ENERGY AND IAQ FRIENDLY VARIABLE VENTILATION RATES, ACCORDING WITH THE PROPOSED INDOOR AIR QUALITY REGULATIONS INCLUDED IN THE SPANISH BUILDING CODE.

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ABSTRACT

The Spanish Building Code (BC) regulates indoor air quality (IAQ) requirements in dwellings by establishing threshold continuous flow rates according to the occupancy, use of the rooms and their usable area. The implementation of this threshold flow allow adequate IAQ.
A revised IAQ requirement have been proposed. These new requirement quantifies the IAQ as a function of CO_2 concentration which means an non continuous flow rates ventilation systems will be able to be used.
In order to reduce the global ventilation rate and save energy related to heating and cooling, research have been conducted to obtain nom continuous flow rates that full fill propose IAQ requirement for some case studies. In addition to this CO2 concentration has been using the continuous ventilation rates including in the current IAQ regulations.
This research has been developed using the CONTAM simulation tool, BD proposed hypothesis and owns hypothesis too. Results show different non continues ventilation rates which are friendly with energy saving and the proposed IAQ levels.

KEYWORDS

Ventilation, IAQ, regulations, energy saving

1 INTRODUCTION

The Spanish Building Code (BC) regulate in the Hygiene, health and the environment Basic Document (acronym in Spanish: DB HS3) the indoor air quality (IAQ) requirements in dwellings. The Building Code sets the minimum continuous flow according to the occupancy, use of the locals and their usability area. The implementation of this threshold flow allow adequate air quality.
The Eduardo Torroja Institute for construction sciences, together with Ministerio de Fomento, has proposed a revised version for the IAQ regulations for dwellings. The proposal quantify the air quality in function of CO_2 concentration and allows non continuous flow.
In order to reduce the ventilation global rate and save climate energy, we simulate and analyse non continuous air flow and the consequence in the IAQ according to the proposal.

2 CURRENT AND PROPOSED IAQ REQUIREMENT

The current IAQ requirement establishes the minimum continuous ventilation rates per habitable rooms. (See Table 1).

Table 1. Building Code minimum ventilation rates

Rooms	Per person	Per usable floor area m^2	Per room
Bedrooms	5 l/s		
Living and dining rooms	3 l/s		
WC and bathrooms			15 l/s
Kitchens		2l/s	

The proposed IAQ requirement uses the CO_2 concentration as an IAQ indicator. The required CO_2 concentration is limited in two ways:

- 900 ppm maximum yearly average;
- 500000 ppm per hour maximum yearly accumulated above 1600 ppm.

Those are design conditions and must be full fill according to other conditions such as occupancy scenarios, CO_2 production rate, yearly average outdoor CO_2 concentration, etc.

3 SELECTION OF CASE STUDIES

The dwelling case studies that have been chosen are the most representative ones in Spain according to Instituto Nacional de Estadística (National Statistics Institute. Population and Housing Census 2011). They are all real dwellings. (See Table 2).

Table 2. Dwellings case study

Dwelling	Kind and composition of dwelling	Number of occupants
3B	Flat: Living + Kitchen + 3 Bedroom + 2 Bathroom; 71 m^2	4
3C	Flat: Living + Kitchen + 3 Bedrooms + 2 Bathrooms; 80 m^2	4
3D	Flat: Living + Kitchen + 3 Bedrooms + 2 Bathrooms;74 m^2	4

The National Statistics Institute provides population recount and knowledge of its structure. According with variables studied, the dwellings and homes more common in Spain have 3 bedrooms, 1 to 4 occupants, and between 60 and 90 m2. The chosen case study are in this group. The included results correspond to 4 occupants because this cases represent the worse results. Figures 1 to 3 represents the national values for the last census.

Dwelling: Structurally separate and independent premise that due to how it was built, re-built, transformed or adapted, it is conceived to be inhabited by persons or it constitutes the regular residence of a person in the moment the census takes place.. (Total number: 25.208.623)

Home (household): Group of persons (one or more) that reside in the same dwelling when the census takes place. (Total number: 18.083.692)

Figure 1. Dwellings vs rooms per number of occupants.

