# How to create a performance-based regulation on ventilation – the French Experience

Valérie Leprince[*1], Baptiste Poirier[2], Gaëlle Guyot[3,4]

*1 Cerema*
*2 rue Antoine Charial*
*Lyon, France*
**Corresponding author: valerie.leprince@cerema.fr*

*2 Cerema*
*9 rue René Viviani,*
*44200 - Nantes, France*

*3 Cerema*
*BPE Research Team, 46, Rue St Théobald, F-38080,*
*L'Isle d'Abeau, France*

*4 Univ. Savoie Mont Blanc,*
*CNRS, LOCIE,*
*73000 Chambéry, France*

## ABSTRACT

In France, in Residential buildings, since 1982 the ventilation regulation imposes air flow rate to be continuously extracted from every room with humidity production. A boosted level of air flow rate shall be reachable in the kitchen. Since the mid-80s demand-controlled ventilation based on humidity level in each room has been allowed, provided that the system is validated by a national commission. In practice, for 40 years every new residential building has a mechanical ventilation system and 95% of them are centralised extract only systems. Since the beginning of the 2010s almost all of them have a humidity-based control. While efficient to mitigate the risk of moisture in buildings, the efficiency of those systems for other pollutants is still under investigation and the very prescriptive regulation limits the innovation possibilities to optimize the energy performance. To tackle this issue and allow the development of systems that would be more energy efficient (hybrid ventilation, low pressure systems, etc.), the French ministry for construction has set-up a working group to create a new performance-based regulation for ventilation.
This working group has defined Key Performance Indicator for ventilation systems, it evaluates the ability of a ventilation system to provide good indoor air quality through indicators on 4 criteria: humidity level, $CO_2$ level, fictive pollutant P1 exposure (emitted constantly) and fictive pollutant P2 exposure (emitted during cooking events. The working group has also discussed validation conditions for systems.
This new performance-based regulation gives specification for what a ventilation system shall provide. This will help to promote ventilation system in refurbishment and decrease $CO_2$ emissions of existing buildings which are heated through combustion appliance for more than 50% of them. It shall also foster the development of ventilation systems with less embodied energy.

## KEYWORDS

Ventilation, Performance based, KPI, France

## 1 INTRODUCTION

The French ESSOC regulation has the objective to promote innovation in every subject including building regulation and therefore ventilation. It aims at creating performance-based regulations as an alternative to existing prescriptive regulations. Those new regulations shall allow to developpe more efficient systems.

In the specific context of ventilation in residential building the French regulation is defined in the « Arrêté de 82 modified in 83 (JOFR, 1982)». This text includes requirement on the

extracted flowrate in each utility rooms (main requirements are given in annex) but does not impose anything on air inlet flowrate in each main room.

The new construction code states that “Air renewal, shall be such as, in normal condition of use, the indoor air pollution does not endanger health and security of occupants and that condensation is avoided, except temporarily”. This is respected if the system:

- Either respects Arrete de 82 requirements
- Or Fulfills Key Performance Indicators levels (named Résultats minimaux – Minimal results) as defined in a Regulatory text to be published by January 2025.

This new regulation is ambitious because defining KPI for ventilation with minimum is still a matter of research, this is worked on in IEA-EBC Annex 86.

The existing European standard EN 16798-1 “Ventilation for buildings. Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics.”(CEN, 2016) describes prescriptive methods with different approaches. Nevertheless, it only deals with the definition of design flowrate. This is actually one of the objectives of the new revision to include Key Performance Indicators in the new version (the revision is in process).

When defining a regulation on ventilation and performance indicator, it is important to first define the objective of the ventilation system in the context of the regulation. Buildings need air-renewal but submarine and the international space station shows that acceptable indoor air quality can be reached without ventilation. Nevertheless, relying only on air- cleaning systems is not reasonable in buildings where pollutants emissions are not controlled.

