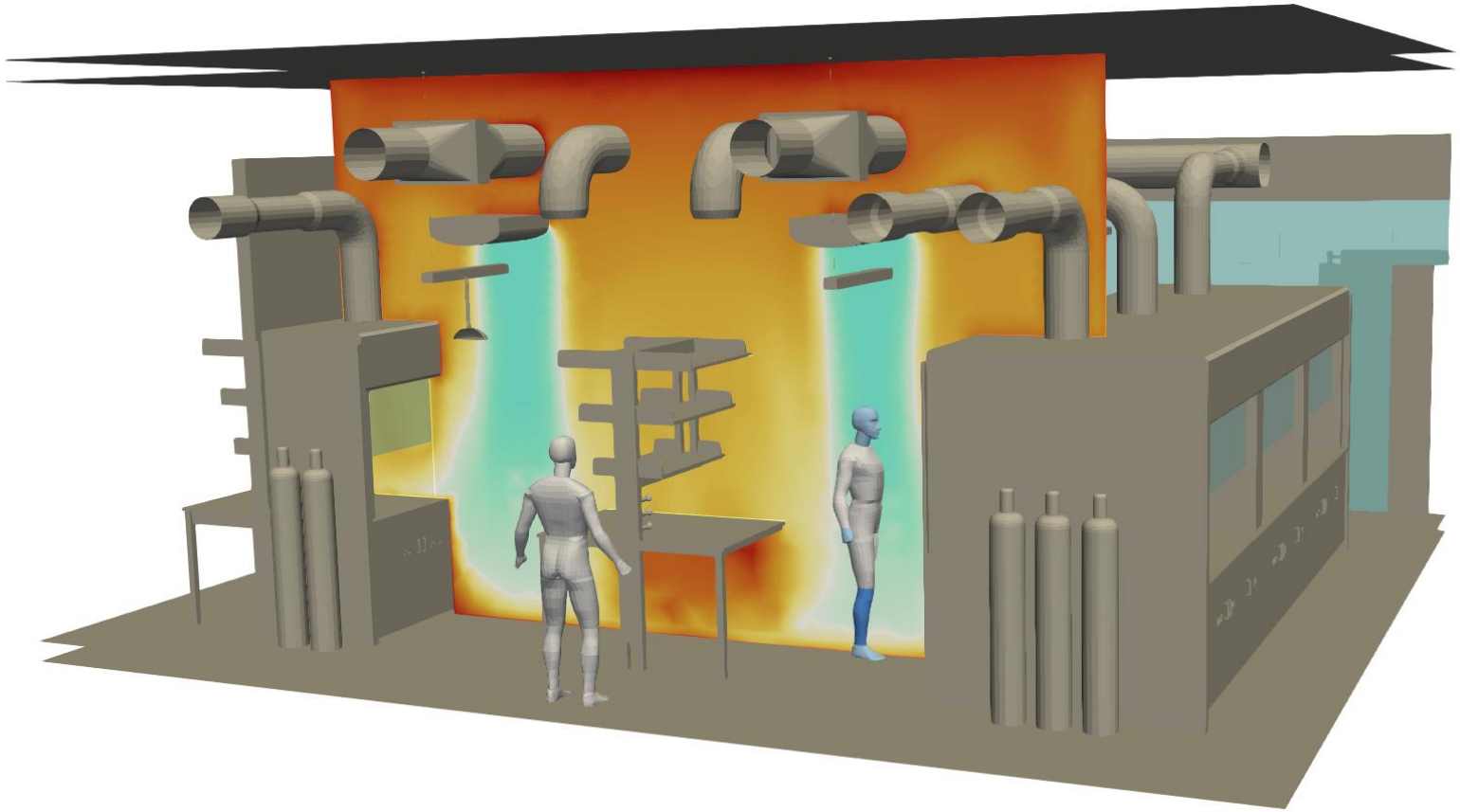
ARUP

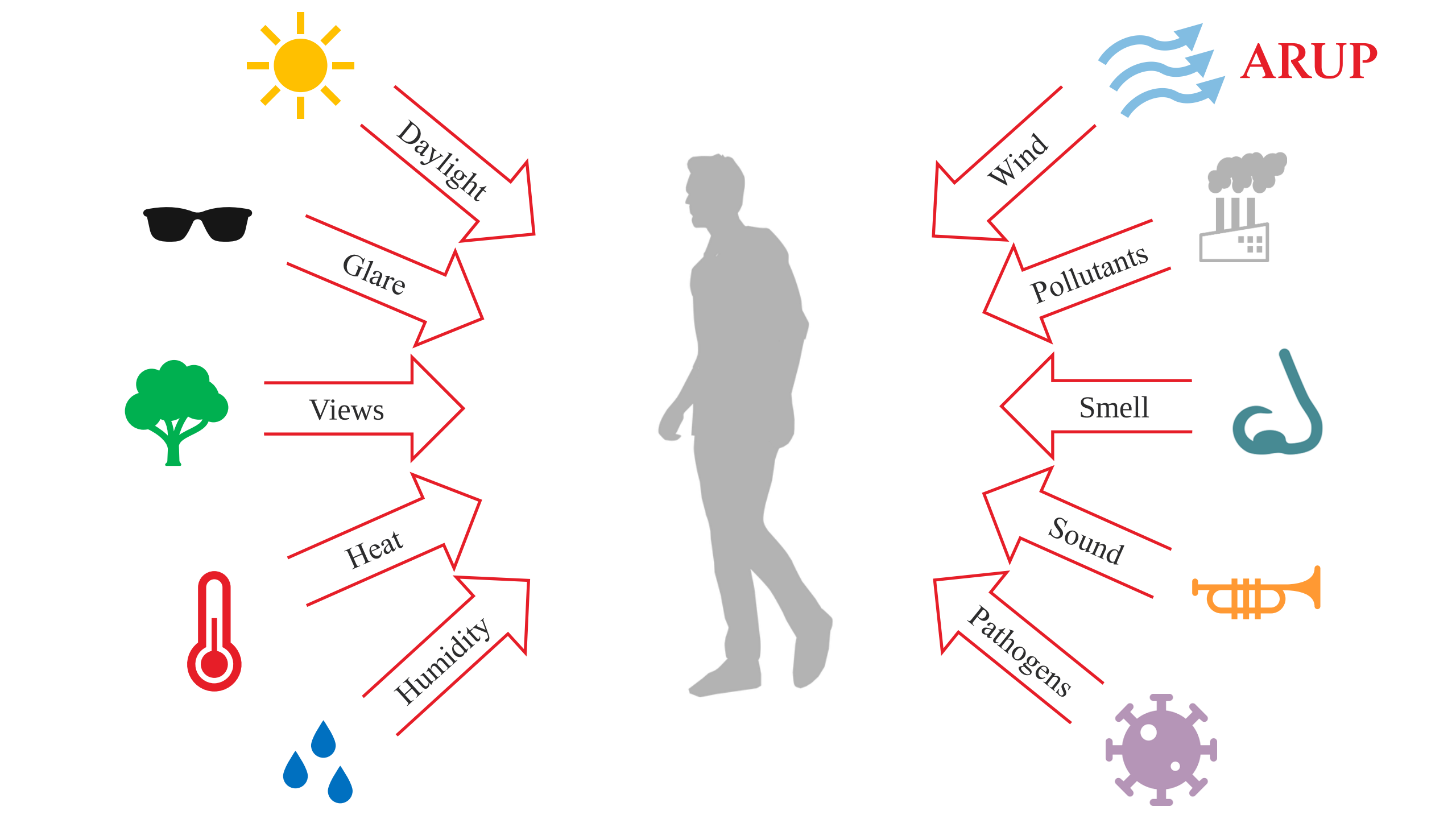
Lab Hazard Mitigation with User-Centric CFD Analysis

Nathaniel Jones, PhD



I²SL Annual Conference and Technology Fair

18 October 2022


ARUP
Daylight
Glare
Views
Heat
Humidity
Wind
Pollutants
Smell
Sound
Pathogens

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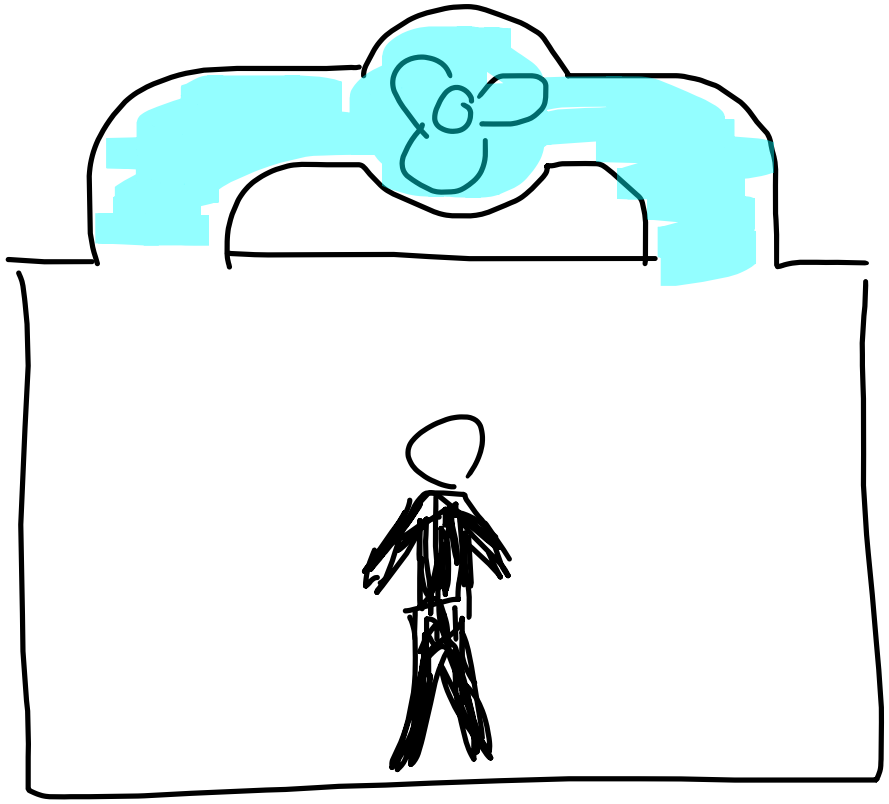
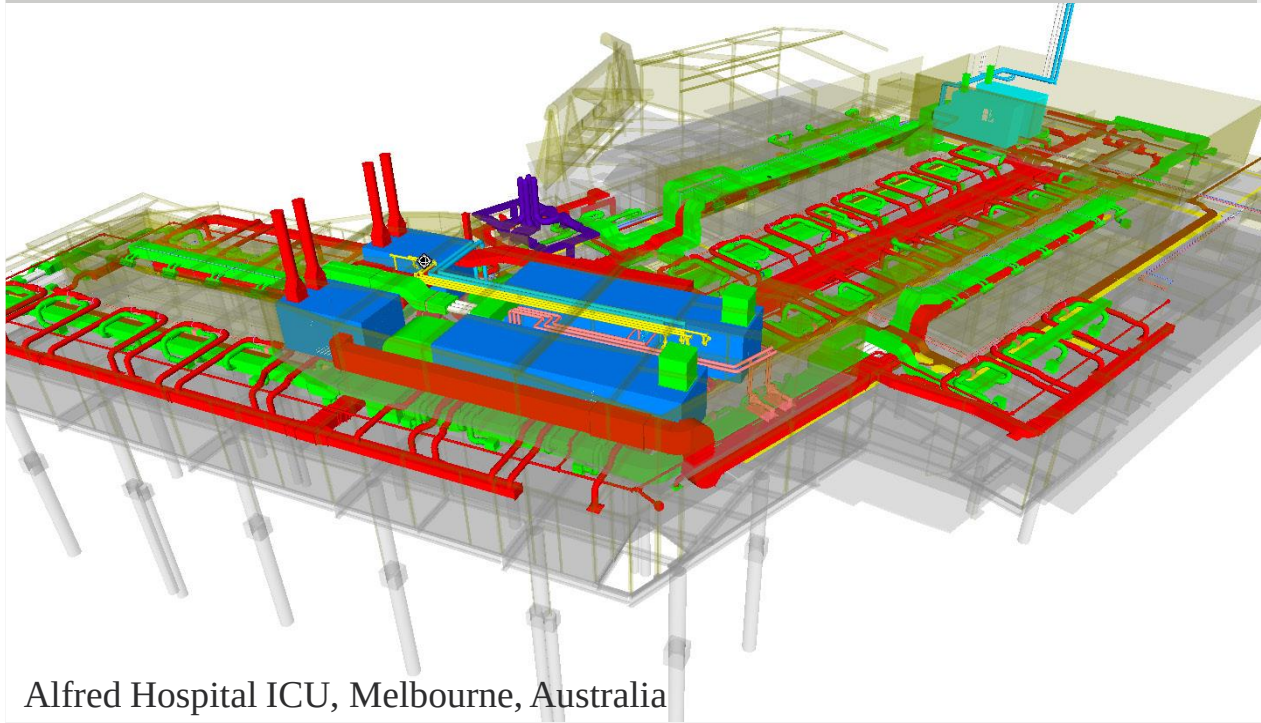
What does it mean to design good ***indoor air quality*** *for a lab?*

A better HVAC system?

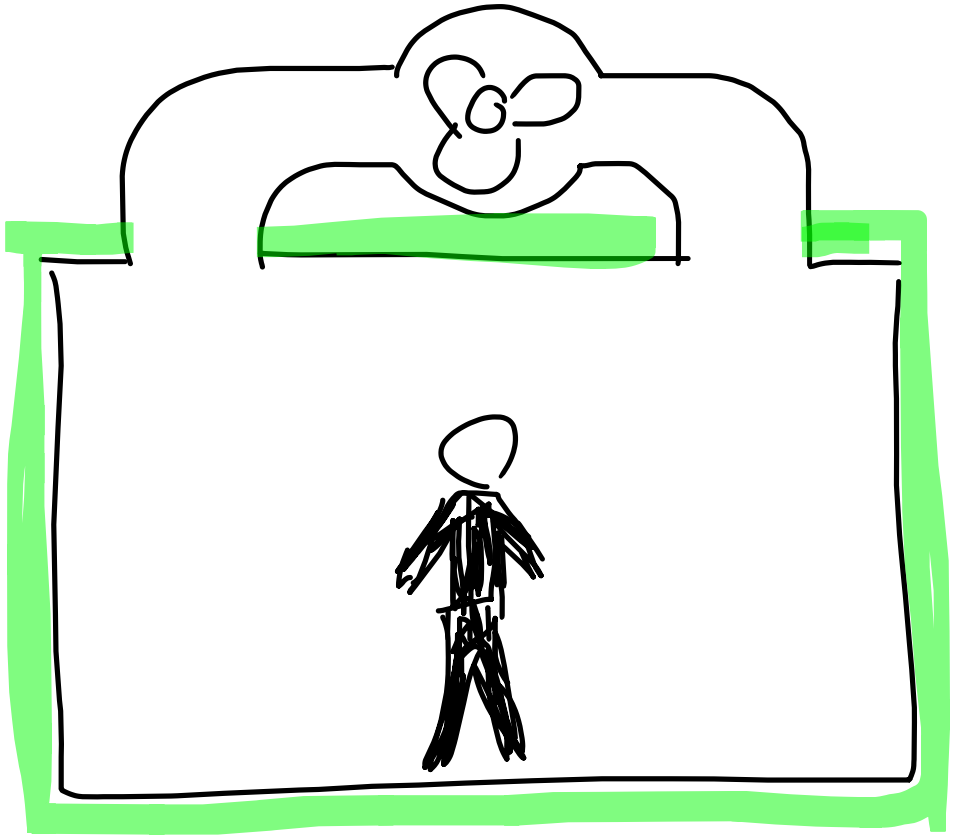


Altius Research Laboratory, Seattle, Washington



Alfred Hospital ICU, Melbourne, Australia

Low emission materials?

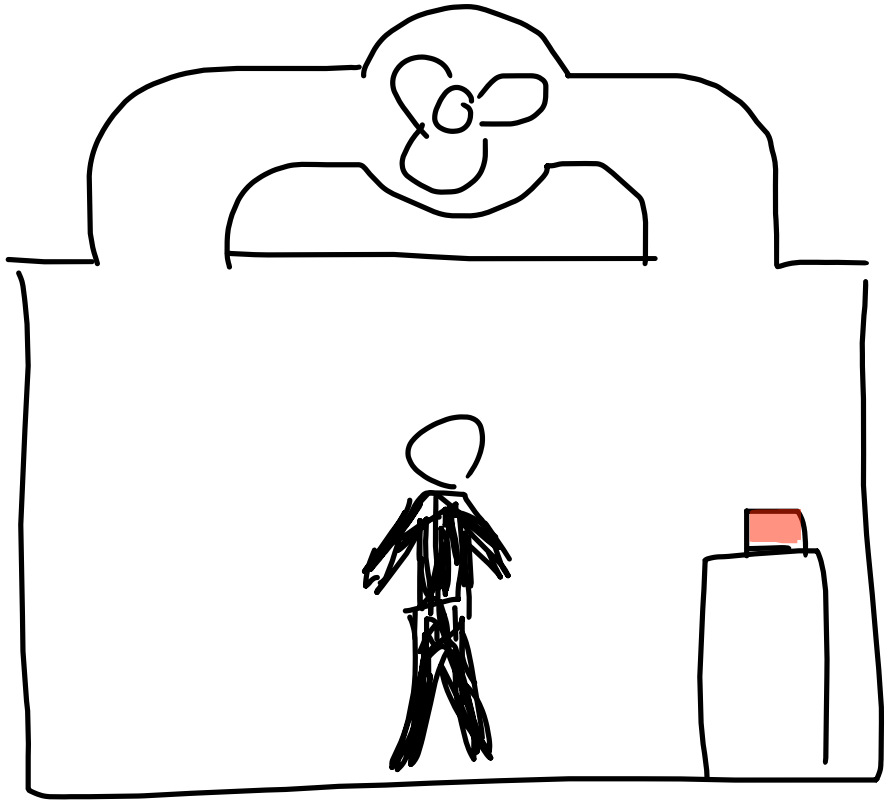


Healthy Materials Strategy, Denmark

Brain and Cognitive Science Center, Cambridge, Massachusetts

© Nick S McCafferty/Arup

Monitoring?



