Country Report Germany Annex 28 Task 1

Further points to be discussed in the second meeting on 16./17. October at CETIAT:
• System definition/delimitation
• Definition of measurement for Task 2 (black box vs. grey box)
• Conclusions of system evaluation for test procedure and calculation method
• Missing items in existing standards for systems to be investigated
• Impact of the different boundary conditions on the test procedure/calculation method
Note that also results of Task 2 and Task 3 are to be discussed on the meeting to decide about the basis for the test procedure and calculation method according to the time schedule of our project matrix (document 21).
Working on the Swiss country report, the following items seem important to me, and I think, they should be contained in the country reports of Task 1 as far as possible.

1 Analysis of the market

1.1 Systems and market share

Commonly the heating system in Germany is floor heating or radiator system with water, heated by one central unit. Statistics about the sales figures in Germany also represent the most commonly used systems:

Year	Brine / Water	Water / Water	Air / Water	**Total : Heat-pumps for space heating**	**Heat pump for hot water**
2002	5.363	1.439	1.524	**8.326**	**4.082**

Changes from 2002 to 2003 (comparison of figures from January till June)

+ 2,93 %	brine / water
- 2,27 %	water / water
+ 30,68 %	air / water
+ 6,6 %	total market (heat-pumps for space heating)

Table 1: Sales figures of heat-pumps in Germany /3/

The most commonly used hydraulic schemes for space heating combined with hot water production:

1) Modulation system – mono-energetic operation (Figure 1)
   market share 20 %, only applied for small heat-pumps (max. 10 kW)
2) Mono operation with de-coupled modulation storage unit / heating water calorifier (Figure 2); market share 50 %
3) Mono-energetic operation – modulation system with heating water calorifier and heating circuit distributor (Figure 3)
   market share 30 %

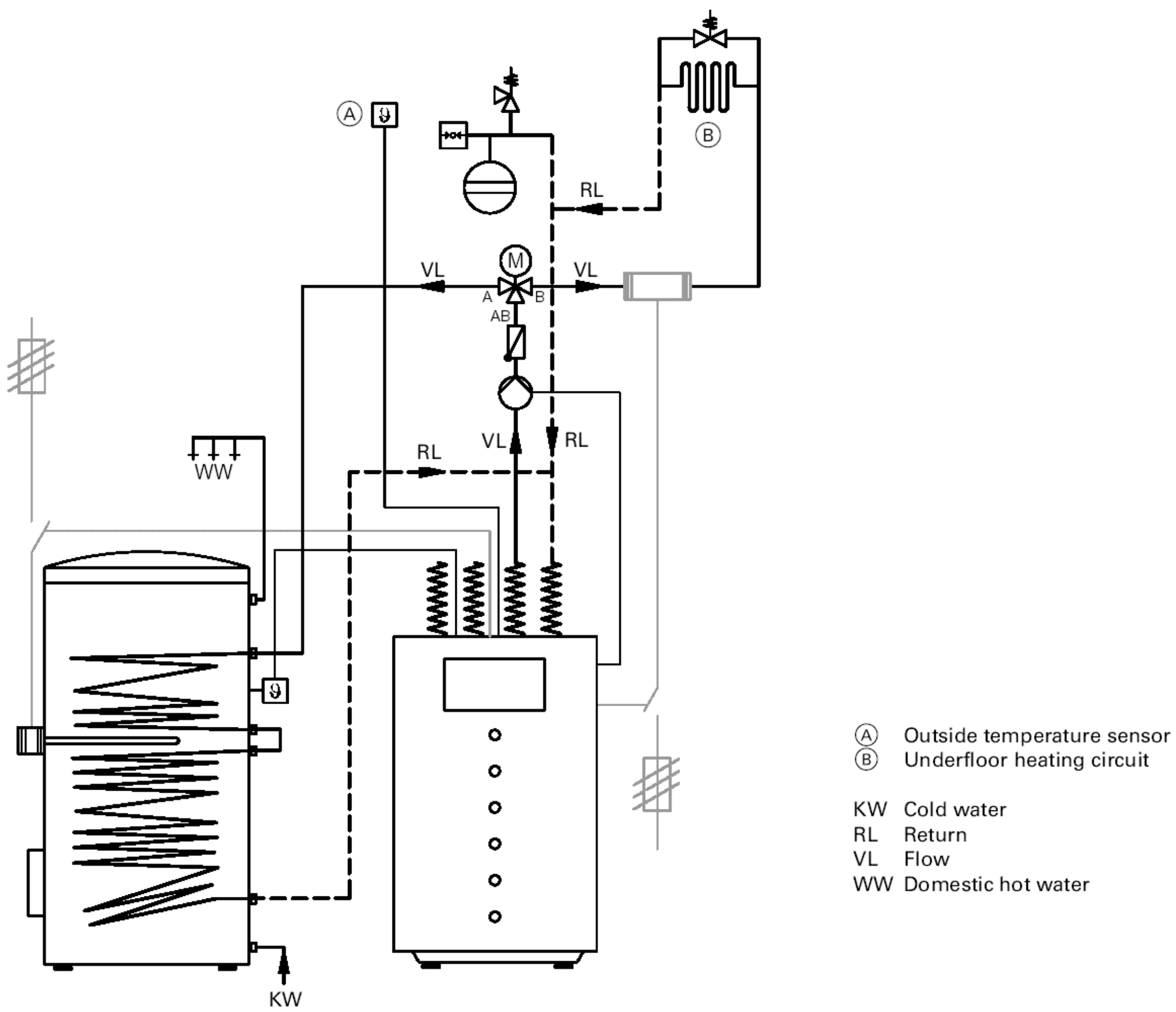
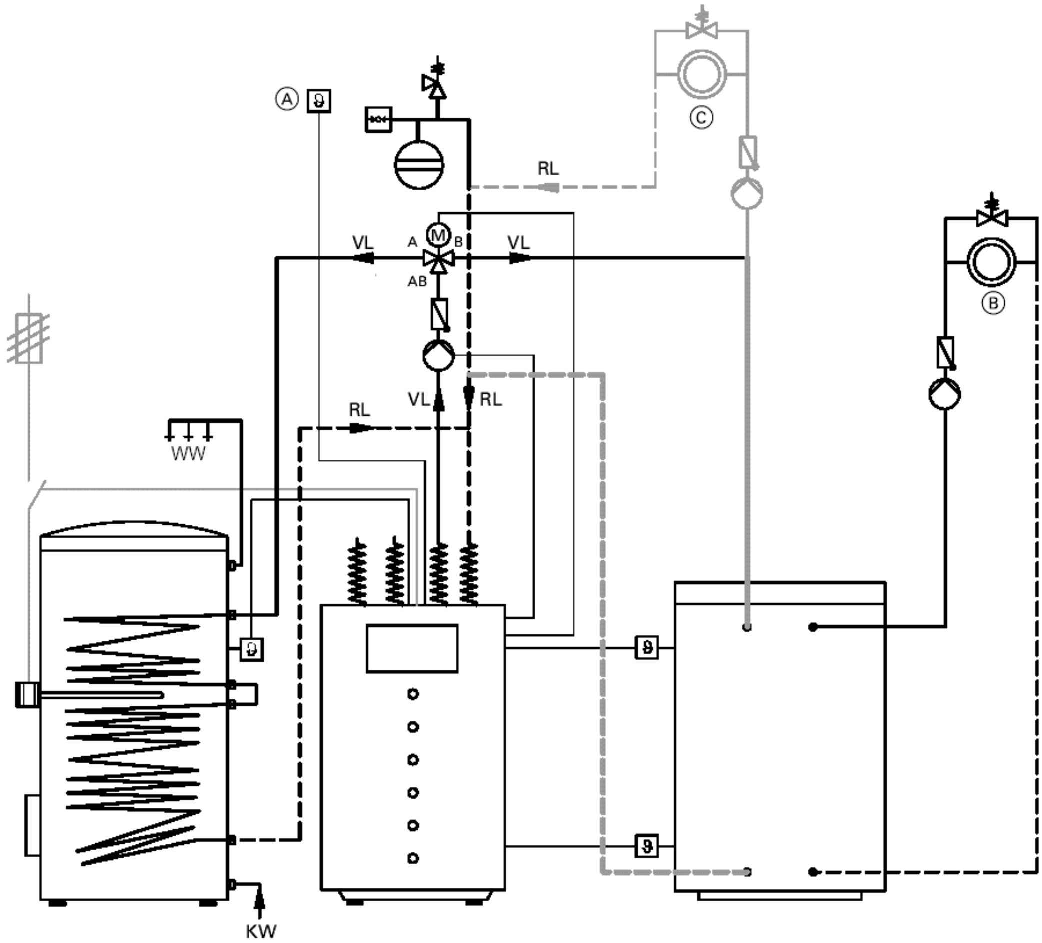


