VENTILATION SOLUTIONS IN NET ZERO ENERGY BUILDINGS, THE ELITHIS TOWER CASE STUDY

Oscar HERNANDEZ[1], Francis ALLARD[2]

1. *Elithis Groupe* *1C Boulevard de Champagne* *21000 Dijon* *France*	2. *Université de La Rochelle* *Avenue Albert Einstein* *17000 La Rochelle* *France*

ABSTRACT

This paper focuses on ventilation solutions of a net zero energy building. We present the monitoring results after two years as part of the PHD programme research “Design, simulation and control of hybrid ventilation systems in high energy performances buildings” founded by Elithis Groupe in parternship with the LEPTIAB of La Rochelle.

The objective of this paper is to study the ventilation solution of a net zero energy building, the thermal comfort and the indoor air quality in terms of CO_2 [1]. We present in the first part, a building description and ventilation principle, in second part we present the energy monitoring results of the Elithis Tower and ventilation consumption system during 2009 and 2010. Finally we show the ventilation performances in terms of energy, CO_2 concentrations and thermal comfort.

Results show an office building with an acceptable thermal comfort with a high energy performance but with a relatively low indoor air quality.

KEYWORDS

HVAC, Triple flux, Ventilation, Energy consumption, positive energy.

INTRODUCTION

The buildings account for more than 40% of energy demand in Europe and more than a third of greenhouse gas emissions, a major effort to improve the energy efficiency of buildings associated with a drastic reduction of their gas emissions of the greenhouse is now necessary. In this sense, changes in regulations, both European and national, converge on large-scale development of new buildings or renovated with very low energy demand. In addition, we consider today that more than a third of the total energy consumed on earth is for the air-conditionning of interior spaces. In air-conditioning strategies of interior spaces, optimal management of ventilation occupies the first position. In addition, ventilation is indeed the oldest and most widely used strategy for controlling the indoor environmental quality.

This paper presents the building together with ventilation - and their related ventilation and control strategies. It also describes the monitoring programme, which includes two years, for heating, cooling, fans (ventilators), pumps, lighting, elevators and plugs and loads equipments. The monitoring also includes one day per month of thermal comfort and average CO_2 concentrations of one level.

BUILDING DESCRIPTION

The Elithis tower (figure 1 and 2) is the first postive energy office building according to the French regulation[1], it is located in Dijon, France. This building is composed of 9 levels and 1 technical level (HVAC systems). It is 33.5 meters high. 4 levels are occupied by Elithis Engineering Company, and the others by the Ademe (Departmental Agency of Energy Management), X-rays medical services, a restaurant and other civil engineering companies.

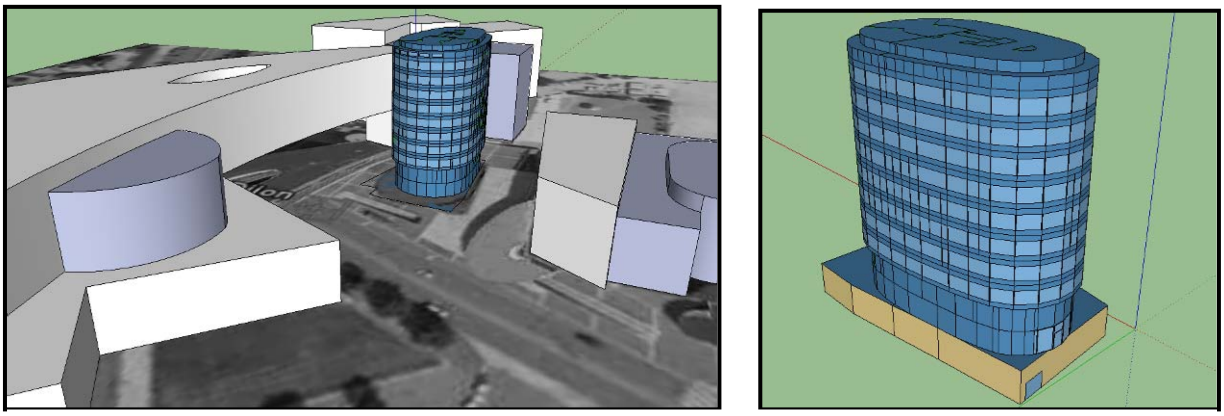

Figure 1. Elithis Tower Energy Plus model

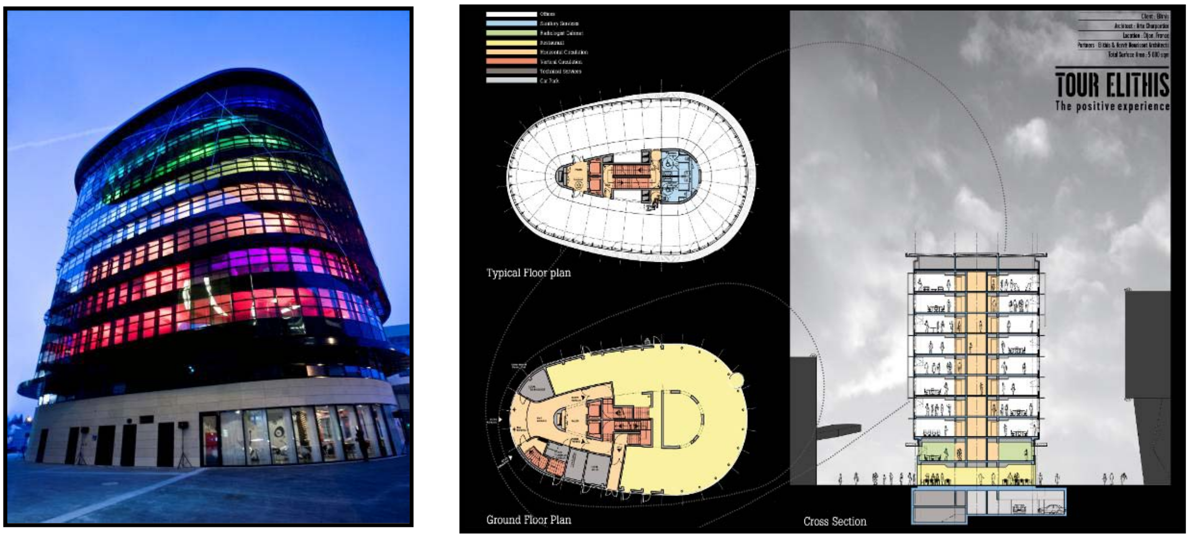

Figure 2. Elithis Tower - Govin SOREL - ARTE CHARPENTIER

The aim of this project was to combine aesthetics, urban integration, thermal comfort, energy, environmental performance and price. The Elithis Tower is a net zero energy building. For this purpose, 7 millions of Euros only were required to construct it.This represents 1400 € per m², which is the usual cost for a standard building in France.

