Lessons from 100 ATES projects
The developments of aquifer storage in the Netherlands

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Abstract

At the beginning of 2000, over 100 projects applying 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 is between 500 and 1000 kWt for most projects. Over 40% of the projects concern large office buildings while the remainder are on the whole evenly distributed over public buildings, hospitals, industry and agriculture.

It has taken over 15 years for Aquifer Thermal Energy Storage (ATES) to become considered a standard technology. This publication discusses the lessons that can be learned from the technological development as well as the role the client, the consultant and the government play therein.

Introduction

In 1982 the SPEOS Aquifer Thermal Energy Storage (ATES) project was realised 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, these also were 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 it particularly concerned: (IEA, 1995)

- 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, see table 1 (IEA 1995).

Table 1: Water treatment methods applicable to ATES

Problem	**Avoid problem**	**Control problem**
Preciptation of carbonates	Ion exchange CO_2 treatment	Fluidized bed reactor/heat exchanger
Precipitation of iron/manganese	Pressurized, air tight system	In-situ oxidation Bioreactor
Gas clogging	Pressurized, air tight system	Partial degassing

Present status in the Netherlands

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 in an office building (storage temperature 30°C) (VAN DER BRUGGEN et al. 1985);
- the storage of winter cold to cool a printing office (storage temperature 6°C) (VAN HOVE et al. 1988);
- the storage of residual heat from a combined heat and power plant for space heating of a university building (storage temperature 90°C) (VAN LOON et al. 1991);
- the storage of solar heat for space heating some 100 residences (storage temperature 60°C) (WIJSMAN 1983).

An aquifer was not used for heat storage in the latter 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, the application of thermal energy storage in aquifers in particular has been further developed in the Netherlands.

At the beginning of 2000, over 100 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, see table 1. 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 1000 kWt. This means that by applying cold storage these projects economise on a large chiller.

The heat released during cooling is stored in the aquifer. If possible the heat is used for heating during the winter season. This combination is called "Cold Storage and Low Temperature Heat Storage", see table 2. The temperature levels of the heat stored in summer are fairly low so that it is not always possible to utilise the heat in winter.

If the realised projects are distinguished per application area, the situation as shown in table 3* occurs. Over 40% of the realised projects involve a combination of 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). The remaining projects are about equally distributed over the other application areas. The category “public 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 thus that cooling, heating and ventilation are for a significant part determined by the fact that there are many people present at the same time.

Table 2: Realised ATES projects – storage temperature

Aim	Type of Storage	Temperature level	Percentage of projects
Cooling	Cold storage	• 12 °C	27
Cooling and heating	Cold storage and low temperature heat storage	• 12 °C 12-20 °C	58
Heating	Low temperature heat storage	20-50 °C	2
Heating	High temperature heat storage	>50°C	3

Table 3: Realised ATES projects-applications

Application	Percentage of projects
Office buildings	43
Hospitals	12
Public buildings (malls, congress centres, etc.)	18
Industry	12
Agricultural applications	15

Lessons from 100 projects

The fact that at the beginning of 2000 there were over 100 ATES projects in operation, and that some tens of projects were under preparation or construction, demonstrates that Aquifer Seasonal Cold Storage and Low Temperature Heat Storage is currently an accepted technology with a commercial basis in the Netherlands. This situation has not arisen without a struggle, however. What are the main lessons that can be learned from the developments between the first pilot projects of the early eighties and the present application of ATES?

The first projects

The first projects had to be technically successful.

For further introduction, it was essential that the first projects functioned properly because new clients almost without exception wanted information or even gathered information themselves on the progress of those projects. This conflicts with the inclination of technicians to highly optimise a new technology on paper. In the case of Aquifer Thermal Energy Storage this led to systems that were too complex, had too many different modes of operation and a too complicated control. The previously mentioned office project in which low temperature solar heat was stored is a particular example of this. Besides storing low temperature heat in an aquifer, that project applied a gas motor heat pump and newly developed solar collectors. The aquifer storage has always functioned without problems. The energy supply system was simplified a few years after operation started.

