H2020 Work Programme

D1.5 - Strategies and Protocols for Input Data Collection

Lead Contractor: RINA-C

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Executive Summary

The present report, SO WHAT D1.5, titled "Strategies and Protocols for Input Data Collection", following the outcomes of the activity presented in D1.4, focuses on the methods for data collection and processing to feed information to the SO WHAT tool.

The Deliverable is articulated into the following Sections:

- Chapter 1 provides an introduction to the report;
- Chapter 2 briefly presents the overall data collection strategy for the SO WHAT project;
- Chapter 3 is the core part of the deliverable and includes the methods specifically designed for data collection, aimed at overcoming typical barriers and at feeding the needed information to the SO WHAT tool;
- Chapter 4 draws the conclusions of the analysis.

In the report, the checklist with minimum data requirements that was developed is analysed, which is articulated into the following main areas: "Industrial site information", "Waste heat/cold recovery & Renewable heat/cold and electricity", "Industrial site processes information", "Industrial site services information", "Automated Meter Reading (AMR) data and energy costs information", "General building information".

For each item of the checklist, the main source of data and information is identified based both on the overall experience of RINA-C in developing energy audits of industrial sites and on the specific experience developed in the last months in liaising with SO WHAT industrial demonstrators for data collection purposes.

To conclude, since an important part of the SO WHAT tool will be constituted by the community tool that focuses - among other topics - on the mapping of H&C demand in the area surrounding the industrial site to identify potential users of the recovered WH/C, this report covers also the methods for the collection of input data for this purpose.

Abbreviations

AMR: Automated Meter Reading

BEMS: Building Energy Management System

CHP: Combined Heat and Power

EMS: Energy Management Software

EN: European Norm

EPC: Energy Performance Certificate

GIFA: Gross Internal Floor Area

H&C: Heating and Cooling

HSE: Health, Safety, Environment

HVAC: Heating, Ventilation, Air Conditioning

KPI: Key Performance Indicator

LPG: Liquefied Petroleum Gas

P&I: Piping and Instrumentation

PPA: Power Purchase Agreement

RES: Renewable Energy Sources

SHP: Shape

ToU: Time of Use

WC: Waste Cold

WH: Waste Heat

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1 Introduction

The objective of SO WHAT Task 1.2, "Overcoming barriers in data collection and data format required" is to identify strategies and procedures to collect data for mapping and quantifying the potential for waste heat and cold recovery and valorisation and for integration of renewables in industrial contexts.

The outcomes of this Task are articulated into two Deliverables, specifically:

- D1.4 on "Requirements for Data Formats and Indicators";
- D1.5 on "Strategies and Protocols for Input Data Collection".

The present report constitutes D1.5 of the SO WHAT project and focuses on the methods to pre-process the available information and data for supplying the SO WHAT tool in order to minimise the overall effort and post-processing. Methods for collecting the inputs to be provided to the SO WHAT community tool for H&C demand mapping purposes are also covered.

They are designed based on the currently available and planned features of the SO WHAT tool, therefore they probably will need to be adjusted during the project, in line with the SO WHAT tool developments as well as in view of the transformation of the tool in a commercial software.

Nevertheless, the methods, protocols and strategies for data collection are designed based on the typical steps needed for the execution of an industrial energy audit, and relying on the outcomes of the analysis presented in D1.4 about data required, information typically available and barriers to data collection.

It is highlighted that this deliverable is based on the experience developed in the SO WHAT project in liaising with industrial demo sites for collecting and processing data and information available, developed with strong synergies and continuous interactions with Task 1.1 and Task 1.6, for which purpose data have been actually collected and processed.

The present Deliverable is articulated into the following Sections:

- Chapter 2 briefly presents the overall data collection strategy for the SO WHAT project;
- Chapter 3 is the core part of the deliverable and includes the methods specifically designed for data collection, aimed at overcoming typical barriers and at feeding the needed information to the SO WHAT tool;
- Chapter 4 draws the conclusions of the analysis.

2 Overall Data Collection Strategy

As part of Task 1.1, the most relevant sources of WH/C are identified and assessed for the SO WHAT industrial demo sites. This initial assessment is performed through the use of existing pieces of SO WHAT modelling tools, which enables, in parallel, an assessment of the performance of these modules as well as of their future development requirements in order to meet the SO WHAT project objectives. At the core of these existing modelling tools lie both a physics-based building (including HVAC systems) energy modelling and simulation software, as well as, more importantly perhaps, a data-based energy modelling and simulation platform for manufacturing environments, as originally developed through the EU FP7 REEMAIN project.

Therefore, data is at the basis of an initial identification and assessment of the SO WHAT demo site WH/C resource potential, thus emphasising the need for developing a data checklist in order to engage with all the demo-sites, individually, about the availability, accessibility and share-ability of a set of data related to the demo site building (including HVACs), their industrial processes and process components, as well as the operation of both the building and the industrial processes, as further detailed in D1.4 and in Section 3.

Regarding the data collection on industrial sites, subsequent to the completion and analysis of a data checklist for all demo sites, different use cases are identified, depending on the type of operational data that can be shared from each facility (i.e. utility bill, partial or detailed sub-metering data, or a combination of these), and a generic stepped workflow is followed towards an initial identification and assessment of their respective WH/C resource potential, as schematized in Figure 1 and further detailed below, including a brief explanation for each step of the workflow:

