ENERGY SAVING AS A CONSEQUENCE OF THE PROPOSED CHANGE IN SPANISH REGULATIONS RELATING TO INDOOR AIR QUALITY.

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ABSTRACT

Recently research at the Eduardo Torroja Institute for construction sciences proposes a new wording for the IAQ regulations for dwellings included in the Spanish Building Code.

The main goal of the earlier research was to adapt required ventilation rates to real needs to achieve a reduction of ventilation rates and energy demand with no negative impact on indoor air quality.

This goal will be achieved by firstly setting maximum values of CO_2 concentration as an indicator of air quality (allowing the use of variable ventilation rate systems), and, secondly, by deriving a table summarizing the minimum continuous ventilation rate threshold values that provide this air quality. As a result, it will be easier to optimize energy demand using either variable flow or lower continuous flow ventilation systems.

For this research, IAQ simulations and energy saving assessment have been performed. IAQ simulations have been developed to optimize the continuous ventilation flows. In this paper the results of the energy saving assessment are presented for different types of dwellings, according to the number of bedrooms and bathrooms and for two distinct Spanish climatic zones. Results show how it should be possible to achieve target CO_2 concentration values in addition to conserving energy.

KEYWORDS

Ventilation, IAQ, regulations, energy saving

1 INTRODUCTION

The current Spanish Building Code came into force in 2006, including IAQ provisions for dwellings. The provision of the code at that time represented a big regulatory step. However, these provisions are not as performance-oriented as was initially anticipated, requiring minimum rates for delivery-to and extraction-from the habitable rooms. These rates are not adjustable, so ventilation systems based on variable ventilation rates are not normally deemed acceptable, unless a comprehensive statement of compliance is provided, justifying the proposed ventilation solution.

In 2010, with the adoption of the recast EPBD, EU Member States faced new challenges. The revised goal is to increase the level of performance - by 2020 - to nearly-zero energy buildings. In order to achieve this goal in Spain, a deep review of the energy requirements was performed in 2013, leading to increased energy efficiency of buildings; though this was deemed insufficient as energy efficiency in buildings is affected as well by ventilation systems.

Therefore the use of variable ventilation systems is desirable, as it would almost certainly produce a reduction of the global ventilation rate and, consequently, a reduction of the heating and cooling energy demand, while maintaining a good level of air quality.

As a consequence, research is now in progress to modify the Spanish regulations to accommodate the use of more efficient systems which are capable of adapting required ventilation rates to real needs. This would mean a reduction in ventilation rates and energy demand but without impact on indoor air quality.

This paper presents the results of the ongoing research that shows how the IAQ requirement can be modified keeping acceptable IAQ values and reducing energy demand.

2 RELEVANCE OF ENERGY DEMAND CAUSED BY VENTILATION

In the European Union it is commonly understood that buildings are responsible for 40% of final energy consumption and 36% of carbon dioxide emissions. For this reason, a reduction of energy consumption and increased use in the building sector of energy from renewable sources can be an important part of measures to reduce energy dependence of the Union and emissions of greenhouse gases. Member States should take adequate measures to ensure that minimum energy performance requirements are set for buildings in order to achieve cost optimal levels.

In Spain, the construction sector has a significant impact on both the country's overall energy consumption and emissions of greenhouse gases. Housing and tertiary buildings represent 26% of global energy consumption, residential sector accounting for 17% of total final consumption. The estimated emissions for each household are more than one ton. This situation is characterized by high external energy dependence, which is close to 80% and well above the European average of 54%.

It is important to highlight the significant technical advances that have occurred in the Spanish building sector since the enforcement in 2006 of the Spanish Building Code (and its energy saving requirements), and more recently in 2013 the approval of the reviewed energy requirements.

Energy demand related to ventilation losses and lack of airtightness is significant. Loads related to air renovation in dwellings can be estimated at 20-40% of total loads produced by heating and cooling. Therefore it is necessary to improve IAQ regulations to reduce the related energy demand.

3 CURRENT IAQ REQUIREMENT

The current IAQ requirement establishes minimum ventilation rates (see Table 1) for delivery-to and extraction-from habitable rooms. These rates have to be provided in a continuous way.

Table 1. 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		2 l/s	

4 PROPOSED IAQ REQUIREMENT

IAQ level is usually characterized by a maximum level of pollutants that may affect people´s health and comfort and which could be achieved by different ventilation systems.

However, common pollutants are not easy to assess, so an indicator is commonly taken to represent the state of the rest of the pollutants. Among the possible pollutants that are commonly produced indoors, CO_2 is the most commonplace and closest related to human activity. Despite the fact that CO_2 does not entail any health risk in the commonly encountered concentrations, CO_2 is nevertheless a reliable indicator of ventilation rate, for which reason it is the most common indicator used in regulations and guides.

