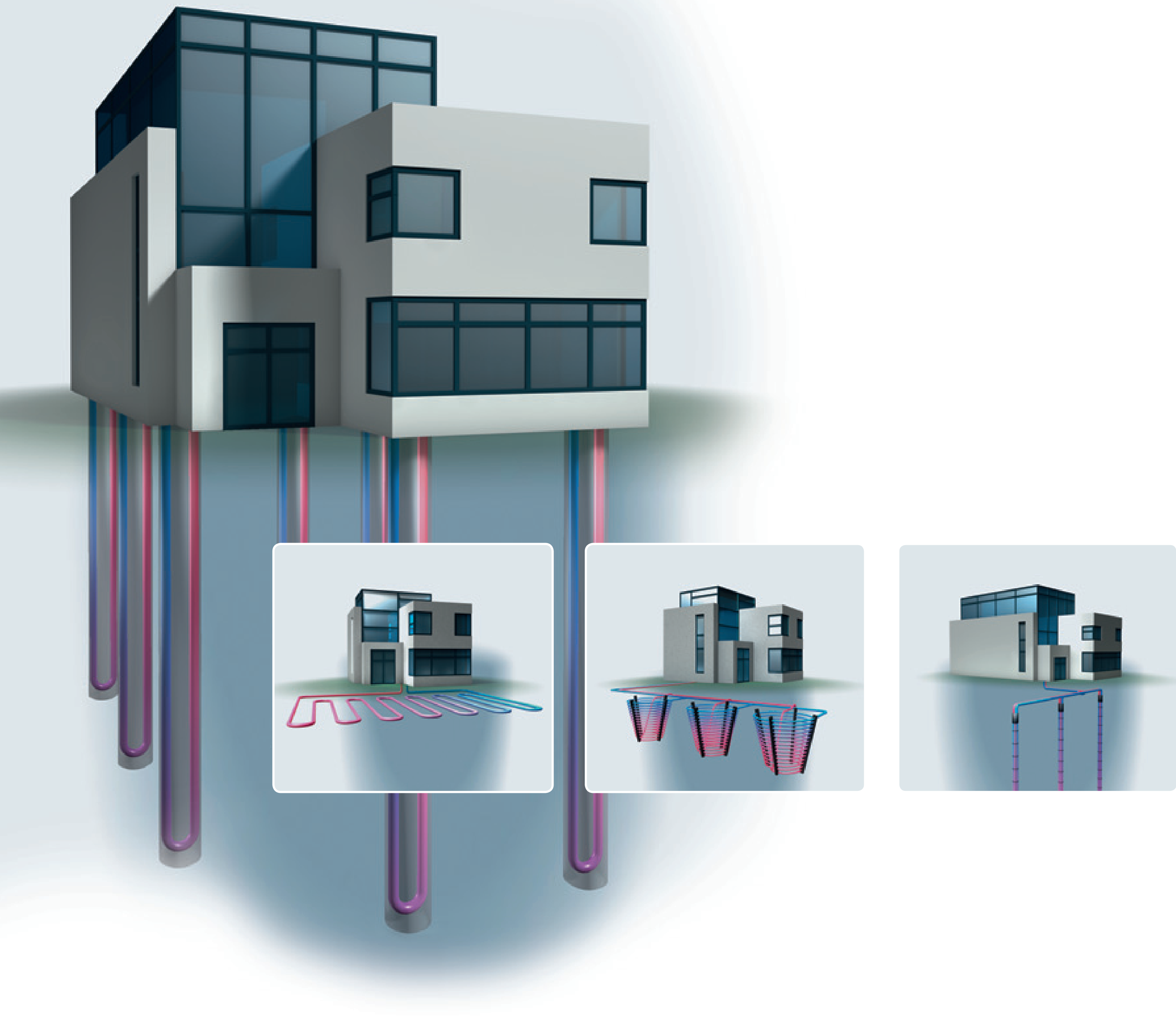
Ground Energy

TECHNICAL INFORMATION



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Introduction

Ground Energy – Independence of the energy situation

Governments across Europe have the ambitious goal of reducing the energy consumption in order to reduce the dependene on fossil fuels such as oil and gas. Renewable energy sources like solar energy and ground energy increasingly gain importance with respect to the future energy demand in buildings. With the 20-20-20 target the EU plans to reduce the energy consumption and greenhouse gas emission by 20 % until 2020 and to increase the use of renewable energy sources to 20 % (2007: 8.5 %) of the energy mix. Therefore various legislative initiatives have been started all over Europe to promote the use of renewable energy sources.

Ground Energy has a number of benefits

- Renewable: Ground energy is available endlessly, 24 hours a day for heating and cooling.
- Environmentally friendly: Any usage of ground energy reduces the emissions of greenhouse gas.
- Safe and controllable: Ground energy is technically mature and has been used for heating and cooling for more than 50 years.
- High performance: a response to all energy demands such as heating, cooling, hot water and energy storage.
- Versatile: applicable in combination with other energy sources.
- Economically sustainable: regionally usable, independent of external suppliers and changes in currency exchange rates.
- Securing the competitiveness: Ground energy increases the industrial competitiveness and as a result has a positive effect on the regional development and employment.

Ground Energy – versatile use

Ground energy cannot only be used as source of energy for radiant heating and water heating but also as an energy source for radiant cooling with very low operating costs. Ground energy can be used in all types of buildings from single-family houses to large office and industrial buildings.

When a ground system is operating it hardly requires any running costs and has a long operating period. Though the investment costs for a ground energy system are slightly higher than for conventional boilers and cooling aggregates the amortization period is shorter due to the low operating costs.

Ground energy as energy source in combination with radiant emitter systems is the all-in-one solution with respect to the combination of heating and cooling.

Such systems are more efficient and easier to install than two separate systems for heating and cooling.

In addition, the radiant emitter systems benefit from the exergy principle in the form of reduction of the operating temperatures for heating and high operating temperatures for cooling. Thus the heat pump can work with a higher efficiency (operating factor) which reduces the power consumption and hence the operating costs accordingly.

Ground Energy – in brief

Fields of application / usages
- Heating
- Hot water
- Cooling
- Energy storage

Environmental aspect
- Reduces the use of fossil fuels
- Reduces the CO_2 emission, where applicable
- Renewable energy source
- When installed and used properly no adverse effects on groundwater and soil

Fields of application
- Single-family homes and apartment blocks
- Private and public buildings
- Industrial buildings
- Office buildings

Technical aspects
- Ground energy is available almost unlimited all-the-year
- No chimney required
- Fully automatic safe operation, low maintenance
- Distributed and central system usage
- Can be combined with other energy sources

Economic aspects
- Low operating expenditures (power required for heat pump, but no fuel costs)
- Low cost of ownership (no emission measurements, no costs for chimney sweep)
- No fuel supplies required
- Comparatively high investment costs
- Amortization dependent on the general development of energy costs
- Efficiency dependent on proper layout of the complete system and electricity tariffs ("heat pump power") of the energy suppliers

Visible thermal heat – Hot spring on Iceland

Geothermy (Greek: geo = earth; thermy = heat) or ground energy is the heat stored in the accessible part of the earth crust. Geothermy describeds both, dealing with thermal energy and its utilization from a technical point of view and the scientific investigation of the thermal situation of the Earth.

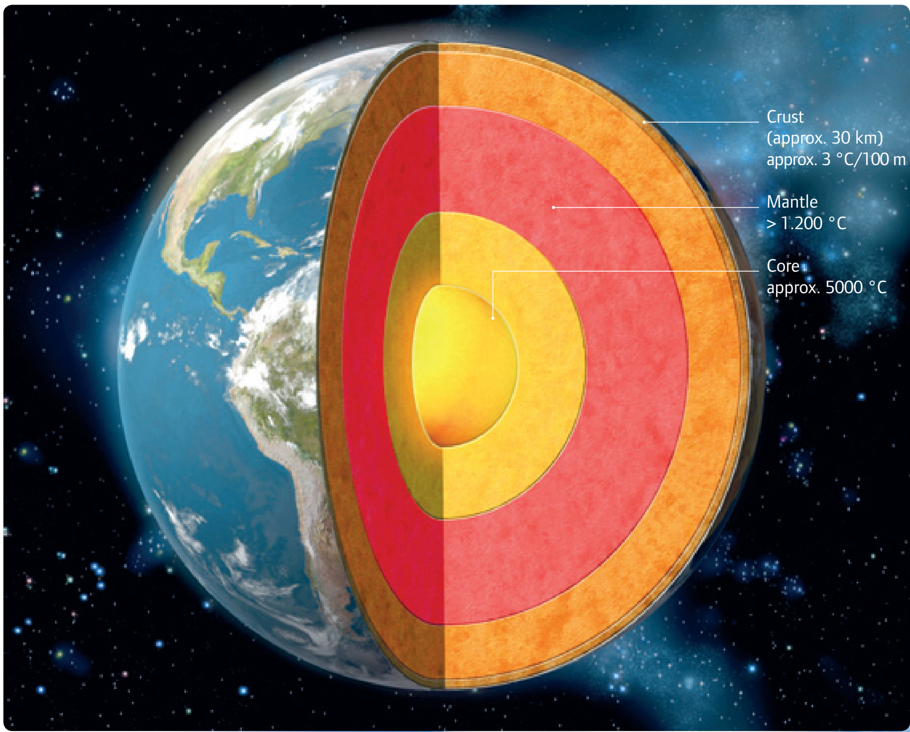
Hot Stuff: Planet Earth – the Energy Source

The crust of the earth in comparison to the diameter of the earth of about 12,750 km is only a thin layer. Below the oceans the crust has a thickness of approximately 5 to 10 km, below the continents it has a thickness of 15 to a maximum of 50 kilometers. High temperatures prevail already in the crust; at the crust's bottom side up to 1,100 °C.

Below the crust there is the mantle which according to petrophysical characteristics is split into the upper and lower mantle and a transition zone. The upper mantle spreads to a depth of approximately 400 km with temperatures of up to 1,400 °C, the transition zone spreads to up to 900 km and the lower mantle to a depth of 2,900 km with temperatures of up to 3,700 °C.

Below 2,900 km begins the earth core with an outer liquid core and an inner solid core. In the outer core temperatures of approximately 4,000 °C prevail, in the inner core probably more than 5,000 °C.

At present the **economic use** of geothermal energy is limited to the upper part of the crust.
A distinction is made between **ground energy collectors** and **deep geothermal energy**.



Shell structure of the earth

Geothermal Energy

Geothermal energy is further divided into two applications or systems: hydrothermal and petrothermal systems.

Hydrothermal Method
With the hydrothermal method naturally occurring thermal water resources (hot water aquifers) are tapped. These aquiferous layers can be used for both direct (heat) and indirect (electricity) energy generation.

Petrothermal Method
With the petrothermal method energy is generated from hot dense rock. The Geothermal energy can be utilized by means of the so-called hot-dry-rock-method. The rock exploited by drilling in a depth of some thousand meters is fractured by water streaming in under very high pressure resulting in hydraulic routing. The subterraneous "heat exchanger" generated this way now directs the energy in the form of water vapor upwards through another borehole, where it either drives turbines to generate electricity or is used for direct heat generation.

Ground Energy

We speak of ground energy in case of application depths of up to 400 m. Here, the temperature increases by 3 °C per 100 m depth on average. The average surface temperature of the earth is approximately 13 °C and is determined through a combination of irradiating solar energy, emission of heat into space, ground flux and variants or interferences of these factors.

In contrast to geothermal energy the ground energy does not provide energy directly in the form of usable heat. For heating and hot water generation the temperature level must be increased to the required value through a heat pump.

