What do we want to achieve in buildings? What is realistic and what is ideal?

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Why indoor air quality (IAQ)?

>85% of 10,000 L air inhaled daily is inhaled in buildings

Effects are not trivial

Current human habitat are buildings

The ”Da-building” code:

- 79 years (average life time)
- **69 years (in buildings)**
- 54 years (at home)
- 26 years (sleeping)

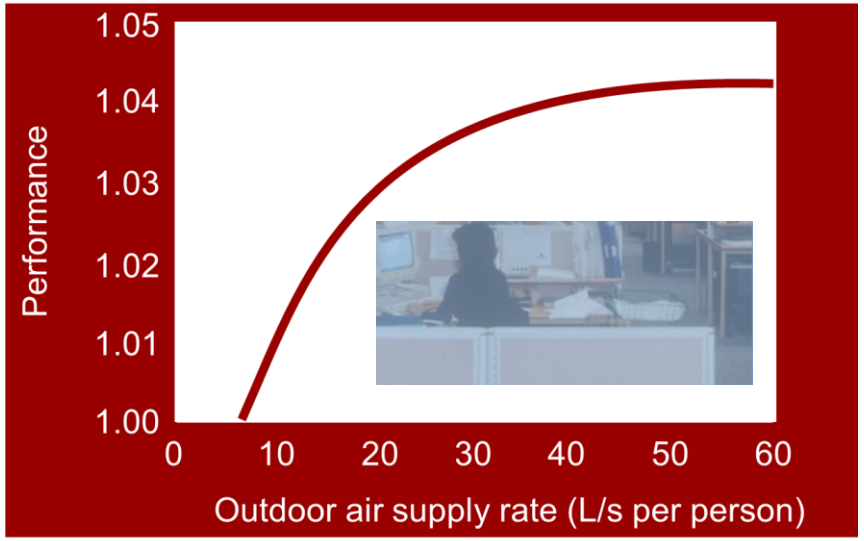
- 4.3 years (commute)

- **6 years (outdoor air)**

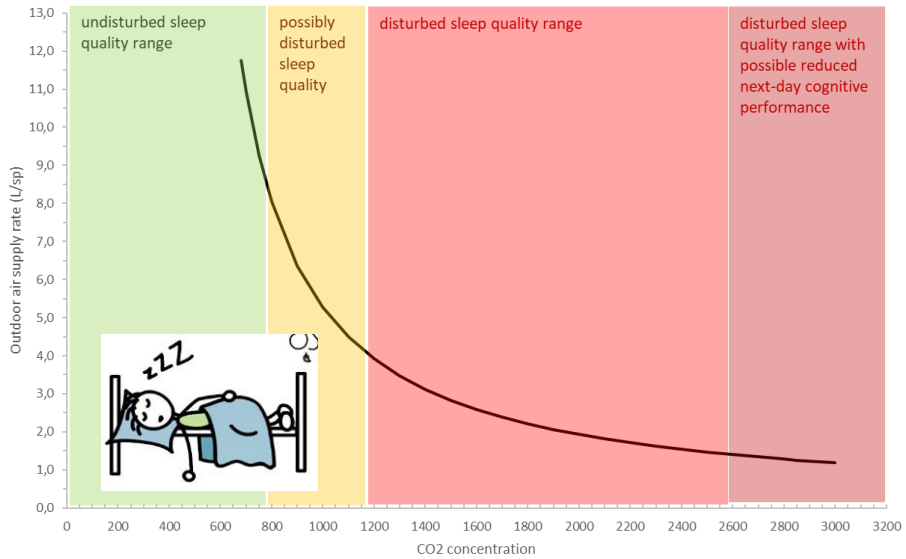
Source: Klepeis et al. (2011)

The main effects are well recognized and characterized

- Reduced comfort and well-being – reduced quality of life
- Increased prevalence of acute non-clinical health symptoms (e.g., headache)
- Reduced work performance, expected loss is at least up to 5%
- Reduced learning of children, expected loss of up to 10-15%
- Increased absenteeism and presenteeism
- Disturbed sleep, poor sleep quality => reduced health, cognitive performance



