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What is smart ventilation?

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1 Introduction

In March 2017, AIVC identified smart ventilation for buildings as a new and important topic to be addressed.

Several actions were defined by AIVC Board about this topic in order to exchange and disseminate information on this topic. A working group of AIVC experts from several countries was created. One of its tasks was to agree on a definition of smart ventilation.

The purpose of this paper is to present and illustrate this definition of "smart ventilation".

2 What is smart ventilation?

2.1 Definition

The definition given by AIVC for smart ventilation in buildings is:

"Smart ventilation is a process to continually adjust the ventilation system in time, and optionally by location, to provide the desired IAQ benefits while minimizing energy consumption, utility bills and other non-IAQ costs (such as thermal discomfort or noise).

A smart ventilation system adjusts ventilation rates in time or by location in a building to be responsive to one or more of the following: occupancy, outdoor thermal and air quality conditions, electricity grid needs, direct sensing of contaminants, operation of other air moving and air cleaning systems.

In addition, smart ventilation systems can provide information to building owners, occupants, and managers on operational energy consumption and indoor air quality as well as signal when systems need maintenance or repair.

Being responsive to occupancy means that a smart ventilation system can adjust ventilation depending on demand such as reducing ventilation if the building is unoccupied.

Smart ventilation can time-shift ventilation to periods when a) indoor-outdoor temperature differences are smaller (and away from peak outdoor temperatures and humidity), b) when indoor-outdoor temperatures are appropriate for ventilative cooling, or c) when outdoor air quality is acceptable.

Being responsive to electricity grid needs means providing flexibility to electricity demand (including direct signals from utilities) and integration with electric grid control strategies.

Smart ventilation systems can have sensors to detect air flow, systems pressures or fan energy use in such a way that systems failures can be detected and repaired, as well as when system components need maintenance, such as filter replacement."

2.2 Explanations and examples

The definition given in 2.1 has been written in order to be easily understood by non-specialists. However, this definition is long and refers to several other notions. It seems therefore useful to provide additional explanations to the interested reader, illustrated by examples.
This is the purpose of Tables 1 to 3 and Figures 1 and 2. They correspond to the 3 first paragraphs of the definition, the 4 other paragraphs giving details.

The **first paragraph of the definition** gives a synthetic description of smart ventilation. It is summarized and illustrated in Table 1 and Figure 1.

What is smart ventilation? (1st paragraph of the definition)		
Text from the definition	***Additional explanations***	***Examples/Comments***
Smart ventilation is a process to continually adjust the ventilation system in time, and optionally by location, to provide the desired IAQ benefits while minimizing energy consumption, utility bills and other non-IAQ costs (such as thermal discomfort or noise).	Ventilation is the process by which 'clean' air (normally outdoor air) is intentionally provided to a space and stale air is removed.	This may be accomplished by either natural or mechanical means.
	Smart ventilation is a process; this implies that smart ventilation is not linked to a specific system. A given ventilation system cannot be smart in itself. Smart ventilation occurs if a process is implemented by which ventilation is continually adjusted in time, and optionally by location, whatever the ventilation system.	A natural ventilation system with only manual control by occupants does not provide smart ventilation because the ventilation system is not adjusted continually.
	Adjustment in time means that the ventilation rate is not constant along time (unless it has been continually checked that it must remain constant).	Ventilation with a constant air flow rate cannot be considered as "smart."
	Adjustment by location means that the ventilation rate can be adjusted for the various rooms, zones, air inlets, or air outlets of a building.	Ventilation in which occupancy detection is used to adjust ventilation rates in each room of a meeting centre is considered smart.
	Smart ventilation continually adjusts the ventilation system. This means that the system receives and analyses without delay any event or parameter identified as requiring system adjustment.	A process by which the ventilation airflow rate is only controlled by a timer changing the set point a few times a day cannot be considered as "smart."
	Smart ventilation must provide the desired indoor air quality (IAQ).	Continual adjustment of the ventilation system must in no case lead to an IAQ level lower than design targets.
	Smart ventilation must minimize energy consumption, due to either air renewal (heating or cooling of fresh air), or the energy consumption of utilities (fans, controls, etc.).	Continual adjustment of the ventilation system must in no case lead to energy consumption higher than design targets.
	Smart ventilation must improve indoor thermal comfort and noise level.	Adjustment of the ventilation system must in no case lead to unacceptable comfort or noise.

