UK Health Security Agency

Healthy Buildings, Sustainability and IAQ

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Building Health Seminar, 7th October 2026, Oulu, Finland

Introduction

- Overview of Sustainable Development
- Why we care about Indoor Air Quality
- IAQ and Sustainable Development
- Policy Framework and Technological Solutions
- Future Directions and Recommendations

Overview of Sustainable Development

What Is Sustainable Development?

UNITED NATIONS

"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

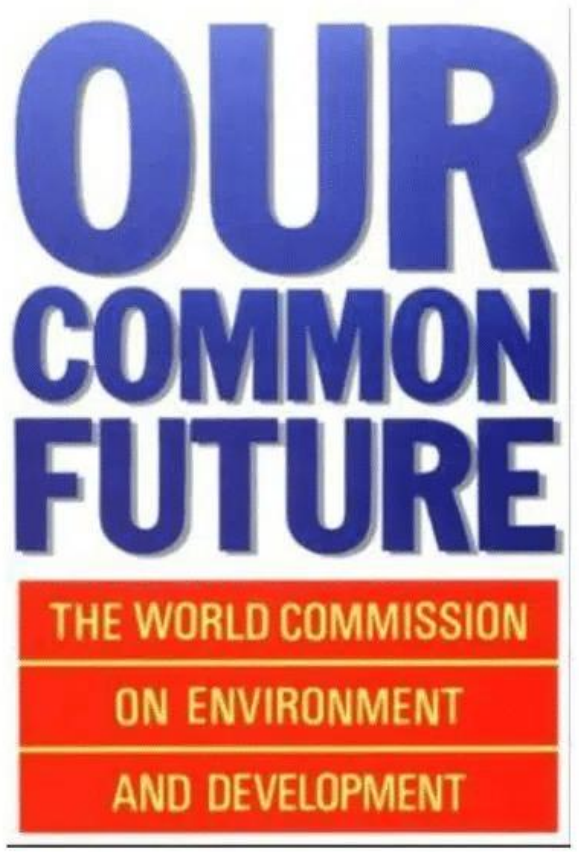
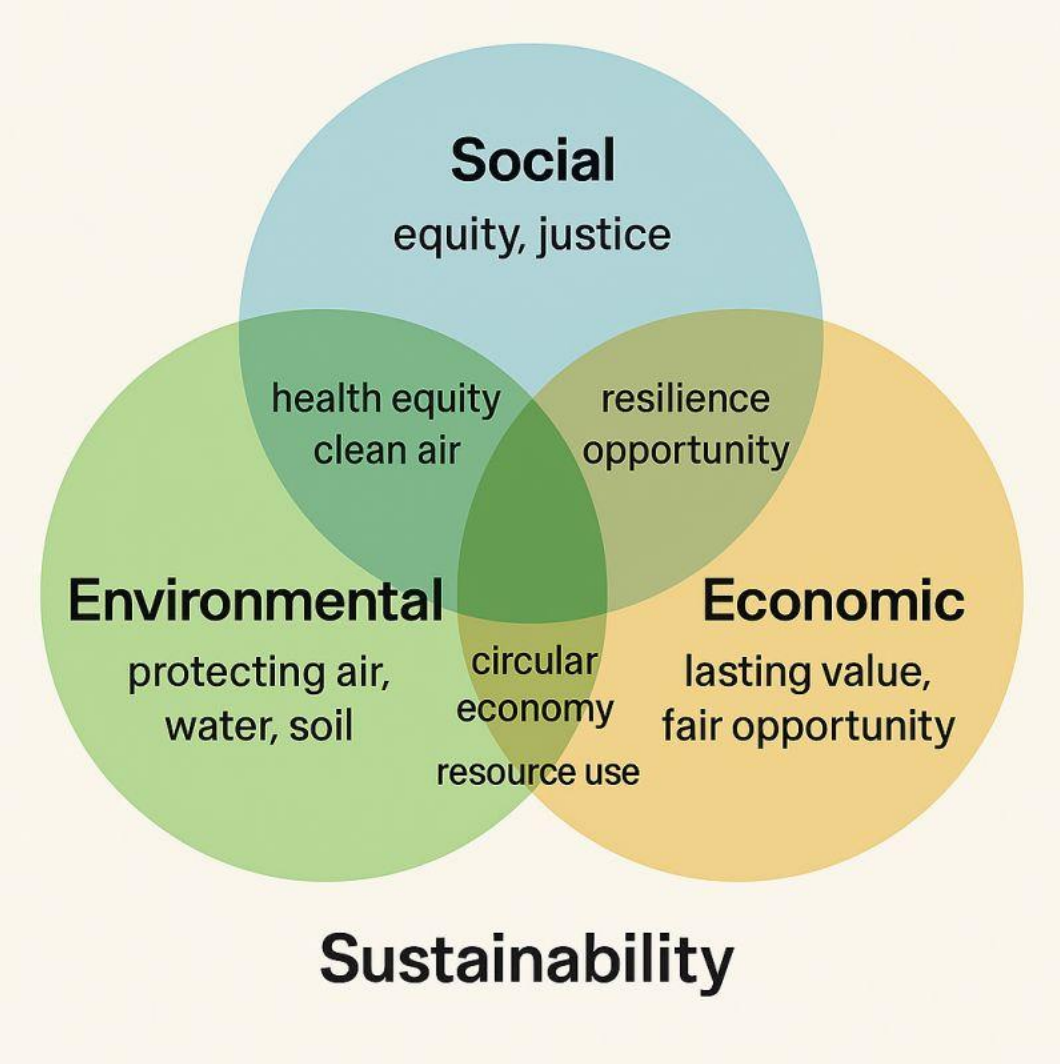
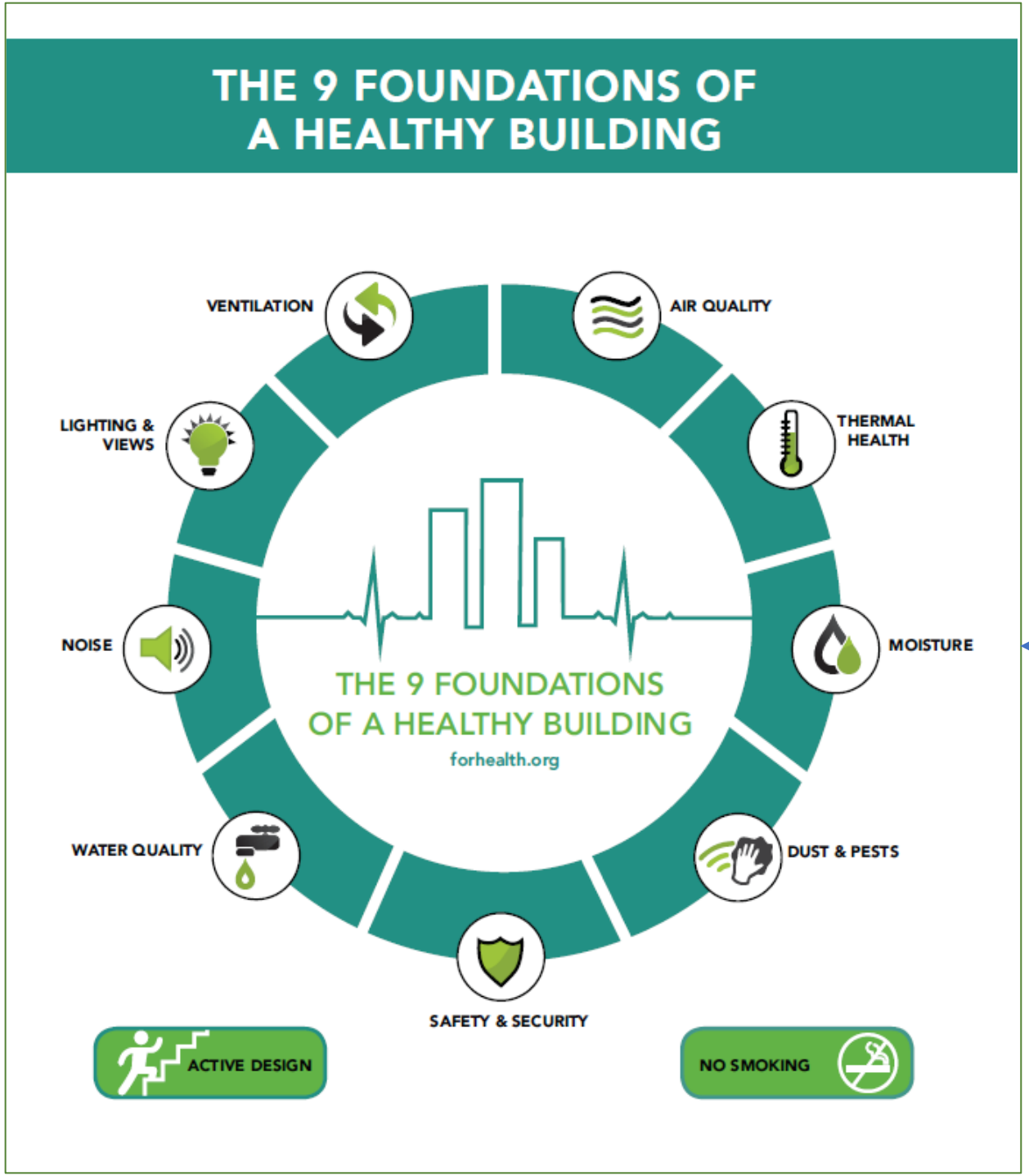


