

BS ISO 13612-2:2014



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Heating and cooling systems in buildings — Method for calculation of the system performance and system design for heat pump systems

Part 2: Energy calculation

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National foreword

This British Standard is the UK implementation of ISO 13612-2:2014.

The UK participation in its preparation was entrusted to Technical Committee RHE/2, Ventilation for buildings, heating and hot water services.

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

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Heating and cooling systems in buildings — Method for calculation of the system performance and system design for heat pump systems —

Part 2: Energy calculation

*Systèmes de chauffage et de refroidissement dans les bâtiments —
Méthode de calcul de la performance du système et de la conception
du système pour les systèmes de pompes à chaleur —*

Partie 2: Calcul énergétique



Reference number
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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 205, *Building environment design*.

ISO 13612 consists of the following parts, under the general title *Heating and cooling systems in buildings — Method for calculation of the system performance and system design for heat pump systems*:

- *Part 1: Design and dimensioning*
- *Part 2: Energy calculation*

Introduction

This International Standard is a part of a series of standards on the methods for calculation of heating system energy requirements and heating and cooling system efficiencies.

- ISO 13612-1 deals with design and sizing of heat pump systems.
- ISO 13612-2 presents the energy calculation method.

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

This part of ISO 13612 presents methods for calculation of the additional energy requirements of a heat generation subsystem in order to meet the distribution subsystem 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, is determined according to products standards.

This method can be used for the following applications:

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

Only the calculation method is normative. The user shall refer to other 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.

NOTE The results of this method can be used to assess the energy performance of the heating/cooling system when summing up the results over a period of calculation.

Heating and cooling systems in buildings — Method for calculation of the system performance and system design for heat pump systems —

Part 2: Energy calculation

1 Scope

This International Standard is applicable to heat pumps for space heating and cooling, heat pump water heaters (HPWH), and heat pumps with combined space heating and/or cooling and domestic hot water production, in alternate or simultaneous operation, where the same heat pump is used for space heating and domestic hot water heating.

This part of ISO 13612 provides a calculation method under steady conditions that corresponds to one calculation step.

The results of this calculation are incorporated in larger building models and take into account the influence of the external conditions and building control that influence the energy requirements for heating and cooling supplied by the heat pump system.

This part of ISO 13612 specifies the required inputs, calculation methods, and required outputs for output thermal power generation for space heating and cooling and domestic hot water production of the following heat pump systems, including control:

- 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 listed in [Table 1](#).

Table 1 — Heating/cooling sources and energy distribution

Source	Distribution
Outdoor air	Air
Exhaust-air	Water
Indirect ground source with brine distribution	Direct condensation/evaporation 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 documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

ISO 13612-1, *Heating and cooling systems in buildings — Method for calculation of the system performance and system design for heat pump systems — Part 1: Design and dimensioning*

ISO 13675, *Heating systems in buildings — Method and design for calculation of the system energy performance — Combustion systems (boilers)*

ISO 13790, *Energy performance of buildings — Calculation of energy use for space heating and cooling*

ISO/TR 16344, *Energy performance of buildings — Common terms, definitions and symbols for the overall energy performance rating and certification*

3 Terms and definitions

For the purposes of this document, the terms and definitions in ISO 13612-1, EN ISO 7345:1995, and ISO/TR 16344 and the following apply.

3.1 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

3.2 application rating conditions

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

3.3 auxiliary energy

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

Note 1 to entry: This includes energy for fans, pumps, electronics, etc. Electrical energy input to a ventilation system for air transport and heat recovery is not considered as auxiliary energy, but as energy use for ventilation.

Note 2 to entry: In EN ISO 9488, the energy used for pumps and valves is called “parasitic energy”.

Note 3 to entry: In the frame of this part of ISO 13612, the driving energy input for electrically driven heat pumps in the system boundary of the COP and an electrical back-up heater is not considered auxiliary energy but only additional electrical input not considered in the COP.

3.4 balance point temperature

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

3.5 bin

statistical temperature class (sometimes a class interval) for the outdoor air temperature

Note 1 to entry: The class limits are expressed in a temperature unit.

3.6 building service

service 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

3.7

calculation period

period of time over which the calculation is performed

Note 1 to entry: The calculation period can be divided into a number of calculation steps.

3.8

calculation step

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

Note 1 to entry: Typical discrete time intervals are 1 h, 1 mon, or one heating and/or cooling season, operating modes, and bins.

Note 2 to entry: In the frame of the bin method, calculation steps are based on outdoor temperature classes.

3.9

coefficient of performance

COP

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

3.10

cumulative frequency

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

3.11

cut-out period

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

3.12

domestic hot water heating

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

3.13

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, and
- the proportional power input of the conveying devices (e.g. fans, pumps) for ensuring the transport of the heat transfer media inside the unit

3.14

electrically driven heat pump

vapour compression cycle heat pump which incorporates a compressor driven by an electric motor

3.15

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

3.16

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 to entry: The energy need is calculated and cannot be easily measured.

Note 2 to entry: 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 are not included in the heat transfer due to the heating (cooling) system.

3.17
energy use for space heating or cooling or domestic hot water

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

Note 1 to entry: 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).

3.18
frequency

<statistical> number of times the event occurred in the sample

Note 1 to entry: The frequencies are often graphically represented in histograms. In the frame of this part of ISO 13612, the frequency of the outdoor air temperature is evaluated based on a sample of hourly averaged data for one year.

3.19
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

3.20
heat pump

unitary or split-type assemblies designed as a unit to transfer heat

Note 1 to entry: 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.

3.21
heat recovery

heat generated by a technical building system or linked to a building use (e.g. domestic hot water) which is utilized 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)

3.22
heat transfer medium

medium (water, air, etc.) used for the transfer of the heat without change of state

Note 1 to entry: The fluid cooled by the evaporator, the fluid heated by the condenser, and the fluid circulating in the heat recovery heat exchanger.

3.23
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

3.24
heating capacity

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

Note 1 to entry: If heat is removed from the indoor heat exchanger for defrosting, it is taken into account.

3.25

heating or cooling season

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

Note 1 to entry: The season lengths are used to determine the operation period of technical systems.

3.26

internal temperature

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

Note 1 to entry: This is the approximate operative temperature according to ISO 7726.

3.27

low temperature cut-out

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

3.28

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

3.29

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

3.30

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

3.31

primary pump

pump mounted in the circuit containing the generator and hydraulic decoupling

EXAMPLE A heating buffer storage in parallel configuration or a hydronic distributor.

3.32

produced heat

heat produced by the generator subsystems

Note 1 to entry: In the context of this part of ISO 13612, this is 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.

3.33

recoverable system thermal loss

part of a 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

3.34

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

3.35

seasonal performance factor

SPF

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

3.35.1

cooling seasonal performance factor

CSPF

ratio of the total annual amount of heat that the equipment can remove from the indoor air when operated for cooling in active mode to the total annual amount of energy consumed by the equipment during the same period

3.35.2

heating seasonal performance factor

HSPF

ratio of the total annual amount of heat that the equipment, including make-up heat, can add to the indoor air when operated for heating in active mode to the total annual amount of energy consumed by the equipment during the same period

3.36

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

3.37

simultaneous operation during the heating period

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)

3.38

simultaneous operation during the cooling period

simultaneous production of output thermal power for the space cooling and domestic hot water system by a heat generator with double service (e.g. by refrigerant desuperheating or condensate subcooling)

3.39

space heating/cooling

process of heat supply for thermal comfort

3.40

standard rating condition

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

3.41

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

3.42

technical building system

technical equipment for heating, cooling, ventilation, domestic hot water, lighting, and electricity production composed of subsystems

Note 1 to entry: A technical building system can refer to one or to several building services (e.g. heating system, heating and DHW system).

Note 2 to entry: Electricity production can include cogeneration and photovoltaic systems.

