IEA Heat Pump CENTRE
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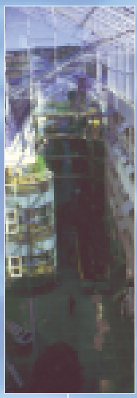

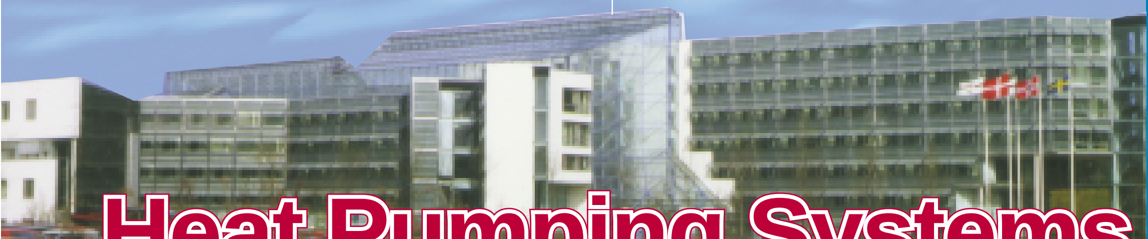

# Heat Pumping Systems and Thermal Storage

**In this issue:**

**ATES and ground-source heat pumps in the Netherlands**

**Underground thermal energy storage with absorption heat pumps**

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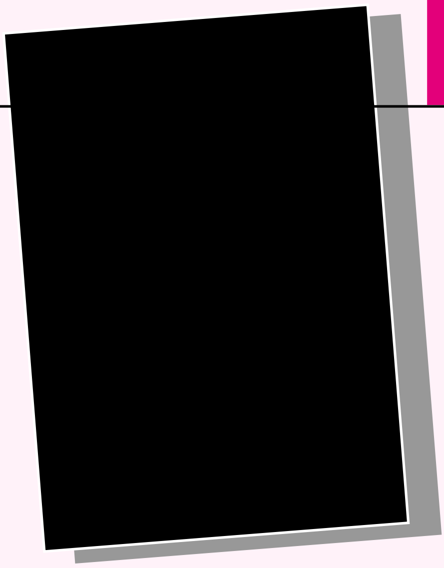

# In this issue

## Heat pumping systems and thermal storage

In many underground thermal energy storage (UTES) systems the heat pump is the key factor for successful operation. Several examples of installations with this combination are presented in this issue, which was produced in collaboration with Annex 8 of the IEA Implementing Agreement on Energy Conservation through Energy Storage.

***Front cover:***
*Photographs showing the head office of SAS airline in Solna, Sweden, utilising an ATES system.*

## TOPICAL ARTICLES


### Underground thermal energy storage with heat pumps An international overview — 10

*Burkhard Sanner, Germany and Bo Nordell, Sweden*

Heat pumps often form an integrated part of underground thermal energy storage (UTES) systems. This article describes the historical development of UTES with heat pumps and the various types of systems and gives an overview of the current international trends.

### ATES and ground-source heat pumps in the Netherlands — 15

*Guido Bakema and Aart Snijders, The Netherlands*

The combination of ATES and heat pump technology is promising for offices and commercial buildings in the Netherlands. A new installation is the one in the Gelredome, a multipurpose stadium in Arnhem.

### Underground thermal energy storage with absorption heat pumps — 18

*Frank Kabus, Germany*

In the new parliament buildings in Berlin, Germany, absorption heat pumps are combined with a cogeneration system and UTES for a balanced and efficient energy supply.

### Heat pump supported ATES applications in Sweden — 20

*Olof Andersson, Sweden*

In Sweden two types of combinations of ATES and heat pumps are used. The article highlights technical experience with these systems, while economical and environmental aspects are also discussed.

### Underground thermal energy storage in the US — 22

*Lynn Stiles, USA*

Ground-source heat pump systems, and as a consequence UTES, are increasingly recognised as an energy-efficient solution for new buildings and retrofits in the US. One of the examples is the project at Richard Stockton College in New Jersey.

### UTES with borehole heat exchangers in Central and Northern Europe — 24

*Burkhard Sanner, Germany and Göran Hellström, Sweden*

In Central and Northern Europe the number of installations using BHE for heat storage in the ground or for heat extraction is still growing. Solar-assisted applications and some heating and cooling installations are described, in the article.


## HEAT PUMP NEWS


| | |
|---|---|
| General | 4 |
| Technology & applications | 6 |
| Working fluids | 7 |
| Markets | 8 |
| IEA Heat Pump Programme | 9 |


## FEATURES


| | |
|---|---|
| Comment | 3 |
| Books & software | 30 |
| Events | 31 |
| National Team contacts | 32 |


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# Energy storage - crucial in new energy systems

*The RD&D efforts and the discussion on new technologies for energy conversion have focused on the environmental consequences of these new energy systems for the last 20 years. The RD&D projects have been important for the progress of sustainable development during the late 1990s. Agenda 21 (a document signed in Rio de Janeiro in 1992 that serves as a blueprint for sustainable development in the 21st century) emphasised the awareness of environmentally benign energy systems. However, discussions on new energy systems have mainly concentrated on systems for environmentally benign energy production. Less attention has been given to efficient use of energy.*

*Energy storage facilities are crucial for both the production side (cutting the peaks) and the energy end-use side (e.g. electricity savings). The view on new energy systems should be broadened to cover the full spectrum: production, transportation, storage and end-use. Storage plants based on utilisation of underground layers, by use of aquifers, rock caverns and duct storage, have proven successful in many countries over the past few years. Heat pumps often form an essential part of these storage plants.*

*Information and market introduction of new technologies require much attention. Technological development runs parallel to information activities at several levels for different target groups. The process of convincing the end-user to apply these new technologies involves many aspects; technology information alone will not be sufficient.*

*The role of international collaboration - within the International Energy Agency (IEA) and other organisations - is important. Technology transfer takes place between many countries sharing their experiences and between various Implementing Agreements (IA) within the IEA. This issue of the IEA Heat Pump Centre Newsletter is the result of collaboration between the IA on Energy Conservation through Energy Storage and the IA on Heat Pumping Technologies. This type of information and promotion of heat pumps, as well as energy storage systems and the integration of these techniques, should continue to go hand in hand with the technological development of those technologies.*

*Björn Sellberg*
*Chairman of the IEA IA on Energy Conservation through Energy Storage*
*Ph.D., Senior Research Officer*
*Swedish Council for Building Research, Stockholm, Sweden*

## NON-TOPICAL ARTICLES

Climate 21 – A Swedish national research programme on heat pumps and refrigeration systems 27
*Peter Rohlin, Sweden*
The government, industries and universities collaborate in a research programme in Sweden that focuses on the energy efficiency of heat pumps and refrigeration systems. This article describes the objectives of the programme and gives some examples of projects that have been implemented.

Heat pumps in cold climates 29
This article describes the Third International Conference on Heat Pumps in Cold Climates, that was held in August 1997.

Seminar on vertical borehole heat exchangers in the Netherlands 30
*Hanneke van de Ven, IEA Heat Pump Centre*
A seminar was held in Utrecht, the Netherlands, where several aspects of vertical borehole heat exchangers were discussed.

# Heat pump news

## Utility programmes for heat pumps

**Austria** - There is currently no federal government programme in Austria for the support of heat pumps, but some provinces and communities support this energy saving and environmentally benign technology. In September 1997, VEÖ, the association of Austrian electricity utilities, began a promotion programme for heat pumps. The budget of this programme is approximately USD 930,000 over three years. Because the emphasis is on increasing public awareness of heat pumps, the campaign concentrates on emotive information and has a minimum of technical information.

Under the umbrella of this promotion programme, provincial utilities such as OKA of Upper Austria, EVN of Lower Austria, SAFE of Salzburg, BEWAG of Burgenland, and TIWAG of Tyrol, are implementing their own local programmes. These programmes concentrate on different strategies, but they all have three common objectives: increasing market penetration of heat pumps, creating a climate of confidence in (the reliability and efficiency of) this technology and gaining satisfied customers. The means used to achieve these goals are:

- financial support;
- consultancy support:
- support for designing borehole heat exchangers for ground-source heat pumps;
- heat contracting; and
- support for improving malfunctioning heat pump installations.

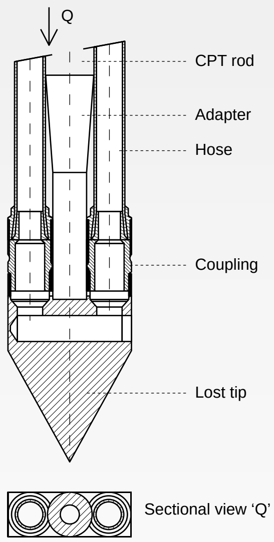
Source: Austrian National Team

## Installation of ground probes explained

**The Netherlands** - In the article 'German symposium on heating and cooling with ground-coupled heat pumps' published in Newsletter Vol.16/1, page 30, a method is described that enables quick installation of ground probes up to 50 m length in soft formations. This method has been developed by the Dutch company A.P. van den Berg Durable Energy. Installation takes place by pressing down a rod to which two plastic U-tubes and a core (tip) are connected. The tip is lost (see Figure), while the rod is pulled back and used again, which makes the operation more economical.

Source: A.P. van den Berg Durable Energy.
E-mail: apb@apvdberg.nl

*Figure: Sectional view of the ground probe.*




## Swiss market guide on heat recovery systems

**Switzerland** - In Switzerland a market guide has been published on heat recovery systems. Room ventilation with heat recovery is becoming more important, mainly due to reduced transmission losses and tighter walls and windows in new buildings. To obtain sufficient air quality, it is necessary either to open the windows periodically or use a mechanical ventilation system. It would not make sense to keep the windows open for longer periods, due to the low-energy concept. If mechanical ventilation is planned, it should be implemented with heat recovery. It offers the additional benefit of further reduction of the energy demand by recovering ventilation heat. As a result the heat demand for tap water is increasingly important, ranging typically from 30 to 50% of the total heat demand.

*Figure: Cover of the market guide on heat recovery systems.*


There are various ways to use the recovered heat. The most obvious solution is to heat the incoming air in a heat exchanger. Another possibility is to use the exhaust air as the heat source for a heat pump to produce hot water or assist space heating. A combination of both these functions is also possible.

The new market guide gives an overview of the various systems that can be used. It is written for home owners, but is also a useful handbook for installers, architects and energy consultants. It features the products of 15 companies in this domain. An address list of specialists is included. With all the relevant arguments in favour of space ventilation with heat recovery, this market guide will help to introduce the technology into the residential market sector. Additional information can be found on the Internet site (www.infel.ch) of the Swiss Center for Electricity Applications, INFEL.

Source: Swiss National Team.

# Norwegian subsidy programme launched

**Norway** - More than 30 TWh electricity and 12 TWh oil is annually being used for space and water heating in Norway, and a considerable growth in electricity demand by industry is expected in the years to come. In order to avoid future electricity shortages, reduce $CO_2$-emissions and develop a more robust and flexible energy system, the Norwegian government is now focusing on energy conservation and renewable energy, including heat pump technology and bioenergy. As a result, the Norwegian Water Resources and Energy Administration (NVE) launched a new subsidy programme for ‘Bioenergy and flexible heating systems’ in February 1998.

The main goals of the programme are to increase the number of energy efficient and flexible heating systems (e.g. bivalent heat pumps), establish regional markets for bioenergy and increase the utilisation of waste heat from industry. Heating installations in residences are not included in the subsidy programme. The subsidies will, on average, cover 15-20% of the additional investment costs compared to conventional heating systems. The total budget for 1998 is approximately USD 1 million. In 1997 subsidies were only granted to bioenergy systems (supply, transport, end-user), and the new subsidy programme is therefore encouraging for the Norwegian heat pump community.

Source: Norwegian National Team.

# ISO Standards for unitary equipment being revised

**USA** - The proposed working draft 5151R (1998-01-15A), a proposed revision of ISO 5151 ‘Non-ducted Air Conditioners and Heat Pumps’ was the topic of ISO TC 86/SC6 Working Group 1 meeting in Milan, February 1998. This was prompted by US comments on the 1994 ISO standard. After considerable discussion of provisions for ‘part-load descriptors’ and associated tests, it was agreed that in the revised standard, part-load testing would be optional with an Informative Annex providing the details for the test method. The test method would include two rating points for single-speed compressors and three rating points for two-speed and variable-speed compressors.

Source: Koldfax, March 1998

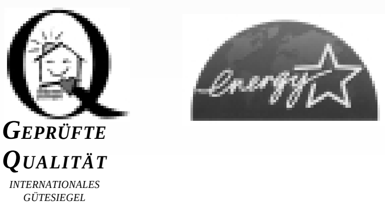
# Heat pump quality labels

**Germany/USA** - The regional heat pump quality label which will become valid in Austria, Germany and Switzerland will be used from 1 October 1998. As announced in Newsletter Vol.15/3, the quality label will be issued if a heat pump meets all test criteria concerning coefficient of performance (COP), noise level and reliability. Tests are performed at the Swiss test centre in Töss. The Figure shows the design of the quality label.

In the USA, the Environmental Protection Agency (EPA) has a voluntary programme that helps heating and air-conditioning contractors promote and sell higher efficiency Energy Star labelled HVAC products, such as GeoExchange heat pump systems, in the residential replacement market. The label minimises consumer confusion about efficiency ratings. The programme includes the label, sales training to help contractors to sell more Energy Star labelled products and a financing tool.

Sources: CCI, 4/1998, Earth Comfort Update

▼ *Figure: The heat pump quality label and the US Energy Star label.*




# Seminar on heat pumps in the Netherlands

**The Netherlands** - The Dutch Technical Association for Installations in Buildings (TVVL) organised a seminar on 25 March 1998 on the current status of heat pump technology in the Netherlands and on the role of heat pumps in the future energy supply. The morning session was dedicated to general issues, such as the status of heat pump technology in the Netherlands and the energy infrastructure for future end-users and the specific role of heat pumps.

The afternoon session had some presentations on experiences with heat pump applications. Topics included experiences with heat pumps and energy storage in aquifers and the monitoring of a residential heat pump project implemented by a utility company. Another presentation gave some insight into the developments of a diffusion-absorption heat pump for residential applications (space and tap water heating). Finally an evaluation was given on technical and economic performances of heat pump boilers, and the requirements for successful implementation.

The discussions and presentations confirmed that economic aspects are crucial to establish a breakthrough of heat pumps onto the heating market in the Netherlands. There is also a need for general quality criteria for heat pump systems. Finally, several speakers emphasised the need for more education on heat pumps for installers and consulting agencies, and for a better cooperation between the different market parties.