1. **Recommended use case identification**: One of the identified use cases is associated with each demo site, which allows for assessing whether minimum data requirements are met for an assessment of WH/C resource potential
2. **Data collection**: Available and shareable data, as per data checklist, is collected from demo sites
3. **Data formatting**: Relevant data is extracted from collected data sources (e.g. energy audit report) and/or data format is adjusted so that it can be integrated into existing SO WHAT modelling tools, in particular for time-series operational data (from utility bills or sub-metering systems)
4. **Data upload**: Formatted time-series operational data is uploaded to online data visualisation and processing platform which is part of existing data-based energy modelling and simulation platform for manufacturing environments
5. **Data mapping**: Uploaded time-series operational data channels are tagged and mapped across different types of energy (e.g. electricity, natural gas, etc.), process, end-use, etc.
6. **Rough-cut profiling**: Where necessary, rough-cut profiling online tool is used to develop more detailed facility's energy consumption profiles (preferably at hourly intervals) from available low-resolution data such as monthly or annual utility bills
7. **Data processing**: Uploaded time series operational data are processed in order to generate energy input and heat output (including waste heat) profiles for industrial processes and process components of interest
8. **Building model**: Creation of a building energy simulation model of the facility (construction and HVAC systems, if necessary)

9. **Industrial process component model**: Creation of process models of the internal manufacturing lines of interest, at a component scale
10. **Data syncing with process components**: Creation and population of process databases, in particular energy inputs and heat outputs (including waste heat) time series operational data
11. **Energy Sankey diagram**: Creation of Energy Sankey diagram for each demo site in order to identify and assess the most relevant sources of WH/C

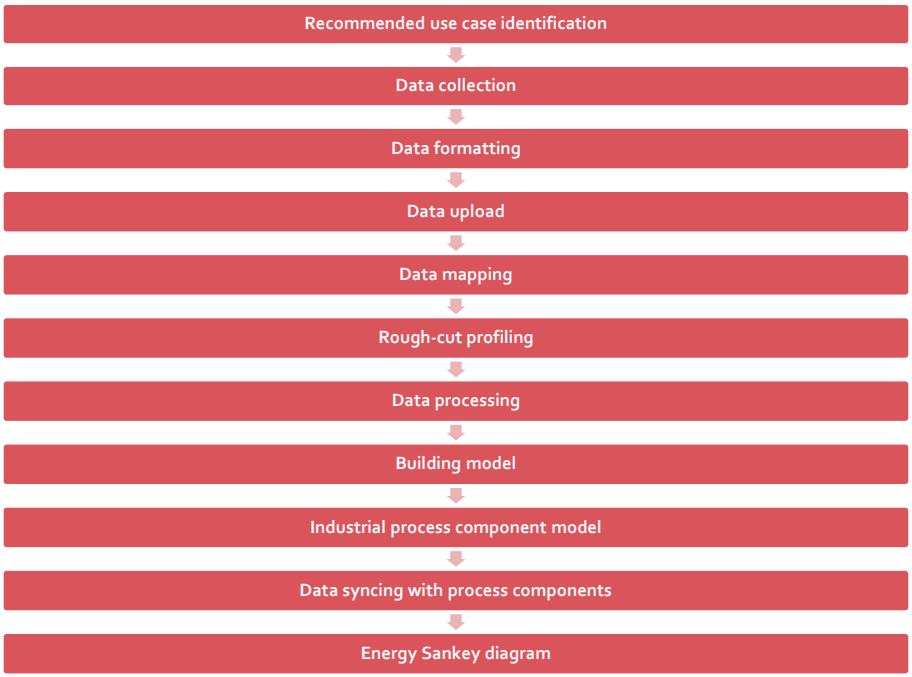

Figure 1 – SO WHAT Overall Data Collection Approach

The analysis carried out in SO WHAT D1.4 focused on the collection of the data required, following the steps of the methodology for a typical energy audit, which corresponds to point 2 and 3 of the above numbered list. Specifically, the data collection strategy has been developed according to a top-down approach, outlined in Figure 2, with an overarching energy analysis and different steps, each characterised by an increasing level of detail.

This aims at focusing the analysis on the areas with the highest potential for WH/C valorisation rather than collecting and inserting in the tool a large amount of very detailed data regarding the whole plant. The plant-level data collection is limited to the minimum parameters needed for an overall characterization of the industrial site, whereas the detailed data gathering is focused on processes and machines of interest for potential WH/C exploitation opportunities.

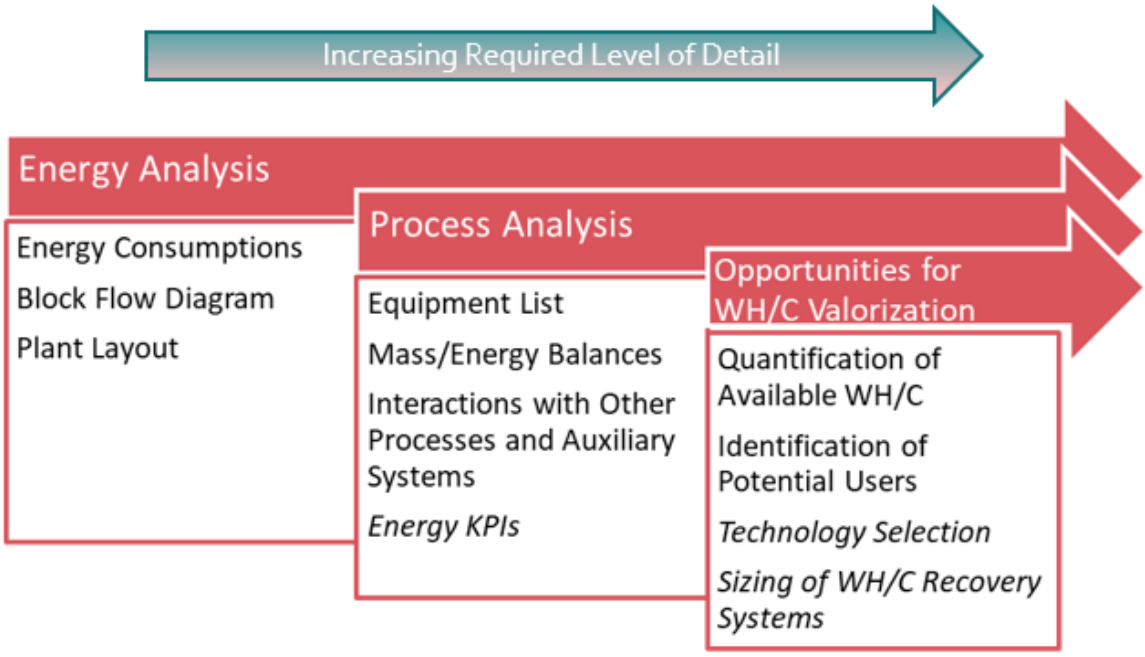

Figure 2 – SO WHAT Data Collection Approach for Identification of WH/C Valorisation Opportunities

