Methodology for assessing the air-exchange performance of residential ventilation systems

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ABSTRACT

Residential ventilation standards, especially in Europe are slowly but substantially moving away from their usual prescriptive approach towards performance based specifications. While academics and policy makers argue about the relevant IAQ indicators, housing developers and end users need to make a choice between the different ventilation system options they are faced with in the market. Although several IAQ rating systems have emerged, a comprehensive assessment method to rate the inherent qualities of the ventilation system itself is not available [6]. In this paper, we propose a methodology for such a rating system based on the ability of the system to deliver the requested amount of air at the right place and time, issued from a project commissioned by the European Ventilation Industry Association (EVIA). The proposed method makes a distinction between the performance in habitable and wet spaces in dwellings and includes technical aspects such as mechanical support of the airflow, automatic control and (where applicable) filtration. The label proposed to communicate the results of the assessment specifies the design flow rate, the performance in each of the space types and a filtration rating separately, allowing end users to objectively compare products that are suited for their particular needs rather than lumping these aspects together in a rating for the 'average' dwelling. This paper is intended as a solicitation of comments from the broader field of ventilation stakeholders on the fundamental structure of the rating system.

KEYWORDS

Performance indicators, residential ventilation systems

1 INTRODUCTION

Until today, differences in the performance of residential ventilation systems remain unaddressed. It is generally assumed that compliance with building codes also implies that the ventilation performance of the various systems is comparable. Existing EPBD and Ecodesign legislation is also based on this assumption and compare ventilation systems only on the basis of their energy performance. The result is a market in which the main reasons for selecting a ventilation system are limited to *energy performance* and *installed costs*. The performance of its primary function *'exchanging air'* for the purpose of achieving acceptable IAQ-levels in all rooms is not a selection criterion.

Various recent field research projects however indicate that there are substantial differences among ventilation systems in the extent in which the requested air exchanges are achieved in the various rooms, resulting in large differences in IAQ-levels, especially in habitable rooms [1,2,3,4,5].

Field research shows that on a dwelling level, the total number of air changes per hour (ach) may be sufficient, but at room level the air exchanges do not always occur in the right place at

the right time [1] . A significant share of the air exchanged by these ventilation systems is therefore in vain and only contributes to a higher energy bill.
In addition there is the fact that occupants cannot properly assess the resulting IAQ-levels. Various pollutants are odourless (radon, CO, various VOC's) and occupants gradually adapt to changing IAQ-levels and simply do not possess the required sensory capacities to accurately perceive the IAQ-levels. In other words, there is no useful feedback as to whether the ventilation system performs adequately (e.g. field studies show that inhabitants can be fairly content with CO_2-concentrations that are far above 2500 ppm) [1,2]. The inhabitant can therefore not be held accountable for his choice of ventilation system, nor for an incorrect (manual) operation of the ventilation systems on the basis of perceived IAQ-levels. In practice the technical system parameters are dominant where the air exchange performance is concerned. And there is a serious need to provide people with objective information concerning the air exchange performance of ventilation systems and their impact on the IAQ-levels in a dwelling.
This blind spot in ventilation system performance has manoeuvred the market into an unintended situation where the energy performance of ventilation systems is assessed without knowing its ventilation performance. Low cost ventilation systems with lower ventilation performance unduly benefit from this situation and burden households with questionable IAQ-levels.

The Residential Working Group of EVIA (European Ventilation Industry Association) initiated a project to investigate whether an effective and transparent method can be constructed to assess the ventilation performance of ventilation systems in residential dwellings. This paper presents the methodological basis for such an assessment method.

2 SCOPE OF THE ASSESSMENT METHOD

2.1 Delimitation of the scope

The initial focus of the assessment method will be on residential ventilation systems. It will only be applicable to ventilation systems that are properly installed according to prevailing building codes and manufacturer guidelines.
Air exchanges for the purpose of extracting cooking fumes are excluded from the assessment method, emphasizing the view of the EVIA Working Group that cooking fumes can better be removed with dedicated cooker hoods. Ventilation systems that use alternating flow directions (supply provision becomes exhaust provision and vice versa) are also excluded from the scope, since representative field research related to their ventilation performance is lacking. Future field research into these types of ventilation systems may lead to further extension of the scope.
Finally ventilation system solutions, that are added for the purpose of filtering or cleaning recirculated indoor air, are excluded from the scope. On the other hand ventilation system solutions that are used for cleaning the outdoor air are included.

