ECO-CITY ADSORPTION COOLING IN HELSINGBORG/ HELSINGØR, SWEDEN / DENMARK

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1. INTRODUCTION

The scientific and technological objective of the ECO-City project is to establish the technological basis and to demonstrate innovative integrated energy concepts in the supply and demand side in three selected communities in Spain, Denmark/Sweden and Norway. The aim is to reduce the demand for heating, cooling and electricity, and supply the remaining needed energy in the most efficient way combined with use of renewable energy sources and support actions.

The ECO-City project is supported by the European Commission DGTREN through the CONCERTO initiative.

In the ECO-City project, several integrated demonstrations are carried out in parallel in each community. This paper concerns the Helsingborg / Helsingør communities, with special focus on polygeneration.

The demonstration of polygeneration in Trondheim is presented in a following separate paper titled "Optimal polygen cooling concept for St. Olavs Hospital in Trondheim, Norway" by G. Eggen, COWI A/S Norway and A. Utne, Trondheim Energy".

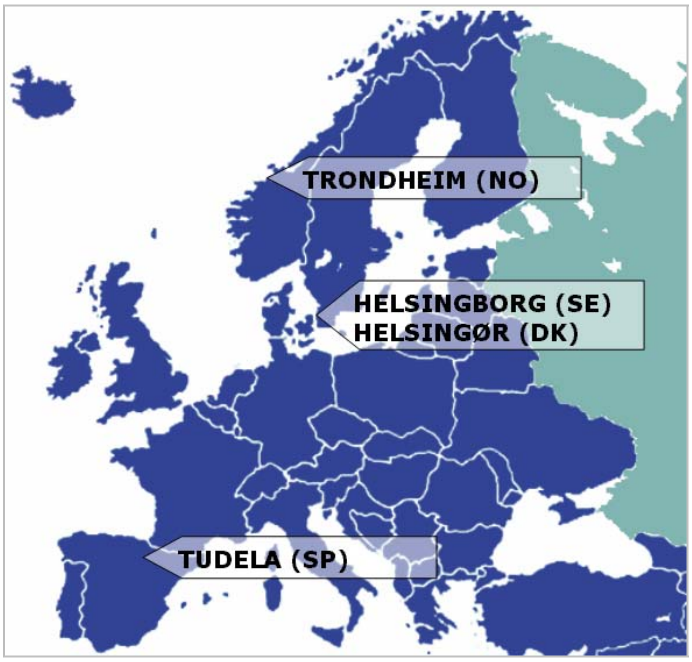

Figure 1. The Communities included in the ECO-City project.

2. DEMONSTRATIONS IN HELSINGBORG + HELSINGØR COMMUNITY

Besides the development of the polygeneration concept for combined heat pump and cooling plant, the following project demonstration elements are included - in brief:

Renewable Energy Supply (RES):

- 2 MW wind turbine
- 5 MW biomass boiler connected to district heating using woodchips
- Optional biogas production based on organic waste
- 140 m^2 solar collectors for domestic hot water production.

Energy efficiency in buildings (RUE):

- Up to 453 dwellings to be ECO-rehabilitated, in total 35,629 m^2.
- 350 new ECO-dwellings, in total 28,271 m^2, with extra insulation, low-energy windows, demand controlled ventilation / heat recovery etc.

- Improved energy efficiency in 25,000 m^2 tertiary buildings covering administration offices, schools and institutions.

Integration of RES and RUE:

The extra renewable energy supply covers the need of the included ECO-buildings after improving their energy efficiency by various RUE actions and use of a RES dominated district heating supply.

3. DESCRIPTION OF THE POLYGENERATION CONCEPT

A new polygeneration concept is studied and developed for later demonstration in this actual community. The concept consists of a combined plant for heating/ cooling using adsorption techniques with a heating capacity of around 0.4 MWth. The system is combined with a borehole geo-exchange system for seasonal underground thermal energy storage (UTES).

The concept of the system is new in two ways:

1. The heat pump / cooling machine is heat driven using district heating (originating from waste heat and heat from co-generation mainly based on combustion of biomass) - the COP for heating is about 1.6 for single-stage plants.

2. The operation strategy, which is to operate the system as follows:
   a. Winter: Heat driven heat pump operation producing low-temperature heating by cooling the UTES / ambient air and incl. recovery of heat from kitchen and server cooling
   b. Winter peak: Additional district heating
   c. Spring / autumn: Free cooling with outdoor air
   d. Summer: Direct cooling via geo-exchange with the cold UTES- i.e. storage of surplus heat and regeneration of the UTES for heat pump operation in the coming heating season
   e. Summer peak: Additional heat driven or electrical driven cooling, depending on loads and tariffs
   f. Autumn: Balancing of regeneration of underground thermal heat storage.

