DEMAND-CONTROLLED VENTILATION

20 YEARS OF IN-SITU MONITORING IN THE RESIDENTIAL FIELD

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ABSTRACT

Is Demand-controlled ventilation a relevant answer to face the new challenges of the Building sector, which requires everyday higher energy efficiency and better indoor air quality? Can Demand-controlled ventilation be considered as an alternative to heat recovery ventilation, through an affordable and low maintenance solution? Since the take off of the DCV in the early 80’s, these questions have been considered many times. Following the expansion of the technology over the world (more than 4.5 million dwellings are already equipped today, only considering humidity controlled ventilation), numerous in-situ monitoring have been conducted to try to better understand the behaviour and the performance of the DCV. Precursor in the field as inventor of humidity controlled ventilation in 1983, Aereco has carried out numbers of monitoring on different ventilation types, in various countries and on specific buildings, measuring in total hundreds of dwellings. With a first large-scale study based on natural ventilation in multi-storey buildings realised in 1993, the research has been completed with experiments on hybrid ventilation and on mechanical exhaust ventilation, individually or collectively managed, to recently lead to the follow-up of on an innovative full room-by-room DCV balanced system with heat recovery.

This proceeding will specially focus on four major monitoring: demonstration project “EE/166/87” (natural ventilation, France, Belgium and Netherlands, 1991-1993), “HR-VENT” (hybrid ventilation, 55 dwellings, France, 2004-2005), “Performance” (collective MEV, 29 dwellings, France, 2008-2009) and the last monitoring that concerns several houses in Germany and France equipped with a full DCV heat recovery (started in 2013).

In parallel to the ventilation systems evolution, the one of the measurements methods and instruments has been remarkable since the first monitoring. From tracer gas to collect the airflows at the first monitoring, we have reached today a level of technology that enables more reliable and more precise multi-parameters measurements through electronic sensors, sending data via internet.

Whatever the ventilation technique it is associated with, the automatic control of the airflows according to the demand has demonstrated benefits at various levels. The first monitoring highlighted the correlation between CO2 and humidity, even in the technical rooms, conferring relevancy to humidity controlled at the exhaust. On all monitoring, the seasonal behaviour of the system when humidity controlled has been found out: following the lower absolute humidity level in winter, the airflows are reduced when the dwellings are unoccupied, leading to energy savings on both the heating and on the fan electrical consumption. On the indoor air quality side, we have checked that the automatic control to the demand enables to optimise it: the system improves the repartition of the airflows among the rooms according to their specific needs, increasing the air renewal in the most occupied and polluted rooms. In addition, DCV monitoring have shown specific phenomena such as the ability to optimise the available pressure through a time-repartition of the exhaust demand dwelling-to-dwelling, when connected to a collective duct. Besides parameters measurements and data collection we brought specific care on occupant’s

acceptance, making surveys every time it was possible. The results have shown that the system was in general very well accepted, highlighting the relevancy of non intrusive and low maintenance systems.

KEYWORDS

Monitoring, Demand-controlled Ventilation, Humidity controlled, Indoor Air Quality, Energy Savings.

1 INTRODUCTION

Since the take off of the Demand-controlled Ventilation in the early 80's, the question of its performance and of its ability to position as an alternative to the heat recovery ventilation has been considered many times. Following the expansion of the technology over the world -more than 7 million dwellings are already equipped today only considering humidity controlled ventilation-, numerous in-situ monitoring have been conducted to better understand the behaviour and the performance of the DCV. Precursor in the field as inventor of humidity controlled ventilation in 1983, Aereco has carried out numbers of monitoring in residential buildings on different ventilation types, in various countries, measuring in total hundreds of dwellings. This paper aims at giving a global overview of the major monitoring that have been hold on Demand-controlled ventilation systems in residential application, dealing with different topics such as indoor air quality, energy efficiency and evolution of measurement instruments

2 20 YEARS OF MONITORING

Monitoring one or several dwellings to assess the performance of a specific building equipment always raises the question of the significance and of the relevancy of the study: how to be sure that these dwellings are representative, so that we can approach the statistical and average behaviour of a system through the follow up of a limited set of dwellings? The multiplication of monitoring campaigns as well as the quantity of monitored dwellings is the only way to evaluate as best the performance of a ventilation system. As application of this principle, Aereco has conducted numerous in-situ experiments on various places testing its Demand-controlled ventilation systems in the residential field, as presented on Figure 1.

