Case Study summary

IEA-ECBCS Annex 48

Heat Pumping and Reversible Air Conditioning

Italy Case Study N°3: Office / industrial building with GSHP with phase-change hot and cold storage

1859-2009

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Introduction

The case study examines a recently completed 8805 m^2 office /industrial building, owned by a private company, located in NW Italy 25 km SE of Torino. The building has a concrete frame structure, ventilated facades, high performance windows, and a green roof.

Two water-to-water reversible heat pumps (94 kW heating and 137 kW cooling each) provide hot water for winter AC and chilled water + hot water from the HP condenser for summer AC. The winter heat source / summer heat sink is a geothermal field consisting of 32 borehole (vertical) single pipe heat exchangers, 100 m deep

Summary

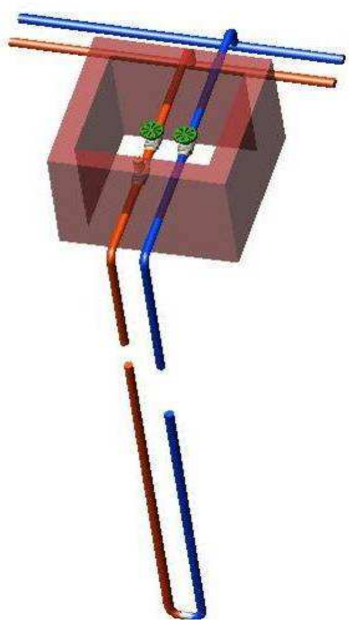
- Location: Chieri, Torino, Italy
- Building sector: office and industrial buildings
- Gross net area: 8805 m²
- Heat pumps nominal cooling capacity: 274 kW
- Heat pumps nominal heating capacity: 188 kW
- U-value external walls: 0.50 W/(m²K)
- U-value windows: 2.6 W/(m²K)

Background

The system guarantees environmental comfort during the whole year in a glazed building of about 8000 squared meters; Basically it’s a geothermal technology that draws energy from the ground throw heat pump during winter, and to release it in the ground during summer. This allows a complete thermal cycle that does not thermally dry up the ground itself. Energy not captured/released from/to the ground is provided electrically. Chilled beams with primary air produced by an air treatment unit and a “four tubes” hydraulic net have been used in order to guarantee environmental comfort.

General concepts

The building is provided with an air–water HVAC system. In the AHU an air-to-air heat exchanger recovers energy from exhaust air. The water system is equipped with variable flow water pumps, fan-coils in the storage and service areas, and chilled beams in the offices. Hot and chilled water are produced by two reversible ground-source heat pumps (GSHP), with bore hole heat exchangers.
In order to reduce the installed heating and cooling power – and consequently to limit the system initial cost, including the cost of the borehole field – it was decided to equip the system with two (hot and cold) phase-changing storage (PCS) vessels.



Schematic view of an underground vertical probe

Technical data of the system:

Heat pumps:

- Water to water
- Cooling power: 137 kW
- Heating power: 94 kW

Phase change storage tanks:

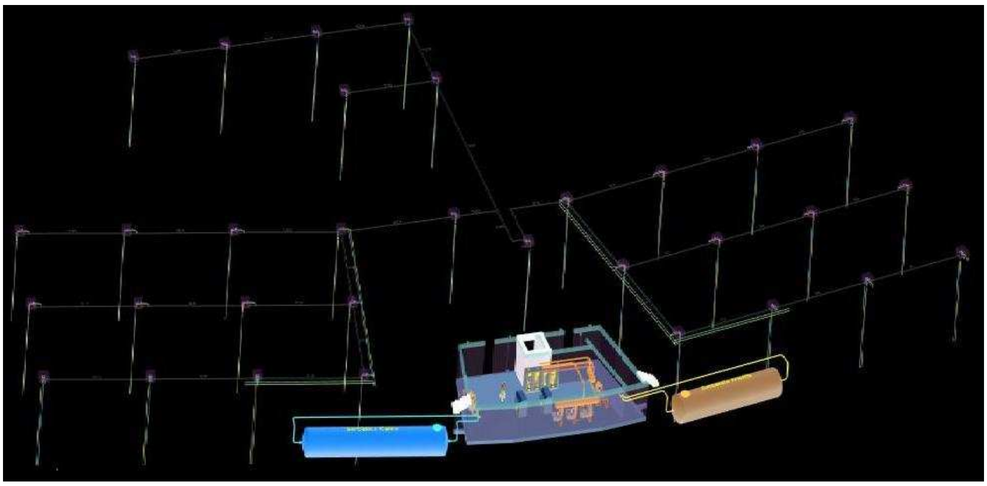
- Heating capacity: 900 kWh
- Cooling capacity: 990 kWh

Advantages

- Almost constant system COP
- Free-cooling with geo-thermal water possible
- Minimizing running cost by appropriate peak/off-peak el. energy contracts

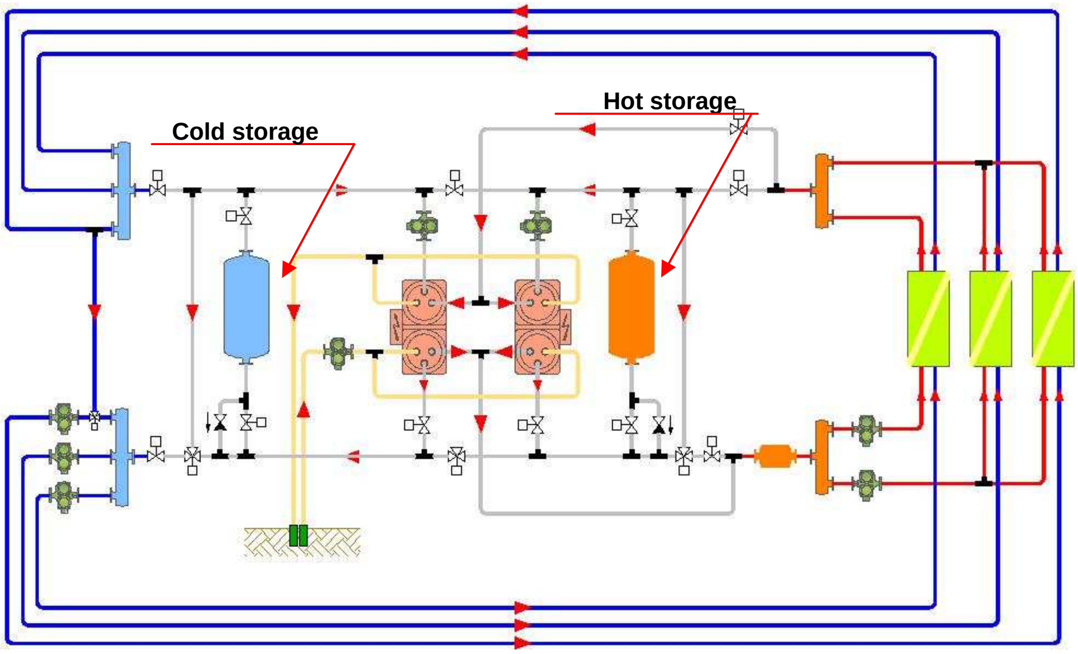
Drawbacks

- Requires large boreholes field
- Requires heat storage vessels
- Higher installation cost than conventional HVAC system



View of the underground boreholes field with the heating/cooling plant and the phase change storage tanks

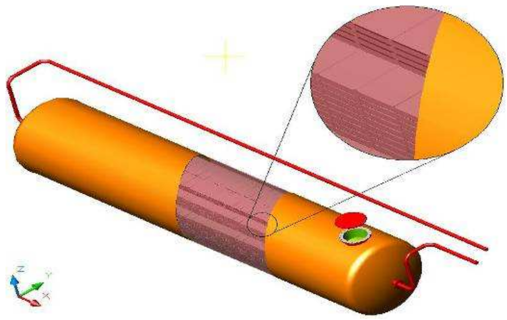
Drilling the boreholes



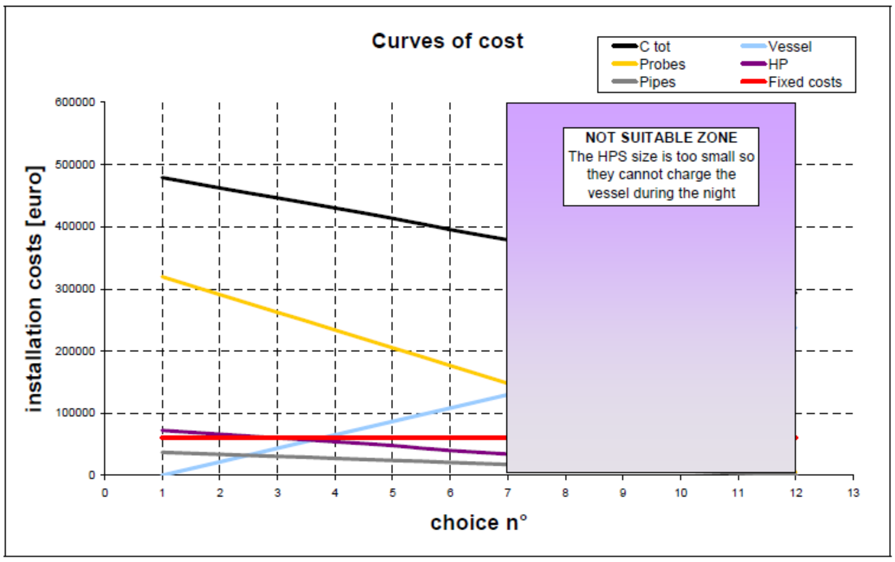
Scheme of the HVAC system

Phase change storage tanks

The economically optimal design of the GSHP system with PCS was based on the cost comparison of a set of 12 combinations of system sizing choices, in which the same total thermal output is covered by different mixes of the three available thermal sources, the two HPs (assumed of equal size) and the PCS. The analysis shows that the optimal solution considers the minimum borehole field size and the maximum storage volume compatible with the possibility of night-time recharging. The thermal capacity of the hot storage is 950 kWh: the average thermal extraction rate is then 95 kW in 10 hrs, with a maximum value of 200 kW in 4.5 hrs. The thermal capacity of the cold storage is 750 kWh: the average thermal extraction rate is then 75 kW in 10 hrs, with a maximum value of 190 kW in 4 hrs.

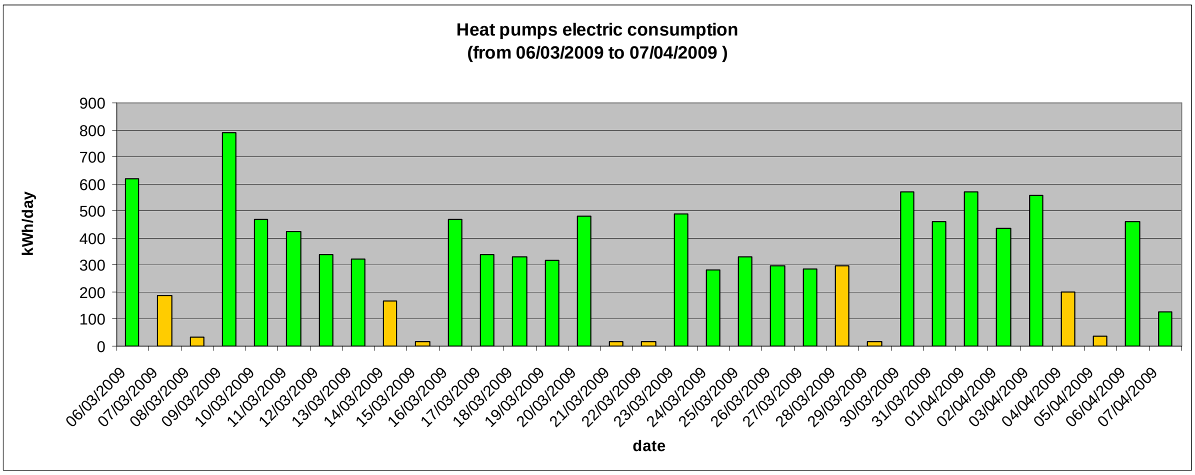


Schematic view of the hot phase change storage tank



Curves of cost for winter season; the cost of each of the twelve solutions was split into five components (Boreholes, Vessels, Fixed costs, Heat pumps, Piping)

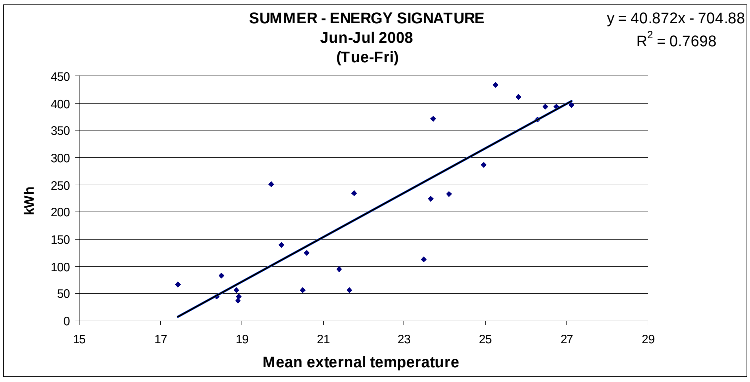
Internal view of the phase change storage tank, the phase change panels are clearly shown



Electric energy consumption of Heat pumps

Monitoring Results

Data collected show low specific consumption during heating and cooling season. In middle season the system was able to operate automatically in free-cooling mode, saving important amounts of electrical energy. For a period the system worked without using the thermal storage vessels; this fact determined an increase of the actual running costs, due to electrical energy peak demand, with respect to the simulation forecasts.



Conclusion

Underground heat is a reliable source for heating/cooling necessity for a water-to-water heat pump. Boreholes perforation account for almost half of the total HVAC system installation cost. The low consumption of the system permits a payback period of 4-10 years in most of new installation. The complexity of this system, nevertheless, need a long period of system calibration, to achieve the maximum efficiency.

Date of case study summary: April 2009

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Literature

IEA-ECBCS Annex 48 website: http://www.ecbcs-48.org

Article: M.Masoero, C.Silvi, G.Pellegrini, Energy Conservation in Buildings: Design and Monitoring of an Office Building with GSHP and Phase-Change Thermal Storage System, Climamed 2009, Lisboa 16-18 April 2009.

IEA-ECBCS Annex 48

IEA-ECBCS Annex 48 is a research project on reversible air conditioning systems in the tertiary sector. The project is accomplished in Energy Conservation in Buildings and Community Systems Program of the International Energy Agency (IEA).

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