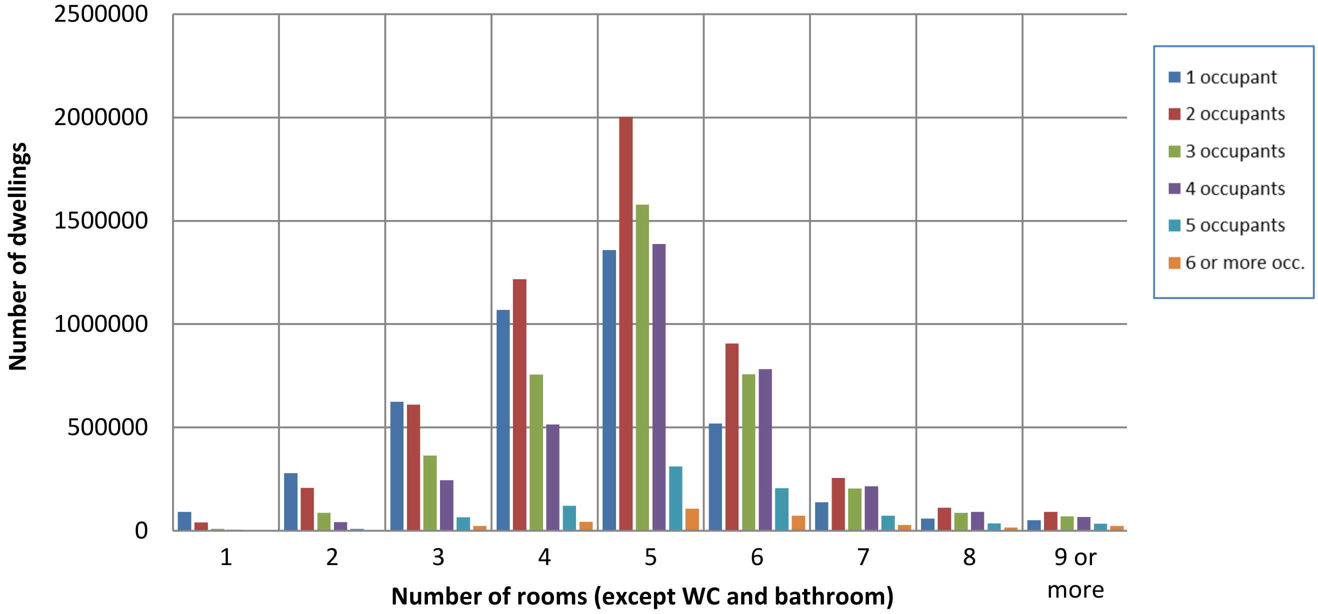


Figure 2. Percentage of dwellings vs usable floor area.

