Case Study summary

IEA-ECBCS Annex 48

Heat Pumping and Reversible Air Conditioning

Belgian Case Study N°2: an 9-storey office building in Charleroi

Université de Liège

Contribution of the University of Liège

Introduction

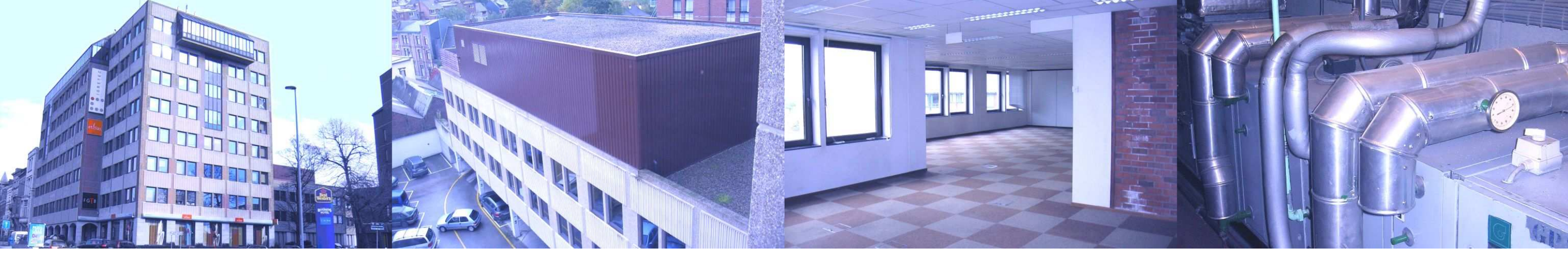
This Summary gives field monitoring result of a medium size office building built in Charleroi (Belgium) in the end of the eighties. From the 9 floors of the construction, only 4, for which energy balance could be worked out, have been studied.

40 people occupy each of these floors from 8 am to 6 pm, 5 days a week. The HVAC system consists mainly of an AHU that supplies conditioned air to the different offices through a duct network. Air can be post heated with 31 local coils distributed over the 4 floors. Local comfort temperature set points can independently be adjusted by occupants within a range of +/- 3°C around a fix value (21°C). A buildi ng energy management system (BEMS) handles all necessary data and implements the control strategies.

The heating system is composed of 3 classical gas boilers (318 kW each). There are also 2 chillers with piston compressors, for a total cooling capacity of 245 kW.

Summary

- Location: Charleroi, Belgium
- Building sector: office
- Gross net area: 7 220 m²
- Studied conditioned net area: 2 960 m² (4 typical floors)
- Chiller nominal cooling capacity: 245 kW
- Boiler nominal heating capacity: 954 kW
- U-value external walls: 0,50 W/(m²K)
- U-value windows: 2,83 W/(m²K)



Background

The aim of these audit and monitoring was first to understand the HVAC system of the building. It also proved very useful in verifying some simulation work done before the monitoring phase (“calibration” of the models). Of course the monitoring was necessary to point out the main energy savings possibilities and in the end evaluate the reversibility potential of the building, which is one of the objectives of the IEA-ECBCS Annex 48 project.

Current transformer for energy counter

Technical concept

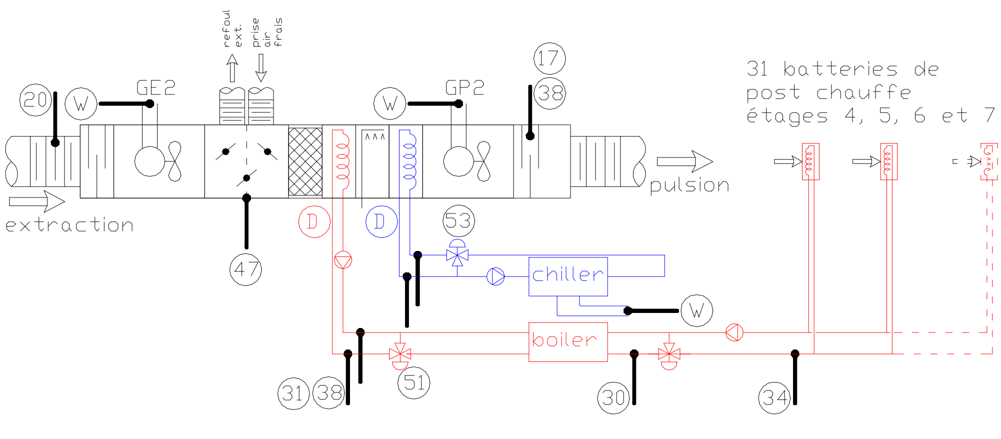
The HVAC System is articulated around an Air Handling Unit (GE2-GP2, see diagram below). After being possibly mixed with fresh air, the return air passes through a heating coil, an adiabatic humidifier and a cooling coil and is finally sent to the distribution duct network.

