Performance 2 project - Winter IAQ campaigns in 13 dwellings equipped with Humidity-based DCV systems: analysis of the ventilation performance after 15 years of use

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SUMMARY

The Performance 2 project (2020-2024) is a French national research project that aims to evaluate the durability of Humidity-based Demand Controlled Ventilation (DCV) systems installed in two multi-family social housing buildings (Paris and Villeurbanne) over than 10 years ago. This evaluation includes the analysis of continuous measurements performed on the ventilation system (sensors located close to the air terminal devices) and two additional Indoor Air Quality (IAQ) campaigns including two other monitors placed in the "dry" rooms conducted in 13 dwellings. IAQ parameters such as CO_2, Relative Humidity (RH), Particulate Matters (PM), and Volatile Organic Compounds (VOC), as well as energy losses and consumption, are being analysed and compared to tenant usages to assess the performance of the ventilation systems. Finally, the results of the on-site campaigns will focus on three main factors:

- the performance of the ventilation systems by comparing, for different regulatory indicators regarding RH and CO_2, the values obtained 15 years ago during on-site campaigns (at commissioning), the values from the Performance 2 project (15 years later), and the results of a numerical approach based on nodal simulations;
- the IAQ, particularly with respect to PM and VOC, assessment based on the values obtained in the dwellings, considering the occupants' behaviour and the location of the sensors (15 years later);
- the energy consumption attributed to ventilation, by comparing the losses due to air renewal calculated 15 years ago and calculated in Performance 2 project.

KEYWORDS

Smart ventilation, residential ventilation, IAQ, energy efficiency, durability, humidity

1 INTRODUCTION AND OBJECTIVES

Relative humidity-controlled mechanical extract ventilation (RH-MEV) systems have been widely used in France for 40 years (Mélois et al., 2023). Most of the new residential buildings

complying with RT 2012 and now RE 2020 energy performance regulations, are equipped with such systems (Mélois et al., 2019) and currently they are considered as a reference system. In 2019, the "Performance 2" project was launched in three phases to (1) conduct a full winter analysis of the system after 13 years of in-situ operation using the installed sensors (non-recalibrated) and without major intervention, (2) collect the air terminal devices (inlet and exhaust units) and sensors for laboratory testing before and after cleaning and maintenance and finally, (3) reinstall the cleaned and maintained ventilation units (where the hygroscopic component reminds intact) with new calibrated sensors. The phase (1) has been described in (Guyot et al., 2022) and phase (2) in (Mélois et al., 2023). This paper presents the methodology and the first results of the data analysis of the measurements collected over 2 years after these phases. The objectives of this study are as follow:

- To evaluate the durability of the RH-MEV systems in two buildings after 15 years, by comparing the current of the energy performance and IAQ (RH and CO_2 only) with the results obtained at the commissioning, as well as the theoretical performances evaluated 15 years ago;
- To assess the performance of the RH-MEV systems regarding others pollutants, including VOC, Formaldehyde, and PM, and regarding CO_2 and RH, using new analyses;
- To investigate the factors influencing "good" or "bad" performances thought analyses of the evolution of ventilation systems conditions, changes in ventilation requirements (occupancy, pollutant emissions), and the impact of the occupants' behaviour (components sealing, use of manual control, cleaning, ...).

2 METHODS

2.1 Case studies, on-site campaigns and previous diagnosis

The two social housing buildings studied are as follows:

- a building of Paris Habitat where 19 dwellings were instrumented by Aereco in 2007 (from the 4th to the 8th floor),
- a building of Lyon Métropole Habitat where 12 dwellings were instrumented by Anjos in 2007.

The Performance 2 campaigns include the following:

- continuous measurements close to the ventilation terminals, which already had CO_2, Temperature and RH sensors in place since the Performance 1 project 15 years ago. VOC and PM were added for Performance 2 for the building in Paris. Additionally, two outdoor weather stations have been installed on the Paris building;
- Two winter campaigns (one in winter 2021-2022 and another in winter 2022-2023) during which two NEMOs IAQ monitors were installed in each voluntary dwelling (one in the living room and one in the parental bedroom). These monitors measured CO_2, Temperature, RH, light VOCs, Formaldehyde and PM. Additionally, an outdoor NEMOs was installed during each winter campaign.

