Case Study summary

IEA-ECBCS Annex 48

Heat Pumping and Reversible Air Conditioning

Belgian Case Study N°3: Ministry Building in Brussels

Université de Liège

Contribution of the University of Liège

Introduction

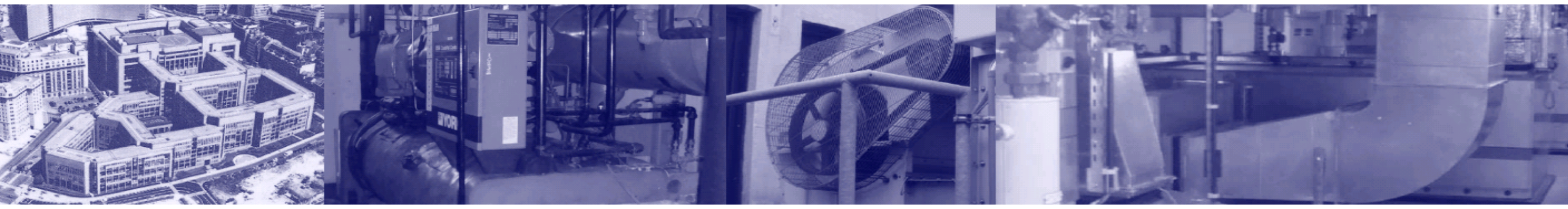
This European Council building was built in 1995 on a 40 000 m² ground area, with about 54 000 m² of useful area, distributed on 10 floors. The whole building is composed of two main parts: the Conference building (25 000 m²) and the General Secretariat (29 000 m²).

The Conference building is the highest part of the site, being distributed on 7 floors and 3 mezzanines. It mainly includes meeting rooms with interpreter cabins, conference and ceremonial rooms and delegation offices, but also three restaurants and one cafeteria. Its maximal occupancy is about 3 500 persons.

The General Secretariat building is organized all around four large patios, allowing a natural lighting of all the rooms. It is connected to the Conference building by two "wings". Its height goes down in terraces from 9 to 7 floors. This building includes mainly offices, printing rooms and computer room. There are also a sport area and a cafeteria. Its maximal occupancy is about 2 500 persons.

Summary

- Location: Brussels, Belgium
- Building sector: office
- Studied conditioned net area: 54 000 m²
- Chiller nominal cooling capacity: 5 MW
- Boiler nominal heating capacity: 7.5 MW



Background

The investigated building is characterized by simultaneous heating and cooling demands during part of the year. The aim of this study was to quantify the heat recovery potential and to identify a heat recovery technology. By recovering heat, the fuel consumption of the boilers could be reduced, yielding a decrease in CO_2 emissions.

Building view

Cooling plant

The cooling plant mainly comprises:

1. Four twin-screw chillers in parallel arrangement, with a total nominal capacity of 5 MW. Capacity control is achieved by means of a slide valve which can modulate the chiller capacity from 100% down to about 10% of full-load. The slide valve control also protects the compressor motor against overloading. Each chiller has a fixed-speed pump on the evaporator and condenser sides.

2. Five counter-flow cooling towers in parallel arrangement. Each tower is equipped with a two-speed centrifugal fan.

3. Four 58 m^3 horizontal encapsulated ice-storage tanks in parallel-series arrangement. The total latent heat capacity is 10.3 MWh.

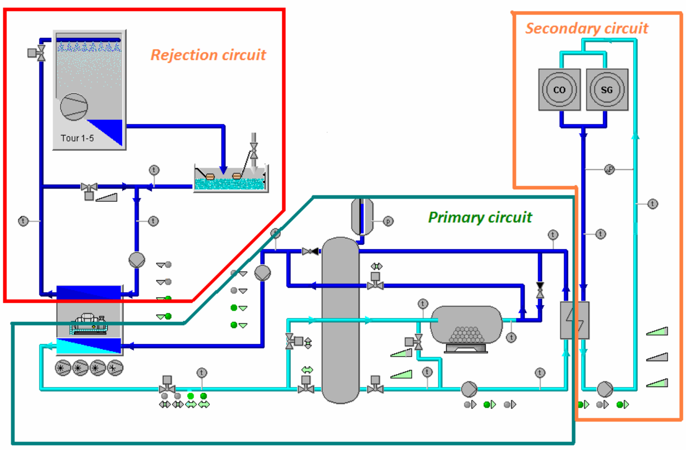
4. Five counter-flow plate heat exchangers in parallel arrangement.

