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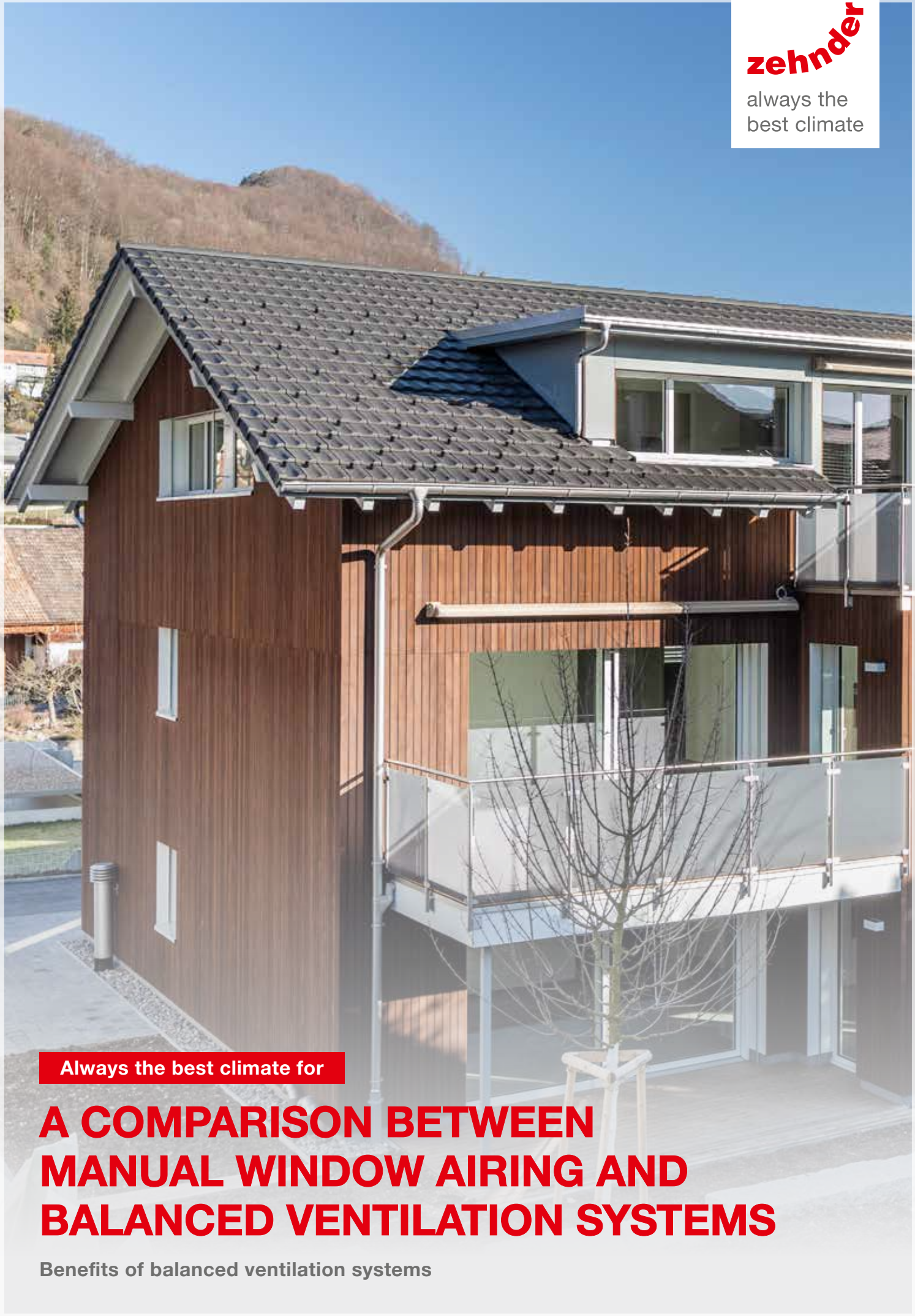

Always the best climate for

A COMPARISON BETWEEN MANUAL WINDOW AIRING AND BALANCED VENTILATION SYSTEMS

Benefits of balanced ventilation systems

1. Importance of indoor air quality

"Go and get some fresh air": This was the advice our grandparents used to give us when we were children. They were right. Every day we breathe around 11,000 litres of air. This is the equivalent of about 50 bathtubs full of air. Even the WHO emphasizes **the importance of fresh air for our health**[1].