Apart from the depth and the type of rock also groundwater plays an important role in energy generation. In Central Europe the groundwater has an almost constant temperature throughout the season. Due to the permanent flow heat energy is constantly supplied for heating or dissipated for cooling.

Even in case of outside temperatures that seasonally vary considerably the temperature in a few meters depth remains relatively constant at an average of 10 °C. Hence, ground energy is a permanently functioning or constant source of energy that enables use over the whole year both for heating and cooling of buildings.

Basics

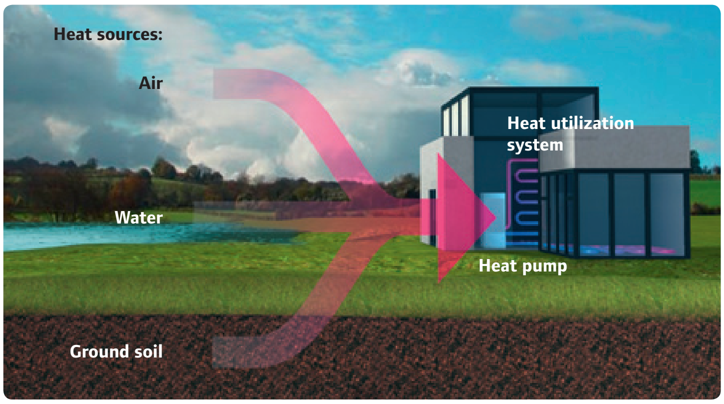
General

When planning the use of ground energy local conditions are of fundamental importance. Determining the soil properties with respect to the water content, the thermal ground soil characteristics, i.e. thermal conductivity, density, specific and latent thermal capacity as well as evaluating the different heat and substance transport processes are pre-requisites to determine and define the capacity of a ground application. The dimensioning of the ground energy source has great impact on the energy efficiency of a heat pump system. Heat pumps with a high capacity have unnecessary high power consumption when combined with a poorly dimensioned heat source.

Region with high ground energy potential

Heat Pump System

A heat pump system is an energy system comprising a heat source, a heat pump and a heat utilization system.



Heat pump system

Heat Source

Heat sources for the pump system can generally be air, water and ground soil. One speaks about ground utilization when ground soil is used as heat source. For the extent of ground utilization mainly geology, hydrology and the climatic conditions and thus the ability for regeneration of the ground soil are of primary importance.

Geology, Hydrology and Climate

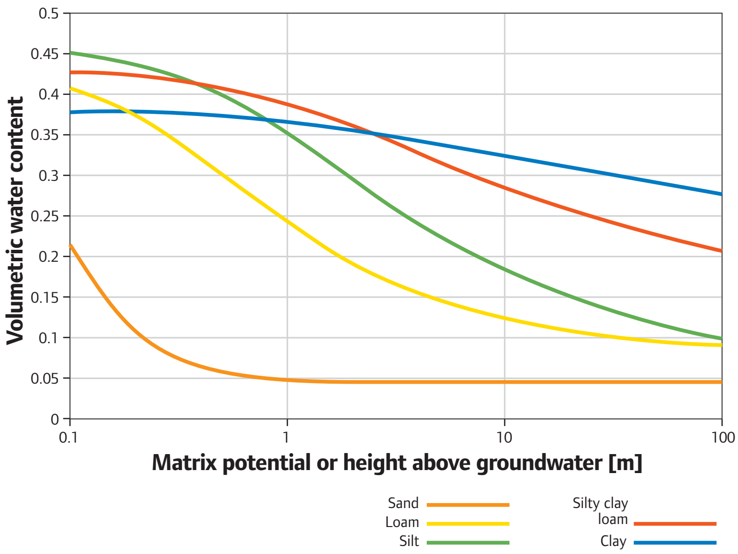
Soils usually have a pore share of 35 and 45 %. If these are filled with water instead of air, the heat conductivity, the density and the specific and latent heat capacity of the soil increase. This has a positive effect on the maximum possible abstraction capacity of a ground collector.

The water content of the soil depends on the climatic conditions, the cultivation, the groundwater level and the hydraulic characteristics (capillarity) of the ground soil. The water contents of the soil are mainly influenced the effects of the capillary rise from the groundwater level and the moisture penetration due to seeping rain water.

The matrix potential Ψ_M (suction pressure) of a soil describes the extent to which existing water is bound in the soil matrix. The lower the water content the more the remaining water is bound to the soil matrix. Mainly the gravitation potential Ψ_G (dynamic pressure) or geodetic height above the groundwater level as well as negligently the osmotic potential, the surcharge load potential and the pressure potential work against the matrix potential. In the stationary state both potentials even out.

$$\Psi_{Ges} = \Psi_M + \Psi_G = 0 \quad \text{[Vol. \%]}$$

Stationary water content subject to the height above groundwater level



Apart from the height above groundwater the average rain water quantity seeping into the soil over a longer period of time has a great impact on the water content of the relevant soil. Short showers that cause a surface runoff have hardly any influence.

The higher the water content of the soil the better the soil allows water to seep in (groundwater permeability). With relatively steady rain over a longer period of time the water content in the soil rises until the rain water can seep in due to gravitation.

The monthly water quantity seeping into the ground results from the difference between rainfall and evapotranspiration (evaporation plus transpiration of the plants). The characteristics of the soil during the heating period are mainly influenced by the months of October and November. During these months the plant growth and the average outside temperature is decreasing, thus the evaporation rate will decrease as well.

Actually the course of rainfall is not very stationary. This is dampened in the top earth layers by the soil capacity and the groundwater permeability dependent on the water content to an extent that in the relevant soil only long-term changes of rainfall affect the water content. Thus the water content in the relevant soil materializes from rainfall averaged over several weeks.

The soils commonly found in nature are mixtures of sand, silt and clay. They comprise the three phases – solid matter, water and gases – the density, heat conductivity as well as specific and latent heat capacity are based on. These characteristics are very difficult to determine due to the many variances and can best be taken from respective reference catalogues for different climatic regions.

Information:

- The specific heat conductivity λ [W/(K · m)] describes the ability of a rock to transport thermal energy by means of heat conduction (conductive heat transport). It is a temperature-dependent material constant.
- The specific heat capacity c_p [MJ/(m³ · K)] specifies the energy quantity that is needed to heat 1 m³ of the rock to 1 K.
  The bigger it is the more heat energy the rock can absorb (store) and eventually release.

Examples of heat conductivity and volume-related specific heat capacity of the subsurface at 20 °C

	Type of rock		Heat conductivity in W/(m · K)	Recommended value	Volume description special heat capacity in MJ/(m³ · K)	Density in 10² kg/m³
Unconsolidated rock	Clay/silt, dry		0.4 – 1.0	0.5	1.5 – 1.6	1.8 – 2.0
	Clay/silt, waterlogged		1.1 – 3.1	1.8	2.0 – 2.8	2.0 – 2.2
	Sand, dry		0.3 – 0.9	0.4	1.3 – 1.6	1.8 – 2.2
	Sand, moist		1.0 – 1.9	1.4	1.6 – 2.2	1.9 – 2.2
	Sand, waterlogged		2.0 – 3.0	2.4	2.2 – 2.8	1.8 – 2.3
	Gravel/stones, dry		0.4 – 0.9	0.4	1.3 – 1.6	1.8 – 2.2
	Gravel/stones, waterlogged		1.6 – 2.5	1.8	2.2 – 2.6	1.9 – 2.3
	Glacial drift		1.1– 2.9	2.4	1.5 – 2.5	1.8 – 2.3
	Peat, earthy brown coal		0.2 – 0.7	0.4	0.5 – 3.8	0.5 – 1.1
Sedimentary rocks	Mudstone/siltstone		1.1 – 3.4	2.2	2.1 – 2.4	2.4 – 2.6
	Sandstone		1.9 – 4.6	2.8	1.8 – 2.6	2.2 – 2.7
	Psephite/breccia		1.3 – 5.1	2.3	1.8 – 2.6	2.2 – 2.7
	Marlstone		1.8 – 2.9	2.3	2.2 – 2.3	2.3 – 2.6
	Limestone		2.0 – 3.9	2.7	2.1 – 2.4	2.4 – 2.7
	Dolomite brick		3.0 – 5.0	3.5	2.1 – 2.4	2.4 – 2.7
	Sulfate rocks (anhydrite)		1.5 – 7.7	4.1	2.0	2.8 – 3.0
	Sulfate rocks (gypsum)		1.3 – 2.8	1.6	2.0	2.2 – 2.4
	Chloride rocks (rock salt-/waste salt)		3.6 – 6.1	5.4	1.2	2.1 – 2.2
	Blue coal		0.3 – 0.6	0.4	1.3 – 1.8	1.3 – 1.6
Magmatic solid rock	Tuff		1.1	1.1		
	Volcanic rock, acid up to intermediary	e.g. rhyolite, trachyte	3.1 – 3.4	3.3	2.1	2.6
		e.g. trachybasalt, dacite	2.0 – 2.9	2.6	2.9	2.9 – 3.0
	Volcanic rock, basic up to ultrabasic	e.g. andesite, basalt	1.3 – 2.3	1.7	2.3 – 2.6	2.6 – 3.2
	Plutonite, acid to intermediary	Granite	2.1 – 4.1	3.2	2.1 – 3.0	2.4 – 3.0
		Syenite	1.7 – 3.5	2.6	2.4	2.5 – 3.0
	Plutonite, basic to ultrabasic	Diorit	2.0 – 2.9	2.5	2.9	2.9 – 3.0
		Gabbro	1.7 – 2.9	2.0	2.6	2.8 – 3.1
Metamorphic solid rocks	low metamorphic grade	Slate	1.5 – 2.6	2.1	2.2 – 2.5	2.4 – 2.7
		Silicous shale	4.5 – 5.0	4.5	2.2	2.5 – 2.7
	medium to high metamorphic grade	Marble	2.1 – 3.1	2.5	2.0	2.5 – 2.8
		Quartzite	5.0 – 6.0	5.5	2.1	2.5 – 2.7
		Mica slate	1.5 – 3.1	2.2	2.2 – 2.4	2.4 – 2.7
		Gneiss	1.9 – 4.0	2.9	1.8 – 2.4	2.4 – 2.7
		Amphibolite	2.1 – 3.6	2.9	2.0 – 2.3	2.6 – 2.9
Other materials	Bentonite		0.5 – 0.8	0.6	~3.9	
	Concrete		0.9 – 2.0	1.6	~1.8	~2.0
	Ice (-10°C)		2.32		1.89	0.919
	Plastic (HD-PE)		0.42		1.8	0.96
	Air (0°C to 20°C)		0.02		0.0012	0.0012
	Steel		60		3.12	7.8
	Water (+10°C)		0.56		4.15	0.999

Source: VDI 4640

Remarks:

In case of unconsolidated rock the density varies considerably with compactness and water content.
With sandstone, psephite and breccia there is an extensive width of heat conductivity; apart from grain material and distribution and the water saturation the type of binding agent or the matrix plays a role.

Groundwater with its high heat capacity of 4.190 J/kgK at 10 °C plays an important role for the abstraction capacity of the ground system. With respect to the groundwater permeability a distinction is made between the pore permeability and the joint permeability with respect to the sub-surface of unconsolidated rock or solid rock. With unconsolidated rock (pore aquifer) especially the grain size and grain distribution, and in case of solid rock the frequency and opening width of the separating joints are decisive for the groundwater permeability. The table below shows reference values for the permeability of unconsolidated rock.

