

Heating systems in buildings — Method for calculation of system energy requirements and system efficiencies

Part 4-1: Space heating generation systems, combustion systems (boilers)

ICS 91.140.10

National foreword

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

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Foreword

This document (EN 15316-4-1:2008) has been prepared by Technical Committee CEN/TC 228 "Heating systems in buildings", the secretariat of which is held by DS.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by November 2008, and conflicting national standards shall be withdrawn at the latest by November 2008.

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

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association (Mandate M/343), and supports essential requirements of EU Directive 2002/91/EC on the energy performance of buildings (EPBD). It forms part of a series of standards aimed at European harmonisation of the methodology for calculation of the energy performance of buildings. An overview of the whole set of standards is given in CEN/TR 15615, 'Explanation of the general relationship between various CEN standards and the Energy Performance of Buildings Directive (EPBD)' ("Umbrella document").

The subjects covered by CEN/TC 228 are the following:

- design of heating systems (water based, electrical, etc.);
- installation of heating systems;
- commissioning of heating systems;
- instructions for operation, maintenance and use of heating systems;
- methods for calculation of the design heat loss and heat loads;
- methods for calculation of the energy performance of heating systems.

Heating systems also include the effect of attached systems such as hot water production systems.

All these standards are systems standards, i.e. they are based on requirements addressed to the system as a whole and not dealing with requirements to the products within the system.

Where possible, reference is made to other European or International Standards, a.o. product standards. However, use of products complying with relevant product standards is no guarantee of compliance with the system requirements.

The requirements are mainly expressed as functional requirements, i.e. requirements dealing with the function of the system and not specifying shape, material, dimensions or the like.

The guidelines describe ways to meet the requirements, but other ways to fulfil the functional requirements might be used if fulfilment can be proved.

Heating systems differ among the member countries due to climate, traditions and national regulations. In some cases requirements are given as classes so national or individual needs may be accommodated.

In cases where the standards contradict with national regulations, the latter should be followed.

EN 15316, *Heating systems in buildings — Method for calculation of system energy requirements and system efficiencies* consists of the following parts:

Part 1: General

Part 2-1: Space heating emission systems

Part 2-3: Space heating distribution systems

Part 3-1: Domestic hot water systems, characterisation of needs (tapping requirements)

Part 3-2: Domestic hot water systems, distribution

Part 3-3: Domestic hot water systems, generation

Part 4-1: Space heating generation systems, combustion systems (boilers)

Part 4-2: Space heating generation systems, heat pump systems

Part 4-3: Heat generation systems, thermal solar systems

Part 4-4: Heat generation systems, building-integrated cogeneration systems

Part 4-5: Space heating generation systems, the performance and quality of district heating and large volume systems

Part 4-6: Heat generation systems, photovoltaic systems

Part 4-7: Space heating generation systems, biomass combustion systems

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

Introduction

This European Standard presents methods for calculation of the additional energy requirements of a heat generation system in order to meet the distribution and/or storage sub-system demand. The calculation is based on the performance characteristics of the products given in product standards and on other characteristics required to evaluate the performance of the products as included in the system.

This method can be used for the following applications:

- judging compliance with regulations expressed in terms of energy targets;
- optimisation of the energy performance of a planned heat generation system, by applying the method to several possible options;
- assessing the effect of possible energy conservation measures on an existing heat generation system, by calculating the energy use with and without the energy conservation measure.

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

1 Scope

This European Standard is part of a series of standards on the method for calculation of system energy requirements and system efficiencies of space heating systems and domestic hot water systems.

The scope of this specific part is to standardise the:

- required inputs;
- calculation method;
- resulting outputs;

for space heating generation by combustion sub-systems (boilers), including control.

This European Standard is the general standard on generation by combustion sub-systems (boilers). If a combustion generation sub-system is within the scope of another specific part of the EN 15316 series (i.e. part 4.x), the latter shall be used.

EXAMPLE Biomass combustion generation sub-systems are within the scope of prEN 15316-4-7.

This European Standard is also intended for the case of generation for both domestic hot water production and space heating. The case of generation only for domestic hot water production is treated in EN 15316-3-3.

2 Normative references

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

EN 297, *Gas-fired central heating boilers - Type B₁₁ and B_{11Bs} boilers fitted with atmospheric burners of nominal heat input not exceeding 70 kW*

EN 303-5, *Heating boilers – Part 5: Heating boilers for solid fuels, hand and automatically stocked, nominal heat output of up to 300 kW - Terminology, requirements, testing and marking*

EN 304, *Heating boilers — Test code for heating boilers for atomizing oil burners*

EN 656, *Gas-fired central heating boilers — Type B boilers of nominal heat input exceeding 70 kW but not exceeding 300 kW*

EN 15034:2006, *Heating boilers - Condensing heating boilers for fuel oil*

EN 15035, *Heating boilers - Special requirements for oil fired room sealed units up to 70 kW*

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*

EN 15316-2-3:2007, *Heating systems in building - Method for calculation of system energy requirements and system efficiencies – Part 2.3: Space heating distribution systems*

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*

EN 15456, *Heating boilers – Electrical power consumption for heat generators – System boundaries – Measurements*

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

EN ISO 7345:1995, *Thermal insulation - Physical quantities and definitions (ISO 7345:1987)*

EN ISO 13790, *Thermal performance of buildings - Calculation of energy use for space heating (ISO 13790:2004)*

3 Terms and definitions

3.1 Definitions

For the purposes of this document, the terms and definitions given in EN ISO 7345:1995 and the following apply.

3.1.1

space heating

process of heat supply for thermal comfort

3.1.2

domestic hot water heating

process of heat supply to raise the temperature of the cold water to the intended delivery temperature

3.1.3

heated space

room or enclosure which for the purposes of the calculation is assumed to be heated to a given set-point temperature or set-point temperatures

3.1.4

system thermal loss

thermal loss from a technical building system for heating, cooling, domestic hot water, humidification, dehumidification, ventilation or lighting or other appliances that does not contribute to the useful output of the system

NOTE Thermal energy recovered directly in the sub-system is not considered as a system thermal loss but as heat recovery and is directly treated in the related system standard.

3.1.5

auxiliary energy

electrical energy used by technical building systems for heating, cooling, ventilation and/or domestic hot water to support energy transformation to satisfy energy needs

NOTE 1 This includes energy for fans, pumps, electronics, etc.

