D.T3.1.2 COMMON TECHNICAL PROTOCOL

Version 1
08 2018

1. Aim of the document

The aim of this document is to provide a common technical protocol for conducting energy audits in public buildings in seven European countries participating in the FEEDSCHOOLS project: Austria, Croatia, Czech Republic, Hungary, Italy, Poland, Slovenia. The protocol shall allow to achieve the following objectives:

- to conduct energy audits in a uniform way, regardless the location of the audited building,
- to compare results of the audit of all buildings involved in the project,
- to allow the peer-review of the audits.

The auditors who conduct energy audits in schools selected to the project (D.T3.1.1), both internal and external experts of the project technical partners, will follow the protocol during their on-site work and when audit report drafting, in order to reach comparable and shared results for all buildings involved in the project.

2. Introduction

2.1. Requirements of EPBD directive on energy audit methodology

The first EU directive on the energy performance of buildings (2002/91/EC, Article 3) committed Member States to apply a methodology, at national or regional level, of calculation of the energy performance of buildings on the basis of the general framework set out in the directive. This obligation has been than maintained in two updates of the directive: 2010/31/EU and 2018/844. Each of EPBD directives has provided rather general framework than specific requirements, focusing on general rules that shall be followed. This resulted in a diverse approach among Member States and wide differences between national/regional calculation methods. The evaluation of Directive 2010/31/EU from 2016[1] shows that there are 35 different national/regional calculation methods for the energy performance of buildings and the great number of them does not follow all EPBD's provisions. The European Commission has identified the following most substantial omissions:

- 4 methodologies (11%) do not cover some building categories of non-residential buildings at all and 5 methodologies (14%) only partly cover some building categories.
- In 13 of the 35 methodologies (37%) measured energy can be used to determine the energy performance for residential buildings and in 18 of the 35 methodologies (51%) for non-residential buildings.
- 7 of the 35 methodologies (20%) in the residential sector and 6 of the 35 methodologies (17%) in the non-residential sector are based on measured energy without any correction which is in contradiction with the requirement of Article 2(4) of EPBD referring to the typical use buildings.
- In total, half of the Member States have a different calculation method for setting and ensuring minimum energy requirements, on the one hand, and for certifying buildings on the other hand.

[1] COMMISSION STAFF WORKING DOCUMENT EVALUATION of Directive 2010/31/EU on the energy performance of buildings SWD(2016) 408 final, https://ec.europa.eu/info/sites/info/files/swd-2016-408-final_en_0.pdf

The new *Directive (EU) 2018/844 of the European Parliament and of the Council of 30 May 2018 amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency* provides more detailed requirements for national/regional methodologies. In particular, the directive specifies that national/regional methodologies shall follow overreaching standards:

a. ISO 52000-1 Energy performance of buildings — Overarching EPB assessment — Part 1: General framework and procedures;

b. ISO 52003-1 Energy performance of buildings — Indicators, requirements, ratings and certificates — Part 1: General aspects and application to the overall energy performance;

c. ISO 52010-1 Energy performance of buildings — External climatic conditions — Part 1: Conversion of climatic data for energy calculations;

d. ISO 52016-1 Energy performance of buildings — Energy needs for heating and cooling, internal temperatures and sensible and latent heat loads — Part 1: Calculation procedures;

e. ISO 52018-1 Energy performance of buildings — Indicators for partial EPB requirements related to thermal energy balance and fabric features — Part 1: Overview of options.

Annex 3 of this document provides an overview of above-mentioned standards.

Having in mind that Directive (EU) 2018/844 is not yet transposed to national laws, it is recommended to use the abovementioned standards within FEEDSCHOOLS, although other analogous standards can be used as well.

2.2. Overview of energy audit methodologies in 7 participating countries

There is no common energy audit methodology that is used in more than one Central European country. Each of analysed countries (AT, CR, CZ, HU IT, PL, SI) has developed its own requirements, which vary in terms of the extent and detail of the audit procedures and report contents. Nevertheless, there are several common elements, which can be found in each national obligations:

- general requirements, describing the scope of the audit and procedures during on-site visits, follow international standards, mainly EN 16247 and ISO 52000-1;
- calculation methods, whenever indicated, are based on international standards;
- if there is no direct indication on methods that have to be used, auditors usually use national versions of international standards to ensure comparability and quality of the work performed.

The table below presents an overview of national requirements, provided in national legislation acts. All seven countries provide energy auditors with general guidelines for conducting energy audits. These guidelines consist of e.g. steps of the energy audit or minimum requirements for auditor. Only three out of seven countries (Croatia, Hungary, Poland) developed its own calculation methodology (usually based on international standards), and in case of one country (Czech Republic), the calculation methodology refers directly to specific international and national standards.

A more detailed description of specific national requirements is presented in Annex 2.

No.	Country	General requirements	Calculation methodology
1	Austria	yes	no
2	Croatia	yes	yes
3	Czech Republic	yes	yes/no (refer to international standards)
4	Hungary	yes	yes

5	Italy	yes	no
6	Poland	yes	yes
7	Slovenia	yes	no

Considering differences among energy auditing systems and national obligations existing in FEEDSCHOOLS countries, as well as objectives of the project which, inter alia, assume comparability of audit results, it was necessary to develop a common methodology of audit conducting.

