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BSI Standards Publication

Energy audits

Part 2: Buildings

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National foreword

This British Standard is the UK implementation of EN 16247-2:2014.

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A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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Foreword

This document (EN 16247-2:2014) has been prepared by Technical Committee CEN/CLC/JWG 1 “Energy audits”, the secretariat of which is held by BSI.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by November 2014 and conflicting national standards shall be withdrawn at the latest by November 2014.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

This Part provides additional material to Part 1 for the Buildings sector and should be used in conjunction with Part 1.

This European Standard is part of the series EN 16247 *“Energy audits”* which comprises the following:

— Part 1 General requirements;

— Part 2 Buildings;

— Part 3 Processes;

— Part 4 Transport;

— Part 5 Competence of energy auditors.

According to the CEN-CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

0 Introduction

An energy audit can help an organization to identify opportunities to improve energy efficiency. It can be part of a site wide energy management system.

The use and operation of buildings requires the provision of services such as heating, cooling, ventilation, lighting, domestic hot water, transportation systems (e.g. elevators, escalators and moving walkways) in buildings and processes. In addition, energy is used by appliances within the building.

The energy consumption depends on:

— local climatic conditions;

— the characteristics of the building envelope;

— the designed indoor environment conditions;

— the characteristics and settings of the technical building systems;

— activities and processes in the building;

— occupant behaviour and operational regime.

Dealing with buildings, the audited objects are sometimes similar, technically simple and numerous (as in the residential sector) but can also be unique, complex and highly technical (such as hospitals, swimming pools and spas, etc.).

Energy audits in buildings may include the whole building or parts of the building or some technical system.

Energy performance indicators (benchmark values, if available) or average statistical specific energy consumption data are usually published nationally for different building types and ages. This information can be used in the analysis to provide comparative energy performance evaluation.

NOTE The energy audits covered under this standard might be independent from building energy performance certification and other legislative requirements.

1 Scope

This European Standard is applicable to specific energy audit requirements in buildings. It specifies the requirements, methodology and deliverables of an energy audit in a building or group of buildings, excluding individual private dwellings. It shall be applied in conjunction with, and is supplementary to, EN 16247-1, *Energy audits — Part 1: General requirements*. It provides additional requirements to EN 16247-1 and shall be applied simultaneously.

If processes are included in the scope of the energy audit, the energy auditor may choose to apply EN 16247-3, *Energy audits — Part 3: Processes*. If on-site transport on a site is included in the scope of the energy audit, the energy auditor may choose to apply EN 16247-4, *Energy audits — Part 4: Transport*.

NOTE This standard may cover multi-dwelling apartment blocks where communal services are supplied from a landlord. It is not intended for individual dwellings and single family houses.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 16247-1, *Energy audits - Part 1: General requirements*

EN 15603, *Energy performance of buildings - Overall energy use and definition of energy ratings*

3 Terms and definitions

For the purposes of this European Standard, the terms and definitions given in EN 16247-1 and the following apply.

3.1
building
construction as a whole, including its envelope and all technical building systems, for which energy may be used to condition the indoor climate, to provide domestic hot water and illumination and other services related to the use of the building and the activities performed within the building

Note 1 to entry: The term can refer to the building as a whole or to parts thereof that have been designed or altered to be used separately.

Note 2 to entry: The building could include its site location and related external environment.

3.2
system boundary
boundary that includes within it all areas associated with the audited object (both inside and outside the audited object) where energy is consumed or produced

Note 1 to entry: Inside the system boundary the system losses are taken into account explicitly, outside the system boundary they are taken into account in a conversion factor.

3.3
energy need
energy to be delivered to or extracted from a building in a defined time period by a technical system to provide a building service

3.4
energy carrier
substance or physical phenomenon that can be used directly or indirectly to be transformed into useful energy

Note 1 to entry: The default energy content of fuels is gross calorific value.

3.5
delivered energy (final energy)
energy, expressed per energy carrier, supplied to the technical building systems through the system boundary, to satisfy the uses taken into account or to produce electricity

Note 1 to entry: Delivered energy can be calculated for defined energy uses or it can be measured.

Note 2 to entry: Energy uses include heating, cooling, ventilation, domestic hot water, lighting, appliances, etc.

3.6
produced energy
heat or electricity generated within the system boundary

Note 1 to entry: Produced energy can be used within the system boundary or exported.

3.7
exported energy
energy, expressed for each energy carrier, delivered by the technical building systems through the system boundary and used outside the system boundary

Note 1 to entry: It can be specified by generation types (e.g. CHP, photovoltaic, etc) in order to apply different weighting factors.

Note 2 to entry: Exported energy can be calculated or it can be measured.

[SOURCE: CEN/TR 15615, 3.19]

3.8
building services
the services provided by the technical building systems and by appliances to condition the indoor environment (thermal comfort, air quality, visual and acoustic quality) and other services related to the use of the building

3.9
technical building system
technical equipment for heating, cooling, ventilation, domestic hot water, lighting and on-site energy production

Note 1 to entry: A technical building system can refer to one or a combination of building services (e.g. heating system include heating, domestic hot water system and controls).

Note 2 to entry: A technical building system is composed of different subsystems and includes controls.

Note 3 to entry: On-site energy production can include heat or electricity.

4 Quality requirements

4.1 Energy auditor

4.1.1 Competency

The energy auditor shall demonstrate that they have qualifications or experience covering the scope, complexity and thoroughness of the audit.

NOTE See prEN 16247–5[1].

4.1.2 Confidentiality

The energy auditor shall respect all the legal and commercial confidentiality requirements agreed with the organization, which cover all parties involved, such as tenants, maintenance organizations, building occupants.

4.1.3 Objectivity

Objectivity is defined in EN 16247-1, 4.1.3

4.1.4 Transparency

Transparency is defined in EN 16247-1, 4.1.4

4.2 Energy audit process

When a sampling method is used, any selected sample of spaces, systems or equipment shall be representative of the whole building or of a group of buildings.

NOTE See Informative Annex A: A flow diagram of the energy audit process.

5 Elements of the energy audit process

5.1 Preliminary contact

The energy auditor shall identify all parties/organizations and their roles in ownership, management, use, operation and maintenance of the building and their respective impacts and interests on energy use and consumption.

NOTE 1 See Informative Annex B: Examples of parties of an energy audit in buildings.

The scope of the audit should be agreed to cover technical interaction of the systems within the building, and the interaction of the systems with the building. Optimization of some specific sector to the exclusion of others may give misleading results.

The agreed aims of the energy audit may contain:

a) reducing energy consumption and costs;

b) reducing environmental impact;

[1] prEN 16247-5 is currently not yet published and is under development.

c) complying with legislation or with voluntary obligations.

The energy audit scope and boundaries shall define what is included, in terms of:

a) which buildings from a list of buildings or parts of a building;

b) which energy services;

c) which technical building systems;

d) which areas and systems outside the building;

e) which energy performance indicators could be used as appropriate to the audit.

The energy audit degree of thoroughness shall be agreed, taking into account that it will impact:

a) time on site;

b) choice of samples;

c) level of modelling;

d) requirements for measurements;

e) level of metering, including sub-metering;

f) level of defining the energy efficiency improvement opportunities;

g) required auditor’s skills.

