THE SUCCESFULL INTRODUCTION OF AQUIFER COLD STORAGE IN THE NETHERLANDS

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ABSTRACT

In the Netherlands, the development of seasonal (heat and) cold storage in aquifers as an energy saving technology started early in the 1980s. The second half of the 1980s saw the realization of the first projects of thermal energy storage in aquifers. The success of the first projects, and the increasing concern with respect to ozone depletion and global warming have resulted in a rapid development of the cold storage technology early in the 1990s.
Today a total of 40 storage projects have been realized or are being built, of which 90 % is used for cold storage or the combination of cold storage and low-temperature heat storage. Most applications are for the building sector (office blocks, hospitals and shopping centres)

1. INTRODUCTION

Long-term storage of thermal energy in the subsoil appears to be a good option to reduce the consumption of fossil fuels. In this context, thermal energy storage is the storage of heat for heating purposes, the storage of cold energy for space and process cooling, and the combined storage of heat and cold.

In China, the Netherlands and Sweden seasonal storage of thermal energy in the soil has been practised on a fairly large scale (Bakema, 1995). In China and the Netherlands, the storage of thermal energy occurs in underground water-bearing sand/sandstone layers (aquifers), whereas in Sweden - next to aquifer storage - use is also made of rock caverns storage and vertical heat exchangers in soil and rock.

The principle of seasonal Aquifer Thermal Energy Storage (ATES) is simple. For cold storage, groundwater is extracted in winter, cooled down and then re-injected into the aquifer for storage. Cooling is accomplished by cold outside air or cold surface water. Wells are used to extract the groundwater and re-inject it into the soil. In summer when cold energy is needed, the cooled water is extracted again and used for cooling.

After having been used, the water is again re-injected into the aquifer. Consequently, this method requires at least two wells at some distance from each other: a "cold" and a "warm" well.
Below, a description will be given of how ATES has developed in the Netherlands. Attention will also be given to the prospects offered by this technology in order to come to a more sustainable energy supply in the future.

2. DEVELOPMENT IN THE NETHERLANDS

The development of ATES in the Netherlands was started early in the 1980s. Initially, seasonal storage of heat was considered a suitable method of storing solar energy to be used for space heating in winter. It soon became apparent that seasonal storage in aquifers is also very useful as a method to store waste heat and cold.

The second half of the 1980s saw the realization of the first projects of thermal energy storage in aquifers. The projects covered the storage of solar energy to be used for an office block (30 °C) (Bruggen van der,1985), the storage of winter cold to be used for a printing industry (6 °C) (Hove van,1988) and the storage of waste heat to be used for a university building (90 °C) (Loon van,1991).

The first projects have been successful, and the economic aspects and environmental advantages of ATES were much better understood meanwhile. This resulted in a rapid development of the cold storage technology early in the 1990s. Today, a total of 40 storage projects have been realized or are being built, of which 90 % is used for cold storage or the combination of cold storage and low-temperature heat storage. About 80 % of the applications is for the buildings sector (office blocks, hospitals and shopping centres). The remaining applications are for industrial cooling and cooling in the agricultural sector.

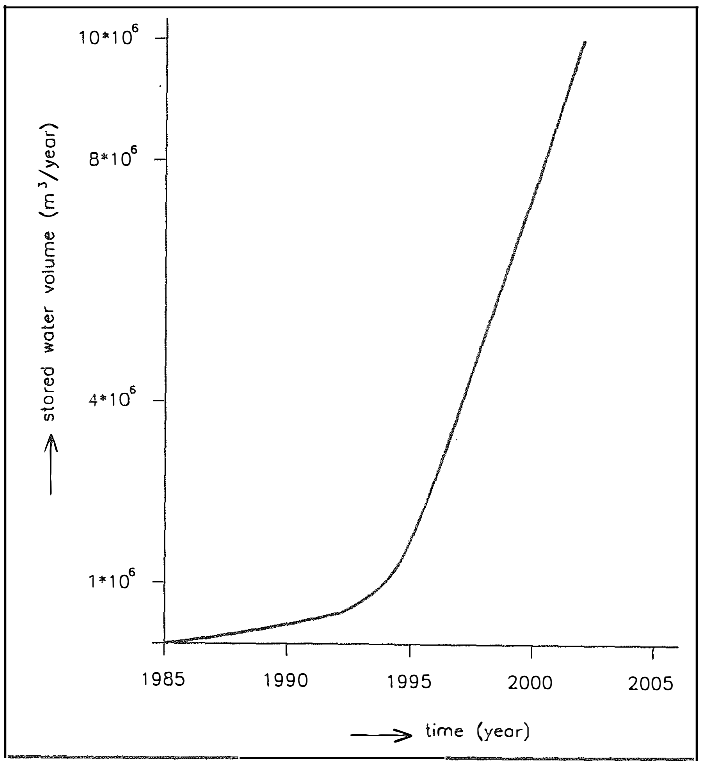

Fig. 1: Amount of ground water used for loading cold storage projects.

