climate of innovation

Technical manual

Heat pumps

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Heat pumps

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Foreword

Climate protection and the provision of futureproof affordable energy are two of the most serious challenges of our time. In order to prevent the atmosphere from heating up further, emissions of greenhouse gases, among them particularly CO_2, must be minimised. This can only be achieved through a significant reduction in the consumption of fossil fuels. This reduction is unavoidable – quite apart from efforts to reduce the effects of climate change – because these resources are finite. Although supplies will still be available for the foreseeable future, prices will continue to rise. Consequently, improving energy efficiency and extending the scope of renewables are key areas of interest.

Politicians have determined ambitious goals for both climate protection and saving energy. The heating sector, as the largest consumer, can make a substantial contribution to these aims. It is, therefore, essential that existing outdated and inefficient heating equipment is replaced as soon as possible. The technology required for this is available right now.

The comprehensive range from Viessmann not only offers highly efficient condensing technology for oil and gas, but also biomass boilers, solar thermal systems and heat pumps for any application area.

Over the past few years, heat pumps have established their place in the heating technology sector. Their share of the new build market is now equal to that of gas condensing systems. However, in modernisation projects, too, heat pumps are gaining in importance. Correctly sized and installed, they can provide heat economically in almost any building and for almost any requirement, whilst treating resources as carefully as possible.

Viessmann expects that in the years to come, heat pumps will play an even greater role in our industry. Firstly, product development continues apace. Large heat pumps can cover additional types of buildings and commercial applications. In the lower output ranges, there is a clear trend towards more compact solutions that make engineering and implementation significantly easier. Our trade partners can be sure that everything fits together as it should. Secondly, an increasing number of heating contractors feel more confident with this technology that is still rather unfamiliar to many. I'm glad that, with this technical manual, we can support our trade partners to propel them to even greater success.

Dr Martin Viessmann

Introduction

This manual provides important information concerning the engineering, layout and operation of heat pump systems. It is intended to be a work of reference as much as a training manual and consultation guide.

How to use this manual

Compared with conventional heat generators, heat pumps are complex machines that require detailed explanation in order to be properly understood, not only by end users, but also by heating contractors and design engineers alike. The basic functions of a boiler operating with oil, gas or biomass, are fairly comprehensible. With heat pumps, however, many fail to overcome the paradox that a "cold" primary source – such as the ground, groundwater or ambient air – can provide heat that is useful for heating the interior of a building. This manual, therefore, dedicates much of its attention to the explanation of the working principles of this fascinating technology.

The following illustrations and descriptions aim to raise the level of understanding of the workings of the most important heat pump system components. Consequently, the diagrams illustrate working principles, and should not be seen as complete installation instructions. These are found in the product documentation, the appliance-specific technical guides and the Viessmann scheme browser.
Information on practical implementation is only represented in this manual if there are specific considerations that must be taken into account when installing heat pump systems.

All other electronic engineering aids mentioned in the following chapters, such as the engineering programs, for example, are available to Viessmann trade partners from their sales engineer contacts; alternatively, they can be downloaded from the internet.

A Principles of heat pump technology

Heat pumps can exploit the latent heat in the environment, bringing it up to useful temperatures. Their potential is almost limitless.

Generally, we perceive warmth as a feeling rather than something quantifiable. We sense that a sunny summer's day, or a cosily heated house in winter is warm and a winter's day or an unheated house is cold.

Scientifically speaking, however, down to absolute zero (0 K = -273.15 °C) matter still contains heating energy.

Heat pumps are able to raise this energy to a useful temperature level.

This chapter explains the principles behind this technology and also describes the essential components of a heat pump.

Viessmann heat pump L-08
from 1981

History of heat pump development

The history of the heat pump goes back much further than is commonly thought. The advanced equipment we use today has its origins in the first refrigeration machines developed almost two centuries ago.

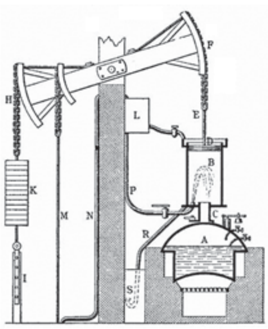


Fig. A.1–1 Newcomen steam engine

For thousands of years, heat was used mainly to heat interiors, to prepare food and to smelt metals.

The invention of the steam engine in the early 18th century brought a further use that revolutionised the world – it converted heat into a mechanical force. To this day, our productivity, mobility and comfort rely on the exploitation of this principle.

Steam engines were known for decades, however, before a proper scientific understanding of the correlation between heat and power was attained.

The findings of Nicolas Léonard Sadi Carnot, generally acknowledged as the "Father of thermodynamics", were of fundamental importance. He investigated cause and effect in steam engines and discovered that all processes involved the conversion from heat into power were generally reversible.

Given the right heat transfer medium, and by applying energy, not only can heat be added to a medium, it can also be extracted from the same – independent of the ambient temperature.

The American, Jacob Perkins, was the first to succeed in implementing this principle. He applied for a patent for one of the earliest compression refrigeration machines in 1835. Until that time, technical temperature reductions were only possible through negative pressure – a discovery that went back to the middle of the 18th century.

All principle components used in modern refrigeration machines and heat pumps can be found in the machine designed by Perkins: a compressor, heat-absorbing and heat-transferring components and a pressure reducing facility. It used ether as its heat transfer medium, which enabled it to achieve temperatures below freezing point. John Gorrie, who received the patent for his ice machine 1851, and James Harrison, who developed the first commercially viable applications (for cooling foodstuffs) brought the idea along further still. The discovery of ammonia as a heat transfer medium by Ferdinand Carre enabled highly explosive ether to be replaced in refrigeration machines in 1859, making their operation far more safe. During the final decades of the 19th century, refrigeration technology established itself in industry, whilst the first decades of the 20th century saw the first refrigerators designed for use in the home.

William Thomson Kelvin provided proof in 1852 that you can also heat with a refrigeration machine and that, by utilising heating energy from the ambience, overall less energy needs to be employed than systems combusting wood or coal. However, it took around 100 more years before the heat pump was first used in building technology.

Fig. A.1–2 Nicolas Léonard Sadi Carnot

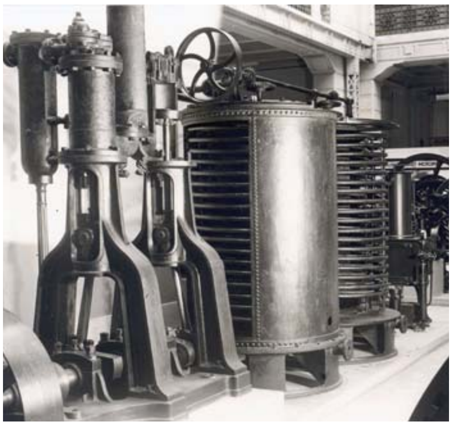
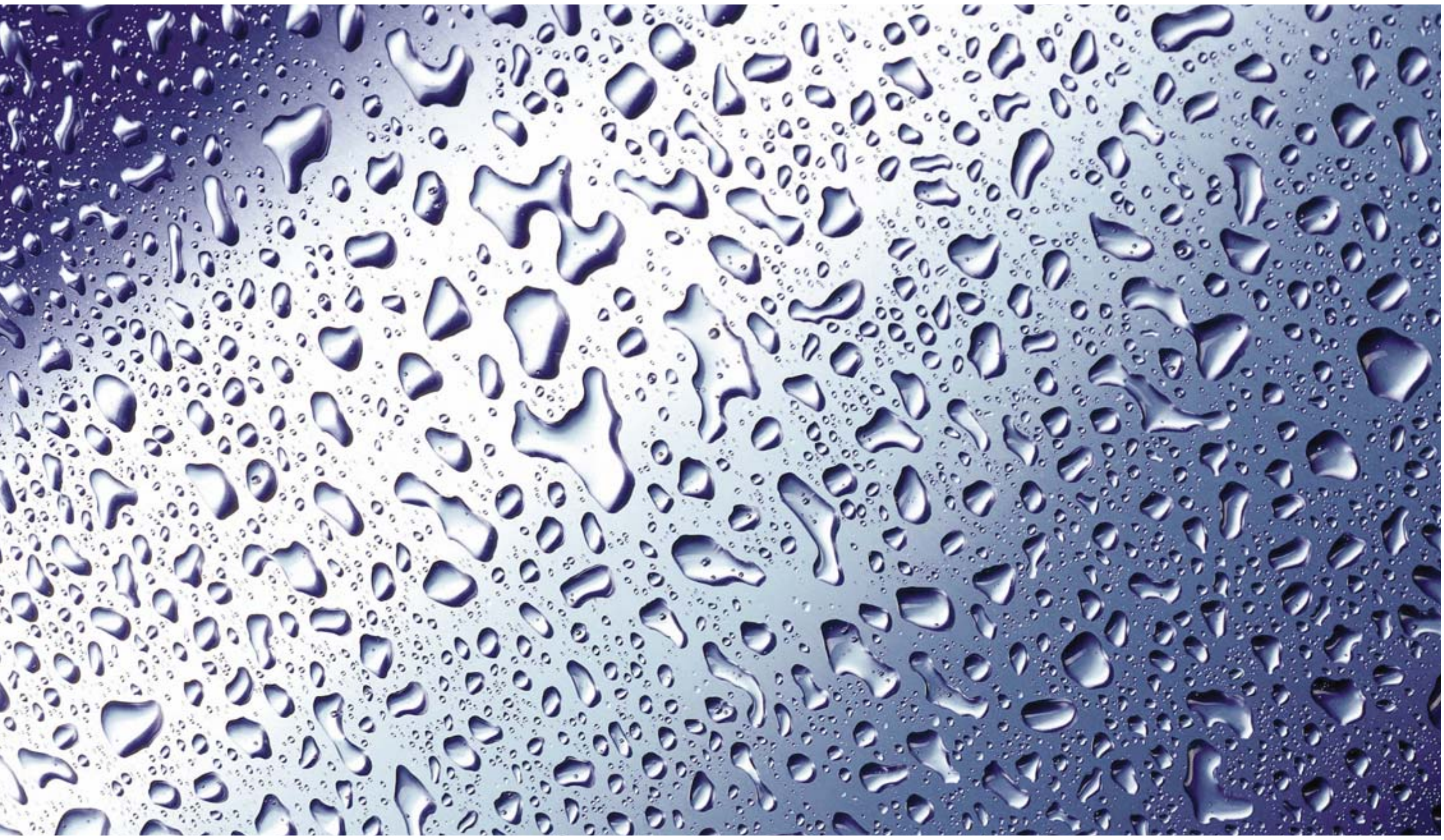


Fig. A.1–3 Linde refrigeration machine from 1877

Following the oil crisis of the 1970s, heat pumps had their first boom in Germany. When oil prices fell again during the 1980s, demand for heat pumps also fell rapidly. Advanced heat pumps, as we know them today, have only been established in the domestic technology sector for about ten years.

Until now, electricity has remained the main driving force for the compressor; in the higher output ranges combustion engines have also been used for the past 30 years, the heat of the exhaust gases also being brought into the heating supply system.



Physical principles

Heating technology in applied situations does not generally have to concern itself with the physical principles of heat generators.

In most cases it is sufficient to observe the technical rules in order to ensure reliable engineering, installation and commissioning. However, it is useful to take a look at the physical correlations, in order to better understand the conditions under which a heat generator, particularly a heat pump, can be best used.

Heat is one form of the inner energy of matter, or in thermodynamic terms, of a system. A heat flux is created where there is the possibility of this energy transferring to another substance (a different system). This always flows towards the lower temperature and never the other way round, i.e. this flow is non-reversible.

A vessel filled with boiling water, for example, will cool down under normal ambient temperatures until it has reached the same temperature as the ambient air. Heat pumps cannot change this law of physics. Instead, they use a different effect, i.e. energy that is brought into a substance does not only lead to an increase in temperature, but also to a change in its aggregated state.

For example, if additional energy is supplied to the vessel containing boiling water, then it will evaporate without increasing its temperature. The amount of energy involved in this change of state is the "secret" with which the heat pump yields energy at a useful temperature level from a "cold" heat source.

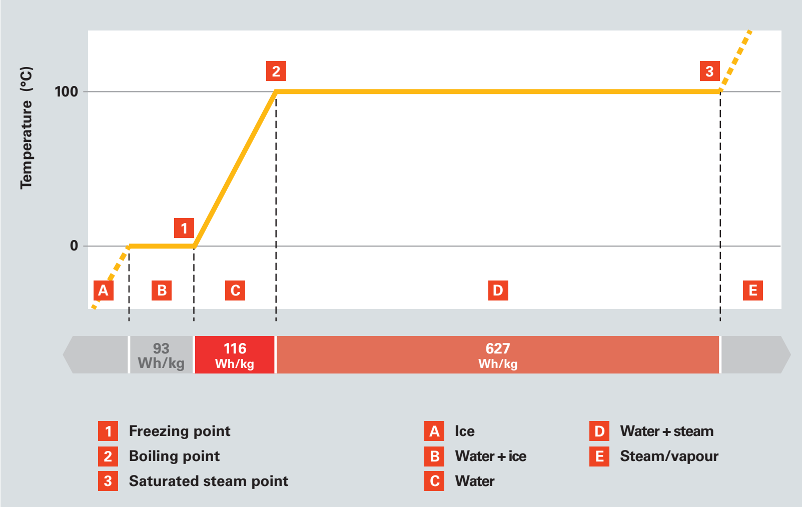
A.2.1 Condensing and evaporating

Condensing and evaporating are two central processes that take place inside a heat pump. "Condensing" describes the phase change of a gas or gas mixture into its liquid aggregation state. "Evaporation" describes the phase change of a liquid or liquid mixture into its gaseous aggregation state.

The amount of energy required for evaporating a liquid differs depending on the substance involved – known as evaporation enthalpy. The evaporation enthalpy is transferred back to the ambience as condensation heat, when the condensing temperature is undershot. Under static pressure conditions, the phase changes are isothermal, i.e. the liquid temperature – irrespective of whether liquid or gaseous – remains unchanged.

Fig. A.2.1–1 shows that 116 Wh of energy is required to raise one litre of water from 0 °C to 100 °C. So it can be deduced that increasing the water temperature by 1 °C requires 1.16 Wh. If the water temperature exceeds 100 °C under normal atmospheric conditions, the water will have to be evaporated completely. In order to achieve that, 627 Wh is required, in other words, more than 500-times the amount of energy will be needed. The same amount of energy will be released, when water vapour condenses again.

Fig. A.2.1–1 Energy content of steam



Heating 1 litre (kilogram) of water to boiling point requires 116 Wh. A further 627 Wh are required to fully evaporate the water (saturated steam point).

Note

Technical literature frequently refers to energy in thermodynamic systems in units of kilojoules (kJ). However, in this manual, watt-hours (Wh) are used.

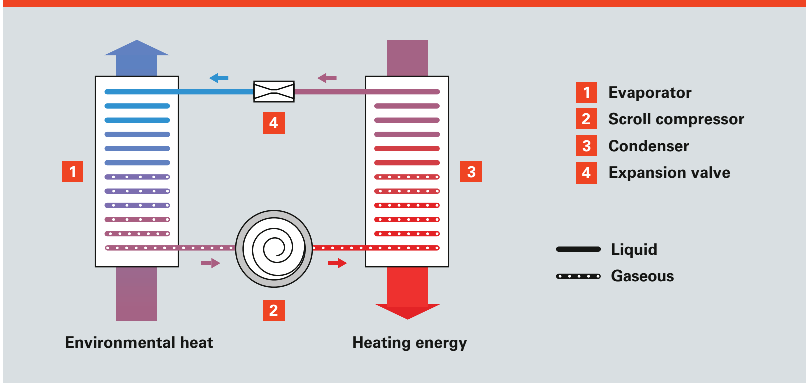
1 J = 1 Ws
3.6 kJ = 1 Wh
3600 kJ = 1 kWh

A.2.2 Refrigerant circuit

Heat pumps work according to this basic principle: The absorption of heat through evaporation at a relatively low temperature is transferred again at a higher temperature level through condensation. These phase changes take place under constant pressure, but without changes in temperature (isothermal). Consequently, the pressure must be increased through the application of mechanical energy in order to reach a higher temperature level.

Fig. A.2.2–1 shows the four stages of a typical circular process in a compression heat pump.

Fig. A.2.2–1 Heat pump function



The refrigerant evaporates at low temperatures and in the process absorbs heat. Compression increases the vapour temperature and the heat is then transferred again through condensation.

Note

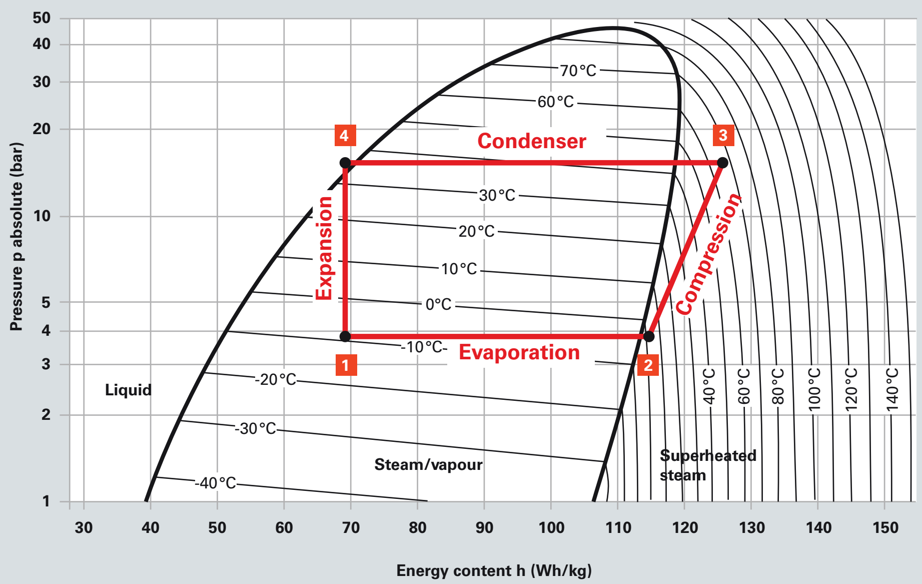
The technical term for the energy content in a thermodynamic system is enthalpy [h] (Greek: en = in and thalpein = to heat).

To aid understanding, this circular process can be illustrated in a pressure/enthalpy diagram (Fig. A.2.2–2). This marks off the pressure (p) logarithmically on the Y axis.

Appliances that employ this process are differentiated according to their use. If the use of the appliance lies on the evaporation side, in other words, involving the extraction of heat, then we are talking about a refrigeration machine. Where the utilisation lies on the condensing side, i.e. the transfer of heat, then we are looking at a heat pump. In general, every refrigeration machine can provide heating and every heat pump can provide cooling.

The log p,h diagram applied in this example shows the physical properties of the R 407C refrigerant used in Viessmann air/water heat pumps.

Fig. A.2.2–2 The log p,h diagram



As part of the heat pump operation, the refrigerant undergoes the following changes in state:

1–2 Evaporation
The refrigerant evaporates. The energy required for this (evaporation enthalpy) is extracted from the environment, e.g. from the outdoor air.

2–3 Compression
With the aid of its drive energy, the compressor raises the pressure and thereby the temperature of the refrigerant vapour. The enthalpy (the energy content) increases.

3–4 Condensing
The refrigerant vapour condenses. During this change, the environmental energy that has been absorbed, plus the drive energy drawn by the compressor, is transferred again.

4–1 Expansion
The refrigerant is expanded, in other words the temperature and pressure of the refrigerant are returned into their original state by means of an expansion valve. The medium can again be evaporated and the process starts again.

A.2.3 Coefficient of performance (COP)

The coefficient of performance is a measure of efficiency and is defined as the ratio between cost and benefit. In relation to a heat pump, this is defined as follows: The benefit is the amount of heat transferred at a high temperature level (condensation), the cost is the drive energy (compression) required to achieve this. For heat pumps, the level of efficiency is expressed as a coefficient of performance – the English abbreviation, COP, is commonly used).

Applying the log p,h diagram, the coefficient of performance of a heat pump is defined as follows:

$$COP = \frac{h3 - h4}{h3 - h2}$$

COP coefficient of performance
h2 enthalpy at the start of compression
h3 enthalpy at the end of compression / start of heat transfer
h4 enthalpy at the end of condensation / end of heat transfer

Example

For the example (red line) in Fig. A.2.2–2 the coefficient of performance is calculated as follows:

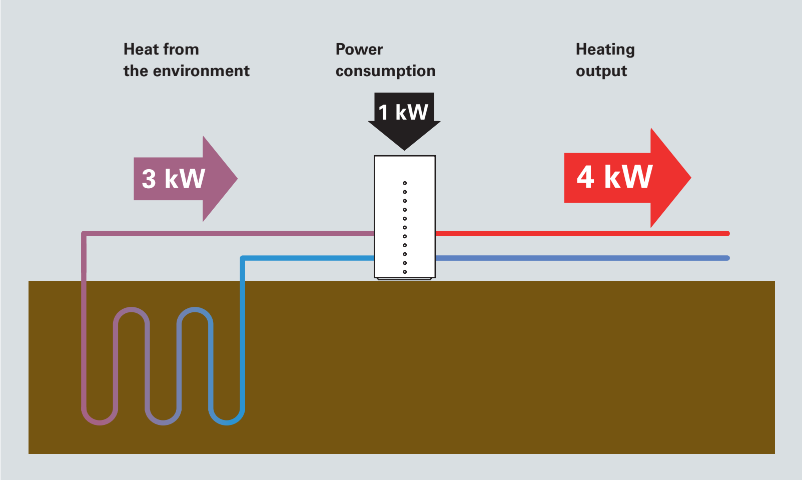
COP = coefficient of performance
2 h2 = 114 Wh/kg
3 h3 = 126 Wh/kg
4 h4 = 69 Wh/kg

$$COP = \frac{126\ \text{Wh/kg} - 69\ \text{Wh/kg}}{126\ \text{Wh/kg} - 114\ \text{Wh/kg}}$$

In this example the heat pump, therefore, has a calculated refrigerant circuit COP of 4.75.

The coefficient of performance of modern heat pumps lies between 3.5 and 5.5. A coefficient of performance of 4 means, for example, that four times as much energy is transferred as useful heating energy than was expended in the form of electrical energy.

Fig. A.2.3–1 The efficiency level as coefficient of performance



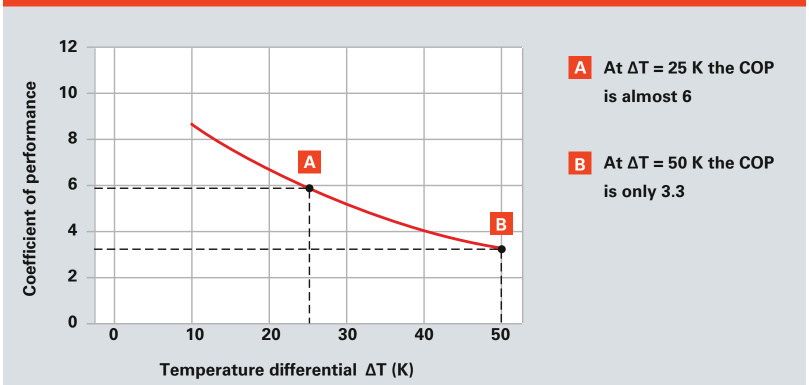
The heating output transferred in this example is four times higher than the expended electrical energy.
The COP is 4.

The lower the temperature differential between the heating circuit flow temperature and the heat source inlet temperature, the higher the coefficient of performance.

The following rule of thumb applies:

- Flow temperature 1 K lower → COP 2.5 % higher
- Source temperature 1 K higher → COP 2.7 % higher

Fig. A.2.3–2 Temperature differential and coefficient of performance



In order to provide comparable coefficient of performances for heat pumps, calculations are made in accordance with DIN EN 14511 and measurements taken at fixed operating points. The operating point is the product of the inlet temperature of the heat source medium (air A, brine B, water W) in the heat pump and the heating water outlet temperature (secondary circuit flow temperature).

For the following heat pump types, the operating points below apply:

Type	**Inlet temperature, heat source**	**Secondary circuit flow temperature**
Air/water	A 2 °C	W 35 °C
Brine/water	B 0 °C	W 35 °C
Water/water	W 10 °C	W 35 °C

A stands for air
B stands for brine
W stands for water

The standard takes the drive output of the heat pump, plus the power consumption of the heat pump control unit, as well as a proportion of auxiliary energy into account, that is required in order to overcome the internal pressure drop of both heat exchangers.

A.2.4 Seasonal performance factor (SPF)

Note

At www.viessmann.com the seasonal performance factor calculator is available to use with heat pumps.

The coefficient of performance (COP) is the ratio between the heating output and the power consumption at a single operating point. The seasonal performance factor is this ratio over a period of 12 months.

The coefficient of performance is used to compare heat pumps with regard to efficiency, yet it is derived from a particular operating point under defined temperature conditions.

For engineering purposes (for example, to be able to specify the consumption costs arising from using a heat pump), it is necessary to consider the system's operation over the whole year. For this, the heat volume transferred over the year is given in relation to the overall electrical power drawn by the heat pump system over the same period.

This includes the amount of power used by pumps, control units, etc. The result is given as the seasonal performance factor β:

$$\beta = \frac{Q_{WP}}{W_{EL}}$$

β seasonal performance factor
Q_{WP} amount of heat in kWh delivered by the heat pump over the course of a year
W_{EL} electrical power in kWh supplied to the heat pump over the course of a year

For forecasting purposes, the simplified calculation process according to VDI guideline 4650 has become the established norm. The so-called BIN process to DIN 18599 is significantly more accurate, but also more complicated.

Main components

Excellent heat pump systems are characterised by their efficiency and operational reliability. This requires the choice of tried and tested components that interact perfectly – from heat source to heat transfer.

The primary circuit of a heat pump includes all of the components that are required for the absorption of environmental energy – e.g. the heat exchangers, brine pumps or fan motors; in the case of water/water heat pumps also the intermediate heat exchangers.

The secondary circuit includes all components required to transfer the energy gain to the consumer.

A.3.1 Compressor

The compressor is the part of the heat pump that acts as the "pump" – it sucks in and compresses the gaseous refrigerant. All compressors are designed to compress gases and would be damaged if liquid droplets in the vapour were to be drawn in. The vapour must therefore be slightly superheated prior to entering the compressor. This superheating is regulated by the expansion valve, the accurate control of this component being vital to overall heat pump efficiency.

A.3.1.1 Compressor types

The effectiveness of the compression process is crucial to the efficiency of a heat pump. Scroll compressors really come into their own when used in heat pumps. This type of compressor is comprised of two interlocking spirals which compress the refrigerant. Scroll compressors operate quietly and with low vibrations; they are maintenance free and extremely durable.

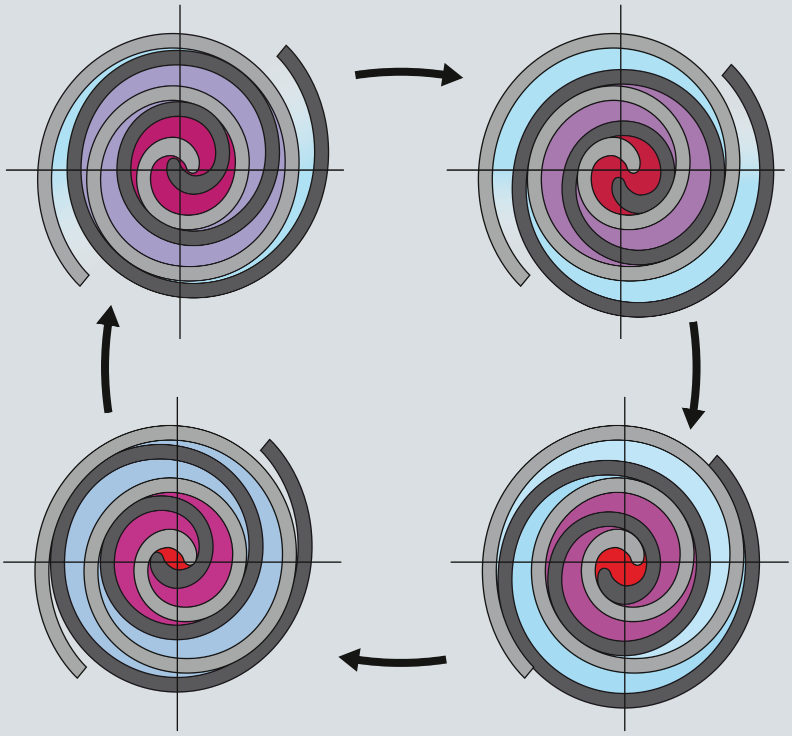
Rotating piston compressors, reciprocating piston and screw compressors are also used. Rotating piston compressors tend to cover the lower output ranges, scroll compressors the low to medium and screw compressors the higher output range.

Fig. A.3.1–1 The scroll compressor

The scroll compressor features two interlocking spiral blocks – one static and one moving.

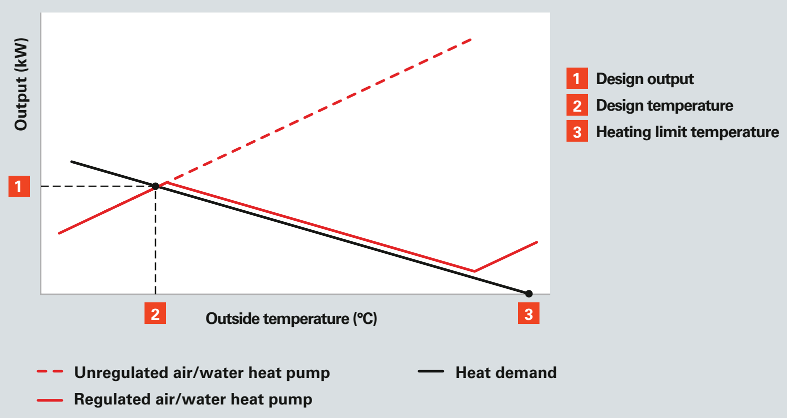
The moving spiral block makes an eccentric rotation, during which three processes take place simultaneously:

- intake (blue segments),
- compression (violet segments),
- expulsion (red segments).



Static spiral block
Moving spiral block

Fig. A.3.1–2 Output control



The heat pump output is matched to the prevailing demand to prevent frequent cycling.

A.3.1.2 Output control

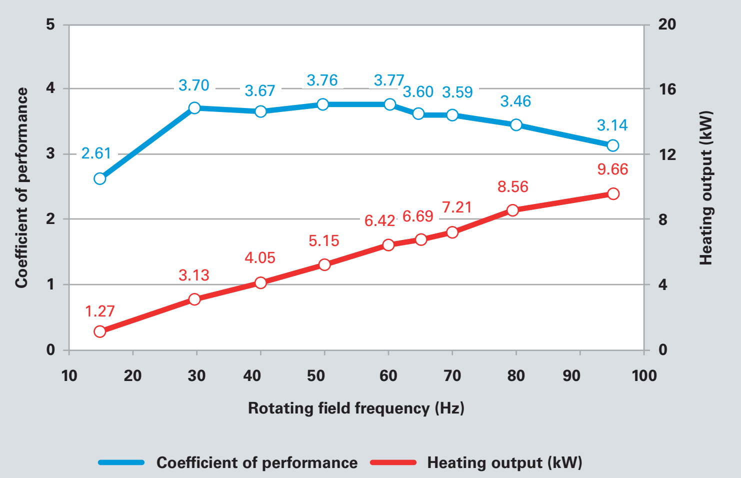
The importance of output control in compressors is gaining in significance. For heat pumps operating with outdoor air as a primary source, output control is particularly suitable, as with this type of heat source major fluctuations in the seasonal performance factor can occur.

In addition, there is a counter-acting trend between output demand and output provision – the colder the outdoor air heat source, the higher the demand for heating energy, and the greater the temperature differential between source and available temperature with corresponding implications for the COP. If the outside temperature increases, the heat demand falls whilst the appliance output rises. In order to prevent frequent cycling of the heat pump, its output is matched to these framework conditions. The compressor output – and consequently also the refrigerant pressure and temperature – are regulated accordingly.

Output control can be achieved by several means. The most frequently applied method for regulating the compressor output involves the deployment of inverter technology – this generates a DC current from the supply voltage (e.g. 230 V ~). Subject to the frequency of the rotating field, the compressor will operate at different speeds and consequently deliver different output ratings. Particularly in partial load operation, inverter compressors operate with a high degree of efficiency.

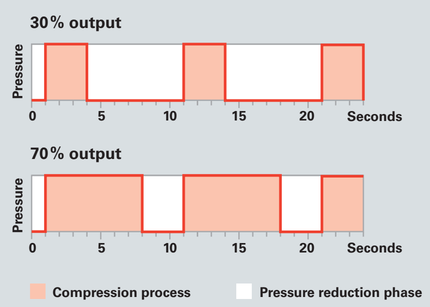
The output control principle becomes apparent upon inspection of these actual values: the heating output is raised as the speed increases.

Fig. A.3.1–3 Inverter compressor for controlled output



Example

Compressor with output control through pressure reduction valve



Output control via a pressure reducing valve in the compressor is another option.

If the solenoid valve opens, the compressor runs without pressure, consequently there is no heating output. Subject to the duration of runtimes, with and without pressure, the output can be regulated between 30 % and 100 %.

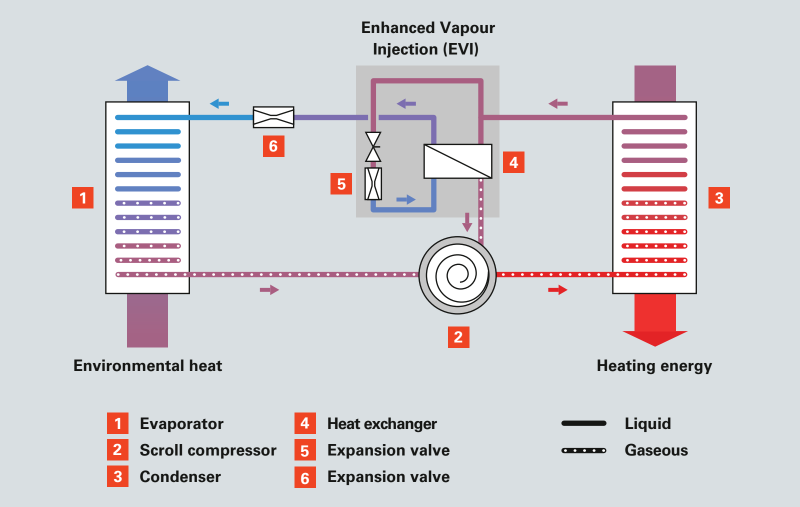
A.3.1.3 Enhanced Vapour Injection – EVI

In buildings, the target temperatures in the secondary circuit are determined by the required heating surface and DHW temperatures. Enhanced Vapour Injection (EVI) into the compressor may be used in order to enable operation, even when there are significant temperature differentials between the source and useful temperature.

The maximum temperature that commercially available refrigerants may reach in the compression process is currently 135 °C; temperatures that are any higher would damage the compressor. With Enhanced Vapour Injection (EVI), the compressed refrigerant vapour is cooled. This happens at a point where compression has been approximately two thirds completed (see Fig. A.3.1–4 and Fig. A.3.1–5).

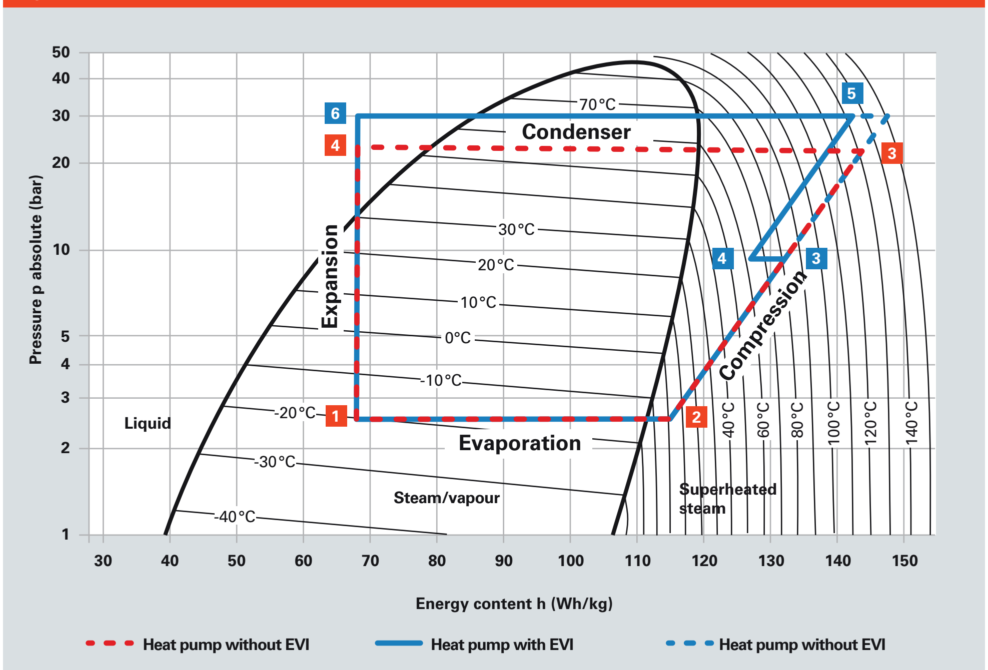
Standard solutions without EVI achieve a temperature rise of 60 K, however with EVI a rise of 80 K can be achieved. Vapour injection enables a flow temperature of 65 °C to be reached, even with low heat source temperatures. This makes EVI particularly appropriate for use with air/water heat pumps, as lower source temperatures can be expected than with geothermal heat or groundwater, for example.

Fig. A.3.1–4 Enhanced Vapour Injection (EVI)



Some of the refrigerant is used downstream of the condenser (3) in order to generate vapour with the aid of an additional heat exchanger (4) and an additional expansion valve (5). This vapour is then injected directly into the compressor (2). This happens at a point where compression has been approximately two thirds completed. EVI cools the refrigerant vapour that has been compressed up to this point.

Fig. A.3.1–5 EVI effect



A heat pump without EVI (red line) can achieve a flow temperature of only 55 °C at a source temperature of –10 °C, since the compression process must stop at 135 °C. EVI (3 to 4, blue line) cools the refrigerant. The pressure can continue to be increased without exceeding the permissible maximum temperature. A flow temperature of 65 °C can be achieved.

The thermostatic expansion valve is hydraulically regulated via a capillary tube.