3.43

technical building subsystem

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

4 Symbols and abbreviated terms

For the purposes of this part of ISO 13612, the symbols and units in [Table 2](#) and indices in [Table 4](#) apply. Abbreviated terms are listed in [Table 3](#).

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	Electrical (auxiliary) energy	J

Table 3 — Abbreviated terms

Abbreviation	Description
ATTD	Accumulated time-temperature difference
DHW	Domestic hot water
SH	Space heating

Table 3 (continued)

Abbreviation	Description
SC	Space cooling
TTD	Time-temperature difference
VCC	Vapour compression cycle
VAC	Vapour absorption cycle

Table 4 — Index

$\Delta\theta$	temperature corrected	eng	engine	nrbl	non-recoverable
θ_{lim}	lower temperature limit	es	storage values acc. to EN 255-3, phase 4	on	running, in operation
θ_{hlim}	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
C	space cooling	hp	heat pump	st	storage
cap	lack of capacity	Int	internal	sby	stand-by
co	cut-out	In	input to subsystem	sk	sink
cold	cold process side	j	index, referring to bin j	sngl	single (operation)
combi	combined operation	k	index	sc	source
crnt	Carnot	Ls	loss	standard	acc. to standard testing
dis	distribution subsystem	Ltc	low temperature cut-out	tot	total
des	at design conditions	max	maximum	w	water, heat transfer medium
Ext	external	n	nominal	W	domestic hot water (DHW), DHW operation
eff	effective				

NOTE The indices specifying the symbols in this part of ISO 13612 are put in the following order:

- the first index represents the type of energy use (H = space heating, W = domestic hot water). If the formula 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.

5 Principle of the method

5.1 Flowchart of the calculation method

Heat pump systems for heating and cooling can be independent or used as part of a system including other generators. [Figure 1](#) explains how the information and output of the calculation are used in such multiple systems. In this case, the heat pump, including its integrated back-up system (if any), is considered as the priority generator.

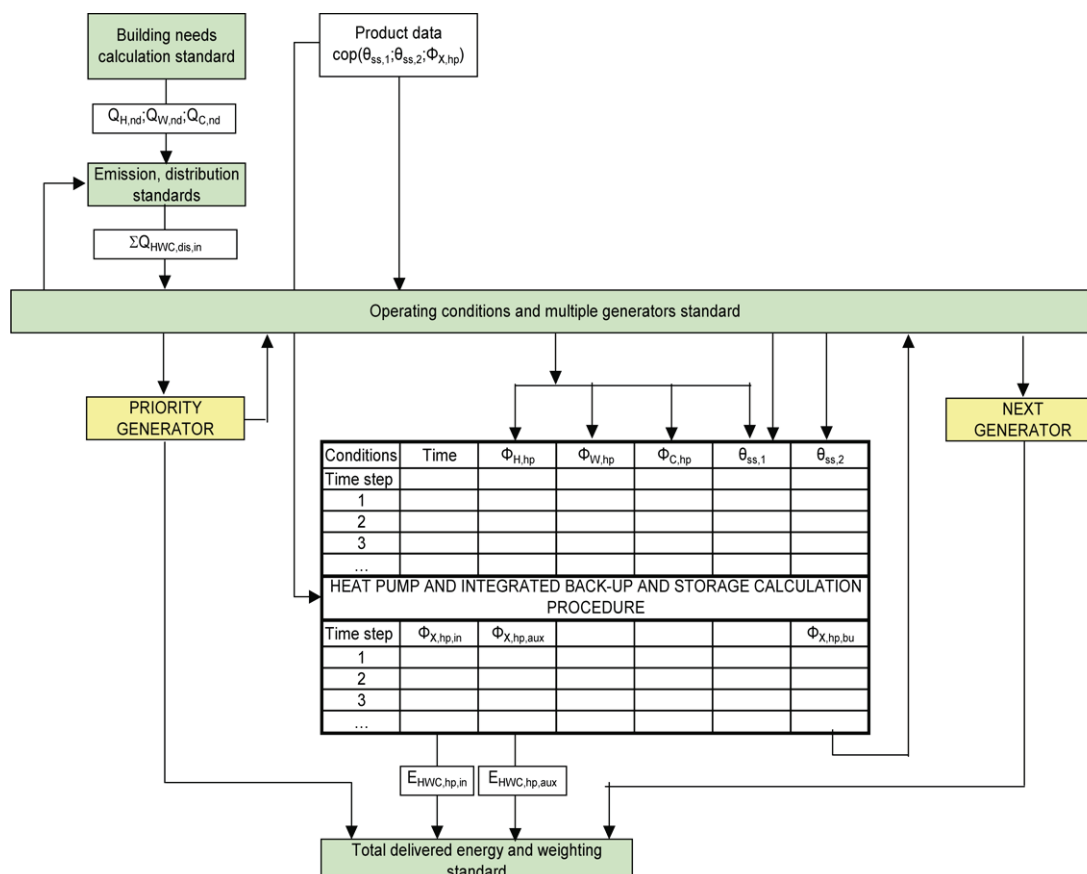


Figure 1 — Heat pump systems and interaction with other generators

The performance calculation method for the generation subsystem is described in the flowchart presented in [Figure 2](#).

The method is based on calculating the amount of energies delivered to the heat pump system using tabulated values. Methods to establish the coefficient of performance (COP) according to the different heat pump system characteristics and available data are presented in [Annexes A, B, C, D](#), and E.

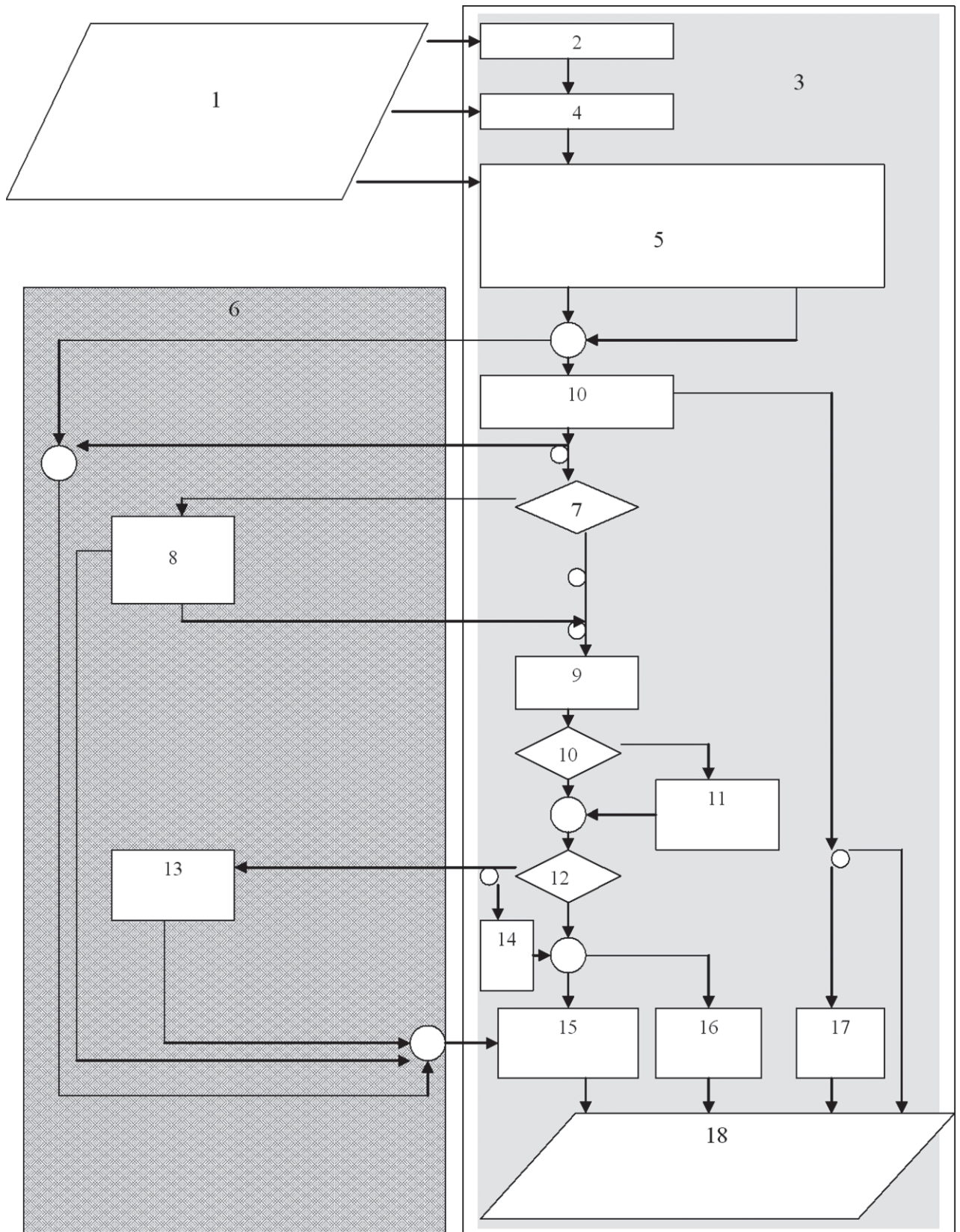
The methodology is based on an hourly calculation as default time step for the calculation. The time step should be adapted according to the climatic data available and the accuracy required for the calculation.

