TYPOLOGY OF HYBRID VENTILATION SYSTEMS AND PRACTICAL EXAMPLES

21ST ANNUAL AIVC CONFERENCE
THE HAGUE, NETHERLANDS, 26-29 SEPTEMBER 2000

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1. SYNOPSIS

This paper aims to identify major characteristics of hybrid ventilation systems, whereby a clear distinction is made between ventilation for Indoor Air Quality control and ventilation as part of a strategy for control of thermal comfort in summer. The aim is to identify the major differences between the various approaches and to develop some kind of rationale.

Various building projects are used as illustration for the classification.

2. WHY VENTILATION ?

Ventilation in buildings is today in most countries considered as an essential aspect in each building project. Whereas in the past, ventilation was automatically linked to indoor air quality control, there is now a growing interest in ventilation as part of an energy efficient strategy for achieving thermal comfort in summer. In order to assess ventilation components and systems, it is therefore essential to explicitly separate ventilation for indoor air quality control and ventilation as part of a thermal comfort strategy in summer (figure 1).

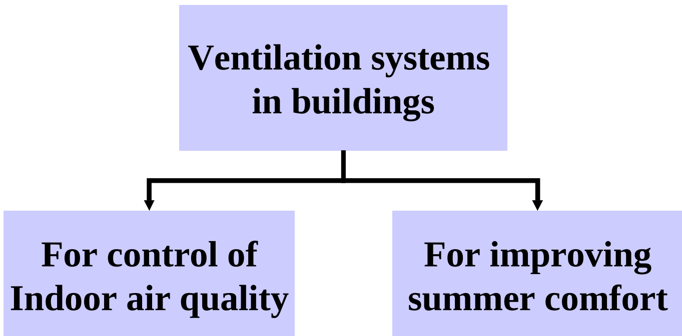

figure 1 : A correct identification of the purpose of ventilation is essential and in practice often not well expressed

As will be further discussed in the next paragraphs, the devices to be used for IAQ control and summer comfort control are in general quite different (an interesting exception is the school in Gronge (Norway)). The major reason for this difference is the fact that, if compared with ventilation for IAQ control, effective night ventilation requires rather high air flow rates. As an illustration, figure 2 shows air flow rates as predicted by ESP-r for IVEG, a new office dwelling in Hoboken (Belgium) where intensive natural ventilation is used at night-time. The average air flow rate for IAQ is showed as well. In this project, presence detection is used for IAQ control.

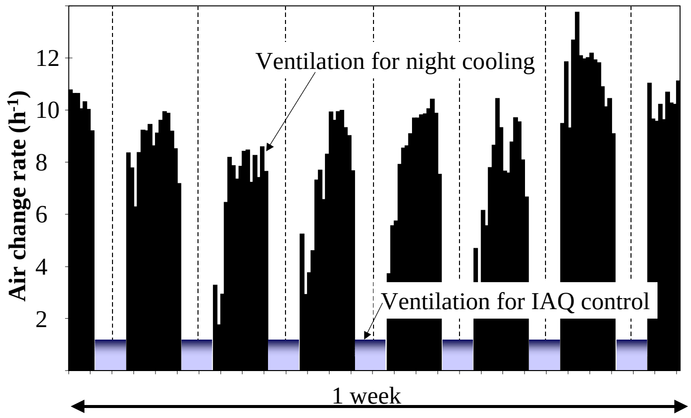

figure 2 : Ventilation for IAQ and thermal comfort : various orders of magnitude

For both types of ventilation, a successful application will only be achieved if a whole range of potential barriers and problems are overcome. The next sections 2.1 and 2.2 discuss the context for ventilation in relation to indoor air quality control and for thermal comfort control respectively, whereas section 9 focuses on potential barriers and how to overcome these..

2.1 Ventilation as part of global strategy for indoor air quality control

In enclosed spaces, it is in most cases not possible to realise a good indoor air quality without specific provisions. Ventilation systems aim to guarantee the possibility of having acceptable indoor air quality.

