

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

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

ICS 91.140.10

National foreword

This British Standard is the UK implementation of EN 15316-4-2:2008.

The UK participation in its preparation was entrusted to Technical Committee RHE/24, Central heating installations.

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

BSI, as the UK member of CEN, is obliged to publish EN 15316-4-2:2008 as a British Standard. However, attention is drawn to the fact that during the development of this European Standard, the UK voted against its approval as a European Standard

The UK voted against this standard on the grounds that it was considered disproportionate to the essential requirements of the EU Energy Performance of Buildings Directive (2002/91/EC), which it supports. In the opinion of the UK committee, EN 15316-4-2:2008 is regarded as unsuitable for existing buildings where the data required are unlikely to be available.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

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Contents

	page
Foreword.....	4
Introduction	6
1 Scope	6
2 Normative references	7
3 Terms, definitions, symbols and units	8
3.1 Terms and definitions	8
3.2 Symbols and units	13
4 Principle of the method	15
4.1 Heat balance of generation subsystem	15
4.2 Energy input needed to meet the heat requirements	18
4.3 Auxiliary energy $W_{HW,gen,aux}$	19
4.4 Recoverable, recovered and unrecoverable heat losses	19
4.5 Calculation periods	19
4.6 Calculation by zones	19
4.7 Heat pumps with combined space heating and domestic hot water production	20
5 Generation subsystem calculation	22
5.1 General.....	22
5.2 Simplified seasonal performance method based on system typology (system typology method).....	22
5.2.1 Principle of the system typology method	22
5.2.2 Calculation procedure of the system typology method	23
5.3 Detailed case specific seasonal performance method based on component efficiency (bin-method).....	24
5.3.1 Principle of the bin method	24
5.3.2 Input data for the calculation with the bin method	28
5.3.3 Calculation steps to be performed in the bin method	29
5.3.4 Heat energy requirements for space heating and domestic hot water mode for the bins	33
5.3.5 Heating capacity and COP at full load	34
5.3.6 COP at part load operation	38
5.3.7 Thermal losses through the generator envelope	39
5.3.8 Calculation of back-up heater	40
5.3.9 Running time of the heat pump.....	48
5.3.10 Auxiliary energy.....	55
5.3.11 Total thermal losses and recoverable thermal loss of the generation subsystem.....	56
5.3.12 Calculation of total energy input.....	58
5.3.13 Summary of output values.....	63
Annex A (informative) Example of evaluation of meteorological data.....	64
Annex B (informative) Default values of parameters for the case specific seasonal performance method	69
B.1 Controller setting of flow temperature (heating characteristic curve).....	69
B.2 Temperature correction factor for domestic hot water storage loading	70
B.3 Average water temperature of domestic hot water storages	70
B.4 Generator envelope	70
B.5 Generation subsystem auxiliaries	71
B.6 Factor f_{combi} for simultaneous operation	71
B.7 Temperature reduction factor linked to location.....	71
B.8 Efficiency value of the electrical back-up heater for space heating or DHW operation	72

Annex C (informative) Calculation method for source and sink temperature correction with fixed exergetic efficiency	73
Annex D (informative) Calculation example	77
D.1 Detailed calculation example	77
D.1.1 System configuration	77
D.1.2 Input data for the calculation (according to 5.3.2)	77
D.1.3 Calculation	80
D.2 Calculation example (spreadsheet format)	99
D.2.1 System configuration	99
D.2.2 Input data for the calculation (according to 5.3.2)	99
D.2.3 Calculation	100
Annex E (informative) Example for tabulated values of the system typology method as national annex for the Netherlands	104
E.1 General	104
E.2 Scope	104
E.3 References	104
E.4 Heat pump seasonal performance	104
E.4.1 Residential buildings	104
E.4.2 Non-residential buildings	105
E.5 Heat pump installation efficiency	106
E.6 Heat pump installation energy consumption	108
E.7 Heat pump installation auxiliary energy consumption	108
Annex F (informative) Example values for parameters to accomplish the case specific heat pump calculation method (bin method)	109
F.1 General	109
F.2 Temperatures	109
F.2.1 Source temperatures	109
F.3 Example values for heating capacity and coefficient of performance for electrically driven heat pumps	111
F.3.1 General	111
F.3.2 Heating capacity	111
F.3.3 COP	114
F.4 Gas engine-driven heat pumps	116
F.4.1 Preface	116
F.4.2 Heating capacity	117
F.4.3 COP	119
F.5 Absorption heat pumps	121
F.5.1 General	121
F.5.2 NH ₃ /H ₂ O heat pumps – outside air-to-water	122
F.5.3 NH ₃ /H ₂ O heat pumps – brine-to-water	123
F.5.4 NH ₃ /H ₂ O heat pumps – water-to-water	124
F.5.5 H ₂ O/LiBr double effect heat pumps	125
F.6 Heat pumps with domestic hot water production (DHW) - Heating capacity of domestic hot water heat pumps	126
Bibliography	127

Foreword

This document (EN 15316-4-2:2008) 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 December 2008, and conflicting national standards shall be withdrawn at the latest by December 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 [13].

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 is part of a series of standards on the methods for calculation of system energy requirements and system efficiencies. The framework for the calculation is described in the general part (EN 15316-1 [9]).

The energy performance can be assessed by determining either the heat generation sub-system efficiencies or the heat generation sub-system losses due to the system configuration.

This European Standard presents methods for calculation of the additional energy requirements of a heat generation sub-system in order to meet the distribution 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. Product data, e.g. heating capacity or *COP* of the heat pump, shall be determined according to European test methods. If no European methods exist, national methods can be used.

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 sub-system, by applying the method to several possible options;
- assessing the effect of possible energy conservation measures on an existing heat generation sub-system, by calculating of the energy use with and without the energy conservation measure.

Only the calculation method is normative. The user shall refer to other European Standards or to national documents for input data. Additional values necessary to complete the calculations are to be given in a national annex, if no national annex is available, default values are given in an informative annex where appropriate.

1 Scope

This European Standard covers heat pumps for space heating, heat pump water heaters (HPWH) and heat pumps with combined space heating and domestic hot water production in alternate or simultaneous operation, where the same heat pump delivers the heat to cover the space heating and domestic hot water heat requirement.

The scope of this part is to standardise the:

- required inputs,
- calculation methods,
- resulting outputs,

for heat generation by the following heat pump systems, including control, for space heating and domestic hot water production:

- electrically-driven vapour compression cycle (VCC) heat pumps,
- combustion engine-driven vapour compression cycle heat pumps,

— thermally-driven vapour absorption cycle (VAC) heat pumps,
using combinations of heat source and heat distribution as listed in Table 1.

Table 1 — Heat sources and heat distribution in the scope of this European Standard

Heat source	Heat distribution
Outdoor air	Air
Exhaust-air	Water
Indirect ground source with brine distribution	Direct condensation of the refrigerant in the appliance (VRF)
Indirect ground source with water distribution	
Direct ground source (Direct expansion (DX))	
Surface water	
Ground water	

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 255-3:1997, *Air conditioners, liquid chilling packages and heat pumps with electrically driven compressors — Heating mode — Part 3: Testing and requirements for marking for sanitary hot water units*

EN 308, *Heat exchangers — Test procedures for establishing performance of air to air and flue gases heat recovery devices*

EN 14511:2007 (all parts), *Air conditioners, liquid chilling packages and heat pumps with electrically driven compressors for space heating and cooling*

CEN/TS 14825:2003, *Air conditioners, liquid chilling packages and heat pumps with electrically driven compressors for space heating and cooling — Testing and rating at part load conditions*

prEN 15203, *Energy performance of buildings — Application of calculation of energy use to existing buildings*

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

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 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*

EN 15316-4-1, *Heating systems in buildings — Method for calculation of system energy requirements and system efficiencies — Part 4-1: Space heating generation systems, combustion systems (boilers)*

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

EN ISO 13790 *Energy performance of buildings — Calculation of energy use for space heating and cooling (ISO 13790:2008)*

EN ISO 15927-6, *Hygrothermal performance of buildings — Calculation and presentation of climatic data — Part 6: Accumulated temperature differences (degree-days) (ISO 15927-6:2007)*

3 Terms, definitions, symbols and units

3.1 Terms and definitions

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

3.1.1

alternate operation

production of heat energy for the space heating and domestic hot water system by a heat generator with double service by switching the heat generator either to the domestic hot water operation or the space heating operation

3.1.2

application rating conditions

mandatory rated conditions within the operating range of the unit that are published by the manufacturer or supplier

3.1.3

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 [15], the energy used for pumps and valves is called "parasitic energy".

NOTE 3 In the frame of this standard, the driving energy input for electrically-driven heat pumps in the system boundary of the *COP* according to EN 14511 and an electrical back-up heater is not entitled auxiliary energy but only additional electrical input not considered in the *COP*.

3.1.4

balance point temperature

temperature at which the heat pump heating capacity and the building heat load are equal

3.1.5

bin

statistical temperature class (sometimes a class interval) for the outdoor air temperature, with the class limits expressed in a temperature unit

3.1.6

building services

services provided by technical building systems and by appliances to provide indoor climate conditions, domestic hot water, illumination levels and other services related to the use of the building

3.1.7

calculation period

period of time over which the calculation is performed

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

3.1.8

calculation step

discrete time interval for the calculation of the energy needs and uses for heating, cooling, humidification and dehumidification

NOTE 1 Typical discrete time intervals are one hour, one month or one heating and/or cooling season, operating modes, and bins.

NOTE 2 In the frame of the bin method, calculation steps are based on outdoor temperature classes.

3.1.9

coefficient of performance *COP*

ratio of the heating capacity to the effective power input of the unit

3.1.10

cumulative frequency

frequency of the outdoor air temperature cumulated over all 1 K bins

3.1.11

cut-out period

time period in which the electricity supply to the heat pump is interrupted by the supplying utility

3.1.12

domestic hot water heating

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

3.1.13

effective power input

average power input of the unit within the defined interval of time obtained from:

- the power input for operation of the compressor or burner and any power input for defrosting;
- the power input for all control and safety devices of the unit;
- the proportional power input of the conveying devices (e.g. fans, pumps) for ensuring the transport of the heat transfer media inside the unit

3.1.14

electrically-driven heat pump

in the frame of this European Standard, electrically-driven heat pumps denote vapour compression cycle heat pumps, which incorporate a compressor that is driven by an electric motor

3.1.15

energy need for domestic hot water

heat to be delivered to the needed amount of domestic hot water to raise its temperature from the cold network temperature to the prefixed delivery temperature at the delivery point, not taking into account the technical building thermal systems

3.1.16

energy need for heating or cooling

heat to be delivered to or extracted from a conditioned space to maintain the intended temperature during a given period of time, not taking into account the technical building thermal systems

NOTE 1 The energy need is calculated and cannot easily be measured.

