Decarbonization and IAQ in Spain: a roadmap

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ABSTRACT

The presentation provides a brief overview of the current situation and a roadmap for decarbonizing the building stock under the context of EU directives. It also discusses how it could be implemented into Spanish building regulations. It examines the evolution of energy and emissions indicators and how they can help tackle the electrification of uses, generalized on-site energy generation, energy storage or building interaction with the grid. Several aspects of indoor air quality are involved in these challenges, including the increasing share of energy use due to ventilation and infiltration as well as the greater prevalence of energy recovery and free cooling capable systems. Further, additional questions arise from the differences in the scenarios used for energy efficiency and IAQ evaluation.

KEYWORDS

Decarbonization, roadmap, IAQ

1 INTRODUCTION

This article aims to provide a current overview of the decarbonisation process between now and 2050 in the European framework, and its transposition into Spanish energy policy and regulations, paying particular attention to those aspects related to building ventilation and indoor air quality.

1.1 European strategy for the decarbonisation of the building stock

The current revision of the Energy Performance of Buildings Directive 2010/31/EU [1] (EPBD) establishes a scenario for the decarbonisation of the European building stock by 2050 with the aim of mitigating climate change by reducing greenhouse gas emissions. It sets a target for all new and existing buildings to be zero-emission buildings by 2050, as well as a number of intermediate milestones, such as those committed to in the so-called European Green Pact [2], a consequence of the Paris Agreement, with a 55% reduction in net greenhouse gas emissions by 2030 compared to 1990 levels, and a further intermediate level by 2040.

The baseline scenario for the EU building stock from which to reach this target is as fo-llows:

- 40% of the EU's final energy and 36% of its emissions are accounted for by buildings,
- 75% of the building stock is inefficient according to current building standards,
- buildings are responsible for about half of the primary fine particulate matter (PM2.5) emissions in the EU, leading to premature deaths and illness.

With this starting point, the European strategy to decarbonise the building stock is based on increasing the rate and depth of building renovations, especially of the most inefficient building stock, as well as improving information on energy efficiency and sustainability, so that this information enables end-users and technicians to make more climate-friendly decisions.

In order to achieve this global objective of climate neutrality, aspects such as the definition of a zero-emission building must be specified. According to Article 2 of the Directive itself, a zero-emission building is a building with a very high energy efficiency (determined in accordance with Annex 1, which states that it shall be expressed by an indicator of primary energy consumption per unit area per year [kWh/m^2]) in which the small amount of energy that is still needed is fully covered by energy from renewable sources generated on-site, from a renewable energy community or from a district heating and cooling system in accordance with the requirements of Annex III.

Therefore the relationship between those defined so far by the EED as nearly zero-energy buildings (NZEB) and zero-emission buildings is that in the latter all the energy used must be from renewable sources, whereas previously it had to be the majority.

Other aspects of the decarbonisation strategy (as set out in the proposal to amend the Energy Efficiency Directive [3] and in Directive 2018/2001 on the promotion of the use of energy from renewable sources [4]) involve the generalisation of renewable production, taking into account the potential of buildings and on-site production, the transformation of mobility, which is also closely linked to buildings, the energy supply networks, which interact with buildings, especially the electricity grid, the potential for energy storage, etc.

1.2 Decarbonization milestones

The strategy and framework established by the directive on the energy efficiency of buildings is specified in milestones and requirements such as that new buildings must be zero-emission buildings by 2027, in the case of public buildings, and by 2030, in all other cases.

In addition, existing buildings must become zero-emission buildings by 2050, with intermediate energy efficiency targets to allow a progressive approach.

The following table shows the entry into force and expected scope of these intermediate requirements, called MEPS (Minimum Energy Performance Standards):

Table 1: Range of energy efficiency scenarios for existing buildings at the intermediate milestones (MEPS)

	Commission Approved Proposals by 15 december 2021 [3]		European Parlament Amendments		European Council Amendments	
Public properties buildings	F in 2027	E in 2030	E in 2027	D in 2030		
Non residential private buildings	F in 2027	E in 2030	E in 2027	D in 2030		
Residential private buildings	F in 2030	E in 2034	E in 2030	D in 2033		
Residential buildings					D in 2033	B in 2040
Non Residential buildings					15% worst in 2030 25% worst in 2034	

2 DECARBONISATION IN SPANISH REGULATIONS

2.1 Technical Building Code (Código Técnico de la Edificación, CTE) and Energy Certification of Buildings (Certificación energética de edificios, CEE)

Spanish regulations incorporate the latest updates of the European Directive until 2021 and are currently in the process of revision to adapt them to the latest revisions of the EPBD. It is foreseeable that an update of the affected standards may be published during 2024.