Source: IEA Heat Pump Centre

# New ASHRAE R&D project

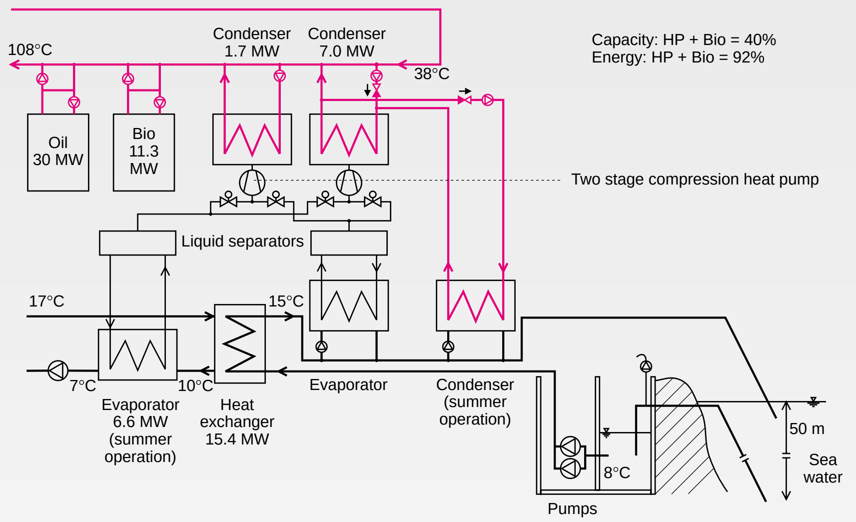
**USA** - The Research Administration Committee (RAC) of the American Society of Heating, Refrigeration and Air-Conditioning Engineers has selected 38 projects as having priority status. One of these is the project ‘Investigation of methods to optimise the environmental benefits of ground-coupled heat pumps’. The research, which will be coordinated by Technical Committee 6.8, has a budget of USD 75,000 and will take about 18 months to complete.

ASHRAE Insights, February 1998

# Innovative district heating and cooling system

**Norway** - In October 1998 the main airport in Norway, Oslo Airport Fornebu, will be replaced by the Oslo Airport Gardermoen. The airport area, ‘New Fornebu’ will become the new centre for information technology (IT) in Norway, and a large number of office buildings and residences will be built here. In 1997 the Norwegian Water Resources and Energy Administration (NVE) launched a technology competition to obtain the most futuristic and environmentally friendly heating and cooling system. The winning proposal, submitted by TechnoConsult, includes a combined district heating and cooling system with heat pumps as well as bioenergy and oil-fired boilers in the central heating and cooling station.

▼ *Figure 1: Layout of the heating and cooling station at New Fornebu.*




The 8.7 MW heat pump will meet approximately 53% of the total annual heat demand. It will use sea water (40 metres deep) as the heat source. Ammonia is regarded as the most promising working fluid for the heat pump units. The 11.3 MW bioenergy boiler using wood chips and bark waste, will meet about 39% of the annual heat demand. During peak load a 30 MW oil-fired boiler will deliver the remaining 8%.

Sea water will be used to meet the base load for cooling directly (15.4 MW) and the heat pump will provide the peak load (6.6 MW). At design conditions the supply/return temperatures in the district heating and cooling system will be 108ºC/38ºC and 7ºC/17ºC, respectively. Maximum supply temperatures from the heat pumps is approximately 50ºC. The large temperature differences will reduce the overall piping and energy costs for the main circulation pumps compared to conventional district heating and cooling systems. In order to obtain these favourable operating conditions, advanced flow-controlled hydronic systems for heating and cooling are required. **Figure 1** shows the proposed central heating and cooling station.

Source: Norwegian National Team.

# AEG winner IEA-DSM dryer promotion competition 1997/1998

**The Netherlands** - The HPC Newsletter Vol.3/97 contained an article on the international IEA-DSM (Demand Side Management) competition for an efficient domestic heat pump tumble dryer. The competition was organised by Novem, the Netherlands Agency for Energy and the Environment. The aim of the competition was to introduce on the European market a clothes dryer that is 50% more efficient than the current best model, i.e. corresponding to efficiency class “A” on the mandatory EU energy label.

On 27 April 1998, AEG was declared the winner of the competition with their model AEG Öko-Lavatherm WP. AEG Germany received the Award of Excellence from Mr Nilsson (Executive Committee IEA-DSM) and Mr Berns (Novem).

This event marked a historic moment in tumble dryer development. The international jury consisted of four experts in laundry testing who work for influential European consumer organisations. The jury report states that AEG Öko-Lavatherm WP fulfils the minimum specifications for the competition. There were 18 different creteria including energy consumption at rated capacity and partial (2.5 kg) load, price for consumers, performance (drying time and evenness of drying) and noise level.

The energy consumption of the Öko-lavatherm WP is approximately 50% lower than for conventional models. AEG has already introduced the heat pump dryer on the German market and will introduce it to several other European countries such as Sweden and the Netherlands. In the Netherlands several energy utilities give financial rebates to purchasers of this very efficient tumble dryer.

In 1998 a new competition round (1998/99) is being organised and manufacturers are invited to send their entries to Novem. The IEA and Novem will be happy to support all manufacturers who wish to introduce super efficient dryers to the European market.

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# Largest Australian ground-coupled air-conditioning system installed

**Australia** - The new headquarters of the Australian Geological Survey Organisation is an exemplary building demonstrating many of the important design elements for energy-efficient building design beautifully integrated into an interesting and pleasing structure.

Features include a compact well-insulated building envelope, orientation of buildings on an east-west axis with plenty of north-facing glass, low ratio of external wall to gross floor area, thermal breaks to prevent the transfer of heat and cold across non-insulated surfaces, efficient controllable daylighting and lighting systems and air conditioning which incorporates a geothermal heat pump system.

A geothermal field of 350 boreholes was drilled below the building site prior to construction. The ground loops contain water. In winter, the constant ground temperature of 17°C is used for heating purposes, while in summer the system takes heat from the building and transfers it to the earth. The field is coupled to 220 water-to-air heat pumps throughout the building. Each pump runs independently and can be switched off when an area is not in use.

Overall, the ground-coupled heat pump system has several advantages, including lower capital cost, reduced energy use, reduced risk of major breakdown, and elimination of cooling towers. This is the largest earth-coupled air-conditioning system in Australia, and it is expected to reduce air conditioning by more than USD 580,000 over its expected 25 year lifespan.

Source: Australian Energy News, March 1998

# Magneto-caloric refrigerator

**USA** - At a meeting of the American Physical Society a new type of material was announced which will enable magnetic cooling. This is possible because of a magneto-caloric effect in a crystalline structure of gadolinium to which silicon and germanium are added. The magneto-caloric effect is the reversible heating and cooling of a medium when the magnetisation is changed and occurs in strong magnetic fields. This effect is very strong with the element of gadolinium. Researchers of the Ames laboratory in Iowa have now improved this effect with a factor 2-6 per on/off cycle, by adding germanium and silicon. Depending on the ratio of these additions cooling can be achieved from 0°C to -253°C, which is even lower than the condensation temperature of hydrogen.

As soon as a large enough quantity of the new material is available, a company specialised in magnetic cooling will test it in a prototype magnetic refrigerator that used to operate on gadolinium only. The researchers expect that within 10 years an energy-efficient refrigerator using the magneto-caloric effect will be available, avoiding the use of refrigerants that are harmful to the environment.

Source: NRC Handelsblad, 4 April 1998 / Science, 27 March 1998

# Chiller uses water as refrigerant

**Germany** - Water is used as the working fluid in a centrifugal, hermetic chiller designed by Wilhelm Salzmann GmbH. A prototype developed and tested at the ILK laboratories in Dresden had completed 5,500 operating hours in late 1997. By using very low pressures (around 6 mbar), water can be evaporated at 1°C, making it possible to use a chilled water flow temperature of 4°C from the direct expansion (DX) heat exchanger. Frequency control of the drive motor enables compressor speed to be varied continuously up to 10,000 rpm – for the prototype this corresponds to refrigeration outputs from 300 to 1,000 kW. The circuit contains 1,000 litres of water. No oil mixing is needed.

Source: JARN, February 1998

# Japanese firm switches to HFCs

**Japan** - Japan's largest manufacturer of domestic air conditioners, Matsushita Electric Industrial Co. Ltd, is to replace the use of HCFC-22 with R-410A in their products by the year 2003. Under the Montreal Protocol, HCFCs are to be phased out for new equipment by 2020 in developed countries, by 2040 in developing countries, and by 2015 in the European Union. R-410A, which has an ODP of zero (but is a greenhouse gas) is a blend of HFC-32 and HFC-125.

Source: OzonAction, January 1998

# Disposing of CFCs

**Germany** - A flood of CFCs for disposal is expected in Germany as plants are shut down or converted before the June 1998 deadline. A high temperature (2,000-2,600°C) cracking unit capable of disposing of CFCs has been developed by Solvay Fluor und Derivate and Westab. The unit, located in Frankfurt, produces hydrofluoric and hydrochloric acids as by-products of the process and can handle 10,000 tons of CFCs per year. Over the past two years the amount of CFCs recycled in Germany totalled 800 and 1,300 tons respectively. The plant is therefore capable of operating on a Europe-wide basis.

JARN, February 1998

# $CO_2$ as secondary refrigerant

**Switzerland** - Freezers at the Co-op Centre in Schaffhausen are the first installation in that country to be indirectly cooled using $CO_2$ (R-744) as a secondary refrigerant. A central ammonia compressor plant delivers cold to two secondary circuits through heat exchangers. One circuit contains liquid $CO_2$ delivering the cold to the freezers and one contains an ethylene glycol solution for the chiller display cabinets. The advantage of using a change-of-phase medium (e.g. $CO_2$) can be seen in the reduction of mass flow in the secondary circuit – less than 10% of what would be needed with brine.

Source: JARN, March 1998

# Ground-source heat pumps penetrate US market

**USA** - Results of the first-ever Energy Information Administration's (EIA) survey of geothermal heat pump manufacturers showed that 155,406 ground-source heat pumps were shipped during the period 1994 through 1996. Based on recent data, 49% of these heat pumps were shipped to the south, 23% to the midwest, and 13% to the northeast of the USA.

Collaborative alliances between the government, the Geothermal Heat Pump Consortium, the International Ground Source Heat Pump Association and industry have expanded consumer awareness and acceptance of ground-source heat pumps. Such efforts have resulted in greater use of ground-source heat pumps where electric utilities and electric service companies provide attractive financing, rebates, guaranteed utility rates, shared savings contracts, and equipment-leasing arrangements. Aggregated data and a description of how geothermal heat pumps operate are available on EIA's Internet site (www.eia.doe.gov/cneaf/solar.renewables/renewable.energy.annual/rea97/geo_heat_pump/geoweb.html).

The aggregated data also will be available in the Renewable Energy Annual 1997, Volume II, scheduled for release in July 1998. The report will be available on EIA's web site and through EIA's National Energy Information Center, Forrestal Building, Washington D.C., 20585, tel.: +1-202-5868800.

Source: US National Team / Energy Information Administration

# Quantum leap in Swiss heat pump sales

**Switzerland -** With an increase of more than 1,000 heat pumps for heating systems, the trend in Swiss heat pump sales is still increasing – 5,225 units for heating and heat recovery were sold in 1997, compared to 4,207 the previous year (see **Figure 1**). In addition, 421 heat pumps were sold for domestic hot water. The exact residential building statistics are not yet available, but around 37% of the newly built single-family houses are now equipped with a heat pump heating system. The medium-term target of 50% is achievable. However, the figures for retrofitting are less positive. With 768 units of up to 20 kilowatt heating capacity sold, this market has remained stable. Approx. 50% of the units sold may have been used to replace old heat pumps. The large retrofit market volume of more than 40,000 units per year continues to be dominated by oil and gas heating systems.

No major changes occurred in the type of heat pumps sold (**Figure 2**). The largest share went to air-to-water heat pumps with 52%, only 1% below the 1996 figure. The brine-to-water types have increased by 1% to 39%, and water-to-water types now account for only 6%. Included for the first time in the statistics are 132 single-room heat pumps which are suitable as replacement for electrical storage heaters. A further increase is also expected here. In all, a pleasing result which will give an extra incentive to the innovative heat pump branch in Switzerland.

*Figure 1: Total Swiss heat pump sales.*

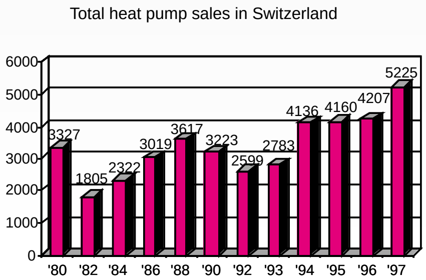
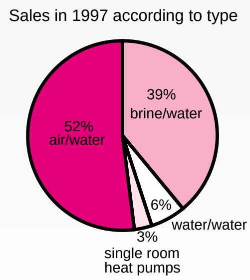



*Figure 2: Sales in 1997 according to type.*




Source: Swiss National Team.

# HP water heaters stimulated in Australia

**Australia** - Water heating can account for up to half the average home heating bill. These costs can be substantially lowered by substituting conventional electric water heating for a solar or heat pump system. However, the higher purchase price of these systems, and instances of incorrect installation, have formed barriers to their widespread use in the past. SEDA, the Australian sustainable energy development authority, has recently completed a successful campaign to overcome these barriers.

The promotional campaign ended on 31 January 1998. At that time, this Energy Smart cashback offer of USD 326 that had been made by manufacturers and SEDA, had been taken up by over 1,100 householders, who installed solar and heat pump water heaters, cutting their energy bills by up to 20% compared to conventional electric heaters.

Source: SEDA Newsbrief, No.4, Autumn 1998

# Japanese RAC giants in trouble

**Japan** - Japanese room air conditioner (RAC) manufacturers which are home electrical appliances giants, are currently facing a very difficult time. This is mainly due to:

- poor sales due to the cool summer and warm winter in 1997;
- excessive stocks, resulting from the depression clouding the whole of Japan and Asia;
- lower prices due to the severer competition;
- increasing development costs for models using new refrigerants and high efficiency models to cope with environmental issues.

Due to predictions that shipments for 1998 would drop to well below 7 million units, several manufacturers have decided to reduce their production.

Source: JARN, February 1998

# Annex 22 workshop in Japan

**Japan** - The third and final (regional) Annex 22 workshop on compression systems with natural working fluids was held in Tokyo, Japan on 16 February 1998. Around 45 participants attended the workshop, which was arranged by the Heat Pump Technology and Thermal Storage Center of Japan (HPTCJ).

The workshop programme included presentations on international cooperation under the Implementing Agreement on Heat Pumping Technologies, the Annex activities in general and R&D projects in the participating countries. In a presentation on the Annex 22 Internet site (www.maskin.ntnu.no/kkt/annex22) a number of successful heat pump installations with natural working fluids were discussed. A comprehensive presentation on indirect refrigeration systems (dual-loop systems) using brine, binary ice or $CO_2$ as secondary fluids was given by the operating agent, SINTEF Energy Research. In the afternoon R&D activities on natural working fluids in Japan, Korea and China were presented. The latter presentations discussed the use of $CO_2$, ammonia and water as working fluids in heat pump and refrigeration systems.

The following day, HPTCJ arranged a post-workshop tour to the Mechanical Engineering Laboratory at Tsukuba Science City and Maekawa compressor manufacturer.