The three steps of the data collection strategy cover the following aspects:

- in the "Energy analysis" step, information is gathered at plant level and covers data on energy consumption, output production and general features of the plant such as working schedule (daily/seasonal), block flow diagram (to identify the main processes and auxiliary/general services and their interactions including material and energy exchanges), site layout (to have information about the location of the main departments and energy users);
- in the "Process analysis" step, based on the outcomes of the previous phase, the main departments/areas of interest are identified and further details are collected, including list of equipment (process/services) in the area with electrical and thermal power and typical use, complemented with data from an energy monitoring system (if present); mass and energy balances are determined for the areas of interest as well as interactions with other processes and the surrounding environment, and energy KPIs are calculated based on the available data;
- in the "WH/C opportunities identification" step, thanks to the energy and material balances built in the previous phase for potentially interesting processes, the available waste heat and cold is quantified for all the identified sources, data are collected to identify the potential use of the recovered energy in the surrounding areas (within the plant or externally, through a district heating/cooling network) and then the needed technologies are identified and the sizing of the equipment is carried out.

Considering the need to feed information to the SO WHAT tool in the right format, which for most of the quantitative information is a data format like SQL, CSV/XLS and XML, and the fact that the needed data are often not available in the desired format, the development of dedicated methods for data pre-processing is needed. Moreover, the possibility of exploiting to this purpose the experience developed in the former EU FP7 REEMAIN project and one of the tools developed by IESRD, i.e. the IES SCAN Robot, has been evaluated.

The areas for which information is collected from industrial sites are:

- Industrial site information;
- Waste heat/cold recovery & Renewable heat/cold and electricity;
- Industrial site processes information;
- Industrial site services information;
- Automated Meter Reading (AMR) data and energy costs information;
- General building information.

Figure 3 – Schematic representation of the Data Collecting Areas

This document, SO WHAT D1.5, and specifically the following chapter 0, focuses on the strategies and protocols for data collection with reference to each topic included in the six above-mentioned areas. However, since another important part of SO WHAT is constituted by the community tool that focuses - among other topics - on the mapping of H&C demand in the area surrounding the industrial site to identify potential users of the recovered WH/C, in section 3.8 also methods for collection of input data for this purpose are presented.

3 Data Processing Protocols

3.1 Overview

Following the analysis carried out in D1.4 on data collection and related barriers, it is useful to briefly recall here which is the typical current situation regarding data availability at industrial plant. Indeed, the protocols for data processing will be tailored on the typically available data.

Energy consumption data for the most important primary energy carriers are generally known, at plant level, at monthly scale from bills; other data typically available are those related to electricity self-produced on site (photovoltaic, cogeneration plants) and for consumption of other fuels (diesel, LPG, coal, biomass, etc.) for which refuelling date and amount are available.

Sub-metering of energy consumption and hourly consumption trends are not so commonly available, due to lack of data made available from suppliers (at plant level) or lack of meters to monitor those values; this is especially true for secondary energy carriers (i.e.: heat related ones – steam, hot/superheated water, chilled water, diathermal oil, hot gases – but also compressed air, etc.). Concerning electricity and natural gas, consumption data at department level might be available in some plants even for cost allocation purposes.

Other important sources of data that are typically available are records of production and raw material consumptions, at least at plant level, as well as lists of machines with nominal data (age, power, production output, etc.), site layout, process flow diagram.

An energy audit report, or for buildings an Energy Performance Certificate, are not always available because not all companies are subject of the obligation to carry out this analysis and few industries performs it voluntarily, although encouraged by national and regional incentives generally available.

It is highlighted that data can be available in different formats and types of documents according to many factors, such as company policies and procedures, age, status and location of the plant, operational practices of external suppliers (for energy supply, monitoring systems, production equipment, operation and maintenance, etc.) and consultants, national and local legislative background and requirements, etc.

The most frequent format for data is constituted by Microsoft Excel® spreadsheets, which are used by almost all companies to keep track of energy- and cost-related values and trends but with templates and formats that are generally very different from one company to another; when available, data provided in this format can be easily processed by the energy auditor; data available in this format include among others:

- elaborations on energy consumptions and costs done for energy management or project controlling purposes at corporate level;
- output of energy monitoring systems, which may have different time resolutions, ranging from 1 second to hourly or daily scale; it is highlighted that such files may be provided at plant level even by electricity, natural gas or water supplier, typically at hourly or daily scale;
- list of machines, elaborated for maintenance or asset management scopes, or created on purpose for energy management activities;
- data on plant production and raw materials consumption, costs and revenues, etc.

Then, most of the drawings, layouts and schemes of recent realization are realized in AutoCAD® DWG format, which also allows easy processing by the energy auditor for the calculation of distances, areas and volumes, as well as for the identification of further information (e.g.: diameter and type of piping, location of chimneys and other emission points, etc.).

To conclude, many other pieces of information may need to be extracted from a wide range of different documents that are available in PDF format.

The availability of information in many different formats with no standard template introduces the need of data pre-processing, partly done by industries and partly by the energy auditor. The following sections of this chapter will focus on the protocols and strategies to be adopted to gather the information required, both in case a primary source of data is available and in case a backup source is needed.