2.2 Defining Ventilation Performance

Pollutant emissions from building- and finishing products, from furniture and from humans activities are the main cause for a deteriorating indoor air quality. The best starting point for

improving IAQ in dwellings obviously is to reduce these source emissions. Selecting proper building materials and interior products is therefore the key strategy.
The second strategy for improving IAQ-levels is ventilation, or exchanging air for the purpose of achieving acceptable IAQ-levels in all rooms. This primary function of a ventilation system can be assessed separately. Occurring IAQ-levels are after all the end result of both source emission strength and air exchange rates in a specific room. Ventilation systems cannot control the source emission strength. In principle, ventilation systems can only control the air exchange rates that occur in specific rooms, and it is this specific function where systems show large differences in performance.

Academic discussions on what the proper metrics are for assessing the overall performance of ventilation systems are ongoing. In specific forums such as AIVC workshops, ASHRAE IAQ and IEA EBC Annex 68 it is stated that 'as of today, there is no clear set of metrics that can be used to assess the overall ventilation performance of a building with regard to its indoor air quality'. It is expected that it will take another 5 to 10 years before this topic can be properly addressed.
For the interim period this paper proposes to use a more pragmatic approach, and to relate the ventilation performance solely to it primary function: *exchanging air for the purpose of achieving acceptable IAQ-levels in all rooms of a dwelling*.

For the envisaged assessment method the following definition is proposed for the air-exchange performance of residential ventilation systems*: 'the ability to achieve requested air exchanges in each room of a dwelling for the purpose of extracting and/or diluting concentrations of all hazardous and annoying substances'.*

The adjective *'requested'* that is used in this definition, refers to the air exchange rates as defined in building codes and will be used as initial reference value. Since field research shows that code compliant ventilation rates in individual rooms are not always achieved [1,2,3,4,5] - especially during presence in habitable rooms – a logical first step should be to assess the air-exchange performance vis-à-vis its design air exchanges rates. These design air exchange rates are generally selected to comply with building codes that often reflect the minimal required air exchange capacity. Because higher air exchange rates automatically lead to improved IAQ-levels, the proposed methodology will also appreciate ventilation rates that exceed these reference values [8].

2.3 Different room types, different ventilation strategy

Dwellings are a series of connected rooms. These rooms can be grouped into two types, both with their own specific requirements concerning ventilation strategy:

- Habitable rooms (living room, bedrooms, study)
- Wet rooms (kitchen, bathroom, toilets, laundry room)

Habitable rooms
In habitable rooms, the main type of pollutants are bio-effluents, building material emissions, emissions from interior products and pollutants from human activities.
Exposure to these emissions occur during presence in these rooms, and because occupancy time typically is long, especially in bedrooms, the risk of exposure is highest in these type of rooms. A good ventilation strategy must therefore be based on the principle that requested ventilation rates are primarily achieved during presence. In these rooms the requested air exchanges must be achieved with air supply provisions that supply clean and fresh outdoor

air. In certain environments this could mean that filtration of the outside air is recommended before feeding the air into the habitable rooms. During absence, a minimum basic ventilation rates should be applied.

Wet rooms
In contrast to the habitable rooms, the main pollutants in wet rooms are moisture, odour, material emissions and pollutants from human activities. Occupancy times are short, as is the exposure to the emissions in these rooms.
Main ventilation strategy in these rooms relates to the extraction of moisture starting at the moment it is produced, until humidity levels are below threshold levels and continue the extraction for a certain period of time to ensure that also the humidity that is accumulated in building materials is removed. The risk of mould and moisture related building problems can thus be reduced. After that, minimum basic ventilation rates can be applied. For wet rooms there are no specific demands regarding the quality of the supplied air, so for energy saving purposes, (used) indoor air is usually supplied.

Most ventilation standards, including the new draft EN16798-1, differentiate between these two type of rooms. Some standards also mention non-occupied spaces like connecting spaces (hall, staircase, etc.). As the name suggest there is no occupancy and a minimum risk of exposure in these spaces. Basic ventilation rates can be applied here, which will be achieved anyhow since these spaces are passageways for the supply air of the wet rooms.

The proposed assessment method will be based on those technical features of a ventilation system that have an influence on the ability of the ventilation system to achieve the requested air exchanges following the ventilation strategy described above for both the habitable rooms and the wet rooms.

3 TECHNICAL SYSTEM PARAMETERS

The following system parameters are considered relevant for the air-exchange performance in habitable rooms and wet rooms. For the proposed assessment method it is essential that these technical parameters are assessed on room level.