NOTE 2 See Informative Annex C: Examples of the scope, aim and thoroughness of energy audits in buildings.

5.2 Start-up meeting

During the start-up meeting the energy auditor shall agree with the organization on:

a) timing of site visits, e.g. whether within or outside normal working hours;

b) level of occupant engagement;

c) areas of restricted access;

d) potential health hazards and risks.

The energy auditor shall, where available, obtain from the organization:

a) set-points and operational limits of indoor environmental conditions (such as temperatures, air flows, illuminance, noise) and any seasonal variations;

b) occupancy patterns for the different range of activities within the building;

c) comments from any occupant or other party on operational performance of the building and the level of the building service;

d) energy certificates prepared for the building;

e) whether any building occupant awareness or motivation programmes have been implemented.

5.3 Collecting data

5.3.1 General

The data collection shall be appropriate to the scope of the energy audit.

5.3.2 Information request

The energy auditor shall collect with the organization the following data as required by the scope of the energy audit:

a) energy carriers, present and available;

b) energy related data:

   1) delivered, produced and exported energy, for each energy carrier (for example identify the energy streams for a CHP unit, or for photovoltaic systems where production is used locally or exported);

   2) energy consumption data (or readings with related time and date) of any available meters or counters (e.g. heat meter, domestic hot water meter, fuel meter, burner hour counter);

   3) data from individual metering, if available;

   4) short-interval (e.g. hourly) energy demand / load curve, if available;

   5) relevant related measurements;

The frequency of the data should be appropriate to the scope and thoroughness of the energy audit. Building energy audits typically deal with monthly consumption data.

The energy related data should be recorded by the building and control system if available.

c) adjustment factors affecting energy consumption:

   1) climatic data (e.g. temperature, degree-days, hygrometry, lighting) from the local building automation and control system (BACS), if available;

   2) occupancy patterns;

Information for quantifying the adjustment factors affecting energy consumption should be recorded by the building control system if available (e.g. occupancy times, degree-hours etc).

d) information on important changes in the past 3 years or the period covered by the available operational data, concerning:

   1) the physical form of the building;

   2) the spaces – either in dimension and/or in use;

   3) the building envelope (renovation of windows, added insulation, etc.);

   4) the technical building systems and the areas they serve;

   5) the tenant arrangements;

   6) occupancy of spaces (different occupancy times, extended hours behaviour and internal loads);

   7) set points and occupant behaviour;

e) values to be used, adapted to the local /national performance indicators (if relevant):

   1) floor area;

   2) building volume;

   3) others;

f) existing design, operation and maintenance documents and information, such as:

   1) as-built building plans;

   2) any external factors that may influence the energy performance of the building (e.g. shading by adjacent trees or buildings);

   3) indications of supplied building services (i.e. which rooms or zones are heated, cooled, ventilated) on the building lay-out plan;

   4) technical building system schematics, indicating the system zones, if any;

   5) control diagrams and settings;

   6) appliance and component data and ratings;

g) the building information model (BIM) and/or design models of the building, if available;

h) energy using equipment in the occupied spaces and other internal loads.

5.3.3 Review of the available data

The energy auditor shall review the information collected and provided by the organization.

The energy auditor shall review the scope and boundaries of the energy audit if it is deemed appropriate once initial information has been received.

The energy auditor shall judge whether or not the information provided by the organization allows the energy audit process to continue and the agreed objectives to be achieved.

Where there is missing data the client will be given a choice to produce the missing data or accept that the auditor will have to make assumptions (that will be clearly detailed).

The energy auditor shall, based on experience and competence, choose the energy using systems and items to be checked on site, depending on the aim, scope and thoroughness of the energy audit.

5.3.4 Preliminary data analysis

The energy auditor shall carry out an analysis of the data collected to:

a) undertake a preliminary analysis of the audited object’s energy balance on the basis of energy data;

b) establish the relevant adjustment factors;

c) establish the relevant energy performance indicators;

d) evaluate the distribution of energy consumption (consumption breakdown) if possible, depending on the measured data available;

e) if there is sufficient information, establish an initial energy reference (energy baseline) to be used for quantifying the impacts of energy saving interventions;

f) plan further data collection and measurement to be carried out during field work.

The energy auditor should develop a preliminary list of energy efficiency improvement opportunities.

5.4 Field work

5.4.1 Aim of field work

The energy auditor shall inspect the audited object(s) within the scope of the audit. The energy auditor shall:

a) inspect the site against the data received;

b) evaluate for each significant building service the actual and future level of service (e.g. temperature, humidity, illuminance level, etc.);

c) check that the technical systems are adequate for the intended purpose, i.e. can deliver the required level of service;

d) evaluate the performance of the technical systems, taking into account the generation, storage, distribution and emission system and control;

e) understand the drivers for the changes in the technical systems, such as seasonal demands;

f) look for energy efficiency improvement opportunities and related constraints and restrictions.

NOTE See Informative Annex D: Checklist for energy audit field work in buildings.

5.4.2 Conduct

The conduct of an energy auditor during field work is defined in EN 16247-1, 5.4.2.

5.4.3 Site visits

Site visits are defined in EN 16247-1, 5.4.3.

The energy auditor shall ask the organization to:

a) arrange access (read only) to building automation and control system (BACS) and electronic data sources;

b) provide authorized assistance for any tests and operations required in the energy audit, e.g. switching on or off systems and equipment;

c) arrange access to the parts of the building which are defined as relevant for conducting the energy audit.

5.5 Analysis

5.5.1 General

In an energy audit in buildings the auditor shall analyse the energy saving potential according to the scope and aim of the audit.

The analysis shall deliver at least:

a) for each building service a comparison of actual against appropriate level of service (such as indoor environmental criteria, etc). The level of service (e.g. temperature, quality of air, illuminance) shall not be compromised by any proposed energy saving measures. Legislative compliance notwithstanding,the level of service may, however, be changed if agreed with the client (e.g. change of indoor temperature to reduce heating or cooling demands);

b) evaluation of the actual performance of the technical systems against a suitable reference;

c) evaluation of the performance of the building envelope;

NOTE Levels of insulation, thermal bridges, air tightness etc.

d) evaluation of the energy performance of the whole building, taking into account the potential interaction between technical systems and the building envelope.

When considering improvements, the energy auditor shall:

a) consider the interaction between the technical building systems, with the building envelope, external environment and the activities performed within the building. EN 15603:2008 allows the quantification of this interaction;

b) take into account all possible impacts for all delivered energy for different time periods (e.g. occupied and unoccupied) and different seasons, that could lead to adverse situations regarding energy savings. (For example, replacement of lighting may decrease internal heat gains, thereby increasing heating loads and reducing cooling loads);

c) evaluate potential impact that energy saving interventions will have on the ratings in the energy performance certificates.

The energy audit should include a review of contracts for the supply of energy and the requirements for the inspection and maintenance of technical equipment in terms of impact on energy efficiency and the cost.

