DEMAND CONTROLLED VENTILATION : CONCILIATING INDOOR AIR QUALITY AND ENERGY SAVINGS

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ABSTRACT

Maintaining a good indoor quality (for people and building conservation) is obviously the first aim of any ventilation system ; nevertheless the main side effect – which is also the most visible one – is to spend energy, for heating first and for transport. In these times of expensive energy, the temptation is high to lower the ventilation flows, with few consideration on indoor air quality. Demand controlled ventilation is still often accused of this behaviour and argued against as being “just a flow reduction”. The philosophy behind demand controlled ventilation is completely opposed to this and come from the indoor air quality level to the energy conservation one : by no mean the purpose is to decrease flows when the demand is high, but to take advantage of the fact that, in some periods, in some condition, the demand is lower and the flow can be adjusted without reverse effect on air quality. The swing between high flows and lower ones will lead to energy benefit compared to a single continuous flow value, on a yearly and statistic base. In dwellings, humidity appears to be the best compromise between representative need, accuracy and cost. Measurement results are given to show the adequacy between humidity and needs in dwellings.
The response of simple and cheap humidity controlled devices is presented on a short and long term time monitoring. The result of the swing between high and low levels is discussed and explained through theoretical examples, French regulation, and monitoring results. The increasing potential for demand controlled ventilation systems is presented through the evolution of the size of apartments and corresponding occupancy in different European countries. As a conclusion, humidity controlled ventilation – natural, assisted, or mechanical – has proved to be a reliable and relatively cheap system, economically valid in new or retrofit, in various climates.

“The first and main purpose of any ventilation system is to provide a good indoor air quality.”

“Ventilation flows have a cost : energy is necessary to heat the air, energy may be necessary to move the air.”

In its 17th report “indoor Air Quality and the use of Energy in Buildings” in 1996, the European collaborative action set out, as a first conclusion :
“Both the rational use of energy and the provision for good IAQ are important aspects of building design and refurbishment. There are potential conflicts between these requirements. The impact of possible energy savings on IAQ should always be discussed before their eventual adoption and if unacceptable, this measures should be avoided”

Ten years later, this conclusion is still valid and of particular interest in these times of high energy cost leading to energy saving measures. New building regulations and standards generally take care of this dual aspect, but retrofitting may be a major threat to IAQ and lack of correct ventilation provision is very common when improving insulation and/or windows. Today's most active area for savings is retrofitting (Kyoto commitments cannot be achieved without taking strong measures in this field), it is thus essential to discuss solutions which are available both for new and retrofitting.

There is considerable misunderstanding in the public of what is demand controlled ventilation system and how it works : a double approach is necessary to understand how Indoor Air Quality can be maintained (or even improved – which means higher flows) and how – in the same time – energy savings can be achieved (which means lower flows).

We have spoken here about maintaining or improving Indoor Air Quality and saving energy. This means that we have first defined a standard reference system, from which we can compare the levels of IAQ and energy spending.
Demand control ventilation does not save energy - nor does a heat recovery system – it spends less energy than the reference system, while achieving a comparable level of IAQ.
The standard reference system is usually taken from the building regulation part dealing with ventilation flows : in general we have a constant flow, although it is not always clear if this flow is a dimensioning one or a real constant one.
The difference is huge : the impact of the occupant may be of considerable importance on the real level if the system relies on his skill to drive the ventilation flows, the calculation of resultant energy cost and IAQ level may be very dependant on use.
This explains why it has been easier, and faster, to implement demand control ventilation where the flows were assumed to be constant, with no influence (or known conventional influence) of the occupants.
The constant flows have been set for a reference use of dwellings, which means that some will be more occupied, … and some will be less : these are the energy saving potentials.
Even in a normally or over-occupied dwelling, there are periods of under-occupancy when it is possible to perform savings.
With demand control ventilation, IAQ has to be understood at room or dwelling level, energy is to be considered on a yearly basis, at a statistic level.

Annex 18 of the IEA (1990) focussed on demand controlled ventilation and pointed out some questions regarding detection type, accuracy, long time behaviour, …
15 years later, we can give some answers.

