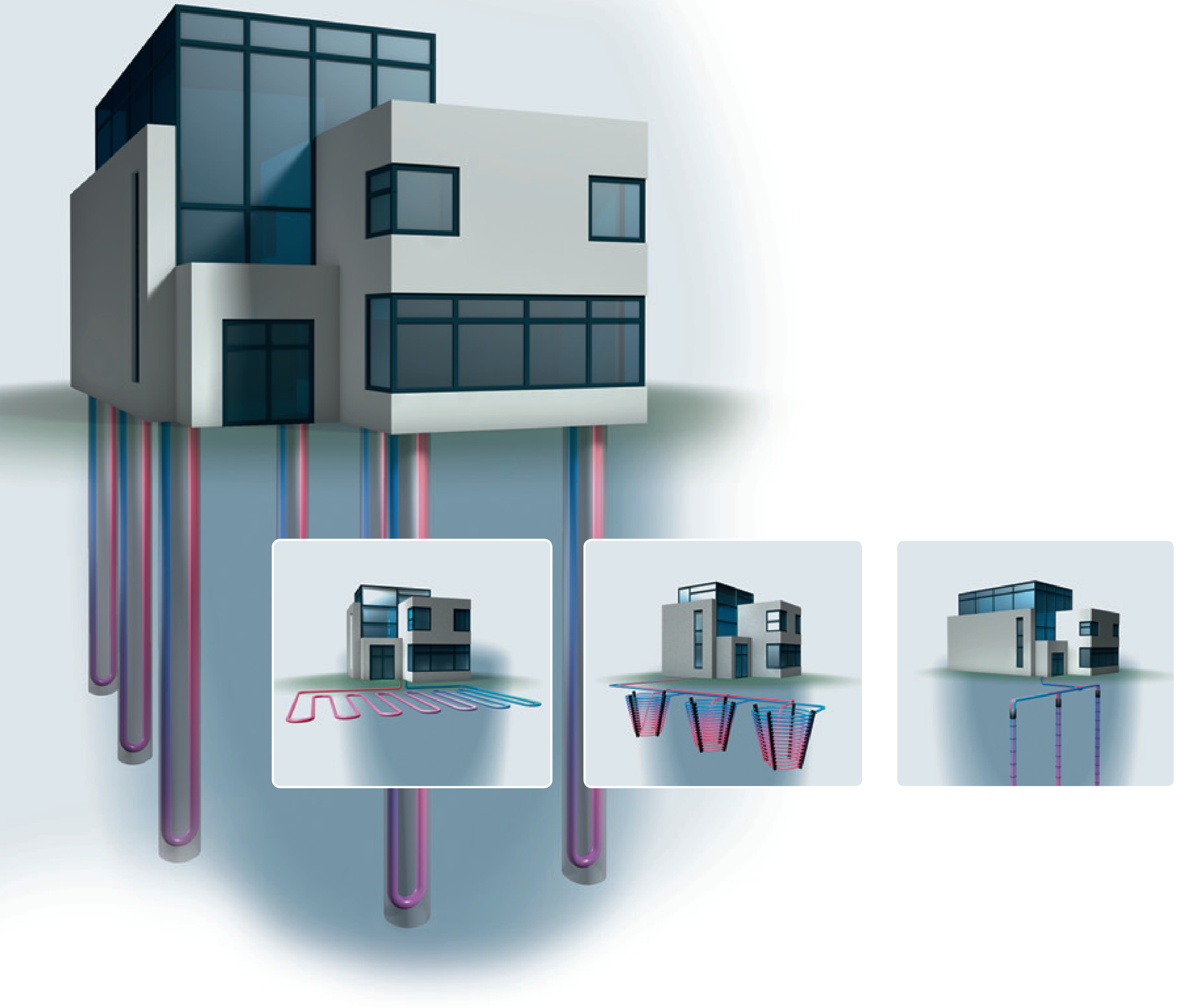
GEOCORE®

uponor

Ground Energy

TECHNICAL INFORMATION



Contents:

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.

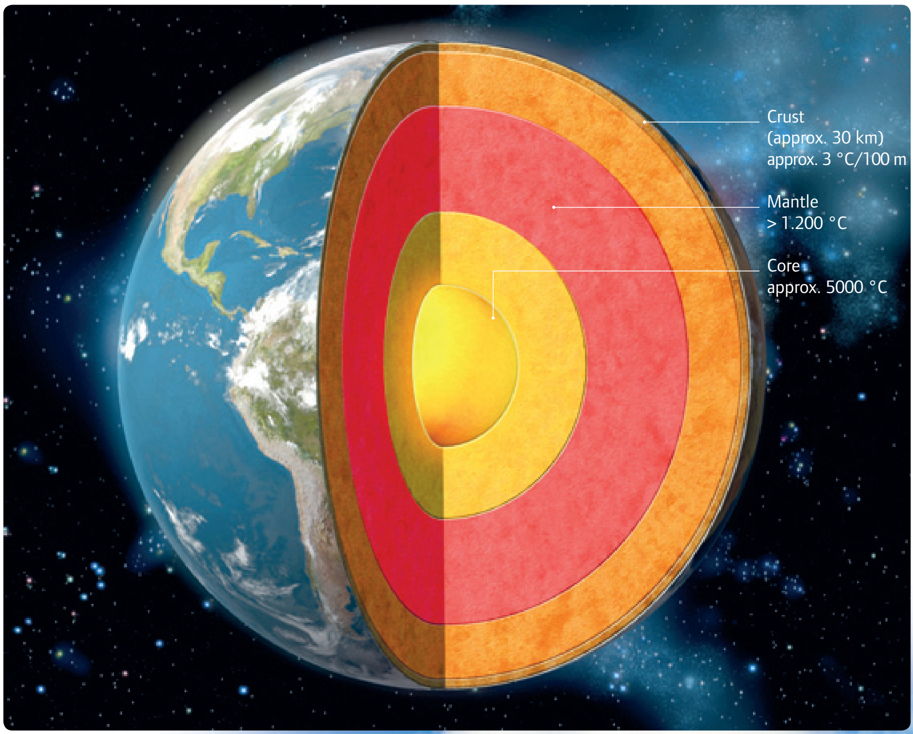
Hot Stuff: Planet Earth – the Energy Source

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.

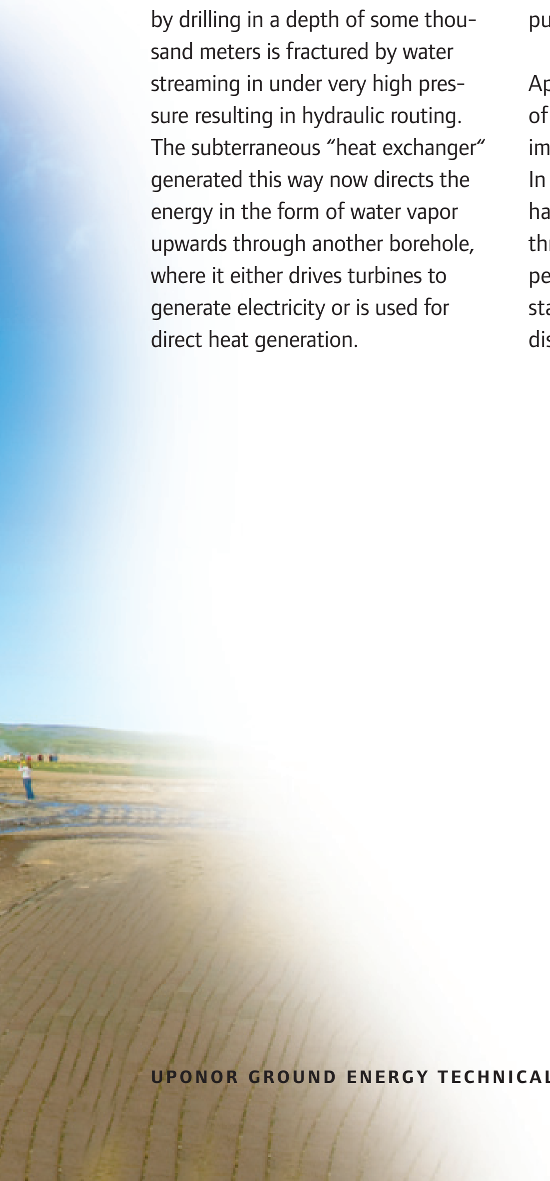
Ground Energy

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

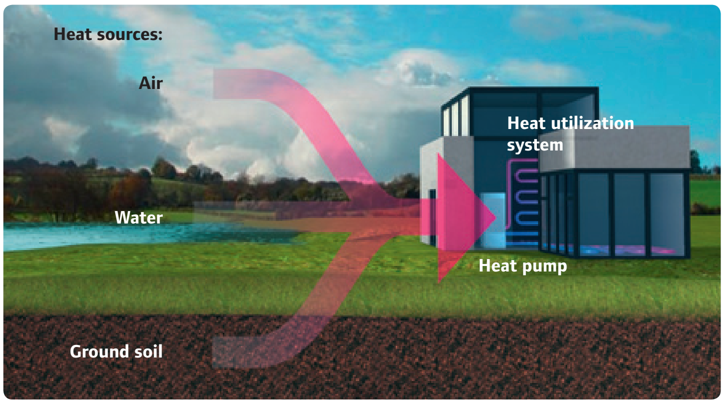
General

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.

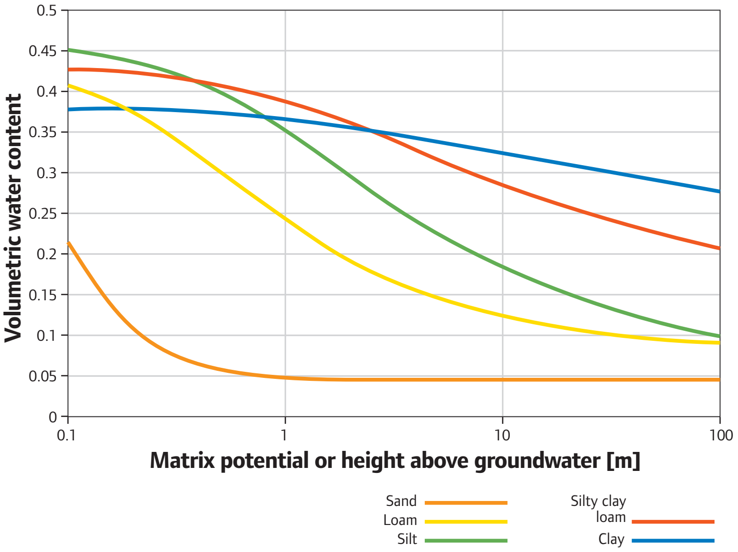
Geology, Hydrology and Climate
Soils usually have a pore share of 35 and 45 %. If these are filled with water instead of air, the heat conductivity, the density and the specific and latent heat capacity of the soil increase. This has a positive effect on the maximum possible abstraction capacity of a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

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.

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.

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)		Volume description special heat capacity in MJ/(m^3 · K)	Density in 10^2 kg/m^3
				Recommended value		
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.

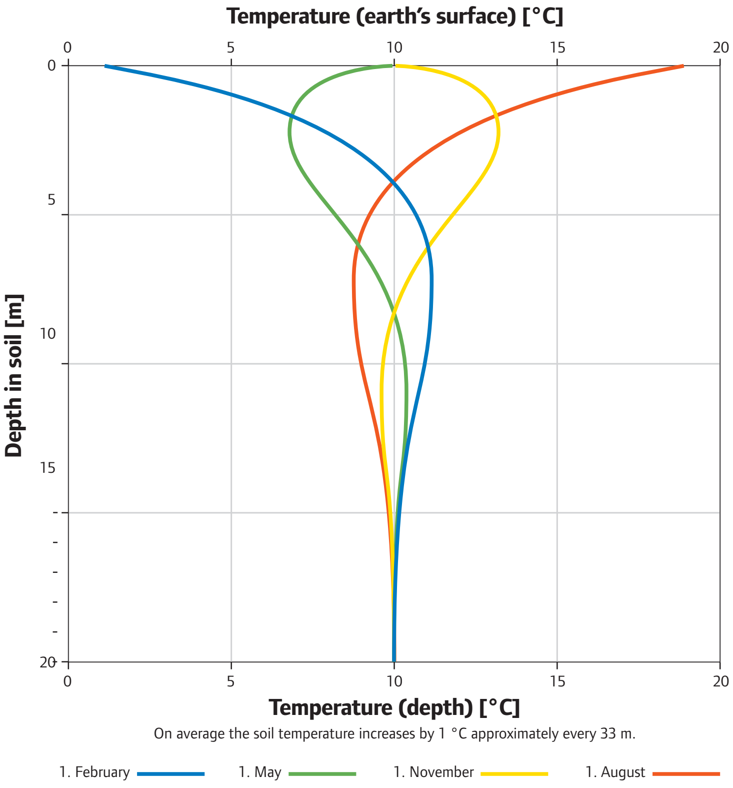
Reference values for the permeability of unconsolidated rock

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.

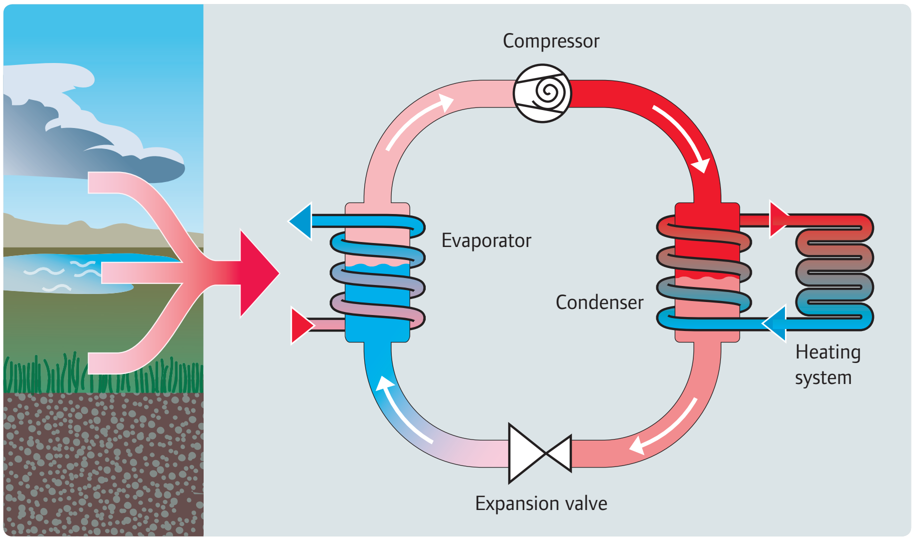
From the course of the shallow soil temperatures over the year it becomes apparent that ground energy is an always functioning and constant source of energy.



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:

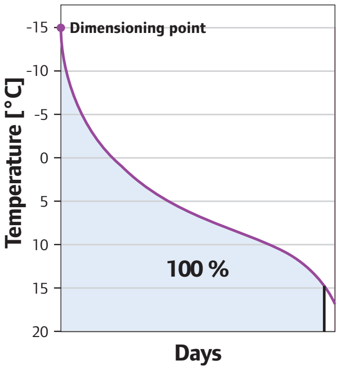
- air/water heat pumps
- water/water heat pumps
- brine/water heat pumps

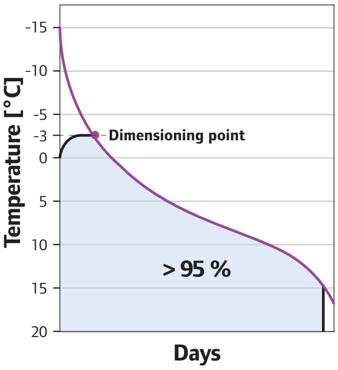
The designation of the heat pump type depends on which medium absorbs the heat (heat transfer medium) and which medium distributes the heat in the house.

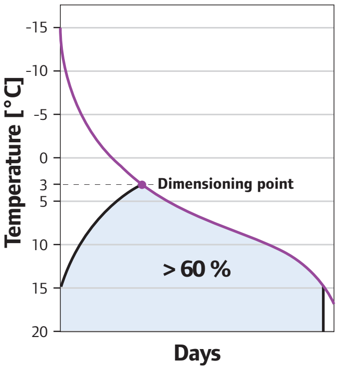
If brine (water / glycol mixture) absorbs the heat through a ground collector and if water dissipates the heat e.g. through an underfloor heating system, this is called a brine/water heat pump.