Several networks connect these elements:

1. A variable flow rate chilled water distribution network, connected to the building ("secondary circuit").

2. A glycol water circuit on evaporator and ice storage tank side ("primary circuit").

3. A warm water circuit connecting the condensers and the cooling towers ("rejection circuit").



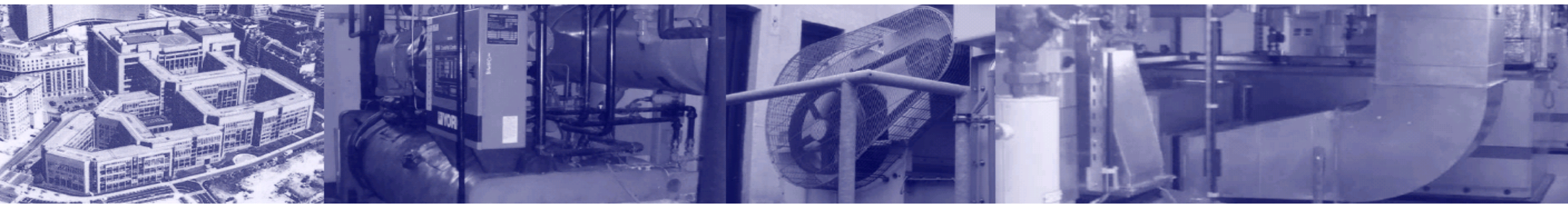
Main components of the cooling plant. On the left: the chillers connected on one side to the cooling towers and on the other side to the primary circuit. On the right: the secondary circuit connected to the buildings Conference (CO) and Secretariat General (SG)

Heating plant

The heating demand is satisfied by means of four boilers. A total installed power of 7.5 MW can be reached by using simultaneously one boiler of 750 W and three boilers of 2250 W. All of the four boilers are equipped with a modulating burner. They can be fed either with natural gas or oil. When they are fed with natural gas, the 750 W boiler and one of the 2250 W boilers can work in a condensing regime. The modulating range of the boilers is 50-100%. The 750 W boiler is continuously used, even in summer for the eventual post-heating and for the sanitary water.

Under the threshold of 3000 kW, only the two condensing boilers are used. Beyond 3000 kW, the two other boilers are used. They are connected in series with the two condensing boilers in order to allow these two boilers to beneficiate from the return water.

The heating plant also comprises a high pressure boiler for the humidification in the CO building. The useful power of the boiler is 1450 or 1250 kW (2155 or 1800 kg/h of saturated dry steam at 5 bar), whether the boiler is fed with gas or oil.



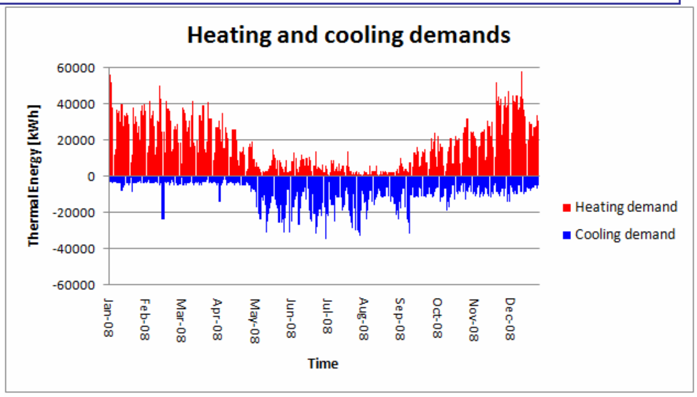
Heat Recovery on chillers by means of heat pumps

The heat recovery potential is shown in the figure hereunder giving the annual heating and cooling demands. Actually, simultaneity between these two demands can be observed during parts of the year.
The heat recovery solution would be to insert a heat pump cycle between the condensers of the cooling plant and the cooling towers. The evaporator of the heat pump is connected in series with the condensers of the chiller (which are in a parallel configuration). With this configuration, condenser leaving water flows through the evaporator of the heat pump. The use of heat pump enables rising the level of temperature of the recovered heat up to 60-70℃ (such heat pumps are commonly named “temperature amplifiers”).

