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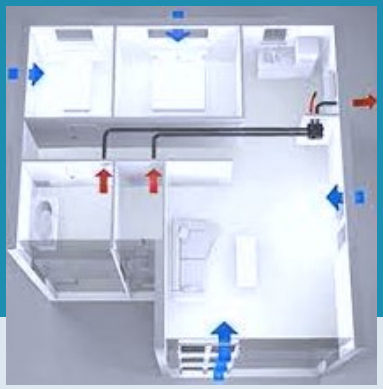
TOWARDS SMART VENTILATION

FLANDERS INNOVATION & ENTREPRENEURSHIP

flux50

Indoor air Quality (IAQ) resilience performance of Smart ventilation: Quantitative assessment framework



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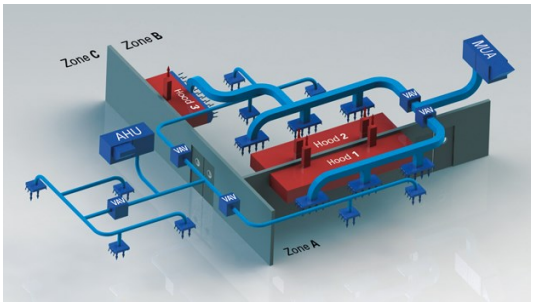
What is resilience performance?

Expected indoor/outdoor conditions

Good breathable air quality
Energy efficient



Unexpected disturbance Or "shock"

Reduced system performance: Indoor space shifts drastically from its **IAQ design conditions**

System needs to be <u>resilient</u>

(-) Accumulation of contaminants

(-) Acute exposure during short duration

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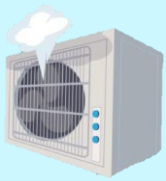
Disruptive Events

Mechanical disruptions



Partial or complete disruption in the operation of the ventilation system (e.g., fan failure, power outages, fouling filters)

Internal disruptions

Occurs inside the space due to excessive indoor pollution event (e.g.,excess occupants beyond capacity of AHU)

External disruptions

Occurs outside the building envelope due to excessive outdoor pollution (e.g., outdoor fire, traffic jams)

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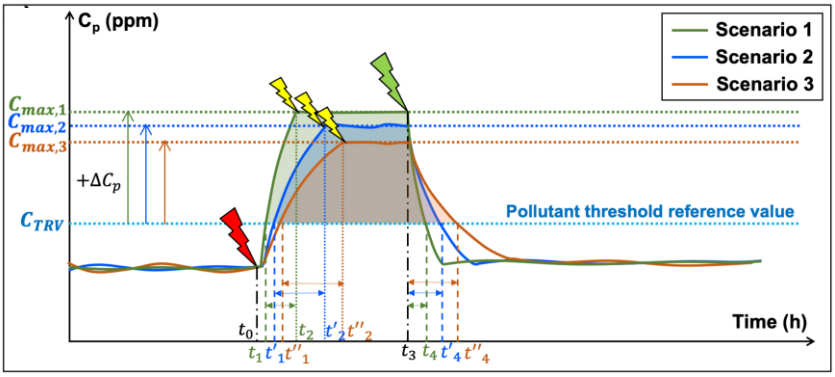
Resilience performance aspects



- Absorptivity
- Recovery
- Degree of impact

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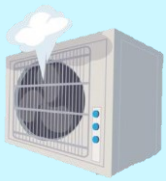
Quantification of disruptive events: the degree of shock

Mechanical disruptions



$$doMS = \underbrace{\frac{\dot{Q}_{a,r} - \dot{Q}_a}{\dot{Q}_{a,r}}}_{Severity} \times \underbrace{\frac{t_s}{t_{occ}}}_{Duration}$$

degree of mechanical shock (**doMS**)

Internal disruptions

$$doIS_s = \underbrace{\frac{ER_s - ER_{s,exp}}{ER_{s,exp}}}_{Severity} \times \underbrace{\frac{t_s}{t_{occ}}}_{Duration}$$

degree of internal shock (**doIS**)

External disruptions

$$doOS_s = \underbrace{\frac{C_{s,oa} - C_{s,oa\,exp}}{C_{s,oa\,exp}}}_{Severity} \times \underbrace{\frac{t_s}{t_{occ}}}_{Duration}$$

degree of outdoor shock (**doOS**)

