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SUPPORT THE DISSEMINATION AND ROLL-OUT OF THE SET OF ENERGY PERFORMANCE OF BUILDING STANDARDS DEVELOPED UNDER EC MANDATE M/480

Report on Case Study to EN 15316-1 Heating and domestic hot water systems, general part

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Final report

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Abbreviations and acronyms in this document:

CEN	**European standards organization**
EN	**European standard**
EPBD	**Energy Performance of Buildings Directive**
EPB standard	**Standard for the calculation of energy performance of buildings, that complies with the requirements given in ISO 52000-1, CEN/TS 16628 and CEN/TS 16629 or later updates**
ISO	**International organization for standardization**
MFH	**Multi-family house**
MS	**EU Member State(s)**
OFF	**Office building**
NA (/ND)	**National Annex or National Datasheet for EPB standards**
NSB	**National Standards Body of CEN and/or ISO**
RER	**Renewable energy ratio**
SFH	**Single family house**
TR	**Technical report (of CEN and/or ISO)**
XLS	**Spreadsheet**

1 Introduction

This document is intended to present the case studies and to discuss the contents of EN 15316-1 and show the effect of choices given in that standard.

This document is focused on the standard EN 15316-1 which is the general module for heating and domestic hot water systems.

This module is the backbone of the calculation of heating and domestic hot water systems. It coordinates the use of the modules concerning each sub-system which is part of a heating and domestic hot water systems. For each connected sub-system, the operating conditions are passed to the specific module, which will provide the required energy input in return.

The calculation of operating conditions such as the flow and return temperatures is performed within this module.

This module includes the specification of the operating schedules of the heating and domestic hot water systems.

The calculation in this case study focuses on the calculation of operating temperature of the hydraulic circuits, which may impact energy performance, due to:

- influence on losses of the distribution circuits;
- influence on generation sub-system performance.

The connection with operating schedules will be discussed with an intermittency example.

To facilitate the calculation, some connected modules have been replaced by simplified correlations:

- emission and control sub-systems have been replaced by an efficiency factor;
- each distribution network has been calculated with a total loss factor and the auxiliary energy for the circulation pumps has been calculated with a simplified model.

2 Executive summary

EN 15316-1 defines the back-bone to which all the other modules concerning the heating systems are connected.

This case study demonstrates how the calculation structure of a heating system according to EN 15316-1 is used to describe a heating system that can be:

- an elementary streamlined system serving one unique thermal zone with one emission system, one distribution and one generator;
- or a system supplying multiple space heating thermal zones;
- or a system with multiple heat generation devices;
- and/or a system providing both heating and domestic hot water, with thermal solar and priority.

This module also defines the operation schedule of the space heating and domestic hot water systems. This time schedule shall be coordinated with the comfort requirement schedule. In these case studies, appropriate operation schedules have been defined directly in the module about EN 16798-1.

This module requires little data to the user, mostly about heat emitter size and the type of hydraulic circuits.

The calculation has been repeated for several types of emitters and data found on operating conditions has been fed to specific modules (such as heat pumps) to identify the impact.

The case study shows that this module contributes to identify significant effects on system efficiency and that its correct use is critical when dealing with:

- heat pumps using technical water as a sink;
- condensing boilers;
- distribution networks.

3 The context of the case study

In the past, the effect of technical systems on energy performance of building has been taken into account by "efficiencies" or "expenditure factors" (it's the same concept, these two values are the reciprocal of each other), which were often just tabulated values depending on the typology of each subsystem. The result was a very simple calculation structure (a series of multiplications or divisions) but this worked only with simple, streamlined, repetitive systems.

The first release of this module, EN 15316-1:2007, introduced the concept of losses and auxiliary energy for each subsystem. This approach allowed to take into account more complex systems by combining inputs, outputs, losses and recovered auxiliary energy for each subsystem, the basic rule being: the input of any subsystem is given by the required output, plus non-recovered losses minus recovered auxiliary energy. Auxiliary energy is also collected independently. The calculation of operating conditions was mentioned but not fully spelled into equations.

The new release, EN 15316-1:2017, explicitly deals with the calculation of operating conditions, taking into account such features of space heating and domestic hot water systems as:

- having several serviced areas (technical system zones), possibly with different emitters, room temperature control and temperature regime;
- having several generation sub-systems, with priority;
- having "nodes" that represent physical headers, interconnecting distribution systems with serviced areas and generators;
- having heat storage with possible thermal solar contribution in the nodes.

This module is the back-bone of heating and domestic hot water systems calculation: all modules of the heating and domestic hot water sub-systems (e.g. distribution, storage) get their input data from EN 15316-1 module and deliver their output data back to EN 15316-1 again.

EN 15316-1 starts with the definition of the space heating and domestic hot water service areas.

For each service area, an operating schedule is established and energy needs are calculated according to the relevant module (EN ISO 52016-1 for space heating or EN 12831-3 for domestic hot water).

Based on energy needs, emitter sizing and control strategy, the flow and return temperature and the flow rate are calculated for space heating. For domestic hot water, the operating temperature is given by system set-point values.

Then, for each connected module, following the physical connection:

- the required energy output and the flow and return temperatures are passed to each sub-system module;
- the required energy input, the auxiliary energy, the recoverable heat losses (and where they are recoverable) are obtained as a result of the calculation by the sub-system module.

The module defines the "nodes". Physically the "nodes" are the headers where several circuits and or generators are connected together.

- If several “loads” (supplied heating or domestic hot water circuits) are connected to a common node (header), an energy balance is performed to get the overall operating conditions of the node, both load and temperatures.
- If a node is served by several “generators”, then the load is distributed according to a priority sequence and to the maximum contribution available from each generator.

Another specific situation is a generator providing several services, e.g. connected to several nodes. The most common case is space heating and domestic hot water service provided by the same generator. In this case

- the generator is connected to several nodes (one per service);
- the generator will satisfy the connected loads according to its own priority logic; the most common logic is domestic hot water first at full load, space heating in the remaining time at part load.

An energy storage may also be considered in a node (EN 15316-5), possibly with a thermal solar system (EN 15316-4-3) contributing to heat the storage.

This process continues until the generation modules (EN 15316-4-X) are reached.

The calculation of generation modules will provide as an output the required amount of a main energy carrier and auxiliary energy, possibly per service, based on operating conditions.

The main energy inputs of the generators and the auxiliary energy of all sub-systems are passed to EN 52000-1 module for the final electric energy balance and weighting.

Recoverable losses and maximum output to thermal zones are passed to EN 52016-1, dealing with energy needs. This may cause an iteration unless recoverable losses are accounted for in the following hour. This is a decision that should be taken at the level of EN ISO 52000-1, when defining the overall calculation procedure.

4 Coverage of the scope

4.1 Introduction

The following criteria can be used to evaluate the coverage of the intended scope of EN 15316-1:

- technologies included in the building and technical systems;
- emitters and related control options
- possible installation configurations;
- performance indicators;
- calculation intervals;
- heat losses recovery.

4.2 Coverage of technologies

This module intrinsically covers any technology used in the connected sub-systems, since it is only the frame for the heating and domestic hot water system calculation and the calculation procedure of operating conditions for each sub-system.

Coverage of technologies depends on the availability of the specific module to calculate the respective sub-system. The available modules in the several parts of EN 15316 cover nearly all technologies currently on the market. This includes renewable energy production and use, such as thermal solar, photovoltaic, biomass use, wind power.

Only a few recent technologies are not yet covered, such as waste water heat recovery and heat pumps providing simultaneous heating and cooling.

Waste water heat recovery by means of heat exchangers can be easily incorporated as a reduction of energy needs for domestic hot water.

Dealing with simultaneous heating and cooling requires further development of both the heat pump (EN 15316-4-2) and chiller (EN 16798-13) standards and a decision on how to merge them.

4.3 Emitters control options

This is a specific technical topic of EN 15316-1 module.

All current heat emitters typologies are covered.

Four control options are predefined which cover most cases when the flow temperature is determined according to the demand. This aspect is explored in details in the accompanying calculation examples of this case study, given the importance of thermal operating conditions of technical systems.

4.4 Coverage of installation configurations

The coverage of the various installation configurations is made possible by nodes, that allow branching of the distribution networks and connecting several generation devices to the same node.

Some more explicit details should be given in EN 15316-1 about the option between alternate and simultaneous operation when a node requires two different operating levels (e.g. space heating and domestic hot water service).

4.5 Coverage of performance indicators

This module provides a general equation for partial energy performance indicators related to each sub-system. The suggested indicator is the efficiency of the subsystem which is assumed as the ration between all outputs and all inputs of a subsystem. Since there are generally thermal inputs and outputs plus auxiliary energy (which is usually electricity), the relative weight of thermal and electric contributions shall be defined to get a meaningful indicator.

4.6 Coverage of calculation intervals

This module is explicitly designed to support both the monthly and the hourly calculation.

Some additional detail should be given for the case of hourly calculation, to prevent inaccurate results in some special cases (sudden changes in heating needs due to varying gains and ideal control assumed in EN ISO 52016-1).

4.7 Coverage of heat losses recovery

EN 15316-1 allows several possible levels of accounting of recoverable heat losses:

- as a reduction of losses of the individual sub-system where losses occur;
- as a reduction of heating needs, for domestic hot water system recoverable losses;
- as a contribution to be passed to the thermal zone balance for explicit consideration.

See clause 7.2 for further details.

5 Definition of the cases

5.1 Rationale of the selection of the cases

The selection of cases is intended to cover the following features:

- operating conditions calculation for a streamlined system;
- several user circuits;
- several generation circuits;
- integration of storage;
- integration of thermal solar.

5.2 Climate

The climate has no direct impact on this module.

Differences in climate are handled by a different sizing of the heat emitters and of the building envelope insulation, so that operating temperatures are approximately the same for all climates for a given type of emitters.

5.3 Types of buildings, new and existing

The type of building and the fact that it is new or existing has no direct impact on this module. There is no variant or option related to the type of building in the standard and in this case study.

The complexity of the system to be described rather depends on the size of the building and mostly on the uniform or various use of its spaces.

It has to be noted that there is no need to have a large or complex building to have variants in the heat emitters, several circuits or several generators. A frequent case is having floor heating as the basis for a residential building but in the bathrooms, due to the limited free floor area and high specific heating needs, radiators are installed, indeed. This obliges the generation sub-system to take into account the highest required flow temperature (or the radiators shall be designed and sized taking into account the low-level operating temperature). The efficiency of a heat pump would be severely affected by a wrong sizing and commissioning of the installation. Appropriate identification of these facts is verified in the case study.

5.4 Operating conditions

The energy needs in each time interval are defined in other modules:

- EN ISO 52016-1 for heating needs
- EN 12831-3 for domestic hot water needs

The choices in this module impact operating temperatures. The most impacting factors on the operating conditions (temperatures) are:

- type and sizing of heat emitters;
- operation schedule;
- control options of heat emitters:
- type of hydraulic connection of the generator and related control options.

These factors are investigated in the following.

5.5 List of selected cases and variants

5.5.1 Case 1: Streamlined system

5.5.1.1 Description

The basic case is a streamlined system which consists only of:

- one heat emission and control subsystem
- one heating distribution network
- one generation sub-system

The single-family house SFH is used as a basis for the calculation.

5.5.1.2 Variant 1: type of emission and control system

The calculation is repeated for different types and sizing of emitters and control options:

- radiators, normally sized, with heating curve and thermostatic valves;
- radiators, normally sized, with heating curve and thermostatic valves, comparison with case with insufficient flow temperature (wrong setting of heating curve);
- floor heating, normally sized, with heating curve and room thermostat;
- fan coil floor, normally sized, with constant flow temperature and room thermostat;
- radiators, normally sized, with flow temperature based on heat demand and thermostatic valves;

Flow and return temperature as well as flow rate are determined in each case.

5.5.1.3 Variant 2: type of generator connection

The calculation is always done with the independent flow rate for the streamlined system. The direct connection implies that the generation flow and return temperatures are the same as the emission. No additional calculation is required.

5.5.1.4 Variant 3: sizing of emitters

The calculation is repeated for the radiator case with a larger sizing.

5.5.2 Case 2: several user circuits

5.5.2.1 Description

The basic case is again the single-family house, with the following configuration:

- the main systems is on floor heating
- bathrooms are using radiators

5.5.2.2 Variant 1 – Sizing of emitters

The sizing of emitters can be used to avoid compromising the efficiency of the whole system.

This is shown by increasing the radiators in the bathroom of the previous example.

5.5.3 Case 3: Several generators

The base case is still the single-family house with a hybrid generator.

The heat pump is used only above 2 °C.

5.5.4 Case 4: storage in the node

Starting from the single-family house, a storage and thermal solar system is added in the node before generation.

5.6 Calculation files summary

The naming convention and the list of the supporting calculation files are given in annex A.

6 Calculation details

6.1 Calculation tools

6.1.1 EN 15316-1 spreadsheet

An enhanced version of the spreadsheet about EN 15316-1 has been prepared for the case study:

- the interface to specify the configuration has been improved;
- a graphic output sheet has been added.

The input data to this module are:

- heating needs profiles calculated with EN ISO 52016-1 module;
- domestic hot water needs profiles calculated with EN 12831-3 module.

Connected sub-systems are integrated with simple models that take into account:

- losses and auxiliary energy use of sub-systems, per service;
- efficiency of generation systems, including the influence of operating conditions.

These simulated subsystems are integrated in the EN 15316-1 spreadsheet. The spreadsheet has a fixed configuration of the thermal zones and systems (shown in figure 1) that covers all the intended combinations. The simpler combinations are simulated setting to zero the data of thermal zones and service areas that are not relevant.

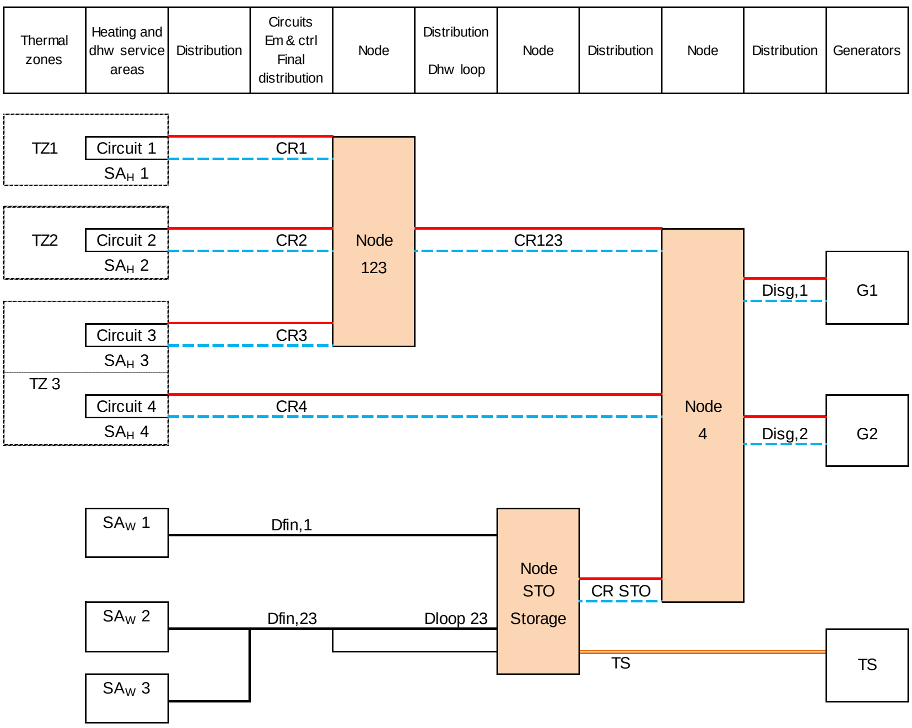

Figure 1 – Default configuration of systems in the Excel for EN 15316-1

6.1.2 Supporting calculations

6.1.2.1 Climatic data – EN 52010

Climatic data are calculated with EN ISO 52010 module, using data from the JRC data-base.