Simulation methodology

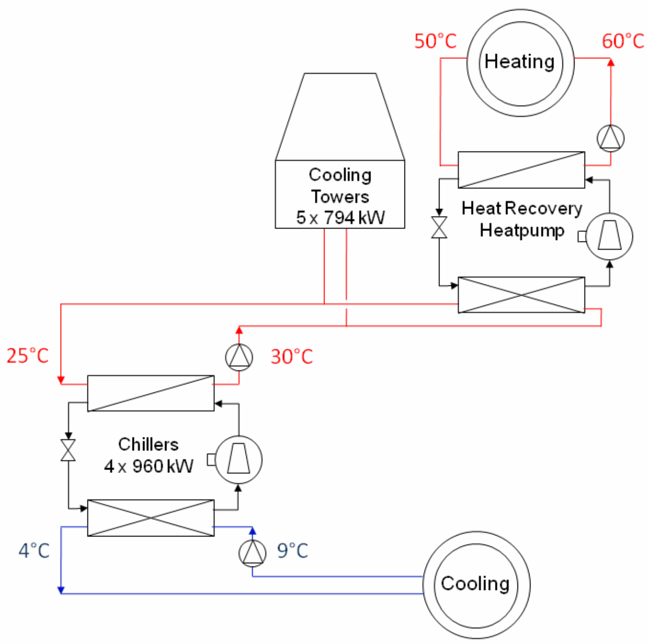
In order to evaluate the potential of heat recovery and of decrease in CO_2 emissions, a simulation model of the cooling plant was developed.

This simulation model associates the sub-models of the chillers, the storages tanks, the cooling tower and the heat recovery heat pump. The chillers, the heat pumps and the cooling towers models are described by their full load and part load performance. The inputs of the simulation are the heating and cooling demands of the building. The way the plant is operated in order to satisfy these demands is described by the simulation model.
The control tries to fully satisfy the heating demand with the heat recovery heat pump. When it is not possible, because of a too low cooling demand, the rest of heating demand is provided by the boilers.

