Energy audits procedure of buildings and multicriteria analysis

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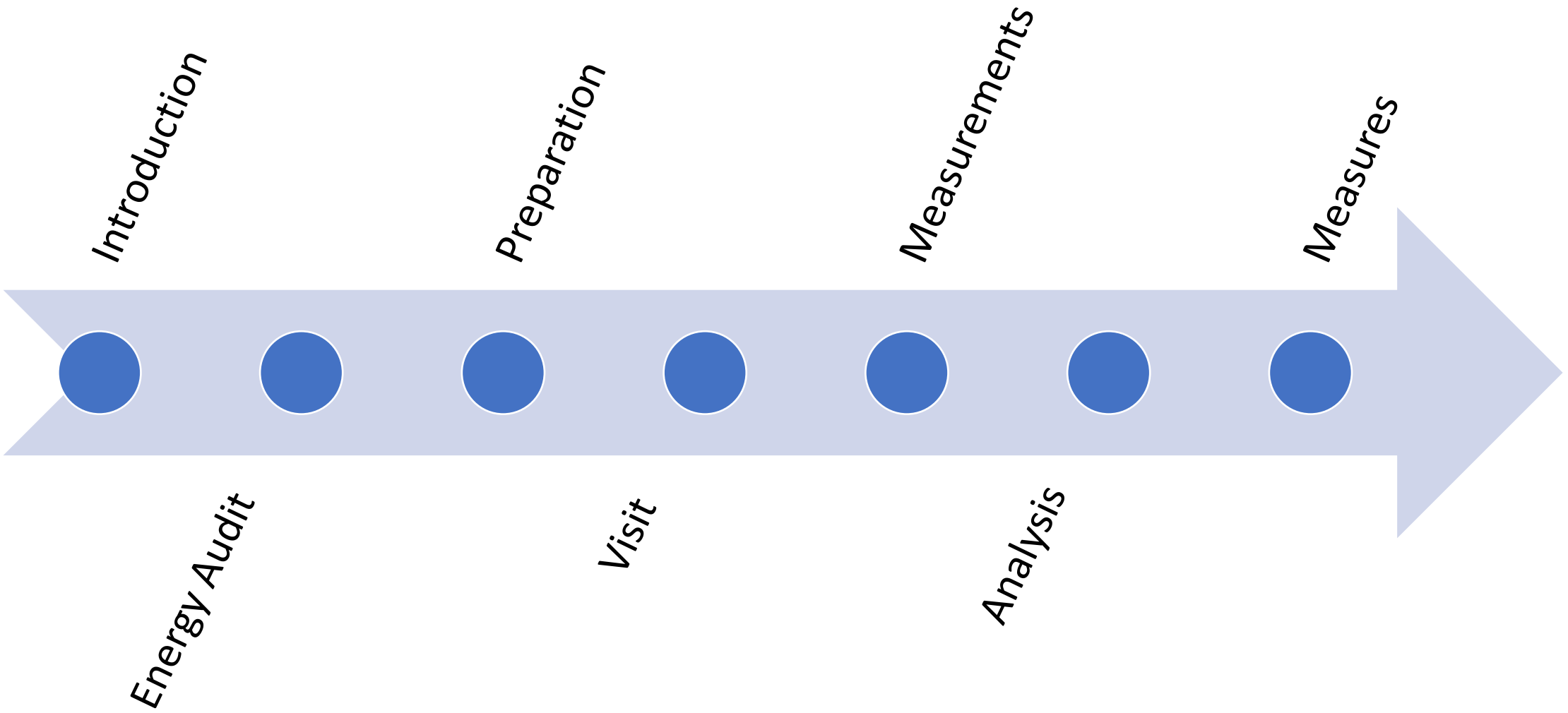

Introduction

- An energy audit is an essential tool of energy management.
- Energy audit is an investigation and detailed analysis of the energy (and water) entering and leaving a building, and is carried out to pinpoint the areas where there is potential for energy efficiency measures and savings.
- The main aim of the energy audit is to identify actions that will lead to savings in energy and costs.
- Other aims:
  - Reduction in carbon emissions
  - Improved environmental conditions for the occupants of the building
  - The development of a system for recording energy use
  - The development of monitoring and targeting schemes

Energy audit

DEFINITIONS

Energy audit is:

- “A systematic, documented verification process of objectively obtaining and evaluating energy audit evidence, in conformance with energy audit criteria and follow by communication of result to the client”.
- “The verification, monitoring and analysis of the use of energy and submission of technical report containing recommendations for improving energy efficiency with cost benefit analysis and an action plan to reduce specific energy consumption”.

