THE ABC OF HEAT PUMPS

FOR A DESIGNER

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Galmet is the largest Polish manufacturer of heating technology with a history spanning 37 years. More than 720 experienced and highly-qualified employees and state-of-the-art machines installed on automated production lines housed in production halls the area of which is more than 45 000m². By combining the technological excellence of our products with the creativity and progress brought to us by our well-educated young staff, as well as the assistance and support of technical advisers at every stage of the investment process, we can provide our customers with optimal, economical, and ecological heating solutions precisely tailored to their individual needs.

All of our products can be re-configured
to the most efficient hybrid heating systems.

hybrid heating systems — solar systems, heat pumps, CH boilers, water heaters

SPIS TREŚCI

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1. INTRODUCTION

The heat pump market is developing dynamically, both in Poland and worldwide. It results from the fact that a heat pump constitutes a reliable, maintenance-free, and economical source of heating. Living in an era of growing environmental awareness, we are pay more and more attention to energy-efficient solutions based on renewable energy sources. Using heat pumps, we can eliminate local pollution (the so-called low emission).

To get well acquainted with the subject of heat pumps, one needs to learn a number of essential basic notions, such as:

air-water heat pump - it is a device that obtains energy from the air and gives it up to water.

ground/water heat pump - it is a device that obtains energy from the ground and gives it up to water. The energy obtained from the ground is collected by a ground-coupled heat exchanger, either horizontally or vertically. Other commonly used nomenclature includes brine-water or glycol-water heat pump.

upper source - the source to which a heat pump transfers heat energy. In the case of Galmet devices, it is usually water, which is a heat-transfer fluid in a central heating system, or domestic water. The heat exchanger of a heat pump, which transfers the generated heat, is called a condenser. In products manufactured by Galmet, it takes the form of a plate heat exchanger or a pipe wound around a tank (if using a heat pump integrated with a tank for utility water).

lower source - the source from which a heat pump obtains heat energy. Galmet devices use either air or ground for this purpose. Heat is taken from a heat exchanger, which is referred to as the evaporator. If used in an air heat pump, the evaporator has the form of a fin heat exchanger, while the evaporator installed in a ground source heat pump has a similar structure to the condenser, i.e. it is a plate heat exchanger. The heat supplied to the evaporator of an air heat pump is obtained directly from the air. As for a ground source heat pump, the lower source is, naturally, the ground, and the heat taken from the ground is supplied to the evaporator with the help of a transfer medium. Propylene glycol is usually used for this purpose.

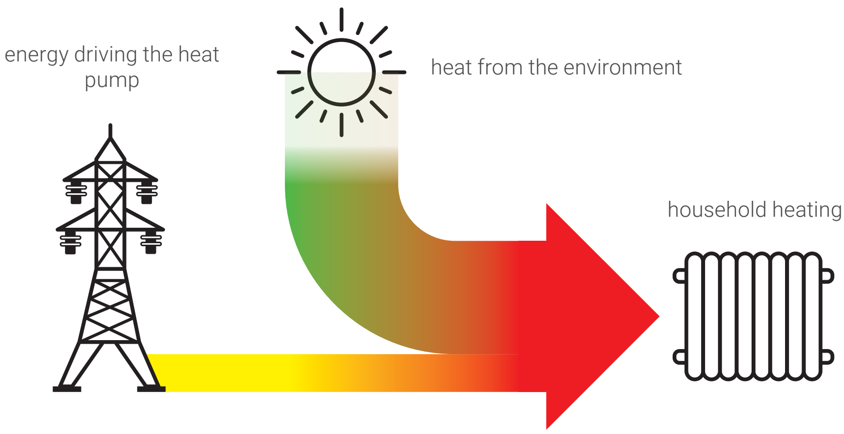
operating point of a device - heat pumps reach different heating values of heating, cooling, or electrical power, depending on various temperatures of the upper or lower source. Operating points constitute reference conditions used to determine parameters of a particular device. An operating point is usually abbreviated. An example of the operating point of an air heat pump: A7W35, where “A” is an abbreviation for “air”. “W” refers to “water”. This means that the inlet air temperature is 7°C and the temperature of water exiting the heat pump is 35°C. In the case of a ground-water heat pump, its operating point can be described as B0W55, for example. The letter “B” means “brine” (brine is the usual name for glycol), while “W” refers to water. Consequently, it means that the temperature of glycol at the inlet to the heat pump is 0°C, and rises to 55°C at the exit from the heat pump.

refrigerant - it is a thermodynamic operating medium, which facilitates the transfer of heat from the evaporator to the condenser of the heat pump, while carrying out specific thermodynamic processes. All Galmet heat pumps are factory-filled with refrigerant, and then hermetically sealed.

operating area of the device - temperature ranges of the lower and upper sources, within which the heat pump is able to operate.

1.1. Definition of a heat pump

A heating unit which, by means of additional energy, raises the temperature of the operating medium from a lower to a higher temperature level, making it possible to use this energy for heating purposes.

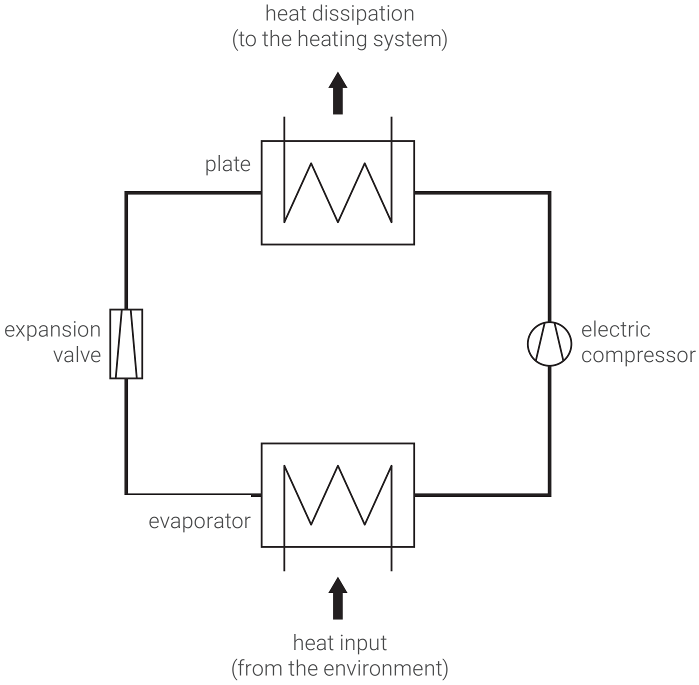


Pic. 1. The principle of operation for a heat pump

1.2. Types of heat pumps

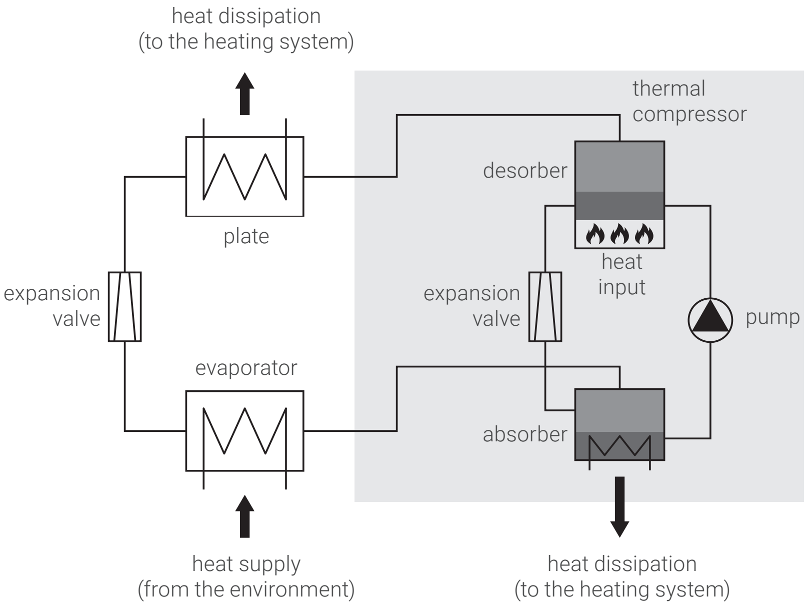
Depending on their type and principle of operation, heat pumps can be divided into the following categories:

- Electric compressor heat pumps - the most technically advanced and popular model of all heat pumps. They are capable of generating usable heat, by taking heat energy from the environment (air, ground) and supplying a certain amount of electrical energy (to the compressor). It is a device featuring a typical refrigerating cycle, which is implemented in every household refrigerator. However, a refrigerator obtains heat from a certain space (the refrigerator chamber), while a heat pump operates based on heat transfer in the upper source.



Pic. 2. Electric compressor heat pumps

- Combustion compressor heat pumps - Their principle of operation is similar to that of an electric compressor heat pump. The only difference is the drive source of the compressor. The compressor of an electric compressor pump is driven by an electric motor that consumes electric energy. As for a combustion compressor heat pump, the compressor is driven by a combustion engine powered by natural gas or diesel oil. This type of heat pump generates combustion gases, which is a disadvantage. However, such combustion gases can also be used for the purpose of household heating.
- Absorption heat pumps - one of the two types of absorption heat pumps. Absorption is the process by which one liquid or gas is absorbed by another liquid or gas at the right temperature and pressure. In appropriate conditions, it is a reversible process. Such devices usually use ammonia as a transfer medium, and it is absorbed by water (solvent). The most important difference is the lack of an electric compressor, which is replaced by a thermal compressor (consisting of an absorber - absorption of ammonia by water, a desorber - separation of ammonia from water by means of heat supply, e.g. by a gas burner, a pump, or an expansion valve).



Pic. 3. Absorption heat pump

- Adsorption heat pumps - the other of the absorption heat pumps. It only operates in the cyclic mode. The adsorbent is alternately undergoing adsorption and desorption of the refrigerant. The complete cycle consists of four stages: heating of deposit, desorption, cooling, and adsorption. However, this type of heat pumps is not used for the purpose of heating buildings. They are only used as industrial cooling machines.
- Vuilleumier heat pumps.
- Thermoelectric heat pumps.

The last two groups are still in their development phase. In fact, electric compressor pumps play the most significant role on the market. Galmet manufactures this type of heat pump, which will be discussed in detail in further sections of the document.

1.3. Application areas for Galmet heat pumps

Galmet heat pumps are heating devices designed to supply heat in single-family houses and public utility buildings. They provide heating and/or domestic hot water. As far as heating systems are concerned, a heat pump works most efficiently in low-temperature systems (surface heating). Heat pumps for supplying domestic hot water are most commonly used in an arrangement combining a heat pump and a boiler, as they perfectly complement each other.

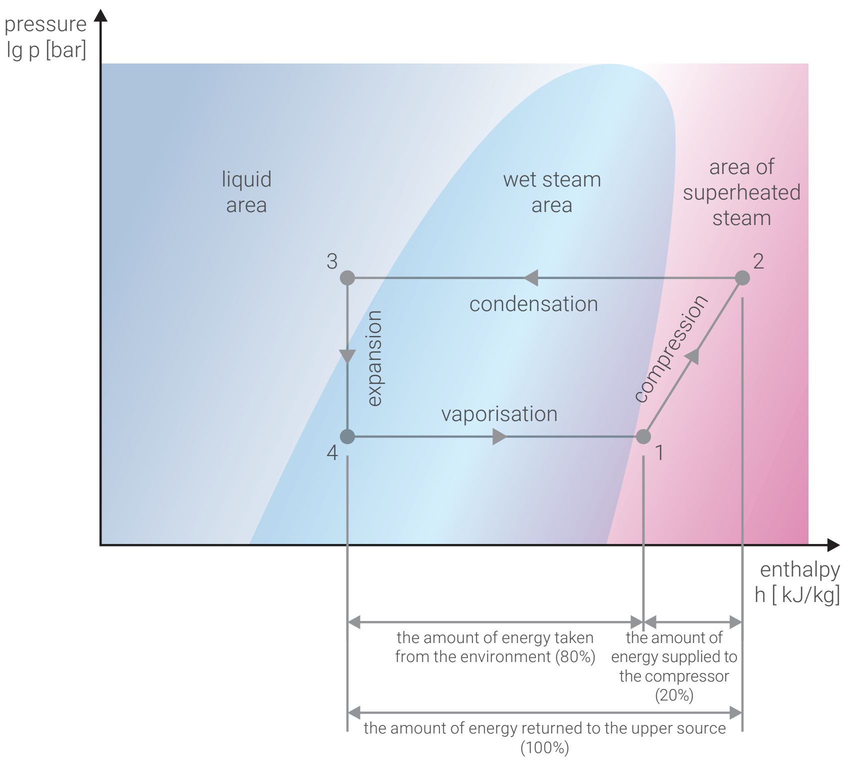
2. ELECTRIC COMPRESSION HEAT PUMP - BASIC INFORMATION

A heat pump is a heating unit, which features a left-handed thermodynamic circuit (the Linde circuit). Circulation is carried out using a refrigerant.

Not every type of refrigerant is suitable for use in compressor systems. It must demonstrate appropriate thermodynamic properties, i.e.:

- The boiling point at ambient pressure should be below zero.
- Chemically stable, non-flammable, non-toxic, non-explosive.
- Chemical inertia in relation to the materials used to build a refrigeration system.
- The refrigerating cycle (see Fig. 4) should occur under overpressure, i.e. at pressures higher than atmospheric.

The following refrigerants are used in Galmet heat pumps: R134a and R410A. The Linde circuit is usually reflected using a lg p-h diagram (p-pressure, h-enthalpy of the refrigerant). The diagram features three areas: liquid (100% liquid medium), superheated steam (100% gas phase), and wet steam (mixture of the liquid and gas phases). The area of wet steam is limited by the so-called saturation curve. Phase transition, namely evaporation or condensation, can occur in the area under the curve. These are isobaric transformations, i.e. occurring under a constant pressure. Outside the area of the curve (in the area of liquid or superheated steam), it is only possible to cool or heat the medium, but it will not change its phase.



Pic. 4. Left-hand refrigerating cycle - the Linde circuit

The basic cycle is carried out using the following four elements:

- Evaporator: process 4-1; evaporation of the medium by supplying heat from the environment.
- Compressors: process 1-2; compression of the medium with electric energy supply, which helps it reach the appropriate temperature level to transfer heat to the upper source.
- Condenser: process 2-3; liquefaction of the medium by transferring heat energy to the upper source (e.g. water).
- Expansion element: process 3-4; expansion of the medium to reduce its pressure and temperature, so that can again extract heat from the lower source in the evaporator.

The four thermodynamic processes shown in the diagram above are necessary to carry out the refrigerating cycle. In this context, we shall take a closer look at how each of the processes goes. In order to cool down a certain space, we have to carry out a process using a medium, which has a lower temperature than the space we intend to cool down, because heat will only flow automatically from a warmer source to a colder source, according to the laws of thermodynamics. Therefore, having a lower source, whether it is air or soil, we need to use a fluid that has a lower temperature than the temperature of the lower source, if we intend to take heat from it. How do we obtain a sufficiently low temperature? As a result of throttling (expansion). We'll discuss this phase later on. Let us assume that we have a fluid capable of cooling down the lower source, i.e. taking heat from it. When heat is taken up, the refrigerant evaporates, i.e. changes its form from liquid to gaseous. The transformation takes place inside the evaporator. The refrigerant that leaves the evaporator after evaporation should be 100% superheated steam. Although it has the form of steam, its temperature is too low to be used for heating purposes. At this point, we need to use another element: the compressor, which compresses gas with the help of electric energy.

Resulting from the compression process, its temperature and pressure increase. One must bear in mind that the amount of energy supplied to the compressor is several times smaller than the amount of energy taken from a renewable source, as shown in the graph above.

Now, going back to the thermodynamic cycle, the compressor has increased both the pressure and temperature of the refrigerant. At this point, its temperature is so high that it can be given up, for example to the water supply of the heating circuit. Therefore, the mentioned heat transfer to the upper source takes place inside the condenser. The temperature of refrigerant is then higher than the temperature of the water to which heat is transferred – otherwise, the process would not take place. By releasing heat, the temperature of the refrigerant is lowered, which leads to its condensation, i.e. its transformation from the gaseous to the liquid phase. When all heat in the upper source is dissipated, the refrigerant still remains under high pressure. We use the aforementioned throttling effect to reduce its pressure, and thus its temperature, so it can again capable of taking heat from the lower source. It takes place inside the expansion valve. This is a component, which contains "a throat". When fluid encounters an obstruction in the form of a throat, while passing through a canal, its pressure drops, which also results in a decrease of its temperature. This is exactly the phenomenon occurring inside the expansion valve.

2.1. Basic components of a heat pump

Pic. 5. Fin heat exchanger

Pic. 6. Plate heat exchanger

Pic. 7. Scroll compressor

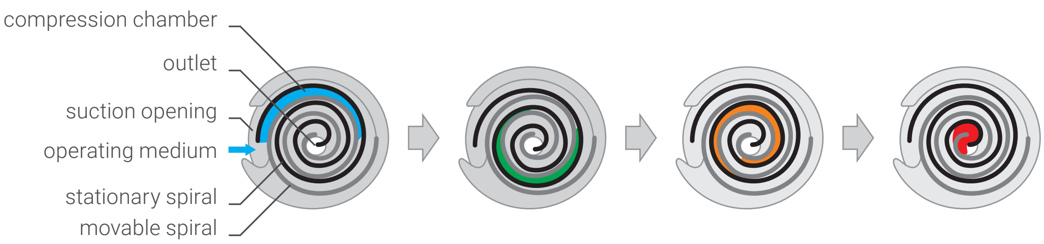
Pic. 8. Rotary compressor

Fin heat exchanger - it is a heat exchanger designed to take heat from the air. This type of heat exchangers features fins, which increase the surface of heat exchange.

Plate heat exchanger - it acts as both the evaporator and condenser in a ground source heat pump, and as the condenser in an air heat pump.

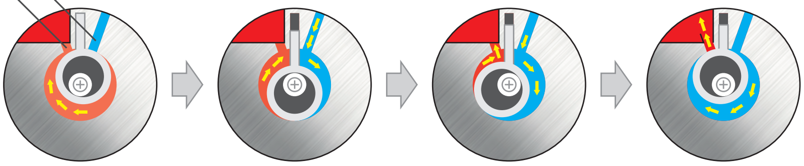
Compressor - it provides energy to the system by increasing both the pressure and temperature of the refrigerant. Galmet heat pumps feature spiral and rotary electric compressors.

In a scroll compressor, compression is carried out using two spirals. One spiral is stationary, while the other one rotates eccentrically. As a result, the space between the spirals is reduced from the suction opening to the discharge opening. It has been shown in the diagram below.



Pic. 9. A diagram demonstrating compression occurring in a scroll compressor

The other type of compressor is a rotary compressor. Compression of gas takes place inside the chambers created by the movement of the rotor. The piston shown in the figure below rotates eccentrically, which constantly reduces the volume of the compression chamber, until compressed gas exits the compressor at the final stage. This marks the start of the cycle for a new portion of gas.



Pic. 10. A diagram demonstrating compression occurring in a rotary compressor

Pic. 11. Electronic expansion valve

Pic. 12. Thermostatic expansion valve

Pic. 13. Fan

Expansion valve - it is a throttling element, which makes it possible to for the refrigerant to expand. The compressor features thermostatic valves, which change their position, when pressure in the capillary tube has changed (resulting from changes in temperature). If using an electronic valve, this signal comes from pressure transmitters and temperature sensors.

Fan - the element forcing air flow through the evaporator in heat pumps working in the air-water system.

Controller - the element controlling the operation of the whole device. Control is carried out by an algorithm and based on temperature or pressure readings.

2.2. Lower sources for heat pumps

The ideal lower source for a heat pump should feature stable and sufficiently high temperature, throughout the year. It must also be capable of regenerating to eliminate the problem of returning too little energy, when the lower source is used. It must also be easily accessible and inexhaustible.

The common lower sources for heat pumps include:

- Air - this source of heat is the easiest to obtain, but outside air is also the most incoherent and least stable source of heat. It is also possible to use air from the interior of buildings, but only in low power devices (for the purpose of producing domestic hot water).
- Ground - it is the most stable source. However, obtaining heat from the ground involves the cost of installing a ground heat exchanger. Consequently, we need to install systems either for direct evaporating of refrigerant in the ground or indirect obtaining of heat with the help of a transfer medium – glycol.
- Water - groundwater is used (two wells are required: a wet well and an absorbing well). The disadvantage of this solution is potential problems with absorption or efficiency of a well. A different way of using water as a lower source is to use surface water (a pond or a lake) and arrange loops of a horizontal heat exchanger in it.

2.3. Efficiency of a heat pump

The energy supplied to the circuit in the form of heat (in the evaporator) comes from a renewable source (soil or air). This energy comes completely free. All other portions of energy are supplied as electricity to drive the compressor. The generated heat is transferred to the upper source in the condenser. The ratio of generated heat to transferred electricity is expressed as the COP coefficient of performance. The coefficient indicates the efficiency of the device. The higher the value it reaches, the more heat energy is obtained in relation to the consumed electricity.

$$COP = \frac{Q_g}{P_{el}}$$

Q_g - the quantity of thermal energy produced [kW]

P_{el} - the quantity of consumed electric energy [kW]

The COP value is a variable for a particular unit. It depends on the temperature of the lower and upper sources. Ideally, the changes occurring in the heat pump can be related to the Carnot cycle. In actual conditions, the achieved efficiency is significantly lower than the one obtained for an ideal cycle. Consequently, an additional correction factor is applied: 0.5. This way, the estimated value is closer to the achievable real value. Calculation of the estimated efficiency of the unit based on temperatures of the lower and upper sources (COP_T) can be carried out using the following formula:

$$COP_T = 0{,}5 \cdot \frac{T_g}{T_g - T_d}$$

T_d - Temperature of the lower source (glycol/air) [K]

T_g - Temperature of the upper source (water) [K]

This coefficient reaches a higher value, as the temperature of the lower source increases and the temperature of the upper source decreases. The higher the value of COP, the more advantageous it is for the user. Therefore, the lower source of a heat pump should have the highest possible temperature (within the operating range of the unit).

For example, assuming the same upper source temperature (35°C) and comparing temperatures of two lower sources (air). i.e. 10°C and -10°C, the following values will be obtained.

External air at 10°C:

T_d - Temperature of the lower source (air): 10°C; 10 + 273 = 283 K

T_g - Temperature of the upper source (water): 35°C; 35 + 273 = 308 K

$$COP_T = 0{,}5 \cdot \frac{308}{308 - 283} = 6{,}16$$

External air at -10°C:

T_d - Temperature of the lower source (air): -10°C; -10 +273 = 263 K

T_g - Temperature of the upper source (water): 35°C; 35 + 273 = 308 K

$$COP_T = 0{,}5 \cdot \frac{308}{308 - 263} = 3{,}42$$

The obtained values confirm that a higher temperature of the lower source results in a higher efficiency of the heat pump. Air/water heat pumps can be exposed to low temperatures. Therefore, the efficiency of this type of units decreases, if outside temperatures are low. However, the main advantage of an air heat pump is its simple installation. It does not require providing an expensive lower source.

On the other hand, when analysing the temperature level of an upper source, it is recommended to keep it as low as possible. As an example, two different cases were analysed: low-temperature heating and high-temperature heating. It was assumed that the temperature of the lower source (air/glycol) was constantly at 0°C.

Low-temperature heating with the supply temperature of 35°C:

T_d - Temperature of the lower source (air/glycol): 0°C; 0 + 273 = 273 K

T_g - Temperature of the upper source (water): 35°C; 35 + 273 = 308 K

$$COP_T = 0{,}5 \cdot \frac{308}{308 - 273} = 4{,}40$$

High-temperature heating with the supply temperature of 50°C:

T_d - Temperature of the lower source (air/glycol): 0°C; 0 + 273 = 273 K

T_g - Temperature of the upper source (water): 50°C; 50 + 273 = 323 K

$$COP_T = 0{,}5 \cdot \frac{323}{323 - 273} = 3{,}23$$

Therefore, the efficiency of a heat pump system decreases with the increasing temperature of water in the upper source. For this reason, it is recommended to use low-temperature systems (underfloor heating, wall heating) to work with a heat pump, as high-temperature heating (radiator heating) generates higher operating costs.

2.4. Seasonal efficiency of a heat pump

In addition to the coefficient of performance (COP), you will also find SCOP in the technical data of the unit, which is the Seasonal Coefficient of Performance taking into account the variability in heat demand of the building and the variability in the efficiency of a heat pump, during the entire heating season. Ground source pumps feature a higher SCOP, because the lower source temperature is more stable for this type of pump. In the case of an air pump, however, an increase in demand for heat from the building lead to a decrease in its efficiency - it is largely dependent on the prevailing weather conditions. The value of SCOP is, of course, influenced by the selected heating system. If you decide to use a low temperature system, you will get a higher seasonal coefficient of performance.

2.5. Comparison between different heat pumps

If you are an investor in need of choosing a heat pump, you should pay attention to the parameters provided by its manufacturer. The important parameters are heating power and COP. PN-EN 14511 is the standard currently in force, according to which one needs to test ground/water and air/water heat pumps used for central heating purposes. With regard to heat pumps designed for domestic hot water, the standard currently in force is EN 16147, which takes into account water consumption cycles. Therefore, products can only be compared when using the same standard and – what is equally important – the same reference parameters.

Air/water pumps used for central heating purposes are external units, which usually undergo tests using supply air of specific humidity and temperatures of 7°C and 2°C. As for ground/water pumps, they are tested while maintaining the temperature of a lower source (glycol) at 0°C. Temperatures of the upper source (water at the exit from a heat pump) are 35°C (for low temperature applications) and 55°C (for high temperature applications).

Therefore, summing up, the following operating points can be distinguished for heat pumps used for the purpose of central heating, according to PN-EN 14511:

<table>
<tr><th>type</th><th>purposes</th><th>Galmet model</th><th colspan="3">operating points</th></tr>
<tr><td>air/water</td><td rowspan="2">Central Heating</td><td>Airmax²</td><td>A7 W35</td><td>A7 W55</td><td>A2 W35</td></tr>
<tr><td>ground-water</td><td>Maxima / Maxima Compact</td><td>B0 W35</td><td>B0 W55</td><td>-</td></tr>
</table>

A - English for "Air"; inlet air temperature

W - English for "Water" - water; water temperature when exiting the heat pump

B - English for "Brine" - brine/glycol; glycol temperature at the inlet to the heat pump

A different standard is applicable to units generating heat for the purposes of producing utility water. As mentioned above, the current standard in force is PN-EN 16147. It takes into account the cycles of water intake (a profile), i.e. it reflects the actual operation of this type of unit more accurately. Such profiles are marked with letters, for example: M, L, or XL. When comparing two units based on the same standard, it is important that the same water intake profile is used for testing, which also depends on the capacity of a tank.

Therefore, summing up, the following operating points can be distinguished for heat pumps used for the purpose of producing domestic hot water, according to PN-EN 16147:

<table>
<tr><th>type</th><th>purposes</th><th>Galmet model</th><th>water intake cycle</th><th colspan="2">operating points</th></tr>
<tr><td rowspan="5">Air/Water</td><td rowspan="6">domestic hot water</td><td>Spectra</td><td>L</td><td rowspan="4">A15 W10-55</td><td rowspan="4">A20 W10-55</td></tr>
<tr><td>Basic 200</td><td>L</td></tr>
<tr><td>Basic 270</td><td>XL</td></tr>
<tr><td>Basic 300</td><td>XL</td></tr>
<tr><td></td><td>L</td><td colspan="2">A20 W10-55</td></tr>
<tr><td>ground-water</td><td>Maxima Compact</td><td>L</td><td colspan="2">B0 W10-55</td></tr>
</table>

A - English for "Air"; inlet air temperature

W - English for "Water"; the temperature range for water heating

B - English for „Brine" - brine/glycol; glycol temperature at the inlet to the heat pump

Naturally, the manufacturer can also use parameters obtained from other operating points, but it is important to base comparison on the same operating point, when comparing different units.

When comparing a Galmet heat pump to other products available on the market, one should therefore pay attention to the referred standard and operating point.

3. AIR/WATER HEAT PUMPS

Air/water heat pumps, i.e. units obtaining heat from the air, are becoming more and more common. They effectively compete with solar collectors, in terms of water preparation in detached houses, mainly due to their simple installation.

The advantages of air/water heat pumps:

- simple and quick installation
- a clean source of heat
- a commonly available lower source - air
- maintenance-free
- no problems with fuel storage
- safety - any explosion or carbon monoxide poisoning not possible

The Galmet catalogue of products includes the following pump models featuring the air/water system:

- Airmax² - for the purposes of central heating and domestic hot water
- Spectra - for the purposes of domestic hot water
- Basic - for the purposes of domestic hot water
- Small - for the purposes of domestic hot water

3.1. Air as the lower source for a heat pump

Air is the simplest source of heat, because we can obtain it directly. The main disadvantage is the incoherence of air as the lower source. Air temperature changes throughout the year. During the period of peak demand (the winter), temperature of the source is the lowest, which reduces the capacity of a heat pump. Therefore, it is important to select the correct unit to ensure sufficient power. If truth be told, there are only a few days throughout an entire year, when temperatures are constantly low. For example, see below for a temperature profile for the city of Jelenia Góra:

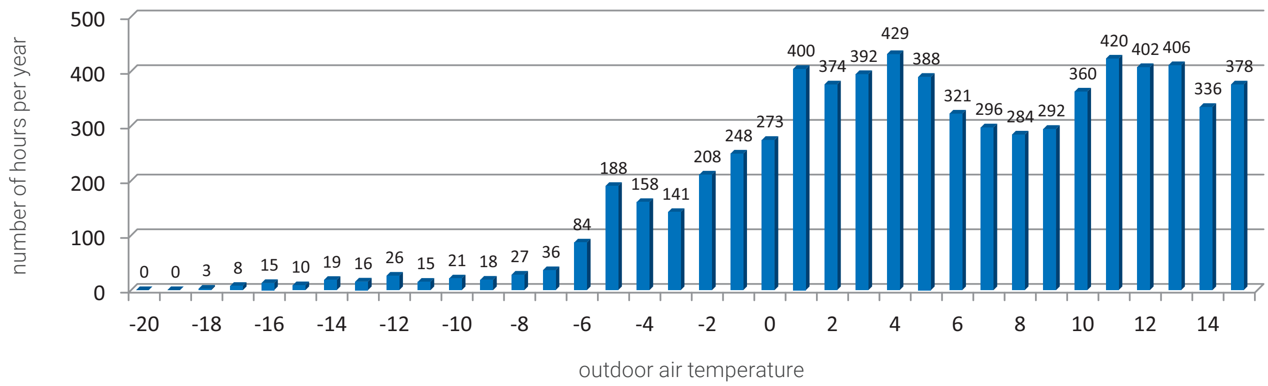


Diagram 1. Distribution of the number of hours per year with a given outdoor air temperature for Jelenia Góra

When analysing the graph above, we see a small number of hours with low temperatures. For that reason, air pumps are not usually selected to operate in the monovalent mode (i.e. they do not work with any other source), but it is usually suggested that they work in the mono-energy mode (supported by a heater, if there is an increase in heat demand), or in the bivalent mode, in some cases (they work with an additional source powered by a different source of energy - e.g. a fireplace). The number of hours required for supporting the pump with an additional source (usually with a heater) is quite small, which makes any possible costs incurred very low.

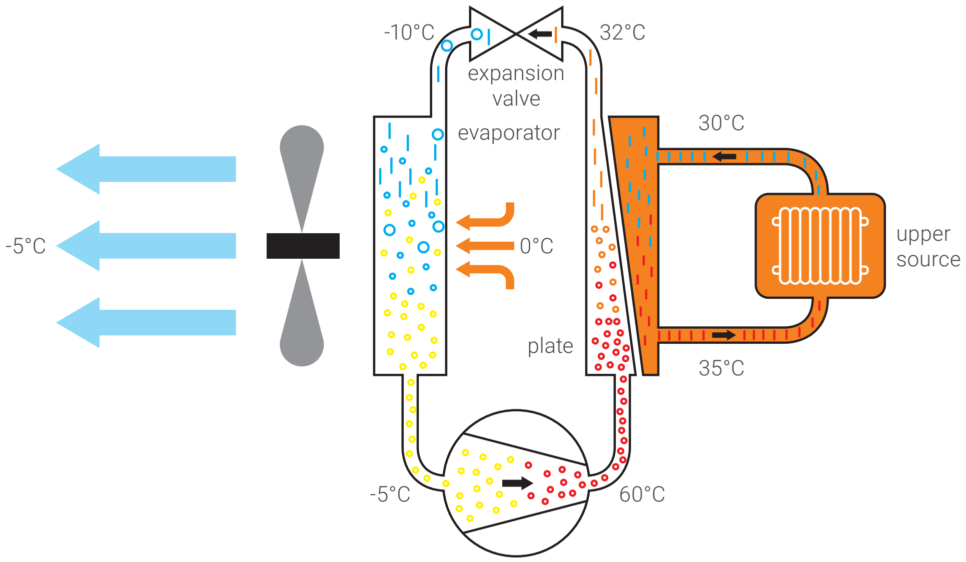
3.2. Air/water heat pumps for CH and DHW - Airmax²

Air/water heat pumps are a heating units providing central and domestic water heating, which take heat from the outside air. This type of heat pumps featured in the catalogue of products by Galmet is the Airmax² model, the only remaining things to install in the house is the water heater and optionally a buffer tank.

In addition to the aforementioned general advantages of air/water heat pumps, the units designed for central heating and domestic hot water have the following features:

- outdoor installation - saves space inside, no boiler room
- easy to install
- low installation cost - no expensive ground heat exchanger

3.2.1. Principle of operation



Pic. 14. The principle of operation for an air/water heat pump

The evaporator installed in an air/water heat pump is a fin exchanger. It is used to evaporate the medium. The evaporated heat is taken from the air. A fan forces air flow through the heat exchanger. After compression is complete, heat is dissipated in a condenser, which is a plate heat exchanger. After expanding, the medium is returned to the evaporator, and the process is repeated.

3.2.2. Technical description of Galmet heat pumps - Airmax²

The Airmax² series of types consists of eight units:

- Airmax² 6 GT
- Airmax² 9 GT
- Airmax² 12 GT
- Airmax² 15 GT
- Airmax² 16 GT
- Airmax² 21 GT
- Airmax² 26 GT
- Airmax² 30 GT

Pic. 15. The Airmax² heat pump From the left: 12 GT/15 GT; 6 GT/9 GT

Performance data of the Airmax² 6-15 GT heat pump series of types:

- Energy efficiency class up to A++.
- High COP: up to 4.72 (A7W35).
- It is possible to obtain co-financing in Germany - entered in the BAFA list.
- The weather system adjusts the pump operating parameters to the weather conditions.
- The possibility of setting an operating schedule for both a heat pump and a circulating pump.
- A reliable scroll compressor and an electronic expansion valve for maximum efficiency.
- An evaporator with an automatic defrosting system and a hydrophobic layer.
- Quiet operation, thanks to modulated fans.
- Working range up to -20°C.
- Natural energy - eligible for funding.

The unit comes with the following standard accessories:

- Complete set of temperature sensors.
- Internet module for remote control of the device.
- Electronic circulation pump built into the device.
- Colour touch panel with thermostat function.

The following optional elements are available:

- Soft start (soft and quiet starting of the compressor).
- The possibility of purchasing a dedicated plate heat exchanger (glycol-water) for the purpose of a water supply system.
- The possibility of purchasing a dedicated three-way valve for the purpose of domestic hot water.

Pic. 16. The Airmax² 21-30 GT heat pump

Performance data of the Airmax² 16-30 GT heat pump series of types:

- Energy efficiency class up to A++.
- High COP: up to 4.70 (A7W35).
- It is possible to obtain co-financing in Germany - entered in the BAFA list.
- The weather system adjusts the pump operating parameters to the weather conditions.
- The possibility of setting an operating schedule for both a heat pump and a circulating pump.
- A reliable scroll compressor with EVI - supply temperature up to 60°C.
- An electronic expansion valve for maximum efficiency.
- An evaporator with an automatic defrosting system and a hydrophobic layer.
- Quiet operation, thanks to modulated fans.
- Working range up to -20°C.
- Natural energy - eligible for funding.

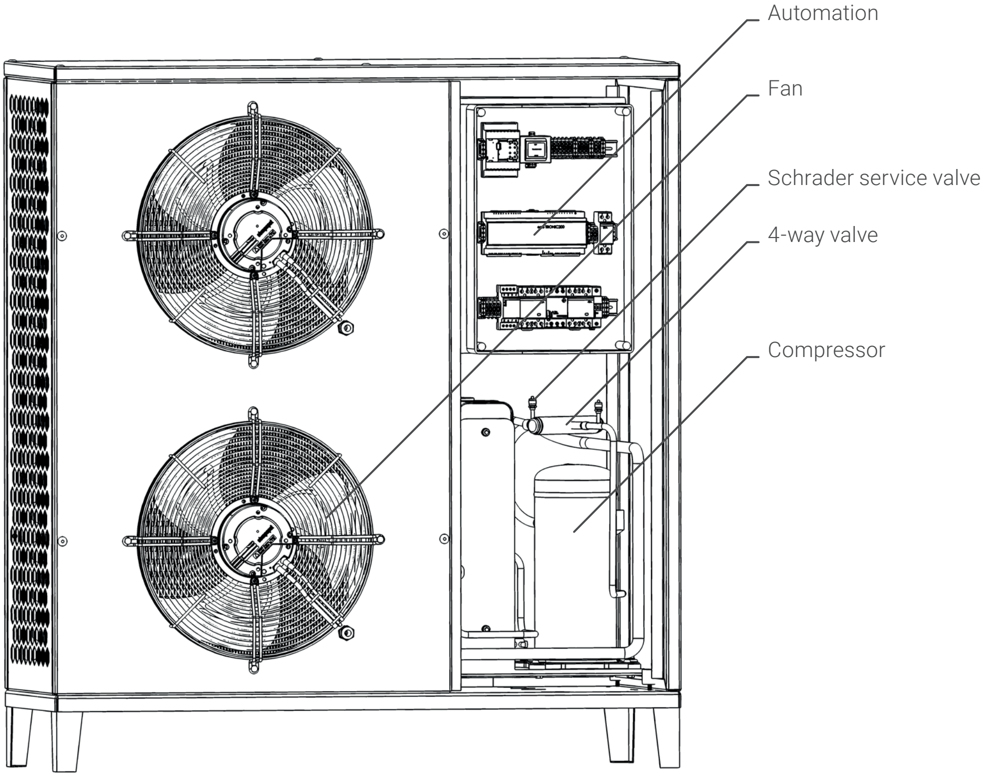
The unit comes with the following standard accessories:

- A complete set of temperature sensors
- An Internet module for remote control of the unit
- An electronic circulating pump integrated in the unit
- A built-in 7kW electric heater
- Smart control of a colour touch panel with the thermostat function.

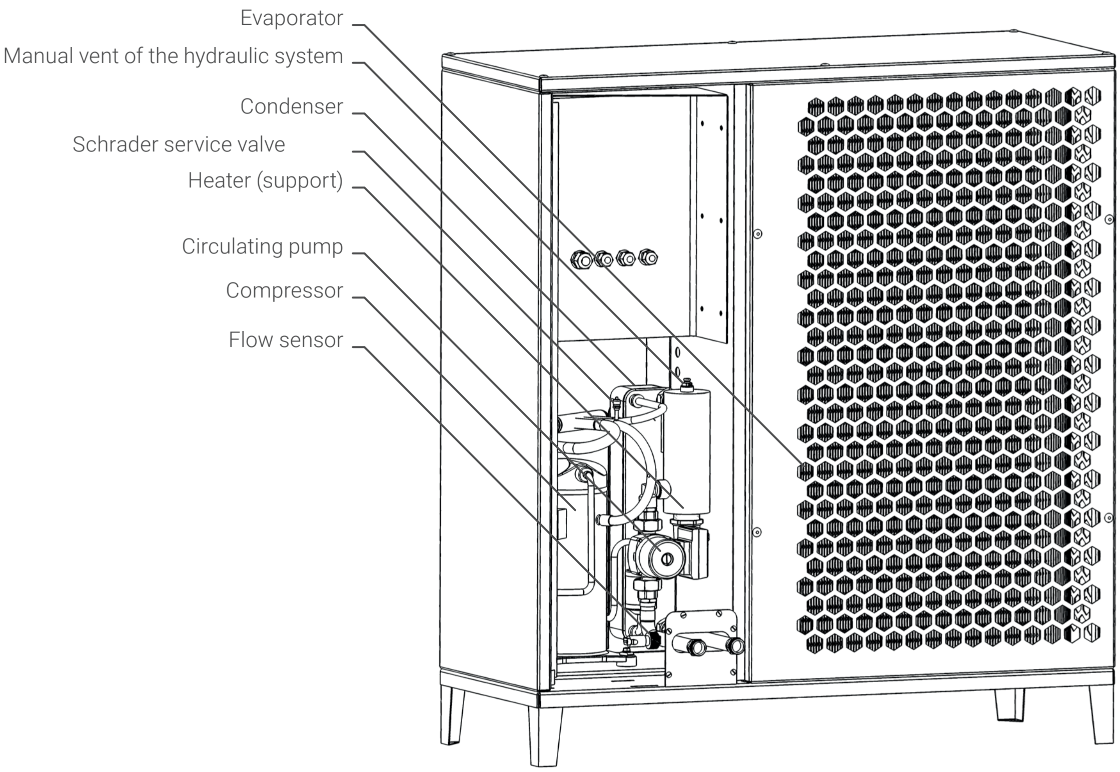
The following optional elements are available:

- The possibility of purchasing a dedicated plate heat exchanger (glycol-water) for the purpose of a water supply system.
- The possibility of purchasing a dedicated three-way valve for the purpose of domestic hot water.

Airmax² is a heat pump designed for operating outdoors. The housing of the unit is made of a material resistant to external factors (aluminium), which ensures durability. The Airmax² heat pump features smart control and high quality components. It has a scroll compressor dedicated for heat pumps (for Airmax²16-30 GT scroll compressors with EVI). It ensures high performance and longevity, as well as low level of noise and vibration in operation. A well-thought-out fin evaporator is covered with a hydrophobic layer, which delays icing of the evaporator by reducing the adhesion forces of moisture, and facilitates drainage of water from the evaporator surface, during defrosting. The unit is equipped with an electronic circulating pump, which features modulated power supply adaptable to the system operation and low power consumption. COP values also take into account power consumption of the circulating pump, so it is not necessary to include it in a simulated model of its operation. The electronic expansion valve precisely controls operation of the unit to maximize the potential of energy accumulated in the ground. It also extends the life of the compressor, preventing non-evaporated refrigerant from entering the compressor. The electronic expansion valve ensures a quick response to changing weather conditions. Airmax² features fans with modulated power, which makes it possible to respond to the actual operating requirements, in a flexible manner. The hybrid structure of the fan blades is the result of combining plastic and glass fibre. The aerodynamic optimisation has resulted in noise reduction. The unit's controller is capable of controlling the circulating pump supplying utility water and setting its operating schedule. It also makes it possible to control heating circuits of a floor heating system and radiators, or an additional heater of the DHW tank.



Pic. 17. Airmax² 6-15 GT heat pump - design; front view



Pic. 18. Airmax² 6-15 GT heat pump - design; rear view

Thanks to its optimal design, the process of defrosting the evaporator is carried out smoothly and precisely. The Airmax[2] heat pump has been tested in an independent, foreign, accredited laboratory. Energy classes, seasonal efficiency coefficients (SCOP), accurate values of heating power and COP for various operating points of the unit were determined. Values of COP also include defrosting cycles, which means that it is not necessary to take into account any additional energy losses for the purpose of defrosting, when calculating the operating costs. The defrosting cycle takes approximately 1-4 minutes and is achieved by reversing the circuit (a 4-way valve). See below for a sample test cycle with defrosting. As a result of frosting, there is a visible power drop. After defrosting, heating power returns to the appropriate level.

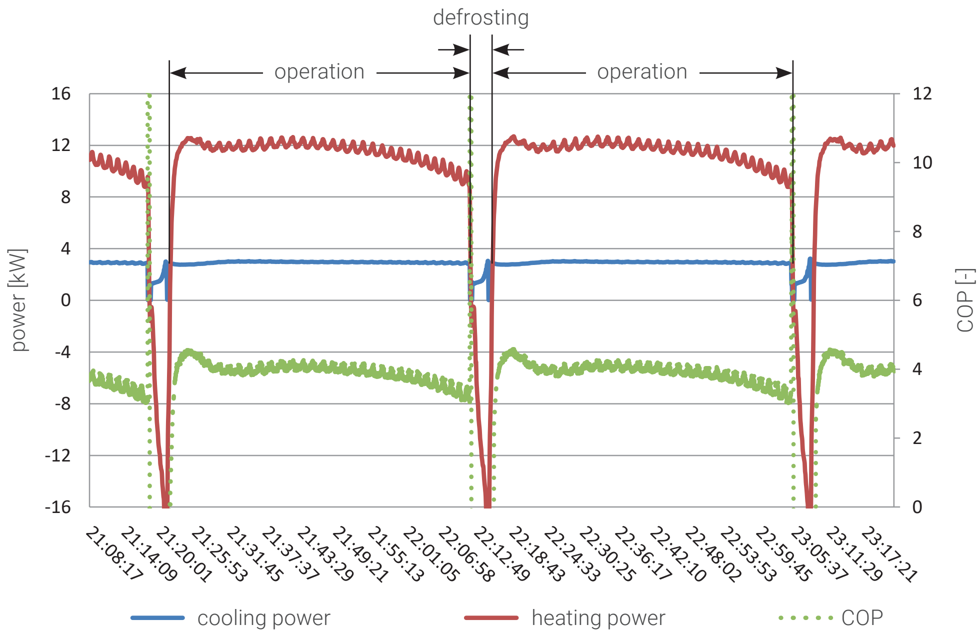


Diagram 2. A sample measuring cycle (A2W35) with defrosting

The frequency of defrosting cycles and their duration depend on the temperatures of the lower and upper sources, as well as air humidity. It would seem that defrosting needs to be carried out more frequently, in low temperatures. At low temperatures, however, air has a lower moisture content, so defrosting may not be necessary for longer periods of the unit's operation. For example, defrosting occurred only once in three hours of the heat pump's operation during the test cycle, according to the A-10W45,88 parameters.

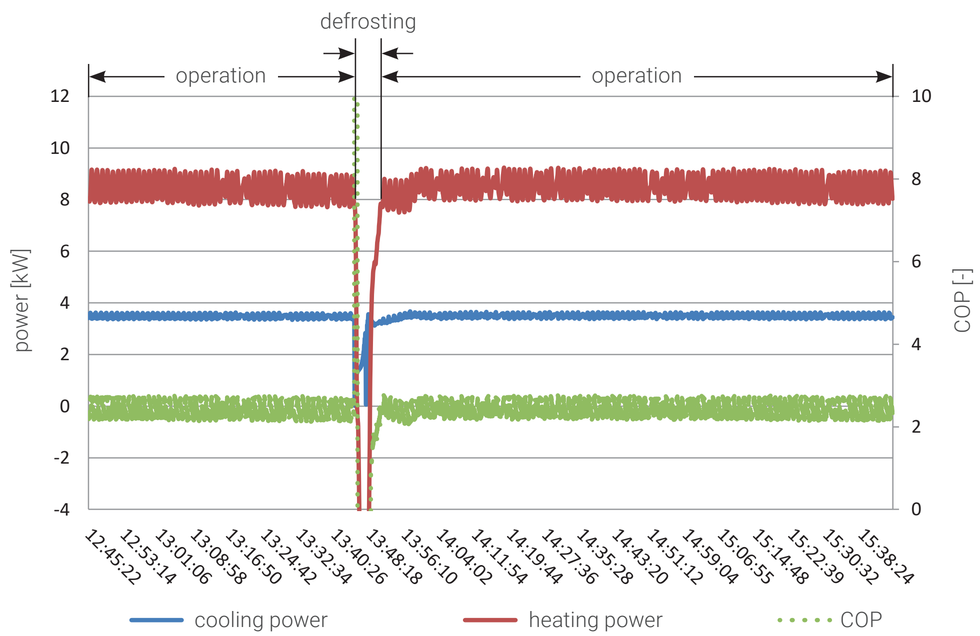
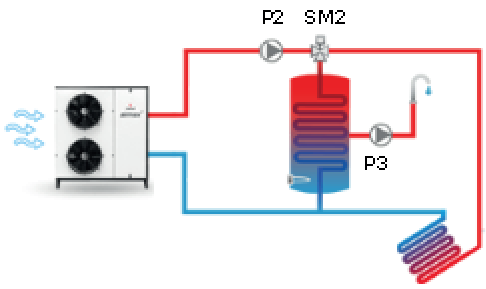
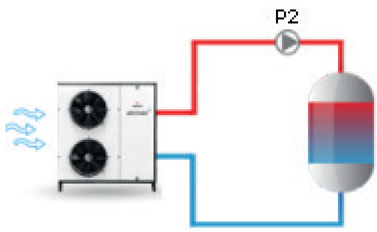


Diagram 3. A sample measuring cycle (A-10W45,88) with defrosting

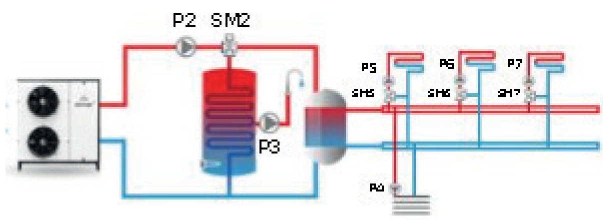
The Airmax² heat pump features the ecoTRONIC200 controller, which supports a number of basic installation options. The user has a choice of three basic control variants:



In the first variant, the heat pump can directly supply the underfloor heating system and the tank's spiral coil for domestic hot water heating. This can be achieved thanks to the built-in upper source circulating pump and a three-way valve. In addition, the heat pump can control the operation of a switching valve for domestic hot water and an additional optional hot water tank heater.



The second variant only includes a buffer tank for water heating. This system does not support domestic hot water. The circulation of water between the heat pump and the buffer tank is ensured by a built-in circulation pump. Further heat distribution from the buffer tank is carried out by an independent external automation.



The final variant includes support for domestic hot water, buffer water heating and heating circuits behind the buffer. The upper source circulation pump and three-way valve are built into the device. The standard version of the controller allows for one floor heating circuit with a mixer, one radiator circuit connected directly to the buffer, or both of these two circuits at once. If there is a need to implement more underfloor heating systems with mixers, an additional expansion module for the controller is necessary (it expands the controller's functions by two additional floor heating circuits with mixers). In this variant, the user has an option to operate a DHW circulation pump as well as an additional optional hot water tank heater.

The aforementioned additional tank heater is used, for example, to quickly heat up domestic water or implement the anti-Legionella mode. In the case of a circulating pump, the controller can be used to program the operating time of the pump. Each Airmax² heat pump is equipped with an external sensor. The buffer can be charged to a constant temperature, regardless of weather conditions, or its preset temperature can be dependent on the outside temperature (heating curve). The temperature after the mixer also results from the heating curve. Heating water is supplied to the radiators directly from the buffer, so that its temperature is equal to that of the buffer. If you decide to use the controller's panel as a thermostat, you can assign it to a heating circuit of your choice. In this case, the circulating pump assigned to the respective circuit stops, when the desired room temperature has been reached (depending on the selected hydraulic arrangement and settings).

3.2.3. Technical data for Galmet heat pumps - Airmax²

The Airmax² heat pump is designed using components of the highest quality from reputable manufacturers. A scroll compressor (scroll/scroll with EVI) of the ZH series designed for heating units; a copper evaporator with aluminium fins; a plate condenser; an electronic expansion valve ensuring accurate regulation. The unit has a built-in electronic circulating pump with adjustable capacity and low power consumption. The fans installed in the unit guarantee the lowest possible noise level. The heat pump's controller is operated intuitively, both by the installer and the user. The Airmax² heat pump has a colour control panel with a touch screen, which can also be used as a thermostat. To this end, you only need to place it in a room, where it is supposed to control temperature. The maximum cable length between the controller and the control panel is 30m. The Airmax² heat pump features an electric heater, which can support operation of the heat pump during periods of increased heat demand, if required.