Fig. A.3.2–1 Thermostatic expansion valve

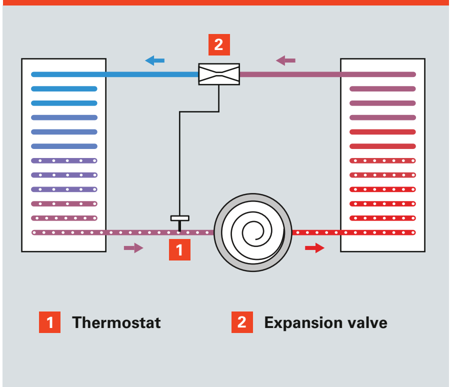
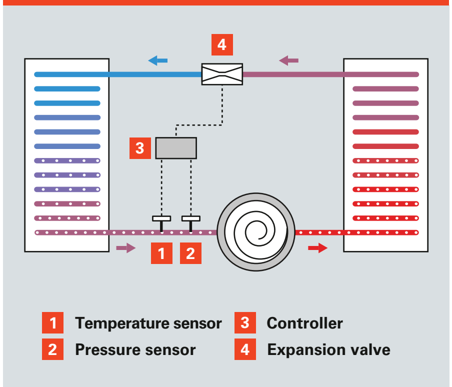


Fig. A.3.2–2 Electronic expansion valve

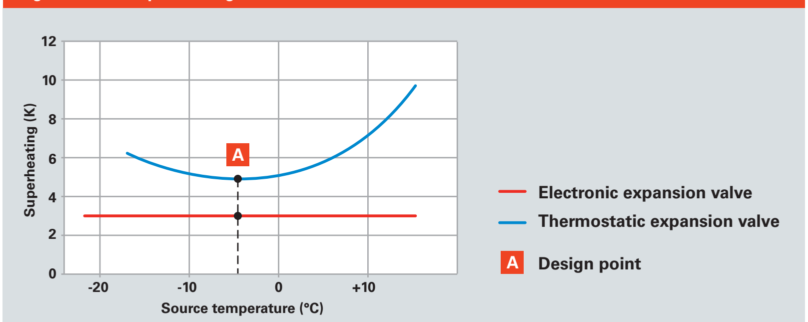


A.3.2 Expansion valve

In the heat pump circuit, the expansion valve has the job of expanding, i.e. reducing the pressure of the liquid refrigerant post heat transfer to the heating system, when the refrigerant is still under high pressure. Consequently, the refrigerant is used in a state that enables the renewed absorption of environmental heat. In order to prevent liquid from entering the compressor, the expansion valve regulates the amount of refrigerant (refrigerant mass flow rate) so that only as much refrigerant enters the evaporator as can be fully evaporated there. The valve ensures that only superheated vapour enters the compressor.

Fluctuations in the source temperature and output necessitate the use of a regulated expansion valve, since the pressure within the refrigerant circuit and consequently also the required temperature changes upstream of the compressor.

Fig. A.3.2–3 Superheating



A.3.2.1 Thermostatic expansion valve

The thermostatic expansion valve is a temperature-controlled valve. It captures the temperature of the suction line to the compressor and regulates the refrigerant metering into the evaporator accordingly.

A.3.2.2 Electronic expansion valve

The electronic expansion valve captures the temperature, as well as the pressure, upstream of the compressor. An electric servomotor inside the expansion valve enables fast and precise control of the refrigerant mass flow rate, resulting in the superheating (in Kelvin) being able to be held constant across the entire range of the compressor output.

Thermostatic expansion valves, on the other hand, only achieve the minimum required superheating at their design point; superheating in all other operating points will be higher.

However, the higher the temperature of the superheated refrigerant, the lower the maximum possible temperature at the condenser (see Fig. A.3.1–5). In addition, the compressor needs to work harder and the heat pump efficiency drops.

The electronic expansion valve quickly and accurately controls the refrigerant mass flow rate, keeping superheating constant across the entire output range.
The thermostatic expansion valve only achieves optimum superheating at the design point – at all other operating points superheating will be too high.

A.3.3 Heat exchanger

This chapter describes the fundamental properties of the heat exchangers in a heat pump. Different heat pump types, some already mentioned above, are described in chapter A.4.

A.3.3.1 Evaporator

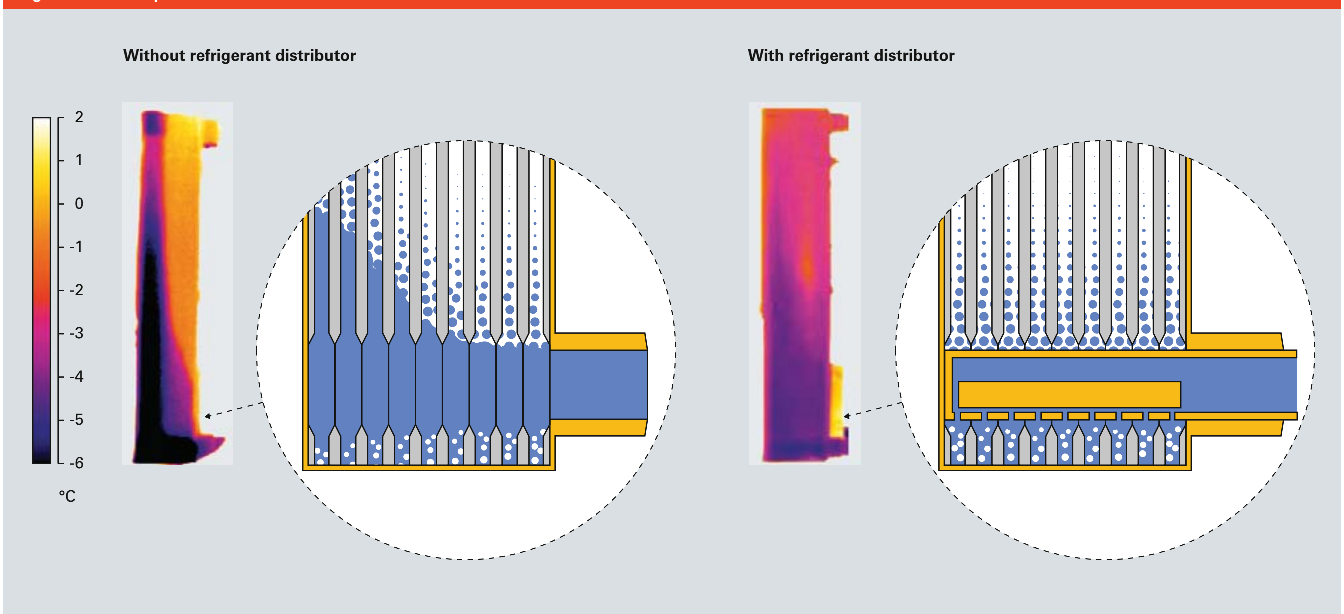
Generally speaking, plate heat exchangers are used as evaporators in brine/water and water/water heat pumps, as these enable high heat transfer rates to be achieved within a comparatively compact design. Under exceptional conditions, coaxial heat exchangers are also used in water/water applications. These safeguard high operational reliability in the case of contaminated water. Special designs are available for the utilisation of waste heat, for example from waste water.

A refrigerant distributor can be employed to increase the output of plate heat exchangers. These distribute the refrigerant evenly across the entire evaporator area, thereby effectively preventing it from simply "shooting through" the heat exchanger. This ensures optimum utilisation of the available area.

Finned heat exchangers are used in air/water heat pumps. On their primary side, these feature an exceedingly large surface area, because the thermal capacity of air is much lower than that of water or glycol:water mixtures.

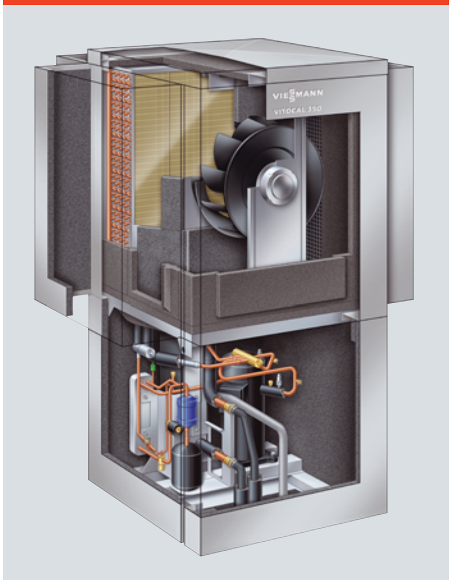
At temperatures near freezing point and below, the water vapour contained in the air freezes onto the heat exchanger fins. Wide fin spacing slows down the icing of the evaporator, but cannot prevent it all together. Iced-up heat exchangers run more noisily and the fans draw more power. In other words, they need periodic defrosting. With advanced air source heat pumps, this takes place automatically and according to need. The less defrost energy is expended, the more efficient the heat pump operation. Finned heat exchangers from Viessmann feature a special coating that ensures that the evaporator is protected from corrosion and that the water runs off quickly during the defrost cycle.

Fig. A.3.3–1 Evaporator with and without distributor



The thermographies illustrate the effect of the refrigerant distributor. Without it (left), refrigerant could "shoot through", resulting in an uneven flow through the heat exchanger. An even flow pattern is achieved with the refrigerant distributor (right).

Fig. A.3.3–2 Air/water heat pump

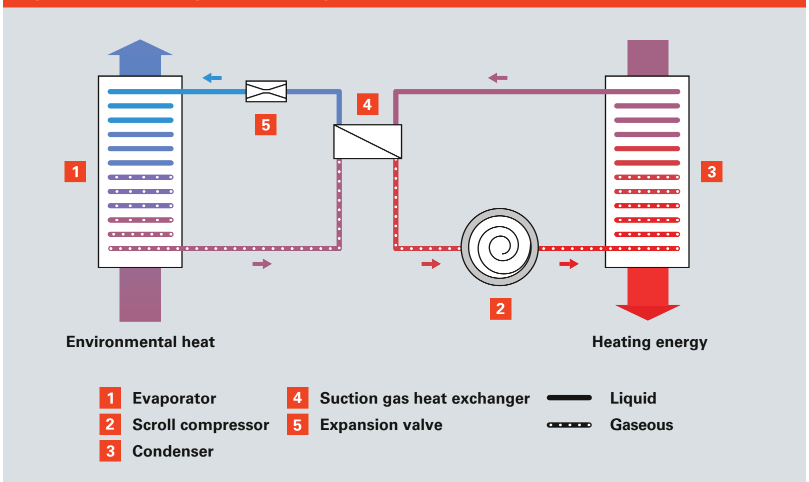


Air/water heat pump
Vitocal 350-A

A.3.3.2 Condenser

In the condenser area, too, plate heat exchangers with a remarkably high heat transfer capacity have been selected. Different designs are only deployed in the output range above 100 kW.

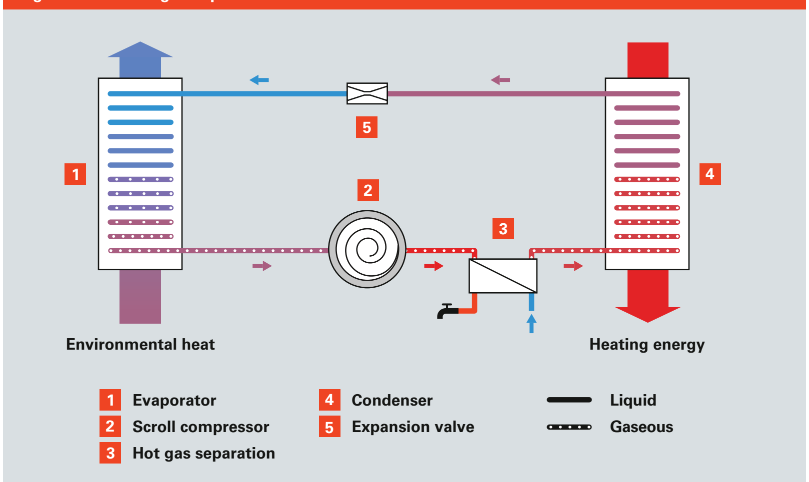
Fig. A.3.3–3 Suction gas heat exchanger



A.3.3.3 Suction gas heat exchanger

The expansion valve control ensures that the refrigerant at the compressor entry point is superheated, in other words completely evaporated. A suction gas heat exchanger improves the operational reliability, particularly with refrigerant mixtures, the constituents of which may have different boiling points. This ensures that no liquid constituents remain in the refrigerant vapour.

Fig. A.3.3–4 Hot gas separation



A.3.3.4 Hot gas separation

Prior to the refrigerant vapour reaching the condenser, part of the hot gas energy can be "siphoned off" and used for raising consumers to a higher temperature level – generally DHW heating. The amount of energy utilised in separation is generally approximately 10 percent of the total amount of heat. The main amount of heat is then transferred, via the condenser, at a slightly lower temperature level to the heating circuit.

Viessmann heat pumps do not employ hot gas separation, as, particularly with fluctuating DHW consumption, there is a risk of the hot gas energy not being required. In this case, the higher pressure drop in the refrigerant circuit on account of the additional heat exchanger would then reduce heat pump efficiency unnecessarily.

A.3.4 Refrigerant

The refrigerant draws heating energy from the heat source (air, ground or water) during evaporation and transports it to the consumer, where it condenses again. Energy is always available in these phase changes. Purely theoretically, though, any substance can be thought of as a refrigerant.

However, a refrigerant suitable for heat pumps must possess some special properties, i.e. it should have as low a boiling point as possible, a low evaporation volume and a high cooling capacity, relative to its volume. In addition, it must not be corrosive to the components and lubricants employed, if possible it should be non-poisonous, non-explosive and non-flammable. Effects on the ozone layer (ODP = Ozone Depletion Potential) and its greenhouse effect (GWP = Global Warming Potential) should be as low as possible.

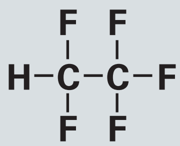
Partially halogenated chlorofluorocarbons (H-CFC) best meet these requirements, and so are generally used in heat pumps. Apart from synthesised refrigerants, natural refrigerants, such as CO_2, propane or butane are also used in some applications. Since the latter two substances are explosive, their use would place high demands on the safety equipment.

DIN 8960 defines the designation of refrigerants. They start with letter "R" (for refrigerant), the following figures then permit conclusions as to their chemical composition (see Fig. A.3.4–1).

Not every refrigerant or refrigerant mixture is suitable for every heat pump type.

Example

The organic refrigerant pentafluoroethane:



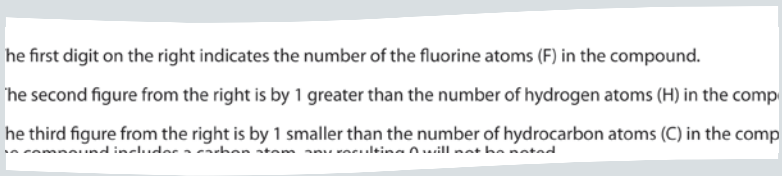
This molecule consists of two carbon atoms (C), one hydrogen atom (H) and five fluorine atoms (F). The sum formula for this compound is therefore C_2HF_5 (R-125).

All refrigerants that have a numbered sequence following the letter "R" starting with a "4" are mixtures of different refrigerants that are not designated in accordance with the system described above. Mixtures are characterised by particularly good physical properties and very favourable environmental characteristics. Selection of the optimum refrigerant depends on the operating conditions of the heat pump, in other words, on the source and target temperature.

Note

To be "halogenated" means that a molecule contains not only carbon, but halogens, too, in other words fluorine, chlorine, bromine or iodine. This may be as complete (fully halogenated) or as partial (partially halogenated) compounds. Partially halogenated hydrocarbons also include hydrogen. The risk they pose to the environment (GWP) is substantially lower than that of fully halogenated, or saturated, hydrocarbons. Hydrocarbons that are free of chlorine pose no risk to the ozone layer, in other words their ODP is zero.

Fig. A.3.4–1 Extract from DIN 8960



he first digit on the right indicates the number of the fluorine atoms (F) in the compound.

he second figure from the right is by 1 greater than the number of hydrogen atoms (H) in the comp

he third figure from the right is by 1 smaller than the number of hydrocarbon atoms (C) in the comp

Fig. A.3.4–2 Viessmann refrigerant table

Refrigerant		Heat pump type		
Type	Composition	**Brine/ water**	**Water/ water**	**Air/ water**
R-410A	50 % R-32 (CH_2F_2, difluoromethane) 50 % R-125 (C_2HF_5, pentafluoroethane)	x	x	x
R-407C	25 % R-125 23 % R-32 52 % R-134a (CF_3CH_2F, tetrafluoroethane)	x	x	x
R-134a	100 % CF_3CH_2F, tetrafluoroethane	x	x	

Primary source potentials

Heat from the sun is stored in the air, water and the ground. This environmental heat is therefore a renewable form of energy that can be utilised by heat pumps.

Heat pumps predominantly use heat from the ground, outdoor air or water as a primary energy source. However, heat pumps can also convert waste heat that would otherwise be left unused, into useful energy.

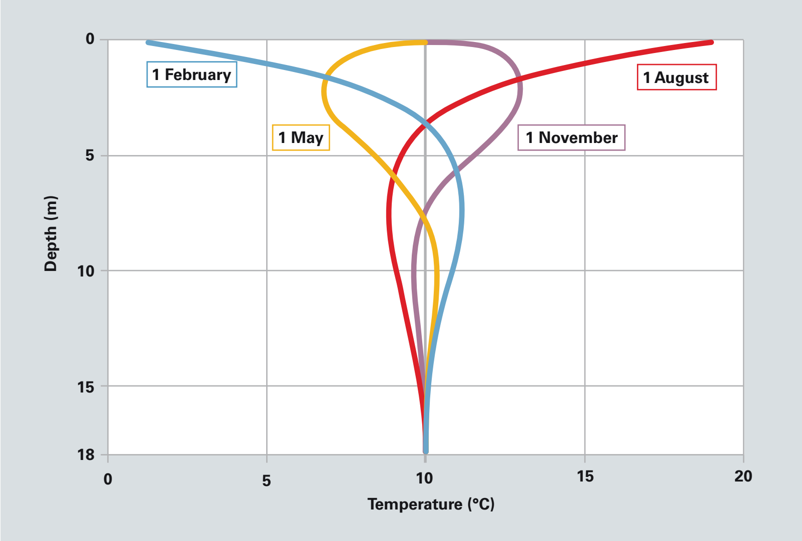
The following chapters describe the different primary sources and the different types of heat pump that can be used to exploit them.

A.4.1 Ground as heat source

"Ground" here, refers to the top layer of the ground, which represents a stable heat source. For example, the temperatures at two metres below ground are relatively constant throughout the year, i.e. between 7 °C and 13 °C.

Energy is recovered with the help of a heat exchanger that is laid in an area near the building to be heated. A heat transfer medium (brine) – a mixture of water and antifreeze – courses through a geothermal collector that spreads out over a large horizontal area or through vertically sunk geothermal probes, and absorbs the heat stored in the ground and transports it to the evaporator of the so-called "brine/water" heat pump. The term "brine/water" heat pump, therefore, means brine in the primary circuit and water in the secondary circuit. Geothermal collectors utilise that amount of heat that penetrates the ground through insolation, rain or melt water.

Fig. A.4.1–1 Annual temperature curve under ground



A.4.1.1 Geothermal collector

With a geothermal collector, plastic pipes are buried under ground at a depth of between 1.2 and 1.5 m. At this depth, the temperature over the whole year is sufficiently stable – the slightly higher amount of heat at lower levels could not justify the additional construction effort (nor the resulting financial outlay).

Wherever possible, the individual lines should be of equal length in order to create identical pressure drop values and consequently identical flow conditions. Where possible they should not exceed 100 m in length, otherwise the resulting pressure drop would demand excessively high pump ratings. The pipe ends come together in return manifolds that are arranged at a slightly higher level (venting), and each line can be shut off separately. Brine is pumped through the plastic pipes using a circulation pump, and in the process it absorbs the heat stored under ground.

A temporary minor frost under ground around the pipelines caused by the heat pump operation has no negative impact, either on the system operation, or on the vegetation above. However, to protect the system, plants with deep roots should be not be grown near geothermal collectors.

Fig. A.4.1–2 Heat source – geothermal collector

The geothermal collector is comprised of plastic pipes laid horizontally into the ground at a depth of 1.2 to 1.5 m.

Fig. A.4.1–3 Heat source – geothermal collector

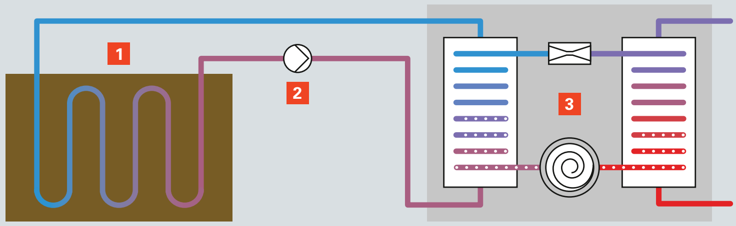


Fig. A.4.1–4 Heat extraction rate – ground

Subsoil	Specific extraction rate
Dry sandy soil	10–15 W/m^2
Damp sandy soil	15–20 W/m^2
Dry loamy soil	20–25 W/m^2
Damp loamy soil	25–30 W/m^2
Ground with groundwater	30–35 W/m^2

Possible specific extraction rates for geothermal collectors.

The area above the geothermal collectors must not be built on or sealed, in order to permit the cooled-down ground to be replenished during spring and summer. Insolation and precipitation ensure that the ground as heat store is available again for heating purposes during the following heating season.

The earthworks required for laying the collector can be accommodated during new build projects without excessive cost implications. For cost reasons, "retrofitting" an existing building with a brine/water heat pump and geothermal collectors is usually not viable.

The available amount of heat, and therefore the size of the required collector area, is largely dependent on the thermophysical properties of the ground and on the insolation energy, i.e. it is subject to the prevailing climatic conditions. For this, ground variables such as the proportion of water, the proportion of mineral constituents, such as quartz or feldspar, as well as the proportion and size of the air-filled pores are important. Storage properties and thermal conductivity are better the more water and mineral constituents are in the ground and the fewer pores are prevalent.

The heat extraction rating for underground areas lies between approx. 10 and 35 W/m^2.

A.4.1.2 Geothermal probe

Major earthworks are required for installing geothermal collectors at a depth greater than 1 m. Installing geothermal probes, on the other hand, can be accomplished in only a few hours using modern drilling equipment. Arrangement and drilling depth are vital factors when installing systems with geothermal probes. Consequently, geologists, or specialist drilling contractors with the corresponding level of expertise, undertake the installation of geothermal probes. Furthermore, an extraction capacity can be contractually agreed with these specialist contractors. Packs that offer heat pump and drilling from a single source promise a high degree of engineering security with guaranteed extraction rate.

In Germany, geothermal probe systems require a permit from a local water board. In most regions, drilling up to a depth of 100 m falls within the responsibility of the local water board. Boreholes that are any deeper need approval from the relevant mining authorities as well.

A pre-fabricated probe is inserted into the borehole, the hollow space between the probe pipe and the borehole is then compacted with a filler material.

Costs for such boreholes including probe, connection line and filling matter are, subject to ground properties, €60 to €80 per meter. A typical detached house, built as a low energy house, requires approximately 6 kW to provide comfortable heating with a heat pump. This requires a borehole depth of approximately 100 metres, which would entail costs of approx. €6000 to €8000.

Design and installation require sound knowledge of ground conditions, the order of ground strata, the ground resistance and the presence, or otherwise, of ground or stratum water, including the determination of water levels and flow direction. Under standard hydrogeology conditions, an average heat extraction of 50 watt per metre probe length can be assumed for geothermal probe systems (according to VDI 4640). Higher extraction rates can be achieved if the probe is installed in a rich seam of groundwater.

Fig. A.4.1–5 Heat source – geothermal probe

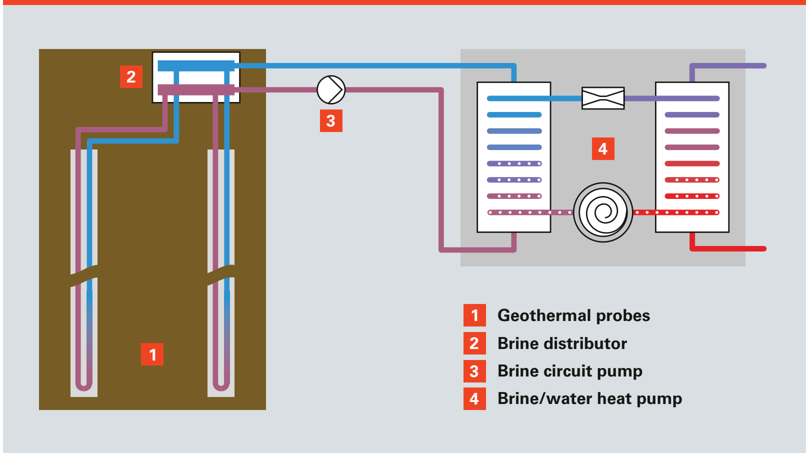
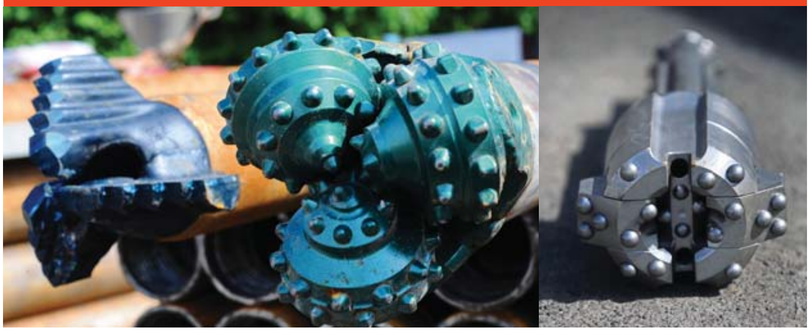


Fig. A.4.1–6 Geothermal probe borehole

Setting a geothermal probe in three stages: drilling the hole; inserting the probe; compacting the filling material.

Fig. A.4.1–7 Drill types



Different types of drills are used, subject to the subsoil and probe dimensions.

Note

Thermal Response Test (TRT):
A defined amount of heat is channelled to the geothermal probe, and the outlet temperature of the water from the probe is captured over several days. The TRT enables the calculation of the effective thermal conductivity of the subsoil around the probe.

Experienced drilling contractors know "their" substrates and can also draw conclusions about the likely extraction rate from drilling samples. In larger probe arrays, test drilling for a Thermal Response Test may also be advisable in order to obtain more accurate bases for engineering.

Brine is used in geothermal probes, as in geothermal collectors, as a heat transfer medium. Brine flows in two pipes from the distributor downwards into the probe and is returned by two further pipes upwards to the header.

Fig. A.4.1–8 Brine distributor for geothermal probes

Possible specific extraction rates for geothermal probes (double U-shaped tubular probes) to VDI 4640 Sheet 2.

Fig. A.4.1–9 Extraction rate – geothermal probes

Subsoil	Specific extraction rate
Standard values	
Poor ground (dry sediment)	20 W/m
Normal solid rock subsoil and water-saturated sediment	50 W/m
Solid rock with high thermal conductivity	70 W/m
Individual rocks	
Gravel, sand, dry	< 20 W/m
Gravel, sand, aquiferous	55–65 W/m
Clay, loam, damp	30–40 W/m
Limestone (solid)	45–60 W/m
Sandstone	55–65 W/m
Acidic magmatite (e.g. granite)	55–70 W/m
Basic magmatite (e.g. basalt)	35–55 W/m
Gneiss	60–70 W/m

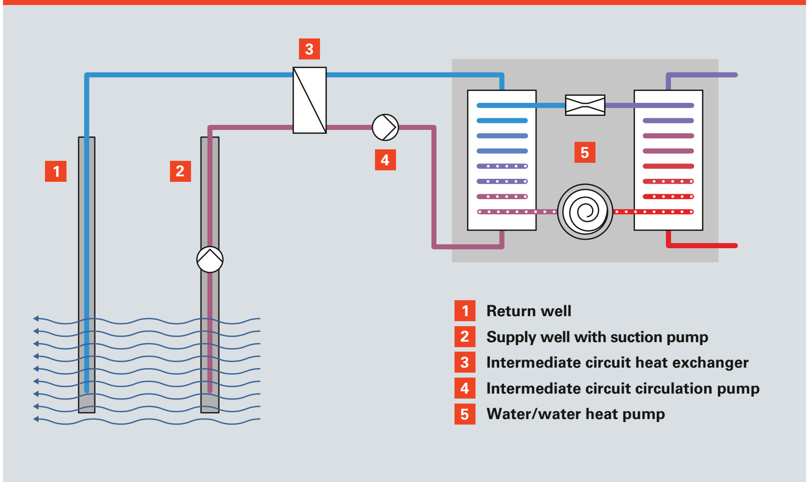
A.4.2 Water as heat source

Water is also a highly suitable heat source for heat pumps. Even on cold winter days, groundwater maintains a constant temperature of between 7 °C and 12 °C. In order to use groundwater for a heat pump, it must be extracted through a supply well and transported to the evaporator of a water/water heat pump. The cooled water is then routed through a return well.

Surface water, too, may be used as a heat source, although it should be noted that the temperatures will fluctuate quite dramatically depending on the season.

The water quality must meet the limits specified by the heat pump manufacturer – the highly efficient plate heat exchangers inside the heat pump are extremely sensitive to fluctuating water quality. In order to prevent any resulting damage, it is generally appropriate to utilise an intermediate circuit heat exchanger. Threaded stainless steel heat exchangers have proven to work well as intermediate circuit heat exchangers – these transfer the environmental heat to a brine circuit. This provides an appropriate level of protection for the heat pump.

Fig. A.4.2–1 Heat source water with intermediate circuit



Utilising an intermediate circuit requires additional pump power and alters the temperature spread – the heating output and the COP of the heat pump will, as a result, drop by a few percentage points.

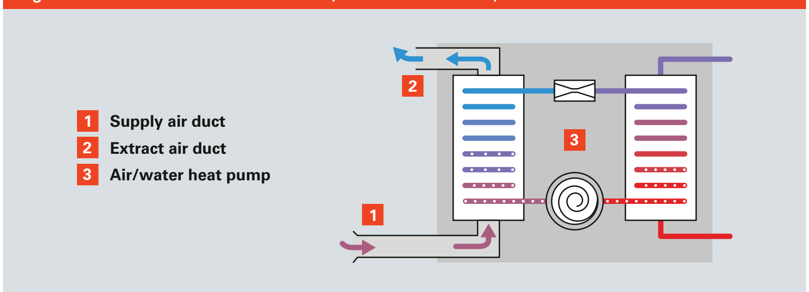
The use of ground and surface water must also be approved by the relevant authority, generally the local water board.

A.4.3 Outdoor air as heat source

Using outdoor air as a heat source requires the least effort of all. Air is drawn in, cooled in the heat pump evaporator and finally discharged again to the ambience.

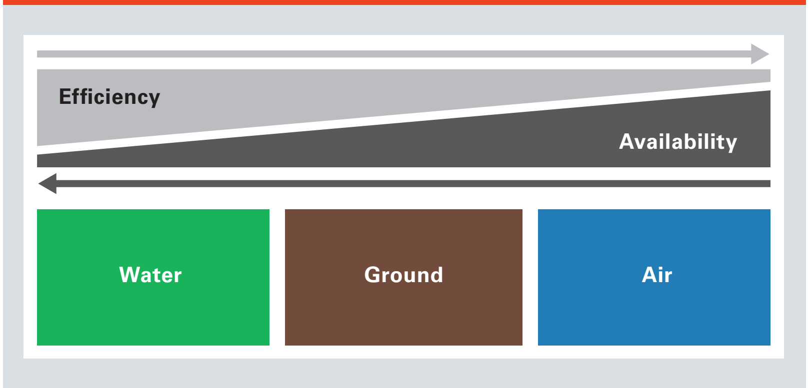
Advanced air/water heat pumps can generate heating energy from outdoor air temperatures as low as –20 °C. However, even with optimum sizing, at such low outside air temperatures, the heat pump can no longer meet the central heating demand completely. For this reason, an additional heat generator heats up the heating water pre-heated by the heat pump to the required flow temperature on very cold days.

Fig. A.4.3–1 Heat source – outdoor air (internal installation)



Air/water heat exchangers handle a relatively large volume of air (3000 to 4500 m^3/h). Consequently the arrangement of the air intake and discharge apertures inside the building must take the noise development into account. The same applies for externally installed heat pumps.

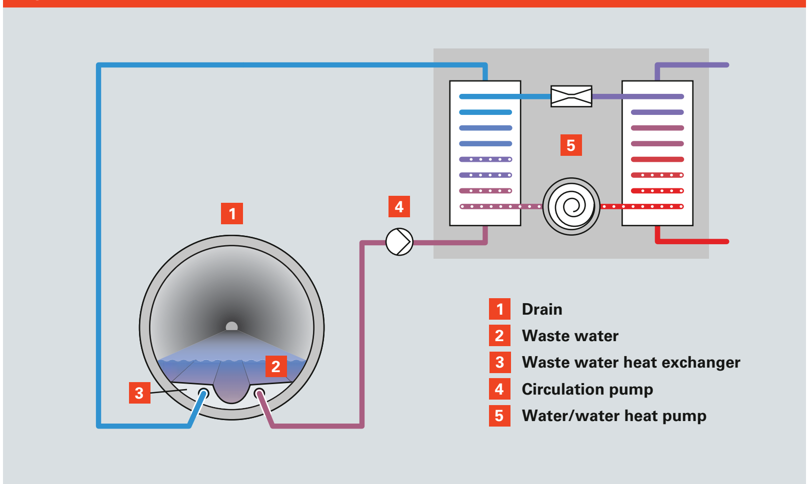
Fig. A.4.4–1 Availability and efficiency



A.4.4 Availability and efficiency – assessment of the primary sources

Fig. A.4.4–1 shows the relationship between different heat sources and heat pump efficiency. This makes it apparent that the heat pump is at its most efficient when coupled to groundwater as a heat source. However, groundwater that can be used for heat pumps is the least available heat source. This ratio is roughly in balance for ground as heat source. Outdoor air as a heat source is available almost without limit. However, heat pump efficiency suffers on account of fluctuating temperatures and the opposing cycle of "low outside temperature, high heat demand".

Fig. A.4.5–1 Heat source – waste water



A.4.5 Waste heat as heat source

Apart from air, water and the ground, waste heat, too, such as from extract air or waste water, can be used as a heat source. Developing waste heat as a heat source is frequently a very affordable measure for providing heat and cooling, as it can offer a comparatively high source temperature and may be available continuously. In industrial processes, the utilisation of waste heat can raise the heat pump COP or significantly optimise an entire process that requires both cooling and heating. Where food production requires cooling and heating, for example, "both sides" of the refrigeration machine can be usefully employed.

Extracting heat from extract air in a ventilation system and its use for heating domestic hot water or heating the supply air has a comparable positive effect. One highly appropriate form of heat recovery is the utilisation of waste water. Here residual energy is extracted from waste water from the living space or from industrial processes by special heat exchangers. This heat is then added to the upstream process.

Fig. A.4.5–2 Waste water heat exchanger

Waste water as a heat source can provide a comparatively high source temperature at a very affordable rate.

A.4.6 Absorber with solar backup

Solar collectors or non-glazed absorbers, too, can be used to improve the temperature level on the primary side of the heat pump. This way, the insolation is used directly for improving the efficiency level.

For example, non-glazed absorbers that utilise the ambient temperature as a heat source can be linked into the evaporator circuit. The absorber is regenerated by insolation in constant operation, in other words, the temperature is held at a high level. With this combination, the improvements of the COP depend on the weather, i.e. they are not constant, as particularly during the heating season insolation is not reliably available. In sizing the absorber, it must be taken into account that it might be covered by snow for certain periods, meaning that insolation can then not be used at all.

In the case of solar thermal systems for solar central heating backup, any energy in combi or buffer cylinders no longer useful to the heating circuit can be used, theoretically at least, for the heat pump by cooling down the cylinder by a few Kelvin. The efficiency of the heat pump (higher source temperature) and the collector system (lower return temperature) would be improved by such a combination.

However, in practical terms, the achievable utilisation would never justify the necessary technical effort. Utilising the phase change in heat stores [heat sources] offers a sensible combination of solar thermal system and heat pump.

Fig. A.4.6–1 Heat source – non-glazed absorber

Historic photographs of non-glazed solar absorbers that utilise insolation and ambient temperature as heat source.

A.4.7 Phase change as "storage" on the primary side

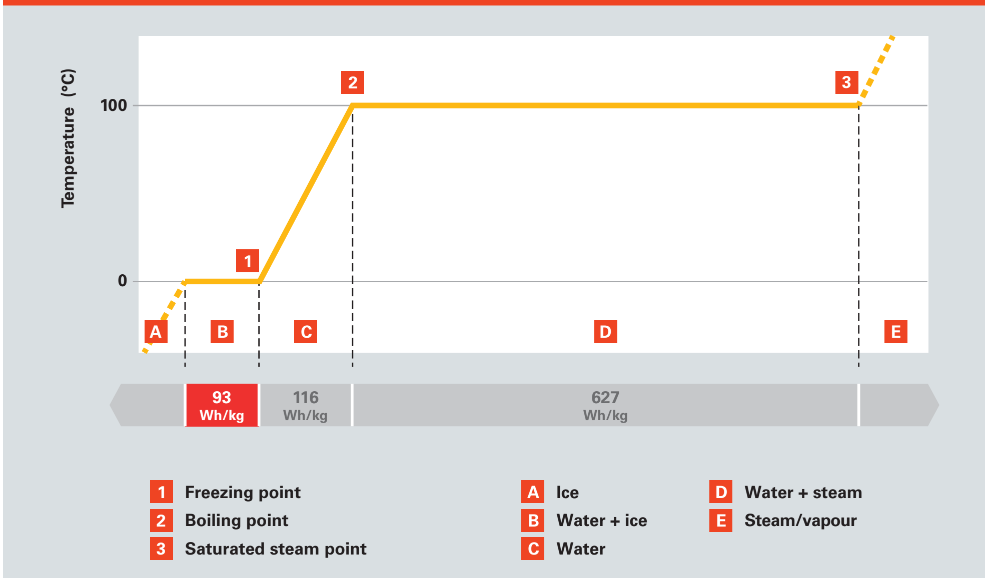
Where water, air and the ground are not available as immediate heat sources, cylinder methods can be deployed as a primary source to utilise the phase change.