Source:Seppanen et al. (2006)

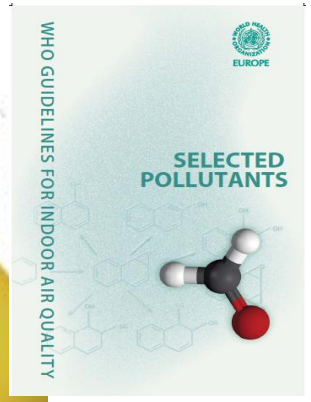


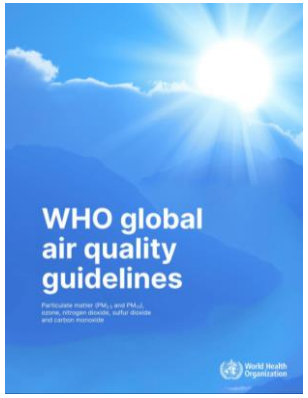
Source:Sekhar et al. (2020)

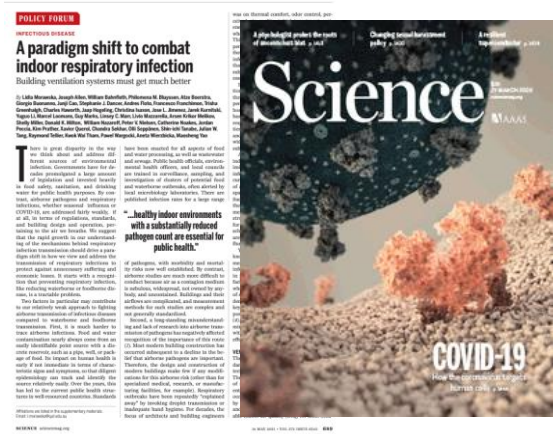
Can we minimize negative effects?

Yes, without any doubt

Among thousands of chemicals in commerce, 1% tested for toxicity but the main unsafe exposures are known….



