Energy Audits and Energy Management in buildings

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- Introduction to Energy Audits
- Procedure for Energy Auditing
- Energy Efficiency improvements
- Typical tools and time frames for energy audits
- Energy Management Systems
- Monitoring and Verification of Energy Savings

Introduction to Energy Audits


Energy Audit
Energy
Management

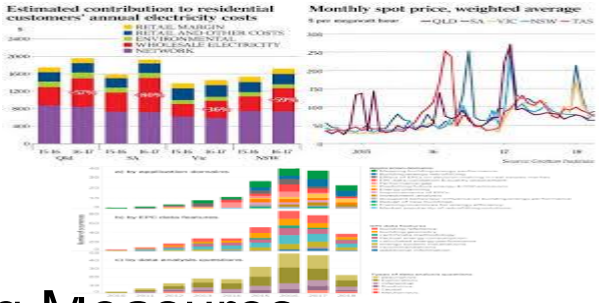
Energy Audits

An energy audit *is a systematic inspection and analysis* of energy use and energy consumption of a site, building, system or organization with the objective of identifying *energy flows* and the *potential for energy efficiency improvements* and reporting them - **EN 16247**

EN 16247 specifies the *requirements*, common *methodology* and *deliverables* for energy audits. It applies to all forms of establishments and organizations, all forms of energy and uses of energy, excluding individual private dwellings.

What is an Energy Audit

Energy Audit involves



- Systematic Record of Energy Data
- Analysis of Energy Data
- Proposal of potential Energy Saving Measures

Need for Energy Audit:

- Minimize Energy Consumption.
- Maximize productivity.
- Achieve Energy efficiency

Why carry out an energy audit?

- To *improve* energy performance and *minimize* the environmental impacts of the building's operations
- To identify *technical opportunities* by evaluating significant process energy-using components or utilities including boilers, refrigeration plant, ventilation systems, building performance, etc.
- To gain a greater *understanding* of a part or all of the building's *energy usage* patterns
- To provide clear *financial information* regarding energy savings opportunities in order to prioritize these items for the building's decision-making process

Why carry out an energy audit?

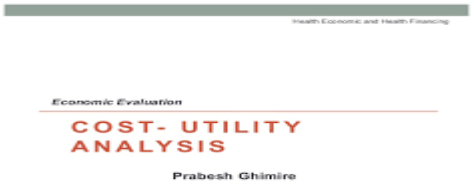
- To identify *potential* for using *renewable energy* supply technologies (e.g. NZEBs)
- To identify *behavioral change* opportunities by evaluating current operations and maintenance practices
- To meet customer and shareholder expectations
- To achieve compliance with legal requirements such as the Energy Efficiency Directive

- ***To contribute to the process for certification to a formal energy management system, as set out in ISO 50001***

Types of Energy Audits

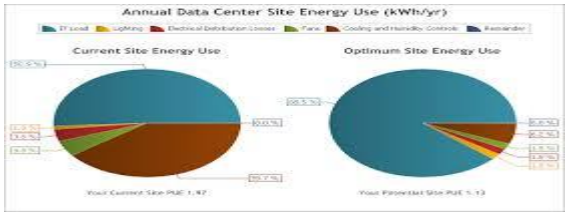
- Walk-Through Audit

- Utility Cost Analysis



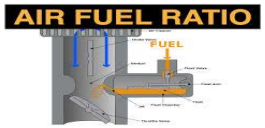
- Standard Energy Audit

- Detailed Energy Audit



Walk-Through Audit

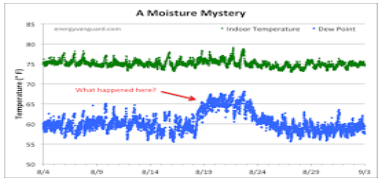
- Short onsite visits for inspection.
- Propose inexpensive and simple actions (housekeeping or of minimum cost).
- Immediate energy savings considered.
- Checking the Operating & Maintenance procedures



✓E.g. Repairing broken windows

✓E.g. Boiler A/F ratios Adjustment

✓E.g. Lowering Cooling Preset Temperatures



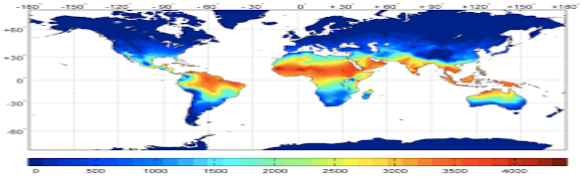
Utility Cost Analysis

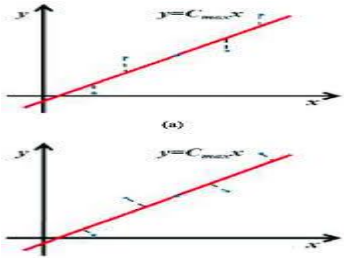
- Establish “Relation” between cost & Utility’s services
- Analyze Operating cost of the Utility
- Obtain data from:
    - Energy Bills
    - Peak Demands.
    - Weather effects identified

- Utility Cost analysis steps include:
    - Verify energy bills & ensure no mistakes made
    - Determine dominant charges
    - Peak demand saving measures
    - Check if alternative cost effective fuels will help

Standard Energy Audit

- Comprehensive Analysis of Energy Systems
- Development of Baseline (of the building's energy use)
    - Identification of Energy Uses
    - Evaluation of Energy Savings
    - Cost Effectiveness of Selected E.E.M.
- Various Mathematical Tools are used
    - Degree day methods
    - Linear regression Methods
    - Simple Pay Back Analysis





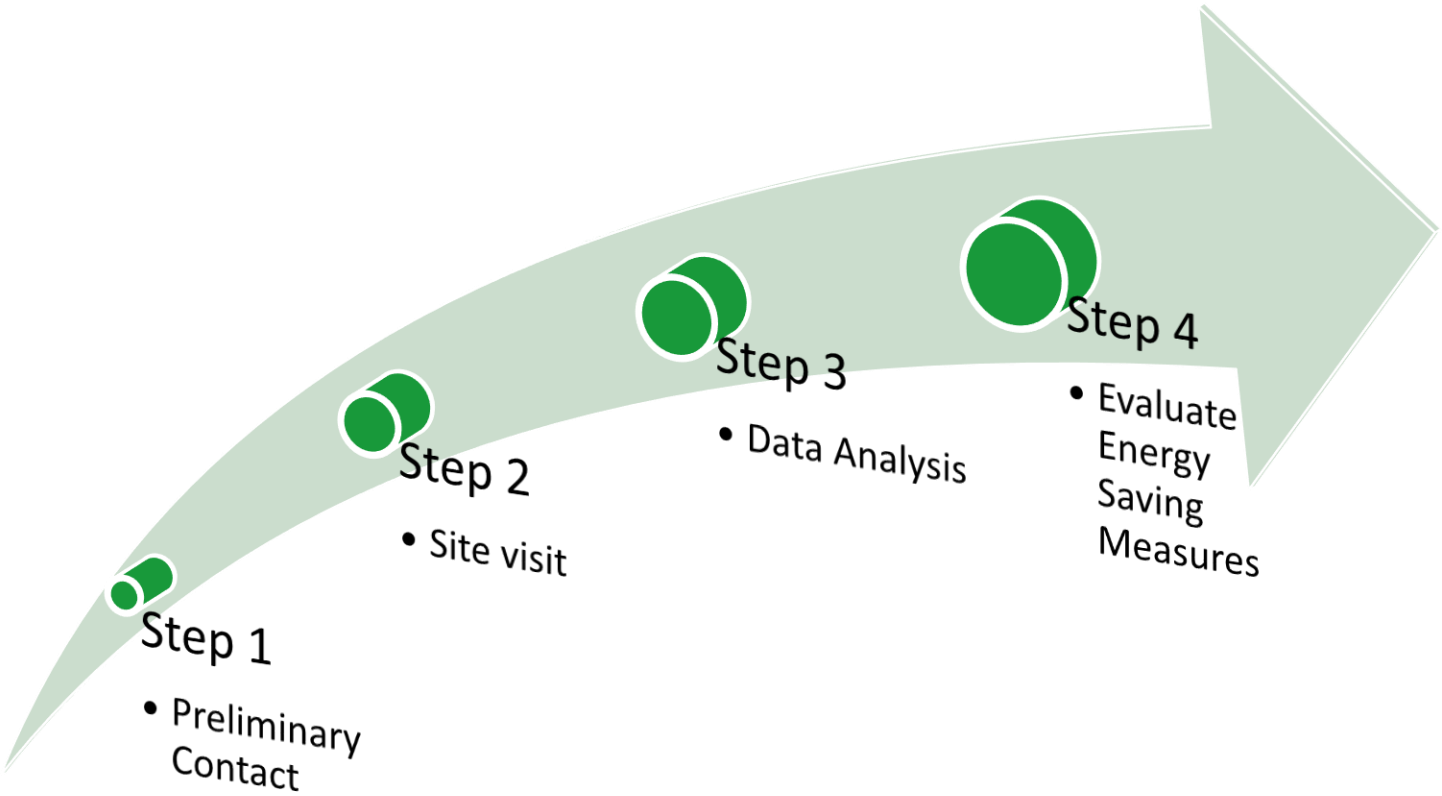
$$\text{Payback Period Formula} = \frac{\text{Initial Investment OR Original Cost of the Asset}}{\text{Cash Inflows}}$$

