QM

Biomass DH Plants

Demand assessment and appropriate system selection

Manual for the EXCEL tool

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The latest version of this manual "demand assessment and appropriate system selection" and the corresponding latest version of the EXCEL tool can be downloaded free of charge from the website "QM for Biomass DH Plants":

www.qm-biomass-dh-plants.com
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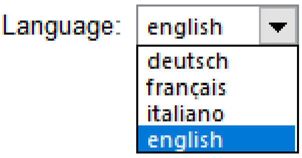
Preface

The excel tool “Demand assessment and appropriate system selection”, in short only referred to as “Demand assessment” is an important part of the quality management system for biomass district heating plants QM for Biomass DH Plants (QM Holzheizwerke®).

The demand assessment tool is available in four languages: German, French, Italian and English. Please select the desired language at the bottom of the first EXCEL sheet («Verbraucher», «Consommateurs», «Consumatore» or «Consumers» - depending on the pre-defined language). The selection is done via a drop-down menu:



This Manual has been translated into English with support of klima**aktiv** QM Heizwerke – the Austrian implementation of QM for Biomass DH Plants. klima**aktiv** is a climate protection initiative of the Austrian Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology (BMK).

Content

1. Demand of individual heat consumers

1.1 New buildings

The **annual heat demand for space heating** in Switzerland, Germany and Austria should be calculated according to DIN EN ISO 52016. [7] in Switzerland, Germany and Austria. Heat gains from solar radiation, people, electrical appliances, etc. are taken into account in this standard.

The calculation of the **annual heat demand for domestic hot water** is usually based on a given standard use.

Today, the **standard heat capacity demand for space heating** in Switzerland, Germany and Austria should be calculated according to EN 12831 [8]. Heat gains from solar radiation, people, electrical appliances, etc. are not taken into account in this standard. On the other hand, an additional heating capacity to compensate for the effects of intermittent heating can be taken into account. If the latter heating capacity is not taken into account, the result is in principle the 24-hour average value without taking heat gains into account.

The average value of the heat capacity demand for **domestic hot water** is calculated by dividing the heat demand for domestic hot water by the heating hours (winter operation) or 8760 hours (all-year operation). The peak value of the domestic hot water heat capacity demand results from the connected load of the water heater. Since mostly storage water heaters are used (hot water preparation by means of instantaneous water heaters is rather rare) it is usually sufficient to divide the annual domestic hot water heat demand by 4000...6000 hours. This takes into account a higher peak load than the theoretical mean value, because on certain days the peak load can be higher than the mean value (depending on the day of the week and the season).

The **temperature requirement** results from the design of the heat capacity, domestic hot water preparation, etc. The design of the radiators, underfloor heating, heat exchangers, etc. is usually based on manufacturer specifications.

1.2 Existing buildings

The calculation of the total **annual heat demand** is based almost exclusively on the previous final energy consumption (e.g. previous heating oil consumption) and the degree of utilisation of the previous heat generator. From this, a breakdown is then made into space heating, domestic hot water and processes. If no reliable data on previous consumption is available or no reliable division of space heating, domestic hot water and processes is possible, measurements (see next paragraph) or estimates (see section "Building area") remain.

The best method for determining the **heat capacity demand** is to determine the load characteristics with the help of measurements. This is always worthwhile, especially for large consumers and for process heat. However, measurements are only possible if there is still enough time and a functioning heat generation system is available.

Experience has shown that useful existing heat demand calculations are hardly ever available or are based on outdated calculation methods. Recalculations usually fail due to the lack of plans with the necessary information on wall construction, etc.

The most common method is to estimate the heat capacity demand from the previous heat demand:

■ Maximum heat capacity demand **space heating**: Division of the heat demand for space heating by a suitable full load operating hours (for explanation and limitations see Box 1).

■ Average heat capacity demand for **domestic hot water**: Division of the heat demand by the heating hours (winter operation) or 8760 hours (all-year operation). In order to take into account a higher peak load than the theoretical mean value, the annual heat demand for domestic hot water is usually divided by 4000...6000 hours.

■ Average heat capacity demand for **process heat**: Division of the heat demand by the operating hours per year (estimated or according to the operating hours meter). Here too, a higher peak load is of course taken into account if required.

It is possible to estimate the **temperature demand** solely on the basis of the existing heat consumers (underfloor heating, radiator heating, water heaters, etc.). However, it is recommended to measure the temperature of the individual heat consumers during cold outdoor temperatures and to extrapolate the measured value pairs (supply/return temperature, outdoor temperature) to design values.

Full load operating hours for space heating

The full load operating hours for space heating [h/a] is defined as the division of the heat demand for space heating [kWh/a] by the maximum heat capacity demand for space heating [kW]. The full load operating hours depends on the annual duration curve of the outdoor temperature at the location of the system, the room temperature, the heating limit and the size of the non-weather-dependent component.

■ The full load operating hours in Table 6 apply to existing residential buildings (space heating without domestic hot water) built before about 1990 (for further information see FAQ 1).

■ These full load operating hours may not be applied to new buildings and very well insulated existing residential buildings with lower heating limits than 15°C; lower values result is case (see FAQ 2).

■ Non-residential buildings also have different full load operating hours due to limited operation and reheating as well as room temperatures and internal loads that differ from residential buildings (see FAQ 3 and FAQ 6).

Box 1

1.3 Building area

The **heat demand** is estimated on the basis of the energy reference area and the specific heat demand. However, the specific heat demand should not be overestimated in the calculation. The specific heat demand for domestic hot water is included in the calculation according to standard use.

Analogous to the existing buildings (see there), a calculation of the **heat capacity demand** is possible from the (here estimated) heat demand.

The **temperature demand** is estimated on the basis of the expected heat consumers.

2. Demand of the total plant

2.1 Problems in determining the heat capacity demand of the entire system

Problems often arise when determining the heat capacity demand of the entire system from data of the individual heat consumers:

■ The heat capacity demand for the entire system results from a mixture of calculated values with more or less large safety margins and real measured values without safety margins.

■ The standard heat capacity demand for space heating, calculated according to EN 12831 [8] is based on a standard outdoor temperature. In contrast, metrological determined load characteristics refer to real outdoor temperatures.

■ The standard heat capacity demand for space heating, calculated in accordance with EN 12831 [8] does not take into account heat gains from solar radiation, people, electrical appliances, etc. In contrast, metrological determined load characteristics correctly take heat gains into account.

■ To estimate the heat capacity demand for space heating in existing buildings from the heat demand, a number of full load operating hours is required, which depends on the annual duration curve of the outdoor temperature at the location of the system, the room temperature, the heating limit and the size of the non-weather-dependent component. Which full load operating hours should be used?

■ The calculation of additional heating capacities to compensate for the effects of intermittent heating (e.g. heating up on Monday morning in an office building after reduced weekend operation) is often not considered.

■ Measured load characteristics can be created for different load cases by regressing daily average values to 1-hour average values. However, it must be noted that metrological determined peak loads are not solely dependent on the heat consumer, but also on the heat generator used for the measurement. The latter has a more or less limiting effect!

■ Load curves determined by measurement often show a considerable non-weather-dependent share of the heating power demand. How should this non-weather-dependent share of the heat capacity demand for space heating be taken into account in new buildings?

■ The average value of the heat capacity demand for domestic hot water (annual heat demand for domestic hot water divided by 8760 hours) is something completely different from the peak value of the heat capacity demand for domestic hot water (connected load of the water heater). The domestic hot water consumption often also varies from day to day (depending on the day of the week and the season).

In order to determine the numbers for the entire plant from a mixture of calculations and real measured values as realistically as possible, the following questions must therefore be answered:

■ How are heat gains taken into account in new buildings?

■ What are the appropriate full load operating hours for determining the heat capacity demand for space heating based on the previous heat demand for existing buildings?

■ How should the non-weather-dependent share of the heat capacity demand for space heating be taken into account?

■ To what extent are additional heating capacities taken into account to compensate for the effects of intermittent heating in the overall system?

■ To which outdoor temperature is the total system referred?

2.2 Heating power demand shown as a load characteristic

The following describes the representation of the heat capacity demand as a load characteristic with outdoor temperatures that are as real as possible. This method has emerged from practical experience with measurements in renovations and extensions of larger technical systems in buildings. It requires empirically supported decisions. The great advantage is that the mixture of data from calculations, from previous energy consumption and from measurements can be clearly presented.

The method is based on the following fundamental considerations:

■ Space heating, domestic hot water and processes must be considered separately for each heat consumer. Therefore, a strict division between space heating, domestic hot water and processes is required.

■ For standard residential buildings, the daily average value for the heat capacity demand for space heating is used in the calculation. Experience and numerous measurements show that the space heating required in residential buildings at a certain outdoor temperature (also daily average) can be supplied at some point within 24 hours - in "packages", so to speak. It is sufficient if the balance is correct again after 24 hours. So-called night setbacks are therefore hardly noticeable in normal residential buildings. This is especially true for residential buildings built after 1985 and for older buildings that have been thermally well renovated. In addition, at very low outdoor temperatures, night time reductions can also be switched off if necessary!

■ Only really difficult systems, in particular systems with reduced weekend operation and the risk of cold blowing ventilation systems, are designed - as moderately as possible - for peak loads.

■ The heat capacity demand for domestic hot water preparation is taken into account as the highest occurring average value (but not as a peak value). All systems should therefore be storage water heaters, and the majority of systems should be equipped with "boiler priority".

■ Safety factors and peak load surcharges are made for the individual heat consumers and must be plausibly justified. Each heat consumer is thus used as realistically as possible in the overall calculation, so that simultaneity factors are not normally required. (Nevertheless, moderate simultaneity factors are of course not "forbidden"). It must always be taken into account that despite "daring" assumptions for some heat consumers, considerable safety margins remain for other heat consumers, so that there is always a certain balance.

■ The representation is done as a load characteristic of the entire system (explanation see Box 2). For space heating, a distinction is made between a weather-dependent and a non-weather-dependent share (independent of the likewise non-weather-dependent shares for the heat capacity demand for domestic hot water and process heat as well as the heat distribution losses in the district heating network).

■ The average heat distribution losses of the district heating network are calculated on the basis of the manufacturer's specifications.

A great advantage of the path via the load characteristic is that the annual duration curve of the heat demand can be calculated from it with the help of the annual duration curve of the outdoor temperature (for explanations see Box 2).

Load characteristic

The load characteristic is the representation of the heat capacity demand as a function of the daily average value of the outdoor temperature. For the outdoor temperature, the 24-hour average value must always be used, whereas the heat capacity demand can be a daily average value (e.g. residential buildings) or a peak value (e.g. bank buildings). The load characteristic of the entire system results from the stacking of several load characteristics (see for example Figure 14). Two different load characteristics are used in the EXCEL tool "Demand assessment":

- Load characteristic for the design of the entire system (extracted form in Figure 14)
- Weighted load characteristic for calculating the annual duration curve of the heat capacity demand (dashed lines in Figure 14)

Annual duration curve of the outdoor temperature

The annual duration curve of the outdoor temperature is the representation of the cumulative frequency of the outdoor temperature as the number of days per year. From Figure 17 for example, the 10-year daily average outdoor temperature in Zurich/Fluntern (CH) was below 4°C on 104 days.

Annual duration curve of the heat capacity demand

The annual duration curve of the heat capacity demand results from the weighted load characteristic and the annual duration curve of the outdoor temperature. From Figure 16 it can be seen, for example, that the heat demand exceeds 760 kW on 104 days. The heat demand for these 104 days results from the area under the curve.

Box 2

3. Requirements according to Q-Guidelines

According to the Q-Guidelines [1] a plausibility check is required for each heat consumer and for the entire system. The calculation of key figures and characteristic curves is required. The key figures and characteristic curves are then to be compared by the Q-manager with information from the literature and empirical values based on his own experience.

3.1 Required key figures for each heat consumer

According to the Q-Guidelines [1] the following key figures are required for the plausibility check for each heat consumer (see Q-requirements No. E.2.4 in Table 4 of the Q-Guidelines):

- Full load operating hours space heating [h/a]
- Full load operating hours domestic hot water [h/a]
- Full load operating hours process heat [h/a]
- Specific heat demand [kWh/(m²a)]
- Specific heat capacity demand space heating [W/m²]
- Specific energy demand domestic hot water [kWh/(m²a)]

3.2 Required key figures and characteristic curves for the entire system

The Q-Guidelines [1] requires the following key figures and characteristic curves for the plausibility check for the entire system (Q-requirements No. E.2.6):

- Max. supply temperature heat consumers [°C] (highest occurring value)
- Max. main return temperature [°C] (highest average main return)
- Full load operating hours for space heating for the entire system [h/a].
- Full load operating hours of domestic hot water for the entire system [h/a].
- Full load operating hours of process heat for the entire plant [h/a].
- Specific heat demand for the entire system [kWh/(m²a)].
- Specific heat demand for space heating for the entire system [kWh/(m²a)].
- Specific heat demand for domestic hot water for the entire system [kWh/(m²a)].
- Load characteristics as a function of the outdoor temperature shown as total of:
  - heat capacity demand space heating weather-dependent [kW]
  - heat capacity demand space heating non-weather-dependent [kW]
  - heat capacity demand domestic hot water [kW]
  - heat capacity demand process heat [kW]
  - heat distribution losses district heating network [kW]
- Annual duration curve of the heat capacity demand calculated from the sum of the above load characteristics
- Independent calculation of the total heat demand using the annual duration curve of the heat capacity demand for comparison with the sum of the heat demand specified by the main planner

4. Status of demand assessment at the individual milestones

The demand assessment and appropriate system selection (demand assessment) is an iterative process. In the QM for Biomass DH Plants project process, a demand assessment is carried out for the first time at Milestone 2, at the design planning stage. This is then repeated at Milestone 3, when the tender project is ready, and at Milestone 5 after the operational optimisation. At Milestone 4, on the occasion of the acceptance, the demand assessment should at least be checked and the system documentation should be updated.