NOTE 2 In EN ISO 9488 [4], the energy used for pumps and valves is called "parasitic energy".

3.1.6

heat recovery

heat generated by a technical building system or linked to a building use (e.g. domestic hot water) which is utilised directly in the related system to lower the heat input and which would otherwise be wasted (e.g. preheating of the combustion air by flue gas heat exchanger)

3.1.7

total system thermal loss

total of the technical system thermal loss, including recoverable system thermal losses

3.1.8

recoverable system thermal loss

part of the system thermal loss which can be recovered to lower either the energy need for heating or cooling or the energy use of the heating or cooling system

3.1.9

recovered system thermal loss

part of the recoverable system thermal loss which has been recovered to lower either the energy need for heating or cooling or the required energy use of the heating or cooling system

3.1.10

gross calorific value

quantity of heat released by a unit quantity of fuel, when it is burned completely with oxygen at a constant pressure equal to 101 320 Pa, and when the products of combustion are returned to ambient temperature

NOTE 1 This quantity includes the latent heat of condensation of any water vapour contained in the fuel and of the water vapour formed by the combustion of any hydrogen contained in the fuel.

NOTE 2 According to ISO 13602-2 [5], the gross calorific value is preferred to the net calorific value.

NOTE 3 The net calorific value does not take into account the latent heat of condensation.

3.1.11

net calorific value

gross calorific value minus latent heat of condensation of the water vapour in the products of combustion at ambient temperature

3.1.12

calculation step

discrete time interval for the calculation of the energy needs and uses

NOTE Typical discrete time intervals are one hour, one month or one heating and/or cooling season, operating modes, and bins.

3.1.13

calculation period

period of time over which the calculation is performed

NOTE The calculation period can be divided into a number of calculation steps.

3.1.14

external temperature

temperature of external air

NOTE 1 For transmission heat transfer calculations, the radiant temperature of the external environment is supposedly equal to the external air temperature; long-wave transmission to the sky is calculated separately.

NOTE 2 The measurement of external air temperature is defined in EN ISO 15927-1, Hygrothermal performance of buildings - Calculation and presentation of climatic data — Part 1: Monthly means of single meteorological elements.

3.1.15

heat transfer coefficient

factor of proportionality of heat flow governed by a temperature difference between two environments

3.1.16

boiler

gas, liquid or solid fuelled appliance designed to provide hot water for space heating. It may (but need not) be designed to provide domestic hot water heating as well

3.1.17

combustion power

product of the fuel flow rate and the net calorific power of the fuel

3.1.18

low temperature boiler

non-condensing boiler designed as a low temperature boiler and tested as a low temperature boiler as prescribed by the Council Directive 92/42/EEC about Boiler Efficiency [1]

3.1.19

condensing boiler

boiler designed to make use of the latent heat released by condensation of water vapour in the combustion flue products. The boiler must allow the condensate to leave the heat exchanger in liquid form by way of a condensate drain

NOTE Boilers not so designed, or without the means to remove the condensate in liquid form, are called 'non-condensing'.

3.1.20

oil condensing boiler

boiler designed to make use of the latent heat released by condensation of water vapour in the combustion flue products of a liquid fuel

[EN 15034:2006]

3.1.21

modes of operation

various modes in which the heating system can operate

EXAMPLES Set-point mode, cut-off mode, reduced mode, set-back mode, boost mode.

3.1.22

on/off boiler

boiler without the capability to vary the fuel burning rate whilst maintaining continuous burner firing. This includes boilers with alternative burning rates set once only at the time of installation, referred to as range rating

3.1.23

multistage boiler

boiler with the capability to vary the fuel burning rate stepwise whilst maintaining continuous burner firing

3.1.24

modulating boiler

boiler with the capability to vary continuously (from a set minimum to a set maximum) the fuel burning rate whilst maintaining continuous burner firing

3.2 Symbols and units

For the purposes of this document, the following symbols and units (Table 1) and indices (Table 2) apply.

Table 1 – Symbols and units

Symbol	Name of quantity	Unit
b	temperature reduction factor	-
c	coefficient	various
c	specific heat capacity	J/kg·K or Wh/kg·K ^{a)}
d	thickness	mm
E	energy in general (except quantity of heat, mechanical work and auxiliary (electrical) energy)	J or Wh ^{a)}
e	expenditure factor	-
f	factor	-
H	calorific value	J/mass unit or Wh/mass unit ^{b)}
H	heat transfer coefficient	W/K
k	factor	-
m	mass	kg
n	exponent	-
N	number of items	Integer
P	power in general including electrical power	W
Q	quantity of heat	J or Wh ^{a)}
t	time, period of time	s or h ^{a)}
V	volume	L
V'	volume flow	m ³ /s or m ³ /h ^{a)}
W	auxiliary (electrical) energy, mechanical work	J or Wh ^{a)}
x	relative humidity	%
X	volume fraction	%
α	loss factor	%
β	load factor	-
Δ	prefix for difference	
η	efficiency factor	%

Table 1 – Symbols and units

Symbol	Name of quantity	Unit
θ	Celsius temperature	°C
ρ	density	kg/m ³
Φ	heat flow rate, thermal power	W
a) If seconds (s) is used as the unit of time, the unit for energy shall be J. If hours (h) is used as the unit of time, the unit for energy shall be Wh. b) Mass unit for fuel may be Stm³, Nm³ or kg.		

Table 2 – Indices

add	additional	gnr	generator	plt	pilot
air	air	grs	gross	pmp	after the combustion chamber
aux	auxiliary	H	heating	Pn	at nominal load
avg	average	i, j, k	indices	Px	at x load
br	before generator	in	input to sub-system	r	return
brm	boiler room	ins	insulation	rbl	recoverable
ch	chimney	lat	latent	ref	reference
ci	calculation step	ls	losses	rvd	recovered
cmb	combustion	m	mean	s	gross (calorific value)
cond	condensing	max	maximum	sat	saturation
corr	corrected / correction	mass	massic	sby	in stand-by operation
ctr	control	min	minimum	st	stoichiometric
dis	distribution	n	nominal	sto	storage
dry	dry gases	net	net	test	test conditions
em	emission	O2	oxygen	th	thermal
emr	emitter	off	off	W	heating system water
f	flow (temperature)	on	on	w	water
fg	flue gas	out	output from sub-system	wfg	water to flue gas
ge	generator envelope	P0	at zero load	z	indices
gen	generation sub-system	Pint	at intermediate load		

Table 2 – Indices

The indices specifying symbols for sub-system energy balance quantities are in the following order:

- the first index represents the use (H = space heating, W = domestic hot water, etc.);
- the second index represents the sub-system (gen = generation, dis = distribution, etc.);
- the third index represents the balance item (ls = losses, in = input, aux = auxiliary, etc.).