Detailed Energy Audit

- Most Comprehensive & Time Consuming
- Use of hand held / stationary instruments
- Sophisticated Computer Simulations
- Carried out for:
    - Evaluating Energy use
    - Identifying Potential savings
    - Recommending Energy Retrofits
    - Evaluating the Cost Effectiveness of Energy Retrofits

General Procedure for an Energy Audit

Energy Audit



Step 1: Preliminary Contact

a) The energy auditor shall agree with the organization on:

1. aims, needs and expectations concerning the energy audit
2. scope and boundaries [EXAMPLE - The whole site and all energy using systems or the boiler plant]
3. degrees of thoroughness required [EXAMPLE - Proportion of apartments in a block to be visited; whether accuracy sufficient for investment decisions is required].
4. timescale to complete the energy audit [depending on complexity of buildings]
5. criteria for evaluating energy efficiency improvement measures [EXAMPLE - pay back period]
6. time commitments and other resources from the organization
7. requirement for data to be collected prior to the energy audit commencing and the availability, validity and format of the energy and activity data
8. foreseeable measurement and/or inspection to be made during the energy audit.

b) The energy auditor shall request information about:

1. The energy audit context [EXAMPLE Energy audit related to a government agreement/scheme]
2. Strategic wider program (planned projects, outsourcing facilities management)
3. Management system (environmental, quality, energy management system or others)
4. Changes that may have an effect on the energy audit and its conclusions
5. Any existing opinions, ideas and restrictions relating to potential energy efficiency improvement measures
6. Expected deliverables and required format of the report
7. Whether a draft of the final report to the organization should be presented for comment.

c) The energy auditor shall inform the organization of any:

1. Special facilities and equipment required to enable the energy audit to be carried out
2. Commercial or other interest which could influence his or her conclusions or recommendations.)

Start-up meeting

a) The energy auditor shall request the organization to:

1. Nominate the person ultimately responsible for the energy audit within the organization

2. Nominate a person to communicate with the energy auditor, where necessary supported by other appropriate individuals constituted as a team for the purpose

3. Inform affected personnel and other interested parties about the energy audit and requirements placed on them in connection with and ensure their cooperation

4. Disclose any unusual conditions, maintenance work or other activities that will occur during the energy audit

b) The energy auditor shall agree with the organization on:

1. Arrangements regarding the access of the energy auditor;
2. safety and security rules;
3. resources and data to be provided;
4. non-disclosure agreements (e.g. tenants in a building);
5. proposed schedule of visits with priorities for each;
6. requirements for special measurements;
7. procedures to be followed for installation of measuring equipment, if needed.

Step 2: Site visit

Walk-through inspection of the building in order to:

- Check operating and maintenance procedures
- Determine the existing energy consuming systems and their operating conditions
  - Systems like lighting, HVAC systems, motors, etc.
- Estimate the occupancy, and the uses of equipment and lighting
  - energy use density and hours of operation

Collecting Data

During the site visit, the energy auditor shall, in cooperation with the organization, collect the following (where available):

1. list of energy using systems, processes and equipment;
2. detailed characteristics of the audited object(s) including known adjustment factors and how the organization believes they influence energy consumption;
3. operational history and past events that could have affected energy consumption in the period covered by the data collected;
4. design, operation and maintenance documents;
5. energy audits or previous studies related to energy and energy efficiency;
6. current and projected tariff, or a reference tariff to be used for the protection of commercial confidence;
7. other relevant economic data;
8. the status of the energy management system

Collecting Data

Examples:

- Collect building geometry data (volume, heating/cooling area, etc.)
  - To extract specific consumption indicators
- Collect energy consumption records of utility data (Optimal 3 years data).
  - To identify a historical energy use pattern.
- Identify the fuel types used
  - to determine the dominating fuel type.
- Determine the patterns of fuel use by fuel type
  - to identify the peak demand for energy use by fuel type
- Analyze the effect of external factors in energy consumption of the building
  - Weather, Occupancy, etc.

Step 3: Analysis

During this phase, the energy auditor shall establish the existing energy performance situation of the audited object.

a) The existing energy performance situation becomes a reference against the improvements that can be measured. It shall include:

    1. a breakdown of the energy consumption by use and source of energy;
    2. energy flows and an energy balance of the audited object;
    3. pattern of energy demand through time;
    4. relationships between energy consumption and adjustment factors (both routine and non-routine);
    5. one or more energy performance indicators suitable to evaluate the audited object.