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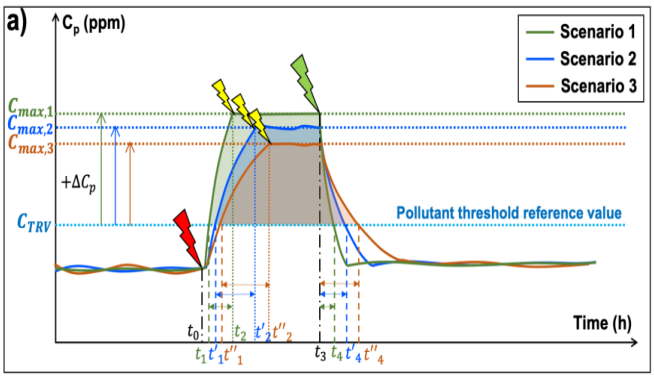
Quantification of resilience aspects

Absorptivity $\varepsilon_{abs} = \frac{\Delta t_{abs}}{t_{occ}}$

Slower absorptivity time is desired

Recovery $\varepsilon_{rec} = 1 - \frac{\Delta t_{rec}}{t_{occ}}$

Faster recovery time is desired



Resilience effectiveness

$$\varepsilon_{res} = \frac{ppm.hours_{ref} - ppm.hours_{system\ under\ shock}}{ppm.hours_{ref} - ppm.hours_{system\ normal\ operation}}$$

Higher effectiveness desired

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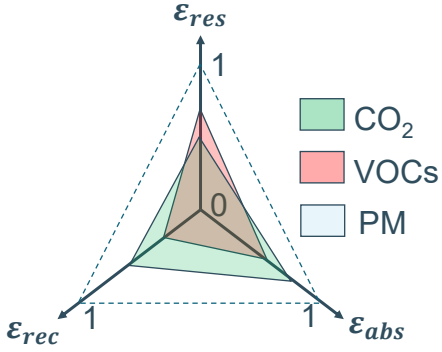
The total resilience score



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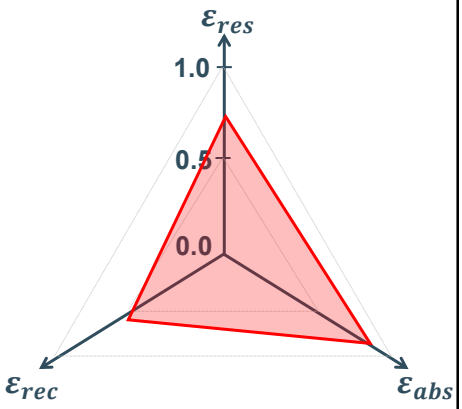

$$RS_{zone} = \frac{5}{13}(RS_{CO_2} + \sum \omega_i RS_i)$$ i = 1 to N (number of Hazardous air pollutants) **0 < RS < 1**

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The total resilience score: Determining the weighting factors

Qualitative approach

Carcinogenic
Mutagenic
Reprotoxic effects
Endocrine disruptions

1 (High evidence) to 5 (No evidence)

VOCs (Formaldehydes, acrolein, aldehydes usually found in classrooms) rank as CMRE2/ PM fine and coarse rank as CMRE1

Quantitative approach: HQ: Hazard Quotient

$$HQ = \frac{Mean\ exposure\ concentration}{TRV\ (threshold\ values)}$$

$\mathrm{HQ}_{\mathrm{mean}}$ or $\mathrm{HQ}_{P95} > 1$

8 Sérafin, Guillaume, Patrice Blondeau, and Corinne Mandin. "Indoor air pollutant health prioritization in office buildings." *Indoor Air* 31.3 (2021): 646-659.

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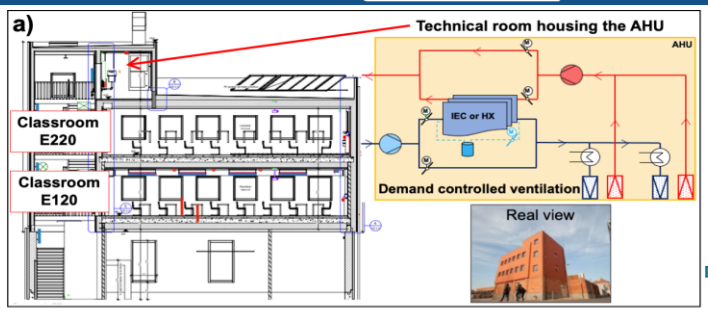
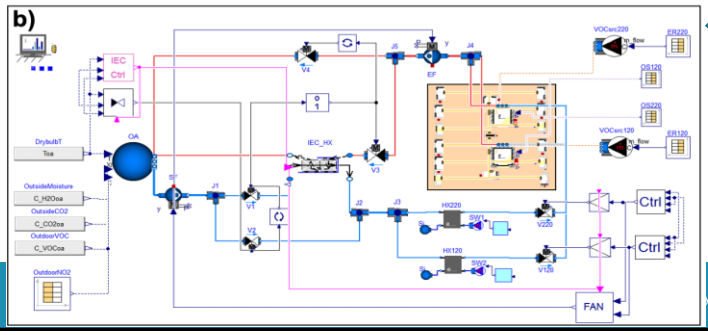
Case study