An overview of the calculation steps to be performed is listed below. A more detailed overview for different system configurations can be seen in the flowchart in [Figure 2](#).

The elementary calculation steps are explained in detail in the part of [Clause 6](#) 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 calculation, simplified and detailed methods are given in connection with the calculation of the running time.

- Step 1: Collection of the input data (see [6.1](#))
- Step 2: Identification of the time step for the calculation (see [6.2](#))
- Step 3: Determination of energy requirements for heating and cooling periods (see [6.3](#))
- Step 4: Construction of the energy delivered by the heat pump system depending on climatic conditions (see [6.4](#))
- Step 5: Calculation of generation subsystem heat losses (see [6.4](#))
- Step 6: Determination of back-up energy (see [6.5](#) for simplified; see [6.6.4](#) for detailed)
- Step 7: Calculation of the running time of the heat pump in different operation modes (see [6.6](#))
- Step 8: Calculation of auxiliary energy input (see [6.7](#))
- Step 9: Calculation of recoverable generation subsystem losses (see [6.8](#))
- Step 10: Calculation of the total driving energy input to cover the requirements (see [6.9](#))
- Step 11: Summary of required and optional output values (see [6.10](#))



Key

- 1 input data (6.1):
 - energy requirement of space heating distribution subsystem;
 - energy requirement of the DHW distribution subsystem;
 - meteorological data;
 - product characteristic;
 - design parameters.
- 2 definitions calculation period time step operation (6.2)
- 3 monovalent mode
- 4 calculation energy requirements for the step time (6.3)
- 5 tabulated value heating capacity/COP for operating conditions (6.4)
tabulated value cooling capacity/COP for operating conditions (6.4)
- 6 bivalent mode
- 7 calculation of generation subsystem heat losses
- 8 evaluation of back-up energy due to operation limit and based on balance point
- 9 calculation of running time
- 10 simultaneous system with three operation modes (Y/N)
- 11 calculation of operating time with simultaneous system with three operation modes
- 12 running time < time step for the calculation (Y/N)
- 13 calculation of back-up energy
- 14 running time = time step for the calculation
- 15 calculation of energy input to cover the heat requirement
- 16 calculation of auxiliary energy
- 17 calculation of recoverable losses
- 18 output data (6.10):
 - energy input to cover the energy requirement;
 - total losses of the generation subsystem;
 - total recoverable losses of generation subsystem;
 - total auxiliary energy input.

Figure 2 — Flowchart of the calculation method

The method is based on calculating the amount of energies delivered to the heat pump system using tabulated values. Methods to establish the tabulated values according to the different heat pump system characteristics are presented in [Annexes A, B, C, D](#), and [E](#).

The methodology is based on an hourly calculation as default time step for the calculation. The time step should be adapted according to the climatic data available and the accuracy required for the calculation.

5.2 System boundary

The system boundary defines the components of the entire heating systems that are considered in this part of ISO 13612. 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 included in the system boundary.

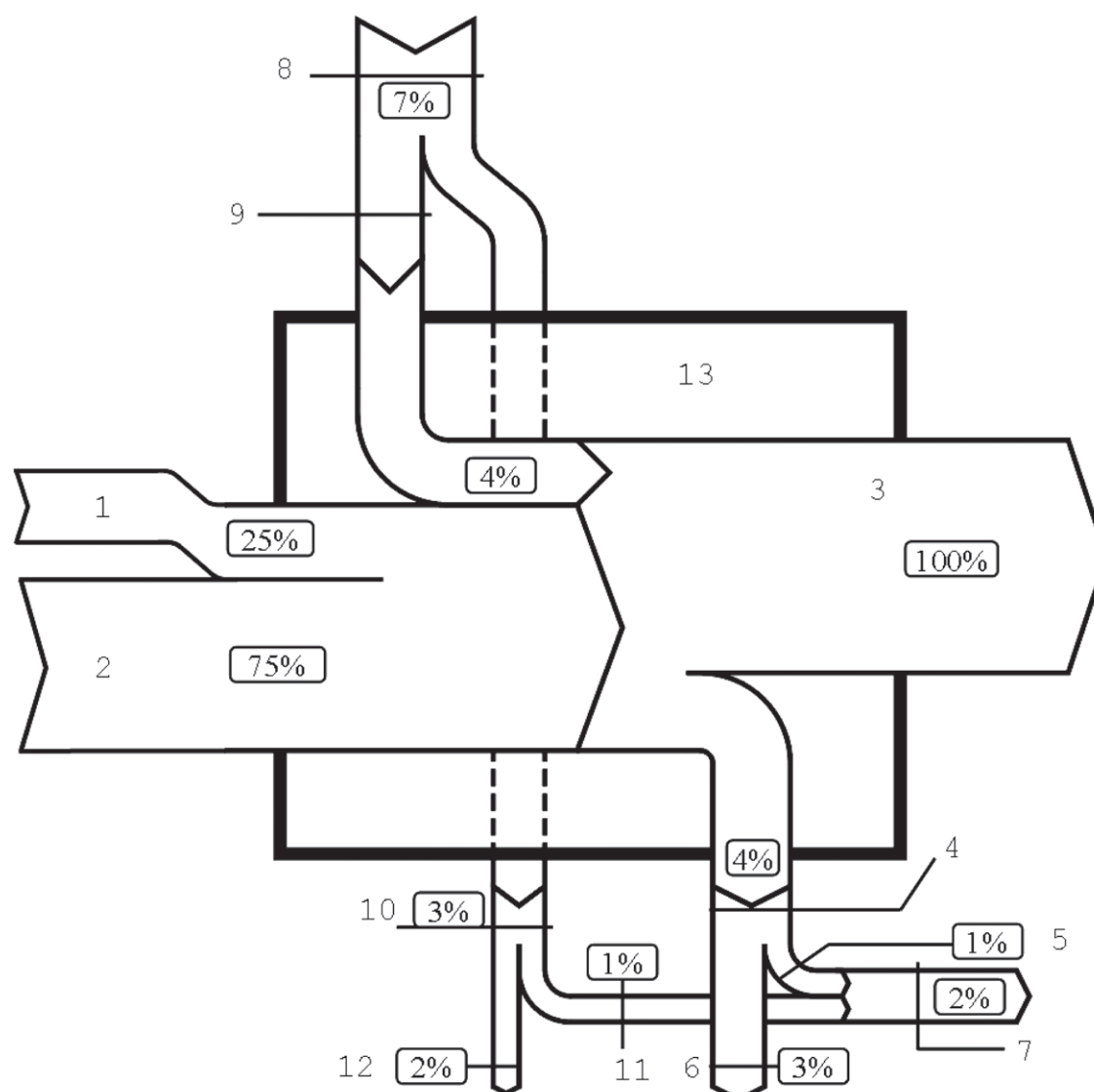
Distribution and emission systems are out of the system boundaries.