Various studies show the impact of bad air[2]. Besides fine dust and other contaminants, the **main indicator** for good indoor air quality is the **CO_2 level within the rooms**. A CO_2 level above a level of 1000 ppm may lead to symptoms such as headaches, indecisiveness or tiredness. But a combination of these bad air contents may even lead to more dangerous respiratory diseases like asthma or even heart attacks.

As we spend almost **90 percent of our time indoors**[3] and **65 percent in our homes**[4], we definitely need to get some fresh air inside our buildings. Nowadays this is a rather difficult job. We frequently live in densely populated cities or near industrial areas. So, even if we frequently open our windows, we might still get some pollution in our lungs. Besides, new and renovated buildings are very well insulated and airtight. This airtightness protects our environment, but it also reduces the air exchange rate. In order to keep the **indoor air quality at a healthy level**, it needs to be exchanged frequently.

Zehnder focuses on innovative solutions for a healthy, comfortable and energy efficient indoor climate with our products and services. Therefore, we wanted to find out **what the best way was to ensure healthy living conditions** in our homes: either by introducing a balanced ventilation system or by regularly opening doors and windows.

We therefore conducted a case study over a full year. An apartment building served as our object of study. Four apartments were monitored on a continuous basis, offering an abundance of data on **indoor air quality, outdoor conditions and energy consumption**. The difference of the apartments: two of them had balanced ventilation and two of them used window ventilation.

The following chapter displays a description of our approach and the parameters of the study. Chapter 3 provides the results of our research project. A summary of our most important findings can be found in chapter 4.

1 See: https://www.who.int/airpollution/household/pollutants/combustion/en/

2 See e.g. Myhrvold AN, Olsen E, Lauridsen O 1996: Indoor environment in schools – pupil's health and performance in regard to CO_2 Concentrations. Proc Indoor Air i96 4: 369 – 374 and BERNDT STENBERG, NILS ERIKSSON, JONAS HÖÖG, JAN SUNDELL, STIG WALL, The Sick Building Syndrome (SBS) in Office Workers. A Case-Referent Study of Personal, Psychosocial and Building-Related Risk Indicators, International Journal of Epidemiology, Volume 23, Issue 6, December 1994, pages 1190–1197

3 https://ec.europa.eu/environment/integration/research/newsalert/pdf/health_impacts_climate_change_indoor_environment_uk_review_447na1_en.pdf

4 See: Harvard, T.H. CHAN School of Public Health 2019: Homes for Health, 36 expert tips to make your home a healthier home. p. 8

2. Approach, general conditions and values

2.1 Object of study

The apartments we compared belong to a house built in 2017 in Büren, Switzerland. The building has **state-of-the-art insulation and a high level of airtightness**. The building has four levels: two floors, a penthouse and a basement. There are two apartments on the first floor and two apartments on the second floor. The apartments on the left have a surface area of 80 m^2 and the ones on the right 113 m^2.[1]

One person lives in the top left apartment, and two in each of the other apartments.

The top apartments have windows to air them. A Zehnder ComfoAir Q350 ventilation unit ventilates the bottom two apartments. The ComfoAir Q units are equipped with an enthalpy exchanger, which exchanges the heat and moisture between the incoming and outgoing air. All doors and windows can be opened.

1 For greater clarity, in the following paragraphs we refer to the first-floor apartments as “bottom apartments” and to the second-floor apartments as “top apartments”.

Figure 1: Building plan view with family size and ventilation type.

2.2 Measured data

Our comparison focuses entirely on the type of ventilation used, the resulting indoor air quality and the necessary energy consumption to heat and cool the apartments.

As an indicator of indoor air quality, the CO_2 values were measured in ppm. According to the recommendations of health organisations, **we considered values above 1000 ppm as unhealthy**, values below 800 ppm to be good, and between 800 ppm and 1000 ppm as medium.

In this study, we also analysed the energy consumption needed to keep the apartments at a comfortable temperature.

2.3 Mode of measurement

The monitored data stems from different sources:

- **The ComfoAir Q units** deliver the balanced ventilation data. It measures and records it every five minutes.
- **Air quality sensors** collect the indoor air quality data every minute.
- The opening of windows is monitored with **contact sensors** that can differentiate between a tilted and an open window.
- A special **distance sensor** is used to measure how far the sliding door is open.
- **A heat pump** provides the energy consumption data for every apartment on an hourly basis.

