Urban Studies and Public Administration
Vol. 8, No. 1, 2025
www.scholink.org/ojs/index.php/uspa
ISSN 2576-1986 (Print) ISSN 2576-1994 (Online)

Original Paper

There Is No More Time.

Strategies for Protecting Health in Confined Spaces

Alberto De Capua[1*]

[1] Department of Architecture and Design (dAeD), Mediterranea University of Reggio Calabria, Italy

[*] Alberto De Capua, E-mail: adecapua@unirc.it

Received: November 10, 2025 Accepted: December 2, 2025 Online Published: December 22, 2025

doi:10.22158/uspa.v8n1p70 URL: http://dx.doi.org/10.22158/uspa.v8n1p70

Abstract

This paper analyses the changes in urban and domestic life following new needs and fears, particularly those that emerged during the recent global pandemic. Here, we want to emphasise how urban and living spaces are central to our resilience and well-being, focusing on the indoor air quality (IAQ) of buildings. Despite its importance, indoor air quality is often overlooked, even though it is linked to known health effects, such as "sick building syndrome", which affects occupants of closed environments equipped with mechanical ventilation and air conditioning. The research highlights that ensuring good indoor air quality is now entirely possible in new buildings, thanks to the possibility of choosing healthy materials, designing effective ventilation systems and controlling humidity and pollutants. The situation is different in existing buildings, where interventions are more complex and expensive. In such contexts, it is essential to assess the specific conditions to identify simple technical solutions where possible, or to plan more structural interventions in cases of hazardous pollutants.

Through a comparative analysis of international standards, studies and projects, this contribution provides useful tools for aware design, based on knowledge of materials and the physicality of the built space. The aim is to promote design that considers the healthiness of indoor environments as an integral part of the quality of contemporary living.

Keywords

environment, sustainable project, ecology, health, iaq

1. Introduction

Following the global energy crisis, Italy has also seen a major transformation in the design criteria adopted for civil buildings. New requirements to reduce energy consumption, particularly in relation to heating and air conditioning, have necessitated technical solutions aimed at increasing the thermal insulation of building envelopes. This improvement in performance, achieved in part using more energy-efficient materials and the refinement of construction techniques, has led to the creation of buildings that are highly efficient but often unhealthy.

The trend towards hermetically sealing indoor environments has led to a drastic reduction in natural air exchange, often replaced by mechanical ventilation systems that are not always adequately designed or maintained. As a result, indoor air can be of poor quality, negatively affecting the comfort and health of occupants. The problem is further complicated by the difficult balance to be achieved between ventilation and energy consumption: to reduce the concentration of certain pollutants, it is necessary to increase the supply of outdoor air, but in other cases, on the contrary, it is precisely increased ventilation that risks introducing additional contaminants or increasing energy consumption, making the solution counterproductive.

In this context, the research aims to supplement the existing regulatory framework by introducing new parameters that consider not only energy performance but also the health, hygiene and functional requirements of indoor environments, both residential and work-related. Improving indoor air quality involves monitoring and measuring several key elements: the number of air changes, whether natural or forced; indoor microclimatic conditions (temperature, humidity, air speed); user behaviour for risk prevention; and space occupancy levels.

Underlying this approach is the belief that digital and intelligent technologies, supported by a high level of knowledge and research and development activities, can provide effective tools for integrated monitoring and management of indoor pollutants. The aim is to improve the liveability and safety of indoor environments, promoting the well-being of users without compromising overall energy efficiency.

In this perspective, a few key operational steps are outlined: risk analysis, assessment of the effects of pollutants on health, identification and measurement of contaminants, adoption of risk reduction techniques and promotion of health education strategies.

A further problem concerns the lack of specific regulations on air quality in confined environments in Italian legislation. The lack of clear standards is hampered by the scarcity of data and reliable knowledge on the risks arising from indoor pollution. Furthermore, risk factors vary significantly depending on the materials used, the building technologies employed, the climate and people's habits. Current regulations, which are heavily focused on energy efficiency, still neglect aspects related to the well-being and health of occupants. However, technological innovation and digitalisation are key tools for overcoming these critical issues, especially for the benefit of the most vulnerable sections of the population. Monitoring tools can be integrated from the early stages of a building project, allowing designers, technicians and building managers to work together to create healthy and safe environments. There are numerous applications for this research, especially in sensitive spaces such as homes, schools and hospitals, where it is essential to protect the well-being of vulnerable individuals.

