Energy Performance of Buildings

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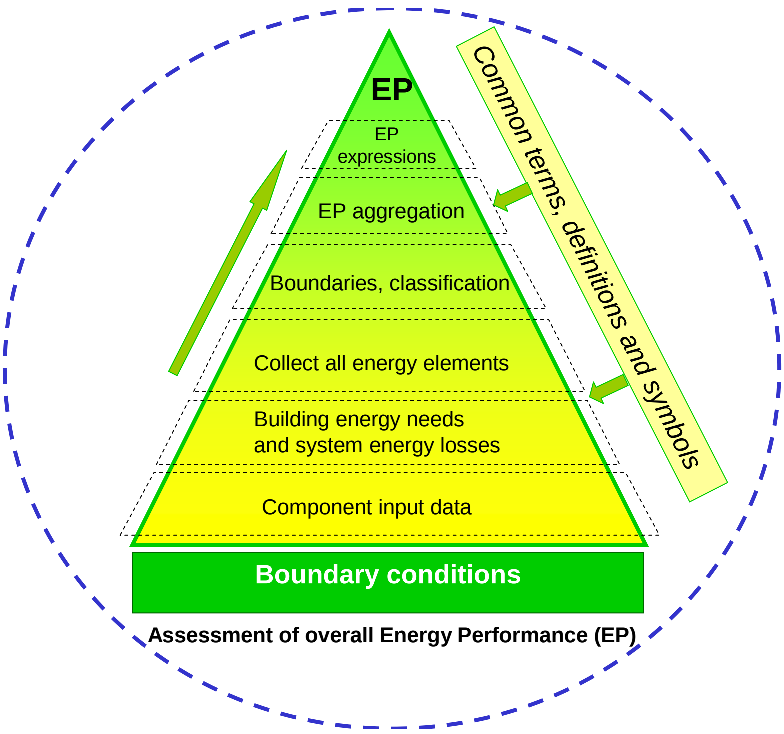
BOOKLET 3

Compilation of Information Papers introducing the CEN standards concerning Heating Systems and Domestic Hot Water



IEE-CENSE

Leading the CEN Standards on Energy performance of buildings to practice
Towards effective support of the EPBD implementation and acceleration in the EU Member States

Intelligent Energy Europe

BOOKLET 3

Compilation of Information Papers introducing the CEN standards concerning Heating Systems and Domestic Hot Water

Content

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General introduction

The aim of the CENSE project is to support the EU Member States and other target groups in gaining awareness and achieving effective use of the European (CEN) standards that are related to the EPBD.

These standards were successively published in the years 2007-2008 and are currently either already being implemented or will soon be implemented in many EU Member States.

The European Commission, DG TREN and DG Enterprise, gave Mandate 343 to CEN. It ordered CEN to develop a methodology for calculating the integrated energy performance of buildings in accordance with the terms set forth in Directive 2002/91/EC (Energy Performance of Buildings Directive-EPBD).

Access to this methodology in the form of European Standards makes it possible to coordinate the various measures for improving the energy efficiency in buildings that are used in the Member States. It will increase the accessibility, transparency and objectivity of energy performance assessment in the Member States (as mentioned in recital (10) of the EPBD).

The role of the EPBD-CEN standards is to provide a common European concept and common methods for preparing energy performance certification and energy inspections of buildings. However, the implementation of these CEN standards in the EU Member States is far from trivial: the standards cover a wide variety of levels and a wide range of interlaced topics from different areas of expertise. They comprise different levels of complexity and allow differentiation and national choices at various levels for different applications.

One of the main activities in the CENSE project is "*to communicate the role, status and content of these standards as widely as possible and to provide guidance on their implementation".* To fulfil this task many Information Papers have been published with background and practical information related to the CEN standards developed in the framework of the EPBD. The Information Papers of each work field in the energy building sector are compiled in a Booklet as present. This Booklet is part of a series consisting of the following volumes:

Booklet 1: Overall Energy Performance of Buildings

Booklet 2: Building Energy Performance

Booklet 3: Heating Systems and Domestic Hot Water

Booklet 4: Ventilation and Cooling Systems

Booklet 5: Inspection of Systems for Heating, Air Conditioning and Ventilation

In each booklet the Information Papers are clustered to the specific appliances, systems, calculation methods, etc. Additional to each Information Paper a PowerPoint presentation is at disposal for dissemination and training purposes. All these documents and more information, like a database with frequently asked questions, are separately available on the CENSE website: ***http://www.iee-cense.eu/***

A second major activity in the CENSE project is "*to collect comments and good practice examples from EU Member States aiming to remove obstacles and to collect and secure results from relevant SAVE and FP6 projects*". This feed back aimed to produce recommendations to CEN for a "second generation" of CEN standards on the energy performance of buildings. Several reports from questionnaires and workshops, draft recommendations, etc. were gradually made available on the CENSE website for comment: ***http://www.iee-cense.eu/***.

All final products from the project will be available at the website before the end of May 2010.

The consortium of the project consists of thirteen partners (from nine different countries) who are all experts and active in CEN-EPBD. They combine this expertise with knowledge and experience of implementation at the national level.

TNO (coordinator)	The Netherlands	www.tno.nl	Berrie van Kampen*, Dick van Dijk*, Hans van Wolferen, Theo Thijssen, Marleen Spiekman
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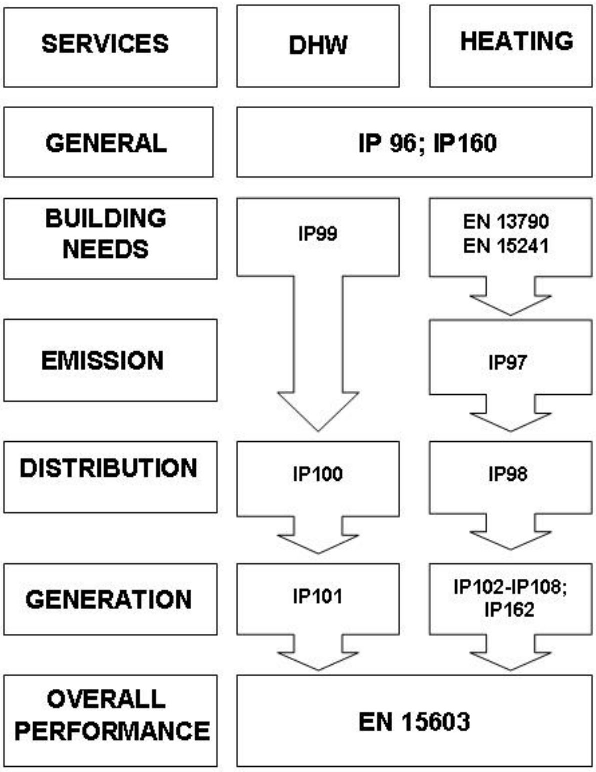
Roulet	Switzerland	www.epfl.ch	Claude-Alain Roulet
JRC (IES)	Eur.Commission	ies.jrc.ec.europa.eu	Hans Bloem

*: Project coordination

Collaboration has been established with the following European umbrella (mainly branch) organizations, such as CEN BT/TC 371, EuroAce, EURIMA, EHI, REHVA, EUROVENT, ESTIF, Euro Heat & Power and ECOS (see website for details).

Heating Systems and Domestic Hot Water, general

The EN 15316-x set of CEN standards covers all aspect of the energy performance of heating systems in buildings. EN 15316-1 is an overview of all the different parts of the calculation, IP96 gives an introduction to this standard.



An important aspect when considering improvements of a building installation to make it more energy efficient is the economic benefit. When the savings meet the investments within a few years, the investment makes sense and in the long term creates a profit. IP160 describes considerations for performing an economic evaluation.

The energy consumption for domestic hot water needs is covered by the EN 15316-3-x set of standards, see cluster 1 of this document for the related information papers. The space heating calculation is covered by the information papers in cluster 2. The calculations are split up in different sections:

- building needs;
- emission;
- distribution;
- generation;
- overall performance.

The emission part for domestic hot water is not developed yet.

Information papers

IP 96: Heating systems in buildings – Method for calculation of system energy requirements and system efficiencies. Part 1: General

IP160: Economic evaluation procedure for energy systems in buildings.

Presentations

Besides Information Papers, corresponding presentations have been prepared to support communication about EN EPBD standards as well as lectures. Presentations often include notes to explain the slides and to support lecture preparation.
Presentations can also be downloaded freely from *http://www.iee-cense.eu/*

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More information can be found at the CENSE project website:
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Information paper on EN 15316-1: "Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies – Part 1: General"

Several European Directives, e.g. the Energy Performance of Building Directive and the Energy using Product Directive, require that minimum requirements be specified. These minimum requirements may affect the building design and the technical building systems. The EN 15316-1 Standard defines the efficiency of heating systems or parts of them (subsystems) and introduces the relevant calculation methods. Dividing the general performance of a building, as indicated in EN 15603 [1], makes it possible to identify the strong and the weak points in the total energy performance of a building. EN 15316-1 could also help in the definition and application of specific requirements for heating systems as included in the recast of the Directive.

The present paper is an introduction to CEN standard EN 15316-1, the framework of a set of standards for space heating and domestic hot water systems (EN 15316-1, 2-1/2, 3-1/2/3, 4-1/…/7). It provides an explanation of the general structure of Part 1 of the Standard, giving more detailed information on the input and output data and providing links with other CEN standards.

1 > Scope of the standard

Due to the complexity of the issue and the number of sub-systems, a set of standards was developed which, taken together, specifies a calculation method for the determination of system energy requirements and system efficiencies of space heating systems and domestic hot water systems. Part 1 of the standard provides a framework for these standards.

It specifies the structure that should be used for the calculation of energy use in space heating systems and domestic hot water systems in buildings. The calculation methods facilitate the energy analysis of the different sub-systems of the heating system, including control (emission, distribution, storage, generation), through determination of the system energy losses and the system performance factors. This performance analysis permits the comparison between sub-systems and makes it possible to monitor the impact of each sub-system on the energy performance of the building.

Calculations of the system energy losses of each sub-system of the heating system are defined in subsequent standards (EN 15316 parts 2-4). The system thermal losses, the recoverable system thermal losses and the auxiliary energy of the sub-systems of the heating system are added together. The system thermal losses of the heating system contribute to the overall energy use in buildings (EN 15603).

The energy performance of the generation sub-system is not covered in detail in this European Standard, but is directly taken into account in EN 15603.

2 > Principle of the method

The calculation method for determining the system thermal losses of a technical building system is based on an analysis of the following sub-systems of the space heating and domestic hot water systems:

- energy performance of the emission sub-system, incl. control;
- energy performance of the distribution sub-system, incl. control;
- energy performance of the storage sub-system, incl. control;
- energy performance of the generation sub-system, incl. control (e.g. boilers, solar collectors, heat pumps, cogeneration units).

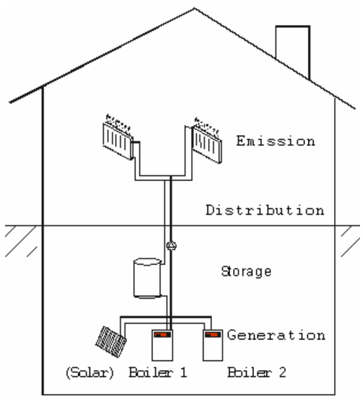

Figure 1:
Input and output data for technical building system i, sub-system j

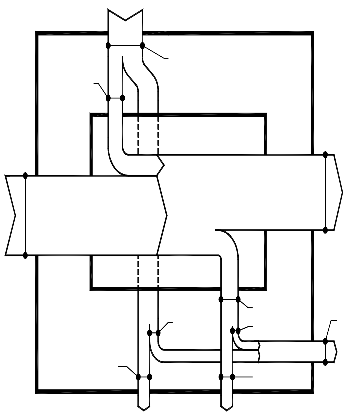

Figure 2:
Input and output data for technical building system i, sub-system j

The storage sub-system can be included in the generation sub-system or detailed separately as the storage sub-system. In the EN 15316-4 standards, the storage sub-system and buffer tanks are taken into account in the generation sub-system. This structure is similar to the physical structure of heating systems (see **figure 1**).

For each subsystem an energy balance is achieved, taking into account energy inputs, energy outputs, system thermal losses, auxiliary energy and recoverable system thermal losses. **Figure 2** illustrates the energy flows for a sub-system.

Based on these data, the calculation results for the sub-system shall comprise:

- energy inputs: energy carrier, thermal energy, electrical energy;
- energy outputs: thermal energy, electrical energy;
- system thermal loss;
- auxiliary energy;
- recoverable system thermal loss.

Calculations may be based on tabulated values or may use values calculated in a more detailed analysis.

3 > Description of the method

Calculation period

The objective of the calculation is to contribute to the evaluation of the annual energy use of the space heating and domestic hot water systems. If there is seasonal heating in the building, the year should at least be divided into two calculation periods, i.e. the heating season and the rest of the year.

Operating conditions

The complexity of the systems considered has to be taken into account by the system designer, through selection and adaptation of the calculation methods. Some guidance on this is provided in Annex C of the standard.

The different parts of EN 15316 contain different methods or indications for the determination of the operating conditions. Several alternative methods may be used to determine the operating conditions. This approach may also be applied to obtain data on the heat contribution of different heat generators in multi-generator installations.

The method(s) selected the relevant input parameters and how to link these methods to determine the energy performance, will be stipulated in a national annex.

Energy performance indicators of space heating and domestic hot water systems or sub-systems

Efficiency is a dimensionless term used to indicate the effectiveness of a technical building system. Efficiencies make possible a practical and straightforward comparison of the effectiveness of systems or sub-systems, of different types and/or of different sizes.

The energy efficiency of a sub-system defined in this standard uses primary energy in the ratio. The energy conversion factor that is used to calculate primary energy will be specified at a national level. Information is provided in EN 15603.

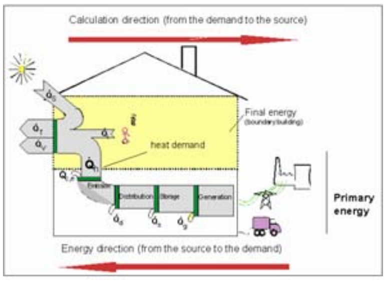

Figure 3:
Energy flow and calculation direction

The efficiencies can be calculated per sub-system (e.g. distribution efficiency, emission efficiency, generation efficiency). The global efficiency of the entire system should be calculated after summing up the system thermal losses and the energy supplies for all relevant sub-systems.

Another way of expressing the energy performance of a system or sub-system is the expenditure factor. This expression is the reciprocal value of the efficiency.

Energy calculation for a space heating and domestic hot water system

The calculation direction goes from the energy needs to the source (e.g. from the building energy needs to the primary energy). The calculation direction is the opposite of the energy flow in the system (see **figure 3**). The calculation is structured according to the components of the heating system (emission, distribution, storage, generation).

For each sub-system, its system thermal loss is calculated and added to its heat output, to determine its required heat input. The auxiliary energy is calculated separately (if there is one) and contributes to the energy losses of the sub-system.

A distinction is made between:

- those parts of the system thermal losses that are recoverable for space heating;
- those parts of the system thermal losses that are recovered directly in the sub-system and which are therefore subtracted from the system thermal losses of the sub-system.

The recoverable system thermal losses for space heating are input values for EN ISO 13790 [2] and EN 15603, in which the recovered system thermal loss for space heating is to be calculated. Two different approaches may be chosen, either the holistic or the simplified approach (see also IP 95)

The system thermal losses recovered in the sub-system (heat recovery) improve the performance of the sub-system, e.g. stack losses that are recovered for preheating the combustion air, water cooled circulation pumps where the cooling water is the distribution medium.

Simplified and detailed methods for the calculation of system energy losses

For each sub-system, simplified and/or detailed calculation methods for determination of system energy losses may be available (according to current technical knowledge and what standards available) and may be applied according to the accuracy required.

The level of detail can be classified according to the following:

Level A	Losses or efficiencies are given in a table for the entire space heating and/or domestic hot water system. Selection of the appropriate value is made according to the typology (description) of the entire system.
Level B	For each sub-system, losses, auxiliary energy or efficiencies are given as tabulated values. Selection of the appropriate value is made according to the typology (description) of the sub-system.
Level C	For each sub-system, losses, auxiliary energy or efficiencies are calculated. The calculation is performed on the basis of the dimensions of the system, its duties, loads and any other data, which are assumed to be constant (or averaged) throughout the calculation period. The calculation method may be based on physics (detailed or simplified) or on correlation methods.
Level D	Losses or efficiencies are calculated by means of dynamic simulations, taking into account the time history of variable values (e.g. external temperature, distribution water temperature, generator load).

Different levels of details may be used for the different sub-systems of the heating system. However, it is essential that the results correspond to the defined output values of the sub-system:

- energy input;
- energy output;
- system thermal losses;
- recoverable system thermal losses;
- auxiliary energy;

in order to ensure proper links to calculations for the following sub-systems and development of a common structure.

4 > FAQ

What is the specific use of the EN 15316 standard, when EN 15603 covers the overall energy use?

The set of EN 15316 standards defines only the performance of heating systems, which are to be included in the overall energy performance defined by EN 15603. By splitting up the overall energy performance, it is possible to identify the strong and weak points in the global performance of a building, so that minimum requirements can also be set up for a sub-system (e.g. heat distribution).

Why does EN 15316 not take into account heat generation?

In order to be coherent with the structure defined in EN 15603 and to enable a direct reference to EN 15316-1, heat generation is not taken into account in the sum of the system losses.

Nevertheless the methodology described in EN 15603 also makes it possible to define performance indicators which take into account the heat generation, in order to evaluate the whole heating system.

5 > References

1. EN 15603 Overall energy use and definition of energy ratings
2. EN ISO 13790 Calculation of building energy use for space heating and cooling

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)
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Information paper on EN 15459

Economic evaluation procedure for energy systems in buildings

Economic calculations provide a powerful incentive for undertaking energy conservation measures. The purpose of this information paper is to provide detailed information about Standard EN 15459. All of the procedural steps and relevant Articles in EN 15459 are listed to show the scope and the detail of the economic calculations that should be performed and the way in which the economic aspects, various costs and technical aspects should be considered.
This standard presents a method for making economic calculations of the functioning of heating systems, using data from other systems that may influence the energy use of the heating system.
This method can be used, in full or in part, for the following purposes:

- to consider the economic feasibility of energy conservation options in buildings;
- to compare different solutions of energy saving options in buildings (e.g. plant types, fuels);
- to evaluate the economic performance of an overall design of the building (e.g. the trade-off between the energy needs and the energy efficiency of heating systems);
- to assess the effect of possible energy conservation measures on an existing heating system, by economic calculation of the cost of the energy use with and without the energy conservation measure.

1 > Scope of the standard

This standard provides a calculation method for the economics of heating systems and other systems that are involved in the energy use of the building. This standard applies to all types of buildings.

The fundamental principles and terminology involved are explained in this standard.

The main items used in the standard are:

- the definitions and structure of the types of costs which shall be taken into account for calculating of the economic efficiency of energy conservation options in buildings;
- the input data required to define the costs of the systems under consideration;
- the methods that are to be used for the calculations;

- the way in which the results of the economic calculations are to be expressed;
- the informative annexes indicating default values for e.g. lifetime, repair costs, maintenance costs, etc., for use in the calculations.

This standard is applicable to calculations of the economic performance of energy conservation options in buildings (e.g. insulation, more efficient generators, distribution systems and lighting, renewable sources, combined heat and power).

2 > Principle of the method

2.1 Organisation of the costs

The approach of the calculation method is to take a global perspective (overall costs). However, depending on the objectives of the investor, the calculation method may be applied considering only certain cost items. For example, calculations of the costs of alternative solutions for heating systems may be performed considering only costs for the domestic hot water system and the space heating system.

Costs are separated into investment costs (including periodic replacement of components) and running costs.

The various types of costs are organised as shown in Figure 1.

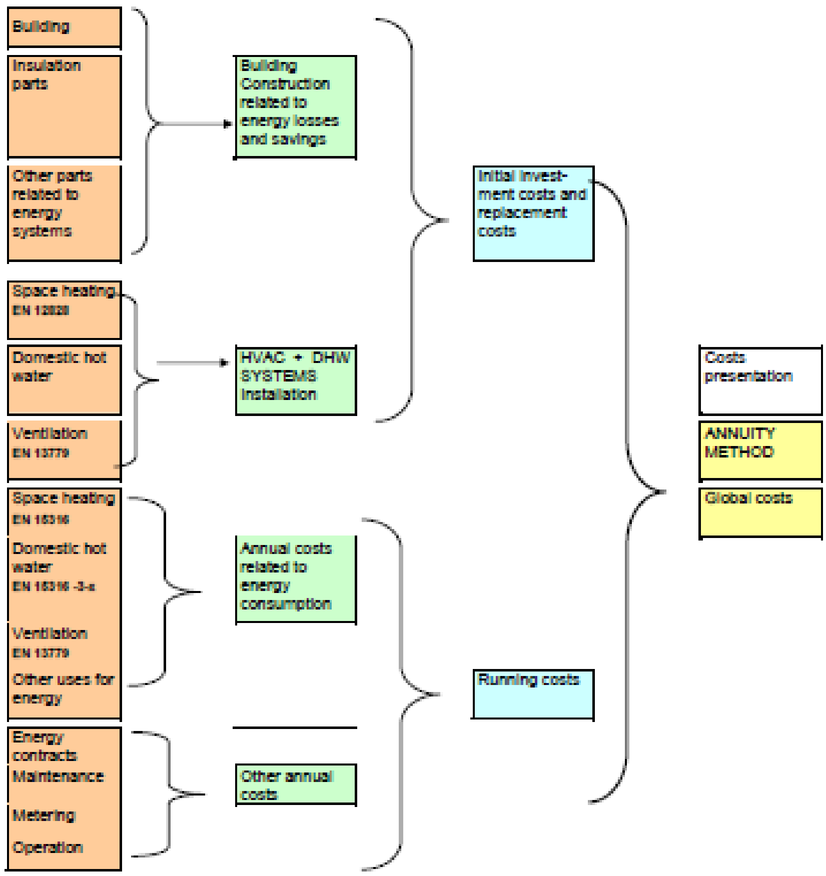


Figure 1 - Organisation of costs

The method is defined in Clause 5 of EN 15459.

2.2 Basic calculations

Clause 5.1 of EN 15459 concerns the calculation of the basic parameters:

- real interest rate
- discount rate
- present value factor
- annuity factor

2.2.1 Global cost

Principles of the calculation – Clause 5.2.1 of EN 15459

Calculation of global cost may be performed using a component or system approach, considering the initial investment C_I and - for every component of a system j - the annual costs for any year i (referred to the starting year) and the final value.

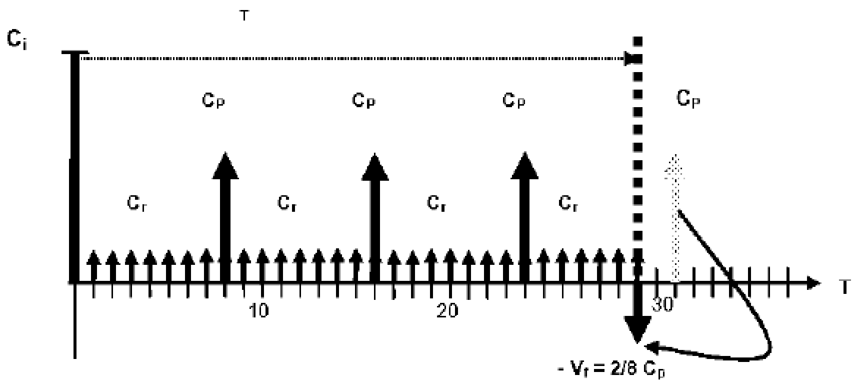
Global cost is a function of the duration of the calculation period τ.

The calculation may be performed either using detailed cost data on an annual basis or from the general economic data for every component.

Dynamic calculations take into account any annual variations in the discount rate or in the development of prices for any of the costs that contribute to the annual costs (e.g. energy costs, operational costs, periodic or replacement costs, maintenance costs and added costs).

Calculation of the final value – clause 5.2.2 of EN 15459

The final value $V_{f,\tau}(j)$ of a component is determined by straight-line depreciation of the initial investment until the end of the calculation period and referred to the beginning of the calculation period (Figure 2).



Key:
C_i initial investment costs
C_r running costs
C_p periodic costs
V_f final value
T calculation period

Figure 2 - Illustration of final value concept

If the calculation period τ exceeds the lifespan τ_n (j) of the component under consideration (j), the whole of the last replacement cost is taken into consideration in calculating the straight-line depreciation.

Total costs for replacement of component j during the calculation period considered (including initial investment), is the sum of:

- the initial investment V_0;
- the replacement costs (A'_0, A''_0, etc.): any time the lifespan of the component is reached, the component shall be replaced, the cost of which must take into account any expected increase (or decrease) in the price of such products and the discount rate.

Figure 3 illustrates an example of this principle, in which the calculation period (τ = T) might be 30 years and the lifespan of the component (τ_n = T_n) might be 12 years).

