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

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Foreword

This document (prEN 15316-1:2005) has been prepared by Technical Committee CEN/TC 228 “Heating systems in buildings”, the secretariat of which is held by DS.

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.

Introduction

This standard constitutes the general part of set of standards on space heating and domestic hot water systems, where subsequent standards should cover specific calculation algorithms.

The calculation method may be used for the following applications:

— judging compliance with regulations expressed in terms of energy targets;

— optimisation of the energy performance of a planned building, by applying the method to several possible options;

— displaying a conventional level of energy performance of existing buildings;

— assessing the effect of possible energy conservation measures on an existing building, by calculation of the energy requirements with and without the energy conservation measure implemented;

— predicting future energy resource needs on a national or international scale, by calculation of the energy requirements of several buildings which are representative of the entire building stock.

1 Scope

This standard specifies the structure for the calculation of energy requirements of space heating and domestic hot water systems in buildings.

It standardise the required inputs and outputs in order to achieve a common European calculation method.

It allows the energy analysis of the different heating subsystems including control (emission, distribution, storage, generation) by comparing the system losses and by defining system performance factors. This performance analysis permits the comparison between subsystems and make possible to monitor the impact of each subsystem on the energy performance of a building.

The calculation of the system losses of each part of the heating subsystems is defined in subsequent standards (prEN 15316 parts 2 to parts 4). The thermal system losses, the recoverable losses and the auxiliary consumption of the heating subsystems are summed up. The heating system losses contribute to the overall energy use in buildings (prEN 15315).

Ventilation systems are not included in this standard (e.g. balanced systems with heat recovery), but if the air is preheated or an air heating system is installed, system losses of these systems are covered by this standard.

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

EN ISO 13790, *Thermal performance of buildings - Calculation of building energy use for space heating and cooling)*

prEN 15315, *Heating systems in buildings – Energy performance of buildings – Overall energy use, primary energy and CO2 emissions*

prEN 15316-2.1 *Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies – Part 2.1: Space heating emission systems*

prEN 15316-2.3 *Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies – Part 2.3: Space heating distribution systems*

prEN 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)*

prEN 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*

prEN 15316-3.3 *Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies – Part 3.3: Domestic hot water systems, generation*

3 Definitions and symbols

To be updated following decisions in CEN/BT WG173

3.1 Definitions

For the purposes of this standard, the definitions given in EN ISO 7345 and the following definitions apply:

3.1.1
Auxiliary energy
Auxiliary energy, normally in the form of electrical energy, is used for circulation pumps, fans, valves and controls. The auxiliary energy requirement may be available as a value for each sub-system, W_x, or as a value for a combination of sub-systems, or as a value for the entire system. Part of the auxiliary energy may be recovered as heat, Q_{rx}.

3.1.2
calculation period
time period considered for calculation of the heat losses and gains (e.g. month, day, boosted sub period)

3.1.3
domestic hot water (DHW) heat demand
quantity of heat to be delivered to the domestic water to raise its temperature from the cold network temperature to the prefixed delivery temperature

3.1.4
efficiency, distribution
the ratio between the energy demand for heating (for the space heating system and/or the domestic hot water system) with an adiabatic distribution system and the energy requirements with a non-ideal distribution system

3.1.5
efficiency, emission:
the ratio between the energy demand for space heating with a uniform internal temperature distribution in the heated space and the energy requirements for space heating with a non-ideal emission system causing non-uniform temperature distribution and non-ideal room temperature control

3.1.6
efficiency, generation
the ratio between the heat demand and the energy requirements

3.1.7
energy requirements for heating
energy to be delivered to the heating system to satisfy the heat demand of the building

3.1.8
final energy
energy required for the space heating and domestic hot water system of the building including auxiliary energy

3.1.9
heat demand, building
heat to be delivered to the heated space to maintain the internal set-point temperature of the heated space

3.1.10
heated space
room or enclosure heated to a given set-point temperature

3.1.11
heating system
technical building system including the space heating system and the domestic hot water system

3.1.12
heating system heat losses, distribution
heat losses of the heat distribution system, including recoverable heat loss

3.1.13
heating system heat losses, emission
heat losses through the building envelope due to non-uniform temperature distribution and control inefficiencies in the heated space

3.1.14
heating system heat losses, generation
heat generator heat losses occurring both during operation and stand-by, and heat losses due to non-ideal control of the heat generator, including recoverable heat loss

