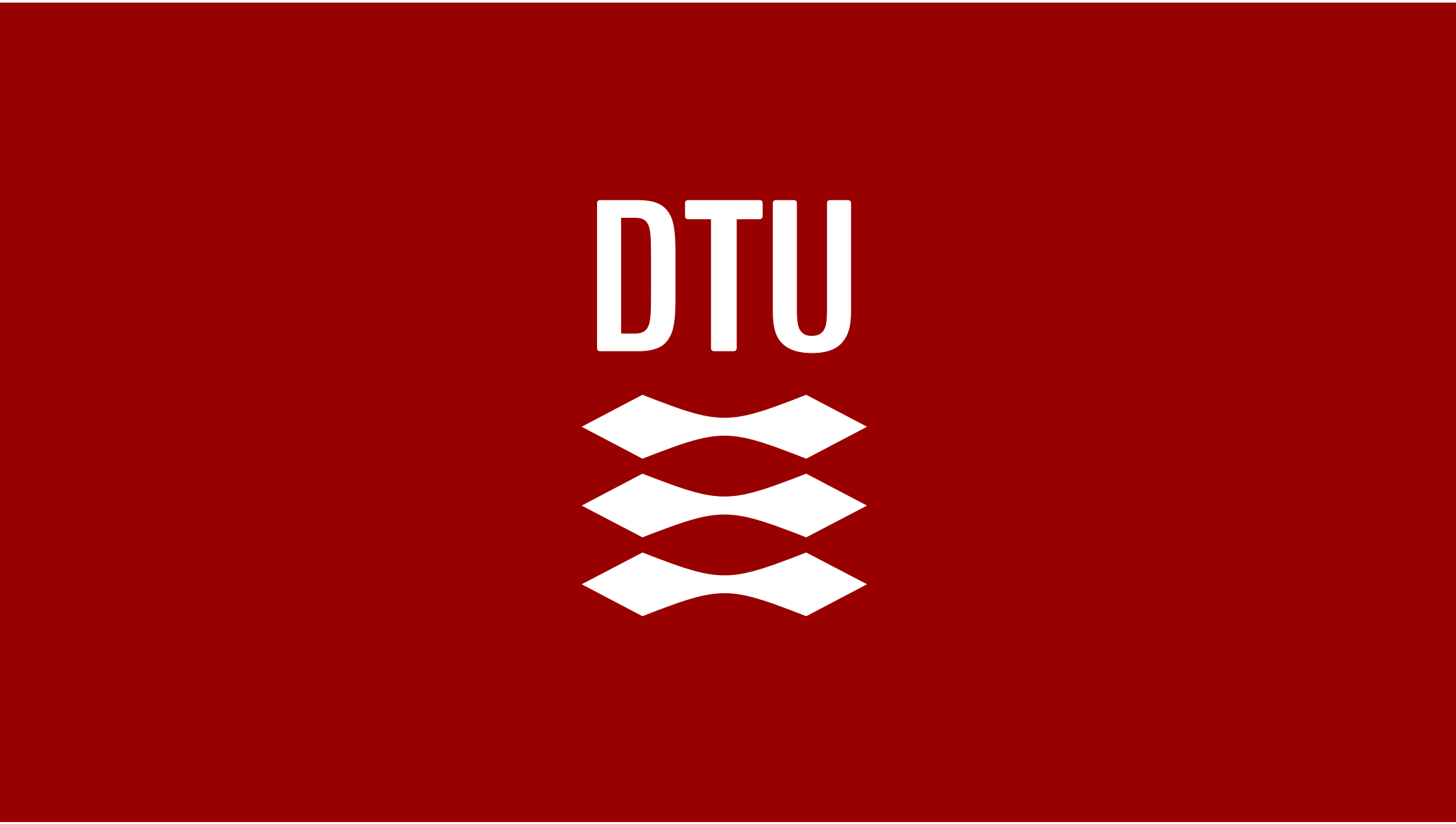
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A general overview of IEA-EBC Annex 78: Supplementing ventilation with gas-phase air cleaning, implementation and energy implications

Outline

- Introduction IEA-EBC Annex 78
- Concept of supplementing ventilation by gas phase air cleaning.
- Testing of gas phase air cleaners
- Energy impacts of using gas phase air cleaning
- Conclusions

Summary

- Operating Agents
  - Bjarne W. Olesen, Technical University of Denmark. Pawel Wargocki, Technical University of Denmark

- Time schedule
  - Preparation phase 01-07-2018 to 30-06-2019
  - Working phase 01-07-2019 to 30-06-2023
  - Reporting phase 01-07-2023 to 30-06-2024

Structure

- Subtask A: Energy benefits using gas phase air cleaning
  - Subtask leader: Alireza Afshari, Denmark
  - Co-leader: Sasan Sadrizadeh , Sweden
- Subtask B: How to partly substitute ventilation by air cleaning
  - Subtask leader: Pawel Wargocki, Denmark
  - Co-leader: Shin-Ichi Tanabe , Japan
- Subtask C: Selection and testing standards for air cleaners
  - Subtask leader: Paolo Tronville, Italy
  - Co-leader: Jinhan Mo, China
- Subtask D: Performance modelling and long-term field validation of gas phase air cleaning technologies
  - Subtask leader: Karel Kabele, Czech
  - Co-leader: Jensen Chang , USA

Concept, ref. ASHRAE 62.1 and EN16798

People Component

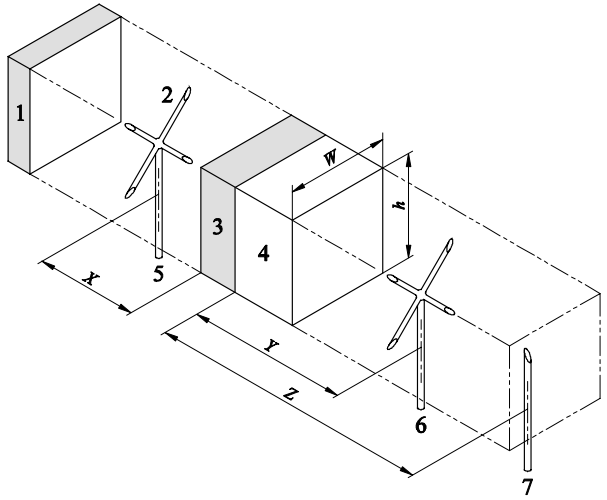
Building Component

Breathing Zone Outdoor Airflow

$$V_{bz} = R_p P_z + R_a A_z$$

- R_p: Minimum l/s/Person
- P_z: Number of People
- R_a: Minimum l/s/m²
- A_z: Building Area

