (DHN or DCN) Construction of a new DHN or DCN Expansion of a DHN or DCN Upgrade of a DHN or DCN, e.g. increase in distribution capacity Shift of heat demand in order to better match WH/C resource availability profile with energy demand profile	

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Requested inputs	Distance to closest DHN/DCN Distribution capacity of closest DHN/DCN Connection status to closest DHN/DCN Heat demand time series Heat demand quality constraints (e.g. reclamation grade, temperature range, heat capacity) Heat demand shifting constraints (increase and reduction magnitude, duration and time limits) Industrial site Energy Sankey Diagram with list of WH/C types, sources, actual sinks and embedded energy Industrial site WH/C resource availability time series
Output	Line chart Share of heat demand met by reuse of WH/C resource available Energy savings Approximate cost of investment [€] (e.g. connection to, or construction or expansion or upgrade of DHN or DCN) Payback period [years]
Main benefits	Economic revenues Increased energy savings compared to baseline
Main "disadvantages"	Investment costs Uncertainty with regards revenues DHN/DCN connection / construction / expansion / upgrade delays Uncertainty with regards shift of heat demand due to required changes in human behaviour against usual patterns Uncertainty with regards WH/C resource availability
Exceptions	If the user does not provide at all, or partially, information about: - Distance to, distribution capacity and connection status of closest DHN/DCN → the tool might be able to retrieve automatically such information from publicly available database, or to focus analysis on the share of heat demand that could be met by WH/C resource, irrespective of DHN/DCN status and characteristics - Heat demand time series → the tool might be able to approximate heat demand time series, as based on output from community energy master planning tool such as the IES iCD platform - Heat demand quality and shifting constraints → Standard constraints might be used as default inputs into SO WHAT tool

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Table 28 Scenario 5.2 description

<table>
<tr><td colspan="3">Scenario 5.2: Thermal Storage evaluation for WH integration into DH networks</td></tr>
<tr><td>Relevant User Type</td><td colspan="2">Industry/ESCO/Municipality</td></tr>
<tr><td rowspan="20">Main Objectives</td><td colspan="2">Energetic Domain</td></tr>
<tr><td>☒Reduction of primary energy consumption</td><td>☐Reduction of final energy consumption</td></tr>
<tr><td>☐Reduction of useful energy demand</td><td>☐Increase share of RES</td></tr>
<tr><td>☐Increase utilization of energy from waste heat sources</td><td>☒Reduction of energy consumption from conventional fuels</td></tr>
<tr><td>☐Reduction of energy consumption from imported sources</td><td>☐DHCN thermal losses reduction</td></tr>
<tr><td>☐DHCN heat density reduction</td><td>☐Operating hours increase</td></tr>
<tr><td colspan="2">Environmental Domain</td></tr>
<tr><td>☒CO2 reduction</td><td>☐Pollutants emission reduction</td></tr>
<tr><td>☐Noise production reduction</td><td>☐Increase share of RES</td></tr>
<tr><td>☐Increase utilization of energy from waste heat sources</td><td></td></tr>
<tr><td colspan="2">Economic Domain</td></tr>
<tr><td>☒Creation of economically feasible H&C scenarios</td><td>☐Operational costs reduction</td></tr>
<tr><td>☐Levelized cost of heat</td><td>☐CO2 reduction cost</td></tr>
<tr><td colspan="2">Social Domain</td></tr>
<tr><td>☐Energy poverty reduction</td><td>☐Job increase</td></tr>
<tr><td>☒Security of supply increase</td><td></td></tr>
<tr><td>Relevant KPIs for evaluation</td><td colspan="2">Energy saving compared to baseline
CO_2 emission abatement compared to baseline
Payback period, net present value, internal rate of return</td></tr>
<tr><td>Example Baseline case</td><td colspan="2">Existing industry with significant unused waste heat potentials during the warm season. Existing district heating system with a short-term (few storage hours) thermal energy storage.</td></tr>
<tr><td>Intervention / Technologies</td><td colspan="2">Installation of a seasonal (sensible or latent heat) thermal energy storage to shift the industrial waste heat from the warm to the cold season, making it available to the district heating network. Strategic daily operation of the seasonal storage that is discharged at high peak load times (e.g. in the early morning) to avoid as much as possible the use of natural gas boilers. Optimal coordination with other heat generation plants (e.g. combined heat and power plants) connected to the district heating network, which could take advantage of the seasonal thermal storage.</td></tr>
<tr><td>Requested inputs</td><td colspan="2">Excess waste heat production time-series
District heat thermal demand time-series
Values of maximum peak thermal power demand
Values of maximum allowed “size” or “price” for the thermal storage
Storage type (sensible, latent, thermochemical)</td></tr>
</table>