The use of passive means and natural resources was a priority so as to reduce the environnemental impact. To achieve thermal and visual comfort in the building, sun and wood were selected as the main energy sources. Thermal comfort was retained because the sun heats the building naturally and provides light all the day long. Visual comfort because the surface fenestration is about 75% of the facades.

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[1] BEPOS (Positve energie building) Only the heating, cooling, ventilation, lighting and hot water are taken into account. (www.effinergie.org)

The thermal mass of the building can be considered as medium because only the “central core” (figure 3) is in concrete. The facades are made of wood and recyclable insulation (cellulose wadding) and 75% of surface fenestration.

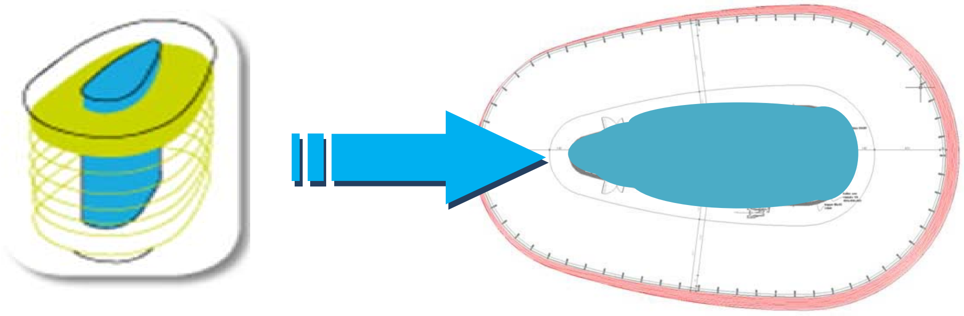


Figure 3. Central core

The design criteria of the building are show in table 1.

Window U	1.1 W/(m² K)
Window g	0.4
Exterior wall U	0.32 W/(m² K)
Base floor U	0.39 W/(m² K)
Roof U	0.22 W/(m² K)
Mean occupant density	15 m²/person (overall average)
Occupied hours	2450 h
Design outdoor temperature for heating	-11°C
Design outdoor temperature and RH for cooling	32°C / 38%
Heating degree days (include base temperature)	2 650 Degree days (base 18°C)

Tableau 1. Enveloppe values

In order to improve a thermal and visual comfort all the levels of the Elithis Tower were designed in an open plan distribution (figure 4.). This solution gives the possibility to improve the air contact with the thermal mass, and increases the efficiency of the natural lighting.

Figure 4.Tipycal level - Elithis Tower

VENTILATION PRINCIPLE

The ventilation principle is mechanical and the air distribution principle is mixing. The building is ventilated by façade slits or by cold beams (figure 5) depends on season.

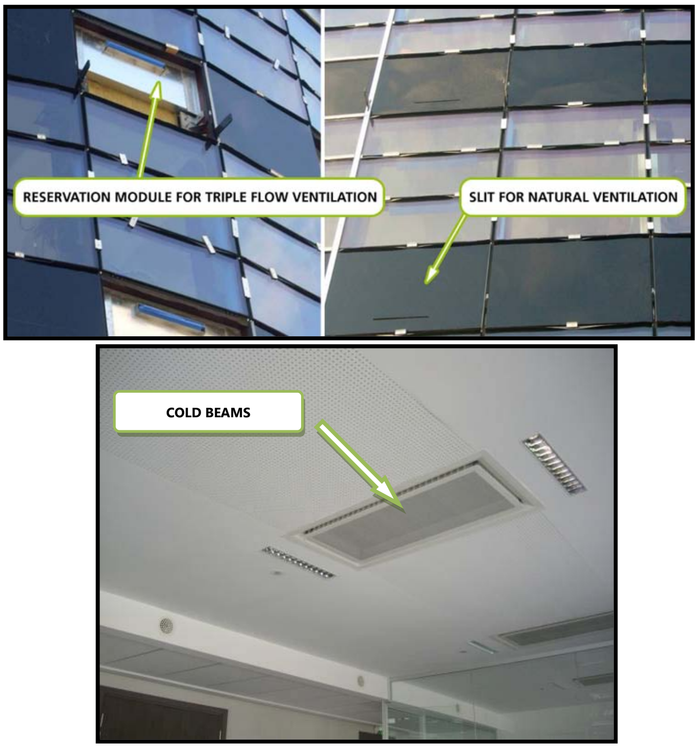


Figure 5. Air distribution principle

The system is controlled by BEMS-system in order to comply with the French ventilation standard code [6] (25 m³/h per person-Office). Three differents ventilation modes were implemented in the Elithis Tower, winter mode, middle season and summer mode (triple flux).

Winter mode

The first one is used for the average cold periods (below or close 0°C). (Figure 6). The enveloppe (1) insulates the building from the exterior temperatures, the solar shield (2) protects the building from solar radiation in summer but gives the possibilty to warm up the building in winter. This combined with the indoor activity (human metabolism and computers) permits gives recovery via a heat exchanger (3). 90% of the indoor energy air can be retrieved to the outside air. This enables to blow air between 16 and 18°C in winter.

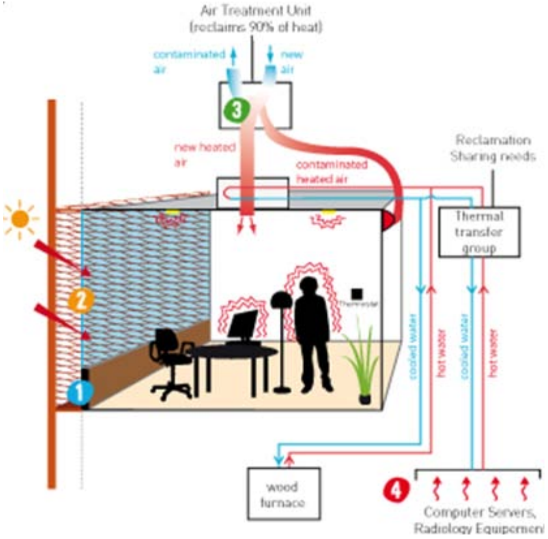


Figure 6. Winter mode

If the outside air temperature are very low a wood furnace produces hot water to the water network of the cold beams. In order to keep the inside air temperature to 22°C (figure 7).

