Indoor air in residential buildings, European perspective

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The good news is …

- **Indoor air is on the (political) agenda!**

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The bad news is …

- **In Brussels we only take ‘half-hearted’ steps to really improve IAQ in Europe**

  Exceptions: outdoor air legislation, EPBD 4* (e.g. IAQ monitoring requirement), Ecodesign (e.g. regarding emissions of cooking appliances)

European and national regulatory environments

The European environment

IAQ has been called a “**regulatory no [wo]man’s land**”, and this becomes apparent after a first look at the myriad of policies and regulations that impact aspects of indoor air quality, on a background of a **lack of a common EU-wide understanding as to what constitutes “a healthy indoor air quality”**. Some EU initiatives display an awareness of this issue, but fail to directly and comprehensively tackle it.

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WHO statement 2002

World Health Organization

Right to Healthy Indoor Air

- P1 Under the principle of the human right to health, everyone has the **right to breathe healthy indoor air**.
- P2 Under the principle of respect for autonomy, everyone has the right to **adequate information** about potentially harmful exposures, and to be provided with effective means for controlling at least part of their indoor exposures.
- …
- P6 Under the principle of accountability, all relevant organizations should establish **explicit criteria** for evaluating and assessing building air quality and its impacts on the health of the population and on the environment.
- …
- P9 Under the Principe of sustainability, **health and environmental concerns cannot be separated**, and the provision of healthy indoor air should not compromise global or local ecological integrity, or the rights of future generations.

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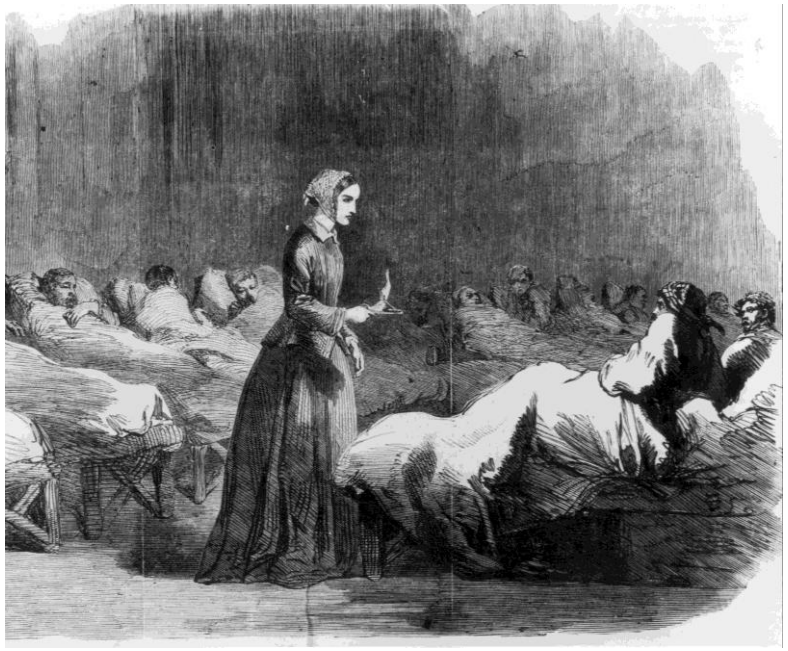
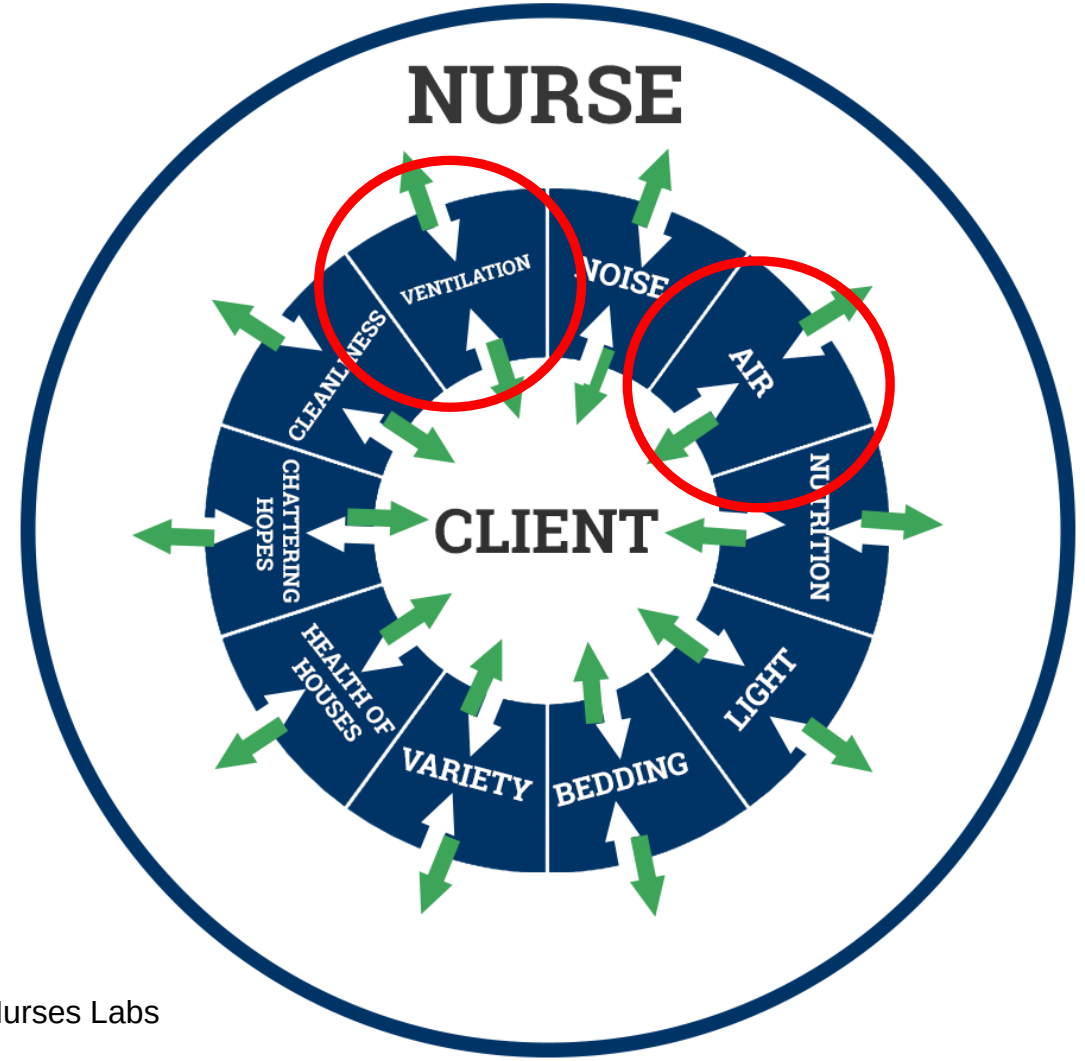
Florence Nightinggale 1860

Nightingale's environmental theory





Sources: Smith Archive & Nurses Labs

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Velux Healthy Homes Barometer

From the 2019 report:

- ‘One out of 6 European adults reports living in unhealthy homes.’
- ‘An alarming 26 million out of the 79 million European children under the age of 15 live in unhealthy homes.’
- ‘About 10-15 percent of new cases of childhood asthma in Europe can be attributed to indoor exposure to dampness and mould.’
- ‘Children from low-income households are at an even higher risk of health issues related to poor indoor climate.’
- ‘Improving ventilation in e.g. schools and reducing dampness and mould in homes across Europe, could increase the European GDP by over €300 billion by 2060.’

