Improving indoor air quality




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CHAIRMAN'S MESSAGE

The Covid-19 epidemic has made everyone aware of the risks of contagion from indoor air circulation in buildings, as well as of the air quality issues associated with living in enclosed spaces. The subject of indoor air quality is hardly new; it has been dealt with in all of France's national health and environment plans since the early 2000s. This comes amid growing alarm over its spiralling cost to society, running into tens of billions of euros each year.

Climate change has also altered our perception of this issue. Reducing emissions involves improving building insulation, which raises new questions about how best to ventilate premises while avoiding ventilation-borne pollution.

Businesses are concerned as both producers and users of various substances, as well as hosts to their employees and customers in their premises or vehicles. What priority do they assign to this issue compared to other environmental concerns when making an investment?

This publication draws on the varied experiences of EpE members and shows that the issue is gaining traction as businesses strive to incorporate it into the design stage of their projects or products. They are also intensifying discussions with stakeholders on ways to address what are perceived as priority issues.

This approach to an emerging and evolving issue has significant benefits in terms of priority selection, cost and long-term performance.

We hope this publication will prove useful to many players in anticipating the concerns their stakeholders may have on this sensitive issue.

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Chairman & CEO, TotalEnergies
Chairman of EpE

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INTRODUCTION

A study published on 17 May 2022 in The Lancet Planetary Health noted that air pollution causes 6.7 million premature deaths worldwide every year[1]. In France, a 2015 report by a Senate committee of enquiry estimated that health spending related to air pollution by social welfare amounted to 3 billion euros, with total expenditure on this issue ranging between 70 and 100 billion euros[2].

Air pollution covers two issues: indoor air quality and outdoor air quality. Initially, the attention of public authorities, consumers and businesses was primarily focused on the external environment and atmospheric pollution. It was not until the 1970s that research on indoor air quality began in earnest, and it took a few more decades for the subject to be recognised as a public health issue. In France, the Indoor Air Quality Observatory (OQAI) was set up in 2001, and in 2004 the First National Health Environmental Plan (PNSE) was drawn up to "protect the population from indoor pollution"[3]. This initiative was subsequently extended in the three following PNSEs. The Covid-19 pandemic has heightened collective awareness of the challenges posed by indoor air pollution.

Our exposure to air pollutants depends on the time we spend daily in various environments, including home, workplace, establishments open to the public, transportation and outdoors. On average, it is estimated that we spend 80% of our time indoors, with 50% at home, 30% in the workplace, childcare centres, educational establishments and transportation, leaving only 20% spent outdoors. Consequently, our primary exposure to air pollutants occurs indoors. Numerous studies show that indoor air is significantly more polluted than outdoor air. Notably, the type of pollutants differs, and so do the applicable regulatory frameworks and remedial solutions. Furthermore, managing indoor air quality impinges on other issues, including the energy performance and environmental footprint of our buildings and transportation system.

In recent years, nearly forty large member companies of the Association française des Entreprises pour l'Environnement (EpE) have collaboratively shared their experience within the framework of the Health & Environment Commission. This collaborative effort aims to identify, understand, and respond to health, environmental and economic issues related to indoor air quality for both their internal operations and external stakeholders. This publication serves as an update on the knowledge gained and the work carried out by this Committee as well as member companies to improve indoor air quality.

1 Fuller (R.) *et al.*, Pollution and health: a progress update, The Lancet Planetary Health, vol. 6, p. e536.
2 Husson (J.-F.) et Aïchi (L.), Le coût économique et financier de la pollution de l'air, Report prepared on behalf of the Committee of Inquiry, Senate No. 610, 9 July 2015, p.18.
3 Plan national santé environnement, Franchir une nouvelle étape dans la prévention des risques sanitaires liés à l'environnement. 2004-2008. National Health & Environment Plan: Crossing a new stage in the prevention of environment-related health risks.

1

Why care about indoor air quality?

1 The challenges and risks of indoor air quality for human health

Several studies show that indoor air has higher concentrations of pollutants than outdoor air, especially that of two common carcinogens: formaldehyde and benzene[4]. Indoor air pollutants can be divided into three categories: biological agents (e.g. allergens), physical agents (e.g. asbestos, radon or particles), and chemical agents (e.g. carbon monoxide, CO_2 or volatile organic compounds). These pollutants have multiple emission sources intrinsically linked to human activities and habits[5], as well as to the construction and decoration equipment and materials used. A Ministry of Solidarity and Health infographic on indoor air quality illustrates this point (figure 1).

In addition to the multitude of emission sources, it was found that indoor air in residential buildings, office buildings or public-access establishments often exhibits higher pollutant concentrations than outdoor air due to the increasing airtightness of buildings and stricter safety and quality requirements. As buildings strive for enhanced energy efficiency (low-energy, passive energy, and positive energy buildings), they become less and less air-permeable, leading to a decline in air quality in the absence of efficient ventilation. Other essential quality requirements, such as sound insulation, inflammability, and material lifetime, necessitate the use of specific materials and products that may themselves emit pollutants. Therefore, addressing indoor air quality improvement issues, must be compatible with building energy, heat and sound performance criteria, and of course safety requirements.

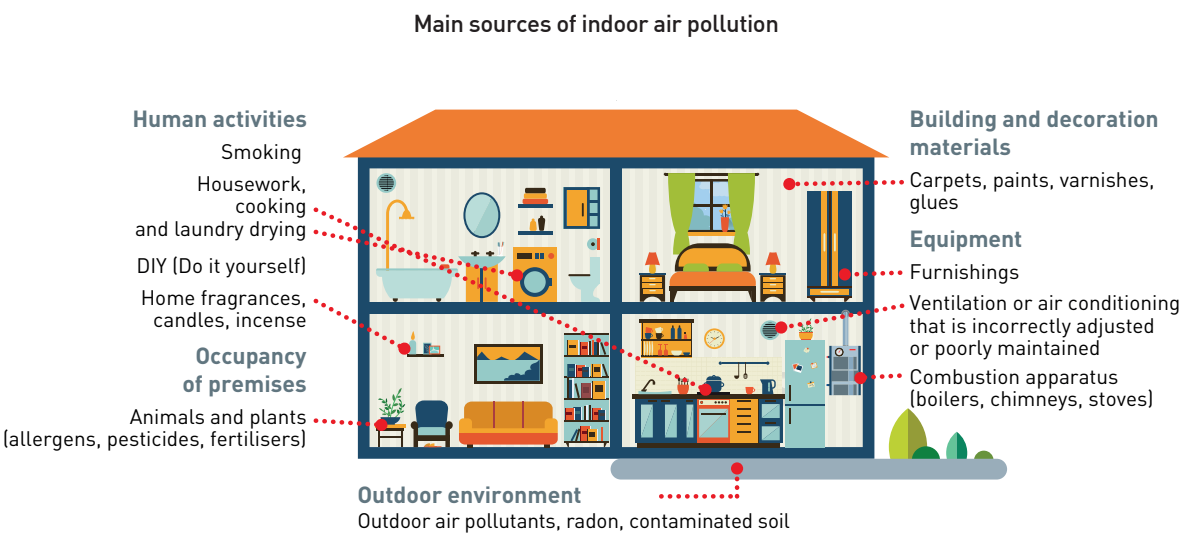


Figure 1 / Infographic on the main sources of indoor air pollution in homes[6].

Exposure to indoor pollutants has various impacts on human health[7]. These pollutants can lead to various illnesses such as poisoning, fertility disorders, or respiratory allergies[8].

In the long term, they can be the cause of respiratory diseases such as chronic obstructive pulmonary disease (COPD) or cancers, as well as cardiovascular diseases. Additionally, poor indoor air quality can result in a loss of concentration, discomfort, headaches and abnormal fatigue. Such symptoms are incompatible with educational or professional activities and unwanted at home.

The effects of human exposure to these indoor pollutants are multifaceted and depend on several factors, including the type of pollutant, size and composition of particles, lifestyle, and the period and dose of exposure.

4 For example: OQAI, Campagne nationale Logements : État de la qualité de l'air dans les logements français. Final Report, November 2006, updated May 2007.
5 For example: Grégoire (A.) *et al.*, Activités domestiques et produits d'usage courant utilisés par les ménages en France. ERS, Vol. 12, No. 2, March-April 2013, pp. 129-138; ADEME, Exposition aux polluants émis par les bougies et les encens dans les environnements intérieurs. Report, July 2017; or Bonnet (P.) *et al.* VOCs in cleaning products used in age care and social facilities: Identification of hazardous Substances. AIMS Environmental Science, No. 5(6), pp. 402-417.
6 Ministry of Solidarity and Health, L'air intérieur : Comment avoir un air intérieur plus sain ? Quels bons gestes adopter. Infographic on air quality.
7 For example: WHO, Indoor air pollution and health; 26 July 2022: https://www.who.int/fr/news-room/fact-sheets/detail/ household-air-pollution-and-health.
8 25 to 30 percent of people today suffer from allergies (respiratory, skin or food) compared to only 2 to 3 percent from 1970-80.

Furthermore, these effects vary from person to person, with certain individuals being more vulnerable to certain substances, such as infants, young children, pregnant women, the elderly, and immunocompromised individuals. Consequently, exposure can lead to miscarriages, premature births, impaired foetal growth or affect the intellectual development of the child.