Image Source: "Our Common Future: The Brundtland Report." World Commission on Environment and Development. Oxford University Press, 1987

The Three Pillars of Sustainability



https://www.linkedin.com/posts/leewberry_sustainability-climateaction-leadership-activity-7380995305372078080-wlLF/

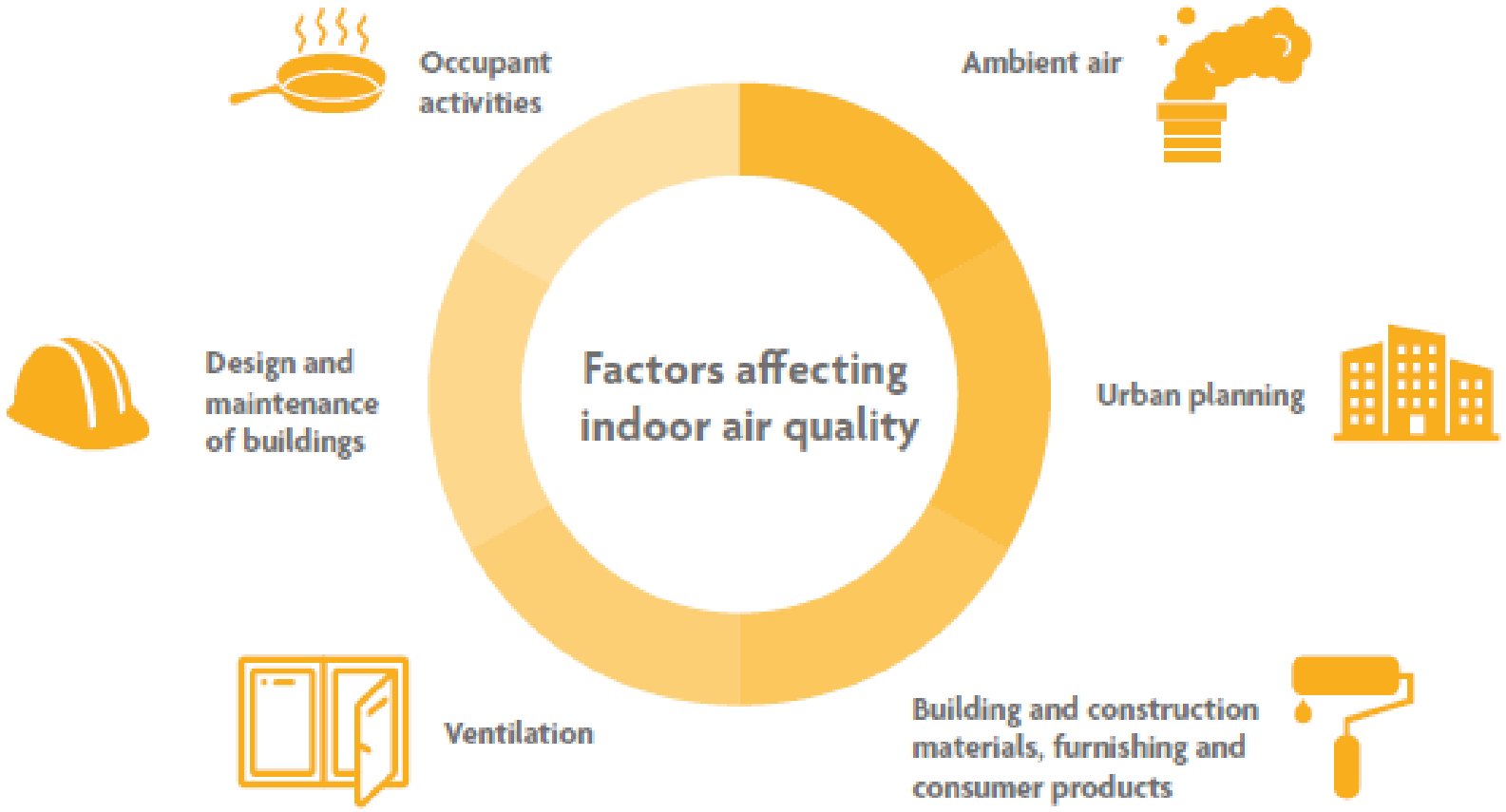




[9 Foundations of a Healthy Building - Healthy Buildings]

Why we care about IAQ

Factors affecting IAQ



▲ Figure 1. Factors affecting indoor air quality.

Dimitroulopoulou S (2021) https://www.the-ies.org/sites/default/files/journals/improving-indoor-air-quality.pdf

Indoor Air Quality matters – Health Effects

Exposure to indoor air pollutants, chemicals and biological contamination is associated with

- respiratory system
- nervous system
- cardiovascular system
- carcinogenicity
- respiratory irritation



RCPCH (2020) NICE (2020) WHO (2021)

Birth and infancy

- Respiratory problems – wheeze, rhinitis, atopic asthma, respiratory infections
- Low birthweight and pre-term birth

Pre-school

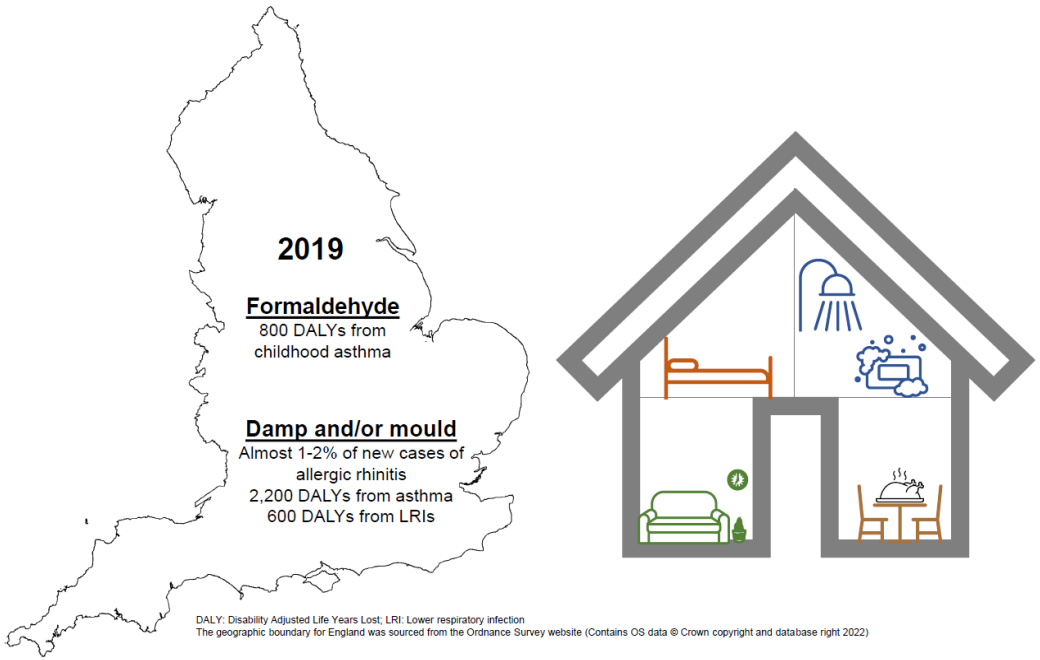
- Respiratory problems – wheeze, allergies, asthma, risk of respiratory diseases and pneumonia
- Eczema and atopic dermatitis
- Greater hyperactivity, impulsivity and inattention