Ventilation is air renewal by purpose-provided means which replaces the air with air coming directly from outdoors. The objective of a ventilation system can be to:

- Maintain healthy indoor air,
    - limit indoor-produced pollutant concentration,
    - and/or limit outdoor-produced pollutant concentration,
- Regulate humidity level to mitigate the risk of condensation and mold development (building lasting quality),
- Ensure olfactive comfort and avoid stuffiness feeling,
- Improve summer comfort,
- Etc.

Additionally, the ventilation system should not compromise acoustic comfort and significantly increase energy consumption.

Works at international level shows that views on main objectives for ventilation systems vary a lot from one country to another. In France the regulation in 1982 has been made in order to :

- First, humidity: avoid condensation,
- Second, health: limit indoor produced pollutant concentration and their transfer from utility rooms to main rooms
- Three, comfort: limit stuffiness feeling and avoid olfactive discomfort due to the transfer of odors from utility rooms (ex. Kitchen to main rooms)

Therefore, our newly defined Key Performance Indicators (KPI) and their target levels will follow this logic.
This paper presents the methodology and reasons behind choices made to create the new performance-based regulation.

## 2 METHODOLOGY

The current French regulation for ventilation that had little change since 1982 is based on a prescriptive approach that impose ventilation airflows to be respected. However, such prescribed ventilation airflows do not necessarily give guaranty for good IAQ. In opposition to *prescriptive approach* a performance-based approach for ventilation systems regulation could be defined based on the definition from CIB W60 commission (Gibson, 1982) frequently cited in literature in building field as :

*" The practice of thinking and working in terms of ends rather than means [...] with what a building or a building product is required to do, and not with prescribing how it is to be constructed."*

Having requirements in terms of performance rather than prescription allow the development of smart ventilation that can be defined as *:*

*" A process to continually adjust the ventilation system in time, and optionally by location, to provide the desired IAQ benefits while minimizing energy consumption, utility bills and other non-IAQ costs (such as thermal discomfort or noise)* (Durier et al., 2018, p. 38)

The construction code states that "Air renewal, shall be such as, in normal condition of use, the indoor air pollution does not endanger health and security of occupants and that condensation is avoided, except temporarily.". While it is a very simple statement it induces a lot of underlying questions such as:

- What is "normal condition of use"?
- What are the criteria for indoor air pollution not to endanger health and security of occupants?
- What indicator to ensure that condensation is avoided, and what "temporarily" means?

Additionally, as those performance indicators will be evaluated prior to construction, not only key performance indicators need to be detailed but also the validation protocol.

### 2.1 Preliminary decisions

Before starting the work on indicators, it has been decided that:

- The validation of systems shall be done building's project by building's project and not for a ventilation system.
    - The agreement is valid only for a given ventilation system in a defined architecture and climate.
    - As some parameters of local climate is difficult to anticipate (such as wind) and may change over the years, parametric study will be done on those parameters

- The ability of a system in a project to fulfill performance indicators level will be validated through preliminary simulations but not through on-site measurements.
    - Nevertheless, the ability of indicators to be compared to on-site measurement is a criterion to define them.

- Today system that fulfill Arrêté de 82 (modified in 83) regulation shall have performance in-line with required levels for indicators but not necessarily systematically comply for all kind of dwelling/location etc.

    - The performance of every existing systems will be evaluated for the 3 French climate zones and all size and configuration of dwellings to help the definition of the required level for key performance indicators
    - A performance-based regulation shall be more "safe-sided" than a prescriptive one.

- Some prescriptive requirements will be kept as a safeguard as everything cannot be planed. The following prescriptive requirements shall be kept:
    - A general and permanent minimum flowrate applying (every rooms shall be ventilated)
        - The foreseen flowrate is twice the second table of Article 4 (see annex 1)
    - A non-closable outlet in each utility rooms
    - A non-closable inlet (or outlet) in each main room
    - Existing requirements on fire-safety
    - Maintenance requirements
    - The system shall not compromise the well-functioning of combustion appliance, if any in the dwelling

- The validation of a project will be done by an independent body with a process to be defined.

