atmosphere

MDPI

Editorial

The Dichotomy between Indoor Air Quality and Energy Efficiency in Light of the Onset of the COVID-19 Pandemic

Gaetano Settimo [1,*] and Pasquale Avino [2,*]

[1] Italian National Institute of Health, Viale Regina Elena 299, 00161 Rome, Italy
[2] Department of Agriculture, Environmental and Food Sciences, University of Molise, Via F. De Sanctis, 86100 Campobasso, Italy
* Correspondence: gaetano.settimo@iss.it (G.S.); avino@unimol.it (P.A.); Tel.: +39-06-499-028-45 (G.S.); +39-0874-404-634 (P.A.)

Keywords: indoor air quality; energy efficiency; COVID-19; ventilation; air exchange; building; schools; human health; air pollution

Recently, there has been a great increase in the importance of issues related to energy efficiency [1] and indoor air quality (IAQ) [2] in public and private buildings. This represents a current and future challenge for all governments. In fact, at this particular moment, they are committed to the achievement and implementation of both the United Nations Framework Convention on Climate Change (UNFCCC) [3] and the various Conferences of the Parties (COP: 26 COPs have been held about the world since 1995), of the National Plan for Energy and Sustainable Development envisaged by the United Nations 2030 Agenda (UN, UNECE, UNEP), of the Green Deals [4] and a new action plan for the circular economy.

IAQ cannot be considered an occasional and individual problem that can be remedied with simple mitigation actions. It has become a global phenomenon (with definitions such as indoor generation and healthy buildings), which concerns every citizen, whether they are a worker or not, and places of residence, workplaces, schools, hospitals, transport and care in each country [5–10]. In response to this trend, and also given the increasing costs (health and economic) that it represents for society, there has been a great increase in the awareness of the necessity for organic multi-level approaches to face the challenge of IAQ safeguarding and of health [11].

In the European Union (EU) directives, the role played by energy efficiency in buildings is clear and well-defined [12,13]: it already contains approaches that must favor both the improvement of energy consumption and the IAQ. To emphasize the potential inherent in energy efficiency measures, the EU has committed itself through recommendations (2016 and 2019 to name a few) to clarify the purpose of the interventions. In an even more significant and effective way, the Green Deal has identified the role of building renovation interventions (Green Deals).

In view of the important public spending decisions that will be taken by governments (at a central, regional and municipality level), which will allow the improvement of buildings to continue as a whole, it should be emphasized that the specific focus of the interventions and renovation plans—often made necessary due to poor conservation conditions—cannot be exclusively oriented to the issues of insulation, containment and energy efficiency of buildings (taking into account local climatic conditions). In fact, there is a risk that such interventions may have the result of altering or worsening the IAQ, the microclimatic conditions [14,15] and the natural ventilation of buildings [16–19]. Therefore, they must follow functional approaches, in many aspects of an integrated and regular type, capable of contributing to the overall improvement of the property portfolio, with the aim of promoting and, in a broader sense, permanently guaranteeing the health of citizens.

Citation: Settimo, G.; Avino, P. The Dichotomy between Indoor Air Quality and Energy Efficiency in Light of the Onset of the COVID-19 Pandemic. *Atmosphere* **2021**, *12*, 791. https://doi.org/10.3390/atmos12060791

Received: 31 May 2021
Accepted: 17 June 2021
Published: 19 June 2021

Similarly, this approach must be adopted for all those sequences of increasingly frequent and massive and generally long-lasting actions/interventions, carried out in different phases, which concern micro and macro renovations, redevelopments, or technical-plant adaptation (water, electricity, thermal, fire protection, etc.) or reclamation (e.g., asbestos).

In the last decade, activities on IAQ in buildings have been a clear priority and common objective of the various prevention plans and programs both at national level (PNP 2010–2012, 2014–2018, 2020–2025 Agreement between Government, Regions) [20] and at European level (Directive 2010/31, 2018/844 just to name a few), and at international level (UN-COP, 2030 Agenda for Sustainable Development-UN, UNECE, UNEP) in accordance with the main actions developed by the World Health Organization (WHO) [21], which today constitute a valuable starting point for the development and dissemination of a general action plan with targeted legislative acts.

