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International Energy Agency
Energy Conservation in Buildings
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Air Infiltration and Ventilation Centre

Hybrid Ventilation

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1 Introduction

1.1 General

For the near future the expectation of experts is that the most promising systems will be based on demand-controlled hybrid ventilation technologies. The impact of further development and the improvement of fully mechanical or fully natural ventilation systems on energy savings and indoor air quality is reaching its limits. The hybrid part of the system is of course the minimisation of the electric power of the fan by improving the fan efficiency and low pressure ducting.

Hybrid ventilation systems can be described as systems providing a comfortable internal environment using different features of both natural ventilation and mechanical systems at different times of the day or season of the year. It is a ventilation system where mechanical and natural forces are combined in a two-mode system. The main difference between conventional ventilation systems and hybrid systems is the fact that the latter are intelligent systems with control systems that automatically can switch between natural and mechanical mode in order to minimise energy consumption and maintain a satisfactory indoor environment.

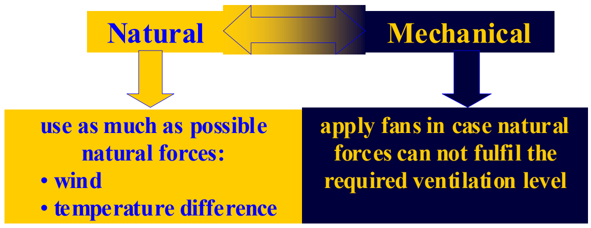

Figure 1 : Schematic picture of the 2 modes of hybrid ventilation

1.2 Energy for ventilation

Since energy due to heating or cooling of ventilation air in general is an important part of the energy demand for a building, it is an opportunity to minimise the energy use for it.
There are two different energy-demanding aspects for ventilation (Figure 2):

- energy to heat or cool the ventilation air
- energy to transport air from intake through the building to outside.

The energy to transport air is for traditional systems roughly 5 -15 % of the energy used for heating and/or cooling the ventilation air.
Hybrid ventilation is a way to minimise both energy-demanding aspects.

1.3 Different modes of hybrid ventilation

Hybrid ventilation is a two-mode system (Figure 1), which is controlled to minimise the energy consumption while maintaining acceptable indoor air quality and thermal comfort.

The two modes refer to natural and mechanical driving forces. Natural driving forces are wind and buoyancy, mechanical driving forces normally means fan(s).

The basic philosophy is to maintain a satisfactory indoor environment by alternating between and combining these two modes to avoid the cost, the energy penalty and the consequential environmental effects of year-round air conditioning. This will lead to controls, which try to maintain the exact required airflow rates. The driving forces must be minimised so the target is to use the minimum of electrical or mechanical energy.

For the near future the expectation of experts is that the most promising systems will be based on demand-controlled hybrid ventilation technologies. The impact of further development and improvement of fully mechanical or fully natural ventilation systems on energy savings and indoor air quality is reaching its limits.

Due to developments over the last ten years the advanced mechanical and natural ventilation systems are approaching each other (Figure 3)

1.4 Control and demand

The heart of a hybrid ventilation system is a sensor based measurement and control strategy. The main difference between conventional ventilation systems and hybrid systems is that the latter are intelligent systems including control algorithms that automatically can switch between natural and mechanical modes in order to minimise the fan energy consumption and optimise comfort. It requires a complete new view on the dimensioning and control of ventilation systems. Either way, the airflow has to be monitored during use of the hybrid systems, because the control of switching from the natural to the mechanical mode needs it. Since the airflow is measured there are also possibilities to adapt the flow to the demand flow. This can either be done by time programming based on the assumed presence of people or with another way of detecting the attendance of people in rooms for instance infrared sensors or CO_2 sensors. The control algorithm for hybrid ventilation is still an important aspect in studies on hybrid ventilation, the important question is when, why and how to switch from the mechanical to the natural mode and vice versa.