With each milestone, the level of information increases, but unfortunately the degree of freedom also decreases accordingly. While a change at Milestone 2 often means only a pencil stroke, at Milestone 4 and Milestone 5 the plant is built and a misjudgement is correspondingly expensive.

Table 3 provides an overview of the status of the demand assessment for the individual milestones. The fourth column, "Heat generation", is only the subject of Chapter 6, but is already listed here for the sake of clarity.

Milestone	Heat consumers	Heating network	Heat generation
2 **Design planning**	■ A list of potential heat consumers is available, and at least 70% of potential customers should have signed a declaration of intent. ■ For new buildings, the planning data on heat, heat capacity and temperature requirements are available (with varying degrees of accuracy depending on the progress of the project). ■ The previous fuel consumption data are available from the existing buildings.	■ A site plan with the location of the central heating plant and the marked branch pipes, branch lines and house connections is available. ■ The district heating network is designed according to size in terms of nominal diameters (no precise pipe network/pressure drop calculation yet). ■ The heat distribution losses have been determined in terms of size on the basis of the linear heat density.	■ The necessary heat, heat capacity and temperature demand is known (see column "Heat consumers"). ■ The fuel range and its availability have been clarified. ■ The system selection (type of firing, monovalent/bivalent, number of boilers) has been made. ■ The power allocation to the boilers has been made. ■ The mode of operation in summer and winter is fixed.
3 **Tender project**	■ The list of heat consumers for the first expansion stage and the final expansion has been determined. ■ For new buildings, the latest planning data on heat, heat capacity and temperature requirements are available. ■ For existing buildings, the previous fuel consumption data have been checked and the temperature demand is reliably available (if possible based on measurements).	■ The location of the central heating plant and the route of the main, branch and house connection pipes have been definitively determined. ■ The final design of the district heating network in terms of nominal sizes and pressure drops is complete. ■ The heat distribution losses have been calculated on the basis of the definitive network design.	■ The fuel range is fixed and a corresponding fuel supply contract is in place. ■ The standard circuit is specified or an equivalent description with principle scheme, functional description, measurement concept, etc. is available. ■ The final principle scheme with registered outputs, temperatures and flow rates is available
4 **Acceptance**	■ The list of heat consumers has been updated.	■ Changes due to the implementation planning have been updated in the installation documentation.	■ Changes due to the implementation planning have been updated in the installation documentation.
5 **Operation optimisation**	■ The operational optimisation has been completed. ■ The list of heat consumers actually connected in the first year of operation has been compiled. ■ The actual heat consumption, necessary peak power and temperature demand of the heat consumers according to the list are known. ■ A comparison of the actual remaining expansion potential and possible further heat consumers (with intention to connect) has been made. ■ If necessary, a concept for the advertising of additional heat consumers has been created.	■ The operational optimisation is completed ■ Changes made in the course of the operational optimisation have been updated in the system documentation. ■ The actual heat losses of the district heating network in the first year of operation are known.	■ The operational optimisation has been completed. ■ Changes made in the course of the operational optimisation have been updated in the system documentation. ■ The actual utilisation of the boilers is known (full load operating hours).

Table 3: Overview of the status of the demand assessment at the individual milestones

5. EXCEL tool «Demand assessment and appropriate system selection»

In order to simplify the calculation of the key figures and characteristic curves required according to the Q-Guidelines [1], the EXCEL tool "Demand assessment and appropriate system selection" (short form: “Demand assessment”) was developed. The demand assessment tool is available in German, French, Italian and English (language selection is possible at the bottom of the first EXCEL sheet in the tool - see preface on page 3). The basic idea is to compare the data determined by the main planner for the individual heat consumers and the overall system with the help of the annual duration curve at the location of the system.

Important

The EXCEL tool "Demand assessment" is an aid

- for the main planner, to determine the load characteristic of the entire system from the heat capacity demand of the individual heat consumers, as required in the Q-Guidelines [1];
- for the main planner to determine the annual duration curve of the heat capacity demand from the load characteristic, the climate data and the comfort requirements for space heating;
- for the main planner to determine the production share of the biomass boiler;
- to check the plausibility of the design data supplied by the main planner.

The EXCEL tool "Demand assessment" simplifies the plausibility check of the design data supplied by the main planner because the key figures and characteristic curves required by QM for Biomass DH Plants are calculated automatically. Although the table is not a planning tool for determining the heat capacity demand and the heat demand of the individual heat consumers, the EXCEL tool can be used as a planning tool for determining the heat capacity demand of the overall system (load characteristic) and the design of the biomass boiler in a bivalent system.

The calculation of the main planner always applies to the final design of the system.

Box 4

5.1 How is the load characteristic determined?

5.1.1 Heat capacity demand for space heating in new buildings

The load characteristic results analogously from the calculation according to EN 12831 [8] with 0 heat capacity at room temperature to standard heat capacity at standard outdoor temperature. This load characteristic is shifted according to Figure 5 in two steps:

1. Parallel shift by the heat gains to the left. This results in the new load characteristic with 0 heat capacity at the heating limit and standard heat capacity at

	standard outdoor temperature
-	room temperature
+	heating limit
=	shifted outdoor temperature

   This step takes into account that the standard heat capacity demand for space heating, calculated according to EN 12831 [8] does not take into account heat gains due to solar radiation, people, electrical appliances, etc. In the plausibility check with the EXCEL tool "Demand assessment", step 1 is carried out automatically for all heat consumers together.

2. Furthermore, it must be taken into account that in the real system, part of the heat capacity demand for space heating is often non-weather-dependent. A shift at the heating limit according to Figure 5 is usually sufficient. Calculations contain sufficient reserves, and often also largely non-weather-dependent compo-

nents are taken into account (e.g. distribution losses), so that a parallel shift is unnecessary. In the plausibility check with the EXCEL tool "Demand assessment", step 2 is carried out solely at the heating limit for all heat consumers together.

Experience in Switzerland has shown that with this method - especially when applied to an entire heating network - sufficient safety margins remain, even when no additional heating capacities are taken into account to compensate for the effects of intermittent heating.

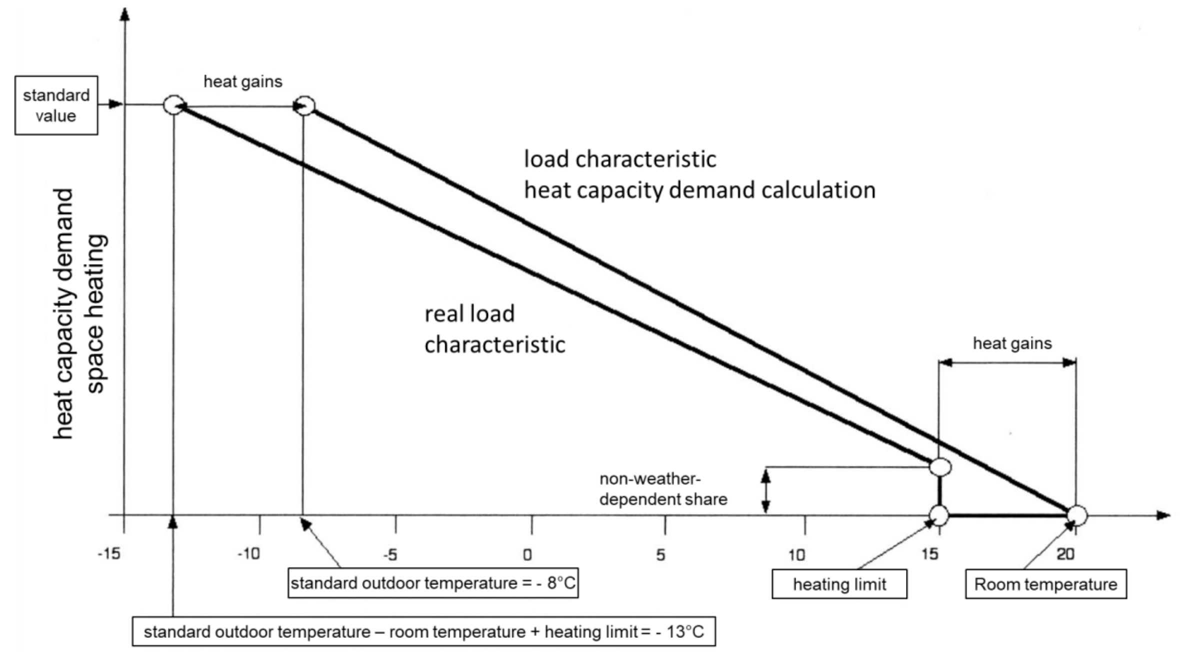


Figure 5: Calculation of the real load characteristic from the load characteristic according to the heat capacity demand calculation by shifting it to the left by the heat gains and up by a non-weather-dependent portion.

Location	**Full load operating hours for residential buildings calculated - based on empirical values from Switzerland - with the help of the EXCEL tool "Demand assessment".**	**Full load operating hours for residential buildings as commonly used in the individual countries**
Zurich (CH)	2050 h/a*	2000...2100 h/a*
Davos (CH)	2800 h/a*	2600...3000 h/a*
Locarno-Monti (CH)	1800 h/a*	1700...1900 h/a*
Graz University (AT)	(1900 h/a)**	1800...1875 h/a***
Tamsweg (AT)	(2350 h/a)**	1766...1840 h/a***
Vienna inner city (AT)	(1700 h/a)**	1714...1813 h/a***
Munich-Airport (DE)	(2050 h/a)**	1913 h/a****
Karlsruhe (DE)	(1750 h/a)**	1611 h/a****

* Long-term empirical values from Switzerland. The data are partly prescribed in cantonal energy ordinances.

** The data for Austria and Germany were calculated solely on the basis of the annual duration curve with the EXCEL tool "Demand assessment" based on the Swiss values. These should only be used as comparative data in Germany and Austria.

*** Source: Handbuch für Energieberater.

**** Source: Recknagel/Sprenger/Hönmann, Taschenbuch für Heizung und Klimatechnik 90/91.

This table does not take into account changes resulting from the change of the reference years 1993-2002 to 2002-2011 (cf. Table 19)

Table 6: Full load operating hours for existing residential buildings (space heating without domestic hot water). These number of full load operating hours must not be applied to new buildings and very well thermally insulated existing buildings with lower heating limits than 15°C.

5.1.2 Heat capacity demand for space heating in existing buildings

The "cold side" of the load characteristic is obtained by dividing the previous heat consumption by the full load operating hours. The full load operating hours are to be determined in such a way that it represents the heat capacity at

  standard outdoor temperature
\- room temperature
\+ heating limit
= shifted outdoor temperature

(analogous to the new buildings in Figure 5).

The full load operating hours for residential buildings without additional heating capacity to compensate for the effects of intermittent heating in Table 6 were calculated - based on empirical values from Switzerland - with the help of the EXCEL tool "Demand assessment" with the following boundary conditions:
- room temperature = 20°C
- lowest outdoor temperature = lowest daily average 2002-2011 for the selected climate station
- heating limit = 15°C
- non-weather-dependent share of heat capacity demand = 5%

FAQ 1 (chapter 6) describes how to determine the full load operating hours of a specific climate station for given boundary conditions. For this purpose, it must be specified by how much larger or smaller the heat demand H1 (right bar "space heating" in Figure 15) calculated from the maximum heat capacity demand with the help of the annual duration curve compared to the heat demand H2, from which the full load operating hours are calculated (left bar "space heating" in Figure 15). This is expressed by the reserve factor, which is defined as follows:

Reserve factor = H1 / H2

With the previously mentioned boundary conditions, for all numbers of full load operating hours in Table 6 the same reserve factor of 1.05 results. In relation to the EXCEL tool, this means that in Figure 15 the right bar "space heating" becomes 5% higher than the left bar. If one or two boundary conditions are changed, the reserve factor of 1.05 changes as follows:

- room temperature = 22°C (or lowest outdoor temperature 2 K lower)	→ Reserve factor only	0.99
- heating limit = 13°C	→ Reserve factor only	0.83
- room temperature = 18°C and heating limit = 13°C	→ Reserve factor only	0.88
- non-weather-dependent share of heat capacity demand = 0%.	→ Reserve factor only	0.93
- room temperature = 18°C (or lowest outdoor temperature 2 K higher)	→ Reserve factor increases to	1.11
- heating limit = 17°C	→ Reserve factor increases to	1.28
- room temperature = 22°C and heating limit = 17°C	→ Reserve factor increases to	1.21
- non-weather-dependent share of heat capacity demand = 10%.	→ Reserve factor increases to	1.16

When changing the room temperature, the heating limit should always be adjusted as well, because the heat gain usually remains the same (example: 20/15°C changed to 18/13°C or 22/17°C). A sensitive reduction of the reserve factor results above all from a lower heating limit or from a smaller, non-weather-dependent share of the heat capacity demand for room heating. This should be taken into account for individual heat consumers. In the case of heating networks in existing settlements, one is usually on the "safe side", as these usually have heating limits of 15...17°C and the non-weather-dependent share of the heat capacity for space heating is, according to experience, 5...10% (independent of the heat capacity demand for domestic hot water, which is also independent of the weather, and the heat distribution losses in the district heating network).

5.1.3 Heat capacity demand for space heating in systems with a metrological determined load characteristic

For residential buildings, the load characteristic of the 24-h average values can be used with a moderate safety margin at the outdoor temperature shifted by the heat gains, which is the same as for the new buildings and for the existing buildings according to Figure 5 for the existing buildings:

  standard outdoor temperature
- room temperature
+ heating limit

= shifted outdoor temperature

For difficult systems, a measured peak load characteristic can be used if this appears necessary (possibly with a safety margin).