3. Common methodology

The FEEDSCHOOLS common methodology of audit conducting is composed of two parts. The first one ("General framework") provides general requirements for energy auditing and defines the attributes of a high quality energy audit. It is based on the international standard EN 16247 and sets framework of auditors' work in terms of the scope of the audit, procedures used, and range of collected data. The other part of the framework ("Methodology for calculating the energy performance of the building") provides guidelines how to perform audit calculations.

3.1. General framework

General requirements of the energy audit methodology follow the international standard EN 16247-1 Energy audits – Part 1: General requirements. This standards is widely recognised in the EU and in several FEEDSCHOOLS partner countries it is explicitly mentioned as a base for energy auditing.

3.1.1. Terms and definitions

For the purposes of this document, the following terms and definitions apply:

- energy audit – systematic inspection and analysis of energy use and energy consumption of a site, building, system or organisation with the objective of identifying energy flows and the potential for energy efficiency improvements and reporting them;
- energy auditor – individual, group of people or body carrying out an energy audit;
- adjustment factor – quantifiable parameter affecting energy consumption (e.g. weather conditions, behaviour related parameters);
- audited object - building, equipment, system, process, vehicle or service which is the subject of the energy audit;
- organisation - person or body who owns, operates, uses or manages the audited object(s);
- energy consumption - quantity of energy applied;
- energy efficiency - ratio or other quantitative relationship between an output of performance, service, goods or energy, and an input of energy;
- energy performance - measurable results related to energy efficiency, energy use and energy consumption;
- energy performance indicator – quantitative value or measure of energy performance, as defined by the organisation;
- energy efficiency improvement measure - amount of saved energy determined by measuring and/or estimating consumption before and after implementation of one or more energy

efficiency improvement measures, whilst ensuring normalisation for factors that affect energy consumption;

- energy use - manner or kind of application of energy – in terms of a scope of the audit, procedures used, and range of collected data.

3.1.2. General requirements regarding energy audit process

Following the provisions of section 4.2 of EN 16247-1, the energy audit process shall be:

a) appropriate to the agreed scope, aims and thoroughness;

b) complete: in order to define the audited object and the organisation;

c) representative: in order to collect reliable and relevant data;

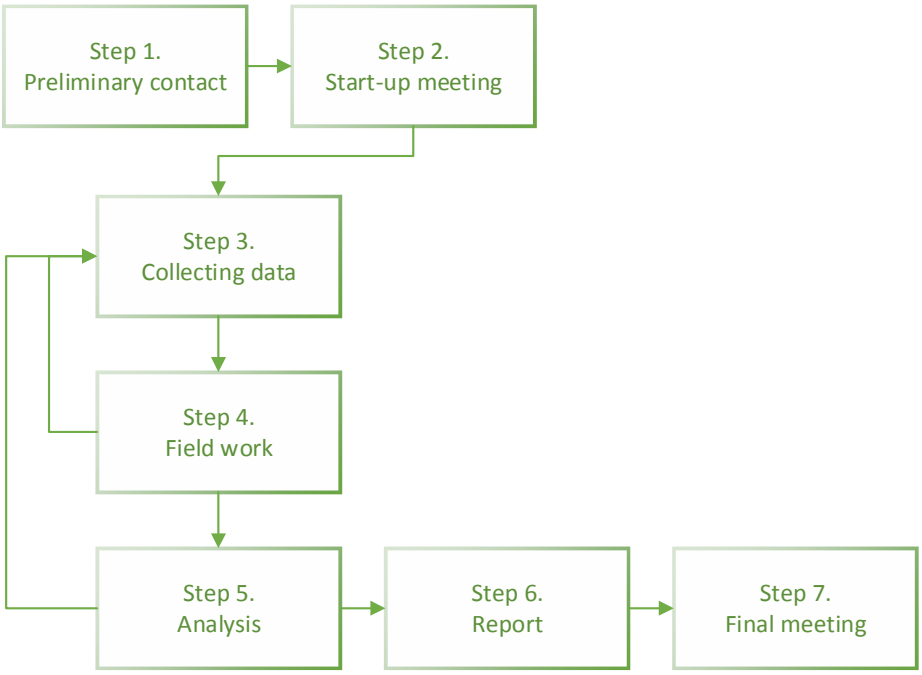
d) traceable: in order to trace the origin and processing of data;

e) useful: in order to include a cost effectiveness analysis of the energy saving opportunities identified;

f) verifiable: in order to allow the organisation to monitor the achievement of the targets of implemented energy efficiency improvement opportunities.

3.1.3. Energy audit steps

Following the provisions of section 5 of EN 16247-1, the energy audit process shall consist of the following steps:



3.1.3.1. Step 1. Preliminary contact

The aim of this step is to discuss with the organisation its needs and expectations, as well as agree on terms of the collaboration and boundaries of both auditor and the organisation. It shall be clearly stated by the organisation what is the scope of the audit (e.g. audit of the whole building, building unit, technical building system), what is the context of the audit (e.g. to check compliance with energy performance requirements, energy certification, tailored energy audit, energy performance inspection etc.), what degree of thoroughness is required and type of assessment required (e.g. calculated design, calculated as built,

measured actual, measured standards / corrected for climate and use) and any other important boundary that would affect auditor's work.

