BS EN 15316-4-5:2007

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

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

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ICS 91.140.10

British Standards

National foreword

This British Standard is the UK implementation of EN 15316-4-5:2007.

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

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Systèmes de chauffage dans les bâtiments - Méthode de calcul des besoins énergétiques et des rendements des systèmes - Partie 4-5 : Systèmes de génération de chauffage des locaux, performance et qualité des systèmes de chauffage urbain et des systèmes de grand volume

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Foreword

This document (EN 15316-4-5:2007) 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of an identical text or by endorsement, at the latest by January 2008, and conflicting national standards shall be withdrawn at the latest by January 2008.

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 prCEN/TR 15615.

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 United Kingdom.

Introduction

This European Standard presents a method for calculation of the energy performance of district heating systems and dwelling substations. The results of the calculations are the primary energy factor of the specific district heating system and the heat losses of the building substations. The method is applicable for all kinds of 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 calculations are based on the performance data of the district heating system and the building substations, respectively, which can be calculated or measured according to this standard and other European Standards cited herein.

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 district heating system and building substations by varying the input parameters;

— assessing the effect of possible energy conservation measures on an existing system by changing the method of operation or replacing parts of the system.

The user needs to refer to other European Standards, European directives and national documents for input data and detailed calculation procedures not provided by this European 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.

1 Scope

This European Standard is part of a set of standards on the method for calculation of system energy requirements and system efficiencies.

The scope of this specific part is to standardise the method of assessing the energy performance of district heating and cooling systems and to define:

— system borders;

— required inputs;

— calculation method;

— resulting outputs.

The method applies to district heating and cooling systems and any other kind of combined production for space heating and/or cooling and/or domestic hot water purposes.

Primary energy savings and CO_2 savings, which can be achieved by district heating systems compared to other systems, are calculated according to prEN 15603.

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 12241, *Thermal insulation for building equipment and industrial installations — Calculation rules (ISO 12241:1998)*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
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. Electrical energy input to the ventilation system for air transport and heat recovery is not considered as auxiliary energy, but as energy use for ventilation.

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

3.2
building substation
technical system to transform the parameter (temperature, pressure etc.) of a district heating system to the parameter of the building heating system and to control the building heating system

3.3
cogeneration
simultaneous generation in one process of thermal energy and electrical or mechanical energy

NOTE Also known as combined heat and power (CHP).

3.4
delivered energy
energy, expressed per energy carrier, supplied to the technical building systems through the system boundary, to satisfy the uses taken into account (e.g. heating, cooling, ventilation, domestic hot water, lighting, appliances) or to produce electricity

NOTE 1 For active solar and wind energy systems, the incident solar radiation on solar panels or on solar collectors or the kinetic energy of wind is not part of the energy balance of the building. It is decided at national level whether or not renewable energy produced on site is part of the delivered energy.

NOTE 2 Delivered energy can be calculated for defined energy uses or it can be measured.

3.5
district heating system
heating system, which supplies hot water or steam to the building thermal system from a heat generation system outside the building. The district heating system transmits heat through networks to a number of remote buildings

3.6
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, 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.

3.7
net energy
energy supplied by the energy systems to provide the required services. Recovered losses or gains are taken into account

3.8
net power production
electrical total power production minus all auxiliary energy consumption

3.9
non-renewable energy
energy taken from a source which is depleted by extraction (e.g. fossil fuels)

3.10
non-renewable primary energy factor
non-renewable primary energy divided by delivered energy, where the non-renewable energy is that required to supply one unit of delivered energy, taking account of the non-renewable energy required for extraction, processing, storage, transport, generation, transformation, transmission, distribution, and any other operations necessary for delivery to the building in which the delivered energy will be used

NOTE The non-renewable primary energy factor can be less than unity if renewable energy has been used.

3.11
power bonus method
all energy inputs are related to the thermal output and the electricity produced is counted as a bonus

3.12
primary energy
energy that has not been subjected to any conversion or transformation process

NOTE 1 Primary energy includes non-renewable energy and renewable energy. If both are taken into account, it can be called total primary energy.