5.1.4 Heat capacity demand for domestic hot water preparation

For storage water heaters with "boiler priority", the average values according to Table 7 can be used in the calculation. These values correspond approximately to a number of full load operating hours of 4000...6000 h/a.

In the case of small-sized water heaters and water heating using instantaneous water heaters, peak values should be used, which are then reduced again by a simultaneity factor for the overall system. Special cases, such as large-scale consumption in a gymnasium during a sporting event, should not be overestimated - a sporting event is not the norm and does not necessarily take place at the lowest outdoor temperature.

Use case	**Domestic hot water heat capacity demand for storage water heaters with "boiler priority" per person**	**Domestic hot water heat capacity demand for storage water heaters with "boiler priority" per energy reference area**
Detached house	250 W/person	5 W/m^2 (corresponds to 50 m^2 /person)
Apartment house	200 W/person	8 W/m^2 (corresponds to 25 m^2 /person)

Table 7: Domestic hot water heat capacity demand for storage water heaters with "boiler priority" (empirical values from Switzerland)

5.2 Weighted load characteristic and annual duration curve of the required heat capacity

The load characteristic can be used to determine the heat capacity required at a specific outdoor temperature. This can be used to design the heat capacity of the biomass boiler in a monovalent single-boiler system or the total heat capacity of the heat generators in a multi-boiler system. However, this load characteristic is unsuitable for

- the distribution of boiler outputs in a multi-boiler system,
- the calculation of the annual duration curve of the required heat capacity,
- the calculation of the total heat demand of the system.

For this purpose, in addition to the load characteristic discussed so far (shown in Figure 14 as solid line) in addition a **weighted load characteristic** (shown in Figure 14 as dashed line) is calculated. The formulas used are summarised in Table 9.

The EXCEL calculations of the overall system assume that all heat consumers have the same room temperature and the same heating limit. This is not always the case: flats for the elderly, hospitals, etc. usually require a higher room temperature than residential buildings, whereas sports halls require a lower one. This can be taken into account as follows:

■ The room temperature of the largest consumer group, for example 20°C, is selected as the room temperature. Without correction of the load characteristic, the calculated annual heat demand would be too low for hospitals, for example, or too high for sports halls. This can be corrected with the correction factor F1 "Heat demand of the heat consumer".

Buildings that are not fully heated throughout the winter, e.g. schools with Christmas, winter and spring holidays (in Switzerland 3...5 weeks during the heating period), have a lower annual heat demand in relation to their required heat capacity than residential buildings (i.e. smaller number of full load operating hours). A correction is also possible here:

■ With a factor F1 < 1, a limited heating operation can be taken into account for space heating.

A heating-up peak for space heating affects the power demand of the heat generator. However, it has no (or only very little) influence on the annual heat demand for space heating.

■ The factor F2 "heating-up peak" is only taken into account in the "real" load characteristic, whereas in the weighted load characteristic the influence of the heating-up peak is neglected.

Simultaneity factors for the entire system can be entered separately for space heating (F3), domestic hot water (F4) and process heat (F5). However, only real "non-simultaneities" should be taken into account (e.g. process heat from systems that are not in operation at the same time, hot water in a winter spa).

■ The simultaneity factors F3, F4 and F5 are only taken into account in the "real" load characteristic, whereas they are neglected in the weighted load characteristic. Since a plausibility check is deliberately omitted for domestic hot water and process heat, the heat demand data of the main planner are used here for the weighted load characteristic.

Correction factors

Correction factors should only be used in clearly justifiable cases. There are fundamental dependencies between the individual correction factors in Table 9:

- A correction factor heating-up peak F2 is only justified if there is limited operation in this building (correction factor F1 < 1); buildings without limited operation may have no heating-up peak at all (except for commissioning at the beginning of the heating period or after malfunctions).
- If, conversely, there is a restricted operation (correction factor F1 < 1), then a heating-up peak F2 also results, unless the heating phase can be spread over a sufficiently long time
- A simultaneity factor F3 is only justified if heating-up peaks F2 of individual buildings do not occur at the same time, or if buildings are not heated at the same time (e.g. in the case of a church and a multi-purpose hall, each with a correction factor F1 < 1, which are not used simultaneously).
- If these dependencies are consistently taken into account, the weighted load characteristic should not become larger than the "real" load characteristic.

Important note: When using correction factors, the effects should always be well considered using Table 9 as help

Box 8

Type of consumption	Correction factors	Calculation of the load characteristic of the entire system (in Figure 14 solid line)	Calculation of the weighted load characteristic used to calculate the annual duration curve of the required heat capacity (in Figure 14 dashed line)
Space heating	$F1_i$ = Correction factor heat demand of heat consumer i * $F2_i$ = Correction factor heating-up peak of the heat consumer i F3 = Simultaneity factor space heating	$F3\sum F2_i \cdot \dot{Q}_i$	$\sum F1_i \cdot \dot{Q}_i$
Domestic hot water	F4 = Simultaneity factor domestic hot water	$F4\sum \dot{Q}_i$	$\frac{Q_a[kWh]}{8760h}$
Process heat	F5 = Simultaneity factor process heat	$F5\sum \dot{Q}_i$	$\frac{Q_a[kWh]}{8760h}$
District heating network		Heat distribution losses	Heat distribution losses

$\dot{Q}_i$ = Heat capacity demand of the heat consumer i [kW].

Q_a = Total annual heat demand [kWh]

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* Since the heat demand of the individual heat consumer cannot be corrected directly, the heat capacity demand for space heating of each individual heat consumer in the weighted load characteristic is multiplied by this correction factor and thus the annual duration curve is corrected.

Table 9: Calculation of the load characteristics

5.3 EXCEL sheet «Consumers»

5.3.1 Inputs main planner

General

- Number
- Designation
- Heat demand assessment based on (e.g. oil consumption, SIA standard, measurement, etc.)
- Energy reference area [m^2]

The energy reference area is the sum of all above-ground and below-ground floor areas of a building where heating or air conditioning is necessary. The energy reference area is calculated gross, i.e. from the external dimensions including limiting walls and parapets. For deviating room temperatures, high rooms, etc., there are country-specific correction factors. As an approximation, the heated gross floor area can be taken as the energy reference area

- Max. supply temperature [°C]
- Max. return temperature [°C]

Space heating

■ Annual heat demand for space heating [MWh/a]

■ Max. heat capacity demand for space heating [kW]
– New building: standard heat capacity demand at standard outdoor temperature (here: lowest outdoor temperature)
– Existing building: By means of the full load operating hours according to Table 6 determined value at the "shifted outdoor temperature".
– Measurement: Measured value at the "shifted outdoor temperature".

■ Correction factor space heat demand [-]
Since the heat demand of the individual heat consumer cannot be corrected directly, the heat capacity demand for space heating of each individual heat consumer in the weighted load characteristic is multiplied by this correction factor and thus the annual duration curve is corrected.

■ Correction factor heating-up peak [-]

Domestic hot water

■ Annual heat demand for domestic hot water [MWh/a]
The annual heat demand for 365 days is to be entered, the winter heat demand is thus calculated as follows:
Winter heat demand = annual heat demand x heating days / 365 days

■ Max. heat capacity demand for domestic hot water [kW]
– Storage water heaters with "boiler priority": Average values according to Table 7
– Small dimensioned water heater and domestic hot water preparation by means of instantaneous water heater: peak values

Process heat

■ Annual heat demand for process heat [MWh/a]
The annual heat demand for 365 days is to be entered, the winter heat demand is thus calculated as follows:
Winter heat demand = annual heat demand x heating days / 365 days

■ Max. heat capacity demand for process heat [kW]

5.3.2 Calculated key figures

Space heating

■ Full load operating hours for space heating [h/a]
Annual heat demand for space heating [kWh/a] / Max. heat capacity demand for space heating [kW]
(correction factors not taken into account)

■ Specific heat demand [kWh/(m²a)]
Annual heat demand for space heating [kWh/a] / Energy reference area [m²]
(correction factors not taken into account)

■ Specific heat capacity demand for space heating for the entire system [W/m²]
Max. heat capacity demand for space heating [W] / Energy reference area [m²]
(correction factors not taken into account)

Domestic hot water

■ Full load operating hours for domestic hot water [h/a]
Annual heat demand for domestic hot water [kWh/a] / Max. heat capacity demand for domestic hot water [kW]

■ Specific energy demand for domestic hot water [kWh/(m²a)]
Annual heat demand for domestic hot water [kWh/a] / Energy reference area [m²]

Process heat

■ Full load operating hours for process heat [h/a]
Annual heat demand for process heat [kWh/a] / Max. heat capacity demand for process heat [kW].

5.4 EXCEL sheet «General information»

5.4.1 Inputs Main Planner

General

■ Country
A catalogue is given.

■ Climate station
A catalogue is given based on the country chosen.

■ Lowest outdoor temperature [°C]

Here the lowest daily average value from 2002 to 2011 of the chosen climate station is given (compilation of some typical climate stations in Table 10). This value is calculated as follows:

$$t_{min,2002-2011} = \frac{t_{min,2002} + ... + t_{min,2011}}{10}$$

$t_{min,2002-2011}$ = lowest daily average value 2002-2011

$t_{min,2002}$ = lowest daily average value 2002

etc.

Climate station	Country	Lowest daily average 2002-2011 [°C]
Bilje	SI	-3
Brnik Letalisce	SI	-11
Davos	CH	-14
Frankfurt Airport	EN	-7
Graz	AT	-9
Hohenpeissenberg	EN	-11
Bald knoll	EN	-12
Karlsruhe	EN	-7
Locarno	CH	-2
Munich Airport	EN	-11
Nova Vas (Bloke)	SI	-13
Tamsweg	AT	-16
Trier Petrisberg	EN	-8
Vienna inner city	AT	-7
Zurich SMA	CH	-7

Table 10: Lowest daily average value of some typical climate stations

■ Room temperature [°C]

■ Heating limit [°C]
The heating limit is the outdoor temperature (daily average) up to which no heating is necessary. In the lowlands, this is around 15°C for normal buildings. Buildings with greater passive energy use are lower, buildings with poor thermal insulation are higher.

■ Max. main supply temperature [°C]

■ Summer operation yes/no?

Space heating

■ Non-weather-dependent share of heat capacity demand for space heating [%]
The share of space heat demand that is not dependent on weather conditions is practically 0% for single-family houses with good thermal insulation. Apartment buildings with extensive heat distribution have a share of about 5...10%. Older residential buildings with poorly insulated heat distribution and often undefined additional consumers (ventilation units, etc.) can be much higher. Heating networks always have a noticeable, non-weather-dependent share of the heat capacity demand for space heating (independent of the heat capacity demand for domestic hot water and process heat, which is also independent of weather conditions, as well as the heat distribution losses).

■ Simultaneity factor space heating [-]

Domestic hot water

■ Simultaneity factor domestic hot water [-]

Process heat

■ Simultaneity factor process heat [-]

District heating network

■ Annual heat losses of the district heating network [MWh/a]
With "Summer operation yes" this is the value over 365 days, with "Summer operation no" it is the value over all heating days.

■ Heat distribution losses [kW]

5.4.2 Calculated total values

General

■ Total energy reference area [m^2]

Space heating

■ Total heat demand for space heating [MWh/a]

■ Max. total heat capacity demand for space heating [kW]
(Correction factors and simultaneity factor not taken into account)

Domestic hot water

■ Total annual heat demand for domestic hot water [MWh/a]

■ Max. total heat capacity demand for domestic hot water [kW]
(simultaneity factor not taken into account)

Process heat

■ Total annual process heat demand [MWh/a]

■ Max. total thermal capacity demand for process heat [kW]
(simultaneity factor not taken into account)

Total heat consumers

■ Total heat demand [MWh/a]

■ Total heat capacity demand [kW]
(Correction factors and simultaneity factors not taken into account)

5.4.3 Calculated key figures

General

■ Max. supply temperature heat consumer [°C]
Highest occurring heat consumer

■ Max. main return temperature [°C]
Highest average value main return

Space heating

■ Full load operating hours for space heating for the entire system [h/a].
Total heat demand for space heating [kWh/a] / max. total heat capacity demand for space heating [kW].
(Correction factors and simultaneity factor not taken into account)

■ Specific heat demand for the entire system [kWh/(m^2a)].
Total heat demand for space heating [kWh/a] / energy reference area [m^2]
(Correction factors and simultaneity factor not taken into account)

■ Specific thermal capacity demand for the entire system [W/m^2]
Max. total heat capacity demand for space heating [W] / energy reference area [m^2]
(Correction factors and simultaneity factor not taken into account)

Domestic hot water

■ Full load operating hours of domestic hot water for the entire system [h/a].
Total heat demand for domestic hot water [kWh/a] / max. total heat capacity demand for domestic hot water [kW] (simultaneity factor not taken into account)

■ Specific heat demand for domestic hot water for the entire system [kWh/m^2a].
Total heat demand for domestic hot water [kWh/a] / total energy reference area [m^2]
(simultaneity factor not taken into account)

Process heat

■ Full load operating hours of process heat for the entire plant [h/a].
Total heat demand for process heat [kWh/a] / max. total heat capacity demand for process heat [kW]. (simultaneity factor not taken into account)

5.5 EXCEL sheet «Heating plant»

In the EXCEL sheet "Heating plant", the main planner can define the system selection. Based on the selected standard hydraulic scheme and the entries made, these are compared with the most important target and default values of QM Biomass DH Plants (QM).

5.5.1 Inputs main planner

Depending on the choice of the standard hydraulic scheme, the corresponding information must be entered or the system choice must be defined. If too many or too few cells are filled in, there are corresponding warnings.