5.3 Physical factors

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 subsystem.

- 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)
- space cooling energy requirements of the distribution subsystem(s)
- effects of variation of source and sink temperature on heating and/or cooling 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 heat losses due to space heating or DHW storage components or space cooling, including the connecting pipework or ducts
- location of the generation subsystem

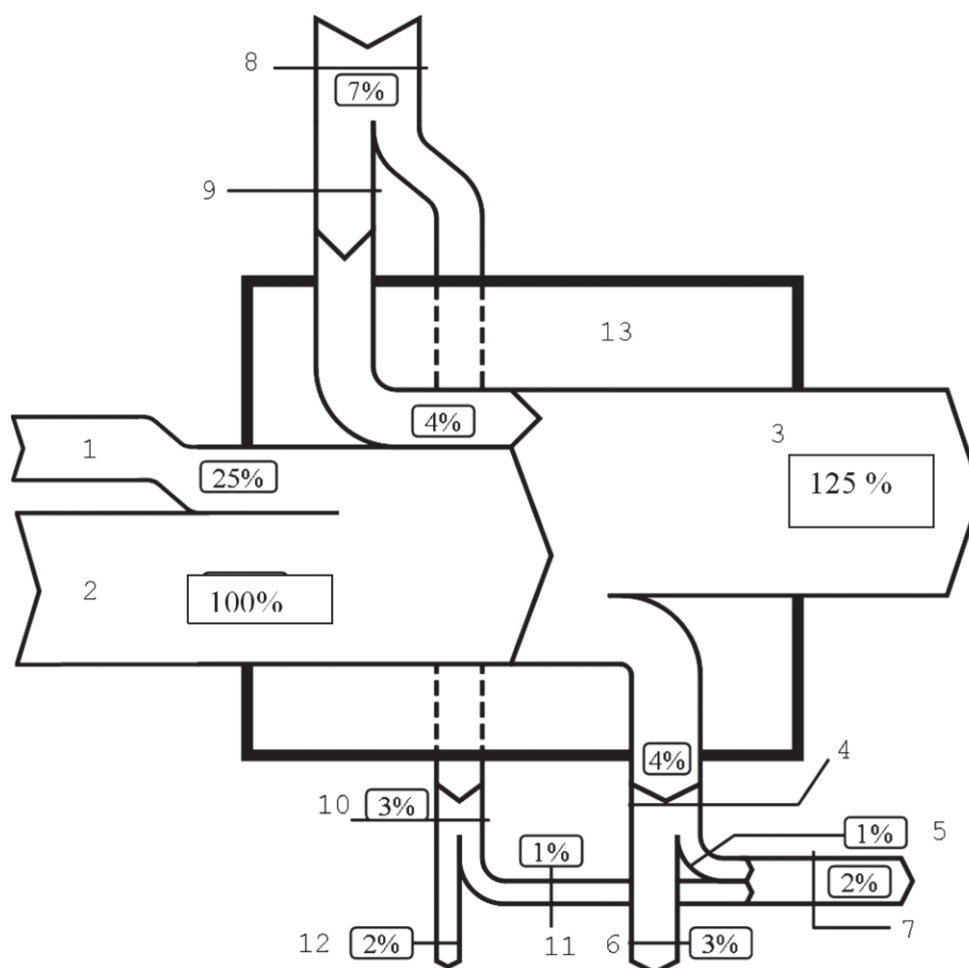
5.4 Schematization of the heat pump for heating and cooling



Key

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

Figure 3 — Example of energy balance of generation subsystem for heating



Key

- | | |
|---|--|
| 1 driving energy input to cover the cooling requirement (e.g. electricity, fuel), $E_{CW,gen,in}$ | 8 auxiliary energy input, $W_{HW,gen,aux}$ |
| 2 extracted energy for cooling, $Q_{CW,gen,in}$ | 9 recovered heat loss of auxiliary components, $Q_{HW,gen,aux,ls,rcv}$ |
| 3 heat output of generation subsystem ($Q_{HW,gen,out} = Q_{HW,dis,in}$) | 10 unrecovered heat loss of auxiliary components, $Q_{HW,gen,aux,ls}$ |
| 4 generation subsystem heat losses, $Q_{HW,gen,ls,tot}$ | 11 recoverable heat loss of auxiliary components, $Q_{H,gen,aux,ls,rbl}$ |
| 5 recoverable generation subsystem heat losses, $Q_{CW,gen,ls,rbl}$ | 12 non-recoverable heat loss of auxiliary components, $Q_{HW,gen,aux,ls,nrbl}$ |
| 6 non-recoverable generation subsystem heat losses, $Q_{HW,gen,ls,nrbl}$ | 13 generation subsystem |
| 7 total recoverable generation subsystem heat losses, $Q_{H,gen,ls,rbl,tot}$ | |

Figure 4 — Example of energy balance of generation subsystem for cooling

The numbers indicated in [Figures 3](#) and [4](#) 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 depending on the physical factors listed before. The numbers given in [Figure 3](#) refer to an electrically driven ground-source heat pump in monovalent space heating-only operation, including buffer storage.

5.5 Input and output of the calculation method

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;
- cooling requirements for air-conditioned space.

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

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

5.6 Energy input needed to meet the heat requirements for electrically driven heat pumps

The energy balance for the electrically driven generation subsystem is given by Formula (1).

$$E_{HW,gen,in} = Q_{HW,gen,out} + Q_{HW,gen,ls,tot} - Q_{HW,gen,in} - k_{gen,aux,ls,rld} \cdot W_{HW,gen,aux} \quad (1)$$

where

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

In case of electrically driven heat pumps, the term $E_{HW,gen,in}$ is the electrical energy input necessary for the heat pump system to cover the energy requirement of the distribution subsystem. It comprises the electrical energy input to the heat pump system and possibly installed back-up heaters.

NOTE For some standards, such as EN 14511, $E_{HW,gen,in}$ 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, eventually, energy for defrost operation and additional heating devices for the oil supply of the compressor (carter heating).

- Thus, $W_{HW,gen,aux}$ only comprises the fractions not included in the COP standard testing. $k_{gen,aux,ls,rvd}$ 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 $k_{gen,aux,ls,rvd} = 0$.
- For total heat losses, $Q_{HW,hp,ls,tot}$, the heat 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 DHW hot water storage, generation subsystem losses in the form of storage heat losses and losses of the connecting circulation pipes to the storage are considered.

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

- $E_{HW,gen,in}$ 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, not only fuel-driven burners but also solar energy or waste heat can be the driving energy input.
- $Q_{HW,gen,out}$, the heat energy output of the generation subsystems, is equal to the heat requirement of the distribution subsystem 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.
- $k_{gen,aux,ls,rvd}$ gives the fraction of the auxiliary energy recovered as thermal energy and depends on the test method. The fraction $k_{gen,aux,ls,rvd} = 0$, if the recovered heat is already included in the COP.

5.7 Auxiliary energy, $W_{HW,gen,aux}$

Auxiliary energy is energy needed to operate the generation subsystem, e.g. the source pump or the control system of the generator.

NOTE As for electrically driven heat pumps, heating capacity and COP in this part of ISO 13612 are calculated on the basis of results from product testing; according to EN 14511, 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, are considered in $W_{HW,gen,aux}$.

