Large-scale performance analysis of a smart residential MEV system based on cloud data

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ABSTRACT

This study is a first large-scale analysis of the performance of a cloud connected and smart residential mechanical extract ventilation (MEV) system based on field data. About 350 units were analysed over a period of 4 months from December 2018 up to March 2019, corresponding with the main winter period in Belgium. Half of the units were installed as a smartzone system which means additional mechanical extraction from habitable rooms as bedrooms.

The air extraction was controlled on different parameters (humidity, CO_2 and VOC) depending on the room type. Indoor climate and IAQ were analysed with respect to design criteria set out in standards as well as fan characteristics and energy consumptions.

Since the ventilation systems are controlled on humidity, periods of RH levels >80% were limited. The typical RH ranges (between 30 and 70% or 25 and 60%) set out in standards for habitable spaces were fulfilled during at least 80% of the time, without causing complaints from the users.

On average, the CO_2 level in bedrooms was <950 ppm during at least 90% of the nighttime. When comparing the MEV with smartzone to literature data of a similar system, the exposure (in ppm.h) to CO_2 >1200 ppm was reduced to 33%, while the ventilation heating energy consumption was 32% lower. This implies a ctrl-factor of 0.26 for the MEV system with smartzone, which is substantially lower than the default values currently used in regulation. The auxiliary energy consumption of the MEV with smartzone was found to be less than 50% of the literature values reported on similar systems.

The average total yearly energy cost related to the operation of the ventilation system (heating and auxiliary energy) was found to be limited to €100, and at least comparable to the operating cost of a MVHR system. Since rooms are often unoccupied or occupied at a low level, advanced demand control technology proves to have a high potential to limit total energy consumption, while assuring a good IAQ.

KEYWORDS

Smart connected ventilation, demand controlled MEV, large-scale in-situ monitoring, indoor air quality, energy consumption

1 INTRODUCTION

Ventilation is a quite complex process whose quality is affected by many parameters related to the manufacturing, design, installation, use and maintenance of the system over its life cycle. Up to now, the design of ventilation is usually descriptive in its approach and the performance is often theoretically analysed under ideal conditions. As a consequence, some of the aforementioned aspects are not taken into account. Nowadays, IoT devices become also available in the residential ventilation industry, allowing to investigate the real performance of these ventilation units during their lifetime. This study is a first global analysis and part of a large research programme to investigate over time the occurring indoor air quality in the main rooms and the overall fan characteristics of a connected demand controlled central mechanical extract ventilation (DC MEV) unit. In the study mainly the performance of units without air extraction in the bedrooms (no-smartzone) and with air extraction in the bedrooms (smartzone) was compared under Belgian winter conditions.

2 LITERATURE STUDY

During recent years, several ventilation field studies in the residential sector were carried out due to the availability of affordable and/or plug-and-play monitoring apparatus.
Kalamees et al. (2006) described a study where the indoor temperature and humidity conditions in 46 lightweight timber-framed detached houses in Finland were measured and analysed.
In France, Berthin et al. (2007) performed in-situ measurements on humidity controlled ventilation systems in 55 occupied apartments to show the effectiveness of demand controlled ventilation.
Staepels et al. (2013) analysed 70 dwellings in Flanders (Belgium) with respect to their indoor environment quality. CO_2 and humidity measurements showed good to reasonably good indoor air quality, independently from the type of ventilation system.
Mikola and Kõiv (2013) monitored indoor air climate in Estonian apartment buildings equipped with several ventilation systems. The IAQ improved when using more mechanical devices to control the air.
In the Netherlands, van Holsteijn and Li (2014) analysed the CO_2-concentrations and relative humidity levels in individual rooms of 62 houses equipped with different types of ventilation systems within the so-called Monicair project. Form the start, the monitored systems were commissioned in order to comply with the regulation requirements. The exposure to CO_2-concentration above 1200 ppm per person was considered. In the study, the ventilation system C4c is quite similar to the one that is investigated in this study using also mechanical extraction in the bedrooms (smartzone). Furthermore, the energy consumption related to the ventilation system was considered, but partly based on theoretical assumptions of for instance the heat recovery efficiency. The type and the size of the ventilation systems in the Netherlands are comparable to those in Belgium due to a similar ventilation regulation.
Guyot et al. (2017) gave an overview of the state of the art, with respect to residential smart ventilation.
Finally, a preliminary large-scale analysis on the same ventilation system as examined in this study was recently carried out by Lokere (2019). Analysis of a typical day profile of CO_2/humidity/VOC and the probability of ventilation higher than minimum rates, showed small peaks around typical moments which can be linked to human activities as cooking and taking a shower or a bath. Part of the dwellings showed overheating, partly caused by severe insulation requirements and weak overheating risk thresholds in Belgian building regulations. Furthermore, it was found that during the heating period in bedrooms, lower temperature levels

were accepted or preferred than the lower limits of the ATL method. The risk of mould growth as examined with the VTT model (Hukka and Viitanen) was negligible.
Moreover, Lokere (2019) found that CO_2 concentrations in bedrooms and kitchens with direct mechanical extract were respectively about 90% and 95% of the time lower than 1000 ppm during periods of active ventilation, proving the high potential of demand controlled ventilation to guarantee good IAQ. Indoor VOC levels were higher during periods of higher indoor (and outdoor) temperature, probably due to the increase of the VOC volatility with higher temperature.
All above mentioned studies were conducted on a smaller scale and/or treated only part of the elements investigated in this article.

3 METHODOLOGY OF THE VENTILATION SYSTEM ANALYSIS

From 2018 on, commercially available "smart" DC MEV (so-called Healthbox 3.0) systems with cloud connection possibility were installed in Belgian houses and residential buildings (see Fig. 1). The cloud connection, which fits into a global strategy on artificial intelligence and data analytics (Vandekerckhove, 2019), allowed to monitor and analyse the characteristics of a growing number of these smart central exhaust units on a large scale. The mechanical extraction took place locally in the wet rooms and in about half of the dwellings also directly from the bedrooms. The system with bedroom extraction is hence forward called "with smartzone", and without extraction from the bedroom "no smartzone", as illustrated in Figure 1.

