P95

04-02-2009

# The different CEN approaches for calculating the energy use for heating and cooling

## (Dynamic and quasi-steady-state method, holistic and simple approach)

**Anna Staudt**
**Hans Erhorn**
Fraunhofer Institute of Building Physics, Germany

More information can be found at the CENSE project website:
*www.iee-cense.eu*

Similar Information Papers on CENSE and/or other European projects can be found at the Buildings Platform website:
*www.buildingsplatform.eu*

The assessment of a building's energy performance includes the energy use for heating, cooling, ventilation, humidification, dehumidification, hot water and lighting. The starting point is typically the determination of energy needs. This paper introduces several calculation procedures for calculating the building energy need for heating and cooling, applying the CEN standards to support the EPBD [1]. The two basic types, differentiated by the time steps used in the calculation, are the quasi-steady-state and the dynamic method. In addition, interactions between buildings and the systems they contain can be accounted for either by the holistic or the simplified approach. These different methods are mentioned in CEN/TR 15615 [2], the Umbrella Document of the CEN standards to support the EPBD. Detailed descriptions and explanations are given in EN ISO 13790 [3], concerning the energy need for heating and cooling, and in EN 15603 [4], concerning overall energy use. (see Figure 1)

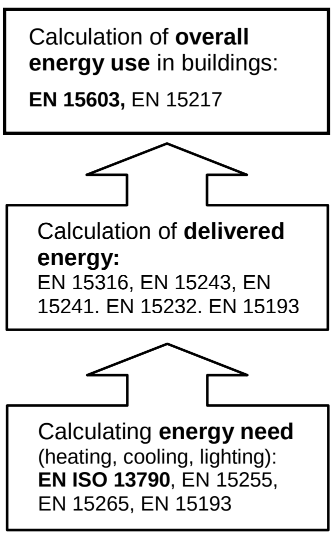



*Figure 1: The series of CEN standards offer different types of calculation methods for different steps of the building's energy assessment.*

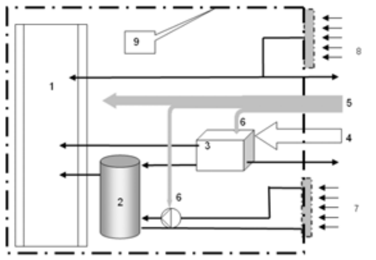
## 1 > General Calculation Procedure

The objective of the calculation procedure is to determine the annual overall energy use, primary energy and resulting emission of $CO_2$. Obtaining a realistic energy-value is essential to enable an authentic rating of the building's energy performance. The advantage of the calculated energy rating over the measured rating is that the user's behaviour and actual weather do not influence the result. Thus, only the performance of the building with its technical building systems is assessed. The different types of rating are presented in EN 15603 (see Information Paper P88).

According to EN ISO 13790 (see also Information Paper P92), the main calculation procedure consists of the following steps. The energy balance of the building and its systems is the basis of the procedure.

- Choice of type of calculation method
- Definition of boundaries
- Definition of internal conditions and external input data (e.g. climate)
- Calculation of the energy need for each time step and zone

Directorate-General for Energy and Transport
EUROPEAN COMMISSION



**Key**

| | | | |
|---|---|---|---|
| 1 | user | 6 | auxiliary energy |
| 2 | storage | 7 | thermal solar collector |
| 3 | boiler | 8 | photovoltaic panels |
| 4 | fuel | 9 | boundary |
| 5 | electricity | | |

*Figure 2: System Boundary. Examples of energy flows across the system boundary*

- Combination of zone-results with corresponding system losses
- Consideration of interactions between zones and/or systems

In both the first and the last step, two different methods are suggested by the CEN standards. There are thus four different approaches for the complete calculation procedure, as each method of one step can be combined with each of the two methods at the other step.

The remaining steps must be followed in each case. Depending on the situation, the building must either be partitioned into multiple zones or may be treated as a single zone. A zone is defined as an area with identical (or similar) use and thermal characteristics and served by the same systems. A clear definition of the so-called "system boundary", which is related to the object of the assessment (e.g. apartment, building, etc.), is required to make a standard assessment possible, for the purpose of comparison. Energy flows can pass through the system boundary (see Figure 2). Specific zoning and boundary rules may be provided at national level.

## 2 > Different types of calculation methods depending on the time step used

Two basic types of method are given, depending on the time step used in the calculation. Even though the intermediate results of both methods vary critically, the final result is usually quite similar.

- **Quasi-steady-state methods**
  Calculation of the heat balance over a sufficiently long time (typically one month or a whole season), which makes it possible to consider dynamic effects by an empirically determined gain and/or loss utilization factor.
- **Dynamic methods**
  Calculation of the heat balance with short time steps (typically one hour), taking into account the heat stored in and released from the mass of the building.