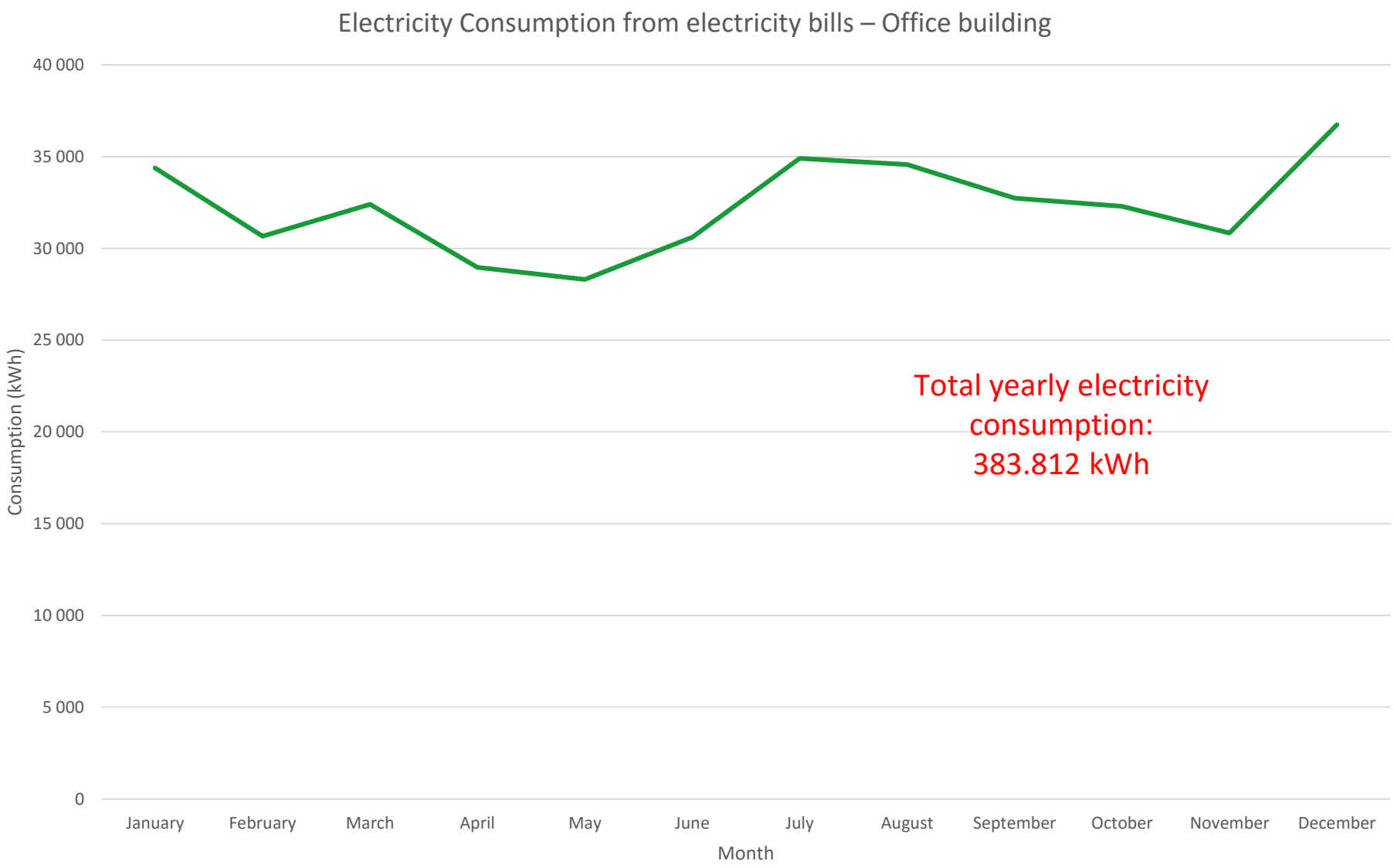
The data

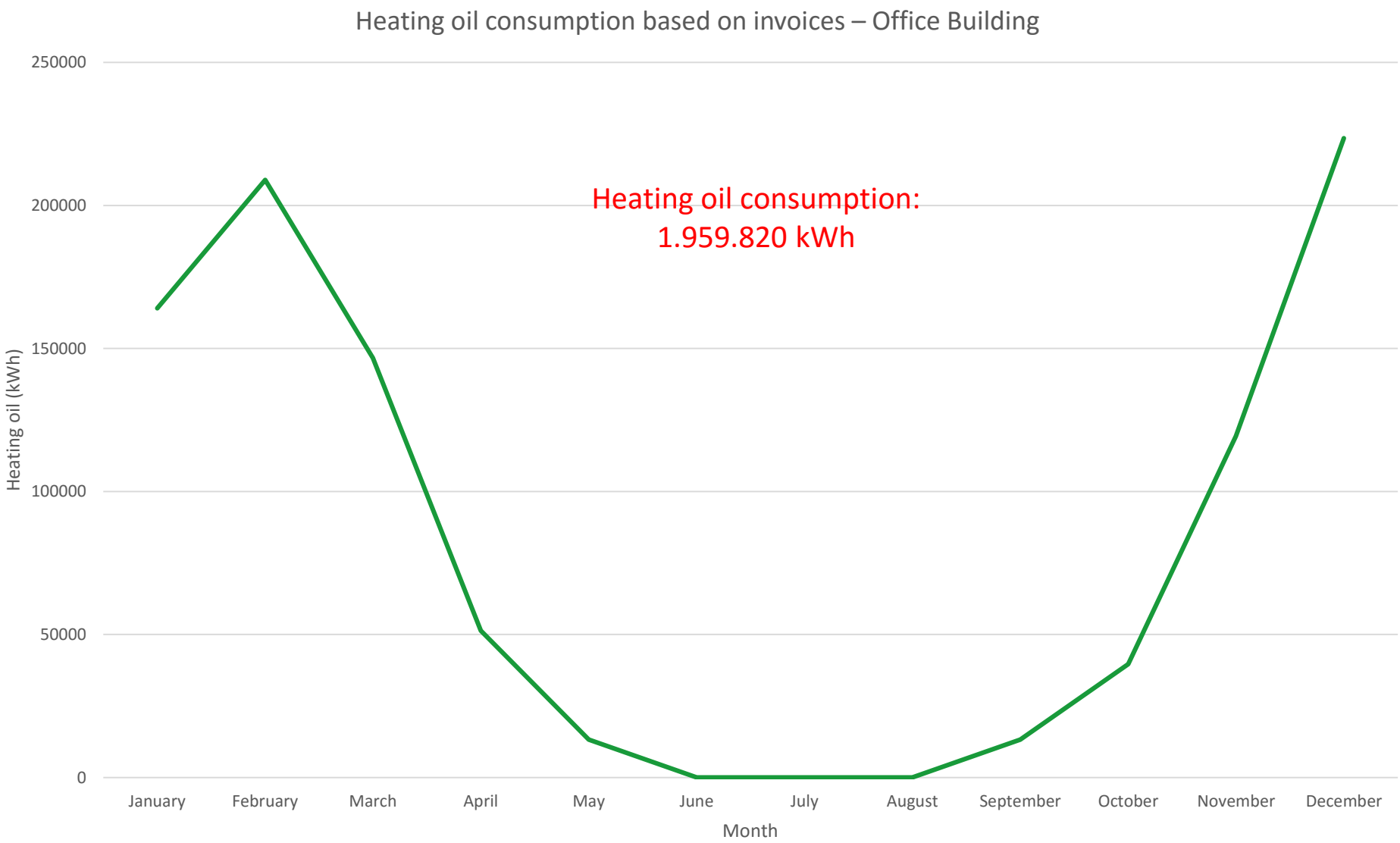
- Consumption data
  - fuel consumption (the last three years are needed) and type of fuel,
  - electric consumption (the last three years are needed).

- Degree days [*indices reflecting demand for energy to heat & cool buildings*] of the last three years for the normalization of consumption

- Use of the building (type and time)

- Construction data (if existent)!


Electricity Consumption from electricity bills – Office building
40 000
35 000
30 000
25 000
20 000
15 000
10 000
5 000
0
Consumption (kWh)
January
February
March
April
May
June
July
August
September
October
November
December
Month
Total yearly electricity consumption:
383.812 kWh


Heating oil consumption based on invoices – Office Building
Heating oil consumption:
1.959.820 kWh
250000
200000
150000
100000
50000
0
Heating oil (kWh)
January
February
March
April
May
June
July
August
September
October
November
December
Month

Benchmarking

Energy indicator	Existing Building	Average building*
Specific electricity consumption (kWh/m2/yr)	123	120
Specific heating consumption (kWh/m2/yr)	218	160
Total	341	280