School age

- Respiratory problems – wheeze, rhinitis, asthma, throat irritation, nasal congestion, dry cough
- Eczema, dermatitis, conjunctivitis, skin and eye irritation
- Reduced cognitive performance, difficulty sleeping

RCPCH (2020) https://www.rcpch.ac.uk/sites/default/files/2020-01/the-inside-story-report_january-2020.pdf

Burden of Disease from poor IAQ



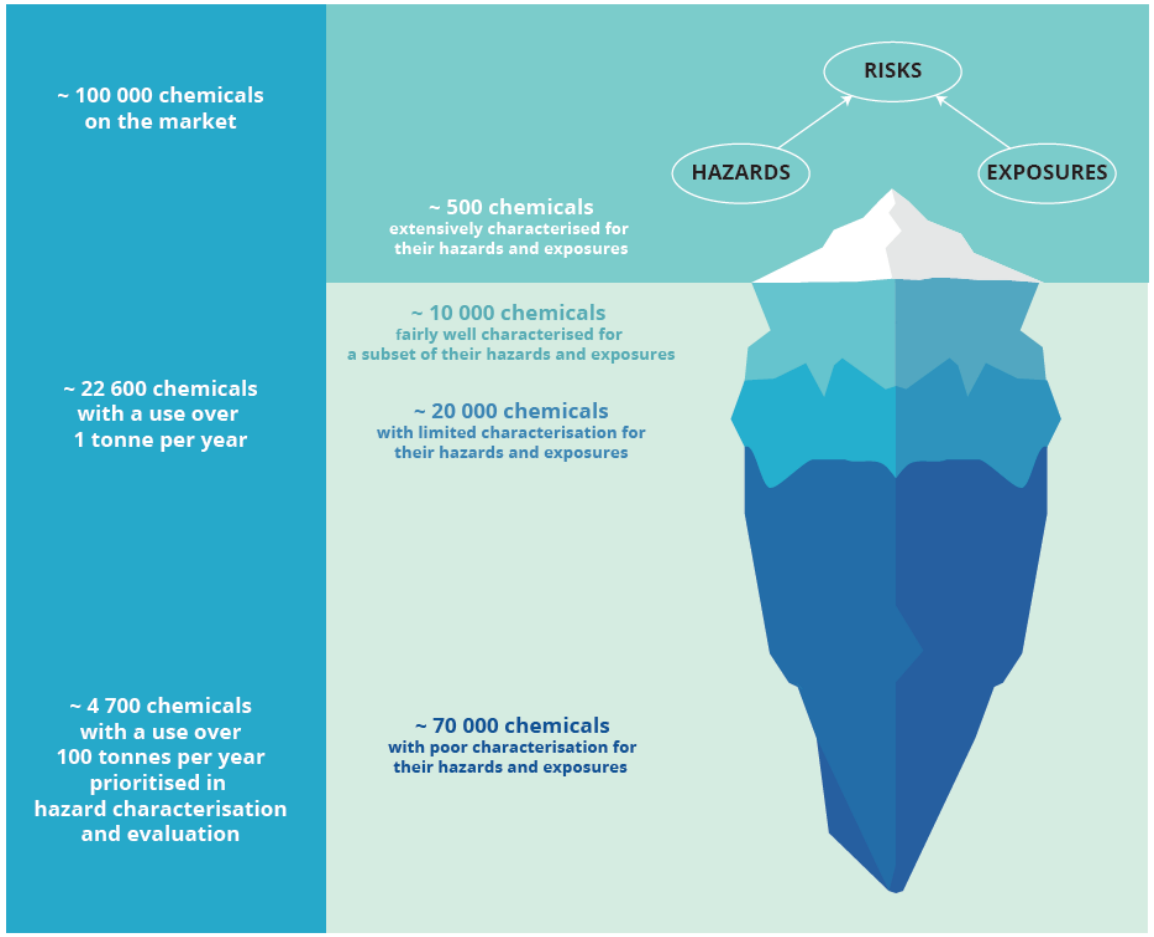
Clark, S.N.; Lam, H.C.Y.; Goode, E.-J.; Marczylo, E.L.; Exley, K.S.; Dimitroulopoulou, S (2023). The Burden of Respiratory Disease from Formaldehyde, Damp and Mould in English Housing. Environments, 10(8), 136. https://doi.org/10.3390/environments10080136

- In 2019, the presence of damp and/or mould in English residences was estimated to be associated with approximately:
  - 5,000 cases of asthma;
  - 8,500 cases of lower respiratory infections among children and adults.

  and contributed to:
  - 1 to 2% of new cases of allergic rhinitis in that year.

- Alternative data sources, primarily from self-reporting suggest that the percentage of dwellings affected by damp and/or mould may be even higher than the estimates used for this study, in which case the total number of cases could be 3 to 8 times greater.

The unknown territory of chemical risks



EEA (2020) The European Environment – State and Outlook 2020

Challenge / Opportunity?

Associations between indoor exposure to chemicals and health

Need to understand the health risks from exposure to both "classic" and "emerging" pollutants (e.g. SVOC) as well as secondary pollutants generated from indoor chemistry (secondary reactions);