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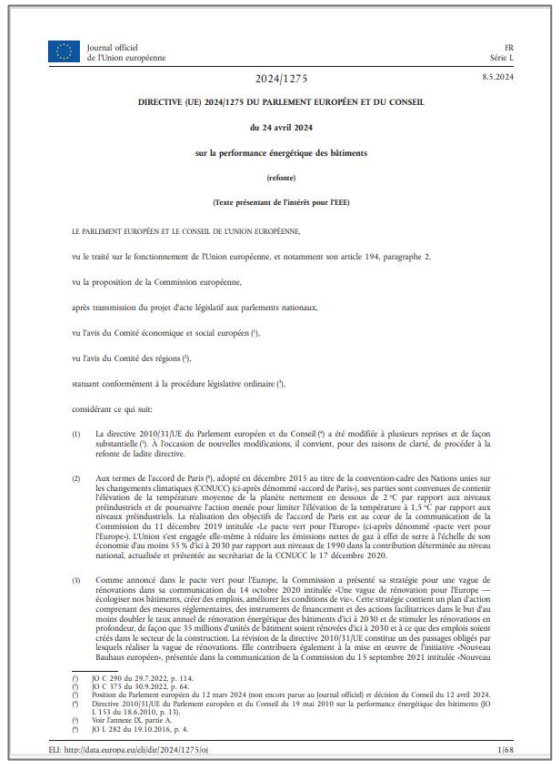
Energy Performance of Buildings Directive / EPBD 4

- The new directive takes a ‘whole building approach’ and looks at building performance in total, beyond just energy performance

From the document:

- ‘Energy requirements shall take account of optimal indoor environmental quality, in order to avoid possible negative effects such as inadequate ventilation, as well as local conditions (…).
- ‘Member States shall require non-residential zero-emission buildings to be equipped with measuring and control devices for the monitoring and regulation of indoor air quality.’
- ‘In existing non-residential buildings, the installation of such devices shall also be required (…) when a building undergoes a major renovation.’
- ‘Member States may require the installation of such devices in residential buildings.’



Journal officiel de l'Union européenne — FR Série L

2024/1275 — 8.5.2024

DIRECTIVE (UE) 2024/1275 DU PARLEMENT EUROPÉEN ET DU CONSEIL

du 24 avril 2024

sur la performance énergétique des bâtiments

(refonte)

(Texte présentant de l'intérêt pour l'EEE)

LE PARLEMENT EUROPÉEN ET LE CONSEIL DE L'UNION EUROPÉENNE,

vu le traité sur le fonctionnement de l'Union européenne, et notamment son article 194, paragraphe 2,

vu la proposition de la Commission européenne,

après transmission du projet d'acte législatif aux parlements nationaux,

vu l'avis du Comité économique et social européen (1),

vu l'avis du Comité des régions (2),

statuant conformément à la procédure législative ordinaire (3),

considérant ce qui suit:

(1) La directive 2010/31/UE du Parlement européen et du Conseil (4) a été modifiée à plusieurs reprises et de façon substantielle (5). À l'occasion de nouvelles modifications, il convient, pour des raisons de clarté, de procéder à la refonte de ladite directive.

(2) Aux termes de l'accord de Paris (6), adopté en décembre 2015 au titre de la convention-cadre des Nations unies sur les changements climatiques (CCNUCC) (ci-après dénommé «accord de Paris»), ses parties sont convenues de contenir l'élévation de la température moyenne de la planète nettement en dessous de 2 °C par rapport aux niveaux préindustriels et de poursuivre l'action menée pour limiter l'élévation de la température à 1,5 °C par rapport aux niveaux préindustriels. La réalisation des objectifs de l'accord de Paris est au cœur de la communication de la Commission du 11 décembre 2019 intitulée «Le pacte vert pour l'Europe» (ci-après dénommé «pacte vert pour l'Europe»). L'Union s'est engagée elle-même à réduire les émissions nettes de gaz à effet de serre à l'échelle de son économie d'au moins 55 % d'ici à 2030 par rapport aux niveaux de 1990 dans la contribution déterminée au niveau national, actualisée et présentée au secrétariat de la CCNUCC le 17 décembre 2020.

(3) Comme annoncé dans le pacte vert pour l'Europe, la Commission a présenté sa stratégie pour une vague de rénovations dans sa communication du 14 octobre 2020 intitulée «Une vague de rénovation pour l'Europe — écologiser nos bâtiments, créer des emplois, améliorer les conditions de vie». Cette stratégie contient un plan d'action comprenant des mesures réglementaires, des instruments de financement et des actions facilitatrices dans le but d'au moins doubler le taux annuel de rénovation énergétique des bâtiments d'ici à 2030 et de stimuler les rénovations en profondeur, de façon que 35 millions d'unités de bâtiment soient rénovées d'ici à 2030 et à ce que des emplois soient créés dans le secteur de la construction. La révision de la directive 2010/31/UE constitue un des passages obligés par lesquels réaliser la vague de rénovations. Elle contribuera également à la mise en œuvre de l'initiative «Nouveau Bauhaus européen», présentée dans la communication de la Commission du 15 septembre 2021 intitulée «Nouveau

(1) JO C 290 du 29.7.2022, p. 114.
(2) JO C 375 du 30.9.2022, p. 64.
(3) Position du Parlement européen du 12 mars 2024 (non encore parue au Journal officiel) et décision du Conseil du 12 avril 2024.
(4) Directive 2010/31/UE du Parlement européen et du Conseil du 19 mai 2010 sur la performance énergétique des bâtiments (JO L 153 du 18.6.2010, p. 13).
(5) Voir l'annexe IX, partie A.
(6) JO L 282 du 19.10.2016, p. 4.

ELI: http://data.europa.eu/eli/dir/2024/1275/oj — 1/68

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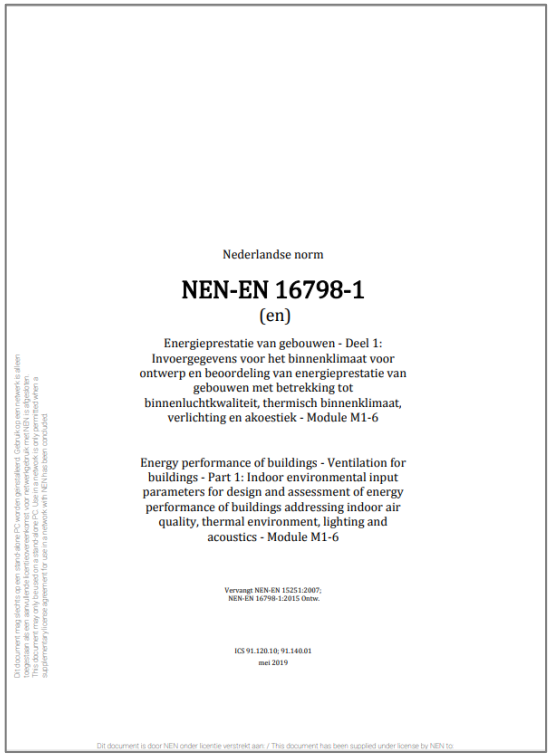
EPBD 4 & it's 'IEQ standard'

- EN 16798-1 '*Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics*'

  (UNDER REVISION)

Category	Expected Percentage Dissatisfied	Airflow per non-adapted person l/(s per person)
I	15	10
II	20	7
III	30	4
IV	40	2,5



Nederlandse norm

NEN-EN 16798-1
(en)

Energieprestatie van gebouwen - Deel 1: Invoergegevens voor het binnenklimaat voor ontwerp en beoordeling van energieprestatie van gebouwen met betrekking tot binnenluchtkwaliteit, thermisch binnenklimaat, verlichting en akoestiek - Module M1-6

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 - Module M1-6

Vervangt NEN-EN 15251:2007; NEN-EN 16798-1:2015 Ontw.