The figure below shows the basic principle.

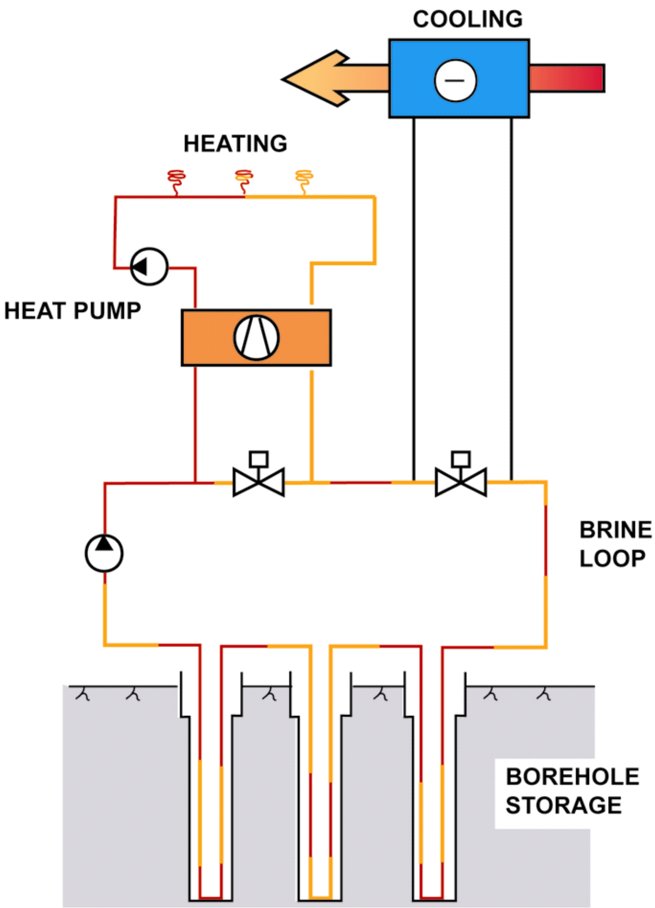

Figure 2. Heating is provided during winter by cooling of the borehole storage, which then in summer can be used for direct cooling, which at the same time regenerates the storage /1/.

The project focuses on use of an adsorption chiller as heat pump. The adsorption cycle is chosen because it has a higher capacity than the absorption cycle at low driving temperatures, as illustrated in Figure 3. At the same time, the adsorption cycle can deliver a higher temperature on the heat sink side, which makes the process suitable for operation in heat pump mode to generate low-temperature heat at about 35°C, sufficient to be used for heating coils in ventilation systems, for floor heating systems and for preheating of water for radiator heating.

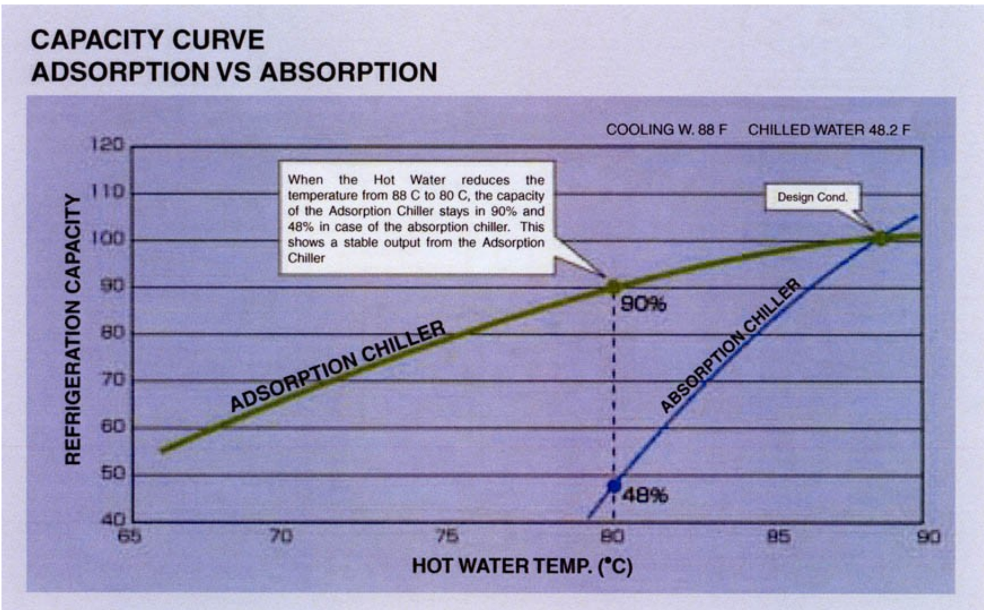

Figure 3. The dependence between capacity and driving hot water temperature of adsorption and absorption cycles /Nishiodo/.