Auxiliary energy is accounted to the generation subsystem as long as no transport energy is transferred to the distribution subsystem. That means, in general, the circulation pump is accounted to the distribution subsystem, unless hydraulic decoupling exists. For 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 accounted to 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.

5.8 Recoverable, recovered, and unrecoverable heat losses

The calculated losses are not necessarily lost. Parts of the losses are recoverable, and parts of these recoverable losses are actually recovered. The recovered losses are determined by the location of the generator and the utilization factor (gain/loss ratio, see EN ISO 13790).

Recoverable heat losses, $Q_{H,gen,ls,rbl}$, are, for example, heat losses through the envelope of a generation subsystem in the 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 $Q_{HW,dis,in}$.

5.9 Calculation periods

Heat pump performance strongly depends on the operating conditions, which are basically the source and the sink temperature. As source and sink temperatures vary over the heating and cooling periods and over the year, the heat pump performance shall be calculated accordingly with an adapted step period, in line with the climatic data used. As default, a step time of 1 h is considered in this part of ISO 13612.

The time step shall be adapted according to the climatic data available and the accuracy required for the calculation.

NOTE For some alternative methods, calculation periods are not oriented at the time scale, i.e. monthly values, but on the frequency of the outdoor air temperature (bin method).

5.10 Calculation by zones

A heating/cooling system may be split up in 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:

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

where

$Q_{H,gen,out,k}$ 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) $Q_{H,dis,in,k}$ shall be distributed among the available generators and the calculation described in [Clause 6](#) shall be performed independently for each generation subsystem k on the basis of $Q_{H,gen,out,k}$. This is accomplished in case of an installed back-up heater.

For intermittent heating, the requirements of ISO 13790 shall be considered.

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 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, and
- cascade cycles with internal heat exchangers.

For these simultaneous concepts, space heating and domestic hot water requirements are covered at the same time. [Annex E](#) gives an example of a hydraulic scheme of a simultaneous operating system using a cascade cycle with condensate subcooling.

For simultaneous system layout, three operation modes shall be distinguished:

- space heating-only (cooling-only) operation:
only the space heating system is in operation only the lower stage heat pump is in operation (winter time, DHW storage entirely loaded);
- domestic hot water-only operation:
only the domestic hot water system is in operation (summer operation, no space heating demand);
- simultaneous operation:
both space heating (or cooling) and domestic hot water operation. For the configuration shown in [Figure 4](#), 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).

For combined cooling and domestic hot water, the calculation shall identify which priority use is considered. In most cases, priority is given to cooling use as DHW is a co-product. Back-up heater is provided the necessary complement to satisfy DHW production.

The calculation implies that both the single operation modes and the simultaneous operation are tested according to standard testing, so heating capacity and COP characteristic of all three respective operation modes are available. As heating capacity and COP characteristic of the simultaneous operation may differ significantly from the other two operation modes, these test results shall be available and taken into account.

6 Generation subsystem calculation

6.1 Input data

Input information for the procedure can consist of the following:

- the type of building and sector;
- climatic data adapted to the local consideration;
- the operating condition (including typical occupancy patterns of the relevant building sector taken into account, comfort level, and room temperature/humidity);
- the heat pump function (space heating, domestic hot water production, space cooling, any combination of these);
- the type of heat pump (electrically driven, engine-driven, etc.);
- the type of energy input (electricity, natural gas, LPG, oil, etc.);
- the type of heat source;
- the source pump or fan power;
- the test results produced in accordance with standard tests (e.g. EN 14511) for electrically driven heat pumps;
- the heating capacity, cooling capacity;
- whether performance data include the effect of an integrated storage, if any;
- integrated domestic hot water storage characteristics (volume/dimensions, specific loss);

- information about control of the heat pump system and priority given to the energy use (e.g. priority to domestic hot water during heating or cooling mode);
- the design and operation of the generation heat pump system, the calculation time-step, and the calculation period;
- characteristics of the integrated back up heater.

The calculation period shall be subdivided into three subperiods as the heat pump system is operating for

- space heating (and domestic hot water),
- space heating and space cooling alternatively,
- space cooling (and domestic hot water).

The climatic data shall be considered as constant for any calculation time step.

6.2 Energy requirements for space heating, space cooling, and DHW mode

6.2.1 Space heating and space cooling mode

The energy requirement of the space heating and space cooling distribution subsystem, $Q_{H,dis,in}$, is specified in [6.1](#).

If data provided are not in line with the time step calculation, then data are derived from data provided by

- using the sum of the heat energy requirement if the time step is greater than the time period between data, or
- using linear interpolation if the time step t_j is lower than the time period between bin scheme and standard locations in a national annex.

6.2.2 Domestic hot water mode

The heat energy requirement of the domestic hot water distribution subsystem $Q_{W,dis,in}$ is calculated according to [6.1](#).

Energy requirements are adapted to the time step accordingly with [6.3](#).

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

6.3 Tabulated values of the COP for heating and cooling at full load

The values of the thermal power provided to the output system are provided according to methods presented in [Annexes A, B, and C](#).

6.4 Heat losses through the generator envelope

6.4.1 Space heating mode

For heat pumps without an integrated storage in the same housing, the losses to the ambience are neglected in the frame of this part of ISO 13612, unless national values are given for the envelope heat loss of the heat pump.

For engine-driven heat pumps, the heat losses of the engine are considered. They shall be evaluated based on test results or manufacturer data. If no values are available, the losses can be estimated by the

efficiency of the engine and a possible fraction of recovered heat. For the redistribution of the total heat losses to the bins or operation modes, if required, the stand-by losses for each step time and the running time (for operational losses) of the heat pump shall be evaluated.

Internal or external heating buffer storage produces losses to the ambient that can be calculated by a stand-by heat loss value for the step time t_j :

$$Q_{H,st,ls,j} = \frac{\theta_{H,st,avg,j} - \theta_{H,st,amb,j}}{\Delta\theta_{st,sby}} \cdot \frac{Q_{st,sby} \cdot 1000[W/kW] \cdot t_j}{24[h/d]} \quad (3)$$

where

- $Q_{H,st,ls,j}$ is the heat loss of the heating buffer storage to the ambient in time t_j (J);
- $\theta_{H,st,avg,j}$ is the average storage temperature of the heating buffer storage in time t_j (°C);
- $\theta_{H,st,amb,j}$ is the ambient temperature at the storage location (°C);
- $\Delta\theta_{st,sby}$ is the temperature difference due to storage stand-by test conditions (K);
- $Q_{st,sby}$ is the stand-by heat loss due to storage stand-by test conditions (kWh/d);
- t_j is the step time t_j (constant) (s).

If the stand-by heat loss from the storage vessel is not available, default values are given in [Annex B](#).

The average storage temperature, $\theta_{H,st,avg,j}$, is to be determined according to the storage control. If the storage is operated depending on the temperature requirements of the heating system, it is approximated as the average temperature of the flow and return temperature of the space heating system, according to Formula (4).

$$\theta_{H,st,avg,j} = \frac{\theta_{H,gen,f,j} - \theta_{H,dis,r,j}}{2} \quad (4)$$

where

- $\theta_{H,st,avg,j}$ is the average storage temperature of the heating buffer storage at time t_j (°C);
- $\theta_{H,gen,f,j}$ is the flow temperature of the space heating generation system at time t_j (°C);
- $\theta_{H,dis,r,j}$ is the return temperature from the space heating distribution system at time t_j (°C).

The flow temperature is evaluated according to the control of the heating system (heating curve, room thermostat), and the return temperature is calculated by interpolating the temperature spread of flow and return temperature between the design temperature spread (at outdoor design temperature) and $\Delta\theta = 0$ at the indoor design temperature.

The same principle applies for the cooling mode.

6.4.2 Domestic hot water mode

If data from storage testing are known, the calculation of the losses of the domestic hot water storage shall be accomplished as for heating buffer storages according to Formula (3). The average storage temperature depends on the applied storage control, the position of the heat exchangers, the temperature sensors, etc. It shall be determined based on the product information. If no information is available, default values of the average DHW storage temperature are given in [Annex B](#).