■ Standard hydraulic scheme according to QM
A catalogue as a drop-down menu for the selection of the standard hydraulic scheme is predefined (Table 11).

Abbreviation	Description
WE1	1 biomass boiler without storage tank
WE2	1 biomass boiler with storage tank
WE3	1 biomass boiler + 1 oil/gas boiler without storage tank
WE4	1 biomass boiler + 1 oil/gas boiler with storage tank
WE5	2 biomass boiler without storage tank
WE6	2 biomass boilers with storage tank
WE7	2 biomass boilers + 1 oil/gas boiler without storage tank
WE8	2 biomass boilers + 1 oil/gas boiler with storage tank
n/a	e.g. more than two biomass boilers

Table 11: Standard hydraulic schemes

■ Nominal heat capacity biomass boiler 1 [kW]
Nominal heat capacity of the small biomass boiler with standard hydraulic scheme according to QM. If no standard hydraulic scheme is installed, the boiler with the smallest nominal heat capacity or, in the case of multiple boiler systems with identical capacities, the nominal heat capacity of one boiler must be specified.

■ Nominal heat capacity biomass boiler 2 [kW]
Nominal heat capacity of the large biomass boiler with standard hydraulic scheme according to QM. If no standard hydraulic scheme is installed, the boiler with the next larger nominal heat capacity or, in the case of multiple boiler systems with identical capacities, the nominal heat capacity of a further boiler must be specified.

■ Total nominal heat capacity of other biomass boilers [kW]
This specification is necessary if no standard hydraulic scheme is selected. The total nominal heat capacity of the remaining boilers not yet specified must be indicated. Example: If four biomass boilers of 100 kW each are installed, then 100 kW must therefore be entered in the line *Nominal heat capacity biomass boiler 1*, 100 kW must also be entered in the line *Nominal heat capacity biomass boiler 2 and* 200 kW (100+100 kW) must therefore be entered in the line *Total* n*ominal heat capacity other biomass boilers* for biomass boilers 3 and 4.

■ Number of boilers installed if there are more than two [-]
This information is necessary if no standard hydraulic scheme is selected. The number of installed biomass boilers must be entered. If four biomass boilers are installed, the number 4 must be entered.

■ Total nominal heat capacity biomass boilers [kW]
Is a calculated value and indicates the total installed nominal heat capacity of the biomass boilers.

■ Total nominal heat capacity bivalent boiler(s) (e.g. oil, gas) [kW]
The total installed nominal heat capacity of bivalent boilers (e.g. oil, gas) must be stated.

■ Thermal storage capacity [m³]
The total installed thermal storage capacity must be specified.

■ Temperature difference between supply and return at the storage [K].
The expected temperature difference over the storage tank must be specified (e.g. boiler supply temperature - main return temperature) at design temperature. If the supply and return temperatures are entered in the EXCEL sheet "Consumers" and a maximum main supply temperature is entered in the EXCEL sheet "General

Information", a maximum possible value is suggested. The value to be entered must not exceed the default value.

■ Minimum average daily heating load with low load operation [%].
According to table 20 of the Q-Guidelines, the corresponding minimum average daily heating load is to be entered based on the type of firing (underfeed or moving grate firing), automatic ignition or ember bed maintenance, with or without storage tank and the fuel water content. Table 20 from the Q-Guidelines is listed in the EXCEL sheet "Heating plant" below.

■ Maximum average daily heating load (value from 70% to 100%) [%]
Based on the type of firing, with or without storage, the fuel as well as the fuel water content, a maximum average daily heating load must be specified. As a rule, the value is between 70% and 100%. For example, a pellet furnace cannot run constantly at full load over 24 hours because of the cleaning of the grate - accordingly, the maximum average daily biomass boiler output must be less than 100%.

■ Max. average daily base load capacity [kW]
How exactly the values for the minimum average daily heating load with low load operation and the maximum average daily heating load are determined is shown in FAQ 7 in chapter 6.
How the max. average daily base load capacity is determined and how this is shown in the diagram "Annual duration curve of the heat capacity demand" is shown in FAQ 8 in chapter 6.

5.5.2 Calculated key figures

The most important key figures are calculated from the information on the consumers, the system and the heating plant and are compared with the target and default values of QM. If the calculated key values are outside the target and default values or range of QM, the key value is marked red. If the characteristic value corresponds to the specifications, the characteristic value appears in green.

■ Full load operating hours of the biomass boiler(s) [h/a].
Result: Total heat demand (proportion covered with biomass) [kWh/a] / Total nominal heat capacity biomass boilers [kW].
Comparison: The comparison value is based on the selected default hydraulic scheme and the corresponding minimum target value in Table 19 of the Q-Guidelines. If no default hydraulic scheme is selected, no comparison value is given.

■ Full load operating hours bivalent boiler(s) [h/a]
Result: Total heat demand (proportion covered with oil/gas) [kWh/a] / Total nominal heat capacity bivalent boiler(s)
Comparison: No comparison value is defined.

■ Annual heat production with biomass [%]
Result: Share of heat demand covered with biomass (area with green marking in Figure 16 corresponds to the annual amount of energy produced with biomass).
Comparison: The comparison value is based on the selected standard hydraulic scheme and the corresponding minimum target value in Table 19 of the Q-Guidelines. If no standard hydraulic scheme is selected, a monovalent system is assumed (100%).

■ Thermal storage capacity [m^3]
Result: The thermal storage capacity corresponds to the input value.
Comparison: For single boiler systems, the thermal storage capacity corresponds to 1 operating hour at the nominal heat capacity of the biomass boiler at the specified temperature difference.
For multiple boiler systems, the thermal storage capacity corresponds to 1 operating hour at 2/3 of the nominal heat capacity of the installed biomass boilers at the specified temperature difference.
For the calculation, the following values are assumed for water at 60°C:
Density = 983.18 kg/m^3; specific heat capacity = 4.183 kJ/(kg K)

■ Low load condition [kW]
Result: Nominal heat capacity of biomass boiler 1 [kW] * Maximum average daily heating load for low-load operation

Comparison: For year-round operation, the comparative value corresponds to the non-weather-dependent heat capacity at outdoor temperatures above the heating limit according to Figure 16. In the case of seasonal operation (heating season), the comparative value corresponds to the non-weather-dependent heat capacity at the heating limit incl. any weather-dependent components according to Figure 16.

■ Design of biomass boilers [%]
Result: Biomass boiler capacity [kW] * 100% / maximum heat capacity demand [kW] according to

Figure 12
The maximum heat capacity demand corresponds to either the maximum value of the load characteristic of the entire system (■) or the maximum value of the weighted load characteristic (◆) and depends on the selected standard hydraulic scheme.
Comparison: The comparison value is based on the selected standard hydraulic scheme and the corresponding target values in Table 19 of the Q-Guidelines. If no standard hydraulic scheme is selected, a monovalent system is assumed (range 100% to 110%).

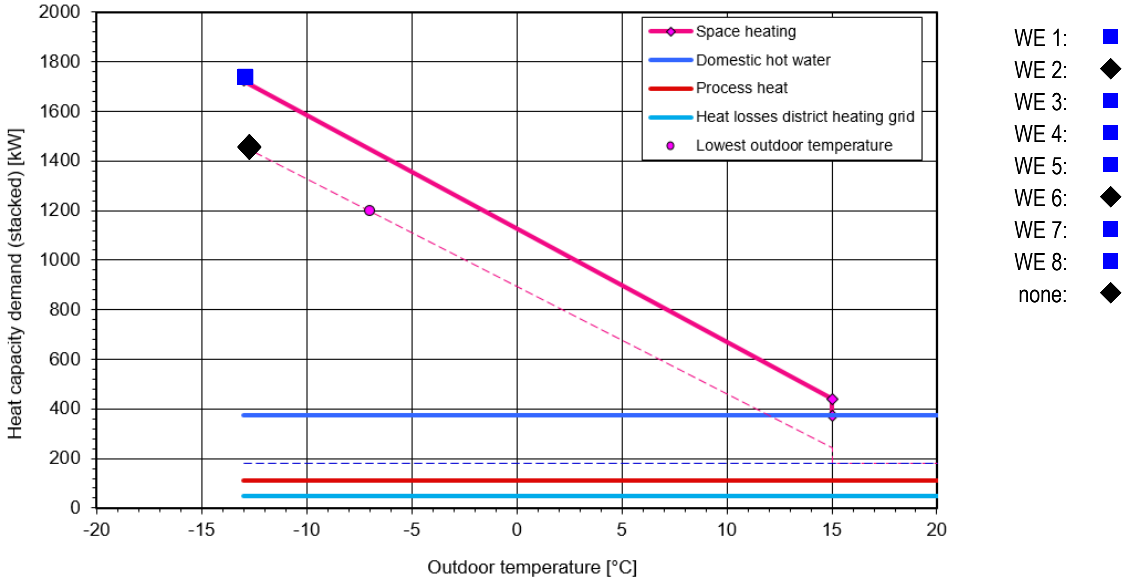

Figure 12: Marking of the maximum heat capacity demand to be taken into account for the design of the biomass boiler on the basis of the load characteristics.

■ Design of bivalent boiler [kW]
Result: The result corresponds to the input value.
Comparison: The comparison value is based on the selected standard hydraulic scheme and the corresponding target value in Table 19 of the Q-Guidelines. If no standard hydraulic scheme is selected, a monovalent system is assumed (no comparison value).

■ Comparison of performance data with energy data [%]
Result: Heat demand for space heating from performance and climate data [MWh/a] * 100% / Heat demand for space heating from energy demand data [MWh/a].
This corresponds to the percentage ratio of the blue bar to the green bar of the column space heating in Figure 15. The blue bar is the calculated heat demand for space heating from the performance data of the individual consumers and the selected climate station. The green bar is the sum of the energy demand data of the individual consumers.
Comparison: With a standard hydraulic scheme, the validity range for monovalent systems is 100% to 110%. For bivalent systems, the validity range is 95% to 105%. If no standard hydraulic scheme is selected, the validity range is also 95% to 105%.

5.6 EXCEL sheet «Images»

The information of the main planner is entered into the EXCEL sheets "Consumers", General information” and "Heating plant". The tool creates a graphical evaluation from this in the EXCEL sheet "Images", which can be used as a basis for the plausibility check by the Q-manager. The graphs are discussed below.

5.6.1 Load characteristics (Figure 14)

All entered performance data are displayed as stacked load characteristics. From bottom to top these are:
- Heat distribution losses, district heating network
- Process heat
- Domestic hot water
- Space heating divided into a non-weather-dependent part and a weather-dependent part

The load characteristic of the entire system is shown as a solid line. The weighted load characteristic, which is used to calculate the annual duration curve of the required heat capacity, is shown as a dashed line.

In the case of the load characteristic for space heating, it should be noted that the correction according to Figure 5 is made automatically for all heat consumers together:
- Shift by the heat gains to the left
- Unilateral upward shift of the non-weather-dependent share at the heating limit

The top load characteristic shows the load behaviour of the entire system as a function of the real outdoor temperature (daily average values). The points mean (from right to left):
- Room temperature
- Heating limit (two points result if a non-weather-dependent part is used)
- Design point of new buildings taking into account the heat gains (drawn at the end of the load characteristic (solid line) because it is represented up to this point).
- Lowest daily average value of the outdoor temperature as the average value of the last 10 years for the selected climate station (drawn on the dashed weighted load characteristic, because this is the lowest outdoor temperature that is taken into account in the calculation of the annual duration curve).

The load characteristics for space heating, domestic hot water and process heat, which are shown as solid lines, can be influenced separately by simultaneity factors, and the load characteristic for space heating also takes into account the correction factor “heating-up peak”. An overview is provided in Table 9.

From the intersections with the heat output, it can be deducted up to which outdoor temperature (daily average) a certain heat production unit is sufficient to cover the demand. (see also FAQ 5 in chapter 6.)

5.6.2 Annual duration curves of the outdoor temperature (Figure 17)

In the EXCEL tool "Demand assessment", 3 annual duration curves are programmed for each of the retrievable climate stations:
- 10-year daily maximum (2002–2011)
- 10- year daily average (2002–2011)
- 10- year daily minimum (2002–2011)

Only the 10-year daily average is used for the evaluation. The other two annual duration curves are shown for information only (for some stations these values are not given at all).

It should be noted that the 10 winters mentioned were relatively "warm". The exceptionally cold January 1985, for example, is not included in these data!

5.6.3 Annual duration curve of the required heat capacity (Figure 16)

From the load characteristic and the annual duration curve of the 10-year daily average values (Figure 17), the programme now calculates the cumulative frequency of the required heat capacity. It must be noted here that the dashed weighted load characteristic according to Figure 14 is used, which was calculated according to Table 9. This means:

- Simultaneity factors are not used
- Only the correction factor “heat demand” is taken into account
- The load characteristics for domestic hot water and process heat are calculated by dividing the annual heat demand by 8760 h, so a plausibility check is deliberately omitted here

The programme now shows individual areas as follows:

■ The annual amount of energy produced with the biomass boiler is framed in green.

■ Blue framed the annual amount of energy produced with the base load source

■ The parts that are not framed add up to the annual amount of energy generated by fossil fuels.

The production shares (in [MWh] and [%]) are shown in the graphs of Figure 18.

Note: Since the tool works with outdoor temperature classes (points on the annual duration curve), the values entered are rounded to the nearest value. The actual calculation is done with the values shown in the diagram, which are also indicated in the " Effectively" column. The values entered may have to be adjusted until the effective values come closest to the desired values.

5.6.4 Comparison of total heat demand (Figure 15)

It is now particularly interesting to compare the total heat demand specified by the main planner with the total heat demand calculated by the programme using the annual duration curve:
- Left bar: Total heat demand according to main planner
- Middle bar: Total heat demand from winter performance data
- Right bar: Total heat demand from summer performance data (always omitted for space heating, and for the others if "Summer operation no" has been selected).