At present, most ventilation standards are descriptive and they do not specify the required air quality in a direct way but only indirectly by specifying the required air flow rates. The primary requirement for ventilation systems is that they realise an acceptable indoor air quality or, if air flow rates are specified, that they meet the specified air flow rates.

In practice, a whole range of other requirements ('secondary' requirements) have to be fulfilled before one can consider a ventilation system performing correctly. The relative importance of each of these secondary requirements can vary substantially between projects. These secondary requirements include :

- Energy use : energy use should be as low as possible for the required air flow rates
- Acoustics : noise levels should be below acceptable limits
- Costs : it is evident that the cost of a ventilation system should be reasonable
- Ease of installation : a very important aspect for installers
- Space use : space use should be limited
- Ease of operation and controllability
- Ease of maintenance : the need for maintenance should be limited and such maintenance should be easily practicable
- Durability : the system should work correctly over a long period of time
- Aesthetics : it must be possible to integrate the system in the building in an aesthetic way
- …

2.2 Ventilation as part of global strategy for summer comfort control

Night ventilation is part of the building tradition in hot and dry climates. It was a very common strategy in Mediterranean architecture and in hot dry climates. In certain cases, wind towers (figure 3) were used for stimulating the impact of night ventilation.

Task XIII, …) in night ventilation strategies and this to a certain extent in parallel with a renewed interest in natural ventilation for IAQ control. In most of the existing realisations, night ventilation is achieved by natural means although there are a number of projects in which mechanical or hybrid ventilation concepts are used.

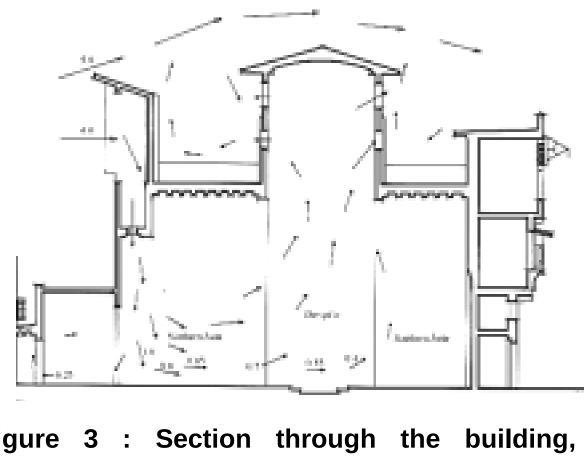

figure 3 : Section through the building, showing how the malqaf and wind produce internal air movement (m/s). Fathy (1986)

There are multiple motivations for this renewed interest: financial motivations (lower investment costs and/or operation costs), positive appreciation by occupants and positive impact on productivity, reduced environmental impact, some pretend an increased robustness and/or increased flexibility and adaptability.

As an illustration of the potential reduction in annual energy cost, data from CIBSE (CIBSE, 1998) can be used: in a well designed building making use of natural ventilation, a substantial energy saving can be expected because of no energy for refrigeration and a very substantial reduction in energy use for fans and pumps.

Quantification of the impact on productivity is less evident. However, there are several studies indicating the potential for such improvements. As an illustration, figure 4 shows the perceived productivity as function of the degree of control. The larger the degree of control, the better the perceived productivity. A building with a concept of night cooling and passive cooling techniques may be contributing to a better degree of control and therefore a better productivity.

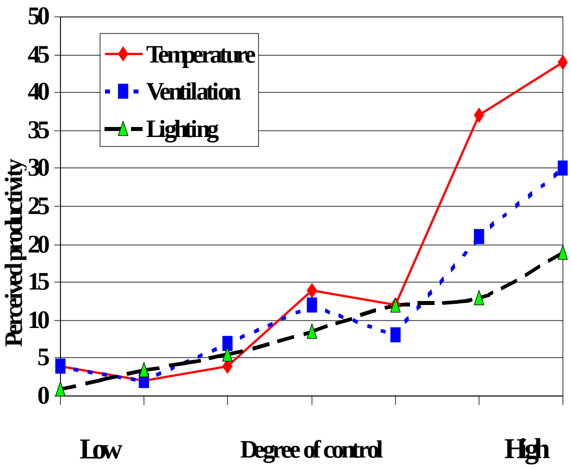

figure 4 : Impact of degree of control on temperature, ventilation and lighting on perceived productivity Source : CIBSE (1998)

A successful night cooling design requires much more than the achievement of the required air flow rates. A whole range of potential barriers can be identified (figure 5).

