OPTIMAL POLYGEN COOLING CONCEPT FOR ST. OLAVS HOSPITAL IN TRONDHEIM, NORWAY

G. Eggen[1], A. Utne[2]
1) COWI A/S, PB 2564 Sentrum, NO-7414 Trondheim, Norway,
e-mail: geeg@cowi.no
2) Trondheim Energi AS, Sluppenvegen 6, NO-7005 Trondheim, Norway,
e-mail: amund.utne@tev.no

ABSTRACT

St. Olavs Hospital is the regional hospital for the Mid-Norway health region. The new University Hospital is being built in the central part of Trondheim. The first clinical centres were completed in 2006. The entire project will be completed in 2014.

Trondheim Energi Fjernvarme AS has delivered district heat to the existing hospital in Trondheim since 1982. The base heat production is from a waste incineration plant. The new hospital also requires cooling. The first part of the central cooling plant at St. Olavs Hospital was built in 2004, and it consists of one absorption chiller with 3 MW cooling capacity, one 3 MW centrifugal chiller and one screw compressor chiller with 1.3 MW cooling capacity. River water is used for cooling the district cooling water when the river water temperatures are low, and for condenser cooling when the water temperatures are high.

In summertime, there is surplus of waste heat from the waste incineration plant in the district heating system. This excess heat is used as the driving energy for absorption chillers. River water is used for condenser cooling in summer, and for direct cooling in winter when the water temperatures are low. This is a very environmentally friendly cooling system, as 60% of the cooling demand is covered by "free cooling" from river water. The additional 40% cooling is produced by an absorption chiller which uses waste heat as driving energy.

1. INTRODUCTION

In the city of Trondheim, the new St. Olavs Hospital is being constructed. Trondheim Energi Fjernvarme AS supplies both district heating and cooling to the hospital. The base heat production is from a waste incineration plant, and cooling is provided by a district heat driven absorption chiller in the summer, and by "free cooling" from the river in the winter when the water temperatures are low. In addition, there are installed compressor chillers for additional cooling as well as for safety reasons.

So far, one 3 MW absorption chiller is installed at St. Olavs Hospital, and another 3 MW chiller is planned to be supplied in 2009. This second absorption chiller plant is an Eco City project, which is a part of the EU Concerto program. The purpose of this paper is to present the status of the district cooling system, and the experiences so far.

2. DISTRICT HEATING AND COOLING IN TRONDHEIM

Trondheim is located in the middle of Norway, and the yearly average temperature is 5ºC. The design outdoor air temperature for heating is -19ºC. The design conditions for cooling are 24ºC temperature and 60% relative humidity.

Trondheim Energi Fjernvarme AS has delivered district heating in Trondheim since 1982. The main energy source of the district heating system is a waste incineration plant at Heimdal. Until 2006, it covered 50 % of the annual energy supply. The waste incineration is more or less constant through the year, and in summertime, there is a surplus heat in the district heating system. The design forward/return district heat water temperature is 120/70ºC. In 2006, the district heating production was 450 GWh.

Trondheim Energi Fjernvarme AS has also built two district cooling systems in Trondheim. The first one at Nedre Elvehavn was established in 2000, and the second plant at St. Olavs Hospital was opened in 2004. Cooling is provided by district heat driven absorption chillers in the summer, and by direct heat exchange with river water in the winter when the water temperatures are low. The design forward/return district cold water temperature is 7/15ºC. In 2006, the district cooling production was 8.5 GWh.

On March 13, 2007, a second waste incineration plant was started-up, with a waste incineration capacity of 15 tons per hour, 120 000 tons per year. The share of heat in the district heating system will increase from 50% to 75-80%. This also means an increase of waste heat in summer from 2007, which may be used as the driving energy for the absorption chillers.

3. DESCRIPTION OF THE DISTRICT COOLING CONCEPT

The excess heat from the waste incineration plant is used as the driving energy for an absorption chiller for district cooling. River water is used for condenser cooling in summer, and for direct cooling in winter when the water temperatures are low.

