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H2020 Work Programme

D1.4 - REQUIREMENTS FOR DATA FORMATS AND INDICATORS

Lead Contractor: RINA-C

Date: 29/05/2020

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Project title			
Supporting new Opportunities for Waste Heat And cold valorisation Towards EU decarbonization			
Project acronym	SO WHAT	**Start / Duration**	**June 2019 (36 months)**
Coordinator	RINA Consulting S.p.A. (RINA-C)		
Website	http://www.sowhatproject.eu		

Deliverable details			
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Deliverable responsible	**RINA Consulting (RINA-C)**		

[1] PU = Public
CO = Confidential, only for members of the consortium (including Commission Services)

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Abbreviations

AMR: Automated Meter Reading

BEMS: Building Energy Management System

CHP: Combined Heat and Power

EN: European Norm

EPC: Energy Performance Certificate

GIFA: Gross Internal Floor Area

H&C: Heating and Cooling

HVAC: Heating, Ventilation, Air Conditioning

LPG: Liquefied Petroleum Gas

P&I: Piping and Instrumentation

PPA: Power Purchase Agreement

RES: Renewable Energy Sources

ToU: Time of Use

WC: Waste Cold

WH: Waste Heat

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Executive Summary

The present report, SO WHAT D1.4, titled "Requirements for data formats and indicators", focuses on the data requirements for energy auditing and specifically for the feeding of information to the SO WHAT tool, as well as on their formats and on the most suitable indicators to compare energy performance data across different industries.

The Deliverable is articulated into the following Sections:

- Chapter 1 provides an introduction to the report;
- Chapter 2 briefly presents the most relevant background information on energy auditing at industrial premises;
- Chapter 3 focuses on data requirements and formats, analysing the data and information needed for the analysis, their availability, shareability and format;
- Chapter 4 analyses the information gathered regarding data availability and formats and identifies the main barriers to data collection;
- Chapter 5 focuses on indicators for assessing energy performance of an industrial site and the related normalization for benchmarking purposes;
- Chapter 6 draws the conclusions of the analysis, creating the connection with D1.5.

In the report, the checklist with minimum data requirements that was developed is presented, 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".

The answers to the checklist provided by SO WHAT industrial demo partners with specific regard to data availability, shareability, confidentiality and format were collected and analysed, and complemented with information available based on the extensive experience of RINA-C in energy auditing activities at industrial premises.

The main outcomes on data availability for the SO WHAT industrial demonstrators are presented in a confidential Annex to the present public Deliverable.

Nevertheless, the analysis allowed highlighting a set of general outcomes related to data availability and formats, as well as identifying the main barriers that obstacle energy-related data collection on an industrial site, which are those briefly summarized below:

- issues related to confidentiality;
- detailed data available only on core processes and machines;
- lack of monitored data on heat carriers;
- lack of detailed information on building characteristics and H&C demand;
- non-standard availability of documents in different plants;
- non-standard format of information across different plants.

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The results of the present analysis will constitute the basis for the following work and specifically on strategies and protocols for data collection, which will be presented in D1.5, with the target of providing data to SO WHAT tool with minimum effort and post-processing need.

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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 D1.4 of the SO WHAT project and focuses on the identification of the data needed for the analysis, the best suitable formats of such data and information and the most relevant indicators to be calculated to achieve a fully normalized comparison across different industrial sites. Special attention is given to the data input already available from existing monitoring systems, which potentially can be directly integrated into the SO WHAT tool.

The needed information is identified and the availability of the requested data is investigated through a checklist for SO WHAT industrial demo partners as well as based on the extensive experience of RINA-C in carrying out energy audits at industrial and tertiary facilities.

The information collected about typical availability and formats of the required data and on the barriers identified to data collection will constitute one of the most important inputs to the second Deliverable of this Task, where strategies and protocols for data collection will be presented.

The present Deliverable is articulated into the following Sections:

- Chapter 2 briefly presents the most relevant background information on energy auditing at industrial premises;
- Chapter 3 focuses on data requirements and formats, analysing the data and information needed for the analysis, their availability, shareability and format;
- Chapter 4 analyses the information gathered regarding data availability and formats and identifies the main barriers to data collection;
- Chapter 5 focuses on indicators for assessing energy performance of an industrial site and the related normalization for benchmarking purposes;
- Chapter 6 draws the conclusions of the analysis, creating the connection with D1.5.

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2 Background Information

This deliverable focuses on requirements for data for SO WHAT tool, which globally coincide with data that are required for an energy audit of an industrial plant. It is therefore useful to provide an overview, in this chapter of the energy audit process and of the required input data.

It is understood that, according to EN 16247-1 technical standard, "an energy audit is a systematic inspection and analysis of the energy use and consumption of a plant, building, system or organisation, with the aim of identifying and reporting on energy flows and the potential for energy efficiency improvements".

The objective of an energy audit is therefore to take a picture of the baseline energy consumptions and flows, to evaluate consumptions – expressed in terms of indicators, usually with reference to the plant production – comparing them with suitable local and international benchmarks and to identify potential actions for improvement of energy efficiency level, carrying out for each a techno-economic feasibility study and defining an energy efficiency action plan or investment plan.

Figure 1, adapted from EN 16247-1 technical standard, provides an overview of the steps of the energy audit process.