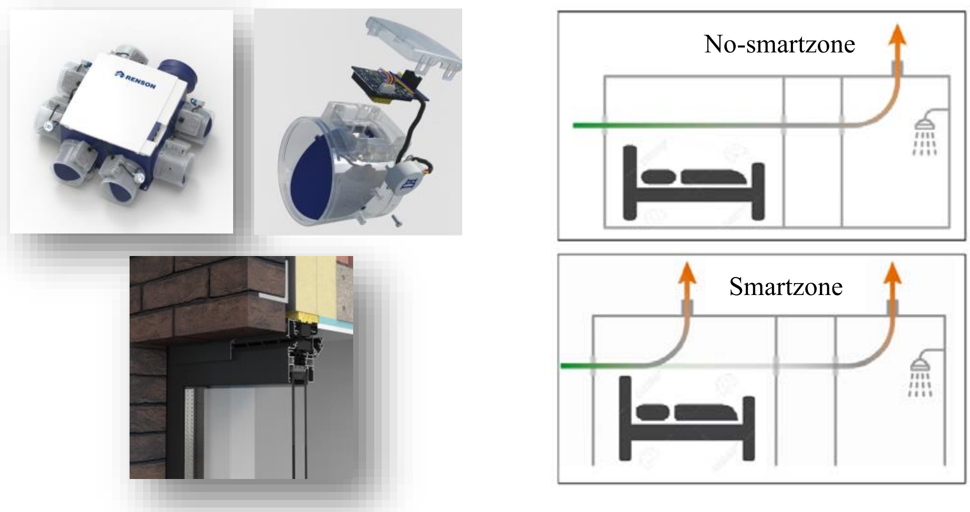

Figure 1: DC MEV system (above-left), passive vents (below-left) and the difference between no-smartzone and smartzone principle (right)

The outdoor air was supplied through passive vents placed on top of the windows in the habitable rooms (Fig. 1). These passive vents are pressure controlled and can additionally be gradually adjusted by the inhabitants between fully open and closed. By means of valves directly attached to the central unit at the end of the extract duct, the air extraction was locally controlled on different parameters depending on the room type: in bathroom and utility room on absolute and relative humidity (AH and RH); in kitchen and bedroom (if extraction available) on CO_2 and in toilets on volatile organic compounds (VOC). Sensors were located at the valves and not within the rooms, which means that sensor values could -to a certain extent-deviate from the room conditions.

The following standard control algorithms were implemented in the system to regulate the extract airflow rate between a minimum and the required airflow capacity of the room according to the Belgian regulations (these nominal flow rates are for open kitchen: 75 m^3/h; bathroom, closed kitchen and laundry: 50 m^3/h; toilet: 25 m^3/h; bedroom: 30 m^3/h).

- CO_2: proportional between 800 – 950 ppm CO_2
- Humidity: step function as a function of a gradient $\Delta AH/\Delta t$ and a RH threshold
- VOC: step function as a function of a gradient $\Delta VOC/\Delta t$

Fan characteristics, such as airflow rates were theoretically derived from sensor values and algorithms, while fan pressure was deduced from power input. A fixed value for the auxiliary consumption of the valves and the sensors was added. The accuracy of the measurements were 2.5%, 2% and 5%, for respectively the power input, RH and CO_2.

By means of an application the user could to some extent adjust the control settings if needed or temporarily overrule the automated extraction. Changing of the standard settings by the user or installer was rarely done, since only allowed in existing buildings, while most units were installed in newly built dwellings. A platform also allowed to interact with relevant stakeholders, such as the installer, the building owner or the occupant, allowing to increase the system quality.

The ventilation units were installed without extra commissioning afterwards to correct or improve the performance of the system. Data were not filtered on false values or outliers. However, in some cases, certain values were not recorded. Lokere (2019) analysed a period of 9 months from May 2018 up to January 2019 with an increasing number of monitored devices, while in this study during the typical Belgian heating period from December 2018 up to March 2019 (temperate maritime climate), the performance of a fixed number of about 350 devices divided over no-smartzone and smartzone types was investigated.

The data of the ventilation IoT devices were securely stored in the cloud for further analysis at a frequency of 5 min. Python code was used to retrieve the desired data and for further processing the data into daily average values per unit or per room.

Different characteristics of the climate and the system were analysed: indoor comfort (CO_2, humidity), fan characteristics (average and nominal airflow, time fraction minimal airflow rate, average pressure and power input) and total energy consumption. Design values of RH and CO_2 concentration as especially specified in the standard EN16798-1 (2019) (replaces the EN15251 standard) were used as criteria to analyse the indoor comfort. Comfort analysis of bedrooms on a large-scale could only take place when direct mechanical extraction with sensor control was present (with smartzone), since sensors were located at the extract valves.

For the data analysis, active ventilation was defined as ventilation at flow rates higher than the minimum control values. In general, the active ventilation period shows a time shift compared to the occupancy period due to the buffering effect of air with respect to air components.

In Flanders (northern half of Belgium) where most of the ventilation units were installed, the newly built housing stock is quite evenly distributed over single-family and multi-family dwellings (VEA, 2019). Commercial data also indicated that the share of installed units over single- and multi-family dwellings is about 50/50. However, at that time, the cloud data from the Healthbox 3.0 could not be sorted on single- and multi-family dwellings.

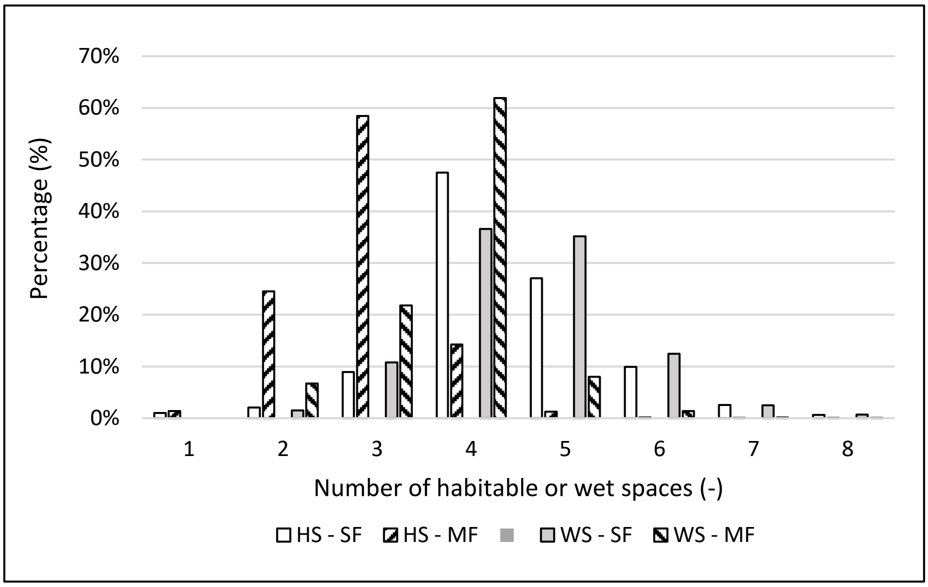

Figure 2: Histogram of the number of habitable (HS) and wet spaces (WS) over the newly built single-family (SF) and multi-family (MF) dwellings in Flanders (VEA, 2019)