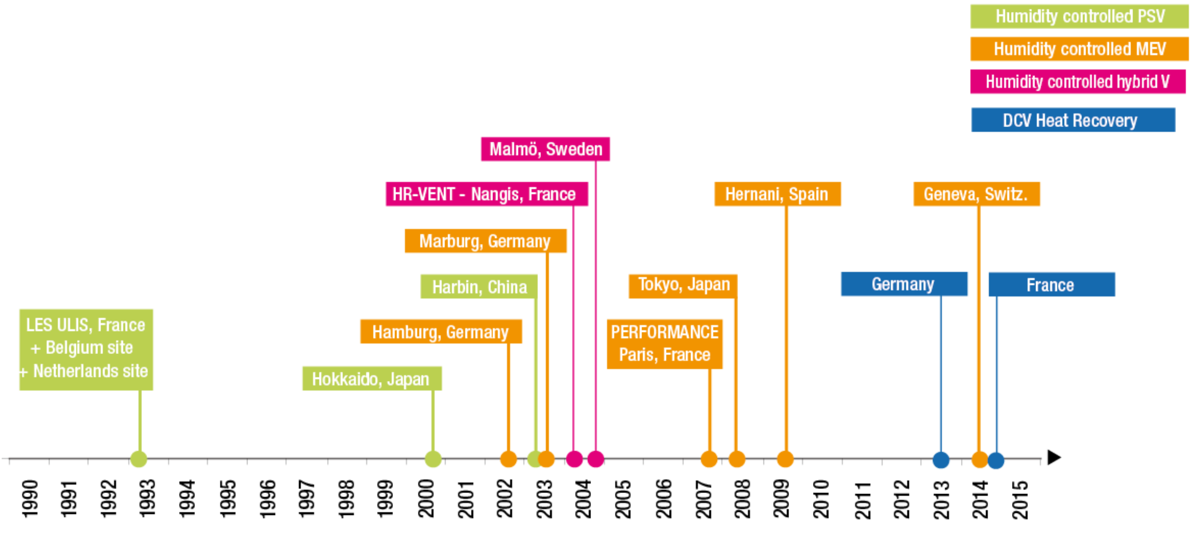


Figure 1: Historic presentation of Aereco major monitoring campaigns on ventilation (Starting dates).

Figure 2: One of the five buildings monitored in "HR-VENT" project (left); One of the two buildings monitored in "Performance" project (right)

3 EVOLUTION OF MEASUREMENT METHODS AND MEANS

The precision and the quality of results of in-situ experiments are very dependent from the sensors and the methodology used. Since our first monitoring of DCV realised in 1993 up to now in 2014, the evolution of the means has been continuous and strong, improving the accuracy of the measurements and enlarging the spectrum of measurable parameters.
From tracer gases used in 1993 in "Les Ulis" monitoring giving punctual measurements up to electronic sensors generalised in the latest monitoring, the airflow measurements have become much more precise and reliable, offering possibilities of a permanent follow up that can be applied to a large set of dwellings.
The data collection has also been considerably eased with the development of WiFi and internet: a recent in-situ experiment applied on a new Demand-controlled heat recovery ventilation system now includes climatic sensors that are directly connected to the local WiFi, sending the data through internet.

4 DEMAND-CONTROLLED VENTILATION SYSTEMS

The typical system measured during the various monitoring we are talking about in this paper is an unbalanced system with humidity controlled air inlets (Figure 3) in the bedroom and living room, humidity and / or presence detection exhaust units (Figure 4) in the wet rooms, and a centralised fan connected to these units. These systems are presented on the following schemes for hybrid ventilation (Figure 5) or for mechanical exhaust ventilation (Figure 6). In these systems, the fan has the singularity to provide a constant pressure for a varying airflow.