ICS 91.120.10; 91.140.01
mei 2019

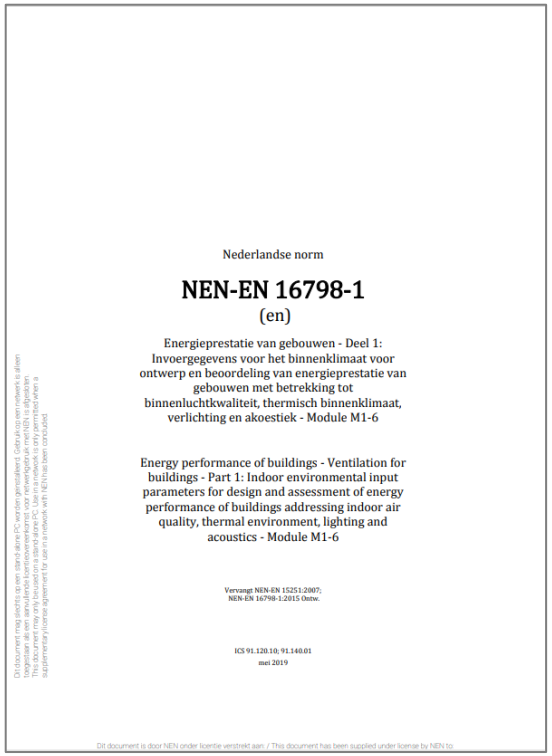
EPBD 4 & it's 'IEQ standard'

- EN 16798-1 '*Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics*'

  (UNDER REVISION)

Category	Expected Percentage Dissatisfied	Airflow per non-adapted person
I		
II		
III		
IV		

Category	Design ΔCO_2 concentration for living rooms (ppm above outdoors)	Design ΔCO_2 concentration for bedrooms (ppm above outdoors)
I	550	380
II	800	550
III	1 350	950
IV	1 350	950



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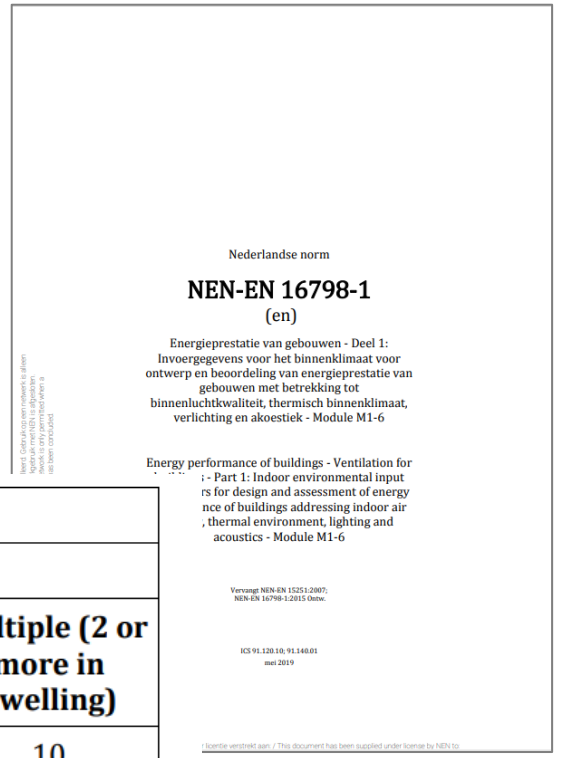
(UNDER REVISION)

Category	Expected Percentage Dissatisfied	Airflow per non-adapted person
I		
II		
III		
IV		

Category	Design ΔCO_2 concentration for	Design ΔCO_2 concentration for
I		
II		
III		
IV		

Number of main rooms in the dwelling	Design extract air flow rates in l/s				
	Kitchen	Bathroom or shower with or without toilets	Other wet room	Toilets	
				Single in dwelling	Multiple (2 or more in dwelling)
1	20	10	10	10	10
2	25	10	10	10	10
3	30	15	10	10	10
4	35	15	10	15	10
5 and more	40	15	10	15	10


Nederlandse norm

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ICS 91.120.10; 91.140.01
mei 2019

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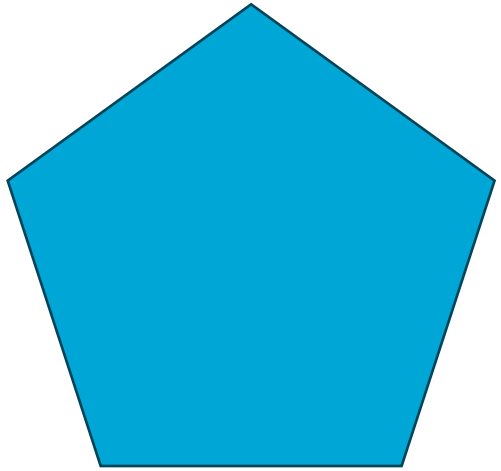
Main factors that determine INDOOR AIR QUALITY

(local) outdoor air quality

indoor sources I, occupant choice / activity related



Indoor sources II, building / building systems related

ventilation system(s)*

IAQ monitoring devices

** e.g. a combination of mechanical ventilation & operable windows*

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EN 16798-1 & operable windows

6.3.5 Access to operable windows

It shall be possible to access operable elements in the building envelop (e.g. windows, ventilation flaps, sky lights) provided for the ventilation, to allow the building occupants to make ventilation and to provide contact to the outside. Alternatively a remote control e.g. by mechatronic drives or operating rods can be used.

NOTE For example, this applies to bedrooms and living rooms in dwellings and other buildings with rooms intended for sleep, e.g. elderly homes. It also applies in schools and child care facilities. Increased air flow rates can be determined according to EN 16798–7. For further guidance see FprCEN/TR 16798–2 [7].