Figure 2 shows the distribution of the number of habitable spaces (HS) and wet spaces (WS), including the kitchen over the newly built single-family (SF) and multi-family (MF) dwellings in Flanders. In SF dwellings the number of habitable rooms and wet rooms is quite similar (peaks at 4-5 rooms), whereas in MF dwellings the number of habitable rooms is clearly one unit less compared to the number of wet rooms. Furthermore, MF dwellings contain on average 1.5 habitable room less compared to SF houses.
In Flanders, the kitchen is usually open to the living room, since the share of closed kitchens is at most 5% and 2% in respectively SF and MF newly built houses. In case of an open kitchen, the IAQ in the living room can be controlled by the extraction in the open kitchen, reducing in that way the number of extract valves in the habitable rooms when applying smartzone. Therefore the IAQ in the kitchen is also considered in this study. Based on data of VEA (2019), the average air tightness n_{50} of the studied houses peaked between 1.5 and 2.0 volumes/h.

4 RESULTS

4.1 Indoor climate

Humidity

Figure 3 illustrates the mean time fraction of RH < 80%, 30% < RH < 70% and 25% < RH < 60% in different rooms (kitchen, bathroom, laundry and bedroom) as a function of time. The mean values over this 4 months period are given in Figure 4. In the different rooms considered the RH values higher than 80% were very limited. The lowest occurrence was found in the kitchen, the highest in the bathroom where water vapour productions are usually highest. Lower peaks in the kitchen can be due to a quasi-permanent heating, the mostly open connection with the (dry) living room and the standard availability of a separate cooker hood to extract water vapour. For the several rooms considered, the average time fraction with RH values <80% was at least 97.5%, as found in the bathroom. The RH values above 80% clearly decreased during the winter period, which can be explained by the decreasing absolute humidity levels outdoors.

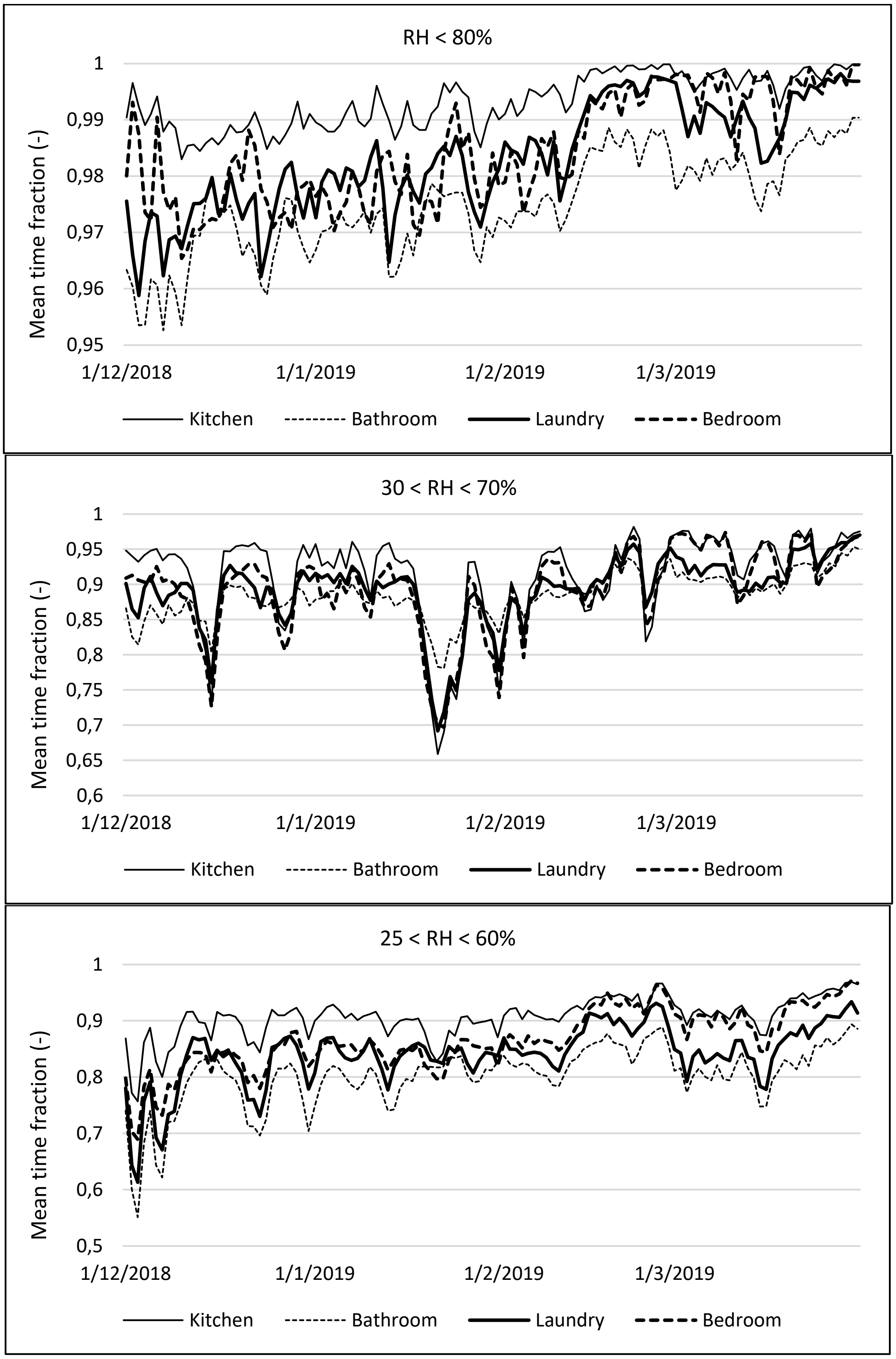

Figure 3: Mean time fraction of RH<80% (above), 30%<RH<70% (middle) and 25%<RH<60% (below) in different rooms over the 4 months period

The time fraction of RH in a certain range, i.e. 30 to 70% or 25 to 60% showed a quite fluctuating trend as a function of time, probably caused by varying outdoor humidity conditions during the winter period. The mean time fraction of RH between 30 to 70% was close to 90%

for the different rooms, with the highest and the lowest time fraction in the kitchen and the bathroom, respectively. This latter logically agrees with the previous findings on RH >80%. When looking to the average time fraction of RH between 25 and 60% in Figure 4, more variation was found between the rooms, with a minimum of 80%. The lowest value was also reported in the bathroom where the highest water vapour productions can be expected. In Figure 3 the range between 25 and 60% RH showed a slightly increasing trend during winter caused by the drying out of the indoor air.