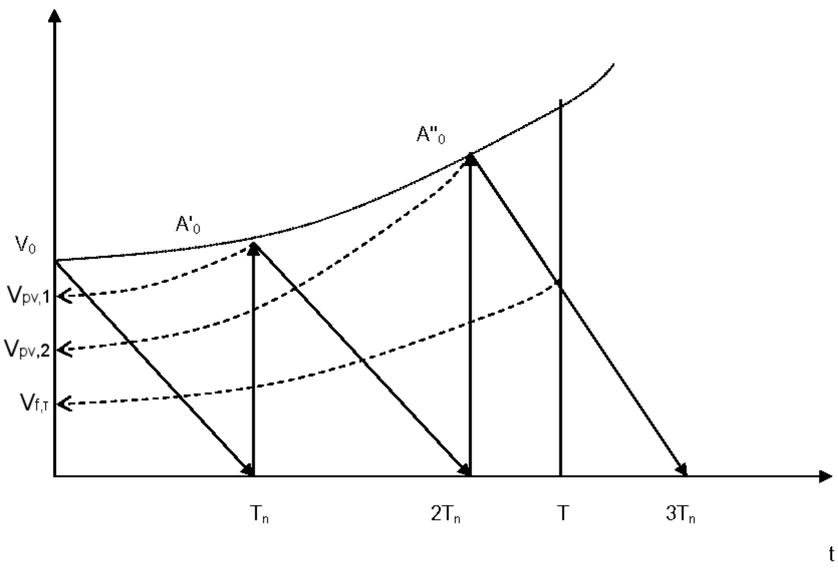


Figure 3 - Development of value during the calculation period

2.2.2 Annuity calculation

An alternative approach is to determine the annuity costs of the building. The annuity calculation method transforms any costs to an average annualized cost.

Whereas the global cost calculation method provides a value of the total costs throughout the calculation period τ, the annuity calculation uses the annuity factor a(n), to transform all costs to annual costs (Figure 4).

The calculations for the period τ considered are of the following three types:

- investment costs, related to the part of the building structure to be taken in account and any components and systems with a service life that is greater than or equal to the designed payback period of the building, are distributed evenly within the intended payback period of the building;
- periodic or replacement costs are distributed evenly over the years between the times that the cost is incurred;
- running costs expressed on an annual basis are by definition annual costs.

Dynamic calculations take into account any annual variations of the discount rate as well as annual variations in the development of prices for any of the costs considered (see 5.3.5 of EN 15459).

A simplified version of the calculation of annualized costs is available in the special case when the discount rate and annual costs are constant during the calculation period.

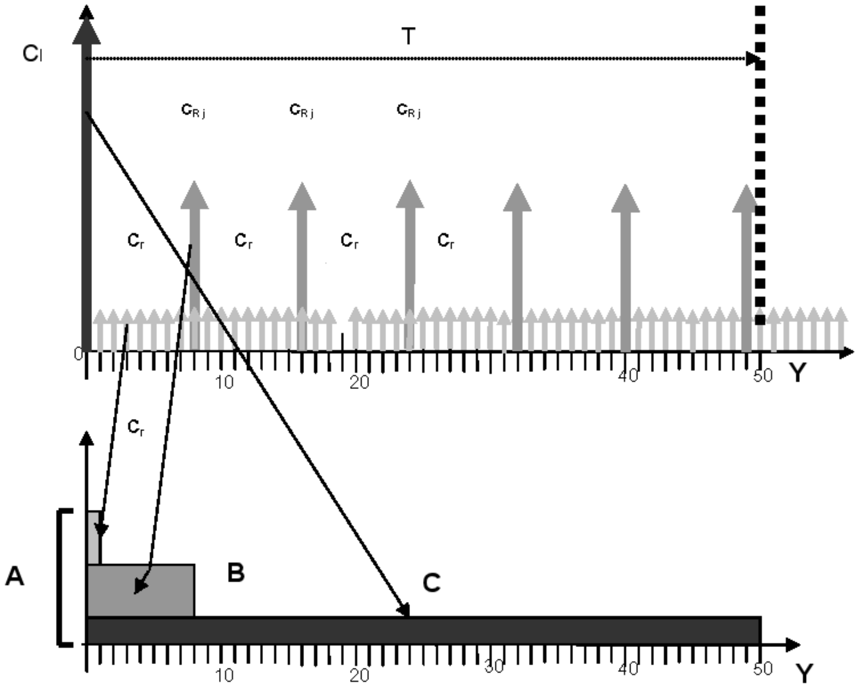


Figure 4 - Annuity cost presentation

Annuity calculation for unchanged component during the design payback period of the building – clause 5.3.2 of EN 15459

All initial costs of the components or part of the systems that remain unchanged during the intended payback period of the building are multiplied by the corresponding annuity factor $a(\tau_{\_Building})$.

Annuity calculation for replaced components – clause 5.3.3 EN 15459

The initial replacement costs shall be multiplied by the corresponding annuity factor depending on R_p (the rate at which the price of the products is expected to change) and the lifespan of the considered component (See Annex A of EN 15459).

Annuity calculation for running costs – clause 5.3.4 of EN 15459

Running costs include annual energy costs, operational costs, maintenance costs and any additional costs for installation and building.

Influence of price development for dynamic calculations – clause 5.3.5 of EN 15459

If annual costs are expected to change during the calculation period, these costs must be multiplied by the price dynamic factor B_x in order to determine the present value of the annual costs throughout the calculation period.

The price dynamic factor is a function of the inflation rate R_i, the market interest rate R and the rate R_x at which the relevant prices are expected to change.

3 > Description of the method step by step.

General

Figure 5 illustrates the different stages of the method, which are described in the following.

The process is consecutive.

Some of the data are for information only (environment of the project: country, location, local constraints, building use, noise…), but shall be documented in order to provide possibility for comparison between buildings or use of conventional costs ratio in the building construction (e.g. cost per area unit).

The parameters shall be chosen in accordance with those considered for the energy certification of the building.

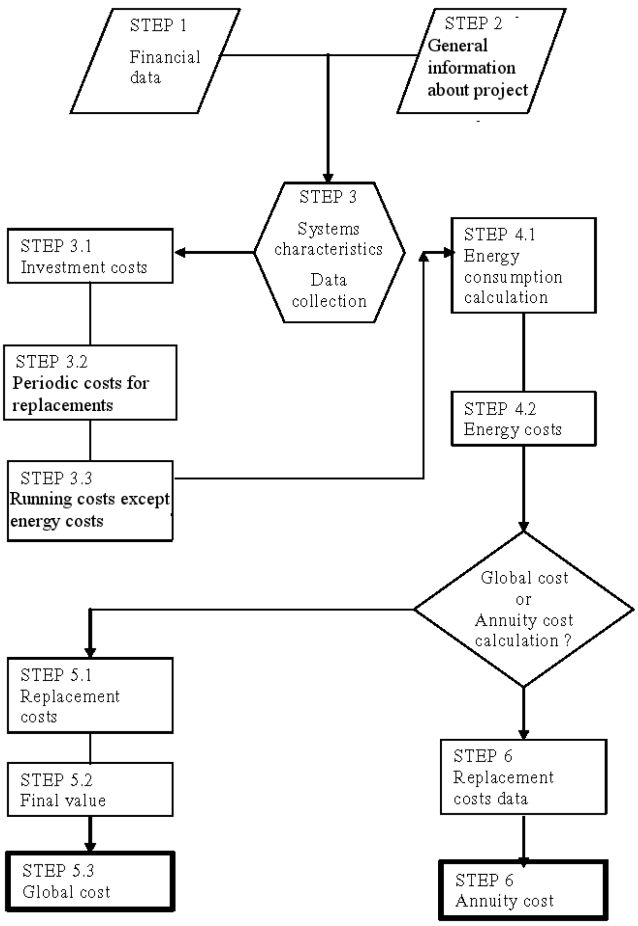


Figure 5 - Flowchart of the different stages of the method

STEP 1 - Financial data

Duration of the calculation – clause 6.2.1 of EN 15459

The time period considered in the calculation can be fixed according to the objectives of the calculation or be they may be specified by the owner of the building. The default value could be the expected lifetime of the building. But it may also be interesting to perform the calculation for a shorter calculation period, e.g. to evaluate the costs during the period of a mortgage.

The time period determines the number of years considered for the global cost calculation method. For the annuity calculation method, only the intended payback period of the building is relevant.

Financial rate – clause 6.2.2 of EN 15459

The inflation rate that is assumed should be calculated or estimated from available economical institute data as an average value over the calculation period.

The market interest rate is the average expected value of the interest rate over the calculation period.

Human operation costs – clause 6.2.3 of EN 15459

The rate of development of human operation costs refers to the costs for operational staff (usually the rate of development of human operation costs is higher than the inflation rate). The average expected value over the calculation period is to be applied.

Energy prices – clause 6.2.4 of EN 15459

As a first approximation, the rate of development of energy prices is considered equal to the inflation rate. This information can be obtained from energy utilities or from the economic analyses regularly provided by the European Commission or national energy forecasting organizations.

NOTE: Supplementary information on water supply costs can be useful in the calculation of annual costs.

STEP 2 - General information about the project

Identification of systems – clause 6.3.1 of EN 15459

In this step, the systems to be considered in the economic calculations are identified and project data necessary to perform the calculations are provided. Information is obtained from the design project and from the contractors.

Environment of the project – clause 6.3.2 of EN 15459

These data are intended for information only and are not used in the calculations. They identify the constraints that could define or influence the energy consumption and the choices between the alternative solutions that are being analysed:

- country or region;
- location of the building, e.g. city centre, urban zone;
- construction constraints on the external aspects of the building (roof, envelope);
- type of building (e.g. row house, detached house, co-housing, multi-story building);
- noise.

Meteorological and environmental data (not mandatory) – clause 6.3.3 of EN 15459

These data are given for information only.

Constraints/opportunities related to energy – clause 6.3.4 of EN 15459

Official energy requirements on building fabric and systems (these data are necessary in order to identify the constraints/opportunities for HVAC systems in relation to energy uses):

- forbidden fuels;
- orientation of the building;
- flue (possible or impossible);
- district heating (existing or nonexistent);
- difficulties related to fuel distribution;
- fuel gas network proximity;
- possible sources of renewable energy (e.g. solar collectors, fuel cells, natural ventilation, heat pump);

Identify customer's approach on comfort and occupancy.

<u>STEP 3 - Systems characteristics</u>

Data collection – clause 6.4.1 of EN 15459

Data concerning components and systems are collected and information about lifespan, maintenance and operation are obtained.

Annex A provides some default values for the most important components.

STEP 3.1 - Investment costs for systems related to energy – clause 6.4.2 of EN 15459

General

This step is applied to the systems identified at Step 2, which are related to energy and energy conservation.

Table 3 of EN 15459 provides examples of different applications of the calculation method.

Investment cost for building construction

This chapter identifies those parts of the structure that are related to energy efficiency or energy use (e.g. building fabrics, insulation, openings, glazing, doors, solar protection). The calculation may be performed with all of the building structure taken into account, but in this case, the influence of the energy system will be reduced.

The lists given in 6.4.2.2 to 6.4.2.8 are meant for information and the listed items need only be taken into account if they are relevant to the objective of the calculation. They include:

- Investment cost for building construction
- Space Heating
  - Generation and storage
  - Distribution
  - Emission
  - Control
- Domestic hot water
- Ventilation
- Space cooling
- Lighting
- Connection to energy supplies
- Other systems

STEP 3.2 - Periodic costs for replacements– clause 6.4.3 of EN 15459

In this step, timing and costs of the replacement of systems and components are obtained.

Some data about the service life of components are presented in Annex A of EN 15459.

STEP 3.3 – Running costs excluding energy costs – clause 6.4.4 EN 15459

1 Operational costs (excluding energy)

Operational costs represent the cost for energy operators of the building.

2 Maintenance and repairs

In this step the inspection and replacement of consumable items, or the annual contracts for cleaning and maintenance of components and systems, are to be considered.

As periodic inspection of energy systems for heating and air conditioning are mandatory, these verifications must be considered as part of the periodic maintenance operations (e.g. for boilers, chillers).

3 Added costs

Include insurance and taxes that are related to energy systems. For example, special taxes related to pollutants or energy use.

STEP 4 - Energy costs

General – clause 6.5.1 of EN 15459

Energy costs fall into two main categories:

- those directly related to energy use as recorded on meters or the total fuel consumption of the building. The method for determination of energy use must use data on the energy content of the fuel furnished by its provider;
- those fixed according to the quantity of energy subscribed with energy utilities or rental for the energy systems (e.g. gas tank, electricity transformation).

For district heating systems, special subscription conditions may apply. Environmental (or social) costs could also be introduced as a cost related to energy.

Energy sales (if relevant) are counted separately as negative costs.

STEP 4.1 - Calculation of energy use – clause 6.5.2 of EN 15459

Calculation should be performed according to standardised methods. EN 15603 allows calculation of the energy use for the whole building. If the economic analysis concerns only some of the energy systems, then the energy consumption calculation must similarly only take these systems into account (i.e. EN 15316 series for space heating and domestic hot water systems)

Reference to the standards (or specific methods, if applicable) should be made when reporting the results of the analysis.

STEP 4.2 - Energy costs – clause 6.5.3 of EN 15459

Energy costs are determined by the tariff for the energy considered. In some cases, energy costs can be calculated from the variable tariffs of the utility. These tariffs (mainly for electricity) may vary during the day and during specific periods of the year.

Renewable energy sources or energy sales (electricity or hot water) must be considered either as a financial income (as electricity from Photovoltaic cells can be sold directly on the electric grid) or as a way to reduce energy costs at the building level (e.g. solar collectors). The design of the system will determine which of these two possibilities apply.

STEP 5 - GLOBAL COST CALCULATION

Step 5.1 Calculation of replacement costs – clause 6.6.1 of EN 15459

Replacement costs throughout the calculation period are calculated from the timing and costs of any expected replacement of systems and components, as determined in Step 3.2.

The present value factor or discount rate is to be used to refer costs to the starting year.

Step 5.2 Calculation of final value – clause 6.6.2 of EN 15459

The final value at the end of the calculation period is determined by summing up the final value of all systems and components.

The final value of a specific system or component is calculated from the lifetime remaining at the end of the calculation period, assuming linear depreciation since its last replacement. The final value is determined as remaining lifetime divided by lifespan and multiplied by last replacement cost, referred to the starting year by the appropriate discount rate.

Figure 3 illustrates the calculation process for one unit (component or system).

Step 5.3 Calculation of global cost – clause 6.6.3 of EN 15459

The different types of cost (initial investment costs, periodic and replacement costs, running costs) and the final value are converted to global cost (referred to the starting year) by applying the appropriate present value factor (or discount rate).

The present value factor (or discount rate) may be different for different types of costs, due to different rates of price development for energy, human operation, products, maintenance and added costs.

The total global cost is determined by summing up the global costs of initial investment costs, periodic and replacement costs, annual costs and energy costs and subtracting the global cost of the final value.
Annex C of EN 15459 illustrates organization of the result data sheet.

STEP 6 - ANNUITY COST CALCULATION

Annuity cost calculation is performed for any component of part of the system according to 5.3.

For the annuity cost calculation, the calculation period is fixed and corresponds to the intended payback period of the building.
The total annualized cost is determined by summing up the annualized costs of systems and components (investment and replacements), the annual costs (operation costs, maintenance costs, added costs) and the energy costs (see Annex D of EN 15459).

The different types of costs are converted to annualized costs by applying the appropriate annuity factor (see the example in Annex E).

For systems and components with a lifespan greater than or equal to the intended payback period of the building, the annualized cost is determined from the initial investment cost and the annuity factor corresponding to the payback period.

For systems and components with a lifespan that is less than the calculation period, the annualized cost is determined from the replacement cost and the annuity factor corresponding to the service life.

Annual costs and energy costs are by definition annualized costs.

The annuity cost corresponds to the average annual cost at year 0.

Annexes A - E

Informative annexes provide useful and detailed information about the economic data on energy systems, systems descriptions, the organisation of data and results in the calculation sheets and provide some examples with detailed calculation steps.

4 > FAQ

Why is there a standard for the economic evaluation procedures for energy systems?

In the recast of the EPBD the Calculation of cost-optimal levels of minimum energy performance requirements is mandated in Article 5. The Commission will develop a comparative methodology and Member States will have to use it for comparison purposes only and shall report the results. The method will cover cost-critical criteria such as investment costs, operating / maintenance costs, and energy costs. An international standard makes this task easier for the Commission and will ensure that the procedure remains transparent.

What are costs taken into account in the economic calculations?

Costs include initial investments costs and annual costs. Annual costs include running costs and any periodic costs for the repair or replacement of components and systems.

Is the calculation limited to the heating systems?

More details are given for the heating systems (e.g. list of components), but the same methodology can be applied to other systems such as lighting and to the building itself.

What are the differences between the global cost method and the annuity cost method?

Global cost calculation is determined by the duration of the calculation period and the final value concept; they estimate the total cost incurred in the period considered. Annuity calculations transform all costs to annual costs by using annuity factors.

5 > References

1. EN 15459, Energy performance of buildings – Economic evaluation procedure for energy systems in buildings, November 2007
2. EN 15603, Energy performance of buildings – Overall energy use and definition of energy ratings, January 2008 *(Calculated energy rating part)*

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Cluster 1: Domestic Hot Water

Sanitary hot water needs, distribution and energy consumption.

Introduction

The energy consumption for domestic hot water (DHW) production is calculated using a three step approach.

Building needs (domestic hot water):
In the first step the tapping requirements of a building are determined. The correct estimation of the domestic hot water needs is essential. This results in volumes and times of hot water need throughout the year (the gross hot water demand) and tapping patterns. Tapping patterns are important for the calculation of distribution and generation losses. Also the estimation of the contribution of each heat generator (e.g. thermal solar) depends on the tapping patterns. The characterization of needs is introduced in information paper IP99.

Emission:
In the case of DHW emission is not taken into consideration yet. Emission systems consist of tapping points and showerheads.

Distribution:
The second step comprises of calculation of the distribution systems. This part of a domestic hot water system is all between the generation system and the point of tapping. Important aspects to be considered in this respect are heat losses and pump energy. IP100 describes the standard on the sanitary hot water distribution system. The distribution losses can be higher than the domestic hot water needs.

Generation:
The gross hot water needs are delivered by heat generators. There are several types of generators available, a lot of which are also used to provide space heating. Space heating and domestic hot water have some distinctively different properties, so there are separate standards on DHW and space heat generation. DHW is different from space heating in that the heat demand has an interval character and a different temperature level.

When there’s no hot water demand, the heat demand is zero. When there is a hot water demand, for example for showering, the heat demand can be on the order of 20 kW. Space heating demand will have a more smooth demand pattern.

Another distinct difference is the temperature level. Where low temperature space heating is being applied more and more, domestic hot water has to be delivered at 55-60 °C. Altogether these conditions result in an efficiency of a generator for producing DHW that is usually slightly less than for space heat generation. The domestic hot water generation is treated in IP101.

The information papers IP99, IP100 and IP101 introduce respectively the EN standards EN 15316-3.1, EN 15316-3.2 and EN 15316-3.

Information papers

IP 99: Domestic Hot Water systems – Characterisation of Needs (tapping requirements)

IP 100: Domestic Hot Water systems – Distribution

IP 101: Domestic Hot Water systems – Generation

Presentations

Besides Information Papers, corresponding presentations have been prepared to support communication about EN EPBD standards as well as lectures. Presentations often include notes to explain the slides and to support lecture preparation.
Presentations can also be downloaded freely from *http://www.iee-cense.eu/*

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03-10-2008

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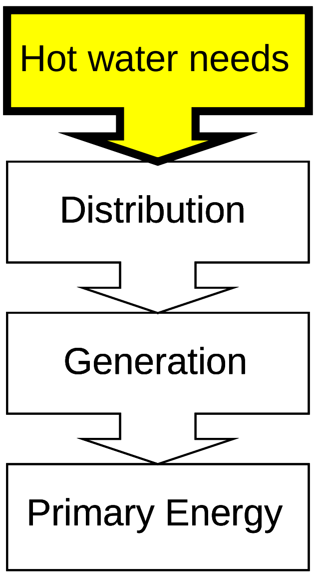

Figure 1: The characterisation of the Hot water needs is the first step in the DHW Energy calculation

Information paper on EN 15316-3-1

Domestic Hot Water systems - Characterisation of Needs (tapping requirements) -

This paper gives a short introduction to the CEN standard EN 15316-3-1 characterising the hot water needs. It contains explanations of the calculation methods with details of the input and output data and the links with related CEN standards.

The correct characterisation of hot water needs is important because the losses of boilers and the distribution system are very sensitive to the couple of frequency and energy content of heat up and cool down at any tapping. Therefore the needs are defined by the energy amount and also by the tapping patterns. The energy amount of hot water needs could represent about 25 % of the final heating needs (or 20 to 25 kWh/m².year) in existing residential buildings. The percentage of hot water needs increases in well insulated houses.

1 > Scope of the standard

The standard gives four methods for calculation of the energy needs of the delivered domestic hot water.

The calculation of the energy needs for domestic hot water applies to a dwelling, a building or a zone of a building

The standard is the first of a series of three standards for calculation of domestic hot water system energy needs and system efficiencies. The two other standards treat distribution (EN 15316-3-2) and generation systems (EN 15316-3-3).

2 > Principle of the methods

The four methods calculate the energy needs at different levels of detail. The hot water needs in MJ/day or MJ/year is the first important input parameter for the energy calculation. Allowing for distribution and generation losses and auxiliary energy, the final energy consumption can be calculated (see figure 1).

In addition to the hot water needs, a detailed tapping pattern may be needed, especially for dwellings and individual hot-water appliances (see figure 2).

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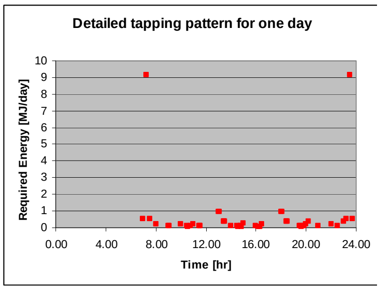

Figure 2: Example of the energy demand of a detailed tapping pattern. The two high level demands are for the shower, most of the other dots represent short tappings in the kitchen.

Figure 3: Hot water needs for dwellings may show great differences, due to different comfort levels of the appliances and the behaviour and demands of users. Here a modern comfort shower is shown as an example, with design capacity of 30 l/min. Despite these differences, in standards a uniform approach is required.

In many single family dwellings, the distribution system consists of distribution pipes of 10 or more metres length without a circulation loop, causing significant start/stop losses. The distribution losses may be in the same order of magnitude as the heat demand.

The performance of individual hot-water appliances depends a lot on the applied tapping pattern. Instantaneous heaters in particular are very sensitive to this since they heat up and cool down at any tapping, causing large start/stop losses.

Circulation systems for distribution and hot water generators using storage systems have constant losses and are less sensitive to the tapping pattern. So for non-residential buildings, detailed tapping patterns are generally not required.

The required inputs depend on the method, but in most cases the following inputs are required:

- building type or function;
- floor area of the building;

The resulting outputs are:

- Hot water energy demand in MJ/day or MJ/year.

Four calculation methods are described:

- Energy need related to tapping programs;
- Energy need related to volume needs;
- Energy need linear with floor area;
- Energy need from tabulated values for different building types or functions.

The methods are summarised below. For all methods a national annex is required. The annexes to the standard provide default values.

3 > Energy need related to tapping programs.

This method is defined in clause 5.2 of EN 15316-3-1 and is characterised by the use of one or more 24-hour cycles that define a number of domestic hot water draw-off needs. Tapping patterns may be given in a National Annex. These must identify the building type(s) for which they can be used. The tapping patterns must include the start time, the energy content of each draw-off, the type of delivery, the corresponding delivery temperature and the minimum temperature required.

For single-family dwellings the tapping patterns detailed in EN 13203-2 can be used. These are given in Annex A of the standard. Reference should be made to EN 13203-2 for a full explanation of these tapping patterns.

The detailed requirements of tapping patterns are especially needed for installations that are sensitive to the dynamics of those patterns, as explained above.

In addition to these patterns a method is required that gives the energy demand as a function of the building size, generally the floor area.

4 > Energy need related to volume requirements

This method is defined in clause 5.3 of EN 15316-3-1 and assumes that required volumes and water temperatures are given to enable energy demand to be calculated. The required volume has a linear or non-linear relation with floor area of the building.

Building function	Specific energy need MJ/ (m^2year)
dwelling	68
bar	15
restaurant	10
prison	15
hospital	55
health service	10
office	5
hotel	45
school	5
sports	45
shops	5

Figure 4: Example of the annual specific energy demand for DHW for different building types.

The input parameters are:
- floor area of the building in m^2;
- temperature of the (cold) inlet water in °C;
- specified temperature of domestic hot water at the tapping point in °C.

The factors to describe the relation between floor area and required volume are fixed parameters. Although not mentioned in the standard text, these factors may depend on the building function, so this may also be an input parameter.

5 > Energy need linear with floor area

This method is defined in clause 5.4 of EN 15316-3-1 and assumes a linear relation between the floor area and the energy demand. Basically, this method is a linear and straightforward version of the previous method, using a specific domestic hot water demand per day based on a water delivery temperature (e.g. of 60°C) and a cold water supply temperature (e.g. of 10°C).
The input parameter is:
- floor area of the building in m^2;

The factor to describe the relation between floor area and required energy is a fixed parameter. Although not mentioned in the standard text, this factor may depend on the building function, so this may also be an input parameter.

6 > Energy need from tabulated values for different building types or functions.

This method is defined in clause 5.5 of EN 15316-3-1 and assumes a (linear) relation between the floor area and the energy demand (see figure 4). Basically, this method is quite similar to the previous methods, but only this method refers to different building types or functions.
The input parameters are:
- the type of building;
- the type of activity carried out within the building;
- the use of a zone within a building where more than one activity is carried out;
- class of activity, such as the category of a hotel (number of stars) or the class of catering establishment.

