Energy Efficiency of Advanced Ventilation Techniques in Non-Residential Buildings and Their Barriers

J. L. Alexandre, M. Silva and A. Freire

Departamento de Engenharia Mecânica (DEmec)
Faculdade de Engenharia da Universidade do Porto
Rua Dr. Roberto Frias 4200-465 Porto Portugal

ABSTRACT

Air renovation inside buildings is crucial to have productive workers, since the lack of good indoor conditions affects human activity and promotes diseases (Fisk, 2000). This happens particularly in non-residential buildings where usually there is high occupation and thus big needs for fresh air. To achieve good indoor air quality (IAQ), actual ventilation solutions need a significant amount of energy, which is estimated to be about 10% of the total energy used in Europe (RESHYVENT, 2004). On the other hand, climate changes due to CO_2 emissions and derived from mankind activities mean that energy use must be rationalized and used in efficient ways. Although some new energy friendly ventilation solutions were developed, they face hard barriers to achieve a considerable market entry and spread. This article aims to understand, behind a technical perspective, why this happens and also analyses what can be the potential energy savings when advanced ventilation techniques are employed over the European main climate zones.

Results show that for European high cooling load climate, where night temperatures are too high, night cooling ventilation can achieve a minor or even an adverse effect. However in a colder climate this strategy together with high inertia construction gets considerable decreases on daily peak temperatures and cooling energy demand. On the cases where natural ventilation was used, energy savings reached more than 20% in energy delivered to the buildings.

KEYWORDS: Ventilation, energy efficiency, non-domestic buildings, night cool ventilation, natural ventilation.

INTRODUCTION

Ventilation is responsible for about 10% (RESHYVENT, 2004) of the total energy use in the EU and about 1/3 of this energy can be spared by the use of more efficient ventilation systems. However it is noticed that sometimes these techniques face hard barriers to get a deep market entry. Ventilation barriers can be separated in two different kinds, which are technical and non-technical barriers. In the Non-technical barriers type it is found barriers linked to economical costs, like low energy prices and payments schemes for designers, or lack of legislation to promote the use of efficient measures. Technical barriers are linked to technical problems like if the technology is suitable for a certain place or if the building designer has the necessary experience and knowledge to successfully dimension an innovative system.

This document makes a special focus on technical barriers analysing some of them for a group of advanced ventilation techniques. Three buildings were chosen as base case studies and used as a reference for the work models that were handled with the help of building simulation software.

BUILDING DESCRIPTION – CASE STUDIES

EPG - UP

Figure 1 – EPG above view

EPG is inserted in a university campus, supporting post-graduation classes and other activities (Figure 1). EPG was built in 2004, and has 2900 m^2 of net area distributed by 3 blocks (Maldonado, 2001).. Ventilation strategies include the use of make-up air handling units (MAUs) in small rooms with extraction made at corridors and staircases. Conventional air handling units (AHUs) are used in high loads spaced and irregular use spaces. Heating and cooling effect is done by a gas-fired boiler and a chiller, respectively. Natural night ventilation removes the heat stored in the walls during occupation time.

PARQUE EXPO

Parque EXPO is a 6-storey building located in Lisbon, Portugal (Figure 2). It is composed by two blocks linked by a full height covered atrium (Eduardo Fernandes, 1997). Floor displacement ventilation is used for air supply to the rooms and extraction is made by the ceiling to the main atrium. AHUs can work with 100% fresh air or a mix with recirculation air. Since both insufflation and extraction ducts are embedded in the slabs it is possible to do some heat recovery. Night cooling by natural means is provided with the help of openings that link the rooms to the outside and to the atrium.

Figure 2 – Parque EXPO view

YIT Keskus

Figure 3 – YIT building view

YIT Keskus is located in Turku, Finland (Figure). This building has 6906m^2, dispersed by five storeys (ThermCO, 2009). YIT is connected to Turku area district heating and cooling network. AHUs supply air to the space in neutral conditions. Open-plan and cellular spaces have a constant air flow, while for meeting rooms ventilation is controlled by attendance and temperature sensors. Indoor space conditions are controlled by radiators for heating and chilled beams for cooling. A heat recovery exchanger is used to reduce energy losses by extraction.