Neuron Health

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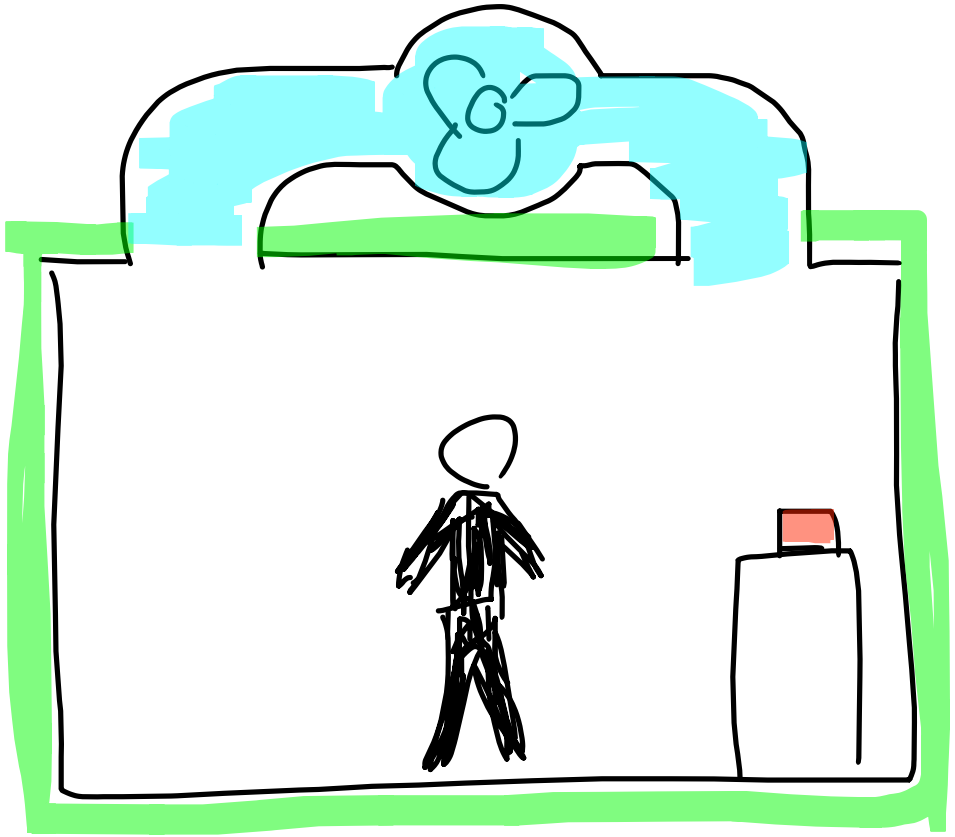
Designing indoor air quality for labs



- [x] Filtering HVAC system
- [x] Healthy materials
- [x] Monitoring
- [ ] Space use

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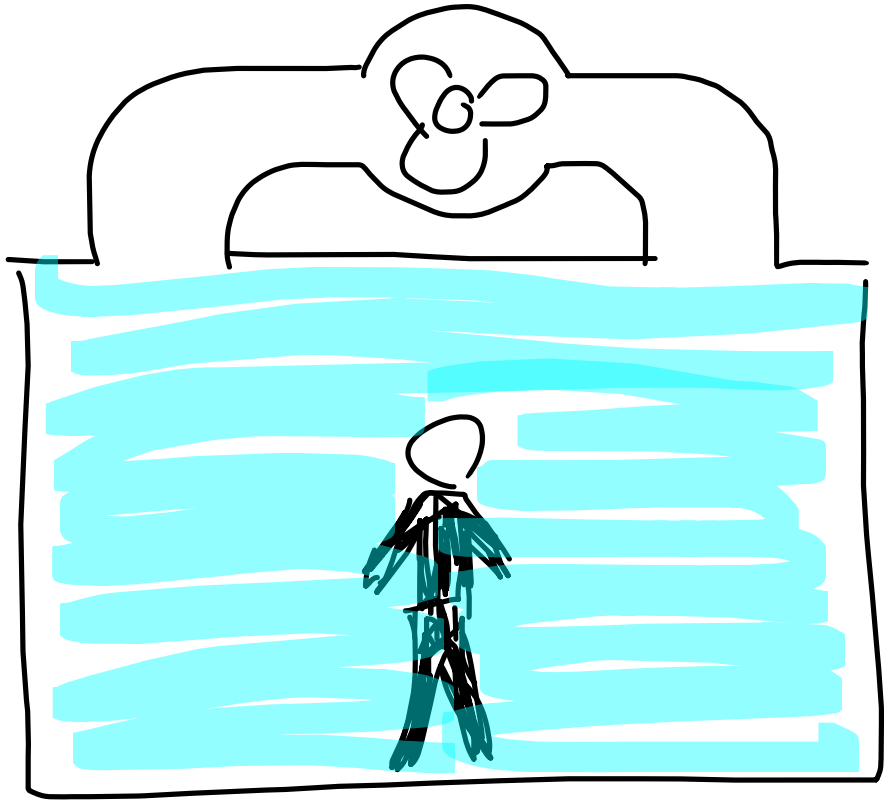
Space use



Case study

Lab benches that create cleaner air

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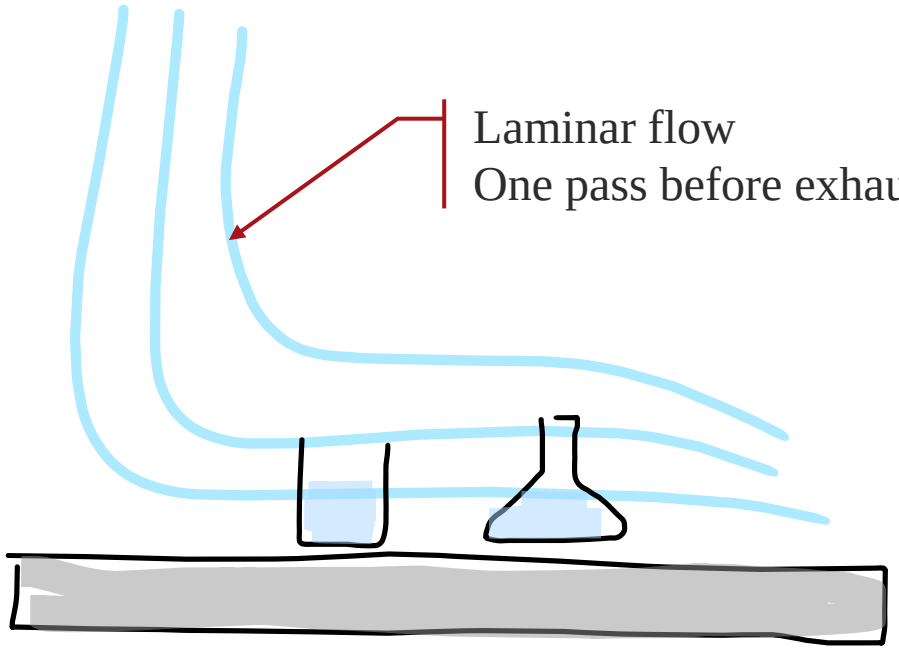
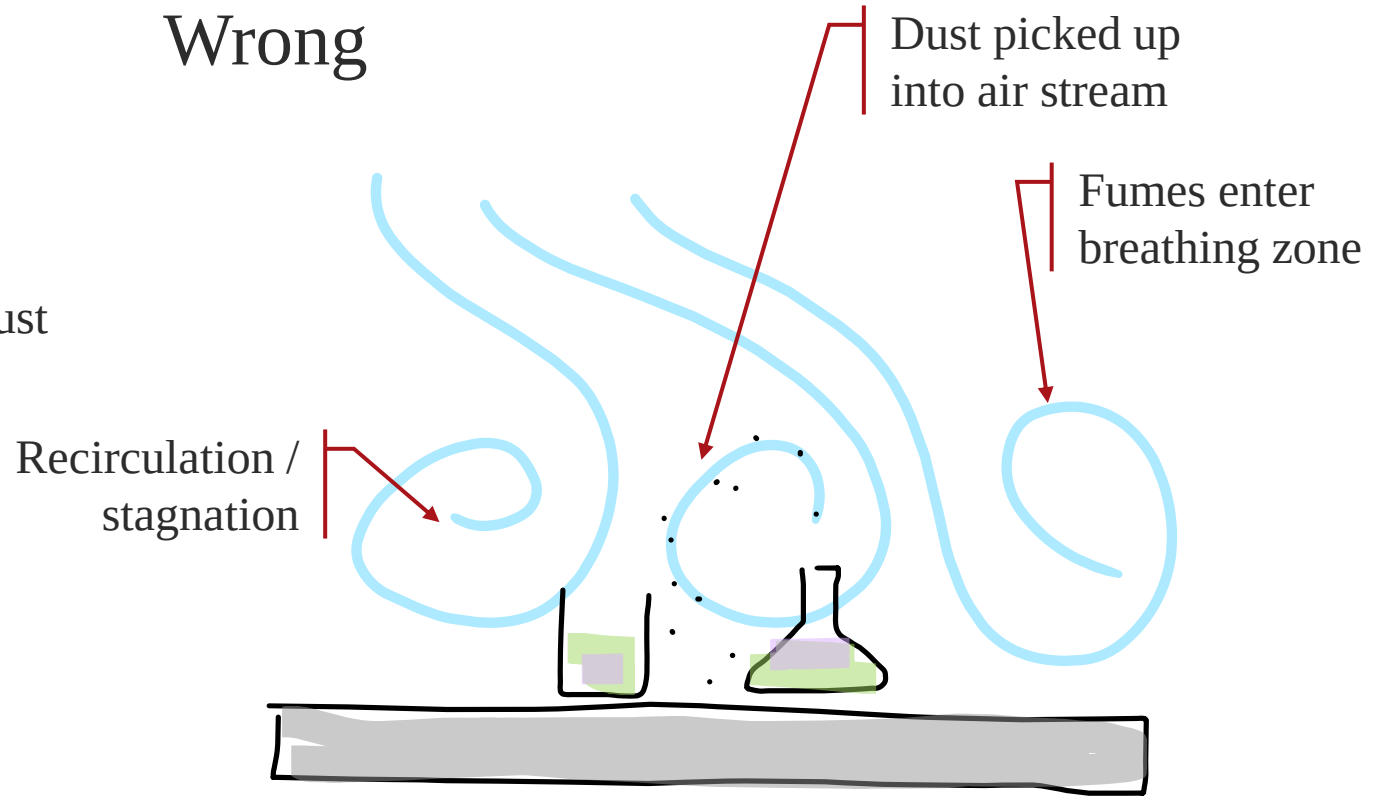
Air circulation for a lab bench

Right



Wrong



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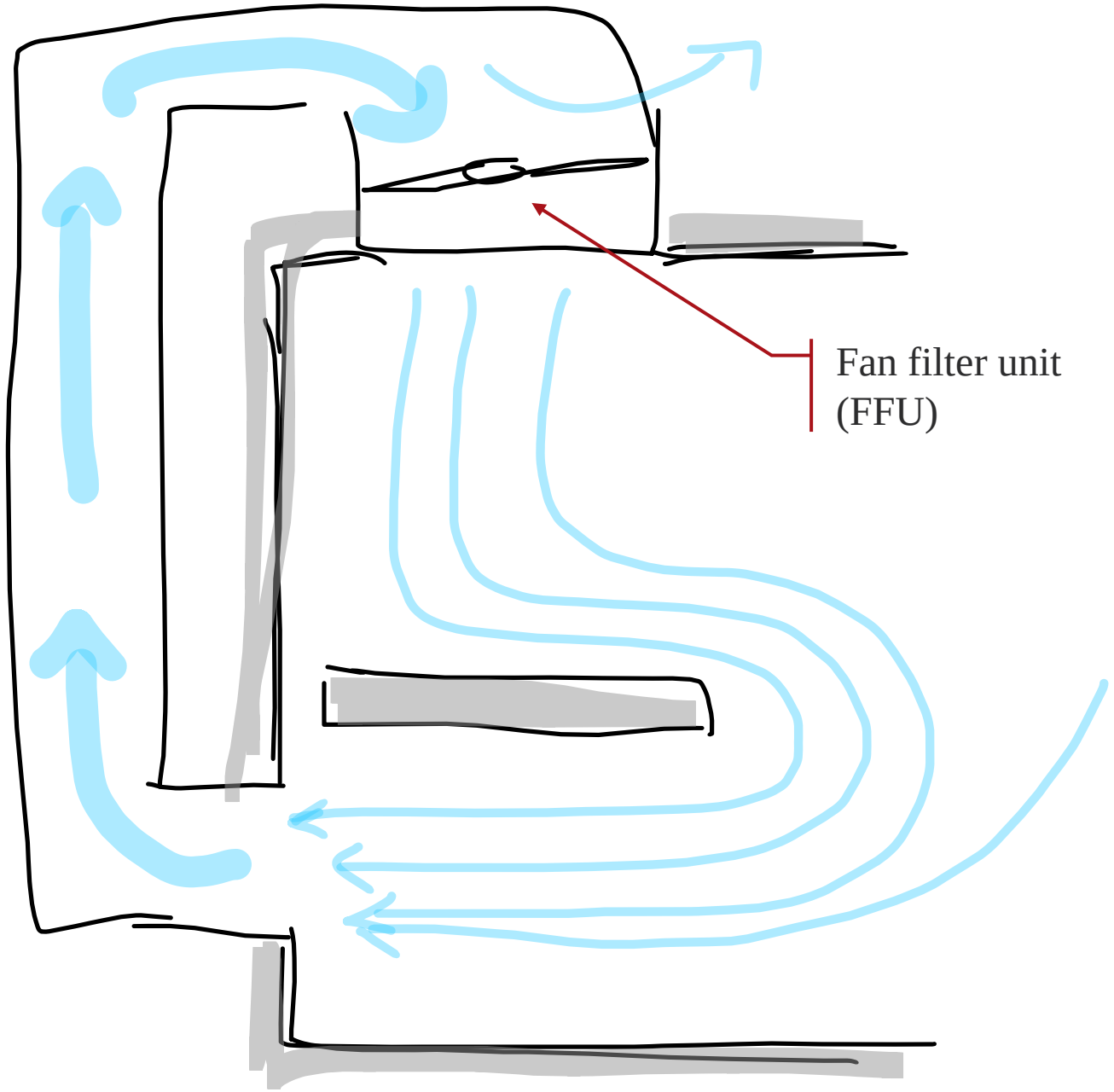

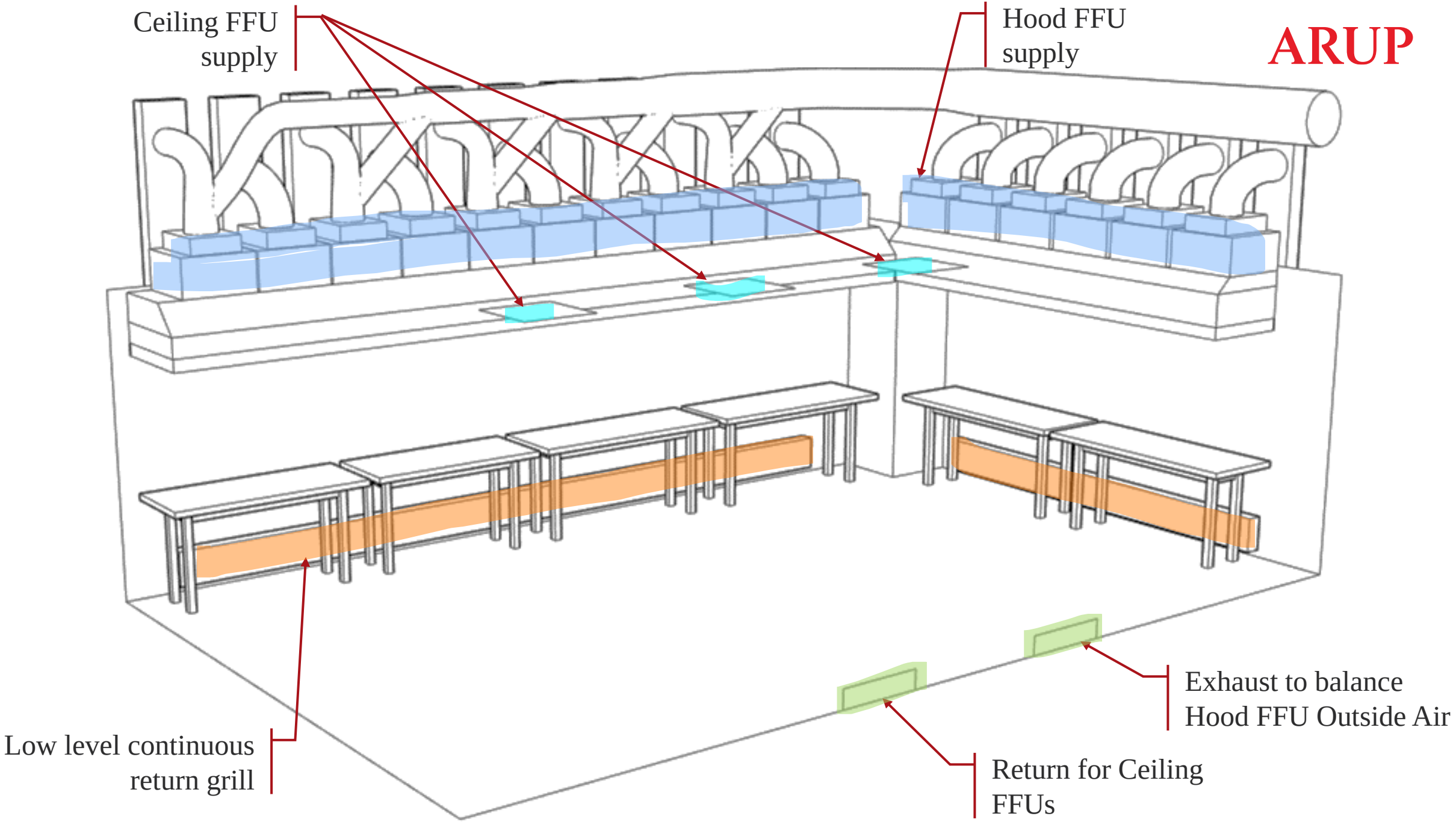
Ceiling FFU supply
Hood FFU supply
ARUP
Low level continuous return grill
Exhaust to balance Hood FFU Outside Air
Return for Ceiling FFUs

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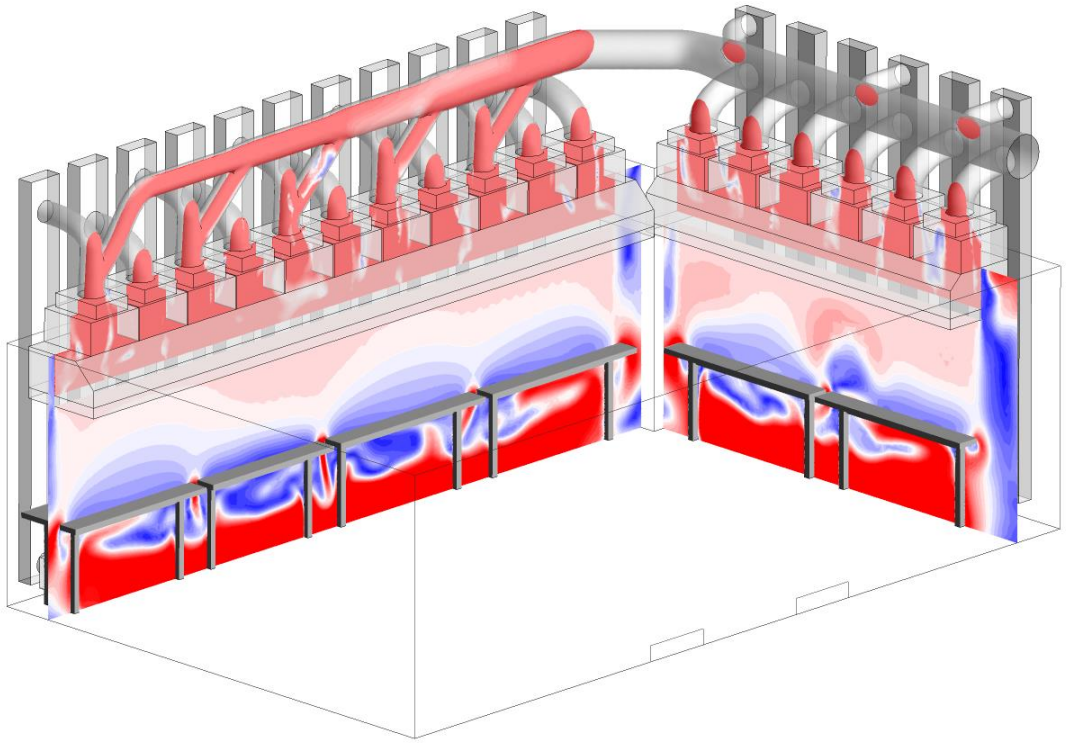
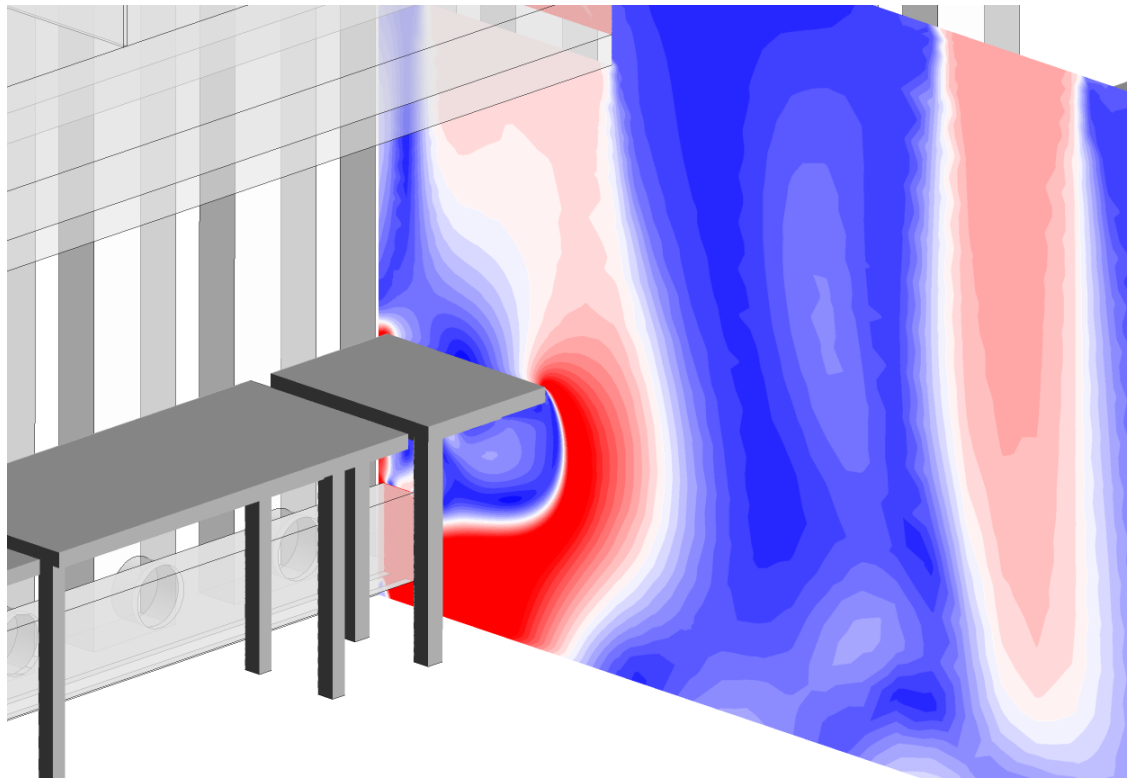
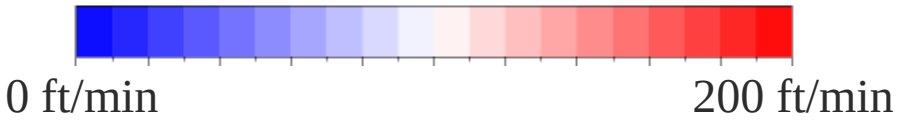
Air speed