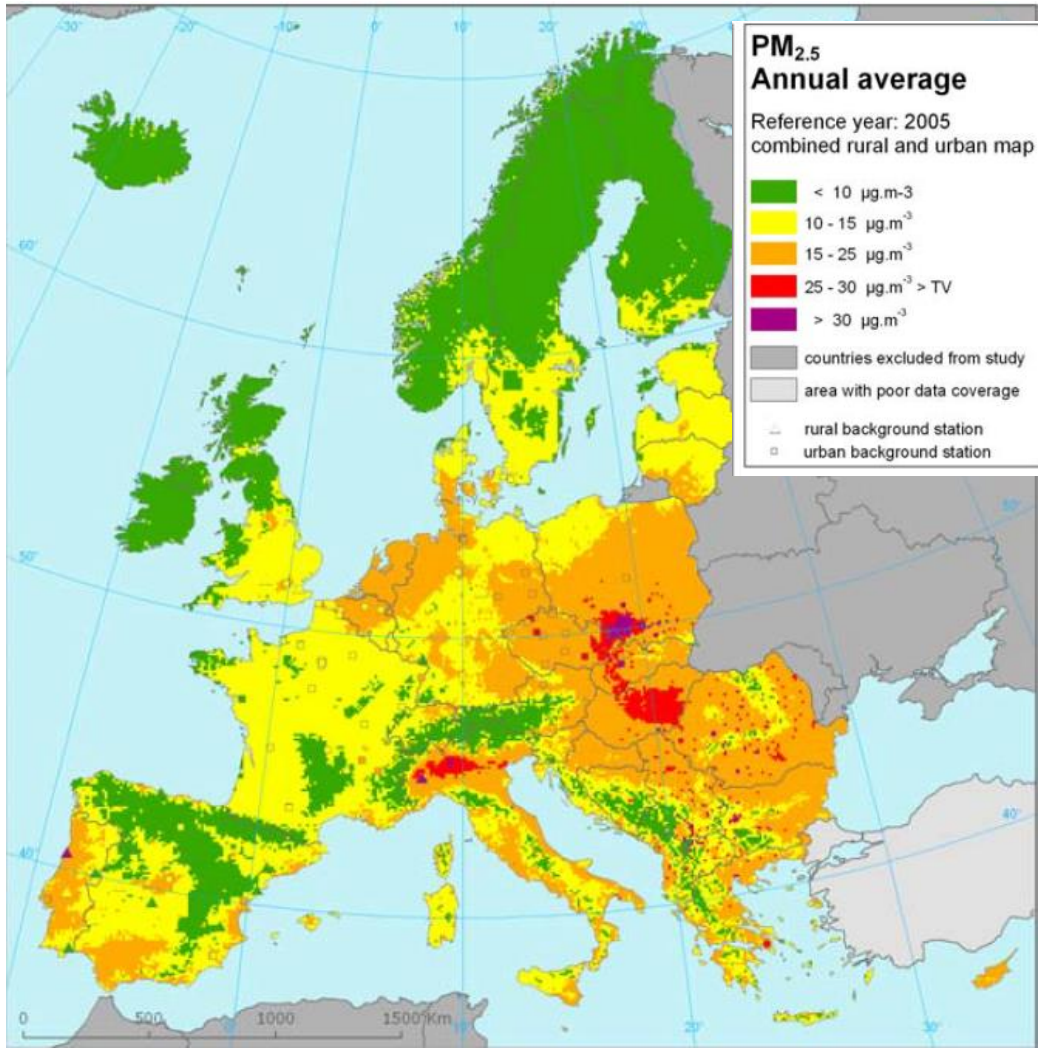




- Carbon monoxide
- Nitrogen dioxide
- Benzene
- Formaldehyde
- Naphthalene
- Trichloroethylene
- Tetrachloroethylene
- Polycyclic aromatic hydrocarbons (PAHs)
- Radon
- PM2.5
- PM10
- Sulphur dioxide
- Ozone

- Infectious agents (airborne pathogens)

Prerequisite: good indoor air requires good outdoor air (one air)



- Indoor air quality issues should be integrated in the ambient air directives accounting for the associated environmental, health, social and economic impacts

Source: ETC/ACC Technical Paper (2008)

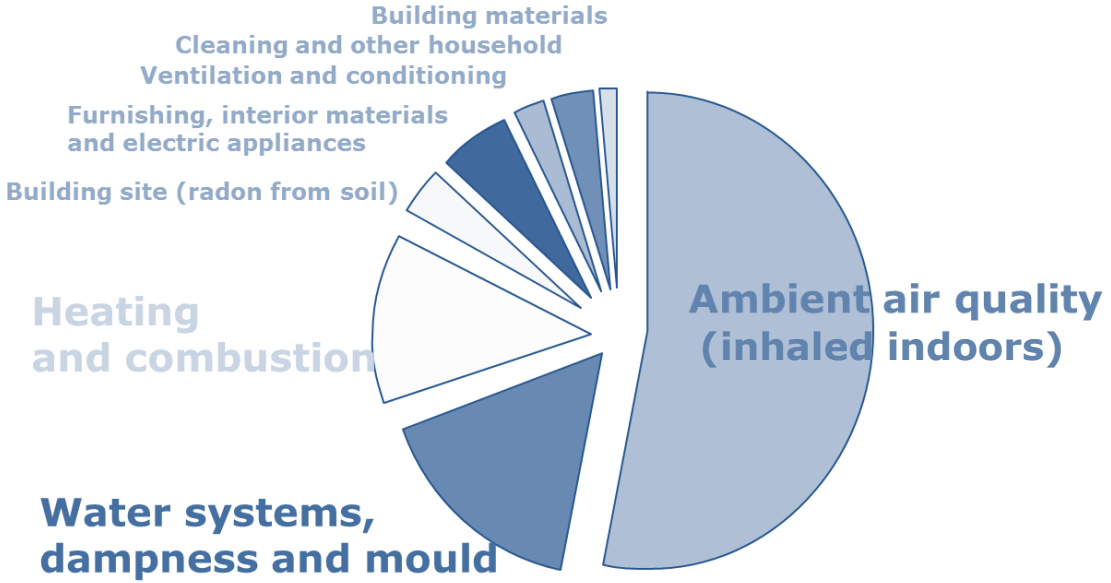
Is it costly?

