Investigation of future ventilation flow rate requirements for dwellings in Belgium: from the application of FprEN16798-1:2016 to proposed robust rules

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ABSTRACT

In the context of the PREVENT project, preparing a possible revision of the Belgian residential ventilation standard, the way of expressing ventilation requirements, among others in terms of ventilation flow rates, needs to be investigated. The aim of this paper is to propose and compare ways of expression of the ventilation requirements in terms of flow rates with respect to their robustness across dwellings.
The application of the different methods proposed in the recently developed new draft standard FprEN 16798-1:2016 has been compared for a series of Belgian dwelling configurations: method based on the perceived air quality, method using criteria for pollutant concentration and method based on pre-defined ventilation flow rates. The calculated flow rates varied significantly depending on the calculation method used.
Based on these results, some rules to express the ventilation requirements in dwellings in Belgium are proposed. One should first consider the ventilation flow rates for normal use during occupied periods. This flow rate could be based on those for occupancy per person proposed in FprEN 16798-1:2016 for non-adapted persons, provided it is higher than those for emissions from building. The determination of the number of persons could be based on a minimum of one person per bedroom, at least one bedroom for two persons, and a number of persons in the living rooms based on the total number of persons in the bedrooms. Second, a minimum flow rate for unoccupied periods and a minimum flow rate for rooms without any IAQ sensor (in case of demand controlled ventilation and manually controlled ventilation) could be set based on the flow rate for the emissions from building materials. Finally, the design flow rate of the system at the building level could depend on the control strategy of the ventilation system (i.e. sensor and actuator location) with a minimum corresponding to the highest value for the total flow rates for occupied periods in the night zone (bedrooms and similar) and those in the day zone (living room and similar).
The proposed rules could lead to more robust and efficient ventilation requirements for dwellings in the future in Belgium.

KEYWORDS

Ventilation flow rates, residential ventilation, bioeffluents, building emissions, humidity

1 INTRODUCTION

The national ventilation standard for dwellings in Belgium (NBN D 50-001) is more than 25 years old. Since then the context of ventilation of dwelling has changed: building are more and more energy efficient and airtight, requesting on one hand robust ventilation requirements, but raising on the other hand the pressure on these requirements to be appropriate and efficient. However, since the publication of this Belgian standard in 1991, some questions remain the same: those about the definition of IAQ, the way of expression of ventilation requirements and the appropriate level of ventilation requirements. Among other issues with the Belgian standard, the minimum required ventilation flow rates are usually higher compared to those required in other European countries (actually, they are similar to those in The Netherlands) (Brelih 2011) and they are, based on repeated statements by trade associations, considered too high by most of the ventilation professionals in Belgium.

In the context of the PREVENT project, preparing a possible future revision of the residential ventilation standard in Belgium, the way of expressing ventilation requirements, among others in terms of ventilation flow rates, needs to be assessed on it's robustness.

The aim of this project was not to carry out research about the appropriate level of IAQ requirements and flow rates, but rather to use the most recent international research results and CEN standard framework on this topic. Nevertheless, there is no general scientific consensus on metrics and associated requirements, as shown for example during the spring 2016 AIVC workshop on this topic.

Recently, the new draft standard FprEN 16798-1:2016 (entitled "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") has been developed. This standard should supersede EN 15251:2007 and is associated with the technical report FprCEN/TR 16798-2. This new standard has been recently rejected at the final vote of the CEN procedure. Nevertheless, since a slightly modified version of the standard is expected to be accepted in the near future, this document is however very important in order to investigate the way of expressing required ventilation flow rates for residential ventilation in Belgium.

The aim of this paper is to propose a way of expression of the ventilation requirements in terms of flow rates for a possible future ventilation standard for dwellings in Belgium. The different methods proposed in FprEN 16798-1:2016 to determine ventilation flow rates have been applied to 5 typical dwelling configurations to serve as basis for the discussion.

2 METHODS

Five typical dwelling configurations have been used for application of the FprEN 16798-1:2016 to determine ventilation flow rates.