Table 1 : Additional explanations and examples/comments for the 1st paragraph of smart ventilation definition

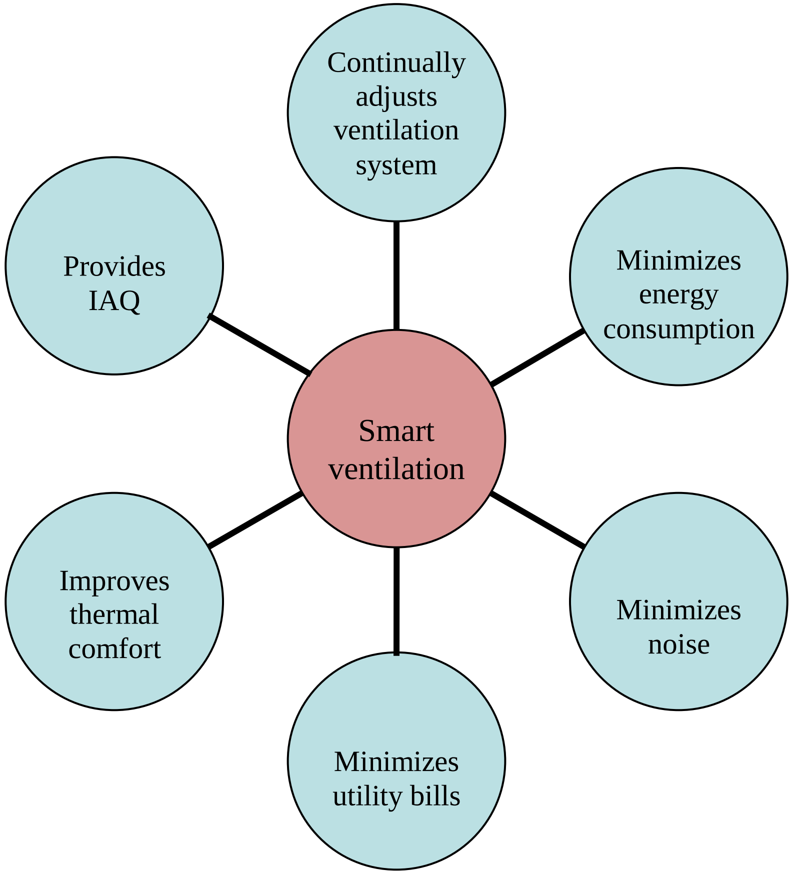

Figure 1: Main features of smart ventilation
(See also Table 1)

