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Gas phase air cleaning effects on ventilation energy use and indicators for energy performance

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Concept for calculation of design ventilation rate
Method 1

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

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Total ventilation rate

$$q_{tot} = n \cdot q_p + A_R \cdot q_B$$

$$q_{supply} = q_{tot} / \varepsilon_v$$

- Where
- ε_v = the ventilation effectiveness (EN13779)
- q_{supply} = ventilation rate supplied by the ventilation system
- q_{tot}= total ventilation rate for the breathing zone, l/s
- n = design value for the number of the persons in the room,
- q_p = ventilation rate for occupancy per person, l/s, pers
- A_R= room floor area, m^2
- q_B = ventilation rate for emissions from building, l/s,m^2

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DTU

PAQ & CADR

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CONCEPT OF SUPPLEMENTING VENTILATION BY GAS PHASE AIR CLEANING.

- **Clean Air Delivery Rate (CADR)**
  - **CADR = $\varepsilon_{PAQ} \cdot Q_{AP} \cdot (3{,}6/V)$**
  - where:
  - **ε_{clean}** or **ε_{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**
  - **$\varepsilon_{clean} = 100(C_U - C_D)/C_D$**

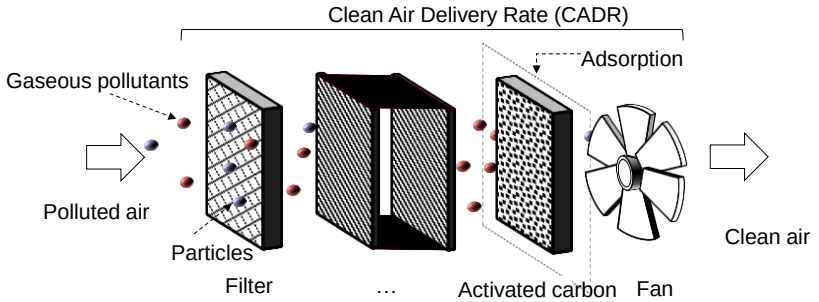
  where:
  - **ε_{clean}** is the air cleaning efficiency
  - C_U is the gas concentration before air cleaner
  - C_D is the gas concentration after air cleaner.
- **Higher Air Quality Category**

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

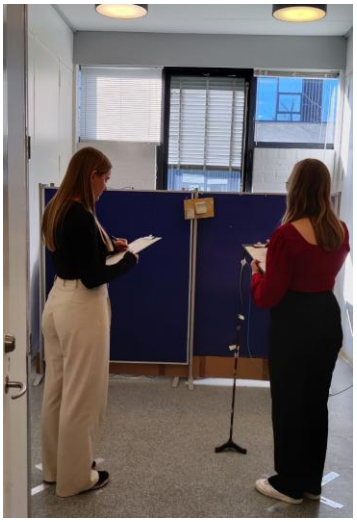
- where:
- ε_{PAQ} is the air cleaning efficiency for perceived air quality;
- Q_o is the ventilation rate without air cleaner, l/s;
- Q_{AP} is the ventilation rate with air cleaner, l/s;
- PAQ is the perceived air quality without the air cleaner, decipol;
- PAQ_{AP} is the perceived air quality without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

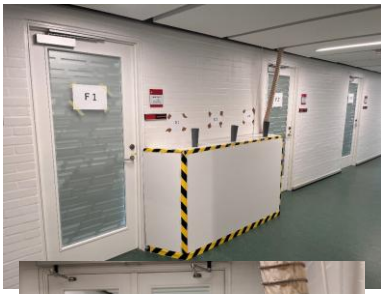
Gas-phase air cleaning

- Removes gaseous pollutants (e.g. benzene, toluene, xylene) & odour.
- Installed centrally or as stand-alone units.
- Consist of filters and a gaseous pollutant removal device.
- Characterized by a CADR



Sensory panel





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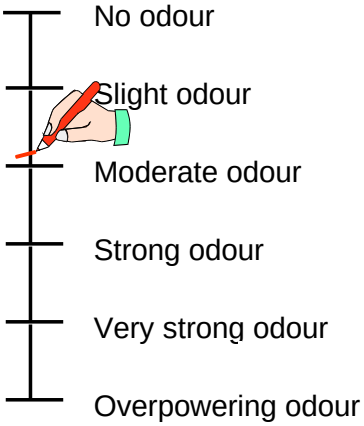
Primary measurements



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PAQ & CADR - Methods

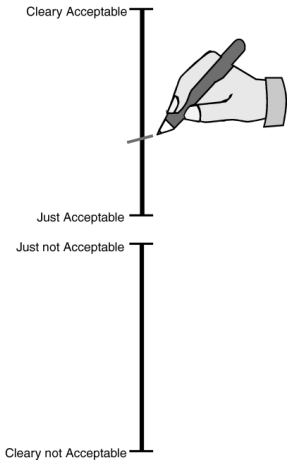
- Perceived air quality (PAQ)

$$PD = \frac{\exp(-0.18-5.28\cdot\overline{ACC})}{1+\exp(-0.18-5.28\cdot\overline{ACC})}\cdot 100\ [\%]$$

