How to reach less than 15 kWh/m² annual final energy use for HVAC in an office building

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The activity of the HDL Company, located in Besançon (France), is to renovate buildings. HDL wanted to show its expertise in energy efficiency in the most credible possible way: by applying it to its new headquarters. In 2008, HDL refurbished an old school (2 036 m²) to establish its new offices. HDL wanted an exemplary operation: reach less than 15 kWh (final energy)/m².year for HVAC consumptions. EDF offered them support by measuring the site energy performance. In this article, we describe the technical characteristics of the building and the HVAC systems in place. Then, for each end-use, we present two years of energy and performance measurements: ground source heat pumps, distribution pumps, ventilation, lighting and others uses. We show the improvements made during these two first years of operation. Finally, to generalize this field case to other refurbishment operations, we propose eleven rules to be applied to achieve this level of consumption. So far and according to our information, this renovation operation remains the most efficient one in France.

Figure 1. HDL's Headquarters.

Building

Habitat Développement Local (HDL) has acquired the former school Jean-Jaurès (2 036 m²) in Besançon (**Figure 1**) and completed a partial expansion to install offices and

Figure 2. Chilled beam during installation.

Figure 3. AHU with rotary exchanger.

create a central building housing the various departmental structures of Habitat. The activity of the company includes renovating and leasing out buildings. Concerned by sustainable development, HDL wanted to show its clients how to master energy efficiency in the most credible possible way: leading by example.

The consultants Image & Calcul, based in Besançon, were entrusted with the task of rehabilitating the site with an ambitious goal: to keep consumption under 50 kWhEp/m².year (Ep: primary energy) for the Heating, Ventilation and Air Conditioning (HVAC) in a region known for its harsh winters (temperature of –13°C) and its hot summers. A high level of energy efficiency was required in terms of energy efficiency.

Minimizing all requirements: heating, cooling and lighting

Losses under base conditions are 65 kW, or 32 W/m². Reinforced insulation in opaque walls –part of the insulation is made from the outside– results in U coefficients around 0.25 W/m².K. In addition to 20 cm of mineral wool, roof insulation is completed with 8 cm of wood wool (U: 0.14 W/m².K). Here the goal is to reinforce thermal inertia in the roof for comfort in summer. Indeed, in addition to its low thermal conductivity, wood wool benefits from high mass density and thermal capacity. In summer, the heat coming from the roof is therefore delayed by 5 to 7 hours, after employees have left the offices.

Windows are aluminum with argon-filled double glazing (Uw: 2 W/m².K). The surface area is limited, covering 28% of the façade on average. This type of glazing is a good compromise between a low solar factor (38%) to limit solar contribution and high light transmission (70%) to promote natural lighting. The upper part of the interior office walls have translucent panels that allow light to pass through to the central walkways. To minimize energy consumption due to lighting, motion detectors were installed in all walkways and service areas. They also control HVAC in meeting rooms.

Installing high efficiency equipment

Distribution terminals are chilled beam modules (**Figure 2**). These are cassettes without fans that require neither filters nor condensation trays. Maintenance is therefore quite simple. These cassettes are operating at high temperature in summer (17°C) and low temperature in winter (35°C). Pretreated air in the central unit is brought into the beams via buses that pass the air over the batteries by induction.

Losses related to air renewal are minimized: Air Handle Unit (AHU) is equipped with a high efficiency rotary heat exchanger with 80% efficiency (**Figure 3**). The two fans are equipped with variable speed drive. Hygroscopic coating on the recuperator humidifies new air in the winter and dries it in the summer.

Figure 4. Water/water heat pumps.

Figure 5. Geothermal probes.

Hot and cold water are produced by two glycol/water heat pumps (**Figure 4**). The heating power of each is 32.6 kW, cooling power is 25.4 kW for absorbed power of 7.2 kW (COP of 4.5 at 0°C/35°C). A 9 kW electric heater is installed on the loop in order to prevent imperfection in implementation of insulation in the rehabilitation. Heat pumps are connected to a field of ten vertical geothermal probes, each penetrating to a depth of 100 meters (**Figure 5**). The size of the field was based on 50 W/ml. In winter, water coming from the probes travels to the heat pump evaporators. In summer, priority is given to the geo-cooling mode: water from the probes supplies the cooling battery of the AHU and the comfort modules, via a heat exchanger. In this case, the building is cooled without electric compression.

In case of heat wave, the heat pump supports the geo-cooling mode. The schematic diagram allows possible heat evacuation from the heat pump condenser to the vertical probes. Most of the circulation pumps are equipped with variable speed drive.

Finally, in addition to motion detectors, T5 type lighting is used. The cost of HVAC part, with the vertical geothermal probes, was 194 €HT/m².

Remarkable result

Final consumptions for all uses reach 50.1 kWh/m².year. HVAC consumptions represented less than a third with 14.5 kWh/m².year (or 37.5 kWhEp). HDL has improved the set goal (50 kWhEp/m².year) despite a harsh winter. Other uses represent two thirds of consumption, or 36 kWh/m².year, ten of which are related to lighting (**Figure 6**).

