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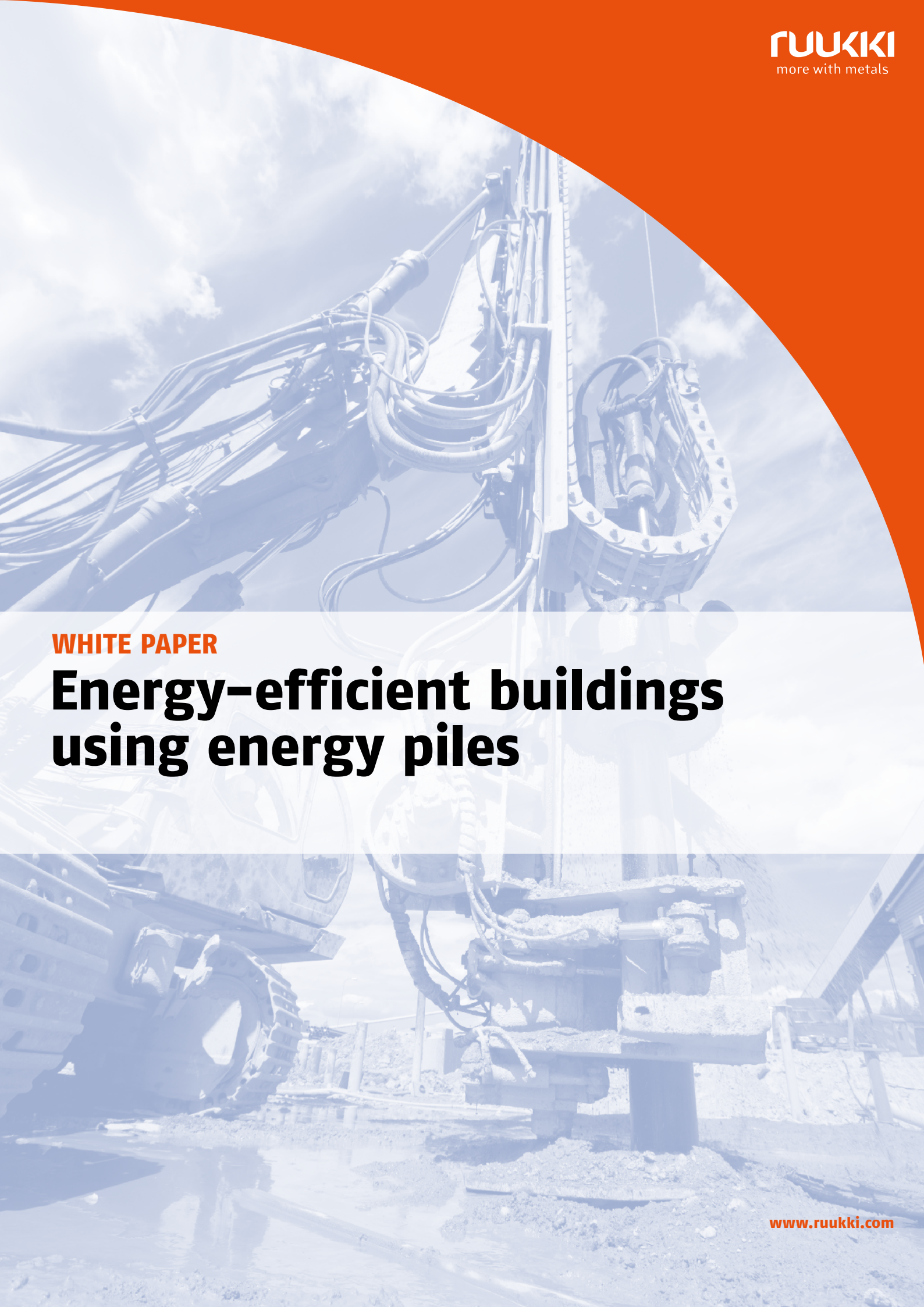


WHITE PAPER

Energy-efficient buildings using energy piles

www.ruukki.com

Ruukki's energy piles combine the foundations of a building with the collection of ground source heat. Energy piles are particularly suitable for offices, hotels and both single-storey and multi-storey commercial buildings that require both heating and cooling depending on the time of year. Energy piles can be used for all buildings whose foundations are based on piles.