The first part of the district cooling plant at St. Olavs Hospital was opened in August 2004, and it contains one absorption chiller with 3 MW cooling capacity, one centrifugal compressor chiller with 3 MW cooling capacity, and one screw compressor chiller with 1.3 MW cooling capacity. The total cooling capacity is 7.3 MW. In the machinery room, there is space for another 3 MW absorption chiller, which is expected to be installed in 2009.

3.1. Design data

The new St. Olavs hospital is built in two phases:

Phase 1. 2003 – 2006:	100 000m^2
Phase 2. 2006 – 2010/14:	120 000 m^2
Total area – 2014:	220 000 m^2

The average design cooling demand at the hospital is calculated to be 45 W/m^2. With a floor area of 220 000 m^2 in 2014, this gives a cooling demand of approximately 10 MW. The cooling demand to be covered by the chiller plant includes a coincidence factor of 0.9, i.e. the design capacity of the chiller plant is 9 MW in 2010 – 2014.

3.2. Direct cooling by heat exchange with river water

St. Olavs Hospital is located close to the riverbank of Nidelven. It is a small river with the maximum depth of 5 m in this area. Figure 1 shows the day mean temperatures of the river water from September 1. 2006 to September 1. 2007.

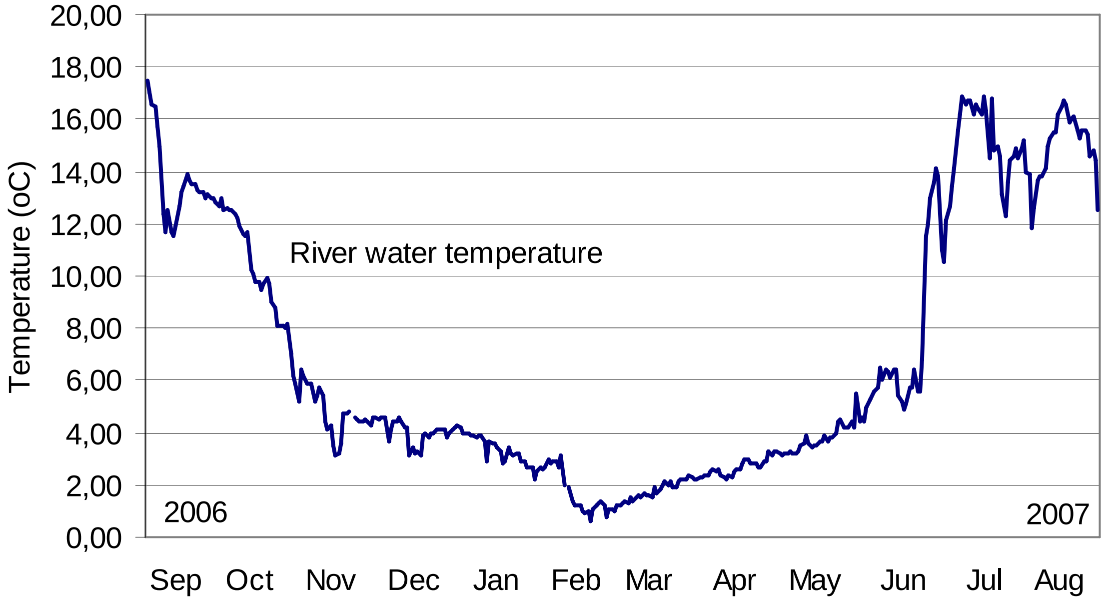

Figure 1. River water temperatures from September 1st 2006 to September 1st 2007

Most of the year, i.e. from October to June, the river water may be used directly for cooling the district cold water. However, in the warmest periods in summer, when the maximum cooling demand occurs, the river water is to warm to perform any cooling. Therefore, the chiller plant must be designed to cover the maximum cooling demand.

3.3. PRINCIPLE OF ABSORPTION COOLING

Figure 2 shows a schematic piping diagram of the district cooling production plant with a heat exchanger for pre-cooling from river water, and a one stage absorption chiller with district heat as the heat source. The condenser is cooled by the same river water system, which serves as pre-cooling load.