In this regard, the international standard EN ISO 13790 mentions three different types of method:

- a fully prescribed monthly quasi-steady-state calculation method (plus a seasonal method as a special option)
- a fully prescribed simple hourly dynamic calculation method
- calculation procedures for detailed (e.g. hourly) dynamic simulation methods

The first two are explicitly covered in the standard, both representing simplified approaches. For detailed descriptions and performance requirements of dynamic simulation methods, other standards (e.g. EN 15265 [5]) are referenced. It must be decided at national level which of these types of method are optional or mandatory. The choice typically depends on the application (the purpose of the calculation), the building type or use and on the complexity of the building and its systems.

Additional aspects influencing the choice of method and the quality of the calculation procedure are for example transparency, robustness and reproducibility. Also simplicity and time- and cost-effectiveness are crucial, resulting in questions like "simple method or simple input?" and "accuracy or cost-effectiveness?". These issues are described and discussed in Information Paper P26 of the EPBD Buildings Platform, which recommends that compromises should be made to identify the optimum approach, which will be somewhere in between these conflicting goals.

This avoids uncertainties and the increasing risk of making mistakes, the higher the level of quality and the more detailed the input parameters are.

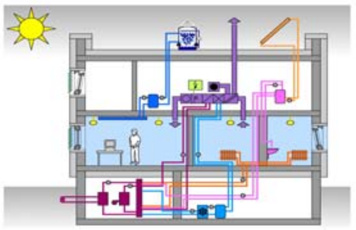


*Figure 3:*
*Many different systems, which interact very considerably with each other, influence the energy requirement.*

## 3 > Different ways of dealing with interactions between a building and its systems

As the calculation should be as realistic as possible, the fact that the different energy-consuming services (heating, cooling, lighting, hot water, etc.) influence each other should not be neglected. These interactions are taken into account by the calculation of heat gains and recoverable system losses. (see Figure 3)

The resulting impact of these interactions on the energy performance of the building is not necessarily positive. Dissipated heat from the lighting system, for instance, leads to increased energy needs for cooling in summer. Which interactions to consider and how they should be considered must be defined at national level. Two approaches, both taking the recoverable thermal losses of the systems into account, are prescribed in EN ISO 13790 and EN 15603 (see Figure 4):

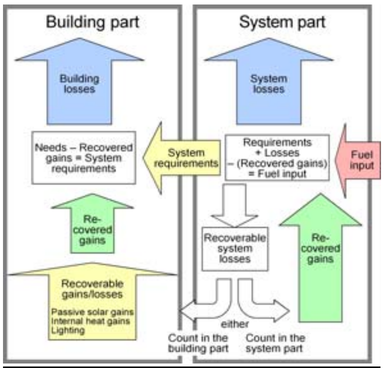



*Figure 4: The CEN-alternatives: holistic or simplified approach.*

*The recovered gains or losses (green arrow) are either adjusted in the system part of the calculation by a global value (right side, simple approach) or incorporated in the internal gains in the building part (left side, holistic approach), which requires a number of iterations.*

› **Holistic approach**
The sum total of the energy flows to and from all heat sinks and sources in the building and to and from the technical building systems, which are recoverable for space heating and/or cooling are considered in the calculation of the thermal energy needs. As there is inevitably an interaction between thermal system losses and energy input, iterations may be required.

The calculation procedure requires the following successive steps:

1. Calculation of the energy needs for heating and cooling without taking into account the recoverable thermal losses of the systems as internal heat gains.
2. The sub-system calculation according to EN 15241 [6], EN 15243 [7] and EN 15316 series [8] and the determination of recoverable thermal system losses.
3. Calculation of the energy needs for heating and cooling with addition of the recoverable thermal system losses to the other heat sources (e.g. solar and internal heat gains), resulting in a new calculation of the energy needs for heating and cooling
4. Repetition of the calculation from step 1 until changes of the energy needs between two iterations are less than a defined limit (e.g. 1 %) or up to a certain number of iterations, as specified at the national level
5. Calculation of the difference between the energy needs at the start of the iteration and at its end, which gives the recovered thermal loss from each system.

› **Simplified approach**
The recovered system heat losses, obtained by multiplying the recoverable thermal system losses by a fixed conventional recovery factor, are directly subtracted from the thermal loss of each technical building system considered. Thus, iterations are avoided.

The calculation procedure requires the following steps:

1. Calculation of the energy needs for heating and cooling without taking the recoverable thermal losses of any system into account in detail, but regarding them as fixed parts of the internal heat gain.
2. The sub-system calculation according to EN 15241, EN 15243 and EN 15316 series and the determination of recoverable thermal system losses: Calculation of the recovered thermal system losses

by multiplying the recoverable thermal losses by a conventional recovery factor and subtraction of these recovered thermal losses from the total thermal loss of each system.