The text does not mention the floor area of the building as an input but this will in general be needed too.

7 > FAQ

What is the relevance of DHW in total building energy needs?
In well insulated dwellings DHW energy needs are comparable to heating energy needs. Also in hospitals, hotels and sport facilities DHW energy needs are high.

Is a national annex required for this standard?
Yes it is. Countries need to decide which method they prefer and which specific energy need, depending on building type, is suitable. A method depending on building function and floor area covers most situations. Appendix B of the standard and the side bar (see figure 4) of this paper give examples.

Is zoning taken into account?
In some dwellings, separate appliances and distribution systems are applied for the kitchen and bathroom. Therefore an indication of the partition of the energy need is approved.

How realistic are reference energy needs?
For individual cases differences up to 50% in DHW energy need may be found between design assumption and practice. In the communication of energy calculation results it should be emphasised that the results concern average values.

8 > References

1. EN 15316-3-1 Domestic Hot Water Systems – Characterisation of needs (tapping requirements)
2. EN 15316-3-2 Domestic Hot Water Systems - Distribution
3. EN 15316-3-3 Domestic Hot Water Systems – Generation
4. EN 13203-2 Gas-fired domestic appliances producing hot water. Appliances not exceeding 70 kW heat input and 300 l water storage capacity. Assessment of energy consumption

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Information paper on EN 15316-3-2

Domestic Hot Water systems - Distribution

This paper gives a short introduction to the CEN standard for calculation of the losses from domestic hot water distribution systems. It contains explanations of the calculation methods with details on the input and output data and the links with other CEN standards. Distribution losses may be 25% or more of total DHW energy needs for distribution pipes of 10 m and more and for large, badly insulated circulation systems.

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

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1 > Scope of the standard

The standard gives methods for calculation of heat losses, the recoverable heat losses and the auxiliary energy of the domestic hot water distribution system. The standard is the second part of a series of three standards for calculation of domestic hot water system energy requirements and system efficiencies (see figure 1). The other standards treat DHW needs (EN 15316-3-1) and generation systems (EN 15316-3-3).

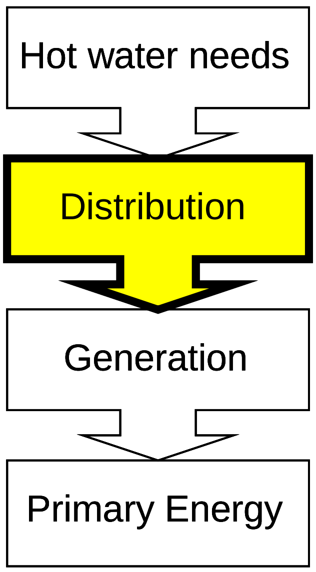

Figure 1: The calculation of the distribution losses / efficiency is the second step in the DHW Energy calculation

2 > Principle of the methods

Domestic hot water distribution systems may consist of a circulation system and/or distribution pipes (see figure 2).
Distribution pipe losses are dominated by the heating up and cooling down of the pipes at any tapping, so these losses are sensitive to the tapping pattern. The standard gives five calculation methods for distribution pipe losses:

- Heat losses related to floor area
- Heat losses related to pipe lengths – simple method
- Heat losses related to pipe lengths – tabulated data method
- Heat losses related to tapping pattern
- Heat losses based on detailed calculation method

Circulation systems are in general operated at constant temperature. Therefore circulation system losses do not depend on tapping patterns. Loss reduction may be achieved by applying pipe insulation and night set-back. The standard gives the following methods to calculate circulation system losses:

- Heat losses related to circulation pipe length
- Heat losses based on detailed calculation method
- Heat losses while circulation is off

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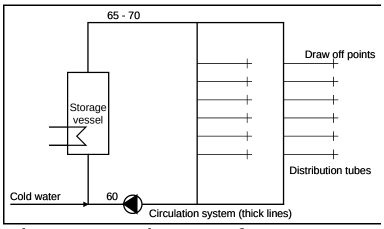

Figure 2: Scheme of a DHW circulation system with two branches and short distribution pipes to the tapping points. This type of system is frequently applied in hotels, hospitals and blocks of flats.

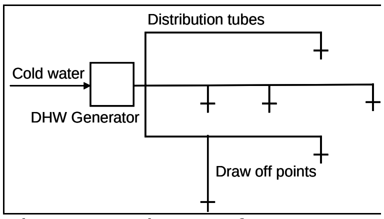

Figure 3: Scheme of a DHW system with only distribution pipes. This type of installation is dominant in single family dwellings.

The total heat losses are the sum of distribution pipe losses (no circulation loop) and circulation system losses (collective part with circulation loop).

Also methods are given to determine auxiliary energy consumption for:
- pumps for circulation systems.
- ribbon or trace heating

To determine distribution losses in dwellings, a detailed tapping pattern is needed. In many single family dwellings, the distribution system consists of distribution pipes of 10 or more meters length without a circulation loop, causing significant start/stop losses (see figure 3). These distribution losses may be in the same order of magnitude as the heat demand.
The methods are summarized below. For all methods a national annex is required. The annexes to the standard provide default values. Required inputs depend on the methods and are also given below.
The resulting outputs are the heat losses in MJ/day or MJ/year.

3 > Distribution pipe losses (without a circulation loop)

Heat losses related to floor area

This method is defined in clause 6.2.2 of EN 15316-3-2. It is a simplified method relating the distribution pipe heat losses only to building floor area. Thus, detailed knowledge of the domestic hot water distribution system is not required. This method can only be applied in a limited number of situations and is usually restricted to domestic buildings with a domestic hot water distribution system that does not involve a circulation loop. If this method is applicable, details for the calculation and the limitations in its use are to be given in a National Annex. Although a detailed knowledge of the domestic hot water distribution system is not required, the pipe lengths should be kept to a minimum. The maximum acceptable distribution pipe length for this method may be given in a National Annex.

Heat losses related to pipe lengths - simple method

This method is defined in clause 6.2.3 and worked out in annex A of EN 15316-3-2. This calculation method takes into account the heat losses due to the full cooling down of the pipe and the water within it after any tapping. It is also possible to include the heat losses from the user outlets in this method.

Details of this method are to be given in a National Annex. A reduction of heat losses in the case of short intervals between the tapping cycles is not taken into account in this calculation method. In such a case the effect of pipe insulation on heat losses must be taken into account. If this is to be considered, details are to be given in a National Annex.
The input parameters for every pipe section are:
- pipe length in m;
- pipe inner and outer diameter in m;
- specific mass and heat capacity of water and pipe material;
- nominal hot water temperature in °C;
- average ambient temperature in °C;
- number of tappings per day for this pipe section.

Heat losses related to pipe lengths - tabulated data method

This method is defined in clause 6.2.4 of EN 15316-3-2. It is based on estimates of the proportion of the heat energy reaching the user outlets for different pipe lengths and diameters. A distinction is made between supplies to kitchens and to bathrooms.

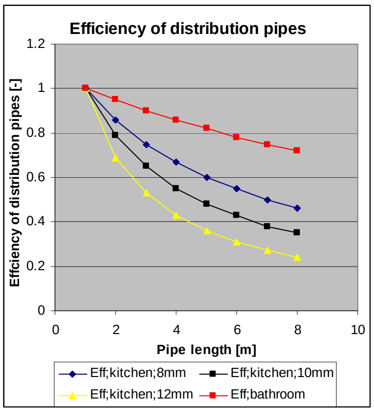

Figure 4: Example of the proportion of useful heat, reaching user outlets (Annex B – tabulated data method) The low efficiencies for the kitchen are the result of the relative small heat demand per tapping. In the bathroom, relative large heat demands per tapping are required.

Detailed knowledge of the domestic hot water distribution system is not required; only the hot water demand rates of kitchen and bathroom are required. If this method is applicable, details for the calculation and suitable tabulated values are to be given in a National Annex. A table of default values is given in Annex B (see figure 4).
The input parameters are:

- pipe length to kitchen and bathroom in m;
- pipe inner diameter to kitchen in m.

Heat losses related to tapping pattern

This method is defined in clause 6.2.5 of EN 15316-3-2. It is based on estimates of the heat losses expressed as a proportion of the domestic hot water energy demand at the user outlet device. The calculation method is described in Annex C. Details of this method, including the equivalent energy loss factors, are to be given in a National Annex.
The input parameters are:

- hot water energy need;
- pipe length in m;
- position of pipes (inside or outside the building)

Heat losses based on detailed calculation method

This method is described in clause 6.2.6 of EN 15316-3-2. It is based on the calculation of the pipe heat loss, assuming an average temperature of the pipe section (part of the distribution system, e.g. section serving the kitchen). The calculation method is worked out in Annex D. Details of this method are to be given in a National Annex.
The input parameters for every pipe section are:

- pipe length in m;
- linear thermal transmission coefficient in W/(m·K);
- average temperature of pipe section in °C;
- average ambient temperature in °C;
- daily utilization period at the corresponding temperature in h/day.

For this method the determination of the average temperature of a pipe section is crucial. It depends on the number of tappings, nominal hot water temperature, ambient temperature and the transmission coefficient. Thus, a full dynamic calculation (not described in the standard or annex), depending on these parameters, is required to obtain the average temperature. But when performing this full dynamic calculation, the heat loss of the pipe is already calculated.

As an alternative a simplified version “Heat losses related to pipe lengths – simple method” is given.

4 > Circulation pipe losses

Heat losses related to circulation pipe length

This method is defined in clause 6.3.2 of EN 15316-3-2. It can be applied if no exact design of the domestic hot water system is available or the pipe insulation thickness is not known. Values (heat losses per pipe length) should be given in a National Annex. A default value is given in Annex D.
The input parameter is:

- circulation pipe length in m.

Figure 5: Example of poor insulation of circulation tubes.

Heat losses based on detailed calculation method
This method is defined in clause 6.3.3 of EN 15316-3-2. It is applicable if exact design data of the domestic hot water system is available. Values (characteristic values for detailed calculation as ambient temperature or length of circulating loop) should be given in a National Annex. If a National Annex is not provided or does not include these data, default values are given in Annex D.
The input parameters are for every pipe section:

- circulation pipe length in m;
- linear thermal transmission coefficient in W/(m·K);
- average temperature of pipe section in °C;
- average ambient temperature in °C;
- daily utilization period at the corresponding temperature in h/day.

Heat losses while circulation is off

This method is defined in clause 6.3.4 of EN 15316-3-2. It assumes a complete cooling down of the system when circulation is off.
The input parameters are for every pipe section:

- circulation pipe volume in m^3;
- average temperature of pipe section in °C;
- average ambient temperature in °C;
- number of circulation pump operating cycles per day.

Heat emission due to accessories

This method is defined in clause 6.4 of EN 15316-3-2. The heat emission from the circulation loop is increased by the energy lost through fittings i.e. valves and flanges and also through pipe hangers.
These heat emission values are estimated by introducing an additional equivalent pipe length. If these losses are to be included in the analysis, details are to be given in a National Annex.

5 > FAQ

What's the relevance of DHW distribution losses in total DHW energy needs?
Distribution losses may be 25% or more of total DHW energy needs for distribution pipes of 10 m and more and for large, badly insulated circulation systems (see figure 5).

Why the standard contains so many different methods?
This reflects both different levels of detail and the different traditions in European countries on this subject.

Is a national annex required for this standard?
Yes it is. Countries need to decide which method(s) they prefer and need to add default values for some methods.
It is recommended to develop a calculation method for distribution systems for dwellings that requires few inputs. In addition a more sophisticated method may be given to allow detailed calculations if additional data are available.
For circulation systems the same approach may be followed, combining the simple method (pipe length only) and the detailed method.

Have the methods been validated?
The methods to determine circulation system losses are based on physics. Correctness is determined by the right assessment of heat loss coefficients and losses due to accessories.
The methods to determine distribution pipe losses have to deal with both the heating up and cooling down of the pipes, in relation to the dynamic profile of the temperature at the tap. Most methods do not deal with this in full detail.

6 > References

1. EN 15316-3-1 Domestic Hot Water Systems – Characterisation of needs (tapping requirements)
2. EN 15316-3-2 Domestic Hot Water Systems - Distribution
3. EN 15316-3-3 Domestic Hot Water Systems - Generation

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[European projects]

P101

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Information paper on EN 15316-3-3 Domestic Hot Water systems - Generation

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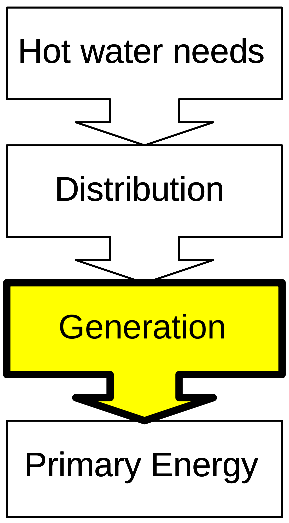

Figure 1: The calculation of hot water generation (losses and efficiency) is the last step in the DHW Energy calculation

Domestic Hot Water (DHW) generation efficiencies range from 50% for old heaters to 90% for modern combi-boilers. In older systems, with an external storage tank, the DHW efficiency can go down to 25%. Major gains in energy reduction may easily be obtained by proper generator selection.

This paper gives a short introduction to the CEN standard EN 15316-3-3, calculating the losses from domestic hot water generation systems. It contains explanations on the calculation methods with details on the input and output data and on links with the other CEN standards.

1 > Scope of the standard

The standard gives methods for the calculation of heat losses, recoverable heat losses and the auxiliary energy of the domestic hot water generation system. The standard is the third part of a series of three standards for the calculation of domestic hot water system energy requirements and system efficiencies (see figure 1). The other standards deal with DHW requirements (EN 15316-3-1) and with DHW distribution systems (EN 15316-3-2). Solar systems are treated in EN 15316-4-3.

2 > Principle of the methods

Domestic hot water generation systems may consist of:

- Complete appliances of different types for single-family dwellings, including direct heated storage water heaters.
- Component-based appliances, including storage vessels, primary circulation pipes and heat generators.

Complete appliances for single-family dwellings may be gas-, oil-, wood- or biomass-fired, electrically heated or heated using a heat pump. Their DHW function may be independent (solo hot water heater) or combined with the heating function (combi-boiler). DHW may be heated directly (i.e. instantaneously) or indirectly, using a storage vessel. The efficiency and losses of all these appliances can be measured, applying one or more 24-hr test tapping patterns, in the way described by EN 13203-2. The efficiency and losses resulting from other patterns of usage may be found by interpolation or by using a correction factor.

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Direct heated storage water heaters may be used in all types of installation. Examples are direct gas- or oil-fired storage heaters and electric immersion heaters. The standard gives a method, based on laboratory measurements.

Component based appliances are in general indirectly heated storage systems. The efficiency and losses of all these appliances are determined by calculations for each component for the given hot water demand.

The heat requirement that must be fulfilled by the DHW generator is the sum of:

› domestic hot water requirements, according to EN 15316-3-1;
› heat losses from the distribution system, according to EN 15316-3-2.

This heat requirement may be reduced by the heat provided by a solar system.

If the heat generator also provides space heating, the performance of the heat generator should be calculated separately for operation during the summer period, when the space heating demand is zero, and the winter period, when both space heating and domestic hot water are provided.

Required inputs depend on the methods.

Resulting outputs are:

› heat losses in MJ/day or MJ/year and/or
› the annual efficiency of the DHW generator
› the recoverable heat losses
› the auxiliary energy.

The methods are set out below. For most methods a national annex is required, providing default values.

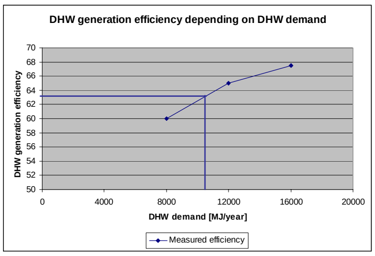

Figure 2: Example of the interpolation between measured efficiencies to obtain the efficiency for the DHW heat requirement.

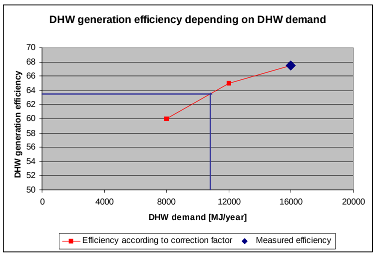

Figure 3: Example of the use of the correction factor for measured efficiencies to obtain the efficiency for the DHW heat requirement.

3 > Complete appliances

Complete appliances for single family dwellings

This method is defined in clause 8 of EN 15316-3-3. It requires measurement of the generation efficiency achieved for one or more 24-hr test tapping patterns. The efficiency and losses for other DHW demands may be found by interpolation or by a correction factor, as illustrated in the side bar (see figure 2 and figure 3).

The correction factor approach requires a national annex.

Direct heated storage water heaters

The efficiency of a direct gas fired domestic storage water heater should be obtained from tests in accordance with EN 89. If no efficiency values are available, minimum values may be provided in a National Annex. These values should not be lower than the default values given in Annex B.

The efficiency of a direct electrically heated domestic storage water heater should be obtained from tests made in accordance with pr EN 50440.

The energy required to maintain the hot water temperature is assumed to be equal to the heat loss to the surroundings. The calculation method is described in Annex C. If values of the parameters for determining the stand-by heat loss are not available, default values must be provided in a National Annex.

For older systems, where no manufacturer's data is available and measurements cannot be made, the values to be used must be given in a National Annex.

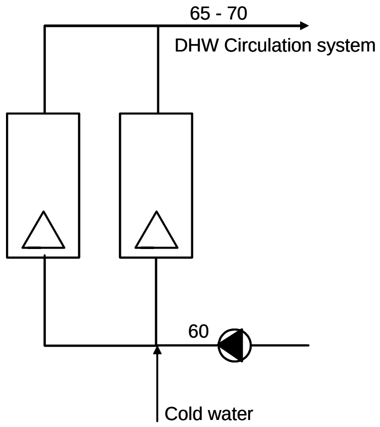

Figure 4: Example of a DHW generator with direct heated storage water heaters. The heat requirement is fulfilled by both heaters together.

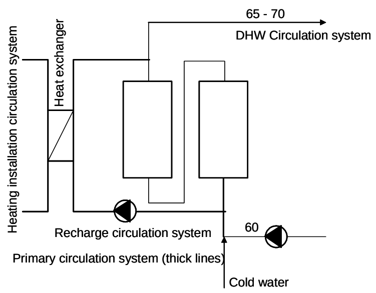

Figure 5: Example of a DHW generator with a heat exchanger and recharge circulation system.

4 > Component based appliances

Component based appliances are in general indirectly heated storage systems. Different types of system lay-out may occur, illustrated in the side bar (figures 4 and 5).

The efficiency and losses of all these appliances are determined by the calculation of the efficiency and losses of each component for the given hot water requirement.

Storage vessels

The method used to determine storage losses is defined in Section 6 of EN 15316-3-3. The storage heat loss is calculated from a stand-by heat loss value, which is corrected for temperature difference. If no measured standby loss values are available, default values from a national annex may be applied, based on storage volume and insulation type and thickness.

Primary circulation pipes

Primary circulation pipes are discussed in Section 7 of EN 15316-3-3. Primary circulation systems are often equipped with a heat exchanger and with a recharge circulation system (see Figure 5). Other configurations may occur. Circulation systems may be operated continuously or at intervals.

A simple method for estimating the heat losses from primary circulation pipes is to use a fixed representative value. Appropriate values must be given in a National Annex.

Detailed methods for calculating the heat loss from pipes are given in EN15316-3-2 (see Information Paper P100). These methods should be followed for calculating the heat loss from primary circulation pipes. If possible, the actual length of the pipes should be used. If no detailed pipe network plan is available, representative values can be used. These values must be given in a National Annex

Heat generators

The total heat loss from a boiler is based on the nominal output efficiency, the stand-by heat loss and the nominal heat output. The calculation method is given in Annex A.

A National Annex may specify default values, if specific test results are not available. For older boilers, for which the efficiency and the stand-by heat loss values may not be known, values may be given in a National Annex.

Auxiliary energy

This method is defined in Section 9 of EN 15316-3-3. Electrical energy is required for the circulation pump(s).

If the circulation pump is contained within the heat generator, the energy required is considered as part of the auxiliary energy for the heat generator. The auxiliary energy measurement, made in accordance with an appropriate appliance standard for the heat generator, should then be used.

If a separate circulation pump is applied, the auxiliary energy requirement should be determined separately. The circulation pump may also be used in the space heating system. Care must be taken to avoid duplicating the energy requirement.

A simplified estimation method or a detailed calculation method may be applied. Methods for calculating the auxiliary energy for circulation loops are given in pr EN15316-3-2 (see information paper P100). Details and default values to be used will be given in a National Annex.

5 > FAQ

What is the relevance of DHW generation efficiencies in total DHW energy needs?

Domestic Hot Water (DHW) generation efficiencies range from 50% for old heaters to 90% for modern combi-boilers. In older systems, with an external storage tank, the DHW efficiency can go down to 25%. Major gains in energy reduction may easily be obtained by proper generator selection.

Is a national annex required for this standard?

Yes it is. Each country must provide appropriate default values for both methods, especially for existing DHW generators, because these values may differ between countries.

Have the methods been validated?

Basically yes. Both methods are based on well-established physical principles.

For complete appliances, efficiencies are measured using realistic tapping patterns. For the component method, accuracy is dependent on correct assessment of the heat loss coefficients of vessels and pipes.

6 > References

1. EN 15316-3-1 Domestic Hot Water systems – Characterisation of needs (tapping requirements)
2. EN 15316-3-2 Domestic Hot Water systems – Distribution
3. EN 15316-3-3 Domestic Hot Water systems – Generation
4. EN 15316-4-3 Energy requirements and efficiencies of thermal solar systems
5. EN 13203-2 Gas-fired domestic appliances producing hot water. Appliances not exceeding 70 kW heat input and 300 l water storage capacity. Assessment of energy consumption
6. EN 89 Gas-fired storage water heaters for sanitary use
7. prEN 50440 Efficiency of domestic electrical storage water heaters

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Cluster 2: Space heating

Space heating generation systems.

Introduction

Emission:

Space heating is usually delivered through radiators, floor heating or air heaters. These emission systems need to maintain the room temperature at the desired level. To achieve this, they will need a heat input from the heat distribution system, and sometimes some auxiliary energy. Factors like non-uniform temperature distribution in a room, control strategy and heat losses are taken into account in calculating the energy consumption needed to maintain the desired room temperature, The emission losses can represent about 10 % of the building space heating consumption. IP97 will elaborate on the calculation procedure for the emission sub-system.

Distribution:

A part of the heating system which is often underestimated is distribution. This part consists of all piping between heat generator and emission body, including circulation pumps and valves. The electrical consumption of a pump can represent about 10 % of the primary energy consumption of a low energy house. Heat losses and energy consumption of the distribution network can exceed 20% of space heating energy demand, especially in the case of continuously circulating high temperature heating schemes. The different aspects to take into account when calculating distribution sub-system heat losses and energy consumption are described in IP98.

Generation:

Providing the need as efficiently as possible is the task of the heating system. This is achieved by choosing an appropriate generator, for which there are several options. Combustion systems like gas boilers are a well known and widely used option. Heat pumps have only recently gained a significant market penetration. Their big advantage is that they “transport” heat instead of generating it, making efficiencies greater than 100% possible. Other generators are thermal solar, combined heat and power, photovoltaic and biomass combustion systems. District heating and other large volume systems have some distinctive properties, so are treated as separate subjects in the generation standards. IP162 covers some general aspects to determine operating conditions of the generators. This includes the special case where more than one type of generator is used. This situation can significantly alter operating conditions of the individual generators.

Information papers

IP 97: Heating systems in buildings – Space heating emission systems

IP 98: Heating systems in buildings – Space heating distribution systems

IP 102: Space heating generation systems – Combustion systems

IP 103: Space heating generation systems – Heat pump systems

IP 104: Space heating generation systems – Thermal solar systems

IP 105: Space heating generation systems – Combined heat and power systems

IP 106: The performance and quality of district heating and large volume systems

IP 107: Space heating generation systems – Photovoltaic systems

IP 108: Space heating generation systems – Biomass Combustion systems

IP 162: Space heating generation systems–Operating conditions and multiple generators

Presentations

Besides Information Papers, corresponding presentations have been prepared to support communication about EN EPBD standards as well as lectures. Presentations often include notes to explain the slides and to support lecture preparation.
Presentations can also be downloaded freely from *http://www.iee-cense.eu/*

Information paper on Space heating emission systems

(EN 15316-2.1: Emission and control).

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

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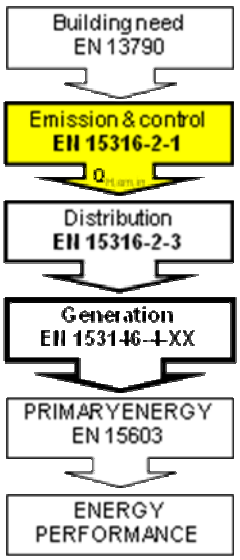

Figure 1. The calculation of the emission losses is the first step in the heating system Energy calculation

The heat emission system is that part of the heating system that is installed inside a space to deliver heat by convection and/or radiation so as to maintain a specified space temperature. The most common emission systems are radiators, floor heating and warm air heaters.

The standard EN 15316-2.1 specifies the approach that is to be used for calculating the additional heat losses and energy requirements of a heat emission system for meeting the building net energy demand.