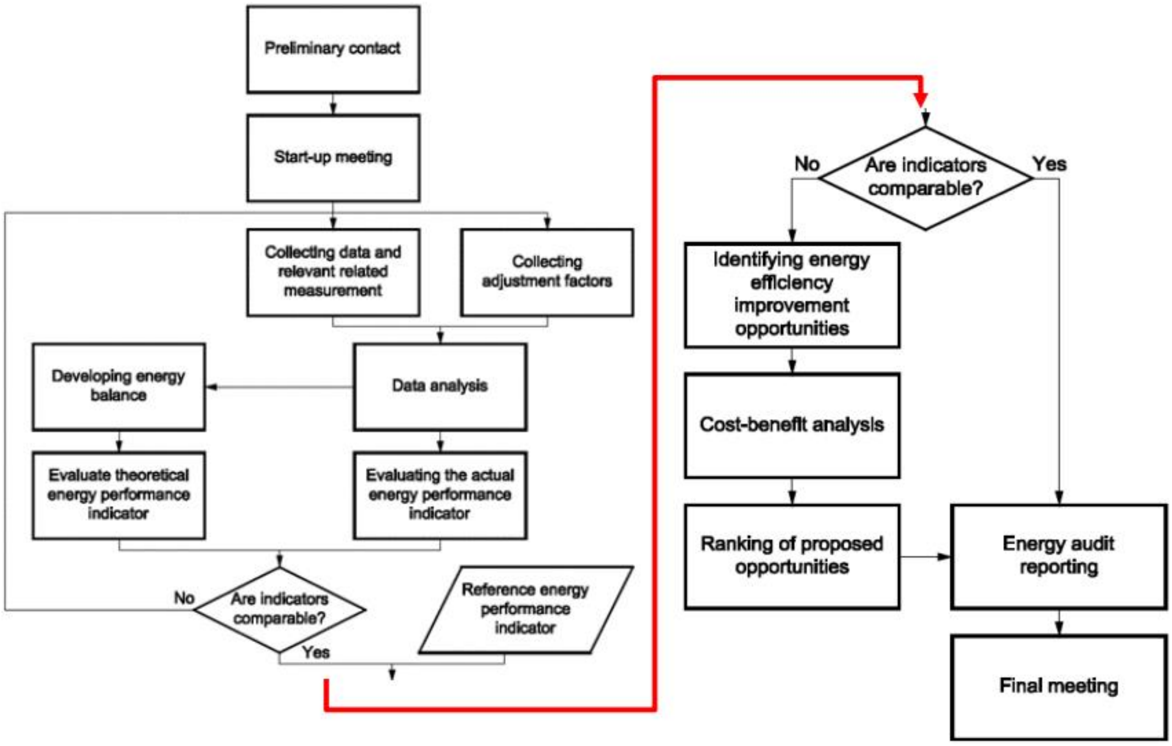

Figure 1 – Energy Audit Process (adapted from EN 16247-1)

According to the same technical standards, the main steps of the energy audit are:

1. Introductory contact, aimed at setting the framework of the analysis with the organisation;

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2. Kick-off meeting, with the aim of identifying data to be collected, measurements to be carried out, measuring equipment to be installed, etc.;
3. Data collection, aimed at collecting information and data regarding energy consumption and related costs, characteristics and use of the equipment using energy, general features of the plant, processes and facilities and quantitative plant production data;
4. Site visit, whose target is to inspect the plant, assess into further detail the typical energy uses, identify areas and processes requiring additional data collection, carry out spot measurements, preliminarily identify potential recommendations for improvement;
5. Analysis, to evaluate the energy performance of the plant, drawing a breakdown of energy consumption for each energy carrier, calculating indicators and benchmarking with reference values, elaborating detailed proposals for improvement of energy efficiency level;
6. Report, which includes a description of general background information about the plant, energy consumption, balances and analysis and an action plan for improving energy efficiency, including recommendations, information about available incentives, profitability analysis, recommendations for monitoring;
7. Final meeting, to present to the organisation the conclusions of the energy audit.

The most important part of the energy audit, at least regarding the identification and analysis of the baseline situation, is the construction of the plant energy model. A detailed description of how to build a plant energy model is provided in the Italian Guidelines for Energy Audits in line with Energy Efficiency Directive prescriptions, prepared by ENEA, the Agency in charge of supporting the Italian Government with energy-related topics including the energy audit process.

The plant energy model is defined as the description of the use of each energy vector within the plant boundaries and may have a different level of detail depending on the data available, on the presence of measuring equipment and on the relevance of the area or department.

Figure 2 presents the template of the plant energy model taken from ENEA guidelines.

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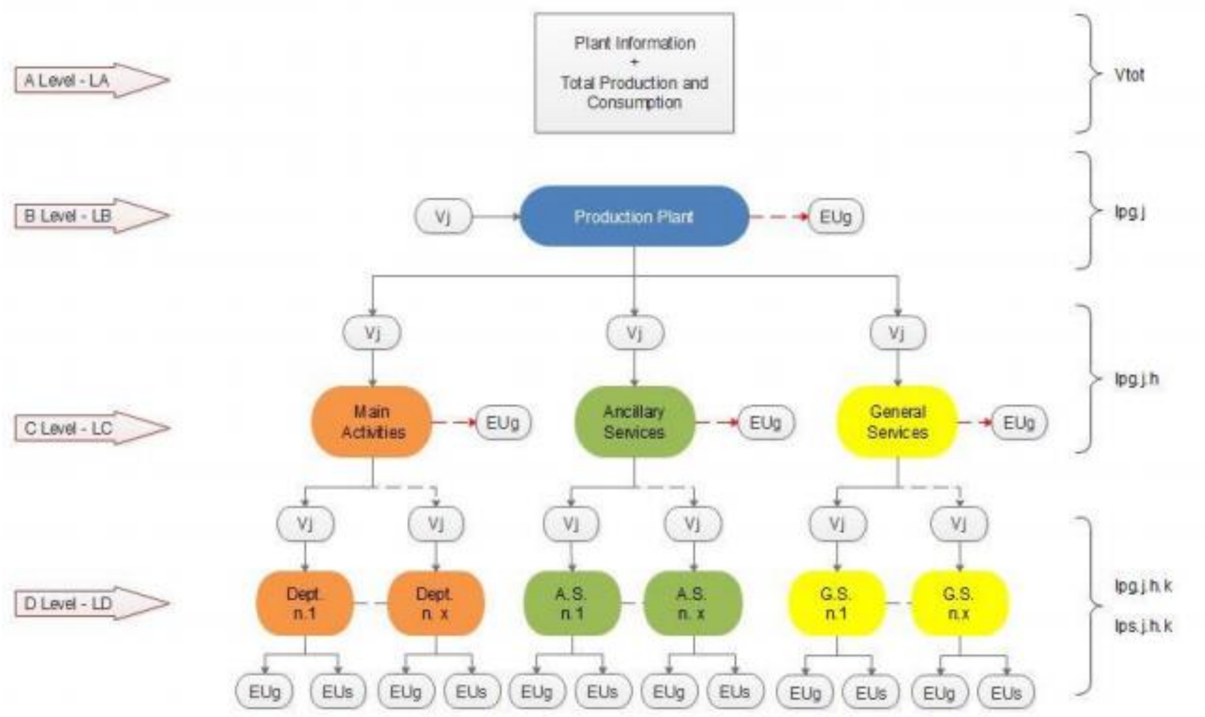