3.2 Industrial Site Information

This section foresees the collection of the following items:

- Layout and plans at site level (.pdf, .dwg, .dxf files); these are generally available in industries because typically included in HSE plans (evacuation, fire safety, etc.); if not, they can be gathered from the drawings of the building or from cadaster documents;
- Energy audit report of the site (if available) and year of completion; following the implementation of art.8 of the EU Energy Efficiency Directive[2], all large companies in Europe need to carry out an energy audit every four year on part of their industrial and tertiary sites; if this document is available, it constitutes a precious source of information and data regarding the energy flows in the site, their breakdown by energy carrier and then by process/service, as well as the identification of potential energy efficiency opportunities to be further analysed;
- List of processes and production lines and components (generally provided in form of a block flow diagram or of a P&I diagram); a P&I diagram is generally available only in well-structured industries, whereas a block flow diagram can easily be drawn – if not already available – by technicians of the Company with the aim to represent the interactions among the different departments and processes realized in the site; the list of the main machines and devices for each department or production process can be available from the energy audit, from maintenance registries or asset databases, or be realized from scratch with detailed surveys in the plant, although this requires a considerable effort;
- List of services (e.g.: boilers, chillers, air compressors, etc.); similarly to the previous point, the list of the auxiliary machines and devices can be available from the energy audit, from maintenance registries or asset databases, or be realized from scratch with detailed surveys in the plant; in the latter case this requires less effort than a survey covering the whole industrial site, and is characterized by the best benefit/cost ratio since auxiliary services are typically those presenting most of the opportunities for optimization and energy recovery;
- List of input and output material types and quantity; the quantity and type of raw materials in input can be gathered from purchase invoices, and those of wastes/by-products from the delivery notes for disposal/treatment; products in output are covered by the following bullet;

[2] Directive 2012/27/EU and subsequent modifications and integrations, available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:02012L0027-20200101&from=EN

in the very seldom cases in which these data are not available, a very simplified mass balance could also be built based on technical datasheets of production machines;

- List of product types and quantity; these data are generally available both for sales and for production management purposes; if a well-structured database is available, it is useful to collect data at a more refined time-scale than the annual one (e.g.: monthly, weekly), to correlate production data with energy consumption values; production data can be expressed in different units depending on the type of product, but it is useful to gather unit mass values, useful for comparing indicators among plants of the same sector but producing different products;
- Layout and plans at industrial process level (pdf, dwg, dxf files); if a detailed layout/plan is available as requested in the first bullet of this list, partial drawings can be extracted at department/process level; otherwise, if a good quality overall layout is not available it is difficult to gathered more detailed ones; in the latter case, it is recommended to ask the Company to realize from scratch the layout only for the areas of specific interest for energy efficiency/recovery purposes, in order to minimize the effort required;
- Energy storage system type (thermal, electrical, chemical, etc.) and capacity; if such a system is present, it must be of recent installation and therefore information on the main features must be available to the Company;
- Energy storage system location and connection to industrial processes (pdf, dwg, dxf files or other diagrams); closely linked to the previous bullet, if such a system is present, physical and energy flow diagrams should be available from the feasibility/design phase;
- Process logistics strategy and constraints (e.g.: just-in-time manufacturing, production line shifts, critical operational constraints, etc.); these pieces of information are typically not outlined in documents, but production management can easily provide a description if needed since it is part of the approach to the plant operation;
- Final product stock capacity and location on-site (e.g.: final product stock constraints, average final product units stocked on-site, minimum and maximum stock capacities, maximum stock duration, etc.); similarly to the previous point, information regarding this topic can be provided by production management department; if not, from the layout of the plant the area and the volume of the building dedicated to storage of final products can be calculated and an estimation can be made;
- Presence of energy sub-metering and/or production data monitoring systems – details, characteristics, monitored vector (e.g.: gas, electricity, heat, etc.), boundaries (e.g.: plant level, per process, per machine, etc.) and time resolution (e.g.: daily, hourly, instant, etc.); if such a system is present, its characteristics can be gathered from the technical offer/technical annex to the contract for its installation, from the user manual or, even more easily, by using the system itself;
- Data storage type for sub-metering and/or monitoring systems (e.g.: spreadsheet, online database, etc.); linked to the previous bullet, if this kind of system is present, information regarding the data storage type can be extracted from the technical offer/technical annex to the contract for its installation, from the user manual, or directly from the metering system itself, by trying to export data in different formats.

3.3 Waste Heat/Cold Recovery & Renewable Heat/Cold and Electricity

This section foresees the collection of information and data regarding the following items:

- Existing installed waste heat-to-power conversion technologies (including waste cold);
- Existing installed waste heat-to-heat recovery technologies (including waste cold);
- Existing installed systems for other renewable energy production (e.g.: Solar Thermal Collector, Cogeneration Heat and Power, Solar Cooling, Solar Parabolic Collector, Solar Photovoltaics, Wind or tidal turbine, etc.);
- Document on any waste heat/cold recovery technologies and RES (e.g.: power output and type, energy production, efficiency, etc.).

For all the above listed items, only one data processing protocol is presented, which corresponds to gathering the available documents on the systems of interest. For each system belonging to this category that is present at the site, the main technical features can be gathered depending on the type of plant from the design documents (if needed) or from the technical offer/technical annex to the contract/user manual. These documents typically include the main nominal characteristics of the system and an estimation of its performance; as concerns the actual performance, if the system has been in place for a sufficient period of time, data can be gathered from a dedicated meter in the sub-metering system, if present, or estimated by the plant management based on the actual working load and time.

For sources of waste heat and cold, information is collected based on requests made in other sections, i.e. paragraph 3.2, 3.4 and 3.5.