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Output	Thermal performance and cost of the storage system Fossil fuel (natural gas) savings
Main benefits	Reduction of the consumption of fossil fuels Reduction of the pollutants and CO_2 emissions Economic revenues
Main "disadvantages"	Investment costs Required space
Exceptions	I. There is lack of detailed time-series, but there are available fragments of time-series or there are available some instantaneous power values → The tool might allow to fill the missing values or directly "built" some simulated thermal demand curves; II. WH production time series and DH time series have different sampling frequency → The tool might allow to "harmonize" both time series.

Table 29 Scenario 5.3 description

Scenario 5.3: WHR from Air Compressors for heat into District Heating Network		
Relevant User Type	Industry/ESCO	
Main Objectives	**Energetic Domain**	
	☒Reduction of primary energy consumption	☐Reduction of final energy consumption
	☐Reduction of useful energy demand	☐Increase share of RES
	☒Increase utilization of energy from waste heat sources	☐Reduction of energy consumption from conventional fuels
	☐Reduction of energy consumption from imported sources	☐DHCN thermal losses reduction
	☐DHCN heat density reduction	☐Operating hours increase
	Environmental Domain	
	☒CO2 reduction	☐Pollutants emission reduction
	☐Noise production reduction	☐Increase share of RES
	☒Increase utilization of energy from waste heat sources	
	Economic Domain	
	☒Creation of economically feasible H&C scenarios	☒Operational costs reduction
	☐Levelized cost of heat	☐CO2 reduction cost
	Social Domain	
	☐Energy poverty reduction	☐Job increase
	☐Security of supply increase	

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Relevant KPIs for evaluation	Power compressor vs power recovery (at the water use temperature) Recoverable energy vs distance compressors to hot water circuits. Energy saving compared to baseline. CO_2 emission abatement compared to baseline Payback period.
Example Baseline case	Existing industry facility that is equipped with high-power air compressors and its processes require medium-temperature water or relatively important hot domestic water consumption. The same consideration applies for the refrigerant compressors of the split cooling machines.
Intervention / Technologies	The installation of an oil-water heat exchanger in the compressor oil cooling circuit will be required. Most compressors manufacturers offer a kit to recover the rejected heat, but it is also possible to use generic kits in case of non-availability of the manufacturer's kit. The measure may also require storage in the water side depending on the hourly profile of the hot thermal demand and the type of compressors (modulated or start-stop).
Requested inputs	Compressor brand, model and power. Time series of compressed air demand (or compressor power energy consumption profile) Time series of hot water energy demand Distance between compressor and hot water production facility. Price of thermal energy or current cost for the industry of producing the required hot water
Output	Heat exchanger power Minimum size of tank accumulators (inertial tanks) [m^3] Annual energy saved. [kWh/y] Approximate cost of investment [€] Payback period [years]
Main benefits	Reduction of the consumption of fossil fuels Reduction of the pollutants and CO_2 emissions Improvement in oil cooling, especially in summer Economic revenues (the most important for an ESCO)
Main "disadvantages"	Investment costs. Required space. Increased electricity consumption due to the additional water pumping.

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Exceptions	I. There is lack of detailed time-series, but there are available fragments of time-series or there are available some instantaneous power values ➔ The tool might allow to fill the missing values or directly "built" some simulated thermal demand curves. II. Power compressor time series and water use time series have different sampling frequency ➔ The tool might allow to "harmonize" both time series III. The current cost of producing hot water is not known (for instance, hot water is produced from steam in a centralized system without specific energy meters) → The tool might have an auxiliary calculator to provide a rough estimation based on providing data like the gas prices, the type of boiler and other technical data.