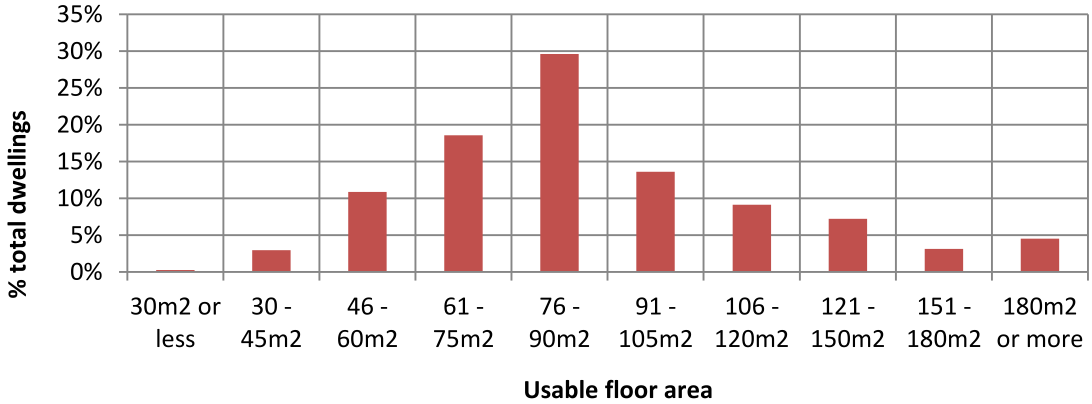
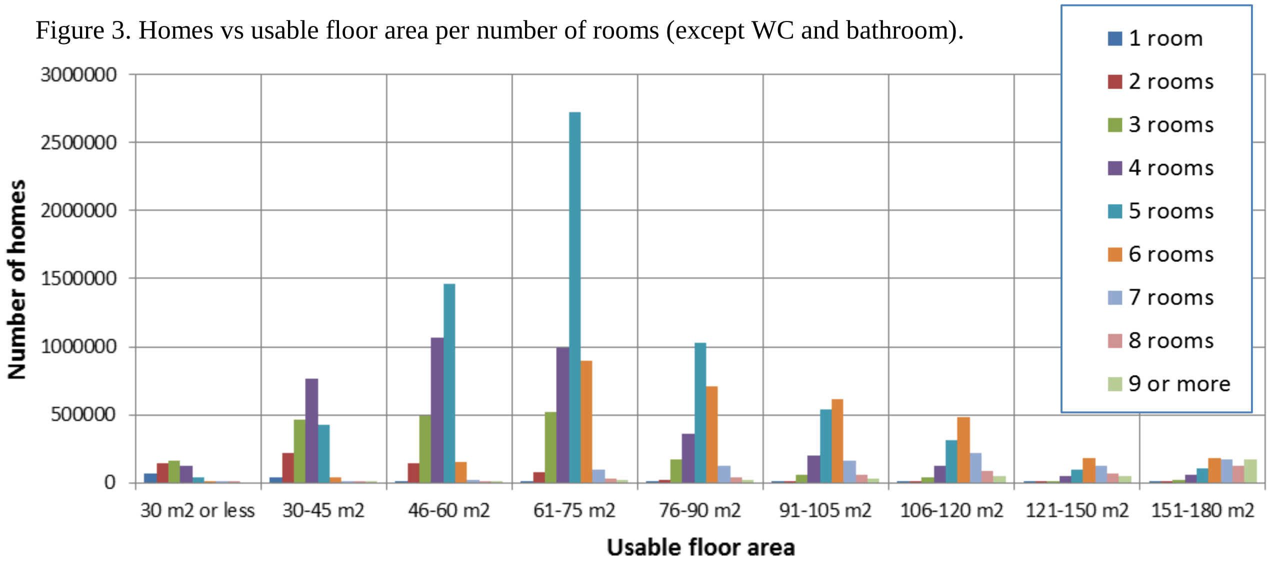


Figure 3. Homes vs usable floor area per number of rooms (except WC and bathroom).



4 PARAMETERS

The most relevant parameters that have been taken in to account are:

- CO_2 generation: 19 l/s (light to moderate intensity activities), 12 l/s (sleeping).
- Occupancy schedule: according to proposed IAQ.
- Occupancy ratio: according with *Population and Housing Census 2011*.
- Dwellings design: according with *Population and Housing Census 2011*.
- Software: CONTAM *Multizone Airflow and Contaminant Transport Analysis Software*.