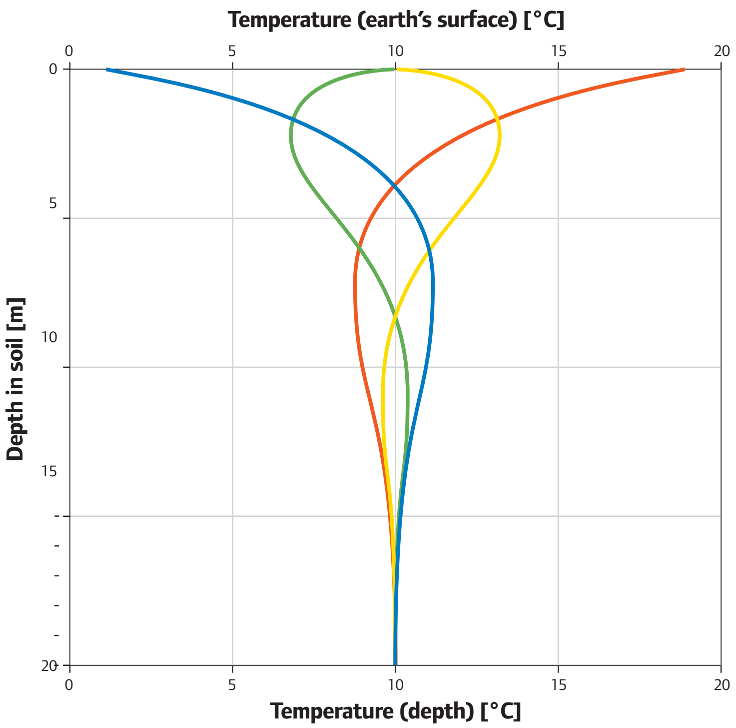
Reference values for the permeability of unconsolidated rock

Unconsolidated rock	Coefficient of hydraulic conductivity k_f [m/s]	Evaluation of the permeability
Pure gravel	above 10^{-2}	highly pervious
Sandy gravel, medium/ torpedo sand	above 10^{-4} to 10^{-2}	highly pervious
Fine sand, silty sand	above 10^{-6} to 10^{-4}	pervious
Silt, clay loam	10^{-8} to 10^{-6}	slightly pervious
Clay, silty clay	below 10^{-8}	impervious

Source: VDI 4640

On average the temperature increases by 3 °C per 100 m depth. The course of the temperatures during the year (Central Europe) in the upper 15 m is shown in the illustration below. In the Winter the outside temperatures may often go below zero degrees, but in a few meters depth the soil temperature already reaches a value of 10 °C on average. In the Summer the outside temperature is almost 20 °C on average, the ground soil in a few meters depth, however, shows almost constant temperatures of 10 °C. This applies in most cases for the transition periods of spring and fall.

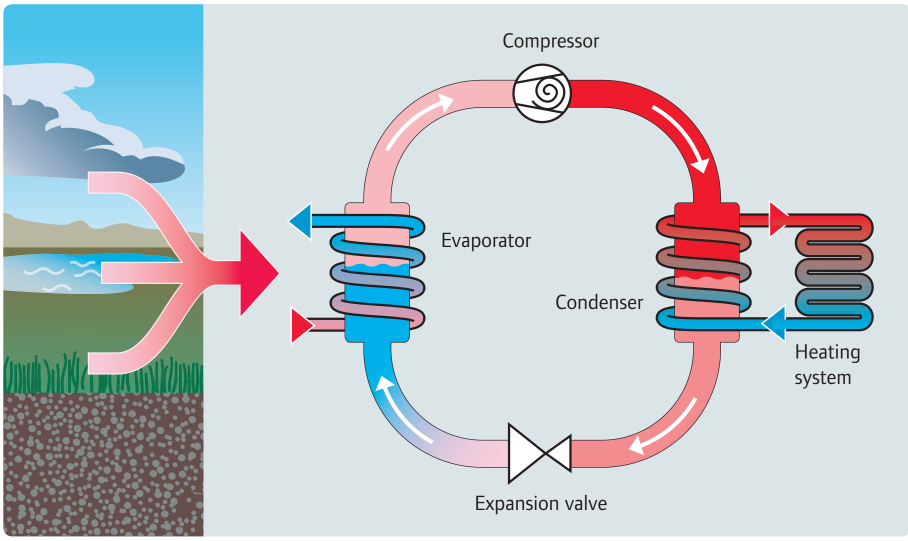
From the course of the shallow soil temperatures over the year it becomes apparent that ground energy is an always functioning and constant source of energy.



On average the soil temperature increases by 1 °C approximately every 33 m.

Heat Pumps

Heat pumps are cold vapor machines by means of which low temperature ambient energy can be utilized for heating or cooling buildings. The ambient energy is extracted from the ambient air, the groundwater or the ground soil. By using electrical power the temperature is brought to the desired level.



Function principle of a heat pump

The cycle running within the heat pump consists of four components: the evaporator, the compressor, the condenser and the expansion valve. The carrier for the thermal energy is a refrigerant with an extremely low boiling point. In the evaporator the refrigerant takes up the heat from the environment and thus becomes gaseous.
In the compressor the gaseous refrigerant is brought to a higher temperature level by compression. To do so, the device needs the external electrical power.
In the condenser the thermal energy is supplied into the heating circle. In the expansion valve the refrigerant is expanded in order to pass through the circle again afterwards.

Heat pumps are categorizes as follows:
- air/water heat pumps
- water/water heat pumps
- brine/water heat pumps

The designation of the heat pump type depends on which medium absorbs the heat (heat transfer medium) and which medium distributes the heat in the house.

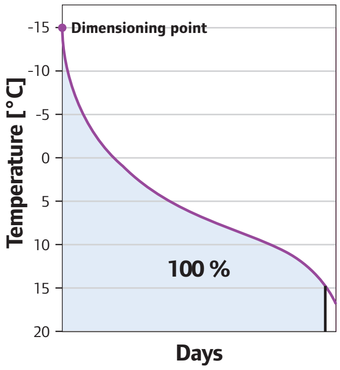
If brine (water / glycol mixture) absorbs the heat through a ground collector and if water dissipates the heat e.g. through an underfloor heating system, this is called a brine/water heat pump.

With respect to the operating modes a distinction is made between:

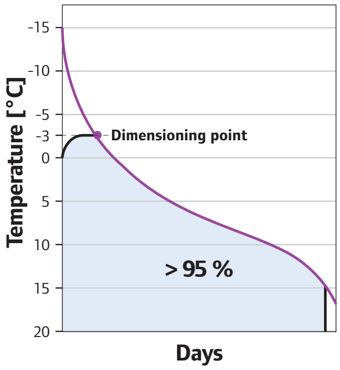
- monovalent (one energy source)
- bivalent (two energy sources)
- monoenergetic (one energy resource).

Air/water heat pumps are directly subject to fluctuations of the outside temperatures. Thus they have the lowest energy efficiency in times when the heat demand is the highest – in the Winter when the ambient air has the lowest energy content. In order to cover these extreme cases, with the air/water heat pump the peak loads can either be accommodated monoenergetically through an additional electric heating (heating rod) or bivalent through a second energy source (e.g. solid fuel boiler).

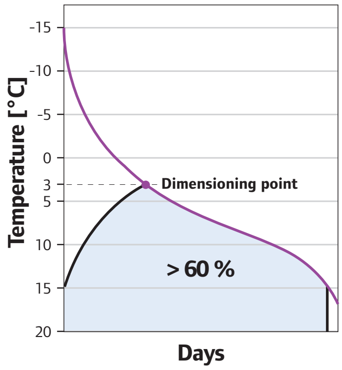
Heat pump with monovalent operating mode

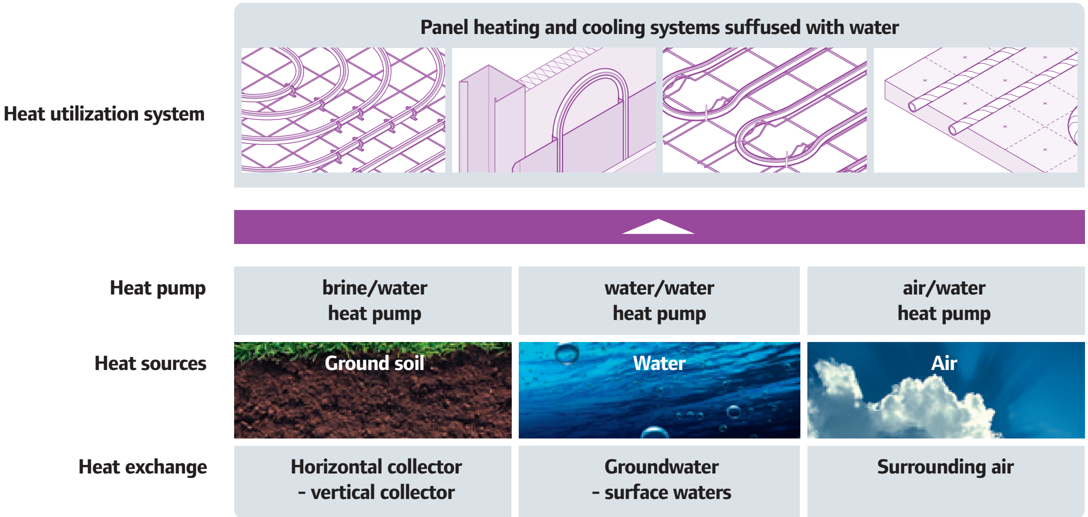


Heat pump with monoenergetic operating mode



Heat pump with bivalent -parallel operating mode





Overview of heat pump systems

For ground applications brine/water heat pumps are used. In this type of pump a water/glycol mixture flows through the heat exchanger. In order to assess the quality of a heat pump system the so-called seasonal performance factor β is used. It shows the ratio of heating energy delivered to electrical energy supplied (rated capacity) over one year.

The higher the seasonal performance factor the higher the efficiency of the heat pump. The usual range is 3 to 4.5.

$$\textbf{Seasonal performance factor } \beta = \frac{\textbf{W (usable thermyl energy)}}{\textbf{W (supplied electrical power)}}$$

Ensuring the operational Safety

To be able to evaluate the energy quantity or capacity that can be extracted from or supplied to the ground by a heat exchanger, criteria must be defined by means of which the efficiency can be measured and with which limit values must not be exceeded.

The following criteria must be met to ensure that the heat pump system is not damaged:

Operational safety is understood as preventing damage of the system and complying with the maximum capacity of a heat pump to ensure that safe operation can be guaranteed over the whole year. With respect to the heat source this means that the brine never falls below the solidification temperature and the minimum brine temperature specified by the heat pump manufacturer.

The brine is cooled down in the evaporator before it heats up again in the heat source. Thus, there are the lowest temperatures in the brine circuit. The common heat carriers that contain water expand during solidification. Hence here is the danger that pipes or the evaporator burst, if the brine solidifies.

The heat carriers mainly used for heat sources are mixtures of water and glycol (mainly monoethylene glycol). With the established mixing ratio of 3:1 a protection against freezing to approx. -14 °C is guaranteed. Therefore it must be ensured not to fall below this temperature at any point. For this reason most manufacturers have integrated safety devices so that the heat pump is switched off early. This function can for instance be taken over by a LP pressure control switch positioned in the suction line leading to the compressor. When falling below the pressure which corresponds to an evaporation temperature of approx. -15 °C or in case of overheating which corresponds to a suction gas temperature of -10 °C, the pressure control switch causes the heat pump to switch off. Depending on the heat transfer characteristics of the evaporator and of the temperature spread in the brine circuit a suction gas temperature of -10 °C corresponds to a brine return temperature of approx. -5 °C.