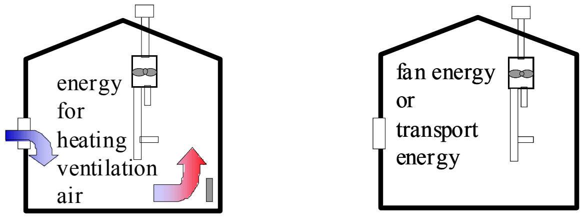

Figure 2 : Energy for heating or cooling and for transport of ventilation air

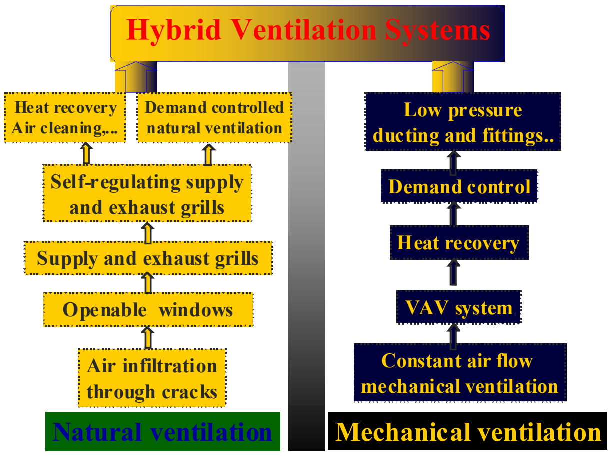

Figure 3 : Recent developments in ventilation systems (P. Wouters PhD - revised)

1.5 Benefits

Since hybrid ventilation consists of the 2 modes natural as well as mechanical there are possibilities to minimise energy use at the same time and improvements in IAQ levels and comfort might be obtained. Hybrid ventilation is also more sustainable than traditional ventilation systems.

The natural mode of the hybrid ventilation is highly appreciated by the users resulting in fewer complaints about ventilation and comfort. Natural ventilation also offers the possibility to maximise ventilation during night in summer resulting in better comfort.
Personal overruling control possibilities can be used and results in an increased awareness of the need for active interaction with these systems, normally resulting in better IAQ and comfort.

1.6 Building consequences

Buildings with hybrid ventilation systems should be airtight. This is of course a necessity for all type of ventilation systems. The infiltration may not disturb the demand on ventilation, it may not lead to unnecessary energy use, and it may not lead to situations where the heating for a room is insufficient resulting in comfort problems.

Hybrid ventilation systems require a complete interaction with building construction and building design. Due to some requirements of the system duct sizing, thermal mass, position of in- and outlets etc., architects or design teams should be open and willing to discuss the integration of the hybrid system.

1.7 Barriers

The main barriers for the application of hybrid ventilation are not the cost as might be expected. (See chapter 4) There are a number of barriers to apply hybrid ventilation:

- Experience and knowledge on hybrid ventilation systems is very limited
- HVAC engineers traditionally think of mechanical ventilation as a solution for ventilation without the risk of being surprised by the unknown
- Design rules and tools are lacking or scarce available
- Design criteria are not always well fitted for hybrid systems
- Some building regulations and or ventilation standards have requirements that are not based on defined performance but descriptive. Most standards and regulations give fixed requirements. They often do not give information about a certain amount of time the required values may be exceeded. If the requirement is expressed as one single value or only a very narrow band is allowed, mechanical ventilation will likely be the chosen option, even if a natural solution averaged over time may give the same result.
- In some countries the rules for paying consultants are such that the consultant is being paid proportional to the cost of the system. Since in certain cases mechanical part of the system might be cheaper there is no incentive to advise a hybrid system
- Natural ventilation inlets for rooms normally have no possibilities for filtering the incoming air, so in the case of filtering it is essential either to have a central natural inlet in which filtering is feasible or mechanical ventilation is a necessity.

1.8 Regulations and standards

There are no standards or regulations preventing the implementation of demand controlled hybrid ventilation in dwellings. In some countries the current regulations may complicate the implementation compared with a traditional ventilation system. The new building codes being developed thanks to the EPBD should remove these barriers and become a market driving force. A harmonised European market would increase the potential for demand controlled hybrid ventilation systems. The building codes and standards, and assessment procedures must be harmonised. The assessment procedures must take into account innovative systems like demand controlled hybrid ventilation. An important step in that direction could be the implementation of the requirements of the above mentioned EPBD.