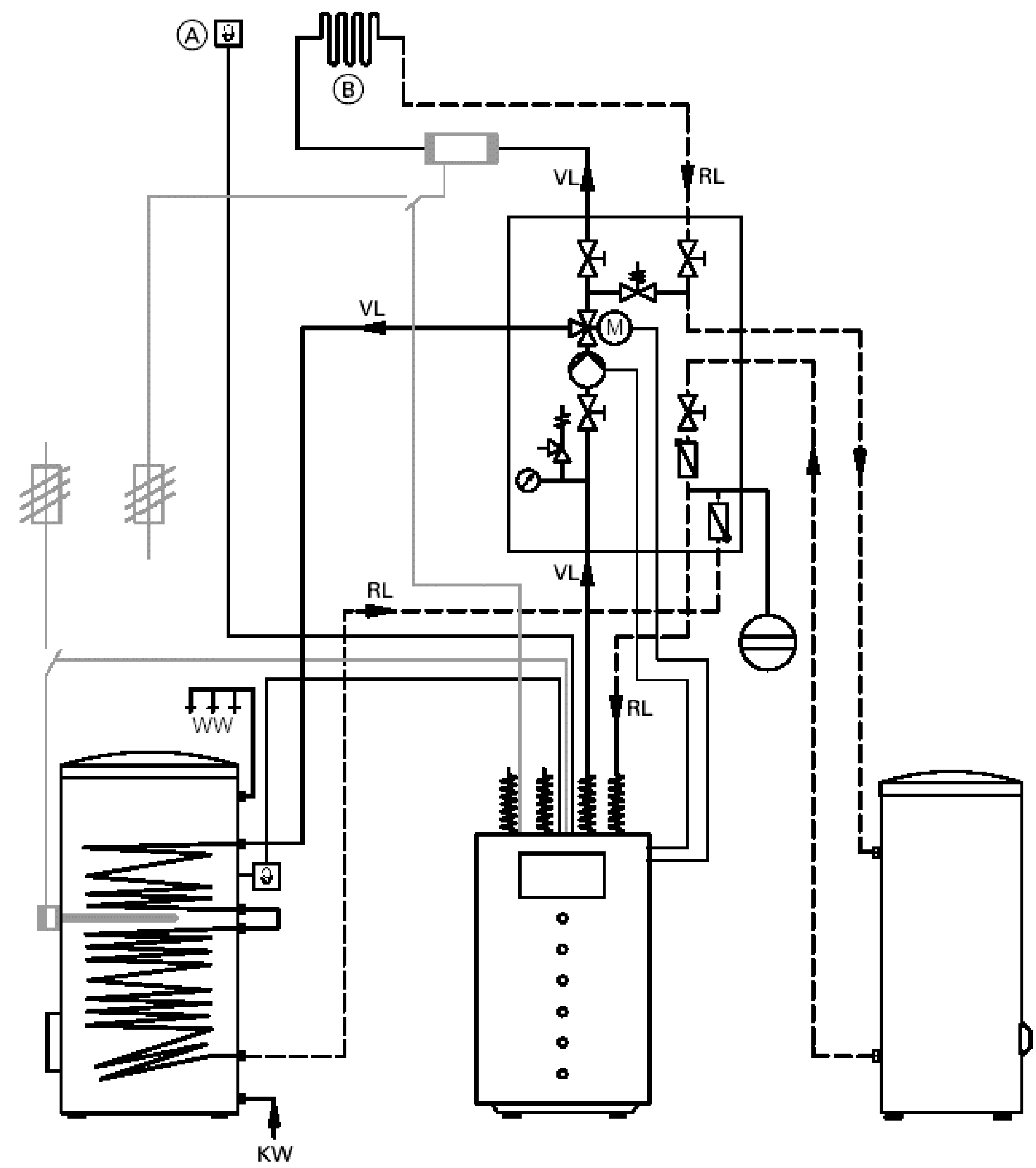
Figure 1: Modulation system – mono energetic operation /2/.



Ⓐ Outside temperature sensor
Ⓑ Heating circuit version 2
Ⓒ Heating circuit version 1

KW Cold water
RL Return
VL Flow
WW Domestic hot water

Figure 2: Mono operation with de-coupled modulation storage unit (heating water calorifier) /2/.