As a conclusion of an Annex18 workshop on DCV for dwellings, it was agreed that humidity problems are of main concern (moisture, mould growth, destruction of wall, …), far higher than the other aspects of IAQ : the general trend was that if ventilation is appropriate to control the humidity aspects, the other should be correctly dealt with too.

The following measurements can confirm these assumptions :

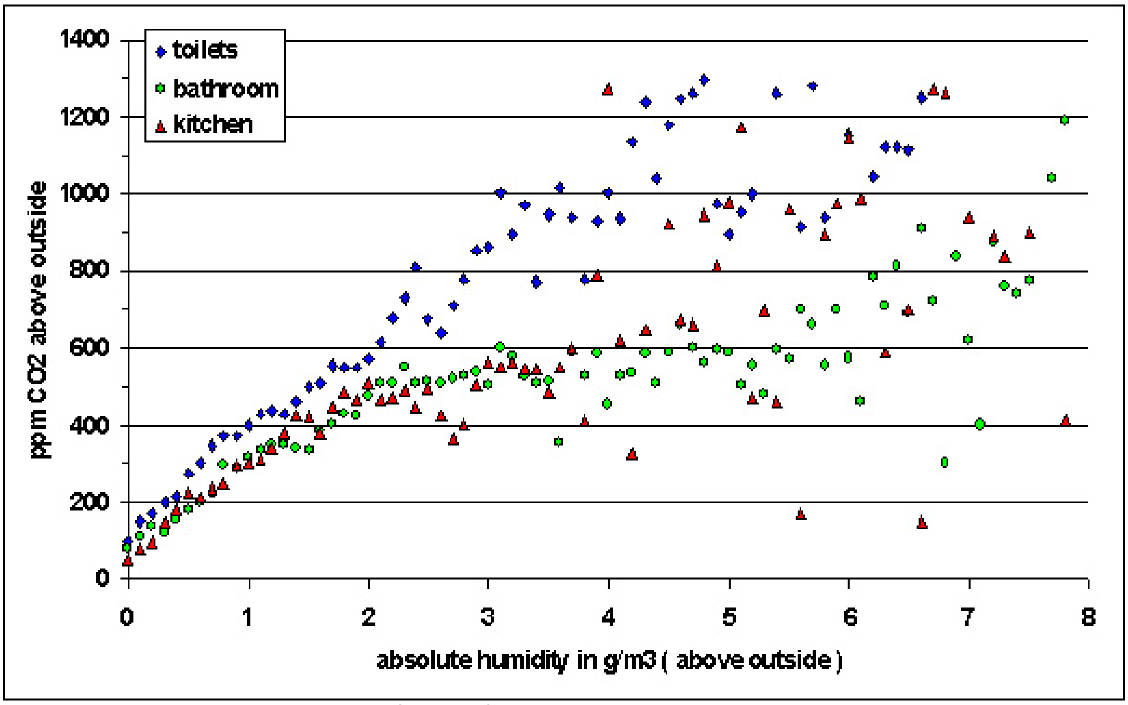

Figure 1. Evolution of the CO^2 and H^2O measured in a passive stack ventilated building

Measured in 1989 for a European project : each point represents an average value for 20 dwellings. Values are presented above outdoor levels, these increase come from human productions in the dwellings (both metabolic and specific activities).

Toilets has no specific emission of water vapour which means that it reflects mainly the human emission : we can see that the curve is very close to a straight line, up to 5 g/m^3 of water. Above this limit we can assume that the general level of the whole dwelling had increased during specific activities in the other rooms and water was moving toward toilets. In the other rooms, specific emissions occur (washing, cooking, showering, …).

For low levels of increase in humidity we can notice that the curve is equivalent to the one in toilets : it refers to times when there is no specific activities in these rooms. For higher levels, we have more humidity increase than CO^2 increase which means that the need for ventilation induced by the humidity level is higher than the one induced by CO^2. In kitchen we can notice some relatively high level in CO^2 also due to the gas cooker, but the general trend remains the same.

As a conclusion, we can take as a basis that, in the wet rooms (kitchen, bathroom and toilets), there is a clear link between the increase of CO^2 and the increase of absolute humidity (above outside level).
There is also a clear trend that humidity control is more suitable than CO^2 control in these rooms, which confirms the Annex 18' workshop conclusion.