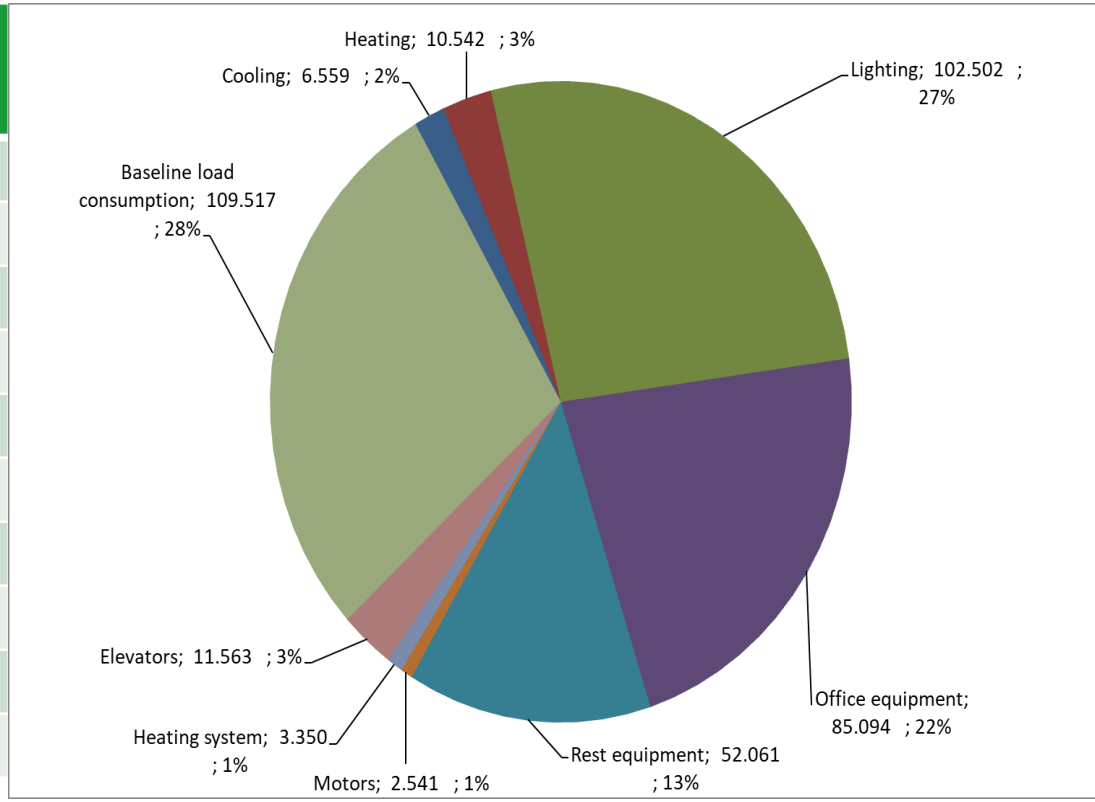
** Statistical data from the National Energy Performance of Building database*
http://www.ypeka.gr/Default.aspx?tabid=907&language=el-GR

Breakdown of Energy Consumption – (2)

Energy bills and technical characteristics of the equipment

In this case where *energy bills and installation characteristics are available*, an in-depth conversation with the technical personnel of the installation carried out during the energy audit where the operational hours, usage coefficient etc. where determined. This fact led to the determination of the energy consumption breakdown.

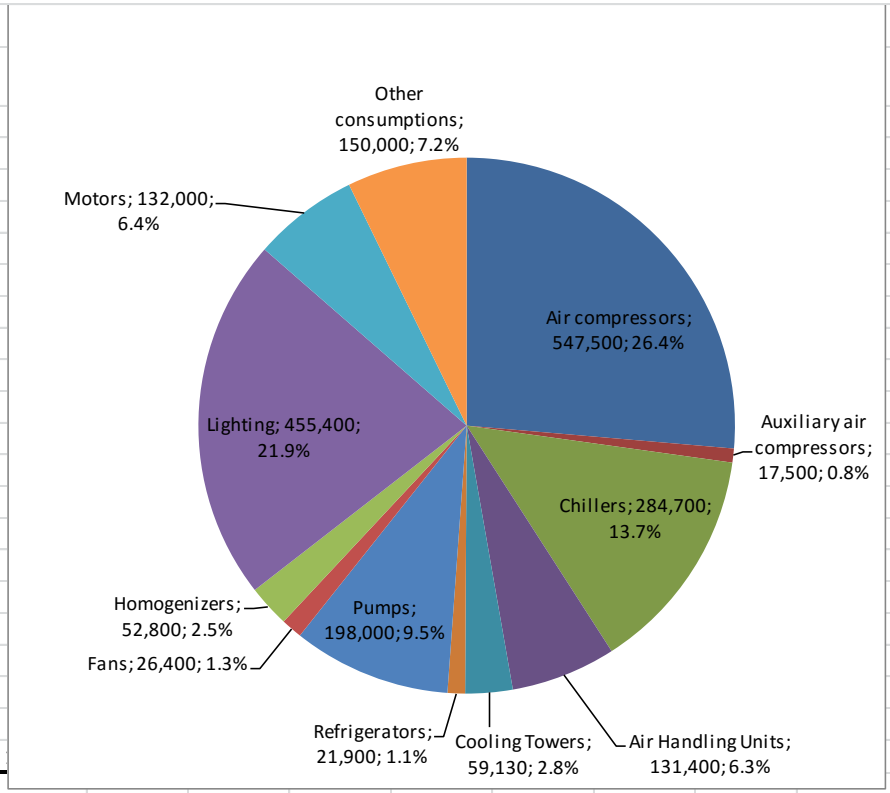
Equipment	Electricity consumption
Cooling	6,559
Heating	10,542
Lighting	102,502
Office equipment	85,094
Rest equipment	52,061
Motors	2,541
Heating system	3,350
Elevators	11,563
Baseline load consumption	109,517
Total consumption	383,730



Breakdown of Energy Consumption – (1)

Based on assumptions and: (1) energy bills, (2) energy company measurements, (3) existing metering devices, (4) new metering devices

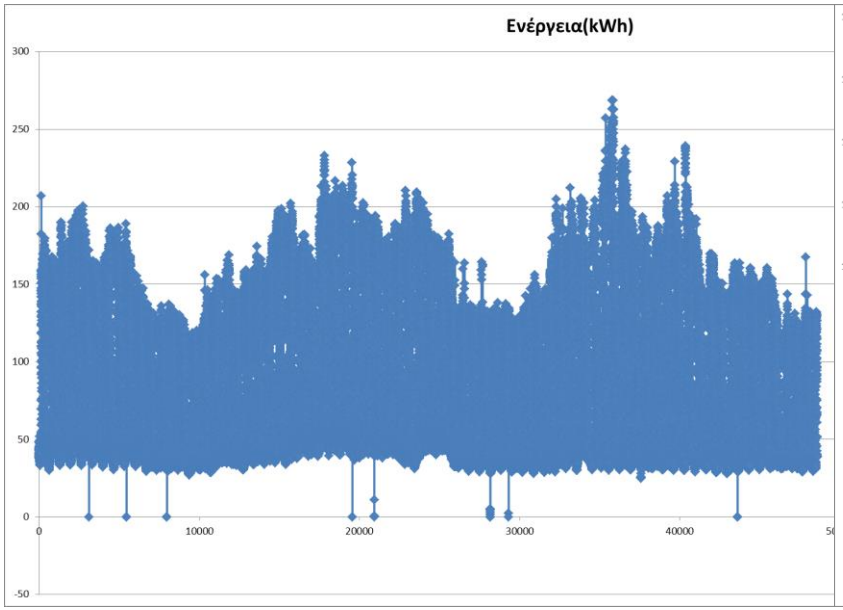
System/Devices	Absorbed Power kW (1)	Operational hours/year (2)	Usage Coefficient (3)	Yearly Energy Consumption (kWh) (1x2x3)	%
Air compressors	125	8760	0.5	547,500	26.4%
Auxiliary air compressors	50	500	0.7	17,500	0.8%
Chillers	65	8760	0.5	284,700	13.7%
Air Handling Units	20	8760	0.75	131,400	6.3%
Cooling Towers	15	8760	0.45	59,130	2.8%
Refrigerators	5	8760	0.5	21,900	1.1%
Pumps	50	6600	0.6	198,000	9.5%
Fans	20	3300	0.4	26,400	1.3%
Homogenizers	40	3300	0.4	52,800	2.5%
Lighting	69	6600	1	455,400	21.9%
Motors	50	6600	0.4	132,000	6.4%
Other consumptions				150,000	7.2%
				0	0.0%
				0	0.0%
				0	0.0%
				0	0.0%
				0	0.0%
				0	0.0%
				0	0.0%
				0	0.0%
Total				2,076,730	1.000