Source: Japanese National Team, March 1998



# Platform absorption technology in the Netherlands

**The Netherlands** - The Dutch Platform for Sorption Technology, which was started in 1996 in the context of the Dutch contribution to Annex 24 on 'Absorption Machines for Heating and Cooling in Future Energy Systems', has successfully evolved into the main knowledge centre for (ab)sorption heat pumps and refrigeration machines in the Netherlands. An important asset of this organisation is the national and international knowledge exchange. The platform has made a status review of sorption technology in the Netherlands, as well as an overview of reports and research results since 1990. This overview will be expanded with the summaries of the most important reports. All this information will be made available in several ways, including the Internet. The platform was initiated by Novem (the Netherlands Organisation for Energy and the Environment) and is coordinated by GASTEC, the research organisation for the Dutch gas utilities. Other participants are ECN, De Beijer RTB, Gasunie, TNO-MEP, Delft University of Technology, Colibri, HoST and Nefit Fasto.

Source: Dutch National Team.



# IEA HPP 1997 annual report published

All International Energy Agency (IEA) Implementing Agreements operate for a fixed period as determined by the Governing Board of the Agency. For the Implementing Agreement on Heat Pumping Technologies, 1997 marked the final year of its current five-year operating period. The governing board approved the extension of the programme for a new period.

Readers can learn more about the progress made by the IEA Heat Pump Programme in its 1997 annual report. This report highlights the main activities undertaken by the Heat Pump Programme during 1997, and provides an overview of the achievements of each ongoing Annex. Contact the Heat Pump Centre for a copy (Order No. HPP-1997).

Contact: IEA Heat Pump Centre

# Ongoing Annexes

Red text indicates Operating Agent. Japan is the Co-operating Agent of Annex 18.

| Annex | Participants |
|---|---|
| **Annex 16**<br>IEA Heat Pump Centre | AT, ES, JP, NL, NO, CH, US |
| **Annex 18**<br>Thermophysical Properties of Environmentally Acceptable Refrigerants | CA, DE, JP, SE, UK, US |
| **Annex 22**<br>Compression Systems with Natural Working Fluids | CA, DK, JP, NL, NO, CH, UK, US |
| **Annex 23**<br>Heat Pump Systems for Single-Room Applications | CA, FR, CH, US, SE |
| **Annex 24**<br>Ab-Sorption Machines for Heating and Cooling in Future Energy Systems | CA, IT, JP, NL, SE, UK, US |

IEA Heat Pump Programme participating countries: Austria (AT), Belgium (BE), Canada (CA), Denmark (DK), France (FR), Germany (DE), Italy (IT), Japan (JP), The Netherlands (NL), Norway (NO), Spain (ES), Sweden (SE), Switzerland (CH), United Kingdom (UK), United States (US).

# Underground thermal energy storage with heat pumps

## An international overview

*Burkhard Sanner, Germany and Bo Nordell, Sweden*

The technology of underground thermal energy storage (UTES) has evolved considerably over the past 25 years. This article reviews this development and summarises the latest technologies and current trends for UTES with heat pumps. UTES is widely used for cold storage and combined cold and heat storage, particularly in Sweden, Canada and the Benelux countries (i.e. Belgium, the Netherlands and Luxembourg). Some new applications are also discussed: industrial process cooling, road de-icing, heat and cold supply at petrol stations, etc. Heat pumps frequently form an integral part of these applications. In addition to this overview, the topical articles found in this issue of the IEA Heat Pump Centre Newsletter give more detail of applied techniques, and present examples from various countries.

It was the French physicist and chemist Lavoisier, who installed a thermometer in the deep vaults beneath the Paris Observatory in the 17th century and proved the constant temperatures at approximately 20 m below street level. Many years later, in 1778, Buffon published observations with that thermometer, and Humboldt noted in 1799 a mean temperature of 12°C with annual variation of not more than 0.024°C in the Paris underground. In the 19th century, many more measurements followed, the most notable those at the Royal Observatory in Edinburgh, UK. The decrease of seasonal temperature variations with depth and the constant temperatures in the subsurface had been demonstrated.

▼ *Offices with aquifer storage and heat pumps at Scarborough Centre, Toronto, Canada.*

Since ancient times, people have known how to make use of the earth's thermal storage capacity to keep food fresh in pits or caves, or to build houses underground in areas with intemperate climates, achieving warmth in winter and coolness in summer. Until the first decades of the 20th century, most breweries in Europe used ice cellars, where blocks of ice from winter were stored below ground level to allow cooling during the summer months. The upcoming refrigeration technology put an end to this tradition, and today artificial cooling has become standard. However, older farm houses still have a cellar to store apples and potatoes, and the most intriguing use of natural subsurface storage has a long tradition and a bright future in the vaults of vineyards and chateaux.

### Historical development

Technical underground thermal energy storage has a 30-year history, which began with cold storage in aquifers in China. Outside China, the idea of UTES started with more theoretical work in the early 1970s. Kazmann (1971) describes various uses of aquifers and states after dealing with heat pumps: "This would utilise the aquifer for the storage of heat on a cyclic basis and would improve the thermodynamic efficiency of the process by salvaging waste heat".

In the 1980s interest in UTES skyrocketed, and several pilot and demonstration plants were built, in combination with solar thermal energy, with waste heat or heat pumps. **Table 1** lists some important examples. Some of the plants listed were purely experimental, others operated successfully for some years and a few are still in use today. The temperature level ranged from around 0°C to more than 150°C in some experiments.

### Classification

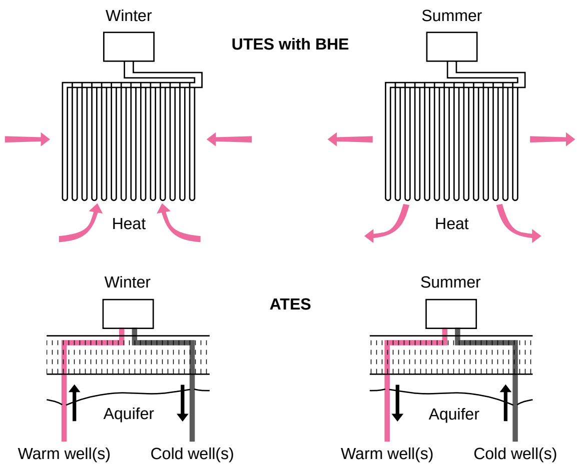
UTES systems can be classified according to:

- storage temperature (low or high);
- storage purpose (heating, cooling, or combined heating and cooling);
- storage technology (open/aquifer, closed/boreholes, or other techniques such as caverns);
- application (residential, commercial, industrial).

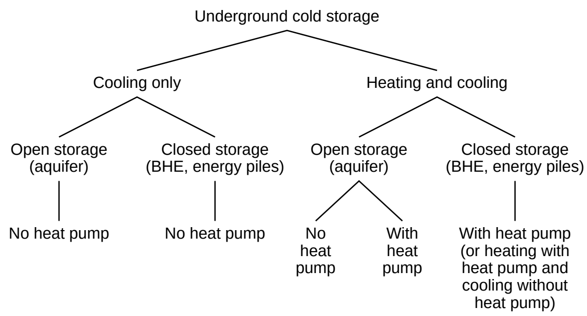
The two basic types of storage technology are shown in **Figure 1**: aquifer thermal storage (ATES) and UTES with borehole heat exchangers (BHE). For ATES, two concepts are possible:

- alternating the flow for loading and

▼ *Figure 1: Layout or UTES with BHE and ATES.*




▼ *Figure 2: Realised underground cold storage alternatives.*




unloading the store, thus exchanging production and injection wells and creating 'warm' wells and 'cold' wells (see the lower part of Figure 1); or

- a continuous flow in one direction, with varying temperatures at the injection well and mean temperatures at the production well. This is used for cooling applications.

## UTES and heat pumps

'Low-temperature UTES' means that storage temperatures range from around 0°C to a maximum of 40-50°C. The technology comprises thermal energy storage for cooling, combined heating and cooling, and low-temperature heating (e.g. as heat source for heat pumps). The boundary between this type of storage and mere ground-source heat pumps (GSHP) is vague. Large GSHP installations with a central borehole- or well-field are in fact special types of UTES plants. To be considered a UTES system in this overview, a GSHP system should have a heat dissipation to (or extraction from) the surrounding ground of no more than 25% of the annual thermal energy turnover. UTES exhibits substantial environmental advantages in reducing greenhouse gases and noxious emissions.

*Cold storage* systems with heat pumps were already described in the IEA Heat Pump Centre Newsletter in 1992. **Figure 2** shows the various alternatives of underground cold storage. These systems always substitute chillers which, compared to thermal storage, have a relatively high energy demand to drive compressors or absorption cycles.

When using heat pumps in combination with underground cold storage, three operation modes are possible (see **Figure 3**). They use either modes one and two (direct cooling only), mode one and three (cooling with heat pump only), or all three modes (direct cooling in spring and during low demand, cooling by heat pump in summer or during peak demand).

Underground *heat storage* in the temperature range below 40°C is usually done to increase the heat-source temperature of heat pumps. Charging the storage can be done by surface water, solar collectors, pipes below paved surfaces, hot air in glassed spaces, low-temperature waste heat, or by other sources. High-temperature

▼ *Table 1: Milestones of UTES development and realisation (the first year of operation is listed).*

| Year | Name | Remarks |
|---|---|---|
| since mid 1960s | several huge ATES plants in China | (Shanghai, Changzou) |
| 1976 | Auburn Univ., Mobile Al., USA | Aquifer experiment, abandoned |
| 1981 | "Sunclay", school, Kungsbacka, SE | BHE, solar coll., diesel engine heat pumps |
| 1981 | 12 houses, Cortaillod, CH | BHE, solar collectors, heat pump |
| 1982 | "SPEOS", Lausanne-Dorigny, CH | ATES experiment, waste heat, abandoned |
| 1982 | Yamagata Univ., Yonezawa, JAP | ATES experiment |
| 1982 | Waste Incineration, Hørsholm, DK | High temp. ATES experiment, abandoned |
| 1982 | Univ. Minnesota, St. Paul, USA | High temp. ATES experiment, abandoned |
| 1982 | Hokkaido Rehabily, Sapporo, JAP | ATES, heat storage |
| 1982 | Univ. Alabama, Tuscaloosa, USA | ATES, cooling |
| 1983 | Lulevärme, Luleå, SE | Boreholes, high temp., operat. suspended |
| 1983 | 224 flats, Aulnay-sous-bois, FR | ATES, with heat pumps |
| 1984 | CSHPSS, Groningen, NL | BHE, solar heat |
| 1985 | Scarborough Centre, Toronto, CAN | ATES, heating and cooling, heat pumps |
| 1987 | Le Plaisir, Thiverval-Grignon, FR | High temp. ATES experiment, abandoned |
| 1987 | Head Office SAS, Frösundavik, S | ATES, heating and cooling, heat pumps |
| 1987 | Perscombinatie, Amsterdam, NL | ATES, cooling |
| 1989 | Jean Sieber SA, Geneva-Meyrin, CH | BHE, solar coll., gas-engine heat pump |
| 1991 | Utrecht Univ., Utrecht, NL | High Temperature ATES, waste heat |

ATES: Aquifer Thermal Energy Storage
BHE: Borehole Heat Exchangers

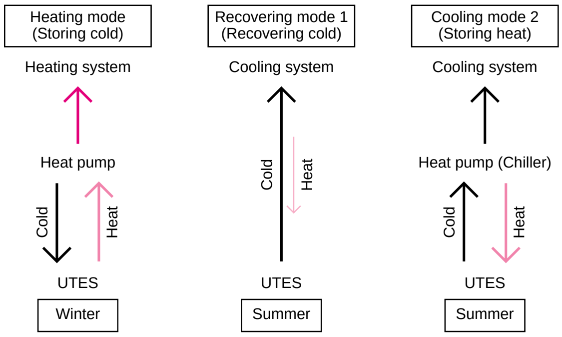



*Figure 3: Operational modes of cold storage UTES with heat pumps.*

UTES systems have storage temperatures above 40 to 50°C. Typical heat sources are solar collectors or waste heat. Various system layouts are possible. Heat pumps are either used at the end of the storage unloading period, when temperatures drop, or for achieving higher supply temperatures. With increasing temperatures, hydrochemical, biological and geotechnical problems increase. Experiments with supply temperatures above 100°C were not successful. Methods for water treatment have been developed for high-temperature ATES, but further work is required. The new Annex 12 of the IEA programme on Energy Conservation through Energy Storage (IEA ECES) addresses the specific problems of high-temperature UTES.

## International trends

Seasonal cold storage is now commercialised in some countries. A recent database made under IEA ECES Annex 7 lists approximately 90 realised projects in the four participating countries (Canada, Germany, the Netherlands, Sweden). Forty of these projects include heat pumps. The total cooling capacity is estimated at 95 GW. In Switzerland and the USA, other projects have been implemented. The size and capacity of cold storage UTES varies widely. A trend towards very large systems can be seen. The district cooling system under construction in Malmö, Sweden, with a capacity of around 10 MW is an example.

Many large capacity GSHP systems built in North America that provide heating and cooling, are UTES installations according to the definition given above. Large central BHE fields ("well-fields") do not have enough interface with the surrounding ground or the ground surface to extract the majority of heat from the area outside the storage volume, or to dissipate a large percentage of the heat to that area. Many of the commercial GSHP installations in the US fall into this category. The database of the Geothermal Heat Pump Consortium in Washington (see p. 22) currently documents over 1,200 commercial GSHP installations.

Regional market penetration of UTES is increasing. The first UTES with heat pump was realised at the Australian Geological Survey, using some 350 borehole heat exchangers 100 m deep and heat pumps. In Poland a group has been formed to study possible UTES applications. Similar activities are taking place in Korea, Indonesia, and Greece. Opportunities for UTES can be found in the Mediterranean region: a feasibility study for Turkey was conducted by IEA Energy Storage Annex 8, and plans for a similar study for Egypt are under consideration. A plan for a cold storage plant for the Çukurova University teaching hospital in Adana, Turkey has been prepared. In a warmer climate it may be difficult to find a cold source for charging the store; in Adana this is provided by the Seyhan river, which brings cold water from the Taurus mountains to the Çukurova lowland in the spring.

Another trend is the use of a single UTES design in series of similar applications, such as a chain of petrol stations, shops, or telecommunication stations. Most interesting are petrol stations in the USA, where borehole heat exchangers are applied to store heat from space cooling, refrigeration, ice-making, etc. and to extract heat by heat pumps for space heating, water heating for car washing, de-icing the car wash area, etc. In February 1998 the Geothermal Heat Pump Consortium documented 11 petrol stations of three oil retail companies that use this system.