Table 30 Scenario 5.4 description

Scenario 5.4: Preliminary analysis of the cost related to DHN link		
Relevant User Type	Industry/ESCO/Municipality	
Main Objectives	**Energetic Domain**	
	☒Reduction of primary energy consumption	☒Reduction of final energy consumption
	☐Reduction of useful energy demand	☐Increase share of RES
	☒Increase utilization of energy from waste heat sources	☐Reduction of energy consumption from conventional fuels
	☒Reduction of energy consumption from imported sources	☒DHCN thermal losses reduction
	☒DHCN heat density reduction	☐Operating hours increase
	Environmental Domain	
	☒CO2 reduction	☒Pollutants emission reduction
	☐Noise production reduction	☒Increase share of RES
	☐Increase utilization of energy from waste heat sources	
	Economic Domain	
	☒Creation of economically feasible H&C scenarios	☒Operational costs reduction
	☒Levelized cost of heat	☒CO2 reduction cost
	Social Domain	
	☒Energy poverty reduction	☐Job increase
	☒Security of supply increase	

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Relevant KPIs for evaluation	CAPEX for the installation OPEX PBP or other relevant economic indicators Technical suitability
Example Baseline case	There is an existing DH(C)N powered by any source, a WH/C source has been identified and characterised
Intervention / Technologies	Creation of a link between the network and the producer: basic information on the heat exchangers and the piping can be provided according to the characteristics of the WH stream(s).
Requested inputs	Strong focus on the business case and options (WP3) to reach a viable solution.
Output	DHN characteristics: energy demand and current energy production, cost of energy, temperature
Main benefits	WH/C characteristics known: temperature, intermittency, available power/energy, heat medium
Main "disadvantages"	Distance among the two of them
Exceptions	I. Default values for heat exchangers and piping will be provided in case the user is not able to provide more accurate data. II. Distance between the source and the sink can be calculated based on a map if not available

Table 31 Scenario 5.5 description

Scenario 5.5: Recover waste heat from a site and transport it for use in other buildings without the need of a DH network or pipes.		
Relevant User Type	Industry/ESCO	
Main Objectives	**Energetic Domain**	
	☒Reduction of primary energy consumption	☐Reduction of final energy consumption
	☐Reduction of useful energy demand	☐Increase share of RES
	☒Increase utilization of energy from waste heat sources	☐Reduction of energy consumption from conventional fuels
	☒Reduction of energy consumption from imported sources	☐DHCN thermal losses reduction
	☐DHCN heat density reduction	☐Operating hours increase
	Environmental Domain	
	☒CO_2 reduction	☐Pollutants emission reduction
	☐Noise production reduction	☐Increase share of RES
	☒Increase utilization of energy from waste heat sources	

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	Economic Domain ☒Creation of economically feasible H&C scenarios — ☒Operational costs reduction ☐Levelized cost of heat — ☐CO2 reduction cost **Social Domain** ☐Energy poverty reduction — ☐Job increase ☐Security of supply increase
Relevant KPIs for evaluation	Payback time Internal Rate of Return Net Present Value Energy savings (site 2) Energy sold (site 1) Total CO_2 budget
Example Baseline case	Two sites (1 and 2) where at 1 there is excess heat not currently recovered and at 2 there is a heat demand currently satisfied with fossil-fuel based solutions or new source of heat demand is expected
Intervention / Technologies	Employ a thermal energy storage system installed on a road truck (or a barge eventually) to connect thermally a waste heat source and a heat sink. The residual heat from the source (site 1) is stored in the mobilized thermal energy storage (M-TES). The heat is then transported to the heat sink (industrial or another site) where it is used, i.e. site 2. Site 2 can be either another industrial facility, a domestic user of an existing district heating network. During charging, the M-TES is parked at the site 1 and it is thermally connected to the waste heat source. The latter is typically in the form of flue gases (or hot liquid stream). Once fully charged with thermal energy the road truck transports the M-TES unit to the Industrial Site 2 where it is discharged to provide thermal energy.
Requested inputs	Latent heat thermal energy storage (LHTES) or thermochemical energy Storage (TCS) in mobile for should be considered because they offer higher energy density and thus reduced storage volume. The latter is a key factor since the maximum allowed volume is the one of a typical shipping container on a road truck.
Output	Thermal parameters of the exhaust heat at the site 1 (temperature, flow rate, pressure, etc), including possible time variation or time availability window during the day.
Main benefits	Thermal parameters of the heat sink at site 2 (heat demand, heat sink temperature), including possible time variation of the heat demand or time windows during which the heat is needed.
Main "disadvantages"	M-TES input parameters (m3), energy storage density, maximum energy stored, storage temperature, costs (€/KWh), cost of transportation (e.g. truck fuel costs), CO2 emissions associated to the transportation, distance (km) between Industrial site 1 and site 2.