The suitability of energy piles for different types of buildings has been assessed by means of analyses, tests and simulations. For example, energy piles can satisfy 71 percent of the heating needs of single-storey commercial buildings in the form of free heat, as well as up to 100 percent of the cooling needs.

The energy pile solution utilises renewable local energy. This improves the environmental efficiency of the property throughout the entire lifespan of the building. In addition to the fact that environmental certification systems take into consideration renewable energy systems in their scoring, they are also important for the users of the building. Environmentally efficient buildings have significantly higher occupancy rates than other buildings in which environmental efficiency has not been prioritised.

Compared with traditional district heating and compressor solutions, the energy pile solution offers 32 percent lower costs over a period of 25 years, including investment and energy costs.

Compared with traditional heating and cooling solutions, the investment in a ground source heat solution based on steel piles can be recovered in just 5 to 8 years depending on conditions and alternative forms of heating.

Energy from the ground using steel piles by Ruukki

Ruukki's steel piles can be used as energy piles to gather heat from the ground and bedrock, and they can be used for both heating and cooling buildings. Both eRD steel piles that are installed by drilling and eRR driven piles can be used as energy piles. The use of energy piles promotes the use of renewable energy sources and can cut energy costs over the long term while looking after the environment. The total potential of energy piles depends on the ground conditions, the number and length of the piles used, and the design of the building.

Steel piles are used for the foundations of a wide range of buildings and structures, such as houses, multi-storey buildings, industrial facilities, transport corridors and bridges. The ground conditions determine whether drilled or driven piles are used. Ruukki's energy piles combine the foundations of a building with the collection of ground source heat. Energy piles are particularly suitable for offices, hotels and both single-storey and multi-storey commercial buildings that require both heating and cooling depending on the time of year. In summertime the heat generated by cooling is returned to the ground, which keeps the temperature level of the ground at an optimal level for energy production and prevents the ground from freezing.