NOTE 2 The energy need can include additional heat transfer resulting from non-uniform temperature distribution and non-ideal temperature control if they are taken into account by increasing (decreasing) the effective temperature for heating (cooling) and not included in the heat transfer due to the heating (cooling) system.

3.1.17

energy use for space heating or cooling or domestic hot water

energy input to the heating, cooling or domestic hot water system to satisfy the energy need for heating, cooling (including dehumidification) or domestic hot water, respectively

NOTE If the technical building system serves several purposes (e.g. heating and domestic hot water) it can be difficult to split the energy use into that used for each purpose. It can be indicated as a combined quantity (e.g. energy need for space heating and domestic hot water).

3.1.18

frequency

(statistical) frequency of an event is the number of times the event occurred in the sample. The frequencies are often graphically represented in histograms. In the frame of this European Standard, the frequency of the outdoor air temperature is evaluated based on a sample of hourly-averaged data for one year

3.1.19

heat generator with double service

heat generator which supplies energy to two different systems, e.g. the space heating system and the domestic hot water system in alternate or simultaneous combined operation

3.1.20

heat pump

unitary or split-type assemblies designed as a unit to transfer heat. It includes a vapour compression refrigeration system or a refrigerant/sorbent pair to transfer heat from the source by means of electrical or thermal energy at a high temperature to the heat sink

3.1.21

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)

3.1.22

heat transfer medium

any medium (water, air, etc.) used for the transfer of the heat without change of state. It can be:

- the fluid cooled by the evaporator;
- the fluid heated by the condenser;
- the fluid circulating in the heat recovery heat exchanger

3.1.23

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

3.1.24

heating capacity Φ_g

heat given off by the unit to the heat transfer medium per unit of time

NOTE If heat is removed from the indoor heat exchanger for defrosting, it is taken into account.

3.1.25

heating or cooling season

period of the year during which a significant amount of energy for heating or cooling is needed

NOTE The season lengths are used to determine the operation period of technical systems.

3.1.26

internal temperature

arithmetic average of the air temperature and the mean radiant temperature at the centre of the occupied zone

NOTE This is the approximate operative temperature according to EN ISO 7726 [14].

3.1.27

low temperature cut-out

temperature at which heat pump operation is stopped and the total heat requirements are covered by a back-up heater

3.1.28

operating range

range indicated by the manufacturer and limited by the upper and lower limits of use (e.g. temperatures, air humidity, voltage) within which the unit is deemed to be fit for use and has the characteristics published by the manufacturer

3.1.29

part load operation

operation state of the technical system (e.g. heat pump) where the actual load requirement is below the actual output capacity of the device

3.1.30

part load ratio

ratio between the generated heat during the calculation period and the maximum possible output from the heat generator during the same calculation period

3.1.31

primary pump

pump mounted in the circuit containing the generator and hydraulic decoupling, e.g. a heating buffer storage in parallel configuration or a hydraulic distributor

3.1.32

produced heat

heat produced by the generator subsystems, i.e. the heat produced to cover the energy requirement of the distribution subsystem and the generation subsystem heat losses for space heating and/or domestic hot water

3.1.33

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

3.1.34

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

3.1.35

seasonal performance factor *SPF*

in the frame of this European Standard, the ratio of the total annual energy delivered to the distribution subsystem for space heating and/or domestic hot water to the total annual input of driving energy (electricity in case of electrically-driven heat pumps and fuel/heat in case of combustion engine-driven heat pumps or absorption heat pumps) plus the total annual input of auxiliary energy

3.1.36

set-point temperature of a conditioned zone

internal (minimum intended) temperature, as fixed by the control system in normal heating mode, or internal (maximum intended) temperature, as fixed by the control system in normal cooling mode

3.1.37

simultaneous operation

simultaneous production of heat energy for the space heating and domestic hot water system by a heat generator with double service, e.g. by refrigerant desuperheating or condensate subcooling

3.1.38

space heating

process of heat supply for thermal comfort

3.1.39

standard rating condition

mandatory condition that is used for marking and for comparison or certification purposes

3.1.40

system thermal losses

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

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

3.1.41

technical building system

technical equipment for heating, cooling, ventilation, domestic hot water, lighting and electricity production composed by sub-systems

NOTE 1 A technical building system can refer to one or to several building services (e.g. heating system, space heating and domestic hot water system).

NOTE 2 Electricity production can include cogeneration and photovoltaic systems.

3.1.42

technical building sub-system

part of a technical building system that performs a specific function (e.g. heat generation, heat distribution, heat emission)

3.2 Symbols and units

For the purposes of this document, the following symbols and units (Table 2), abbreviations (Table 3) and indices (Table 4) apply.

Table 2 — Symbols and units

Symbol	Name of quantity	Unit
ϕ	Thermal power, heating capacity, heat flow rate	W
η	Efficiency factor	-
θ	Celsius temperature	°C
ρ	Density	kg/m ³
$\Delta\theta$	Temperature difference, - spread	K
Δp	Pressure difference	Pa
b	Temperature reduction factor	-
c	Specific heat capacity	J/(kg·K)
DH	Degree hours	°Ch
COP	Coefficient of performance	W/W
COP_t	Coefficient of performance for the tapping of hot water	W/W
E	Quantity of energy, fuel	J
f	Factor (dimensionless)	-
β	Load factor	-
m'	Mass flow rate	kg/s
N	Number of items	-
k	Factor (fraction)	-
P	Power, electrical power	W
Q	Quantity of heat	J
SPF	Seasonal performance factor	-
t	Time, period of time	s
T	Thermodynamic temperature	K
V	Volume	m ³
V'	Volume flow rate	m ³ /s
W	Auxiliary (electrical) energy	J

Table 3 — Abbreviations

ATTD	Accumulated time-temperature difference
DHW	Domestic hot water
SH	Space heating
TTD	Time-temperature difference
VCC	Vapour compression cycle
VAC	Vapour absorption cycle

Table 4 — Indices

$\Delta\theta$	temperature corrected	eng	engine	nrbl	non recoverable
θ_{lim}	lower temperature limit	es	storage values according to EN 255-3:1997, phase 4	on	running, in operation
θ_{lim}	upper temperature limit	ex	exergetic	opr	operating, operation limit
amb	ambient	f	flow	out	output from subsystem
aux	auxiliary	gen	generation subsystem	p	pipe
avg	average	H	space heating	r	return
bal	balance point	hot	hot process side	rbl	recoverable
bu	back-up (heater)	ho	hour	rvd	recovered
cap	lack of capacity	hp	heat pump	st	storage
co	cut-out	i	internal	sby	stand-by
cold	cold process side	in	input to subsystem	sk	sink
combi	combined operation	j	index, referring to bin j	sngl	single (operation)
crnt	carnot	k	index	sc	source
dis	distribution subsystem	ls	loss	standard	according to standard testing
des	at design conditions	ltc	low temperature cut-out	tot	total
e	external	max	maximum	w	water, heat transfer medium
eff	effective	n	nominal	W	domestic hot water (DHW), DHW operation

NOTE The indices specifying the symbols in this standard are put in the following order:

- the first index represents the type of energy use (H = space heating, W = domestic hot water).
If the equation can be applied for different energy uses by using the values of the respective operation mode, the first level index is omitted;
- the second index represents the subsystem or generator (gen = generation, dis = distribution, hp = heat pump, st = storage, etc.);
- the third index represents the type (ls = losses, gs = gains, in = input, etc.);
- other indices can be used for more details (rvd = recovered, rbl = recoverable, i = internal, etc.);
- a prefix n means non, rbl - recoverable, nrbl – non-recoverable.

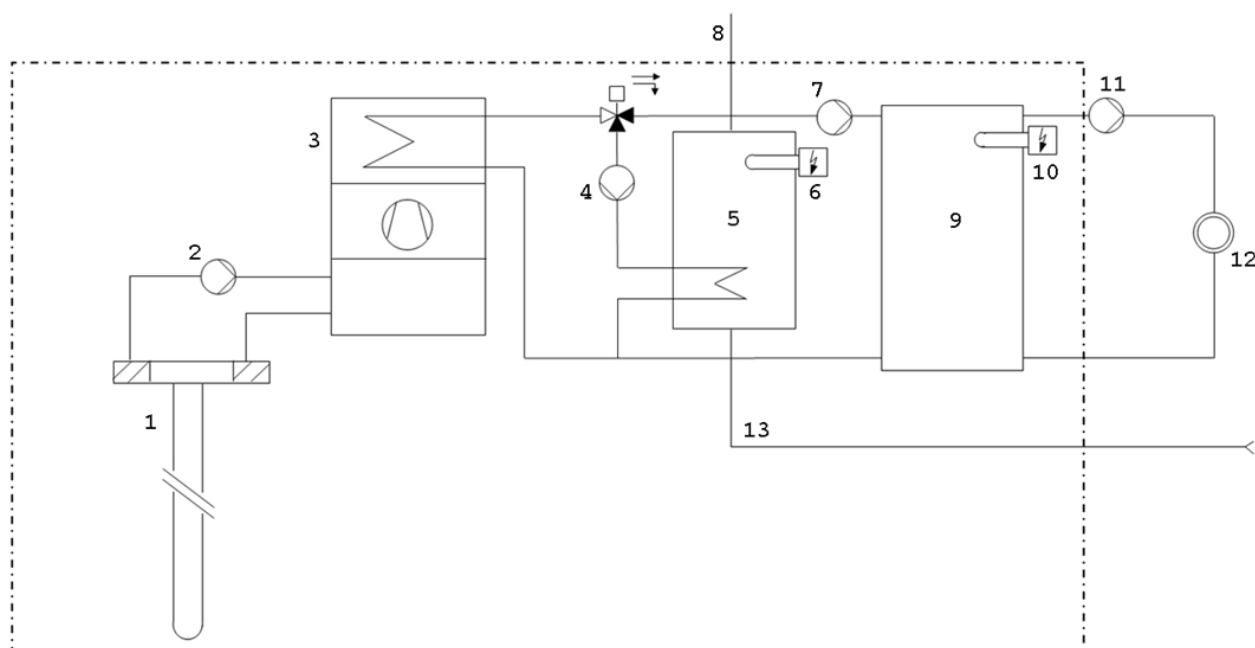
The indices are separated by a comma.