2 Classification of hybrid systems

2.1 Concepts of hybrid systems

Three hybrid ventilation concepts can be defined:

- alternate use of natural and mechanical ventilation
- fan assisted natural ventilation
- stack and wind supported mechanical ventilation.

All buildings with hybrid systems up till now are far from what might be the optimum solution. There is a knowledge gap on dimensioning and control of hybrid ventilation systems.

2.2 Alternate use of mechanical and natural ventilation

The first example given is a system for a dwelling in which a fully balanced system is installed, but if the outside weather conditions allow natural ventilation the mechanical system is shut down. In extreme weather conditions ,either too cold or too warm, the natural system will be shut down and the mechanical system will take over.

Some indication for occupants in which case the mechanical or natural mode should be based on the number of occupants; their activity and the weather are helpful.

One can imagine that this system is not the optimum of hybrid ventilation but it is a typical example of trying to minimise the energy use and give people maximum control.

2.3 Fan assisted natural ventilation

An example of a hybrid ventilation concept for apartment building that originally had combined natural ventilation ducts. The system works under most weather conditions with natural forces. But in case the wind and buoyancy forces do not fulfil the required ventilation level, the special developed fan starts to run.

The air enters through inlets in the façade. Through a concrete duct with a so called shunt duct the air will be extracted from the WC, Bathroom and kitchen in the individual apartment. A fan can support the flow through the system.

2.4 Stack and wind supported mechanical ventilation

The system shown here is an industrial hybrid ventilation system with limited building impact. The fan energy though is limited due to wind and stack effect. Moreover during some periods of the year the system is running without mechanical forces. The system has a low resistance heat recovery system that also works under circumstances of natural driving forces. The system is also applied in dwellings. It is a typical mechanical ventilation design but low-pressure distribution was taken in account to make the available natural sources a relevant part of the driving forces.

The buildings in which the system is applied are just ordinary buildings without any specific hybrid ventilation item in the building fabric. The application of this system is almost unlimited, bust cost and investment plays a decisive role.

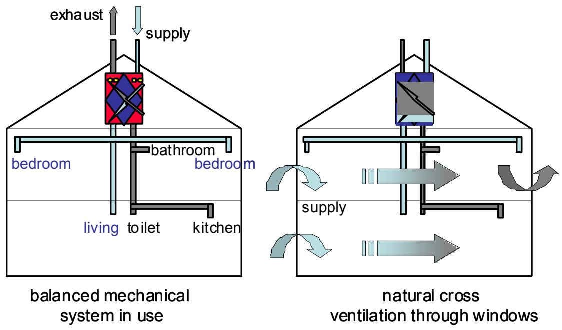

Figure 4 : Mechanical (left) and natural (right) ventilation mode

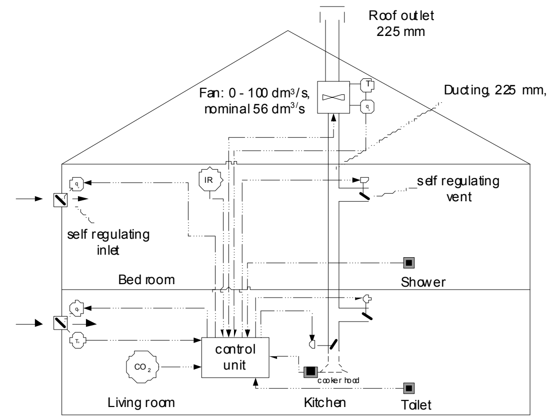

Figure 5 : Example of dwelling with fan assisted ventilation

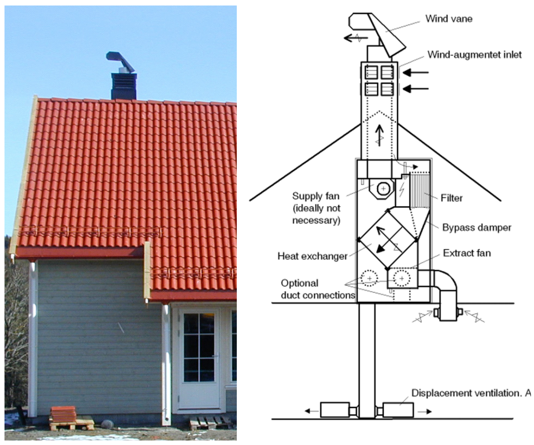

Figure 6 : Typical mechanical system with support of natural forces

3 Research and Developments

3.1 Research items

All hybrid ventilation concepts as described in chapter 2 will be far from optimal. It was a first approach for all design teams. A lot of knowledge is still lacking and a number of research items are still not answered:

- what ventilation strategy should be chosen to optimise the energy efficiency, indoor air quality and the thermal comfort;
- what control strategy is the most appropriate,
- what control parameters should be used under the different climate conditions and demanded flow rates,
- how to size or dimension the ventilation systems for both natural and mechanical modes, including components of the system such as openings, ducts, fans, internal overflows, heat exchangers etcetera.

3.2 Developments

In the development of hybrid systems currently on the way in a number of European countries, the following aspects play an important role:

- local exhaust versus central exhaust
- tuning supply and exhaust
- self controlled air inlets
- low pressure ducting supported by wind and buoyancy
- optimal cowl design
- demand control by IR, CO2, RH sensors or time control
- optimal dimensioning of the ducting
- optimisation of fan design

4 Cost of hybrid systems

4.1 General

Costs are one of the main decision factors for the selection of ventilation systems. This leads to a ventilation system that merely meets the requirements of building regulations at the lowest initial costs. Decision makers are often not aware of the impact the quality of the ventilation system can have on life-cycle costs for both the ventilation system itself and the building. Therefore, cost specifications should include:

- Initial (investment) costs
- Maintenance costs
- Energy costs

It is difficult to get the cost figures and compare them. National legislation, regulations and energy policy might affect the cost considerably.

The initial and total costs of some of the case studies in the Hybvent project are given at Figure 7 and Figure 8.

4.2 4.4 Maintenance costs

A limited amount of data on specific maintenance costs for hybrid ventilation systems is available. Below an indication of the different maintenance activities for hybrid ventilation systems is given.

- Regular maintenance: The following maintenance activities may be required: cleaning of grilles, filters, and culverts, measurement of air flows (balancing), and incidentally the replacement of filters.
- Complaint maintenance: Complaints are extremely rare. A high level of satisfaction of users of the system has been reported.
- Costs of maintenance of the building as a result of the ventilation system: There are no known effects on the building that would require additional maintenance.

4.3 Energy costs

Hybrid ventilation systems are expected to have a high potential for the reduction of energy consumption in buildings. Energy cost in the case studies of the Hybvent project vary from 7 – 26 €/m² floor area.

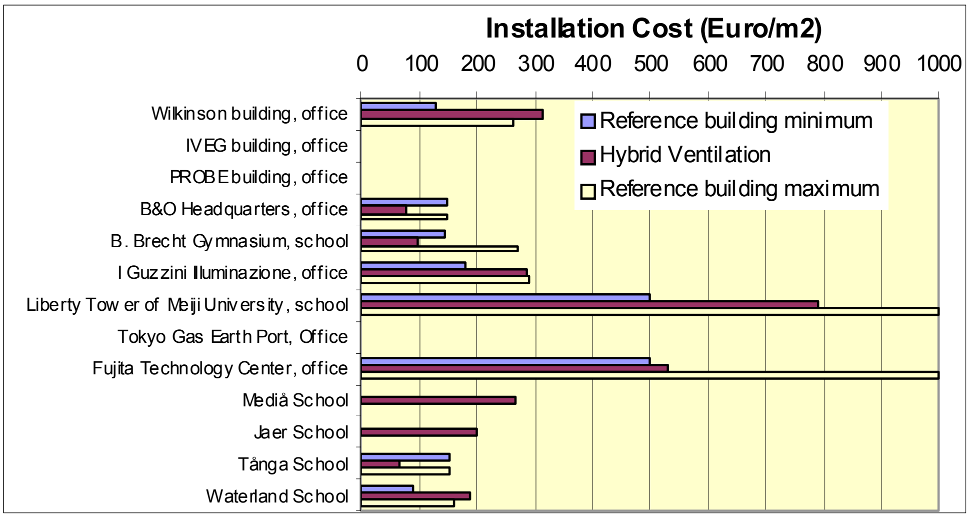

Figure 7 : Initial installation cost for some of hybrid ventilation systems compared with references from Hybvent