Solidification enthalpy can be used as an energy source for heat pumps – the regeneration (melting) is caused by ambient heat and a solar thermal system. Apart from water (ice), paraffins, too, can be used, for example. The principle is always the same, i.e. the chain "gaseous to liquid" within the heat pump is extended by the link "liquid to solid" on the source side.

Practical experience has shown that a combined utilisation of a phase change storage and solar backup absorbers as "primary source" results in more efficient systems.

The phase change of one kilogram of ice into water at the same temperature requires 93 Wh.

Fig. A.4.7–1 Heat storage – phase change



The phase change of water into ice as heat storage is utilised in a complex heat exchanger bank inside an underground tank.

Fig. A.4.7–2 Heat storage – phase change

Alternative types of heat pump

Heat pumps not only utilise energy contained in the change of an aggregated condition. Other types exist that work on different principles.

In previous chapters, types of heat pump were described that utilise the phase change from the liquid to the gaseous state. However, there are further state variables, the change of which is connected with deployment of energy, which make them available for heat pumps.

For example, if you add salt to a vessel containing water, the salt will dissolve and distribute evenly throughout the water. During this process, the water will cool down. If this process were to be reversed, energy would need to be added to the solution until the water has been evaporated and salt crystals remain.

This chapter describes heat pumps that drive liquids out of solutions or solid bodies utilising environmental energy.

A.5.1 Compression heat pumps with internal combustion engine

Generally, compressor heat pumps can also operate with natural gas, diesel or biofuel (rapeseed oil). An internal combustion engine instead of an electric motor is used to drive the compressor. This requires additional effort/expenditure for sound insulation, exhaust gas routing and fuel supplies.

Compression heat pumps with internal combustion engine drive can also utilise the waste heat from the combustion process as heating energy.

A.5.2 Absorption heat pumps

Generally speaking, absorption heat pumps follow the same physical principles as compression heat pumps. Contrary to these, absorption heat pumps are generally operated with natural gas and are used with a thermal compressor in place of a mechanical one.

The solvent pump requires only little power input (electricity). Energy for the thermal compressor is supplied in the form of heat. Any number of heat generators can be utilised, and with certain combinations of materials, even solar thermal systems.

An absorption heat pump is highly efficient, it has no moving parts apart from the solvent pump and operates relatively quietly.

Absorption heat pumps with a high output range (in excess of 50 kW) are state of the art in the form of refrigeration machines. In the lower output range to approximately 2 kW, these appliances are used in propane-operated camping refrigerators, for example. Currently, there are no solutions suitable for standard production for deployment as heat generators in the medium output range.

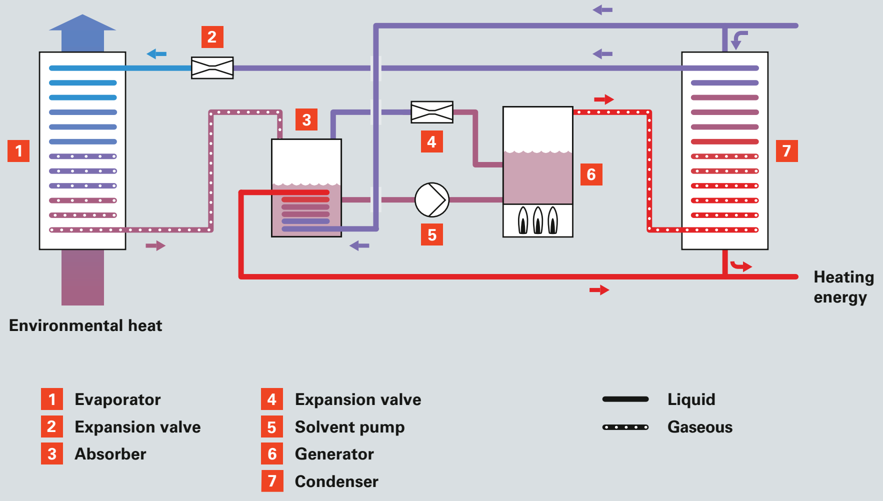
Note

Sorption describes all processes in which a material is enriched in a phase or on the periphery between two phases.

Absorption describes the enrichment within a phase. With this process, a substance enters the interior of a solid body or liquid.

Adsorption describes the enrichment on the periphery between two phases. Liquid or gaseous components are absorbed on a solid surface – e.g. of active charcoal or zeolites.

Fig. A.5.2–1 Absorption heat pump function



Evaporation
The refrigerant (conventionally ammonia) is evaporated whilst environmental energy is absorbed (1).

Absorption
The refrigerant vapour flows into the absorber (3), where it is absorbed by a solvent (generally water). This condensation generates heat – it is transferred to the heating system by means of a heat exchanger.

Thermal compression
The combination of materials of refrigerant and solvent created in the absorber, is transported by the solvent pump (5) to the generator, also known as the "thermal compressor" (6). Both parts of the combination of materials have different boiling points – the dissolved refrigerant has the lower boiling point. The dissolved refrigerant is now driven out or evaporated with the aid of heat supplied or through a gas burner.

Condensing (I)
The liquid solvent separated in the generator and which is under high pressure, is returned to the absorber via an expansion valve (4). Here, solvent and refrigerant vapour meet and condense whilst transferring heat.

Condensing (II)
The refrigerant vapour, which also features high pressure and temperature levels, flows into the condenser (7) and transfers its condensation heat to the heating system.

Expansion
An expansion valve (2) expands (depressurises) the liquid refrigerant to its original pressure and temperature level in order to be able to be evaporated again whilst absorbing environmental heat.

A.5.3 Adsorption heat pumps

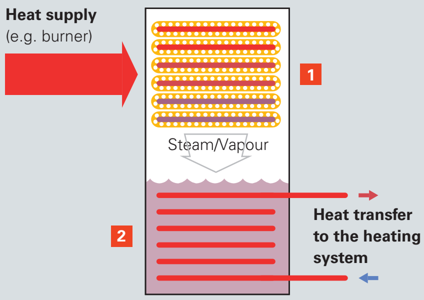
The adsorption heat pump operates with solid matter, such as active charcoal, silica gel (glass-like silicate) or zeolite, for example. The mineral, zeolite, has the property of attracting water vapour, to bind itself to same (to adsorb) and in the process to give off heat in the temperature range up to approx. 300 °C. This is described as exothermic reaction.

As for the heat pumps already described, the process of heat absorption and transfer is a circular process for adsorption heat pumps as well – however operation is periodical, i.e. in two distinct phases. Adsorption heat pumps of this type require a vacuum system.

Just like the absorption heat pump described in Fig. A.5.2–1, this type, too, has been in use as a refrigeration machine in the higher output range for some time. The application for heating detached houses and two-family houses is currently under development. The technical effort is comparatively high due to the need for a vacuum.

Fig. A.5.3–1 Adsorption heat pump function

Desorption phase

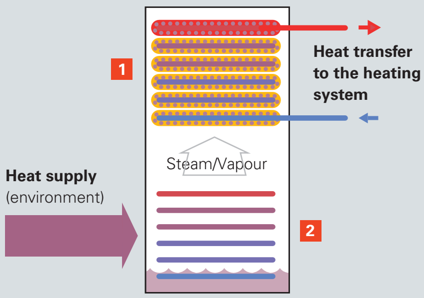


1 **Heat exchanger with zeolite**
2 **Heat exchanger**

Desorption
In the first phase, the heat exchanger coated with a solid material (silica gel or zeolite) (1) receives heat generated by a burner or a solar thermal system. The water bound in the solid material is driven out (desorbed) through this heat application and flows to the second heat exchanger (2) in the form of vapour.

Condensing
In this phase, that heat exchanger acts as a condenser. It transfers the heat that is released through condensing the water vapour to the heating system. Heat supply ends when the zeolite has reached the required level of dryness. The bound water is fully evaporated and condensed on the second heat exchanger.

Adsorption phase



Evaporation
In the second phase, the heat exchanger (2) takes on the function of evaporator. Environmental energy is supplied via this heat exchanger until the water has evaporated completely.

Adsorption
The water vapour flows back to the coated heat exchanger (1) and is adsorbed there as water by the silica gel or zeolite. The heat dissipated by the solid material during this stage reaches the heating system via the heat exchanger. A complete period of this heat pump process has been completed as soon as the water vapour has been adsorbed fully.

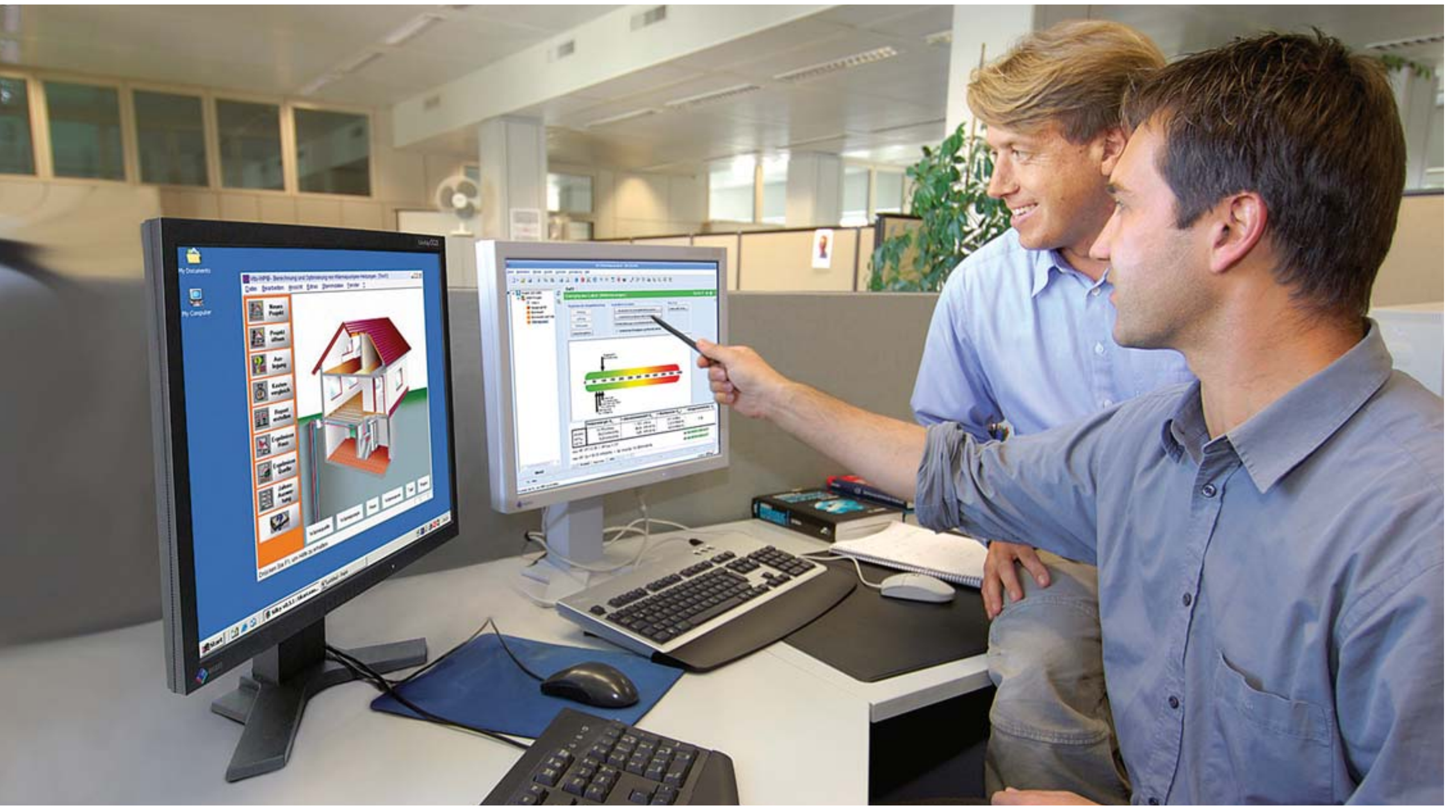
B General conditions

Before investing in a heat pump system, customers are sure to want to go through a proper consultation phase. To advise them successfully, a simple understanding of how the appliance works is no longer enough – greater expertise is required.

Today, many factors influence the decision as to whether to invest in the potential this new type of heating system has to offer. How futureproof is the decision for a certain type of fuel? Does the system meet all statutory requirements? Is the investment worthwhile when it comes to the expected operating costs?

These questions must also be able to be answered in connection with the use of a heat pump. Contrary to conventional heat generators, questions about the availability and affordability of the electricity required to power the compressor remain deep areas of concern.

This chapter deals with the factors that are crucial for assessing the feasibility of using heat pumps.



"Electrical power" as the driving energy

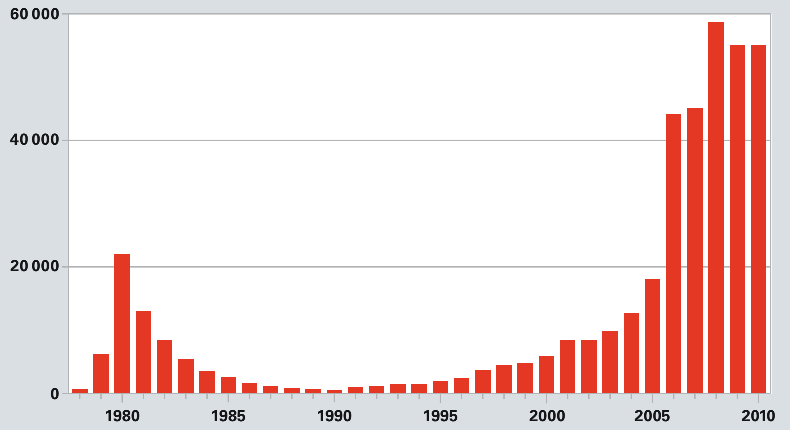
For heat pumps with an electrical drive, power consumption is a key factor.
The following chapter describes the way this subject should be correctly addressed.

The utilisation of fossil fuels, which have provided us with heat over the past 100 years, is now in transition.

Effects on our climate, reducing availability and the rising costs of gas, oil and coal have contributed to the fact that solar energy and biomass, and now heat pumps, have become a permanent fixture in the portfolio and not only in the German heating technology sector. The number of heat pumps as a proportion of the heat generators installed each year in Germany has been on the rise since 1990.

Sales figures indicate that the heat pump market is subject to fluctuations due to external influences that either encourage or retard its development (just as with solar thermal and biomass systems). Heat pumps are still not seen as an obvious choice, but rather as an exception to the rule. Many potential investors are put off by their lack of familiarity with the technology, as well as the general public perception of heat pumps as "electric heating systems". This uncertainty in coming to judgement is equally prevalent amongst public bodies and authorities.
For example, it took seven years following the start of the market incentive scheme (MAP) initiated by the Federal government [of Germany], before heat pumps received subsidies, in other words before they were accepted as "renewables". For heat pump technology to succeed in the market it is necessary to address the subject of "heat pumps and electricity".

Fig. B.1–1 The market trend for heat pumps



Heat pumps experienced their first successful phase around 1980 as a result of the oil crisis. Stronger market growth later on can be linked to the rise in oil prices since 2000.

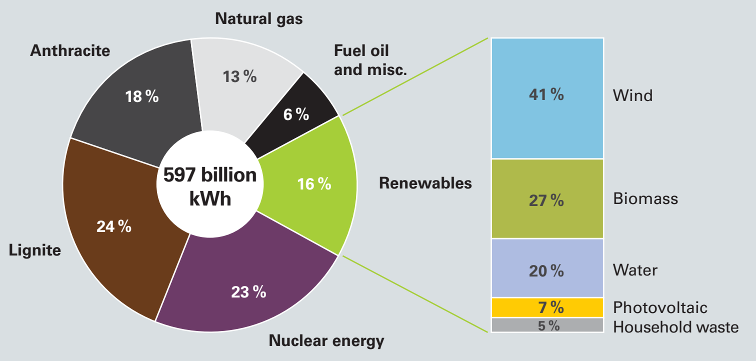
B.1.1 Power mix in Germany

In Germany, power is predominantly generated in condensing power stations – primarily coal fired or nuclear. Although the proportion of renewables, such as hydro-electric power, wind power and photovoltaics is on the increase, at only 18 percent, its contribution to the German power mix is still small.

This figure is at the root of one of the most important prejudices against the use of electricity in the heating market. It seems counter-intuitive to generate electricity by heat in a coal fired or nuclear power station with its associated low levels of efficiency, in order to reconvert this into heat in a building.

This objection is fully justified when it comes to electrical resistance heaters (e.g. night storage heaters), but not to heat pumps. Apart from the electrical auxiliary energy (e.g. circulation pumps), the heat pump only uses electrical power to drive the compressor. It is only the consumption of this amount of electricity that differentiates the heat pump

Fig. B1.11 Gross power generation 2009 in Germany



With the increasing proportion of renewables in the power generation mix in Germany, the ecological quality of electricity improves – in other words heat pump operation is becoming ever "greener".

from conventional combustion technology and solar thermal systems.

The power consumption of heat pumps is, nevertheless, frequently used as a blanket argument against this technology; consequently a detailed consideration of this subject is appropriate.

Two factors are, therefore, highly relevant when assessing the energy facts concerning heat pumps and their comparability with alternative heat generators:

- What is the ratio between expended power and the heating energy yielded from its deployment (seasonal performance factor)?
- How is the electricity used to be assessed from an energy point of view?

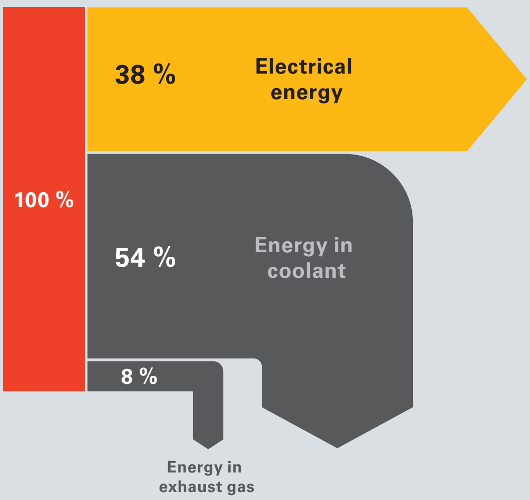
To answer the second question, we need the primary energy factor determined by the legislature. This stipulates how electricity (as well as gas, oil and wood) should be assessed in primary energy terms (see Fig. B.1.1–2).

To calculate the primary energy factor of all electricity generated in Germany, a power station mix is applied, in other words an average for all types of generation.

The primary energy factor has been reduced twice since the introduction of the Energy Saving Ordinance (EnEV) in 2000, in other words, it has been adjusted to the average power generating structure in Germany. This reflects increasing efficiencies in generation, but it largely indicates the increasing proportion of power generated from renewables.

The constantly increasing proportion of power generated from renewable sources of primary energy in the power mix will continue to lower the primary energy factor, that is, it will make heat pump operation more "green".

Fig. B.1.1–2 Primary energy factor



Power generation in an average condensing power station

Primary energy used	100 %
■ available electrical energy	38 %
■ heat loss in coolant	54 %
■ flue gas losses	8 %

Dividing the primary energy expended by the available electrical power results in the factor used to assess the primary energy of the generated electricity.

In this case, the primary energy factor is as follows:
100/38 = 2.6

B.1.2 Security of supply

The power supply system in Germany is one of the most reliable in the world. The high security of supply is, therefore, a relevant variable for the decision making process that speaks for or against the use of a heat pump – not least because the operation of most other heat generators in buildings also depends on electrical power (pumps, controllers, etc.).

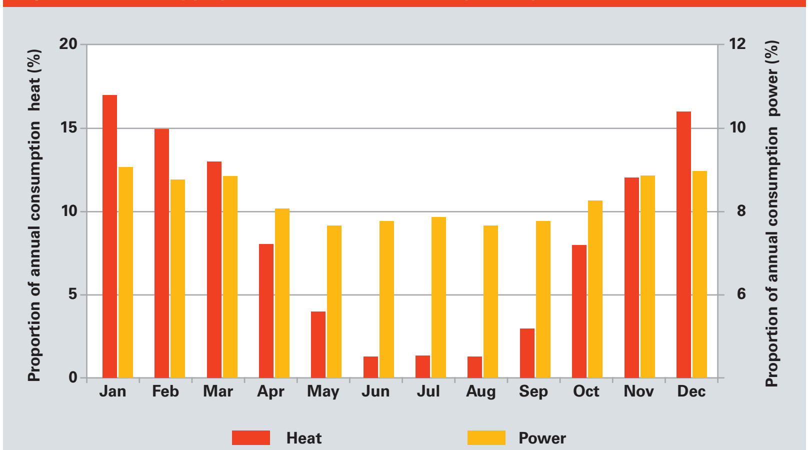
In the endeavour to expand the application of heat pump technology it is important that a reliable, sustainable and affordable supply of electricity can be assured in the long term.

Heat pumps consume most power during the heating season. This makes for an excellent "fit" between the heat pump demand profile (relative to the required amount of electricity) and the generation profile of wind power systems, for example.

For heat pumps to find wider acceptance it is relevant whether their operation further increases load peaks in the grid or whether the system can be regulated so that it can be supplied with power at times of low demand.

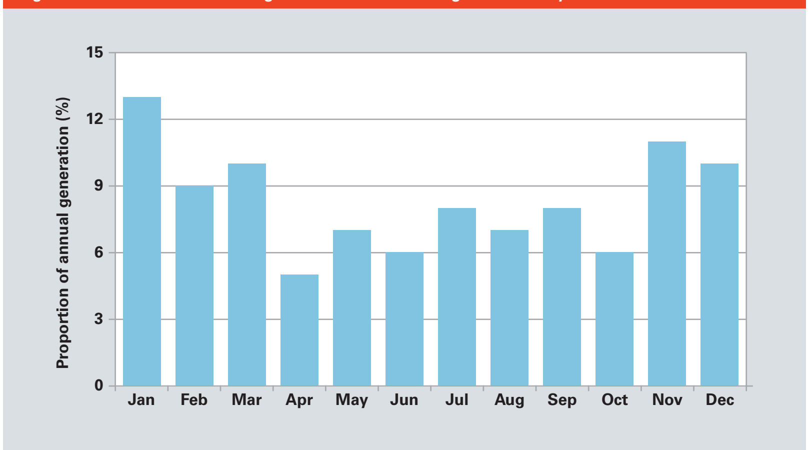
More and more heat pumps are used as heat generators, consequently increasing the power demand in winter.

Fig. B.1.2–1 Monthly proportions of the annual consumption of power and heat (EFH sector)



The growing proportion of wind energy in power generation makes the use of heat pumps for generating heat ever more appropriate, as generation and consumption curves in the winter months increasingly converge.

Fig. B.1.2–2 Power from wind generation fed into the grid over the year



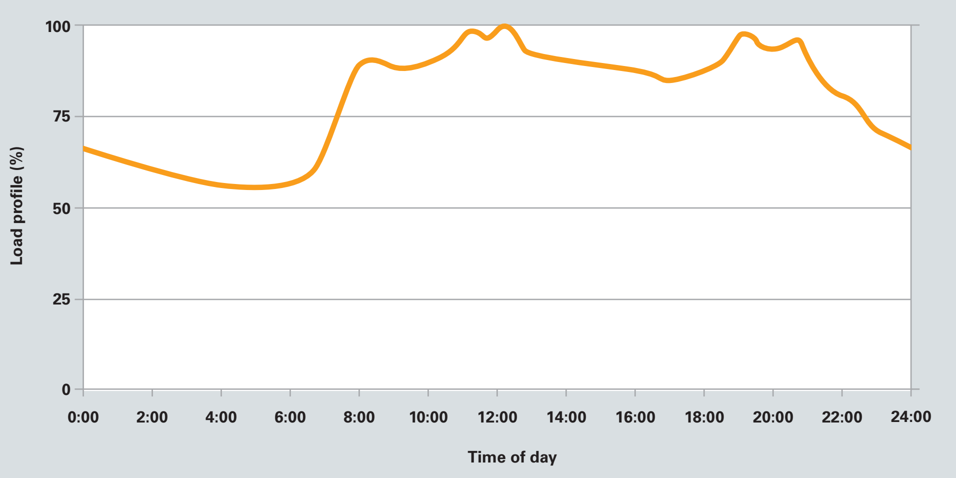
When considering the typical power load curve for a single day (see Fig. B1.2–3) it is easy to recognise that the supply system experiences its peak (relative to the grid and power generation) during the middle of the day. During this time, power tariffs paid by the power supply utilities to the power exchange, are also at their peak.

This situation forms the background to the special heat pump power tariffs and the associated "power-OFF times" [in Germany]. Power supply utilities now sell electricity to their customers more cheaply during the low load times of the day. In return, they temporarily cut off the power supply to heat pumps during certain short periods.

This commercial approach also has technical consequences, for if, as a result of careful planning, the machines can operate outside the peak load times, then the daily load profile of the grid will be balanced.

To balance the daily load profile, power supply utilities offer special heat pump tariffs – with favourable electricity tariffs at low load times and short "power-OFF" times during load peaks.

Fig. B.1.2–3 Typical daily load profile in the power grid



B.1.3 Smart metering

The rising proportion of power generated from renewables in the power mix requires ever more intelligent control of supply and demand. Smart metering aims to advance this control and to achieve the described "smoothing" of the load profile in power consumption. In addition, generation peaks from wind and solar power should be brought to suitable consumers in an appropriate way.

Now, smart metering ensures that the power supply increasingly determines power consumption and not – as happened until recently – that supply follows demand. The latter becomes increasingly difficult with increasing generation capacity, particularly from wind and solar power installations.

Heat pumps will play an ever more important role in this complex and fundamental restructuring of the power grid. There are many consumers that, with little technical effort, could be dovetailed into this system. For example, freezers can be switched off for several hours – insulation commonplace today prevents any critical temperature increase.

Without intelligent load management it would be pure coincidence whether an appliance switches its load to the power grid during peak times or not. However, if the appliance "knows" that there is a glut of energy right now, it could switch itself on. For freezers this means that it lowers the internal temperature a few degrees below the set value. This provides a buffer for a longer period when no power needs to be drawn.

Switching a heat pump follows a similar pattern. Possible overshoots or undershoots of the room temperature (during heating and cooling), appropriate sizing of buffer cylinders and a modulating operation, open up the possibility of linking heat pumps efficiently into an intelligent power grid.

Fig. B.1.4–1 Photovoltaic systems

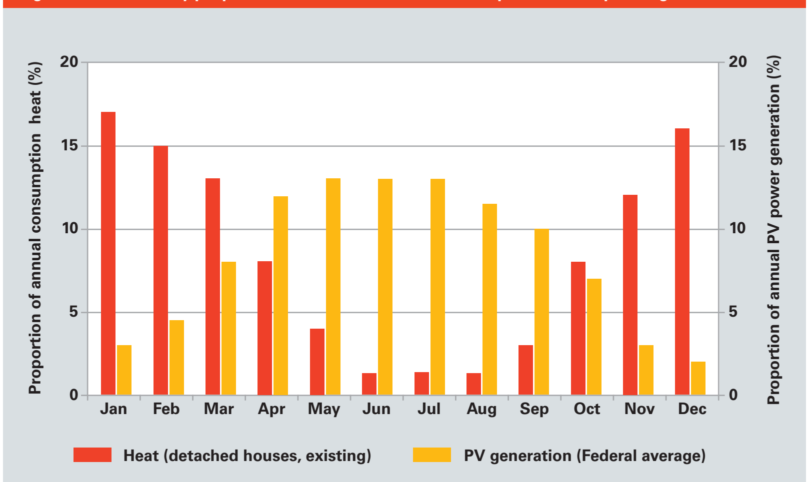
B.1.4 Heat pumps and photovoltaics

It seems an obvious choice to install a photovoltaic system in conjunction with a heat pump. The PV system could then generate the amount of power consumed for heating the building during the year – in other words heating by heat pump without CO_2 emissions.

In spite of the obvious imbalance between PV power generation (focus in the summer months) and heat consumption (focus in the winter months) shown in Fig. B.1.4–2, linking a heat pump and photovoltaic system is a sensible decision when considering the annual energy statement.

The more the power grid, advances, the better the it will be able to absorb seasonal fluctuations in power generation and distribution, and the less important will be the simultaneity of generation and consumption. The energetic assessment of a heat pump improves under this aspect, as it does when taking the changes in the power mix into account.

Fig. B.1.4–2 Monthly proportion of the annual heat consumption and PV power generation



Taking the annual energy statement into consideration, the linking of a heat pump and PV system is a sensible decision.

B.1.5 Competition for electric power

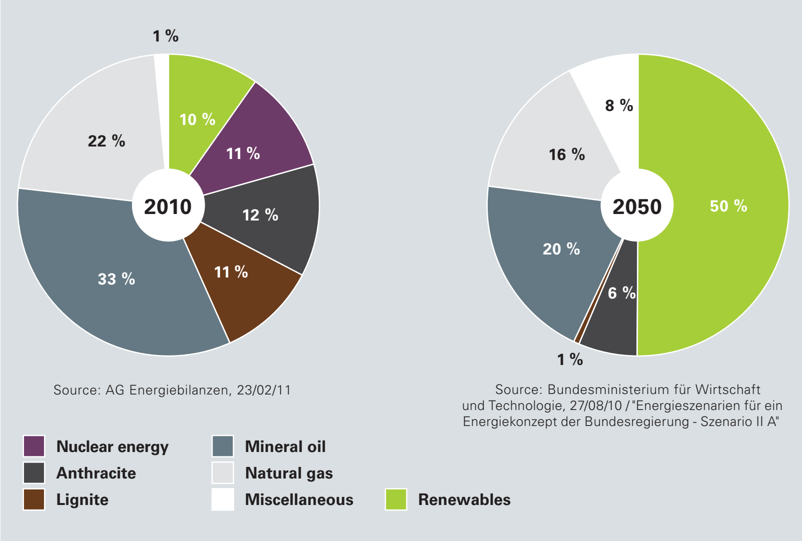
Within the context of the utilisation of electricity in heat pumps, the question frequently arises as to whether the use of power would not be more sensible in other energy sectors, in other words whether – ecologically speaking – better effects could not be achieved, for example in the use of electricity to provide mobility.

This discussion misses the point for the following reasons: All considerations on the future of energy provision take a very long view, some as far ahead as 2050 or the end of this century. Such considerations are necessary in order to be able to pave the way appropriately now for future developments. Most of these considerations result in our energy demand being covered either exclusively or at least predominantly by renewables at the end of the relevant period under consideration. In addition, rough estimates provide indicators as to the percental contribution likely to be made by the individual renewable primary energy sources. What these considerations cannot deliver is a detailed forecast as to the way in which the respective fuel types will make this contribution.

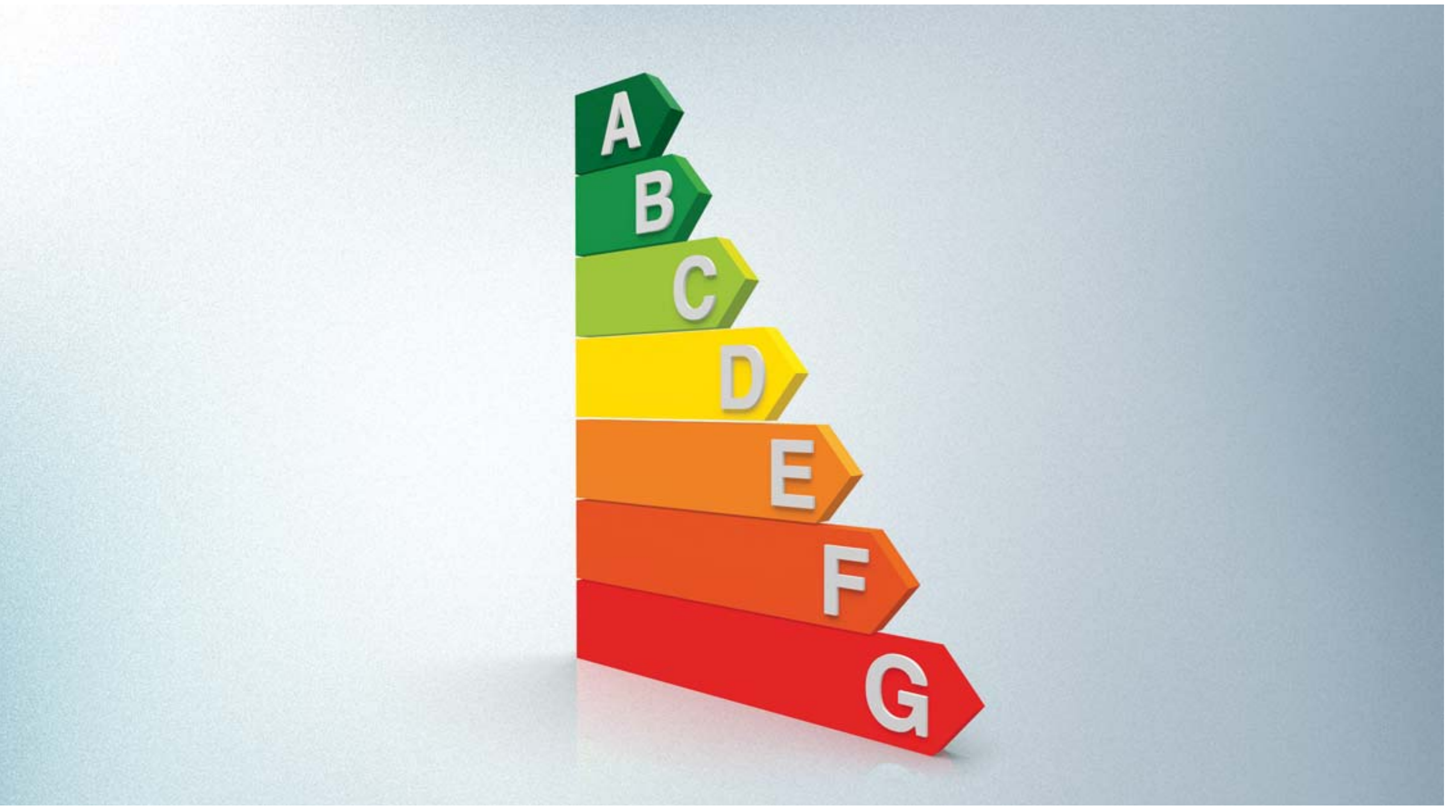
The question must therefore be asked in each case where energy is being consumed, where the potential for energy savings lie and which energy source is the most appropriate for covering the remaining demand. If we were to try and determine today the precise nature of consumption and generation mix and consequently also the technology mix 30 to 40 years ahead, technical progress would more likely be hindered rather than driven forward. For example, biomass can be combusted, liquefied or converted into power. Power generated from renewables can be consumed, stored centrally or in a consumer (vehicle battery or building heated by a heat pump). Although storage and conversion will inevitably lead to lower efficiency, they are unavoidable for any realistic scenario.

We don't currently know where particular forms of energy will be available. In the building sector only time will be able to provide an answer to the following question: Which heat generator offers – relative to the actual project – the highest primary energetic efficiency? With this in mind, the heat pump will play a very important role.

Fig. B.1.5–1 Energy generation in the future



In Germany, the primary energy consumption in 2010 was 14,000 Petajoule (PJ) and is forecast for 2050 with 7000 PJ. The forecast for 2050 was produced on behalf of the Federal Ministry of Economics and Technology.



Statutory framework conditions

EnEV, Heating Act and Energy Label: The efficiency and linking of renewables in heat generation are also increasingly subject to statutory framework conditions. In this connection, heat pumps offer many benefits.

In Germany, the energy consumption of buildings accounts for approximately 40 % of total energy consumption. Consequently, this sector is highly important to the energy-political measures introduced by federal and regional governments. As a result, the German heating technology market is increasingly influenced by statutory framework conditions.

B.2.1 Heat pumps in the EnEV

In 2002, [in Germany] previously applicable regulations on thermal insulation and system engineering were brought together under the Energy Saving Ordinance (EnEV). The EnEV benchmark for assessing the energetic quality of a building is the primary energy demand – this value has been further reduced over the past years as part of the updating of this statutory instrument.

The reduction of the "primary energy demand" factor results in increasing demands made of buildings and the efficiency of heating systems. The energy performance certificate of a building (see Fig. B.2.1–2) illustrates this clearly.

The final energy demand in kWh/(m^2 p.a.) of the building is essentially determined by the building envelope and the ventilation losses. Here, certain values must not be exceeded.

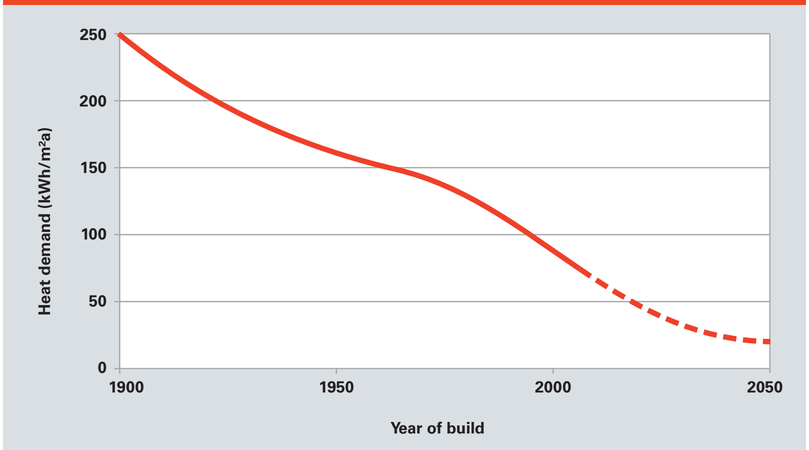
The primary energy demand of a building, also in kWh/(m^2 p.a.), results from the type of heating, for which all types of fuel are assigned different primary energy factors (see Fig. B.2.1–3).

Fig. B.2.1–3 Primary energy factors

Fuel type	Primary energy factor EnEV 2009
Fuel oil	1.1
Natural gas, LPG	1.1
Wood	0.2
Power	2.6
Environmental energy (solar energy, environmental heat, ...)	0.0

The primary energy demand is the benchmark for assessing the energetic quality of a building.

Fig. B.2.1–1 Heating energy demand in buildings (standard for the year of construction)



Contemporary residential buildings have clearly improved when it comes to their heat demand – and progress here will not stop.