Not, if benefits are considered

Economic implications are considerable

- Exposure in buildings estimated in EU to cause >2 mil healthy-life years lost due to poor IAQ (ca. €200 billion annually)
- This effects is comparable with, e.g. road traffic injuries, cost similar to GDP of Cyprus
- 200 million in Europe live with allergies, asthma and COPD

- *COVID-19 costs in Denmark were 30,000 healthy life years in Denmark (only) partly attributable to poor IEQ (€1 trillion/mo globally)*



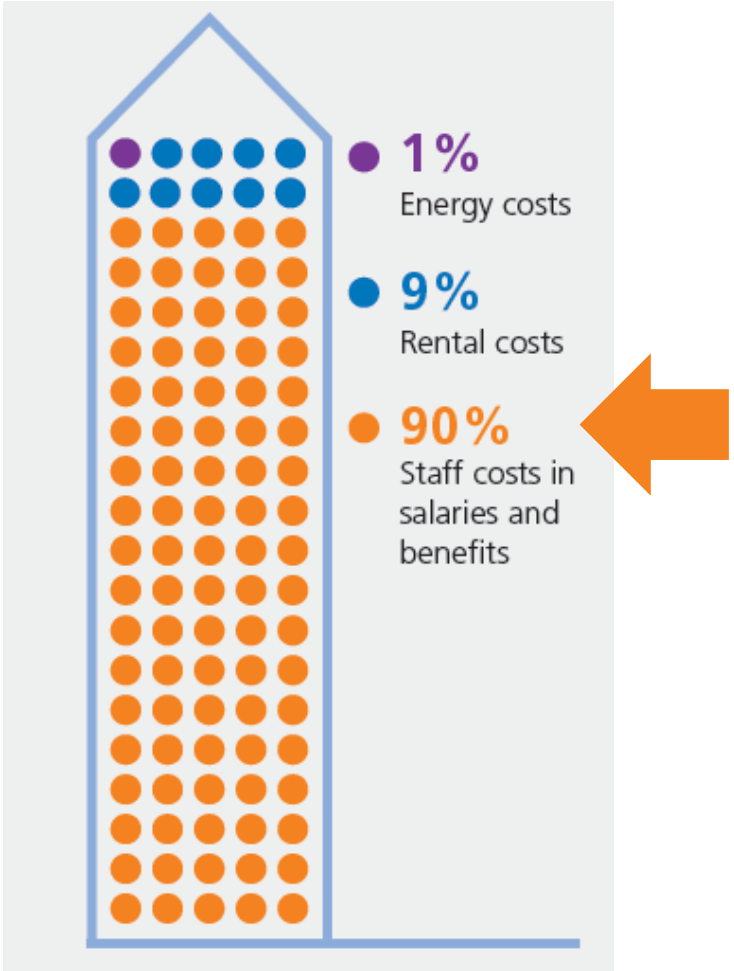
ETS excluded!

Source: ENVIE (2009)

Economic implications are considerable

- Modest gains in work performance can deliver significant financial benefits – even 1% increase in productivity is cost-effective
- Pay-back times are usually <1 (max. 2) years

- Too short sleep (<7 hours) causes 3.7-6 working days lost per year

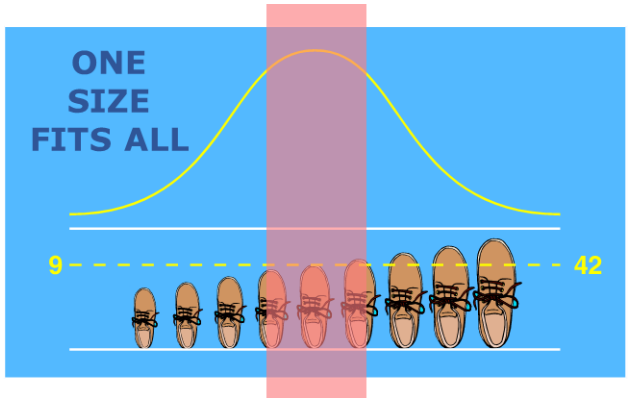


Source: WGBC (2014)