Due to the safety reasons mentioned above and partly due to the maximum possible pressure ratio of the compressor this temperature is specified as the limit by most heat pump manufacturers. Therefore, the heat source system has to be laid out so that the brine return temperature into the heat pump does not fall below -5 °C also during peak loads in the Winter.

The table below shows an example of a calculation of the cost of ownership of a heat pump compared to a traditional heating system.

Exemplary comparison of cost of ownership in Germany

	Gas	Heat pump
Required heat energy [kWh]	20,000	20,000
Efficiency/Seasonal performance factor	85%	4
Energy quantity obtained [kWh]	23,529	5,000
Price per kWh [ct/kWh]	6.68	13.61
Basic price [€/year]	142.8	41 ,40
Operating costs [€/year]	1,714.56	721.90
Costs exhaust gas measurement [€/year]	45.11	–
Total cost [€/year]	1,759.65	721.90
Difference [€/year]	–	1,037.75
Costs in per cent	**100%**	**41%**

Heating emitter systems

Low temperature systems are especially suited to operate together with heat pump systems. Due to the large surface the required operating temperatures are only slightly above (heating) or below (cooling) the room temperature which considerably improves the energy efficiency of heat pumps used for ground energy systems.

Low-temperature systems include radiant heating and cooling systems in which water is circulated:

- underfloor heating and cooling system
- wall heating and cooling systems
- ceiling heating and cooling systems

In radiant heating or cooling systems the energy is almost exclusively transferred through radiation and not through convection. Thus drafts and stirring up of dust are avoided. Since radiant heating and cooling systems are "invisible" they do not take up valuable space and offer almost unlimited freedom with respect to the design and furnishing of rooms as well as an optimal ratio of interior space and usable space.

Underfloor heating and cooling Systems
There are tailormade system solutions not only for new buildings but also for retrofitting existing floors. To increase comfort these systems can also be used for interior cooling. When planning ahead the cooling function can be retrofitted later.

Underfloor heating and cooling systems are installed in different ways. The most typical types for new buildings and renovation are:

- Low height systems
- Wet systems
- Dry systems

Wall heating and cooling Systems
As an alternative to underfloor heating or cooling systems or to extend the heating or cooling surfaces wall systems can be used.

A distinction is made between:
- Dry wall systems
- Wet wall systems

Dry wall systems are used for renovating, if the floor construction is not to be changed or must not be changed. Apart from existing walls additional lightweight constructions walls (stud walls) can be used as heating or cooling surfaces. Depending on the wall construction the system is installed below the panelling or directly in the plaster layer. Wet wall systems are used in case of partial renovating or when new plaster is applied.

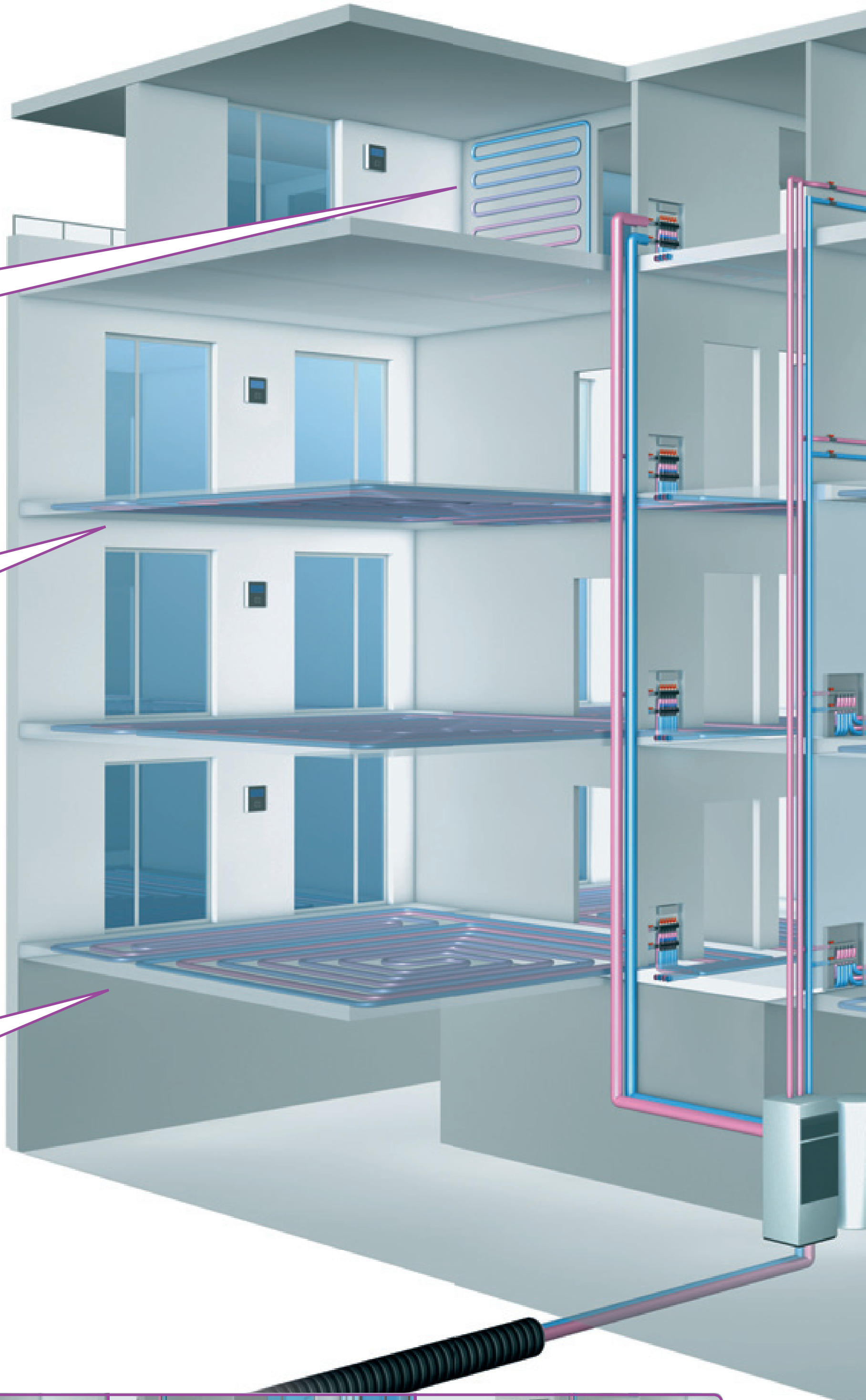
Ceiling heating and cooling Systems
Heating and cooling in the form of ceiling heating and cooling systems is increasingly used for reasons of comfort and efficiency compared to air conditioning systems.

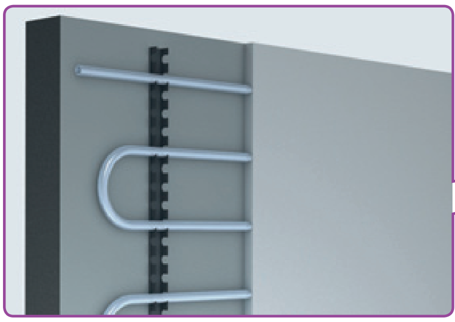
With ceiling heating and cooling systems a distinctin is made between the following types:

- Suspended ceilings or ceiling panels
- Activation of thermal mass or concrete core activation

Suspended ceilings are used in new builds and renovation. Heating and cooling in ceiling panels is activated by installing pipes in which water is circulated directly in the ceiling panels.

Concrete ceilings are used for cooling or heating of multi-story buildings. This future-oriented solution results in thermally active ceilings by means of pipe registers in which water is circulated also in module construction. Concrete core activation is used to ensure thermal comfort in the building in a simple, environmentally friendly and cost-saving way. Concrete core activation should be used for buildings with low or medium cooling loads in order to work against heating-up in the Summer. In buildings with medium or high cooling loads the concrete core activation can be used to cover the basic loads.





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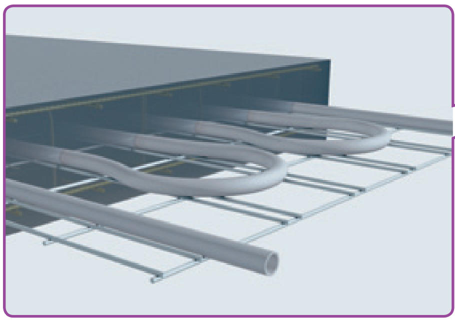

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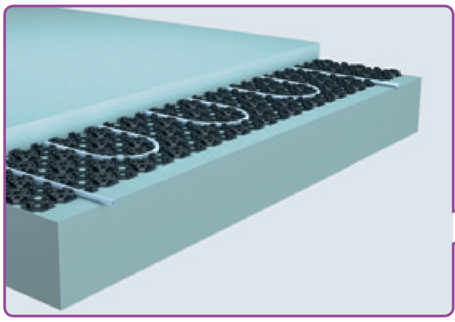

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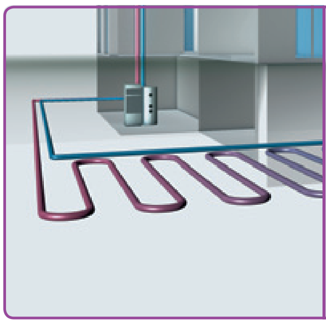
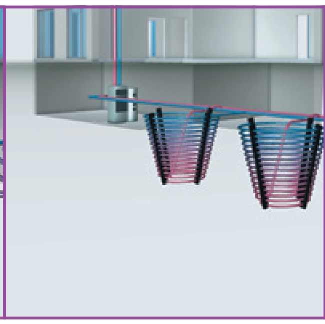
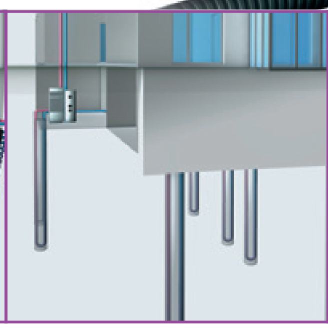