Table 1. The main components of the Airmax² heat pump

component	Airmax²							
	6 GT	9 GT	12 GT	15 GT	16 GT	21 GT	26 GT	30 GT
compressor	scroll (spiral) ZH				scroll (spiral) ZH with EVI			
evaporator	fin, aluminium/copper				fin, aluminium/copper			
plate	condenser				condenser			
expansion valve	electronic				electronic			
circulating pump of the upper source	UPM3 25-75 Flex AS 130		UPML GEO 25-105 130 PWM		UPML GEO 25-105 130 PWM	UPMXL GEO 25-125 130 PWM		
fans	axial-flow - 1 item		axial-flow - 2 items		axial-flow - 1 items			
controller	ecoTRONIC 200-G				ecoTRONIC 200-G			
heater	7 kW				7 kW			

Pic. 19. Circulating pump UPM3 FLEX AS

The Airmax² 6 GT and 9 GT models are equipped with a FLEX AS PWM-controlled circulating pump. The controller sends an appropriate PWM signal, which reduces or increases the pump's, in order to maintain the correct temperature differences inside the condenser of the heat pump. The FLEX AS pump has signalling diodes of which one indicates the operating status, and the other four indicate the efficiency of the pump, during its operation. The maximum head of the UPM3 25-75 Flex AS 130 circulating pump is 7.5m. The maximum power consumption is 60W. FLEX AS is a circulating pump of the highest energy class and the EEI ≤20 coefficient.

Table 2. Nominal flow through the condenser of the Airmax² 6 and 9 GT heat pump and power consumption of circulating pumps (UPM3 25-75 Flex AS 130)

technical specification	Airmax² 6 GT	Airmax² 9 GT
nominal water flow through the condenser [m³/h]	1,06	1,39
nominal power consumption of the circulating pump* [W]	32	40

* When determining COP of the heat pump, power consumption of the circulating pumps was taken into account. Therefore, do not add it, when creating a simulation of operating costs.

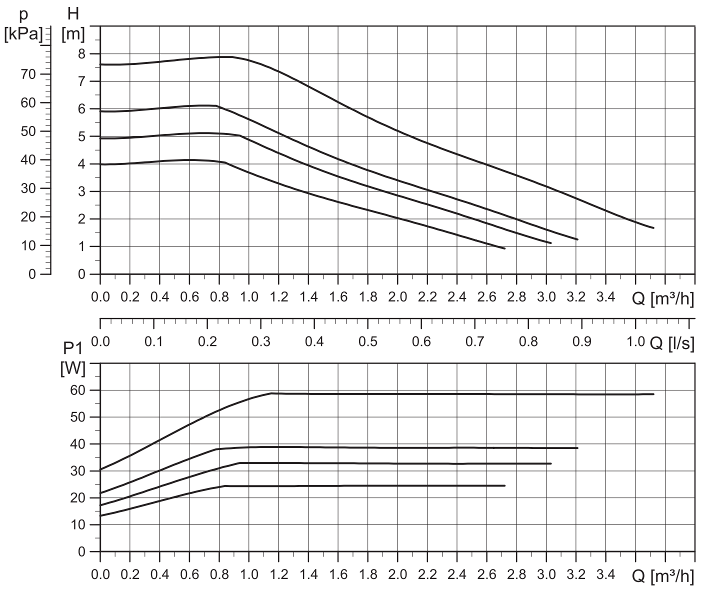


Diagram 4. Performance characteristics of the UPM3 25-75 Flex AS 130 circulating pump

Pic. 20. UPML GEO circulating pump

The UPML GEO 25-105 130 PWM electronic circulating pump, controlled by the PWM signal, also ensures flow through the condenser in the Airmax^2 12, 15, and 16 GT pump models. The highest energy class (EEI < 0.23) ensures low energy consumption. The maximum head of the circulating pump is 10.5m, while the maximum current consumption is 140W.

Table 3. Nominal flow through the condenser of the Airmax^2 12, 15, and 16 GT heat pumps and power consumption of the circulating pumps (UPML GEO 25-105 130 PWM)

technical specification	Airmax^2 12 GT	Airmax^2 15 GT	Airmax^2 16 GT
nominal water flow through the condenser [m^3/h]	1,89	2,39	2,68
nominal power consumption of the circulating pump* [W]	60	75	80

* When determining COP of the heat pump, power consumption of the circulating pumps was taken into account. Therefore, it should not be taken into account when creating simulation of operating costs.

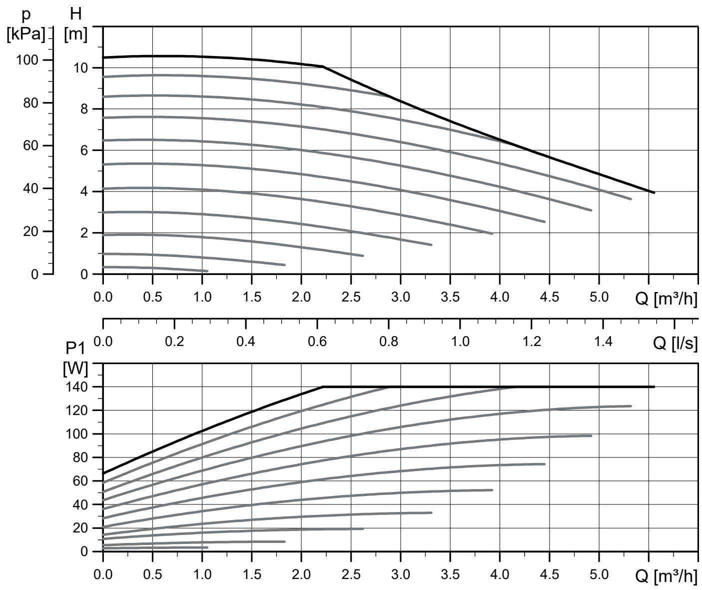


Diagram 5. Performance characteristics of the UPML GEO 25-105 130 PWM circulating pump

Pic. 21. UPMXL GEO circulating pump

The UPMXL GEO 25-125 130 PWM electronic circulating pump, controlled by the PWM signal, also ensures flow through the condenser in the Airmax^2 21-30 GT pump models. The highest energy class (EEI < 0.23) ensures low energy consumption. The maximum head of the circulating pump is 12.5 m, while the maximum current consumption is 180 W.

Table 4. Nominal flow through the condenser of the Airmax^2 21-30 GT and power consumption of the circulating pumps (UPMXL GEO 25-125 130 PWM)

technical specification	Airmax^2 21 GT	Airmax^2 26 GT	Airmax^2 30 GT
nominal water flow through the condenser [m^3/h]	3,62	4,49	5,15
nominal power consumption of the circulating pump* [W]	100	120	135

* When determining COP of the heat pump, power consumption of the circulating pumps was taken into account. Therefore, it should not be taken into account when creating simulation of operating costs.

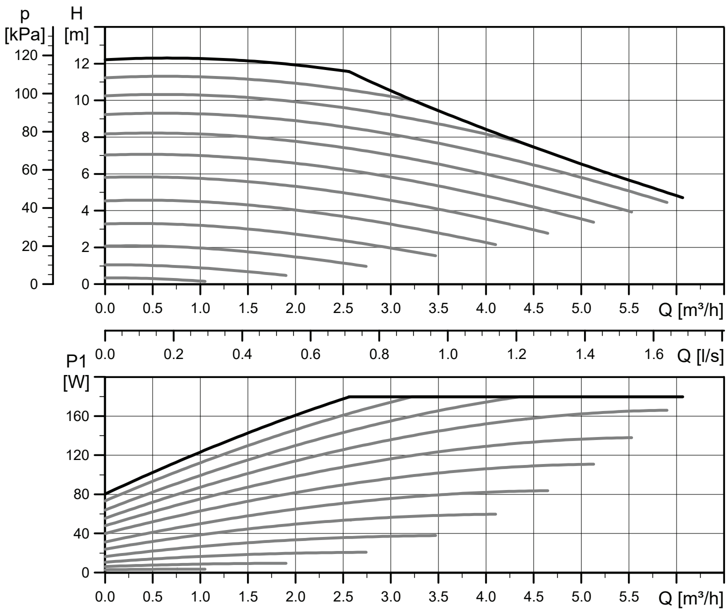


Diagram 6. Performance characteristics of the UPMXL GEO 25-125 130 PWM circulating pump

As shown above, values of heating, cooling, electrical, and COP depend on temperatures of the upper and lower sources. These parameters change to a larger extent particularly in units operating in the air/water system, which results from the large temperature span of the lower source.

Table 5. Basic technical data concerning the Airmax^2 heat pump

technical specification		unit	Airmax^2							
			6 GT	9 GT	12 GT	15 GT	16 GT	21 GT	26 GT	30 GT
Catalogue No.		-	09-260600	09-260900	09-261200	09-261500	09-261600	09-262100	09-262600	09-263000
heating power	(A7W35)[1]	kW	6,17	8,11	11,00	13,93	15,55	20,98	26,01	29,82
COP		-	4,37	4,61	4,72	4,61	4,70	4,58	4,61	4,65
electric power		kW	1,41	1,76	2,33	3,02	3,31	4,59	5,64	6,41
heating power	(A2W35)[1]	kW	4,63	6,09	8,31	10,07	11,25	15,03	18,75	21,42
COP		-	3,28	3,44	3,58	3,55	3,55	3,46	3,51	3,52
electric power		kW	1,71	1,77	2,32	2,84	3,17	4,34	5,34	6,09
heating power	(A7W55)[1]	kW	5,52	7,31	9,83	12,54	15,75	21,22	26,40	30,10
COP		-	2,59	2,70	2,79	2,92	3,25	3,14	3,20	3,18
electric power		kW	2,13	2,71	3,52	4,30	4,85	6,76	8,25	9,47
dimensions [H x W x D]		mm	730 x 1295 x 520		1305 x 1295 x 520		1399 x 1477 x 700	1862 x 1690 x 700		
hydraulic connections		-	1"	1"	1"	1"	1"	5/4"	5/4"	5/4"
maximum working temperature		°C	30				30			
minimum working temperature		°C	-20				-20			
maximum supply temperature		°C	57				60			
refrigerant		-	R410A				R410A			
quantity of refrigerant		kg	2,1	2,1	3,2	3,2	5,0	5,5	6,5	7,0
method of defrosting		-	reversal of circulation				reversal of circulation			
power of the electric heater		kW	7				7			
number of fans		-	1		2		2	1		
acoustic power[2]		dB	65,0	66,5	70,0	73,3	73,5	74,4	75,0	75,5
sound pressure[3]		dB	45,0	46,5	50,0	53,3	53,5	54,4	55,0	55,5
power supply voltage and frequency		V/Hz	400/50				400/50			
starting current (without a starting current limiter)		A	28	43	52	62	70	101	128	118
the approximate value of the starting current when using a limiter (soft-start)[4]		A	17	26	31	37	42	61	77	71

[1] Acc. to EN 14511.
[2] Acc. to EN 12102.
[3] Within a distance of 4 m.
[4] Soft start in Airmax^2 heat pumps - optional.

The range of possible operating temperatures is determined by the operating area of the unit. The maximum and minimum water temperatures apply to the heating circuit, i.e. at the outlet of the heat pump.

Table 6. The working range for the Airmax^2 6-15 GT heat pump

	Airmax^2 6-15 GT		Airmax^2 16-30 GT	
air temperature [°C]	maximum water temperature [°C]	minimum water temperature [°C]	maximum water temperature [°C]	minimum water temperature [°C]
-20	45	20	50	25
-10	57	20	60	25
7	57	20	60	25
30	57	35	60	35

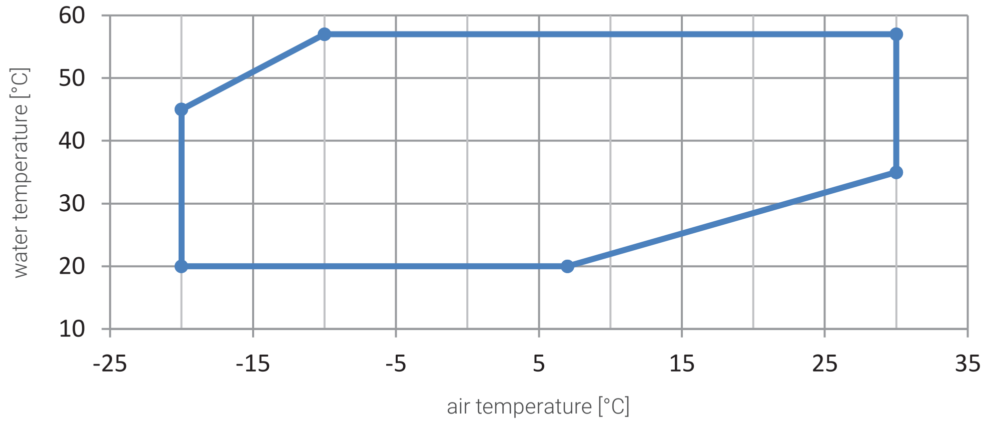


Diagram 7. The working range for the Airmax² 6-15 GT heat pump

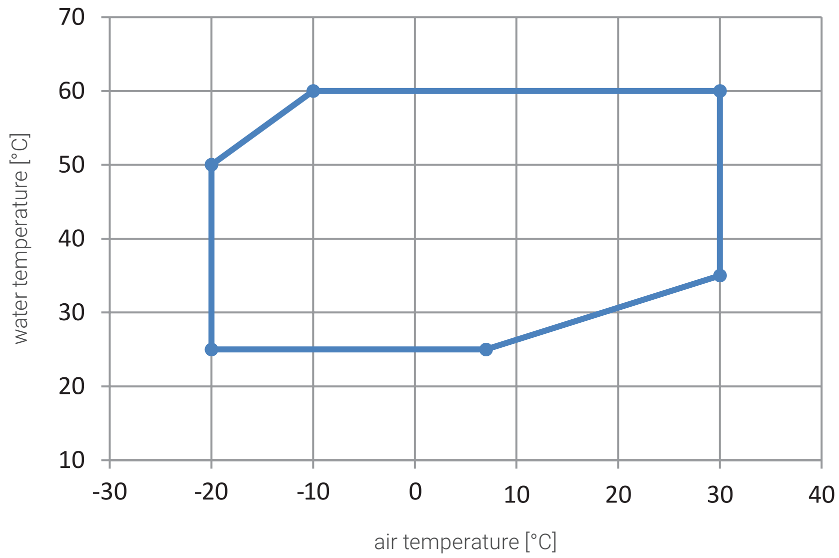


Diagram 8. The working range for the Airmax² 16-30 GT heat pump

The value of COP is an instantaneous value. The value of SCOP, i.e. the seasonal coefficient of performance of room heating, is definitely more important to the client. It is defined for a given climate and in two temperature levels W35 and W55, in accordance with the standard. W35 corresponds to the temperature of the water supplying the heating circuit of 35°C - this applies to underfloor heating, i.e. low-temperature heating. W55 corresponds to the temperature of the water supplying the heating circuit of 55°C - this applies to radiator heating. Low-temperature heating is always defined by higher efficiency ratios.

Table 7. Power supply parameters for Airmax^2 heat pumps

technical specification		unit	Airmax^2							
			6 GT	9 GT	12 GT	15 GT	16 GT	21 GT	26 GT	30 GT
SCOP[1]	moderate climate (W35)	-	3,55	3,65	3,94	4,01	4,07	3,93	3,99	4,01
η_s[2]		%	139,2	143,0	154,6	157,5	159,8	154,2	156,7	157,5
energy class		-	A+	A+	A++	A++	A++	A++	A++	A++
$P_{designh}$		kW	4,10	5,45	7,45	9,30	10,58	14,12	17,58	19,79
SCOP[1]	moderate climate (W55)	-	2,84	2,96	3,07	3,09	3,13	3,04	3,12	3,13
η_s[2]		%	110,8	115,5	119,6	120,6	122,4	118,8	121,7	122,3
energy class		-	A+	A+	A+	A+	A+	A+	A+	A+
$P_{designh}$		kW	3,89	5,40	7,18	9,10	10,86	14,49	18,20	20,18
$P_{designh}$	cool climate (W35)	kW	5,41	7,16	9,79	12,39	12,36	15,58	19,17	24,99
	cool climate (W55)	kW	5,00	6,87	9,22	11,81	13,29	15,13	21,19	23,53
	warm climate (W35)	kW	4,63	6,09	8,31	10,58	10,70	14,27	17,80	20,30
	warm climate (W55)	kW	4,43	6,01	8,07	10,14	11,05	14,63	18,30	20,40

[1] Acc. to EN 14825.
[2] Seasonal space heating efficiency.

Table 8. Other installation information - Airmax^2

technical specification		Airmax^2				Airmax^2			
		6 GT	9 GT	12 GT	15 GT	16 GT	21 GT	26 GT	30 GT
electrical safety device		C20	C25	C25	C32	C32	C32	C40	C40
power supply cable	type	5 x 4 mm^2						5 x 6 mm^2	
	length	3,5 running metres							
control panel cable	type	4 x 0,5 mm^2							
	length[1]	5 running metres							
temp. sensor (buffer, tank for domestic hot water)	type	2 x 0,5 mm^2							
	length[2]	5 running metres							
temperature sensor (heating circuits)	type	2 x 0,5 mm^2							
	length[2]	2 running metres							
conduit (three-way switching valve for domestic hot water)	type	4 x 1 mm^2							
	length	5 running metres							
Circulating pumps (heating circuits, circulating, plate heat exchanger-buffer)	type	3 x 1,5 mm^2 (additional circulating pumps to be connected via contactors)							
international protection marking		IP24							
hydraulic connections[3]		1" brass					5/4" brass		

[1] The cable can be extended up to 30 m.
[2] The cable can be extended up to 15 m.
[3] Do not reduce the inner diameter of the pipe, as this will cause resistance of flow.

3.2.4. Performance data for Galmet heat pumps - Airmax^2

Each unit in a given series of types has their dedicated performance characteristics. The W35 characteristics is suitable for low-temperature applications (underfloor heating). The W55 characteristics is suitable for high-temperature applications (radiator heating). 35, 45, and 55 correspond to the values of water temperature (°C) at the outlet of the heat pump. When analysing the diagrams below, you will see a difference in the characteristics regarding a standard scroll compressor and a compressor with the EVI technology. At lower air temperatures, EVI makes it possible to obtain more heating power for higher parameters of feed water.

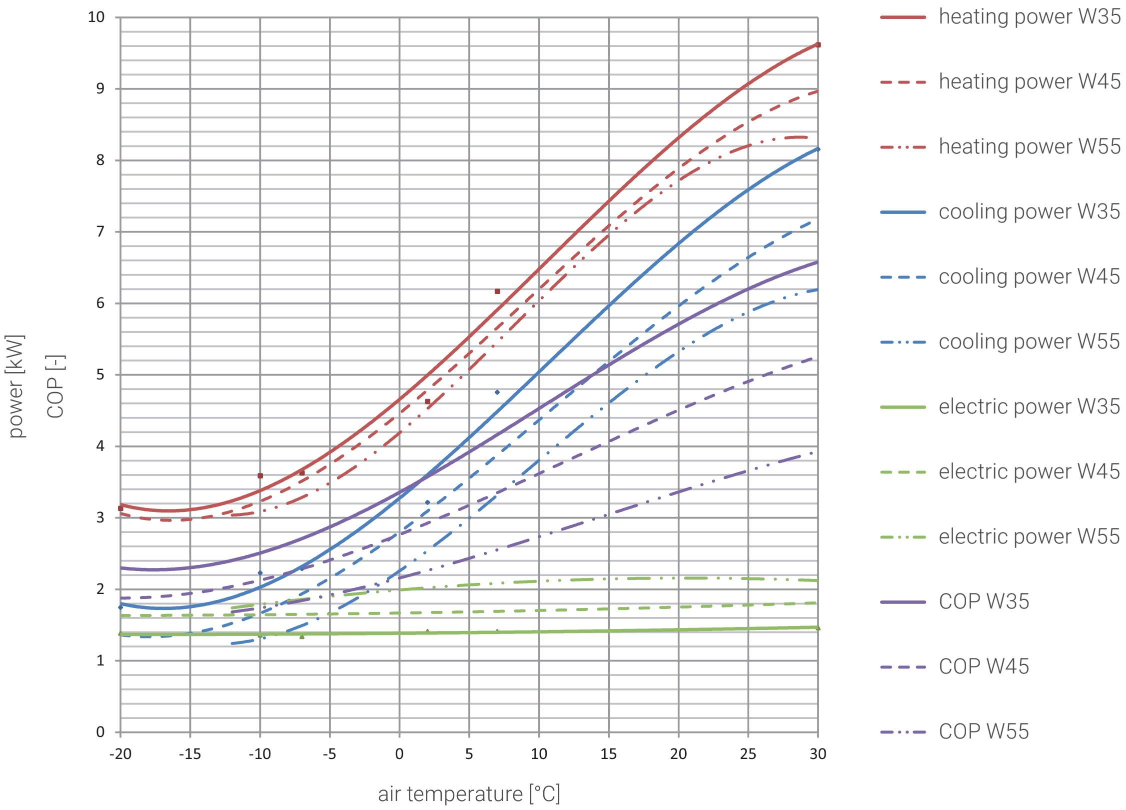


Diagram 9. Performance data for Airmax² 6 GT

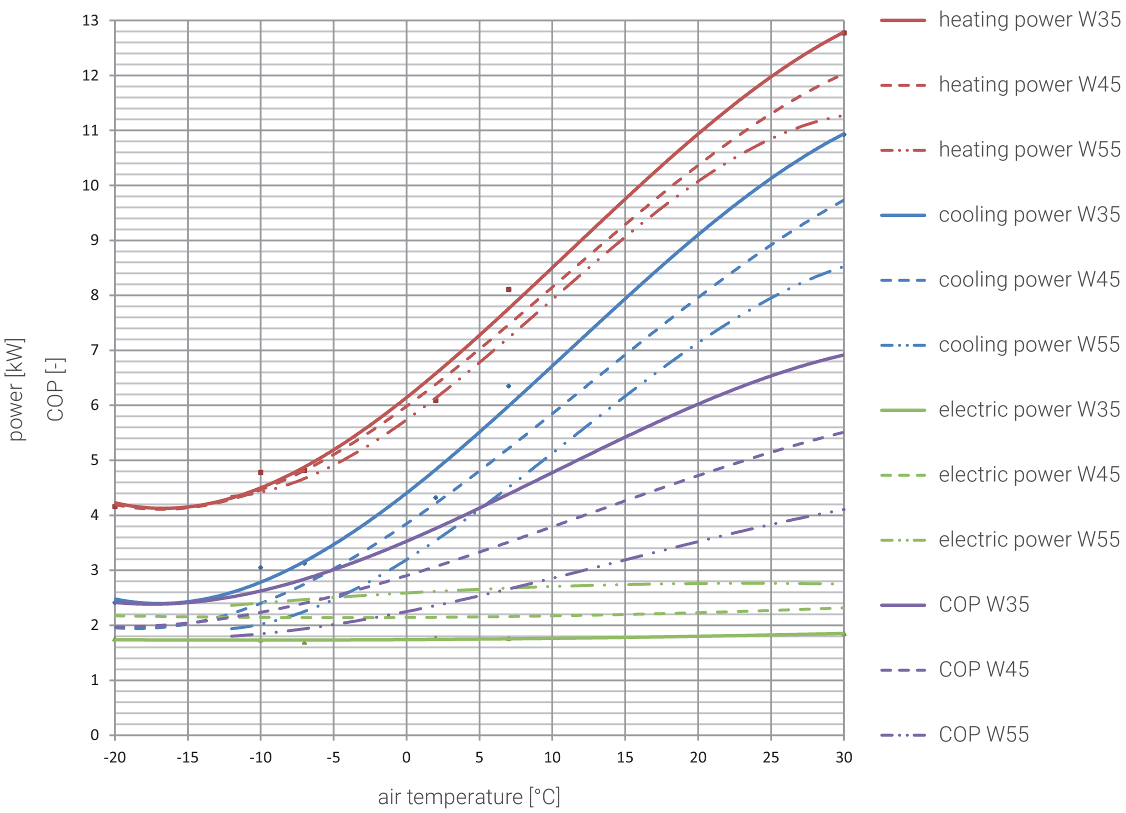


Diagram 10. Performance data for Airmax² 9 GT

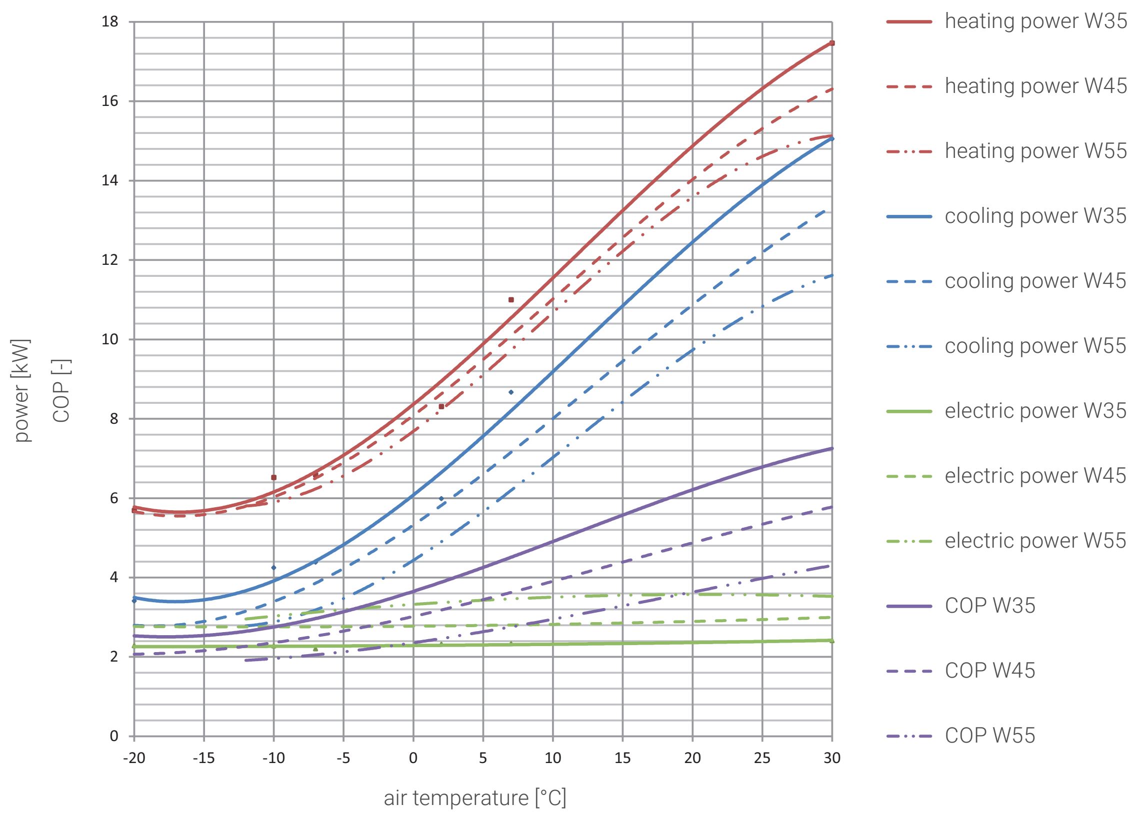


Diagram 11. Performance data for Airmax² 12 GT

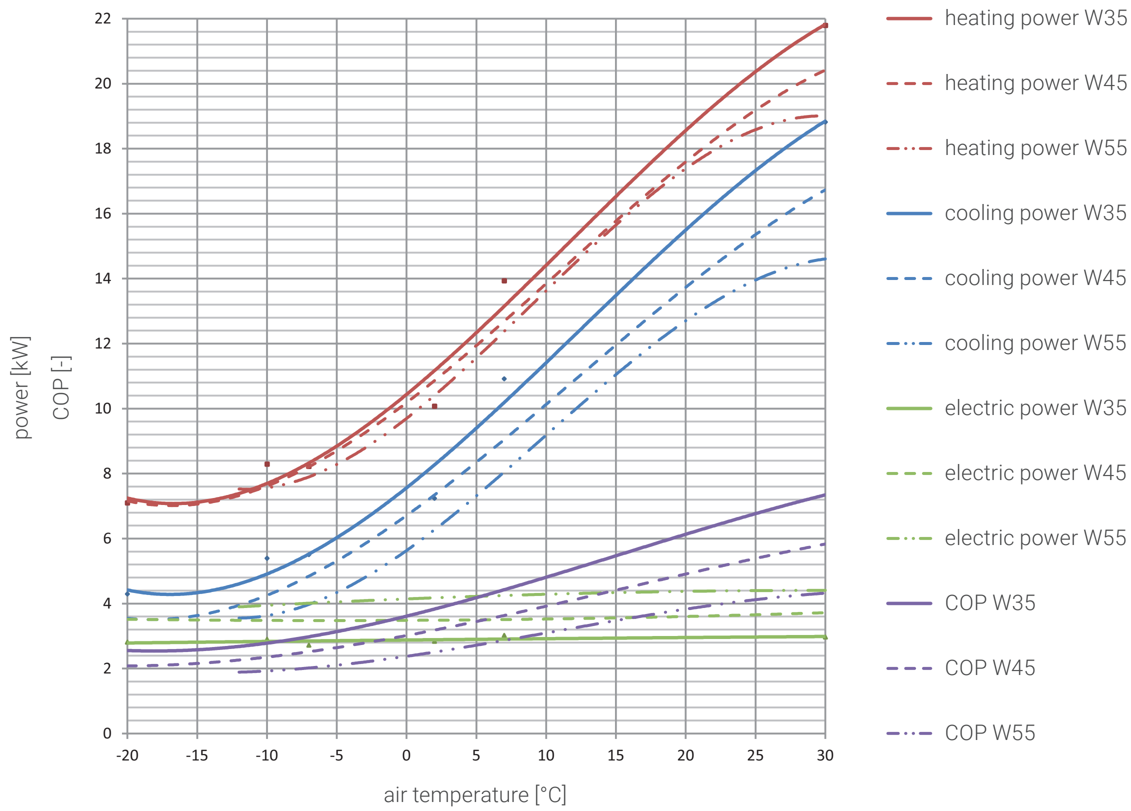


Diagram 12. Performance data for Airmax² 15 GT

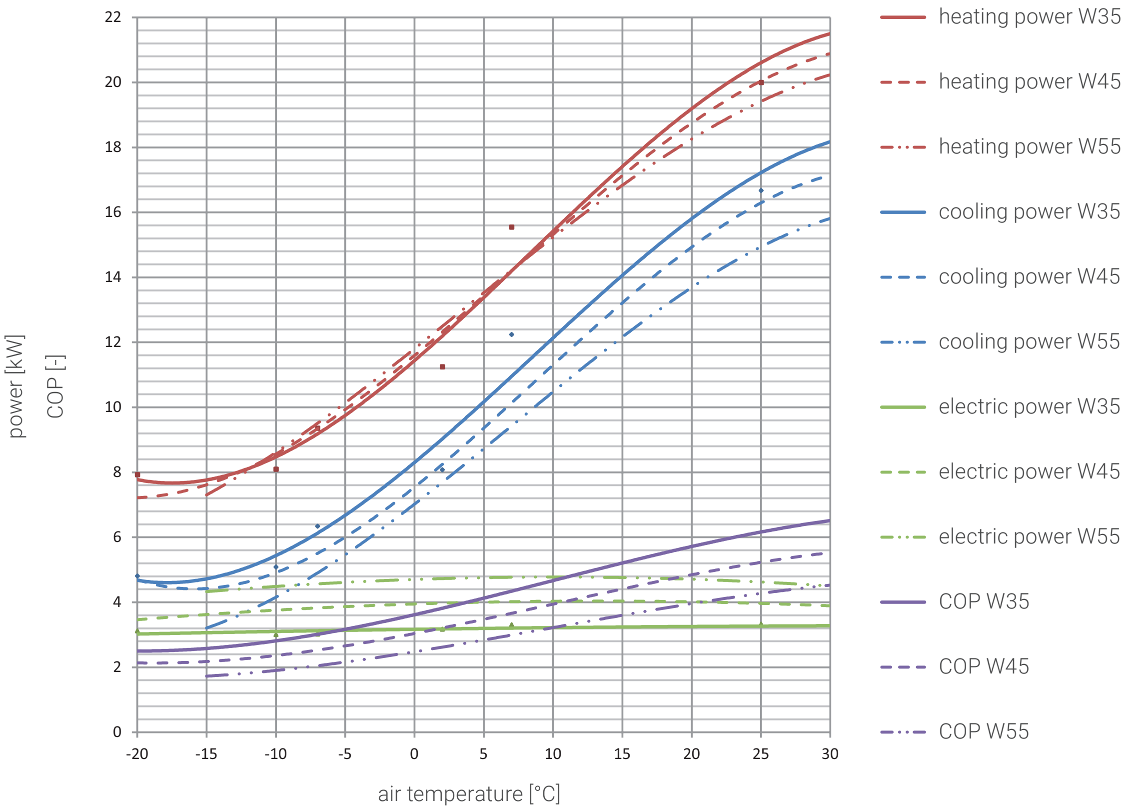


Diagram 13. Performance data for Airmax² 16 GT

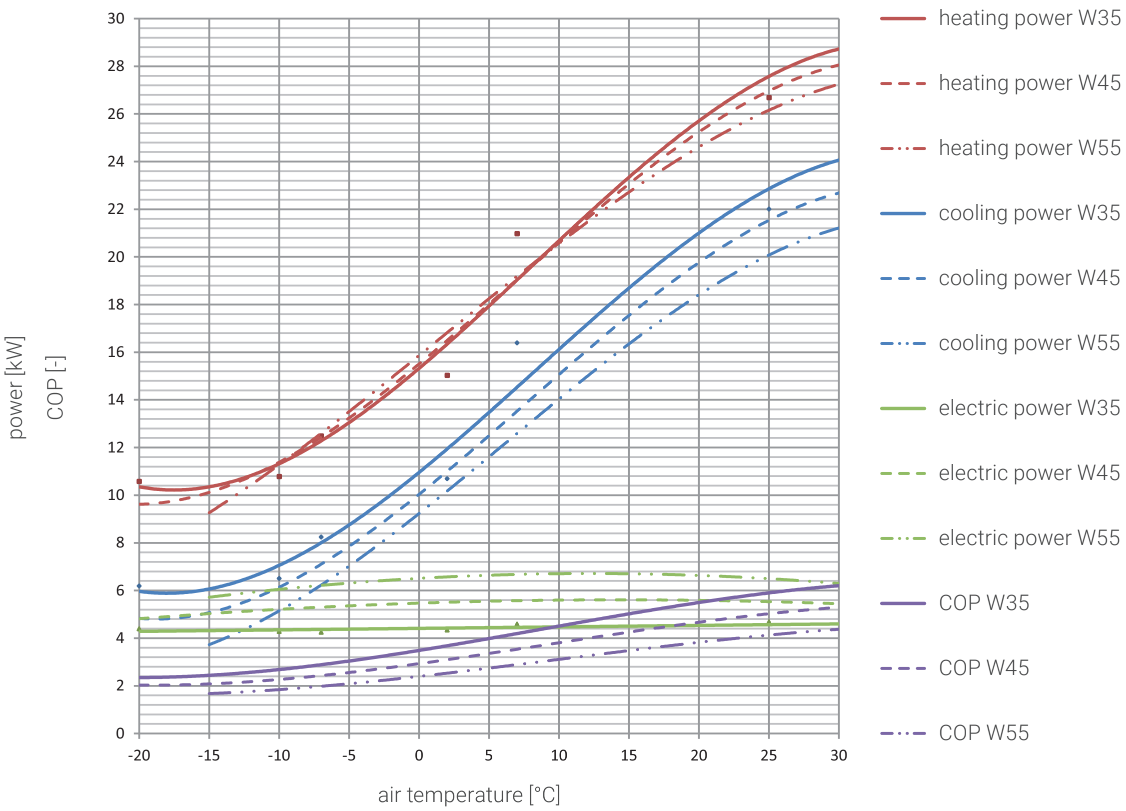


Diagram 14. Performance data for Airmax² 21 GT

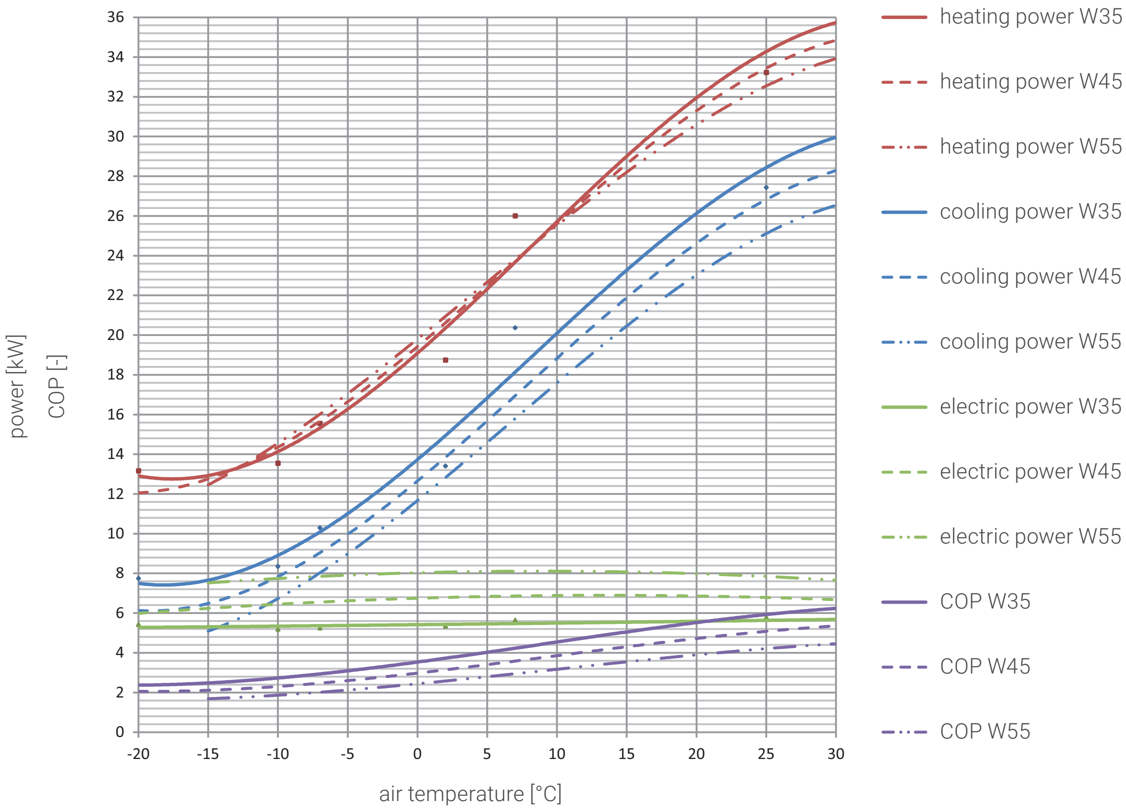


Diagram 15. Performance data for Airmax² 26 GT

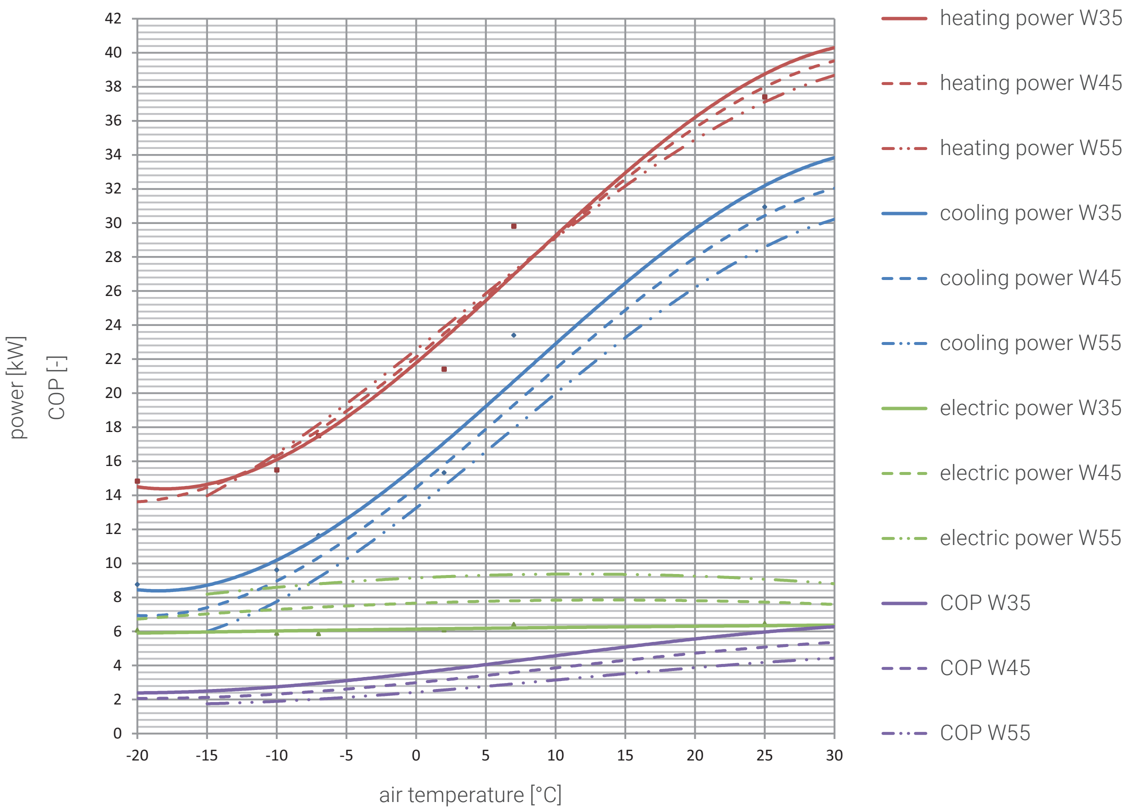


Diagram 16. Performance data for Airmax² 30 GT

3.3. Air/water heat pumps for DHW

We can distinguish between heat pumps integrated with a tank (a heater with a heat pump), and heat pumps connected to an independent tank.

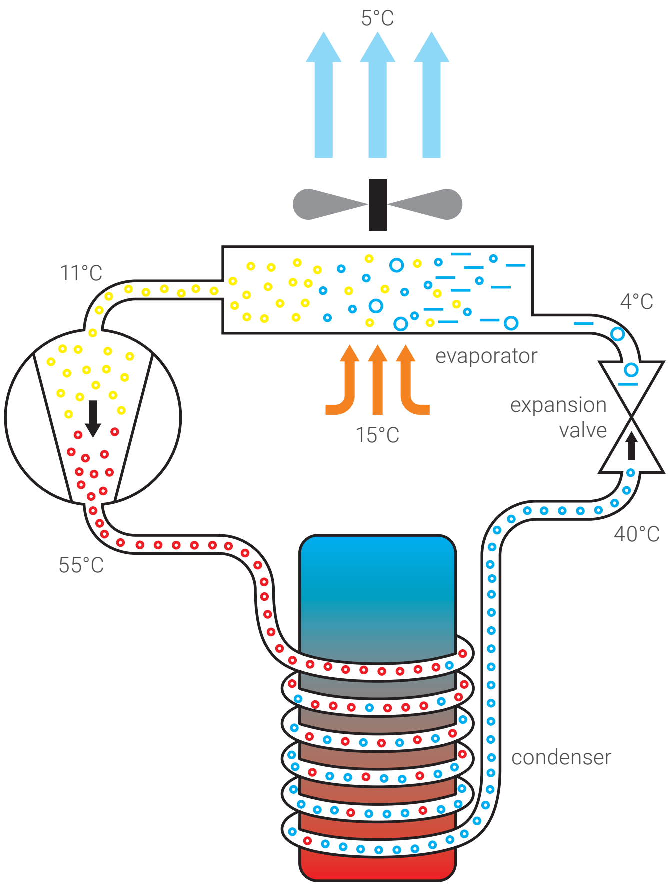
The advantages of air/water heat pumps for domestic hot water include:

- easy in operation
- the possibility of working indoors
- the possibility of using a heat pump to dehumidify the air and for partial air-conditioning of a room
- maintenance-free
- the possibility of connecting an additional source (a boiler for central heating, a solar panel). By connecting a boiler for central heating with a heat pump for domestic hot water, we will have hot water in the summer without firing up the boiler.

3.3.1. Principle of operation

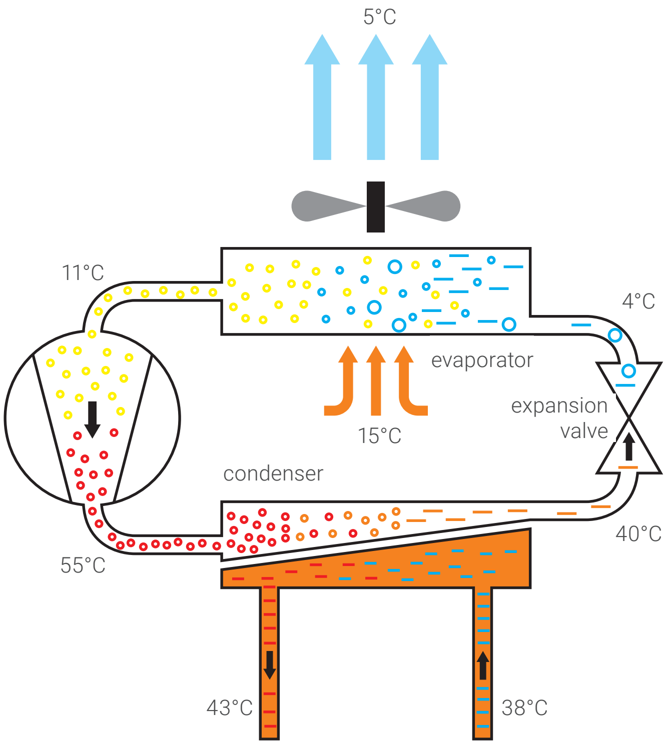
The evaporator installed in an air/water heat pump is a fin exchanger. It is used to evaporate the medium. The evaporated heat is taken from the air. A fan forces air flow through the heat exchanger. The noise generated by air heat pumps results mainly from the noise generated by air circulation. The compressor's operating volume is low, comparable to that of a refrigerator. Circulation of the thermodynamic medium and the side of the lower source are similar to those of the Airmax^2 model or any other air/water heat pump. Heat is dissipated by way of the condenser of the heat pump, after the evaporated medium has been compressed by the compressor. After expanding, the medium is returned to the evaporator, and the process is repeated.

In the case of heaters with a heat pump (the Basic and Spectra models), their built-in condenser has a special design. It is an aluminium pipe wound around the tank, which transfers heat to drinkable water through the wall of the tank.



Pic. 22. The design and principle of operation of the heater with a heat pump

In the case of a heat pump for domestic hot water not integrated with a tank (the Small model), it has a built-in condenser in the form of a plate heat exchanger. In this heat exchanger, heat is dissipated to water by the thermodynamic medium. The flow is forced by a circulating pump installed in the system (separated from the unit). The heat pump can be connected directly to a utility water system or to the coil pipe. The selected variant of connection determines the type of a circulating pump to be installed. If connected directly, the circulating pump pumps utility water, which means that it requires hygienic certification. If connecting by way of a coil pipe, the circulating pump forces water circulation in a closed circuit, between the plate heat exchanger of the heat pump and the coil pipe of the tank (it is recommended to use water of low hardness). The value of pressure in a closed circuit should be 0.5-1.0bar. In this case, standard circulating pumps for boiler water are used. The circulating pump is controlled by way of the heat pump's controller.



Pic. 23. The design and principle of operation of the Small heat pump

3.3.2. Technical description of a heat pump for DHW with a tank - Spectra, Basic

Pic. 24. The Basic 200 heat pump

Performance characteristics of the Basic heat pump types of series:

- The highest energy efficiency class: A+ (Basic 200), A (Basic 270 and Basic 300).
- Capacity of the heater: 200, 270, and 300l.
- Compact dimensions.
- COP value: now up to 3,49 (A15W10-55).
- Water is heated up to 55°C.
- Additional spiral coil pipes to connect external sources.
- A controller with the ECO, ANTILEGIONELLA, PARTY function, and the possibility of working with an additional source: e.g. a solar system or a boiler for central heating.
- The possibility of setting an operating schedule for both a heat pump and a circulating pump.
- Drying and partial air-conditioning of the room during operation.
- Low energy consumption - only 402W (for Basic 200).
- A defrosting system and the operating range of up to -7°C (for Basic 300)
- Natural energy - eligible for funding.

The unit comes with the following standard accessories:

- DIELECTRIC PROTECTION® - anti-corrosion protection prolonging the life of the tank.
- A 2 kW electric heater for heating water during periods of increased energy demand.
- A complete set of temperature sensors.

The following optional elements are available:

- A sensor to control the solar circuit.
- Dedicated ventilation elements are available.

Pic. 25. The Spectra heat pump

Performance characteristics of the Spectra and Spectra Smart heat pumps:

- The highest energy efficiency class: A+.
- High efficiency, COP is 3,52 at (A20/W10-55) and 3,49 at (A15/W10-55).
- SQUARE Jacket Design® - unique and elegant shape of the housing.
- Tank capacity 200L, which provides domestic hot water for a family of 4-5 people.
- Water heated up to 55°C.
- A spiral coil pipes makes it possible to work with a boiler for central heating or solar collectors.
- A controller with a colour touch panel.
- The possibility of setting an operating schedule for a heat pump and a circulating pump.
- Low energy consumption - only 450W.
- Drying and partial air-conditioning of the room, when the unit is operating.

The Spectra Smart model features the following standard functions:

- Simple control - a controller with a colour touch panel and an intuitive "tile" menu.
- Convenient in use - an active titanium anode managed by the heat pump's controller
- Cost-effective - the ECO mode guarantees the most efficient operation of the pump.
- Comfort - the TURBO mode ensures express water heating.
- Safety - the HOLIDAY mode protects the heat pump during standby.

The unit comes with the following standard accessories:

- DIELECTRIC PROTECTION® - anti-corrosion protection prolonging the life of the tank.
- A 2 kW electric heater for heating water during periods of increased energy demand.
- A complete set of temperature sensors.

The following optional elements are available:

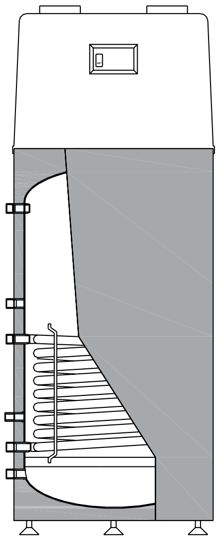
- A sensor to control the solar circuit.
- Dedicated ventilation elements are available.

The Spectra and Basic models are heat pumps designed to supply domestic hot water. They can operate using outdoor or indoor air, although they are intended for indoor installation. When working using recirculated air from a room, it is necessary to ensure adequate ventilation and the minimum cubic volume of the room equal to 30m3. Additionally, remember to keep the required distance of 1.5m between the air inlet and outlet (use an elbow to separate both stream in the most convenient way). When in operation, the heat pump cools down the air and at the same time dehumidifies it, by condensing moisture content in the air. Therefore, it is possible to direct the cooled air to any room, in order to partially cool it down. Please note that the cooling effect occurs only when the unit is in operation, i.e. when heating up water. Use ventilating ducts, if the heat pump works using the outside air, or when air is taken or discharged to the adjacent room. Air ducts should not exceed 5m along a straight line at the inlet and outlet, while each elbow causes additional local resistance (deducting 2m from the available length). Galmet offers ventilating elements (made of galvanized sheet metal), which can be used when installing heat pumps. See below for examples of installed configurations. The range of operating temperatures for these units is from 7°C to 35°C (-7°C to 35°C for Basic 300), which means that they need to be supported by a heater (a standard heater built in the tank) or an additional source, during the winter season, if drawing air from the outside. If integrated with a heat pump, the heater is enamelled and equipped with magnesium anodes to protect it – the anodes must be changed periodically. If using a titanium anode, perform periodic inspections of its operation. Each tank also has appropriate external insulation to reduce heat loss.

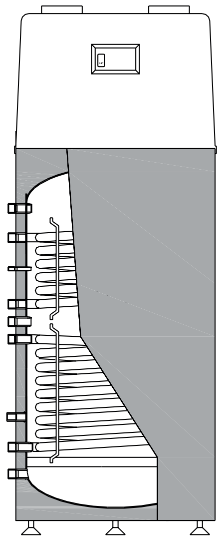
The Basic types series includes 4 units:

- Basic 200 with one additional coil pipe
- Basic 270 with one additional coil pipe
- Basic 270 with two additional coil pipes
- Basic 300 with one additional coil pipe

The Spectra model is only available in the 200l version with one additional coil pipe. The Spectra Smart version of the heat pump is also available, which features a titanium anode as a standard - it ensures maintenance-free operation.