What to do first: what is realistic?
Standards, IAQ rating, source control and ventilation

Change the standards for indoor air, they are not sufficiently ambitious

- Minimum standards
- Address needs for an average person
- Neglecting individual preferences and differences
- Comfort (satisfaction) main design criteria
- Only risk reduction
- No strive for an innovation



Ideally standards should ensure

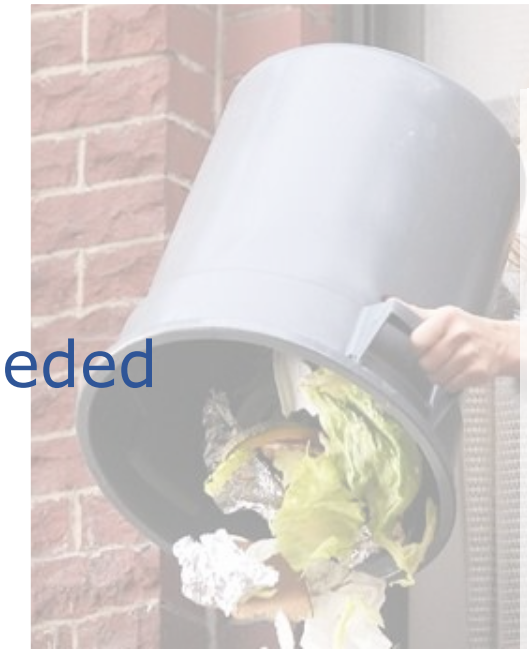
Resilience
Flexibility
Diversity
Preferences
Monitoring/Compliance
Equal risk in all buildings

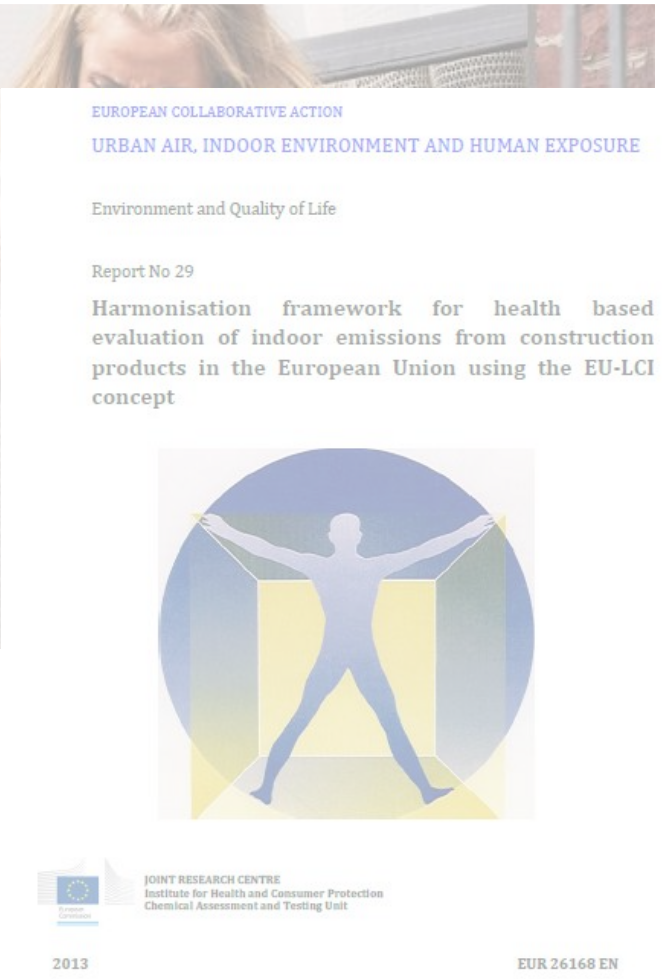
We must revisit ventilation requirements (and technical solutions - air distribution)

- Base
  - A basic requirement that must always be satisfied
  - Intended to dilute and exhaust just occupant bioeffluents, all other pollutants being at permissible levels
  - Example: 4 L/s per person proposed by the EU HealthVent project (no infection control)
- Base +, if Base is not met
- Endemic/Pandemic, in the case of local epidemic/pandemic (incl. infection control)