Within the state regulatory structure related to building, we have different documents and procedures that allow the total transposition of the European directive, setting the objectives established in it:

1. Within the Spanish Technical Building Code, the Basic Document on Energy Saving (DB-HE) (RD 314/2006) [4] is the one that develops and transposes a large part of the objectives of the EPBD.

   It is the technical standard applicable to newly constructed buildings and existing buildings when certain interventions are carried out in them, and aims to ensure that adequate conditions of habitability and comfort of its occupants are achieved by making rational use of energy, reducing its consumption to sustainable limits and ensuring that a large part of this consumption comes from renewable sources.

   The DB-HE sets, in relation to energy consumption, two global indicators, evaluated following the calculation methodology established in the UNE-EN ISO 52000-1:2019 Overall assessment of the energy performance of buildings. Part 1: general framework and procedures:

   - the total primary energy consumption ($C_{ep,tot}$), which limits the total energy needs of the building, including energy from renewable sources.
   - primary energy consumption from non-renewable sources ($C_{ep,nren}$), which limits the use of non-renewable resources.

   The calculation of these indicators has to be done with hourly calculation procedures and so far only the consumed resources are evaluated (step A in terms of EN ISO 52000-1) and the positive impact of energy export to the grid is not taken into account (grid export factor k_exp=0).

2. On the other hand, the Energy Certification of Buildings (EEC), developed in Royal Decree 390/2021, of June 1, approving the basic procedure for the certification of the

energy efficiency of buildings [7], is established as an instrument of information to the end user, without prescriptive value. It shares calculation methodology with the DB-HE, and uses as main indicators:

- CO_2 emissions in the use phase of the building
- the consumption of primary energy from non-renewable sources (C_ep,nren), which shares with DB-HE

3. Finally, the Long-term Strategy for the Energy Rehabilitation of the Building Sector in Spain (ERESEE) [8], which was last updated in 2020, addresses the rehabilitation of the existing building stock by setting a roadmap with intervention scenarios, concrete measures and progress evaluation indicators to achieve the energy rehabilitation of the building stock and the decarbonization of the sector by 2050. It is currently being revised and transformed into a National Building Rehabilitation Plan (PNRE), the draft of which will be presented in 2025.

2.2 Evolution of technical regulations

In the roadmap towards decarbonisation, the evolution of Spanish regulations proposes to establish the following lines in line with the objectives of the EPBD:

- Progressive adjustment of the primary energy consumption limits already established in line with the zero emission buildings targets.

- Incorporation of global CO_2 emissions through LCA (Life Cycle Assessment). The current adjustment of the energy efficiency of the building in its use phase due to the development and implementation of energy saving regulations, means that it represents a smaller and smaller percentage of the total CO_2 emissions related to the building from the cradle or construction cycle (choice of materials, systems, origin of products and transport, etc.) to its demolition or demolition. Thus, the revision of Directive 2010/31/EU on the energy performance of buildings establishes the Global Warming Potential (GWP) of buildings, which must be calculated in accordance with standard EN 15978:2011. *Sustainability in construction. Assessment of the environmental performance of buildings. Calculation methods* (9), and to be incorporated in energy certificates for new buildings between 2027 and 2030.

- Electric vehicles are expected to play a crucial role in decarbonization as well as the use of soft mobility, to which building codes are already contributing and should continue to do so by:
  - the implementation in buildings of charging infrastructure in parking lots (through the obligation of pre-wiring, for example, and the minimum number of charging points in relation to the total number of parking spaces)
  - establishing requirements for a minimum number of parking spaces for bicyclesElectric vehicles are expected to play a crucial role in decarbonisation as well as the use of soft mobility, so building codes are already contributing and should continue to do so through.