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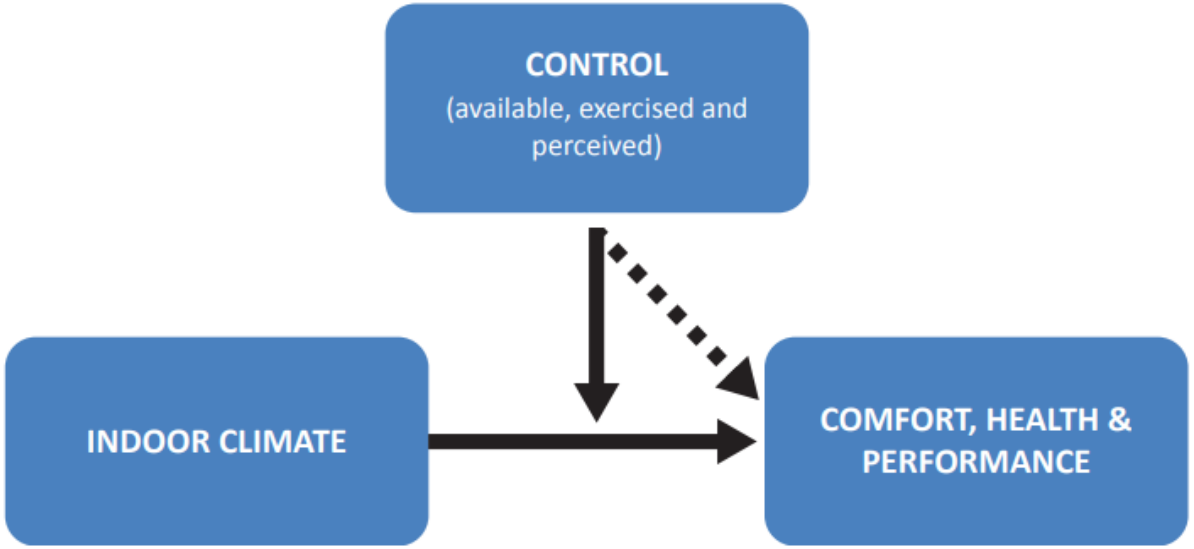
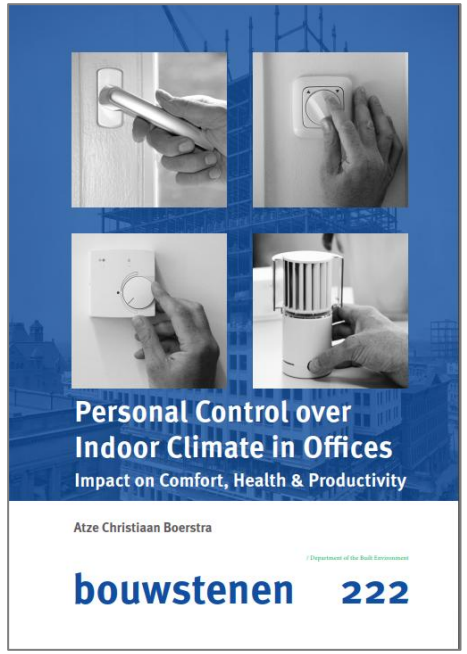
Intermezzo: importance of personal control options

- Human responses to sensory stimuli are modified when those that are exposed have control over those stimuli.
- It is not just the objectively measured indoor climate that affects perception of and satisfaction with one's environment.
- Control (access to operable windows, thermostats etc) acts as a 'moderator'.





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EN 16798-1 & air filtration

6.3.6 Filtration and air cleaning

The influence of the position of outdoor air intakes, filtration and air cleaning shall be considered. If filtration and air cleaning is used the following points shall be considered:

— reducing the amount of airborne pollutants (pollens, moulds, spores, particles, dust) from the outdoor air intake by passing the air through a filter or similar device;

— passing secondary air through a filter or other air cleaning technology to reduce the amount of pollutants in the indoor air;

Picture from www.zehnder.nl

Importance of source control (e.g. use of low emission flooring)

Max van Pettenkofer - German ‘hygienist’ (1818-1901) that conducted groundbreaking research related to (clean) water supply, sewage systems & ventilation

One of his more famous quotes:

‘If there is manure in the room,
don’t open the window,
stead remove the manure’

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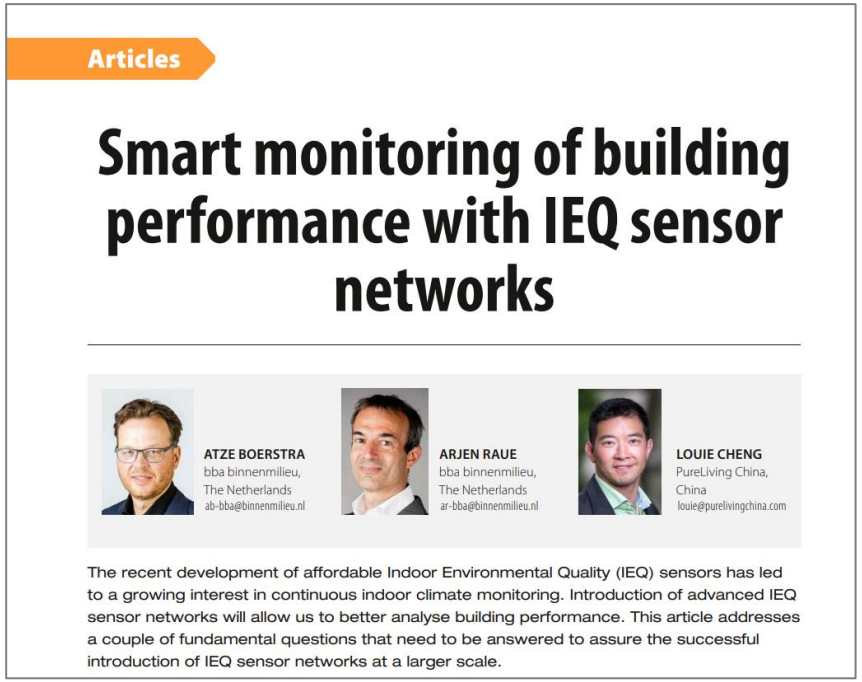
EPBD4 & IAQ monitoring requirement

- New & renovated non-residential buildings shall be equipped with measuring and control devices that monitor IAQ and temperature
- Suggested parameters to measure include CO_2, CO, PM and VOC's
- (IAQ monitoring is optional in new / renovated appartements)

Source: www.aranet.com



Articles

Smart monitoring of building performance with IEQ sensor networks

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The recent development of affordable Indoor Environmental Quality (IEQ) sensors has led to a growing interest in continuous indoor climate monitoring. Introduction of advanced IEQ sensor networks will allow us to better analyse building performance. This article addresses a couple of fundamental questions that need to be answered to assure the successful introduction of IEQ sensor networks at a larger scale.

Source: REHVA journal

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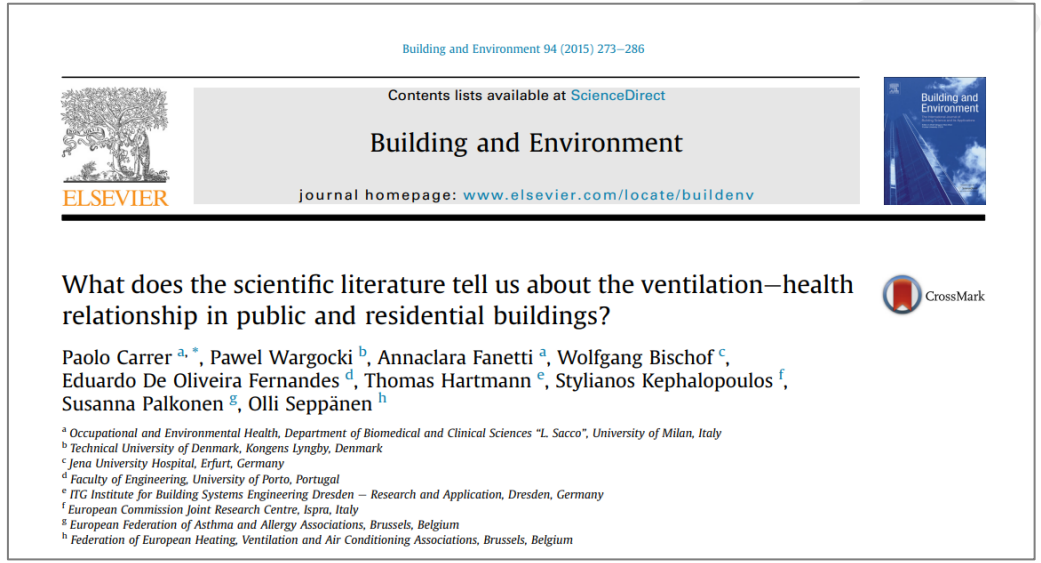
Ventilation requirements > how much fresh air is enough?