For this case study, only data for Strasbourg were used, no difference is expected if testing with other climates. System performance will change but this is a concern for sub-systems modules.

See preparatory work document and case study on EN ISO 52010-1 for further details.

A copy of the file with the climatic data for the chosen location in included in the case study material (*00 - ISO_52010-1_TMY_Strasbourg_8_planes.xlsx*).

6.1.2.2 Domestic hot water needs – EN 12831-3

Domestic hot water needs were calculated according to EN 12831-3, assuming:

- net floor area: 142 m^2;
- tapping profile: proportional to ERP tapping cycle XL;
- cold water temperature: 11,2 °C, average yearly external temperature;
- water volume calculated with table B.5 of EN 12831-3 (average value for single family house).

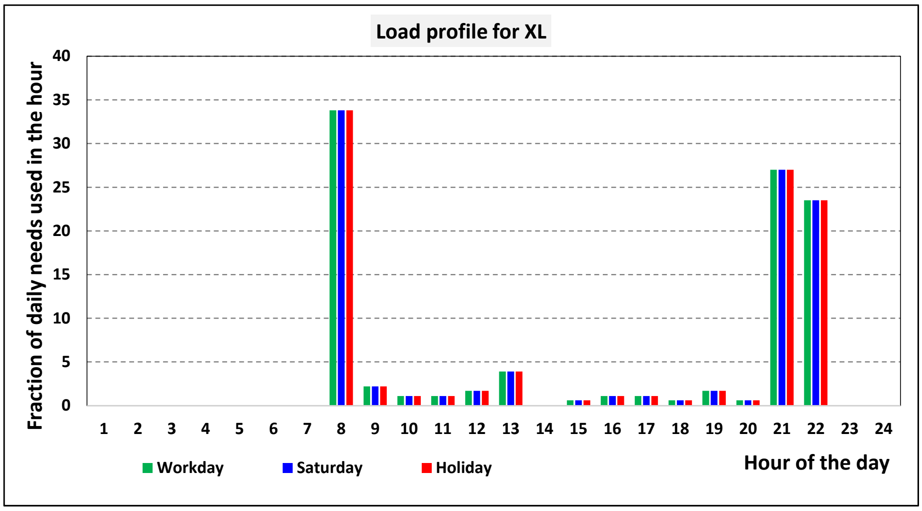

Figure 2 – XL tapping profile

Name	Symbol	**Software name**	Unit	Value
Energy flow data				
Daily volume need	$V_{W;nd;d;\theta draw}$	VW_ND_D_THETA DRAW	m³	0,2055
Daily energy need	$Q_{W;nd;d}$	QW_ND_D	kWh	7,34
Yearly total of volume needs	$V_{W;nd}$	VW_ND	m³	75,01
Yearly total of energy needs	$Q_{W;nd}$	QW_ND	kWh	2.680

Figure 3 – Results of domestic hot water needs calculation according to EN 12831-3

6.1.2.3 Use profiles – EN 16798-1

The use profiles are taken from EN 16798-1 default profiles. The profiles for residential, detached house is used as shown in figure 4.

RESIDENTIAL_Det_house_with_HUDU **12**

Source data sheet **RES_det_house_HUDU**

Space area	m^2	142
Space volume	m^3	357,4
Comfort category		II
Type of building		Low polluting
Ventilation calculation option		Method 3 - Air exchange rate

Figure 4 – Selection of the use profiles to generate heating needs

More details on the use of this spreadsheet are given in the specific case study on EN 16798-1.

Only continuous operation is considered.

6.1.2.4 Heating needs and building description – EN ISO 52016-1

Heating needs are calculated using the EN ISO 52016-1 module, taking into account the climatic data mentioned in the previous clause.

The building description assumed the following properties (moderately insulated building, code "M")

- U value walls: 0,35 W/m^2K
- U value roof: 0,25 W/m^2K
- U value windows: 1,50 W/m^2K
- U value floor: 0,80 W/m^2K
- Ventilation: natural, air exchange rate 0,60 h^{-1} (comfort category II)

The resulting heating needs are shown in the following figures 5 and 6 and table 1.

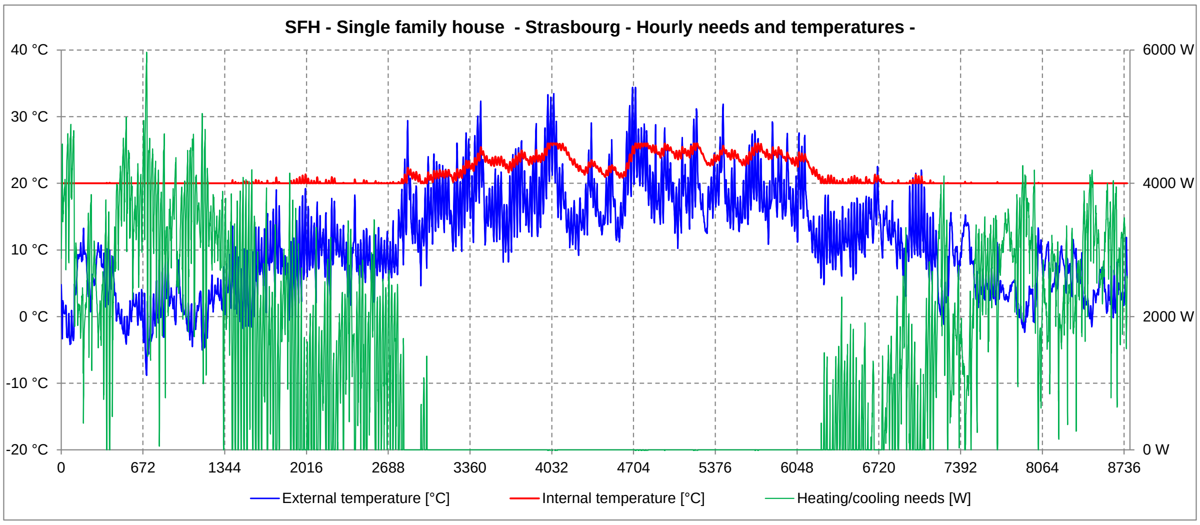

Figure 5 – External temperature, indoor temperature and heating needs

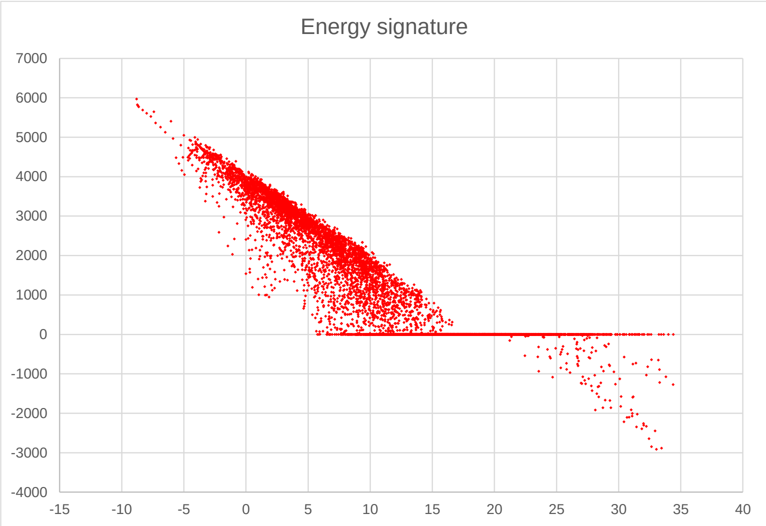

Figure 6 – Hourly heating and cooling needs as a function of outdoor temperature (energy signature of needs)

Table 1: Monthly totals of hourly energy needs

Month	External temperature	Hourly heating needs	Hourly cooling needs
	$\vartheta_{e;air,m}$	$Q_{H;nd,m}$	$Q_{C;nd,m}$
	°C	kWh	kWh
January	2,7	2.356	0
February	2,0	2.183	0
March	7,7	1.113	0
April	10,1	886	0
May	17,1	19	0
June	18,1	0	63
July	19,5	0	29
August	18,9	0	19
September	14,7	129	0
October	11,5	749	0
November	5,4	1.816	0
December	5,4	2.356	0
YEAR	**11,1**	**11.233**	**110**

6.1.2.5 Heat pumps, EN 15316-4-2

The resulting operating conditions were processed in the excel file for the heat pump (EN 15316-4-2) to demonstrate the influence of operating conditions.

More information is available in the case study about EN 15316-4-2, heat pumps.

6.1.2.6 Storage and thermal solar

The storage for domestic hot water has been calculated with the respective modules EN 15316-5.

Thermal solar integration would be straightforward, using the module for EN 15316-4-3 in combination with the module for EN 15316-5. This feature doesn't affect the calculation in EN 15316-1. The only effect is that the heat required to heat the storage is reduced. An example of this calculation can be found on the case study about the single-family house.

6.2 Calculation chain

The calculation was performed in the order shown in table 2.

Table 2: Calculation sequence

Calculation step	File
Calculate climatic data for the three climates	00 – ISO_52010-1_TMY_XXXXX_8_planes.xlsx
Calculate the domestic hot water needs	10 – EN 12831-3 – SFH.xlsx
Calculate the use profiles according to climate and operation schedule	10 - EN_16798-1_SFH-X-AVG-II-CNT_HUDU.xlsm
Define configuration for heating needs calculation depending on operation schedule and building insulation	20 - ISO_52016-1_SFH_M_YYY-II-CNT_DESC.xlsx
Calculate heating needs according to climate and configuration	21 - ISO_52016-1_SFH_M-AVG-II-CNT-CALC.xlsm
Calculate required heat output and flow temperature for heating	30x - EN_15316-1_SFH_M_AVG_XXX_XX_XX_XXXC.xlsm (*)
Calculate storage and optional thermal solar.	35 - EN 15316_5_SFH_M_AVG.xlsm
Calculate heat pump performance	40x - EN_15316-4-2_SFH_M_AVG_XXX_XX_XX_XXX.xlsm(*)
(*) See annex A to this document for the detailed list of files and code names.	

6.3 Streamlined system

6.3.1 Basic set-up

6.3.1.1 Introduction

The basic set-up of the streamlined system consists of:

- one emission and control subsystem, based on radiators, heating curve and thermostatic valves with variable flow rate;
- one distribution subsystem;
- one generation subsystem, a boiler, with independent flow rate connection.

Specific calculation file: *30b - EN_15316-1_SFH_M_AVG_RAD_HC_VF_IFC.xlsm*

6.3.1.2 Input data of EN 15316-1

The product technical data consists in the description of the installed heat emitters.

A series of data define the nominal conditions of each type of emitter, as shown in figure 7. These are default data that seldom change. The nominal temperature difference on water side (i.e. between flow and return in nominal conditions) may be sometimes adjusted depending on the application.

	Emitters nominal Δϑ air	Emitters exponent n	Emitters nominal Δϑ water
	°C		°C
Radiator	50	1,3	20
Floor heating	15	1,1	5
Fan-coil	25	1	10
Special option 1	30	1,2	10
Last option	50	1,3	10

Figure 7 – Nominal conditions of heat emitters

The type and rated power of emitters is required for each heating service area, as shown in figure 8. In this case, only heating service area 1 is used.

			Heating service area 1	Heating service area 2	Heating service area 3	Heating service area 4
Emitters nominal power of service area i	$\phi_{H;em;nom;sah,i}$	kW	8	8	8	8
Type of emitters in service area i			Radiator	Radiator	Floor heating	Fan-coil

Figure 8 – Type and nominal power of installed of heat emitters

The type of emitters is obvious and if the nominal power is not known, a default value is the heat load of the service area. This value is known because the required data is also used to calculate the energy need.

For existing buildings, it has been common practice to install heat emitters with a nominal power equal to the heat load. Emitters should be sized to obtain the desired flow temperature, which usually results in an installed power which is a multiple of the heat load.

The first example is with radiators. Only the values for service area 1 are relevant.

The process design data determine the behavior of the system. The important choices are the type of flow temperature control and the type of emitter power control.

All the other values are default parameters that may change only for special designs.

HEATING EMISSION CIRCUITS DATA			
Description	Symbol	Unit	Heating service area 1
Floor area	$A_{sah;1}$	m²	142
Emitter power control type			Type 2 - Variable flow
Flow temperature control type			Type 2 - Based on outdoor temperature
Data for option based on outdoor temperature			
Minimum outdoor temperature	θext;min;sah,1	°C	-10
Maximum outdoor temperature	θext;max;sah,1	°C	16
Maximum flow temperature	θem;flw;max;sah,1	°C	45
Minimum flow temperature	θem;flw;min;sah,1		28
Data for option constant flow temperature			
Contant flow temperature	*θem;flw;sah,1*	°C	42
Data for options based on heat demand			
Max flow temperature HZ1	$\theta_{H;em;flw;max;sah,i}$	°C	45
Max Δθ flow / return HZ1	$\Delta\theta_{H;em;w;max;sah,1}$	°C	8
Desired return temperature HZ1	$\theta_{H;em;ret;req;sahz,1}$	°C	20
Mixing valve for HZ1	$MIX_{sah,i}$	0/1	0
Mixing valve Δθ for HZ1	$\Delta\theta_{H;em;mix;sahz,1}$	°C	2
Desired load factor with ON-OFF for	$\beta_{H;em;req;sah,1}$	%	80
Minimum flow temperature for HZ1	$\theta_{H;em;flw;min;tz,1}$	°C	28

Figure 9 – Choices and parameters to define the process design data

6.3.2 Results with radiators, variable flow and generator direct connection

For this variant the options are:

- Emitters flow temperature depending on outdoor temperature (outdoor temperature reset).

  This is the most common choice. Flow temperature is 75 °C at design external temperature -10 °C and goes down to 40 °C at 16°C outdoor temperature.

  This is an additional option, not described in EN 15316-1 annex C. The standard allows additional criteria and this is strongly recommended for addition.
- Variable flow control of emitters.

  This option corresponds to the use of thermostatic valves.
- Normal sizing of emitters

  Emitters nominal power is equal to the heat load of the building.
- Constant generation flow rate, independent from distribution flow rate.

  There is an hydraulic decoupling between heating distribution and generator.

Figure 10 shows the resulting temperatures in the first part of the year.