Introduction

The energy entering the building comes from a number of sources (oil, coal, gas, electricity, etc.) and “free” sources, such as solar radiation and people, which supply light and heat. All this energy is eventually converted to heat and leaves the building via a number of routes:

- Transmission through the building envelope,
- Flue losses
- Infiltration and ventilation losses, etc.

The energy is used to power: heating equipment, lighting, cooling equipment, fans, pumps, cooking appliances, refrigerators, appliances (computers, printers, etc.), larger items of machinery, lifts and escalators, etc.

Energy audit

Benchmarking – preliminary cost analysis, comparison with similar energy efficiency solutions and/or industries, etc.

Preliminary audit (walk-through) – available data mostly used for a simple analysis of energy use and performance of the technical systems. Does not require measurements and detailed data collection. It is not time consuming and results are rather generic and include simple economic calculations.

Detailed audit (diagnostic audit) – detailed data and information on all technical systems is required. Detailed measurements and data inventory is needed for each system (pumps, fans, compressors, etc.). The economic calculations should cover at least NPV, IRR, LCC, etc. The result is list of clearly defined measures that the client should implement in order to improve the energy efficiency of the building.

Investment-grade audit – includes also complete technical and economic analysis at the investment level.

Energy audit

<table>
<tr><td></td><td>Models of scan</td><td colspan="2">Models of analyzes</td><td></td></tr>
<tr><td>Smaller objects</td><td>basic, "walk-through" audit</td><td colspan="2">selective audit</td><td>Selected by auditor</td></tr>
<tr><td rowspan="2">Larger objects</td><td rowspan="2">preliminary audit</td><td colspan="2">targeted audit</td><td rowspan="2">Selected by owner representative</td></tr>
<tr><td>for specif. systems</td><td>detailed</td></tr>
<tr><td></td><td>Appropriate for buildings, etc.</td><td colspan="2">Appropriate for industrial processes</td><td></td></tr>
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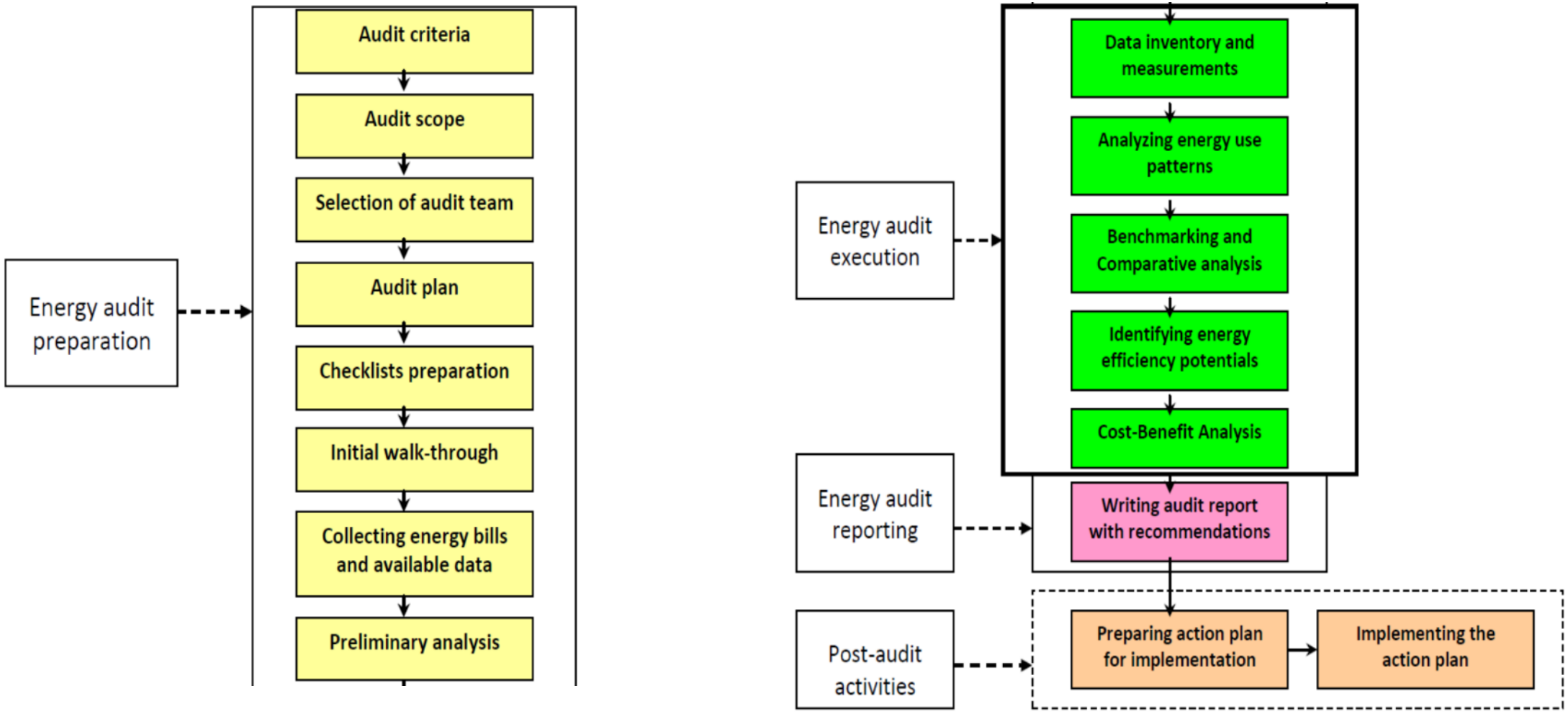
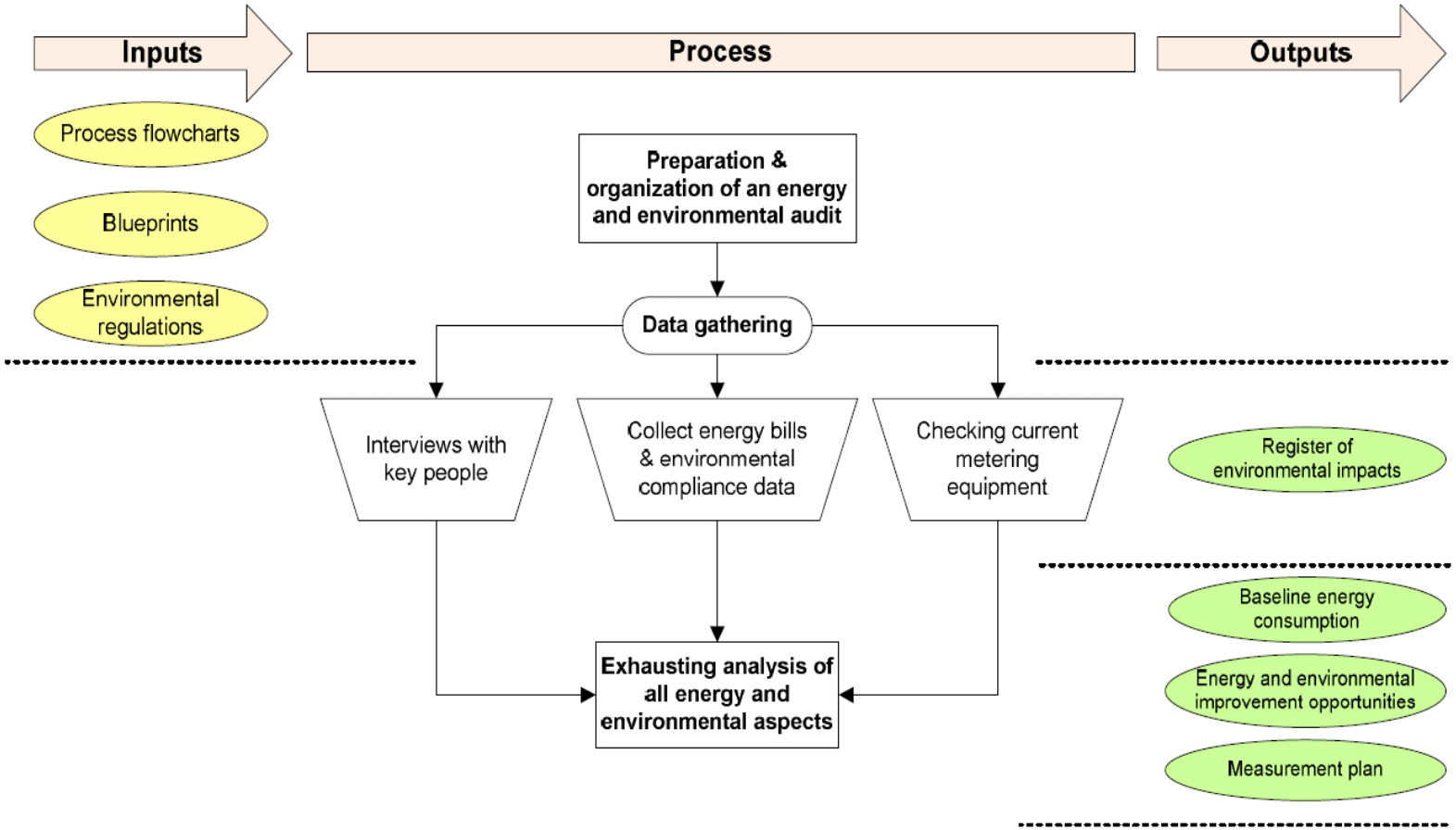
Energy audit