Primary system parameters (to be assessed per room)

- Type of air exchange provision (direct/indirect, driving forces: natural/mechanical)
- Maximum installed air flow capacity
- Type of operation and controls
- Filtration method

Secondary parameters, like thermal comfort and noise production are kept out of this initial assessment because they are generally adequately described in building codes, related standards and guidelines. Furthermore, installers have a large influence on these aspects that are often not system related but installation-quality related. These topics can however be handled separately in a technical sheet in a more qualitative manner.

3.1 Type of air exchange provisions

Code compliant ventilation systems require an air supply and an air exhaust provision in every room of a dwelling. The type of these supply and exhaust provision play a very important role in determining the ability of the ventilation system to achieve the requested air exchanges in that room. A distinction will be made in the forces driving the air exchanges (natural or mechanical) and in the connection the supply or exhaust provision has with the outside (direct or indirect). An indirect connection means that the air is supplied or exhausted through one (or more) intermediate spaces. Both parameters will influence the ability of the ventilation system to achieve requested air exchanges in the room concerned. Natural and indirect provisions are subject to larger uncertainties than mechanical and direct ones.

3.2 Maximum installed air flow capacity

The maximum installed air flow capacity limits the air exchange rate that can be achieved in the room concerned and as such limits the influence the ventilation system can have on the IAQ-levels in that room.

3.3 Type of operation and controls

Extremely important for assessing the ability of the ventilation system to achieve the requested air exchanges at the right time is the type of operation and control methods that are selected. The range of options varies from no, to manual to automatic operation and if automatic operation is available, there is a large range of technical options. Apart from the control parameter (time, RH, CO_2, VOC, presence, etc.) that is used, various other aspects may also influence the air-exchange performance, like e.g. the sample room (which is not always the room considered), the limit values (set points) of the selected control parameter, the modulation type and the modulation range.

3.4 Filtration method

Finally the quality of the supplied outdoor air will influence the ventilation performance. Although outdoor air in general is cleaner than the indoor air [9], in specific regions and for pollutant sensitive inhabitants it can be necessary to apply filters to clean the outdoor air. If such is the case the filter type according to EN-ISO 16890 will be used for assessing the filtration quality.

4 ASSESSMENT AND CALCULATION PRINCIPLE

The influence these technical system parameters will have on the occurring air exchange rates in the individual habitable rooms and wet rooms and their respective weights in the assessment will be based on several sources and methods, amongst which:

- Existing standards and building codes
- Results of real life monitoring studies
- Simulation studies
- Scientific literature

For all assessment values for which no existing valid source can be found and used, a logical and transparent line of reasoning will be communicated for consultation.

4.1 Basic score for air exchange provisions

Core of the assessment method is the valuation of the various types of air exchange provisions with regards to the probability that installed air exchange rates are actually achieved in both the habitable rooms and wet rooms. This assessment will primarily be based on real life monitoring results and simulation studies. The effect of operating mechanisms and controls will be excluded from this assessment. The result is a basic score reflecting the probability that the installed air exchange rates are achieved, given the selected air exchange provisions for the habitable and the wet room.

4.2 Multiplier for operation and control method

In a next step, the influence of the operating and control methods are assessed. Depending on the type of room and related ventilation strategy, the operating and control methods used can have different values. For habitable rooms, the criterion is to achieve requested air exchanges with clean outdoor air during presence and apply basic ventilation rates during absence. For wet rooms the criterion is to extract moisture and odours when generated and continue these air exchanges until humidity is sufficiently removed including accumulated humidity in rendering and building materials; after that basic ventilation rates are sufficient. Operating and control types will be assessed in the light of these criteria and will be expressed as multiplier/modifier for basic scores that are determined on the basis of the applied air exchange provisions.
Values reflecting the influence that various operating methods have, will be based on the typical use of these operating methods and are acquired from available field research regarding this topic. The influence that controls have on the basic score for the air exchange provisions will be based on simulations, type and quality of the sensors used and a clear understanding of the control mechanism and its relation to the reference ventilation strategy for the room type.
The multipliers that are determined here can either increase or decrease the basic score for the air exchange provisions.