5.5.2 Energy breakdown

The energy auditor details:

a) breakdown of the delivered energy by energy carrier in terms of consumption, cost and emissions in consistent units (e.g. pie-charts);

b) breakdown the energy end-use by service and other use in absolute or specific numbers and in consistent energy units (e.g. pie-charts);

c) if applied, inventory of installed onsite energy production and export to third parties, in absolute numbers.

The energy breakdown shall be representative of the energy input and energy use. Also, it shall be clear which energy flows are based on measurements and which on estimations/calculations.

NOTE 1 See Informative Annex E: Examples of the analysis of energy use in buildings.

NOTE 2 See Informative Annex F: Examples of analysis checklist for energy audits in buildings.

5.5.3 Energy performance indicators

The calculation of the energy performance indicators (specific energy use) or building specific baselines shall be included in the analysis as appropriate. The energy auditor and organization shall agree on the energy performance metric(s) to be used.

NOTE See Informative Annex G: Examples of energy performance indicators in buildings.

5.5.4 Energy efficiency improvement opportunities

The energy auditor shall identify energy efficiency improvement opportunities on the basis of:

a) their own expertise;

b) comparison against benchmarks if applicable;

NOTE This can provide first indication of improvement opportunities, but will not provide details.

c) the building's and technical systems' age, condition, how they are operated and maintained;

d) the technology of existing systems and equipment in comparison to the best available technology;

e) best practices.

NOTE 1 See Informative Annex H: Examples of energy efficiency improvement opportunities in buildings.

NOTE 2 See Informative Annex I: Examples of analysis and savings calculations in energy audits in buildings.

5.6 Report

5.6.1 General

The reporting format shall be targeted such that it is relevant to both technical and executive personnel.

The energy savings interventions should be reported in the following categories:

a) high cost measures (building shell, technical building equipment, etc.);

b) low cost measures (adaption of operation mode, reduction of supply losses, etc.);

c) training and awareness of end-users (training and motivation, and behaviour change);

d) review requirements of comfort, health and well-being (temperature- and humidity-level, room size, etc.).

5.6.2 Content of report

NOTE See Informative Annex J: Examples of the reporting of an energy audit in buildings.

The report should include recommendations for future measurement and verification methods for the energy saving interventions proposed. See Annex K for an example.

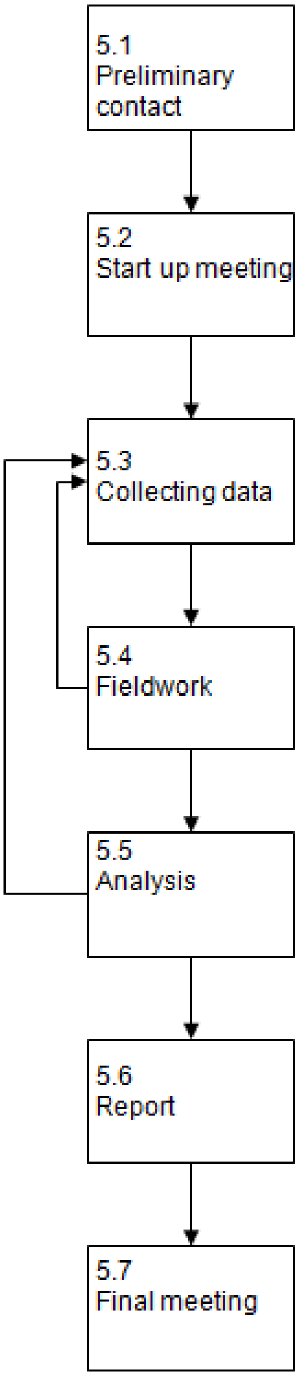
5.7 Final meeting

The requirements for a final meeting are defined in EN 16247-1, 5.7.

Annex A
(informative)

Energy audit process flow diagram

The main steps of the energy audit process are shown below.



Annex B
(informative)

Examples of parties of an energy audit in buildings

Examples of parties involved in a building energy audit and their roles are shown below.

There needs to be suitable authority from the energy audit client to instruct the appropriate organizations and people to support the energy auditor.

NOTE (x) means indirect involvement

Table B.1

Party	Possible recipient of the energy audit	Data provider	Involved in the meetings	Involved in the field work
building or apartment owner	X	X	X	
property manager	X	X	X	
facilities manager	X	X	X	X
engineering services manager		X	X	X
operation and maintenance staff		X	X	X
security staff			(x)	(x)
occupant				
staff (who work there permanently)			(x)	Partly
temporary (patients, clients in a shop)				
tenants				
commercial	X	sometimes	no, unless the recipient	X
residential	(x)		no, unless the recipient	X

Annex C
(informative)

Examples of the scope, aim and thoroughness of energy audits in buildings

C.1 General

The energy audits in buildings may have different levels of thoroughness as shown below.

Table C.1

	THE SCOPE		
Specific System/Area	LIMITED	WIDE	Every System / All Site
	THE THOROUGHNESS		
General Potential Assessment	Light touch	Detailed	Detailed Potential Assessment
	THE AIM		
General screening of saving potential	GENERAL SAVING AREAS	SPECIFIC SAVING MEASURES	Specific Proposals

C.2 Examples of how to define the energy audit aim

Pointing out general saving areas:

a) energy savings may be possible by adjusting ventilation operation schedules (to define the changes in individual time schedules a more thorough audit is needed);

b) improving the boiler plant operation will increase the efficiency.

Listing specific saving measures:

c) for each individual energy saving measure the estimated energy saving in each energy carrier to be shown in the report.

C.3 Examples of how to define the energy audit scope

Limited energy audit scopes:

a) technical systems: audit one system (e.g. ventilation and air conditioning in building A or the chiller plant in building C)

b) energy service: audit one energy service (e.g. heating in buildings A, B and C)

Wide energy audit scopes:

c) audit all energy using technical building systems and all energy services (heating, cooling, domestic hot water);

d) comprehensive energy audit, including all energy use (including building envelope, technical building services, appliances and equipment).

C.4 Examples of how to define the energy audit thoroughness:

Light touch:

a) spend appropriate time on site, checking the low-cost savings and the most significant energy uses;

b) check the parameters (such as time schedules, temperature set points, etc.) influencing energy consumption in the building automation and control system (BACS), not by individual measurements;

c) perform only some sample measurements e.g. on room temperatures;

d) estimate energy savings by using simple energy calculation tools.

Detailed:

e) checking all energy using systems and equipment, spend on site as much time as required for thorough survey of all systems;

f) perform extensive measurements on temperatures, air flows, electricity use, etc. and spend on site as much time as required for the thorough measuring scheme;

g) simulate building energy performance by using dynamic calculation tools.

Annex D
(informative)

Examples of checklists for energy audit field work in buildings

D.1 General

In visiting the building and systems, the energy auditor should gather suitable information to evaluate actual performance of the audited object and to assess feasibility of improvements.

D.2 Checklist

This checklist contains examples for the auditor's field work (what to inspect) but it can be also used for defining the scope of the audit or initial data collection.