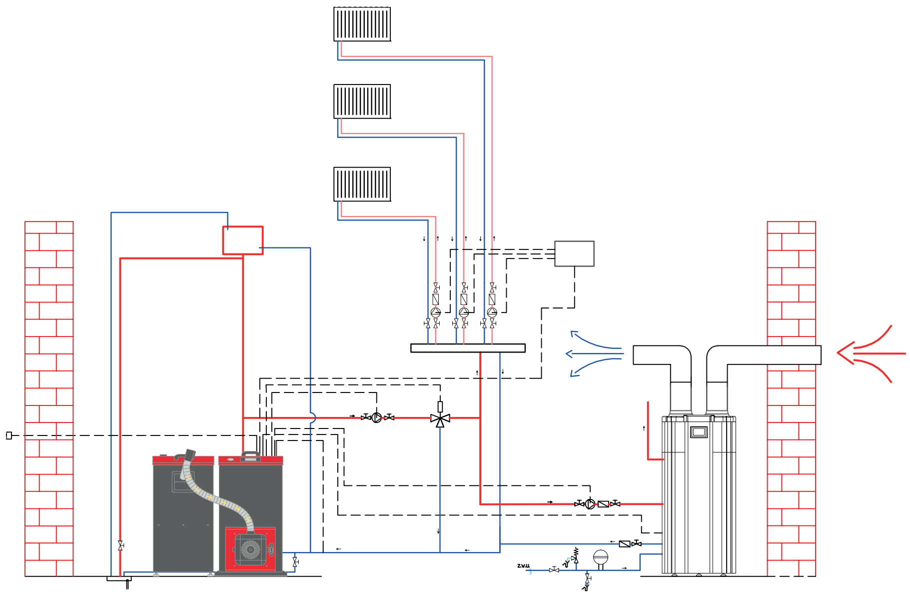


Pic. 26. A heater with one additional coil pipe



Pic. 27. A heater with two additional coil pipes

Consequently, every heater equipped with a heat pump has an additional coil pipe as a standard. A steel coil pipe is used to connect an additional source, i.e. boiler and/or a solar panel. The most common solution is to combine a heat pump (Basic, Spectra) with a boiler for central heating. In the case of a boiler system, the heat pump comes with an additional sensor, as a standard. The heat pump's controller or the boiler's controller can be used to control loading of the tank (or the external circulating pump, to be more specific), by means of the boiler for central heating. The diagram below demonstrates the latter of the two versions.

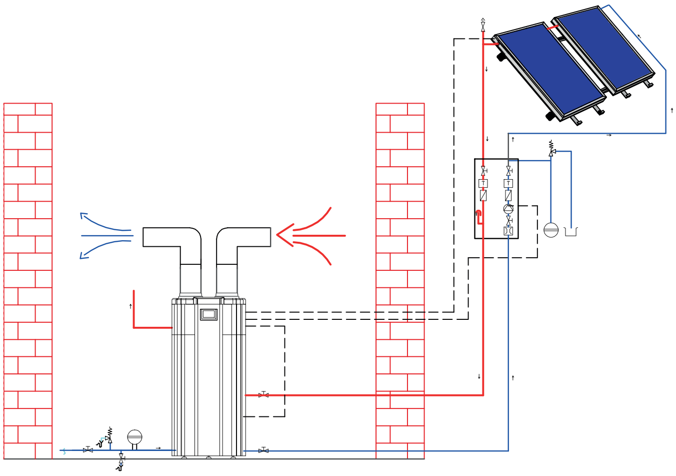


Pic. 28. The diagram for connecting the Spectra heat pump to a pellet boiler

If using a solar panel kit, it will be sufficient to purchase the PT1000 sensor (a solar sensor is not supplied with the unit, as a standard). The heat pump's controller activates the additional solar circulating pump, based on temperature reading from the sensor. In this case, it will not be necessary to purchase a solar panel kit controller, as the heat pump's controller will take over its role. However, this controller can only support one additional source, so one of the sources must be supported by external automation, when selecting a heater with two coil pipes.

The controllers used in heat pumps for domestic hot water with a tank:

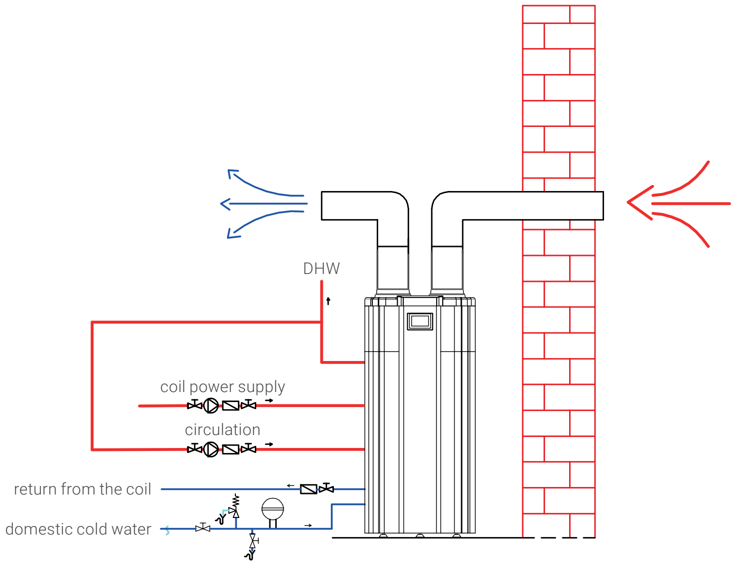
- ST 53 - a controller for the Basic and Small heat pumps
- ST 530 - a controller for the Spectra heat pumps



Pic. 29. The diagram for connecting the Spectra heat pump to solar collectors

Both controllers feature a number of additional functions, including: Anti-legionella (disinfecting superheating), Week (time schedule of heat pump operation), Party (quick water heating using all available sources), Anti-Freeze (protects the tank against water freezing).

In addition, the controllers are capable of operating the circulating pump and setting its schedule of operation. In the case of a circulating system, it is important to optimally adjust its operating cycles to reduce energy losses.



Pic. 30. Installation of a heat pump for domestic hot water with domestic hot water circulation

3.3.3. Technical data of the Spectra heat pump

The Spectra heat pump was designed using components, which guarantee high efficiency. They include a rotary compressor, a copper evaporator with aluminium fins, a thermostatic expansion valve, and a centrifugal fan. The heat pump's controller has a colour touch display, which can be operated intuitively, both by the installer and the user. As a standard, the Spectra pump is equipped with a 2kW electric heater to support operation of the heat pump during periods of increased demand for hot water, or to provide water, when the supply air has a low temperature and there is no additional source, if required. The Spectra model is only available in the 200l version with one additional coil pipe. The Spectra heat pump tank is protected with magnesium anodes.

The Spectra heat pump is also available in a Smart version (cat. no. 09-363100Q). In this version, a titanium anode is installed in the heat pump tank, ensuring full maintenance-free operation. In addition, the Smart version controller offers a tiled interface that provides even more intuitive control. This controller is also upgraded with additional functions, like Vacation and Turbo (faster one-time water heating).

Table 9. The main components of a heater with the Spectra / Spectra Smart heat pump

component	technical specification
compressor	compressor
evaporator	fin, aluminium-copper
plate	wound around the tank
expansion valve	thermostatic
centrifugal	fan
controller	ST-530
heater	copper

Heaters with a heat pump for utility water are tested, according to PN-EN 16147. The operating parameters correspond to the supply air at 15°C and 20°C, cold water at 10°C, and domestic hot water at 55°C.

Table 10. Basic data for the Spectra / Spectra Smart heat pump

technical specification	unit	Spectra / Spectra Smart
catalogue no.	-	09-363100 / 09-363100Q
average heating power	kW	2
COP[1]	-	3,49
COP[2]	-	3,52
maximum working temperature	°C	55
dimensions [H x W x D]	mm	1560 x 660 x 670
weight	kg	115
acoustic power[3]	dB	55,7
sound pressure[4]	dB	45,0
pump operating range:	°C	+7/+35
rated air flow	m^3/h	512
maximum length of air-ducts	m	10
refrigerant	-	R134a
quantity of refrigerant	kg	1,2
power consumption of the heat pump	kW	0,453
electric heater power	kW	2
total heating power (heat pump + heater)	kW	4
power supply voltage and frequency of the device	V/Hz	230/50
maximum power consumption	A	10,8
international protection marking	-	IP22
water intake profile (according to EN-16147)	-	L
maximum volume of mixed water (V_{40})[1]	l	247
reference temperature (Θ_{WH})[1]	°C	52,80
maximum volume of mixed water (V_{40})[2]	l	243
reference temperature (Θ_{WH})[2]	°C	52,73
suggested electrical protection	-	C16
connection nozzles	-	1" (3/4" – circulation)

1 EN-16147 A15W10-55
2 EN-16147 A20W10-55
3 Acc. to EN 12102.
4 Within a distance of 2 m.

To clarify: the values of maximum volume of mixed water and reference temperature are calculated by testing, according to PN-EN 16147. Water consumption starts (under specific conditions), when the pre-set temperature in the tank is set to 55°C and the tank is heated, until the temperature of the water exiting the tank is 40°C. The average temperature during water consumption is determined by the reference temperature. However, the volume of hot water intake at that time is defined as the maximum volume of mixed water.

Table 11. Tank parameters for the Spectra / Spectra Smart heat pumps

tank parameters	unit	value
material	-	steel/enamel
rated capacity of the tank	l	200
gross capacity of the tank	l	210
actual capacity of the tank	l	202
number of steel coil pipes	pcs.	1
heat exchanger surface (coil pipe)	m^2	1
heat exchanger volume (coil pipe)	l	7
maximum operating pressure of the tank	MPa	1,0
maximum operating pressure of the coil pipe	MPa	1,6
maximum operating temperature of the tank	°C	100
maximum operating temperature of the coil pipe	°C	110
heat exchanger power (70/10/45°C)	kW	33,6
capacity (70/10/45°C)	l/h	800
heat exchanger power (80/10/45°C)	kW	44,8
capacity (80/10/45°C)	l/h	1070

Table 12. Power supply parameters for Spectra / Spectra Smart heat pumps

technical specification	unit	value
η_{wh} [1]	%	142
annual energy consumption (AEC) [2]	kWh	721

[1] Seasonal efficiency of water heating
[2] Assuming an inlet air temperature of 20°C

The time required to heat the tank with the heat pump depends on the temperature of supply air and the temperature range of water heating. For example, when testing the unit, the process went as follows for a Spectra heat pump and the air temperature of 15°C:

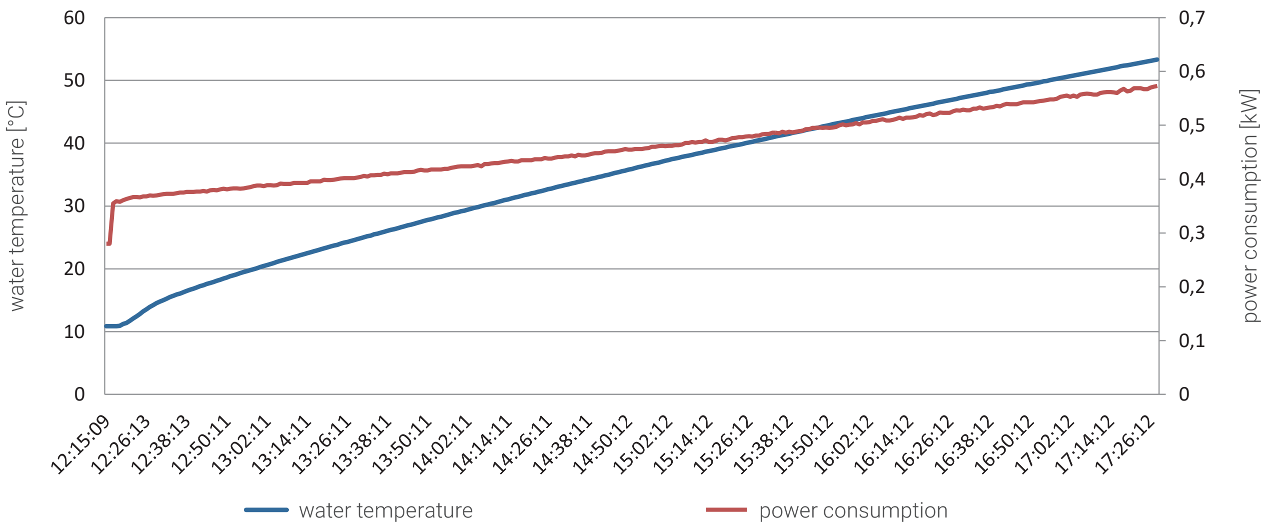


Diagram 17. The water heating cycle by a Spectra heat pump (A15 / W10-55)

In total, the heating time (at the air temperature of 15°C) was 313 minutes. The average power consumption at that time was 453W. Power consumption may vary at other operating points. The time needed to heat the water depends on the temperature of the supply air – see below for a diagram of this relationship.

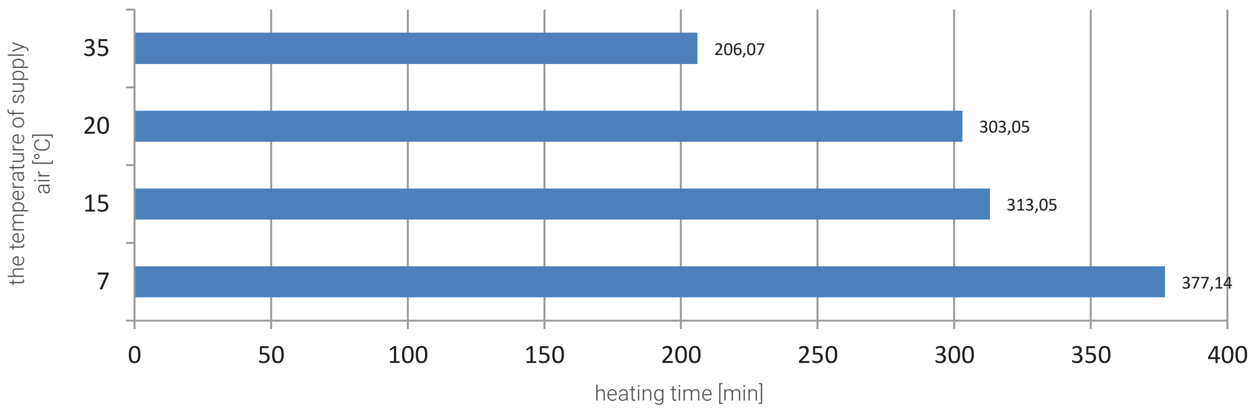


Diagram 18. Water heating times of 10-55°C at different supply air temperatures (Spectra)

It is possible to plot a curve over the entire operating range to show the relationship between the temperature of supply air and the heating time of water. In addition, the diagram below shows the changes in heating and electrical power.

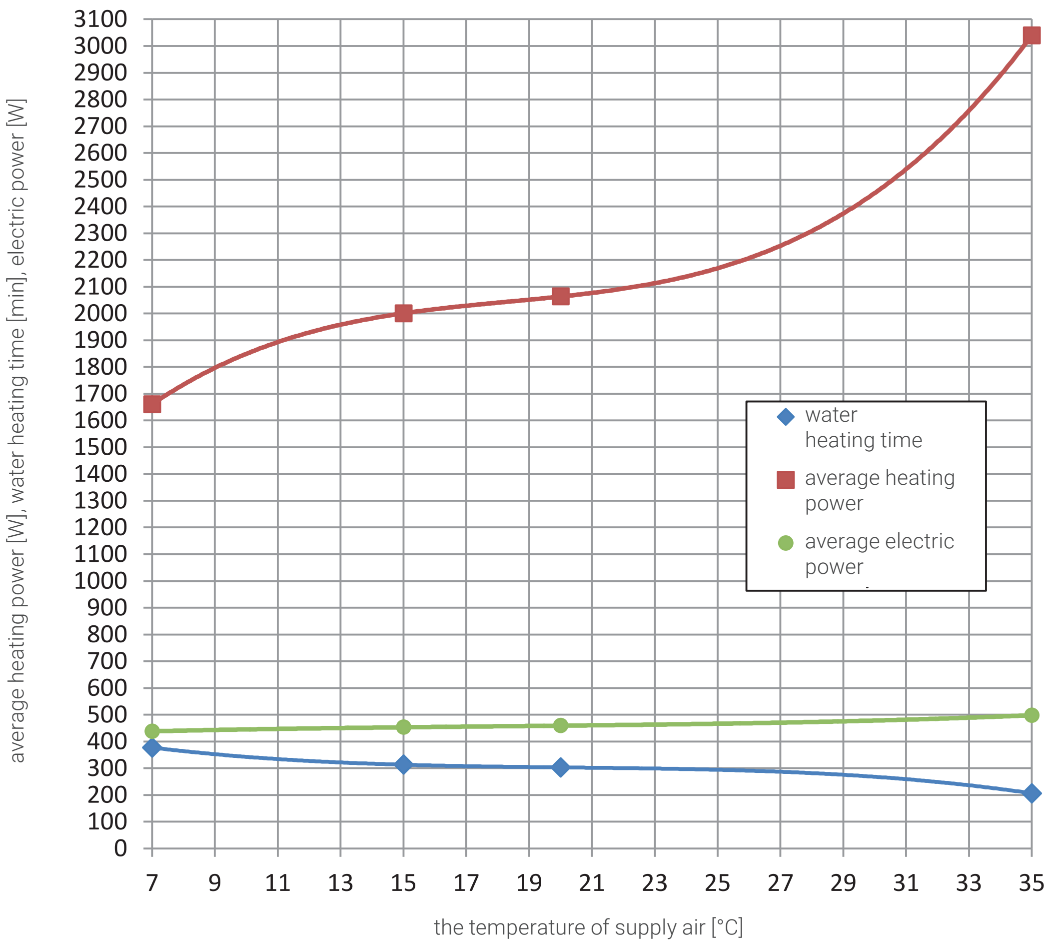


Diagram 19. Performance characteristics of the Spectra heat pump in relation to the temperature of supply air

The simplest way to demonstrate the efficiency (COP) of a heat pump is to compare the heating power with the electric power consumed at the same time. See below for changes in the efficiency of heating:

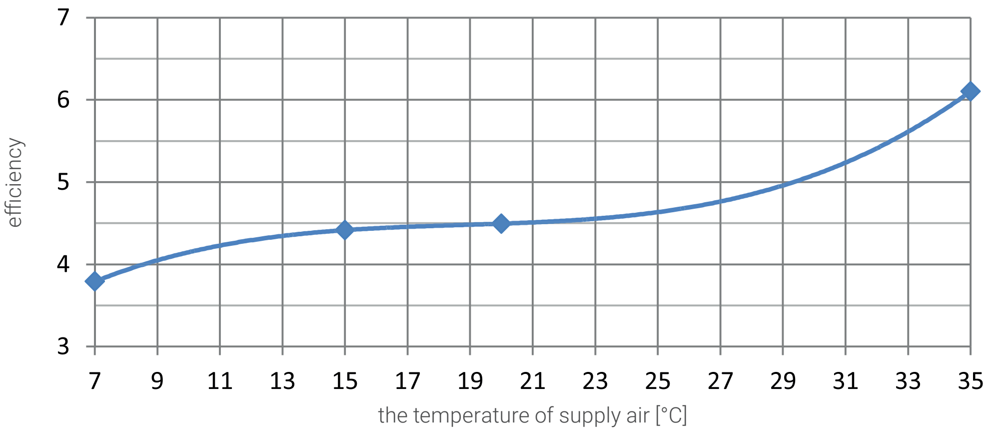


Diagram 20. The average efficiency of heating the Spectra heat pump in relation to the temperature of supply air

COP of a heat pump calculated only for the time required to heat the tank (as presented in the characteristics above) is a completely different value, than the one specified in PN-EN 16147, as it takes into account a sample daily cycle of water consumption, losses in standstill, and operating in a higher range of water temperatures. The table above shows the values compliant with the standard.

According to EN 16147, a test for the Spectra heat pump, for example at an air temperature of 15°C, goes as follows:

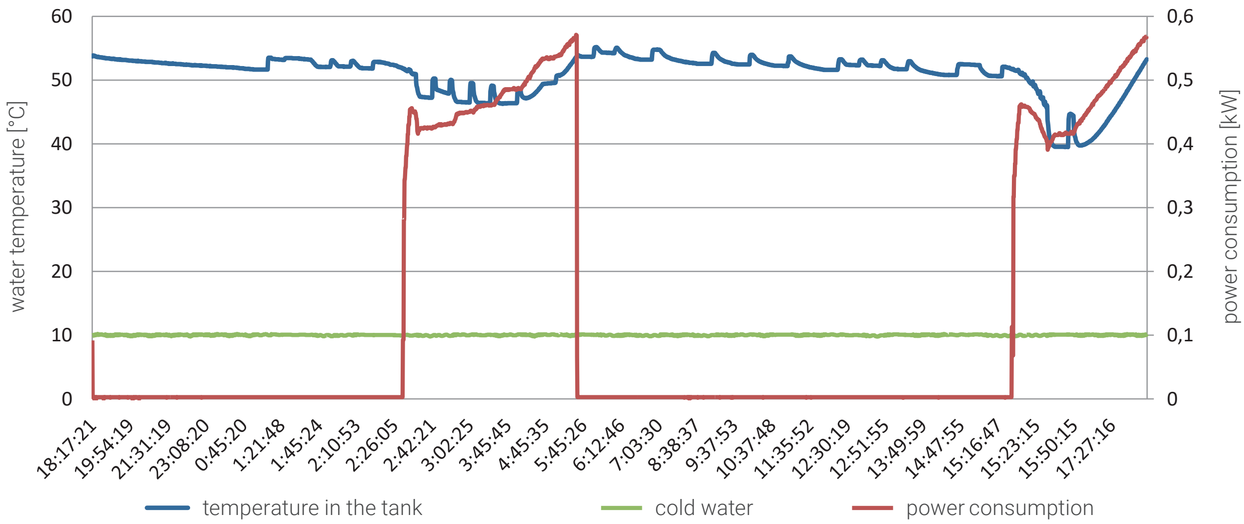


Diagram 21. Operation of the Spectra heat pump during a water consumption cycle (A15)

3.3.4. Technical data of the Basic heat pump

The Basic heat pump was designed using components, which guarantee high efficiency. They include a rotary compressor, a copper evaporator with aluminium fins, a thermostatic expansion valve, and a centrifugal fan with high compression, similarly as in all Spectra pumps. The heat pump's controller has a monochromatic display, which can be operated intuitively, both by the installer and the user. As a standard, the Basic pump is equipped with a 2kW electric heater to support operation of the heat pump during periods of increased demand for hot water, or to provide water, when the supply air has a low temperature and there is no additional source, if required. The Basic model is available in the following versions: 200l with one coil pipe, 270l with one or two coil pipes, and 300l with one coil pipe. The Basic heat pump tank is protected with magnesium anodes.

Table 13. The main components of a heater with the Basic heat pump

component	manufacturer / type
compressor	compressor
evaporator	fin, aluminium-copper
plate	wound around the tank
expansion valve	thermostatic
centrifugal	fan
controller	ST 53
heater	copper

Heaters with a heat pump for utility water are tested, according to PN-EN 16147. The operating parameters correspond to the supply air at 15°C and 20°C, and the temperature of cold water intake at 10°C and domestic hot water at 55°C.

Table 14. Basic data for the Basic heat pump

technical specification	unit	Basic 200	Basic 270		Basic 300
catalogue no.	-	09-353102	09-355102	09-355202	09-356100
average heating power	kW	2	2		2
COP (Coefficient of Performance)	-	3,49[1]	3,06[1]		2,36[1]
		3,76[2]	3,36[2]		2,69[2]
maximum working temperature	°C	55	55		55
dimensions [height x diameter]	mm	1500 x 670	1730 x 670		1900 x 670
weight	kg	120	130	150	135
acoustic power[4]	dB	57,0	56,0		62,0
sound pressure[5]	dB	46,0	45,0		51,0
pump operating range:	°C	+7/+35	+7/+35		-7/+35
rated air flow	m^3/h	365	313		328
maximum length of air-ducts	m	10	10		10
refrigerant	-	R134a	R134a		R134a
quantity of refrigerant	kg	1,2	1,2		1,2
power consumption of the heat pump	kW	0,402	0,413		0,418
electric heater power	kW	2	2		2
total heating power (heat pump + heater)	kW	4	4		4
power supply voltage and frequency of the device	V/Hz	230/50	230/50		230/50
maximum power consumption	A	10,7	10,7		10,6
international protection marking	-	IP22	IP22		IP22
water intake profile (according to EN-16147)	-	L	XL		XL
maximum volume of mixed water (V_{40})[1]	l	197	346		392
reference temperature (Θ_{WH})[1]	°C	50,27	54,68		52,50
maximum volume of mixed water (V_{40})[2]	l	199	347		392
reference temperature (Θ_{WH})[2]	°C	50,07	55,01		52,65
suggested electrical protection	-	C16	C16		C16
connection nozzles	-	1" (3/4" circulation)	1" (3/4" circulation)		1" (3/4" circulation)

[1] EN-16147 A15W10-55
[2] EN-16147 A20W10-55
[3] Acc. to EN 12102.
[4] Within a distance of 2 m.

To clarify: the values of maximum volume of mixed water and reference temperature are calculated by testing, according to PN-EN 16147. Water consumption starts (under specific conditions), when the pre-set temperature in the tank is set to 55°C and the tank is heated, until the temperature of the water exiting the tank is 40°C. The average temperature during water consumption is determined by the reference temperature. However, the volume of hot water intake at that time is defined as the maximum volume of mixed water.

Table 15. Power supply parameters for Basic heat pumps

technical specification	unit	Basic 200	Basic 270	Basic 300
η_{wh}[1]	%	151	138	112
annual energy consumption (AEC)[2]	kWh	679	1212	1499

[1] Seasonal efficiency of water heating
[2] Assuming an inlet air temperature of 20°C

Table 16. Tank parameters for Basic heat pumps

Tank parameters	unit	Basic 200 with 1 coil	Basic 270 with 1 coil	Basic 270 with 2 coils	Basic 300 with 1 coil
material	-	stal/emalia			
rated capacity of the tank	l	200	270	270	300
gross capacity of the tank	l	210	278	278	299
actual capacity of the tank	l	202	270	264	291
number of steel coil pipes	pcs.	1	1	2	1
heat exchanger surface (coil pipe)	m^2	1	1	1/0,7	1
heat exchanger volume (coil pipe)	l	7	7	7/4,9	7
maximum operating pressure of the tank	MPa	1,0			
maximum operating pressure of the coil pipe	MPa	1,6			
maximum operating temperature of the tank	°C	100			
maximum operating temperature of the coil pipe	°C	110			
heat exchanger power (70/10/45°C)	kW	24	24	24/17	24
capacity (70/10/45°C)	l/h	570	570	570/410	570
heat exchanger power (80/10/45°C)	kW	32	32	32/22	32
capacity (80/10/45°C)	l/h	760	760	760/540	760

The time required to heat the tank depends on the temperature of supply air and the temperature range of water heating. For example, when testing the unit, the process went as follows for a Basic 200 heat pump and the air temperature of 15°C:

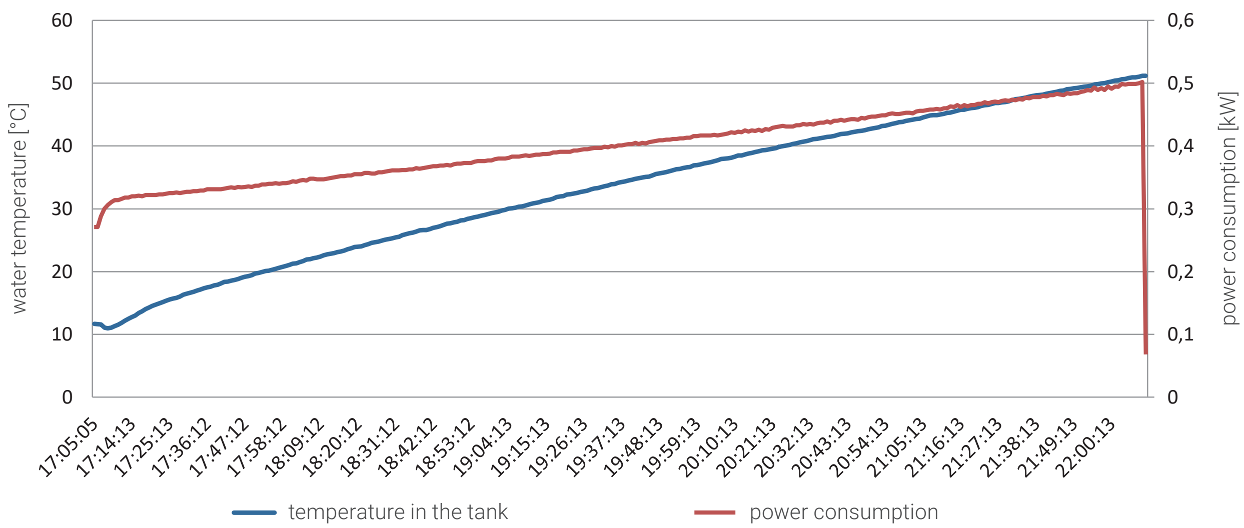


Diagram 22. The water heating cycle by the Basic 200 heat pump (A15/W10-55)

In total, the heating time (at the air temperature of 15°C) was 304 minutes. The average power consumption at that time was 402 W. Power consumption may vary at other operating points. The time needed to heat the water depends on the temperature of the supply air – see below for a diagram of this relationship.

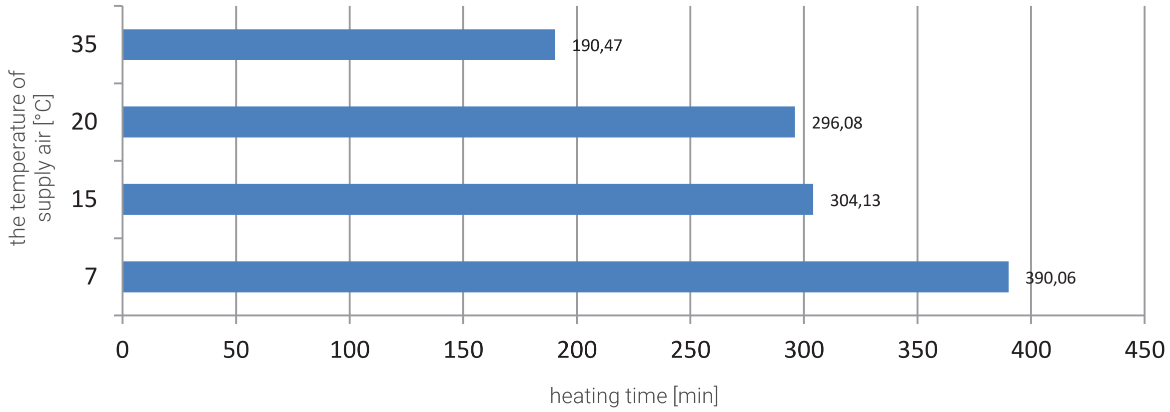


Diagram 23. Water heating times at 10-55°C for different supply air temperatures (Basic 200)

As a result, it is possible to establish the following relationship between the temperature of supply air and the water heating time. In addition, a curve showing the changes in heating and electrical power has also been plotted.

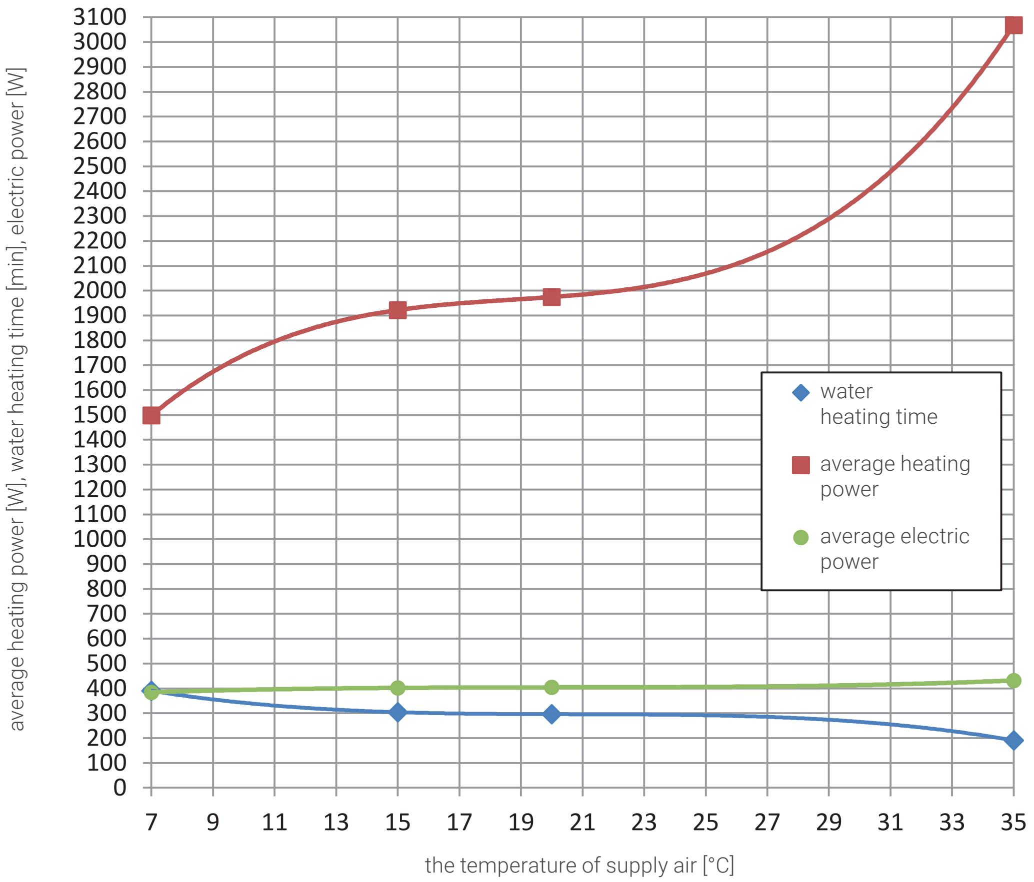


Diagram 24. Performance characteristics of the Basic 200 heat pump in relation to the temperature of supply air

The simplest way to demonstrate the efficiency (COP) of a heat pump is to compare the heating power with the electric power consumed at the same time. See below for changes in the efficiency of heating:

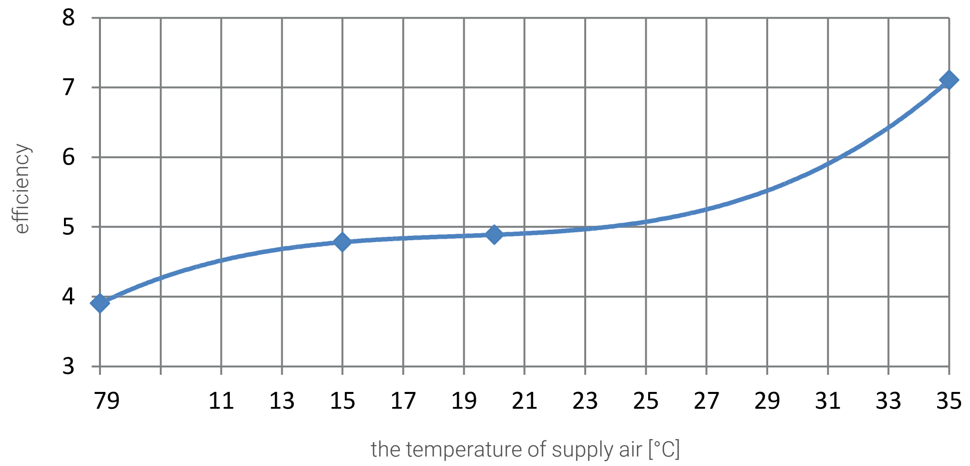


Diagram 25. The average efficiency of the Basic 200 heat pump in relation to the temperature of supply air

COP of a heat pump calculated only for the time required to heat the tank (as presented in the characteristics above) is a completely different value, than the one specified in PN-EN 16147, as it takes into account a sample daily cycle of water consumption and losses in standstill. The table above shows the values compliant with the standard. According to EN 16147, a test for the Basic 200 heat pump, for example at an air temperature of 15°C, goes as follows:

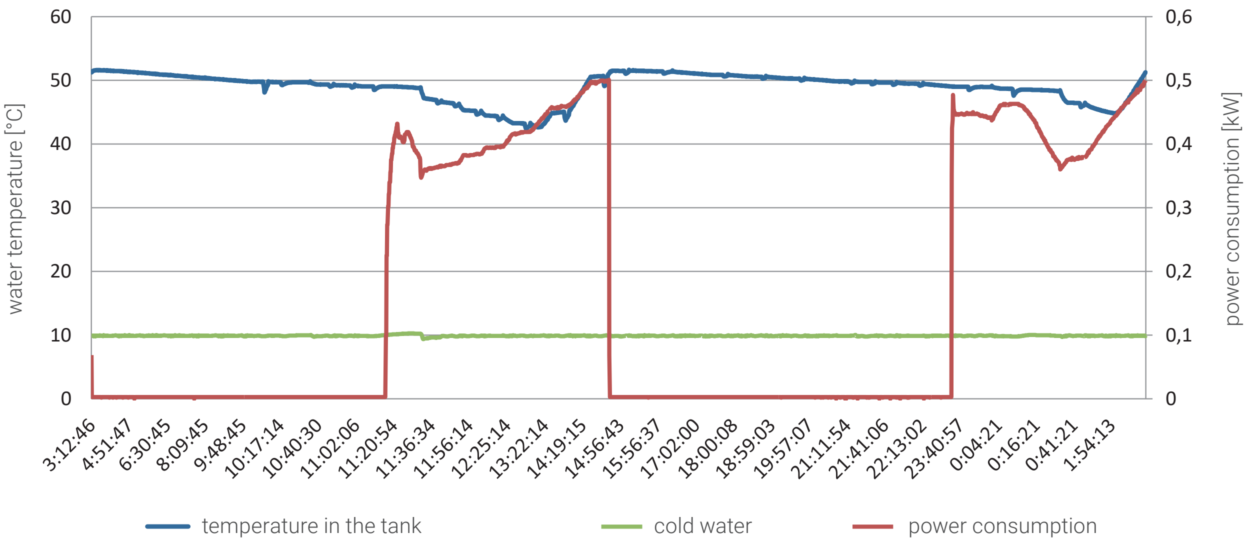


Diagram 26. Operation of the Basic 200 heat pump during a water consumption cycle (A15)

3.3.5. Technical description of a Small heat pump for DHW without a tank

Pic. 31. The Small heat pump

Performance characteristics of the Small heat pump:

- Energy efficiency class: A.
- Value of COP: 3.75 (A15W35).
- Water is heated up to 55°C.
- Low power consumption: 0,375kW.
- Possibility to connect to most of the heat exchangers of a working installation.
- Capable of working with a solar system.
- A controller with the ECO, ANTILEGIONELLA, and PARTY functions, and the possibility of working with an additional source: e.g. a solar system or a boiler for central heating.
- Supports a circulating pump of an additional source (e.g. solar panels, a boiler).
- The possibility of setting an operating schedule for both a heat pump and a circulating pump.
- Drying and partial air-conditioning of the room, when the heat pump is operating.
- Clean, natural energy - eligible for funding.

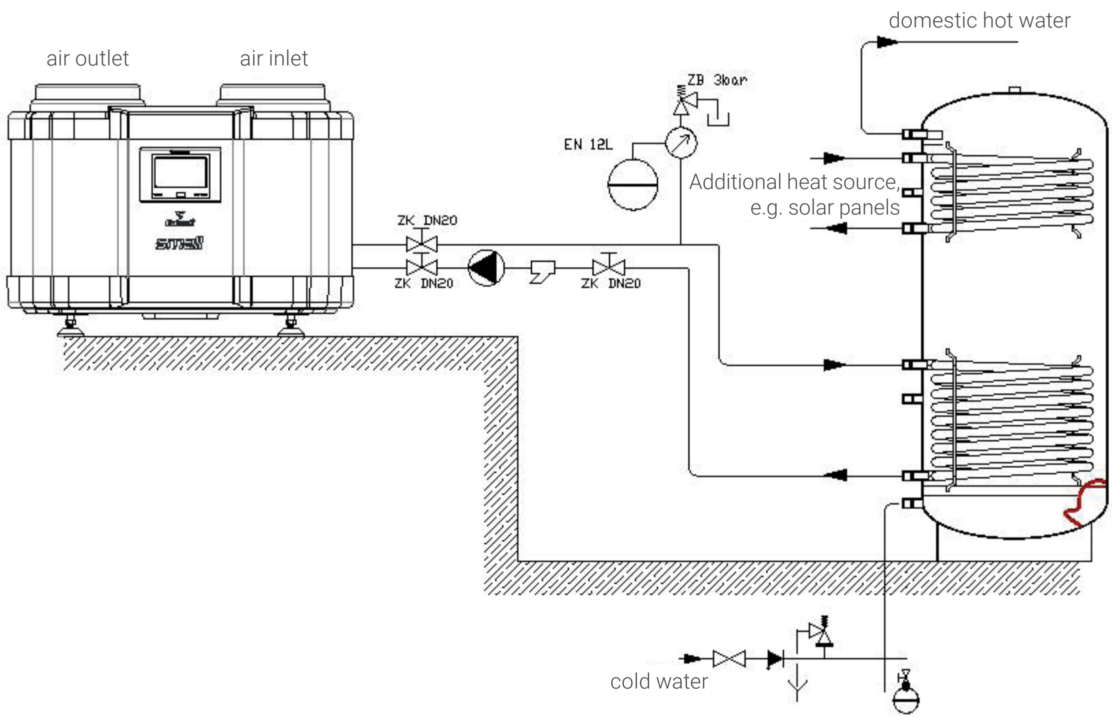
The unit comes with the following standard accessories:

- A complete set of temperature sensors.

The following optional elements are available:

- A sensor to control the solar circuit.
- Dedicated ventilation elements are available.
- Dedicated circulating pumps.

The Small heat pump is a unit designed to provide domestic hot water. It must be connected to a separate tank. The connection can be made through a coil pipe the minimum surface area of which is 1m² or directly to a utility water system (use a suitable circulating pump for this purpose). A circulating pump, which forces circulation between the unit and the tank, must be installed in the system. If the unit is connected to a coil pipe, then pressure in the system should be 0.5-1bar.



Pic. 32. Connecting a Small heat pump to the coil pipe of a SGW(S)B bivalent tank

Table 17. Dedicated circulating pumps for the Small heat pump

catalogue no.	description	purpose
09-000001	ALPHA1 L 25-40 180 circulating pump	connecting a Small heat pump to the coil pipe of a tank
09-000002	ALPHA1 N L 25-40 180 circulating pump	connecting a Small heat pump directly to a tank for utility water

These units can work with outdoor or indoor air, but they need to be installed indoors, just like Basic or Spectra models. When working using recirculated air from a room, it is necessary to ensure adequate ventilation and the minimum cubic volume of the room equal to 30m3. The distance between the inlet and outlet ducts must be at least 1.5m (use an elbow to separate both streams of air). When operating, a Small heat pump cools down and dehumidifies the air. Drying takes place by condensing moisture from the air, and condensate is drained from the pump via a condensate hose. Cooled air can be used for partial air-conditioning. Similarly as in Basic and Spectra heaters, air ducts should not exceed 5m along a straight line at the inlet and outlet, while each elbow causes additional local resistance (deducting 2m from the available length). The range of operating temperature for the Small heat pump is 7-35°C, which means that they require an additional source (a boiler) or a heater, during the winter season. The controller of the Small heat pump can control an additional tank heater (2kW) - it is an optional feature. The additional heater is installed in the tank for utility water and controlled by the controller of the heat pump. The Small heat pump features the ST 53 controller, similarly to the Basic heat pump. This controller supports an additional source (an additional pump for a boiler or a solar panel) and a circulating pump, and it also has many useful functions described in more detail in item 3.3.2. of this document. It takes 455 minutes for a 200l tank to heat up to (10-55°C) at 20°C.

3.3.6. Technical data of the Small heat pump

The Small heat pump includes a rotary compressor, a copper evaporator with aluminium fins, a thermostatic expansion valve, and a centrifugal fan. The heat pump's controller is operated intuitively, both by the installer and the user. It has a monochrome touch display.

Table 18. Main components of the Small heat pump

component	manufacturer / type
compressor	rotary
evaporator	fin, aluminium-copper
condenser	plate
expansion valve	thermostatic
centrifugal	fan
controller	ST 53

Table 19. Basic data for the Small heat pump

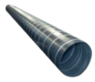
technical specification	unit	Small
catalogue no.	-	09-240201
average heating power	kW	2
COP	-	3,75 (A15/W35) [1]
		2,64 (A20/W10-55) [2]
maximum working temperature	°C	55
dimensions [H x W x D]	mm	460 x 660 x 670
weight	kg	36
acoustic power [3]	dB	61
sound pressure [4]	dB	50
pump operating range:	°C	+7/+35
rated air flow	m^3/h	261
maximum length of air-ducts	m	10
refrigerant	-	R134a
quantity of refrigerant	kg	0,5
maximum high pressure value	bar	25
maximum low pressure value	bar	11
power consumption of the heat pump	kW	0,375
power supply voltage and frequency of the device	V/Hz	230/50
maximum power consumption	A	10,5 [5]
international protection marking	-	IP22
suggested electrical protection	-	C16
connection nozzles	-	¾"

1 According to EN 14511; A - air inlet temperature; W - water outlet temperature of the heat pump.
2 According to PN-EN 16147; A - air temperature; W - temperature range of water heating; water intake profile L.
3 Acc. to EN 12102.
4 Within a distance of 2 m.
5 When connecting a 2kW electric heater to the unit.

3.3.7. Ventilation elements designed for air/water heat pumps for DHW

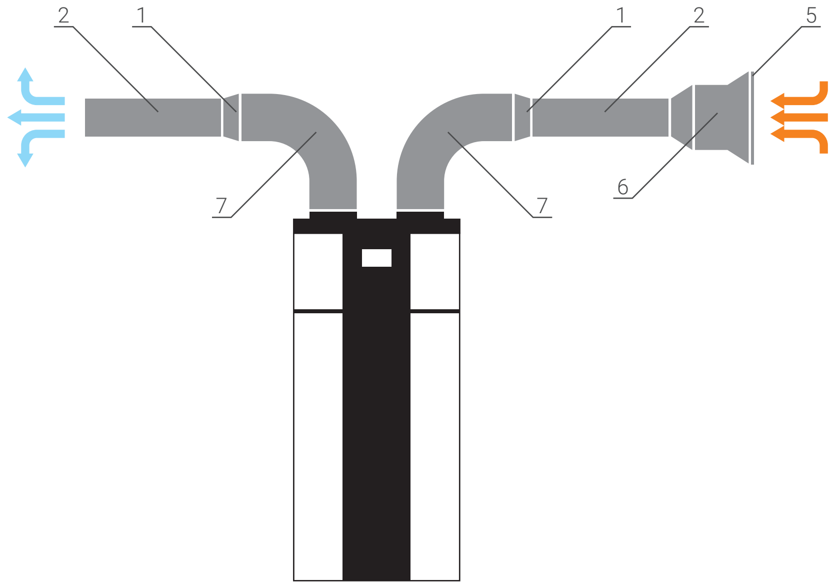
Ventilation elements are used for the drawing/discharging of air from/to another room or outside. When designing this type of solution, take into account the resistance of air flow through the particular system. It is recommended to use smooth pipes. Corrugated pipes cause increased resistance of air flow. If a heat pump uses air drawn from a room, make sure it is ventilated and has the minimum required cubic volume, which has been described in more detail earlier in this publication.

Table 20. Ventilation elements for Basic, Spectra, and Small heat pumps

Item	cat. no.	name	image	purpose
1	M-009656	reduction ø200/160 sleeve/nipple		Spectra, Small
2	M-009657	ventilation pipe ø160/160 sleeve/sleeve (pipe sold in section 1.5 running metre each)		Basic, Spectra, Small
3	M-009658	pressed elbow ø160/160 nipple/nipple		Basic, Spectra, Small
4	M-009659	t-piece ø160/160 two-sided nipple/nipple with an entry guide		Basic, Spectra, Small
5	M-009660	wall-mounted intake vent, ø250 nipple		Basic, Spectra, Small
6	M-009661	reduction ø250/160 sleeve (for intake vent)/nipple		Basic, Spectra, Small
7	M-009663	elbow ø200/200 sleeve/nipple		Spectra, Small
8	M-009664	pipe clamp ø160		Basic, Spectra, Small
9	M-009665	connector ø160/160 nipple/nipple		Basic, Spectra, Small

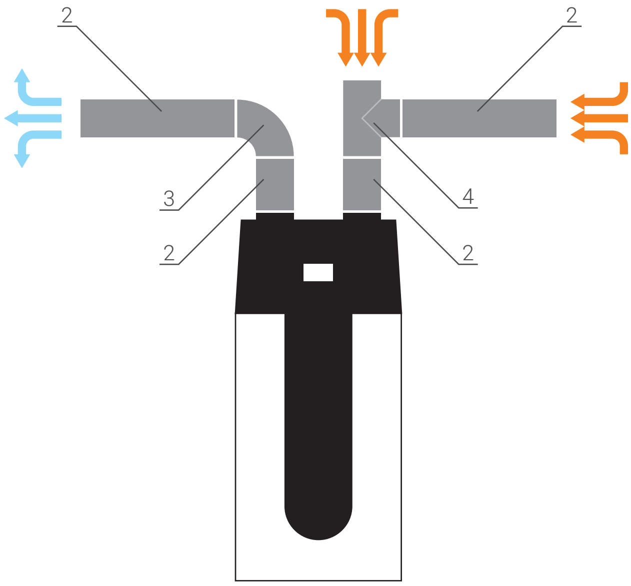
See below for sample configurations based on the aforementioned ventilation elements.

The first configuration shows the connection of a Spectra heat pump, when drawing air from the outside and discharging it to an adjacent room. The inlet has an elbow and a pipe, and, optionally, a reducing connector with an intake vent. Now, in reference to the available length of a straight duct equal to 5m: a 2m elbow, a 1.5m pipe, which in total is less than 5m, which falls within the limit. As for the outlet duct: a 2m elbow, a 1.5m pipe, which is also within the limit.



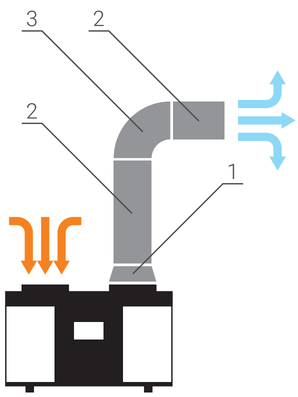
Pic. 33. An example of air duct configuration for the Spectra heat pump

Another sample configuration: a Basic heat pump, air drawn from a room or from the outside and discharged outside. Two intakes points are possible, if using a T-pipe and a damper. Additionally, a pipe and a standard elbow were used. In reference to the available length of a straight duct equal to 5m, the following elements were installed at the inlet duct: a 1.5m pipe, a 2m T-pipe, a 0.5m pipe, and at the outlet duct: a 1.5m pipe, a 2m elbow, and a 0.5m – all of which, in total, are less than 5m, which falls within the limit.



Pic. 34. An example of air duct configuration for the Basic heat pump

A sample configuration of air ducts for a Small heat pump is based on drawing air directly from a room discharging it to the outside. There are no additional elements installed at the inlet, but the outlet features the following: a reducing connector, an elbow, and two pipe sections. In reference to the available length of a straight duct equal to 5m: a 1m pipe, a 2m elbow, a 0.5m pipe, which falls within the limit, i.e. Less than 5m.



Pic. 35. A sample configuration of air ducts for the Small heat pump

4. GROUND/WATER HEAT PUMPS

Among all maintenance-free sources of heat, heat pumps operating in the ground/water system, i.e. units taking heat from the ground, are the cheapest to operate . To obtain heat from the ground, it is necessary to make a ground heat exchanger.