A system includes a maintenance process and the description of its inspection protocol to check and maintain its performances.

### 2.2 Definition of input parameters for simulations

The starting point to define input parameters for simulations was the CPT 3615 that defines simulations to be performed in the context of "Avis Techniques" (technical approbation) to be obtained for humidity-based demand control ventilation (Groupe Spécialisé n° 14.5, 2015)

In such performance-based approaches the choice for the input parameters are crucial as they directly impact the calculated performance for ventilation. Indeed, several points were questioned and defined (in Table 1) regarding:

| | |
|---|---|
| **The weather and outdoor boundary conditions**<br>- How to consider the locals weather conditions and local environment around the building? (Temperature, humidity, wind speed, solar radiation)<br>- Which outdoor pollutants and what background level or pollution scenarios need to be considered?<br>**The indoor conditions**<br>- What are the indoor air parameters to be considered when assessing IAQ performance?<br>- What are the activities, materials, and furniture to be considered?<br>- And what are the associated indoor air pollutant emission scenario? | **The occupancy**<br>- How many occupants in the buildings?<br>- What are their occupancy schedules and behaviour (windows and doors opening) for pollutant exposition calculation?<br>- What are the bio-effluent ($CO_2$ and moisture) emission profiles of the occupants?<br>**Building properties**<br>- What is the level of detail needed for the envelope description (airtightness, filtration/ infiltration of pollutant from outdoor)<br>- What is the level of detail needed for room definition (number of zones, airtightness between zone)?<br>**Simulation tools**<br>- What building simulation models is needed (aeraulic model/thermal model) ?<br>- What are the relevant simulation period and time step? |

Table 1 : Discussed inputs options and retained choice (in bold) for simulation.

| Parameter | Discussed options | Complexity | Choice and reasons behind |
|---|---|---|---|
| **Wheater and outdoor boundary conditions** | | | |
| *Temperature* | **Default temperature for a given climate zone** | * | Using the standardized weather files from the RE2020; one weather file function of the climate zone ; adapted environment roughness coefficient for a given location ; elevation correction ; adapted pressure facade coefficient Cp ; |
| | Temperature corrected for a given location | ** | |
| *Humidity* | **Default outdoor humidity for a given climate zone** | * | |
| | Outdoor humidity corrected for a given location | ** | |
| *Wind speed* | Default wind speed for a given climate zone | * | |
| | **Wind speed corrected for a given location** | ** | |
| | Wind speed corrected for a given location including buildings and vegetablizations around | *** | |
| *Solar radiation* | Default solar radiation for a given climate zone | * | |
| | **Solar radiation corrected for a given location** | ** | |
| | Solar radiation corrected for a given location with, mask and shading around the building | ** | |
| *Number of Pollutant* | No outdoor pollutant interaction | - | With only the CO2 as outdoor pollutant with a 400 ppm constant background level; choice limited by available data or difficulties of modelling a more dynamic pollutant level in a regulation |
| | **Same pollutants than indoor** | ** | |
| | Same pollutants than indoor with additional specific pollutants from outdoor | ** | |
| *Scenario of outdoor pollutant* | **Default constant background level** | * | |
| | Dynamic pollutant level from standardized scenario or measurement | ** | |
| | Dynamic pollutant level based on simulation | *** | |
| **Indoor conditions** | | | |
| *Number of indoor air parameters* | The historical: Co2, Humidity | * | The selected KPI (described in next section) are based on CO2 and humidity; completed with two fictive pollutant P1 and P2 for background level exposure and peak emission exposure |
| | Historical + health risk : Formaldehyde, PM2.5, … | *** | |
| | Historical + specific risk : Radon… | ** | |
| | **Historical + fictive / generic pollutant** | * | |
| *Activities* | One by pollutant | * | Moisture and CO2 emission by the occupants; additional moisture emissions from several activities breakfast, lunch, dinner, shower, laundry, laundry dry; Constant background emission for P1 pollutant; punctual emissions for P2 during cooking activities |
| | **Pollutant with multiples activities as sources** | **(*) | |
| *Scenario of pollutant emission* | Constant emission rate as a background average level with default values | ** | |
| | **Dynamic emission rates with default values** | ** | |
| | Dynamic with default values and interaction between pollutant | *** | |
| | From measurement | ** | |
| *Materials and furniture* | no interaction | * | Water vapour equivalent surface for absorption |
| | **Hygroscopic moisture buffer effect** | ** | |
| | Furniture pollutant release / absorption | ** | |

