Energy calculation

1) In order to verify the compliance of a building with the minimum requirements of energy performance, the energy calculation is performed with respect to the standard use of the building, using the input parameters which are set out in this regulation and which characterise the indoor and outdoor climate, the periods of use and operation of the building and the utility systems, heat gains and the building's air leakage rate. The other necessary input parameters are taken from the building design documentation.
2) For the purposes of the energy calculation, it is not necessary to perform a detailed division of the building into zones. Small residential buildings and buildings with a single purpose of use may be regarded as a single zone for the purposes of the energy calculation. Large buildings are to be divided into as many zones as required according to their purposes and periods of use.
3) In this regulation, the buildings' purposes of use are the purposes of use set out in the regulation entitled Minimum Requirements for Energy Performance enacted in accordance with subsection 72 of section 3 of the Building Act.

Outdoor climate

Regardless of the building's location, the energy calculation and the verification of compliance with the summertime indoor temperature requirement are performed on the basis of the data of the Estonian test reference year. The test reference year represents the typical outdoor climate of three decades (1970–2000) and therefore is not suited to be used for the calculation of the heating power need. Where the test reference year is used for calculating the cooling load, it should be borne in mind that the results are not applicable to the cooling load in the case of a warmer than average summer.

Indoor climate

1) The energy calculation uses the indoor temperature set-points and ventilation air flow rates set out in the regulation entitled Minimum Requirements for Energy Performance.

2) In the case of a simplified calculation which treats indoor temperature as a constant, the indoor temperature set-points are used as the indoor temperature value (e.g., in residential buildings 21 °C for heating and 27 °C for cooling). In the case of a dynamic calculation, the relevant values are used as the heating and cooling set-points of a thermostat. Where the

building lacks a cooling system, the difference between the summertime indoor temperatures and the cooling set-point must be calculated.

3) Outside of occupied hours, the ventilation air flow rate of a non-residential building is deemed to be 0.15 $l/(sm^2)$ in the out of operation mode of the ventilation system.

4) In the case of a variable air volume ventilation system in which the air flow rate varies and whose control function operates in accordance with the quality of air (the carbon dioxide (***CO_2)*** content or a combination of CO_2 content and, for example, temperature or humidity values), the air flow rates set out in the regulation entitled Minimum Requirements for Energy Performance enacted in accordance with subsection 72 of section 3 of the Building Act are used as the maximum air flow rates of the relevant rooms. Where a system with a variable air flow rate is used for the purpose of cooling, the maximum air flow rate is determined according to the cooling need. The minimum air flow rate and the ventilation control function must, in general, be selected such as to avoid exceeding the 1000 ppm maximum volume fraction of CO_2 while the corresponding value in outdoor air is 400 ppm.

Calculation of energy need

Principles of calculation of energy need and summertime indoor temperatures

- The calculation of energy need follows the principles of the standard EVS-EN ISO 13790 which are applied in accordance with this section.
- The calculation of the energy need for space heating takes into account the need to heat infiltration air and the heating of ventilation supply air in the room from supply air temperature to indoor temperature.
- When calculating the energy need for the heating of ventilation air, the heat recovery of the ventilation system is taken into account. The energy need for the heating of ventilation supply air includes the heating of the ventilation air before and/or after heat recovery or, in ventilation systems without heat recovery, the heating of the supplied outdoor air from the outdoor temperature to indoor temperature.
- Heat gain is calculated following the requirements specified in section 6. The calculation of solar radiation which enters the building through glass surfaces takes into account different solar protection solutions (such as solar protection glass, internal and external

window blinds, grates, awnings) as provided in the design solution, as well as the shadows cast on glass surfaces by surrounding objects and by parts of the building itself.

- The energy need for the heating of household water is calculated.
- The parameters set out in section 6 are used in calculating the summertime indoor temperature and the energy need for space cooling. The cooling of rooms by air change achieved through the opening of windows is not taken into account in the calculations for non-residential buildings. In the case of residential buildings, only the opening of windows to the airing position and the air change driven by the difference between outdoor and indoor temperature are taken into account (the windows are closed when the temperature falls to the heating set-point). The verification of compliance with the summertime indoor temperature requirement provided in the regulation entitled Minimum Requirements for Energy Performance established in accordance with subsection 72 of section 3 of the Building Act takes into account the fact that the degree hours requirement applies to the occupied hours of the building and that outside those hours the indoor temperature may be higher, but will not be taken into account.