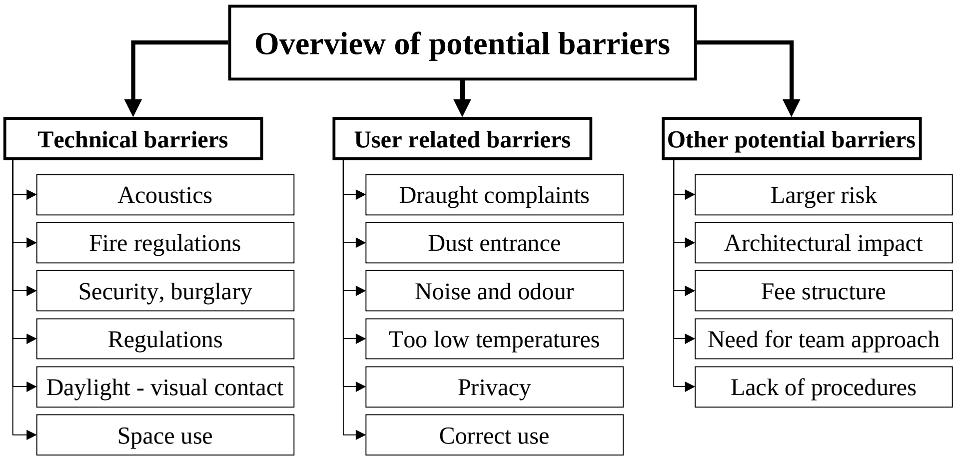

figure 5 : Successful night ventilation for summer comfort requires handling of a whole range of potential barriers

3. HYBRID VENTILATION

In the past, ventilation systems were in general only used for IAQ control and they were classified in 2 categories : (constant air flow) mechanical ventilation systems and (manually controlled) natural ventilation systems.

During the last 2 decades, interesting developments can be observed for both categories (see figure 6):

- As far as mechanical ventilation systems are concerned, demand controlled ventilation systems have received quite a lot of attention (as was found in IEA Annex 18 'Demand controlled ventilation'). The last years, specific efforts are done for optimising the energy use of such systems by developing low pressure ventilation systems in combination with high efficiency fans, e.g. the European JOULE project TIPVENT;
- As far as natural ventilation systems are concerned, supply, transfer and exhaust grills have become quite common in many countries. Self-regulated devices allow to better take into account varying weather conditions. A further optimisation is obtained (e.g. air cleaning at low pressure differences, heat recovery systems.) More recently, demand controlled natural ventilation systems, whereby advanced electronic control is applied are becoming available. In order to compensate during certain periods of time the lack of sufficient pressure differences, fan assisted systems have been developed.

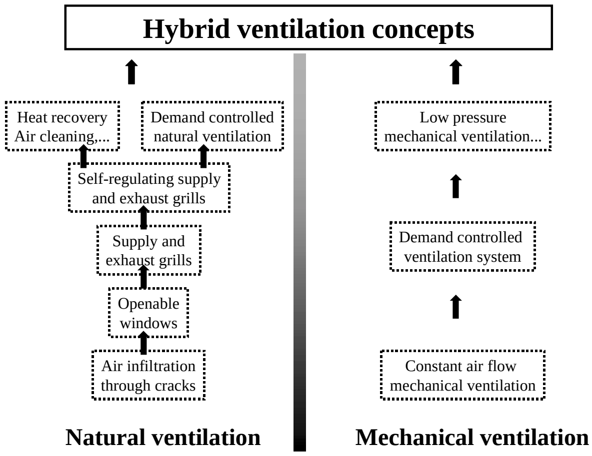

figure 6 : The future ?: merging the best of natural and mechanical ventilation...