The calculation method is used for the following applications:

- Calculation of the additional energy losses in the heat emission system;
- Optimisation of the energy performance of a planned heat emission system, by applying the method to several possible options;
- Assessing the effect of possible energy conservation measures on an existing heat emission system, by calculating the energy requirements with and without the energy conservation measure implemented.

The user shall refer to other European Standards or to national documents for input data and detailed calculation procedures not provided by this standard

The EN standard 15316-2.1 was published in January 2008.

1 > Scope of standard

The scope of this specific part (2.1) of the standard is to standardise the required inputs, the outputs and the approach used in the calculation method, in order to achieve a common European calculation method.

The energy performance may be assessed either in terms of the heat emission system efficiency or in terms of the increased space temperatures due to heat emission system inefficiencies.

The methods are based on the analysis of the following characteristics of a space heating emission system, including its control:

- non-uniform space temperature distribution;
- emitters embedded in the building structure;
- control accuracy of the indoor temperature.

The energy required by the emission system is calculated separately for thermal energy and electrical energy in order to determine the final energy, and subsequently the corresponding primary energy is calculated.

The calculation factors for conversion of energy requirements to primary energy shall be decided at a national level.

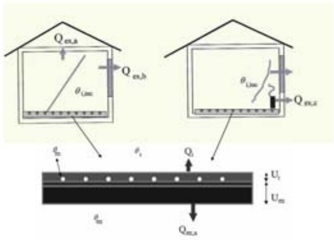

Figure 2: Effects due to non-uniform temperature distribution and to the position of the heat emitter

2 > Principle of the methods

The input to the calculation is the building energy need for heating, EN ISO 13790). The output is the energy to be delivered by the heat distribution system (EN 15316-2.3) and the energy losses (thermal and auxiliary energy) in the heat emission system (see Figure 1).

Emission losses are due to three factors, namely, non-uniform temperature distribution, losses to the outside from heating devices embedded in the structure, and losses due to non-perfect control of the indoor temperature (EN15316-2.1). The heat energy losses of heat emission are calculated as:

$$Q_{em,ls} = Q_{em,str} + Q_{em,emb} + Q_{em,ctr} \quad [J] \qquad (1)$$

where:

$Q_{em,str}$ heat loss due to non-uniform temperature distribution in Joule (J);

$Q_{em,emb}$ heat loss due to emitter position (e.g. embedded) in Joule (J);

$Q_{em,ctr}$ heat loss due to control of indoor temperature in Joule (J).

These different heat losses in the heat emission system are illustrated in Figures 2 and 3.

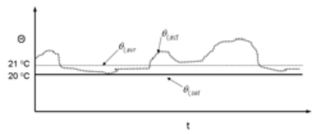

Figure 3: Effect of control accuracy as efficiency or an equivalent increase in space temperature

A non-ideal control may cause temperature variations and drifts around the set point temperature, due to the physical characteristics of the control system, sensor locations and the characteristics of the heating system itself. This may result in increased or decreased heat losses through the building envelope compared to heat losses calculated with the assumption of constant internal temperature. The ability to utilise internal gains (from people, equipment, and solar radiation) depends on the type of heat emission system and control method (Figure 3). The calculation of energy use according to EN ISO 13790 is based on a constant internal temperature, while the real room temperature (as indicated in Figure 3) will vary according to the control concept and in response to variations in internal loads.

Two methods are recommended in the standard for taking these variations into account. They do not give exactly the same results, but the same trend. The two methods, which will be described in Chapters 3 and 4, must not be mixed.

Note: If the increased temperature in the building element has been taken into account in the calculations according to EN ISO 13790, this must not be done again. For a slab on ground, and for large buildings, it is important to use the equivalent U_e value according to EN ISO13370 or EN 12831.

3 > Method using efficiencies of the emission system.

The evaluation of the heat energy losses of heat emission ($Q_{em,ls}$) takes place monthly or in another time period in accordance with equation (2).

$$Q_{\text{em,ls}} = \left(\frac{f_{\text{Radiant}} f_{\text{int}} f_{\text{hydr}}}{\eta_{\text{em,ls}}} - 1 \right) Q_{\text{H}} \qquad (2)$$

where

$Q_{em,ls}$ is the additional loss of the heat emission (time period), in J

Q_H is the net heating energy (time period) (EN ISO 13790), in J;

f_{hydr} is the factor for the hydraulic balancing.

f_{int} is the factor for intermittent operation (intermittent operation is to be understood as a time-dependent option for temperature reduction for each individual room space);

$f_{radiant}$ is the factor for the radiation effect (only relevant for radiant heating systems);

$\eta_{em,ls}$ is the total efficiency level for the heat emission in the room space

The total efficiency level η_{em} is fundamentally evaluated as

$$\eta_{em} = \frac{1}{(4 - (\eta_{str} + \eta_{ctr} + \eta_{emb}))} \qquad (3)$$

where

η_{str} is the partial efficiency level for a vertical air temperature profile;

η_{ctr} is the partial efficiency level for room temperature control;

η_{emb} is the partial efficiency level for specific losses from the external components (embedded systems).

In individual application cases this breakdown is not required. The annual expenditure for the heat emission in the room space is calculated as

$$Q_{\text{em,ls,a}} = \sum Q_{\text{em,ls}} \qquad (4)$$

where

$Q_{em,ls,a}$ is the annual loss of the heat emission, in kWh;

$Q_{em,ls}$ is the loss of the heat emission (in the time period) in accordance with Equation (2), in kWh.

Default values for the different efficiencies and factors can be found in an informative annex to the standard. Some of these values are based on real data from experiments and/or computer simulations, while others are based on a consensus. Examples of the values included in the annexes are given in Tables 1 to 3.

EXAMPLE 1 Radiator external wall; over-temperature 42.5 K; P-controller (2 K)

$\eta_{Str} = (\eta_{str1} + \eta_{str2})/2$ = (0.93 + 0.95)/2 = 0.94;

η_{ctr} = 0.93; η_{emb} = 1

$\eta_{em,ls}$ =1/(4 - (0.94 + 0.93 + 1))= 0.88

EXAMPLE 2 Floor heating - wet system (water); two-step controller; floor heating with a high level of heat insulation

η_{Str} = 1.0; η_{ctr} = 0.93;

For η_{emb} an average value is to be formed from the data for the main parameters "system" and "specific heat losses via laying surfaces".

$\eta_{emb} = (\eta_{emb1} + \eta_{emb2})/2$

$\eta_{emb} = (\eta_{emb1} + \eta_{emb2})/2$= (0.93 + 0.95)/2 = 0.94

$\eta_{em,ls}$ = 1/(4 - (1.0 + 0.93 + 0.94)) = 0.88

Factor for intermittent operation:
f_{int} = 0.98

Factor for radiation effect:

f_{rad} = 1.0

Factor for hydraulic balancing:

f_{hydr} same as for radiators

Table 1. Efficiencies for free heating surfaces (radiators); room heights ≤ 4 m

Influential parameters		Efficiencies: η_{str} (η_{str1})	Efficiencies: η_{str} (η_{str2})	Efficiencies: η_{ctr}	Efficiencies: η_{emb}
Room space temperature control	un-controlled, with central supply temperature control			0.80	
	Master room space			0.88	
	P-controller (2 K)			0.93	
	P-controller (1 K)			0.95	
	PI-controller			0.97	
	PI-controller (with optimisation function, e.g. occupancy detection, adaptive controller)			0.99	
Over-temperature (reference Θ_i = 20 °C)	60 K (e.g. 90/70)	0.88			
	42.5 K (e.g. 70/55)	0.93			
	30 K (e.g. 55/45)	0.95			
specific heat losses via external components (GF = glass surface area)	radiator location internal wall		0.87		1
	radiator location external wall		0.83		
	GF without radiation protection		0.88		1
	GF with radiation protection[a]		0.95		1
	- normal external wall				1

a The radiation protection must prevent 80% of the radiation losses from the heating body to the glass surface area by means of insulation and/or reflection.

Table 2. Factor for hydraulic balancing: f_{hydr}

Influential parameters	Factor for hydraulic balancing, f_{hydr}
Non balanced systems	1.03
Signed balancing report and in compliance with EN 14336 more than 8 emitters per automatic differential pressure control or only static balanced systems	1.02
Signed balancing report and in compliance with EN 14336, Max 8 emitters per automatic differential pressure control	1.00

Table 3. Efficiencies for component integrated heating surfaces (panel heaters); room heights ≤ 4 m

influence parameters		Part efficiencies			
		η_{str}	η_{ctr}	η_{emb}	
Room space temperature control	Heat carrier medium: water				
	- uncontrolled		0.75		
	- uncontrolled, with central supply temperature control		0.78		
	- uncontrolled with average value formation ($\vartheta_V - \vartheta_R$)		0.83		
	- Master room space two-step controller/P-controller		0.88		
	- PI-controller		0.93		
	Electrical heating		0.95		
	-two-step controller		0.91		
	- PI-controller		0.93		
System	Floor heating			η_{emb1}	η_{emb2}
	- wet system	1		0.93	
	- dry system	1		0.96	
	- dry system with low cover	1		0.98	
	Wall heating	0.96		0.93	
	Ceiling heating	0.93		0.93	
Specific heat losses via mounting surfaces	Panel heating without minimum insulation in accordance with DIN EN 1264				0.86
	Panel heating with minimum insulation in accordance with DIN EN 1264				0.95
	Panel heating with 100% better insulation than required by DIN EN 1264				0.99

4 > Method using equivalent increase in internal temperature

The internal temperature is increased by the spatial variation due to stratification, depending on the emitter, and by the control variation depending on the capacity of the control device, assuring a homogeneous and constant temperature.

The equivalent internal temperature, $\theta_{int,inc}$ taking into account the emitter, is calculated by:

$$\theta_{\text{int},inc} = \theta_{\text{int},ini} + \Delta\theta_{str} + \Delta\theta_{ctr} \qquad (^\circ C) \qquad (5)$$

where:

$\theta_{int,ini}$ initial internal temperature (°C);

$\Delta\theta_{str}$ spatial and vertical variation of temperature;

$\Delta\ \theta_{ctr}$ control variation.

The influence of an equivalent increase in internal temperature due to losses from the heat emission system may be calculated in two different ways:

1. By multiplying the calculated building heat demand, Q_H, with a factor based on the ratio between the equivalent increase in internal temperature, $\Delta\theta_{int,inc}$, and the average temperature difference for the heating season between the indoor and outdoor temperatures for the space:

$$Q_{em,ls} = Q_H \cdot (1 + \Delta\theta_{int,inc} / (\theta_{int,inc} - \theta_{e,avg})) \qquad [J] \qquad (6)$$

2. By recalculation of the building heat energy requirements, according to EN ISO 13790, using the equivalent increased internal temperature as the set point temperature of the conditioned zone. This second approach leads to better accuracy.

For η_{str} an average value is to be formed from the data for the main parameters "over-temperature" and "specific heat losses via external components".

$$\eta_{str} = (\eta_{str1} + \eta_{str2})/2$$

Examples of input values are listed in Tables 4 to6.

Table 4. Spatial variations by type of emitter and the corresponding spatial class at nominal load (K)

		Spatial variation for ceiling height			
Class of spatial variation	Heat emitter	< 4m	Between 4 and 6 m	Between 6 and 8m	> 8m
A	Floor	0	0	0	0
B	Air with air return < 3m Radiant emitters Low temperature emitters Radiated ceiling panels Fan coils with air discharged below	0.2	0.8	1.2	1.6
C	Other emitters	0.4	1.2	2	2.8

Table 5. Spatial variations for radiators as a function of water temperature and thermal load (K)

Excess Temperature Reference internal temperature : 20°C	Off	Nominal load
$\Delta T > 40$ K	0	0.4
$\Delta T \leq 40$ K	0	0.2

Table 6. Control variation

	Standard	**Control variation** $\Delta\theta_{ctr}$ **(K)**	
		off	Nominal thermal load
Direct electric emitter with built in controller	IEC 60 675	0.4	0.9
Thermostatic radiator valve	EN 215	0.45*hysteresis	0.45*(hysteresis + water temperature effect)[1]
Individual zone control equipment	EN 15500	0.5 CA	CA[2] (defined in the standard and certified)
Other controller if emission can be totally stopped		0.9	1.8
No control		2	4

1 : With values of hysteresis and water temperature effect from a test report of the thermostatic valve according to EN 215.

2 : The control accuracy (CA) of the controller is obtained from *Systems in buildings — Installation and commissioning of water based heating* EN 15500.

5 > Auxiliary energy

For each electrical device forming a part of the heat emission system, the following data must be identified to determine the electrical auxiliary energy W_{em} :

- electrical power;
- duration of operation;
- proportion of the electrical energy converted to heat and emitted into the heated space.

$$W_{em} = W_{ctr} + W_{others} \tag{7}$$

where

W_{em} is the auxiliary energy (in the period), in kWh;

W_{ctr} is the auxiliary energy of the control system (in the period), in kWh;

W_{others} is the auxiliary energy of fans and additional pumps (in the period), in kWh.

Calculations must be specified in a national annex. Default calculations are given in (informative) Annex C of the standard.

6 > FAQ

Why two methods? Where do they come from?

The two methods represent the different approaches of the corresponding German and French standards. As both standards were well developed and reliable, it was decided to include both approaches as possible methods.

Will the two methods lead to the same results?

The two methods will not give the same result, but they do show the same trend. For comparison between different systems the same method must be used.

Are national annexes always required?

No, the default input values in the standard can be used.

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Link: www.iee-cense.eu

Original text language: English

7 > References

1. EN 15316-2.1, Heating systems in buildings: Method for calculation of system energy requirements and system efficiencies - Part 2-1:Space heating emission systems
2. EN ISO 13790:2008, Thermal performance of buildings - Calculation of energy use for space heating and cooling
3. EN 15316-2.3:2007, Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies - Part 2-3: Space heating distribution systems
4. EN 13370:2007, Thermal performance of buildings - Heat transfer via the ground - Calculation methods
5. EN 12831, Heating systems in buildings - Method for calculation of the design heat load
6. EN 14336, Heating systems in buildings — Installation and commissioning of water based heating systems
7. EN 215, Thermostatic radiator valves — Requirements and test methods
8. EN 15500, Electronic individual zone control equipment

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[European projects]

P98

12-10-2008

Information paper on EN 15316-2-3 Heating systems in buildings Space heating distribution systems

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Distribution subsystems look simple but underestimation of losses can give unexpected results. Distribution losses are affected not only by piping insulation but also by operating temperatures. High unexpected losses (up to 20%) usually occur in constant high temperature distribution schemes (most new centralized heating systems in Italy). In these cases very high insulation levels are necessary to prevent poor system performance. Also, when too little insulation is installed initially, any retrofit solution is tremendously expensive.

Also, the water distribution circuit type may affect generator performance. Experience has shown that a number of 'condensing generators do not condense at all (thus losing up to 10% efficiency) because of poor consideration of distribution circuits effect on water temperature.

Electric energy can also be a concern. A circulator of 100 W kept running 24/24 for 180 days in a 100 m² flat would use 10 kWh/m² (with a primary energy factor of 2,5)!

This paper gives a short introduction to the CEN standard EN 15316-2-3 for calculating heat losses and auxiliary energy needs from heating system distribution systems. It contains explanations of the calculation methods with details on the input and output data and links with other CEN standards.

The basis of the detailed method is simple physics but this standard defines a method to build sound correlations to simplify calculations in most common cases. Consideration is also given to operating temperatures, which are relevant to the performance of modern generation systems (heat pumps and condensing boilers).

The standard was approved at formal vote in May 2007.

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

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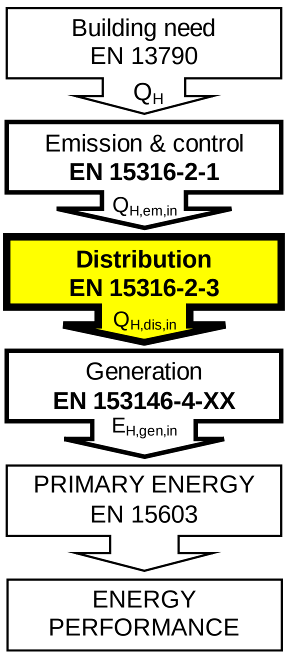

Figure 1: *The calculation of the distribution losses is the second step in the heating system Energy calculation*

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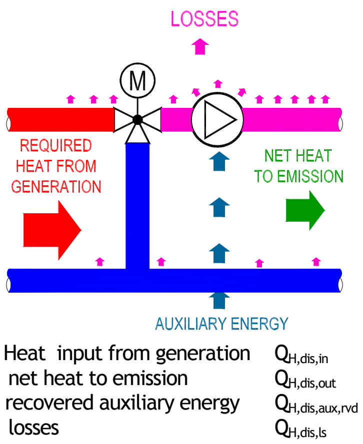

Figure 2: *Basic energy balance of the distribution subsystem*

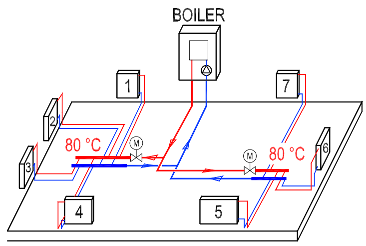

Figure 3: *Star (or parallel) distribution network with zones*

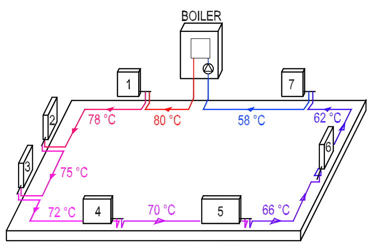

Figure 4: *Ring (or single-pipe or series) distribution network*

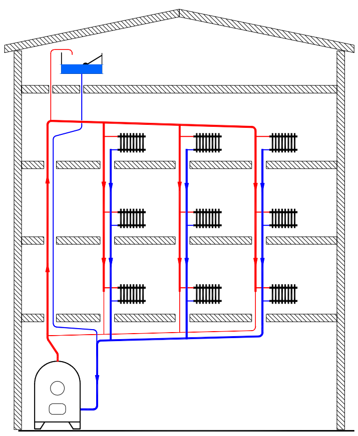

Figure 5: *Vertical shafts distribution network (typical of older buildings)*

1 > Scope of the standard

This standard gives both detailed and simplified methods for the calculation of heat losses and auxiliary energy needs of the distribution sub-system for heating. It is part of the EN 15316 series for the calculation of heating system energy requirements and system efficiencies.

The required heat output, $Q_{H,dis,out}$, is calculated according to the part of the standard dealing with heat emission and control (EN 15316-2-1) and forms an input to this standard.

Pipe sizing is not covered by this standard; its purpose is meant to calculate the in-use energy performance of a given heating system distribution network, either existing or as designed and sized.

This standard also includes a method (clause 8) to calculate water temperature (flow and return) within the distribution network at actual operating conditions. This is required for detailed calculation of losses as well as for performance calculation of boilers and heat pumps.

The domestic hot water distribution sub-system is treated in EN 15316-3-2, even though there are many common concepts.

This standard covers water based distribution networks. Heat losses from air ducts are covered in the ventilation standards: EN 15241 clause 6.3.2 and EN 15243 clause E.1.2.

2 > Principle of the methods

The detailed calculation of heat losses takes into account the following factors for each homogeneous pipe element:

- length of pipe element;
- conductivity and thickness of insulating layer;
- location (indoor, outdoor, underground, embedded within walls, etc.);
- internal (water) and external (surroundings) temperature;
- operation time.

This standard allows three levels of calculation of heat losses:

- detailed approach;
- detailed approach with simplified input;
- tabulated values.

The common input data is the heat required by the attached emission and control sub-system(s) $Q_{H,em,in}$.

Some losses can be towards the heated space and are therefore recoverable. This standard allows both explicit and implicit calculation of recovered heat losses:

- explicit calculation means that recoverable losses are given as an output of this calculation. These data are used, together with recoverable losses from other parts, to calculate actual recovered losses that reduce heating needs (see EN 15603).
- Implicit calculation means that recovered losses are taken into account as a reduction of losses within the distribution part. There is no data output for recoverable losses.

The auxiliary energy calculation starts from the mechanical energy need for water circulation, given by flow rate and total head loss. This information comes from the heating system design. The effect of the pump efficiency is taken into account by a series of correction factors accounting for the various influences on pump performance.

Three levels of auxiliary energy calculation are allowed: detailed, simplified and tabulated. The recovery of auxiliary energy, as heat, is taken into account, too.

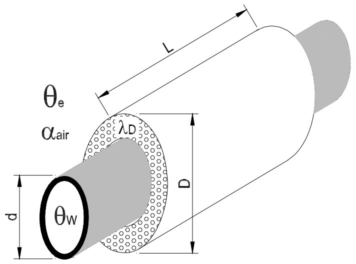

Figure 6: Detailed approach for heat losses.
Parameters required to calculate heat losses of a pipe element:
L: length of element
d: pipe outer diameter
D: insulation outer diameter
λ_D: insulation conductivity
a_{air}: external heat transfer coefficient
θ_W: water temperature
θe: surrounding temperature

Figure 7: *Detailed approach. A non-insulated pipe is accounted for explicitly.*

The water temperature calculation is performed according to the following data:
- energy to be supplied to the heated space during the calculation interval;
- type of emitters (i.e. radiators, panels, etc.);
- type of emitter control (i.e. on/off, varying flow, varying temperature, etc.);
- type of hydraulic connection of emitters (i.e. direct connection, with mixing valve, with by-pass valve, etc.).

The common output data is
- heat required from the generation sub-system(s) $Q_{H,dis,in}$;
- auxiliary energy need for distribution $E_{H,dis,aux}$;
- recoverable losses, if not already accounted for as reduction of losses;
- flow and return temperature.

Annex A of the standard specifies how to generate simplified methodologies for calculation of distribution heat loss. An example of a complete calculation, using the simplified method, is given in clause A.5.

Specific input for detailed and simplified methods is detailed in the following paragraphs.

3 > Distribution heat losses

Distribution heat losses calculation is defined in clause 7 of EN 15316-2-3.

Detailed calculation method

The detailed calculation defined in clause 7.2 is the reference method.

The principle is to sum up all losses from pipe elements using basic physics formulae (see figure 6).

For each element the following data is needed:
- pipe length in m;
- linear thermal transmittance (loss factor) in W/(m·K)
- temperature of water inside the pipe in °C;
- surroundings temperature in °C.

The linear thermal transmittance of the pipe element has to be calculated according to clause 7.3 which requires knowledge of the following values: (see figure 6):
- pipe outer diameter in m;
- thickness of insulating layer in m;
- thermal conductivity of insulating layer in W/(m·K);
- external heat transfer coefficient in W/(m²·K).

For embedded or underground pipes, the following additional data are also required
- depth from ground surface in m;
- thermal conductivity of walls or ground in W/(m·K);
- distance between pipes running parallel to each other.

Any non-insulated piping element is also taken into account explicitly (see figure 7) as losses from non insulated pipes equals losses of 10 to 20 times longer insulated pipes.

Simplified method for heat loss calculation

The simplified method is defined in clause A.3 (see figures 8 and 9)

The basic idea is to use the detailed method with simplified input data:
- the distribution network is divided into three parts: horizontal distribution, vertical distribution and terminal connection pipes;

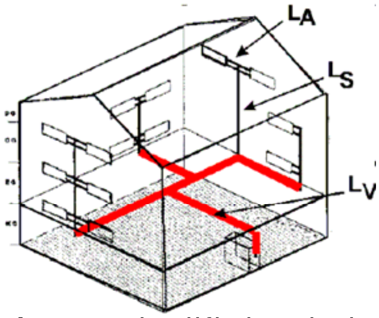

Figure 8: *Simplified method: Length of pipes in parts L_A, L_S and L_V are given through correlations with building dimensions.*

Table A.4 — Approximation of pipe lengths (two-pipe heating systems)

Values	Result	Unit	Part V (from the generator to the shafts)	Part S (vertical shafts)	Part A (connection pipes)
Mean surrounding temperature		°C	13 respectively 20	20	20
Pipe length in case of shafts in outside walls	L	m	$2 \cdot L_L + 0.01625 \cdot L_L \cdot L_W^2$	$0.025 \cdot L_L \cdot L_W \cdot h_{ev} \cdot N_{ev}$	$0.55 \cdot L_L \cdot L_W \cdot N_{ev}$
Pipe length in case of shafts inside the building	L	m	$2 \cdot L_L + 0.0325 \cdot L_L \cdot L_W + 6$	$0.025 \cdot L_L \cdot L_W \cdot h_{ev} \cdot N_{ev}$	$0.55 \cdot L_L \cdot L_W \cdot N_{ev}$

Figure 9: *Simplified method: correlations between pipe length and building dimension.*

$A_{h,z}$ [m²]	Generators with standard water volume – Two-pipe-system with radiators – Type of pump control: pump not controlled	dpconst	dpvariabel
100	99	64	53
150	126	82	68
200	151	98	82
300	196	127	106
400	238	154	129
500	278	180	150
600	316	205	171
700	354	229	192
800	391	253	211
900	427	276	231
1 000	463	299	250

Figure 10: *Tabulated method for auxiliary energy need Auxiliary energy need in kWh/year is given:*

- *as a function of zone floor area (row)*
- *for 5000 heating hours per year*
- *according to pump control type (3 columns)*
- *according to distribution network typology (separate tables)*

- a total length for each part is estimated according to the floor area and the external dimensions of the building; the total estimated length is used instead of the individual element lengths;
- linear thermal transmittances are given in tables according to building age and type.

The correlations between building size and pipe length and the tables for linear thermal transmittances may be modified on a national basis to reflect local building practices and dates of changes to regulations.