…

| Parameter | Discussed options | Complexity | Choice and reasons behind |
|---|---|---|---|
| **Occupancy** | | | |
| *Number of occupants* | Single/couple occupation: 1 occupant by room -1 if n° room >3 | * | Conventional occupation hypothesis according to INSEE survey (INSEE 2006); with however an attention on the impact that could have on CO2 controlled ventilation systems |
| | Family occupation: 1 occupant by room and 2 in master bedroom | * | |
| | **Standardized occupation** | | |
| *Time spends by room* | **Default standardized schedules** | * | Standardized occupation scenario according to GS14.5 o (Groupe Spécialisé n° 14.5, 2017); and reinforced occupation applying week-end occupation all the week |
| | Probabilistic models statistic behaviour | ** | |
| *Doors and windows interaction* | **No opening** | * | No interaction considering the worst situation when all the windows and doors are closed, the air should be able to circulate in rooms. |
| | Default standardized schedules | * | |
| | Probabilistic models statistic behaviour | ** | |
| *Occupant bio effluent profile* | **Default standardized: same for all the occupant** | * | However, an Awake and Asleep distinction is made |
| | Differencing function of the occupant (adult, child, morphology) | ** | |
| **Building proprieties** | | | |
| *Room distribution* | **Default: one zone per room** | * | Regrouped zone may not be adapted for specific ventilation strategy at the room level; thus, keeping one zone per room as default. |
| | Regrouped: zone with room regrouped by type / space | * | |
| *Representation of airtightness (distribution)* | **Uniform** | * | Uniform distribution proportional by wall surface; using a Q4Pa permeability level of: 0.4 m3/(h.m²) in individual housing / 0.65 m3/(h.m²) for collective buildings (from median value of CEREMA data base) |
| | Non-uniform | ** | |
| | From measurement | *** | |
| *Air leakage between zone* | No air leakage | * | At this stage only the door undercutting; adapted function of the building |
| | **Door undercutting** | * | |
| | Uniform air leakage from the wall | ** | |
| | Non-uniform / from measurement | *** | |
| *Pollutant filtration* | **No filtration** | * | Models and knowledge on filtration through leakage still early and not ready to be implemented in regulation |
| | Constant filtration rate | ** | |
| | Dynamic filtration | *** | |
| **Simulation tools** | | | |
| *Aeraulic model* | **Pressure code multi zone** | * | |
| | CFD | *** | |
| *Thermal model* | **No thermal model just aeraulic** | * | During the winter, the indoor temperature is constant and during the summer it is the average of the last 18 hours of the outdoor temperature. |
| | Coupled thermal model | ** | |
| *Simulation period* | Default during winter heating period | * | some KPI needs the yearly calculation |
| | **Yearly** | ** | |
| *Simulation time step* | **In minutes** | * | 15 minutes timestep; compromising with available data and calculation time. |
| | Hourly | * | |

## 2.3 Definition of Key Performance Indicators

The following questions needs to be answered to define performance indicators

- On which criteria shall the system be evaluated to determine whether he fulfill the regulation
  - Indoor air parameters – which ones?
  - $CO_2$, humidity, $PM_{2.5}$, Radon, fictive polluants, etc.
  - Energy parameters
- Which indicators for each criterion?
  - Criteria on rooms or occupant's exposition
  - Cumulated exposure
  - Maximum exposure
  - A multi-criteria aggregation, in this case the impact of the weight distribution needs to be clearly explored in order to propose distribution adapted to the IAQ
  - Else?
- Which level of requirements on indicators
  - Absolut acceptable threshold
  - Relative performance regarding a reference system ? (theoretical or ideal system)
  - Else?