It is important that all parties realise that the first projects have to be successful. It means that clients will have to accept some problems in the start-up phase and that the research institutes, consultants and contractors involved in the construction will in retrospect note that they have put money into the project in order to solve the problems in the start-up phase. This is however inevitable to gain experience with a new technology: "experience is what you get, when you don't get what you want".

Technological developments

The technical possibilities are greater than first appear.

In the first projects thermal energy storage was added to an energy supply system as an additional component. The rest of the system determined the boundary conditions for the storage system: cold storage had to supply 6 °C to be able to utilise the cold in the conventional building cooling systems. No account was taken of the specific properties of aquifer cold storage whereby a higher temperature (8-10 °C) is better because then fewer problems occur when loading the store during winter. In later projects building heating and cooling systems were adapted so that a better utilisation of the stored cold and low temperature heat became possible. In this development HVAC engineers especially play a major part.

In Figure 1 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 over-dimensioned so that the required cold (air temperature and relative humidity) can be achieved with a relatively high supply water temperature. During the winter season the same water/air are used to 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.

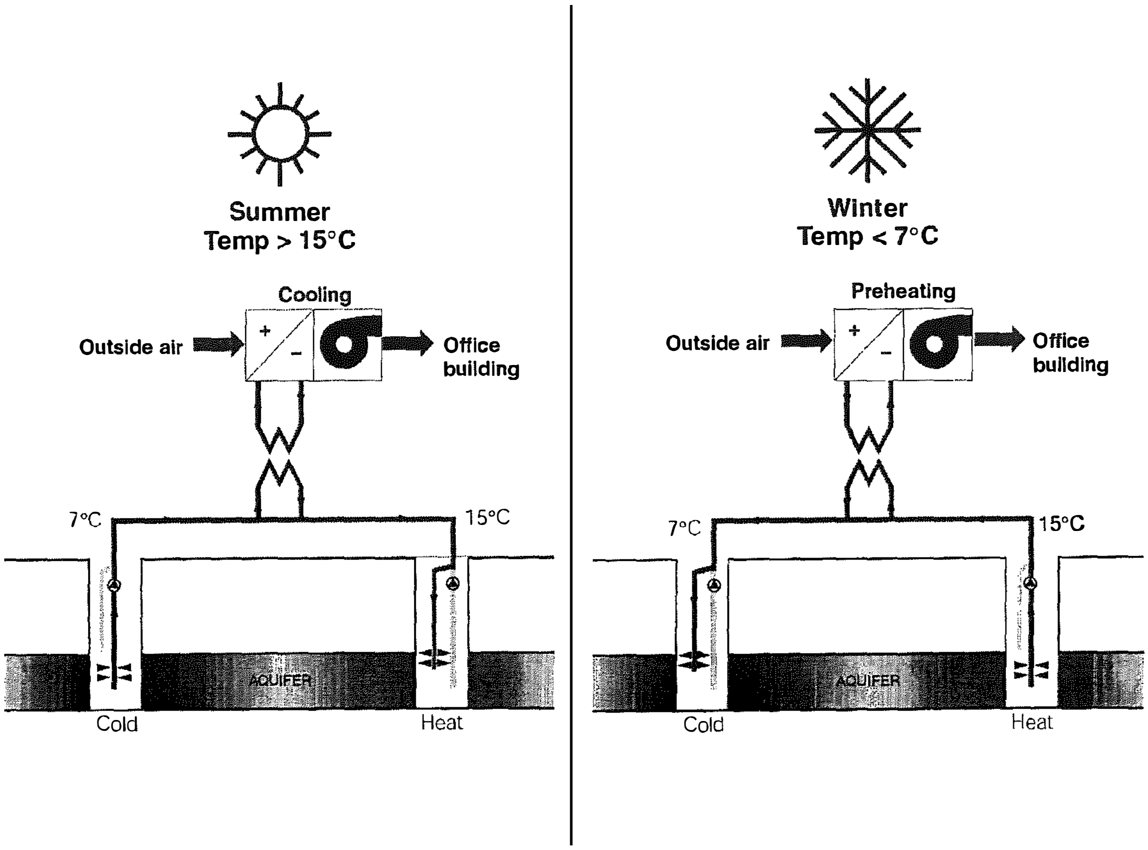

Figure 1. ATES system integrated with building airconditioning system.