Ⓐ Outside temperature sensor
Ⓑ Underfloor heating circuit

KW Cold water
RL Return
VL Flow
WW Domestic hot water

Figure 3: Mono-energetic operation – modulation system with heating water calorifier and heating circuit distributor /2/.

1.2 Cooling with heat-pumps

Active cooling has almost no market share in Germany. Natural cooling has a small share (few percent).

1.3 Systems under development

- Air to air and air to water heat-pump systems for passive houses, combined with hot water production and ventilation (compact unit)
- Heat-pumps with CO_2 and other natural refrigerants due to the „Eckpunktepapier“ of the German ministry for environment. In this paper the ministry discusses a possible prohibition of F-Gases until 2008 / 2012.

1.4 Data delivered by the manufacturer

Most producers give TÖSS-data (EN 255) /1/ and information for the installation. Some manufacturers also deliver a more detailed correlation of primary / secondary temperatures with heating power and electric consumption:

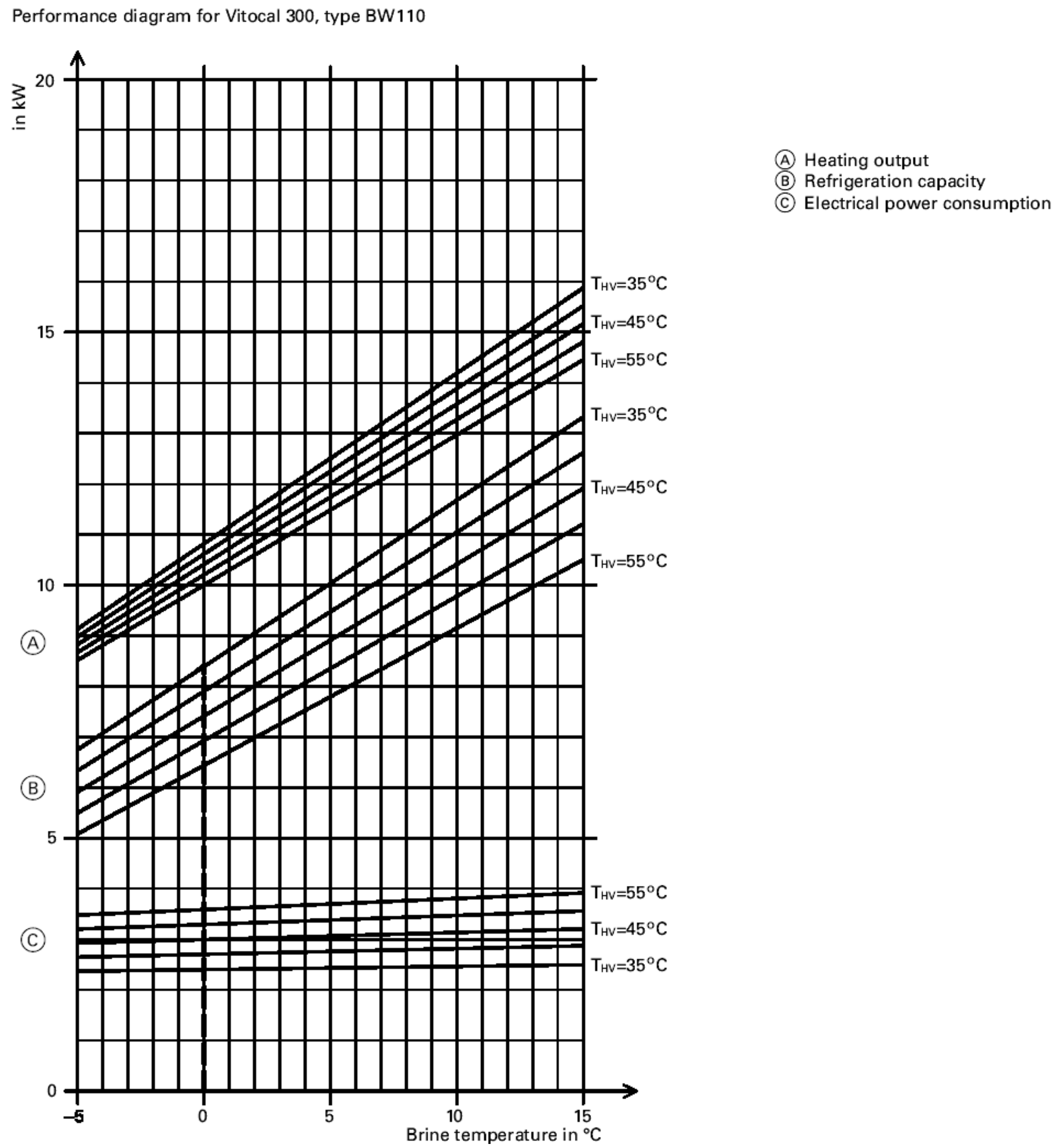


Figure 4: Dependency of brine temperature, water temperature, heating power and electric power consumption /2/.

1.5 Required efficiencies

A minimum efficiency is not demanded by a standard but for the “Gütesiegel” is Minimum measured COP (according to EN 255)

- Air / Water : 3.0 (at A2/W35)
- Brine / Water : 4.0 (at B0/W35)
- Water / Water : 4.5 (at W10/W35)

Some mains give other values for financial support. This values differ from company to company and also differ from year to year. There are no general values.

2 Standards

2.1 General

Heat-pumps:

General current regulations and directives

BImSchG	Federal Immissions Act heat pumps are "Systems" acc. to the Federal Immissions Act
TA Lärm	Noise emissions regulations
DIN 4701	Regulations for calculating the energy requirements of buildings
DIN 4108	Thermal insulation in building structures above ground
DIN 4109	Noise insulation in building structures above ground
VDI 2067	Efficiency calculations for energy consumers, operational and economic principles
VDI 2081	Noise reduction in technical ventilation systems
VDI 2715	Noise reduction in hot water and heating water systems
VDI 4640	Technical utilisation of subterranean areas, ground-coupled heat pump systems, pages 1 and 2

Water-related regulations

DIN 1988	Technical regulations for DHW installations
DIN 4751	Safety equipment for hot water heating systems
DIN 4807	Expansion vessels part 5: Sealed expansion vessels with diaphragm for DHW heating systems
DVGW Code of practice W101	Guidelines for protected water areas Part one: Protected areas for groundwater

Electrical regulations

Carry out the electrical connection and electrical installation in accordance with VDE regulations (DIN VDE 0100) and the technical connection requirements laid down by your local electricity supplier (or local regulations.)