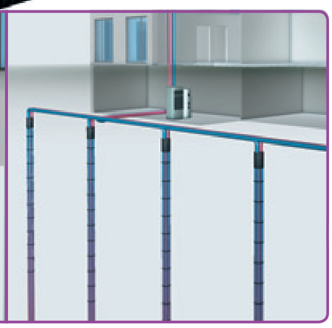
Uponor Horizontal Collectors



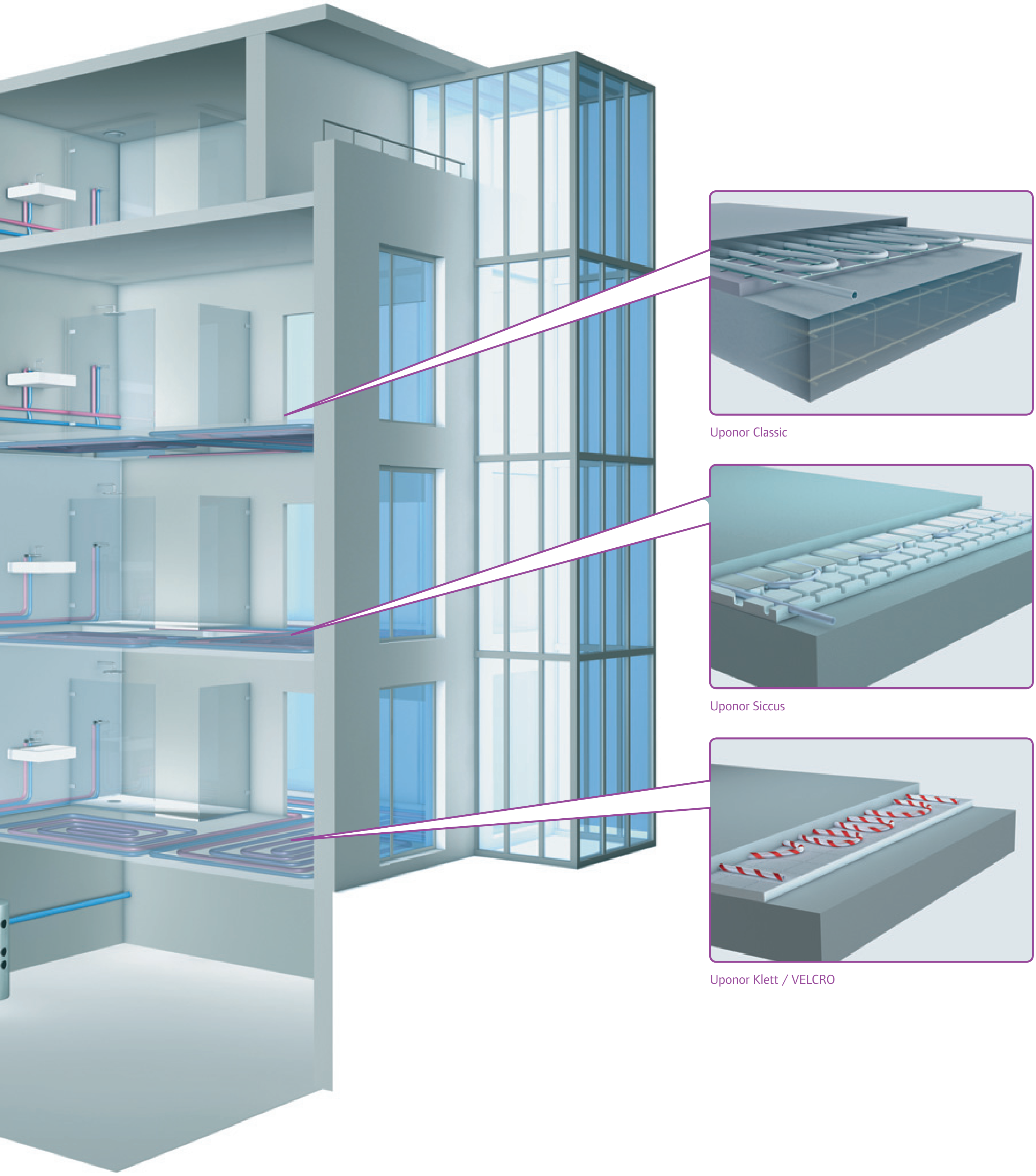
Uponor Energy Cages



Uponor Energy Piles



Uponor Vertical Collectors


Uponor Classic
Uponor Siccus
Uponor Klett / VELCRO

Ground Energy utilization Systems

System Overview

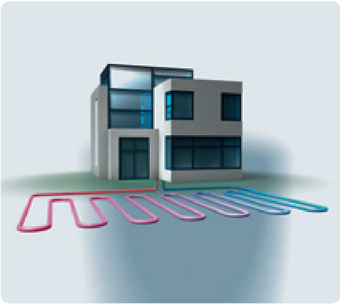
With ground energy collectors (heat exchangers) a distinction is made between Horizontal and vertical collectors.

Conventional ground energy systems can be classified as follows:

Horizontal
- Horizontal collector or surface collector (earth-to-air heat exchanger)
- Spiral and energy cages
- Rift collectors

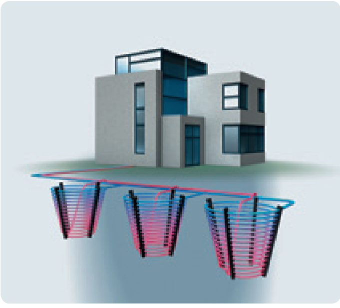
Vertikal
- Boreholes
- Energy piles and slotted walls

The suitability of the respective ground energy system depends on the environment (soil properties and climatic conditions), the performance data, the operating mode, the type of building (commercial or private), the space available and the legal regulations.



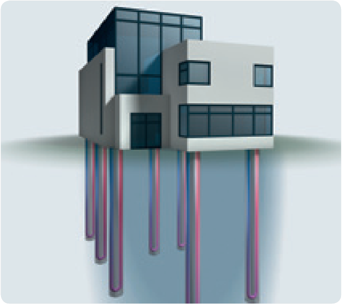
Horizontal Collectors

Heat exchangers that are installed horizontally or diagonally in the upper five meters of the ground (surface collector). These are individual pipe circuits or parallel pipe registers which are usually installed next to the building or under the ground slab.



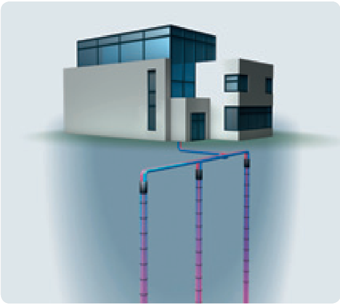
Energy Cages

Heat exchangers that are installed vertically in the ground at lower levels. Here, individual pipe circuits are arranged in spiral or screw shape. Energy cages are a special form of horizontal collectors.



Energy Piles

Heat exchangers in pile foundations that are installed in areas with insufficient load capacity. Individual or several pipe circuits are installed in foundation piles in U-shape, spiral or meander shape. This can be done with prefabricated foundation piles or directly on the construction site where the pipe circuits are placed in prepared boreholes that are then filled with concrete.



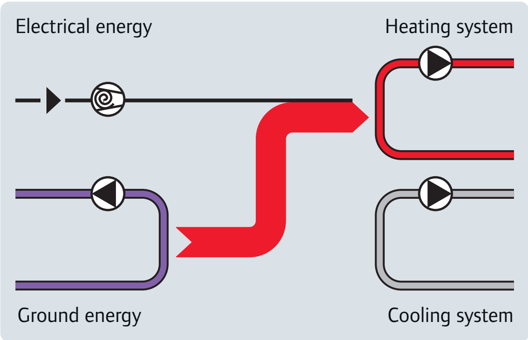
Vertical Collectors

Heat exchangers that are installed vertically or diagonally in the ground. Here one (single U-probe) or two (double U-probe) pipe circuits are inserted in a borehole in U-shape or concentrically as inner and outer tube.

Operating modes

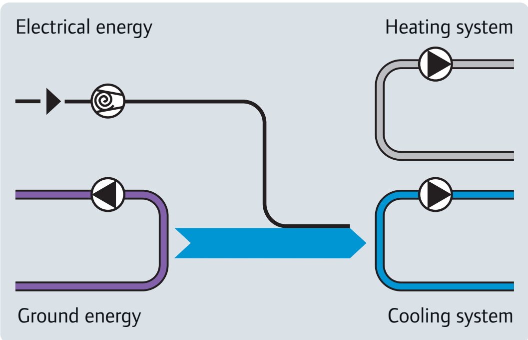
The operating mode and the resulting operating cost of the heat pump are defined according to the heating and cooling requirements of the respective building.

Heating operation



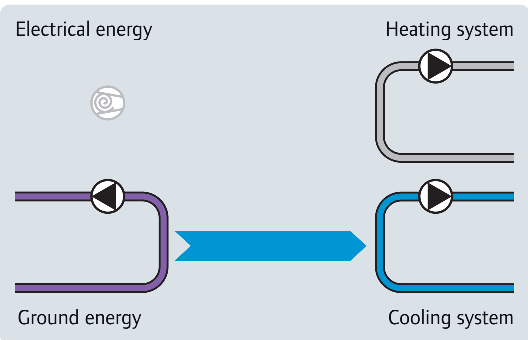
- Ground energy is used as heat source
- The heat pump increases the media temperature to a level utilizable for the building.

Cooling operation (active)



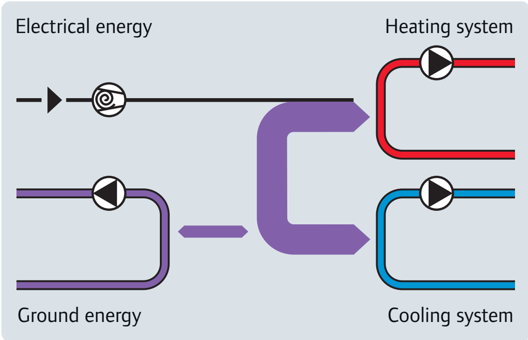
- Ground energy is used as heat sinks (cooling source)
- Temperature level for passive cooling insufficient
- Compressor active
- Dual operation possible

Cooling operation (passive/free cooling)



- Ground energy is used as heat sink (sold source)
- Temperature level from ground energy sufficient for passive cooling – only circulation pump is active
- No dual operation possible
- Very low operating costs

Heating and cooling – dual operation



- Depending on the energy balance in the building the ground energy is used as heat source and heat sink (cold source)

Selection matrix of ground energy systems depending on the operating mode and system size

Mode of operation	Heating		Cooling			
			Active		Passive / Free Cooling	
System size	< 30 kW	> 30 kW	< 30 kW	> 30 kW	< 30 kW	> 30 kW
Vertical Collector	●	●	●	●	●	●
Horizontal Collector	●	○	○	–	○	–
Energy Cage	●	●	○	–	●	–
Energy Pile	●	●	○	○	●	○

● applicable ○ limited use dependent on the general conditions

Passive cooling – free cooling

Ground energy is the only system that enables so-called passive cooling or free cooling. Vertical collectors are the most effective solution of all potential applications for this operating mode.

A pre-requisite for this is the use of a radiant heating or cooling system.

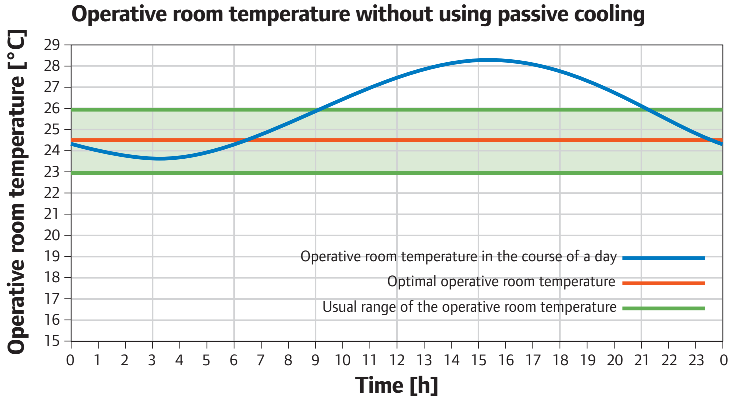
The “free cooling” operating mode has several advantages for the user and the environment:

- Increased living comfort due to an agreeable room climate
- Improvement of the seasonal performance factor of the whole system by regeneration of the ground soil
- Minimum additional investment costs, low operating costs
- Saved resources
- Environmentally compatible

Due to the improved insulation of new buildings the ratio of heating and cooling changes. Where in the past the focus was on heating, now cooling is more in the focus due to increased demands for comfort. Modern buildings increasingly tend to overheat in warmer periods of the year. To work against this effectively shading measures are taken. To achieve an operative room temperature (comfort temperature) of 26 °C, the cooler temperatures stored in the ground is used and transferred to the building through a radiant system.