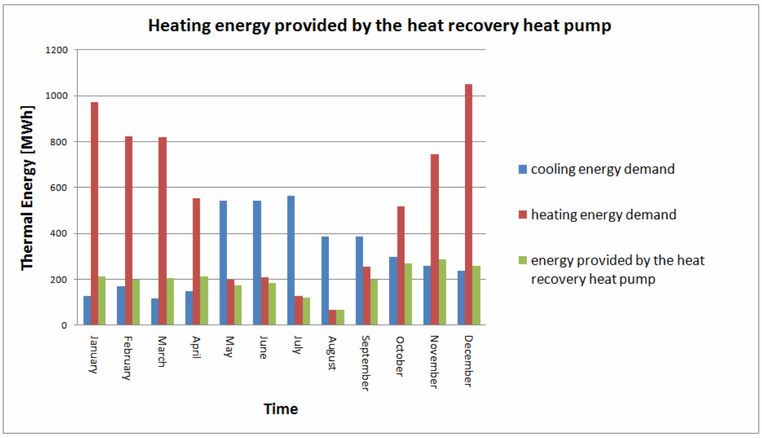


Annual evolutions of the cooling and heating demands

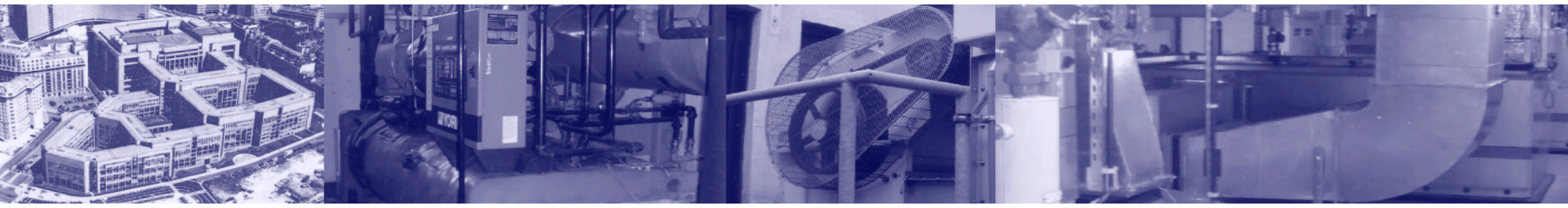
View of a heat recovery heat pump available on the market



Connection of the heat recovery heat pump to the chilled water plant

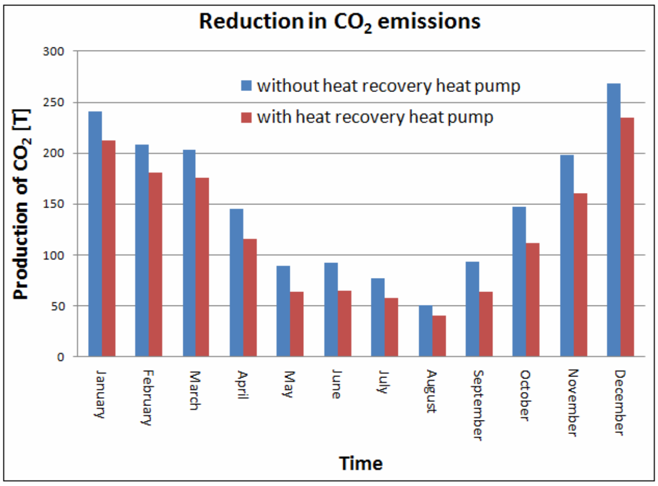


Monthly cooling and heating demands and heating energy provided by the heat pump



Simulation results

The simulation results predict a limited decrease in the CO_2 production (18%), which can be explained by the fact that only 36% of the total heating demand is produced by de heat recovery heat pump. The profiles of the cooling and heating demands limit the use of the heat recovery heat pump. Buildings characterized by a constant high cooling demand through the year (cooling demand associated to computer room for instance) would be more appropriate for such heat recovery heat pumps.



Monthly reduction in CO_2 emissions

For low outside air temperatures, the heat recovery heat pump is not sufficient to ensure alone the heating demand. The heat pump usually works between 40℃ and 70℃. Fortunately the most of the heat demand is produced when the outside temperature is higher than 3.5℃ which means a hot water temperature lower than 65℃. The average COP of the heat pump is 3.4, while that of the chiller is 4.2.

Another way to improve the global performance of the heat recovery system would be to store the heat produced by the condensers, when the cooling and heating demands do not coincide on a given day (for instance, when chillers are running during the night for loading the ice storage tanks).

Note that the decrease in the electrical consumption of the cooling tower is negligible because the total electrical energy supplied to the cooling tower is only 7% of the total electrical consumption of the central cooling plant.

Contact Information

Université de Liège
Thermodynamics laboratory
Campus du Sart-Tilman Bât. B49
4000 Liège
www.labothap.ulg.ac.be

Université de Liège
Département des sciences et gestion de l’environnement
Avenue de Longwy, 185
6700 Arlon

Date of case study summary: May 2010

Literature

IEA-ECBCS Annex 48 website: http://www.ecbcs-48.org
Harmonac website: http://www.harmonac.info

IEA-ECBCS Annex 48

IEA-ECBCS Annex 48 is a research project on reversible air conditioning systems in the tertiary sector. The project is accomplished in Energy Conservation in Buildings and Community Systems Programme of the International Energy Agency (IEA).

Internet: http://www.ecbcs-48.org