Of course, this evaluation cannot be used without discussion. Each group must be looked at separately and compared with the real conditions.

Space heating: Actually, both bars should be about the same size. However, since heat demand calculations (new buildings) and full load operating hours (existing buildings) contain safety factors, the right bar will usually be somewhat larger. Also, taking into account a realistic part of the heat capacity that is not dependent on weather conditions causes the right bar to increase.

Domestic hot water: Because a plausibility check is deliberately omitted here, the left bar necessarily corresponds to the sum of the middle and right bars. If "Summer operation no" was selected, the right bar is omitted, but the left bar is still higher by the summer share, since for reasons of consistency the main planner always requires the entry of the annual value (the summer share is not generated by the biomass boiler). The distribution between the middle and the right bar depends on the selected climate station, the room temperature and the heating limit.

Process heat: Because a plausibility check is deliberately omitted here, the left bar necessarily corresponds to the sum of the middle and right bars. If "Summer operation no" was selected, the right bar is omitted, but the left bar is still higher by the summer share, since for reasons of consistency the main planner always requires the entry of the annual value (the summer share is not generated by the biomass boiler). The distribution between the middle and the right bar depends on the selected climate station, the room temperature and the heating limit.

District heating network: The main planner must specify the heat distribution losses and the annual heat losses for the district heating network. Here, a plausibility check of the two values, that are to be specified, is possible. The design of the system determines in advance whether the district heating network is in operation in summer or not. Therefore, the annual heat losses for a system without summer operation is smaller than it would be for the same system with summer operation.

5.6.5 Production shares (Figure 18)

- Production shares of the total plant
- Production shares of the biomass boiler
- Production shares of the base load source
- The difference "total plant - (biomass boiler + base load source)" must be generated using fossil fuels

5.6.6 Design information

Thanks to the EXCEL tool, two load characteristics are available for designing the system (Box 13).

The load characteristic of the entire system shown as a solid line is used to design:
- Heat capacity of the biomass boiler(s) for monovalent systems without storage tank
- Heat capacity of the biomass boiler(s) for bivalent systems without storage tank (designed for 60...70%)
- Heat capacity of the biomass boiler(s) for bivalent systems with storage tank (designed for 50...60%)
- Heat capacity demand of the heat consumers

The weighted load characteristic shown in dashed lines and the annual duration curve calculated from it are used to design:
- Heat capacity of the biomass boiler(s) for monovalent systems with storage tank
- Pipe network/pressure drop calculation of the heating network
- Heat demand data for the economic efficiency analysis

See also FAQ 5 in chapter 6 on this topic.

Box 13^

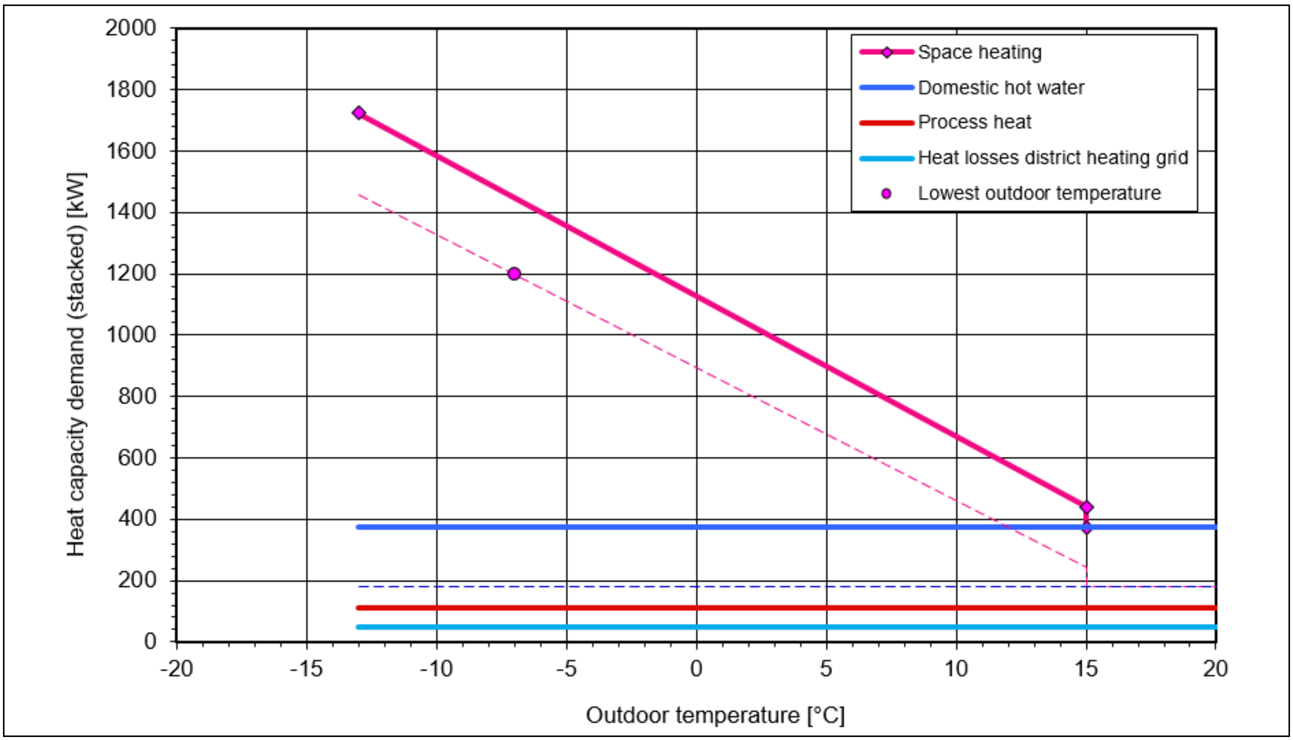

Figure 14: The load characteristic of the entire system is shown as solid lines; the weighted load characteristic for calculating the annual duration curve of the required heat capacity is shown as dashed lines.

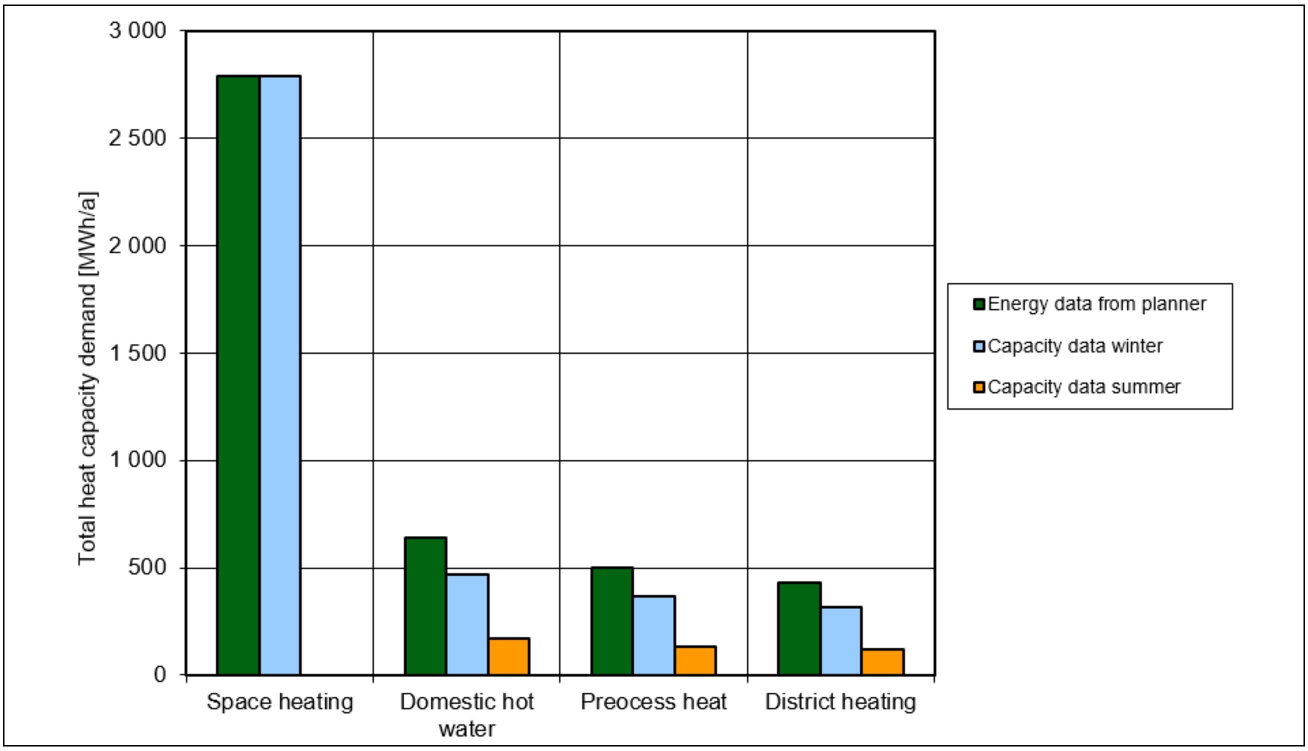

Figure 15: Comparison of total heat demand

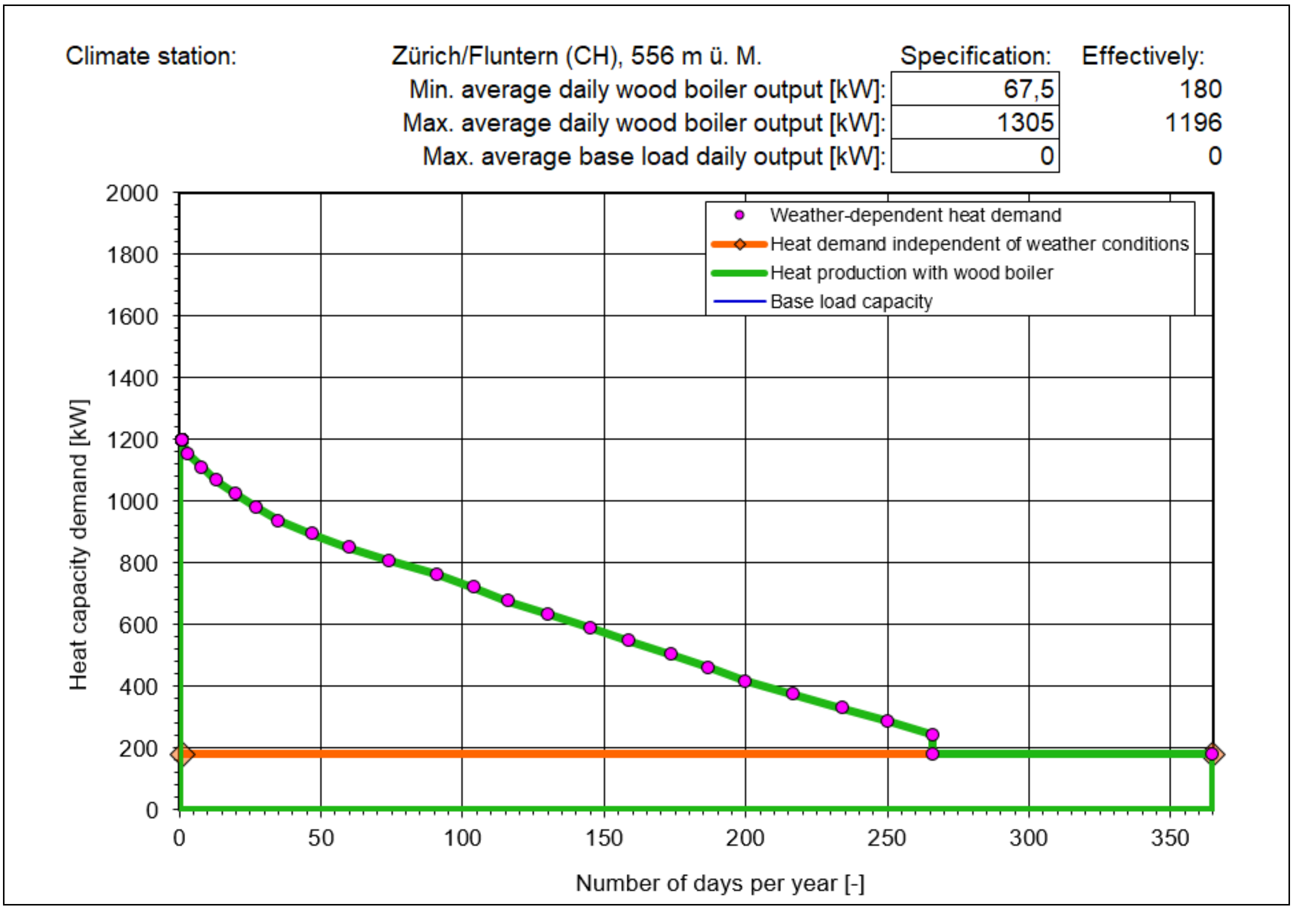

Figure 16: Annual duration curve of the required heat capacity with biomass boiler share (green) and base load share (blue); Note: the heat gains have already been taken into account in the load characteristic.