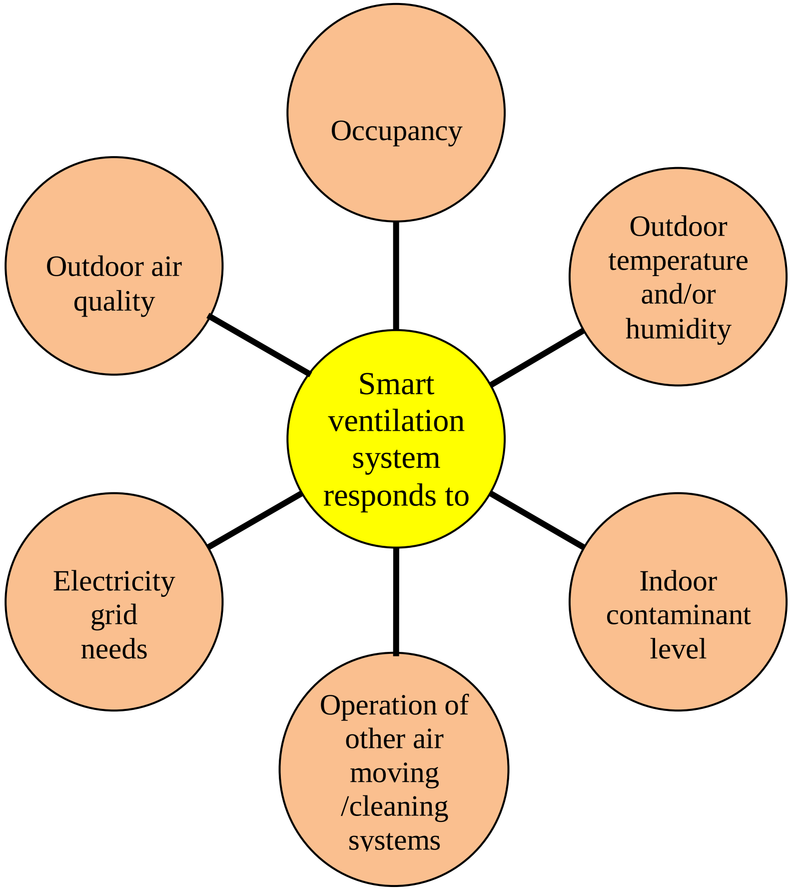

Figure 2: Parameters to which a smart ventilation system can respond
(See also Table 2)

The **second paragraph of the definition** of smart ventilation (see 2.1) describes the parameters to which a smart ventilation system can be responsive. This is summarized and illustrated in Table 2 and Figure 2.

Which parameters a smart ventilation system can respond to? (2nd paragraph of the definition)		
Text from the definition	***Additional explanations***	***Examples/Comments***
A smart ventilation system adjusts ventilation rates in time or by location in a building to be responsive to one or more of the following: occupancy, outdoor thermal and air quality conditions; electricity grid needs; direct sensing of contaminants; operation of other air moving and air cleaning systems.	Occupancy can be detected and the signal used to adjust ventilation rate.	The 4th paragraph of the definition provides additional details: *Being responsive to occupancy means that a smart ventilation system can adjust ventilation depending on demand such as reducing ventilation if the building is unoccupied.*
	Outdoor thermal conditions (temperature and/or humidity) can be measured and used to adjust ventilation rates.	The 5th paragraph of the definition provides additional details: *Smart ventilation can time-shift ventilation to periods when a) indoor-outdoor temperature differences are smaller (and away from peak outdoor temperatures and humidity), b) when indoor-outdoor temperatures are appropriate for ventilative cooling, or c) when outdoor air quality is acceptable.* This time-shift can save energy for heating or cooling. In warm seasons, outdoor air - when cooler than indoors - can be introduced to reduce cooling needs (ventilative cooling).
	Fresh air rates can be reduced in case of poor outdoor air quality.	This is detailed in the 5th paragraph of the definition: *Smart ventilation can time-shift ventilation to periods […] when outdoor air quality is acceptable.* This can improve IAQ.
	Smart ventilation can respond to electricity grid needs (load reduction, peak leveling, demand response, etc.)	The 6th paragraph of the definition provides additional details: *Being responsive to electricity grid needs means providing flexibility to electricity demand (including direct signals from utilities) and integration with electric grid control strategies.* This can reduce energy bills and contributes to the sustainability of the electricity grid.
	Smart ventilation can respond to the direct sensing of indoor contaminants.	This is a form of demand controlled ventilation.
	Operation of other air moving systems can be used to signal the adjustment of the ventilation system, in order to avoid duplication or reduce mutual disturbance of both systems.	Example: operation of a kitchen hood, bath fan, toilet fan, vented dryer, economizer, night cooling system, direct evaporative cooling system or summer cooling fan.
	Operation of an air cleaning system, can be used to adjust the ventilation system, in order to avoid duplication of both systems.	Precaution must be taken against air cleaning by-products, whose presence can require air renewal so that they are taken out of the building. Allowance for reduction of ventilation when air cleaning is used may or may not be permitted.