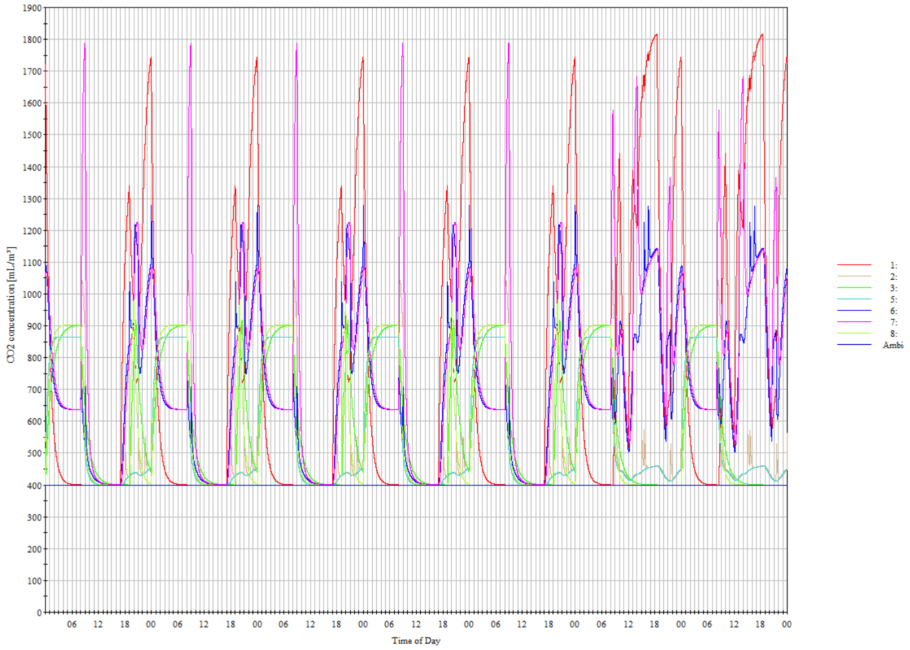
5 CURRENT IAQ REQUIREMENT RESULTS

The current regulation provide good results in general. Only shows a high CO_2 accumulated value when the kitchen usable floor area is too small. In this case, the accumulated above 1600 ppm per year exceed the 1600 ppm. The highest CO_2 concentration are in the in the kitchen, because of the expected high occupants activity (high CO_2 generation) and the expected high number of people present in the kitchen at the same time. Usually living room and kitchen have the high average. In the bedrooms, nigh average of 900ppm become a yearly average of 550-600 ppm.
Table 3 shows the obtained CO_2 results for the case studies with a continuous ventilation rates that provide fulfilment of the current IAQ requirement.

Table 3. Results with continuous ventilation rates that provide fulfilment of the requirement.

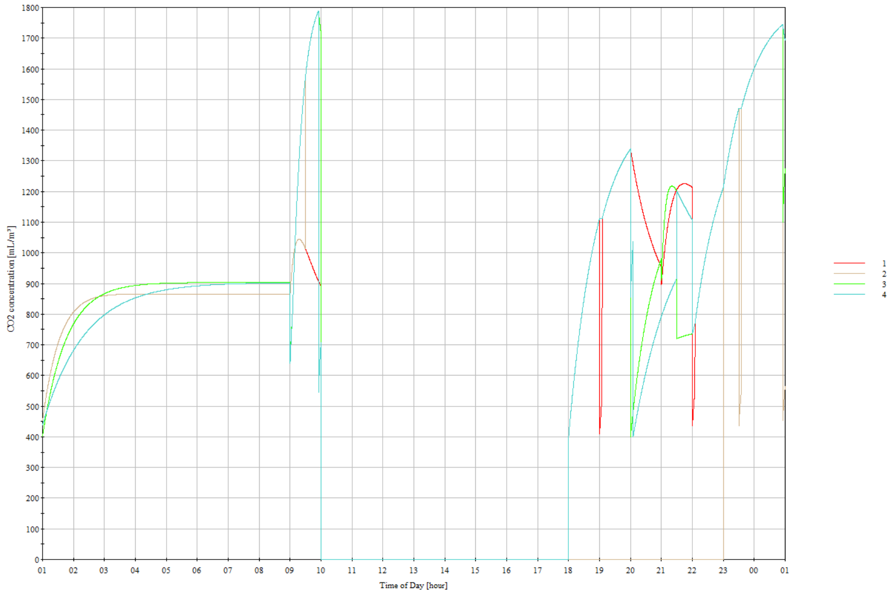
	Occupants	**Kitchen usable floor area**	**WC and bathrooms**	**CO_2 yearly average per room (highest value)**	**Accumulated above 1600 ppm per year**	**Continuous ventilation rate**	
Dwelling	**Number of**	**m^2**	**Number of**	**ppm**	**ppm/year**	**l/s**	**h^{-1}**
3B	4	5.87	2	Kitchen 765	Living 1375332	42	0.7870
3C	4	8.47	2	Kitchen 756	Cocina 60084	47	0.7805
3D	4	10.65	2	Kitchen 660	0	51	0.9180

Figure 4a. Dwelling 3B: CO_2 concentration evolution per room during a week.