Non-insulated elements may be taken into account with an equivalent length of (insulated) pipe.

Tabulated heat loss calculation

Distribution heat losses (kWh/year) are given in tables for each type of distribution system.

Values in the tables may be calculated at national level with the simplified or detailed method.

Great care must be given in specifying boundary conditions for such tables. Boundary conditions include:

- insulation levels;
- network topology;
- temperature levels;
- type of water circuit.

4 > Auxiliary energy demand

The distribution auxiliary energy calculation is defined in clause 6 of EN 15316-2-3.

Detailed method

The reference method is the detailed calculation procedure, which is defined in clause 6.3.

The calculation starts from the knowledge of flow rate and heat loss from which the mechanical energy required to circulate the water in the distribution circuit is calculated.

The effects of pump type, pump control mode, varying flow rate and the distribution network typology, according to varying heat requirements, are described by a series of multiplying factors:

- β takes into account part-load operation of the heating system
- f_S, the correction factor for supply flow temperature control, takes into account the presence or absence of outdoor temperature compensation;
- f_{NET} is the correction factor for hydraulic networks and differentiates between ring line, star type or vertical column network (see figures 3, 4 and 5);
- f_{SD} takes into account any oversizing of the heat emitters;
- f_{HB} takes into account any hydraulic unbalance;
- f_{GPM} takes into account integrated management of the circulation pump within the heat generator;
- f_η takes into account pump mechanical efficiency;
- f_{PL} takes into account pump performance at part load;
- f_{PSP} takes into account correct selection of the pump compared to the design requirement;
- f_C takes into account the type of pump control.

Tabulated values, graphs, formulas and instructions to calculate all the required factors are given in clauses 6.3.4, 6.3.5 and A.1.3.

The calculation of auxiliary energy requirement is performed on a yearly

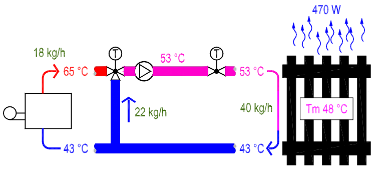

Figure 11: *Emitter connection through a mixing valve. Typical for central control or for lower temperature emitters. Distribution network temperature is the same as emitters temperature Flow rate before the mixing valve is less than in the emitters.*

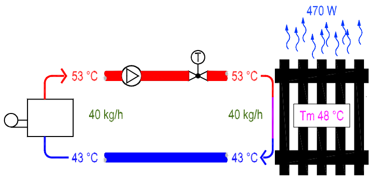

Figure 12: *Direct connection of heat emitters to the boiler room collectors. Typical for thermostatic valves. Distribution network temperature is the same as emitters temperature Flow rate in the distribution network is the same as in the emitters.*

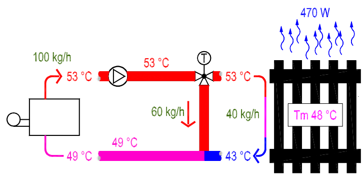

Figure 13: *Emitter connection with a by-pass. Typical for the connection of HVAC hot heat exchanger or single pipe circuits. Distribution network losses increase when the emitter power is reduced. Flow rate in the network is greater than required by the emitters causing higher auxiliary energy needs.*

basis. Clause 6.5 specifies how to split the yearly value into monthly values.

Auxiliary energy recovery as heat is covered in clause 6.6. A simple proportionality is considered appropriate.

Simplified method

The simplified method is described in clause A.1.

The simplification consists of grouping and reducing the number of correction factors.

Tabulated method

The tabulated method is described in clause A.2 (see figure 10).

Distribution auxiliary energy need is given in kWh/year according to the floor area of the heated zone, the distribution type and the pump control type.

Tables are filled with values calculated with the detailed method.

Values in the tables are to be calculated at national level with appropriate assumptions reflecting local practices.

5 > Water temperature calculation

Calculation of flow and return water temperature is required because actual operating conditions have a strong influence on modern heat generator performance.

- Condensing boilers are sensitive to water return temperature to the boiler. The effect can be as high as ±10% on boiler efficiency;
- Heat pumps are sensitive to water flow temperature to distribution system. The effect can be as high as ±20% on the COP.

In both cases, the lower the water temperature, the better the generator performance. Unfortunately the highest water temperatures are required when the most energy and the highest power level is required. Therefore a correct calculation of water temperature according to operating conditions is necessary to calculate generator performance.

Clause 8 of EN 15316-2-3 gives a procedure to calculate flow and return temperature at the beginning of each single distribution circuit. The effect of connecting multiple distribution circuits to the boiler room collectors and the influence of the generator hydraulic connections are described in annex H of EN 15316-4-1.

Flow and return temperatures at emitter level is calculated first. They depend on:

- the type of emitters (radiators, embedded panels, air heaters);
- the size (nominal power) of installed emitters;
- the monthly load (actual operating average power);
- the type of control of the emitters;
- the operation time.

Three basic types of emitter control are specified (see figures 11 to 13):

- constant flow rate, varying temperature (parallel connection of emitters without local control) (figure 11);
- constant flow temperature, continuously varying flow rate (thermostatic valves) (figure 12 and 13);
- both flow rate and flow temperature constant, on/off operation (room thermostat control).

Also the effect of the hydraulic connection is taken into account. Three basic types of connections have been considered

- mixing valve (figure 11);

- direct connection (figure 12);
- by-pass control (figure 13).

This highlights the effect of hydraulic connections. Ignoring this fact may prevent condensation even with low temperature emitters whilst proper design allows attainment of the highest efficiencies with condensing boilers even in the coldest months and using radiators.

6 > FAQ

Why 3 levels (detailed, simplified and tabulated method) for heat loss calculation?

No single method is the right solution for all cases.

The detailed method will always work but requires a lot of input data.

The simplified method is a good compromise in many cases. The simplification of input may come from correlations or from the knowledge of the network typology. Pipe lengths are then dependent on building size.

The tabulated method is obviously the fastest and the simplest but there are very often hidden boundary conditions, like temperature patterns according to water circulation in distribution network:

- losses are usually proportional to energy requirements when there is a continuous control of either flow rate (thermostatic valves) or temperature (central control);
- losses are constant or may even increase with lower heating energy requirements when there is permanent circulation at high temperature in the main shafts (by-pass control of emitters, zones with 3-way valves).

Are national annexes always required?

Yes.

The detailed method requires few national data.

The simplified and tabulated methods are based on correlations and tables that are prepared nationally.

7 > References

1. EN 15316-3-2 Domestic Hot Water systems - distribution

CENSE partners:
TNO (NL; coordinator), CSTB (FR), ISSO (NL), DTU (DK), Fraunhofer (DE), ESD (GB), FAMBSI (FI), EDC (IT)
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Information paper on Space heating generation systems Combustion systems

EN 15316-4-1 (Boiler efficiency).

An efficient combustion system is an interesting and useful solution for reduction of energy consumption in a building. The annual generation efficiency of space heating combustion systems, related to the gross calorific value, varies from about 60% (old boilers) to 95% (condensing boilers).

This paper gives a short introduction to the CEN standard 15316-4-1 to calculate boiler losses, fuel input and auxiliary energy consumption. It contains explanations on the three available calculation methods, with details on the input and output data and the links with the other CEN standards.

The EN standard 15316-4-1 was published in May 2008.

1 > Scope of standard

This standard is part of a series (EN 15316) for the calculation of heating system energy requirements and system efficiencies (see **figure 1**).

This standard gives three calculation methods of the annual energy performance of heat generation for space heating with boilers (combustion systems) using liquid and gaseous fuels, including generator control.

This standard does not cover solid fuel boilers and air heaters which are treated as dedicated parts (EN 15316-4-6 and prEN 15316-4-7 respectively).
Specific parts of EN 15316-4 are dedicated to other generation devices (heat pumps, solar systems, etc.) as well (see **figure 2**).

Boiler sizing is not covered by this standard. This standard is intended to calculate the in-use energy performance of a given boiler, either existing or as designed and sized.

The heat output to be provided by the generator is needed as input data. This is given by the heat input required by the distribution subsystem(s) and calculated according to the distribution part, EN-15316-2-3.

This standard gives little guidance regarding calculation of boiler operating conditions, although these are taken into account in the proposed methods. A separate information paper to be used for all heat generators (heat pumps, cogeneration, etc.) will be provided on this topic.

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

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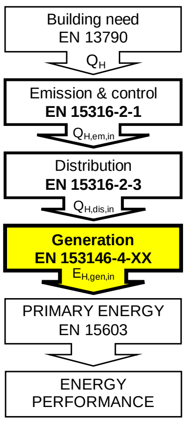

Figure 1: Generation is the 3rd step in the heating system calculation.

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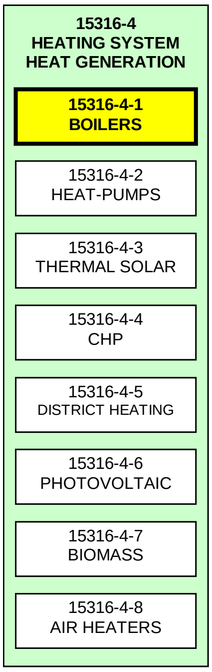
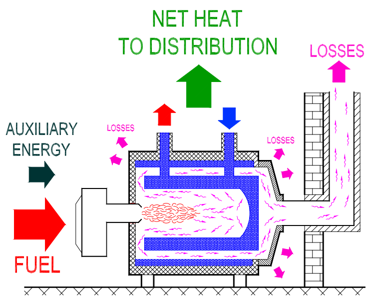


Figure 2: Part 4 of EN 15316 covers generation sub-systems. Separate sub-parts cover the various generation devices



Fuel input	$E_{H,gen,in}$
= net heat to distribution	$Q_{H,gen,out}$
– recovered auxiliary energy	$Q_{H,gen,aux,rvd}$
+ losses	$Q_{H,gen,ls}$

$$E_{H,gen,in} = Q_{H,gen,out} - Q_{H,gen,aux,rvd} + Q_{H,gen,ls}$$

Figure 3: Generation subsystem basic energy balance.

Domestic hot water generation sub-systems are treated in the standard EN 15316-3-3. However, this standard may be used to assess the heat generation for hot water production when an indirectly heated storage system is using the heating boilers as heat source. Required heat output for domestic hot water distribution (or storage) is taken into account as input data in this case.

In the case of multiple generators, the total required heat output to the connected distribution subsystem(s) shall be distributed amongst the available generation subsystems (individual heat output required from each generator), taking into account any priority or limit. With this input data, each generation subsystem shall be calculated according to the relevant part of EN 15316-4.

2 > Principle of the methods

The three methods calculate fuel and auxiliary energy consumption of one or more boilers to fulfill the heat demand of the attached distribution subsystem(s). Boiler performance may also be given as an (annual) efficiency.

The methods take into account boiler heat losses and/or recovery due to the following physical factors (see **figure 3**):

- flue gas losses (burner on);
- draught losses (burner stand-by);
- envelope losses (burner on and stand-by);
- auxiliary energy use (standby/electronics, gas valve, pump, fan);
- auxiliary energy recovery.

The common input data is the heat required by the attached distribution sub-system(s) $Q_{H,dis,in}$. Optionally, the additional load for domestic hot water distribution subsystem $Q_{W,dis,in}$ may be taken into account when using a single generator for both services.

Other input data is required to characterize:

- type and characteristics of the heat generator(s) (atmospheric, condensing, etc.);
- location of the heat generator(s) (heated room, unheated room, ..);
- operating conditions (time schedule, water temperature, etc.);
- control strategy (on/off, multistage, modulating, cascading, etc.).

The basic outputs are:

- fuel consumption $E_{H,gen,in}$;
- auxiliary energy consumption $W_{H,gen,aux}$;

that are used as an input in EN 15603 to calculate primary energy required by the heating system.

Other optional output information that may be extracted relates to:

- generation total heat loss (flue gas, draught and envelope losses);
- recoverable generation heat losses (explicit or already taken into account as a reduction of losses = recovered losses)
- seasonal generation efficiency.

Three performance calculation methods are described:

- boiler typology method;
- case specific method;
- boiler cycling method.

These three methods are worked out below.

The following types of input data may be used as available:

- data declared by the boiler manufacturer;
- on site measurements;
- tabulated default data.

Table P.1: Gross boiler seasonal efficiency for single boiler for heating
Source: NL

Boiler type (efficiencies at net values)	Gross seasonal boiler efficiency
Local gas or oil heater (incl. pilot flame)	65 %
Gas fired air heater (excl. pilot flame)	
– no test data	75 %
– full load net efficiency >= 88,5 %	80 %
– Gaskeur HR 100 label (part load net efficiency >= 101 %)	90 %
– Gaskeur HR 104 label (part load net efficiency >= 105 %)	92,5 %
– Gaskeur HR 107 label (part load net efficiency >= 108 %)	95 %
Oil fired boiler for a single dwelling, within the heated space or Oil fired boiler for a non residential building with a “user surface” <= 500 m², within the heated space. Efficiency excl. pilot flame.	75 %
Oil fired boiler for a single dwelling outside the heated space or Oil fired boiler boiler in a collective heating installation for more dwellings or Oil fired boiler for a non residential building with a “user surface” > 500 m² or with the boiler outside the heated space. All efficiencies excl. pilot flame.	70 %

Figure 4: Sample efficiency table for boiler typology method (source: NL).

3 > Boiler typology method.

This method is defined in clause 5.2 of EN 15316-4-1 and is based on pre-calculated annual efficiencies, depending on a limited set of data which may consist of a table and/or simple correction formulas. An example of this method, developed for the UK, is given in Appendix A of the standard. The Netherlands uses this type of method, but applied utilizing a different approach.

The method requires a specific national annex with tables and/or formulas, suitable for the climate and installation characteristics. This is required, because annual boiler performance depends strongly on boiler load, design temperature, control strategy, boiler room temperature, outdoor climate and boiler parameters. For buildings with equal installation design and equal boiler efficiencies, similar generation seasonal efficiency will be found.

The procedure to determine (national) precalculated values involves:

- Identify repetitive heating system typologies.
  Typical installations schemes should be identified, taking into account
  - boiler type (atmospheric, forced draught, condensing…);
  - individual/collective systems;
  - system design temperature;
  - control strategy (heating curve, room thermostat);
  - boiler room type (heated, unheated);
  - installation year (effect of regulation changes, fuel).
- Identify basic operating conditions (average monthly load profile, average temperature levels according to emitters and common design practices).
- Identify other relevant boundary conditions that may influence performance.
- Identify classes of boilers, according to part load and/or full load efficiency (this may be related to national label systems).
- Perform the calculations with a detailed method and get the correlation factors for the tables (efficiencies, loss factors, etc.) in the various identified conditions.
- Verify compatibility in the case of multiple corrections.

The calculation methods mentioned below can be used to obtain the table values. Also, other validated boiler models may be used.

This method is suitable for new boilers and existing boilers with a (national) label or other efficiency indication. The method may include corrections for measured efficiencies (usually based on flue gas measurement, see EN 15378).

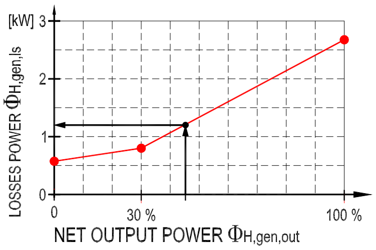


Figure 5: CASE SPECIFIC METHOD Graph showing the basic linear relationship between output load ΦH,gen,out and losses power ΦH,gen,ls. Interpolation is here made between part load and full load.

4 > Case specific method

This method is defined in clause 5.3 of EN 15316-4-1.

The considered calculation interval of this method can be the heating season, however a shorter period (month, week, or the operating modes) is preferable.

For the calculation period the full load, part load and stand by power

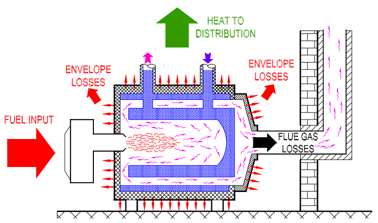


Figure 6: Boiler cycling method
Heat flows and losses with burner ON

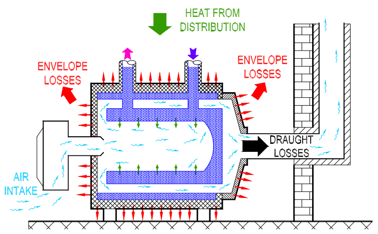


Figure 7: Boiler cycling method Heat flows and losses with burner OFF

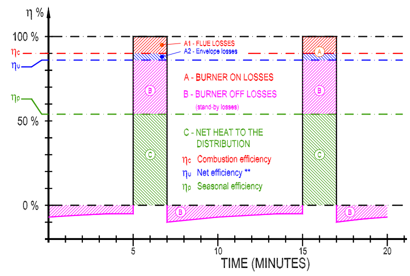


Figure 8: Graph showing the combination of losses during boiler on- and off-time and corresponding efficiency definitions.
A + B + C is the fuel used but the net useful heat to distribution is only C
A are burner ON losses
B are burner OFF losses

losses are calculated from net efficiency data, corrected for real operating conditions. Real losses are found by interpolation of losses power between the two nearest output load situations (see **figure 5**). A similar interpolation is performed to calculate auxiliary energy required by the boiler.

Fuel input is calculated by adding losses to required net output, taking into account recovered auxiliary energy.

Boiler type (atmospheric, forced draught, condensing, etc.) and control (single stage, modulating, etc.) are taken into account in the boiler efficiency input data. Actual operating conditions are taken into account through correction of efficiency data.

Parameters required to characterize the boiler are:

- generator output at full load (reference boiler power);
- generator efficiency at full load;
- generator average water temperature at test conditions for full load;
- generator output at intermediate load;
- generator efficiency at intermediate load;
- generator average water temperature at test conditions for intermediate load;
- stand-by heat loss at test temperature difference;
- difference between mean boiler temperature and test room temperature in test conditions;
- power consumption of auxiliary devices at full load;
- power consumption of auxiliary devices at intermediate load;
- stand-by power consumption of auxiliary devices;
- minimum operating boiler temperature.

Full load and part load test data are generally available for new or recent boilers as they are required by the Boiler Efficiency Directive (92/42/EEC). For existing old boilers, these data are generally not available

Standby-losses and auxiliary power consumption data are generally not available.

Default data shall be given in a national annex to complete data for new boilers, and to use this method for existing boilers, as these factors are not easily measured directly.

Additional boiler input parameters are:

- correction factor of full-load efficiency;
- correction factor of intermediate load efficiency.

No procedure to determine these data is given. They should be given in a national annex. Annex B of the standard gives default values for these factors.

Actual operating conditions input data are:

- net heat output to the heat distribution sub-system(s);
- average water temperature in the boiler;
- return water temperature to the boiler (for condensing boilers);
- boiler room temperature;
- temperature reduction factor depending on the location of the generator.

These data should come from calculations according to other parts of EN 15316 or from default values.

Annex B to the standard contains a complete set of default parameters for this method that can be used as a reference and template to develop a national annex.

According to the combustion technique there are:

- *atmospheric burners*
- *forced draught burners*
- *premixed burners*

According to the heat output control there are

- *single stage boilers*
- *multi-stage boilers*
- *modulating boilers*

According to the capability to recover latent heat from the flue gases

- Non-condensing boilers
- Condensing boilers

Generation capacity may be split over different generators; splitting; splitting ranges from a single boiler to a cascade connection of up to 8 boilers (modular units)

Other factors may influence significantly generation performance:

- *indoor/outdoor boiler installation*
- *sizing of the boiler in comparison with actual building needs (load factor effect)*
- *hydraulic connection with the heating system*

Fitting this big variety of boilers and influences into a single method is challenging.

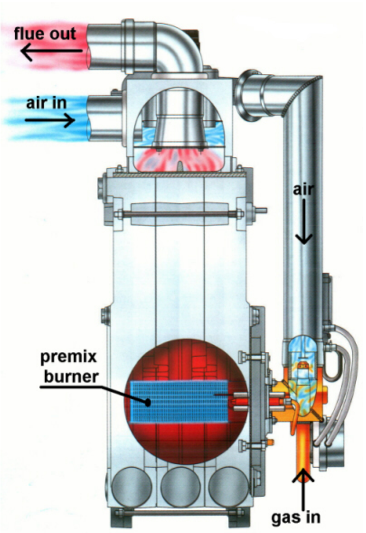


Figure 9: Boiler typology- e.g. Premix type burner

5 > Boiler cycling method

This method is defined in clause 5.4 of EN 15316-4-1. This method performs an analysis of boiler losses.

The calculation interval for this method is usually one month, but can also be a shorter period.

For single stage burners, the calculation interval is divided into two situations, with specific loss calculation for both situations:

- **Burner ON** time (see **figure 6**)
  flue gas losses and envelope losses are considered here;
- **Burner OFF** time (stand-by) (see **figure 7**)
  draught losses and envelope losses are considered here.

Figure 8 is showing the combination of the two situations.

For each calculation interval the burner-on time is calculated depending on the system heat demand. For both on and off-time, losses are calculated using boiler characterization data, correction formulas and tabulated parameters to take into account actual operating conditions (i.e. water temperature).

The required amount of fuel is obtained according to combustion power and calculated on-time.

Boiler type (atmospheric, forced draught, condensing, etc. see **figure 9**) is taken into account through specific loss factors.

Multistage and modulating generators (effect of burner control) are taken into account by addition of a third reference state: burner ON at minimum continuous power. The performance of these boilers is calculated assuming that the following operating conditions are possible:

- if the power required by the distribution system is less than the minimum ON power, the boiler will cycle just as a single stage boiler;
- if the power required by the distribution system is higher than the minimum ON power, the boiler will stay ON continuously and its loss factors are calculated by interpolation between minimum load and maximum load values.

The same method is used, with some adjustments, to deal with modular boilers (i.e. a set of interconnected small boilers).

Condensation latent heat recovery is calculated according to flue gas composition and temperature and taken into account as a "bonus" (reduction) of flue gas losses.

Flue gas temperature is calculated as the sum of:

- water return temperature, which depends on the operating conditions of emitters and distribution system (heating system effect);
- temperature difference between flue gas temperature and water return temperature (boiler effect).

Actual operating conditions are taken into account through correction of loss factors according to water temperature and load and calculation of flue gas temperature (for condensing boilers).

Basic boiler characterization input parameters (single stage) are:

- maximum combustion power of the generator (test conditions);
- heat loss factors at test conditions for flue gas losses (burner on), draught losses (burner stand-by) and envelope losses (burner on and stand-by);
- average boiler water temperature at test conditions for burner on;

Boilers typologies, age, maintenance status are extremely various.
Some pictures show what can be found out there when dealing with existing boilers.

Old atmospheric boiler in a boiler room

A couple of recent boilers installed outdoors

Force draught boiler within a boiler room

Figure 10: Examples of existing boilers

- average boiler temperature at test conditions for burner off;
- temperature of test room;
- electrical power consumption of auxiliary appliances (before the generator, typically burner fan) and related recovery factor;
- electrical power consumption of auxiliary appliances (after the generator, typically primary pump) and related recovery factor.

For condensing boilers, the following additional input data are required:

- temperature difference between flue gas temperature and boiler return water temperature;
- flue gas oxygen content.

For multi-stage and modulating burners, the following additional data are required:

- minimum combustion power with burner on;
- heat loss factors for flue gas losses (burner on) at minimum combustion power;
- auxiliary energy power at minimum combustion power.

For multi-stage and modulating condensing boilers, the following additional data are required:

- temperature difference between boiler return water temperature and flue gas temperature at minimum combustion power;
- flue gas oxygen contents at minimum combustion power.

Full load and part load flue gas losses with burner on are generally available for new boilers. Standby-losses and power consumption data are not typically available, nor are they easily measured.

Additional data for condensing boilers are not always available but are easily measured.

For existing boilers (see **figure 10**) data may not be available. Only flue gas losses with burner on and additional data for condensing boilers are easy to obtain by direct measurement.

Missing data shall be estimated using tables with default values. Annex C to 15316-4-1 gives an example of such tables.

Additional boiler input parameters:

- exponents n, m and p for the correction of heat loss factors.

No procedure to determine these data is given. They should be given in a national annex. Annex C to 15316-4-1 gives an example of such tables.

Actual operating conditions input data:

- net heat output to the heat distribution sub-system(s);
- average water temperature in the boiler;
- return water temperature to the boiler (for condensing boilers);
- boiler room temperature;
- reduction factor taking into account recovery of heat losses through the generator envelope, depending on location of the generator.

These data should come from calculations according to other parts of EN 15316 or from default values.

Annex C to the standard contains a complete set of default parameters for this method that can be used as a reference and template to develop a national annex.

Boiler cycling method concepts may be used as a basis to generate simplified methods for in-situ evaluation of seasonal energy performance of boilers. An example can be found in EN 15378 (boiler and heating system inspection).

6 > FAQ

Why 3 methods?

No single method provides a correct solution for all cases. A simplistic method may not be able to show the effect of improvements, whilst a detailed method may be unecessarily time consuming for common situations.

The boiler typology method has proven to be a reliable and easily applied method, suitable for use by people with minimal modeling skills in common situations.

The other two methods may be used to determine the values for the typology method. They also may be used for situations out of scope of the typology method.

Additional (national) annexes for specific parameters are required, to avoid confusion regarding the use of the method and discussions on the reliability of the results.

What was the aim in developing the 3 methods?

The boiler typology method aims to extreme simplicity.

The case specific method is meant to use as far as possible boiler directive data.

The boiler cycling method is meant to deal with existing boilers/buildings, to keep a connection with directly measurable parameters and to calculate operating performances of condensing boilers.