Other indices may follow for more details (rvd = recovered, rbl = recoverable, etc.).

4 Principle of the method

4.1 Heat balance of the generation sub-system, including control of heat generation

4.1.1 Physical factors taken into account

The calculation method of the generation sub-system takes into account heat losses and/or recovery due to the following physical factors:

- heat losses to the chimney (or flue gas exhaust) during total time of generator operation (running and stand-by);
- heat losses through the generator(s) envelope during total time of generator operation (running and stand-by);
- auxiliary energy.

The relevance of these effects on the energy requirements depends on:

- type of heat generator(s);
- location of heat generator(s);
- part load ratio;
- operating conditions (temperature, control, etc.);
- control strategy (on/off, multistage, modulating, cascading, etc.).

4.1.2 Calculation structure (input and output data)

The calculation method of this standard shall be based on the following input data from other parts of the EN 15316-X-X series of standards:

- heat demand of the distribution sub-system(s) for space heating $\Sigma Q_{H,dis,in}$, calculated according to EN15316-2-3;
- heat demand of the distribution sub-system(s) for domestic hot water $\Sigma Q_{W,dis,in}$, calculated according to EN 15316-3-2, where appropriate.

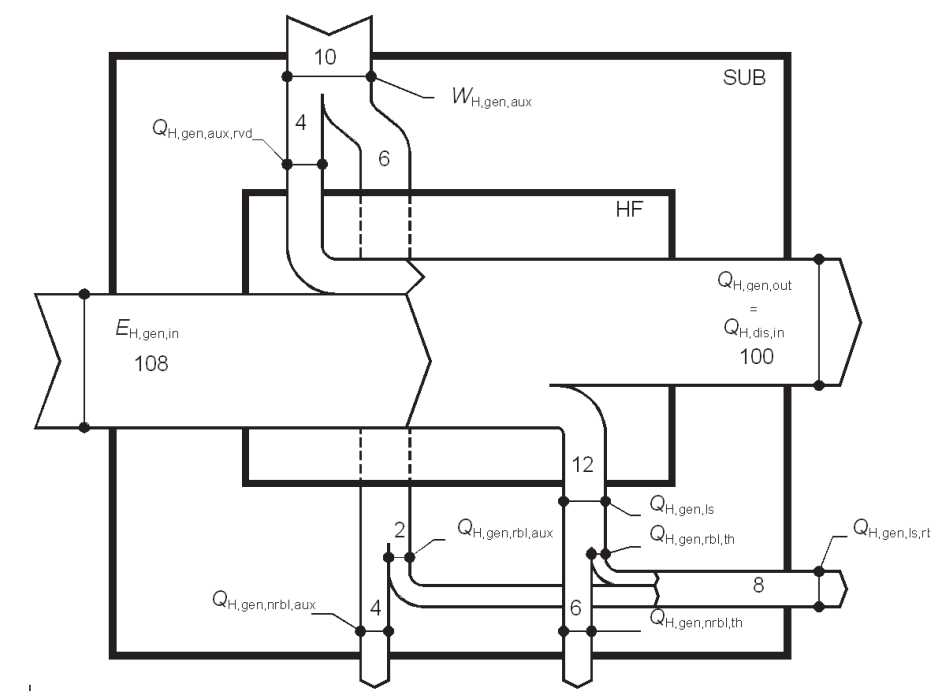
The performance of the generation sub-system may be characterised by additional input data to take into account:

- type and characteristics of the generation sub-system;
- generator settings;
- type of the generation control system;
- location of the generator;
- operating conditions;
- heat requirement.

Based on these data, the following output data are calculated by this standard:

- fuel heat requirement, $E_{H,gen,in}$;
- total generation thermal losses (flue gas and generator envelope), $Q_{H,gen,ls}$;
- recoverable generation thermal losses, $Q_{H,gen,ls,rbl}$;
- generation auxiliary energy, $W_{H,gen,aux}$.

Figure 1 shows the calculation inputs and outputs of the generation sub-system.



Key

SUB	Generation sub-system balance boundary
HF	Heating fluid balance boundary (see equation (1))
$Q_{H,gen,out}$	Generation sub-system heat output (input to distribution sub-system(s))
$E_{H,gen,in}$	Generation sub-system fuel input (energyware)
$W_{H,gen,aux}$	Generation sub-system total auxiliary energy
$Q_{H,gen,aux,rvd}$	Generation sub-system recovered auxiliary energy
$Q_{H,gen,ls}$	Generation sub-system total thermal losses
$Q_{H,gen,ls,rbl}$	Generation sub-system thermal loss recoverable for space heating
$Q_{H,gen,ls,th,rbl}$	Generation sub-system thermal loss (thermal part) recoverable for space heating
$Q_{H,gen,aux,rbl}$	Generation sub-system recoverable auxiliary energy
$Q_{H,gen,ls,th,nrbl}$	Generation sub-system thermal loss (thermal part) non recoverable
$Q_{H,gen,aux,nrbl}$	Generation sub-system non recoverable auxiliary energy

NOTE Figures shown are sample percentages.

Figure 1 – Generation sub-system inputs, outputs and energy balance

4.2 Generation sub-system basic energy balance

The basic energy balance of the generation sub-system is given by

$$E_{H,gen,in} = Q_{H,gen,out} - Q_{H,gen,aux,rvd} + Q_{H,gen,ls} \quad (1)$$

where

- $E_{H,gen,in}$ heat requirement of the generation sub-system (fuel input);
- $Q_{H,gen,out}$ heat supplied to the distribution sub-systems (space heating and domestic hot water);

$Q_{H,gen,aux,rvd}$ auxiliary energy recovered by the generation sub-system (i.e. pumps, burner fan, etc.);

$Q_{H,gen,ls}$ total losses of the generation sub-system (through the chimney, generator envelope, etc.).