Prerequisite for the success 1
Source control

- Sources dominate
- Great diversity of sources
- Great diversity of products purchased and used by people
- Minimum standardization is needed – else no progress





- Example: Building Material Labelling EU-LCI concept: used only in the context of material emission testing, around 200 pollutants with LCI values

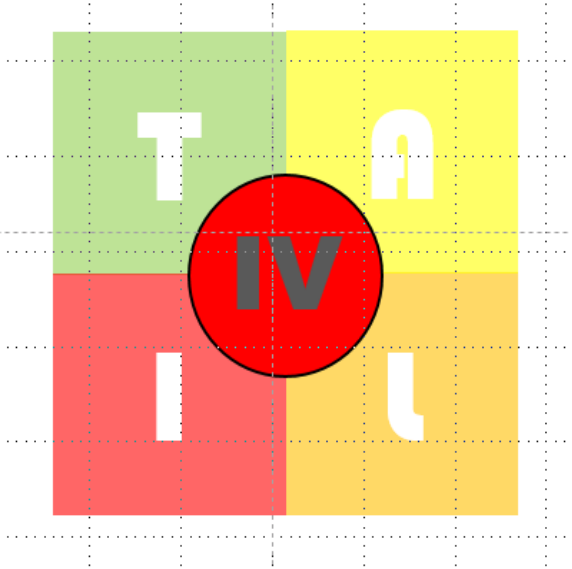
Prerequisite for the success 2
We must agree on and select pollutants for monitoring, example below

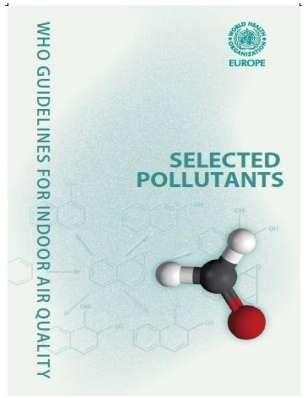
- Carbon dioxide (CO_2)
- Ventilation rate

- Nitrogen dioxide (NO_2)
- Benzene
- PM2.5
- Formaldehyde (HCHO)
- Radon
- Ozone

WHO Air Quality Guidelines

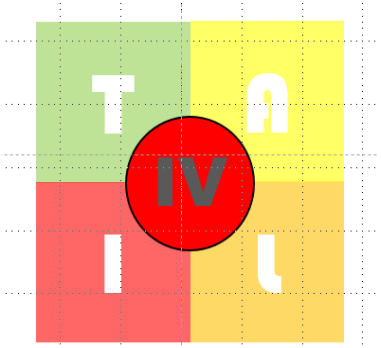
- Ozone (chemical transformations and harmful by-products)





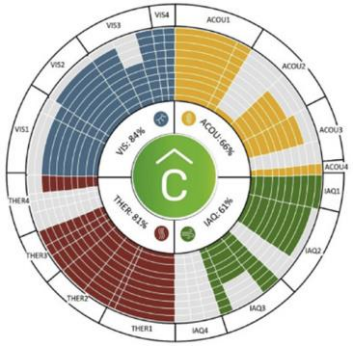
Prerequisite for the success 3
Rating scheme supporting monitoring and documentation of compliance

- Useful data for all building stakeholders
- Additional incentives for improvement of IAQ
- Create benchmark, reference, building data-base
- Monitor performance – compliance and maintenance
- Input to control and energy simulation
- Input to economic calculations
- Demonstrate invisible - occupants feel secure (no risks)
- Raise awareness



Source: Wargocki et al. (2020)

TAIL
(performance rating)



Source: Larsen et al. (2020)