- The disappearance of fossil fuel systems by 2030, prohibiting their sale and installation.

- Electrification of building uses and services (EPB uses) and decarbonisation of supply networks. The implementation in the regulations of the possibility of

exporting on-site renewable electricity production for evaluation within the energy efficiency of the building (kexp=1), will favour and feed back into the use of electrical systems that meet the demands of the EPB uses of the building and allow the amount of energy they still need to use to be fully covered by energy from renewable sources.
Taking into consideration the export factor to the grid (k_{exp}) will imply a modification of the interaction of the building with the grid, which will affect the possibility of self-consumption of the building itself and the possibilities and facilities for thermal and electrical storage, which in the case of the electric vehicle can establish an interaction with the building as a recharge battery in one direction or the other.

3 DECARBONISATION AND ITS RELATION TO BUILDING VENTILATION

3.1 Ventilation and energy impact

3.1.1 The weight of ventilation and infiltration in energy demand

With the progressive increase in insulation levels required by regulations and the growing use of renewable inputs in services such as DHW, the exchange of air with the outside is having an increasing impact on the energy performance of the building. It is therefore important to adjust ventilation flow rates to the actual conditions of use, control air infiltration, use heat recovery and air treatment strategies or take advantage of free cooling possibilities by controlling ventilation.

The following graph shows the impact, in terms of consumption, of different ventilation flow rates and the use of heat recovery units in a residential building located in Madrid, a D3 climate with a heating degree-day (HDD18) of 2225 and a cooling degree-day (CDD25) of 175:

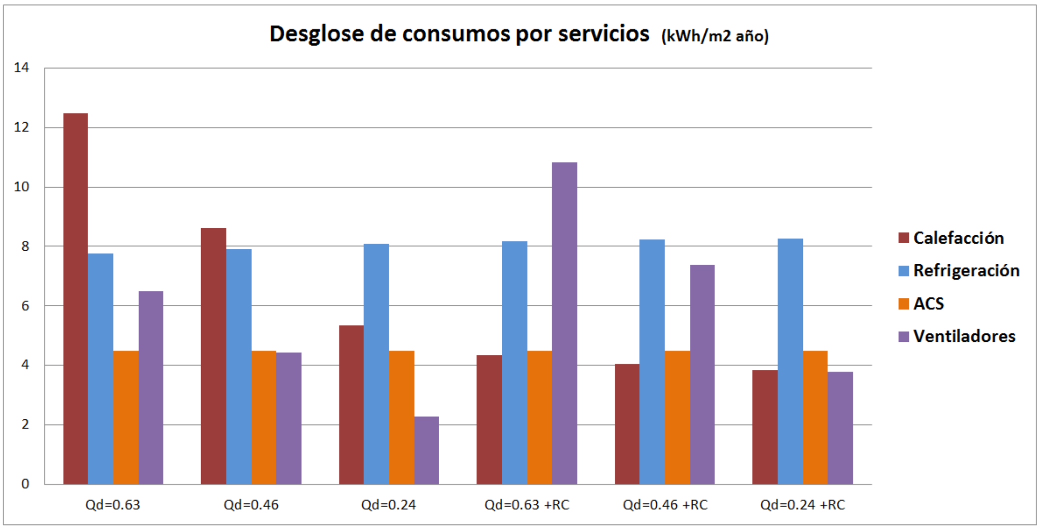

Figure 1: Graph of analysis of energy consumption broken down by services for a residential building in Madrid (D3 climate zone). Qd: Design flow rate; RC: Heat recovery unit.

3.1.2 Evolution of ventilation-related requirements

Due to the significant impact on the building's energy performance of air exchange with the outside, partly derived from ventilation requirements, it is of vital importance to adjust and control the associated consumptions.