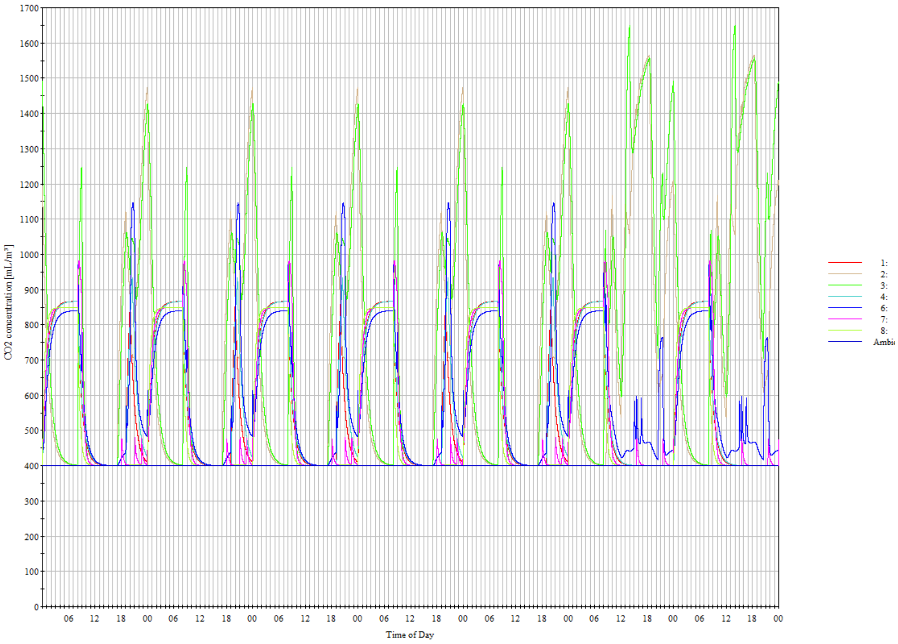
1: Living | 2: Bathroom (en-suite) | 3:Bedroom 3 | 5: Double principal bedroom (suite)
6: Bathrrom 2 | 7: Kithchen | 8: Bedroom 2 | Last one: Ambient

Figure 4b. Dwelling 3B: Occupants exposure during a working day in the dwelling



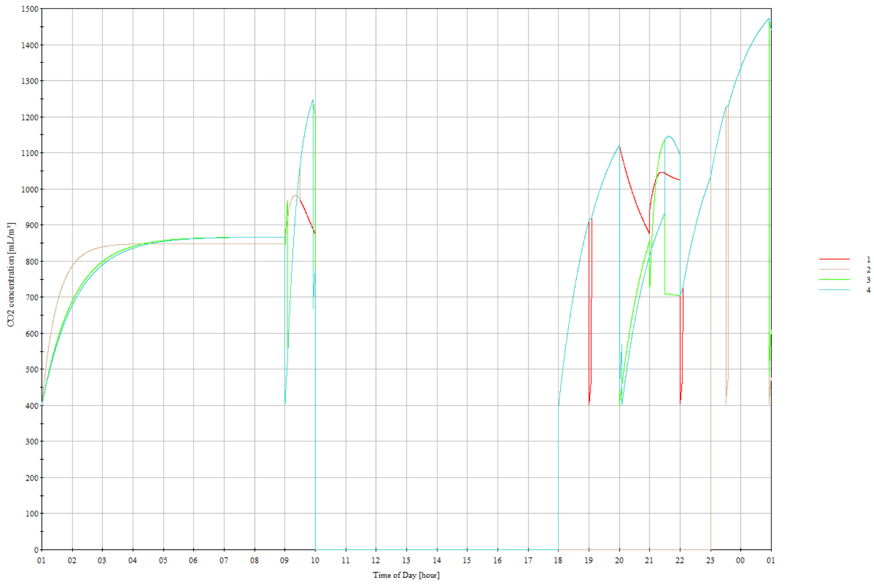
1: occupant 1 2: occupant 2 3: occupant 3 4: occupant 4

Figure 5a. Dwelling 3C: CO_2 concentration evolution per room during a week.



1: Bedroom 2 2: Living 3: Kithchen
4: Bedroom 3 6: Bathrrom 2 7: Bathroom (en-suite)
8: Double bedroom (suite) Last one: Ambient

Figure 5b. Dwelling 3C: Occupants exposure during a working day.