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Exceptions	I. The user might know the latent heat storage material and melting temperature, but they do not know the storage energy density or vice versa → the software should embed a Table which provides the main property data for a set of phase change materials; II. The thermal power demand of Site 2 is high and the user is afraid that it cannot be met by the discharging process of the mobilized storage → the tool should guide in the proper selection of the storage material by taking into account also the power density; III. There might be lack of information about the time series of the Site 2 thermal demand. However, if it is known that the Site 2 is e.g. a big residential building its thermal demand time series can be obtained through weather data combined with building simulation.

Table 32 Scenario 5.6 description

Scenario 5.6: Use of absorption chillers in a district heating network		
Relevant User Type	ESCO	
Main Objectives	**Energetic Domain**	
	☐Reduction of primary energy consumption	☐Reduction of final energy consumption
	☐Reduction of useful energy demand	☐Increase share of RES
	☒Increase utilization of energy from waste heat sources	☐Reduction of energy consumption from conventional fuels
	☒Reduction of energy consumption from imported sources	☐DHCN thermal losses reduction
	☐DHCN heat density reduction	☒Operating hours increase
	Environmental Domain	
	☐CO2 reduction	☐Pollutants emission reduction
	☐Noise production reduction	☐Increase share of RES
	☒Increase utilization of energy from waste heat sources	
	Economic Domain	
	☒Creation of economically feasible H&C scenarios	☐Operational costs reduction
	☐Levelized cost of heat	☐CO2 reduction cost
	Social Domain	
	☐Energy poverty reduction	☐Job increase
	☒Security of supply increase	
Relevant KPIs for evaluation	Energy savings compared to baseline Additional revenues compared to baseline Payback period [years]	

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Example Baseline case	Main actors want to take advantage of available heating resources in a district heating system for cooling purposes during the summer, such as potential waste heat sourced from connected industrial sites, or from other connected sources such as boilers, thus allowing for an increase in revenues during the summer and reducing the payback period of the installation
Intervention / Technologies	Installation of absorption chiller in existing DHN
Requested inputs	DHN heating/cooling demand time series
Output	DHN heating sources time series, availability and levelised cost of energy supply
Main benefits	Conventional cooling systems levelised cost of energy supply
Main "disadvantages"	Absorption chiller capacity [kW]
Exceptions	If the user does not provide at all, or partially, information about: - Distance to, distribution capacity and connection status of closest DHN/DCN → the tool might be able to retrieve automatically such information from publicly available database, or to focus analysis on the share of heat demand that could be met by WH/C resource, irrespective of DHN/DCN status and characteristics - Heat demand time series → the tool might be able to approximate heat demand time series, as based on output from community energy master planning tool such as the IES iCD platform - Heat demand quality and shifting constraints → Standard constraints might be used as default inputs into SO WHAT tool

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Table 33 Scenario 5.7 description

Scenario 5.7: Heat Pumps with PV panels into DH network	
Relevant User Type	ESCO
Main Objectives	**Energetic Domain** ☒Reduction of primary energy consumption ☐Reduction of final energy consumption ☐Reduction of useful energy demand ☐Increase share of RES ☒Increase utilization of energy from waste heat sources ☐Reduction of energy consumption from conventional fuels ☐Reduction of energy consumption from imported sources ☐DHCN thermal losses reduction ☐DHCN heat density reduction ☐Operating hours increase **Environmental Domain** ☒CO2 reduction ☒Pollutants emission reduction ☐Noise production reduction ☐Increase share of RES ☐Increase utilization of energy from waste heat sources **Economic Domain** ☐Creation of economically feasible H&C scenarios ☒Operational costs reduction ☐Levelized cost of heat ☐CO2 reduction cost **Social Domain** ☐Energy poverty reduction ☒Job increase ☐Security of supply increase
Relevant KPIs for evaluation	Fuel savings Cost savings NPV CO_2 emission reduction
Example Baseline case	DH system located in a site with good solar irradiation levels and availability of space for installation of PV generators. Heating demand required throughout the year and mostly covered by natural gas boilers.
Intervention / Technologies	A DH operator wants to evaluate the possibility of using heat pumps combined with solar thermal to produce hot water or to preheat the return water flow in order to reduce the fuel consumption of the DH boilers. The HPs could also be used for peak shaving using electricity from the grid.
Requested inputs	Supply/return temperature of DH COP of HPs CAPEX/OPEX of HPs Performance of PV panels (e.g. conversion efficiency) CAPEX and volume (m^3) of TES Heat and electricity demand profiles, possibly electricity prices profiles