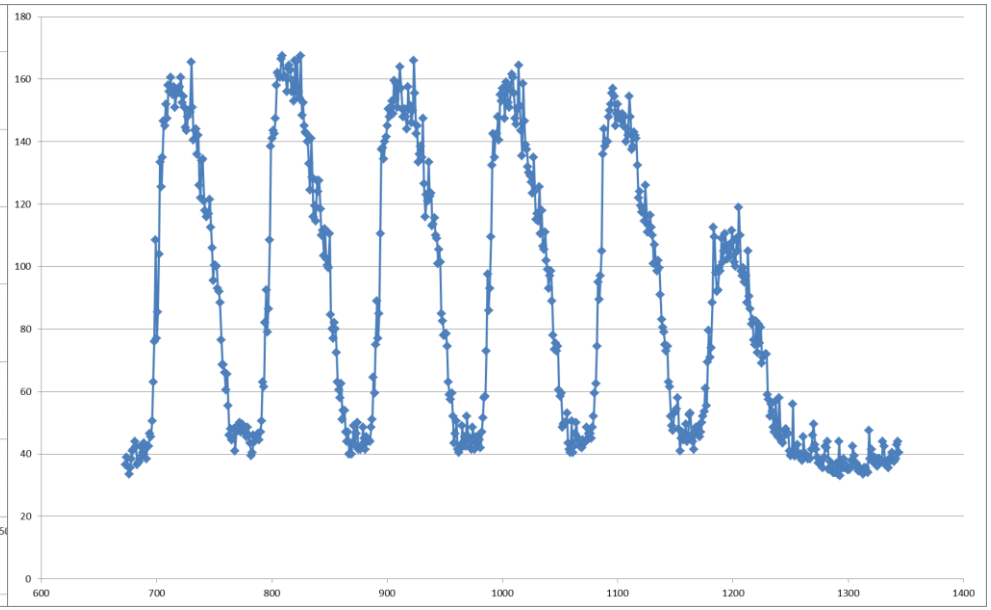


Breakdown of Energy Consumption – (3)

Energy company measurements

In the case of installations that have an electrical supply of medium voltage (e.g. 20.000 V), the energy companies usually have *readily-available yearly measurements* from 5-min to 1 hour intervals. These can be very useful to disaggregate energy usages.





Breakdown of Energy Consumption – (4)

Existing Building Management System (BMS) measurements

In the case of some modern buildings, a BMS system is sometimes installed which allows a *better estimation of the breakdown of the energy consumption*. Even in this case however, there are often several difficulties. Typical examples include:

- BMS systems that only produce non-workable print-outs which are filed for EN ISO 14001 procedures (e.g. hotel in Athens).
- BMS systems that only monitor specific sub-circuits which are not always those required by the energy auditor (e.g. hotel in Athens)
- BMS systems that only give alarms when something doesn't work but don't collect information

Breakdown of Energy Consumption – (5)

New measurements

In the majority of cases, new measurements are a necessity if one wants to reliably and accurately break down the energy consumption.

In order to do this, at least one (1) week of multiple measurements is needed in order to cover the load profiles of both weekdays and weekends.

Optimally, one should aim to have detailed weekly measurements for each season of the year (i.e. summer, autumn, winter and spring).

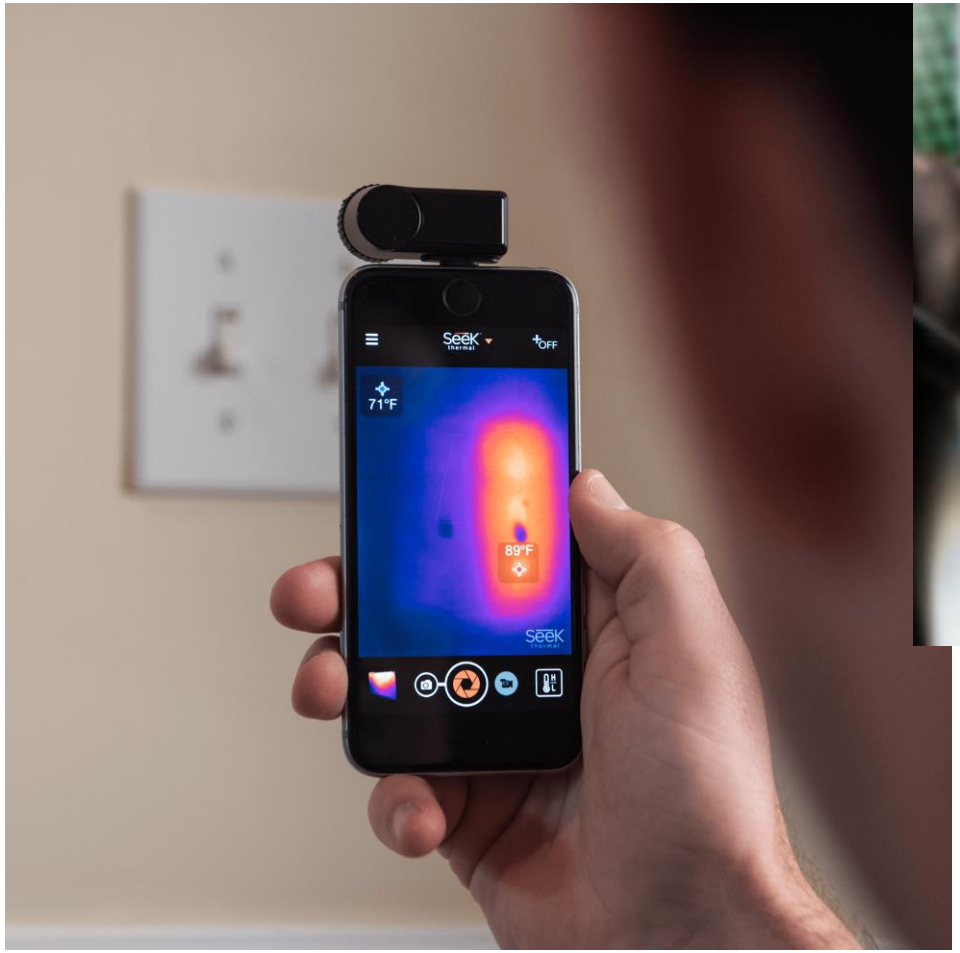
Moreover, even if the client has available measurements, in order to reliably propose energy efficiency measures, the energy auditor should also undertake his/her own measurements for verification purposes.

Electrical measurements – Electricity meter analyzer

Optimally, the mains switch should be turned off when connecting the device, otherwise it is recommended that the building electrician makes the necessary connections.