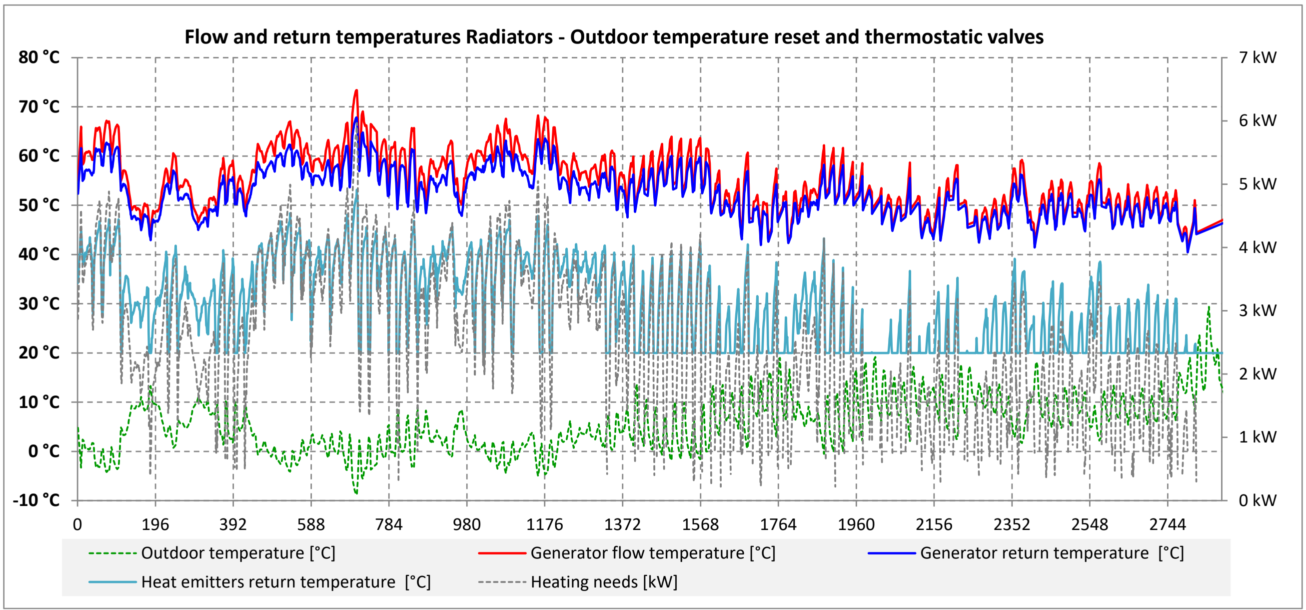

Figure 10 – Operating conditions during the first 4 months of the year

The same data can be presented as the flow and return temperature of the heat emitters and of the generator as a function of outdoor temperature, as shown in figure 11.

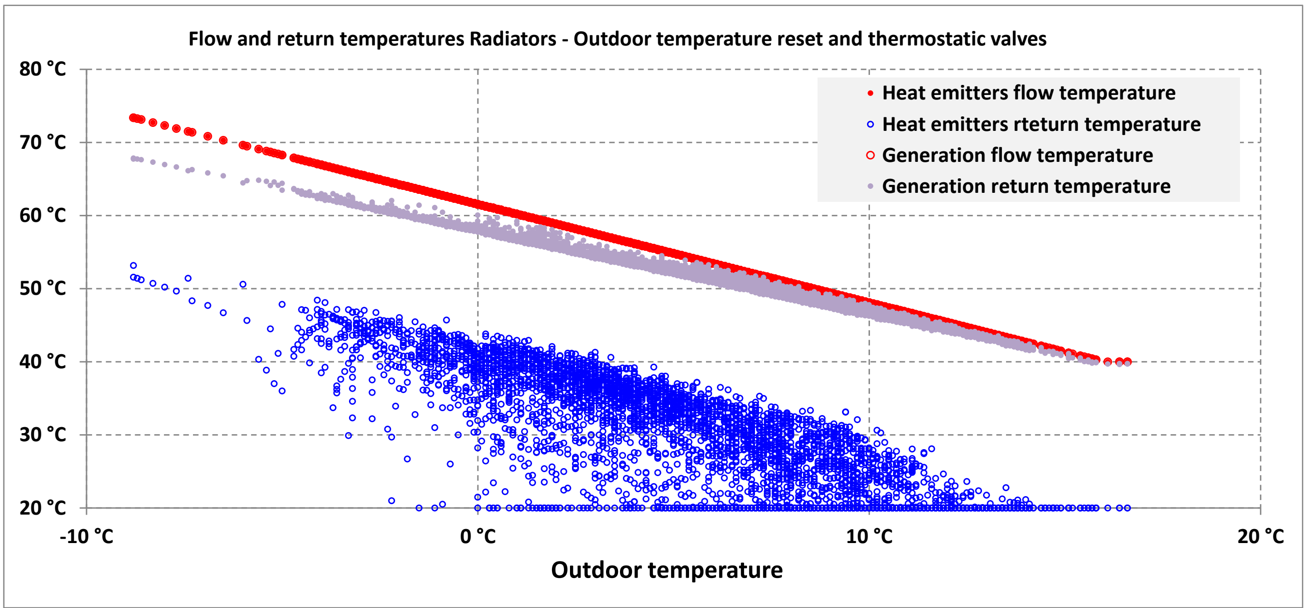

Figure 11 – Flow and return temperatures as a function of outdoor temperature

This shows that the outdoor temperature reset is correctly taken into account and the return temperature of the emitters may vary depending on the variable value of needs when the same value of the external temperature occurs in different hours along the year.

Since the flow rate in the generator is independent (896 l/h) and much higher than in the emitters (as shown in figure 12, average value is 103 l/h), the return temperature to the boiler (average is 52,3 °C) is much higher than the return temperature from the emitters (average is 30,2 °C): this is correctly identified and the consequence is that condensation in the boiler will be minimal whereas a direct connection of the boiler would allow condensation during most of the heating season. However, a direct connection requires a boiler that may operate with a flow rate as low as an average 103 l/h, which is true only for a minority of small boilers on the market.

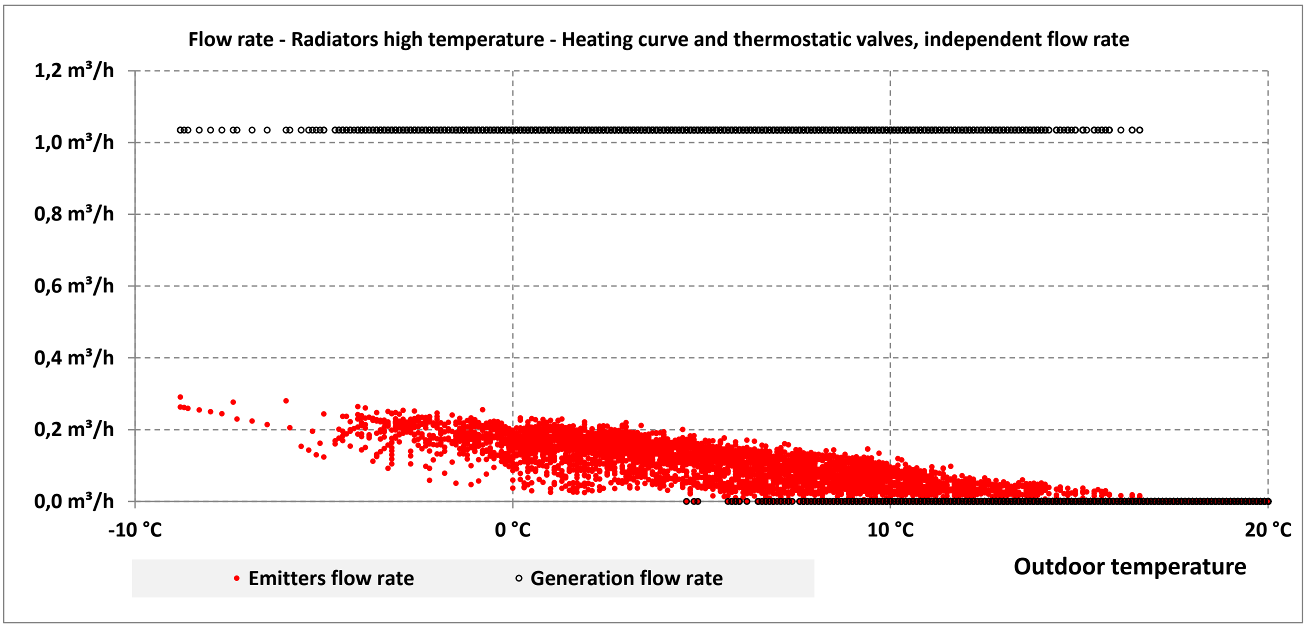

Figure 12 – Emitters (distribution) and generation flow rate as a function of outdoor temperature

Another possible presentation of the data is the flow and return temperature of the heat emitters and of the generator as a function of required output power, as shown in figure 13. The flow temperature points expand to a cloud because a given value of the required power output of the heat emitters (heating needs plus emission and control losses) may be required with different values of the external temperature. Consequently, the outdoor temperature reset will set a different flow temperature and the thermostatic valves will react by adjusting the flow rate (and therefore average and return temperature) of the heat emitters to get the same power.

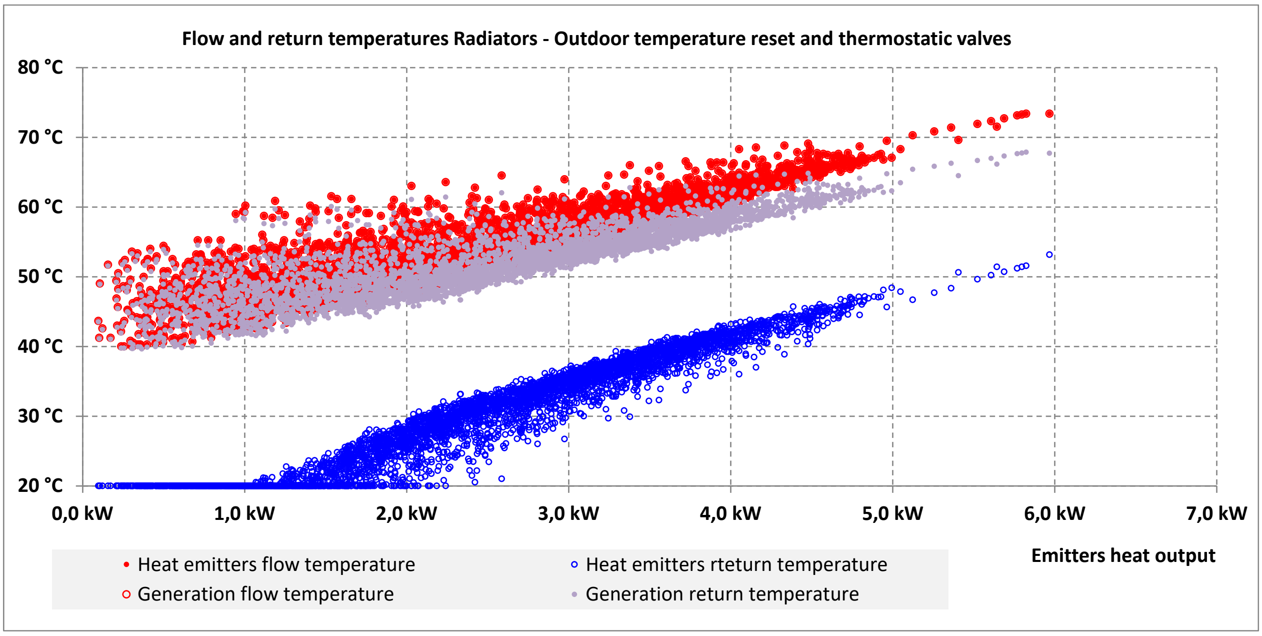

Figure 13 – Flow and return temperatures as a function of required output power

This figure clearly shows that the setting of the controls is correct.

The following figure 14 shows the same graphs if the temperature reset setting is lowered (taken from calculation file: *30b - EN_15316-1_SFH_M_AVG_RAD_HC_VF_IFC_hc_too_low.xlsm*):

- maximum temperature is reduced from 75 to 65 °C flow temperature at -10°C external temperature;
- minimum temperature is reduced from 40 to 35 °C flow temperature at 16°C external temperature;

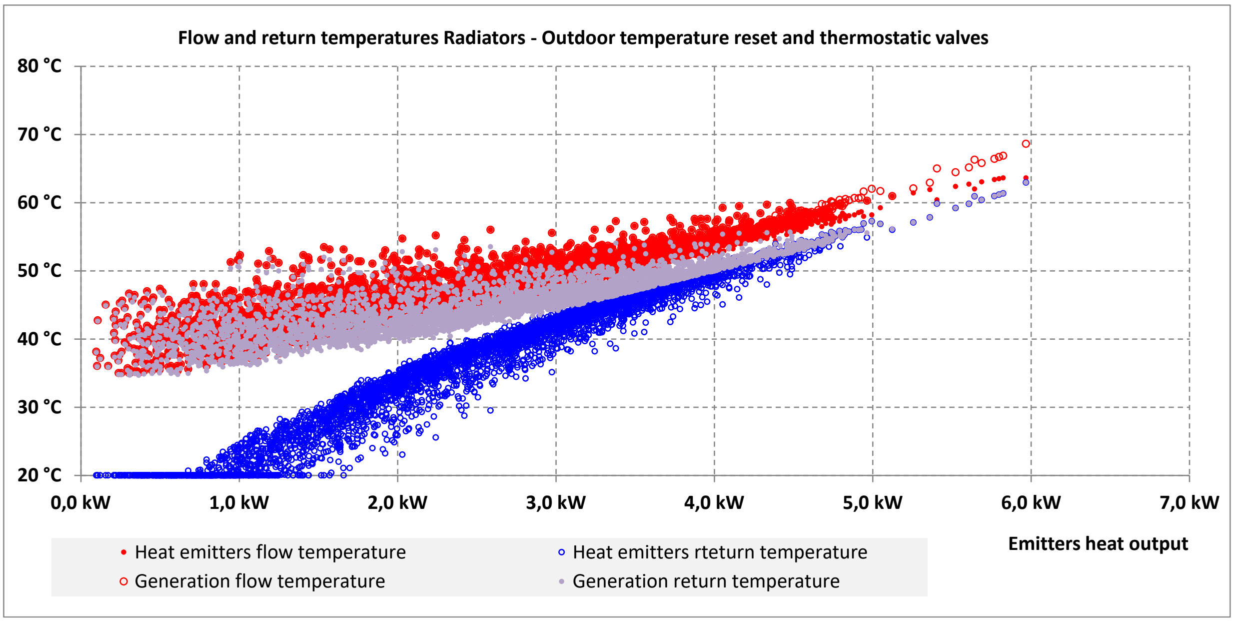

Figure 14 – Flow and return temperatures as a function of required output power with reduced setting of the outdoor temperature reset

Figure 15 is the same as figure 10.

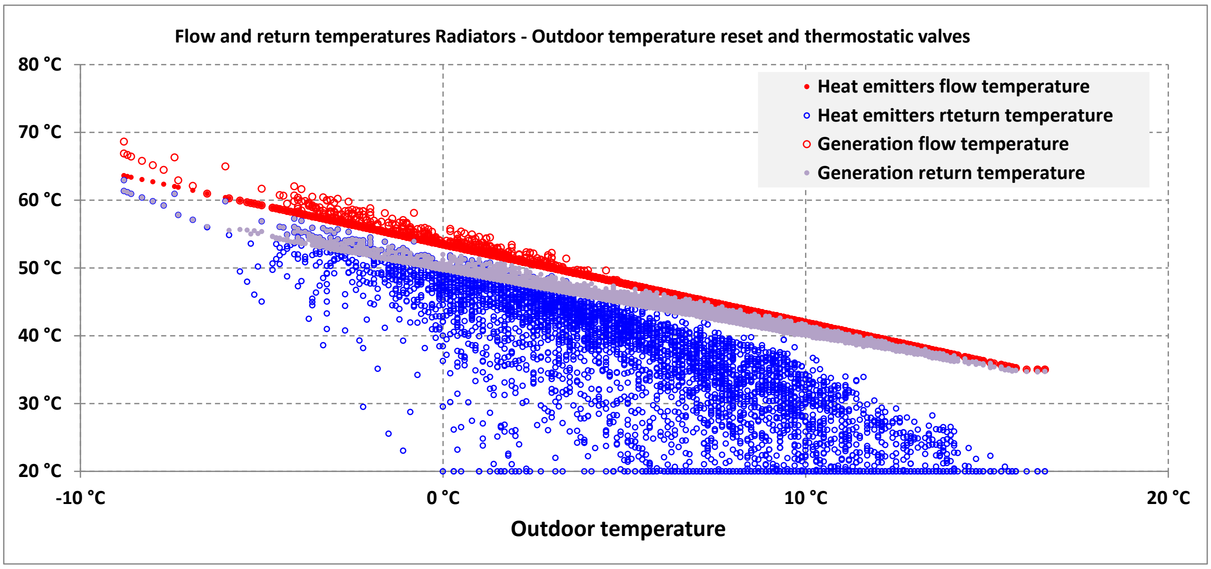

Figure 15 – Flow and return temperatures as a function of outdoor temperature, with reduced setting of the outdoor temperature reset

Both figures clearly indicate that the flow temperature is insufficient at low outdoor temperature and still correct at high outdoor temperature: the thermostatic valves require a higher flow rate to compensate the decreased power output because of the reduced flow temperature.