## R&D within the IEA

The development of UTES was strongly supported by IEA cooperation, as **Table 2** shows. Today Annex 8 (Energy Storage) is the focal point for all activities related to UTES (see box on the Annex organisation and participants), and new

*Table 2 IEA-Annexes dealing with UTES or related technologies*

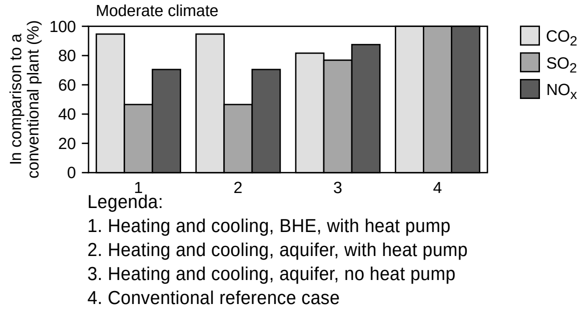
| | |
|---|---|
| **Renewable Energy Working Party**: | |
| *IA Solar Heating and Cooling* | |
| Task 7: | Central Solar Heating Plants with Seasonal Storage (closed) |
| **Energy End Use Working Party**: | |
| *IA Heat Pumping Technologies* | |
| Annex 2: | Development of a Vertical Earth Heat Pump System (closed) |
| Annex 8: | Advanced In-Ground Heat Exchange Technology for Heat Pumps (closed) |
| *IA Energy Conservation through Energy Storage* | |
| Annex 1: | Large Scale Thermal Storage Systems Evaluation (closed) |
| Annex 3: | ATES-plant SPEOS, Lausanne-Dorigny, Switzerland, and other activities (closed) |
| Annex 6: | Environmental and Chemical Impact of Water Treatment for Aquifer Storage (closed) |
| Annex 7: | Innovative and Cost-Effective Seasonal Cold Storage Applications (closed) |
| Annex 8: | Implementing Underground Thermal Energy Storage Systems (ongoing) |
| Annex 12: | High Temperature UTES (ongoing) |
| Annex 13: | Design, Construction and Maintenance of UTES wells and boreholes ongoing) |
| Annex 14: | Low Temperature UTES (in preparation) |

Annexes aimed at developing specific technologies have just been launched. The regular training activities in Annex 8 include seminars for engineers and architects in combination with experts meetings. The first software course for modelling UTES systems was given in March 1998 following the Geothermal Heat Pump Conference at Richard Stockton College, USA. Educational material, such as overhead sheets, is currently being prepared and will be available from the Annex Internet site.

In ECES Annex 7, a report concerning cold storage UTES was written in 1992 (PWC, 1992), and a state-of-the-art report on all UTES in ECES Annex 8 was compiled in 1994 (Bahema et. al., 1995). A system analysis using a theoretical building and various scenarios was carried out in ECES Annex 7 in 1993, to select the most promising cold storage concepts. Environmental aspects were also considered (see **Figure 4**). The highest $CO_2$ reductions can be achieved without a heat pump, but in that case the level of $SO_2$ emissions is relatively high due to the oil consumed in the heating system. With heat pumps, most of the fuel oil for heating is replaced by electricity, resulting in lower $SO_2$ emissions. This calculation was made for an electricity generation mix containing 65% fossil fuels (coal and oil), and thus $CO_2$ emissions are only reduced by approximately 10%. For other mixes with less $CO_2$ generation from electricity production (e.g. like in Sweden or Switzerland), the emission reductions would be much higher.

▼ *Headquarters of SAS airline, Solna Sweden.*

▶ *Figure 4: Emissions of $CO_2$, $SO_2$ and $NO_x$ in a new building (theoretical system analysis) compared to a conventional cold storage plant (= 100%).*




## UTES without heat pumps

Except for the UTES applications with heat pumps described above, a short impression of the opportunities of UTES applications without heat pumps should be given here. These applications either use high-temperature solar heat or waste heat and retrieve heat from the ground at temperatures that are high enough for direct heating, or they use low temperatures for cooling purposes.

Solar heating at high temperature levels was investigated in the project on central solar heating plants with seasonal storage. Several demonstration plants were built in the 1980s (Dalenbäck, 1990). New installations are planned or under construction, e.g. the BHE-storage in Neckarsulm-Amorbach, Germany, where solar collectors will provide heat that is stored for use in a small district heating system in wintertime. A pilot plant consisting of 36 BHE has been operational since autumn 1997 to verify the theoretical simulations before proceeding with the large store.

*Cold storage* without heat pumps or chillers has some advantages (for example higher $CO_2$ emissions reduction, see **Figure 4**). It is best used with aquifers, and operational experiences are rather good. A combination of BHE and cooling without chillers or storage is achieved in TELIA's telecommunica-tions stations in Sweden. There are 1,200 stations of which 120, during this initial stage, will be cooled directly by boreholes drilled into crystalline bedrock. So far, some 10 plants with a cooling load of 20-200 kW have been built using 4-60 boreholes, each 150-200 m deep. Another interesting application is the cooling of TerraCom's 56 ground-based TV stations which have a continuous cooling load of 120 kW. In this case the water-cooled TV transmitters accept a temperature of 40°C, which means that approximately 24 boreholes/station will be adequate.

A recent development is the use of UTES for de-icing roads. After an early test in combination with an ATES plant in 1983 in Japan (Yamagata University), the development continued around 1992 with several smaller applications realised in Japan and a demonstration system on a bridge in Därligen, Switzerland. The solar radiation onto the road surface is used as heat source for a heat store. In Därligen, peak temperatures of 60°C were found in the pavement, and supply temperatures to the store of up to 35°C were measured. The plant in Därligen was carefully monitored and operated successfully throughout the winters since autumn 1994. The latest example is a motorway bridge in Amarillo, Texas. A heat pump keeps one of the traffic lanes ice-free, to compare it with direct heating. In particular, for bridges in cold regions, UTES may be an environmentally benign alternative to de-icing. Other applications are also being studied, e.g. airport runways or sports stadiums.

## Outlook

The development of UTES in the near future is expected to include the following aspects:

- a rapidly increasing number of cold storage or heat/cold storage plants, with heat pumps for all storage types (as well as without heat pumps if an aquifer is available). The development in the Netherlands, with 50 aquifer cold storage plants, a growth rate of 10-20 projects each year and an increasing use of heat pumps in smaller aquifer stores, may be experienced in other countries too;
- a growing number of new applications, e.g. de-icing of roads or runways, will be realised;
- a new trend towards higher storage temperatures can be seen, resulting in a number of demonstration plants and accompanied by further R&D to solve specific high-temperature problems.

In many UTES systems the heat pump is and will continue to be the key factor to successful operation. Improvement in heat pump technology can make UTES more efficient, and better UTES systems can provide an optimum environment for beneficial heat pump operation.

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The topical articles in this issue have been prepared in cooperation with Annex 8 'Implementing Underground Thermal Energy Storage Systems' of the IEA Implementing Agreement on Energy Conservation through Energy Storage (ECES). In this Annex implementation of UTES systems is achieved through various activities, mainly collection, evaluation and dissemination of information. The Annex issued a state-of-the-art-report for 1994, UTES potential studies for some countries, and a design software evaluation. Seminars to the industry are regularly organised in conjunction with expert's meetings. The first computer workshop was held in March 1998. An inventory of project case studies is being prepared.

The participating countries and national teams are:

| | |
|---|---|
| Belgium | • Vlaamse Instelling voor Technologisch Onderzoek VITO, attn Dr Paul Dirven, Boeretang 200, B-2400 Mol |
| Canada | • Environment Canada, attn. Mr Frank Cruickshanks, 45 Alderney Drive, Dartmouth, Nova Scotia B2Y 2N6 |
| Germany | • Justus-Liebig-University, Institute of Applied Geosciences, attn Dr Burkhard Sanner, Diezstrasse 15, D-35390 Giessen<br>• Technical University of Munich, Landtechnik Weihenstephan attn Mr Manfred Reuss, Voettinger Str. 36, D-85354 Freising<br>• Stuttgart University Institute of Thermodynamics and Heat Technology attn Mr Seiwald, Pfaffenwaldring 6, D-70568 Stuttgart |
| Japan | • Hokkaido University, Dept. Environmental Engineering, attn Prof. Kiyoshi Ochifuji, N13-W8, Kita-ku, Sapporo |
| Sweden | • Luleå University of Technology, Water Resources Engineering, attn Dr Bo Nordell, S-97187 Luleå<br>• Lund University of Technology, Dept. Mathematical Physics, attn Dr Göran Hellström, PO Box 118, S-22100 Lund<br>• VBB VIAK AB, attn Dr Olof Andersson, Geijersgatan 8, S-21618 Malmö |
| The Netherlands | • IF Technology, attn Mr Guido Bakema, PO Box 605, NL-6800 EA Arnhem |
| Turkey | • Çukurova University, Chemistry Department, attn Dr Halime Paksoy, TR-01330 Adana |
| USA | • Richard Stockton College of New Jersey, Natural Sciences, attn Dr Lynn Stiles, Route 575, Pomona NJ 08240 |

If you wish to learn more about the work of this Annex, please visit our Internet site (http://www.sb.luth.se/vatten/projects/iea/a8.html)

**Literature**

Bakema, G., Snijders, A. & Nordell, B. (eds.); *Underground Thermal Energy Storage*, State of the Art 1994; pp 83; IEA ECES Annex 8, IF Technology, Arnhem, the Netherlands; 1995.

Dalenbäck, J.-O. (ed.); *Central solar heating plants with seasonal storage, status report*.; pp 105; SCBR D14; Stockholm, Sweden; 1990.

Kazmann, R.G.; *Exotic Uses of Aquifers*. ; J. Irrig. Drain. Div., ASCE, 97/IR3; pp 515-522; New York, USA; 1971.

Morofsky, E.; *Seasonal cold storage building and process applications: a standard design option?*; Proc. 7th Int. Conf. Energy Storage Megastock 97; pp. 1009-1014; Sapporo, Japan; 1997.

PWC; *Innovative and Cost-Effective Seasonal Cold Storage Applications, Summary of national state of the art reviews*; pp 40; IEA ECES Annex 7, Public Works Canada, Ottawa; 1992.

Sanner, B. & Chant, V.G.; *Seasonal Cold Storage in the Ground using Heat Pumps*; Newsletter IEA Heat Pump Centre 10/1; pp. 4-7; Sittard, the Netherlands; 1992.

# ATES and ground-source heat pumps in the Netherlands

*Guido Bakema and Aart Snijders, The Netherlands*

In the last twenty years aquifer thermal energy storage (ATES) and heat pump technology have been developed independently. However, the combination of these technologies has recently shown good prospects in offices and commercial buildings. One of the projects where heating and cooling is provided by ATES and a heat pump is a new multipurpose soccer stadium (Gelredome) in Arnhem, the Netherlands. The stadium is equipped with several other novel facilities such as a mobile playing field, solar collectors and a sliding roof.

This article describes the developments in the Netherlands and gives more details on the application in Arnhem.

## Thermal storage

The development of ATES in the Netherlands started in the early 1980s. Initially, seasonal heat storage was considered a suitable method for storing solar energy to be used for space heating in winter. It soon became apparent that seasonal storage in aquifers is also very useful for storing waste heat and cold. During the second half of the decade the first projects of thermal energy storage in aquifers were realised. The projects included the storage of solar energy for an office block (30°C), storage of winter cold for a printing industry (6°C) and storage of waste heat from a cogeneration installation for a university building (90°C). Better understanding of the economic aspects and environmental advantages of ATES, plus the success of the first projects, resulted in rapid development of energy storage technology early in the 1990s.

Nowadays, 60 storage projects have been realised or are in progress (see **Figure 1**), of which 90% provide cold storage or the combination of cold storage and low-temperature heat storage. Approximately 80% of the applications are found in the building sector, mainly office blocks, hospitals and shopping centres. The remaining applications are for industrial cooling and cooling in the agricultural sector. A relatively small number of cold storage projects use a heat pump.

## Economic aspects

Payback periods for the use of cold storage or combined heat and cold storage in the building sector are favourable. The simple payback period of 50% is less than five years, whereas 90% are less then ten years. This is explained by the fact that traditionally the cooling in this sector was achieved by compression chillers. The investment costs for these machines are avoided by using cold storage and balancing the investment costs for a cold storage system. In several cases, the investment required for cold storage appears to be even lower than for chillers.

Cold storage as well as combined cold and heat storage use natural energy in the form of heat or cold. Utilising this energy source therefore requires only a limited amount of auxiliary energy (for submersible pumps etc.). For this reason, cold storage can be considered a renewable energy technology, the use of which is encouraged by the Dutch government. The potential contribution from cold storage to the energy production in the Netherlands in the year 2020 has been stipulated in the Third Energy Review by the Ministry of Economic Affairs. The annual contribution is estimated at 15 PJ, which corresponds to approximately 500 million m$^3$ of natural gas savings per year.

## Success factors

The main reasons for the success of ATES on the Dutch market are:

- aquifers are available under every major city;
- the government has responded positively towards ATES, by subsidising feasibility and market studies;
- the relatively high price of electricity compared to natural gas;
- the increasing environmental consciousness of private companies;
- the prohibition of CFCs;
- the positive attitude of licensing authorities.

*Figure 1: Status of ATES projects in the Netherlands.*

At present, cold-energy storage is considered a proven technology. In the years to come, the number of cold-storage projects will increase further, partly because of an increasing environmental awareness. The expected growth rate is between 20 and 30 new projects per year.

## Ground-source heat pumps

Since the discovery in 1960 of one of the world's largest natural gas fields, space and water heating in the Netherlands is mainly obtained via gas-fired boilers. Recently, however, the monopoly of natural gas been threatened by the re-introduction of electric heat pumps.

Several reasons can be mentioned for the renewed interest in heat pumps. First of all, technological developments have brought about improvements in the efficiency of heat pumps. Secondly, the newest power plants generate electricity with an increased efficiency up to a remarkable 56%. Furthermore, for electric power utilities heat pump technology can be a way to strengthen their control of the heating market, which to date mainly meant control of the gas industry. Finally, in its attempts to maximise the efficient use of non-renewable energy sources, the government is also interested in heat pumps. The electricity utilities expect approximately 200,000 heat pumps to be installed by the year 2005 in new houses in the Netherlands.

## Use of ground water

Heat can be extracted from the subsoil using ground water or ground heat exchangers. In the Netherlands, 95% of the shallow subsoil (<200 m below surface level) consists of aquifers. It is relatively easy and inexpensive to extract ground water from these layers. Because of its relatively high temperature (approximately 11-12°C), this ground water makes an excellent heat source for a heat pump. Ground water systems are also more economic than ground heat exchangers, except for small systems (<100 $kW_{th}$).

The cheapest way of using ground water is to discharge it into the sewer after it has been used by the heat pump. However, the Dutch government does not grant licences for such systems, mainly because good quality ground water is relatively scarce. Re-injection of ground water dispels the authorities' main objection. To achieve "sustainable utilisation" of ground water (i.e. present utilisation should not form a barrier to future utilisation) restoration of the thermal equilibrium in the subsoil is preferred. For a ground water heat pump system, this can be achieved by extracting ground water from the extraction well in summer and heating it using outside air (dry heaters), the sun (solar collectors), surface water or surplus heat from buildings. The warmed ground water is then re-injected into the subsoil where it mixes with the cold ground water from the previous winter season. However, a better way to restore the thermal balance in the subsoil is to utilise the cold energy which is injected in winter in a combined ATES and heat pump system.