At the European Union level, in relation to IAQ, there is a legislative delay that must be quickly filled. As reported in [2], there is a different approach strategy to the IAQ problem in the various countries of the European community. Therefore, there is a need to issue a specific and unique regulation that contains suitable references for chemical (such as gaseous and particle pollutants) and biological pollutants in line with those developed by the WHO, with the most recent and easy-to-use specific protocols and procedures envisaged by the ISO 16,000 Indoor Air Quality standard [22] in its various parts, and which also take into account the various guidelines of the working groups of the individual countries.

It should be emphasized that the current system of health prevention and protection laws has also the language used has been confusing, difficult and ambiguous, including the scope of application. This has not helped the achievement: it has often resulted in confused and disoriented technicians and operators working both in the development of programs and processes for energy efficiency and IAQ and in the improvement of human health. In many cases, this ambiguous language has influenced or slowed down the identification of the correct choice of preventative actions.

Therefore, it is necessary to implement a series of new strategies; appropriate and organized radical interventions, which depend on many factors that cannot be limited to single items as has been the case up to now (for example, electrical, water, anti-seismic, fire, architectural, or energy efficiency safety) without including the improvement of IAQ as one of the main subjects of intervention or priorities. All these adaptation interventions contribute significantly to the IAQ and to the health status of those who use that building [23]. An integrated, responsible, and global approach to daily prevention is therefore necessary, as is effective specific training and awareness-raising action on air quality issues. This approach must take into account the following factors: the changes, functions and versatility of the national building park, the new requirements for living, the sustainable management of the building, the IAQ according to the guidelines already identified by WHO in 2000 [24].

In this current pandemic period [25,26], IAQ has been a novelty for many people, even among scientists themselves. However, the authors would like to underline that this is an old issue, which has already been seen from another point of view (e.g., the theory of miasmas in the 19th century and the Sick Building Syndrome (SBS) [27] in the 20th century). The COVID-19 emergency has brought to light the often-underestimated issue of the role that the IAQ plays in influencing the state of human health [28], and that preserving the quality of our environment is an integral part of public health plans and programs. In recent months, all the integrated actions and functional approaches to improve the IAQ, made necessary by the spread of COVID-19, have led to an increase in manual air changes (simultaneous opening of windows and balconies) in order to dilute any contamination of specific pollutants in the air by reducing the concentration and risk of exposure of those who live/work indoors [29]. It should be underlined that during this pandemic period, the chemical and microbiological pollution of indoor environments, a less well-known and

more delicate problem than outdoor pollution, has taken on considerable importance, also for reasons related to the measurement and assessment of risk. [30].

The problem arises—at least for the plant engineering part of the question—too often in an engineering and mechanical key, the functionality of a system is measured according to its efficiency and not according to its effectiveness, with results that can be misleading. The authors wish to emphasize that mechanical interventions for proper ventilation are the tool for achieving good IAQ (and should not be the aim).

It is now known that many systems have been designed with the use of an air recirculation rate (a measure exclusively linked to a reduction in the system's energy consumption) [31]. It is worth remembering that no ventilation system can eliminate all risks. However, if the design is oriented towards the user and the health of the users, and is correctly designed—combining both the concepts of energy efficiency and air changes, in addition to the main references of WHO or those developed by the working groups of the various EU member countries (too often forgotten in the design phase)—and maintained in efficient operation, these ventilation systems can certainly help to reduce the risks of exposure and virus contamination (health ventilation). It is worth remembering that in various European documents (e.g., promoting healthy and highly energy-efficient buildings in the European Union, e.g., Healthvent [32]) the performance gap emerges between what was designed and what was measured (e.g., stagnation of stale air, high concentrations of VOCs, CO_2, relative humidity).

This leads the authors to note that, on this subject, there is a multitude of proposals for combatting indoor pollution (chemical and microbiological) and methods of sanitation which—perhaps precisely in the absence of an ordered and organized knowledge of problem—chemists and biologists/microbiologists tend to disagree on, proposing that their ideas better than others, losing sight of the objective.