NOTE $Q_{H,gen,ls}$ takes into account flue gas and generator envelope losses, part of which may be recoverable according to location. See 4.4, 5.3.5 and 5.4.4.

If there is only one generation sub-system

$$Q_{H,gen,out} = f_{ctrl} \cdot \sum_i Q_{H,dis,in,i} + \sum_j Q_{W,dis,in,j} \quad (2)$$

where

f_{ctrl} factor taking into account emission control losses. Default value of f_{ctrl} is given in Table D.1. Other values may be specified in a national annex, provided that emission control losses has not been already taken into account in the emission part (EN 15316-2-1) or in the distribution part (EN 15316-2-3).

If there are multiple generation sub-systems or multiple boilers, see 4.6, 5.3.3 and 5.4.9.

If the generator provides heat for heating and domestic hot water, the index H shall be replaced by HW. In the following only H is used for simplicity.

4.3 Auxiliary energy

Auxiliary energy is the energy, other than fuel, required for operation of the burner, the primary pump and any equipment whose operation is related to operation of the heat generation sub-system. Auxiliary energy is counted in the generation part as long as no transport energy from the auxiliary equipment is transferred to the distribution sub-system (example: zero-pressure distribution array). Such auxiliary equipment can be (but need not be) an integral part of the generator.

Auxiliary energy, normally in the form of electrical energy, may be partially recovered as heat for space heating or for the generation sub-system.

Examples of recoverable auxiliary energy:

- electrical energy transmitted as heat to the water of the primary circuit;
- part of the electrical energy for the burner fan.

Example of non-recoverable auxiliary energy:

- electrical energy for electric panel auxiliary circuits, if the generator is installed outside the heated space.

4.4 Recoverable, recovered and unrecoverable system thermal losses

Not all of the calculated system thermal losses are necessarily lost. Some of the losses are recoverable and part of the recoverable system thermal losses are actually recovered.

Example of recoverable system thermal losses are:

- thermal losses through the envelope of a generator installed within the heated space.

Examples of non-recoverable system thermal losses are:

- thermal losses through the envelope of a generator installed outside the heated space;
- thermal losses through the chimney installed outside the heated space.

Recovery of system thermal losses to the heated space can be accounted for:

- either as a reduction of total system thermal losses within the specific part (simplified method);
- or, by taking into account recoverable system thermal losses as gains (holistic method) or as a reduction of the energy use according to EN 15603.

This European Standard allows both approaches.

Generation system thermal losses recovered by the generation sub-system are directly taken into account in the generation performance.

EXAMPLE Combustion air preheating by flue gas losses.

4.5 Calculation steps

The objective of the calculation is to determine the energy input of the heating generation sub-system for the entire calculation period (usually one year). This may be done in one of the following two different ways:

- by using average (usually yearly) data for the entire calculation period;
- by dividing the calculation period into a number of calculation steps (e.g. months, weeks, bins, operation modes as defined in EN ISO 13790) and perform the calculations for each step using step-dependent values and adding up the results for all the steps over the calculation period.

NOTE Generation efficiency is strongly dependent on the load factor and this relationship is not linear. To achieve precision, the calculation steps should not be longer than 1 month.

4.6 Multiple boilers or generation sub-systems

The primary scope of this European Standard is to calculate losses, fuel requirement and auxiliary energy requirements for an individual boiler.

If there are multiple generation sub-systems, the general part allows for a modular approach to take into account cases where:

- a heating system is split up in zones with several distribution sub-systems;
- several heat generation sub-systems are available.

EXAMPLE 1 A separate circuit may be used for domestic hot water production.

EXAMPLE 2 A boiler may be used as a back-up for a solar and/or cogeneration sub-system(s).

In these cases, the total heat requirement of the connected distribution sub-systems $\sum_i Q_{X,dis,in,i}$ shall equal the total heat output of the generation sub-systems $\sum_j Q_{X,gen,out,j}$:

$$\sum_j Q_{X,gen,out,j} = \sum_i Q_{X,dis,in,i} \quad (3)$$

NOTE X is used as an index in equation (3) to mean space heating, domestic hot water heating or other building services requiring heat from a generation sub-system.

If there are several generation sub-systems, the total heat demand of the distribution sub-system(s) shall be distributed among the available generation sub-systems. The calculation described in 5.2, 5.3, 5.4 and/or other relevant parts of EN 15316-4 shall be performed independently for each heat generation device j , on the basis of $Q_{H,gen,out,j}$.

Criteria for distribution of the total heat demand among the available generation sub-systems may be based on physical, efficiency or economic considerations.

EXAMPLE 3 Solar or heat pump sub-system maximum heat output.

EXAMPLE 4 Heat pumps or cogeneration optimum (either economic or energetic) performance range.

Appropriate criteria for specific types of generation sub-systems can be found in the relevant parts of the EN 15316-4-X series of standards.

Procedures to split the load among multiple combustion generators (boilers) are given for basic cases in 5.3.3 and 5.4.9.

EXAMPLE 5 Given $\Sigma Q_{H,dis,in}$, the maximum output of a solar generation system $Q_{H,sol,out}$ should be calculated first, and subsequently the heat output that can be provided by a cogeneration system is added $Q_{chp,gen,out}$. The rest ($Q_{H,gen,out,boil} = \Sigma Q_{H,dis,in} - Q_{H,sol,out} - Q_{chp,gen,out}$; see Figure 2) is attributed to boilers and may be further split among multiple boilers according to 5.3.3 and 5.4.9.