VDE 0100	Installing HV systems with rated voltage up to 1000 V
VDE 0105	Operation of HV equipment
EN 60335 -1 and -40 (VDE 0700 -1 and -40)	Safety of electrical devices for domestic use and similar purposes

Additional standards and regulations for dual-mode heat pump systems

VDI 2050	Heating stations, technical principles for design and implementation

Table 2: National regulations and standards for heat-pumps /2/.

Ventilation systems:

- DIN 1946

Domestic hot water systems:

- DVGW technical guidelines
- DVGW Arbeitsblatt W 551: heat up the total content of the hot water system (boiler, pipes) over 60°C once a day. The regulation is not applied to boilers with less than 400 litres and to pipes with less than 3 litres.
- Trinkwasserverordnung (Regulation for drinking-water systems)

2.2 Testing

Heat-pumps:
Standard testing procedure is EN 255 for air to water and brine to water, water to water and air to air heat-pumps. This tests are usually done at TÖSS, the values are published in a bulletin /1/. There is no other institute recognised by the D-A-CH (Germany, Austria, Switzerland).
For the Netherlands heat-pumps are tested by TNO as TÖSS is not certified according to ISO 9000.
Other systems like heat-pumps combined with ventilation (with heat recovery) and hot water production are not covered by EN 255. The testing is done according to conditions fixed by DIBt (Deutsche Institut für Bautechnik – German Institute for Building Technology) specially for each machine.

Ventilation systems:
- Fans according to DIN EN 24 613
- Thermal performance DIN EN 13 141 – 7 and DIN EN 13 141 – 8.
- Noise according to DIN 4109
- Heat exchangers according to EN 308

Domestic hot water systems:
- DIN 4708 (performance test of water calorifier)
- DIN 4758-8 (thermal losses of water calorifier)

2.3 Calculation of the seasonal performance

2.3.1 Method of VDI 2067

Calculation of the annual performance according to VDI 2067, No. 6 (technical guideline). The method is similar to the one proposed by SPF (see Annex28_N19, presentation of Mr. Wemhoener).

2.3.2 Method of DIN 4702-8 (not for heat-pumps)

For other heating systems (gas, oil, ...), the DIN 4702-8 defines an annual performance. Here, the heating demand is divided in five equal parts. For each part an average outside temperature an heating demand is defined.

Relative heating demand ϕ [%]	Outside temperature $t_{außen}$ [°C]
63	- 3,9
48	0,6
39	3,3
30	6,0
13	11,1

Table 3: Heating demand and outside temperature in DIN 4702/8

The annual performance („Normnutzungsgrad“) is:

$$\eta_N = \frac{5}{\sum_{i=1}^{5} \frac{1}{\varepsilon_i}} \ ,$$

where ε_i is the COP at each point in table 2.

The correlation of outlet temperature of the heat source and the ambient temperature is fixed.

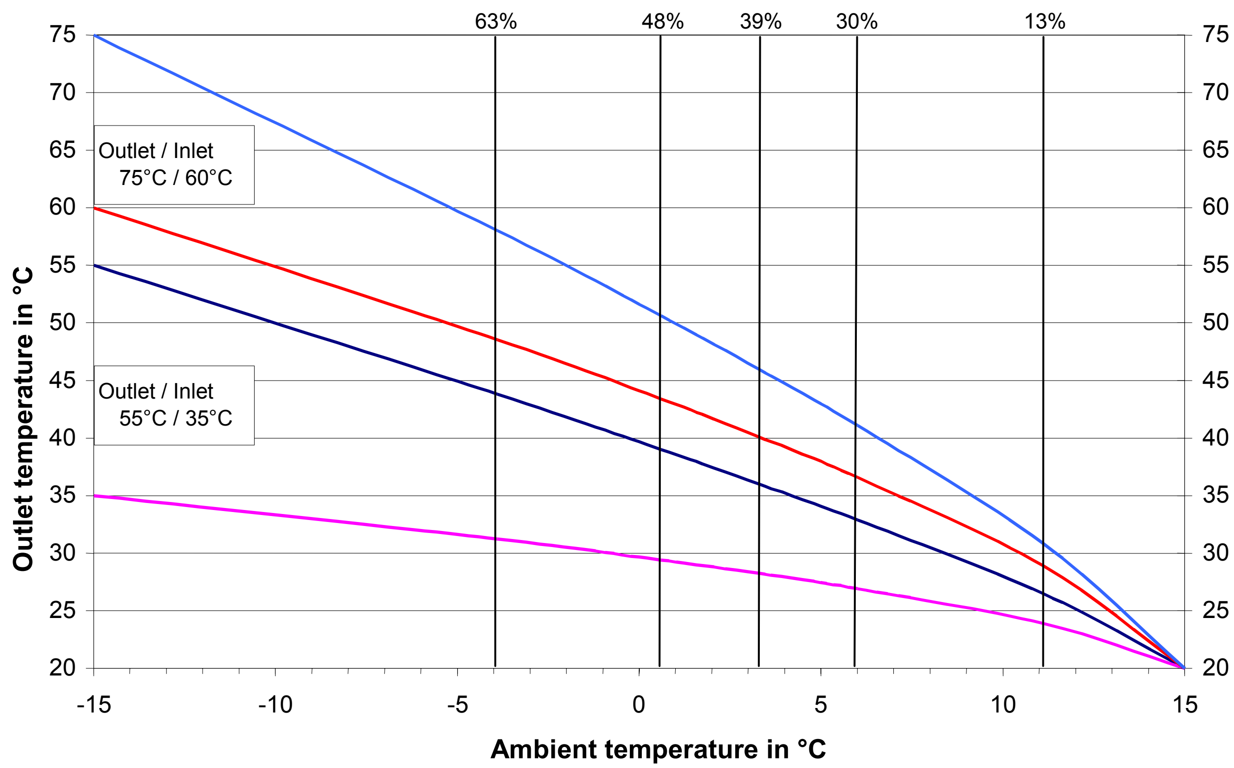


Figure 5: Correlation of ambient temperature and in/outlet temperatures for two different heating systems.