- CADR

$$CADR = \frac{q-q_{GPAC}}{q}\cdot 100\ [\%]$$

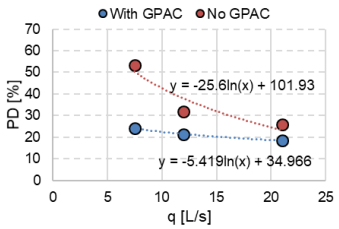
where q and q_{GPAC} are for the same PD with or without GPAC



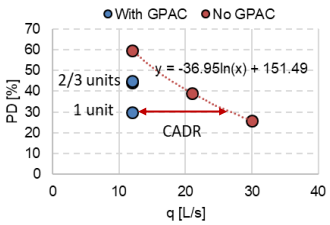
Wargocki, Pawel; 2004. "Sensory Pollution Sources in Buildings." 14(Suppl 7):82–91. doi: https://doi.org/10.1111/j.1600-0668.2004.00277.x

PAQ & CADR - Results

- With GPAC, dissatisfaction rate **reduced** for the same outdoor air flow rate
- With GPAC, outdoor air flow rate can be **reduced** for the same PD
- Increasing n_{GPAC} did not improve PAQ
- CADR:
  a) 50% (12 L/s)
  b) 30% (9 L/s)



a) building emissions only



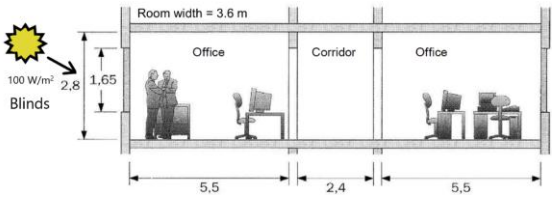
b) bio-effluents and building emissions

Energy use

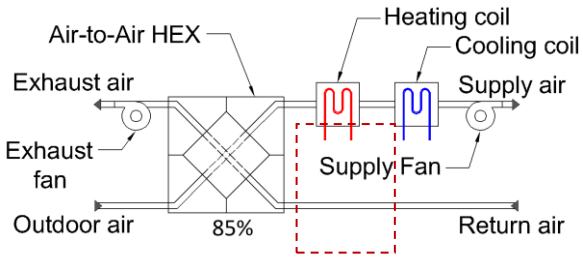
Methods - Energy

Simulation

- Copenhagen, DK
- $T_{OP,SP}$ 20 to 26 °C
- Ventilation: CAV
- Scenarios
  - with and without HEX
  - 2x pollution levels VLP and LP



Source: Olesen and Dossi, 2004



Bogatu et al. "Gas-Phase Air Cleaning Effects on Ventilation Energy Use and the Implications of CO2 Concentration as an IAQ Indicator for Ventilation Control.", Proceedings of Building Simulation 2021, 2021.

Clean Air Efficiency (CAE)

Methods - CAE

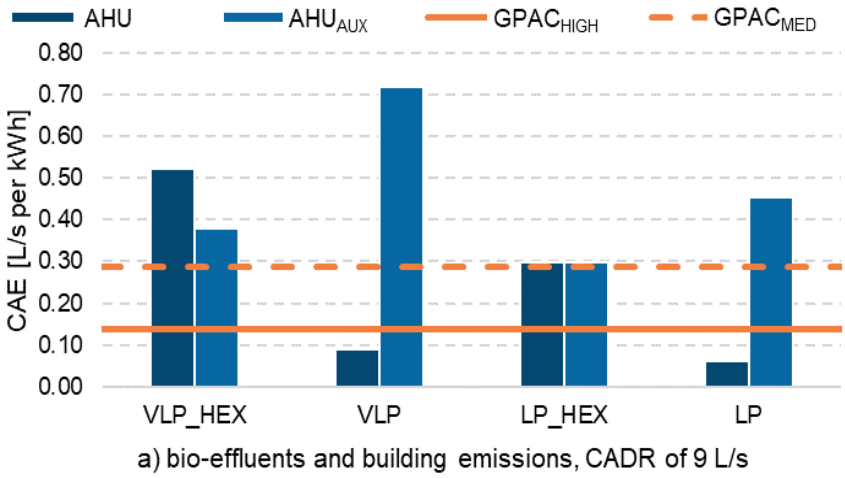
Indicator for comparing the efficiency of the AHU and stand-alone air cleaner

$$CAE = \frac{\text{CADR}}{Energy\ use} \quad [\text{L/s per kWh}]$$

Amount of air, **CADR in L/s**, and energy use for **heating, cooling, and AUX** or **GPAC**

Results - CAE

- If the GPAC is compared only to AHU_{AUX}, the GPAC is never efficient
- If a HEX is included the GPAC is not efficient
- Higher savings can be achieved if GPAC can be operated at a setting lower than HIGH (22 W)



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Conclusions

- CAE can be used to compare different solutions for providing clean air into the space.
- In Copenhagen, DK (high heating load), GPAC was competitive only if the AHU was not equipped with a HEX.
- GPAC more efficient when it removed both bio-effluents and building emissions.
- GPAC can be used to either improve IAQ or reduce air flow rate