In an absorption chiller, the mechanical compressor is replaced by a "solution circuit with an absorber and a generator" as shown at the right hand side at Figure 2. Water is the refrigerant, and lithium bromide – LiBr, is the absorption fluid.

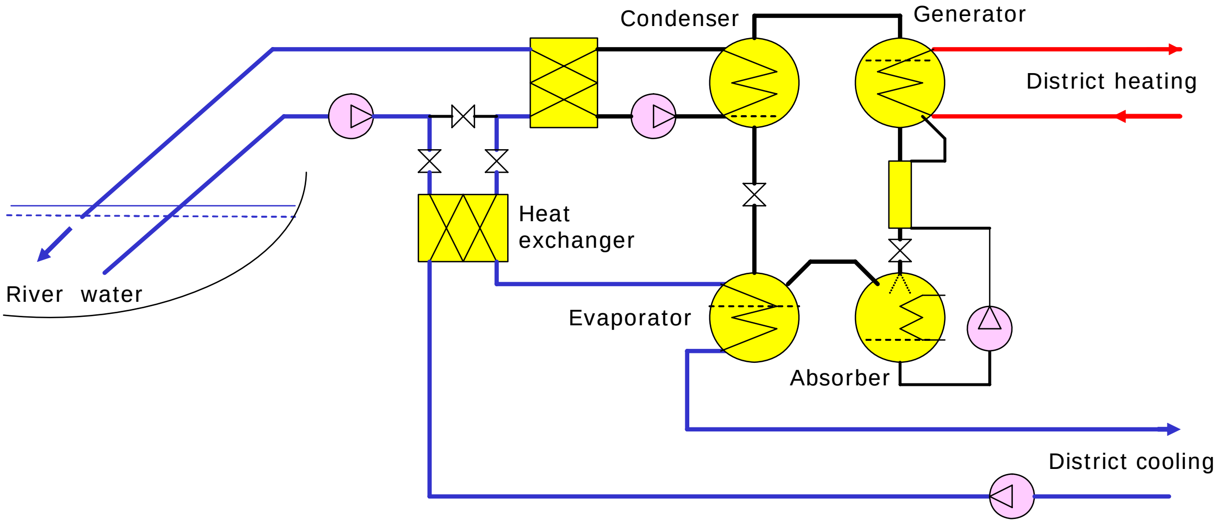

Figure 2. Principle of cold production plant with heat exchangers and absorption chiller.

Water is sprayed into the evaporator at very low pressure, and it evaporates by extracting heat from the district cooling water. By spraying lithium bromide into the absorber, the water vapor will be absorbed from the evaporator into the lithium bromide liquid. The water/LiBr-mixture is pumped to the generator, whereby the pressure is increased. In the generator, heat is added to boil the water (separating

H_2O and LiBr). The water vapor is led to the condenser where it is condensed by heat rejection to the river water. From the condenser, water is expanded into the evaporator for cooling the district cooling water.

The strong lithium bromide liquid is drained from the boiler and back to the absorber to absorb more vapor from the evaporator, and the process continues. By installing a heat exchanger between the strong lithium bromide liquid from the generator and weak liquid, the efficiency of the absorption process will increase because the strong salt solution’s capacity to bind water increases the colder the solution is.

The lowest district heating temperature into the boiler is approximately 85ºC with an evaporation temperature of 5ºC and a condensing temperature of 30-40ºC. If the district heat temperature is increased to e.g. 105ºC, the cooling capacity will increase 30-40%.

The absorption cooling plant works with a COP of 0.7, while a mechanical cooling plant will work with a COP of approximately 4, depending on the condenser cooling temperatures. The efficiency of the absorption plant is thus much lower, but on the other hand, the absorption plant may be run by waste heat while the compressor plant must be driven by electricity. Since the investments for a large absorption cooling plant is not much higher than for a mechanical refrigeration plant, the price relation between electricity and waste heat must be equal or higher than 6 in order to give a profitability for the absorption plant. This means that the absorption cooling plant is a profitable cooling system only when waste heat is available.