- Familiarity with equipment (e.g. type of clamps, battery functionality, electrical outlet functionality)
- Range of clamps available
- Safety issues (e.g. gloves, protection for gloves, dust)

Thermographic camera



Temperature/Humidity/Lighting level loggers

- Remember to set the time before operating

Flue gas analyzer

- Familiarity with equipment
- Measurement during steady operation of the boiler.
- Check filter
- Portable printer with magnet is very useful

Thermal energy measurements

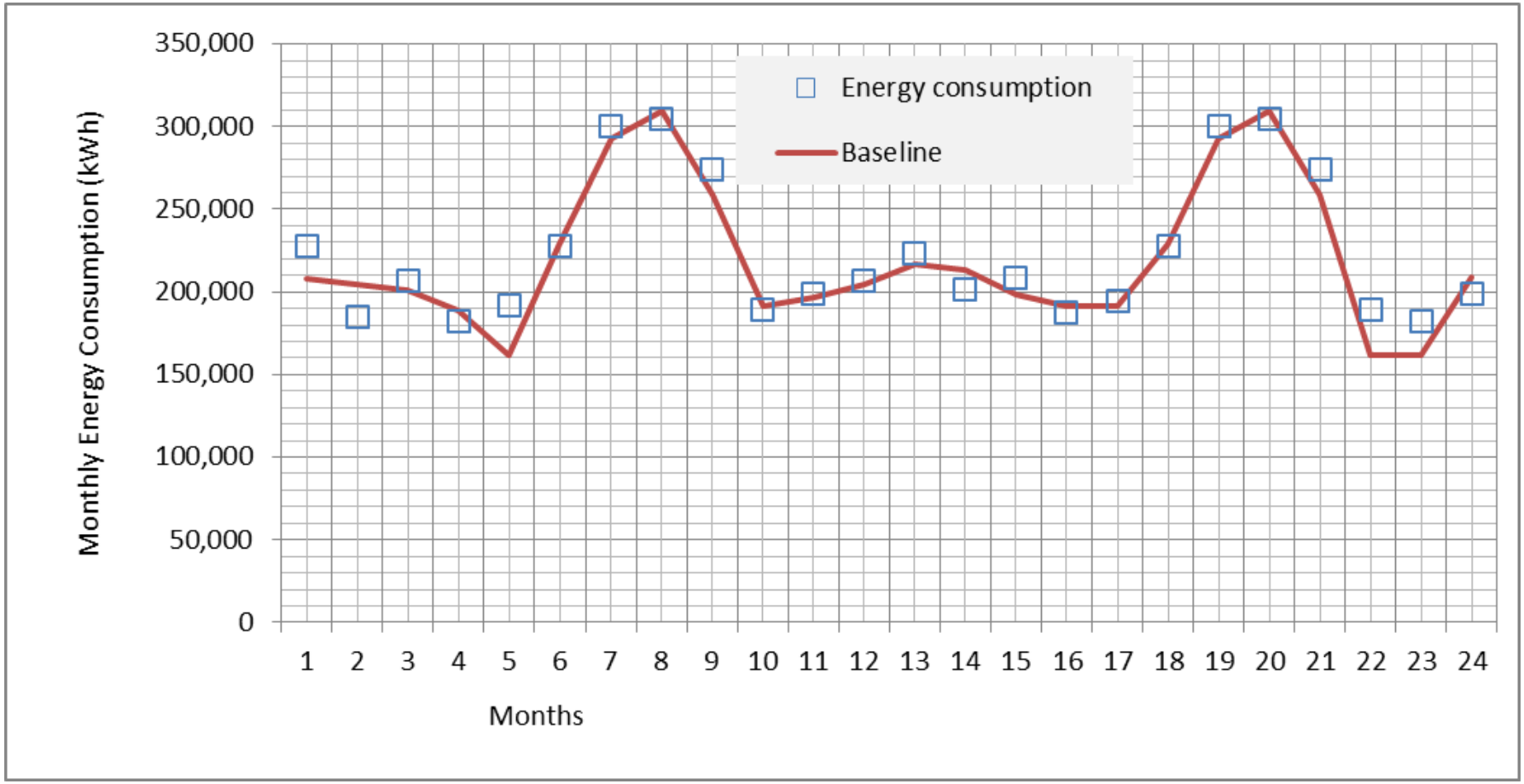
Non-intrusive method

- Ultrasound
- Clean surface required
- Dimensions of pipe necessary
- Two-phase fluid cannot be measured accurately

Intrusive

- Requires cutting of pipes
- Flow rate meter and temperature sensors

Energy Consumption and Baseline



Step 4: Energy Efficiency Improvements

Based on the existing energy performance situation of the audited object, the energy auditor shall identify energy efficiency improvement opportunities.

b) The energy auditor shall evaluate the impact of each energy efficiency improvement opportunity on the existing energy performance situation based on:

1. the financial savings enabled by the energy efficiency improvement measures;
2. the necessary investments;
3. the return on investment or any other economical criteria agreed with the organization;
4. the other possible non-energy gains (such as productivity or maintenance);
5. the comparison in terms of both cost and energy consumption between alternative energy efficiency

Energy saving actions shall be ranked upon the agreed criteria.

c) In those cases where it is appropriate to the agreed scope aim and thoroughness of the energy audit, the energy auditor shall complement these results with:

1. requirements for additional data;
2. the definition of need for further analysis.

d) The energy auditor shall:

1. evaluate the reliability of data provided and highlight defaults or irregularities;
2. use transparent and technically appropriate calculation methods;
3. document the methods used and any assumption made.
4. subject the results of the analysis to appropriate quality and validity checks
5. consider any regulatory or other constraints of the

Drawing-up of an energy saving action plan

The Energy Auditor has to draw up an action plan for the in-time implementation of the proposed energy efficiency measures, if such a task is foreseen in the audit's terms, based on the time-programming principles.

This planning should be made for each phase of implementation and includes:

- targets and measures that have to be implemented in each phase,
- the time-schedule of each phase,
- the requested organization and the budget for the implementation costs,
- the determination of the way that the work-progress will be monitored,
- the delimitation of the monitoring/measuring or/and evaluation of each phase results procedure.

References

- European Energy Directive 27/2012
- EN 16247 – part 1. General Requirements
- Guidebook for Energy Audits. 2017. Hellenic Ministry of Energy and Environment

Typical tools and time frames for energy audits

Time frames

The time taken to perform an energy audit depends on:

- the availability of energy data,
- the size of the site, and
- the complexity of the systems:

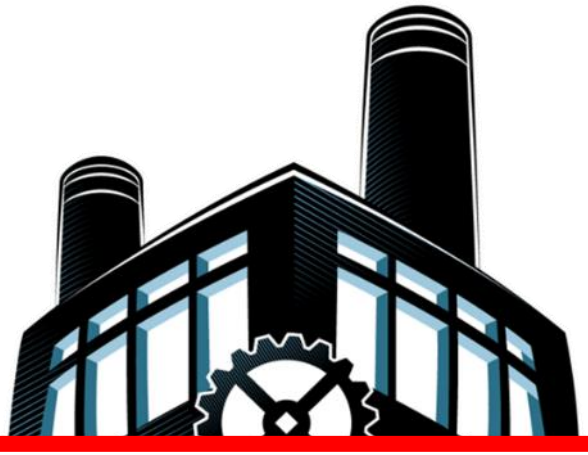
- A walk-through audit might take only a few hours for a simple site for which information is readily available.
- On more complex sites, a week or more could be easily spent simply on analyzing invoices and records.

ENERGY MANAGEMENT SYSTEMS

What is Missing in the Project-Based Approach to Energy Efficiency?

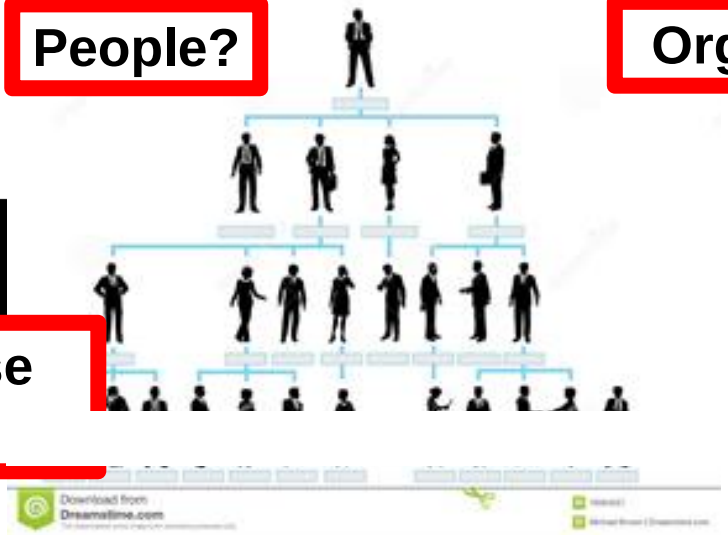
Project-Based Focus on Technological Change

But what about…



Organizational Barriers?