Concept, supplementing ventilation



Key

1 diffusor and Δp device
2 sampling points – should be of "fork" type or similar with multiple inlet points to make a compounded sample over the whole cross section
3 GPACD under test
4 GPACD section of test duct
5 upstream sampling point for T_U, RH_U, p_U and C_U at X mm before the GPACD
6 Downstream sampling point for T_D, RH_D, p_D and C_D at Y mm after the GPACD
7 Q, air flow rate sampling point at Z mm after the GPACD
W internal width of the test duct along the GPACD section, 3+4
h internal height of the test duct along the GPACD section, 3+4

Figure 1 — Normative section of test stand showing ducting, measurement parameters and sampling points

ISO 10121-1:2014 "Test method for assessing the performance of gas-phase air cleaning media and devices for general ventilation - Part 1: Gas-phase air cleaning media"

- **Clean Air Delivery Rate (CADR)**
  - $\mathbf{CADR = \varepsilon_{PAQ} \cdot Q_{AP} \cdot (3{,}6/V)}$
  - where:
  - ε_{clean} or $\varepsilon_{PAQ.}$ is the air cleaning efficiency
  - Q_{AP} · is the air flow through the air cleaner, l/s;
  - V is the volume of the room, m^3.

- **Air Cleaning Efficiency**
  - $\varepsilon_{clean} = 100(C_U - C_D)/C_D$

  where:
  - ε_{clean} is the air cleaning efficiency
  - C_U is the gas concentration before air cleaner
  - C_D is the gas concentration after air cleaner.

Methods and standards for testing gas-phase air cleaners

Standard/Protocol	Methods	Challenge Gaseous	Measured Gaseous	Performance index
Air cleaner, Standardization Administration of China (GB/T-18801)	Pulldown	Single species gas e.g.,	Formaldehyde toluene	CADR
Air cleaner, Standardization Administration of China (GB/T-18801)	Singlepass	Single species gas e.g.,	Formaldehyde toluene	Single-pass efficiency
Reduced Energy Use Through Reduced Indoor Contamination in Residential Buildings, NCEMBT (NCEMBT 061101), US report	Pulldown	Eight VOCs mixture	$TVOC_{toluene}$ formaldehyde	CADR
Air cleaner, Japanese Standard Association (JIS C 9615-2007)	Singlepass	NO_2, SO_2	NO_2, SO_2	Single-pass efficiency
Air cleaners of household and similar use, Japan Electrical Manufacturers Association (JEM 1467-1995)	Pulldown	Tobacco smoke	Ammonia, acetaldehyde, and acetic acid	Removal rate
Independent air purification devices for tertiary sector and residential applications - Test methods - Intrinsic performances, Association Française De Normalisation (XP B44-200)	Singlepass	Four VOCs mixture	Acetone, acetaldehyde, heptane, and toluen	Single-pass efficiency, CADR
Test method for assessing the performance of gas-phase air cleaning media and devices for general ventilation (ISO 29464:2017)	Singlepass	VOCs, acids, bases, and others	VOCs, acids, and bases, and others	Single-pass efficiency

Source: Afshari et al. (2022)

Challenges

- Only a few pollutants examined
- No methods for identifying by-products

BYPRODUCT GENERATION INCOMPLETE OXIDATION

- Aldehydes → **formaldehyde**, formic acid, CO
- **Alcohols** → aldehydes → acids → shorter carbon chain alcohols and acids →**formaldehyde**, methanol → CO_2 and H_2O
- Benzene → phenol
- 1-Butanol → butanal (butyraldehyde), butanoic acid, ethanol, acetaldehyde, (propanal (propionaldehyde) and propanol, propanoic acid) → (ethanol, **formaldehyde**) → methanol, **formaldehyde** and formic acid
- Ethanol → methanol, acetaldehyde, **formaldehyde**, acetic acid, formic acid
- Methanol → methyl formate (measured in liquid form only), **formaldehyde**, methylal (formaldehyde dimethyl acetal
- Toluene → benzaldehyde, benzoic acid, cresol, benzyl alcohol, phenol, benzene, formic acid

Source: Mo et al. (2009)

Assessments of perceived air quality

INTERNATIONAL STANDARD **ISO 16000-28**

First edition
2012-03-15

Indoor air —

Part 28:
Determination of odour emissions from building products using test chambers

Air intérieur —

Partie 28: Détermination des émissions d'odeurs des produits de construction au moyen de chambres d'essai

Test Panel

- Trained
- Untrained

Odour

- Acceptance
- Intensity
- Hedonic tone

Examples of diffuser and mask used for odour evaluatio

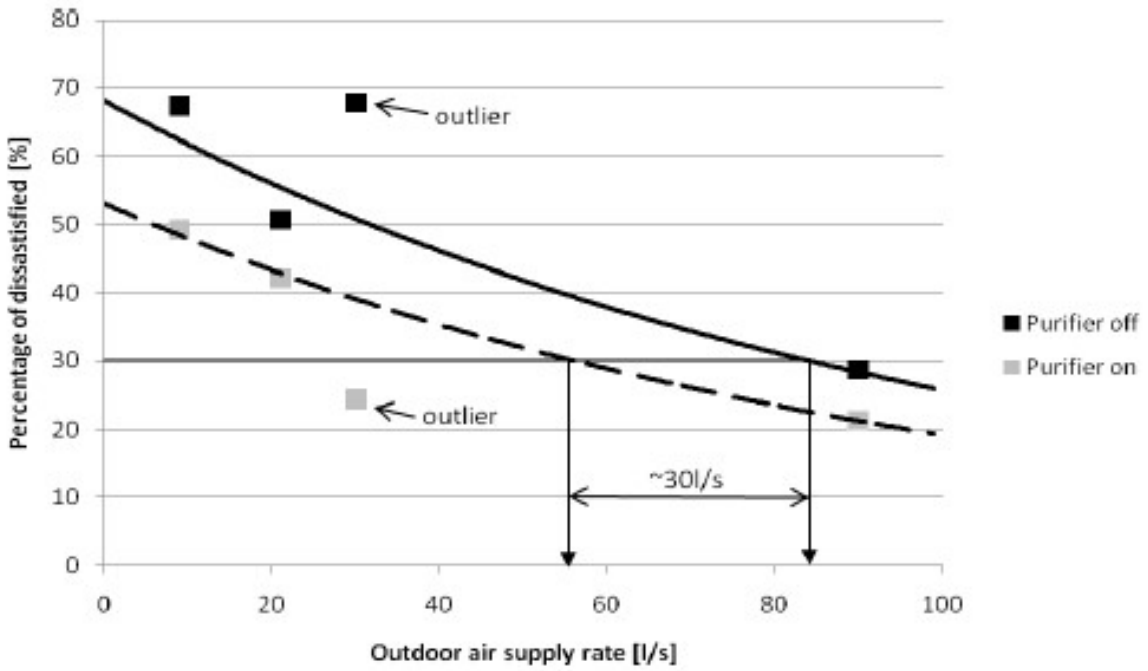
Figure C.1 — Diffuser

$$\varepsilon_{PAQ} = Q_o / Q_{AP} \cdot (PAQ / PAQ_{AP} - 1) \cdot 100$$

where:

- ε_{PAQ} is the air cleaning efficiency for perceived air quality;
- Q_o is the ventilation rate without air cleaner, l/s;
- Q_{AP} is the ventilation rate with air cleaner, l/s;
- PAQ is the perceived air quality without the air cleaner, decipol;
- PAQ_{AP} is the perceived air quality without the air cleaner, decipol

Use of perceived air quality, example



Energy simulations, example

Source: Bogatsu et al. (2021)

Methods – air cleaner

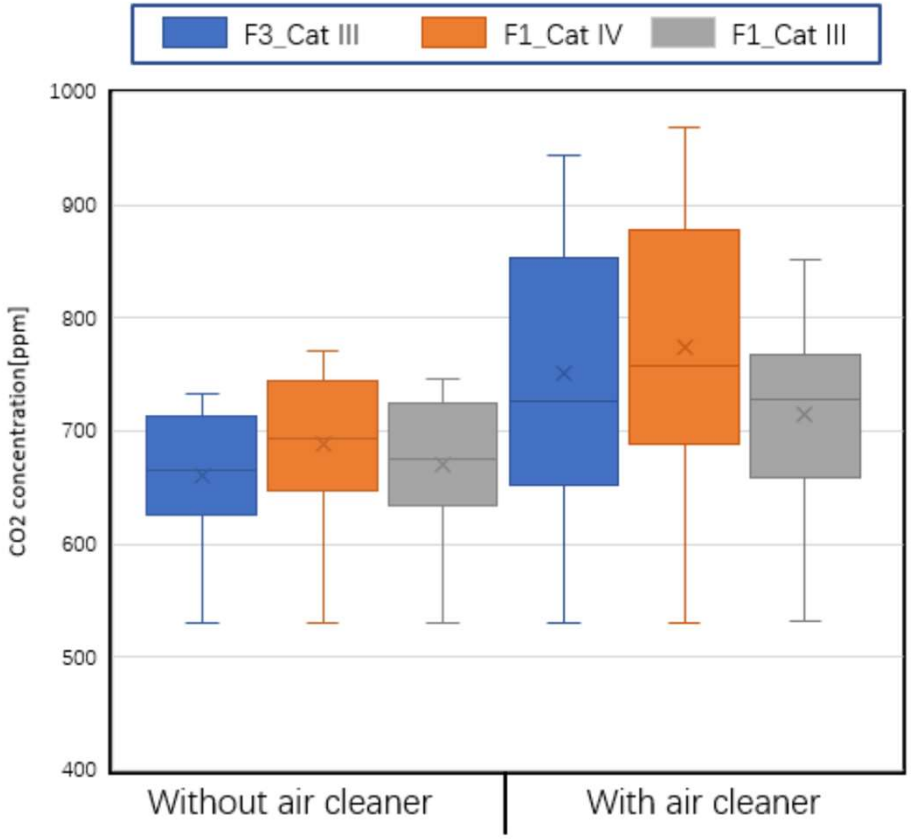
- Stand-alone air cleaner
- Air cleaner supplies clean air without any by-products
- Scenario
  - **F3 building materials and people**
  - **F1 building materials only**
- Improve IAQ from Category IV or III to Category II; PD determined empirically

Category	Level of expectation	PD [%]
IEQ_I	High	10
IEQ_{II}	Medium	20
IEQ_{III}	Moderate	30
IEQ_{IV}	Low	40

Source: EN 16798-1:2019

Results – IAQ

- CO_2 concentration below 1200 ppm
- Absolute CO_2 concentration (outdoor 400 ppm)



Results – IAQ

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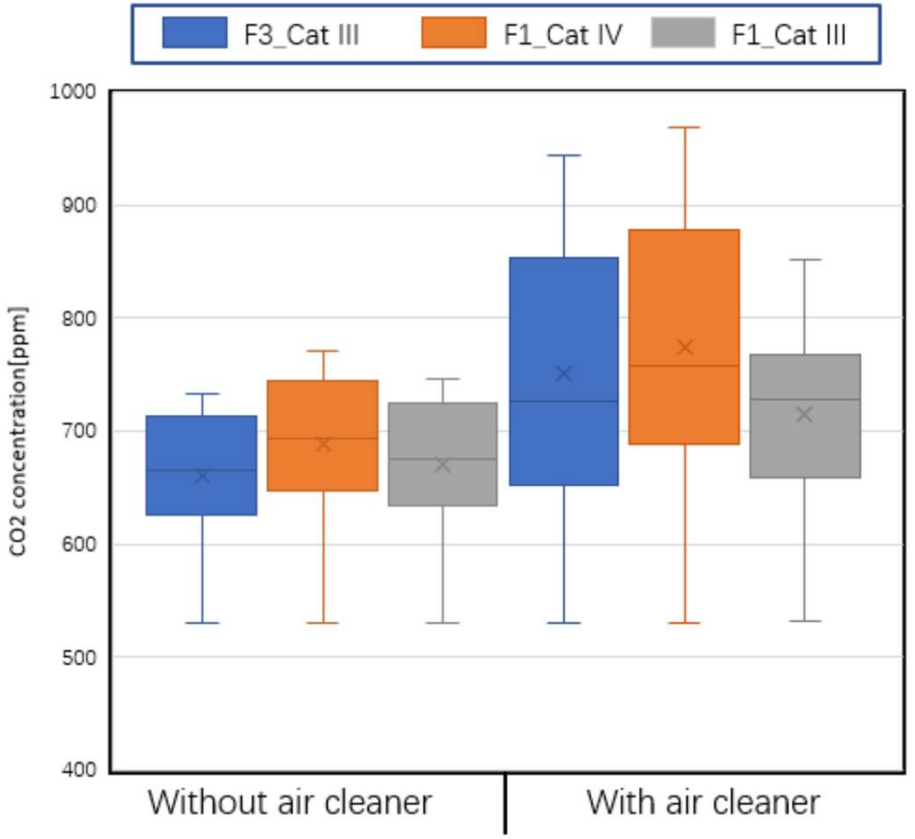
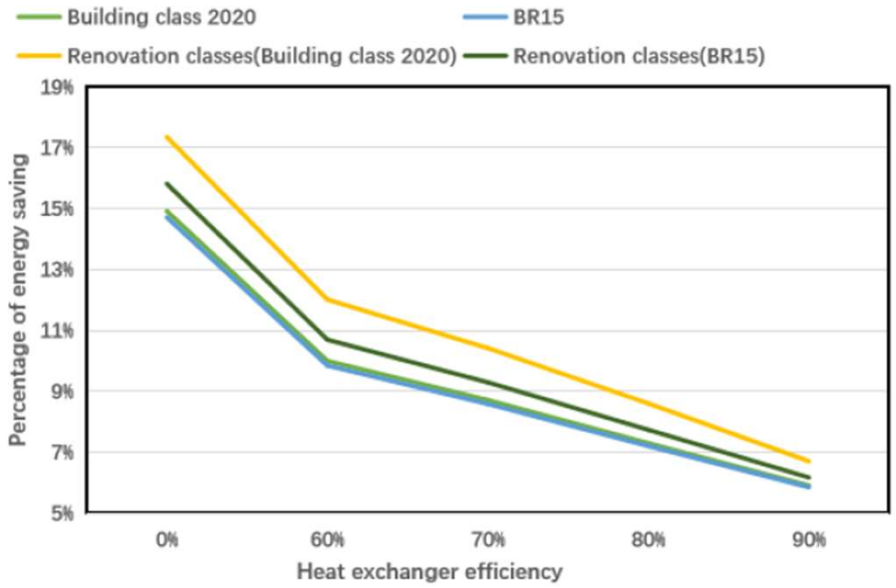