NOTE 2 For a building, it is the energy used to produce the energy delivered to the building. It is calculated from the delivered and exported amounts of energy carriers, using conversion factors.

3.13
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

3.14
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 energy use of the heating or cooling system

3.15
renewable energy
energy from a source that is not depleted by extraction, such as solar energy (thermal and photovoltaic), wind, water power, renewed biomass

NOTE In ISO 13602-1, renewable resource is defined as "natural resource for which the ratio of the creation of the natural resource to the output of that resource from nature to the technosphere is equal to or greater than one".

3.16
surplus heat
hot streams from industry that is a by-product, impossible to avoid at production of the industrial product and could not be used for inside the industrial production

NOTE High quality heat from industry that can be used to produce electricity are not considered as surplus heat.

3.17
total primary energy factor
non-renewable and renewable primary energy divided by delivered energy, where the primary energy is that required to supply one unit of delivered energy, taking account of the energy required for extraction, processing, storage, transport, generation, transformation, transmission, distribution, and any other operations necessary for delivery to the building in which the delivered energy will be used

NOTE The total primary energy factor always exceeds unity.

4 Symbols and abbreviations

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	coefficient depending on the type of dwelling substation and its insulation level	-
D	coefficient depending on the type of dwelling substation and its control	-
E	energy in general, including primary energy, energy carriers (except quantity of heat, mechanical work and auxiliary (electrical) energy)	kWh [a]
f	primary energy factor	-
H	heat exchange coefficient	kWh/K
Q	quantity of heat	kWh
W	auxiliary (electrical) energy, mechanical work	kWh
η	efficiency	-
σ	relation of power production to heat production of a cogeneration appliance	-
β	relation of heat produced by a cogeneration appliance to the total heat production	-
Θ	temperature	°C
Φ	heat power	kW
[a] The unit depends on the type of energy carrier.		

Table 2 — Indices

amb	ambient	el	electrical	ls	loss
aux	auxiliary	F	fuel	out	output
chp	combined heat and power	gen	generation	P	primary
del	delivered	hn	heating network	rbl	recoverable
dh	district heating system	i, j	indices	T	thermal
e	external	in	input	tot	total

5 Principle of the method

5.1 General

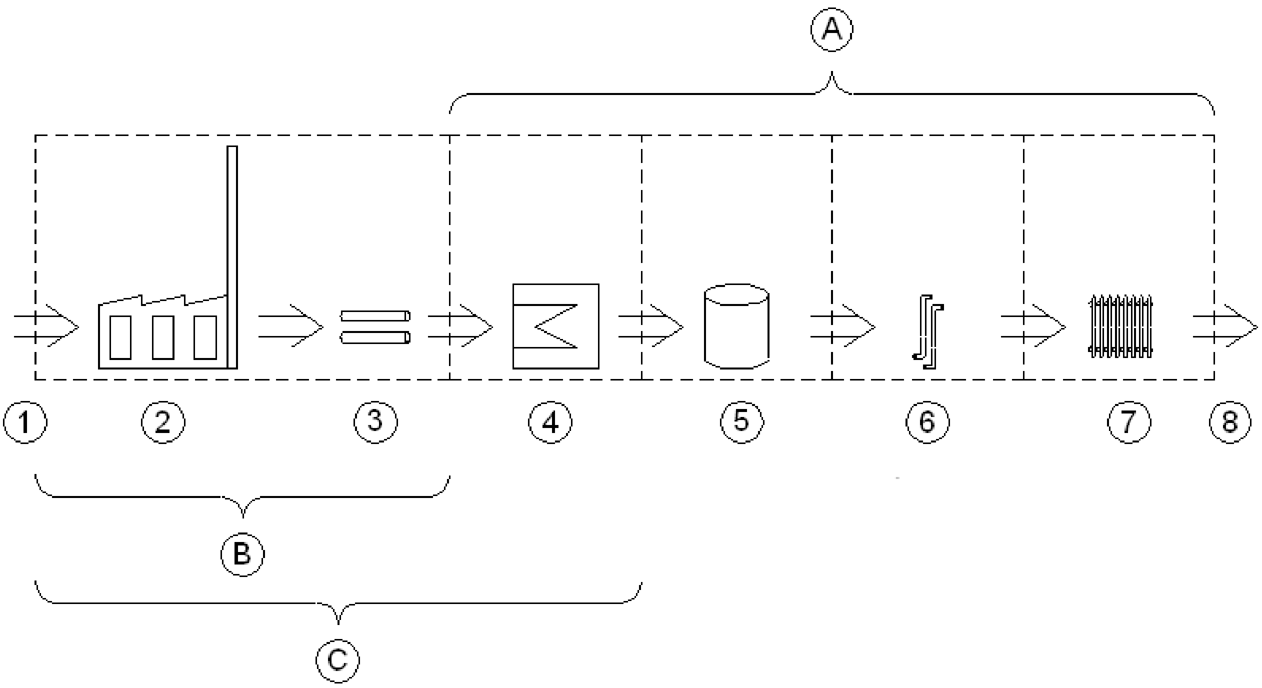
The performance of a district heating system is evaluated by dividing the district heating system into two parts according to Figure 1:

— 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, which consists of the heat generation appliances and the district heating network up to the primary side of the building substations. All systems needed to operate the system are included. The district heating system is rated by the balance of primary energy consumption of the heat generation and the heat delivered to the building substations.

The inside part is the building substation, including all systems from its primary side to the building heating system. 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.



Key

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 European Standard

Figure 1 — Systematics for rating the performance of district heating systems

5.2 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 $f_{P,dh}$ of the specific district heating system. The primary energy factor of a district heating system is defined as the primary energy input $E_{P,in}$ to the system divided by the heat Q_{del} delivered at the border of the supplied buildings, i.e. at the primary side of the building substations. Thus, the heat losses of the heating network are taken into account as well as all other energy used for extraction, preparation, refining, processing and transportation of the fuels to produce the heat. The primary energy factor is calculated by:

$$f_{P,dh} = \frac{E_{P,in}}{Q_{del}} \qquad (1)$$

where

$E_{P,in}$ is the primary energy input to the system;

Q_{del} is the heat delivered at the border of the supplied buildings.

The total primary energy factor is greater than or equal to one, while the non-renewable primary energy factor is defined to be greater than or equal to zero[1)].

The primary energy factor has to be determined within the thermodynamic system borders of the specific district heating system. This is usually the area supplied by one heating network bordered by the primary side of building substations.

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

For this energy balance, electrical power is included as well, using a primary energy factor according to that part of the fuel mix, which is replaced by heat and power cogeneration (power bonus method).

Waste heat, surplus heat and regenerative heat sources are included by appropriate primary energy factors. Primary energy factors for fuels and electricity (informative values) are given in prEN 15603. According to the regional situation of energy supply, deviating values may be defined in a national annex.

NOTE Especially in regions where surplus heat or waste heat is important, attention should be brought to the definition of primary energy factors for these types of energy inputs.

Thermal losses and auxiliary energy in the building substation are taken into account not as part of the district heating system but as part of the building heating system (see 5.3, 6.2 and Figure 1).

In principle, the energy balance is given by:

$$f_{P,dh} \cdot \sum_j Q_{del,j} + f_{P,el} \cdot E_{el,chp} = \sum_i f_{P,F,i} \cdot E_{F,i} \qquad (2)$$

where

$f_{P,dh}$ is the primary energy factor of the district heating system;

$f_{P,F,i}$ is the primary energy factor of the i-th fuel or final energy input;

$f_{P,el}$ Is the primary energy factor of replaced electrical power;

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1) In the case of heat and power cogeneration based on regenerative energy such as biogas, negative non-renewable primary energy factors may occur. These are set equal to zero.

$\Sigma Q_{del,j}$ is the sum of the heat energy consumption measured at the primary side of the building substations of the supplied buildings within the considered time period (usually one year);

$E_{el,chp}$ is the cogenerated electricity as defined in Annex II of Directive 2004/08/EC within the same considered time period;

$E_{F,i}$ is the final energy consumption of the i-th fuel for the production of heat and power within the same considered time period.

5.3 Energy requirements of the building substations

The energy performance of the building substations is rated by evaluation of their heat losses.