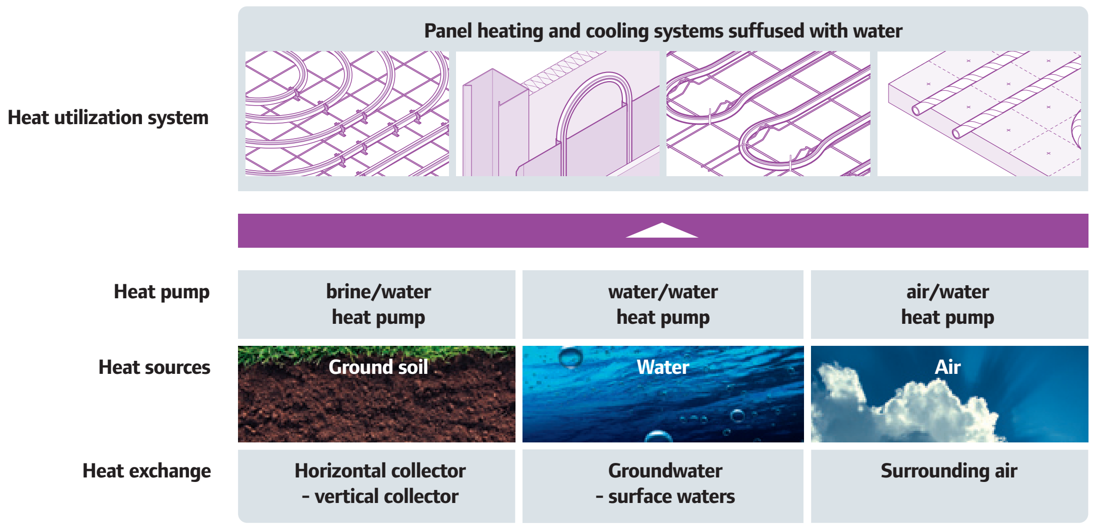
With respect to the operating modes a distinction is made between:
- monovalent (one energy source)
- bivalent (two energy sources)
- monoenergetic (one energy resource).

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.

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

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

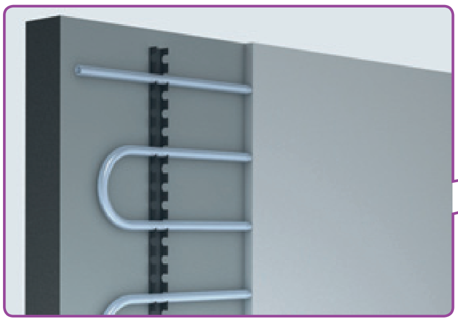
Heating and cooling in the form of ceiling heating and cooling systems is increasingly used for reasons of comfort and efficiency compared to air conditioning systems.

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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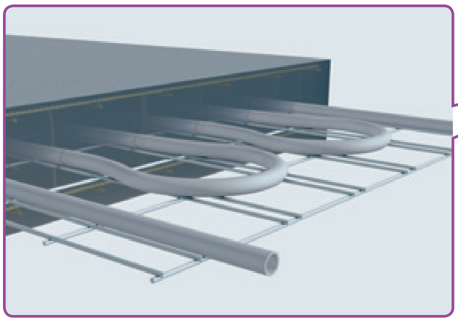

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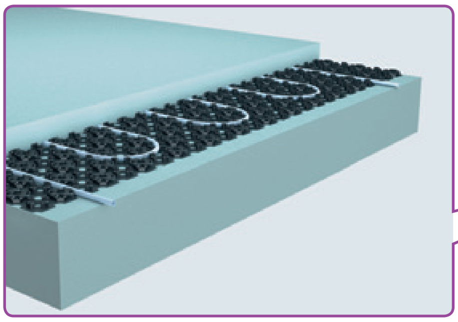

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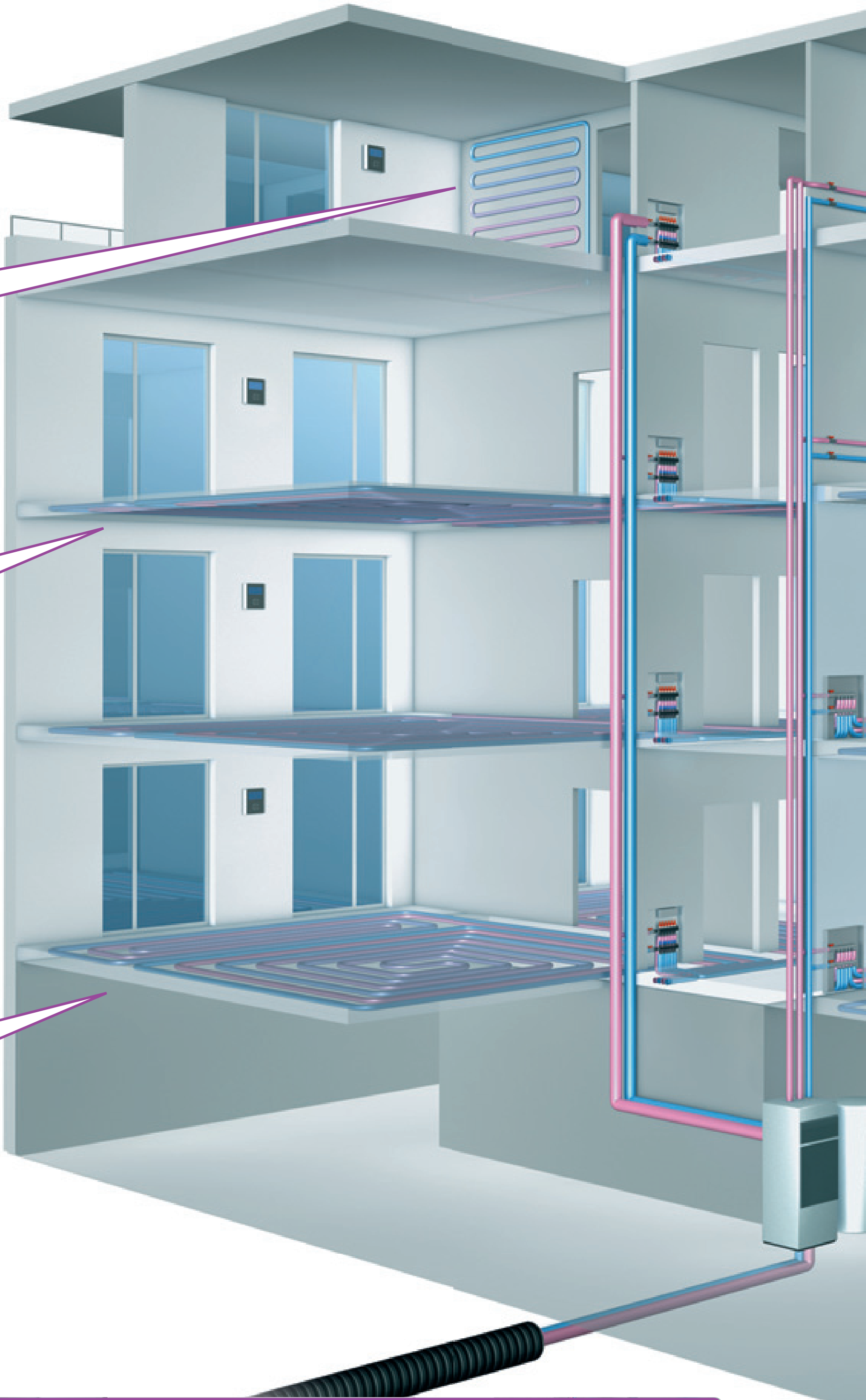
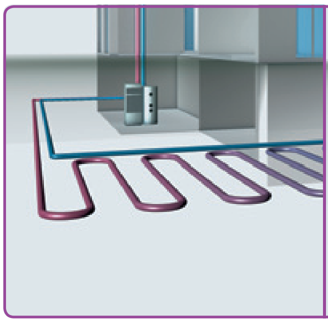
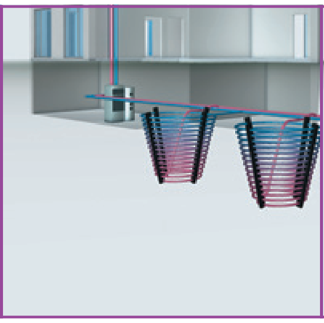
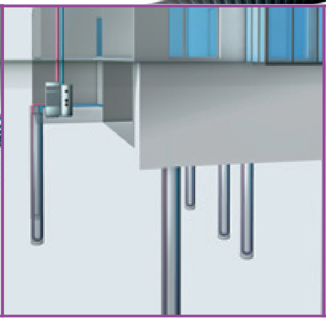




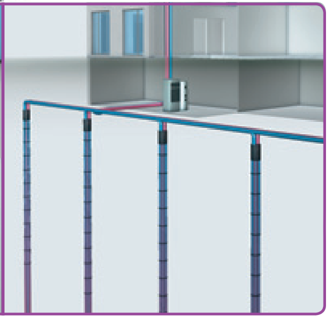
Uponor Horizontal Collectors



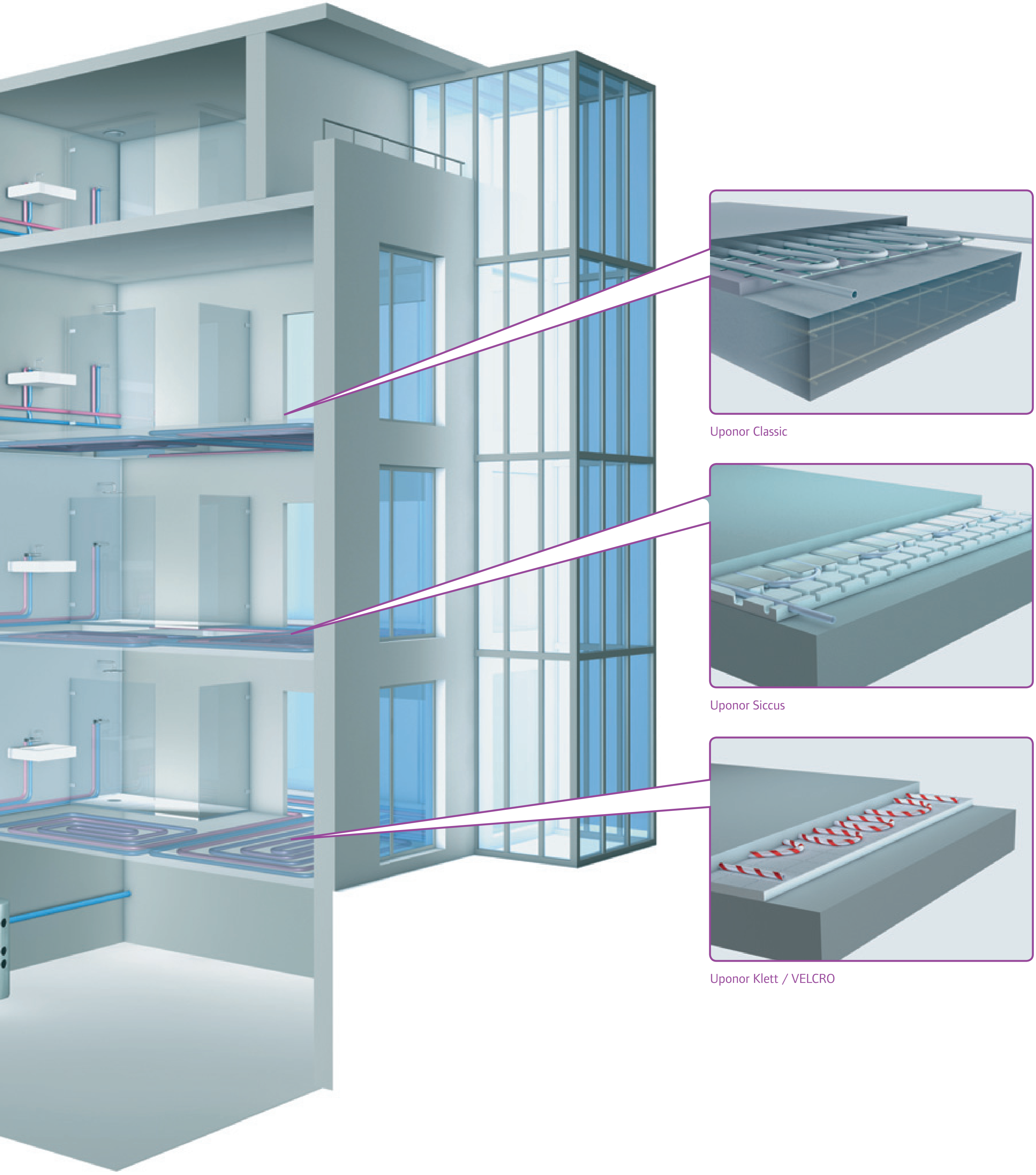
Uponor Energy Cages



Uponor Energy Piles



Uponor Vertical Collectors



Uponor Classic

Uponor Siccus

Uponor Klett / VELCRO

Ground Energy utilization Systems

System Overview

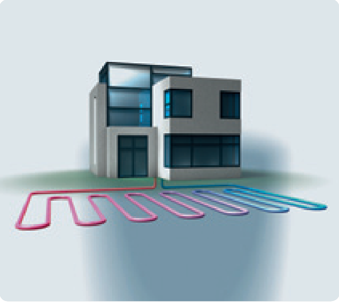
With ground energy collectors (heat exchangers) a distinction is made between Horizontal and vertical collectors.

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

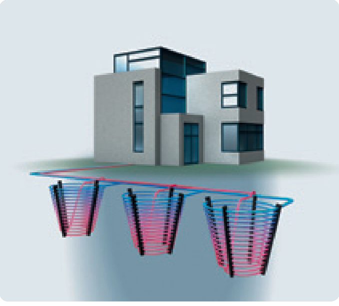
Vertikal
- Boreholes
- Energy piles and slotted walls

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.



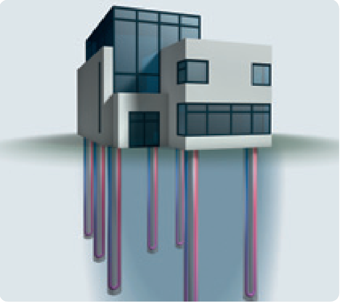
Horizontal Collectors

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.



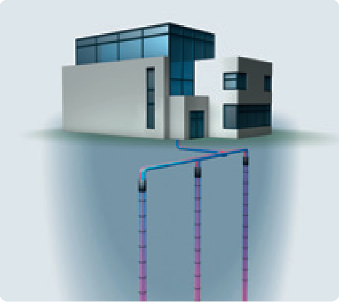
Energy Cages

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.



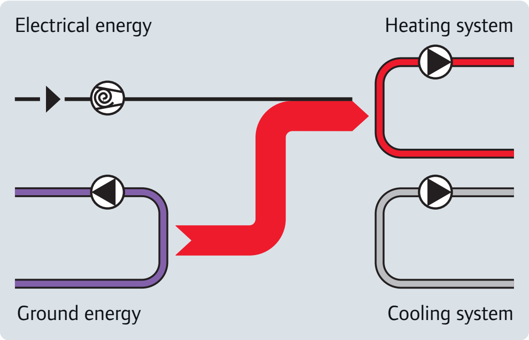
Vertical Collectors

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

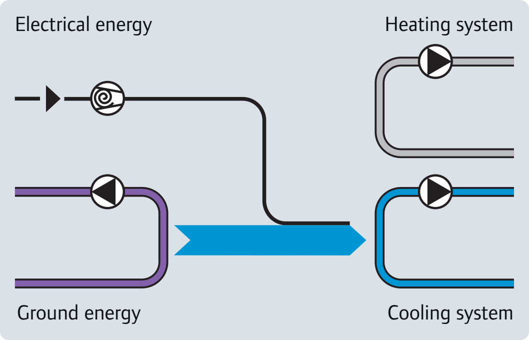
The operating mode and the resulting operating cost of the heat pump are defined according to the heating and cooling requirements of the respective building.

