HEAT PUMP FOR DISTRICT COOLING AND HEATING AT OSLO AIRPORT, GARDERMOEN

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ABSTRACT

At Gardermoen, one of the largest groundwater reservoirs in Norway is located. This aquifer is used for both heating and cooling of Gardermoen Airport. In the summer, ground water is pumped from cold wells and used for cooling before it is returned to the warm wells. In winter, this process is turned around, as ground water from the warm wells is used as heat source for the heat pump.

The heat pump is mainly designed for cooling, and the design cooling demand is 9 MW. The district cooling water is pre-cooled by the ground water, and post cooled by the combined heat pump/refrigeration plant. The base heat load is covered by the heat pump. Additional heat is supplied from a heat energy central with biofuels as well as oil heated and electrically heated boilers.

During the last years, heat production from the heat pump was about 11 GWh/year, and the heat pump also provides about 8 GWh/year of the cooling demand. In addition, approximately 3 GWh/year cold is produced by direct heat exchange with ground water. Compared with a district heating system heated by fossil fuels, and a conventional refrigeration system for district cooling, the pay back period for the aquifer heat pump system is within a couple of years.

Key Words: ***heat pumps, district cooling, district heating, aquifer thermal energy systems (ATES).***

1 INTRODUCTION

Oslo Airport Gardermoen was opened in 1998. The total building floor area is 180 000 m^2, and the buildings are equipped with large glass walls. This means large cooling demands in summer as well as large heating demands in winter.

The airport is located on one of the largest groundwater reservoirs in Norway. This aquifer is used for both heating and cooling of Gardermoen Airport.

This poster gives a short general view of different ground source heat pump systems for heating and cooling, and presents the aquifer thermal energy system (ATES) at Oslo Airport Gardermoen.

2 SURVEY OF GROUND SOURCE HEAT PUMPS FOR HEATING AND COOLING

The ground can be used as a cold and heat source in two different ways: Either directly by pumping ground water to be used as cold distribution water or heat source for heat pumps, or indirectly be pumping a brine through tubes in boreholes in rock in a closed loop between the boreholes and the building.

2.1 Borehole Systems

Most of the ground source heat pumps are borehole based heat pumps. In most cases, they have been used for heating only purposes. When heat is extracted from the boreholes, the temperature will decrease, and the number and depth of boreholes must be designed so that the brine temperature will not be too low. The brine is, however, suitable for cooling purposes, and the cooling load removed from the building is stored in the rock surrounding the boreholes. When the borehole system is used for both heating and cooling purposes, the size of the borehole system may be decreased considerably.

Figure 1 shows how the cold distribution system may be connected to the borehole system. If the cold distribution system is designed for high cooling water temperatures, the borehole system may cover the total cooling demand of the building. If there are small cooling demands in the building, exhaust air past the ventilation air-to-air heat exchanger may also be used to charge the ground with heat.