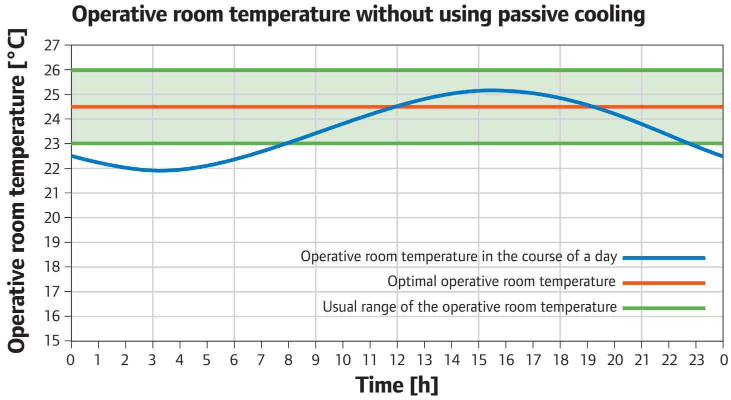
By discharging excess heat from the building into the ground the ground is actively regenerated, i.e. it heats up again. In single family houses more heat is extracted from the soil in the Winter than is resupplied in the Summer. This can be regarded as unproblematic since usually during the transition from heating to cooling period there is sufficient time for the passive or natural regeneration. The active regeneration supports this additionally. When using passive cooling only minimal additional investment costs arise. Monitoring of the dew point and switching over from heating to cooling can be taken over by modern regulating or radiant heating and coolings system, like for instance the Dynamic Energy Management (DEM). Additional costs only occur for the dew point sensors

Operative room temperature without using passive cooling



Operative room temperature without using passive cooling
The illustration on the left shows the course of the temperature inside a room with outer shading on a typical summer day in July. Overheating of the room is obvious.

Operative room temperature without using passive cooling



Operative room temperature using passive cooling
The use of the passive cooling function results in a clear improvement of the operative room temperature.

and mounting. In case of passive cooling only the brine circulation pump and the emitter circulation pump of the system are operating. The heat pump compressor does not run. Thus the operating costs are limited to the power consumption of the circulation pump(s).

Example calculation – potential annual costs – passive cooling

	Brine circulation pump	Emitter circulation pump
El. power	5 – 70 W	16 – 310 W
El. power with calculated flow rate	60 W	55 W
Operating time	800 h	800 h
Total annual energy demand	48 kWh	44 kWh
Electricity tariff per kWh	0.20 €/kWh	0.20 €/kWh
Annual energy costs	9.60 €	8.80 €
Total energy costs		**18.40 €**

Example calculation – potential annual cost – active cooling

	Compressor	Emitter circulation pump
El. power	2,300 W	16 – 310 W
El. power with calculated flow rate	–	55 W
Operating time	800 h	800 h
Total annual energy demand	1,840 kWh	44 kWh
Electricity tariff per kWh	0.20 €/kWh	0.20 €/kWh
Annual energy costs	368.- €	8.80 €
Total energy costs		**376.80 €**

Horizontal Collectors

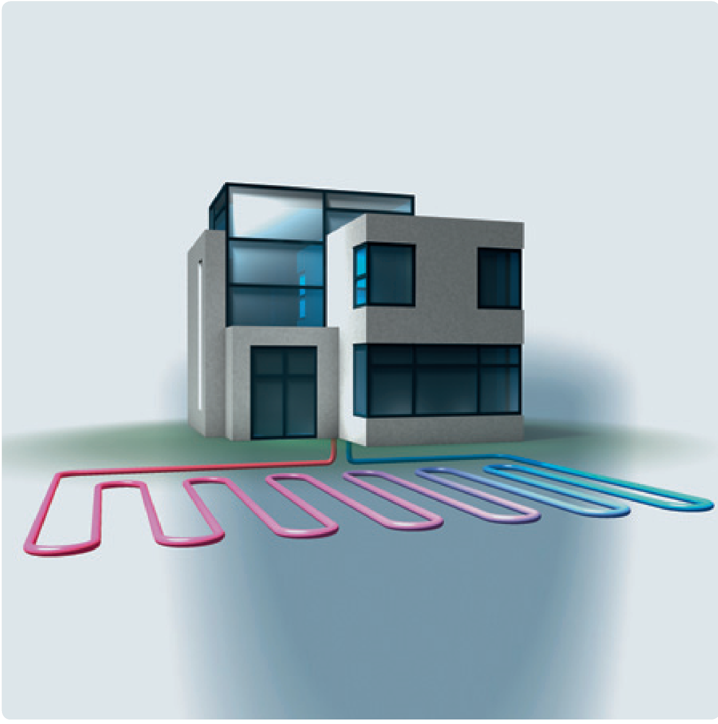
System/scope of application

Application description

Horizontal collectors are the most widely used variant of ground energy exchangers. They consist of horizontal pipes, i.e. pipes laid in parallel to the surface of the earth.

Benefits

- Comparably low investment costs
- Good seasonal performance factor
- Easy installation
- Ideal solution for single family or multi-family houses as well as small business and industrial applications
- Low installation depth without affecting the hydrologic balance



Schematic illustration of a horizontal collector system

Depending on the respective requirements and conditions the individual pipe loops are laid at distances of 0.5 to 0.8 m (with pipe diameters of 40 mm 1.2 to 1.5 m) – similar to the pipe loops of an underfloor heating system. The supply and return pipes of the individual pipe loops are combined in collecting and distribution chambers or manifolds and routed to the heat pump.

Note:

Combining horizontal collectors with the Uponor EPG6 cooling station makes an ideal free-cooling solution.

The important benefit of the horizontal collectors is the low investment with a relatively high seasonal performance factor. Of all ground energy systems the horizontal collector is the variant with the lowest costs involved. A relatively large space of unsealed garden is to be planned.

An alternative to the horizontal collectors is the activation of the foundation slabs for heating and/or passive cooling. Here, no additional space apart from the actual building is required. Since most buildings are based on foundation slabs, strip foundations or deep foundations or a combination therefore, utilization of the ground energy heat through the foundations would be useful.

Below the foundation slab or floor slab, i.e. between ground soil and slab usually a so-called blinding layer is integrated which consists of lean concrete or fine gravel. To utilize the ground energy collector pipes can be integrated here.
The capacities that can be reached with foundation slabs are limited and clearly lower than with horizontal collectors that are not overbuilt; Here apart from the soil condition the groundwater level and groundwater flux are of fundamental importance. Temperatures below the frost level are to be avoided in any case!

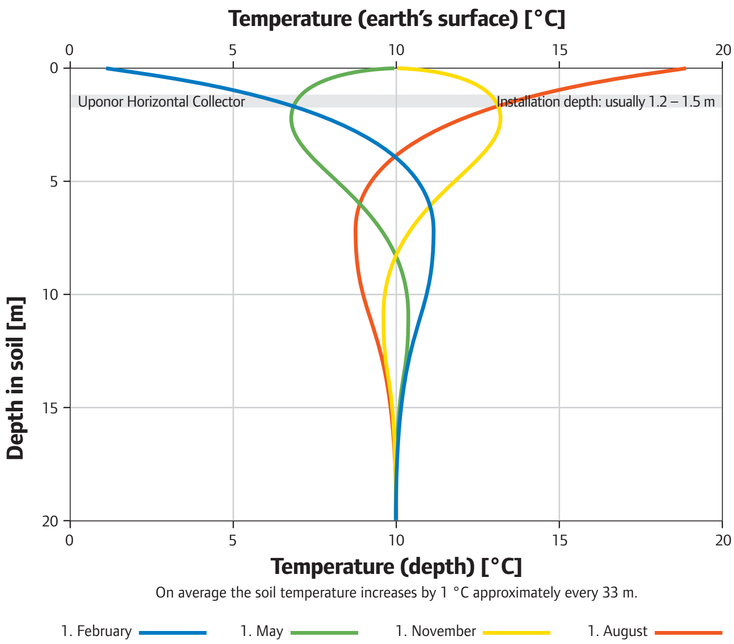
Functioning

Up to 99 % of the heat extracted from the ground soil by horizontal collectors is solar energy stored in the ground soil and not ground energy from the earth core. For this reason the thermal contact with the surface of the earth is decisive for the efficiency.
In the Winter the net solar energy hitting the ground soil is the lowest, but the extraction of heat of ground energy collector by means of heat pumps is the highest. The extracted energy is the solar energy stored in the ground soil during summer. The basic storage capacity of the ground soil can be put down to the phase change of the water existing in the ground soil. In order to enable a horizontal collector to utilize this storage capacity it is necessary that the top edge of the collector which can have any shape is positioned below the natural frost line.

Physical properties of the characteristic soil types

	Unit	Sand	Clay	Silt	Sandy clay
Water content	% Vol.	9.3	28.2	38.1	36.4
Heat conductivity	W/mK	1.22	1.54	1.49	1.76
Specific heat capacity	J/kg K	805	1,229	1,345	1,324
Density	kg/m³	1,512	1,816	1,821	1,820

Source: VDI 4640



Laying of the individual pipe loops

Fixing of the pipe loops on reinforcement mesh

Application limits

The efficiency of a horizontal collector mainly depends on the water content of the surrounding ground soil. In sandy soil with its low capillary action, rainwater seeps quickly into deeper earth layers. Clay soil with a high capillary effect, however, can keep the water much better against gravity. These differences cause the volumetric water content of sand to be usually below 10 % and that of clay to be above 35 %. Thus in clay more than double the amount of water per ground soil volume is available as latent storage for a horizontal collector than in sandy soil. In addition, water contained in the ground soil improves the heat conductivity, whereby stored heat from deeper earth layers and the solar energy of the earth's surface can flow much easier to the collectors.

In the table on the previous page a distinction is made between sand, clay, silt and sandy clay which reflect the wide spectrum of soils existing in nature very well.

Sand in this context is loose soil consisting of individual grains (> 50 mm). In this type of soil the capillary effect is extremely low and the groundwater permeability is high. Thus rainwater seeps quickly into deeper layers which above the groundwater results in a low volumetric water content below 10 %.

Clay mainly consists of a mixture of sand and silt, while silt is a soil with medium-fine graininess (between 2 mm and 50 mm). These cohesive soils usually have volumetric water contents between 20 and 40 % and are therefore better suited for horizontal collectors than sand.

In sandy clay of which the biggest fraction consists of very fine grains (< 2 mm) the capillary effect is even higher resulting in volumetric water contents above 30 %.

The exact physical properties vary from place to place which among other things is caused by different precipitation amounts. The following table shows the mean values of the physical properties of the different soil types.

Within Europe the climatic differences are so big that it does not make sense to lay horizontal collector according to the same rules. In warmer climes a higher surface-specific abstraction capacity is possible without causing damage of the system or the environment.

Building and the environment

During heating the horizontal collectors extract heat from the ground soil, so that afterwards it cools down to below the temperature of the undisturbed ground soil. When dimensioning systems it is to be ensured that the surrounding ground soil and the environment are not heavily affected or damaged.

In general it is possible that the flora above a horizontal collector develops slightly delayed in the Spring. Since the horizontal collector is usually positioned in depths below one meter and only few roots of bedding plants drift into this depth, the effect is low. In principle any type of plant can be planted on the horizontal collector field, even trees. Ground energy pipes in the usual depth cannot be damaged by roots and the effect on the plants caused by pipes is minimal.

It is not the sensitive cooling but rather the ice formation in the Winter that can cause damage. When falling below the pipe surface temperature of 0 °C the water existing in the surrounding ground soil starts to freeze. Slight ice formation usually is not problematic, since in the Winter also the undisturbed ground soil freezes up to a depth of 0.5 m – 0.8 m and melts with rising temperatures

Reference values for the dimensioning of horizontal collectors

Subsurface	Specific abstraction capability qE with 1.800 h/a [W/m²]	Specific abstraction capability qE with 2.400 h/a [W/m²]	Installation distance [m]	Installation depth [m]	Distance to supply pipes [m]
Dry, non-cohesive soils	10	8	1	1.2 – 1.5	> 0.7
Cohesive soils, damp	10 – 30	16 – 24	0.8	1.2 – 1.5	> 0.7
Water saturated sand/gravel	40	32	0.5	1.2 – 1.5	> 0.7

During longer operating periods both the specific abstraction capacity q and the specific annual abstraction factor are to be considered.
For ground energy collectors this should be between 50 and 70 kWh/(m² year). Reference value for ground energy collector training according to VDI 4640: valid for heating operation and water heating only!