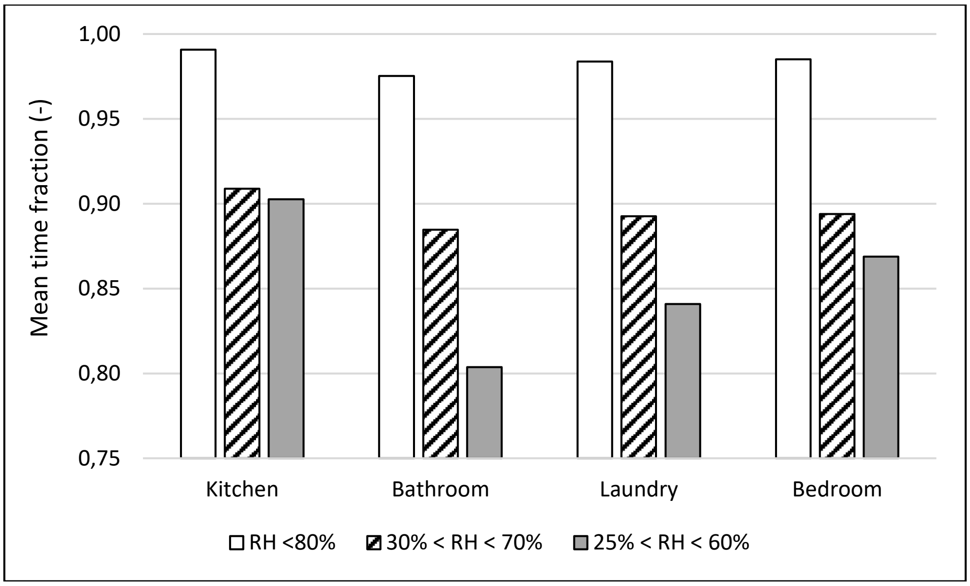

Figure 4: Mean time fraction of RH<80%, 30%<RH<70% and 25%<RH<60% in different rooms

Furthermore, instead of the time fraction, the percentage of rooms in which a certain RH range occurs was analysed in Figure 5. More in particular, the number of rooms was determined in which the RH is permanently (= 99% of the time) lower than respectively 80%, situated between 30 to 70% or between 25 to 60%.

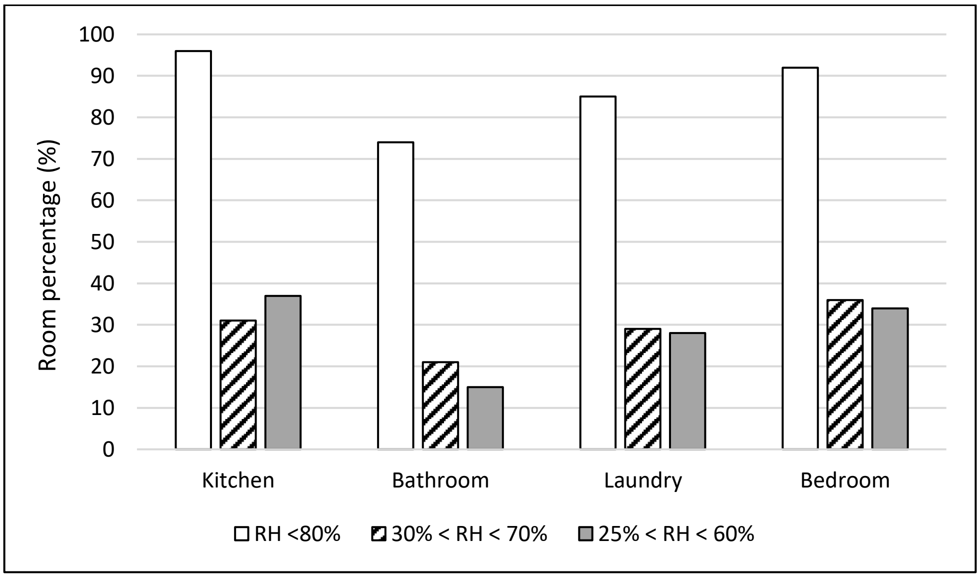

Figure 5: Percentage of rooms in which the RH is permanently (= 99% of the time) lower than respectively 80%, situated between 30 to 70% and between 25 to 60%

Figure 5 points out that in at least 70% of the rooms considered, the RH was permanently lower than 80%. The number of rooms complying permanently to the ranges 30-70% or 25-60% varies between 15 and 40% approximately. A higher percentage of habitable rooms as kitchen and bedrooms instead of wet rooms complied to the RH ranges set out for these kind of rooms, as can be expected. However, the rooms with RH values outside the criteria during part of the time were not cause for complaints from the users. In addition, Lokere (2019) found a negligible risk on mould growth in the different rooms. Newly built houses are well insulated without thermal bridges to prevent condensation. Further research will focus on the elements giving rise to higher humidity especially in living rooms. Besides, it must be kept in mind that in contrast to the absolute humidity, possible temperature fluctuations of the air in the extract duct caused by heat losses or gains between the room and the sensor location (at the box) can influence the measured RH compared to the real room value, which magnitude must be further investigated in the ongoing research.

CO_2 concentration

The IAQ was analysed based on CO_2 categories defined in the EN16798-1 standard for habitable rooms as (mainly open) kitchen and bedroom, as illustrated in Fig. 6. Data for the kitchen were derived as an average from systems without and with smartzone, whereas bedroom results concerned only smartzone systems. The data were selected on 2 different bases: day or night time and during active ventilation (when airflow rate in the room is higher than minimum, corresponding best with the unknown occupancy period). Substantial differences occur between these selections. In the bedroom, the CO_2 levels belong 80 to 90% of the nighttime to category 1 or 2 (< 950 ppm), with a main fraction in category 1 (< 800 ppm). In 90% of the bedrooms with extraction, the CO_2 level was <1200 ppm during at least 95% of the nighttime. When considering only active ventilation (during occupancy) this percentage varied between 70 and 80%, with a dominant group in category 2 and only about 20% in category 1. Comparing the results during nighttime and active ventilation points at that approximately half of the night, ventilation is at its minimum flow rate (< 800 ppm) due to no occupancy, low occupancy and deep sleep with CO_2 levels lower than 800 ppm. When considering the total daytime instead of the nighttime, the smartzone system also worked on its minimum flow rate during half of the time (see Fig. 8).

