MODULE 1

CHAPTER 3_DATA COLLECTION AND FORMATTING

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Abbreviations

CHP: Combined Heat and Power

DH: District Heating

DHC: District Heating and Cooling

EU: European Union

GHG: Greenhouse Gas

KPI: Key Performance Indicator

LCOH: Levelized Cost of Heat

RES: Renewable Energy Sources

TES: Thermal Energy Storage

WH/C, WH/WC: Waste Heat/Cold

WHTC: Waste Heat to Cold

WHTH: Waste Heat to Heat

WHR: Waste Heat Recovery

WHP: Waste to Power

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SHORT SUMMARY

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1 Introduction to Energy Audits

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.

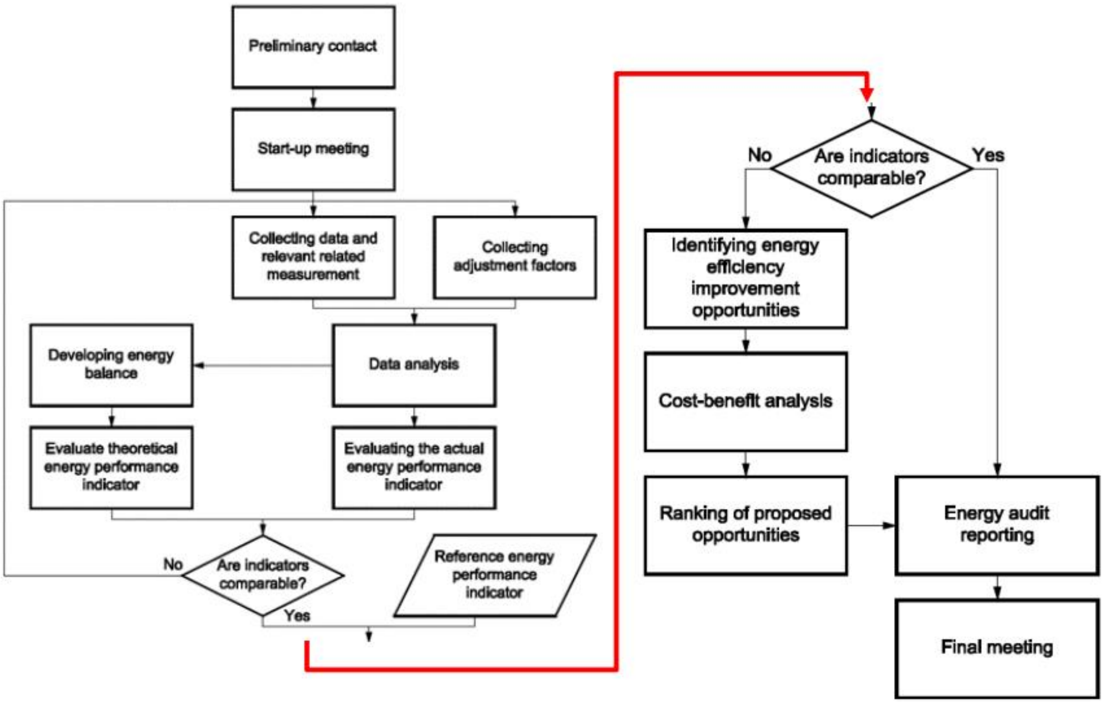

Figure 1 – Energy Audit Process (adapted from EN 16247-1)

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;
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;

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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.