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Output	HP capacity PV capacity RES generation Primary energy consumption Electricity consumption
Main benefits	Increased renewable generation from solar Reduce fuel consumption from DH boilers Reduced operating costs due to exploitation of electricity prices Increased flexibility in operation due to TES installation Reduced CO_2 emissions
Main "disadvantages"	Additional complexity due to the need of coordinating the operation of heat pumps and the fluctuation of electricity generation from PVs and thermal energy storage. The scenario likely involves the use of large-scale HPs; location of the HPs is likely to be constrained by the configuration of the district considered and in particular by the availability of heat source such as sewage and ambient waters
Exceptions	I. The user does not know the COP of the heat pump, but they know the temperature of the waste heat source and the supply temperature → the software provides an estimate of the COP based on the temperature lift and the type of heat pump; II. The user wants to evaluate the reduction of the natural gas consumption of the boiler due to water preheating → a lumped model of a boiler should be made available to assess the reduction of the operating costs.

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Table 34 Scenario 5.8 description

<table>
<tr><td colspan="3">Scenario 5.8: Conduct a cost benefit analysis of expanding a district h/c network or constructing a new one, to connect to newly identified waste heat sources and users</td></tr>
<tr><td>Relevant User Type</td><td colspan="2">ESCO/Municipality</td></tr>
<tr><td rowspan="20">Main Objectives</td><td colspan="2">Energetic Domain</td></tr>
<tr><td>☐Reduction of primary energy consumption</td><td>☐Reduction of final energy consumption</td></tr>
<tr><td>☐Reduction of useful energy demand</td><td>☐Increase share of RES</td></tr>
<tr><td>☒Increase utilization of energy from waste heat sources</td><td>☐Reduction of energy consumption from conventional fuels</td></tr>
<tr><td>☐Reduction of energy consumption from imported sources</td><td>☐DHCN thermal losses reduction</td></tr>
<tr><td>☐DHCN heat density reduction</td><td>☐Operating hours increase</td></tr>
<tr><td colspan="2">Environmental Domain</td></tr>
<tr><td>☐CO2 reduction</td><td>☐Pollutants emission reduction</td></tr>
<tr><td>☐Noise production reduction</td><td>☐Increase share of RES</td></tr>
<tr><td>☒Increase utilization of energy from waste heat sources</td><td></td></tr>
<tr><td colspan="2">Economic Domain</td></tr>
<tr><td>☒Creation of economically feasible H&C scenarios</td><td>☐Operational costs reduction</td></tr>
<tr><td>☐Levelized cost of heat</td><td>☐CO2 reduction cost</td></tr>
<tr><td colspan="2">Social Domain</td></tr>
<tr><td>☒Energy poverty reduction</td><td>☐Job increase</td></tr>
<tr><td>☒Security of supply increase</td><td></td></tr>
<tr><td>Relevant KPIs for evaluation</td><td colspan="2">Share of heat met by WH/C resource
Shares of WH/C resource exported to DHN/DCN
Energy savings compared to baseline
Additional revenues compared to baseline
Payback period [years]</td></tr>
<tr><td>Example Baseline case</td><td colspan="2">Main actors want to know the share of heat demand from a group of nearby buildings, or from a district heating network (DHN), that can be met through the reuse of the excess waste heat/cold (WH/C) resource available from an industrial site that is located in the neighbourhood.</td></tr>
<tr><td>Intervention / Technologies</td><td colspan="2">Connection to an existing district heating or cooling network (DHN or DCN)</td></tr>
<tr><td>Requested inputs</td><td colspan="2">Construction of a new DHN or DCN</td></tr>
<tr><td>Output</td><td colspan="2">Expansion of a DHN or DCN</td></tr>
<tr><td>Main benefits</td><td colspan="2">Upgrade of a DHN or DCN, e.g. increase in distribution capacity</td></tr>
</table>