2. Reference area

The text critically analyses the current state of global society, marked by growing environmental, social and economic unsustainability caused by the increasingly profound and pervasive impact of human activity. As early as the 1970s, the famous 1972 Club of Rome Report — written by Dennis Meadows and his research team at MIT — predicted that exceeding the planet's ecological limits would compromise the future of humanity. Subsequent editions of the report, in 1992 and 2004, confirmed and exacerbated those predictions, denouncing the collective inability to reverse the trend towards unsustainability (Meadow et al.,1972, 1992, 2004). Today, reality has perhaps surpassed even the most pessimistic predictions. In this context, contemporary society continues to pursue an idealised vision of development and progress, which, however, turns out to be a modern variant of myth, as Serge Latouche (2019) argues. This model, based on continuous growth, consumption and privatisation of common goods, is eroding both natural heritage and social cohesion. Global inequality and environmental degradation are in fact two sides of the same structural problem. The current socio-economic model exacerbates the overexploitation of resources, compromises the planet's capacity for regeneration and fails to consider essential ecological limits.

The current climate, energy and environmental crisis is therefore an unequivocal sign of failure. Authors such as Luca Mercalli and Timothy Morton emphasise that this crisis is no longer an abstract risk, but a condition that is already underway, experienced daily by billions of people. The onset of extreme weather events, resource scarcity, desertification and biodiversity loss make it clear that "it is already happening", even if many tend to ignore it or psychologically repress it. Morton speaks of a real collective trauma, which the media and institutions often trivialise or exploit.

In this complex scenario, the project — understood as environmental, urban, architectural and technological planning — takes on a central role. It can become a tool for resistance, mitigation and adaptation. The project must not only respond to immediate needs for efficiency and health but also facilitate a cultural shift towards a new form of sustainable cohabitation on the planet. It must contribute to the normalisation of sustainable behaviour, acting concretely on physical spaces, materials, technologies and everyday practices.

Gianfranco Bologna's essay (2022) highlights how the contemporary challenge is to live on the planet in an equitable and dignified manner, without exceeding the absorption capacity of ecosystems. Sustainability is no longer an ethical aspiration or an abstract principle, but a structural necessity to avoid collapse. The constant increase in the world's population — which has reached 8 billion — and the parallel increase in consumption and waste require a profound revision of productive and cultural paradigms.

This highlights the need to set clear and binding limits within which economic systems must operate. It is not just a question of green technologies, but of rethinking the entire relationship between humans, the environment and development. The urgency of this reformulation is evidenced by concrete events: rivers running dry, uncontrolled fires, heat waves, rising sea levels, loss of habitable land. As Antonio Scurati writes, today we all perceive climate change directly as a tangible experience that jeopardises the quality of life and safety of communities.

So, sustainable projects have an active and transformative function. On the one hand, it is proposed as a tool for containing the effects of the environmental crisis; on the other, it can become a vehicle for inclusion and social justice, especially through the regeneration of common goods, both social and environmental. In contexts marked by scarcity of resources and growing tensions, sustainable design also means creating solidarity, building relationships and producing cohesion. The project, therefore, is not only technical or aesthetic, but also political and cultural. Here, we also want to question prospects. The ecological balance of the planet is now compromised, and according to Brown (2002) and Giovannini (2014), we are on the verge of a "perfect storm", where entire ecosystems, economies and local communities are at risk of collapse even before the scientific targets set for 2050 are achieved. This requires us to act immediately, without waiting for technological solutions to save us, but by resorting to resilient, concrete, replicable and sustainable strategies.

In this sense, the COVID-19 pandemic has represented a symbolic and material turning point: it has highlighted the fragility of our systems and the centrality of environmental design as a tool for containing and rethinking spaces. It has shown how design can be a preventive action, capable not only of reacting to disasters, but also of anticipating and mitigating them.

This contribution therefore aims to go beyond the theoretical definitions of sustainability to explore its operational implications in the field of design. It is necessary to make visible not only the risks but also the concrete opportunities of a new design approach capable of combining progress, justice and responsibility. Design can no longer be limited to improving what already exists but must anticipate future changes and prepare society to live in different conditions, which may be harsher but also more conscious and supportive.