The organisation shall be asked to specify issues that might influence the audit and improvements implementation, in particular:

- regulatory or other constraints affecting the scope or other aspects of the proposed energy audit;
- strategic wider programme (planned projects, outsourcing facilities management);
- management system (environmental, quality, energy management system or others);
- any existing opinions, ideas and restrictions relating to potential energy efficiency improvement measures.

On the other hand, the auditor shall inform the organisation about the measurements and inspections that will be made during the on-site visits, and what data shall the organisation provide prior the field work starts. It is also important to notify the organisation about commercial or other interest which could influence auditor's conclusions or recommendations.

3.1.3.2. Step 2. Start-up meeting

The aim of the start-up meeting is to brief all interested parties about the energy audit objectives, scope, boundaries and depth, and agree the practical arrangements for the energy audit. The meeting could be taken in person or take a form of remote interactive discussion (e.g. phone call, teleconference). The energy auditor shall describe the processes, means and schedule of the energy audit and the possible need for additional metering equipment.

During the meeting, the organisation shall nominate the main responsible person for the energy audit, as well as a person who will be the main "contact point" for the auditor and will provide him/her with all necessary data and information. The organisation shall also inform all internal stakeholders (e.g. technical staff, teachers) about the audit and how this would affect their standard duties (e.g. that they will be asked to assist the auditor during the inspection).

The auditor shall ask the organisation about the limitations regarding the on-site visits (e.g. unusual conditions, maintenance work, access restrictions, safety and security rules etc.). The auditor shall inform about all necessary resources and data that organisation shall provide him/her with, as well as requirements for special measurements. He/she shall also propose a schedule of visits.

During the meeting, arrangements for access for the energy auditor shall be made, and procedures to be followed for installation of measuring equipment shall be agreed.

3.1.3.3. Step 3. Collecting data

The following data (if necessary and available) shall be collected by the auditor, with the assistance of the organisation:

a) list of energy-using systems, processes and equipment;

b) detailed characteristics of the audited object(s) including known adjustment factors (climate or exploitation related ones, e.g. out-of-use period during the year) and how the organisation believes they influence energy consumption;

c) historical data;

   1) energy consumption;

   2) adjustment factors;

   3) relevant related measurements;

d) operational history and past events that could have affected energy consumption in the period covered by the data collected;

e) design, operation and maintenance documents;

f) energy audits or previous studies related to energy and energy efficiency;

g) current and projected electricity and/or heat and/or gas tariff, or a reference tariff to be used for the protection of commercial confidence;

h) other relevant economic data;

i) the status of the energy management system.

3.1.3.4. Step 4. Field work

The aim of the field work is to collect preliminary data and information about the energy performance of the object, to understand the specificity of the object (e.g. operating routines, user behaviour). The inspection shall allow the auditor to prepare some preliminary ideas for energy efficiency improvement opportunities, as well as to identify additional quantitative data is needed for later analysis.

During the field work, the energy auditor shall ensure that measurements and observations are made in a reliable fashion and in situations which are representative of normal operation and, where relevant, under appropriate weather conditions. Whenever an unexpected difficulty occurs, the auditor shall inform the organisation about the issue.

During the on-site visit, the auditor shall be assisted (guided) by a representative(s) of the organisation, who shall have necessary competences and authority to carry out direct operations on processes and equipment if required. The auditor shall get an access to the technical documentation relevant to the audit scope (e.g. building plans, manuals etc.)

3.1.3.5. Step 5. Analysis

The aim of this step is to analyse the collected data, to determine the energy performance of the audited object and to conclude by presenting improvement options.

The analysis shall consist of the following elements:

1) Description of the existing situation:
   - a breakdown of the energy consumption by use and source;
   - energy flows and an energy balance of the audited object;
   - pattern of energy demand through time;
   - relationships between energy consumption and adjustment factors;
   - one or more energy performance indicators suitable to evaluate the audited object.
2) Identification of energy efficiency improvement options. Each measure shall be evaluated in the following terms:
   - energy savings;
   - investment costs;
   - financial savings;
   - the return on investment or any other economic criteria agreed with the organisation;
   - other possible non-energy gains (e.g. improvement of the use conditions);
   - technical interactions between multiple actions.

3) Documentation of the methods and data used:
   - calculation methods;
   - assumptions made;
   - indication of defaults and abnormalities of the data analysed;
   - results validation (e.g. comparison with reference objects or rates, review by another auditor).