If no values on storage stand-by losses are available, the calculation shall be carried out according to Formula (3), with values based on the volume of the storage vessel given in a national annex. If no national values are available, default values are given in [Annex B](#).

6.4.3 Cooling mode

For the cooling mode, the same principles as the one used for the heating mode apply.

- For heat pumps without an integrated storage in the same housing, the losses to the ambience are neglected in the frame of this part of ISO 13612, unless national values are given for the envelope thermal losses of the heat pump.
- For engine-driven heat pumps, the thermal losses of the engine are considered. They shall be evaluated based on test results or manufacturer data. If no values are available, the losses can be estimated by the efficiency of the engine and a possible fraction of recovered heat. For the redistribution of the total thermal losses to the bins or operation modes, if required, the stand-by losses for each step time and the running time (for operational losses) of the heat pump shall be evaluated.

Internal or external buffer or ice storage produces losses to the ambient that can be calculated by a stand-by heat loss value for the step time t_j in accordance with Formula (3).

6.4.4 Heat losses of primary circulation pipes

Heat losses of the primary circulation pipes between the heat generator and the storage vessel shall be added to the storage losses.

6.5 Calculation of back-up heater

6.5.1 General

Back-up energy can be required for two reasons.

- Temperature operating limit of the heat pump (i.e. the temperature that can be reached with the heat pump is restricted to a maximum value). This fraction of back-up energy is treated in [6.5.2](#).
- Multivalent design of the generator subsystem (see boundary conditions in [5.10](#)), i.e. the heat pump is not designed for the total load. Then, a fraction of back-up energy is required due to a lack of heating capacity of the heat pump.

For the calculation of the back-up operation due to a lack of capacity, a simplified and a detailed method are given.

The simplified method is based on the evaluation of the cumulative frequency and the balance point and, depending on the operation mode, the low temperature cut-out. It is described in [6.5.2](#). The method assumes that the balance point is known and all influencing factors (e.g. power demand for space heating and DHW operation, cut-out times of the electricity supply, etc.) have been taken into account.

For the detailed method, a 1 K energy balance is accomplished for the range of lower source temperatures up to the temperature where no back-up energy is needed. It should be applied, if the balance point is not known or difficult to calculate, e.g. in systems with simultaneous operation, or if 1 K bins are chosen for the calculation anyway. The balance point is no longer an input since it follows from the energy balance expressed by the required running time. The method is described in [6.6.4](#) in connection with the evaluation of the running time.

6.5.2 Back-up energy due to the operation limit temperature of the heat pump in heating mode

Depending on the refrigerant and the heat pump internal cycle, the maximum temperature level that can be produced with the heat pump is restricted by an operation limit. If temperatures above a certain

temperature are required, they cannot be produced by the heat pump but have to be reheated by a back-up heater. Therefore, the fraction of back-up energy due to the operation limit of the heat pump can be calculated using Formula (5).

$$k_{\text{bu,opr},j} = \frac{Q_{\text{bu,opr},j}}{Q_{\text{gen,out},j}} = \frac{m'_w \cdot c_w \cdot (\theta_{n,j} - \theta_{\text{hp,op}}) \cdot t_{\text{hp,on},j}}{Q_{\text{gen,out},j}} \quad (5)$$

where

- $k_{\text{bu,opr},j}$ is the fraction of back-up energy due to the operation limit of the heat pump in time t_j (-);
- $Q_{\text{bu,opr},j}$ is the back-up heat energy due to the operation limit of the heat pump in time t_j (J);
- $Q_{\text{gen,out},j}$ is the heat energy requirement of the distribution subsystem in time t_j (J);
- m'_w is the mass flow rate of the heat transfer medium (kg/s);
- c_w is the specific heat capacity of the heat transfer medium [J/(kg·K)];
- $\theta_{n,j}$ is the nominal temperature requirement of the system at time t_j (°C);
- $\theta_{\text{hp,op}}$ is the operation limit temperature of the heat pump (maximum temperature, that can be reached with the heat pump operation) (°C);
- $t_{\text{hp,on},j}$ is the running time of the heat pump at time t_j (s).

For the space heating operation, the fraction $k_{\text{H,bu,opr},j}$ usually does not occur, i.e. $k_{\text{H,bu,opr},j} = 0$, since the design of the heat emission subsystem is usually adapted to required temperature levels below the operation limit of the heat pump.

For DHW operation, higher temperatures than the operation limit may be required so that the heat pump delivers the heat up to the operation limit temperature, e.g. 55 °C, and the additional temperature requirement, e.g. up to 60 °C, is supplied by the back-up heater. The fraction of back-up heat energy supplied to the domestic hot water system is given by Formula (6).

$$k_{W, \text{bu}, \text{opr}, j} = \frac{Q_{W, \text{bu}, \text{opr}, j}}{Q_{W, \text{gen}, \text{out}, j}} = \frac{\rho_w \cdot V_{w, j} \cdot c_w \cdot (\theta_{w, \text{out}} - \theta_{\text{hp}, \text{opr}})}{\rho_w \cdot V_{w, j} \cdot c_w \cdot (\theta_{w, \text{out}} - \theta_{w, \text{in}})} = \frac{(\theta_{w, \text{out}} - \theta_{\text{hp}, \text{opr}})}{(\theta_{w, \text{out}} - \theta_{w, \text{in}})} \quad (6)$$

where

$k_{W, \text{bu}, \text{opr}, j}$ is the fraction of back-up energy in DHW mode due to the operation limit of the heat pump at time t_j (-);

$Q_{W, \text{bu}, \text{opr}, j}$ is the DHW back-up heat energy due to the operation limit of the heat pump at time t_j (J);

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

ρ_w is the density of the heat transfer medium (kg/m³);

$V_{w, j}$ is the volume of the hot water draw-off at time t_j (m³/s);

c_w is the specific heat capacity of water [J/(kg·K)];

$\theta_{W, \text{out}}$ is the temperature of the hot water at storage outlet (°C);

$\theta_{\text{hp}, \text{opr}}$ is the operation limit temperature of the heat pump (maximum temperature that can be reached with the heat pump operation) (°C);

$\theta_{W, \text{in}}$ is the temperature of the cold water inlet (°C).

The operation limit temperature shall be taken from manufacturer data or evaluated based on the applied refrigerant.

6.6 Running time of the heat pump

6.6.1 General

The running time of the heat pump depends on the heating/cooling capacity, given by the operating conditions, and on the heat requirement, given by the distribution subsystem. The running time can be calculated by Formula (7):

$$t_{\text{hp}, \text{on}, j} = \frac{Q_{\text{hp}, j}}{\phi_{\text{hp}, j}} \quad (7)$$

where

$t_{\text{hp}, \text{on}, j}$ is the running time of the heat pump at time t_j (s);

$Q_{\text{hp}, j}$ is the produced heat energy by the heat pump at time t_j (heat energy requirement of the distribution subsystem and generation subsystem losses) (J);

$\phi_{\text{hp}, j}$ is the heating (or cooling) capacity of the heat pump at time t_j (W).

The running time at step j , $t_{\text{hp}, \text{on}, j}$, shall be considered for verification that this running time is lower than the time step calculation.

- If yes, calculate the part load factor, then the corrected COP.
- If no, link to the back-up heater (additional energy to be supplied) and HP at full load.

The produced heat by the heat pump can be calculated by Formula (8).

$$Q_{hp,j} = (Q_{gen,out,j} + Q_{gen,ls,j})(1 - k_{bu,cap,j}) \quad (8)$$

where

$Q_{hp,j}$ is the produced heat energy by the heat pump at time t_j (energy requirement of the distribution subsystem and generation subsystem losses) (J);

$Q_{gen,out,j}$ is the heat energy requirement of the distribution subsystem at time t_j (J);

$Q_{gen,ls,j}$ is the generation subsystem heat losses at time t_j (J);

$k_{bu,cap,j}$ is the fraction of heat energy covered by the back-up heater at time t_j (-).