2.3.3 Method of DIN 4701-10 (for all heating systems)

In the standard DIN 4701-10 an other calculation method is presented. The advantage is the direct comparison of different heating systems (boiler, heat-pump, ...) since all heating systems are characterised by the primary energy use. The basic equation is:

$$Q_P = (Q_h + Q_{tw}) \cdot e_P$$

with

Q_P primary energy use of a building

Q_h heating demand
Q_{tw} hot water demand
e_P Aufwandszahl

Three different calculation methods for the Aufwandzahl are allowed:

1. determination by diagrams
2. table calculation method
3. detailed calculation

For hot water with a heat pump the Aufwandzahl is the reciprocal of the COP, corrected by factors:

$$e_{TW,g} = \frac{1}{\varepsilon_N \cdot F_1 \cdot F_2}$$

with: ε_N COP according to DIN EN 255/3
F_1 correction for hot water temperature
F_2 correction for heat source

For the heating, the Aufwandzahl is the reciprocal of the annual performance:

$$e_{L,g,WP} = 1 / \beta_{WP}$$

The annual performance may become difficult (as for example for exhaust air heat pumps with an air to air heat recovery), but still it is represented by one equation, achieved by the correction of the three measurement points:

$$\beta_{HP} = \varepsilon_{N(A-3)} \cdot F_{\vartheta-3} + \varepsilon_{N(A4)} \cdot F_{\vartheta4} + \varepsilon_{N(A10)} \cdot F_{\vartheta10}$$

with: β_{HP} annual performance in [-]
$\varepsilon_{N(A-3)}$ COP at ambient air temperature of -3°C, in [-]
$\varepsilon_{N(A4)}$ COP at ambient air temperature of 4°C, in [-]
$\varepsilon_{N(A10)}$ COP at ambient air temperature of 10°C, in [-]
$F_{\vartheta-3}$ correction for –3°C, in [-]
$F_{\vartheta4}$ correction for 4°C, in [-]
$F_{\vartheta10}$ correction for 10°C, in [-]

For a brine water heat pump the equation is::

$$\beta_{HP} = \varepsilon_{N(B0/W35)} \cdot F_{\vartheta} \cdot F_{\Delta\vartheta}$$

with: β_{HP} annual performance in [-]
$\varepsilon_{N(B0/W35)}$ COP according to EN 255 at B0/W35, in [-]
F_{ϑ} correction for brine temperature, in [-]
$F_{\Delta\vartheta}$ correction for temperature difference of the heating system (inlet-outlet), in [-]

For an air to water heat pump the annual performance is derived by a correction of EN 255 values:

$$\beta_{HP} = (\varepsilon_{N(A-7/W35)} \cdot F_{\vartheta-7} + \varepsilon_{N(A2/W35)} \cdot F_{\vartheta2} + \varepsilon_{N(A10/W35)} \cdot F_{\vartheta10}) \cdot F_{\Delta\vartheta}$$

with: β_{HP} annual performance in [-]
$\varepsilon_{N(A-7/W35)}$ COP according to EN 255 at A-7/W35, in [-]
$\varepsilon_{N(A2/W35)}$ COP according to EN 255 at A2/W35, in [-]

$\varepsilon_{N(A10/W35)}$	COP according to EN 255 at A10/W35, in [-]
$F_{\vartheta-7}$	correction for A-7, in [-]
$F_{\vartheta 2}$	correction for A2, in [-]
$F_{\vartheta 10}$	correction for A10, in [-]
$F_{\Delta\vartheta}$	correction for heating system, in [-]

The correction factors for the heating demand have to be determined with regard to other national standards for the calculation of the heating demand of the building, in Germany the DIN 4108-6 (developed on the base of EN 832).
For the hot water production it should be possible to find values for the factors which do not depend on a country. The big influence factor is the calculation of the heating demand (which differs from country to country).

2.4 Energy demand of the house

- EnEV (general standard for houses and heating systems)
- DIN 4108-6 Heating demand of the house
- DIN V 4701 (calculation methods for heating demand and DHW demand), only till 2004-08-01
- EN 12831 (instead of DIN 4701)
- EN 12828 (hot water based heating systems)

2.5 Meteorological data

For the system design different minimum and average outside temperatures are given by DIN 4701 or EN 12831.
For a more detailed system design (which is not required by the standard), meteorological data sets are the "Test Reference Years" from DWD (Deutscher Wetter-Dienst). There are 12 data sets for different regions in western part of Germany. Unfortunately for the eastern part of Germany the Test Reference Years are not yet available. Usually for the eastern part of Germany the program Meteonorm is used.

3 Heat-pump design

The energy demand of the building for heating an hot water is calculated according to DIN 4701. For further design of the heat-pump there is no common standard. Some manufacturers give a calculation method for the system design.

5.3 Summary of the planning steps for a heat pump system

1. Determining the building data (see also check list on page 100)
   - Calculating the precise heating load of a building acc. to DIN 4701
   - Calculating the hot water demand
   - Determining the method of heat transfer (radiators or underfloor heating system)
   - Determining the temperature of the heating systems (aim: low temperatures).
2. Sizing the heat pump
   - Determining the heat pump operating mode (mono, mono-energetic) (see page 17 and 18)
   - Considering possible off-periods of the power supplier (see page 17)
   - Determining and sizing the heat source (see from page 19)
   - Sizing the DHW cylinder (see page 35).
3. Determining the remaining and financial framework conditions
   - Heat source permit procedures (ground probe, wells)
   - Clarifying state and local subsidies
   - Power tariffs and subsidies from your regional power supply company.
4. Determining interfaces and responsibilities
   - Heat pump heat source
   - Heating system heat source
   - Power installation (heat source).
5. Drilling contract
   - Sizing the ground probe (drilling contractor)
   - Service contracts
   - Drilling work.
6. Electrical work
   - Ordering an electricity meter
   - Routing power and control cables
   - Installing the meterbox.

Table 4: Recommendations of Viessmann for the heat-pump design /2/.

3.1 Sizing of heat pumps

Please note:
For heat pump systems operating in mono-mode, accurate sizing is particularly important, as equipment which is too large is frequently too costly. Therefore avoid oversizing.

First, establish the standard building heat demand $\dot{Q}_N$. For your discussion with your client and preparing an offer, it usually suffices to determine the approximate heat demand.

Before ordering any heating system, establish the heating demand of the building in accordance with DIN 4701 (or local regulations) and select the heat pump accordingly.

Mono operation

In mono operation, the heat pump system must, as sole provider of heating energy, cover the entire heating demand of the building acc. to DIN 4701.
To be able to calculate the required heating output, additions to compensate for off-periods enforced by your power supply company may need to be considered.
The power supply may be interrupted for a maximum of 3 × 2 hours within a 24-hour period (in Germany).
Specific regulations may need to be considered by customers who have entered special contracts.
Because of building inertia, 2 hour off-periods will not be considered when sizing the performance supplements.
The time between two off-periods, where power is available, must be at least as long as the previous off-period.