Energy audit



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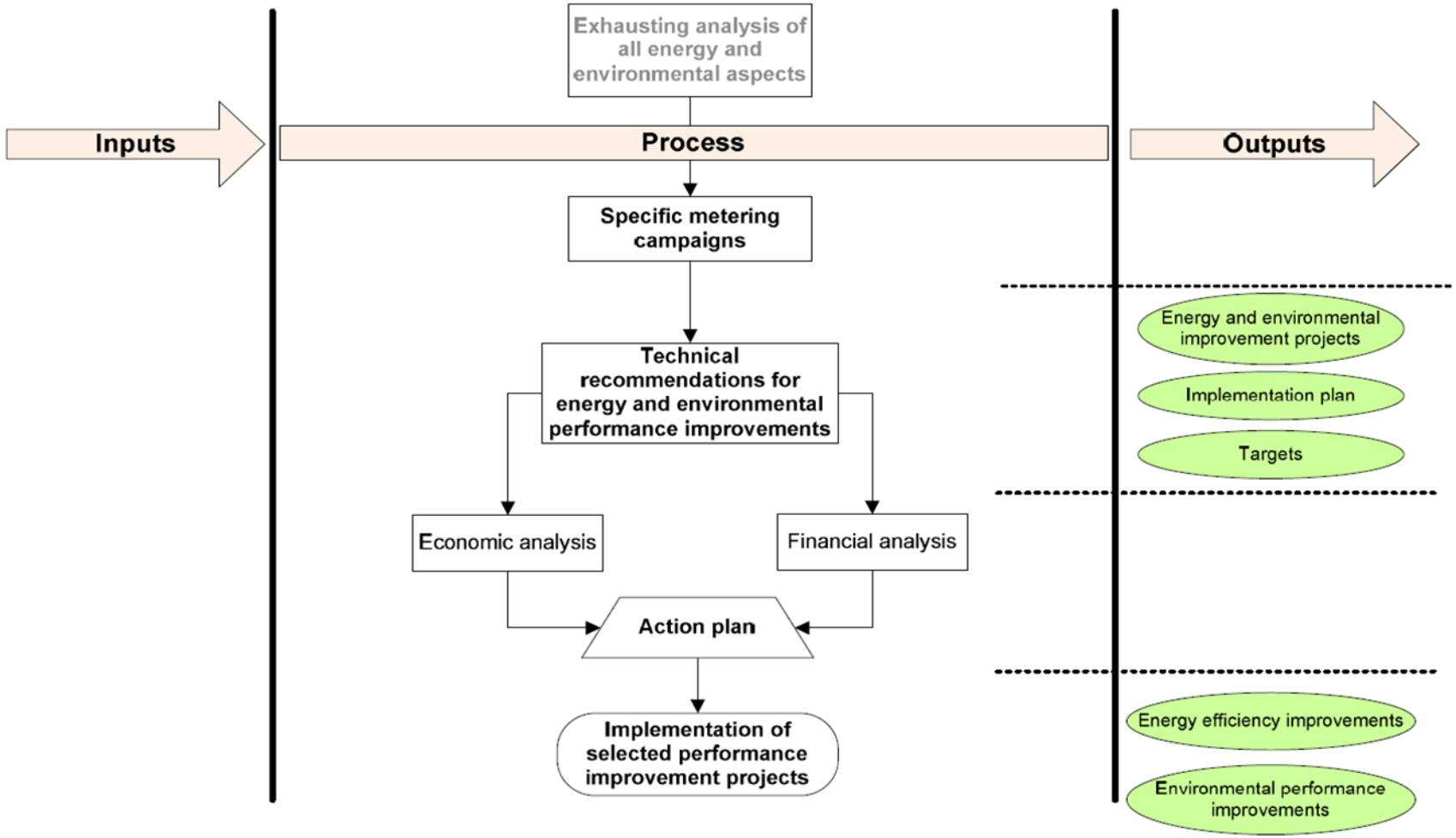