Figure 2 – Template for Plant Energy Model, from ENEA Guidelines

It is highlighted that the tree structure foresees an analysis at different levels:

- Level A only provides the total energy consumption and the total production of the plant;
- Level B analyses the consumption of the specific energy carrier with reference to the production of the plant, calculating a suitable indicator;
- Level C provides the breakdown of consumptions of each vector among three types of users, i.e. "main activities", "auxiliary services" and "general services", which are defined below, and calculates suitable indicators for each area;
- Level D identifies a further breakdown compared to the previous level, calculating the consumption of each vector for each department/area/service or machine and calculating for each item two suitable indicators, one referring to the total production of the plant and one to the specific production of the department/area/service/machine; e.g. for air compressors that constitute a typical auxiliary service at industrial plants, the calculated indicators are the electricity consumption per unit of volume of compressed air and the electricity consumption for air compression per unit of product of the plant.

As mentioned above, three main types of energy users are identified in the plant energy model:

- Main activities, which are related to the specific plant production such as, for example, the main furnace in a glass production plant or a kiln system in a cement production plant; areas/departments belonging to this category should be clearly identifiable from the point of view of the energy needs and the specific end uses;

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- Auxiliary services are all the secondary activities supporting the main ones, such as compressed air systems, thermal power plants, refrigeration units, materials handling systems, etc.;
- General services include all the activities linked to the main production/service process, such as lighting, HVAC, offices, etc.

The data requirements and formats that will be presented in the following chapter will be defined in line with the needs of the above-defined general energy audit process but with a certain degree of customization aimed at the use of the SO WHAT tool.

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3 Data Requirements and Formats

The aim of this chapter is to provide an overview of the approach to data collection adopted in the SO WHAT project and customized to the use of the tool, to describe the checklist adopted to collect the data from the demo sites and to provide indications about the format of the data to be provided.

3.1 Overall Approach to Data Collection

The SO WHAT approach to data collection has been defined following the steps of the methodology for a typical energy audit.

As outlined in the previous chapter, a plant energy model can have different levels of detail depending on the availability of data and also on the interest of an area, department or of an energy vector for the analysis. In this regard, since the main focus of the SO WHAT project is on the identification of the potential opportunities for waste heat and cold valorisation, the data collection approach has been tailored to these topics.

Data collection has been designed according to a top-down approach, as outlined in Figure 3, with each step characterised by an increasing level of detail.

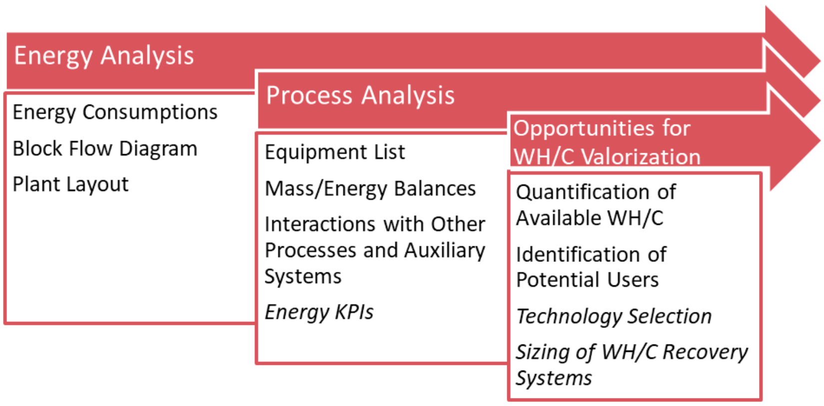

Figure 3 – SO WHAT Overall Data Collection Approach

A brief introduction to the activities foreseen for each data collection step is presented below:

- 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 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;

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- 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.

It is highlighted that the above described data collection approach is tailored on the needs of the SO WHAT tool since it prevents the user collecting and inserting in the software 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 waste heat and cold exploitation opportunities.

3.2 Minimum Data Requirements and Data Collection Checklist

In parallel to the definition of the framework approach to data collection for SO WHAT project, a set of activities were carried out by RINA-C and IESRD to engage the industrial demo sites and gather information from them on the availability and shareability of the data needed for the tool.

To this aim, a checklist was developed that lists the main data required for the use of the SO WHAT tool from the industrial side, based on the existing REEMAIN software, which constitute the foundation for the development of the tool. The checklist includes a significant number of items, since all the parameters needed to model the processes and services of the industry under analysis are present.

Specifically, most of the data requested in the checklist will be needed in the SO WHAT tool to create a model of the industrial site, breaking down the energy consumptions possibly available from bills at monthly level among different users and at a more refined time scale, based on the features of the different departments and devices, on their typical use, on-off cycles and production schedule, etc.

In case an energy monitoring system is installed at the industrial site, which covers the main processes and services providing historical and live data on their energy consumption, these data could be directly integrated into the SO WHAT tool, thus making not necessary to collect detailed data for all the aspects presented in the checklist.

Industrial demo sites were asked to answer the checklist specifying, first of all, whether the requested information is available, is ready to be accessed and is shareable with project partners and potentially with an external consultant supporting the industry with energy-related topics.

This preliminary information was used to tailor the above-presented SO WHAT data collection approach, to carry out the analysis that is the main focus of the present deliverable, i.e. on barriers to data collection, on formats and indicators, as well as for the analysis that is presented in SO WHAT D1.5, focusing on "Strategies and Protocols for Input Data Collection".

An extract for the template of the data collection checklist is presented in Figure 4, whereas its contents are described in detail below.