Principles of calculation of heat loss through the building envelope

1) In the calculation of heat losses, the area of the building envelope is calculated on the basis of internal dimensions of the building (the dimensions between internal surfaces of walls or ceiling and floor together with rooms and load-bearing and non-load-bearing partitions). Where heat losses are calculated separately for each room, the area of the relevant envelope section is calculated using the centre-line measures of partitions and inserted ceilings.
2) The heat losses of the building envelope (exterior walls, floors and roofs) are calculated on the basis of the thermal transmittance of the envelope and its area as calculated on the basis of the internal dimensions of the building. Regular thermal bridges (e.g., stiffeners, masonry anchors) are taken into account in accordance with their thermal transmittance values. The heat losses of irregular thermal bridges (e.g., the junctions of exterior wall and exterior wall, exterior wall and inserted ceiling, floor and exterior wall, warm roof and exterior wall, as well as window to wall fixing junctions) are taken into account separately in accordance with the thermal transmittance values of linear and point thermal bridges. If necessary, the total specific heat loss (heat loss in watts at a temperature difference of one degree) of the

building envelope calculated according to the method described above is converted into average thermal transmittance of the building envelope by dividing the total specific heat loss of the envelope with the area of the envelope which is determined according to the rules of the calculation software used.

3) The thermal transmittance of the building envelope is based on the data obtained from the building design documentation.
4) The building’s heat loss to the ground is determined on the basis of a dynamic one-dimensional calculation which assumes a heat-accumulating soil layer whose thickness is at least one metre and below which the temperature remains constant at 7 °C, or on the basis of a dynamic three-dimensional calculation, or by using tabulated values of the temperature of the ground beneath the building.

Efficient energy use, sometimes simply called energy efficiency, is the goal to reduce the amount of energy required to provide products and services. For example, insulating a home allows a building to use less heating and cooling energy to achieve and maintain a comfortable temperature. Installing fluorescent lights, LED lights or natural skylights reduces the amount of energy required to attain the same level of illumination compared with using traditional incandescent light bulbs. Improvements in energy efficiency are generally achieved by adopting a more efficient technology or production process or by application of commonly accepted methods to reduce energy losses.

There are many motivations to improve energy efficiency. Reducing energy use reduces energy costs and may result in a financial cost saving to consumers if the energy savings offset any additional costs of implementing an energy efficient technology. Reducing energy use is also seen as a solution to the problem of reducing greenhouse gas emissions. According to the International Energy Agency, improved energy efficiency in buildings, industrial processes and transportation could reduce the world's energy needs in 2050 by one third, and help control global emissions of greenhouse gases.

Energy efficiency and renewable energy are said to be the twin pillars of sustainable energy policy and are high priorities in the sustainable energy hierarchy. In many countries energy efficiency is also seen to have a national security benefit because it can be used to reduce the level of energy imports from foreign countries and may slow down the rate at which domestic energy resources are depleted.

Energy audit reports of buildings

An energy audit is an inspection, survey and analysis of energy flows, for energy conservation in a building, process or system to reduce the amount of energy input into the system without negatively affecting the output(s). In commercial and industrial real estate, an energy audit is the first step in identifying opportunities to reduce energy expense and carbon footprints.

When the object of study is an occupied building then reducing energy consumption while maintaining or improving human comfort, health and safety are of primary concern. Beyond simply identifying the sources of energy use, an energy audit seeks to prioritize the energy uses according to the greatest to least cost effective opportunities for energy savings.

A home energy audit is a service where the energy efficiency of a house is evaluated by a person using professional equipment (such as blower doors and infrared cameras), with the aim to suggest the best ways to improve energy efficiency in heating and cooling the house.

An energy audit of a home may involve recording various characteristics of the building envelope including the walls, ceilings, floors, doors, windows, and skylights. For each of these components the area and resistance to heat flow (R-value) is measured or estimated. The leakage rate or infiltration of air through the building envelope is of concern, both of which are strongly affected by window construction and quality of door seals such as weatherstripping. The goal of this exercise is to quantify the building's overall thermal performance. The audit may also assess the efficiency, physical condition, and programming of mechanical systems such as the heating, ventilation, air conditioning equipment, and thermostat.