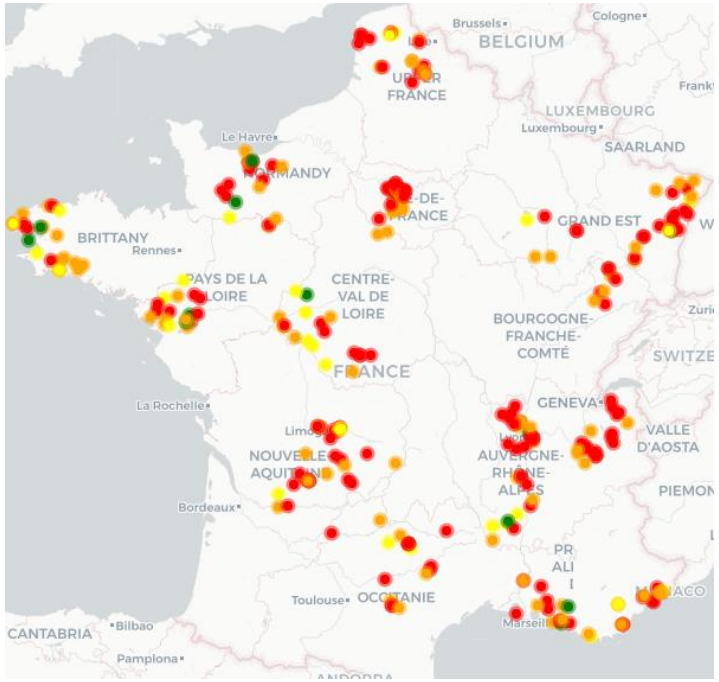
IEQ-Compass
(asset rating)

Source: European Commission

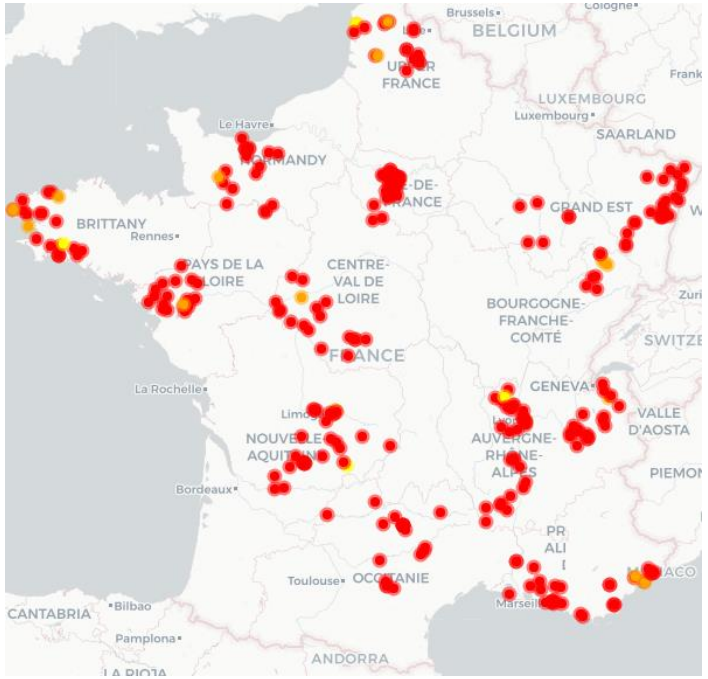
A common language for assessing and reporting on the sustainability performance of buildings

Illustrate invisible, TAIL for 308 schools in France, example

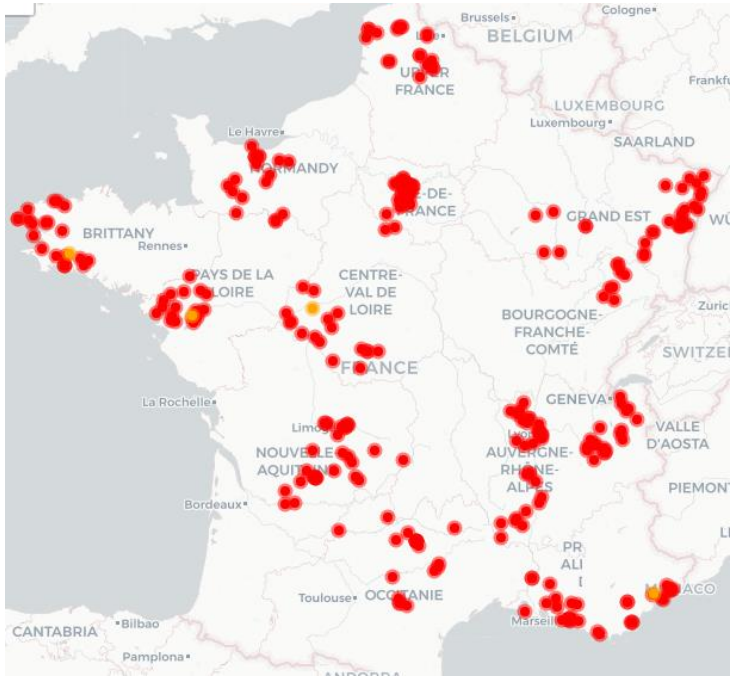
High, desired	Medium	Ordinary	Low - undesired