Combining this step with provisions of standard ISO 52000-1, the overall calculation procedure shall consist of the following calculation steps:

1. Define the building category, or, if differentiated, for each space category, the internal conditions of use (temperature, humidity, occupancy, internal heat gains, time schedule).
2. Define the external conditions (climatic data).
3. Divide the building into zones, if needed – e.g. divide the building into classrooms, canteen, and sport hall.
4. For each calculation interval (e.g. one month), calculate the energy needs for heating, cooling and (de)humidification and domestic hot water. For each of the technical building systems related to the EPB services, calculate the energy use, including auxiliary energy, the contribution of RES and the recoverable thermal losses. Take into account the impact of building automation and control.
5. Repeat the loop for individual calculation interval, if interaction between the different processes, including the effect of recoverable heat losses, are not taken into account by either simplification or by introducing the interaction to the next calculation level.
6. Calculate on-site energy production.
7. Calculate delivered and exported energy components.
8. For each calculation interval, weight delivered and exported energy as primary energy or any other indicator.
9. Sum individual step results.
10. Calculate the delivered or weighted energy per part of a building.
11. Calculate partial performance indicators such as sub-system efficiencies, load factors, fractional contribution or thermal solar systems.
12. Provide a calculation report.

3.1.3.6. Step 6. Report

The content of the report shall follow the structure provided in Annex 1 of this document. Templates of specific deliverables within FEEDSCHOOLS will be provided by the WP T3 coordinator and will be based on this structure.

When reporting the audit results, the energy auditor shall comply with the following general rules:

- ensure that the energy audit requirements agreed with the organisation have been met;
- check the quality of the report before submission to the organisation;
- provide comment on the data collected during the audit: its consistency, quality, contribution to the analysis;
- clearly state parts of the work which results from calculations, simulations and estimations;
- document all assumptions made;

- state the accuracy of estimations.

Following provisions of EN ISO 52016-1, to provide the highest possible quality of the report, all input data shall be listed and justified, e.g. by reference to international or national standards, or by reference to the appropriate documents. When the input data are not the standard data, an estimate of the accuracy and source of input data shall be given. The report shall also contain reference to the documents prescribing the methods used.

3.1.3.7. Step 7. Final meeting

The aim of the final meeting is to summarise the work done and to present the results of the audit. During the meeting, the auditor shall hand over the report on the energy audit and present the results in an accessible and understandable way. The presentation shall include not only the explanation of the results, but also their meaning, in particular in terms of possible further decisions to be made by the organisation.

3.2. Methodology for calculating the energy performance of the building

The specific calculations of indicators necessary to assess the energy performance of the building shall follow recognised methods and algorithms. It is strongly recommended to base the calculation on the following international standards (or their national adaptations). Regardless the choice made, the selected calculation method shall be clearly pointed in the audit report.

3.2.1. General requirements

a) **ISO 52000-1** Energy performance of buildings — Overarching EPB assessment — Part 1 art 1: General framework and procedures[2];

b) **ISO 52003-1** Energy performance of buildings. Indicators, requirements, ratings and certificates. General aspects and application to the overall energy performance[3];

c) **ISO 52018-1** Energy performance of buildings — Indicators for partial EPB requirements related to thermal energy balance and fabric features — Part 1: Overview of options

d) **EN 16247** Energy audits - Part 1: General requirements;

e) **EN 16247** Energy audits - Part 2: Buildings.

3.2.2. Heating systems

a) **ISO 52016-1** Energy performance of buildings - Energy needs for heating and cooling, internal temperatures and sensible and latent heat loads - Part 1: Calculation procedures[4].

b) **ISO 52010-1** Energy performance of buildings — External climatic conditions — Part 1: Conversion of climatic data for energy calculations

c) **EN 12831** Energy performance of buildings – Method for calculation of the design heat load:

   i. Part 1: Space heating load;

   ii. Part 3: domestic hot water systems heat load and characterisation of needs.

d) **EN 15316** Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies:

[2] ISO 52000-1 superseded EN 15603 Energy performance of buildings. Overall energy use and definition of energy ratings

[3] EN ISO 52003-1 superseded EN 15217 Energy performance of buildings - Methods for expressing energy performance and for energy certification of buildings

[4] EN ISO 52016-1 superseded EN ISO 13790 Energy performance of buildings - Calculation of energy use for space heating and cooling

i. Part 1 General and Energy performance expression, Module M3-1, M3-4, M3-9, M8-1, M8-4;
ii. Part 2 Space emission systems (heating and cooling), Module M3-5, M4-5;
iii. Part 3 Space distribution systems (DHW, heating and cooling), Module M3-6, M4-6, M8-6;
iv. Part 4-1 Space heating and DHW generation systems, combustion systems (boilers, biomass), Module M3-8-1, M8-8-1;
v. Part 4-10 Wind power generation systems, Module M11-8-7;
vi. Part 4-2 Space heating generation systems, heat pump systems, Module M3-8-2, M8-8-2;
vii. Part 4-3 Heat generation systems, thermal solar and photovoltaic systems, Module M3-8-3, M8-8-3, M11-8-3;
viii. Part 4-4 Heat generation systems, building-integrated cogeneration systems, Module M8-3-4, M8-8-4, M8-11-4;
ix. Part 4-5 District heating and cooling, Module M3-8-5, M4-8-5, M8-8-5, M11-8-5;
x. Part 4-8 Space heating generation systems, air heating and overhead radiant heating systems, including stoves (local), Module M3-8-8;
xi. Part 5 Space heating and DHW storage systems (not cooling), Module M3-7, M8-7.