Estimate of the heat demand based on the heated surface area

The heated surface area (in m^2) is multiplied by the following specific heat demand:

Energy-efficient house	10 W/m²
Low energy house	40 W/m²
New building (good thermal insulation)	50 W/m²
House (standard thermal insulation)	80 W/m²
Older house (without specific thermal insulation)	120 W/m²

Example:
New building with good thermal insulation, surface area
180 m² → Estimated heat demand 9 kW

Theoretical design for 3 × 2 hours off-periods

Calculated heat demand 9 kW
Maximum off-period 3 × 2 hours at minimum outside temperature acc. to DIN 4701

A 24 hour period therefore results in a daily heating demand of:

9 kW × 24 h = 216 kWh

Due to the off-periods of 3 × 2 hours, only 18 h/day are available to cover the maximum daily heating demand. Due to building inertia, 2 hours will be ignored.

$$\frac{216\ \text{kWh}}{(18 + 2)\ \text{h}} = 10.8\ \text{kW}$$

From a purely arithmetical aspect, a heat pump with a heating output of 10.8 kW would be sufficient.
Given a maximum off-period of 3 × 2 hours per day, the heat pump output would need to be increased by 17%.
Frequently, off-periods are only invoked on demand. Please ask your local power supply company about off-periods.

Table 5: Design of heat-pump power according to DIN 4701, respecting cut-off times from the mains /2/.

Hot water demand is determined according to DIN 4701, but only if the hot water consumption exceeds a certain percentage of the total heating power.

Supplement for DHW heating

For general house building, a maximum consumption of approx. 50 litres per person per day at approx. 45 °C is assumed. This represents an additional heating output of approx. 0.25 kW per person given a water heating period of 8 h. This supplement is only taken into consideration if the total of the supplementary output is higher than 20% of the heating demand calculated acc. to DIN 4701.

	DHW demand at a DHW temperature of 45 °C in litres per person/day	**Specific available heat** in Wh per person/day	**Recommended supplement for DHW heating** in kW/person*1
Low demand	15-30	600-1200	0.08-0.15
Normal demand*2	30-60	1200-2400	0.15-0.30

or

	At a reference temperature of 45 °C	**Specific available heat** in Wh per person/day	**Recommended supplement for DHW heating** in kW/person*1
Apartment (billing according to consumption)	30	approx. 1200	approx. 0.15
Apartment (flat rate billing)	45	approx. 1800	approx. 0.225
Detached house*2 (average demand)	50	approx. 2000	approx. 0.25

**1For a DHW cylinder heat-up time of 8 h*
**2Select a higher performance supplement if the actual DHW demand exceeds the stated values.*

Table 6: Hot water demand /2/.

Bivalent operation are taken into account by some manufacturers (no standard).

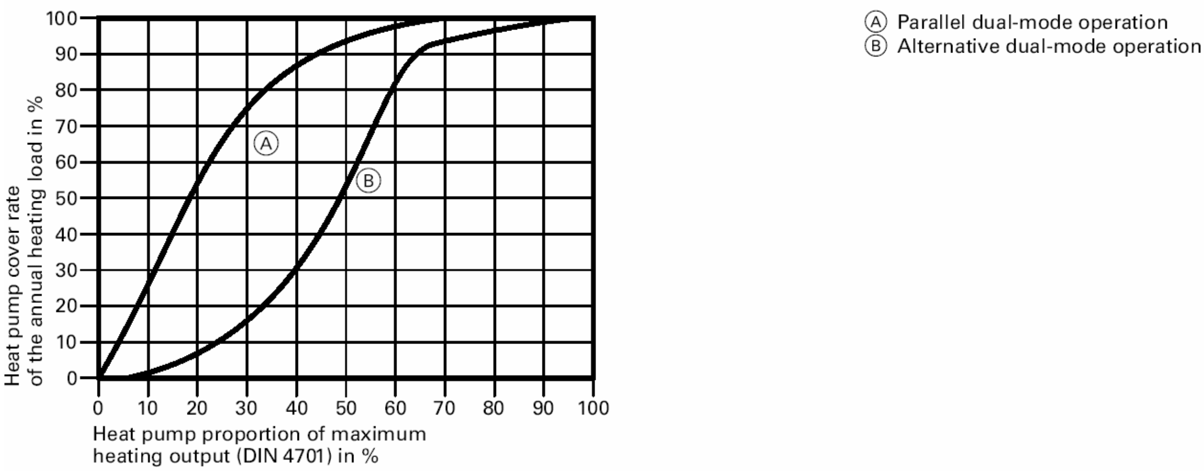
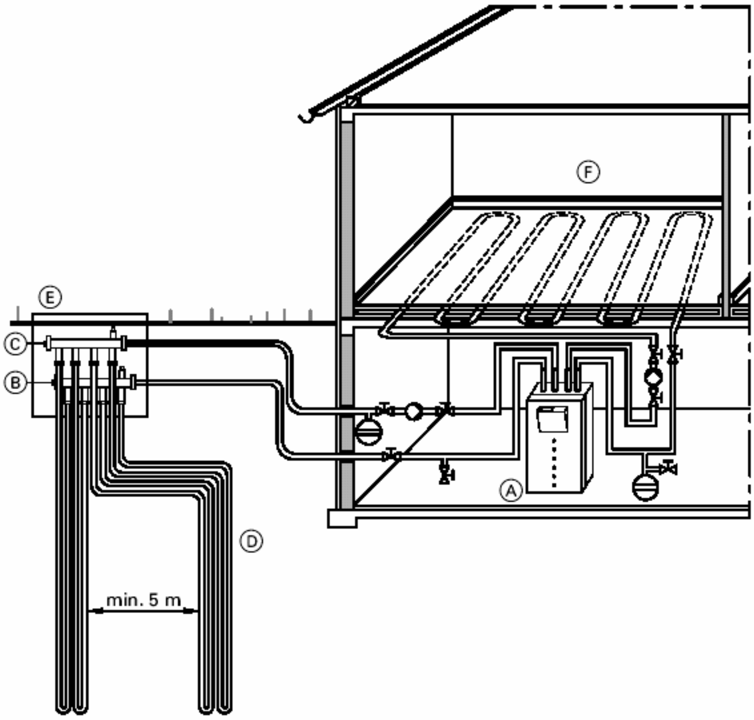


Figure 6: Dual-mode heating systems, parallel and alternative dual-mode operation /2/.

Heat recovery with ground probes



Ⓐ Vitocal 300/350 heat pump
Ⓑ Brine distributor (return)
Ⓒ Brine distributor (flow)
Ⓓ Ground probe (duplex probe)
Ⓔ Central duct
Ⓕ Low temperature heating system

For reasons of space requirements, horizontal ground collectors are frequently not viable in new building projects. In urban areas particularly, small building plots provide tight limits for such applications. For this reason, today vertical ground probes are increasingly utilised, which are set into depths between 50 and 150 m.
Probes are made of PE pipes.
Generally, four pipes are installed in parallel (double U-shaped probe). From the distributor, brine flows through two pipes downwards and returns through two further pipes to the header.