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Main "disadvantages"	Shift of heat demand in order to better match WH/C resource availability profile with energy demand profile
Exceptions	If the user does not provide at all, or partially, information about: - Distance to, distribution capacity and connection status of closest DHN/DCN → the tool might be able to retrieve automatically such information from publicly available database, or to focus analysis on the share of heat demand that could be met by WH/C resource, irrespective of DHN/DCN status and characteristics - Heat demand time series → the tool might be able to approximate heat demand time series, as based on output from community energy master planning tool such as the IES iCD platform - Heat demand quality and shifting constraints → Standard constraints might be used as default inputs into SO WHAT tool

4.6 Stage 6: Scenarios for Recover and Reuse waste heat/cooling to provide power at a community level.

Table 35 Scenario 6.1 description

Scenario 6.1: Recovery of industrial WH for electricity production (to be sold to the grid or local community)		
Relevant User Type	Industry/ESCO/Municipality	
Main Objectives	**Energetic Domain**	
	☒Reduction of primary energy consumption	☐Reduction of final energy consumption
	☐Reduction of useful energy demand	☐Increase share of RES
	☒Increase utilization of energy from waste heat sources	☐Reduction of energy consumption from conventional fuels
	☐Reduction of energy consumption from imported sources	☐DHCN thermal losses reduction
	☐DHCN heat density reduction	☐Operating hours increase
	Environmental Domain	
	☒CO2 reduction	☐Pollutants emission reduction
	☐Noise production reduction	☐Increase share of RES
	☒Increase utilization of energy from waste heat sources	
	Economic Domain	
	☒Creation of economically feasible H&C scenarios	☐Operational costs reduction
	☐Levelized cost of heat	☒CO2 reduction cost

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	Social Domain ☐Energy poverty reduction ☐Job increase ☒Security of supply increase
Relevant KPIs for evaluation	Reduction of waste heat energy compared to baseline [kWh] Additional electricity generation compared to baseline [kWh] Additional electricity exported to grid compared to baseline [kWh] Electricity generation efficiency compared to generator design efficiency Additional revenues compared to baseline Payback period [years]
Example Baseline case	Existing industry with processes that emit high thermal capacity waste heat at medium/high temperatures, e.g. fume in combustion processes or steam from steam generation plants.
Intervention / Technologies	Waste heat (medium temperature) utilisation for generation of electricity by ORC-processes Waste heat (high temperature) utilisation for generation of electricity by steam processes
Requested inputs	Waste heat medium type (e.g. fume, steam) Waste heat thermal capacity Waste heat temperature range Time series of waste heat flow rate and temperature Grid connection maximum export capacity Electricity price
Output	Electricity generator type Electricity generator size and efficiency range [kW - %] Annual electricity generation [kWh] Approximate cost of investment [€] Payback period [years] Planning permission need
Main benefits	Economic revenues (the most important for an ESCO)
Main "disadvantages"	Investment costs Uncertainty with regards revenues Grid code constraints Increased operational costs and upskilling of manpower Required space for installation of new process Modification of the fume filtering and exhaust process, with increased risk of formation of condensates in the chimney that can reduce its useful life and have a negative environmental impact
Exceptions	If the user does not provide at all, or partially, information about: - Time series of waste heat flow rate and temperature offer user to analyse scenario H-01 and/or H13 - Grid connection maximum export capacity and electricity price the tool should be able to run an unconstrained analysis in terms of maximum export capacity, and based on default electricity price values - Waste heat medium type, thermal capacity and temperature range Standard values for identical industrial site category might be retrieved from database and used as default inputs into SO WHAT tool

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Table 36 Scenario 6.2 description

Scenario 6.2: RES potential evaluation		
Relevant User Type	ESCO/Municipality	
Main Objectives	**Energetic Domain**	
	☒Reduction of primary energy consumption	☒Reduction of final energy consumption
	☐Reduction of useful energy demand	☒Increase share of RES
	☒Increase utilization of energy from waste heat sources	☒Reduction of energy consumption from conventional fuels
	☒Reduction of energy consumption from imported sources	☐DHCN thermal losses reduction
	☐DHCN heat density reduction	☐Operating hours increase
	Environmental Domain	
	☒CO_2 reduction	☒Pollutants emission reduction
	☐Noise production reduction	☒Increase share of RES
	☒Increase utilization of energy from waste heat sources	
	Economic Domain	
	☒Creation of economically feasible H&C scenarios	☐Operational costs reduction
	☐Levelized cost of heat	☒CO_2 reduction cost
	Social Domain	
	☐Energy poverty reduction	☐Job increase
	☒Security of supply increase	
Relevant KPIs for evaluation	RES share Size of RES plant Primary energy saving compared to baseline CO_2 emission abatement compared to baseline Payback period Fossil fuels reduction	
Example Baseline case	No RES already installed or a reduced amount. The user wants to evaluate the potential for thermal RES in the area and electrical ones.	