3.1.15
heating system heat losses, total
sum of the heat losses from the heating system, including recoverable heat loss

3.1.16
net heat requirements
heat requirements reduced by the quantity of the recovered system heat loss

3.1.17
recoverable (usable) system heat loss
part of the heat loss, from the space heating and domestic hot water system, which may be recovered to lower the heat demand for space heating

3.1.18
recovered (used) system heat loss
part of the recoverable system heat loss which lowers the heat demand for space heating and which is not directly taken into account by reduction of the heating system heat losses

3.1.19
system operation period (heating period)
the time where system output is available to satisfy the requirements

3.1.20
thermal zone
part of the heated space with a given set-point temperature, in which a negligible spatial variation of the internal temperature is assumed

NOTE: In EN ISO 13790, the term for "demand" is "use".

3.1.21
Heat sink
Output of the totality of the heat energy drawn out of the building. This does not include heat removed from the building by means of the air-conditioning cooling system.

3.1.22
Heat source
Sources of quantities of heat at temperatures above the internal temperature which are conducted into the building zone or which are generated inside. This does not include controlled heat input via technical systems in order to maintain the set indoor temperature.

3.2 Symbols and units

To be updated following decisions in CEN/BT WG173

For the purposes of this standard, the following symbols and units (see Table 1) and indices (see Table 2) apply:

Table 1 : Symbols and units

Symbol	Name of quantity	Unit
c	specific heat capacity	J/(kg·K)
e	system performance coefficient (expenditure factor)	-
E	primary energy	J
f	conversion factor	-
m	mass	kg
$\dot{M}$	mass flow rate	kg/s
t	time, period of time	s
T	thermodynamic temperature	K
Q	quantity of heat, energy	J
Φ	thermal power	W
V	volume	m^3
$\dot{V}$	volumetric flow rate	m^3/s
W	electrical auxiliary energy	J
η	efficiency	-
θ	celsius temperature	°C
ρ	density of water	kg/ m^3

Table 2 : Indices

a	air	gs	gains	r	recovered
c	control	h	heating energy	s	storage
d	distribution	i	internal	t	total
		in	input to system	out	output from system
em	emission	l	loss	w	domestic hot water
e	external	nr	non-recovered losses	x	indices
f	final	off	off	0	entering
g	generation	on	on		
gl	generation, losses	p	primary		

4 Principle of the method

4.1 Technical system losses for space heating and domestic hot water

The calculation method of the system losses is based on an analysis of the following parts of a space heating and domestic hot water system:

— the emission system energy performance including control;

— the distribution system energy performance including control;

— the storage system energy performance including control;

— the generation system energy performance including control
(e.g. boilers, solar collectors, heat pumps, cogeneration units).

Note: This structure is similar to the physical structure of heating systems

The energy required for the heating system is calculated separately for thermal energy and electrical energy.

The generation system energy performance is not detailed in this standard because directly taken into account in prEN 15315.

If the storage system can be included in the generation sub-system or detailed as the storage system. In the prEN 15316-4 standards the storage and buffer tanks are taken into account in the generation parts.

Figure 1 illustrates the calculation of input data and output data for a given sub-system, i.e. sub-system “x”.

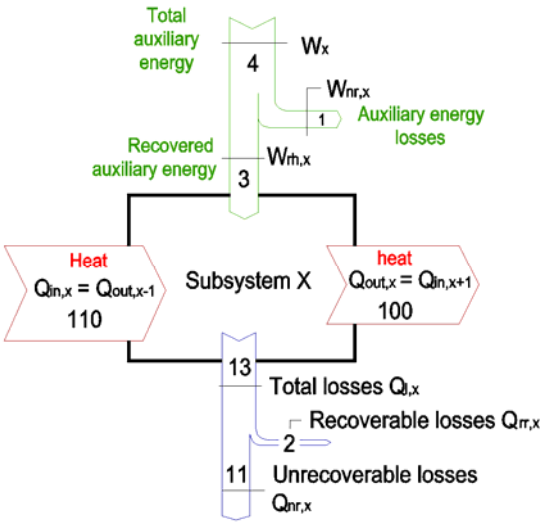


Figure 1 — Input and output data for heating sub-system

Index x should be replaced by one of the following according to the actual sub-system:

em	emission	d	distribution
s	storage	g	generation
z	other		

Based on these data, the output from the sub-system calculation shall comprise:

- the thermal and electrical input;
- the thermal and electrical output;
- the system heat loss;
- the auxiliary energy consumption;
- the recoverable heat losses.