Heating operation



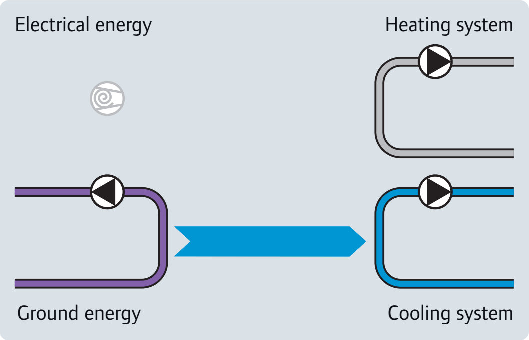
- Ground energy is used as heat source
- The heat pump increases the media temperature to a level utilizable for the building.

Cooling operation (active)



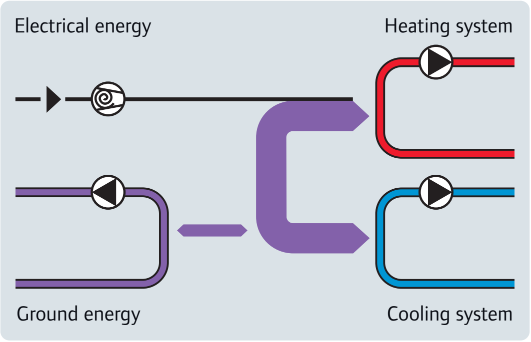
- Ground energy is used as heat sinks (cooling source)
- Temperature level for passive cooling insufficient
- Compressor active
- Dual operation possible

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.

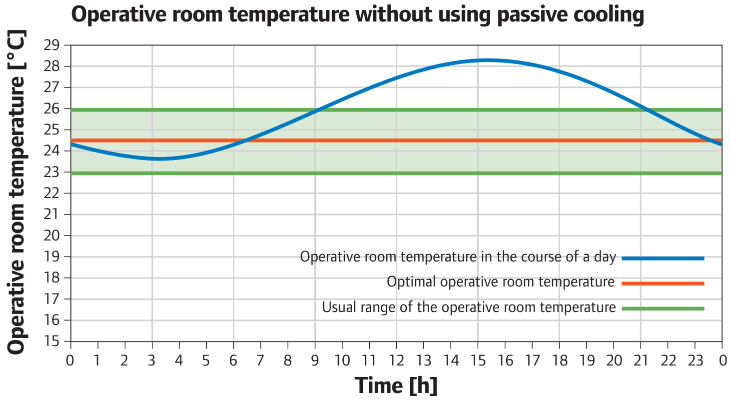
A pre-requisite for this is the use of a radiant heating or cooling system.

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

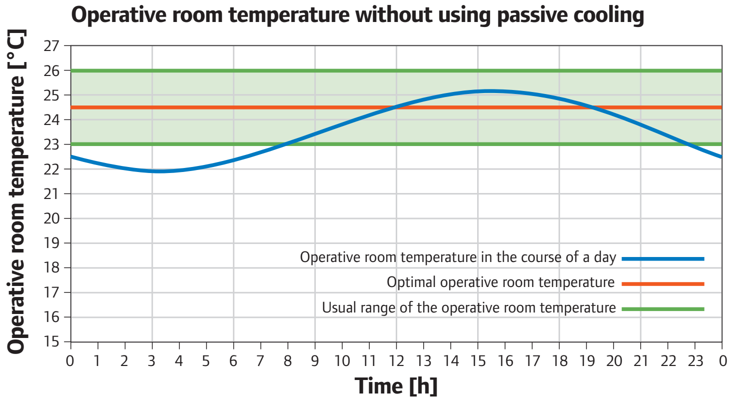
- Increased living comfort due to an agreeable room climate
- Improvement of the seasonal performance factor of the whole system by regeneration of the ground soil
- Minimum additional investment costs, low operating costs
- Saved resources
- Environmentally compatible

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
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 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

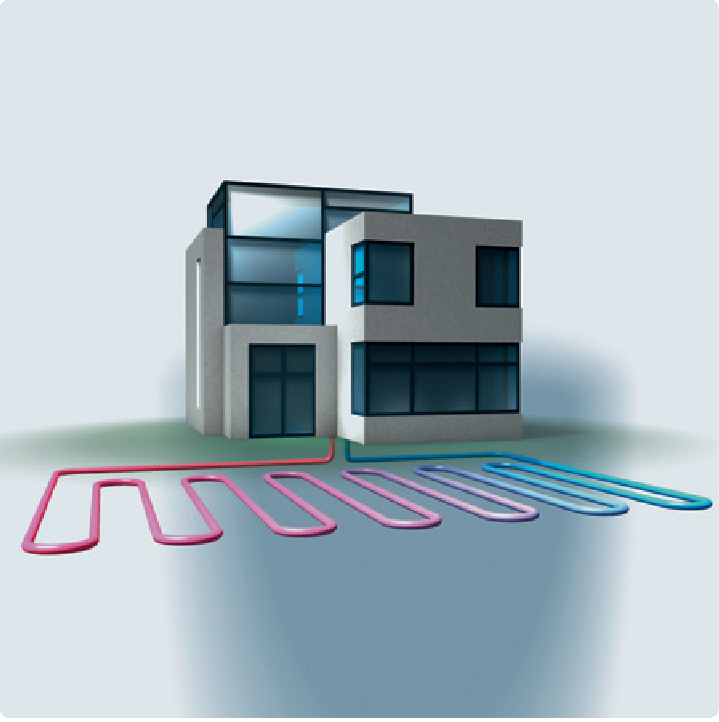
System/scope of application

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!

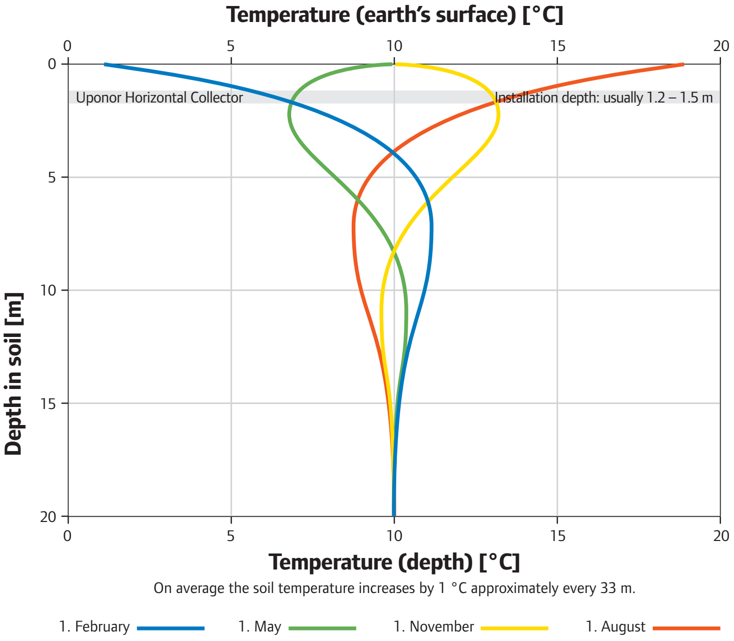
Functioning

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



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

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.

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

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}.

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

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.

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

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.

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

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.

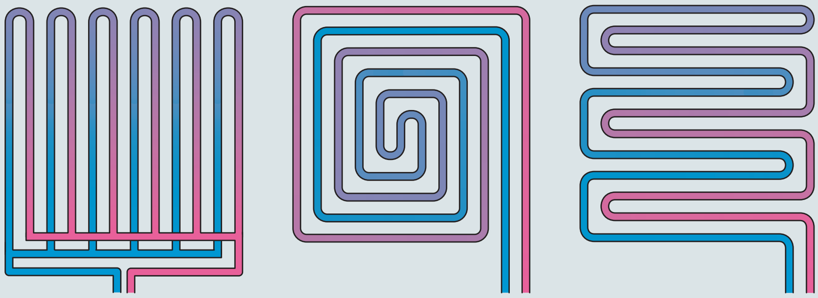
Laying and installation

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.

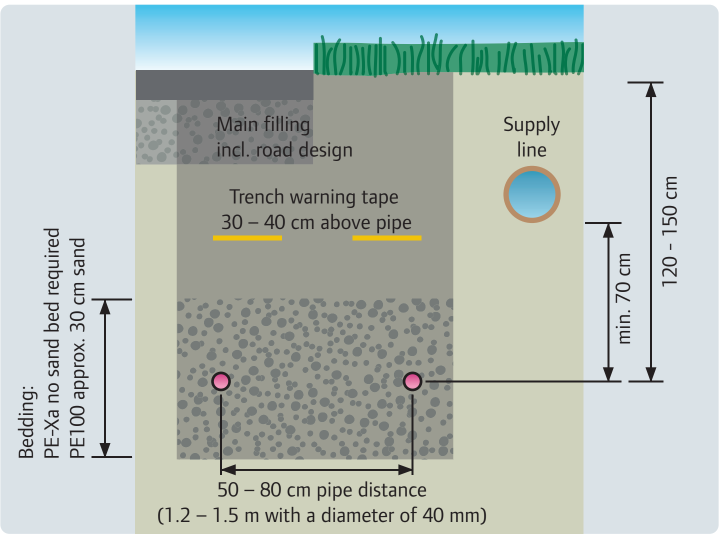
If possible, horizontal collectors should be laid in a minimum depth of 1.2 m up to a maximum depth of 1.5 m to ensure optimal regeneration of the ground soil without the risk of naturally falling short of the freezing point. In addition the heat pump system is filled with brine – usually a mixture of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

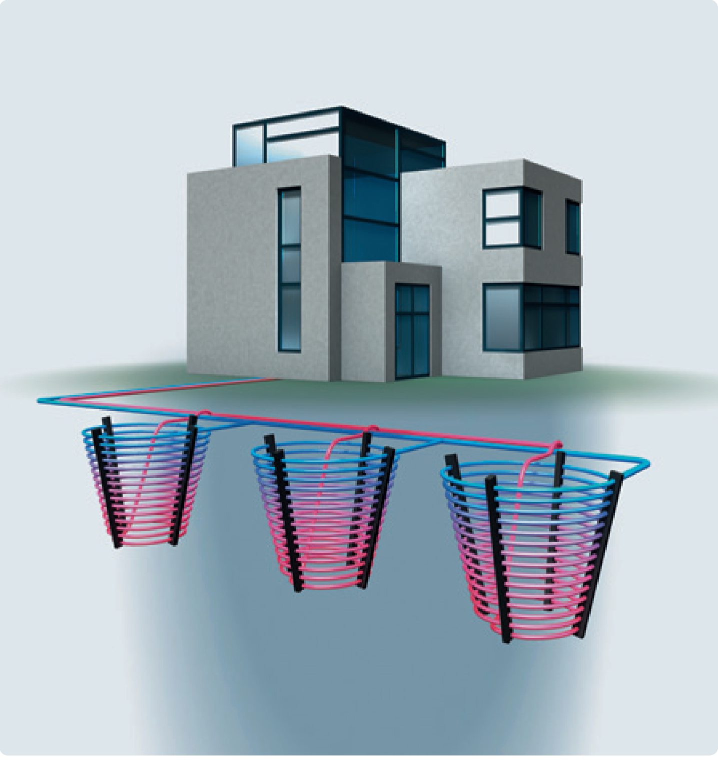
PE-Xa pipe dimension [mm]	Inner diameter [mm]	Water volume [l/m]
25 x 2.3	20.4	0.327
32 x 2.9	26.2	0.539
40 x 3.7	32.6	0.835

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.

Energy Cages

System/scope of application



Schematic illustration of an energy cage system

Your benefit

- Economically and energetically effective for ground energy
- Ideal solution for single-family and multi-family houses and small business and industrial applications
- small landscape required while at the same time good utilization of the soil volume
- Constant heat extraction
- Low installation depth without effects on the groundwater level

Note:

The combination of a ground energy cage with the Uponor EPG6 cooling station is an ideal free-cooling solution.

The energy cage is a special design of the horizontal collectors. Energy cages are used when deep drillings or deep foundations are not possible for reasons of water law conditions or for hydrological reasons, or when the available space is too small. The energy cage is an economically and energetically very effective alternative in the field of ground energy.

The Uponor Energy Cage is the ideal solution for single-family or multi-family houses as well as small business and industrial applications.

Application description

While operating the brine (water-glycol mixture) circulates through the energy cage and extracts heating from the Ground. In combination with a heat pump the temperature level will be lift up to an useable operation temperature.

In the warm Summer months the cool ground soil temperature can be used for passive cooling, also known as free-cooling. During this process usually only the brine circulation pump of the heat pump is running. Therefore the energy consumption during the cooling phase is restricted to a minimum and clearly more cost-effective than conventional cooling variants.

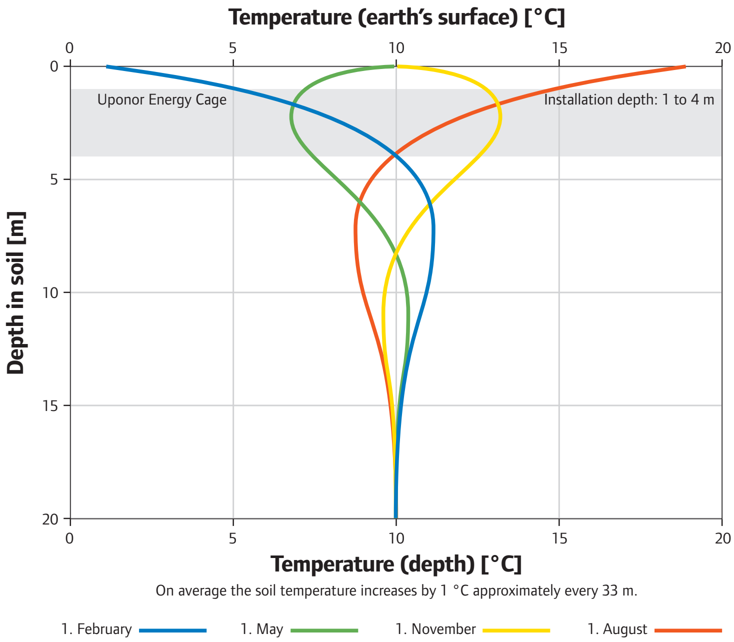
The condition for the above, however, is an radiant heating and cooling system. The targeted alternating stress on the ground through heating and cooling creates an energy balance in the subsurface and thus guarantees a long-serving energy source.

The Uponor Energy Cage is designed for use in a depth of 1-4 meters. The energy cage is installed close to the surface and are positioned in a depth where seasonal temperature fluctuations occur. Hence, the ground soil temperature is 100 % affected by weather conditions. Seasonal fluctuations are measurable up to a depth of approx. 20 m (regional differences); daily fluctuations up to a depth of approx. 1 m. In addition a clear phase shift between air temperature and ground soil temperature can be seen. In November the highest ground soil temperature prevails and in May the lowest, vice versa to the outer temperatures. This is caused by the fact that on the one hand the ground soil is a poor heat conductor and on the other hand has a large heat storage capacity.

As a result the solar energy (solar radiation) that permeates the first meters of the earth's surface in early summer, is stored for several months. The ground soil temperature decreases slower than the air temperature. At the beginning of the heating period the highest temperatures occur in the ground soil; the lowest prevail at the beginning of the cooling period.

In the installation depths of the Uponor Energy Cage a relatively constant temperature prevails over the whole year ranging from approx. 7 to 13 °C. The conical shape of the Uponor Energy Cage enables utilization of a large ground soil volume despite its relatively small surface area.

Thus the large ground soil volume and the steady heat extraction prevent untimely freezing of the direct environment. In cases of extreme load it is only possible that ice forms on the side of the energy cage. However, when reducing the load this ice formation will degenerate. Due to the fact that the extraction temperatures are almost constant this is an ideal energy source for the heat pump. Thus the efficiency of the heat pump is considerably increased. The preferred use is in a capacity range of up to 30 kW.



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

Defined collector pipe distance with the Uponor Energy Cage

Installation of the Uponor Energy Cage

Application limits

Due to the large-volume conical shape of the Uponor Energy Cage an increased surface for the absorption of ground energy is created and the content volume for the heat transfer medium, the brine, is maximized. Thus the thermal energy can be extracted from the ground soil more consistently.

The so-called freezing solid is avoided since the heat extraction takes place below the frost line in depths between 1 to 5 m. Thereby, effects on the ecological microorganisms in the soil are avoided. Due to this fact the surface above the installed Uponor Energy Cage can be used as garden area without any effects. Overbuilding and sealing of the area should be avoided.