The heating part consists of 3 Ygnis high efficiency gas boilers (without condensation) of 318 kW each. Nominal temperatures at the boilers are 70/90℃. For the cold production, two air condenser chillers equipped with a total of 4 Bitzer piston compressors. The nominal cold production capacity is 245 kW, the COP of the devices is 2.

There are 31 post-heating coils spread all over the 4 levels. The VAV terminal units, in the different offices, allow the people to adjust the local temperature within the range +/- 3℃ around a fixed setting (21℃). Th ere are 2 to 4 VAV boxes per post-heating coil. These boxes are located in the false ceiling downstream of the post-heating coils. 5 little splits are present in technical zones.

A BEMS manages the whole system and allows the monitoring of more than 300 data variables.

Meteorological station on the roof



Main components of the HVAC system

Technical data of the unit/building

- Internal gains: 20 W/m²
- AHU ventilation rate: 30 000 m³/h
- Pulsion ventilator: 18 kW
- Extraction ventilator: 10 kW
- VAV boxes opening range: 30-100%
- Hot water loop pumps: 4,5 kW
- Chiller pumps: 1,85 kW



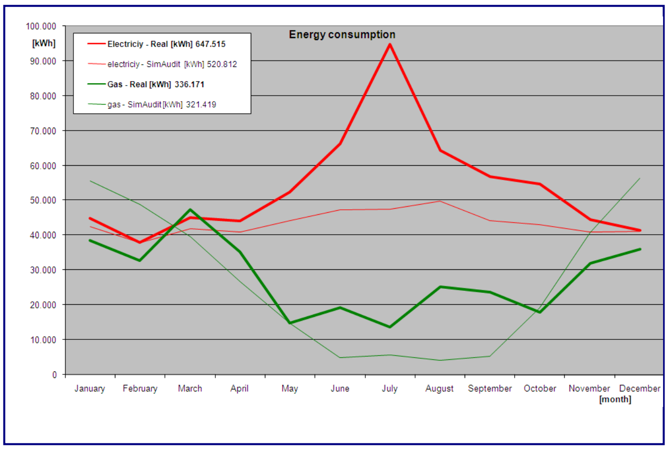

Field monitoring

The first step in the audit process was to collect energy consumptions records and to compare them with the actual measured data. There came a first shock: the electricity consumption is up to 3 times the one estimated in the simulations.

It was clear that some of our hypothesis were wrong. The analysis of the data coming from the different sensors provided some explanations. First, the electricity consumptions of the AHU, of the chiller, of the splits and of the 6th floor tend to prove that these equipments were operating non-stop during the whole year. This over consumption can explain the biggest part of the difference between the simulated and the real figures. Moreover, these non-stop operations lead to increased internal gains, and thus cooling loads… Secondly, the temperature set points are always higher than 21℃ in winter, and always under 24℃ in summer. This means high heating needs in winter and high cooling needs in summer. Some other issues, like the choice of temperature set point for GP2 or for the hot water generated by the gas boilers can also explain cases where energy is killed.

After reviewing with the energy manager of the building, some changes were applied. But complaints about comfort arose and the management had to be partly changed back. After a new analysis of the data, we could clearly notice a zone of the building where the temperatures were increasing too much in summer and falling down in winter. This zone was thus better insulated. In the end, the management of the building is still far from being optimal. It showed us the complexity of applying on the field the theoretical changes that seem to be obvious.

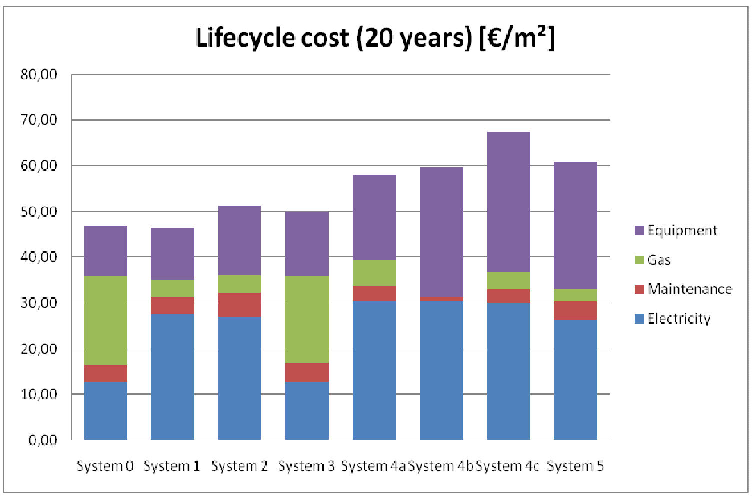
For the purpose of the project, an estimation of the savings that could be achieved using some reversible systems was performed. The results obtained using the simulation tool (developed by the Thermodynamics Laboratory) are based on an "optimal" consumption of the given building.