3.4 Industrial Site Processes Information

This section foresees the collection of information and data regarding the following items:

- Process name; this shall be indicated by the plant management in the block flow diagram describing the plant activities, mentioned in section 3.2;
- Processed product name, category (final product, by-product, sub-product, waste) and unit (t, m^3, m^2, etc.); to be specified by plant management;
- Process components name; this information shall be indicated by the plant management on the table listing the machines, mentioned in section 3.2;
- Processed product maximum flow rate; this information is available from the technical datasheet of the machinery realizing the specific production process; if not available, it shall be evaluated by the plant management or estimated by monitoring the production for a given amount of time and specifying if the production process is continuous or batch;
- Production profile for process material inputs and outputs; this information is unlikely to be available in a specific document or report, therefore probably needs to be gathered directly from the plant management, based on spot measurements possibly carried out or on their knowledge of the typical operation of the process under different conditions;
- Process energy inputs, consumption, peak demand and/or demand profile; similarly to the previous bullet, the nominal values of these inputs/consumptions may be taken from the technical datasheets of the machinery realizing the process, whereas the real operational data (which may significantly differ from the nominal ones) can only be provided by the plant

management based on spot measurements possibly carried out or on their knowledge of the typical operation of the process under different conditions;

- Process inputs from industrial site services (e.g.: steam/hot water/compressed air, etc.); the same considerations given for the previous bullet apply, probably with a lower degree of accuracy due to the typical lower interest for secondary energy carriers compared to primary ones in industrial plants;
- Process heat/cold output types and waste heat/cold types (e.g.: air, water, gas, etc.), strategy (e.g.: released into space, extracted, etc.) and temperature ranges; qualitative process-related information and data regarding temperature and type of heat carrier are available from the process monitoring system, if present, or can directly be provided from the plant management; as concerns quantity of hot/cold water/air/gases, a higher uncertainty should be accepted since these aspects are typically not monitored or analysed unless a potential opportunity for WH/C valorisation has already been evaluated;
- Presence of process energy sub-metering and/or production data monitoring systems – details, characteristics, monitored vector (e.g.: gas, electricity, heat, etc.), boundaries (e.g.: per process, per machine, etc.) and time resolution (e.g.: daily, hourly, instant, etc.); same as in paragraph 3.2;
- Data storage type for sub-metering and/or monitoring systems (e.g.: spreadsheet, online database, etc.); same as in paragraph 3.2.

3.5 Industrial Site Services Information

This section foresees the collection of information and data regarding the following items:

- Service name; this shall be indicated by the plant management in the block flow diagram describing the plant activities, mentioned in section 3.2;
- Service peak operating capacity; this information can be extracted from the technical datasheet of the machine providing the specific service;
- Service operating hours (day/night, working days only, continuously, etc.); this information shall be provided by the plant management based on typical operational practices;
- Service percentage rating (against peak operating capacity) during operating and non-operating hours; if a sub-metering system is in place, this information could be extracted from it; otherwise, an estimation could be provided by the plant management, based on spot measurements possibly carried out or on their knowledge of the typical operation of the service under different conditions;
- Service idle periods during daily operation (number and duration); similarly to the previous bullet, this information could be extracted from the sub-metering system if present, otherwise estimated by the plant management, based on spot measurements or on their knowledge of the typical operation of the service under different conditions;
- Service production calendar and detail of stop and maintenance periods; this information shall be provided by the plant management based on typical operation and maintenance schedules applied to the specific service;
- Service energy inputs (e.g.: electricity, fuel, etc.), consumption (daily and/or weekly and/or monthly and/or yearly), peak demand and/or demand profile; the nominal values of these inputs/consumptions may be taken from the technical datasheets of the machinery providing the service, but the real operational data can only be provided by the plant management

based on spot measurements possibly carried out or on their knowledge of the typical operation of the service under different conditions;

- Service output to industrial site process(es); due to the typical absence of a monitoring system on secondary energy carriers, it is very unlikely that these aspects monitored; a quantitative estimation could be discussed with the plant management but a higher degree of uncertainty shall probably be accepted on this aspect;
- Service heat/cold output and waste heat/cold type(s) (air, water, gas, etc.), strategy (i.e. released into space or extracted?) and temperature range(s); same as in paragraph 3.4;
- Presence of service energy sub-metering and/or production data monitoring systems – details, characteristics, monitored vector (e.g.: gas, electricity, heat, etc.), boundaries (e.g.: per process, per machine, etc.) and time resolution (e.g.: daily, hourly, instant, etc.); same as in paragraph 3.2;
- Data storage type for sub-metering and/or monitoring systems (e.g.: spreadsheet, online database, etc.); same as in paragraph 3.2.

3.6 Automated Meter Reading (AMR) Data and Energy Costs Information

This section foresees the collection of information and data regarding the following items:

- Fossil fuel consumption at annual level (t/y or Nm^3/y or l/y, and/or corresponding kWh/y); primary data can be taken from the bills/invoices for energy supply; conversion into final/primary energy values shall be carried out based on officially recognized values for density and heating values; data may even be available in summary spreadsheets prepared for plant management purposes;
- Electricity consumption at annual level (kWh/y); primary data can be taken from the bills/invoices for energy supply; data may even be available in summary spreadsheets prepared for plant management purposes;
- Electricity bills, to gather data on total energy costs for electricity and breakdown of monthly energy bills in energy and cost terms; if all the bills are not available, unit costs for electricity can be extracted from the latest bill, or even from the contract signed with the supplier;
- Fossil fuel bills, to gather data on total energy costs for fossil fuels and breakdown of monthly energy bills in energy and cost terms; similarly to the previous item, in case all the bills are not available, unit costs for fuels can be extracted from the latest bill, or even from the contract signed with the supplier;
- Existing energy supply tariffs and schemes (e.g.: ToU tariffs) and/or agreements (e.g.: PPA); these values can be extracted from contracts signed with relevant authorities in case of supply tariffs or clients in case of PPA;
- Existing energy metering infrastructure (e.g.: smart metering) and characteristics (time and space resolutions, remote data access and sharing, etc.); as already mentioned in section 3.2, in case such a system is present at the plant, its characteristics can be gathered from the technical offer/technical annex to the contract for its installation, from the user manual or directly from the use of the system itself;
- Presence of any building energy management system (BEMS) and controlled systems (e.g.: lighting control, HVAC control, etc.); similarly to the previous point, if such a system is present, its characteristics can be extracted from the technical offer/technical annex to the contract for its installation, from the user manual or directly from the system itself;