It can be suggested that IAQ will also benefit from the measures taken to tackle outdoor air pollution. However, some measures that are useful for outdoor air quality, can have negative effects on indoor air. Energy efficiency actions to save energy, for example, can lead to the accumulation of indoor pollutants, if there are no compensatory measures (e.g., natural or mechanical ventilation HVAC). It should be underlined that energy efficiency represents the ability to consume as little energy as possible, avoiding the generalization of the different applications, using the best techniques available on the market, developing regulation and adopting more conscious and responsible behavior towards energy use.

Furthermore, considering past experience on outdoor air quality and what has been detailed so far, planning the territory becomes very important. The identification of all anthropogenic and natural sources of gaseous and particle pollutants and their impact on the population are fundamental issues for reducing local emissions. Source mitigation is the first step in reducing local emission concentrations in areas with a high population density. The design of urban structures becomes important, in order to avoid the accumulation of pollutants.

If no (short-term) strategy can be adopted (for example, it is not possible in any way to increase the air changes), other complementary measures can be used. An example is the use of air purifiers, including mobile ones. The caveat is that a similar device cannot replace ventilation (natural or mechanical). From the point of view of use, care must be taken when choosing to buy one. Portable air purifiers are generally more effective in smaller spaces and when equipped with high efficiency air filters (e.g., HEPA filters). There are different types of filters: they are classified according to their filtration efficiency capacity. The filter will only retain liquid or solid particles in suspension and not gases, so it will not affect the level of CO_2 present.

In case there is a need to use purification devices, before buying them it is necessary to consider certain factors, such as: purification technologies used; air flow rates (many devices have insufficient air flow rates); type of air filters used; release of purification by-products that can be persistent and dangerous; data available on tests carried out that demonstrate proven efficacy and safety in the conditions of use; certifications; noise;

operation; etc. The cubature/square footage of the environments are important when it comes to the efficiency of the air filter. For example, the potential of the purifier (air flow) must be correct for the size of the room (cubature, number and positioning of windows, doors, number of people, activities, etc.). Another important factor is positioning: the direction of the air flow must go from clean to less clean areas.

This technical analysis model of the plant has recently been heavily criticized in the USA, where it was developed. The fundamental question concerned the effectiveness in contrast to the virus risk (i.e., COVID-19 in this case). The answer was partial and unsatisfactory with respect to the problem: important considerations and updates emerged in the approach to the problem and in the technological solutions in the field (meaning an ethical approach to the problem).

Healthy buildings that incorporate energy efficiency approaches can offset some emissions of air pollutants, thus providing what is called a health benefit.

In the UN annual report for buildings and construction, the total energy consumption and global CO_2 emissions related to the construction sector in 2020 are quantified [33]. Global energy consumption for the construction sector remained at the same level as in 2018, 35%, while CO_2 emissions increased again to around 28%. The emissions of the entire construction sector amount to 38% of the total energy.

The occurrence of this pandemic must make it clear that IAQ is a priority parameter in the design of a building [34]. Greater integration is needed to ensure that energy efficiency interventions are carried out with IAQ playing a clear and central role. Energy efficiency and IAQ must not conflict with each other but must be complementary. In Italy, in relation to IAQ, there is a legislative delay that must be quickly bridged, with the issuing of a specific act that contains suitable references for chemical and biological pollutants in line with those developed by the WHO, taking into account the most recent and easy-to-use specific protocols and procedures provided by the ISO 16,000 Indoor Air standard [22] in its various parts and by the reports of the ISS Indoor Pollution GdS. Even the current system of health prevention and protection laws has resulted in the use of confusing, difficult and ambiguous language, including the scope, which has not helped, indeed often has resulted in confusing and disorienting the technicians and operators of the NHS and other interested parties (e.g., school managers, RSPP, municipal technical offices, owners of school buildings, etc.), engaged in various capacities in the development of energy efficiency programs and processes and IAQ. This has led to a slowing of pace in the identification of the correct choice of preventative actions, and in the optimization of the level of well-being and the improvement of the IAQ of national traditional buildings. Therefore, an integrated, responsible and global approach to daily prevention is necessary (an effective specific training and awareness-raising action on air quality issues should not be forgotten) which properly takes into account the changes, functions and versatility of the national building park, the new requirements for living, the sustainable management of the building, and the IAQ according to the guidelines already identified by the WHO in the early 2000s. It is therefore necessary to intervene in redevelopment aspects, by introducing elements of sustainability even beyond purely energy assessment-based factors.