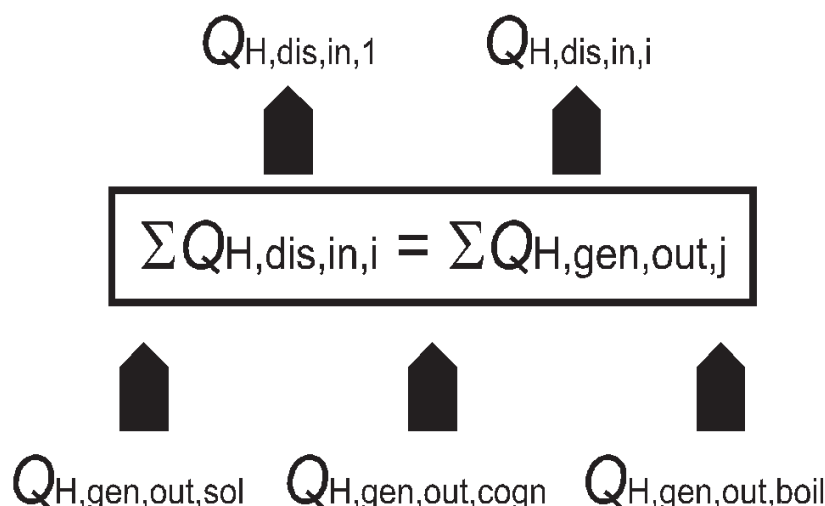


Figure 2 – Example of load splitting among generation sub-systems

4.7 Using net or gross calorific values

Calculations described in 5 may be performed according to net or gross calorific values. All parameters and data shall be consistent with this option.

If the calculation of the generation sub-system is performed according to data based on fuel net calorific values H_i , total losses $Q_{H,gen,ls,net}$, non recoverable thermal losses $Q_{H,gen,ls,th,nrbl,net}$ and generation sub-system energyware $E_{H,gen,in,net}$ (i.e. fuel input for combustion systems) based on net calorific values may be converted to values $Q_{H,gen,ls,grs}$, $Q_{H,gen,ls,th,nrbl,grs}$ and $E_{H,gen,in,grs}$ based on gross calorific values H_s by addition of the latent heat of condensation Q_{lat} according to the following:

$$Q_{lat} = E_{H,gen,in,net} \cdot \frac{H_s - H_i}{H_i} \quad (4)$$

$$E_{H,gen,in,grs} = E_{H,gen,in,net} + Q_{lat} \quad (5)$$

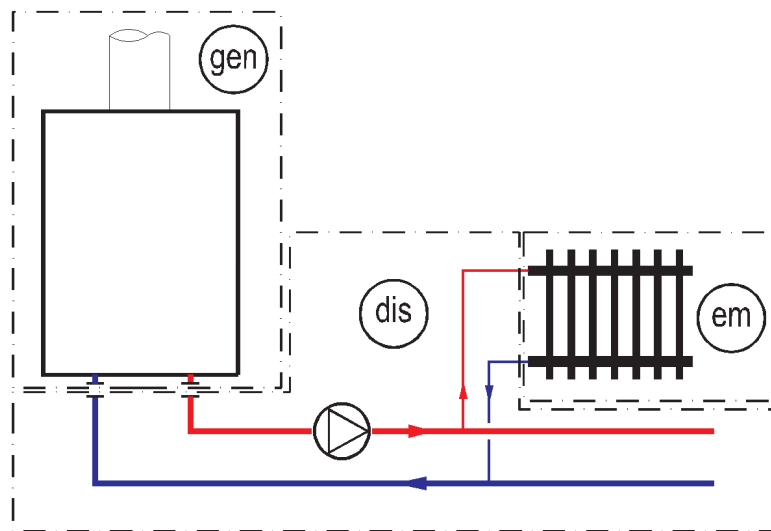
$$Q_{H,gen,ls,grs} = Q_{H,gen,ls,net} + Q_{lat} \quad (6)$$

$$Q_{H,gen,ls,th,nrbl,grs} = Q_{H,gen,ls,th,nrbl,net} + Q_{lat} \quad (7)$$

4.8 Boundaries between distribution and generation sub-system

Boundaries between generation sub-system and distribution sub-system should be defined according to the following principles.

If the generation sub-system includes the generator only (i.e. there is no pump within the generator), the boundary with the distribution sub-system is represented by the hydraulic connection of the boiler, as shown in Figure 3.

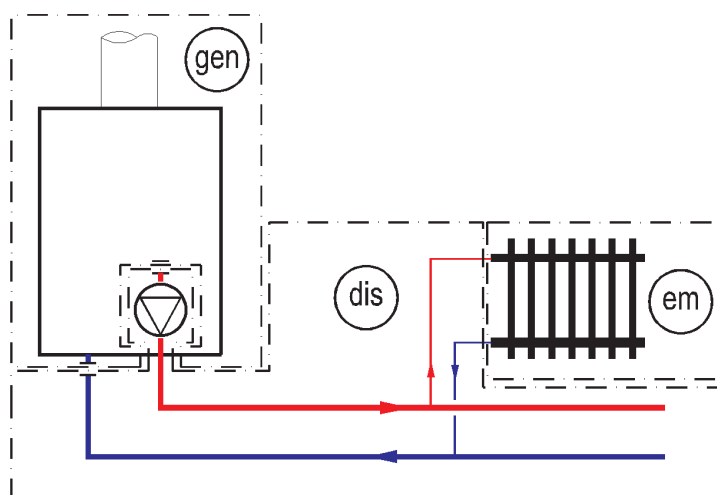


Key

gen	generation sub-system
dis	distribution sub-system
em	emission sub-system

Figure 3 – Sample sub-systems boundaries

A pump physically within the boiler is however considered part of the distribution sub-system if it contributes to the flow of heating medium to the emitters. An example is shown in Figure 4.

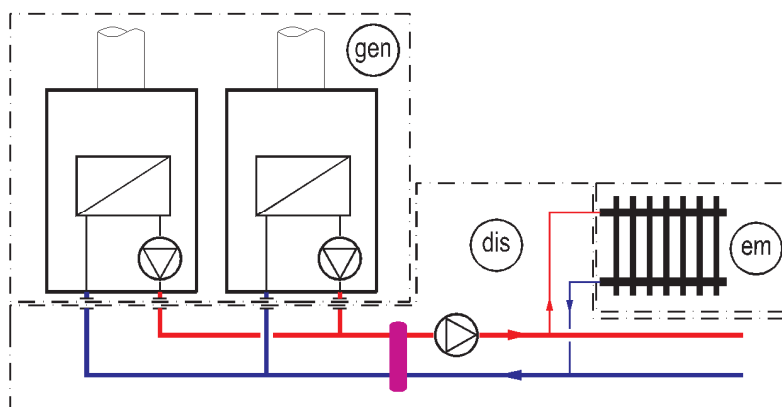


Key

gen	generation sub-system
dis	distribution sub-system
em	emission sub-system

Figure 4 – Sample sub-systems boundaries

Only pumps dedicated to generator requirements may be considered within the generation sub-system. An example is shown in Figure 5.