A home energy audit may include a written report estimating energy use given local climate criteria, thermostat settings, roof overhang, and solar orientation. This could show energy use for a given time period, say a year, and the impact of any suggested improvements per year. The accuracy of energy estimates are greatly improved when the homeowner's billing history is available showing the quantities of electricity, natural gas, fuel oil, or other energy sources consumed over a one or two-year period.

Some of the greatest effects on energy use are user behaviour, climate, and age of the home. An energy audit may therefore include an interview of the homeowners to understand their patterns of use over time. The energy billing history from the local utility company can be calibrated using heating degree day and cooling degree day data obtained from recent, local weather data in combination with the thermal energy model of the building. Advances in computer-based thermal modeling can take into account many variables affecting energy use.

A home energy audit is often used to identify cost effective ways to improve the comfort and efficiency of buildings. In addition, homes may qualify for energy efficiency grants from central government.

Recently, the improvement of smartphone technology has enabled homeowners to perform relatively sophisticated energy audits of their own homes. This technique has been identified as a method to accelerate energy efficiency improvements.

Types of energy audit

The term energy audit is commonly used to describe a broad spectrum of energy studies ranging from a quick walk-through of a facility to identify major problem areas to a comprehensive analysis of the implications of alternative energy efficiency measures sufficient to satisfy the financial criteria of sophisticated investors.

Numerous audit procedures have been developed for non-residential (tertiary) buildings (ASHRAE; IEA-EBC Annex 11. Audit is required to identify the most efficient and cost-effective Energy Conservation Opportunities (ECOs) or Measures (ECMs). Energy conservation opportunities (or measures) can consist in more efficient use or of partial or global replacement of the existing installation.

The main issues of an audit process are:

- The analysis of building and utility data, including study of the installed equipment and analysis of energy bills;
- The survey of the real operating conditions;
- The understanding of the building behaviour and of the interactions with weather, occupancy and operating schedules;
- The selection and the evaluation of energy conservation measures;
- The estimation of energy saving potential;
- The identification of customer concerns and needs.

Common types/levels of energy audits are distinguished below, although the actual tasks performed and level of effort may vary with the consultant providing services under these broad headings. The only way to ensure that a proposed audit will meet your specific needs is to spell out those requirements in a detailed scope of work. Taking the time to prepare a formal solicitation will also assure the building owner of receiving competitive and comparable proposals.

Generally, four levels of analysis can be outlined (ASHRAE):

- **Level 0** – Benchmarking: This first analysis consists in a preliminary Whole Building Energy Use (WBEU) analysis based on the analysis of the historic utility use and costs and the comparison of the performances of the buildings to those of similar buildings. This benchmarking of the studied installation allows determining if further analysis is required;
- **Level I** – Walk-through audit: Preliminary analysis made to assess building energy efficiency to identify not only simple and low-cost improvements but also a list of energy conservation measures (ECMs, or energy conservation opportunities, ECOs) to orient the future detailed audit. This inspection is based on visual verifications, study of installed equipment and operating data and detailed analysis of recorded energy consumption collected during the benchmarking phase;
- **Level II** – Detailed/General energy audit: Based on the results of the pre-audit, this type of energy audit consists in energy use survey in order to provide a comprehensive analysis of the studied installation, a more detailed analysis of the facility, a breakdown of the energy use and a first quantitative evaluation of the ECOs/ECMs selected to correct the defects or improve the existing installation. This level of analysis can involve advanced on-site measurements and sophisticated computer based simulation tools to evaluate precisely the selected energy retrofits;
- **Level III** – Investment-Grade audit: Detailed Analysis of Capital-Intensive Modifications focusing on potential costly ECOs requiring rigorous engineering study.

Bench marking

The impossibility of describing all possible situations that might be encountered during an audit means that it is necessary to find a way of describing what constitutes good, average and bad energy performance across a range of situations. The aim of benchmarking is to answer this question. Benchmarking mainly consists in comparing the measured consumption with reference consumption of other similar buildings or generated by simulation tools to identify excessive or unacceptable running costs. As mentioned before, bench marking is also necessary to identify buildings presenting interesting energy saving potential. An important issue in bench marking is the use of performance indexes to characterize the building.