4 Principle of the method

4.1 Heat balance of generation subsystem

System boundary

The system boundary defines the components of the entire heating systems that are considered in this European Standard. For the heat pump generation subsystem the system boundary comprises the heat pump, the heat source system, attached internal and external storages and attached electrical back-up heaters. Auxiliary components connected to the generation subsystem are considered, as long as no transport energy is transferred to the distribution subsystem. For fuel back-up heaters the required back-up energy is determined in this European Standard, however, the efficiency calculation shall be accomplished according to the appropriate other part(s) of EN 15316 (see 4.6). The system boundary is depicted in Figure 1.



Key

- | | |
|---|--|
| 1 heat source system (here: vertical borehole heat exchanger) | 8 DHW hot water outlet |
| 2 source pump | 9 heating buffer storage |
| 3 heat pump | 10 space heating back-up heater |
| 4 DHW storage loading pump | 11 circulation pump space heating distribution subsystem |
| 5 DHW storage | 12 heat emission subsystem |
| 6 DHW back-up heater | 13 DHW cold water inlet |
| 7 primary pump | |

Figure 1 — System boundary of the generation subsystem

Physical factors taken into account

The calculation method takes into account the following physical factors, which have an impact on the seasonal performance factor and thereby on the required energy input to meet the heat requirements of the distribution subsystems:

- type of generator configuration (monovalent, bivalent);
- type of heat pump (driving energy (e.g. electricity or fuel), thermodynamic cycle (VCC, VAC));
- combination of heat source and sink (e.g. ground-to-water, air-to-air);
- space heating and domestic hot water energy requirements of the distribution subsystem(s);
- effects of variation of source and sink temperature on heating capacity and *COP* according to standard product testing;
- effects of compressor control in part load operation (ON-OFF, stepwise, variable speed units) as far as they are reflected in the heating capacity and *COP* according to standard testing; or further test results on part load operation exist;
- auxiliary energy input needed to operate the generation subsystem not considered in standard testing of heating capacity and *COP*;
- system thermal losses due to space heating or domestic hot water storage components, including the connecting pipework;
- location of the generation subsystem.

Calculation structure

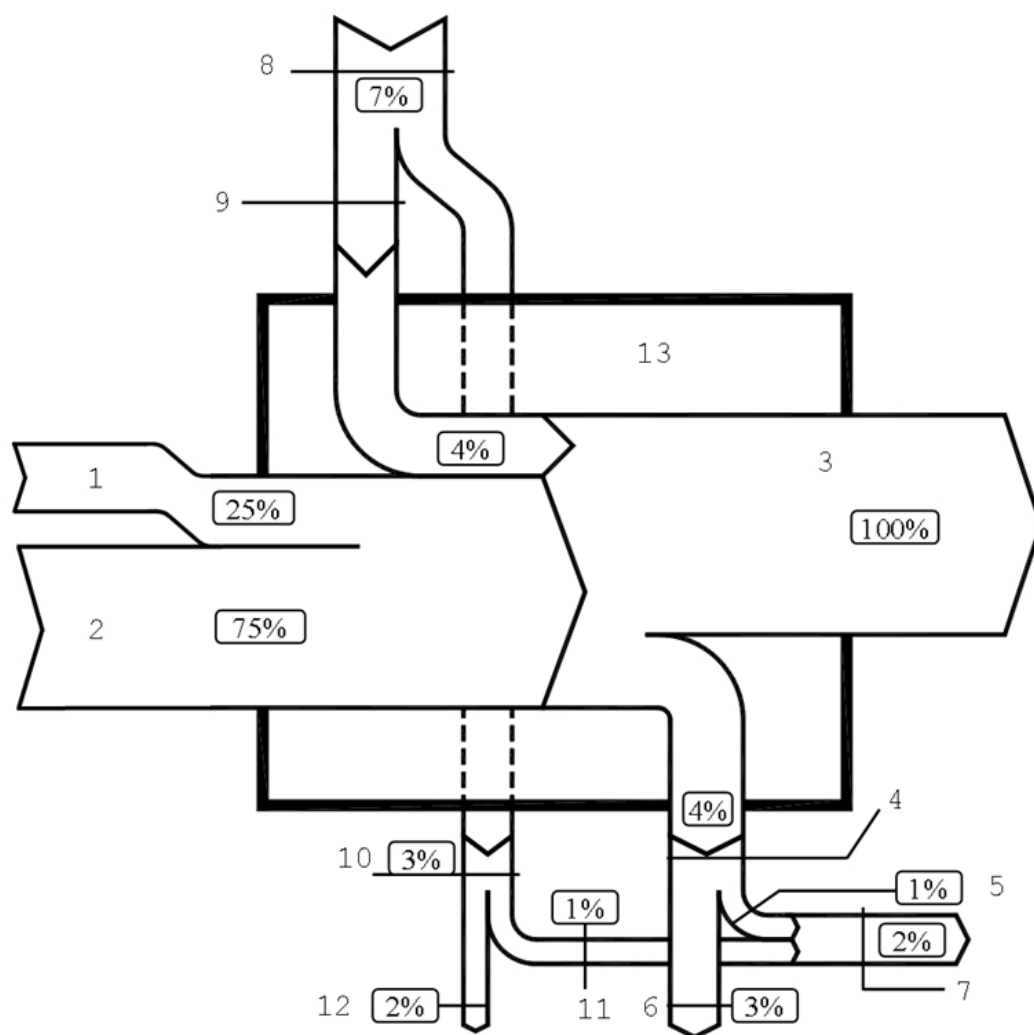
The calculation is performed considering the following input data:

- type, configuration and design of the generation subsystem;
- type of control of the generation subsystem;
- ambient conditions (outdoor air temperature, variation of source and sink temperature in the year);
- heat requirements for space heating and/or domestic hot water.

Based on these input data, the following output data are calculated

- required energy input as driving energy $E_{\text{HW,gen,in}}$ (electricity, fuel, waste heat, solar heat) to meet the space heating and/or domestic hot water requirements;
- total generation subsystem thermal loss $Q_{\text{HW,gen,ls,tot}}$;
- total recoverable generation subsystem thermal losses $Q_{\text{HW,gen,ls,rbl,tot}}$;
- total required auxiliary energy $W_{\text{HW,gen,aux}}$ to operate the generation subsystem.

The following heat balance depicted in Figure 2 can be made for the generation subsystem given in Figure 1.



Key

- | | |
|---|---|
| 1 driving energy input to cover the heat requirement (e.g. electricity, fuel) $E_{HW,gen,in}$ | 8 generation subsystem total auxiliary energy $W_{HW,gen,aux}$ |
| 2 ambient heat used as heat source of the heat pump $Q_{HW,gen,in}$ | 9 generation subsystem recovered auxiliary energy $Q_{HW,gen,aux,ls,rld}$ |
| 3 heat output of the generation subsystem corresponding to the heat requirement of the distribution subsystem(s) $Q_{HW,gen,out} = Q_{HW,dis,in}$ | 10 generation subsystem unrecovered auxiliary energy $Q_{HW,gen,aux,ls}$ |
| 4 generation subsystem thermal losses $Q_{HW,gen,ls}$ | 11 generation subsystem recoverable auxiliary energy $Q_{HW,gen,aux,ls,rbl}$ |
| 5 generation subsystem thermal loss (thermal part) recoverable for space heating $Q_{HW,gen,ls,rbl}$ | 12 generation subsystem non-recoverable auxiliary energy $Q_{HW,gen,aux,ls,nrbl}$ |
| 6 generation subsystem thermal loss (thermal part) non-recoverable $Q_{HW,gen,ls,nrbl}$ | 13 generation subsystem |
| 7 generation subsystem thermal loss recoverable for space heating $Q_{HW,gen,ls,rbl,tot}$ | |

Figure 2 — Energy balance of generation subsystem

The numbers indicated in Figure 2 refer to the percentage of the energy flows to cover the distribution subsystem heat requirement (100 %). They are intended to give an idea of the size of the respective energy flows. The numbers vary dependent on the physical factors listed before. The numbers given in Figure 2 refer to an electrically-driven ground-source heat pump in monovalent space heating-only operation including a heating buffer storage.

4.2 Energy input needed to meet the heat requirements

The energy balance for the electrically-driven generation subsystem is given by

$$E_{\text{HW,gen,in}} = Q_{\text{HW,gen,out}} + Q_{\text{HW,gen,ls}} - Q_{\text{HW,gen,in}} - k_{\text{gen,aux,ls,rvd}} \cdot W_{\text{HW,gen,aux}} \quad [\text{J}] \quad (1)$$

where

- $E_{\text{HW,gen,in}}$ is the driving electrical energy, fuel or heat input to cover the heat requirement of the distribution subsystem; (J)
- $Q_{\text{HW,gen,out}}$ is the heat energy requirement of the distribution subsystems; (J)
- $Q_{\text{HW,gen,ls}}$ is the thermal losses of the generation subsystem; (J)
- $Q_{\text{HW,gen,in}}$ is the ambient heat energy used as heat source of the heat pump; (J)
- $k_{\text{gen,aux,ls,rvd}}$ is the recovered fraction of auxiliary energy ; (-)
- $W_{\text{HW,gen,aux}}$ is the auxiliary energy input to operate the generation subsystem. (J)

In case of electrically-driven heat pumps:

- the term $E_{\text{HW,gen,in}}$ is the electrical energy input to cover the heat requirement of the distribution subsystem. It comprises the electrical energy input to the heat pump and possibly installed electrical back-up heaters. Since for electrically-driven heat pumps, the energy input to the heat pump is calculated based on the standard testing according to EN 14511, $E_{\text{HW,gen,in}}$ also includes the fractions of the auxiliary energies included in the *COP*. According to EN 14511 the auxiliary energies at the system boundary of the heat pump are taken into account, i.e. the energy for control and safety devices during operation, the proportional energy input for pumps and fans to ensure the transport of the heat transfer media inside the unit as well as eventual energy for defrost operation and additional heating devices for the oil supply of the compressor (carter heating);
- thus, $W_{\text{HW,gen,aux}}$ comprises only the fractions not included in the *COP* according to the EN 14511 standard testing. $k_{\text{gen,aux,ls,rvd}}$ describes the fraction of auxiliary energy, which is recovered as thermal energy, e.g. for pumps where a fraction of the auxiliary energy is directly transferred to the heat transfer medium as thermal energy. This fraction is already contained in the *COP* according to EN 14511 for electrically-driven heat pumps, so $k_{\text{gen,aux,ls,rvd}} = 0$;
- for thermal losses $Q_{\text{HW,gen,ls}}$, the thermal losses of the heat pump over the envelope are neglected, unless heat loss values of the heat pump are known, e.g. given in a national annex. For systems with integrated or external heating buffer or domestic hot water storage, generation subsystem thermal losses in form of storage thermal losses and thermal losses from the connecting circulation pipes to the storage are considered.