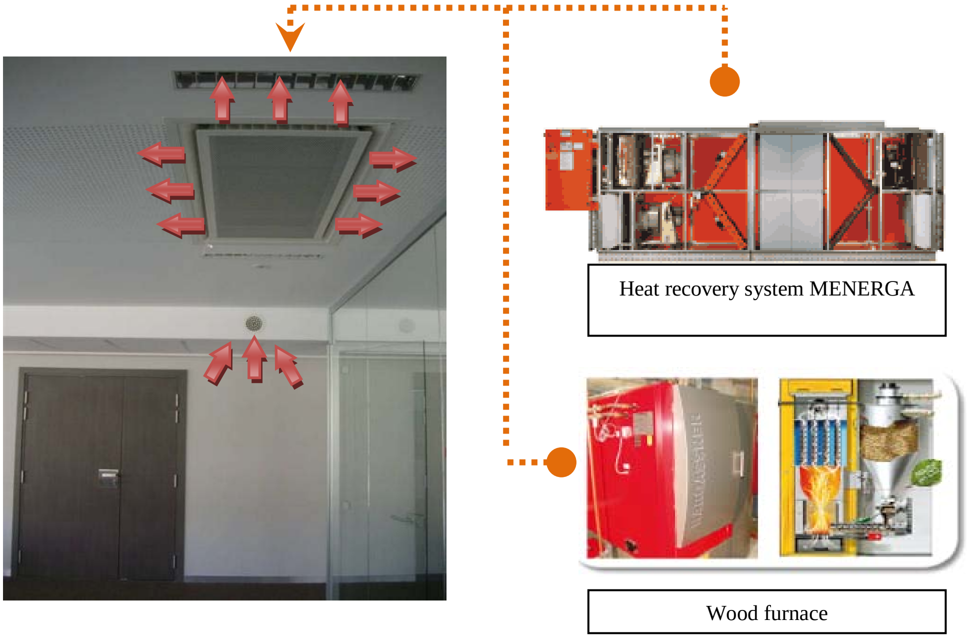


Figure 7. Air Distribution - cold beams

Mid seasons mode (spring and fall) :

In spring and fall when the outside air temperature increases (T°C > 10). The outdoor air conditions are interesting to cooling the building. At this moment (mid-seasons) the winter mode is turned-off, the BEMS-system opens the facade slits (1) and the air extraction is insured by a lower pression fan (2) (Figure 8). This is called “Triple flux®”.

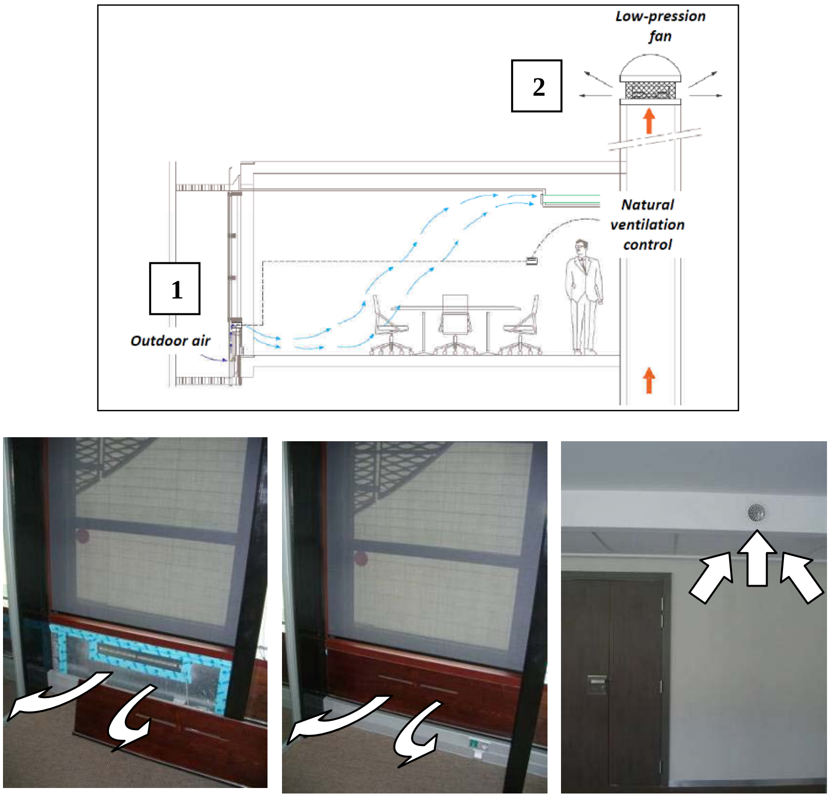


Figure 8. Mid seasons system

As is shown in figure 9, the solar shading blocks solar radiations (1) but provides a perfect natural lighting, the enveloppe (3) and the central core combined to the system, allow low temperatures to be maintained throughout the building.

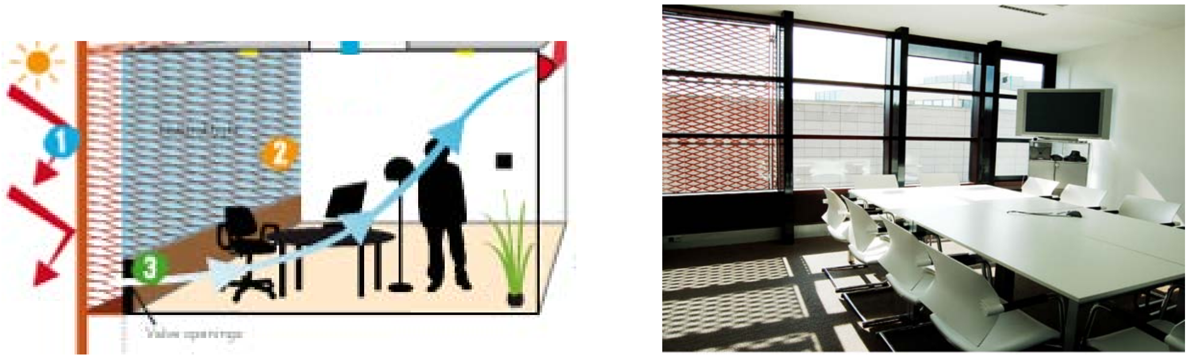


Figure 9. Solar shading protection

Night Ventilation:

This system also uses night ventilation. When the building is empty (nights and weekends) and when the outside air temperatures are lower than indoors, the building can be overventilated by 3 air changes per hour, 30000 m³/h.