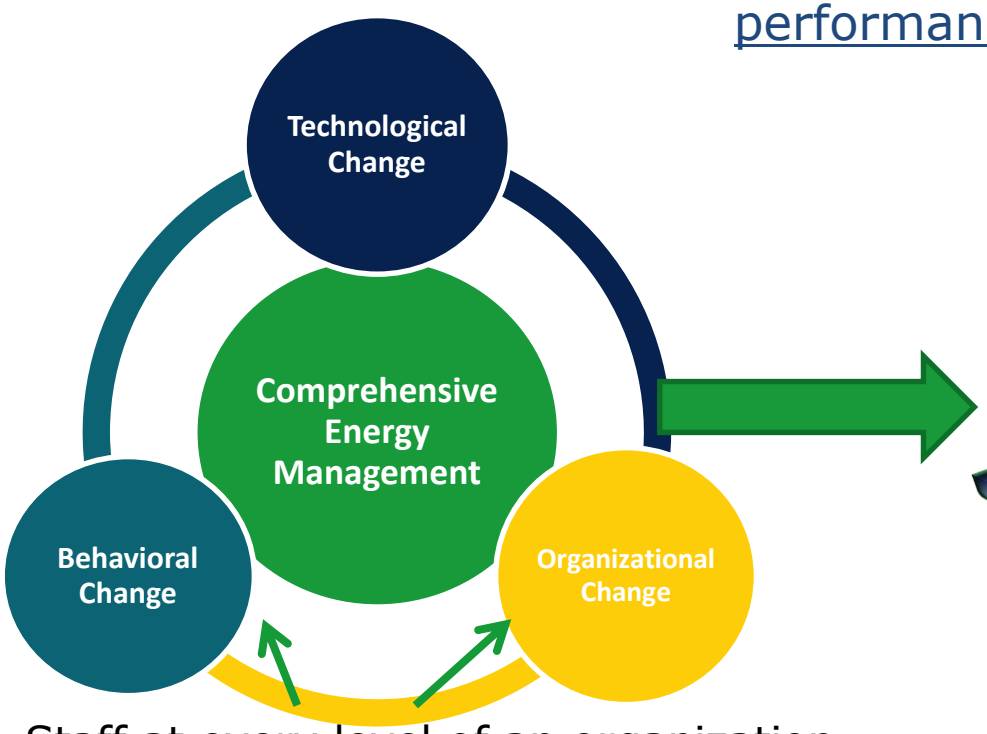
People?

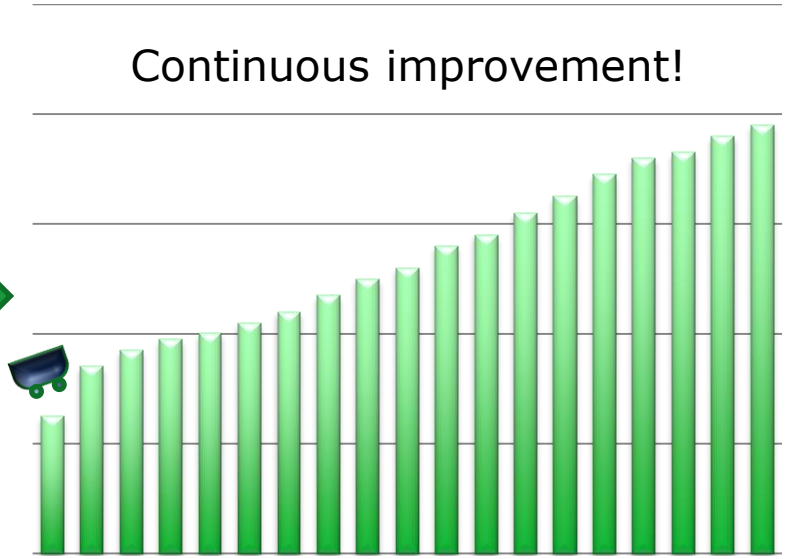


Overall Energy-Use Strategy?

A More Comprehensive Approach To Energy Efficiency Is Needed

Organizations that target behavioral and organizational barriers, as well as technological, can achieve continuous improvement in energy performance.





Energy & Cost Savings
(over time)

Staff at every level of an organization need to be engaged and involved in order to achieve energy goals!

ISO 50001 - A Key Strategy For Fighting Climate Change

Over +50 countries have worked together through ISO to create a globally-relevant standard that countries can leverage to meet their international climate commitments

International Organization for Standardization

ISO 50001 is:

- Ambitious and Quantifiable:
  - Relevant to sectors that account for over 50% of global energy use
  - Data-driven action to improve energy performance on a continual basis
- Transparent, comparable and verifiable:
  - Globally-harmonized; transparent certification process; internationally-relevant
- Business Friendly

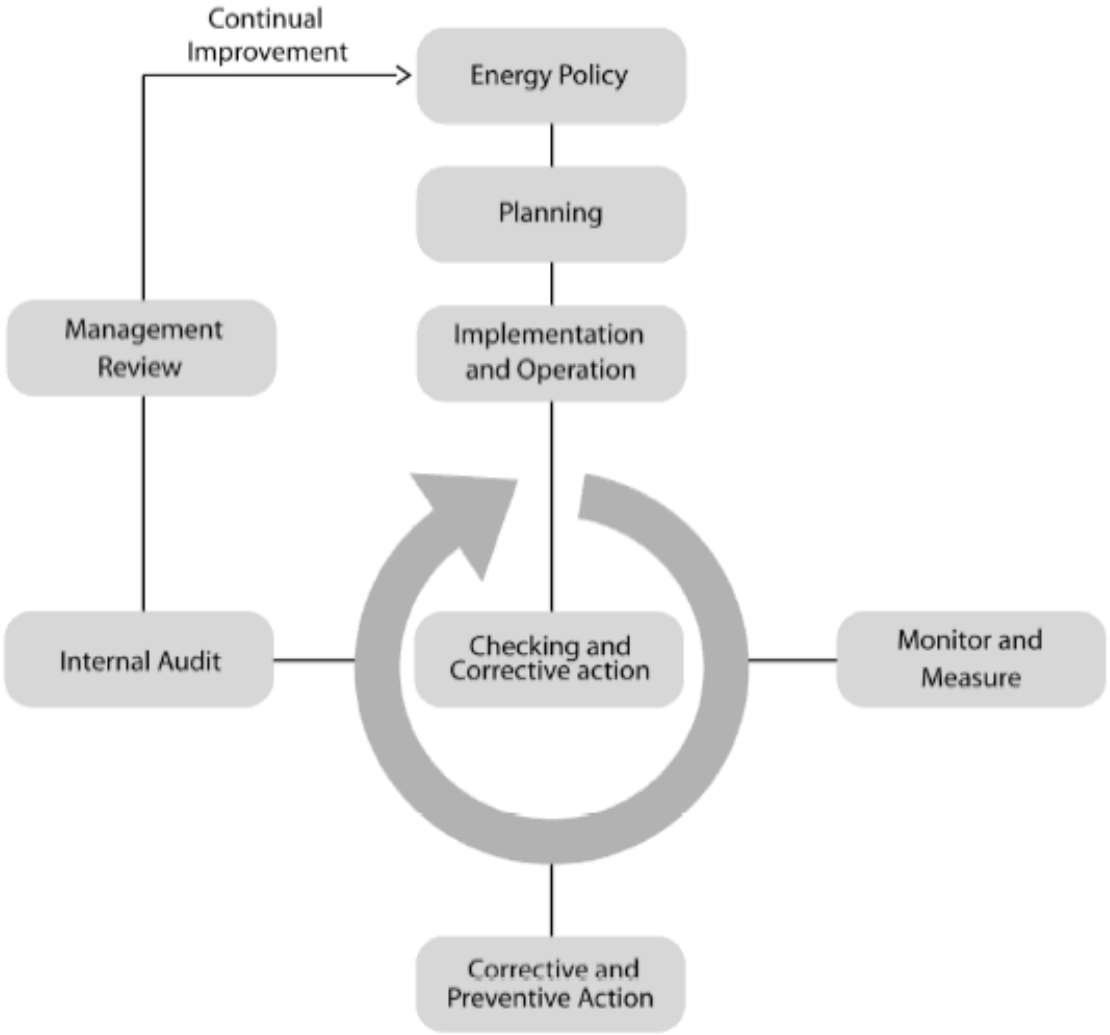
~15,000 certified sites worldwide since 2011

What Are Energy Management Systems (EnMS)?