Model in Modelica, Dymola



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Scenarios

Demand controlled balanced mechanical ventilation (DCV)
Constant air volume system (CAV)
DCV without filters

Mechanical shock (doMS: 0 to 1)
Internal shock (doIS: 0 to 1)
Outdoor shock (doOS: 0 to 1)

Contaminants: CO_2, VOCs, $PM_{2.5}$, PM_{10}

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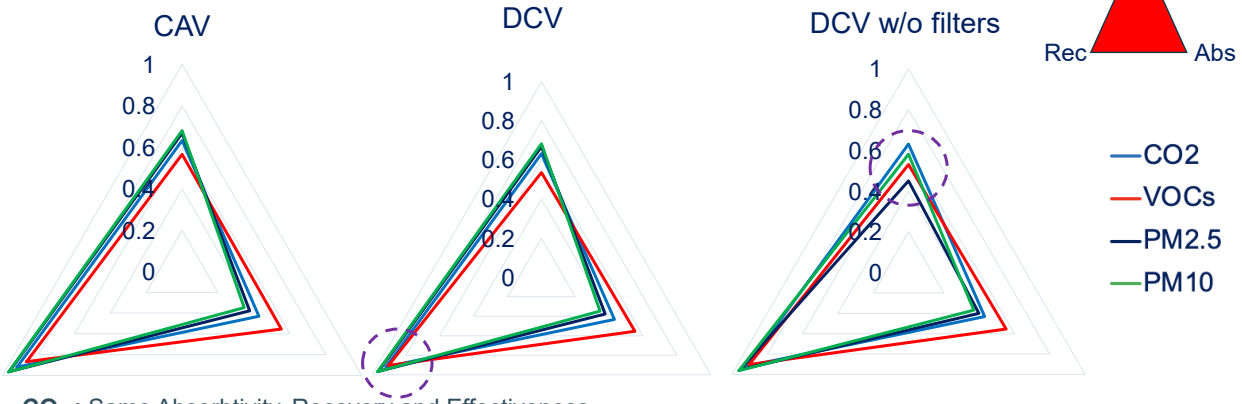

CO_2 : Same Absorbtivity, Recovery and Effectiveness

VOCs: Same Absorptivity but DCV has better recovery and CAV has better effectiveness

PM: Same Absorbtivity, Recovery and Effectiveness. DCV w/o filters has significantly lower effectiveness

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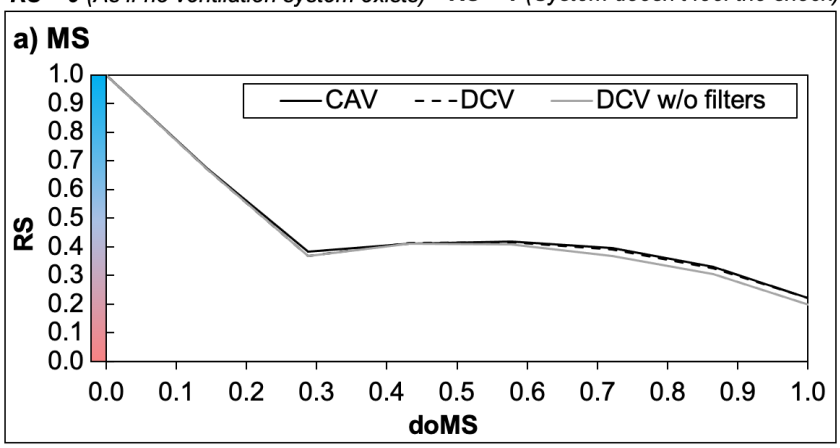
Resilience score (RS): Mechanical shock (MS)