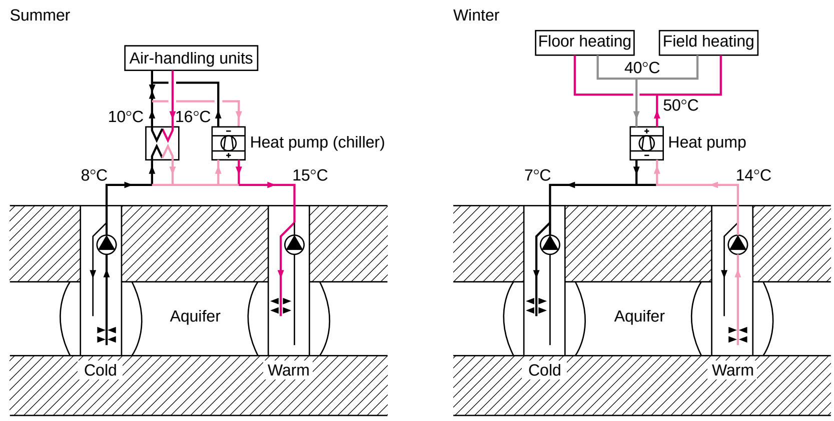
A heat pump with a coefficient of performance (COP) of 3-4 uses less energy than a gas-fired boiler with 90% efficiency. The overall COP may be adversely affected, if warm tap water is prepared by the heat pump. In addition to energy efficiency, the success of heat pumps will largely depend on the connection to the subsoil. If contractors and heat pump suppliers have inadequate knowledge of the hydrological and thermal behaviour of the subsoil, there is a risk that poorly functioning systems are built. For the moment, research into systems with ground water source heat pumps, as well as the realisation of such systems, will continue in the Netherlands. In a few year's time results will show whether these systems really contribute to a sustainable energy supply.

## Heat pumps and ATES

The Gelredome stadium is one of the projects using a combination of ATES and heat pump. The Gelredome stadium - a USD 70 million project - will

▼ *Figure 2: Photo of the Gelredome stadium - installation of ATES.*

▼ *Figure 3: Energy storage with heat pump at Gelredome.*




accommodate 27,000 spectators (see **Figure 2**). Apart from soccer matches other sporting events and concerts will take place in the stadium. In winter, the soccer pitch and base floor will need heating, while in summer the stadium will need cooling for offices and congress facilities.

In winter, the heat pump (with a heating capacity of 410 kW) will supply 70% of the required heat. The remainder is provided by a gas-fired boiler. Ground water is used as the heat source for the heat pump and is extracted via two wells (see **Figure 3**). Once the ground water has given off its heat, it is re-injected into the subsoil via a cold well. In summer, cold is supplied either directly (without heat pump) or indirectly (with heat pump). The cold-storage system can provide a direct cooling capacity of approximately 2,800 kW. This is achieved by extracting ground water at a rate of 0.069 $m^3/s$ from the cold well and, after supplying its cold energy via the air-handling unit, injecting it into the warm wells.

Under very extreme summer weather conditions, the stadium may demand an extra 10% more cold energy. In this case, the heat pump (which is connected to the supply line of the air handling unit) will be used as a chiller, the condenser of which is also cooled by the cold storage. It should be noted that in summer this system supplies cold 95% of the time without using the heat pump. If the cold ground water was only used to cool the condenser of the chiller (heat pump), a considerable part of the energy saving that could be achieved with the system, would not be realised.

## Advantages

Compared with a conventional installation using chillers for cooling and a gas-fired boiler for heating, the combined system of energy storage with a heat pump results in a 45% energy saving. In summer, in cooling mode, the only energy consumer is the submersible pump in the cold well. The number of cold-storage systems with heat pumps is increasing. A major reason for this is that the supply temperature of the heating systems in modern office buildings is less than 50°C. Additionally, an important aspect is that the heat pump produces cold energy as a by-product of heating. With this cold energy the cold-storage system can be charged in a relatively simple way with low energy requirements. A further advantage is the fact that heat injected into the subsoil in summer, can improve the heat pump COP in winter. Finally, the heat pump has the option of serving as a chiller when there is insufficient cold-energy supply from the subsoil.

## Conclusion

ATES has proven to be a reliable and sustainable way of cooling and heating buildings and industrial processes. The ground water heat pump shows good prospects for heating in residential areas and commercial buildings. The combination of both systems has even more advantages. The system is especially suitable for situations where there is a balance between the heating and cooling demand. For the Netherlands, this means that a combined system of ground water heat pumps and ATES can be very suitable for commercial buildings and offices, but less feasible for residential buildings.

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# Underground thermal energy storage with absorption heat pumps

*Frank Kabus, Germany*

The new parliament buildings of the Federal Republic of Germany are being built in the centre of Berlin, along the River Spree surrounding the ‘Reichstag’, the old parliament building. The new buildings should be in use by the year 2000. The objective was to use the most environmentally friendly technology for the construction. To achieve this a cogeneration concept for producing power, heat and cold has been developed for the new buildings. Absorption heat pumps/chillers, driven by the hot water from the cogeneration plant, generate both heat and cold. An underground aquifer storage system for heat and cold has been incorporated to balance the temporary discrepancy between energy production and the end-use energy demand. This article describes the new installation.

## Energy supply

The overall energy demand of the complex is as follows:

- power: 8,600 kW (19,500 MWh/a);
- heat: 12,500 kW (16,000 MWh/a); and
- cold 6,200 kW (2,800 MWh/a).

The base load of electrical power is generated in block-type cogeneration plants. Eight machines, driven by esterified vegetable oil, generate the power according to the actual demand. The total electrical power generation capacity is 3,200 kW. The remaining electricity demand is met from the mains grid.

The heat demand is met by the cogeneration units plus additional peak load boilers. At a temperature level of 110°C, it is distributed by a central primary network to all consumers, where it supplies heat directly to a high-temperature network with supply/return temperatures of 90/60°C, as well as a low-temperature network with supply/return temperatures of 45/30°C. For cold distribution two separate networks are also used, with temperature levels of 16/19°C and 6/12°C respectively.

## Heat and cold storage

Since the heat and power demand curves of the systems are not synchronous, there is a temporary excess of heat produced by the cogeneration units (particularly in summer), but at other times, e.g. in winter, supply is insufficient. For this reason a system with seasonal storage of waste heat was chosen.

Approximately 300 m below the River Spree there is a sandstone layer, where pore spaces are filled with mineralised thermal water. This layer is 29 m thick and is separated from the top layers by a clay cover approximately 70 m thick. The hydraulic properties allow pumping off or reinjecting up to 100 $m^3$/h of brine. This brine-bearing aquifer is used for heat storage.

At a shallower level there are Quaternary/Tertiary water-bearing strata. The hydraulic conditions allow both the production and injection of 60 $m^3$/h through a well. For this project, an optimum flow rate of 300 $m^3$/h was identified, resulting in six warm and six cold wells, redundancy included. This is used as the cold store.

Three single-stage absorption heat pumps/chillers with cooling capacities of 850, 700 and 400 kW respectively are driven by the hot water from the cogeneration plant to generate low-temperature heat and cold. Each machine has access to the hot and cold store to be used either as heat source or for discharging waste heat.

▼ *Photo : Heat pump/chiller installation at the Reichstag building.*

Figure 1 : Heat flows in summer.

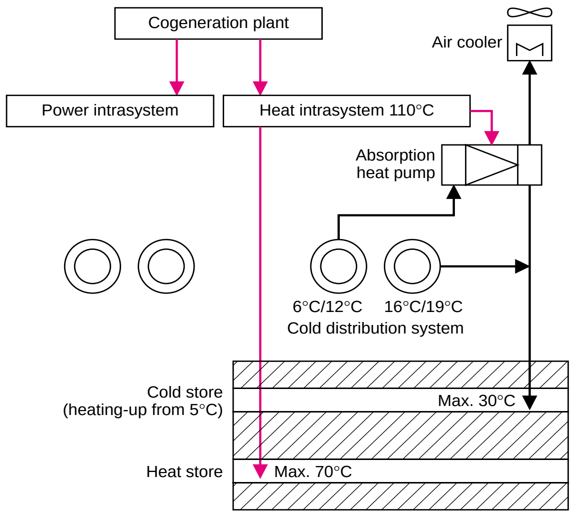
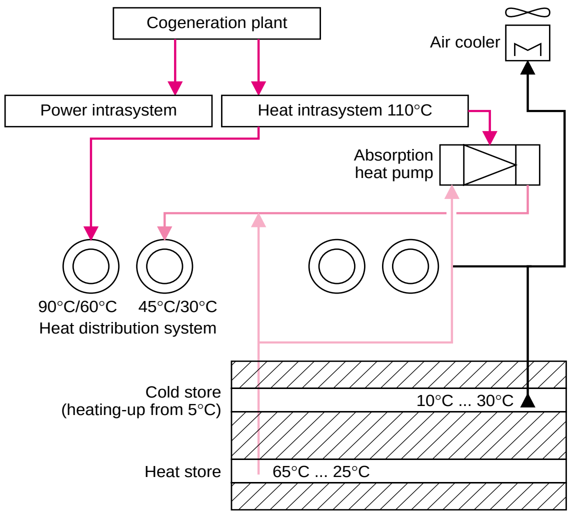



Figure 2 : Heat flows in winter.




## Charging and discharging

**Figure 1 and 2** show the two principle modes of operation for the integrated energy transmission system. The surplus heat produced by the cogeneration plants in summer is stored in the heat store. The store is charged with 70°C waste heat. In winter the heat is recovered at a temperature ranging from 65 to 25°C. A major share of the heat is supplied in direct heat exchange to the low-temperature heating systems. When the temperature in the aquifer drops, it is further cooled by absorption machines used as heat pumps, which transform the heat to a temperature of 45°C so that it can still be used in the low-temperature heating systems.

The cold store is used to cool the buildings. In winter, the water is cooled down to a minimum temperature of 5°C, primarily via cooling towers when the outside temperature is low. As previously stated, the store is also cooled down by the absorption machines during production of low-temperature heat.

## Cooling

The cold stored in winter is supplied in summer via heat exchangers to the ‘high-temperature’ (16/19°C) cooling system. The cooling demand is also provided with the chillers through the cold store. Initially, the water from the store gives off cold to the ‘high-temperature’ cooling network, and is therefore heated up to 17°C. It then gives off more cold (and is thus further heated to a maximum of 30°C) in the chillers. It is then returned to the store. In this way the heat source of the heat pumps is regenerated in the cold store for the following winter. The peak load total cooling demand is met by the chillers and the additional cooling towers.

Each of the underground thermal energy storage systems consists of two fields with one or more wells, which are drilled approximately 300 m apart, to avoid thermal interaction between the cold and warm wells. For storage in summer, water is pumped off from the cold side of the stores, charged with heat and supplied to the warm side. This means that the high temperature heat storage is charged with waste heat of the cogeneration units, and that the low temperature heat storage is charged with waste heat of the cooling systems and the chillers.

For discharge in winter, the direction of flow in the system concerned is reversed, i.e. water is pumped off from the warm side of the stores. After heat is extracted from the water it is supplied to the cold side. From the high temperature heat storage heat is extracted by direct heating or by the heat pump. From the low temperature heat storage heat is extracted by cooling towers or by heat pump.

## Emissions reduction

The equipment installed in the new parliament buildings supplies 82% of the required electricity and up to 90% of the annual heat demand (including the driving energy of the absorption machines) via the block-type cogeneration units that cover 37% of the electricity peak load. The cold store provides 60% of the cooling demand in summer. The expected result is a 20% reduction of $CO_2$ emissions compared to a conventional power-heat-cold cogeneration unit.

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# Heat pump supported ATES applications in Sweden

*Olof Andersson, Sweden*

Ever since the first oil crisis in the mid 1970s, ground water has been used as a source of energy for heat pump applications. Several thousands of such systems were installed until the mid 1980s. However, when oil prices dropped heat pumps became less popular. Meanwhile, a new development was taking place where aquifers were considered for storing thermal energy (ATES). Since these applications store heat at moderate temperatures, heat pumps are usually used to retrieve the energy from storage. In recent years this technology has become a very promising option for conservation of fossil fuels and efficient use of electricity.

Although each application is unique, heat pump supported ATES systems in Sweden can be divided into two types:

- seasonal storage of heat from surface water to be used as an energy source for the heat pumps (four plants);
- seasonal storage of waste heat and cold to be used for heating and cooling, supported by heat pumps (18 plants).

## System descriptions

The concept of a system of the first category is shown in **Figure 1**. These systems include three loops that are separated by heat exchangers. During the summer months the surface water loop transmits energy to both the heat pump loop and the ground water loop at temperature levels ranging from approximately 5-20°C. The aquifer is then reloaded with heat when the surface water temperature exceeds 10°C. During the winter months the surface water system is shut down and the stored energy in the aquifer becomes the single source of energy to the heat pump. The typical temperature of the ground water in the warm well is 10-14°C, though it is re-injected through the cold well at 3-4°C. The existing plants were all constructed during the late 1980s, mainly to reduce oil consumption. Most of them are large-scale systems which are connected to district heating systems.

The second category described above is the most common system. The principle is illustrated in **Figure 2**. These systems were designed to cover the cooling demand of the user. The system therefore replaces conventional cooling in separate buildings. On a larger scale it is used for district cooling or combined district heating and cooling. In winter the warm well in the aquifer serves as a source of energy to a heat pump supplying heat to a single building or a district heating system. During that process the ground water is chilled and this 'waste cold' is stored in the cold part of the aquifer. In summer, the cold ground water is used for space cooling. Consequently, the ground water is warmed up again and stored on the warm side of the aquifer.

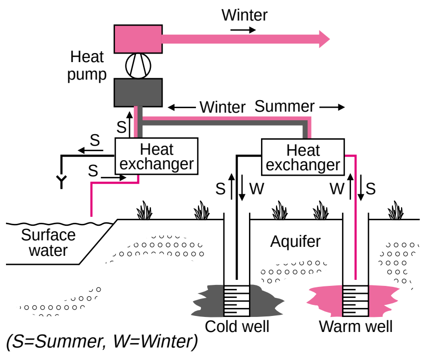
To cover peak cooling demands, the heat pump can be used as a supporting chiller, with the condenser heat being transferred to the ground water system through a second heat exchanger. The waste heat from air conditioning and excess heat from the condenser will be used the following winter. Typical ground water temperatures range from 5-7°C in the cold well of the aquifer and from 12-15°C in the warm well. However, using the heat pump as a chiller may increase the temperature in the warm well to a certain extent.

The existing plants range in cooling capacity from 50 to 2,500 kW. The most common size is 300-800 kW cooling capacity. These systems have been installed in a wide variety of applications mainly covering industries, offices and other commercial buildings.

## Technical experiences

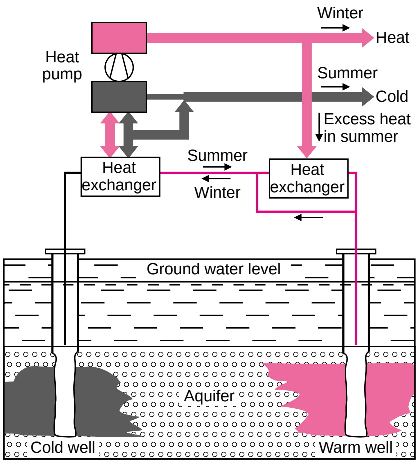
There are undoubtedly a number of potential failures that could occur in a complex system such as ATES with a heat pump. As far as the ground water side of the system is concerned, there

▼ *Figure 1: Layout for seasonal storage system using surface water.*




*(S=Summer, W=Winter)*

▼ *Figure 2: Layout for combined heating and cooling with a heat pump in the system.*




are a number of processes involved that might create operational disturbances, including hydrochemical-induced scaling, corrosion and well clogging. **Table 1** summarises technical failures that occurred in the existing installations and steps taken to solve these problems.