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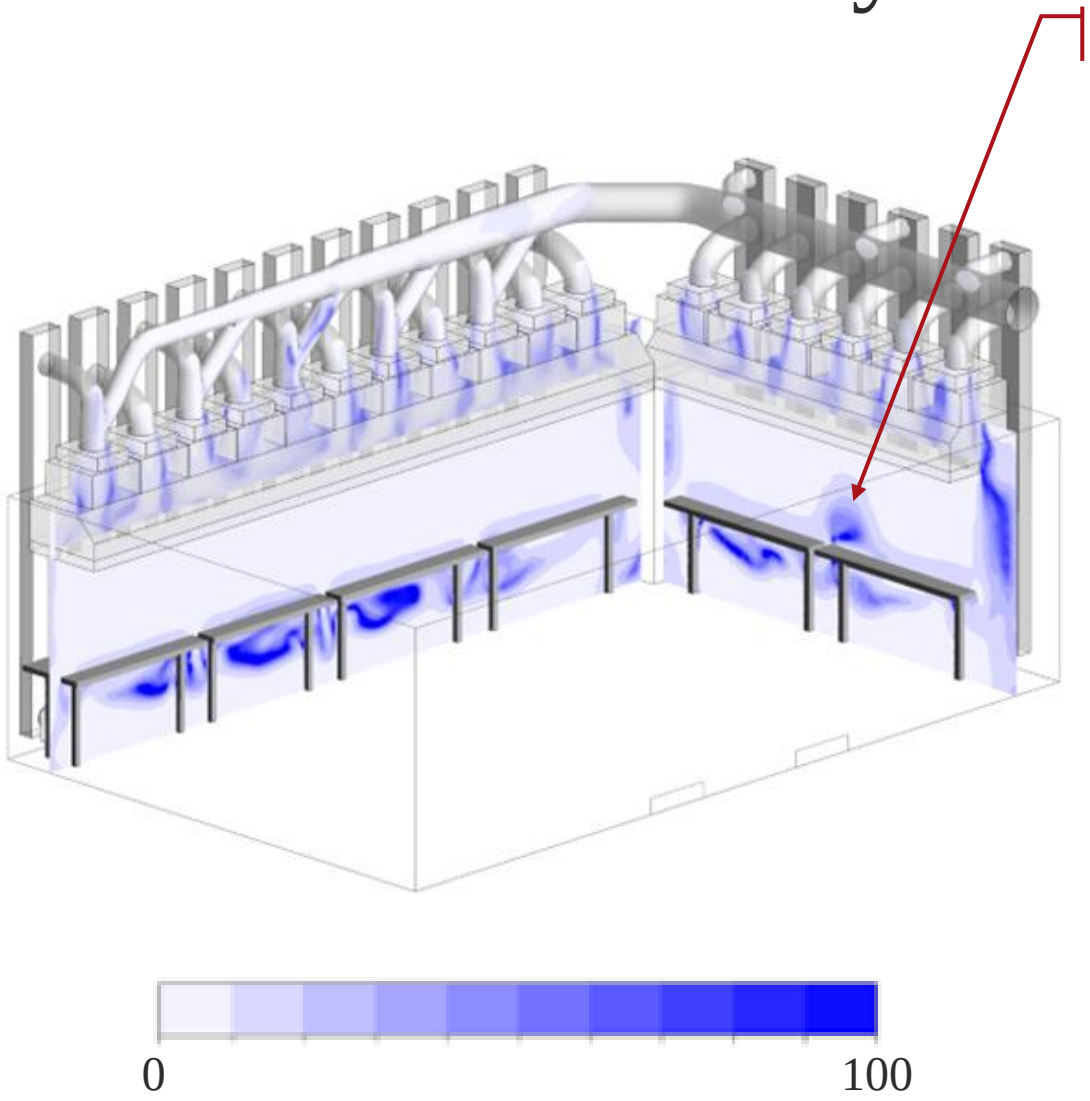
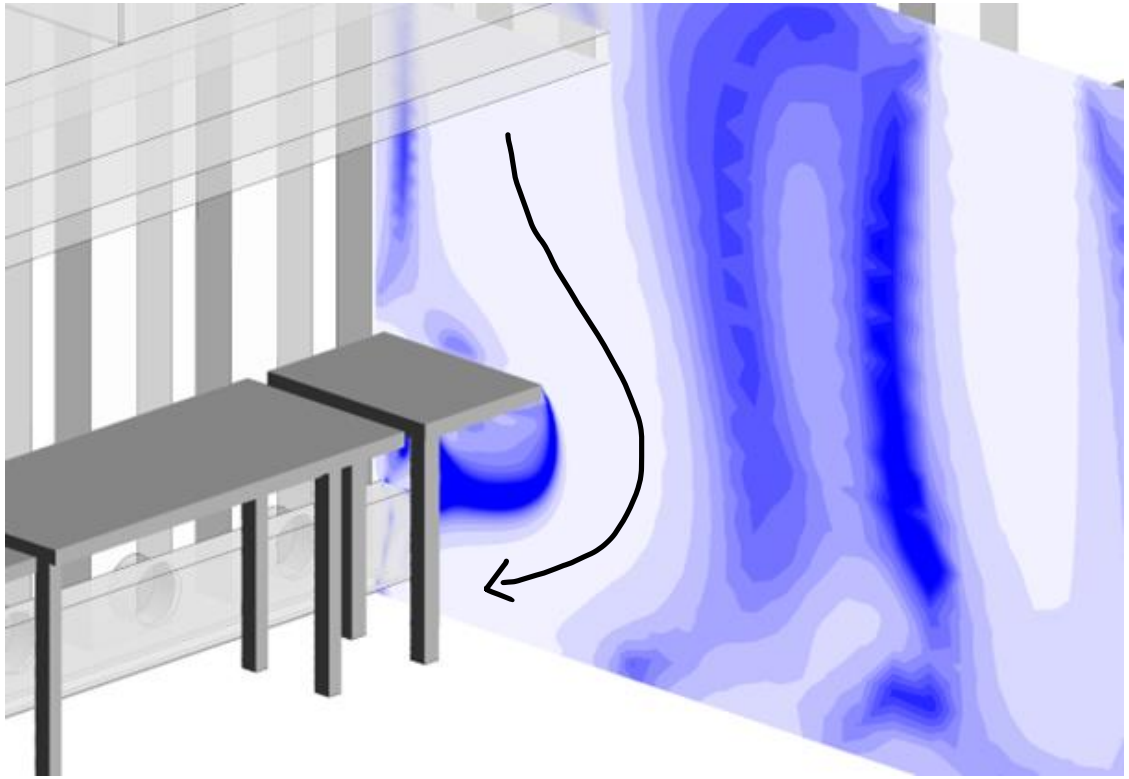
Turbulence intensity





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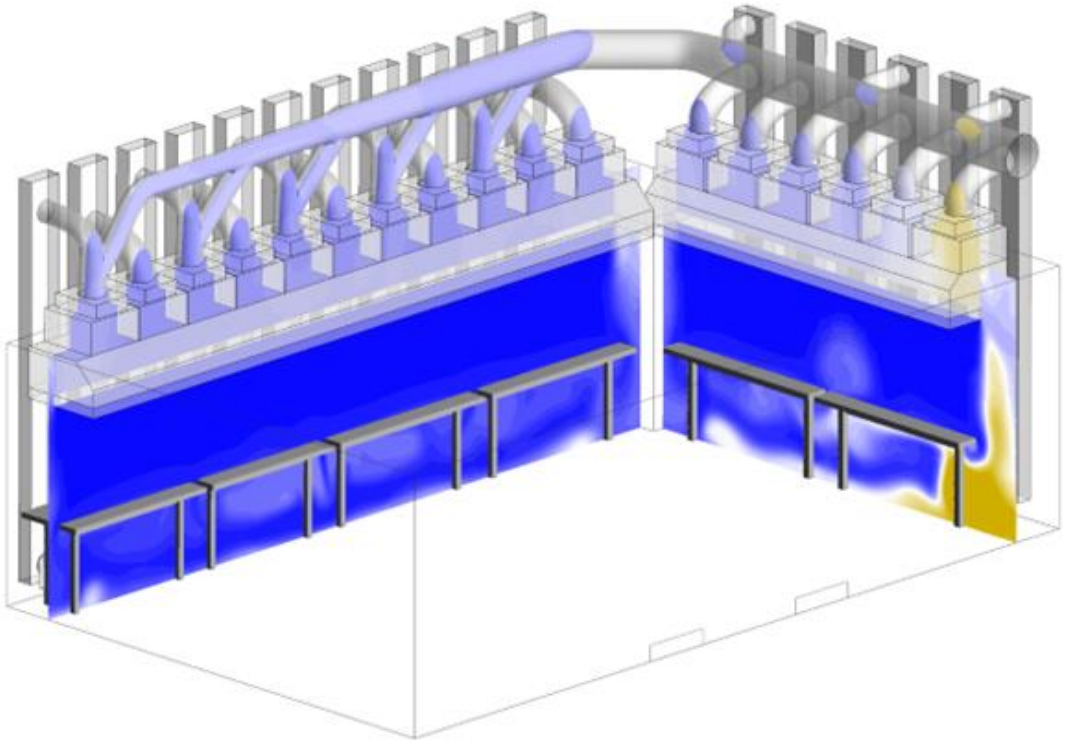
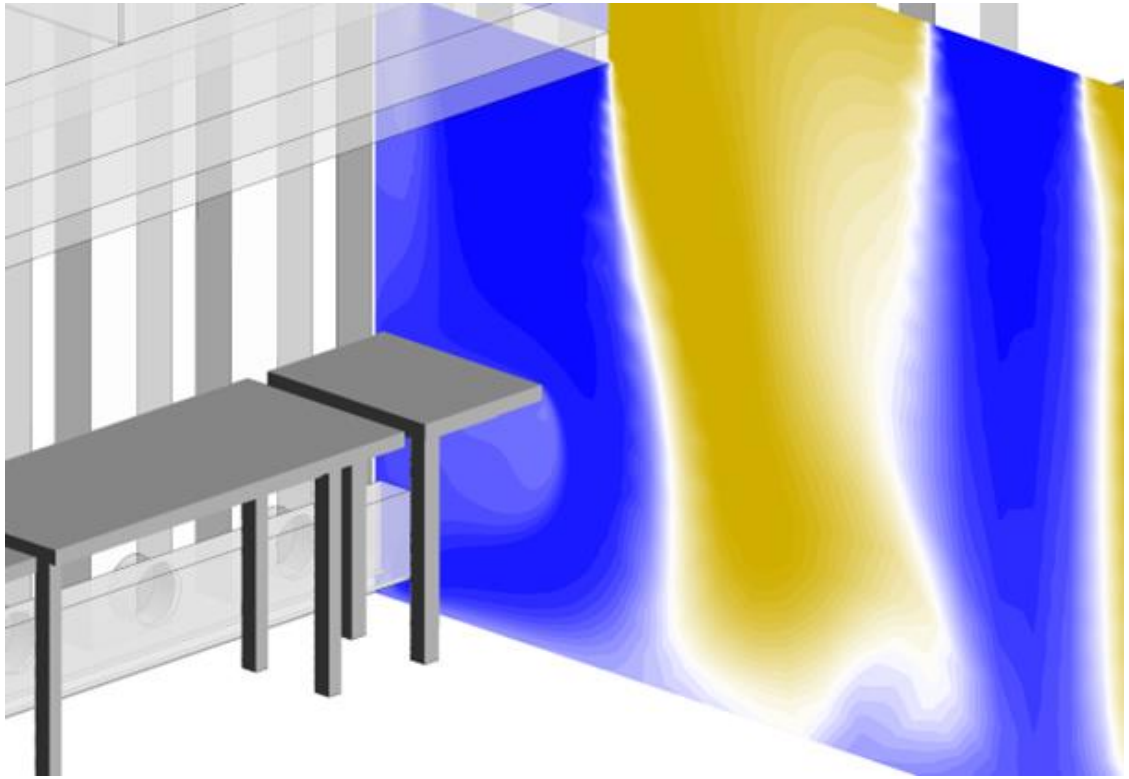
Age of air





0 minutes 1 minute

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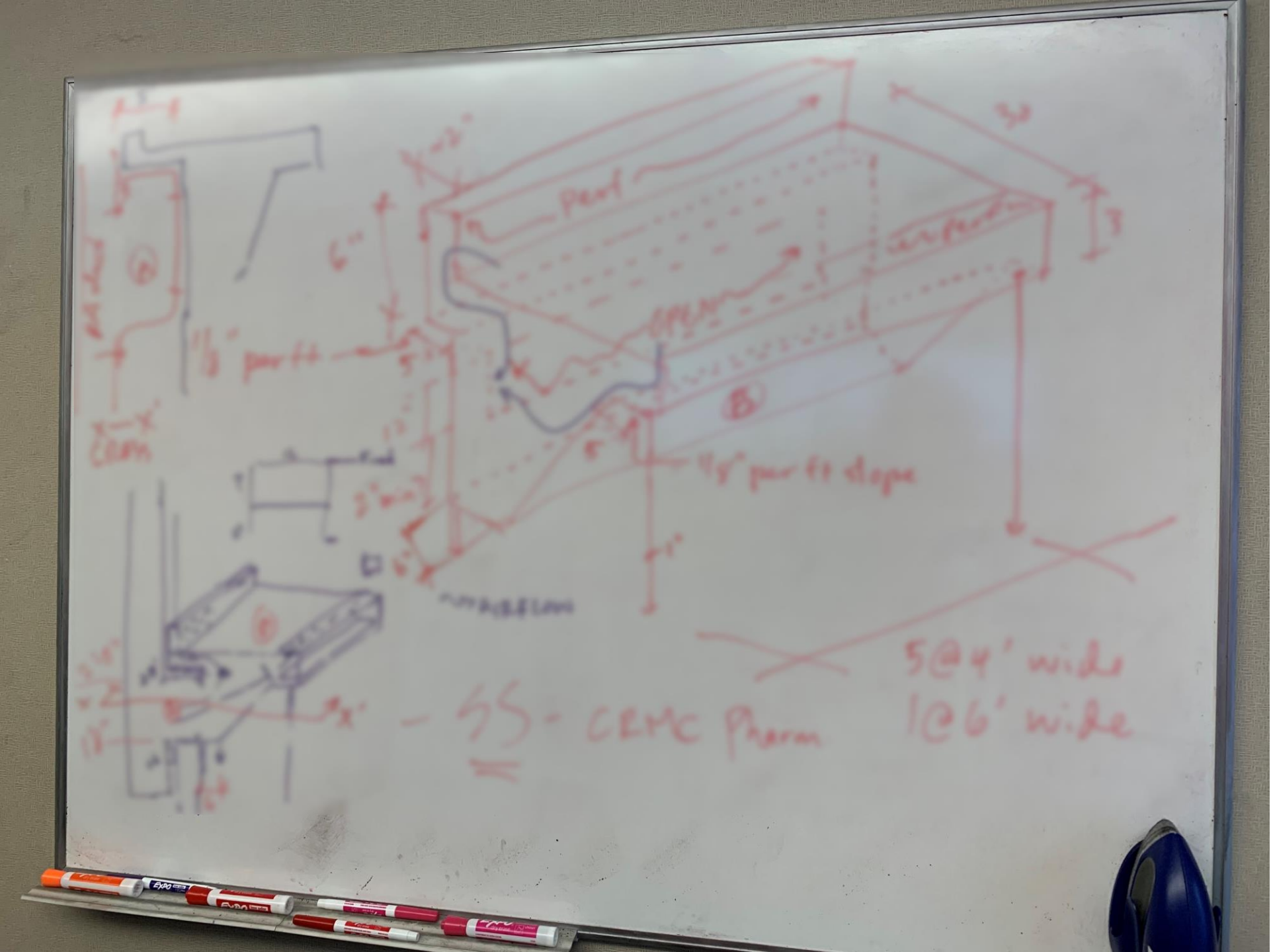

Rethink

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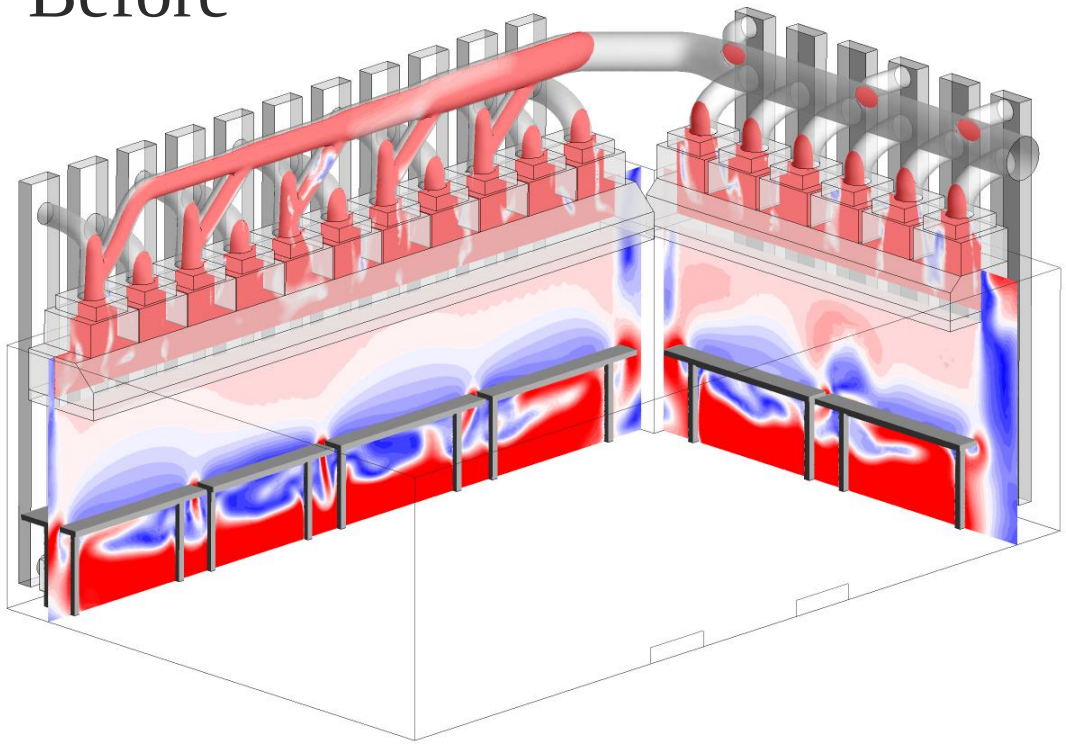
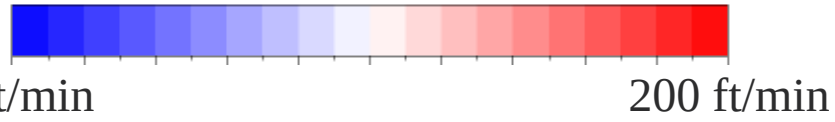
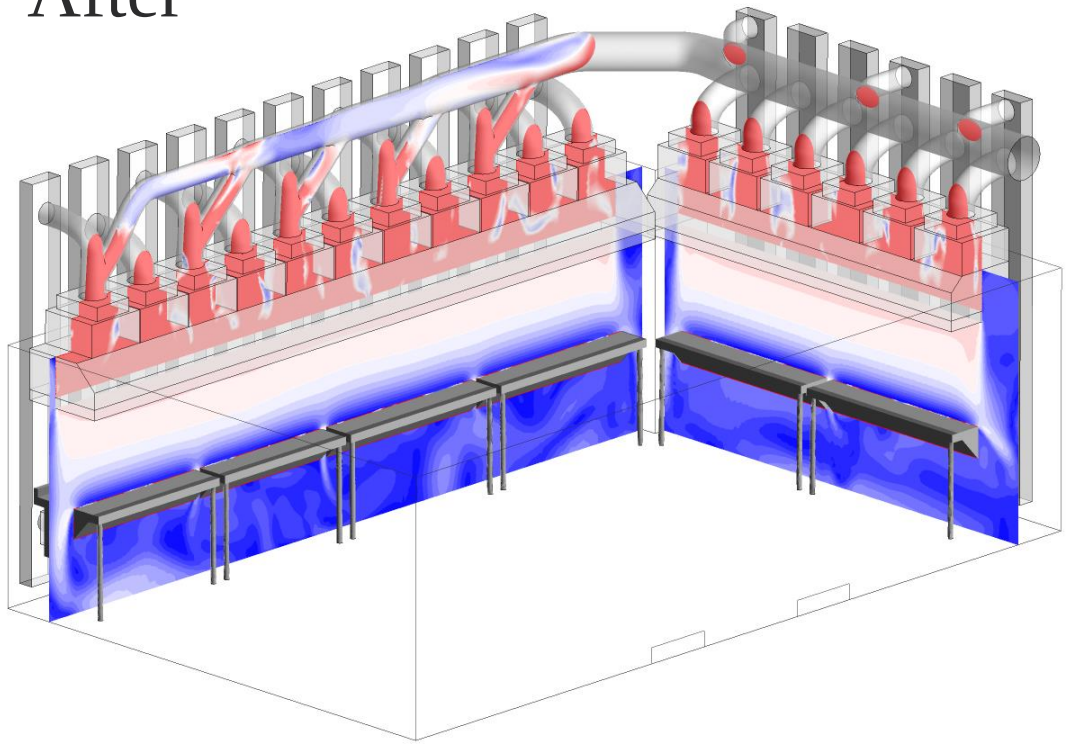
Air speed