- **Objectives:**
  - **Measure & baseline**
  - **Monitor & plan**
  - **Continually improve energy efficiency**

- **Main criteria:**
  - Management System Approach
    →The organization makes commitment

  - Requirement for a corporate policy to manage energy efficiency
    - Plan,Do,Check,Act and continuous improvement
    - Similar structure as ISO 14001 (different requirements)



Key Requirements of Energy Management Systems

Examples extracted from EN 16001 and ISO 50001

- Establish, implement and maintain an **energy policy** with commitment for achieving energy performance (energy efficiency & use of renewable sources)
- Define priorities and set appropriate **objectives and targets** using **energy performance indicators** and have in place an energy metering plan
- Conduct an initial **diagnosis of energy consumption** for all activities (including past, present and future energy consumption)
- **Identify the main factors** that have an influence on energy consumption
- Establish the **relationships between energy consumption and energy factors**
- Build a **periodic forecast of energy consumption** and identify opportunities of energy savings
- Consider energy consumption in the decision process for **design** and **procurement** of **all** equipment, raw materials or services
- Identify applicable **regulation** and/or other requirements (such as clients' specifications)
- **Management** review of activities to ensure that the policy is implemented and that the EnMS remains appropriate.

EnMS concerns …..

- ISO 50001 is applicable to any organization whatever the size, industry or geographical location.
- It is particularly relevant if the organization operates energy intensive processes or faces a greenhouse gas emissions challenge.

All activities and industries are concerned

- Manufacturing (Aerospace, Automotive, Electrical, Electronics…)
- Process industries & Mining (Chemical, Pharmacy, Metals, Paper, Cement, Glass, Wood, Oil&Gas …)
- Power & Utilities (Energy Production, Energy and Water Distribution, Water and Waste Treatment…)
- Food
- Construction & Real estate
- Transportation & Infrastructures
- Retail
- Services (Healthcare, Finance, Insurance, Telecom, Tourism…)
- Government & Public organizations (Public Administration, Public sector service delegation …)

References

- Advancing Sustainable Energy Cooperation in North America. November 2016. Ms. Graziella Siciliano. Energy Management Working Group. U.S. Department of Energy

- Energy Management System ISO 50001. Baudouin Hue. Bureau Veritas.

MONITORING AND VERIFICATION OF SAVINGS

IPMVP Protocol

The International Performance Measurement and Verification Protocol (IPMVP) Volume I is a guidance document describing common practice in measuring, computing and reporting savings achieved.

The IPMVP presents a framework and four measurement and verification (M&V) Options for transparently, reliably and consistently reporting a project's saving.

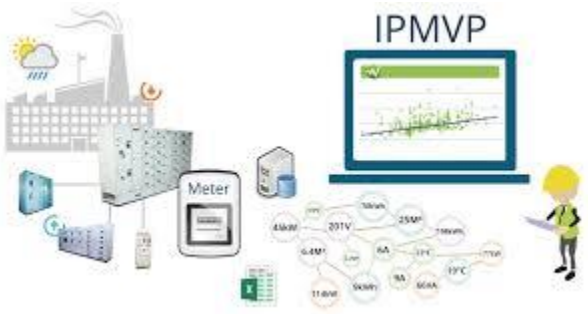
M&V activities include *site surveys, metering of energy or water flow*(s), *monitoring of independent variable(s), calculation, and reporting*. When adhering to IPMVP's recommendations, these M&V activities can produce verifiable savings reports.

The IPMVP is intended to be used by professionals as a basis for preparing savings reports.

M&V activities consist of some or all of the following:

- meter installation calibration and maintenance,
- data gathering and screening,
- development of a computation method and acceptable estimates,
- computations with measured data, and
- reporting, quality assurance, and third party verification of reports.

When there is little doubt about the outcome of a project, or no need to prove results to another party, *M&V* may not be necessary. However, it is still wise to verify that the installed equipment is able to produce the expected *savings*.



Option A

IPMVP Option	How Savings Are Calculated	Typical Applications
A. Retrofit Isolation: Key Parameter Measurement *Savings* are determined by field measurement of the key performance parameter(s) which define the *energy* use of the *ECM*'s affected system(s) and/or the success of the project. Measurement frequency ranges from short-term to continuous, depending on the expected variations in the measured parameter, and the length of the *reporting period*. Parameters not selected for field measurement are *estimated. Estimates* can based on historical data, manufacturer's specifications, or engineering judgment. Documentation of the source or justification of the *estimated* parameter is required. The plausible *savings* error arising from *estimation* rather than measurement is evaluated.	Engineering calculation of *baseline* and *reporting period energy* from: ○ short-term or continuous measurements of key operating parameter(s); and ○ *estimated* values. *Routine* and *non-routine adjustments* as required.	A lighting retrofit where power draw is the key performance parameter that is measured periodically. Estimate operating hours of the lights based on building schedules and occupant behavior.

Option B

IPMVP Option	How Savings Are Calculated	Typical Applications
B. Retrofit Isolation: All Parameter Measurement *Savings* are determined by field measurement of the *energy* use of the *ECM*-affected system. Measurement frequency ranges from short-term to continuous, depending on the expected variations in the *savings* and the length of the *reporting period*.	Short-term or continuous measurements of *baseline* and *reporting-period energy*, and/or engineering computations using measurements of proxies of *energy* use. Routine and non-routine adjustments as required.	Application of a variable-speed drive and controls to a motor to adjust pump flow. Measure electric power with a kW meter installed on the electrical supply to the motor, which reads the power every minute. In the *baseline period* this meter is in place for a week to verify *constant* loading. The meter is in place throughout the *reporting period* to track variations in power use.

Option C

IPMVP Option	How Savings Are Calculated	Typical Applications
C. Whole Facility *Savings* are determined by measuring energy use at the whole *facility* or sub-*facility* level. Continuous measurements of the entire *facility's energy* use are taken throughout the *reporting period*.	Analysis of whole *facility baseline* and *reporting period* (utility) meter data. *Routine adjustments* as required, using techniques such as simple comparison or regression analysis. *Non-routine adjustments* as required.	Multifaceted energy management program affecting many systems in a *facility*. Measure energy use with the gas and electric utility meters for a twelve month *baseline period* and throughout the *reporting period*.

Option D

IPMVP Option	How Savings Are Calculated	Typical Applications
D. Calibrated Simulation *Savings* are determined through simulation of the *energy* use of the whole *facility*, or of a sub-*facility*. Simulation routines are demonstrated to adequately model actual *energy* performance measured in the *facility*. This Option usually requires considerable skill in calibrated simulation.	Energy use simulation, calibrated with hourly or monthly utility billing data. (Energy end use metering may be used to help refine input data.)	Multifaceted energy management program affecting many systems in a facility but where no meter existed in the *baseline* period. Energy use measurements, after installation of gas and electric meters, are used to calibrate a simulation. *Baseline* energy use, determined using the calibrated simulation, is compared to a simulation of *reporting period* energy use.

Thank you for your attention!

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