In general, the simplified approach works well for middle-rate buildings without cooling and with simple system configurations, which meet the common standard, as average values form the basis of the simplification. But for high performance buildings or very old ones that are built with low energetic quality, the global consideration of heat gains and losses may lead to incorrect results. The reasons for this are, for example, the overrating of solar gains that may interfere with internal gains and thus be considered twice or the global adjustment of losses, which are for instance highly inaccurate, when internal piping is not insulated. Also, the general predetermination of the duration of a fixed heating-period (e.g. 185 days in Germany) implies a source of error in buildings with extremely high or low thermal insulation values. Regarding these extreme cases, the holistic approach manages to adapt by calculating iteratively, as the duration of the heating and cooling periods respond flexibly to losses and to realistic solar and internal heat gains, including the recoverable thermal losses from each building system. The same calculation method is thus appropriate for calculating the energy performance of a building with high energy needs (Class F) and of a high performance building (Class $A^{++}$).

The quality of a building's performance is thus a crucial aspect when choosing a suitable method. In addition, the choice depends, among other considerations, on the technical building system. In general, the more complex the system and the better the building performance (e.g. passive houses), the more appropriate it is to apply the holistic approach. Nevertheless, both methods do take recovered thermal system losses into account in the final energy rating.

## 4 > Example-Application of different methods in German standards

In Germany, different standards must currently be applied for residential and non-residential buildings. DIN V 4108 [9] and DIN V 4701 [10] cover the calculation procedure for residential buildings, using the simple approach, whereas DIN V 18599 [11] applies the holistic approach for non-residential buildings. Both procedures are based on quasi-steady-state methods, generally using months as time-steps. For the simple approach, the use of yearly time-steps is also allowed under some circumstances.

In the calculation procedure for residential buildings, the computation of the energy need (DIN V 4108-6) is strictly separated from the calculation covering the buildings' systems (DIN V 4701-10). Thus, interactions are hardly considered. In addition, lighting, which generally influences the heating needs, is only covered indirectly, as a fixed part of the internal gains. As most recently built residential buildings are of middle-rate quality, this calculation procedure, applying the simple approach, usually results in realistic values.

DIN V 18599 offers a holistic interdisciplinary calculation procedure, taking interactions explicitly into account. It is based on the division of complex buildings into several zones, whereas simple buildings can be modelled as one zone. Zones are areas of similar use and conditioning in terms of heating, ventilation and cooling. The energy need of each zone is first determined. Several iteration-steps follow to calculate the actual required energy, taking all interactions between the different zones and the different services into account. Thus, the calculation is based on a model closely representing reality. The current German regulations only stipulate the application of DIN V 18599 for non-residential buildings. However, as part of the next revision, which is momentarily undergoing the political approval process in the federal parliament and will be adopted in 2009, the standard may also be applied for residential buildings. After a transition period, during which both methods (simple and holistic) can be used for residential buildings, the intention is to harmonise the calculation procedure and energy performance requirements for all types of buildings.

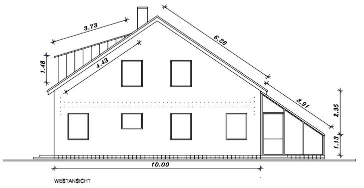


*Figure 5:*
*Example-building for German standards*

**Example of a Calculation**

As mentioned before, the simplified approach leads to correct results for middle-rate buildings because of the use of mean values. Thus the final energy rating calculated by either method for these buildings is very similar, whereas intermediate results may vary noticeably due to the simplifications. This effect is illustrated by the following example of a calculation of the energy rating of a single family house, applying both German standards and thus both calculation methods, simplified and holistic. The building considered, published in the standard DIN V 4108-6 and shown in Figure 5, represents a typical dwelling with heat insulation according to the standard of 1995 that is naturally ventilated. A condensing boiler is located inside the thermal envelope, as well as the distribution pipelines for space heating and domestic hot water, which both have circulation pumps.
Performing the two different types of calculation yields the following results [12]:

| | Simple Approach | Holistic Approach | Ratio |
|---|---|---|---|
| **Energy need for heating** | 15.673 kWh/a | 10.591 kWh/a | 68% |
| **Energy use for heating** | 21.399 kWh/a | 23.997 kWh/a | 112% |
| **Auxiliary energy** | 668 kWh/a | 596 kWh/a | 89% |
| **Primary energy** | 25.543 kWh/a | 25.571 kWh/a | 100% |

The table clarifies the consistency of the calculated final primary energy (last row), whereas the intermediate results clearly differ. Concerning the energy use for heating (second row in the table), it is worth noting that the two values are based on different references: the value used in the simple approach is based on the net calorific value, whereas that of the holistic approach is based on the gross calorific value.