As a result, the division between natural and mechanical ventilation is becoming rather weak in many cases. More fundamentally, one observes that there is a tendency for combining the best of both technologies : intelligent natural ventilation if appropriate, efficient mechanical ventilation if required. This tendency is valid also for ventilation in relation to thermal comfort in summer.

This new tendency is called hybrid ventilation. It is the subject of IEA annex 35 'HybVent'.

Hybrid ventilation systems are in the framework of IEA 35 defined as (Heiselberg, 1998):

> *"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. "*

4. BUILDING EXAMPLES

In the presentation, 6 buildings are used. It must be stressed that the fact that these buildings are included in this paper not necessarily mean that they are excellent buildings with respect to indoor climate and energy efficiency. The major reason why they are included is their innovative ideas with respect to ventilation for IAQ and/or thermal comfort.

Two leading building examples:

- The *Commerzbank* in Frankfurt (Germany), arch. N. Foster
- The *New Parliament Building* in London (UK), arch. Richard Rogers Partnership

Besides these 'high-profile' buildings, there are also four more classical buildings :

- The Primary *school in Gronge* (Norway), arch. Letnes
- The *PROBE building* at BBRI (Belgium), (renovation)
- The *IVEG building* in Hoboken (Belgium), arch. Lemaire & Musse
- The *Keppekouter building* in Aalst (Belgium), arch. Declercq E.

5. OPTIMISATION CHALLENGES

In case hybrid ventilation systems have as major purpose to guarantee appropriate indoor air quality, there is clearly a need for optimisation : too low air flow rates will lead to unacceptable indoor air quality conditions whereas too high air flow rates will result in unnecessary energy use (figure 7). Advanced control strategies are very important.

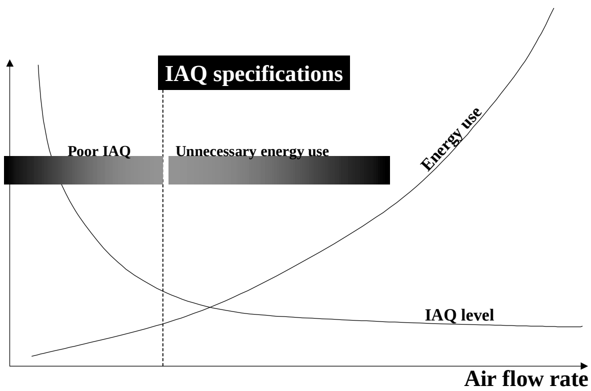

figure 7 : Optimisation challenge for ventilation with respect to IAQ control

If hybrid ventilation systems have as major purpose to contribute to acceptable thermal comfort conditions in summer, the optimisation challenge is not so crucial, unless strict thermal comfort conditions are specified.

In this latter case, a less advanced control strategy is allowed. Moreover, one can also count more on the occupants since they can quite well assess the thermal comfort conditions. However, given the fact of the slow reaction time with respect to the thermal comfort conditions, automated control may be recommended. An overview of the critical aspects is given in table 2.

Aspect	IAQ control	Thermal comfort control
Indoor climate target	In most countries and projects well defined targets for IAQ or air flow rates.	Requirements in most standard quite strict although practice and recent research indicate the acceptability of more flexible criteria
Occupants able to judge indoor climate conditions	No, only if very poor IAQ conditions	Yes, occupants can quite well identify if conditions poor

table 1 : (to be continued)

Aspect	IAQ control	Thermal comfort control
Reaction time between ventilation action and modification of indoor climate	Short reaction time	Thermal inertia is in most cases very important, therefore in most cases early control crucial
Need for automatic and refined control procedures	Strong need if optimisation of IAQ and energy is considered to be important	In most cases refined control not crucial but automated control may be beneficial

table 2 : Key characteristics of IAQ and thermal comfort control

At present, the specifications with respect to thermal comfort in summer and especially those regarding indoor air quality are quite heavily debated within the research community and in many standardisation committees.