Figure 3: Humidity controlled air inlet

Figure 4: Demand-controlled exhaust unit (MEV)

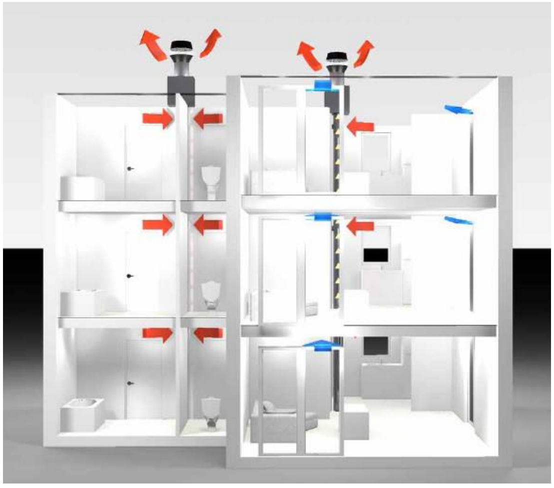


Figure 5: System scheme in hybrid ventilation

Figure 6: System scheme in mechanical exhaust ventilation (MEV)

5 IN-SITU WORKING OF DEMAND-CONTROLLED VENTILATION SYSTEMS

5.1 Instantaneous behavior

One of the first objectives of a monitoring on ventilation is to check that the system in-situ working conforms to the laboratory measurements. The dynamic working of the Demand-controlled ventilation, with its airflows constantly moving according to the humidity or to the presence[1] has been measured in most of the experiments as a key result.

HR-VENT monitoring (humidity controlled system with hybrid ventilation) has given the opportunity to check the working of the extract grilles. Figure 7 presents the day variation of the aperture according to the relative humidity for a humidity sensitive extract grille located in

[1] for the majority of the products in Aereco's range

a bathroom. We can see that the variations of aperture –so the airflow for a given pressure- follow well the evolution of the relative humidity, with a high reactivity.

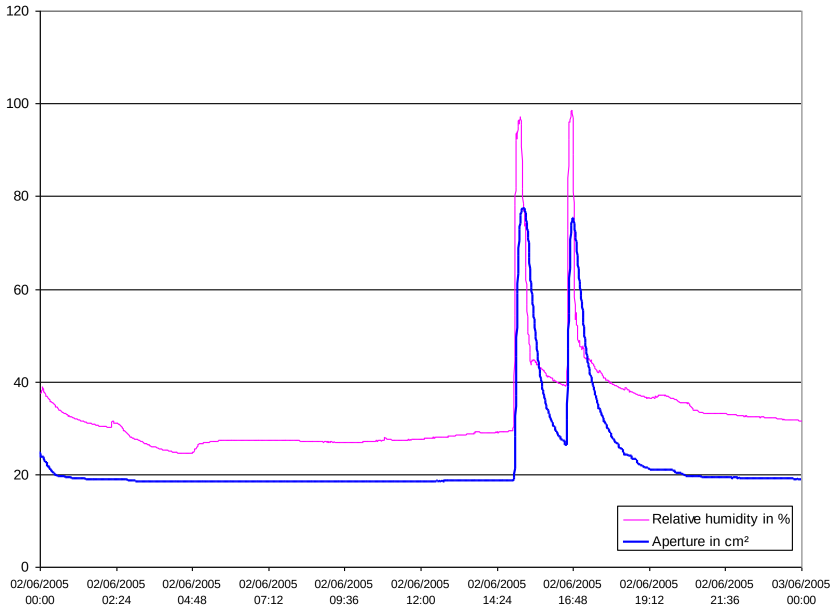


Figure 7 : Aperture vs. relative humidity of a humidity sensitive extract grille in the bathroom. “HR-VENT” project.

The working of the system has also been observed at the level of the air inlets during the “Performance” monitoring (humidity controlled system in mechanical exhaust ventilation). The scheme Figure 8 shows that the airflow at 10 Pa (noted “Qea 10 Pa”) of the humidity controlled air inlet follows quite well the variations of the relative humidity (RH) in a bedroom.