Before



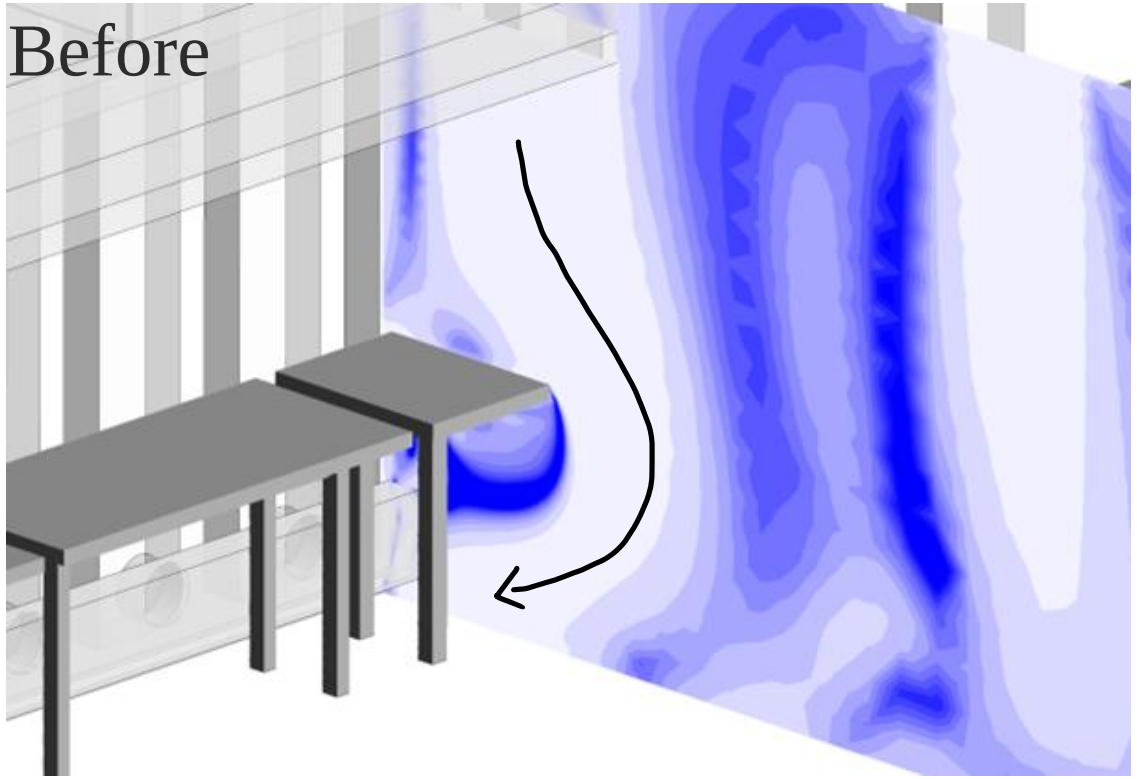


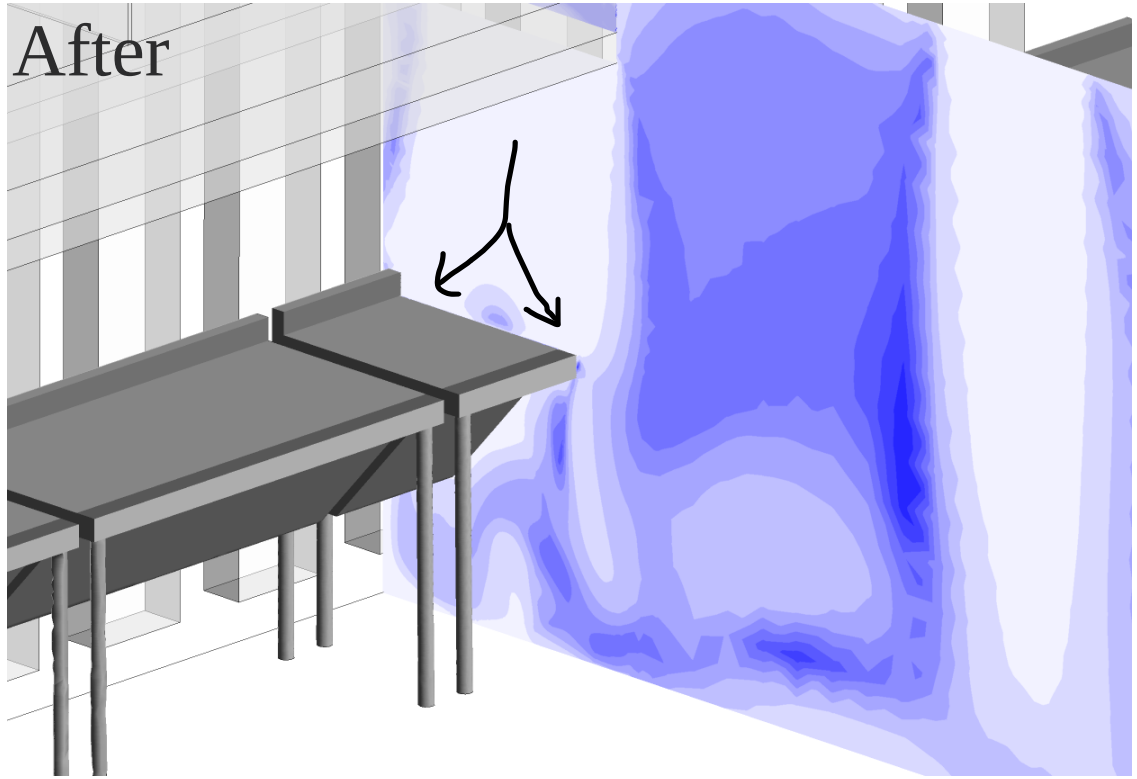
After



ARUP

Turbulence intensity





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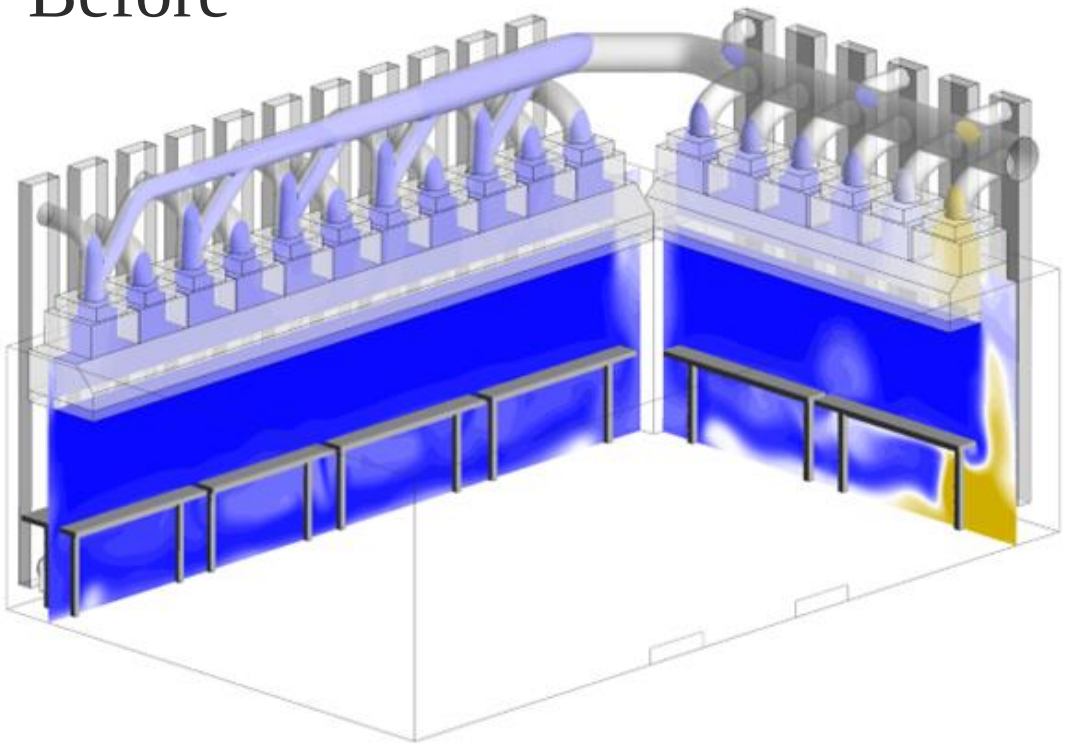
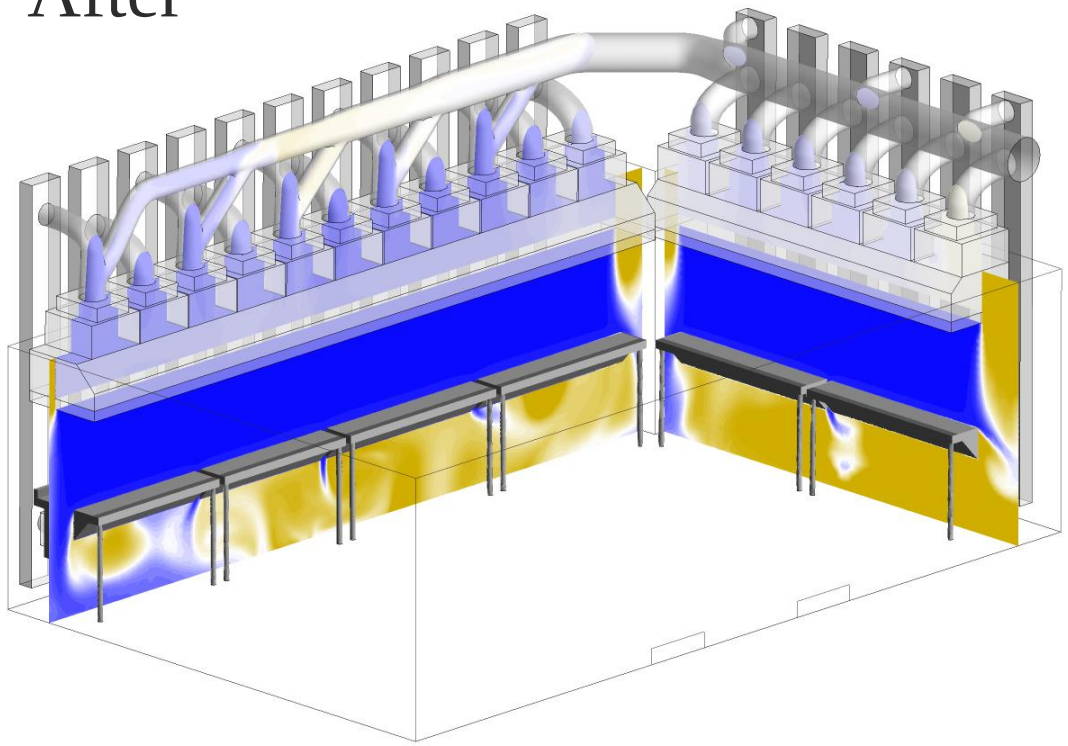
Age of air

Before



0 minutes 1 minute

After



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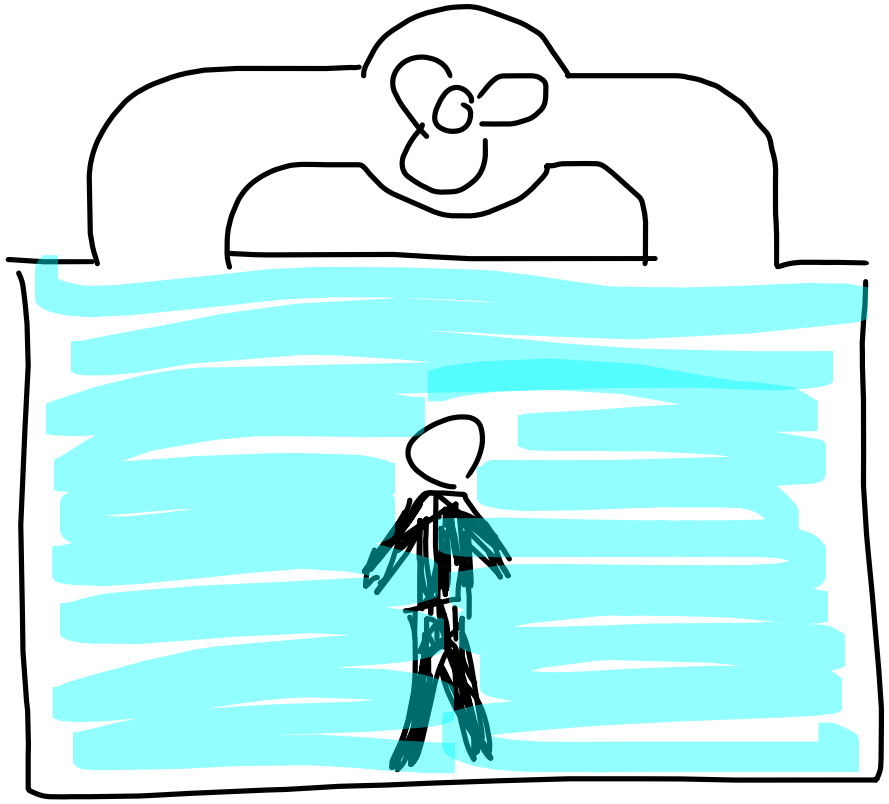
Space use



Case study

Chemical containment in a teaching lab

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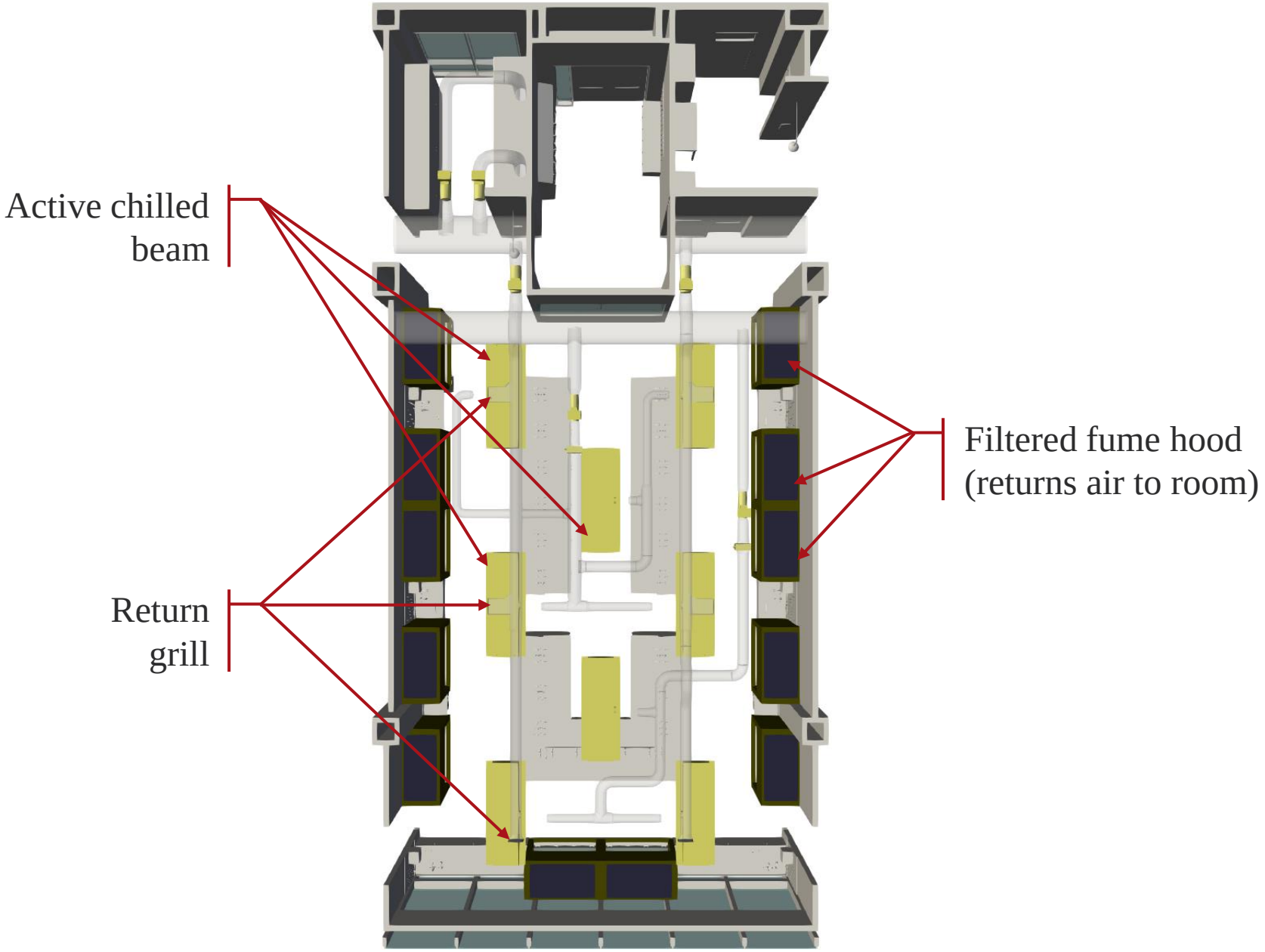
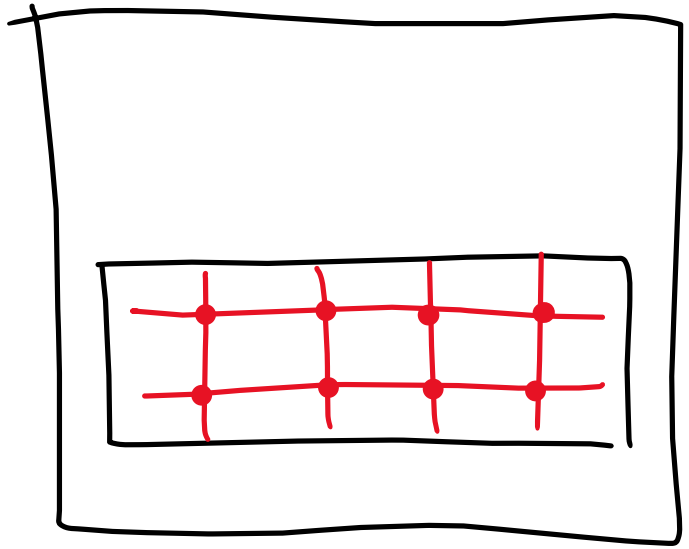
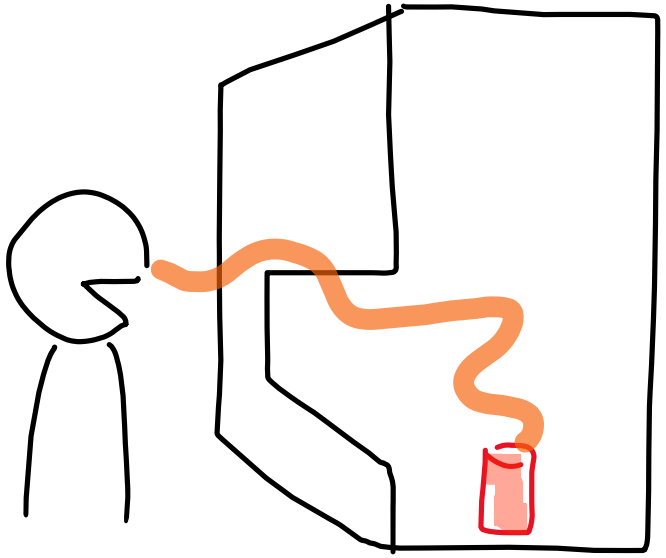

Active chilled beam
Return grill
Filtered fume hood (returns air to room)

ASHRAE 110



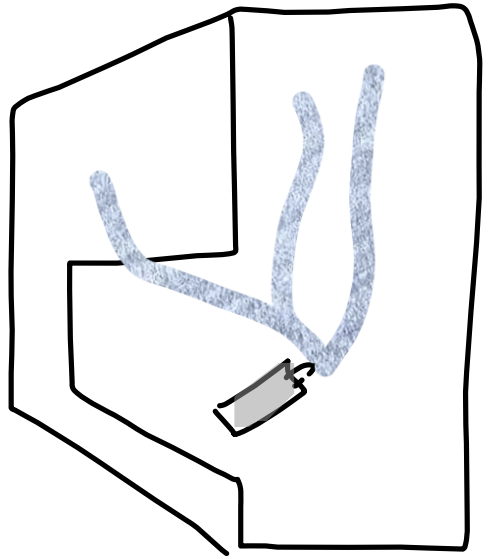
Face velocity

An anemometer is placed at points on a rectangular grid roughly 1 foot apart over the sash opening.