The information includes statistics from 18 plants for the period 1983-1996. With the exception of the abandoned plant the problems have been solved satisfactorily. Furthermore, technical mistakes made in the early stages of ATES development have been identified and could be avoided in later designs.

## Economic aspects

The calculated payback periods for the first seven ATES plants were around 3-4 years for combined heating and cooling systems, and 5-10 years for storage of heat only. Data taken from feasibility studies for the latest plants (built from 1993 onwards) show that these are all highly profitable. The data used in the marketing efforts for ATES technology are shown in **Table 2**. These are basically theoretical calculations which to some extent are supported by experiences from the newer existing plants. One example is an installation at a SAS (Scandinavian airlines) office where the system provided cooling and heating with an average system COP of 5.5 between the years 1989 and 1993.

▼ *Table 1: Technical problems and solutions.*

| **Description of problem** | **Measures taken** |
|---|---|
| Severe clogging of injection wells due to aeration and iron precipitation. | • Wells abandoned and replaced with infiltration pounds |
| Decreased well capacity down to 25% of the original capacity. | • Stimulation using airlifting and acid treatment, then construction of additional wells. |
| Clogging of wells and tubes due to iron precipitation caused by a mixture of oxidised and reduced ground water entering the well. | • Cure with in situ nitrate infiltration proposed but never realised. Plant eventually abandoned.<br>• The oxidised water entrance to the well was sealed off by a packer at another plant |
| Corrosion of pumps, tubes and fittings caused by high salinity and/or aeration. | • Change pump and tubes to a more corrosion resistant material.<br>• Change system to not allow aeration in the damaged well. |
| Initial control errors or difficulties due to a complex control technique. | • Two cases solved or improved by operational experience and minor reconstruction. |
| Biofouling and corrosion of heat-exchanger due to saline surface water. | • Corrosion solved by changing from stainless steel to titanium.<br>• Biofouling solved by better filtration and a permanent heat exchanger cleaning system. |
| Thermal breakthrough between warm and cold wells due to an unbalanced system and not enough distance between wells. | • Solved by drilling a new warm well at a safe distance from the cold well. |

▼ *Table 2: Data for new installations using ATES in Sweden.*

| Type of ATES | Coefficient of performance (COP) | Energy conservation* (%) | Simple payback* (years) |
|---|---|---|---|
| Heat pump supported heating and cooling | 5-6 | 80-85 | 1-3 |
| Heating only with heat pump in the system | 3-4 | 60-75 | 4-8 |

* Compared to conventional systems

## Environmental aspects

Special studies performed to assess the environmental aspects of underground thermal energy storage conclude that the main environmental impact is normally limited to a local temperature change within the aquifer and its immediate surroundings.

Many of the ATES projects are to some extent motivated by (expected) positive environmental effects. For example, cold storage applications will reduce the use of harmful refrigerants (CFCs) by replacing conventional chillers. This has been an important factor for most of the latest decisions on ATES applications. Furthermore, in at least two cases, reduced noise and a better indoor environment were reasons for choosing ATES installations. The most important benefit is the energy conservation that the systems provide, see **Table 2**. Reducing the consumption of fossil fuel and a more effective use of electricity will strongly contribute to a reduction of carbon dioxide, sulphur, and nitrogen oxide emissions.

## Conclusions

In Sweden, the most common ATES configuration is a heat pump supported heating and cooling system, which is mainly installed in offices and other commercial buildings. In recent years, there has also been increased interest in using this technology for district heating and cooling.

The most common technical problem encountered relates to hydrochemical processes resulting in well clogging and corrosion. Even if most problems have now been solved and knowledge has been gained from these mistakes, there is a further need for better understanding and preventive design methods within the field of well technology and water chemistry.

Economically most ATES concepts are compatible with conventional systems. This is mainly due to the fact that the COPs of the ATES systems are considerably higher and hence the conservation of energy costs will pay back the additional investment cost in a comparatively short period of time.

Experience indicates that no severe environmental impacts are to be expected. ATES systems would even be beneficial to the local and global environment due to their high potential for energy conservation. ATES' potential to reduce emissions of harmful gases such as CFCs, $CO_2$, $SO_X$ and $NO_X$ will be helpful in bringing this technology to a broader commercial market.

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# Underground thermal energy storage in the US

*Lynn Stiles, USA*

In the 1970s and early 1980s underground thermal energy storage (UTES) was already considered an interesting technology in the US, and several projects with aquifer thermal energy storage (ATES) were started. In the 1980s, interest waned and the budget available for UTES stimulation decreased. However, independent of these early efforts a quiet revolution was occurring. Ground-source heat pumps (GSHP) drew attention, being an efficient technology for heating and cooling. This brought new possibilities for another type of UTES system, namely underground thermal energy storage with borehole heat exchangers. This article highlights the developments concerning UTES in the US.

Four ATES pilot projects were realised as a result of the work carried out under the Energy Conservation Through Energy Storage Implementing Agreement in the late 1970s and early 1980s. The United States participates in this Agreement as well as in most of the Annexes related to underground thermal energy storage (UTES). The results include two projects in Alabama (Tuscaloosa and Auburn), one in New York (Melville, L.I.) and one in Minnesota (St. Paul). However, in later years interest in UTES declined, along with the budget from the US Department of Energy (DoE), and only two of these projects are currently in operation.

## GSHP systems

In the 1990s, single-family homeowners discovered ground-source heat pump systems as a means of providing efficient heating and cooling,

▼ *Aerial view of the Richard Stockton campus.*

particularly in the warmer regions of the US. GSHP systems dissipate heat and 'cold' in the ground. For small applications, the heat dissipation is a large percentage of the total energy turnover. This is different from larger well fields that store heat from season to season. In those fields dissipation of heat is small compared to storage over a six month period. Therefore, large single well fields for ground-source heat pump systems are, whether by design or not, in fact underground seasonal thermal energy storage systems. The growing interest in ground-source heat pumps induced a renewed interest in underground thermal energy storage. An example of such a system is presented later in this article.

## Consortium

The growing interest in GSHP was confirmed in 1993, when the US Environmental Protection Agency (EPA) issued a report 'Space conditioning: the next frontier' which concluded that GSHP systems are a current technology with the potential to significantly reduce greenhouse gas emissions in the near future. As a result of this report the EPA and DoE forged a partnership, the Earth Comfort Program, in which over 100 electric utilities and scores of commercial companies involved in ground-source heat pump systems are cooperating. This resulted in the establishment of the Geothermal Heat Pump Consortium in 1995 (ground-source heat pumps are also referred to as geothermal heat pumps in the US).

Nowadays, over 37 international associated institutions around the world and over 500 trade allies have joined this consortium. The single goal of the GHPC is to increase the installation rate tenfold within five years. This means that the consortium aims at an average growth of 58% per annum. In this way, ground-source heat pump systems would move out of a niche market and into the main marketplace. Although this objective is laudable, it appears that it will not be met. Nevertheless, the present increase is approximately 22% per annum, and over 1200 commercial and institutional applications have been identified to date.

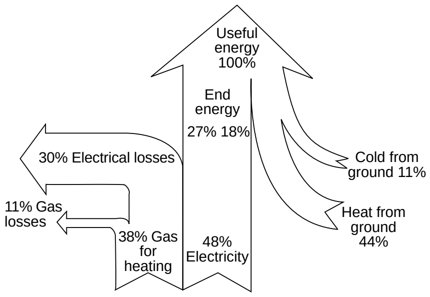
## Stockton College

The Richard Stockton College in New Jersey is an example of a large single well field that works as an underground thermal storage system. The system has been in operation since 1994.

It has the largest single BTES (borehole thermal energy storage) well field, encompassing over 1.2 million $m^3$. The borehole heat exchangers used are of the U-tube closed-loop type. Four hundred boreholes, with a depth of 135 m, are penetrating three aquifers within saturated sands and clays. It is calculated that less than 2% of the thermal energy stored during the first summer of operation moved outside the well field within six months.

In this case the heating, ventilation and air-conditioning system design (including heat pumps with a cooling

▼ *Figure 1: Energy flows for GSHP system at Stockton College.*




▼ *Table 1: Environmental Benefit of Stockton College Geothermal Installation.*

| | Reduced emissions (t/a) | Equivalent cars |
|---|---|---|
| $CO_2$ | 2,207 | 459 |
| $NO_X$ | 5.4 | 186 |
| $SO_X$ | 10.9 | 3,395 |

capacity of over 5,000 kW) does not balance the thermal load on the field as a well-designed UTES system should. The amount of heat stored in the field during the cooling season (1 April - 15 October) is about twice the amount of cold stored during the heating season (15 October - 31 March). It can therefore be concluded that the field is slowly heating up. The aquifers are moving heat away from the field so that it is not likely to overheat. In the original design it was decided that a cooling tower could be added later if there was too much heat accumulation (over approximately 6°C). Although the system at Stockton College is not an optimal design, over USD 300,000 per year have been saved by energy cost reductions. These cost savings result in a payback period (of additional investment cost compared with a retrofit with a conventional system) of 8 to 12 years. As shown in **Table 1**, the reduced electrical and natural gas demand results in substantial reductions of on- and off-site emissions. They are summarised in terms of taking the equivalent number of American cars off the road permanently.

**Figure 1** illustrates the energy flow from primary sources and the ground for the GSHP system at Richard Stockton College. This shows that only 86% of the heating and cooling comes from primary energy. The system relies on natural gas more than a standard design, so the percentage will be even lower for newer installations or those not using natural gas for part of the heat load.

## Optimisation

In the US, over a dozen BTES installations (using GSHP systems) have been identified from over 1,200 commercial and institutional installations on the GHPC list. However, these installations were not designed to optimise seasonal storage, i.e. like the Stockton project they were designed to rely on heat dissipation in the soil. There has not been any attempt yet to use the stored cold from the winter directly for cooling.

This is both bad news and good news. If ground-source heat pump systems are already financially attractive without optimisation using seasonal underground thermal energy storage, then better designs explicitly incorporating UTES hold great promise. However, in some large projects a choice has been made against ground-source heat pump systems because of a poor return on investment.

An important factor is the higher initial investment costs for ground-source heat pump systems compared to conventional systems. Bivalent systems could change the financial equation for GSHP systems, by bringing the initial costs down or increasing the savings. Bivalent systems use a ground-source heat pump as the base load and either a boiler or chiller (depending on whether the demand is dominated by heating or cooling) as a peak load unit. Several designers are using this approach. One disadvantage can be that a chiller is used during the summer at peak cooling demand times. A better system would use the potential for seasonal cold storage - running a cooling tower only during cold winter periods. Another option would be to preheat fresh air in the winter and store that cold for the summer.

## Other examples

Even though many large systems have not been optimised in the US there are still many success stories. Applications are as diverse as there are buildings, with installations in medical centres, schools, office buildings, and churches to mention just a few.

Recently a large hotel was built in Geneva, New York, using energy piles (foundation piles with heat exchanger coils), while there have also been several mini-mart (petrol, small market and car wash) applications. The food coolers produce heat all year round, and the car wash needs heat all year round. One study showed a payback period of less than 3 years for a new installation.

Another example is the Fort Polk project described in IEA Heat Pump Centre Newsletter Vol.16/01. This included a retrofit of 4,003 apartments, town houses and duplexes on a military base, that reduced the electricity demand by over 32% and lowered electrical peak demand by around 40%.

## Future role

In summary, GSHP systems, and as a consequence UTES, are well on the way to becoming a standard package to be considered for both new buildings and retrofits. It is a part of the national agenda to reduce $CO_2$ emissions, and as more experience with designing GSHP systems is available in the US, seasonal UTES will certainly play a larger role in the future.

To view a large list of applications, please visit the GHPC Internet site (http://www.ghpc.org), where information about membership, GHPC reports, etc. can also be found.

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# UTES with borehole heat exchangers in Central and Northern Europe

*Burkhard Sanner, Germany and Göran Hellström, Sweden*

Borehole heat exchangers (BHE) are technically the easiest way to obtain access to the earth as a thermal storage medium. Their use has several advantages, although a larger number of BHE are usually required to achieve the same heating or cooling capacity as a certain number of ATES (aquifer thermal energy storage) wells. Therefore the initial costs of BHE are higher. Preferably the possibility of using ATES at a specific site should be checked, and if this option is rejected, then BHE should be used. This article describes several applications in Central and Northern Europe which use heat pumps in combination with BHE for heating only, both heating and cooling, or cooling only.

For BHE technology pipes are inserted into boreholes or are driven directly into soft ground, and a heat carrier fluid is circulated through the pipes which extracts heat from, or rejects heat to, the surrounding ground. BHE do not require specific hydrogeologic situations in the underground layers. However, ground conditions do have an impact on the system layout. With BHE, no risks of insufficient ground water yield or adverse hydrochemical properties arise, and no well maintenance or water treatment is necessary.

The most common types of borehole heat exchangers (BHE) in Europe are U-tubes, usually made from plastic (polyethylen for relatively low temperatures), or simple tube-in-tube (coaxial) designs (see **Figure 1**). In crystalline rock with stable boreholes, open boreholes (tube-in-hole) can also exchange heat with the ground. The cross-section of this type of BHE is similar to the third type in Figure 1, but with the borehole wall replacing the outer tube. The type most common today is the double-U-tube, though single-U-tubes are also used, particularly in Northern Europe. Coaxial BHE are only used in a few cases.

## System types

**Table 1** lists examples of UTES plants with different heat sources, from early plants (1981) to recent installations. The systems can be grouped into three basic categories:

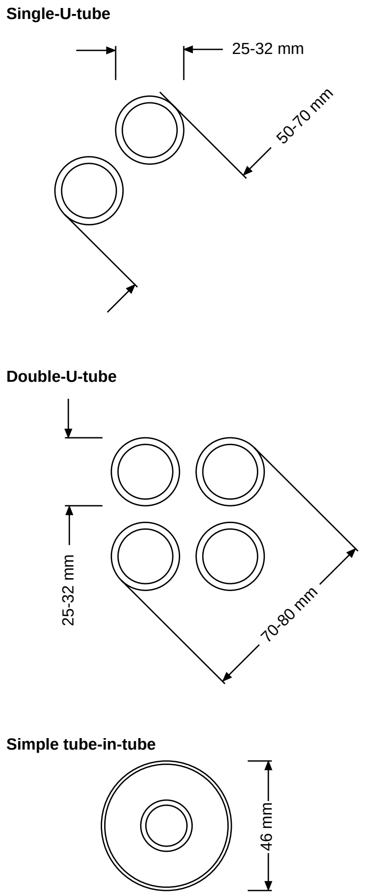
- heat pumps for heating only, with heat storage to increase source temperature or to assist in thermal recovery of the earth;
- heat pumps for both heating and cooling, using the underground layers as a heat store;
- systems for cooling only, with or without chillers to achieve certain temperature levels, and with cold storage in wintertime.