3.2.3. Ventilation

a) **EN 16798-5-1** Energy performance of buildings. Ventilation for buildings. Calculation methods for energy requirements of ventilation and air conditioning systems[5].
b) **EN 16798** Energy performance of buildings - Ventilation for buildings – Calculation methods:
   i. Part 3 For non-residential buildings. Performance requirements for ventilation and room-conditioning systems;
   ii. Part 5 Calculation methods for energy requirements of ventilation and air conditioning systems;
   iii. Part 7 Calculation methods for the determination of air flow rates in buildings including infiltration.

3.2.4. Lighting

a) **EN 15193** Energy performance of buildings. Energy requirements for lighting. Specifications.

3.2.5. Thermal performance

a) **EN ISO 10077** Thermal performance of windows, doors and shutters - Calculation of thermal transmittance:
   i. Part 1 General;
   ii. Part 2 Numerical method for frames.
b) **EN ISO 13370** Thermal performance of buildings - Heat transfer via the ground - Calculation methods.

[5] EN 16798-5-1 superseded EN 15241 Ventilation for buildings - Calculation methods for energy losses due to ventilation and infiltration in buildings

c) **EN ISO 13788** Hygrothermal performance of building components and building elements - Internal surface temperature to avoid critical surface humidity and interstitial condensation - Calculation methods.

d) **EN ISO 13789** Thermal performance of buildings - Transmission and ventilation heat transfer coefficients - Calculation method.

e) **EN ISO 15927** Hygrothermal performance of building - Calculation and presentation of climatic data:

   i. Part 1:2003 Monthly means of single meteorological elements;

   ii. Part 2:2009 Hourly data for design cooling load;

   iii. Part 3:2009 Calculation of a driving rain index for vertical surfaces from hourly wind and rain data;

   iv. Part 4:2005 Hourly data for assessing the annual energy use for heating and cooling;

   v. Part 5:2004 Data for design heat load for space heating;

   vi. Part 6:2007 Accumulated temperature differences (degree days);

f) **EN ISO 6946** Building components and building elements - Thermal resistance and thermal transmittance - Calculation methods.

3.2.6. Economic performance

a) **EN 16627** Sustainability of construction works - Assessment of economic performance of buildings - Calculation methods.

3.2.7. Environmental performance

a) **EN 15978** Sustainability of construction works - Assessment of environmental performance of buildings - Calculation method.

Annex 1: Energy audit report template

The content of the Energy audit report follows the provisions of Annex J of EN 16247-2 and section 5.6.2 of EN 16247-1.

The exact content of the report shall be appropriate for the scope, aim and thoroughness of the energy audit. The minimum content of the energy audit report shall contain the following sections:

Energy audit report

1. Summary of the energy performance of the building and suggested improvement options
   - 1.1. Summary of the existing state of the building
   - 1.2. Suggested implementation programme and its expected results
   - 1.3. Summary table: current state, possible savings, investment costs
   - 1.4. Summary table: suggested measures, energy savings, financial savings, payback time

2. Introduction
   - 2.1. General information of audited organisation
   - 2.2. Energy auditor(s)
   - 2.3. Context of the energy audit - scope, aim and thoroughness, timeframe and boundaries;
   - 2.4. Description of audited object
   - 2.5. Energy audit methodology
     - 2.5.1. relevant standards
     - 2.5.2. regulations
     - 2.5.3. information on data collection

3. General building data
   - 3.1. Building identification (location, age, area)
   - 3.2. Climatic data
   - 3.3. Historical energy and water consumption and production
     - 3.3.1. Electricity/Gas/Oil/solid fuel/water Consumption
     - 3.3.2. Energy and water expenses
     - 3.3.3. Renewable Energy Sources
     - 3.3.4. Other Generation
     - 3.3.5. Final Energy Consumption and CO_2 Emissions (according to the national emission factors)
   - 3.4. Building exploitation, maintenance and management

Energy audit report

4. Existing state of building energy systems
   - 4.1. Heating system
   - 4.2. Water and sewage system
   - 4.3. HVAC
   - 4.4. Cooling system
   - 4.5. Electric system
   - 4.6. Building envelope
   - 4.7. Renewable energy sources
   - 4.8. Lightning system
   - 4.9. Other systems

5. Energy efficiency improvement options
   - 5.1. Heating system
   - 5.2. Water and sewage system
   - 5.3. HVAC
   - 5.4. Cooling system
   - 5.5. Electric system
   - 5.6. Building envelope
   - 5.7. Renewable energy sources
   - 5.8. Lightning system
   - 5.9. Other systems
   - 5.10. User behaviour change
   - 5.11. Other suggestions
   - 5.12. Assumptions used in calculating savings and the resulting accuracy of the recommendations (including energy tariffs)
6. Renovation scheme
   - 6.1. Aim of the renovation plan
   - 6.2. Criteria for ranking energy efficiency improvement measures
   - 6.3. Potential interactions with other proposed recommendations
   - 6.4. Suggested measures (optimal implementation plan)
   - 6.5. Impact of the renovation scheme
     - 6.5.1. Final Energy Consumption and CO2 Emissions after improvement actions
     - 6.5.2. Energy Performances
     - 6.5.3. Environmental Performances
7. Attachments

Legend: data source

D.T3.X.1 Data collection

D.T3.X.2 On site Energy Audits

D.T3.X.3 Energy simulations and technical improvement options

Annex 2: Overview of national requirements for energy auditing

Austria

There are two documents regulating procedures and methods of the energy audit. Both of them provide general guidelines for conducting energy audits. Nor specific requirements neither calculation methodology is provided.