These formulae can be applied for the different operation modes. The following items shall be considered.

Back-up calculation

The fraction of back-up energy for DHW due to the operation limit of the heat pump has to be taken into account, since the fraction of back-up energy due to a lack of capacity follows from the energy balance (see 6.6.4). That means only the fractions $k_{bu,opr,j}$ due to the operation limit temperature are considered.

Operation mode (heating and/or DHW)

For heat pumps operating in SH-only mode or DHW-only mode, the energy requirement is given by the actual space heating or domestic hot water heat requirement respectively, i.e. the energy requirement of the distribution subsystem and the generator losses.

For heat pumps operating alternately on the SH and DHW system, total running time of the heat pump is determined by the sum of the space heating and domestic hot water heat energy requirements, produced at the respective heating capacity of the heat pump, with priority given to provide energy to the DHW system (default mode).

For heat pumps operating simultaneously for heat production for SH and DHW, the running time has to be distinguished according to the state of operation. As the heat pump characteristic by simultaneous operation may differ significantly from the heat pump characteristic by the two single operation modes, the three operation modes may have to be evaluated:

- space heating-only operation: running time is determined by the heat requirement of the space heating system and the respective characteristic of the heat pump in space heating-only mode;
- DHW-only operation: running time is determined by the domestic hot water requirement and the respective characteristic of the heat pump in DHW-only mode;
- simultaneous operation: running time is determined by the energy produced by simultaneous operation. The heating capacity of the heat pump in simultaneous operation has to be applied.

However, depending on the system configuration, not all three operation modes may occur in simultaneous operating systems. There are system configurations, for instance, where only simultaneous operation takes place in wintertime, so no space heating-only operation occurs. This is the case for instance in combined operating systems with desuperheating that work on a combi-storage for space heating and DHW. In this case, only two characteristics, DHW-only and simultaneous combined, shall be taken into account and the time period of simultaneous operation is given by the heating season. The running time is evaluated based on these two characteristics.

Additional calculations of the energy fractions and the running times for systems where all three operation modes occur are given in 6.6.2.

The total running time at time t_j can be calculated by Formula (9):

$$t_{hp,on,tot,j} = t_{H,hp,on,sngl,j} + t_{W,hp,on,sngl,j} + t_{HW,hp,on,combi,j} \quad (9)$$

where

- $t_{hp,on,tot,j}$ is the total running time of the heat pump at time t_j (s);
- $t_{H,hp,on,sngl,j}$ is the running time in space heating-only operation at time t_j (s);
- $t_{W,hp,on,sngl,j}$ is the running time in DHW-only operation at time t_j (s);
- $t_{HW,hp,on,combi,j}$ is the running time in simultaneous operation at time t_j (s).

Depending on the type of system, only some of different contributions exist, while the others are zero (e.g. the running time for space heating in DHW-only systems).

Operation mode (cooling and/or DHW)

For heat pumps operating in SC-only mode, the energy requirement is given by the actual space cooling, i.e. the energy requirement of the distribution subsystem and the generator losses.

Running time calculation identical to the space heating only mode:

For heat pumps operating alternately on the SC and DHW system, total running time of the heat pump is determined by the sum of the space cooling and domestic hot water heat energy requirements, produced at the respective cooling capacity of the heat pump.

For heat pumps operating simultaneously for heat production for SC and DHW, the running time has to be distinguished according to the state of operation. As the heat pump characteristic by simultaneous operation may differ significantly from the heat pump characteristic by the two single operation modes, the three operation modes may have to be evaluated.

NOTE Simultaneous operation of heat pump systems for space cooling and DHW is used in specific cases when the energy used for DHW is low versus the energy use for space cooling or when the heat pump system is used for pre-heating of the DHW.

First step: Identify operating conditions and energy requirements for both energy uses.

Calculate separately the running time for space cooling and domestic hot water.

- Identify the minimum value and check which energy output is reached for both energy requirements.
- Then calculate the energy left for the single mode operation.
- Check if the corresponding running time matches the time step calculation.

Second step: Calculate the additional running time necessary to complete the energy requirements.

If the calculated running time is higher than the available time step calculation, then identify the load for other generators (heating/cooling).

6.6.2 Additional calculations for simultaneous operating heat pumps with three operation modes

6.6.2.1 Principle

When all three operation modes occur, the running time in the different operation modes has to be determined.

Since simultaneous operation only takes place in times of space heating and domestic hot water load, the running time is evaluated to characterize simultaneous operation. The maximum possible simultaneous operation is characterized by the minimum of required running time for space heating and DHW operation. Subsequently, the resulting maximum running time in simultaneous operation may then be corrected with a correction factor in order to take into account further controller impact.

After the estimation of the running time in simultaneous operation, the respective energies produced in simultaneous operation are calculated, and then the energy produced in SH-only and DHW-only can be determined by energy balances. As a last step, the running time in SH-only and DHW-only operation is calculated based on these energies.

NOTE Since running time is related to produced energy, but storage losses of the DHW system may be expressed by the electricity input according to EN 255-3, the net energy to cover the heat requirement is calculated for the DHW system by subtracting the storage losses.

6.6.2.2 Calculation steps

The maximum running time in simultaneous operation is calculated by Formula (10):

$$t_{\text{HW, hp, on, combi, max, j}} = \min(t_{\text{H, hp, on, j}}, t_{\text{W, hp, on, j}}) \quad (10)$$

where the running time for DHW operation is calculated with the heating capacity in simultaneous operation according to Formula (11):

$$t_{\text{W, hp, on, j}} = \frac{Q_{\text{W, hp, j}}}{\phi_{\text{W, hp, combi, j}}} \quad (11)$$

and, analogously, according to Formula (12) for space heating operation:

$$t_{\text{H, hp, on, j}} = \frac{Q_{\text{H, hp, j}}}{\phi_{\text{H, hp, combi, j}}} \quad (12)$$

where

$t_{\text{HW, hp, on, combi, max, j}}$	is the maximum possible running time in simultaneous operation at time t_j (s);
$t_{\text{W, hp, on, j}}$	is the running time in DHW operation at time t_j (s);
$Q_{\text{W, hp, j}}$	is the produced heat energy by the heat pump for DHW at time t_j (J);
$\phi_{\text{W, hp, combi, j}}$	is the DHW heating capacity of the heat pump in simultaneous operation at time t_j (W);
$t_{\text{H, hp, on, j}}$	is the running time in space heating operation at time t_j (s);
$Q_{\text{H, hp, j}}$	is the produced heat energy by the heat pump for space heating at time t_j (J);
$\phi_{\text{H, hp, combi, j}}$	is the space heating capacity of the heat pump in simultaneous operation at time t_j (W).

The running time in simultaneous operation mode may also be influenced by the control and the load profiles. However, controller impact depends strongly on the setting and the system configuration and can be taken into account by a specific correction factor according to Formula (13):

$$t_{\text{HW,hp,on,combi},j} = f_{\text{combi}} \cdot t_{\text{HW,hp,on,combi,max},j} \quad (13)$$

where

- $t_{\text{HW,hp,on,combi},i}$ is the running time in simultaneous operation in time t_j (s);
 - $t_{\text{HW,hp,on,combi,max},i}$ is the maximum possible running time in simultaneous operation at time t_j (s);
 - f_{combi} is the correction factor, taking into account the impact of the control system (-).
- NOTE Adequate factors for typical controller setting shall be given in a national annex based on a specific evaluation of the system configuration.