Table 2: Additional explanations and examples/comments for the 2nd paragraph of smart ventilation definition

In order to respond to the parameters listed in Table 2, smart ventilation systems use information received from sensors that are integrated to the system or installed independently.
In addition, smart ventilation systems can include, for their own control, sensors for pressure, air velocity, air flow rate.
In most cases, these sensors emit an electrical signal that is received, treated and used by the system for its adjustment. It is then often possible to make the information included in this signal available to persons that need it, either locally or through internet and smart phones.

The **<u>third paragraph of the definition</u>** of smart ventilation (see 2.1) describes the information that can be delivered by smart ventilation to the persons who need or are interested by such information. This is summarized and illustrated by Table 3.

Information that can be delivered by a smart ventilation system (3rd paragraph of the definition)					
Text from the definition	***Information that can be collected by sensors***	***Information that can be derived from the information collected by sensors***	***To whom can this information be useful?***		
			Building owners	***Building occupants***	***Building managers***
Smart ventilation systems can provide information to building owners, occupants, and managers on operational energy consumption and indoor air quality as well as signal when systems need maintenance or repair.	Presence of occupants Number of occupants	Ventilation needs	To know occupation and use of the building/zones/rooms		
	Outdoor temperature Outdoor humidity	Cooling needs, ventilative cooling potential, heating needs	For information and possible actions to reduce heating/cooling needs		To manage heating/cooling, including ventilative cooling
	Outdoor contaminant concentrations	Outdoor air quality index	For information and possible actions to reduce contaminant transfer to indoors		
	Operating conditions of the fans	Electrical consumption, ventilation rate	For information		The last paragraph of the definition provides more explanations: *Smart ventilation systems can have sensors to detect air flow, systems pressures or fan energy use in such a way that systems failures can be detected and repaired, as well as when system components need maintenance, such as filter replacement.*
	Indoor contaminant concentrations	Indoor air quality	For information and possible actions, to limit indoor exposure to contaminants		
	Operating conditions of the ventilation system (pressures, flow rates, velocities) and of the other air moving/cleaning systems	Energy use, ventilation rate, maintenance or repair needs	For information and possible actions (to improve system effectiveness		

Table 3: Additional explanations and examples/comments for the 3rd paragraph of smart ventilation definition

3 Perspectives

3.1 Does smart ventilation mean complex systems?

Smart ventilation requires a more complex system than a ventilation system without any controls.

This additional complexity is required to get smart ventilation, including features such as electricity grid interaction or controls depending on outdoor conditions, in order to optimise energy use without compromising IAQ.

This increased integration of the ventilation system environment in its control strategy is part of the trend towards smart buildings. It is made possible because of the progress made on sensors from one side and on information and communication technologies from the other side.

3.2 Smart ventilation: a contributor to smart buildings

In the proposal for a revised Directive on the Energy Performance of Buildings (Nov. 2016) [1], the European Commission, citing the need to define a smartness (or smart readiness) indicator, explained that the smartness of a building covers "*flexibility features, enhanced functionalities and capabilities resulting from more interconnected and built-in intelligent devices being integrated into the conventional technical building systems. The features shall enhance the ability of occupants and the building itself to react to comfort or operational requirements, take part in demand response and contribute to the optimum, smooth and safe operation of the various energy systems and district infrastructures to which the building is connected.*"

Even if this definition of smart buildings refers mainly to energy issues, it is clear that smart ventilation is a key contributor to smart readiness of buildings, not only for reducing energy impacts but also providing IAQ.