4.3 Proposed calculation principle

The envisaged calculation principle for determining the air-exchange performance of a ventilation system in a specific dwelling is as follows:

INPUT DATA

a) Specification of dwelling characteristics
   Notification of number, type and surface of the habitable rooms and number and type of the wet rooms.

b) Selection of ventilation system type
   To be based on the air-exchange provisions in the habitable rooms and wet rooms (see table 1. below)

Table 1. Ventilation system types

<table>
<tr><th></th><th colspan="2">habitable rooms</th><th colspan="2">wet rooms</th></tr>
<tr><td rowspan="2">System 1</td><td>supply</td><td>exhaust</td><td>supply</td><td>exhaust</td></tr>
<tr><td>natural direct</td><td colspan="2">natural indirect</td><td>natural direct</td></tr>
<tr><td rowspan="2">System 2</td><td>exhaust</td><td>supply</td><td>supply</td><td>exhaust</td></tr>
<tr><td>natural direct</td><td colspan="2">mechanical indirect</td><td>natural direct</td></tr>
</table>

System 3	supply	exhaust	supply	exhaust
	natural direct	mechanical indirect		mechanical direct
System 4	supply	exhaust	supply	exhaust
	natural direct	mechanical direct	mechanical indirect	mechanical direct
System 5	supply	exhaust	supply	exhaust
	mechanical direct	mechanical indirect		mechanical direct
System 6	exhaust	supply	supply	exhaust
	mechanical direct	mechanical indirect		mechanical direct
System 7	supply	exhaust	supply	exhaust
	mechanical direct	mechanical direct	mechanical direct	mechanical direct
Combination of systems*				

* In case a combination of systems is selected, the dwelling is split up in sections with their own ventilation system type. For each system the air-exchange performance is calculated for all the rooms that are served.

c) Selection of maximum design air exchange rates per room: Q_{design}
Depending on ventilation system type, selected air-exchange rates for habitable rooms may be linked with the air-exchange rates of the wet rooms.

Because the principles for dimensioning the air-exchange provisions - especially the provisions using natural driving forces - may differ per member state, a uniform and EU-wide applicable convention will be needed here.

d) Selection and specification operating and control methods
After selection of the ventilation system type a pre-set of possible control options are presented with default values.

e) Selection of type of filters used for cleaning the outdoor air before the supply to habitable rooms

OUTPUT DATA

f) Specification of probability that installed air-exchange rates are achieved (i.e. basic score per room) based on selected air-exchange provisions: P_{basic}

g) Specification of multipliers for selected operating and control methods per room: $f_{control}$
For habitable rooms multipliers are determined both for periods of absence and presence.

h) Calculation of the air-exchange performance per room: $Q_{design} * P_{basic} * f_{control}$

i) Calculation of the combined air-exchange performance for all habitable rooms; weight factors for specific habitable rooms on the basis of occupation time may be used here.

j) Calculation of the combined air-exchange performance for all wet rooms.

k) Specification of filtration performance.

Filtration performance is determined for each habitable room based on the type of filter that is used. Overall filtration performance is determined by combining and weighing the performance of individual rooms.

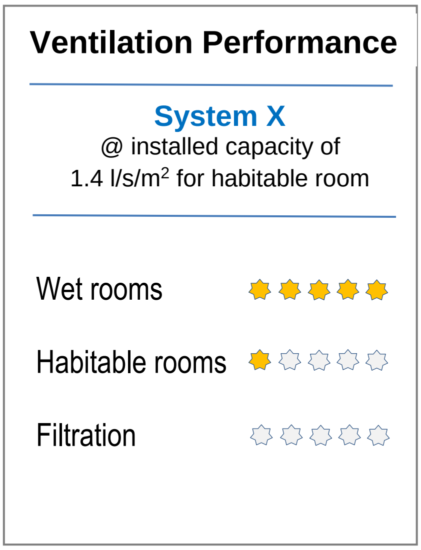
4.4 Presentation

Apart from a technical sheet in which all relevant system specifications and corresponding valuation is explained, it is proposed to use a simple and clear representation of the final result of the assessment in a ventilation performance label.
The information such a label should contain must be clear and understandable for the average customer and contain those items that are relevant for system evaluation. It is proposed that the label contains the following information:

1) Ventilation system type and installed capacity in [l/s/m^2] in habitable rooms.
2) Ventilation performance wet rooms, indicated with a 5 star ranking
3) Ventilation performance habitable rooms, indicated with a 5 star ranking
4) Filtration performance, indicated with a 5 star ranking

In anticipation of a final design of such a Ventilation Performance Label, a preliminary presentation of the presentation principle is given in figure 1 below.

Figure 1.
Content Ventilation Performance Label



5 ACKNOWLEDGEMENTS

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