The advantages of ground/water heat pumps:

- a clean source of heat
- low operating costs
- a stable source of heat
- a commonly available lower source - ground
- maintenance-free
- no problems with fuel storage
- safety - any explosion or carbon monoxide poisoning not possible

The disadvantages associated with systems based on ground/water heat pumps:

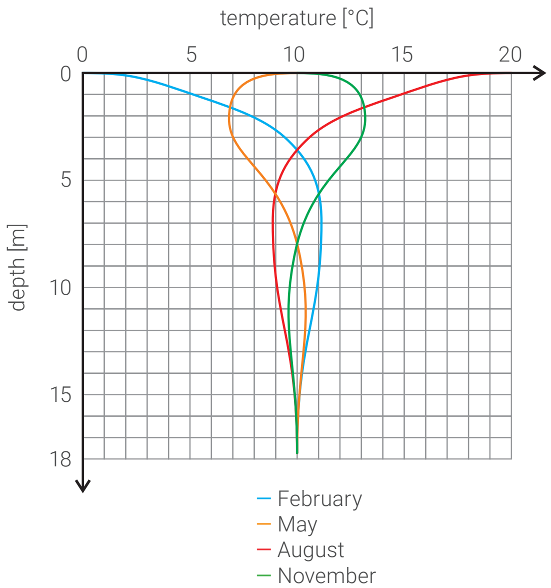
- it is necessary to make a ground heat exchanger, which increases investment costs
- there is a risk that the heat exchanger for the lower source will be made incorrectly, which will cause incorrect operation of the unit or even prevent it from operating

The model of a Galmet heat pump operating in the ground/water system offered in its product catalogue:

- Maxima - for the purposes of central heating and domestic hot water heating
- Maxima Compact - for the purposes of central heating and domestic hot water heating

4.1. Ground as the lower source

To obtain heat from the ground, it is necessary to make a ground heat exchanger in the form of vertical probes or a horizontal heat exchanger. Units operating in the ground/water system take heat from the ground by way of a transfer medium (glycol). Lower sources for ground heat pumps have been described in more detail below. The ground offers the advantage of a more stable temperature of the lower source, when compared to that of air pumps. Below a certain depth, the ground maintains a constant temperature throughout the entire year, while in the layers closer to the surface, the temperature changes (throughout the year).



Pic. 36. Changes in ground temperatures throughout the year, in relation to depth

Below the depth of 15m, the ground maintains constant temperature - at approx. 10°C. Vertical probes use mostly geothermal heat. In the case of horizontal heat exchangers, ground temperatures demonstrate significant fluctuations throughout the year. In horizontal heat exchangers, a geothermal heat flux is practically negligible, as they use heat from solar radiation. Their regeneration is supported by rainfall. Selecting a wrong ground heat exchanger may result in a low temperature of the glycol returning from the ground (which reduces the efficiency of a pump). Therefore, make a careful selection taking into account local soil conditions. If ground heat pumps are used, incorrect design of a ground heat exchanger may create a high risk of wearing out the heat source.

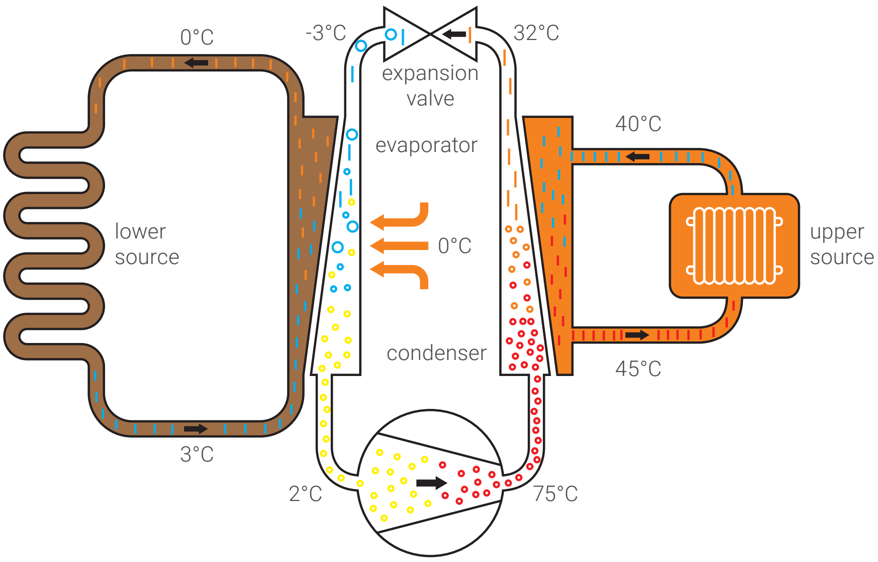
4.2. Ground-water heat pump for CH and DHW - Maxima and Maxima Compact

These are heating units providing heating and utility water, which take heat from the ground. This type of heat pumps featured in the catalogue of products by Galmet are the Maxima and Maxima Compact models.

The advantages of ground/water heat pumps for central heating and domestic hot water:

- Silent in operation
- Maintenance-free: they provide both heating and utility water
- Modern design

4.2.1. Principle of operation



Pic. 37. The principle of operation for a ground/water heat pump

The ground-water heat pump evaporator has the form of a plate heat exchanger, where the heat supplied from the ground via glycol is received. In the exchanger, the coolant evaporates. The heat for evaporation comes from the ground. The flow of glycol through the heat exchanger is forced by a circulating pump (built-in the unit - Maxima 7-16 GT and Maxima Compact 7-12 kW, or installed outside - Maxima 20-42 GT). After compression is complete, heat is dissipated in a condenser, which is a plate heat exchanger. The coolant in the condenser transfers heat to the water. Then, the medium undergoes an expansion process, after which it is again directed to the evaporator and the process is repeated. The water that has received heat from the heat pump system transports the heat to the upper source, that being the heating system or/and the domestic hot water storage tank (which can be a separate unit or built-in with heat pump, like in the Maxima Compact version).

4.2.2. Technical description of Galmet heat pumps - Maxima

The Maxima series of types consists of eight units:

- Maxima 7 GT
- Maxima 10 GT
- Maxima 12 GT
- Maxima 16 GT
- Maxima 20 GT
- Maxima 28 GT
- Maxima 34GT
- Maxima 42 GT

Pic. 38. The Maxima 7 GT-16 GT heat pump

Pic. 39. The Maxima 20 GT-42 GT heat pump

Performance data of the Maxima 7-16 GT heat pump series of types:

- Highest energy class: A++
- High COP: up to 4.5 (B0W35).
- The first Polish heat pump with the EHPA-Q certificate, operating in the ground/water system.
- The possibility to obtain co-financing in Germany - entered in the BAFA list.
- A reliable scroll compressor.
- The possibility of heating rooms, providing utility water and water for swimming pools.
- The weather system adjusts the pump operating parameters to the weather conditions.
- The possibility of setting an operating schedule for both a heat pump and a circulating pump.
- The possibility of controlling the operation of an electric heater in the tank, a circulating pump, and heating circuits.
- An electronic expansion valve for maximum efficiency.
- Consistent performance throughout the entire heating season.
- It uses Renewable Energy Sources.
- Eligible for funding.

Performance data of the Maxima 20-42 GT heat pump series of types:

- Highest energy class: A++
- High COP: up to 4.67 (B0W35).
- High supply temperature: up to 65°C (a high-temperature heat pump).
- Ideal for buildings with an increased demand for thermal energy.
- The possibility to obtain co-financing in Germany - entered in the BAFA list.
- A reliable scroll compressor with EVI.
- The possibility of heating rooms, providing utility water and water for swimming pools.
- The weather system adjusts the pump operating parameters to the weather conditions.
- The possibility of setting an operating schedule for both a heat pump and a circulating pump.
- The possibility of controlling a three-way valve for supply domestic hot water, an electric heater in the tank, a circulating pump, and heating circuits.
- An electronic expansion valve for maximum efficiency.
- Consistent performance throughout the entire heating season.
- It uses Renewable Energy Sources.
- Eligible for funding.

The unit comes with the following standard accessories:

- A complete set of temperature sensors.
- An Internet module for remote control of the device.
- Soft Start (soft start of the compressor), which ensures a longer life of the unit and quiet starting.
- Electronic circulating pumps built in the unit.
- A three-way switching valve for supplying domestic hot water, built in the unit.
- Smart control of a colour touch panel with the thermostat function.

The following optional elements are available:

- A dedicated Maximus heat exchanger with the biggest possible spiral coil pipe, a titanium anode, and a 2 kW heater.

The unit comes with the following standard accessories:

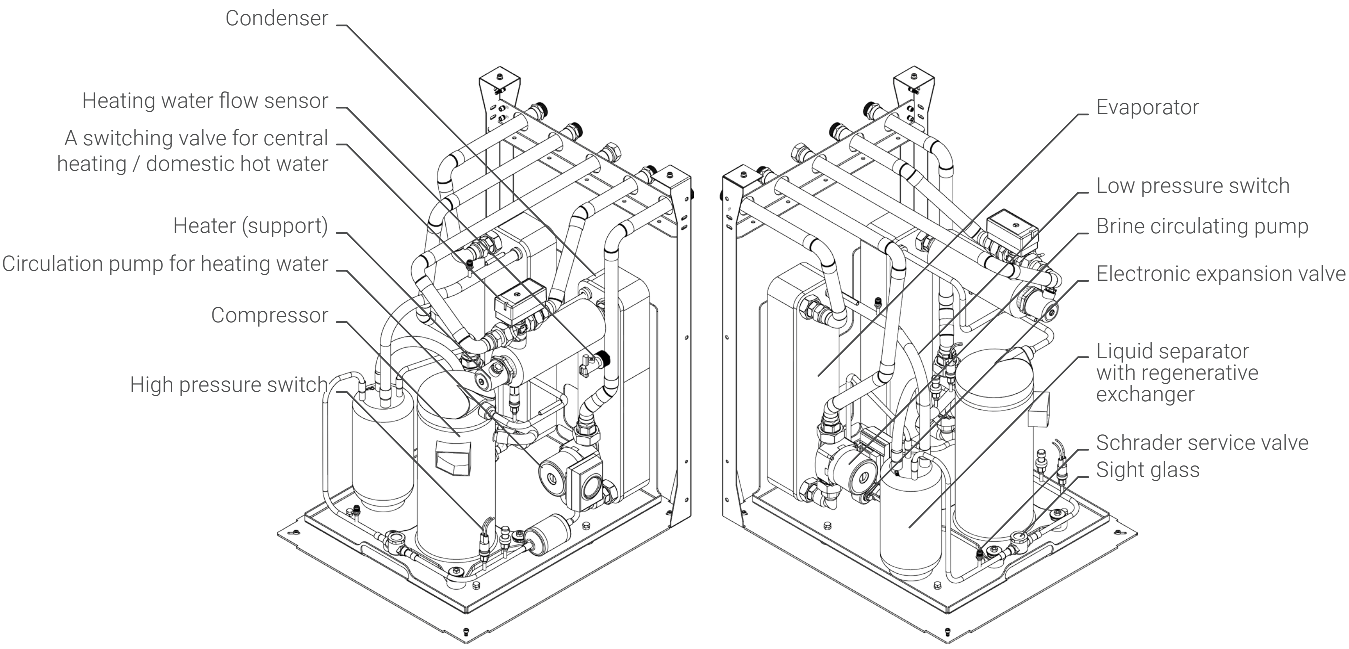
- A complete set of temperature sensors.
- An Internet module for remote control of the device.
- Soft Start (soft start of the compressor), which ensures a longer life of the unit and quiet starting.
- Electronic circulating pumps are delivered with the unit.
- Smart control of a colour touch panel with the thermostat function.

The following optional elements are available:

- The possibility of purchasing a dedicated three-way valve with an actuator for the purpose of supplying domestic hot water.

Maxima is a ground-water heat pump designed to work with a glycol ground exchanger. It has been equipped with intelligent control and high-quality components. A scroll type compressor dedicated for heat pumps was used. It ensures high performance and longevity, as well as low level of noise and vibration in operation. The Maxima 7-16 GT pump model features a standard scroll compressor, while the Maxima 20-42 GT model has a scroll compressor with EVI (vapour injection into the compressor). When using a compressor with the EVI technology, a new portion of the medium flows into the compressor, during compression. It is a portion of the liquefied medium which evaporates after passing through the additional expansion valve and the additional heat exchanger, and then it is directed to the medium pressure section of the compressor. When a fresh portion of steam is injected, the temperature of the medium in the compressor goes down, while maintaining the already obtained pressure. This way, it is possible to obtain higher condensation pressures, which also increases the temperature of the water exiting the heat pump. As a result, the Maxima 20-42 GT pump models are categorised as high-temperature heat pumps.

The Maxima heat pump features electronic circulating pumps with modulated power, which adapt to the system operation and ensure low power consumption. The circulating pumps force glycol and water through the unit. The 7-16 GT heat pump is built into the unit, while the 20-42 GT pump is an independent device delivered with the unit, as a standard. The electronic expansion valve precisely controls the operation of the unit to maximize the potential of energy accumulated in the ground. It also extends the life of the compressor, preventing non-evaporated refrigerant from entering the compressor. The Maxima 7-16 GT is equipped with a three-way switching valve for supplying domestic hot water, which facilitates installation of the heat pump. The Maxima 20-42 GT model support this type of valve, but as an independent component (not supplied with the device). The controller of the Maxima heat pump is capable of controlling the circulating pump supplying utility water and setting its operating schedule. It also makes it possible to control heating circuits of a floor heating system and radiators, or an additional heater of the DHW tank.



Pic. 40. The Maxima 7-16 GT heat pump - internal structure

The Maxima heat pump has been tested in an independent, foreign, accredited laboratory. Energy classes, seasonal efficiency coefficients (SCOP), accurate values of heating power and COP for various operating points of the unit were determined. COP values also take into account power consumption of the circulating pumps, so it is not necessary to include them in a simulated model of their operation. See below for a sample diagram for Maxima 16 GT during testing (low-temperature application - W35).

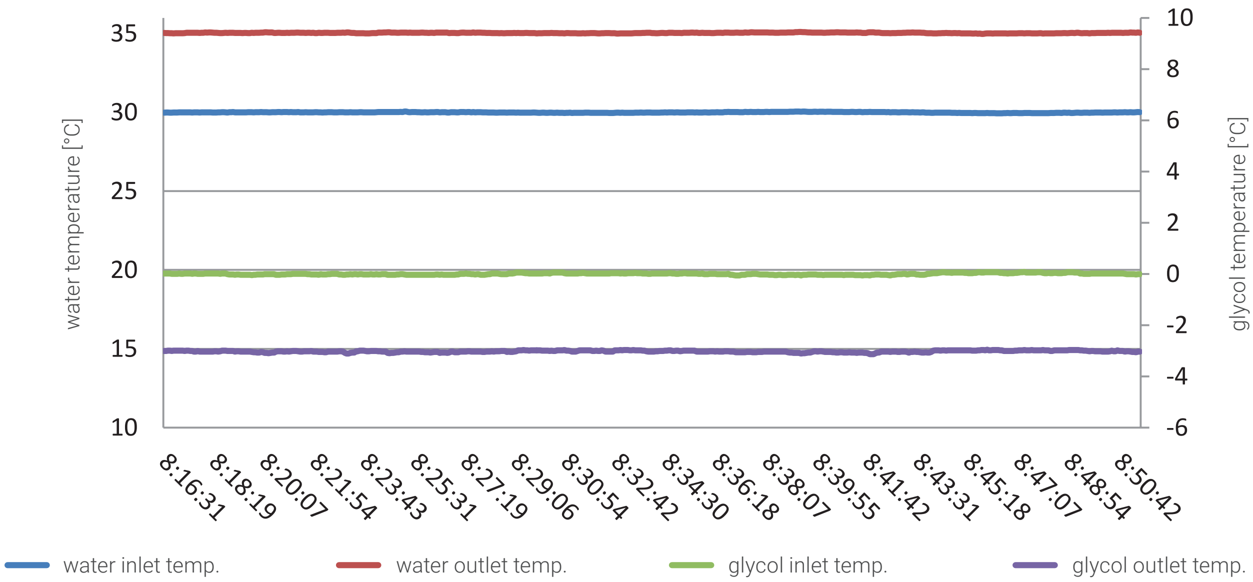


Diagram 27. A sample measuring cycle - Maxima 16 GT (B0W35)

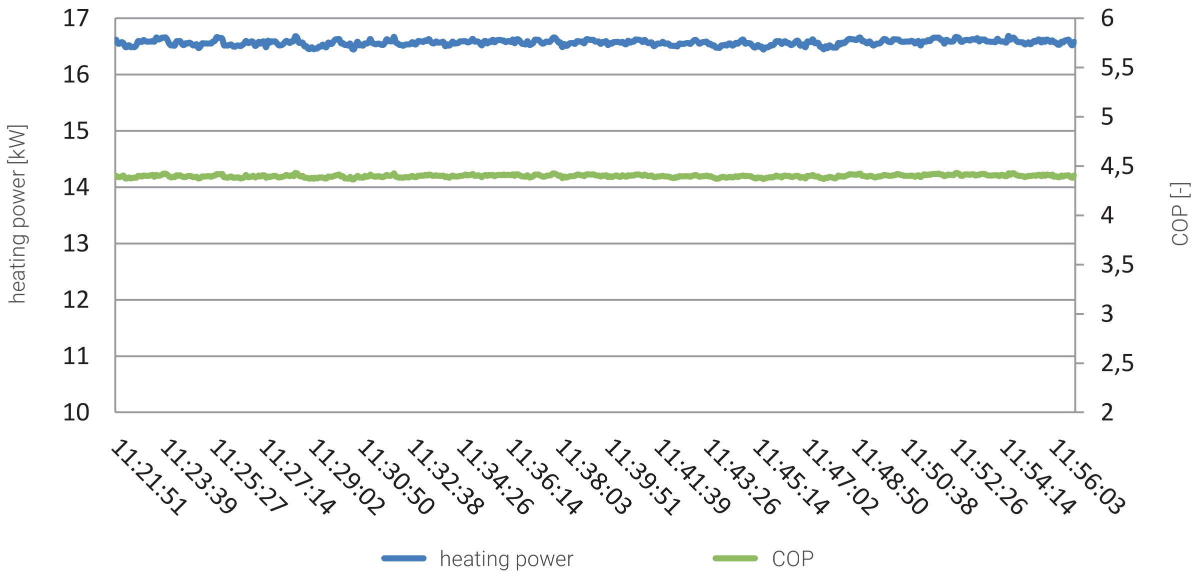
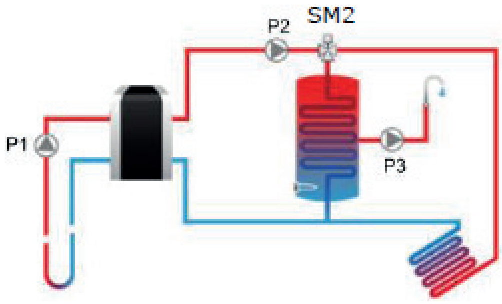
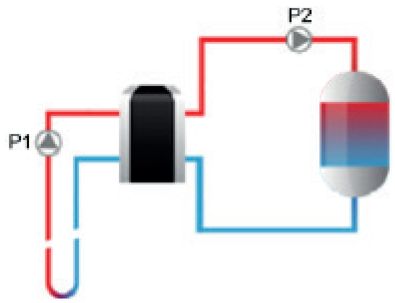


Diagram 28. A sample measuring cycle - Maxima 16 GT (B0W35)

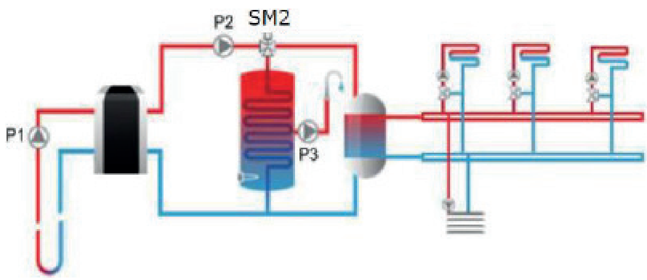
The Maxima heat pump ecoTRONIC100-G controller supports several basic installation variants. The user has a choice of three basic control variants:



The heat pump can supply the underfloor heating and the domestic hot water tank's coil directly. Circulation is possible thanks to the upper source circulation pump built-in the device and a three-way valve. In addition, the heat pump can operate the utility water circulation pump and an additional domestic hot water tank heater. A brine circulation pump built-in the device is also supported.



The second control variant is a system with a heating water buffer tank only. Intended for systems without DHW heating. The water circulation between the heat pump and the buffer tank is provided by the built-in circulation pump. Further heat distribution from the buffer is carried out by using an independent external automation. A brine circulation pump built-in the device is also supported.



Another control variant includes support for DHW, buffer water heating and heating circuits "behind" the buffer. The upper and lower source circulation pump and three-way valve are built-in the device. The standard version of the controller allows the implementation of one floor heating circuit with a mixing valve or one radiator heating circuit connected directly to the buffer, alternatively it is also possible to implement these two circuits simultaneously. If there is a need to implement more floor heating circuits with mixing valves, an additional expansion module for the controller is necessary (it adds another two floor heating circuits with mixing valves). In this control variant, the user has the option of operating a DHW circulation pump as well as an additional DHW tank heater.

The aforementioned additional DHW tank heater it is used for quick heating of domestic hot water or to enable the Anti-legionella mode. As for the circulation pump, it can also be programmed by the controller. Each Maxima heat pump is equipped with an external temperature sensor. The water in the buffer can be heated to a desired temperature irrespective of atmospheric conditions or it can depend on the external temperature sensor's readings (heating curve). The temperature "behind" the mixing valve also also follows the heating curve. Heating water is fed directly to the radiators from the buffer, so its temperature is equal to the buffer's temperature. By deciding to use the controller's panel as a thermostat, is possible to choose which heating circuit it will be assigned. Subsequently, the circulation pump of the given circuit can be stopped after receiving information about reaching the set temperature in the room (depending on the selected control variant and settings).

4.2.3. Technical description of Galmet heat pumps - Maxima Compact

The Maxima Compact series of types consists of three units:

- Maxima Compact 7 GT
- Maxima Compact 10 GT
- Maxima Compact 12 GT

Pic. 41. The Maxima Compact heat pump

Performance data of the Maxima Compact heat pump series of types:

- Highest energy class: A+++.
- High COP: up to 4,5 (B0W35).
- A reliable scroll compressor.
- Heat pump with 316L stainless steel water tank - all in one device.
- The weather system adjusts the pump operating parameters to the weather conditions.
- The possibility of setting an operating schedule for both a heat pump and a circulating pump.
- The possibility of controlling the operation of an electric heater in the tank, a circulating pump, and heating circuits.
- An electronic expansion valve for maximum efficiency.
- Consistent performance throughout the entire heating season.
- It uses Renewable Energy Sources.
- Eligible for funding.

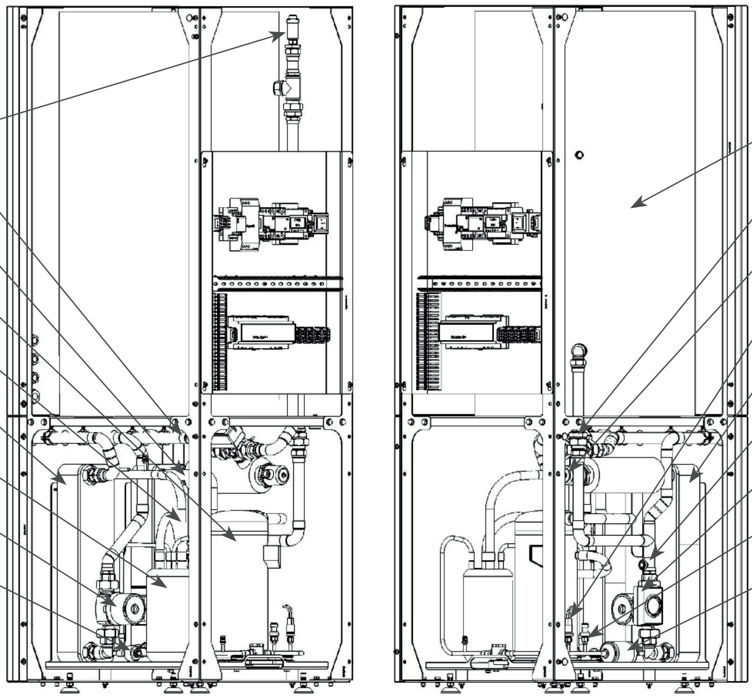
The unit comes with the following standard accessories:

- A complete set of temperature sensors.
- An Internet module for remote control of the device.
- 316L stainless steel water tank built-in the device.
- Soft Start (soft start of the compressor), which ensures a longer life of the unit and quiet starting.
- Electronic circulating pumps built in the unit.
- A three-way switching valve for supplying domestic hot water, built in the unit.
- Smart control of a colour touch panel with the thermostat function.

Maxima Compact is a ground-water heat pump designed to work with a glycol ground exchanger. It has been equipped with intelligent control and high-quality components. A scroll type compressor dedicated for heat pumps was used. It ensures high performance and longevity, as well as low level of noise and vibration in operation.

The Maxima heat pump features electronic circulating pumps with modulated power, which adapt to the system operation and ensure low power consumption. The circulating pumps force glycol and water through the unit.

The electronic expansion valve precisely controls the operation of the unit to maximize the potential of energy accumulated in the ground. It also extends the life of the compressor, preventing non-evaporated refrigerant from entering the compressor. Maxima Compact features an integrated stainless steel water tank. The device is also equipped with a three-way switching valve for supplying domestic hot water. The configuration used in the Maxima Compact heat pump series - with a built-in domestic hot water tank, makes the installation easier and ensures compact design of the device - as it does not require a large space for installation. The controller of the Maxima Compact heat pump is capable of controlling the circulating pump supplying utility water and setting its operating schedule. It also makes it possible to control heating circuits of a floor heating system and radiators.



Pic. 42. The Maxima Compact heat pump - internal structure

Table 21. Maxima Compact heat pump's water tank parameters

technical specification	unit	value
material	-	stainless steel 316L
nominal capacity	l	170
storage capacity*	l	145
coil capacity	l	17,7
number of steel coils	pcs.	1
coil's surface	m^2	3,6
tank's maximum working pressure	MPa	0,6
coil's maximum working pressure	MPa	0,6
tank's maximum working temperature	°C	75

* According to (UE) 812/2013, 814/2013.

The Maxima Compact heat pump has been tested in an independent, foreign, accredited laboratory. Energy classes, seasonal efficiency coefficients (SCOP), accurate values of heating power and COP for various operating points of the unit were determined. COP values also take into account power consumption of the circulating pumps, so it is not necessary to include them in a simulated model of their operation. The Maxima Compact series has also been tested in domestic hot water heating mode in the tank built into the device, which allowed for precise determination of efficiency and energy classes also in domestic hot water heating mode.

Below is an example graph for Maxima Compact 12 GT from the tests carried out (DHW heating in a tank built into the device).

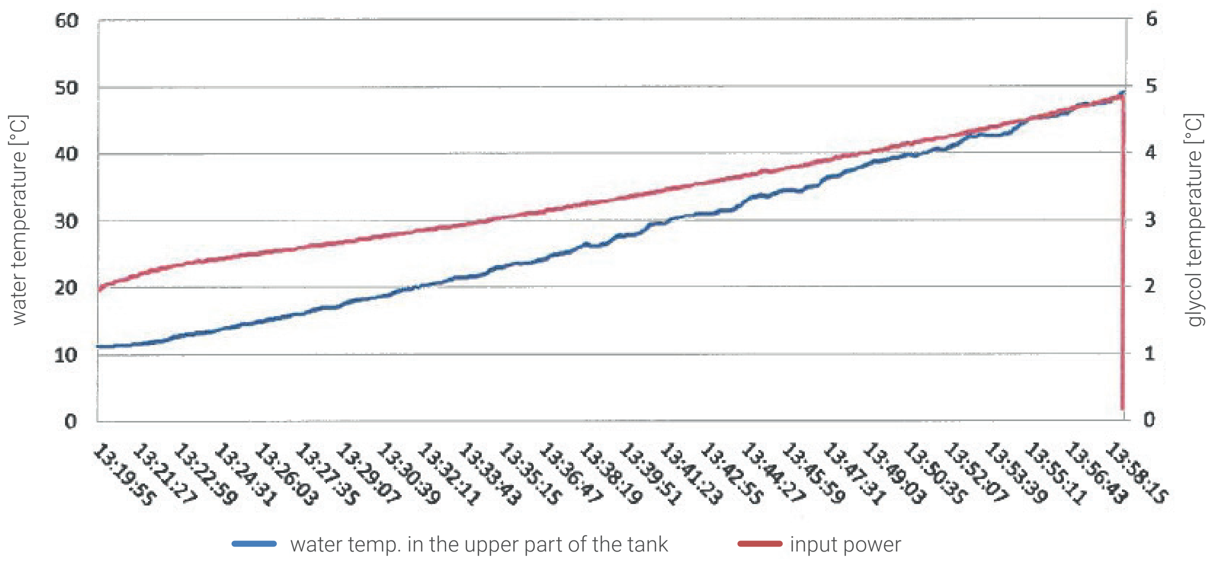


Diagram 29. An example of the heating cycle of the DHW tank built into the device – Maxima Compact 12 GT

The Maxima heat pump features the ecoTRONIC100 controller, which supports the same number of installation options as in the case of the Maxima heat pumps. The user has a choice of several options, like direct underfloor heating with domestic hot water heating, a system with only a buffer tank, or systems with domestic hot water and central heating via a buffer, followed by the operation of heating circuits in several variants.

4.2.4. Technical data for Galmet heat pumps - Maxima and Maxima Compact

The Maxima and Maxima Compact heat pumps were designed using components of the highest quality from reputable manufacturers. They include a scroll compressor dedicated to heating units, an evaporator, a plate condenser, and an electronic expansion valve for precise regulation. The units have a built-in electronic circulating pumps with adjustable capacity and low power consumption. The heat pumps' controller is intuitive, both by for the installer and the user. It has a control panel with a colour touch screen, which can also be used as a thermostat. The Maxima 7-16 GT and Maxima Compact 7-12 GT heat pumps have an electric heater to support the operation of the heat pump, during periods of increased heat demand, if necessary. The user can only permit its operation, when the outside temperature drops below a certain level. In Maxima 20-42 GT heat pumps, the heater is an external component. It will be installed inside a buffer tank.

As mentioned above, the control panel installed by default on the heat pump can be used as a thermostat for the respective circuit. To this end, you only need to place it in a room, where it is supposed to control temperature.

Table 22. The main components of the Maxima heat pump

component	Maxima							
	7 GT	10 GT	12 GT	16 GT	20 GT	28 GT	34GT	42 GT
compressor	scroll (spiral) ZH				scroll (spiral) ZH z EVI			
evaporator	plate							
condenser								
expansion valve	electronic							
circulating pump upper source	UPM3 25-75 Flex AS 130			UPML GEO 25-105 130 PWM	Magna 3 32-100			Magna 3 32-120
circulating pump lower source	UPML GEO 25-105 130 PWM				Magna 3 32-100			Magna 3 32-120
controller	EcoTRONIC 100-G							
heater	7 kW				-			

Table 23. The main components of the Maxima Compact heat pump

component	Maxima Compact		
	7 GT	10 GT	12 GT
compressor	scroll (spiral) ZH		
evaporator	plate		
condenser			
expansion valve	electronic		
circulating pump upper source	UPM3 25-75 Flex AS 130		
circulating pump lower source	UPML GEO 25-105 130 PWM		
controller	EcoTRONIC 100-G		
heater	7 kW		

Pic. 43. Circulating pump UPM3 FLEX AS

The Maxima 7-12 GT and Maxima Compact 7-12 GT heat pumps have the FLEX AS circulating pump controlled by a PWM signal. To maintain the corresponding temperature differences in the heat pump's condenser, the controller gives the appropriate PWM signal so that the pump speed is reduced or increased as required. The FLEX AS pump has signalling diodes of which one indicates the operating status, and the other four indicate the efficiency of the pump, during its operation. The maximum head of the UPM3 25-75 Flex AS 130 circulating pump is 7.5m. The maximum power consumption is 60W. FLEX AS is a circulating pump of the highest energy class and the EEI<20 coefficient.

Circulation pumps are an integral part of the heat pump, so during the tests their power consumption has been taken into account in determining the efficiency of the device.

Table 24. Nominal flow through the condenser of the Maxima / Maxima Compact 7, 10, and 12 GT heat pumps and power consumption of the circulating pumps (UPM3 25-75 Flex AS 130)

technical specification	Maxima / Maxima Compact 7 GT	Maxima / Maxima Compact 10 GT	Maxima / Maxima Compact 12 GT
nominal water flow through the condenser [m³/h]	1,25	1,69	2,15
nominal power consumption of the circulating pump* [W]	30	40	50

* When determining COP of the heat pump, power consumption of the circulating pumps was taken into account. Therefore, it should not be taken into account when creating simulation of operating costs.

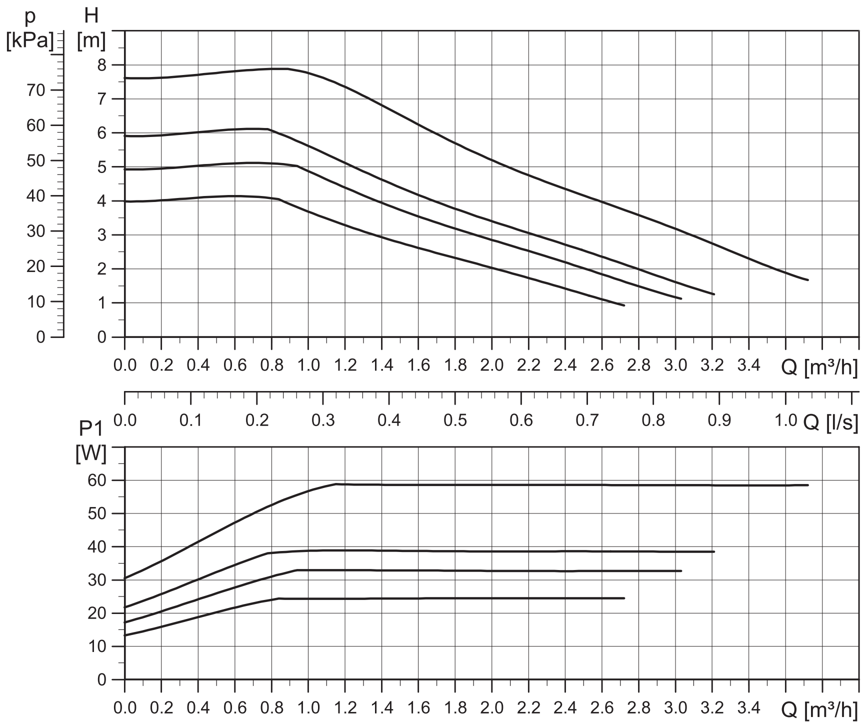


Diagram 30. Performance characteristics of the UPM3 25-75 Flex AS 130 circulating pump

Pic. 44. Circulating pump UPML GEO

The UPML GEO 25-105 130 PWM electronic circulating pump, controlled by the PWM signal, ensures flow through the condenser in the Maxima 16 GT heat pump, and through the evaporator in the 7-16 GT models. Low energy consumption ensures the highest energy class (EEI <0.23). The maximum head of the circulating pump is 10.5m, while the maximum current consumption is 140W.

Table 25. Nominal flow through the condenser of the Maxima 16 GT heat pump and power consumption of the circulating pumps (UPML GEO 25-125 130 PWM)

technical specification	Maxima 16 GT
nominal water flow through the condenser [m³/h]	2,85
nominal power consumption of the circulating pump* [W]	80

* When determining COP of the heat pump, power consumption of the circulating pumps was taken into account. Therefore, it should not be taken into account when creating simulation of operating costs.

Table 26. Nominal flow through the condenser of the Maxima 7-16 GT and Maxima Compact 7-12 GT heat pumps and power consumption of the circulating pumps (UPML GEO 25-125 130 PWM)

technical specification	Maxima / Maxima Compact 7 GT	Maxima / Maxima Compact 10 GT	Maxima / Maxima Compact 12 GT	Maxima / Maxima Compact 16 GT
nominal water flow through the condenser [m³/h]	1,71	2,30	2,99	3,94
nominal power consumption of the circulating pump* [W]	55	60	85	110

* When determining COP of the heat pump, power consumption of the circulating pumps was taken into account. Therefore, it should not be taken into account when creating simulation of operating costs.

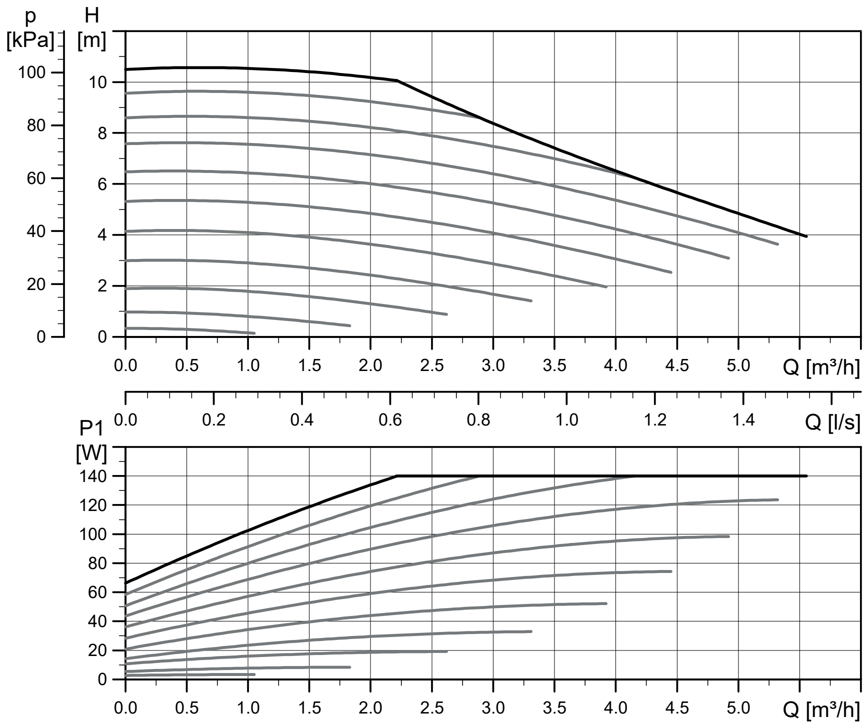


Diagram 31. Performance characteristics of the UPML GEO 25-105 130 PWM circulating pump

Pic. 45. Pompa obiegowa Magna 3

The flow in the upper and lower sources (via the condenser and evaporator) of the Maxima 20-34GT pump models is provided by the Magna 3 32-100 circulating pump. Magna 3 is an electronic circulating pump controlled by a 0-10V signal. An expanded user interface with a TFT display ensures comfort of use. A control panel with high quality silicone buttons provides intuitive operation. The maximum head of the Magna 3 32-100 circulating pump is 10m, while the maximum current consumption is 180W. Magna 3 32-100 is a circulating pump of the highest energy class and the EEI ≤19 coefficient. When determining the efficiency of the device, power consumption of the circulating pumps during testing was taken into account.

Table 27. Nominal flow through the condenser of the Maxima 20, 28, and 34 GT heat pumps and power consumption of the circulating pumps (Magna 3 32-100)

technical specification	Maxima 20 GT	Maxima 28 GT	Maxima 34GT
nominal water flow through the condenser [m³/h]	3,40	4,87	5,69
nominal power consumption of the circulating pump* [W]	60	100	120

* When determining COP of the heat pump, power consumption of the circulating pumps was taken into account. Therefore, it should not be taken into account when creating simulation of operating costs.

Table 28. Nominal flow through the evaporator of the Maxima 20, 28, and 34 GT heat pumps and power consumption of the circulating pumps (Magna 3 32-100)

technical specification	Maxima 20 GT	Maxima 28 GT	Maxima 34GT
nominal glycol flow through the condenser [m³/h]	4,72	6,80	7,82
nominal power consumption of the circulating pump* [W]	90	125	135

* When determining COP of the heat pump, power consumption of the circulating pumps was taken into account. Therefore, it should not be taken into account when creating simulation of operating costs.

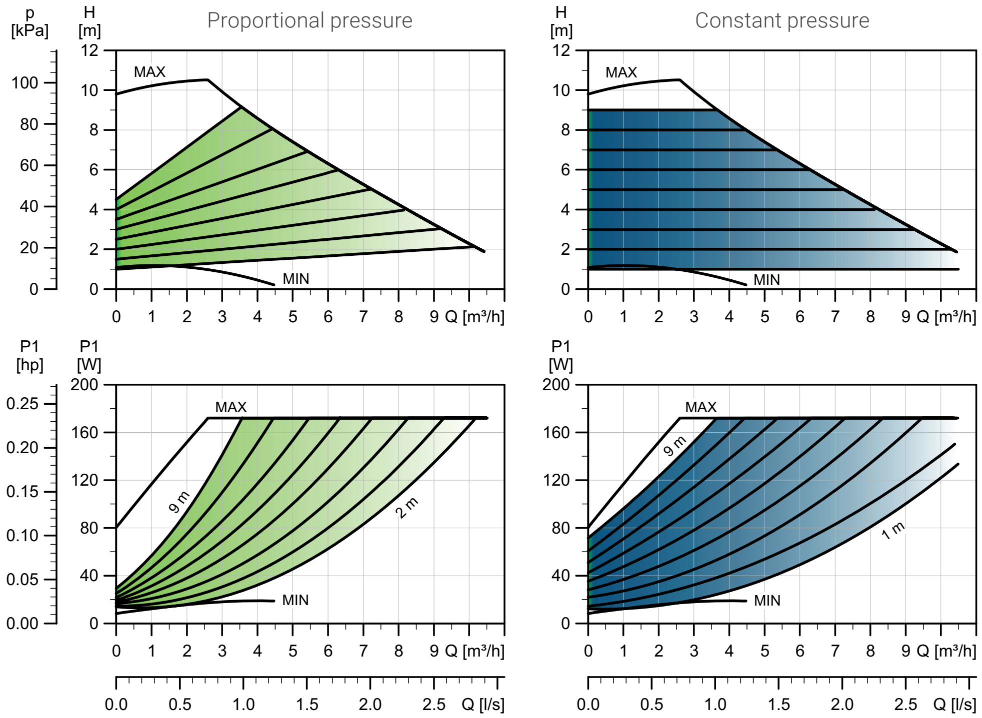


Diagram 32. Performance characteristics of the Magna 3 32-100 circulating pump

Flow in the upper and lower sources (via the condenser and evaporator) of the Maxima 42 GT unit is provided by the Magna 3 32-120 circulating pump. The maximum head of the Magna 3 32-120 circulation pump is 12m. The maximum current consumption is 336W. Magna 3 32-120 is a circulating pump of the highest energy efficiency class and the EEI factor ≤ 18.

Table 29. Nominal flow through the condenser of the Maxima 42 GT heat pump and power consumption of the circulating pump (Magna 3 32-120)

technical specification	Maxima 42 GT
nominal water flow through the condenser [m³/h]	7,16
nominal power consumption of the circulating pump* [W]	150

* When determining COP of the heat pump, power consumption of the circulating pumps was taken into account. Therefore, it should not be taken into account when creating simulation of operating costs.

Table 30. Table 28. Nominal flow through the evaporator of the Maxima 42 GT heat pump and power consumption of the circulating pump (Magna 3 32-120)

technical specification	Maxima 42 GT
nominal glycol flow through the condenser [m³/h]	9,91
nominal power consumption of the circulating pump* [W]	190

* When determining COP of the heat pump, power consumption of the circulating pumps was taken into account. Therefore, it should not be taken into account when creating simulation of operating costs.

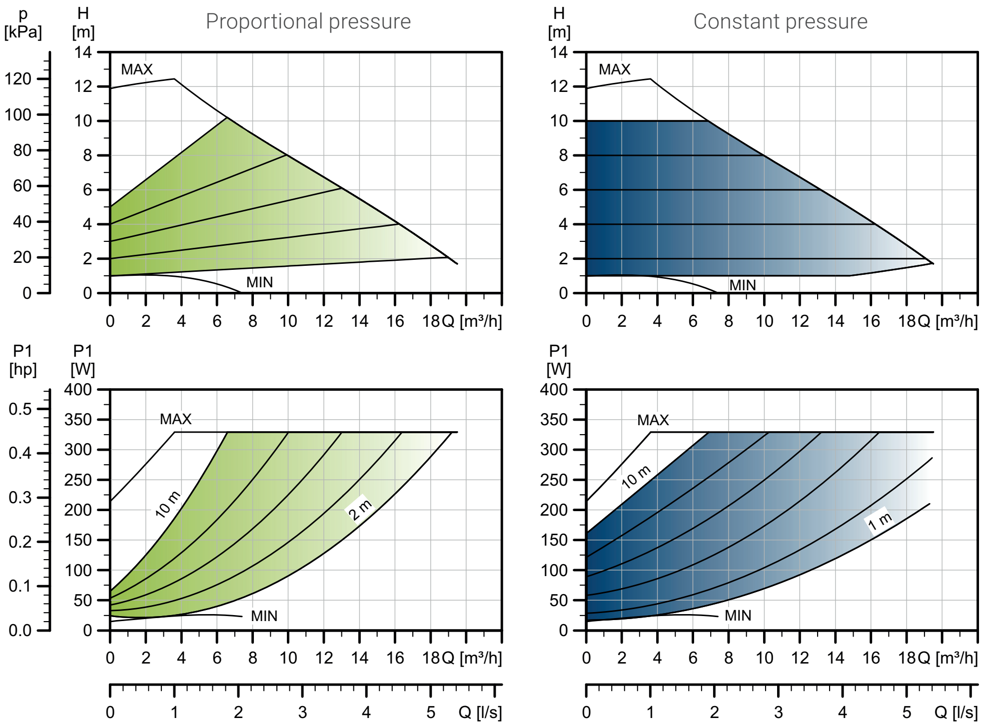


Diagram 33. Performance characteristics of the Magna 3 32-120 circulating pump

As shown above, values of heating, cooling, electrical, and COP depend on temperatures of the upper and lower sources. The nominal operating parameters listed in the table below are B0W35 and B0W55.

Table 31. Basic data for the Maxima heat pump

technical specification		unit	Maxima							
			7 GT	10 GT	12 GT	16 GT	20 GT	28 GT	34GT	42 GT
heating power	B0W35[1]	kW	7,25	9,85	12,50	16,57	19,60	28,10	32,85	41,30
COP		-	4,32	4,46	4,50	4,40	4,59	4,67	4,40	4,53
electric power		kW	1,68	2,21	2,78	3,77	4,27	6,02	7,47	9,12
heating power	B0W55[1]	kW	6,85	9,23	11,80	15,48	20,10	28,15	34,10	41,91
COP		-	2,75	2,88	2,86	2,87	3,02	3,01	2,85	3,08
electric power		kW	2,49	3,21	4,12	5,39	6,66	9,35	11,96	13,61
dimensions [H x W x D]		mm	1060 x 590 x 720				1105 x 730 x 925			
hydraulic connections		-	1”	1”	1”	1”	5/4”	5/4”	6/4”	6/4”
maximum glycol temperature		°C	20							
minimum glycol temperature		°C	-5							
maximum supply temperature		°C	60				65			
refrigerant		-	R410A							
quantity of refrigerant		kg	2,1	2,4	2,7	2,9	4,0	5,5	6,0	7,0
power of the electric heater		kW	7				-			
acoustic power[2]		dB	44,0	45,0	47,0	49,3	58,5	60,5	62,0	63,4
sound pressure[3]		dB	33,0	34,0	36,0	38,3	47,5	49,5	51,0	52,4
power supply voltage and frequency		V/Hz	400/50							
starting current (without a starting current limiter)		A	43	52	62	75	101	118	140	174
approximate value of the starting current when using a limiter (soft-start)[4]		A	26	31	37	45	61	71	84	104

[1] Acc. to EN-14511. [2] Acc. to EN-12102. [3] Within a distance of 2 m. [4] Soft start is a standard feature in all Maxima heat pumps.

Table 32. Basic data for the Maxima Compact heat pump

technical specification		unit	Maxima Compact		
			7 GT	10 GT	12 GT
heating power	B0W35[1]	kW	7,25	9,85	12,50
COP[1]		-	4,32	4,46	4,50
electric power		kW	1,68	2,21	2,78
heating power	B0W55[1]	kW	6,85	9,23	11,80
COP [1]		-	2,75	2,88	2,86
electric power		kW	2,49	3,21	4,12
COP (DHW)[2]		kW	2,66	2,11	2,52
dimensions [H x W x D]		mm	1840 x 630 x 760		
hydraulic connections		-	1"	1"	1"
hydraulic connection for hot water circulation		-	¾"		
maximum glycol temperature		°C	20		
minimum glycol temperature		°C	-5		
maximum supply temperature		°C	60		
refrigerant		-	R410A		
quantity of refrigerant		kg	2,1	2,4	2,7
power of the electric heater		kW	7		
acoustic power[3]		dB	51,5	52,5	54,4
sound pressure[4]		dB	40,5	41,5	43,4
water intake profile		-	L		
maximum volume of mixed water (V_{40})[2]		l	199,7	192,8	198,4
reference temperature (O_{WH})[2]		°C	55,85	51,97	54,15
power supply voltage and frequency		V/Hz	400/50		
starting current (without a starting current limiter)		A	43	52	62
approximate value of the starting current when using a limiter (soft-start)[5]		A	26	31	37

[1] Acc. to EN-14511. [2] Acc. to EN-16147. [3] Acc. to EN-12102. [4] Within a distance of 2 m. [5] Soft start is a standard feature in all Maxima Compact heat pumps.

See below for the working range of the unit. The maximum and minimum water temperatures apply to the heating circuit, i.e. at the outlet of the heat pump. The range of glycol temperatures is from -5°C to 20°C.

Table 33. The working range of Maxima and Maxima Compact heat pumps

	Maxima 7-16 GT / Maxima Compact 7-12 GT		Maxima 20-42 GT	
glycol temp. [°C]	maximum water temp. [°C]	minimum water temp. [°C]	maximum water temp. [°C]	minimum water temp. [°C]
-5	55	20	60	20
0	60	20	65	20
10	60	20	65	20
20	60	35	65	40

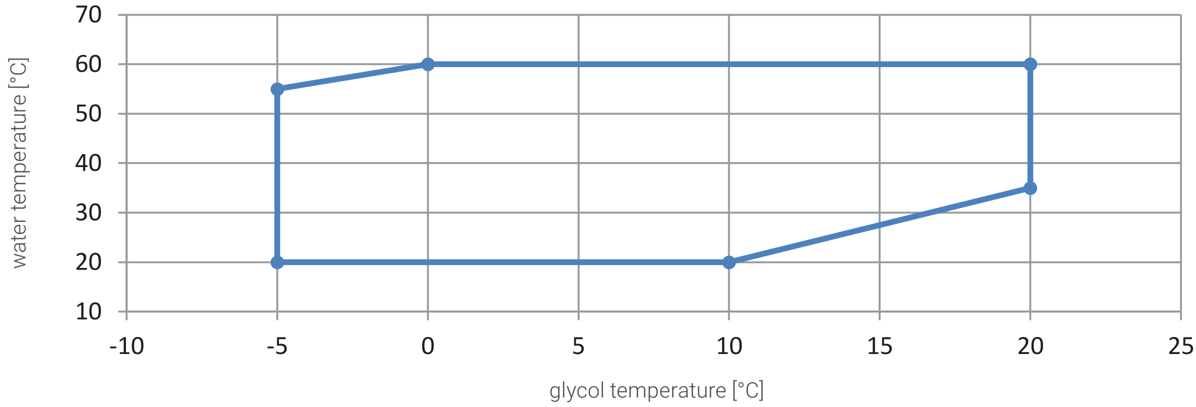


Diagram 34. The working range of the Maxima 7-16 GT / Maxima Compact 7-12 GT heat pumps

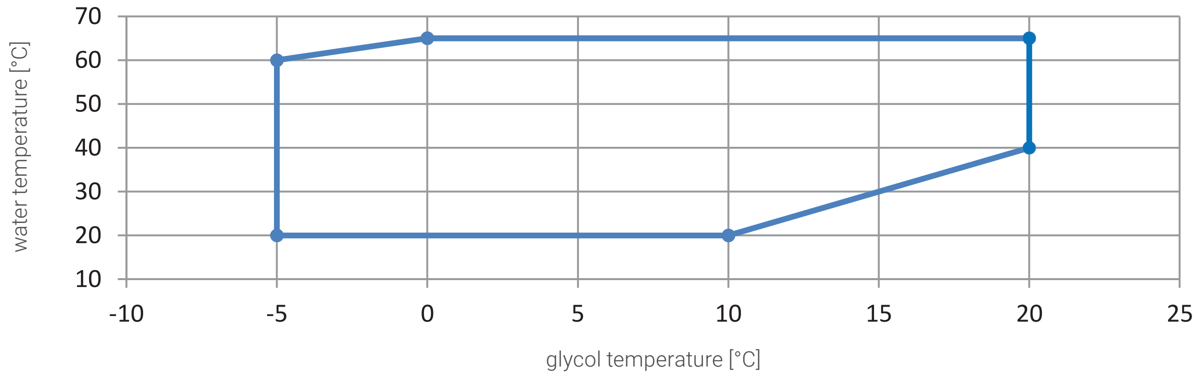


Diagram 35. The working range for the Maxima 20-42 GT heat pumps

As mentioned above, the value of COP is an instantaneous value. The value of SCOP, i.e. the seasonal coefficient of performance of room heating, is definitely more important to the client. It is higher for ground heat pumps, than for air pumps. It is defined for a given climate and in two temperature levels, i.e. W35 and W55, in accordance with the standard. W35 corresponds to the temperature of the water supplying the heating circuit of 35°C - this applies to underfloor heating, i.e. low-temperature heating. W55 corresponds to the temperature of the water supplying the heating circuit of 55°C - this applies to radiator heating, i.e. high-temperature heating. Low-temperature heating is always characterised by higher performance ratios, so it is recommended to use it in systems having a heat pump.