In this line, in the evolution of the CTE DB-HE, work is being done on several fronts:

1. Adjustment of ventilation flow rates and use of demand-controlled ventilation systems;
2. Improving the airtightness treatment of the thermal envelope and the use of heat recovery systems and other ventilation techniques.
3. Ventilation systems and retrofitting

3.2 Adjustment of ventilation flow rates

3.2.1 Discrepancies in the calculation of ventilation flow rates

In the Technical Building Code [5] the energy model and the air quality model do not agree exactly in relation to the flow rates considered since:

- There are differences between the volume of the habitable premises considered for air quality purposes (CTE DB-HS / RITE) with respect to the volume of the thermal envelope of the CTE DB-HE: within the thermal envelope there may be distribution spaces, lobbies, technical rooms, etc... that are not part of the dwellings, which normally have lower ventilation needs and, although their ventilation needs should be taken into account in a differentiated manner, the reality is that they are usually assimilated to the flow rates required for the living areas, not always ensuring the same, and increasing the ventilation flow rate of the building for the purposes of the energy calculation.

- There are also differences in the use scenarios: the design flow rate for air quality control is set in relation to the maximum required flow rate and this is usually transferred mechanically as the representative average flow rate, again increasing the ventilation flow rate in the energy calculation.

As a result, unnecessarily high levels of existing ventilation flow rates are often used for energy modeling, which tend to overestimate both the energy impact of such service and the potential savings derived from its control without any benefit in terms of air quality.

It seems necessary to make progress in clarifying the calculation of ventilation flow rates to be used in the energy calculation and their relationship with those derived from air quality requirements.

3.2.2 Demand-controlled ventilation systems

Both CTE DB-HS and RITE establish their ventilation requirements to ensure the indoor air quality of buildings in performance terms, using CO2 as the main indicator, so that a precise adjustment of ventilation needs can be reflected in better energy performance.

In recent years there has been a popularization and cheapening of ventilation equipment capable of adjusting effective ventilation levels to specific needs at any given time depending on occupancy levels or some pollutants, ensuring more reliable indoor air quality, making such a ventilation strategy feasible in more and more cases.

However, it is still relatively common that design flow rates derived from constant ventilation flow systems are still considered in the energy calculation. The use of demand-controlled ventilation systems can be expected to play an important role in reducing energy requirements in buildings and there is a need to clarify how they should be considered for energy calculation purposes, especially in less complex buildings and with simplified assessment tools.

3.3 Improved airtightness treatment

3.3.1 Air tightness of the thermal envelope as an energy efficiency strategy

As can be seen in the table, the air tightness values of the thermal envelope currently applied to new residential buildings are not particularly demanding. However, they have served to put on the agenda of the sector's technicians the importance of this parameter in controlling energy demand and avoiding the risk of undesirable infiltration levels from the comfort point of view.

Table of air permeability requirements (n50) for new residential buildings of more than 120m^2 of DB-HE1

Tabla 3.1.3.b-HE1 Valor límite de la relación del cambio de aire con una presión de 50 Pa, n_{50} [h^{-1}]

Compacidad V/A [m^3/m^2]	n_{50}
V/A <= 2	6
V/A >= 4	3

Los valores límite de las *compacidades* intermedias (2<V/A<4) se obtienen por interpolación.

An important issue to take into account is that, in mild climates, as is the case in much of Spain, with a reduced thermal gap between indoors and outdoors, the energy performance of more demanding levels of air tightness may be low and its interest will depend on other aspects such as the characteristics of the ventilation system, passive strategies used, etc.

While a higher level of infiltration is, in principle, favorable in terms of air quality, an excessive level is detrimental in terms of comfort and results in an unreliable supply of outside air. Moreover, in many climates, this uncontrolled air supply does not ensure minimum indoor air quality levels while maintaining a significant impact on the energy balance.

On the other hand, for the sake of energy efficiency, we must assess the potential risks associated with the lack of air permeability of buildings taking into account that, especially in residential buildings, the level of maintenance of facilities is very poor and entrusting the entire indoor air quality to increasingly complex technical systems in operation and maintenance may be questionable.

Thus, we believe that the indiscriminate tightening of the regulatory levels of airtightness of the building envelope is not advisable, having to evaluate the cases in which it is an appropriate strategy, but it seems necessary to improve the control of air permeability in some conflictive points of the envelope (passages of facilities, meeting of holes and walls, recessed boxes of facilities, etc ...) setting the obligation to adopt specific construction practices of detail in the execution of these elements, in order to minimize the problems of discomfort.

3.3.2 Use of exhaust air heat recovery systems

The reduction in regulatory levels of energy demand has made the advantages of reducing infiltration levels, to reduce the total air exchange with the outside, and the use of exhaust air heat recovery systems, to avoid energy losses due to air exchange, more interesting in terms of economic and energy efficiency. In many climates this is already an essential strategy.