According to the National Agency for Food, Environmental and Occupational Health Safety (ANSES), the socio-economic cost for France attributable to indoor air pollution alone (taking into account its impact on collective well-being) amounts to approximately 19 billion euros a year[9].

2 The regulatory and normative framework for indoor air quality

Our workgroups reviewed air quality in four categories of enclosed space:

- **residential buildings**;
- **establishments open to the public**;
- **workplaces**, divided between premises with non-specific pollution (office buildings), lavatories and premises with specific indoor pollution (involving the use and emissions of substances that pose health hazards). This publication specifically addresses the first category of premises;
- **transport**.

In France, several measures are in force that either fully or partly regulate indoor air pollution.

The ELAN law of 2018 incorporated indoor air quality among the factors to be taken into account in the construction of energy-efficient, environmentally sound, and healthy buildings[10]. More recent measures have been adopted by the "Climate and Resilience" law of 22 August 2021[11]. For older housing, the installation of general and continuous ventilation is mandatory "at least during the period when the outdoor temperature makes it necessary to keep the windows closed"[12]. Buildings subject to reinforced sound insulation, must have continuous ventilation throughout all seasons, with a minimum air flow rate based on the number and type of rooms per dwelling. While ventilation systems are not required, dwellings must comply with a number of requirements such as air inlet points in all main rooms, air outlets in service rooms, and free flow of air. As such, there is no comprehensive measure regulating air quality in new, existing or retrofit homes which takes into account other considerations than the presence of ventilation systems and air flow. For offices, affecting over 19 million employees, the Labour Code requires employers to provide the premises with natural or mechanical ventilation on a permanent basis with minimum air flow thresholds (25 m^3 per hour per occupant)[13].

On the other hand, special attention is given to such public-access establishments as nurseries, primary and secondary schools and vocational training institutions. These are subject to stricter standards which target specific pollutants (formaldehyde, benzene, CO_2) along with their respective emission sources[14]. The scope of these measures will be gradually extended to other public-access establishments[15]. Lastly, concerning transport, neither France nor the European Union currently has regulations governing air quality in passenger vehicle cabins or the quality of air inside underground stations where passenger trains run.

In addition to these regulations, the World Health Organization (WHO), ANSES and France's High Council for Public Health (HCSP) issue indoor air guide values that define pollutant concentration levels in the air with the aim of avoiding, preventing or reducing their harmful effects on health. Such expertise provides guidance for both public authorities and private entities. For instance, based on the expertise of ANSES and HCSP, a 2011 decree[16] established guide values for formaldehyde and benzene.

Similarly, Action 14 of the Fourth National Health Environmental Plan 2021-2025 (PNSE 4) outlines the priority measures to be implemented in this area:

- investigating indoor air quality in homes across France;
- supporting stakeholders in the building industry to address indoor air quality issues;
- making it mandatory to check ventilation installations during the acceptance of new buildings;
- continuously improving indoor air quality in establishments that host sensitive populations;
- incorporating information on ventilation and airing in energy performance assessments;
- improving air quality in underground railway stations.

9 ANSES, Étude exploratoire du coût socio-économique des polluants de l'air intérieur. Study Report, April 2014, p. 69.
10 Environmental regulation for new buildings in 2020 (RE2020) under law No. 20218-1021 of 23 November 2018 on housing, urban development and digital technology, known as the ELAN law.
11 Law No. 2021-1104 of 22 August 2021 on combating climate change and strengthening resilience to its effects.
12 Article 1 of the decree of 24 March 1982 relating to the ventilation of homes.
13 Articles R. 4222-1 to-9 of the Labour Code.
14 Article L. 221-8 et seq. of the Environment Code.
15 In 2025, these establishments will include social and medico-social centres, long-term care facilities attached to healthcare institutions and penal institutions for minors. Covered fitness and sports facilities in which aquatic activities are practised are no longer concerned by this oversight process because they are considered to be specific pollution premises under the Labour Code. See French government, Qualité de l'air intérieur. 4 April 2023.
16 Decree No. 2011-1727 of 2 December 2011 on indoor air guide values for formaldehyde and benzene.

In addition, regulations mandate the labelling of certain products or materials to disclose their volatile pollutant emissions. Since 1 September 2013, all building products that come into contact with indoor air (paints, varnishes, glues, materials, coatings and carpets) must be labelled with their pollutant emissions[17]. This labelling divides products into four classes: A+, A, B and C for the highest emissions (figure 2). The regulations, however, do not cover all products likely to emit volatile pollutants and exclude household products[18], essential oils, scented candles and incense. Moreover, the labelling is based on measurements taken after 28 days of emission, which means it does not account for immediate emissions from the product (such as when a paint can is opened).

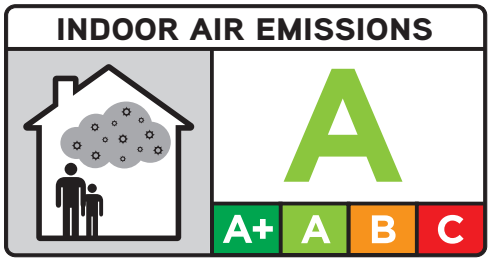


Figure 2 / Example of regulatory labelling for building products in contact with indoor air.

The scope of all these provisions is thus limited since they do not cover all enclosed spaces nor all pollutants in their different stages of life. In its opinion of May 2022, the French Economic, Social and Environmental Council deemed these regulatory texts inadequate[19]. This situation hampers the implementation of air quality improvement systems often costly and burdensome for businesses and individuals alike. Moreover, like many health and environmental issues, the positive impacts of improving air quality on the health of employees, occupants or users are often delayed and challenging to measure. Added to this is the difficulty of reconciling air quality with the energy and environmental performance of buildings, the latter being backed by multiple regulatory measures and economic incentives (see chapter 2).

Nevertheless, there is a noticeable increase in people's interest in preserving their quality of life and health. The surge in the market for CO_2 sensors and their widespread deployment in residential, office and school buildings since the pandemic have contributed significantly to promoting general awareness. In some cases, this is reflected in improvements in and better maintenance of ventilation systems for premises and/or greater care in the choice of a number of everyday products. As of 2022, 60% of French people expressed concerns about the risks associated with indoor air quality in transport (car, bus, metro, etc.), 57% in nurseries and schools, 54% in their workplace, and 44% in their homes[20]. Consequently, there is mounting pressure from societal expectations regarding this issue.

Internationally, awareness of this issue is also on the rise. For example, hotels, restaurants, cafés and cinemas in Belgium are now required to monitor indoor air quality and implement action plans[21]. In Quebec, indoor air quality is monitored in all schools[22]. Similarly, in the United States, the Biden-Harris administration is funding significant plans to improve air quality in buildings[23].

While air quality still ranks relatively low among priorities, the issue is gaining importance in business forums and agendas. Chapters 2 and 3 of this document delve into studies and measures implemented by EpE member companies and others to improve air quality management in the buildings and transport they oversee. The final chapter explores strategies for improving the utilisation of enclosed spaces.

17 Ordinance of 19 April 2011 relating to the labelling of building products or wall or floor coverings and paints and varnishes with their volatile pollutant emissions.
18 For cleaning products, however, there are standardised emission control protocols or hazard symbols governing their use.
19 CESE, Pour une politique publique nationale de santé-environnement au cœur des territoires. Opinion 2022-008, 24 May 2022, p. 14.
20 ADEME, Attitudes des Français à l'égard de la qualité de l'air et de l'énergie en 2022 – Vague 9. Report, December 2022, Table 14, p. 15.
21 Service public fédéral, Adoption de la loi sur la qualité de l'air Intérieur. 1 December 2022.
22 Quebec, Air Quality in Schools. 21 July 2023.
23 The White House, Fact Sheet: Departments and Agencies Commit to Cleaner Indoor Air Across the Nation. 8 December 2023.

2

Improving air quality in buildings

We spend most of our time in buildings, averaging about 20 hours a day, making them a major determinant of our daily health and well-being. Numerous factors related to indoor air quality can impair human health, ranging from inadequate ventilation, building airtightness, and poor outdoor air quality to issues like humidity and the presence of chemicals. Physical factors, like excessively high or low temperature, noise pollution and poor lighting also contribute. Some buildings can even lead to "sick building syndrome" (SBM)[24].

Beyond the health implications, buildings account for about 23% of France's CO_2 emissions and 43% of its total energy consumption. Upgrading existing and new buildings is thus a pivotal element in the fight against climate change and the improvement of public health.

Recognising these challenges and in response to heightened concerns from public authorities and customers, construction companies are intensifying efforts to incorporate a health dimension, particularly focusing on air quality, into their commercial offerings for new buildings. The challenge becomes more complex with existing buildings, which do not always involve the same stakeholders. This chapter delves into research projects and offers insight into measures implemented by companies to ensure ongoing air quality management or to integrate this criterion into building retrofits.

1 Construction of new buildings: factoring air quality into the earliest phases of a project

The new construction market is driven by several key trends:

- reduction of carbon emissions (net zero emissions);
- energy efficiency and lower building energy consumption;
- the circular economy;
- health and well-being, with the focus on comfort of premises, indoor air quality and removal of toxic substances from construction products and buildings.