Fig. B.2.1–2 Energy performance certificate

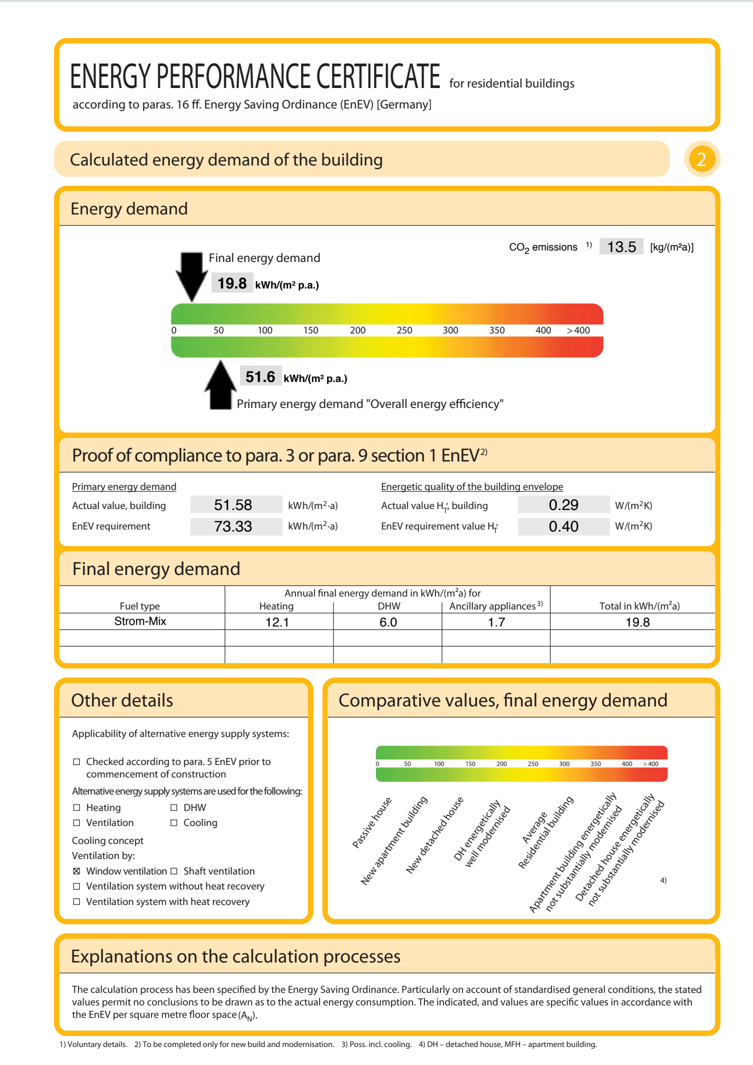
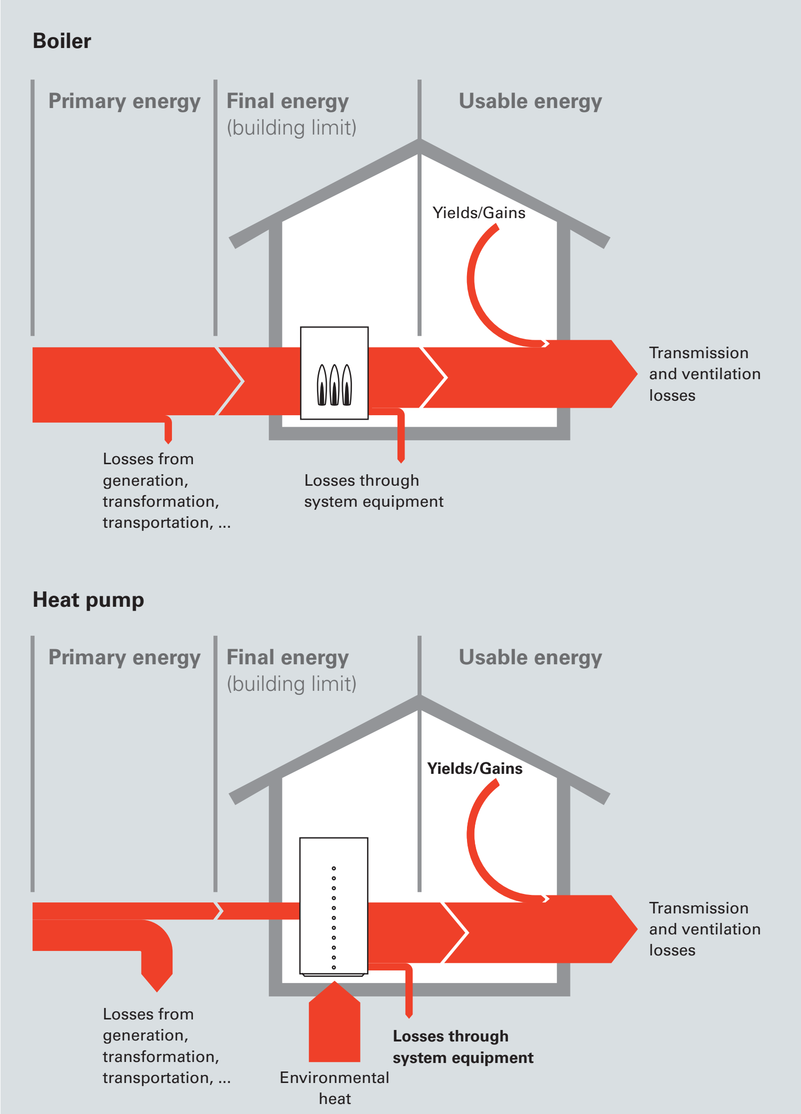


Fig. B.2.1–4 Primary energy demand to EnEV



Example

EnEV certificate when heating with a heat pump:

Primary energy Q_p = (heat demand Q_h + DHW Q_w) * expenditure of energy value e_P + cooling energy $Q_{P,C}$

Primary energy demand	Heat demand	Domestic hot water	Energy expenditure value	Cooling energy
10,811 kWh/a 33.43 kWh/(m²a) 10.70 kWh/(m³a)	11,398 kWh/a 35.24 kWh/(m²a) 11.28 kWh/(m³a)	4043 kWh/a 12.50 kWh/(m²a) 4.00 kWh/(m³a)	0.70	- kWh/a - kWh/(m²a) - kWh/(m³a)

1. Check maximum transmission heat loss

HT' = 0.26 W/(m²K) ≤ HT'max = 0.40 W/(m²K) ⇒ VERIFICATION PROVIDED
No closer HT' check required

2. Check maximum primary energy demand

Qp = 33.43 kWh/(m²a) ≤ Qp,max = 70.63 kWh/(m²a) ⇒ VERIFICATION PROVIDED
No closer Qp check required

Calculation of the primary energy demand of heat pumps in buildings

The primary energy factor for electricity is relevant when determining the primary energy demand for heating by means of a heat pump. This flows into the EnEV calculation, together with other appliance and system-specific factors in the form of the system expenditure of energy value [e_p].

The appliance expenditure of energy value identifies the efficiency of energy conversion in heating systems and consequently, for a heat pump, depends directly on the seasonal performance factor (see chapter A.2.4): The higher the seasonal performance factor, the lower the appliance expenditure of energy value. The calculation process is regulated as follows:

$$e_{H,g} = \frac{1}{\beta_{WP}}$$

$e_{H,g}$ heat pump expenditure of energy value
β_{WP} heat pump seasonal performance factor

In connection with calculating the seasonal performance factor, DIN 4701-10 differentiates according to heat pump type and takes the energy demand of additional auxiliary drives into account, such as the brine pump, for example. Further system-specific correction factors are included. When engineering a heat pump system, it is not necessary to calculate the expenditure of energy value in isolation, as significant data is stored in the corresponding programs developed for the EnEV certificate (see chapter D.3.2).

B.2.2 Heat pumps in the Renewable Energies Heat Act [EEWärmeG]

The law to encourage the use of renewable energy sources in the heating sector (Renewable Energies Heat Act) effective since the 1 January 2009, specifies a certain proportion of renewables for the heating of new buildings (in some federal states, similar statutes also apply to building modernisation). This act must be taken into account in addition to the EnEV. If you decide in favour of heating with a heat pump, this must provide at least 50 % of the required heating energy.

The Renewable Energies Heat Act specifies certain minimum requirements concerning the seasonal performance factor for the appliances used. The obligation to use is deemed to have been met if an air/water or air/air heat pump achieves a calculated seasonal performance factor of at least 3.5. For all other types, a calculated seasonal performance factor of at least 4 applies.

If the heat pump is also used for DHW heating in the building, the required seasonal performance factor is reduced by 0.2 percentage points respectively.

It may be necessary for systems that incorporate a heat pump to be equipped with a heat and electricity meter.

Practical experience over the past few years has shown that heat pumps have developed into one of the most efficient and affordable solutions when it comes to the requirements of the Renewable Energies Heat Act.

B.2.3 European framework directives

Like many other technology sectors, the heating of buildings is also increasingly determined by European directives which are subsequently reflected in national statutes. For example, the Germany EnEV is embedded in the EU Directive 2002/91/EC on the overall energy efficiency of buildings (EPBD = Energy Performance of Buildings Directive).

In future, systems used for heating buildings within the EU will also be subject to the ErP (Energy related Products)/Eco Design Directive 2009/125/EC. In future, an increasing number of products will be labelled in line with these new regulations, that should provide consumers with better information on energy efficiency. This method is already well known from refrigerators and other domestic appliances.

When this technical manual went to press no final decision had been made as to how these regulations would be implemented in detail for heating systems. However, it is already apparent that heat pumps will be added to the best energy category.

Economic considerations

In addition to the undisputed positive ecological effects of a well sized heat pump system, economic benefits also weigh in their favour.

In most cases, heat pumps require an initial high investment; ground sourced systems can soon enter five figures. However, low operating costs are the trade-off.

A professional consultation on viability highlights what is important, and makes the decision easier for owners.

It is recommended to draw on an established procedure, such as that in VDI 2067, when taking an overall look at the efficiency of a heating system. This ensures that all factors that are required for the correct calculation are taken into account.

Compared to conventional heat generators, heat pumps require a comparatively high level of investment – irrespective of possible subsidies – which makes the accurate calculation of capital outlay essential. Operating costs, on the other hand, are comparatively low – any efficiency calculation is therefore less sensitive to future energy cost escalations than for gas or oil fired heat generators, for example. In order to determine the necessary amount of fuel or electricity required, the seasonal performance factor is applied, not the efficiency (as for boiler systems).

Experience shows that the running costs are around 50 % lower than those of fossil fuels; maintenance costs, too, are low.

Any comparison between a heat pump system and other forms of heating system consequently depends strongly on the applied return on capital and the assumed energy price escalation. It has proven to be appropriate that investors should be drawn into the determination of these positions. That makes the calculation more transparent and traceable.

Example

Comparison of operating costs and economy

Project details

New build, located in: Brandenburg, heat demand 6 kW, central heating (underfloor heating system) and domestic hot water

Heat pump

Brine/water heat pump, mono mode, probe depth 100 m, seasonal performance factor 4.4

Alternatives

Oil heating system (efficiency 85 %)
Gas heating system (efficiency 90 %)
Pellet heating system (efficiency 90 %)

Energy costs

Power	16 Ct/kWh
Oil	6.7 Ct/kWh
Gas	7.0 Ct/kWh
Pellets	5.1 Ct/kWh

Investment costs

Heat pump (incl. probe)	€17,906
Oil boiler (incl. oil tank)	€13,836
Gas boiler (incl. connection)	€9742
Pellet boiler (incl. pellet store)	€16,142

Running costs per annum (incl. service, etc.)

Heat pump	€599
Oil heating system	€1099
Gas central heating	€1212
Pellet heating system	€895

Total costs p.a.*

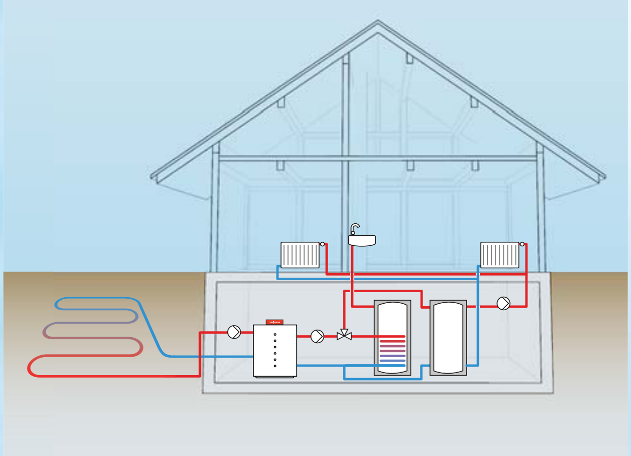
Heat pump	€1699
Oil heating system	€2203
Gas central heating	€1967
Pellet heating system	€2200

*Total costs: Time frame: 20 years, interest rate: 6 %, investment outlay and annual operating costs

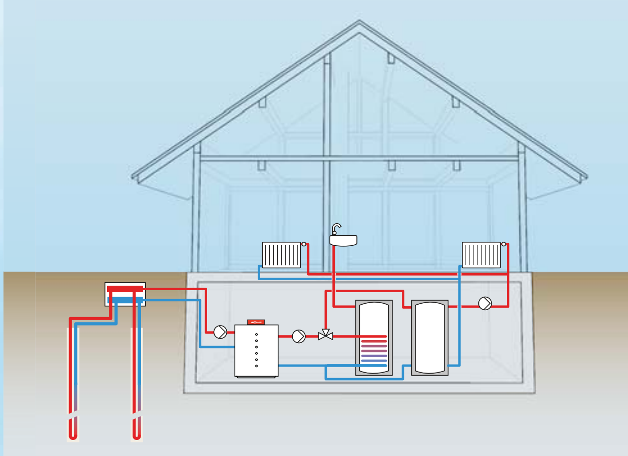
Sample calculations from the Viessmann heat pump engineering program Vitodesk 200

The amortisation of a heat pump can be further influenced in a positive way by possible special tariffs offered by power supply utilities (see chapter B1.2.).

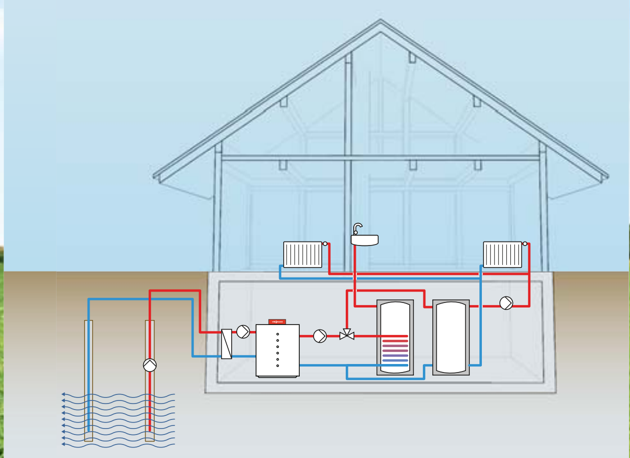
Ground source (collector)



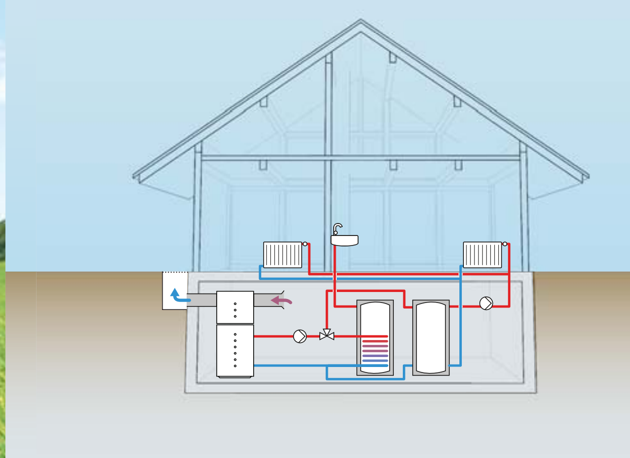
Ground source (probe)



Ground source (groundwater)



Air source



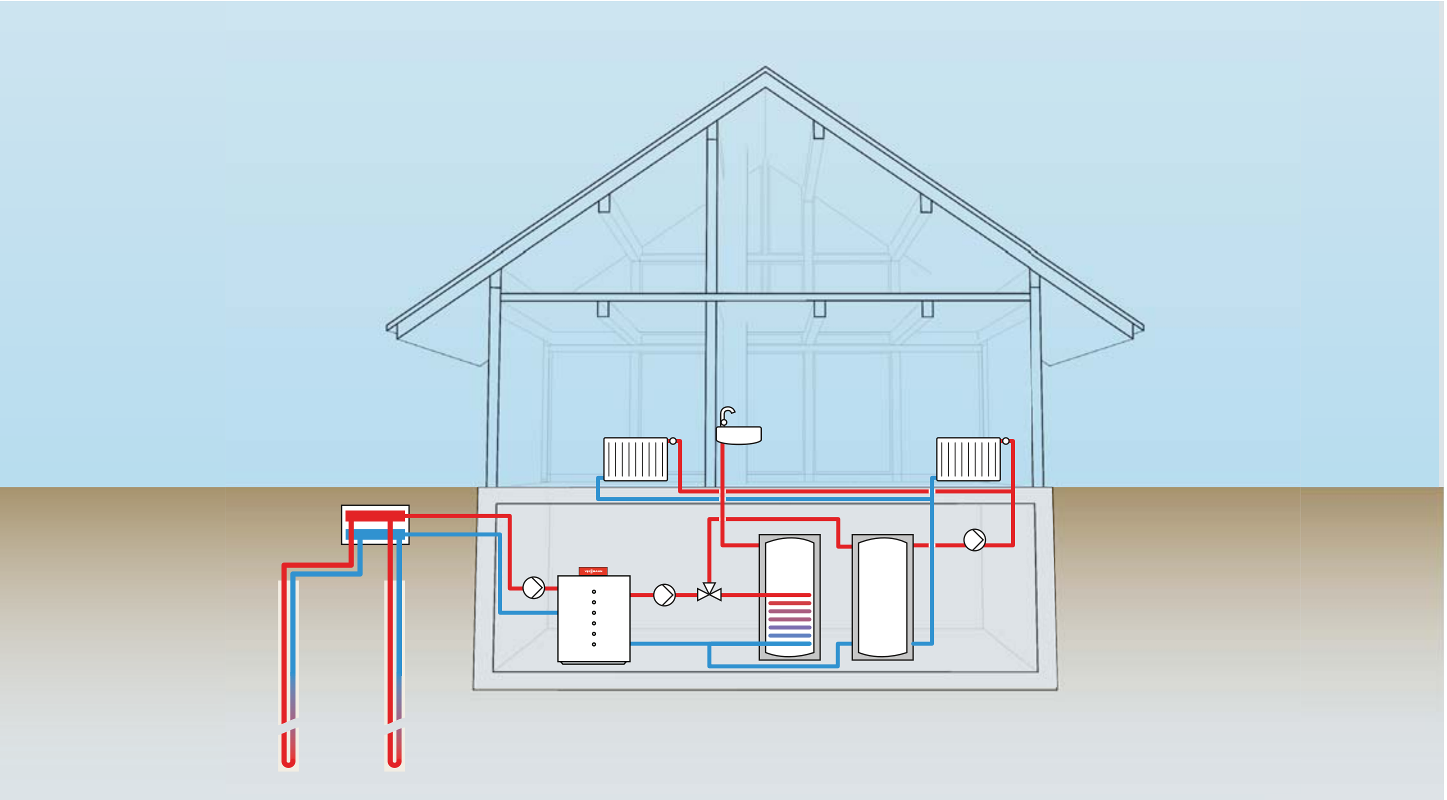
C Engineering and sizing the primary source

Chapter A describes the different energy sources available for use with heat pumps and their relative potential. The following chapter deals with the technical principles of developing these heat sources.

Different heat pump types are able to utilise various primary sources. The decision as to which heat source is most suitable depends on local conditions.

Brine/water heat pumps use the ground as primary energy source, either by deploying geothermal collectors or geothermal probes. Water/water heat pumps are used where water is available as a heat source. Air/water heat pumps utilise outdoor air or extract air as a primary source.

The following applies in every case – only careful engineering and sizing of the primary source can provide the basis for an efficient heat pump system.



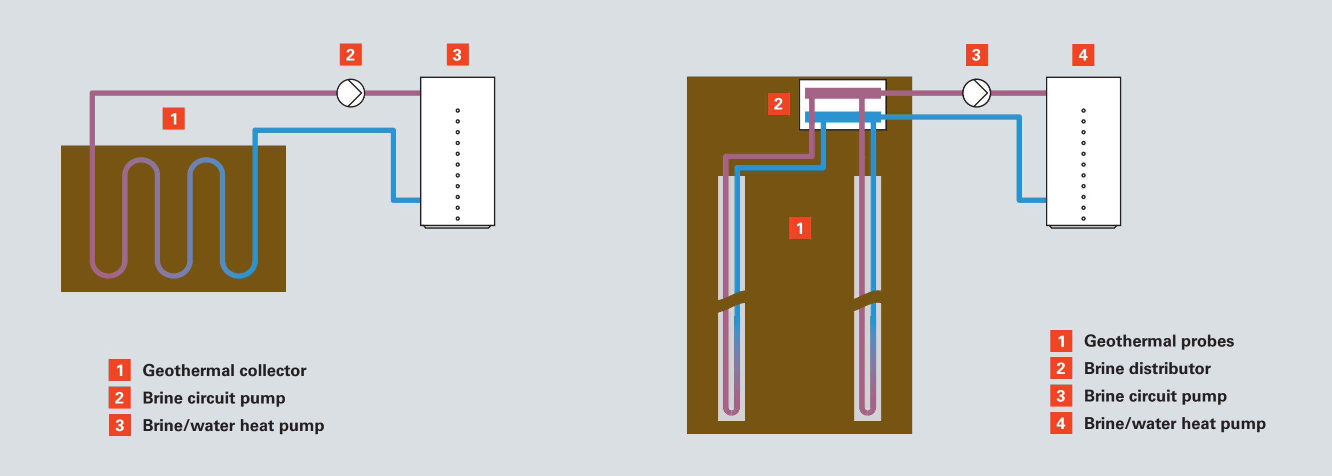
Brine/water heat pumps

Brine/water heat pumps generally use the ground as a heat source. For this, either geothermal collectors or geothermal probes are used.

The engineering of the heat sources is generally oriented on the extraction rate of the relevant subsoil. For this, the cooling capacity of the heat pump, not its heating output, is taken as the reference variable. Relevant details can be found in the appliance datasheets.

The calculation then results either in the required probe length (m) or the area of the geothermal collector (m^2). These permit the respectively required pipe lengths for the actual heat exchanger (subsoil/brine) and associated connection lines to be derived. The pressure drop calculation that builds on this data, as well as the sizing of the primary circuit pump, follow conventional rules of heating technology.

Fig. C.1.1–1 Geothermal collector and geothermal probe



Brine/water heat pumps use the ground as a heat source. For this, geothermal collectors or geothermal probes are used.

C.1.1 Sizing the heat source

Generally, plastic pipes (PE 80 or PE 100) are used as probes and geothermal collectors. For the calculation, the outside diameters are of primary importance as it is from these that the exchanger surface area and consequently the transfer rate of the pipe are derived.

The internal diameter, from which content and pressure drop are derived, results from the following:

$$DI = DA - 2 \cdot S$$

DI internal diameter in mm
DA external diameter in mm
S wall thickness in mm

For the wall thickness, which is crucial for pressure resistance, the SDR (Standard Dimension Ratio) factor is also used for plastic pipes. This denotes the ratio between outside diameter and wall thickness.

$$SDR = \frac{DA}{S}$$

SDR Standard Dimension Ratio (SDR value)
DA external diameter in mm
S wall thickness in mm

The lower the SDR value, the more pressure-resistant the pipe. The DN details that generally refer to the internal diameter, is a standard determination and refers to an average wall thickness.

Fig. C.1.1–2 SDR value

		Wall thickness (mm)	
DN	DA	SDR 11	SDR 7.4
15	20	1.9	2.8
20	25	2.3	3.5
25	32	2.9	4.4
32	40	3.7	5.5
40	50	4.6	6.9
50	63	5.8	8.6

The SDR value provides information about the pressure resistance of plastic pipes.

Note

When purchasing the geothermal probe drilling as a service, the extraction rate should be contractually agreed. Viessmann offers heat pumps with appropriate probe drilling as a package.

For larger probe systems, a geological engineering firm should be asked to provide a simulation of the extraction rates of a probe array. Viessmann offers this through its Geothermie department. Your local Viessmann sales office is the contact for this service.

C.1.1.1 Sizing geothermal probe systems

Determining the extraction rate of probes depends heavily on the local geological layers and may fluctuate by up to 100 %. As a first proximate value, 50 W/m can be assumed. Using geological maps, the extraction rate for the specific location can be estimated more accurately. The thermal conductivity of the individual rock formations and the specific extraction rate are described in chapter A.4.

A specialist contractor should provide the detailed calculation and engineering of the probe system. When determining the required extraction rate, not only the actual heat pump output, but also the seasonal performance factor to be delivered by the heat pump, will be taken into consideration. For example, a heat pump in a parallel dual mode system will deliver a significantly higher seasonal performance factor with the same heating output than a heat pump operated in mono mode. In that case, the probe would have to be sized correspondingly larger.

The following factors need to be observed when sizing the hydraulic pipework of a probe system and its connection lines:

- an even flow rate through every probe,
- from three probes upwards, the use of a probe manifold with control valves to provide the possibility of hydraulic balancing,
- a low pressure drop across the entire probe system (affects the required electrical pump rate of the primary pump),
- the material used and the heat transfer medium must be compatible with each other.

Pressure drop and brine pump size can be calculated if the pipe lengths are known (see chapter C.1.3).

C.1.1.2 Sizing geothermal collector systems

Horizontal geothermal collectors utilise the upper layer of the subsoil as a heat source – they should be laid no less than 20 cm below the frost line up to a depth of approx. 1.5 m. The amount of heat available at this level depends largely on the thermo-physical properties of the subsoil, from the level of insolation and the climatic conditions (precipitation). No buildings must be erected above geothermal collectors, nor must the surface above collectors be sealed.

In order to achieve the lowest possible pressure drop across the entire system, a maximum length of 100 m per pipe circuit has proven to be practical.

Two options are available for calculating the required area of geothermal collector:

- Calculation to VDI 4640
- Calculation to BDH Code of Practice no. 43

Determination of the collector area to VDI 4640

VDI 4640 Part 2 provides standard values for possible extraction rates for geothermal collectors relative to three different soil types (see Fig. C.1.1–4).

The clearances between pipe runs are set for the determination of the specific pipe length, so that a complete freezing over of the subsoil is prevented. Maintaining these clearances ensures that the layers of ice that form around the pipes cannot "join" together.

For PE pipes with diameter DA 20 (DN 15) the recommended clearance is 30 cm, resulting in a specific pipe length of 3 m of pipe per square metre of geothermal collector area (= 3 m/m^2).

With diameter DA 25 (DN 20) the recommended clearance is 50 cm, resulting in a specific pipe length of 2 m of pipe per square metres geothermal collector area (= 2 m/m^2).

The number of pipe circles or loops results from the maximum length of the individual circles of 100 m, the specific pipe length and the required total area of the geothermal collector.

$$N_{RK} = \frac{F_E \cdot L_{RL}}{100\ \mathrm{m}}$$

N_{RK} number of pipe circles
F_E total area of the geothermal collector
L_{RL} specific pipe length per m^2

The following formula enables the required collector area to be calculated:

$$F_E = \frac{Q_K}{q_E}$$

F_E required total area of geothermal collector in m^2
Q_K heat pump cooling capacity in W
q_E maximum area-specific extraction rate in W/m^2

Determination of the collector area to BDH Code of Practice no. 43

The Code of Practice no. 43, issued by the BDH, provides extraction rates for geothermal collectors in diagram form. These are based on the different climatic regions to DIN 4710, which enables a more accurate calculation than the above mentioned process to VDI 4640 (see Fig. C.1.1–5).

The extraction rate can be determined for the relevant climate zone – starting with the cooling capacity of the heat pump – in conjunction with the soil type and the clearance between pipe runs.

As an example for one of the 15 climate regions, on which the DIN 4710 is based, climatic region 7 (Kassel) has been highlighted.

Fig. C.1.1–3 Clearances for geothermal collector runs

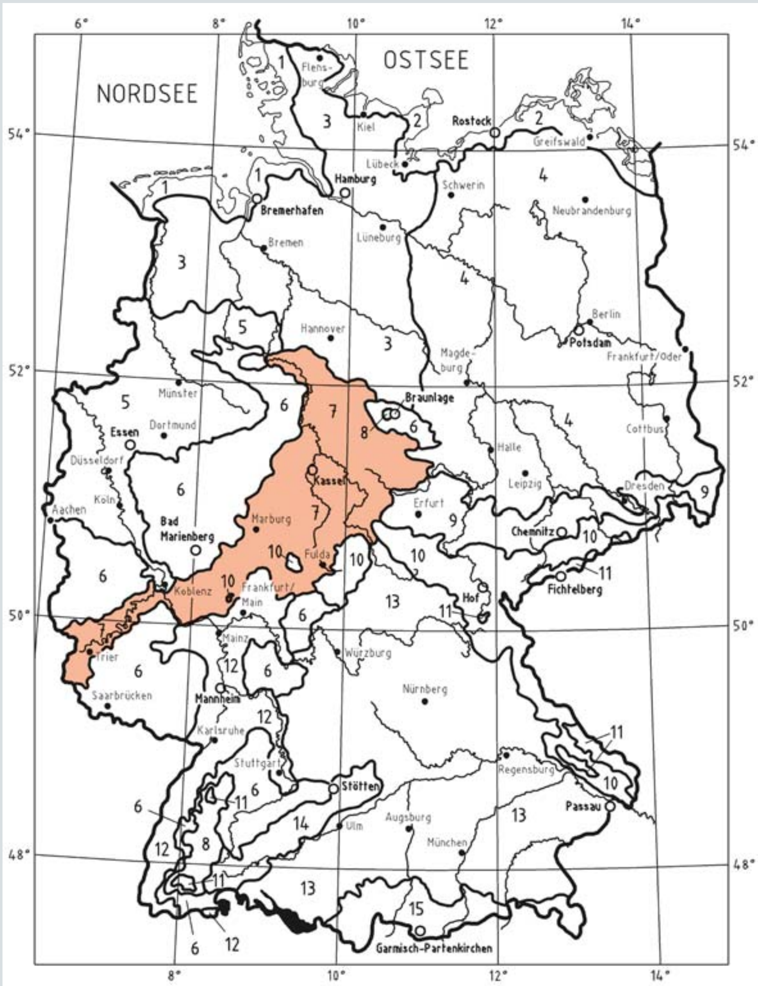
DA	DN	Routing clearance cm	Length of pipe m/m²
20	15	30	3
25	20	50	2
32	25	70	1.5

Fig. C.1.1–4 Extraction rates of geothermal collectors

Subsoil	Specific extraction rate	
	for 1800 h	for 2400 h
Dry non-binding soil	10 W/m^2	8 W/m^2
Binding soil, damp	20–30 W/m^2	16–24 W/m^2
Water-saturated sand/gravel	40 W/m^2	32 W/m^2

The dryer the subsoil, the lower the extraction rate for geothermal collectors.

Fig. C.1.1–5 Climatic regions to DIN 4710

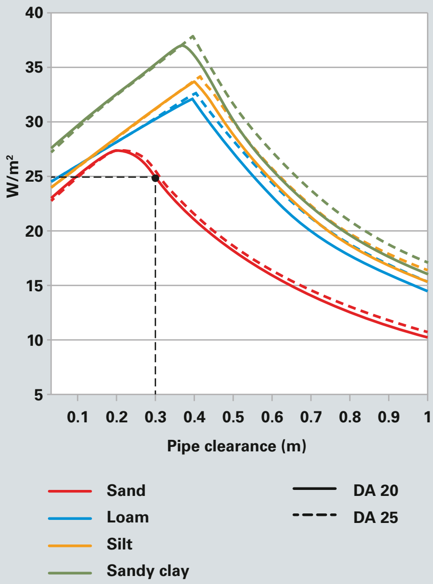


Note

In addition, it provides values for geothermal collectors with DA 32 pipework – in practical applications, however, this size of pipe is hardly ever used, as it is extraordinarily difficult to lay.

Example

For the area around Kassel (climatic zone 7 to DIN 4710), the BDH Code of Practice no. 43 provides values for the maximum area-specific extraction rate (q_E) for various clearances between pipe runs and different types of soil.



Example

Data for the compact heat pump
Vitocal 333-G BWT 108

Heating output: 7.8 kW (at B 0 °C / W 35 °C)
Cooling capacity: 6.3 kW (at B 0 °C / W 35 °C)
Brine content: 3.9 l
Mono mode operation (1800 h)
Calculated extraction rate for the location (sand): 25 W/m²

This enables the required total surface area of the geothermal collector to be determined:

Q_K = 6300 W
q_E = 25 W/m²
F_E = 6300 W / 25 W/m²

The required total surface area of the geothermal collector is approximately 250 m².

A PE pipe 25 x 2.3 (DA 25) is selected for the pipework.

At a maximum length of 100 m and a clearance between pipe runs of 0.5 m (= specific pipe length of 2 m/m²), the following number of required pipe circles/loops results for DA 25 (DN 20):

$$N_{RK} = \frac{250\ m^2 \cdot 2\ m/m^2}{100\ m}$$

The number of pipe circles is 5.

C.1.2 Heat transfer medium

To achieve trouble-free heat pump operation, glycol-based antifreeze is used in the primary circuit. This must protect against frost down to at least –15 °C and contain suitable anti-corrosion inhibitors. Ready-mixed media ensure an even distribution of the solution.

The Viessmann "Tyfocor" heat transfer medium, based on ethylene glycol (ready-mixed, suitable down to –15 °C, green), is recommended.

Required amount of heat transfer medium

The content of the individual probes or geothermal collectors, that of the interconnecting lines and valves, as well as that of the heat pump, are added together to determine the required amount of heat transfer medium.

The individual values can be taken from Fig. C.1.2–1. Consult manufacturer's details in the case of deviating pipe diameters or wall thicknesses.

$$V_R = V_{VL} + V_{EK} + V_{WP}$$

V_R required amount of heat transfer medium in l
V_{VL} content of interconnecting lines in l
V_{EK} content of the individual geothermal collector circuits in l
V_{WP} heat pump content in l

Note

When selecting the heat transfer medium, always observe the stipulations of the authorising body. If this body permits the exclusive use of heat transfer media without inhibitors for corrosion protection or water as heat transfer medium, the following frost protection measures can be taken:

- use of an additional separating heat exchanger (similar to the intermediate circuit for water/ water heat pumps),
- increasing the probe surface area and filling with water.

Fig. C.1.2–1 Pipework content

External ∅ pipe x wall thickness mm	DA	DN	Volume in l per m pipe
20 x 2.0	20	15	0.201
25 x 2.3	25	20	0.327
32 x 3.0 (2.9)	32	25	0.531
40 x 2.3	40	32	0.984
40 x 3.7			0.835
50 x 2.9	50	40	1.595
50 x 4.6			1.308
63 x 3.6	63	50	2.445
63 x 5.8			2.070

Example

Apart from the 5 pipe circles of 100 m each of PE pipe 25 x 2.3 (DA 25), the pipework content includes a supply line of 10 m made from PE pipe 32 × 3.0 (DA 32).

V_{EK} = 5 · 100 m · 0.327 l/m
V_{VL} = 10 m · 0.531 l/m
V_{WP} = 3.9 l

V_R = 5 · 100 m · 0.327 l/m + 10 m · 0.531 l/m + 3.9 l

The pipework content 172.71 l.

C.1.3 Flow rate and pressure drop in the brine circuit

Apart from the system temperature in the secondary circuit, sizing the heat source system, including the pipework, is vital for the efficiency of the heat pump system – this concerns primarily the selection of the flow rate in the primary circuit.

The lower the temperature differential in the brine circuit, the higher the source temperature at the evaporator – which in turn increases the machine efficiency. For probes and geothermal collectors, a temperature differential of 3 K is recommended when calculating the flow rate; up to 5 K is permissible.

At 3 K, a mixture of 85 % water and 15 % glycol and a flow rate in the brine circuit of 184 l/h per kW result.

This value underscores the importance of a primary circuit pressure drop that is as low as possible for overall system efficiency.

Example

Heat pump cooling capacity:
6.3 kW (with B 0 °C / W 35 °C)

Brine circuit flow rate = 6.3 kW · 184 l/(h · kW)

The total flow rate in the brine circuit is approximately 1160 l/h.

Where the total flow rate and the number of probes or geothermal collectors are known, the total pressure drop can be determined using corresponding diagrams.