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. This parameter shows the relationship between the CO_2 concentrations reached above a limit value and their duration over a year. It can be calculated as the sum of the areas (in ppm•h) within the representation of the CO_2 concentration as a time function and the limit value.

These required concentration levels shall be achieved under certain design conditions (such as occupancy scenarios, CO_2 production rate, yearly average outdoor CO_2 concentration, etc.), that should be set in the regulation. That is, it is a “design performance” because it can only be measurable *in situ* under these conditions.

5 PROPOSED VERIFICATION METHOD

Fulfilment of the requirement is achieved through expert methods (such as specialized software), but it is convenient for the regulations to provide a simplified verification method for designers. This simplified method shall be easy to use by non-expert practitioners and will consist of a table with different ventilation rates (continuous) that will provide fulfilment of the requirement for different dwelling types.

The dwelling case studies that have been chosen for the assessment have been classified taking into account their bedroom and bathroom counts (See Table 2). They are real dwellings representative of the ones that have been recently built (the Spanish population and dwelling census has been used).

Table 2. Dwellings case study

Kind and composition of dwelling	**Case study**
Flat: Living/Kitchen+1 Bedroom+1 Bathroom	1
Flat: Living+Kitchen+2 Bedrooms+2 Bathrooms	2
Flat: Living+Kitchen+3 Bedrooms+2 Bathrooms	3
Flat: Living+Kitchen+4 Bedrooms+2 Bathrooms	4
Terraced house: Living+Kitchen+4 Bedrooms+2 Bathrooms	5

These ventilation rates are obtained from the results of an analysis of CO_2 concentration with pollutants distribution software CONTAM. CONTAM is a multi-zone airflow and contaminant transport analysis software application developed by the National Institute of Standards and Technology (NIST-US).

This analysis consists of simulating these dwellings (with an occupancy scenario) with different ventilation rates in order to optimize them achieving the required IAQ requirements.

Table 3 shows, for the different dwelling case studies, the lowest continuous ventilation rates that fulfil IAQ requirements.

Table 3. Continuous ventilation rates values

Dwelling case study	**Continuous ventilation rate (1) (l/s)**	**Total whole dwelling continuous ventilation rate (l/s)**	**Yearly average CO_2 concentration (2) (ppm)**	**Yearly accumulated over 1.600 ppm (2) (ppm·h)**
1	6	12	816	0
2	8	24	812	145860
3	11	33	789	150020
4	11	33	848	247000
5	8	24	826	105560

(1) In kitchen and each bathroom.
(2) The highest value per room in each dwelling.

6 ENERGY DEMAND ASSESSMENT

The energy demand assessment has been carried out using *Herramienta Unificada Lider-Calener* (HULC, June 2015). HULC is a whole building energy simulation program that is used to assess energy demand and consumption. It comprises the earlier software tools LIDER and CALENER, allowing both assessment of energy qualification and fulfilment of the energy saving requirements updated to 2013 changes. It is offered by the *Ministerio de Fomento* and the *Ministerio de Industria, Energía y Turismo - Instituto para la diversificación y ahorro de la energía* (IDAE) (Spain), having been developed by *Grupo de Termotecnia de la Asociación de Investigación y Cooperación Industrial de Andalucía*, (AICIA), *Escuela Técnica Superior de Ingenieros* from *Universidad de Sevilla*, with the collaboration of *Unidad de Calidad en la Construcción* from *Instituto Eduardo Torroja de Ciencias de la Construcción* (IETCC-CSIC).

The assessment has been developed for:

- five dwellings (see table 2),
- ventilation rates from the current IAQ regulations (see table 1) and rates obtained from the proposed requirement (see table 3),
- cooling and heating demand,
- two climatic zones,
- two orientations: North and South, to assess the effect of solar gain, which is quite important in Spain.

In the case of the flats, in order to assess the most exposed case, top floor dwellings were considered.

The Spanish Building Code classifies Spain in 24 climatic zones according to several parameters such as temperature, relative humidity, solar radiation…These climatic zones are characterized by two digits: a letter which refers to winter conditions and a number which refers to summer conditions. The chosen climatic zones are A3 (Cádiz) and D3 (Madrid), both with similarly extreme summer climates but different winter climates, *A* being mild and *D* severe.