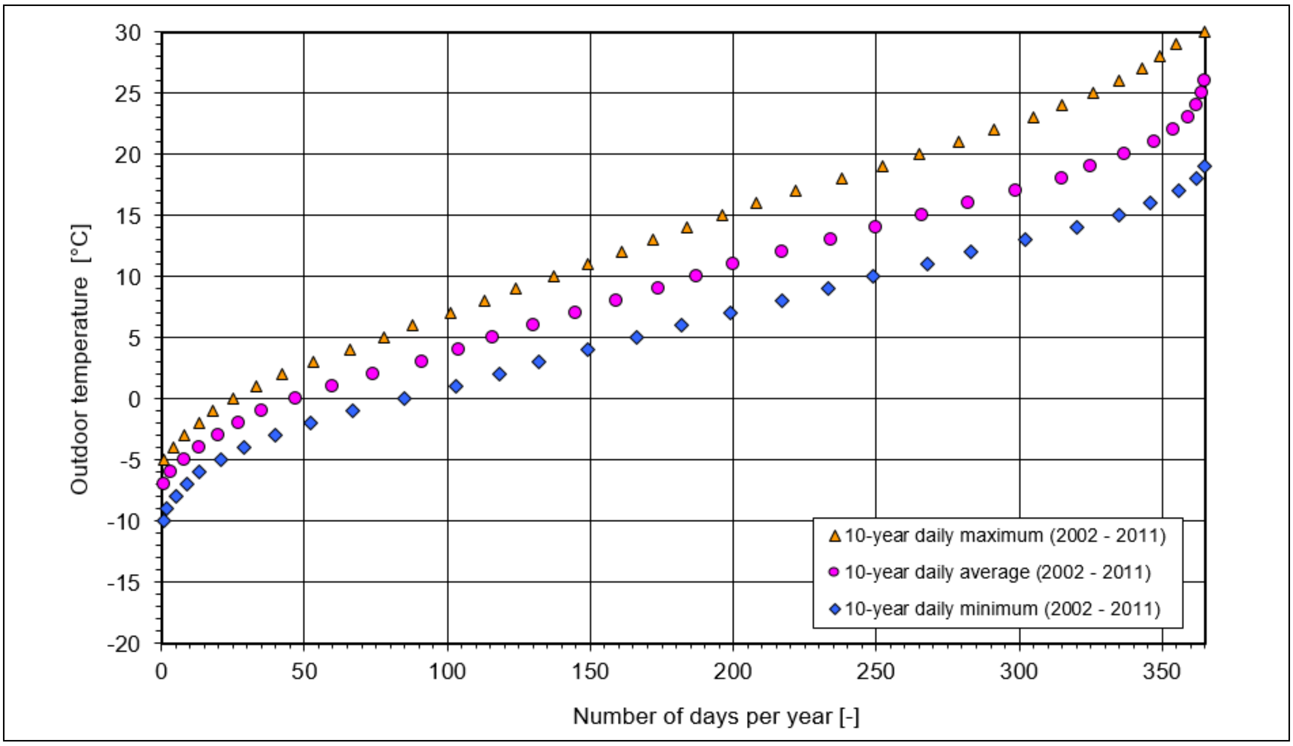

Figure 17: Annual duration curves of outdoor temperature (Zurich/Fluntern)

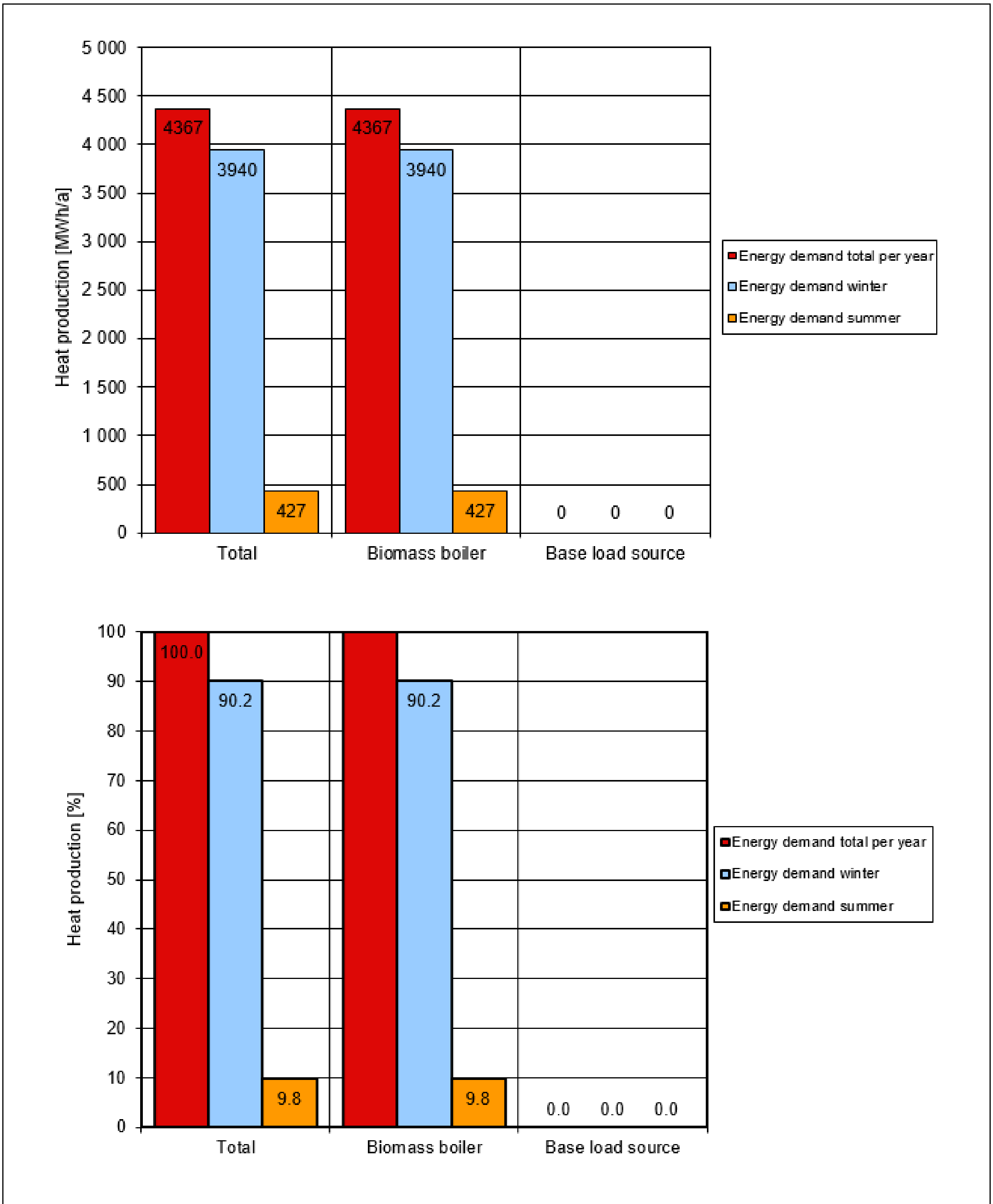

Figure 18: Total heat production and production shares of the biomass boiler and the base load source in [MWh] (top) and in [%] (bottom); the difference "total plant - (biomass boiler + base load source)" must be generated by fossil fuels.

5.7 EXCEL Sheet «Q-plan table»

Adapted to the planning progress, the Excel spreadsheet for the Q-Plan is to be completed and attached to the supplementary document for each milestone. In order to minimise the administrative effort, the Excel spreadsheet for the Q-Plan has now been integrated into the demand assessment as an EXCEL sheet "Q-plan table".

The default currency is "Swiss francs” (CHF) and the default fuel is "wood chips". Colleagues from other countries can change the currency unit to Euros if necessary. The fuel "pellets" is also available for selection. When adjusting the currency, the units are adjusted in the table. When adjusting the fuel, the units and the calculation of the silo size are adjusted.

From the EXCEL sheets "Consumer", "General information" and "Heating plant", the most important planning data are transferred to the column “Plan” and only the following data need to be added:

- Heat demand via the network (default: 100% of total demand; formula entry possible)
- Heat capacity demand via the network (default: 100% of total demand; formula entry possible)
- Length of district heating network
- Filling level of the storage silo
- Gross size of the storage silo
- Energy content per cubic meter for wood chips or per kilogram for pellets
- Investment costs of heat production
- Investment costs of heating network
- Temperature of the main supply pipe
- Temperature of the main return pipe

The following agreements or target values can be predefined for the key figures. These are used for control purposes:

- Full load operating hours of the heat consumers
- Linear heat density / connection density of heating network (default is > 2.0)
- District heating network losses (default is < 10%)
- Heat distribution costs per linear metre
- Specific investment costs of heating network
- Specific investment costs of heat production
- Total full load operating hours of the biomass boiler(s) (default from system selection EXCEL sheet "Heating plant")
- Total full load operating hours of other heat production units
- Storage size: Coverage the full load demand in number of days (+ 30 LCM), (default for wood chips 5 - 7 days; no default for pellets)

For the conclusion of the Q monitoring with milestone MS5, the sheet “Q-plan table” with the latest planning status is to be taken as a basis for comparison. The actual values of the considered operating year are to be filled in the column “Is, MS5”, which allows a comparison with the planning data.

6. Frequently asked questions (FAQ's)

FAQ 1: How do I determine the full load operating hours for a given climate station under given boundary conditions?

In order to determine the full load operating hours for a specific climate station, the boundary conditions for the desired building type must first be selected. In Table 6 the following values, which should roughly correspond to a standard existing residential building, are used as a basis:

- Lowest outdoor temperature — Lowest daily average 2002-2011 (Table 10 or Table 19)
- Room temperature — 20°C
- Heating limit — 15°C
- Non-weather-dependent share — 5%

If the very different country-specific standard outdoor temperatures were taken as the lowest outdoor temperature, this would result in different full load operating hours, for example for Lindau (Germany), Bregenz (Austria) and St. Margrethen (Switzerland), although these locations are only a few kilometres apart and certainly have the same climate. Therefore, the lowest daily average value 2002-2011 was used as a substitute for the lowest outdoor temperature.

The full load operating hours for a particular climate station can now be determined as follows:

1. For a single heat consumer, enter the boundary conditions listed above and set all correction factors to 1.0. Enter a round number as the heat demand, e.g. 100 MWh/a (corresponding to 100%).
2. Change the maximum heat demand until the right bar "space heating" in Figure 13 becomes slightly larger than the left one, e.g. 105 MWh/a (corresponding to 105%), which would correspond to a reserve factor of 1.05.
3. The resulting full load operating hours can be taken as a generally valid value for existing residential buildings in the area of the selected climate station.

The full load operating hours of Table 6 have been calculated and supplemented in Table 19 for some typical climate stations. The reserve factor is 1.05 with the exception of Davos and Kahler Asten, where it is 1.13 to avoid too high values. All values were rounded down to 50.

Climate station	Country	Lowest daily average temperature 2002-2011 [°C]	Full load operating hours [h/a]
Bilje	SI	-3	1750
Brnik Letalisce	SI	-11	2050*
Davos	CH	-14	3000*
Frankfurt Airport	EN	-7	1850
Graz	AT	-9	1950*
Hohenpeissenberg	EN	-11	2350
Bald knoll	EN	-12	2650*
Karlsruhe	EN	-7	1800*
Locarno	CH	-2	1800
Munich Airport	EN	-11	2050
Nova Vas (Bloke)	SI	-13	2150
Tamsweg	AT	-16	2400*
Trier Petrisberg	EN	-8	1950*
Vienna inner city	AT	-7	1750*
Zurich SMA	CH	-7	2150*
* Minor change due to change of reference years 1993-2001 to 2002-2011			

Table 19: Full load operating hours of some typical climate stations

Basically, it's always about the same thing: I want to know for a certain building type in a certain climate area:
- What is the maximum heat capacity demand for a given heat demand? This case is typical for the renovation of the heat generation system in existing buildings (the heat demand is known from the previous fuel consumption).
- What is the heat demand for a given maximum heat capacity demand? This case is typical for new buildings: I know the maximum heat capacity demand from the heat capacity demand calculation according to EN 12831 [8] and would like to determine the heat demand from it.

In the simplest case, a suitable number of full load operating hours is taken for fixed boundary conditions (e.g. from Table 19). However, the problem can also be approached in a more differentiated way for a wide range of boundary conditions by using the EXCEL tool "Demand assessment":
- Given is the heat demand and I find the maximum heat capacity demand for any boundary conditions
- Given is the maximum heat capacity demand and I find the heat demand for any boundary conditions
- I change the boundary conditions and see what happens... (see FAQ 2 and FAQ 3)

FAQ 2: What are the full load operating hours of a highly thermally insulated building?

The full load operating hours according to Table 19 do not apply to highly thermally insulated buildings (e.g. Minergie, KfW 40, lowest energy house). With the help of the EXCEL tool, however, this question can also be answered by entering the typical boundary conditions for a highly thermally insulated building:

- Norm outdoor temperature	Lowest daily average 2002-2011 (example: Zurich -7°C)
- Room temperature	20°C
- Heating limit	12°C (lower heating limit as a result of the good thermal insulation and passive energy use)
- Non-weather-dependent share	0% (non-weather-dependent losses tend to be smaller)

For a highly thermally insulated building in Zurich, the full load operating hours result to 1350 h/a.

FAQ 3: How do I determine the correction factor heat demand F1?

Given: Retirement home with room temperature 2 K higher than the rest of the building stock

Wanted: Correction factor heat demand F1 > 1 (cf. Table 9)

Procedure:

1. Enter the retirement home as a single heat consumer. Set the room temperature and heating limit to the values valid for the retirement home, e.g. 22/17°C. This results in the values for the heat capacity demand and heat demand valid for the retirement home and thus the height H1 of the right bar "space heating" valid for the retirement home in Figure 15.
2. Set room temperature and heating limit according to the rest of the building stock, e.g. 20/15°C. This reduces the heat demand in Figure 15 from H1 to H2.
3. The correction factor must now be selected so that the value H1 is reached again:
   Correction factor heat demand F1 = H1 / H2

The same procedure can be used to determine the correction factor for a new, well thermally insulated house. In this case, the correction factor is F1 < 1. A correction is also necessary for limited operation. Finding the correct correction factor here is more complicated.

Given: School building with 5 weeks of Christmas, winter and spring holidays during the heating period, which is 35 weeks long in total; room temperature during this period 15°C, heating limit 10°C (no heating above this outdoor temperature).