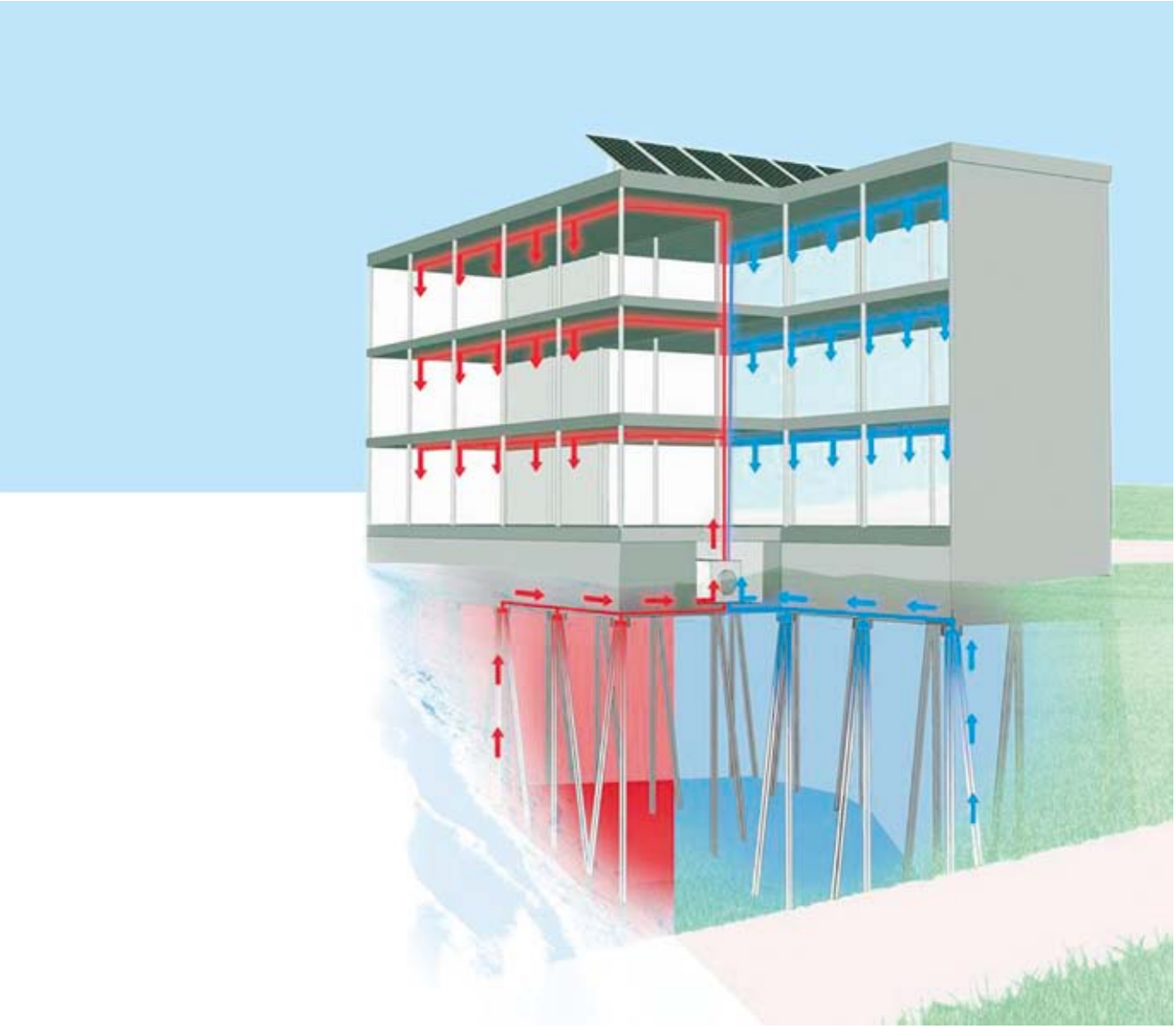
Steel piles should generally be used to gather ground source heat whenever the piling depth is approximately 15 metres or more. Shorter piles can also be used in so-called hybrid solutions, in which both steel piles and thermal wells (heat sinks) are used to gather the ground source heat. Compared with traditional ground source heat collection based on thermal wells, a higher number of energy piles are needed. Nevertheless, using steel piles is still economically viable as separate thermal wells are generally not needed with energy piles. In traditional ground source energy solutions, one third of the costs are generated specifically from building the thermal wells.

What is ground source heat and how is it gathered?

Heating and cooling solutions based on ground source (geothermal) heat utilise free energy. Compared with direct electric heating or district heating, ground source heat is energy that is produced locally, underneath the property, and therefore does not need to be transferred over long distances.

Ground source heat is solar and geothermal energy that is stored in the ground. Traditionally, heat is collected from the ground using either horizontal pipes that are installed approximately 1 metre beneath the surface of pipes that are installed in holes drilled in the bedrock. Thermal wells that are drilled into the bedrock are typically around 14 centimetres wide and 200 metres deep. If the bedrock is covered by loose soil, protective piping is used for this portion. In both solutions the pipes carry a mix of water and antifreeze, usually alcohol or potassium formate.

Ground source heat can be used in both large buildings and individual houses. A heat pump is used to convert the energy into heat. Heat pumps mechanically evaporate and condense the circulating heat exchange fluid (refrigerant). Vaporisation requires heat, which is extracted from the ground. Vaporisation takes place in the heat pump's evaporator. The resulting steam is compressed at



high pressure, which makes it heat up. The high pressure hot steam is cooled in the condenser, where it liquefies. The heat that is released heats up the water or air flowing through the condenser. The heated air or water is then fed into the heating system.

A properly designed and installed heat pump operates reliably and with a high temperature coefficient. The efficiency of the heat pump is measured by a thermal coefficient, which is the ratio of heating power to the amount of electrical power required. For example, a thermal coefficient of 3 means that 3 kW of heating power is generated for each 1 kW of electrical power.

In ground heat solutions, low temperature heat distribution methods should be favoured. The optimal heat distribution methods for heat pumps are floor heating and various systems based on heat radiation panels. Similarly for cooling solutions, high temperature systems covering large areas are recommended.