Results – Energy

- Including energy use of air cleaner
- Dependent on energy mix



Primary energy factors in Denmark

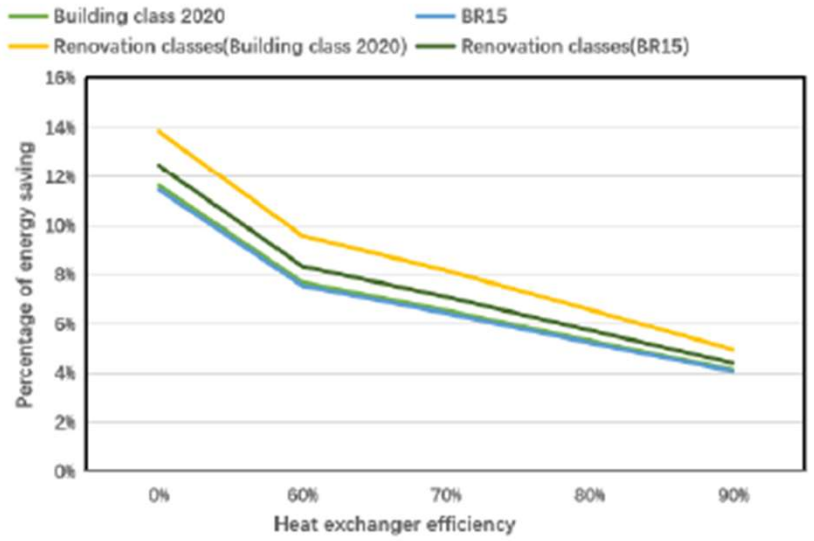
	Electricity	District heating
BR15	2.5	0.8
Renovation classes of BR15	2.5	1
Building Class 2020	1.8	0.6
Renovation classes of Building Class 2020	1.5	1

Energy saving potential, F3 Building materials and people

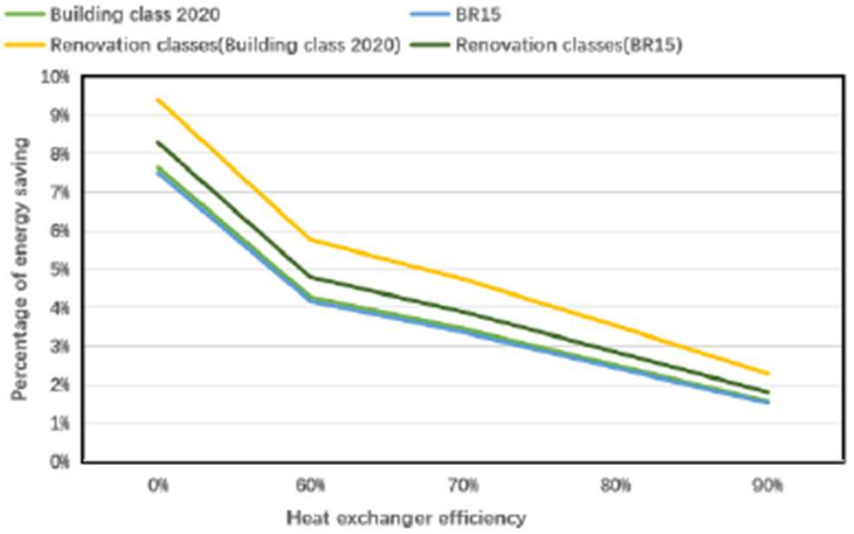
Results – Energy

- Including energy use of air cleaner
- Dependent on energy mix and airflow rate

IAQ Category IV to II



IAQ Category III to II



Energy saving potential, F1 Building materials

Summary, energy impact

- Simulations for different climates with air cleaner providing CADR resulting in up to 50% reduction in outdoor air supply rate (Cat. II, EN16798)
- Depending on the climate, simulated energy savings reached between 1.9% and 18.2%; the savings were achieved by reducing the energy use for heating, cooling, and transporting the ventilation air