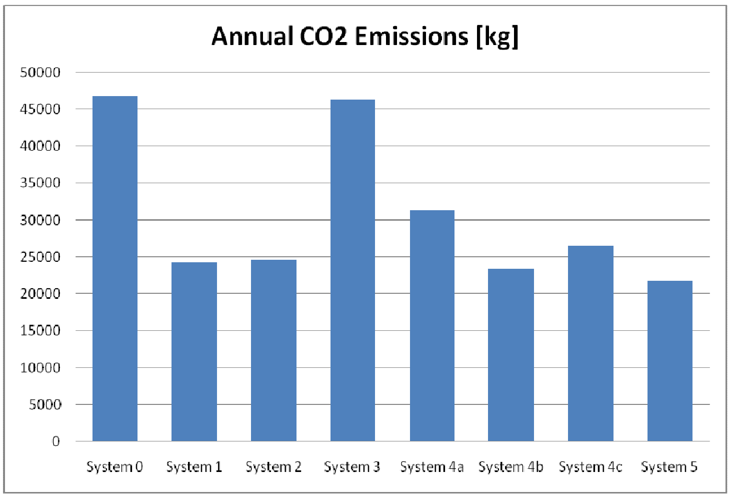


Comparison between the simulated energy consumptions (thin lines) and the measured ones (thick lines). Gas is red, electricity is green.

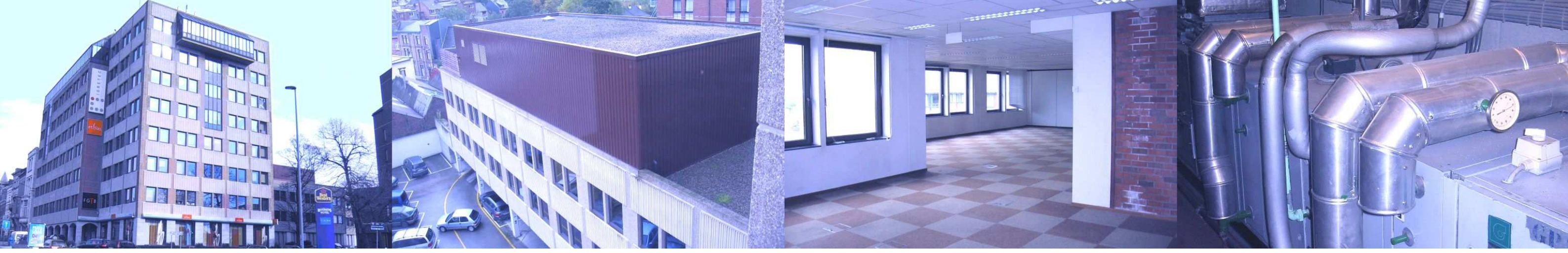
Field monitoring material

- BEMS (different temperatures, humidity ratios, pressures, register positions, set points…)
- Meteo station: outside temperature, humidity ratio and solar radiation
- Current transformers for energy counters (chiller, splits and consumption of a complete floor)
- Ultra-sonic flow meter and temperature sensors on hot and cold water collector
- CO2 sensor





Results of the evaluation tool



Conclusion

This case study was very instructive on many points:

- The monitoring is very important to cross-check the information given by the management and/or the BEMS. Wrong hypothesis about the system lead to very different energy consumptions.
- If necessary, adaptations to the system and/or the building can bring huge energy savings, before evaluating reversible systems. In our case, a reversible system in the building as such would have been a non-sense.
- Even with a very good cooperation with people in charge, it is not always easy to propose and apply changes to a system that is working (risks for comfort conditions…)
- The economical aspects are always essential. Investments need to be carefully thought, even more nowadays, given the actual economical context. In our case, we know that such investments won't be possible.
- The evaluation of the reversible systems consumptions, even theoretical, remains crucial. Future new or retrofit projects could take advantage of these results.

Results of the evaluation tool

- System 0: a basic system based on air cooled chiller and a gas boiler. This system is used as the reference;
- System 1: a reversible air-to-water heat pump coupled with a backup boiler;
- System 2: an exhaust ventilation heat pump coupled with a backup boiler;
- System 3: a dual condenser heat pump coupled with a backup boiler;
- System 4a: a water loop system using a heat rejector and a boiler;
- System 4b: a water loop system using a vertical ground exchanger and a heat rejection device;
- System 4c: a water loop system using a vertical ground exchanger and a boiler.

The results shown on the previous page point two main alternatives to the classical system: system 1 and system 5. For system 1, the primary consumption is reduced and the overall life cycle price remains almost constant. The system 5 is the greenest. The results for the CO_2 emissions confirm the trend but are not shown here because each country has different conversion factors (for the primary energy, a mean value of the European values was used).

Further readings

Links to internal reports about the case study.

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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