These indexes can be:

- Comfort indexes, comparing the actual comfort conditions to the comfort requirements;
- Energy indexes, consisting in energy demands divided by heated/conditioned area, allowing comparison with reference values of the indexes coming from regulation or similar buildings;
- Energy demands, directly compared to "reference" energy demands generated by means of simulation tools.

Walk-through (or) preliminary audit

The preliminary audit (alternatively called a simple audit, screening audit or walk-through audit) is the simplest and quickest type of audit. It involves minimal interviews with site-operating personnel, a brief review of facility utility bills and other operating data, and a walk-through of the facility to become familiar with the building operation and to identify any glaring areas of energy waste or inefficiency.

Typically, only major problem areas will be covered during this type of audit. Corrective measures are briefly described, and quick estimates of implementation cost, potential operating cost savings, and simple payback periods are provided. A list of energy conservation measures(ECMs, or energy conservation opportunities, ECOs) requiring further consideration is also provided. This level of detail, while not sufficient for reaching a final decision on implementing proposed measure, is adequate to prioritize energy-efficiency projects and to determine the need for a more detailed audit.

General audit

The general audit (alternatively called a mini-audit, site energy audit or detailed energy audit or complete site energy audit) expands on the preliminary audit described above by collecting more detailed information about facility operation and by performing a more detailed evaluation of energy conservation measures. Utility bills are collected for a 12- to 36-month period to allow the auditor to evaluate the facility's energy demand rate structures and energy usage profiles. If interval meter data is available, the detailed energy profiles that such data makes possible will typically be analyzed for signs of energy waste. Additional metering of specific energy-consuming systems is often performed to supplement utility data. In-depth interviews with facility operating personnel are conducted to provide a better understanding of major energy consuming systems and to gain insight into short and longer term energy consumption patterns. This type of audit will be able to identify all energy-conservation measures appropriate for the facility, given its operating parameters. A detailed financial analysis is performed for each measure based on detailed implementation cost estimates, site-specific operating cost savings, and the customer's investment criteria. Sufficient detail is provided to justify project implementation. The evolution of cloud-based energy auditing software platforms is enabling the managers of commercial buildings to collaborate with general and specialty trades contractors in performing general and energy system-specific audits. The benefit of software-enabled collaboration is the ability to identify the full range of energy efficiency options that may be applicable to the specific building under study with "live time" cost and benefit estimates supplied by local contractors.

Investment-grade audit

In most corporate settings, upgrades to a facility's energy infrastructure must compete for capital funding with non-energy-related investments. Both energy and non-energy investments are rated on a single set of financial criteria that generally stress the expected return on investment (ROI). The projected operating savings from the implementation of energy projects must be developed such that they provide a high level of confidence. In fact, investors often demand guaranteed savings. The investment-grade audit expands on the detailed audit described above and relies on a complete engineering study in order to detail technical and economical issues necessary to justify the investment related to the transformations.

Simulation-based energy audit procedure for non-residential buildings

A complete audit procedure, very similar to the ones proposed by ASHRAE and Krarti (2000), has been proposed in the frame of the AUDITAC and HARMONAC projects to help in the implementation of the EPB (“Energy Performance of Buildings”) directive in Europe and to fit to the current European market.

The following procedure proposes to make an intensive use of modern BES tools at each step of the audit process, from benchmarking to detailed audit and financial study:

Bench marking stage: While normalization is required to allow comparison between data recorded on the studied installation and reference values deduced from case studies or statistics. The use of simulation models, to perform a code-compliant simulation of the installation under study, allows to assess directly the studied installation, without any normalization needed. Indeed, applying a simulation-based benchmarking tool allows an individual normalization and allows avoiding size and climate normalization.

Preliminary audit stage: Global monthly consumptions are generally insufficient to allow an accurate understanding of the building's behaviour. Even if the analysis of the energy bills does not allow identifying with accuracy the different energy consumers present in the facility, the consumption records can be used to calibrate building and system simulation models. To assess the existing system and to simulate correctly the building's thermal behaviour, the simulation model has to be calibrated on the studied installation. The iterations needed to perform the calibration of the model can also be fully integrated in the audit process and help in identifying required measurements and critical issues.