Key

gen	generation sub-system
dis	distribution sub-system
em	emission sub-system

Figure 5 – Sample sub-systems boundaries

5 Generation sub-system calculation

5.1 Available methodologies

In this standard, three performance calculation methods for the heat generation sub-system are described corresponding to different use (simplified or detailed estimation, on site measurements, etc.). The calculation methods differ with respect to:

- required input data;
- operating conditions taken into account;
- calculation steps applied.

For the first method (see 5.2), the considered calculation step is the heating season. The performance calculation is based on the data related to the Council Directive 92/42/EEC about Boiler Efficiency [1]. The operation conditions taken into account (climate, distribution sub-system connected to the generator, etc.) are approximated by typology of the considered region and are not case specific. If this method is to be applied, an appropriate national annex with the relevant values shall be available.

The second method (see 5.3) is also based on the data related to the Council Directive 92/42/EEC about Boiler Efficiency [1], but supplementary data are needed in order to take into account the specific operation conditions of the individual installation. The considered calculation step can be the heating season but may also be a shorter period (month, week and/or the operation modes according to EN ISO 13790). The method is not limited and can be used with the default values given in informative Annex B.

The third method (see 5.4) distinguishes in a more explicit way the losses of a generator which occurs during boiler cycling (i.e. combustion losses). Some of the parameters can be measured on site. This method is well adapted for existing buildings and to take into account condensation heat recovery according to operating conditions.

The calculation method to be applied is chosen as a function of the available data and the objectives of the calculation.

Further details on each method are given in the respective parametering informative Annexes (A, B and C).

5.2 Seasonal boiler performance method based on system typology (typology method)

5.2.1 Principle of the method

This method assumes that

- climatic conditions,
- operation modes,
- typical occupancy patterns of the relevant building sector,

have been considered and are incorporated in a procedure to convert standard test results of boiler efficiency (as used for the Council Directive 92/42/EEC about Boiler Efficiency [1]) into a seasonal efficiency for the relevant building sector.

The stages within the seasonal efficiency calculation procedure are:

- a) adapt test results for uniformity, taking account of boiler type, fuel and specific conditions for testing imposed by the Council Directive 92/42/EEC about Boiler Efficiency [1] and the relevant standards;

- b) adjust for annual performance in installed conditions, taking account of regional climate, operation modes and occupancy patterns typical of the relevant building sector;
- c) perform the calculations and determine fuel heat requirement, total generation thermal loss (as an absolute value), recoverable generation thermal loss, auxiliary energy, recoverable auxiliary energy.

The procedure allows for national characteristics of the relevant building sector.

5.2.2 Calculation procedure

5.2.2.1 Selection of appropriate seasonal efficiency procedure

A seasonal efficiency calculation procedure is selected from the appropriate national annex on the basis of the following information:

- region (climate) in which the building is situated;
- building sector (housing, commercial, industrial, etc).

The procedure shall include limitation in use, relevant boundary conditions and reference to validation data.

The procedure shall be defined in a national annex. If there is no appropriate national annex, this method cannot be used.

Annex A (informative) is an example of a seasonal efficiency calculation procedure, known as SEDB_UK, and it represents conditions in the housing sector of the UK.

5.2.2.2 Input information required for the seasonal efficiency procedure

Input information for the procedure shall comprise:

- heat demand of the distribution sub-system(s) for space heating $\Sigma Q_{H,dis,in}$ calculated according to EN15316-2-3;
- heat demand of the distribution sub-system(s) for domestic hot water $\Sigma Q_{W,dis,in}$ calculated according to EN 15316-3-2, where appropriate.

Input information for the procedure may comprise:

- full-load and 30 % part-load efficiency test results produced in accordance with standard tests as required for the Council Directive 92/42/EEC about Boiler Efficiency [1];
- boiler type (condensing or not, combination or not, hot water store included or not, etc);
- fuel used (natural gas, LPG, oil, etc);
- boiler power output (maximum and minimum if a range);
- ignition method (permanent pilot flame or not);
- burner type (modulating, multistage or on/off);
- internal store included in efficiency tests (yes/no);
- store characteristics (volume, insulation thickness).

5.2.2.3 Output information obtained from the seasonal efficiency procedure

Output information from the procedure shall comprise:

- $E_{H,gen,in}$ fuel heat requirement;
- $W_{H,gen,aux}$ auxiliary energy;
- $Q_{H,gen,ls,rbl}$ recoverable system thermal losses for space heating.

5.3 Case specific boiler efficiency method

5.3.1 Principle of the method

This method is related to the Council Directive 92/42/EEC about Boiler Efficiency [1] and is based on the following principle:

- a) data are collected for three basic load factors or power outputs:
 - $\eta_{gnr,Pn}$ efficiency at 100 % load;
 - $\eta_{gnr,Pint}$ efficiency at intermediate load;
 - $\Phi_{gnr,ls,P0}$ losses at 0 % load;
- b) efficiency and losses data are corrected according to boiler operating conditions (temperature);
- c) losses power at 100 % load $\Phi_{gnr,ls,Pn}$ and at intermediate load $\Phi_{gnr,ls,Pint}$ are calculated according to corrected efficiencies;
- d) calculation of losses power corresponding to the actual power output is made by linear or polynomial interpolation between losses powers for the three basic power outputs;

NOTE For the case specific boiler efficiency method, all powers and the load factor β_{gnr} are referred to generation sub-system output.

- e) auxiliary energy is calculated taking into account the actual power output of the boiler;
- f) recoverable generator envelope thermal losses are calculated according to a tabulated fraction of stand-by heat losses and boiler location;
- g) recoverable auxiliary energy is added to recoverable generator envelope thermal losses to provide total recoverable thermal losses.