Summer mode

Figure 10 describes the principles of the ventilation system implemented during the summer period. When the outdoor air temperature is below 26°C, the mid seasons system is turned-off, free-cooling at this moment isn’t enough due to the outside air conditions.

When this happens (T out > 26°C) an adiabatic evaporative system treats the air in order to reduce the temperature. On the first stage the outside air is sprayed with fresh water so as to reduce its temperature (adiabatic) and to blow fresh air into the building. The second stage applies only when the outside temperature increases (T out > 30°C). A heat pump produces “cold” water for the cold beams. Each cold-beam is equiped with a water network, so it is possible to drive along “cold water” or “hot water”. This combination allows the indoor air temperature to be maintained below 26°C whatever outdoor conditions are in summer period. This is illustrated in figure 10.

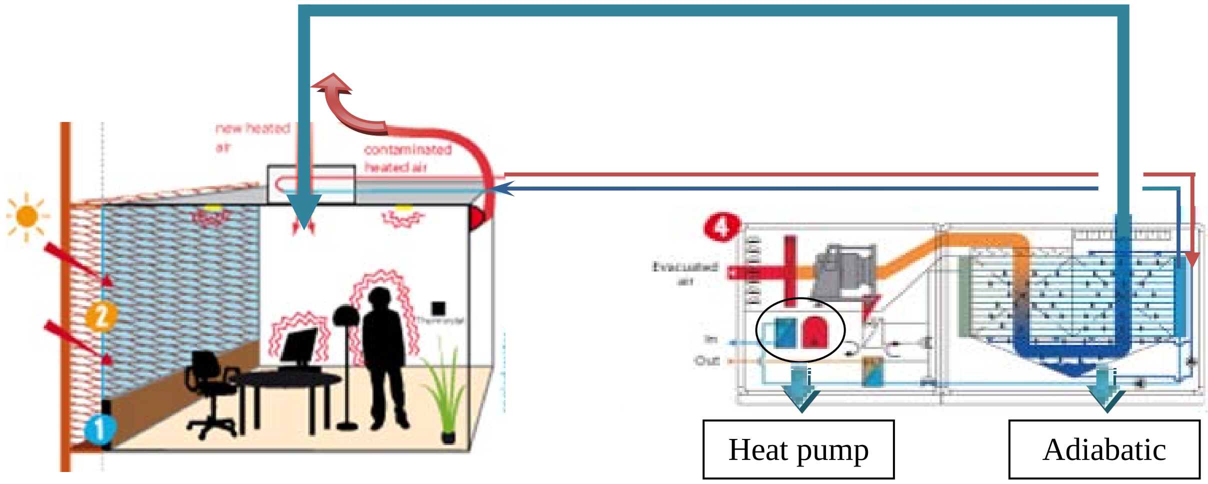


Figure 10.Cooling system

VENTILATION CONTROL STRATEGY

We saw the ventilation solutions of the Elithis Tower, now we are going to focus us on the functional analysis. The control of the ventilation strategy depends on temperature, humidity levels and occupancy.

288 temperature sensors and 9 humidity sensors control the inside air temperature and humidity (32 T°C sensors per level – 1 H% sensor per level). A weather station gives the outdoor conditions (T°C, H%, wind direction, wind speed). As regards occupancy, no control is performed, since a schedule was "a priori" defined (7:30 – 18:30). The ventilation system is controlled as presented on Figure 11.

When the indoor air temperatures are below to 21 or higher to 24, winter and summer respectively, the air central unit (MENERGA) treats the air in order to comply the requirements (heating or cooling). When the outdoor air temperatures are lower than indoor but the indoor air temperature is between 21-24°C or higher to 22°C (Only winter) the BEMS-system gives priority to the "triple flux®" system. For night ventilation a previous schedule is defined and the BEMS-system control this strategy.

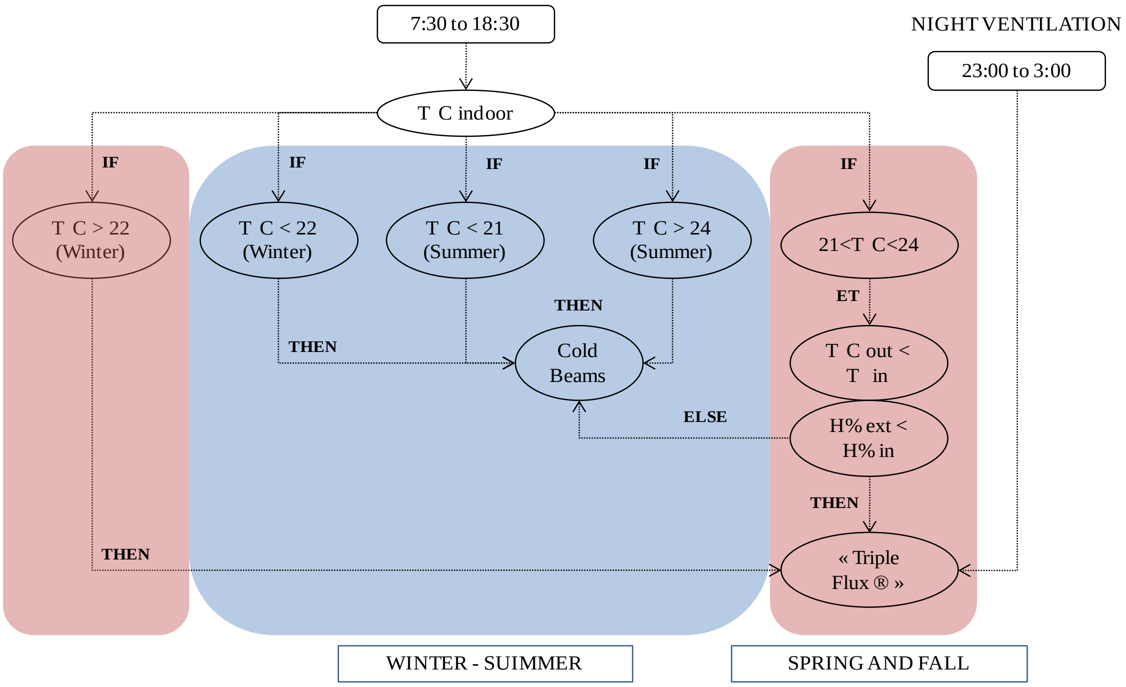


Figure 11. BEMS-System - Elithis Tower

MONITORING PROGRAMME

The monitoring programme was divided in three parts: energy consumption, thermal comfort survey and CO_2 concentrations survey. As regards energy consumption, the building was monitored all over 2009 and 2010. For thermal comfort survey, the monitoring period was started in June 2010 and for the CO_2 concentrations survey only the 7th level was monitored during the spring season 2011.