Three simulation models were created and based on the three buildings. This was done using TRNSYS (Klein) and IDA-ICE(IDA-ICE) simulation software. The results from these initial building models worked as a reference, for comparison with the results obtained for the modified models.

VENTILATION SOLUTIONS

Three different ventilation solutions were studied, i.e. natural ventilation, night cooling and variable air volume. In the next sections some known barriers of these ventilation solutions will be presented with some results that were obtained for each building and ventilation solutions.

NATURAL VENTILATION

Natural ventilation depends on natural phenomena to achieve air renovation within a building. The technical barriers that this solution faces are linked to wind availability, building orientation, available openings and space pollutants generation(Awbi, 2008).

A seasonal evaluation on natural ventilation rates was made. It was noticed that in general air flows are higher in January than in July (see Figure 4 and 5). Still for some zones, like zone 1(Z1) and zone 11(Z11) the average air rates stayed above the reference values (mechanical) for the two months.

The influence of window opening factor on air renovation was analyzed with EPG building model. The model was run twice with two different window opening factors, 30% and 50%. Windows were set to automatically open when CO_2 levels reach 800ppm, for a certain zone.

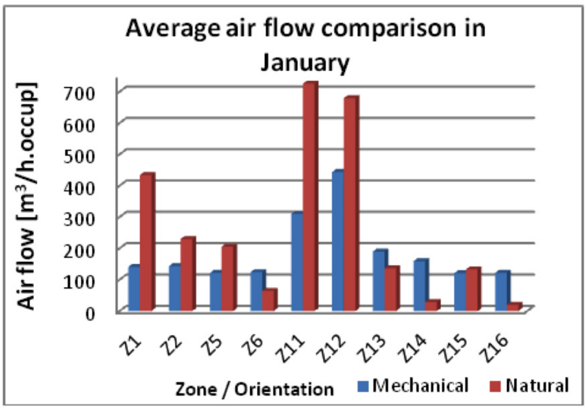

Figure 4 – Average air flow for January

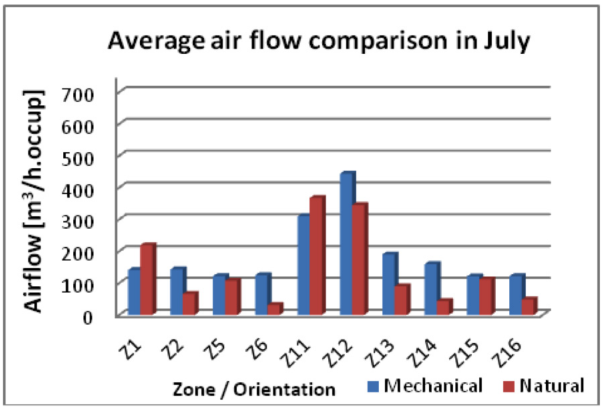

Figure 5 – Average air flow for July

Figure shows that the variation on the window factor from 30 to 50% leads to a significant reduction on the number of hours with bad CO_2 levels. However in zones with high occupation density, natural ventilation can be ineffective. So this change allows that natural ventilation can be employed in higher occupation places.