The natural regeneration of the touched ground is given by regular solar radiation and moistening of the ground soil by rain and snowmelt. The low installation depth prevents a change in the water balance. The compact size of the Uponor Energy Cage requires up to 60 per cent less space for the complete energy cage field than a comparable horizontal collector.

Szenarios such as uneven heaving of the ground soil by massive ice ring formation in case the dimensioning is too small, or formation of an ice patch below the surface which would cause rain and melt water not to seep in, usually do not occur with energy cages.

Physical properties of the characteristic soil types

	Unit	Sand	Loam	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

In the table above a distinction is made between sand, loam, silt and sandy clay which reflect the wide spectrum of soils existing in nature.

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 %.

Loam 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 the biggest fraction of which 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 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 warm climes a higher surface-specific abstraction capacity is possible without causing damage of the system or the environment.

The benefits of the Uponor Energy Cage are:

- No planning and cost-intensive drilling work
- Simple building approval procedure (duty of disclosure, depending on the country)
- Due to the low installation depth use even in water protection areas possible
- No effects on the groundwater
- No risk of freezing solid, no effects on utilization as garden, no effects on capillary action of the soil
- Quick regeneration of the ground soil by sun, rain and snow melt
- Passive cooling
- Low space required, 50 – 60 % lower than with horizontal collectors
- Installation possible on plots of land with difficult access where heavy drilling equipment cannot be used
- Quick installation
- Maintenance-free system

Dimensioning of Energy Cages

When dimensioning an energy cage system the following aspects must be considered:

The basis for the right dimensioning of the energy cage system is the correct calculation of the heating load and the concrete analysis of the soil type and ground soil humidity.

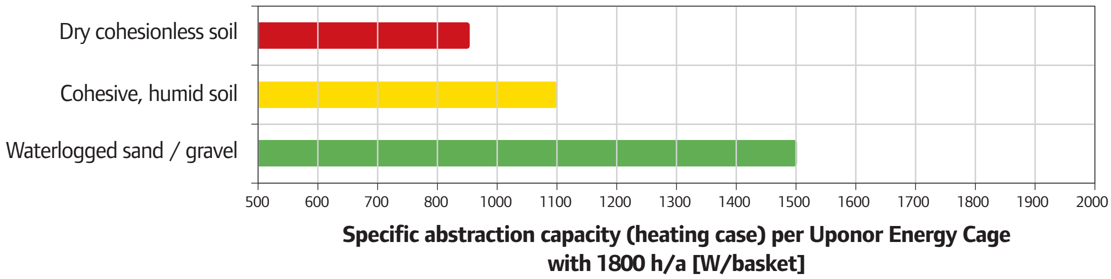
Selection of emitter system

For an energy cage system as well as for all other ground energy systems the selection of the respective emitter system and system temperature is extremely important. To ensure the highest possible efficiency of the system it should be selected to be as low as possible.

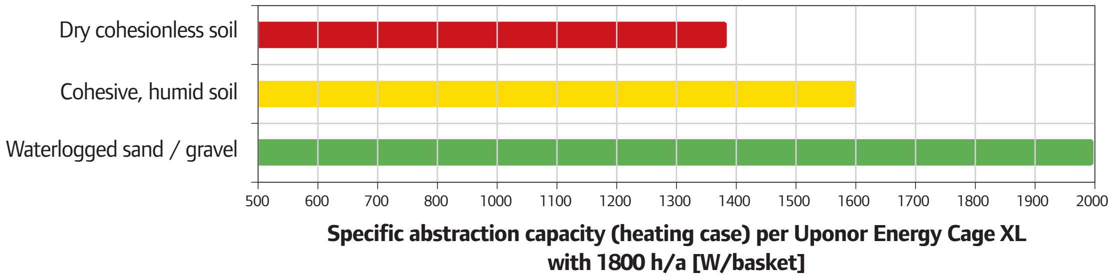
As a rule of thumb the following applies:
An increase of the flow temperature by 1 Kelvin means approx. 2.5 % more energy required. Recommended flow temperature for area heating systems: max. 35°C

Based on experience the following reference values were determined for the dimensioning of the Uponor Energy Cages. They are used to assess the soil conditions. Soil classes 1-4 (DIN 18300) are suitable for the installation of an Uponor Energy Cage. From soil class 5 the manufacturer must be contacted.

Reference value for the dimensioning of an Uponor Energy Cage



Reference value for the dimensioning of an Uponor Energy Cage XL



If it should not be possible to clearly classify the soil on the construction site, the ground soil should be analyzed by a geologist.

With operating modes > 1,800 h the number of Uponor Energy Cages must be adapted to the soil conditions.

The required heat pump must be selected by the manufacturer or heating engineer. He selects the respective heat pump model based on the heating load, the system temperatures, the application and the operating time. This results in the cooling and heating capacity.

The following example shows how to calculate the required number of Uponor Energy Cage:

	Singe-family house
Calculated heating capacity *	6 kW
Refrigerant capacity	4 kW (according to HP manufacturer)
Soil property max. abstraction capacity of an Uponor Energy Cage	Cohesive, humid soil 1.2 kW
Required no. of energy cages	4
Brine volume	336 l
Ground energy manifold size	2 outgoings

* incl. hot water and blocking time of the utility company; 1,800 h operating period

The calculation of the pressure loss refers to the example given above. Here just the data for monothylene glycol is used.

	Monoethylene glycol 29%
Density kg/m³	1,051
c_p kJ/(kg · m)	3,72
Viscosity Pa · s	0.00313
Mass flow kg/s	0.36
Max. no. of baskets in row	2
Flow velocity m/s	0.32
Pipe length PE-Xa 32 x 2.9 mm per Cage incl. connection line in m	150
Pipe length PE-Xa 32 x 2.9 mm by series connection of 2 Cages in m	300
Pressure loss of the energy cage series connection incl. integrated connection line	280 mbar
Pressure loss Uponor ground energy manifold, 2 outgoings	30 mbar
Total pressure loss incl. manifold	310 mbar

Laying and installation

Entering trees, lines (water, telephone, wastewater, etc.) on the site plan must be considered. Only this way can potential problems be clarified beforehand and the exact position of the energy cage can be defined. Uponor Energy Cages can be connected in series. The position of the individual energy cages can be defined as requested.

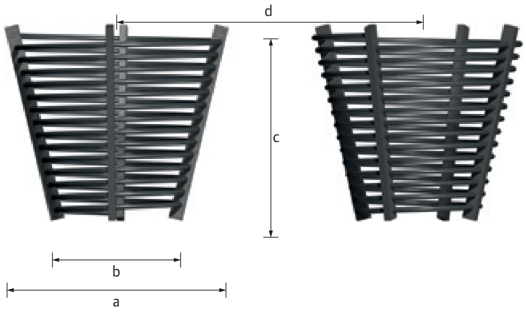
Take care that the energy cages are not overbuilt with structures such as garages, carports, cellars, swimming pools or streets. Otherwise natural regeneration is no longer possible.

The following distances must be maintained:
The minimum distance to foundations, adjacent plots, traffic areas, swimming pool and tap water and wastewater lines must be 1.5 to 2 meters. The ideal distances between the energy cage and the space required can be found in the table listing the technical data.

The Uponor Energy Cage consists of 150 m PE-Xa pipe of 32x2.9 mm dimension while the Uponor Energy Cage XL consists of 200 m pipe. The pipe is fixed on a framework of four foamed polyurethane brackets. The tapered conical increases the surface to absorb the ground energy and the volume for the energy transport medium. The PE-Xa pipe makes the Uponor Energy Cage resistant to slow and fast crack growth. Especially when refilling the energy cage excavation pit the Cage can get into contact with sharp-edged filling material. When using conventional materials, e.g. PE 100, the pipes would be damaged. The soil would have to be exchanged for a humus/sand mixture. This is not required when using the Uponor PE-Xa pipe.

Uponor Energy Cage PE-Xa

Technical data	Energy Cage	Energy Cage XL
Pipe meter	150 m	200 m
Diameter top (a)	2.4 m	2.4 m
Diameter bottom (b)	1.4 m	1.4 m
Height (c)	2.0 m	2.7 m
Pipe distance	114 mm	114 m
Cage volume	6.1 m³	8.1 m³
Center distance Cage middle-middle (d)	6.0 m	7.0 m
Pure space required in case of layout in row / Cage	15 – 20 m²	20 – 25 m²
Pure space required in case of parallel lay-out / Cage	35 – 40 m²	35 – 40 m²
Circuitry	max. 2 in series	directly individually at manifold
Brine volume	84 ltr.	108 ltr.
Abstraction capacity (guaranteed with 1800 full load hours per year)	1.1 – 1.5 kW	1.6 – 2.0 kW
Pipe fixing	PU-foam strip with fixing tape	
Integrated connection line for flow and return flow	20 m	25 m



The Uponor Energy Cage should be connected according to the Tichelmann principle which says that with the same pipe lengths and same cross-sections also identical flow rates and flow conditions prevail. It has to be ensured that the pipe lengths do not differ by more than 10 %.

20 or 25 m flow and return flow connecting lines are already integrated in the Uponor Energy Cage. If in exceptional cases this should not be sufficient, the line can be extended using the Uponor Quick & Easy connection technology or electrofusion fittings.

It must be ensured that the connection lines have the same length to avoid different pressure conditions. If this cannot be avoided, an adjustment can be made using the flowmeters at the Uponor ground energy manifolds.

Uponor Energy Cages are usually installed in a depth of 1.4 meters. The installation time is approx. 1 hour per kW heating capacity, i.e. for a singe-family home with 6 kW approx. one working day should be calculated.

The Uponor Energy Cages are delivered to the construction site on trucks. Due to their low weight they can either be rolled to the construction site after unloading or can be positioned using an excavator.

Installation of the energy cage

For the soil excavation the excavator should have a minimum weight of 5-7.5 tons depending on the scope of the project. If there is sufficient space, bigger excavators are preferable – In the ideal case an excavator with a two-meter humus shovel.

The energy cage excavation pit can be refilled with the soil excavated before. It has to be ensured that the excavation soil is washed in when refilling the energy cage excavation pit. To avoid settlement compacting equipment can be used after refilling. Otherwise settings might occur during the first two years.

The Uponor Energy Cage should be installed following the steps below:

1. Excavation work
2. Fitting of the Uponor Energy Cage and refilling of excavation pit
3. Connection to manifold
4. Pressure test
5. Filling the system
6. Acceptance and documentation of energy cage system

With a suitable excavator a square excavation of approx. 2.5 x 2.5 m is made for the first Uponor Energy Cage and Energy Cage XL to be fitted. The excavation depth depends on the regional frost line. In most regions this is 0.7 – 1.2 m below the earth's surface. Hense an excavation depth between 3.2 – 3.7 m can be assumed. Then a connection trench with a depth of 1.2 m is cut from the first excavation hole to the manifold.

Before the energy cage can be lowered into the excavation pit some additional preparatory steps should be taken.
The connection line integrated in the energy cage must be pulled out of the inside and fixed to the pipe turns using cable ties. With this step the "twist" is removed from the connection line which facilitates laying of the pipe in the connection trench later.

The following pictures illustrate this again.

After the excavation work the energy cage is lowered into the excvation pit using a suitable machine (excavator) and refilled with the soil excavated before. It is important to wash it in with sufficient water. The other energy cages are positioned accordingly.


Detaching the connection lines


Positioning the connection lines


Fixing the return flow line


Fixing the flow line


Excavation of the installation pit


Positioning the energy cage


Washing in the filling material


Refilling of the Uponor Energy Cage PE-Xa


Installed and compacted energy cage

It has to be ensured that the planned minimum distances of the energy cages among each other are maintained. Then connection trenches are cut between two each of the individual energy cages of the Cage field aligned with the top edge of the energy cage. Then these two energy cages are connected in series. The Uponor Energy Cage XL must be connected individually.

Depending on the installation variant now the individual connection lines already integrated in the energy cage, the energy cages connected in series or the extened connection lines are connected to the Uponor ground energy manifold and mounted on the manifold by means of compression fittings.

Depending on the volume flow of the energy cage system the connection lines can have different dimensions. This has to be calculted in advance. The house duct should be sealed watertight to pressure. Alternatively the Uponor manifold shaft can be used.

The pressure test according to EN 805 has to be carried out on each pipe run.

The energy cage system must be filled with an anti-freeze solution according to VDI 4640 for up to minimum -15 °C. When using Uponor anti-freeze solutions this corresponds to a mixing ratio of 3:1. The brine quantity required for the energy cage can be found in the technical data. The anti-freeze solution and the water must be mixed in a sufficiently large container, before the Uponor Energy Cage is filled with the mixture!

After completion of the Uponor Energy Cage field it is recommended to enter the actual position of the Cage in the site map and to mark it with pipe run numbers. This documentation is useful for assigning the pipes to the manifold and for evidence for the authorities. The person installing the system is responsible for compliance with all valid standards and regulations. An acceptance procedure for the system has to take place.

Important

The anti-freeze solution and the water must be mixed in a sufficiently large container before the Uponor Energy Cage is filled with the mixture!

Example for the right mixing ratio:

Brine volume

	Uponor Energy Cage	Uponor Energy Cage XL
Total brine volume	84 l	108 l
Mixing ratio	3:1	3:1
>Anti-freeze solution	21 l	27 l
>Water	64 l	81 l

Water volume per pipe dimension

PE-Xa pipe dimension [mm]	Inner diameter [mm]	Water volume [l/m]
32 x 2.9	26.2	0.539

Legal regulations

The country-specific regulations such as VDI 4640 and Wasserhaushaltsgesetz (Federal Water Act) (D), SIA D-0190, SIA S 0179 and BAFU-Vollzugsrichtlinie (CH), österreichische Wasserrechtsgesetz, Gewerbeordnung und Bauordnung (Austrian Water Rights Act, Industrial Code and Building Code are to be observed for all energy cage systems.

Energy Piles

System/scope of application

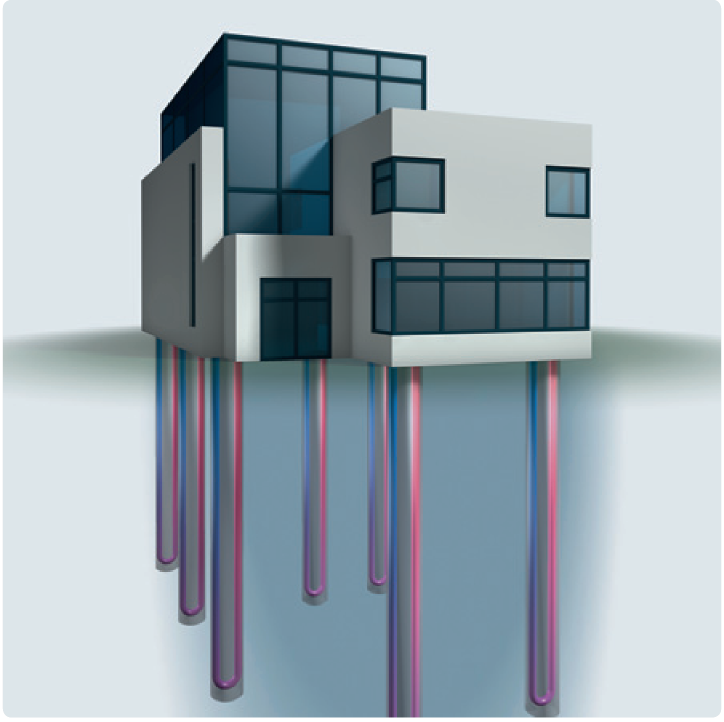
Application description

An energy pile has to fulfil two functions:

The main function is the load transfer into the ground; the secondary function is the use as ground energy transfer medium. By using the foundation pile as energy pile its load-bearing capacity must not be affected.