4. EXPERIENCES FROM THE COOLING PLANT AT ST. OLAVS HOSPITAL

During 2005, several new large buildings were connected to the district cooling system, and for the time being, approximately 100 000 m^2 floor area is cooled by the district cooling plant. The design cooling demand was expected to be

4.5 MW, and with a coincidence factor of 0.9, the capacity demand from the chiller plant is 4 MW.

4.1. Cold production

Figure 3 shows the daily mean ambient air temperatures, and Figure 4 shows the daily maximum and minimum cooling demands from September 1. 2006 to September 1. 2007. The measured temperatures and cooling production is registered every 10 minutes.

Most of the year, the cooling demands varies from approximately 500 kW to 800 kW, and this seem to be quite constant at ambient temperatures below 17ºC. The district cooling is used to cool computer and communication rooms, medical technical equipment, condenser cooling of local refrigeration equipment etc. At higher temperatures than 17ºC, district cooling is also used to cool the ventilation air and some local comfort cooling, and the cooling demand increases considerably.

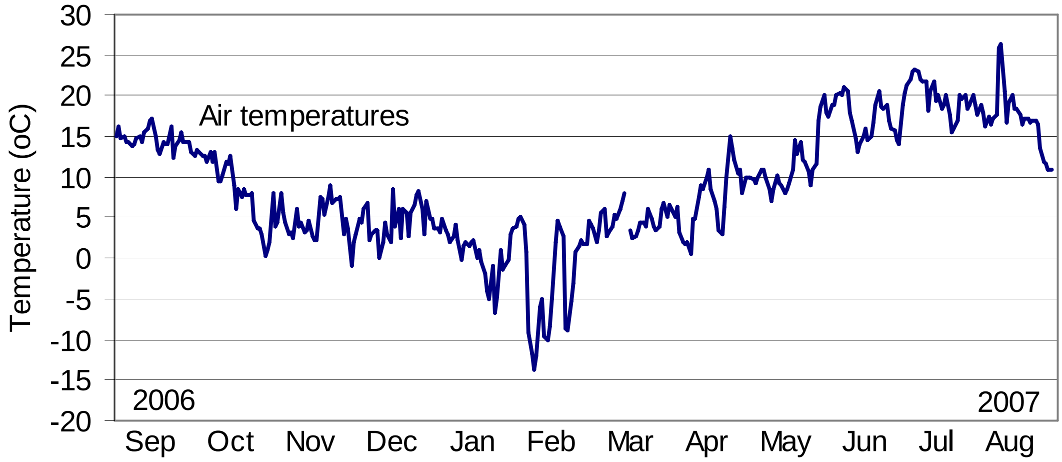

Figure 3. Daily mean ambient air temperatures from September 06 to September 07

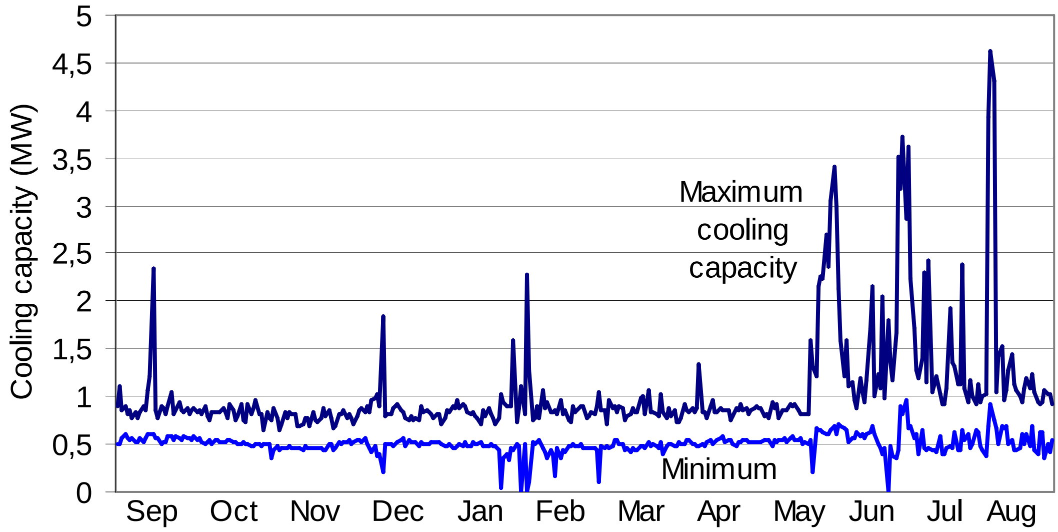