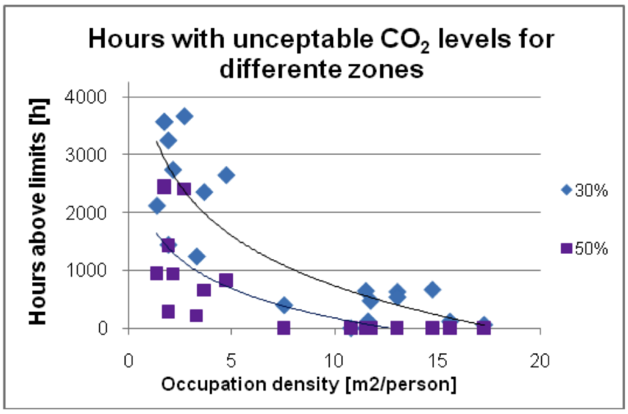

Figure 6 – Hours of bad CO2 concentration values

Besides bringing ventilation energy to zero, natural ventilation also leads to a reduction in space thermal energy demand. As it is displayed in TABLE 1, the both two natural solutions have lower energy consumption for heating and cooling. The higher energy reduction is found at the case with smaller window opening factor. This is justified by the fact that lower air rates, mean less air volume to be treated.

TABLE 1 : Energy comparison for natural ventilated case

	Natural Vent.				Reference case		Diff. 30% [%]		Diff 50% [%]	
	30% open		50% open							
Distribution [kWh/m²]	Heat	Cool	Heat	Cool	Heat	Cool	Heat	Cool	Heat	Cool
Thermal Energy	49	0.4	67	0.6	85	8	-42.4	-95.5	-20.9	-93.0
Ventilation	0		0		17.6		-		-	
Other Gains	70.4		70.4		70.4		0		0	
TOTAL	119.8		138		181.0		-33.8		-23.8	

Night Cooling

Usually night cooling is inadequate when night temperatures aren't low enough to remove the heat from the building or when the building isn't correctly orientated to catch the wind action (ASHRAE, 2006).

EPG was set to work as a natural ventilated case assisted by fan-light windows opening during summer night hours. Simulation was run with the climatic data from two European capitals, Athens and Lisbon. The number of occupied hours above 25ºC, for the worst zones and for the two cases is presented at Figure 7 and 8.

There weren't significant changes compared with the reference case, when night cooling was used in Athens.. Even if a BMS was used, which only allows night cooling during favourable hours, the results remain similar. This happens because Athens has too high temperatures during night hours.

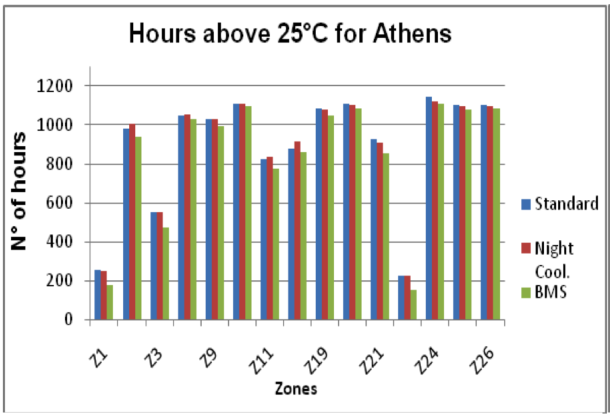

Figure 7 – Contrast between reference and night cooling solutions in Athens

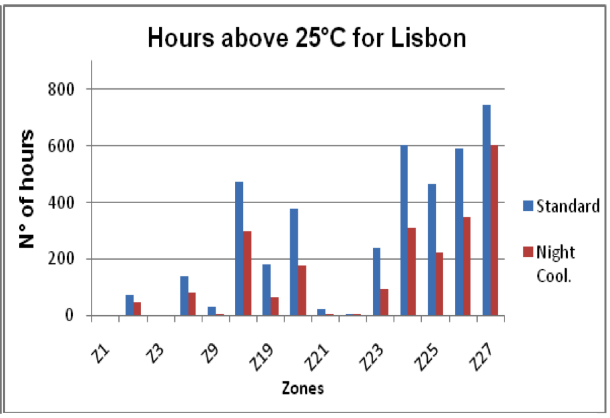

Figure 8 – Contrast between reference and night cooling solutions in Lisbon

According to Figure 8, when night ventilation solution was used in Lisbon, the number of hours above 25% had a big reduction. The results reveal that Lisbon weather is more suitable for night cooling that Athens weather.