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Demonstration Sites Data Checklist	*Example*				
Participant Organisation Name Code	*xxxx*				
Participant Location	*Dublin (IE)*				
Participant Sector	*R&D*				
Respondent Title	*Facility Manager*				
Industrial site audit report and year of completion	*Audit report number and year of completion*				
Industrial site list of processes	*process = e.g. production line and components within this production line*				
Industrial site list of services	*service = e.g. boiler, chiller, air-compressing system, etc., that is not directly integrated as a component within a production line, but that serves a component within a production line or various components within several*				
Industrial site list of input and output material type(s), quantity unit and range(s) of temperature	*e.g. cold water (m^3), hot water (m^3), solids (kg), liquids (m^3), recycled (kg), etc. input temperature below 100 °C, output temperature within 200-250 °C range*				
Industrial site list of input and output product type(s), quantity unit and range(s) of temperature	*e.g. biscuits (kg), dough (kg), etc. output temperature within 75-100 °C range*				
Industrial site layout, plans, at industrial process level	*pdf, dwg, dxf files*				
Industrial site energy storage system type (thermal, electrical, chemical, etc.),	*e.g. ice thermal storage, 200 MW*				
Industrial site energy storage system location and connection to industrial	*pdf, dwg, dxf files or other diagrams*				
Industrial site and/or industrial process logistics strategy and constraints	*e.g. just-in-time manufacturing process, production line shifts, critical operational constraints, etc.*				
Industrial site and/or industrial process 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.*				
Are there any Industrial site energy sub-metering and/or production data monitoring systems installed? If so, please specify	*e.g. Yes, overall energy consumption (gas, electricity, heat, etc.), i.e. for all manufactory site processes, monitored and data collected on a 15-min basis*				
Where are the data collected from Industrial site sub-metering and/or monitoring systems stored?	*e.g. online database*				
Waste heat/cold recovery & Renewable heat/cold and electricity		**Available? (Y/N)**	**Readily accessible? (Y/N)**	**Shareable? (Y/N)**	**Specify or Comment**
Existing waste heat-to-power conversion technologies (including waste cold) in operation or installed	*e.g. ORC (Organic Rankine Cycle), etc.*				
Existing waste heat-to-heat recovery technologies (including waste cold) in operation or installed	*e.g. Heat recuperators/regenerators, Heat pumps, Sorption chillers, District heating or cooling, etc.*				
Existing other renewable energy systems (RESs) in operation or installed for heat/cold or electricity generation	*e.g. Solar Thermal Collector (STC), Cogeneration Heat and Power for heating or cooling (CHPH or CHPC), Solar Cooling (SC), Solar Parabolic Collector (Solar PC), Solar Photovoltaics (Solar PV), Wind or tidal turbine*				
Document on any waste heat/cold recovery technologies and RESs	*e.g. Photovoltaics (Solar PV) panels area, inclination, orientation, type, manufacturer's data, electricity production; Solar Thermal Collector (STC) panels area, inclination, orientation, manufacturer's data; CHP fuel type, heat output (rated output), thermal efficiency (rated output), power efficiency (rated output), fraction of rated heat output at minimum output, thermal efficiency (minimum output), power efficiency*				

Figure 4 – Extract from Template of Data Collection Checklist

The checklist is articulated into the following sections:

- 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.

In the following sections, the content of each part of the checklist is presented, with a particular focus, when needed, on the reason why each question is asked in the context of an energy audit and specifically in the use of SO WHAT tool.

3.2.1 Industrial Site Information

Under this section of the checklist, the following inputs are requested:

- Layout and plans at site level (pdf, dwg, dxf files);
- Energy audit report of the site (if available) and year of completion;
- List of processes and production lines and components (generally provided in form of a block flow diagram or of a P&I diagram);
- List of services (e.g.: boilers, chillers, air compressors, etc.);
- List of input and output material types, quantity and ranges of temperature;
- List of product types, quantity and ranges of temperature;
- Layout and plans at industrial process level (pdf, dwg, dxf files);
- Energy storage system type (thermal, electrical, chemical, etc.) and capacity;
- Energy storage system location and connection to industrial processes (pdf, dwg, dxf files or other diagrams);
- Process logistics strategy and constraints (e.g.: just-in-time manufacturing, production line shifts, critical operational constraints, etc.);
- 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.);
- 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.);
- Data storage type for sub-metering and/or monitoring systems (e.g.: spreadsheet, online database, etc.).

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

Under this section of the checklist, the following inputs are requested:

- 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.).

3.2.3 Industrial site processes information

Under this section of the checklist, the following inputs are requested for each process:

- Process name;
- Process components name;
- Processed product category;
- Processed product name;
- Processed product unit;
- Processed product maximum flow rate;
- Production profile for process material inputs and outputs;
- Process energy inputs, consumption, peak demand and/or demand profile;
- Process inputs from industrial site services (e.g.: steam/hot water/compressed air, etc.);
- Process heat/cold output types (e.g.: air, water, gas, etc.), strategy (e.g.: released into space, extracted, etc.) and temperature ranges;
- 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.)
- Data storage type for sub-metering and/or monitoring systems (e.g.: spreadsheet, online database, etc.).

3.2.4 Industrial Site Services Information

Under this section of the checklist, the following inputs are requested for each service:

- Service name;
- Service peak operating capacity;
- Service operating hours (day/night, working days only, continuously, etc.);
- 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;
- 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;
- Service output to industrial site process(es);
- Service heat/cold output type(s) (air, water, gas, etc.), strategy (i.e. released into space or extracted?) and temperature range(s);
- Service waste heat/cold type(s) (air, water, gas, etc.), use(s) and temperature range(s);

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- 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.)
- Data storage type for sub-metering and/or monitoring systems (e.g.: spreadsheet, online database, etc.).

3.2.5 Automated Meter Reading Data and Energy Costs Information

Under this section of the checklist, the following inputs are requested:

- Fossil fuel consumption at annual level (t/y or Nm^3/y or l/y, and/or corresponding kWh/y);
- 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;
- 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.);
- Existing energy supply tariffs and schemes (e.g.: ToU tariffs) and/or agreements (e.g.: PPA);
- Presence of any building energy management system (BEMS) and controlled systems (e.g.: lighting control, HVAC control, etc.)
- 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.).

3.2.6 General Building Information

Under this section of the checklist, the following inputs are requested for each building:

- Building ID based on national/local cadaster or building database and/or internal building ID;
- Construction year;
- Building conditions (bad, fair, good);
- Ownership (e.g.: Tenancy, Owner-occupied, etc.);
- 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);
- HVAC fuel or energy carrier used;
- Floor area (GIFA / net);
- Floor plans (pdf, dwg, dxf files);
- Elevation plans (pdf, dwg, dxf files);
- Section plans (pdf, dwg, dxf files);
- Fenestration area;
- Construction material type(s);

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- Energy Performance Certificate (EPC) level (with recommendations);
- Site photographs.