Tracer gas test

A tracer gas is released in the fume hood. The concentration is measured in the breathing zone and periphery.



Flow visualization

Smoke released in the fume hood should be carried smoothly to the fume hood exhaust.

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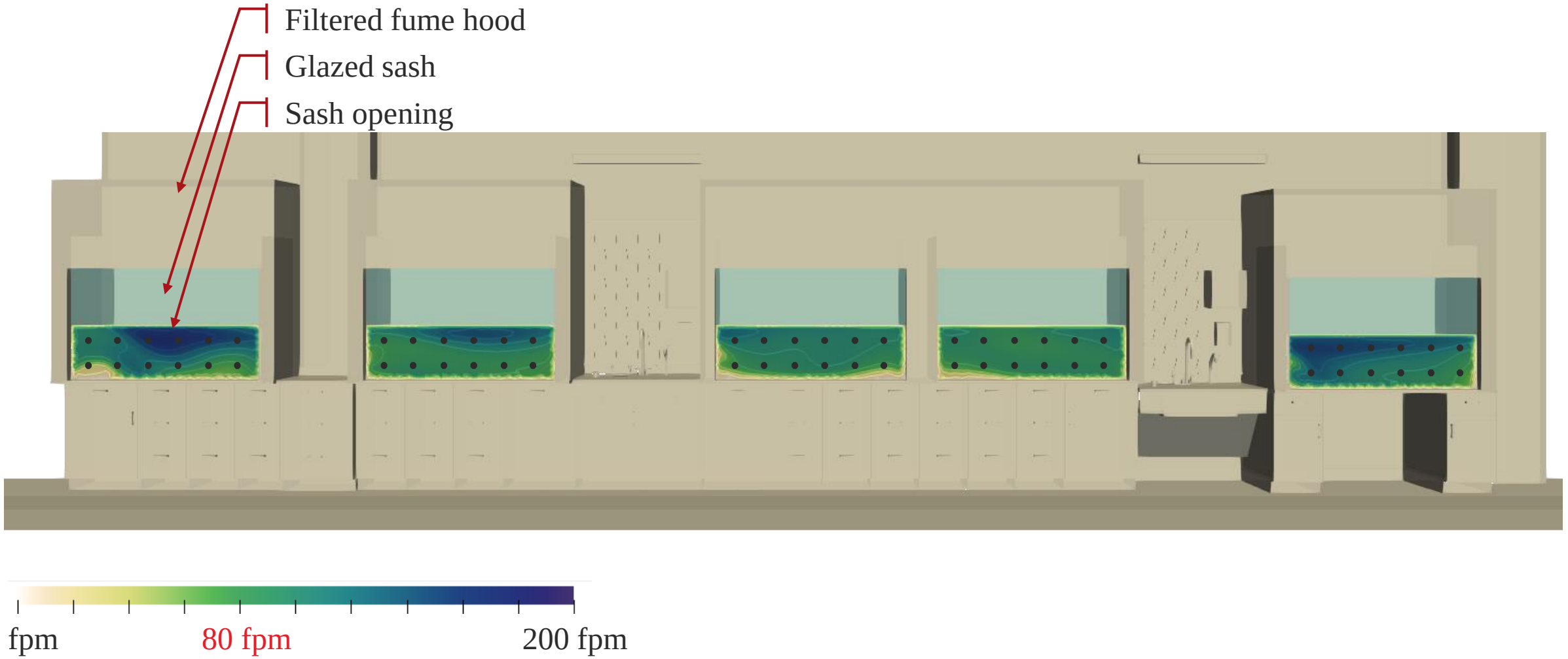
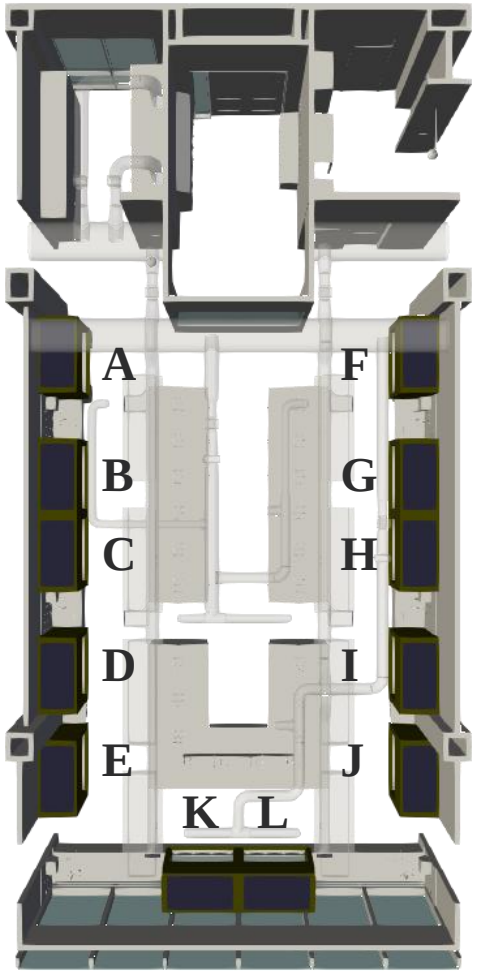
Trust but verify

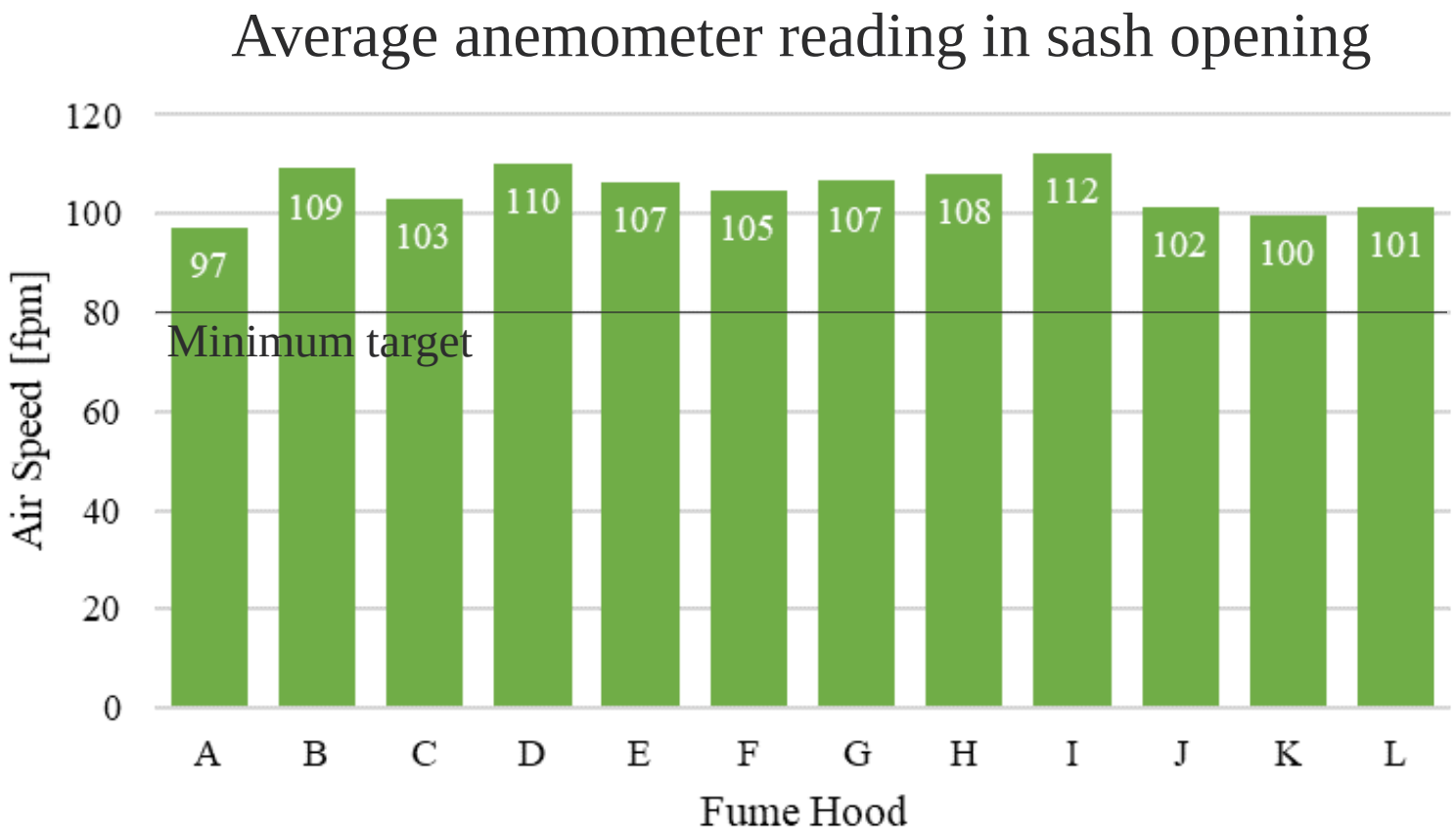
Face velocity



Trust but verify

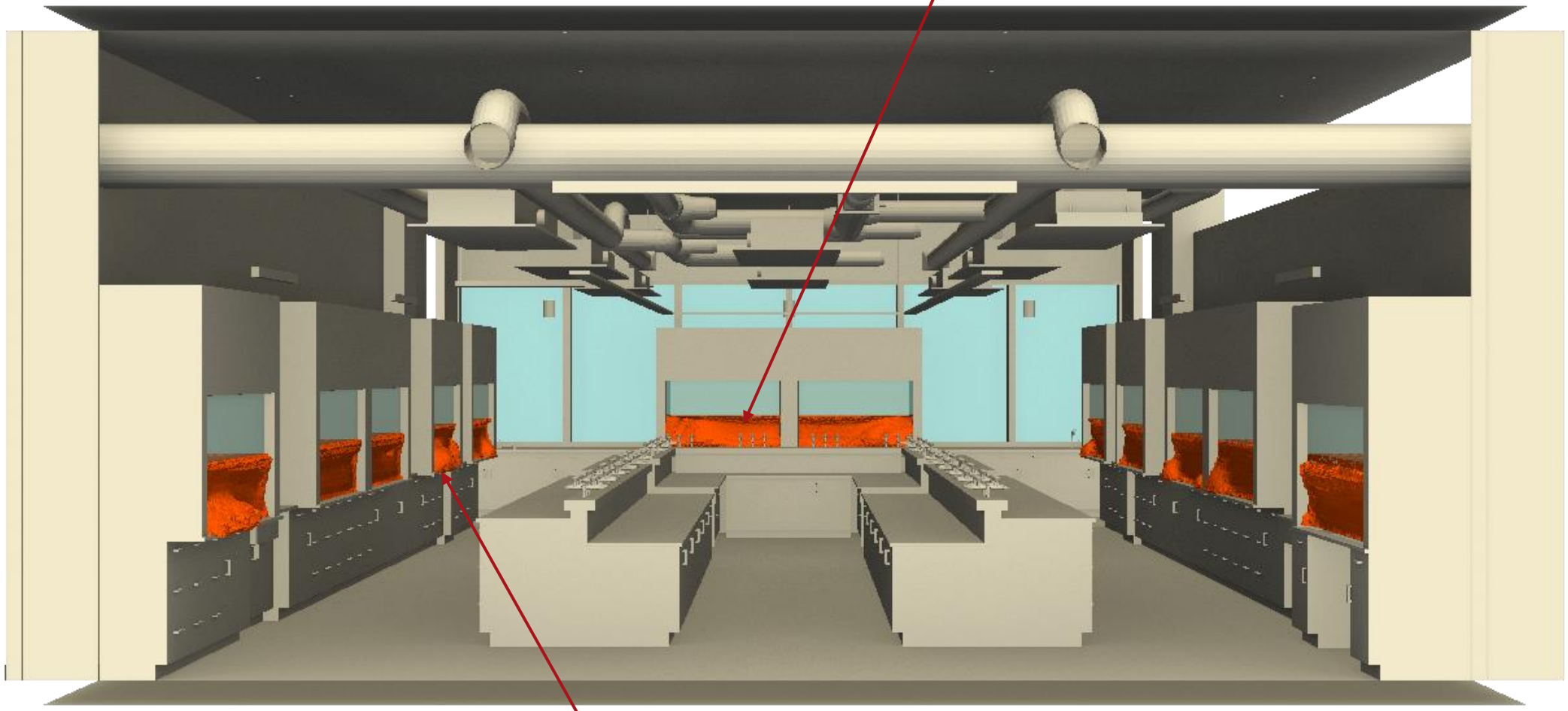
Face velocity





Trust but verify

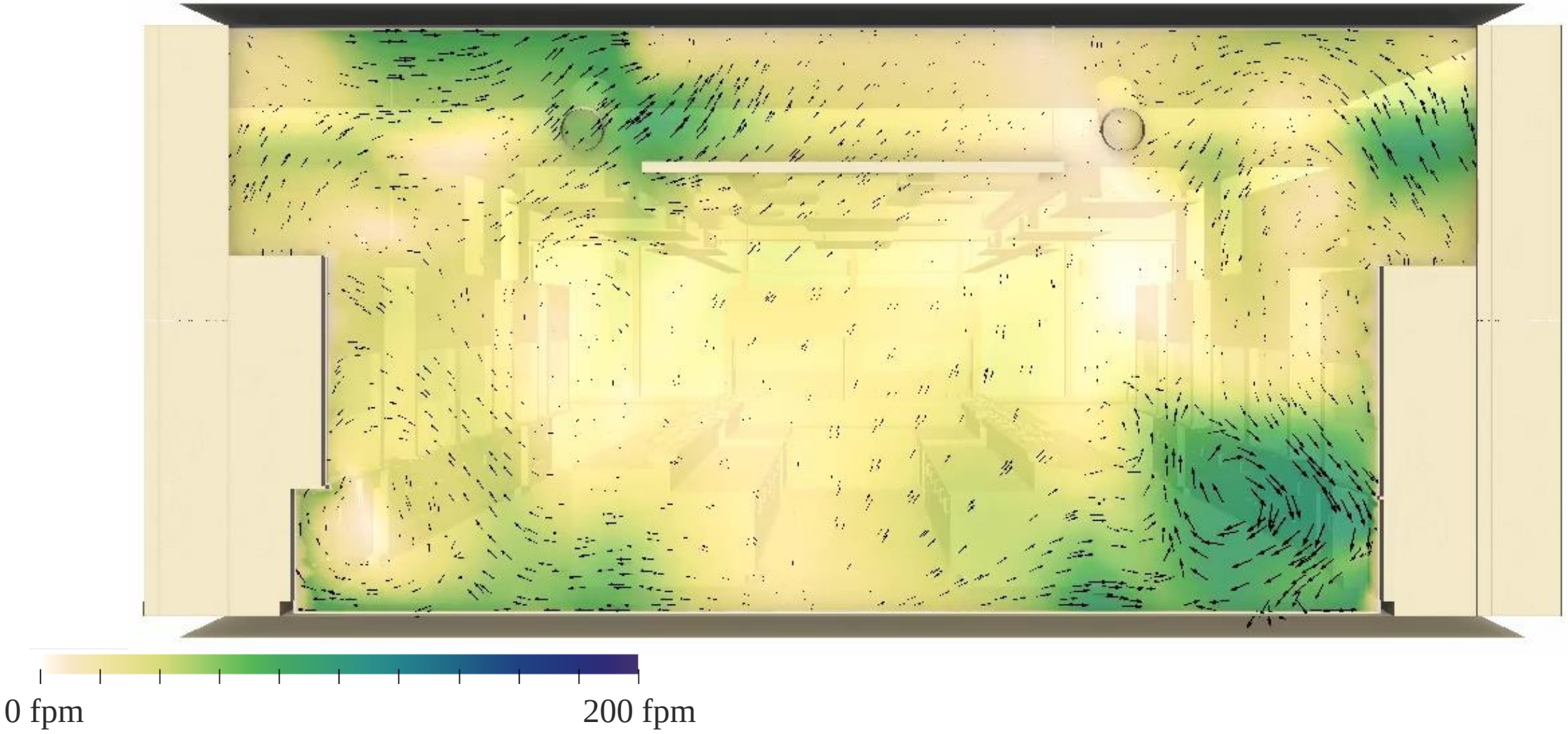
Tracer gas test



ARUP

Trust but verify

Flow visualization



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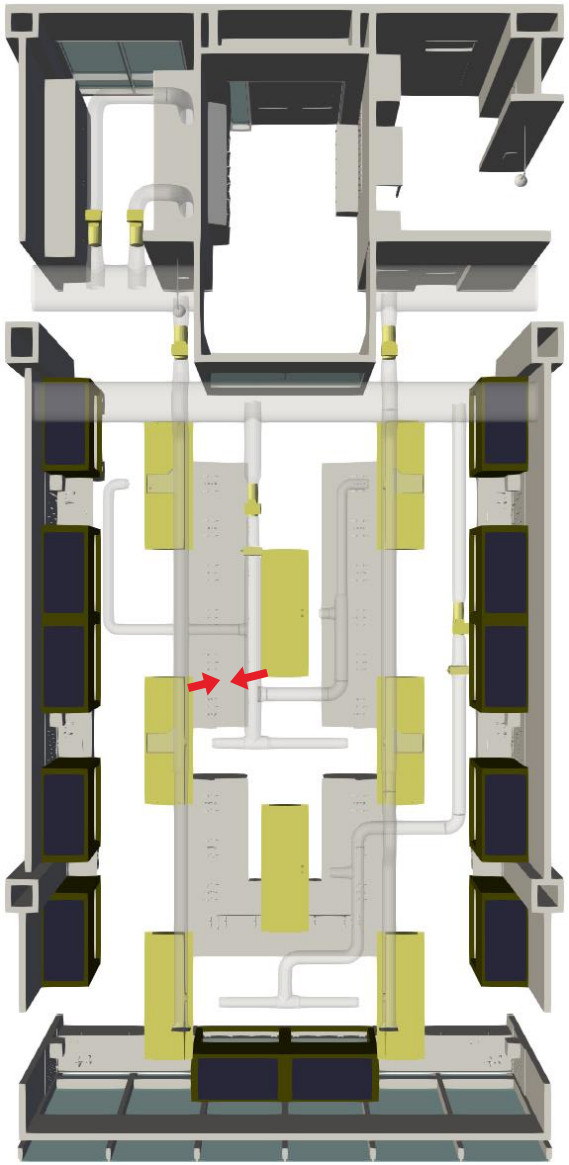
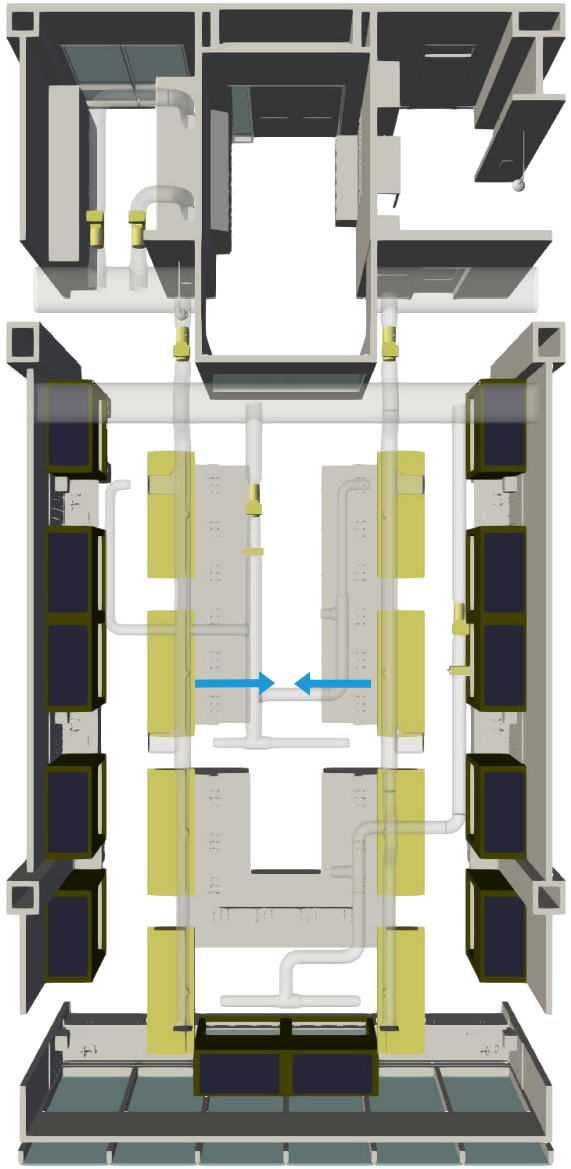
Original