The total pressure drop results from adding the pressure drop in the supply line and the pressure drop in a parallel pipe circuit.

$$\Delta p = \Delta p_{supply\ line} + \Delta p_{pipe\ circuit}$$

Δp	total pressure drop in mbar
$\Delta p_{supply\ line}$	pressure drop in the supply line in mbar
$\Delta p_{pipe\ circuit}$	pressure drop in the pipe circuit in mbar

Example

The total flow rate in the brine circuit is 1160 l/h. With 5 pipe circles (parallel) of 100 m each PE pipe 25 x 2.3 (DA 25), the flow rate is therefore 1160/5 = 232 l/h

Supply line pressure drop:
10 m supply line PE pipe 32 × 3.0 (DA 32) with 1160 l/h pressure drop per m: 3.0 mbar, total 30.0 mbar

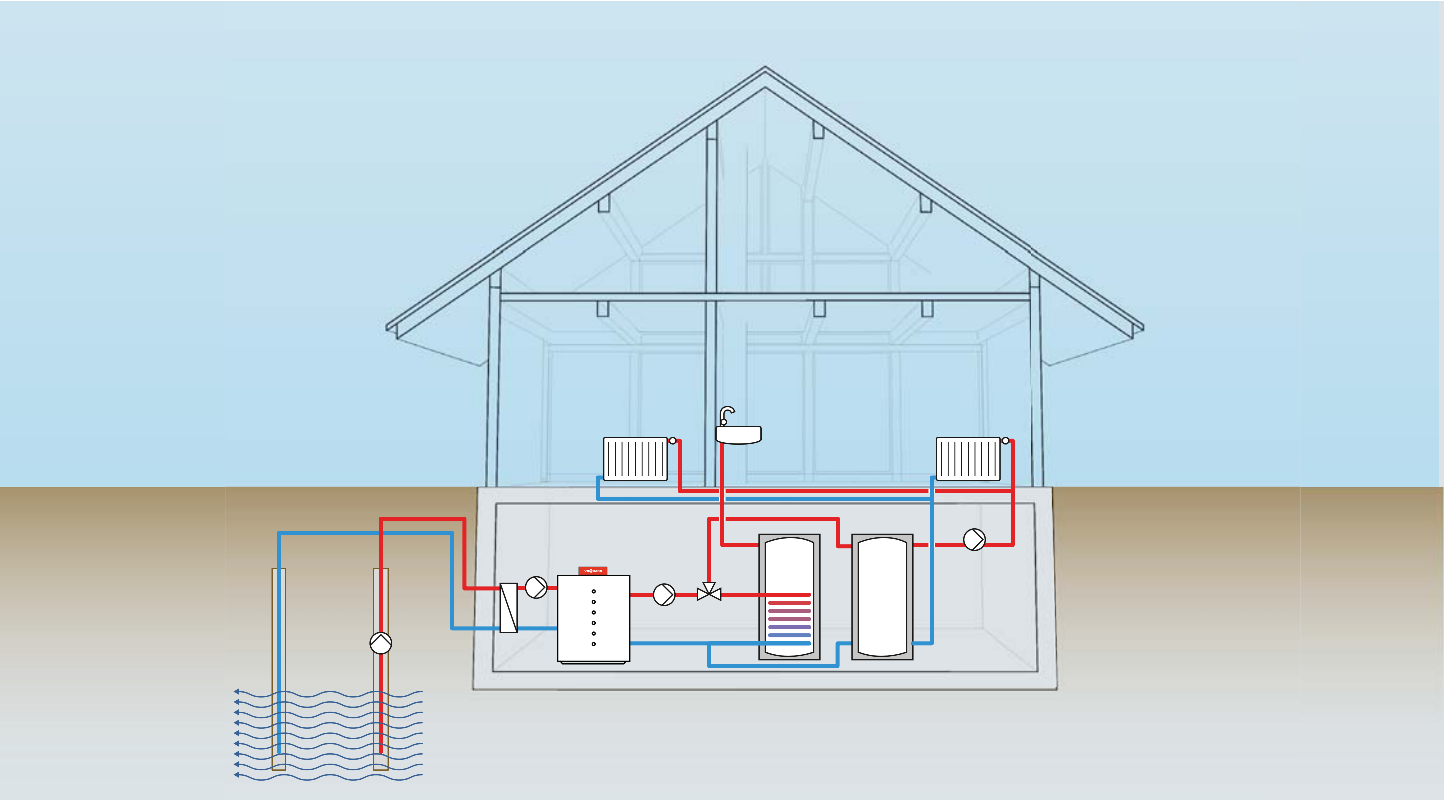
Pipework pressure drop:
100 m PE pipe 25 x 2.3 (DA 25) with 232 l/h pressure drop per m: 0.7 mbar, total 70.0 mbar

Δp = 70.0 mbar + 30.0 mbar

The total pressure drop is 100 mbar.

For heat pumps with an integral brine pump, the calculated pressure drop must be compared to the permissible pressure drop of the primary circuit to be connected. This detail can be found in the datasheet.

For heat pumps without an integral brine pump, the calculated pressure drop and flow rate are used to size an external pump. For this, the pressure drop on the evaporator side of the heat pump must also be considered. This information is also found in the datasheet.



Water/water heat pumps

Apart from groundwater, coolant can also be used as an energy source. Only in rare cases can surface water be used as a heat source. Generally speaking, the water quality must be observed, which is why the use of an intermediate circuit is recommended.

Groundwater offers a constant temperature of 7 °C to 12 °C all year round. Groundwater is extracted via a supply well and transported to the heat pump. After extracting heat, the cooled water is returned into the ground via a return well.

When utilising surface water, it should be noted that temperatures will be subject to greater seasonal fluctuations. For both types of water, the relevant authority must grant permission [the respective water board in Germany].

As water qualities are subject to wide variation, it is recommended to use an intermediate circuit heat exchanger as protection for the plate heat exchangers inside the heat pump. For this purpose, threaded stainless steel heat exchangers have proven to be a good choice.

C.2.1 Groundwater

At least two wells are required when using groundwater directly as a heat source. Engineering and implementation of this well system requires the services of a licensed well contractor. Utilisation of groundwater requires an official permit [in Germany].

Subject to correct engineering and implementation, water/water heat pumps can achieve very high seasonal performance factors on account of their high primary temperatures. However, when engineering, various factors must be taken into consideration:

- Is sufficient groundwater available?
  A volume of 250 l/h per kW heat pump cooling capacity should be available permanently; the pump rate should be verified through a pump test.
- The maximum temperature change must not exceed +/– 6 K.
- Observe the chemical composition and quality of the groundwater (electrical conductivity, oxygen, iron and manganese content). Subject to the chemical composition, there is a risk of corrosion for pipework and system components, as well as the risk of the supply and return wells silting up.
  A chemical analysis of the groundwater is therefore recommended in every case.

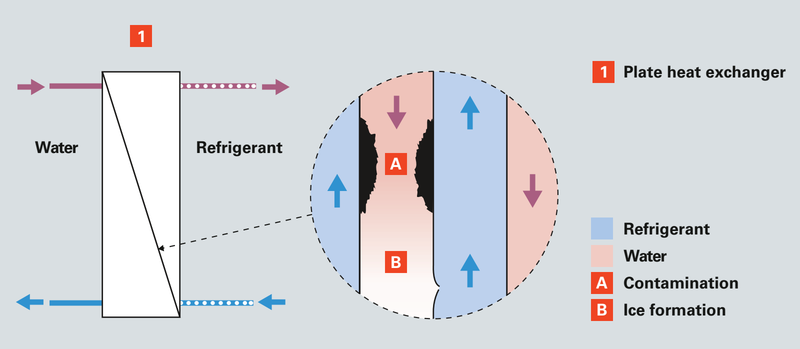
The temperature differential in the primary circuit is of great importance to water/water heat pumps as it is for brine/water heat pumps where the efficiency of the overall system is concerned. On account of the higher source temperature, for water as a primary source, a flow rate based on a 3 K temperature differential is recommended; 6 K maximum is permissible.

This maximum value should never be exceeded. For winter, a groundwater temperature of 8 °C can be assumed, higher temperature differentials could therefore result in the heat exchanger freezing up.

Intermediate circuit

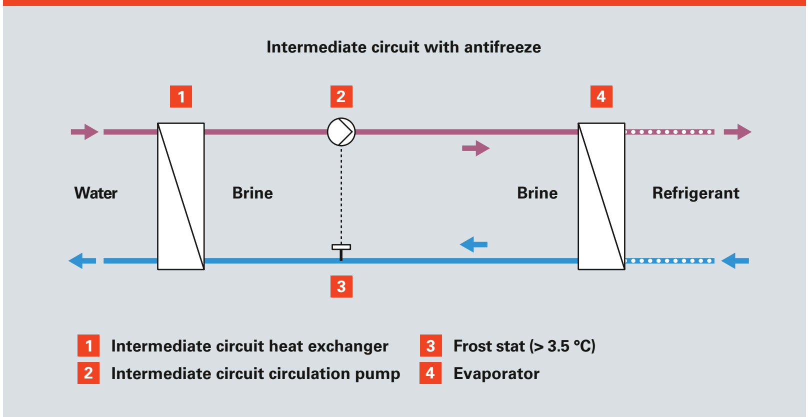
In currently available heat pumps, brazed plate heat exchangers have established themselves for transferring the heat from the primary to the refrigerant circuit. These heat exchangers are subjected to high energetic stresses and they are in constant contact with the heat source medium in the primary circuit. For water/water heat pumps, the primary medium is water in which the most divers chemical constituents have dissolved. As mentioned above, there is therefore a risk of corrosion and sedimentation – with copper-brazed as well as with stainless steel welded and nickel-brazed plate heat exchangers.

Fig. C.2.1–1 Plate heat exchanger at risk



Localised contamination leads to a partial freezing of the water below the contaminated layer on account of its insulating effect. This reduces the flow velocity, the water temperature falls below the freezing point and an ice plug forms. This can result in the bursting of the heat exchanger, leading to irreparable damage to the refrigerant circuit.

Fig. C.2.1–2 Intermediate circuit heat exchanger



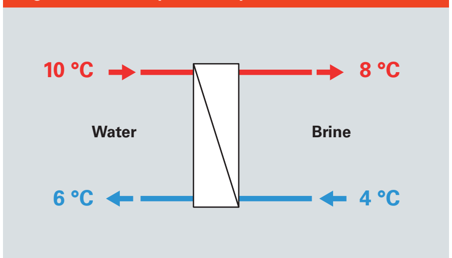
The level of potential risk from sedimentation and corrosion is ultimately determined by the quality of the water used. Consequently, an intermediate circuit offers a high degree of operational reliability for the system – even if the water quality can change during the service life of the system.

To calculate the intermediate circuit heat exchanger, a temperature spread from 6 °C to 10 °C (water) or from 4 °C to 8 °C (heat transfer medium) is recommended. The output to be transferred depends on the cooling capacity according to the datasheet.

The flow rate, resulting from the heat pump cooling capacity, must be determined in order to size the circulation pump of the intermediate circuit. In addition, the sum total of all pressure drop values for the intermediate circuit heat exchanger, evaporator heat exchanger and intermediate circuit pipework must be taken into account.

These recommended temperature spreads form the basis for sizing the intermediate heat exchanger.

Fig. C.2.1–3 Temperature spread

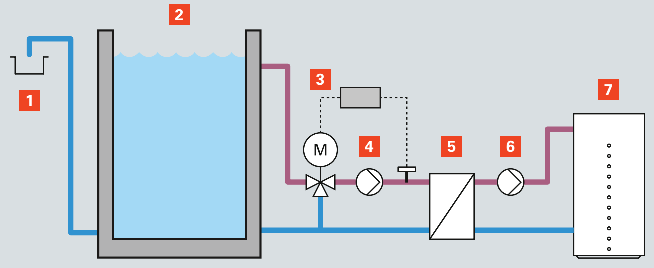


C.2.2 Coolant

When using coolant as a heat source, for example from industrial waste heat, observe the following:

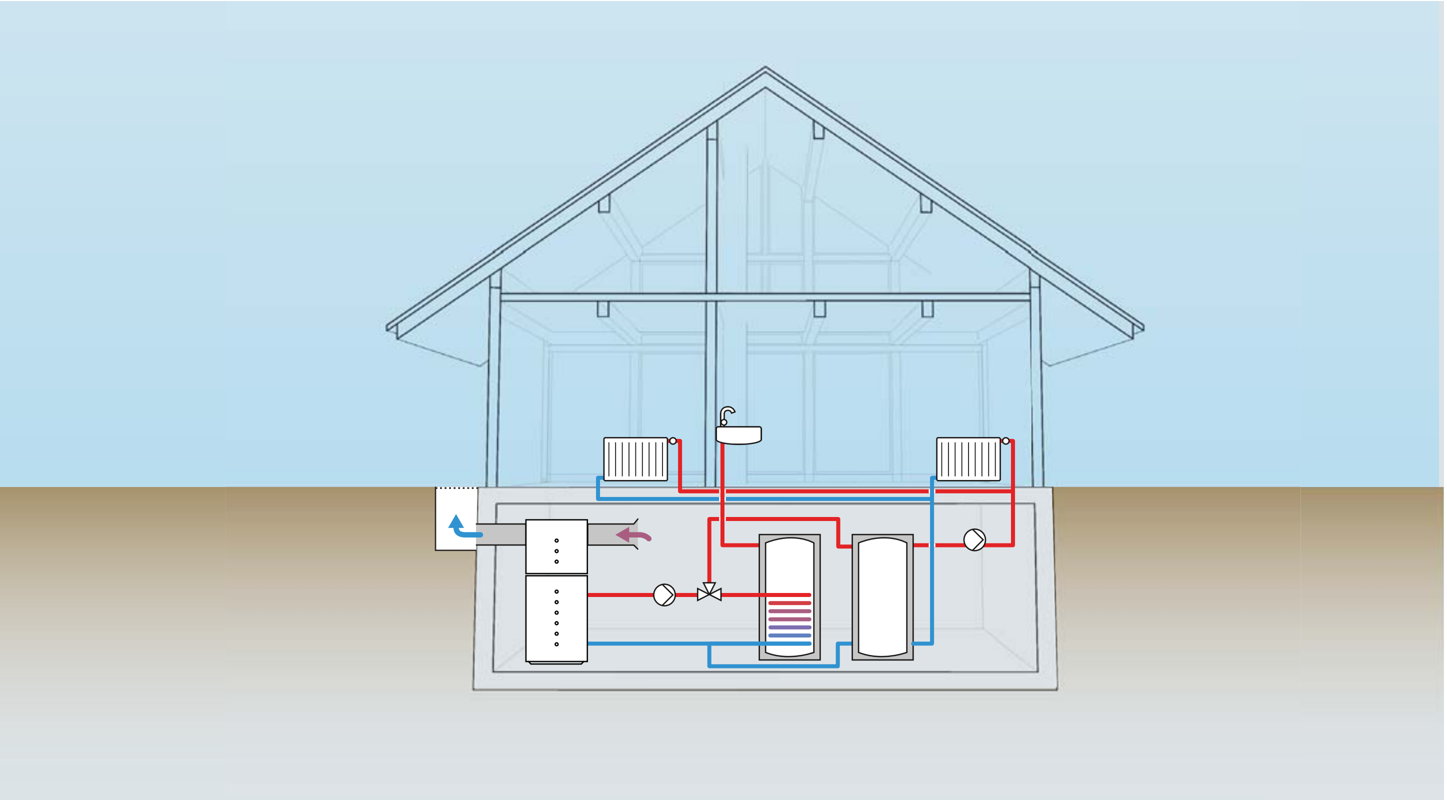
- The available amount of water must correspond at least to the minimum flow rate.
- Avoid maximum primary temperatures in excess of 25 °C. This can be governed by means of a hold-down controller.
- In this case, too, the use of an intermediate circuit is recommended.

Fig. C.2.2–1 Coolant as heat source



1 Overflow
2 Water container
3 Motorised valve with hold down control
4 Primary pump
5 Intermediate circuit heat exchanger
6 Intermediate circulation pump
7 Heat pump

The temperature in the primary circuit must be limited when using coolant as a heat source.



Air/water heat pumps

Using air as a heat source requires the least effort of all.
Air is drawn in, cooled in the heat pump evaporator and finally discharged again to the ambience.

Air as a primary source has two special characteristics that must be observed when planning the use of an air source heat pump; these are explained in this chapter.

Firstly, it is warmer in summer than in winter. This influences the heat pump's output and efficiency. Secondly, the fans, that are an essential part of the machine, generate noise that must be acoustically assessed on-site.

C.3.1 Air/water heat pumps with unregulated compressor

In the building heating sector, heat pumps are used with output-controlled and uncontrolled compressors.

Under certain operating conditions, unregulated, so-called "fixed speed compressors" achieve better seasonal performance factors. At a constant source temperature (for example extract air) or when there is a high heat demand in summer (for example for open air swimming pool heating), the use of regulated compressors is not compelling. However, heat pumps with unregulated compressors for heating buildings generally require a buffer cylinder in order to be able to operate efficiently. For sizing such cylinders, see chapter D.2.2.

C.3.2 Sizing/engineering

C.3.2.1 Heat pump output

When using air as a heat source, observe that the heat pump heating output increases with rising outside temperatures and drops with falling outside temperatures. Mono mode operation would consequently require very large systems. This in turn would mean that the heat pump was oversized for the majority of its runtime. As a result, air source heat pumps are predominantly operated in dual mode. The dual mode point should be between –3 °C and –10 °C outside temperature so that the heat pump can cover the largest possible proportion of the annual heat load (see chapter D).

Ideally, the heat load of the building will be covered closely by the heat pump at the given standard outside temperature. Although the output stages of Viessmann heat pumps are very close to each other, an "accurate" sizing of the machine is only rarely possible. In other words, the available outputs will, in most cases, lie either above or below the heat load.

When selecting a suitable heat pump, initially the model, the output of which lies below the heat load of the building, will be chosen. A simulation determines the proportion of reheating of the required annual heat load. DIN EN 15450 limits electrical reheating to a maximum of 5 %. If the result lies below that value, that heat pump can continue to be used for planning purposes.
A simulation program assists in the calculation of the necessary output of any electrical reheater. The output diagram of a heat pump can be used to explain the calculation path. Here, the output is shown subject to source and flow temperature.

Example	
Heat load of the building:	15 kW
Standard outside temperature:	–14 °C
System temperatures:	45/35 °C

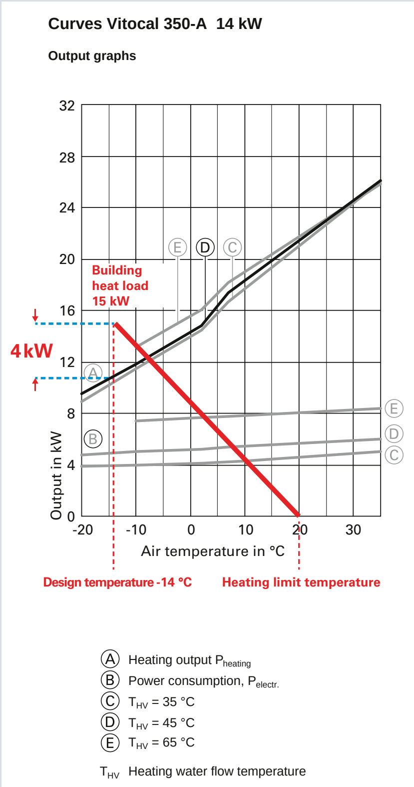
The simulation of a 14 kW heat pump delivers a proportion of electrical reheating (heating rod) on the annual heat load of 2 %.

Example

The heat load curve for the building example (red line) is overlays the diagram of the 14 kW heat pump.

The heat load in the temperature range to the left of the intersection of both curves can no longer be covered by the heat pump.

This example indicates approximately 4 kW that must be covered by a second heat generator.



If the heat pump is used for DHW heating in summer, an air temperature of 35 °C is assumed to determine the maximum output. With this design, a spread of 10 K can be assumed.

$$\dot{Q} = \dot{m} \cdot c \cdot \Delta t$$

$\dot{Q}$ output (of the heat pump) in W
$\dot{m}$ flow rate in l/h
c thermal capacity (of water) in Wh/(kg K)
Δt temperature differential (spread) in K

This formula is rearranged as follows in order to calculate the maximum flow rate:

$$\dot{m} = \frac{\dot{Q}}{c \cdot \Delta t}$$

Example

The heating output of a 14 kW heat pump (at A 35 °C / W 65 °C) is up to 26 kW.

For the connection lines, this means:
Heat pump output: 26 kW
Spread: 10 K

$\dot{Q}$ = 26,000 W
c = 1.16 Wh/(kg·K)
Δt = 10 K

$$\dot{m} = \frac{26{,}000\ \text{W}}{1.16\ \text{Wh/(kg·K)} \cdot 10\ \text{K}} = 2241\ \text{l/h}$$

The pipework must be sized for a flow rate of 2200 l/h.

C.3.2.2 Sizing and connection lines

It is well known that the output of air source heat pumps depends on the outside temperature. Consequently, the connection lines to the heating system require careful engineering. This means that the hydraulic connections between the heat pump and the heating system are sized for the point of maximum possible heat pump heating output. It must be ensured that the heating output generated by the heat pump can be reliably transferred to the downstream system.

When engineering air source heat pumps it is extremely important to differentiate between heat pumps installed internally and externally. With externally sited heat pumps, particularly the sound propagation into the ambience must be considered in planning; for internally sited heat pumps the air duct system requires additional attention.

C.3.3 Acoustic engineering

The acoustic assessment of heat generators and distribution equipment in building services has become increasingly more important in recent years. Whilst keeping the user's comfort in mind, flow noise in pipelines and structure-borne noise transmission from pumps or other technical drives should be prevented. In this respect, heat pump systems are no different to other heat generators.

However, by using air as a primary source, fans bring a component into play, the sound emissions of which require attention during engineering, particularly when machines are sited outdoors.

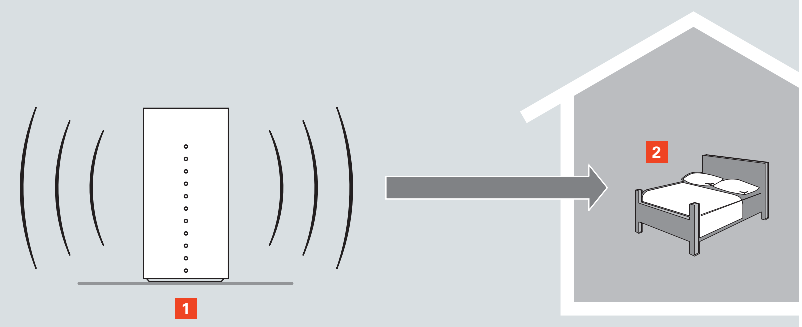
The sound power level, L_W, describes the entire sound emission radiated by the heat pump in all directions, independent of ambient conditions (reflections). The sound power level is determined under laboratory conditions and represents the assessment variable for heat pumps in direct comparison.

The sound pressure level, L_P, is a measure used to give an indication as to the noise volume perceived at a specific location. In other words it describes what "arrives" at the ear. The sound pressure level is substantially influenced by the distance from the source of noise and ambient conditions. The sound pressure can be measured locally and is the assessment variable for location-specific immissions of individual systems. It offers pointers for a suitable installation site for the heat pump.

Compression heat pumps generate noise during operation that may have consequences for the selection of the installation site. Careful planning is therefore required, particularly for air source heat pumps installed outdoors. The manufacturer's datasheet provides details on the sound power level of the appliances.

With externally sited heat pumps, the sound immissions in the rooms most affected and requiring protection are measured. In order to determine these values, sound immissions outside the building, measured 0.5 m from the centre of the open window, are decisive.

Fig. C.3.3–1 Sound pressure level and sound power level



1 Sound source (emission site)
Measuring variable: sound power level L_W

2 Sound immission (immission site)
Measuring variable: sound pressure level L_P

The sound power is emitted by the source of sound. The sound pressure is perceived at the ear.

Fig. C.3.3–2 Standard immissions values for type of immission outside buildings

	During the day	At night
In industrial areas	70 dB(A)	70 dB(A)
In commercial areas	65 dB(A)	50 dB(A)
In urban areas, villages and mixed areas	60 dB(A)	45 dB(A)
In general residential areas and small housing estates	55 dB(A)	40 dB(A)
In purely residential areas	50 dB(A)	35 dB(A)
In spa areas, hospitals and care homes	45 dB(A)	35 dB(A)

Extract from the TA Lärm [Germany]

The standard values are specified in the TA Lärm [Germany].

According to DIN 4109, rooms requiring protection are the following:

- living and bedroom
- children's bedrooms
- utility rooms/offices
- training rooms/study rooms

Note

A precise sound immissions prognosis must be produced (consult an acoustic engineer) if the heat pump sound pressure level as estimated from the table differs by more than 3 dB(A) from the permissible standard value given by the TA Lärm.

In order to assess the acoustic implications of the heat pump installation site, the expected sound pressure level on rooms requiring protection must be calculated.

The following formula enables the estimation of the sound pressure level derived from the sound power level of the appliance, the installation location and the respective distance from rooms requiring protection:

$$L_P = L_W + 10 \cdot \log\left(\frac{Q}{4 \cdot \pi \cdot r^2}\right)$$

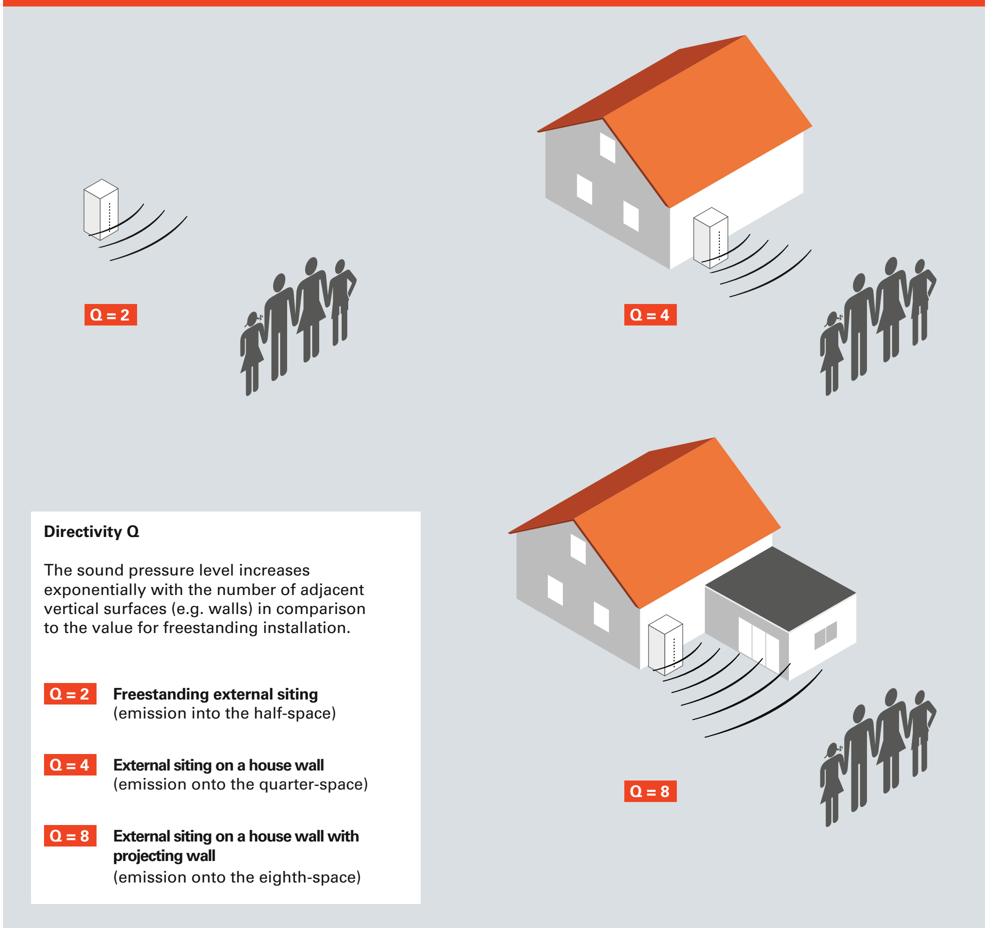
- L_P sound pressure level at the receiver (standard value to TA Lärm)
- L_W sound power level at the source of sound (details from the datasheet)
- Q directivity
- r distance between receiver and source of sound

The directivity, Q, takes the spacial radiation conditions at the source of sound into consideration. If the source of sound is placed in a completely unobstructed room, sound waves propagate in the air in every direction equally in the shape of a sphere. In this case, the directivity Q = 1.

If the source of sound is floorstanding, the sound waves can only propagate in the form of semi spheres; the directivity, Q, is then 2. The tighter the radiation angle (quarter-space, eighth-space), the higher the directivity and sound level at the receiver.

The sound pressure level at the room to be protected therefore reduces (starting with the actual sound power level at the appliance) subject to distance and directivity.

Fig. C.3.3–3 Directivity



Directivity Q

The sound pressure level increases exponentially with the number of adjacent vertical surfaces (e.g. walls) in comparison to the value for freestanding installation.

Q = 2 **Freestanding external siting** (emission into the half-space)

Q = 4 **External siting on a house wall** (emission onto the quarter-space)

Q = 8 **External siting on a house wall with projecting wall** (emission onto the eighth-space)

Fig. C.3.3–4 Distance from the source of sound

Directivity Q	Distance from the sound source in m								
	1	2	4	5	6	8	10	12	15
	Sound pressure level L_P relative to the sound power level L_W in dB(A) measured at the appliance								
2	-8	-14	-20	-22	-23.5	-26	-28	-29.5	-31.5
4	-5	-11	-17	-19	-20.5	-23	-25	-26.5	-28.5
8	-2	-8	-14	-16	-17.5	-20	-22	-23.5	-25.5

Determining the sound pressure level based on the sound power level.

Example

Selected heat pump 14 kW

The siting on a building wall results in directivity Q 4. The building is situated in a general residential area in accordance with a local building plan. Here, the permissible standard immission value at the receiver during daytime is 55 dB(A) and at night 40 dB(A).

Sound power according to datasheet:

Vitocal 350-A Type	14 kW
Sound power level L_W – Fan stage 1 – Fan stage 2 – Fan stage 3	 56 dB(A) 57 dB(A) 59 dB(A)

To determine the required minimum clearance to rooms requiring protection, the sound power level at fan stage 3 (59 dB(A)) is taken into consideration at installation situation Q 4.

Reduction of sound pressure level through clearance (to Fig. C.3.3–4)

Daytime

The sound pressure level reduces by 5 dB(A) at 1 m distance

59 dB(A) – 5 dB(A) < 55 dB(A)

The heat pump can be sited at 1 m distance from rooms requiring protection.

At night

The sound pressure level reduces by 19 dB(A) at 5 m distance

59 dB(A) – 19 dB(A) = 40 dB(A)

The heat pump can be sited at 5 m distance from rooms requiring protection.

Viessmann controllers offer an optional night setback. If this parameter is set, the sound power level for fan stage 2 can be assumed.

The table in Fig. C.3.3–4 or the Viessmann system sizing aid can be used (see Fig. C.3.3–5) to provide an easy determination of the sound pressure level and the required minimum clearances.

For further information on the Viessmann sizing aid, see chapter D.

Fig. C.3.3–5 Sound calculations with the heat pump sizing aid

The plastic slider is used just like a slide rule.

Fig. C.3.4–1 Air routing with internal installation

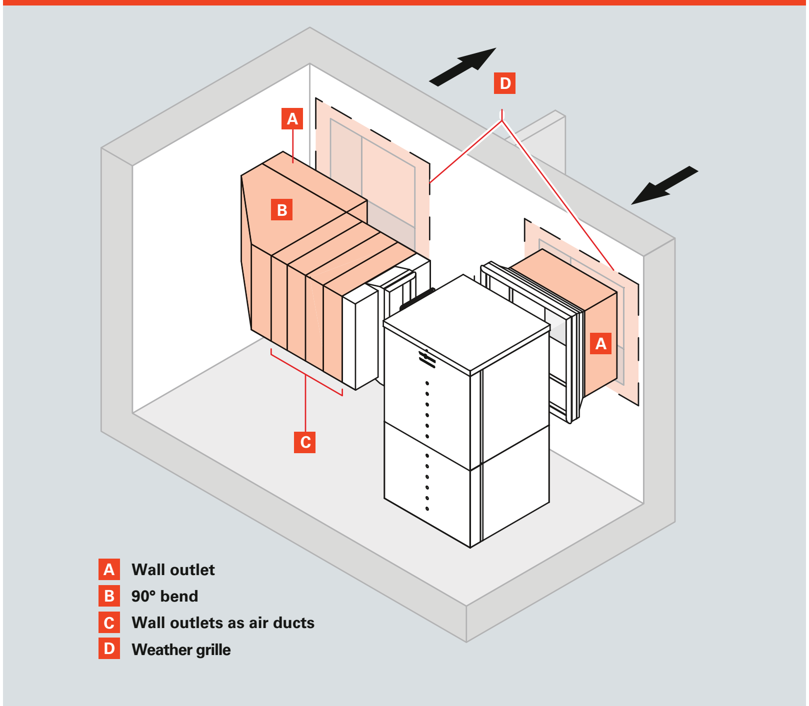
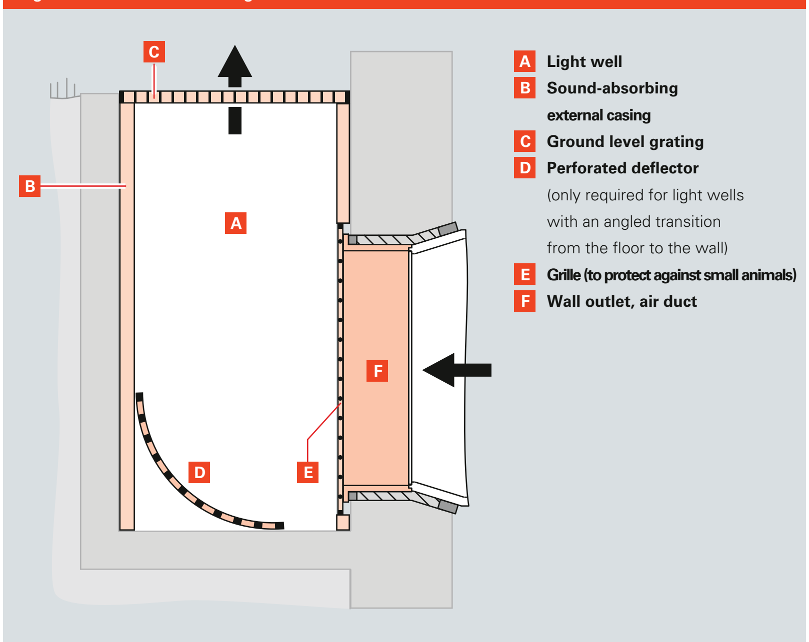


Fig. C.3.4–2 Air duct with light well



C.3.4 Air routing for internally sited air/water heat pumps

For internally sited air/water heat pumps, the outdoor air required as heat source is routed to the heat pump via a duct system. It is therefore necessary to carry out a pressure drop calculation for the duct system.

The datasheets for the heat pump specify the maximum permissible pressure drop that the fan must overcome. The intended duct system should be checked using these values.

The pressure drop values for the air ducts depend on the air flow rate. The datasheets of the individual components assign the individual pressure drop values to the different heat pump types.

$$\Delta p < \Delta p_{avail}$$

Δp total pressure drop in Pa
Δp_{avail} permissible pressure drop in Pa

$$\Delta p = \sum \Delta p1 + \sum \Delta p2 + \sum \Delta p3$$

$\sum \Delta p1$ total of individual pressure drop values, wall outlet
$\sum \Delta p2$ total of individual pressure drop values, 90° bend
$\sum \Delta p3$ total of individual pressure drop values, weather grille

For the connection of air ducts below ground level, ensure that the cross-sections are large enough in order to minimise air noise. It is therefore recommended to ensure favourable flow patterns when routing air inside a light well (see Fig. C.3.4–2).

Example

Heat pump 14 kW, sited internally.

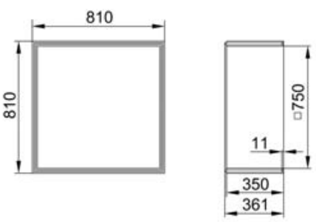
The datasheet specifies a maximum permissible pressure drop of 45 Pa.

The air supply requires a duct of 3.5 m length, overall.

The duct comprises:

- 10 wall outlets of 0.35 m each = 3.5 m
- one 90° air duct bend
- two weather grilles

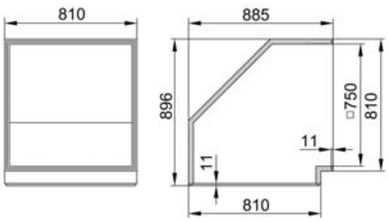
Wall outlet, straight



Pressure drop per metre air duct

	Vitocal 350-A 14 kW
Air flow rate	4000 m³/h
Pressure drop	0.07 Pa

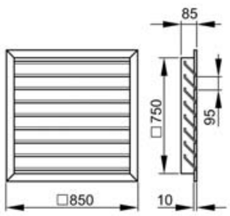
Air duct, 90° bend



Pressure drop per 90° bend

	Vitocal 350-A 14 kW
Air flow rate	4000 m³/h
Pressure drop	2.0 Pa

Weather grille



Pressure drop

	Vitocal 350-A 14 kW
Air flow rate	4000 m³/h
Pressure drop	20 Pa

Heat pump 350-A, output 14 kW	
Air flow rate	4000 m^3/h
Permissible pressure drop Δp_{verf}	45 Pa
Pressure drop per metre wall outlet:	0.07 Pa
Pressure drop 90° air duct bend:	2.0 Pa
individual pressure drop weather grille:	20 Pa

Total pressure drop

$\Delta p = 3.5 \cdot 0.07\,Pa + 2.0\,Pa + 2 \cdot 20\,Pa = 42.245\,Pa$

$\Delta p < \Delta p_{verf}$

The intended duct system can be operated with the selected machine.


VIESSMANN
VITOCAL 300

D System engineering

Whilst the previous chapter considered the different energy sources available for use with heat pumps, this chapter turns its attention to the way that heat pumps interact with other components. Only carefully devised planning and engineering turns efficient appliances into efficient systems.

In building services, efficiency is achieved through optimum interaction between all components employed. Given this pre-requisite, it is essential that the engineering and layout of a heating system meet the three following requirements: user convenience, reliable operation and the lowest possible use of primary and auxiliary energy.

This chapter provides design engineers and heating system installers with information that is important for the correct selection of appliances and determination of conditions, in order to be able to significantly influence the efficiency of the overall system on the heat transfer side. At the end of this chapter Viessmann engineering aids for trade partners are explained in full.

Operating modes

Subject to the required application and the associated temperature, heat pumps can operate in different ways, as individual appliances or in combination with additional heat sources.

The efficiency of the heat pump is essentially dependent on the downstream system and the maximum necessary flow temperature. In new buildings, the downstream system can be designed from the start to operate efficiently with low system temperatures (e.g. area heating systems). However, systems in modernisation projects are frequently encountered that can only be matched to a sole heat pump operation with some difficulty, or that have a very high heat demand. Nevertheless, heat pumps can still be used efficiently if their integration into the system as a whole is clearly determined at the planning stage.

A heat pump can be operated in mono or dual mode. For dual mode operation, we differentiate between alternative, parallel and partially parallel operating modes.

D.1.1 Mono mode operation

The heat pump covers the entire heat load of the building and the DHW heating, as sole heat generator. For this, the maximum system temperature must be below the maximum flow temperature that the heat pump can achieve.

D.1.2 Dual mode operation

Apart from the heat pump, a second heat source is essential – this provides either a proportion of the required heating output or a necessary higher system temperature. If the second heat source is an electric booster heater (for example a heater rod or an instantaneous heating water heater), it is referred to as "mono energetic operation".

D.1.2.1 Parallel operating mode

Down to a certain outside temperature (dual mode point), the heat pump covers the entire heat load of the building. Below that temperature, a second heat source will be started.

This operating mode has consequences when planning the heat source: With mono mode systems, the heat pump output has a certain relationship with the extracted amount of heat. In parallel mode, the heat pump runtime extends, in other words it extracts more energy from the heat source. This must be taken into consideration, particularly when sizing probes and geothermal collectors.

