ECES Annex 12

"High Temperature Underground Thermal Energy Storage"

Fifth report to the Executive Committee
24.-25.5.2000

Phase 2 of Annex 12 was approved during the 47th Executive Committee Meeting in Berlin in November 1999, and Germany continued to act as Operating Agent.

The number of countries interested is small, but comprises the locations of the most important HT-ATES plants:

- Belgium
- Canada ?
- Germany
- the Netherlands
- Sweden

Two experts meetings have been conducted within phase two:
XM 4, Stuttgart, D, September 1999
XM 5, Arnhem, NL, May 2000

With funding for the German project and the leading of Annex 12, work could gain momentum in spring 2000. The current status can be seen from the XM 5 minutes attached to this report as Attachment B.
Attachment A shows the current HT-UTES activities in the different countries.

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Appendix A

Recent or ongoing HT-UTES activities

Status: Annex 12 meeting 18.5.2000

Belgium:	BTES planned for VITO in Mol (with monitoring), supported by EC, called „TESSAS“
Canada:	?
Germany:	ATES Reichstag Berlin ATES Rostock-Brinkmannshöhe BTES Neckarsulm plans for BTES in Attenkirchen plans may be reconsidered for Neubrandenburg, ATES, waste heat (deep aquifer >1000m) HT-TED and ATES-METSAC under construction
Netherlands:	Evaluation of Utrecht ATES ongoing Monitoring of Hooge Burch ATES ongoing
Sweden:	Anneberg (Danderyd), BTES, solar heat, under construction A study concerns a HT-BTES for waste heat to heat a runway at Luleå Kallax airport (increased runway length) Plans for HT-ATES in southern Sweden in early stage HT-TED planned

Appendix B

Minutes of the 5th Expert´s Meeting in IEA ECES Annex 12 High Temperature UTES

18.-19.5.2000, Arnhem, the Netherlands

Participants:
Paul Dirven, VITO, Mol, B
Göran Hellström, Lund Univ., Lund, S
Michael Koch, ISWA, Univ. Stuttgart, D
Thomas Meyer, Univ. Lüneburg, D
Joachim Poppei, GTN GmbH, Neubrandenburg, D
Manfred Reuß, Landtechnik Weihenstephan, Freising, D
Wolfgang Ruck, Univ. Lüneburg, D
Burkhard Sanner, IAG, Univ. Gießen, D
Thomas Schmidt, ITW, Univ. Stuttgart, D
Guus Willemsen, IF Technology, Arnhem, NL

Begin 18.5.2000, 9.00

B. Sanner opened the meeting and welcomed the participants to Arnhem.
After the adoption of the agenda and a short introductory round, G. Willemsen gave an update on the situation of high-temperature ATES in the Netherlands:

In **Utrecht** serious problems arose which stopped the operation of the store in autumn 1999 for the time being:
- Leaking casing joint in the warm well
- Co-generation plants are at the end of planned lifetime, high investment is required for refurbishment

It is probably cheaper to buy heat and power from outside than to repair the store and co-generation plant.

In **Hooge Burch**, also some problems occured, but the plant is running now satisfactorily. The major problem is a return temperature from the heating net higher than predicted, allowing for only little unloading of the store.
The water treatment needs to be improved, and three options have been investigated:

- Ca-Na-ion exchange is not feasible due to permitting problems and the need to discharge large quantities of regeneration salt.

- CO_2-addition was considered, but simulations with PHREEQUE over 5 cycles showed a rapid increase in the required dosage, and CO_2-pressure would go to 1 bar in the second cycle.
- The exisiting addition of HCl brought pH-drops during standstill, corrosion even of stainless steel in the HCl-environment, and required frequent calibration of pH electrodes. Water treatment now will be optimized in dosage and control on the basis of new calculations; required dosage over the years is much lower than with CO_2.

A bottleneck for HT-ATES is seen in the complicated operation. According to G. Willemsen, HT-ATES is economically feasible only in larger plants (Utrecht being the lower limit). Recent experiences of Utrecht and Hooge Burch could yet be included in the project sheets to be published with the Annex 12 phase 1 report.