In case of combustion engine-driven and absorption heat pumps:

- $E_{\text{HW,gen,in}}$ describes the driving energy input to cover the heat requirement of the distribution subsystem. For combustion engine-driven heat pumps, this driving energy is fuel, e.g. as diesel or natural gas. For thermally-driven absorption heat pumps, fuel-driven burners as well as solar energy or waste heat can be the driving energy input;
- $Q_{\text{HW,gen,out}}$ is the heat energy output of the generation subsystems which is equal to the heat requirement of the distribution subsystems and contains all fractions of heat recovered from the engine or the flue gas of the engine, i.e. recovered heat from the engine is entirely considered within the system boundary of the generation subsystem;

- $k_{\text{gen,aux,ls,rvd}}$ gives the fraction of the auxiliary energy recovered as thermal energy and depends on the test method. The fraction $k_{\text{gen,aux,ls,rvd}} = 0$ if the recovered auxiliary energy is already included in the COP .

4.3 Auxiliary energy $W_{\text{HW,gen,aux}}$

Auxiliary energy is energy needed to operate the generation subsystem, e.g. the source pump or the control system of the generator. As for electrically-driven heat pumps, heating capacity and COP in this European Standard are calculated on the basis of results from product testing, according to EN 14511, and only the auxiliary energy not included in the test results, e.g. the power to overcome the external pressure drop and the power in stand-by operation, shall be considered in $W_{\text{HW,gen,aux}}$.

Auxiliary energy is accounted for in the generation subsystem as long as no transport energy is transferred to the distribution subsystem. Thus, in general the circulation pump is considered in the distribution subsystem, unless a hydraulic decoupling exists. For a hydraulic decoupling between the generation and various distribution subsystems, e.g. by a heating buffer or domestic hot water storage in parallel configuration, the primary pump is considered in the generation subsystem as well.

In this case, the power to overcome the external pressure drop has to be taken into account. If no primary pump is considered, since there is no hydraulic decoupling between the generation and distribution subsystem, the COP -values have to be corrected for the internal pressure drop, which is included in the COP -values by the standard testing.

4.4 Recoverable, recovered and unrecoverable heat 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 is actually recovered. The recovered losses are determined by the location of the generator and the utilisation factor (gain/loss ratio, see EN ISO 13790).

Recoverable thermal losses $Q_{\text{HW,gen,ls,rl}}$ are e.g. heat losses through the envelope of a generation subsystem, e.g. in form of storage losses when the storage is installed in the heated space. For a generation subsystem installed outside the heated space, however, the heat losses through the envelope of the generator are not recoverable. Flue gas losses of fuel engine-driven heat pumps are considered not recoverable, since all recovered flue gas losses inside the generation subsystem limits are contained in the heat output $Q_{\text{HW,gen,out}}$.

4.5 Calculation periods

Heat pump performance strongly depends on the operating conditions, basically the source and the sink temperature. As source and sink temperatures vary over the heating period and the year, the heat pump performance is evaluated in periods of defined source and sink temperature. Thus, calculation periods are not oriented at the time scale, i.e. monthly values, but on the frequency of the outdoor air temperature.

However, an appropriate processing of the meteorological data may be used to carry out the calculation with monthly or hourly averaged values, if necessary.

NOTE Exactness of measured COP values according to EN 14511 for electrically-driven heat pumps are in the range of 5 %. Comparison of a bin calculation described in 5.3 on an annual basis and field monitoring values showed an exactness of the calculation in the range of 6 %. So, with regard to the expense for the computation, an annual or monthly approach seems sufficient.

4.6 Calculation by zones

A heating system may be split into zones with different distribution subsystems. A separate circuit may be used for domestic hot water production.

Several heat generation subsystems may be available.

The total heat requirement of all the distribution subsystems, for instance of the space heating operation, shall equal the total heat output of the generation subsystems:

$$\sum_j Q_{H,gen,out,j} = \sum_k Q_{H,dis,in,k} \quad [J] \quad (2)$$

where

$Q_{H,gen,out,j}$ is the space heating heat energy requirement to be covered by generator j ; (J)

$Q_{H,dis,in,k}$ is the heat energy requirement of space heating distribution subsystem k . (J)

When more generators are available (multivalent system configuration), the total heat demand of the distribution subsystem(s) $\sum Q_{H,dis,in,k}$ shall be distributed among the available generators and the calculation described in Clause 5 shall be performed independently for each generation subsystem j on the basis of $Q_{H,gen,out,j}$. This is accomplished in case of an installed back-up heater.

For intermittent heating, the requirements of EN ISO 13790 shall be considered. These are considered already in the calculation of the heat requirements according to EN 15316-1 [9] or EN 15316-2-1 [10], respectively.

4.7 Heat pumps with combined space heating and domestic hot water production

For combined operation of the heat pump for space heating and domestic hot water production, two kinds of operation modes can be distinguished, alternate and simultaneous operation.

In alternate operation, the heat pump switches from the space heating system to the domestic hot water system in case of domestic hot water demand, e.g. in the system configuration shown in Figure 1 with a domestic hot water storage in parallel. Domestic hot water operation is usually given priority, i.e. space heating operation is interrupted in case of domestic hot water heat demand.

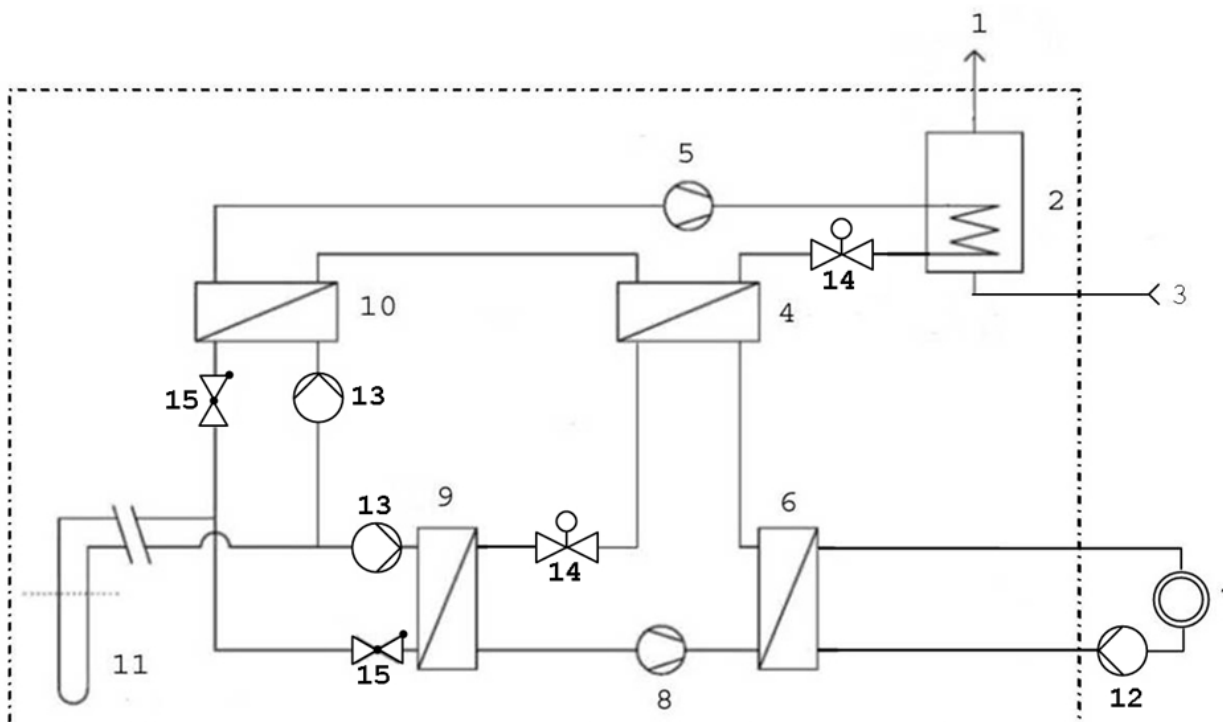
Newer simultaneous operation concepts of heat pumps aim at improving the heat pump cycle to achieve better overall efficiencies by using temperature adapted heat extraction by means of:

- desuperheating and/or condensate subcooling;
- cascade cycles with internal heat exchangers.

For these simultaneous concepts, space heating and domestic hot water requirements are covered at the same time. Figure 3 gives a sample of a hydraulic scheme of a simultaneous operating system using a cascade cycle with condensate subcooling.

For simultaneous system layout, three operation modes have to be distinguished:

- space heating-only operation:
only the space heating system is in operation, e.g. in the configuration shown in Figure 3, only the lower stage heat pump is in operation (winter time, domestic hot water storage entirely loaded);
- domestic hot water-only operation:
only the domestic hot water system is in operation, e.g. in the configuration shown in Figure 3, only the upper stage heat pump is in operation and the heat is extracted from the ground source (summer operation, no space heating demand);
- simultaneous operation:
both space heating and domestic hot water operation. For the configuration shown in Figure 3, both stages are in operation. The heat for the lower stage heat pump is taken from the ground source and the heat for the upper stage heat pump is taken from the condensate subcooling of the lower stage heat pump (winter operation, DHW storage partly unloaded).



Key

- | | |
|---|---|
| 1 hot water outlet of the DHW system | 8 compressor lower stage |
| 2 condenser of upper stage in DHW storage | 9 evaporator lower stage |
| 3 cold water inlet of the DHW system | 10 heat exchanger to ground source upper stage |
| 4 condensate subcooler as evaporator of the upper stage | 11 vertical borehole ground heat-exchanger |
| 5 compressor upper stage | 12 circulation pump space heating distribution system |
| 6 condenser lower stage | 13 source pump |
| 7 heat emission subsystem | 14 expansion valve |
| | 15 non-return valve |

Figure 3 — Sample system with simultaneous operating heat pump with cascade cycle layout using condensate subcooling for domestic hot water production

The calculation used in this European Standard implies that both the single operation modes and the simultaneous operation are tested according to standard testing, so heating capacity- and *COP* characteristics of all three respective operation modes are available. As heating capacity- and *COP* characteristics of the simultaneous operation may differ significantly from the other two operation modes, these test results have to be available and taken into account.