The question remains for the other rooms : we know that the absorption-desorption phenomena is more active in habitable rooms as the materials used are in general more permeable to humidity and result in a damping coefficient.
Is humidity variation connected to CO^2 variation or mainly connected to damping behaviour of furniture ?

The following measurements can give a track for answering this question :

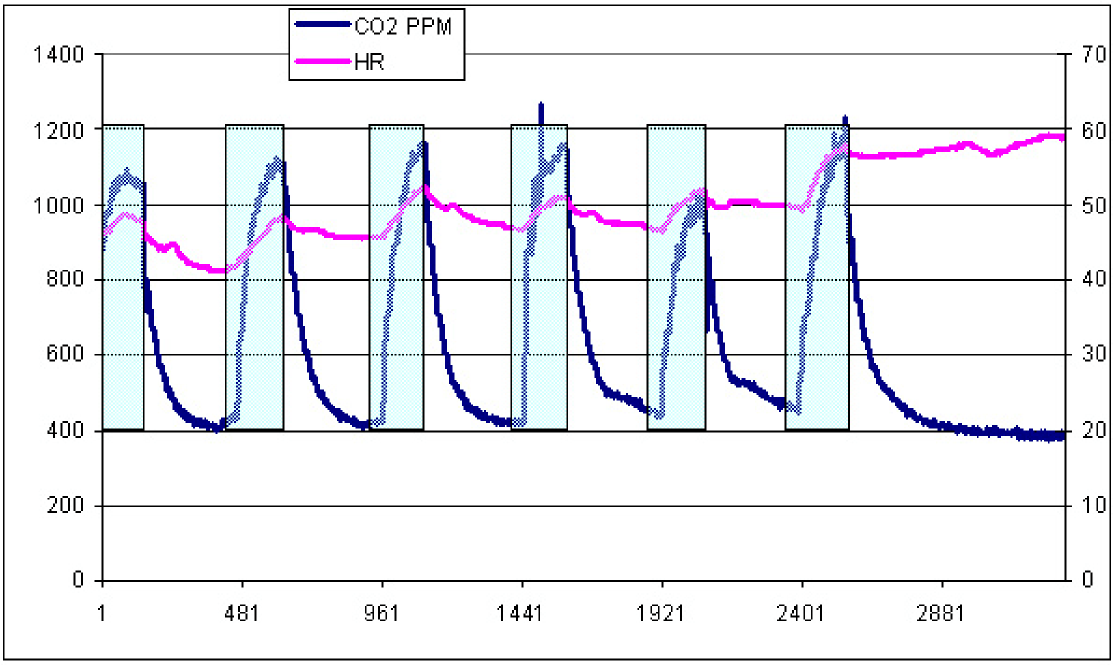

Figure 2. CO2 and humidity levels in a number of bedrooms, occupied by one person

At the first glance, the evolution of CO^2 in this bedroom seems to be much higher than the evolution of relative humidity, we can also notice that the relative humidity is increasing on a smooth curve and not only when people is in the room, the correlation does not seem very strong.

If we concentrate on times when the person is inside the room (night : blue boxes) and calculate the evolution of the absolute humidity from the beginning to the end of the night and the corresponding evolution of the CO^2, we get the next figure :