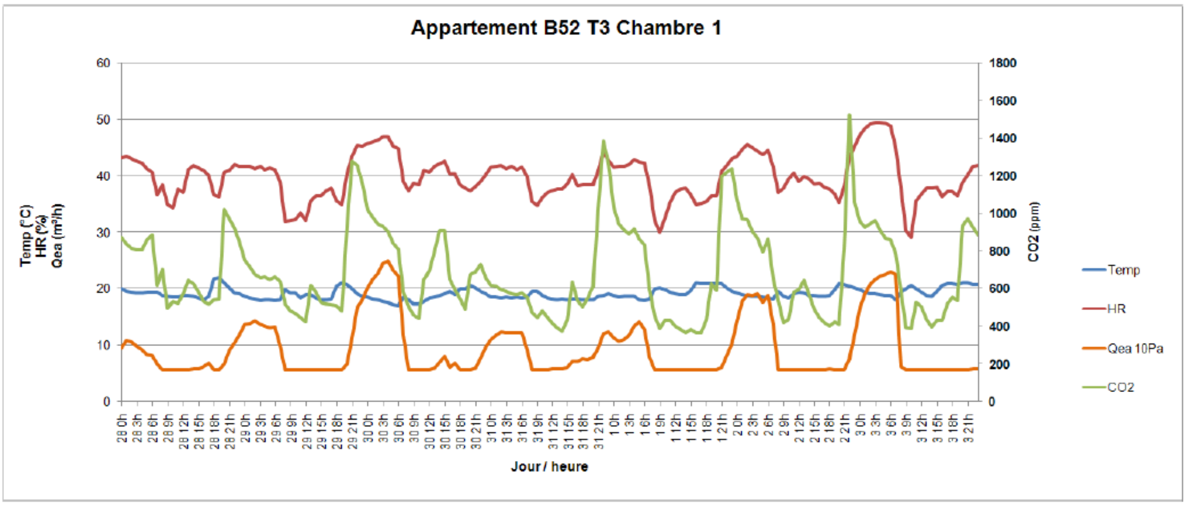
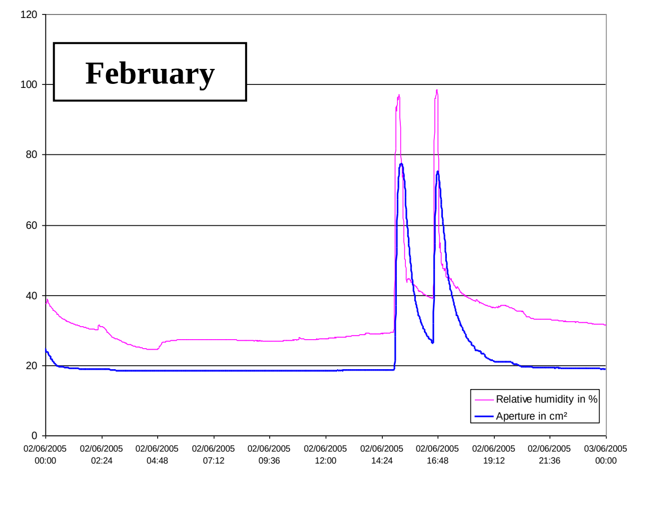
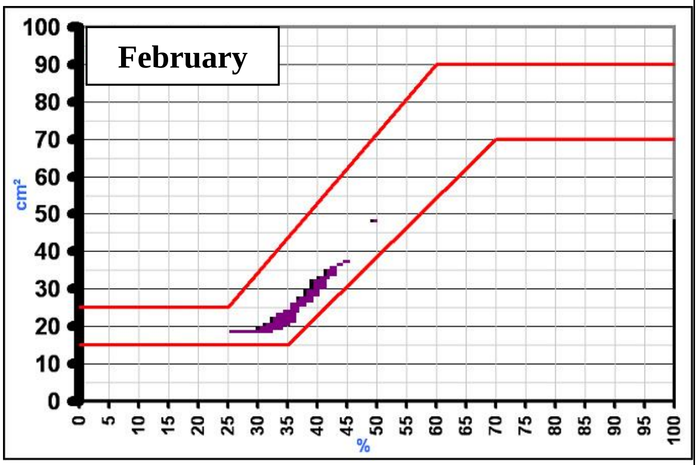


Figure 8 : Airflow @ 10 Pa (“Qea 10 Pa”), Relative humidity (“HR”), CO_2 and Temperature in a bedroom equipped with a humidity controlled air inlet during one week. “Performance” project.