European HEALTHVENT study:

- Objective was to reanalyze epidemiological evidence on the link between outdoor air ventilation rates and health.
- Lowest ventilation rates at which no effects on health outcomes were observed were at **6 to 7 L/s per person** (= cat. II level EN 16798-1).
- Some field studies even suggest that no-effect limit is at 25-40 L/s per person (!).



Building and Environment 94 (2015) 273–286

Contents lists available at ScienceDirect

Building and Environment

journal homepage: www.elsevier.com/locate/buildenv

What does the scientific literature tell us about the ventilation–health relationship in public and residential buildings?

Paolo Carrer [a, *], Pawel Wargocki [b], Annaclara Fanetti [a], Wolfgang Bischof [c], Eduardo De Oliveira Fernandes [d], Thomas Hartmann [e], Stylianos Kephalopoulos [f], Susanna Palkonen [g], Olli Seppänen [h]

[a] Occupational and Environmental Health, Department of Biomedical and Clinical Sciences "L. Sacco", University of Milan, Italy
[b] Technical University of Denmark, Kongens Lyngby, Denmark
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[d] Faculty of Engineering, University of Porto, Portugal
[e] ITG Institute for Building Systems Engineering Dresden – Research and Application, Dresden, Germany
[f] European Commission Joint Research Centre, Ispra, Italy
[g] European Federation of Asthma and Allergy Associations, Brussels, Belgium
[h] Federation of European Heating, Ventilation and Air Conditioning Associations, Brussels, Belgium

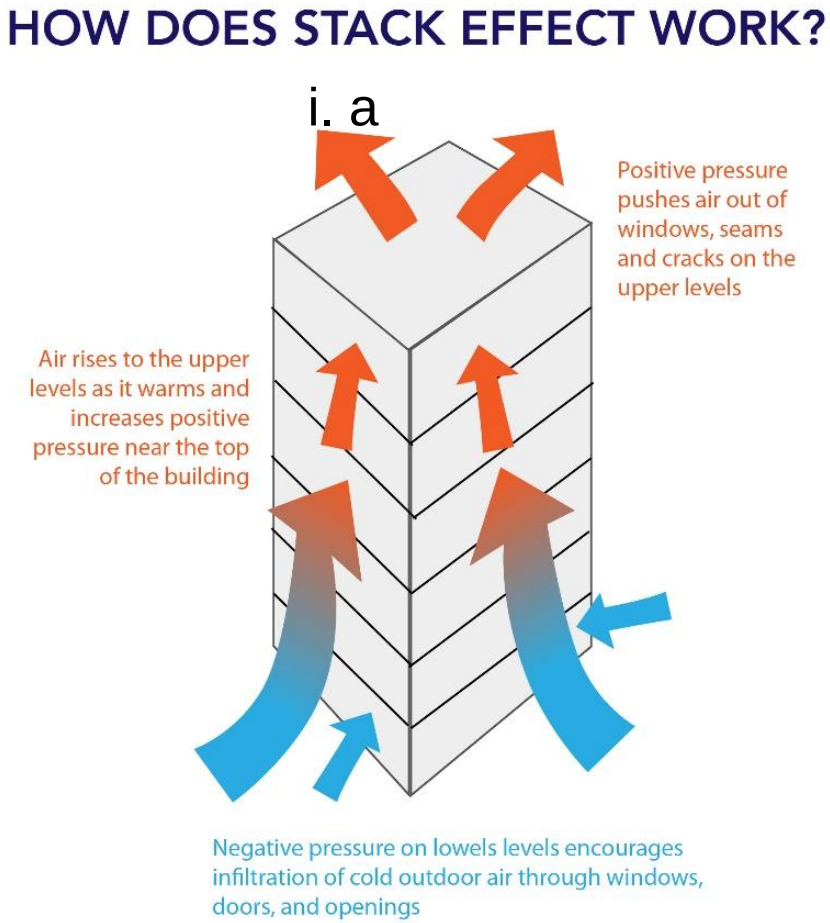
Why do we ventilate?

- to prevent olfactory discomfort (e.g. stuffy air complaints)
- to ensure a building does not become a ‘sick building’ (occupants suffering from building related symptoms)
- to decrease infection risk (e.g. COVID, influenza, measles, tuberculosis)
- to enhance quality of live for those that suffer from asthma, COPD and other lung diseases
- to boost productivity
- to extract humidity and other pollutants (often only locally within a structure)
- to enable certain processes (e.g in hospital, cleanroom, printing house, food industry)
- to get rid of access heat

How to ventilate? A few basics

- For ventilation one needs
  supply device, ii. an exhaust device, and
  iii. overflow measures

- The 3 main forces that can generate air flows are:
  i. wind pressure,
  ii. stack effect (‘schoorsteeneffect’) and
  iii. (mechanical) fans



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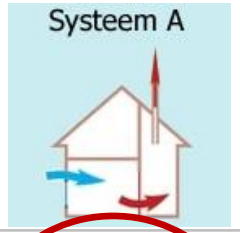
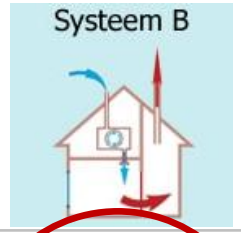
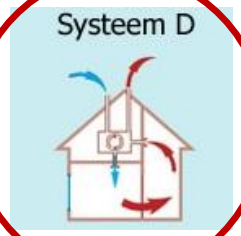
System types