5.1 Ventilation for IAQ

As indicated above, optimisation between IAQ and energy use is important during the heating season. Outside the heating season, there is no real optimisation challenge, the more ventilation (with clean outdoor air), the better for the indoor air quality.

During heating season	Outside heating season
▪ Limiting pollution sources ▪ Choice of appropriate IAQ targets and related air flow rates ▪ Optimum air supply to occupants (ventilation efficiency) ▪ Adapting air flow rates to IAQ needs (demand controlled ventilation,…) ▪ Minimising energy use (heat recovery,…)	▪ Limiting pollution sources ▪ Air flow rates may be higher than during heating season ▪ Optimum air distribution still important ▪ No need for adapting air flow rates to needs ▪ Fan energy

table 3 : Issues of concern for ventilation in relation to IAQ control

5.2 Ventilation for summer comfort

Ventilation as part of a strategy for summer comfort means in most cases the use of night ventilation, whereby the aim is to cool down the thermal mass. The major issues of concern are avoidance of too low temperature at the start of the working hours (this may be a problem if the weather conditions suddenly change) and an appropriate control strategy of the ventilation devices.

6. VENTILATION FOR IAQ CONTROL

Hybrid ventilation covers a whole range of possible strategies. Hybrid ventilation can mean :

- switching in time between natural ventilation and mechanical ventilation (§6.1);
- a natural ventilation system for most of the time but with support of mechanical ventilation (fan assisted) if the pressure differences are not sufficient (§6.2);
- mechanical ventilation system, but with optimal use of the available natural forces (6.3).

6.1 Alternative use of natural and mechanical ventilation

- Concept

  The ventilation strategy is based on the combination of two fully autonomous systems whereby the control strategy consists in a switching between both systems.

- Example

  An example is the *Commerzbank* in Frankfurt. The objective is that during the largest part of the year, the IAQ control is done by means of natural ventilation. However, if there is too much wind, if it is too hot,… use is made of a mechanical ventilation system. Both systems are completely separated.

6.2 Fan assisted natural ventilation

- Concept

  The ventilation strategy is aimed to be essentially a natural ventilation concept. However, during periods of insufficient pressure differences and/or during periods of increased demands, there is fan assistance. In case the ductwork distribution system is of a low pressure concept, low pressure fans can be applied which, if advanced control strategies are used, allow to make optimal use of the available pressure differences due to stack and wind effect.

- Example

  The *school in Gronge* is an interesting example of such fan assisted natural ventilation system. Most of the time, the system works fully naturally.

  There are also a number of interesting Swedish school projects which make use of such hybrid ventilation concept.

6.3 Stack and wind supported mechanical ventilation

- Concept

  The ventilation strategy is based on mechanical ventilation during periods that air supply is required. However, the system design counts on a maximum use of the available pressure differences from wind and stack effect.

- Example

  The Norwegian Building Research Institute has developed in the framework of the European JOULE- project NATVENT an air to air heat recovery system whereby optimal use is made of the available natural forces.

7. VENTILATION FOR SUMMER COMFORT

7.1 Passive cooling concepts

- Concept

  The objective is to achieve acceptable thermal comfort conditions by making use of passive means only, whereby intensive (night-time) ventilation is a crucial part of the strategy.

- Examples
  - The ***PROBE*** building in Limelette is fully counting on passive measures for achieving thermal comfort in summer. The hybrid ventilation aspect in this building consist in the combination of a purely natural ventilation system for summer comfort with a purely mechanical ventilation for IAQ control.
  - In another Belgian building (Keppekouter building in Aalst), the natural supply concept is very similar as in the PROBE building, but large roof fans are used for air extraction. These fans are installed instead of natural ventilation ducts because of the minimal space use of the fans.