The electrical energy consumption of auxiliary equipment can be neglected.

The heat losses depend on:

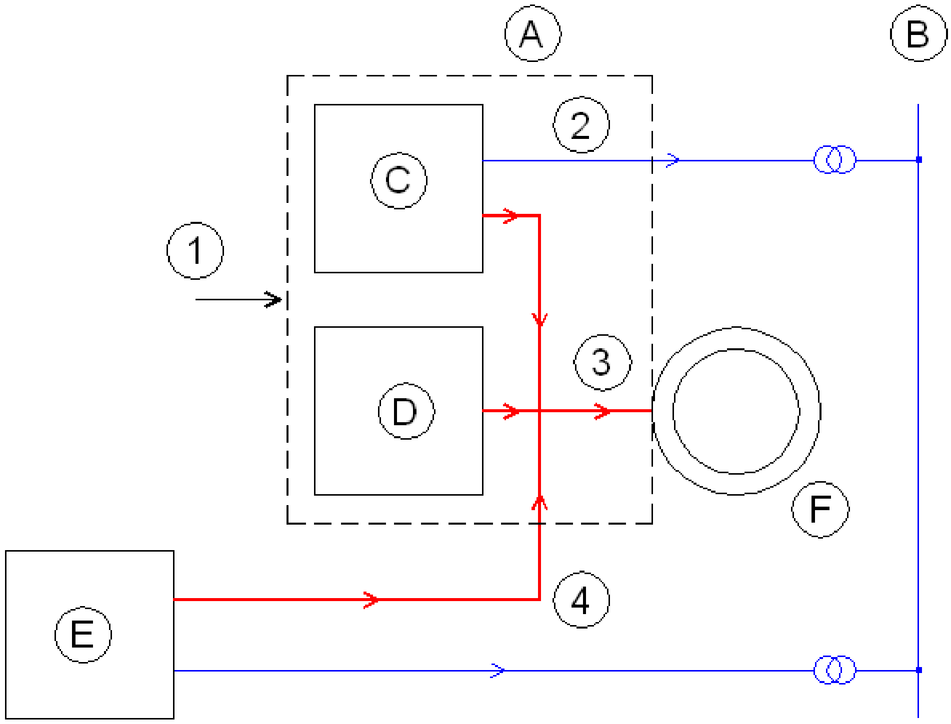
- thickness and the material of the insulation;
- piping material;
- surface of the whole piping system;
- load of the substation;
- difference between the heating media temperatures and the ambient temperature.

6 District heating system calculation

6.1 Primary energy factor

6.1.1 Calculation based on measurements

For existing district heating systems, all required inputs are usually known by measurements. The method of calculation is indicated in Figure 2.



Key

A system border: district heating system

B power supply network

C cogeneration plant, internal

D heating plant

E cogeneration plant, external

F heat consumers

1 $\sum_i E_{F,i}$

2 $E_{el,chp}$

3 $\sum_j Q_{del,j}$

4 $Q_{chp,e}$

Figure 2 — Method of the energy balance for an existing district heating system

The required inputs for the calculation are:

$E_{F,i}$ fuel input (final energy) to the heating plants and the cogeneration plants within the considered system within the considered time period (usually one year). This energy is measured at the point of delivery;

$f_{P,F,i}$ primary energy factor of the fuel inputs (final energy). Informative values of these factors are given in prEN 15603 or in a national annex;

$E_{el,chp}$ electricity production of the cogeneration plants of the considered system within the considered time period;

$Q_{chp,e}$ heat delivery to the considered system from external cogeneration plants within the considered time period;

$\Delta E_{el,chp,e}$ power losses of external cogeneration plants due to heat extraction within the considered time period (relevant only if heat is delivered to the considered system from outside, and this parameter is only applied if $f_{P,chp,e}$ is not available);

$f_{P,el}$ primary energy factor of electrical power;

$Q_{del,j}$ heat energy consumption measured at the primary side of the building substations of the supplied buildings within the considered time period;

η_{hn} efficiency of the heating network. Values of η_{hn} should be given in a national annex. The values usually range between 0,70 and 0,95.