The calculations may be based on tabulated values or more detailed methods.

4.2 Calculation periods

Note: The objective of the calculation is to determine the annual energy use of the space heating and domestic hot water system.

Heat losses should be calculated separately for each calculation period. The average values shall be consistent with the selected time intervals. This may be done in one of the following two different ways:

— by using annual data for the system operation period and performing the calculations using annual average values;

— by dividing the year into a number of calculation periods (e.g. months, weeks, etc.), performing the calculations for each period using period-dependent values and sum up the results for all the periods over the year.

If there is seasonal heating in the building, the year should be divided at least into time of the heating season and the time of the rest of the year.

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

NOTE: Efficiency is the most traditional dimensionless term used to indicate effectiveness of an energy transformation system. Efficiencies serve a practical and straightforward comparison of effectiveness of systems or sub-systems of different type and/or different size.

The energy efficiency η of each sub-system is defined as:

$$\eta_x = \frac{f_h \cdot Q_{outx}}{f_h \cdot Q_{inx} + f_w \cdot W_x} \quad (1)$$

Where:

f energy conversion factor for each type of energy used (e.g. thermal, electrical)
This factor shall be given at a national basis;

W_x auxiliary energy of the sub-system;

Q_{outx} heat output of the subsystem;

Q_{inx} heat input of the sub-system;

The global efficiency of the entire system should be calculated after summation of heat losses and energy supplies.

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

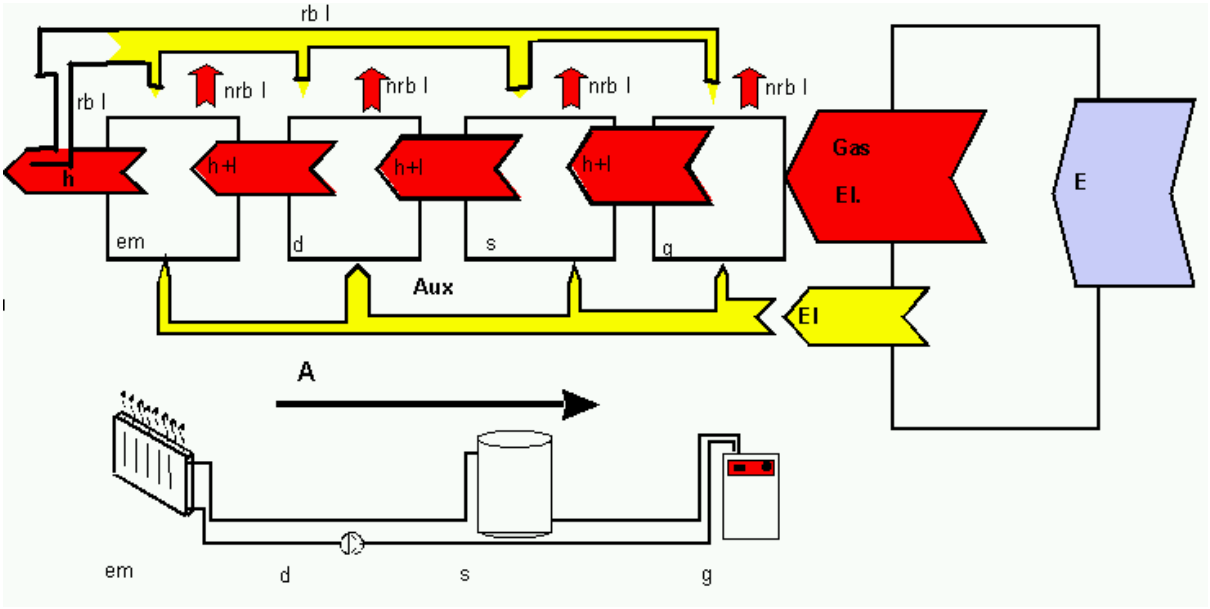
Other performance factors could be most useful. Suitable tabulated values for a sub-system are the following ratios (or their reciprocals):

$$\eta_{hx} = \frac{Q_{outx}}{Q_{inx}} \qquad I_{wx} = \frac{W_x}{Q_{outx}} \qquad (2)$$

5 Energy calculation for a space heating and domestic hot water system

5.1 Energy losses from the space heating system

The energy flow, the calculation direction and the structure of the space heating system is shown in figure 2.