In the context of the French regulation on ventilation it has been decided not to evaluate performances according the energy performance as it is already included in the energy performance calculation. In France, to fulfill the objective of ventilation defined in the introduction the chosen criteria regarding indoor quality are the following :

- Humidity
- $CO_2$
- A fictive pollutant P1 emitted continuously in every rooms with an emission rate proportional to the area
- A fictive pollutant P2 emitted in the kitchen during cooking events at mid-day and in the evening.

Choosing fictive pollutants allows to cover multiple ones instead of picking one. Regarding humidity, the limit will be set only on high humidity level. It has been decided that it was not for ventilation to deal with low humidity level under the French climate, humidifying systems shall deal with this issue in some specific cases. It is better if for $CO_2$ and humidity the indicator can be measured for this regulation to be used as a reference scale.

The foreseen Key Performance Indicators are the following ones:

*For $CO_2$:*

- For each room, the $CO_2$ concentration (in ppm) below which it remains 67 (or 70%) of occupied time
  - This indicator reflects the mean operating conditions
  - An indicator in ppm is more easily readable than a cumulative exposure in ppm.h
- For each room, the $CO_2$ concentration (in ppm) below which it remains 95% (or 99%) of the occupied time
  - This Indicator reflets pic conditions

*For Humidity:*

- For every room, a maximum percentage of time over 75% of relative humidity in the winter. The maximum value will depend on the type of room (as surface finishing standards depend on it)
- Under discussion : For every room a maximum number of hour when at least one leak is overpressures and the humidity level is above 75%

*For the fictive pollutants P1 and P2:*

- The mean exposure (for the most exposed person)
- The maximum exposure over one hour (moving average, for the most exposed person).
- *Under discussion:* An indicator to evaluate the transfer of pollutant P2 to the other rooms.

## 3 CONCLUSIONS

After 40 years, France is about to have an alternative to its prescriptive regulation on ventilation. Developing a performance-based regulation should promote smart ventilation and open the market to systems that will maintain or improve the indoor air quality, limit the energy use of building and limit their embodied energy.

In France, more than 71% of electricity is produced by nuclear plants, 21% are renewable and only 8% are from thermal plant (RTE, 2020). Therefore, the impact on $CO_2$ emissions of reducing electrical needs is limited. In new building heating is mostly done through electric heat pumps. Others impact of ventilation on building energy use are also mostly provided by electricity (air conditioning and fan energy). Thus, the impact of the performance-based regulation on the $CO_2$ emission of new building due to energy use will probably be limited.

Nevertheless, this new regulation should help decarbonize the full building stock for two reasons. First, it will at last give a framework and guidelines for refurbishment and for existing building, indeed existing regulation is not applicable most of the time in refurbishment for multiple reasons:

- Ventilation systems that respects the French prescriptive regulation usually work at high pressure (around 100 Pa), this imposes tight ductwork mostly made in galvanized steel in multi-family buildings. In refurbishment, it is usually impossible to keep existing concrete shaft and install a system consistent with the Arrete 1982.
- Installing a centralized system in refurbishment is often challenging.

Therefore, as there is no applicable legal text to refer to, ventilation is often forgotten in refurbishment projects. Having this legal framework will allow to developpe ventilation systems compatible with refurbishment issues while guarantying the required indoor air quality. In 2015, gaz heats dwellings of 39% of families, fuel oil 12% and 5% for wood (INSEE, 2017). It means that for more than 50% of existing buildings optimizing the ventilation system directly decrease the impact of the building on CO2 emissions.