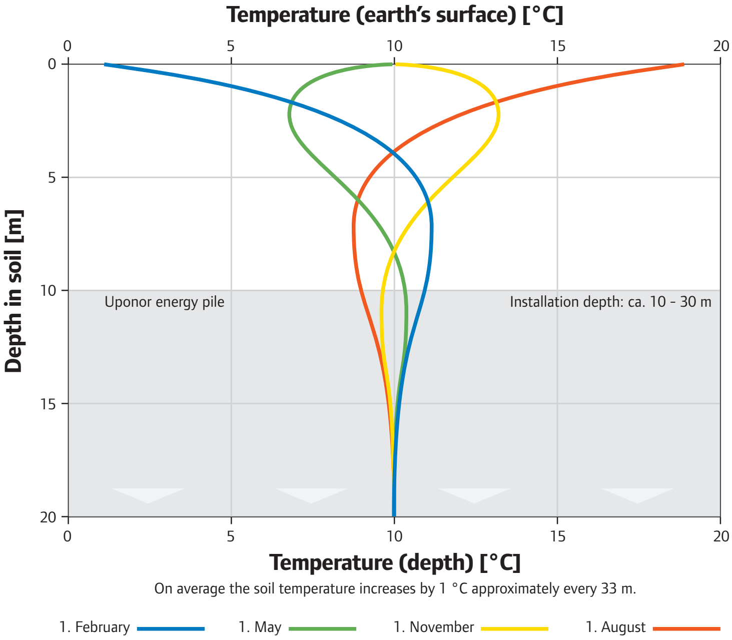
Application limits

A reduction of the load-bearing capacity of the pile (formation of frost, reduction of cross-section due to heat exchanger pipes) must be excluded in any case by temperature limitation and static tests. Energy pile systems are often ground load systems. Peak loads must be covered by additional ground energy systems, if necessary.



Schematic illustration of an energy pile system

Single-family houses with deep foundations usually can be provided monovalently with Energy Piles due to their excellent insulation – however, this is a rare application.



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

Benefits

- Very low additional investment cousts in case of planned pile foundations
- Base-loadable
- Can be used with all deep foundations
- Ideal solution for residential and non-residential applications

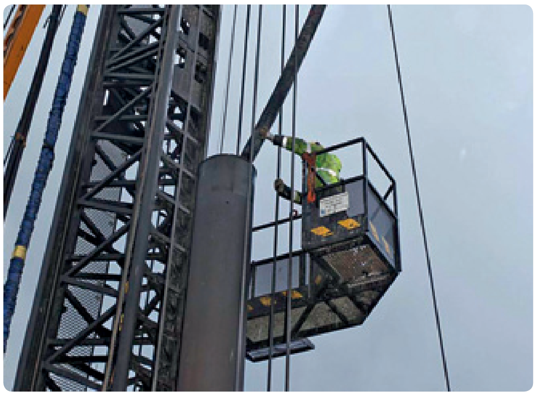
The building statics determine the layout and number of foundation piles. A layout of foundation piles according to energetic aspects is often not economical (exception: e.g. low-cost pre-fabricated driven piles, that are partly also used as "lost piles").

An energy pile system should be operated as alternating storage systematically changing heating and cooling operation. Thus an optimal specific abstraction capacity is achieved both for heating and cooling generation. The temperature balance of the energy pile system can be designed in a sustainably stable manner. With an almost even heat balance over the years the mutual thermal interferene of adjacent Energy Piles is minimized.

From experience with medium-sized and big energy pile systems the basic load operation is the most economical one. For this an optimum ratio of capacity and work is to be planned and defined during dimensioning. Mainly the heating and cooling work performed determines the efficiency of the energy pile system.

Installing the reinforcing cages

Concreting procedure of the in-situ piles



Filling pipe for concreting

Supervision of the pile assembly

Foundation piles

When it comes to foundation piles a distinction is made between the type of assembly and the installation.

Type of assembly

Pre-fabricated pile
Pile is pre-fabricated completely or in parts before installing it into the ground.

- Massive concrete piles
- Hollow spun concrete piles
- Steel pipes

In-situ concrete pile
Pile is assembled on site in the ground by filling a cylindrical void with concrete.

Type of installation

Ram and press pile.
Pile is rammed into the ground or pressed into the ground under static pressure.

Bored pile.
Pile is installed in a borehole. The boreholes can be generated using different drilling methods.

Drilling methods

- **Kelly-method.**
  With the Kelly method uncased, partly cased, fully cased or slurry-supported bored piles are produced. The drilling tool is fixed on a telescopic Kelly bar. When using a full encasing the bore pipes are drilled into the ground until they reach the required depth and drilling is continued until they reach the final depth.
- **Kelly-method with pile base expansion**.
  Pile base expansions are based on the principle of a circular symmetric extension of the diameter at the bottom of the borehole. The outer load capacity of the pile is increased by enlarging the endbearing area of the pile in the bearing soil. The extension measure is defined in consideration of the existing soil and the geometric limiting criteria according to statical requirements. Another possibility to increase the load-bearing capacity is shaft grouting. With this method the skin friction of the bore pile is increased by filling it up with cement suspension.
- **SOB-method**
  This pile drilling method is an auger drilling procedure which enables a high drilling meterage in firm ground. With this method a continuous flight auger is used as a drilling tool. After reaching the final depth of the borehole the inner tube of the hollow stem auger is fed with concrete from bottom to top.
- **DKS-method.**
  The dual rotary head system is the combination of the SOB method with continuous drill auger and the Kelly method with encasing. The result is an encased boring generated with a continuous flight auger.
- **VDW-method**.
  The against-the-wall system was developed out of the demand to be able to erect new buildings directly in front of existing buildings in cities. The production principle corresponds to that of the DKS method, but smaller diameters are used.


Assembly of a bore pile


Prefabricated concrete bored pile

Foundation pile types

Bored piles (hollow-spun piles)

Bored piles (hollow-spun piles) are round piles made of concrete that are transferred into the ground through different drilling procedures. They divert structural loads into deeper, solid soils, stringed together form a retaining wall for excavation pits or terraces, remove obstacles in the soil or block groundwater below the surface. Corresponding to the use length, diameter, material, design and layout of the individual piles can be varied.

Special type of bored piles are micro-piles. These are foundation elements with a diameter of up to 300 mm, by means of which loads are trasnferred into deeper solid ground layers through skin friction. The special feature of the micro-pile is that with a small diameter a high load bearing can be achieved by targeted pressure grouting technologies.

Due to a multitude of device variants highly productive procedures for the production of small diameter bored piles also in confined areas are possible.

Buildings that were damaged by uneven settlements can be stabilized by and/or raised by prestressed micro-piles. Adapted to the respective soil conditions micropiles can be assembled with various drilling methods. The bored piles are provided with continuous reinforcement that absorbs tensile loads, pressure or alternating loads.

The load transfer to the surrounding ground is achieved by filling or grouting the borehole with cement mortar (with or without support grain). The pile is post grouted in order to increase the skin friction / load transfer.

Hollow-spun concrete ram piles

The Hollow-spun concrete ram piles is an extremely economical and technically sound alternative to conventional foundation systems. The ductile ram pile is a quick, flexible and simple foundation system, in which ductile cast iron pipes – depending on the length required with pipe segement, that are plugged into one another using sleeves – are rammed into the ground to transfer loads.

Depending on the soil properties the pile is constructed as end-bearing pile or as pressure-grouted pile. Depending on the load to be transferred different pipe diameters with the respective wall thicknesses are available for pile construction. Due to the use of lightweight and agile hydraulic excavators also minor building activties in confined space can be carried out. The piles are installed on the construction site by means of a double-acting hydraulic hammer almost without vibration.

Pressed massive concrete pile

The pressed massive concrete pile is built up of sections which are pressed into the ground by a hydraulic system. An existing building or a ballast arrangement provides the reaction necessary for this. The pile is built up of reinforced concrete sections placed on top of each other. Soil can be excavated from the pile through the hollow pile core so that the pile reaches the required depth without a large reaction being required. When the pile is at the correct depth, an enlarged base is made by compacting metal containers with a dry mortar mixture under the pile. The pile core is filled with concrete. This working method is vibration free.

Since light, dismountable machines are used, this system is extremely well suited for working under difficult conditions and in very confined working spaces.
The pressed massive concrete pile is mainly used for underpinning work. The reaction required in this case is usually provided by the building itself by means of a new concrete floor cast on site. Anchors are concreted into this concrete floor and holes are left open through which the piles are pressed. The picture at the top of this page shows how this method works. By using this technique it is possible to fix the piles onto the floor at a preload.
The minimum working height is 0.8 m. As a result it is possible to force a jacked reinforced concrete pile under an existing foundation. This existing foundation is then used as the counterweight for jacking the pile.

Pre-fabricated concrete piles

Pre-fabricated concrete piles are manufactured with circular cross-section or a square cross-section without void. They transfer high building loads to deeper solid ground through skin friction and load transfer and are provided with continuous reinforcement.

Pre-fabricated ram concrete pile

The pre-fabricated ram concrete pile is a very economical and technically sound alternative to conventional foundation systems as well.

The pre-fabricated full-wall piles are installed on the construction site almost without vibration using a double-acting hydraulic hammer.

Depending on the subsurface it is possible that the originally planned positioning depth is not reached and the pile has to be cut to length. In case of activation with pipe loops the removal of surplus concrete bears the risk that the heat exchanger pipes are damaged.

In-situ piles

With large-diameter bored piles the soil is not pushes aside but a steel pipe with an opening on the bottom is drilled into the ground. The soil is then removed and an inner steel reinforcement is inserted and filled with in-situ concrete. Then the steel pipe is pulled out again. This type of in-situ pile is used for statically sophisticated foundations such as high-rise buildings.

Inserting the steel reinforcing cage in the borehole

Slotted walls

Slotted walls are walls assembled in the ground from so-called in-situ concrete that can reach in great depths. The walls – thickness according to statical requirements and equipmed used – are manufactured with low-noise and low-vibration methods.

Slotted walls show minim deformations, and are therefore mainly used as retaining walls in inncer city foundations. Due to their relatively high watertightness they are also used at outer wall of the building to be constructed. In special cases individual slotted wall elelments are also used for deep foundations. Cut-off walls seal dams and retain landfill sites, take storages or other industrial plants that may jeopardize the groundwater.

By means of special grippers or milling cutters the ground is opened up into the depth forming slots, whereupon the slot is continuously secured by means of a slurry fluid.

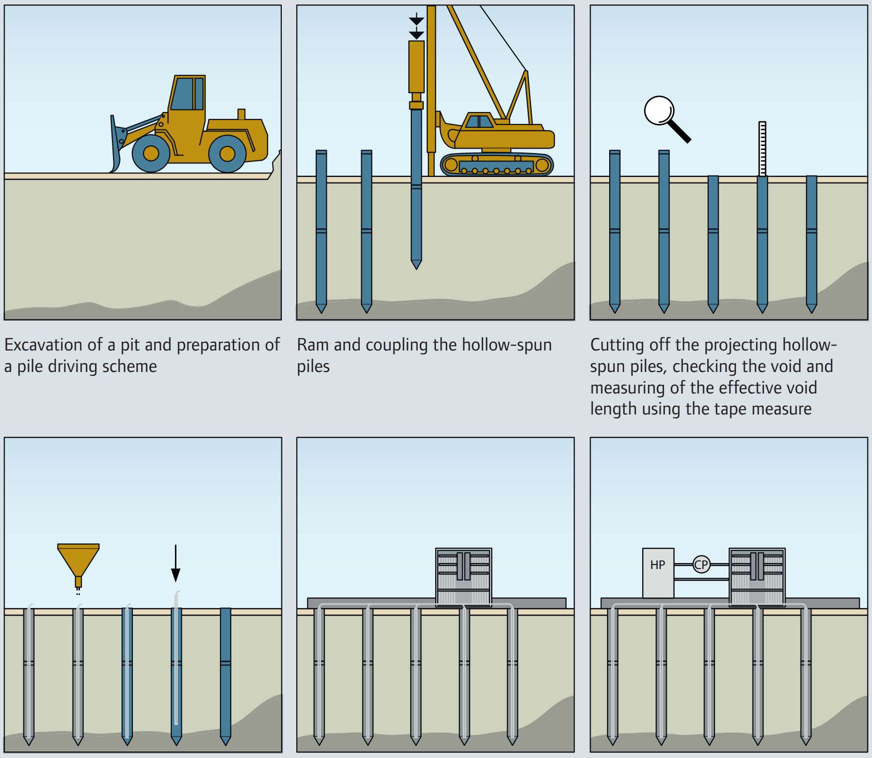
- **In-situ concrete slotted wall.** When the required wall depth is reached the slurry fluid usually is replaced by reinforced concrete so that statically effective and groundwater retaining walls can be assembled.
- **Single-phase sealing walls.** Single-phase sealing walls are slotted walls made of a self-hardening suspension which are constructed in a slot excavated in the ground. The self-hardening suspension is at the same time used as support suspension. Sealing elements such as diaphragms or sheet pilings can be installed additionally.

Activation of foundation piles

Bored piles (hollow spun piles)
Hollow-spun concrete ram piles and press piles are only provided with collector pipes after they have been driven into the ground. This is also a big advantage of the hollow-spun concrete piles since the collector pipes can be adapted to the actual insertion dept and the risk of damage of the collector pipes can be minimized by inspecting the pile void in advance.

Similar to borehole collectors two pipe loops are lowered into the ground and filled up with backfill material. In case of narrow bending radii of the pipe loops it is recommended to use electrofusion U-bends or alternatively borehole collectors can be inserted directly. During backfilling it is to be ensured that the backfill material shows high heat conductivity, good contact to the materials under different environmental conditions and that it can be fed in without creating voids.

The supply and return flow of a respective energy pile can be bundled through Y-pieces or T-pieces and combined in groups with other piles.



Excavation of a pit and preparation of a pile driving scheme

Ram and coupling the hollow-spun piles

Cutting off the projecting hollow-spun piles, checking the void and measuring of the effective void length using the tape measure

Fitting of the double U-collector and subsequent filling o the void

Laying and mounting of the horizontal connection lines incl. connection to the manifold connection group. Pressure test of the complete system concreting of the foundation slab.

Completion of the shell and mounting of the circulation pump (CP) and heat pump (HP)

Installation of thermally activated hollow-spun piles

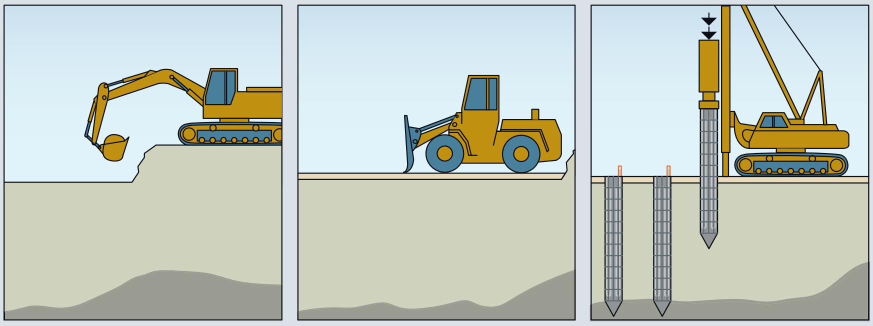
Pre-fabricated ram concrete piles

Pre-fabricated ram concrete piles are already equipped with the respective collector pipes at the factory. To do so, the collector pipe is fixed on the inside of the reinforcing cage and the pile is constructed by concreting. The number of pipe loops is adapted to the pile form and the pile diameter.

A recess for the connection lines is to be provided at the bottom of the pile. The pipe ends are led out of the pile so that they protrude after installation. During installation the direction of the projecting pipe ends should be selected so that the connection line does not have to be led around the pile.

Depending on the subsurface it is possible that the originally planned positioning depth is not reached and the pile has to be cut to length. In case of activation with pipe loops the removal of surplus concrete bears the risk that the heat exchanger pipes are damaged.

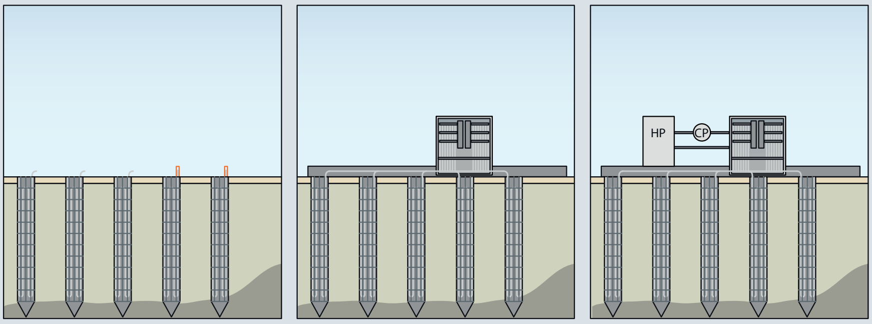
The benefit of using pre-fabricated concrete piles is that the fitting and pressure tests are carried out in the factory and damages of the heat exchanger pipes are excluded due to concreting of the pile on the construction site.