Key

rb l	recoverable losses for space heating
nrb l	non recoverable loss
h	heat
l	loss
aux	auxiliary
gas	gas
el	electricity
E	primary energy
A	calculation direction
em	emission
d	distribution
s	storage
g	generation

Figure 2 — Energy flow, calculation direction and structure of a space heating system

The calculation starts with the heat need. For each sub-system, its heat loss, $Q_{h,x}$, is calculated and added to its heat output, to determine its required heat input.

As the emission heat losses increase the building envelope heat losses, these may be determined directly together with the heat need, without differentiating one from the other, according to EN ISO 13790 and with the data defined in prEN 15316-2.1.

The heat loss of a sub-system does not include the auxiliary energy. The electrical energy requirement W_x is calculated separately (if there is one), but the electrical energy also contributes to the system energy losses of the sub-system.

A distinction is made between

- parts of the system losses which are recoverable for the space heating;
- parts of the system losses which are recovered directly in the sub-system and subtract from the system heat losses of the sub-system.

The recoverable system losses for space heating contributes to the calculation of the recovered system losses according to prEN 13790 or by using a specific utilisation factor as presented in prEN 15315. The recovered system losses are subtracted from the space heat demand.

Directly in the sub-system recovered heat losses are not recoverable for space heating, but higher the performance of the sub-system: e.g. recovered stack losses for preheating the combustion air, water cooled circulation pumps where the cooling water is the distribution medium.

NOTE: Annex A provides an example for the heat emission sub-system.

The heat system losses of the space heating system without building generation devices, Q_{sh}, are calculated as follows:

$$Q_{sh} = Q_{h,em} + Q_{h,d} \quad (3)$$

where:

$Q_{h,em}$ heat loss of the heat emission sub-system according to prEN 15316-2.1;

$Q_{h,d}$ heat loss of the heat distribution sub-system according to prEN 15316-2.3;

The recoverable heat losses of the space heating system without building generation devices, $Q_{sh,rb}$ are calculated as follows:

$$Q_{sh,rb} = Q_{h,em,rb} + Q_{h,d,rb} \quad (4)$$

where:

$Q_{h,em,rb}$ recoverable heat loss of the heat emission sub-system according to prEN 15316-2.1;

$Q_{h,d,rb}$ recoverable heat loss of the heat distribution sub-system according to prEN 15316-2.3;

The electricity use as auxiliary energy of the space heating system without building generation devices, $Q_{sh,aux}$ is calculated as follows:

$$Q_{sh,aux} = Q_{h,em,aux} + Q_{h,d,aux} \quad (5)$$

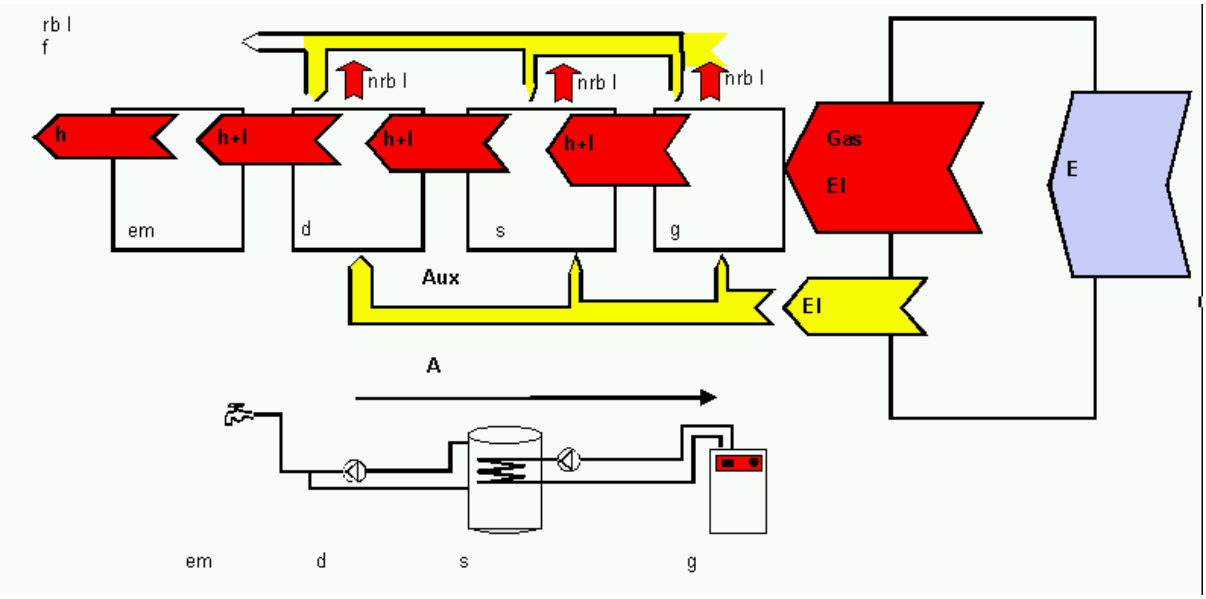
where:

$Q_{h,em,aux}$ auxiliary energy of the heat emission sub-system according to prEN 15316-2.1;

$Q_{h,d,aux}$ auxiliary energy of the heat distribution sub-system according to prEN 15316-2.3;

5.2 Energy losses from the domestic hot water system

The energy flow, the calculation direction and the structure of the domestic hot water system is shown in figure 3.



Key

rb l	recoverable losses for space heating
nrb l	non recoverable loss
h	heat
l	loss
aux	auxiliary
gas	gas
el	electricity
E	primary energy
A	calculation direction
em	emission
d	distribution
s	storage
g	generation

Figure 3 — Energy flow, calculation direction and structure of a domestic hot water system

The calculation starts with the heat needs. For each sub-system, its heat loss, Q_{wx}, is calculated and added to its heat output, to determine its required heat input.

The heat loss of a sub-system does not include the auxiliary energy. The electrical energy requirement, W_x, is calculated separately (if there is one), but the electrical energy also contributes to the system energy losses of the sub-system.

A distinction is made between

- parts of the system losses which are recoverable for the space heating;
- parts of the system losses which are recovered directly in the sub-system and subtract from the system heat losses of the sub-system.

The recoverable system losses for space heating contributes to the calculation of the recovered system losses according to prEN 13790 or by using a specific utilisation factor as presented in prEN 15315. The recovered system losses are subtracted from the space heat demand.

Directly in the sub-system recovered heat losses are not recoverable for space heating, but higher the performance of the sub-system: e.g. recovered stack losses for preheating the combustion air, water cooled circulation pumps where the cooling water is the distribution medium.

NOTE: Annex A provides an example for the heat emission sub-system.

NOTE: The calculation sheet (see annex B) provides an example for a space heating system with an electrical domestic hot water system. This sheet combines the results of the calculation for each sub-system regardless of the calculation method used to determine the system losses of each sub-system.

The system heat losses of the domestic hot water system, without building generation devices, Q_{sw}, are calculated as follows:

$$Q_{sw} = Q_{sw,em} + Q_{sw,d} + Q_{sw,s} \quad (6)$$

where:

$Q_{sw,em}$ heat loss due to a non-ideal emission system (i.e. tap),
e.g. where there will be a delay before the outlet temperature reaches the desired temperature;

$Q_{sw,d}$ heat loss of the domestic hot water distribution system according to prEN 15316-3.2;

The recoverable heat losses of the domestic hot water system without building generation devices, $Q_{sw, rb}$ are calculated as follows:

$$Q_{sw, rb} = Q_{sw,em,rb} + Q_{sw,d,rb} \quad (7)$$

where:

$Q_{sw,em,rb}$ recoverable heat loss of the heat emission sub-system;

$Q_{sw,d,rb}$ recoverable heat loss of the heat distribution sub-system according to prEN 15316-3.2;

The electricity use as auxiliary energy of the domestic hot water system, without building generation devices , $Q_{sw, aux}$ are calculated as follows:

$$Q_{sw, aux} = Q_{sw,em,aux} + Q_{sw,d,aux} \quad (8)$$

where:

$Q_{sw,em,aux}$ auxiliary energy of the heat emission sub-system according;

$Q_{sw,d,aux}$ auxiliary energy of the heat distribution sub-system according to prEN prEN 15316-3.2.$Q_{sw,s,aux}$

5.3 Simplified and detailed methods for calculation of the total system energy loss

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

Unless otherwise required, for new buildings with already designed space heating and domestic hot water systems and also for new domestic hot water systems installed in existing buildings detailed calculation methods in accordance with the level C or level D are applicable.

Any parameter may be used for the calculations. However, it is essential that the results correspond to the defined output values (required heat input for the sub-system, electrical energy requirement, recoverable heat losses) and that the performance indicators (input data required) follow the structure described in this standard, in order to ensure proper links to calculations for the following sub-systems and development of a common structure.