The second heat source raises the output of the overall system. Based on DIN 4701-10, the proportion of the overall heat demand covered by the heat pump can be calculated (see Fig. D.1.2–4).

Fig. D.1.1–1 Mono mode operation

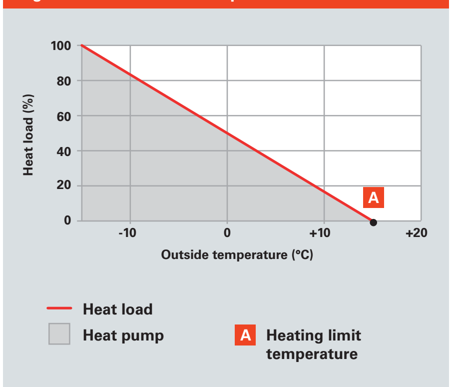
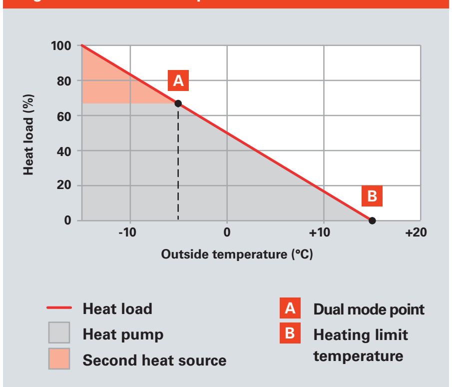


Fig. D.1.2–1 Parallel operation



Either the heat pump is the only heat generator (Fig. D.1.1–1) or it is backed up by a second heat generator from a certain heat load upwards (Fig. D.1.2–1).

The following is critical for the sizing of a heat source: Either the heat pump switches off when the dual mode point has been reached (Fig. D.1.2–2) or it continues to operate in parallel with the second heat generator (Fig. D.1.2–3).

Fig. D.1.2–2 Alternative operation

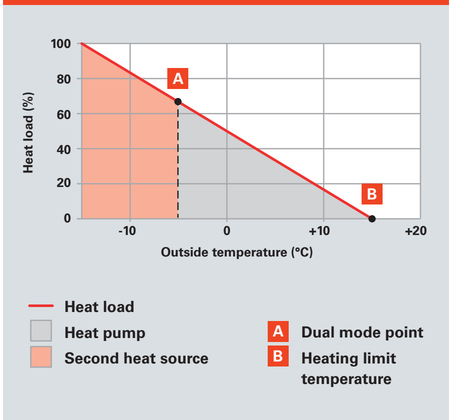
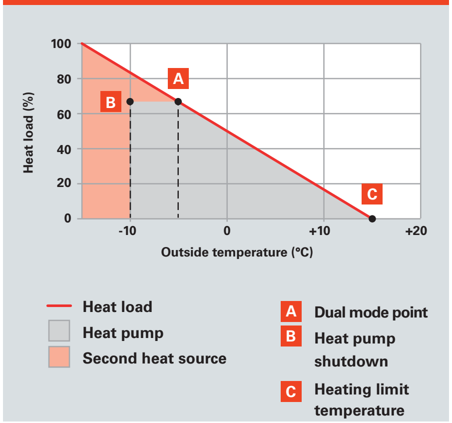


Fig. D.1.2–3 Partially parallel operation



D.1.2.2 Alternative operating mode

Up to the dual mode point, the heat pump covers the heat load of the building on its own and then passes the entire heat generation to the second heat generator. From this dual mode point onwards, the heat pump remains switched off. The second heat generator can cover the entire heat load at the required temperature levels. In this operating mode the heat source will be sized with reference to the heat pump output.

D.1.2.3 Partially parallel operating mode

Up to dual mode point, the heat pump covers the entire heat load of the building. Below the dual mode point, a second heat generator will be started in addition to the heat pump.

The heat pump operates in parallel to the second heat generator until the maximum flow temperature has been reached and then shuts down.

The second heat generator is sized for the entire heat load, the same as with the alternative operating mode. With this operating mode, the heat source must be sized with reference to the entire heat pump heating output.

The heat pump coverage is specified by DIN 4701-10 and also acts as basis for calculation in the VDI 4650 (see Fig. D.1.2–4).

Proportion of coverage of a system operated in dual mode subject to the dual mode point, output proportion and heat pump operating mode.

Fig. D.1.2–4 Heat pump rate of coverage (extract from DIN 4701 Part 10)

Dual mode point ϑ_{Biv} [°C]	-10	-9	-8	-7	-6	-5	-4	-3
Output portion μ [-]	0.77	0.73	0.69	0.65	0.62	0.58	0.54	0.50
Coverage $\alpha_{H,g}$ [-] for dual mode parallel operation	1.00	0.99	0.99	0.99	0.99	0.98	0.97	0.96
Coverage $\alpha_{H,g}$ [-] for dual mode alternative operation	0.96	0.96	0.95	0.94	0.93	0.91	0.87	0.83

Dual mode point ϑ_{Biv} [°C]	-2	-1	0	1	2	3	4	5
Output portion μ [-]	0.46	0.42	0.38	0.35	0.31	0.27	0.23	0.19
Coverage $\alpha_{H,g}$ [-] for dual mode parallel operation	0.95	0.93	0.90	0.87	0.83	0.77	0.70	0.61
Coverage $\alpha_{H,g}$ [-] for dual mode alternative operation	0.78	0.71	0.64	0.55	0.46	0.37	0.28	0.19

D.1.3 Cascade systems

Heat pumps are predominantly used in detached and two-family houses. Generally, this output range can be covered by standard products. However, the market for higher heating outputs is growing, as employed in apartment buildings, municipal facilities and the industrial sector, for example. Here, heat pumps are used to cover the heating and DHW demand, as well as for cooling the building.

Standard and bespoke heat pumps are available for these purposes. In order for standard heat pumps to be able to deliver higher heating outputs efficiently, smaller units are often assembled into cascaded systems.

A cascade is comprised of several modules and offers crucial benefits, e.g. individual modules can be handled more easily during the building phase and thus enable a more flexible engineering of systems. This facilitates the joining of modules with different output and flow temperatures into a single system. As a result, a cascade system can be matched to the individual demand of the project in question.

D.1.3.1 Cascade systems with the same temperature level

Cascade systems can be designed so that the intermittent output demands can be satisfied in stages, i.e. through individual modules with different output ratings. The cascade controller starts individual modules subject to the output demand of the building. Generally, the common return temperature serves as the "control variable".

D.1.3.2 Cascade systems with different temperature levels

Systems with simultaneously different temperature demands can also be supplied efficiently by means of a cascade system. If, in an apartment building, there is a simultaneous demand for DHW and central heating, a high temperature heat pump with a flow temperature of 70 °C can heat the DHW cylinder to 60 °C, whilst different modules in the cascade can deliver central heating at a substantially lower temperature level. This would not be possible with a single machine.

Smaller partial systems can be assembled into cascades to provide a higher heating output.

Fig. D.1.3–1 Cascade systems

D.1.4 Combination with renewables

Heat pumps in alternative or parallel operation can also be combined with other renewable energy sources. In combinations with solar thermal systems, the insolation is connected as priority; in the case of biomass boilers, the operating mode depends on the conditions dictated by the building.

D.1.4.1 Heat pump and solar thermal system

The combination of a heat pump and a solar thermal system provides an opportunity to link two systems that operate with renewable primary energy. As with any heat generator, solar thermal systems can also provide backup for the heat pump in DHW heating, central heating and swimming pool water heating. The relevant sizing principles are described in the Solar thermal technical guide, chapter C.3.

The solar thermal system provides the heat pump with relief from DHW heating for a large part of the year (times when the heat pump generally operates with lower efficiency). Apart from compact heat pumps with an integral solar cylinder, DHW cylinders with pre-fabricated solar assemblies are available to build combined systems (see Fig. D.1.4–2).

During the summer months, the efficiency of air source heat pumps may rise with the increasing outside temperature, however, every unit of primary energy is an energy unit gained.

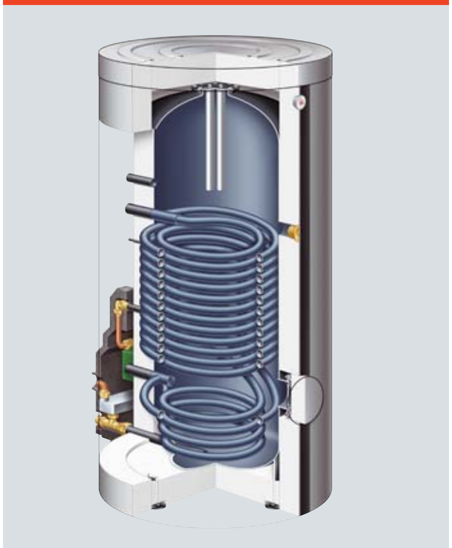
On account of the low flow temperatures of heat pump systems, excellent coverage rates can be achieved in conjunction with solar central heating backup. Combination buffer cylinders or separate cylinder systems are used to link in solar energy. Combi cylinders offer the benefit of requiring little space and installation effort.

Fig. D.1.4–1 Compact heat pump

Compact brine/water heat pump Vitocal 343-G, with the option of linking in a solar thermal system.

Combining a heat pump with a solar thermal system can also be appropriate when operating a swimming pool, since – subject to design – very large amounts of energy need to be provided. In such cases, the heat pump must only provide coverage for peak demands.

Fig. D.1.4–2 DHW cylinder



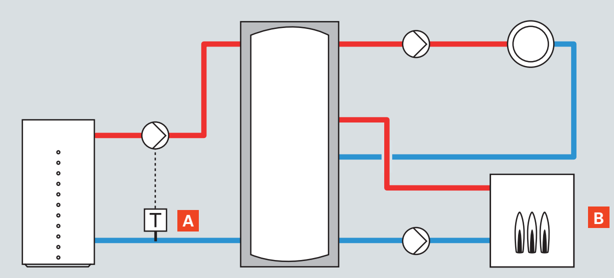
DHW cylinder Vitocell 100-CVW, with solar internal indirect coil.

D.1.4.2 Heat pump and biomass

A further opportunity for linking renewables into heat pump systems lies in the connection of biomass systems. These may take the form of pellet stoves or fire place inserts with back boilers, stationary log, pellet or woodchip boilers. These may be automatic or manually charged systems.

The heating water buffer cylinder provides the hydraulic link. The heat pump control unit monitors the temperature inside the heating water buffer cylinder and calls for heat from the heat pump subject to demand. When combining biomass systems and heat pump systems, the heat pump must be reliably protected against excessively high temperatures from the buffer cylinder. This is generally achieved by means of a high limit safety cut-out that interrupts the buffer primary pump.

Fig. D.1.4–3 Heat pump and biomass



A High limit safety cut-out
B Biomass boiler

Linking a biomass boiler into the heat pump system.

Secondary circuit

Apart from a sufficiently sized heat source and the selection of a suitable operating mode, the sizing and implementation of the secondary circuit are crucial factors for the efficiency of the heat pump.

The maximum flow temperature of the heating system, the spread between system temperatures, the DHW demand, as well as the hydraulic design of the secondary circuit system, all have a decisive impact on energy consumption and running costs. Although this applies generally to all systems employing advanced heat generators, the loss of efficiency with heat pumps can be significantly higher as a result of poorly engineered or implemented heating circuits than, for example, with condensing boilers. Careful system engineering is therefore essential.

Heat pump systems should operate on the secondary side with a spread of between 5 and 10 K. This enables the condenser to operate with an efficient average condensing temperature (condensation).

In the following, the heating operation and DHW heating are described separately.

D.2.1 DHW heating

DHW heating using heat pumps can be covered – subject to requirements – with the following systems:

- Centralised DHW heating by means of a DHW heat pump
- Centralised DHW heating by means of storage in a DHW cylinder
- Centralised DHW heating by means of storing the heating water in a buffer cylinder and centralised freshwater module
- Decentralised heating via individual apartment stations
- Decentralised heating via electrical instantaneous water heater

D.2.1.1 Temperature and hygiene considerations

When designing DHW heating systems, two principle requirements must be met, that if considered separately would result in different sizing and system components. For reasons of hygiene, the amount of stored DHW should be kept to a minimum; in other words DHW cylinders with a small volume should be selected. The smaller the cylinder volume, the greater the heat generator output to cover the heat demand. Given a good modulation level, this is easily accomplished with conventional heat generators and it is comparatively affordable.

When the heat generator only delivers a limited output, a larger cylinder capacity will be required in order to be able to cover the DHW demand. In other words, planning DHW heating when using heat pump systems requires great care.

The DVGW Code of Practice W 551 differentiates between small and large systems where hygiene is concerned. Small systems are DHW systems in detached and two-family houses – independent of the volume of the DHW cylinder and the content of the pipework. Systems with a cylinder capacity below 400 l and a pipework content no larger than 3 l between the DHW cylinder connection and the draw-off point, are also considered to be small systems.

Systems in apartment buildings and public installations are considered to be large if their cylinder capacity exceeds 400 l and/or the water content in each pipeline between the DHW cylinder and the draw-off point is greater than 3 l.

For large systems, the DVGW Code of Practice W 551 requires a permanent DHW outlet temperature of at least 60 °C at the DHW cylinder. The return temperature of the DHW circulation pipe must be at least 55 °C.

The DHW content of preheat stages must be heated to 60 °C, or higher, at least once every day. For small systems, an outlet temperature of 60 °C must be maintained.

On account of the refrigerants used, conventional heat pumps can generally achieve maximum flow temperatures of between 55 °C and 65 °C. With a flow temperature of 55 °C, DHW temperatures of 48 °C can be achieved; with a flow temperature of 65 °C, maximum DHW temperatures of 58 °C can be reached. In order to achieve these temperatures in the DHW cylinder, heat pumps operate with a very low coefficient of performance (COP 2.5 – 3.3, depending on the heat source temperature).

Cylinders need to be reheated to an outlet temperature of 60 °C in order to meet the hygienic requirements of DHW cylinders in apartment buildings. This may be brought about by a dual mode heat generator, by heat pumps with flow temperatures of up to 75 °C developed specifically for this purpose, or by direct electric heaters.

D.2.1.2 Determining the demand

Various approaches for assessing demand are followed in practical applications:

For residential buildings, sizing is often carried out to DIN 4708 Part 2. Taking into account the sanitary amenities of the individual apartments/residential units, the number of occupants/users and utilisation factors, the demand factor N can be determined. This demand factor, together with the boiler output and the NL factor of the cylinder, flow into the engineering calculations for heating the domestic hot water.

However, this design and sizing procedure, though suitable for boilers, cannot generally be transferred to heat pump systems, as the NL factor of cylinders are hardly ever available for the flow temperatures that arise during heat pump operation.

It is, therefore, appropriate to implement the sizing via the heat amount required in the system. For this, several factors should be considered that exert a mutual influence upon each other: the daily demand, the peak demand, the expected losses, as well as the heat pump heating output available for reheating the DHW cylinder.

In the reference period, the required DHW output must be available in the form of stored DHW or as heating output.

For sizing, initially the maximum daily DHW demand and the corresponding pattern of consumption must be established. Apart from actual consumption values, average draw-off profiles can also be used for this calculation. These are shown in the EN 15450 in Appendix E, as examples for three user groups; these can be individually expanded.

The period with the highest output demand is determined from the load profile. The output demand in turn leads to a cylinder size.

Note

As an estimate, a daily average water demand of 1.45 kWh per day can be applied. At a storage temperature of 60 °C, this corresponds to 25 l of water per person.

Appendix E of EN 15450 provides details on the draw-off volume according to draw-off type.

Fig. D.2.1–1 EN 15450: Assumptions on the draw-off volume

Draw-off pattern	Energy kWh	Volume l	Required value for $\Delta\theta$ K	Draw-off duration at the specified mass flow rate min			
				At 3.5 l/min	At 5.5 l/min	At 7.5 l/min	At 9 l/min
Light use	0.105	3	30	0.9	0.5	0.4	0.3
Floor washing	0.105	3	30	0.9	0.5	0.4	0.3
Cleaning	0.105	2	45	0.6	0.4	0.3	0.2
Dishwasher, light use	0.315	6	45	1.7	1.1	0.8	0.7
Dishwasher, moderate use	0.420	8	45	2.3	1.5	1.1	0.9
Dishwasher, heavy use	0.735	14	45	4.0	2.5	1.9	1.6
Heavy use	0.525	15	30	4.3	2.7	2.0	1.7
Showering	1.400	40	30	11.4	7.3	5.3	4.4
Bathing	3.605	103	30	29.4	18.7	13.7	11.4

Appendix E of EN 15450 details average draw-off profiles for three user groups. Details on the timing and amount of energy for DHW drawings are provided that are helpful when planning DHW heating with a heat pump.

Fig. D.2.1–2 EN 15450: Average draw-off profile of an individual person (36 l at 60 °C)

No.	Time of day hh:mm	Energy draw-off priority kWh	Reference period for partial storage systems		Draw-off pattern	Required value for Δ (to be reached during draw-off event) K	Minimum value of Δ for the start of counting the energy utilisation °C
1	07:00	0.105			Light use		25
2	07:30	0.105			Light use		25
3	08:30	0.105			Light use		25
4	09:30	0.105			Light use		25
5	11:30	0.105			Light use		25
6	11:45	0.105			Light use		25
7	12:45	0.315			Dishwashing	50	0
8	18:00	0.105			Light use		25
9	18:15	0.105			Cleaning		45
10	20:30	0.420			Dishwashing	50	0
11	21:30	0.525			Light use		45
	Q_{DP} **[kWh]**	**2.1**	**1.78**	**0.945**			
	t_{DP} **[hh:mm]**	**14:30**	**9:00**	**1:00**			
					36 l at 60 °C		

Fig. D.2.1–3 EN 15450: Average draw-off profile of a family (without bathing, 100 l at 60 °C)

No.	Time of day hh:mm	Energy draw-off priority kWh	Reference period for partial storage systems		Draw-off pattern	Required value for Δ (to be reached during draw-off event) K	Minimum value of Δ for the start of counting the energy utilisation °C
1	07:00	0.105			Light use		25
2	07:15	1.400			Showering		40
3	07:30	0.105			Light use		25
4	08:01	0.105			Light use		25
5	08:15	0.105			Light use		25
6	08:30	0.105			Light use		25
7	08:45	0.105			Light use		25
8	09:00	0.105			Light use		25
9	09:30	0.105			Light use		25
10	10:30	0.105			Floor washing	30	10
11	11:30	0.105			Light use		25
12	11:45	0.105			Light use		25
13	12:45	0.315			Dishwashing	45	10
14	14:30	0.105			Light use		25
15	15:30	0.105			Light use		25
16	16:30	0.105			Light use		25
17	18:00	0.105			Light use		25
18	18:15	0.105			Cleaning		40
19	18:30	0.105			Cleaning		40
20	19:00	0.105			Light use		25
21	20:30	0.735			Dishwashing	45	10
22	21:15	0.105			Light use		25
23	21:30	1.400			Showering		40
	Q_{DP} **[kWh]**	**5.845**	**5.740**	**2.24**			
	t_{DP} **[hh:mm]**	**14:30**	**14:15**	**1:00**			
					100.2 l at 60 °C		

Fig. D.2.1–4 EN 15450: Average draw-off profile of a family (with bathing, 200 l at 60 °C)

No.	Time of day hh:mm	Energy draw-off priority kWh	Reference period for partial storage systems		Draw-off pattern	Required value for Δ (to be reached during draw-off event) K	Minimum value of Δ for the start of counting the energy utilisation °C
1	07:00	0.105			Light use		25
2	07:05	1.400			Shower		40
3	07:30	0.105			Light use		25
4	07:45	0.105			Light use		25
5	08:05	3.605			Bathroom	30	10
6	08:25	0.105			Light use		25
7	08:30	0.105			Light use		25
8	08:45	0.105			Light use		25
9	09:00	0.105			Light use		25
10	09:30	0.105			Light use		25
11	10:30	0.105			Floor washing	30	10
12	11:30	0.105			Light use		25
13	11:45	0.105			Light use		25
14	12:45	0.315			Dishwashing	45	10
15	14:30	0.105			Light use		25
16	15:30	0.105			Light use		25
17	16:30	0.105			Light use		25
18	18:00	0.105			Light use		25
19	18:15	0.105			Cleaning		40
20	18:30	0.105			Cleaning		40
21	19:00	0.105			Light use		25
22	20:30	0.735			Dishwashing	45	10
23	21:00	3.605			Bathroom	30	10
24	21:30	0.105			Light use		25
	Q_{DP} **[kWh]**	**11.655**	**11.445**	**4.445**			
	t_{DP} **[hh:mm]**	**14:30**	**13:55**	**1:00**			
					199.8 l at 60 °C		

Example

Apartment building

6 residential units with 3 occupants per unit

When designing a DHW heating system, the reference period with the highest energy demand is taken from Fig. D.2.1–4.

1	19:00	0.105			Light use
2	20:30	0.735			Dishwashing
3	21:00	3.605			Bathroom
4	21:30	0.105			Light use
	Q_{DP} [kWh]	11.655	11.445	4.445	
	t_{DP} [hh:mm]	14:30	13:55	1:00	
					199.8 l at 60 °C

Sizing according to reference period

The reference period with the highest energy demand is the time from 20:30 to 21:30 h – during that time, 4.445 kWh are required for domestic hot water.

Individual engineering steps can be implemented using these details.

The total energy demand during a reference period is calculated as follows:

$$Q_{DPB} = N_{NE} \cdot Q_{DPB\ NE}$$

Q_{DPB} energy demand during a reference period in kWh

$Q_{DPB\ NE}$ energy demand of a residential unit during a reference period in kWh

N_{NE} number of residential units with identical profiles

Example

For the sample system, this means:

$Q_{DPB\ NE}$ = 4.445 kWh

N_{NE} = 6

Q_{DPB} = 6 · 4.445 kWh

The total energy demand during a reference period is 26.67 kWh.

The required amount of DHW can be calculated from the total energy demand during a reference period.

$$V_{DP} = \frac{Q_{DPB}}{c_w \cdot (t_{set} - t_{cw})}$$

V_{DP} required amount of DHW in litres during a reference period

Q_{DPB} energy demand during a reference period in kWh

c_w specific thermal capacity (= 1.163 Wh/kg · K for water)

t_{set} set cylinder temperature

t_{cw} cold water temperature

Example

For the sample system, this means:

Q_{DPB} = 26.67 kWh

c_w = 0.001163 kWh/kg K

t_{set} = 60 °C

t_{cw} = 10 °C

$$V_{DP} = \frac{26.67\ \text{kWh}}{0.001163\ \text{kWh/kg·K} \cdot (60\text{-}10)\text{K}}$$

The amount of DHW required during the reference period is 459 l.

When selecting a cylinder, take the following losses into account:

- cylinder loss through heat transfer via its surface,
- loss through admixing incoming cold water.

The cylinder loss will be specified in the relevant manufacturer's technical datasheets.

15–20 % of the cylinder capacity can be assumed to be a supplement compensating for the cylinder volume that cannot be used.

$$V_{cyl\text{-}min} = V_{DP} \cdot 1.15$$

$V_{cyl\text{-}min}$ minimum cylinder volume in litres

V_{DP} required amount of DHW in litres during a reference period

1.15 15 % admixing loss

Example

For the sample system, this means:

V_{DP} = 459 l
15 % mixing loss

$V_{cyl\text{-}min}$ = 459 l · 1.15

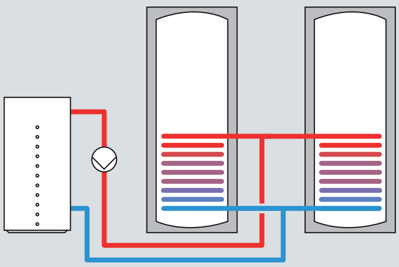
The required minimum cylinder volume is 528 l.

2 optional cylinders are available:

Version 1:
Cylinder with internal indirect coil

In this case, two DHW cylinders, each with 390 l capacity are selected. According to datasheet, the cylinder losses are 2.78 kWh/24 h. The cylinder losses across the entire reference period have been taken into account sufficiently by the larger cylinder capacity.

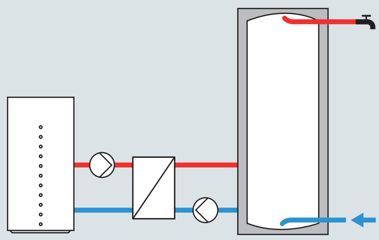
The DHW cylinders offer the opportunity to safeguard the outlet temperature of 60 °C by means of an electric immersion heater in the upper third.



2 cylinders linked in parallel

Version 2:
Primary store with external heat exchanger

For this, a 750 l cylinder is selected. According to the datasheet, the cylinder losses are 3.2 kWh/24 h. For this option, too, a cylinder outlet temperature of 60 °C must be assured. Subject to heat pump type, reheating of the cylinder by a second heat generator or electrical means is required.



Primary store with external heat exchanger

In the following step, the heat pump heating output required for DHW heating must be calculated. This value is the required supplement for DHW heating to the heat pump heating output. This depends on the time available between individual reference periods.

$$Q_{WP} = \frac{V_{cyl} \cdot c_w \cdot (t_{set} - t_{cw})}{T_{heat\text{-}up}}$$

- Q_{WP} heat pump heating output in kW required for DHW heating
- V_{cyl} cylinder capacity (total) in l
- c_w specific thermal capacity (= 1.163 Wh/kg · K for water)
- t_{set} set cylinder temperature
- t_{cw} cold water temperature
- $T_{heat\text{-}up}$ time between reference periods in h

Example

For the sample systems, the following assumption is made for the time between the two reference periods:

[illegible]	[illegible]			Light use
09:00	0.105			Light use
09:30	0.105			Light use
10:30	0.105			Floor washing
11:30	0.105			Light use
11:45	0.105			Light use
12:45	0.315			Dishwashing
14:30	0.105			Light use
15:30	0.105			Light use
16:30	0.105			Light use
18:00	0.105			Light use
18:15	0.105			Cleaning
18:30	0.105			Cleaning
19:00	0.105			Light use
20:30	0.735			Dishwashing
21:00	3.605			Bathroom
21:30	0.105			Light use
Q_{DP} [kWh]	**11.655**	**11.445**	**4.445**	
$_{DP}$ [hh:mm]	**14:30**	**13:55**	**1:00**	

11.5 hours between both reference periods

For cylinder version 1, the following calculation results:

V_{cyl} = 2 · 390 l
c_w = 0.001163 kWh/kg K
t_{set} = 60 °C
t_{cw} = 10 °C
$T_{heat\text{-}up}$ = 11.5 h

$$Q_{WP} = \frac{2 \cdot 390\ \text{kg} \cdot 0.001163\ \text{kWh/kg·K} \cdot (60–10)\text{K}}{115\ \text{h}}$$

The heating output required for DHW heating is 3.94 kW.

If the period between two reference periods is very short, in other words the heat pump output required for DHW heating is very high, two alternatives could be considered: Either the cylinder size is increased by the value for the second reference period, or a second heat generator is provided as a dual mode heat generator for DHW heating. The latter may be the better solution where costs are concerned, since the development of the heat pump primary source requires only little outlay. This is frequently the case in larger apartment buildings.

When sizing by means of reference periods, a plausibility check is recommended as a final step. The heating output calculated for the heat-up time must be greater than the calculated essential output at a constant draw-off rate over the whole day.

$$Q_{WP} > Q_{DPT} \cdot N_{NE}$$

Q_{WP} heat pump heating output in kW required for DHW heating
N_{NE} number of residential units with identical profiles
Q_{DPT} output demand for daily consumption in kW

Example

For the sample system, this means:

11:30	0.105			Light use
11:45	0.105			Light use
12:45	0.315			Dishwashing
14:30	0.105			Light use
15:30	0.105			Light use
16:30	0.105			Light use
18:00	0.105			Light use
18:15	0.105			Cleaning
18:30	0.105			Cleaning
19:00	0.105			Light use
20:30	0.735			Dishwashing
21:00	3.605			Bathroom
21:30	0.105			Light use
Q_{DP} **[kWh]**	**11.655**	**11.445**	**4.445**	
t_{DP} **[hh:mm]**	**14:30**	**13:55**	**1:00**	
				199.8 l

Constant drawn-off over the entire day

Q_{WP} = 3.94 kW
N_{NE} = 6
Q_{DPT} = 11.445 kWh / 24 h

$$3.94\ \text{kW} > 6 \cdot \frac{11.445\ \text{kWh}}{24\ \text{h}}$$

3.94 kW > 2.86 kW

Correlation of the individual steps for determining demand:

1. Determining the load profile
2. Determining the energy demand of the longest periods
3. Calculating the theoretical cylinder capacity to safeguard the provision during the longest periods
4. Determining the actual cylinder capacity through supplementary factors to compensate for radiation and mixing losses
5. Determining the required heat pump heating output
6. Plausibility check on daily demand
7. Considering the DHW heating output

Simplified procedure

For detached or two-family houses with a standard sanitary equipment level, the required cylinder size and the required heating output can be determined by means of a simplified procedure:

25 l (60 °C) per person is assumed to cover the daily demand (see chapter D.2.1.2). For cylinder sizing up to approximately 10 persons, this value is doubled so as to obtain the required minimum cylinder volume. This minimum volume is recalculated for the actual storage temperature.

$$V_{cyl} = V_{tset}$$

$$V_{tset} = V_{DP60} \cdot \frac{(60 - t_{cw})}{(t_{set} - t_{cw})}$$

V_{cyl} cylinder capacity (total) in litres
V_{tset} DHW capacity at t_{set} in litres
V_{DP60} DHW capacity at 60 °C in litres
t_{set} set cylinder temperature
t_{cw} cold water temperature

Example

Detached house with 4 occupants:
4 persons · 25 l · 2 = 200 l (60 °C)

V_{DP60} = 200 l
t_{set} = 50 °C
t_{cw} = 10 °C

$$V_{tset} = 200\ \text{l} \cdot \frac{(60 - 10)\text{K}}{(50 - 10)\text{K}}$$

At 50 °C, a cylinder capacity of 250 l results.

Fig. D.2.1–5 Mono mode DHW heating

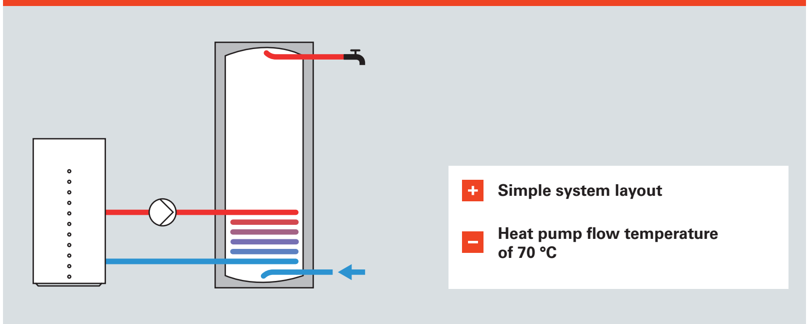


Fig. D.2.1–6 Mono energetic DHW heating

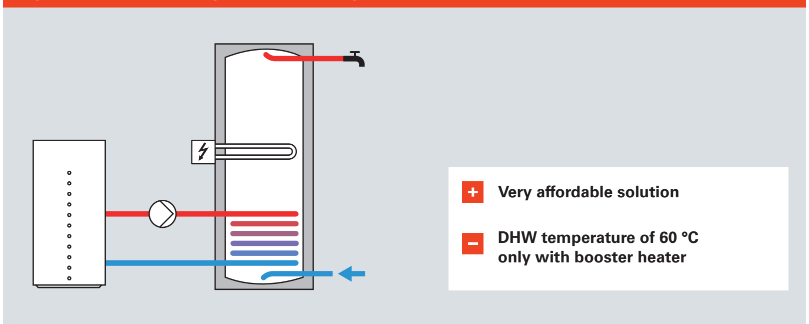
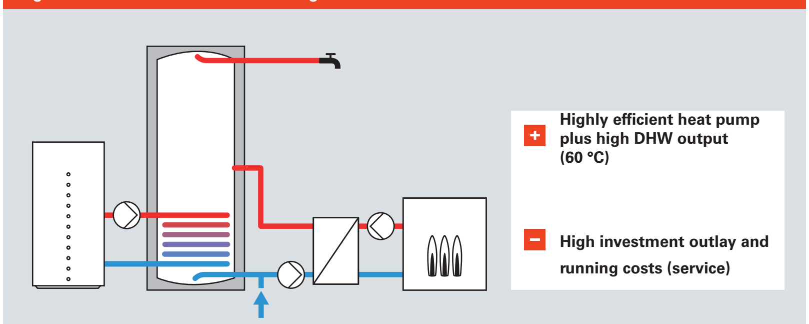


Fig. D.2.1–7 Dual mode DHW heating



D.2.1.3 System selection for DHW heating with a heat pump

All operating modes described in chapter D.1 can also be applied to DHW heating. However, the correct relationship between the indirect coil surface area and heat pump output must be taken into account (see note on page 103).

Mono mode DHW heating

The heat pump as sole heat generator covers the entire DHW demand. The simple system layout is of real benefit. However, in order to achieve a heat-up to 60 °C, the heat pump must deliver a flow temperature of 70 °C.

Mono energetic DHW heating

The heat pump covers the entire DHW demand up to the maximum flow temperature. Any demand beyond that is covered directly by electric heater rods. With this affordable solution, a DHW temperature of 60 °C that may be required or desirable, can only be achieved by means of the heater rod. The same applies to the energy consumption for DHW circulation.

Dual mode DHW heating

The heat pump covers the base load, and the second heat generator covers that part of the range where the heat pump operates uneconomically. This solution offers an extremely efficient heat pump operation, at the same time as delivering a very high DHW output at a high temperature level (60 °C). Disadvantages, however, include comparatively high investment and running costs (maintenance).

Centralised DHW via DHW heat pumps

DHW heat pumps are a sensible and easy-to-install supplement, particularly for heat generators that are not run continuously. This is the reason they are primarily deployed in modernisation projects.

The energy contained in the indoor air can be used by advanced DHW heat pumps to provide domestic hot water. To transfer the energy to the heat pump, a fan draws the indoor air over the heat pump evaporator. The high temperature level required for DHW heating is achieved by the heat pump process, as the compressor and refrigerant have been optimised to meet this requirement.

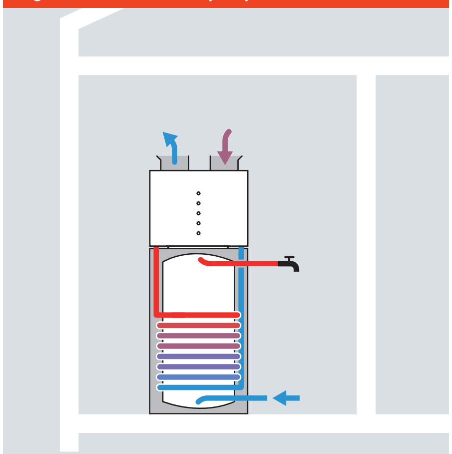
DHW heat pumps can be used as a recirculation air or extract air heat pump (see Fig. D.1.2–9 and D.1.2–10).

In recirculation air mode, the heat pump cools the ambient air and channels the heating energy into the domestic hot water. For this operating mode, the essential available minimum room volume must be taken into account when selecting the installation room. A minimum of 15 m^3 per kW installed heat pump output is recommended. As a positive side-effect the heat pump can also dehumidify the cellar, a function that is sometimes required.

A simple mechanical ventilation system enables the DHW heat pump to operate with extract air. The exhaust air is specifically drawn from toilets, kitchen or other rooms and used for heating domestic hot water. The cooled exhaust air is expelled to the outdoors via an air duct. Supply air is drawn into the building via humidity-controlled supply air apertures.

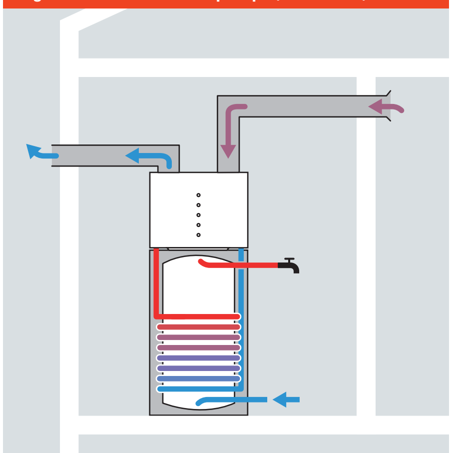
D.2.1–8 DHW heat pump Vitocal 160-A.

Fig. D.2.1–9 DHW heat pumps (recirculation air)



DHW heat pumps in recirculation air mode extract heat from the ambient air and dry it in the process by condensing the humidity contained in the air.

Fig. D.2.1–10 DHW heat pumps (extract air)



In extract air mode, DHW heat pumps also act as a simple mechanical ventilation system.

DHW cylinders

DHW cylinders must meet specific requirements in order to be able to be used efficiently in heat pump systems. Firstly, the surface area of the internal indirect coils must be sized large enough to be able to transfer the heat pump heating output, even at the end of the cylinder heating. Heat pumps operate with lower temperatures than boilers. Consequently, the temperature differential inside the heat exchanger is small; the same goes for the output to be transferred.

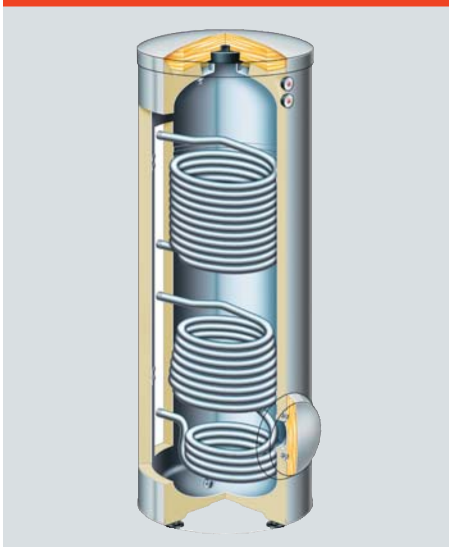
Rule of thumb: A heat exchanger surface area of 0.25 m^2 should be available per transferred kilowatt heating output. For unregulated air source heat pumps, apply the maximum heating output in summer for this. In addition, a large volume standby section is required for a high draw-off rate, since generally, small output levels must be transferred (see D.2.1.2. sizing).

Consequently, the indirect coil is not drawn right up in to the top section of the cylinder, otherwise the heat pump would cool down the DHW in the first phase of cylinder heating, which would reduce the draw-off capacity.