In short, the essay proposes a vision of design as an ethical and collective act, capable of responding to the climate crisis with concrete, scalable and widespread tools. The project is not a simple aesthetic or functional response, but the privileged place of a new ecological awareness, combining vision, responsibility and transformation. Only in this way will it be possible to tackle the challenges of our time in a structural way, overcoming the logic of renunciation and instead opening to a new culture of limits, solidarity and coexistence.

The challenges of environmental sustainability and building innovation can only be addressed by incorporating the evolution of the regulatory, technological and social context into architectural design. The starting point is the observation that, despite a historical phase characterised by significant public and private investment, Italy lags considerably behind in systematically adopting and applying the innovations necessary to transform building production in a sustainable and qualitative sense. Today, architectural design is faced with increasing complexity, which requires interdisciplinary skills and the ability to interpret complex contexts: political, economic, technological and environmental. Nicola Sinopoli (2005) emphasises the need for conscious design training, capable of combining form, constructability, sustainability and the ability to respond to changing needs, within a framework of globalisation that affects materials, technologies and production processes. Architecture is no longer just a technical or artistic discipline, but a strategic hub capable of significantly influencing the environmental future of the planet. Today, quality design is not limited to good aesthetics or regulatory compliance but is based on the ability to produce buildings that perform well in terms of energy, economy and the healthiness of spaces, contributing to the quality of urban life. However, in Italian urban areas and suburbs, it is difficult to see an actual paradigm shift: the transformations taking place are often fragmented and ineffective in relation to the scale of the environmental challenges.

Architectural design is now faced with two major challenges: drastically reducing energy consumption and minimising the impact of buildings on health and the environment. In industrialised countries, the construction sector is responsible for a significant proportion of energy consumption and CO_2 emissions. This requires a radical rethinking of the way we build: a revolution that can no longer be postponed and which, at the same time, represents an extraordinary opportunity to innovate design in an environmental sense.

Technology is a fundamental tool in this transition, not only to improve the energy performance of buildings, but also to design healthy, self-sufficient habitats capable of generating their own energy needs on site from renewable sources. The new generation of buildings can, in fact, become “energy powerhouses” as well as living spaces, contributing directly to the reduction of collective energy needs (Rifkin, 2008).

Although sustainability is a global issue, its effective implementation depends on local policies. In Italy, some public administrations have begun to include incentives for sustainable construction in building regulations, such as volumetric bonuses or tax relief. However, these regulations often take a partial and non-integrated approach, focusing almost exclusively on increasing the thermal insulation of the building envelope, leaving other relevant aspects of the environmental project in the background.

Energy saving is undoubtedly central, as energy consumption determines much of a building’s environmental impact over its life cycle. But sustainability cannot be reduced to a technical or energy issue: a systemic approach is needed that considers all stages of a building’s life cycle and its multiple impacts, not only on the environment but also on people’s health and well-being.

The Italian context shows strong resistance to structurally embracing the culture of sustainability. Despite growing awareness of environmental problems and repeated warnings from scientists and environmentalists, the Italian building system still appears to be anchored to conservative and innovation-averse thinking. The implementation of European directives is often delayed, and the spread of a sustainable design culture is still too limited.

The challenge, in this sense, is twofold: on the one hand, decision-making mechanisms, regulations and reward systems need to be reformed to steer the market towards sustainable construction; on the other hand, it is necessary to build a new design culture capable of integrating economic development and environmental protection, technological innovation and urban quality.

The European Union has included environmental protection in the construction sector among its strategic objectives. This implies an obligation for Member States to reduce resource consumption and improve living conditions. Environmental parameters are therefore changing design requirements, profoundly transforming the established structures of architectural discipline.

However, significant contradictions remain in the debate on sustainability: on the one hand, there is widespread acceptance of the general principles of sustainability; on the other, there is often a lack of effective operational tools, systematic controls and a design culture capable of translating these principles into concrete actions.