For a long-term analysis, we averaged the data received from points 1 and 2, turning them into hourly values.
In addition, we used an **airing factor**, which is the number of windows that are open and the duration for which they are open. The factor ranges from 0% with all doors and windows closed to 100% with all of them completely open.

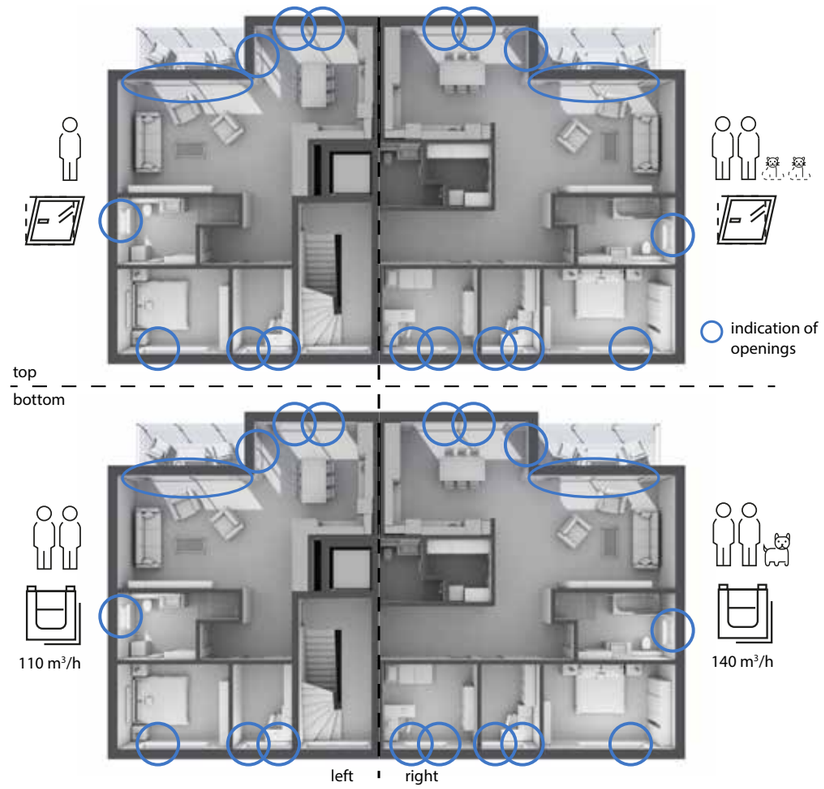

Figure 2: Floor plan of the four analysed apartments with family size, ventilation type and airing possibilities indicated by blue circles.

3. The results in detail

3.1 Indoor air quality

3.1.1 A sample day in summer

As Figure 3 shows, **the apartment with balanced ventilation has an average CO_2 value between 400 and 600 ppm in the living room and bedroom**. During the night, the CO_2 increases. During the day, the occupants are probably at work but the ventilation system continues to exchange/refresh the air. As a result, the average CO_2 value in the apartment drops from nearly 600 ppm to 400 ppm. In the evening, the CO_2 value increases slightly. Nevertheless, throughout the day, the average indoor air quality is good.

The occupants with manual ventilation keep a few windows open at night. The occupants leave the house in the morning with one window in the tilted position, which does not lead to sufficient exchange of indoor air. The CO_2 value stays at around 800 ppm during the day. When the occupants return home in the evening, all windows and doors are closed. As a result, the CO_2 increases up to 1200 ppm. Throughout the day the CO_2 value does not fall below 600 ppm. Despite the window ventilation used, there is even **medium (800-1000 ppm CO_2) to poor indoor air quality (above 1000 ppm CO_2)**.