7.2 Combination of passive and active cooling

- Concept

  The objective is to achieve during most of the time acceptable comfort conditions by using night time ventilation and without the use of active cooling. However, active cooling (often with limited cooling capacity) can be applied during extreme weather conditions.

- Examples
  - In the *IVEG* building, the objective is to achieve thermal comfort by making use of passive measures. During the design phase, the possibility of a limited active cooling power has been considered, whereby the air flow rate for IAQ control can be cooled down and dehumidified. This active cooling power allows a 2 K temperature reduction during extreme weather conditions. In the *Commerzbank*, there is a combination of passive control measures (open windows, minimisation of internal loads,…) and active cooling (cold ceilings) during extreme conditions.

8. VARIOUS TYPE OF COMPONENTS FOR HYBRID VENTILATION CONCEPTS

As such, there are no real hybrid ventilation components. A hybrid ventilation system in nearly all cases exist of a combination of components which can be used in purely natural systems or purely mechanical systems.

However, in order to allow a correct design and functioning of a hybrid ventilation system, the availability of appropriate components is essential. In this paragraph, just 3 examples of components are briefly described.

- Low pressure ductwork

  In order to allow a combination of natural and mechanical forces in air distribution system, it is essential that a low pressure ductwork design is chosen and implemented.

- Low pressure fans with advanced control mechanism

  In order to allow a combination of natural and mechanical forces in air distribution system, it is also essential to use fans which operate under low pressure differences and which have an advanced control mechanism : frequency controlled, air flow controlled,….

- Low pressure static heat exchanger

  In order to allow a combination of natural and mechanical forces in an air distribution system with heat recovery system, it is essential that the heat exchanger has a low pressure drop. The Norwegian design is an example of such approach.

9. SPECIFIC BOUNDARY CONDITIONS

As indicated in section 2, a successful application of ventilation for IAQ control and for summer comfort control requires that a whole range of potential barriers is correctly handled. In this chapter, some of these potential barriers is briefly reviewed and examples are presented.

9.1 Draught control

Draught control is a major reason for not using ventilation devices or for closing them. An interesting example for minimising draught problems is the façade design in the Commerzbank (See figure 11).

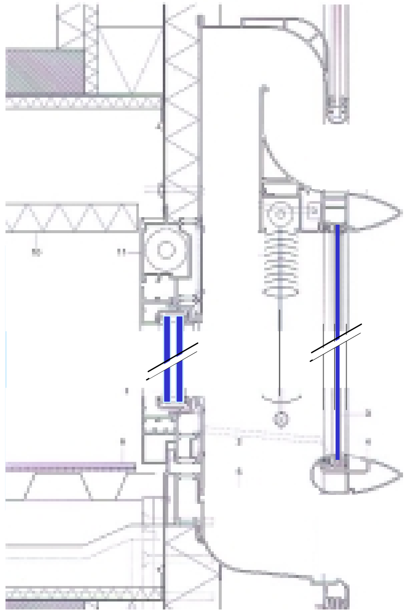

figure 8 : The façade design in the Commerzbank building

9.2 Security

Risk of burglary or a feeling of lack of security may also lead to the closing of certain ventilation devices. The use of louvres can be an appropriate solution for limiting the risk of burglary and therefore increasing the possibility for a correct system operation. Another approach is to situate the air intake at secure locations as is done in e.g. the New Parliament building in London.

9.3 Air preheating

Especially in cold climates, too low supply temperatures may be a major reason for not using the air supply devices. The solution applied in e.g. the Gronge school allows to avoid such draught complaints.

9.4 Outdoor air pollution

It is important that the air supply is of good quality. Since in the case of the New Parliament building it was not evident to guarantee a good air quality at street level, air intake at roof level was applied.

9.5 Acoustical problems

In case the outdoor noise levels are too high during operation hours of the building, there is a major risk that the ventilation devices will not be used.

9.6 Fire regulations

Fire prevention imposes zoning, which can limit the efficiency of natural or hybrid ventilation, especially for night cooling.