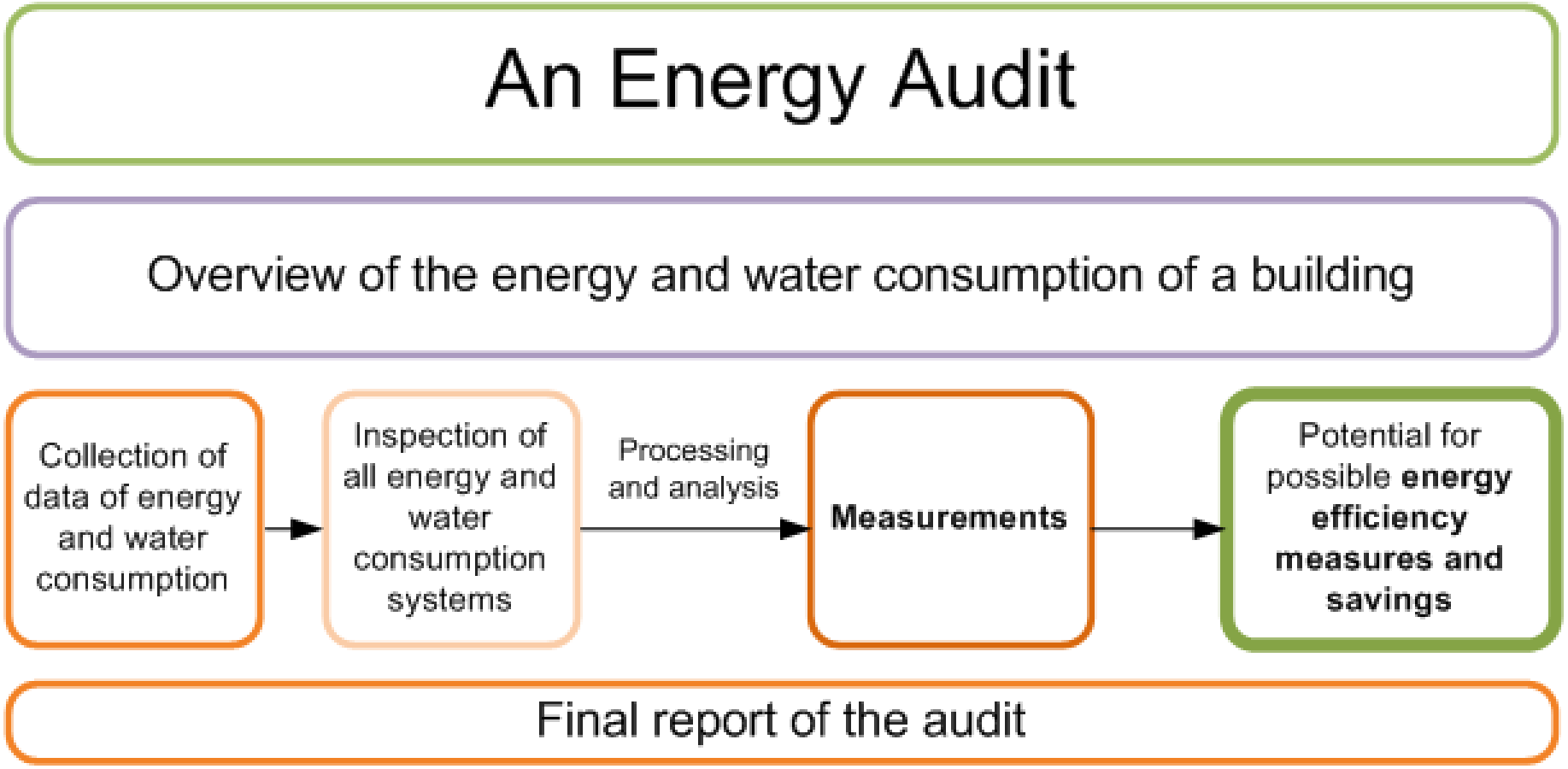
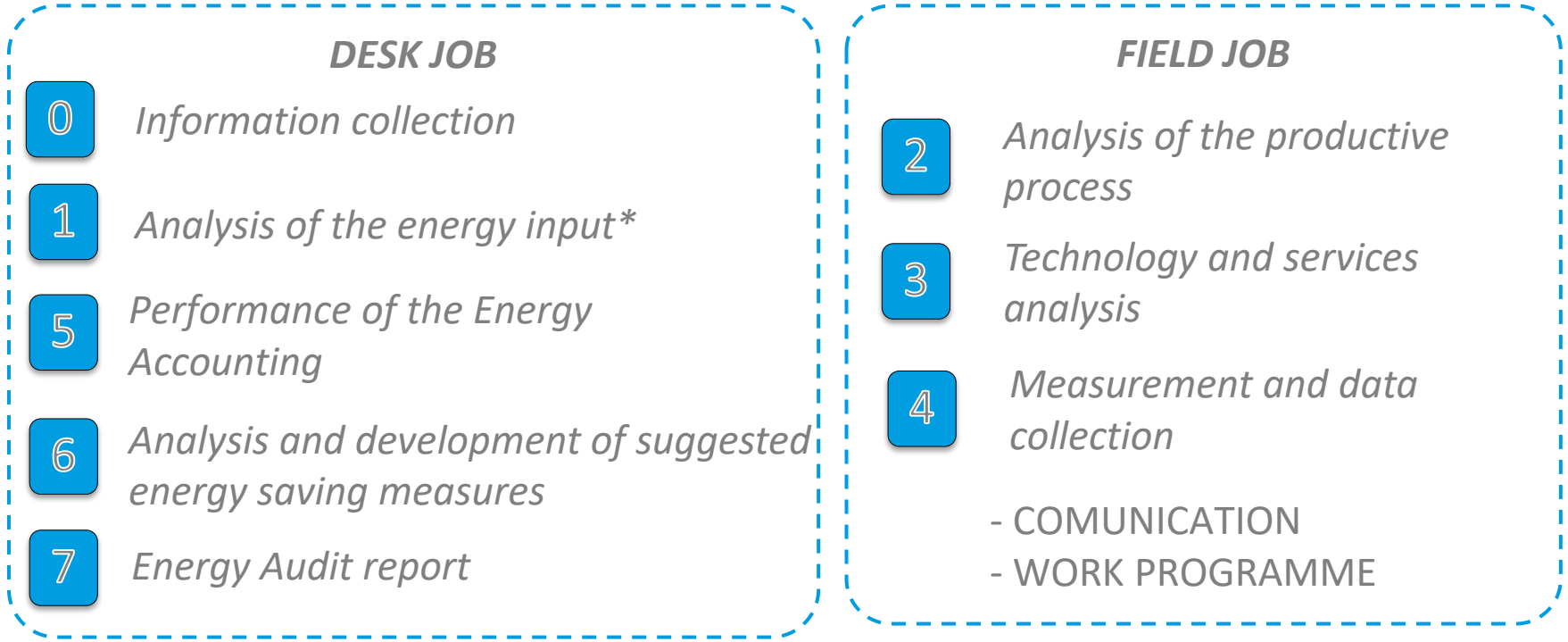