The relatively high time fraction of category 1 (about 20% < 800 ppm CO_2) during active ventilation is related to different elements such as:

- aggregation of the data: CO_2 as an average and active ventilation as a single value over 5 min
- setpoint set lower than 800 ppm
- temporarily override of the demand control
- several bedrooms which are connected to 1 common valve, instead of separately.

For bedrooms, the mean time fraction with CO_2 levels in category 3 (moderate IAQ < 1350 ppm) and 4 (bad IAQ > 1350 ppm) were limited to respectively 30% and 5% of the time during active ventilation. This means that the extract capacity of 30 m^3/h in bedrooms can be considered as a minimum design value. Van Holsteijn and Li (2014) reported in the Monicair study similar results with a fraction of at most 1 hr or 10% of the night time that CO_2 concentrations were higher than 1200 ppm.

The IAQ in the kitchen was analysed during daytime and active ventilation based on the CO_2 categories as illustrated on the right part of Fig. 6. The IAQ belongs nearly permanently to category 1 and 2 (< 1200 ppm). The difference with the findings in the bedroom can be explained by the shorter occupancy period, the larger room volume of the open kitchen, the presence of a cooker hood and the CO_2 categories according to the EN16798-1 that are less severe in kitchens than in bedrooms. During active ventilation the time percentages with CO_2 levels lower than 800 ppm and between 800-950 ppm were slightly higher than in the bedroom, due to less severe conditions in the kitchen.

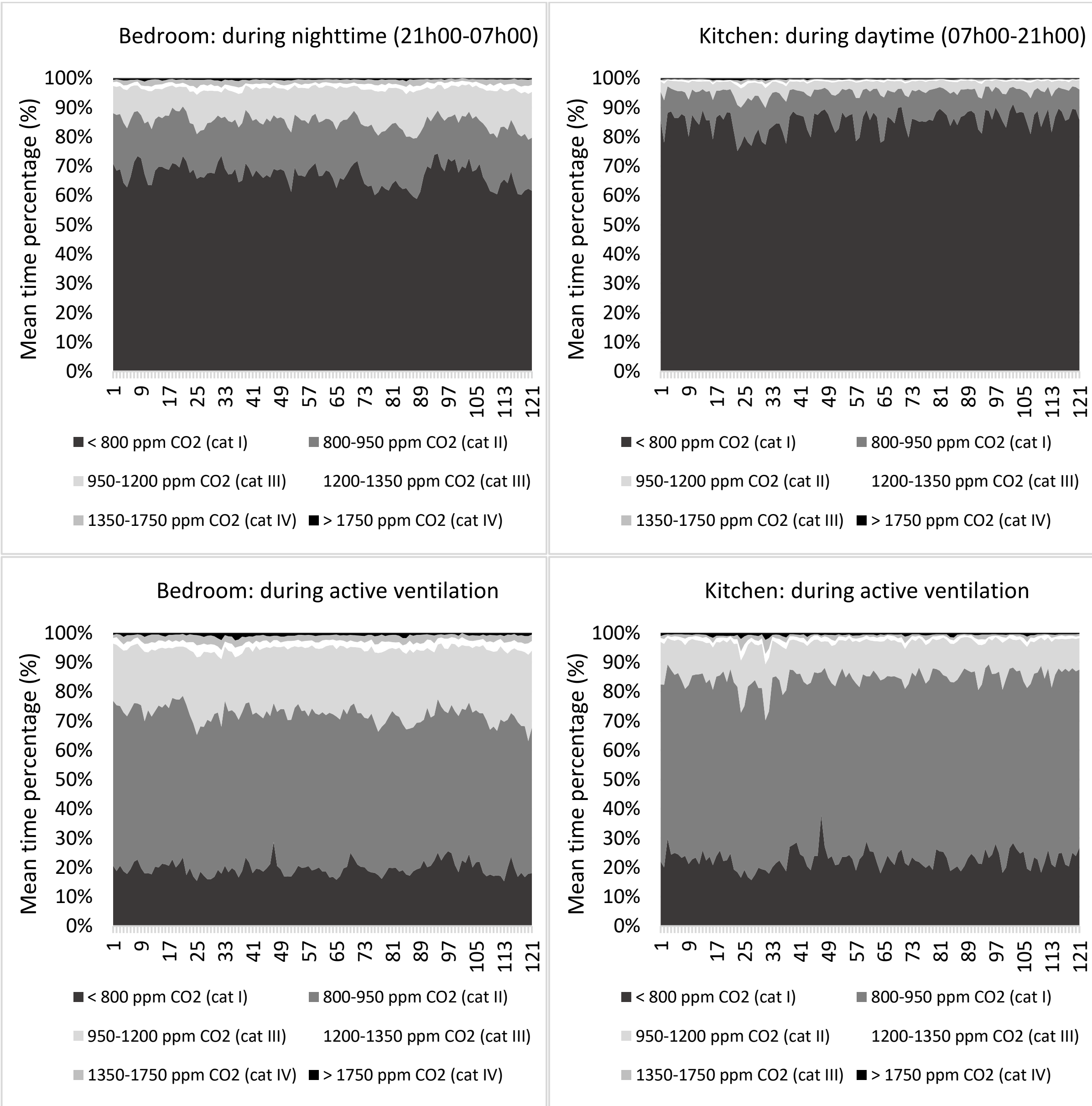

Figure 6: Mean daily time percentage of CO_2-categories according to the EN16798-1 standard for bedroom (left) and open kitchen (right) during day or nighttime (above) and during active ventilation (below)

When looking over the wintertime period a constant trend containing some fluctuations was observed, which can be caused by user behaviour (difference between week and weekend days) and wind conditions.

Furthermore, the exposure to CO_2 expressed as the cumulative CO_2-concentration above 1200 ppm (in ppmh) was calculated, since this is a commonly used parameter in IAQ research. The average daily exposure over the dwellings was 245 ppmh/day which is only 33% of the

733 ppmh/day reported by van Holsteijn and Li (2014). This big difference can be explained by the lower control setpoint of 950 ppm instead of 1200 ppm.
Since large-scale data of the IAQ in bedrooms without direct extraction is not available, some dwellings without smartzone were monitored separately. It was found that many elements have an impact on the IAQ in the bedrooms, such as size of the supply opening, position of the door, occupancy level and wind direction. As a consequence, CO_2 levels can vary between very good (< 1000 ppm) and very bad (> 2000 ppm). In general, omitting direct extraction from the bedroom gave rise to maximum CO_2 level in the parent bedroom belonging to category 4 (> 1350 ppm).