- Presence of any smart sensor in the building (e.g.: temperature, humidity, CO_2 sensors, etc.) and related location; if such a system is present and no technical drawing/scheme is provide to describe location and type of sensors, information regarding this aspect can be taken from the use of the system itself;
- Data storage type for smart sensors and related systems (e.g.: spreadsheet, online database, etc.); linked to the previous bullet, if this kind of system is present, information regarding the data storage type can be extracted from the technical offer/technical annex to the contract for its installation, from the user manual, or directly from the metering system itself, by trying to export data in different formats

3.7 General Building Information

This section refers to general pieces of information, data and documents to be directly provided by the user, most of which are always available or can be easily estimated. For this reason, most of the items do not foresee a more specific data collection protocol than simply collecting the information or document and providing it to the SO WHAT tool.

These items include:

- Building ID based on national/local cadaster or building database and/or internal building ID; this requires only gathering the suitable document from the cadaster; if not available, a unique internal ID can be assigned arbitrarily from the user;
- Construction year; if an official information about this is not available from the cadaster or the local municipality, it can be estimated based on the history of the company or, if unknown, even estimated from a first analysis of the construction materials and style;
- Building conditions (bad, fair, good); estimated according to a qualitative analysis of the building envelope and of the ordinary/extraordinary maintenance activities carried out in the last five years;
- Ownership (e.g.: Tenancy, Owner-occupied, etc.); information known by the Company administration;
- Hours of use (Morning/Evening/Night, working days only, etc.); information known by the Company, it can be gathered either from internal reporting documents (e.g.: registries of working hours for machines provided with working hours monitoring system) or estimated based on typical production schedules; if the activities present monthly or seasonal variation, the distribution of production hours over the different months of the year shall be provided;
- Building type (e.g.: Office, Production Department, Warehouse, etc.); it is just a description of the purpose of the building;
- Address; as reported in the official cadaster document;
- HVAC system type (separately for heating, cooling, ventilation); this information shall be provided by the Company, attaching the datasheets or at least providing the nominal power of the main equipment used (e.g.: boilers, chillers, air handling units, etc.);
- HVAC fuel or energy carrier used; this is a qualitative information that is known by the Company and, if not, can be estimated depending on the energy carriers used at the site and on the technology installed;
- Floor area (GIFA / net); it can be gathered from the drawings of the building or from cadaster documents; if not available, the gross area can be roughly estimated on site and the net area calculated as a percentage of the gross floor area;

- Floor plans (pdf, dwg, dxf files); these should be available for most of the sites, at least for fire safety/evacuation plans purposes or from the cadaster; if not available, at least a very simplified layout of the building with the main dimensions shall be realized and provided;
- Elevation plans (pdf, dwg, dxf files); these might be not available for old buildings; as backup option it requested to indicate the internal/external height of the building/floor;
- Section plans (pdf, dwg, dxf files); these might be not available and no additional backup option is proposed;
- Fenestration area; it can be gathered from the drawings of the building prospects or even from the invoices for the purchase of the windows; if not available, the value can be estimated as a percentage of the total area of external walls;
- Construction material type(s); if not known, can be estimated by the used based on the period of construction;
- Energy Performance Certificate (EPC) level (with recommendations); to be provided only if available; no backup method proposed;
- Site photographs, if available.

3.8 H&C Demand Mapping Inputs

As concerns the SO WHAT community tool and specifically for the part focused on the mapping of H&C demand in the area surrounding the industrial site to identify potential users of the recovered WH/C, in SO WHAT D1.8 two different approaches were proposed, i.e. a top-down and a bottom-up approach.

The top-down approach is the easiest to implement and require only a limited amount of input data. Indeed, the mapping for heating, cooling and DHW is carried out as distribution over the selected areas of the city of the total energy demand. The assessment is therefore based on two main inputs:

- total final energy consumption of the area of interest;
- information or assumptions about technologies installed in the area of interest.

Specifically, it is required to provide the breakdown of final energy consumption by:

- Sector: Residential and Tertiary;
- Type of system: Single Building Solution or District Heating and Cooling Network;
- Energy end-use: Heating, Domestic Hot Water and Cooling (the share between heating and domestic hot water is required if the user has available final energy consumption combining heating and DHW);
- Energy source: for heating and DHW: natural gas, electricity, fuel oil, other fossil fuels, geothermal, solar, biomass, waste heat; for cooling: natural gas, electricity, waste heat and geothermal.

These data shall be available to the municipality in case energy planning activities have already been carried out (e.g.: redaction of a Sustainable Energy Action Plan, of a Heat Atlas or of other energy planning documents), or can be gathered from the local utility (DH operator if present, or gas/electricity distributor).

In case of lack of input data, default values coming from EU databases can be adopted; for instance, data aggregated at national level can be used and downscaled according to the population of the city of interest. In this framework, relevant databases are:

- Heat RoadMap Europe – Dataset for Heating and Cooling Demand[3]
- European Building Stock Database[4]
- European Settlement Map 2015 –release 2019 (2-10m spatial resolution)[5]
- Corine Land Cover 2018 map[6]

On the other hand, the bottom-up approach aims at quantifying and mapping the georeferenced heating, cooling and DHW demand for each building at district scale, starting from information available for the buildings of the selected area. For this reason, the amount of input data needed is higher than for the top-down approach: the list of information required is presented in Table 1. In this case it is clear that a detailed shapefile of the district with main features of the buildings is needed, which can be gathered from the local cadaster or realized specifically for this analysis; no backup solution is proposed for the required input data, therefore if this input is not available it is mandatory to carry out the analysis according to the top-down approach only.