5.3.2 Input data to the method

5.3.2.1 Boiler data

The boiler is characterised by the following values:

- Φ_{Pn} generator output at full load;
- $\eta_{gnr,Pn}$ generator efficiency at full load;
- $\theta_{gnr,w,test,Pn}$ generator average water temperature at test conditions for full load;

- f_{corr,P_n} correction factor of full-load efficiency;
- $\Phi_{P_{\text{int}}}$ generator output at intermediate load;
- $\eta_{\text{gnr},P_{\text{int}}}$ generator efficiency at intermediate load;
- $\theta_{\text{gnr},w,\text{test},P_{\text{int}}}$ generator average water temperature at test conditions for intermediate load;
- $f_{\text{corr},P_{\text{int}}}$ correction factor of intermediate load efficiency;
- $\Phi_{\text{gnr},\text{ls},P_0}$ stand-by heat loss at test temperature difference $\Delta\theta_{\text{gnr},\text{test},P_0}$;
- $\Delta\theta_{\text{gnr},\text{test},P_0}$ difference between mean boiler temperature and test room temperature at test conditions;
- $P_{\text{aux},\text{gnr},P_n}$ power consumption of auxiliary devices at full load;
- $P_{\text{aux},\text{gnr},P_{\text{int}}}$ power consumption of auxiliary devices at intermediate load;
- $P_{\text{aux},\text{gnr},P_0}$ stand-by power consumption of auxiliary devices;
- $\theta_{\text{gnr},w,\text{min}}$ minimum operating boiler temperature.

Data to characterise the boiler shall be taken from one of the following sources, listed in priority order:

- a) product data from the manufacturer, if the boiler has been tested according to EN 297, EN 303-5, EN 304, EN 656, EN 15034, EN 15035 and/or EN 15456 (auxiliary power data);
- b) default data from the relevant national annex;
- c) default data from Annexes B or D.

It shall be recorded whether or not the efficiency values include auxiliary energy recovery.

5.3.2.2 Actual operating conditions

Actual operating conditions are characterised by the following values:

- $Q_{H,\text{gen},\text{out}}$ heat output to the heat distribution sub-system(s);
- $\theta_{\text{gnr},w,m}$ average water temperature in the boiler;
- $\theta_{\text{gnr},w,r}$ return water temperature to the boiler (for condensing boilers);
- $\theta_{i,\text{brm}}$ boiler room temperature;
- b_{brm} temperature reduction factor depending on the location of the generator.

5.3.3 Load of each boiler

5.3.3.1 Generation sub-system average power

Generation sub-system average power $\Phi_{H,\text{gen},\text{out}}$ is given by:

$$\Phi_{H,\text{gen},\text{out}} = \frac{Q_{H,\text{gen},\text{out}}}{t_{\text{gen}}} \quad (8)$$

where

t_{gen} total time of generator(s) operation.

5.3.3.2 Single boiler generation sub-system

If there is only one generator installed, the load factor β_{gnr} is given by:

$$\beta_{\text{gnr}} = \frac{\Phi_{\text{H,gen,out}}}{\Phi_{\text{Pn}}} \quad (9)$$

where

Φ_{Pn} nominal power output of the generator.

5.3.3.3 Multiple boilers generation sub-system

5.3.3.3.1 General

If there are several boilers installed, distribution of the load among boilers depends on control. Two types of control are distinguished:

- without priority;
- with priority.

5.3.3.3.2 Multiple generators without priority

All generators are running at the same time and therefore the load factor β_{gnr} is the same for all boilers and is given by:

$$\beta_{\text{gnr}} = \frac{\Phi_{\text{H,gen,out}}}{\sum_i \Phi_{\text{Pn},i}} \quad (10)$$

where

$\Phi_{\text{Pn},i}$ nominal power output of generator i at full load.

5.3.3.3.3 Multiple generators with priority

The generators of higher priority are running first. A given generator in the priority list is running only if the generators of higher priority are running at full load ($\beta_{\text{gnr},i} = 1$).

If all boilers have the same power output Φ_{Pn} , the number of running generators $N_{\text{gnr,on}}$ is given by:

$$N_{\text{gnr,on}} = \text{int} \left(\frac{\Phi_{\text{H,gen,out}}}{\Phi_{\text{Pn}}} \right) \quad (11)$$

Otherwise running boilers have to be determined so that $0 < \beta_{\text{gnr},j} < 1$ (see equation (10))

The load factor $\beta_{\text{gnr},j}$ for the intermittent running generator is calculated by:

$$\beta_{\text{gnr},j} = \frac{\Phi_{\text{H,gen,out}} - \sum_{i=1}^{N_{\text{gnr,on}}} \Phi_{\text{Pn},i}}{\Phi_{\text{Pn},j}} \quad (12)$$

where

$\Phi_{\text{Pn},i}$ nominal power output of generator i running at full load;

$\Phi_{\text{Pn},j}$ nominal power output of intermittent running generator.

5.3.4 Generators with double service (space heating and domestic hot water production)

During the heating season, the heat generator can produce energy for the space heating installation and the domestic hot water (double service).

Calculation of the thermal losses for a generator running for domestic hot water service only, is specified in the domestic hot water part of this standard, EN 15316-3-3 [3].

The domestic hot water generation also influences the heating part of a double service generator in respect of:

- running temperature of the generator;
- running time;
- load.

The running temperature of the generator may be modified if domestic hot water production is required. The dynamic effects of this temperature modification (heating up, cooling down) are neglected in this part of the standard.

The needs for domestic hot water production may extend the heating up period, if the generator is already running at nominal power. The impacts on the time periods (heating up, normal mode, etc.) defined in EN ISO 13790 are neglected.

The domestic hot water production increases the load of the double service generator. This effect is taken into account by increasing the generation sub-system load during the considered period by:

$$Q_{\text{HW,gen,out}} = f_{\text{ctrl}} \cdot Q_{\text{H,dis,in}} + Q_{\text{W,dis,in}} \quad (13)$$

and using $Q_{\text{HW,gen,out}}$ instead of $Q_{\text{H,gen,out}}$ in equation (8).

NOTE Equation (13) is the same as equation (2).

In general, the considered calculation period is the same for domestic hot water production and for space heating.