Temperature

The average daily mean temperature measured by all the units without and with smartzone is plotted as a function of the running mean outdoor temperature $T_{e,ref}$ (source: Belgian RMI) in Figure 7. $T_{e,ref,i}$ on day i is defined as $T_{e,i} + 0.8T_{e,i-1} + 0.4T_{e,i-2} + 0.2T_{e,i-3}$. The mean indoor temperature was about 21°C with a clear spread between 15 and 25°C, showing that in some rooms as bedrooms lower air temperatures are accepted. More detailed results on instantaneous temperatures instead of daily mean values can be found in Lokere (2019). As explained before, profound research is needed on the heat exchange between ducts and indoors to come to conclusions.

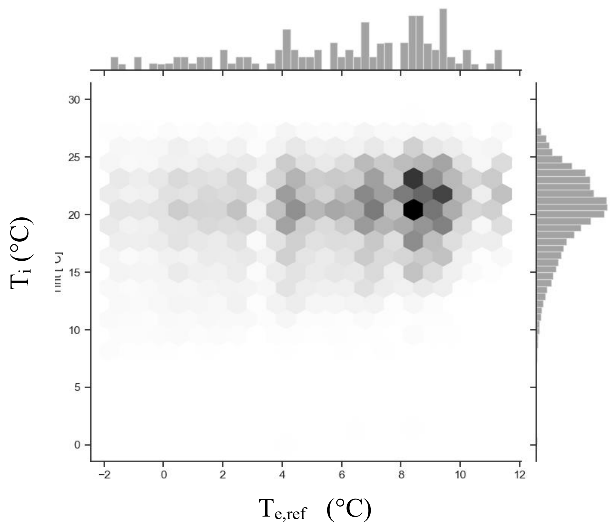

Figure 7: Distribution of the daily mean indoor temperature of all the rooms measured (without and with smartzone) plotted as a function of the running mean outdoor temperature

4.2 Fan characteristics and energy consumption

The fan characteristics and the energy consumption were analysed by comparing no-smartzone and smartzone systems. The average values over the 4 months period of several parameters of the connected units were set out as a box plot in Figure 8 to 10 (daily average in case of time fraction of minimal flow rate MF).

When analysing the time fraction of minimum airflow rate MF over the entire box (= none of the valves is activated), the daily average time fraction is about 75 and 50% for the no-smartzone and smartzone system. The high fractions of both systems proved already the huge potential of demand controlled ventilation to save energy. When comparing no-smartzone with smartzone systems, on average 25% of the time or 6 hours/day, the smartzone system is activated in at least one of the bedrooms to guarantee IAQ. The spread in time fraction is quite large indicating that substantial differences occur over time and between the units. The relation of this MF time fraction with the period of non-occupancy could be further investigated.

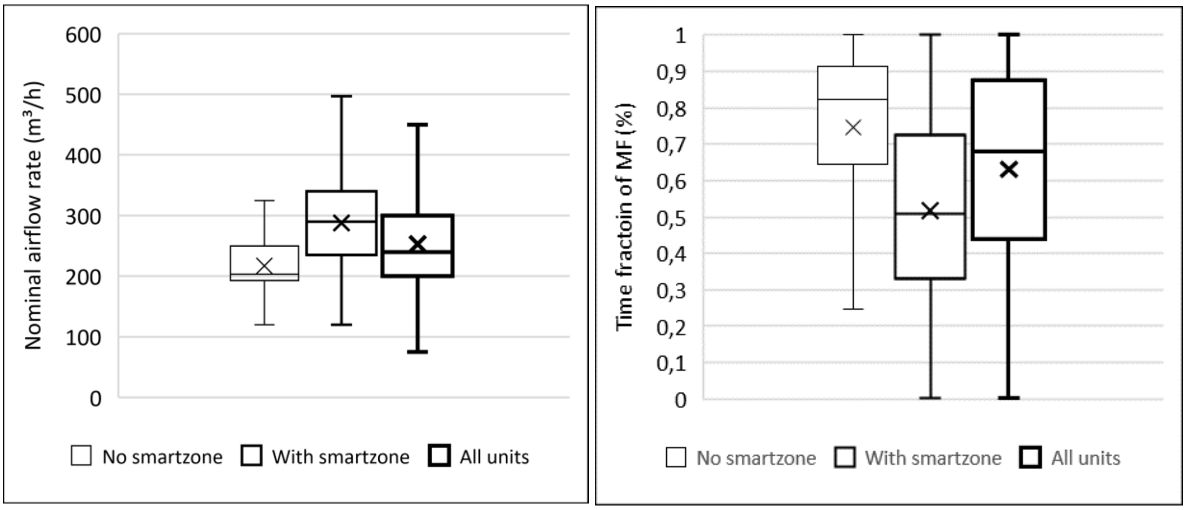

Figure 8: Nominal airflow rate (left) and the average time fraction of minimal ventilation MF (right) of the units

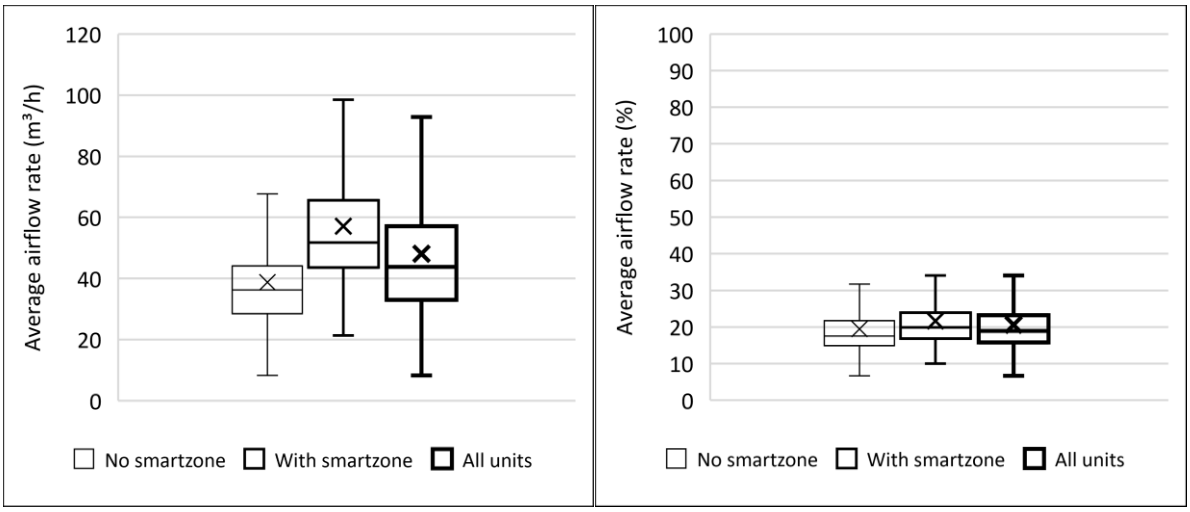

Figure 9: Average airflow rate of the units expressed as "m³/h" (left) and "%" (right)