1: occupant 1 2: occupant 2 3: occupant 3 4: occupant 4

6 PROPOSE IAQ REQUIREMENT RESULTS

Non continuous ventilation rate allow reduces the total ventilation air flow because a reduction of ventilation during non occupancy periods also increase the ventilation ratio according with occupancy increase. The proposed IAQ open the door to non continuous ventilation flows and smaller global ventilation rates.

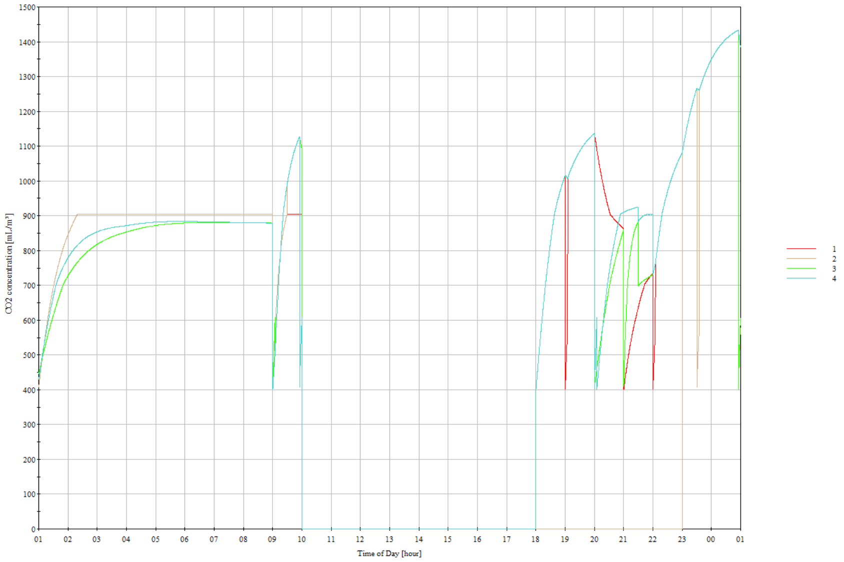
The obtained results show similar concentrations and occupant exposure to those ones obtained with the continuous flow establish in the current regulation.

A reduction of flow during non occupancy periods reduces the global rate. However, non ventilation during non occupancy periods is non recommended because there are other contaminants come from furniture and construction materials. There fore the flow during non occupancy periods have been set in a minimum valor. Simulations have been carried out with diferreent minimum valor of ventilation flow rate for the non occupancy periods: such as 20% of the maximum ventilation rates and 2 l/s.
Table 2 and figure 6 shows results for non continuous ventilation rates that provide fulfilment of the proposed requirement, with a 20% of the maximum ventilation flow during non occupancy periods.
It is easy maintain the accumulated above 1600 ppm per year bellow 0 in a simulation tool bases on CO2 concentration. But in a different control system, would be necessary have this item to control the punctual high concentrations.

Table 2. Non continuous ventilation rates that provide fulfilment of the requirement. 20% ventilation rate.

	Occupants	**Kitchen usable floor area**	**WC and bathrooms**	**CO_2 yearly average per room (highest value)**	**Accumulated above 1600 ppm per year**	**Global ventilation rate**	
Dwelling	**Number of**	**m^2**	**Number of**	**ppm**	**ppm/year**	**l/s**	**h^{-1}**
3B	4	5.87	2	Living 697	0	37.8	0.71
3C	4	8.47	2	Living 688	0	38.5	0.64
3D	4	10.65	2	Living 700	0	38.1	0.69

Figure 6. Dwelling 3D: Occupants exposure during a working day.



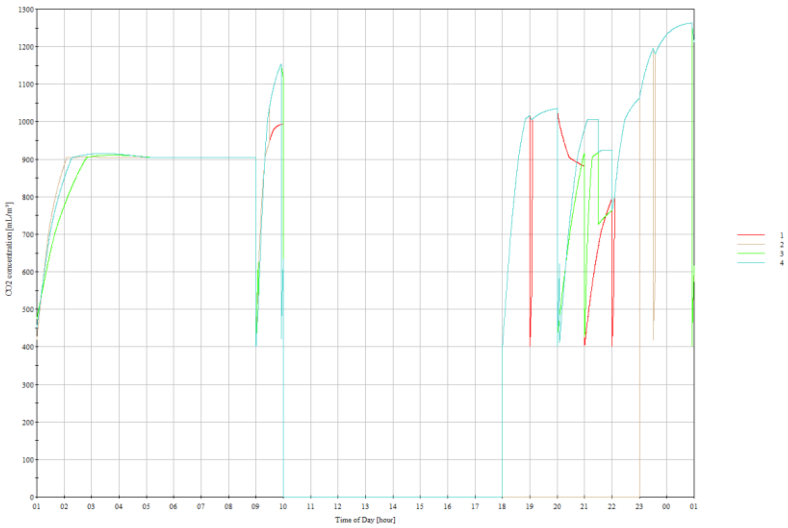
1: occupant 1 2: occupant 2 3: occupant 3 4: occupant 4