RS = 0 *(As if no ventilation system exists)* ***RS = 1*** *(System doesn't feel the shock)*



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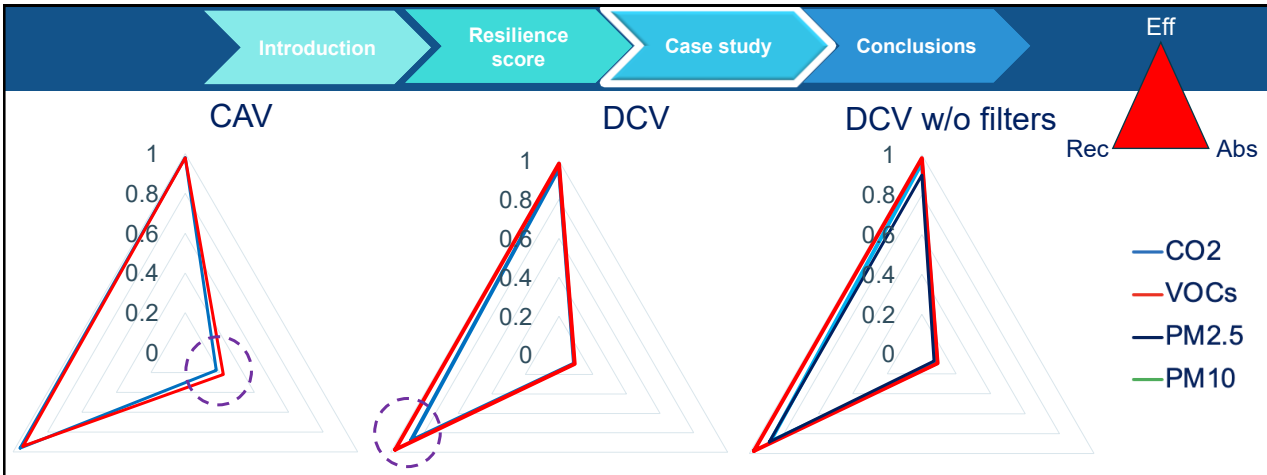

CO_2 : Same Effectiveness, but CAV has slower gradual absorbtivity and faster recovery

VOCs: Same Effectiveness (very high in both), CAV has significantly slower absorptivity, DCV has slightly faster recovery

PM: Only challenged at high shock intensities and for the case of DCV w/o filters

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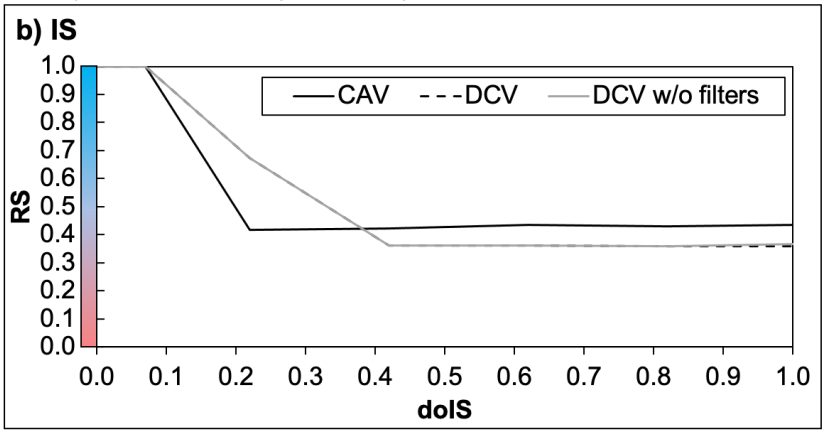
Resilience score (RS): Indoor shock (IS)

***RS = 0** (As if no ventilation system exists)* ***RS = 1** (System doesn't feel the shock)*



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Conclusions

- **Resilience score** for **IAQ resilience** assessment was developed
- **Smart** vs **Conventional** ventilation **IAQ resilience** during **disruptive events**:
  - Mechanical shocks: Smart **=** Conventional
  - Internal shocks: Smart **<** Conventional
  - Outdoor shocks: Smart **>** Conventional
- **Filters**: No pronounced effect in the case of Mechanical and Internal shocks but more so in Outdoor shocks
- Framework should be tested for more case studies (residential, offices) and more systems (mechanical extract, natural ventilation, personalized systems, other smart control strategies, etc.)

Thank you for listening

Next speaker:

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