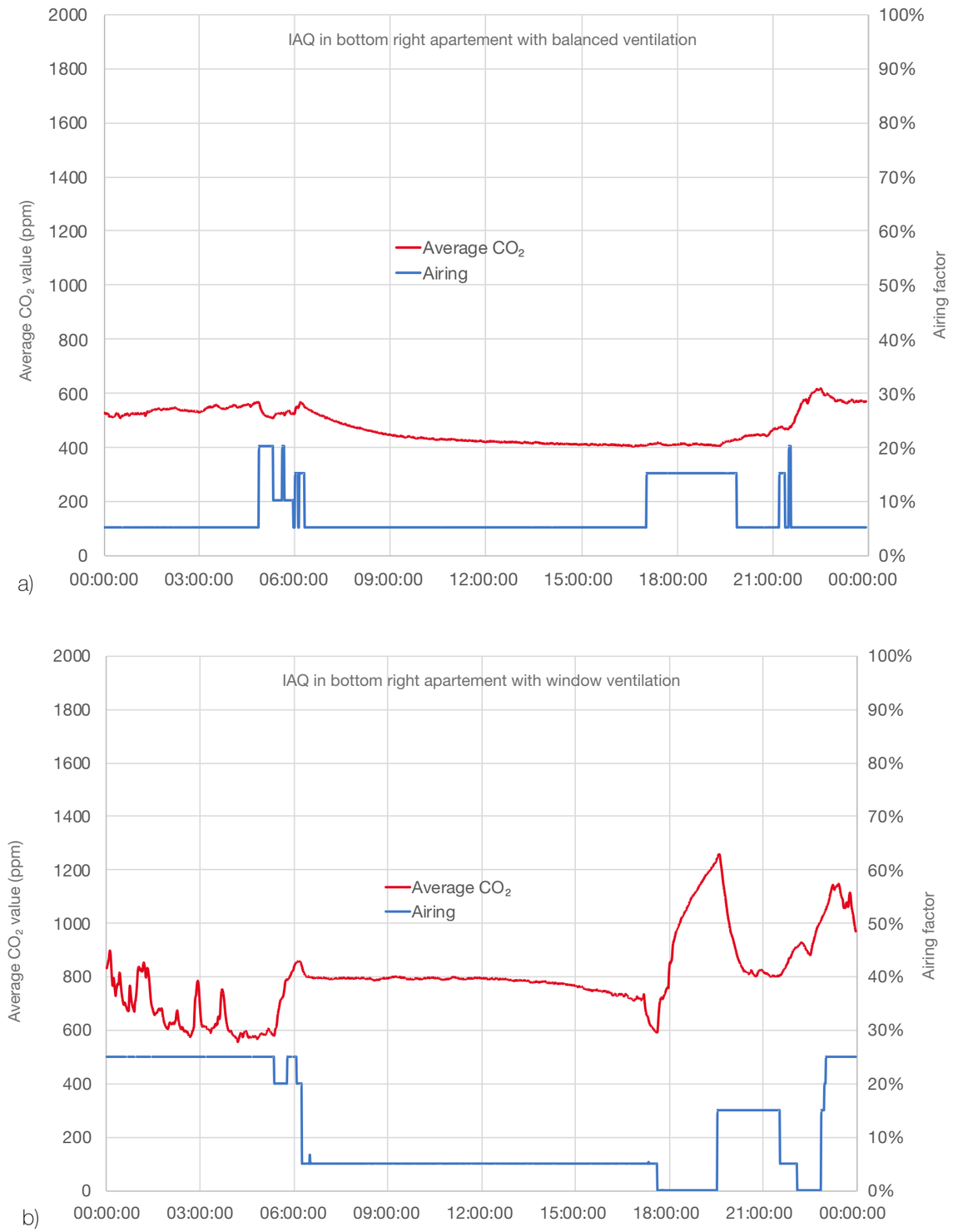

Figure 3: Example of airing factor and CO_2 values during a summer's day for a balanced ventilated apartment (a) and one with only manual airing (b).

3.1.2 Indoor air quality over a periode of one year

Figure 4 shows CO_2 values of all the monitored rooms as carpet plots. These carpet plots show at what time of day and in which season the indoor air quality is good, medium or poor.
Apartments with automatic ventilation systems have a better indoor air quality than apartments with window ventilation only.

Most of the time, the balanced ventilation ensures a sufficient air exchange in the room. Of course, there will sometimes also be visitors, especially during the Christmas holidays. Bear in mind that for the sake of reliable monitoring results, we instructed the occupants to keep the ventilation flow setting at a constant level.