These five dwelling configurations are a flat studio, an apartment with 1 bedroom, a medium house with 3 bedrooms and relatively small spaces, the same medium house but with relatively larger space surface areas, and finally a large house with 5 bedrooms. The composition of the dwellings and the surface area of the spaces are given in Table 1.

The following general methods described in the document FprEN 16798-1:2016 have also been applied on the 5 typical dwellings, using indoor air quality of category II as described in this document.
Method 1 is based on perceived air quality with the sum of the flow rate for bioeffluents (7 l/s.pers.) and the flow rate for building emissions (0.35, 0.7 and 1.4 l/s.m² respectively for very low polluting buildings LPB-1, low polluting buildings LPB-2 and non-low-polluting buildings LPB-3).
Method 2 is using limit values of substance concentration. Two substance concentrations have been considered with this method 2: 800 ppm of CO_2 (corresponding to a flow rate of 7 l/s.pers for emission rate of 20 l/h.pers.) and 100 µg/m³ of formaldehyde (limit recommended by WHO) combined with material sources showing a maximum concentration of 100 µg/m³ after 28 days of testing according to CEN/TS 16516 for the sum of all the materials (floor, ceiling and walls)

present in the space. This could correspond for example to emission of formaldehyde from only the floor material with a maximum concentration of 100 µg/m³ after 28 days (as currently required for example for new building in Belgium); or to a combination of emissions of formaldehyde from all the floor, ceiling and wall materials (with the same loading factors as for the reference room in CEN/TS 16516: 1 for the walls and 0.4 for the floor and the ceiling) leading to a sum of concentration after 28 days not higher than 100 µg/m³. Given the size of the reference room (12 m² of floor area) and of the flow rate (15 m³/h) in CEN/TS 16516, this correspond to an average flow rate of 0.35 l/s.m² of floor area.
Method 3 is based on predefined ventilation flow rates. The documents FprEN 16798-1:2016 and FprCEN/TR 16798-2:2016 propose different approaches using predefined flow rates for residential applications. The 2 following approaches have been used in this comparison: (1) supply air flow based on perceived IAQ for adapted persons (with 2.5 l/s.pers and 0.15 l/s.m²) and (2) design extract air flow rates as described in Table I.8 of FprEN 16798-1:2016 (20-40 l/s for kitchen, 10-15 l/s for bathroom, 10 l/s for other wet room, 10-15 l/s for toilets).

The ventilation flow rates required in the current Belgian standard NBN D 50-001 have also been applied on the 5 dwellings for the comparison.

Table 1: Composition of the 5 dwelling configurations, showing the surface area of the spaces (in m²), the total surface area (in m²) and the number of occupants in the dwellings.

	Flat studio	**Apartment**	**Medium house, small spaces**	**Medium house, large spaces**	**Large house**
Living room	25	30	30	45	55
Corridor 1		8	12	16	20
Kitchen	10	10	10	16	16
Toilet 1		2	2	2	2
Bedroom 1		16	12	18	18
Bedroom 2			8	12	12
Bedroom 3			8	12	12
Bedroom 4					10
Bedroom 5					10
Corridor 2			10	12	16
Bathroom 1	6	8	8	12	12
Bathroom 2					8
Toilet 2			2	2	2
Laundry					8
Total surface	41	74	102	147	201
Nb of persons	1	2	4	4	6

3 RESULTS AND DISCUSSION

Beside the general method (method 1 to method 3) to determine ventilation flow rates, the documents FprEN 16798-1:2016 and FprCEN/TR 16798-2:2016 propose different approaches using default design ventilation air flow rates for residential buildings:

- Total air change rate for the dwelling;
- Supply air flow rates based on air flow rates per person;
- Supply air flow rates based on perceived IAQ for adapted persons;
- Design extract air flow rates.