However, if the domestic hot water is produced only during specific operation modes (e.g. only during normal mode or if a priority control is fitted), the calculation may be performed independently for the two operation modes:

- once taking into account $t_{\text{gnr,H}}$ (operation time for space heating) and $\Phi_{\text{Px,H}}$ (calculated with $Q_{\text{H,dis,in}}$ and $t_{\text{gnr,H}}$) and operating conditions for space heating service;

- once taking into account $t_{\text{gnr},W}$ (operation time for domestic hot water production) and $\Phi_{P_x,W}$ (calculated with $Q_{W,\text{dis},in}$ and $t_{\text{gnr},W}$) and operating conditions for domestic hot water production.

Losses, auxiliary energy and fuel input for the two operation modes are summed up at the end of the calculation.

5.3.5 Generator thermal losses

5.3.5.1 Generator thermal loss calculation at full load

The efficiency at full load η_{gnr,P_n} is measured at a reference generator average water temperature $\theta_{\text{gnr},w,\text{test},P_n}$. This efficiency has to be adjusted to the actual generator average water temperature of the individual installation.

The temperature corrected efficiency at full load $\eta_{\text{gnr},P_n,\text{corr}}$ is calculated by:

$$\eta_{\text{gnr},P_n,\text{corr}} = \eta_{\text{gnr},P_n} + f_{\text{corr},P_n} \cdot (\theta_{\text{gnr},w,\text{test},P_n} - \theta_{\text{gnr},w,m}) \quad (14)$$

where

η_{gnr,P_n} generator efficiency at full load. If the performance of the generator has been tested according to relevant EN standards (see 5.3.2.1), it can be taken into account. If no values are available, default values shall be found in the relevant national annex or in B.3.1;

f_{corr,P_n} correction factor taking into account variation of the full load efficiency as a function of the generator average water temperature. The value should be given in a national annex. In the absence of national values, default values are given in B.3.3. If the performance of the generator has been tested according to relevant EN standards (see 5.3.2.1), it can be taken into account;

$\theta_{\text{gnr},w,\text{test},P_n}$ generator average water temperature at test conditions for full load (see B.3.3);

$\theta_{\text{gnr},w,m}$ generator average water temperature as a function of the specific operating conditions (see 5.3.9).

In order to simplify the calculations, the efficiencies and heat losses determined at test conditions are adjusted to the actual generator average water temperature. It is allowed, as it is physically correct, to adjust the performance at each load according to the actual generator average water temperature of each load.

The corrected generator thermal loss at full load $\Phi_{\text{gnr},ls,P_n,\text{corr}}$ is calculated by:

$$\Phi_{\text{gnr},ls,P_n,\text{corr}} = \frac{(100 - \eta_{\text{gnr},P_n,\text{corr}})}{\eta_{\text{gnr},P_n,\text{corr}}} \cdot \Phi_{P_n} \quad (15)$$

where

Φ_{P_n} generator output at full load.

5.3.5.2 Generator thermal loss calculation at intermediate load

The efficiency at intermediate load $\eta_{\text{gnr},P_{int}}$ is measured at a reference generator average water temperature $\theta_{\text{gnr},w,\text{test},P_{int}}$. This efficiency has to be adjusted to the actual generator average water temperature of the individual installation.

The temperature corrected efficiency at intermediate load $\eta_{\text{gnr},P_{int},\text{corr}}$ is calculated by:

$$\eta_{\text{gnr,Pint,corr}} = \eta_{\text{gnr,Pint}} + f_{\text{corr,Pint}} \cdot (\theta_{\text{gnr,w,test,Pint}} - \theta_{\text{gnr,w,m}}) \quad (16)$$

where

- $\eta_{\text{gnr,Pint}}$ generator efficiency at intermediate load. If the performance of the generator has been tested according to relevant EN standards (see 5.3.2.1), it can be taken into account. If no values are available, default values shall be found in the relevant national annex or in B.3.1;
- $f_{\text{corr,Pint}}$ correction factor taking into account variation of the efficiency as a function of the generator average water temperature. The value should be given in a national annex. In the absence of national values, default values are given in B.3.3. If the performance of the generator has been tested according to relevant EN standards (see 5.3.2.1), it can be taken into account;
- $\theta_{\text{gnr,w,test,Pint}}$ generator average water temperature (or return temperature to the boiler for condensing boilers) at test conditions for intermediate load (see B.3.3);
- $\theta_{\text{gnr,w,m}}$ generator average water temperature (or return temperature to the generator for condensing boilers) as a function of the specific operating conditions (see 5.3.9).

The intermediate load depends on the generator type. Default values are given in D.2.

The corrected generator thermal loss at intermediate load $\Phi_{\text{gnr,ls,Pint,corr}}$ is calculated by:

$$\Phi_{\text{gnr,ls,Pint,corr}} = \frac{(100 - \eta_{\text{gnr,Pint,corr}})}{\eta_{\text{gnr,Pint,corr}}} \cdot \Phi_{\text{Pint}} \quad (17)$$

where

- Φ_{Pint} generator output at intermediate load.

5.3.5.3 Generator thermal loss calculation at 0 % load

The generator stand-by heat loss at 0 % load $\Phi_{\text{gnr,ls,P0}}$ is determined for a test temperature difference according to relevant testing standards (i.e. EN 297, EN 483/A2, EN 303, EN 13836 and EN 15043). If the performance of the generator has been tested according to relevant EN standards (see 5.3.2.1), it can be taken into account. If no manufacturer or national annex data are available, default values are given in B.3.2.

The temperature corrected generator thermal loss at 0 % load $\Phi_{\text{gnr,ls,P0,corr}}$ is calculated by:

$$\Phi_{\text{gnr,ls,P0,corr}} = \Phi_{\text{gnr,ls,P0}} \cdot \left(\frac{\theta_{\text{gnr,w,m}} - \theta_{\text{i,brm}}}{\Delta\theta_{\text{gnr,test,P0}}} \right)^{1,25} \quad (18)$$

where

- $\Phi_{\text{gnr,ls,P0}}$ stand-by heat loss at 0 % load at test temperature difference $\Delta\theta_{\text{gnr,test,P0}}$;
- $\theta_{\text{gnr,w,m}}$ generator average water temperature (or return temperature to the generator for condensing boilers) as a function of the specific operating conditions (see 5.3.9);
- $\theta_{\text{i,brm}}$ indoor temperature of the boiler room. Default values are given in B.5.3;
- $\Delta\theta_{\text{gnr,test,P0}}$ difference between generator average water temperature and test room temperature at test conditions. Default values are given in B.3.2.