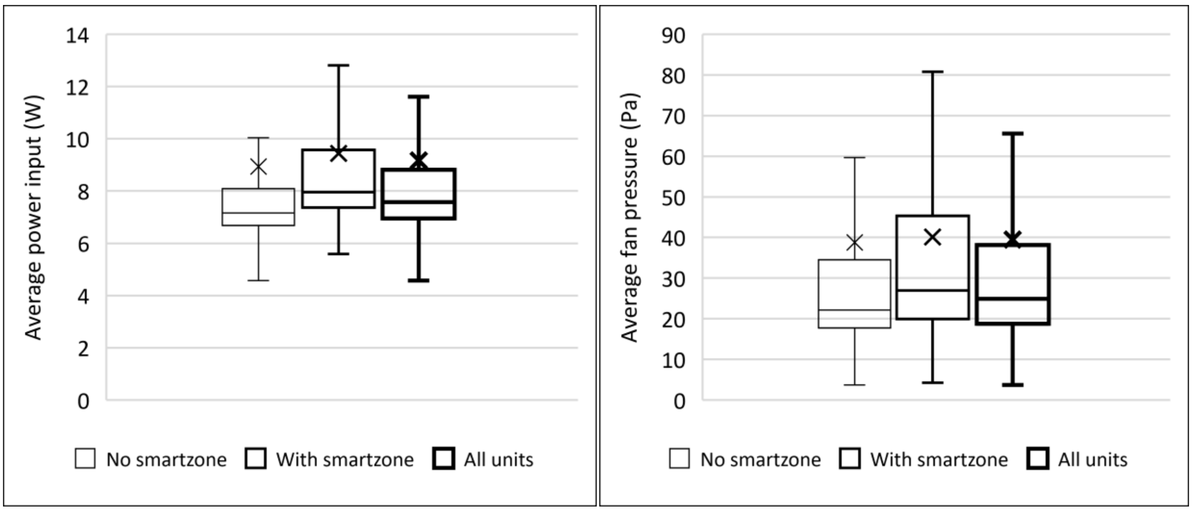

Figure 10: Average power input (left) and average fan pressure of the units (right)

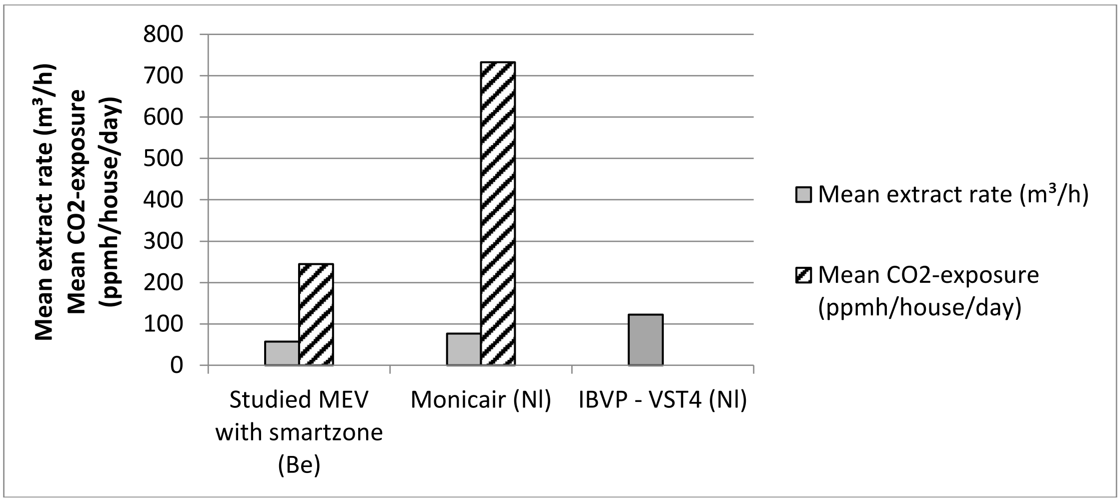

Figure 11: Mean extract rate (m³/h) and mean CO_2-exposure (ppmh/house/day) > 1200 ppm compared to literature values

The average extract airflow rate of 57.1 m³/h of the smartzone systems was about 50% higher than the value of 38.8 m³/h for no-smartzone systems, however, the IAQ realised with the smartzone system was also better. This was clearly due to the higher installed nominal airflow capacity via the additional extraction points and the higher mean ventilation levels in bedrooms than in wet rooms.
The mean nominal airflow rate (= ventilation capacity) of 288 m³/h of smartzone systems was on average about 32% higher than the value of 218 m³/h of no-smartzone systems.

Compared to the study of van Holsteijn and Li (2014) and Valk et al. (2019) who found an average extract rate of 76.9 m³/h for a similar ventilation system with smartzone (C4c), the cloud data average extract rate is 26% lower. This is quite remarkable since the MEV system studied controlled the air on a lower setpoint of 950 ppm instead of 1200 ppm in the habitable rooms. Nominal airflow rates of both ventilation systems were also comparable. Furthermore the IBVP tool of Valk et al. (2019), which should form the basis for the new ventilation performance standard NEN1087 in the Netherlands, suggests an average air exchange rate (AER) of 122 m³/h for a similar so-called VST4 system. This latter IBVP value is more than twice the average airflow rate monitored in real circumstances. Figure 11 illustrates the low average airflow rate and the low CO_2-exposure when applying the studied MEV system with smartzone compared to literature values.

The airflow rate expressed as a fraction of the installed nominal capacity, the so-called reduction or ctrl-factor was about 0.20 in case of smartzone systems. Usually, the ctrl-factor is expressed to the nominal airflow rate of systems with no smartzone. In that case the ctrl-factor of the smartzone systems becomes 0.26. In the Belgian (EPB), Dutch (NTA8800) and European (EN13142) regulation, the default ctrl-factor for MEV systems with local control and detection in all rooms is substantially higher with values of 0.43, 0.55 and 0.50, respectively. In case of the no-smartzone system, the ctrl-factor cannot be determined since the assumption of equal IAQ is not guaranteed for the bedrooms under the monitored airflow rates.