Table 1: H&C Demand Mapping – Input needed for Bottom-Up Approach

Parameter	Source
Building ID	SHP of the District
Project ID	User input
Study area name	User input
Country	User input
Building Geometry	SHP of the District
Footprint area	SHP of the District
Height or Number of Floors	SHP of the District or LiDAR *If the end user does not provide the information about "number of floors"
Hourly outside air temperature	weather webserver
Year of construction	SHP of the District
Building Use	SHP of the District

[3] HeatRoadmapEurope4. [Online] [Cited:] https://heatroadmap.eu/.
[4] European Building Stock Database. [Online] https://ec.europa.eu/energy/en/eu-buildings-database).
[5] The European Settlement Map 2019 release. [Online] https://ec.europa.eu/jrc/en/publication/european-settlement-map-2019-release.
[6] Corine Land Cover 2018 map. [Online] https://land.copernicus.eu/pan-european/corine-land-cover/clc2018.

4 Conclusions

The present D1.5 of the SO WHAT project is focused on the methods to pre-process the information and data available from industrial sites and supply the SO WHAT tool by minimising the overall effort and post-processing needs. Methods for collecting the inputs to be provided to the SO WHAT community tool for H&C demand mapping purposes are also covered.

These methods are designed based on the currently available and planned features of the SO WHAT tool, therefore they probably will need to be adjusted during the project, in line with the SO WHAT tool developments as well as in view of the transformation of the tool in a commercial software.

However, the methods, protocols and strategies for data collection are designed relying on the outcomes of the analysis presented in D1.4 about data required, information typically available and barriers to data collection, thus should reflect the typical steps and activities needed for analysis of energy flows in industrial sites.

Table 2 summarizes, for each type of information needed for industrial sites, the primary data source whose use is recommended and the backup option to gather the needed data, to be adopted if the primary source is not available. The same approach is adopted in Table 3, which summarizes the data needed for H&C demand mapping and the potential sources to be exploited.

Table 2: Industrial Site Data Collection - Summary of Data Processing Protocols and Sources for each Information Required

Information	Primary Source	Secondary Source
Industrial Site Information		
Layout and plans at site level (pdf, dwg, dxf files)	Site layout	HSE plans Cadaster documents
Energy audit report of the site (if available) and year of completion	Energy audit report	None
List of processes and production lines and components (generally provided in form of a block flow diagram or of a P&I diagram)	Block Flow Diagram P&I Diagram	Energy audit report Public information (e.g. website) Scheme by plant management
List of services (e.g.: boilers, chillers, air compressors, etc.)	Maintenance registries Asset databases	Energy audit report List by plant management
List of input and output material types, quantity and ranges of temperature	Invoices/delivery notes	Energy audit report Simplified mass balance
List of product types, quantity and ranges of temperature	Sales department data Production management data	Energy audit report List by plant management
Layout and plans at industrial process level (pdf, dwg, dxf files)	Detailed site layout	HSE plans with notes by plant management
Energy storage system type (thermal, electrical, chemical, etc.) and capacity	Technical datasheet	Energy audit report Device label Notes by plant management
Energy storage system location and connection to industrial processes (pdf, dwg, dxf files or other diagrams)	Technical drawings Design documents	Notes by plant management
Process logistics strategy and constraints (e.g.: just-in-time manufacturing, production line shifts, critical operational constraints, etc.)	Operation manuals	Energy audit report Public information (e.g. website) Details by plant management
Final product stock capacity and location on-site (e.g.: final product stock constraints, average final product units stocked on-site, minimum and maximum stock capacities, maximum stock duration, etc.)	Details by plant management	Estimation based on layout, areas and volumes

Information	Primary Source	Secondary Source
Presence of energy sub-metering and/or production data monitoring systems – details, characteristics, monitored vector (e.g.: gas, electricity, heat, etc.), boundaries (e.g.: plant level, per process, per machine, etc.) and time resolution (e.g.: daily, hourly, instant, etc.)	Technical drawings Technical specifications Technical proposal/contract	Energy audit report Screenshots of EMS software
Data storage type for sub-metering and/or monitoring systems (e.g.: spreadsheet, online database, etc.)	Technical specifications Technical proposal/contract	Energy audit report Trials on EMS software Indications by plant management
Waste Heat/Cold Recovery & Renewable Heat/Cold and Electricity		
Existing installed waste heat-to-power conversion technologies (including waste cold)	Technical specifications Technical proposal/contract	Machinery labels Notes by plant management
Existing installed waste heat-to-heat recovery technologies (including waste cold)		
Existing installed systems for other renewable energy production (e.g.: Solar Thermal Collector, Cogeneration Heat and Power, Solar Cooling, Solar Parabolic Collector, Solar Photovoltaics, Wind or tidal turbine, etc.)		
Document on any waste heat/cold recovery technologies and RES (e.g.: power output and type, energy production, efficiency, etc.)	Sub-metering system	Indications by plant management on working time/load Literature data
Industrial Site Processes Information		
Process name	Block Flow Diagram	Energy audit report Public information (e.g. website) Notes by plant management
Process components name	Machinery list Block Flow Diagram	
Processed product category	Block Flow Diagram	
Processed product name		
Processed product unit		
Processed product maximum flow rate	Technical datasheet	Energy audit report Machinery labels
Production profile for process material inputs and outputs	Sub-metering system	Energy audit report Notes by plant management
Process energy inputs, consumption, peak demand and/or demand profile		
Process inputs from industrial site services (e.g.: steam/hot water/compressed air, etc.)		