Development of a new standard for testing gas-phase air quality performance

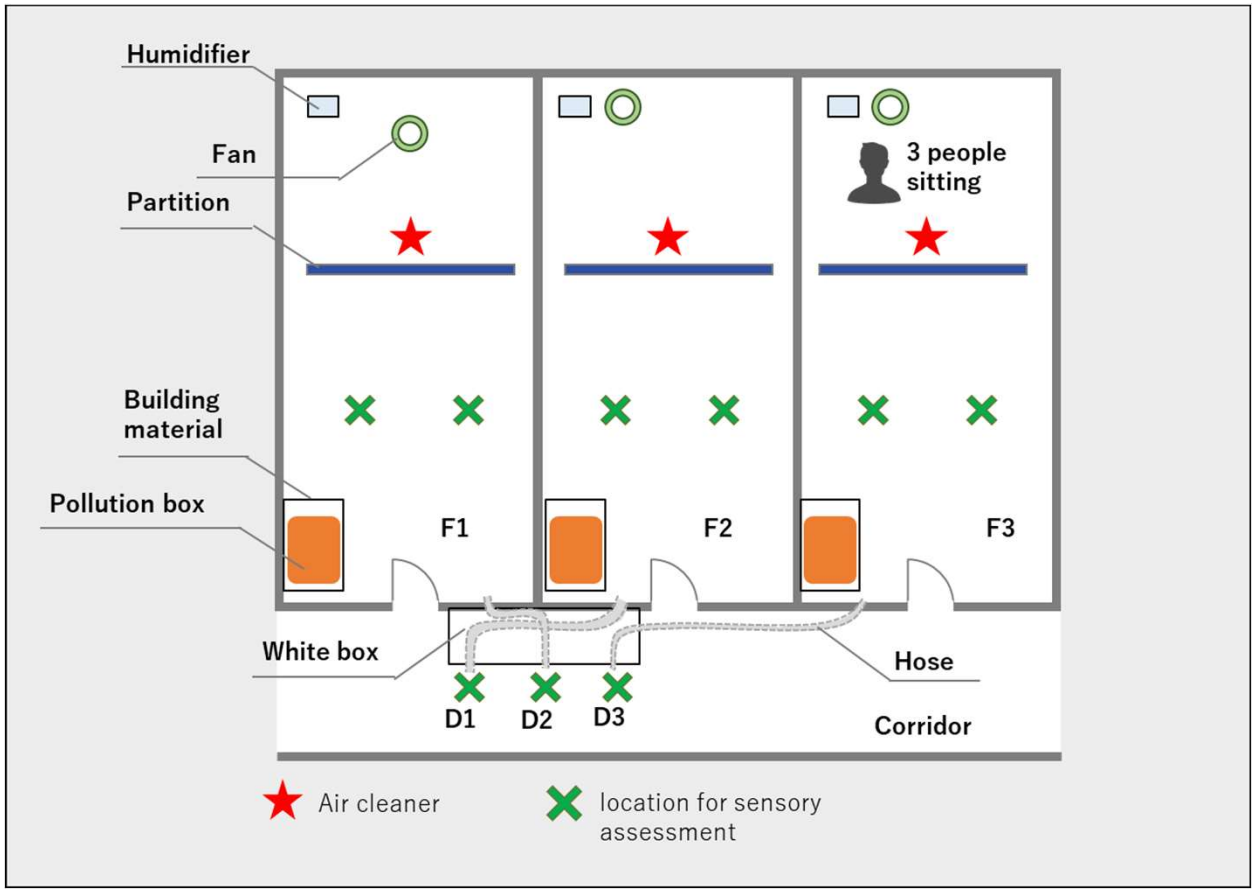
Proposal

- Two-stage-testing
- Stage 1: Pass/no pass with respect to the effect on indoor air quality
- Stage 2: Determine clean air delivery rate (CADR) and compare with equivalent ventilation requirements

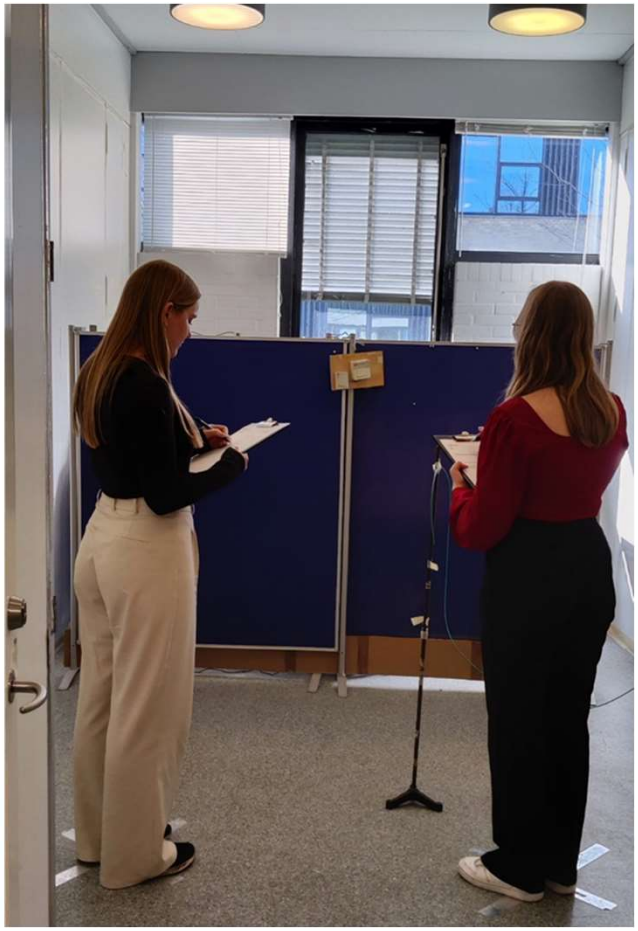
- Use sensory assessment of air quality by human panel (ultimately chemical measurements)