Information on other ATES:

- One plant in Sweden in early stage, more info next meeting.
- One geothermal plant in Paris (depth ca. 700 m) uses storage to increase temperature in wells (?? facts to be confirmed).
- The Neubrandenburg project, mothballed last year because of uncertainties in the opeation of the co-generation, may now be re-considered with the new energy law in Germany.

J. Poppei presented the current status of the monitoring for the Reichstag building, Berlin, and (supported by T. Schmidt) of the new ATES in Rostock-Brinkmannshöhe.

Changing to BTES, P. Dirven first presented the TESSAS borehole store in Mol. Money from the EC was granted for construction and monitoring. It is planned to use different BHE-types and grouts to check their performance. Monitoring will begin in 2002 (i.e. after the end of this annex), but design and modeling could be part of annex 12.

The next two speakers also presented BTES projects: M. Reuß talked about plans for an ATES in Attenkirchen and the status of realisation, and T. Schmidt gave an update on the situation with the BTES in Neckarsulm.

G. Hellström informed about the Anneberg project in Stockholm area: It is planned to achieve a solar fraction of up to 70 % with 50 houses. The decision on drilling is made (100 boreholes 65 m deep), and double-U-tubes of 32 mm are planned. Also in Luleå plans for a new BTES are considered.

Before the lunch break, chemical monitoring at the Reichstag building in Berlin was presented by Th. Meyer. First samples have been taken on 4.5.2000; the first analysis made show a good agreement with those from the design phase (the water is still pumped mainly in one direction, so fresh groundwater is produced).

After lunch, M. Koch showed the general layout of the aquifer test equipment. The basic installation shall be finished in mid July, and components from Lüneburg university installed in atumn. First tests will be made at a well in Stuttgart-Büsnau (ISWA), then in Lüneburg; good and easily accessible test sites with known water behaviour then could be Rostock and Hooge Burch.

Thermal response testing was presented by M. Reuß. In discussion the measurement of undisturbed ground temperature was stressed (by circulating or with separate log). A suggestion was made to have different reponse test rigs at the site in Mol later this year to compare measuring and evaluation strategies on a single site. Tests for higher temperature applications could be made in Anneberg, Luleå, Mol and Neckarsulm (new part).

The presentation part was closed with a short report from the recent annex 13 meeting in Canada, given by G. Hellström and M. Reuß.

Finally the workplan and common activities were discussed. Subtask leaders had to be revised:

Subtask	Leader
B, Monitoring	B. Sanner
B1, Monitoring of thermal performance, T. Schmidt	
B2, Monitoring of env. and chem. aspects, W. Ruck	
B3, Modeling and simulation, not yet determined	
B4, Control issues, operating strategies, etc., M. Reuß	
C, ATES groundwater suitability and water treatment	M. Koch
D, BTES ground parameter invest. and BHE optimiz.	G. Hellström
E, Components, list of specifications	B. Sanner
F, System concepts and economy	P. Dirven

Status of participating countries:

Germany	participating, national project, OA
Belgium	participating, national project
Netherlands	participation not confirmed (intention declared at XM47)
Sweden	participation not yet confirmed, but travel money available
Canada	?

B. Sanner thanked G. Willemsen and IF Technology very much for the perfect meeting opportunities and all the support given, and closed the meeting on 18.5.2000 ca. 17.30.

On 19.5.2000, a technical visit allowed the experts to see the two Dutch high temperature ATES at Hooge Burch and Utrecht (see attached fact sheets). All participants took that opportunity and attended in the tour.

Fact sheet:

Gouda

Name:
Hooge Burch

Site:
Zwammerdam near Gouda, the Netherlands

Operated/Designed by:
Hooge Burch / DWA, IF Technology

Project History:

1996	Test drilling
1998	Start of operation in April

The plant is in operation

Short description of plant:
- ATES
- 2 wells 150 m deep at 70 m distance
- Stainless steel screens 6" with gravel pack
- Flow rate for loading 20 m^3/h, for unloading 25 m^3/h
- Heat source are two heat and power co-generation engines in the technical building, with a combined electric power output of 610 kW_{el}. The heat retrieved from lubricant oil cooler, motor cooling water and flue gases adds up to 950 kW_{th}, delivering water of 90 °C. The excess heat of power production in summertime is stored and retrieved in winter for supply of ca. 600 kW_{th} to the heating facility. The co-generation engines serve also as emergency power generators.
- The buildings housing ca. 550 mentally handicapped persons have been build in 1977 and originally were heated with gas boilers from a central technical building via a warm water net. The area covers 45 ha, of which 50’000 m^2 are used for buildings.
- Pipes between wells and technical room are made of glassfiber-reinforced resin
- Total cost of system (co-generation and ATES) 2,8 mio. Dfl (ca. 1.3 mio. Euro)
- Storage loading temperature 90 °C