An inventory of the ventilation installations was carried out, partly applying the French Promevent protocol (Bailly Melois and Mouradian, 2018). A laboratory study of the terminals and sensors was conducted to characterize the state of the terminals, asses the current hygro-regulated performance of the ventilation terminals, and verify the operation and reliability of the on-board sensors (Mélois et al., 2023).

2.2 Evaluation of the durability of the RH-MEV systems performances

During Performance 1 project (2007-2009), 19 dwellings in Paris and 12 dwellings in Villeurbanne were monitored during the first months after commissioning. Several analyses

were conducted from these data and where possible, the same analyses will be performed from Performance 2 project to enable result comparison. The main analyses focused on energy performance, the fan consumptions and airflow rates (Figure 1). These measurements were compared to theoretical values obtained using French software SIREN, considering the number of rooms in the dwellings.

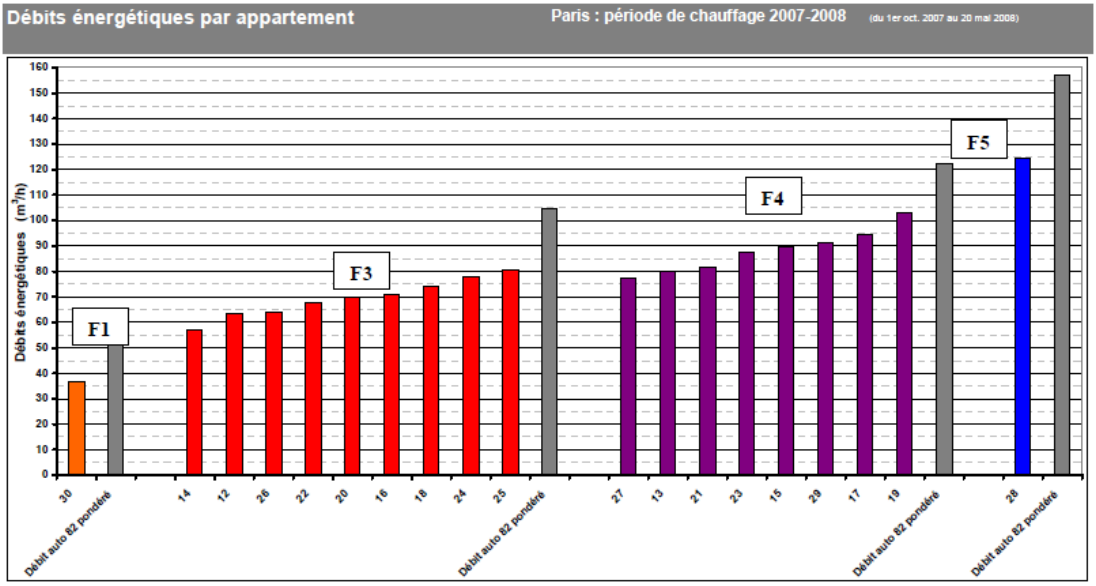

Figure 1: Average airflow rates (2007-2008 season) per apartment compared with weighted flow rates for March 1982 (SIREN evaluation) at the Paris site – Performance 1 project final report

For the CO_2 concentrations, the dynamic of the CO_2 were analysed during the year. The cumulative hours above 1000 ppm during heating season in bedrooms were calculated, and the correlation between CO_2 concentrations and intake airflows was analyzed (Figure 2).