Table 34. Power supply parameters for Maxima / Maxima Compact heat pumps

technical specification		unit	Maxima / Maxima Compact*							
			7 GT	10 GT	12 GT	16 GT	20 GT	28 GT	34GT	42 GT
SCOP[1]	moderate climate (W35)	-	4,56	4,64	4,69	4,63	4,61	4,76	4,60	4,69
η_s[1]	moderate climate (W35)	%	174,3	177,7	179,6	177,0	176,3	182,5	176,1	179,6
energy class	moderate climate (W35)	-	A++	A++	A++	A++	A++	A++	A++	A++
$P_{designh}$	moderate climate (W35)	kW	8,30	11,10	14,10	18,81	19,60	28,10	32,85	41,30
SCOP[1]	moderate climate (W55)	-	3,33	3,42	3,45	3,59	3,75	3,79	3,63	3,79
η_s[1]	moderate climate (W55)	%	125,1	128,9	129,9	135,5	141,8	143,5	137,0	143,7
energy class	moderate climate (W55)	-	A++	A++	A++	A++	A++	A++	A++	A++
$P_{designh}$	moderate climate (W55)	kW	7,97	10,54	13,45	17,68	22,27	31,75	38,19	46,84
$P_{designh}$	cool climate (W35)	kW	8,90	12,20	15,40	20,55	23,90	34,18	40,02	50,58
	cool climate (W55)	kW	8,50	11,50	14,70	19,33	23,03	32,25	38,88	47,48
	warm climate (W35)	kW	8,50	11,60	14,70	19,51	21,09	30,21	35,24	44,63
	warm climate (W55)	kW	8,10	10,90	13,90	18,32	20,10	28,15	34,10	41,91

η_s Seasonal space heating efficiency.
* The Maxima Compact series consists of 7, 10 and 12 GT models.
[1] Acc. to EN 14825.

Table 35. Power supply parameters for Maxima Compact heat pumps in DHW heating mode

technical specification	unit	Maxima Compact		
		7 GT	10 GT	12 GT
SCOP[1]	%	112,43	88,97	106,03
η_{wh}	kWh	910,6	1150,7	965,6
annual energy consumption (AEC)	-	A	A	A

η_{wh} Energy efficiency of water heating.

Table 36. Other information regarding installation - Maxima

technical specification			Maxima							
			7 GT	10 GT	12 GT	16 GT	20 GT	28 GT	34GT	42 GT
electrical safety device			C20	C20	C25	C25	C25	C25	C32	C40
power supply cable		type	5 x 4 mm^2							5 x 6 mm^2
		length	3,5 running metres							
control panel cable		type	4 x 0,5 mm^2							
		length[1]	2 running metres							
temp. sensor (buffer, tank for domestic hot water)		type	2 x 0,5 mm^2							
		length[2]	5 running metres							
temperature sensor (heating circuits)		type	2 x 0,5 mm^2							
		length[2]	2 running metres							
conduit (three-way switching valve for domestic hot water)		type	valve installed in the heat pump as a standard				4 x 1 mm^2			
		length					5 running metres			
circulating pumps (for the lower and upper sources)	power supply	type	circulating pumps installed in the heat pump as a standard				3 x 1,5 mm^2 (circulating pumps to be connected via contactors)			
		length					5 running metres			
	control	type					2 x 0,5 mm^2 (0-10 V)			
		length					5 running metres			

circulating pumps (for heating circuits, circulation circuits)	type	3 x 1,5 mm² (additional circulating pumps to be connected via contactors)		
international protection marking		IP24		
hydraulic connections[3]		1” brass	5/4” brass	6/4” brass

[1] The cable can be extended up to 30 m.
[2] The cable can be extended up to 15 m.
[3] Do not reduce the inner diameter of the pipe, as this will cause resistance of flow.

Table 37. Other information regarding installation - Maxima Compact

technical specification			Maxima Compact		
			7 GT	10 GT	12 GT
electrical safety device			C20	C20	C25
power supply cable		type	5 x 4 mm²		
		length	3,5 running metres		
control panel cable		type	4 x 0,5 mm²		
		length[1]	2 running metres		
temp. sensor (buffer)		type	2 x 0,5 mm²		
		length[2]	5 running metres		
temperature sensor (domestic hot water tank)		type	installed in the heat pump		
		length			
temperature sensor (heating circuits)		type	2 x 0,5 mm²		
		length[2]	2 running metres		
conduit (three-way switching valve for domestic hot water)		type	valve installed in the heat pump as a standard		
		length			
circulating pumps (for the lower and upper sources)	power supply	type	circulating pumps installed in the heat pump as a standard		
		length			
	control	type			
		length			
circulating pumps (for heating circuits, circulation circuits)		type	3 x 1,5 mm² (additional circulating pumps to be connected via contactors)		
international protection marking			IP24		
hydraulic connections[3]			1” brass		
hydraulic connection for hot water circulation[3]			¾” stainless steel		

[1] The cable can be extended up to 30 m.
[2] The cable can be extended up to 15 m.
[3] Do not reduce the inner diameter of the pipe, as this will cause resistance of flow.

4.2.4. Performance data for Galmet heat pumps - Maxima and Maxima Compact

Performance characteristics have been created for each unit of every types of series, based on a constant temperature of glycol of 0°C and variable water temperature at the exit from the heat pump. The supply temperature of 35°C refers to low-temperature applications (underfloor heating) while 55°C to high-temperature applications (radiator heating). The diagrams below demonstrate the variability of COP values marked with labels. At the constant temperature of glycol, the cooling capacity and the value of COP decrease as the temperature of the upper source rises, while electric power consumption increases. The nominal parameters of the unit are calculated at the C0W35 operating point.

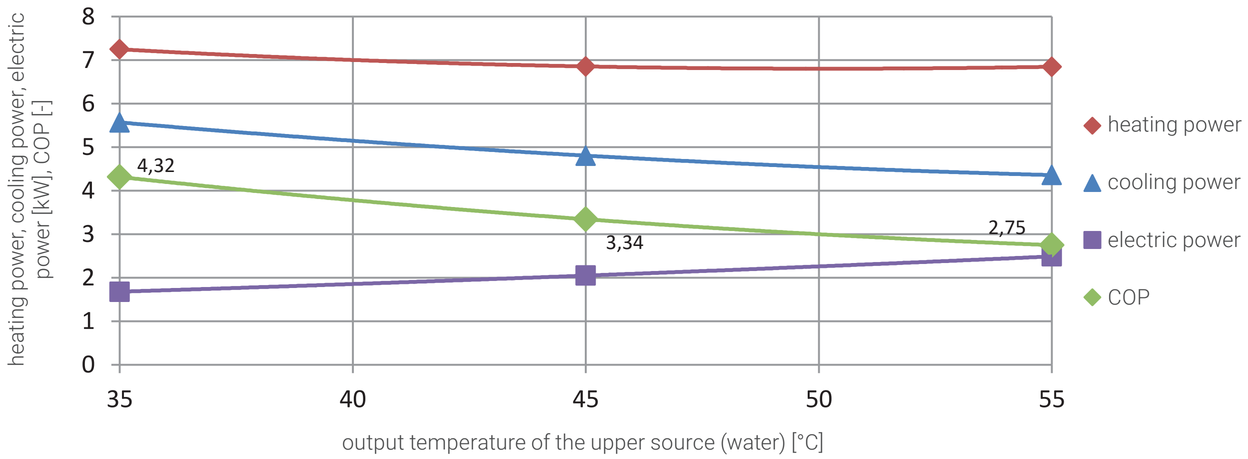


Diagram 36. Performance data for Maxima 7 GT and Maxima Compact 7 GT (B0)

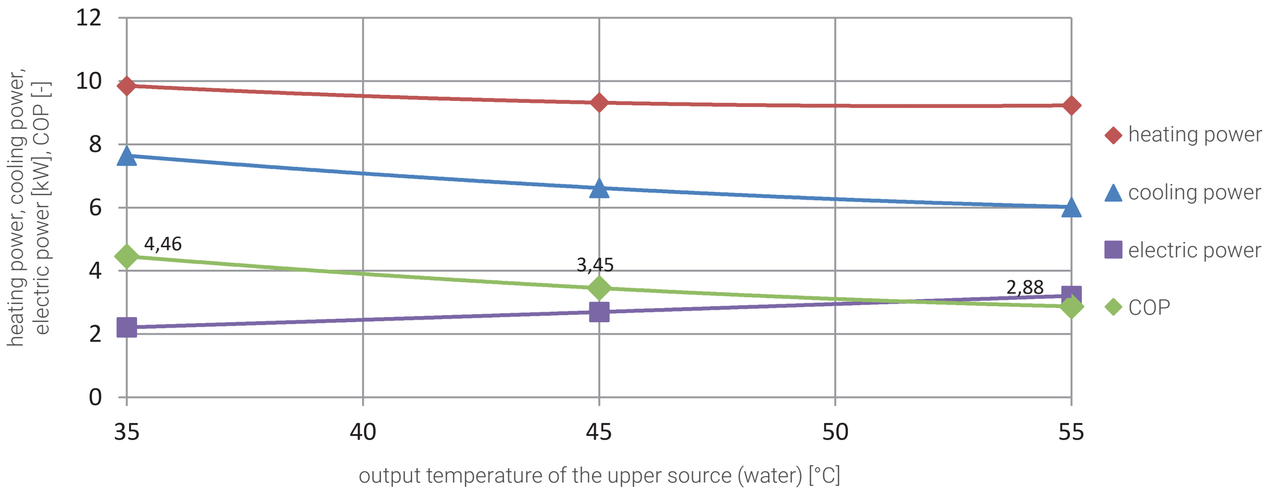


Diagram 37. Performance data for Maxima 10 GT and Maxima Compact 10 GT (B0)

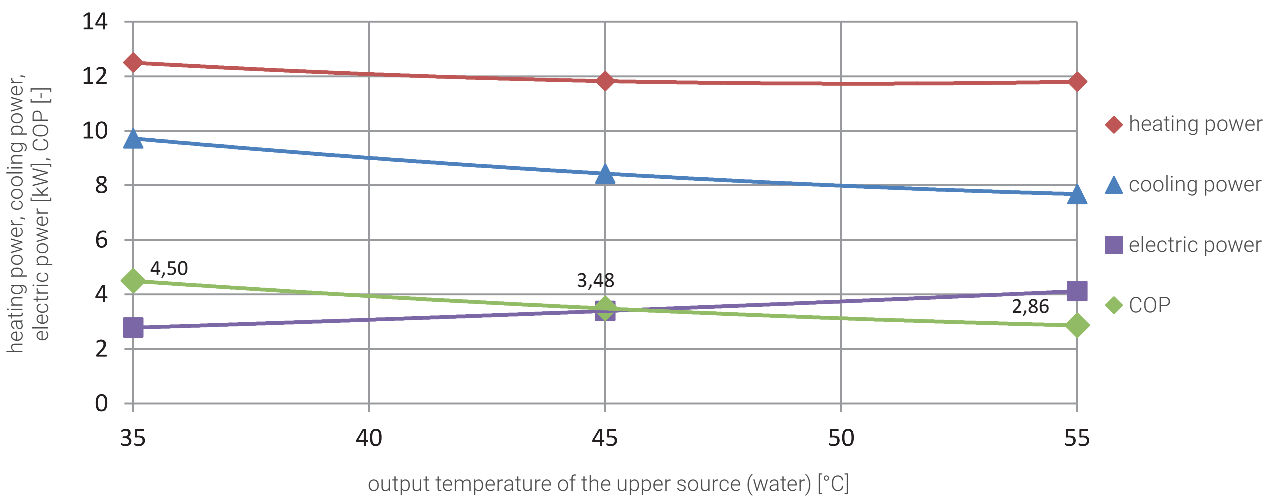


Diagram 38. Performance data for Maxima 12 GT and Maxima Compact 12 GT (B0)

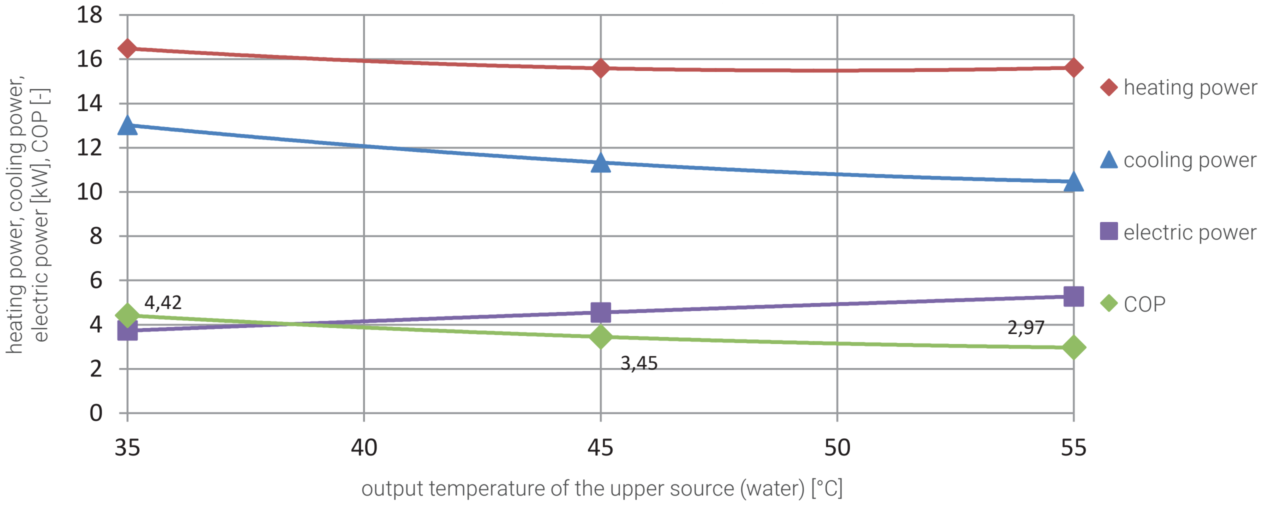


Diagram 39. Performance data for Maxima 16 GT (B0)

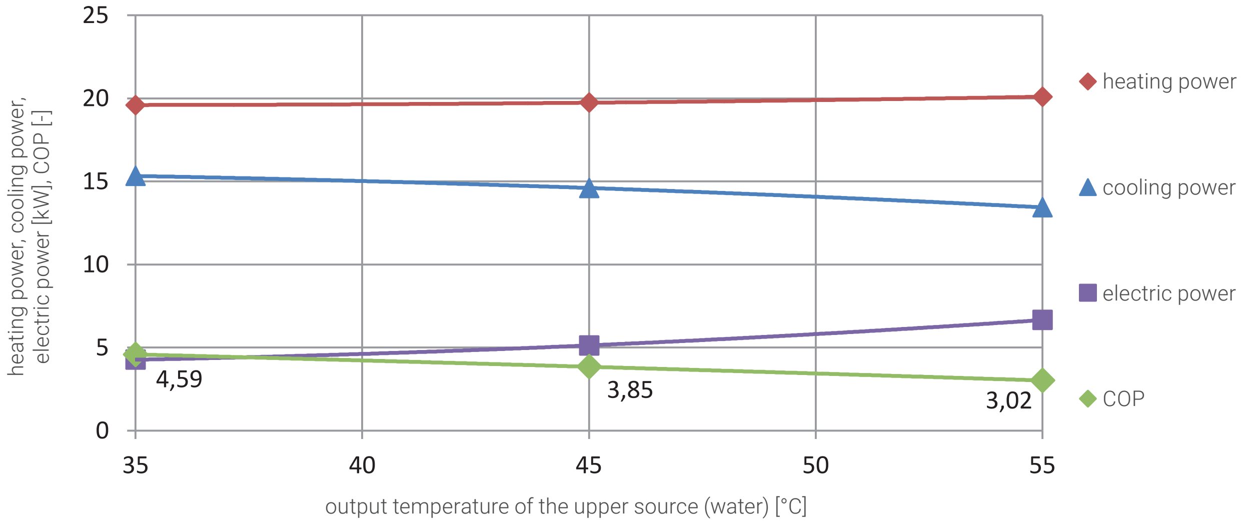


Diagram 40. Performance data for Maxima 20 GT (B0)

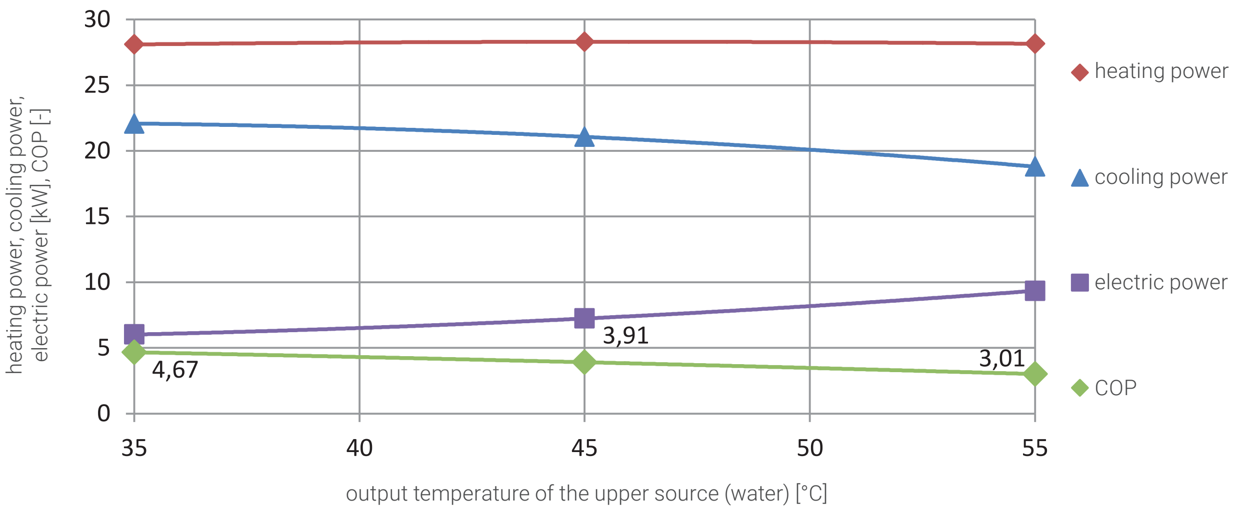


Diagram 41. Performance data for Maxima 28 GT (B0)

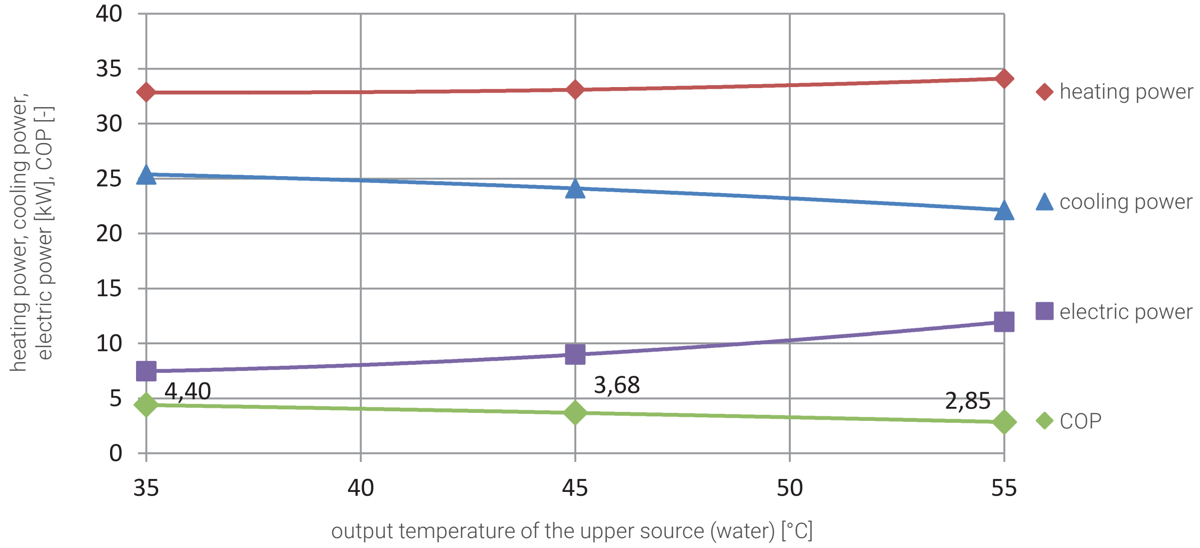


Diagram 42. Performance data for Maxima 34GT (B0)

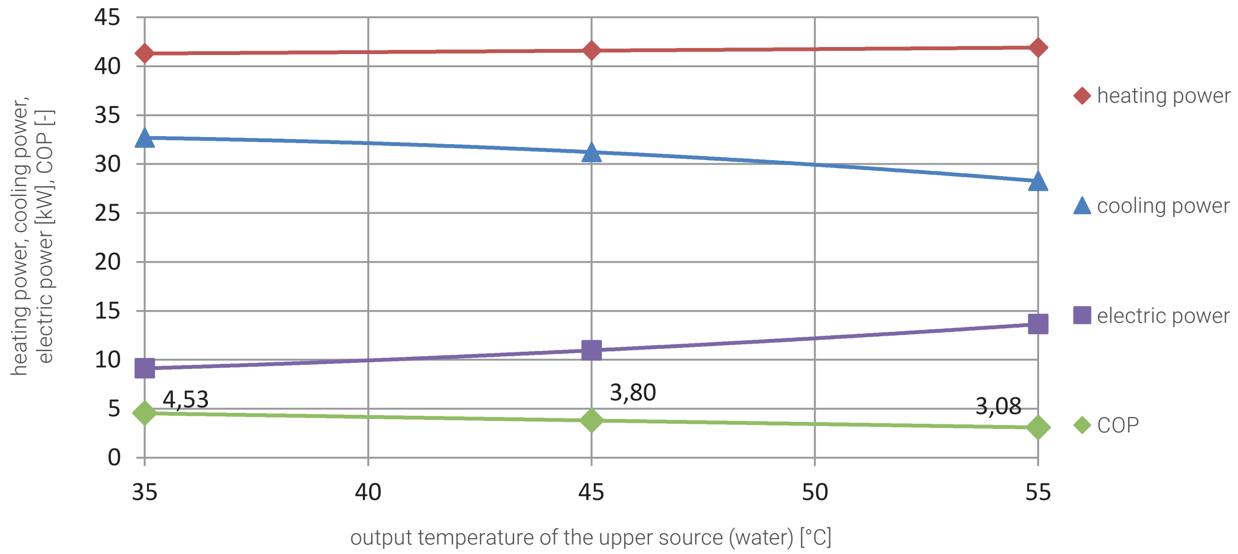


Diagram 43. Performance data for Maxima 42 GT (B0)

It is worth noting the differences in the performance characteristics of the 7-16 GT models, which feature a standard scroll compressor, and the 20-42 GT models equipped with scroll compressors based on the EVI technology. This technology makes it possible to maintain a high level of heating power while increasing the temperature of the upper source.

According to the standard, heat pumps are normally tested at the glycol temperature of 0°C (at the inlet to the heat pump), but in fact the temperature changes throughout the year, and a heat pump installed in a system rarely operates under rated conditions. The reached temperature depends on the type of soil and its thermal capacity. The parameters also depend on the depth of a borehole or the depth at which a horizontal heat exchanger is located. The temperature also depends on the number of working hours per year, because soil exposed to high thermal load may not regenerate well. The average annual temperature is usually around 2-5°C, resulting in higher efficiency of the unit than under rated conditions. Changes in the temperature of the lower source also lead to changes in heating, cooling and electrical power. See below for the performance characteristics of Maxima and Maxima Compact heat pumps for the following temperatures of glycol: 10°C, 5°C, 0°C, -5°C.

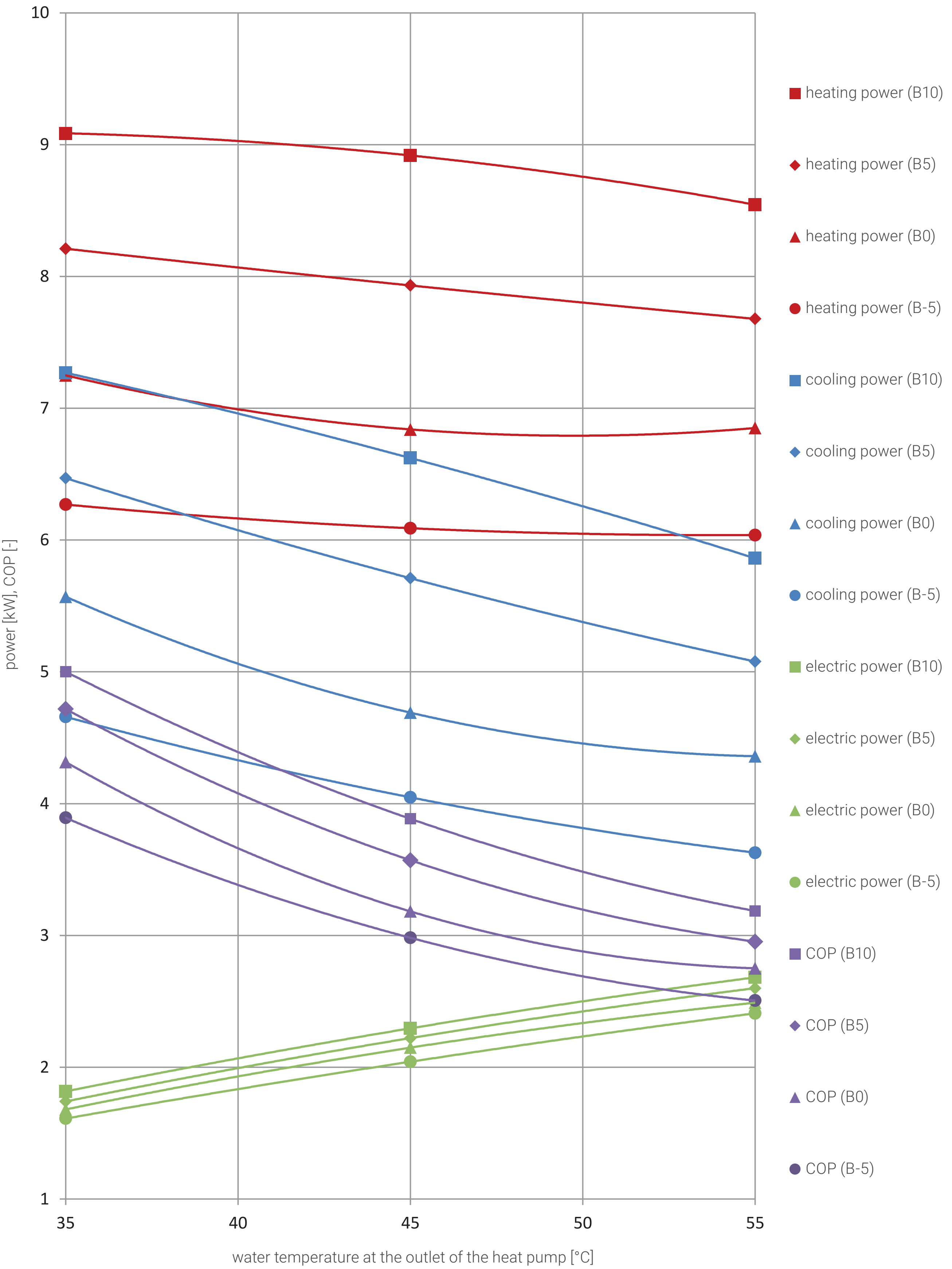


Diagram 44. Performance data of the Maxima 7 GT and Maxima Compact 7 GT heat pumps, in terms of glycol temperatures: -5°C, 0°C, 5°C and 10°C

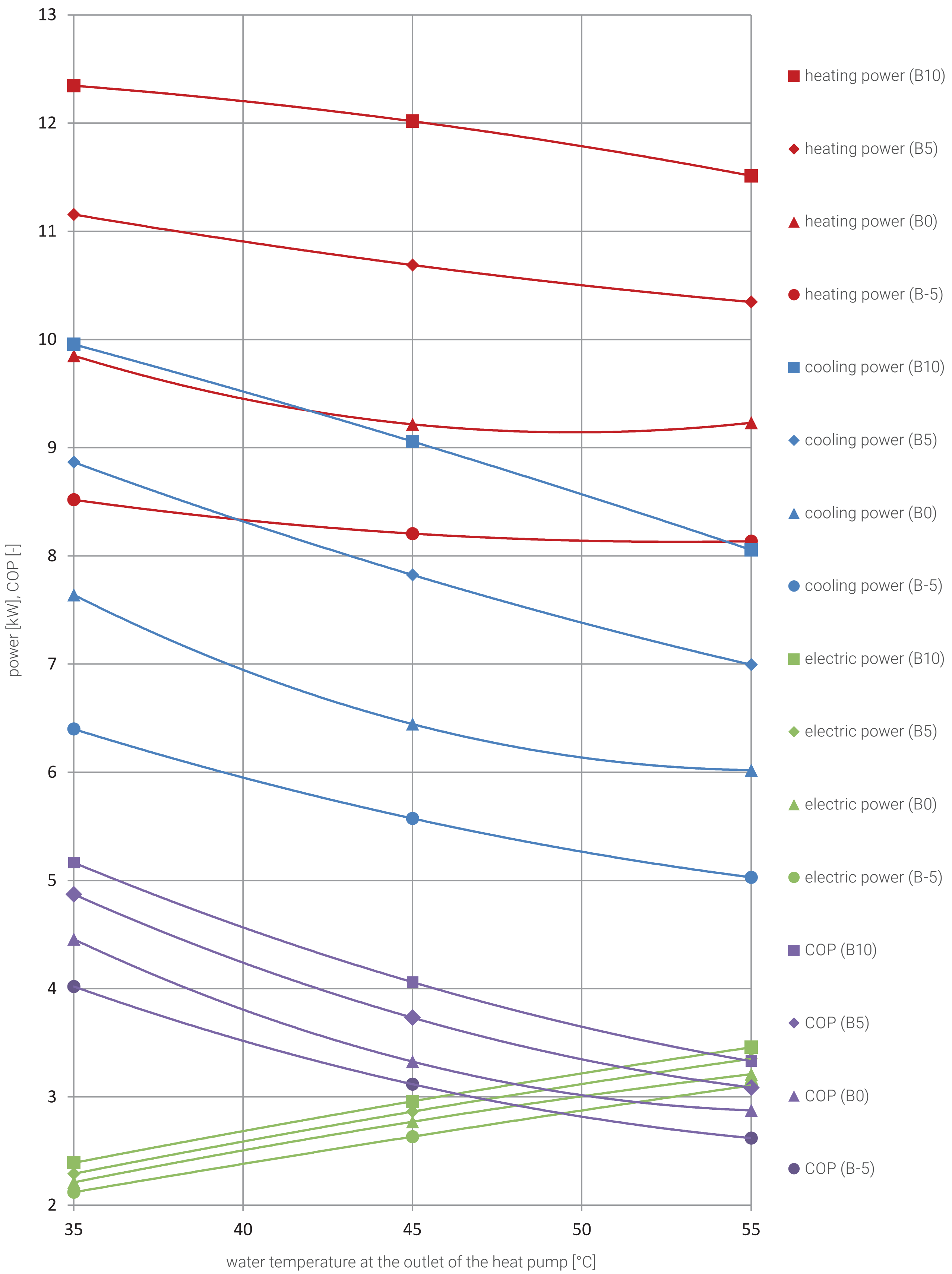


Diagram 45. Performance data of the Maxima 10 GT and Maxima Compact 10 GT heat pumps, in terms of glycol temperatures: -5°C, 0°C, 5°C and 10°C

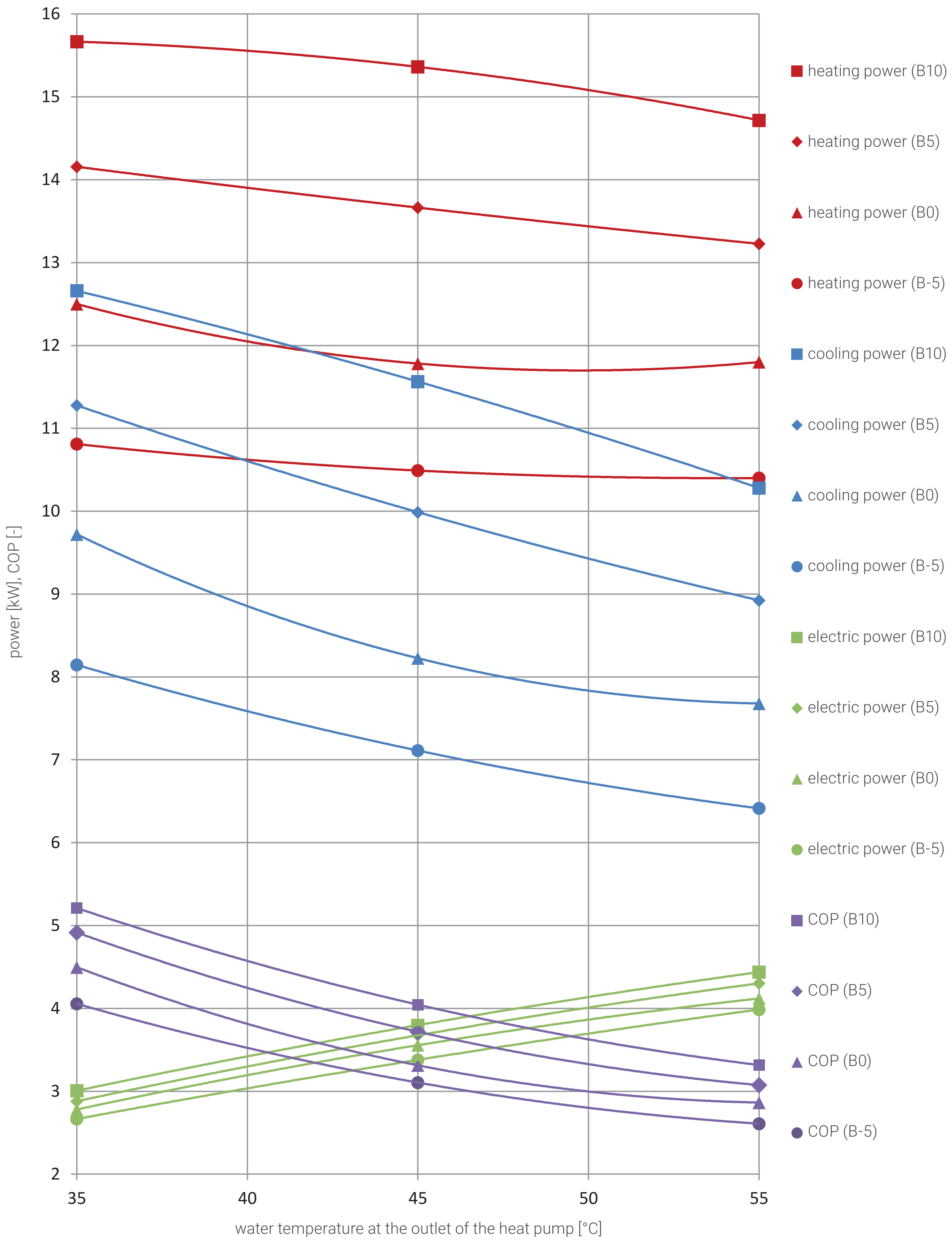


Diagram 46. Performance data of the Maxima 12 GT and Maxima Compact 12 GT heat pumps, in terms of glycol temperatures: -5°C, 0°C, 5°C and 10°C

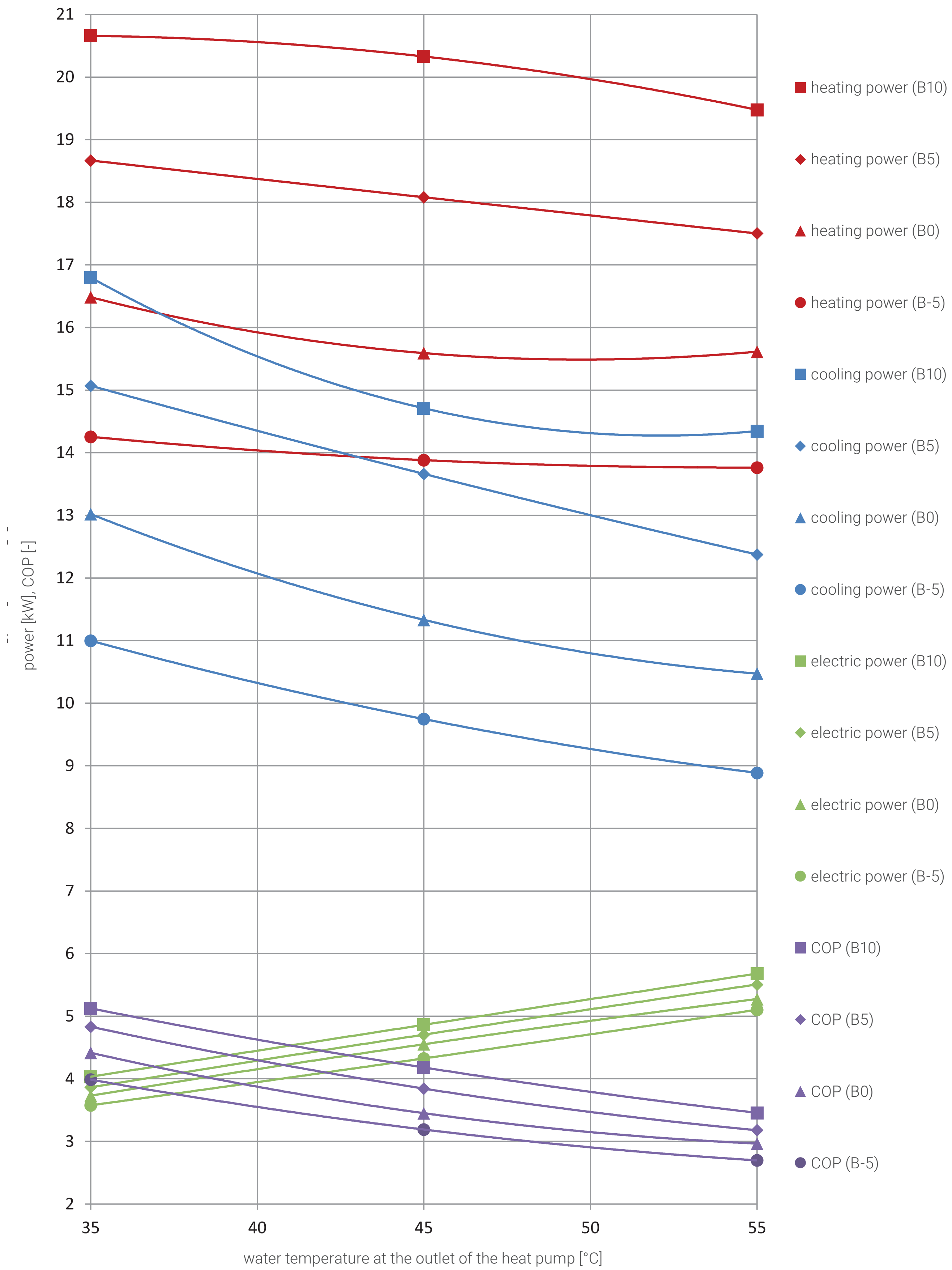


Diagram 47. Performance data of the Maxima 16 GT heat pump, in terms of glycol temperatures: -5°C, 0°C, 5°C, and 10°C

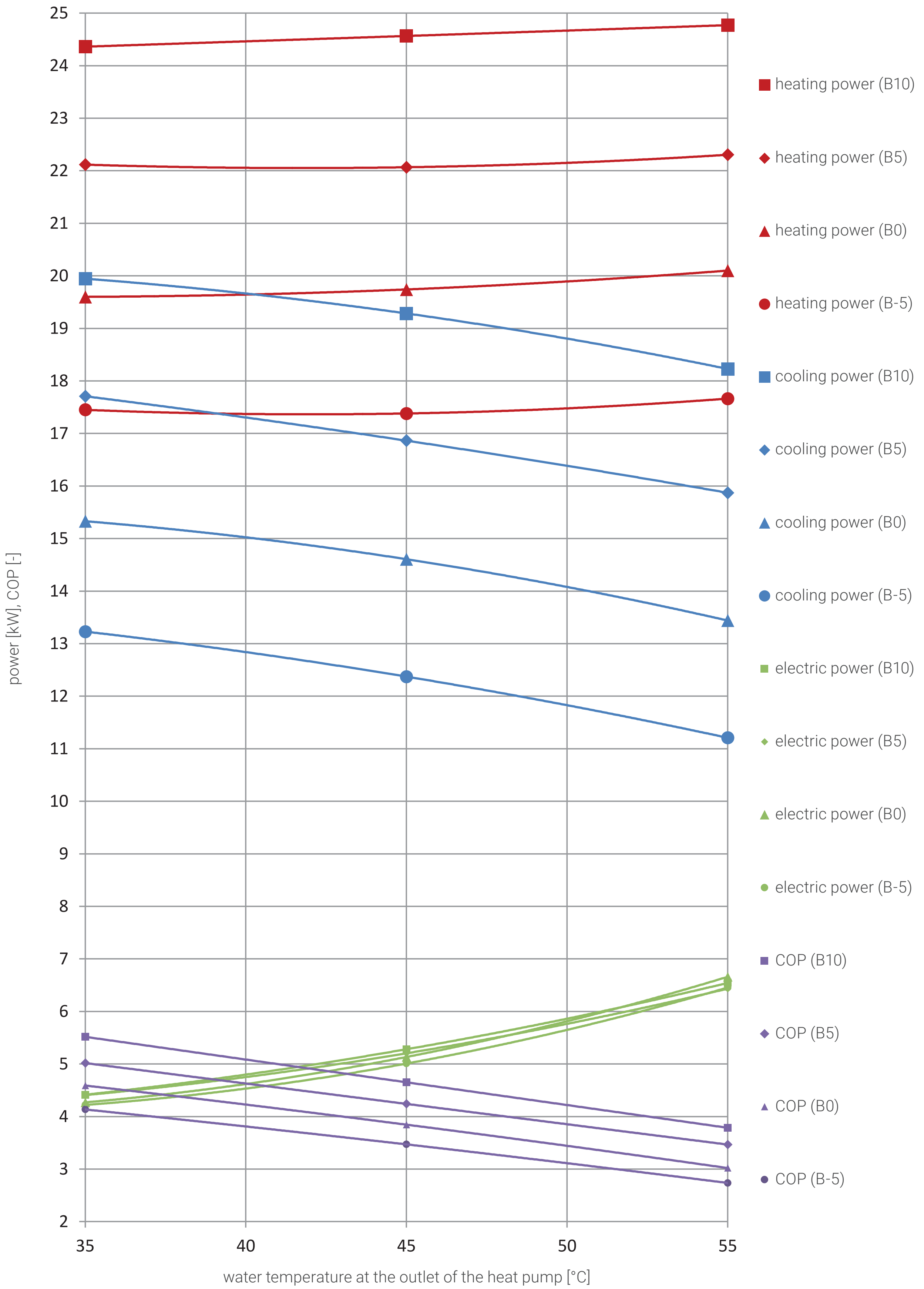


Diagram 48. Performance data of the Maxima 20 GT heat pump, in terms of glycol temperatures: -5°C, 0°C, 5°C, and 10°C

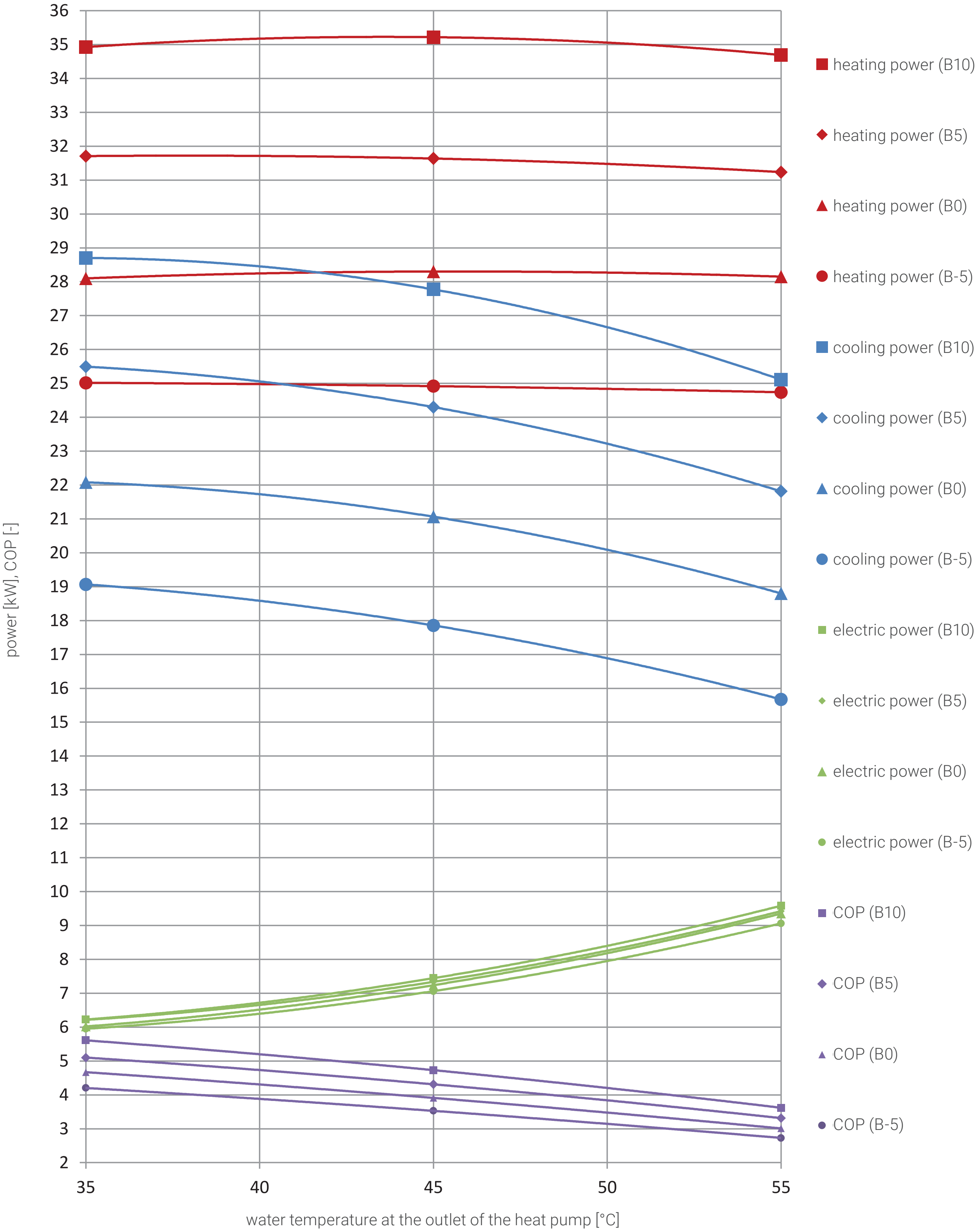


Diagram 49. Performance data of the Maxima 28 GT heat pump, in terms of glycol temperatures: -5°C, 0°C, 5°C, and 10°C

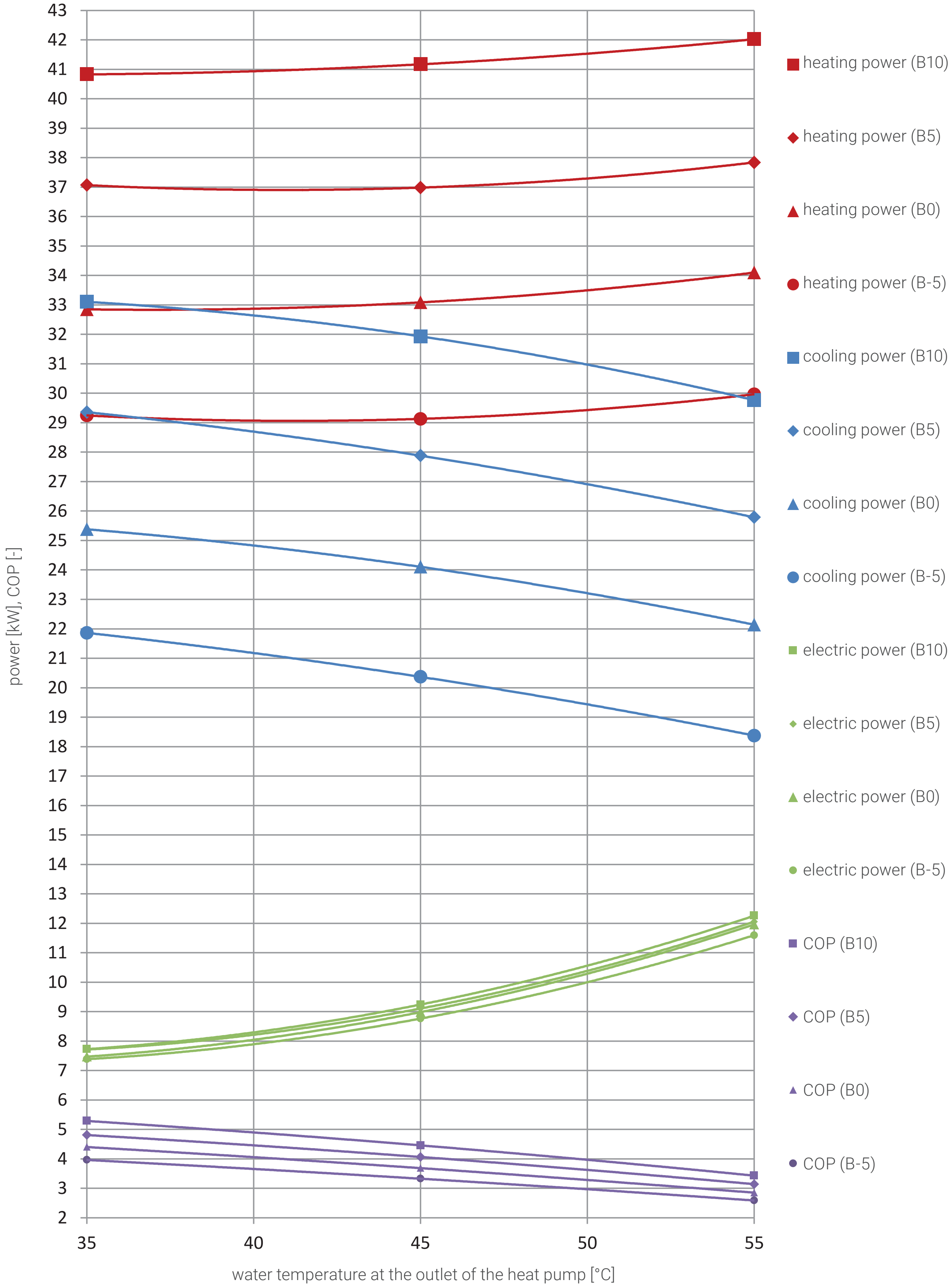


Diagram 50. Performance data of the Maxima 34 GT heat pump, in terms of glycol temperatures: -5°C, 0°C, 5°C, and 10°C

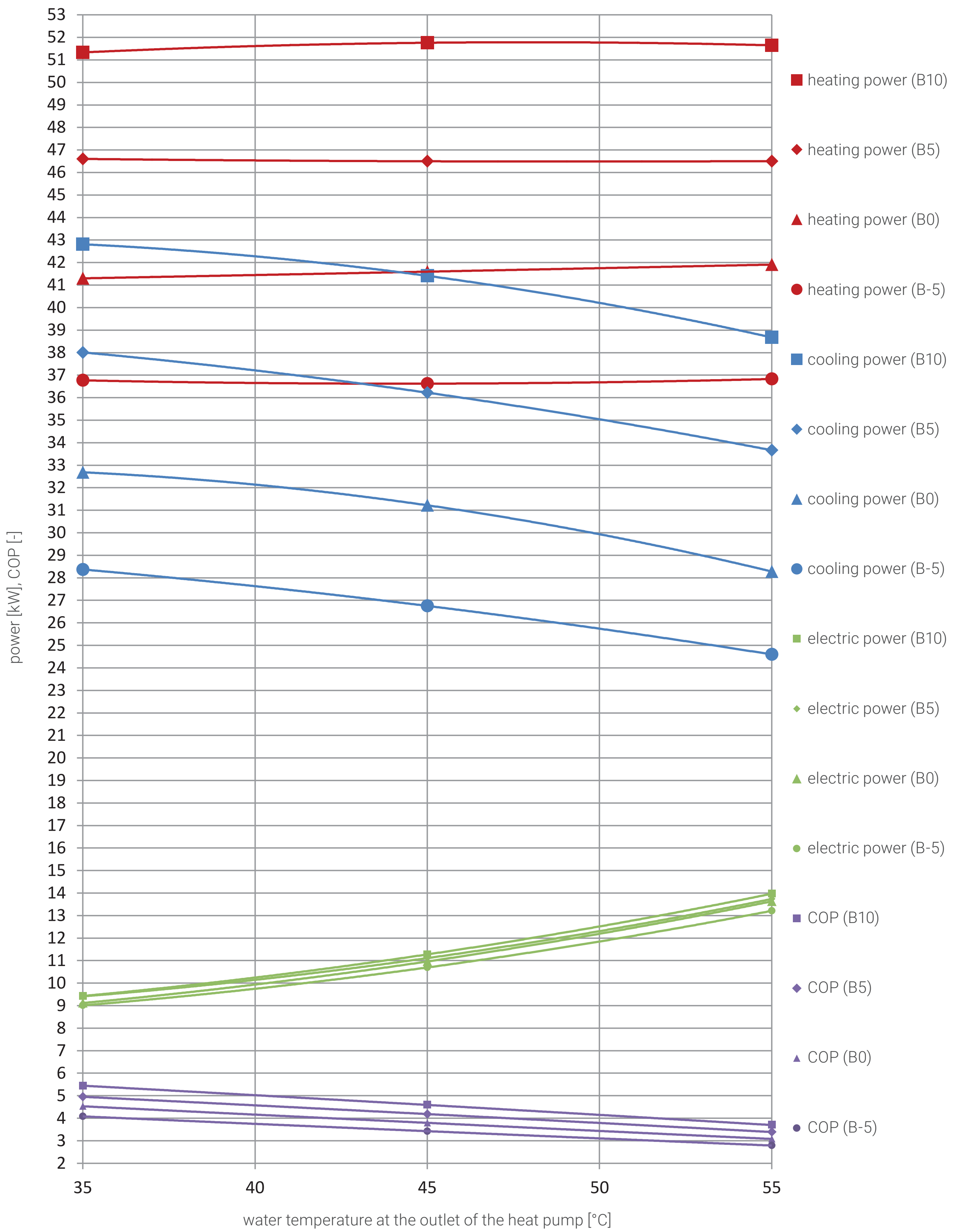
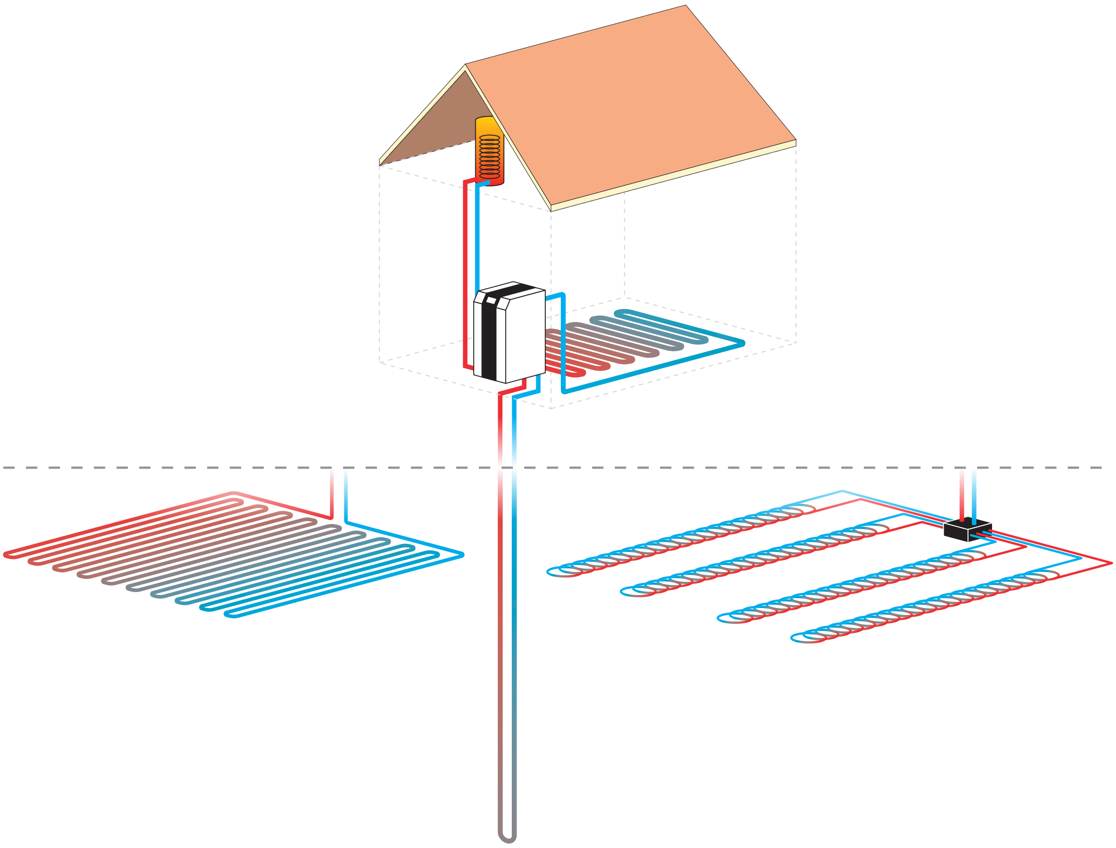


Diagram 51. Performance data of the Maxima 42 GT heat pump, in terms of glycol temperatures: -5°C, 0°C, 5°C, and 10°C

4.3. The lower sources for ground source heat pumps

The lower source of a ground source heat pump (Maxima and Maxima Compact) can be a vertical probe or a horizontal heat exchanger. Pipes of the heat exchanger are filled with a low-solidifying liquid, e.g. propylene glycol at 30-35% concentration and a freezing point of -15°C. The heat transfer medium must not cause groundwater or soil pollution, if it leaks.