Need to characterise chemicals indoors through systematic monitoring

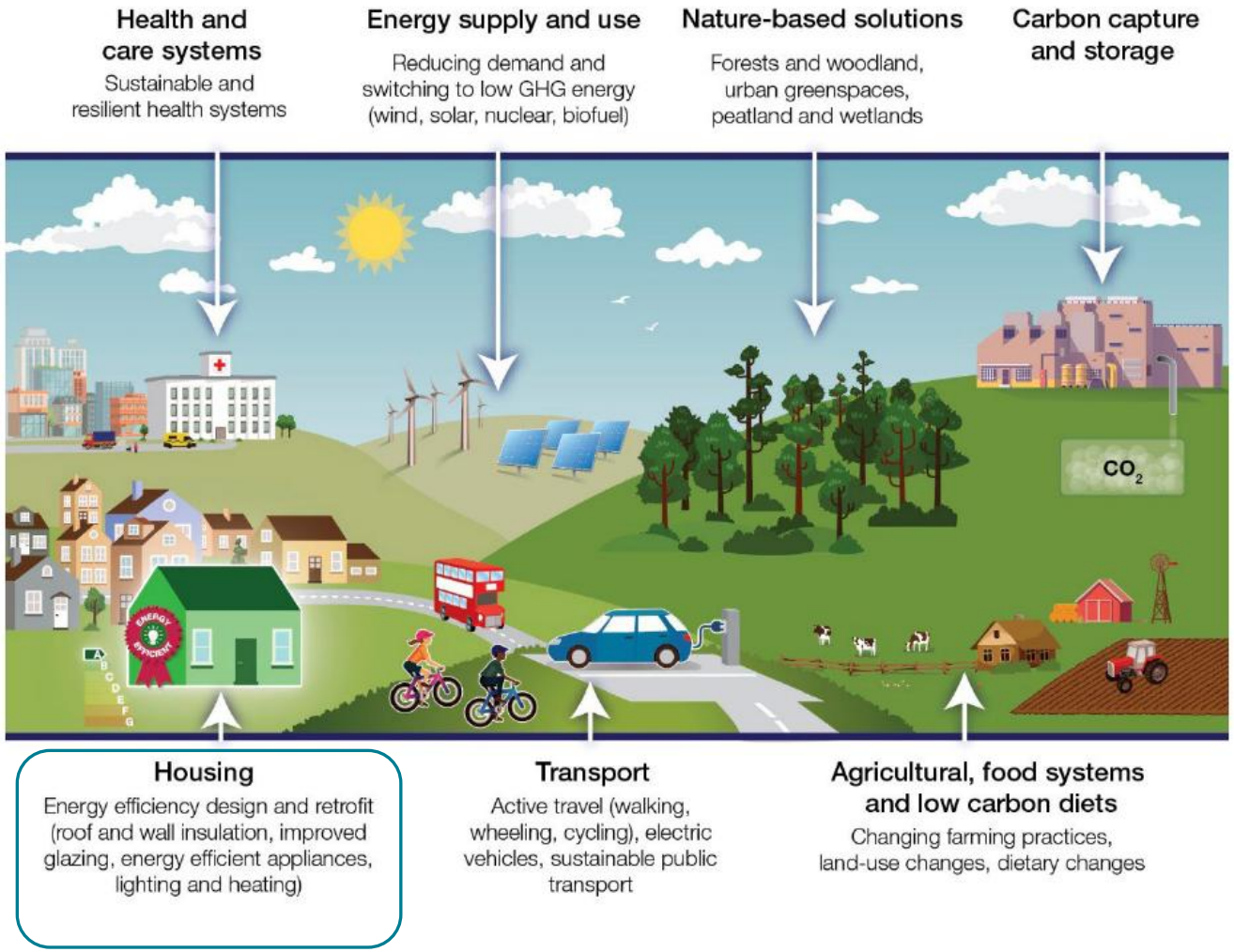
IAQ and Sustainable Development

How IAQ supports Sustainability



https://www.un.org/sustainabledevelopment/news/communications-material/

Net zero - Measures to achieve

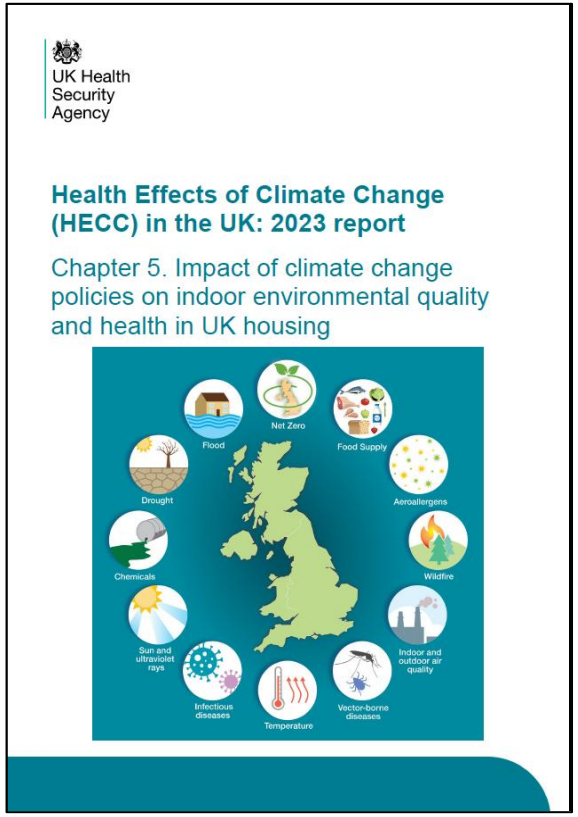


[HECC 2023 report chapter 14. Net zero: health impacts of policies to reduce greenhouse gas emissions (publishing.service.gov.uk)]

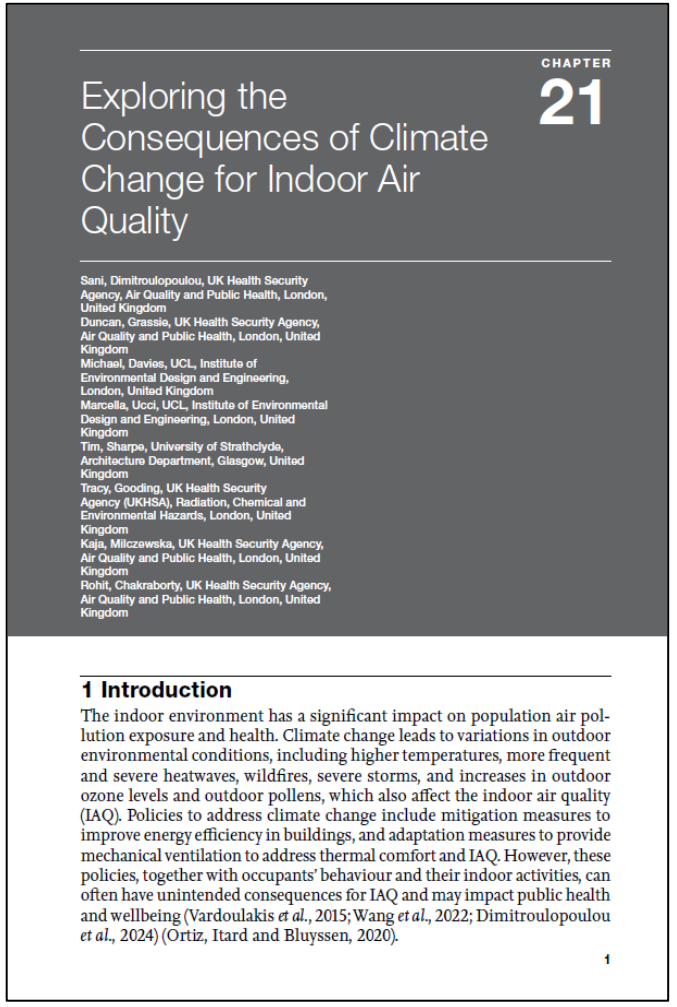
Energy Efficiency vs IAQ

Impact of net-zero policies

- Require significant changes in the performance of both new and retrofitted buildings
- Need to understand how current and emerging building infrastructure design, construction, and materials used may affect IEQ parameters and hence our health and wellbeing.



HECC report 2023. Chapter 5: Impact of climate change policies on indoor environmental quality and health in UK housing (publishing.service.gov.uk)


CHAPTER 21

Exploring the Consequences of Climate Change for Indoor Air Quality

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1 Introduction

The indoor environment has a significant impact on population air pollution exposure and health. Climate change leads to variations in outdoor environmental conditions, including higher temperatures, more frequent and severe heatwaves, wildfires, severe storms, and increases in outdoor ozone levels and outdoor pollens, which also affect the indoor air quality (IAQ). Policies to address climate change include mitigation measures to improve energy efficiency in buildings, and adaptation measures to provide mechanical ventilation to address thermal comfort and IAQ. However, these policies, together with occupants' behaviour and their indoor activities, can often have unintended consequences for IAQ and may impact public health and wellbeing (Vardoulakis *et al.*, 2015; Wang *et al.*, 2022; Dimitroulopoulou *et al.*, 2024) (Ortiz, Itard and Bluyssen, 2020).

1

New Perspectives in Indoor Air Quality, Elsevier, 2026, ISBN 9780443266430, https://doi.org/10.1016/B978-0-443-26643-0.00018-2

Indoor Air Quality Legislation

Indoor air quality legislation: A focus on the current standards

Focus on:

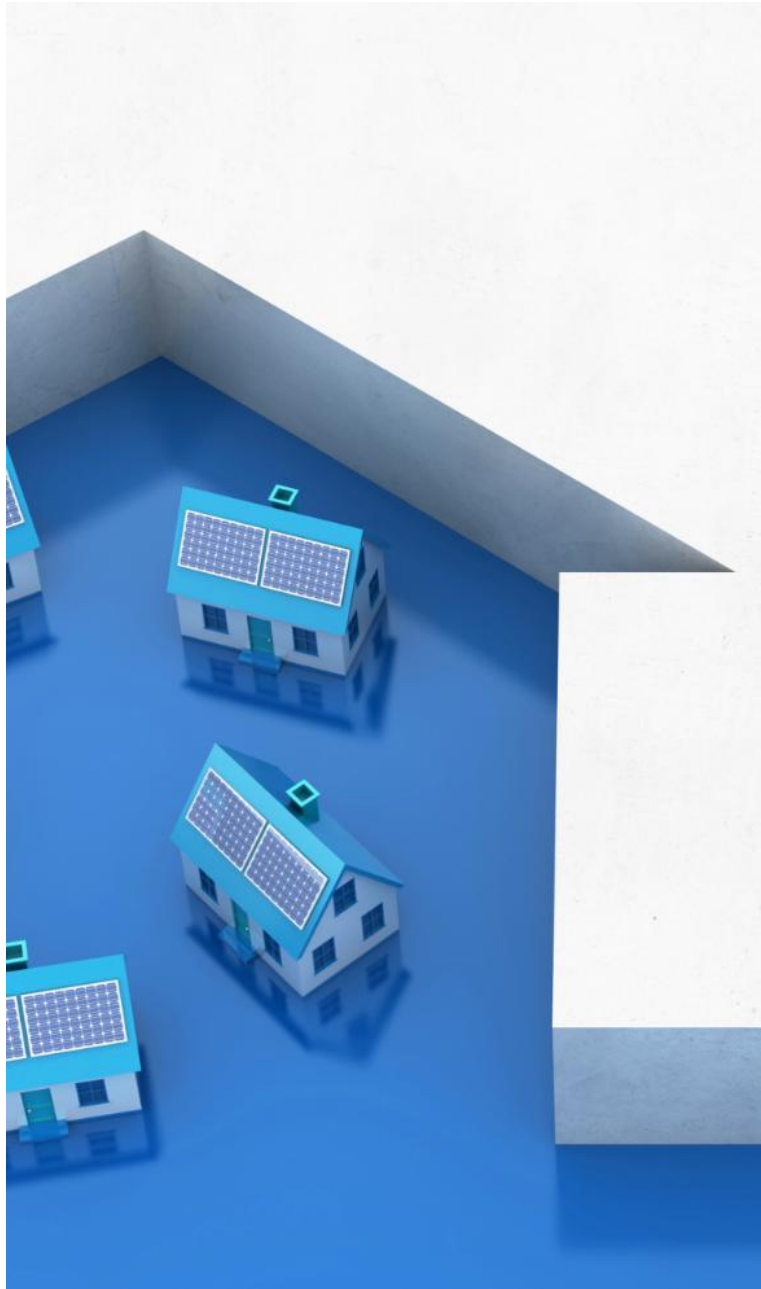
- history of indoor air quality guidelines
- existing IAQ guidelines,
- regulatory standards, and
- enforcement practices

to

- determine their effectiveness,
- identify weaknesses, and
- highlight opportunities

for strengthening public health protection

Chapter 2 of *New Perspectives in IAQ* by ISIAQ's STC 34 (Dimitroulopoulou et al., 2026) and its global IAQ database (https://ieqguidelines.org/)



Early Awareness and Legislation

- Hippocrates (5th century BC), emphasised the importance of environmental quality on health:

"If you want to learn about the health of a population, look at the air they breathe, the water they drink, and the places where they live."

- Medieval Legislation

England's 1273 Smoke Abatement Act banned coal use, marking the first IAQ-related law to protect health.

- Industrial revolution

Professors of hygiene:
Max Joseph von Pettenkofer (1818-1901) in Germany
Elias Heyman (1829-1889) in Sweden
made extensive epidemiological studies in homes, schools, and other buildings, to find causes of morbidity.



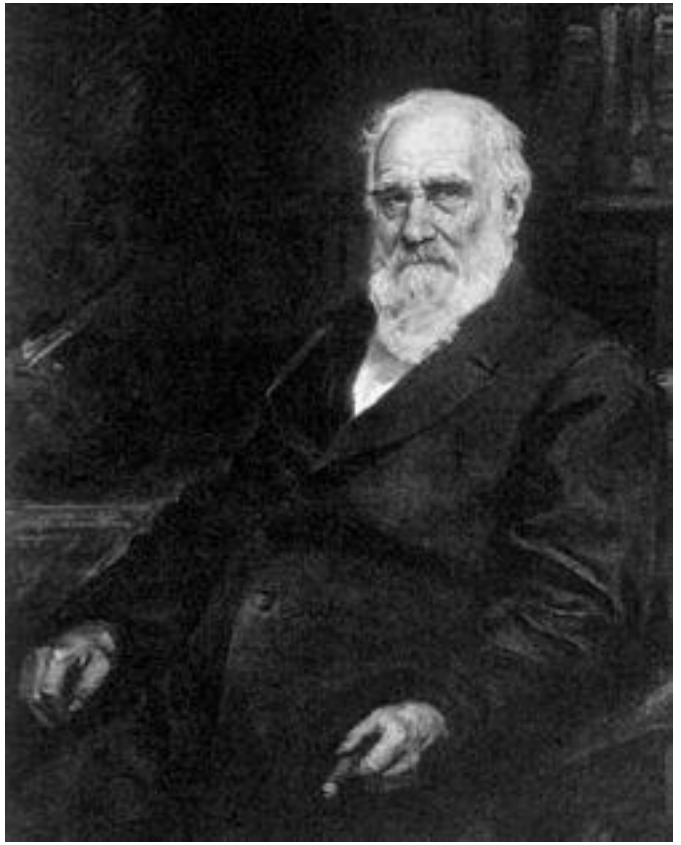
Ventilation

CO2 was measured as a proxy for ventilation.
Pettenkofer – 1st Professor in hygiene, 1853

- CO2 was not important itself but was an indicator of the amount of other noxious substances produced by men.
- Air was not fit for breathing if CO2 concentration (with man as the source) was above 1000 ppm (including CO2 from ambient air);
- Good indoor air in rooms where persons stay for a long time (bedrooms) should not exceed 700 ppm, to keep the persons comfortable (Pettenkofer, 1858).

Rise of IAQ Standards

1970s energy crises reduced ventilation, raising IAQ concerns and leading to standards such as ASHRAE 62.

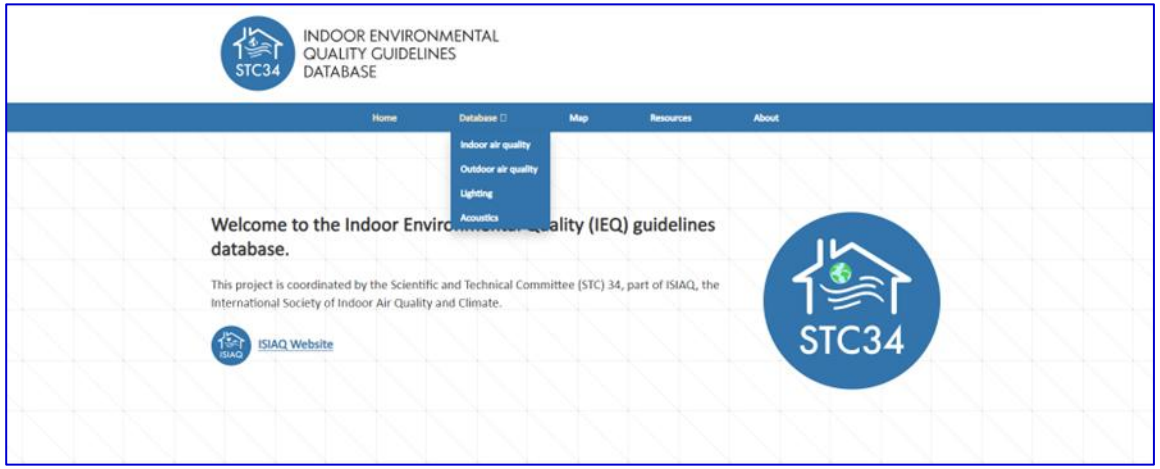


Max Joseph von Pettenkofer
(1818–1901)

Current IAQ legislation

- Unlike outdoor air pollution, IAQ is governed by diverse and uneven guidelines that differ by nation and building type.
- Indoor Air Quality regulation is fragmented worldwide, with inconsistent standards that often lag behind scientific evidence
- Governments use guidelines, standards, and regulations to target
  - ventilation requirements,
  - indoor air pollutant limits,
  - emissions from materials and activities.