Are national annexes always required?

The boiler typology method requires that a national annex be developed, as tables contain efficiency values that are calculated to reflect common situations which are specific to each country. Default values include the effect of varying legislation (→ time references in tables), product development, design practice, climatic effect, system typologies etc., all of which are potentially variable between countries. Annex A is an example of the result of this analysis for the UK.

Case specific and boiler cycling methods come with annexes (annex B and C) where default values are given to cover a much broader set of cases, and adjustments may be required to develop a national annex using them as a template.

Where do the methods come from?

The boiler typology method is a general table-approach method.

The case specific method is based on the French TH-2000 rules.

The boiler cycling method is based on the Italian standard UNI 10348.

What if I have more generation subsystems?

The total heat input to all connected distribution subsystems shall be calculated first.

Then the share amongst the available generation subsystems (individual heat output required from each generation subsystem) shall be determined, taking into account any priority or limit.

Each generation subsystem shall be calculated according to the relevant part of EN 15316-4.

What is the potential impact of boiler generation subsystem?

Boiler seasonal efficiency can roughly range from 70% to 105% (based on lower calorific value), with reference to oversized on-off atmospheric boilers and correctly operating modulating condensing boilers, respectively.

A low load factor has a larger negative impact on traditional (non condensing) boilers.

Condensing boiler performance depends on actual operating conditions (load and water temperatures), covering a range of approximately 10%.

7 > References

1. EN 15316-4-1Combustion systems
2. EN15316-2-3 Heating distribution subsystem
3. EN15316-3-3 Domestic hot water generation subsystem
4. EN 15603 Overall energy use
5. EN 15378 Inspection of boilers and heating systems

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Information paper on Space heating generation systems Heat pump systems

EN 15316-4-2 (Heat pump performance)

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A well performing heat pump is an interesting option to reduce the energy consumption of a building. The annual generation efficiency of electrical heat pump systems, related to the gross calorific value of primary energy, varies from about 120% (COP=3) to 200% (COP=5) for heating (gross power generation efficiency of 40%). For gas heat pumps annual gross efficiency varies between 120 and 160% (COP of 1.2 to 1.6).

This paper gives a short introduction to the CEN standard 15316-4-2 for calculating the seasonal heat pump energy performance for heating and hot water production. It contains explanations on the available calculation methods, with details on the input and output data and links to other relevant CEN standards.

The EN standard 15316-4-2 was published in 2008.

1 > Scope of standard

This standard is part of a series (EN 15316) for the calculation of heating system energy requirements and system efficiencies (see **Figure 1**).

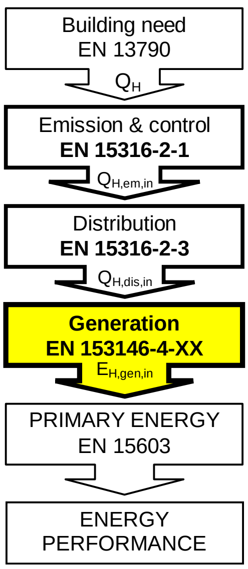

Figure 1: Generation is the 3rd step in the heating system calculation.

The standard covers heat pumps for space heating, hot water production or both. The standard applies for all heat pump principles, including electric compression heat pumps, combustion engine driven compression heat pumps and absorption heat pumps.

The standard gives two methods for calculating the annual energy performance of heat generation using heat pumps.

Heat pump sizing is not covered by this standard. This standard is meant to calculate the in-use energy performance of a given heat pump, either existing or as designed and sized.

The heat output to be provided by the generator is required as input data. This is given by the heat input required by the distribution subsystem(s) and calculated according to the appropriate distribution standard, EN-15316-2-3.

This standard gives some guidance on the calculation of heat pump operating conditions, even though these are taken into account by the proposed methods.

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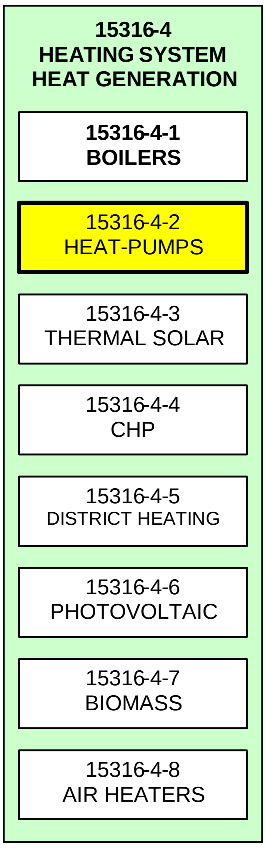

Figure 2: Part 4 of EN 15316 covers generation sub-systems. Separate sub-parts cover the various generation devices

Figure 3: Example of an individual soil-water combi heat pump.

Domestic hot water generation sub-systems are dealt with in the standard EN 15316-3-3, but the present heat pump standard may be used to assess the heat generation for hot water production when an indirectly heated storage system is using the heat pump as heat source (see **Figure 3**). The required heat output for domestic hot water distribution (or storage) is taken into account as input in this case.

In the case of multiple generators, the total required heat output to the distribution subsystem(s) must be assigned appropriately to the generation subsystems (individual heat output required from each generator), taking into account any priority or limit. With this input data, each generation subsystem should then be calculated according to the relevant part of EN 15316-4 (see **Figure 2**).

2 > Principle of the methods

The two methods calculate the power or fuel and auxiliary energy consumption of one or more heat pumps that is required to fulfill the distribution subsystem(s) heat demand. Heat pump performance may also be given as an (annual) COP.

The methods allow the following system types and characteristics:

› system functions: space heating and/or domestic hot water (DHW)
› optional application of space heating and/or DHW storage vessels including the connecting pipe work
› type of heat pump system (monovalent, bivalent)
› driving energy of the heat pump (electricity or fuel)
› thermodynamic cycle of the heat pump (Vapour Compression Cycle or VCC, Vapour Absorption Cycle or VAC)
› type of heat source (outdoor air, exhaust air, indirect ground source (brine, water), direct ground source (direct expansion of refrigerant), ground water, surface water)
› type of heat sink (water, air, direct condensation of refrigerant)
› location of the heat pump system

The methods take into account the following physical factors:

› energy requirements of the heating and/or DHW distribution subsystem
› effects of variation of source and sink temperature on heating capacity and COP according to standard product testing
› effects of compressor control in part load operation (ON-OFF, stepwise, variable speed units) as far as they are reflected in the heating capacity and COP according to standard testing or further test results for operation under partial load.
› auxiliary energy input needed to operate the generation subsystem not considered in standard testing of heating capacity and COP
› system heat losses due to space heating or DHW storage vessels including the connecting pipe work.

The common input data is the heat required by the attached distribution sub-system(s) and/or the load for a domestic hot water distribution subsystem.

The basic outputs are:

› energy consumption (gas, power) for heating and /or domestic hot water
› auxiliary energy consumption.

Outputs are used as an input in EN 15603 to calculate the primary energy required by the heating system and /or the DHW system.

Heat pump type	Gross seasonal heat pump efficiency ($\eta_{hp;i}$)	
System design flow temperature $\theta_{flow;design}$	$\theta_{flow;design} \leq 35$ °C	$35 < \theta_{flow;design} \leq 45$ (°C)
First performance level for individual or collective electric heat pump, without any performance requirements, with heat source:		
— Soil	$3.8 \times \eta_{el}$ [a]	$3.4 \times \eta_{el}$ [a]
— Groundwater	$4.5 \times \eta_{el}$ [a]	$4.1 \times \eta_{el}$ [a]
— Outside air	$3.7 \times \eta_{el}$ [a]	$3.3 \times \eta_{el}$ [a]

Figure 4: Sample efficiency table for boiler typology method (source: NL)

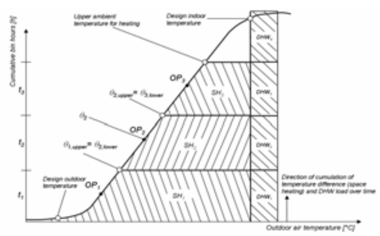

Figure 5: Bin hours vs. outdoor air temperature – sample with 3 bins and constant daily DHW heat energy requirement

Other optional output information may be extracted:

- recoverable generation heat losses (explicit or already taken into account as a reduction of losses)
- seasonal generation efficiency (COP).

Two performance calculation methods are described:

- system typology method;
- BIN method.

These methods are described in more detail below.

The following types of input data may be used if available:

- data declared by the heat pump manufacturer;
- on-site measurements;
- tabulated default data.

3 > Heat pump typology method.

This method defined in clause 5.1 of EN 15316-4-2 gives pre-calculated annual efficiencies, depending on a limited set of heat pump, heat source and installation characteristics. The method may consist of a table and/or simple correction formulas. An example of this method, developed for The Netherlands, is given in Appendix E of the standard (see **Figure 4).**

The method requires a specific national annex with tables and/or formulas, suitable for the climate and for the characteristics of the installation. This is required, because annual heat pump performance depends strongly on heat pump load, design temperature, control strategy, heat source type, outdoor climate and heat pump parameters. For buildings with the same installation design characteristics, the same heat source type and the same nominal COP for the heat pump, similar annual generation efficiencies will be obtained.

The procedure for determining precalculated values involves:

- Identify repetitive heating system typologies.
  Typical installations schemes should be identified, taking into account
  - heat pump type and/or performance characteristics;
  - heat source type (soil, ground water, outside air);
  - individual/collective systems;
  - system design temperature;
  - control strategy (heating curve, room thermostat).
- Identify basic operating conditions (average monthly load profile, average temperature levels according to emitters and common design practices).
- Identify other relevant boundary conditions that may influence performance.
- Identify classes of heat pumps, using nominal efficiencies according to EN 14511 part 2 (this may be related to national label systems).
- Perform the calculations with a detailed method and get the correlation factors for the tables (annual COP) in the various identified conditions.
- Verify compatibility in the case of multiple corrections.

The calculation method mentioned below can be used to obtain the table values. Other validated models may also be used.

This method is suitable for new and existing heat pumps with a (national) label or other efficiency indication.

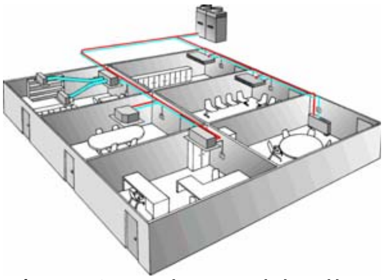

Figure 6: Modern multi-split and single-split systems are used for cooling and heating. In the heating function they are treated as heat pumps.

4 > BIN method

This method is defined in clause 5.2 of EN 15316-4-2.

The calculation interval used in this method can be the heating season, but preferably a shorter period (month, week, or periods of defined operating conditions).

If the operating conditions of heat source and installation are equal to the test conditions of EN 14511 part 2, the measured COP's may be used directly. However, in most cases interpolation between test resultats is required to determine the COP for different operating conditions (BINs - see **figure 5).**

Parameters required to characterize the heat pump are:

- COP at full load for two or three test conditions according to EN 14511 part 2
- COP at partial load (if the heat pump allows partial load operation)
- power consumption of auxiliary devices at full load
- power consumption of auxiliary devices at intermediate load
- stand-by power consumption of auxiliary devices
- minimum operating boiler temperature

Most test data are generally available for new or recent heat pumps. Existing heat pumps may have been tested according to EN 255 part 2, the predecessor of EN 14511.

Default data shall be given in a national annex for new heat pumps and to make it possible to use this method for existing heat pumps, since they are not easy to obtain by direct measurement.

Actual operating conditions input data are:

- net heat output to the heat distribution sub-system(s);
- flow and return water temperature;
- heat source temperature.

These data should come from calculations according to other parts of EN 15316 or from default values.

Annex B to the standard contains a complete set of default parameters for this method that can be used as a reference and template when developing a national annex.

5 > FAQ

Why are two methods given?

No single method can provide the correct solution for all cases. A too simple method may not be able to show the effect of improvements whilst a detailed method may be time wasting for commonly occurring situations.

The heat pump typology method has proved to be a reliable and easy to use method, suitable for use by people with few modeling skills in common situations.

The BIN method may be used to determine the values for the typology method. The method also may be used for situations outside the scope of the typology method. The method requires only standard heat pump input data. Additional (national) annexes for specific parameters are also required.

Are national annexes always required?

The heat pump typology method requires that a national annex should be developed to provide an appropriate set of efficiency values that have been calculated to reflect common situations that are typical for each country. Default values embed the effect of varying legislation (→ time references in tables), product development, design practices, climatic effects, system typologies etc. all of which can be very different in the various countries. Annex E is an example of the result of this analysis for The Netherlands.

The BIN method is supported with annexes (annex A, B and C) where default values are given to cover a much broader set of cases and few adjustments may be required to develop a national annex if they are used as a template. Annex D gives an example of the use of the BIN method.

What are the goals of each method?

The boiler typology method is characterised by extreme simplicity.
The BIN method enables optimal use of measured heat pump data.

6 > References

1. EN 255 part 2 Air conditioners, liquid chilling packages and heat pumps with electrically driven compressors – Heating mode
2. EN 15316-4-2 Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies - Space heating generation systems, heat pump systems
3. P98 EN15316-2-3 Heating distribution subsystem
4. P101 EN15316-3-3 Domestic hot water generation subsystem
5. EN 15411 Air conditioners, liquid chilling packages and heat pumps with electrically driven compressors for space heating and cooling
6. EN 15603, Overall energy use and definition of energy ratings, CEN, January 2008

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Information paper on EN 15316-4-3

Energy requirements and efficiencies of thermal solar systems

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

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Thermal solar systems can reduce energy consumption for domestic hot water. System specifications have a large influence on the energy saving potential. Thermal solar systems can also be used to support space heating.
This paper gives a short introduction of the CEN standard for calculating the contribution of thermal solar systems to domestic hot water and/or space heating needs in buildings, EN 15316-4-3. It contains explanations of the calculation methods with details on the input and output data and the links with the other CEN standards.

1 > Scope of the standard

Standard EN 15316-4-3 provides a method for assessing the energy performance of thermal solar systems for space heating and/or domestic hot water. It is part of a set of standards on the methods to be used for calculating the energy perfomance of heat generation systems in buildings.

The method is applicable for thermal solar systems for space heating, domestic hot water (DHW) production, and any combination of both (combi systems providing both DHW and space heating).

The method may be applied for:

- Determining the energy performance of a thermal solar system;
- Judging compliance with regulations expressed in terms of energy targets;
- Optimising the energy performance of a planned system;
- Assessing the effects of energy conservation measures on existing systems.

Only the calculation method and the input parameters are normative. All of the values required for calculation should be given in national annexes.

The standard described is part of a framework for calculating the total energy consumption of buildings. A diagram of the framework is given in Figure 1. A more detailed description is given in Standard EN 15603 and in Information Paper: IP88.

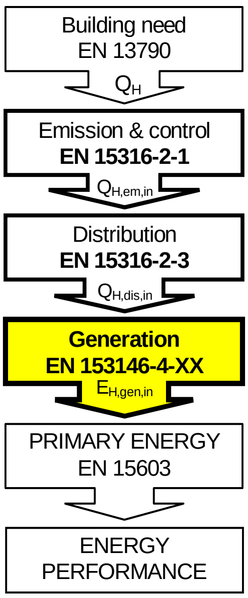

Figure 1: Generation is the 4th step in the heating system calculation.

2 > Principle of the method

The performance of thermal solar systems is determined by the following parameters:

- Type and configuration of the thermal solar collectors and system;
- Product characteristics according to product standards;
- Storage tank parameters;
- Collector loop and distribution thermal losses;
- Control of the system;

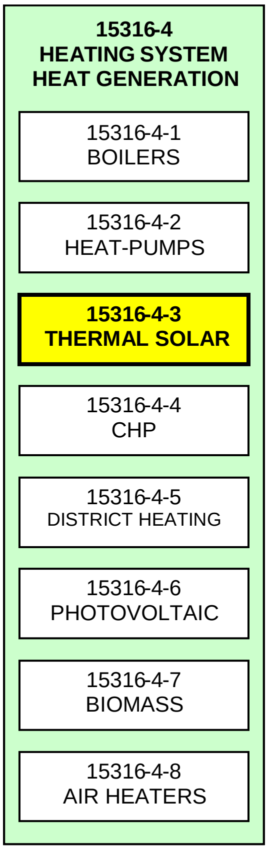

Figure 2: Part 4 of EN 15316 covers generation sub-systems. Separate sub-parts cover the various generation devices

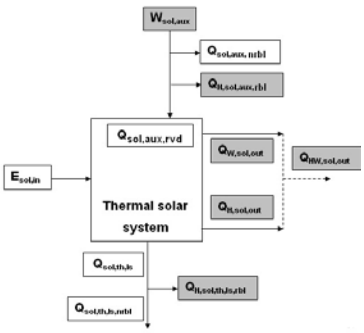

Figure 3: Heat balance for a solar preheat system / solar-only system.

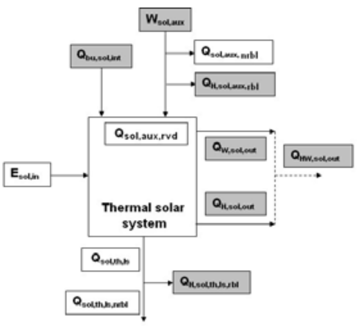

Figure 4: Heat balance for a solar-plus-supplementary system.

- Climate conditions;
- Auxiliary energy of the solar collector pump and control units;
- Heat use of the space heating distribution system;
- Heat use of the domestic hot water distribution system.

An important step in the method is the determination of the heat demand of the building, as heat demand and thermal output are related.

Energy need for space heating:

- Space heating needs (see EN ISO 13790 and Information Paper IP92);
- Thermal losses from space heating emission (see EN 15316-2-1; IP97);
- Thermal losses from space heating distribution (see EN 15316-2-3; IP98).

Energy need for domestic hot water (DHW):

- Required energy for domestic hot water needs, including emission losses (see EN 15316-3-1; IP99);
- Thermal losses from domestic hot water distribution (EN 15316-3-2; IP100).

The actual energy demand applying to the thermal solar system depends on the needs for space heating, DHW or both and on the configuration of the thermal solar system (preheat system, solar-plus-supplementary system, solar-only system).

Based on these data, the application of the thermal solar standard provides the following outputs:

- Heat delivered by the thermal solar system;
- Auxiliary energy consumption (pump, control equipment, freezing protection, etc.)
- Recoverable and recovered auxiliary energy;
- Recoverable and recovered thermal losses of the storage tank.

The heat balances of two different thermal solar systems are shown in Figure 3 and Figure 4.

The calculated thermal losses are not necessarily lost. Parts are recoverable, and parts of these recoverable losses are actually recovered. This is accounted for in the standard.

The thermal solar system may influence other components of the heating system of a building. It is therefore necessary to take into account the effect of the system's heat output and of recovered losses on, for example, the temperature levels and the operation-time of the other heat generators in the heating system.

Calculation periods

The objective of the calculation is to determine the annual heat output. This may be achieved either:

- by using annual data for the system's operation period and performing the calculation using annual average values, or;
- by dividing the year into a number of calculation periods (months or operation periods defined in EN ISO 13790), performing the calculation for each period and adding the results obtained over a full year.

3 > Description of the method

Two different methods can be used to calculate the energy performance of a thermal solar system. This enables the use of different types of input data:

- Method A: System data from system tests, default values given in the format of EN 12976-2 (performance indicators) or system simulations;
- Method B: Component data (from component tests or default input values)

The first step in both methods is to determine the system characteristics. Combining those with climate conditions, bound by the heat load, the solar thermal output can be calculated. The next step is to calculate auxiliary energy consumption. Finally, recoverable and non-recoverable thermal losses are calculated.

Using method A, specific system parameters/characteristics (control strategies) can better be taken into account. Method B uses only test results (or default values for components).

Method A is limited to systems delivering domestic hot water only, which have been tested according to EN 12976-2. For combi-systems with a collector area smaller than 6 m^2 that have been tested according to EN 12976-2, Method A can also be used, but space heating is then not considered in the performance calculation.

Method A - Using system data (results from system tests)

The calculation method consists of the following steps:

- Collect performance indicators from test results;
- Determine solar output;
- Determine the auxiliary energy consumption;
- Calculate the system's thermal losses:
  - Thermal losses from the storage tank;
  - Thermal losses from the distribution between the system and the back-up heater;
- Calculate the recoverable losses:
  - Recoverable auxiliary consumption;
  - Recoverable thermal losses of the storage tank;
  - Recoverable thermal losses of the distribution system.

To simplify and avoid iterative calculations, the following assumptions are made:

- The heat use to be applied shall take into account needs (DHW) and thermal losses from the distribution system;
- For a preheat system, thermal losses between the system and the back-up heater shall not be added to the heat use applied;
- Thermal losses (from storage tank and collector loop) shall not be added to the heat use applied.

The determination of the output from thermal solar systems distinguishes:

- Solar-only and solar preheat system – determination of monthly solar output;
- Solar-plus-supplementary system – determination of monthly solar output;
- Auxiliary energy consumption;
- System thermal losses;
- Recoverable losses.

Method B - Using component data (results from component tests)

This calculation method consists of the following steps:

- Define the use(s) applied to the system (input data for this calculation);
- Calculate different ratios and characteristics of collector and storage;
- Calculate the thermal solar output;
- Calculate the auxiliary energy consumption;
- Calculate the thermal losses of the system;
- Calculate the recoverable losses.

The same assumptions to simplify the calculation as for method A are made.

The output-data of the calculation for the thermal solar system distinguishes between three cases:

- Domestic hot water production only;
- Space heating only;
- Solar combi-system (DHW and space heating).

Using this method, the reduced operation time of the non-solar heat generators, the reduced auxiliary energy consumption of back-up heaters and the reduction of their thermal losses can also be determined.

4 > FAQ

Why are two different methods provided in EN 15316-4-3 to calculate the efficiency of thermal solar systems?

No single method is the correct solution for all cases. A too simple method may not be able to show the effect of improvements while a detailed method may waste time in straightforward situations.

Method A will give very accurate results because it is based on system tests. The method is applicable to systems that produce only domestic hot water, which is momentarily the case for the majority of systems. In this method, because of the fact that it is based on system tests, each different configuration of the components has to be tested separately.

Method B is more flexible and can be used for a greater variety of systems, for example for thermal solar systems supplying heat for space heating. Being based on components, this method is versatile, but less accurate.

Are national annexes always required?

Standard EN 15316-4-3 on thermal solar systems provides only the calculation procedure. The values have to be determined by a national annex. This approach is used because national characteristics such as climatic effects, design practices, system typologies, etc. have a large impact on the yield of thermal solar collectors. This is taken into account by using the values that are applicable to a country and which are available in the national annex for that country.

5 > References

1. EN 12976-2: Thermal solar systems and components - Factory made systems - Part 2: Test methods
2. EN ISO 7345: Thermal insulation - Physical quantities and definitions (ISO 7345:1987)
3. EN ISO 13790: Energy performance of buildings - Calculation of energy use for space heating and cooling (ISO 13790:2008)
4. EN 15316-2-1: Heating systems in buildings - Method for calculation

of system energy requirements and system efficiencies - Part 2-1: Space heating emission systems

5. EN 15316-2-3: Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies - Part 2-3: Space heating distribution systems
6. EN 15316-3-1: Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies - Part 3-1: Domestic hot water systems, characterisation of needs (tapping requirements)
7. EN 15316-3-2: Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies - Part 3-2: Domestic hot water systems, distribution
8. EN 15316-4-3: Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies - Part 4-3: Heat generation systems, thermal solar systems

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Information paper on EN 15316-4-4

Heat generation systems, building-integrated cogeneration systems

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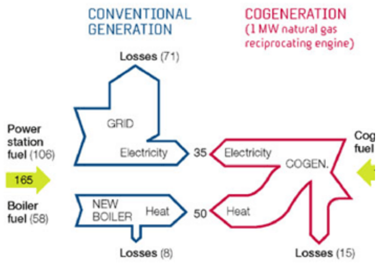

Figure 1: Flow diagram of energy balance of conventional generation versus cogeneration.

Cogeneration means the combined production of electricity and heat in an energy conversion facility. Unlike a boiler, micro-CHP (CHP: Combined Heat and Power) generates electricity together with heat. The advantage of the combined production of heat and power lies in the more efficient use of fuel, as the thermal losses of the electricity production can be used for heating, and in the corresponding reduction of emissions, such as SO_2, NOx and CO_2 (see Figure 1).
A broad range of mature technologies is available for cogeneration, using several kinds of energy carrier, such as conventional fuels, biomass and hydrogen. Building-integrated cogeneration systems usually involve small systems, such as mini- and micro-CHP units and fuel cells.
Most units operate in grid-parallel mode, which means the building continues to receive some of its electrical power from the electrical grid when the load exceeds the production, but they may also export some electricity to the grid when it is not.
This paper provides a short introduction to CEN standard EN 15316-4-4, which defines a method for calculating the primary energy use, electricity production, thermal output and recoverable losses of building integrated cogeneration units forming part of a heat generation system (for space heating and domestic hot water) in a building. An explanation of the calculation method is also provided, with details on the input and output data and links to other CEN standards.

1 > Scope of the standard

Standard EN 15316-4-4 covers only cogeneration units that are heat-led, which means that heating is their primary function and no heat is dumped. Facilities whose primary purpose is generating electricity are not covered, not even if their waste heat is used for district heating so that they are classed as cogeneration facilities.