The authors consider the topic reported in this paper very important for improving human health of populations who are used to living/working indoors. Regarding suggestions for actions and steps forward, the authors would like to remember that the Directive [35] reports in detail on the activities to be carried out: "The energy performance of buildings should be calculated on the basis of a methodology, which may be differentiated at national and regional level. That includes, in addition to thermal characteristics, other factors that play an increasingly important role such as heating and air-conditioning installations, application of energy from renewable sources, passive heating and cooling elements, shading, IAQ, adequate natural light and design of the building. The methodology for calculating energy performance should be based not only on the season in which heating is required, but should cover the annual energy performance of a building. That methodology should consider existing European standards". At the same time, further EU recommendations

report that across Europe the minimum energy performance requirements need to be gradually tightened, to avoid the deterioration of IAQ and the health of the population. Climate change objectives can conflict with efforts to reduce air pollution. Insulating buildings to reduce energy loss can limit ventilation, leading to poor IAQ if the buildings are not properly designed. An example is the measures that incentivize the use of biomass for home heating; they can negatively impact indoor and outdoor air quality and damage health.

Author Contributions: G.S. and P.A. equally contributed to conceptualization and writing. Both authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Publicly available datasets were analyzed in this study.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Huynh, A.; Barkokebas, R.D.; Al-Hussein, M.; Cruz-Noguez, C.; Chen, Y. Energy-efficiency requirements for residential building envelopes in cold-climate regions. *Atmosphere* **2021**, *12*, 405. [CrossRef]
2. Settimo, G.; Manigrasso, M.; Avino, P. Indoor air quality: A focus on the European legislation and state-of-the-art research in Italy. *Atmosphere* **2020**, *11*, 370. [CrossRef]
3. United Nations Framework Convention on Climate Change. Available online: https://unfccc.int/ (accessed on 5 May 2021).
4. European Commission. Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions. The European Green Deal. COM/2019/640 Final. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1588580774040&uri=CELEX:52019DC0640 (accessed on 28 May 2021).
5. Stabile, L.; Buonanno, G.; Avino, P.; Fuoco, F.C. Dimensional and chemical characterization of airborne particles in schools: Respiratory effects in children. *Aerosol Air Qual. Res.* **2013**, *13*, 887–900. [CrossRef]
6. Manigrasso, M.; Vitali, M.; Protano, C.; Avino, P. Temporal evolution of ultrafine particles and of alveolar deposited surface area from main indoor combustion and non-combustion sources in a model room. *Sci. Total Environ.* **2017**, *598*, 1015–1026. [CrossRef]