5 Generation subsystem energy performance calculation

5.1 General

In this European Standard, two performance calculation methods for the generation subsystem are described corresponding to different applications (simplified or detailed estimation). The two methods differ with respect to:

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

The two methods and their field of application are shortly described in the following:

Simplified seasonal performance method based on system typology, see 5.2 (tabulated values)

For this method, the considered calculation period is the heating season. The performance is chosen from tabulated values for fixed performance classes of the heat pump, based on test results according to heat pump test standards, e.g. EN 14511 for electrically-driven heat pumps. The operating conditions (climate, design and operation of the heating system, heat source type) are based on typology of implementation characteristics and are not case specific. This method allows a country/region specific approach and requires a country/region specific national annex. Therefore, if there is no appropriate national annex available with the adapted values, this method cannot be used.

The tabulated values are in particular useful if limited information on the generation subsystem exists, as may be the case for existing buildings, where for instance the *COP* of the heat pump has to be estimated.

Detailed case specific calculation based on component efficiency data, see 5.3 (Bin-method)

This method is also based on the test results according to heat pump test standards, e.g. EN 14511 for electrically driven heat pumps, but supplementary data are needed in order to take into account the specific operating conditions of each individual installation. Therefore, the calculation period is split up in bins dependent on the outdoor air temperature. The calculation is carried out for the corresponding bin operating conditions of the heat pump. The method shall be carried out with product data for the heating capacity and the *COP*. Example values given in the informative Annex F illustrate the data needed to perform the calculation.

As site specific meteorological conditions and specific test results for an individual heat pump are considered, this method is suited to prove the compliance with building regulations.

The calculation method to be applied can be chosen dependent on the available data and the objectives of the user.

5.2 Simplified seasonal performance method based on system typology (system typology method)

5.2.1 Principle of the system typology method

This method assumes that:

- climatic conditions,

- design and operation of the heating system, including typical occupancy patterns of the relevant building sector,
- type of heat source,

have been considered and incorporated in a procedure to convert standard test results of heat pump *COP*, e.g. according to EN 14511 for electrically-driven heat pumps, into a seasonal performance factor (*SPF*) for the relevant building sector, e.g. domestic and non-domestic.

The steps within the simplified seasonal performance calculation procedure are:

- adapt test results for uniformity, taking into account the type of heat pump and the type of energy input;
- adjust for seasonal performance at installed conditions, taking into account the climatic conditions, the design and operation of the heating system and the type of heat source;
- deliver results (annual energy consumption, generation thermal loss, auxiliary energy, total recoverable generation thermal loss, optionally *SPF*).

Thereby, the procedure allows for national characteristics of the relevant building sector.

For some heating systems, buffer storage vessels are applied to diminish heat pump cycling. These storage systems are considered to be part of the generation subsystem and their losses are taken into account in the generation subsystem, regardless if the storage vessels are an integral part of a specific heat pump and included in heat pump testing or are located external. For integral storages, their losses may be included in the *COP/SPF* of the heat generation subsystem depending on the testing applied. Storage systems for domestic hot water are also part of the generation subsystem.

In order to provide consistent values within this part of the standard, the tabulated values of the national annex shall be produced using the detailed method, e.g. the bin-method described in 5.3 or any other method for the fixed boundary conditions of the different performance classes and building typologies, respectively. As the tabulated values are simplified values intended as conservative estimation of the energy input to the system, the tabulated values of the system typology method shall not deliver better values than the detailed calculation with the bin-method.

5.2.2 Calculation procedure of the system typology method

Selection of appropriate seasonal performance

A seasonal performance factor is selected from the appropriate national annex on the basis of the following information:

- country/region (climate) in which the building is situated;
- building sector (residential building, non-residential building, industrial, etc.);

If there is no appropriate national annex, this method cannot be used. Annex E (informative) is an example of a national annex of tabulated values of seasonal performance factors (including consideration of a possibly installed back-up heater) for residential and non-residential buildings in the Netherlands.

Input information required for the simplified seasonal performance method

Input information for the procedure may consist of:

- heat pump function (space heating, domestic hot water production, combination);
- type of heat pump (electrically-driven, engine-driven, etc.);

- type of energy input (electricity, natural gas, LPG, oil, etc.);
- type of heat source;
- source pump or fan power;
- test results produced in accordance with standard tests, e.g. according to EN 14511 for electrically-driven heat pumps;
- heating capacity;
- internal heating system storage included in efficiency tests (yes/no);
- internal domestic hot water storage characteristics (volume/dimensions, specific loss).

Output information obtained from the seasonal performance method

The output information for the procedure consists of:

- total annual energy input to the generation subsystem;
- generation subsystem total thermal losses;
- generation subsystem auxiliary energy;
- generation subsystem thermal loss recoverable for space heating;
- optionally, the seasonal performance factor.

5.3 Detailed case specific seasonal performance method based on component efficiency (bin-method)

5.3.1 Principle of the bin method

The required energy input e.g. for the space heating operation mode $E_{H,gen,in}$ according to Equation (1) to cover the heat requirement of the distribution subsystem, e.g. the electricity input for electrically-driven heat pumps, can be determined according to the equation

$$E_{H,gen,in} = \sum_j \frac{Q_{H,gen,out,j} + Q_{H,gen,ls,j}}{COP_{H,hp,j}} \quad [J] \quad (3)$$

where

- | | | |
|-------------------|---|-------|
| $E_{H,gen,in}$ | is the electrical energy input to cover the heat requirement of the space heating distribution subsystem; | (J) |
| $Q_{H,gen,out,j}$ | is the heat energy requirement of the distribution subsystem in bin j
(equal to heat output of the generation subsystem in bin j); | (J) |
| $Q_{H,gen,ls,j}$ | is the thermal losses of the generation subsystem in bin j; | (J) |
| $COP_{H,hp,j}$ | is the coefficient of performance of the heat pump for a period of constant operating conditions. | (W/W) |

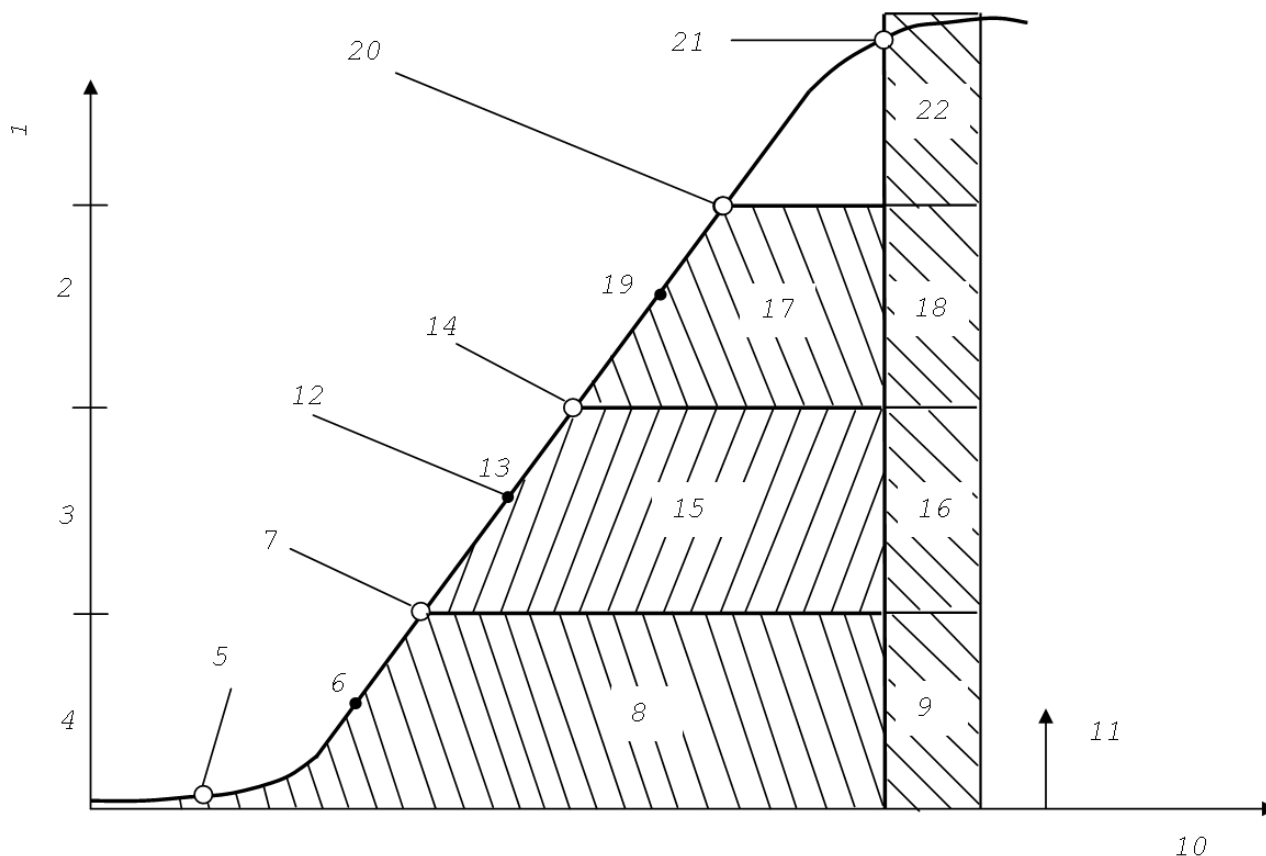
Equation (3) takes into account that the thermal losses of the generation subsystem $Q_{H,gen,ls,j}$ have to be covered by the generator as well.

However, as the heat pump heating capacity and *COP* strongly depend on the operating conditions, mainly on the source and sink temperature, the calculation can be performed for a number of j periods defined by constant source and sink temperature conditions, and results are summed-up, which is expressed by the summation in Equation (3). Thus, to determine the required energy input, basically the *COP* as well as the heat energy requirement and generation subsystem thermal losses at the defined operating conditions have to be evaluated.

To evaluate the heat energy requirement of the distribution subsystem, the heat load for space heating and domestic hot water has to be known. If detailed information on the heat load are not available, e.g. if only monthly or annual values of the heat energy are given, the energy requirement dependent on the temperature operating conditions can be estimated by evaluating the outdoor air temperature.

Actually, the bin method is based on an evaluation of the cumulative frequency of the outdoor air temperature depicted in Figure 4. The annual frequency of the outdoor air temperature based on hourly averaged values is cumulated and divided into temperature intervals (bins), which are limited by an upper temperature θ_{lim} and a lower temperature θ_{lim} . Operating conditions of the bins are characterised by an operating point in the centre of each bin. For the calculation it is assumed that the operating point defines the operating conditions for the heat pump of the whole bin. The evaluation of the annual frequency and the cumulative annual frequency from hourly averaged data of an entire year is given in Annex A.