The BEMS-system is composed of 1600 sensors and provides access to the total energy consumption of the building. It is also possible to survey other parameters such as inside temperatures, humidity, illumination, occupancy. An overview of the measured parameters in each level is showed in the next figure.

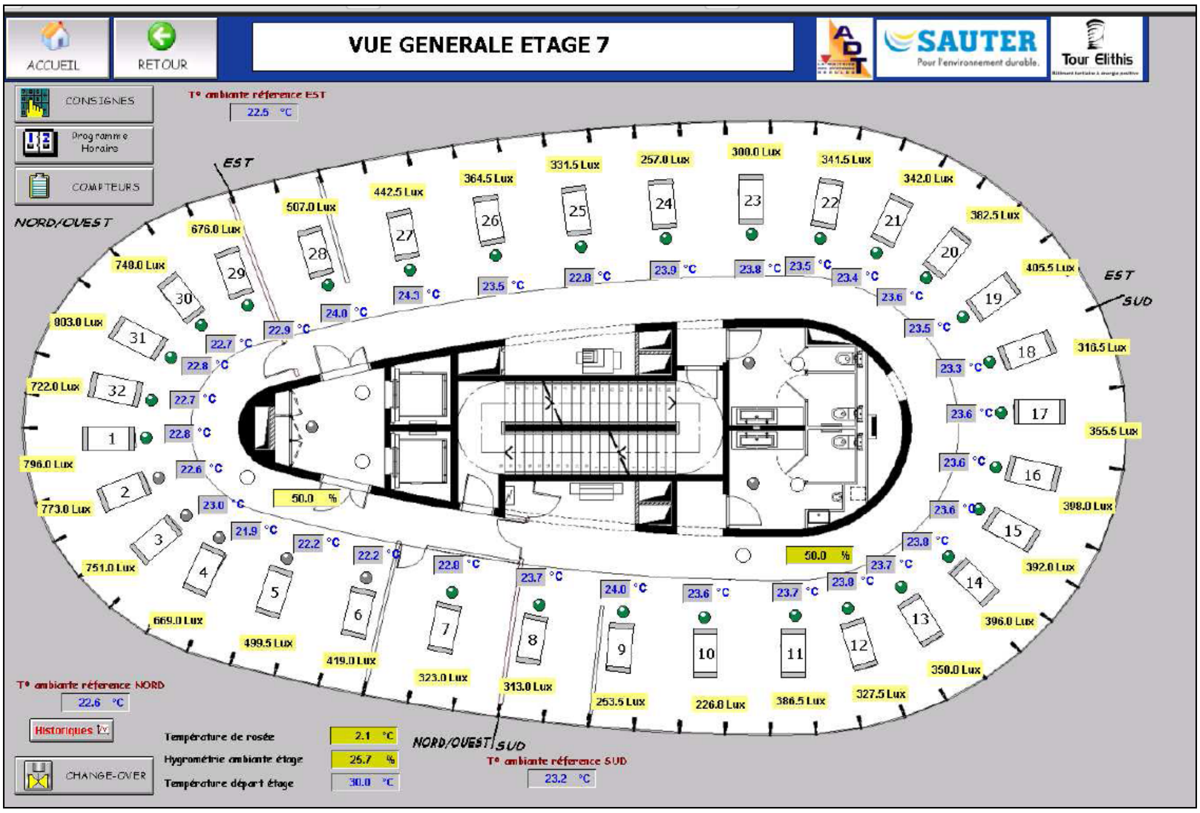
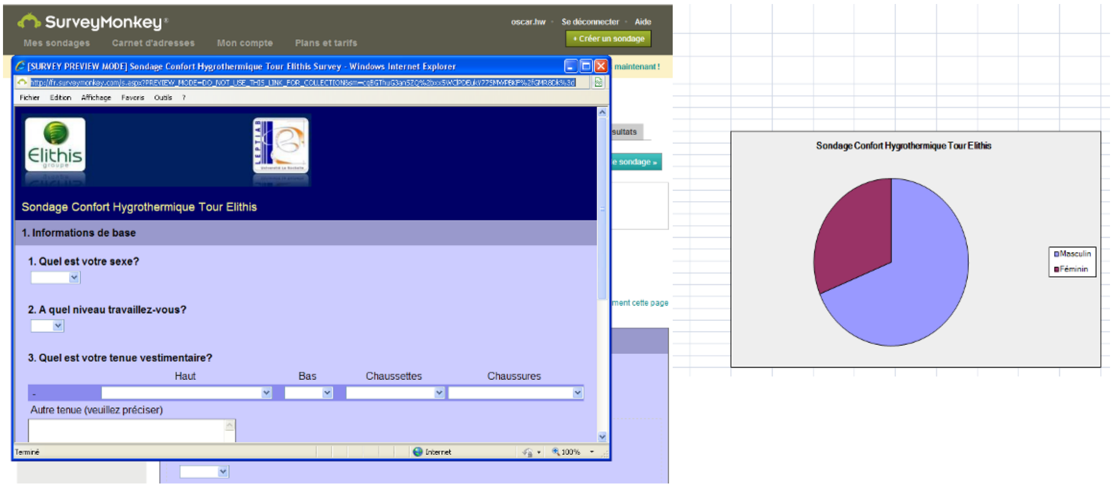


Figure 12. Inside parametres measured - SAUTER

An additional sensor was installed on the 7th level in order to fulfil the requirement of the programme (CO_2). In general, date was recorded every 10 seconds, which is very precise.

For thermal comfort survey (ISO 7730 [2], ASHRAE 55 [3]), a questionnaire was created into a site web. This gave us the possibility to manage the questionnaire by internet, no paper was required therefore we could handle the results more efficiently (figure 13). More than 600 questionnaires were sended to the Elithis Tower users. Only 400 answers were collected during this period. An answer peak was recorded one day per month.