Figure 4. Daily maximum and minimum cooling demands from September 1. 2006 to August 31. 2007.

Figure 5 shows the variation of cooling production during a normal winter day, and during the warmest day in Trondheim this summer, with 30ºC as the maximum temperature, and 20ºC as the minimum temperature in the night.

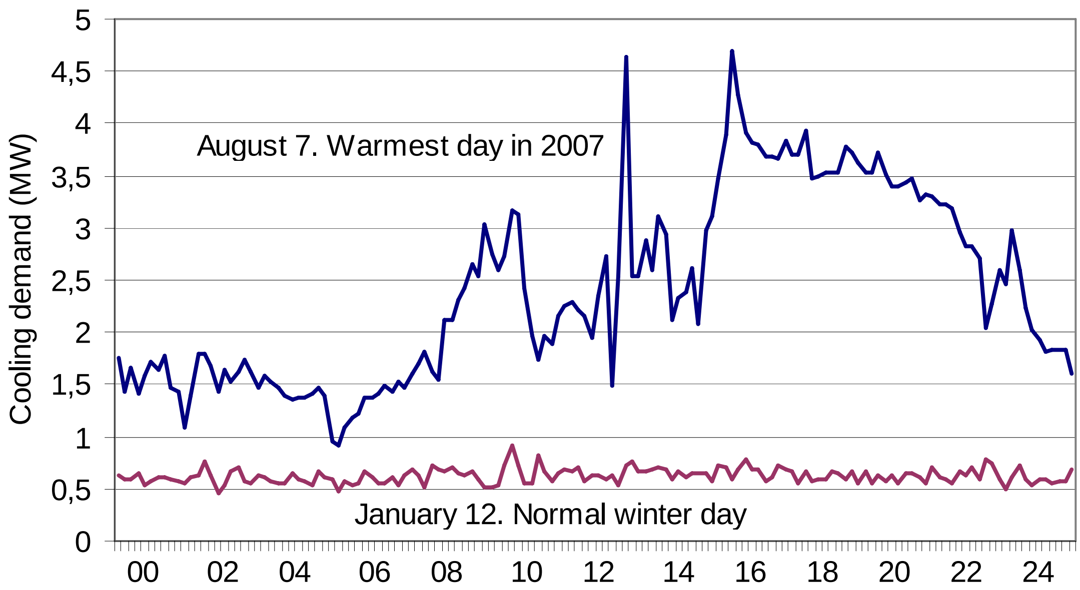

Figure 5. Cooling demand variations through a warm and a cold day

The maximum cooling load registered in summer 2007 was about 4.6 MW, but this was registered only two times with a duration of 10 min each time. From Figure 5, we can see that the maximum hourly mean cooling capacity is approximately 4 MW, and this is in good agreement with the calculated design cooling demands.

4.2. District cooling production from different cooling sources

Figure 6 shows the monthly cooling production from different cooling sources throughout one year. During the 8 coldest months, the cooling demand is covered by ”free cooling” from river water (Nidelven). The total cooling production from September 1. 2006 to September 1. 2007 was 6 400 MWh. From this, 3 760 MWh was “free” cooling from river water, and 2 640 MWh was produced by the chiller plant. Thus, nearly 60% of the cooling demand was covered by direct heat exchange with river water, and 40% was covered by the chiller plant.