The temperature difference between the outdoor air temperature and the indoor design temperature defines a heating degree hour (also called time temperature difference (TTD) according to EN ISO 15927-6 for a base temperature of the design indoor temperature, normally 20 °C). It corresponds to the heat load for space heating. Therefore, the area under the cumulative frequency, the cumulative heating degree hours, corresponds to the energy requirement for space heating, since the temperature difference (corresponding to the heat load) is cumulated over the time. The cumulative heating degree hours (DH_H) are also called accumulated time temperature difference (ATTD) in EN ISO 15927-6. Analogously, the DHW load depicted as constant daily profile in Figure 4 can be cumulated. Although DHW heat energy is not dependent on the outdoor temperature but may have a connection to the bin time, the operating conditions for the heat pump are relevant as well. Summarising, the energy requirement for the operating conditions defined by the operating point can be characterised by the cumulative heating degree hours.

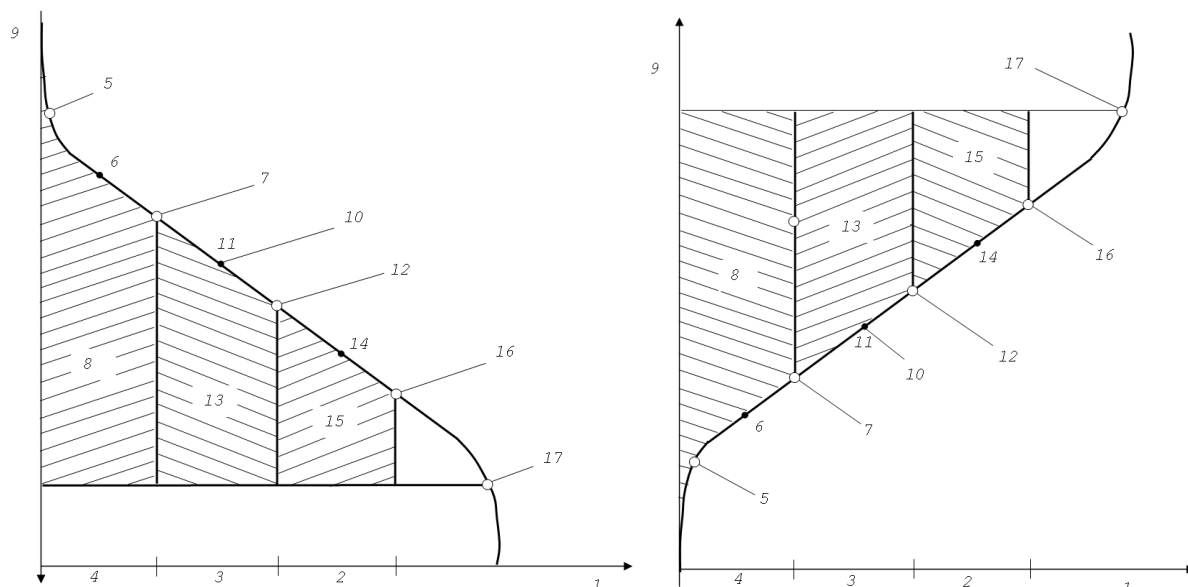


Key

- | | |
|---|---|
| 1 cumulative bin hours [h] | 12 θ_2 |
| 2 t_3 | 13 OP_2 |
| 3 t_2 | 14 $\theta_{2,lim} = \theta_{3,lim}$ |
| 4 t_1 | 15 SH_2 |
| 5 design outdoor temperature | 16 DHW_2 |
| 6 OP_1 | 17 SH_3 |
| 7 $\theta_{1,lim} = \theta_{2,lim}$ | 18 DHW_3 |
| 8 SH_1 | 19 OP_3 |
| 9 DHW_1 | 20 upper ambient temperature for space heating = $\theta_{3,lim}$ |
| 10 outdoor air temperature [°C] | 21 design indoor temperature |
| 11 direction of cumulating temperature difference (space heating load) and DHW load over time | 22 DHW_4 |

Figure 4 — Bin hours vs outdoor air temperature – sample with 3 bins for space heating (SH) and constant daily domestic hot water (DHW) heat energy requirement (4 bins for DHW)

Another common way to depict the cumulative frequency is a 90° clockwise rotation called duration curve, which is shown in Figure 5 left hand side. Since this implies a negative temperature (y-) axis, a horizontally flipped diagram depicted in Figure 5 right hand side is found as well. In the following, the cumulative frequency is depicted as in Figure 4 in line with the evaluation of frequency of the outdoor air temperature described in Annex A.



Key

- | | |
|---------------------------------------|--|
| 1 cumulative bin hours [h] | 10 θ_2 |
| 2 t_3 | 11 OP ₂ |
| 3 t_2 | 12 $\theta_{2,hlim} = \theta_{3,llim}$ |
| 4 t_1 | 13 SH ₂ |
| 5 design outdoor temperature | 14 OP ₃ |
| 6 OP ₁ | 15 SH ₃ |
| 7 $\theta_{1,hlim} = \theta_{2,llim}$ | 16 upper ambient temperature for space heating = $\theta_{3,hlim}$ |
| 8 SH ₁ | 17 design indoor temperature |
| 9 outdoor air temperature [°C] | |

Figure 5 — Outdoor air temperature vs bin hours (duration curve) - sample with 3 bins for SH-only

COP values, however, are normally only known at discrete test points based on standard product testing. The number of bins depends on the type of heat pump, the available information on the heat pump characteristic according to the standard testing and the calculation period.

Criteria for the choice of bins are:

- operating points shall be spread more or less evenly over the entire operation range;
- operating points shall be chosen at the test points as far as possible in order to include the available information on the heat pump characteristic (e.g. EN 14511) as exact as possible. Bin limits are to be set approximately in the middle between the operating points;
- number of bins shall reflect the changes in source and sink temperature. If both source and sink temperatures are constant over the whole operation range, one bin may be enough. In the case of big changes, more bins shall be chosen. For a monthly calculation period, less bins may be required than in an annual calculation.

On the other hand, 1 K bins can be chosen, so that the heating capacity and the COP is interpolated as described in 5.3.5.1.3. In general, number of bins shall at least correspond to the different source temperatures defined by the test points of EN 14511 (standard and application rating) in order to consider the relevant impact on the characteristic, e.g. due to defrosting in case of outdoor air-to-water heat pumps. If more information is available, e.g. according to manufacturer information based on the standard testing, more bins can be chosen to accommodate the available information. If not enough test points are available,

the heat pump characteristic is interpolated to the respective source/sink temperatures, see 5.3.5.1.3, or the exergetic efficiency method given in Annex C can be applied. Observe that the operating point temperature (corresponding to the outdoor air temperature) corresponds directly to the source temperature in the testing only in case of outdoor air source heat pumps. For ground-coupled heat pumps, for instance, the dependency of the source temperature on the outdoor air temperature has to be considered in order to determine the operating points, see 5.3.5.1.3.

The cumulative frequency is only dependent on the outdoor air temperature, and therefore does not take into account solar and internal gains. Even though the amount of energy is correct by using the heat energy requirement of the distribution subsystem according to EN 15316-2-3, the redistribution of the energy to the bins depends also on the used gains (internal and solar). For existing buildings and newer standard houses, the approximation with regard to the outdoor air temperature is quite good, while for new solar passive houses, it may get worse.

For a monthly calculation period, the cumulative frequency evaluated for a monthly data set is a good approximation of the redistribution of the solar and internal gains. Therefore, for a monthly calculation period, the cumulative frequency shall be calculated as the accumulated time temperature difference (ATTD) according to EN ISO 15927-6 with a base temperature of the design indoor temperature, normally 20 °C. This corresponds to the approach of EN ISO 13790 for a monthly calculation period. For each month, the calculation is accomplished for the bins chosen according to the available information on the heat pump characteristic.

For an annual calculation period, a correction of the redistribution to the bins can be made by using an upper temperature limit for heating dependent on the fraction of used solar and internal gains evaluated by the calculation according to EN ISO 13790. The upper temperature limit for heating can either be derived by the controller settings or be based on the used gains and building type. The higher the fraction of used gains is, the lower the heating limit has to be chosen. However, this is an approximation and a more exact redistribution is delivered by a monthly calculation.

For each bin, the heating capacity and the *COP* are evaluated from standard testing. The difference between the heat requirements and the heat energy delivered by the heat pump has to be supplied by the back-up heater in case of a bivalent system configuration. Storage and other generation subsystem thermal losses and electricity input to auxiliaries are calculated as well. The total energy input in form of electricity, fuel or heat is determined by summing-up the results for each bin for the whole period of operation. Depending on the existence of a back-up system and its operation mode, supplied back-up energy is determined and summed-up too in order to calculate the overall energy consumption.

5.3.2 Input data for the calculation with the bin method

Boundary conditions:

- meteorological data:
 - frequency of the outdoor air temperature of the site in 1 K resolution or hourly average values of the outdoor air temperature for an entire year (e.g. test reference year TRY or Meteonorm [1]);
 - outdoor design temperature of the site.

Space heating (SH) mode:

- indoor design temperature;
- heat energy requirement of the space heating distribution subsystem according to EN 15316-2-3;
- type and controller setting of the heat emission subsystem (flow temperature of the heating system dependent on the outdoor air temperature, e.g. heating characteristic curve or characteristic of room thermostat), temperature spread at design conditions, upper temperature limit for heating;

- heat pump characteristics for heating capacity and *COP* according to product test standards (e.g. according to EN 14511 for electrically-driven heat pumps) and guaranteed temperature level that can be produced with the heat pump;
- results for part load operation, e.g. according to CEN/TS 14825 for electrically-driven heat pumps, if available;
- for the simplified calculation method of the back-up energy, the balance point;
- system configuration:
 - installed back-up heater: operation mode, efficiency (fuel back-up heater according to EN 15316-4-1);
 - installed heating buffer storage: stand-by loss value, flow temperature requirements;
- power of auxiliary components (source pump, storage loading pump, primary pump, stand-by consumption).

Domestic hot water (DHW) mode:

- heat energy requirement of domestic hot water distribution subsystem according to EN 15316-3-2;
- temperature requirements of DHW operation: cold water inlet temperature (e.g. 15 °C), DHW design temperature (e.g. 60 °C);
- heat pump characteristics for DHW heating capacity and *COP* according to product test standards (e.g. according to EN 255-3 for electrically-driven heat pumps);
- set temperature for the energy delivery by the heat pump (e.g. at 55 °C due to heat pump operating limit);
- parameters of the domestic hot water storage (stand-by loss value);
- installed back-up heater: operation mode, efficiency (fuel back-up heaters are calculated according to EN 15316-4-1).