Pic. 46. The lower source of a ground source heat pump, from the left: a horizontal-meander, vertical, horizontal-spiral heat exchanger

4.3.1. Vertical probe

The vertical probe uses geothermal heat, but its stream is only present at the depth below 15-25m. In the layers of soil closer to the surface, the so-called neutral layer, it is negligibly small. Regeneration inside that layer is provided by solar radiation and rainwater. Therefore, it would ill-advised to make a number of shallow bore-holes instead of a single deep one, because we are particularly interested in obtaining geothermal heat, when using a vertical probe. It is necessary to drill a bore-hole, in order to obtain heat by way of a vertical probe. When drilling, it is necessary to remember about the required permits, or projects, in accordance with the applicable geological and mining law. A bore-hole drilled deeper than 30m will always require a project of geological work. Then, such a project is submitted to Starosty. If making bore-holes for the purpose of providing lower sources for heat pumps, the depth of drilling is usually around 70-100 meters. This option has been demonstrated in the table below: it requires a project of geological work and a mining plant operations plan, if the bore-hole will be located within a mining zone.

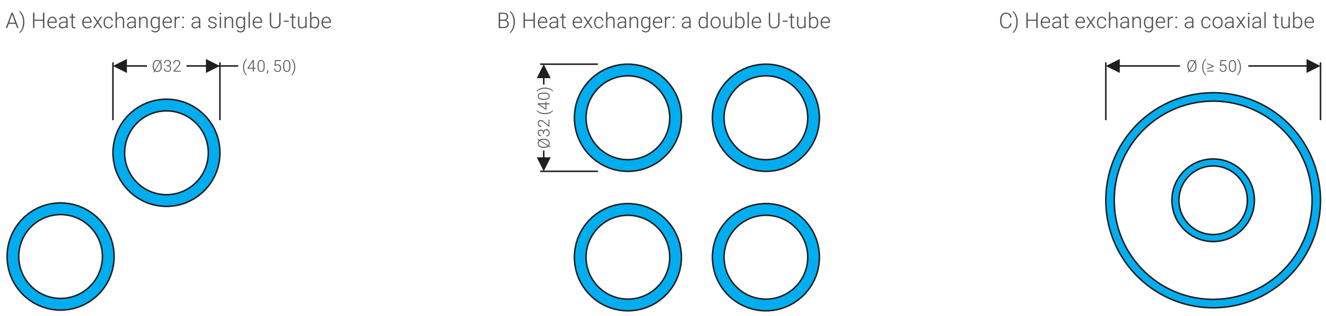
Table 38. Documents required for drilling bore-holes

depth of bore-hole [m]	a project of geological work		a mining plant operations plan	
	outside the mining zone	within the mining zone	outside the mining zone	within the mining zone
≤30	no	yes	no	no
≤100	**yes**	**yes**	**no**	**yes**
>100	yes	yes	yes	yes

Additionally, it is required to draw up geological documentation and then submit it to a geological administrative body, after completing work.

There are three basic types of heat exchangers introduced into bore-holes:

- a single U-tube
- a double U-tube
- a coaxial pipe



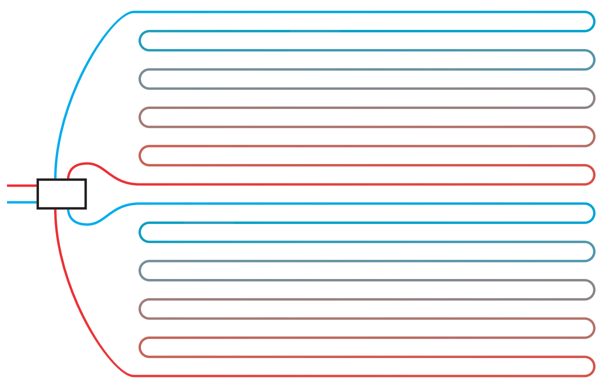
Pic. 47. The basic types of vertical heat exchangers for ground heat pumps

A special sinker bar is used to place the pipe in a bore-hole, as well as spacers, i.e. elements that make it possible to maintain an adequate distance between the supply and return pipes. This protects the pipes against thermal faults. After placing a probe inside the bore-hole, it is filled with a material providing good thermal conductivity. A good filling should provide thermal conductivity at least equal to that of the ground. The pipe that injects filling is introduced into the bore-hole together with the pipe of the heat exchanger. After filling the bore-hole, there should be no air gaps around the pipe, as they would insulate the pipe and limit thermal conduction. After installing the heat exchanger, check its air-tightness. The heat pump can be started up at least 7 days after installing the probe. If large-size ground source heat pump have been installed, it is recommended to perform a TRT (Thermal Response Test), which will precisely calculate the thermal efficiency of the ground.

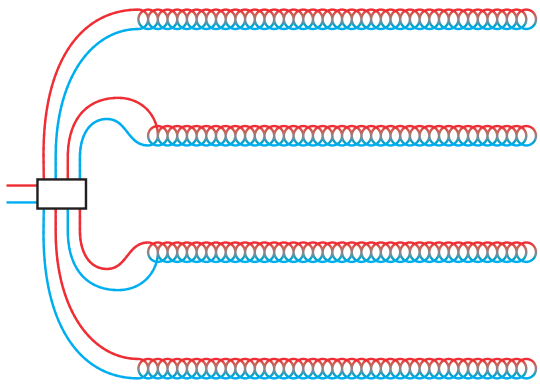
4.3.2. Horizontal heat exchanger

A horizontal heat exchanger does not require a building permit. Prior to its installation, notify the relevant local government agency about your intention to make one. The heat accumulated in the surface layers of soil comes mainly from solar radiation, although rainwater is also capable of regenerating soil. Therefore, locate the heat exchanger in a free area of the plot, i.e. without any development. The best option is to install it in an area with vegetation, which develops a shallow root system (a lawn is usually sown above the heat exchanger). A ground heat exchanger, which provides insufficient heat output (i.e. made incorrectly) can delay vegetation of plants.

There are two basic versions of a horizontal heat exchanger: meander and spiral.

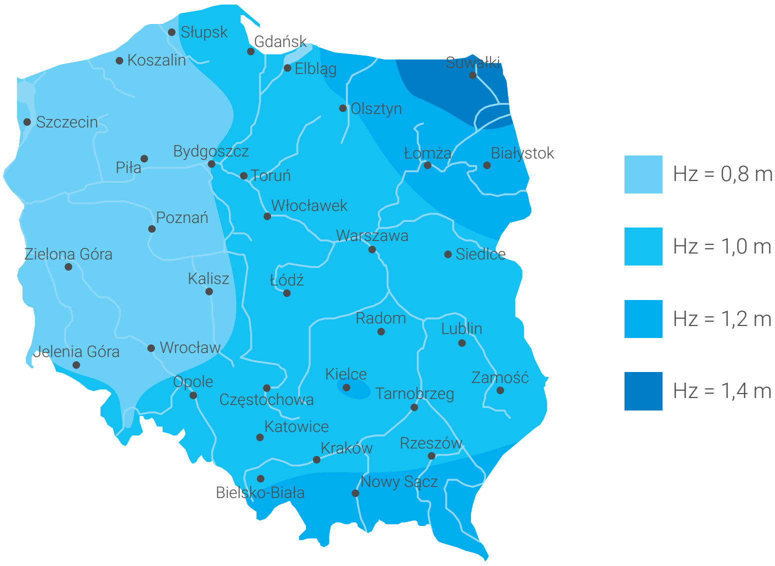


Pic. 48. A horizontal meander heat exchanger



Pic. 49. A horizontal spiral heat exchanger

A horizontal collector shall be located at the depth of 20-40cm below the freezing depth. There are 4 freezing depth zones distinguished in Poland. After completing excavation to the appropriate depth, install pipes in sand backfill (the type of pipe and soil determine the necessity to use sand backfill). It is recommended to use geotextiles under the sand backfill, if there are rocks at the bottom of the excavated hole. If using pipes of increased durability, it is possible to use clean, levelled, and stable subsoil, which can be placed on the bottom layer of the excavation, instead of sand backfill. Perform a pressure test, after completing pipe-laying. Place a warning tape 50cm above the heat exchanger pipes. Start a heat pump at least two months after the heat exchanger has been installed. A horizontal heat exchanger usually consists of several sections (loops). To connect them, install a distributor in the building or in an external well. Pipes connected to the distributor must be located at a suitable depth, as well. One must remember that pipes of the heat exchanger must be laid at the right temperature, as it determines the bending radius of the pipe.

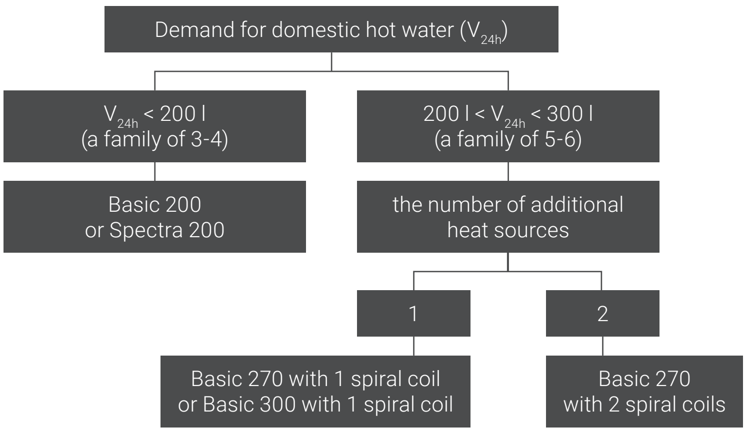


Pic. 50. Freezing depth zones in Poland, according to PN-EN 1997-1:2008

5. DESIGNING SYSTEMS WITH HEAT PUMPS FOR DHW

The most common solution is to connect a heat pump to a domestic hot water system (Basic, Spectra, Small), adding a boiler for central heating. In the winter season, the boiler provides hot water, while during the summer and transitional periods, it is provided by the heat pump. The user can already have a tank for utility water, and intends to have it connected to an ecological source of heat. In that is the case, it will be necessary to analyse the tank's suitability for use. If there is no tank, i.e. a new system will be designed, then we can choose a standard heater with a heat pump, or a high-power Airmax² heat pump (if large amounts of hot water are required, or the pump is to provide domestic hot water throughout the year, as the operating range of these units is up to -20°C), depending on the demand for hot water.

Heaters with a heat pump are used mainly in detached houses or in public utility buildings, where water demand does not exceed 300 litres. If the user chooses a heater with a heat pump, then the following two models are available: Spectra and Basic. A distinctive feature of the Basic heat pump is a 270l variant with one or two coil pipes. See below is for a handy diagram.



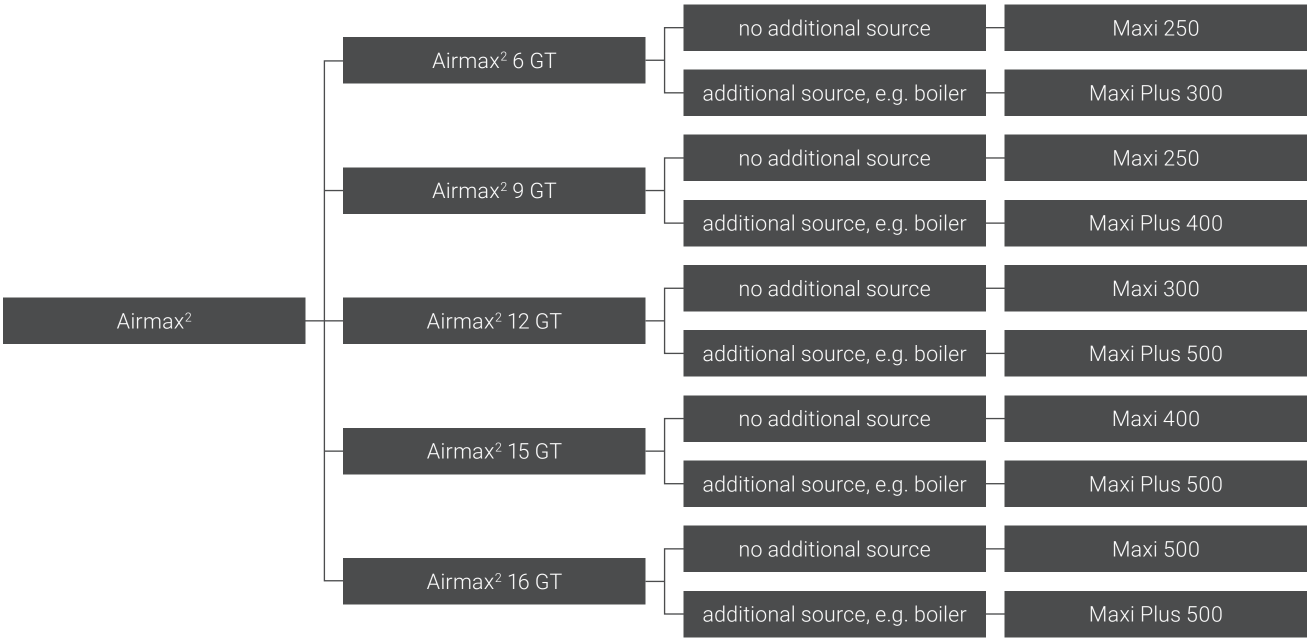
Use the Airmax² heat pump, if dealing with buildings with a high demand for domestic hot water, e.g. hotels, restaurants, residential communities, or if the heat pump is to provide water all year round (within the range of air temperatures from -20°C to +30°C). This solution can be implemented in combination with a Maxi or Maxi PLUS tank (two coil pipes for two heat sources). When selecting a suitable tank, take into account the surface of the coil pipe and the time required to heat up utility water. The table below shows surfaces of coil pipes (optimal and minimum). If a larger coil pipe is used for a given heat pump, it will not have any negative consequences. However, using a smaller coil pipe will result in an incorrect operation of the unit.

Table 39. Surfaces of coil pipes, when connecting the Airmax² heat pump

model of heat pump	minimum surface of coil pipe [m²]	optimum surface of coil pipe [m²]
Airmax² 6 GT	1,85	2,47
Airmax² 9 GT	2,43	3,24
Airmax² 12 GT	3,30	4,40
Airmax² 15 GT	4,18	5,57
Airmax² 16 GT	4,67	6,22
Airmax² 21 GT	6,29	8,39
Airmax² 26 GT	7,80	10,40
Airmax² 30 GT	8,95	11,93

Therefore, when designing any system with an Airmax² heat pump connected to the coil pipe, it is imperative to follow the recommendations for the minimum surface area of the coil pipe, when selecting the tank.

See below for tanks manufactured by Galmet, dedicated to specific models of Airmax² heat pumps. Selection of tanks is based on the minimum required surface area of the coil pipe in relation to the power of a heat pump. The higher the power of the heat pump, the bigger the required surface of the coil pipe and the larger the volume of the tank. The Maxi types of series is dedicated to tanks designed for heat pumps with a single coil pipe. Choose Maxi PLUS (a tank with two coil pipes), if you intend to connect an extra source to the tank, in addition to the heat pump itself.



It is always possible to select a low-power heat pump to work with a larger tank, if the Airmax² heat pump will be used only for supplying domestic hot water. For example, you can choose the Airmax² 6 GT heat pump to work with Maxi 500. However, at this point it is necessary to take into account the time required to heat up the water – it must not be too long, because the operating time of the compressor will exceed the recommended 2000 hours, annually. The heating time depends on the power of the heat pump, which is variable, as it depends on the temperature of outside air. Therefore, we must take into account the temperature of air for which we intend to achieve the specific heating time.

Heating time (t_n) can be calculated using the following formula:

$$t_n = \frac{\rho \cdot V/1000 \cdot c_p \cdot \Delta T}{Q_g \cdot 3600}$$

t_n - water heating time [h]

ρ - water density [kg/m³]

V - tank capacity [l]

c_p - specific heat of water [kJ/(kg•K)]

ΔT - temperature range of water heating [K]

Q_g - heating power of the heat pump [kW]

For example, in the case of the Airmax² 6 GT heat pump, use the performance characteristics of the unit, in order to read the heating power at 0°C (all performance data can be found in the publication). If we intend to heat up domestic hot water, it will be advisable to use the W55 characteristic curve, as it corresponds to a high-temperature application. See an example below:

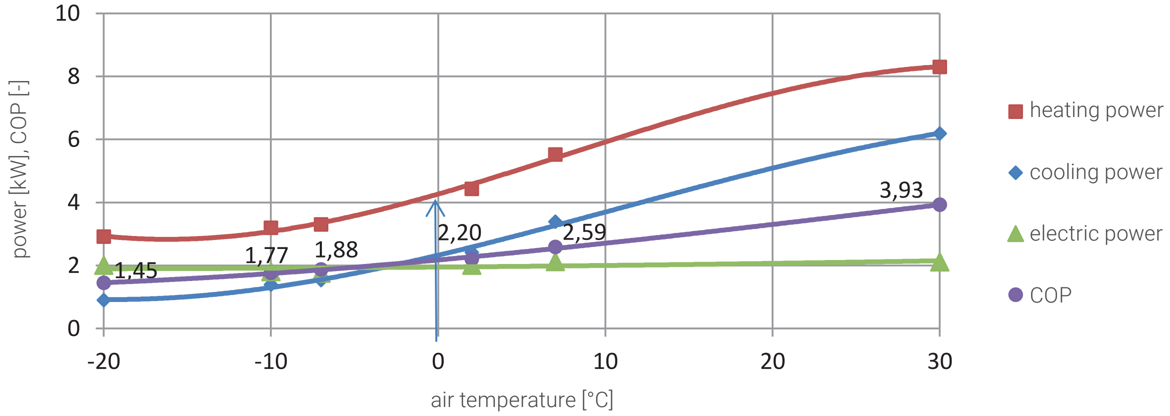


Diagram 52. A characteristic curve of the Airmax² 6 GT (W55) heat pump; determining the heating power at the outdoor air temperature of 0°C

In the case of Airmax² 6 GT, the heating power is 4.3 kW at the supply air temperature of 0°C. Consequently, the time required to heat up 500l of water from 10°C to 55°C, for example, will be:

$$t_n = \frac{1000 \cdot 500/1000 \cdot 4{,}189 \cdot 45}{4{,}3 \cdot 3600} = 6{,}09 \text{ h}$$

It may take slightly longer, due to the losses from the tank to the environment. See below for the characteristic curve demonstrating the estimated heating times of a given volume of water, using the Airmax² 6 GT heat pump. The lower the temperature of supply air, the longer the heating time (this results from a decrease in the heating power of the unit).

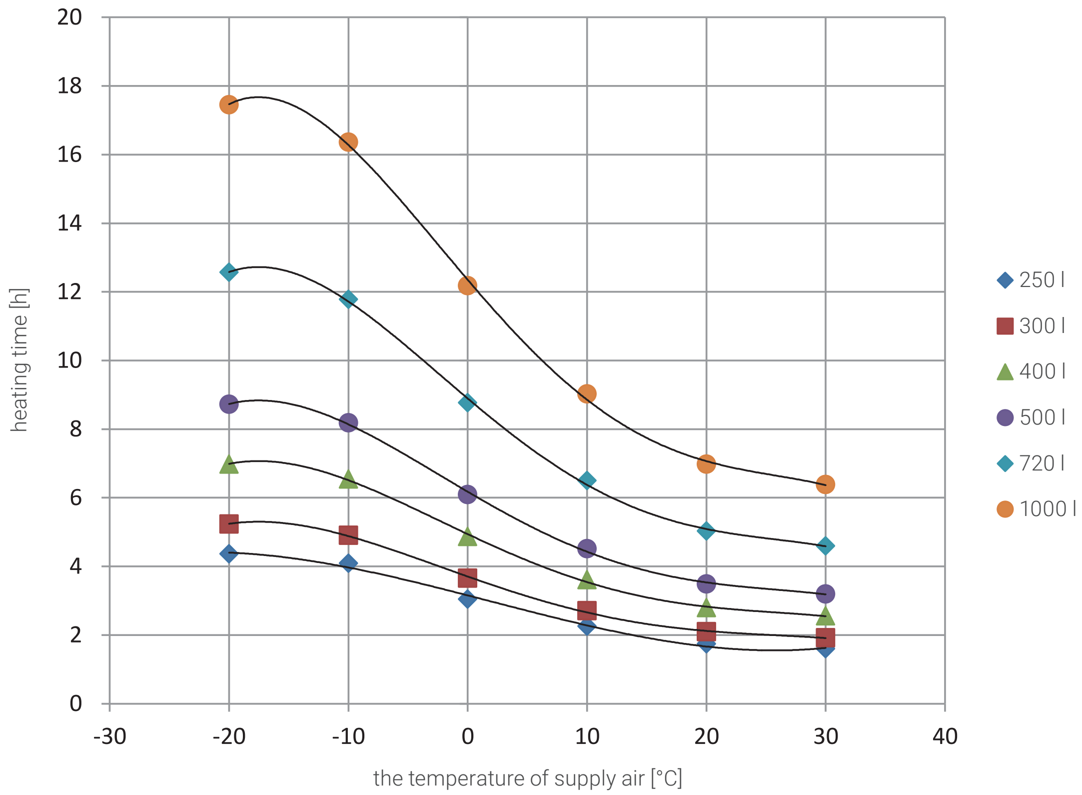


Diagram 53. Airmax² 6 GT - the estimated heating time of tanks of 250-1,000l in volume (AT=45K)

As mentioned above, the operating time of the compressor should not exceed 2,000h/year. It may be problematic to estimate this value, since the power output of the unit changes in correspondence to the various atmospheric conditions throughout the year. When determining the estimated operating time of the Airmax² heat pump used for domestic hot water , one can use the average temperature of outside air in a given location and the heating power corresponding to it.

The operating time of the Airmax² heat pump for domestic hot water throughout the year (t_r) can be calculated using the following formula:

$$t_r = \frac{\rho \cdot V/1000 \cdot c_p \cdot \Delta T}{Q_{g(T_{avg})} \cdot 3600} \cdot n_d$$

t_r - the operating time of the heat pump throughout the year [h/year]

ρ - water density [kg/m³]

V - tank capacity [l]

c_p - specific heat of water [kJ/(kg•K)]

ΔT - temperature range of water heating [K]

$Q_{g(T_{avg})}$ - heating power of the heat pump for the annual average air temperature [kW]

n_d - number of days in a year

The average annual temperature in Poland can be assumed to be 8°C, for the purpose of preliminary calculations. See the table below for more accurate temperature values for individual cities.

Table 40. The average annual outdoor temperature for each individual location

city	the average annual outside temperature [°C]
Białystok	6,7
Bielsko-Biała	7,8
Gdańsk	7,9
Jelenia Góra	6,9
Kalisz	7,9
Katowice	7,8
Kielce	7,2
Kołobrzeg	7,6
Kraków	8,0
Kłodzko	7,3
Legnica	8,4
Łódź	7,6
Mikołów	6,9
Nowy Sącz	7,9
Olsztyn	6,9
Piła	7,6
Przemyśl	7,9
Suwałki	6,0
Szklarska Poręba	6,9
Terespol	7,2
Warszawa	7,8
Wrocław	8,4
Zakopane	5,0
Zamość	7,2
Zgorzelec	6,9
Zielona Góra	8,2

For example, the operating times of the compressor of the Airmax[2] 6 GT heat pump have been compared, assuming a 24h demand of 500l and 1,500l. Regarding the particular heat pump, the value of $Q_{g(T_{avg})}$ read from the characteristic curve is 5.8kW, assuming that the number of days in a year is 365 and the average annual temperature 8°C.

Demand of 500 l/day:

$$t_n = \frac{1000 \cdot 500/1000 \cdot 4{,}189 \cdot 45}{5{,}8 \cdot 3600} = 1648\ \text{h}$$

Demand of 1500 l/day:

$$t_n = \frac{1000 \cdot 1500/1000 \cdot 4{,}189 \cdot 45}{5{,}8 \cdot 3600} = 4943\ \text{h}$$

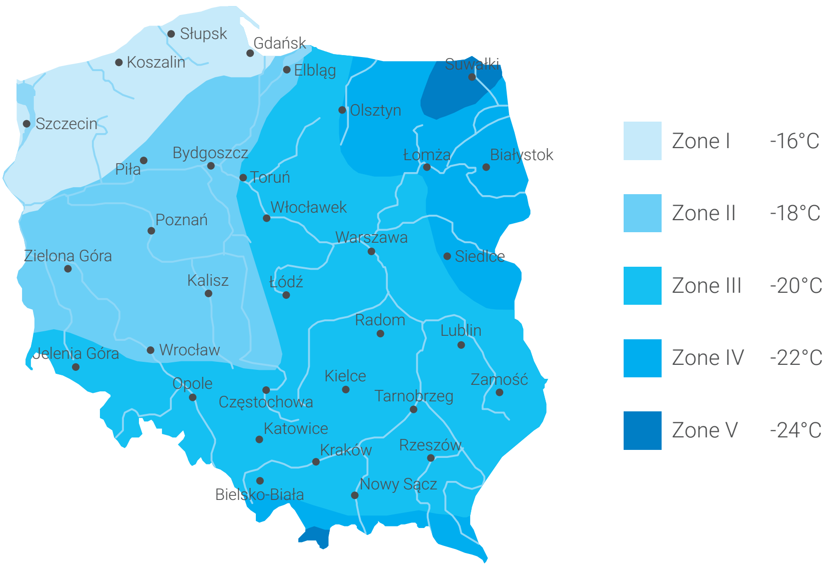
With a demand of 500l/day, the estimated operating time of the compressor is correct (less than 2,000h/year). However, given the demand of 1,500l, the estimated operating time of the compressor is well above the recommended threshold. In this case, select a heat pump of higher power.

6. DESIGNING SYSTEMS WITH HEAT PUMPS FOR CH AND DHW

It is necessary to optimally select the following three components to ensure the proper operation of a heat pump:

- Installation of a lower source (it will be simpler, if an air pump is used)
- A heat pump (correct selection of its type and power output, and its operating mode)
- Installation of an upper source (heating system – a low-temperature one gives best results, a tank for utility water, and a buffer for heating water)

The first step in selecting a unit dedicated to a particular building is to determine its **thermal load ($Q_{building}$)**, i.e. power losses generated in the building. The value of demand is expressed as the total value in kW, W, or in the form of individual demand expressed in W/m². This demand should be calculated in compliance with PN-EN 12831, and it depends on the degree of insulating power of the building, the applied construction technologies, as well as on the climatic zone in which the building is located. In order to determine the value of demand, we need to take into account the losses occurring through transparent and opaque partitions, the roof, and the ground, as well as ventilation losses. As far as climate zones are concerned, Poland is divided into 5 zones. A design outdoor temperature has been determined for each of the zones. This is the temperature at which heat losses from the building are calculated.



Pic. 51. The climate zones in Poland, according to PN-EN 12831

If no accurate information regarding the demand is available, we can use the estimated values of individual demand for buildings erected in different years, as shown in the table below.

Table 41. The estimated individual demand for heat in buildings, corresponding to the period of time in which they were erected

individual demand for heat [W/m²]	type of building
130-200	buildings dating from before 1980
70-130	buildings dating from before 1990
60-100	buildings dating from before 2000
40-60	buildings dating from before 2005
10*-50	new buildings

* Passive housing standard

The product of the individual demand for heat and the heated area makes it possible to calculate **($Q_{building}$)**:

$$Q_{building} = q \cdot A$$

q - individual demand for heat [W/m²]

A - the heated are of the building [m²]

Estimating on the basis of house types is another possibility to approximate the value of heat demand.

Table 42. The estimated individual demand for heat in buildings, corresponding to their type

individual demand for heat [W/m²]	type of building	the standards applied
100-200	building not thermally improved	no thermal insulation, double glazing, gravity ventilation
60-80	building after thermal improvement	thermal insulation, double glazing, gravity ventilation
40-50	new buildings	thermal insulation, thermally insulated panes, gravity ventilation
25-40	low-energy buildings	thermal insulation, thermally insulated panes, recuperation
10-15	Passive buildings	thermal insulation, thermally insulated triple glass, recuperation

For example, assuming the individual demand of 50W/m² on the basis of the table above, the heat demand for a newly built single-family house with the heated area of 150m² will be:

$$Q_{building} = 50 \cdot 150 = 7500 = 7{,}5 \text{ kW}$$

The next phase is to determine the hot water demand, and then **additional power required for domestic hot water (Q_{dhw})**. As a standard, the demand for one person per day is 50l/day, but it depends on individual requirements of residents. This additional power can be assumed to be 0.25kW per person.

$$Q_{dhw} = 0{,}25 \text{ kW} \cdot n$$

n - the number of people using utility water

For example, in there are 4 residents in a house:

$$0{,}25 \text{ kW} \cdot 4 = 1 \text{ kW}$$

Summing up the heat demand of the building and the additional power for domestic hot water, it is possible to calculate the total required **peak heating power of the unit (Q)**.

$$Q = Q_{building} + Q_{dhw}$$

$Q_{building}$ - heating power required for central heating

Q_{dhw} - additional power for domestic hot water

If operation of heat pumps is temporarily interrupted by the electricity supplier, one must take into account additional power required for that purpose – however, this seldom happens. Summing up the determining the demand for heating power:

heat demand of the building
- estimated value
- the exact value acc. to PN-EN 1026:12831

→ additional power for domestic hot water
- 0,25 kW per person

→ the total required heating power
- optionally, take into account the time of interrupting the operation of heat pumps

6.1. Operating modes for heat pumps - the bivalent point

When designing a system with a heat pump, it is necessary to specify its operating mode.

The monovalent mode: The heat pump provides 100% of the building's heat demand. The total heat load is only satisfied by the heat pump. It is the only source of heating.

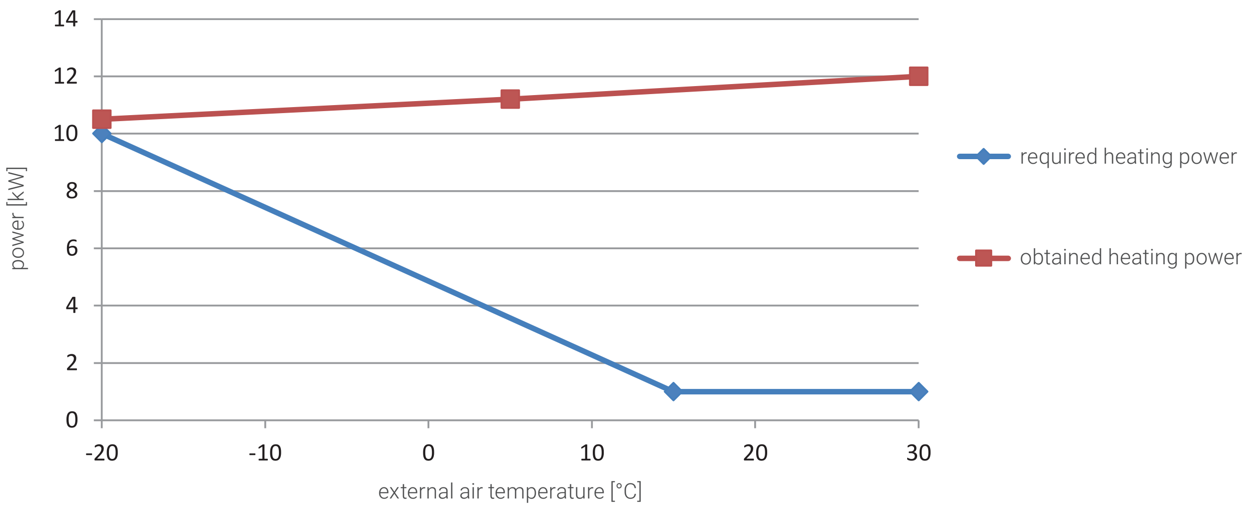


Diagram 54. The monovalent mode

The output of the heat pump is greater than the required output, within the entire range of outside air temperatures. The monovalent mode is intended mainly for ground heat pumps, which offer relatively stable power during the whole heating season. However, air pumps can also operate in this mode. It depends on the selected unit. Nonetheless, one must bear in mind that it is not advisable to select air pumps to operate in the monovalent mode, because their power will significantly decrease in low temperatures of the outside air. Therefore, the air pump selected for monovalent operation must be significantly oversized. On the other hand, as mentioned above, the number of days when the outside temperature is continuously low is rather small. Consequently, such a decision would be unjustified economically.

It is necessary to get acquainted with the concept of a bivalent point, in order to move forward with presenting subsequent operating modes. If the output of a heat pump is lower than the required heating output, within a certain temperature range, then the intersecting curves create a **bivalent point**.

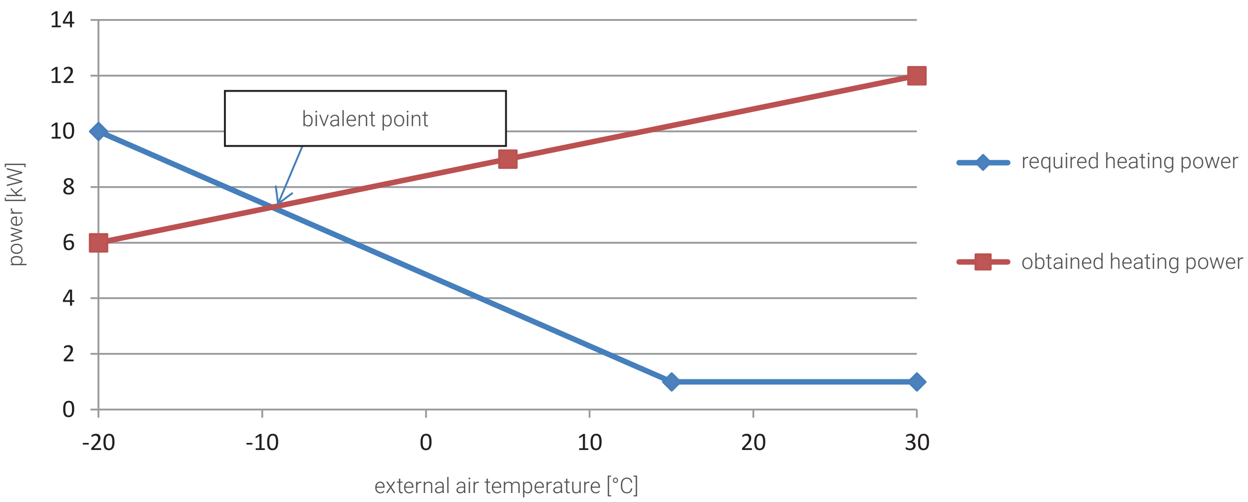


Diagram 55. An example of a bivalent point

When below the bivalent point, a heat pump must be supported by an additional source. If it is an electric heater, then it will lead to the mono-energy mode, as both sources are dependent on the current. If the supporting source is independent of the electric power, the pump will operate in the bivalent mode. An example of such an additional source is a boiler for central heating. Consequently, moving forward to other possible operating modes for a heat pump, we can distinguish the following:

The parallel mono-energy mode: The heat pump is supported by an electric heat source, i.e. a heater. The parallel mode is distinguished by the heater operating in parallel with the pump, below the bivalent point, which means that it only compensates for the power shortage of the heat pump.

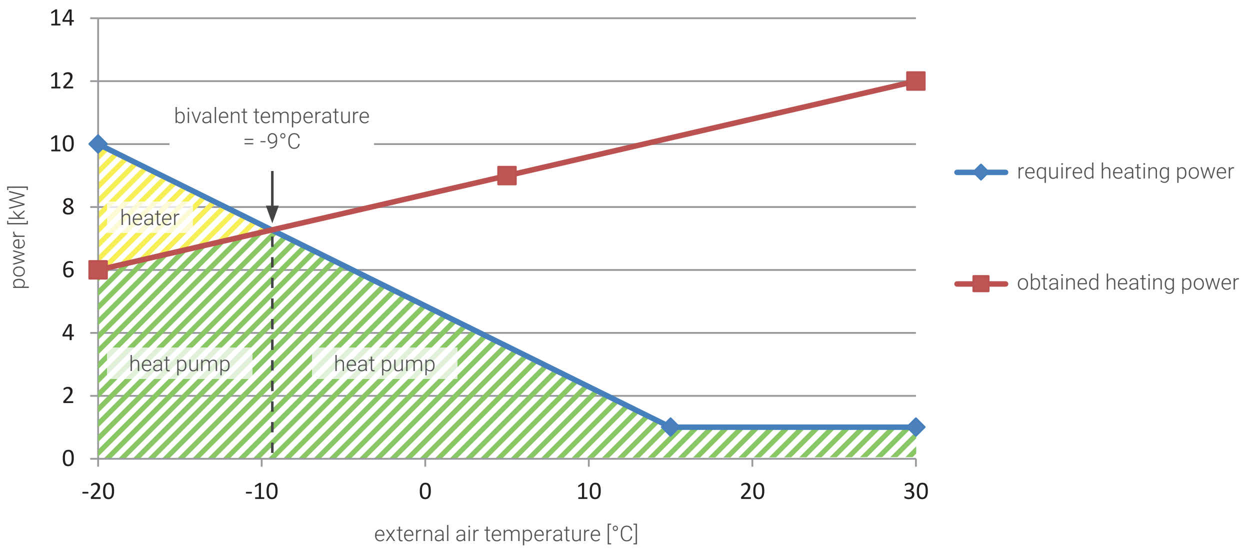


Diagram 56. The parallel mono-energy mode

Above the bivalent temperature, the heat pump has sufficient power to satisfy the heat demand. However, power shortage occurs below the bivalent point, which means that the heater starts operating simultaneously with the heat pump. This mode is dedicated for air pumps (e.g. Airmax[2]). Select power rating of the heat pump in such a way that the bivalent point for a given building is around -10°C.

The alternative mono-energy mode: The heat pump is supported by an electric heat source, i.e. a heater.

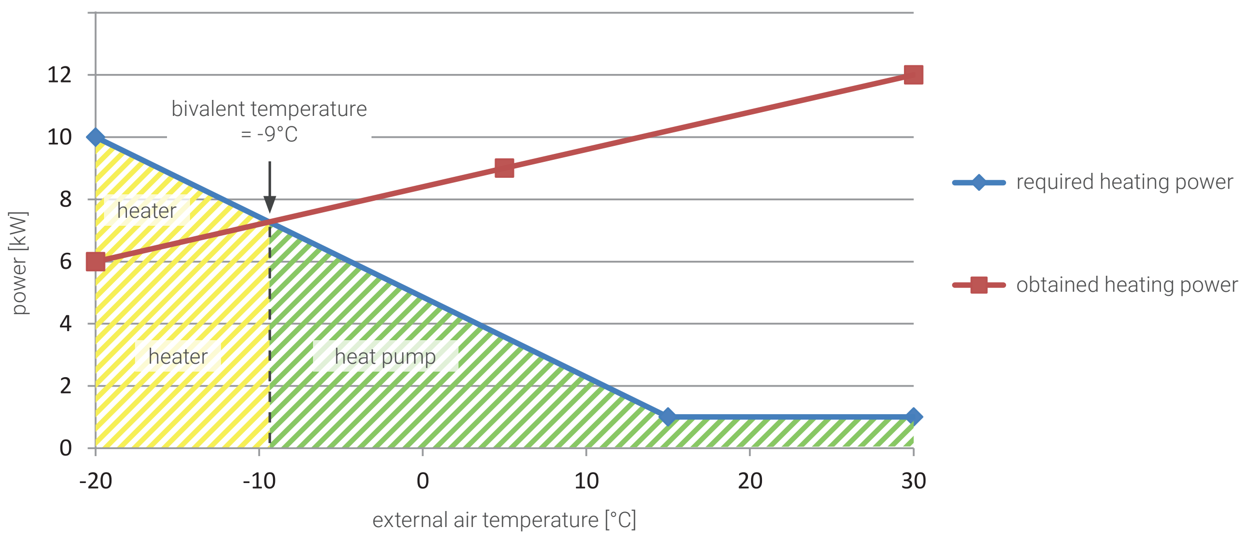


Diagram 57. The alternative mono-energy mode

The alternative mode is distinguished by the heat pump switching off below the bivalent point, leaving the heater to work on its own. As far as the Galmet algorithm for pump control is concerned, such a situation generally does not occur. The situation in which the heater operates on its own can only occur, if the compressor has exceeded its working range.

The parallel bivalent mode: The heat pump is supported by a heat source powered by a different energy (gas, coal, oil, etc.), i.e. a gas boiler.

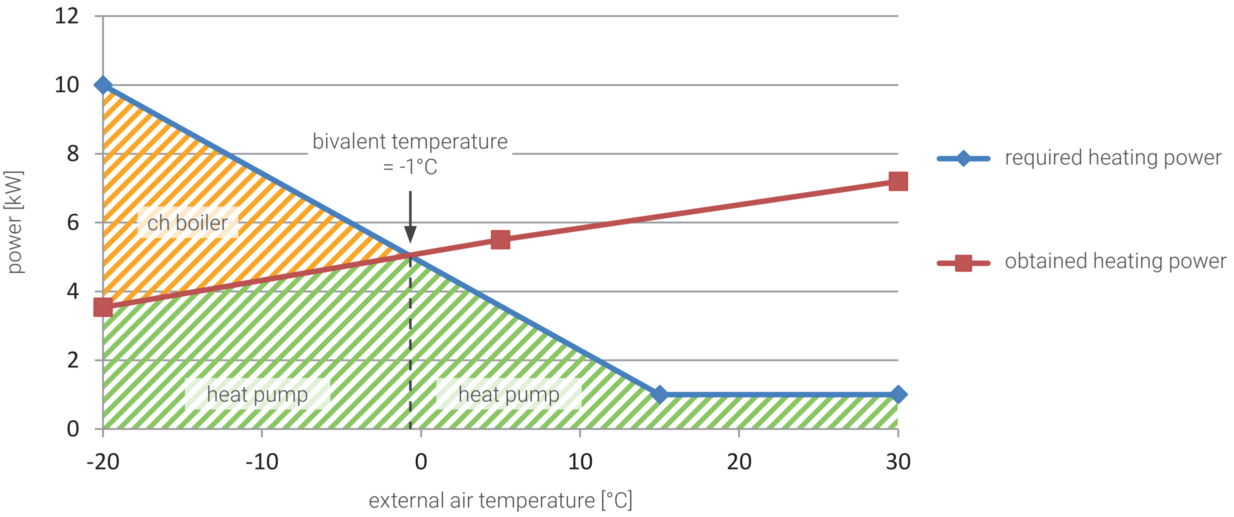


Diagram 58. Parallel bivalent mode

This mode is usually used for the purpose of thermal efficiency improvement. If we already have a boiler operating as part of the system, but we intended to install a heat pump to improve the efficiency of our boiler room, the pump will operate in the bivalent mode. The heat pump will operate on its own, if its power is sufficient to satisfy the demand of the building in the given outdoor temperatures. However, if its output reaches insufficient values, in terms of demand, the boiler will be activated to provide a supporting source of heat. In the parallel operating mode, the boiler and the heat pump operate simultaneously.

The alternative bivalent mode: Below the bivalent temperature, the heat pump is replaced by a source of heat powered by a different energy (gas, coal, oil, etc.), i.e. a coal boiler.

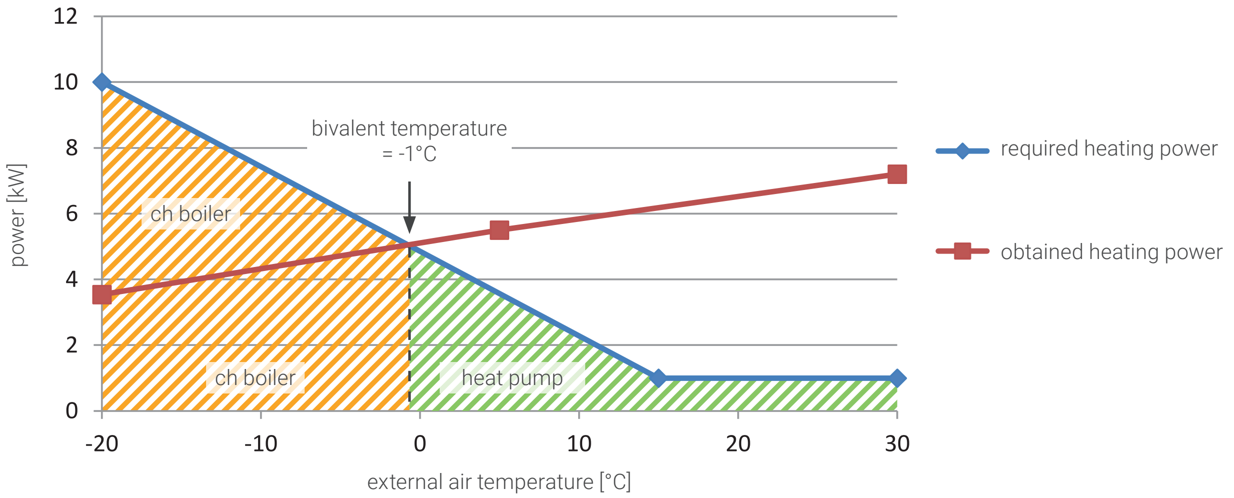


Diagram 59. The alternative bivalent mode

As previously indicated, the bivalent mode is usually used to improve the efficiency of our boiler room. Above the bivalent point, the heat pump works on its own. Below the bivalent temperature, a coal boiler takes over the role of the source of heat. In the alternative mode, we assume that the heat pump is switched off.

6.2. Designing systems with an air heat pump for CH and DHW - Airmax^2

6.2.1. Determining the bivalent temperature

Heat pumps, which are part of the air/water system, usually operate in the mono-energy mode, so it is allowed to support them with an electric heater. Although it is also possible to make the pump operate in the monovalent mode, it is recommended to select the mono-energy mode with the bivalent temperature around -10°C (this generates lower investment costs, which sometimes even reduces the operating costs). To determine the bivalent temperature, use the characteristic curves of the heat pump and the building. In relation to the first of the two, select W55 for high-temperature applications, and W35 for low-temperature applications. **The characteristic curve of the building**, i.e. the relationship between the power demand and the outside temperature, can be plotted as follows:

- Point A is the value of the maximum heat demand at the design outdoor temperature (Q).
- Point B is the value of the required power at the maximum heating temperature.

The point at which both characteristic curves intersect is exactly the bivalent point. The hatched area in the following diagram is the amount of heating power that must be replenished by a heater or other additional source of heat. It results from the fact that the required heating power is higher than the available power output of the heat pump, below the bivalent temperature.