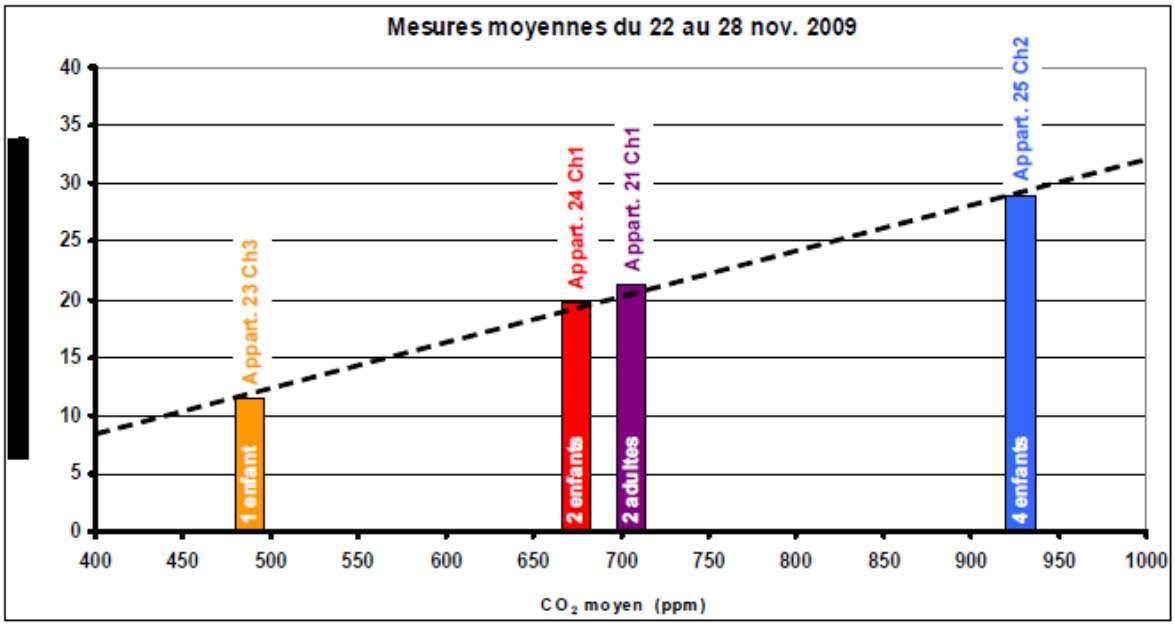

Figure 2: Evolution of the average air inlet flow rate at 10 Pa as a function of the average CO_2 level in a room for several dwellings – Performance 1 project final report

Regarding the relative humidity, calculations were performed to evaluate the risk of condensation on windows (Figure 3), as well as the number of hours with a RH above 75% has been evaluated for each room.