In response to these needs, tools have been developed to support design and environmental assessment. These are design criteria geared towards energy saving, material recycling, indoor air quality, water use reduction, and so on. These criteria have been collected in scoring systems, such as BREEAM and LEED, which allow buildings to be given a sustainability rating based on verifiable indicators. These systems have been very successful, especially in international markets, because they have responded to a growing demand for environmental quality certification from investors and buyers. In the United States, for example, LEED-certified skyscrapers have significantly influenced the commercial value of properties, contributing to the spread of a sustainability-oriented market.

The advantages are clear: well-designed buildings reduce energy costs by up to 70%, improve the health of occupants and offer greater economic returns to investors, while the increase in construction costs is now marginal (around 5%).

Despite the usefulness of scoring systems, they do have some critical issues. Firstly, the performance-based approach risks becoming prescriptive, as the project is fragmented into a sum of specific requirements, often lacking an overall vision. This type of assessment tends to optimise individual aspects without verifying the overall performance of the building. Secondly, there is often a lack of a systemic and integrated approach that considers the interactions between the various design components. Finally, there is generally no genuine life cycle assessment, especially about building materials. The energy embodied in materials and that consumed during use are treated separately, without a unified vision.

Sustainable development is one of the main challenges of the 21st century. Architectural design must therefore be based on a comparative assessment of possible solutions, considering environmental, economic and social implications. The goal must be to reduce overall energy consumption and optimise the environmental balance of the entire life cycle of the building. In this context, it is essential to promote a design culture based on scientific knowledge, critical awareness and social responsibility. Only in this way will it be possible to address environmental challenges effectively, overcoming the fragmented and prescriptive approach of current systems.

The text is a dense and articulate reflection on the need for a radical renewal of architectural design. In the face of a system that is still lagging in embracing sustainability issues, there is an urgent need for a new design culture capable of addressing the environmental, social and technological transformations of our time. Sustainable design is not an option, but a systemic, cultural and operational necessity. In this sense, the challenge for the future is to fully integrate the principles of sustainability into everyday design practice, making it the preferred tool for guiding urban and building development towards scenarios that are truly compatible with life on the planet.

3. Discussion

Energy saving and environmental sustainability are now at the heart of the debate on contemporary architecture and building policies. These issues not only guide the most advanced design practices but are also gradually taking on a decisive role in the redefinition of urban planning and building regulations. However, in practice, there is a marked gap between principles and their concrete application: most buildings, both residential and industrial, are still constructed without any real attention to energy efficiency or reducing environmental impact. Although there is growing interest on the part of professionals and public administrations, truly virtuous solutions remain, unfortunately, isolated and marginal, unable to trigger systemic change. This delay is also reflected in the behaviour of users, who are not incentivised to reduce consumption, given the poor energy efficiency of existing buildings. Thus, dependence on energy-intensive technologies, designed to compensate for the performance limitations of buildings, ends up exacerbating the environmental and energy crisis.

The construction sector is deeply inadequate in the face of the energy challenge. Blackouts, rising energy costs, climate change and polluting emissions are unmistakable signs of a system that is no longer able to guarantee a sustainable quality of life. In this critical scenario, the way we “build” needs to be radically rethought.

While awareness campaigns promoted by national and European institutions, tax incentives and regulatory updates aimed at improving the energy performance of buildings are underway, there remains a cultural resistance to change. The adoption of sustainable practices by citizens remains insufficient, hampered by established habits and a widespread lack of environmental awareness. Real change can only come about with the active involvement of the population, which must be educated to choose environmentally friendly solutions in their everyday decisions.

International experience shows that change is possible. Countries such as Germany and the United Kingdom have significantly reduced emissions through the extensive use of renewable sources, particularly as an alternative to coal. Japan stands out for its massive adoption of photovoltaic technologies and the high number of ISO 14001-certified building products. These examples show that technological innovation, when accompanied by strong political and regulatory support, can become a lever for systemic transformation.

On the contrary, an analysis of Italian construction production in the 2000s paints a bleak picture. New buildings are often characterised by a single-function approach, with obsolete technical solutions and materials identical to those used in the 1970s. Examples of sustainable construction are scarce, and there is a worrying continuity with anachronistic design practices.

Italy's weakness in the field of sustainability also extends to new technologies. Innovations related to information communication technology, for example, are rarely found in the construction sector, beyond the limited use of design software in large professional studios. The lack of engineering and innovation in production processes is a further obstacle to the ecological transition of the construction sector.