## Solar assisted

Several ‘solar assisted heat pumps with ground storage’ demonstration plants were built in the 1980s. In most cases the goal of these systems was not to achieve high temperatures in the ground, but to avoid, through artificial recharge a gradual decrease of ground temperatures. The results of these activities were not very promising in economic terms, because solar collectors were rather expensive and the ground heat exchanger (e.g. BHE) was not much cheaper than in conventional ground-source heat pump systems. Two ways to improve the economy were tested: cheaper ground coupling using short BHE, and simpler solar collectors.

*Cheaper ground coupling* was used in a few demonstration plants in Bavaria, where a simple auger drilling rig was mounted on agricultural equipment.

▼ *Figure 1: Typical cross-sections of borehole heat exchangers (BHE) used for UTES in Europe.*




Another attempt was made in Sweden with a device to push plastic single-U-tubes into soft clay. In 1997 a Dutch company presented a device for pushing plastic pipes into soft ground (see page 4).

*Table 1: Examples of UTES-plants with borehole heat exchangers (BHE) and heat pumps in Central and Northern Europe.*

| Year | Location | No. BHE | Depth (m) | Remarks |
|---|---|---|---|---|
| **Mainly heating, heat source solar collectors** | | | | |
| 1981 | Cortaillod, CH | 400 | | Houses |
| 1981 | Kungsbacka, SE | 612 | | School |
| 1982 | Kleinviecht, DE | 34 | 9 | Residence |
| 1982 | Treviglio, IT | 414 | 11 | 2 blocks of houses |
| 1983 | Kungsbacka, SE | 244 | 8-12 | Housing area |
| 1983 | Kerava, FI | 54 | >20 | 22 houses, additional water storage |
| 1983 | Musile di Piave, IT | 16 | 15 | Factory |
| 1988 | Donauwörth, DE | 103 | 10 | Office, workshop and house |
| 1989 | Geneva-Meyrin, CH | 258 | 15 | Factory and offices |
| 1997 | Schorfheide, DE | 15 | 32 | School |
| 1997 | Stuttgart, DE | 28 | 100 | Senior citizens housing |
| **Mainly heating, various other heat sources** | | | | |
| 1979 | Utby, SE | 37 | 10 | House, ambient air |
| 1985 | Hagsätra, SE | 25 | 80 | Sun court |
| 1987 | Söderköping, SE | 384 | 18 | School, ambient air |
| 1990 | Cortaillod, CH | 7 | 65 | Social centre |
| 1993 | Zermatt, CH | 18 | 40-95 | 13 apartments |
| 1995 | Storforsen, SE | 32 | 160 | Hotel, river water recharge |
| 1996 | Strömstad, SE | 20 | 130 | School |
| **Heating and cooling** | | | | |
| 1984 | Finspång, SE | 24 | 110 | Supermarket |
| 1985 | Finspång, SE | 120 | 120 | 750 apartments |
| 1987 | Gedern, DE | 4 | 50 | House |
| 1988 | Kristinehamn SE | 17 | 110 | Offices, apartments, |
| 1989 | Upplands Väsby, SE | 64 | 110 | Offices and hotel |
| 1990 | Düsseldorf, DE | 77 | 35 | Passive solar office |
| 1990 | Järfälla, SE | 20 | 110 | Shop, office |
| 1991 | Linden, DE | 4 | 50 | Office and workshop |
| 1992 | Rathenow, DE | 10 | 60 | Factory |
| 1992 | Wetzlar, DE | 8 | 80 | Laboratory |
| 1992 | KristinehamnSE | 15 | 110 | Shops, offices |
| 1993 | Kreuzlingen, CH | 93 | 12 | Factory, energy piles |
| 1994 | Wollerau, CH | 32 | 135 | Factory |
| 1995 | Cottbus, DE | 12 | 50 | Restaurant, environmental centre |
| 1995 | Grabs, CH | 570 | 14 | Factory, energy piles |
| 1996 | Sargans, CH | 100 | 20 | Factory, energy piles |
| 1996 | Mettmann, DE | 12 | 100 | Museum |
| 1996 | Tranås, SE | 8 | 170 | Factory, office |
| 1997 | Rosheim/Alsace, FR | 9 | 50 | Office and factory hall |
| **Cooling only** | | | | |
| 1999 | Frankfurt/Main, DE | 112/100 | 30 | High-rise office, energy piles |

In areas with sedimentary or igneous rock, the only way to install BHE is to drill a hole. Advanced drilling technology with down-the-hole hammers (DTH) and, in recent years, the G-hammer (a water-driven DTH), allowed substantial reductions in drilling costs.

## Applications

In some Swedish cases, warm ambient air or river water (in summer) are used for thermal recharge. An interesting approach, in combination with passive solar energy use, is the ‘Suncourt’ principle, for example in an apartment building in Stockholm, Sweden (**Figure 2**). The large glass-covered atrium acts as a solar collector in winter and keeps the surroundings warm, while throughout the summer the cold heat exchanger fluid from the BHE is heated by the warm air inside the atrium, preventing the atrium air from over-heating and restoring thermal equilibrium in the ground.

Heating up the subsurface to temperatures that are considerably higher than those of the surrounding ground only makes sense for large installations, where the relative heat losses are smaller. An example is the factory in Meyrin, Switzerland where 950 m$^2$ of solar collectors are installed on the roof of the building. They heat 258 BHE with double-U-tube and 15 m depth to a temperature of around 30°C in the centre of the store. Four hundred m$^2$ of the solar collectors mainly supply hot tap water, and supply heat to the ground only if no water needs to be heated. The heated ground acts as a heat source for a gas engine-driven heat pump with a heating capacity of 200 kW.

In the second plant, an information centre situated in a nature reserve area, the Schorfheide in Brandenburg, the solar collectors are much bigger in relation to the heat pump, and are effectively used to recharge the thermal capacity of the ground. A heat pump with 23 kW heating capacity is coupled to 15 BHE, each 32 m deep. A total of 110 m$^2$ of solar collectors heat the tap water and recharge the BHE with a maximum temperature of 40°C. There is no peak or backup heating system.

The prospects for solar energy storage in combination with heat pumps are unclear. The economic viability is still uncertain, as both methods require large investments. Without subsidies such systems can only be economically realised today in special cases. Examples are:

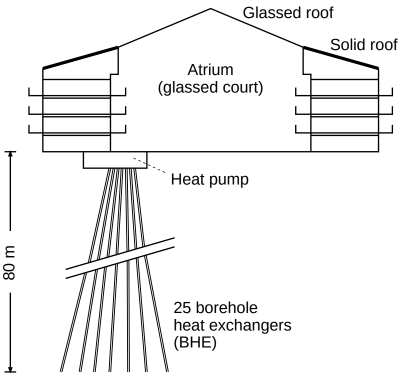
- Zermatt – with high elevation, a long heating season and a summer too short for recovery;
- Schorfheide – a nature reserve area where the building function is to promote environmental consciousnes.

However, primary energy savings can be higher with solar assisted systems than with simple ground-source heat pumps. This may cause a revival of this technology with currently increasing energy taxes etc.

## Heating and cooling

From an economic point of view, BHE combined with heat pumps are often viable even at current energy prices, if there is a heating and cooling demand.

*Figure 2: Schematic of Höstvetet building, Hagsätra/Stockholm, Sweden.*




For a UTES system, the double function of the ground (BHE) lowers the specific cost, and operational expenses are lower, especially if running a chiller in cooling mode can be avoided. A further advantage is the high reduction of emissions in cooling mode, compared to chillers. Some examples of successful plants are given below.

In a chemical laboratory, UEG in Wetzlar, Germany, BHE are used for direct cooling (thus without heat pumps, see **Figure 3**). The ratio between the amount of cold delivered to the ventilation system and the energy consumption of the circulation pump in the boreholes is 56:1. In wintertime, the heat pump with 47 kW heating output delivers 111 MWh of heat. Additional heat from a peak gas boiler is only required for some 20 hours per winter.

Simultaneously, the heat pump stores cold in the ground. During most of the year, parts of the building need cooling for electronic equipment and chemical devices. The reduction of $CO_2$ emissions, compared to conventional heating and air conditioning, was calculated to be around 48%.

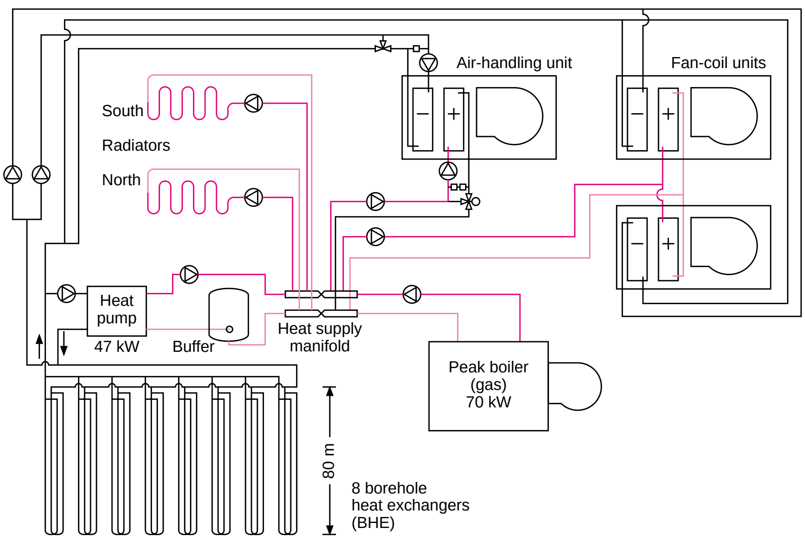
An interesting option for BHE are so-called energy piles. Concrete piles for building foundations are equipped with plastic pipes which serve as ground heat exchangers. The number of applications has grown in recent years, mainly in Austria and Switzerland.

## Cooling only

In contrast to UTES systems using ground water (ATES), cooling-only storage plants with BHE are rare. One example is a 198 m high bank office in Frankfurt, Germany. The ground is not ideal for high-rising buildings, so a massive pile foundation was necessary. The building's basement reaches 20 m below the ground surface, and an extensive retaining wall was necessary to protect the surrounding buildings. This wall also consists of piles, which are partly used as energy piles.

All piles are made on site, by drilling a hole, inserting the steel reinforcement cage with heat exchanger pipes attached to it, and casting concrete into the hole.

*Figure 3: Schematic of UEG-plant, Wetzlar, Germany.*




The cooling demand of 3.6 MW is met by a combination of two absorption chillers, two compression chillers, a short-term ice storage system, and the UTES with energy piles. The energy piles will contribute approximately 500 kW to the total cooling capacity. In wintertime the UTES is charged with cold from the ambient air, using dry coolers on the roof. Operation of the system will start in 1999.

## Successes

One particular success story is taken from Sweden, where the city of Strömstad is making a very ambitious effort to reduce oil dependency by using ground-coupled heat pumps. The rocky terrain is unsuitable for district heating networks. Instead, 140 heat pump installations have been installed using a total of 400 boreholes to provide heating for apartments housing half of the 6,000 inhabitants. The improvement in air quality is reported to be visible.

The state of the art of successful design and installation practices is described in the draft version of a new guideline VDI 4640 "Thermal Use of the Underground", which was published in February 1998 in Germany. The first two sections deal with environmental and legal aspects, and with ground-source heat pumps. A third section, addressing UTES, is under development. The guideline may positively influence the use of ground heat throughout Central Europe and help to continue development and realise sound application.

It can be concluded that in Central and Northern Europe the number of systems using BHE for heat storage in the ground or for heat extraction is still growing. Successful system designs exist and have proven their applicability over almost two decades.

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# Climate 21 – A Swedish national research programme on heat pumps and refrigeration systems

*Peter Rohlin, Sweden*

The Swedish National Energy Administration (formerly NUTEK) has launched a new national research programme “Climate 21” in collaboration with partners from the Swedish refrigeration and heat pump industry and universities. The programme is a broadened continuation of a previous programme called ”Alternative Refrigerants”. It started in July 1997 and will continue into the next century. The budget for this new programme is USD 7 million. The Swedish National Energy Administration finances the programme for 40%, with the remainder being contributed by the participating companies.

The programme focuses on energy efficiency of heat pumps and refrigeration systems. Development of units and systems is carried out to limit the use of primary energy, taking commercial possibilities and the state of the art into account. Applications should focus on the complete system and lead to environmental benefits.

The programme covers the entire range, from components and units to systems. The programme may, to some extent, also include standardisation and safety aspects, both mechanical and electrical. Areas affected by the programme are:

- efficiency of compressors (including the electric motor);
- efficiency of heat exchangers;
- heat and mass transfer properties of working fluids during phase change;
- thermophysical properties of alternative refrigerants;
- multiple-function control systems;
- distribution system for heating and cooling;
- heat sources for heat pumps, including external heating systems;
- free cooling and heat recovery systems;
- system simulation and optimisation;
- reliability and control of air quality and temperature;
- consequences for electricity distribution systems;
- life cycle analysis;
- environmental aspects;
- economy of different thermodynamic solutions.

## Participants

In the preparation of the programme special efforts have been made to involve small companies with limited research budgets. Sweden hosts some of the world’s largest companies in the area of heat pumping and refrigeration technology and they are also strong supporters of this programme.

Around 25 companies have joined the programme. Several projects are already in the startup phase and some projects still continue from the previous programme. Six departments at four different universities are involved in the programme. The work to initiate new projects within the programme continues and new partners can enrol at any time.

## Collaboration

The objective of the programme is to strengthen the Swedish industry in the long term. This is accomplished by cooperation between universities and industry which leads to mutual exchange and transfer of knowledge. The programme will contribute to a national knowledge development in the field. It should also increase international collaboration, which in turn should result in heat pump and refrigeration systems that are characterised by high energy efficiencies and low environmental impact at low cost.

The aims of the programme include the following:

- facilitate the exchange of knowledge and information between industries and universities;
- establish contacts and mutual understanding by stimulating united actions by industry and universities in different projects, to solve problems of industrial relevance;
- maintain a high degree of competence within Swedish universities and promote the graduation of PhD and graduate students;
- increase the knowledge base and generate directions for energy efficiency of heat pumps and refrigeration systems with working fluids that have zero ozone depleting potential;
- verify theoretical results by experimental studies in laboratory and field tests.

The energy efficiency of conventional refrigeration systems or heat pumps can be increased by more efficient components, such as compressors or heat exchangers, or by optimisation of the system as a whole. Both aspects will be illustrated by several projects from the programme.

## Working fluids

The first project is entitled *‘Replacement of R22 in new and existing facilities - energy efficiency, economy and environmental consequences’*. The general aim of the project is to clarify technical, economic and environmental consequences of a conversion to new chlorine-free refrigerants from, primarily, R22. In a number of case studies comparisons of R22 with appropriate replacements will be made. The aim is to be able to predict energy and practical consequences of the choice of refrigerant in different system configurations, where today R22 would be chosen as refrigerant.