On the first two issues, the new-build sector is subject to environmental regulation RE2020 which sets mandatory performance targets backed by an accurate system of measurements and progressive goals (thresholds to be achieved in 2022, 2025, 2028 and 2031)[25]. The targets focus on energy restraint and decarbonisation, reduction of construction's carbon impact and building comfort during periods of intense heat. The regulation also mandates the verification of mechanical ventilation systems in new residential buildings.

Concurrently, construction players are making voluntary commitments to air quality. These commitments align with new-build construction certifications that integrate air, quality of life and respect for the environment (HQE certification), with some focusing solely on user health and well-being (WELL Building Standard or OsmoZ certifications).

24 In 1983, this syndrome was defined by a WHO expert group of as "a combination of atypical symptoms including headache, fatigue, eye and nostril irritation, dry skin, and concentration disorders in people working in confined spaces".

25 Ministry for Ecological Transition, RE2020: Éco-construire pour le confort de tous. Press kit, updated on 18 February 2021.

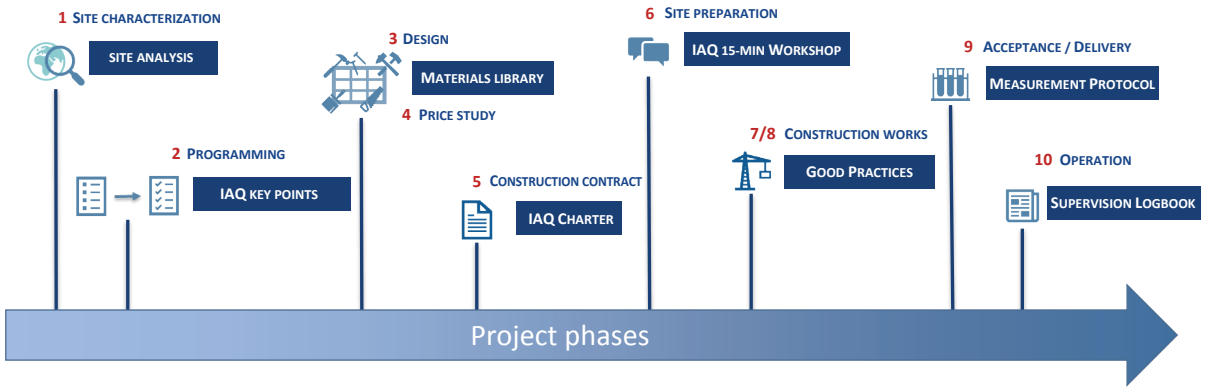
Reconciling climate, energy and health criteria involves rethinking the way buildings are constructed. Across the different project phases, the key elements of healthy construction are site preparation, the search for low-emission materials and best practices, whose successful implementation relies on construction workers being well-informed and committed to doing the right thing. As demonstrated by VINCI Construction, this process involves a global and systemic mobilisation of all stakeholders involved in the design and construction of a building.

QAI Ready: VINCI Construction's healthy air guarantee policy

The **QAI Ready approach** was developed at VINCI Construction in 2017 with the aim of guaranteeing future customers and residents good indoor air quality in buildings. It is based on an indoor air quality management plan to achieve the objectives set at each phase of the project, and incorporates the following key points:

- **programming:** VINCI Construction defines clear and measurable objectives according to the type of project;
- **design:** the teams ensure control of pollution sources by sizing air renewal equipment, choosing filtration levels and recommending low-emission materials;
- **completion:** VINCI Construction monitors compliance with its requirements and promotes awareness of best practices among workers;
- **acceptance/delivery:** teams monitor key indicators during a preliminary set of measurements taken by "near reference" devices[26]. At the same time, they evacuate surplus pollution before the intervention of COFRAC accredited service providers in charge of carrying out the measurement campaigns.

The QAI Ready approach can be extended during **operation**. To preserve the level of air quality during occupancy, VINCI Construction offers site instrumentation with real-time monitoring stations for analysis, awareness-building and air quality management.



26 "Near reference" is a more flexible approach than traditional monitoring methods, as it is backed by high-performance instruments and leveraging compact, low-power measurement technologies to facilitate and accelerate deployment.
For further information go to https://www.aeroqual.com/blog/near-reference-air-quality-monitoring.

Ensuring good air quality in new buildings relies on several factors and involves multiple stakeholders:

- incorporating indoor air quality from the construction site selection and building design phases; the room for manoeuvre is subsequently much more limited. Flexibility in this regard may be limited, especially in cases of reusing industrial wastelands;
- availability of transparent and reliable information on the materials used, their composition and their emissions of volatile organic compounds (VOCs), i.e. what Saint-Gobain committed to in its Health Product Transparency policy;
- awareness-building and training of all stakeholders in the value chain on these issues and best practices (project managers, sales teams, marketing teams, etc.);
- proper understanding by the builder of the commercial or economic value of implementing air quality standards;
- last but not least, incentives and/or binding regulations.

Health Product Transparency in the construction sector: Saint-Gobain's feedback

The construction sector is increasingly careful about the health and well-being of users and the chemical composition of the materials used is at the heart of the priorities.

Saint-Gobain has adopted a Health Product Transparency initiative, aiming to disclose the list of chemicals in a product as well as associated hazards. There are several difficulties in this initiative:

- gathering accurate knowledge of all substances in the materials purchased and processed by the group;
- intellectual property;
- information traceability;
- dealing with standards and methods which have proliferated in recent years, differ from region to region and are not always aligned with EU regulations.

Saint-Gobain has accordingly drawn up a medium-term action plan to characterize the composition of its products, manage intellectual property issues, ensure the traceability of information, and develop a standard adapted to the EU context.

In addition to transparency, the phase out of toxic substances has become a prerequisite for innovation projects thanks to the implementation of the Group's Health Policy[27].

This initiative is an integral part of Saint-Gobain's commitments as a leader in sustainable construction, helping to increase the Group's competitive edge and access to the certified sustainable building market.

27 https://www.saint-gobain.com/sites/saint-gobain.com/files/media/document/Health-Policy.pdf.

Today, integrating indoor air quality considerations into building construction offers several competitive advantages for developers: meeting market demand (customers and users); projecting a responsible and quality image; achieving standout quality standards (certification and labelling); reducing buildings' risk hazard.

While the process is still in its early stages, the new-build market is gradually incorporating this health dimension with the other decarbonisation and energy performance mandated by legislation. However, businesses remain reliant on the decisions of their customers in an area that still lacks standards. Undoubtedly, harmonised, more binding and/or incentivising regulations in this area would accelerate the trend.

2 Maintenance and cleaning of premises: key factors in maintaining indoor air quality

Whether designed and built to meet strict air quality specifications or not, office buildings, those open to the public and individual or collective dwellings must, at minimum, have natural or mechanical ventilation to ensure adequate air renewal.

Many buildings, however, either lack an adequate air renewal system or have poorly maintained ones that do not function properly. Additionally, air quality monitoring, audit frequency and the criteria monitored differ from one building to another (see chapter 1).

For example, the majority of small shops and restaurants lack a ventilation system or windows. Yet, under the national energy restraint plan, shopkeepers are prohibited from keeping doors open while air conditioning or heating is in operation[28].

Regarding establishments open to a sensitive public, the Indoor Air Quality Observatory carried out a nationwide campaign between 2013 and 2017 to measure a wide range of pollutants at 301 French kindergarten and elementary schools. In these public-access establishments, two-thirds of CO_2 measurements revealed a high level of uncirculated air in rooms occupied by the children. The Observatory also noted that in three-quarters of the schools assessed, there was no proper ventilation system, either mechanical or natural. The only way of renewing the air was to open the windows, placing the responsibility on teachers to remember to do so during each break. The campaign found the widespread presence of VOCs (aldehydes) and semi-volatile organic compounds (phthalates, pesticides, PAHs), as well as ubiquitous $PM_{2.5}$ fine particle pollution[29] in French schools[30].

For old housing, although it is mandatory under the 1982 decree, ventilation is not always available or adequate. Moreover, even for new dwellings where the ventilation system is checked upon delivery, the device is only efficient if properly maintained.

In offices, air that is too dry or humid or not adequately renewed, temperatures that are too low or high, or noise pollution are all factors contributing to the development of sick building syndrome in some employees. This, in turn, leads to a decline in well-being and efficiency at work.

In order to remedy poor air quality or simply to maintain good air quality in the premises, it is crucial to use a step-by-step process to measure air quality, identify pollution sources, install appropriate ventilation systems, and use and properly maintain those systems. Veolia's teams have been working in this manner for many years, striving to provide customers with tailored solutions that are the most appropriate to their needs. By following these steps, it becomes possible to limit or even avoid the installation of energy-intensive and costly air purification systems.

28 Government plan published on 6 October 2022 to reduce the country's energy consumption of 10% by 2024 through 15 flagship measures targeted at individuals, businesses, central government and local authorities.

29 Particles called $PM_{2.5}$ are particles with a diameter of 2.5 microns. They consist of a mix of different chemical compounds. PM_{10} particles are those with a diameter of 10 microns.