- No testing of long-term performance

Experimental validation, setup



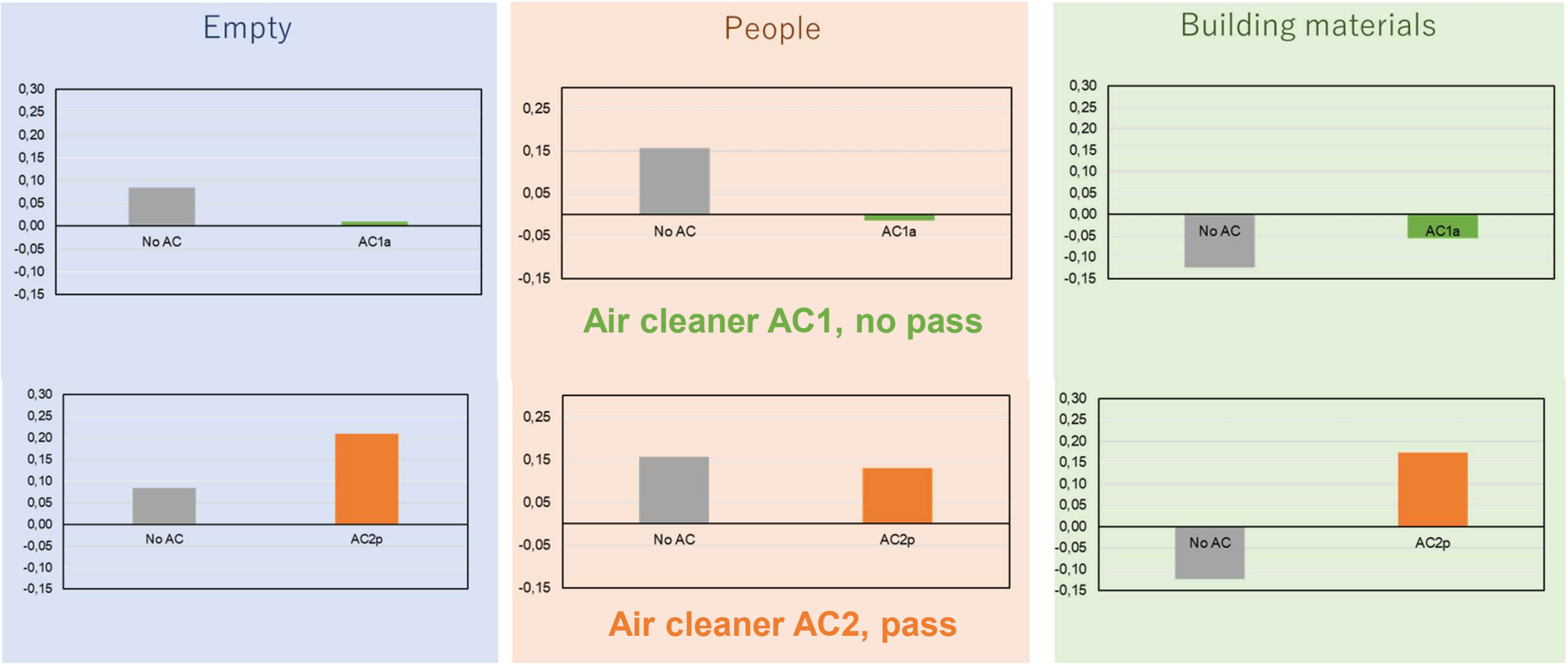
Sensory assessments



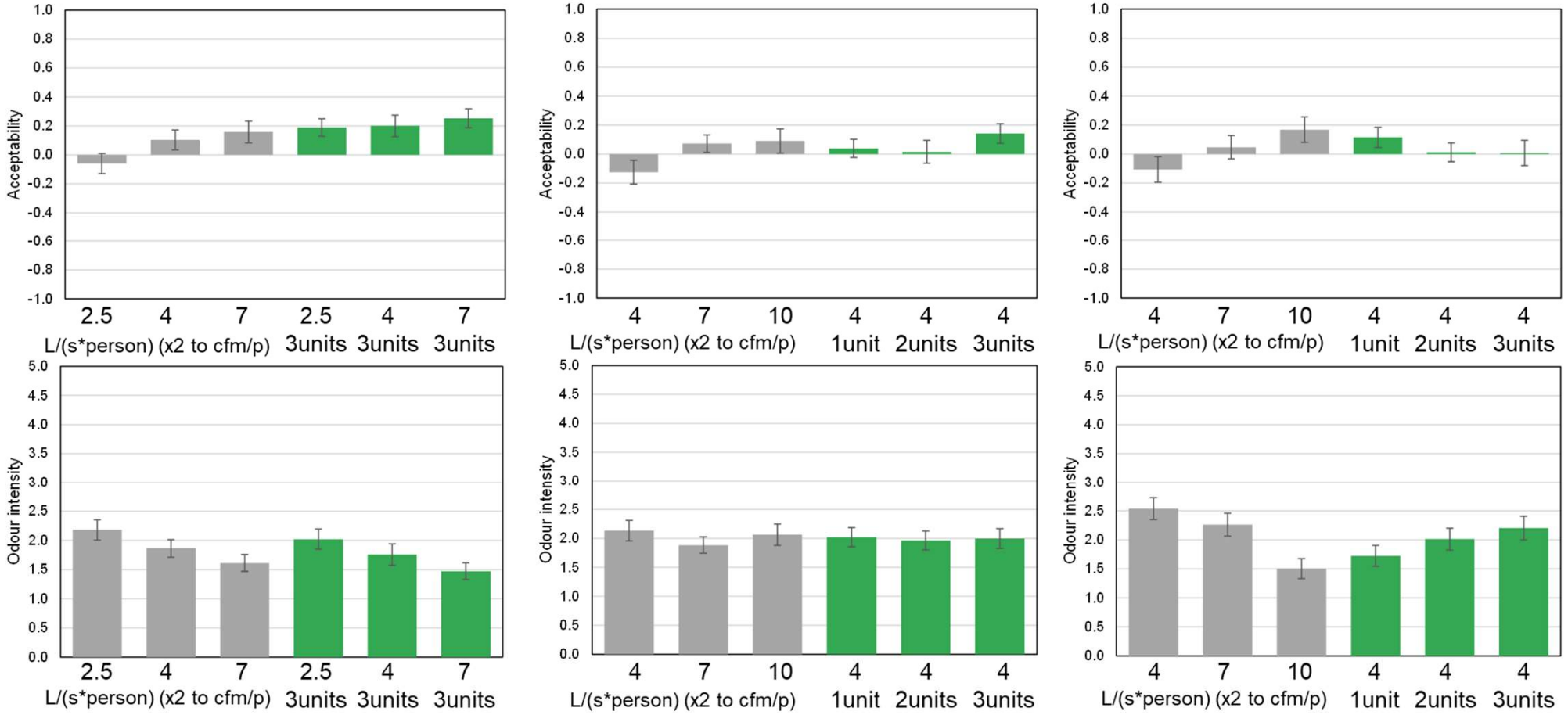
Overall protocol

- Portable air cleaners were tested; all operated at close to the maximum capacity
- Air cleaners were challenged with different types of pollutants representing people and building materials
- Conditions under test: ca. 23oC (73oF) and 50%RH
- Up to four levels of ventilation with outdoor air were tested
- Different number of air cleaners were placed in the rooms during testing
- Measurements of air quality were performed with air cleaners idled and in operation