Dual mode solar cylinders are also suitable to achieve as high a heat exchanger surface area [indirect coils] as possible. Both indirect coils are linked in series. However, in this case, the volume standby section is smaller than with special heat pump cylinders.

In compact heat pumps, cylinder size and indirect coil surface area are matched to the heat pump output – thereby making the engineering process easier.

Fig. D.2.1–12 Dual mode DHW cylinder



Vitocell 300-B DHW cylinder

Fig. D.2.1–11 DHW cylinder

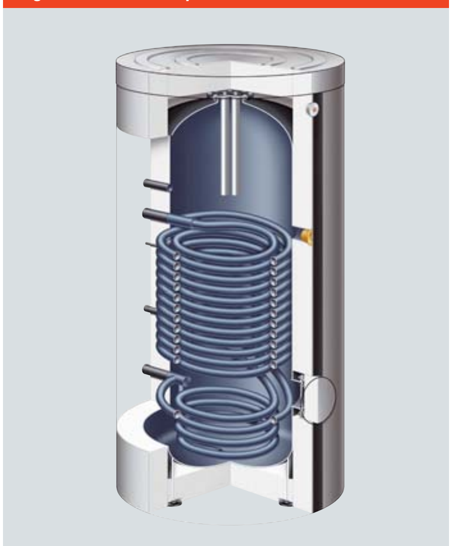


Fig. D.2.1–11
Vitocell 100-V type CVW, DHW cylinder

Fig. D.2.1–13 Compact heat pump

Fig. D.2.1–13
Vitocal 222-G compact brine/water heat pump

Primary store systems

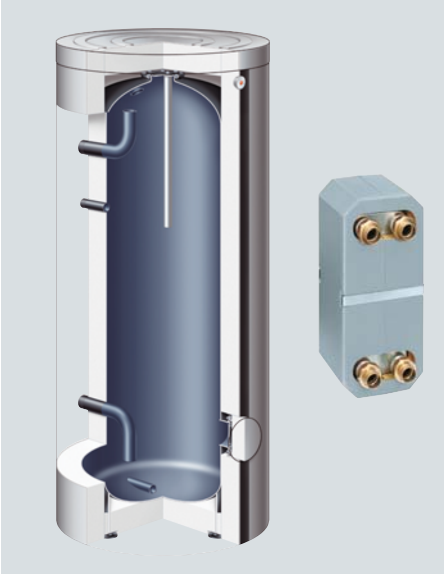
Where high load peaks need to be covered, or where large heat pumps are to be used, the deployment of primary stores with external heat exchangers is appropriate. External heat exchangers offer the benefit of enabling the heat exchanger surface area to be selected in any size. This enables high outputs to be transferred with small temperature differentials.

For heat pump operation, the primary stores need to be equipped with so-called "heating lances". Using a heating lance reduces the entry velocity of the heated water – thereby retaining the temperature stratification inside the cylinder. This is necessary as heat pumps, on account of their narrow spread across the evaporator, only tolerate a slight rise in temperature.

Sizing the heat exchanger
Plate heat exchangers are frequently used for primary store systems. These heat exchangers offer the benefit that a very large heat exchanger surface area can be provided in a relatively small space.

The size of the plate heat exchanger is crucial for the maximum achievable DHW temperature. The smallest possible temperature differential between the primary and secondary circuit is the design goal. Figure D.2.1–16 shows possible temperature spreads for the heat exchangers of the primary store systems. When sizing, it should be noted that the spread on the primary side is dictated by the heat pump and can only be varied within a very narrow band. The size of the plate heat exchanger can be calculated by means of corresponding programs. The flow rates and pressure drop values that have been determined are required when selecting circulation pumps.

Fig. D.2.1–14 Primary store with heating lance



Vitocell 100-L, with heating lance

The heating lance reduces the inlet flow rate and consequently protects the temperature stratification inside the cylinder.

Fig. D.2.1–15 Heating lance function

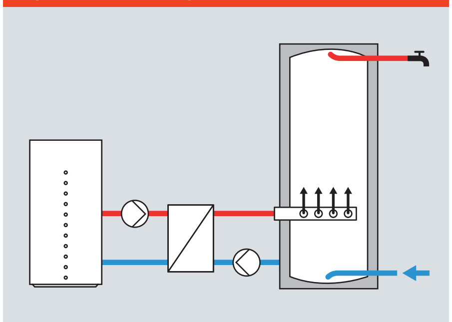
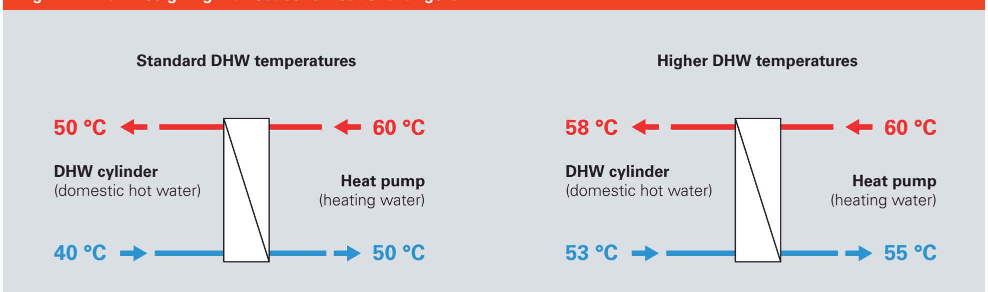


Fig. D.2.1–16 Designing indirect coils/heat exchangers



Freshwater modules are particularly suitable for covering a high output demand.

Sizing pumps for primary store systems
Both the heating and the cylinder primary pump will be sized on the basis of the calculated flow rates and pressure drop values from sizing the heat exchanger.

The efficiency of the primary store system can be substantially improved by intelligent speed control of the primary pump on the secondary side. Initially, the primary pump runs at a very low speed when there is a cylinder heating demand – this results in low flow rates with high stratification temperatures. At the end of heating, the pump will run at maximum speed. This enables the transfer of the heat pump output at very high temperature levels – which in turn prevents the heat pump from cycling.

Note

Combi and buffer cylinders essentially store heating water, it is often thought that the temperature requirements of DIN 1988 or those of the DVGW Code of Practice W 551 of at least 60 °C do not need to be maintained. However, that part of the combi cylinders that holds DHW is subject to the same requirements. For freshwater modules, the content of the pipework between the freshwater module outlet and the draw-off point is crucial (< 3 l).

Combi cylinders

Currently, there is rising interest in the use of heat pumps with stoves, solar thermal systems or additional heat generators, both for central heating and DHW heating. Combi buffer cylinders offer a way of achieving this – these are heating water buffer cylinder and DHW cylinder in a single unit. The main benefit of this type of cylinder is its low space requirement.

Essentially, two types of combi buffer cylinders are known:

- **Tank-in-Tank systems**
- **Combi cylinders with integral instantaneous water heater principle**

Special requirements apply to the integration of combi buffer cylinders in heat pump systems:

The target temperatures in combi buffer cylinders must be higher than for DHW cylinders. As a result, achievable DHW outputs are generally very low on account of the low heat pump flow temperatures.

Cylinders with integral inner cylinder are only suitable for very low DHW demands, since the reheating (as with duplex walled cylinders) is brought about by the comparatively small surface area of the inner cylinder that acts as a heat exchanger.

Combi cylinders act simultaneously as heating water buffer cylinders and as DHW cylinders.

Fig. D.2.1–17 Tank-in-Tank system

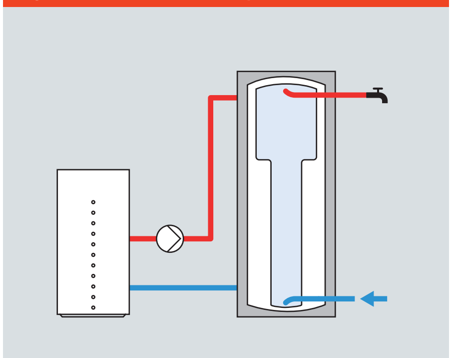
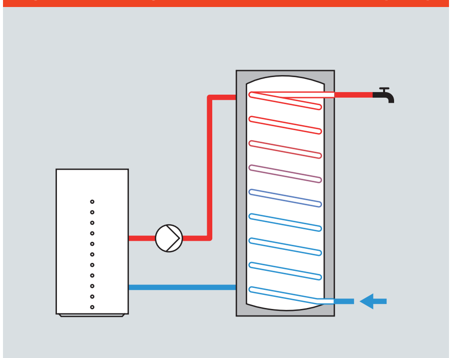
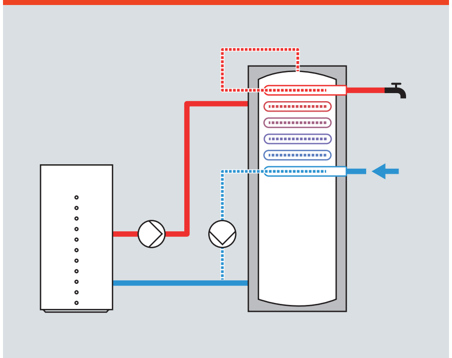


Fig. D.2.1–18 Integral instantaneous water heater principle



Combi cylinders with an adapted instantaneous water heater principle were also developed specifically for heat pumps. Specifically, these are coaxial booster heat exchangers that are activated when there is an increase in DHW demand, by "kicking in" additional circulation pumps. This enables the heat exchanger output to be raised significantly, even when only minor temperature differentials between heating and the required DHW temperature prevail.

Fig. D.2.1–19 Coaxial booster heat exchanger

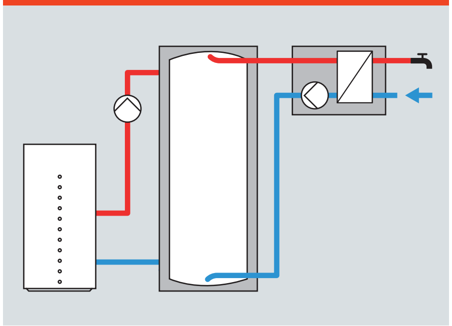


In the case of a higher DHW demand or small temperature differentials, the transfer rate of heat exchangers/indirect coils is increased with an additional circulation pump.

Freshwater systems

A further method of heating domestic hot water is offered by so-called "freshwater systems". These are comprised of a heating water buffer cylinder and one or more freshwater modules. With these systems, heating water is stored inside a heating water buffer cylinder and transferred via a plate heat exchanger to the DHW distribution system.

Fig. D.2.1–20 Buffer cylinder with freshwater module



Generally speaking, freshwater modules are prefabricated assemblies comprising pumps, valves, plate heat exchangers and a control unit. By regulating the primary pump flow rate, fast and accurate control of the selected DHW is enabled. The flow rate control is supported by an electronic flow meter in the secondary circuit.

For a high DHW output demand, several modules can be linked in parallel to form a cascade.

The benefit of a freshwater module lies in the possible coverage of a high output demand without having to store domestic hot water. It should be noted that, as with combi cylinders, the buffer cylinder temperature must be higher than the required DHW temperature by the temperature differential of the heat exchangers.

D.2.2 Heating operation

D.2.2.1 Heating hydraulics requirements

The heat pump requires a minimum runtime in order to ensure that the compressor can operate without faults. In scroll compressors, for example, this ensures correct lubrication with oil. The compressor minimum runtime is a default value stored in the heat pump control units. During the minimum runtime, it must be ensured that the heat generated by the heat pump can be transferred to the heating system, otherwise high pressure faults might occur.

The minimum runtime produces the required water volume at the minimum flow rate. The latter is always specified in the manufacturer's documentation and should always be maintained.

The minimum water volume required in the distribution lines depends on the maximum heat pump heating output. For Viessmann heat pumps, the minimum required volume is 3 l/kW heating output. For air source heat pumps, the maximum heat pump heating output in summer should be considered.

Heating water buffer cylinders are used if the heating circuit water volume is insufficient, in order to ensure the minimum flow rate for the intended minimum runtime.

Note

The minimum water volume in the pipework (e.g. when connecting an overflow valve) must be large enough to safeguard the minimum flow rate. Viessmann recommends a minimum volume of 3 l/kW heating output.

Operation without a buffer cylinder is also possible for systems with a large water content, such as underfloor or area heating systems, for example. In such cases, an overflow valve or low loss header should be installed in order to maintain the minimum flow rate. However, in both cases, the required water volume should be observed and should be taken into account by ensuring a suitable distance from the heat pump (pipe content). When using a low loss header, it must be ensured that the flow rate on the secondary side of the heat pump is greater than the total of all flow rates on the heating circuit side.

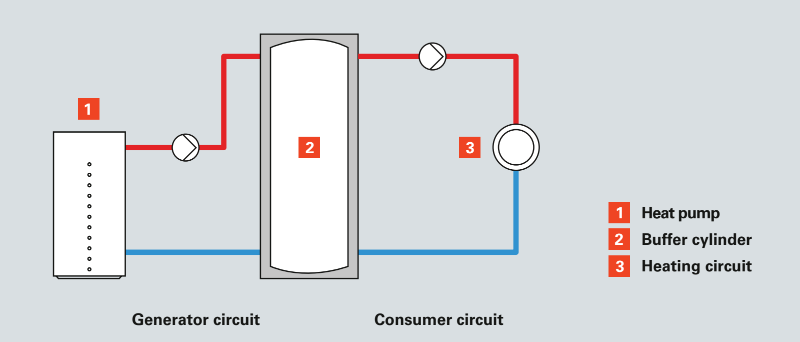
D.2.2.2 Buffer cylinders

Buffer cylinders in heat pump systems can meet two functions:

- They provide a hydraulic safety feature and ensure the runtime optimisation of the heat pump system.
- They bridge power-OFF times enforced by the power supply utility.

Buffer cylinders can be used as series or parallel buffer cylinders.

Fig. D.2.2–1 Buffer cylinder connected in parallel



Buffer cylinders connected in parallel also take over the function of a low loss header.

Parallel buffer cylinders

Buffer cylinders linked in parallel separate the heat pump from the heating circuit, thereby also taking on the function of a low loss header.

Hydraulic separation is always required when operating with several heating circuits. The use of this kind of circuit is the safest method for preventing hydraulic errors. In parallel operation, the required minimum flow rate for the heat pump can be ensured independently of the flow rate in the heating circuit.

For sizing the linking pipework and the circulation pumps, the maximum possible heat pump heating output and a spread of 5 – 7 K are applied (for calculation, see D.3, engineering aids). The flow rate in the generator circuit must be sized larger than the total of the flow rates on the heating circuit side. The buffer temperature is regulated via the defaulted set value through the required highest heating circuit temperatures.

Benefits:
- robust hydraulic system,
- hydraulic separation of heating circuit and generator circuit,
- several heating circuits can operate in parallel.

Disadvantages:
- The generator circuit requires an additional circulation pump (additional drive energy).
- The heating circuit with the highest temperature level dictates the target temperature inside the buffer cylinder. Consequently, the heat pump operates with slightly higher flow temperatures on average. This means higher radiation losses than with buffer cylinders linked in series in the return (see D 2.2.2.).

Buffer cylinders in series

Buffer cylinders in series are more favourable in terms of expenditure of energy, but hydraulically they are more demanding. They are intended to increase the heating circuit volume. Subject to system installation site, one differentiates between flow and return buffer cylinders. The minimum flow rate must be ensured by fitting an overflow valve, as these buffer cylinders are hydraulically connected in series. This valve is adjusted so that the minimum flow rate is assured when all heating circuits are closed.

These systems can be recommended for systems with only one heating circuit. The installation of a buffer cylinder brings the benefit of being able to integrate an immersion heater into the cylinder as a second heat generator.

Positioning in the return results in low cylinder radiation losses, then again the cylinder cannot be reheated. Return buffer cylinders are only used to increase the system volume and to increase the compressor runtime.

Fig. D.2.2–2 Buffer cylinder connected in series (flow)

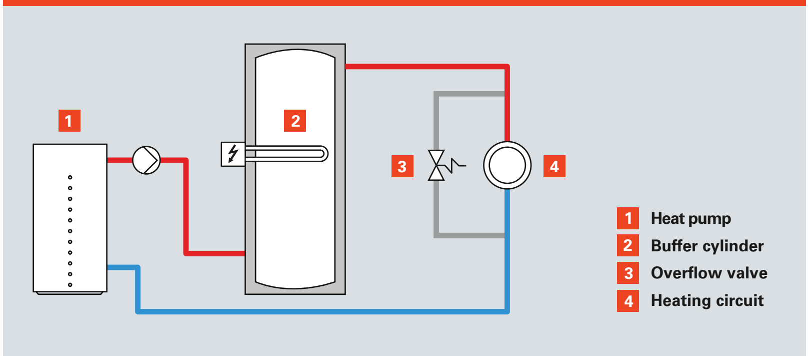
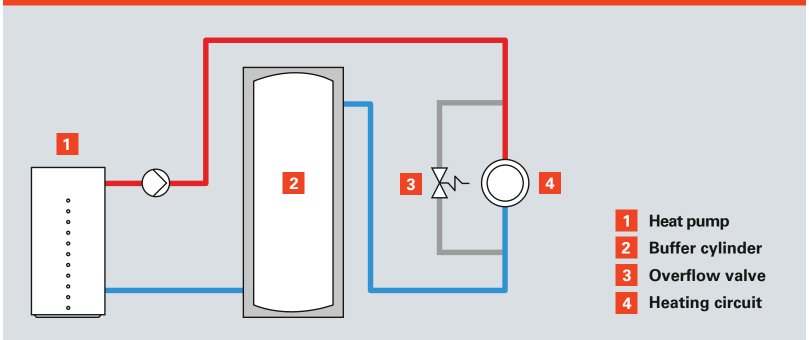


Fig. D.2.2–3 Buffer cylinder connected in series (return)



Buffer cylinders connected in series are energetically more advantageous, but will require an overflow valve to safeguard the minimum flow rate.

Sizing buffer cylinders

Buffer cylinders are sized in accordance with their required function, either to bridge power-OFF times or to hold the minimum flow rate available in the distribution lines.

If the buffer cylinder is sized to bridge the power-OFF times, a volume large enough will result so that the other functions are assured.

Buffer cylinder for providing the minimum volume

The minimum volume for a safe heat pump operation is 3 l/kW. This volume must be available in heating circuits with static heating surfaces even when no heat is being drawn off, in other words when thermostatic valves are closed. For area heating systems, the volume in the pipework between heat generator and distributor or system separation towards the area heating system is decisive.

Buffer cylinder for runtime optimisation

Heat pumps can be optimised through the longest possible runtimes and associated long pauses. Parameters for this operating mode are defaulted by the heat pump controller.

Insofar as the minimum volume is available, area heating systems require no additional cylinder for optimising the heat pump runtime, as the capacity of its heating surfaces is sufficient. With static heating surfaces, longer breaks in the heat pump operation could result in a marked cooling down of the heating surfaces (low mass, high water content). In this case, a buffer cylinder volume of at least 20 l/kW heating output would be recommended.

$$V_{HP} = Q_{WP} \cdot V_{HP\ min.}$$

V_{HP} heating water buffer cylinder volume in litres

Q_{WP} rated heat pump heating output (absolute) in kW

$V_{HP\ min.}$ recommended minimum volume in kW heating output for static heating surfaces in litres

Example

Calculation of the necessary volume of the heating water buffer cylinder for one heat pump with an output of 15 kW and static heating surfaces:

Q_{WP} = 15 kW

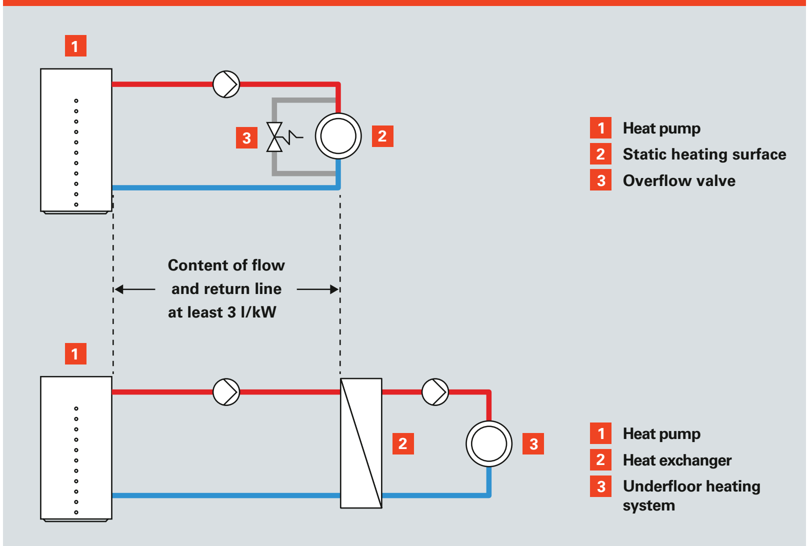
$V_{HP\ min.}$ = 20 l

V_{HP} = 15 kW · 20 l/kW

The heating water buffer cylinder has a volume of 300 l.

A minimum volume in the connection lines must be maintained in order to safeguard the minimum flow rate.

Fig. D.2.2–4 Minimum volume in the heating circuit



Buffer cylinder for bridging power-OFF periods

Frequently, heat pump tariffs provide the option of power supply utilities being able to shut down the system at certain times (see chapter B). Generally, such instances do not last longer than two hours. The contractually agreed power-OFF times must be taken into account when determining the heat pump output and require a storage option to be considered for these periods. With underfloor heating systems embedded in the screed, the storage mass is usually large enough to bridge these times. A buffer cylinder will be required in the case of static heating surfaces or area heating systems laid dry. It is not necessary to size this cylinder for the total maximum amount of energy that is required during the power-OFF time of the building. In residential buildings, for a maximum power-OFF time of two hours, a value of 60 l buffer cylinder volume per kW heating output has proven to be acceptable.

$$V_{HP} = Q_{WP} \cdot V_{HP\ OFF}$$

V_{HP} heating water buffer cylinder volume in litres

Q_{WP} rated heat pump heating output (absolute) in kW

$V_{HP\ OFF}$ recommended minimum volume per kW heating output for up to 2 hours power-OFF time in litres

Example

Calculation of the necessary volume of the heating water buffer cylinder for one heat pump with an output of 15 kW and up to 2 hours power-OFF time.

Q_{WP} = 15 kW
$V_{HP\ OFF}$ = 60 l

V_{HP} = 15 kW · 60 l/kW

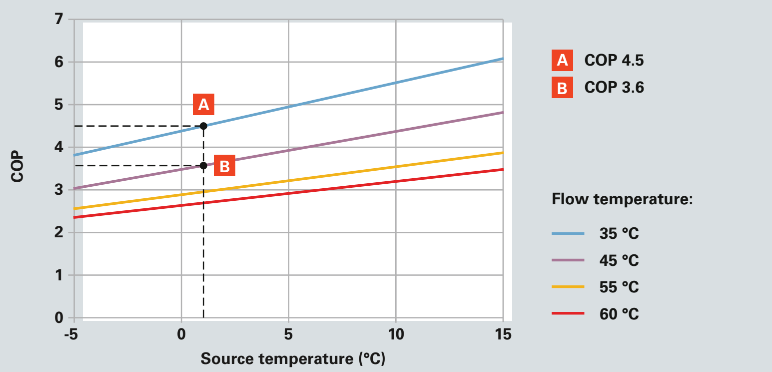
The heating water buffer cylinder has a volume of 900 l.

D.2.2.3 Heat transfer

For system engineering, the following principle applies: System temperatures are selected to be as low as possible. Reducing the flow temperature by 1 K can improve the COP by up to 2.5 %. Consequently, sizing the heating surface requires particular attention – during commissioning and adjustment, the heating curves and thereby the flow temperatures must be optimally matched to the system.

To be able to achieve low temperatures, fan-assisted radiators can also be used alongside area heating systems. For area heating systems, the spread should be 7 K, for radiators 10 K and for fan-assisted radiators between 5 and 10 K. In new buildings, these values can generally be achieved quite easily, as the heating surfaces to be fitted can be sized accordingly.

Fig. D.2.2–5 Heating circuit flow temperature and efficiency



At the same source temperature, the coefficient of performance drops significantly with higher heating circuit flow temperatures.

In modernisation projects, too, system temperatures should be kept as low as possible (see also chapter D.1). Although heat pumps can achieve flow temperatures in excess of 70 °C, these should only be utilised for DHW heating. For heat pumps operating in mono mode, system temperatures in excess of 55 °C should be avoided. Different engineering approaches are followed in existing buildings with higher system temperatures. Where modernisation includes, not only an update of the heating system, but also major updating of the building envelope, it is perfectly feasible that the existing heating surfaces can cover the reduced heat demand with lower flow temperatures. The heating surfaces must be modernised or supplemented for the mono mode operation of the heat pump where the demand cannot be adequately reduced.

Area heating systems

On account of their low design temperatures, area heating systems are particularly suitable for heat pump heating systems. Essentially, these are used in the form of underfloor or wall heating systems. In addition, complete structural sections – as so-called "concrete building component activation" – can be heated. The relatively low surface temperatures create a pleasant ambient climate through radiated heat. Underfloor heating systems with extremely low installed height that can be installed on existing floors, were developed especially for modernisation projects.

Fan convectors

Conventional radiators transfer their heat into the room by means of radiation and natural convection. With fan convectors, heat transfer by convection is significantly increased through forced circulation, which in turn enables flow temperatures to be significantly reduced. Forced circulation is achieved through integral, electrically operated fans. Subject to design, fan convectors can be used for heating, as well as cooling. A condensate drain is required for cooling operation.

Fig. D.2.2–6 Area heating systems

An underfloor heating system enables low temperatures in the heating circuit that are favourable for heat pumps.

Fig. D.2.2–7 Ultra low temperature radiators

On account of their higher heat transfer rate, fan convectors also enable low flow temperatures.

D.2.3 Cooling

Air conditioning units are able to meet the very diverse requirements of ambient conditions. The most important task undertaken by these appliances is the creation of the so-called "comfort range" when considering the room temperature and relative humidity. The comfort range describes the ambient conditions under which people feel comfortable and are at their most productive.

With room air conditioning it is important to note that the set room air temperature is adjusted depending on the outside temperature. The room air temperature should not be more than 5 K below the outside temperature. Greater temperature differentials can lead to problems with acclimatisation. Room climate is affected by the following factors: room air temperature, relative humidity, air movement, surface temperature of walls, level of activity and type of clothing of the persons inside the room, plus air purity.

Fig. D.2.3–1 Air conditioning

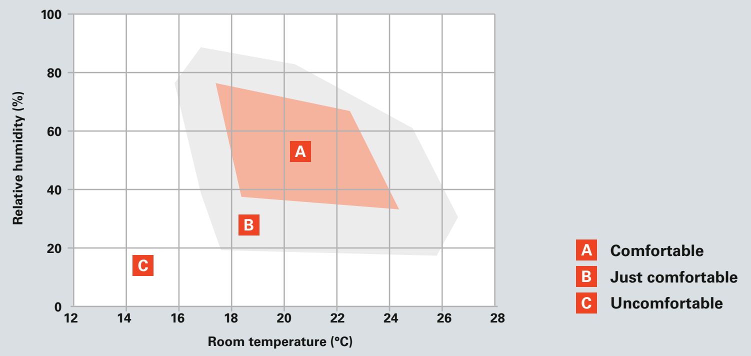


Fig. D.2.3–2 Cooling load

Empirical values for estimating the cooling load in Central Europe

Type of room	**Cooling load** relative to room volume
Living space	30 – 40 W/m³
Offices	50 W/m³
Showrooms	50 – 60 W/m³
Glass extensions	up to 200 W/m³

D.2.3.1 Principles

The indoor air is cooled and dehumidified in order to bring it into the comfort range. Engineering and sizing the cooling system requires the calculation of the cooling load and the consideration of the dew point (see below).

Cooling load

The term "cooling load" describes the heat flux that must be dissipated in order to maintain the required ambient condition.
The following factors influence the cooling load:

- external factors, such as insolation and transmission,
- internal factors, such as the number of persons, lighting, electrical appliances,
- possible material flux (e.g. proportion of outdoor air).

EN ISO 13790 provides the basis for calculating the cooling load, VDI 2067 offers a simplified method. Simple calculating programs are available for estimating the cooling load of individual rooms (see chapter D.3.2).

For this, the cooling load is calculated by means of the room dimensions, the orientation of window areas, simple structural details and a detailing of internal loads.

Empirical values can also be used to provide an initial estimate of the cooling load of individual rooms.

Dew point

The dew point temperature is that point below which water vapour condenses. At the dew point, the relative humidity is 100 %. Water vapour condenses (sweating) when the surface temperature of bodies is lower than the dew point temperature of the ambient air.

For air handling technology, the dew point temperature is of particular importance: Condensate will be created on cooling surfaces if their actual temperature falls below the dew point temperature. This dehumidifies the indoor air.

D.2.3.2 System types

With system types, we differentiate as to whether cooling is performed with the application of drive energy for the compressor (active cooling) or exclusively with the primary source (ground or water) (natural cooling).

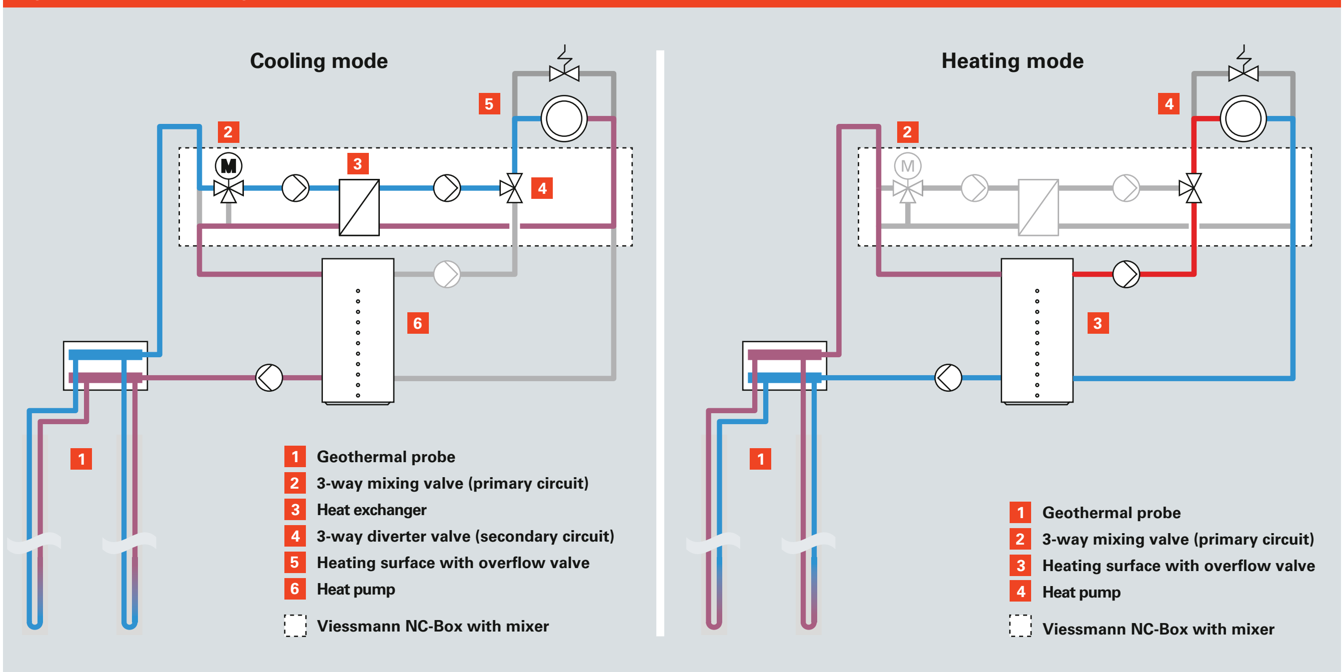
Passive cooling

Passive cooling is also known as "natural cooling". From a room, this system extracts heat that is transferred to the primary source. For this, the heat pump compressor is idle. An additional heat exchanger provides the system separation.
Natural cooling with brine/water heat pumps is highly efficient, as it requires the operation of only two circulation pumps. During natural cooling, the heat pump will only be started to produce domestic hot water. The primary temperature rises on account of the heated heat transfer medium, which results in an improvement of the performance factor during DHW heating. Prefabricated assemblies can be used with Viessmann heat pumps to utilise natural cooling.

Natural cooling is possible with the following systems:
- underfloor heating system,
- fan convectors,
- chilled ceilings,
- concrete core tempering.

The indoor air can only be dehumidified in conjunction with natural cooling if fan convectors are used – this requires a condensate drain. With cooling via alternative heating surfaces the system is regulated so that condensation, i.e. undershooting the dew point on the heating surfaces, is avoided.

Fig. D.2.3–3 Passive cooling



Active cooling

The compressor runs when actively cooling in the heat pump process. A diverter valve changes over the functions of evaporator and condenser. The heat pump cools the building with the available cooling capacity. The constant cooling capacity available is subject to the output of the heat pump. With active cooling, the cooling capacity is significantly higher than with natural cooling.

The changeover between heating and cooling mode can be effected either outside the heat pump or via a 4-way diverter valve in the refrigerant circuit.

Brine/water heat pumps
With brine/water heat pumps, the changeover between heating and cooling mode is generally made by hydraulic peripheral equipment.
With active cooling, the refrigerant circuit is operational – but not for heating. The internal control unit reverses the output and input functions and now actively transfers heat from the building to the geothermal probe.

Only cooled heating water courses through the heating circuit. The heat removed from the internal areas can also be used directly, for example for DHW heating or for heating a swimming pool.

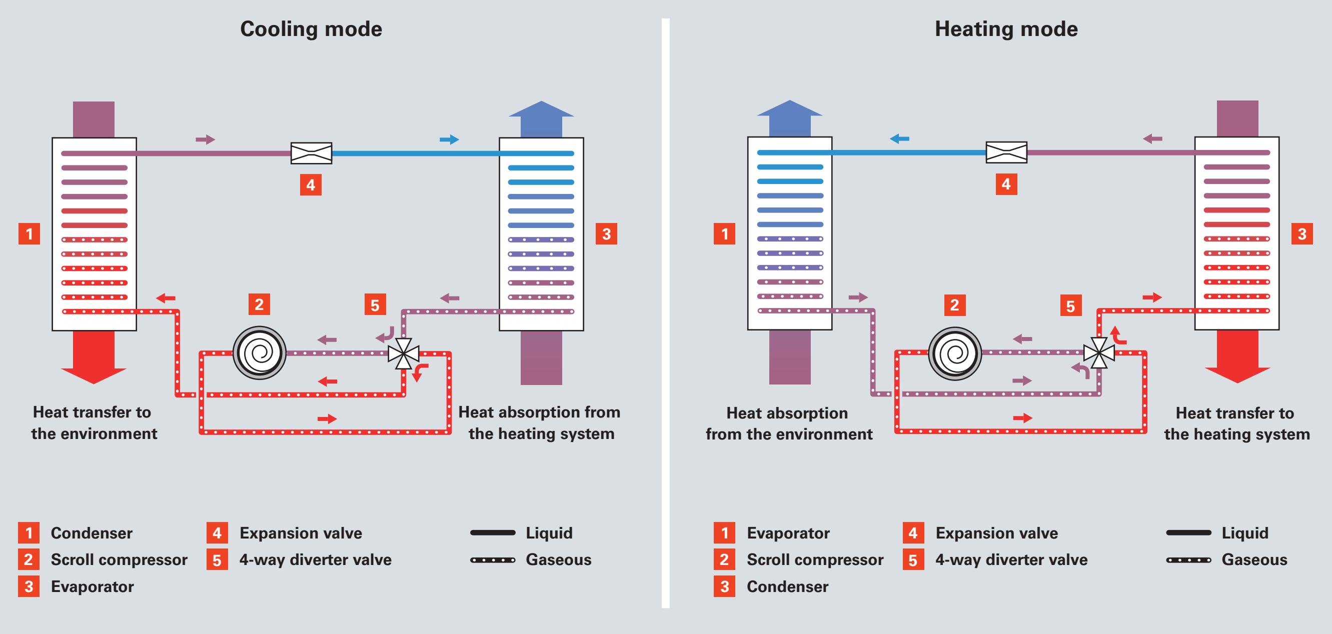
Air/water heat pumps
With air/water heat pumps, the changeover between heating and cooling mode is brought about by means of a 4-way diverter valve in the refrigerant circuit. The compressor continues to operate unchanged, whilst the valve reverses the flow direction of the refrigerant.

In heating mode, the air:refrigerant heat exchanger takes on the role of evaporator, and the refrigerant:water heat exchanger that of condenser. In cooling mode, the 4-way valve reverses the function of both heat exchangers – the air:refrigerant heat exchanger becomes the condenser and the refrigerant:water heat exchanger becomes the evaporator. This cools the circulating heating circuit water.

Note

In cooling mode, heat is transferred to the geothermal collectors or probes. It is frequently a subject of discussion whether this heat can be "stored" in the ground for a later heating operation in order to improve the COP of the machine or even to reduce the system development costs (reduced probe depths). This is not possible with smaller systems – however, on very large probe arrays regeneration via cooling operation can be appropriate. However, a geological assessment would always be required for this.

Fig. D.2.3–3 Active cooling



D.2.3.3 Cooling transfer

The cooling capacity can be transferred into the internal space by various systems. When planning and selecting these systems, building characteristics (underfloor heating system) as well as the intended requirements of ambient conditions (dehumidification, ambient temperature) must be taken into account.

Area cooling

With area cooling systems, the peripheral areas of an interior space (ceilings, floor or walls) are cooled. Systems that can be used for this purpose are chilled ceilings, concrete core tempering or cooling via the underfloor heating system. With all area cooling systems, the dew point temperature must not be undershot on any of the said surfaces to prevent condensation. Area cooling systems cannot provide dehumidification for the indoor air, which must be provided by additional systems, if required.

If the indoor air is not being dehumidified, the relative humidity increases with falling room temperature – which can result in a reduction of comfort.

Area cooling systems are frequently referred to as "silent cooling" as they are frequently implemented without fan assistance. However, there are now also fan-assisted systems that facilitate a higher cooling capacity.

It is now often the case that the underfloor heating system in smaller buildings is also used as a cooling system. For this, cold water is pumped through the pipework of the underfloor heating system, thereby cooling the floor and tempering the room. With this system, up to 25 W/m² can be transferred – subject to the individual case, this equates approximately to one quarter of the total cooling load.