The standard defines a standard method for the calculation of energy requirements, electricity production, thermal output and recoverable losses of CHP units that form part of a space heating generation system in a building. EN 15316-4-4 is one of a set of standards on methods for the calculation of system energy requirements and system efficiencies (see Figures 2 and 3).

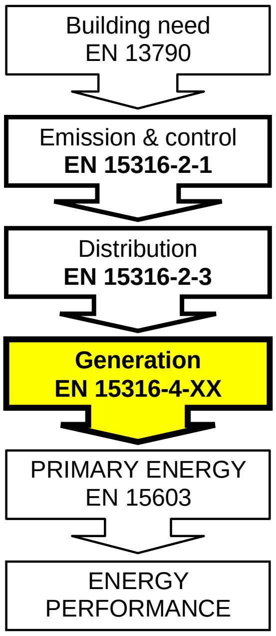

Figure 2: Set of European CEN-standards, and their connections

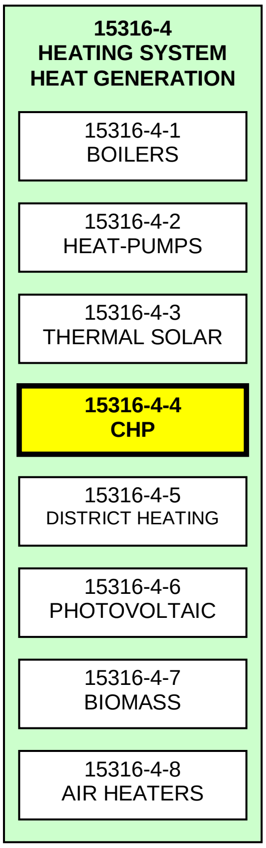

Figure 3: EN 15316-4: the series of CEN-standards covering generation

The heat generated in the process of generating electricity is used for space heating, the domestic hot water supply and can even be used to drive an absorption chiller. Peak load boilers of conventional design can be used when the heat output of the CHP plant is insufficient to meet the instantaneous heat demand, but the CHP unit will usually be the preferred heating system.

Primary energy savings and reduction of CO_2 emissions, which can be achieved by cogeneration units compared to the separate production of heat and use of grid electricity, are calculated according to EN 15603 (Information Paper: IP88).

The method may be applied for:

- Determining the energy performance of a combined heat and power system,
- Determining whether they are in compliance with regulations expressed in terms of energy conservation targets,
- Optimising the energy performance of a planned system,
- Assessing the effect of energy conservation measures on an existing system.

Only the calculation method and its input parameters are normative. All input values should be given in national annexes. The framework for the calculation method is described in EN 15603.

The calculation is based on the performance characteristics of the units that are available in product standards, and on a number of other characteristics of the system (e.g. the running conditions).

The standardised test of building-integrated cogeneration units for heating systems may be stipulated at national level. As soon as European test methods become available, these should be used.

2 > Principle of the method

Two main operational modes can be distinguished:

- The cogeneration unit is dimensioned to run at full load most of the time, so that the heat output of the CHP unit supplies the base heat load of the installation.
- The cogeneration unit acts as a substitute boiler and is able to meet the whole heating demand of the building.

The operational mode and the heating demand of the building(s) determine the total heat to be supplied by the CHP unit. The operational mode, in combination with the system's configuration, will also have a large influence on the operating conditions, specifically the time running at full and partial load. This must be taken into account, because the performance of a cogeneration unit (thermal efficiencies, electrical output) decreases considerably under partial load operation (see Figure 4).

The heat output of the cogeneration installation is limited to the total heat demand of the building(s).

The **system boundaries** for the cogeneration sub-system include the cogeneration unit only. Electrical connection components are only taken into account when they form part of the unit and are tested together with it.

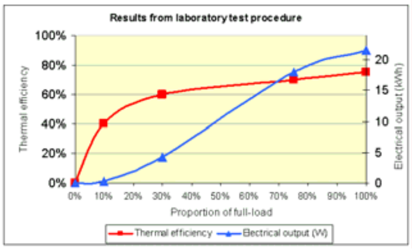

Figure 4: Load-performance curves for thermal efficiency and electrical output (example only)

Auxiliary energy consumption is taken into account. Only the net power production minus all auxiliary energy consumption, e.g; for pumps inside the system boundaries, is counted.

System thermal losses are deemed to be not recoverable for space heating needs, because in most cases the CHP unit will not be in the occupied volume of the building**.**

Calculation periods:

System thermal losses should be calculated separately for each calculation period and the average values used in the calculation must be those applicable to the selected time intervals. This may be achieved either:

› By using annual data for the system operation period and performing the calculation using annual average values, or
› By dividing the year into a number of calculation periods (months, weeks), and then performing the calculation for each period using period-dependent values and summing up the results over the year.

All methods used to calculate partial load and the annual performance of CHP systems must be validated. The factors to be taken into account include but are not limited to:

› Water temperature (return/flow),
› Start /stop effects,
› Partial load operation,
› Air inlet temperature.

3 > Description of the methods

The calculation methods are presented in Clause 5 of EN 15316-4-4.

Corresponding to the operational modes, two calculation methods are given in the standard:

› The "fractional contribution method" (Clause 5.6).
  › The CHP unit supplies only a fractional contribution of the heat demand (base load),
› The "annual load profile method" (Clause 5.7).
  › The CHP unit acts as a substitute boiler.
  › The thermal and electrical energy performance of the cogeneration unit over the full load range must be known. From the load-performance curve for thermal efficiency (blue) and electrical output (red), the values at 10% intervals over the load range from 0 to 100% are determined (see Figure 4).
  › It is assumed that the cogeneration unit is heat-led and controlled, so that no heat is dumped.

In principal, the annual load profile method could also be applied in the "fractional contribution" situation, but the fractional contribution method is easier to use and achieves sufficient accuracy for the purpose.

Fractional contribution method

The calculation method consists of the following steps:

› Annual heat output of the cogeneration installation (cl. 5.6.1);
› Annual fuel input for the cogeneration installation (cl. 5.6.2);
› Annual system thermal loss of the cogeneration installation (cl. 5.6.3);
› Annual electrical energy output of the cogeneration installation (cl. 5.6.4).

Annual load profile method

This method estimates the annual energy performance of a cogeneration installation from knowledge of the performance under different operating conditions (e.g. partial load, water temperature, ambient temperature) and the annual load profile of the cogeneration. It is thus well suited for cogeneration installations in which the load varies over a large range throughout the year and operation at low load strongly decreases the annual energy performance (e.g. cogeneration installations that supply the entire heat demand of a building and thus operate as a substitute boiler).

For this method, the thermal and electrical energy performance of the cogeneration unit over the full load range must be known. This should be ascertained by suitable laboratory tests under a number of different partial-load conditions.

The calculation method consists of the following steps:

- Determining the energy performance for the full range of load conditions (cl. 5.7.2);
- Determining the annual load profile taking into account regional climate data (e.g. expressed as degree-days), design heat load, plant size ratio and control strategies (cl. 5.7.3). See for example Figure 5;
- Annual heat output of the cogeneration installation (cl. 5.7.4);
- Annual fuel input for the cogeneration installation (cl. 5.7.5);
- Electrical energy output of the cogeneration installation (cl. 5.7.6);
- Annual average thermal efficiency of the cogeneration installation (cl. 5.7.7);
- Annual system thermal loss of the cogeneration installation (cl. 5.7.8). All system losses are related to the thermal output; the electricity produced is counted as a bonus (power bonus method).

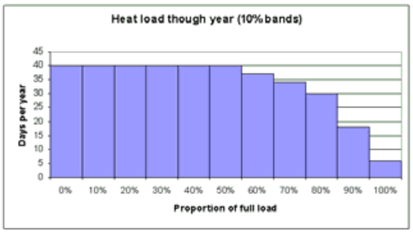

Figure 5: Annual load profile of the cogenerator (example only)

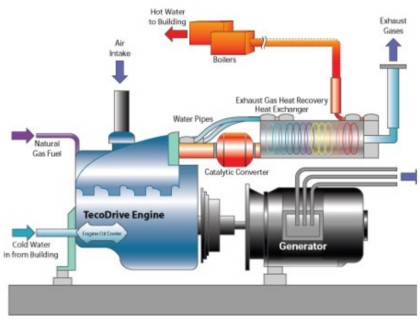

Figure 6: Scheme of a cogeneration system

4 > Recommendations - FAQ

What is building-integrated cogeneration?

It is a cogeneration unit installed to supply electricity, space heating, domestic hot water and possibly cooling within a building (see Figure 6). It can operate as the only heating/cooling appliance of the building or in combination with other heat generators, such as boilers or electrical chillers. Unlike district heating systems, where heat and electricity are generated at central plants and transmitted through networks to a number of remote buildings, a building-integrated cogeneration unit produces heat for use within the building. The electricity produced by the integrated cogeneration unit may be used within the building or may be exported.

What is Micro-CHP?

CHP stands for combined heat and power, so it indicates a unit that generates both heat and electrical power, which is termed cogeneration. The European Cogeneration Directive defines micro-CHP as cogeneration units with an electrical capacity of less than 50 kW. Micro-CHP products typically run as heating appliances, providing space heating and warm water in residential or commercial buildings in place of conventional boilers.

What is a "power bonus method"?

It is a method for calculating thermal efficiency in which all energy inputs are related to the thermal output only, considering the electrical energy produced as a bonus.

5 > References

1. EN 15316-4-4: Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies - Part 4-4: Heat generation systems, building-integrated cogeneration systems
2. EN 15603: Energy performance of buildings – Overall energy use, CO_2 emissions and definition of energy ratings
3. European cogeneration directive: 2004/7/EC

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Information paper on EN 15316-4-5 The performance and quality of district heating and large volume systems

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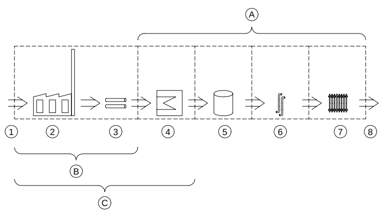

1	fuel input	7	Emission
2	heat (and power) generation	8	heating demand of the building
3	heating network		
4	building substation	A	building heating system
5	storage	B	district heating system
6	distribution	C	covered by this standard

Figure 1: Systematic of rating the performance of district heating systems

District heating systems distribute steam or hot water to multiple buildings. The heat can be provided from a variety of sources, including geothermal, cogeneration plants, waste heat from industry and purpose-built heating plants. The oldest district heating system still in operation has warmed a French village from geothermal hot springs since the early fourteenth century. District heating is an important energy source for countries in transition in Eastern Europe, as it covers 60% of heating and hot water needs, and in the Nordic countries (market share over 50% in Finland, Denmark, Sweden). The main interest in district heating for overall energy calculation is related to its low primary energy conversion factor, due to performing technologies as cogeneration and the use of renewable energies or waste energy.

This paper gives a short introduction to the CEN standard for the calculation of the energy performance of district heating systems and dwelling substations. It contains explanations on the calculation methods, with details on the input and output data and the links with the other CEN standards.

1 > Scope of the standard

The standard provides a method of assessing the energy performance of district heating systems. It is part of a set of standards on the method for calculation of system energy requirements and system efficiencies.

The results of the calculation are the primary energy factor of a specific district heating system, and the energy performance of the building substation.

The method is applicable for various heat sources, including heat and power cogeneration. The method is independent of the use of the heat supplied, including subsequent generation of cooling energy in the building.

The method may be applied in the same way for district cooling, based on cogeneration or use of lake or sea water.

The calculation is based on the performance data of the district heating system and the building substation, respectively, which can be calculated

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or measured according to this standard.

Only the calculation method and the accompanying input parameters are normative. All values required to parameter the calculation method should be given in a national annex, containing appropriate national values.

Primary energy and CO_2 savings achieved by district heating systems relative to other systems, are calculated according to EN 15603.

2 > Principle of the method

The performance of a district heating system is evaluated by dividing the system into two parts according to **figure 1**:

- outside part, i.e. parts of the system situated outside the building;
- inside part, i.e. parts of the system situated inside the building.

The outside part is the district heating system, depicted by "B" in **figure 1**. It consists of the heat generation appliances and the district heating network up to the primary side of the building substation. All elements required to operate the system are included.

It is rated according to the balance of primary energy consumption of heat generation and the heat delivered to the building substations.

The inside part refers to the building substation, including all systems from its primary side to the building heating system, e.g. the pipes and valves situated at the primary side (district heating side) of the heat exchanger and the heat exchanger itself (if present). The building substation is depicted by "4" in **figure 1**. There may be one or more substations in a building.

The building substation is rated by its additional energy requirements. Thus, the building substation can be considered to replace the heat generator within the building.

*Figure 2:
District heating distribution pipes*

District heating system situated outside the building - primary energy factor

The performance of a district heating system can be rated by evaluating the primary energy factor of the specific district heating system.

The primary energy factor of a district heating system is defined as the primary energy input to the system divided by the heat delivered at the border of the supplied buildings, i.e. at the primary side of the building substation.

The heat losses of the heat distribution piping system are taken into account, in addition to all other energy used for extraction, preparation, refining, processing and transportation of fuels related to heat production.

The primary energy factor has to be determined within the thermodynamic system borders of the specific district heating system. This is typically the area supplied by one heat distribution piping system bordered by the primary side of building substation.

Within this area, all energy inputs and all energy outputs are considered. Energy input to the system is weighted by its specific primary energy factor.

Required inputs are:

- primary energy input to the system;
- heat delivered at the border of the supplied buildings.

Energy requirements of the building substation

The energy performance of the building substations is rated by evaluating their heat losses. The electrical energy consumption of auxiliary equipment is neglected.

The heat losses depend on:

- the thickness and the material of the insulation;
- the piping material;
- the surface of the whole piping system;
- the load of the substation;
- the difference between the heating media temperatures and the ambient temperature.

Figure 3:
Incineration plant connected to the district heating network Spittelau / Vienna designed by Austrian artiste Hundertwasser More than 500 000 t per year of waste treated in Vienne district net

Resulting outputs are:

- primary energy factor;
- thermal loss of the building substation;
- auxiliary energy consumption;
- recoverable heat losses.

The methods are described below. For all methods a national annex is required providing default values.

3 > Description of the method

Primary energy factor

The calculation is defined in clause 6.1 of EN 15316-4-5. Two methods are presented in the standard for determining the primary energy factor:

- - calculation based on measurements;
- - calculation from design data.

— Calculation based on measurements

This method is defined in clause 6.1.1 of EN 15316-4-5. For existing district heating systems, all required inputs can be determined by measurements.

External heat supply to the district heating system

External heat deliveries to the considered district heating system should be treated in the same way as a fuel input, by weighting the external heat delivery according to its primary energy factor.

Calculation examples are provided in annex A of EN 15316-4-5.

— Calculation from design data

This method is defined in clause 6.1.2 of EN 15316-4-5. For cogeneration systems, the design data are used as input for the calculation.

Energy requirements of a building substation

A building substation is characterised by the insulation level of its components. This level is described in EN ISO 12241.

The energy requirement of a dwelling substation is the heat loss of the substation.

— Auxiliary energy consumption

The auxiliary energy consumption is neglected.

— Recoverable heat losses

If the building substation is located inside the heated space, the total heat losses of the building substation are recoverable. If the building substation is located in an unheated part of the building, no part of the heat losses of the building substation is recoverable.

4 > FAQ

The building owner can not influence directly the performance of the district heating system. Should the evaluation boundary (system boundary) not be limited to the building?

The building owner has the choice of the energy used (e.g. for the heating they can choose electricity, gas or district heating). The impact on the environment and the energy dependence of the country etc. will be different depending on their choice. Therefore the energy choice should be taken into account in the rating of a building. Of course, precautions should be taken in order to prevent undesirable changes in district heating performance.

Shall the primary energy conversion factor of district heating systems be evaluated for the whole country, or for each district heating system separately?

This decision has to be made in the national annex of the standard. There is no technical difficulty in determining the primary energy conversion factor for each district heating system. Some universities are offering this service. It is also possible to differentiate the primary energy conversion factor by using a typology (e.g. part of cogeneration units, ratio of renewable energy use).

Figure 3:
District heating sub station

Do the energy certificates take into account the performance of the district heating systems?

Not currently in all European Member States, as in some countries the rating of the building is limited to the delivered energy (final energy), and not based on primary energy. Article 5 "new buildings" and the "General framework for the calculation of energy performance of building" of the Directive on the energy performance of buildings (EPBD), indicates that the influence of district or block heating shall be considered.

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5 > References

1. EN 15603 Overall energy use and definition of energy ratings
2. EN ISO 12241 Thermal insulation for building equipment

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.

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15316-4 HEAT / POWER GENERATION

- 15316-4-1 BOILERS
- 15316-4-2 HEAT-PUMPS
- 15316-4-3 THERMAL SOLAR
- 15316-4-4 CHP
- 15316-4-5 DISTRICT HEATING
- **15316-4-6 PHOTOVOLTAIC**
- 15316-4-7 BIOMASS
- 15316-4-8 AIR HEATERS

Figure 1: Set of standards

Information paper on EN 15316-4-6 Photovoltaic systems

Photovoltaic production has been increasing by an average of 48 percent each year since 2002, making it the world's fastest-growing energy technology. At the end of 2007, according to preliminary data, cumulative global production was 12,400 megawatts. Building-integrated photovoltaics are increasingly incorporated into new domestic and industrial buildings as a principal or ancillary source of electrical power, and are one of the fastest growing segments of the photovoltaic industry.

This paper gives a short introduction to the CEN standard EN 15316-4-6, calculating the electricity production of building integrated photovoltaic systems. It contains explanations on the calculation methods with details on the input and output data and the links with the other CEN standards.

1 > Scope of the standard

This standard presents a method for the calculation of the electricity production of building integrated photovoltaic systems. It is part of a set of standards for calculation of system energy requirements and system efficiencies (see figure 1).
The calculation method does not take into account:

- electrical storage;
- hybrid solar system (e.g. PV-thermal solar systems).

Only the calculation method and the accompanying input parameters are normative. All values required to parameter the calculation method should be given in a national annex, containing appropriate national values.

Primary energy savings and CO_2 savings, are calculated according to EN 15603.

2 > Principle of the method

The calculation is based on the performance characteristics of the products, given in product standards, and on additional characteristics required to evaluate the performance of the products being included in the system.

Electricity produced by the photovoltaic system is calculated considering the following input data:

- annual solar irradiation on the photovoltaic system;
- peak power;
- system performance factor;
- reference solar irradiance.

The result of the calculation is the electrical output of the photovoltaic panel.

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The influence of shadowing effects of parts of the building (like chimneys, ventilation units etc.) on the yearly produced electricity shall be considered.

The method is described below. A national annex is required, providing default values.

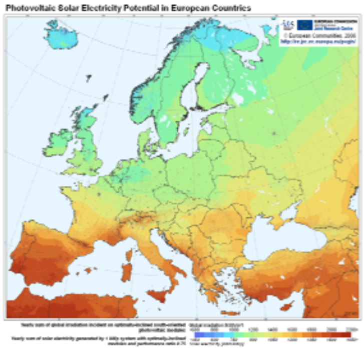

Figure 2 : Map of solar electricity potential in Europe

3 > Description of the method.

The method is defined in clause 5 of EN 15316-4-6. The electricity produced by the photovoltaic system is calculated in kWh/year.

Solar irradiation on the photovoltaic modules

The calculation is defined in clause 5.2 of EN 15316-4-6. For the annual solar irradiation on a horizontal surface in a geographic region, maps providing suitable values exist (see figure 2). Those are corrected by a tilt and orientation conversion factor, for calculating the solar irradiation on the photovoltaic module surface (see figure 3).

Values shall be given in a national annex (default values see annex B).

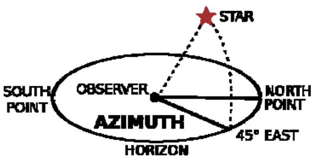

Figure 3: Geometric corrections (azimuth).

Peak Power

The calculation is treated in clause 5.3 of EN 15316-4-6. The peak power is obtained under standard test conditions. If this value is not available, it can be calculated by the total surface of all photovoltaic modules (without frame) multiplied by a peak power coefficient, depending on the type of building integration of the photovoltaic module.

Values shall be given in a national annex (default values see annex B).

System performance factor

The system performance factor is defined in clause 5.4 of EN 15316-4-6. It takes into account the performance of the building integrated photovoltaic system (see figure 4), depending on:
- conversion system from direct current (dc) to alternating current (ac);
- actual operation temperature of the photovoltaic modules;
- building integration of the photovoltaic modules.

Figure 4 : Building integrated photovoltaic installation (SOLUX House, Germany).

Distinction between different building integration could be made according to the type of ventilation of the photovoltaic modules. Values shall be given in a national annex.

Thermal output of the photovoltaic panel
Thermal output is treated in clause 5.5 of EN 15316-4-6. No thermal output is taken into account, as the standard is not dealing with hybrid systems.

Note:
All generation modules (e.g. combustion systems, heat pumps, cogeneration units, etc) in the EN 15316-4 series have the same defined outputs to simplify the module integration, even if the topic is not treated in the standard.

Auxiliary energy consumption
Auxiliary energy is treated in clause 5.6 of EN 15316-4-6. Auxiliary energy consumption is taken into account by applying only the net power production (the total power production minus all auxiliary energy consumption inside the sub-system boundaries).

System thermal losses
System thermal losses are treated in clause 5.7 of EN 15316-4-6. No system thermal losses are taken into account. The standard does not deal with hybrid systems.

Recoverable system thermal losses

Recoverable system thermal losses are treated in clause 5.8 of EN 15316-4-6. No losses are recoverable for the diminution of the space heating needs.

4 > FAQ

What are the components of a photovoltaic (PV) system?

A PV system is made of different components. These include PV modules (groups of PV cells, see figure 5), which are commonly called PV panels; one or more batteries; a charge regulator or controller for a stand-alone system; an inverter for a utility-grid-connected system.

How long do PV systems last?

A well-designed and maintained PV system will operate for more than 20 years. The PV module itself, without moving parts, has an expected lifetime exceeding 30 years. Experience shows that most system problems occur due to poor installation. Failed connections, insufficient wire size and use of components not rated for direct current application are the primary causes.

Figure 5: Photovoltaic cells.

5 > References

1. EN 15603 Overall energy use
2. EN 15316-4-6 Photovoltaic systems

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[European projects]

P108

27-10-2008

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Information paper on EN 15316-4-7 Space heating generation systems – Biomass Combustion systems

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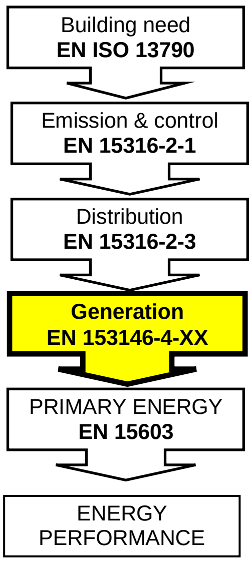

Figure 1: EN 15316 series

Biomass combustion is one of the oldest heat generation techniques. The European market of biomass boilers <50 kW has increased to approximately 50% since 2001. The greatest increase of approximately 280% took place for wood chip boilers, although Logwood boilers constitute the most populous boiler type, with a total number of c.a. 187.000 in 2007.

This paper gives a short introduction to the CEN standard 15316-4-7 for calculation of boiler losses, fuel input and auxiliary energy consumption. All of the technologies contributing to the growth of the boiler market are taken into account in the standard. This paper contains explanations regarding the calculation method, with details on the input and output data and links with other CEN standards. This standard enables the integration of biomass boilers in the overall (i.e. holistic) energy evaluation of a building. Because of the CO_2 absorption during its growth, biomass fuels may have a very low primary energy conversion factor of < 0.5. Therefore the use of biomass boilers is an effective means for achieving low primary consumption and CO_2 emissions.

1 > Scope of standard

The standard provides calculation methods for the energy performance of heat generation of biomass combustion systems with respect to:

- type of stocking device (automatic or by hand);
- type of biomass fuel (pellets, chipped wood or log wood);
- including control.

This standard is part of the EN 15316 series (see **figure 1**) for calculation of heating system energy requirements and efficiency. The required heat output, according to the distribution part EN-15316-2-3, must be available as an input for this standard.

The domestic hot water generation sub-system is treated in the standard EN 15316-3-3, although EN 15316-4-7 may be used to assess the heat generation for hot water production, when an indirectly heated storage system used heating boilers as a heat source. In this case, the required heat output for domestic hot water distribution (or storage) is taken into account as an input.

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15316-4
HEATING SYSTEM
HEAT GENERATION

15316-4-1
BOILERS

15316-4-2
HEAT PUMPS

15316-4-3
THERMAL SOLAR

15316-4-4
CHP

15316-4-5
DISTRICT HEATING

15316-4-6
PHOTOVOLTAIC

15316-4-7
BIOMASS

15316-4-8
AIR HEATERS

This standard is intended to calculate the in-use energy performance of a given boiler, either existing or new. Boiler sizing and the calculation of boiler operating conditions are not covered by this standard.

2 > Principle of the methods

The structure of this standards is very close to EN 15316-4-1 (combustion boilers - see information paper P102).

In general, the methods calculate fuel and auxiliary energy consumption of one or more boilers to match the attached distribution subsystem(s) heat demand. Boiler performance may also be given as an (annual) efficiency.

The calculation period can be divided into a number of calculation steps (e.g. months, weeks, bins, operation modes as defined in EN ISO 13790)

The methods take into account boiler and accumulator storage heat losses, and/or recovery due to the following physical factors:

- flue gas losses (boiler on for boilers stocking by hand);
- draught losses (boiler off);
- envelope losses (boiler on and off);
- auxiliary energy use (standby/electronics, ignition, charge, pump, fan);
- auxiliary energy recovery.