Sondage Confort Hygrothermique Tour Elithis

1. Informations de base

1. Quel est votre sexe?

2. A quel niveau travaillez-vous?

3. Quel est votre tenue vestimentaire?

Haut	Bas	Chaussettes	Chaussures

Autre tenue (veuillez préciser)

Figure 13. Survey comfort questionnaire

MEASUREMENT RESULTS

The monitoring period for energy consumptions has been calculated from the 1st April 2009 to the 31 March 2011. Two years were measured and the balance is showed in figure 14. On the left side (blue) we have the total energy used by the Elithis tower, heating, cooling, ventilation, lighting, pumps, elevators, plugs and PV production are included. For the French standards only the energy used by elevators and plugs aren't take in count.

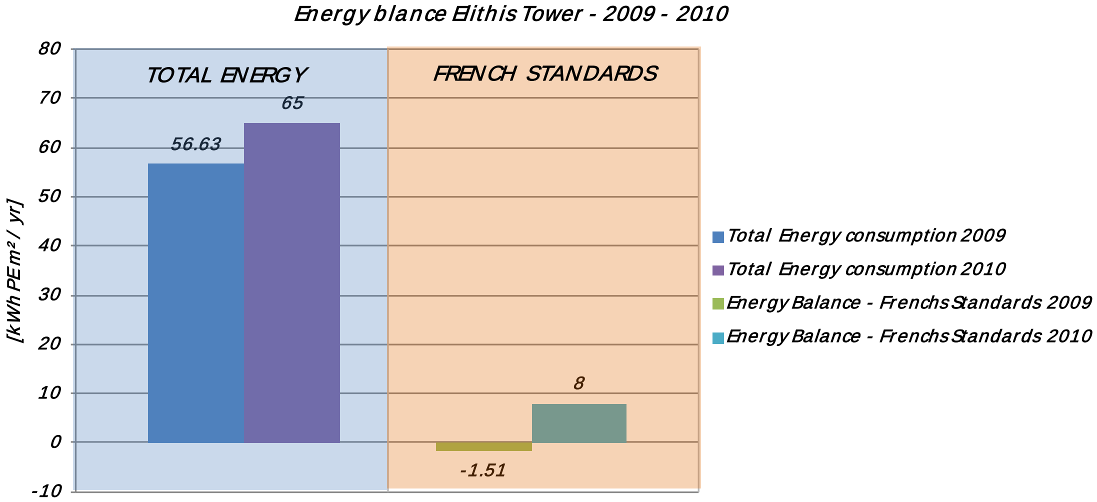


Figure 14. Energy Balance Elithis Tower

If we compare 2009 and 2010 values a difference can be noted. Many reasons could account for this situation. One of the most significant involved the heating consumption. Comfort was achieved during the winter season. At the beginning 2009, the building was heated at 19°C. This temperature wasn't high enough to insure the thermal comfort of the occupants. So the heating temperature in 2010 was increased to 22°C. As a consequence, 2°C in the heating temperature requires twice more energy. (Figure 15). Furthermore, the total energy production by the photovoltaics pannels. 2 kWh PE m² / yr less produced in 2010. This could be explain the difference between 2009 and 2010.

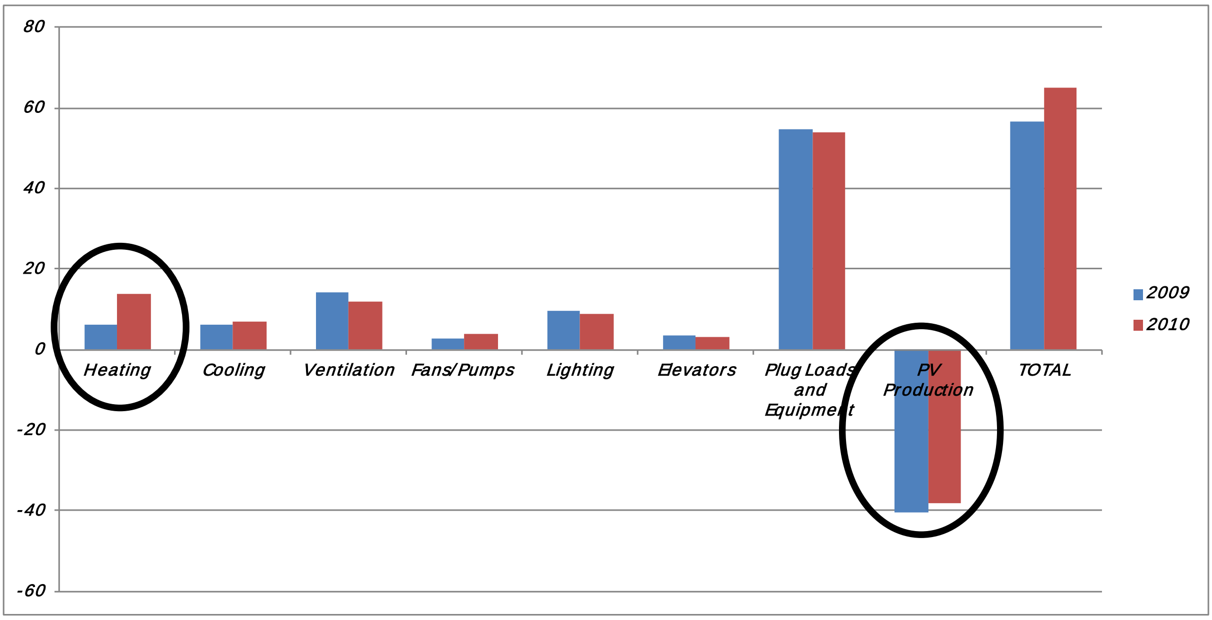


Figure 15. Total Energy Balance share

Now if we take a look at the ventilation system energy consumption the difference between 2009 and 2010 was significant. In 2009 the part of the ventilation system represented 15% of the total energy whereas in 2010 it amounted only to 12%. (Figure 16)