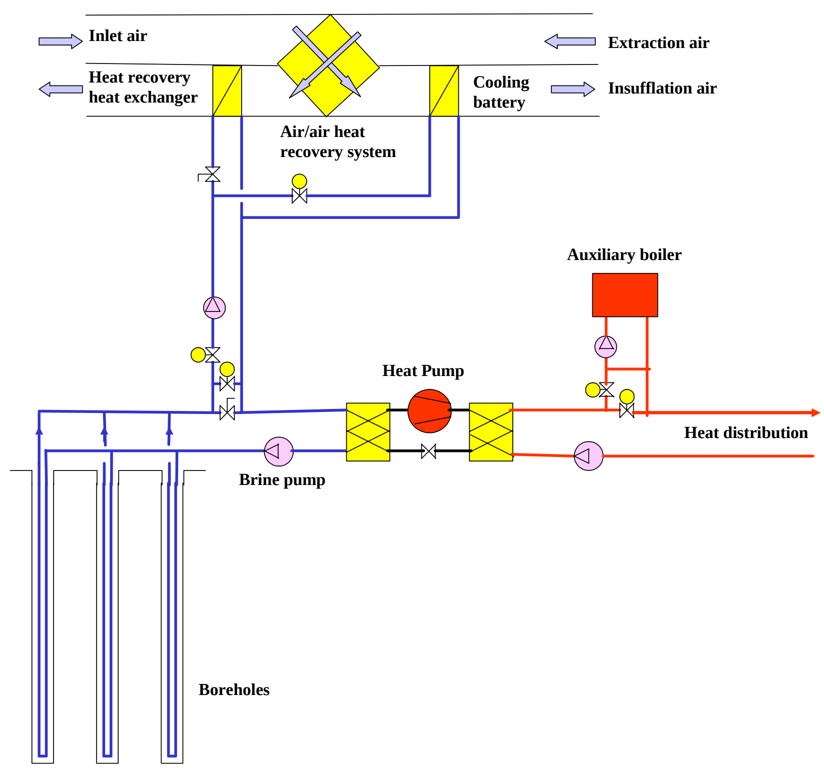

Fig. 1. Ground coupled heat pump with cooling from borehole system.

Borehole thermal energy storage systems are easy to construct, simple to operate and need very little maintenance. The borehole system is the most expensive part of the heat pump system, and their payback times are quite long.

2.2 Groundwater Systems

If ground water is available in sufficient amounts and with a satisfactory quality, it is a very good cold source, as well as a heat source for heat pumps. Compared with other heat sources, it will give us a good and cheap heat pump solution.

Most of the ground water sources in Norway are fluvial deposits with continuous water feed from rivers and lakes etc., and these sources may be used for both cooling only and heating only purposes, as well as for combined cooling and heating purposes.

A ground water based heat pump for both cooling and heating is normally built with a closed brine circuit between the ground water system and the heat pump, Fig. 2. A mixture of ethanol or ethylene glycol and water is used as brine for heat pump systems.

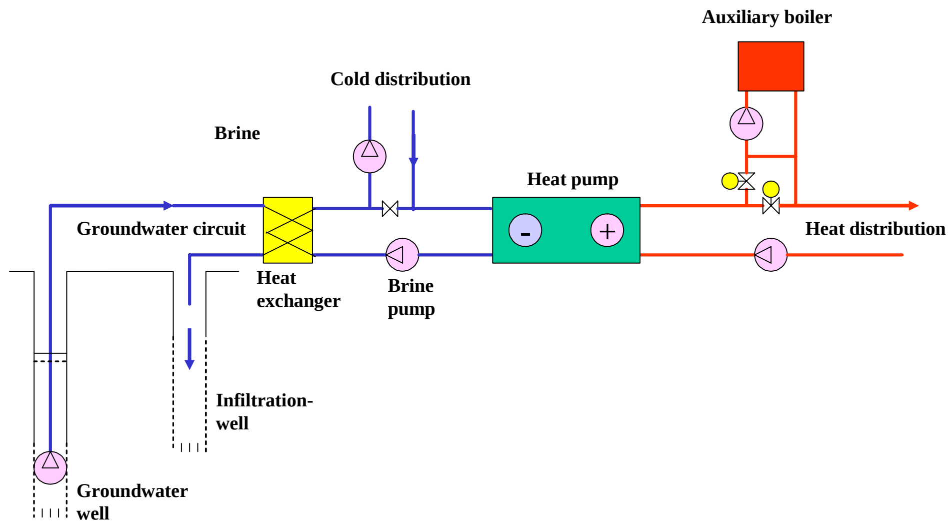

Fig. 2. Ground water based heat pump for both heating and cooling.

Aquifers are established as glaciofluvial deposits with a layer of sand and gravel in a hollow tray of clay or rock. The feed water of the aquifer is primarily rainfall, and therefore, in order to gain thermal balance of the system, heat which is stored into the system in summer must be extracted in wintertime. The heat pump system at Oslo Airport Gardermoen is an ATES system (aquifer thermal energy storage system).

There are, however, some obstacles in designing and building groundwater based heat pumps and cooling systems, as e.g. iron or calcium in the ground may result in clogging of the heat exchangers which have a detrimental effect for such systems. When the ground water is exposed to the air, formation of iron oxide occurs, acting as a powder which tightens heat exchangers and wells etc. It is therefore important to undertake water analysis before establishing a ground water based cooling and/or heat pump system (Lindblad-Påsse).

Groundwater systems need a lot of maintenance, but the investments are normally small compared with borehole systems, and payback times are normally very short.

2.3 Soil Cool

A considerable part of the energy consumption in Europe goes to run mechanical cooling systems. In order to reduce the energy consumption and CO_2 emissions related to cooling, the EU Commission and Nordic Energy Research were in 2003 – 2004 funding a project on underground cold storage systems – “Soil Cool”.

The purpose of the project was the task of sharing, expanding, exploiting and disseminating knowledge within design and optimization of underground cold storages. The project was building on top of experience gathered through several years of IEA work on heat pumps and cold storage. Six countries were participating in the project, with COWI in Denmark as the project manager:

- Denmark (COWI)
- Sweden (Lund Tekniske Högskola)
- Lithauen (Vilnius University)
- Finland (VTT Building and Transport)
- Germany (SWT Stuttgart)
- Norway (COWI and Hjellnes Cowi)

As a part of the work, a number of cases of ground source cooling were presented. The ATES system at Oslo Airport, Gardermoen was presented as the Norwegian country case

3 DESCRIPTION OF THE HEAT PUMP SYSTEM AT OSLO AIRPORT, GARDERMOEN

At Gardermoen, one of the largest groundwater reservoirs in Norway is located. The area consists of glaciofluvial deposits. The soil structure in the area consists of different layers of clay, sand and gravel. The depth to the ground water is 13-14 m, and the storage is located at approximately 20-45 m below surface level.

This aquifer is used for both heating and cooling of Gardermoen Airport. The ground water system consists of 18 wells, 9 ”warm” and 9 ”cold” wells, each with a diameter of 450 mm that were drilled down to 45 m depth. Each well is supplied with its own ground water pump and its own injection tube. The wells are connected to the heat pump/refrigeration system as shown in Fig. 3.

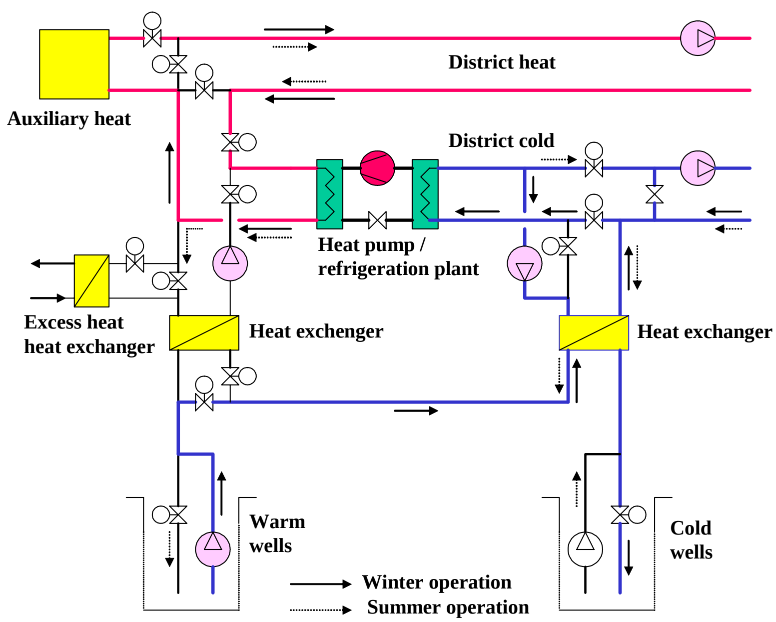

Fig. 3. Ground water based heat pump system for both heating and cooling.

In the summer, ground water is pumped from cold wells and used for cooling before it is returned to the warm wells. In winter, this process is turned around as ground water from the warm wells is used as heat source for a heat pump before it is drained to the cold wells.

The design cooling demand is 9 MW. The district cooling water is pre-cooled by the ground water with a cooling capacity of 3 MW, and post cooled by the combined heat pump/refrigeration plant with a cooling capacity of 6 MW.

The design heat demand for space heating is 18 MW (Grønnesby). The base heat load is covered by the heat pump. Additional heat is supplied from a heat energy central with four oil heated boilers and one electrically heated boiler. In addition, the district heating plant of Gardermoen Fjernvarme with biofuels as the primary energy source is connected to the plant. In this way, Gardermoen Airport has got an environmental friendly and flexible energy system.

The heat pump is mainly designed for cooling purposes, but it can also cover heating demands up to 50ºC temperature level. Ammonia was chosen as the working fluid for the heat pump because it is a natural fluid and thereby environmental friendly for the global environment, but also because it is an excellent working fluid. However, since ammonia is poisonous, the energy plant was built in a separate building at approximately 1 km distance from the terminal building for safety reasons.

The heat and cold from the energy central is transported through insulated district heat and cooling pipelines to the terminal building and to other operational buildings as well as a hotel and a conference centre at Gardermoen Airport. In addition, heat is also used for snow melting at airplane setback areas. The heat is distributed as low temperature heat, e.g. through 40 000 m^2 floor heating system, and most of the floor heating systems are also used for cooling in summer.

3.1 Design Data

District heating:

Design heat demand without snow:	18 MW
Design heat demand with snow:	22 MW
Design forward/return temperature – district heat:	70/40ºC
Estimated heat energy consumption:	32 500 MWh/year

District cooling:

Design cooling demand:	9 MW
Design forward/return temperature – central plant:	7/17ºC
Design forward/return temperature – local plant:	9/19ºC
Estimated cold energy consumption:	5 000 MWh/year

Heat pump:

Working fluid:			NH_3
Cooling capacity – summer:	6 000 kW	– winter (part load):	3 900 kW
Heating capacity – summer:	7 500 kW	– winter (part load):	4 800 kW
Evaporating temp. – summer:	5ºC	– winter:	1ºC
Condensing temp. – summer:	44ºC	– winter:	48ºC

Ground water wells:	9 warm and 9 cold wells
Depth:	45 – 50 m
Diameter – borehole:	450 mm
Diameter – filter tube:	250 mm

Warm wells water temperatures – in/out in summer: 30/20ºC – out in winter: 4.5ºC
Cold wells water temperatures – out in summer: ≈ 4.5ºC – in during winter: ≈ 4.1ºC
Location: Cold wells are located approximately 150 m east of warm wells

4 OPERATIONAL EXPERIENCES

The groundwater based district heating and cooling plant has been in operation since the airport was opened in 1998. There have been some problems connected to clogging in the groundwater wells. There are no problems connected to pumping the water out of the wells, but in some cases, it has been difficult to press the water back into the infiltration wells. During 2004, six of the nine wells were in operation on both the cold and the warm side. Each well was operated with maximum 20 – 25 m^3/h ground water capacity, while the design groundwater circulation was 30 m^3/h. This means approximately 50% reduction of the cooling capacity. Therefore, Gardermoen Airport has to carry out a cleaning process for the ground water wells at a few years interval, and the ground water heat exchangers are cleaned every second year.

Figure 4 shows the effect-duration curves for the heating and cooling plants at Oslo Airport, Gardermoen.

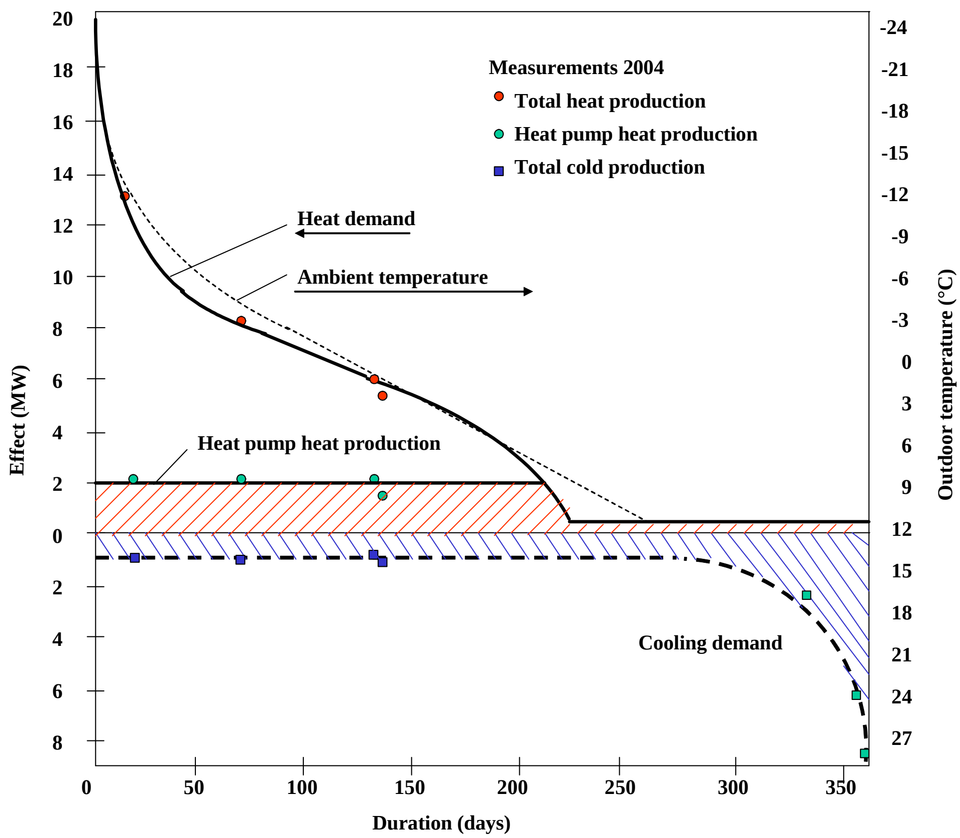

Fig. 4. Effect-duration curves for heating and cooling demands.

4.1 Economy of ATES System

Table 1 shows the heat and cold production as well as the energy consumption for the ATES system at Oslo Airport Gardermoen. The economy for the aquifer heat pump system is also presented in the table.

The maintenance costs of the ATES system is 2% annually of the total investment. The electricity price is on the average 10 c/kWh, and the price for district heat for supplementary heating as well as for alternative heating is set to 9 c/kWh.

Table 1. Technical end economical data for ATES at Oslo Airport Gardermoen compared with a traditional heating and cooling system

Plant		ATES	Conventional plant
Technical data			
Heat production from heat pump	(MWh/yr)	11 000	0
Heat production from heating plant	(MWh/yr)	27 000	38 000
Direct cooling from ATES	(MWh/yr)	3 000	0
Cold production from refrigeration plant	(MWh/yr)	8 000	11 000
Total energy production	(MWh/yr)	49 000	49 000
Energy consumption			
Electricity – heat pump/refrig. plant	(MWh/yr)	4 000	3 000
District heat and oil	(MWh/yr)	27 000	38 000
Total energy consumption	(MWh/yr)	31 000	41 000
Economical data			
Investments			
- Heat pumps / refrigeration systems	(USD)	950 000	1 300 000
- Aquifer system	(USD)	1 700 000	0
Total investments	(USD)	2 650 000	1 300 000
Annual costs			
Capital costs – heat pumps (a = 0.103)	(USD/yr)	97 850	133 900
– aquifer syst. (a = 0.073)	(USD/yr)	124 100	0
Maintenance (0.02 x Tot. investment/yr)	(USD/yr)	53 000	26 000
Energy costs – electricity (10 c/kWh)	(USD/yr)	400 000	300 000
– district heat (9 c/kWh)	(USD/yr)	2 439 000	3 420 000
Total annual costs	(USD/yr)	3 104 950	3 879 900
Total specific annual cost	(c/kWh)	6.3	7.9
Pay-back periode		2 years	

The heat pump cover approximately 70% of the total cooling demand at Gardermoen Airport, and most of it is produced when the heat pump is operating for heat production. The rest is covered by direct cooling from the ground water. The alternative cooling system is to design a mechanical refrigeration system to cover 100% of the cooling demand. A 9 MW air cooled refrigeration system with ammonia as the working fluid would cost approximately 1.3 mill. USD, i.e. the extra costs for the aquifer-based heat pump system is approximately 1.35 mill. USD.

REFERENCES

Annika Lindblad-Påsse: Järnutfällingsproblemer i grundvattenvärmesystem. Byggforskningsrådet – Rapport R 109: 1986

Roar Grønnesby: Oslo Lufthavn AS: Orientering om det termiske anlegget (Oslo Airport Gardermoen: Survey of the heating and cooling system)