When using exhaust air heat recovery it is very important to reduce infiltration levels to guarantee the energy efficiency of the heat recovery, to ensure that there is no significant air exchange outside the recovery equipment.

Although all equipment already includes thermal bypass systems and current regulations provide for their availability, we must remember that, in many climates and for many conditions of use, this is a key aspect of the operation of a ventilation system with heat recovery, at the risk of worsening the energy performance.

It would therefore be advisable to tighten the airtightness conditions in cases where heat recovery systems are used.

3.3.3 Other ventilation-based energy efficiency strategies

The need to ensure indoor air quality requires, in almost all cases, the use of technical systems capable of ensuring such performance.

In addition to heat recovery, other ventilation techniques such as free cooling, the use of thermal bypass in the presence of recuperators, etc. also play a relevant role and, although we believe that their regulatory treatment is, in general, adequate, it is probably necessary to improve their knowledge on the part of technicians and facilitate their integration into energy calculation tools.

3.4 Ventilation and building renovation

The energy rehabilitation of residential buildings involves, in a large number of cases, the replacement of windows with higher quality carpentry and glazing, and also a lower air permeability. This often implies a reduction in the air quality of these residential spaces when it depends on infiltration, for example, in the absence of mechanical ventilation systems.

In the case of tertiary buildings, as a result of the requirements derived from the COVID-19 pandemic in relation to ventilation needs or as a result of interventions aimed at improving energy efficiency, there is often the introduction of mechanical ventilation systems, in many cases previously non-existent, including in many cases a system for heat recovery from the exhaust air.

In both cases, the need to address simultaneously and in an integrated manner the energy and indoor air quality aspects is evident, making both requirements compatible, which can serve respectively as levers to improve both performances.

Given the specific characteristics of building retrofitting, it is probably necessary to improve the knowledge of best practices and available alternatives through application guides and other tools, in order to facilitate the successful resolution of interventions and to take advantage of the opportunities they offer.

4 CONCLUSIONS

In high efficiency buildings, the consumption linked to air transport and ventilation systems is significant and comparable to that of other services, so it is essential to advance along lines of adjustment of the required flow rates, facilitate the incorporation of new technologies when appropriate, improve the efficiency of existing systems and promote best practices. Air quality and ventilation technologies are closely linked to achieving the goal of climate change mitigation and must be addressed in an integrated manner, paying special attention to building renovation.

5 REFERENCES

[1] Proposal for a Directive of the European Parliament and of the Council on the Energy Performance of Buildings (recast) (2021) (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52021PC0802)

[2] Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Comitee of Regions. The European Green Deal (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2019%3A640%3AFIN)

[3] Proposal for a Directive of the European Parliament and of the Council on energy performance (recast) (https://eur-lex.europa.eu/legal-content/ES/TXT/?uri=CELEX:52021PC0558)

[4] Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources (https://eur-lex.europa.eu/legal-content/ES/TXT/?uri=celex%3A32018L2001)

[5] Royal Decree 314/2006, of 17 march, Spanish Technical Building Code, Basic Document on Energy Saving (DB-HE) (https://www.boe.es/boe/dias/2006/03/28/pdfs/A11816-11831.pdf)

[6] UNE-EN ISO 52000-1:2019 Overall assessment of the energy performance of buildings. Part 1: general framework and procedures (https://www.une.org/encuentra-tu-norma/busca-tu-norma/norma?c=N0061777).

[7] Royal Decree 390/2021, of 1 june, approving the basic procedure for the certification of the energy performance of buildings (https://www.boe.es/buscar/act.php?id=BOE-A-2021-9176)

[8] 2020 Update of the Long-term Strategy for the Energy Rehabilitation of the Building Sector in Spain. (ERESEE) (https://www.mitma.gob.es/recursos_mfom/paginabasica/recursos/es_ltrs_2020.pdf)

[9] EN 15978:2011. *Sustainability in construction. Assessment of the environmental performance of buildings. Calculation methods* (https://www.une.org/encuentra-tu-norma/busca-tu-norma/norma?c=N0049397