Excavation of a pit

Preparation of a pile driving scheme

Driving the pre-fabricated concrete piles



Removal of the protective coating and installing of the 90° brackets

Laying and mounting of the horizontal connection lines incl. connection to the manifold connection group. Pressure test of the complete system concreting of the foundation slab.

Completion of the shell and mounting of the circulation pump (CP) and heat pump (HP)

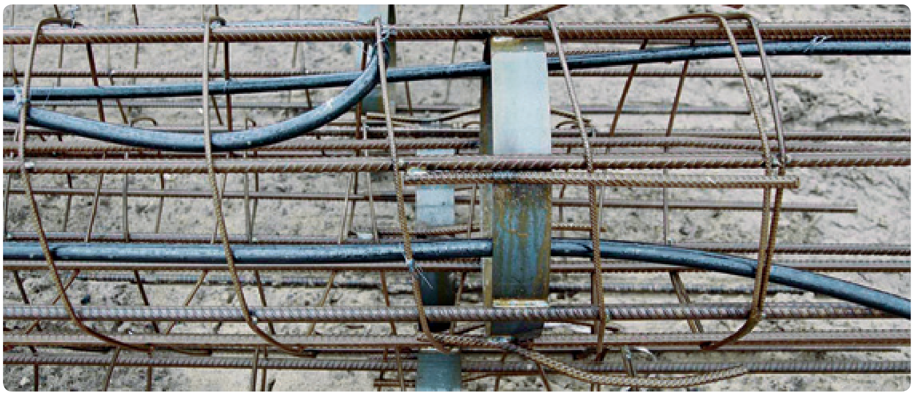
Installation of thermally activated pre-fabricated concrete piles

In-situ concrete piles

With piles that are manufactured with the in-situ concrete method the reinforcing cage is provided with the collector pipes before inserting it into the prepared borehole. The collector pipes are usually mounted on the inside of the reinforcement cage to avoid damage of the pipes when inserting the reinforcing cage into the borehole.. When doing this the collector pipes are fixed vertically endless in a spiral at the reinforcing cage wall or crosswise at the pile foot or in individual pipe loops with redirection (Omega bow) at the reinforcing cage wall or crosswise at the pile foot in the reinforcing cage using cable ties.


Storage of fitted reinforced cages


Connection lines made of Uponor ground energy PE-Xa pipes

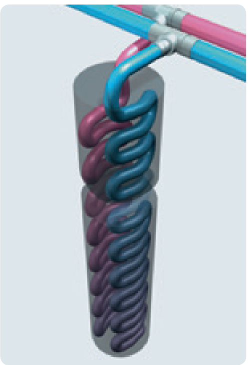

Pipe loops fitted in the reinforced crates

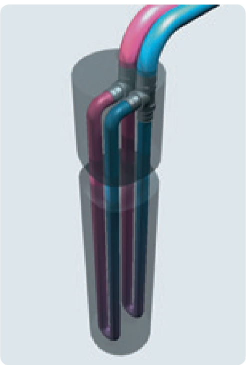

Inserting the PE-Xa pipe loops


Cutting the inserted pipe loops to length


Fixing the pipe loops

Installation variants


Installation in meander-shape


Installation of parallel pipe loops


Installation of pipe loops crosswise


Installation in spirals

Especially with small pile diameters the bending radii are to be considered. In case of narrow bending radii it is recommended to use pipe bend supports or electrofusion U-bends.

In case of short pile lengths laying as a meander in the pile with a supply and return flow line directly to the manifold is possible. The number of pipe loops to be inserted depends on the diameter of the reinforcing cage. Reference values are:

Pile diameter	Number of vertical pipes
20 – 70 cm	4 – 6 U-bends or with electrofusion U-bends in the foot area
75 – 80 cm	4 – 6 with Omega-bow in the foot area
90 – 120 cm	6 – 8
130 – 180 cm	8 – 12

The supply and return flows of an energy pile can be bundled through a pile head manifold, a Y-piece or T-piece and combined with other piles in a group. In case of different construction levels the pipe ends at the pile head are to be provided with protective pipes or pie insulation at least over the length of the concrete to be removed after the pile was assembled. All pipe ends are to be sealed to prevent dirt from entering.

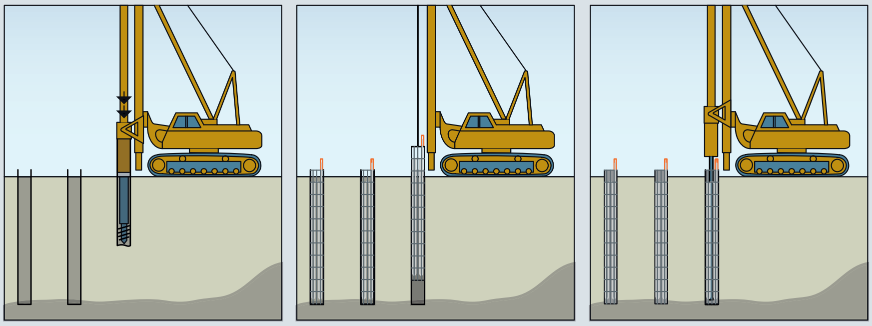
Basically, when inserting components into the foundation pile made of concrete the potential statical weakening has to be considered.

To prevent damaging of the collector pipes the pile is to be concreted with a filling tube (tremie method). During filling it has to be ensured that the tremie hose does not damage the pipes. When compacting the concrete no concrete vibrators must be used. If the pile is concreted by dumping, the concrete labourer has to be notified.

Slotted walls

With slotted walls that are assembled on site the reinforcing cages must be provided with collector pipes before inserting them. The collector pipes are usually fitted on the inside of the reinforcing cages to prevent damage of the pipes when inserting the reinforcing cage into the borehole.

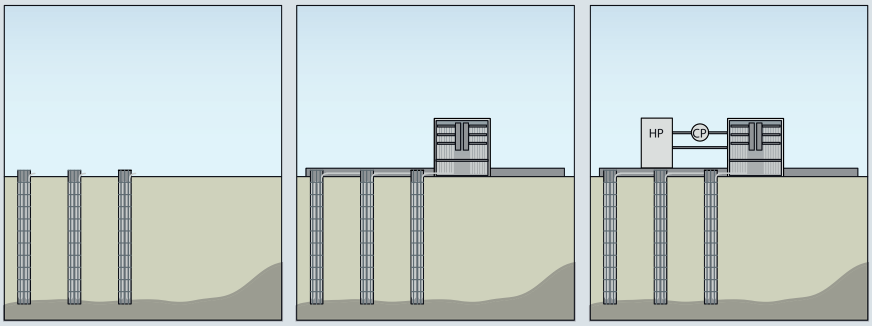
Conventional foundation pile lengths are approx. 10 – 30 m. The temperatures in the top layer of the earth vary with the seaons. As soon as they fall below the frost limit these fluctuations diminish. From a depth of approx. 15 m the ground soil has a widely constant temperature.



Creating the borehole by drilling with an auger drill and ramming of drill pipes

Inserting the reinforcement with pipe registers

Filling of the drill pipes with concrete using the Tremie method and simultanous pulling of the drill pipes



Removal of the protective coating and installing of the 90° bends

Laying and mounting of the horizontal connection lines incl. connection to the manifold connection group. Pressure test of the complete system. Concreting of the foundation slab.

Completion of the shell and mounting of the circulation pump (CP) and heat pump (HP)

Installation of thermally activated in-situ concrete piles

Dimensioning of Energy Piles

The dimensioning of Energy Piles depends on the annual operating hours of the heat pump systems and the design of the concrete piles as well as the mutual interference of the Energy Piles.

The lower the thermal resistance R_E of the energy pile the higher the heat transfer. The thermal resistance indicates the loss in temperature during the transition of the heat from the subsurface to the heat transfer medium (brine). Decisive criteria for the thermal resistance are the bored pile diameter, the heat conductivity of the pile material and the type of energy pile.

A smaller pile diameter reduces the thermal resistance. Higher heat conductivity of the pile material reduces the loss of heat during the heat transfer or reduce the thermal resistance.

Thus the thermal resistance of the energy pile R_E consists of the transition resistances of individual elements and the specific material resistances.

Transition resistances:
Ground soil < > pile material < > pipe < > heat transfer medium (brine)

Material resistances:

$$R_E = R_c + R_R + R_P \quad [W/(m^2K)]$$

R_c	Heat-transfer coefficient heat transfer medium / pipe
R_S	Heat transfer coefficient pipe loops
R_P	Heat ransfer coefficient pile material

The required length of the pipe loop L is based on the specific abstraction capacity q_E of the subsurface and the refrigerant capacity Q_O of the brine/water heat pump.

$$L = \frac{Q_O}{q_E} \quad [m]$$

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

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

When dimensioning the connection lines of the Energy Piles 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

Specific abstraction capacity per meter pile depth

Subsurface	**Specific abstraction capacity q_E per meter pile depth for heating capacities up to 30 kW**	
	1800 h/a	**2400 h/a**
Poor underground, dry sediment	25 W/m	20 W/m
Normal rocky underground and water saturated sediment	60 W/m	50 W/m
Consolidated rock with high thermal conductivity	84 W/m	70 W/m

During longer operating periods both the specific abstraction capacity q and the specific annual abstraction factor are to be considered.

Source: VDI 4640

factor β of the heat pump system. The maximum flow velocity should be 1 m/s. The flow velocity in the Energy Piles should be turbulent, since a turbulent flow improves the heat transfer from the pipe to the brine thus increasing the brine temperature.

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 power requirement 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.

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

If a model with lower heating capacity or shorter pipe loops is used when selecting the heat pump, the operating hours of the heat pump increase. This means the energy pile is under more strain or a higher annual abstraction factor results. To compensate the increase of operating hours the pipe loop length has to be extended resulting in higher power consumption.

For the dimensioning of energy pile systems knowledge of the thermal properties of the subsurface is very important. The calculation of the heat conductivity from undisturbed samples of drill cores of a test drilling are principally possible but a very elaborate method which can only be carried out in a laboratory.

The dimensioning of energy pile systems using simulation programs requires information about the effective thermal conductivity over the complete borehole length. This information is obtained directly on site by the Thermal Response Test (TRT).

Thermal Response Test
The Thermal Response Test is carried out with an assembled energy pile. During this test the energy pile is fed with a constant thermal capacity which is then extracted. The evaluation is made based on the Kelvin line-source theory. The results show the exact geological conditions on the site over the complete energy pile length and under typical operating conditions including the effects of a potentially existing groundwater flux.

Due to the complex geological and hydro-geological correlation of the energy pile dimensioning as well as the special technical know-how planning, simulation and dimensioning of energy pile systems must only be carried out by experts.

Laying and installation

Energy pile systems should always be operated as alternating heating and cooling exchangers. Due to the overbuilt surface natural heat supply is not sufficient and hence when utilizing the system over several years the temperature level in the relevant ground soil would decrease and fall below the actual usage limit. During heating operation the temperature level should be as low as possible (< 35 °C) and during cooling as high as possible (> 16 … 18 °C).

All Energy Piles including their connection lines should have the same length and should be connected to a heat pump according to the Tichelmann principle through a supply and return flow manifold with collecting pipes.

When laying the pipes according to the Tichelmann principle the required energy pile length is split into Energy Piles connected in parallel for the respective abstraction capacity. Thus with respect to the pressure loss the volume flow of the individual Energy Piles, the pipe lengths and pipe diameters are to be considered.

If it is not possible to install Energy Piles incl. connection lines of the same length, a hydraulic compensation must take place using balancing valves to maintain the same pressure loss in each pipe loop.

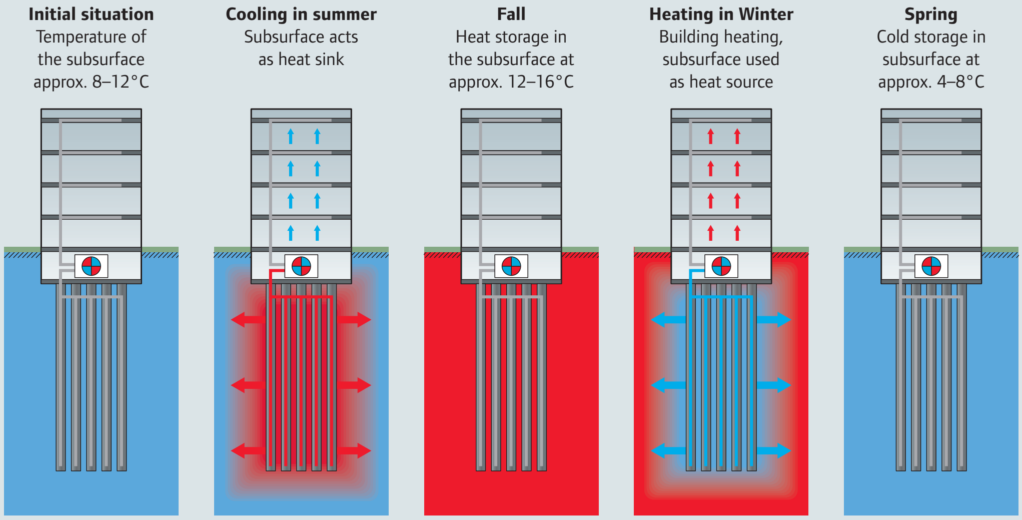
The supply and return flows of an energy pile can be bundled through a pile head manifold, a Y-piece or T-piece and combined with other piles in a group.

The connection to the horizontal connection line is done at the pile head. The pipe ends are led out of the pile head so that the connection lines do not have to be guided around the pile. With 90 ° pipe fittings the vertical pipe lines out of the bored pile are connected to the horizontal lines so that no air pockets form in this area.

The connection lines are to be laid with minimum slope to the manifold to enable venting. This is preferably done horizontally in the blinding layer or in a sand bed – with PE-Xa pipes no sand bed is required – under the foundation slab up to the respective manifold.

It is to be ensured that the connection lines are not placed in direct

Energy piles: Thermal utilization of the subsurface



Initial situation
Temperature of
the subsurface
approx. 8–12°C

Cooling in summer
Subsurface acts
as heat sink

Fall
Heat storage in
the subsurface at
approx. 12–16°C

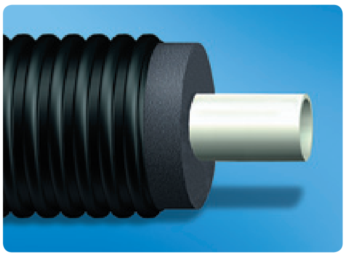
Heating in Winter
Building heating,
subsurface used
as heat source

Spring
Cold storage in
subsurface at
approx. 4–8°C

contact to each other in order not to cause a thermal short-cut between the supply and return flow. In the ideal case the return flow connections should be designed as insulated pipe variant e.g. with Uponor Ecoflex Thermo Mini.

The connection lines can either be guided to the respective manifold individually (parallel) or in a bundle (serial). The benefit of connecting each individual pile with the respective manifold is that in case of a failure of a pile only the capacity of that pile is lost.

All manifolds and fittings should be installed in accessible rain protected chambers outside the building. All Energy Piles should be equipped with ball valves at the manifolds to be able to shut them off. The connection lines are to be connected to the manifolds in a stress-free manner.



Uponor Ecoflex Thermo Mini

The mutual interference of the Energy Piles must be considered. The definition of the quantity and the layout of the Energy Piles according to energetical aspects usually is not possible and is defined through the static conditions of the building. A possibility to cause an effect are so-called "lost piles", i.e. those are not thermally activated or additionally installed as Energy Piles without static requirements.

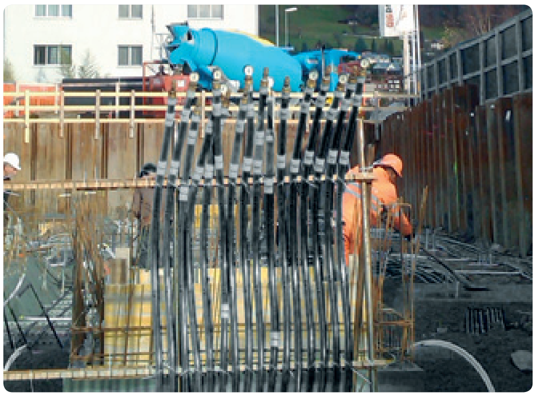
Pipe connections which are assembled on the building side and not accessible should be done with maintenance free connection technique e.g. Uponor Quick & Easy or Electrofusion fittings.