## 5 > FAQ

**There are two methods, both taking the recoverable thermal losses of the building systems into account. Which approach (holistic or simplified) should be used, and when?**

National documents define under which conditions the two methods are to be applied. The choice of method depends on several aspects. First the purpose of the assessment should be considered, as it influences the level of detail required. The type and complexity of the building and its technical system are also relevant parameters. In general, the holistic approach is applied for complex systems and when a high level of detail is required.

**What are the advantages and disadvantages of the holistic and the simplified approach, which both take account of the interactions between the building and its systems?**

The primary advantage of the more detailed and thus more advanced method (holistic approach) is the higher quality and reliability of the results, due to the very realistic model on which the calculation is based. The intermediate results are quite exact and very appropriate for further more detailed analysis. Its main disadvantages are the need for suitable computer software for the complex calculation and the longer time required to perform the calculation.

The advantages mentioned above represent the disadvantages of the simplified approach, which uses a very approximate model. Nevertheless, the results can definitely be used to assess and compare the energy performance of simple buildings with conventional performance. The advantages of the simplified approach are the shorter time required to perform the calculation, and the fact that it can be done by hand.

**What is the difference between EN ISO 13790 and EN 15603?**

EN ISO 13790 describes calculation methods for the energy need for heating and cooling for each building zone, whereas EN 15603 deals with the overall energy use and the energy performance of buildings, collating the results from other standards, including those from EN ISO 13790.

## 6 > References


1. CEN/TR 15615, Explanation of the general relationship between various European Standards and the Energy Performance of Buildings Directive (EPBD) – Umbrella Document, CEN, Brussels (April 2008)
2. EU-Directive, Energy Performance of Buildings (EPBD). Directive 2002/91/EC (2002).
3. EN ISO 13790, Energy performance of buildings – Calculation of energy use for space heating and cooling, ISO, March 2008
4. EN 15603, Energy performance of buildings – Overall energy use and definition of energy ratings, CEN, Brussels (Jan. 2008)
5. EN 15265, Energy performance of buildings – Calculation of energy needs for space heating and cooling using dynamic methods – General criteria and validation procedures, CEN, Brussels (Aug. 2007)
6. EN 15241, Ventilation for buildings – Calculation methods for energy losses due to ventilation and infiltration in commercial buildings, CEN, Brussels (2007)
7. EN 15243, Calculation of room temperatures and of load and energy for buildings with room conditioning systems, CEN, Brussels (2007)
8. EN 15316 series, Heating systems in buildings – Method for calculation of system energy requirements and system efficiencies. CEN, Brussels (March 2007)
9. DIN V 4108-6, Wärmeschutz und Energieeinsparung in Gebäuden, Teil 6: Berechnung des Jahresheizwärme- und des Jahresheizenergiebedarfs. DIN Deutsches Institut für Normung, Beuth Verlag, Berlin (2003)
10. DIN V 4701-10, Energetische Bewertung heiz- und raumlufttechnischer Anlagen, Teil 10: Heizung, Trinkwassererwärmung, Lüftung. DIN Deutsches Institut für Normung, Beuth Verlag, Berlin (2003)
11. DIN V 18599: Energetische Bewertung von Gebäuden – Berechnung des Nutz-, End- und Primärenergiebedarfs für Heizung, Kühlung, Lüftung Trinkwarm-wasser und Beleuchtung. DIN Deutsches Institut für Normung, Beuth Verlag, Berlin (2007)
12. Schilling, J.: DIN V 18 599, Teil 5, Teil 8 und Teil 9 - Energetische Bewertung von Gebäuden, Heizungs- und Trinkwarmwasseranlagen. Presentation at the DIN-Conference, 13.02.2008, Berlin (2008)



**CENSE partners:**
TNO (NL; coordinator), CSTB (FR), ISSO (NL), Fraunhofer-IBP (DE), DTU (DK), ESD (GB), FAMBSI (FI), EDC (IT)
**Associated partners:**
HTA Luzern (CH), BRE (GB), Viessmann (DE), Roulet (CH), JRC IES (EC)
*Link: www.iee-cense.eu*


Original text language: English


**Disclaimer:** CENSE has received funding from the Community's Intelligent Energy Europe programme under the contract EIE/07/069/SI2.466698.



The content of this document reflects the author's view. The author and the European Commission are not liable for any use that may be made of the information contained therein.



The EPBD Buildings Platform has been launched by the European Commission in the frame of the Intelligent Energy – Europe, 2003-2006 programme. It is managed by INIVE EEIG (www.inive.org), on behalf of DG Energy and Transport.



The information in this publication is subject to a Disclaimer and Copyright Notice;
see *http://www.buildingsplatform.eu/legal_notices_en.html*
© European Communities, 2009
Reproduction is authorised provided the source is acknowledged