A second project concerns *'New refrigerant blends to replace R22 in heat pumps for district heating'*. In Sweden approximately 20 heat pumps for district heating use R22. Those turbo compressor-driven machines with capacities over 5 MWth have a total refrigerant filling of 330 tons. They annually supply 2.8 TWh to the district heating networks. In many cases heat pumps and cooling machines have been converted to R134a. If these large heat pumps with R22 are converted to R134a the energy-efficiency reduction is estimated at 15%. Additionally there are costs involved for actually replacing R22 with R134a. The emissions of greenhouse gases, sulphur and nitrogen oxides will rise. Other refrigerants, such as R407C, that are used in some systems to replace R22, are not suitable for temperatures in district heating networks. The aim of this project is to find a tailor-made blend to replace R22, by combining commercial refrigerants currently available.

## Food sector

The project named 'The energy-efficient food store in theory and practice' will study the state of the art in refrigerating technology for food stores, and use this information to develop computer tools for energy optimisation of food stores. For the different technical solutions the environmental aspects will be highlighted, together with energy consumption reduction and the expected economic outcome.

The project on *'Energy-efficient display cabinets'* aims to map the energy flows of display cabinets in the food retail sector and subsequently analyse the possibilities of reducing these flows. A combination of fluid dynamical modelling and experimental studies in a laboratory test cabinet should provide improved knowledge about the air distribution inside the cabinet as well as on the exchange with ambient air. The laboratory cabinet will also be used to investigate whether an entirely new concept can reduce energy use while simultaneously improving the temperature quality of the merchandise.

## Components

Another project covers *'Heat transfer and pressure drop during evaporation in small brazed plate heat exchangers'*. The aim of the project is to increase the knowledge on mechanisms of heat transfer and pressure drop in plate heat exchangers. This will be realised through visualisation studies and systematic investigations on the influence of the different geometric parameters. The ultimate goal is to present correlations for predicting heat transfer and pressure drop. The possibility of using numeric techniques for predicting heat transfer and pressure drop will also be investigated.

The aim of the project on *'Refrigerant blends in systems'* is to map and quantify a number of special effects which occur when using refrigerant blends. The main focus will be on tube-and-shell-type condensers and evaporators. The project will be carried out by combining theoretical studies, calculations and experiments, both full scale and for individual tubes.

## Integrated systems

A project that emphasises the entire system is *'Integrated heat pumps systems for optimum operation'*. By introducing integrated control systems, not only for components within the heat pump (expansion valve, compressor, fans and pumps etc.) but also for the entire system (such as distribution system, defrosting and additional heat requirement systems), a higher seasonal performance factor (SPF) may be reached in heat pumps for single-family houses. The optimal solutions for different types of distribution systems and house layouts will be studied.

This project is related to the project on *'Simulation of heat pump systems in single-family houses'*. The aim is to obtain algorithms and finally a universally accepted computer programme for calculating energy savings and environmental impact of a heat pump installation in a single-family house. The programme will be module-based. Different modules will describe the heat pump, heat sink and heat source, construction of the house, distribution system, climate etc. All major heat pump companies in Sweden, electricity utilities and heat pump organisations support the project.

## Dissemination

Information and results generated within the programme are published regularly. The secretariat handles the information flow resulting from the projects by distributing reports, newsletters and internal seminars and workshops. Information and results will not be exclusively available to the participants in the programme. Results will be presented continuously through literature, at national and international conferences and on the programme's Internet site. An open workshop will be held at least once a year and plans exist to organise an international workshop at the end of the programme period. Although it is a national programme, most of the information will be available in Swedish and English. International exchange of information is hereby encouraged.

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# Heat pumps in cold climates

**Canada -** While cold climates present a challenge for heat pump equipment, consumer interest and acceptance is rising and increasing numbers of businesses, industries and institutions are experiencing the financial and environmental benefits of heat pumps. The Third International Conference on Heat Pumps in Cold Climates was held at Acadia University in Nova Scotia, Canada, in August 1997. The meeting was co-sponsored by Nova Scotia Power, Newfoundland Power and Natural Resources Canada, and was attended by 44 international participants in addition to a Canadian contingent of 80.

A total of 44 papers were presented over the two days in two parallel sessions and two poster sessions. In the opening session an international heat pump market overview was presented and the deregulation of the utility industry was discussed.

Technical sessions covered design tools, alternative refrigerants to R-22, novel and advanced heat pumps and measured heat pump performance assessments. The first presentation in the session on design tools concerned heat pump modelling in TRNSYS. A large residential heat pump project in Fort Polk, USA (see Newsletter volume 16/01, page 16) was used as an example to show how effective simulation tools can be in predicting and evaluating large-scale projects. The renewed GS2000‘ software was discussed, as well as a DOE/ORNL heat pump design model, highlighting the application for R-22 alternatives comparison. This topic was also covered in a separate session. Alternatives for heat pump water heaters and the use of R-407C and R-410A in residential air-source heat pumps were discussed.

Another session was devoted to gas-fired heat pumps. One presentation summarised the results of a field demonstration in Toronto, Canada of natural gas engine-driven heat pumps (GHP), to gain operating experience with the technology. The results were satisfactory, and it was concluded that this GHP would be competitive to many electric air-to-air heat pumps, but not as cost-effective as a typical gas furnace and electric air-conditioning combination. A second presentation in this session covered an assessment of the Canadian commercial market for Generator-Absorber heat exchange (GAX) absorption heat pumps.

The session on novel and advanced heat pumps discussed some of the latest developments. One presentation discussed the INSIDER air-source heat pump, which is designed for use in manufactured (or mobile) homes in cold climates. The concept is now being extended to other residential structures, mainly high-density multi-family buildings. A second presentation discussed advanced concepts for cold climate heat pumps. Cold climate heat pump objectives require that higher capacities are reached at much lower ambient temperatures and that the air delivery temperature provided by the heat pump must be at a comfortable level. Compression cycle modifications to reach these objectives are two-stage compression, interstage compression, variable speed drives and the use of additional heat exchangers. Other concepts included modifications to the system refrigerant. The range of applicability and the state of technology development were reviewed for all concepts. An overview was made of the advantages, limits, potential initial costs and operating costs. The analysis and results clearly indicated the technical feasibility of providing efficient heat pumps for cold climates using electricity and free energy from the ambient air. Operating cost savings can be significant for all climates. However, additional component and system development and testing are required to demonstrate operational reliability, performance and cost benefits.

For the first time, the conference included heat pump marketing sessions. In the first of these sessions marketing approaches and successes were discussed, including a presentation of the experiences of the Geothermal Heat Pump Consortium, USA. Two other sessions discussed the lessons learned from utility incentive programmes and marketing in the new deregulated electric industry environment. Other sessions presented experiences with heat pumps in commercial buildings and efforts to increase the efficiency of heat pumps in the market through standards and market transformation initiatives.

Copies of the conference proceedings are available from Caneta Research Inc. The 480 page document costs USD 50. An order form can be requested by fax (+1-905-542-3160) or e-mail (caneta@compuserve.com).

*Source: Chris Ireland, Caneta Research / Hanneke van de Ven, IEA Heat Pump Centre.*

# Seminar on vertical borehole heat exchangers in the Netherlands

*Hanneke van de Ven, IEA Heat Pump Centre*

A national seminar held in Utrecht, the Netherlands on 2 April 1998, discussed the developments regarding vertical borehole heat exchangers (BHE). The workshop aimed to create support for formulating uniform guidelines for the application of BHE to stimulate the introduction of heat pump systems in the Dutch market.

Currently, practically no standards or regulations are applicable in the Netherlands for the different parts of the system. In other countries such as Germany they do exist or are being developed. This also applies to BHE: adequate guidelines for sizing and installation do not exist in the Netherlands. As a consequence, no performance requirements can be formulated.

One of the main consequences of the use of ground-coupled heat pumps could be that a larger vertical ground water flux will occur because the structure of the soil is modified by installing ground heat exchangers. This can affect the quality of the ground water. Another consequence is the altered ground temperature. Local freezing can occur if the density of ground heat exchangers is too high. This should be avoided by heat recharging in summer or changing the size or configuration of the BHE. Besides the fact that it can change the composition of the ground water, it can also influence saturated foundation of buildings because the ground expands when it freezes.

The need for determining local thermo-physical properties of the ground, was also discussed. Thermal conductivity varies with the structure of the soil, while the borehole resistance depends on the filling material of the borehole. Both parameters influence the length of borehole needed to meet a certain heat demand. To be able to determine the properties of the ground on location, GroenHolland and IF Technology have developed a mobile container in which measurements can be performed.

## Conclusions

The first aspect that needs further investigation is the application of BHE in newly developed areas, with a high housing density (around 40 per hectare). This could result in insuff-icient heat supply for the houses after some years. More research is necessary, and care-ful design of large-scale projects is required.

Although a permit to apply a BHE is unnecessary in the Netherlands, certain precautions should be taken as stated in the Dutch Ground Protection Act. This requires careful planning, and may lead to alternative design of ground-coupled heat pump systems including devices for leak detection or using different working fluids.

Quality standards should reduce the risk of poorly designed installations, and increase acceptance of the technology. The new German VDI 4640 standard will lead to quality improvement in ground-coupled heat pump installations.

The use of ground water could avoid some of the problems that might occur with BHE. Ground water in the Netherlands has a constant temperature of 10-12°C. To use it as a reliable heat source, the quality in terms of oxygen content and other potential clogging elements checked by analysing its constitution.

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**ASHRAE TransactionsCD**

Available from: ASHRAE Customer Service, 1791 Tullie Circle N.E., Atlanta, GA 30329, USA. Fax: +1-404-3215478. Price: USD 147. Order code: 94081.

*The TransactionsCD gives full-text images of all technical and symposium papers presented at the 1998 ASHRAE Winter Meeting in San Francisco, USA. Data can be searched by title, author, topic and subject matter.*

**Heat pumps**

Available from: CIP. Contact: Prof. Dr Alojz Poredos, University of Lubljana,
fax: +386-61-218567.

*This book contains the proceedings of the conference held in Zrece, Slovenia on 17-18 April 1998. Most papers are in the Slovenian language, but they all have an English summary. Topics covered include compression and absorption heat pumps, several applications and thermodynamics.*

**World market for air conditioning**

Available from: BSRIA, Mrs Louise Stapleton, Old Bracknell Lane West, Bracknell RG12 7AH, United Kingdom. Fax: +44-1344-487575. E-mail: enquiries@bsria.co.uk. Published 1998. Price: GBP 7,000 (for all countries, all products).

*This worldwide market study contains market data from 1995-2000 for residential/light commercial products, unitary products and chillers for 94 countries. The data includes market sizes by volume and by value and average selling prices. Other features are a geopolitical summary of each country, including basic information about the countries and a market commentary, providing a summary of the market trends identified from the research including brands, manufacturers and import/export trends.*

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**IEA Heat Pump Programme Annual Report 1997**
Order No. HPP-1997,
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Annex 18 report January 1998
Order No. HPP-AN18-5
NLG 80 or NLG 40 in member countries and in Ca, De, Se and UK

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**Compression Systems with Natural Working Fluids**
Annex 22 Workshop Proceedings, January 1998. Order No. HPP-AN22-3
NLG 120 or NLG 60 in member countries and in Ca, Dk, Se and UK

**Ab-Sorption Machines for Heating and Cooling in Future Energy Systems**
Annex 24 Proceedings, December 1997
Order No. HPP-AN24-1
NLG 120 or NLG 60 in HPC member countries and in Ca, It, UK

**Building HVAC Equipment Regulations and Standards**
Workshop Proceedings, June 1997
Order No. HPC-WR-18
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**Air-Conditioning & Refrigeration New Tech '98 (ART'98)**
**Environmentally Friendly Refrigeration '98 (EFR'98)**
9-12 June 1998 / Beijing, China
Organised by the Chinese Association of Refrigeration
Contact: Beijing Onis Expo Co., Mr Liang Liang
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E-mail: onis@public3.bta.net.cn

**Developments in commercial and industrial markets; and compressor design II short course**
12-13 July 1998 / West Lafayette, Indiana, USA
Contact: Cynthia Quillen, Purdue University.
Fax: +1-765-4940787
E-mail: herlconf@ecn.purdue.edu

**1998 International Compressor Engineering Conference; and 1998 International Refrigeration Conference**
14-17 July 1998 / West Lafayette, Indiana, USA
Contact: Cynthia Quillen, Purdue University
Fax: +1-765-4940787
E-mail: herlconf@ecn.purdue.edu

**Eurotherm seminar on thermodynamics, heat and mass transfer of refrigeration machines and heat pumps**
6-7 July 1998 / Nancy, France
Contact: Prof. M FEIDT, LEMTA - University of Nancy
Fax: +33-3-83595551
E-mail: mfeidt@ensem.u-nancy-fr

**Hygiene, quality and security in the cold chain and in air conditioning**
16-18 September 1998 / Nantes, France
Organised by IIR
Contact: Symposium Nantes 98
Fax: +33-02-51882020

**Wärmepumpen-Expo**
5-7 November 1998 / Bern, Switzerland
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Tel.: +41-31-3524113

**1999 International Sorption Heat Pump Conference**
24-26 March 1999 / Munich, Germany
Contact: Dr Martin Hellmann, ZAE Bayern, Walther-Meissnerstrasse 6, D-85748 Garching, Germany
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**20th International Congress of Refrigeration of the IIR**
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**IEA HEAT PUMP PROGRAMME EVENTS**

**Heat Pump Systems for Single-Room Applications**
Annex 23 Workshop
16-19 June 1998 / Niagara Falls, USA
Contact: Frank Lenarduzzi, Ontario Hydro Technologies
Fax: +1-416-2076565

**Heat Pumps - A Benefit for the Environment**
6th IEA Heat Pump Centre Conference
30 May - 2 June 1999 / Berlin, Germany
Technical visits on 3 June 1999
Planning sessions on market status / strategy, technology and applications
Information available from the Heat Pump Centre

## Next Issue

Alternative Working Fluids
Volume 16 - No.3/1998

## International Energy Agency

The International Energy Agency (IEA) was established in 1974 within the framework of the Organisation for Economic Co-operation and Development (OECD) to implement an International Energy Programme. A basic aim of the IEA is to foster cooperation among its participating countries, to increase energy security through energy conservation, development of alternative energy sources, new energy technology and research and development.

## IEA Heat Pump Programme

Set up by the IEA in 1978, the IEA Heat Pump Programme carries out a strategy to accelerate the development and use of heat pumps, in all applications where they can reduce energy consumption for the benefit of the environment. Within the framework of the programme, participants from different countries collaborate in specific heat pump projects known as Annexes.

## IEA Heat Pump Centre

A central role within the programme is played by the IEA Heat Pump Centre (HPC), itself an Annex. The HPC contributes to the general aim of the IEA Heat Pump Programme, through information exchange and promotion. In the member countries (see right), activities are coordinated by National Teams. For further information on HPC products and activities, or for general enquiries on heat pumps and the IEA Heat Pump Programme, contact your National Team or the address below.

The IEA Heat Pump Centre is operated by

Novem

Netherlands agency for energy and the environment

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