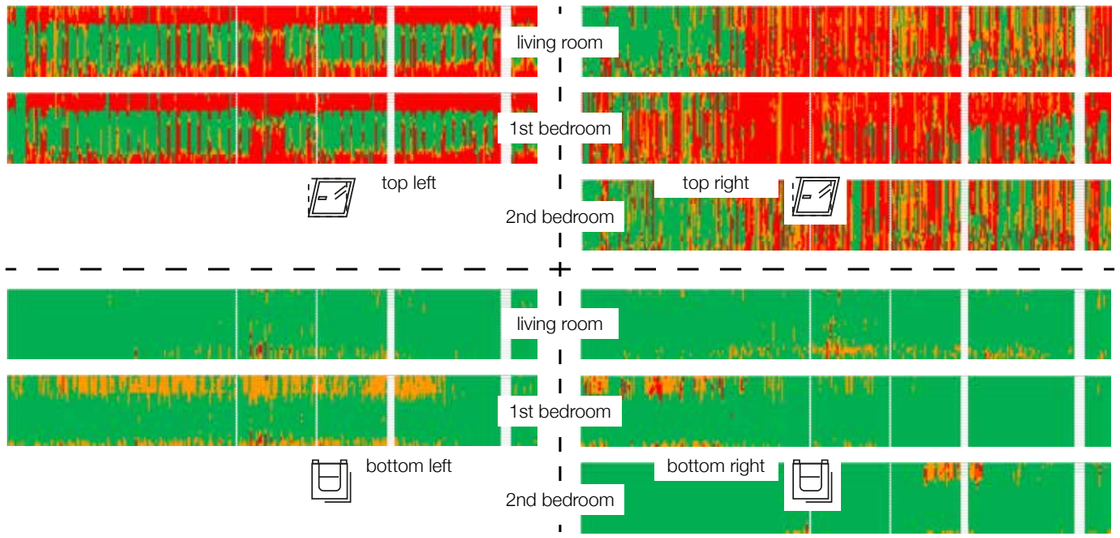

Figure 4: Indoor air quality over one year in all the rooms of the apartments.
Individual carpet plots range horizontally from July 2019 until June 2020 and vertically downwards from 0:00 to 23:00. The green colour symbolizes good Indoor Air Quality (IAQ), orange stands for medium IAQ and red for poor IAQ.

3.1.3 Number of hours with unhealthy CO_2 values

We also counted the **number of hours when the CO_2 level exceeded 1000 ppm**. As can be seen in Figure 5, there is a huge difference between apartments with balanced ventilation and those with manual window airing. **The typical value is below 100 hours for balanced ventilation and 3000 to 5000 hours with window ventilation**.

This means that in the manually aired apartments the indoor air quality is about 30 to 50 times more often at an unhealthy level. In total, apartments with balanced ventilation only have unhealthy CO_2 values 1% of the time throughout the year; meanwhile apartments with window airing have them between 30% and 60% of the time.

Figure 5: Floor plan of the building with monitored number of hours with CO_2 values above 1000 ppm. Airing factor based on the entire year.

3.2 Energy consumption for heating and cooling the apartments

As the indoor air quality turned out to be so good in apartments with balanced ventilation we wanted to measure the impact on the energy consumption of the continuously fresh air flow of the balanced ventilation compared to window ventilation.

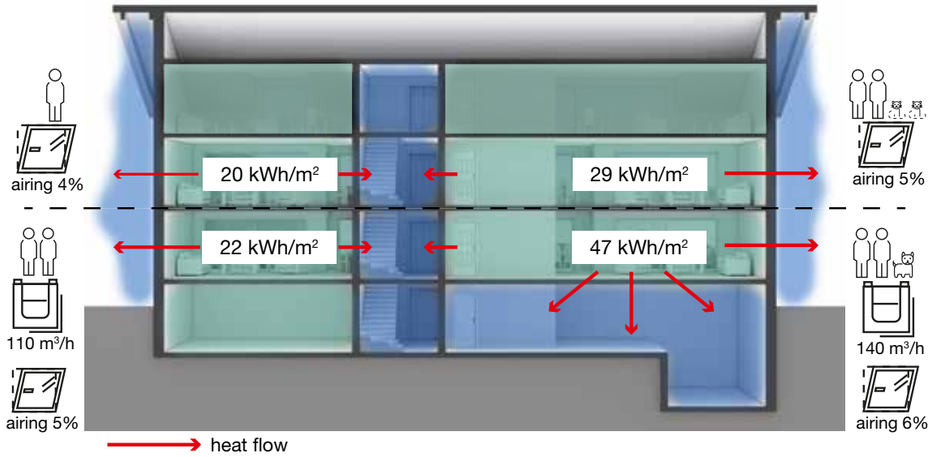

Figure 6: Total heating consumption (in kWh/m²) in one year for the apartments. Also shown are the average airing factors over the months from October 2019 until March 2020. Conditioned spaces are marked in green, un-conditioned spaces are marked in blue. The winter outdoor environment is indicated in blue. The expected heat flow by transmission is indicated with red arrows.