The common input data is the heat required by the attached distribution sub-system(s). The additional load for a domestic hot water distribution subsystem may be taken into account when using a single generator for both services.

Other input data is required to characterize:

- type and characteristics of the heat generator(s);
- location of the heat generator(s);
- operating conditions (time schedule, water temperature, etc.);
- type and characteristics of the accumulator storage system(s);
- control strategy (on/off, multistage, modulating, cascading, etc.).

The basic outputs are:

- fuel consumption;
- auxiliary energy consumption;

which are used as an input in EN 15603 to calculate primary energy required by the heating system.

Other output information is available:

- generation and accumulator storage total heat loss (flue gas, draught and envelope losses);
- recoverable generation and accumulator storage heat losses (explicit or already taken into account as a reduction of losses);
- seasonal generation efficiency.

The performance calculation methods for biomass combustion systems differ with respect to:

- type of stocking device (automatic or by hand);
- type of biomass fuel (pellets, chipped wood or log wood).

These two methods are described below.

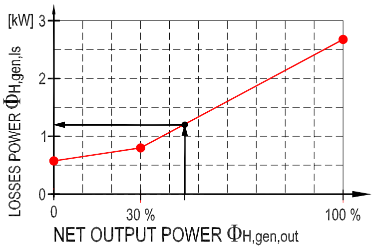


Fig.2: CASE SPECIFIC METHOD Graph showing the basic linear relationship between output load $\Phi_{H,gen,out}$ and losses power $_{H,gen}$,ls. Interpolation is here made between part load and full load.

100 % full load
30 % part load
0 % stand by

	fluegas losses	envelope losses	asch losses
boiler heating up	x	x	
boiler heating operation	x	x	x
boiler cooling down		x	x
boiler in fired bed operation		x	
boiler in non operation			

Figure 3: Specific losses at different situations

Applying the methods, the following types of data may be used:

- data declared by the boiler manufacturer;
- on site measurements;
- tabulated default data.

3 > Boiler with automatic stocking

The calculation method for biomass boilers with automatic stocking (method (1)) is comparable to the methods used for automatically fired boilers using oil or gas (clause 5.3 of EN 15316-4-1).

For the calculation period, power and losses of full load, part load and standby are calculated from net efficiency data, adjusted by interpolation for real operating conditions. Real losses are interpolated between these different load situations as shown in **figure 2** “case specific method”. A similar interpolation is performed to calculate auxiliary energy.

Full load and part load test data are generally available for new or recent boilers, but not for existing old boilers.

Standby-losses and auxiliary power consumption data are partly available from different producers of new boilers, but not for existing old boilers.

Default data shall be given in a national annex to complete missing data for new boilers, and to allow the use of this method for existing boilers, since the required values are not easy to obtain by direct measurement. Additional boiler input parameters are:

- correction factor of full-load efficiency;
- correction factor of intermediate load efficiency.

No procedure to determine these data is given. They should be given in a national annex. Default values for these factors are given in annex A.

Input data for actual operating conditions are:

- net heat output to the heat distribution sub-system(s);
- average water temperature in the boiler;
- boiler room temperature;
- temperature reduction factor depending on the location of the generator.

These data should come from calculations according to other parts of EN 15316, or from default values.

Annex A of the standard contains a complete set of default parameters that can be used as a reference and template to develop a national annex.

4 > Boiler stocking by hand

Two performance calculation methods for boilers with stocking by hand are described.

Method (1) (see chapter 7.3 case specific boiler efficiency method) is based on data related to the test procedures according to EN 303-5. However, supplementary data are needed in order to take into account the specific operation conditions during the heating period. This method is comparable to that used for boilers with automatic stocking (see above), and with the method defined in clause 5.3 of EN 15316-4-1.

Method (2) (see chapter 7.4 boiler cycling method) explicitly distinguishes losses which occur during boiler cycling. Some of the parameters can be measured on site. This method is comparable with that defined in clause 5.4 of EN 15316-4-1.

The second method (2) performs an analysis of boiler losses.

The calculation interval is divided into five situations (see **figure 3**), with specific loss calculations for each situation:

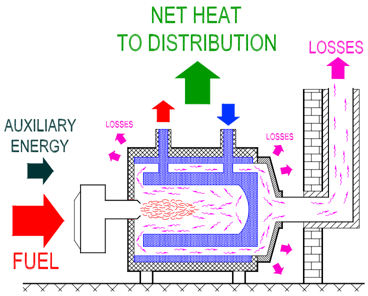
- boiler heating up;
- boiler heating operation;
- boiler cooling down;
- boiler in fire bed operation;
- boiler in non operation.

For each calculation interval the time is calculated depending on the system heat demand. For each situation the losses are calculated using boiler characterization data.

Fuel requirement is obtained according to combustion power and calculated total operation time.

Basic single stage boiler characterization input parameters (see **figure 4**) are:

- maximum combustion power of the generator (test conditions);
- heat loss factors at test conditions for flue gas losses, draught losses and envelope losses depending on the different situations;
- average boiler water temperature at test conditions for boiler on;
- average boiler temperature at test conditions for boiler off;
- temperature of test room;
- electrical power consumption of auxiliary appliances (before the generator, typically burner auxiliaries) and related recovery factor;
- electrical power consumption of auxiliary appliances (after the generator, typically primary pump and accumulator storage) and related recovery factor.



Generation subsystem basic energy balance

	Fuel input	$E_{H,gen,in}$
=	net heat to distribution	$Q_{H,gen,out}$
–	recovered auxiliary energy	$Q_{H,gen,aux,rvd}$
+	losses	$Q_{H,gen,ls}$

$$E_{\mathrm{H,gen,in}} = Q_{\mathrm{H,gen,out}} - Q_{\mathrm{H,gen,aux,rvd}} + Q_{\mathrm{H,gen,ls}}$$

Figure 4: Energy balance

Annex A to 15316-4-7 provides examples of default values.

Actual operating conditions input data:

- net heat output to the heat distribution sub-system(s);
- average water temperature in the boiler;
- boiler room temperature;
- reduction factor taking into account recovery of heat losses through the generator envelope, depending on location of the generator.

These data should come from calculations according to other parts of EN 15316, or from default values.

Annex A of the standard contains a complete set of default parameters for this method. It can be used as a reference and template to develop a national annex.

5 > FAQ

Why two methods?

No single method provides a correct solution for all cases. A simplistic method may not be able to show the effect of improvements, whilst a detailed method may be unnecessarily time consuming.

Method (1): Boilers with automatic stocking operate similarly to boilers for liquid and gaseous fuels. For simplification of calculations, there are also default values given for hand-stocked boilers.

Method (2): The boiler cycling method is good practice for existing boilers.

Are national annexes always required?

Case specific and boiler cycling methods have annexes (annex A and B) where default values are given. If dedicated national values are required, they have to be written in a national annex .

Where do the methods come from?

The methods for boilers with both automatic stocking and stocking by hand are based on Austrian knowledge.

What was the aim in developing the two methods?

Method (1): The case specific method is intended to use boiler efficiency data, if possible.

Method (2): The boiler cycling method is intended to deal with existing boilers, to keep a connection with directly measurable parameters.

6 > References

1. EN 303-5 Heating boilers for solid fuels
2. EN 15316-4-1 Space heating systems - Combustion systems (boilers)
3. EN 15316-4-7 Space heating systems – Biomass combustion system
4. EN15316-2-3 Heating distribution subsystem
5. EN15316-3-3 Domestic hot water generation subsystem

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Intelligent Energy Europe

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[European projects]

P162

19-03-2010

Energy Performance of Buildings

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Heating system operating conditions and multiple heat generators

Specific topic report

Operating conditions can have a large influence on the performance of heating systems. This paper provides an overview of the operating conditions of the distribution systems and heat generators covered by the EN 15316 series of standards, with a section focusing on operating conditions in systems with multiple heat generators. Similar considerations apply to cooling systems but these are covered by another standard, EN 15243, and are thus outside the scope of this paper.

1 > Scope of this information paper

The set of EN standards for determining the energy performance of buildings uses a step-by-step approach. As shown in Figure 1, the final result of the calculation sequence is the energy performance of the building, determined according to standard EN 15603. Focusing on heating, EN 15603 uses the energy needed for heat generation as input, which in turn uses the energy required by the distribution systems as input. This is given by EN ISO 13790, which determines the energy needs of the building.

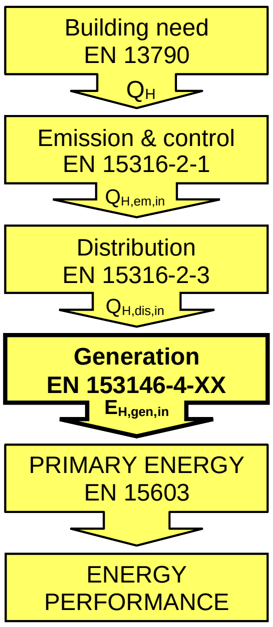

Figure 1: Structure of standards on energy performance of buildings.

In the generation standards, EN 15316-4-X, although there is no unified approach, the general idea is to feed product test data into a generator model. Test data are obtained under standard testing conditions (i.e. 60/80 °C for boilers) that are not the actual average operating conditions. The effects of actual operating conditions are taken into account in the generator model because they are not negligible (example: condensing boilers, heat pumps…). The efficiency of the distribution network also depends on operating conditions. Control strategy may for example change the average operating temperature of the network, and thus influence heat loss (See Figures 2 and 3). The first part of this paper focuses on the aspects that must be kept in mind when determining the actual operating conditions of a system.

When the distribution system is fed by multiple generators, a calculation procedure is needed for the load distribution. However, the fact that multiple generators are present is in most cases not accounted for in the consideration of operating conditions; the generators are treated as if they were independently operating generators. In most cases this simplification has little effect on the outcome of the calculation, but in some cases the effects can be significant. These cases are reviewed in the second part of this information paper.

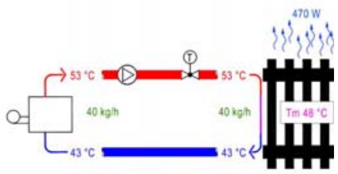

Figure 2: System with flow rate control. At reduced power, the average temperature of the network decreases and losses are proportional to the heat emitted. Distribution efficiency is approximately constant at different loads.

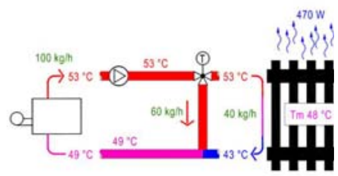

Figure 3: System with by-pass control. At reduced power, the average temperature of the network increases and losses are not proportional to the heat emitted. Distribution efficiency drops at low loads.

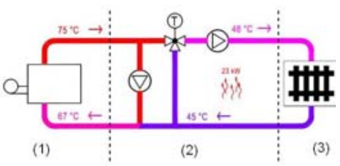

Figure 4: Example of heating system with sub-systems generation (1), distribution (2) and emission (3). The example highlights that the operating temperature of the generator may be different from that of the distribution network.

2 > Operating conditions

Some of the operating conditions influencing the performance of distribution systems and generation systems are:

- Flow and return temperature of the heat transporting medium
- Flow rate of the heat transport medium
- Heat demand
- Source conditions (applies mainly to heat pumps)
- On/off cycling / modulating
- Boiler room conditions

The EN 15316 set of standards takes into account all of these factors.

3 > Flow and return temperature

The operating temperature of the heat transport medium influences the performance of various parts of the heating system:

- Distribution losses depend on distribution temperature
- Boiler envelope losses depend on boiler temperature
- Condensing boiler performance depends on return temperature
- Heat pump performance depends on generator flow temperature

Heat pump efficiency drops significantly at higher heat emission temperatures. Condensing boiler performance depends mainly on the water return temperature. Other generators may have a weaker dependency on operating temperatures, but there will always be some dependency. Therefore a good estimation of the operating temperature of the generation sub-system is needed.

Flow and return temperature in the distribution network and in the generator are very often not the same because of the effect of mixing valves, by-passes, other control devices and hydraulic connections.

A general calculation procedure for the water temperature at all points in the heating installation is therefore required. This procedure is included in the EN 15316 series of standards but is distributed in the relevant parts, namely distribution (EN 15316-2-3, clause 8) and combustion boiler (EN 15316-4-1, annex H).

The heating system temperatures calculation procedure includes the following steps:

- Determine the average emitter temperature. This includes consideration of required average power, emitter type and size.
- Determine emitter flow and return temperature. This includes consideration of the control mode of emitters, which might be constant flow variable temperature, constant flow temperature continuously variable flow rate, constant flow temperature intemittent flow rate, constant flow temperature and flow rate variable heat exchange rate.
- Determine the distribution mains collector flow temperature (at least the distribution flow temperature)
- Determine the generator flow and return temperature. This includes consideration of generator flow rate control (independent, direct connection, etc.).

Figure 4 gives an example of the temperature levels in a heating system.

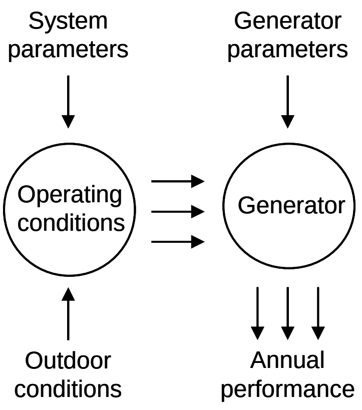

Figure 5: Diagram of generator efficiency calculation.

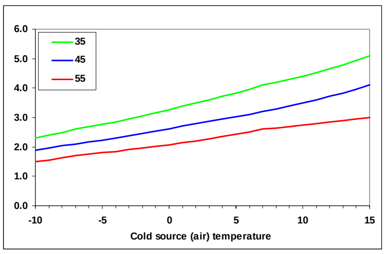

Figure 6: Typical performance chart of an air to water heat pump (COP as a function of air temperature for 3 water temperature levels)

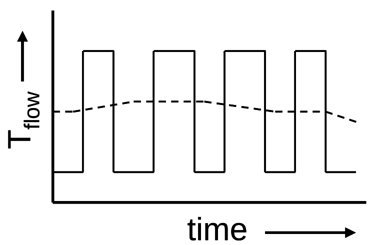

Figure 7: Example of flow temperature as function of time for on/off controlled (solid) and variable capacity (dash) generator.

4 > Flow rate of heat transfer medium

For heat pumps, the flow rate through the condenser will influence the flow temperature, and thus indirectly influence the performance of this generator. A lower flow rate will result in a higher flow temperature, because of increased heat transfer in the condenser. This is why the flow rate has to be taken into account when calculating system performance.

The COP dependence on source and sink temperatures applies only if the design flow rate of the heating system is equal to the flow rate used in standard testing. When the flow rate deviates, the COP should be corrected for this deviation. EN 15316-4-2 gives a formula for correcting the COP for deviating flow rates.

Flow rate requirements can also play an important role for condensing boilers. Many boilers have a minimum flow rate requirement. Actual operating conditions may result in a very low flow rate on the system side (thermostatic valves on radiators, 3 way mixing valves on floor heating). If the flow rate in the boiler is higher, hot water from the boiler flow will be recirculated to the boiler, resulting in a higher return temperature and lower performance (see Figure 3). This effect is taken into account in the temperature calculation provided in EN 15316-4-1 annex H.

5 > Source conditions

Some generators, such as heat pumps, transfer heat from a source (air, water, ground…) to a sink (the heating medium or domestic hot water). The same is true for heat transferred by air conditioning units, chillers or heat pumps in cooling mode. For these systems one of the operating conditions that have the greatest effect on efficiency is the source temperature.

Several sources are exploited, such as the ground, groundwater, outside air or exhaust air. Depending on the source temperature variation, the COP will show a certain fluctuation. Figure 6 is an example of actual heat pump performances for an air to water heat pump in which the COP varies in the range 1,5 to 5,0 as a function of the operating conditions.

This strong dependency makes a good estimate of source temperature crucial in an accurate determination of heat pump performance. Where simply taking monthly averaged values may suffice for other conditions, it is an oversimplification for the source temperature. Although monthly values can be used, further adjustments must be applied to take into account the extreme temperatures. Another way is a bin method, in which hours or days are distributed over temperature bins which represent source conditions. The wider the range of conditions, the more bins have to be used.

6 > On-off cycling / modulating

On/off cycling has a number of effects. Start-up may require energy use just to re-establish operating conditions. On-Off operation will always be at a higher power level than is required for continuous operation, resulting in a higher temperature level, which may reduce efficiency. Figure 7 gives an example of such an effect.

7 > Multiple heat generators

A special case when considering operating conditions occurs when multiple heat generators supply the same distribution system. This can be in small bivalent systems in dwellings, such as integrated boiler and solar

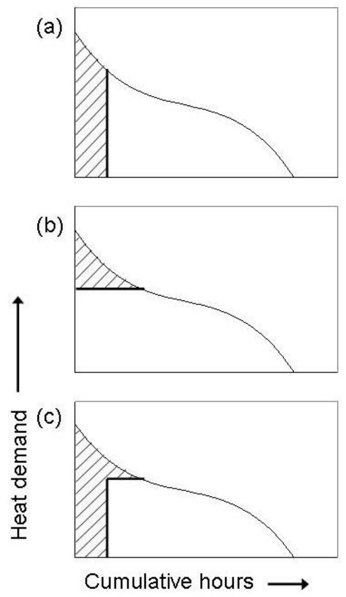

Figure 8: Cumulative hours as function of outside temperature. Shaded area is provided by back-up heater. The three operation modes are (a) alternate, (b) parallel and (c) partly parallel.

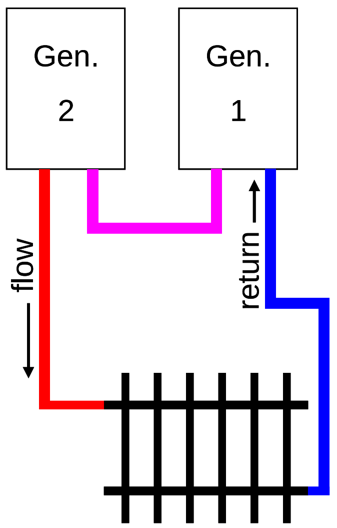

Figure 9: Setup of two generators in series operation mode as can be found in domestic buildings. The temperature at the cold water inlet is clearly different for the two generators.

systems for domestic hot water (DHW), or in large installations in office buildings. Depending on the configuration and operation mode of the system, the operating conditions of a generator may be very different from when the same generator is used alone.

Important aspects to take into consideration when determining the operating conditions of the different generators are:

- Fraction of demand per generator
- Operation mode
- Load distribution
- Temperature levels
- Configuration of the installation

Fraction of demand per generator

The first thing to determine when dealing with multiple generators in a system is how the total heat demand is distributed over the different generators. When different types of generators are used, each will have its own efficiency. This efficiency will be weighed by the fraction of the heat demand to be supplied by that generator (although the calculation procedure will involve a consideration of the sum of the required energy carriers).

As an example, when a heat pump is used with an electrical back-up heater, the overall system efficiency will be very different when the back-up heater supplies 20% of the total heat demand, than when it supplies only 3%.

Operation mode

Possible operation modes are:

- Parallel
- Partly parallel
- Alternate

In parallel mode, available generators run simultaneously.

This includes cases where a small generator is given the task of the base load, like a small cogeneration unit. Another example is the parallel operation of condensing boilers or other types of heat generators that achieve their best performance at part load.

Partly parallel mode is a combination of the previous two modes.

In alternate mode the different generators are never operating simultaneously. While any one of the generators is operating, the others are not. A control system determines which of the generators is operating at any given time.

Consideration of the different operation modes is usually included in the standards for the specific generator typologies, where this is relevant. EN 15316-4-2 (heat pumps) includes back-up heater calculations and alternate mode operation for heating and DHW operation.

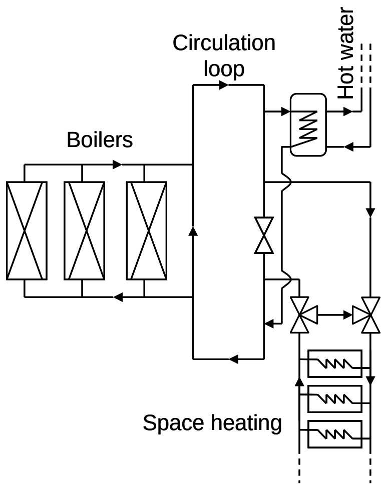

Figure 10: Heating system of a large building where hot water and space heating are supplied by one circulation loop. The temperature of the loop is dictated by the hot water sub-system.

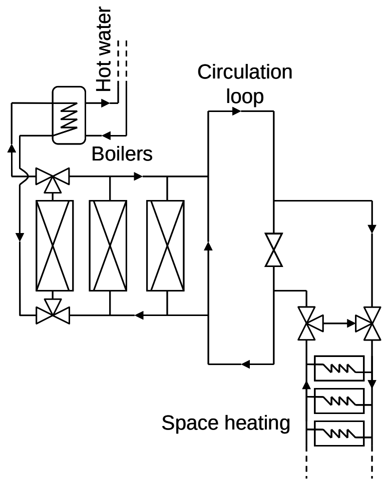

Figure 11: Heating system diagram where space heating and hot water are uncoupled. The left boiler can switch between hot water and space heating production, while the other boiler always operate at the lower space heating temperature level.

Load distribution
A heat generator operating alone will have a certain load profile. This profile, depicted in Figure 8, shows the number of hours or days in which the generator has to meet a certain demand (load). A higher demand is usually associated with lower outside temperatures. Operating temperatures and source temperature may also depend on outside temperature. This in general results in a COP which is a function of the outside temperature.

For heat pumps this effect is largely linked to lower source temperatures. Condensing boilers will show reduced condensation when operating temperatures and power are higher, which leads to a decreased efficiency. The efficiency of conventional boilers and electrical heaters will generally show little decrease for lower outside temperatures.

When multiple generators are present, the load curve will always differ from individual operation. In alternate operation, the back-up heater will operate only at low outside temperatures, while the main heater encounters only the lower heat load conditions, so for neither generator can annual or monthly averaged conditions be used for calculating their performance (see Figure 8). The same holds true for other operation modes.

Generator setup
In parallel and partly parallel operation, heat generators will sometimes be running simultaneously. In many cases one of the generators will act as a pre-heater while the other supplies the remainder of the heat load (see Figure 9).

Both generators will then have an average operating temperature that is different from what they would encounter in individual operation. The first generator will have a cold water supply temperature equal to the return water temperature. This is the same as for individual operation. The hot water outlet temperature on the other hand will be lower than it would be in individual operation. Efficiency for this generator will therefore in general be higher in this configuration.

The second generator will be operating with conditions which are less favourable in terms of efficiency than in individual operation. The cold water supply, and therefore the average operating temperature, will be higher. This usually results in a decline of efficiency.

Configuration
Besides generator configuration, the configuration of the rest of the installation influences performance as a function of the operating conditions. These effects will be most noticeable in large commercial and industrial buildings, because such installations are very complex and this results in a greater effect of the operating conditions on the generators.

First, due to large distances and large number of zones, a circulation loop is often used to maintain comfort through short waiting times and individual control. A circulation loop must be maintained at a certain temperature, so operating temperatures are higher. Losses in the circulation system will also be high, because the water is at a constant high temperature.

Hot water has to be supplied at a relatively high temperature, not least to prevent the development of legionella bacteria. Space heating is provided by a closed system and can be supplied at much lower temperatures. As discussed earlier, lower temperatures will usually increase efficiency.

Because of these different temperature levels it is very important to consider how these two functions are configured in the installation. When both functions are coupled to the same circulation loop (Figure 10), the

	Boiler type			
	Electrical back-up heater	Conventional boiler (before 1975)	Non condensing boiler	Condensing boiler
Individual operation	η_{el}	75%	80%	95%
Back-up	η_{el}	73%	78%	90%

Figure 12: Example of how the efficiencies of different heat generators may differ in individual or back-up operation.

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temperature level of the loop will be dictated by the hot water sub-system. This forces the heating system to operate at that temperature level, decreasing efficiency, and distribution losses will be much higher. The same applies when two separate heat emission systems are used, for example floor heating and air heating.

When hot water and space heating are uncoupled (Figure 11), the generators can operate at temperatures closer to the optimum, increasing efficiency and reducing losses. Therefore, when calculating the energy performance of a large heating system, the temperature levels in the system must first be determined. The temperature levels at which the generators will be operating must be taken into account when determining the annual energy performance of the generators.

8 > Recommendations

The effects explained in this paper should be taken into account when calculating the energy efficiency of a heating (or cooling) installation. Some generators are very sensitive to conditions, others are not. An efficient generator may perform poorly if it is not appropriate for the overall installation.

In an installation comparable to the one depicted in Figure 9, a heat pump is often used as the first generator, while an electrical heater or boiler is used as the second generator. In this situation the heat pump is operating under favourable conditions and will achieve high efficiencies. The heater or boiler will have somewhat unfavourable conditions, but is not very sensitive to these conditions.

However, even in this case, the unfavourable conditions of the second generator should be taken into account, see for example Figure 12.

The EN 15316 series of standards includes the necessary procedures for taking operating conditions into account.
The modular structure of the calculation procedure makes it possible to allow for the priority assigned to multiple generators, though this is mentioned for some particular cases only in the EN 15316 series of standards. These aspects should be considered more thoroughly in a future revision, possibly in the general part of EN 15316 (i.e. 15316-1).

9 > References

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