7. Manigrasso, M.; Protano, C.; Astolfi, M.L.; Massimi, L.; Avino, P.; Vitali, M.; Canepari, S. Evidences of copper nanoparticle exposure in indoor environments: Long-term assessment, high-resolution field emission scanning electron microscopy evaluation, in silico respiratory dosimetry study and possible health implications. *Sci. Total Environ.* **2019**, *653*, 1192–1203. [CrossRef]
8. Settimo, G.; Gola, M.; Capolongo, S. the relevance of indoor air quality in hospital settings: From an exclusively biological issue to a global approach in the Italian context. *Atmosphere* **2020**, *11*, 361. [CrossRef]
9. Gola, M.; Settimo, G.; Capolongo, S. How Can design features and other factors affect the indoor air quality in inpatient rooms? Check-lists for the design phase, daily procedures and maintenance activities for reducing the air concentrations of chemical pollution. *Int. J. Environ. Res. Public Health* **2020**, *17*, 4280. [CrossRef]
10. Settimo, G.; Indinnimeo, L.; Inglessis, M.; De Felice, M.; Morlino, R.; di Coste, A.; Fratianni, A.; Avino, P. Indoor air quality levels in schools: Role of student activities and no activities. *Int. J. Environ. Res. Public Health* **2020**, *17*, 6695. [CrossRef]
11. European Court of Auditors. Energy Efficiency in Buildings: Greater Focus on Cost-Effectiveness Still Needed. Available online: https://op.europa.eu/webpub/eca/special-reports/energy-efficiency-11-2020/en/index.html (accessed on 28 May 2021).
12. Carrer, P.; Wargocki, P.; De Oliveira Fernandes, E.; Hänninen, O.; Kephalopoulos, S.; Allard, F.; Asikainen, A.; Asimakopoulos, D.; Asimakopoulou, M.-N.; Bischoff, W.; et al. *European Collaborative Action—Urban Air, Indoor Environment and Human Exposure, Report No 30, Framework for Health-Based Ventilation Guidelines in Europe, EUR 27640 EN*; Publications Office of the European Union: Luxembourg, 2020; ISBN 978-92-79-54143-8. JRC88207. [CrossRef]
13. Kephalopoulos, S.; Geiss, O.; Barrero, J.; D'Agostino, D.; Paci, D. *Promoting Healthy and Energy Efficient Buildings in the European Union: National Implementation of Related Requirements of the Energy Performance Buildings Directive (2010/31/EU), EUR 27665 EN*; Publications Office of the European Union: Luxembourg, 2017; ISBN 978-92-79-70594-6. [CrossRef]
14. Tobia, L.; Santostefano, M.; Casilli, A.; Spera, G.; Paglione, M.; Tarquini, M.; Grandi, G.; Tiberti, S.; Paoletti, A. Assessment of microclimatic conditions in open space offices through more than 600 measurements. *G. Ital. Med. Lav. Ergon.* **2004**, *26*, 147–148.
15. Valeriani, F.; Cianfanelli, C.; Gianfranceschi, G.; Santucci, S.; Spica, V.R.; Mucci, N. Monitoring biodiversity in libraries: A pilot study and perspectives for indoor air quality. *J. Prev. Med. Hyg.* **2017**, *58*, E238–E251.
16. Wilson, J.; Dixon, S.L.; Zuluaga, M.; Jacobs, D.E.; Breysse, J.; Berger, D. Venting for health: Indoor air quality improvements from upgraded ventilation systems in multifamily high-rise housing. *Energy Effic.* **2020**, *13*, 1727–1735. [CrossRef]
17. Zender-Świercz, E. Review of IAQ in premises equipped with façade–ventilation systems. *Atmosphere* **2021**, *12*, 220. [CrossRef]