Information	Primary Source	Secondary Source
Process heat/cold output types (e.g.: air, water, gas, etc.), strategy (e.g.: released into space, extracted, etc.) and temperature ranges	Technical drawings Process monitoring system	Energy audit report Estimation by plant management
Process waste heat/cold types (e.g.: air, water, gas, etc.), uses and temperature ranges		
Presence of process energy sub-metering and/or production data monitoring systems – details, characteristics, monitored vector (e.g.: gas, electricity, heat, etc.), boundaries (e.g.: per process, per machine, etc.) and time resolution (e.g.: daily, hourly, instant, etc.)	Technical drawings Technical specifications Technical proposal/contract	Energy audit report Screenshots of EMS software
Data storage type for sub-metering and/or monitoring systems (e.g.: spreadsheet, online database, etc.)	Technical specifications Technical proposal/contract	Energy audit report Trials on EMS software Indications by plant management
Industrial Site Services Information		
Service name	Block Flow Diagram	Energy audit report Notes by plant management
Service peak operating capacity	Technical datasheet	Energy audit report Machinery label
Service operating hours (day/night, working days only, continuously, etc.)	Sub-metering	Spot measurements Energy audit report Notes by plant management
Service percentage rating (against peak operating capacity) during operating and non-operating hours		
Service idle periods during daily operation (number and duration)		
Service production calendar		
Service stop and maintenance periods	O&M Manual	Energy audit report Notes by plant management
Service energy inputs (e.g.: electricity, fuel, etc.), consumption (daily and/or weekly and/or monthly and/or yearly), peak demand and/or demand profile	Sub-metering	Energy audit report Estimation by plant management Literature data
Service output to industrial site process(es)	Sub-metering	
Service heat/cold output type(s) (air, water, gas, etc.), strategy (i.e. released into space or extracted?) and temperature range(s)	Technical drawings Service monitoring system	
Service waste heat/cold type(s) (air, water, gas, etc.), use(s) and temperature range(s)		

Information	Primary Source	Secondary Source
Presence of service energy sub-metering and/or production data monitoring systems – details, characteristics, monitored vector (e.g.: gas, electricity, heat, etc.), boundaries (e.g.: per process, per machine, etc.) and time resolution (e.g.: daily, hourly, instant, etc.	Technical drawings Technical specifications Technical proposal/contract	Energy audit report Screenshots of EMS software
Data storage type for sub-metering and/or monitoring systems (e.g.: spreadsheet, online database, etc.)	Technical specifications Technical proposal/contract	Energy audit report Indications by plant management Trials on EMS software
Automated Meter Reading Data and Energy Costs Information		
Fossil fuel consumption at annual level (t/y or Nm^3/y or l/y, and/or corresponding kWh/y)	Energy bills	Energy audit report Sub-metering system Estimation by plant management
Electricity consumption at annual level (kWh/y)		
Electricity bills, to gather data on total energy costs for electricity and breakdown of monthly energy bills in energy and cost terms		Energy audit report Contracts for energy supply
Fossil fuel bills, to gather data on total energy costs for fossil fuels and breakdown of monthly energy bills in energy and cost terms		
Existing energy metering infrastructure (e.g.: smart metering) and characteristics (time and space resolutions, remote data access and sharing, etc.)	Technical drawings Technical specifications Technical proposal/contract	Energy audit report Screenshots of EMS software
Existing energy supply tariffs and schemes (e.g.: ToU tariffs) and/or agreements (e.g.: PPA)	Contracts with authority and/or client	Energy audit report Notes by plant management Literature data
Presence of any building energy management system (BEMS) and controlled systems (e.g.: lighting control, HVAC control, etc.)	Technical drawings Technical specifications Technical proposal/contract	Energy audit report Screenshots of software
Presence of any smart sensor in the building (e.g.: temperature, humidity, CO_2 sensors, etc.) and related location		
Data storage type for smart sensors and related systems (e.g.: spreadsheet, online database, etc.)		Energy audit report Trials on EMS software
General Building Information		
Building ID based on cadaster/building database,or internal building ID	Cadaster data	Internal ID
Construction year		Estimation by plant management
Building conditions (bad, fair, good)	Energy Performance Certificate	Self-evaluation by management

Information	Primary Source	Secondary Source
Ownership (e.g.: Tenancy, Owner-occupied, etc.)	Company data	Energy Audit Report Public Information (e.g. website)
Hours of use (Morning/Evening/Night, working days only, etc.)		
Building type (e.g.: Office, Warehouse, etc.)		
Address		
HVAC system type (separately for heating, cooling, ventilation)	Technical datasheets Technical drawings	Energy audit Typical HVAC systems for type of building from literature
HVAC fuel or energy carrier used		
Floor area (GIFA / net)	Site layout and drawings Notes by plant management	Estimated by plant management Estimated by energy auditor based on photos, construction period, etc-
Floor plans (pdf, dwg, dxf files)		
Elevation plans (pdf, dwg, dxf files)		
Section plans (pdf, dwg, dxf files)		
Fenestration area		
Construction material type(s)		
Energy Performance Certificate (EPC) level (with recommendations)	Energy Performance Certificate	Energy Audit Report Public Information (e.g. website)
Site photographs	Site photographs	None

Table 3: H&C Demand Mapping Data Collection - Summary of Data Processing Protocols and Sources for each Information Required

Method	Parameter	Source
Top-down	Total final energy consumption of the area of interest	Municipality or Energy Utility SEAP or Heat Atlas Downscale from national level databases
Top-down	information or assumptions about technologies installed in the area of interest (sector, type of system, energy end-use, energy source)	Municipality or Energy Utility SEAP or Heat Atlas Downscale from national level databases
Bottom-up	Building ID	Cadaster SHP of the District
Bottom-up	Project ID	User input
Bottom-up	Study area name	User input
Bottom-up	Country	User input
Bottom-up	Building Geometry	Cadaster SHP of the District
Bottom-up	Footprint area	Cadaster SHP of the District
Bottom-up	Height or Number of Floors	Cadaster SHP of the District or LiDAR
Bottom-up	Hourly outside air temperature	weather webserver
Bottom-up	Year of construction	Cadaster SHP of the District
Bottom-up	Building Use	Cadaster SHP of the District