5.3.3 Calculation steps to be performed in the bin method

An overview of the calculation steps to be performed is listed below. A more detailed overview for different system configurations is given in the flow chart in Figure 6.

The individual steps are explained in detail in the remaining part of 5.3 as indicated. For each step, the description covers the different operation modes (space heating, domestic hot water) and the different types of heat pumps (electrically-driven, engine-driven, absorption), if applicable. Additionally, for the back-up energy calculation, a simplified and a detailed method is given in connection with the calculation of the running time.

A stepwise calculation example is given in Annex D.

- Step 1: Determination of energy requirement of the single bins (see 5.3.4);
- Step 2: Correction of steady state heating capacity/*COP* (e.g. EN 14511) for bin source and sink temperature operating conditions (see 5.3.5);
- Step 3: If required, correction of *COP* for part load operation (see 5.3.6);
- Step 4: Calculation of generation subsystem thermal losses (see 5.3.7);

Step 5: Determination of back-up energy of the single bins (see 5.3.8, simplified in 5.3.8.3, detailed in 5.3.9.4);

Step 6: Calculation of the running time of the heat pump in different operation modes (see 5.3.9);

Step 7: Calculation of auxiliary energy input (see 5.3.10);

Step 8: Calculation of generation subsystem thermal loss recoverable for space heating (see 5.3.11);

Step 9: Calculation of the total driving energy input to cover the requirements (see 5.3.12);

Step 10: Summary of resulting and optional output values (see 5.3.13).

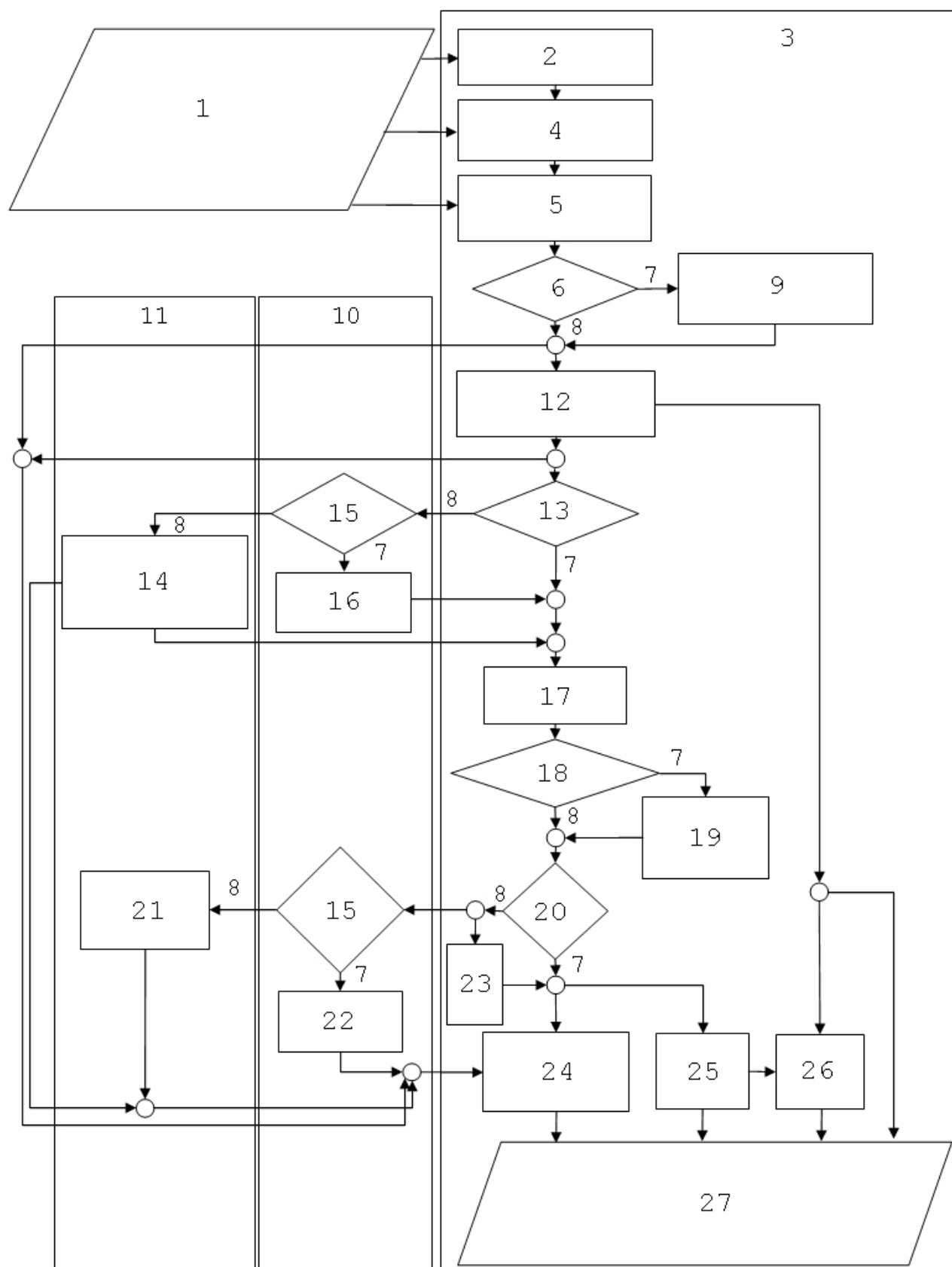


Figure 6 — Flow chart of the bin calculation method

Key

- 1 **input data, see 5.3.2**
 - energy requirement of space heating distribution subsystem
 - energy requirement of the domestic hot water distribution subsystem
 - meteo data
 - product characteristics
 - design parameters
- 2 definitions of calculation periods and bins
see 5.3.1
- 3 monovalent
- 4 calculation of energy requirements/bin time
see 5.3.4
- 5 correction of heating capacity/*COP* for operating conditions
see 5.3.5
- 6 part load test available
- 7 yes
- 8 no
- 9 correction of *COP* for part load operation
see 5.3.6
- 10 bivalent detailed
- 11 bivalent simplified
- 12 calculation of generation subsystem thermal losses
see 5.3.7
- 13 monovalent system
- 14 evaluation of back-up energy due to operation limit and based on balance point
see 5.3.8.1/2
- 15 detailed back-up energy calculation
- 16 calculation of back-up energy for operation limit
see 5.3.8.1/2
- 17 calculation of running time
see 5.3.9.1
- 18 simultaneous system with 3 operation modes
- 19 calculation of running time for simultaneous system
see 5.3.9.2
- 20 running time < eff. bin time
- 21 calculation of additional back-up energy
see 5.3.8.3
- 22 calculation of back-up energy
see 5.3.9.4/5
- 23 running time = eff. bin time
- 24 calculation of energy input to cover the heat requirement
see 5.3.12
- 25 calculation of auxiliary energy
see 5.3.10
- 26 calculation of thermal loss recoverable for space heating
see 5.3.11
- 27 **output data: see 5.3.13**
 - energy input to cover the heat requirement
 - generation subsystem total thermal losses
 - generation subsystem thermal loss recoverable for space heating
 - total auxiliary energy input

5.3.4 Heat energy requirements for space heating and domestic hot water mode for the bins

5.3.4.1 Space heating mode

The heat energy requirement of the space heating distribution subsystem $Q_{H,dis,in}$ shall be calculated according to EN 15316-2-3.

The space heating requirement of bin j can be calculated by a weighting factor which is derived from evaluating the cumulative frequency of the outdoor air temperature by means of cumulative heating degree hours (DH_H). The evaluation of the cumulative heating degree hours from tables based on the hourly outdoor air temperature is described in Annex A.

The weighting factors are calculated by the equation

$$k_{H,j} = \frac{Q_{H,gen,out,j}}{Q_{H,gen,out}} = \frac{DH_{H,\theta hlim,j} - DH_{H,\theta llim,j}}{DH_{H,tot}} \quad [-] \quad (4)$$

The space heating energy requirement of the respective bin is hence calculated by

$$Q_{H,gen,out,j} = k_{H,j} \cdot Q_{H,gen,out} \quad [J] \quad (5)$$

where

$k_{H,j}$	is the weighting factor of the heat pump operation for space heating of bin j ;	(-)
$Q_{H,gen,out,j}$	is the heat energy requirement of the space heating distribution subsystem in bin j ;	(J)
$Q_{H,gen,out}$	is the total heat energy requirement of the space heating distribution subsystem;	(J)
$DH_{H,\theta hlim,j}$	is the cumulative heating degree hours up to the upper temperature limit of bin j ;	(°Ch)
$DH_{H,\theta llim,j}$	is the cumulative heating degree hours up to the lower temperature limit of bin j ;	(°Ch)
$DH_{H,tot}$	is the total cumulative heating degree hours up to the upper temperature limit for space heating.	(°Ch)

The cumulative heating degree hours for the respective climatic regions shall be given in a national annex or taken from national standardisation. It is also possible to define weighting factors for a fixed bin scheme and standard locations in a national annex.

The bin time is calculated as the difference of the cumulative time at the upper and lower bin limit according to the equation

$$t_j = (N_{ho,\theta hlim,j} - N_{ho,\theta llim,j}) \cdot 3600 \quad [s] \quad (6)$$

where

t_j	is the time in bin j ;	(s)
$N_{ho,\theta hlim,j}$	is the cumulative number of hours up to the upper temperature limit of bin j ;	(h)
$N_{ho,\theta llim,j}$	is the cumulative number of hours up to the lower temperature limit of bin j .	(h)

A summation of all bin times t_i for space heating constitutes the heating season. Attention should be paid to national regulation on the heating season.

However, for the heat pump operation there may be time restrictions, so that not the entire bin time is available for the heat pump operation, e.g. a possible cut-out time of the electricity supply on the background of particular tariff structures for heat pumps by the utility. Thus, the effective bin time is the time in the bin according to Equation (6) reduced by the cut-out time per day and is calculated by

$$t_{\text{eff},j} = t_j \cdot \frac{24 - t_{\text{co}}}{24} \quad [\text{s}] \quad (7)$$

where

$t_{\text{eff},j}$ is the effective bin time in bin j ; (s)

t_j is the time in bin j ; (s)

t_{co} is the cut-out hours per 24 hours (1 day). (h/d)

5.3.4.2 Domestic hot water mode

The heat energy requirement of the domestic hot water distribution subsystem $Q_{\text{W,dis,in}}$ shall be calculated according to EN 15316-3-2.