Microscopic and macroscopic behavior

Long term monitoring campaigns enable to highlight a major phenomenon inherent to the humidity controlled ventilation: its statistical seasonal behavior. On the chart Figure 9 we can compare a microscopic view and a macroscopic view of the aperture of the humidity controlled extract grille for different climatic seasons. Due to the evolution of the average indoor relative humidity along the year, the grille is mainly closed in cold season; in hot season the grille aperture opens wider. In parallel to this statistical behavior, the charts on the left column remain that the humidity controlled extract grille always reacts to the humidity giving punctually a high airflow when needed, in cold as in hot season. Only the <u>average</u> aperture varies according to the thermal season during the year. This lower airflow level during the cold season allows to save energy on thermal losses due to ventilation.

<table>
<tr><th>Instantaneous / punctual behavior (on day)</th><th>Statistical behavior (two months)</th></tr>
<tr><td>
</td><td>
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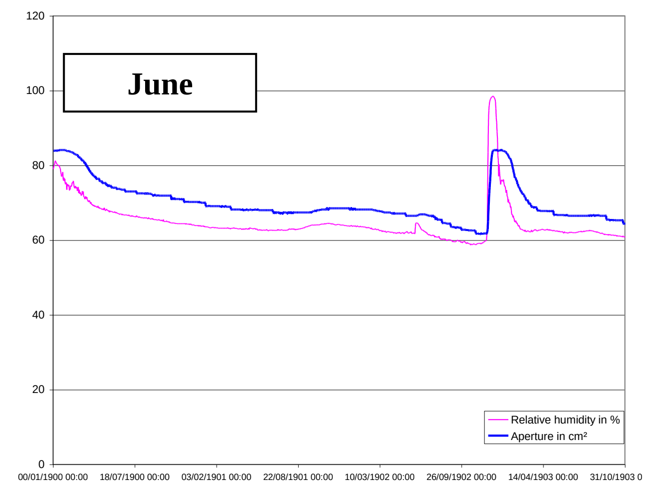
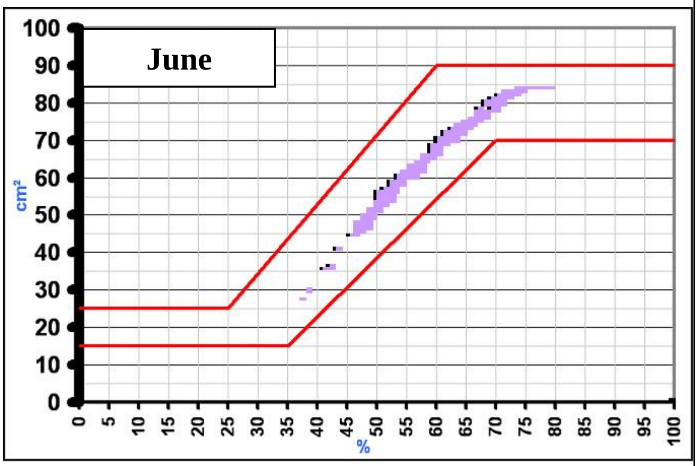
<tr><td>
</td><td>
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Figure 9 : Microscopic day-view and macroscopic monthly view of the variation of Aperture Vs Relative humidity of a humidity sensitive extract grille in a bathroom. HR-VENT project.

6 INDOOR AIR QUALITY

6.1 IAQ in the technical rooms

From 1993, a first monitoring ("Les Ulis", humidity controlled passive stack ventilation) gave the evidence that CO_2 elevations are correlated with H_2O ones in the technical rooms. Either humidity and CO_2 evolve through a linear –or close to- scheme (case of the toilets – see Figure 10), or H_2O increases more than CO_2 (in the bathroom or in the kitchen – see Figure 11 and Figure 12). Considering this phenomenon, driving the exhausted airflow according to humidity offers a guarantee of well reacting to potential elevations of CO_2, whatever the technical room, giving full consistency to the humidity controlled extract grilles.