In the system concept shown in Figure 1 there is a risk of heat exchanger freezing and thus being damaged in winter, which has occurred in a few projects. A solution for this problem is the application of water/air heat exchangers provided with Thermo Guard equipment developed in Sweden (BRÄNNSTRÖM 1991) now on the market in the Netherlands. The batteries may still freeze but no damage will be incurred.

This example illustrates that technological development is not finished as soon as the new component, in this case aquifer storage, functions well. Other examples of further developments include:

* the application of what is called a mono-well in which two filters are placed in one borehole, for small-scale projects;
* the integration of wells for thermal energy storage with the fire extinguishing system in industrial projects.

Role HVAC engineer

Most HVAC engineers avoid risks.

At present aquifer cold storage is considered one of the options to save energy when cooling and heating large office buildings. All renowned installation consultancy companies have by now designed some projects applying ATES. In the early stages of ATES application however, the large installation consultancy companies were reserved about recommending this technology to their clients. It were the small companies, who saw the possibility of distinguishing themselves by applying new technologies, who contributed to the success of the first ATES projects.

Role client

The motives of clients to apply ATES have changed in the course of time.

The first clients (early adapters) recognised the environmental advantages of the new technology and *offered an opportunity to apply it* for a first time rather than that they applied the technology on the basis of economical motives. At the same time they capitalised on the publicity opportunities offered by the attention the media gave to the first subsoil cold and heat storage projects. To minimise their technical and financial risks, the first clients also made sure that their technions had sufficient time to follow the implementation day by day.

As faith in ATES technology increased, deciding whether or not to apply ATES became based on more conventional economic, social and location-specific factors.

For projects with relatively large cooling and heating capacities the economical boundary conditions are favourable: because chillers are avoided the *additional investments* for aquifer storage are small while there is a considerable saving on energy consumption. This results in a payback period of about 5 years. Furthermore, it has become generally accepted that investment decisions include environmental aspects. In many cases this has resulted in ATES being chosen instead of a conventional system with chillers and gasfired boilers despite the fact that applying ATES involves *extra complications* for the client such as additional licenses and more parties on the building site (geohydrological consultant and drilling company).

Role government

Subsidy arrangements do not warrant the implementation of a new technology.

Besides financing R&D activities, financial support from the government has proven necessary for the first (demonstration) projects in order to lay a foundation for the implementation of the technology. In the follow-up phase subsidising feasibility studies has contributed to lowering the threshold to at least compare the application of ATES with a conventional installation before starting a project.

At present aquifer cold storage is ranked among the renewable energy resources because ambient cold is used for cooling (and possibly ambient heat for heating). For businesses, project developers and institutions that apply renewable energy resources, there are fiscal facilities or subsidies. The impact of such arrangements on the application of cold storage particularly lies in that the government recognises that ATES application contributes to a socially desirable development.

On the other hand, the client encounters the government as licensor for the use of groundwater. To this end, questions about the environmental impacts of ATES must be answered by or on behalf of the client, while during operation the project must be monitored and reported on. In this way the government has two faces towards the client: that of the stimulating party for the application of ATES and that of the party that raises barriers against its application. Tuning the policy between the various ministries and the national and provincial authorities has therefore certainly been as important for the implementation of ATES as the subsidy arrangements.

Present projects

As soon as a technology has passed the stage of childhood, numerous parties appear on the market to take the pickings.

The fact that ATES has become a standard technology does not only appear from the fact that tens of projects are implemented each year. This situation is further illustrated by the developments on the market:

- various parties on the market, such as drilling companies and installation companies, are starting to offer turn-key cold storage systems:
- standardised cold storage systems are entering the market, in particular for small-scale projects;
- some utilities are offering to supply cooling to clients with large-scale projects whereby the cold storage system is owned and managed by the utility.

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