According to DIN 4140-2 all connection lines 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.

To avoid freezing of the heat exchanger, pipes, connection lines and the evaporator the heat pump system is filled with brine – usually a mixture of water and glycol (heat transfer medium).

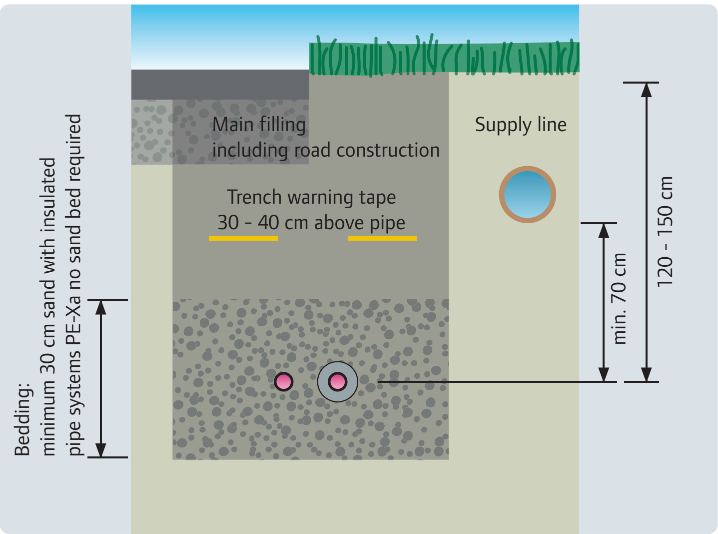
Important

For static aspects the temperature limits (min. > 0 °C/max. 25 – 30 °C) have to be considered.



Pressure test of the energy pile installations

Connection of Energy Piles using Uponor PE-Xa pipes



Bedding of the connection lines. Flow not insulated – backflow insulated

Heat transfer media for heat exchanger pipes and connection lines 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 glycol percentage is usually 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. Depending on the type of pipe used the connection lines 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.

Fixing of the connection lines (height in the ground and distance) can be done using Hooks or by fitting the pipes on reinforcement mesh.

Important

The antifreeze and the water must be mixed in a sufficiently large container before the Uponor energy pile is filled with the mixture!

Water volume per pipe dimension

PE-Xa pipe dimension [mm]	Inner diameter [mm]	Water volume [l/m]
20 x 2.0	16.0	0.201
25 x 2.3	20.4	0.327
32 x 2.9	26.2	0.539
40 x 3.7	32.6	0.835
50 x 4.6	40.8	1.307
63 x 5.8	51.4	2.075
75 x 6.8	61.4	2.961
90 x 8.2	73.6	4.254
110 x 10.0	90.0	6.362
125 x 11.4	102.2	8.203

Legal regulations

Country-specific approval of the responsible authorities may be required for energy pile systems. VDI 4640 and Wasserhaushaltsgesetz (Federal Water Act) (D), SIA D-0190, SIA D 0179 and BAFU-Vollzugsrichtlinie (CH), österreichische Wasserrechtsgesetz, Gewerbeordnung und Bauordnung (Austrian Water Rights Act, Industrial Code and Building Code are to be observed.

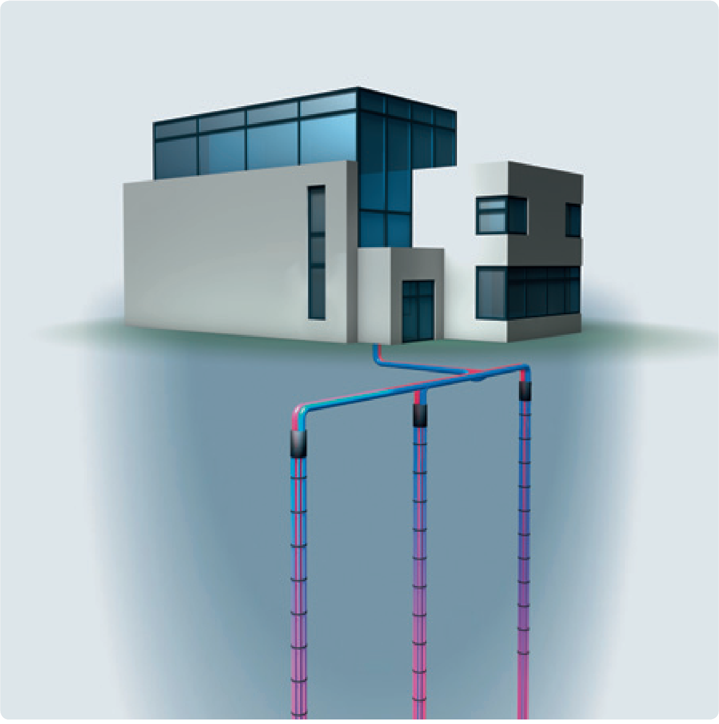
Vertical Collectors

System/scope of application

To use ground energy often vertical collectors are used to save space. Vertical collectors can be used in almost all subsurfaces.

Benefits

- Comparatively space-saving type of ground energy system
- Various subsurfaces can be used for installation
- Both active and passive (free) cooling and heating possible
- Ideal solution for residential and non-residential applications



Schematic illustration of a vertical collector system

Application description

Basically, vertical collectors are heat exchangers which are installed vertically in the ground soil. The available heat in the soil combined with a heat pump will be lifted up to a usable temperature level for heating and domestic hot water preparation. Such as other ground energy systems vertical collectors can also be used for passive (free) and active cooling in the Summer. This is one of the main benefits compared to conventional heating systems. While cooling the building in the Summer the absorbed heat is transferred to the ground.

The required abstraction capacity depends on the geological and climatic conditions, the heat extraction technology and the seasonally fluctuating heat demand of the consumer. For higher capacities so-called collector fields can be generated. This is a combination of several vertical collectors.

Uponor Simple U-collector

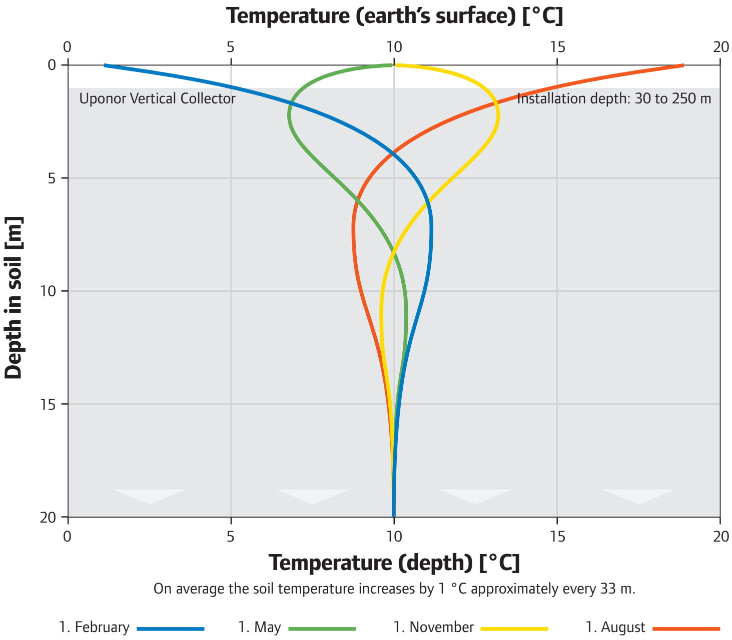
Uponor G12

Application limits

A vertical collector usually consists of one or two parallel U-shaped plastic pipes. A heat transfer liquid, the so-called brine, a mixture of water and anti-freeze circulates in both pipes. The brine extracts heat out of the ground soil, transports it to the evaporator of the heat pump and flows cooled down back into the vertical collector. The extracted Energy from the ground soil is heated up through the heat pump to the required temperature level of the heating system. Usually the supply temperature is approx. 35 °C. The system temperature should be as low as possible to create the conditions for a high seasonal performance factor.

Depending on the system the vertical collectors for ground energy use have a length of up to 400 m. Weldings between U-bend and pipe are tested with a pressure test according to EN 805 at the factory. On the site welding of a vertical collector is not allowed. The vertical collector probe must be delivered to the construction site pre-fabricated and pressure tested.

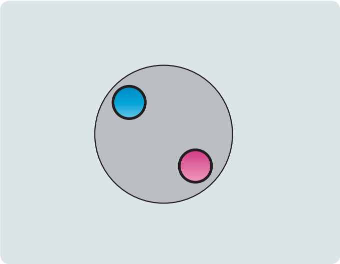
The temperatures in the top layer of the earth vary with the seasons. However, when falling below the frost limit these fluctuations clearly diminish. From a depth of 15 m the ground soil has an almost constant temperature. Thus vertical collectors are rarely subject to temperature fluctuations.



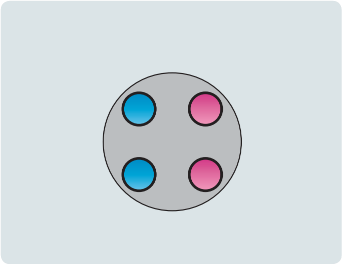
On average the soil temperature increases by 1 °C approximately every 33 m.

Vertical Collector Types

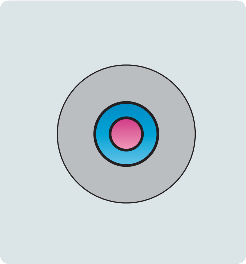
There are three different basic designs of vertical collectors:



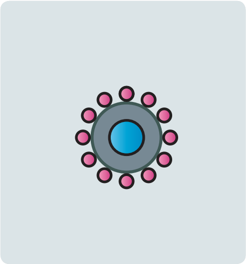
Cross-section of a single U-collector



Cross-section of a double U-collector



Cross-section of a coaxial collector



Special type: insulated pipe with outer non-insulated pipes fixed in a circle

Single U-collector
A single U-collector consists of two collector pipes that are connected at the bottom by a U-shaped PE welded fitting. Thus the single U-collector has one supply and one return flow pipe.

Double U-collector
A double U-collector consists of four collector pipes which are connected at the bottom – in pairs by a double U-shaped PE welded fitting. Hence, the double U-collector has got two supply and two return flow pipes.

Coaxial collector
Coaxial is the designation for congruent rotation axes of three-dimensional elements. Hence, a coaxial collector is a collector that consists of two collector pipes, which are integrated into each another (inner pipe and outer pipe). As a result depending on the kind of use the inner pipe either becomes the supply or the return flow.

Dimensioning of Vertical Collectors

The dimensioning of vertical collectors depends on the subsurface conditions, the annual operating time of the heat pump system, the borehole diameter, the borehole filling, and position of the pipes in the borehole and of the mutual interference of vertical collector systems.

The lower the thermal borehole resistance R_b, the higher the heat transfer. The thermal borehole resistance indicates the temperature loss during the transfer of the heat from the subsurface to the heat transfer medium (brine). Decisive criteria for the borehole resistance are the borehole diameter, the heat conductivity of the re-filling material and the type of the vertical collector.

A small borehole diameter decreases the borehole resistance. Higher heat conductivities of the borehole filling reduce the heat loss during the heat transfer and reduce the borehole resistance. Thus the thermal borehole resistance is a combination of the transitions resistances of individual elements and the specific material resistances.

Transition resistances:
Ground soil < > borehole filling < > pipe < > heat transfer medium (brine)

Material resistances:

$$R_b = R_c + R_S + R_V \quad [W/(m^2K)]$$

R_c Heat-transfer coefficient heat transfer medium / pipe
R_S Heat transfer coefficient vertical collector pipe
R_V Heat-transfer coefficient re-filling material

The required collector length L depends on the specific abstraction capacity q_E of the subsurface and the refrigerant capacity Q_O of the brine/water heat pump.

$$L = \frac{Q_O}{q_E} \quad [m]$$

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

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

When dimensioning the connection lines of the vertical collector 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

Specific abstraction capacity per meter vertical collector

Subsurface	Specific abstraction capacity q_E per m vertical collector for heating capacities up to 30 kW	
	1800 h/a	2400 h/a
Poor underground, dry sediment	25 W/m	20 W/m
Normal rocky underground and water saturated sediment	60 W/m	50 W/m
Consolidated rock with high thermal conductivity	84 W/m	70 W/m

During longer operating periods both the specific abstraction capacity q and the specific annual abstraction factor are to be considered.
For vertical collectors these should be between 100 and 150 kWh/(m · a).
For Switzerland the dimensioning conditions of the AWP/FWS apply.

Source: VDI 4640

factor β of the heat pump system. The maximum flow velocity should be 1 m/s. The flow velocity in the ground probes should be turbulent, since a turbulent flow improves the heat transfer from the pipe to the brine thus increasing the brine temperature.

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

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

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

As a rule of thumb the following applies:
With the monovalent dimensioning of a brine/water heat pump the capacity of the heat pump must be at least 100 % of the total capacity requirement.

For the dimensioning of bigger vertical collector systems (> 30 kW) knowledge of the thermal properties of the subsurface is very important. The calculation of the heat conductivity from undisturbed samples of drill cores of a test drilling are principally possible but a very elaborate method which can only be carried out in a laboratory.

The dimensioning of vertical collector systems using simulation programs requires information about the effective thermal conductivity over the complete borehole length. This information is obtained directly on site by the Thermal Response Test (TRT).

Thermal Response Test
The Thermal Response Test is carried out with a manufactured ground probe. During this test the ground probe is fed with a constant thermal capacity which is then extracted. The evaluation is made based on the Kelvin line-source theory. The results show the exact geological conditions on the site over the complete borehole length and under typical operating conditions including the effects of a potentially existing groundwater flux.

Due to the complex geological and hydro-geological correlation of the ground probe dimensioning as well as the special technical know-how planning, simulation and dimensioning of vertical collector systems must only be carried out by experts.

Laying and installation

All vertical collectors including their connection lines should have the same length and should be connected to a heat pump according to the Tichelmann principle through a supply and return flow manifold with collecting pipes.

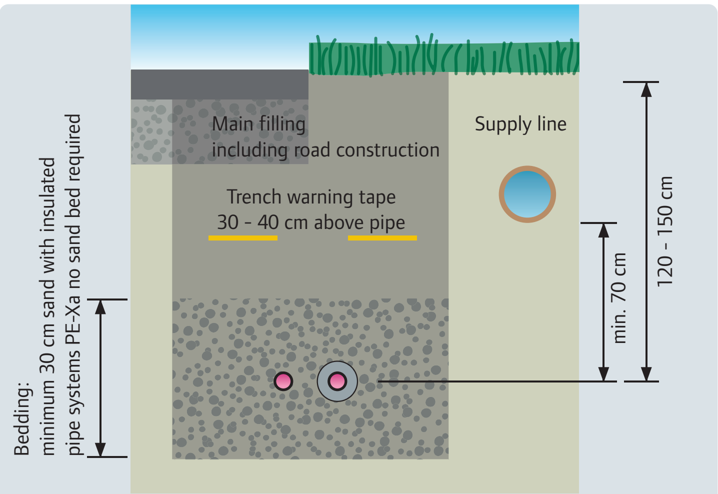
When connecting the vertical collectors according to the Tichelmann principle the required collector length is split into vertical collectors of the same length. The collectors are connected parallel. Thus with respect to the pressure loss the volume flow of the individual vertical collectors, the pipe lengths and pipe diameters are to be considered.

If it is not possible to install the vertical collectors incl. connection lines of the same length, a hydraulic compensation must take place using balancing valves to maintain the same pressure loss in each pipe loop.

The connection lines are to be laid with minimum slope to the manifold to enable venting.

Operating safety
All manifolds and fittings should be installed in rain protected chambers outside the building. Moreover, the horizontal collectors should be equipped with ball valves at the manifolds to be able to shut them off. The connection lines are to be connected to the manifolds in a stress-free manner.