1) Standard *EN ISO 16247-1 Energy audits. General requirements*

The standard provides general guidelines for conducting energy audits. It recognises that there are differences in approach to energy auditing in terms of scope, aims and thoroughness, but seeks to harmonise common aspects of energy auditing in order to bring more clarity and transparency to energy auditing services. The energy audit process is presented as a set of chronological steps. Nor specific requirements neither calculation methodology is provided.

2) Federal Energy Efficiency Law (EEL) Annex III

The Act sets minimum requirements regarding energy audits for large companies. Public buildings are not mentioned, although there are several requirements of a generic nature that could be applied to energy audit regardless the building type:

a. The data collection related to the energy performance of the building must include the following:

- ownership and user agreements;
- external shape of the building (e.g. L-shape, T-shape, H-shape);
- site plan of the building or groups of buildings (e.g. orientation of the building, surrounding of the building);
- building dimensions;
- use of the building (e.g. office, production);
- building envelope (U-values of components);
- building technical equipment;
- energy export to third parties;
- climatic conditions inside the building (e.g. interior temperature, humidity, exposure, shading);
- energy certificate, if available.

b. The building inspection must include the following:

- assessment of the actual level of each building supply performance, taking into account age, storage and distribution, emission system and control (e.g. temperature, humidity, degree of illuminance);
- understanding the drivers of changes in the technical systems, such as seasonal requirements.

c. As part of the recommended energy efficiency measures, at least the following points shall be considered:

- definition of the appropriate level of the building technical equipment performance;
- interactions of the building technical equipment with the building envelope and the external environment;

- condition, operation and maintenance of the building and technical systems;
- comparison of the existing building and technical equipment with the best available technologies available on the market.

Considering the investment costs, the following suggestion shall be applied:

- Whenever possible, rely on lifecycle cost analysis rather than simple payback periods. If possible, dynamic calculation methods shall be used to evaluate energy efficiency measures.

Croatia

There are three biding legal documents which apply to energy auditing.

1) Regulation on energy audits and energy certification of buildings (Official Gazette 88/17)

This Regulation stipulates the method and the conditions for the implementation of the energy audit of the building and regular audit of the heating system and the cooling or air conditioning system in the building, the content of the reports on these audits, the method of energy certification, the content and appearance of the energy certificate and criteria for buildings with low energy needs, method of energy management in buildings, determination of energy efficient measures and their cost effectiveness.

Annex 3 presents a set of tables, which a report of an audit of the heating system and the cooling or air conditioning system shall contain.

2) Methodology of performance of energy audits of construction works

The methodology (available on: http://www.mgipu.hr/doc/EnergetskaUcinkovitost/Propisi/Metodologija-2017.pdf) provides a set of actions and procedures for conducting energy audits of buildings. An integral part of Methodology is the Algorithm for Calculating Energy Properties of Buildings published on the website of the Ministry of Construction and Physical Planning (www.mgipu.hr), which prescribes the method of calculating all the required values for the calculation of the energy performance of the building and the development of the energy certificate (e.g. insulation, heating systems and preparation of domestic hot water, cogeneration systems, district heating systems, photovoltaic systems, ventilation and air conditioning systems for heating and cooling, lighting). The methodology is accompanied by a set of detailed calculation methodologies of specific parts of a building, e.g. heating and DHW system, HVAC, lightning system. The calculation methodology for heating system is based on the standard HR EN 15316:2008, although some parts follow other standards, in particular EN 15603, EN ISO 13790, EN 12241, EN 12831. The methodology is very detailed and presents formulas for calculation all steps required for determination of the primary energy consumption of a building.

The most important provisions of the methodology:

- Chapter 3 provides a list of data points, in all types if installations (heat, water etc.), required to be collected during the audit.
- Chapter 5.5 provides a detailed algorithm of calculating energy for lightning (based on standard HRN EN 15193: 2008)
- Chapter 5.6 provides an algorithm of calculating energy required for heating QH,nd and Primary energy consumption Eprim (based on HRN EN 15316 Standard)
- Chapter 7 provides a requirements for a table of contents of a report

3) Technical regulation on energy economy and heat retention in buildings (Official Gazette 128/15)

The Technical regulation prescribes:

- technical requirements regarding the rational use of energy and heat retention of the construction part of the building, technical heating systems,
- ventilation, cooling, air conditioning, hot water preparation and
- lighting that need to be fulfilled when designing and building new
- buildings and during the use of buildings that are heated to indoor temperature higher than 12°C.