Collector pipe loops made of PE-Xa

Generation of a floor slab collector

in the Spring. However, due to two effects ground soil or the environment might be negatively affected in case the ice formation is too heavy.

Expansion of the water during freezing

The water existing in the pores of the ground soil extends its volume when freezing. If only relatively few pores are filled with water the ice formation does not have remarkable effects, since the ice can then expand into the adjacent pores filled with air. However, when the water content is high, stress occurs with different consequences.

First the water close to the collector freezes and expands. Due to the expansion the ground soil around the collector pipe is pressed to the outside. Especially loamy soils keep this shape even after the ice has melted in the Spring. Thus the thermal contact between the collector pipe and the ground soil is interrupted. Only by increased rainfall can the space in between be filled again.

Water damage in the Spring

When the radii of ice around the individual collector pipes grow together the vertical humidity transport is interrupted. Then the melting water formed in the Spring and the increasing amount of rainwater cannot seep into the ground. Mud is produced on the earth's surface. Especially on steep hills continuous ice layers below waterlogged soil can cause landslides. However, with a ground slope of up to 15 % the horizontal collector can be installed in parallel to the surface of the earth without problems.

It has to be considered that ice radii that potentially grow together melt down in the Spring on time to ensure that the water can seep into the space. Since the annual course of temperatures and the start of vegetation in the Spring are regionally very different it is not useful to fix a due date for this. Instead the point of time when the average ambient temperature over two to four day reaches a limit temperature of 12.0 °C is considered appropriate. This point of time usually is between the middle of April and the middle of May. Until then the ice radii should have melted down to an extent that they are not longer in contact with each other. Then the water seeping in accelerates the further melt down. The effects of water damage are especially high in case of well saturated sandy soils close to the groundwater level, since with these soils usually the water can seep in easily and the ice layer would hinder the natural drainage. In clayed soils the water only seeps in slowly also when they are frozen which is why a closed ice layer has a minimal effect on the natural drainage. When dimensioning the horizontal collector in accordance with VDI 4640 environmental effects are not to be expected.

Dimensioning of Horizontal Collectors

Apart from the soil properties and climatic conditions the dimensioning of horizontal collectors depends on the annual operating hours of the heat pump system. Usually a maximum of 1800 h operating hours is assumed.

The required collector area for horizontal collectors is based on the specific abstraction capacity q_E of the soil and the refrigerant capacity Q_O of the brine/water heat pump.

$$A_{min} = \frac{Q_O}{q_E} \quad [m^2]$$

The refrigerant capacity corresponds to the capacity share of the heat pump extracted from the environment and forms the difference of the heating capacity Q_H and the electric power consumption P_{el}.

$$Q_O = Q_H - P_{el} \quad [W]$$

The required collector pipe length L_K is calculated out of the required collector surface A_{min} and the distance s of the collector pipes.

$$L_K = \frac{A_{min}}{s} \quad [m]$$

When reducing the pipe distance while maintaining the same abstraction capacity there is principally the risk of mud formation in the Spring. The ice radii around the pipes would then not melt in time, in order to provide space for the rainfall to seep in. When increasing the pipe distance the brine temperature decreases for the same heat extraction. In the case of peak loads the brine return temperature would then fall below -5 °C, which might result in a switch-off of the heat pump. Thus, a deviation from the pipe distance by more than 5 cm always requires a reduction of the surface-specific abstraction capacity.

Example calculation

- Heat pump (data of manufacturer)
  - Heating capacity Q_H = 8.9 kW
  - el. power consumption P_{el} = 1.98 kW

  → Refrigerant capacity Q_O = 6.92 kW
- Horizontal collector (data acc. to VDI 4640)
  - Annual usage period 1,800 h
  - Abstraction capacity q_E = 25 W
  - Installation distance s = 0.8 m

  → Collector area A_{min} = 277 m²

  → L_K = 346 m
- Dimensioning of horizontal collector

  → 4 Heating circuit à 100 m

  → Actual installation distance = 0.69 m

When dimensioning the collector pipes low pressure losses are to be ensured – important: increased viscosity of the brine compared to the medium water – since the pump capacity reduces the seasonal performance factor β of the heat pump system.

In case of monovalent dimensioning of the brine/water heat pump the heat sources must be dimensioned to meet the capacity requirement of the building Q_G and not that of the heat pump.

The total heating capacity Q_{WP} includes the capacity requirement of the building Q_G and for the domestic hot water heating Q_{ww} in consideration of a blocking time Z.

$$Q_{WP} = (Q_G + Q_{WW}) \cdot Z \quad [W]$$

If a model with lower heating capacity or smaller collector surface is used when selecting the heat pump, the operating hours of the heat pump increase. This means the collector is under more strain or a higher annual abstraction factor results. To compensate the increase of operating hours the collector surface has to be increased resulting in a higher power consumption.

Careful planning and dimensioning of horizontal collectors is indispensable. Undersizing is to be avoided, it leads to a decrease of the brine temperatures and thus to poor seasonal performance factors.

Undersizing can result in continuously decreasing heat source temperatures; in extreme cases the operating limit of the heat pump is reached.

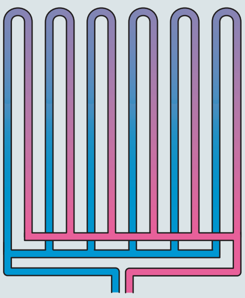
Laying and installation

Earthwork represents a considerable cost factor of horizontal collectors. Basically it is possible to remove the ground soil over the full area or to lay the pipe loops in trenches or to use non-disruptive methods. With the open excavation method a trench is excavated with a relatively small excavator with a shovel width that coresponds to the pipe distance. Then a pipe loop is laid in this trench. When the second trench is excavated for another pipe loop the excavated soil can be used to backfill the first trench. During backfilling it must be ensured to densify the groud soil as best as possible, because loose material reduces the capillary effect which results in a low water contant and thus poorer thermal properties.

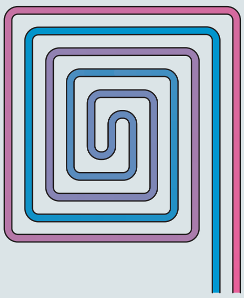
Laying in trenches, however, is only useful with pipe distance > 40 cm. With smaller distances there mostly is no alternative to excavate over the full area. The main disadvantage here is that the double quantity of ground soil has to be moved since the strips of land between the trenches are not available. In addition free space is required to store the complete excavated soil.The transport of the excavated soil to the free space and back to the collector field are additional work steps, which would not occur when laying the pipes in trenches. The non-disruptive laying is the most efficient variant, however the respective equipment must be provided.

All pipe loops of the horizontal collectors laid in the ground soil should have the same length and can be connected to a heat pump through supply and return flow manifolds with collecting pipes according to the Tichelmann principle.

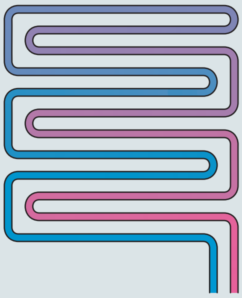
When laying the pipes according to the Tichelmann principle the required pipe length is divided in pipe loops switched in parallel for the respective abstraction capacity. Thus with respect to the pressure loss the flow in the individual pipe loops, the pipe lengths and pipe diameters are to be considered. The individual collector circuits can be designed as pipe loops (picture Tichelmann installation), spirals or double meanders.



Tichelmann piping principle with the heating circuits designed as pipe loops



Laying system heating circuit as a spiral



Laying system heating circuit as a double meander

Possible installation variants

According to VDI 4640 the pipe loops should not exceed a maximum length of 100 m and their collecting line and distribution line should not exceed a length of 30 m to the heat pump due to pressure losses. If it is not possible to lay pipe loops of the same length a hydraulic compensation must be used for balancing valves to maintain the same pressure loss in each pipe register.

Operational safety

Pipe loops of the same length are to be laid with minimum slope to the manifold to enable venting of the horizontal collector. All manifolds and fittings should be installed in rain protected chambers outside the building. Moreover the pipe loops should be equipped with ball valves at the manifolds to be able to shut them off. The collector pipes are to be connected to the manifolds in a stress-free manner.

Sealing of the collector surfaces is to be avoided. When installing a ground energy collector below the foundation slab of a building the functionality of the collector or the surrounding ground soil is to be regarded as energy store. Long-term operation is only ensured with the same heat extraction and heat input level (heating and cooling function) over the year because regeneration of the soil by surficial energy input is excluded.

Pipe connections assembled on the construction side that are not accessible are to use maintenance free connection methods e.g. Uponor Quick & Easy or electrofusion fittings.

According to DIN 4140-2 all collector pipes in the area of the wall duct as well as all brine-carrying pipes installed in the house must be insulated (insulation resistant to water vapor diffusion) to avoid condensing water.

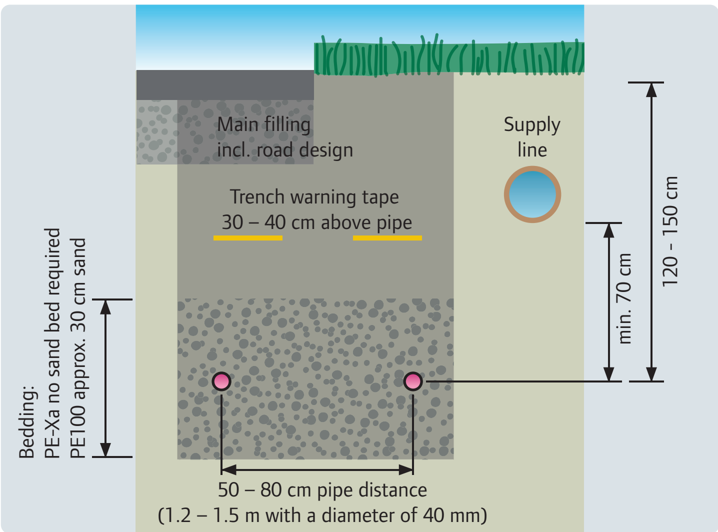
If possible, horizontal collectors should be laid in a minimum depth of 1.2 m up to a maximum depth of 1.5 m to ensure optimal regeneration of the ground soil without the risk of naturally falling short of the freezing point. In addition the heat pump system is filled with brine – usually a mixture of water and glycol (heat transfer medium) to avoid freezing of the collector and the evaporator.

Heat transfer media for collector pipes are always to be selected so that in case of a leakage a groundwater and soil contamination is avoided or kept as low as possible. Non-toxic or biodegradable organic sustances regarding VDI 4640 should be selected.

Take care that filling and discharge of the system is possible. To avoid overfilling the heat pump system has to be equipped with a safety valve. The brine has to be mixed before filling it into the heat pump system to ensure proper blending and thus to avoid freezing at certain points. The glycol percentage usually is between 25 – 30 %. Thus the pressure losses of the collector pipes are by 1.5 -1.7 higher as filled with pure water. This has to be considered when dimensioning the pump. The pressure test has to be carried out in accordance with EN 805.

Important

The antifreeze agent and the water must be mixed in a sufficiently large container before the horizontal collector is filled with the mixture!



Bedding of the horizontal collector in accordance with VDI 4640

Depending on the type of pipe used the pipe loops are to be laid in a sand bed. Only when using Uponor PE-Xa pipes embedding in sand is unnecessary due to their resistance to slow and fast crack growth.