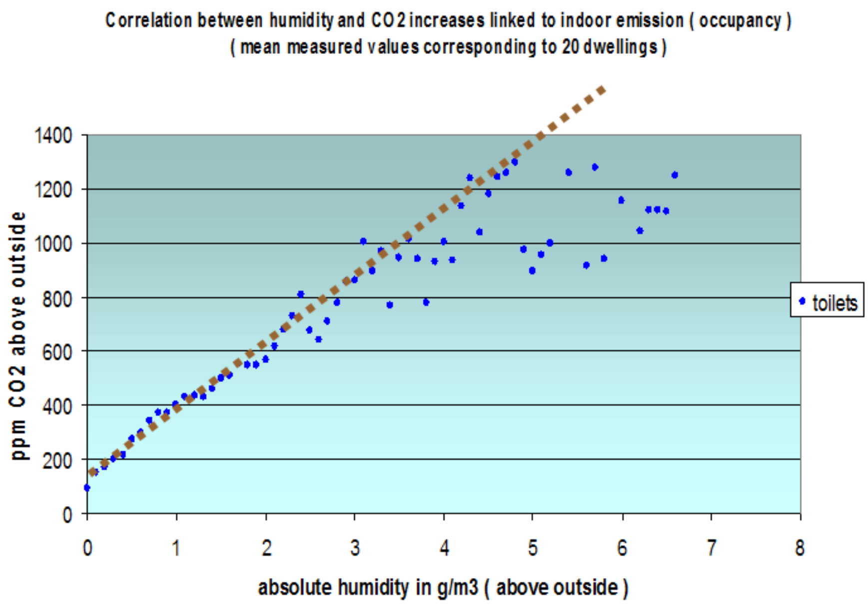

Figure 10 : Correlation between elevations of CO_2 and absolute humidity in the toilets

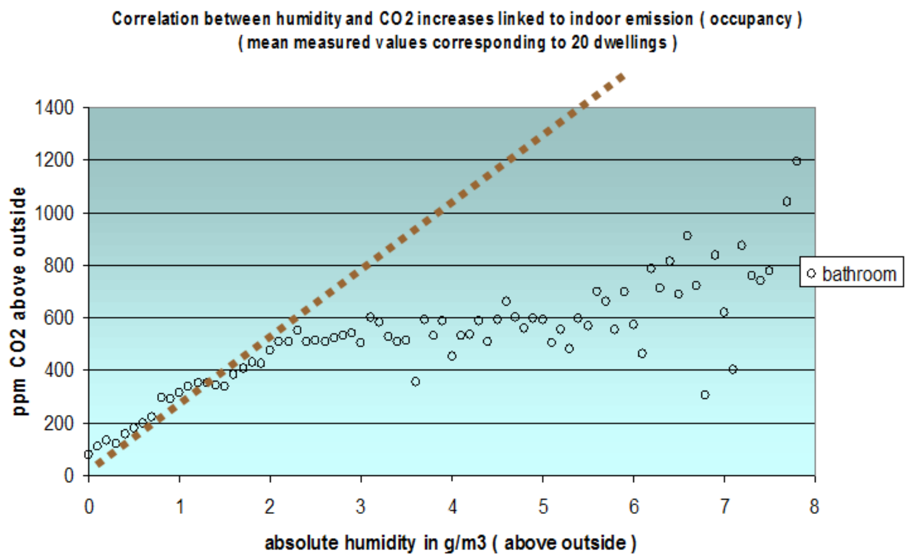

Figure 11 : Correlation between elevations of CO_2 and absolute humidity in the bathroom