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Intervention / Technologies	Evaluation of RES potential, the potential from the higher level (total available to technical is examined): • PV • (micro wind) • Solar thermal • Biomass • (CHP) • Geothermal • (heat-pumps) To make the analysis effective, two aspect should be considered: 1. We are considering a group of building therefore the specificity of each of them are hidden in one unique profile. 2. The analysis should be performed at hourly level since the big fluctuation of some RES within a day Therefore, by coupling the aggregated hourly profile of the demand with the hourly profile from RES the analysis will result less detailed.
Requested inputs	Geographical location Space available for the installation Characteristics of demand (thermal, temperature) Energy consumption profile city/district/industry Cost of energy produced / Price of energy Incentives for RES installation Other constraints
Output	• Available potential in terms of power and energy for various RES sources • Dimension of RES installed: kW of the plant potentially to be installed • CAPEX and OPEX of solutions, based on the plant dimension and calculated info Expected production profile over the day and yearly
Main benefits	Possibility to analyse in parallel several types of RES High-level and detailed analysis of the RES potential High-level techno-economic feasibility
Main "disadvantages"	Retrieve input data about consumption Risk of confidentiality data for prices/costs Risk of not meaningful output if too many assumptions are required
Exceptions	I. Maps on the geographical potential can be generated if the available space is not identified II. General productivity of the field can be evaluated if no information about the consumptions are provided

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5 Conclusions

This deliverable contains the list and description of the scenarios to be provided as an input to the definition of the SO WHAT tool, in parallel and complementary to the definition of use cases. Besides, the methodology followed to obtain, improve and finally generate this list of scenarios and their description is included. Last but not least, the methodology for the selection of scenarios is described as a six stage process to guide the user through the 34 different scenarios so that they can choose to apply the correct simulations that best suit their context and requirements.

Taking into account the expertise of the participants in the task linked to this deliverable (T2.4), a lot of know-how and knowledge have been gathered to define these scenarios, to try to cover most of the different situations that the SO WHAT tool should take into account. Besides, all the technical solutions identified in WP1 have been taken into account, and also tool's workflow and user needs from other WP2 tasks. Information about KPIs (coming from WP3 and WP4) has been considered too and will be detailed in D4.1. This list provides a wide but detailed spectrum of scenarios to be implemented, minor changes are expected to happen within the tool development following the Agile principle.

As explained, the methodology followed to obtain the scenarios begun with a community brainstorming process where a large number of possible scenarios have been created in an unordered process. The next step has been to organize the proposed scenarios to avoid overlaps and to be sure that no scenario was out of the scope of the project. The technologies described in WP1 have been taken into account, because it is useless to propose a waste heat/cold recovery scenario if there is not any mature technology that makes possible this recovery.

Another aspect considered has been the origin of the recovered heat. In this case, it has been decided that the origin of the recovered heat has to be industrial while the destination of the recovered heat can be the same industry itself, another industry or third-party users of a residential, government or service type. Therefore, the possible scenarios for heat recovery with non-industrial origin have been ruled out.

As multiple iterations have been done during the scenario description (the main involved partners described a subset of scenarios, then CAR review them and send its feedback, and this has been done at least twice. Finally, all the scenarios have been reviewed by all the involved partners), all of these descriptions have been reviewed by most of the involved partners to try to avoid prior biases and prejudices.

As stated in the document, an underlying hierarchy has been identified in the list of scenarios, so they have been divided into high and low level scenarios. Low-level scenarios are a kind of "specialisation" of the linked high-level scenario.

All the information obtained in the scope of this task and deliverable will be useful to develop the SO WHAT tool in WP4 as takes into account a lot of expertise and covers most of the real scenarios with which the SO WHAT tool should deal with.

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