A mechanical ventilated night cooling solution was also simulated, with YIT building model. A small reduction in the building total energy consumption was obtained for this case (see TABLE 2). However, cooling energy demand decreased 23%, being counterbalanced by a growth in fan energy spent. A primary energy analysis should be made, as this new distribution can mean an higher primary energy use.

TABLE 2 – Detailed energy consumption for night ventilation case

	Basic	NV	Diff.		Basic	NV	Diff.
Separated consumption	*kWh/m²a*	*kWh/m²a*	*%*	**Separated consumption**	*kWh/m²a*	*kWh/m²a*	*%*
Space heating	45.6	46.0	1	**Ventilation**	13.4	16.6	24
Supply air heating	9.6	9.7	0	**Internal Gains**	43.2	42.7	-1.2
District Cooling	18.2	14.3	-21	**Total delivered energy**	130.0	129.3	-1

Variable Air Volume

A Demand control ventilation solution was studied using YIT model. Usually this solution is applied to spaces with intermittent use, like gymnasiums, meeting rooms and auditoriums. Therefore a typical barrier that designers must face is to know how quick the cost savings related to energy will return the initial system higher costs (ASHRAE, 2006). Sometimes VAV systems also have limitations to control temperature, humidity and air renovation, all at the same time (Awbi, 2008).

TABLE 3 - Detailed energy consumption for demand controlled ventilation case

	Basic	VAV	Diff.		Basic	VAV	Diff.
Separated consumption	*kWh/m²a*	*kWh/m²a*	*%*	**Separated consumption**	*kWh/m²a*	*kWh/m²a*	*%*
Space heating	45.6	41.8	-8	**Ventilation**	13.4	4.9	-63
Supply air heating	9.6	2.8	-71	**Internal Gains**	43.2	43.3	0.2
District Cooling	18.2	24.7	35	**Total delivered energy**	130.0	117.5	-10

Energy reductions were found not only at the ventilation field but also in other fields, like supply air heating (see TABLE 3). The result was a global energy reduction close to 10%. Since air flow is variable and as happens in natural ventilation lower air rates mean less air to be treated and thus less thermal energy spent.

CONCLUSIONS

The results showed that it is possible to get considerabe energy savings with natural ventilation. However to ensure a good performance designers and other professionals should pay attention to several details like appropriate window opening factor or what will be the space occupation type and density.

Natural night cooling performs well only when night temperatures are low enough to remove the heat from the buildings inside. The employment of a mechanical night cooling solution should be always carefully considered as the energy savings can be very small and even none when the analysis is made in primary energy terms.

The VAV system confirmed the principle that lower air rates also mean less energy spent for space conditioning. Consequently a significant building overall energy reduction was experienced for this case.

REFERENCES

ASHRAE (2006) GreenTips. ASHRAE greenguide: the design, construction, and operation of sustainable The ASHRAE professional series. Butterworth-Heinemann.

AWBI, H. B. (Ed.) (2008) Ventilation Systems Design and performance, Taylor & Francis.

EDUARDO FERNANDES, F. A. (1997) Estudo de caso II - Edifício dos Serviços Administrativos da Parque EXPO'98.

FISK, W. J. (2000) Health and Productivity Gains From Better Indoor Environments and their Relationship with Building Energy Efficiency. Annual Review of Energy and the Environment, 25, 29.

IDA-ICE EquaSimulation.

KLEIN, S. A. TRNSYS reference manual, http://sel.me.wisc.edu/trnsys.

MALDONADO, E. (2001) BUSINESS INNOVATION CENTRE. IN COMMUNITIES, C. O. T. E. (Ed.) Building 2000.

RESHYVENT (2004) Cluster project on demand controlled hybrid ventilation in residential buildings with specific emphasis of the integration of renewables 5th Framework.

THERMCO (2009) Simulation Study: Low-Energy Cooling in North Europe. IN COOLING, T. C. I. B. W. L.-E. (Ed.).

ACKNOWLEDGMENTS

We wish to thank to Building Advent project partners and also we wish to acknowledge to Intelligent Energy Europe (IEE) for their funding of this research project.