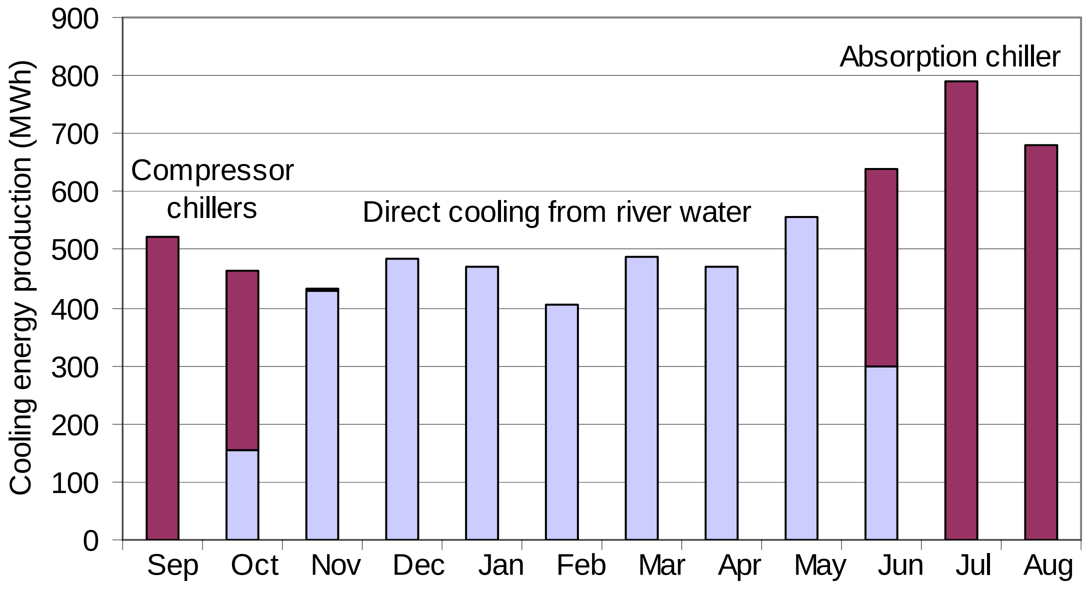

Figure 6. Cold production from different cooling sources from September 1. 2006 to September 1. 2007

In 2006, most of the cooling from the chiller plant was produced by compressor chillers, because there was hardly waste heat available from the district heating plant to be used as driving energy for the absorption chiller at St. Olavs Hospital. However, on March 13. 2007, a new large waste incineration plant was started-up in order to increase the heating capacity to the district heating system. This also means an increase of waste heat in summer from 2007, which may be used as the driving energy for the absorption chiller. Therefore, after the rise of river water temperatures in June this year, the absorption chiller has produced nearly all the cooling energy needed for the district cooling plant at St. Olavs Hospital. The compressor chillers have been in use only in the warmest days when the absorption chiller capacity was not sufficient to cover the cooling demand.

4.3. Operation experiences

When the chiller plant was started up in 2004, the cooling demands were too small for the 3 MW absorption chiller, and cooling from the chiller plant were mainly performed by the screw compressor chiller.

Since 2006, the cooling demand has rarely been less than 400 kW, and there has not been any problems connected to the absorption chiller nor the river water supply system. At the smallest capacities, however, the absorption chiller has to operate on/off.

Trondheim Energy Fjernvarme AS started its first district cooling plant at Nedre Elvehavn in Trondheim in 2000. This plant has got two district heat driven absorption chillers, each with a cooling capacity of 1 500 kW. One of the absorption chillers at Nedre Elvehavn was investigated as part of a master degree study at the Norwegian University of Science and Technology in Trondheim in 2002 (1). As a part of this project work, the efficiency of the chiller at part load operation was investigated, Figure 7.