3.3 Data Formats

Based on the analysis of the checklists received by the SO WHAT industrial demo sites as well as on the experience in industrial energy audits of the consortium partners, it is understood that no standard format across different industrial sites can be identified for the requested information.

Data can be available in different formats and types of documents according to a wide range of internal and external 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 s 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. These may include among others:

- energy bills and invoices produced by suppliers;
- energy audit reports, feasibility studies, design documents for energy-related interventions;
- technical datasheets for installed equipment;
- offers and proposals by potential suppliers for new equipment;
- scanned versions of drawings, layouts and diagrams realized in the past or made not available in an editable format.

The availability of information in many different formats with no standard template across different companies introduces the need of a time-consuming pre-processing phase, whose aim is of gathering

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all the required information and data and the translation into the desired format. This step is generally done partly by industries (when answering the checklist/questionnaire provided by the energy auditor) and partly by the energy auditor, who generally extracts the required data and information from the documents provided by the industry.

In view of the use of these data in a software tool, there is a strong need to develop tailored strategies and protocols for input data collection, which is the focus of SO WHAT D1.5. Indeed, data collection, pre-processing and homogenisation represented a significant challenge for the project given the number and the very different industrial sites involved.

Moreover, there is a strong interest in the potential use of an automated tool for data collection from the available sources; to this aim, the following section presents the features of the robot tool developed by IESRD.

3.4 IES SCAN Robot Integration in SO WHAT Data Collection

Based on the typical formats for the information and data to be collected for the use of SO WHAT tool, the use of a dedicated tool developed by IESRD may be of interest, namely the IES SCAN Robot.

Indeed, in order to facilitate the real-time data acquisition aspect of the former EU H2020 funded REEMAIN project, a seamless link from the demo sites via a real-time dedicated API database connection was required. To achieve this, the IES SCAN Robot can be utilised. The IES SCAN Robot was originally developed through an FP7 funded project called Energy IN TIME and is a small program that can be placed on the client's computer to automatically transmit real-time data to the IES SCAN database at predetermined intervals. This requires no maintenance from the user once the set-up is complete and provides several advantages to achieve the data integration requirements for the REEMAIN platform, which was initially used to assess the potential for waste heat and cold from the industrial demo sites, as required in the context of SO WHAT Task 1.1 activities:

- it runs automatically and regularly keeps data on IES SCAN up to date with the latest data on the local machine;
- it runs as a Windows service, so there is no application for a user to accidentally close, and if power is lost for any reason it will start running as normal once the computer is turned back on without any user intervention.

The robot is designed to handle SQL, CSV and XML data import. Although the ability to collect real time data from a demo site meter/machine and link this seamlessly into IES software was developed in REEMAIN, it was not possible to implement successfully due to either the lack of metered technology at the demo site, or due to data security issues concerned with installing an IES piece of software on a demo site local server. Efforts will be made in SO WHAT to enable this to occur and some development is required in the existing software to implement effectively.

3.5 Polls on Data Collection and Energy Monitoring

In addition to the collection of data through the checklist and to the related analysis, during the second General Assembly of the SO WHAT project, held through videoconference tools in April 2020, a poll was organized to ask project partners for their input on the following topics:

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- whether confidentiality is a barrier to provide data;
- which is the current situation of energy monitoring at their plant (question only to SO WHAT demo site partners);
- what does their energy monitoring system cover (question only to SO WHAT demo site partners);
- which are the main benefits of energy monitoring.

The received answers are presented in Figure 5, Figure 6, Figure 7 and Figure 8.

Regarding confidentiality (Figure 5), most of the respondents answered that it constitutes a barrier to provide data, mainly to competitors and to the public, but even to partners of the SO WHAT consortium and to a potential energy consultant.

As concerns the current situation of energy monitoring (Figure 6), most of the respondents have in place an energy monitoring systems, which in half of the cases is at plant level and in the remaining half is at department or machine level. It is however highlighted that few of the respondents monitor energy consumptions only from bills.

Concerning the monitored energy carriers (Figure 7), when a monitoring system is in place, it always includes electricity consumptions and in most cases also fuel consumption; secondary energy carriers like heat (steam, hot water) or water consumption are less frequently monitored.

To conclude, with reference to benefits of energy monitoring (Figure 8), most of the respondents are aware of the fact that it allows identifying opportunities for energy saving, but also for waste heat and cold valorisation and project cost controlling.