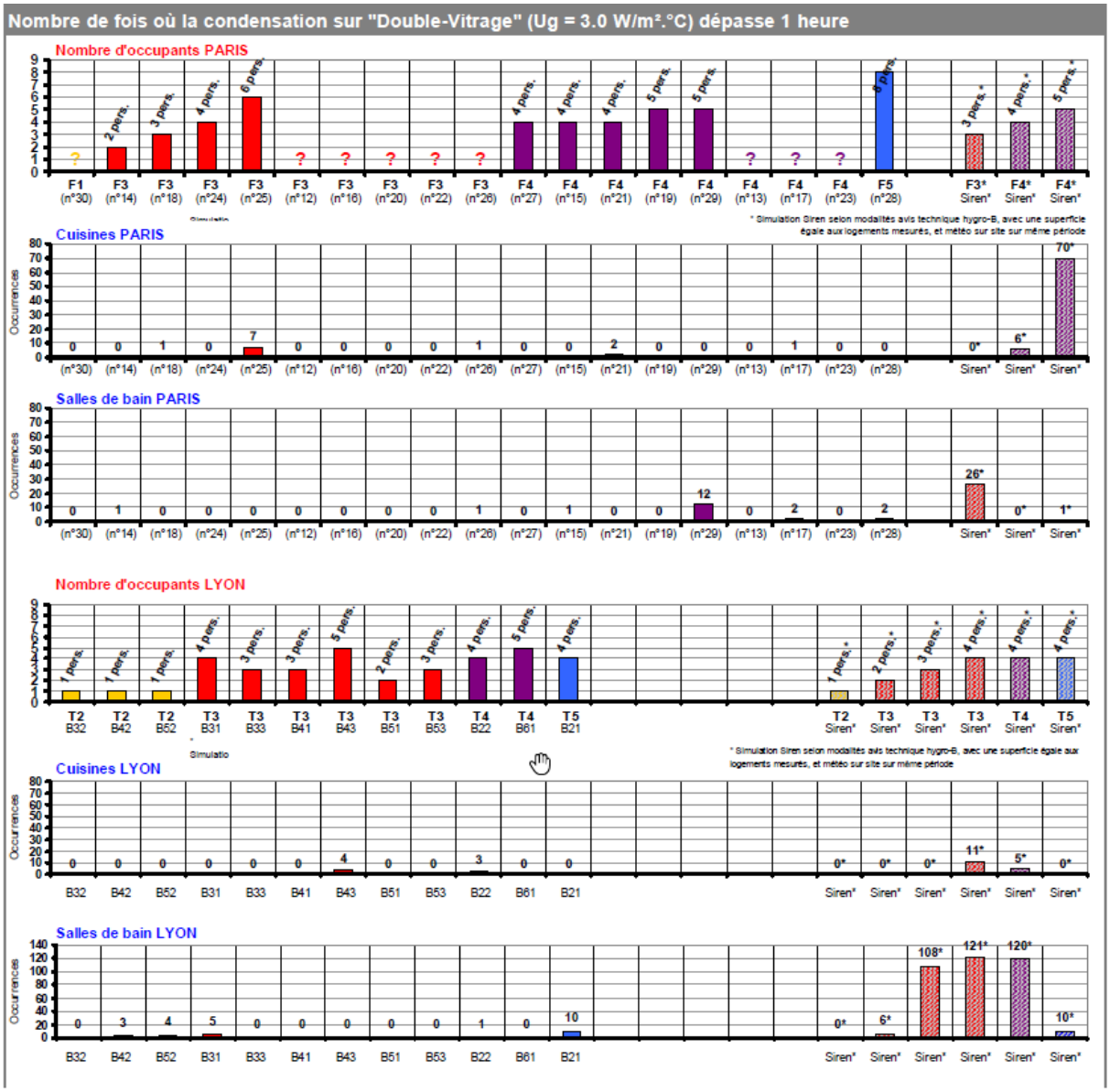

Figure 3: Comparison of condensation risks (occurrences) evaluated from on-site measurement and calculated by SIREN – Performance 1 project final report

2.3 Evaluation the performance of the RH-MEV systems regarding others pollutants

During Performance 1 project, no pollutant was measured. Therefore, the durability of the performance regarding the IAQ cannot be evaluated. However, the current performances can be assessed to determine when the system is adequate or not for providing good IAQ in the dwellings. In Paris, in order to have a representative measurement of the pollution in the room, the VOC and PM sensors were installed near the exhaust units and near the air inlets but out of their flow. Data was collected in 15 dwellings over 2 year period. Furthermore, data from the winter campaigns (two weeks at the end of 2021 for seven dwellings and two weeks at the end of 2022 for four dwellings) collected using the NEMOs monitors will be analysed.

In Villeurbanne, since no additional sensors were installed, only the measurements taken with the NEMOs during the winter campaigns have been evaluated (two weeks at the beginning of 2021 for six dwellings and two weeks beginning of 2023 for five dwellings).

To characterize the IAQ, it is necessary to determine indicators and stablish “good/bad” scales. These indicators are being defined according to:

- State of the art regarding health recommendations and thresholds;
- Previous large scale IAQ campaigns in dwellings on-site;
- Accuracy of the performed measurement.

2.4 Evaluation of the evolution of the ventilation systems conditions

A diagnostic was conducted for each dwelling at the beginning of the project to evaluate the condition of the terminal devices and the internally mounted air transfer devices. In certain dwellings, additional pressure difference measurements were conducted at the Air Terminal Devices (ATDs). Then, during the laboratory phase each collected ATD was classified depending on its condition (Mélois et al., 2023).

2.5 Evaluation of the evolution of the ventilation needs

In the past 15 years, the occupancy and the use of the dwellings have evolved. An interview was conducted in each voluntary dwellings during the winter campaigns to collect data regarding the number of occupants, their presence schedule, their bathrooms habits, and the potential sources of indoor pollution (household products, cosmetics, cooking habits, ...). Additionally, the occupants were asked to fill in a weekly log during the campaigns period (Mélois et al., 2022). The data collected from these documents will be compared to the data collected during Performance 1 project.