Energy audit



Energy audit

An energy audit consists of 8 main steps that can be performed in the office of the auditor in the field.



NOTE: *The information is requested prior to the visit in order to resolve any doubt or further information on it

Energy audit

The energy audit process may be divided into a number of phases:

- Pre-survey information and data collection
- The building survey
- Analysis of the data collected
- Formulation of energy-saving solutions
- Reporting of results

Pre-survey data collection

- Introductory meeting with the administration and head of maintenance services
- Initial questionnaire
- Data collection
- Meeting with the head office of the institution
- Basic information required:
  - The contact person
  - The basic building characteristics
  - Gather all the plans from the contractor and the maintenance personnel

Pre-survey data collection

- Important to collect as much information as possible about the building
- Utility bills provide useful information on the amount of energy (and water) purchased and tariffs paid
- Readings from any sub-meters should be used if available (if these are not available then this might be potential area for improvement)
- Regular readings taken manually (also a potential EE measure)
- Bills will show maximum demand charges (load-shifting potential)
- Bills going back number of years (at least 3) will enable long-term trends in energy usage
- The most recent energy/water bill is needed as well

Pre-survey data collection

- Any plans, elevations or technical data on the building should be obtained (useful information od dimensions, construction materials, possibly U-values, and important information on the building services plan (type, size and control strategy)
- The collected information may include:
  - Electricity/gas/oil/solid fuel/water utility bills
  - Plans/elevations/design of the building (incl. building services systems)
  - Location of the building (climate)
  - Information on the controls and building management system (BMS)
  - Information on the structure of the building (U-values, materials, etc.)
  - Information on the building’s purpose, hors of work and operation

Walk-through survey

- Walk-through survey will provide much additional information which cannot be obtained from the plans
- There are often changes made (extensions, new ventilation plant, additional insulation, etc.)
- The condition of the building should also be noted (e.g., cleanliness of light fittings, etc.)
- Interviews with building managers, engineers, caretakers and others can provide useful anecdotal evidence and better understanding of the operation of the building
- Sometimes is good (with the employer's permission) to interview the building users or issue questionnaires.

Walk-through survey

- Conditions in the building may be measured as well, various hand-held devices are available nowadays: for temperature, humidity, lighting level, CO_2 level, etc. (provide only indication of the conditions prevailing at the time of the survey)
- Spot reading can be useful in identifying potential problems (problems with temperature control, etc.)
- Other control issues may also be identified:
  - Do users have manual override for heating controls?
  - Are there open windows immediately above working radiators?
  - Can the user adjust light levels?
  - Where are the light switches?
  - Are computers switched off at night?
  - Is there manual control of ventilation?
  - Are fans switched on at night for night cooling?

Walk-through survey – building envelope

- Surfaces and sizes, orientation and building characteristics (roof, floors, windows, walls, etc.)
- The working schedule of the building
- Number of employees, number of workers
- The heated and cooled area and/or volume
- The referent climatic data

Walk-through survey – heating system

- Detailed inspection of the boiled rooms is essential
- The characteristics of the heating system, the boiler, the distribution system and the medium, the heating elements (radiators, etc.)
- Working schedule, power and efficiency, regulation, etc.
- Standard of maintenance (maintenance plans)
- Hydraulic balance of the system
- Connection to other systems (DHW or steam)
- Any specific problems such as broken valves, leaks, missing lagging and other defects should be noted

Walk-through survey – domestic hot water

- Collect all the technical characteristics of the domestic hot water (DHW) system including distribution system and the medium
- Technical data such as power and efficiency
- Working schedule and regulation
- Standard of maintenance (maintenance plans)
- Connection to other systems (connection to heating system, connection to alternative heating systems, etc.)

Walk-through survey – cooling, ventilation and air conditioning system

- Listing all the technical characteristics of all three systems, the distribution part and the medium, the cooling/ventilation elements such as convectors, fans, etc.
- Technical data such as power and efficiency
- Working schedule and regulation
- Standard of maintenance (maintenance plans)
- Split systems
- Connection to other systems such as cooling, refrigeration, etc.