Stage 1 results, passed/not passed



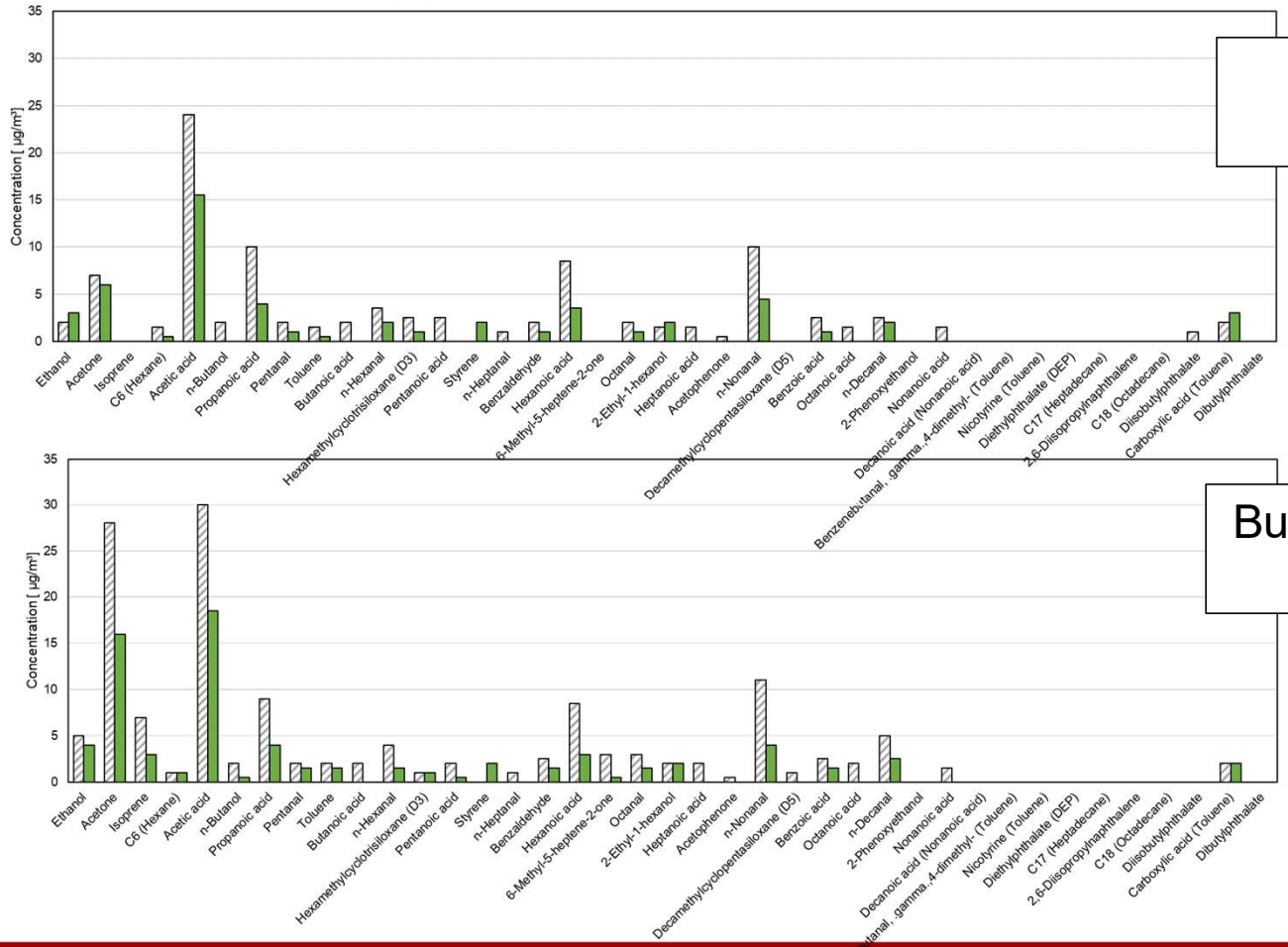
Stage 2 results



Chemical testing

w/o air cleaner
4 L/s per person

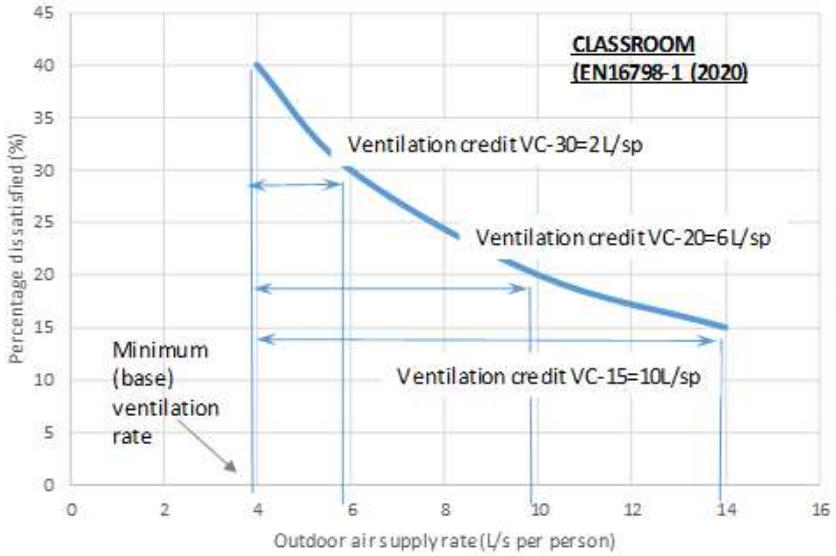
w/ air cleaner PAC1
(3 units)
4 L/s per person