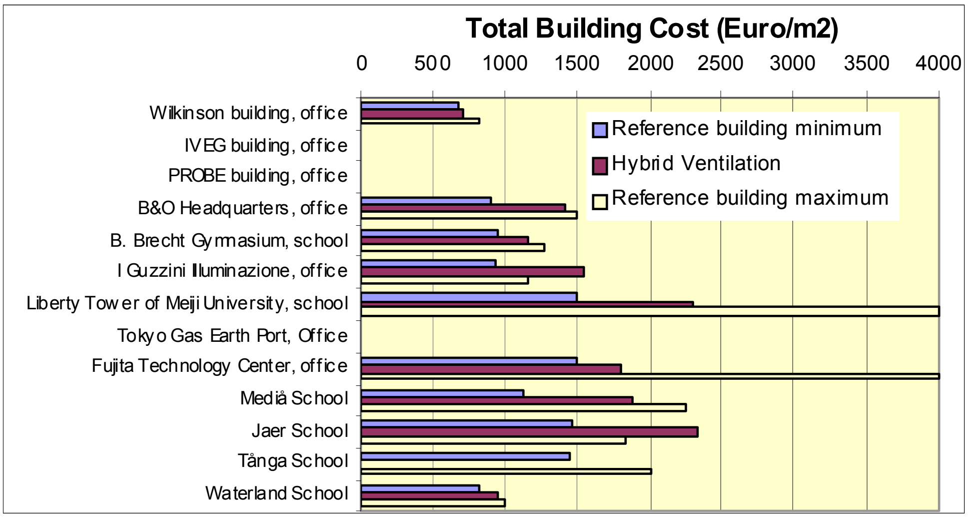

Figure 8 : Total building cost for some of the case study buildings compared with references from Hybvent

5 Designing Hybrid ventilation systems

The hybrid ventilation process is very dependent on the outdoor climate, the microclimate around the building as well as the thermal behaviour of the building and it is, therefore, essential that these factors are taken into consideration in the basic design step. The output from the first step is a building orientation, -design and -plan that minimises the thermal loads on the building in overheated periods, that together with the selected ventilation strategy makes it possible to exploit the dominating driving forces (wind and/or buoyancy) at the specific location and that ensures a proper air distribution through the building. It is also important that issues like night cooling potential, noise and air pollution in the surroundings as well as fire safety and security are taken into consideration.

In the climatic design step the natural ventilation mode of the hybrid system is designed. The location and size of openings in the building as well as features to enhance the driving forces as solar chimneys and thermal stacks are designed according to the selected strategy for both day and night time ventilation. Passive methods to heat and/or cool the outdoor air are considered as well as heat recovery and filtering. Appropriate control strategies for the natural ventilation mode are determined and decisions are made regarding the level of automatic and/or manual control and user interaction.

In step three the necessary mechanical systems to fulfil the comfort and energy requirements are designed. These can range from simple mechanical exhaust fans to enhance the driving forces to balanced mechanical ventilation or air conditioning systems.

The hybrid ventilation and corresponding whole system control strategy are determined to optimise the energy consumption while maintaining acceptable comfort conditions.
Effective and efficient climatisation and ventilation of indoor spaces has the best chance for success when the design process is carried out in a logical, subsequent manner with increasing detail richness towards final design, and in the framework of a design procedure.

In the case of hybrid ventilation the need for a design procedure is even more evident due to the comprehensive design team, where users, building owner, architect, civil engineer and indoor climate and energy counsellor must all be involved – simultaneously.
A HVAC design procedure consists of different phases: conceptual design phase, basic design phase, detailed design phase and design evaluation.

6 References

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The Air Infiltration and Ventilation Centre provides technical support in air infiltration and ventilation research and application. The aim is to promote the understanding of the complex behaviour of the air flow in buildings and to advance the effective application of associated energy saving measures in the design of new buildings and the improvement of the existing building stock.