This demonstrates that the module correctly identifies the operating conditions.

This is also an example of the valuable insight on technical systems operation that can be offered by an hourly method associated with a rational presentation of data. The example shown in figures 11 to 15 are extremely valuable information for design purpose. The graphs provide visually the information needed to specify the initial setting of the outdoor temperature reset and the consequences if the setting is too high (very low flow rate, difficulties to keep a stable indoor temperature control) or too low (high flow rate, higher return temperature, insufficient output power to fulfil needs).

The calculated flow rate is another valuable design information to select the right boiler, that shall be able to operate at that low flow rate to optimise condensation. Other popular solutions can be simulated with further options, such as the speed control of the primary circulation pump (boiler pump) according to the temperature difference in the boiler circuit.

6.3.3 Results with floor heating

The previous calculation has been repeated in the same conditions but assuming a floor heating.

For this case, the outdoor temperature reset setting is:

- maximum flow temperature 45 °C at -10°C external temperature;
- minimum flow temperature 28 °C at 16°C external temperature.

Specific calculation file: *30c - EN_15316-1_SFH_M_AVG_FLR_HC_TH_IFC.xlsm*

The results for the flow and return temperature and the flow rates are shown in figures 16 through 18.

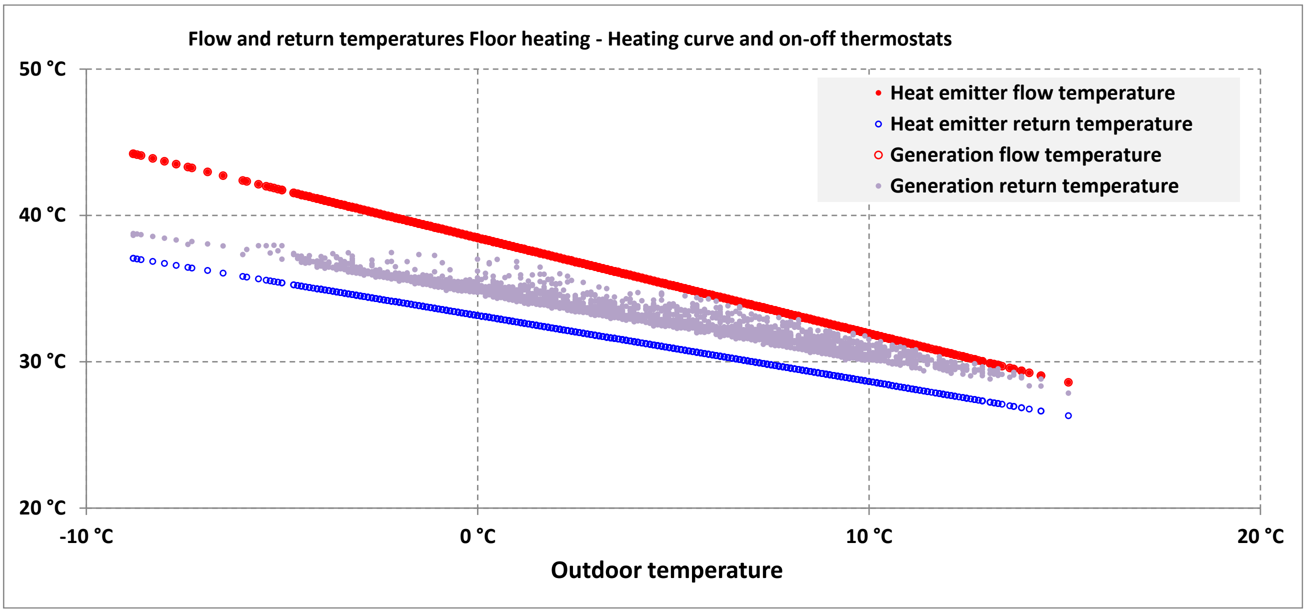

Figure 16 – Flow and return temperatures as a function of outdoor temperature

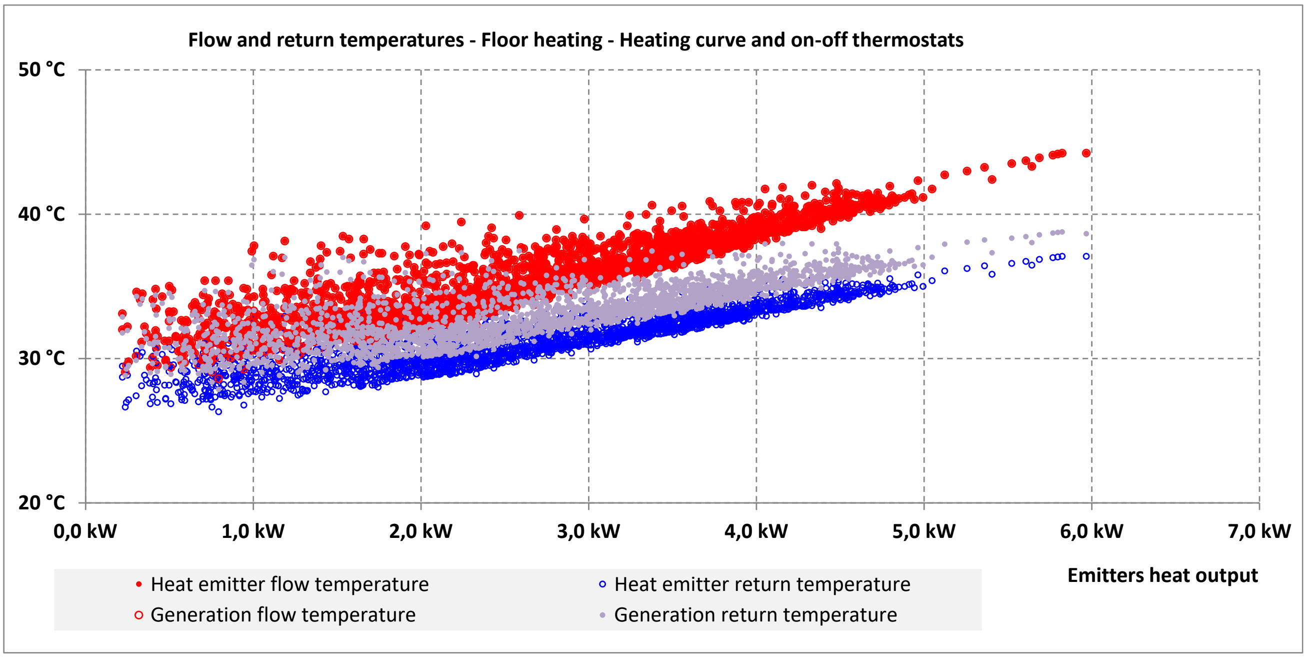

Figure 17 – Flow and return temperatures as a function of required output power

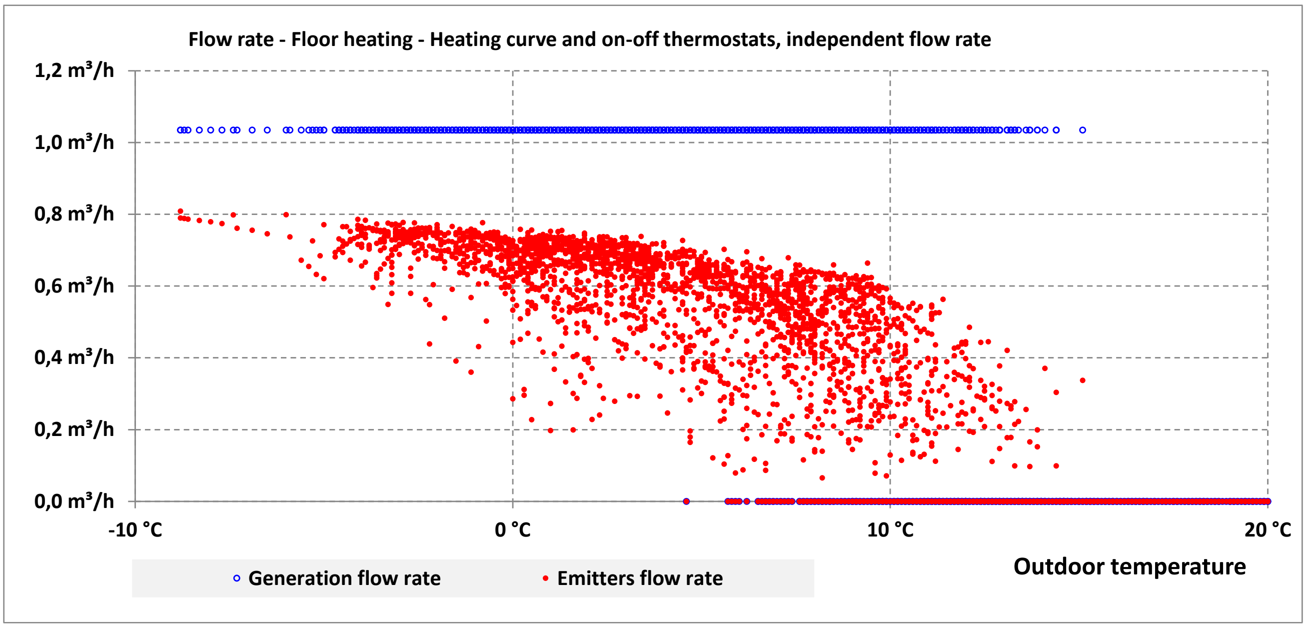

Figure 18 – Emitters (distribution) and generation flow rate as a function of outdoor temperature

Temperatures are lower than with “normal” radiators, which facilitates the optimization of the operation of condensing boilers and heat pumps. The flow rate diagram allows to check if the flow rates in the heat pump always exceeds the flow rate in the distribution. If not, the flow temperature of the heat pump (generation circuit) would have to rise and this means 2…3% less efficiency for each single °C of unnecessary temperature raise of the heat pump flow temperature. This is valuable information for the system design and system operation optimization that comes for free with the hourly calculation method.

To demonstrate the high influence of operating conditions on the efficiency of heat pumps, the COP of a sample air top water heat pump is calculated with the meaningful combinations of heat emitters and control options:

- Fan coil with constant flow temperature
- Oversized radiators, heating curve and demand-controlled flow temperature

This variant with floor heating, heating curve and room thermostats is used as a reference since it is the most common for new buildings and potentially the most effective. The domestic hot water requirements have been taken into account because they oblige the heat pump to operate for some time at full load after domestic hot water storage recharge. The required input to the domestic hot water storage has been calculated with EN 12831-3, heat losses according to EN 15.316-3 (simplified module within EN 15316-1 spreadsheet) and EN 15316-5 spreadsheet (storage). The results for this case are shown in table 3.

Table 3: Sample heat pump performance with floor heating

Interval	Heating output $Q_{H;hp;out}$ kWh	Source temperature θ_{src} °C	Flow temperature $\theta_{H;hp;out}$ °C	COP Heating COP_H -	DHW output $Q_{W;hp;out}$ kWh	COP DHW COP_W -
January	2.651	2,60	36,74	3,58	334	2,26
February	2.456	2,12	37,23	3,65	301	2,23
March	1.245	6,41	34,68	3,69	334	2,52
April	994	8,69	33,20	3,76	323	2,67
May	4	15,40	32,88	3,35	334	3,05
June	0				323	3,07
July	0				334	3,13
August	0				334	3,14
September	135	10,19	32,51	3,04	323	2,88
October	839	9,67	32,53	3,42	334	2,70
November	2.045	5,21	35,00	3,82	323	2,42
December	2.226	5,24	34,95	3,97	334	2,43
YEAR TOTAL	**12.596**	**5,46**	**35,05**	**3,70**	**3.931**	**2,67**

Specific calculation files:

- *30c - EN_15316-1_SFH_M_AVG_FLR_HC_TH_IFC.xlsm*
- *40c - EN_15316-4-2_SFH_M_AVG_FLR_HC_TH_IFC.xlsm*

6.3.4 Results with fan-coils

The previous calculation has been repeated in the same conditions but assuming a fan-coil heating.

For this case, the flow temperature is assumed constant. The indoor temperature is controlled by the on-board thermostat of the fan-coils. Flow rate is constant in the system.

The results for the flow and return temperature and the flow rates are shown in figures 19 through 21.