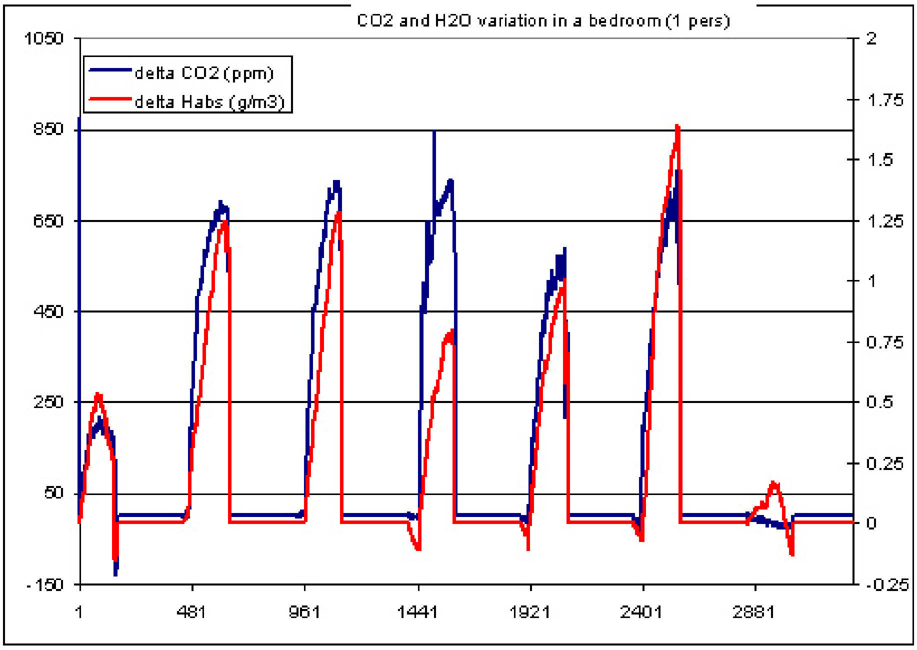

Figure 3. CO2 and humidity variation in a bedroom occupied by one person

Once again we have a clear trend of a strong correlation between CO^2 increase and humidity increase (although not perfect). The calculation (from the CO^2 levels) gives a damping coefficient of around 50% : part of the water is absorbed in the material (we miss the information of outside levels in this measurement, ongoing monitoring in France and Latvia (Riga) will give more information).

It is important to notice here that the detection of a variation of humidity in habitable rooms is possible and linked to the occupancy but that it cannot rely only on relative humidity alone. This is why the air inlets, if humidity demand controlled, must include a temperature coefficient that adapts the response to outside conditions (see AIVC presentation : “thermal behaviour of humidity controlled air inlet” for a complete analysis on the subject).

For all rooms in a dwelling, the average relative humidity will vary according to the seasons, following in a large way the outside absolute humidity. As the absolute outside humidity is always lower in winter, the basic flow will be lowered accordingly (we can note that, for humidity problems – condensation, mould growth, … -, the air is more efficient in winter that in the other seasons). A side effect, especially for cold climates, is to limit the time when the indoor relative humidity is too low for comfort, not using humidification process (which often costs a substantial part of the recovery in heat recovery constant flow systems)

If we have an empty dwelling, it is clear that the flow will follow strictly this outside level. The human metabolism and specific activities will increase this level and must be detected to adjust the flow when needed.

We have here the main point of demand controlled ventilation in general and humidity controlled ventilation in dwellings in particular : the average flows will lower during cold season, but the individual flows have to follow the demand : long term monitoring show this dual response :

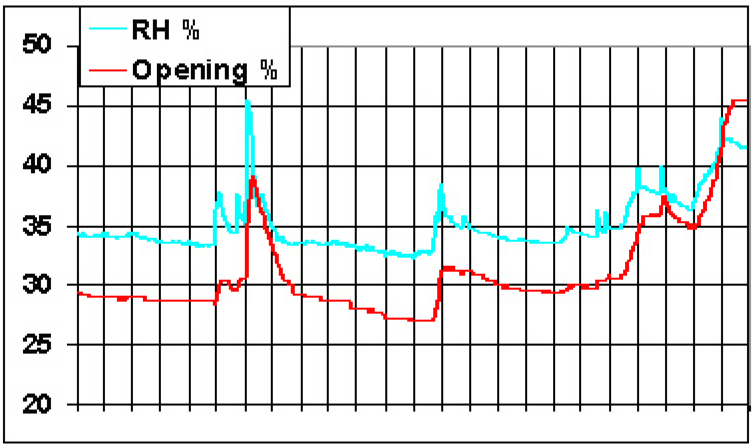

Figure 4. Response of a humidity controlled grille in a bathroom on a 24 hours basis

When the humidity rises, the response of the grille is a quick change in opening, giving higher flow.