Table 3 and figure 7 shows results for non continuous ventilation rates that provide fulfilment of the proposed IAQ requirement too. In this case, the ventilation per room during non occupancy periods are always 2l/s.

Table 3. Other variable ventilation rates possibility: 2l/s not occupancy ventilation flow.

	Occupants	**Kitchen usable floor area**	**WC and bathrooms**	**CO_2 yearly average per room (highest value)**	**Accumulated above 1600 ppm per year**	**Global ventilation rate**	
Dwelling	**Number of**	**m^2**	**Number of**	**ppm**	**ppm/year**	**l/s**	**h^{-1}**
3B	4	5.87	2	Living 683	0	29.64	0.55
3C	4	8.47	2	Living 690	0	30.45	0.51
3D	4	10.65	2	Living 688	0	30.16	0.55

Figure 7. Dwelling 3D. Working day occupants exposure. 2l/s non occupancy ventilation flow.



It is possible optimize the ventilation rates in order to minimize the global rate according to the proposal IAQ by providen the maximum flow when 1400ppm CO_2 concentration is reach. The maximum ventilation when concentration reach 1400pppm is the maximum concentration according to 900ppm average in the whole time. The results show:

- the global ventilation rate is smaller;
- the IAQ is fulfill the DB HS3 requirements;
- the occupant exposure average (time at home) is high (see figure 8), compared with figure 6 and 7, but the locals concentration averages maintain under 900ppm (see figure 9).

Table 4. Non ventilation flow during non occupancy periods

	Occupants	**Kitchen usable floor area**	**WC and bathrooms**	**CO_2 yearly average per room (highest value)**	**Accumulated above 1600 ppm per year**	**Global ventilation rate**	
Dwelling	**Number of**	**m^2**	**Number of**	**ppm**	**ppm/year**	**l/s**	**h^{-1}**
3B	4	5.87	2	Bedroom3 885	0	15.13	**0.28**
3C	4	8.47	2	Bedroom3 893	0	15.37	**0.26**
3D	4	10.65	2	Bedroom2 856	0	15.13	**0.27**

Figure 8. Dwelling 3D. Working day occupants exposure. No ventilation flow during non occupancy periods and focus only in reduce global ventilation rates.