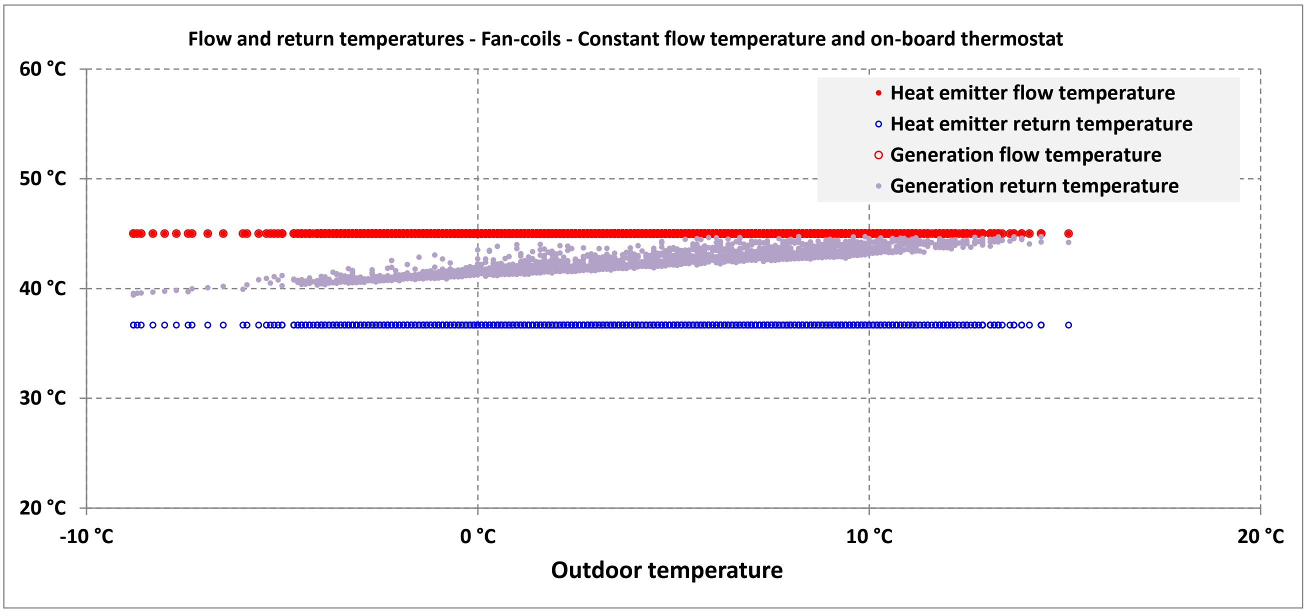

Figure 19 – Flow and return temperatures as a function of outdoor temperature

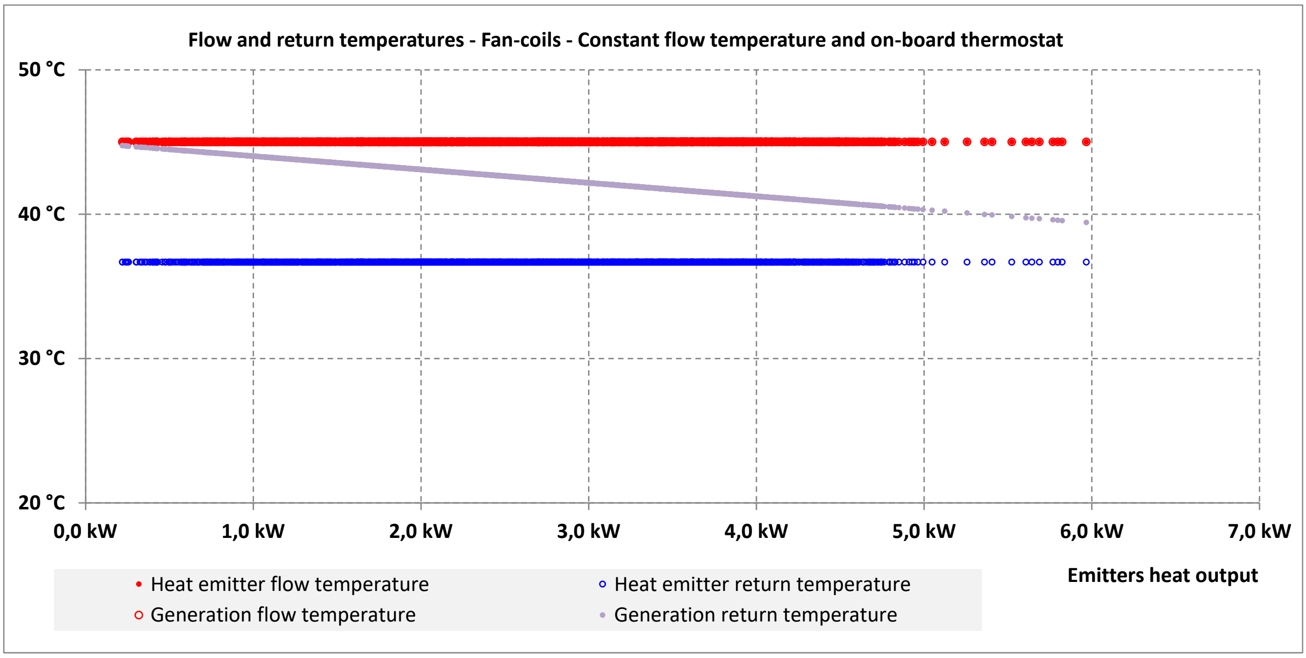

Figure 20 – Flow and return temperatures as a function of required output power

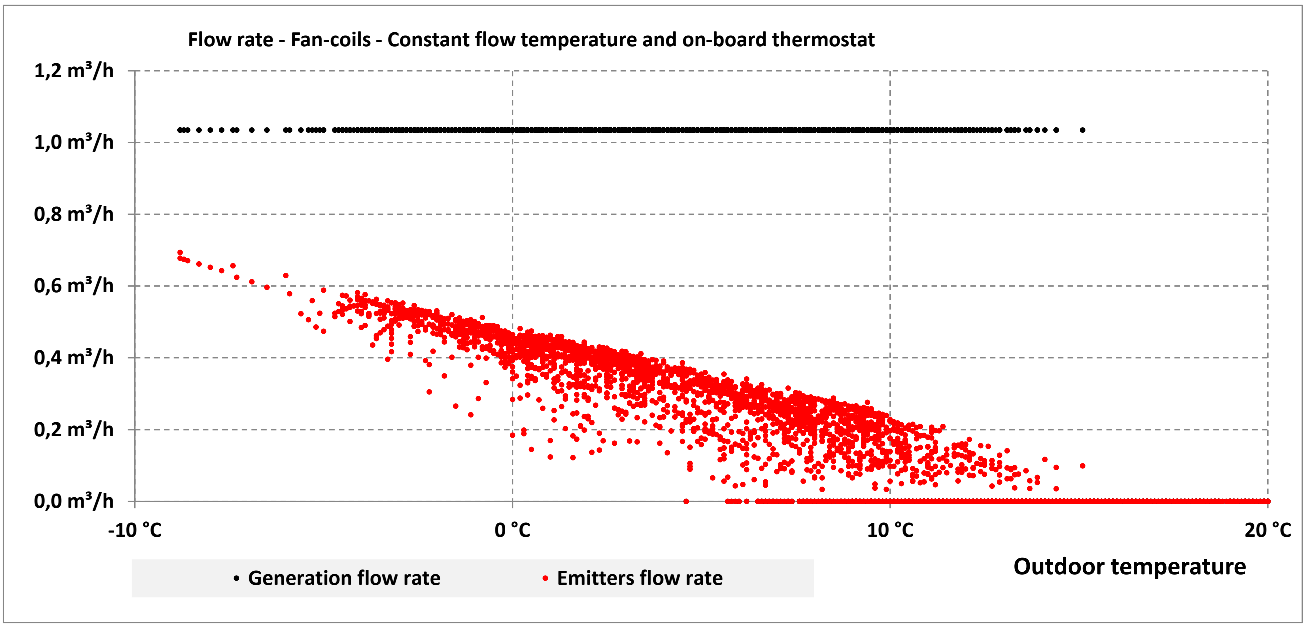

Figure 21 – Emitters (distribution) and generation flow rate as a function of outdoor temperature

Correctly, the calculation indicates that the return temperature increases at low loads because water is bypassed through the fan-coils when the fan is off.

The resulting performance of the sample heat pump is shown in table 4.

Table 4: Sample heat pump performance with fan coils

Interval	Heating output $Q_{H;hp;out}$ kWh	Source temperature θ_{src} °C	Flow temperature $\theta_{H;hp;out}$ °C	COP Heating COP_H -	DHW output $Q_{W;hp;out}$ kWh	COP DHW COP_W -
January	2.674	2,60	45,00	3,05	334	2,26
February	2.475	2,12	45,00	3,11	301	2,23
March	1.266	6,41	45,00	2,99	334	2,52
April	1.017	8,69	45,00	2,93	323	2,67
May	5	15,40	45,00	2,66	334	3,05
June	0				323	3,07
July	0				334	3,13
August	0				334	3,14
September	140	10,19	45,00	2,43	323	2,88
October	862	9,67	45,00	2,75	334	2,70
November	2.071	5,21	45,00	3,12	323	2,42
December	2.254	5,24	45,00	3,18	334	2,43
YEAR TOTAL	**12.764**	**5,46**	**45,00**	**3,05**	**3.931**	**2,67**

Specific calculation files:

- *30d - EN_15316-1_SFH_M_AVG_FCL_CO_BP_IFC.xlsm*
- *40d - EN_15316-4-2_SFH_M_AVG_FCL_CO_BP_IFC.xlsm*

The comparison with table 3 shows that:

- the required output for heating is slightly different due to the higher temperature and therefore higher distribution losses;
- the source temperature is the same;
- the average flow temperature is 10 °C higher;
- the COP for heating is 17,6 % lower;
- operating conditions and COP are the same for domestic hot water.

6.3.5 Result with radiators sized for low temperature and flow temperature based on outdoor temperature

The initial calculation described in clause 6.3.2 is repeated in the same conditions but assuming an oversizing factor of radiators of 2,5. This means that the nominal power of installed radiators is 2,5 times the heat load.

For this case, the outdoor temperature reset setting is:

- maximum flow temperature 45 °C at -10°C external temperature;
- minimum flow temperature 28 °C at 16°C external temperature.

The results for the flow and return temperature and the flow rates are shown in figures 22 through 24.

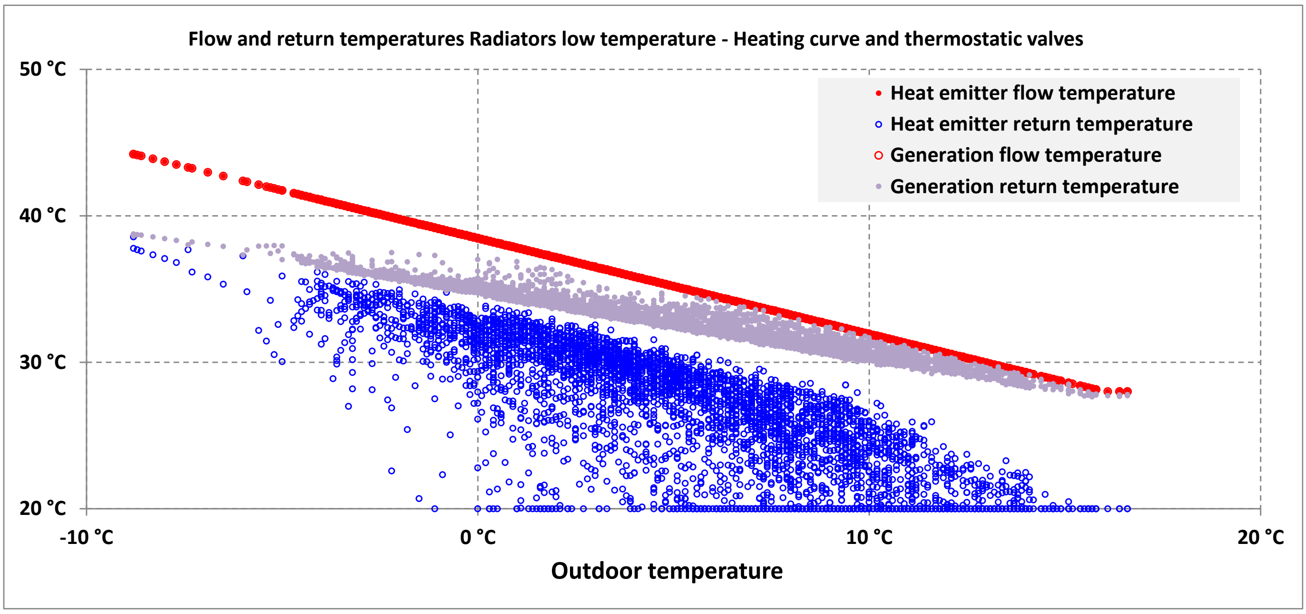

Figure 22 – Flow and return temperatures as a function of outdoor temperature

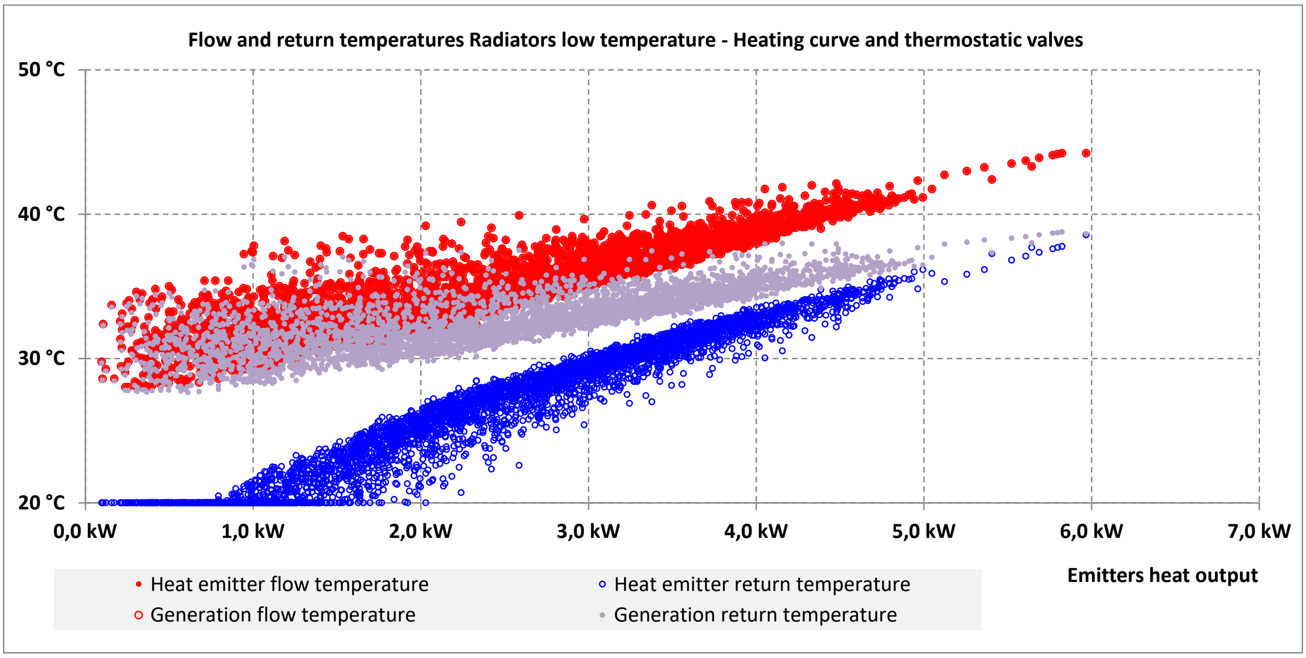

Figure 23 – Flow and return temperatures as a function of required output power

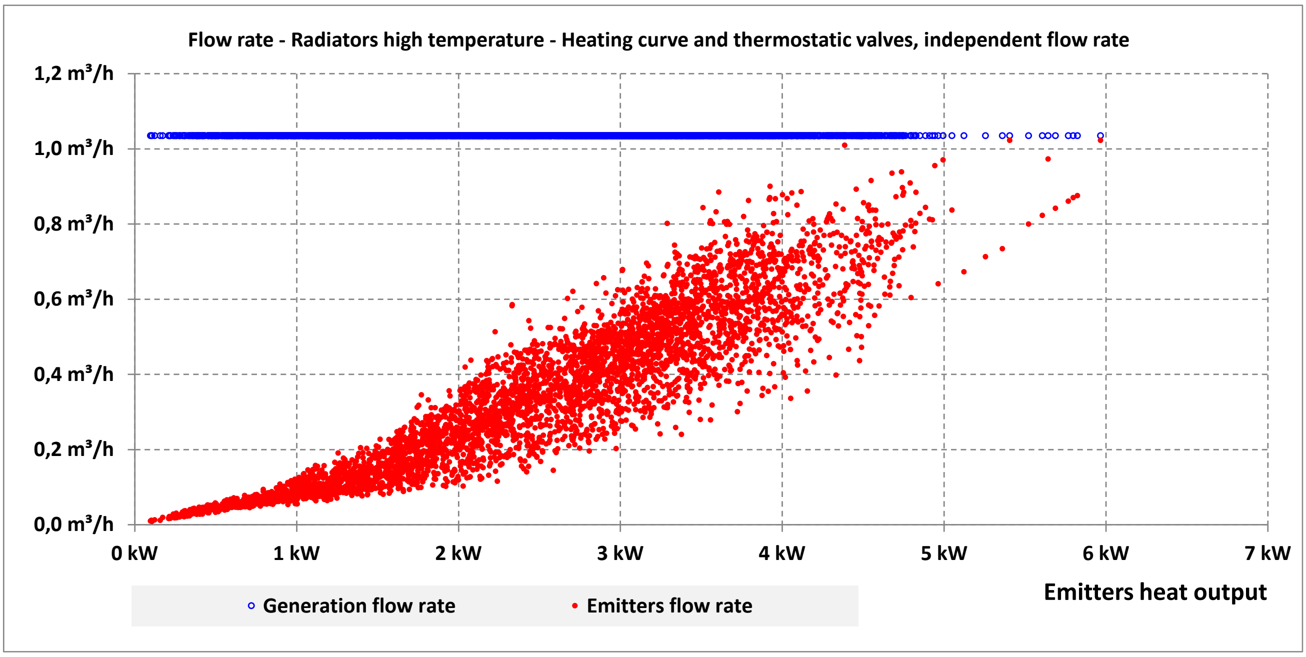

Figure 24 – Emitters (distribution) and generation flow rate as a function of outdoor temperature

The increased level of insulation of new and deeply renovated buildings greatly reduces the heat load (shifting from U-values around 0,8 W/m^{2}K to U-values around 0,2 W/m^{2}K means reducing the heat losses of walls by a factor 4). Therefore, installing the “usual size” of radiators already results in a high oversizing. This is also true when insulating an existing building: the existing heat emitters are automatically oversized and this allows operating the heating system at a lower temperature. This EPB standard takes this fully into account.