Wanted: Correction factor heat demand F1 < 1 (cf. Table 9)

Procedure:

1. Enter the school building as a single heat consumer. Set room temperature and heating limit according to normal operation, i.e. 20/15°C. Read off the resulting heat demand H1 (right bar " space heating " in Figure 15).

2. Set room temperature and heating limit according to reduced operation, i.e. 15/10°C. Read off the resulting heat demand H2.
3. Energy saving = 5/35 x (H1 - H2)
4. Correction factor heat demand F1 = (H1 - energy saving) / H1

Of course, this method is not very accurate: it does not distinguish when exactly in the course of the year the holidays are, nor does it take into account the reheating after the holidays. These effects that are not taken into account could still be considered in point 3 by an additional factor (< 1).

FAQ 4: How do I determine the correction factor heating-up peak F2?

A heating-up peak is always associated with limited operation. If, for example, the heating is reduced or switched off completely overnight in a residential building, the return flow comes back cold in the morning. Example 1:
- Supply /return temperature in normal operation = 50/40°C
- Supply /return temperature after night setback = 50/20°C
- Correction factor heating-up peak F2 thus theoretically 3.0 (cf. Table 9)

This high value is hardly ever reached in reality because the existing heat generation system usually has a limiting effect. This must be taken into account especially in the case of measured heating-up peaks.

The calculation according to EN 12831 leads to very different heating-up peaks [8]. See example 2:

$\Phi_{RH} = A \cdot f_{RH}$

Φ_{RH} = Additional heat capacity required [W]
A = Floor area of the heated room [m²]
f_{RH} = reheating factor [W/m²]

The so-called "reheating factor" according to EN 12831 [8] is, strictly speaking, a performance surcharge. It is given as a function of the indoor temperature drop during the night setback (2...4 K), the reheating time (1...4 h) and the building mass (light, medium, heavy). The values are in the range of 4...36 W/m². With an assumed specific heat capacity demand in the range of 20...50 W/m², this theoretically results in correction factors for the heating-up peak F2 in the range of (50+4)/50 = 1.08 to (20+36)/20 = 2.8.

FAQ 5: How do I design a system using the load characteristic and the annual duration curve?

The EXCEL tool works with two load characteristics: the load characteristic of the entire system shown in solid lines and the weighted load characteristic shown in dashed lines. The most important principles of when to use which load characteristic have already been listed in Box 13.

The **load characteristics of the entire system (solid lines)** are used to design:
- Heat capacity of the biomass boiler(s) for monovalent systems without storage tank
- Heat capacity of the biomass boiler(s) for bivalent systems without storage tank (designed for 60...70%)
- heat capacity of the biomass boiler(s) for bivalent systems with storage tank (designed for 50...60%)
- Heat capacity demand of the heat consumers

All simultaneity factors (space heating F3, domestic hot water F4 and process heat F5) as well as all correction factors for the heating-up peak F2 of the individual heat consumers are taken into account in the load characteristic of the entire system (see Table 9). This load characteristic represents the highest heat capacity demand to be covered by the heat generation system as a whole. This load characteristic should also be used when considering individual heat consumers.

The weighted load characteristics shown in dashed lines and the annual duration curves calculated from it are used for the design of:
- Heat capacity of the biomass boiler(s) for monovalent systems with storage tank
- Pipe network/pressure drop calculation of the heating network
- Heat demand data for the economic efficiency analysis

The dashed weighted load characteristic only takes into account the correction factor heat demand F1 (see FAQ 3 and Table 9). For domestic hot water and process heat, the average power demand is calculated based on the annual heat demand specified by the main planner (see also Table 9). Although this deliberately avoids a plausibility check, it does take into account reasonably realistic average values.

If the influence of the simultaneity factor F3 and the correction factors for the heating-up peak F2 is greater than that of the correction factors heat demand F1, it is possible within the EXCEL tool that the weighted load characteristic becomes higher than the load characteristic of the entire system. However, it must always be taken into account that a heating-up peak is always associated with limited operation. Therefore, the influence of the correction factor for limited operation on the energy demand must always be greater than that of the associated heating-up peak - without energy savings the reduced operation would make no sense at all!

A simultaneity factor F3 is only justified if heating-up peaks F2 of individual buildings do not occur at the same time, or if buildings are not heated simultaneously (e.g. in the case of a church and a multi-purpose hall, each with a correction factor F1 < 1, which are not used simultaneously). If these dependencies are consistently taken into account, the weighted load characteristic should not become larger than the "real" load characteristic. Compare also Box 8.

The **annual duration curve** is calculated from the weighted load characteristic. The area under the curve represents the energy demand.

In the graph of Figure 16 the minimum and maximum average daily biomass boiler output can be indicated. This results in two boundary lines:

■ Boundary line upwards with the maximum possible average daily output to be covered by the biomass boiler

■ Boundary line to the right indicating,
- at which minimum average daily output the biomass boiler should still be used
- and on how many days of the year the biomass boiler will thus be in operation

The tool frames the annual amount of energy produced with biomass and shows the shares (in [MWh] and [%]) in the graphs of Figure 18.

Note: Since the tool works with outdoor temperature classes (points on the annual duration curve), the values entered are rounded to the nearest value. The actual calculation is based on the values shown in the diagram, which are also indicated in the " Effectively" column.

FAQ 6: How can non-residential buildings with uncertain data and mixed uses be taken into account?

Since the data basis for non-residential buildings is often uncertain and, in addition, various parameters cannot be specified individually in the EXCEL tool, non-residential buildings must be treated individually. Table 20 shows the differences between non-residential buildings and normal residential buildings by means of some frequently occurring differences.

The data in Table 20 are based on empirical values from measurements, energy analyses, etc. The most reliable value is the heat demand [kWh/(m^2 * a)], as this is based on actual consumption data. The corresponding installed specific heating capacity [W/m^2] has already had to be corrected with an oversizing factor. The full load operating hours are then obtained by dividing the two numbers.

Higher full load operating hours result:

- with increasing altitude (compared to the required peak demand, the area under the annual duration curve is large).
- with higher room temperature (more heat produced with the same boiler, i.e. boiler runs longer)

Lower full load operating hours result:

- with a warmer climate, with better thermal insulation, with better utilisation of heat gains (compared to the required peak demand, the area under the annual duration curve is small).
- with a lot of peak load (a larger boiler is required for the same heat production)
- for longer interruptions in operation, e.g. seasonal hotels (design of the boiler for year-round operation, perhaps even for additional heating-up peaks, but less heat is produced).

Residential construction: It can be assumed that these data are relatively accurate, as this is where the most data are available. For the sake of simplicity, a distinction is made between the Swiss Plateau and the mountain region, and then again between:
- Building stock (larger stock of existing buildings with varying degrees of refurbishment)
- Existing building (satisfactorily refurbished)
- New building (built according to today's standards)

Shops and restaurants: According to data from various sources, the heat demand of simple shops and restaurants (no shopping centres) is comparable to residential construction (more ventilation losses, but more internal waste heat). In terms of heat capacity, higher values result from design for peaks (e.g. air heater). As a result, the full load operating hours are significantly lower than in residential construction.

Note: Orderly waste heat utilisation (e.g. from central refrigeration machines) is part of heat generation. On the other hand, waste heat that cannot be used in an orderly manner (lighting, decentralised freezers with heat dissipation to the room air, etc.) is not part of heat generation and must therefore be taken into account in the heat demand calculation.

Hotels without wellness areas: The data for space heating are similar to those for residential buildings, as long as there are no interruptions in operation; the domestic hot water demand is higher in hotels, but again dependent on interruptions in operation.

Indoor swimming pools: Only general data are known, all of which are extremely high, both for heating and power demand. The often heavily oversized heat generators are contrasted by high base loads for domestic hot water and bath water heating. Taking this oversizing into account, experience shows that similar full load operating hours can be expected as in residential construction, as long as year-round operation is involved.

Note: In addition to the actual indoor swimming pool with changing rooms, sanitary facilities, etc., restaurants, fitness rooms, etc. are often also part of the overall facility. These additional areas are not included in the data according to Table 18.

Wellness areas in hotels: These can be treated separately as swimming pools: one column for the hotel rooms, a separate column for the wellness area and possibly also a separate column for a large hotel restaurant (similar to example 1).

Other non-residential buildings: How higher room temperatures in retirement homes and restricted usage times in school buildings can be taken into account has already been discussed in FAQ 3 (see there).

	Housing	**Shops and restaurants**	**Hotels without wellness area**	**Indoor swimming pools, wellness areas in hotels**
Problems	■ Heat capacity demand calculation without heat gains, but these are relatively well known and are taken into account in the EXCEL tool ■ Relatively well known, uniform domestic hot water demand ■ No restricted operation or only during the night	■ Often unreliable heat capacity demand calculation ■ Often poorly known waste heat loads ■ High air heater connected load ■ Restricted operating hours in terms of day and week ■ Domestic Hot water consumption in restaurants high and in shops low (but varies by sector)	■ Heat capacity demand calculation like residential construction, but the heat gains are less well known ■ Widely varying, seasonal operating times possible ■ High domestic hot water peaks that do not occur in normal residential construction	■ Often unreliable heat capacity demand calculation ■ Often poorly known waste heat loads ■ High connected capacity of the bath water heat exchangers ■ Restricted operating hours in terms of day, week and year ■ Large daily domestic hot water consumption with high peak demand
Specific heat demand	■ Swiss Plateau: Stock 100 kWh/(m²a) Exis. buildings 80 kWh/(m²a) New buildings 40 kWh/(m²a) ■ Mountain region: Inventory 120 kWh/(m²a) Exis. buildings 100 kWh/(m²a) New buildings 50 kWh/(m²a)	■ Swiss Plateau: Exis. buildings 80 kWh/(m²a) New buildings 40 kWh/(m²a) ■ Mountain region: Exis. buildings 100 kWh/(m²a) New buildings 50 kWh/(m²a)	■ Swiss Plateau: Exis. buildings 80 kWh/(m²a) New buildings 40 kWh/(m²a) ■ Mountain region: Exis. buildings 100 kWh/(m²a) New buildings 50 kWh/(m²a) ■ Lower values possible with interruptions in operation	■ Swiss Plateau: Exis. buildings 300 kWh/(m²a) New buildings 150 kWh/(m²a) ■ Mountain region: Exis. buildings 375 kWh/(m²a) New buildings 190 kWh/(m²a) (including domestic hot water and bath water heating)
Full load operating hours space heating	■ Swiss Plateau: Stock 2000 h/a Exis. buildings 2000 h/a New buildings 1300 h/a ■ Mountain region: Stock 2500 h/a Exis. buildings 2500 h/a New buildings 1600 h/a	■ Swiss Plateau: Exis. buildings 1350 h/a New buildings 900 h/a ■ Mountain region: Exis. buildings 1700 h/a New buildings 1100 h/a	■ Swiss Plateau: Exis. Buildings 2000 h/a New buildings 1300 h/a ■ Mountain region: Exis. buildings 2500 h/a New buildings 1600 h/a ■ Lower values possible with interruptions in operation	■ Swiss Plateau: Exis. buildings 2000 h/a New buildings 1300 h/a ■ Mountain region: Exis. buildings 2500 h/a New buildings 1600 h/a (including domestic hot water and bath water heating)
Specific heat capacity demand space heating	■ Swiss Plateau: Stock 50 W/m² Exis. buildings 40 W/m² New buildings 30 W/m² ■ Mountain region: Stock 50 W/m² Exis. buildings 40 W/m² New buildings 30 W/m²	■ Swiss Plateau: Exis. buildings 60 W/m² New buildings 50 W/m² ■ Mountain region: Exis. buildings 60 W/m² New buildings 50 W/m²	■ Swiss Plateau: Exis. buildings 40 W/m² New buildings 30 W/m² ■ Mountain region: Exis. buildings 40 W/m² New buildings 30 W/m² ■ Same values necessary with interruptions in operation	■ Swiss Plateau: Exis. buildings 150 W/m² New buildings 125 W/m² ■ Mountain region: Exis. buildings 150 W/m² New buildings 125 W/m² (including domestic hot water and bath water heating)
Specific energy demand domestic hot water	■ Single-family house: 15...20 kWh/(m²a) ■ Apartment building: 25...30 kWh/(m²a)	■ Restaurants higher values than housing: 30...70 kWh/m² ■ Sales shops lower values than residential buildings: 5...15 kWh/m²	■ Significantly higher values than MFH, but possibly compensated by low occupancy: 30...50 kWh/(m²a)	■ Domestic hot water preparation and bath water heating are included in the key figures listed above. With the help of these key figures, therefore, only the approximate total demand can be estimated. An example of the breakdown between space heating, domestic hot water and process heat (bath water heating) is shown in Example 2.
Full load operating hours domestic hot water	■ Not 8760 h/a as daily consumption varies; recommendation: 4000...6000 h/a	■ Lower values than residential building (higher power peaks): 2000...3000 h/a	■ Lower values than residential building (higher power peaks): 2000...3000 h/a	
Specific heat capacity demand domestic hot water	■ Single-family house: 5 W/m² ■ Apartment building: 8 W/m²	■ Restaurants higher values than housing: 25 W/m² ■ Sales shops lower values than residential construction: 5 W/m²	■ The specific domestic hot water demand is much higher than in the MFH: 15...25 W/m²	

Table 20: Comparison of some non-residential buildings with residential buildings

Example 1: Mixed use of flats with shops and/or restaurants in the same building

For ventilation systems in shops, restaurants, etc., there are often no reliable heat capacity demand calculations available, but for example only the connected loads of the air heaters. In addition, there are often unknown waste heat loads and limited operating times, which are also not precisely known. The uncertain data basis of such ventilation systems can of course not be improved by the EXCEL tool, but at least an attempt should be made to separate this uncertain data from the reliable data and to "trim" it to plausible values.