Geology:
- Aquifer at 140-150 m depth
- Saltwater (ca. 3-4 g/l Cl^-)

Water treatment:
HCl-addition

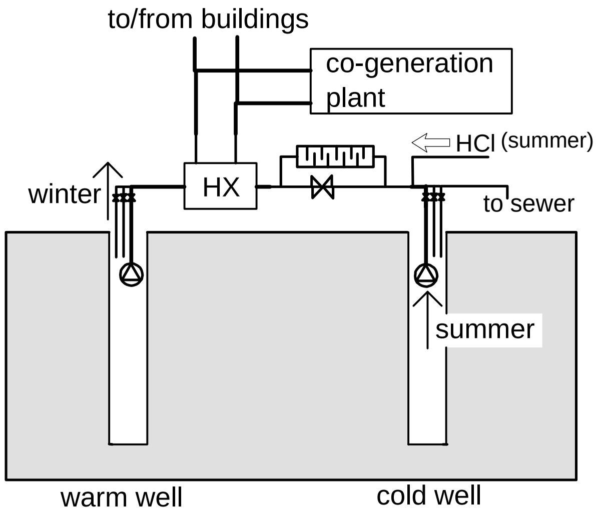

Fig. 1: Schematic of the operation of Hooge Burch ATES

Operational experience

The begin of operation was in April 1998 with loading of the store. Until end of 1998, the heat injected amounted to 1350 MWh, the heat retrieved to only 50 MWh (due to the relatively low temperature of the store after loading, and high heating net return temperature). The return temperature in the Hooge Burch net can be as high as 70 °C, but should be kept preferably around 50 °C.

The high return temperature of the net is a major problem. To operate the store effectively under these circumstances, a higher amount of water of 90 °C is required around the warm well. However, the heat source allows a heating of the groundwater by ca. 45 K only. To increase temperature in the warm well as soon as possible, after the first loading cycles the volume around the warm well with ca. 50 °C is pumped directly back to the cold well (winter 1999/2000). In a next step in spring/summer 2000 the warm water will be pumped again from the cold well and heated by another 45 °C, to achieve the final temperature of 90 °C.

Deep shaft pumps as used in Utrecht were no longer available in the required quality, and so submersible pumps had to be used. Pumping is done in three fixed steps in each of the two directions. To keep back-pressure in the injection wells at the right value for each step, two injection pipes with differing diameter are installed in each well, and electrical valves allow to adjust three total diameters (pipe a, pipe b, and both pipes).

The water treatment system originally was another source of problems. The ion exchanger method was not possible because of permitting problems and the need to discharge large quantities of regeneration salt. The addition of HCl as chosen here brought pH-drops during standstill, corrosion even of stainless steel in the HCl-environment, and required frequent calibration of pH electrodes. Water treatment now will be optimized in dosage and control on the basis of new calculations.

<u>Fact sheet:</u>

Utrecht

Name:
Utrecht University ATES

Site:
Campus "De Uithof" of Utrecht University, at the outskirts of Utrecht, the Netherlands

Operated/Designed by:
Utrecht University / Bredero, Heidemij

Project History:

1987	Feasibility study
1990	Start of construction
1991	Start of operation

The plant is still in operation

Short description of plant:

- ATES
- 2 wells 260 m deep at 70 m distance
- Stainless steel screens 6" with gravel pack
- Flow rate for loading 100 m^3/h, for unloading 50 m^3/h
- Heat source are two co-generation plants on the university campus, with an electric power output of 3.75 MW and 4 MW, resp. The excess heat of power production in summertime is stored and retrieved in winter for supply of ca. 2.6 MW to the campus heating facility.
- Storage loading temperature 90 °C