On the chilled water side, the system can produce chilled water at normal temperatures and even down to 3^{o}C, but in order to utilise free cooling from air and the UTES system, it is recommended to design cooling coils for a chilled water flow temperature as high as possible, e.g. 10-14^{o}C.

The adsorption system has very few moving parts and is proven reliable in operation as cooling machine for decades. When used as heat pump, some minor modifications are needed on the control side and connecting pipe loops and use of frequency controlled pumps. The technical lifespan for the adsorption system is 30 years and 50-100 years for the borehole geo-exchange system, compared to 10-15 years for a compressor cooling system.

The new heat driven polygeneration concept developed in this project forms the basis for intended demonstration at domestic, industrial and commercial consumers. Especially interesting will be to monitor the dynamics of this system as basis for optimisation of control strategy and to pave the way for further exploitation.

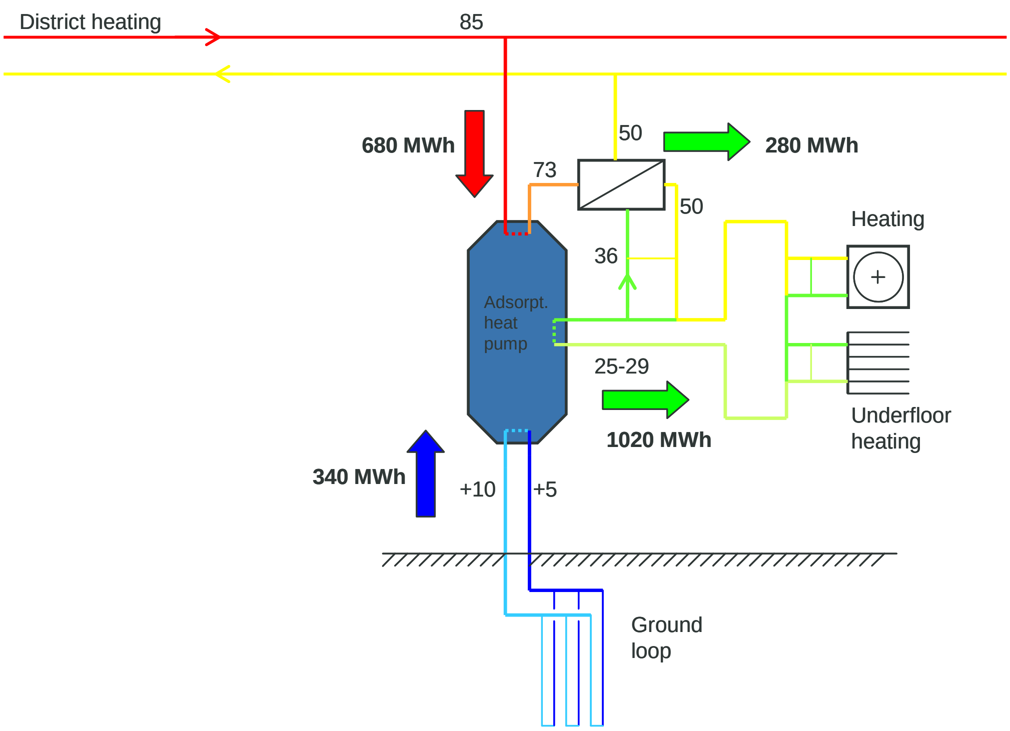

Figure 4. Principle diagram for the adsorption polygeneration system shown in heat pump mode, with indication of typical operation temperatures and yearly delivered.

Figure 5. Photo of a 0.5 MW Mycom adsorption cooling machine, of double size of the demonstration plant planned for Helsingborg /Mycom; Albring/.

The project team has investigated various locations for such a demonstration plant and has especially studied possibilities of a new 30.000 m^2 IKEA warehouse to be constructed in Helsingborg, which has formed the basis for the investigation of the technical and economic feasibility.

4. BASIC DESIGN DATA

Model calculations and economic optimisation of the heating and cooling system have led to the following configuration of a polygeneration plant to be compared with the reference.