The installation distance of horizontal collectors is to be selected so that growing together of the ice radii that form around the collector pipes is avoided. These distances usually are between 0.5 m and 0.8 m (1.2 – 1.5 m for 40 mm diameter).

The installation distance between horizontal collectors and other supply lines (gas, water, heat, power, etc.), buildings, circulation space, neighboring plots and swimming pools should be at least 0.7 m. Fixing of the pipe loops (height in the ground and cleanrance) can be done using pegs or by fitting the pipes on reinforcement mesh.

Water volume per pipe dimension for horizontal collectors

PE-Xa pipe dimension [mm]	Inner diameter [mm]	Water volume [l/m]
25 x 2.3	20.4	0.327
32 x 2.9	26.2	0.539
40 x 3.7	32.6	0.835

Legal regulations

Country-specific approval of the responsible authorities may be required for horizontal collectors. VDI 4640 and Wasserhaushaltsgesetz (Federal Water Act) (D), SIA 384/6 and BAFU-Vollzugsrichtlinie (CH), österreichische Wasserrechtsgesetz, Gewerbeordnung und Bauordnung (Austrian Water Rights Act, Industrial Code and Building Code are to be observed.

Detailed planning

Determining the basics

The basis for the initial planning phase is the coordination between all people involved. During this the basic utilization objectives and the energy capacities to be provided are defined:

1 Only heating
2 Only cooling
3 Combination of heating/cooling
4 Heat and cold storage

Apart from the basic utilization in this planning state parameters of the heating and cooling systems (target temperatures, heating and cooling capacities, seasonal performance factor, etc.) which are to be connected to the ground energy system with heating or cooling generation system have to be coordinated with the person in charge of TGA planning. For the correct system dimensioning additional analyses or test work might be required. They are to be considered as special tasks and must be agreed with the client in advance.

Planning phases

Based on the objectives and the research and analysis of the soil properties the ground energy utilization procedures that can be applied at the respective site can be elaborated.

In the design planning the dimensions and parameters and the processes for the installation of the system are defined, such as:

- Heating and cooling generation system (heat pump/chiller)
- Mode of operation, performance parameters (energy efficiency factor)
- Dimensions, layout, connections to heating and cooling systems, connections to ground energy system, etc.
- Ground energy system
- Layout of boreholes
- Design of distribution system
- Space required for implementation
- Personnel skills
- Material of the probes and collectors to be installed
- Proceeding and material utilization for borehole grouting
- Operating fluid for circuit
- Function tests and checks

Placing / Realization

If it was previously not possible to carry out a Thermal Response Test (TRT) for ground probe installations at a pilot hole, it is recommended, to carry out this test at the first installed probe. Then a simulation can be conducted based on the measured parameters. If necessary, the planning has to be adapted. Before commissioning ground energy systems that use heat transfer fluid circuits with pump for heat exchange with the soil, the system has to be filled with a suitable ready-mix of heat transfer fluid and then to be purged. A pressure test of all circuits according to EN 805 has to be documented. In addition, before commissioning the system the constant flow through the ground energy exchangers has to be checked and corrected, if necessary. To monitor the pressure a manometer displaying the allowed pressure range is to be installed at the ground energy exchange system. When using heat transfer fluids the system is to be secured againsts leakage.

The future operator of the system is trained in the operationg of the system, servicing of the system and troubleshooting.

Subsequent to the planning phase it is recommended to check the operation of the system, to optimize it, if necessary and to adapt the pattern of use to the ground energy system.

Determining the basics

Determining the energy demand

Determining the heating/cooling demand	TGA
Clarify /define tasks	TGA
Energy and capacity requirement, determining type and scope; agreement with client	TGA
Analyze whether ground energy is an alterative to conventional systems	TBA/TGA

Result: Ground energy is an (economical) alternative to conventional systems.

Check feasibility

check approval ability

Checking the legal approval situation	TBA
Identifying country-specific requirements and licensing requirements and orders	TBA
Check utilization rivalry	TBA

Result: Ground energy utilization variants that are licensable in consideration of the requirments of the authorities.

Clarify geology, hydro-geology, hydrology (qualitative) by research and evaluation of databases and planning documents and maps, collection of data	TBA
Evaluation of reports and documents, extraction of data	TBA
Plausibility check of data	TBA
Compiling and assessment of the hydro-geological site conditions based on the available data and documents	TBA
Analysis of project risk factors	TBA
Information about thermal and hydraulic environmental effects	TBA
Determine exploration demand / test work	TBA
Assessment of relevant geothermal ground parameters (among others heat flow / heat conductivity of the soil, groundwater balance, groundwater quality)	TBA
Detailed assessment of demand heating/cooling, adaptation heat/cooling demand to ground energy potential	TGA

Result: Preliminary assessment of the ground energy potential on site.

If necessary, more detailed definition of basics / test work

Determination of parameters (through test drilling with sampling and anaylsis of soil and groundwater samples, geophysics)	TBA
Planning and implementation of other geotechnical / geophysical exploration work	TBA
Hydro-geological expertise	TBA
Execution of environmental impact studies	TBA
Foundation concepts	TBA
Information about financing models and subsidies	TBA
Coordination with specialists involved, revision based on objections and ideas	TBA/TGA

Result: Ground energy utilization variants that are ready for approval and take into account licensing requirements and orders and are classified as realizable based on the assessment of the geothermal potential on site.

Preliminary planning

Discussion of variants (type of ground energy generation) and proposal of technically feasibly preferred solutions and presentation of disqualification variants	TBA
Pre-dimensioning of ground energy systems and the respective civil engineering works	TBA
Planning and execution of other geo-technical/ geophysical exploration work	TBA
Assessment of framework conditions (e.g. space available on site)	TBA
Assessment of framework conditions (e.g. usage pattern)	TGA
Preliminary planning control engineering, energy distribution	TGA
Pre-dimensioning of a preferred variant of the ground energy system based on e.g. simulation results	TBA
Preparation of a functional schematic of building services engineering	TGA
Preliminary notes on building services engineering	TGA
Profitability studies / cost estimate for variants	TBA/TGA
Coordination with specialists involved, revision based on objections and ideas	TBA/TGA

Updating of definition of basics / test work

Modeling of the heat exchange / the temperature distribution in the soil	TBA
Planning and execution of other geo-technical/ geophysical exploration work	TBA

Result: Economically preferred variant of a ground energy system on the site.

Design engineering

Proof of the thermal capacity of the ground and the ground engergy system through calculations based on the data collected in the previous planning phases	TBA
Specification of number and dimensioning of ground energy structures (vertical collectors, horizontal collectors, well systems, energy foundations, etc.) of the heating / cooling systems and the measuring systems	TBA/TGA
Identification of contracting parties / owners, coordination with public agencies, preparation of drilling permits	TBA
Selection and dimensioning of the required system parts, layout of building systems engineering	TGA
Preparation of field mapping ready for approval	TBA/TGA
Translation of the concept into working steps, preparation of building and cost plans	TBA/TGA
Calculation and dimensioning	TBA
Preparation of occupational safety / safety concepts	TBA/TGA
Concept of a measuring program to optimize operations / adjustment of the ground energy system	TBA

Result: Design engieering of a ground energy system on the site.

Approval planning

Negotiations with pubic authorities	TBA
Obtaining the permit to enter the property	TBA/TGA
Preparation of applications for exemptions	TBA/TGA
Preparation of application with respect to counties and communities' water rights	TBA
Preparation of drilling notification	TBA
Notification of / filing applications with the responsible authorities	TBA
Construction permit planning	TGA

Result: Readily prepared application documents / filing the application.

Implementation planning

Definition of the boring site, illustration with initial measurement and definition of geodatic point	TBA
List of performance parameters for heating and cooling system, definition of connection points	TGA
List of precision specifications	TGA
Repeated alignment with building or system plan	TBA/TGA
Preparation of performance description and specification of the building services engineering from house connection	TGA
Revision and detailing of draft of system parts of building equipment	TGA
Illustration of solution ready for implementation	TBA/TGA
Preparation of schedules and security coordination plans	TBA/TGA

Result: Planning ready for implementation

Preparation of placing

Definition of type of tender (public, selective tenedering, single tender action)	TBA/TGA
List of bidding documents, preparation of technical specifications incl. quantity definition comprising description of the building and contract specification or performance range of the ground energy system	TBA
List of bidding documents, preparation of technical specifications incl. quantity definition comprising description of the building and contract specification or services specification of building services engineering from house connection	TGA
Elaborating the contractual conditions	TBA/TGA
Coordination of time schedules both for tender/placement and the execution of construction work with other specialists involved	TBA/TGA
Compiling the bidding documents, documents of ground energy system and building services engineering and handover to project manager / architect	TGA

Result: Tender

Participation in placement

Obtaining offers	TBA/TGA
Revision and evaluation of the offers, preparation of price comparison list	TBA/TGA
Revision and evaluation of additional quotations (e.g. change of tdrilling technology, changes in dimensioning of systems)	TBA
Participation in negotiations with bidders	TBA/TGA
Updating cost calculation/cost control	TGA
Preparation of order placing, preparation of placing proposal	TBA/TGA

Result: Placing

Site supervision

Supervision of drilling work (instructing the drilling team, operative decision to start construction /interruption of drilling, if applicable inspection of ground energy systems)	TBA
Evaluation of findings from drilling work	TBA
Coordination of document provision (layer profiles, drilling and backfilling reports, material lists for pipes and backfill materials, pressure tests)	TBA
Cost stipulation and control	TGA
Monitoring of quality and schedules	TGA
Participation in inspections, pressure tests, material sampling process	TBA
Coordination of inspections by authorities	
Revision of compliance with specification, regulations and established code of practice	TGA
Coordination and checking of technical modifications	TGA
Support in preparing construction measurements	TGA
Coordination of document provision (layer profiles, drilling and backfilling reports (if backfilling required) , material lists for pipes and backfill materials, pressure tests, operating manuals)	TBA
Preparation and certification of mine planning	TBA
Filing the documentation with the the authorities in charge	TBA
Data entry in database	TGA
Evaluating the contents of the data	TGA
Participation in preparation of operating instructions or training of the user	TGA
Involvement in commissioning	TGA
Acceptance, hand-over, documentation	TGA
Deficiency statement, monitoring the remedy of deficiencies	TGA

Result: Execution of tasks according to plan

Object support and documentation

Commissioning, adaptation of usage pattern, participation in adjustment phase	TBA/TGA

Result: System ready for operation

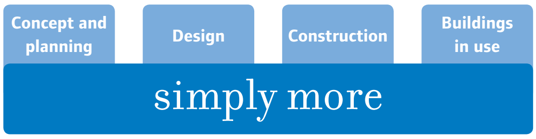
Shutdown

Already when planning a system to utilize ground energy the dismantling of the system has to be taken into account. When shutting down the system it has to be ensured that the system parts remaining in the ground to not cause direct or indirect damage to the environment in the long.

The heat transfer fluid in the heat exchangers has to be purged with fresh water and to be disposed of properly. Heat exchanger pipes can remain in the ground provided they are non-toxic and made of corrosion-resistant material. Then they have to be backfilled completely with a suitable material to ensure that they are sealed in a sustainable manner. If it cannot be excluded that the heat exchanger pipes are a risk to the environment, they have to be removed and the void to be backfilled in consideration of the soil layers. The approval authorities are to be notified about the dismantling of ground energy exchangers.

Uponor offers construction professionals uncompromising quality, leadingedge expertise and long-lasting partnerships. As a leading international company, we are known for our solutions that help create better human environments.

Uponor's Simply More philosophy includes services for all stages of the construction process – from the first concept of a project to a building in use.



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