Combination = HYBRID

		Supply	
		Natural	Mechanical
Exhaust	Natural		
	Mechanical		

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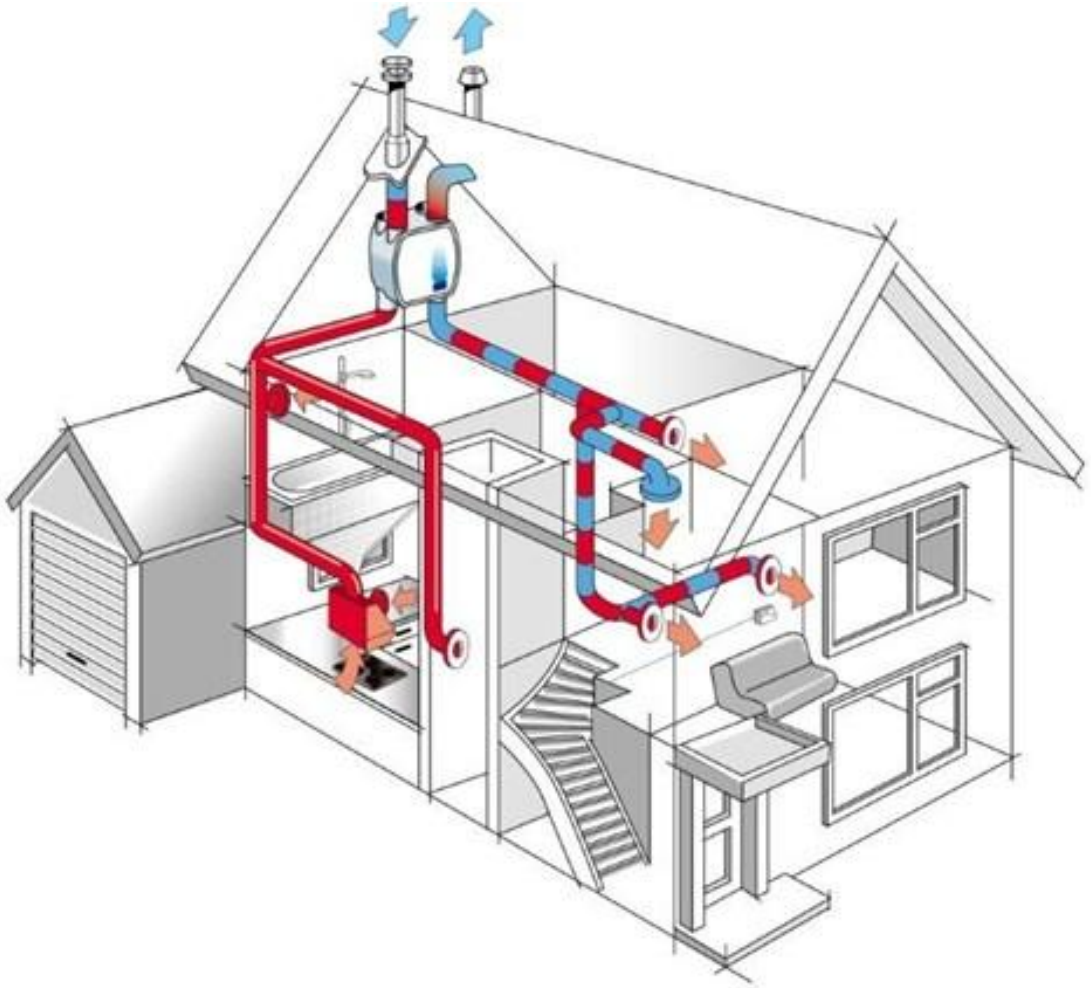
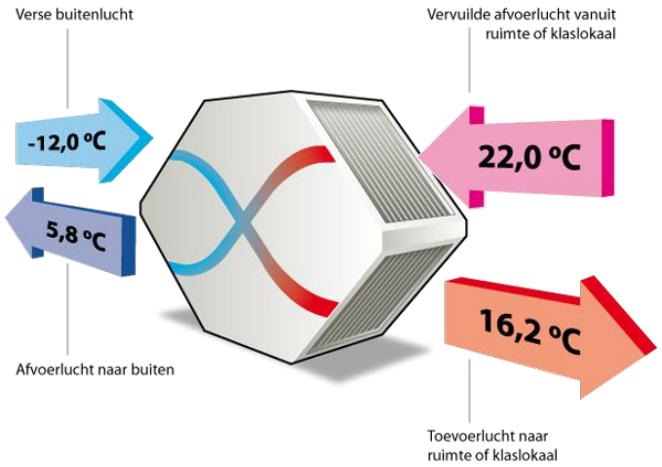
Example: system D solution for dwelling





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System D ventilation system components

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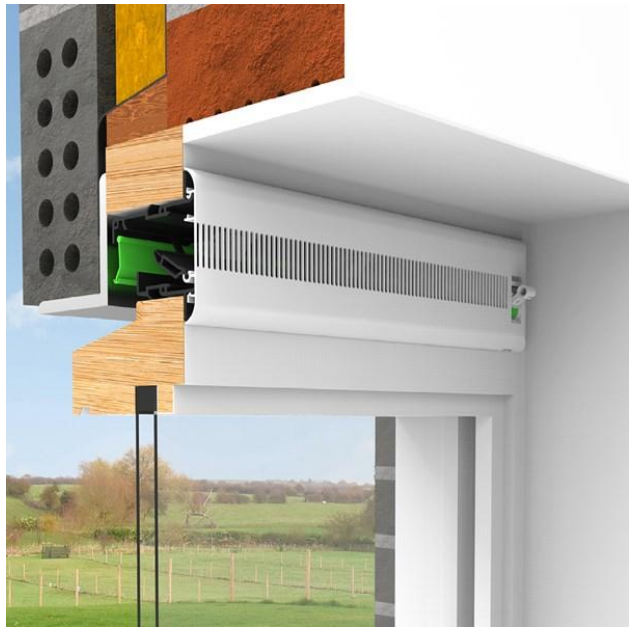
The alternative > regulated natural supply & mechanical exhaust



Pirctures: www.ventilatieshop.com & www.duco.nl

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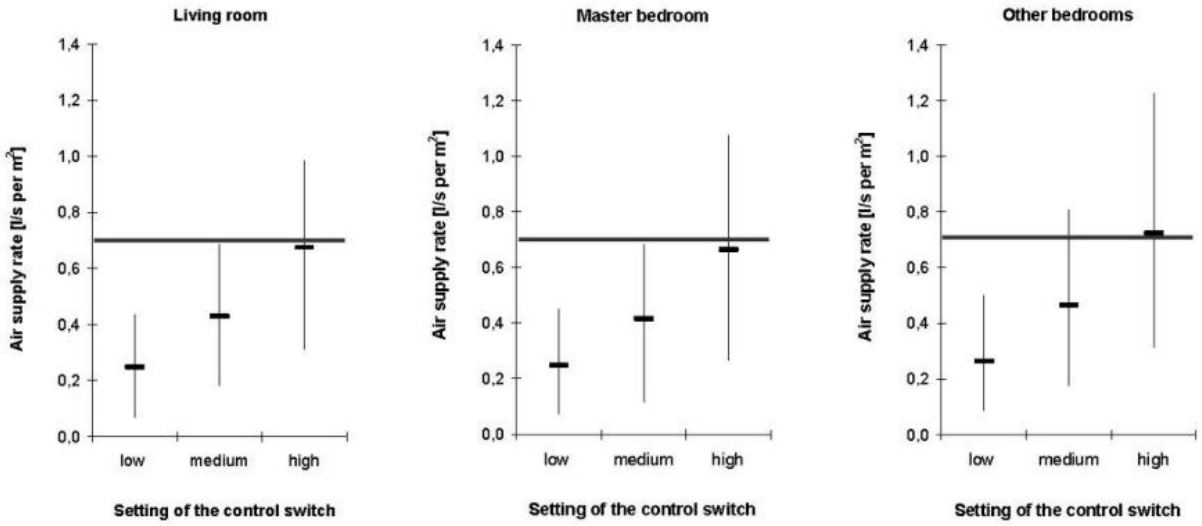
Actual performance of system C and D

Dutch study from 2011 in 299 (new) dwellings (50-50 system C and D); conclusions:

- Shortcomings are common in many homes and for both system C and D; these include insufficient ventilation rates, high noise levels and unclean systems.
- Indoor environmental quality was perceived more positive in homes with system C when considering air quality, perceived air-dryness, noise and perceived control options.