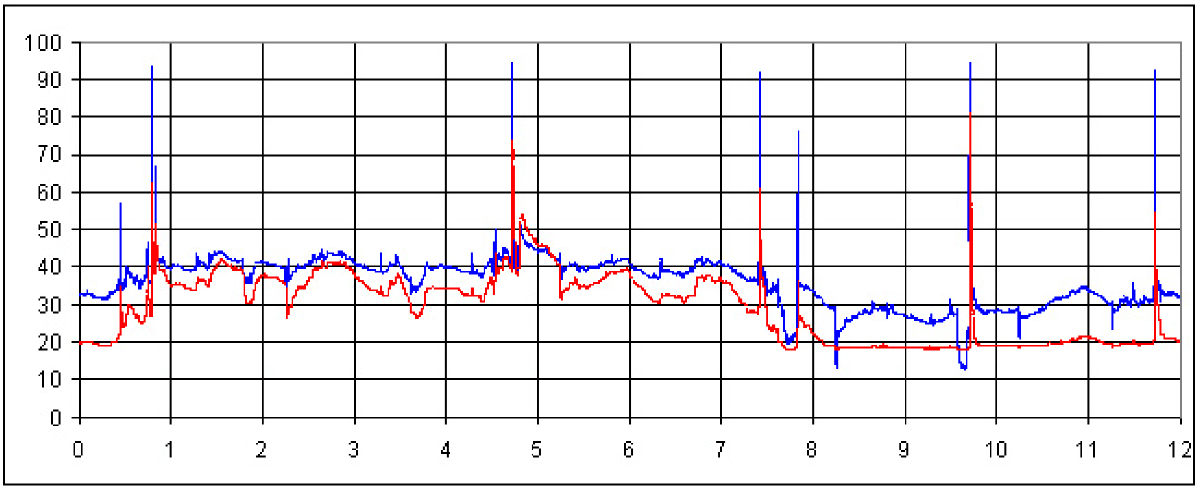

Figure 5. Response of a humidity controlled grille in a bathroom on 12 days in February

This graph shows clearly a base line for low demand periods, and high response when the demand increases.

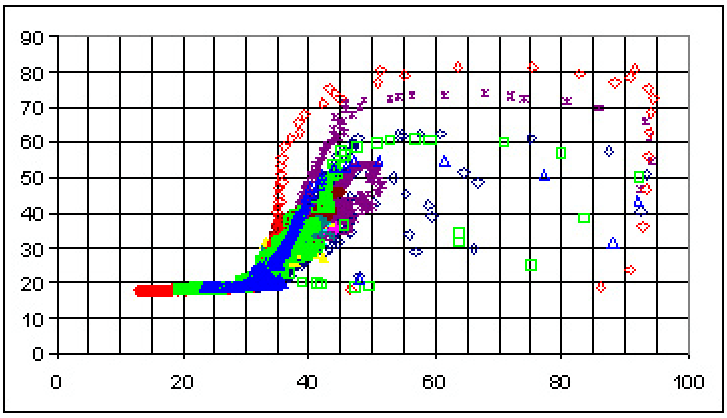

Figure 6. Response of a humidity controlled grille in a bathroom on 12 days in a XY representation

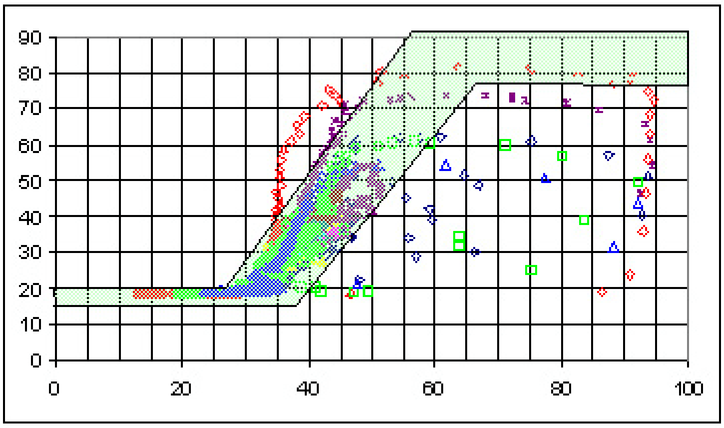

Figure 7. Response of a humidity controlled grille in a bathroom on 12 days in a XY representation

In this graph the normal range is represented in shaded area. The points outside are representative of the time response : when the increase or decrease of humidity is very fast, there is a slight delay in the resulting aperture. The totality of the points outside the shaded area represent less than 90 minutes on 12 days : 0, 5% which is negligible.