30 For more information: OQAI, Qualité de l'air et confort dans les écoles en France : premiers résultats de la campagne nationale. Bulletin de l'OQAI, No 11, June 2018.

Veolia solutions guaranteeing indoor air quality

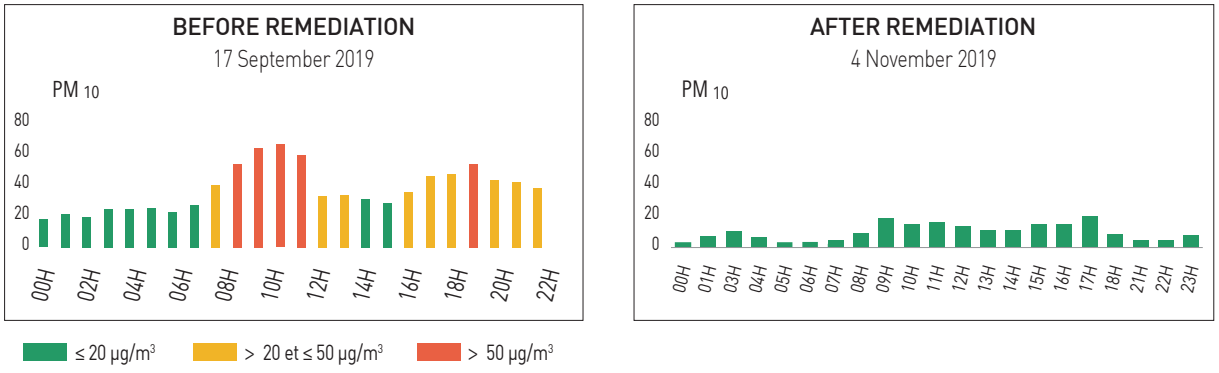
Veolia's approach to guaranteeing air quality in a building is based on three complementary programs:

- **"*Air Control*":** assess and explain pollution phenomena by identifying their permanent and invisible nature and evaluating their level;
- **"*Air Performance*":** treat this pollution by implementing techniques adapted to the remediation method required for the type of building;
- **"*Air Human*":** given the impact of individual behaviour on indoor air quality, bring together various stakeholders to achieve sustainable outcomes. Measures include training/awareness-raising sessions and reports to monitor results for the benefit of occupants and decision makers.

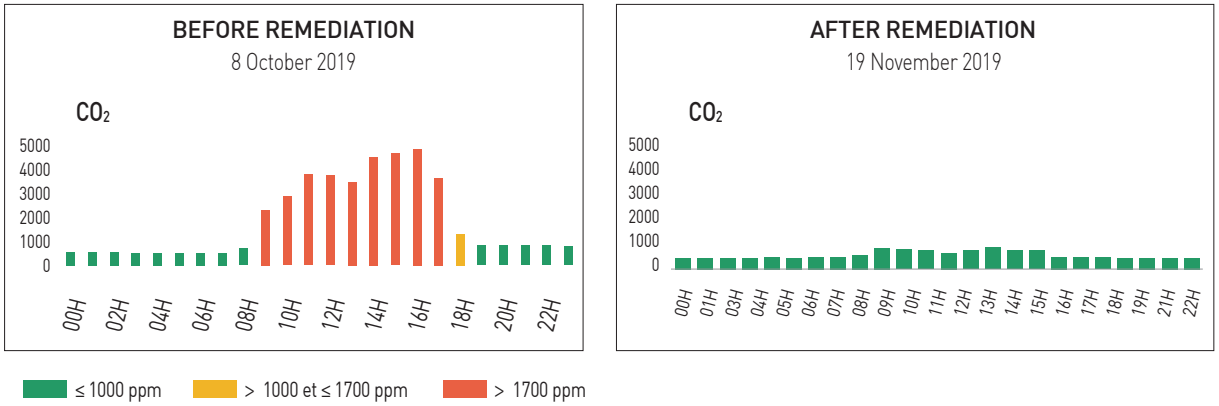
The solutions enable two challenges to be met simultaneously: improving air quality significantly and sustainably, and controlling energy consumption related to the ventilation system. Indeed, the issue of energy management is closely linked to that of air quality. That is why it is crucial to have both air and energy expertise in order to implement new or rehabilitation projects enabling the environmental and health challenges of buildings to be addressed.

The results obtained, for example in Raincy's schools (see illustration), can be applied to office buildings, hospitals, nursing homes, shopping centres, hotels, etc.

PM_{10} particle (pollution from external sources)



CO_2 (pollution from internal sources)



Additional instruments, such as protocols and guides developed by the HQE-GBC Alliance[31], are available and can be deployed to assist stakeholders in improving their practices such as air quality measurement. Veolia and some builders, such as VINCI Construction and Nexity, also provide real-time solutions for monitoring indoor air quality to better understand fluctuations.

However, all such measures, depending as they do on building owners' and users' readiness to deploy and maintain ventilation and air quality monitoring systems, remain rare. It is difficult to raise awareness of the issue, particularly as the positive health impacts of these actions are not easily quantifiable. Nevertheless, some scientific studies support the adoption of these measures. For instance, a joint study by Harvard and Syracuse Universities[32] establishes a link between indoor air quality and workers' cognitive performance (attention, memory, perception, reasoning, etc.). Workers exposed to poor air quality exhibit a decline in productivity. Another study highlights a decrease in the productivity of students working in poorly ventilated classrooms[33]. Yet other reports show that poor air quality can lead to an increase in days off work. Improving indoor air quality not only enhances a company's image but also improves productivity and reduces absenteeism, as employee well-being is closely linked to corporate economic performance.

However, the tools necessary to better measure the positives externalities of these actions are still lacking. Similarly, the economic and productivity spinoffs may not occur uniformly across all types of premises. In the absence of incentives, the installation and maintenance of building ventilation systems tends to be seen as a financial cost with no concrete benefit, whether for individuals, community or businesses.

The scenario changes for establishments open to a sensitive public, as they are subject to stricter regulations that mandate meeting certain thresholds for pollutants other than CO_2 and require regular monitoring. For instance, Babilou has adopted a multi-player approach, aiming not only to prevent a deterioration of the indoor environment in its nurseries by reducing pollutant emissions at the source but also to enhance the ventilation facilities of the premises.

Babilou

Indoor air quality management and improvement programme within the Babilou nursery network

To meet the ever-increasing regulatory requirements for establishments open to a sensitive public and as part of its commitment to sustainable education©, the Babilou nursery network's indoor air quality approach focuses on two main areas.

Building design and maintenance

For the development of new nurseries nationwide, Babilou has drafted a management charter that systematically sources sustainable materials with low or no VOC emissions. To do so, suppliers are challenged on the emission reports of their products (floors, paints[34], furniture, educational materials, etc.).

Regarding HVAC (heating, ventilation and air conditioning) equipment, Babilou favours double-flow ventilation for its positive impact on air quality, backed by a maintenance contract to ensure its long-term effectiveness. Similarly, Babilou is increasingly installing reversible air conditioners but no more fuel or gas boilers.

Nursery organisation

Providing a healthy environment for young children is Babilou's priority. This is particularly illustrated by the implementation in each of its establishments of a several-times-a-day ventilation protocol with relevant training for all professionals.

Following a successful experiment conducted across ten nurseries, Babilou has decided to supply all its buildings with green and labelled hygiene and maintenance products. This measure has significantly improved air quality as well as working conditions for professionals (products which irritate less).

Proper implementation of all these actions is checked every year through specialist auditors. Other projects are under preparation.

31 https://www.hqegbc.org/.

32 Allen (J. G.) *et al.*, Associations of cognitive function scores with Carbon dioxide, Ventilation, and volatile Organic Compound exposures in Office workers: A controlled Exposure Study of Green and conventional Office environments. Environmental Health Perspectives, 2015, 124(6), pp. 805-812.

33 For example: Sadrizadeh (S.), Indoor air quality and health in schools: A critical review for developing the roadmap for the future school environment, Journal of Building Engineering, 2022, Vol. 57, 104908.

34 Paints that emit less than 1 g of VOC per litre.

3 Building retrofit: factoring air quality into the economic equation

Building retrofit is crucial for energy, climate and economic issues, as well as public health. In France, seven million homes are poorly insulated, 4.8 million of which can be described as "thermal sieves" (i.e. almost 10% of total households)[35]. Beyond the excessive energy consumption associated with poorly insulated homes, there are significant health and economic impacts, including fatigue, chronic pathologies, respiratory problems, cardiovascular diseases, and premature death. The lack of insulation costs the French healthcare system 750 million euros each year[36]. Improving thermal and energy performance is also a major challenge for office buildings and public-access establishments.

For over a decade, public authorities have sought to combat fuel poverty and reduce greenhouse gas emissions through building improvements and energy retrofits. The 2018 ELAN law, for instance, made it mandatory to reduce energy consumption in office buildings. This requirement was later detailed in the "office building decree" of 2019[37] which established deadlines and reduction targets. More recently, the energy retrofit plan for buildings, published in 2021, has designated energy retrofit a national priority. The plan aims to upscale home renovation, expedite energy upgrades and savings in office buildings, and boost competitiveness and innovation in these sectors. To this end, 1.4 billion euros have been earmarked by the plan with specific thermal and energy performance targets for buildings. Simultaneously, the climate and resilience law of 2021 makes it mandatory to carry out and disclose the energy performance assessment for buildings. This assessment must specify the condition of the building's ventilation and airing systems.