The output of the calculation is the primary energy factor $f_{P,dh}$ of the considered district heating system, which yields from Equation (2):

$$f_{P,dh} = \frac{\sum_i E_{F,i} \cdot f_{P,F,i} - E_{el,chp} \cdot f_{P,el}}{\sum_j Q_{del,j}} \tag{3}$$

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 Q_e by its primary energy factor $f_{P,e}$.

If cogenerated heat $Q_{chp,e}$ is delivered to the considered district heating system from an external cogeneration plant and its primary energy factor $f_{P,chp,e}$ is not known, due to lack of information on some of the inputs of the above calculation, the appropriate contribution to the numerator of Equation (3) can instead be determined from the power loss $\Delta E_{el,chp,e}$, due to the heat extraction of the external cogeneration plant, the efficiency $\eta_{hn,e}$ of the external heating network and the primary energy factor $f_{P,el}$ of electrical power:

$$f_{P,chp,e} \cdot Q_{chp,e} = f_{P,el} \cdot \frac{\Delta E_{el,chp,e}}{\eta_{hn,e}} \tag{4}$$

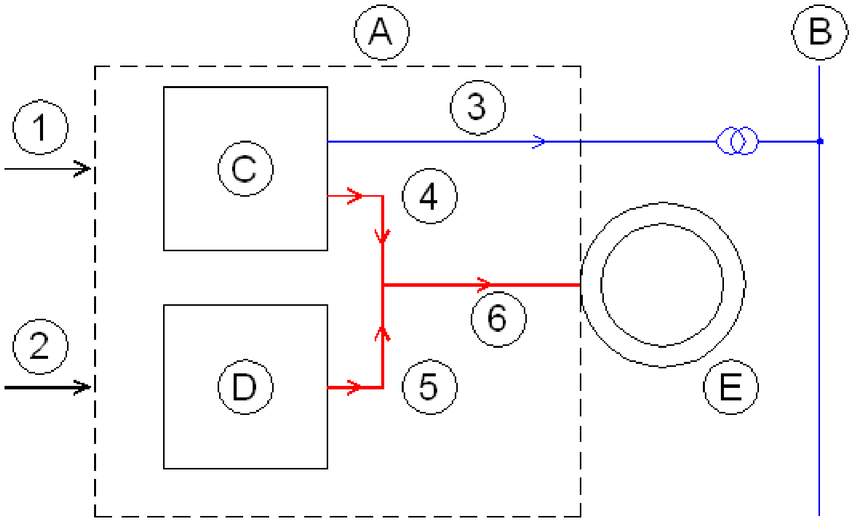
The power losses $\Delta E_{el,chp,e}$ of external cogeneration plants, delivering heat to the considered district heating system, should be determined from the total power losses of these plants and the relation of the heat delivery to the considered district heating system to the total heat production of these plants:

$$\Delta E_{el,chp,e} = \Delta E_{el,chp,e,tot} \frac{Q_{chp,e}}{Q_{chp,e,tot}} \tag{5}$$

Calculation examples are provided in Annex A.

6.1.2 Calculation from design data

For cogeneration systems, the usual design data are used as input for the calculation. The method of calculation is indicated in Figure 3.



Key

A system border: district heating system

B power supply network

C cogeneration appliance

D heat generator

E heat consumers

1 $E_{F,chp} = \frac{E_{el,chp} + Q_{chp}}{\eta_{chp}}$

2 $E_{F,T,gen} = \frac{Q_{T,gen}}{\eta_{T,gen}}$

3 $E_{el,chp} = \sigma \cdot Q_{chp}$

4 $Q_{chp} = \beta \cdot Q_{Gen}$

5 $Q_{T,gen} = (1-\beta) \cdot Q_{Gen}$

6 $Q_{Gen} = \frac{\sum_j Q_{del,j}}{\eta_{hn}}$

Figure 3 — Method of energy balance on the basis of design data

Efficiencies determined according to the appropriate European Standards should be used:

Combustion heat generator: $$\eta_{T,gen} = \frac{Q_{T,gen}}{E_{F,T,gen}} \quad (6)$$

cogeneration appliance: $$\eta_{chp} = \frac{E_{el,chp} + Q_{chp}}{E_{F,chp}} \qquad (7)$$

where

$E_{F,T,gen}$ is the fuel consumption of the combustion heat generator during the considered time period (usually one year);

$Q_{T,gen}$ is the heat production of the combustion heat generator measured at the output of the generator during the same considered time period;

$E_{F,chp}$ is the fuel consumption of the cogeneration appliance during the same considered time period;

$E_{el,chp}$ is the power production of the cogeneration appliance measured at the output of the appliance during the same considered time period;

Q_{chp} is the heat production of the cogeneration appliance measured at the output of the appliance during the same considered time period.

Besides the efficiency characteristics of the products, the following design data are required for the calculation:

- σ, power to heat ratio, relation of power production to heat production of the cogeneration appliance:

$$\sigma = \frac{E_{el,chp}}{Q_{chp}} \qquad (8)$$

- β, relation of heat produced by the cogeneration appliance to the total heat production:

$$\beta = \frac{Q_{chp}}{Q_{chp} + Q_{T,gen}} = \frac{Q_{chp}}{Q_{Gen}} \qquad (9)$$

The efficiency factor of the heating network η_{hn} should be evaluated in a national annex. Usual values range between 0,70 and 0,95.

The energy balance of Equation (2) becomes:

$$f_{P,dh} \cdot \sum_j Q_{del,j} + f_{P,el} \cdot E_{el,chp} = f_{P,chp} \cdot E_{F,chp} + f_{P,T,gen} \cdot E_{F,T,gen} \qquad (10)$$

Solving this equation for $f_{P,dh}$ and replacing all terms by the design data and the product efficiency characteristics, respectively, yields:

$$f_{P,dh} = \frac{(1+\sigma)\cdot\beta}{\eta_{hn}\cdot\eta_{chp}} \cdot f_{P,chp} + \frac{1-\beta}{\eta_{hn}\cdot\eta_{T,gen}} \cdot f_{P,T,gen} - \frac{\sigma\cdot\beta}{\eta_{hn}} \cdot f_{P,el} \qquad (11)$$

A calculation example is given in Annex A.

6.1.3 Auxiliary energy consumption

Auxiliary energy consumption is taken into account by applying only the net power production – i.e. the total power production minus all auxiliary energy consumption, e.g. for pumps – in the above energy balances.

If there is no electricity production in the district heating system, the energy consumption of the auxiliary equipment for heat generation and heat transportation has to be specifically taken into account in the energy balances.

6.1.4 Recoverable heat losses

No losses are recoverable.

6.1.5 Calculation period

It is recommended to use one year as the calculation period. Primary energy factors may be calculated separately for the winter period and the summer period. According to this method, it is even possible to calculate monthly balances; however this is usually too complex.

6.2 Energy requirements of a building substation

6.2.1 General

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

The energy requirement of a building substation comprises the system thermal loss and the auxiliary energy consumption of the substation.

6.2.2 System thermal loss

The system thermal loss of a building substation is calculated by:

$$Q_{dh,gen,ls} = H_{dh,gen} \cdot (\Theta_{dh,gen} - \Theta_{amb}) \quad \text{in kWh per year} \qquad (12)$$

where

$Q_{dh,gen,ls}$ is the system thermal loss of the heat generation (building substation);

$H_{dh,gen}$ is the heat exchange coefficient of the building substation given by Equation (13) in kWh/K·per year;

$\Theta_{dh,gen}$ is the average temperature of the building substation given by Equation (14) in °C;

Θ_{amb} is the ambient temperature at the location of the building substation in °C.

$$H_{dh,gen} = B_{dh,gen} \cdot \Phi_{dh,gen}^{\ 1/3} \quad \text{in kWh/K per year} \qquad (13)$$

where

$B_{dh,gen}$ is the coefficient (-) depending on the type of building substation and its insulation level. Values for $B_{dh,gen}$ should be given in a national annex. If national values are not available, informative values are given in Annex B;

$\Phi_{dh,gen}$ is the nominal heat power of the building substation in kW.