If we go further, for a whole year of functioning, we could expect a average flow dependant of the season: that is what has been recorded in Hokkaido (northern and coldest part of Japan, the winter temperature is often under –20°C).
In this graph we have represented 12 months, from October to September, of the opening of two grilles installed in an occupied house (hall-staircase) : the green points represent the average opening of the month, the span of the curve give the span of the opening in the same period.

The curve given by the green spots gives a clear view of the evolution of the average flow in the house and explain how the energy is managed through this evolution.

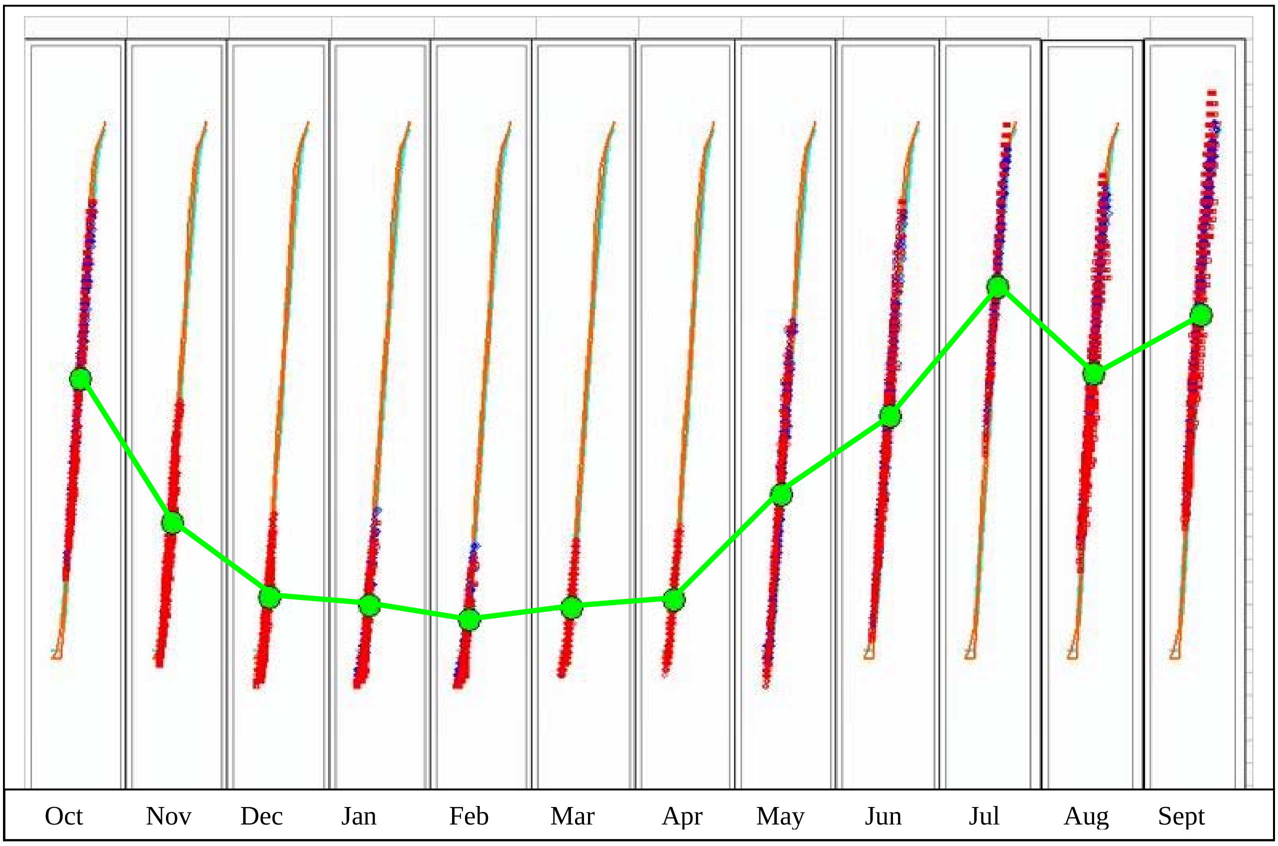

Figure 8. Response of 2 humidity controlled grilles on a 12 months basis in Hokkaido (Japan)

Another monitoring has been done in France, in retrofitted blocks of flats (55 dwellings, 5 blocks) with humidity controlled hybrid ventilation on a two years basis, with a measurement each minute (1 million points per day).