Walk-through survey – electricity (other)

- Indoor and outdoor lighting system
- Important to collect number of lamps, power and operating hours
- List of all the other usual and specific equipment such as IT equipment, various kitchen appliance, washers, etc. (power and operating hours)
- Overall efficiency and regulation
- Standard of maintenance (maintenance plans)

Walk-through survey – renewable energy

- Installed power and energy production
- How are the renewable energy systems connected to building technical systems
- What is the purpose of such renewable energy source
- Analysis of distribution system
- Overall efficiency and regulation
- Standard of maintenance (maintenance plans)

Walk-through survey – water supply

- Is there a pressure control system
- Number and type of water sources and end-user appliances
- Is there an alternative water source(s)?
- Is there any water leakages when no one is using it?

Analysis of the data collected

- The form and extent of the analysis depends on the number of factors:
  - The depth of the audit
  - The nature of the building
  - The degree to which the energy consumption data can be disaggregated into end-uses
  - The needs of the client
- For complex buildings it is worth to model the performance using proprietary software for simple steady-state heat loss calculations or detailed hourly simulations of HVAC performance
- If there is accurate input data available then it is possible to simulate the effect on energy consumption by changing for example building envelope insulation, improving boiler efficiencies, etc.

Analysis of the data collected

- The results of analysis should include at lease:
  - Analysis of all the energy and water bills and definition of referent energy/water consumption
  - Model the energy and cost balance
  - Model the balance for each type of energy and water consumer
  - Compare the calculated energy demand with the referent consumption
- Measured or estimated energy consumption should be compared with that of other buildings having the same function
- Comparisons are normally based on $kWh/y/m^2$

Analysis of the data collected - metering

- Easy to measure:
  - Temperature and humidity
  - Surface and sizes of building envelope (laser distance meter)
  - Lux measurement (lux meter)
- Not so easy to measure
  - Thermal camera (thermography)
  - Water pressure and consumption (ultrasound)
  - Ventilation losses, air penetration (blower door test)
  - Boiler efficiency measurement (direct and indirect, waste gasses, etc.)
  - Electricity data (active and reactive power, energy, power factor, etc.)

Formulation of energy-savings solutions

- The analysis of the data collected should result in the identification of where energy use is high and where there is waste.
- Such “waste” can be reduced by implementation of no-cost solutions (changes to occupant behaviour, low-tech solution such as adding blinds to the windows) to highly engineered and costly measures (installation of combined heat and power system, etc.).
- After the suitable means of energy reduction are identified, the estimated savings should be calculated and their cost effectiveness should be assessed.

Formulation of energy-savings solutions

- The energy efficiency measures should be calculated according to the referent energy consumption (real consumption from energy and water bills)
- The energy efficiency measures are technically, ecologically and economically evaluated
- The energy efficiency measures should be transparently calculated and presented
- The energy efficiency measures should be calculated in accordance with local norms and laws

Reporting

- The report can be made to the client outlinging:
  - The present state of the building
  - An analysis of current energy use
  - Identification of areas of waste and where energy can be saved
  - Details of the kinds of intervention which will reduce energy use
  - Details of the savings possible
  - The cost-effectiveness of the methods recommended
- Measures can be listed in order of preference (lowest cost, shortest payback, highest net present value (NPV), etc.
- List of best options should be presented to management in the form of an energy audit report.

Reporting

- The energy audit report should include:
  - Description of building – dimensions, materials, location, orientation, purpose. Hours used.
  - Description of heating/cooling/lighting system, air-handling units, boilers, fittings, controls
  - Thermal comfort – state whether conditions are acceptable
  - Energy consumption – bills, estimates. If not available, state what you would need to do to find out – what measurements to make.
  - Comments on specific points about the operation of the buildings. Does everything work as it should, is it well maintained, and so on?
  - List of where you think energy is being wasted, where and how savings could be made
  - Calculations based on 6 to show the cost-effectiveness (or otherwise) of measures
  - Specific recommendations

Q&As

Thank you for your attention!

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