and

$$\Theta_{dh,gen} = D_{dh,gen} \cdot \Theta_{dh,gen,in} + (1 - D_{dh,gen}) \cdot \Theta_{dh,gen,out} \quad \text{in °C} \quad (14)$$

where

$D_{dh,gen}$ is the coefficient (-) depending on the type of building substation and its control. Values for $D_{dh,gen}$ should be given in a national annex. If national values are not available, informative values are given in Annex B;

$\Theta_{dh,gen,in}$ is the average heating medium temperature of the primary (input) circuit of the building substation in °C. Typical values should be given in a national annex. If national values are not available, informative values are given in Annex B;

$\Theta_{dh,gen,out}$ is the average heating medium temperature of the secondary (output) circuit of the building substation in °C, calculated in the same way as for any other type of heat generator (see prEN 15316-4-1).

The above equations are numerical equations. As the unit of the nominal heat power of the building substation is kW, the result of the calculation of the system thermal loss $Q_{dh,gen,ls}$ is kWh per year.

6.2.3 Auxiliary energy consumption

The auxiliary energy consumption is neglected.

$W_{dh,gen,aux} = 0$

6.2.4 Recoverable heat losses

If the building substation is located inside the heated space, the total heat losses of the building substation are recoverable.

$Q_{dh,gen,ls,rbl} = Q_{dh,gen,ls}$

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.

$Q_{dh,gen,ls,rbl} = 0$

Annex A
(informative)

Calculation examples

A.1 Typical situation of public utilities of a city

The public heat and power supply company of a city operates a cogeneration plant and a heat plant in another part of the city. Natural gas is used as fuel. The system border is the total heat supply area. The following figures were measured during one year:

Total heat consumption, measured at the primary side of the dwelling substations:	ΣQ_{del}	350 000 MWh/year
Annual gas consumption of the cogeneration plant, measured at the delivery point of the gas:		1 050 000 MWh/year
Annual gas consumption of the heating plant, measured at the delivery point of the gas:		50 000 MWh/year
Total gas consumption:		1 100 000 MWh/year
The unit of the gas consumption refers to the combustion energy (gross calorific), including the condensation enthalpy. Thus, the total gas consumption has to be corrected according to the condensation enthalpy, which is 10 %. Corrected value (net calorific) of the total gas consumption:	ΣE_F	1 000 000 MWh/year
Total power production, measured at the input to the public power supply network:		350 000 MWh/year
Internal power requirements for pumps etc.:		3 000 MWh/year
Net power production:	$E_{el,chp}$	347 000 MWh/year

No other values of Equation (3) apply. The primary energy factor of natural gas is 1,10 and the primary energy factor of electrical power is 2,80. The primary energy factor of the district heating system is determined from Equation (3):

$$f_{P,dh} = \frac{\sum_i E_{F,i} \cdot f_{P,F,i} - E_{el,chp} \cdot f_{P,el}}{\sum_j Q_{del,j}}$$

$$f_{P,dh} = \frac{1{,}000{,}000 \cdot 1.10 - 347{,}000 \cdot 2.80}{350{,}000} \approx 0.37$$

A.2 Typical situation of an industrial power plant supplying internal requirements and a city nearby

A large industrial complex operates its own power plant mainly for the internal requirements of power, heating and cooling energy. Further, the plant serves a nearby city with heat. The city district heating network is operated by a public enterprise of the city. The system border is the city district heating system.

From the technical data of the power plant and from measurements at the points of delivery, the following data are known:

Maximum power capacity of the plant at full condensation operation:		350 MW
Average power capacity during heat extraction operation:		300 MW
Power loss due to heat extraction (350 - 300) / 300:		16 7 %
Total annual power production of the plant:		2 200 000 MWh/year
Total annual heat extraction of the plant:		1 900 000 MWh/year
Total annual power loss of the plant (16,7 % of 2 200 000 MWh/year)		366 700 MWh/year
Total annual heat delivery to the city district heating system:		1 600 000 MWh/year
Net power loss due to the district heating system (delivered heat / total heat · power loss = 1 600 000 / 1 900 000 · 366 700):	$\Delta E_{el,chp,e}$	308 800 MWh/year
Total heat consumption within the district heating system:	ΣQ_{del}	1 400 000 MWh/year