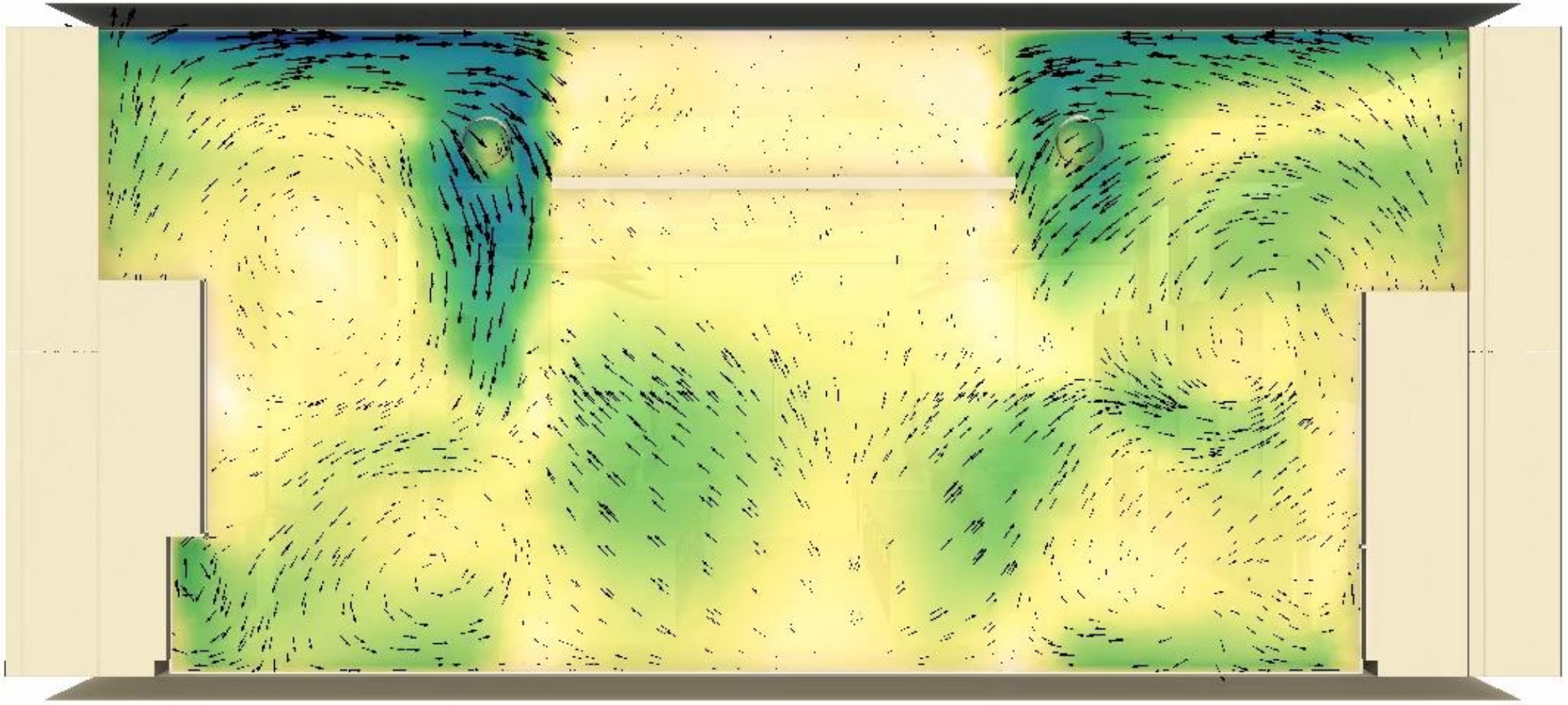




Modified

Modified layout

Flow visualization



0 fpm

200 fpm

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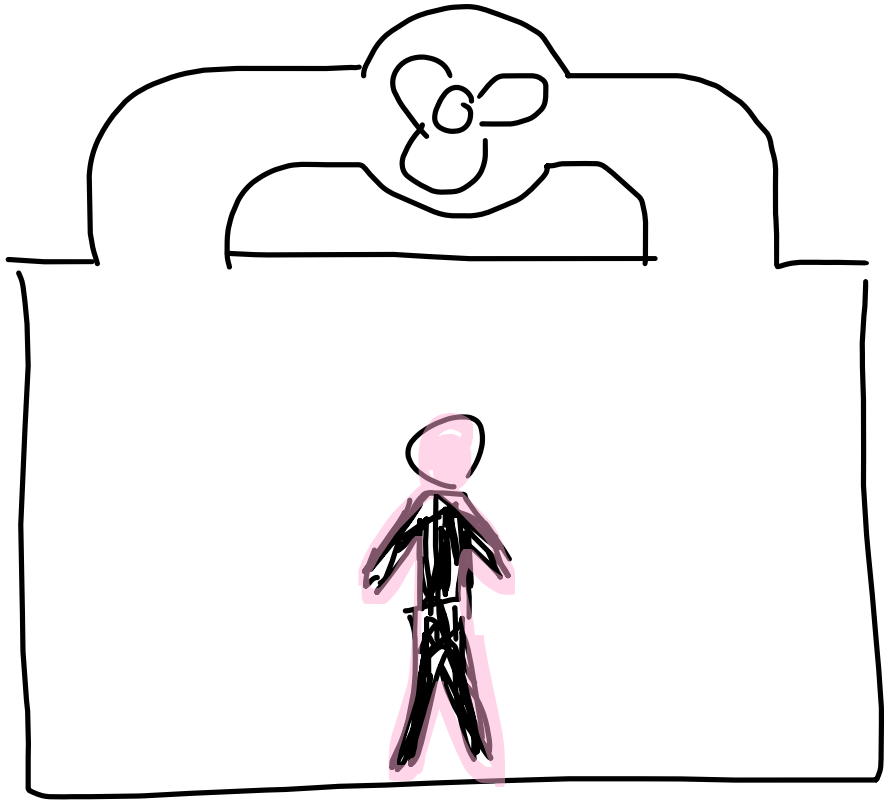
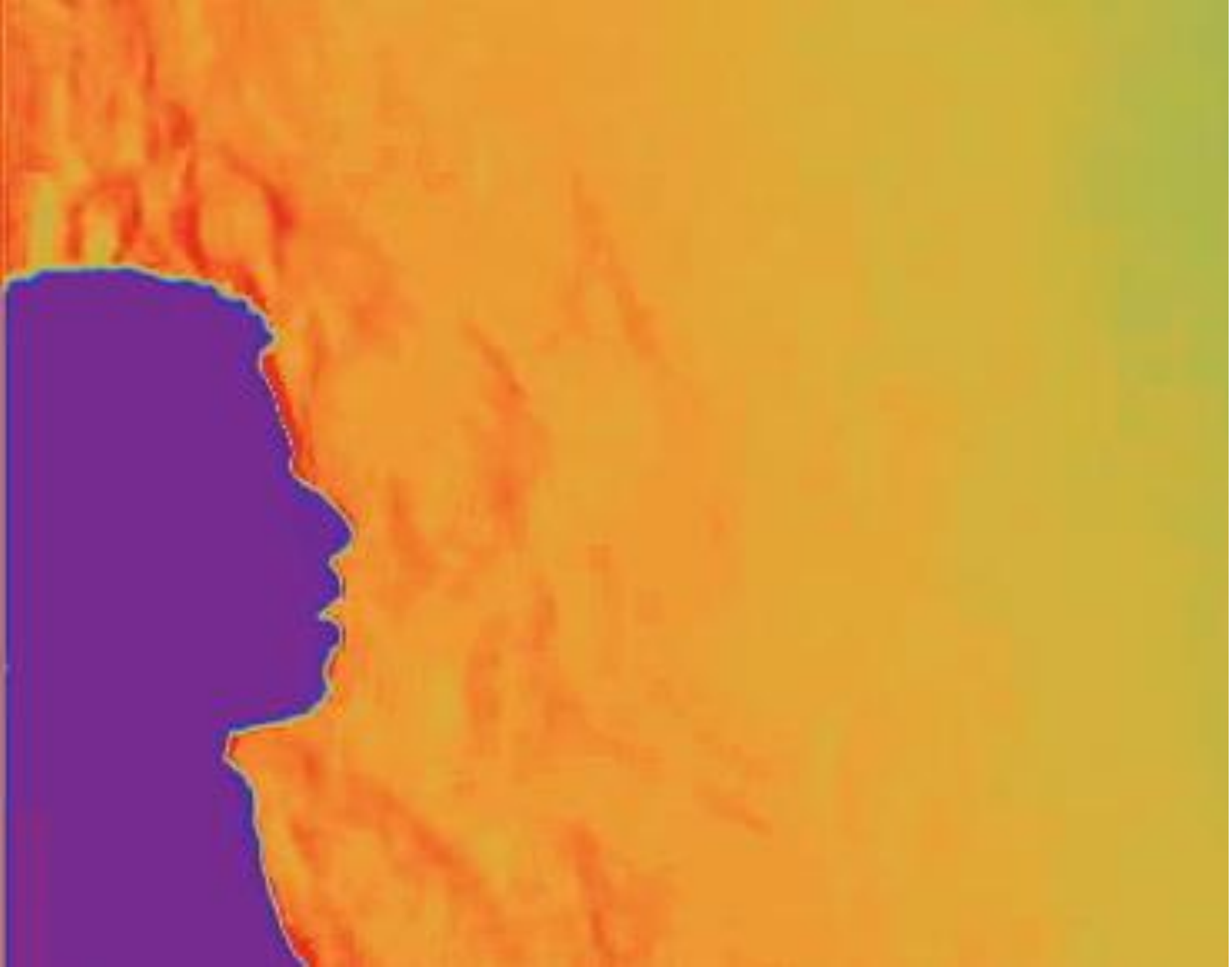
Occupants



- [x] Filtering HVAC system
- [x] Low emission materials
- [x] Monitoring
- [x] Space use
- [ ] Occupants



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Schlieren videos of breathing and coughing, from Bauhaus-Universität Weimar
https://vimeo.com/399120258 (Colorized by Arup)

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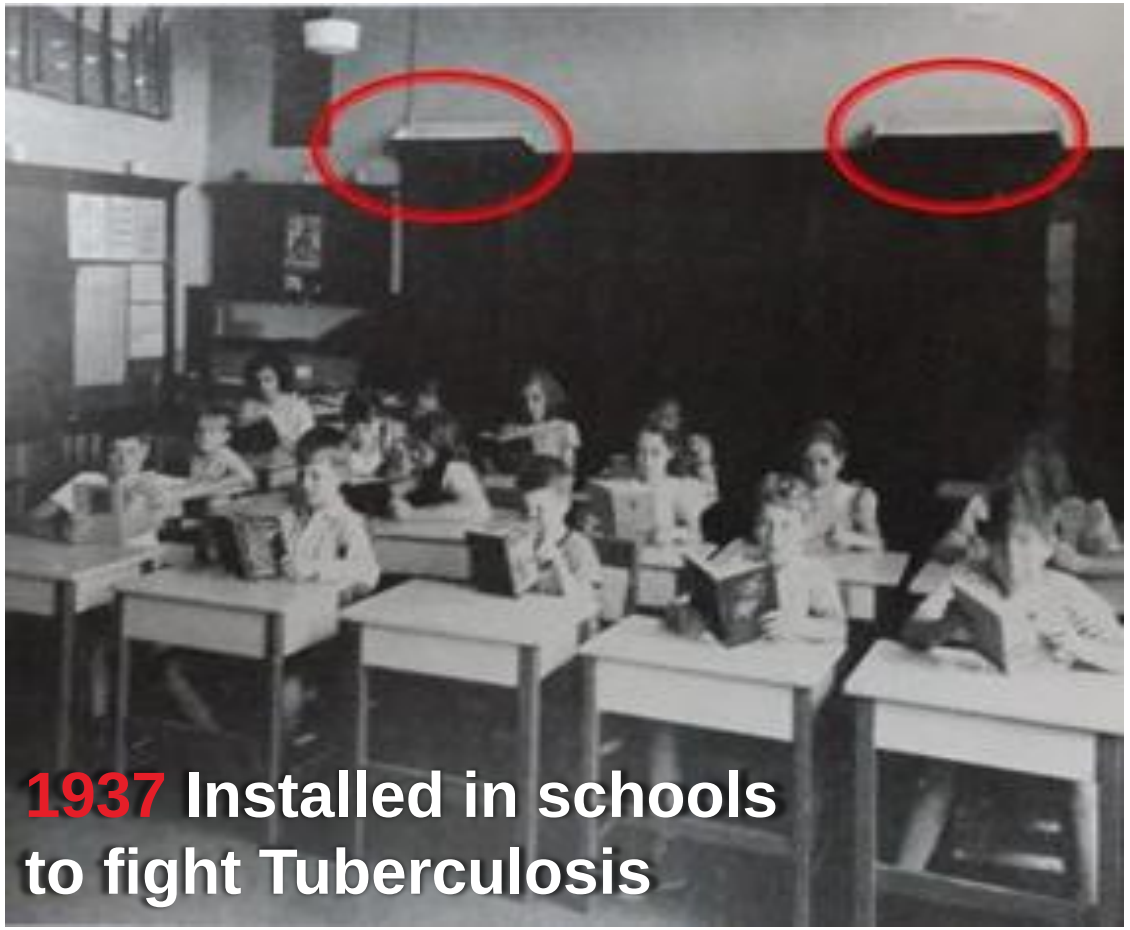
Ultraviolet germicidal irradiance (UVGI)



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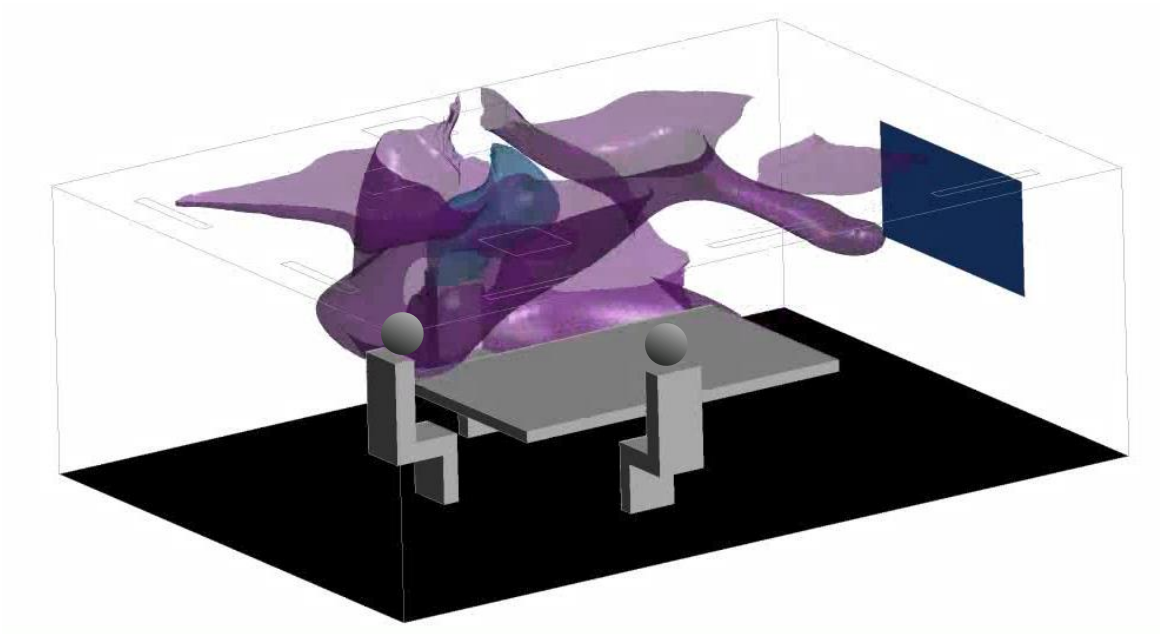
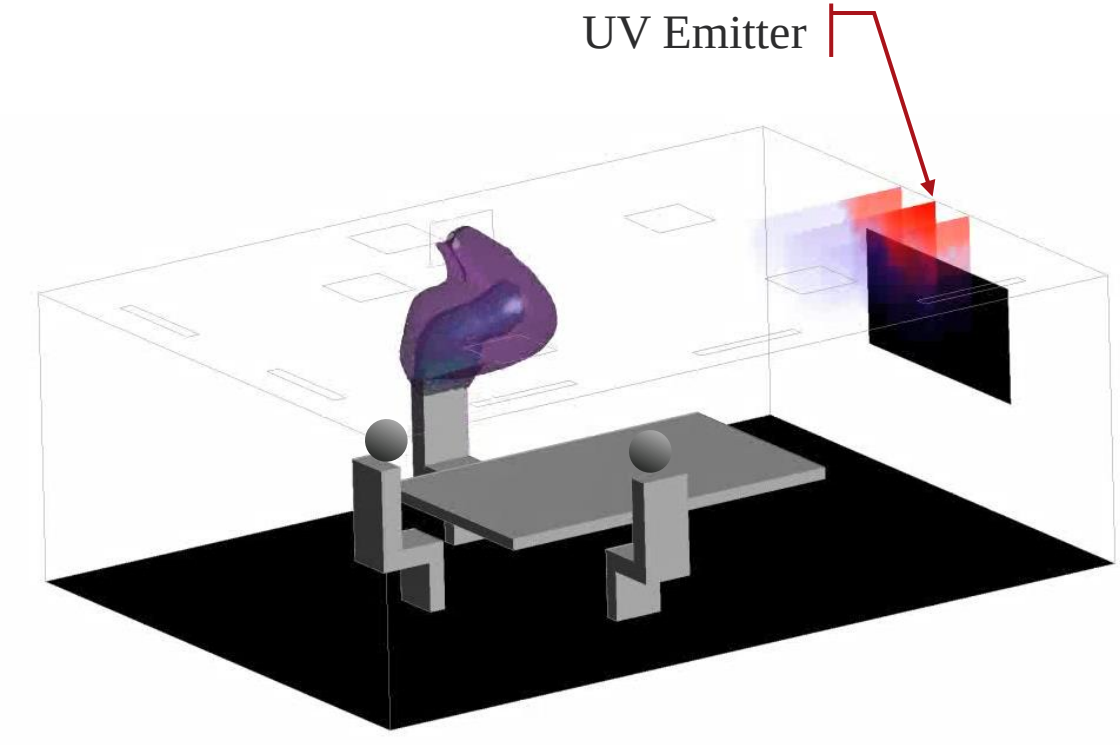
COVID-19

Upper-room ultraviolet germicidal irradiance (UVGI)





Jones *et al*., 2021. *Simulation of COVID-19 ultraviolet disinfection using coupled ray tracing and CFD*. Building Simulation 2021.