Quality of thermal environment (T)



IAQ (I)



Overall quality of indoor environment (TAIL)

Source: Tran et al. (2023)

What about humidity?

Worthy of attention

Dry, humid, or …

- High humidity levels need to be avoided => condensation, mould, house dust mite allergy

- Perception of dry air => caused by the elevated air pollution levels and temperatures
- Acceptable low humidity levels depend on many factors, including building location and purpose, age of occupants, and climatic conditions
- Low relative humidity cause eye problems and aggravates physiology of the upper airways
- Low relative humidity may reduce defence mechanisms against air pollution and microbes through mucociliary clearance and immune defence
- A need for humidification should be carefully considered

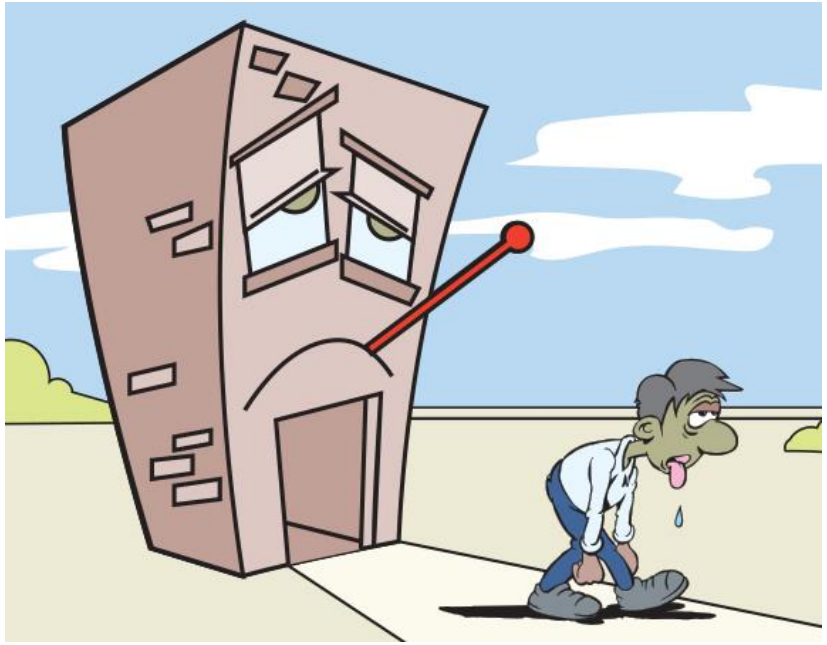
Source: Allairsensense; Airreviews

What do we want to achieve in buildings?

Buildings being green and healthy

Healthy buildings => create healthy environment for occupants

A healthy building should not compromise the basic human requirements of every building occupant and foster high quality of life, good health, optimal physical and mental activity, and sleep quality



Promoting health and not only avoiding risks

For example:

- *creating positive sensations*
- *fulfilling preferences and allowing active adaptation*
- *enhancing health resilience and immune response*

What is necessary?

A paradigm change

Take-aways

- **Paradigm change** incl. infection control
- **IAQ must not be compromised**, similarly to water and food quality
- **High indoor** air quality **= high outdoor** air **quality**
- We **must act on existing evidence** and we know what to do
- **IAQ rating** is a must
- **Benefits** are high, must be considered
- **Health must be promoted** in buildings, not only risk reduction

We must think of clean air as we think of clean water and fresh food. Here we do not compromise, nor should we do so with the indoor climate

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THANK YOU

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