ISIAQ – International Society of IAQ and Climate - Indoor Environmental Quality open database



https://ieqguidelines.org/

Toyinbo O, et al., on behalf of the STC 34 / ISIAQ (2022). Open database for international and national indoor environmental quality guidelines. Editorial; Indoor Air ;32:e13028. https://doi.org/10.1111/ina.13028

Dimitroulopoulou S, et al., (2023). Indoor Air Quality Guidelines from across the world: An appraisal considering energy saving, health, productivity and comfort. Environment International, 178, 108127 https://doi.org/10.1016/j.envint.2023.108127

Haverinen-Shaughnessy U et al. (2025) Towards equitable and sustainable indoor air quality guidelines – a perspective on mandating indoor air quality for public buildings, Indoor Environ. 2, 100070, https://doi.org/10.1016/j.indenv.2024.100070

Clinchard S, et al. (2025). Lessons learned from developing the worldwide IEQ guidelines database. Indoor Environments, Volume 2, Issue 4, 2025, 100124, https://doi.org/10.1016/j.indenv.2025.100124

- An ISIAQ Scientific and Technical Committee (STC34) was officially launched in September 2020.
- The committee has created an open IEQ guideline database to identify guidelines, standards and regulations from around the world for residential and public buildings, held regular online meetings, and organised workshops at ISIAQ conferences.
- ISIAQ data show 165 regulated chemicals globally.

Ventilation standards

- Ventilation remains the foundation of IAQ policy, but requirements vary widely - shift toward health-based ventilation standards rather than comfort-based ones.

- Standards specify outdoor air supply per person or floor area or ach, varying by building type, activity level and country.
  - Offices: 5–10 L/s per person,
  - Schools: 4–8 L/s/p,
  - Kitchens: around 20 L/s exhaust
  - EU-funded HealthVent (2018): health-based airflow rate of 4 L/s per person, provided indoor sources are eliminated and WHO IAQ guidelines are met

- Pandemic: ASHRAE Standard 241: Introduced during the COVID-19 pandemic to reduce infection risk (Equivalent Clean Airflow (ECA) combining outdoor air, filtration, and inactivation to reduce infection risk)
  - Office: 15 L/s/p
  - Healthcare waiting room: 45 L/s/p

- Post-pandemic, proposal for mandatory IAQ standards for public buildings:
  - minimum 14 L/s/p when occupied (Morawska et al., 2024) >
  - WHO's 10 L/s/p for non-residential settings during COVID-19 (WHO, 2021b).

NVG NORDIC VENTILATION GROUP Scientific collaboration

REHVA

Revision of European standard EN 16798-1: Ventilation and air cleaning in reducing airborne transmission





“Low Level Carbon Dioxide Indoors—A Pollution Indicator or a Pollutant? A Health-Based Perspective” (Lowther et al., 20?)

CO_2 Guideline Concentration (ppm)	Country	Standard	Year	Description
750	Finland	Revised Finnish classification of indoor environment, Society of Indoor Air Quality and Climate (FISIAQ [18])	2018	Best quality, highest occupant satisfaction (S1 target value, <350 above outdoor level)
800	International	WELL Building Standard [19]	2016	(non-residential)
	Hong Kong	HKSAR-Indoor Air Quality Management Group [20]	2019	8 h average (excellent class) (non-residential)
950	Finland	Revised Finnish classification of indoor environment, Society of Indoor Air Quality and Climate (FISIAQ [18])	2018	Good indoor air quality (S2 target value, <550 above outdoor level)
950	International	BREEAM (Building Research Establishment Environmental Assessment Method) [21]	2019	High indoor air quality (non-residential)
1000	UK	British Standard (BS EN 16798-1:2019) [10]	2019	Good indoor air quality (residential and non-residential)
	UK	BB101—Department for Education (DfE [9])	2018	Good IAQ (schools)
	US	US EPA Facilities Manual Vol 2: Architecture and Engineering Guidelines [22]	2020	8 h average
	China	GB/T 18883-2002, Indoor air quality standard. Standards Press of China [23]	2002	24 h average (0.1% CO_2 = 1000 ppm)
	Hong Kong	HKSAR-Indoor Air Quality Management Group [20]	2005	8 h average (good class)
	Germany	Federal Environment Agency (UBA) [24]	2008	Hygienically safe
	Singapore	Singapore Institute of Environmental Epidemiology (SAIQG) [25]	1996	8 h average
	Korea	Korea Occupational Safety and Health Agency (KOSHA), Guideline development for evaluation and management of office air quality (II) [26]	2005	8 h average (office)
	Malaysia	Industry COP on IAQ Malaysia (DOSHM) [27]	2010	8 h average

CO_2 Guideline Concentration (ppm)	Country	Standard	Year	Description
1030	International	US Green Building Council (USGBC)—Leadership in Energy and Environmental Design (LEED) [28]	2010	
1100	ASHRAE	ANSI/ASHRAE 62.1-2019. Ventilation for acceptable indoor air quality [29]	2019	Acceptable (no greater about 700 ppm above outdoor levels)
1100	Canada	National Collaborating Centres for Public Health (NCCEH) [30]	2019	A surrogate for human comfort (odour) but not considered a health risk
	Finland	Revised Finnish classification of indoor environment, Society of Indoor Air Quality and Climate (FISIAQ [18])	2018	Acceptable (S3 target value, <800 above outdoor)
1200	UK	BB101—Department for Education (DfE [9])	2018	Acceptable (schools)
	UK	British Standard (BS EN 16798-1:2019) [10]	2019	Medium indoor air quality
	International	BREEAM (Building Research Establishment Environmental Assessment Method) [21]	2019	Medium indoor air quality (non-residential)
1250	Portugal	SAÚDE E AMBIENTE E AÇÃO CLIMÁTICA Portaria n.º 138-G/2021 (Diário da República, 1.ª série, 2021) [31]	2021	Protection threshold and tolerance margin (commercial buildings)
1500	UK	BB101—Department for Education (DfE [9])	2018	Acceptable max (schools)
1750	UK	BB101—Department for Education (DfE [9])	2018	Need for additional ventilation (schools)
	UK	British Standard (BS EN 16798-1:2019) [10]	2019	Poor indoor air quality (residential and non-residential)
	International	BREEAM (Building Research Establishment Environmental Assessment Method) [21]	2020	Moderate or low indoor air quality (non-residential)
1000–2000	Germany	Federal Environment Agency (UBA) [24]	2008	Hygienically noticeable
>2000	Germany	Federal Environment Agency (UBA) [24]	2008	Hygienically unacceptable
2800	UK	BB101—Department for Education (DfE [9])	2018	(schools)
5000	UK	HSE EH40/2005 Workplace exposure limits [32]	2018	Permissible exposure limit 8 h time (workplaces)
	Australia	National Occupational Health and Safety Commission (NOHSC) [33]	1995	8 h average working day (workplaces)
	International	Chartered Institute of Building Service Engineers (CIBSE) KS17 [8]	2011	8 h time-weighted average
	US	National Institute for Occupational Safety and Health (NIOSH) [34]	2019	
	Germany	Commission for the Investigation of Health Hazards of Chemical Compounds in the Work Area (MAK) [35]	2014	8 h average

Indoor air pollutant guidelines / standards

- Health-based guidelines (e.g., WHO, Health Canada) provide a scientific health foundation for national IAQ policies worldwide.
- Chemical and biological pollutants pose major regulatory challenges; only a small fraction of harmful substances have health-based limits
- WHO (2010) guidelines for individual VOCs:
  - Benzene (C6H6), formaldehyde (HCHO), nitrogen dioxide (NO2), CO, naphthalene, polycyclic aromatic hydrocarbons (PAHs), radon (Rn), trichloroethylene, tetrachloroethylene, particulate matter (PM)
  - no safe levels of exposure or thresholds for benzene and PAHs
- WHO (2021): same values for outdoor and indoor air
- Most frequently addressed pollutants are HCHO, CO_2, CO, Rn, PM, and NOx



https://ieqguidelines.org/

TABLE 2.1 Ranges of regulations or guidelines in residential and nonresidential buildings (ISIAQ STC34, 2020).