Main item	Sub-items to inspect	Check
The building envelope	Heating related properties	
	Permeability	
	Cooling related properties	
	Daylighting related properties including glazing type	
The heating system(s) and control	Room equipment	
	Distribution	
	Generation and thermal storage	
The domestic hot water system(s) and control	Fixtures	
	Distribution	
	Storage	
	Generation and thermal storage	
The cooling system(s) and control	Room equipment	
	Distribution	
	Generation and thermal storage	
The ventilation and air conditioing system and control	Room equipment	
	Air-handling units	
	Heat recovery	
The lighting system and control		
Domestic appliances		
Office appliances		
Other appliances (e.g. medical)		
Internal transport systems	Elevators, escalators, moving walkways	
Freeze-protection systems and control	Heated areas, trace heating	
Electric energy distribution	Transformers, UPS, reactive power correction	

Other utilities	Steam, compressed air, medical gases	
The building automation and control system (BACS)		
Other energy using systems	Swimming pools	

D.3 Building visit checklist

This checklist below can be used for the auditor’s field work as a guide to the places to visit (where to go).

Main item	Places to be visited	Check
The building envelope	Roof	
	Walls	
	Windows	
	Basement	
The heating system(s) and control	the boiler room	
	heat distribution rooms	
	distribution manifolds and channels	
The domestic hot water system(s) and control	the boiler room	
	storage	
	individual domestic	
The cooling system(s) and control	the chiller room or the roof where cooling equipment is located	
The ventilation and air conditioning system and control	mechanical rooms where air handling units are located	
	technical spaces	
The lighting system and control	sample rooms, by usage	
	common areas	
	external illuminated areas	
Domestic appliances	sample residential dwellings	
Office appliances	sample rooms, by usage	
	data centres	
Other appliances (e.g. medical, ...)		
Internal transport systems	elevators, escalators, moving walkways…	
Freeze-protection systems and control	power distribution panels	
	protected areas	
	heated areas, trace heating,..	
Electric energy distribution	the transformer room	
	power distribution rooms	
	UPS room	

Other utilities	the steam generation plant	
	steam distribution headers	
	condensate collection tanks and pumps	
	the compressors room	
	compressed air headers and drains	
	swimming pool plant	
	other service production rooms	
	other distribution	
The building automation and control system (BACS)	electronic access	
Other energy using systems	Swimming pools	

D.4 The building envelope

Aspects to be considered in visiting each building envelope elements:

a) U-value and possible improvements and restrictions (accessibility, height, possible resulting thermal bridges, conflicts with building use and appearance);

b) shading and possible improvements and restrictions (for glazed elements and cooling);

c) thermal inertia of the building;

d) air tightness;

e) joints and thermal bridges.

NOTE This is not the same as indoor spaces visit. The focus here is on the building elements and their properties.

Indoor spaces:

a) typical/sample rooms for each use (apartments, offices in an office building, classrooms in a school);

b) spaces with high air flows / ventilation rates (auditoriums, conference centers, restaurants);

c) spaces where there is heavy energy use / high electrical load:

    1) kitchen;

    2) computer / server rooms;

    3) pool areas, etc special rooms;

Outdoor areas:

a) main entrances;

b) loading areas;

c) parking area lighting and car heating;

d) electrically heated areas / snow melting.

D.5 Useful documents

The energy auditor needs documents and drawings of the building and its technical systems for the audit work.

The auditor should be aware that even if documents are available, they may not contain the correct information/latest updates and therefore all essential information should be checked during site inspection.

Examples of relevant documents:

a) building:

   1) building plans;

   2) Building zoning;

      i) asset register;

      ii) building energy log book;

      iii) energy performance certificate;

      iv) display energy certificate;

b) systems (for each within the scope of the audit):

   1) functional diagram;

   2) control diagram;

   3) operating settings list;

      i) air conditioning inspection report;

      ii) mechanical and electrical schematics;

   4) operating schedules;

c) historical data:

   1) delivered energy records and/or bills (for electricity, gas, liquid and solid fuels as approporiate);

   2) heat metering records;

   3) cooling metering records;

   4) domestic hot water records;

   5) other metering records (any other than delivered, like readings from hour counters);

   6) climatic records.

Annex E
(informative)

Examples of the analysis of energy use in buildings

E.1 Overview of the energy use in a building

The building energy audit may cover all or some of the technical building systems and energy flows depending on the agreed scope of the energy audit.

Energy use in a building is linked to:

a) the supply of comfort services (e.g. heating, domestic hot water, ventilation, etc.);

b) the activities in the building and the use of appliances to support activities (e.g. household appliances, computers, office machines, etc.);

c) other energy uses;

Energy supply chain is detailed as:

a) energy needs;

b) for comfort services are determined by the energy balance of the building envelope, taking into account losses, gains and interaction with technical systems;

c) for other services are determined by appropriate balance or accounting procedure (e.g. number, power and utilisation time of devices, appliances, etc.);

d) delivered energy is converted and distributed by the technical systems to fulfill the needs;

e) energy is delivered to the building by energy carriers.

Technical systems are usually analysed as consisting of the following subsystems:

a) generation;

b) storage, to decouple time of generation and use, and optimize sizing and power of generation plant;

c) distribution;

d) room equipment (such as heat emitters, cooling elements and lighting) and their control, that takes into account transfer of energy from systems into the serviced space.

The energy flows of a building are illustrated in the Figure E.1 below.

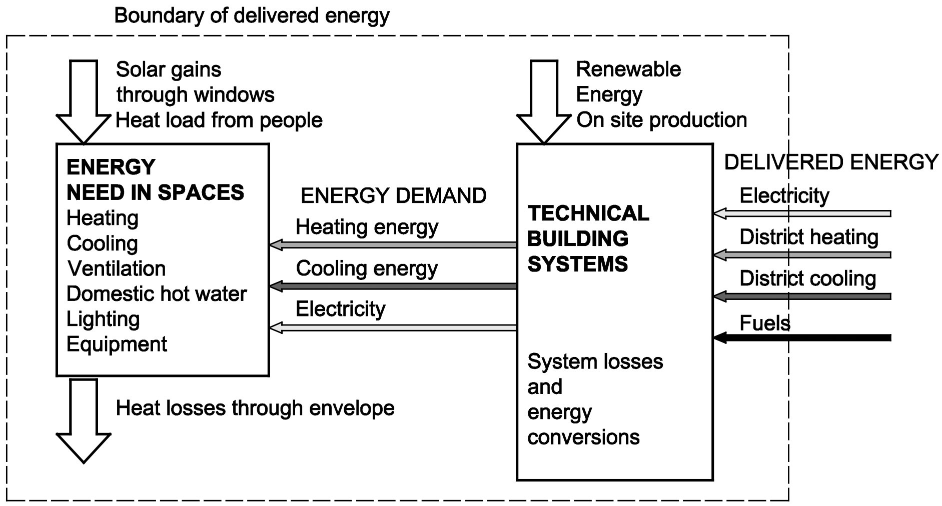


Figure E.1 — Energy flows of a building

E.2 Analysis of the energy use in a building

The energy audit in a building will necessarily include some modelling or calculations to determine the current energy use profile and the energy efficiency improvement opportunities. The energy modelling or calculation should be at a level appropriate to the scope and thoroughness of the energy audit.

The modelled energy use should ideally be checked for consistency with actual measured energy consumption.