The central role of the construction sector in determining energy consumption and pollutant emission levels makes it clear that energy efficiency is not only a technical issue, but first and foremost a cultural one. In this sense, we need to move beyond the idea that improving environmental performance can be achieved solely through partial solutions or the adoption of individual innovative components.

The energy problem cannot be solved by focusing solely on the materials or technologies used. On the contrary, a systemic vision is needed, capable of viewing the building as a complex organism in which each element interacts with the others to ensure optimal overall performance. This holistic approach is the only one capable of guaranteeing a real and lasting improvement in the environmental quality of buildings.

Furthermore, the way in which a space is lived in and inhabited has a strong impact on the efficiency of the building. The link between living culture and energy performance is profound: it is therefore necessary to invest in user education and the promotion of conscious and responsible behaviour.

To effectively address environmental challenges, architectural design must take an integrated approach, capable of operating simultaneously on multiple levels:

- Environmental level: this involves understanding the natural, climatic and urban context in which the building project is located. Site-sensitive design allows natural resources – such as solar radiation or ventilation – to be exploited to improve comfort and reduce consumption.
- Typological level: the choice of building type directly affects energy efficiency. Compact, well-oriented buildings with adequate functional distribution are easier to air-condition and maintain more stable internal conditions.
- Technical-construction level: this concerns the use of high-performance materials, the adoption of appropriate technologies and careful installation. Advanced construction solutions can improve thermal insulation, reduce heat loss and extend the durability of the building.

This integrated approach allows the project to be read as a synthesis of environmental, cultural, technological and social issues. It is not, therefore, simply a matter of choosing "eco-friendly" materials or high-efficiency systems, but of imagining a new concept of architecture, capable of relating to the context and the real needs of people.

The environmental crisis requires a profound revision of the design, regulatory and cultural paradigms of the construction sector. It is no longer enough to make small adjustments or rely on isolated experiments. A comprehensive strategy is needed, based on:

- a systemic vision of the building project.
- serious investment in the technical and environmental culture of operators.
- the integration of individual behaviour and design solutions.

- an alliance between institutions, professionals and citizens for a common goal.

Only in this way can the construction sector play an active role in the fight against climate change, significantly reducing consumption and emissions and contributing to the construction of a healthier, fairer and more sustainable environment. Ultimately, the energy and environmental transition cannot be entrusted solely to technical progress but must be supported by a new culture of living, based on responsibility, awareness and shared innovation.

4. Results

In industrialised countries, people spend up to 90% of their time in confined environments such as homes, offices, schools and hospitals. This percentage is even higher among the most vulnerable groups of the population, such as children, the elderly and the sick. This prolonged exposure makes individuals more vulnerable to the risks associated with poor indoor air quality (IAQ), a phenomenon that has seen a steady increase in pollutants in closed environments over the last few decades.

The introduction of stricter energy criteria, following the global energy crisis, has led to significant changes in civil construction. The drive to reduce energy consumption has led to highly insulated buildings that limit air exchange with the outside. Although these buildings perform better in terms of thermal efficiency, they often fall short in terms of indoor air quality, as natural ventilation has been replaced by artificial systems that are sometimes inadequate or malfunctioning.

According to ISS Report No. 11/2021, improving indoor air quality is a fundamental pillar in safeguarding public health. Ventilation is crucial in mitigating the risk of microbiological contamination. However, there is still no universally accepted definition of “good air quality”. The only prevailing operational definition is that provided by ASHRAE (2013), according to which acceptable air must not contain known contaminants in harmful concentrations and must be satisfactory to at least 80% of exposed people.

Italy lacks specific legislation on indoor air quality. Although there are active multidisciplinary working groups, such as the “National Study Group on Indoor Pollution” of the Istituto Superiore di Sanità (National Institute of Health), no binding national regulations have yet been produced. Even within the European Union, few Member States have developed comprehensive regulatory instruments: risk factors vary considerably due to different construction techniques, climatic conditions, materials used and lifestyles.

The main difficulty in defining a single regulatory threshold lies in balancing comfort, health and energy savings. For example, to dilute some pollutants, it is useful to increase the flow of outside air, while for others, the opposite may be beneficial. This contradiction complicates the formulation of standardised strategies and highlights the need to integrate existing regulations with targeted hygienic-functional parameters and updated guidance values.