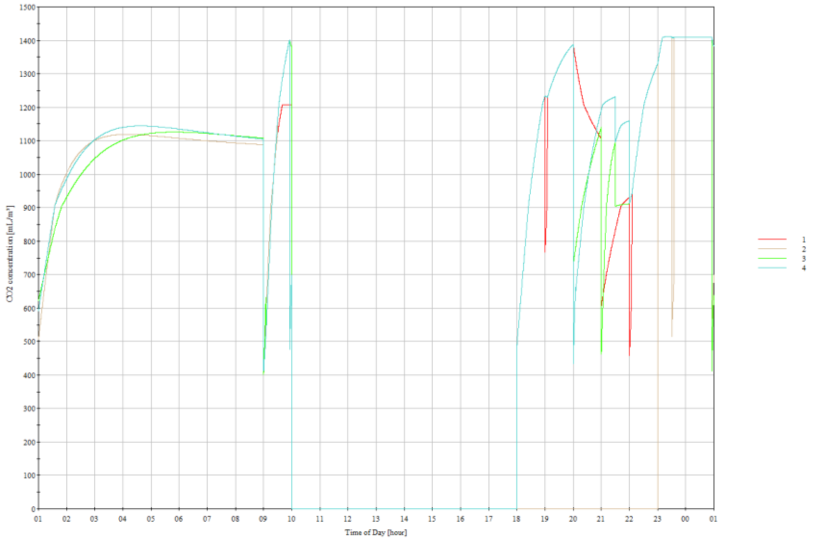
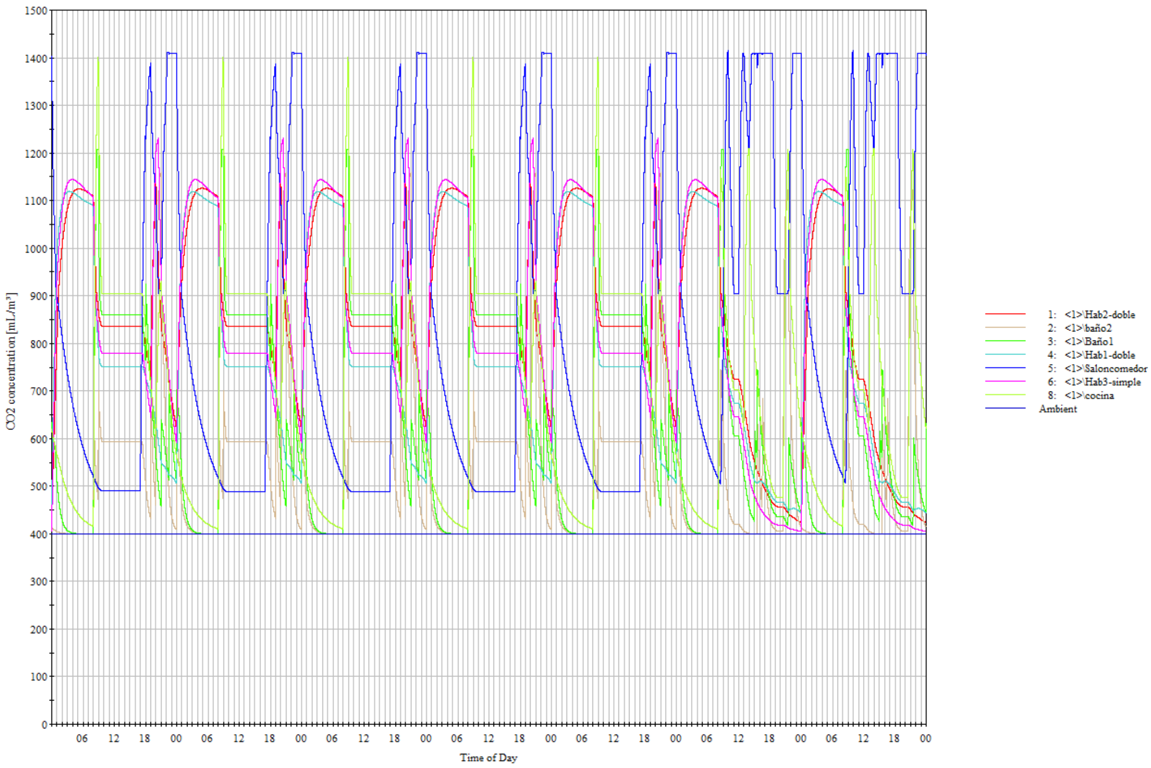


Figure 9. Dwelling 3D CO_2 concentration evolution per room during a week.



1: Bedroom 2   2: Bathroom 2   3: Bathroom 1 (in suite)   4: Double principal bedroom (suite)
5: Living   6: Bedroom 3   8: Kitchen   Last one: Ambient

4 CONCLUSIONS

This study shows how it should be possible, for one of the most common dwellings distribution in Spain, to reduce the ventilation rates. This is possible using non continuous

ventilation flow rates, according with the proposed requerements for the IAQ regulations, saving energy for heating and cooling without impacting air quality.
However, not any ventilation rates provide adecuates IAQ levels. Assessment much be carried out in each case to optimize this rates, taking in to account providing minimum ventilation rates for non occupancy periods is highly recommended.
Some possibilities according with the proposed IAQ regulation decreased the IAQ respect the continuous flow.
The lower ventilation rates with a good IAQ could be obtained if the ventilation system can change the ventilation flow according with the number of occupants and the real needs.

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