However, these approaches can lead to very different total flow rates for the dwelling, as demonstrated by the examples treated in FprCEN/TR 16798-2:2016, for example for a one-bedroom dwelling, with 67 m³/h, 50.4 m³/h and 34.96 m³/h respectively for the first 3 approaches listed here above. This is probably the result of a compromise, in these documents, between the very different approaches, standards and requirements currently in use in the different countries across Europe. However, this does not converge to an equivalent IAQ between the different methods described in the standard. Therefore this does not answer to the need of a robust and founded way to describe ventilation requirements for dwellings, as needed for the moment to develop a new standard in Belgium. Moreover, the need for IAQ should be the same for the occupants in residential or in commercial buildings, which seems to not be the case in these documents.

Therefore, in this study, we applied the general methods described in FprEN 16798-1:2016 to determine flow rates, to 5 typical dwelling configurations, representative for the Belgian market. The flow rates obtained with these methods have been compared to the flow rates required in the current standard for dwellings in Belgium. The total ventilation flow rate per dwelling is presented in Figure 1, for the 5 type of dwellings, in the following order: required flow rate for supply in the current Belgian standard, required flow rate for extraction in the current Belgian standard, method 1 for very low polluting building (LPB-1), method 1 for low polluting building (LPB-2), method 1 for non-low-polluting building (LPB-3), method 2, method 3 with predefined flow rates for adapted persons, and finally method 3 with design extract airflow rates.

These results of the comparison confirm very different flow rates according to the approach used. The proportion of the flow rate from one approach to each other was very similar for the different types of dwelling tested (except, to some extent, for the flat studio).

The highest flow rate was always obtained with the method 1 and non-low-polluting building and the lowest with the method 3 for adapted persons for residential applications, with a factor of around 7 between these extreme values. This difference is huge. Even if the building emission can largely vary from one building to another, the risk to have non-low-polluting building or high emission rates is probably as high in residential buildings as it is in commercial buildings. If anything, the floor area per person is usually higher in dwellings, so the weight of emissions in determining the flow rate should be higher. The predefined flow rate for dwellings for adapted persons could maybe be too low in case of high building emissions in dwellings. On the other hand, method 1 based on perceived IAQ for both bioeffluents and building emissions on a cumulative basis could be a bit too conservative for residential buildings. For example, even for the very low polluting building, the flow rates resulting from method 1 are close to or even (substantially) higher (except for the flat studio) the those prescribed in the current flow rates in the Belgian standard which are already considered to be very high. By the way, FprCEN/TR 16798-2:2016 recommends to consider that the persons are adapted in residential applications. Maybe we could at this stage distinguish between some criteria for the health and some for comfort. Method 2 from FprEN 16798-1:2016 is interesting for that point of view.

The flow rates resulting from the method 2 are quite intermediate between those for method 1 and those for adapted persons in residential buildings. Method 2 allows to calculate the design flow rate for the most critical or relevant pollutant (or group or pollutants). Method 2 allows then to consider different pollutants and to look at the most critical one. So in stead of the cumulative basis supposed in method 1, it considers the maximum of the flow rates required for each type of pollution. This can be applied for the CO_2, in order to achieve sufficient comfort against bioeffluents for example, and for the building emissions, in order to limit the health risk for the occupants. In this comparison, this has been done for a CO_2 concentration of 800 ppm above outdoor (corresponding to 7 l/s.pers) and for formaldehyde with a concentration limit value of 100 µg/m³ in the spaces (as recommended by the WHO) and building materials with a total emission corresponding to 100 µg/m³ after 28 days of testing according to the CEN/TS 16516. This corresponds to a ventilation flow rate for the building emission of 0.35 l/s.m². Applying method 2 could also be done for different hypothesis about the building emissions, based for example on practical definitions of different types of building load, from very low polluting buildings to non-low-polluting building (as used for method 1). The advantage of this method 2 is to look at the most critical pollutant as explained above.