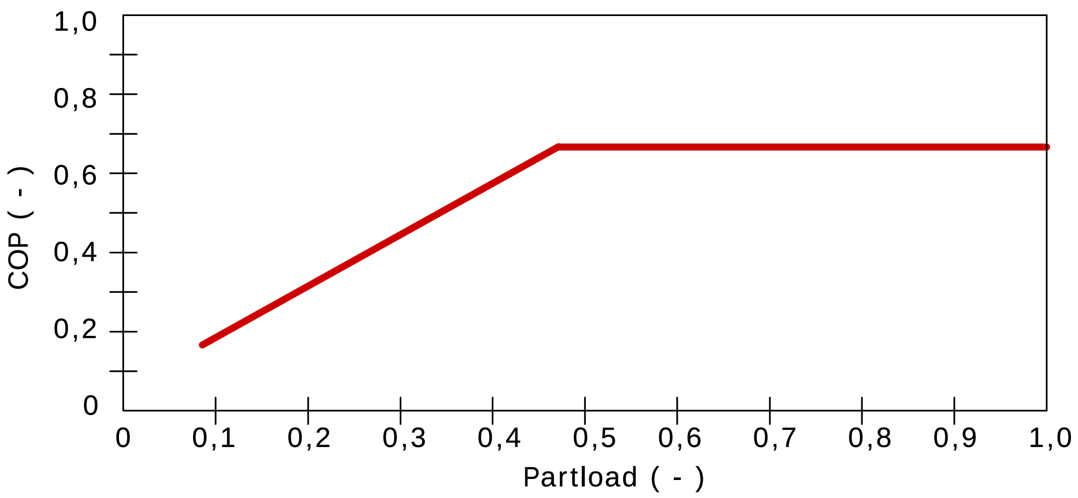

Figure 7. Coefficient of performance (COP) at part load operation

As shown in Figure 7, the COP decreases quickly when the part load is below 45% of the maximum capacity. The absorption chiller at St. Olavs Hospital is most of the year operating with 20% average part load, and the average COP is 0.3. When the development of the hospital is finished in 2014, the average part load is increased to 40%, and the COP has raised to approximately 0.6, which is close to the maximum value.

5. PLANS FOR FURTHER DEVELOPMENT OF THE DISTRICT COOLING PLANT

The main reason for participating in the Eco-City project was that Trondheim Energi Fjernvarme AS sooner or later has to install another 3 MW chiller at the district cooling plant at St. Olavs Hospital. It is also expected that this extra chiller is another absorption chiller. The decision to install a new absorption chiller must be based on two facts:

1 the cooling demand increases so that a new chiller is needed

2. There is surplus heat from the waste incineration plants available to run this new absorption chiller in summer

In order to provide information for the decision of installing a new absorption chiller, Trondheim Energi Fjernvarme AS has instrumented the district cooling plant in order to generate periodic reports from the operation of the district cooling plant.

The most important information requested is:

- Cooling production from different sources (heat exchange with river water,absorption chillers, compression chillers)
- District heat for driving absorption chillers.
- Electric energy consumption for compressors and pumps etc.
- Temperature measurements of all process streams of the central chiller plant

One important goal for this project is to find the optimal way to produce cooling in summer, e.g. by the absorption cooling plant or by compressor cooling plants. Based on the measurements and the experiences by users and operation staff, the operation that gives the least consumption of electricity as well as the least demand for maintenance will be evaluated. Large absorption chillers normally need a certain capacity to avoid on/off operation, and the project will try to find the optimal cooperation between absorption cooling and compressor cooling when the cooling demands are low.

The new absorption chiller must be installed in 2009 in order to be the object of measurements in 2010 for final report to the Eco-City project in October 2010.

6. CONCLUSION

The maximum cooling demand for Phase 1 of St. Olavs Hospital has exceeded 4 MW, and this is in good agreement with the calculated design cooling demands. This means that when the construction of the hospital is completed in 2014, the cooling demand will probably be about 9 MW, and there is need for a new chiller.

In 2007, there have not been any problems connected to the absorption chiller nor the river water supply system.

REFERENCES

1 M. Gretland: Fjernvarmedrevet absorpsjonskjøleanlegg for klimakjøling. Nedre Elvehavn kjølesentral. Prosjektoppgave høsten 2002. NTNU.