For cost reasons, heating systems based on ground source heat should not be specified to cover the maximum temporary needs of the building. In order to keep the investment viable, a secondary source of energy should be included to cover peak heating needs. For example, electric heating can be used for the peak heating needs during cold winters.

Part of the year, mostly in the spring, mechanical compressor refrigeration can be replaced by a free-flow solution. The lower temperatures of the liquid from the ground can be utilised as is without having to use a compressor that runs on electricity. In the summer the condenser heat generated from refrigerating can be directed back to the ground, which improves the ground's energy balance throughout the year. Also in summer, the cold energy from the ground can be utilised, for example to pre-cool the ventilation. This option is particularly practical for apartment buildings that do not have separate air-conditioning equipment.

How are the piles used to collect energy?

The type of steel pile is always selected according to the foundation conditions, after which the most suitable heat collection system is selected according to the type of pile. Ground source heat collector pipes are installed inside the hollow steel piles. The piles are then concreted so that the ground source energy can be transferred efficiently to the heat transfer fluid inside the pipes. When the fluid passes through the lowest point of the pile its temperature changes, warming up in winter and cooling down in summer. The process then continues in the ground source heat pump in the same way as in traditional thermal well solutions.

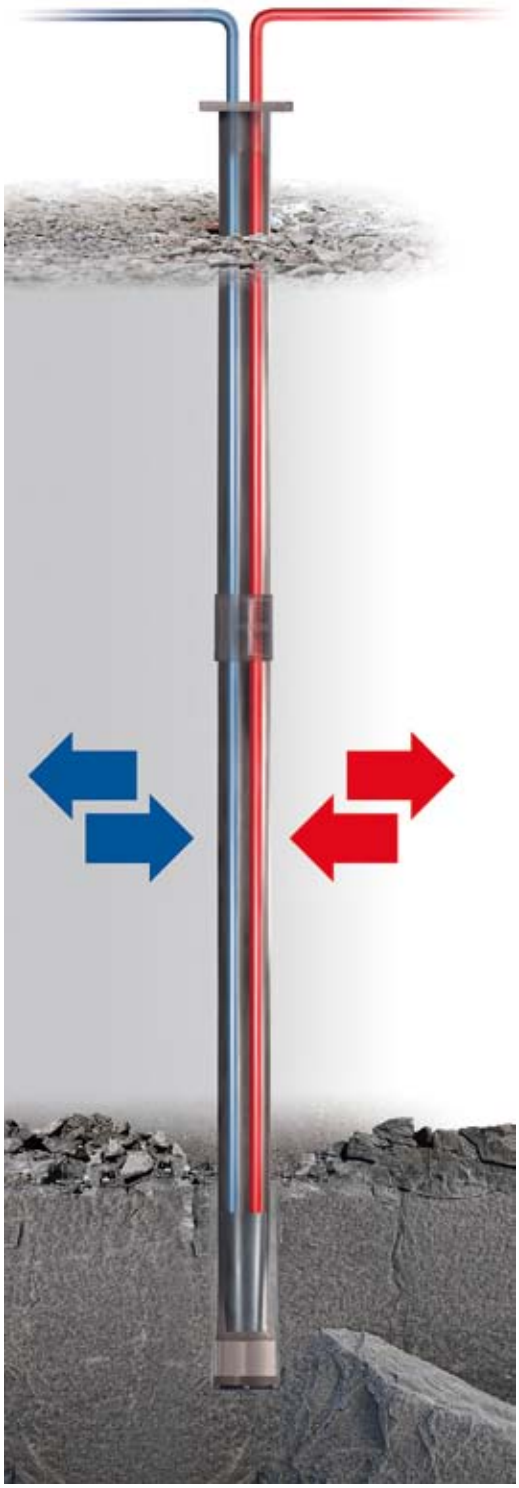
Energy piles can also be utilised in hybrid solutions, in which part of the energy is collected from the steel piles and part from traditional thermal wells drilled in the bedrock. When using Ruukki's eRD drilled steel piles, a bedrock thermal well with a dimension smaller than the pile can be drilled as an extension to the pile. This eliminates the need to use separate protective piping for the soil layer.