This design choice allows to have the same flow temperature with radiators as floor heating and is a viable option to use heat pumps with radiators in well insulated buildings.

This design option is correctly taken into account by this module.

The resulting performance of the sample heat pump is shown in table 5.

Table 5: Sample heat pump performance with oversized radiators and heating curve

Interval	Heating output $Q_{H;hp;out}$ kWh	Source temperature θ_{src} °C	Flow temperature $\theta_{H;hp;out}$ °C	COP Heating COP_H -	DHW output $Q_{W;hp;out}$ kWh	COP DHW COP_W -
January	2.647	2,60	36,74	3,58	334	2,26
February	2.452	2,12	37,23	3,65	301	2,23
March	1.238	6,41	34,68	3,68	334	2,52
April	987	8,69	33,20	3,75	323	2,67
May	4	15,40	32,88	3,31	334	3,05
June	0				323	3,07
July	0				334	3,13
August	0				334	3,14
September	133	10,19	32,51	3,00	323	2,88
October	833	9,67	32,53	3,40	334	2,70
November	2.039	5,21	35,00	3,82	323	2,42
December	2.221	5,24	34,95	3,97	334	2,43
YEAR TOTAL	**12.555**	**5,46**	**35,05**	**3,70**	**3.931**	**2,67**

Specific calculation files:

- *30f1 - EN_15316-1_SFH_M_AVG_RAD_HC_VF_IFC_OVSZ.xlsm*
- *40f1 - EN_15316-4-2_SFH_M_AVG_RAD_HC_VF_IFC_OVSZ.xlsm*

The comparison with table 3 shows that:

- the required output for heating is the same;
- the source temperature is the same;
- the average flow temperature is the same (because the same heating curve setting was used);
- the COP is the same;
- operating conditions and COP are the same for domestic hot water.

This shows that heat pumps may be used with radiators but achieving a good performance depends on the correct sizing of radiators compared to the required power. EN 15316-1 allows to check the correct sizing of emitters since the design phase.

6.3.6 Result with oversized radiators and flow temperature based on demand

The calculation in the previous case is repeated with the option that flow temperature be controlled by the heat demand.

The results for the flow and return temperature and the flow rates are shown in figures 25 through 27.

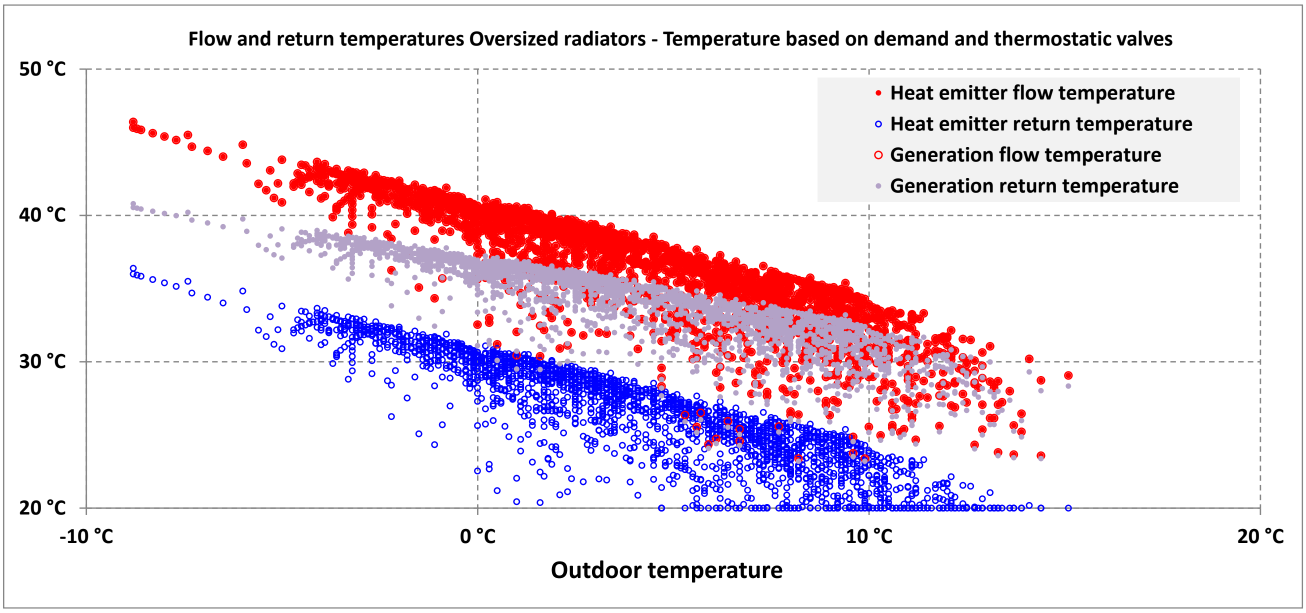

Figure 25 – Flow and return temperatures as a function of outdoor temperature

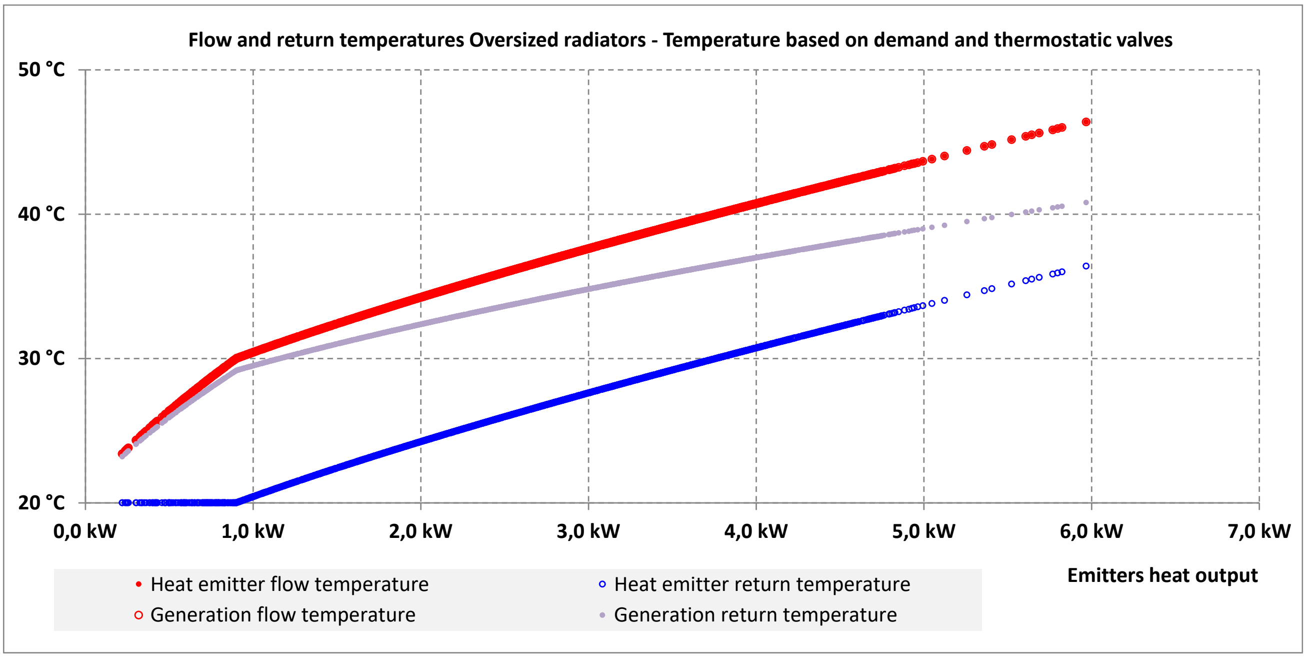

Figure 26 – Flow and return temperatures as a function of required output power

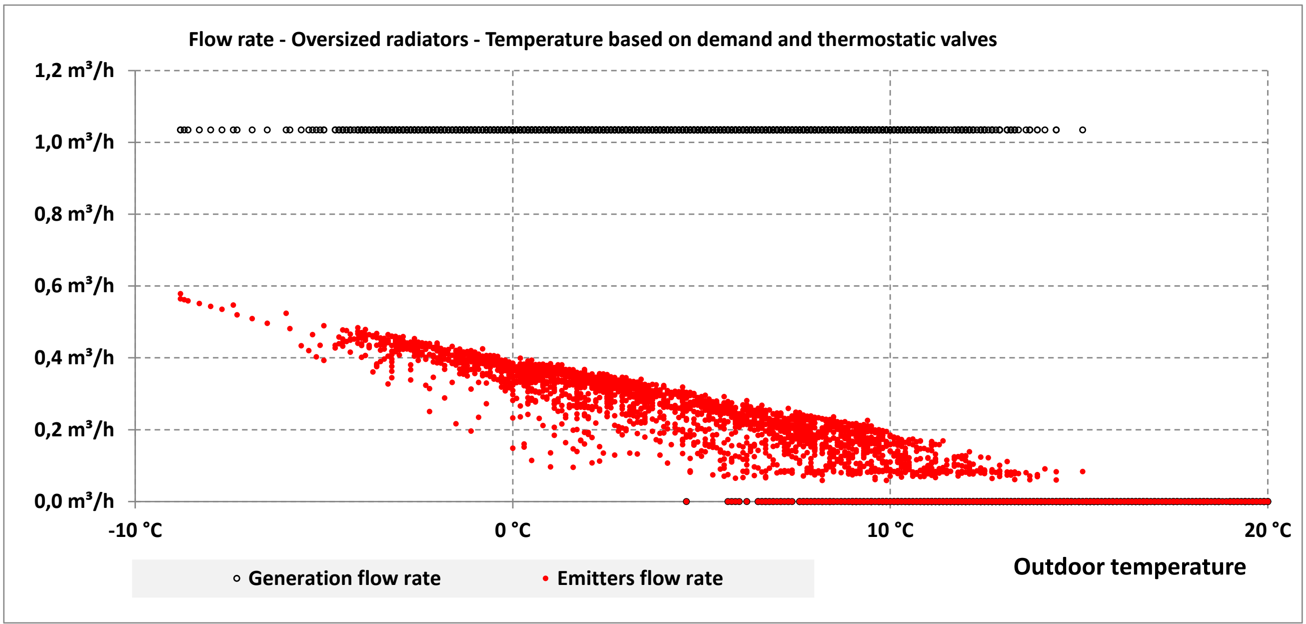

Figure 27 – Emitters (distribution) and generation flow rate as a function of outdoor temperature

This is the original option that can be found in annex C of EN 15316-1 for the thermostatic valves.

This option was intentionally developed for the monthly calculation but it can be used when this type of flow temperature control is used.

The resulting performance of the sample heat pump is shown in table 6.

Table 6: Sample heat pump performance with oversized radiators and flow temperature according to heat demand

Interval	Heating output $Q_{H;hp;out}$ kWh	Source temperature θ_{src} °C	Flow temperature $\theta_{H;hp;out}$ °C	COP Heating COP_H -	DHW output $Q_{W;hp;out}$ kWh	COP DHW COP_W -
January	2.647	2,60	38,10	3,47	334	2,26
February	2.452	2,12	38,51	3,54	301	2,23
March	1.237	6,41	34,25	3,67	334	2,52
April	986	8,69	33,06	3,71	323	2,67
May	4	15,40	31,58	3,39	334	3,05
June	0				323	3,07
July	0				334	3,13
August	0				334	3,14
September	133	10,19	30,31	3,08	323	2,88
October	832	9,67	32,09	3,38	334	2,70
November	2.038	5,21	36,01	3,71	323	2,42
December	2.221	5,24	36,40	3,83	334	2,43
YEAR TOTAL	**12.550**	**5,46**	**35,70**	**3,61**	**3.931**	**2,67**

Specific calculation files:

- *30f - EN_15316-1_SFH_M_AVG_RAD_DM_VF_IFC_OVSZ.xlsm*
- *40f - EN_15316-4-2_SFH_M_AVG_RAD_DM_VF_IFC_OVSZ.xlsm*

The comparison with tables 3 and 5 (same sizing of emitters but different control strategy) shows that:

- the required heat output for heating is the same;
- the source temperature is the same;
- the average flow temperature is 0,65 °C higher;
- the COP for heating is 2,4 % lower;
- operating conditions and COP are the same for domestic hot water.

The difference with heating curve is due to the fact that the flow temperature has been calculated so that a minimum temperature difference of 10 °C is kept between flow and return in the distribution circuit. This is required to limit the flow rate in the thermostatic valves. This result suggests that the heating curve setting that was assumed in the previous variant was slightly optimistic and should be corrected.

This shows that even slight details like the control strategy play a potentially significant role (0,65 °C higher flow temperature means already 2,5% less efficiency for the heat pump in this case). EN 15316-1 allows to check the correct option and suggest an initial setting of controls since the design phase.

6.4 Case with several user circuit

6.4.1 Base case

The base case is the same house but it is assumed that:

- floor heating is installed in most rooms, which account for 80% of the heating needs
- radiators are installed in the bathrooms, which account for the remaining needs

The calculation is performed assuming that the generator has an independent flow rate. If the connection were direct, then the flow and return temperatures would be the same as that of the node, which are calculated and displayed anyway.

6.4.2 Base case results

The calculation according to EN 15316-1 correctly takes into account that:

- each circuit has its own flow temperature requirements
- the operating conditions of the heat generation device (actually, the input to each node) depends on the highest required temperature and on the sum of flow rates
- if the generator flow rate is independent from the circuit flow rate, flow and return temperature for the generator are corrected accordingly.

The results for the flow and return temperature and the flow rates are shown in figures 28 through 30.