Source: Balvers, J. et al. (2012) 'Mechanical ventilation in recently built Dutch homes: technical shortcomings, possibilities for improvement, perceived indoor environment and health effects', Architectural Science Review, 55(1), pp. 4–14.



Measured air supply in different rooms (system D only)

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Dutch indoor climate label (inspired by ALDREN project)

- Objective: to develop a label that provides insight for ‘buildings in use’ related to the quality of all 4 indoor environmental parameters: air, temperature, sound and light.
- Developed by bba binnenmilieu in cooperation with TVVL, Binnenklimaat NL & TNO.
- Reference performance criteria from EN 16798-1 & other existing standards
- *(Main version for now only for offices…)*

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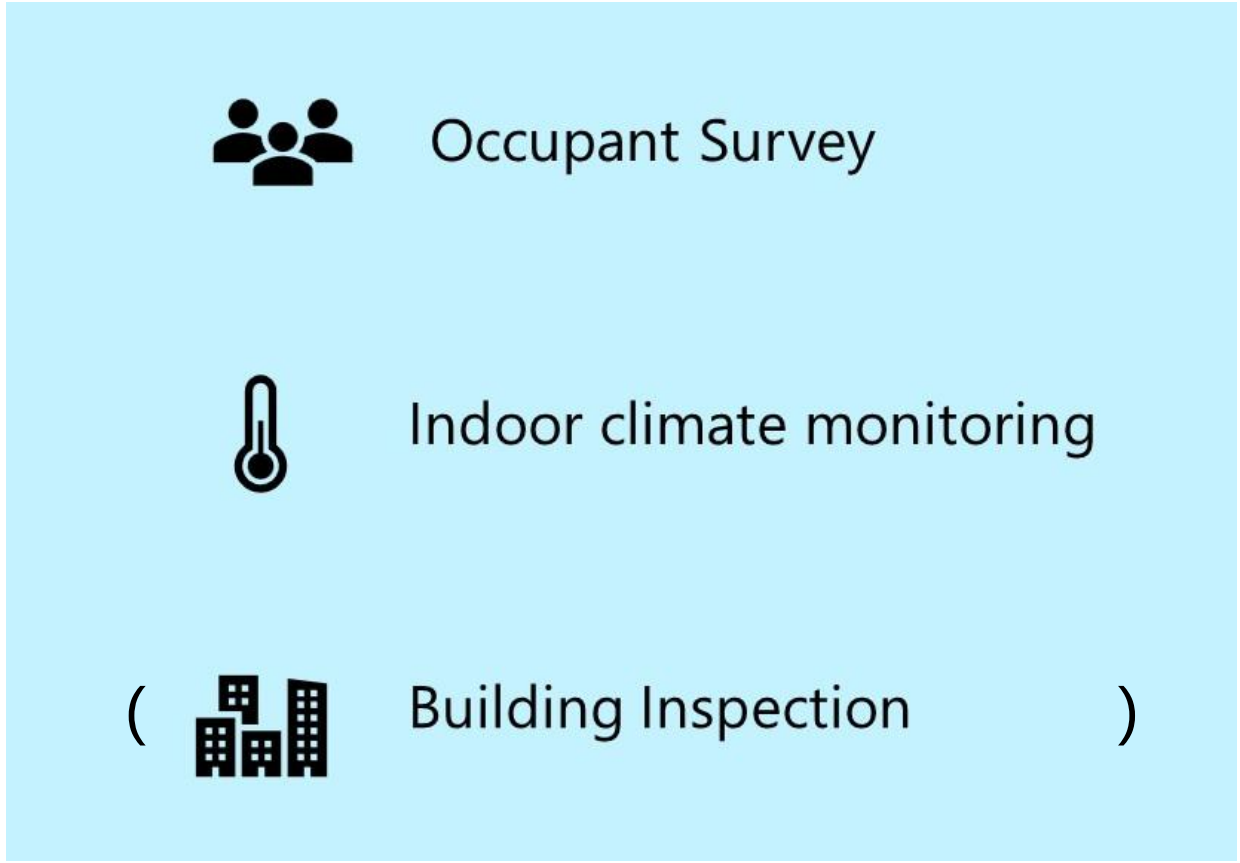
Methodology



Klasse C - VOLDOENDE

Klasse B - GOED
extra t.o.v. klasse C

Klasse A - ZEER GOED
extra t.o.v. klasse B

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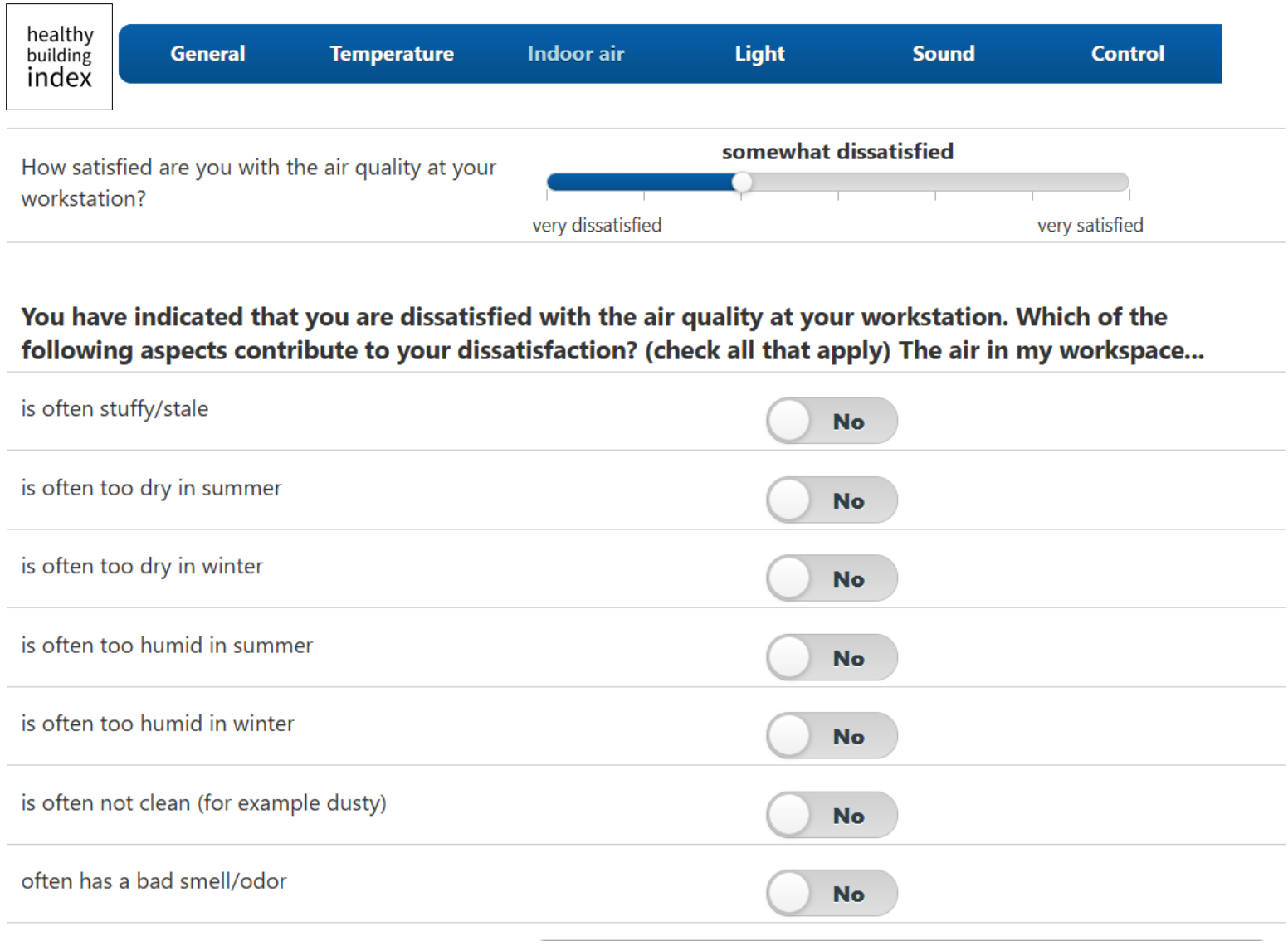
Occupant Survey, example question about indoor air