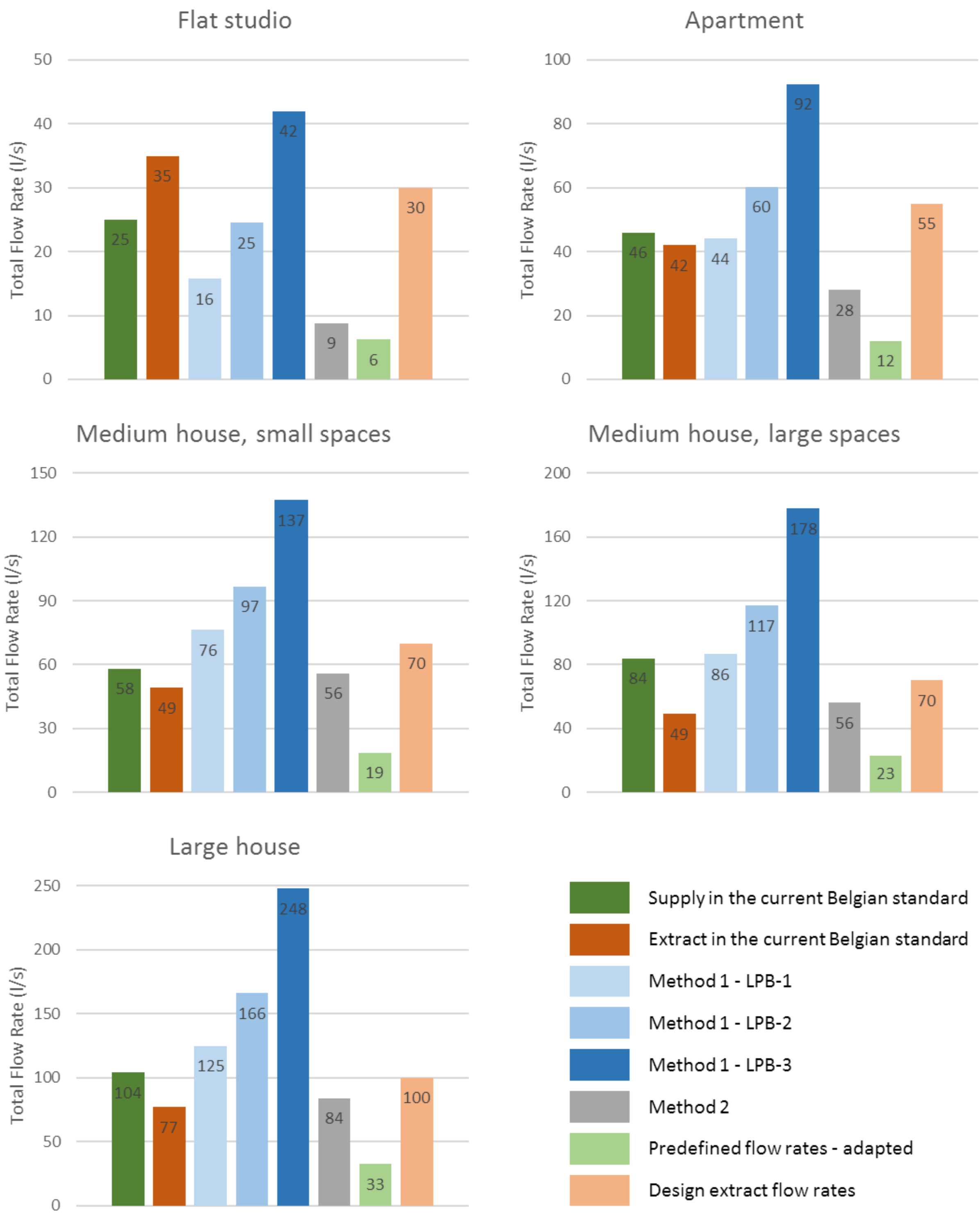

Figure 1: The total ventilation flow rate per dwelling, for the 5 type of dwellings as indicated, calculated according to the Belgian standard: required flow rate for supply in the current Belgian standard, required flow rate for extraction in the current Belgian standard; and according to FprEN 16798-1:2016 and FprCEN/TR 16798-2:2016: method 1 for very low polluting building (LPB-1), method 1 for low polluting building (LPB-2), method 1 for non-low-polluting building (LPB-3), method 2, method 3 with predefined flow rates for adapted persons, and finally method 3 with design extract airflow rates.