To avoid mutual thermal interference vertical collectors should be installed with a minimum distance independent of the environment (country-specific). In case of aquifeours subsurfaces the vertical collectors should be positioned at a right angle to the groundwater flow direction. Sealing of the areas where the vertical collectors are installed must be avoided.



Bedding of the connection lines. Supply not insulated – return flow insulated

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

Pipe connections which are assembled on the building side and not accessible should be done with maintenance free connection technique e.g. Uponor Quick & Easy or Electrofusion fittings.

According to DIN 4140-2 all connection lines 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.

To avoid freezing of the vertical collector installation and the evaporator the heat pump system is filled with brine – usually a mixture of water and glycol (heat transfer medium).

Construction and the environment

Heat transfer media for heat exchanger pipes and connection lines 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.

Water volume per pipe dimension

PE-Xa pipe dimension [mm]	Inner diameter [mm]	Water volume [l/m]
40 x 3.7	32.6	0.835
50 x 4.6	40.8	1.307
63 x 5.8	51.4	2.075
75 x 6.8	61.4	2.961
90 x 8.2	73.6	4.254
110 x 10.0	90.0	6.362
125 x 11.4	102.2	8.203

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 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 vertical collectors are pre-fabricated when delivered to the construction site. In order to install the vertical collector after drilling it has to be filled with water before installation to avoid buoying upwards. Usually additional weights are attached on the probe foot. These have to be included in the calculation of the borehole lengths.

The selection of the borehole diamter depends on the design of the vertical collector and on the country-specific conditions. The smaller the borehole diamter the better the heat transfer.

If backfilling of the vertical collector is required, this should be done with thermally improved backfill material. Standard backfill materials such as bentonite have a thermal conductivity of 0.7 – 0.8 W/mK; thermally improved backfill materials show a thermal conductivity of up to 2.5 W/mK. Thus higher brine temperatures can be achieved or the required probe lengths can be reduced while maintaining the same brine temperature. Grouting of the vertical collectors under pressure through filling pipe and injector pipe should always be done from bottom to top to prevent formation of voids.

Spacers between the probe pipes prevent thermal short-circuits between supply and return flow. By means of spacers the probe pipes are fixed onto the borehole wall further to the outside and thus the heat transfer from borehole wall to the probe pipes is improved.

Important

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

The pressure test has to be carried out in accordance with EN 805. This test has to be carried out shortly after backfilling – before hardening of the backfill material or only after hardening of the backfill material to avoid the formation of an air ring gap between pipe wall and backfill material after releasing the pressure. The formation of an air ring gap leads to an insulating effect by the air and thus to a clear reduction of the heat transfer to the pipe wall and the heat transfer medium.

Legal regulations

Country-specific approval of the responsible authorities may be required for vertical collectors, especially locally varying regulations such as 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, Commodo-Law (Lux) are to be observed.

Executing drilling companies should be certified according to DVGW W120 (D), and be able to produce a FWS seal of quality groundprobe (CH), BRL SIKB 2000 (NL).

Fixing of the connection lines (height in the ground and distance) can be done by fitting the pipes on reinforcement mesh or by using Ground Hooks.

Uponor quality materials

PE-Xa

With their long service life and enormous robustness Uponor PE-Xa pipes do not only provide security of supply but also an excellent price / performance ratio. For a slight extra users gain unmatched security over decades.

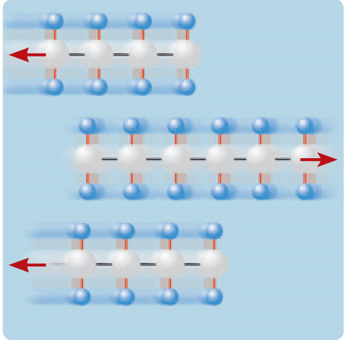
Uponor is the only company that offers an extended warranty of 10 years incl. compensation for damage up to an amount of 1 million Euro in individual cases for laying pipes without sand bed according to the generally valid regulations.

Apart from the combination with the Uponor Quick & Easy fitting system the Uponor PE-Xa pipes are weldable by means of conventional Electrofusion fittings and show the same quality as the connection of non cross-linked polyethylene pipes.

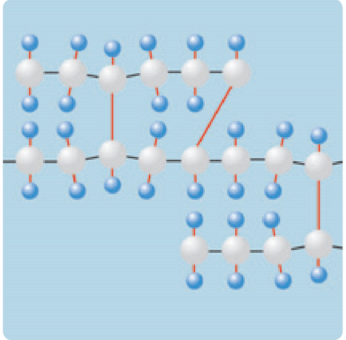
When manufacturing Uponor PE-Xa pipes polyethylene molecules are connected to a high-density three-dimensional network in a patented procedure. Due to this cross-linking the pipe gets outstanding thermal and mechanical properties which make it first choice for sophisticated ground energy applications.

Uponor ground energy PE-Xa pipes are high pressure cross-linked according to the patented Engel method. In this process the high-quality polyethylene material is melted and formed into a pipe in so-called ram extruders. Due to the high temperature generated in this process and the high pressure the added peroxide react in the melting process and partly separates hydrogen atoms from the carbon atoms of the polyethylene molecular chains. At these free spots now the molecular chains can interconnect. A stable three-dimensional network is generated which cannot "unloop". Therefore PE-Xa pipes are especially suitable for all laying procedures that put strain on the material.

Reconversion of kinks with hot air



„Unlooping"the moecular chain under strain in non-cross-linked polyethylene



The molecular structure of cross-linked polyethylene PE-Xa prevents unlooping under strain

In contrast to non-cross-linked polythylene pipes cross-linked polyethylene pipes feature the so-called memory effect. This is the effort of the material to go back to its original shape almost automatically after a forced deformation for example by expansion.

Even kinks can be remedied by heating the pipe to maximum 140 °C.

The memory effect of the PE-Xa pipes is the decisive mechanism in connection with the Uponor connection technique Quick & Easy. Here, the PE-Xa pipe is expanded, the fitting inserted and due to the memory effect the PE-Xa shrinks back with the required sealing force and without additional sealing elements on the fitting – quickly and safely!

Full wall pipes made of PE 80 or PE 100 provide many benefits compared to metallic pipes. But they must always be laid in a sand bed – an elaborate and cost-intensive process. Pipes manufactured from peroxide cross-linked polyethylene PE-Xa, however, are very ductile, can be exposed to high mechanical strain and can be installed without a sand or gravel bed according to DVGW Worksheet W 400-2. Often the excavated soil can directly be used for backfilling. This saves time and money.

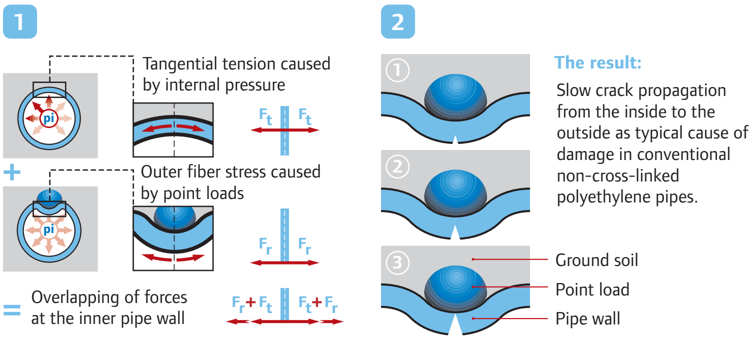
If plastic pipes are laid without a sand bed, they are exposed to very high strain. Outer fiber stress caused by point loads on the outside, e.g. due to stones and bodies and the tangential tension of the pipe affected by the internal pressure act together on the pipe. Both forces overlap at the pipe inner wall. In non-cross-linked polyethylene pipes cracks in the pie wall result, that spread to the outside in the course of time.

With Uponor ground energy PE-Xa pipes no cracks occur and spread over the material thanks to the special cross-linking. This decisive material benefit was confirmed by independent tests (S4, Notch, FNC-Test). An important criterion for installation without a sand bed is the analysis of the creeping strength of the pipes in the FNCT (Full Notch Creep-Test). With this test the tensile strength of a material sample at increased temperatures is measured. To do so, a sample is notched all around with 10 % of the material thickness and exposed to a tensile force in a tempered surfactant bath.

Now the time is measured until a crack forms due to the notch, the crack propagates and the pipe finally bursts. Testing of Uponor PE-Xa pipes at a temperature of 95 °C was stopped after 14,300 hours without damage. Extrapolated to the test temperature of 80 °C which is usual for PE this leads to a creep strength of more than 70,000 hours – a value that is way beyond the performance of state-of-the-art non-cross-linked PE materials.

Laying of PE-Xa pipes without sand bed

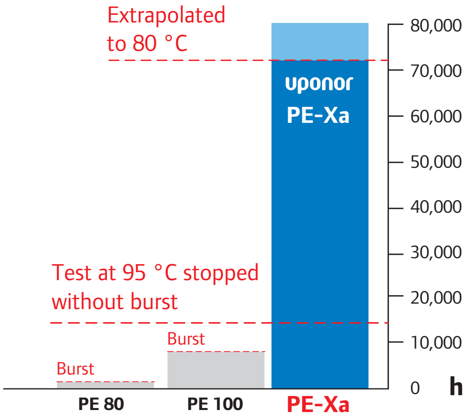
Formation of cracks in non-cross-linked PE pipes



Uponor ground energy PE-Xa achieves the best results in the four most important tests:

- **Slow crack propagation:** Test stopped without results (at 14,300 h)
- **Quick crack propagation:** S4-Test did not show any crack propagation
- **Creep strength:** 30 years of real test time result in a service life of more than 100 years
- **Performance when exposed to point load:** no effects, approved for installation without sand bed according to DVGW W400-2

FNCT – σ = 4 N/mm · creep time at υ = 80 °C



Due to this high resistance to mechanical strain Uponor PE-Xa pipes are specially suited for ground energy:

With in-situ concrete Energy Piles there might be mechanical strain and damage when fixing the pipes on the reinforcing cage, when inserting the equipped reinofrcing cage but also when concreting the pile.

Due to the processes on a construction site connection lines for vertical collectors and Energy Piles are often subject to mechanical strain during and after installation. The result is inadequate lining of pipes and strain on the pipes caused by people and machinery.

An additional benefit of the PE-Xa pipes is that they are not embedded in sand; dry sand for instance is a poor thermal bed when it comes to horizontal collectors due to its low heat conductivity. With PE-Xa pipes the original soil material that usually shows a better conductivity can be used for embedding – apart from the higher energy efficiency this saves costs.

Quick & Easy

Uponor PE-Xa pipes (high pressure cross-linked after the Engel method) feature a thermal memory, the so-called memory effect. This results in an outstanding resetting ability which we use for the Quick & Easy connection technique. If an Uponor PE-Xa pipe is expanded with a suitable tool, it will go back to its original shape within a short period of time. With this connection the pipe material becomes a sealing material. It connects force-fit and form-fit with the Quick & Easy Fitting. a 100 % secure connection of fitting pipe is ensured without O-rings.

First a retaining ring is pushed onto the pipe end in order to then expand it together with the retaining ring. To do this a hydraulic manipulator and expander heads for different Uponor PE-Xa pipe types and dimensions are used.

Before the pipe end tries to go back to its original shape the Uponor Quick & Easy Fitting is inserted. Already after a few seconds the pipe shrinks to its original size and an absolutely secure and tight connection results. Depending on the working temperature often shortly after completion of the installation work, a leak test can be carried out.

For ground energy applications the Uponor Quick & Easy range of fittings made of PPSU is available. The high-performance plastic polyphenyl sulfone (PPSU) stands out with high mechanical strength and resistance to temperature.

Pushing on the retaining ring

Expanding the pie end

Pushing the pipe on the fitting nipple

Project planning

Project scheduling

Project implementation

The planning tasks in the field of ground energy can be split into two areas: The ground energy planning (TBA planning) and the TGA planning.

The TBA planning covers the ground energy system while the TGA planning covers the technical building installations/building services.

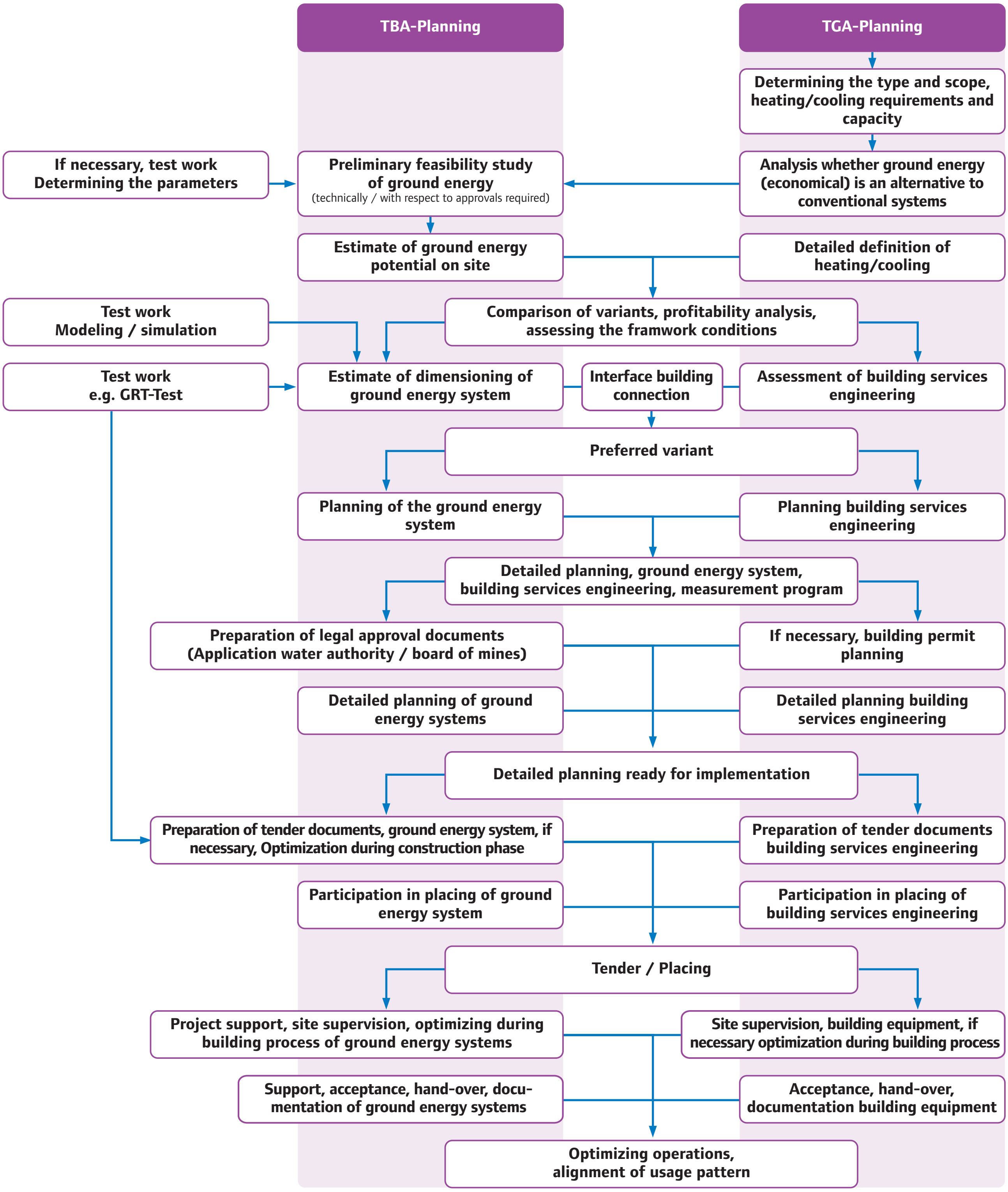
Below the planning process including contents and assignment of tasks for ground energy system planning and for planning of the technical building installations is shown to provide an overview of the necessary tasks and to provide the engineer with an instrument for the implementation sequence of these tasks. In addition this schedule is to facilitate the communication between client and the different specialist engineers and monitoring of task completion.

Planning steps

1. Defining the basics
2. Preliminary planning
3. Design engineering
4. Approval planning
5. Implementation planning
6. Preparing the placing
7. Cooperation in the placing process
8. Site supervision
9. Object maintenance, documentation

Planning schedule. Source: Manja Gust, HGN Hydrologie GmbH, Niederlassung Magdeburg, 2008

Contents / task assignment



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.

Concept and planning | Design | Construction | Buildings in use

simply more

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