Table 4 shows the composition for the building envelope. The width of the insulation and the air permeability of windows have been set to fulfil energy saving regulations in each climatic zone. In the case of the more extreme climate, insulation is thicker and permeability is smaller. In D, air permeability is lower than 27 $m^3/h \cdot m^2$, and in A, lower than 50 $m^3/h \cdot m^2$, using in both cases timber windows double glazed 4/12/4 mm.

Table 4. Composition of buildings ‘envelope

	Composition	**Width (m)**	**Conductivity (W/m·K)**
Façade walls	Solid brick wall	0.115	0.991
	Cement mortar render	0.015	0.55
	Not ventilated cavity	0.050	-
	Rockwool insulation board	0.080/0.060 (1)	0.031
	Gypsum board	0.010	0.25
Roof	Gravel layer	0.150	2.00
	XPS insulation board	0.080/0.060 (1)	0.034
	Felt	0.005	0.05
	Waterproofing membrane	0.005	0.230
	Lightweight mortar	0.100	0.410
	Ceramic pot and beam slab	0.300	-
	Unventilated air space	0.010	0.15
	Gypsum board suspended ceiling	0.010	0.25

(1) The first value corresponds to D3 and the second one to A3.

7 RESULTS

Table 5 shows the results of the energy demand assessment.

Table 5. Energy demand

Dwelling case study	**Climatic zone**	**Orientation**	**Energy demand**					
			Current IAQ requirements [Kw·h/m²·year]		**Proposed IAQ requirements [Kw·h/m²·year]**		**Reduction (%)**	
			Heating	**Cooling**	**Heating**	**Cooling**	**Heating**	**Cooling**
1	D3	North	64.66	12.43	30.62	11.26	53	9
		South	39.25	15.25	9.78	14.4	75	6
	A3	North	14.8	12.42	3.95	11.43	73	8
		South	0.93	15.13	0	14.49	100	4
2	D3	North	68.2	10.6	50.95	9.88	25	7
		South	49.49	13.43	33.09	12.82	33	5
	A3	North	18.14	10.59	11.8	9.92	35	6
		South	4.39	13.27	1.37	12.71	69	4
3	D3	North	54.94	12.87	43.39	12.47	21	3
		South	33.73	18.25	23.51	18.01	30	1
	A3	North	11.89	12.86	8.17	12.49	31	3
		South	1.09	18.18	0.15	17.97	86	1
4	D3	North	51.32	11.07	31.77	10.35	38	7
		South	41.87	13.95	23.22	13.33	45	4
	A3	North	11.36	11.08	5.21	10.45	54	6
		South	4.8	13.93	1.07	13.36	78	4
5	D3	North	53.03	13.8	23.6	12.83	55	7
		South	47.2	15.08	19.01	14.18	60	6
	A3	North	7.34	13.57	0.83	12.65	89	7
		South	4.58	14.79	0.13	13.97	97	6

8 CONCLUSIONS

The results of this study show how it should be possible to achieve target IAQ requirements based on lower continuous ventilation rates than the ones that are currently required, thus saving energy for heating and cooling without impacting air quality.