IAQ parameter	Unit	Residential buildings		Nonresidential buildings	
		Guidelines	Regulations	Guidelines	Regulations
Physical parameters					
Temperature	°C	16–28	18–28	16–28	17–28
Relative humidity	%	30–70	40–75	20–80	30–80
Chemical pollutants					
Carbon dioxide	ppm	800–1000	850–1670	800–1000	1000–1500
Carbon monoxide (8 h) guidelines	mg/m^3	4–10	ND	4–10	ND
Carbon monoxide (8–24 h) regulations	ppm	ND	10–3	ND	10–35
Nitrogen dioxide (1 h)	$\mu g/m^3$	80–200	ND	40–200	ND
Particulate matter PM10 (24 h)	$\mu g/m^3$	50–150	50–200	50–150	50–200
Particulate matter PM2.5 (24 h)	$\mu g/m^3$	25–37.5	25–40	25–37.5	25–40
Formaldehyde	$\mu g/m^3$	30–100	100	30–100	100
Benzene	$\mu g/m^3$	80	No safe level—10	80	No safe level—30
Tetrachloroethylene	$\mu g/m^3$	40–150	ND	40–150	ND
Trichloroethylene	$\mu g/m^3$	100	ND	No safe level—150	ND
Naphthalene	$\mu g/m^3$	10	ND	10	ND
Polycyclic aromatic hydrocarbons	-	no safe level	ND	No safe level	ND
Ozone (8 h)	$\mu g/m^3$	40–120	30–120	40–120	30–120
Radon	Bq/m^3	100–300	100–200	100–300	100–200
TVOCs (8 h)	ppm	<1	ND	<1	ND
Biological pollutants					
Bacteria	CFU/m^3	ND	500–1000	ND	500–1000
Molds/Fungi	CFU/m^3	<500	500	<500	ND

IAQ, Indoor air quality; *ND*, no data available; *TVOC*, total volatile organic compound.

Biological pollutants

Microorganisms

- Bioaerosols:
  - bacteria (*Legionella pneumophila*)
  - fungi (*Aspergillus fumigatus*),
  - viruses (e.g., *influenza virus*)
- Allergens (dust mites)

Sources:
Occupants, potted plants, pets, and infiltrating outdoor air;
Air humidifiers, plumbing systems, and HVAC systems;
Conditions leading to episodically or chronically wet surfaces, poor ventilation, too low or too high air temperature, and increased humidity

Quantification

- the total number of bacteria and total number of fungi

Few national regulations: the recommended concentrations of bacteria and fungi for indoor air should not exceed 1000 CFU/m^3

- Dampness can be assessed indirectly based on visual observations or moisture measurements; better correlation with health effects than measurements of airborne microorganisms do.
- Currently, not possible to conduct standard measurements of viruses in the air, due to analytical difficulties.

Damp and mould in the UK



The size of the problem

- An estimated 962,000 to 6.5 million (4% to 27%) households in England live with damp and mould
- People living in private or social rented housing are more likely to live in a home with damp and mould than owner occupiers.
- Each year, the NHS spends an estimated £1.4 billion annually on treating illnesses associated with living in poor housing. This is reportedly an under-estimate of the true picture.
- Poor housing will cost an estimated over £135.5bn over the next 30 years without urgent action

Guidance on the health risks of damp and mould in the home (UK)

- Damp and mould: understanding and addressing the health risks for rented housing providers - GOV.UK (www.gov.uk) published 7 September 2023
- Government commitment following the tragic death of 2-year-old Awaab Ishak who died from a severe respiratory condition due to prolonged exposure to mould in his home
- Primarily aimed at social and private rented housing providers who need to be clear on: the health risks to tenants, their legal responsibilities and what they can do to address and reduce the risk of damp and mould
- A collaborative effort between Office for Health Improvement and Disparities (OHID), UK Health Security Agency (UKHSA) and Department for Levelling Up, Housing and Communities (DLUHC)
- Established an expert advisory group and engaged with over 200 people from organisations representing landlords, tenants, academics, experts on building design, environmental and public health professionals



- Awaab's Law (2025)
- Awaab's Law: Guidance for social landlords - Timeframes for repairs in the social rented sector (2026)
- Revised HHSRS (2026)

- In October 2025, the Hazards in Social Housing (Prescribed Requirements) (England) Regulations 2025 – Awaab's Law come into effect. Awaab's Law is a UK legal requirement that forces social housing landlords to investigate and fix emergency hazards and dangerous damp and mould within strict, fixed timeframes
- In July 2026, Guidance for social landlords - Timeframes for repairs in the social rented sector was published, which is a guide to implementation of Awaab's Law. Awaab's Law: Guidance for social landlords - Timeframes for repairs in the social rented sector - GOV.UK
- The revised Housing Health and Safety Rating System (HHSRS) that is used to assess health and safety hazards in homes was published in June 2026. It is risk-based, set out in regulation and covers a range of 21 potential hazards. Local authorities are required to have regard to it when assessing hazards. Among the hazards are included damp and mould growth and indoor air pollutants. Housing Health and Safety Rating System (HHSRS): Operating guidance - GOV.UK

Awaab's Law requirements on social landlords

The Regulations mean **landlords must**:

- Investigate any potential **emergency hazards** and, if the investigation confirms emergency hazards, undertake relevant safety work as soon as reasonably practicable. The investigation and the work must both take place within **24 hours** of becoming aware of the hazard.
- Investigate any potential **significant hazards** within **10 working days** of becoming aware of them;
- Produce a written **summary of investigation findings** and provide this to the tenant within **3 working days** of the conclusion of the investigation.
- Undertake relevant **safety work** within **5 working days** of the investigation concluding, if the investigation identifies a significant hazard.
- Begin, or take steps to begin, **any supplementary preventative work** to prevent a significant or emergency hazard recurring within **5 working days** of the investigation concluding, if the investigation identifies a significant or emergency hazard. If steps cannot be taken to begin work in **5 working days** this must be done as soon as possible, and work must be physically started **within 12 weeks**.
- Satisfactorily complete supplementary preventative works within a reasonable time period.
- Secure the **provision of suitable alternative accommodation for the household**, at the social landlord's expense, if relevant safety work cannot be completed within specified timeframes.
- Keep the **tenant updated** throughout the process and provide information on how to keep safe.

Awaab's Law: Guidance for social landlords - Timeframes for repairs in the social rented sector - GOV.UK

Current challenges for IAQ standards (ISIAQ's views)

- IAQ standards differ globally due to local climate and building practices, and economic resources requiring ongoing improvement.
- Many IAQ standards lack solid scientific health basis and do not fully address emerging health issues like infectious diseases.
- Socioeconomic and political conditions strongly influence IAQ legislation: Political priorities, industry pressures, energy costs, and national income all shape regulatory limits.
- Global harmonisation remains difficult despite international guidance and scientific consensus.

While universal numeric standards may be impractical,

universal principles —health-based evidence, source control, and adaptive ventilation — are achievable.



Opportunities

- Due to climatic and regional differences, individual countries may use:
  - guidelines provided by the WHO or health organisations
  - standards e.g., from the International Organization for Standardization

  and set local limiting values considering the specific characteristics of their regions.

- Critical review of existing standards is required; standards should evolve alongside new health and energy challenges