Modified Wells-Riley

Probability of infection

Number of infectors

Breathing rate

Quanta generation

Exposure time

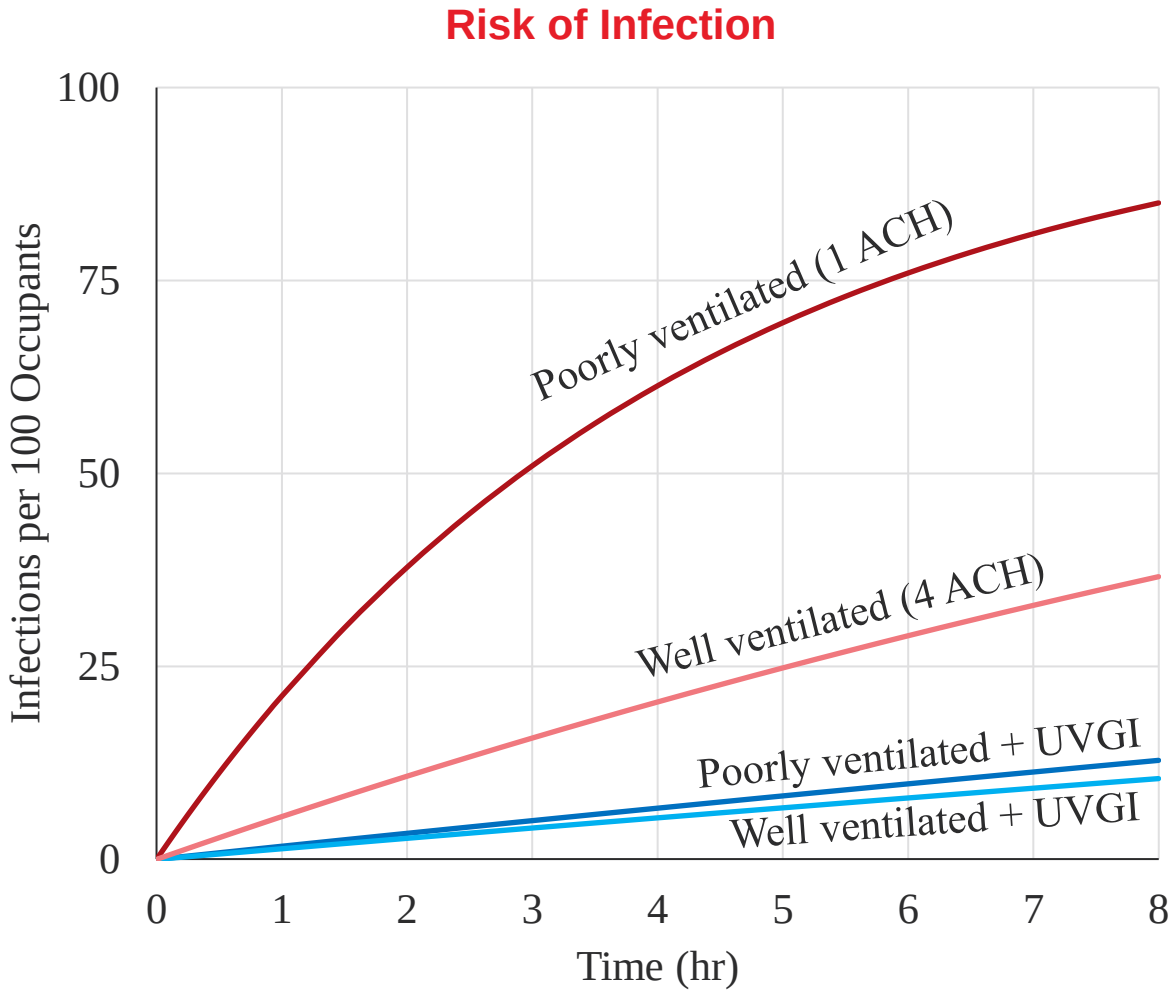
$$P = 1 - e^{\frac{-Ipqt}{Vk_{eqv}}}$$

$$k_{eqv} = k_v + k_d + k_i + zE\frac{H_{uv}}{H}$$

Ventilation Rate

Susceptibility to UV

UV Irradiance



Jones *et al.*, 2021. *Simulation of COVID-19 ultraviolet disinfection using coupled ray tracing and CFD.* Building Simulation 2021.

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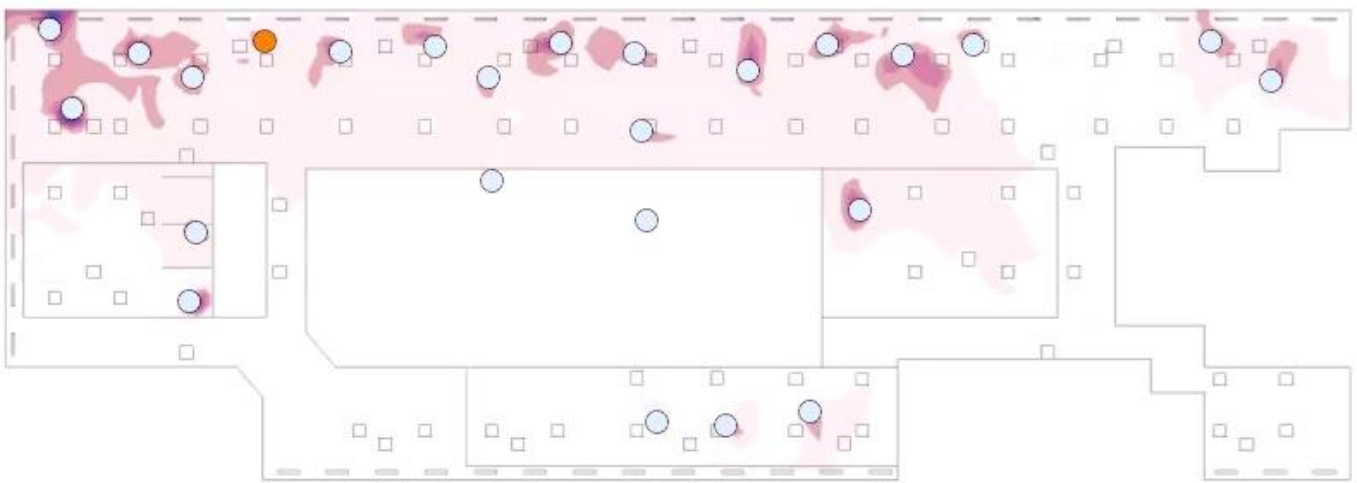
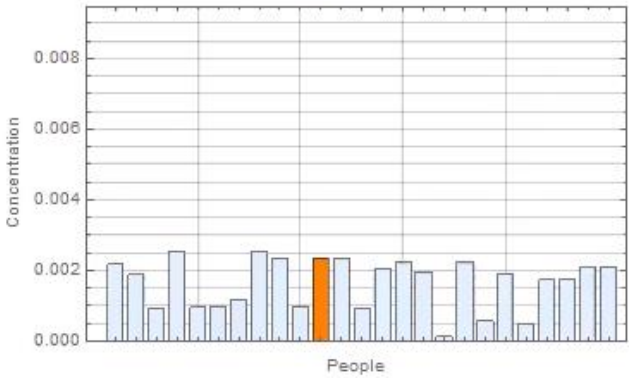
People movement

Time



Instantaneous concentration experienced



5–minute average concentration experienced by Person 24

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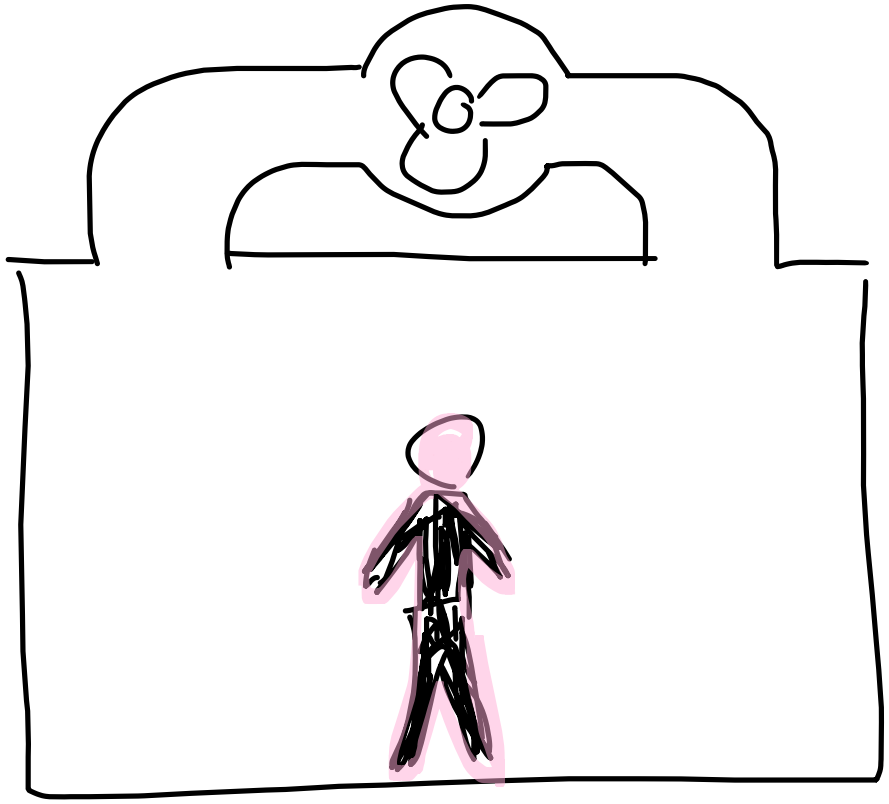
Occupants



Digression

Where did our "*scientific*" basis for thermal comfort come from?

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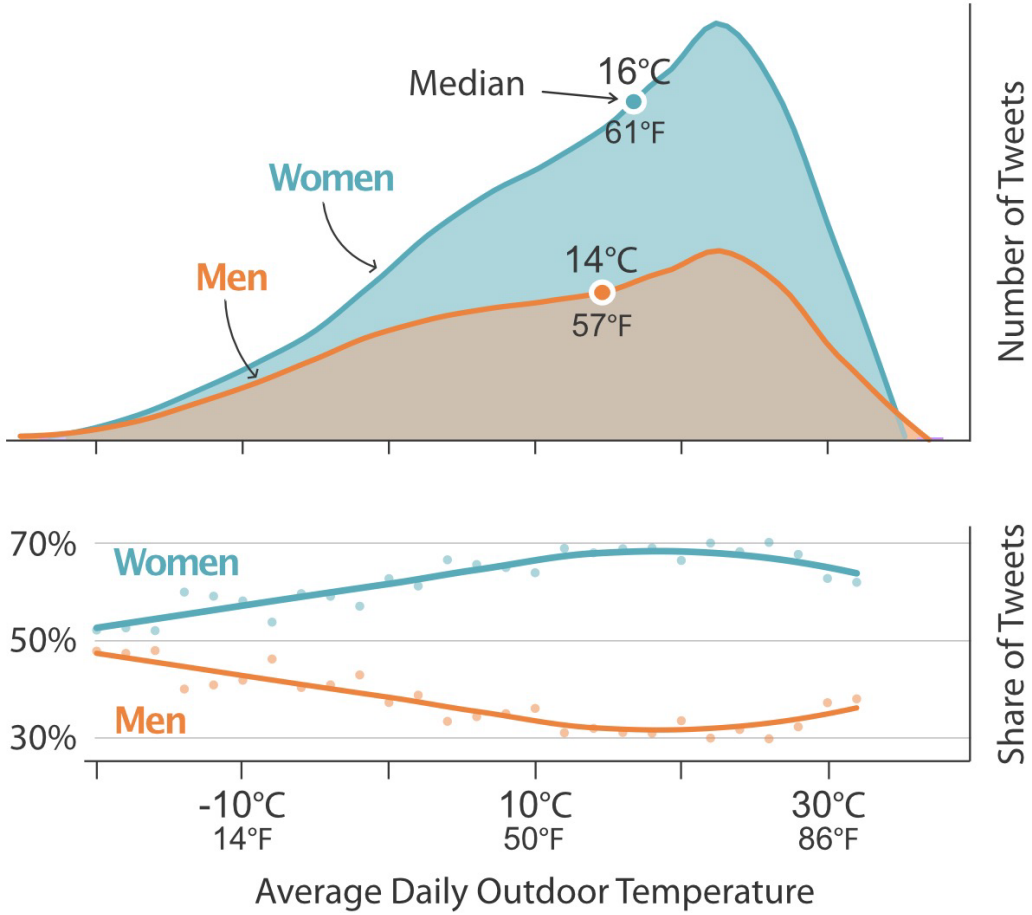
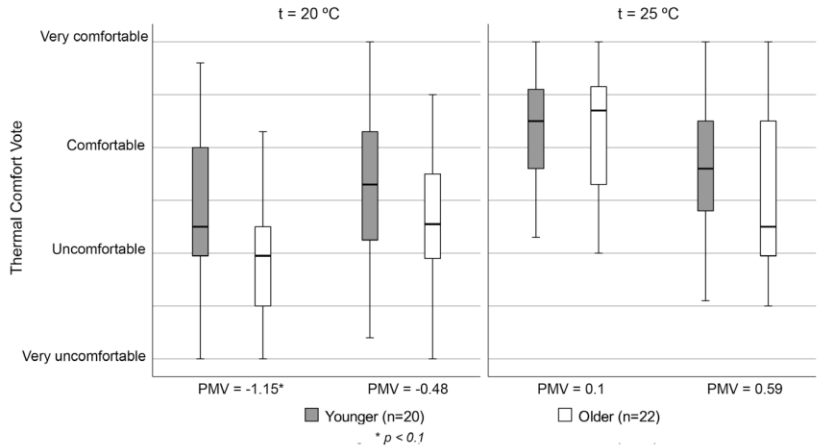
Gender

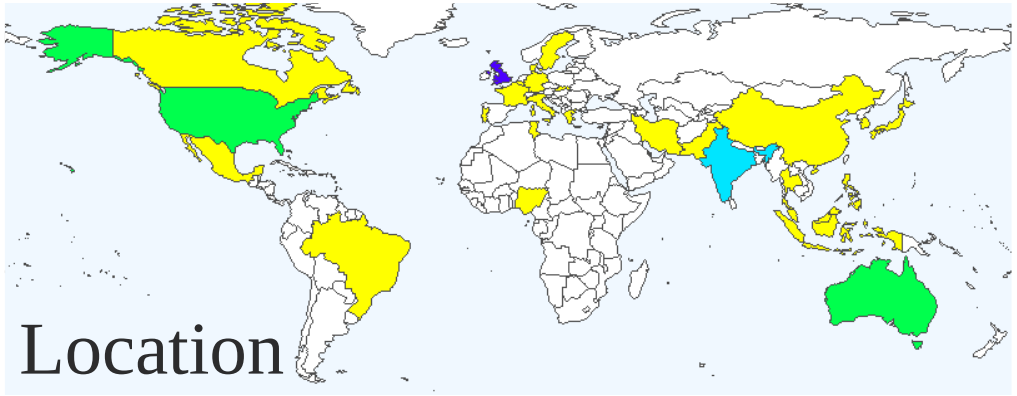


Parkinson *et al.*, 2021. *Overcooling of Offices Reveals Gender Inequality in Thermal Comfort*. Scientific Reports.

Age



Soebarto *et al.*, 2019. *A thermal comfort environmental chamber study of older and younger people*. Building and Environment.



Parkinson *et al.*, 2020. *Nudging the adaptive thermal comfort model*. Energy and Buildings 206.

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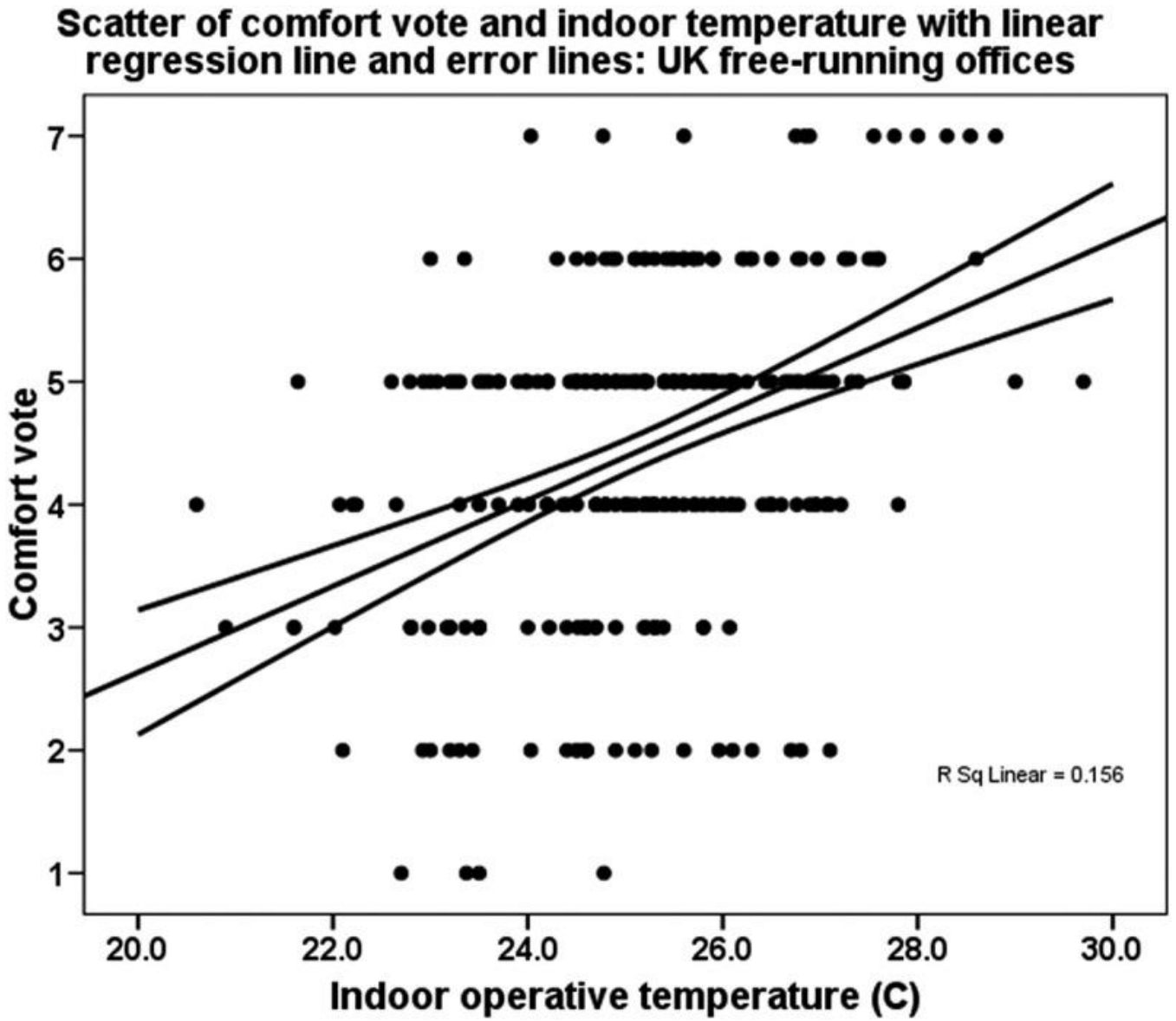

Nicol, Humphreys, and Roaf. *Adaptive thermal comfort: principles and practice*. London: Routledge; 2012.