Starting 1 January 2023, homes with an energy performance assessment of G+ (i.e. final energy consumption over 450 kilowatt hours per square metre per year) are no longer allowed to be rented. Further bans are on their way: G in 2025, F in 2028 and E in 2034. As things stand, rents for so-called "thermal sieves" have been frozen.

As a result, the stated goals, tools deployed, and actors mobilised mainly focus on the energy and thermal performance of buildings. While improved energy performance is crucial for health and well-being, it is not the sole factor that should be considered. Building retrofit presents a key opportunity to replace materials that may contain problematic chemicals or emit VOCs, to install suitable and efficient and energy-saving ventilation systems, to reduce humidity levels, to improve sound insulation, and to increase exposure to natural light. All these factors collectively contribute to improving the health and well-being of occupants.

But how do you encourage economic players and individuals to make health a priority when it is simultaneously being reported that the **energy** retrofit bill for French homes alone will amount to 246 billion euros? Under the ELAN law of 2018, the Ministry of Solidarity and Health has provided some initial answers by asking the HCSP to develop a home characterisation tool based on the dwelling's positive and negative impacts on the health and well-being of its inhabitants. This tool, known as "Domiscore", was launched in 2020 and consists of a multi-criteria grid that can be filled out by everyone[38]. Several issues are broached, including indoor air and exposure to air-borne and ground-based environmental hazards.

Nevertheless, the tool comes with several limitations. Firstly, its scope is restricted to housing. Secondly, the criteria assessed are minimal: presence or absence of windows and ventilation in the rooms, presence of moisture, mould, radon or asbestos, and presence of equipment using a carbonaceous fuel which increases the risk of carbon monoxide emissions. This simplistic approach can be explained by the desire of the designers to provide a tool that is accessible and user-friendly for everyone. Similarly, because it complements existing tools, the environmental impact of buildings is not taken into consideration. Thirdly, assessment and results disclosure are not mandatory. Be that as it may, Domiscore allows owners and tenants carrying out the assessment to identify health issues related to their home and even to initiate a home improvement plan. Awareness of these health issues by the public and the building industry would likely be greater if the assessment were to be performed systematically and integrated with the energy performance assessment.

35 CESE, Pour une politique publique nationale de santé-environnement au cœur des territoires. Opinion 2022-008, 24 May 2022, p. 27.
36 Initiative Rénovons, Coûts et bénéfices d'un plan de rénovation des passoires thermiques, énergétiques à horizon 2025. Economic study, February 2017, p. 3.
37 Decree No. 2019-771 of 23 July 2019 relating to the obligation to reduce final energy consumption in office buildings.
38 https://www.hcsp.fr/domiscore.cgi/debut.

Some certifications actively promote the inclusion of health - particularly air quality - criteria in building retrofit practices:

- **WELL Building Standard[39] certification:** aimed at office buildings, it introduces standards for employee well-being in companies. The certification reviews seven key criteria regarding both new and existing (or renovated) buildings: air, water, light, physical activity, comfort, nutrition and psychological well-being;

- **HQE[40] certification:** it applies to office and residential buildings, neighbourhoods and infrastructure in construction, development or retrofit projects. The certification, based on a multi-criteria grid that seeks a balance between respect for the environment, quality of life and economic performance, involves third-party auditing.

Obtaining these certifications provides a mark of quality for buildings, offering them a competitive advantage. In alignment with this, one of the studies of EDF's R&D teams aims to identify tools that would make it possible to integrate health, in particular indoor air quality, into the economic equation of renovation for all types of buildings.

Innovative indoor air quality solutions research study

Ensuring good indoor air quality (IAQ) to preserve occupants' health and comfort is a major public health concern, and one which attracts significant interest and commitment from the EDF Group. In accordance with its corporate purpose, this commitment is reflected at EDF Group level in research studies aimed at delivering innovative solutions for indoor air quality.

EDF R&D addresses the IAQ issue in conjunction with the energy and environmental performance of buildings. Its research aims to develop methods and tools with which to assess the impact of constraints and requirements on the energy, environmental and economic performance of buildings, while taking into account the health aspects.

For this purpose, EDF R&D has a joint laboratory with the University of La Rochelle's Laboratory of Engineering Sciences for the Environment (LaSIE) and the CNRS' **4evLab laboratory**[41]. This laboratory addresses three key issues: indoor air quality, humidity control, and urban energy. On IAQ in particular, the laboratory focuses on the reliability and completeness of scientific approaches, as well as on their applicability in the field. One of the laboratory's flagship projects is the **CEE Smart Reno programme**[42], which factors the comfort and health of occupants into the energy retrofit of buildings. One application concerns the development of robust and relevant indicators which go beyond the energy dimension and integrate IAQ into the economic equation of the renovation project.

Dalkia, an EDF subsidiary, implements global solutions for integrating IAQ with energy performance. After an accurate assessment, continuous measurement sensors adapted to pollutants are combined with adaptive ventilation and energy recovery systems. This makes it perfectly possible therefore to maintain good IAQ and control energy consumption.

By means of this global approach, EDF intends to reconcile **good indoor air quality**, preservation of occupant health at the workplace and lower energy consumption.

Research is also underway to reconcile the challenge of air quality with the energy performance of buildings. For example, in June 2022 the French Institute for Building Energy Performance (IFPEB) the Centre of Expertise for Risk, Mobility and Development Studies (CEREMA) and 11 private and public players jointly launched "Hub Air Energie" - a 24-month experiment across 15 sites[43] designed to "better understand the link between indoor air quality and lower energy consumption, and to find solutions that allow those issues to be consistent with the comfort and health needs of users"[44].

39 https://www.wellcertified.com/.
40 https://www.hqegbc.org/qui-sommes-nous-alliance-hqe-gbc/la-certification-hqe/.
41 https://lasie.univ-larochelle.fr/4evLab.
42 https://smart-reno.univ-lr.fr/.
43 One high school, four middle schools, five schools and five private-sector office buildings (offices and shopping mall).
44 https://www.ifpeb.fr/travaux/hub-air-energie/.

3

Improving air quality in transportation

Since we spend a significant portion of our time in public or private transport (even more for people who work in this sector), corporate thinking in the Health & Environment Commission has naturally focused on indoor air quality management in enclosed office spaces. This chapter sets out measures implemented by some members of Entreprises pour l'Environnement to improve the monitoring and quality of air inside vehicles and underground railway stations.

1 Vehicle interiors

Air quality in vehicle interiors can be negatively affected by various categories of pollutants from three primary emission sources:

- indoor emissions (materials);
- emissions from occupants (anyone entering the vehicle brings pollutants);
- emissions from outside.

Managing indoor air quality in cars depends on two key criteria: emissions from materials and air treatment within the passenger cabin.

The initial analyses of materials-related air quality were undertaken by German carmakers in the 1990s against a background of growing polymer use in passenger cabins (VDA standards). In the 2000s, a series of ISO (12219-1 to 10) standards were issued to measure air quality in the passenger cabin.

At a more legally binding level, South Korea, Japan and Russia adopted over a decade ago regulations governing air quality in vehicle interiors. Today, the most detailed and comprehensive regulation is that of South Korea. Every year, it tests more than a dozen vehicles[45], and since 2021 imported ones as well. All results are made public, and in cases of non-compliance, the Korean authorities issue a press release which is only rescinded upon proof of compliance[46].

The European Union currently lacks a binding legal framework for this issue but is seeking to regulate formaldehyde emissions. Similarly, France does not have legally binding measures to regulate indoor air quality in vehicles. China is more volatile in its decisions, which makes it difficult to anticipate its requirements.

Regarding air treatment, there are presently no globally applicable standards or regulations. However, two working groups are currently considering a test methodology:

- The United Nations Economic Commission for Europe (UNECE) Vehicle Interior Air Quality (VIAQ) Working Group, which is expected to submit its final report in 2025;
- The European Committee for Standardization (CEN) Workshop 103, whose final report initially expected in 2022 is delayed.

To anticipate and apply the regulations and demonstrate a quality-based approach to its customers, the Renault Nissan Mitsubishi Alliance is committed to making all its vehicles compliant with the world's lowest regulatory limit in force for each issue. To this end, Renault Group has put in place various measures to better manage emissions from the materials used and to optimise air treatment inside its vehicles.

Similar to building ventilation systems, vehicle ventilation units also need regular maintenance (filter change every year). These best practices are outlined in user manuals and, in some cases, communicated through advertising.

45 Analysis of concentrations of formaldehyde, acetaldehyde, acrolein, benzene, ethylbenzene, toluene, xylene and styrene.
46 For example: The Korea News Plus: Mercedes car fails to keep Korea's air quality standard. 10 January 2023.

Improving air quality management in vehicle interiors

A vehicle is an enclosed space operating in a polluted environment. Renault is working to reduce pollutants in the passenger cabin to preserve occupants' health. It has two major lines of action.