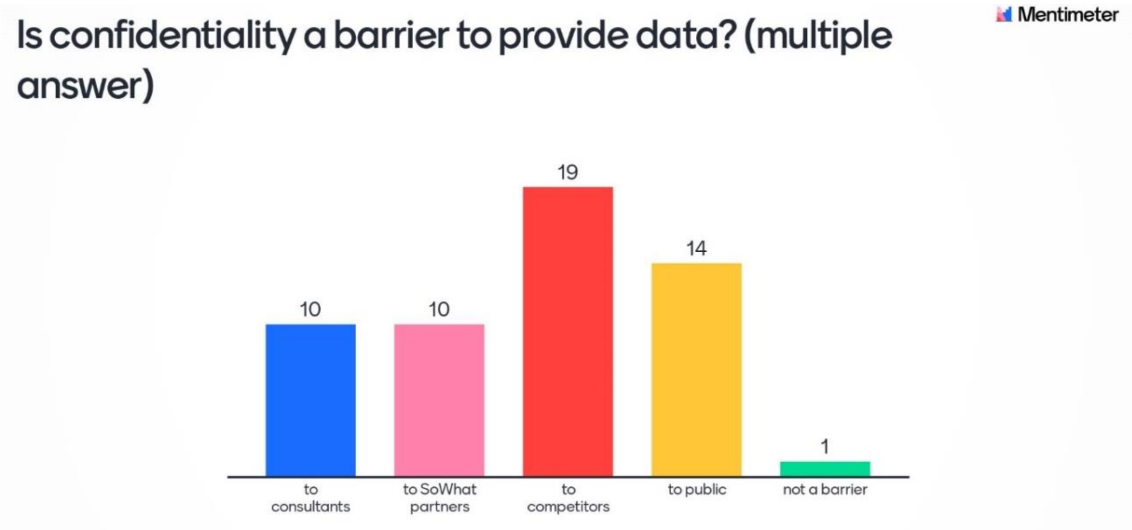

Figure 5 – Results of Poll on Data Confidentiality

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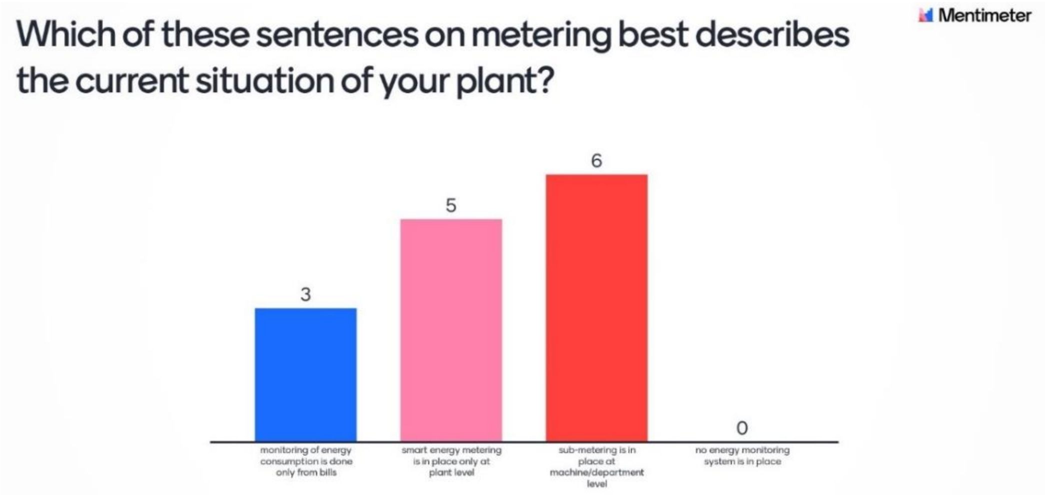

Figure 6 – Results of Poll on Current Metering Situation

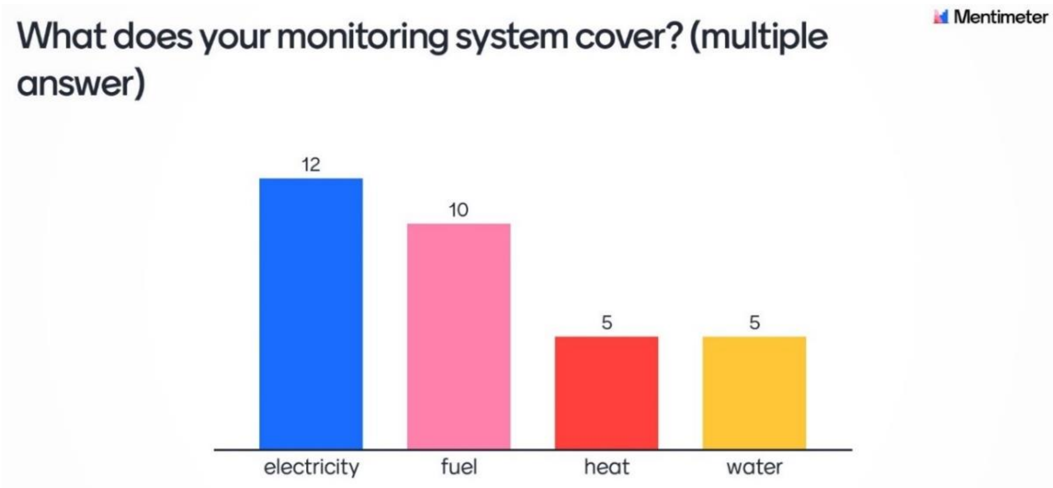

Figure 7 – Results of Poll on Features of Monitoring System

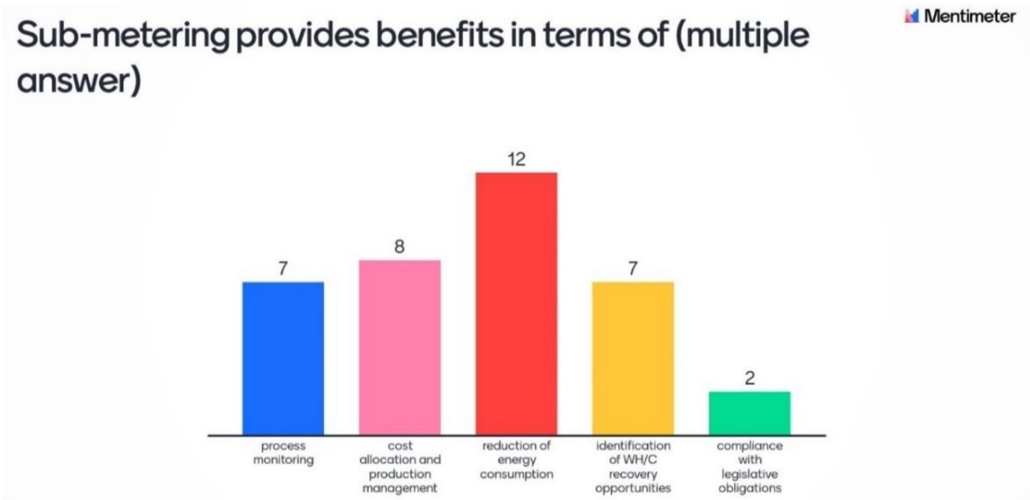

Figure 8 – Results of Poll on Benefits of Monitoring System

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4 Barriers to Data Collection

This chapter is articulated into two sections, one focusing on the outcomes of the analysis on data collection and one specifically on the main identified barriers that can obstacle the collection of the required information.

4.1 Main Findings Regarding Data Collection

Based on the analysis of the answers given by SO WHAT industrial demo partners to the checklist for minimum data requirements, a screening of the available data for each demo was carried out and the outcomes are presented in Annex 1 to the present Deliverable. Since the above-mentioned screening contains confidential data related to the industrial demo sites, Annex 1 of this Deliverable is considered as confidential, differently from the core part that is a public document.