In the 1996/1997 winter season approx. 4 x 10^6 m^3 of groundwater (100.000 m^3 for one project) is to be cooled and re-injected within the actually realized cold storage projects. This amount is expected to be more than doubled in the following five years (see figure 1). This expectation is also based on the fact that there is an increasing interest in cold storage among the industry.

3. DEVELOPMENT OF SYSTEM CONCEPTS

The first few cold storage projects in the buildings sector were designed as shown in figure 2. In winter, the cold storage is charged by cooling down the groundwater in a cooling tower. The building is heated by a gas boiler. In summer, the cold storage system takes care of the cooling of the building.

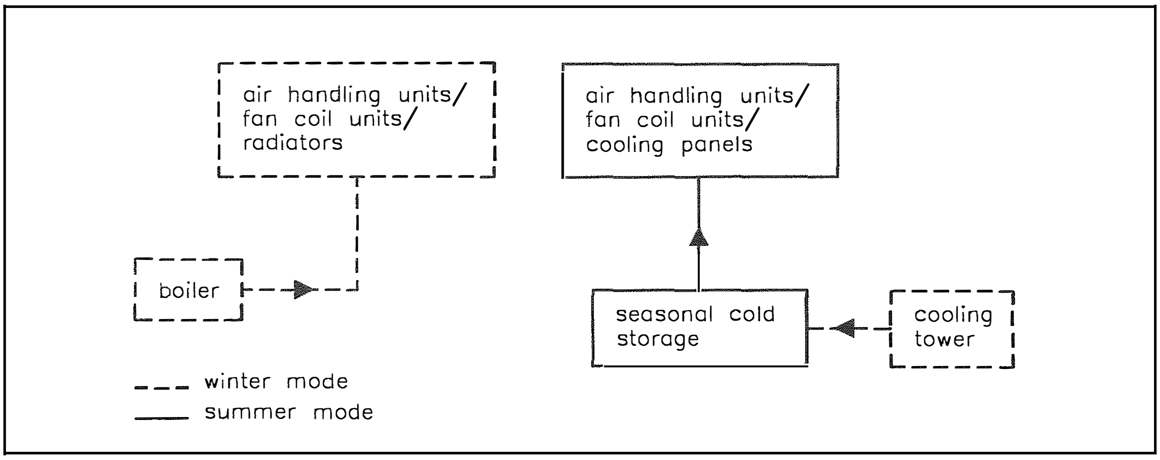

Fig 2: Cold storage for the buildings sector

Figure 3 shows an improvement on this system. The concept shown is very suitable for buildings in which the cooling is performed completely or for the greater part by means of ventilation air. The cooling coils in the air-handling units not only take care of cooling the building in summer but also of charging the storage system in winter. During the charging of the storage system the ventilation air is pre-heated. Consequently, in this case there is combined storage of heat and cold, as the heat originating from the ventilation air is stored in summer and utilized in winter, and the cold originating from the ventilation air is stored in winter and utilized in summer. In many instances this results in a duplication of the energy saving compared with the concept according to figure 2.

4. ECONIMIC ASPECTS

Pay-back times for cold storage and combined cold and heat storage to be used for the buildings sector are favourable. This is explained by the fact that the traditional way of cooling in this sector is with compression cooling machines. With cold storage it is no longer necessary to invest in cooling machines. This partly balances the investments to be made for the realization of a cold storage system compared with investments that would have been necessary for cooling machines. In several cases, the investments required for cold storage appear to be even lower than those to be made for cooling machines (Bakema, 1996)