18. Megahed, N.A.; Ghoneim, E.M. Indoor Air Quality: Rethinking rules of building design strategies in post-pandemic architecture. *Environ. Res.* **2021**, *193*, 110471. [CrossRef] [PubMed]
19. *UNI EN Energy Performance of Buildings—Ventilation for Buildings—Part 1: Indoor Environmental Input Parameters for Design and Assessment of Energy Performance of Buildings Addressing Indoor Air Quality, Thermal Environment, Lighting and Acoustics*; UNI EN 16798-1:2019; UNI: Milan, Italy, 2019.
20. Proposta di "Piano Nazionale di Ripresa e Resilienza". Documento XXVII n. 18, XVIII Legislatura. 2021. Available online: http://www.senato.it/leg/18/BGT/Schede/docnonleg/41806.htm (accessed on 20 May 2021).
21. Global Alliance for Buildings and Construction & UN Environment. Global Roadmap towards Low-GHG and Resilient Buildings. Available online: http://globalabc.org/resources/publications/global-roadmap-towards-low-ghg-and-resilient-buildings (accessed on 23 May 2021).
22. ISO. *Indoor Air—Part 6: Determination of Volatile Organic Compounds in Indoor and Test Chamber Air by Active Sampling on Tenax TA Sorbent, Thermal Desorption and Gas Chromatography Using MS or MS-FID*; ISO 16000-6:2011; ISO: Geneva, Switzerland, 2011.
23. Etxebarria-Mallea, M.; Oregi, X.; Grijalba, O.; Hernández-Minguillón, R. The impact of energy refurbishment interventions on annual energy demand, indoor thermal behaviour and temperature-related health risk. *Energy Policy* **2021**, *153*, 112276. [CrossRef]
24. WHO. Guidelines for Indoor Air Quality: Selected Pollutants. Available online: https://www.euro.who.int/__data/assets/pdf_file/0009/128169/e94535.pdf (accessed on 5 May 2021).
25. Barua, S.; Nath, S.D. The impact of COVID-19 on air pollution: Evidence from global data. *J. Clean. Prod.* **2021**, *298*, 126755. [CrossRef]
26. Goodwin, L.; Hayward, T.; Krishan, P.; Nolan, G.; Nundy, M.; Ostrishko, K.; Attili, A.; Cárceles, S.B.; Epelle, E.I.; Gabl, R.; et al. Which factors influence the extent of indoor transmission of SARS-CoV-2? A rapid evidence review. *J. Glob. Health* **2021**, *11*, 10002. [CrossRef] [PubMed]
27. Jones, W. Horizons: Sick building syndrome. *Appl. Occup. Environ. Hyg.* **1990**, *5*, 74–83. [CrossRef]
28. Cheek, E.; Guercio, V.; Shrubsole, C.; Dimitroulopoulou, S. Portable air purification: Review of impacts on indoor air quality and health. *Sci. Total Environ.* **2021**, *766*, 142585. [CrossRef] [PubMed]
29. Khan, D.S.; Kolarik, J.; Hviid, C.A.; Weitzmann, P. Method for long-term mapping of occupancy patterns in open-plan and single office spaces by using passive-infrared (PIR) sensors mounted below desks. *Energy Build.* **2021**, *230*, 110534. [CrossRef]
30. ISS Working Group Environment and Indoor Air Quality. Ad interim provisions to prevent and manage the indoor environment in relation to the transmission of the infection by the SARS-CoV-2 virus. Updating Rapporto ISS COVID-19 n. 5/2020 Rev. 2. Version of April 18, 2021. *Rapp. ISS COVID-19* **2021**, *11*, 21. Available online: https://www.iss.it/rapporti-covid-19/-/asset_publisher/btw1J82wtYzH/content/rapporto-iss-covid-19-n.-11-2021-indicazioni-ad-interim-per-la-prevenzione-e-gestione-degli-ambienti-indoor-in-relazione-alla-trasmissione-dell-infezione-da-virus-sars-cov-2.-aggiornamento-del-rapporto-iss-covid-19-n.-5-2020-rev.-2.-versione-del-18-aprile (accessed on 1 June 2021).
31. Aviv, D.; Chen, K.W.; Teitelbaum, E.; Sheppard, D.; Pantelic, J.; Rysanek, A.; Meggers, F. A fresh (air) look at ventilation for COVID-19: Estimating the global energy savings potential of coupling natural ventilation with novel radiant cooling strategies. *Appl. Energy* **2021**, *292*, 116848. [CrossRef] [PubMed]
32. Carrer, P.; De Oliveira Fernandes, E.; Santos, H.; Hänninen, O.; Kephalopoulos, S.; Wargocki, P. On the development of health-based ventilation guidelines: Principles and framework. *Int. J. Environ. Res. Public Health* **2018**, *15*, 1360. [CrossRef] [PubMed]
33. United Nations Environment Programme. 2020 Global Status Report for Buildings and Construction: Towards a Zero-Emission, Efficient and Resilient Buildings and Construction Sector. Nairobi. 2020. Available online: https://globalabc.org/sites/default/files/inline-files/2020%20Buildings%20GSR_FULL%20REPORT.pdf (accessed on 28 May 2021).
34. Poirier, B.; Guyot, G.; Geoffroy, H.; Woloszyn, M.; Ondarts, M.; Gonze, E. Pollutants emission scenarios for residential ventilation performance assessment. A review. *J. Build. Eng.* **2021**, *42*, 102488. [CrossRef]
35. European Commission. Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings. *O. J.* **2010**, *153*, 13–35. Available online: https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=celex:32010L0031 (accessed on 14 June 2021).