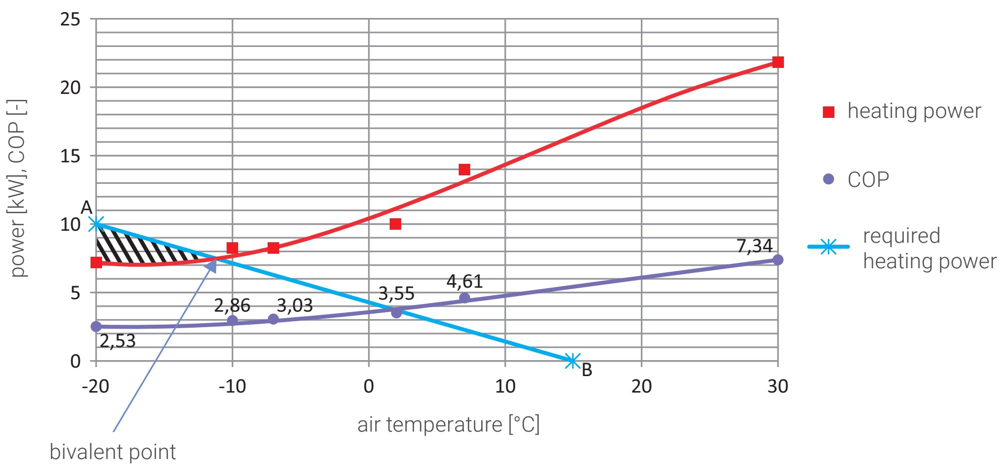


Diagram 60. Determining the bivalent point

Table 43. Temperature thresholds for different types of buildings

type of building	temperature threshold [°C]
no thermal improvement	18
thermal improvement	15
new building	15
low-energy	12
passive	10

In the sample diagram above, the temperature of 15°C was assumed for both new and thermally improved buildings. If a heat pump is also used to supply hot water, then the heating power of the building at the threshold temperature, and at any higher temperature, will be equal to the additional power required for domestic hot water. This is the situation demonstrated in the sample characteristics shown below.

6.2.2. An example of using the Airmax^2 15 GT pump in different types of buildings

See below for an analysis of the Airmax^2 15 GT heat pump used to heat buildings of various total areas (having different design heat loads). The same individual heat demand of 50 W/m^2 was assumed for all the buildings. Since the analysis was based on an underfloor heating system, the W35 operating characteristics were adopted for the heat pump. In each case, the additional power for domestic hot water was also taken into account. - 1 kW (200l/24h, 4 people). Then, the following four characteristic curves were plotted:

- 440 m^2, $Q_{building}$ = 22 kW, Q_{dhw} = 1 kW, Q = 23 kW
- 280 m^2, $Q_{building}$ = 14 kW, Q_{dhw} = 1 kW, Q = 15 kW
- 160 m^2, $Q_{building}$ = 8 kW, Q_{dhw} = 1 kW, Q = 9 kW
- 120 m^2, $Q_{building}$ = 6 kW, Q_{dhw} = 1 kW, Q = 7 kW

The design outdoor temperature was adopted for climate zone III: -20°C. The temperature threshold for a new building - 15°C.

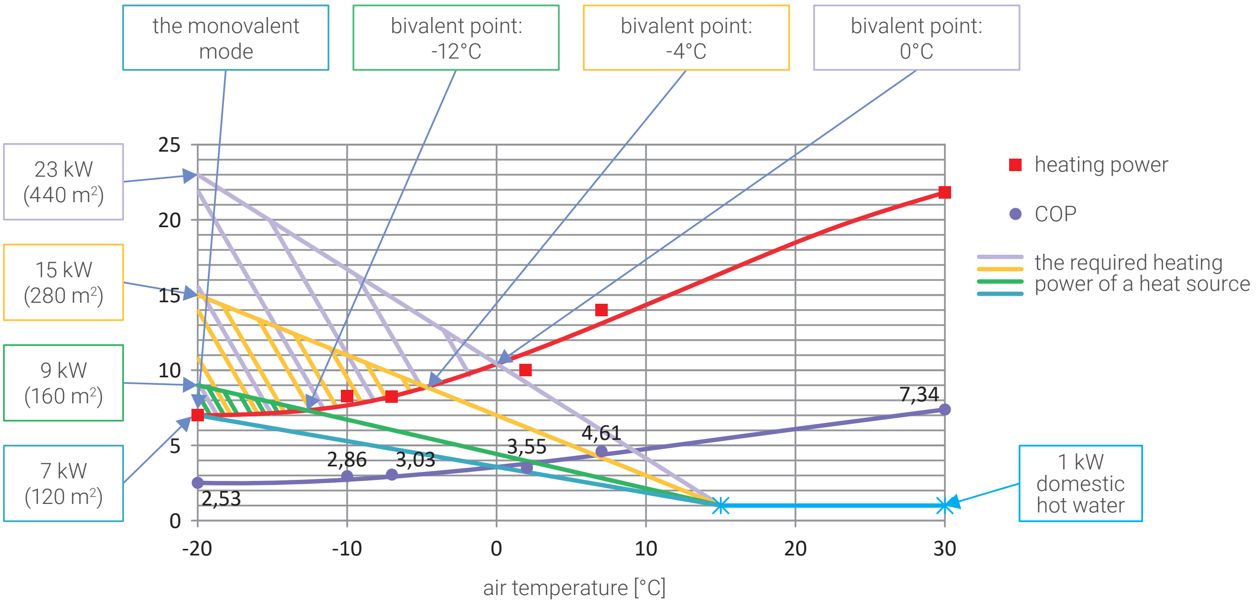


Diagram 61. Use of the Airmax²15 GT heat pumps in four different buildings with underfloor heating systems and heat demand of 200l/24h

In the building with the smallest heated area (120m²), the Airmax² 15 GT heat pump would operate in the monovalent mode, i.e. the pump would satisfy 100% of the building's heat demand.

- 120 m² - the monovalent mode; the pump does not require any support

As mentioned above, this mode is not usually used in systems equipped with an air pump. High power of a heat pump entails higher investment costs, and makes it necessary to select a tank for domestic hot water equipped with a coil pipe of sufficiently large surface area.

Bivalent points were obtained for the successive buildings, which means that a heat pump installed in such building would operate in the mono-energy or bivalent mode:

- 160 m² - the bivalent point is at -12°C and the green hatched area (operation of a supporting source) is small
- 280 m² - the bivalent point is at -4°C and the yellow hatched area (operation of a supporting source) has grown significantly
- 440 m² - the bivalent point is at 0°C. The additional source will have to provide the majority of required energy. The pump will have to run in the bivalent mode, as a 7kW heater installed in the heat pump will not be sufficient. Choosing the alternative bivalent mode, select a boiler to operate at the peak power, i.e. 23kW. If the parallel bivalent mode is used, then the power of the boiler should replenish the shortage of power on the side of the heat pump (the difference between the peak demand and the pump's power at the design temperature), which is 16kW in the example above.

To sum up, as shown in the example above, the building of 160m²should have an Airmax² 15 GT heat pump operating in the mono-energy mode, because it is the case in which we have reached the bivalent temperature closest to the recommended -10°C.

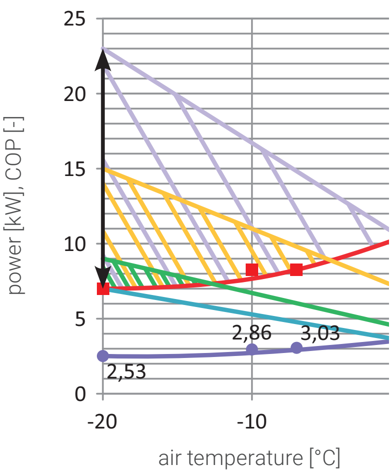


Diagram 62. Determining the power of an additional source in the parallel bivalent mode

6.2.3. Analysing a selection of Airmax² heat pumps for a sample building

The following analysis is based on a single building for which four heat pump models have been compared. The building has a heated area of 160m² and standard demand of 50 W/m² ($Q_{building}$ = 8 kW), and its domestic hot water consumption is 200l/24h, Q_{dhw} = 1 kW, Q = 9 kW.

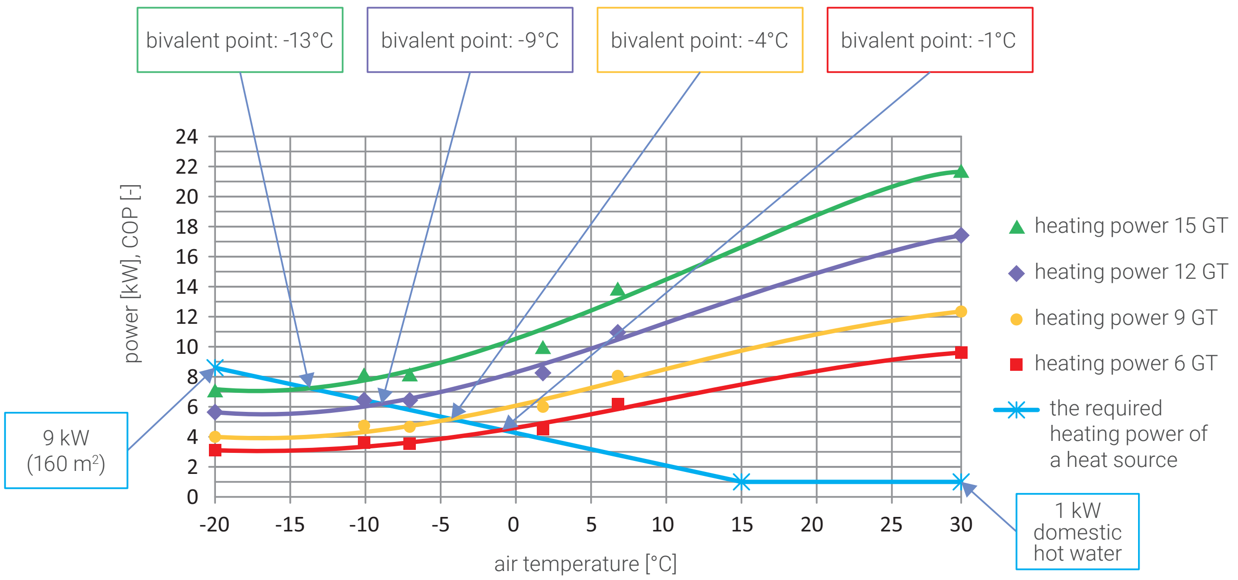


Diagram 63. The use of four models of Airmax² heat pumps in a sample building with underfloor heating, heat demand of 8kW and additional power required for domestic hot water 1kW

The following bivalence points were obtained:

- Airmax² 6 GT: -1°C
- Airmax² 9 GT: -4°C
- Airmax² 12 GT: -9°C
- Airmax² 15 GT: -13°C

In the building shown in the example, any Airmax² heat pump can be operated in the mono-energy mode, as power shortage even for the smallest of the pumps is less than the power of the heater built into the pump. The required minimum heater power is the difference between the maximum heat demand of the building and the power of the heat pump at the design temperature. Referring to the above example, the difference for Airmax² 6 GT is shown in the diagram below:

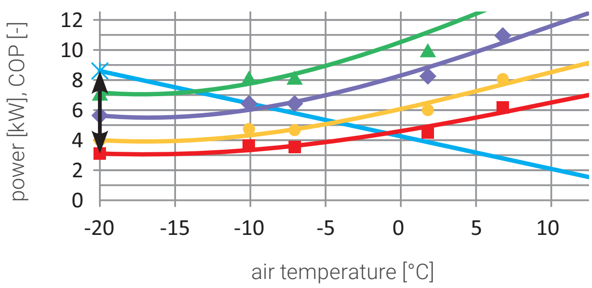


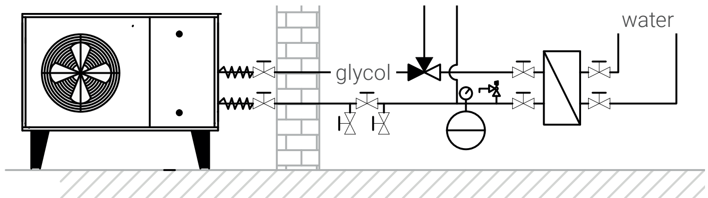
Diagram 64. Determining power shortage of the heat pump, i.e. the minimum heater power for Airmax² 6 GT in the mono-energy mode

As shown in the diagram above, the minimum power requirement for the heater of Airmax² 6 GT is 6kW. This pump model has a 7kW heater, which means that the pump supported by the heater can heat up the building. However, if 6 and 9 GT pumps were in operation, it would involve providing a large portion of electric energy by the heater. Therefore, it is recommended to choose the 12-15 GT models (as their bivalent temperature is closer to the suggested -10°C).

To sum up, any heat pump can be adapted to the needs of any building, but it is important to know the assumptions it should meet, i.e. the mode it will operate in and the preferred temperature of the bivalent point.

6.2.4. Airmax² - Installation requirements

- 3-phase voltage, 400 V is required
- It is necessary to ensure draining of condensate, which is generated naturally during operation of the pump, and also during defrosting. It is possible to use gravel foundation.
- When choosing a location for installation, take into account the noise emission from the unit.
- The pump will be installed outside the building, so any heating water present on the outside could freeze, leading to damage to the system and/or the unit. For this reason, it is recommended to use glycol in heating systems or glycol/water heat exchangers. The use of a heat exchanger allows the heating system to be filled with water. Glycol protects the system against freezing, on the outside. It is recommended to use glycol with a freezing point of -30°C. As an intermediate heat exchanger a glycol/water plate heat exchanger can be used or a SG(B) buffer tank with large enough spiral coil.



Pic. 52. Use of a glycol/water plate heat exchanger in installations with Airmax² heat pump

Table 44. Dedicated glycol/water plate heat exchangers for systems with the Airmax² heat pump

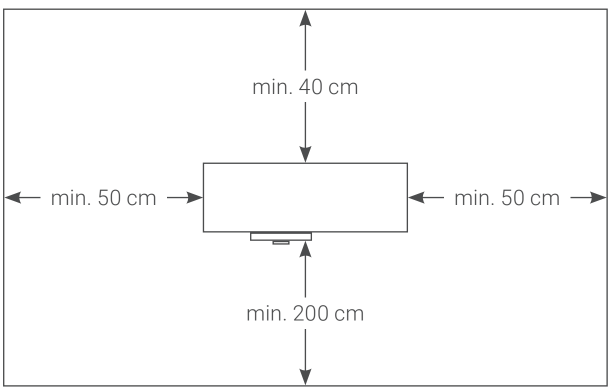
model of heat pump	dedicated plate heat exchanger	catalogue No.
Airmax² 6-9 GT	SWEP 40	09-000102
Airmax² 12-16 GT	SWEP 60	09-000103
Airmax² 21 GT	SWEP 70	09-000104
Airmax² 26-30 GT	SWEP 100	09-000105

Table 45. Dedicated SG(B) buffer tanks for installation with an Airmax² heat pump

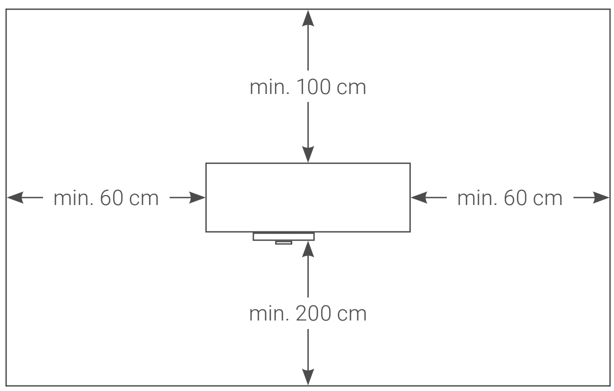
model of heat pump	dedicated buffer tank	coil surface (as a glycol/ water heat exchanger)	storage capacity of the buffer tank	catalogue no.
Airmax² 6-9 GT	SG(B) Maxi 300	3,8 m²	284 l	71-304100N
Airmax² 12-15 GT	SG(B) Maxi 400	6,0 m²	366 l	71-404100N
Airmax² 16 GT	SG(B) Maxi 500	7,5 m²	459 l	71-504100N

Connecting a heat pump to an exchanger with not enough heat exchange surface will result in a high pressure error in the heat pump.

- When installing the unit, maintain sufficient distances from the surrounding elements. The minimum distance from a wall is 40cm or 100cm, depending on the model. Since air is ejected from the unit to the front, it is recommended to keep an adequate distance from the front face of the unit. In terms of optimal positioning of the unit in relation to the cardinal directions, this depends on the function of the heat pump. If the unit is operated for domestic hot water, it is recommended to install it on the north side, so that the pump does not exceed the operating range, in high temperatures. On the other hand, it is recommended to install the pump on the south side, if it will only provide heat for the building. Naturally, the goal here is to achieve the most favourable air temperatures possible, also bearing in mind the risk of having excessive temperatures in the summer. The problem can be alleviated by using shading or roofing.

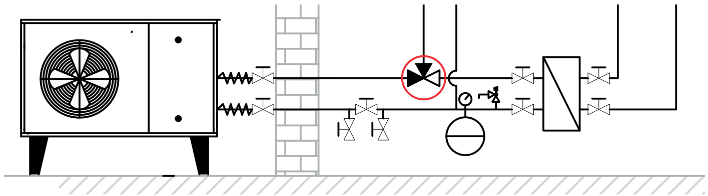


Pic. 53. The required mounting distances for Airmax² 6-15 GT (view from top)

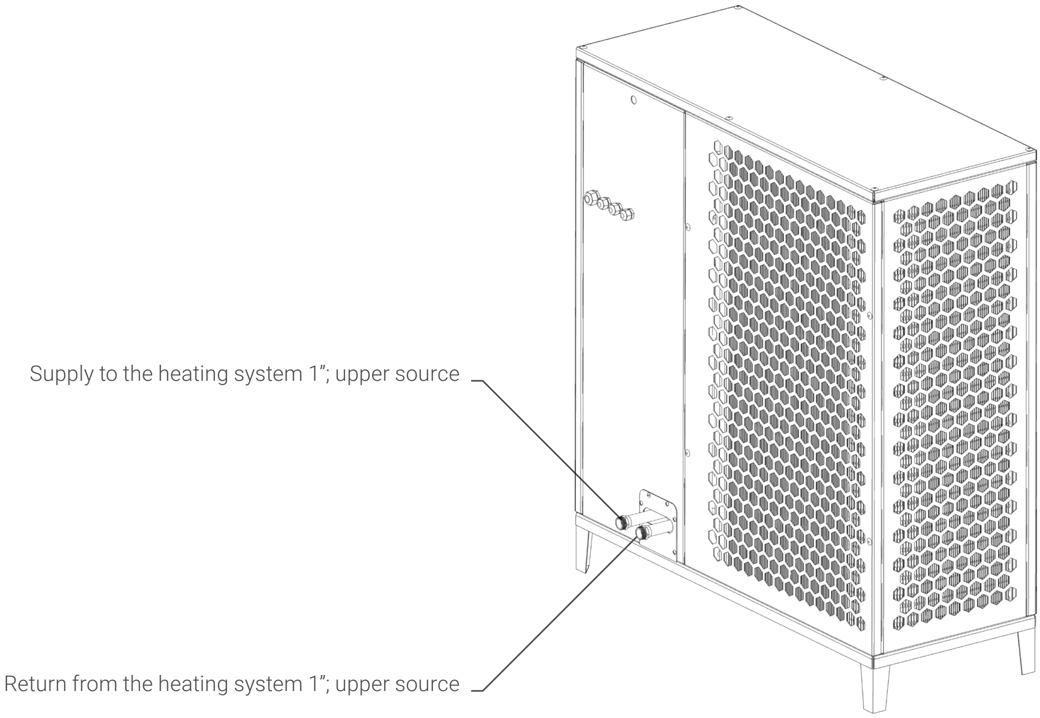


Pic. 54. The required mounting distances for Airmax² 16-30 GT (view from top)

- The heat pump must be connected to a Maxi or Maxi PLUS tank, if it will provide domestic hot water. Maxi tanks are also available in a combined version - combined in one housing with a buffer, but hydraulically independent. These are tanks featuring a coil pipe of a larger surface area to connect a heat pump. Hot water is supplied via a three-way switching valve. It is also possible to use a combined tank (a tank within a tank - Kumulo) or a sanitary stratified tank (Multi-Inox).

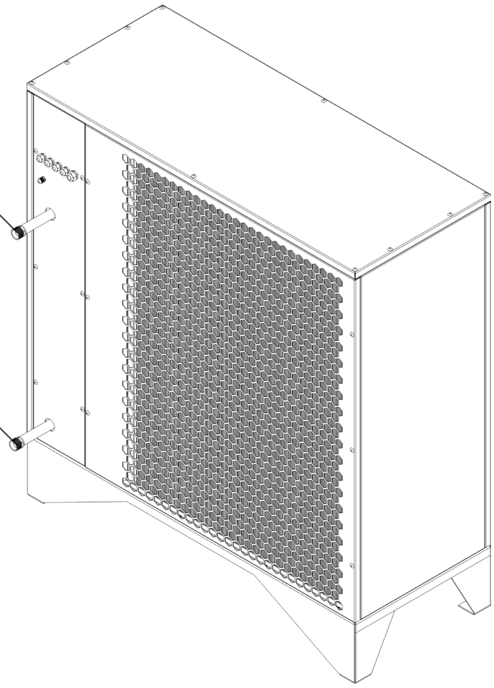


Pic. 55. A three-way switching valve



Pic. 56. A diagram of hydraulic connections for the Airmax² 6-15 GT heat pump

DESIGNING SYSTEMS WITH HEAT PUMPS FOR CENTRAL HEATING AND DOMESTIC HOT WATER



Pic. 57. A diagram of hydraulic connections for the Airmax² 16-30 GT heat pump

Table 46. A dedicated three-way valve with an actuator for Airmax² heat pumps

Heat pump model	Technical specification		Catalogue No.
Airmax² 6-16 GT	AZV 643 G1" upper source, Kvs 8m³/h	A valve with an actuator	M-006896
Airmax² 21-30 GT	VBI60.40-25L G6/4" GW, Kvs 25m³/h	Valve	09-000201
	GLB341.9E	Valve actuator	09-000200

- It is recommended to make the connection using a copper pipe of the correct internal diameter, taking into account its thermal insulation.

Table 47. Inner diameters of pipes connected to Airmax² heat pumps

Heat pump model	Connection – the inner diameter of a pipe [mm]
Airmax² 6 GT	Ø 20
Airmax² 9-16 GT	Ø 26
Airmax² 21-30 GT	Ø 32

- In systems where a hydraulic separator is required, it is possible to use the SG(B) buffer tanks with capacities from 40 to 140 l.

6.2.5. Airmax² - Selecting a tank for domestic hot water (Maxi, Maxi Plus)

It is necessary to select a tank with a larger surface area of the coil pipe intended to work with the heat pump, in order to supply domestic hot water to the heat pump. To ensure the correct operation of the heat pump providing domestic hot water, it will be necessary to ensure an adequate **surface area of the coil pipe (A_m)**. It is assumed that 0.4 m² of the coil pipe's surface area is required per 1kW of the nominal capacity of the heat pump, to ensure optimum selection. The minimum threshold is 0.3 m².

$$A_w = Q_n \cdot p_w$$

Q_n - rated power of the heat pump at the A7W35 operating point [kW]

p_w – the optimum coefficient is 0.4 and the minimum coefficient is 0.3 [m²/kW]

For example, the rated heating power for the Airmax² 9 GT heat pump is 8.11kW, calculating the required surface are of the coil pipe, according to the formula above:

$$A_w = 8{,}11 \cdot (0{,}3 \div 0{,}4) = 2{,}43 \div 3{,}24 \text{ m}^2$$

Therefore, it is possible to choose the Maxi 250 tank with the coil pipe's surface area of 3m², or Maxi 300 with the coil pipe's surface area of 3.8m². When selecting a tank with two coil pipes, you can use Maxi PLUS 400 with a coil pipe of the surface area of 3.8m² to work with the heat pump. See below for a table with tanks for domestic hot water dedicated to the Airmax² series of heat pumps.

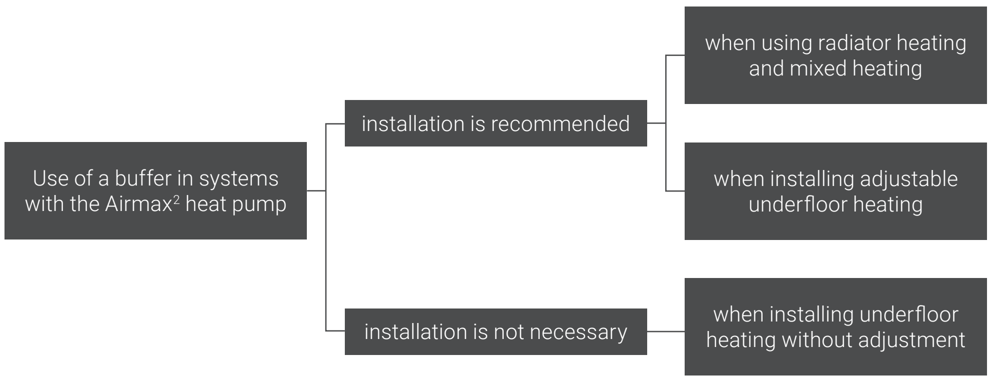
Table 48. The suggested Maxi and Maxi PLUS tanks for Airmax² heat pumps

heat pump model	surface area of the coil [m²]		suggested Maxi tank	surface area of the coil pipe in a Maxi tank [m²]	suggested Maxi PLUS tank	surface area of the coil pipe for a heat pump in a Maxi PLUS tank [m²]
	optimum	minimum				
Airmax² 6 GT	2,47	1,85	Maxi 250	3,0	Maxi Plus 300	2,2
Airmax² 9 GT	3,24	2,43	Maxi 250	3,0	Maxi Plus 400	3,8
			Maxi 300	3,8		
Airmax² 12 GT	4,40	3,30	Maxi 300	3,8	Maxi Plus 400	3,8
					Maxi Plus 500	4,8
Airmax² 15 GT	5,57	4,18	Maxi 400	5,0	Maxi Plus 500	4,8
			Maxi 500	6,0		
Airmax² 16 GT	6,22	4,67	Maxi 400	5,0	Maxi Plus 500	4,8
			Maxi 500	6,0		
Airmax² 21 GT	8,39	6,29	Maxi 700	6,5		
Airmax² 26 GT	10,40	7,80	Currently, there are no standard tanks with a sufficiently large coil pipe offered. In such cases, use enamelled tanks without coil pipes and with an external plate heat exchanger, or systems featuring several tanks.			
Airmax² 30 GT	11,93	8,95				

As already mentioned, it is possible to select a tank with a larger capacity and, consequently, a larger coil pipe, but one needs to take into account the heating time and the operating time of the unit throughout the year. Connecting the heat pump to a coil pipe, which has insufficient surface area, will result in a high pressure error occurring in the pump. This error can particularly occur in high outdoor temperatures, i.e. when supplying utility water in the summer season.

6.2.6. Airmax² - Selecting a SG(B) buffer tank for heating water

The buffer is an element stabilising the operation of the unit and protecting the heat pump against too many activations. It is especially required in systems with radiator heating (either total or partial). Conventional radiators quickly reach the required temperature, which causes the heat pump to shut down. They cool down equally quickly, which causes the pump to restart. Such timing is not recommended, as it reduces life of the compressor. The buffer is used for hydraulic separation of the heat pump system and the heating system. It provides the required independent flow through the heat pump's condenser. For example, it would be impossible to maintain the required flow and a proper heat reception without a buffer, when heating circuits are closed in a heating system with precise thermostatic control. The following diagram summarises all of the aforementioned cases.



As far as the buffer capacity of the system is concerned, it depends on the assumptions made in the project. If the buffer is to be a standard stabilising element, we assume its capacity to be 30l/kW of the rated power of the heat pump. However, if the heat pump is to operate in a double tariff system of electric energy, then the buffer is to work as a battery, and its capacity is assumed to be 60l/kW of the rated power of the heat pump. Therefore **buffer capacity (V_b)** can be calculated using the following formula:

$$V_b = Q_n \cdot v$$

Q_n - rated power of the heat pump at the A7W35 operating point [kW]

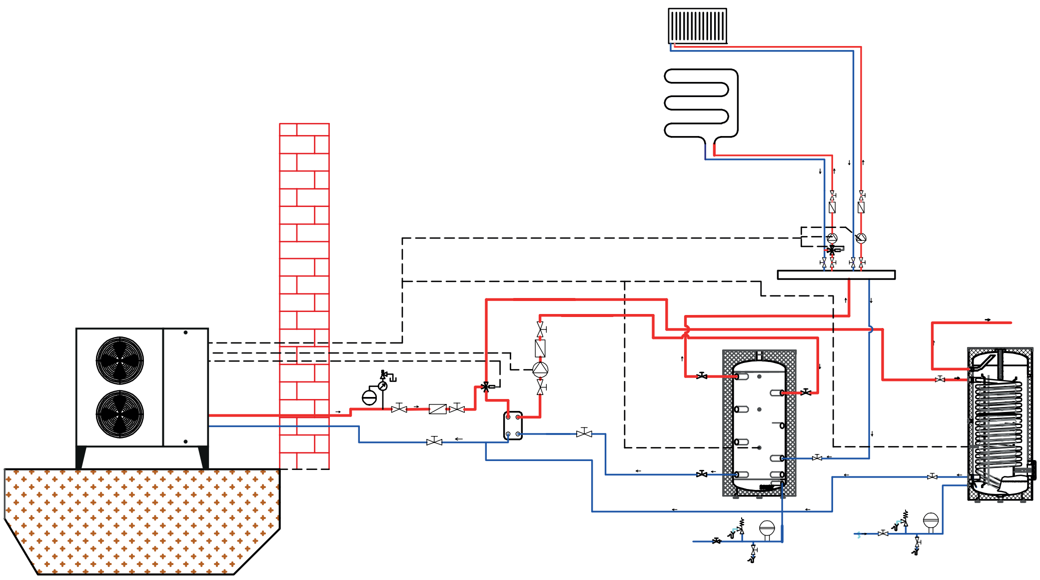
v - the recommended standard coefficient: 30l/kW (if operating in a double tariff system - 60l/kW)

See below for a table with the suggested buffer models:

Table 49. The suggested buffer tanks for Airmax² pumps - assuming the rated power of 30l/kW

model of heat pump	surface area of the coil [m²]		the suggested buffer capacity [l]	suggested buffers	coil surface (glycol-water exchanger) [m²]	the actual capacity of the suggested buffer [l]
	optimum	minimum				
Airmax² 6 GT	2,47	1,85	185	SG(B) 200	-	223
				SG(B) 300	-	305
				SG(B) Maxi 300	3,8	284
Airmax² 9 GT	3,24	2,43	243	SG(B) 200	-	223
				SG(B) 300	-	305
				SG(B) Maxi 300	3,8	284
Airmax² 12 GT	4,40	3,30	330	SG(B) 300	-	305
				SG(B) 400	-	396
				SG(B) Maxi 400	6,0	366
Airmax² 15 GT	5,57	4,18	418	SG(B) 400	-	396
				SG(B) Maxi 400	6,0	366
				SG(B) 500	-	467
Airmax² 16 GT	6,22	4,67	467	SG(B) 500	-	467
				SG(B) Maxi 500	7,5	459
Airmax² 21 GT	no dedicated SG(B) buffers with large spiral coil		629	SG(B) 800	-	728
Airmax² 26 GT			780	SG(B) 800	-	728
				SG(B) 1000	-	883
Airmax² 30 GT			895	SG(B) 1000	-	883

If a boiler or fireplace is to be connected to the buffer as an additional source of heat, then you can use a buffer with a standard steel coil pipe. See below for a conventional system with an Airmax² heat pump, a buffer tank without coils, a Maxi tank for domestic hot water, and an intermediate plate heat exchanger:



Pic. 58. A diagram of the system with a heat pump, a buffer tank, a Maxi tank, and a plate heat exchanger

In case of the plate intermediate exchanger not being the desired solution, a SG(B) buffer with large coil can be used. The coil will be act as a heat exchanger (glycol/water) in the system

6.2.7. Airmax² - selecting a combined tank (a tank within a tank) - SG(K) Kumulo

A combined tank is used to connect more sources, for example a heat pump, a boiler, and solar collectors. Design-wise, this tank combines a buffer and a tank for domestic hot water. It can also be used in systems, where selected capacity of a heat pump relatively large, in relation to the demand for domestic hot water. The selected buffer capacity is similar to the diagram of buffer capacity selection shown above.

Table 50. The suggested combined SG(K) Kumulo tanks (a tank within a tank) for Airmax² pumps - assuming the rated power of 30l/kW

model of heat pump	the suggested buffer capacity [l]	the suggested combined tanks	the actual buffer capacity [l]	the actual capacity of a tank for domestic hot water [l]
Airmax² 6 GT	185	SG(K) Kumulo 300/80	220	80
		SG(K) Kumulo 380/120	260	120
Airmax² 9 GT	243	SG(K) Kumulo 380/120	260	120
Airmax² 12 GT	330	SG(K) Kumulo 500/160	340	160
		SG(K) Kumulo 600/200	400	200
Airmax² 15 GT	418	SG(K) Kumulo 600/200	400	200
		SG(K) Kumulo 800/200	600	200
Airmax² 16 GT	467	SG(K) Kumulo 600/200	400	200
		SG(K) Kumulo 800/200	600	200
Airmax² 21 GT	629	SG(K) Kumulo 800/200	600	200
Airmax² 26 GT	780	SG(K) Kumulo 1000/200	800	200
Airmax² 30 GT	895	SG(K) Kumulo 1000/200	800	200

6.2.8. Airmax² - selecting a SG(K) Kumulo combined tank - combination of Maxi water heater and a buffer tank in one housing

This type of combined tank is a combination of two types of tanks in one housing: the Maxi tank and a small capacity buffer. It is a solution for users who do not have a large space for mounting a heat pump together with the necessary equipment. These tanks are not hydraulically connected in any way, they operate independently.

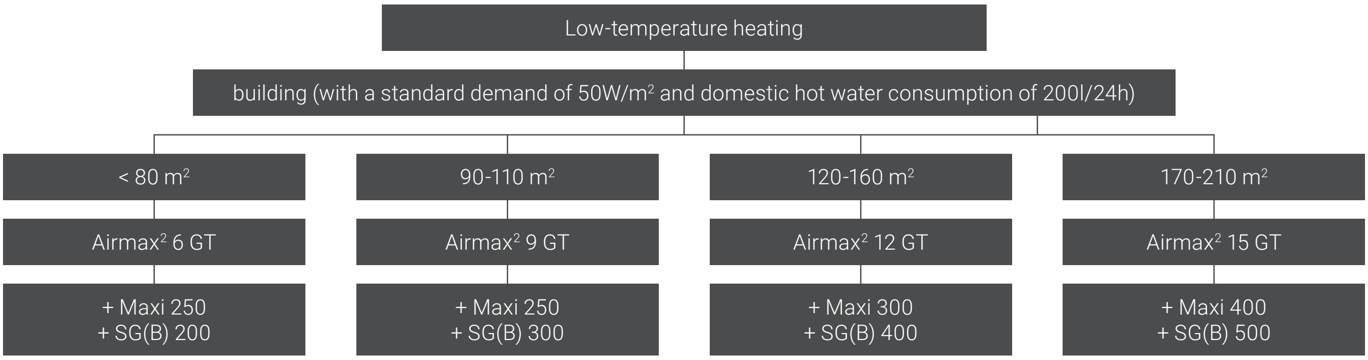
Table 51. Suggested combined tanks SG(K) Kumulo (Maxi tank and a buffer in one housing) for Airmax² heat pump - assuming the rated power of 25 l/kW

model of heat pump	surface area of the coil [m²]		suggested SG(K) Kumulo tank	surface area of the coil pipe in the DHW tank [m²]	capacity of the DHW tank [l]	suggested capacity of the buffer tank [l]	actual capacity of the buffer tank [l]
	optimum	minimum					
Airmax² 6 GT	2,47	1,85	SG(K) Kumulo 250/135	3	237	154	135
Airmax² 9 GT	3,24	2,43	SG(K) Kumulo 250/135	3	237	203	135

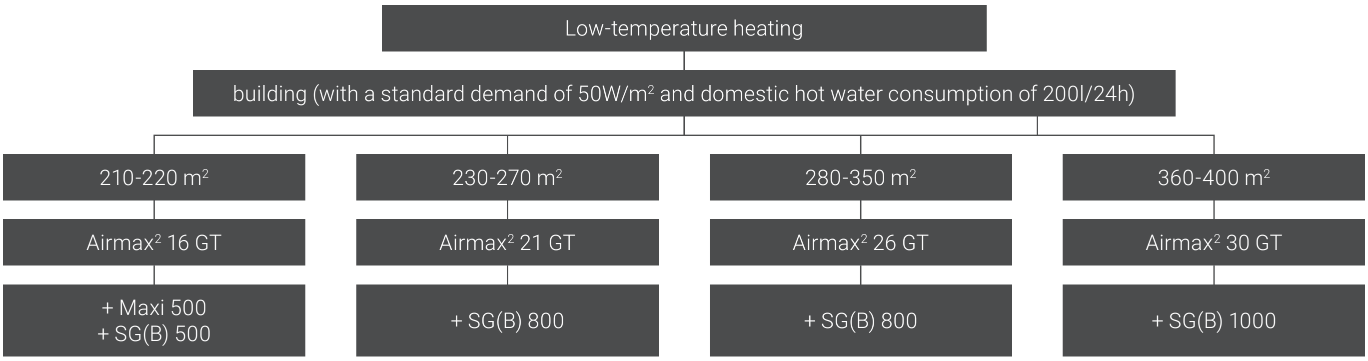
6.2.9. Airmax^2 - a preliminary approximate selection of a system with an air heat pump for a standard building

The diagrams below will come handy, when making a preliminary selection of a solution for a standard single-family house (with a demand of 50 W/m^2 and hot water consumption of 200l/24h).

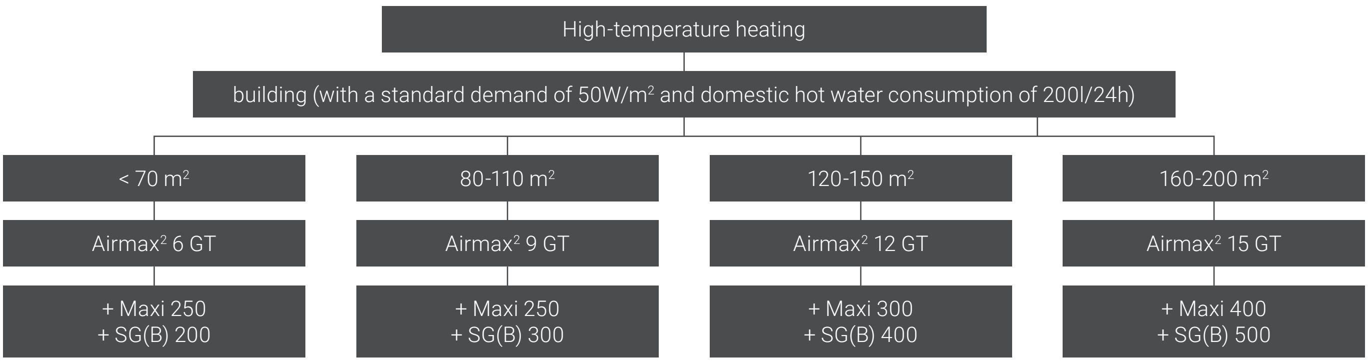
When selecting a low-temperature heating system (underfloor or wall heating), then the Airmax^2 heat pump (6-15 GT) is intended for houses with a heated area of up to 210 m^2, taking into account the afore-mentioned assumptions. See below for a diagram facilitating selection of a low-temperature heating system:



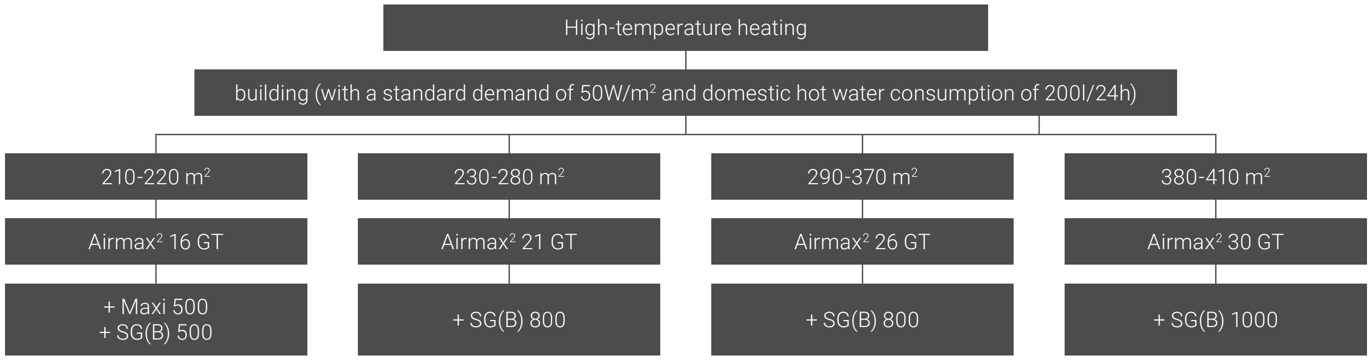
The Airmax^2 16-30GT types of series of pumps allows to heat buildings up to 400m^2, based on the same assumptions:



If selecting a high-temperature heating system (radiator heating), then the Airmax^2 6-15 GT heat pump is intended for houses with a heated area of up to 200m^2, taking into account the afore-mentioned assumptions. See below for a diagram facilitating selection of a high-temperature heating system:



The Airmax^2 16-30 GT types of series of pumps allows to heat buildings up to 410m^2, based on the same assumptions for high-temperature heating:



6.3. Designing systems with a ground heat pump for CH and DHW - Maxima and Maxima Compact

6.3.1. Analysing a selection of Maxima / Maxima Compact heat pumps for a sample building

The analysis refers to a building with a total area of 210m², for which the total required heating power is: Q = 11.5kW. The building has a standard demand of 50W/m² ($Q_{building}$ = 10.5kW), domestic hot water consumption is 200l/24h (Q_{dhw} = 1kW). See below for a characteristic curve of the building and all of the Maxima / Maxima Compact heat pumps.

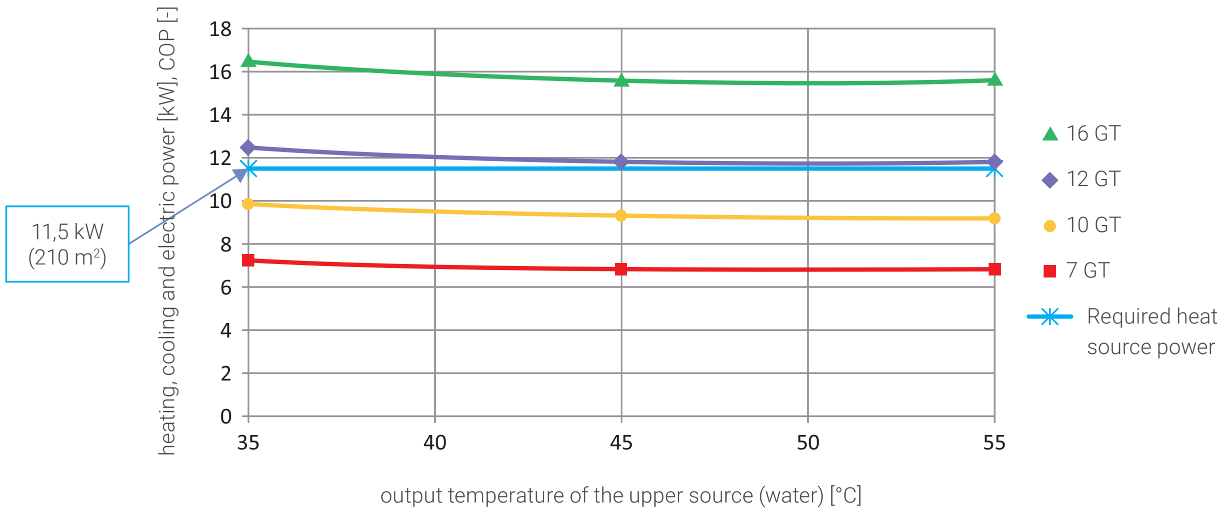


Diagram 65. Selection of a Maxima heat pump for a sample building with a heat demand of 10.5kW and additional power consumption for the purpose of domestic hot water 1kW

Such a selection will be simpler for ground source pumps, than for air pumps. Select a unit of such parameters, which make it possible to operate in the monovalent mode. This requires choosing a pump model of a higher capacity, than the required capacity of a heat source power for a particular building. In the example above, this will result in selecting Maxima 12 GT or Maxima Compact 12 GT.

6.3.2. Maxima and Maxima Compact - installation requirements

- 3-phase voltage, 400V is required
- The unit is intended for indoor installation only. According to EN 378, the **minimum cubic capacity (V)** of the room shall be calculated as follows:

$$V = N \div PL$$

N – Filling the heat pump with refrigerant [kg]

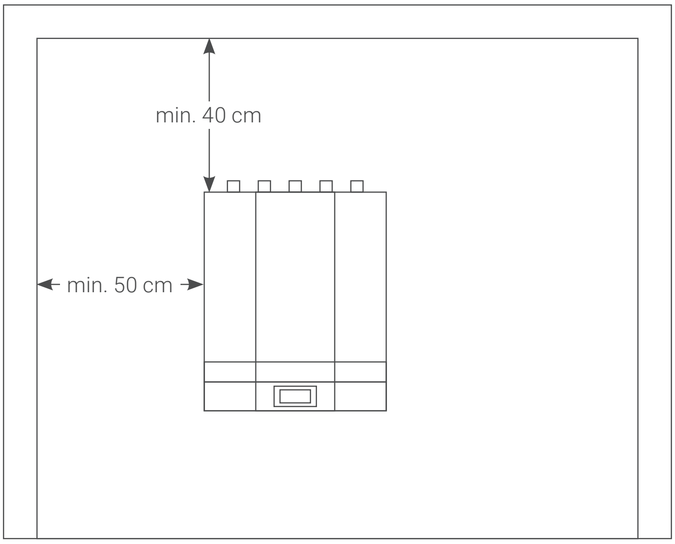
PL – The practical limit of concentration [kg/m3] (it is 0.44kg/m3 for the R410A refrigerant)

The table below demonstrates the minimum volume of the room for the given unit.

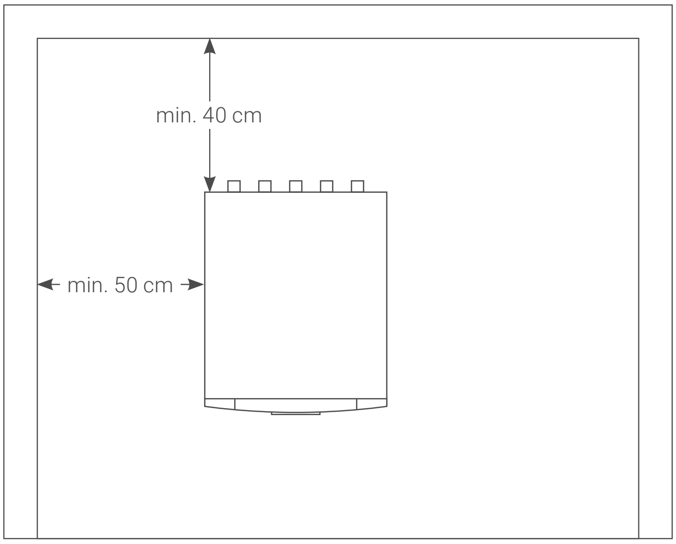
Table 52. The minimum cubic capacity of the room for installing the Maxima / Maxima Compact heat pump

model of heat pump	quantity of refrigerant [kg]	minimum cubic capacity of the room [m^3]
Maxima 7 GT / Maxima Compact 7 GT	2,1	4,8
Maxima 10 GT / Maxima Compact 10 GT	2,4	5,4
Maxima 12 GT / Maxima Compact 12 GT	2,7	6,1
Maxima 16 GT	2,9	6,6
Maxima 20 GT	4,0	9,1
Maxima 28 GT	5,5	12,5
Maxima 34GT	6,0	13,6
Maxima 42 GT	7,0	15,9

- Install the unit in such a manner, which provides free access for future inspections or maintenance. Leave a clearance of at least 50cm from side walls of the unit, and 40cm from the rear wall.

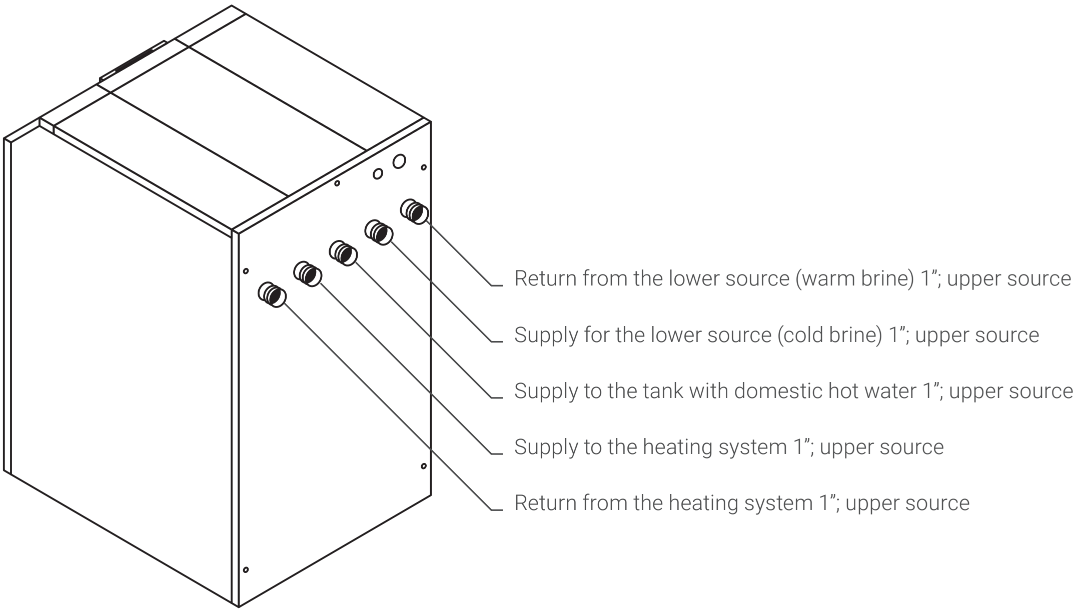


Pic. 59. Installation of a Maxima heat pump - minimum distances (view from top)



Pic. 60. Installation of a Maxima Compact heat pump - minimum distances (view from top)

- When planning a location for installation, keep in mind that the unit must be installed vertically (maintain a maximum deviation of 40° from the vertical axis)
- The Maxima heat pump (7-16 GT) comes equipped with a switching valve for domestic hot water, which means that it only requires a suitable tank to supply domestic hot water (e.g. Maxi, Maxi PLUS or a tank combining a buffer tank with a Maxi tank in one housing).

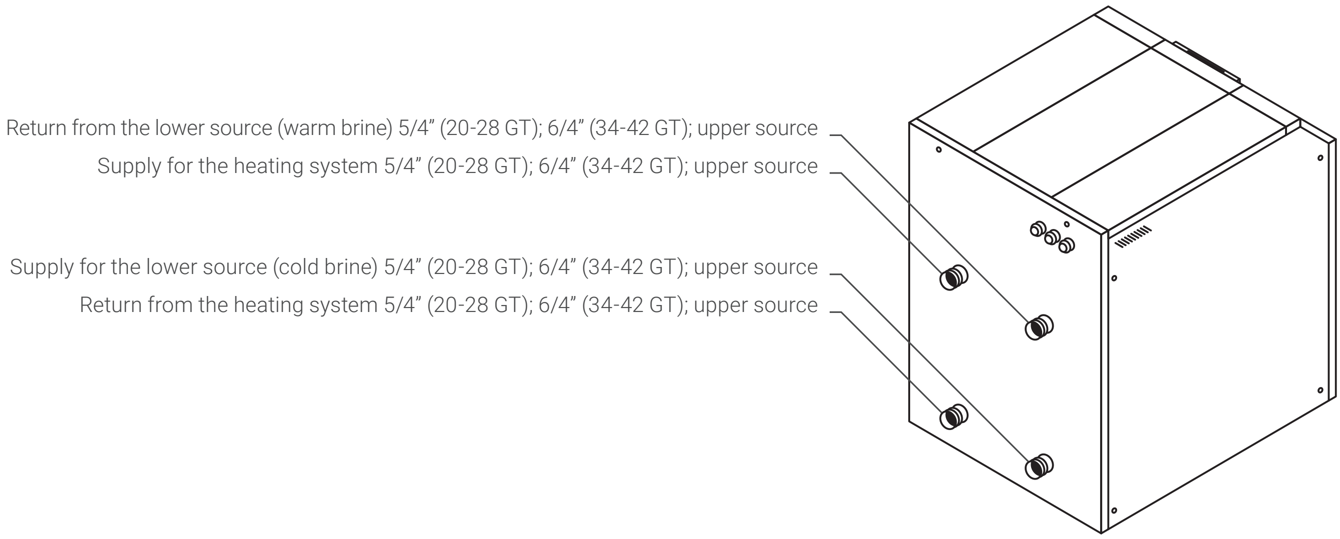


Pic. 61. A diagram of hydraulic connections for the Maxima 7-16 GT heat pump

A three-way switching valve constitutes an external element of the Maxima 20-42 GT pump models, and it can be controlled by the controller of a heat pump.