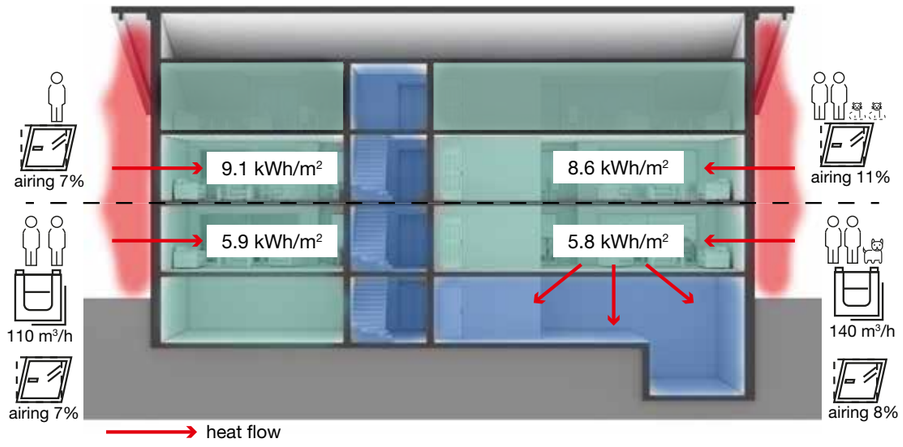

Figure 7: Total cooling consumption (in kWh/m²) for the apartments. Also shown are the average airing factors over the months from April until September 2020. Conditioned spaces are marked in green, un-conditioned spaces are in blue. The summer outdoor environment is indicated in red. The expected heat flow by transmission is indicated with red arrows.

The total amount of heating consumption in every apartment is shown in Figure 6. The results show that the two left apartments have a similar energy consumption for heating, although the bottom left apartment has a bit higher level of airing with windows.

The bottom right apartment needed much more energy – nearly twice as much as the bottom left apartment with the same ventilation. This was partly due to the cellar underneath it, which was neither heated nor cooled. The other apartments all had warm indoor spaces above and below them. This is the so-called **'neighbour effect'**: the amount of energy used depends on the average indoor temperature of the adjacent spaces. Another reason was **the higher thermostat setting** in the bottom right apartment.

The monitored use of heating and cooling for an apartment depends on the **airing factor**. This is logical, because the outdoor air coming in via the window has to be adapted to the desired temperature. Figure 6 and 7 show, for the same airing factor the energy consumption for heating and cooling is lower with balanced ventilation.

In Figure 6, we compare the total heating consumption of 22 kWh/m² of the bottom left and 29 kWh/m² of the top right apartment with the same use of windows (same airing factor of 5%). We see that addition of a balanced ventilation system does not bring more energy consumption for heating, in fact it has 24% less.

In Figure 7, we compare the total cooling consumption of 5.9 kWh/m² and 9.1 kWh/m² of the two left apartments, with the same airing factor. It can be concluded that the addition of a balanced ventilation system saves about 35% of the cooling consumption.

4. Conclusion

The comparison of the indoor air quality has shown that the bottom apartments with balanced ventilation have a much better indoor air quality than the top apartments with manual airing. Looking at the CO_2 values, we have demonstrated that **occupants with a balanced ventilation system live in a much healthier environment**.

The ventilation system provides a constant fresh air exchange in the rooms. Manual airing only brings in fresh air when multiple windows are open. Averaged over a prolonged period of time, window ventilation does not provide the same level of good-quality air as a balanced ventilation does. Unlike what might be expected, **window ventilation is not able to provide a healthy indoor climate**, as in 30-60% of the time CO_2 values exceeds 1000 ppm.

The total energy consumption when ventilating the rooms appears to depend on the amount and the time duration that the windows are open. **The addition of balanced ventilation with heat and cold recovery does not lead to a higher energy consumption and improves the indoor air quality dramatically**.

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