The level of details 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 systems.

Level B) For each sub-system, losses, electrical energy requirements 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, electrical energy requirements or efficiencies are calculated. Calculation is done on the basis of dimensions of the system, duties, loads and any other data which is assumed constant (or averaged) throughout the calculation period. The calculation method may be based on physics (detailed or simplified) or correlation methods.

Level D) Losses or efficiencies are calculated through 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, as available, for the different sub-systems of the heating system.

Annex A
(informative)

Sample of Sub-system
Heat emission sub-system

General

The heat requirements for the emission sub-system take into account the extra losses through the building envelope due to the following factors:

- non-uniform internal temperature distribution in each thermal zone (e.g. stratification, emitters along outside wall/window);
- emitters embedded in the building structure towards the outside;
- control strategy (e.g. local, central, setback).

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

- the type of emitters (e.g. radiator, convector, floor/wall/ceiling systems);
- the type of room/zone thermal control strategy and equipment (e.g. thermostatic valve, P, PI, PID control) and their capability to reduce the temperature variations and drift;
- the emplacement of the embedded emitter in the outside walls.

In order to respect the general structure of the system loss calculations, the performance of the emission sub-system should be given by:

- the type of the heating system;
- the type of the control system (including optimiser);
- the characteristics of the embedded emitters.

Based on these data, the output from the emission sub-system calculation should comprise:

- the emission system heat loss;
- the auxiliary energy consumption;
- the recoverable heat losses.

The calculations may be based on tabulated values or more detailed methods, but no other input data should be required.

Annex B
(informative)

Sample calculation of a space heating system and electrical domestic hot water system

			SPACE HEATING			DOMESTIC HOT WATER		
			A	B	C	D	E	F
	NEEDS		Heat demand			Hot water demand		
Q_x	Heat demand	kWh/period	100			20		

	System losses		heat loss $Q_{h,x}$	auxiliary energy W_x	recoverable loss Q_{rhh}	heat loss $Q_{w,x}$	auxiliary energy W_x	recoverable loss Q_{rwh}
Sle	Emission loss	kWh/period	10	2	2	0	0	0
Ie	Input emission (Q_x+Sle)	kWh/period	110	2	2	20	0	0
Sld	Distribution loss	kWh/period	15	4	10	10	2	5
Id	Input distribution (Ie+Sld)	kWh/period	125	6	12	30	2	5
Sls	Storage loss	kWh/period	-	0	0	10	1	6
Is	Input storage (Id+Sls)	kWh/period	125	6	12	40	3	11
Slg	Generation loss	kWh/period	25	1	16	0	0	0
Ig	Input generation (Is+Slg)	kWh/period	150	7	28	40	3	11
			↓ Net heat requirement		↓ Recoverable heat loss			↓ Recovered heat loss
		kWh/period	**133**	←	**14**	**+**		**3**

	Final energy		$Q_{f,h}$	W_h	**Total space heating**	$Q_{f,w}$	W_w	**Total hot water**
Q	Heat/energy requirement	kWh/period	133	7	**140**	40	3	**43**
f	Primary energy conversion factor	(-)	1	3	**-**	3	3	**-**
E	Primary energy ($Q \cdot f$)	kWh/period	133	21	**154**	120	9	**129**
	System performance coefficient $e = E/Q_x$	(-)			**1.54**			**6.45**

Annexe C
(informative)

Splitting and/or branching of the heating system

The heating system structure may be complex, e.g. including:

— more than one type of emitter, serving multiple zones;

— more than one “load” connected to the same generation system (typically space heating and domestic hot water production may be served by the same generation system);

— more than one generation system;

— more than one storage system;

— different types of energy used in the building.

Use of overall average values may not be practical (as this requires proper weighting), may not be available or may lead to significant errors.

In general, these cases may be solved by following the physical structure of the heating system.

Example 1: Heat requirements and emission losses of two parts of the heating system may be calculated separately and added up to provide the heat output for a common distribution sub-system.

Example 2: Heat requirements of the space heating distribution and the domestic hot water distribution sub-systems (and/or storage sub-systems) may be calculated separately and added up to provide the heat output for a common generation sub-system.

Example 3: Heat requirements of a distribution sub-system may be calculated and divided on more than one generation sub-system (the splitting may change over time).

This kind of “modularity” is always possible if the principle of addition of losses is respected.