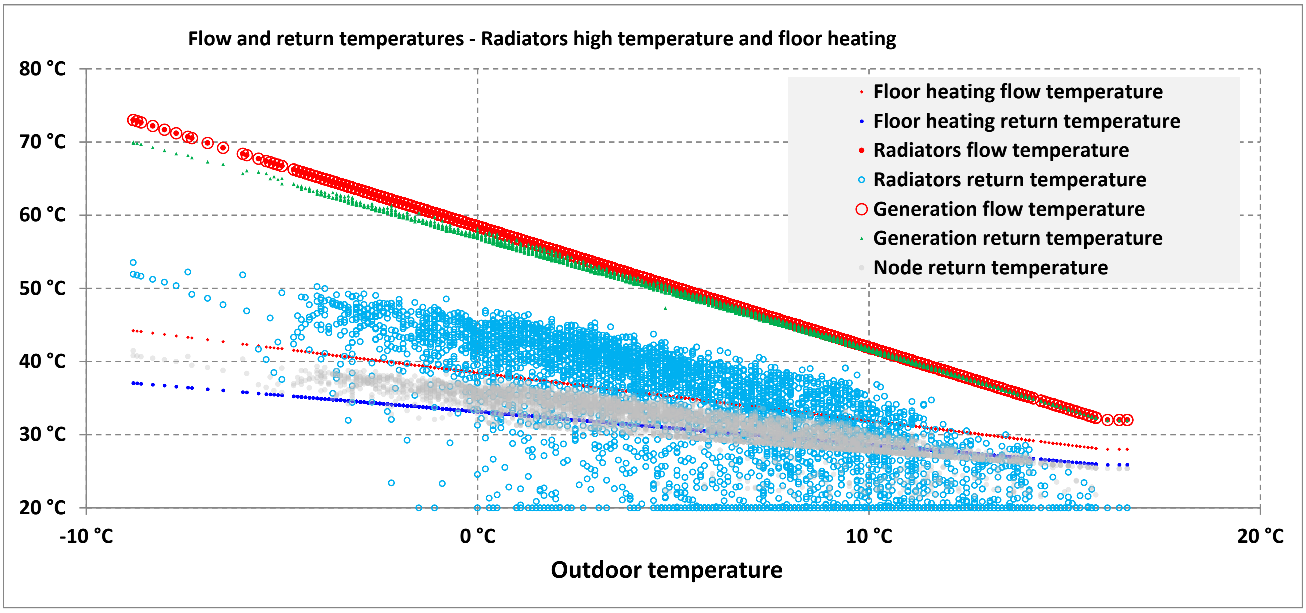

Figure 28 – Flow and return temperatures as a function of outdoor temperature

Specific calculation file: *30g - EN_15316-1_SFH_M_AVG_FLRRAD_HC_THVF_IFC.xlsm*

Figure 28 shows the different behaviour of the circuits and the effect of the mixing return water from the two circuits:

- flow temperatures are straight lines, since they depend on outdoor temperature (outdoor temperature reset);
- return temperature from floor heating is a line, because control mode is ON-OFF with a constant flow rate in the panels;
- return temperature from the radiators is a cloud (light blue circles) because a different power may be required with the same outdoor temperature;
- return temperature of the node is the grey cloud;
- flow temperature to the generator is the same as flow temperature to the radiators;
- return temperature to the generator is the green cloud, quite near to flow temperature because in this example the flow rate in the distribution circuits is much lower than the constant indpednent flow rate in the generator.

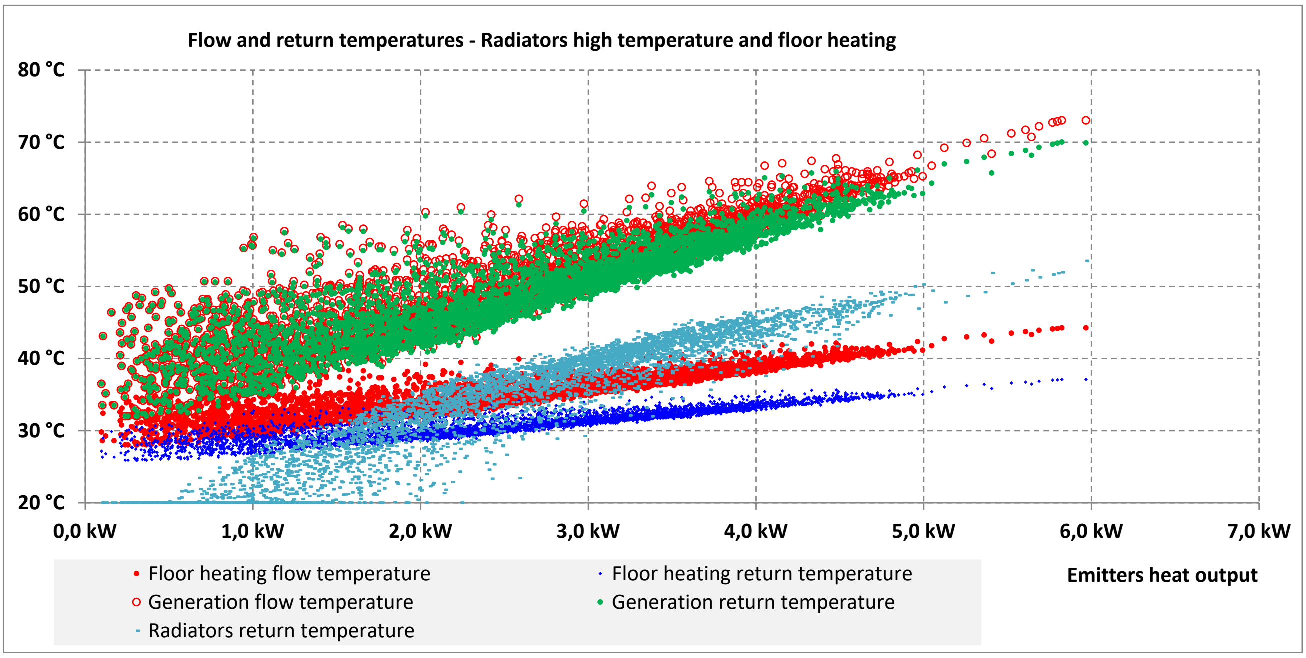

Figure 29 – Flow and return temperatures as a function of required output power

Figure 29 shows the same information as figure 28 but the temperatures are given as a function of the required power output instead of the outdoor temperature. Therefore, all temperature trends are clouds because the same power can be required at different outdoor temperatures, hence flow temperatures.

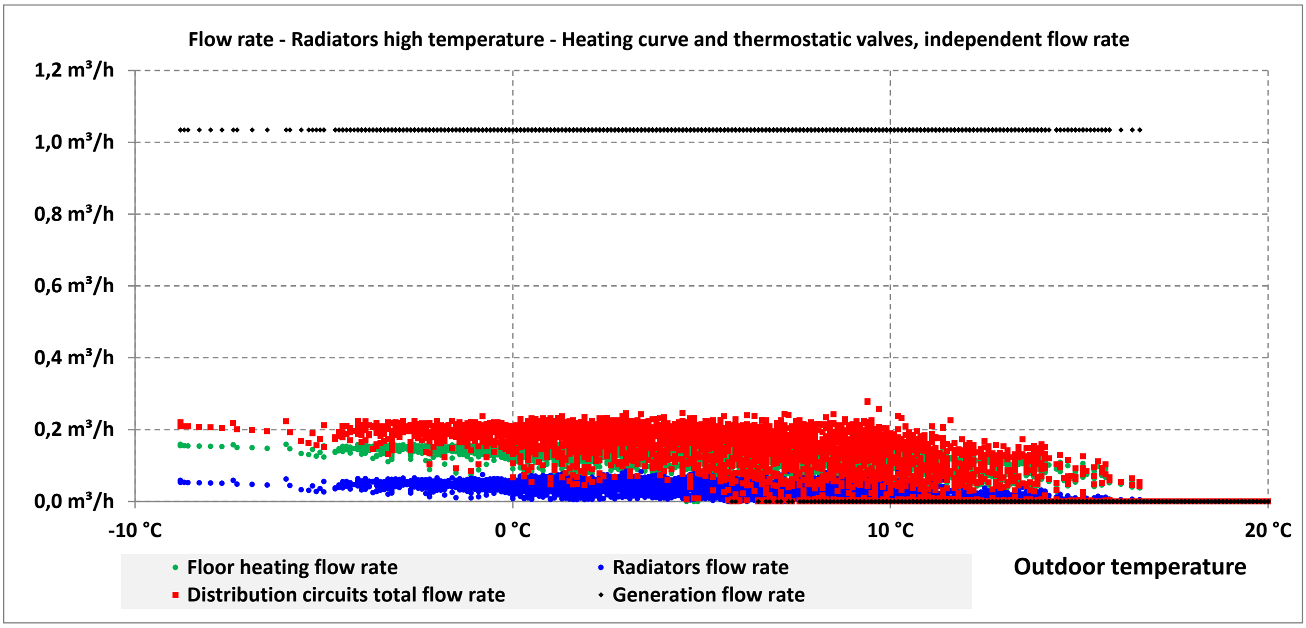

Figure 30 – Emitters (distribution) and generation flow rate as a function of outdoor temperature

Figure 30 shows the flow rates in the heating system. The flow rate indicated as "to the floor heating" is not the flow rate in the panels but the flow rate before the mixing valve. The result is that a very low flow rate is required for this installation (it's a common configuration). If the generator is operating at an independent and constant flow rate (around 0,8...1,2 m^3/h is common for a boiler for a single-family dwelling) the return temperature to the boiler is nearly the same as the flow temperature and much higher than the return temperature of the node, as shown in figures 28 and 29. The consequence on a condensing boiler is a reduced condensation rate and reduced efficiency. This can be avoided by:

- either using a direct connection of the boiler (but not all boilers allow this for technical reasons);
- or using a variable speed control of the generation circuit pump (primary pump), which may be set to get ta constant temperature difference between flow and return of the boiler.

EN 15316-1 can identify these effects and their consequences on generation efficiencies are taken into account in the generation modules of the EPB standards.

6.4.3 Variant: radiators sized for low temperature operation

The building and systems configuration is the same as before but the radiators are size to operate at a low temperature, comparable with that of the floor heating.

The flow temperature of the radiators circuit has been calculated based on demand.

Specific calculation file: *30h - EN_15316-1_SFH_M_AVG_FLRRAD_HC_THVF_IFC_rad_ovsz.xlsm*

The results for the flow and return temperature and the flow rates are shown in figures 31 through 33.

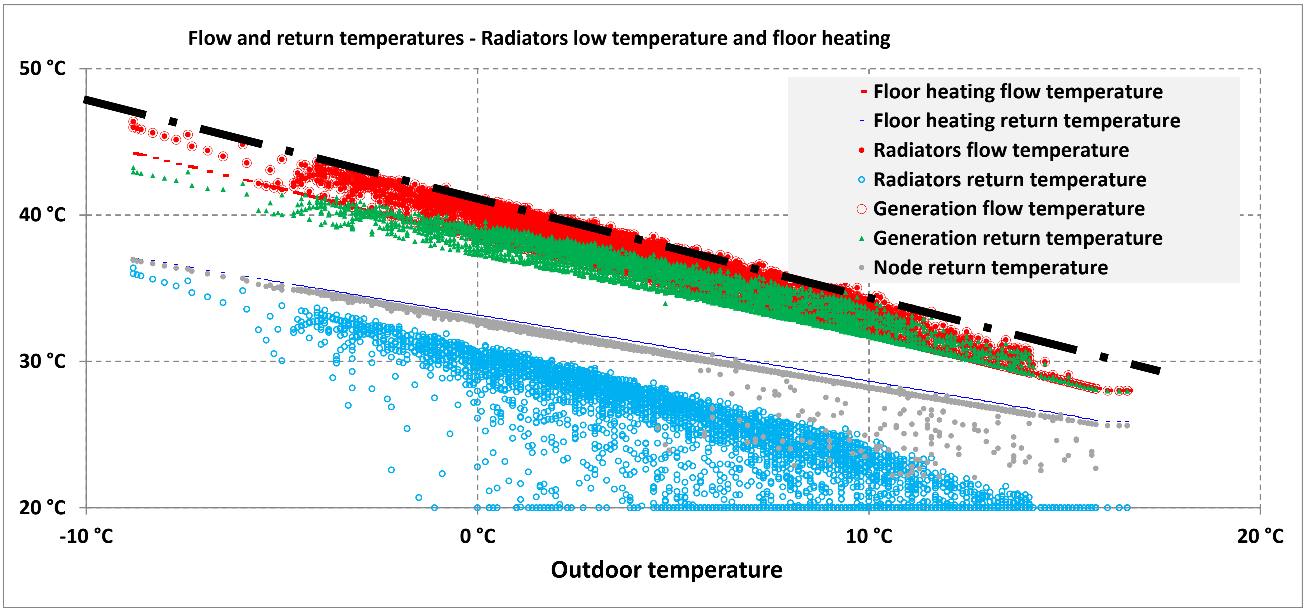

Figure 31 – Flow and return temperatures as a function of outdoor temperature

Figure 31 shows the different behavior of the circuits and the effect of the mixing return water from the two circuits.

Compared to figure 28:

- the flow temperature to the radiators is a cloud because a different power may be required with the same outdoor temperature;
- the flow and return temperatures to the generator are much lower.

The required setting of the heating curve for the radiators can be readily determined by observing the graph: the black dash-dot line will guarantee that the flow temperature is enough in any case.

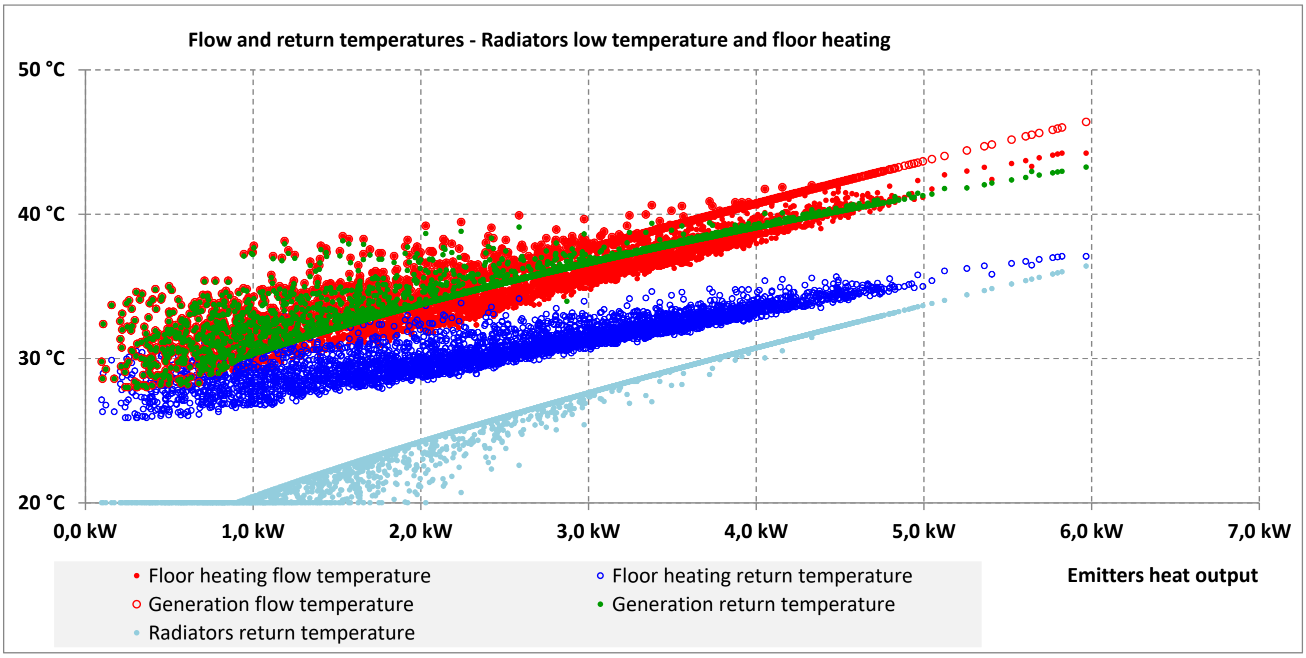

Figure 32 – Flow and return temperatures as a function of required output power

Figure 32 shows the same information as figure 31 but the temperatures are given as a function of the required power output instead of the outdoor temperature.