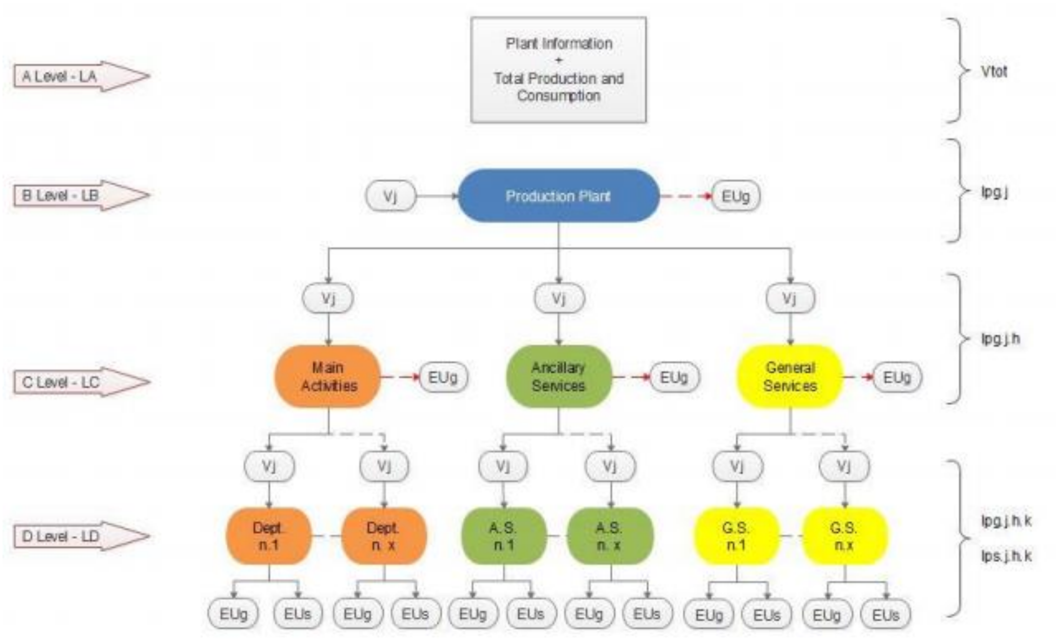

Figure 2 – Template for Plant Energy Model, from ENEA Guidelines

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;

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- 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;
- 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.

2 Data Collection Approach

Data collection is the core task of an energy audit and of the identification and assessment of WH/C resource potential. Typically, a data checklist is developed, to gather information on the demo site building (including HVACs), industrial processes and related components, as well as the operation of both the building and the industrial processes.

For the use of the SO WHAT tool, the data collection workflow is articulated into the following steps:

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.;

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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.

Since the energy model of the industrial site 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, the data collection approach has been tailored to the main focus of the SO WHAT project, i.e. the identification of the potential opportunities for waste heat and cold valorisation. The approach is top-down, as outlined in Figure 3, with each step characterised by an increasing level of detail.