Ground energy probes are installed either by drilling or by ramming, depending on their respective design. Systems of this type require a permit from your local water board.
Drillings up to a depth < 100 metres are subject to approval from your local water authority. Drillings > 100 meters must be approved by your local mining board.
A specialist contractor should be engaged to carry out the drilling work, with whom the extract rate guarantee should be contractually agreed (e.g. for 10 years).
Actual tests have proven that, given sound hydro-geological conditions, particularly where flowing groundwater is present, a mono-mode heat pump operation is possible without permanent cooling of the ground.
Detailed knowledge of ground conditions, the sequence of earth layers, the ground resistance as well as the presence of ground or stratum water with a precise determination of the water level as well as its flow direction are pre-requisites for the planning and introduction of ground probes.
Given standard hydro-geological conditions, a ground probe system can be assumed to provide a mean probe output of 50 W/m length of probe (acc. to VDI 4640). If the probe is installed in a rich seam of groundwater higher extraction rates could be achieved.

Figure 7: Design criteria for ground probes /2/

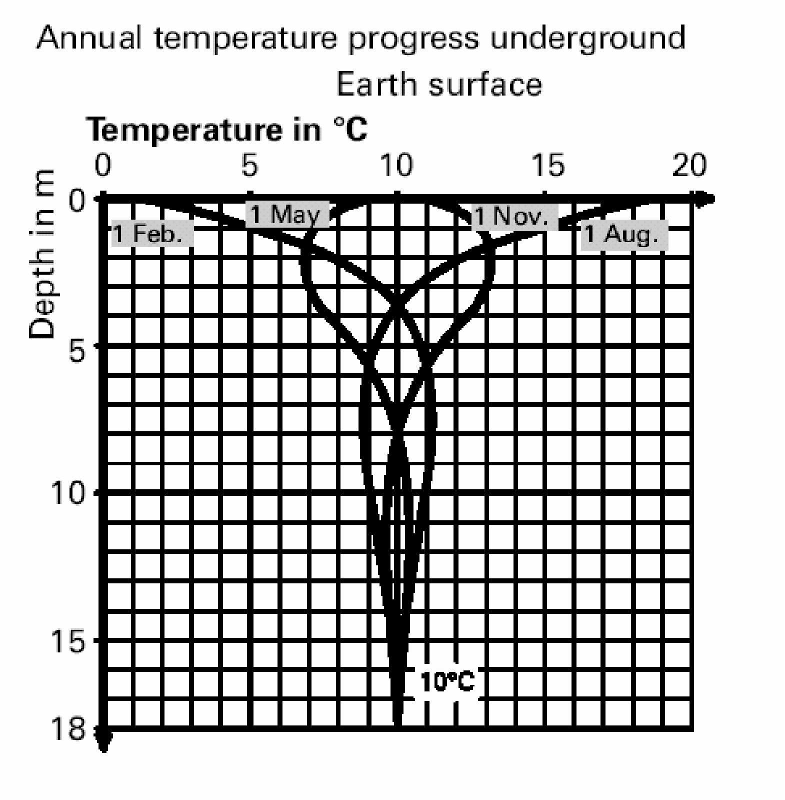
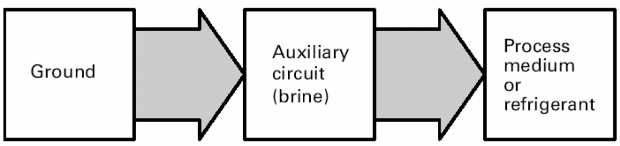


Figure 8: Ground temperatures according to VDI 4640

Ground collector

Heat flow from the ground



Energy is transferred via horizontal collectors or via ground probes.
This energy is transferred from the soil to the auxiliary circuit (brine circuit), which in turn transfers the energy to the process medium inside the heat pump.

Ground as energy source means the upper earth layer down to a depth of 1.2 to 1.5 m (see page 5). Energy is recovered with the help of a heat exchanger which is laid into an area without building structures near to the building to be heated.
The energy flowing from deeper layers only amounts to 0.063 to 0.1 W/m^2, and can be ignored as energy source for the upper layers.
The available energy volume and, therefore, the dimension of the necessary area greatly depends on the thermo-physical properties of the relevant ground as well as on the irradiation energy, i.e. on climatic conditions.

The thermal properties, such as the volumetric thermal capacity and the thermal conductivity, are very much subject to the consistency and make-up of the ground.
Magnitudes, such as the water proportion, the proportion of mineral constituents, such as quartz or feldspar, as well as the proportion and size of the air-filled pores are important to the sizing calculations.
To put it simply, the storage characteristics and heat conductivity are greater, the more water the ground contains, the higher the mineral content and the lower the proportion of pores.

The extract capacity for ground lies between approx. 10 and 35 W/m^2.

Dry sandy soil	q_E = 10-15 W/m^2
Damp sandy soil	q_E = 15-20 W/m^2
Dry loamy soil	q_E = 20-25 W/m^2
Damp loamy soil	q_E = 25-30 W/m^2
Ground with groundwater	q_E = 30-35 W/m^2

This determines the necessary ground area, subject to the heat demand of the house and the ground structure.
The necessary ground area is calculated in accordance with the refrigeration capacity $\dot{Q}_K$ of the heat pump:
Difference between the heat pump output ($\dot{Q}_{WP}$) and its power consumption (P_{WP}).

$$\dot{Q}_K = \dot{Q}_{WP} - P_{WP}$$

Figure 9: Design criteria for ground collectors (no standard) /2/

Groundwater/water heat pumps achieve high performance factors. All the year round, groundwater has an almost constant temperature of 7 to 12 °C (see fig.). Compared with other heat sources, the temperature level needs to be raised only a little higher to be useful for heating purposes.
However, it is recommended – this applies to detached and semi-detached houses – that the groundwater is not pumped from depths greater than approx. 15 m (see recommended dimensions in the bottom figure). Otherwise, the investment for the lifting equipment would be too high. Commercial or large scale systems may find that pumping even from greater depths could still be viable.

Maintain a clearance of 5 m between the supply well and the return well. Supply and return wells must be aligned in the flow direction of the groundwater to prevent a "flow short circuit" (see fig.). Construct the return well so that the water exists below the groundwater level.