The analysis of the following graphs shows perfectly how demand controlled ventilation can conciliate indoor air quality and energy control : if we look at one dwelling, we can see again the response of the individual grilles to a change of the demand, in all seasons, with an increased average opening in summer compared to winter : the energy management is effective at the dwelling level by reducing the average flows in cold periods.

If we look at more apartments, the total flow is less and less changing (the needs are not the same and not occurring at the same time in the different dwellings) when the number of apartments increases. This is the major feature of demand controlled ventilation for energy management : statistically the needs are different and allow to lower the average flow : in an empty dwelling the flow can be reduced at a maximum while in a very occupied one, the flow will be less reduced, in less occupied periods.

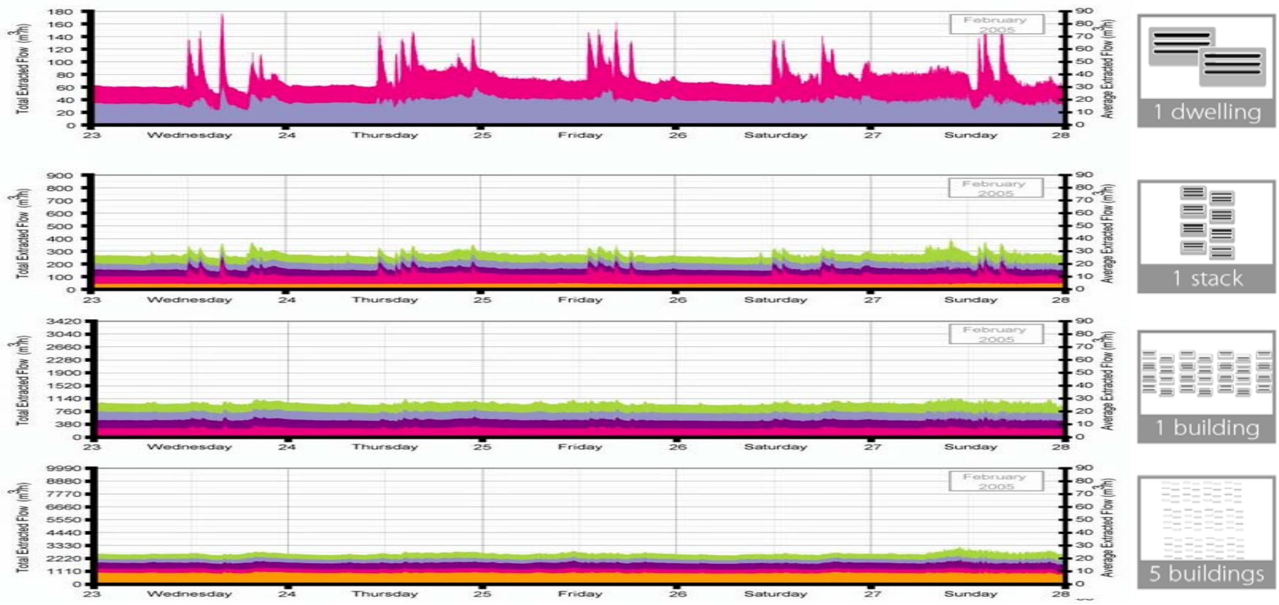

Figure 9. average flow in winter period (lower)