The effectiveness of measures to protect indoor air quality depends primarily on the ability to accurately and systematically monitor key environmental parameters. These include: the number and quality of air changes (natural or mechanical); microclimatic parameters (temperature, humidity, ventilation); human behaviour (opening windows, use of chemicals, etc.); and the level of crowding in rooms.

To develop an adequate measurement strategy, it is essential to clarify the objectives, understand the chemical and physical characteristics of the pollutants to be monitored, and analyse the interaction between pollutants, materials and surfaces, as well as the contribution of outdoor air quality. It is important to remember that air quality guidelines are useful indicators, but they are not exhaustive: risk assessment also depends on the vulnerability of the exposed population and specific environmental conditions.

The IAQ analysis is divided into two main operational phases:

1) Development of the preliminary research plan
2) Detailed design of the field verification

The first phase consists of formulating the reasons that justify the need to monitor a specific environment. It is divided into three sub-phases:

- Definition of the specific objectives of the verification.
- Choice of measurement instruments and techniques.
- Drafting of the preliminary project, which will form the basis for the field intervention.

The second, more operational phase involves six fundamental steps:

- Final selection of the instruments.
- Determination of the sample size and sampling scheme.
- Definition of technical specifications and operating protocols.
- Experimental verification of the instruments.
- Performance of preliminary tests.
- Final drafting of the executive project.

This structure allows for a complete assessment of the sources of contamination and how they affect indoor air, ensuring the possibility of implementing effective risk containment strategies.

The crucial issue that emerged from this reflection concerns the tension between energy needs and indoor environmental quality. The adoption of insulation and building closure systems, aimed at reducing heat loss and consumption, has the side effect of worsening microclimatic conditions and increasing the concentration of pollutants. The environmental project must therefore take an active role in combining energy efficiency, living comfort and air quality.

It is essential to move beyond the traditional technical concept and embrace a systemic approach that is capable of relating the building, its materials, its technologies and the behaviour of its users to the environmental and social context in which it is located. Sustainability cannot be reduced to a mere energy balance, but must include quality of life and public health, in an integrated perspective involving architects, engineers, hygienists, doctors and public decision-makers.

In order to initiate significant change in the sustainable and healthy design of buildings, it is necessary to:

- include mandatory parameters for indoor air quality in national legislation;
- promote environmental certification tools that include specific IAQ indicators;
- enhance interdisciplinary scientific research on risk factors, sources and long-term effects;
- encourage public awareness policies to spread a culture of indoor well-being;
- make air quality assessment mandatory in new construction and redevelopment projects.

Only through an integrated vision, based on objective data and the participation of multiple skills, will it be possible to answer the implicit question: "Are we reducing energy consumption, but breathing better?". The answer lies in a comprehensive rethinking of the project, of living and of the shared responsibilities between users, designers and institutions. Indoor air quality is not a secondary variable, but a right that must be guaranteed on a par with energy efficiency. Both dimensions are now interdependent, and it is the task of contemporary design to balance them in a harmonious and responsible manner.

5. Conclusion

In the field of contemporary architectural design, environmental, social and health challenges require a profound rethinking of housing and construction models. Climate emergencies, the crisis of natural resources and recent pandemic experiences have accentuated the need for an integrated approach to the design of built space, based on principles of environmental sustainability and protection of human health. These needs are accompanied by new cultural and design awareness that is pushing for a transformation of traditional paradigms, aiming for more responsible, equitable and ecologically compatible construction.

One of the cornerstones of this transformation concerns the reduction of resource consumption, both material and energy. This objective is linked to the adoption of a circular logic in construction processes, introducing the concept of the useful life cycle of buildings, materials and construction systems. The aim is to favour design solutions that allow reuse and recycling, limiting the environmental impact throughout the entire life cycle of the building, from production to dismantling. In this context, environmental assessment is not limited to the design phase but becomes a criterion that cuts across all phases of the construction process.