The DHW energy and, analogously, the space heating energy produced in simultaneous operation, is calculated by Formula (14):

$$Q_{\text{hp,combi},j} = \phi_{\text{hp,combi},j} \cdot t_{\text{hp,on,combi},j} \quad (14)$$

where

- $Q_{\text{hp,combi},j}$ is the produced heat energy in simultaneous operation of the respective operation mode at time t_j (J);
- $\phi_{\text{hp,combi},j}$ is the heat pump heating capacity in simultaneous operation of the respective operation mode in time t_j (W);
- $t_{\text{hp,on,combi},j}$ is the running time in simultaneous operation in time t_j (s).

The rest of the heat energy is produced in SH-only and DHW-only operation and is determined by the formula for the respective operation modes:

$$Q_{\text{hp,sngl},j} = Q_{\text{hp},j} - Q_{\text{hp,combi},j} \quad (15)$$

where

- $Q_{\text{hp,sngl},j}$ is the produced heat by the heat pump in the respective single operation in time t_j (J);
- $Q_{\text{hp},j}$ is the produced heat energy by the heat pump in time t_j (J);
- $Q_{\text{hp,combi},j}$ is the produced heat energy by the heat pump in simultaneous operation in time t_j (J).

NOTE Since EN 255-3 gives the electricity to cover the heat losses of the DHW storage in form of an electrical stand-by power input, the DHW heat energy requirement is evaluated by subtracting the storage losses. If no values according to EN 255-3 are available, the subtraction of the storage losses is not necessary.

The allocation of the DHW-storage losses to the single and simultaneous operation modes is done by f_{combi} .

So, the DHW heat energy requirement in DHW-only and in simultaneous operation can be calculated by subtracting the storage losses according to Formula (16):

$$Q_{W,hp,out,sngl,j} = Q_{W,hp,sngl,j} - Q_{W,st,ls,j} \cdot (1 - k_{W,bu,j}) \cdot (1 - f_{combi}) \quad (16)$$

where

- $Q_{W,hp,out,sngl,j}$ heat requirement of the DHW distribution subsystem covered by the heat pump in DHW-only operation at time t_j (J);
- $Q_{W,hp,sngl,j}$ produced DHW energy by the heat pump in DHW-only operation at time t_j (J);
- $Q_{W,st,ls,j}$ DHW storage losses at time t_j , calculated in 6.4.2 (J);
- f_{combi} correction factor to take into account controller effect, corresponds to the fraction of simultaneous operation (-);
- $k_{W,bu,j}$ fraction of DHW heat energy covered by the back-up heater at time t_j (-).

$$Q_{W,hp,out,combi,j} = Q_{W,hp,combi,j} - Q_{W,st,ls,j} \cdot (1 - k_{W,bu,j}) \cdot f_{combi} \quad (17)$$

where

- $Q_{W,hp,out,combi,j}$ is the heat requirement of the DHW distribution subsystem covered by the heat pump in simultaneous operation at time t_j (J);
- $Q_{W,hp,combi,j}$ is the produced DHW energy by the heat pump in simultaneous operation at time t_j (J);
- $Q_{W,st,ls,j}$ is the DHW storage losses at time t_j (calculated in 6.4.2) (J);
- f_{combi} is the correction factor to take into account controller effect, corresponds to the fraction of simultaneous operation (-);
- $k_{W,bu,j}$ is the fraction of DHW heat energy covered by the back-up heater at time t_j (-).

The respective running time in SH-only and DHW-only operation modes are calculated according to Formula (6).

NOTE Testing according to EN 255-3 does not deliver a heating capacity for the domestic hot water operation as an output. However, required data to evaluate an average heating capacity are provided by the testing in phase 2 of EN 255-3.

6.6.3 Boundary condition for the total running time

The total running time must not be longer than the effective step time; thus, the total running time has to fulfil the boundary condition

$$t_{\text{hp,on,tot},j} = \min(t_{\text{eff},j}, t_{\text{H,hp,on,sgnl},j} + t_{\text{W,hp,on,sgnl},j} + t_{\text{HW,hp,on,combi},j}) \quad (18)$$

where

- $t_{\text{hp,on,tot},j}$ is the total running time of the heat pump in time t_j (s);
- $t_{\text{eff},j}$ is the effective bin time in time t_j (s);
- $t_{\text{H,hp,on,sgnl},j}$ is the running time in space heating-only operation in time t_j (s);
- $t_{\text{W,hp,on,sgnl},j}$ is the running time in DHW-only operation in time t_j (s);
- $t_{\text{HW,hp,on,combi},j}$ is the running time in simultaneous operation in time t_j (s).

If the calculated total running time is longer than the effective bin time, this is due to a lack of heating capacity of the heat pump. In this case, the effective bin time is the running time and the missing back-up energy is calculated according to [6.6.5](#).

The same principle applies to the cooling mode.

6.6.4 Back-up calculation: Back-up energy due to lack of capacity (for heating)

The detailed evaluation of the back-up energy is based on the evaluation of the running time according to the boundary conditions given in [6.6.3](#). The comparison of the running time is accomplished, until the outdoor air temperature is reached, at which the effective time for the time considered is longer than the required running time (step calculation time). The sample balance and the required calculations are summarized in [Table 5](#). If the system is of alternate type, the running time in simultaneous operation is zero.

For the time steps with a lack of running time, i.e. required running time is longer than the effective step calculation time, the heating capacity of the heat pump is not sufficient to cover the total requirement. The resulting back-up energy can be calculated based on the control strategy using Formula (19), i.e. the back-up heater either supplies heat to the space heating system or the DHW system as calculated in [6.6.5](#).

Table 5 — Table containing the required calculation for the detailed determination of back-up energy

Label	Value for time t_j
Outdoor air temperature, θ_e (1 K t_j)	$\theta_{e,min} / \theta_{e,min} + 1$
Energy to be produced for SH, $Q_{H,hp,j}$, acc. to Formula (7)	
Energy to be produced for DHW, $Q_{W,hp,j}$, acc. to Formula (7)	
Heating capacity for SH, $\phi_{H,hp,sngl,j}$, acc. to HP characteristic	
Heating capacity for DHW, $\phi_{W,hp,sngl,j}$, acc. to HP characteristic	
Heating capacity for SH combined, $\phi_{H,hp,combi,j}$, acc. to HP characteristic	
Heating capacity for DHW combined, $\phi_{W,hp,combi,j}$, acc. to HP characteristic	
Running time for SH, $t_{H,hp,on}$, acc. to Formula (6)	
Running time for DHW, $t_{W,hp,on}$, acc. to Formula (6)	
Running time combined, $t_{hp,combi}$, acc. to Formula (12)	
Total required running time $t_{hp,tot,j}$ acc. to Formula (8)	
Theoretical time to cover energy requirement at time t_j , $t_{eff,j}$	
Difference total running time to effective bin time	
Required back-up energy, $Q_{bu,cap,j}$, acc. to Formula (18)	

6.6.5 Calculation of additional back-up energy due to lack of capacity

The additional back-up energy due to a lack of capacity is calculated by multiplying the missing running time with the heating capacity of the heat pump in SH-only or DHW-only operation according to Formula (19):

$$Q_{bu,cap,j} = \phi_{hp,sngl,j} \cdot (t_{hp,on,tot,j} - t_{eff,j}) \quad (19)$$

where

- $Q_{bu,cap,i}$ is the additional back-up energy due a lack of capacity (J);
- $t_{hp,on,tot,j}$ is the total (calculated) running time of the heat pump at time t_j (s);
- $t_{eff,j}$ is the theoretical operating time at time t_j (s);
- $\phi_{hp,sngl,j}$ is the heating capacity of the heat pump in the respective single operation mode (W).

The control strategy determines if the back-up energy is supplied to the space heating or the domestic hot water systems. If no control strategy is known, it is assumed, that the back-up heater supplies 50 % of the back-up energy to the space heating system and 50 % of the back-up energy to the DHW system.