Detailed audit stage: At this stage, on-site measurements, sub-metering and monitoring data are used to refine the calibration of the BES tool. Extensive attention is given to understanding not only the operating characteristics of all energy consuming systems, but also situations that cause load profile variations on short and longer term bases (e.g. daily, weekly, monthly, annual). When the calibration criteria is satisfied, the savings related to the selected ECOs/ECMs can be quantified.

Investment-grade audit stage: At this stage, the results provided by the calibrated BES tool can be used to assess the selected ECOs/ECMs and orient the detailed engineering study.

Concepts of Green Buildings – ratings of Green buildings

Green building (also known as green construction or sustainable building) refers to both a structure and the using of processes that are environmentally responsible and resource-efficient throughout a building's life-cycle: from siting to design, construction, operation, maintenance, renovation, and demolition.

Green architecture, or green design, is an approach to building that minimizes harmful effects on human health and the environment. The "green" architect or designer attempts to safeguard air, water, and earth bychoosing eco-friendly building materials and construction practices.

Green building, or sustainable design, is the practice of increasing the efficiency with which buildings and their sites use energy, water, and materials, and reducing building impacts on human health and the environment over the entire life cycle of the building.

Green architecture is a sustainable method of green building design: it is design and construction with the environment in mind. Green architects generally work with the key concepts of creating an energy efficient, environmentally friendly house.

Green building (also known as green construction or sustainable building) refers to both a structure and the using of processes that are environmentally responsible and resource-efficient throughout a building's life-cycle: from siting to design, construction, operation, maintenance, renovation, and demolition. In other words, green building design involves finding the balance between homebuilding and the sustainable environment. This requires close cooperation of the design team, the architects, the engineers, and the client at all project stages. The Green Building practice expands and complements the classical building design concerns of economy, utility, durability, and comfort.

Although new technologies are constantly being developed to complement current practices in creating greener structures, the common objective of green buildings is to reduce the overall impact of the built environment on human health and the natural environment by:

- Efficiently using energy, water, and other resources
- Protecting occupant health and improving employee productivity
- Reducing waste, pollution and environmental degradation

A similar concept is natural building, which is usually on a smaller scale and tends to focus on the use of natural materials that are available locally. Other related topics include sustainable design and green architecture. Sustainability may be defined as meeting the needs of present generations without compromising the ability of future generations to meet their needs. Although some green building programs don't address the issue of the retrofitting existing homes, others do, especially through public schemes for energy efficient refurbishment. Green construction principles can easily be applied to retrofit work as well as new construction.

Green buildings often include measures to reduce energy consumption – both the embodied energy required to extract, process, transport and install building materials and operating energy to provide services such as heating and power for equipment.

As high-performance buildings use less operating energy, embodied energy has assumed much greater importance – and may make up as much as 30% of the overall life cycle energy consumption.

To reduce operating energy use, designers use details that reduce air leakage through the building envelope (the barrier between conditioned and unconditioned space). They also specify high-performance windows and extra insulation in walls, ceilings, and floors. Another strategy, passive solar building design, is often implemented in low-energy homes. Designers orient windows and walls and place awnings, porches, and trees to shade windows and roofs during the summer while maximizing solar gain in the winter. In addition, effective window placement (daylighting) can provide more natural light and lessen the need for electric lighting during the day. Solar water heating further reduces energy costs.

Onsite generation of renewable energy through solar power, wind power, hydro power, or biomass can significantly reduce the environmental impact of the building. Power generation is generally the most expensive feature to add to a building.

As a result of the increased interest in green building concepts and practices, a number of organizations have developed standards, codes and rating systems that let government regulators, building professionals and consumers embrace green building with confidence. In some cases, codes are written so local governments can adopt them as bylaws to reduce the local environmental impact of buildings.

Green building rating systems such as BREEAM (United Kingdom), LEED (United States and Canada), DGNB (Germany), CASBEE (Japan), and VERDEGBCe (Spain) help consumers determine a structure's level of environmental performance. They award credits for optional building features that support green design in categories such as location and maintenance of building site, conservation of water, energy, and building materials, and occupant comfort and health. The number of credits generally determines the level of achievement.

Green building codes and standards, such as the International Code Council's draft International Green Construction Code, are sets of rules created by standards development organizations that establish minimum requirements for elements of green building such as materials or heating and cooling.