When looking at all the boxes, the mean operating pressure of the fan was respectively 38.9 and 40.1 Pa for the no-smartzone and smartzone systems (maximum pressure level of the unit is 350 Pa). Median pressure values, however, were substantially lower. Also the average power input of no-smartzone and smartzone systems was quite similar with values of 9.0 and 9.4 W, respectively, including the power consumption due to electronics and sensors (maximum power input of the unit is 85 W at 400 m³/h and 200 Pa). These average values were about 1.5 W higher than the median values, pointing out that the design or installation of some units was not optimal, giving rise to higher mean electricity consumptions. The small difference between no-smartzone and smartzone systems was realized by means of smart fan and valve control. The required auxiliary energy per unit of airflow rate of the unit, the so-called specific power index SPI as defined in the standard EN13142, was equal to nearly 0.23 and 0.16 Wh/m³ for the no-smartzone and smartzone respectively.

Extrapolating the average power input to an entire year, resulted in a yearly auxiliary consumption of the extract system of about 79 kWh and 82 kWh for no-smartzone and smartzone systems, corresponding to a total electricity cost of about €20 in case of an electricity price of 0.25 €/kWh. Van Holsteijn and Li (2014) and Derycke et al. (2018) found an electricity consumption of more than twice that high for similar systems with also extraction from the habitable rooms, i.e. 187 and 186 kWh, respectively. The substantial lower energy consumption in this study is due to a recent optimisation of the MEV system at the hardware- and software-level and probably due to a lower overall occupancy level and a larger dataset.
The C4a system without smartzone and without local control in the wet rooms, as investigated by van Holsteijn and Li (2014) and Valk et al. (2019), showed a lower yearly auxiliary consumption of 50 kWh and a higher average airflow rate of 95 m³/h compared to the no-smartzone system investigated. The CO_2-exposures in case of C4a, however, were considerably higher.

The average ventilation heat losses could be estimated based on a mean measured indoor air temperature of 21°C, a mean outdoor temperature of 6°C over a 6 months heating period from November up to April in Belgium and a 85% efficiency of the heating system, approaching 5350 MJ for a smartzone system. These ventilation heating losses are 32% lower than the value of 7874 MJ reported by van Holsteijn and Li (2014) for a similar heating season. Assuming a gas price of 0.05 €/kWh, the yearly average heating cost for ventilation with the smartzone MEV system is about €75.
It can be stated that in many cases the total yearly energy cost related to the operation of the smartzone ventilation system (heating and auxiliary energy) will be limited to €100.

Within the Ecodesign framework and its requirement to provide consumers with accurate information regarding energy consumption, it is relevant to compare the smartzone MEV-results with a MVHR system. Ecodesign and its labelling scheme must allow consumers to identify how energy efficient a product actually is and to assess a product's potential to reduce energy costs. In order to make this comparison, the following assumptions were made for the balanced MVHR system:

- The real average airflow rate is 125 m²/h which equals half of the mean nominal airflow rate system of 250 m³/h over all the units (cf. Fig. 8).
- This average airflow rate, which varies between a minimum and a maximum value, is assumed to assure an adequate IAQ in case of no zone controlled systems.
- The overall efficiency of the heat recovery unit in-situ is 60% taking into account real circumstances such as leakages, defrosting, unbalance, pollution, usability of recovered heat, … This lower recovery efficiency in practice compared with laboratory measurements is justified by studies as Merzkirch et al. (2015), Faes et al. (2017) and Knoll et al. (2018).

Under these assumptions the ventilation heat losses are about 4700 MJ or nearly 12% lower than the MEV system with smartzone. The similar heat losses of both the MVHR and the smartzone system are comprehensible since the mean ctrl-factor of 0.26 of the MEV system corresponds with a virtual heat saving efficiency of 74%. Besides, the real electricity consumption of a MVHR system will be at least 4 times higher due to the presence of 2 fans and the much higher pressure losses in the unit caused by filtering and heat recovery (Derycke et al., 2018). As a consequence, since electricity is at least 3 to 4 times more expensive than gas, the mean yearly energy cost of a MVHR system will not be lower than that of the MEV with smartzone.

5 CONCLUSIONS

This study is a first large-scale analysis (350 units) of the performance of a smart residential and cloud connected mechanical extract ventilation (MEV) system based on field data in Belgium during the winter period. Half of the units were equipped with the smartzone option which consists of additional CO_2-controlled extraction in the habitable rooms next to the wet rooms.

The above analysis on air humidity showed that big data can be expressed in several ways to come to conclusions. The indoor climate of a kitchen, which is a so-called wet room, is not substantially more humid than a bedroom as dry room, due to the presence of a cooker hood, the always open connection of the kitchen to the living room and the quasi continuous comfort temperature. The bathroom had the most humid indoor climate, however a limited time period or number of rooms with a RH > 80% was found. RH ranges for habitable rooms as set out in standards seem quite severe to fulfil permanently, as also found in other studies.

The period over which the CO_2 concentration is analysed is quite crucial when analysing the time fractions of different CO_2 categories, since occupancy is not known. In bedrooms with smartzone, ventilation is at its minimum flow rate approximately half of the night due to no occupancy, low occupancy or deep sleep with CO_2 levels lower than 800 ppm. On average, the CO_2 level in bedrooms was <950 ppm during at least 90% of the nighttime. Compared to literature data with smartzone technology, the exposure to CO_2 on the one hand and the ventilation heating energy consumption on the other hand was respectively 67% and 32% lower. The CO_2-exposure when not applying extraction in the bedroom was clearly higher. The ctrl-factor of the MEV system with smartzone of 0.26 was substantial lower than default values used in regulation.

The electricity consumption of the MEV system with smartzone was found to be less than 50% of the reported literature values. It could be stated that in many cases the total yearly energy cost related to the operation of the ventilation system (heating and auxiliary energy) will be limited to €100.

Since rooms are often unoccupied or occupied at a low level, advanced local demand control is highly energy-efficient. Due to technological and digital evolutions MEV systems with smartzone combined with natural supply (also called VST4) are able to guarantee IAQ in every room and perform energetically equally or better than MVHR systems in countries with a mean winter temperature not lower than freezing point.

In further research the huge amount of data will be explored by focusing -among others- on the behaviour of the system under summer conditions, on the possible deviation between measured sensor values and room conditions and the reasons of suboptimal performance of some units.

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