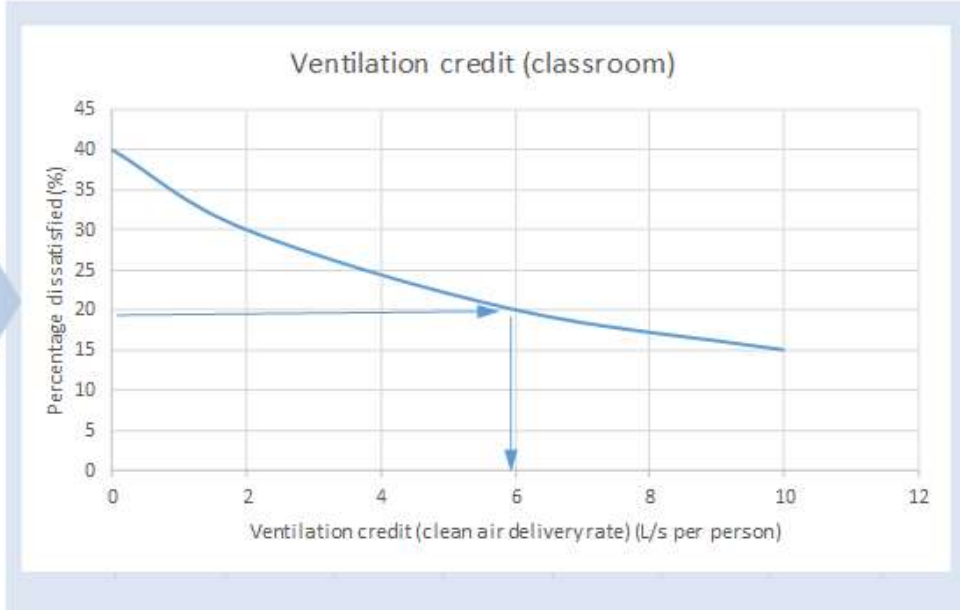


Building materials

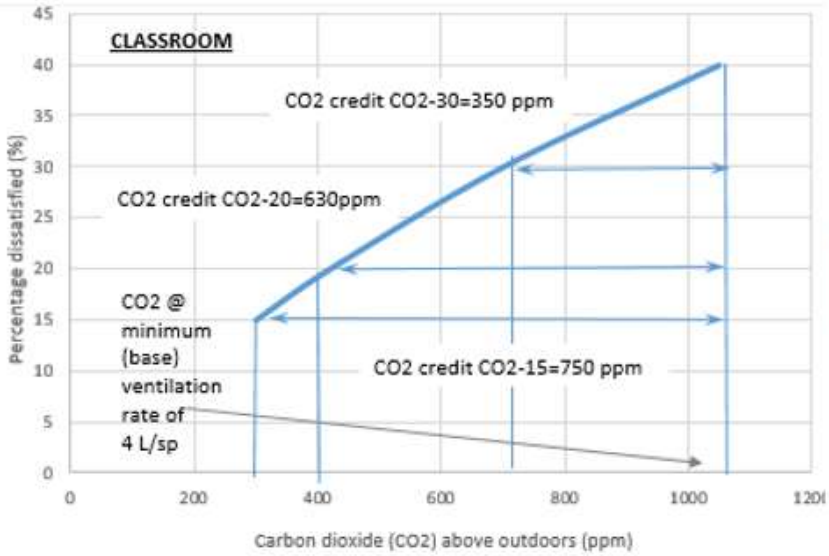
Building materials & people

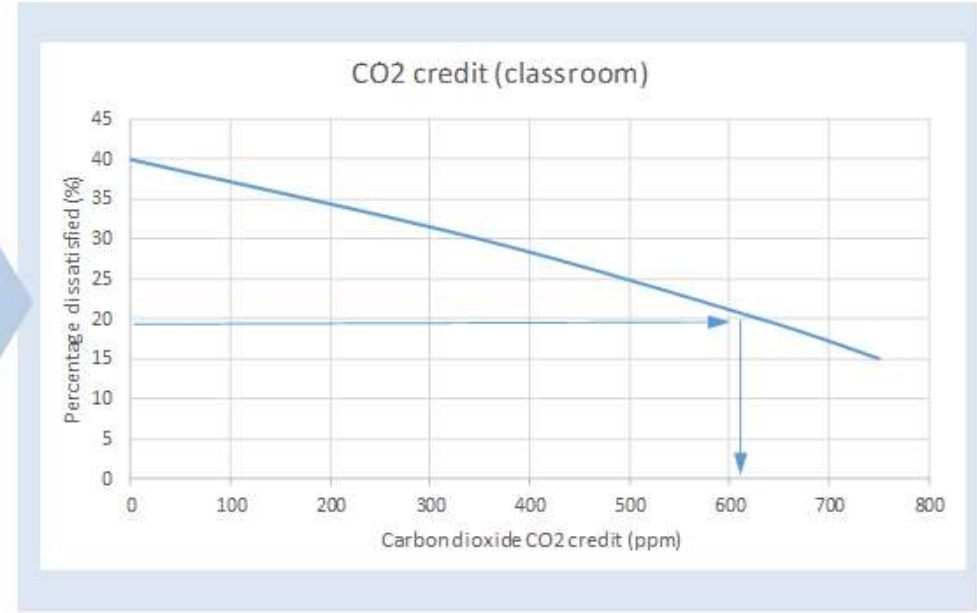
Ventilation credit or CADR?, new concept





CO_2 credit


CLASSROOM
CO2 credit CO2-30=350 ppm
CO2 credit CO2-20=630ppm
CO2 @ minimum (base) ventilation rate of 4 L/sp
CO2 credit CO2-15=750 ppm
Percentage dissatisfied (%)
Carbon dioxide (CO2) above outdoors (ppm)


CO2 credit (classroom)
Percentage dissatisfied (%)
Carbon dioxide CO2 credit (ppm)

Conclusions

- A concept for substituting part of the required ventilation with gas phase air cleaning technology has been presented
- There is a need for new testing standards that considers perceived air quality and human emissions as a source.
- It must be verified that the reduced ventilation rate is still high enough to dilute individual contaminants.
- Adjusted CO_2 criteria must be used to express the indoor air quality and to use for demand-controlled ventilation.

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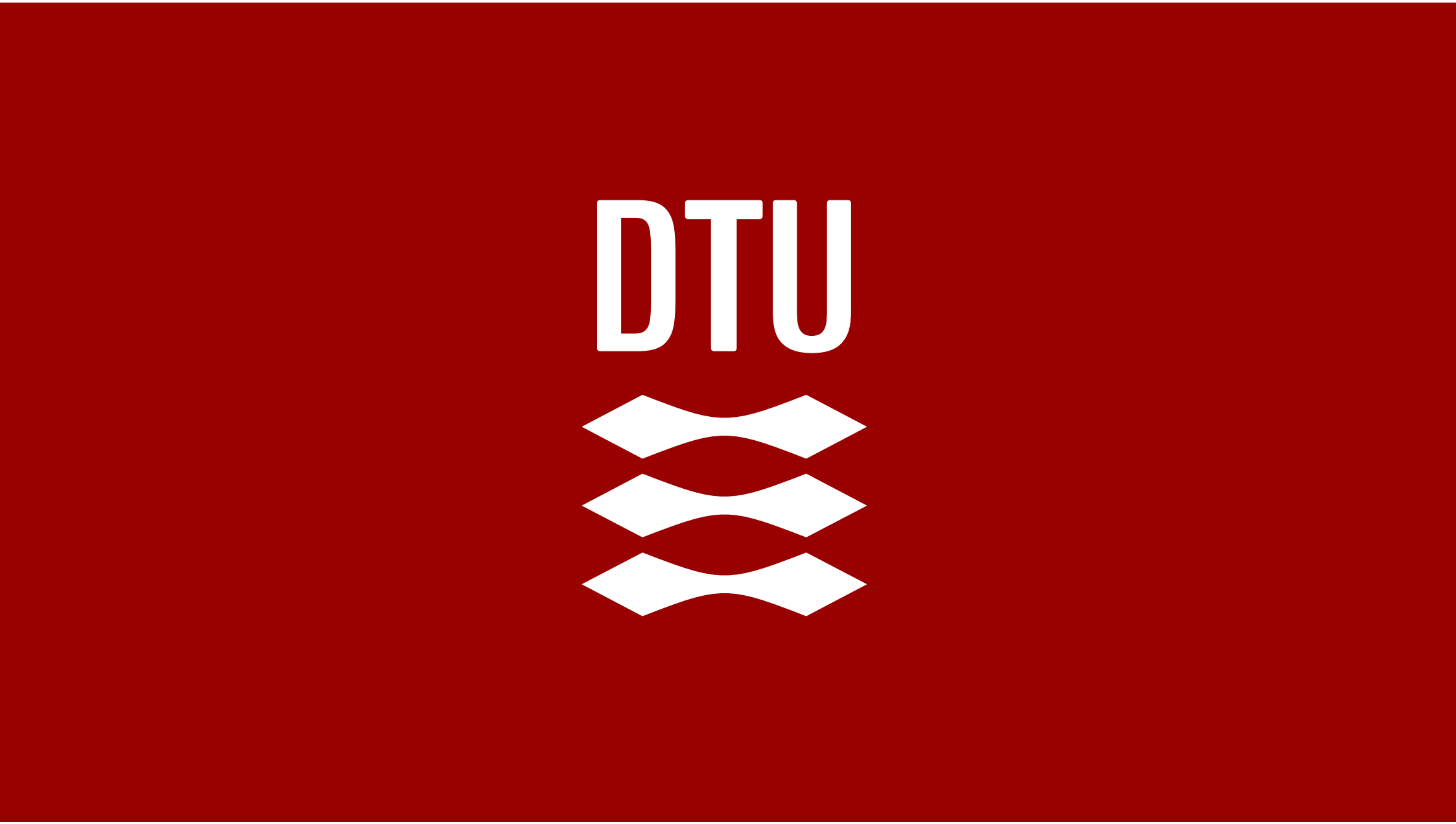
Thank You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