Choice of materials, with a view to limiting volatile organic compound (VOC) emissions and odours from materials. All materials have to be validated with regard to their emissions and only those whose emission levels comply with international regulations are selected.

Filtration of air entering the passenger cabin. Many technological building blocks are integrated into the vehicle's ventilation system to ensure healthy air in the passenger cabin. In particular, there is a cabin filter, sensors to activate air recycling according to external pollutant levels, and air purification cycles.

The ongoing electrification of vehicles will affect air quality management in two-tier vehicle interiors. On the one hand, electrification will reduce external pollutants emitted by internal combustion engines (e.g. nitrogen dioxide) which enter the passenger cabin. However, particles emitted by brake abrasion and by contact between tyres and the road will remain. On the other hand, it will affect the operation of the air treatment system since the latter runs on energy and its use will reduce the vehicle's range.

The aviation industry encounters similar challenges, marked by specific regulations and special concern for energy consumption.

EC2S Clean Aviation Project: reducing air quality-related energy consumption in aircraft cabins

The Environment Control System (ECS) plays an important role in ensuring air quality and thermal comfort in the aircraft cabin. To pressurise the aircraft cabin, air is taken from the engines outside, compressed by the engine's compressor stage, then regulated by ECS to the required temperature and mixed by it with the air already in the cabin. Standard ECS, however, remains one of the main sources of energy consumption in the aircraft.

The Clean Sky 2 - EC2S (Environment Control Secondary System) project is managed by Hutchinson and run in collaboration with its partners CEA, Tera Sensor and Tera Environnement. The purpose of this project is to filter pollutants in order to increase the rate of recycled air inside the cabin through a secondary recycling loop, thus reducing energy consumption. This system complements the primary ECS system.

EC2S is designed on the one hand to provide a first-in-class air recirculation system allowing up to 100% recycling with the most advanced built-in air treatment processes and sensors, and on the other to demonstrate its effectiveness and potential certification in the Clean Sky 2 demonstrator. This solution has four cornerstones:

- a multi-technology air treatment system covering the broadest temperature/airflow conditions;
- world-class sensors brought in from the automotive industry to ensure reliability and cost-effectiveness;
- a compact EC2S pack that can be easily connected to an "in-service" aircraft ECS system;
- a common monitoring system to divide the ECS function between primary ECS and EC2S based on the optimisation of fuel consumption.

This innovative system filters fine particles (PM), CO_2 and volatile organic compounds (VOCs). Freed of its pollutants, the air can be fully recycled, thus reducing the power taken from the engines during fresh air compression.

The device has been tested and its principle validated in field trials on a bench-test Fraunhofer aircraft cabin.

2 Underground railway stations

Ever-increasing use is being made of underground railway stations. The Transilien suburban railway network handles five million passengers a day[47] and employs over 25,000 staff. The last few years have therefore seen rising concerns[48] over the quality of air at underground stations. The challenge is to offer passengers and employees using these spaces satisfactory air quality. While gas pollution is low in underground spaces, the pollution mainly consists of coarse and fine particles (PM_{10} and $PM_{2.5}$). The main sources of this pollution are wear and tear of the wheels due to braking, contact between rolling materials and track, raising of dust when trains pass, people and, for some stations, outdoor air pollution. The first two sources are specific to all rail transport in France[49] and abroad. The levels of particulate pollution depend on factors like the type of rolling stock, traffic density and frequency, station layout and the efficiency of ventilation systems.

In May 2022, ANSES issued an opinion and report updating its 2015 inventory on the knowledge of particle toxicity and related health effects. The report highlighted a significant concentration of fine particles at underground stations, with levels "much higher" than in urban air. These particles also exhibit a different composition and a high metal content.

Although knowledge is still limited, the Agency notes that epidemiological and toxicological data "suggests possible effects on autonomic cardiac function, systemic inflammation, oxidative stress, and inflammation of the respiratory tract, particularly in sensitive populations"[50]. As such, ANSES recommends continued monitoring and analysis of health risks and proposes limits on particle concentrations in the air based on the time spent underground.

The Fourth National Health Environmental Plan (PNSE 4) aims to improve air quality at underground stations, among others, by providing a "guide containing recommendations for the measurement of particles and the metals they contain"[51]. This guide, drawn up by the National Institute for Industrial Environment and Risks (INERIS)[52], in collaboration with rail operators, provides background and support material for operators in charge of measuring air quality at underground stations.

In this context, and in the absence of specific regulations for underground stations based on health effects, the French rail operator SNCF has adopted a set of measures to reduce the concentration of coarse and fine particles in the air, drawing in particular on the recommendations of the INERIS guide.

Example of an air quality monitoring system adopted by SNCF.

47 ANSES, Qualité de l'air des enceintes ferroviaires souterraines. Revue de littérature sur les effets sanitaires. Proposition de concentrations en particules dans l'air à ne pas dépasser. ANSES opinion, collective expert report, May 2022, p. 6.
48 For example, Le Monde: Pollution de l'air dans le métro : une étude alerte sur le niveau de particules fines. 23 May 2023.
49 Paris and its suburbs, Marseille, Lyon, Lille, Toulouse and Rennes.
50 ANSES, Qualité de l'air des enceintes ferroviaires souterraines. Revue de littérature sur les effets sanitaires. Proposition de concentrations en particules dans l'air à ne pas dépasser. ANSES opinion, collective expert report, May 2022, p. 9.
51 French Government, Un environnement, une santé. 4e Plan National Santé Environnement. April 2021, pp. 49-50.
52 INERIS, Recommandations pour la réalisation de mesures harmonisées de la qualité de l'air dans les enceintes ferroviaires souterraines. Background report/guides, 26 November 2020.

Monitoring and developing new innovative technologies: SNCF actions for better air quality

SNCF has drawn up a three-part emissions action plan to improve air quality in trains and underground railway stations.

Understand: application of the harmonised measurement protocol recommended by the French government and continuous monitoring of air quality at three stations, in conjunction with Airparif[53]. SNCF also participates in various research projects[54].

Reduce: reduction of emissions from rolling stock by optimising braking systems (low emission blocks and linings, electric braking).

Collect: at underground stations, installation of ventilation equipment and testing of innovative air treatment technologies and systems for sucking brake particles from the train, with the support of the Île-de-France Region and Île-de-France Mobilités (IdFM).

SNCF also monitors chemical and biological pollutants on trains and develops new filtration and indoor air quality improvement systems.

In the Île-de-France Region, transport operators can count on the support of the regional authorities to implement these measures. Following its "Let's change the air" plan (2016-2022), the Île-de-France Region launched a "New Air" plan (2022-2027) which proposes to halve pollution from current levels by 2030 in line with WHO recommended thresholds. To this end, it has adopted eight actions, including one on improving air quality in and through public transport. The Region plans to invest six million euros to significantly improve air in the twenty most polluted underground stations by 2028.

In addition, transport operators have the opportunity to share their best practices through the international COMET (Community of Metros) network[55] as well as the International Association of Public Transport (UITP)[56].

53 https://www.airparif.asso.fr/gares-rer-et-metros.

54 Europe's Rail Joint Undertaking (ERJU) Project on improving air quality at underground stations and on trains; ADEME ToxinTransport project on the toxicological characterisations of particles taken from the air and emitted by rolling stock; thesis on the dispersion mechanisms of particles emitted during the mechanical braking of trains in underground stations...

55 https://communityofmetros.org/.

56 https://www.uitp.org/.

4

Improving utilisation of enclosed spaces

Outdoor pollution, building and furnishing materials, decoration products, and occupant activities and behaviour (combustion appliances, equipment, cleaning, DIY, deodorisation, pets, smoking, temperature, humidity, ventilation and airing methods, etc.) are the main sources of indoor air pollution. Actions to combat poor air quality include those mentioned earlier, i.e. air renewal of the premises and, as a last resort and supplement, air purification. However, even the best ventilation and air treatment systems require maintenance and measures in place to reduce or eliminate sources of pollution. In other words, indoor air quality is intrinsically linked to how buildings or other enclosed spaces are used.

In this final chapter, we describe the measures implemented by various players to raise public awareness of this issue and promote good practices, as well as the information published to help implement them.

1 Raising awareness and disseminating air quality management best practices

The implementation of awareness-raising and training measures for individuals, employees and users on issues and good practices is of fundamental importance in improving indoor air quality in these spaces. Tailored actions and communication are all the more effective when adapted to the target population, building infrastructures, ventilation systems, and location. For example, ventilation by opening windows is not the most advisable approach when the building is located next to a major road. Similarly, some of the communication messages are seemingly contradictory. Domestic wood heating is an example. Encouraged for its renewable quality, it can contribute to atmospheric and indoor air pollution. In response, the Ministry for Ecological Transition launched an action plan on 23 July 2021 to halve fine particles emitted by domestic wood heating, aiming to replace 600,000 old appliances by 2025. In some regions, the purchase of wood heating appliances is subject to regulations (e.g. Greater Lyon and Nord-Isère).

This raises a number of questions:

- Which players should be mobilised to provide information?
- What messages and information should be conveyed?
- How can this information be adapted and provided to the target audience?