Energy pile and thermal well solutions are always individually designed. In principle, the following alternatives are available:

- Steel piles are used to collect ground source energy
- Steel piles are used together with bedrock thermal wells (hybrid solution)
- Energy is collected from bedrock thermal wells, but steel piles are used as protective piping for the soil layer above the bedrock.

The choice depends on the type of parallel energy sources that are available and how much of the total energy can be collected by the piles. The design of the building and number of floors also influences the decision. For example, low buildings have a relatively higher number of piles available in proportion to the space in the building. Costs can be compared on a lifespan basis.

In order to effectively utilise energy piles, the heating and cooling solutions of the building must be designed to be compatible with ground source energy.

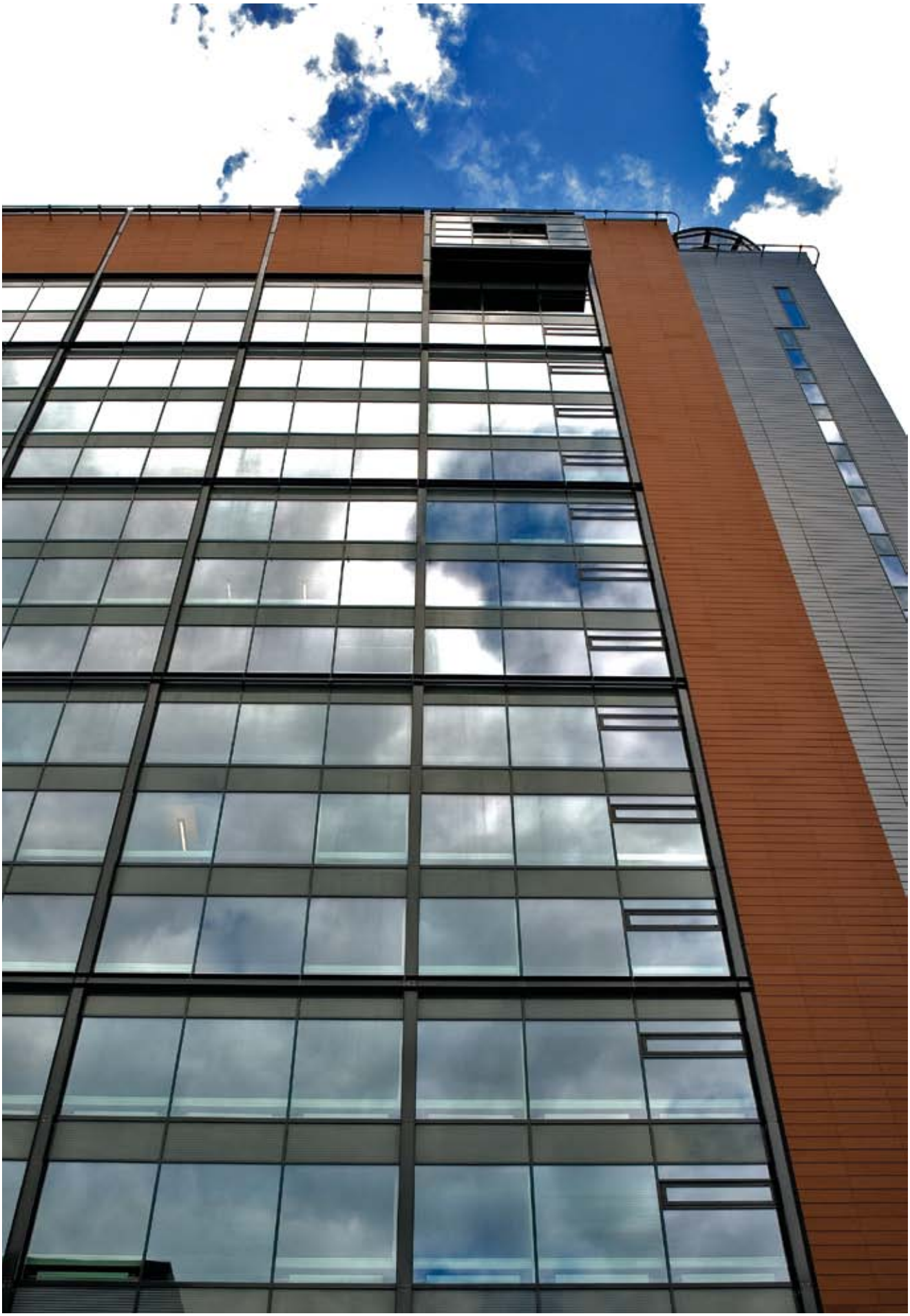


Saving energy and the environment

The energy pile solution reduces energy consumption and generates savings in building operating costs. Piles can be used together with several parallel energy sources, so the source of heating energy can be adjusted according to market prices. This means that even if a parallel energy source has to be changed, energy piles will also function together with the new energy source. When energy piles are used to cool buildings, they serve as a free energy source, eliminating the need to pay for connecting to the district cooling network.

Compared with traditional heating and cooling solutions, the investment in a ground source heat solution based on steel piles can be recovered in just 5 to 8 years depending on conditions and alternative forms of heating.

Piles utilise renewable energy that improves the environmental efficiency of the property. Locally produced energy supports both environmentally friendly construction and the use of environmentally friendly buildings throughout their entire lifespan. This is why most environmental certification systems take into consideration renewable energy systems in their scoring. The use of renewable energy is also increasingly important for the users of the building. According to research carried out in the USA, environmentally efficient buildings have significantly higher occupancy rates than other buildings in which environmental efficiency has not been prioritised.



Examples of energy pile applications

According to a study of energy piles, they were shown to be extremely suitable for utilising renewable energy. Their suitability was assessed in properties for which modelled heating and cooling energy profiles were available. The evaluation was conducted by means of simulations.

The results for a single-storey commercial building and a three-storey office building are presented here as examples.

1-storey commercial building

A hardware store was chosen to represent a typical one-storey commercial building. The heat insulation level of the building meets the regulations for 2010, and the ventilation system has an adequate level of heat recovery. The building has water-circulation floor heating and cooling.

- Total area = 8400 m²
- 264 energy piles, depth = 20 m
- Thermal conductivity of the ground = 1.1 W/m,K
- Heating energy demand = 34 kWh/m²,a
- Cooling energy demand = 10.4 kWh/m²,a
- Floor heating and cooling

The energy pile solution covers 71 percent of the heating energy demand and 100 percent of the cooling energy demand as free energy.

If the building required more cooling energy, the condenser heat from the cooling equipment could be stored efficiently in the ground using the energy piles. The favourable heating-cooling ratio could be utilised most by food shops that use a lot of refrigeration equipment, such as supermarkets.

3-storey office building

The heat insulation level of the small three-storey office building that was chosen for this study meets the regulations for 2010, and the heat recovery level is typical of office buildings. A relatively high amount of energy is required for cooling the building.

- Total area = 2700 m²
- 30 energy piles, depth = 15 m
- Thermal conductivity of the ground = 1.6 W/m,K
- Heating energy demand = 54 kWh/m²,a
- Cooling energy demand = 53 kWh/m²,a
- Radiation panel heating and cooling

The free ground source heat energy collected from the pipes accounted for 58 percent of the annual heating energy. The ground source heat system utilises the energy from the piles and requires electricity from the grid to operate. The ground source heat system covers almost 80 percent of the buildings total heating energy needs, and the remaining 20 percent is covered by district heating.

Ground source cooling covers 88 percent of the cooling energy demand as free energy. The high level of cooling energy is achieved primarily due to the free-flow technique. Compressor cooling is required only to cover peaks during hot weather.

According to a 25-year lifespan analysis of the property, the costs of the traditional district heat and compressor cooling solution amounted to 513,000 euros, whereas the comparable costs of the energy pile solution amounted to 348,000 euros. This comparison includes investment and energy costs for both solutions.

The carbon footprint of the energy pile system (t. CO_2 eq.) over the 25-year period was just 40 percent that of the district heating solution when the unused district heating effect of the electricity production method is not taken into account.

Further information

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