Nevertheless, the analysis of the answers to the checklist, complemented with the experience of consortium partners in industrial energy audits, allowed drawing more general results on data collection, which are summarized in the following bullets:

- energy consumption data for the most important primary energy carriers (i.e.: electricity and natural gas) at plant level are generally available at monthly scale from bills;
- the same data at plant level are not always available at daily/hourly scale because not all suppliers of electricity and natural gas make them available to customers – due to the type of meters installed, to the local legislation or to corporate procedures – but sometimes also because customers do not download such data from the suppliers' portals;
- for other primary energy carriers than main ones (i.e.: diesel/gasoline/LPG or other liquid fuels, coal/biomass or other solid fuels), consumption data may be available on more scattered bases, for example based on refuelling date and amount, which is not completely representative of the distribution of consumptions;
- for secondary energy carriers (i.e.: heat related ones – steam, hot/superheated water, chilled water, diathermal oil, hot gases – but also compressed air, etc.), monitoring is generally limited to their production and only in seldom cases their distribution and consumption is covered; this means for example that the electricity consumption of the air compressor or the natural gas consumption of the steam boiler are known but the use of compressed air or of steam of a certain department or machine is not and can only be estimated;
- for electricity self-produced internally to the plant, e.g. through a photovoltaic or a cogeneration plant, typically monitoring devices are in place due to the legislative requirement to monitor their production in order to receive the related incentives or quantify the related taxes;
- regarding plant and department production and the consumption of raw materials, data are generally available because correlated with project controlling activities;
- the breakdown of energy consumption among different areas and machines of the plant is generally known only if a monitoring system is present that covers the consumption of one or more energy carriers for the specific department;

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- energy consumption indicators are very seldom calculated by industries for external benchmarking purposes, i.e. .for comparison with best practices and identification of potential margins for improvement; it is somehow more frequent that internal benchmarking is applied, i.e. comparison of energy performance indicators of a period compared to the same period of the previous years for energy and process monitoring purposes;
- a full energy audit report is not always available; although the EU Energy Efficiency Directive has introduced the obligation for large companies to carry out an energy audit of their facilities every four years, and this obligation has been transposed into national legislation by all EU Member States, the national implementations foresee that multi-site companies can perform energy audits only on a part of their sites, provided that it is representative of their range of plants for use, size, energy consumption and location;
- a list of machines with nominal data (age, electric and thermal power, nominal output, etc.) is available in most cases for process-related equipment and main auxiliary services but sometimes not for secondary auxiliary equipment and general services (e.g.: HVAC systems, lighting, offices, etc.);
- the records of machines use, in terms of on/off hours, actual load compared to the nominal value, etc. is generally not available unless an energy monitoring system is in place or the machine is provided with a hours-counter due to maintenance reasons (like in the case of diesel-fuelled generators or electric air compressors);
- the breakdown of heating and cooling and/or domestic hot water demand among different areas of the plant is generally not known;
- the layout of the industrial plant is generally available, even for compliance with health and safety and first aid/firefighting legislation, but the indication of the exact location of machines and plants or the layout of the steam/water/compressed air distribution networks is sometimes not available or updated, especially in small and medium-sized industries;
- the characteristics of the building envelope in terms of thickness, materials, presence and features of thermal insulation layers, datasheet of the windows and doors, etc. are not always available, unless the building has recently been constructed and/or a recent energy performance certificate has been issued for the building;
- the location and characteristics (size, gas flowrate/temperature/composition, etc.) of chimneys where exhaust gases are emitted to air may be available from Environmental Impact Assessments and/or other permitting documents, if required by the local/national legislation.

4.2 Barriers to Data Collection

Based on the main outcomes of the analysis on data collection presented in the previous section, the following main barriers to data collection were identified:

- confidentiality issues, which obstacle the provision of documents that are available within the plant or the company; this barrier seems to be unjustified when the concerns are related to sharing information with project partners – for which a confidentiality agreement is in place based on the Consortium Agreement – or with an energy consultant, whose role is to

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support the company in energy-related topics and where needed is ready to sign a non-disclosure agreement based on the needs of the client;

- detailed data available only on core processes and machines; this barrier does not allow a uniformly detailed analysis of energy consumptions and features for example for auxiliary services that usually are those presenting the most important opportunities for waste heat and cold valorisation (e.g.: economizers on steam boilers, heat recovery from compressors' cooling air or water, from chillers/heat pumps, etc.);
- lack of monitored data on heat carriers (steam, hot water, chilled water, hot gases and fluids, etc.), which obstacles the identification of possible users for the potentially recovered waste heat and cold or even of potential opportunities for waste heat and cold recovery;
- lack of detailed information on building characteristics and H&C demand, which obstacles the estimation of the heat demand and consequently like in the previous bullet the identification of possible users for the potentially recovered waste heat and cold;
- non-standard availability of documents in different plants, which constitutes a barrier for the elaboration of data collection strategies and protocols, especially in view of the use in an automated tool;
- non-standard format of information across different plants, with the same effects of the previous barrier.

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5 Indicators

As outlined in Chapter 2 focusing on background information on energy auditing, the calculation of energy performance indicators and the comparison with relevant local and international benchmarks – especially those related to best practices – is one of the core aspects of the energy assessment of an industry. Indeed, it allows identifying the existing gaps and spotting potential margins for improvement, thus laying the bases for the study of feasibility of potential improvement actions.

It is understood that benchmarking can be carried out:

- internally, with the aim of assessing the performance of the same plant, process or machine in different years;
- externally, by comparing the performance of the plant with other similar plants – based for example on publications and reports issued by category associations – or with available best practices – based for instance on BREF documents by the JRC of the European Commission for the specific industrial sector).

In both cases, the first required step is to calculate the specific energy consumptions in term of ratio between the input and the output of the system under analysis.

This can easily be done at plant level (for each single energy carrier or as a whole, converting all inputs into primary energy) considering the total production of the plant, but also for all areas and departments and even for single machines belonging to production departments and auxiliary/general services, following the plant energy model approach described in Chapter 2.