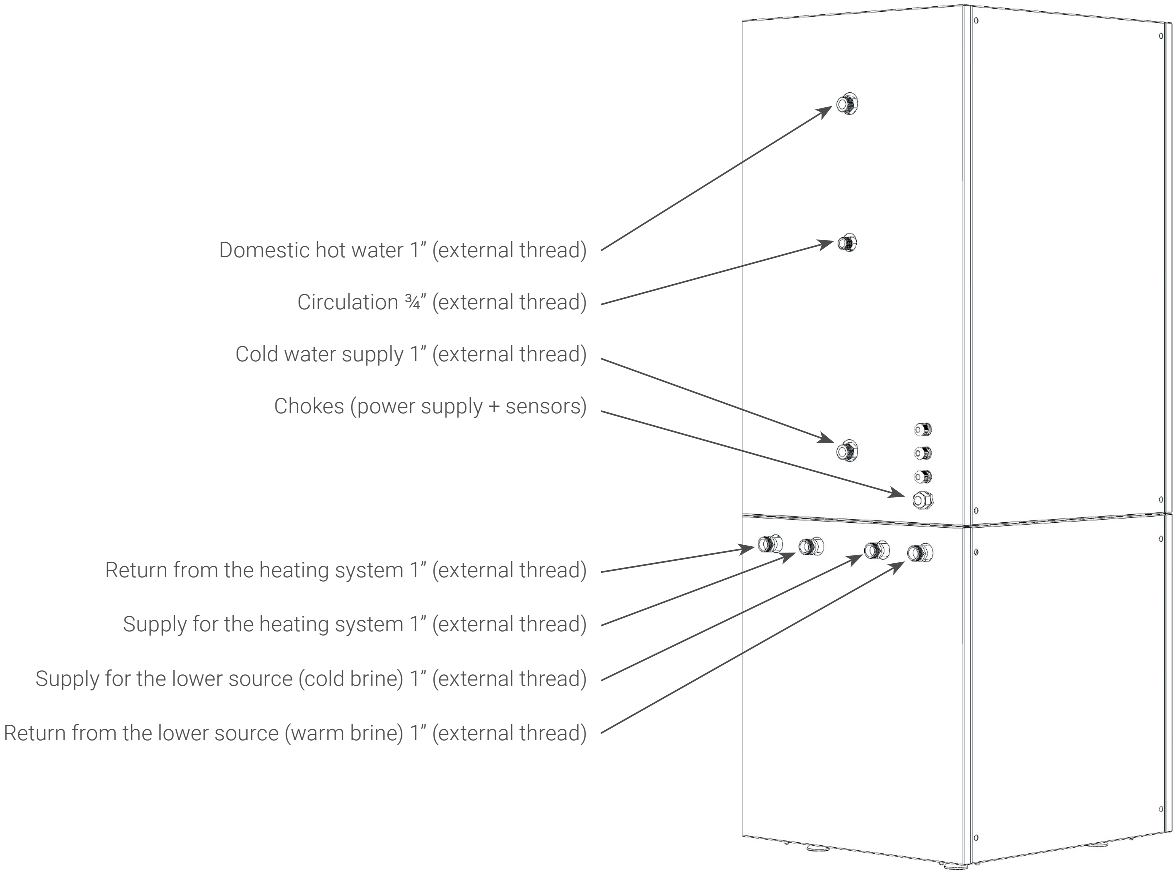
Table 53. A dedicated three-way valve with an actuator for Maxima heat pumps

heat pump model	technical specification		catalogue no.
Maxima 20-42 GT	VBI60.40-25L G6/4” GW, Kvs 25 m^3/h	Valve	09-000201
	GLB341.9E	Valve actuator	09-000200



Pic. 62. A diagram of hydraulic connections for the Maxima 20-42 GT heat pump

- The Maxima Compact heat pump (7-16 GT) comes equipped with a switching valve for domestic hot water. In one housing with the heat pump a DHW water tank is enclosed.



Pic. 63. A diagram of hydraulic connections for the Maxima Compact 7-12 GT heat pump

- It is recommended to make the connection using a copper pipe of the correct internal diameter. Take into account its thermal insulation.

Table 54. Inner diameters of pipes connected to Maxima / Maxima Compact heat pumps

model of heat pump	connection – the inner diameter of a pipe [mm]
Maxima 7 GT / Maxima Compact 7 GT	Ø 20
Maxima 10-16 GT / Maxima Compact 10-12 GT	Ø 26
Maxima 20-28 GT	Ø 32
Maxima 34-42 GT	Ø 39

- Carefully design the lower source system (glycol system) to ensure the correct operation of the heat pump. It is recommended to use 30-35% propylene glycol (freezing point -15°C).
- In systems where a hydraulic separator is required, it is possible to use the SG(B) buffer tanks with capacities from 40 to 140 l.

6.3.3. Maxima - selecting a tank for domestic hot water (Maxi, Maxi Plus)

It is necessary to select a tank with a larger surface area of the coil pipe intended to work with the heat pump, in order to supply domestic hot water to the heat pump. To ensure the correct operation of the heat pump providing domestic hot water, it will be necessary to ensure an adequate **surface area of the coil pipe (A_m)**. It is assumed that 0.3 m^2 of the coil pipe's surface area is required per 1kW of the nominal capacity of the heat pump, to ensure optimum selection.

$$A_w = Q_n \cdot p_w$$

Q_n - rated power of the heat pump at the A0W35 operating point [kW]

p_w - the optimum coefficient is 0.3 [m^2/kW]

For example, the rated heating power for the Maxima 10 GT heat pump is 9.85kW, which makes it possible to calculate the required surface area of the coil pipe, according to the formula above:

$$A_w = 9,85 \cdot (0,3) = 2,96\ m^2$$

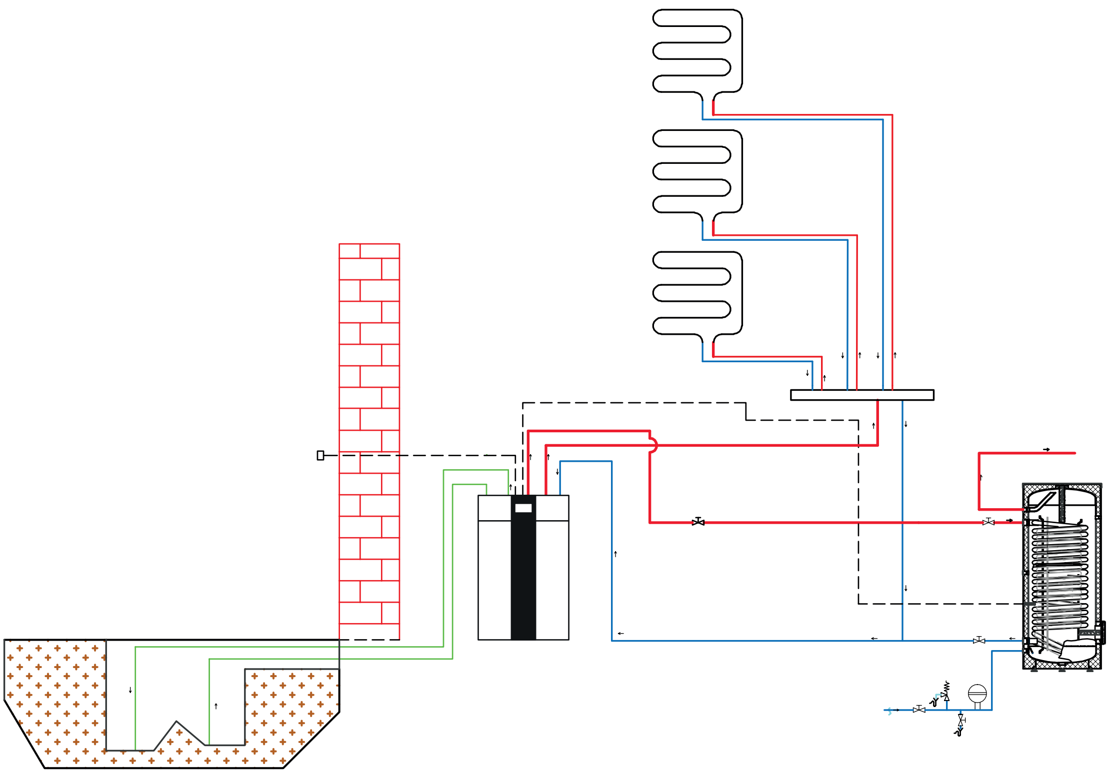
Therefore, you can choose the Maxi 250 storage tank with the coil pipe's surface area of 3m². When selecting a tank with two coil pipes, you can use Maxi PLUS 400 with a coil pipe of the surface area of 3.8m² to work with the heat pump. See below for a table with tanks for domestic hot water dedicated to the Maxima series of heat pumps. The largest surface area of a coil pipe dedicated to Maxi tanks is 6m², which renders it impossible to select standard tanks for Maxima 28-42 GT pump models. In such cases, it is possible to use an additional, external plate heat exchanger and an enamelled tank without any coils, in order to provide domestic hot water. Alternatively, it is possible to order a custom-made tank, which has a coil pipe of a larger surface area.

Table 55. The suggested Maxi and Maxi PLUS tanks for Maxima heat pumps

model of heat pump	optimum surface of coil pipe [m²]	suggested Maxi tank	surface area of the coil pipe in a Maxi tank [m²]	suggested Maxi PLUS tank	surface area of the coil pipe for a heat pump in a Maxi PLUS tank [m²]
Maxima 7 GT	2,18	Maxi 250	3,0	Maxi Plus 300	2,2
Maxima 10 GT	2,96	Maxi 250	3,0	Maxi Plus 400	3,8
		Maxi 300	3,8		
Maxima 12 GT	3,75	Maxi 300	3,8	Maxi Plus 400	3,8
Maxima 16 GT	4,97	Maxi 400	5,0	Maxi Plus 500	4,8
		Maxi 500	6,0		
Maxima 20 GT	5,88	Maxi 500	6,0		
Maxima 28 GT	8,43	Currently, there are no standard tanks with a sufficiently large coil pipe offered. In such cases, use enamelled tanks without coil pipes and with an external plate heat exchanger, or systems featuring several tanks.			
Maxima 34 GT	9,86				
Maxima 42 GT	12,39				

It is crucial to choose the right tank to work with a heat pump, because the heat pump connected to a coil pipe of insufficient surface area could result in a high pressure error occurring in the pump.

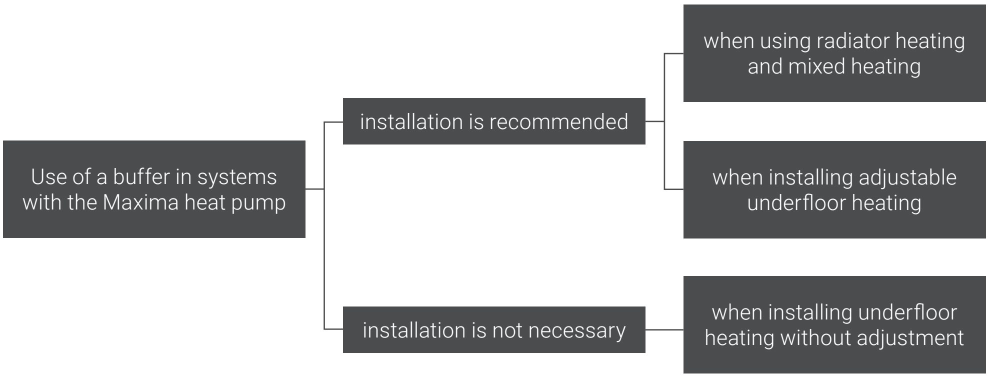
The simplest system with a Maxima heat pump is a one with a tank for domestic hot water and an underfloor heating system connected directly.



Pic. 64. System diagram with a Maxima heat pump (7-16 GT) and a Maxi tank

6.3.4. Maxima / Maxima Compact - selecting of a SG(B) buffer for heating water

As already mentioned, the buffer is an element stabilising the operation of the unit and protecting the heat pump against too many activations. It is especially required in systems with radiator heating (either total or partial). Connecting the heat pump directly to the radiator system will result in frequent activating of the pump, which reduces life of the compressor. As mentioned earlier, conventional radiators quickly reach the required temperature, which causes the heat pump to shut down. They cool down equally quickly, which causes the pump to restart. The buffer is used for hydraulic separation of the heat pump system and the heating system. It provides the required independent flow through the heat pump's condenser. For example, it would be impossible to maintain the required flow and a proper heat reception without a buffer, when heating circuits are closed in a heating system with precise thermostatic control. The following diagram summarises all of the aforementioned cases.



The capacity of a buffer to be installed depends on design assumptions. If the buffer is a standard stabilising element, then assume the capacity of 30l/kW as the rated power of the heat pump, just as for an air pump. However, if the heat pump is to operate in a double tariff system of electric energy, then the buffer is to work as a battery, and its capacity is assumed to be 60l/kW of the rated power of the heat pump. Therefore, **buffer capacity (V_b)** can be calculated using the following formula:

$$V_b = Q_n \cdot v$$

Q_n - rated power of the heat pump at the B0W35 operating point [kW]

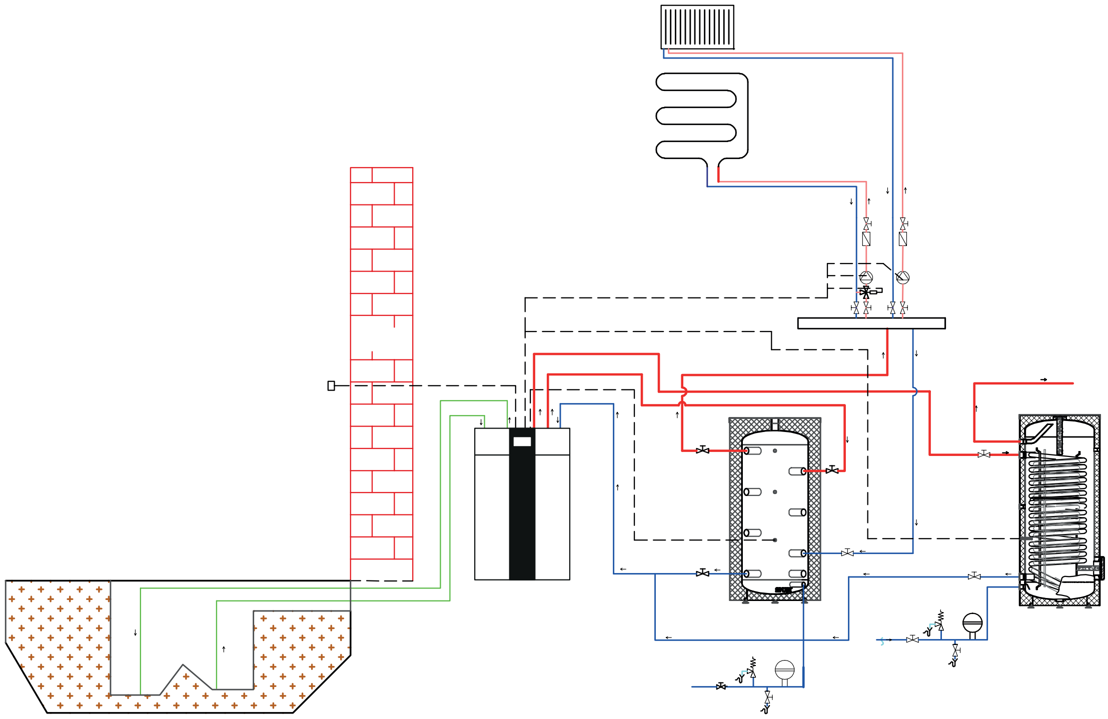
v - the recommended standard coefficient: 30l/kW (if operating in a double tariff system - 60l/kW)

See below for a table with the suggested buffer models:

Table 56. Proposed buffer tanks for Maxima / Maxima Compact heat pump - assuming 30 l/kW nominal power

model of heat pump	the suggested buffer capacity [l]	suggested buffers	the actual capacity of the suggested buffer [l]
Maxima 7 GT / Maxima Compact 7 GT	218	SG(B) 200	223
		SG(B) 300	305
Maxima 10 GT / Maxima Compact 10 GT	296	SG(B) 300	305
		SG(B) 400	396
Maxima 12 GT / Maxima Compact 12 GT	375	SG(B) 400	396
Maxima 16 GT	497	SG(B) 500	467
Maxima 20 GT	588	SG(B) 500	467
		SG(B) 800	728
Maxima 28 GT	843	SG(B) 1000	883
Maxima 34 GT	986	SG(B) 1000	883
Maxima 42 GT	1239	SG(B) 1500	1479

If a boiler or fireplace is to be connected to the buffer as an additional source of heat, then you can use a buffer with a standard steel coil pipe. A conventional system with a Maxima heat pump, a buffer tank, and a Maxi tank for domestic hot water Has the following arrangement:



Pic. 65. System diagram with a Maxima heat pump (7-16 GT) and a Maxi tank

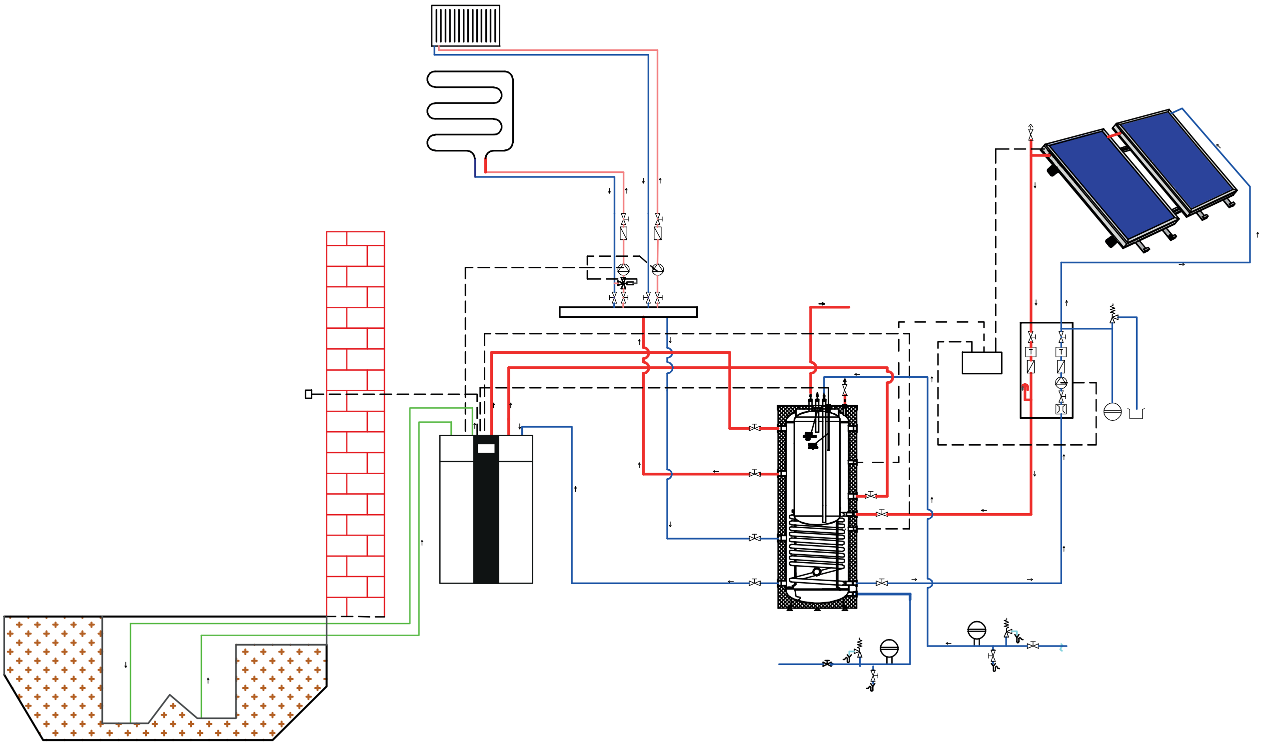
6.3.5. Maxima - Selecting a SG(K) Kumulo combined tank (tank within a tank)

A combined tank is used to connect more sources, for example a heat pump, a boiler, and solar collectors. Design-wise, this tank connects the buffer with the tank for domestic hot water, which saves space in the boiler room. It can also be used in systems, where the selected capacity of a heat pump is relatively large, in relation to the demand for domestic hot water (this makes it quite difficult to select a tank with a coil pipe of sufficient surface area). The selected buffer capacity is similar to the diagram of buffer capacity selection shown above.

Table 57. The suggested combined tanks (a tank within a tank) for Maxima heat pumps - assuming the rated power of 30l/kW

model of heat pump	the suggested buffer capacity [l]	the suggested combined tanks	the actual buffer capacity [l]	the actual capacity of a tank for domestic hot water [l]
Maxima 7 GT	218	SG(K) Kumulo 300/80	220	80
		SG(K) Kumulo 380/120	260	120
Maxima 10 GT	296	SG(K) Kumulo 380/120	260	120
		SG(K) Kumulo 500/160	340	160
Maxima 12 GT	375	SG(K) Kumulo 500/160	340	160
		SG(K) Kumulo 600/200	400	200
Maxima 16 GT	497	SG(K) Kumulo 600/200	400	200
		SG(K) Kumulo 800/200	600	200
Maxima 20 GT	588	SG(K) Kumulo 800/200	600	200
Maxima 28 GT	843	SG(K) Kumulo 1000/200	800	200

Below is an exemplary installation diagram with Maxima heat pump and solar collectors, which, in this case, are used for DHW heating and to assist the central heating.



Pic. 66. System diagram with a Maxima heat pump (7-16 GT), solar collectors and SG(K) Kumulo combined heat accumulation vessel

6.3.6. Maxima - selecting of a SG(K) Kumulo combined heat accumulation vessel

This type of vessel is a combination of two types of tanks in one housing: the Maxi water heater and a small capacity buffer tank. It is a solution for users who do not have a large space for mounting a heat pump together with the necessary equipment. These tanks are not hydraulically connected in any way, as they operate independently of each other.

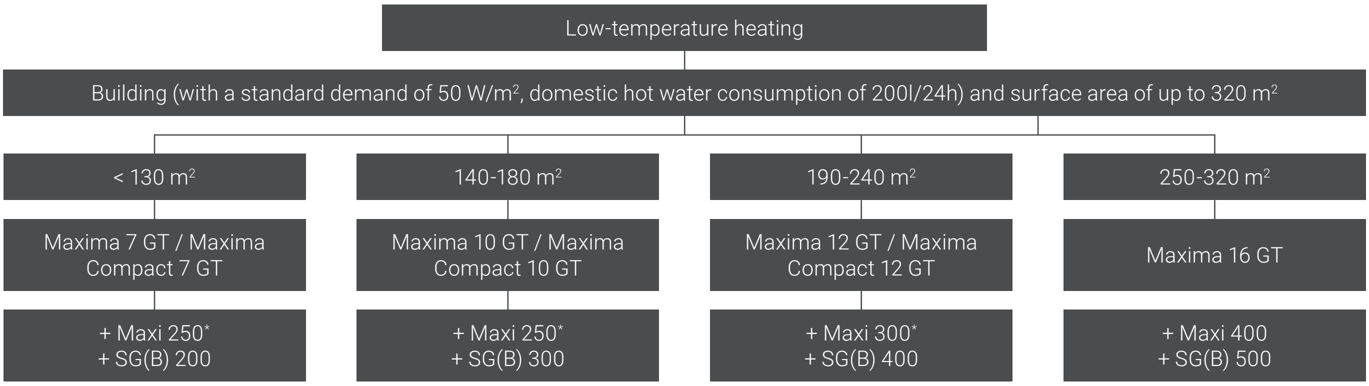
Table 58. Proposed SG(K) Kumulo combined vessel (Maxi tank and buffer in one housing) for the Maxima heat pump - assuming nominal power of 25 l / kW

model of heat pump	optimal coil surface [m²]	the suggested SG(K) Kumulo vessel capacity [l]	surface area of the coil pipe in the tank [m²]	DHW tank capacity [l]	buffer tank capacity [l]	actual buffer tank capacity [l]
Maxima 7 GT	2,18	SG(K) Kumulo 250/135	3	237	181	135
Maxima 10 GT	2,96	SG(K) Kumulo 250/135	3	237	246	135

6.3.7. Maxima / Maxima Compact - a preliminary approximate selection of a system with an air heat pump for a standard building

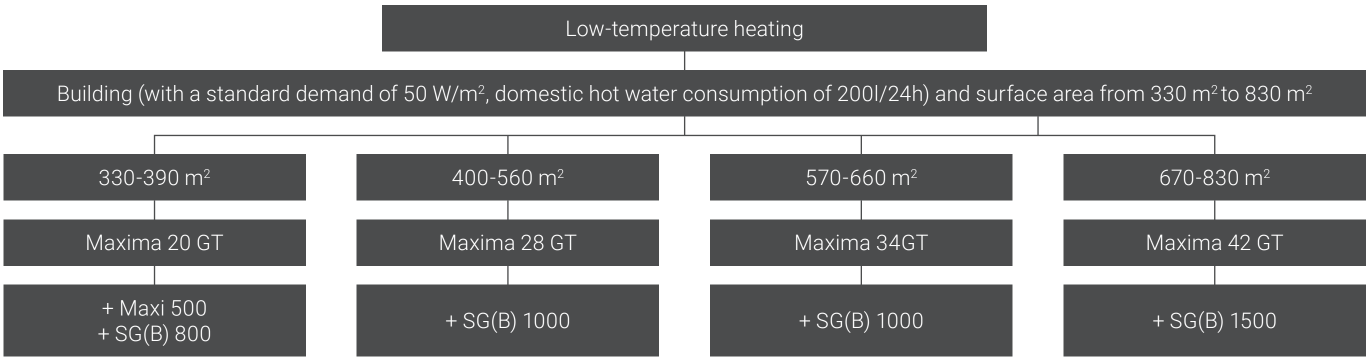
The diagrams below will come handy, when making a preliminary selection of a solution for a standard single-family house (with a demand of 50W/m^2 and hot water consumption of 200l/24h).

When selecting a low-temperature heating system (underfloor or wall heating), then the Maxima heat pump (7-16 GT) is intended for houses with a heated area of up to 320 m^2, taking into account the afore-mentioned assumptions. While Maxima Compact heat pump (7-12 GT) is intended for houses with a heated area of up to 240 m^2. See below for diagrams facilitating selection of a low-temperature heating system:

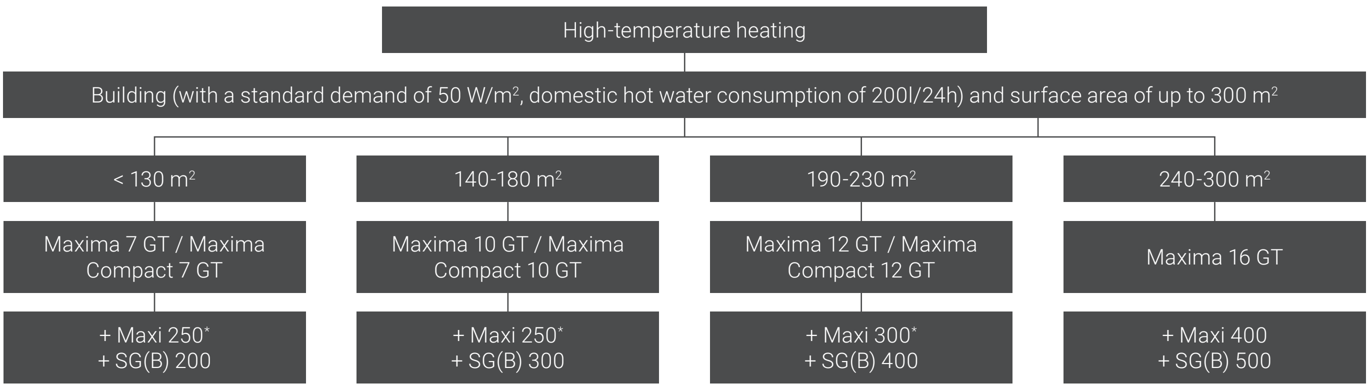


* Maxi water heater is dedicated Maxima series heat pumps only. Maxima Compact heat pumps already have a built-in domestic hot water tank.

In the case of high-temperature Maxima heat pump models (20-42 GT), we can provide heat in buildings with surface area of up to 830 m^2 with low-temperature heating.

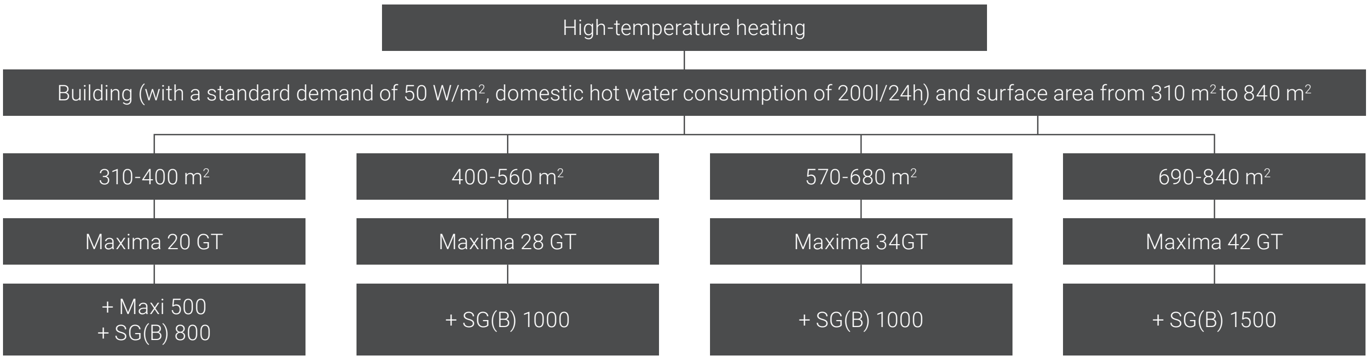


When choosing high-temperature (radiator) heating, the Maxima heat pump (7-16 GT), is intended for houses with a heated area of up to 300 m^2, taking into account the afore-mentioned assumptions. While Maxima Compact heat pump (7-12 GT) is intended for houses with a heated area of up to 230 m^2. Selection diagram for high-temperature heating below:



* Maxi water heater is dedicated Maxima series heat pumps only. Maxima Compact heat pumps already have a built-in domestic hot water tank.

By choosing the Maxima 20-42 GT models we can provide heat in the building of surface area of up to 840 m² (radiator heating). For models with high heating power, it becomes impossible to choose a tank with large enough heat exchange surface. In such cases, it is necessary to use external heat exchangers or systems with several tanks in order to obtain a suitable heat exchange surface. Therefore, it is only feasible to recommend a Maxi water heater for Maxima 20 GT, for all subsequent models, it is only the feasible to recommend a buffer tank, as shown in the diagram below.

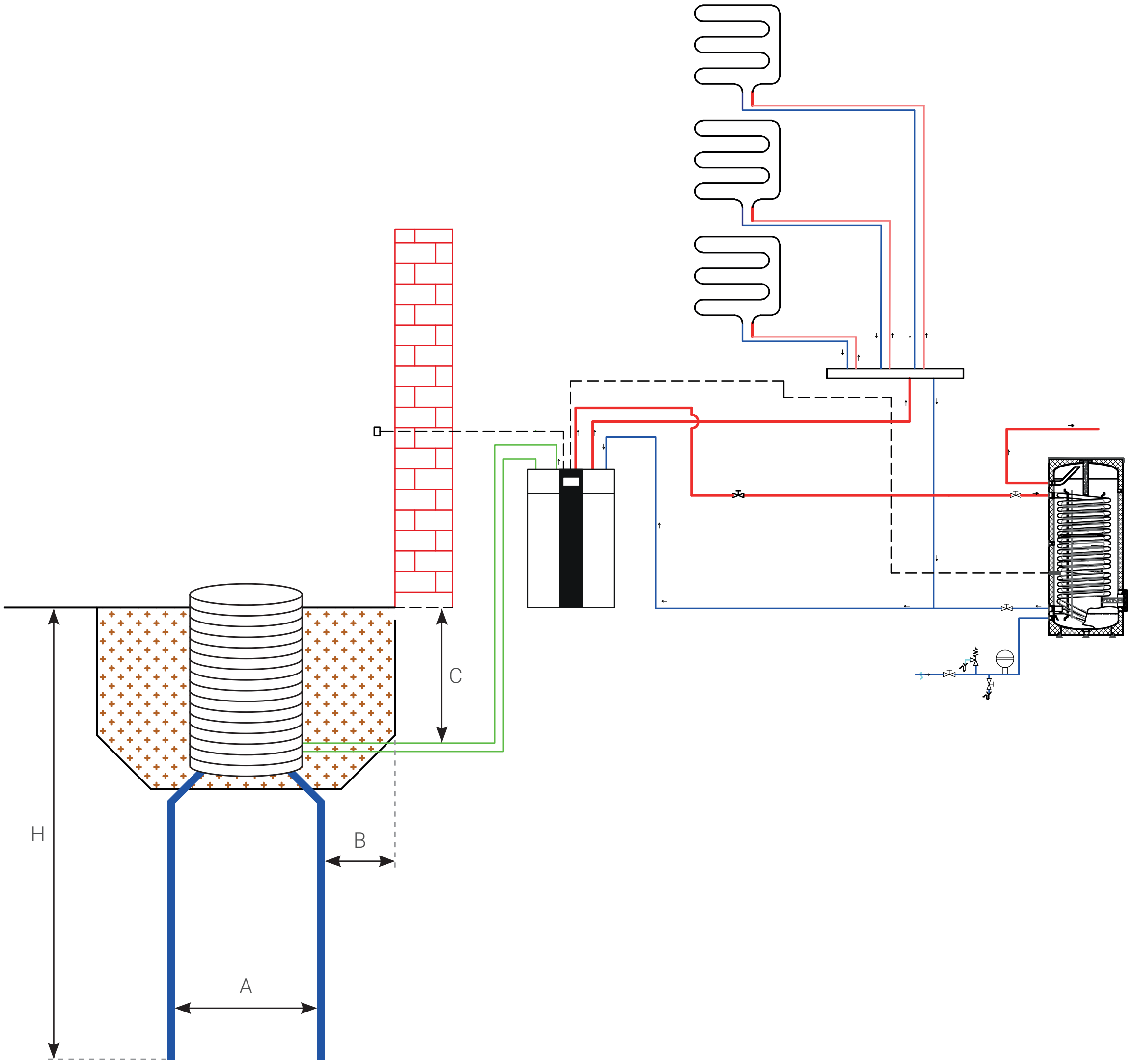


6.4. Designing the Maxima and Maxima Compact heat pumps lower heat source

The lower source of a ground-water heat pump is a very important element of the installation. Its correct design guarantees correct operation of the device. It is important to take into account the local conditions. The choice of a vertical exchanger carries a higher investment costs than that of a horizontal exchanger, but the operating costs with a vertical exchanger are slightly lower. So again its up to the investor to must choose the optimal solution.

6.4.1. Vertical exchanger selection, design guidelines

Vertical exchanger is the only option in case of small building plot. However, it should be noted that in order for the vertical exchanger to function properly, certain distances from the building's foundations (1,5 m) and the plot border (3 m) must be maintained. It is also necessary to maintain an appropriate distance between the boreholes (6-8 m depending on the depth of the well). The supply pipes are led 20-40 cm below the ground's freezing zone. The manifold is usually placed in a manhole so that it can be easily accessed. Wall-mounted internal manifolds are also used.



Pic. 67. Location of the vertical exchanger - required distances

Minimum distances:

- from foundations B > 1,5 m
- minimum depth (C), from 20 to 40 cm below the ground's freezing zone
- A = 6 m at depth H < 70 m
- A = 8 m at depth 70 ≤ H < 100 m
- ≥ 3 m from the property border
- ≥ 1,5 from plumbing, sewage, electric, gas, heating and similar installations, as well as from trees with deep roots

The length of the borehole should be determined after learning the **heat output of the soil**. In other words, the amount of energy that can be taken from the ground per one linear meter of the exchanger. The exact value can be found by performing a TRT (Thermal Reaction Test) or by knowing the geological distribution of soil layers. Knowing the geological distribution, it is possible to calculate the heat transfer coefficient for a given soil. Below is a helpful table with approximate ground heat outputs:

Table 59. Heat output of the soil - vertical exchanger

soil type	estimated heat output [W/m]
dry ground (λ < 1,5 W / (m • K))	20-25
normal soil and water-saturated sediment (1,5 W/(m • K) < λ < 3,0 W / (m • K))	50-60
solid rock with high thermal conductivity (λ > 3,0 W / (m • K))	70-84

If the soil's heat output is not known exactly, it can be estimated at 40 W/m. The compressor's operation time should not exceed 2000 hours per year. If it does, then the lower source will be more loaded. In such case, to allow proper thermal regeneration of the soil, it is recommended to increase the probe length by 5% for every 100 hours exceeding the limit of 2000 h. For example, when the working time will be 2300 h/year, the exchanger length should be extended by 15%. To calculate the length of the borehole, use the cooling capacity of the device that will be taken from the ground.

Table 60. Cooling power of the Maxima / Maxima Compact heat pumps

model of heat pump	Maxima 7 GT / Maxima Compact 7 GT	Maxima 10 GT / Maxima Compact 10 GT	Maxima 12 GT / Maxima Compact 12 GT	Maxima 16 GT	Maxima 20 GT	Maxima 28 GT	Maxima 34GT	Maxima 42 GT
cooling power [W]	5570	7640	9720	12800	15330	22080	25380	32180

From the quotient of the cooling capacity of the device and the unit capacity of the soil we get the required **length of the borehole (l_o)**:

$$l_o = \frac{Q_{chn}}{q_v}$$

Q_{chn} - nominal cooling power of the heat pump at the operating point B0W35 [W]

q_v – heat output of the soil [W/m]

For example, for the Maxima 7 GT heat pump, assuming the reception of heat from the ground (q_v) is at 40 W/m, we get:

$$l_o = \frac{5570}{40} = 139{,}25 \text{ m}$$

The required length of the exchanger is less than 140 m, so it would be necessary to drill two 70 m boreholes. The table below provides estimated borehole lengths for all Maxima / Maxima Compact heat pumps.

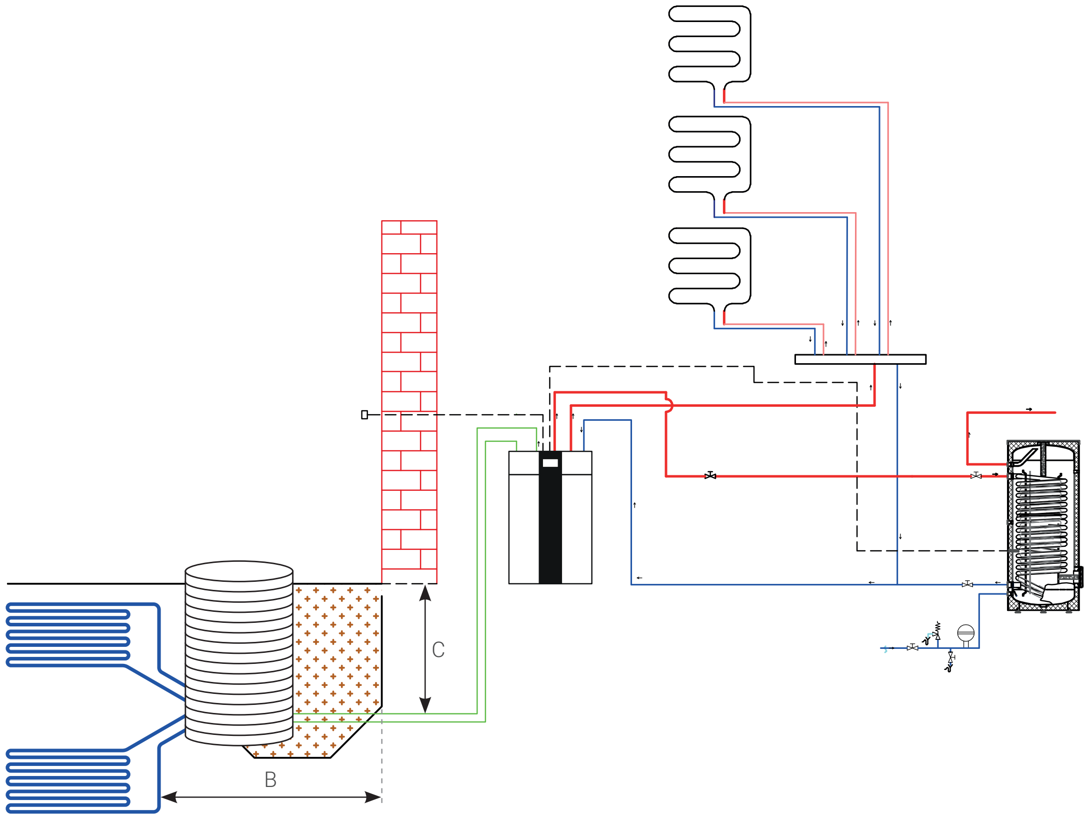
Table 61. Estimated exchanger length - vertical borehole (assuming heat output of the soil of 40 W/m)

model of heat pump	estimated required length of the heat exchanger [m]	required number of boreholes [m]
Maxima 7 GT / Maxima Compact 7 GT	139	2 x 70 m
Maxima 10 GT / Maxima Compact 10 GT	191	2 x 96 m
Maxima 12 GT / Maxima Compact 12 GT	243	3 x 81 m
Maxima 16 GT	326	4 x 82 m
Maxima 20 GT	383	4 x 96 m
Maxima 28 GT	552	6 x 92 m
Maxima 34 GT	635	7 x 91 m
Maxima 42 GT	805	9 x 89 m

As mentioned earlier, the heat exchanger can be installed in a form of a single or double u-tube with a diameter of 32 or 40 mm. This choice does not affect the required length of the boreholes, the only difference is the flow resistances.

6.4.2. Horizontal exchanger selection, design guidelines

The horizontal exchanger requires a large area of undeveloped land. Of course, appropriate distances from building's foundations (0,5 m) and the plot border (3 m) must be maintained. The supply pipes together with the heat exchanger are led 20-40 cm below the ground's freezing zone. The manifold is usually placed in a manhole so that it can be easily accessed. Wall-mounted internal manifolds are also used.



Pic. 68. Location of the horizontal exchanger - required distances

Minimum distances:

- from foundations B > 0,5 m
- minimum depth (C), from 20 to 40 cm below the ground's freezing zone
- ≥ 3 m from the property border
- ≥ 1,5 from plumbing, sewage, electric, gas, heating and similar installations, as well as from trees with deep roots

When it comes to designing a horizontal heat exchanger, just like in the case of a vertical exchanger, the heat output of the soil is very important. Knowing the geological structure of the soil, one can assume the following values of its efficiency:

Table 62. Heat output of the soil - horizontal exchanger

soil type	estimated heat output [W/m²]
dry sandy soil	10-15
moist sandy soil	15-20
dry loam soil	20-25
moist loam soil	25-30
soil that conducts groundwater	30-35

If the soil's heat output is not known exactly, it can be estimated at 20 W/m². The compressor's operation time should not exceed 2000 hours per year. If it does, then the lower source will be more loaded. In such case, to allow proper thermal regeneration of the soil, it is recommended to increase the probe length by 5% for every 100 hours exceeding the limit of 2000 h. For example, when the working time will be 2200 h/year, the exchanger length should be extended by 10%. When installing the exchanger, it is recommended to make a minimum of 2 loops (2 circuits of a horizontal ground heat exchanger), they should be of equal length. To calculate the surface of the heat exchanger, just like in the case of a vertical borehole, use the cooling capacity of the device that will be taken from the ground.

Table 63. Cooling power of Maxima / Maxima Compact heat pumps

model of heat pump	Maxima 7 GT / Maxima Compact 7 GT	Maxima 10 GT / Maxima Compact 10 GT	Maxima 12 GT / Maxima Compact 12 GT	Maxima 16 GT	Maxima 20 GT	Maxima 28 GT	Maxima 34GT	Maxima 42 GT
cooling power [W]	5570	7640	9720	12800	15330	22080	25380	32180

From the quotient of the cooling capacity of the device and the unit capacity of the soil we get the required **surface of the horizontal exchanger (l_o)**:

$$l_o = \frac{Q_{chn}}{q_v}$$

Q_{chn} - nominal cooling power of the heat pump at the operating point B0W35 [W]

q_v – heat output of the soil [W/m]

For example, for the Maxima 10 GT heat pump, assuming the reception of heat from the ground (q_v) is at 20 W/m, we get:

$$l_o = \frac{7640}{20} = 382 \text{ m}^2$$

The required surface of the exchanger is 382 m^2.

At this point, it is necessary to choose which type of horizontal exchanger to use. You can opt for a meander or spiral exchanger. Types of exchangers were described in more detail earlier in this publication.

In the case of a meander exchanger, the next step is to determine the pipe spacing and its length. Spacing of 0,6-1,0 m are frequently used. Recommended spacing depends on the type of soil:

Table 64. Recommended spacing and diameter of the horizontal exchanger

soil type	recommended pipe spacing [m]	recommended pipe diameter d_n x g [mm]
dry soil	0,6	25 x 2,3
average soil	0,7	32 x 2,9
moist soil	0,8-1,0	40 x 3,7

By choosing the pipe spacing it is possible to determine the approximate **length of the horizontal exchanger (l_o)**:

$$l_o = \frac{A_o}{e_p}$$

A_o - required exchanger surface [m^2]

e_p – pipe spacing [m]

Therefore, for the analysed example:

$$l_o = \frac{382}{0,7} = 546 \text{ m}$$

The total length of the pipe should be divided into loops. The recommended length of a single loop depends on the diameter of the pipe used:

Table 65. Minimum and maximum loop length depending on the exchanger's diameter

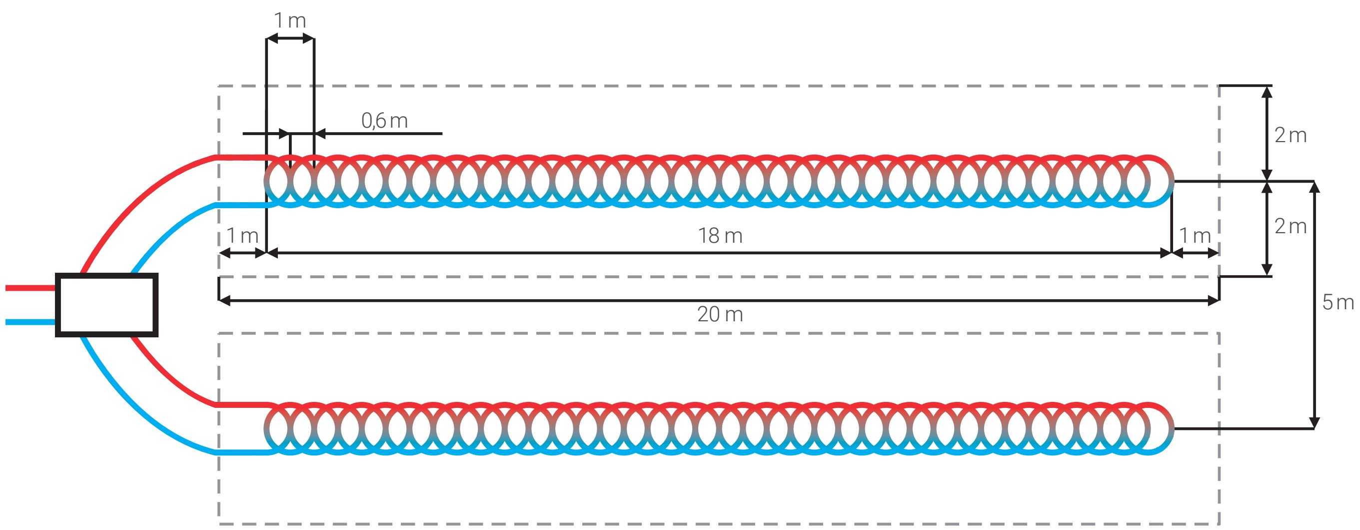
pipe diameter used [mm]	minimum loop length [m]	maximum loop length [m]
25	50	125
32	80	200
40	140	300

The table below shows the estimated horizontal heat exchanger surfaces for all Maxima / Maxima Compact heat pump models

Table 66. Estimated surface of the horizontal heat exchanger (assuming heat output of the soil of 20 W/m²) - selection of horizontal meander exchanger

model of heat pump	estimated required heat exchanger surface [m²]	pipe diameter used [mm]	pipe spacing [m]	estimated pipe length [m]	proposed quantity and length of the exchanger's loops [m]
Maxima 7 GT / Maxima Compact 7 GT	279	25	0,6	465	4 x 116 m
		32	0,7	399	3 x 133 m
		40	0,8	349	2 x 175 m
Maxima 10 GT / Maxima Compact 10 GT	382	25	0,6	637	6 x 106 m
		32	0,7	546	4 x 137 m
		40	0,8	478	2 x 239 m
Maxima 12 GT / Maxima Compact 12 GT	486	25	0,6	810	8 x 101 m
		32	0,7	694	5 x 139 m
		40	0,8	608	3 x 203 m
Maxima 16 GT	651	25	0,6	1085	9 x 121 m
		32	0,7	930	7 x 133 m
		40	0,8	814	4 x 204 m
Maxima 20 GT	767	25	0,6	1278	11 x 116 m
		32	0,7	1096	6 x 183 m
		40	0,8	959	4 x 240 m
Maxima 28 GT	1104	25	0,6	1840	15 x 123 m
		32	0,7	1577	8 x 197 m
		40	0,8	1380	5 x 276 m
Maxima 34 GT	1269	25	0,6	2115	17 x 124 m
		32	0,7	1813	10 x 181 m
		40	0,8	1586	6 x 264 m
Maxima 42 GT	1609	25	0,6	2682	22 x 122 m
		32	0,7	2299	12 x 192 m
		40	0,8	2011	7 x 287 m

The spiral exchanger comes in sections with a pipe length of 125 m and a diameter of 32 mm. The surface area of each section of the exchanger is equal to 80 m². The advantage of the spiral exchanger is the smaller scale of earthworks, as it only requires digging of 1 m wide ditches. However, in the case of a meander exchanger, it is necessary to completely collect the soil layer under which the exchanger will be laid.



Pic. 69. Spiral exchanger

When choosing a spiral exchanger, the lower source for a Maxima / Maxima Compact heat pump will be as follows:

Table 67. Estimated surface of the horizontal heat exchanger (assuming heat output of the soil of 20 W/m²) - selection of horizontal spiral exchanger

model of heat pump	estimated required heat exchanger surface [m²]	recommended spiral exchanger (loop length 125 m)	estimated required ground surface [m²]	surface of earthworks [m²]
Maxima 7 GT / Maxima Compact 7 GT	279	4	360	72
Maxima 10 GT / Maxima Compact 10 GT	382	5	450	90
Maxima 12 GT / Maxima Compact 12 GT	486	7	540	126
Maxima 16 GT	651	8	630	144
Maxima 20 GT	767	9	810	162
Maxima 28 GT	1104	13	1170	234
Maxima 34 GT	1269	15	1350	270
Maxima 42 GT	1609	18	1620	324

7. CONCLUSION

Heat pumps are devices that allows the use of renewable energy sources like ground or air. Additionally, by using electricity generated from renewable energy sources (e.g. from a photovoltaic installation or wind farm), it is possible to obtain a zero-emission heating technology. The heat pump can also act as the main source of heat in a hybrid heating system, with (for example) solar collectors or a pellet boiler as an additional heat sources. Choosing the optimal and the most comfortable heating system is not an easy task for the investor, it is however worth to at least consider renewable energy sources like the heat pump if only for the sake of the environment around us.

All of the tests for the Galmet heat pumps were carried out by:

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