The domestic hot water heat requirement in bin j is calculated with the weighting factor for domestic hot water operation according to the equation

$$k_{\text{W},j} = \frac{Q_{\text{W,gen,out},j}}{Q_{\text{W,gen,out}}} = \frac{t_j}{t_{\text{tot}}} \quad [-] \quad (8)$$

and the domestic hot water energy requirement of bin j follows according to the equation

$$Q_{\text{W,gen,out},j} = k_{\text{W},j} \cdot Q_{\text{W,gen,out}} \quad [\text{J}] \quad (9)$$

where

$k_{\text{W},j}$ is the weighting factor of the heat pump operation for DHW operation of bin j ; (-)

$Q_{\text{W,gen,out},j}$ is the heat energy requirement of the domestic hot water distribution subsystem in bin j ; (J)

$Q_{\text{W,gen,out}}$ is the total heat energy requirement of the DHW distribution subsystem; (J)

t_j is the bin time in bin j ; (s)

t_{tot} is the total time of DHW operation (e.g. year round operation). (s)

NOTE Instead of a daily constant domestic hot water consumption expressed by the bin time, a profile of the domestic hot water consumption dependent on the outdoor air temperature can be considered.

5.3.5 Heating capacity and COP at full load

5.3.5.1 Space heating mode

5.3.5.1.1 General

The steady state heating capacity and COP are taken from standard test results of European test methods, e.g. according to EN 14511 for electrically-driven heat pumps. If European test standards are not available, e.g. for simultaneous operation, national methods shall be used. According to EN 14511, standard testing is performed at a standard rating point and several application rating conditions. Since the COP characteristic has the most significant impact on the heat pump performance, care shall be taken that COP-values are reliable. All available test points shall be taken into account, at least the test points prescribed by the standard testing (standard rating and application rating).

If national methods evaluate the heating capacity and the *COP* at different conditions as according to the test conditions of EN 14511, e.g. if the heating capacity and the *COP* value are related to the outlet temperature of both evaporator and condenser, this shall be stated clearly in the calculation report.

If flow conditions deviate between testing and operation, the *COP* characteristic has to be corrected due to different temperature conditions at the condenser. The method for the correction is given in 5.3.5.1.2.

To determine data for the whole range of source and sink temperatures, linear inter- and extrapolation between the test points is applied both for the source and for the sink temperature, if necessary. Interpolation is performed between the temperatures of the two nearest test points. Extrapolation is performed by the nearest two points to the target point.

If, nevertheless, only one test point is available, correction for source and sink temperature can be done with the fixed exergetic efficiency approach described in Annex C instead of interpolating the data, which is not possible in case of one test point. However, good results are only obtained near the test point.

Some example values for the illustration of the data needed to accomplish the calculation for electrically-driven heat pumps are given in F.3.

The source of the data shall be stated clearly in the calculation report (e.g. test data from standard test institutes, manufacturer data, etc.). Preference shall be given to data from test institutes.

5.3.5.1.2 Correction of the *COP* characteristic for the temperature spread at the heat pump condenser

Evaluation of the *COP* dependency on the source and sink temperature is only correct if the mass flow rate corresponds to the mass flow rate used during the standard testing, since otherwise different temperature conditions exist at the heat pump condenser. Therefore, the temperature spread of the heat pump, based on the mass flow rate defined by the design of the emission subsystem, has to be taken into account. Temperature spread and mass flow rate are linked by the equation

$$\Delta\theta = \frac{\phi_{hp}}{m'_w \cdot c_w} \quad [K] \quad (10)$$

where

$\Delta\theta$ is the temperature spread on the condenser side of the heat pump; (K)

ϕ_{hp} is the heating capacity of the heat pump; (W)

m'_w is the mass flow rate of the heat transfer medium on the condenser side of the heat pump; (kg/s)

c_w is the heat capacity of heat transfer medium. (J/(kg·K))

In case of testing according to EN 14511 for electrically-driven heat pumps, the temperature spread at the standard rating point is fixed to 5 K. With the temperature spread, the mass flow rate for the testing is determined and applied to all test points. Thus, the temperature spread during testing for the different operating points can be determined according to Equation (10). The temperature spread in operation can be determined by the mass flow in operation which is evaluated at outdoor design conditions.

If the temperature spread in testing and operation differs, the average temperature in the condenser during operation is different from during the testing and therefore *COP* values have to be corrected. The correction can be derived based on the method of fixed exergetic efficiency given in Annex C according to the equation

$$COP_{\Delta\theta} = COP_{\text{standard}} \cdot \left[1 - \frac{\frac{\Delta\theta_{\text{standard}} - \Delta\theta_{\text{opr}}}{2}}{\left\{ T_{\text{sk}} - \frac{\Delta\theta_{\text{standard}}}{2} + \Delta T_{\text{sk}} - (T_{\text{sc}} - \Delta T_{\text{sc}}) \right\}} \right] \quad [\text{W/W}] \quad (11)$$

where

$COP_{\Delta\theta}$	is the <i>COP</i> corrected for a different temperature spread in testing and operation;	(W/W)
COP_{standard}	is the <i>COP</i> derived from standard testing (e.g. according to EN 14511);	(W/W)
$\Delta\theta_{\text{standard}}$	is the temperature spread on the condenser side due to standard test conditions;	(K)
$\Delta\theta_{\text{opr}}$	is the temperature spread on the condenser side in operation due to the design of the heat emission subsystem;	(K)
T_{sk}	is the sink temperature;	(K)
ΔT_{sk}	is the average temperature difference between heat transfer medium and refrigerant in condenser;	(K)
T_{sc}	is the source temperature;	(K)
ΔT_{sc}	is the average temperature difference between heat transfer medium and refrigerant in evaporator.	(K)

The average temperature difference in the condenser and evaporator between the heat transfer medium and the refrigerant can be approximated by $\Delta T_{\text{sk}} = \Delta T_{\text{sc}} = 4$ K for water based components. In the case of air based components $\Delta T_{\text{sk}} = \Delta T_{\text{sc}} = 15$ K is to be set. However, it has to be secured that the minimum temperature difference between the heat transfer medium and the refrigerant is kept.

NOTE Correction factor can be tabulated based on the combination of temperature spreads in testing and operation. The results of the correction according to Equation (11) correspond to the correction factors given in the tabulated values VDI 4650-1 [5] for air-to-water heat pumps and average temperature conditions e.g. the test point A2/W35.

5.3.5.1.3 Interpolation of heating capacity and *COP* for the temperature conditions

Based on the respective corrected characteristic of the $COP_{\Delta\theta}$ and the heating capacity, interpolation for the actual temperature conditions at the operating point of the respective bin is performed.

The following source temperature applies for the respective type of heat pump:

- for an outdoor air heat pump, the source temperature is given by the outdoor air temperature based on the meteorological data of the site;
- for a ground- or water-source heat pump, the return temperature of the ground-loop or water-loop heat exchanger or the ground water inlet temperature has to be used, respectively. As ground and water temperature depend on the site, values shall be given in a national annex. If a national annex is not available, an example profile for ground source heat pumps is given in F.2.1.3 and an example temperature for ground water is given in F.2.1.4;
- for an exhaust-air heat pump without heat recovery, the source temperature corresponds to the indoor temperature. In case of an installed heat recovery, either combined test results of the heat pump and the heat recovery shall be used or an evaluation of the inlet temperature by the temperature change coefficient of the heat recovery, e.g. according to EN 308, shall be applied.

The actual sink temperature can be calculated according to:

- either the controller settings of the heating system (heating curve, room thermostat);

— or the temperature requirements of a possibly installed heating buffer storage.

If the controller settings of the heating system are not known, typical controller settings for the heating curve for different kinds of emission subsystems are given in B.1.

5.3.5.2 Domestic hot water mode

Electrically-driven domestic hot water heat pumps are tested as unitary systems, including the domestic hot water storage in the system boundary, according to EN 255-3. This standard testing determines the COP value for the extraction of domestic hot water, which is denoted COP_t in EN 255-3, at one standard test point, which depends on the type of the heat pump.

The COP_t value is only valid for the extraction of domestic hot water and not for the loading of the storage without extraction of domestic hot water (stand-by operation), since the temperature conditions are different. However, the standard testing determines an electrical power input to cover the storage losses, denoted P_{es} , so electrical energy consumption to cover storage stand-by losses can be expressed by this value.

The sink temperature conditions of domestic hot water systems may change during the year. However, for calculation purposes the sink temperature conditions can be considered constant over the whole operation range as long as the draw-off temperature of the domestic hot water does not change much.

Due to varying source temperatures for the heat pump operation, the operation period and thus COP values may have to be corrected for these conditions. As only one standard test point depending on the type of heat pump is defined in EN 255-3, a temperature correction of the COP by interpolation is not possible. Therefore, a correction based on a fixed exergetic efficiency described in Annex C should be applied. However, the method shall only be applied near the test point.

If no values according to EN 255-3 are available, the calculation for alternate operating systems is performed by evaluation of the space heating characteristic at an average domestic hot water temperature calculated according to the equation

$$\theta_{W,avg} = f_{W,st} \cdot \theta_{hp,opr} \quad [^{\circ}\text{C}] \quad (12)$$

where

$\theta_{W,avg}$	is the average hot water loading temperature;	($^{\circ}\text{C}$)
$f_{W,st}$	is the correction factor for storage loading temperature;	(-)
$\theta_{hp,opr}$	is the operation limit temperature of the heat pump	($^{\circ}\text{C}$)

(maximum hot water temperature that can be reached with the heat pump operation).

The temperature correction factor $f_{W,st}$ takes into account that the loading starts at lower temperatures than the maximum hot water temperature, which can be reached by the heat pump operation (see also 5.3.8.2), due to colder water at the storage heat exchanger. The hot water loading temperature increases during the loading to temperatures slightly above the maximum hot water temperature due to the required temperature difference for the heat transfer. Therefore, the average temperature for the loading is lower than the maximum hot water temperature, which can be reached by the heat pump operation. Values of $f_{W,st}$ or the average loading temperature $\theta_{W,avg}$ shall be given in a national annex. If no national annex is available, a default value is given in B.2.

5.3.5.3 Engine-driven and absorption heat pumps

Steady state heating capacity and COP are taken from test results. The same considerations concerning correction according to temperature conditions as described in 5.3.5.1 and 5.3.5.2 apply depending on the test method used. Example values of the required input data from testing for the space heating operation mode are given in: