

Aquifer Thermal Energy Storage in the Netherlands

Status beginning of 2005

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ABSTRACT

At the beginning of 2005, over 400 projects applying aquifer cold storage or a combination of cold storage and low temperature heat storage were operational in the Netherlands. The cooling capacity supplied through cold storage lies between 500 and 2000 kWt (140 – 570 Tons) in most projects, the largest realised project has a cooling capacity of 20,000 kWt (5,700 Tons). Some 45% of the projects concern large office buildings while the remainder are distributed over commercial buildings, hospitals, housing, industry and agriculture. Recently, an increasing number of projects are mixed use projects, combining retail space, offices, and housing.

1. HISTORY

In 1982 the SPEOS Aquifer Thermal Energy Storage (ATES) project was realized in Dorigny, Switzerland. This project was a high temperature pilot project in the framework of the IEA Storage Programme. Similar pilot projects were realised in Denmark (Hørsholm) and the USA (St. Paul - Minnesota) during the same period.

Although it was intended to fit the pilot projects into an energy supply system after the experimental phase, this did not occur in any of the projects due to serious operational problems. However, this also was the value of those pilot projects for the development of ATES: they made clear what the technical problems were that had to be solved before ATES could be applied on a commercial basis. For high temperature heat storage (storage temperature $>50^{\circ}\text{C}$ (122°F)) it particularly concerned:

- clogging of wells and heat exchangers due to fines and precipitation of minerals;
- water treatment to avoid operational problems resulting from the precipitation of minerals;
- corrosion of components in the groundwater system;
- automatic control of the groundwater system.

In the period 1985-1995 much research was done to solve the technical problems. This research was partially undertaken within national research programmes and partly within the framework of the IEA Storage Programme. The research has demonstrated that the technical problems encountered can be solved. Furthermore, it has made clear that the technical problems faced in cold storage and low temperature heat storage are much smaller than those met in high temperature heat storage (IEA 1995).

In the Netherlands, Aquifer Thermal Energy Storage started to be implemented in the early eighties. In first instance the objective was to store solar energy for space heating in winter. R&D activities and the first demonstration projects were financed within the framework of the National Research Programme on Solar Energy (Nationaal Onderzoek Programma Zonne-energie). The first demonstration projects concerned:

- the storage of solar heat for space heating some 100 residences (storage temperature 60°C (140°F)) (WIJSMAN 1983);
- the storage of solar heat for space heating in an office

building (storage temperature 30°C (86°F)) (VAN DER BRUGGEN et al. 1985);

- the storage of winter cold to cool a printing office (storage temperature 6°C (43°F)) (VAN HOVE et al. 1988).

An aquifer was not used for heat storage in the first project; instead vertical soil heat exchangers were used. Given the good experience with the first aquifer storage projects and the fact that in the Netherlands aquifers can be found almost everywhere, in particular the application of thermal energy storage in aquifers has been further developed in the Netherlands.

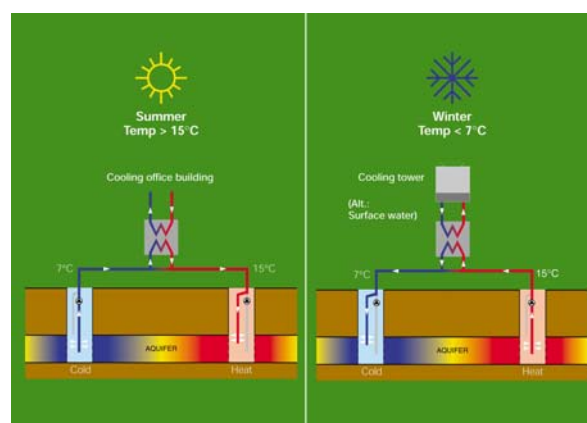


Figure 1. Principle of cold storage to cool an office building.

2. PRESENT STATUS IN THE NETHERLANDS

At the beginning of 2005, over 400 projects in which ATES is applied have been realised in the Netherlands; almost every major city has a number of projects in operation. The aim of most ATES projects is to store cold in winter for cooling in summer. In general, cooling is direct, that is to say without using a chiller. In most projects the cooling capacity supplied from storage lies between circa 500 kWt and 2000 kWt (140 – 570 Tons). This means that by applying cold storage these projects economise on a large chiller.

The heat released during cooling is stored in the aquifer also. If possible, the heat is used for heating during the winter season. This combination is called "Cold storage and low temperature heat storage". The largest ATES project in operation is for supplying cooling and low temperature heat to the buildings and laboratories on the campus of Eindhoven University. Both the cooling and heating capacity of the store are 20,000 kWt (5,700 Tons and 68MBtu/h respectively).

If the realised projects are categorized by application area, the situation is as shown in table 1. About 45% of the realised projects involve cooling and heating of office buildings. This generally concerns large office buildings that have air conditioning (floor area between 10,000 and 100,000 m^2 (100,000 – 1,000,000 ft^2) as well as groups of

office buildings. The remaining projects are distributed over various other application areas. The category “commercial buildings” concerns buildings with large numbers of visitors such as shopping malls, congress centres, exhibition halls, airport terminals and amusement parks. The common characteristic of these buildings is that cooling, heating and ventilation are for a significant part determined by the fact that there are many people present in the building at the same time.

| Application | Realized by the end of 2003 (% of projects) |
|--|---|
| Office buildings | 45 |
| Hospitals | 12 |
| Commercial buildings (malls, congress centres, etc.) | 14 |
| Housing area's | 5 |
| Industry | 13 |
| Agricultural applications | 11 |

Table 1. ATEs projects by application.

3. SYSTEM CONCEPTS

In the first projects, thermal energy storage was added to the building energy supply system as an additional “component”. Figure 1 shows a schematic of this concept. During the winter period the aquifer store is charged with cold by cooling groundwater through a cooling tower or surface water. The building is heated by means of a gas-fired boiler. During the summer period the building is cooled with the cold stored. Compression chillers are not applied. So, by using seasonal storage for cooling in summer with winter cold, a source of renewable energy is created.

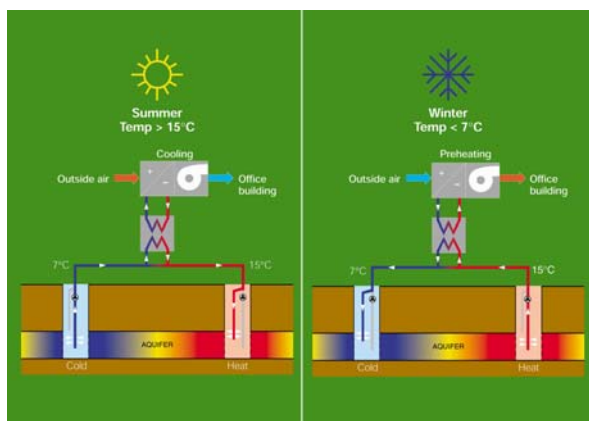


Figure 2. ATEs system integrated with building air conditioning system.

In Figure 2 an example is given of a system concept for a building in which the storage system is integrated into the air conditioning system. This concept is especially applicable for buildings in which cooling is entirely or almost entirely via ventilation air. The water/air heat exchangers in the air handling units are dimensioned in such a way that the required cooling load (air temperature and relative humidity) can be achieved with a relatively high supply water temperature. During the winter season the same water/air heat exchanger is used to pre-heat the ventilation air, using the low temperature heat stored. The

heat released in summer when cooling the ventilation air is stored and utilised in winter, while the cold groundwater created then is stored and used for cooling in summer. In this way, generally double the amount of energy is saved in comparison to the concept in Figure 1.

Figure 3 shows a system concept in which heating in winter is done by means of a heat pump. This heat pump uses groundwater as low temperature heat source so that the cold store is charged with cold. In summer the cold store provides for cooling. The heat released then is stored in the soil via the warm well, making it available for the next winter period. This concept is applied most frequently in office buildings.

In the first system concept (Figure 1) ambient cold is stored and used for cooling the office building. The system concepts shown in Figures 2 and 3 are characterised by the integration of cooling and heating.

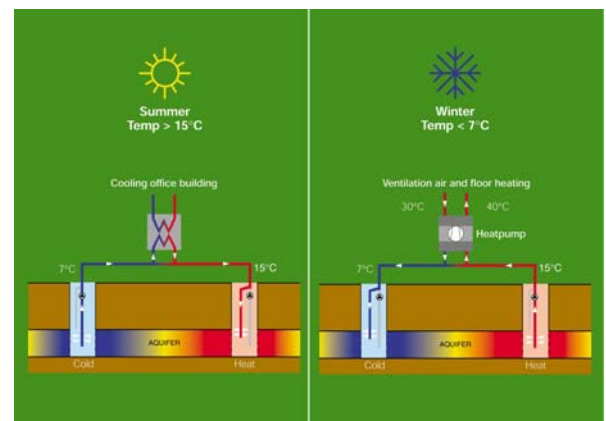


Figure 3. ATEs system integrated with building heat pump system.

4. ENERGY SAVING AND PROFITABILITY

To determine the energy saving by and the profitability of cold storage (and the combined cold and low temperature heat storage) it is important to establish a reference situation. In the application of cold storage for air conditioning in office buildings, cooling with chillers and heating with high efficiency gas-fired boilers is taken as reference situation. The energy saving that can be realised with a cold storage system according to the concept in Figure 1, amounts to some 75% of the electricity consumption required for cold generation using chillers. This implies that under the climatic conditions of the Netherlands some 150,000 kWh/year can be saved on electricity consumption for an office building with a cooling load of 1000 kWt (280 Tons). If low temperature heat can also be utilised (system concept according to figure 2), the saving on primary energy is approximately twice as large. The cold storage system for a building with a cooling load of 1000 kWt (280 Tons) generally consists of two wells: a cold well and a warm well, each with a groundwater flow rate of about 100 m³/h (450 Gpm).

The payback period of an aquifer cold storage system (whether or not combined with low temperature heat storage) for air conditioning in office buildings is favourable. The investment for the groundwater system amounts to 250 to 400 Euro per kW cooling capacity (excl. VAT). This sum includes all the investment required to realize the cold storage system, thus including for example the cost of the control unit, the permits required, etc. Given that chillers with appertaining provisions (e.g. grid connections and cooling towers) do not have to be

purchased, these investments are saved. Thus the *incremental investment* for an ATES system in comparison to the reference system with chillers is small. In some projects it has even appeared that the cold storage system requires a lower investment than the reference situation. The incremental investments for the ATES system should be earned back by the lower running cost, particularly due to lower energy consumption. In many cases, the application of cold storage for air conditioning office buildings proves profitable starting from a cooling load of about 500 kWt (140 Tons). Of course there must be a suitable aquifer at not too great a depth, that is not deeper than 100 m (330 ft) below surface. The payback period usually is under five years in such cases (BUI TENHUIS 1997).



Figure 4. “De Resident” offices, the Hague. ATES cooling (2,500 kWt (710 Tons)) according to system concept 1.

5. MARKET DEVELOPMENTS

That ATES has become a standard technology in the Netherlands does not only appear from the fact that about 50 projects are implemented each year. This situation is illustrated also by the recent developments on the market:

- various parties on the market, such as drilling companies and HVAC contractors, are offering turn-key ATES systems;
- standardised components and ATES systems are entering the market, e.g. for the integrated heat pump and ATES system;
- some utilities are offering their clients to supply cooling with ATES based district cooling systems, whereby the system is owned and managed by the utility.



Figure 5. IKEA store, Duiven. ATES cooling (600 kWt (170 Tons)) and low temperature heating according to system concept 2.



Figure 6. Mixed use project, Amsterdam. Heat pump system and ATES cooling (4,500 kWt (1,300 Tons)) according to system concept 3.

6. REFERENCES

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