The flow rates based on design extract air flow rates from FprEN 16798-1:2016 are intermediate compared to the other calculated flow rates. But they are always higher compared to the required flow rates for extraction in the current ventilation standard in Belgium. The practice in Belgium has however shown that the required flow rates for extraction in Belgium (for example used for exhaust mechanical ventilation system, widely spread in the Belgian market) are largely sufficient to control the humidity from the wet spaces. To our knowledge, no problem of moisture or building damage has been reported since more than 25 years in buildings with extract flow rates corresponding to the current standard in Belgium.
These extract flow rates from FprEN 16798-1:2016 are also (slightly to substantially) higher that the supply flow rates obtained with the other methods, especially method 3 for adapted persons, method 2 and method 1 for very low polluting building. However previous research work in Belgium showed that the control of bioeffluents (with a flow rate of 7 l/s.pers corresponding to category II in the draft standard) is the limiting factor compared to the control of humidity in the wet spaces (Van Gaever et al. 2017). In other words, the average flow rate needed to control humidity in the wet spaces is significantly lower compared to the average supply flow rate needed for the occupants based on 7 l/s.pers.

4 PROPOSED APPROACH FOR THE BELGIAN STANDARD

In the context of the development of new basis for a future ventilation standard for dwellings in Belgium (PREVENT project), different solutions have been investigated for the expression of the ventilation requirements for dwellings. These solutions are, at least partially, based on the currently available CEN documents FprEN 16798-1:2016 and FprCEN/TR 16798-2:2016 discussed in this paper.
The proposed approach for the requirements of ventilation of dwellings in the context of the PREVENT project is summarized hereafter.

4.1 Sources of pollutants in dwellings and rationales for ventilation requirements

The main pollutant sources in dwellings are bioeffluents from the persons, humidity in the wet spaces and emissions from materials. Bioeffluents can be considered to mainly impact the comfort of and the perceived IAQ by the occupants. Humidity control is crucial to avoid moisture problems and mold developments (and to limit the associated health risks). Emissions from materials impact the comfort ant the perceived IAQ, but presents above all a risk for the health of the occupants.

Among these sources, only the emissions from materials can partly be controlled at the source by choosing low emitting products and materials. Ideally, the ventilation flow rates in a standard for dwelling should then take into account the building load for the material emissions in order to encourage owners, builders and designers to choose for low emitting products.

According to the approach of the method 2 from FprEN 16798-1:2016, the flow rate of a space and of the whole building should be based on the most critical pollutant among the above mentioned sources, bioeffluents, humidity and building emissions.

4.2 Design flow rates per space depending on the space type

Because the occupant can spend a lot of time in the same space in a dwelling (for example in the bedroom during night), the way of requiring flow rates in dwelling should be done at the level of each space.

For the living spaces such as the living room and the bedrooms, the flow rate should be determined for the most critical pollutant: the bioeffluents or the building emissions.
For the building emission, the idea is to fix different flowrates per surface area of the space (in l/s.m²) for different categories of building emission load, as described for method 1 in FprEN 16798-1:2016. More investigation is still needed to propose these flow rates and practical definitions of these building categories for the Belgian market.
For the bioeffluents, the proposed flow rate corresponds to category II of FprEN 16798-1:2016, with a flow rate of 7 l/s.pers. The way to determine the number of person per space has also to be sufficiently robust. The current proposition is as follows. Each living space has to be attributed to one of these two following space types: living room (or equivalent, for example hobby room) or bedroom (or equivalent, for example study room). In a dwelling there are at least one living room and one bedroom for 2 persons (or a combination of both in a studio). The additional bedrooms are considered for 1 person. The number of persons for each living room is determined by the sum of the persons for the bedrooms (i.e. number of bedrooms + 1). In case of several living rooms and bedrooms, the attribution between both is free for the designer of the building but the impact on the total flow rate is limited, as shown in the Table 2.