Basically, the EXCEL tool is designed for the three areas "space heating", "domestic hot water" and "process heat". Since the load of ventilation systems depends on the weather, a separate area "space heating" must be separated for them. The easiest way to do this is to use two columns per house, one for the flats with a secure data basis and one for the shops with an uncertain data basis. On this occasion, it makes sense to also consider the domestic hot water separately. Table 21 shows an example.

For "trimming" to plausible values, the factors F1 to F5 according to Table 9 are available:

- With the "correction factor heat demand F1" it is possible to correct individually for each heat consumer (i.e. each column in Table 21) the weighted load characteristic, which is used to calculate the annual duration curve of the required heat capacity. This **average load characteristic** represents the 24-hour average value of the required heat capacity as a function of the outdoor temperature.
- The "correction factor heating-up peak F2" can be used to individually correct the load characteristic for each heat consumer (i.e. each column in Table 21) in order to correct the load characteristic of the entire system. This is the **peak load characteristic,** which represents the required peak load as a function of the outdoor temperature. In practice, however, this peak load is only required at the design outdoor temperature; at higher outdoor temperatures, the total output of the system is always available in an emergency.
- The simultaneity factors F3, F4 and F5 are not suitable for individual corrections, as they have the same effect on all heat consumers.

Basically, two initial situations must be distinguished:

Initial situation A: The heat demand [kWh/a] and the installed (or planned) connected load [kW] are known. Here, with the help of the full load operating hours from Table 20 an estimate of the degree of oversizing can be made. The average load characteristic is then corrected according to the degree of oversizing, while the peak load characteristic is not corrected at all or is corrected according to the existing situation.

Initial situation B: Only the heat demand [kWh/a] is known. By dividing the heat demand by the corresponding full load operating hours from Table 20 the heat capacity demand is obtained. The average load characteristic is not corrected in this case; on the other hand, the peak load characteristic can be corrected by a peak load factor according to the situation at hand.

The example in Table 21 is based on initial situation A. The data for the flats are plausible and were therefore not corrected (both correction factors set to 1). However, the connected load in the shops with the probably heavily oversized ventilation air heaters was corrected downwards by a factor of 0.7 with regard to the average load characteristic (representing the 24-hour average); the peak load characteristic, on the other hand, was not corrected.

Note: In principle, correction factors are not taken into account when calculating the key figures in the EXCEL tool. In the example of Table 21 the full load operating hours and the specific heat demand are also given with the correction factor taken into account (in brackets). These values now roughly correspond to the expected data in Table 20 (Swiss midland, existing buildings).

General	Number	1	2
	Designation	House 1	House 1
		1ST – 3RD FLOOR	GROUND FLOOR
		Flats	Shop
	Energy reference area [m²]	1200	400
	Max. supply temperature [°C]	85	85
	Max. return temperature [°C]	55	55
Space heating	Heat demand [MWh/a]	100	35
	Max. heat capacity demand space heating [kW]	50	35
	Correction factor heat demand [-]	1	0.7
	Correction factor heating-up peak [-]	1	1
Domestic hot water	Annual heat demand for domestic hot water [MWh/a]	10	2
	Max. heat capacity demand domestic hot water [kW]	2	1
Process heat	Annual heat demand process heat [MWh/a]	0	0
	Max. heat capacity demand process heat [kW]	0	0
Space heating	Full load operating hours space heating [h/a]	2000	1000 (1429*)
	Specific heat demand [kWh/m²a]	83	88
	Specific heat capacity demand [W/m²]	42	88 (61*)
Domestic hot water	Full load operating hours domestic hot water [h/a]	5000	2000
	Specific energy demand domestic hot water [kWh/m²a]	8	5
Process heat	Full load operating hours process heat [h/a]		
* With consideration of the correction factor 0.7			

Table 21: Example of mixed use of flats with a shop on the ground floor of the same house

Example 2: Allocation of the total consumption of an indoor swimming pool to space heating, hot water and process heat (bath water heating). The following data are known:
- Swiss midland, existing building, satisfactorily renovated
- Energy reference area indoor swimming pool and associated rooms = 1000 m²
- Energy reference area restaurant = 400 m²
- Energy reference area flats = 200 m²
- Total energy consumption = 350 MWh/a (reliable data, as calculated from previous fuel consumption).
- Total installed capacity of the existing heat generation plant = 220 kW (probably heavily oversized).

Step 1: Allocation of energy consumption with the help of Table 20:
- Apartments space heating = 200 m² x 80 kWh/(m²a) = 16 MWh/a
- Apartments hot water = 200 m² x 8 kWh/(m²a) = 1.6 MWh/a
- Restaurant space heating = 400 m² x 80 kWh/(m²a) = 32 MWh/a
- Restaurant hot water = 400 m² x 50 kWh/(m²a) = 20 MWh/a
- Indoor swimming pool thus 350 - (16+2+32+20) = 280 MWh/a

Step 2: The energy consumption in the indoor swimming pool is distributed approximately between 40...60% to space heating and to 60...40% to hot water + bath water heating. Choosing the middle results in:
- Indoor pool space heating = 0.5 x 280 MWh/a = 140 MWh/a
- Indoor pool hot water = 0.25 x 280 MWh/a = 70 MWh/a
- Indoor pool bath water heating = 0.25 x 280 MWh/a = 70 MWh/a

Step 3: Allocation of the heat capacity demand with the help of Table 20:
- Apartments space heating = 16 MWh/a / 2000 h/a = 8 kW
- Apartments hot water = 1.6 MWh/a / 4000 h/a = 0.4 kW
- Restaurant space heating = 32 MWh/a / 1350 h/a = 24 kW
- Restaurant hot water = 20 MWh/a / 2500 h/a = 8 kW
- Indoor pool space heating = 140 MWh/a / 1700 h/a = 82 kW
- Indoor pool hot water = 70 MWh/a / 2000 h/a = 35 kW

- Indoor pool bath water heating = 70 MWh/a / 4500 h/a = 16 kW
- Total = 174 kW (in comparison, the installed capacity is 220 kW).

Step 4: Fill in the data into the EXCEL tool. As general settings are selected:
- Climate station = Zurich with -9°C
- Room temperature = 20°C
- Heating limit = 15°C
- Non-weather-dependent share = 0%

The currently installed capacity available for space heating in the indoor swimming pool is:
220 - (8+1+24+8+35+16) = 128 kW
However, the calculation in step 3 with a full load operating hours of 1700 h/a resulted in only 82 kW. Now there are two possibilities:
- If this currently installed peak power of 128 kW is to remain in the peak load characteristic, the weighted load characteristic must be corrected with the factor F1 (see Table 9) (in Table 22: F1 = 82 kW /128 kW = 0.64 has been selected).
- However, it can also be corrected to a value in between (e.g. 100 kW instead of 128 kW and the correction factor then becomes F1 = 100 kW / 128 kW = 0.78).

In any case, the output must be adjusted so that the energy demand calculated by the EXCEL tool is slightly higher than the energy demand calculated from the previous fuel consumption.

General	Number	1	2	3
	Designation	Indoor swimming pool	Indoor swimming pool	Indoor swimming pool
		Flat	Restaurant	Bad
	Energy reference area [m²]	200	400	1000
	Max. supply temperature [°C]	85	85	85
	Max. return temperature [°C]	55	55	55
Space heating	Heat demand [MWh/a]	16	32	140
	Max. heat capacity demand space heating [kW]	8	24	128
	Correction factor heat demand [-]	1	1	0.64
	Correction factor heating-up peak [-]	1	1	1
Domestic hot water	Annual heat demand for domestic hot water [MWh/a]	1.6	20	70
	Max. heat capacity demand domestic hot water [kW]	0.4	8	35
Process heat	Annual heat demand process heat [MWh/a]	0	0	70
	Max. heat capacity demand process heat [kW]	0	0	16
Space heating	Full load operating hours space heating [h/a]	2000	1333	1094 (1709*)
	Specific heat demand [kWh/m²a]	80	80	140
	Specific heat capacity demand [W/m²]	40	60	128 (82*)
Domestic hot water	Full load operating hours domestic hot water [h/a]	4000	2500	2000
	Specific energy demand domestic hot water [kWh/m²a]	8	50	70
Process heat	Full load operating hours process heat [h/a]			4375
* With consideration of the correction factor 0.64				

Table 22: Example of the division of an indoor swimming pool with different uses

FAQ 7: How are the values for the average daily output determined?

Since the tool works with outdoor temperature classes (points on the annual duration curve), the values entered are rounded to the nearest value. The actual calculation is done with the values shown in the diagram, which are also indicated in the "Effectively" column. The values entered may have to be adjusted until the effective values come closest to the desired values.

Minimum average daily biomass boiler output

The best way to proceed here is as follows:

1) Determination of the heat demand in summer operation in kWh per day (heat demand domestic hot water preparation + losses storage tank and district heating network).
   Example: 3'000 kWh per day

2) Calculation of the average daily heating load in summer operation in kW from (1). This value can now be entered as the minimum average daily biomass boiler output.
   Example: 3'000 kWh / 24 h = 125 kW

3) Determination of the minimum average daily heating load in low-load operation required for the present system configuration in percent according to FAQ 12 in [9].
   Example: 15%

Check: (2) and (3) result in the maximum permissible nominal output of the biomass boiler (in the case of two biomass boilers, this would be the maximum permissible nominal output of the smaller biomass boiler). Can this demand be met in the choice of system?
Example: 125 kW / 0.15 = 830 kW

Possible problems: In the lower range, the jumps of the effective possible values are relatively large. By changing the default value, it must be tested which effective value is used most sensibly.

Maximum average daily biomass boiler output

It should be noted here that, correctly, the nominal output of the biomass boiler with reference fuel (in the case of several boilers, their total output) cannot be used because the cumulative frequency curve indicates the average daily power demand and the actual course of the power demand fluctuates greatly throughout the day. A biomass boiler of 1'000 kW can therefore not cover an average daily heating load of 1'000 kW, but less. How much less depends on various factors:

■ Experience shows that systems with storage and a sluggish heating network (many small consumers) can be operated with a blocked oil/gas boiler very close to the nominal output of the biomass boiler(s) without the temperature in the network collapsing. The maximum average daily biomass boiler output may be set correspondingly higher for systems with storage.

■ In systems without a storage tank and a nimble heating network (few large consumers), the temperature in the network collapses much faster, and the oil/gas boiler has to be switched on correspondingly sooner.

■ The decisive question is: How well does the automatic sequence control prevent the oil/gas boiler from being switched on too early, especially during the morning peak? By releasing the oil/gas boiler manually as late as possible (only when the temperature in the network really drops), the degree of coverage with biomass can be noticeably increased.

It must always be taken into account that the EXCEL tool is an approximation of the not exactly known reality. The following values could be entered as a maximum average daily biomass boiler output (non-binding guide values):
- Systems with storage tank: 90% of the nominal power
- Systems without storage tank: 70...80% of the rated output

FAQ 8: How is the Maximum Average Base Load Source determined, and how will it be displayed in the "Annual duration curve of the required heat output" diagram (Figure 16)?

If there is no base load source, set this value to zero.

If a base load source is available (e.g. electricity production with ORC system), its maximum average daily power can be entered. Up to the red line "heat demand independent of weather conditions", the value is transferred exactly to the " Effectively" column; above this, the values are rounded to the outdoor temperature class.

Potential problems: In the area above the red line "heat demand independent of weather conditions", the jumps of the effectively possible values are relatively large. By changing the default value, it must be tested which effective value is used most sensibly.

Attention: Every change of the input value influences all values in the column "Effectively". As a result, the other values must be checked and adjusted if necessary.

7. References

[1] Ruedi Bühler, Hans Rudolf Gabathuler, Andres Jenni: Q-Leitfaden. Straubing: C.A.R.M.E.N. e.V., 2nd edition 2007. ISBN 978-3-937441-91-3. (Series of publications QM Holzheizwerke, Volume 1).

[2] Hans Rudolf Gabathuler, Hans Mayer: Standard circuits - Part I. Straubing: C.A.R.M.E.N. e.V., 2nd, expanded edition 2010. ISBN 978-3-937441-92-1. (Series of publications QM Holzheizwerke, Volume 2).

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[5] Alfred Hammerschmid, Anton Stallinger: Standard-Schaltungen - Teil II. Straubing: C.A.R.M.E.N. e.V., 2006. ISBN 978-3-937441-95-6. (Schriftenreihe QM Holzheizwerke, Band 5)

[6] Bernhard Enzesberger, Johann Reinalter: Ratgeber zur Biomassekesselausschreibung (Version Österreich). Straubing: C.A.R.M.E.N. e.V., 2009. ISBN 978-3-937441-89-4. (Schriftenreihe QM Holzheizwerke, Band 6).

[7] DIN EN ISO 52016-1:2018-04: Energy performance of buildings - Energy demand for heating and cooling, indoor temperatures and sensible and latent heating loads - Part 1: Calculation method (ISO 52016-1:2017); German version EN ISO 52016-1:2017.

[8] DIN EN 12831-1:2017-09: Energy performance of buildings - Method of calculation of standard heating load - Part 1: Space heating load, module M3-3; German version EN 12831-1:2017.

[9] Frequently Asked Questions (FAQ). Problems that occur frequently are recorded as FAQs as quickly as possible and posted on the Internet. These can then be downloaded free of charge as individual FAQs or as a complete FAQ collection.

Note: The titles [1] to [6] as well as the latest version of this manual for the Excel tool “Demand assessment and appropriate system selection” and the corresponding latest version of the EXCEL tool can be downloaded from the QM for Biomass DH Plants website.
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