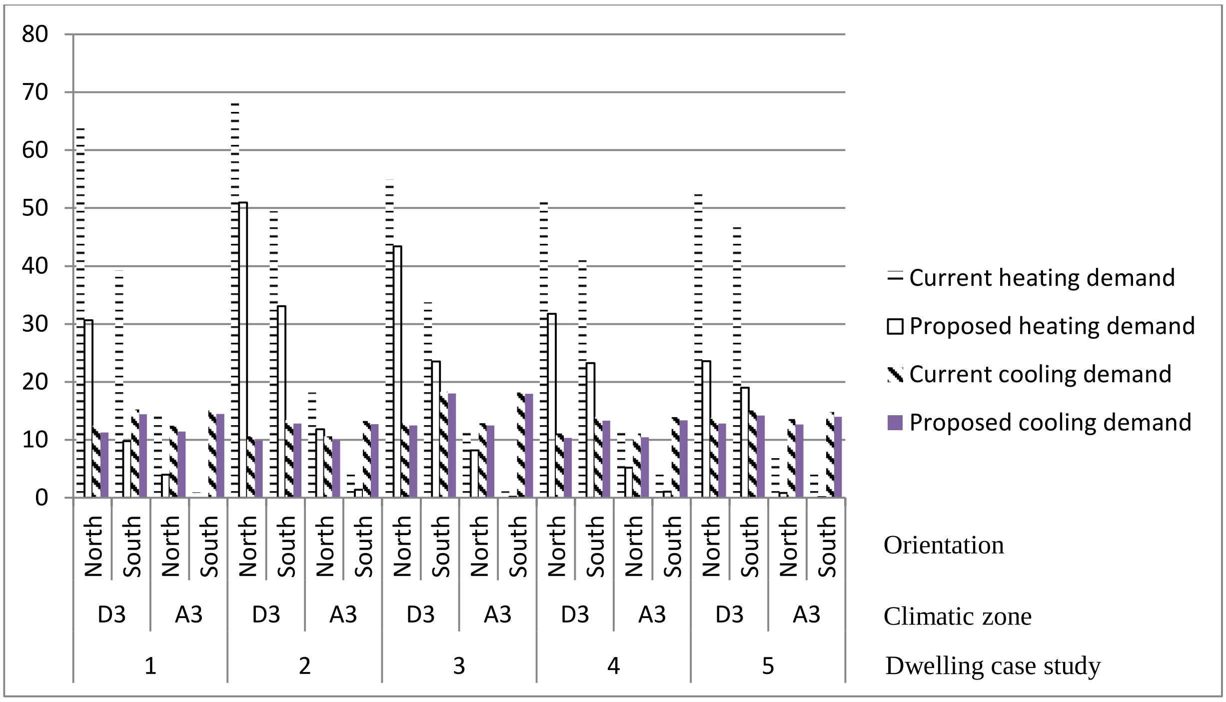

Figure 1. Energy demand comparison

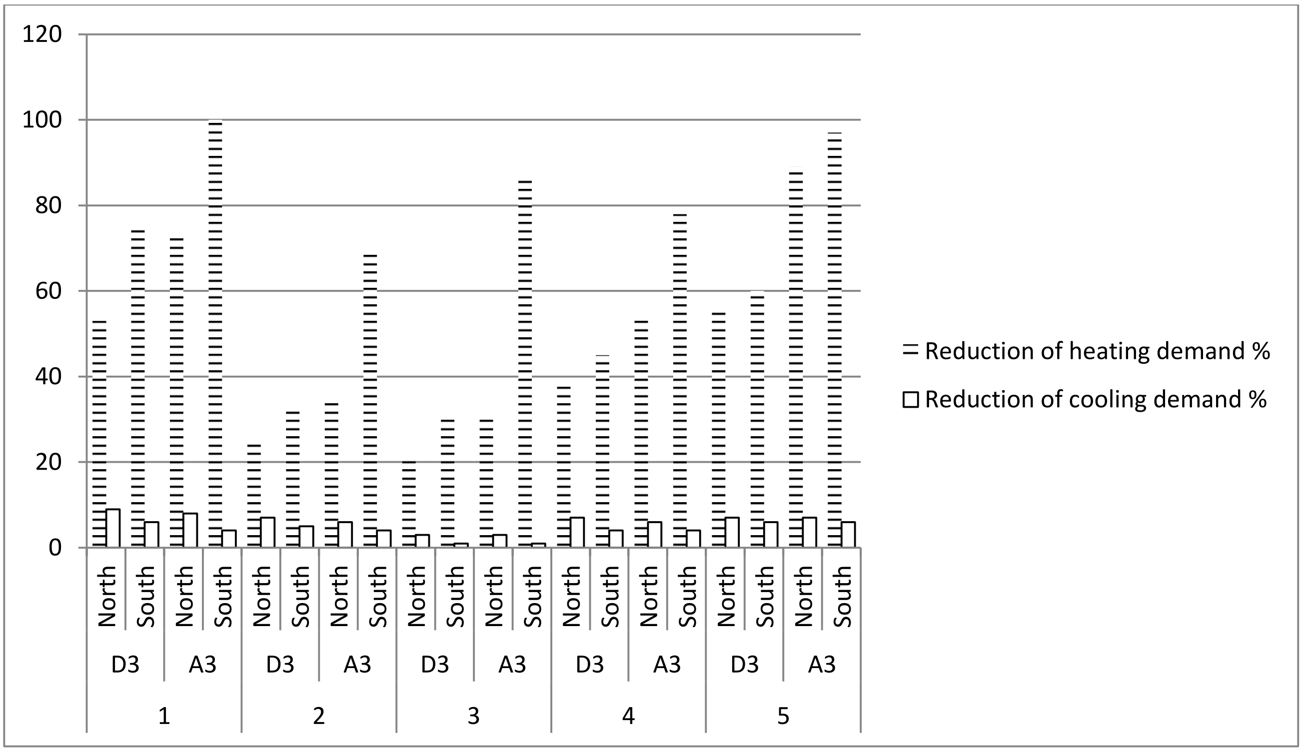

Figure 2. Reduction of demand

In all cases both energy demands get reduced, although the reduction is much bigger for heating ranging from 21 to 100%.

The most sensitive climatic zone and orientation are respectively A3 and South.

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