Polygeneration plant:

District heating (peak and reserve)	990	kW

Adsorption heat pump with COP 1.5 470 kW
(240 kW cooling)

Peak compressor cooling 2 x 260 kW

Free cooling with air 1125 kW

Geo-exchange boreholes (15 x 230 m) 105 kW

Investment costs (total plant) 1.06 mill. EUR

<u>Reference plant:</u>

District heating 1200 kW

Compressor cooling / heat pump with COP = 3.8 3 X 260 kW

Free cooling with air 1000 kW

Investment costs (total plant) 0.65 mill. EUR

<u>Energy demand:</u>

Heating demand 1200 MWh/year

Cooling demand 600 MWh/year

The economic calculations are based on the following assumptions:

<u>Energy costs (Helsingborg, Sweden):</u>

Electricity	(950 SEK/MWh)	102 EUR/MWh
District heating, winter	(427 SEK/MWh)	46 EUR/MWh
District heating, summer	(272 SEK/MWh)	29 EUR/MWh

<u>Energy costs (Helsingør, Denmark):</u>

Electricity	(1552 DKK/MWh)	208 EUR/MWh
District heating, (marginal)	(430 DKK/MWh)	58 EUR/MWh

5. ECONOMIC FEASIBILITY

Due to national differences in tariffs, the result of the economic calculations obviously show different economic savings for the actual location in Helsingborg in Sweden and a similar installation, if located in Helsingør in Denmark.

In both locations, it is not economically feasible to produce cooling based on district heating only unless the marginal cost of the district heating is very low, due to surplus on the system during summer. This surplus of waste heat, which is a fact during summer, is not sufficiently reflected in the present tariffs for private consumers. Utilities, however, may consider being producers of heat driven cooling, provided that they own the production plant on ESCO basis, even if it is located at the premises of a consumer. If this path is followed, it would be natural to use the system to produce low-temperature heating as well. This option has not yet been thoroughly investigated in this project to a level where it is possible to draw conclusions.

So far, the private economics for a plant located and owned by the consumer has been analysed. The O&M costs and yearly savings compared with the reference are shown below with present Swedish and Danish tariffs.

Table 1. O&M cost and yearly savings with location in Sweden:

Operational costs EUR p.a.	**Reference**	**Polygen Helsingborg**
District heating fixed	13.655	13.655
District heating variable	55.023	39.433
Electricity for compr. cooling	16.107	6.097
Electricity for adsorp. cooling	0	262
Major maintenance (10 year overhall)	15.101	12.837
Normal maintenance	4.582	3.574
Total O&M costs	99.915	75.858
Yearly savings		24.057

Table 2. O&M cost and yearly savings with location in Denmark:

Operational costs EUR p.a.	Reference	Polygen Helsingør
District heating fixed	13.655	13.655
District heating variable	69.326	49.684
Electricity for compr. cooling	32.893	12.451
Electricity for adsorp. cooling	0	536
Major maintenance (10 year overhall)	15.101	12.837
Normal maintenance	4.582	3.574
Total O&M costs	126.259	92.737
Yearly savings		33.523

Table 3. Simple pay-back period of the extra costs of the polygen concept in comparison with the reference:

Simple pay-back period, years	Helsingborg	Helsingør
With-out support	17,2	12,3
With EU support to eligible extra costs	6,7	4,8

6. CONCLUSIONS AND FURTHER WORK

The technical feasibility has been evaluated by COWI, Öresundskraft (the energy utility of Helsingborg) and Lund University, based on previous experience and site visits to geo-exchange and adsorption cooling plants, followed by technical investigations and optimisation of the concept in relation to energy balances. The conclusion on technical feasibility is that the concept and involved technology are promising and suitable for the site investigated.

The economic feasibility for a plant in Helsingborg is also good when the actual EC-support in the ECO-City project is taken into consideration, but without EC-support it is not yet feasible in Helsingborg with the present energy costs. But energy prices are expected to increase in the future, which over time will make the concept feasible without support.

The private economic feasibility for a location in Helsingør in Denmark is much better due to the Danish energy taxation of electricity, but a suitable end-user and site for the plant have not been identified yet.

As we have EC-support available, it is now the plan to continue the work for a demonstration in Helsingborg with the new IKEA warehouse as preference; but at the same time, we will investigate alternative possibilities, also on the Danish side, as well as possibilities outside the ECO-City community.

REFERENCES:

/1/ Preliminary Analysis of General Conditions for Polygeneration Cooling in Helsingborg, DRAFT, O. Andersson & G. Hellström, Lund University, October 2006.