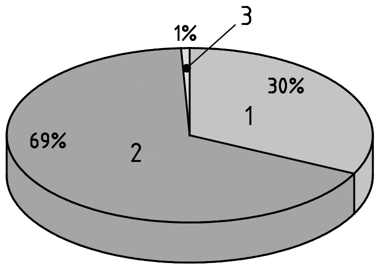
The calculation shall ideally reflect actual values and conditions (use, occupancy, indoor temperatures, climate, etc), not standardized ones.

For comfort services, once the building model is established and validated against actual energy use, energy performance indicators such as specific energy consumption (kWh/m^2.y), efficiencies of systems and subsystems, shall be compared to appropriate reference values to generate preliminary ideas for energy saving opportunities.

The identified energy efficiency improvement opportunities shall be ordered where appropriate in a defined sequence to optimize the energy savings. The sequence will depend on how each opportunity (or measure) may impact on the saving potential of each of the others.

E.3 Energy breakdown examples

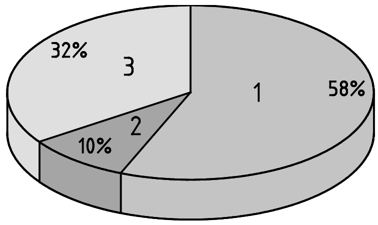
The energy consumption breakdown can be done in different ways. Some examples of typical breakdown pie- charts illustrating the energy use in buildings are shown below.



Key

1 Heating
2 Electricity
3 Water

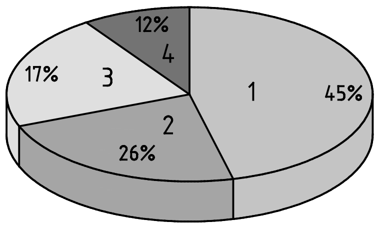
Figure E.2 — Yearly cost breakdown



Key

1 Ventilation
2 Heating
3 Domestic hot water

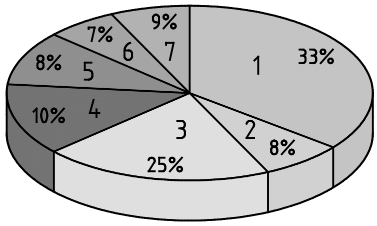
Figure E.3 — Heating energy consumption breakdown



Key

1 Air-handling unit 1
2 Air-handling unit 2
3 Air-handling unit 3
4 Air-handling unit 4

Figure E.4 — Ventilation heating energy consumption breakdown



Key

1	Lighting	5	Water chillers
2	Electical heating	6	Kitchen
3	Fans	7	Socket loads, appliances
4	Pumps		

Figure E.5 — Electricity consumption breakdown

Annex F
(informative)

Examples of analysis checklists for energy audits in buildings

F.1 General

The following checklist includes aspects that can be considered in looking for energy saving opportunities. It is not exhaustive and the auditor should work on a case by case basis. Similar information may be found for heating, cooling and ventilation systems also in:

EN 15378:2007 — Annex E;

EN 15239:2007 — Annexes I and J;

EN 15240:2007 — Annex H;

EN 15232:2012 — Clause 5, Table 2.

F.2 Checklist

Main item	Typical energy saving measures	Check
The building envelope	improving U-values	
	improving air tightness	
	reducing thermal bridges	
	improving solar shading (cooling load reduction)	
	adjustable solar shading adoption (to adapt for different seasonal heating/cooling/lighting balance)	
	improving U-values	
The heating system(s) and control		
Room equipment	single room control available?	
	zoning according to use (implies distribution modifications).	
	avoid stratification in high ceiling rooms	
	avoid summer time heating	
	avoid simultaneous heating and cooling of the same space	
Distribution	zoning (is it possible to improve control with appropriate zoning?)	
	layout and location (external, unheated, heated…)	
	control mode (constant flow/variable flow) and temperature regime	
	pumping energy optimisation	
	piping insulation (type, thickness)	
Storage (if any)	dimensions	
	insulation	
	temperature regime	

Main item	Typical energy saving measures	Check
	location	
Generation	select generator type according to available energy carrier and distribution temperature requirement	
	combustion or conversion efficiency improvement	
	temperature control of generation	
	appropriate capacity control	
The domestic hot water system(s) and control	faucets and water flows (reduce needs)	
	distribution: appropriate insulation	
	temperature regime of storage and distribution ring	
	generation source: generator type selection, thermal solar integration	
	local generation for small loads	
The cooling system(s) and control		
Room equipment	avoid simultaneous heating and cooling of the same space	
	suggest proper settings	
	introduce timing control or occupancy driven control	
Distribution	pumping auxiliary energy demand	
	control of temperatures: avoid mixing	
Generation	chilled water / cooling production	
	winter time cooling / free cooling	
	temperature control of generation	
	appropriate capacity control	
Heat rejection	condenser water temperature	
	fan and pump energy	
The ventilation and air conditioning system and control	air flows	
	operation schedules/ventilation needs/demand based ventilation	
	air flow and temperature control	
	heat recovery	
	efficiency of heat recovery	
	fan electricity	
The lighting system and control	lamp types change to higher efficiency (lumen/W)	
	lighting levels (lux / W/m2)	
	lighting control / schedules	
	daylighting	
Domestic appliances	energy efficient equipment	
	stand-by mode	
	appropriate use	
Office appliances	energy efficient equipment	
	stand-by mode	

Main item	Typical energy saving measures	Check
	appropriate use	
Other appliances (e.g. medical, ...)	energy efficient equipment	
	stand-by mode	
	appropriate use	
Internal transport systems	energy efficient equipment	
	demand-based operation	
Freeze-protection systems and control	temperature setpoints	
	avoid unnecessary heating	
Electric energy distribution	transformer losses	
	reactive power / compensation	
Other utilities		
Steam	steam needs	
	minimize steam pressure	
	steam generator type	
	steam distribution headers	
	condensate traps	
	condensate recovery	
Compressed air	users needs reduction	
	users pressure minimisation	
	system leaks	
	compressor specific needs (kWh/m^3)	
	compressor control	
	heat recovery from compressors	
The building automation and control system (BACS)	Improving energy saving functions of the BACS	
	appropriate settings and operation	
Other energy using systems		
Pool	pool covers	
	water / air temperature difference	
	heat recovery	
Kitchen	energy efficient equipment	
	stand-by mode	
	appropriate use	
Computer / server spaces	energy efficient equipment	
	stand-by mode	
	appropriate use	
Occupant behaviour	Change of occupant numbers or working patterns	
	Change behaviour	

Annex G
(informative)

Examples of energy performance indicators in buildings

G.1 General

Indicator reference values may include, as available:

a) legal requirement for new buildings;

b) legal requirement for renovations;

c) best available technology;

d) typical (statistical) values for existing or new buildings.

G.2 Global indicators

Examples of yearly energy indicators:

a) kWh/(m^2·year) or kWh/(m^3·year) for heating, cooling, domestic hot water, ventilation, electricity and combinations thereof;

b) kWh/(m^2·K·day) for heating;

c) kWh/m^3 for domestic hot water;

d) kWh/(person.y), kWh/patient-day, etc.

Similar indicators can be used based on CO_2 or costs.