A second fundamental axis concerns energy efficiency. New buildings, but also renovations of existing buildings, must aim for high levels of energy performance, with particular attention to the integration between the building envelope and systems. This strategy includes the use of renewable energy sources — solar, wind, geothermal — and the reduction of fossil fuel use, in line with European climate and energy directives. However, it is not just a matter of improving certification figures: the real challenge is to build environments that, in addition to consuming little energy, offer high standards of comfort, health and quality of life. A sustainable project, therefore, is not limited to meeting technical or regulatory requirements, but is a broad and complex undertaking that involves the physical and mental well-being of the inhabitants. In this context, indoor air quality (IAQ) control is essential, yet it is often overlooked in the design process. The air we breathe in closed environments can contain a variety of pollutants:

volatile organic compounds (VOCs), particulate matter, formaldehyde, allergens, bacteria and viruses. Their presence is closely linked to the materials used, ventilation systems, installed technologies and how spaces are used.

The challenge is therefore twofold: on the one hand, to ensure high energy performance of buildings, and on the other, to maintain good indoor air quality. These objectives are not always compatible. For example, high airtightness of the building envelope can reduce consumption, but at the same time compromise air exchange and increase the accumulation of harmful substances.

For this reason, it is essential to design buildings that integrate health and hygiene parameters, such as ventilation rates, occupancy levels, microclimatic conditions and user behaviour, with energy efficiency parameters.

Within this integrated vision, the definition of design Variables and Invariants is central. Invariants represent the essential principles related to health, safety and living comfort, while variants allow the design to be flexibly adapted to specific social, cultural and environmental contexts. When correctly applied, this approach ensures quality and adaptability, avoiding the rigidity and standardisation that often compromise the liveability of environments.

Scientific research plays an essential role in this process. It is necessary to strengthen research on environmental exposure, associated health risks, measurement methods and mitigation technologies. In particular, it is necessary to promote:

1) Exposure and risk assessments, through the analysis of housing conditions, determining factors and the relationships between sources and pollutants.

2) Studies on health effects, in areas such as environmental epidemiology, respiratory diseases, allergies and toxicological mechanisms.

3) Measurement methodologies for the standardisation of sampling techniques and the characterisation of emissions from building materials.

4) Air quality improvement techniques, such as filtration, controlled ventilation, environmental sensors and intelligent monitoring systems.

5) Training and awareness-raising tools for both designers and the general public to promote virtuous and informed behaviour.

In Italy, legislation on indoor air quality is still fragmented and incomplete. Unlike in other European countries, there are no binding standards or threshold values for many indoor pollutants. Current regulations focus almost exclusively on energy efficiency, neglecting the health and quality aspects of living. This regulatory imbalance highlights the urgent need to revise building regulations, product certification methods and post-construction control systems, introducing broader criteria of health, comfort and sustainability.

The experience of the COVID-19 pandemic has accelerated this awareness. The home has become the main place of our lives, revealing structural criticalities, social inequalities and design inadequacies. A "low-energy" building is not enough: we need architecture that puts people, their health, safety and quality of life back at the centre. In this sense, it is essential to move beyond a purely technical view of sustainability and adopt a more humanistic, multidisciplinary and well-being-oriented approach.

It is also appropriate to rethink the ways in which the various figures involved in the building process collaborate. A sustainable project is not the result of a single skill set, but requires cooperation between architects, engineers, biologists, doctors, sociologists, technologists, administrators and citizens. Only through an integrated network of knowledge and responsibility is it possible to define new intervention strategies based on updated standards, validated scientific data and shared principles.

Finally, we need to develop an educational and cultural vision of housing sustainability. It is essential to raise awareness among people, and in particular vulnerable individuals, of environmental risks and the importance of living in healthy and safe spaces. In this sense, digitalisation offers useful tools for environmental monitoring, intelligent building management, accessibility to information and personalisation of environments. However, technology must be at the service of people and not vice versa: innovation only makes sense if it is geared towards improving everyday life.

In conclusion, sustainable design is not just a question of materials or technologies. It represents a new culture of living, capable of combining environment, health, equity and innovation. An approach focused on public health, air quality, functional flexibility and social resilience is now essential to give concrete meaning to the concept of "sustainable development" in the construction sector.

References

AA.VV. (2014). *Air Sensor Guidebook*. U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-14/159 (NTIS PB2015-100610).

ANSI/ASHRAE/IES Standard 90.1-2013. (2013). *Energy Standard for Buildings Except Low-Rise Residential Buildings.*

Baglioni, A., & Piardi, S. (1990). *Costruzione e salute*. Franco Angeli, Milano.