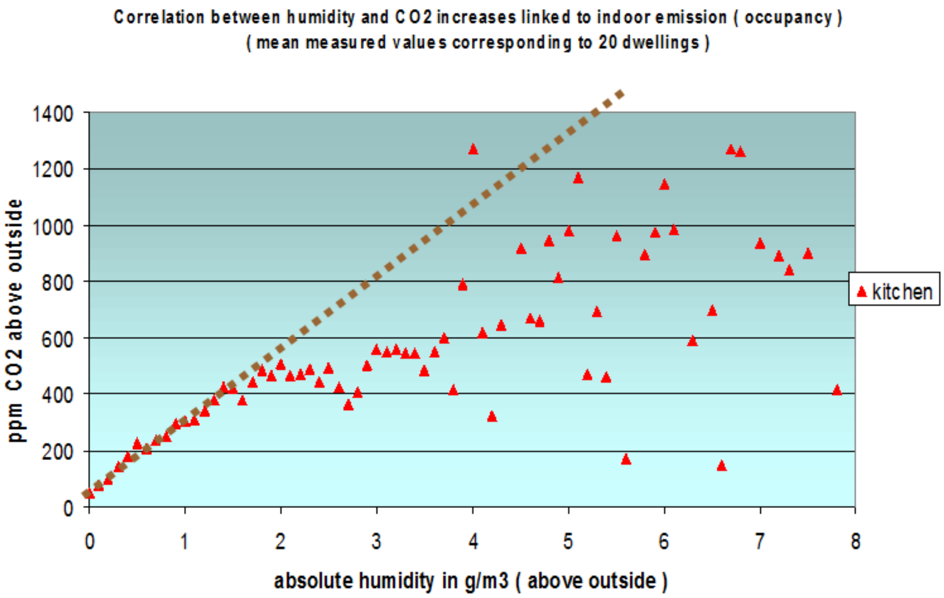

Figure 12 : Correlation between elevations of CO_2 and absolute humidity in the kitchen

6.2 IAQ in the main rooms

"Performance" project has given complementary results at the level of the humidity controlled air inlets. The measurements of CO_2 in two different bedrooms equipped with humidity controlled air inlets during one year show that the indoor air quality can be ensured in a low occupied bedroom (with one adult) as well as in a high occupied one (with four adults) as presented Figure 13. The peak of CO_2 concentration has shifted from 700 ppm in the low occupied bedroom to 950 ppm in the highly occupied one, but even in that case, the 1500 ppm level is not exceeded more than a very few hours.

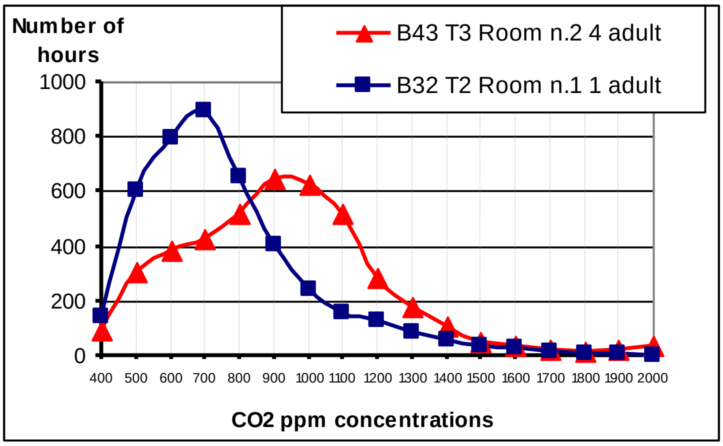

Figure 13 : CO_2 concentrations (absolute) in two bedrooms with different occupations (blue - square: 1 adult, red triangle: 4 adults).

7 ENERGY PERFORMANCE

7.1 Energy losses due to the air renewal

The Figure 14 presents the average measured equivalent airflow for energy[2] per dwelling during a complete heating season.

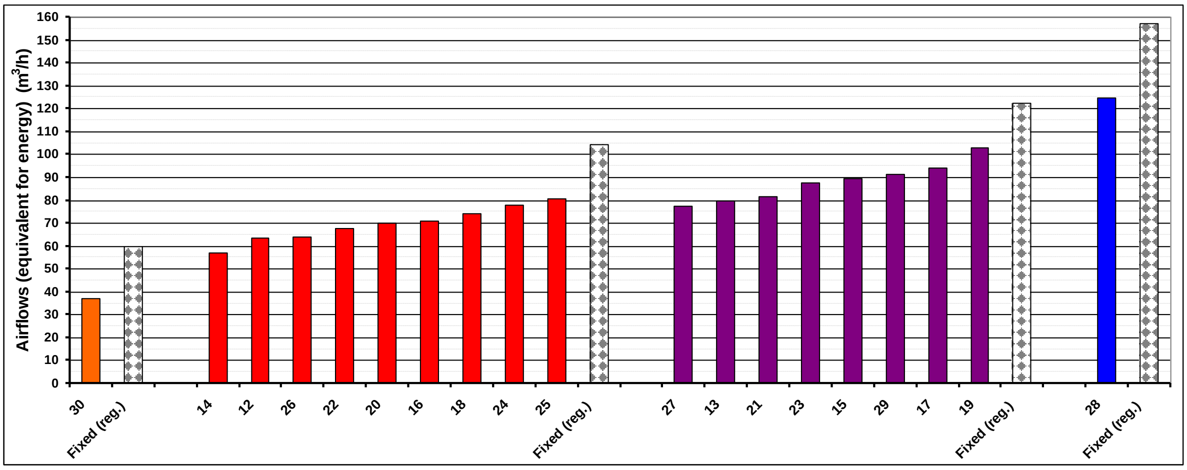

Figure 14 : Statistical equivalent airflows for energy per dwelling on Paris site. Rated by dwelling types. Comparison with French regulatory constant airflow (grey squares). 2007-2008 heating period.