10. LEVELS OF DESIGN INTEGRATION AND INDUSTRIALISATION

Hybrid ventilation concepts can vary widely by the level of integration and industrialisation.

10.1 Industrial hybrid ventilation system with limited building impact

The Norwegian concept of static heat recovery can be considered (once produced in industrial conditions) as an industrial system, which has limited interaction with the building design.

10.2 Fully integrated design of hybrid building

The other extreme is e.g. the Gronge school, where the whole architecture and installation design is fully linked and integrated. In this case, a very close collaboration between architects and mechanical engineers is essential.

10.3 Moderate integration level

An example of a more moderate integration level between the work of architects and mechanical engineers is e.g. the IVEG building. Essential in the architectural design was the concept for louvres in the façade and for two large chimneys for air exhaust.

10.4 Marginal integration level

In case of the PROBE building, there is almost no interaction between the design considerations for the IAQ control and the summer comfort control.

11. SYNTHESIS

Hybrid ventilation systems cover a very wide range of technologies and designs.

All the buildings presented in this paper make use of natural ventilation during at least certain parts of the year. Moreover, in all buildings, there is use of fan assisted ventilation and there is also the use of advanced technology. In some of the buildings, active cooling is foreseen. In figure 9, the ventilation strategies applied in 4 of these buildings are schematically represented. It clearly shows that hybrid ventilation is not a single concept but that it covers a whole range of strategies.

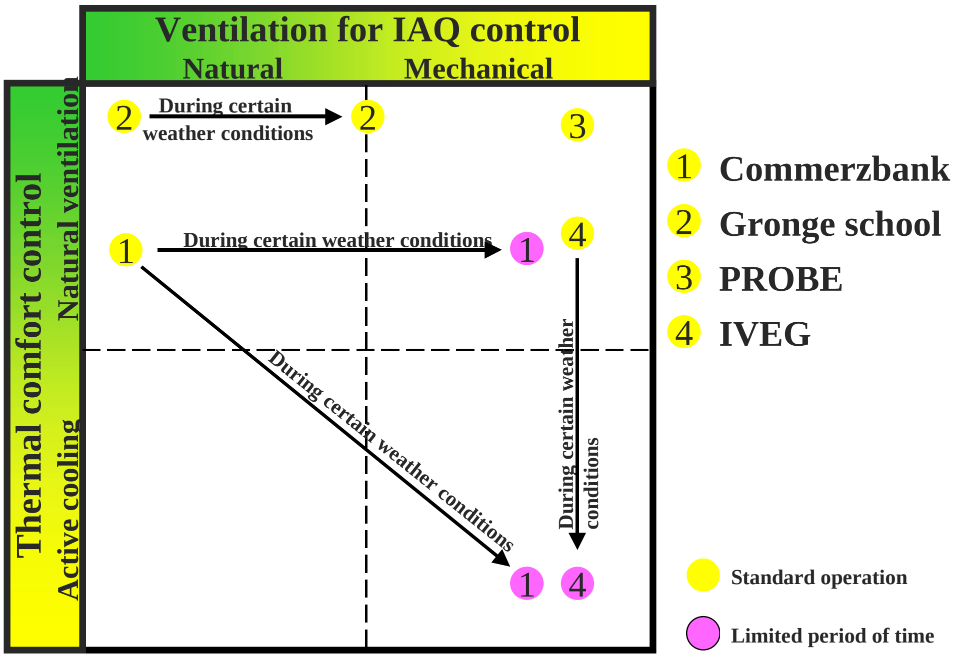

figure 9 : Synthesis of ventilation strategies for 4 of the buildings discussed in this paragraph

12. ACKNOWLEDGEMENTS

This work has been carried out in the framework of the IEA BCS Annex 35 project 'Hybvent'. The authors like to express their gratitude to the Flemish, Walloon and the Brussels Capital Regions, the Belgian Federal Ministry for Economic Affairs and IVEG for their financial support.

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For IEA Annex 35 HybVent, see : http://hybvent.civil.auc.dk/hotel/hybvent/hybvent.htm