3 FIRST RESULTS

3.1 Data completeness

In order to be able to show statistical results that are representative of reality over a predefined period of time, a preliminary study of the data needed to be done. Figure 4 is an example of the percentage of the CO_2 data that has been collected over the year 2022, for each dwelling in Paris. In most cases, more than 98% of the period has been monitored. There were only three cases (rooms) were the collection partially failed (P10, bathroom, P11 in the kitchen, and P15, also in the kitchen). In the future analysis these specific cases will be considered.

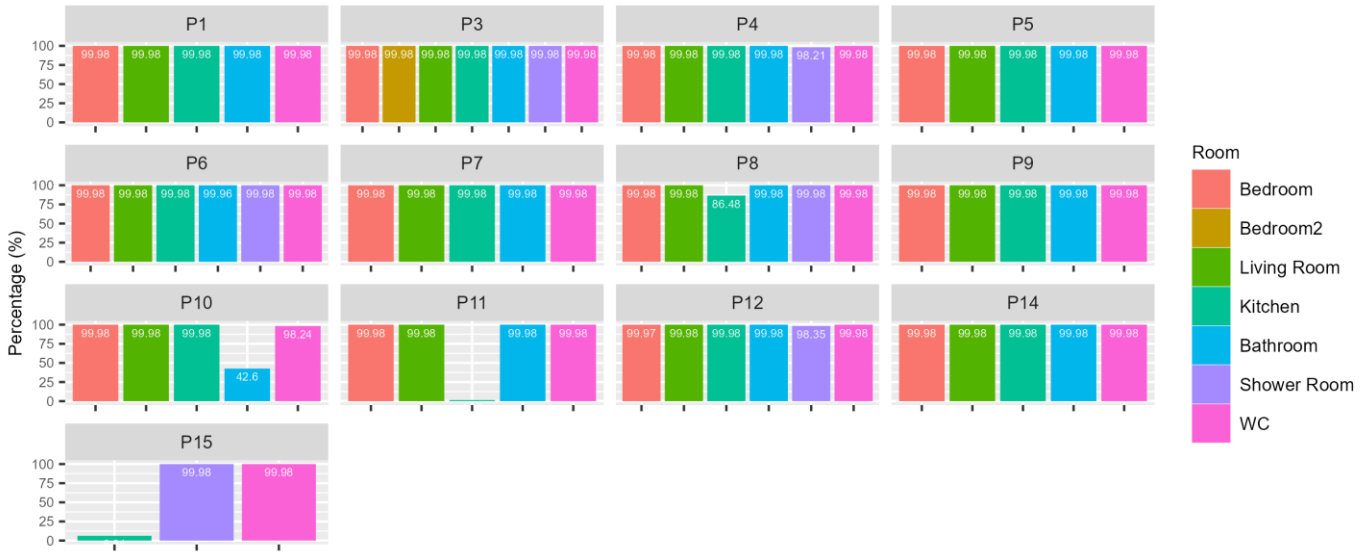

Figure 4: Percentage of CO_2 data collected in Paris over 2020

3.2 Comparison data during winter campaigns

Some parameters are measured by different sensors: continuous measurements from the sensors installed next to the ventilation ATDs and punctual IAQ campaigns from the NEMOs. To identify potential accuracy issues, additionally to the inter-comparisons carried out during the laboratory phase of the project, both acquisitions were compared (Figure 5).