Cooling via fan convectors

To achieve an higher gain in comfort, cooling with fan convectors offers the option of cooling and dehumidifying the indoor air. Cold water at a temperature below the dew point flows through the fan convectors, where it is channelled through a finned heat exchanger. Indoor air is routed across this heat exchanger under fan assistance. This cools the indoor air and the flowing water heats up. Condensate forms on the heat exchanger surface which must be routed via the condensate pan. Please note: The connection lines to the fan convector must be insulated with vapour diffusion-proof material to prevent condensate forming on the pipes.

Fan convectors can be implemented as 2-line or 4-line versions. In the 2-line system, cold water flows through the heat exchanger for cooling operation; when heating is required, hot water flows through the same exchanger. In 4-line systems, the fan convector features two separate heat exchangers – one for cold water in cooling mode and one for hot water in heating mode.

For sizing fan convectors, the required room temperature and the cold water inlet temperature play major roles. The greater the differential between these two temperatures, the more cooling capacity the fan convector will transfer. The reverse applies as follows: A smaller appliance may be used in the case of a large differential between the cold water inlet and the room temperature.

Cooling via ventilation systems

Ventilation systems can also provide cooling. However, the achievable cooling capacity for a single room is limited by the temperature at which the air is blown into the room. This temperature should not fall below 14 °C in order to avoid the unpleasant perceptions of draughts. This can provide a cooling capacity of approximately 5 W per 1 m³/h air flow brought into the room.

For this type of application, a cooling bank is fitted into the ventilation unit which cools the air flowing through it. If dehumidification of the ambient air is required, the surface temperature of the cooling bank will be below the dew point – this condensates the water in the air flow. With this application, an additional water separator, and possibly a reheating bank, may be required in the central ventilation unit. In addition, more stringent hygiene requirements apply to the maintenance of the appliance.

The dehumidification function is omitted for this reason in ventilation appliances for controlled domestic ventilation.

Output calculation and engineering aids

The required output of a heat pump is determined in the same way as that of any other heat generator. In mono mode or in mono energetic operation, the heat pump must be sized in accordance with DIN EN 12831 as the sole heat generator.

One particular aspect to remember when sizing heat pump systems is the consideration of power-OFF times that may be applied subject to special electricity tariffs.

For determining output, Viessmann offers its trade partners a sizing program that calculates not only the heat pump parameters, but also those of a suitable DHW cylinder.

As an additional engineering aid, Viessmann heat pump system sizing aids and the Viessmann scheme browser are also available. These enable efficient heat pump systems to be engineered step by step and with great reliability.

D.3.1 Determining the heat pump output

How to calculate DHW demand and requirements to be observed regarding heat transfer to rooms have already been described in chapter D.2.

In order to be able to determine the heat pump output, possible power-OFF times imposed by the power supply utility must be taken into account, alongside the heat load and the DHW demand.

In the case of special power tariffs for heat pumps, the power supply utility has the right to interrupt the power supply for up to 2 hours up to three times per day – these "out times" need to flow into the calculation of the daily building energy statement.

The size of the heat pump in mono mode systems is determined in two steps:

Step 1: Determining the daily heat demand in the design state
Step 2: Dividing the daily heat demand by the number of heating hours that are actually possible

Example

The building heat load is 12 kW.
The power-OFF times are 3 x 2 hours.

Daily possible heating hours:
24 h – 6 h power-OFF time = 18 h

Daily heat load of the building:
12 kW · 24 h = 288 kWh

Heat pump heating output:
288 kWh / 18 h = 16 kW

DHW heating will only be taken into consideration when sizing the heat pump, if the required output for DHW heating during heat-up times (see chapter D.2.1) is higher than 20 % of the heat load.

Example

The building heat load is 12 kW. The output required for DHW heating is 2 kW.

20 % of the heat load is 12 kW · 0.2 = 2.4 kW

2 kW < 2.4 kW

No supplement for DHW heating is required.

Note

Under the climatic conditions prevalent in Germany, practical experience has shown that for power-OFF times of up to 2 hours per day, no supplement needs to be applied to the heat pump output, in other words it can be sized purely on the basis of the building heat load. Although this makes it theoretically possible that some of the rooms of the building will fail to be held at the target temperature consistently, in normal heating operation in residential buildings this is highly unlikely.

Fig. D.3.2–1 Viessmann heat pump engineering program

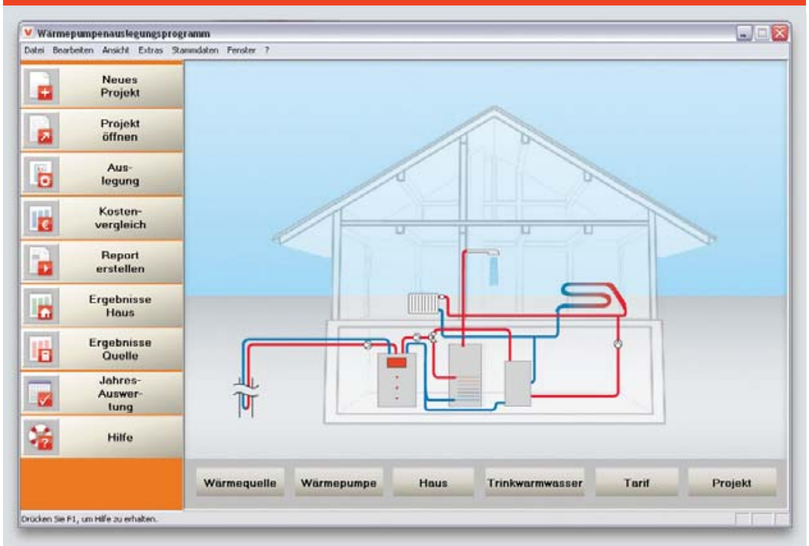
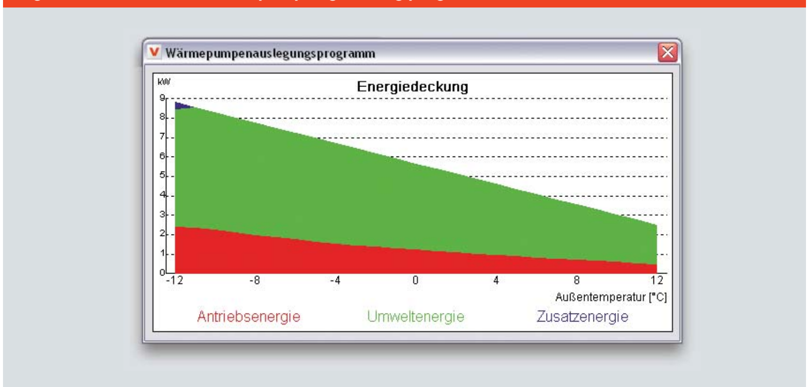


Fig. D.3.2–2 Viessmann heat pump engineering program



D.3.2 Sizing aids for heat pump systems

Heat pump engineering program

Heat pump systems can be mathematically simulated and sized using the heat pump engineering program. For existing buildings, the necessary output is determined on the basis of consumption values; for new buildings, heat load calculations form the foundation. The program then offers a matching heat pump and a suitable DHW cylinder.

The result can be compared with alternative heating systems by means of an energy cost comparison. In addition, it is possible to undertake a viability calculation.

Apart from calculating the seasonal performance factor in accordance with VDI 4650, the proportion of renewables as part of the total heat provision can also be calculated. This value can then be adopted into the EnEV calculations, or serve as a certificate verifying the fact that statutory requirements have been met.

The program can also show some of the heat pump engineering results in graphic form making it particularly useful during customer consultations.

This program is made available to all Viessmann trade partners; licences are available from all external sales engineers.

Heat pump system sizing aid

The heat pump system sizing aid is a simple means for determining the pipework size, the selection of a suitable cylinder and also to assess the sound emissions.

Pipework is sized according to the specified temperature differentials of between 5 K and 10 K in the secondary circuit (see chapter D.2). The expected pressure drop can also be calculated. This also makes the system sizing aid a quick calculator for system integration by the heating contractor.

The system sizing aid enables the sound pressure level (see chapter C.3.3) to be determined subject to the distance from the installation site. In other words, details on the expected sound emissions, and in particular of air handling units, can be quickly provided.

The system sizing aid is available online or may be obtained in the form of a plastic "slide rule" from the external Viessmann sales engineers.

Fig. D.3.2–3 Viessmann heat pump system sizing aid

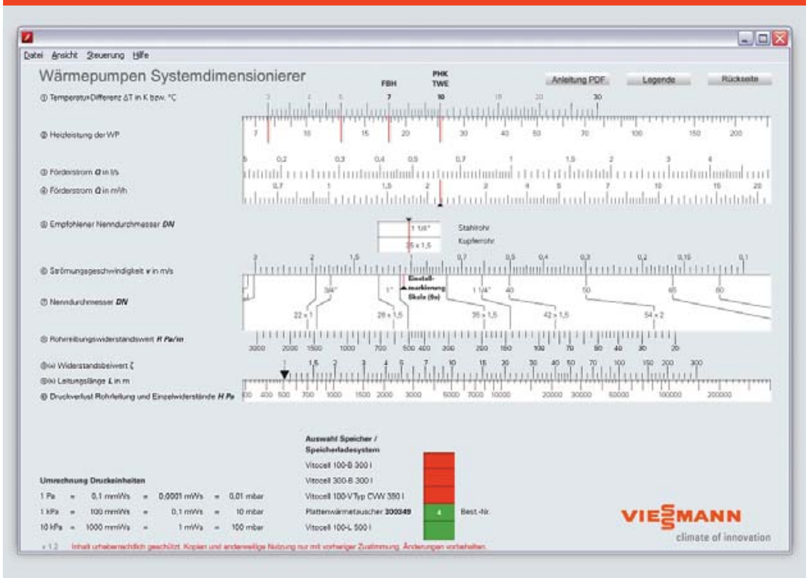
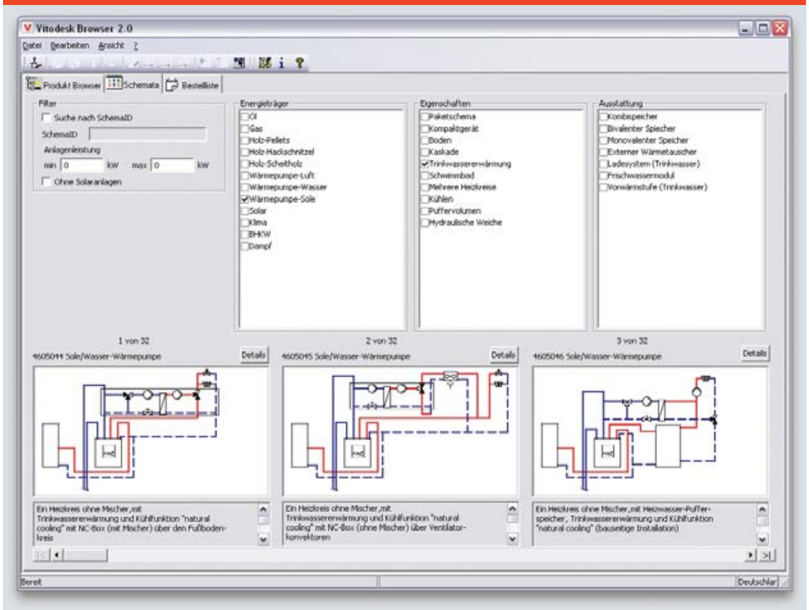


Fig. D.3.2–4 Example heat pump system sizing aid

Fig. D.3.2–5 Viessmann Vitodesk browser



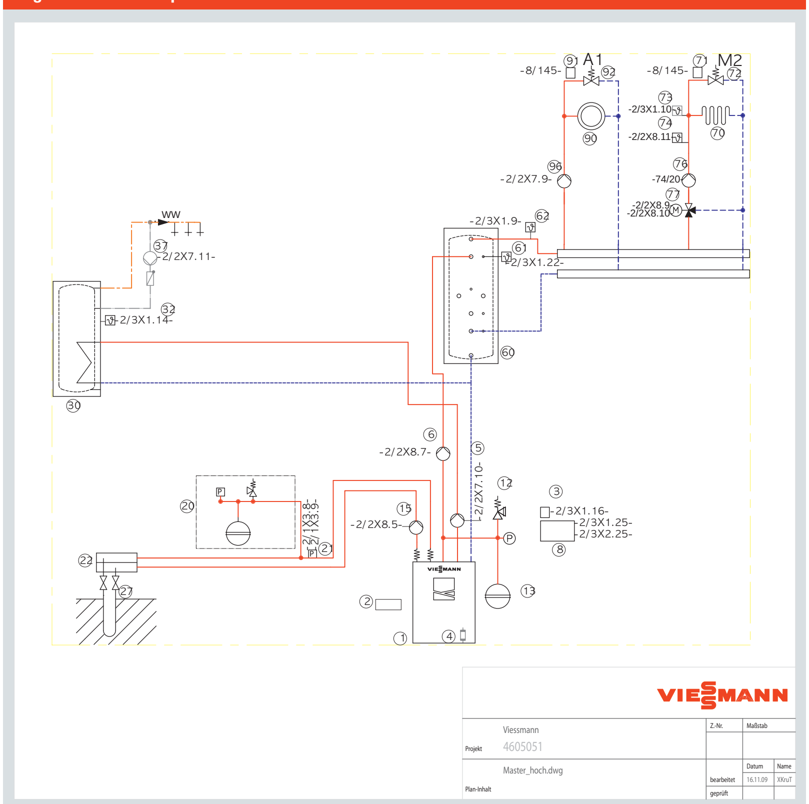
Vitodesk browser

The Viessmann scheme browser offers complete hydraulic schemes, wiring diagrams and function descriptions for all heat generators and the most frequent combinations of heat generators. The easy user prompts facilitate the location of the most suitable hydraulic scheme in just a few steps. The schemes are provided in the form of .dwg files which can be edited, or as PDF files.

These hydraulic schemes show all main system components. Only project-specific shut-off valves, air vent valves and safety equipment need to be added. Generally, these schemes are not provided with dimensions, in other words the output limits of individual products are not taken into account.

Therefore, when selecting components, it should be checked whether these are suitable for the required output, for example cylinders with internal indirect coils. It may be necessary to select an alternative scheme, for example with a stratification primary store system.

Fig. D.3.2–6 Example scheme browser



All actuators and sensors are clearly identified in the schemes with designations and terminals in the controller.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Appendix

In addition to the technical information provided for engineering purposes, this appendix includes information that may be useful and appropriate for practical applications.

The most important steps necessary for a successful engineering and installation project are listed as a brief summary. Those points that should be taken into consideration as part of the engineering process have been collated.

In order to do justice to the requirements and expectations a heat pump demands, regular inspection and optimisation are always recommended. The references to inspection and optimisation show what matters most.

Use the keyword index of essential terms to make this manual a useful professional guide for everyday use.

The path to an efficient heat pump system

When planning a solar thermal system, it is often just as important to look at its viability as its technical aspects.

1. Recording the current situation and the result of customer consultations

A decision in favour of a heat pump system requires competent and extensive consultation – this is particularly the case for modernisation projects. Generally speaking, as heat pump systems require a greater level of investment than conventional heat generators, in our experience, the expectations of potential investors are correspondingly high, particularly regarding the ecology and efficiency of the intended system. Sufficient time needs to be scheduled during the consultation to discuss these expectations adequately, so that technological limits, too, can be discussed. Heat pumps are heat generators, how much they can save depends largely on the prevailing operating conditions. Disappointment can be avoided if the interested parties can be made familiar with the relevant general conditions concerning their investment as soon as possible.

In order to be able to carry out a professional consultation, extensive data on the actual conditions in the existing building need to be recorded in the case of modernisation projects. This includes, not only the building characteristics, but also any installed heating system. The existing heating surface sizes, flow temperatures and pipework dimensions in particular, need to be considered, too. Using the average annual energy consumption figures and the heat pump engineering program, you can provide an initial overview of appropriate system options, the costs to be expected and the potential savings.

Chapter B.3 provides detailed information on the viability calculation.

2. Calculating the heat load

System engineering starts with calculating the heat load. This is essential both for new build and modernisation projects alike, in order to achieve an optimum engineering of the heat pump system.

DIN EN 12831 forms the basis for determining the heat load. The resulting value would be the maximum heat load of the building that must be covered by the output of the heat generator.

Deriving the heat load from the EnEV energy performance certificate of the building is not possible.

The energy performance certificate indicates the final energy demand, amongst others. This can be matched with the results of the special engineering required for sizing a heat pump system.

In new build, where no reference consumptions can be known from previous years, the final energy demand from the energy performance certificate serves as a basis for engineering. It may be used, when engineering ground-coupled heat pumps, to determine the extraction rate as well as the amount of heat to be extracted.

3. Determination of the system temperature in the heating circuit

The lower the system temperature, the higher the efficiency of the heating system. Every increase in flow temperature by 1 K reduces the heat pump COP by 2.5 %.

Where a heat pump system is intended to be used in new build projects, generally area heating systems will be used in order to achieve the lowest possible system temperatures and consequently a high degree of energy efficiency.

Existing static heating surfaces offer a worst COP and, as a result, poorer seasonal performance factors, since their flow temperatures are higher than those of area heating systems. To achieve the maximum possible efficiency in modernisation projects, the following steps should be taken in order to keep the heating system flow temperatures reliably below 55 °C:

- Generally, heating surfaces should be re-calculated.
- The flow temperature demand of the individual heating surfaces must be balanced.
- Individual heating surfaces with high temperature demand must be replaced or supplemented.

In any case, a heating circuit calculation and hydraulic balancing should be included in the quotation for any modernisation project.

Knowing the heat load, the annual energy demand and the system temperatures are the essential foundation for further engineering steps.

4. Checking and determining the heat source

Prior to determining the heat source, its specific general conditions must be checked vis-a-vis the specific project.

Air
The option of using an air/water heat pump depends on the installation site. The requirements of TA Lärm [in Germany] must be observed in order to avoid a noise nuisance.

For internally sited heat pumps, the installation location should be selected so that an adequate amount of air can be supplied over the shortest possible duct system.

Brine
The extraction rate, and the amount of heat to be extracted, form the basis for engineering ground-coupled systems. This requires the expert support of experienced drilling contractors or the Viessmann Geothermie department. Using the ground as a primary source requires a detailed calculation rather than estimation.

The distance between the probe installation or geothermal collector and the heat pump must be determined. The greater the distance, the higher the required pump rate of the brine pump.

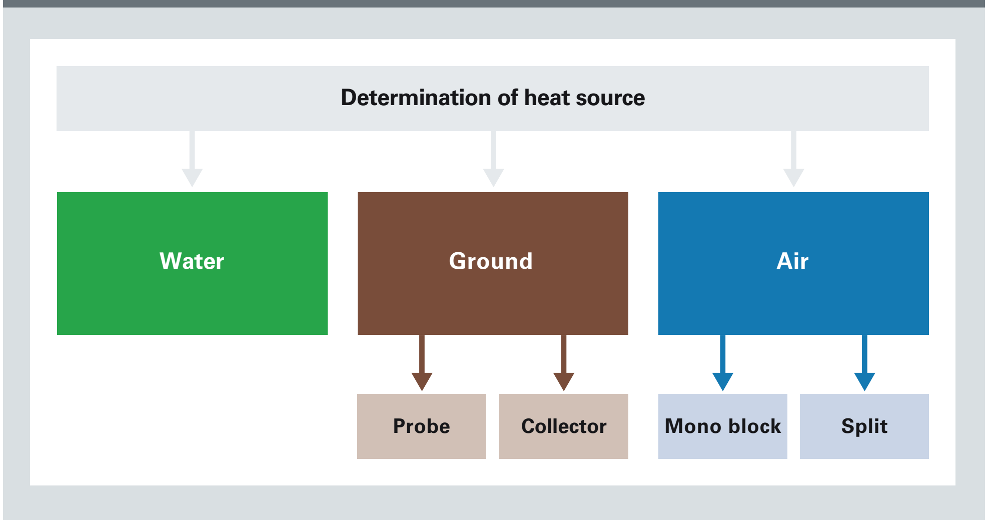
Probe systems require a permit from the water board (generally for bore holes up to 100 m deep) or the mining authority [in Germany]. It should be checked whether any existing conditions can actually be met.

Utilising geothermal equipment requires heavy plant. Therefore a check is required as part of the engineering process whether sufficient space and access is available.

Water
In order to use groundwater as a heat source, it must be checked whether this is available in adequate volume and quality. For a detached house, the groundwater depth should be above 15 m in order to keep the power consumption for the well pump within justifiable limits.

Chapter C provides detailed information on the selection of the heat source.

Heat source selection



5. Determining the provision of domestic hot water (DHW)

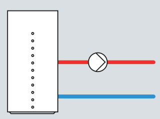
Essentially, demand is the critical factor for determining the type of DHW heating. In the residential sector, the decision as to which system to employ is determined by draw-off rate, draw-off peaks and hygiene requirements. The most common errors are avoided if the relevant heat exchanger areas are accurately tailored to the spread and output of the heat pump.

In the case of utility buildings, for example office buildings, it should be carefully examined whether the installation of a centralised DHW heating system is appropriate. Where demand is low, DHW should not be stored, as the cylinder and DHW circulation losses would result in unnecessary cylinder heating cycles. Where the comparatively poor COP of heat pumps used for DHW heating is taken into account, a decentralised electrically operated system can, in such case, provide a more efficient solution.

Chapter D.2 provides detailed information on DHW heating.

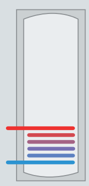
6. System engineering

Important points for system engineering at a glance



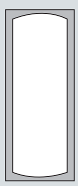
Content of flow and return lines for systems without buffer cylinder

at least 3 l/kW



Area of indirect coils in the DHW cylinder

at least 0.25 m²/kW



Buffer cylinder capacity

20 l/kW (runtime optimisation)
60 l/kW (bridging power-OFF periods)

Once output and type of primary source have been established, system temperatures are crucial for determining whether to select mono or dual mode operation. As dual mode operation means either an additional outlay or (in the case of electric booster heaters) a negative influence on efficiency, the decision can only be made based on a system simulation.

The dual mode point should lie between –3 °C and –7 °C. In mono energetic systems, the proportion of direct electrical booster heating should be as low as possible, i.e. the dual mode point should be as low as possible.

All other pipework engineering steps follow the same rules as when using conventional heat generators. This also applies to the creation of comprehensive documentation.

7. Installation and commissioning

As long as no work on the refrigerant circuit is necessary, the requirements for the installation of a heat pump correspond to those of other heat generators, where trade expertise is concerned.

KlimaChem.VO (ordinance on climate protection from changes through emissions of certain fluorinated greenhouse gases) specifies the requirement for competent personnel when installing refrigerant lines for split heat pumps. Viessmann offers relevant technical courses.

The system efficiency will be proven in its daily operation. This makes commissioning, with comprehensive function checks on the intended properties such as those following, essential:

- Hydraulic balancing of primary and secondary circuits with checking intended flow rates.
- Checking the design DHW temperature.
- Setting the heating curves in accordance with the design system temperature.
- Setting control parameters of the existing hydraulics.
- Checking fluids, such as the brine concentration in the case of brine/water heat pumps.

8. Instructions

Advanced heat pumps are safe to operate, and as easy to understand from the operations viewpoint, as any systems employing conventional heat generators.

However, efficient operation requires a utilisation that calls for a certain understanding and care, particularly where system temperatures are concerned. Changing individual operating parameters may have an impact on efficiency – this must be made clear to system users. It is appropriate to set parameters, such as set temperatures and power-OFF times at the controller together with users whilst they are being introduced to the system.

The correlation with other heating system components should be explained. In order to maintain an efficient operation, it is necessary that

- the control of the entire system is regulated by the heat pump control unit in dual mode systems,
- room temperature controllers, including thermostats, are operated in a subordinate manner,
- DHW switching times are set as near to times of consumption as possible.

Information on inspection and optimisation

Safeguarding the efficiency of the heat pump system not only requires regular servicing, but also checking the system characteristics. This may highlight ways as to how to optimise the system.

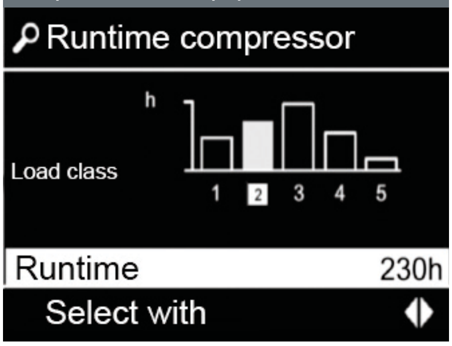
The requirements of inspection and maintenance for heat pump systems are generally comparable with those of conventional heat generators, as long as the amount of refrigerant in the entire system does not exceed 3 kg.

A competent contractor should always inspect and, where possible, optimise a heating system after it has been installed. In the case of new build, this optimisation is critically important, as a higher energy demand prevails in the year of construction on account of the moisture contained within the structure.

In the case of ground-coupled heat pumps, the extraction of heat should be checked regularly during the period when the building is being dried out. The source temperature can drop to a critical level if too much heat is being extracted, resulting in a risk of damage to the probe system. If the energy expenditure for drying the building is excessive, a second heat generator should be linked in to cover this additional demand.

Viessmann heat pump controllers offer an operating log feature to assist inspection and optimisation. Here, energy statement and load categories can be recorded.

Compressor runtime display



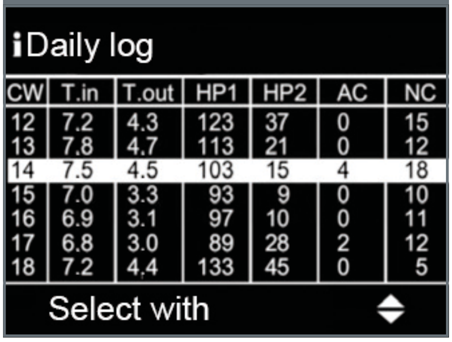
The assignment of hours run to load categories permits conclusions to be drawn as to what temperature levels were actually achieved inside the building and whether optimisation potentials might possibly still exist. The hours run can be individually scanned for any load category.

These categories illustrate the temperature differential between the evaporation and condensation temperature (ΔT V/K).

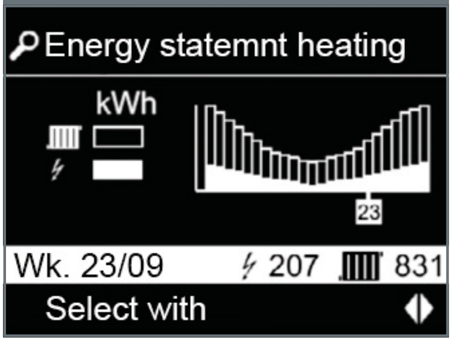
Load category	Hours run at $\Delta T_{V/K}$
1	$\Delta T_{V/K} < 25$ K
2	25 K $< \Delta T_{V/K} < 32$ K
3	32 K $< \Delta T_{V/K} < 41$ K
4	41 K $< \Delta T_{V/K} < 50$ K
5	$\Delta T_{V/K} > 50$ K

The longer the runtimes with low temperature differentials, the more efficient the heat pump operation.

Operator's log display



Energy statement display



Information regarding the amount of electricity used and the heating energy transferred helps to determine the weekly efficiency level.

The operator's log provides opportunities for further possible analysis. This stores additional information over time. For each calendar week (CW = calendar week) the following values can be checked:

	Average temperatures
T.in	Heat pump intake
T.out	Heat pump outlet
	Hours run
HP1	Heat pump stage 1
HP2	Heat pump stage 2
AC	Active cooling mode
NC	Natural cooling function

In systems with an electronic expansion valve, an additional "Heating energy statement" can be created for each calendar week. This indicates the ratio between electrical power consumed and transferred heating energy, in other words it determines a weekly efficiency level. For air source heat pumps, this enables the operating characteristics of the heat pump to be analysed at different outside temperatures.

Based on this data, it can be ascertained whether the compressor runtimes and temperature curves correlate with the intended operating conditions. Checking the heating circuit (Is the system well balanced? Are there heating surfaces that are too small, which "pull up" the [temperature level of] entire system?) and the set DHW temperatures, plus reheating, can inform about any optimisation potential. In the case of systems with several heat generators, experience shows that adjusting the dual mode point is another way of improving efficiency.

Keyword index

Individual solutions with efficient systems

The comprehensive Viessmann product range
he comprehensive product range from Viessmann offers individual solutions with efficient systems for all applications and all energy sources. For decades, the company has been supplying highly efficient and clean heating systems for oil and gas, as well as solar thermal systems along with heat generators for sustainable fuels and heat pumps.

The comprehensive product range from Viessmann offers top technology and sets new benchmarks. With its high energy efficiency, this range helps to save heating costs and is always the right choice where ecology is concerned.

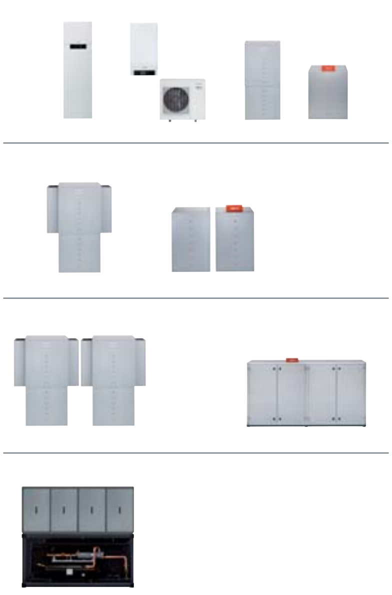
Individual and economical
Viessmann offers the right heating system for any demand – wall mounted or floorstanding, in individual combinations – all are futureproof and economical. And whether for detached houses or two-family homes, large residential buildings, commercial/industrial use or for local heating networks; for modernising existing properties or new build – they are always the right choice.

Key performers
The Viessmann Group sets the technological pace for the heating industry. This is what the Viessmann name represents, and also what the names of the subsidiaries in the Group represent, as they are founded on the same pioneering spirit and power of innovation.

Wood combustion technology, CHP and biogas production
up to 50 MW

Heat pumps for brine, water and air

up to 2 MW



Air conditioning technology

System components

The comprehensive product range from Viessmann: Individual solutions with efficient systems for all energy sources and applications

The product range for all fuel types and output ranges:

- Boilers for oil or gas up to 116 MW heating or 120 t/h steam output
- Solar thermal systems
- Photovoltaics
- Heat pumps up to 2 MW
- Wood combustion systems up to 50 MW
- Combined heat and power modules up to 30 MW_{el}
- Systems for the production of biogas from 18 kW_{el} to 20 MW_{gas}
- Biogas upgrading plants up to 3000 m^3/h
- Air conditioning technology
- Heating system components
- Services

Viessmann is extremely highly specialised in all these market segments, yet at the same time the company has a crucial advantage over specialist suppliers: Viessmann understands heating technology as a systematic whole and offers unbiased advice on technology and fuel type. This guarantees the best solution for every application.

Viessmann Group

VIESSMANN

KWT

KÖB

MAWERA

ESS

HKB

BIOFERM

Schmack

Carbotech

The comprehensive Viessmann product range

Detached houses

Apartment buildings

Commerce / Industry

Local heating networks

Oil boilers

Architect's own home,
Bad Füssing, Germany

Residential development, Zi Wei
Garden Xi'an, China

Ameco A380 Hangar Beijing,
China

European Parliament, Strasbourg,
France

Gas boilers

Detached house, Kevelaer,
Germany

"Wohnoase" residential park in
Regensburg, Germany

Porsche Leipzig,
Germany

European Parliament, Brussels,
Belgium

Solar thermal and
photovoltaics

Heliotrop Freiburg,
Germany

HafenCity, Hamburg,
Germany

City of Tomorrow, Malmö,
Sweden

The Palm Jumeirah,
Dubai

Wood combustion
technology, CHP, and
biogas production

Detached house, Wiesloch,
Germany

Hotel Lagorai Cavalese,
Italy

Congressional Centre,
Brunstad, Norway

Monastery, St. Ottilien,
Germany

Heat pumps for
brine, water and air

Loftcube Regional Garden
Show, Neu-Ulm, Germany

Studio flats, Brandenburg,
Germany

University library, Bamberg,
Germany

Residential estate, Pfäffikon,
Switzerland

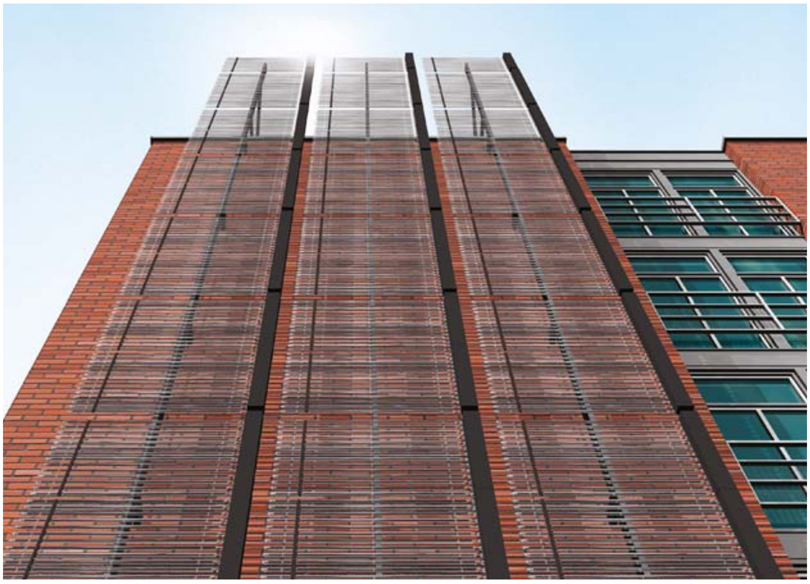
The comprehensive product range from Viessmann: Individual solutions
with efficient systems for all energy sources and applications

Futureproof heating technology for all requirements

Energy consumption worldwide has doubled since 1970 and will triple by 2030. The result: The fossil fuels, oil and gas, are dwindling, energy prices are on the rise and excessive CO_2 emissions continue to affect our environment. Energy efficiency is a must if we want our future to be secure.

In almost every industrial nation, supplying heat to residential and commercial buildings accounts for the largest share of energy consumption – consequently it also offers the greatest savings potential. Advanced efficient heating systems from Viessmann are in use around the world, not only in many private households, but also in numerous major international projects, where they make a sizeable contribution to the efficient use of energy resources.

In these projects, Viessmann again and again faces up to the most varied challenges to supply efficient heating technology by offering innovative solutions – in historical listed buildings as well as in modern industrial complexes and the large-scale residential and industrial arena.



City of Tomorrow, Malmö, Sweden


VIESSMANN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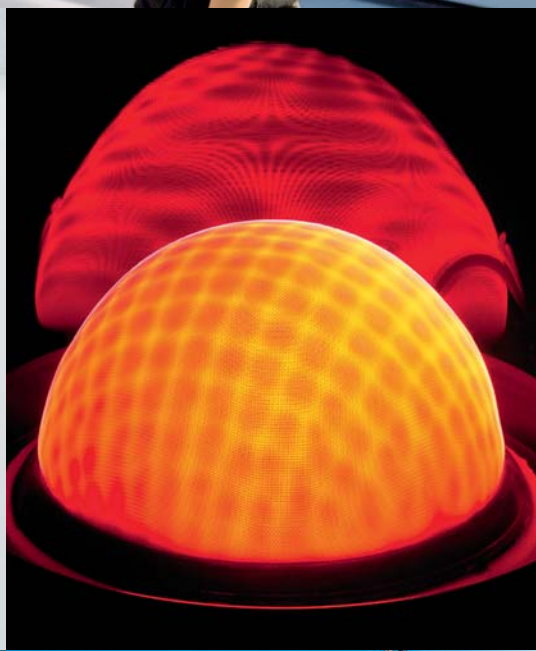
VITOLADENS 300




VIESSMANN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VIESSMANN
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Viessmann – climate of innovation

The Viessmann brand promise concisely expresses all that we hope to achieve. It is our key brand message and, together with our brand label, is an identifying feature throughout the world. "Climate of innovation" is a promise on three levels: It is a commitment to a culture of innovation. It is a promise of high product utilisation and, at the same time, an obligation to protect the environment.

Comprehensive range for all fuel types
Viessmann is one of the leading international manufacturers of heating systems and, with its comprehensive product range, offers individual solutions in the shape of efficient systems for all applications and types of fuel. The company is now run by the third generation of the Viessmann family, and has been supplying particularly efficient and clean heating systems for several decades.

Acting in a sustainable manner
For Viessmann, to take responsibility, means a commitment to act in a sustainable way. This means bringing ecology, economy and social responsibility into harmony with each other, ensuring that current needs are satisfied without limiting the basis for life for the generations to come.

Efficiency Plus
With the "Efficiency Plus" sustainability project that commenced in 2005, Viessmann demonstrates at its own site in Allendorf that the political goals set for 2050 with regard to climate and energy can already be achieved today with commercially available technology.

By utilising renewables and by improving the energy, material and operational efficiency we not only improve our competitiveness but also secure our production site.

Deutscher Nachhaltigkeitspreis
Deutschlands nachhaltigste Produktion 2009

Deutscher Nachhaltigkeitspreis
Deutschlands nachhaltigste Marke 2011

Viessmann was awarded the German Sustainability Prize for the "most sustainable production 2009" and as being the "most sustainable brand 2011".

For the particularly efficient utilisation of energy through the innovative heat recovery centre at the company's main site in Allendorf/Eder, Viessmann was rewarded with the Energy Efficiency Award 2010.

Viessmann Group

Company details
- Established in: 1917
- Employees: 9600
- Group turnover: €1.86 billion
- Export share: 55 percent
- 24 manufacturing plants in 11 countries
- Sales companies and representations in 74 countries
- 120 sales outlets worldwide

Comprehensive range of products from Viessmann for every type of fuel and all output ranges
- Boilers for oil and gas
- Solar thermal systems
- Photovoltaics
- Heat pumps
- Wood combustion systems
- Combined heat and power
- Biogas production plants
- Biogas upgrading plants
- Air conditioning
- Heating system components
- Services

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A.4.1–2	Ebner OG, Sitzendorf, Austria
B.1.1–1	BDEW, AG Energiebilanzen
B.1.4–2	Solarenergie-Förderverein Deutschland (SFV)
S. 56	Pixel – Fotolia.com
B.2.1–2	dena
S. 60	U21, Hanover
C.1.1–3	VDI 4640
C.1.1–4	VDI 4640
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D.2.1–1	DIN EN 15450
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climate of innovation

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