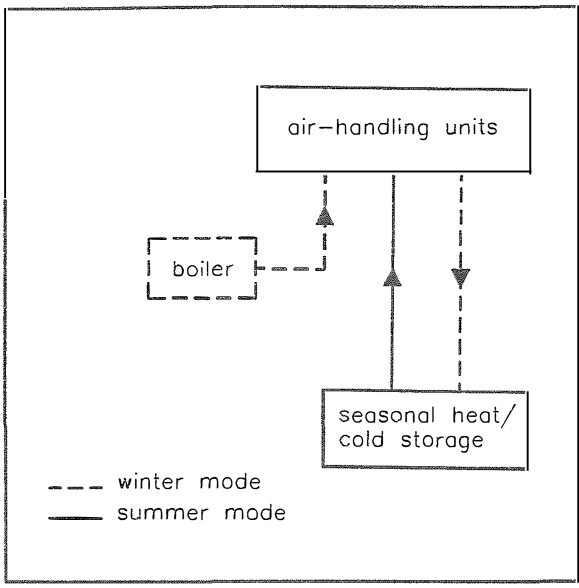

Fig. 3: Combined storage of cold and heat for the buildings sector

Pay-back times in industrial projects, where cooling is achieved by means of cooling machines (reference system), are comparable with those in the buildings sector. Several industries do not cover their cooling demand with cooling machines but with groundwater which, after having been used for this purpose, is discharged into the surface water. The pay-back time of cold storage in this situation is less favourable (5 to 15 years), as no investments in cooling machines are involved in the "reference system". Here, the profitability fully depends on government levies imposed on the extraction and discharge of groundwater. When cold storage is used, no such levies will be imposed. Because the amounts of these levies have considerably risen the last few years and are expected to rise even more, the prospects for the application of cold storage in the industrial sector are good.

An economic aspect that goes beyond the scope of individual users, is the fact that in major cities the maximum load on the electricity network is shifting from the winter to the summer season due to the increasing cooling demand. This implies that a reduction in the increase in electricity demand achieved by using cold storage will make it possible that extensions to the electricity network and enlargements of the electricity generating capacity can be postponed or even avoided.

5. ENVIRONMENTAL BENEFITS OF COLD STORAGE

Cold storage (or combined heat and cold storage) in aquifers will affect the natural temperature of groundwater. Generally, the temperature around the warm well will be a few degrees centigrade above the natural temperature level and that around the cold well a few degrees below the natural groundwater temperature. Detailed research has been carried out to investigate whether these temperature changes might cause any adverse impacts on the chemical and microbiological compositions of groundwater. Research has shown that this is not the case (Snijders, 1991).

A quantification of the environmental benefits of using cold storage depends on the reference chosen.
Cold storage with industries that are already extracting groundwater for cooling, will result in a saving of groundwater. In practically all cases, the groundwater involved

here is of a high quality (fresh groundwater suitable for the production of drinking water).

The reference for the application of cold storage (and combined cold and heat storage) in the buildings sector is cooling with compression cooling machines. In this case, the main environmental advantage of cold storage is resulting from the energy saving brought about by cold storage. The saving amounts to approx. 75 % of the electrical energy needed to generate cold energy with compression cooling machines.

Cold storage (and combined cold and heat storage) means that use is made of ambient cold (and heat). Utilizing this energy source only requires a limited amount of auxiliary energy. For that reason, cold storage can be considered a renewable energy source. The use of renewable sources is encouraged by the Dutch government. The potential contribution by cold storage to the energy production in the Netherlands in the year 2020 has been laid down in the 3rd Energy Review of the Ministry of Economic Affairs (Ministry of Economic Affairs, 1995). This annual contribution is estimated at 15 PJ, which corresponds with a saving of approx. 500 million m^3 of natural gas per year.

The public utility companies, in consultation with the Dutch government, have taken the responsibility to realize part of the desired reduction in the emissions of CO_2, SO_2, NO_x etc. Considering this responsibility and the fact that public utility companies are expanding their commercial activities, a number of public utility companies have started to offer the supply of cold energy to their clients. This cold energy is supplied next to electric power, heat and water, and is generated by means of cold storage. Meanwhile, several projects have been realized in this way, which are beneficial to the client in that the investments as well as management and maintenance of the cold storage are taken care of by the public utility company. This role of the public utility companies is expected to be a factor favouring the rapid increase in the number of cold storage projects in the near future.

7. EVALUATION

Looking back on the introduction of ATES on the Dutch market, some reasons can be pointed out for the success:
- There are aquifers in every major city.
- By subsidizing large numbers of feasibility and market studies, the Government has shown their positive attitude towards ATES.
- The relatively high price of electricity.
- The increasing environmental consciousness of private companies.
- The prohibition of using CFC.
- The positive attitude of licensing authorities.

The 10-year experience has led to the fact that ATES is accepted on the market as a "proven" technology. This status means that ATES is considered an alternative when designing an energy supply system for large buildings. Through that ATES can play a significant role towards a sustainable way of cold and low temperature heat supply in the buildings sector and the industry.

The growth in the number of ATES projects depends on a number of conditions:
- In the centre of some large cities a concentration of ATES projects is developing. If these individual projects are not combined, further growth will be difficult. The use of district cooling systems will better guarantee the increase of ATES.
- For a growing number of ATES projects there is a conflict of interest between ATES and other groundwater users. The licensing authorities will only permit ATES as long as the positive effects on the emission reduction will balance the potential adverse effects on the groundwater system.
- The level of the levies on groundwater consumption and discharge will determine the number of industries changing their groundwater cooling system towards ATES.

8. LITERATURE

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