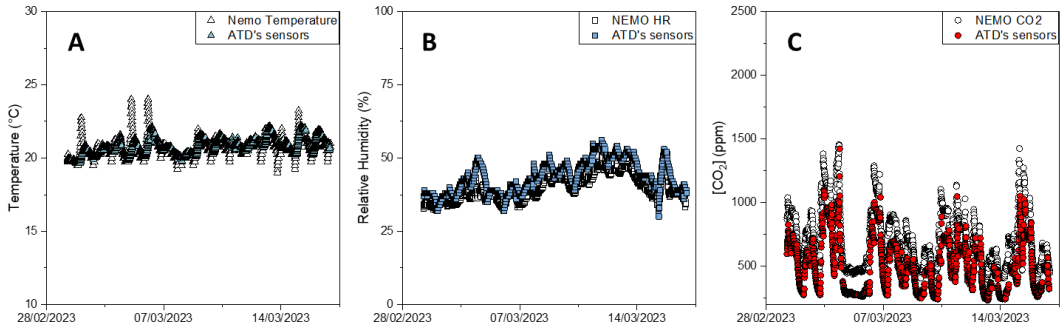

Figure 5: Comparison of data collected by two different sensors in one bedroom (Villeurbanne) for Temperature sensors (A), Relative humidity sensors (B) and CO_2 sensors (C).

3.3 CO2 concentration depending on the type of room

With a RH-MEV system, the airflow is mechanically extracted from the kitchen, bathroom, and toilets, and enters naturally by the living room and the bedrooms due to the depressurization created by the extraction system. Figure 6 represents the CO_2 concentration for each apartment and room. It can be observed that for most of the dwellings, the CO2 concentration is higher in the bedrooms (in red) compared to the other rooms.

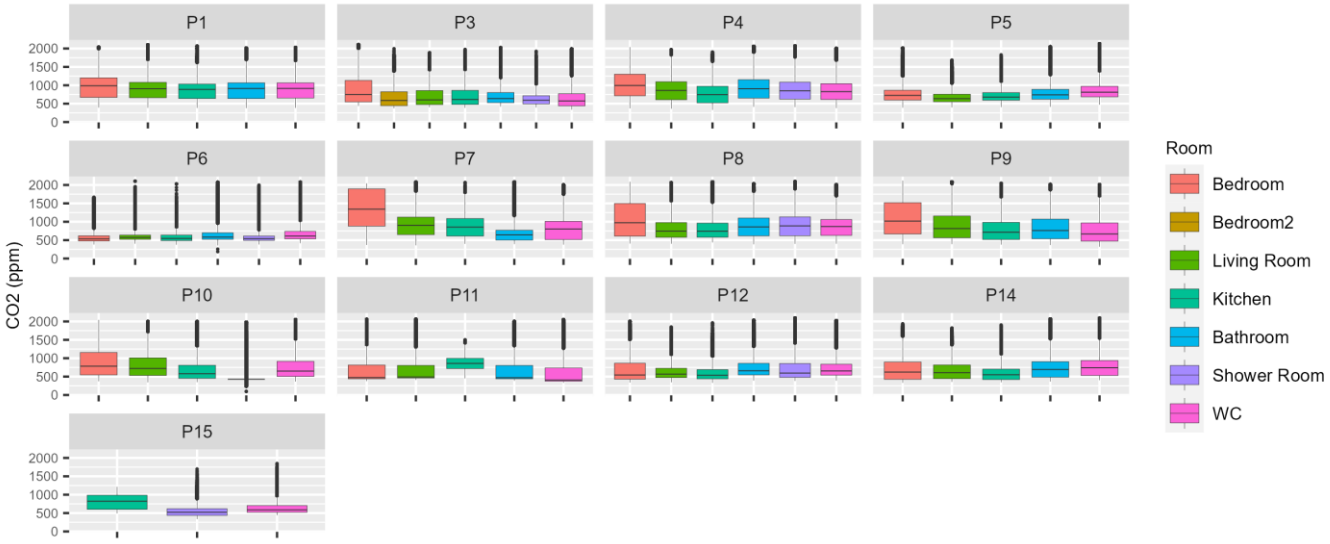

Figure 6: $C0_2$ concentrations measurements with continuous monitoring in Paris for each dwelling depending of the type of room

Additionally, regarding to the number of hours past above 2000 ppm for each room (described in Figure 7), it is observed that the ventilation is sometimes not enough to evacuate the CO2 in the bedrooms (in red).