Second the decarbonization of the building's sector is not only based on the reduction of the energy use but also on the reduction of buildings' materials impact. This regulation should allow the development of low-tech ventilation systems (natural, hybrid, low- pressure systems etc.). Those systems may induce as much or more energy use for the building but have less impact on embodied energy which is now considered in the French energy performance regulation RE2020.

Regarding the timeline, the objective is to define key performance indicators by the end of 2023 and to publish the regulation (including certification process) by 2025.

## 4 DISCLAIMER

This document gives an overview of the work performed by the French working group "ESSOC", the information provided in this document reflects the preliminary conclusion of the group in June 2023, this conclusion may change in the coming month. Neither the ministry for construction, nor members of the GT ESSOC group can be held for responsible for the content of this document.

## 5 ANNEX 1 : MAIN REQUIREMENTS OF ARRETE DU 24 MARS 1982

- Art. 1: The air renewal in dwelling is general and permanent at least during the heating season.
- Art2: The air renewal system shall include natural or mechanical inlet in main rooms and outlet in utility rooms. The air shall circulate between main and utility rooms
- Art 3: The ventilation system shall be able to reach, simultaneously or nor the following values:

| **Number of main rooms in the dwelling** | **Extract flowrate in $m^3/h$** | | | | |
|---|---|---|---|---|---|
| | **Kitchen** | **Bathroom** | **Other room with water source** | **Toilet** | |
| | | | | **Only one** | **Multiple ones** |
| **1** | 75 | 15 | 15 | 15 | 15 |
| **2** | 90 | 15 | 15 | 15 | 15 |
| **3** | 105 | 30 | 15 | 15 | 15 |
| **4** | 120 | 30 | 15 | 30 | 15 |
| **5 or more** | 135 | 30 | 15 | 30 | 15 |

- Art4: The total extract flowrate can be reduced as follow :

| | **Number of main rooms** | | | | | | |
|---|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** | **6** | **7** |
| **Total minimal flowrate in $m^3/h$** | 35 | 60 | 75 | 90 | 105 | 120 | 135 |
| **Minimal flowrate in $m^3/h$** | 20 | 30 | 45 | 45 | 45 | 45 | 45 |

If the ventilation system automatically control flowrate to maintain an indoor air quality that is not dangerous for occupant and avoid condensation (except temporarily) the flowrate can be reduced. Provided that the system has been validated by the ministry in charge of construction

| | **Number of main rooms** | | | | | | |
|---|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** | **6** | **7** |
| **Total minimal flowrate in $m^3/h$** | 10 | 10 | 15 | 20 | 25 | 30 | 35 |

and health. In any case the total extracted flowrate shall at least be:

- Art.5: air inlet shall be designed to reach extracted flowrates defined at article 3.

Additional requirements are set for fire safety and interaction with combustion appliance.

## 6 REFERENCES

CEN. (2016). EN 16798-1 *Energy performance of buildings—Part 1 : Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics*

Durier, F., Carrié, F. R., & Sherman, M. (2018, mars). V*IP 38 : What is smart ventilation? AIVC. http://aivc.org/sites/default/files/VIP38.pdf*

Gibson, E. (1982). *Working with the performance approach in building (Report of Working Commission W060 CIB Publication 64). International Council for Research and Innovation in Building and Construction.*

Groupe Spécialisé n° 14.5. (2015). *Cahier des Prescriptions Techniques communes : Systèmes de ventilation mécanique contrôlée simple flux hygroréglable.*

INSEE. (2017). Dossier—*La facture énergétique du logement a baissé depuis 2013 malgré la hausse de la fiscalité.*

Arrêté du 24 mars 1982 *relatif à l'aération des logements, 0073*

RTE - Direction innovation et données. (2020). *Bilan Electrique 2019. Le réseau de transport d'électricité*. https://assets.rte-france.com/prod/public/2020-06/bilan-electrique-2019_1_0.pdf