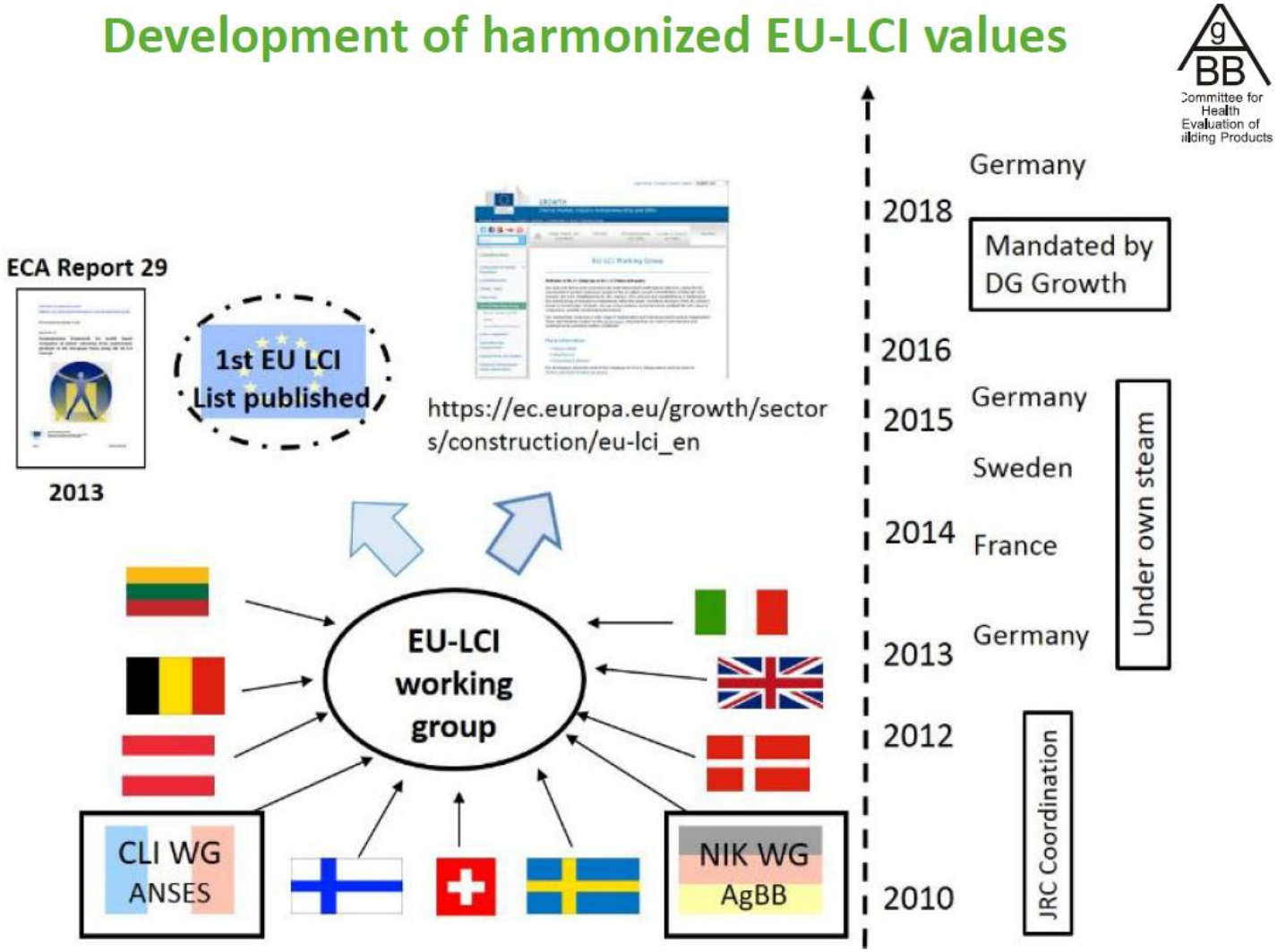
- Strong IAQ legislation raises awareness, improves building practices, and reduces disease burden in communities.

- Incorporating IAQ into energy and sustainability policies boosts health outcomes, productivity, and reduces healthcare costs.

Technological Solutions

Control of emissions

Development of harmonized EU-LCI values



Kindly provided by Ana Maria Scutaru (UBA)

Smart Building Technologies for IAQ Management



Smart Ventilation Systems

Advanced ventilation systems use IAQ sensors to monitor pollutants and adjust airflow to optimise indoor air quality while saving energy.

Portable Air Purifiers

Portable purifiers with HEPA and activated carbon filters effectively remove particulate matter and VOCs, respectively, for healthier environments.

Emerging IAQ Technologies

Innovations like photocatalytic oxidation, electrostatic precipitators remove specific pollutants, whereas use of sensors enhance pollutant monitoring.

Leveraging these technologies, indoor environments are not only comfortable and productive but also aligned with global sustainability objectives.

Future Directions and Recommendations

Challenges and Opportunities Ahead

Financial and Regulatory Challenges

Financial constraints and regulatory gaps limit widespread adoption of advanced IAQ technologies globally.

Balancing Ventilation and Energy

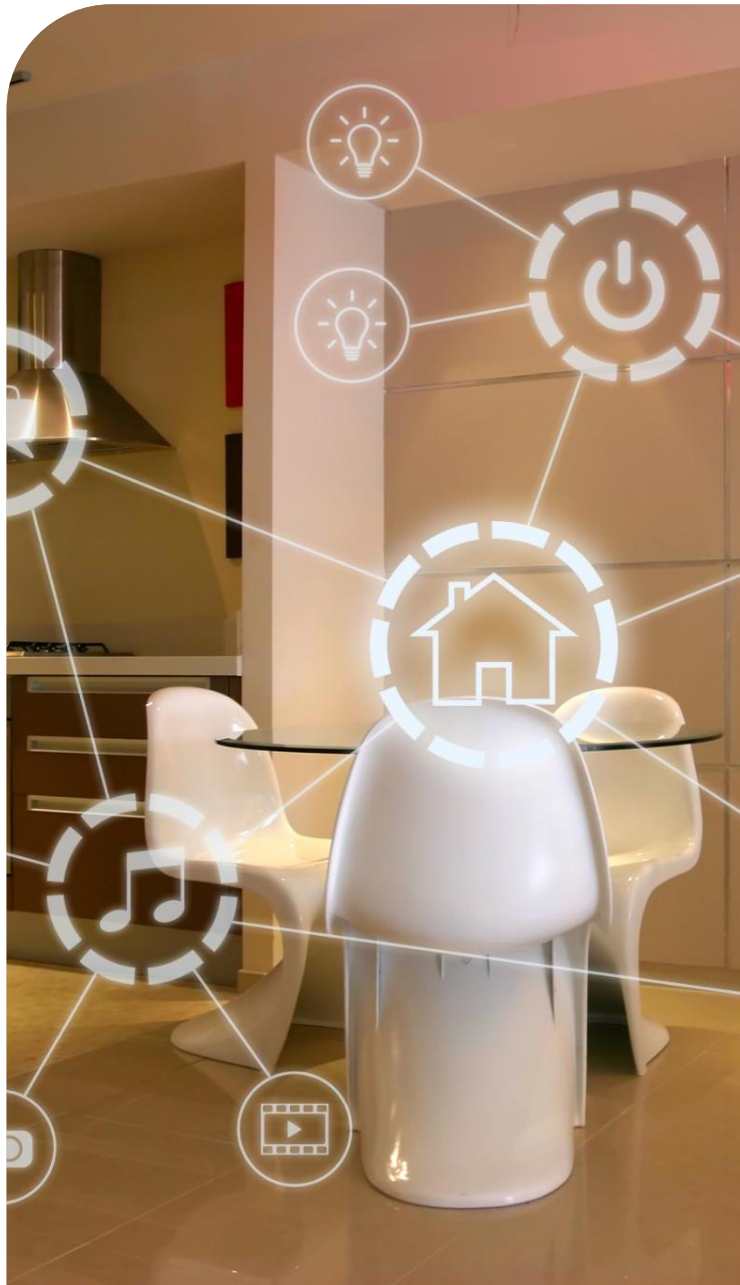
Improving IAQ while maintaining energy efficiency poses technical and economic challenges for buildings.

Behavioral and Educational Factors

Occupant behaviors and cultural norms influencing IAQ, requiring targeted citizens' education and engagement.

Technological and Collaborative Opportunities

Digital technologies, green certifications, and international collaboration offer opportunities to optimise and mainstream IAQ management.



Way ahead

Multi-sectoral IAQ Approach:

Align health, environment, and economic goals by integrating IAQ into national sustainability and climate plans.

Building Regulations / Standards:

Mandate IAQ monitoring systems and energy-efficient ventilation solutions with financial incentives to ensure compliance.

Public-Private Partnerships & Research:

Encourage collaboration to deploy advanced IAQ technologies and develop affordable solutions for low-income areas.

Education: Campaigns to raise awareness among occupants and facility managers

International Cooperation: harmonise IAQ principles internationally (health-based limits, source control and adaptive ventilation), for wider impact.

By addressing challenges proactively and taking advantage of opportunities, stakeholders can transform **IAQ** from a **niche concern** into a **core pillar of ESG Strategy,** delivering benefits across health, climate, and equity dimensions.

Government + Industry + Academia:
We produce our best
when we ALL work together



Thank you

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