Examples of graphical indicators:

e) Energy signature for heating (See Annex K)

G.3 Detailed indicators

Indicators for:

a) U-value of structures (may include the effect of thermal bridges);

b) kWh/m^3 auxiliary energy for ventilation;

c) efficiencies of systems and subsystems;

d) expenditure factors of systems and subsystems.

Annex H
(informative)

Examples of energy efficiency improvement opportunities in buildings

The energy auditor should propose energy efficiency improvement opportunities including one or more of the following list, which is not exhaustive:

a) measures in order to reduce or to recover the energy losses;

Example: Improve insulation, heat recovery.

b) replacement, modification or addition of equipment;

Example: High efficiency boilers, variable speed motors, energy efficient lighting.

c) more efficient operation and continual optimization;

Example: Operating schedules, control parameter adjustment, maintaining the installed equipment to its best performance.

d) improved maintenance;

Example: Maintenance planning, instruction of the operation and maintenance staff.

e) deployment of behavioural change programmes;

Example: Training, energy awareness campaigns.

f) improvement of energy management.

Example: improvement in metering and monitoring plan, implement energy management system.

The energy auditor shall categorize the energy improvement solutions into:

a) no cost (set-point and time schedule adjustment, switching off lights, closing doors, etc.);

b) low cost (adding or improving controls, etc.);

c) high cost investments (thermal insulation of building envelope, major technical system modifications, renewable energy, CHP, etc).

In energy audits in buildings it is usual to rank the energy efficiency improvement opportunities by simple payback time but this does not exclude the use of other financial metrics.

The energy savings interventions should be ranked in order of an appropriate financial metric, the nature of which should be agreed with the client. In order of most informative (and complexity) these include:

a) Life Cycle Cost Assessment;

b) Internal Rate of Return;

c) Net Present Value;

d) Simple Payback.

Annex I
(informative)

Examples of analysis and savings calculations in energy audits in buildings

I.1 Roof insulation

I.1.1 Introduction

This example illustrates the calculation of the achievable savings of an energy efficiency improvement opportunity taking into account the entire energy chain (i.e. interactions with other parts of the building),

The example is a residential building (block of flats) in Italy with a centralised heating system where the on site inspection revealed an uninsulated roof (this is very common in Italy).

The energy saving opportunity is the insulation of the last slab, as shown in Figure I.1a) and Figure I.1b).

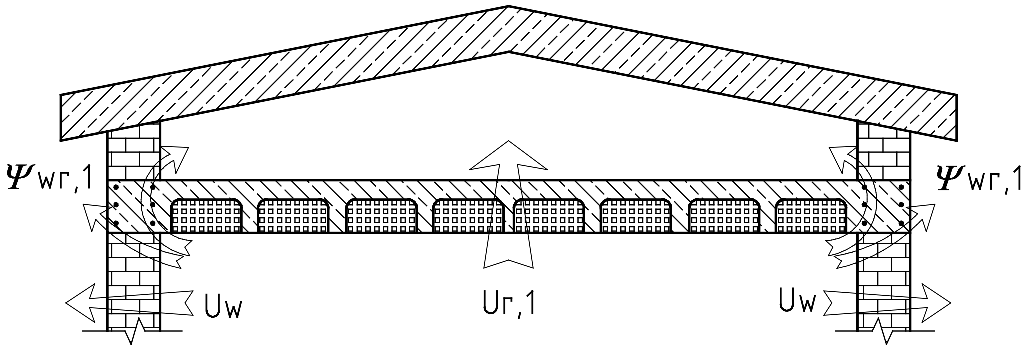


Figure a) — Roof insulation before

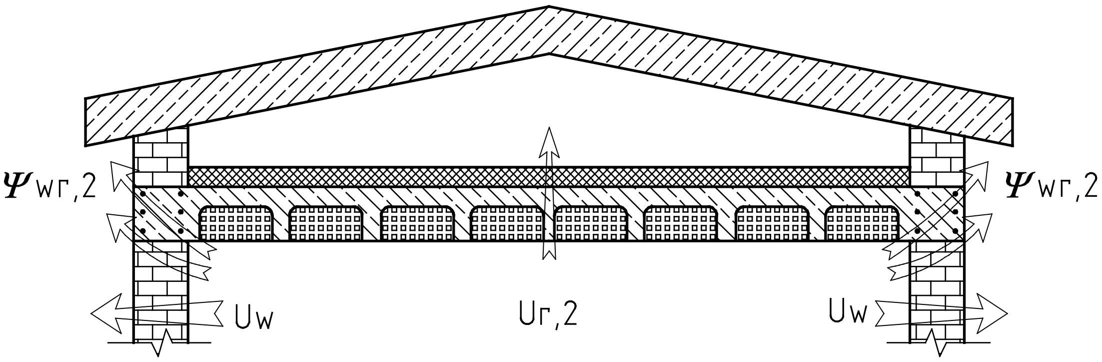


Figure b) — Roof insulation after

Key

- Uw Thermal transmittance (U-Value) of the wall (W/(m^{2}K))
- Ur Thermal transmittance (U-Value) of the roof (W/(m^{2}K))
- Ψwr Thermal conductivity of the roof-wall intersection (W/(mK))

Figure I.1 — Roof Insulation

The roof insulation will reduce the energy losses by transmission. This will turn into a reduction of:

a) energy needs (depending on building envelope energy balance);

b) delivered energy (depending on technical systems effect);

c) primary energy (depending on energy conversion factors);

d) costs (depending on energy carrier specific cost).

The suggested energy efficiency improvement will be effective if:

a) there is a reduction in primary energy;

b) the pay-back is significantly lower than the expected lifetime of the improvement.

If the space under the roof is cooled, the energy consumption for cooling is also reduced. This further improves the economic efficiency of the improvement option.

An energy saving calculation is required.

I.1.2 Analysis

The first reference is the legal requirement for a roof slab U-value, which is 0,38 W/(m^{2}K) (in Italy). The U-value is obviously much higher and insulation on top of the slab shall be investigated.

During building visit, the information concerning possibility and effectiveness of slab insulation shall be recorded:

a) is there suitable access to the under-roof space? This may limit the insulation technique;

b) is the under-roof space in use?;

c) are there partition walls (very often roof supporting)? Each one will be an additional thermal bridge, or specific provisions shall be added, which will increase costs;

d) how near to the edge can the roof be insulated? This determines the thermal bridge at the interface.

The energy saving calculation can be performed after the insulation technique has been assessed.

I.1.3 Energy savings calculation

The energy saving calculation can be performed repeating the complete energy performance calculation (tailored rating) according to EN 15603, EN ISO 13790, EN 15316 and related standards. If so the interactions between building envelope elements and systems are taken into account.

An example of a simple energy and economic savings calculation is shown in the following table.