Based on the plant energy model built for the specific industrial site, once the consumption of each user (area, production department, process, machine, according to the level of the analysis) has been determined, an indicator representing the specific consumption of the user can be calculated, with reference both to the final product of the plant ("general indicators") and to the product of the single user ("specific indicators"). More in detail:

- for "main activities" general and specific energy performance indicators are both related to the final product of the industrial site;
- for auxiliary services, general energy performance indicators are related to the final product of the industrial site, whereas specific energy performance indicators are related to the output of the service (e.g.: the amount of steam produced by a boiler or of compressed air of a compressor); the two indicators are linked through the consumption of the service output per unit of final product (e.g.: the amount of steam or compressed air used per unit of product, following the examples presented above);
- also for general services, general indicators are calculated with reference to the final product of the industrial site, whereas specific energy performance indicators are correlated with the output of the service (e.g.: illuminance level for lighting systems, heating/cooling degree days for H&C systems, etc.); in this case, there is not always a physical correlation between the general and the specific indicators (e.g.: there is not direct correlation between the illuminance level in the production departments and the production of the industry), but the calculation of the two types of indicators is of interest to evaluate on one hand the share of

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each general service over the total energy consumption of the site and on the other hand to assess the energy performance of the specific service.

Figure 9, taken from the already mentioned ENEA Guidelines for energy audits, shows an example of the application of the plant energy model approach to the calculation of general and specific energy performance indicators for main activities, auxiliary services and general services.

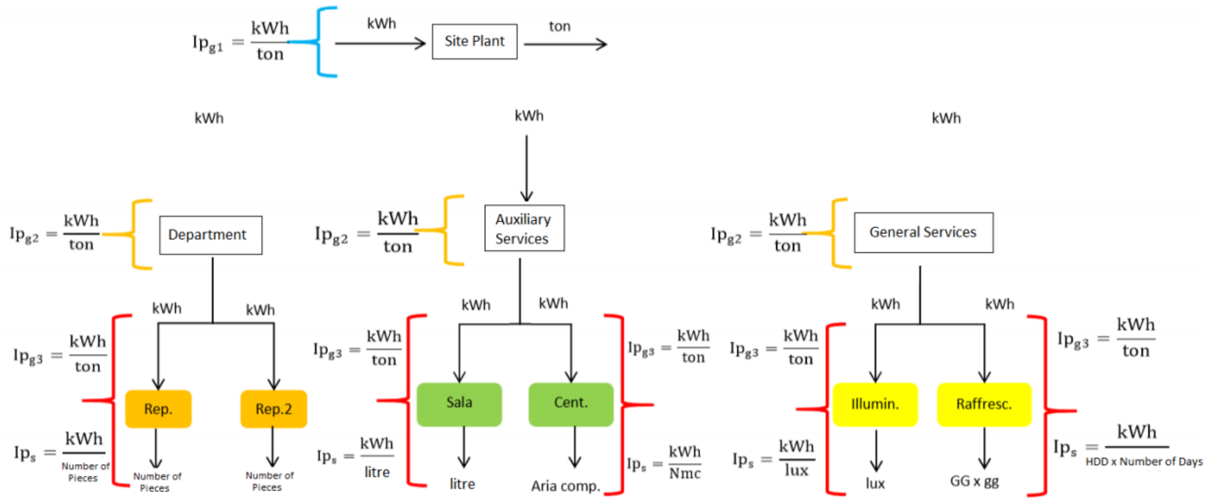

Figure 9 – Example of General and Specific Indicators, from ENEA Guidelines

A non-exhaustive list of the indicators that can be calculated based on the above presented approach includes the following items:

- electricity consumption;
- natural gas or other fuel consumption;
- thermal energy carrier consumption (e.g.: for thermal energy carriers purchased externally, like in the case of connection to a DHC network, or for internally produced carriers);
- primary energy consumption associated to the use of the above-mentioned energy carriers;
- emissions of greenhouse gases, both direct and indirect, associated to the use of the above-mentioned energy carriers.

The above-listed indicators can be calculated with reference to:

- the output of the whole industrial plant, expressed in a suitable unit (e.g.: mass or volume);
- the output of the single specific department or service, expressed in a suitable unit;
- the efficiency of energy conversion for specific energy-related devices such as boilers, heat pumps or chillers, combined heat and power plants or electricity generators working with conventional or renewable sources, etc.;
- the illuminance level and the footprint area for lighting systems;
- the heating/cooling degree days and the footprint area for H&C systems;
- the building volume and air exchange rate for ventilation/air filtration systems;
- the footprint area, the number of workplaces, the person working hours for offices;
- the distance travelled for transport systems, e.g. company cars/trucks.

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6 Conclusions

The present Deliverable has focused on the data requirements for energy auditing and specifically for the feeding of information to the future SO WHAT tool, as well as on their formats and on the most suitable indicators to compare energy performance data across different industries.

A checklist with minimum data requirements was developed, in line with current IES software requirements articulated into the following main topics: "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".

The answers to the checklist provided by SO WHAT industrial demo partners with specific regard to data availability, shareability, confidentiality and format were collected and analysed, and complemented with information available based on the extensive experience of RINA-C in energy auditing activities at industrial premises.

This allowed highlighting a set of main outcomes related to data availability and formats, as well as identifying the main barriers that obstacle energy-related data collection on an industrial site, which are those briefly summarized below:

- issues related to confidentiality;
- detailed data available only on core processes and machines;
- lack of monitored data on heat carriers;
- lack of detailed information on building characteristics and H&C demand;
- non-standard availability of documents in different plants;
- non-standard format of information across different plants.

Based on the outcomes on data formats and availability and on the above barriers, the strategies and protocols for data collection are defined and presented in D1.5, with the aim of providing data to SO WHAT tool by minimizing the subsequent effort and need for post-processing.

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7 References

EN, Technical Standard 16247-1:2012, "Energy audits - Part 1: General requirements", https://standards.cen.eu/dyn/www/f?p=204:110:0::::FSP_PROJECT,FSP_ORG_ID:35014,234049&cs=1B2781618A92D90EA1460D4E8A69161CB

BAFA, "Guidelines for Energy Audits", http://www.bafa.de/ea_guidelines

ENEA, "Guidelines for Energy Audits under Article 8 of the EED: Italy's Implementation Practices and Tools", https://www.efficienzaenergetica.enea.it/component/jdownloads/send/40-pubblicazioni/377-guidelines-energy-audits-obligation-in-italy.html

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