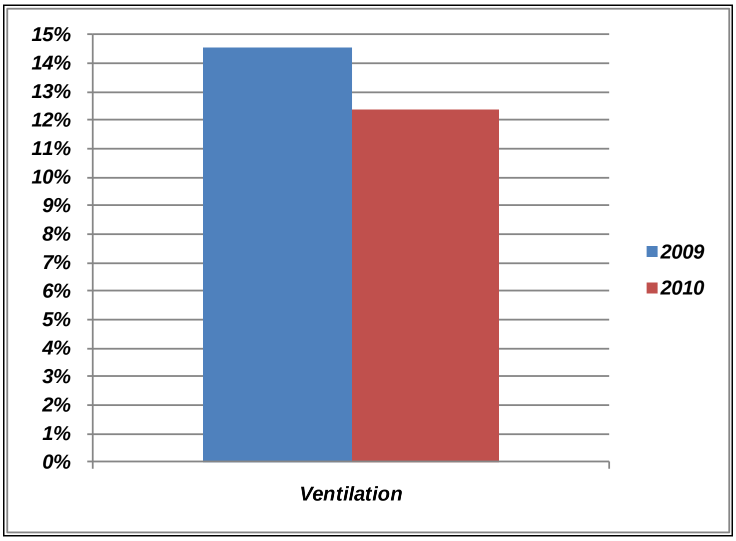


Figure 16. Ventilation energy consumption

The first year (2009) was an optimisation period. During this year, many modifications were implemented. First of all, the "triple flux" system was performed, the regulation band was modified in order to give priority to this system. Second, a high loss pressure was measured in 2009 due to an important number of acoustic pannels. Many acoustic pannel were removed but this solution didn't modify the acoustic comfort of the building. No complaints were registered during the comfort survey. And third, leakages in the air ventilation network [4,5] were detected and the periodicity of the maintenance was increased. This modifications enabled a final gain of 3% of the total energy, which represents 2.1 kWh PE m² / yr.

As stated above, the total energy used by the building in 2010 was 103 kWh PE m² / yr. The part of the ventilation was 12 kWh PE m² / yr. Now we are going to focus on the energy consumption of the different ventilation strategies.

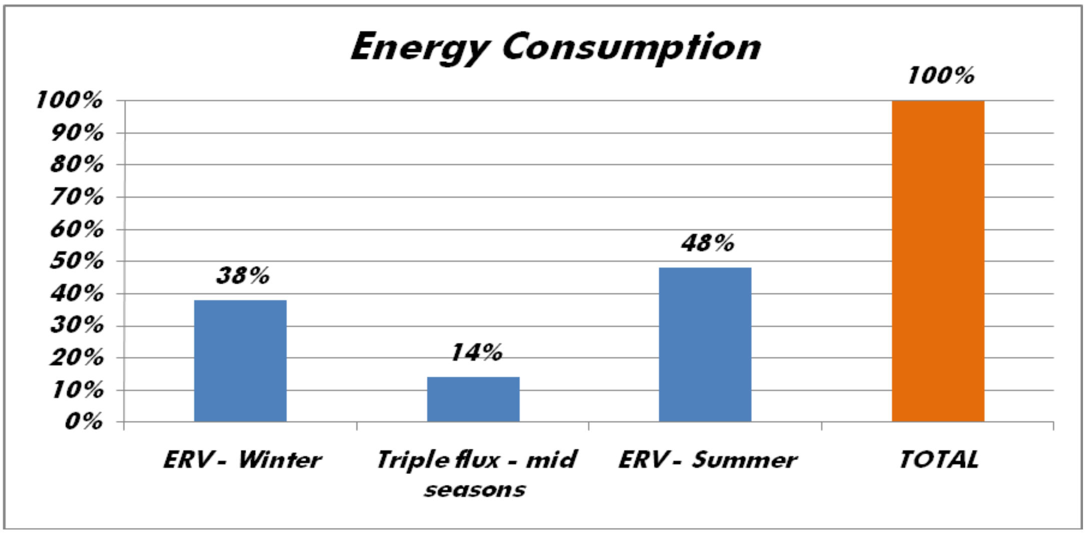


Figure 17. Energy consumption - Elithis Tower ventilation strategies

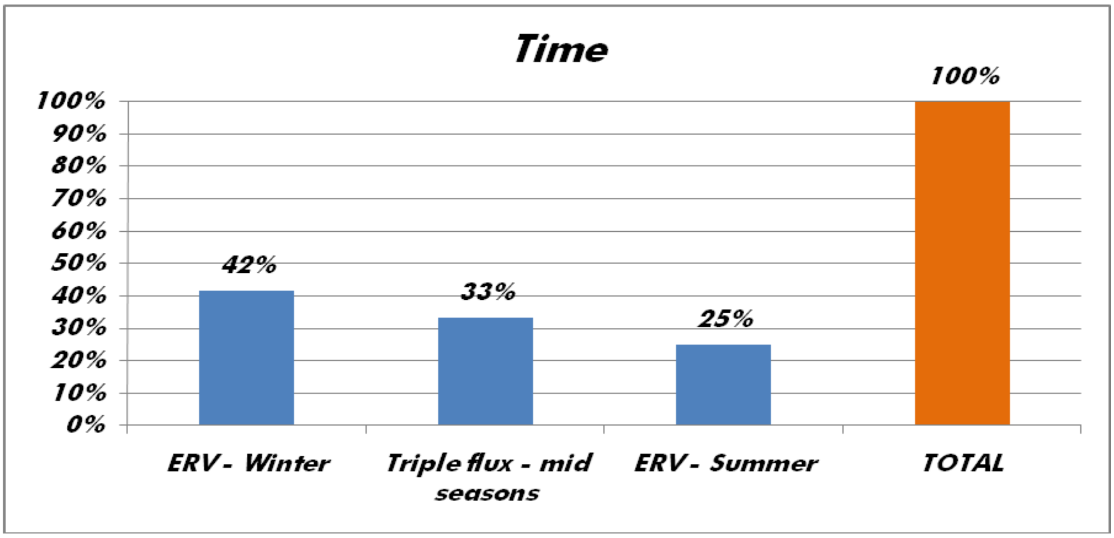


Figure 18. Time consumption - Elithis Tower ventilation strategies

The figures 17 and 18 show the energy and time consumption of each ventilation strategy. If we compare these graphs, we can see that the energy used by the mid seasons system represents only 14% of the energy required for ventilation while time consumption represents 33%. Only 1.68 kWh PE m² / yr was used by this strategy (mid-season), regarding time only 808 hours were consumed. That represents 0.00207 kW per hour. That is very low compared with the other strategies (winter and summer).

The regulation of this system remains very delicate. The weather plays an important role because, any change in humidity (Ex: storm) will force the system to turn-off. As a consequence, the energy balance may be different. That problem is related to the cold-beams. Now we focus on thermal comfort and CO_2 concentrations.

Thermal confort

The objective of this survey was to characterize the thermal comfort inside the building and the air quality. The results are given below according to a level of satisfaction.

Parameter	Satisfaction level (in %)
Temperature in the building	71.3%
Air quality	61%

Table 2. Sastisfaction percentage - Elithis Tower

The temperature level of the atmosphere in the building seems slightly comfortable. According to ASHRAE 55, indoor environnement can be considered comfortable when the satisfaction rate is above 80%. It is to be noted that the atmosphere of the Tower Elithis is not as comfortable as we had hoped.