The disparity of the measured equivalent airflows results from the adaptation of the ventilation system to various occupations, activities, occupant behaviours and dwelling sizes. The comparison with the French regulatory reference (fixed airflow, grey triangles bar) shows the statistical airflow reduction –thus the heating energy savings- given by the DCV system. The measured savings on the airflow for this project have been evaluated at 30% in average (55% if extrapolating to the statistical average occupancy in France). It is important to understand that this statistical airflow reduction does not affect the IAQ as the system still reacts to punctual high needs with high airflows, as discussed before in the paper.

7.2 Fan consumption

An additional advantage of the Demand-controlled ventilation is to reduce the average power consumption of the fans by reducing the average global exhaust airflow. Through "Performance" project, the measurements have shown that the energy consumption of the fan has been reduced between 35% to 50% in comparison with the French reference for a constant airflow ventilation system.

8 CONCLUSIONS

As a specialist of demand-controlled ventilation, Aereco has carried out numerous in-situ monitoring in the residential field to evaluate the performance and the behaviour of its ventilation systems since 1993. The evolution of the technology for measurements devices has offered new opportunities in the experiment field for larger, more accurate and multi-

[2] The equivalent airflow for energy corresponds to the fix equivalent airflow in terms of heat losses through ventilation. It takes into account the indoor-outdoor temperature difference.

parameters monitoring. The working of the demand-controlled ventilation systems has been validated in real occupancy conditions, notably the one of the humidity controlled ventilation, at the level of the air inlets as well as for the exhaust units.
Long term monitoring campaigns enable to observe a major phenomenon inherent to the humidity controlled ventilation: its statistical seasonal behavior. Giving naturally an average airflow lower in winter than in summer, the humidity controlled ventilation saves energy on heat losses, from 30% to 55% in the measured dwellings. The monitoring campaigns have also demonstrated that the instantaneous airflow can be very high when needed with this system, even in winter where the average airflow is low. The indoor air quality is then optimized at every moment. A complementary advantage of the demand-controlled ventilation is to reduce the average fan power consumption, as a consequence of the low statistical airflow induced by the system. The very positive results from the numerous monitoring conducted allow to consider the demand-controlled ventilation as a real alternative to the heat recovery ventilation systems in the residential field.
In-situ monitoring are and will always be the most effective way to assess and to validate the real performance of ventilation systems, moreover when they are innovative: the occupants behavior and the dwelling configuration can hardly be strictly repeated in laboratory.

9 REFERENCES

Air.H. (2009). *"Performance de la ventilation et du bâti" Final report (2009).* Ademe convention n.0504C0114.

Jardinier, M. (2006). *"Demand controlled ventilation : conciliating IAQ and energy savings."* Moscow, Cold Climate 2006 conference.

Savin J.L., Berthin S. and Jardinier M. (2005). *"Assessment of improvements brought by humidity sensitive and hybrid ventilation/ HR-Vent project".* 26th AIVC conference, Brussels.

Savin, J.L., Jardinier, M. and Siret, F. (2004). *"In-situ performances measurement of an innovative hybrid ventilation system in collective social housing retrofitting".* 25th AIVC conference.

Savin J.L and Bernard A.M., 2009. *"Performance" project: Improvement of the ventilation and building air tightness performance by implementing a quality approach when building and monitoring of results in occupied dwellings in France.* AIVC Conference 2009.

Siret, F., Savin, J.L., Jardinier, M. and Berthin, S. (2004). *" Monitoring on hybrid ventilation project - first results."* 25th AIVC conference.

Siret, F. and Jardinier, M. (2004). *"High accuracy manometer for very low pressure."* 25th AIVC conference.

Wouters, P., Geerinckx, B, L'Heureux, D., Simonnot, J. and Phaff, J. (1993). *"Passive humidity controlled ventilation for existing dwellings"* - Demonstration project EE/166/87. December 1993