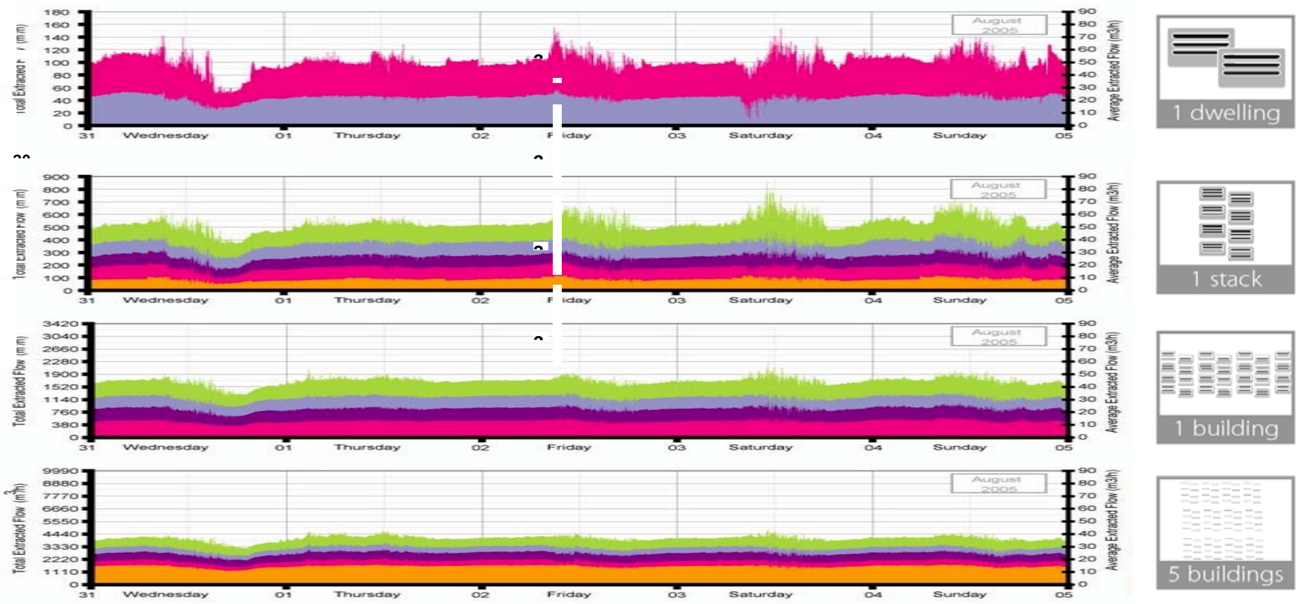

Figure 10. average flows in summer period (higher)

Demand controlled ventilation is more and more seen as an alternative to heat recovery systems, the regulations in Europe are now more open to it, following the French experience.
In France the system has been experimented from the early 80', more than 1,5 million dwellings are now equipped (2 millions worldwide), with no trend of particular drawback compared to a classic constant flow ventilation system. The level of energy reduction is around 35% to 55% of the part needed to heat the air (depending of the reference and the system used), the energy needed for transport can also be lowered, by using a variable fan or hybrid system. Humidity controlled systems are a standard in French building and represent more than 50 % of new building.

The potential for demand controlled ventilation is high and will become higher as the density of occupancy is lowering on a global trend for years in all countries :

Table 1. French statistical numbers (INSEE):

	1973	1984	1992	2002
M² / occupant	25	31	34	37
Over occupancy	4.7%	1.7%	1.3%	0.9%
Moderate over occupancy	17%	11.1%	9.6%	9.3%
Normal occupancy	29.4%	26%	22.8%	22.6%
Moderate under occupancy	25.6%	29.4%	26.7%	25.7%
Under occupancy	23.3%	31.8%	39.7%	41.6%

(m²/occupant : the figures are related to the whole stock and not only urban areas where the size is smaller)

In 2005, the trend continues and the number of under occupied dwellings (which is the main source of energy economies) will reach 70% in a few years. The idea of demand controlled ventilation was implemented in France in 1983 from the figures of 1978 (55% of under occupied dwellings) when it was found that savings were possible.

In urban area of Russian federation, the number of square meter per person has increased by 26 % in 12 years only :

from 15.7 m² in 1990 to 17.2 m² in 1995,
to 19.2 im² n 2000 and 19.8 m² in 2002.

Although the size is still lower than in western countries, the trend is clear and will continue, giving more opportunities to use demand controlled ventilation to control the energy demand, maintaining the IAQ level.

Humidity controlled systems exist in mechanical, hybrid or natural ventilation (exhaust type) which can easily be used in new building or retrofitting (often with re-use of existing ducts). The cost of humidity controlled system is usually 3 to 4 times the price of a classical exhaust only system (installation cost is the same) which gives a short payback period (depending of energy cost and winter temperature).

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