But since 2009 several improvements have been made allowing an increase in the occupants' satisfaction rate. If we take a close look at the level of comfort throughout the campaign between 2010 and 2011, we notice in several instances, a satisfaction rate above 80% (Table 3).

Lower values were also recorded but this could be explained by the fact that the daily average temperature exceeded the monthly values:

Month	Day			Day Average T°C	Month average T°C	Satisfaction [%]
January	2011	27	Jeudi	4	-0.4	89
Febrary	2011	3	Jeudi	2.5	2.5	75
March	2011	14	Lundi	11	6.3	75
April	**2011**	**11**	**Lundi**	**15.5**	**13.8**	**45**
May	**2011**	**12**	**Jeudi**	**18**	**16**	**60**
June	**2011**	**22**	**Mercredi**	**21**	**18.1**	**63**
July	2011	8	Vendredi	19.5	21.4	80
August	2011	29	Lundi	20	18.8	75
September	2011	Not finished				
October	2010	27	Vendredi	9.5	10.9	87
November	**2010**	**29**	**Lundi**	**0**	**6.7**	**65**
Décember	2010	20	Lundi	4	0.3	74
					Average	**71.6**

Tableau 3. Thermal comfort - Survey monitoring

Unfortunately, explaining and better characterizing the level of comfort in the building didn't allow the collection of data several days a month, as some answers are not representative in this kind of questionnaires.

Indoor air quality

The only parameter monitored during this campaign was CO2. Several values were recorded, the maximum value was 2000 ppm in a meeting room, but in the local office "open space R 7", the maximum concentration recorded was about 1000 ppm (figure 19).

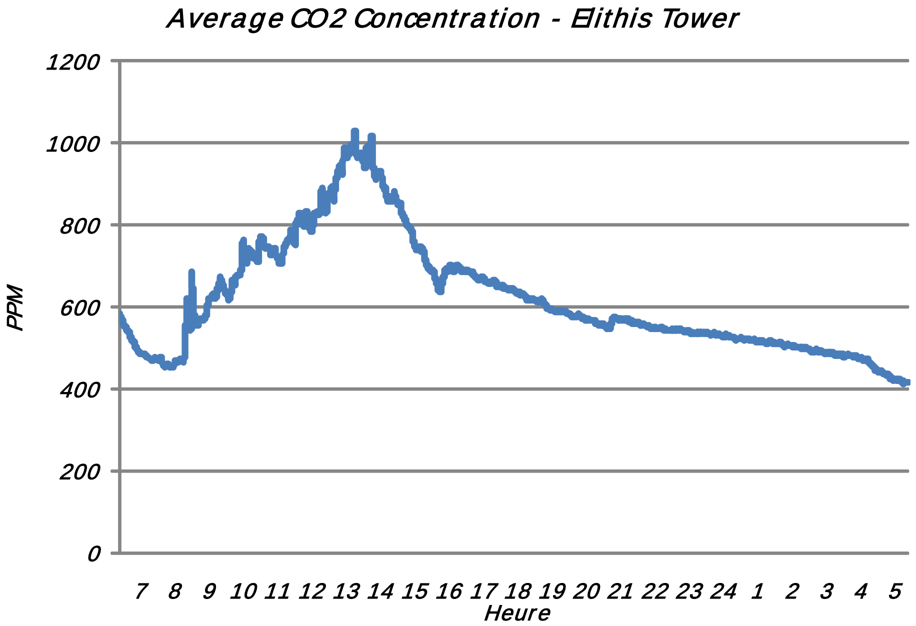


Figure 19. CO2 Concentrations

CO2 is not a gas that can assess the air quality but the level of confinnement; As consequence it hasn't been possible to determine the cause of discomfort by almost 40%. Air analysis (VOC and aldehydes) are underway to get a clearer picture of the problem.

CONCLUSIONS

The results of the monitoring of the Tower Elithis were very interesting. Compared with French standards, the Elithis Tower in 2009 ranked as the first office building with positive energy. And compared with other buildings the Elithis Tower used less energy than a classical office building. The environmental impact is reduced and so the Elithis Group goals have been reached.

We saw that the part of the ventilation energy consumption is about 15% compared with the total energy used by the building. This value could be different depending on the building. Controlled heat loss and low values air tightness modify the energy used by ventilation. As we saw in this paper, in the Elithis Tower the heating energy used in 2010 was higher. This difference alters the part of the ventilation system. It’s therefore important to take care of the energy used individually and not globally. It’s not possible to have this generalized.

The ventilation system “triple flow®” could produce significant savings, but its performances are linked to outside conditions and internal gains. Ventilation systems themselves aren’t effective. The combination with other parameters as envelope, solar protection, or employee’s behavior could guarantee the energy performances.

Thermal comfort is a parameter that was closely monitored. In the thermal comfort analysis many parameters will modify the thermal perception. The results show a thermal satisfaction percentage of 70%. However this was analyzed during a short term monitoring (1 day per month), consequently we don’t know if in a long term analysis the result would be the same.

High windows surface and "open space" requires tighter ventilation control. In temperature conditions above average, thermal comfort is modified. The cause could be radiant temperature. The users of the Elithis Tower are more exposed to outside conditions. In the next papers, this parameter will be studied.

A building with a high efficiency level is quite feasible but when we take indoor air quality into account, thermal comfort and energy performance become much more complicated.

The control system is an important point. Innovative systems are necessary but they should be regulated and anticipate the changing conditions of temperature. Poor control can lead to overconsumption.

The air quality is a parameter that could not be monitored in a fairly precise way. We disclosed problems in air quality which, however, are not linked to CO2 levels. We expect therefore to do indoor air analysis (COV and aldehydes).

PERSPECTIVES

Other more accurate monitoring programmes will be implemented shortly. The size of database was a difficulty. A significant number of data are recorded every 10 seconds, as a consequence the management is complicated.

We found 40% of dissatisfaction and we couldn’t find a relation. As part of the PHD these funded by Elithis Group and supported by Francis ALLARD of the LEPTIAB of La Rochelle the relation between energy performance, indoor air quality and thermal comfort will be studied.

New surveillance surveys regarding comfort will be soon implemented. A long term monitoring will be conducted. A software tool coupled with the GTC will also be implemented in order to recover the necessary information (temperature, humidity).

Other modes of regulation will be developed to allow the building to be more efficient. In addition, they will be modeled and tested as part of the PHD these.

ACKNOWLEDGEMENTS

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