Table I.1

Description	Symbol	Unit	Before	After	Difference
Roof U-value	U	$W/(m^2K)$	1,9	0,35	
Roof gross area	S	m^2	200	200	
Perimeter thermal bridge	Ψ_{wr}	W/(mK)	0,05	0,8	
Perimeter	L	M	60	60	
Heat loss coefficient	H	W/K	383	118	
Unheated space heat loss correction factor	b_{tr}		0,8	0,9	
Winter severity		Kday	2400	2400	
Transmission heat loss	$Q_{H,tr}$	kWh	17.649	6.117	
Heating system efficiency	$\eta_{H,sys}$	%	65	65	
Delivered energy to cover transmission heat loss	$Q_{H,gen,in}$	kWh	27.152	9.411	
Fuel unit (gas)			m^3		
Fuel calorific value	Hi	kWh/m^3	9,6	9,6	
Fuel amount		m^3	2.828	980	
Fuel cost		€/m^3	0,75	0,75	
Yearly cost of heat losses		€	2.121	735	1.386
Specific yearly cost of heat losses		€/m^2	10,61	3,27	7,34
Insulation cost		€/m^2		35,00	
Pay-back time		Years			4,8

I.1.4 Comments

The calculation of energy savings depends on the entire chain of energy delivery, transformation, transport within the building and loss.

The energy effectiveness of the insulation of a building element depends on:

a) type of heat emission control system: it shall be able to reduce the heat emission in rooms under the newly insulated slab, otherwise the effect of the roof insulation is nearly zero; If this is not true (example: heating curve only) the heating system efficiency $\eta_{H,sys}$ can't be assumed to be constant but decreases after the insulation;

b) $\eta_{H,sys}$ overall efficiency of the heating system;

c) b_{tr} factor of the under-roof space which is increased by the insulation layer;

d) increase of the perimeter thermal bridge Ψwr;

e) stability of the gain utilisation factor for the energy need balance. The calculation example assumes that the gain utilisation factor is unchanged.

The economic effectiveness of this energy saving opportunity also depends on:

a) fuel (energy carrier) calorific value Hi;

b) fuel (energy carrier) specific cost.

If this energy efficiency improvement is combined with a change in the fuel (oil Æ gas), the economic effect shall be evaluated with the new fuel or the fuel change effect shall be evaluated with the reduced delivered energy.

The energy saving can be calculated via a complete energy balance of the building and the system using standardized methods including EN ISO 13790 and EN 15316.

In any case appropriate parameters shall be used to take care of the effects on the entire energy chain, from the heat losses to the delivered energy.

I.2 Ventilation system

I.2.1 Introduction

This example illustrates the calculation of the achievable savings in improving the use and operation of an air handling unit.

The air handling unit serves the classrooms of a typical school building in Finland. The building is connected to the district heating network. The air handling unit has a heating coil, there is no cooling and no heat recovery.

In the energy audit it is found out that the operating time of the air handling unit can be reduced to match better the occupancy schedule of the classrooms. Also the supply air temperature setpoint can be reduced, the existing value is too high and this causes excessive indoor temperatures in the classrooms. The air handling unit has still some technical lifetime remaining, so the energy auditor investigates the possibilities for adding heat recovery into the system. There is enough space in the mechanical room and the necessary changes in the ducts can be made so that a water-glycol heat recovery can be installed.

I.2.2 Analysis

There are three separate energy saving measures, two of them are fairly easy to implement. The changing of the operating time can be done by adjusting the time-schedule in the building automation system, so it is a no cost measure. The temperature set-point change needs temperature detector replacement and calibration so it is a low cost improvement. The installation of heat recovery requires design, HVAC and electrical works so it is a high cost measure.

Adding heat recovery into the air handling unit will increase the pressure loss in the supply and extract system. If the original airflow is maintained in the system, the fan capacity shall be adjusted to meet the increased pressure loss. This means that the fan will consume more electricity after the heat recovery coils have been installed. Therefore the heat recovery addition will save heating energy but the change in fan electricity will have a negative energy impact.

The energy saving and costs of each individual improvement can be estimated. However, it is obvious that the energy efficiency improvements which are implemented into the same system will affect the savings of each other. Therefore the order of the implementation shall be defined.

The saving measure implemented after another measure will not save as much as an individual measure because the initial situation has changed after the first measure.

I.2.3 Energy savings calculation

The energy saving for each individual improvement is calculated using the Finnish energy auditor's calculation tool, Motiwatti. This tool is able to calculate the consumption of the air handling unit (heating energy and electricity) in the initial situation and after each saving measure.

Table I.2

Initial situation	
Air flow of AHU	2,5 m^3/s
Operating time	06–21, 5 days a week
Supply air temperature setpoint	21 °C
Fan pressure increase	550 Pa supply 300 Pa extract

The energy costs are: 40 eur/MWh for heating and 95 eur/MWh for electricity. The energy saving of each measure is shown below.

Table 1.3

Energy saving measures (as individual measures)			
		Saving in heating energy MWh/a	Saving in electricity MWh/a
1 Change operating time	06–18, 5 days a week	34	5
2 Change temperature setpoint	18 °C	31	0
3 Install heat recovery	55 % efficiency, additional pressure loss 200 Pa	89	−12

The total saving effect of the individual energy saving measures is 154 MWh/a in heating energy and −7 MWh/a in electricity. The total cost saving of the individual measures is 5 495 eur/a.

In reality the sequence of the energy saving measures shall be taken into account and this will affect the savings.

The order of the measures is defined:

1) change operation times;

2) adjust temperature;

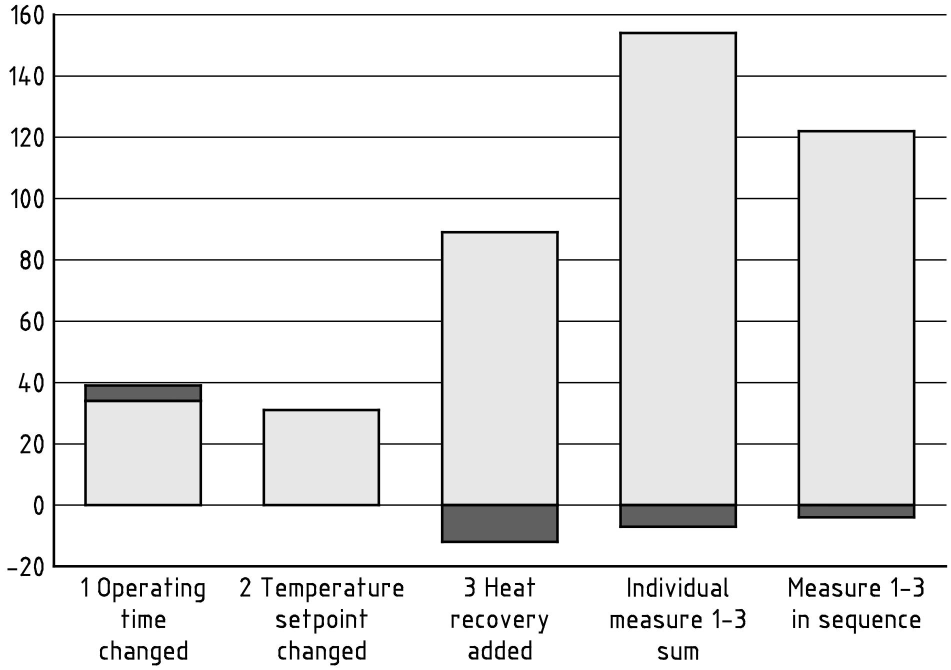
3) install heat recovery.