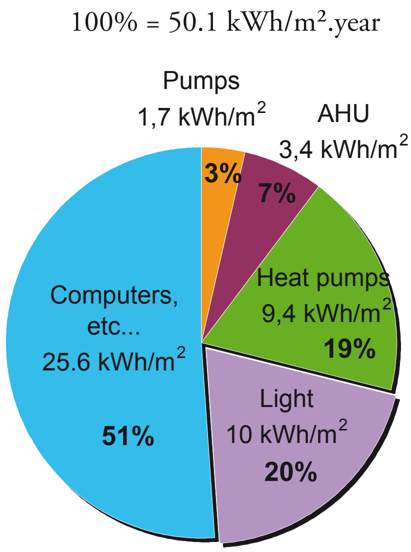

Figure 6. Distribution of annual consumption by use.

Heat pumps are operating under excellent conditions: their average annual COP machine is 4.2 and close to 4 when including consumption of the pump that irrigates the geothermal probes. Despite the cold weather during the winter of 2009–2010, electric output was never required. Geo-cooling was able to provide necessary cooling (**Figure 7**).

Table 1 shows the changes of consumption rate between the first and the second year of operation. The improvements come from better settings, especially concerning programming intermittency, detection of air flow leaks in ventilation pipes, cleaning clogged pump filters, lowering condenser temperature, etc.

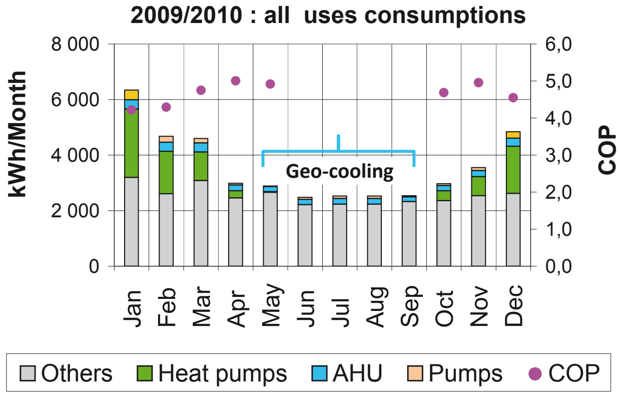

Figure 7. Monthly changes by uses and COP of the heat-pump.

Table 1. Comparison of consumption between the first and second year of operation.

Consumptions by use	First year "First commissioning"	Second year "Refinement settings"
Pumps	2,5	**1,7**
AHU	4,8	**3,4**
Heat pumps	12,5	**9,4**
HVAC	19,8	**14,5**
Others	37,8	**35,6**
Total	57,6	**50,1**
Heating needs	52	**43**
Cooling needs	3	**6**
COP*	3,8	**4,15**
Degrees days (Average thirty 2555)	2594	2486

kWh/m2.year

* : including the pump that irriguates the probes

"Class A" in terms of greenhouse gas emissions

When including lighting consumption, this site reaches a class B energy label, and class A in terms of greenhouse gas emissions. A gas boiler and air/water cooling unit solution (performance estimated at 95%) would have been positioned in class B also, but in class B concerning greenhouse gases emissions. The vertical geothermal solution reduces CO_2 emissions by two-thirds.

Competitive operating budget

Geothermic solutions have a clear advantage over fossil fuels in terms of operating costs: MWh of heat from the heat pumps is around 28 € Tax Free/MWh (set premium included, the site has a "yellow tariff" for electricity). With a gas boiler, it would have been close to 45 € Tax Free/MWh. Under these conditions, the costs of the energy station are particularly low, reaching 5.6 €/m², all uses included. The HVAC annual cost represents 1.9 €/m² with 1.3 for the heat pumps. It's remarkable. This operation shows that geothermic solutions are an excellent source of eco-efficient energy.

It has allowed HDL, with the involvement of all players, to achieve its ambitious target. Two bars that are difficult to achieve, in primary energy, were passed: 40 kWhEp/m².year for HVAC and 130 for all uses. In comparison to the various studies carried out by EDF R&D and current literature on the subject, in our opinion, this renovation project has the best performance in the country in terms of energy eco-efficiency.

Conclusions

HDL wanted an exemplary refurbishment for its headquarters in terms of energy efficiency. This operation shows that we can, at reasonable costs (HVAC = 194 €/m²) reach less than 15 kWh/m².year for HVAC and less than 25 including lighting. To achieve these levels of consumption on others operations, it will, whenever possible, be necessary to apply the eleven following principles:

- Insulate the walls at 0.25 W/m².K;
- Insulate the roof at 0.15 W/m².K;
- Install windows with Ug of 1.1 W/m².K, preference for PVC;
- Limited the glazed surface to 30% of the vertical walls;
- Systematize for lighting, the installation of T5 tubes with presence detection;
- Install a double flow AHU with rotary exchanger;
- Choose auxiliaries (pumps and fans) with variable electronic speed;
- Install - the cornerstone of all - thermodynamic machine with a COP close to 4 (water table or vertical probes according constraints on site).

If these technical points are followed with these organizational measures:

- Regular controls on site during refurbishment phase;
- Scrupulous (even zealous…) commissioning;
- Energy monitoring at the first start in winter,
- then, the renovation will, certainly, be a success.