Banham, R. (1995). *Ambiente e tecnica nell'architettura moderna*. Biblioteca Universale Laterza, Bari.

Berglund, B., Lindvall, T., Samuelsson, I., & Sundell, J. (1991). Prescriptions for healthy buildings. In *Healthy Buildings '88, Healty Buildings '88. Conclusions and Recomandations for Healthier Buildings* (pp. 5-14). Stockolm, Swedish Council for Building Research.

Bologna, G. (2002). La nuova economia per un futuro sostenibile. In L. R. Brown (Ed.), *Eco-economy* (pp. 9-18). Roma.

Brown, L. R. (2002). *Eco-economy* (p. 37). Editori Riuniti, Roma.

Carotenuto, R., Pezzimenti, F., Della Corte, F. G., Iero, D., & Merenda, M. (2021). Ranging with frequency dependent ultrasound air attenuation. *Sensors*, *21*, 4963. https://doi.org/10.3390/s21154963.

De Capua, A. (2019). *Il Miglioramento della Qualità Ambientale Indoor negli Interventi di Riqualificazione Edilizia*. Roma, Legislazione Tecnica.

De Capua, A. (2008). *Tecnologie per una nuova igiene del costruire. Contributi per l'innovazione dei Regolamenti edilizi comunali*. Roma, Gangemi editore.

European Collaborative Action. (1989). *Sick Building Syndrome*. Report n°4, Ispra Estabilishment (VA).

European Collaborative Action. (1999). *Urban Air, Indoor Environment and Human Exposure*. "Environment and Quality of Life", Report No 20 "Sensory Evaluation of Indoor Air Quality".

Giovannini, E. (2014). *Scegliere il futuro. Conoscenza e politica al tempo dei Big Data*. Il Mulino, Bologna.

Kelly Fr, J., & Fussell Julia, C. (2015). Air pollution and public health: Emerging hazards and improved understanding of risk. *Environmental Geochemistry and Health*, *37*(4), 631-649. https://doi.org/10.1007/s10653-015-9720-1

Latotuche, S. (2014). *La scommessa della decrescita*. Milano, Feltrinelli.

Mancini et al. (2016). *Misure di qualità dell'aria esterna ed interna in un edificio ad elevate prestazioni adibito ad uffici di proprietà della PA per la ottimizzazione delle portate di aria di ricambio finalizzate all'efficienza energetica*. ENEA, Università Roma La Sapienza, Ministero Dello Sviluppo Economico, Report RdS/PAR2016/268.

Meadows, D. H., Meadows, D. L., & Randers J. (1972). *The limit to growth*. Universe book, New York (tr. it. 1972, *I limiti dello sviluppo,* Mondadori), Milano.

Meadows, D. H., Meadows, D. L., & Randers, J. (2004). *Limits to growth. The 30-year update*. Chelsea Green Publishing Company.

Meadows, D. H., Meadows, D. L., & Randers, J. (1992), *Beyond the limits*. Chelsea Green Publishing Company.

Mercalli, L. (2020) *Non c'è più tempo. Come reagire agli allarmi ambientali*. Mondadori, Milano.

Morton, T. (2018) *Noi, esseri ecologici*. Laterza, Bari-Roma.

Moschandreas, D. J. (1991). Risk assessment and the indoor environment. In B. Berglund, & T. Lindvall (a cura di), *Healty Buildings '88* (pp. 147-152). Conclusions and Recomandations for Healthier Buildings. Stockolm, Swedish Council for Building Research.

Rifkin, J. (2008). Case a tutta energia. In *L'espresso*, n. 18 dell'8 maggio.

Scurati, A. (2022). Ridiamo un senso al futuro. *Corriere della Sera*, *6*, 1-6.

Sinopoli. (2002). *La tecnologia invisibile*. Franco Angeli, Milano.

US EPA. (1989). *Indoor Air facts No. 6: Report to Congress on indoor air quality*. ANR-445, august.

US EPA U.S. E.P.A. (1991). *Introduction to Indoor Air Quality. A Self-Paced Learning Module* (pp. 46-62).

Whorton, M. D., Larson, S. R., Goprdon, N. J. et al. (1987). Investigation and work-up of tight building syndrome. *J. Occupational Medical*, *29*, 142-147.