3.3 Smart ventilation in standards and regulations

In Europe:

In the European Energy Performance of Buildings package of standards, smart ventilation can be considered using the control parameter f_{ctrl} defined in the European Standard EN 16798-7:2017 [2]; however, this standard provides little information on how to determine this key characteristic for specific systems. In fact, f_{ctrl} is a weighing factor affecting the airflow rate actually delivered compared to the airflow rate the system shall be able to provide (design airflow rate according to FprEN 16798-1:2017 [3]), and thereby the energy performance assessment. It is a system characteristic that depends on the control strategy (including the quality of the sensors), but also the occupation scenario, climate, or calculation time step. In Europe, there is at present no standard to characterize the f_{ctrl} parameter for such systems, but several countries (for example Belgium and France) have schemes or rules for this, yet restricted to demand-controlled ventilation

The European regulation 1253/2014 [4] implementing the Energy-Related Products Directive also includes a ventilation control factor, CTRL, for residential ventilation units that influences the Specific Energy Consumption of the unit, which is to be declared by the manufacturer or importer. The regulation defines in Annex VIII the control factor for 2 types of systems that may be qualified as smart under our present definition:

- *'central demand control' means a demand control of a ducted ventilation unit that continuously regulates the fan speed(s) and flow rate based on one sensor for the whole ventilated building or part of the building at central level;*
- *'local demand control' means a demand control for a ventilation unit that continuously regulates the fan speed(s) and flow rates based on more than one sensor for a ducted ventilation unit or one sensor for a non-ducted unit.*

In the US:

The current version of ASHRAE Standard 62.2 [5] covering residential ventilation and IAQ incorporates smart ventilation. It includes a prescriptive standard setting continuous ventilation rates, but there is also an Equivalent Ventilation section which says that any system will comply if "the same or lower annual exposure […] would be provided" and that the "calculations shall be based on a single zone with a constant contaminant emission rate." The exposure needs only be calculated for period of time that the building is occupied.

Philosophically, this makes ASHRAE Standard 62.2 a pollutant exposure standard and not a ventilation standard. Because the state of knowledge is not yet good enough to know the specifics of the contaminants of concern, the standard assumes constant contaminant emission of an unspecified contaminant to derive equivalence with the prescriptive ventilation rate.

As a more practical matter, the standard offers an operational approach for determining the equivalent ventilation rate to show compliance. That calculation can be used in two different types of smart ventilation system. The first one allows one to schedule ventilation rates. This kind of approach is best when one knows well in advance what the needs are because of occupancy, utility rates, weather or outdoor air quality. One must show that the annual exposure during occupied periods is equivalent to the constant ventilation result.

The second method involves real time control. It requires more sensing and control technology but allows the ventilation system to respond to changing (i.e. real-time) conditions. These conditions might include occupancy, outdoor air quality, or energy costs. One must show that the exposure of the previous time period (typically a day) is equivalent to the constant ventilation result.

Traditional demand-controlled ventilation (DCV) systems are not in use in dwellings in the US but are sometimes used in commercial buildings. To date there are no non-residential standards in the US that allow smart ventilation systems beyond DCV.

4 References

[1] European Commission, 2016. Proposal for a Directive of the European Parliament and of the Council amending Directive 2010/31/EU on the energy performance of buildings. Document 2016/0381 (COD).

[2] European standard EN 16798-7:2017. Energy performance of buildings. Ventilation for buildings. Calculation methods for the determination of air flow rates in buildings including infiltration (Modules M5-5).

[3] European draft standard FprEN 16798-1:2017. Energy performance of buildings. Part 1: Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics (Module M1-6).

[4] European Commission. Commission Regulation (EU) No 1253/2014 of 7 July 2014 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for ventilation units.

[5] ANSI/ASHRAE Standard 62.2-2016. Ventilation and acceptable indoor air quality in low-rise residential buildings.

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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.