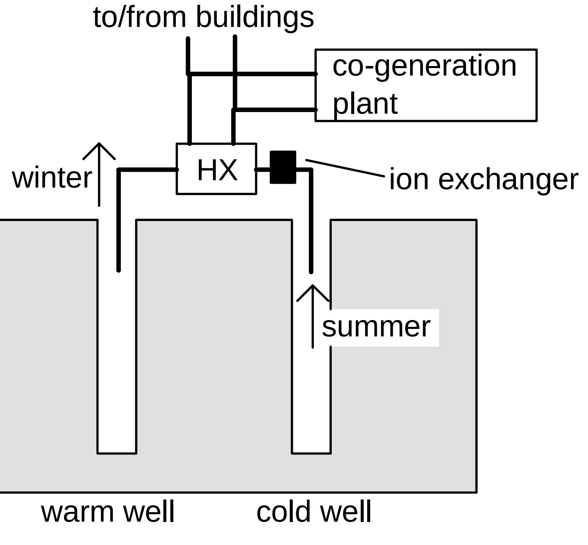

Fig. 1: Schematic of the operation of Utrecht ATES

Geology:

- On the site are 3 aquifers at 10-50, 65-120 and 195-300 m depth
- The store is located in a section of the third aquifer, 210-260 m below ground surface, and consists of medium coarse sand (0.2-0.4 mm) of Tertiary age
- Average horizontal permeability $5.8 \cdot 10^{-5}$ m/s
- Groundwater velocity ca. 2 m/a
- The water is slightly brackish (Cl: 43-380 mg/l)
- Natural groundwater temperature is 15 °C

Water treatment:
Ca-Na-ion exchange

Operational experience

The startup was made in March-May 1991 in four temperature steps (15, 40, 65 and 90 °C).

The building system and thus the district heating return temperature was higher as in the design, lowering the storage unloading performance. Nevertheless, the operators are happy to have more running of the co-generation, the heat retrieval is of second importance. The energy balance for the first three cycles is shown below:

Year	Heat loaded (MWh)	Heat unloaded (MWh)	Efficiency	
			measured	predicted
1991	5280	708	13.4	24
1992	2650	1003	37.8	45
1993	5340	1722	32.3	56

The water treatment system could not be controlled completely automatic. To avoid too high contents of Na^+-ions in the injected water (resulting in swelling of clay minerals and clogging in the aquifer), frequent chemical analysis of water was required. Thus the water treatment constantly caused work and uncertainty, and had to be operated between clogging and scaling from carbonates and swelling of clays. Another source of troubles were the deep shaft pumps, being expensive and not very reliable.

The increase in injection pressure observed in the mid 90´s was a measuring error of the flowmeters. When the system was operated without the water treatment in 1997, one well was clogged within weeks, showing the importance of the treatment. The well is cleaned and the system repaired. The deep shaft pump in the cold well was replaced by a submersible pump.

Electricity production over the last years was between 49 GWh in 1995 and 43 GWh in 1998.

In 1999 a leak developed in the warm well, preventing any further heat injection unless repair is done. With the cogeneration plant at the end of its service life, major investment would also be necessary to operate the heat source for a longer time. Buying heat from district heating and electricity from the grid might be a cheaper option with current energy prices, and the project is stopped for the time being.

Economy

The cost for the project were 2.4 mio. Dfl (1.1 mio. Euro). In addition, 3 mio. Dfl (1.36 mio. Euro) were spent for R&D, monitoring, and other accesorial cost.
Savings for the operation of the plant as calculated in the feasibility study and with results from 1991/92:

	Feasibility study	1991/92
Savings of purchase of electricity	-625’000 Dfl	-784’560 Dfl
Savings for waste heat use	-125’000 Dfl	-35’000 Dfl
Maintenance and operation co-generation plant	+204’000 Dfl	+288’400 Dfl
Fuel for co-generation plant	+66’300 Dfl	+84’000 Dfl
Total savings (investment not calculated)	479’700 Dfl	447’160 Dfl
Savings in Euro	220’500 Euro	205’500 Euro

Savings in the last years averaged 350’000 Dfl (159’000 Euro)

Literatur Utrecht

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