It also prescribes above mentioned technical requirements reconstruction of existing buildings that need to be fulfilled when designing and implementing reconstruction of existing buildings.

This Technical Regulation also defines Criteria for nearly Zero Energy Building (nZEB).

Czech Republic

The main legal act which regulates the issue of energy auditing is the Regulation on energy auditing and energy audit report (Vyhláška č. 480/2012 Sb., available on https://www.zakonyprolidi.cz/cs/2012-480/zneni-20161011). The regulation specifies the scope of the energy audit and energy assessment and the content of the energy audit. An energy audit report describes a current state of a building and its installations, assessment of the technical state, and proposes energy efficiency measures. In general, the scope of the report is in line with the standard EN ISO 16247. Nevertheless, the regulation does not indicate any calculation method, although energy auditors follow Czech adaptation of international standards, in particular the following:

- 73 0542 – Method of estimation of energy balance of glazed area in external building structures
- ČSN 73 0540 Thermal protection of buildings
- EN 15217 – Energy performance of buildings - Methods for expressing energy performance and for energy certification of buildings
- EN 15241 – Ventilation for buildings - Calculation methods for energy losses due to ventilation and infiltration in buildings
- EN 15265 – Energy performance of buildings - Calculation of energy needs for space heating and cooling using dynamic methods - General criteria and validation procedures
- EN 15316 – a set of 12 standards „Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies“
- EN 15978 – Sustainability of construction works - Assessment of environmental performance of buildings - Calculation method
- EN 16247
- EN 16627 – Sustainability of construction works - Assessment of economic performance of buildings - Calculation methods
- EN 16798 – a set of 5 standards „Energy performance of buildings - Ventilation for buildings – Calculation methods“
- EN ISO 10077 – Thermal performance of windows, doors and shutters - Calculation of thermal transmittance
- EN ISO 13370
- EN ISO 13789 – Thermal performance of buildings - Transmission and ventilation heat transfer coefficients - Calculation method

- EN ISO 13790 – Energy performance of buildings - Calculation of energy use for space heating and cooling
- EN ISO 15927 – Hygrothermal performance of building - Calculation and presentation of climatic data

Hungary

Procedures of energy auditing are regulated by the following acts:

1) 2015 LVII Energy efficiency act

The act sets general environment of energy auditing. It does not include any specific technical guidelines for auditors to be followed.

2) Governmental regulation 176/2008 on the certification of the buildings energy performance

The regulation sets general provisions regarding certification of the buildings energy performance. It includes certification rules, content of the certificate, quality control rules, certification costs etc. It also establishes 12 building classes, from AA++ (<40 kWh/m^2a) to JJ (>500 kWh/m^2a). It does not include any specific calculation methods, although it indicates that the calculation shall be based on the regulation 7/2006.

3) Ministerial regulation 7/2006 on the determination of the building energy performance

Annex 2 of the regulation provides a methodology of determination of the building energy performance. It consists of calculation methods, which shall be followed when determining energy characteristics of the building. The Annex allows to use a simplified or detailed method. Formulas of simplified method are provided. When using a detailed method, an auditor shall follow national adaptations of the following international standards: EN 6946, EN ISO 10211, EN ISO 13370, EN ISO 13790.

Italy

Procedures of energy auditing are regulated by two parts of the international standard *EN ISO 16247 Energy Audits: Part 1 General requirements and Part 2 Buildings*.

The standard provides general guidelines for conducting energy audits. It recognises that there are differences in approach to energy auditing in terms of scope, aims and thoroughness, but seeks to harmonise common aspects of energy auditing in order to bring more clarity and transparency to energy auditing services. The energy audit process is presented as a set of chronological steps. Nor specific requirements neither calculation methodology is provided.

Poland

Procedures of energy auditing are regulated by the following acts:

1) Regulation of the Minister of Infrastructure of 17 March 2009 on the scope of a building energy audit

The Regulation presents requirements for an audit report. In particular it provides tables which have to be included into the report: a front page (consisting of general information about a building and an auditor as well as a table of contents), a summary of an audit (general information about the building and comparison of technical conditions of a building – existing and after a modernisation), a list of optimal energy efficiency measures, efficiency of a heating system components. A methodology for choosing an optimal energy efficiency measure is presented as well. No algorithm of calculations is presented.

2) Regulation of the Minister of Infrastructure and Development of 27 February 2015 on methodology for determining the energy performance of a building

The regulation provides a detailed algorithm and calculation formulas for determining energy performance of a building. The methodology shall be used also to calculate energy savings of energy efficiency measures. A detailed algorithm of calculating all necessary indicators is specified. Some part of calculation is based on national adaptations of the following international standards: EN ISO 6946, EN 14351-1, EN 13830, EN 12831:2006, EN ISO 14683:2008, EN ISO 10211:2008, EN ISO 10456:2009, EN ISO 10456:2009, EN 14351-1.