Building inspection with risk factor checklist

Climate

- Wintercomfort
- Summer comfort
- Journey
- Blowdown ventilation

Sound

- Room acoustics
- Use of space/layout
- Installation sound
- Sound insulation internally
- Soundproofing façade

Indoor air

- Air exchange capacity
- Blowdown ventilation
- Hygiene supply
- Outdoor Sources
- Internal bronnen

Light

- Artificial light
- Daylight
- View
- Brightness Barrier

	KLIMAAT Risico's wintercomfort
	Ja
Slechte thermische isolatie glas (enkel glas / dubbel glas U>3 W/m2K)	○
Slechte thermische isolatie dicht delen gevels	○
Verwarmingsysteem via lucht	○
Onvoldoende verwarmingsvermogen	○
Lage bezettingsgraad (>15 m2 pp op kamerniveau)	○
Centrale regeling ruimtetemperatuur (niet per zone)	○
Geen mogelijkheid tot handmatige naregeling ruimtetemperatuur stookseizoen	○

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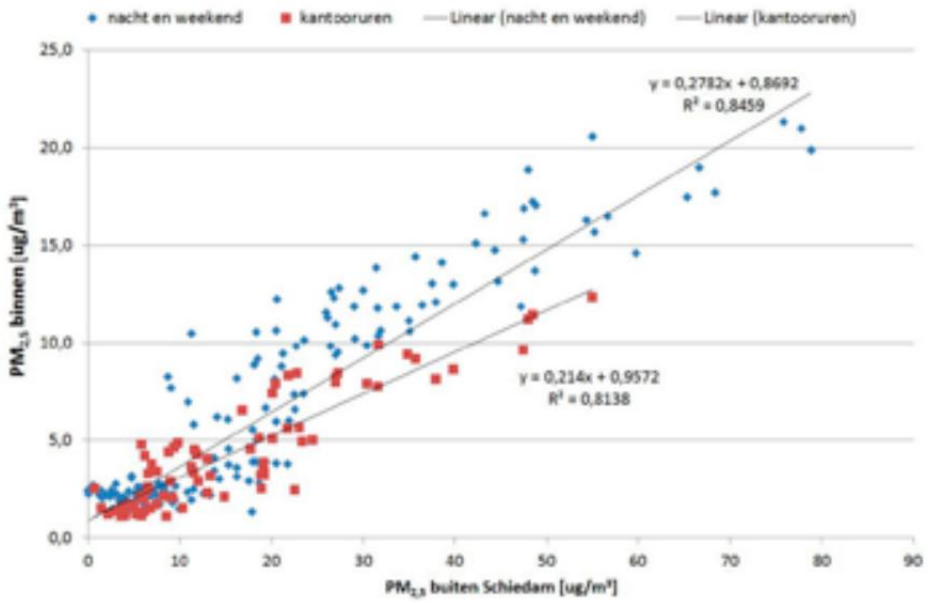
Continuous monitoring - when & how?

Temperature, humidity & CO_2 concentration

- For a year.
- Sample interval max. 15 minutes.
- At least 95% of the data must be available for analysis



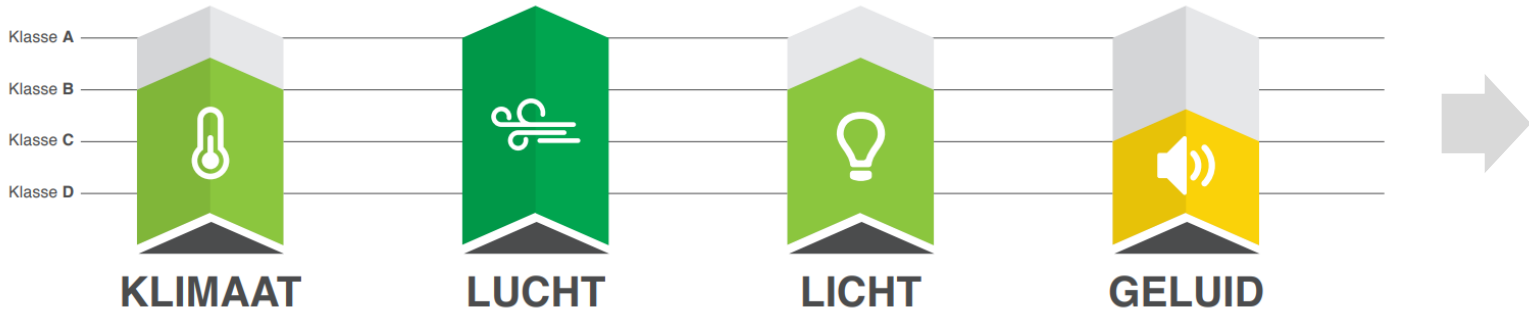
Particulate matter (PM2.5)

- To be measured for at least 1 week consecutively in 2-3 spaces.
- During this 1 week period the following requirements are met:
  1. the PM2.5 outdoor concentration is at least 4 hours < 5 micrograms/m³
  2. the PM2.5 outdoor concentration is at least 4 hours > 20 micrograms/m³
- If the outdoor conditions weren't adequate than longer period is needed.

Source: P. Jacobs, 2015 'PM2.5 meetprotocol voor kantoren'

The end result

Assessment per theme based on
outcomes of the verification protocol



Score per theme

Indoor climate label

More information via www.binnenklimaatlabel.nl

Take home messages

- Good news: indoor air is on the (political) agenda
- New EPBD 4 requirements (IAQ monitoring, replacement present EN 16798-1) do help
- But… further changes should first and for all come from member states themselves

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Take home messages

- Good news: indoor air is on the (political) agenda
- New EPBD 4 requirements (IAQ monitoring, replacement present EN 16798-1) do help
- But… further changes should first and for all come from member states themselves

Residential building related areas that need attention are for example:

- Minimum fresh air requirements in building codes (e.g. for bedrooms)
- Actual performance of ventilation systems
- Avoidance of installation noise issues (esp. when using system D)
- Use of air filtration systems in locations with mediocre outside air
- Obligation to combine base ventilation solutions with operable windows

The (further) introduction of a TAIL like labelling system would be useful too

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