The primary energy factor of the district heating system is determined from Equation (3):

$$f_{P,dh} = \frac{\sum_i E_{F,i} \cdot f_{P,F,i} - E_{el,chp} \cdot f_{P,el}}{\sum_j Q_{del,j}}$$

The primary energy factor of electrical power is 2,80 and the efficiency of the external heating network is 0,90. Using Equation (4) and (5) yields:

$$f_{P,chp,e} \cdot Q_{chp,e} = f_{P,el} \cdot \frac{\Delta E_{el,chp,e}}{\eta_{hn,e}} \quad \text{with} \quad \Delta E_{el,chp,e} = \Delta E_{el,chp,e,tot} \frac{Q_{chp,e}}{Q_{chp,e,tot}}$$

$$f_{P,dh} = \frac{2.80 \cdot 308{,}800}{0.90 \cdot 1{,}400{,}000} \approx 0.69$$

A.3 Typical situation of a small heat and power cogeneration system

A small heat and power cogeneration system is planned to supply a new settlement of 100 one-family houses. The design heat load of the settlement is 500 kW and the base load is 50 kW. A gas engine shall be used for heat and power cogeneration. Its heat power is 50 kW, the electrical power is 40 kW and the fuel consumption is 115 kW. The cogeneration module can operate 6 000 hours per year determined from the frequency of the heat loads. The remaining heat is produced by gas fired heating boilers. The total heat energy requirement equals 1 400 hours full load operation per year. All efficiency values are based on net calorific values.

Efficiency of the cogeneration module: η_{chp} = (40 + 50) / 115 = 0,78

Efficiency of the heating vessels: $\eta_{T,gen}$ = 0,87

Efficiency of the heating network: η_{hn} = 0,90

Power to heat ratio of the cogeneration module: σ = 40 / 50 = 0,80

Cogeneration heat to total heat ratio: β = (50 · 6 000) / (500 · 1 400) = 0,43

The primary energy factor of natural gas is 1,10 and the primary energy factor of electrical power is 2,80. The primary energy factor of the district heating system is determined from Equation (11):

$$f_{P,dh} = \frac{(1+\sigma)\cdot\beta}{\eta_{hn}\cdot\eta_{chp}}\cdot f_{P,chp} + \frac{1-\beta}{\eta_{hn}\cdot\eta_{T,gen}}\cdot f_{P,T,gen} - \frac{\sigma\cdot\beta}{\eta_{hn}}\cdot f_{P,el}$$

$$f_{P,DH} = \frac{(1+0.80)\cdot 0.43}{0.90\cdot 0.78}\cdot 1.10 + \frac{1-0.43}{0.90\cdot 0.87}\cdot 1.10 - \frac{0.80\cdot 0.43}{0.90}\cdot 2.80$$

$$\approx 0.94$$

Annex B
(informative)

Building substation performance

Table B.1 — Coefficient $B_{dh,gen}$ as a function of insulation class and type of network

	Insulation class of the components of the dwelling substation according to EN ISO 12241			
Insulation of secondary circuit	4	3	2	1
Insulation of primary circuit	5	4	3	2
Type of network	**Coefficient $B_{dh,gen}$ [-]**			
Hot water, low temperature	3,5	4,0	4,4	4,9
Hot water, high temperature	3,1	3,5	3,9	4,3
Vapour, low pressure	2,8	3,2	3,5	3,9
Vapour, high pressure	2,6	3,0	3,3	3,7

Table B.2 — Average primary heating medium temperature $\Theta_{dh,gen,in}$ and coefficient $D_{dh,gen}$ according to the type of dwelling substation

Type of dwelling substation	**Average primary heating medium temperature $\Theta_{dh,gen,in}$ (°C)**	**Coefficient $D_{dh,gen}$ (-)**
Hot water, low temperature	105	0,6
Hot water, high temperature	150	0,4
Vapour, low pressure	110	0,5
Vapour, high pressure	180	0,4

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2) To be published.

3) To be published.

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