Table 2: Illustration of the impact of the attribution of the type of space (living room or bedroom) on the total flow rate of the dwelling (in l/s), depending on the number of living rooms and bedroom respectively.

Number of living rooms	**Number of bedrooms**									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	28	42	56	70	84	98	112	126	140	154
2	42	63	84	105	126	147	168	189	210	231
3	56	84	112	140	168	196	224	252	280	308
4	70	105	140	175	210	245	280	315	350	385
5	84	126	168	210	252	294	336	378	420	462

For the wet spaces such as kitchen, bathroom, toilet, etc., the required flow rates in the current standard can be considered sufficient to control the humidity in these spaces, as discussed above (see § 3). These flow rates are as follows: 21 l/s for an open kitchen, 14 l/s for a bathroom and equivalent wet space, and 7 l/s for a toilet.

4.3 Control and flow rate in use

Beside the design flow rate, it should be still possible to control the flow rates depending on the real needs during use of the dwelling, thanks to automatic Demand Controlled Systems (DCV) or manually controlled systems. In this context, the minimum operational flow rate should be determined for periods of absence of needs in the different spaces.

For the wet spaces, the flow rates could be regulated based for example on relative humidity detection. Minimum flow rate for wet spaces are probably not critical because the limiting factor for ventilation of dwellings has been identified to be the flow rate to control the bioeffluents from the persons (see § 3).

For the living spaces, the flow rates could be regulated manually or based on the presence or on the CO_2 concentration in the spaces. However, because the living spaces are not only ventilated for the bioeffluents but also to control the building emissions (sse § 4.1), the minimum flow rates for periods with low need (manually controlled on lower position, no detection of presence or CO_2 concentration lower than threshold values for example) in living spaces should be at least the flow rate to control these building emissions, as described above (see § 4.2). The aim of this minimum flow rate is double: (1) ensure a minimum flow rate for

material emissions in case a person is present (in case of manually control or CO_2 detection for example); and (2) ensure a minimum flow rate during absence to limit the concentration of pollutants when a person enters the room.
Moreover, it is sometimes possible to have only a limited number of sensors (presence of CO_2) for example only in the main living room and/or the main bedroom. In this case, a minimum flow rate during use for the spaces not equipped with a sensor should also be foreseen. For this purpose, the minimum flow rate of 4 l/s.pers proposed in the HealthVent project and recommended in the FprEN 16798-1:2016 could be an interesting basis. This flow rate should also be the minimum flow rates in case of manually controlled regulation (local or central) because this is equivalent to the absence of sensors in the spaces.

During use, the total supply and total extract flow rates should be equilibrated at the level of the building, by adjusting them towards the highest of both values.

4.4 Design of the system at building level

Finally, the design total flow rates of centralised system have to be determined. This could depend on the type of regulation of the system.

In case of no regulation or only centrally regulated systems, the total design flow rate at building level should be the sum of the design flow rates per space (see § 4.2). And the total supply and total extract flow rates should be equilibrated at the level of the building, by adjusting them towards the highest of both values.

In case of regulation of the flow rates locally (for example flow rates regulated independently for each space) or by zones (for example night and day zones), the design total flow rate at the building level could be lower because the probability to have a need of ventilation in all the spaces at the same time is low. The design total flow rate should be at least equal to the total design flow rate of each zone, night zone and day zone.

5 CONCLUSIONS

The application of the different methods proposed in the recently developed new draft standard FprEN 16798-1:2016 has been compared for a series of typical Belgian dwelling configurations.
The calculated flow rates varied significantly depending on the calculation method used. These results emphasize the need for more coherent and robust methods of determination of flow rate requirements for dwellings in the CEN standard framework.
Based on these results, rules to express the ventilation requirements in dwellings for a future ventilation standard in Belgium have been proposed. The proposed rules could lead to more robust and efficient ventilation requirements for dwellings in the future in Belgium.

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