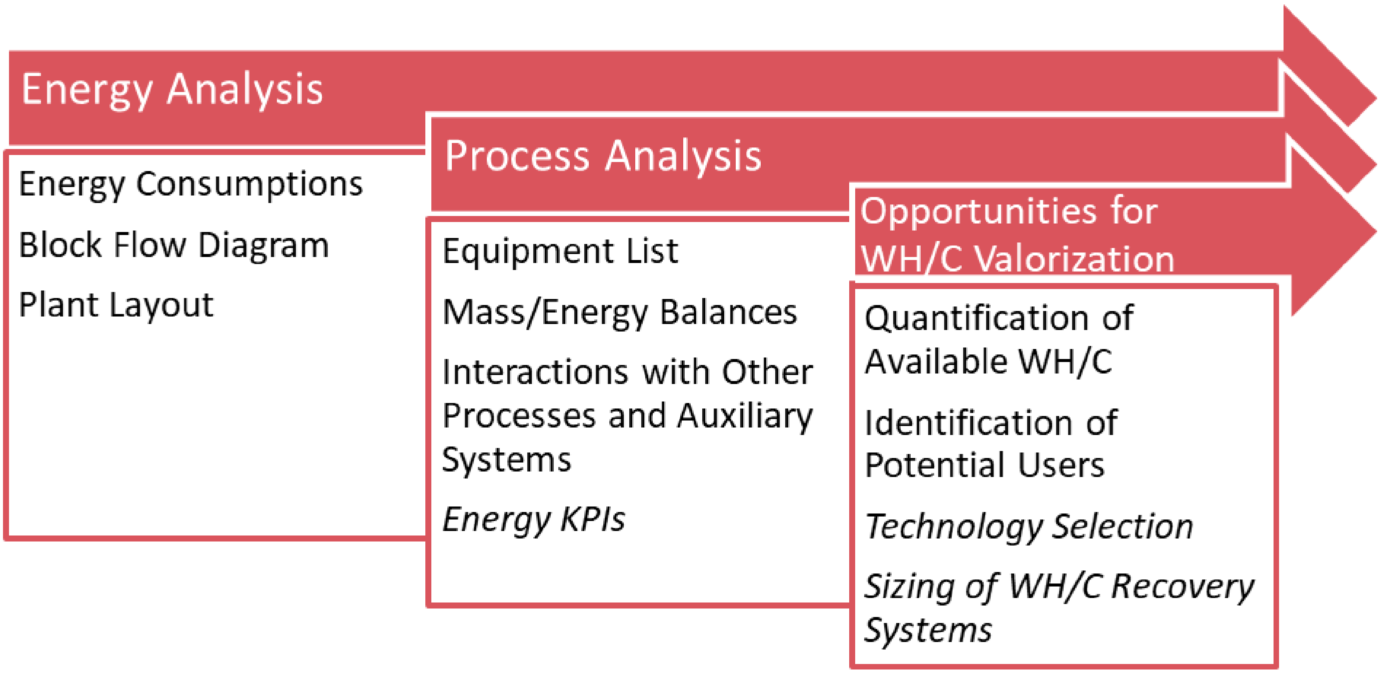

Figure 3 – SO WHAT Overall Data Collection Approach

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

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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;
- 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.

Specifically, a checklist was developed that lists the main data required for the use of the SO WHAT tool from the industrial side. 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. These data will be used 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.

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.

It is specified that 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.

3 Data Formats

It is clear 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

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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 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.

4 Issues and Barriers to Data Collection

Based on the analysis carried out, the following main findings on data collection can be extrapolated:

- 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

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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;
- 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.

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 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.

5 Indicators

As outlined above, 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 improvements.

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;

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- 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.

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 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 4, 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.

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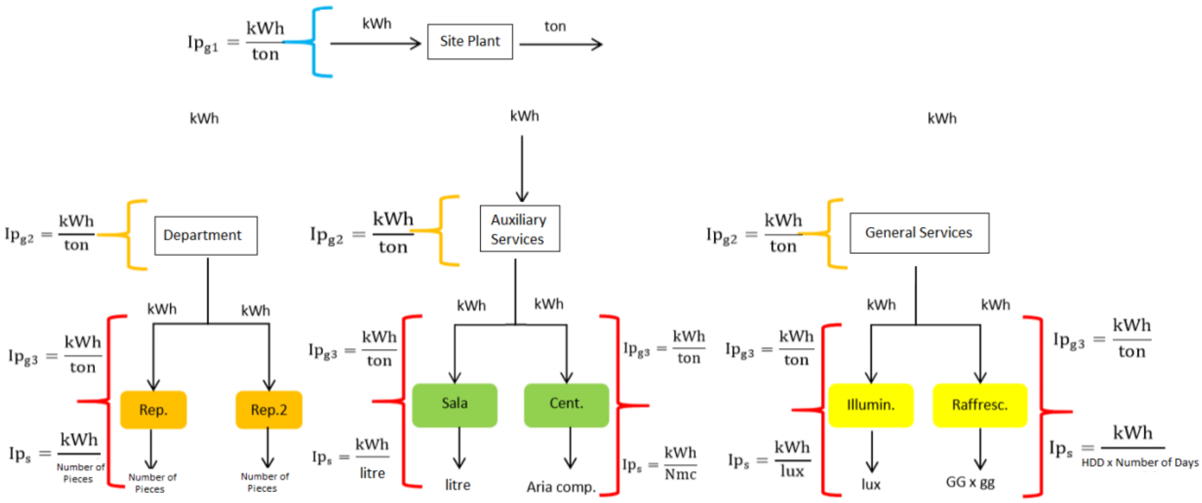

Figure 4 – Example of General and Specific Indicators, from ENEA Guidelines

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.

6 Data Sources and Processing Protocols

Table 1 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.

Table 1 – Typical Data Sources

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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
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

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Information	Primary Source	Secondary Source
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.)		
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

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Information	Primary Source	Secondary Source
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)		
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

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Information	Primary Source	Secondary Source
Electricity consumption at annual level (kWh/y)		Sub-metering system Estimation by plant management
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
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

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Information	Primary Source	Secondary Source
HVAC fuel or energy carrier used		Typical HVAC systems for type of building from literature 7
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

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9 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:35014,2340498&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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