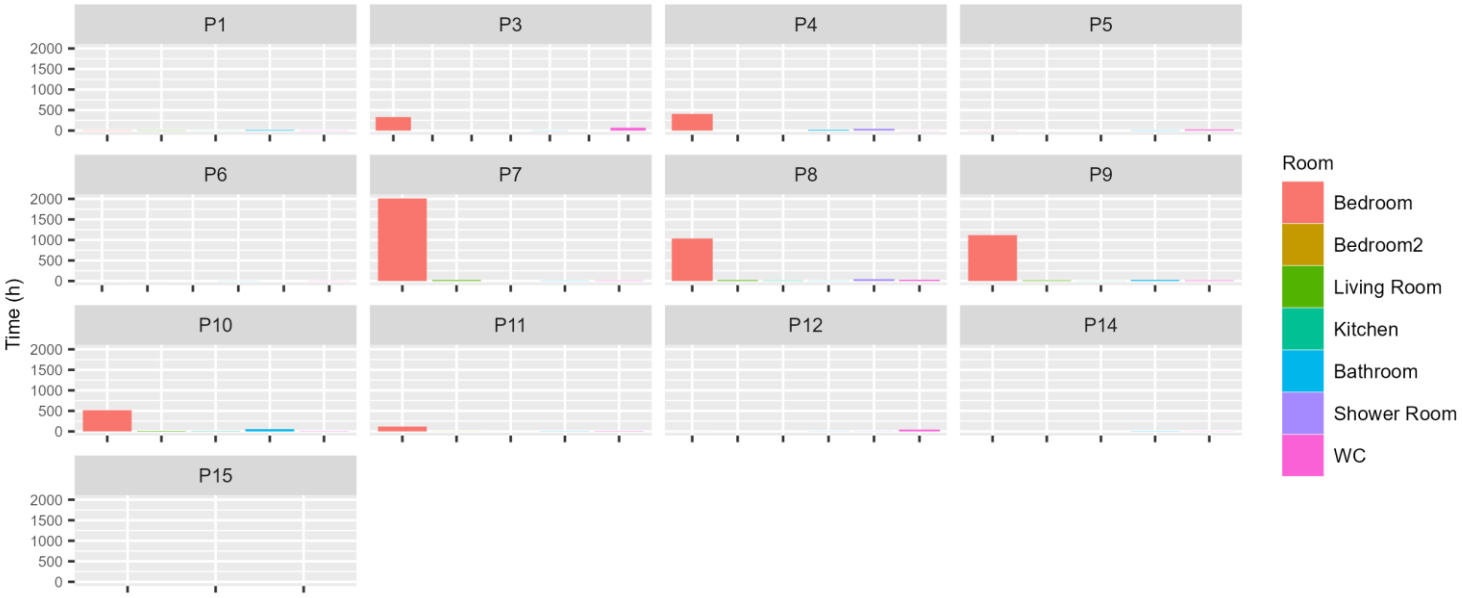

Figure 7: CO_2 concentrations - number of hours past above 2000 ppm for each room in each dwellings in Paris

3.4 Correlation between airflow at terminal devices and IAQ (CO2 and RH)

The airflow at ATDs must depend on the RH. The good system operation was assessed in laboratory conditions (Mélois et al., 2023). A similar analysis is carried but in real conditions by verifying that the measured airflow rates correspond adequately to the measured RH (Figure 8).