Different players may be involved. Public authorities are uniquely placed to disseminate scientifically reliable messages to a wide body of the population. For instance, the Ministry for Ecological Transition and Territorial Cohesion popularises indoor air quality issues on its website and lists relevant regulations and public policies. Moreover, National Air Quality Day[57] is organised annually on October 14th to bring together all public and private players, experts, students and citizens around this theme to discuss air quality issues, actions, studies, and best practices. The Ministry of Health and Prevention also popularises health issues related to air pollution through infographics on its website, guiding the general public on appropriate actions[58].

57 https://www.ecologie.gouv.fr/jnqa.
58 Ministère de la Santé et de la Prévention, Qualité de l'air intérieur : comment agir ? Recommendations, 22 October 2013, updated 3 March 2022.

Public actions can also be better targeted by harnessing research output. A case in point is CEREMA. To facilitate implementation of the new regulatory provisions, it has brought out a guide for local authorities and managers of private establishments on monitoring indoor air quality in places hosting children[59]. The guide contains both information about the monitoring protocol to be implemented and fact sheets on raising awareness among users and occupants. The national education system is another avenue for raising awareness among young people, which then spills over to families. ADEME, the Environmental and Energy Management Agency, has for this purpose published "ecol'air", a best practices guide for communities, professions, and school users[60].

Civil society and associations can promote awareness in the public and in some communities by passing on best practices to them. For example, the interdisciplinary and intergenerational institution Collège SEIQA (a French acronym for Health, Indoor Environment and Air Quality)[61] brings together health professionals, businesses, students, communities and experts to encourage discussion and thinking on indoor air quality in particular, raise awareness and improve people's daily lives.

SEIQA college: a melting pot of health and environment knowledge and experiences

The interdisciplinary and intergenerational SEIQA (Health, Indoor Environment and Air Quality) college aims to develop a mutual understanding of health and environment issues.

Because exposure to environmental pollution impacts our health and needs to be better controlled, especially for the most vulnerable sections of the population, because we have the right to live in a balanced and healthy environment, and because climate changes have extreme consequences and trigger health and environmental crises, we need to come together and develop common thinking, find appropriate solutions and no longer work in isolation within our field of activity.

SEIQA college brings together allergists, environment students and businesses that offer solutions to improve the indoor environment and air quality. One of the main objectives of the college is to stimulate thinking and innovation through the cross-disciplinarity of students, businesses and public services concerned with health, indoor environment and air quality. Several tools are available to gather knowledge and share experiences. These include the monthly newsletter of the college, the series of webinars on air quality professions and key observers, and the annual morning symposium on the state of the art and the diverse experiences highlighting a current health and environment issue (role and place of citizens in reducing their environmental exposures (2021), and air quality and child health in the community (2022).

59 Cerema, Guide d'accompagnement à la mise en œuvre de la surveillance réglementaire de la qualité de l'air intérieur dans certains établissements recevant du public. Accompanying practical guide, February 2023.

60 ADEME, Écol'air : un établissement qui respire, c'est bon pour l'avenir – Les outils pour une bonne gestion de la qualité de l'air dans les écoles. Keys to action, 2018.

61 https://rlabconseil.com/college-seiqa/.

Health professionals, scientific experts, and learned societies are essential contributors to the dissemination of scientific knowledge for decision-making among various stakeholders. This is especially true of the Association for the Prevention of Air Pollution (APPA)[62], the French Health & Environment Association (ASEF) and the French-speaking Health & Environment Society (SFSE), all of whom carry out broad actions in the fields of health and the environment to inform and bring together experts, communities, health professionals, businesses[63], and the general public. In some regions, indoor environment advisers (CEI), often attached to APPA, can perform air quality audits, measure pollutants and help asthmatic patients in adopting various practices to improve the indoor environment in their homes.

Lastly, businesses also play an important role, whether by raising awareness of these issues among their employees, implementing measures to reduce pollution at the source, or assisting other actors in deploying such measures. The solutions deployed by Veolia, for example, include identifying and understanding building-specific pollution sources so that the most appropriate reduction protocol can be adopted when installing ventilation and air treatment systems (see box chapter 2), as well as involving and training stakeholders in best practices.

VEOLIA

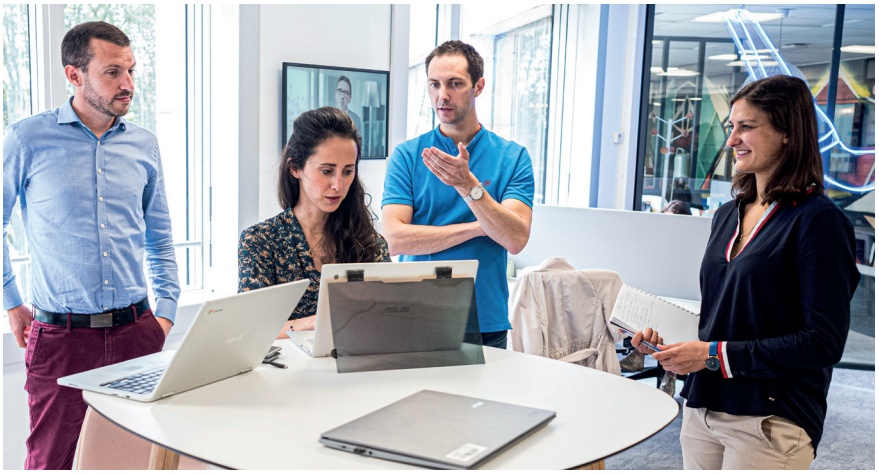
The Veolia Air Human approach: involving stakeholders to better manage indoor air quality

In addition to addressing the technical challenges of air measurement or purification, Veolia intends to make occupants, employees and staff "actors" in the improvement of indoor air quality.

The "Air Human" approach, which involves all stakeholders, is based primarily on raising awareness among the people concerned.

It ensures that stakeholders adopt adequate behaviours to improve air quality. This applies equally to the purchasing department choosing cleaning products to be used in a building (having an immediate impact on volatile organic compound concentrations, for example), as to occupants choosing not to open the windows of a building when the air is polluted outside by particles, pollen or pesticides.

Dedicated tools, such as web and mobile applications, are available to promote interactions with users and understand their perception of indoor air quality. It is indeed essential to take account of the perceptions of building users who can sometimes identify particular problems such as odours (the human nose being a very sensitive "sensor"). In some specific situations, as for example in the event of a fire near a building (forest fire or industrial incident), these tools can also reassure occupants that air treatment system is working properly and indoor air quality remains good.



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62 https://www.appa.asso.fr/.
63 For example, EDF is an active member of SFSE.

In-company support initiatives are instrumental in empowering employees with knowledge, tools and best practices in air quality management. They stimulate thinking, even extending it beyond the workplace to impact individual habits. However, there is often a decline in interest within a few months of installing a ventilation or air treatment systems, unless a major malfunction occurs.

Societal expectations regarding indoor air quality are on the rise and have become a regular topic of discussion. Despite this, indoor air quality remains a sensitive and underestimated issue. A large section of the population still thinks they are not exposed to air pollution within their homes. The invisible nature of indoor air quality deterioration underscores the need for continuous efforts to educate all stakeholders, fostering a more systemic vision that avoids contradictory and, at times, anxiety-provoking messages. This is what more and more businesses are focusing on.

2 Helping choose products used in or brought into enclosed spaces

As well as raising awareness among stakeholders, information is needed to implement best practices. How do you choose building materials (paint, coatings, varnishes, glues, textiles), furniture, household products, air fresheners, etc. in terms of their impact on indoor air quality?

French lawmakers as well as the Ministry for Ecological Transition have provided some initial answers by introducing mandatory labelling for all materials coming into contact with indoor air which indicates their emissions into the air (see chapter 1)[64]. This labelling has incentivized companies to adopt the best-performing products thereby cleaning up the market. Moreover, some carcinogenic, mutagenic and toxic substances for reproduction[65] have been banned from use in building materials and decoration products since 2009. The Grenelle 2 law of 2010[66] introduced similar labelling for furniture products. Then in 2015 ANSES published a report setting out a list of 21 priority substances identified among the "661 substances [...] identified and [...] considered as being potentially emitted by furniture products"[67]. However, challenges in implementation persist. That explains why, despite draft regulations and decrees being forwarded for consultation in 2017, implementing legislation is yet to be adopted[68]. The Ministry for Ecological Transition is working on information gathering and labelling for some consumer products that emit volatile pollutants, such as air fresheners (incense, candles, diffusers) and cleaning products.

Although still evolving, the regulation does not yet cover all products. Businesses, encouraged by the development of labelling, have begun contributing to this effort by marketing products that produce fewer emissions or do not contain certain chemicals and voluntarily providing necessary and relevant information. This is the approach adopted by Saint-Gobain for building materials in contact or not with indoor air (see box chapter 2).

In turn, we see a proliferation of so-called environment-friendly cleaning products on the market possessing various properties and intended for multiple uses. The same is true for certifications, some of which, such as Indoor Air Comfort[69] proposed by Eurofin, promote products with lower emission rates and compliant with all VOC requirements in Europe. Other certifications take into account the broader environmental impact of products (e.g. EU Ecolabel[70]). This trend is reflected in the emergence of air purifying products or sensors designed to monitor indoor air quality.