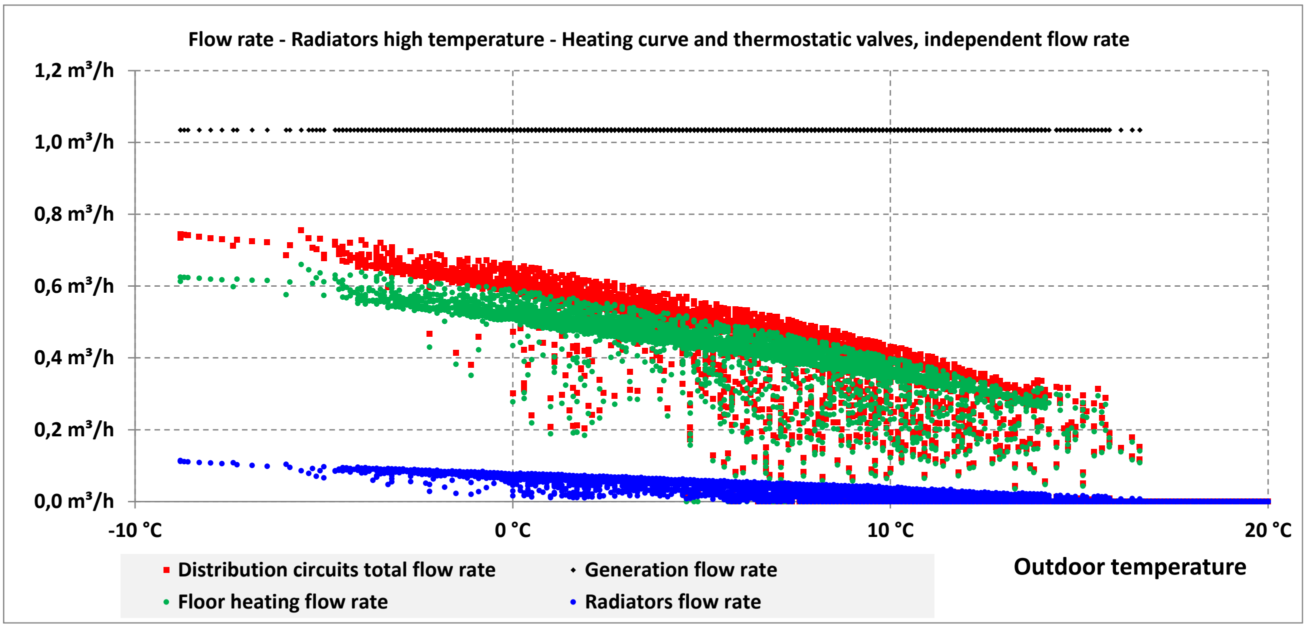

Figure 33 – Emitters (distribution) and generation flow rate as a function of outdoor temperature

Figure 33 shows the flow rates in the heating system. Compared to figure 30 the total flow rate is higher because there is nearly no mixing required for the floor heating circuit.

7 Analysis

7.1 Completeness

The structure allows both several loads and several generators for each node.

The procedures defined in this standard support both a monthly and hourly calculation of operating conditions and priorities.

Considering that:

1. the performance of heat pumps and condensing boilers is strongly dependent on operating conditions (flow and return temperature);
2. the losses from distribution networks are quite significant and their correct estimation depends on the operating time schedule and the average temperature in each section of the system;

then the calculation of operating temperatures is a must to get a reliable estimation of energy performance.

Further considering that:

1. several systems have several generators (most common examples are boiler and heat pump but also boiler and thermal solar) that use different energy carriers, so it is necessary to identify the load to each generator to get the right amount of energy carriers;
2. the energy performance depends on the amount and timing of the energy interaction with the electricity grid;
3. previous items 1 and 2 are very difficult to handle with monthly methods (they require "averaging factors" which are case specific);
4. an hourly presentation of the operating conditions allows a better understanding of the design and operational choices, from the design stage;
5. the weighting factors may be changing with an hourly time scale;

then it is evident that an hourly calculation method to determine operating conditions is a must for the transparent and reliable evaluation of the energy performance of modern buildings.

Some of these effects are highlighted in the other case studies of this series. As an example, the importance of the amount and timing of the exchange of energy with the electricity grid is demonstrated in the case study about EN 52000-1. The amount and timing of the electricity used depends on which generator is used, when it is used, for which load and with which efficiency.

It has to be noted that the available control options for distribution circuits should be completed with a simple outdoor temperature reset.

Also, the control options for nodes should be further detailed mathematically and completed.

The demonstration of the sensitivity of generation efficiency to operating conditions calculated according to EN 15316-1 has been performed o heat pumps, which is the most sensitive generation technology and the one which is being adopted in the large majority of new buildings. A similar analysis can be performed to demonstrate the influence of operating conditions on condensing boiler efficiency. This would show that:

- the efficiency of condensing boilers is less sensitive to operating conditions than that of heat pumps. The range of the thermal seasonal efficiency that can be achieved (on lower calorific value) is roughly 95% to 105%.
- the dominating influence factor is the return temperature to the boiler, which is strongly influenced by control options and minimum flow rate limitations in the boiler.

The potential impact in the case of boilers is therefore

- less than in the case of heat pumps
- much more linked to control strategies whereas for heat pumps the dominating factor is the sizing of heat emitters (unless there are severe mistakes).

Other generation technologies (such as cogeneration, biomass boilers, district heating) are less sensitive to operating temperature.

EN 15316-1 allows in any case to calculate the operating temperature and highlight any sensitivity of any generation technology. Similarly, the hourly time step allows to take fully into account any sensitivity of generation technologies to part load operation.

7.2 Functionality

In general, the standard provides the expected results and identifies correctly the temperature level of the installation.

The procedure adapts for all tested conditions.

The interaction between technical systems and thermal zones can be handled with several level of detail.

Thermal losses may occur in each technical subsystem. Depending on where they occur, thermal losses may be:

- non-recoverable, that is they are released outside the conditioned space or any adjoining unconditioned space. They will not contribute to satisfy the heating needs or add-up to cooling needs.
- recoverable, that is they are released within a conditioned space or an adjoining unconditioned space. There is a chance that lost heat may contribute indeed to satisfy space heating needs or add-up to space cooling needs.

Recoverable heat losses, depending on circumstances will, totally or partly contribute to satisfy space heating needs or add-up to space cooling needs.

There are at least three possible routes to handle recoverable losses.

1. Recoverable losses of a space heating subsystem (example: heat losses of a heating distribution section) may be accounted directly within that subsystem as a reduction of the losses depending on the probability that they are recovered, that is that they will contribute indeed to the intended service.

   A factor is required to define the percentage of recoverable losses that are actually recovered. It will depend, inter alia, on the type of space heating emission control.

   This option is possible only for losses of space heating subsystems.
2. Recoverable losses of any technical subsystem (that is for any service) may be accounted globally as a reduction of heating needs.

   A factor is required to define the percentage of recoverable losses that are actually recovered. It will depend, inter alia, on the type of space heating emission control.

   This option is frequently used for domestic hot water system losses.

   This option causes an iterative calculation if applied to losses of space heating subsystems.

   This option should be complemented by a similar procedure in EN 16798-9 to take into account the additional cooling load due to domestic hot water losses.

   This option may be used when cooling is not a concern.

3. Recoverable losses of any technical subsystem (that is for any service) may be accounted into the respective thermal zone in which they are released.

   This is the most complete and detailed method and it takes into account all possible interaction between technical systems and building envelope.

   This causes an iteration. For the hourly calculation, the iteration may affect significantly calculation time. Iteration may be prevented by accepting that recoverable losses be accounted in the next calculation interval (only for hourly calculation interval).

   This option requires a coordination with the module for energy need calculation EN ISO 52016 and possibly also with the ventilation calculation, EN 16798-X series.

Which option to select depending on the building typology, and climate should be decided at an overarching level since it may imply coordination with the modules about thermal balance, ventilation a and cooling.

7.3 Sensitivity

EN 15316-1 highlights correctly the differences between the several possible solutions.

The product data (size of emitters, nominal flow rate of generators) are taken into account.

The main driving parameter is the nominal power of emitters compared to the required heat output. However, the effect of

- hydraulic connections;
- flow rate in the generators;
- control strategies;

are identified and taken into account, either in the sense of increasing or compromising operating conditions and hence the performance of distribution networks and connected generators.

7.4 Usability

7.4.1 End user

The standard is easy to use. The input parameters are a limited number and well defined.

The only one parameter that changes for each individual system is the nominal power of installed heat emitters. At design stage, this should be known. When calculating existing building, the heat load can be used as a default value (the input data for energy needs allow to calculate the heat load as well, so the default value is always available in the context of an energy performance calculation).

The other parameters can be all assumed as default values, except for special design cases which have to be recognised and correctly evaluated, indeed.

7.4.2 Standardisation bodies

Some care is required in identifying and setting correctly the choices about handling of recoverable losses. See previous clause 7.2 for further details.

8 Conclusions and recommendations

EN 15316-1 covers adequately the calculation of operating temperature of the heating and domestic hot water systems.

The modular and flexible structure allows to accommodate complex configurations of technical systems, with several service areas, nodes and several generation devices with priorities.

The comparison of heat pump performance depending on emitter sizing and emission control options demonstrate how much this calculation method is needed for sensitive generation devices like heat pumps.

The default set of calculation modules for distribution and generation circuits (annexes C and D to EN 15316-1) should be extended making use of the possibility to add custom modules. The case study demonstrated that the following extension would be useful.

- Setting up additional alternatives for the distribution circuits flow temperature.

  Currently annex C to EN 15316-1 only considers flow temperature based on demand, which is fine only for monthly calculation or when there is no information on the designed or actual settings.

  This is easy to integrate and for the purpose of the case study two additional options were added and tested in the improved accompanying excel:

  - flow temperature depending on outdoor temperature (classic “heating curve”);
  - constant flow temperature (typical use is for fan-coils).

- Defining more alternatives for the generation circuits flow rate.

  Currently annex D to EN 15316-1 only considers direct connection (same flow rate in the distribution and generation circuits) and independent, constant flow rate in the generation circuit.

  The basic options were enough for the considered cases but additional options may be required to analyze correctly circuits with condensing boilers, such as:

  - generation flow rate controlled according to the temperature difference of the generation circuit (common option of several condensing boilers);
  - minimum recirculation flow rate, used a minimum temperature in the boiler is required, e.g. when condensation shall be avoided on old boilers and biomass boilers.

  This has not been introduced in the improved spreadsheet but it is relatively easy to implement.

- Defining explicit options to handle the combination of:

  - priorities between generators connected to the same node, considering cascade and parallel operation;
  - priorities within each generator connected to several services.

  The enhanced spreadsheet includes a sheet (“***Sample_sequence***”) with a suggested methodology to determine the right calculation order of the generation devices.

  Better and more comprehensive algorithms may be proposed in connection with BACs.

Additionally, the choices about the handling of recoverable losses should be mentioned at overarching level to ensure full consistency with the needs calculation (both heating and cooling, EN ISO 52016-1) and the ventilation calculation (EN 16798 series of standards)

Annex A

Supporting calculation files

A.1 File name coding

The files are identified with a code which is built in the following way.

Files for EN 15316-1: **NNa - STANDARD_BBB_X_CLI_EEE_ETC_EFC_GFC.XLSM**

where

- **NNa** is
  - a progressive number **NN** identifying the calculation order (30 for this standard in this case study)
  - a letter **a…z** to identify the files related to specific changes and variants
- **STANDARD** is the standard code
  - **EN 15316-1** General part for heating (the object of this case study)
- **BBB** is the building type
  - **SFH** for Single family house
  - **MFH** for Multi-family house
  - **OFF** for office

  NOTE: only **SFH** is used in this case study
- **X** can be:
  - **E** for existing building (low insulation)
  - **M** for medium insulation
  - **N** for new building (high insulation)

  NOTE: only **M** is used in this case study
- **CLI** is the climate code
  - **AVG** for average climate
  - **CLD** for cold climate
  - **WRM** for warm climate
- **EEE** indicates the emitter type
  - **RAD** for radiators
  - **FLR** for floor heating
  - **FCL** for fan-coil

  Two codes may be combined for multiple circuit examples (e.g. FLRRAD for floor heating and radiators)
- **ETC** indicates the type of emitter temperature control
  - **HC** for heating curve
  - **DM** for demand control

- **EFC** indicates the type of flow rate control in the emitters
  - **VF** for variable flow-rate
  - **TH** for ON-OFF thermostat control
  - **BP** for by-pass control
- **GFC** indicates the type of flow rate control in the generation system
  - **DIR** for direct connection
  - **IFC** for independent, constant flow

Climatic data files are coded:

NN - STANDARD_ TMY_Location_Orientations.XLSM

where

- **NN** is a progressive number identifying the calculation order
- **STANDARD** is the standard code, in this case ISO_52010
- **TMY** for true meteorological year
  - **Location** is the name of the location
  - **Orientations** an info on the orientations included for solar radiations on exposed planes

Other files are coded

NNa - STANDARD_BBB_X_CLI_C_OP__OTH.XLSM

where

- **NNa** is
  - a progressive number **NN** identifying the calculation order
  - an optional letter **a** to identify the files related to cases and variants
- **STANDARD** is the standard code
  - EN 12831-3 domestic hot water needs
  - EN_16798-1 Use profiles
  - ISO_52016-1 building description and heating needs calculation
- **BBB** is the building type
  - **SFH** for Single family house
  - **OFF** for office
  - **KND** for kindergarten
  - **MET** for meeting room
- **X** can be:
  - **E** for existing building
  - **M** for medium insulation
  - **N** for new building
- **CLI** is the climate code
  - AVG for average climate

  - CLD for cold climate
  - WRM for warm climate
- **C** indicates the comfort category
  - I / II / III
- **OP** indicates operation type of heating
  - CNT for continuous
  - INT for intermittent (night set back)
- **OTH** indicates other information
  - **OVSZ** for (intentionally) oversized emitters

A.2 Calculation files list

00 - ISO_52010-1_TMY_Strasbourg_8_planes.xlsx

05 - EN 12831-3_SFH.xlsx

10 - EN_16798-1_SFH-X-AVG-II-CNT_HUDU.xlsm

20 - ISO_52016-1_SFH_M_YYY-II-CNT_DESC.xlsx

21 - ISO_52016-1_SFH_M-AVG-II-CNT-CALC.xlsm

30b - EN_15316-1_SFH_M_AVG_RAD_HC_VF_IFC.xlsm

30b - EN_15316-1_SFH_M_AVG_RAD_HC_VF_IFC_hc_too_low.xlsm

30c - EN_15316-1_SFH_M_AVG_FLR_HC_TH_IFC.xlsm

30d - EN_15316-1_SFH_M_AVG_FCL_CO_BP_IFC.xlsm

30e - EN_15316-1_SFH_M_AVG_RAD_DM_VF_IFC.xlsm

30f - EN_15316-1_SFH_M_AVG_RAD_DM_VF_IFC_OVSZ.xlsm

30f1 - EN_15316-1_SFH_M_AVG_RAD_HC_VF_IFC_OVSZ.xlsm

30g - EN_15316-1_SFH_M_AVG_FLRRAD_HC_THVF_IFC.xlsm

30h - EN_15316-1_SFH_M_AVG_FLRRAD_HC_THVF_IFC_rad_ovsz.xlsm

35 - EN 15316_5_SFH_M_AVG.xlsm

40c - EN_15316-4-2_SFH_M_AVG_FLR_HC_TH_IFC.xlsm

40d - EN_15316-4-2_SFH_M_AVG_FCL_CO_BP_IFC.xlsm

40f - EN_15316-4-2_SFH_M_AVG_RAD_DM_VF_IFC_OVSZ.xlsm

40f1 - EN_15316-4-2_SFH_M_AVG_RAD_HC_VF_IFC_OVSZ.xlsm

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[11] ENERC32017-437-SI2-785.185, Case study on Multi-family House October 31, 2021

[12] ENERC32017-437-SI2-785.185, Case study on Office building October 31, 2021

Please check the EPB Center website for the overview and most recent versions of the other case study reports.

Link: EPB Center support documents

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