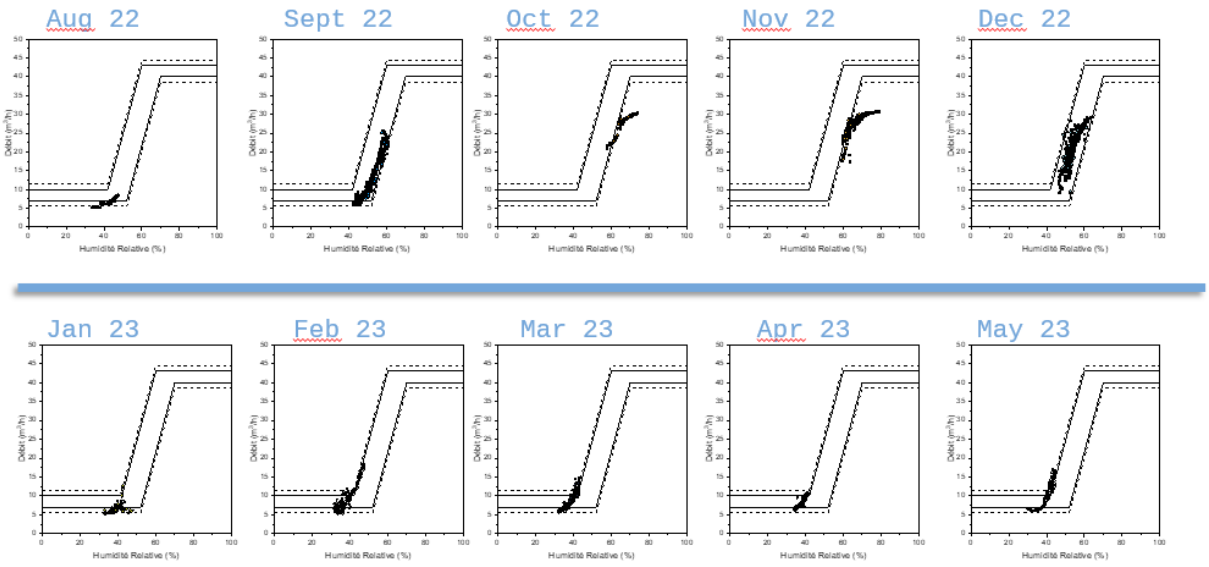

Figure 8: One year airflow rates measured at ATD depending on the measured RH in one bedroom (Villeurbanne)

The RH-MEV systems adapt the airflow only based on the RH. Therefore, the correlation between the measured airflow and the measured concentration of different pollutants was studied to evaluate the good regulation and then ensure a good IAQ in “normal conditions”. Figure 9 presents the correlation between CO_2 concentration and measured airflows at ATD in

a living room in Villeurbanne. As a result, it is shown that for high values of CO_2 the airflow is not maximal. A deep analysis is necessary to understand these specific cases.

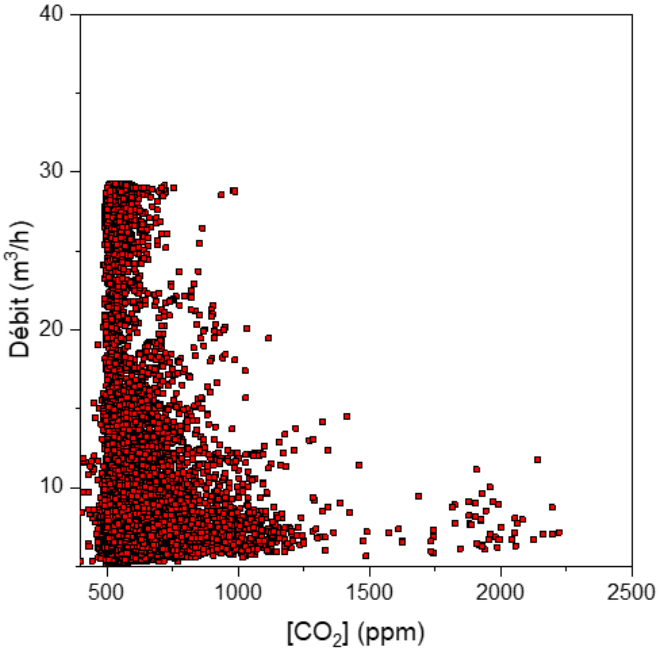

Figure 9: CO_2 concentration and airflow at ATD (with ΔP = 20 Pa) in a living room (Villeurbanne)

4 CONCLUSIONS AND PERSPECTIVES

During Performance 2 project, data have been collected thanks to continuous monitoring, winter measurement campaigns and occupants interviews. The challenge now is to organize the analysis in order, first, to meet the initial objectives of the project: to evaluate the durability of the RH-MEV systems, and to identify their performances regarding energy consumptions and IAQ depending on the occupants 'use. First analyses of this data are being performed to compare the current performances to initial and theoretical performances. Deep analyses will be performed depending on these first results in order to identify the reasons behind the results. Data may be use for other purpose, for example to validate new model developed for the new regulation and to explore the feasibility of continuous evaluation of ventilation through cheap but reliable monitoring.

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