Faced with a plethora of products and labels, the Association for Clinical Research in Allergy and Asthma (ARCAA) was set up in 2006 to offer scientific expertise and advice to patients, businesses and communities.

64 Ten pollutants (formaldehyde, acetaldehyde, toluene, tetrachloroethylene, xylene, trimethylbenzene, dichlorobenzene, ethylbenzene, 2-butoxyethanol, and styrene) are targeted, along with total VOC emissions.
65 Trichloroethylene, benzene, dibutyl phthalate and bis(2-ethylhexyl) phthalate.
66 Law No. 2010-788 of 12 July 2010 on France's national commitment to the environment.
67 ANSES, Expertise en appui à l'étiquetage des produits d'ameublement. ANSES opinion, collective expert report, June 2015.
68 French government, Étiquetage des produits d'ameublement sur leurs émissions en polluants volatils. Public consultations from 18 January to 10 February 2017. For further information: Cerema, Qualité de l'Air Intérieur : repères et cadre juridique. Logements, ERP et bâtiments tertiaires. 2021, p. 16.
69 https://www.eurofins.com/consumer-product-testing/industries/construction-building/indoor-air-comfort/.
70 https://www.ecolabel.be/fr.

ARCAA approval and certification process

The share of allergic and asthmatic patients in the population is constantly increasing and, according to the WHO, should account for 50% of the French population by 2050.

Faced with many potential sources of allergens in their daily lives (at the workplace, during leisure time, or at home), and in the absence of government-issued labels, these patients turn to their doctor for solutions to reduce their exposures.

To plug this gap, the ARCAA (Association for Clinical Research in Allergies and Asthma) has developed and introduced the "Allergens Controlled" (AC) and "Indoor Air Controlled" (AIC) labels to identify products or buildings with lower concentrations of potential allergens and indoor air pollutants.

The labels target both manufacturers (of cosmetics, textiles, air purifiers, and household products) so as to improve their product ranges and the general public, which will be able to choose products validated by third-party experts. The AIC label is offered to establishments open to the public, such as nurseries, schools, hotels, old people's homes, etc. Specifications are drawn up by expert doctors and validated by a hospital specialist.

The chosen criteria are based on the regulations in force and evolve to reflect regulatory changes. Experts are not directly related to label applicants.

In this way the labels guarantee quality and safety for patients, serve as a reference for physicians and constitute a commercial asset for the company that sells the product or owns the establishment. They in fact help to bring greater comfort to allergy sufferers, while boosting the confidence and satisfaction of these consumers.

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Information transparency, availability and legibility are all essential factors for enabling businesses, professionals, employers, individuals, and users to make informed choices in respect of indoor air quality. However, standards need to be harmonised in the face of their proliferation and complexity.

The development of scientifically validated labels is therefore relevant both as a guarantee for individuals and as a mark of confidence and quality for companies. That may also encourage businesses to reduce VOC and other emissions from their products and replace or reduce chemicals.

CONCLUSION

We spend 80% of our time on average in enclosed spaces and the air there is two to five times more polluted than outdoors. Many scientific studies show that exposure to these pollutants has various impacts on human health ranging from disorders (difficulty concentrating, headaches, etc.) to more serious problems (respiratory pathologies, growth retardation in children, etc.). In France, the socio-economic cost of indoor air pollution is estimated at more than 19 billion euros a year[71]. Accordingly, the issue of air quality is a growing concern for people, the scientific community, public authorities and businesses.

The various sources of indoor air pollution include everyday habits, equipment, materials, and decoration, as well as the increasing airtightness of enclosed spaces and inadequate air renewal. Similarly, the energy performance of such spaces also has an impact on health, whether through lack of insulation (introduction of external pollutants, humidity, large temperature variations) or through pollutants emitted by certain types of heating (fuel or wood, for example). The overall improvement of existing and new buildings is therefore a decisive factor both in the fight against climate change and in the drive for energy restraint and better public health.

The European Union in general, and France in particular, is gradually acknowledging the significance of these issues, but existing regulations as yet do not systematically or simultaneously deal with all aspects. For instance, indoor air quality issues are rarely addressed in regulations related to building retrofits, passenger vehicles or underground railway stations. Likewise, labelling on VOC emissions is limited to some products.

Within the EpE Health & Environment Commission, approximately forty large companies have engaged in discussions with each other and their stakeholders to explore ways of sharing best practices and accelerate actions to improve indoor air quality. The key drivers include:

- identification and monitoring of pollution sources, which implies a change in people's purchasing and use behaviour and habits, as well as in the choice of materials used for building or vehicle construction;
- air renewal in premises, which presupposes the existence of approved and well-maintained ventilation and airing systems in those spaces or the implementation of ventilation protocols;
- if necessary and in addition to the previous actions, air purification.

The challenges for businesses are many and varied. For those involved in building, maintaining or renovating enclosed spaces, the goal is to strike the right balance between thermal, energy and indoor air quality performance. Businesses involved in designing, producing and marketing materials or products used in these buildings face the challenge of obtaining transparent and accessible information on the chemicals contained and incorporating indoor air quality considerations into product design. All other businesses have a leading role to play in improving air quality in their premises and educating and training their employees in best practices.

Initial studies reveal that the factoring of air quality into the construction, maintenance and renovation of buildings, vehicles and underground stations is already under way. However, maturity levels differ depending on the stage of life of the building or vehicle in question. Integrating indoor air quality into the design stage is indeed the best solution as the room for manoeuvre is then much smaller. Moreover, addressing and reconciling energy performance, greenhouse gas emissions and air quality from the earliest design phases helps optimise costs. That is why maintenance, improvement or retrofit measures for old buildings and vehicles have greater difficulty factoring in indoor air quality.

71 ANSES, Étude exploratoire du coût socio-économique des polluants de l'air intérieur. Study report, April 2014, p. 69.

That notwithstanding, building-sector companies are to some extent being encouraged to make such efforts by regulation or the prospect of regulation, but above all by their customers and the rapid growth of certifications that factor in air and other quality-of-life and environmental respect criteria. Such measures are still fairly limited because of a lack of harmonisation of standards and labels, poor interdisciplinary knowledge on how to balance energy, thermal and health issues, the lukewarm market response to those issues, and the failure by project owners and end customers to take into account the positive externalities associated with improved air quality in buildings. Educating project owners and end customers (i.e. the general public) is key to long-term success.

The discussions in the EpE commission have also highlighted measures implemented by some players to reduce the quantity of unwanted chemicals present in products or materials used in enclosed spaces, and/or to increase the transparency of product composition. Much of the knowledge is still fragmented, and there is a potential for increased public-private cooperation involving scientific experts and other relevant stakeholders to encourage research and transparency.

Finally, user behaviour in these spaces has a decisive impact on indoor air quality. While concerns are growing, the issue is still underestimated by most people, highlighting the need for ongoing educational efforts. Some businesses have started to work on this issue with their stakeholders. The relevance and scope of the messages would undoubtedly be enhanced by greater collaboration between public and private players, the scientific community, and civil society.

List of figures

List of abbreviations

ADEME	Agence de la transition écologique (Ecological Transition Agency)
ANSES	Agence nationale de sécurité sanitaire de l'alimentation, de l'environnement et du travail (National Agency for Food, Environmental and Occupational Health Safety)
APPA	Association pour la prévention de la pollution atmosphérique (Association for the Prevention of Air Pollution)
ARCAA	Association de recherche clinique en allergologie et asthmologie (Association for Clinical Research in Allergy and Asthma)
CEN	Comité européen de normalisation (European Committee for Standardization)
CEREMA	Centre d'études et d'expertises sur les risques, la mobilité et l'aménagement (Centre of Expertise for Risk, Mobility and Development Studies)
CNRS	Centre national de la recherche scientifique (National Centre for Scientific Research)
COPD	Chronic obstructive pulmonary disease
ERJU	Europe's Rail Joint Undertaking
HCSP	Haut Conseil de la santé publique (High Council for Public Health)
HVAC	Heating, Ventilation and Air Conditioning
IAQ	Indoor Air Quality
IdFM	Île-de-France Mobilités
IFPEB	Institut français pour la performance du bâtiment (French Institute for Building Performance)
OQAI	Observatoire de la qualité de l'air intérieur (Indoor Air Quality Observatory)
PNSE	Plan national santé environnement (National Health Environmental Plan)
SBM	Sick Building Syndrome
SEIQA	Santé, Environnement Intérieur et Qualité de l'Air (Health, Indoor Environment and Air Quality)
UITP	Union internationale des transports publics (International Association of Public Transport)
UNECE	United Nations Economic Commission for Europe
VIAQ	Vehicule Interior Air Quality
VOC	Volatile Organic Compound
WHO	World Health Organization

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About EpE

Association Française des Entreprises pour l'Environnement (EpE), set up in 1992, brings together around sixty major French and international companies who share their best practices and work together to better integrate the environment into their strategies and operations. Its *raison d'être* - one planet and a prosperous world - sums up the resolve of its members to lead their own ecological transition as well as that of society, and to ensure that economic development compatible with planetary boundaries is socially accepted, indeed desired. EpE is the French partner of the World Business Council for Sustainable Development (WBCSD).

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