Slovenia

Procedures of energy auditing are regulated by the Regulation on the methodology for the development and content of the energy audit (Official Gazette of the Republic of Slovenia, No. 41/16). The regulation sets minimum requirements for energy audits, which consists of five general rules for auditors. It also specifies a methodology of conducting energy audit. The auditor shall follow either national adaptation of an international standard ISO 50002 or a series of standards EN 16247 (EN 16247-1, EN 16247-2, EN 16247-3 and EN 16247-4). Regardless the choice made by an auditor, each standard provides general guidelines for conducting energy audits. Nor specific requirements neither calculation methodology is provided.

Annex 3: Overview of international standards indicated by Directive (EU) 2018/844

ISO 52000-1 Energy performance of buildings — Overarching EPB assessment — Part 1: General framework and procedures

This document establishes a systematic, comprehensive and modular structure for assessing the energy performance of new and existing buildings (EPB) in a holistic way. It is applicable to the assessment of overall energy use of a building, by measurement or calculation, and the calculation of energy performance in terms of primary energy or other energy-related metrics. It takes into account the specific possibilities and limitations for the different applications, such as building design, new buildings 'as built', and existing buildings in the use phase as well as renovation.

ISO 52003-1 Energy performance of buildings — Indicators, requirements, ratings and certificates — Part 1: General aspects and application to the overall energy performance

The set of EPB assessment standards produces a great number of overall and partial EPB indicators as outputs. This document provides general insight to both private parties and public regulators (and all stakeholders involved in the regulatory process) on how to make good use of these outputs for different purposes (post-processing). This document describes the relation between the EPB indicators and the EPB requirements and EPB ratings, and it discusses the importance of project-specific, tailored values as requirement or reference for certain EPB indicators. This document also includes a couple of possible EPB labels and it lists the different steps to be taken when establishing an EPB certification scheme. This document provides standardized tables for reporting in a structured and transparent manner the choices that are to be made with respect to overall EPB requirements. The tables are non-restrictive, thus allowing for full regulatory flexibility. This document does not provide such tables for partial EPB requirements (related to the fabric or technical buildings systems), as this is dealt with in other documents.

ISO 52010-1 Energy performance of buildings — External climatic conditions — Part 1: Conversion of climatic data for energy calculations

This document specifies a calculation procedure for the conversion of climatic data for energy calculations. The main element in this document is the calculation of solar irradiance on a surface with arbitrary orientation and tilt. A simple method for conversion of solar irradiance to illuminance is also provided. The solar irradiance and illuminance on an arbitrary surface are applicable as input for energy and daylighting calculations, for building elements (such as roofs, facades and windows) and for components of technical building systems (such as thermal solar collectors, PV panels). Other parameters of climatic data needed to assess the thermal and moisture performance of buildings, building elements or technical building systems [like wind, temperature, moisture and long-wave (thermal) radiation] are to be obtained according to the procedures in ISO 15927-4. These data are listed in this document as input and passed on as output without any conversion. The reason for passing these data via this document is to have one single and consistent source for all EPB standards and to enable any conversion or other treatment if needed for specific application.

ISO 52016-1 Energy performance of buildings — Energy needs for heating and cooling, internal temperatures and sensible and latent heat loads — Part 1: Calculation procedures

This document specifies calculation methods for the assessment of:

- the (sensible) energy need for heating and cooling, based on hourly or monthly calculations;
- the latent energy need for (de-)humidification, based on hourly or monthly calculations;
- the internal temperature, based on hourly calculations;
- the sensible heating and cooling load, based on hourly calculations;
- the moisture and latent heat load for (de-)humidification, based on hourly calculations;
- the design sensible heating or cooling load and design latent heat load using an hourly calculation interval;
- the conditions of the supply air to provide the necessary humidification and dehumidification.

The calculation methods can be used for residential or non-residential buildings, or a part of it, referred to as “the building” or the "assessed object". This document also contains specifications for the assessment of thermal zones in the building or in the part of a building. The calculations are performed per thermal zone. In the calculations, the thermal zones can be assumed to be thermally coupled or not. The calculation methods have been developed for the calculation of the basic energy loads and needs, without interaction with specific technical building systems, and for the calculation of the system specific energy loads and needs, including the interaction with specific systems. The hourly calculation procedures can also be used as basis for calculations with more extensive system control options. This document is applicable to buildings at the design stage, to new buildings after construction and to existing buildings in the use phase.

ISO 52018-1 Energy performance of buildings — Indicators for partial EPB requirements related to thermal energy balance and fabric features — Part 1: Overview of options

The set of EPB assessment standards produces a great number of overall and partial EPB indicators as outputs, which can be used for different purposes. This document deals with the use as requirement of partial EPB indicators related to the fabric and related to the thermal balance of the building. Thermal balance aspects concern both the heating and cooling needs and the free floating temperatures, especially with respect to overheating or too cold indoor temperatures. This document can support both private parties and public regulators (and all stakeholders involved in the regulatory process) with the “post-processing” of these outputs. This document provides standardized tables for reporting, in a structured and transparent manner, the choices that are to be made with respect to the partial EPB requirements covered by this document. The tables are non-restrictive, thus allowing for full regulatory flexibility.