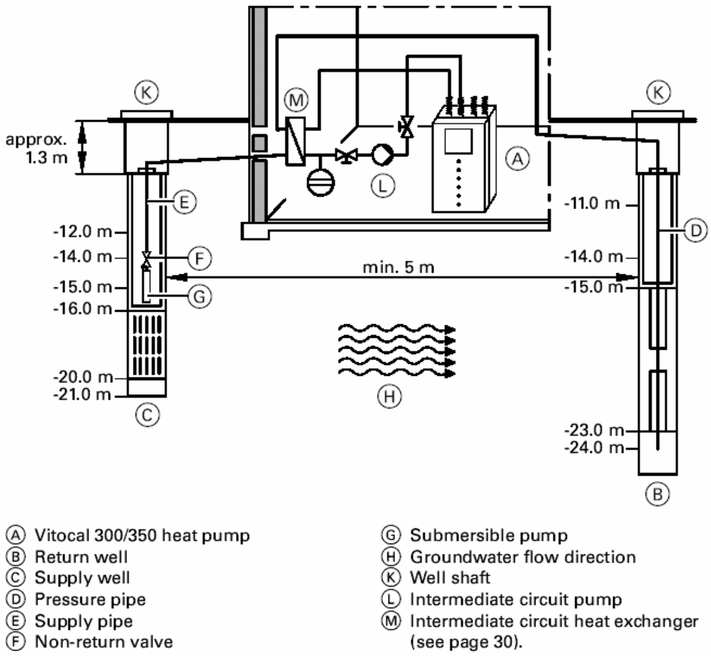


Figure 10: Design criteria for ground water heat-pumps (no standard) /2/

In many regions, ground water heat-pumps need the permission of local authorities /2/. The Approval may be subject to certain conditions. Insofar as connection and use of public water supply are compulsory, a permit for the utilisation of groundwater as heat source may be required from the parish council.

4 Electric power supply

3.12 Power supply and tariffs

According to current Federal tariffs (in Germany), the electrical demand for heat pumps is considered domestic usage. Where heat pumps are used to heat buildings, the local power supply company may have to grant an appropriate permission.
Check the connection conditions required by your local power supply company. It is particularly relevant to establish whether a mono and/or mono-energetic operation using a heat pump is feasible.
Information about basic and work prices, about the possibility of using a cheaper night tariff and possible off-periods are important when designing your system. Address any questions relating to these issues to your client's local power supply company.

Application procedure

To assess the effects of operating heat pumps on the mains supply system of your local power supply company, the following details are required:

- User address,
- location where the heat pump is to be used,
- type of demand acc. to general tariffs (household, agriculture, commercial, professional and other use),
- intended heat pump operation,
- heat pump manufacturer,
- type of heat pump*1,
- supply rating in kW*1,
- max. start-up current in ampere (manufacturer's details)*1,
- max. heat demand of the building in kW.

Requirements regarding the electrical installation of heat pumps

- Observe the technical conditions of supply stipulated by your local power supply company.
- Your local power supply company will supply you with information about the required monitoring and switching equipment.
- Provide a separate electricity meter for the heat pump.

Viessmann heat pumps operate with
- 400 V~ for the heat pump and
- 230 V~ for the control voltage circuit. The 6.3 A fuse for the control voltage circuit is integrated into the control panel.

Figure : Information about power supply and tariffs /2/.

5 Refrigerants

Refrigerants with F and Cl are forbidden in Germany (like R 22).
End of 2002 the German ministry for environment published a paper where a prohibition of F-gases is discussed. The reason is that during the Kyoto conference the German government promised to reduce CO_2 emissions /4/.

6 What is missing in EN 255?

Combined hot water production and heating:

- Part load buffering in the DHW storage tank
- Combination of heat-pumps with solar thermal systems

Combined ventilation and heating:

- EN 255 is not valid for exhaust air heat pumps with variable air flow rate.
  Suggestion: determine the air flow rates according to DIN EN 13141.
- The ventilation heat exchangers for the heat recovery are tested according to EN 308. Unfortunately this gives different measurement points than EN 255 for exhaust air heat pumps.
- Combined use of exhaust air and ambient air as a heat source for the heat pump is not regarded. This is of special interest for heating systems in ultra-low energy houses an passive houses.

General

- Comparison of electric heat pumps, thermal boilers and thermal heat pumps: The annual performance of electric heat pumps is calculated with VDI 2067, No. 6. There is no direct comparison to other heating systems (gas, oil, biomass) DIN 4702/8 and direct electric heating systems (EnEV).

7 Suggestions for a calculation method

We suggest the different methods for the standard. All methods should be based on the comparison of primary energy use:

7.1 Diagram determination method

It should be possible to define a standard diagram (or table) calculation method, for example as it is given in DIN 4701-10. This method is sufficient for standard systems.
To do: A detailed review of the heating demand is necessary for a final evaluation of this method.

7.2 Simplified calculation method

A method as presented by C. Wemhoener (similar to VDI 2067) should be sufficient for more complex systems. This values lead directly to an annual performance which may be used in characterising the heat-pump in a building (method of EnEV). As it has been shown in a

study /5/ there is almost no difference of the calculation according to DIN 4702/8 and VDI 2067 when the full load is taken into account. But usually for the characterisation of oil or gas boilers the full load point is not regarded.
To do: The method has to be verified (an possibly extended) for a comparison with boilers (and other heating systems).

7.3 Detailed calculation method

For standard systems the detailed calculation is not necessary. But a new EN 255 should be open for other systems and give the opportunity to calculate them on a daily / hourly basis or more detailed dynamic simulations.

For the daily method, the heating demand for each day is calculated by a static model from the heat losses and gains of the house /6/. The hot water demand is given per day.
The heating system has to cover the energy demand of the day. The heating power is determined by a static model from average source and sink temperature for the day. If the heat-pump is not able to cover the energy demand, an additional heat source is switched on (dual-mode parallel) or the heat pump is switched off according to source temperatures (dual-mode bivalent). Energy demand of the control, pumps and fans is determined per day. Solar thermal collectors of other heat sources can be included in the model.

For more detailed dynamic simulations, an extension of the MATLAB-Carnot models would be helpful. Possibilities today:

- Linear heat pump model (suitable for brine / water and water / water heat-pumps)
- Refrigerant properties
- Properties of humid air

Future extensions (and possible contributions to Annex 28):

- Detailed compressor model
- Detailed models of heat exchangers as evaporator, condenser, de-superheater und sub-cooler
- Condensing and freezing model of air heat exchangers
- Simple model of air to water heat-pump with appropriate corrections for defrost mode

8 Literature

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