The energy saving of each measure when implemented in this order is shown below.

Table I.4

Energy saving measures (in sequence)			
		Saving in heating energy MWh/a	Saving in electricity MWh/a
1 Change operating time	06–18, 5 days a week	34	5
2 Change temperature setpoint	18 °C	25	0
3 Install heat recovery	55 % efficiency, additional pressure loss 200 Pa	64	−9

The total saving effect of the energy saving measures (when all three have been implemented) is 123 MWh/a in heating energy and −4 MWh/a in electricity. The total cost saving of the individual measures is 4 255 eur/a.



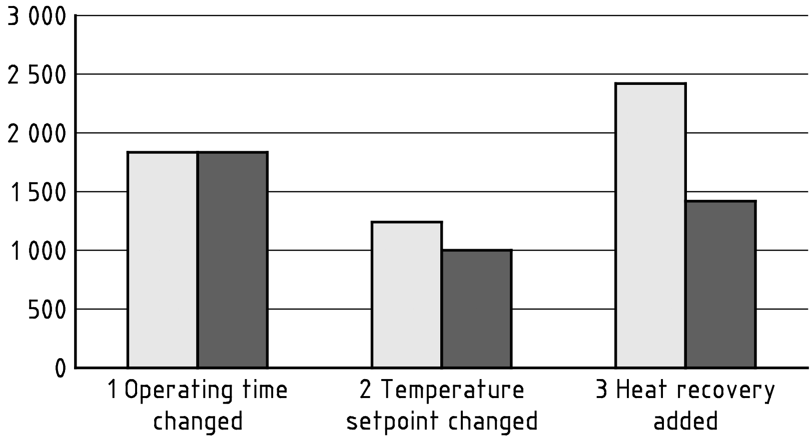
Key

■ Electricity

□ Heating

NOTE The yearly energy cost savings of the measures as individual measures and when implemented in sequence

Figure I.2 — Yearly savings (MWh/a)



Key

□ Individual

■ In sequence

NOTE: The yearly energy cost savings of the measures as individual measures and when implemented in sequence.

Figure I.3 — Yearly savings (eur)

I.2.4 Comments

It is important that the energy auditor is aware of the technical interaction of different saving measures so that the effect of the measures is not overestimated.

Annex J
(informative)

Examples of the reporting of an energy audit in buildings

J.1 General

An example of the table of contents for a comprehensive building energy audit is given below. The energy auditor should modify this according to the scope of the energy audit.

J.2 Table of contents

Introduction:

— description of a building audit;

— method of work;

— auditor's contact information.

1. Summary of the energy use of the building and suggested saving measures:

— introduction of the present consumption level, specific consumptions;

— main saving measures in heating, electricity and water;

— summary table: present situation, saving potential, investments;

— summary table: suggested saving measures, their effect on energy and costs, payback time for each measure.

2. Basic data of the building:

2.1. Site information;

2.2. Connections to networks;

2.3. Consumption of energy and water;

2.4. Operation, maintenance and facility management.

3. Audit on the mechanical and electrical systems (describing the existing situation):

3.1. Heating system;

3.2. Water and sewage system;

3.3. Ventilation and air conditioning systems;

3.4. Cooling systems;

3.5. Electrical systems;

3.6. Building envelope;

3.7. Other systems.

4. Suggested energy efficiency improvement opportunities (describing the improvements):

4.0. Tariffs used in energy saving calculations;

4.1. Heating systems;

4.2. Water and sewage system;

4.3. Ventilation and air conditioning systems;

4.4. Cooling systems;

4.5. Electrical systems;

4.6. Building envelope;

4.7. Other systems;

4.8. Change in user behaviour;

4.9. Other suggestions.

Appendices.

Annex K
(informative)

Example of energy improvement verification method in buildings

K.1 General

The energy audit report should make recommendations about future measurement and verification of savings. This annex describes one method which could be applied to heating or cooling systems.

K.2 Energy signature

After the implementation of the energy efficiency improvement there is a need to verify that energy saving has been achieved. One effective method is the use of the energy signature where climate normalisation is important. See also EN 15603:2008

Object of the energy saving measures:

a) building block with 15 apartments (5 floors);

b) centralized heating system with heating curve control;

c) delivered fuel for heating before energy improvement: 16,000 l oil per year (152 kWh/m^2·year).

Energy saving measures:

a) boiler replacement with gas condensing boiler;

b) room control (thermostatic valves);

c) individual heat metering;

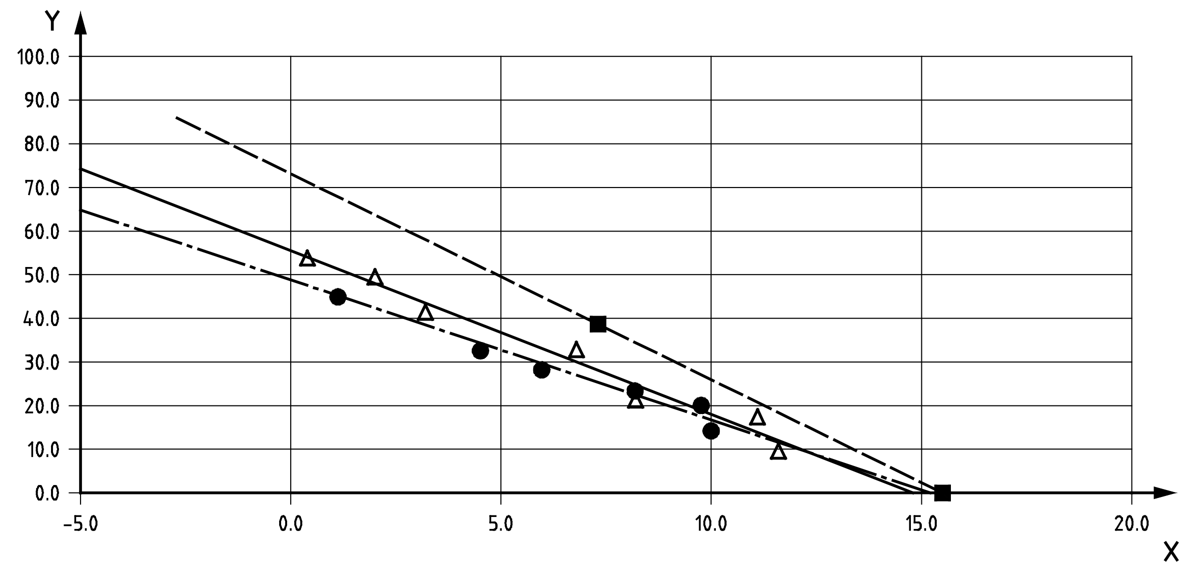
d) roof insulation.

Energy signature has been repeated:

a) with historical data (average yearly consumption corrected according to degree-days);

b) with renovation design data (monthly energy calculation data);

c) with first year after renovation operating data (monthly operating data).



Key

X External temperature (°C)

Y Energy signature (kW)

■ Before modification

Δ Design energy signature

● First year after modification

Figure K.1 — Actual operating data slightly below designed improvements

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