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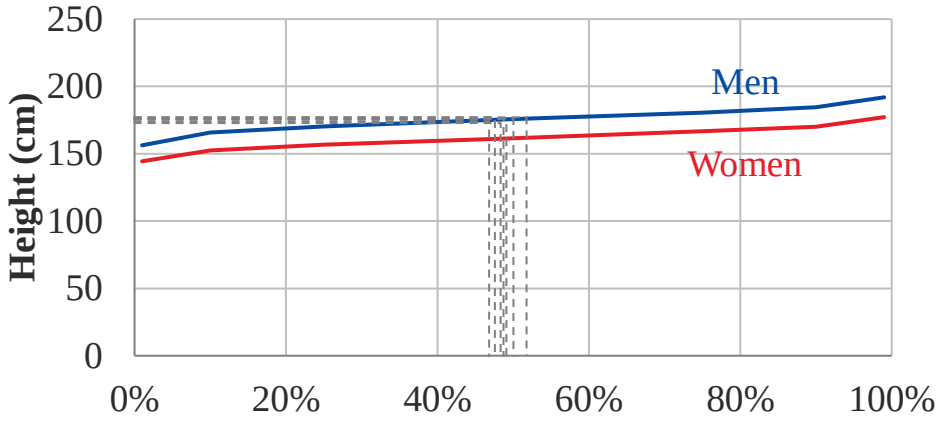
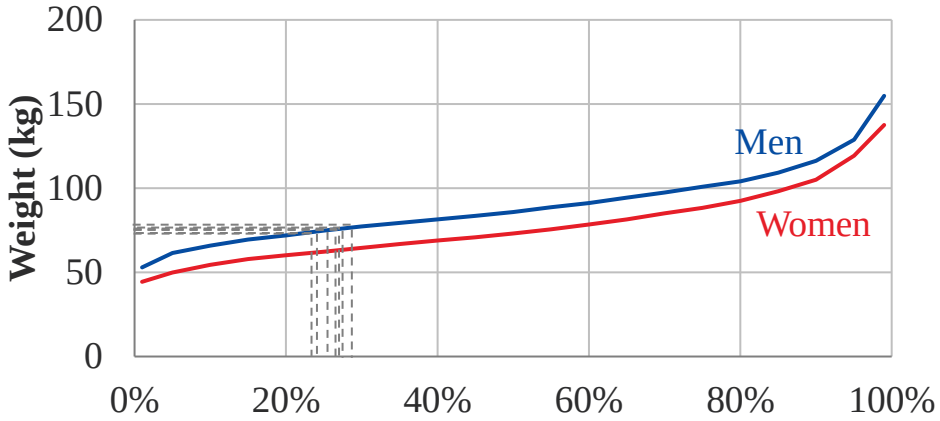
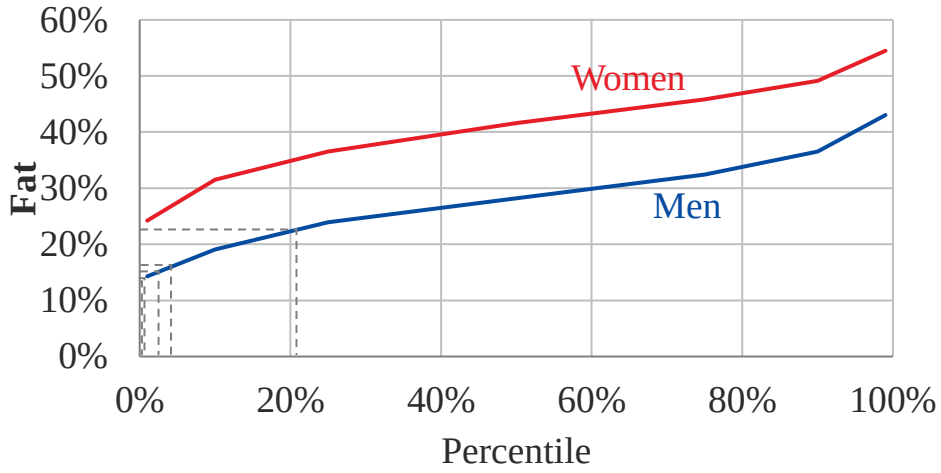
Source	Height (cm)	Weight (kg)	Fat (%)
Stolwijk (1971)	172	74.1	15







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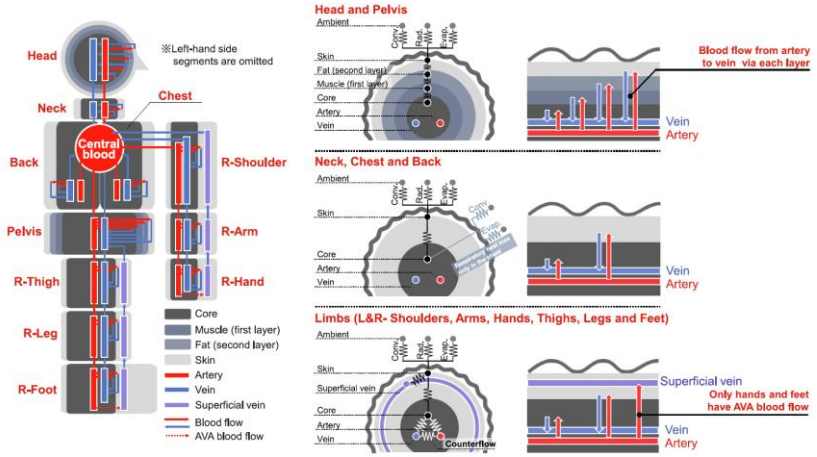

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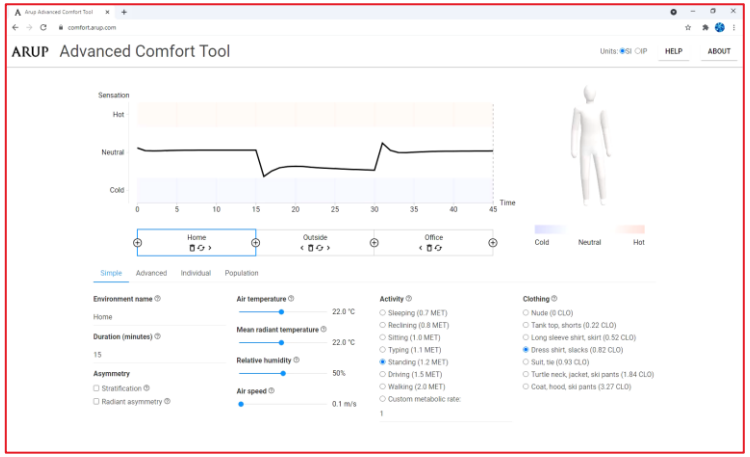

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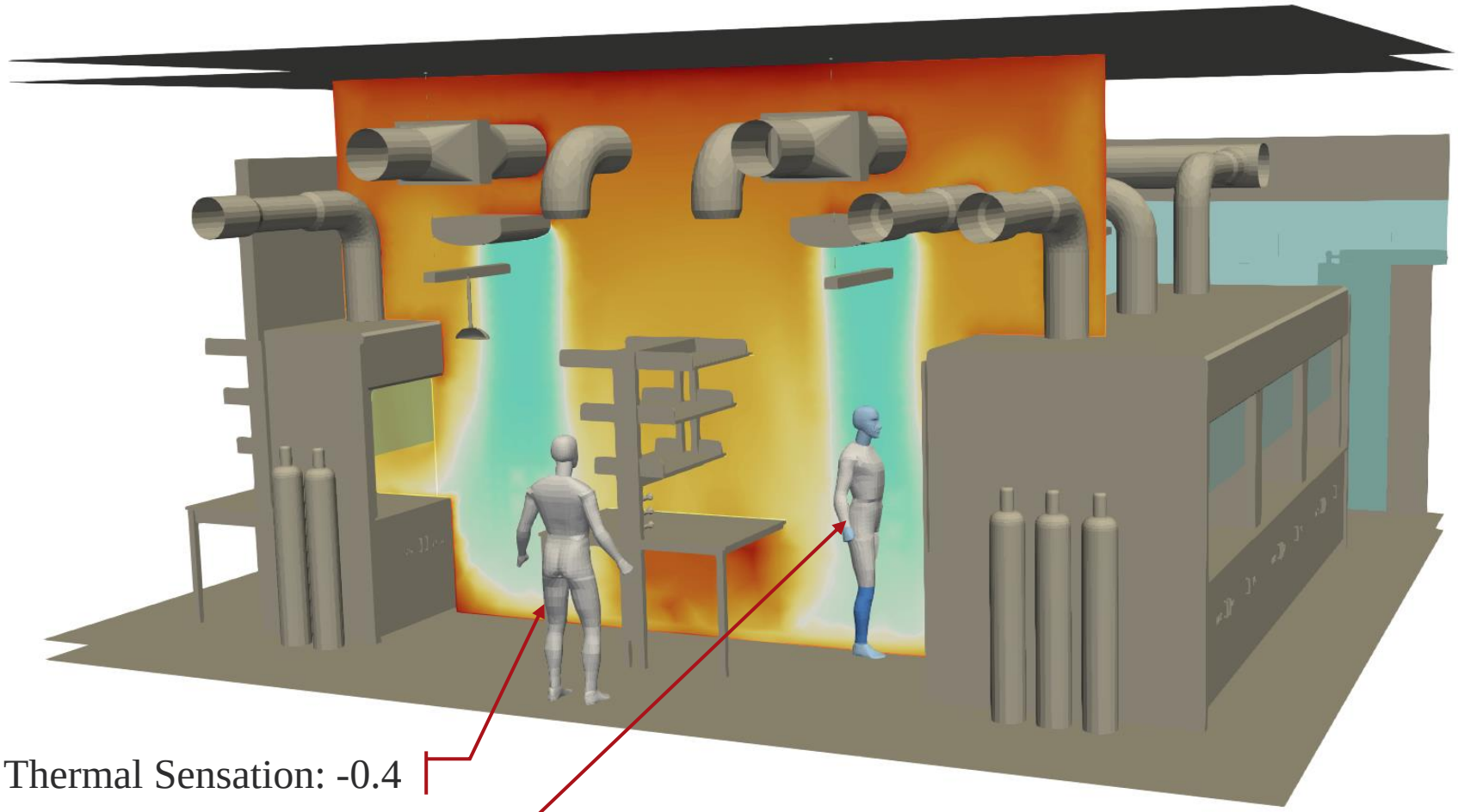
Air

80 °F

70 °F

60 °F



Thermal Sensation: -0.4

Thermal Sensation: -1.1
Legs and hands colder

Occupants

Hot

Warm

Neutral

Cool

Cold

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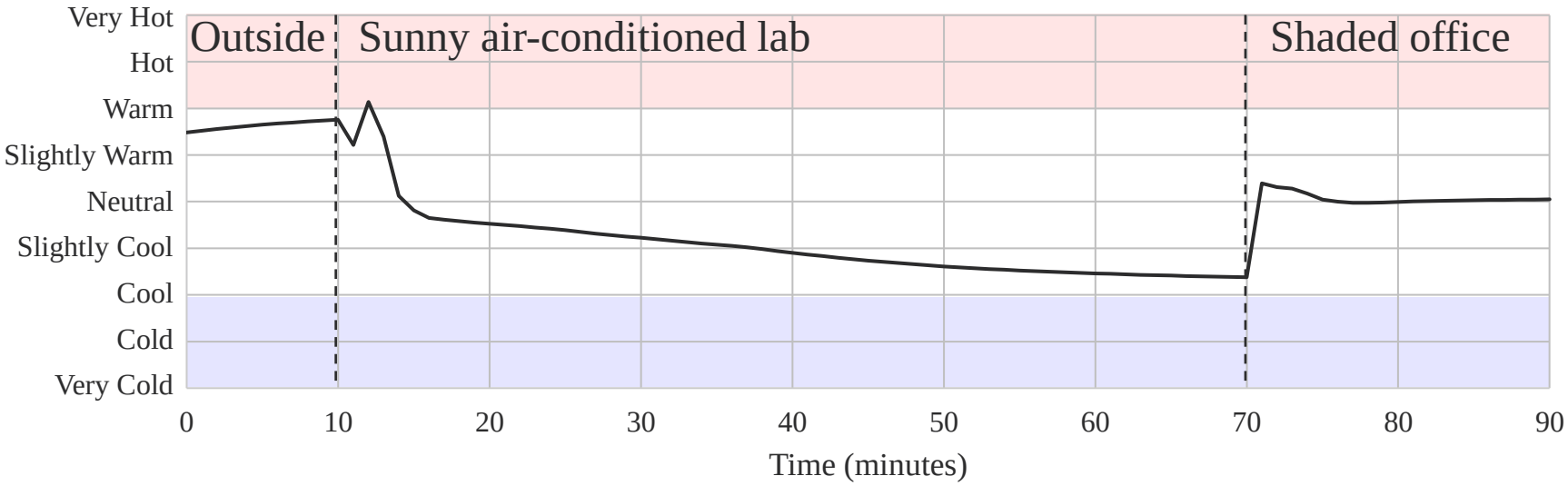
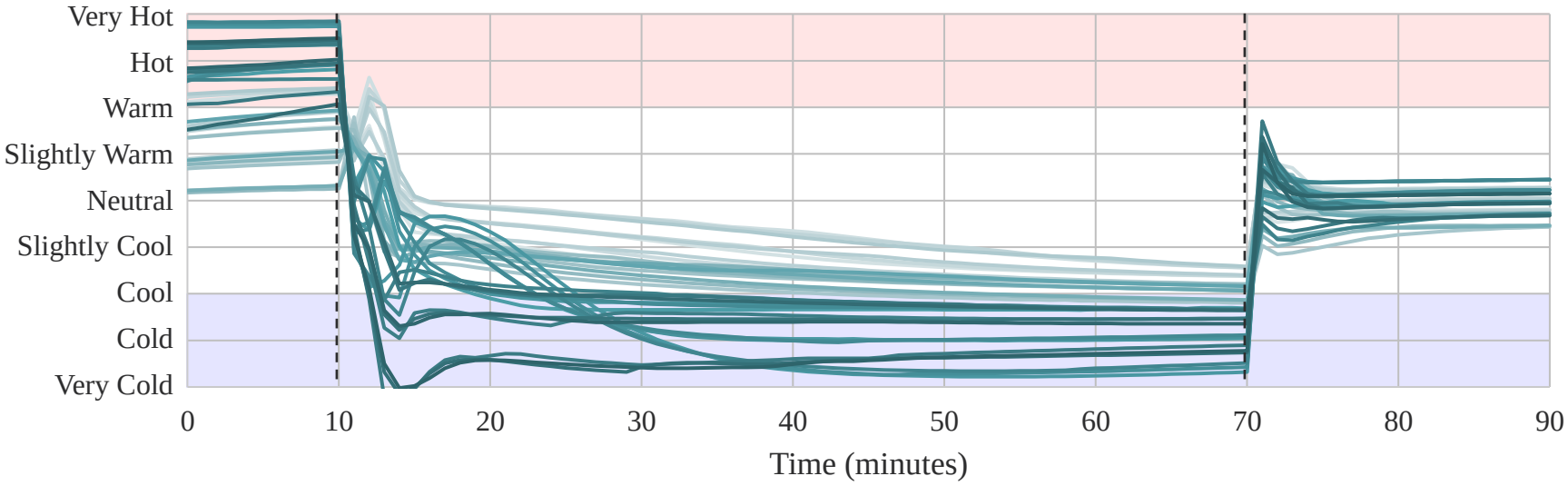
Thermal Comfort of “Standard Man”



Population Thermal Comfort



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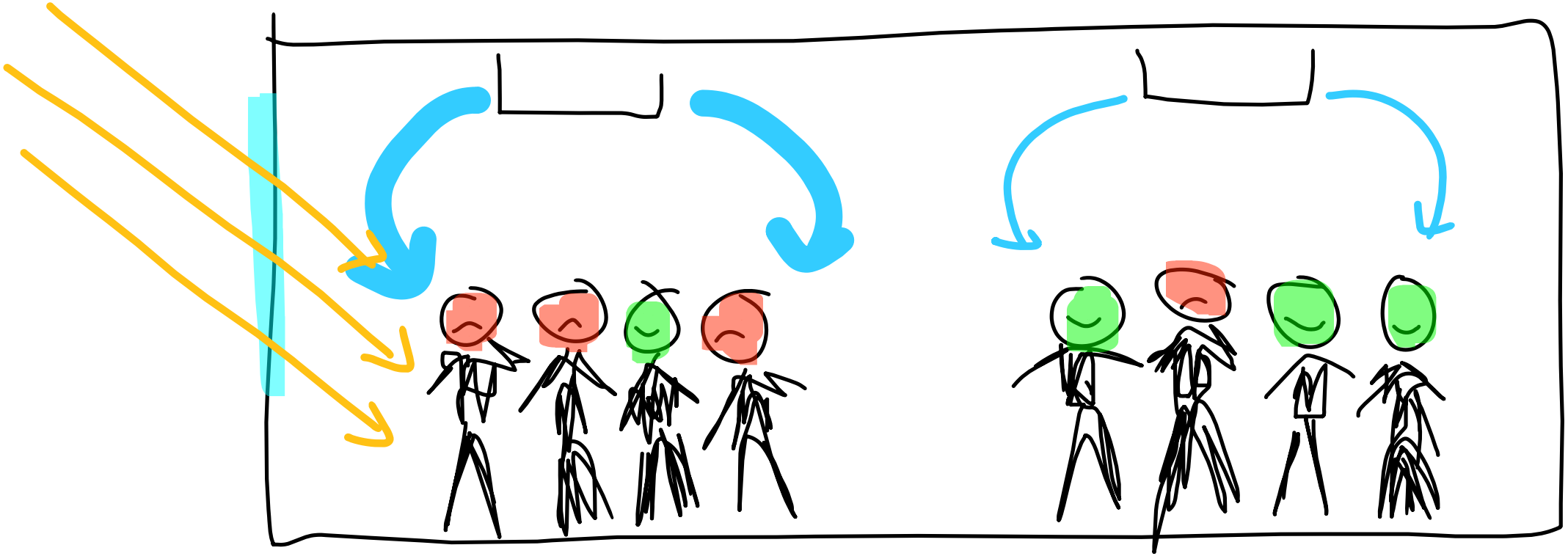

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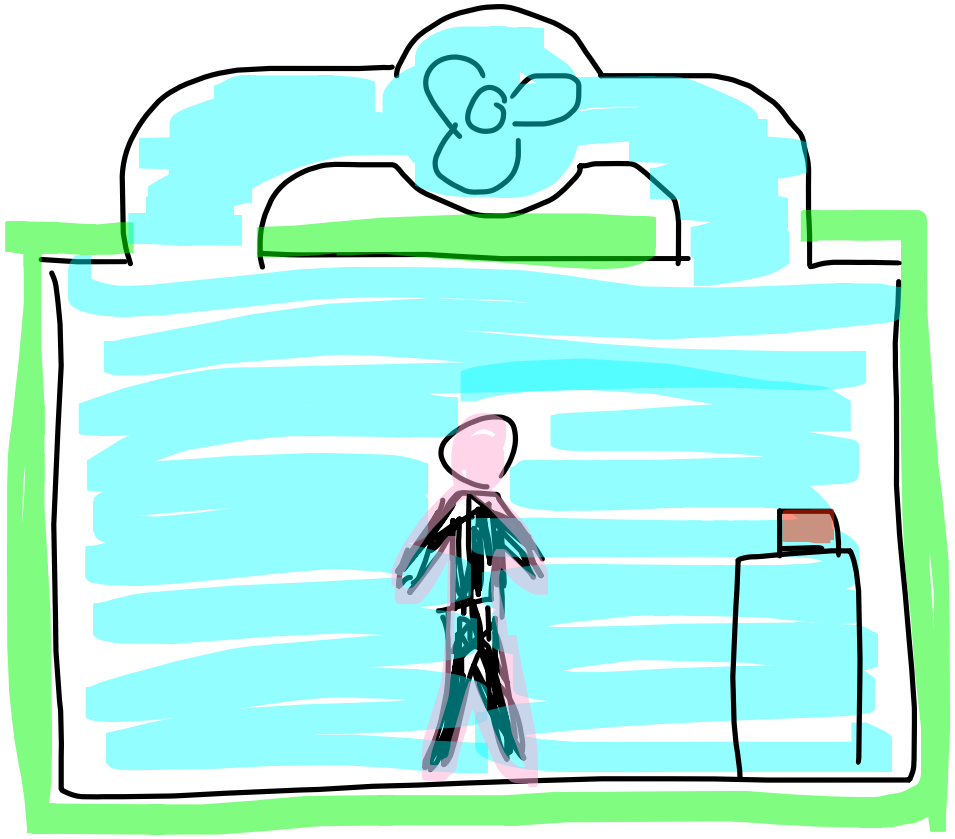
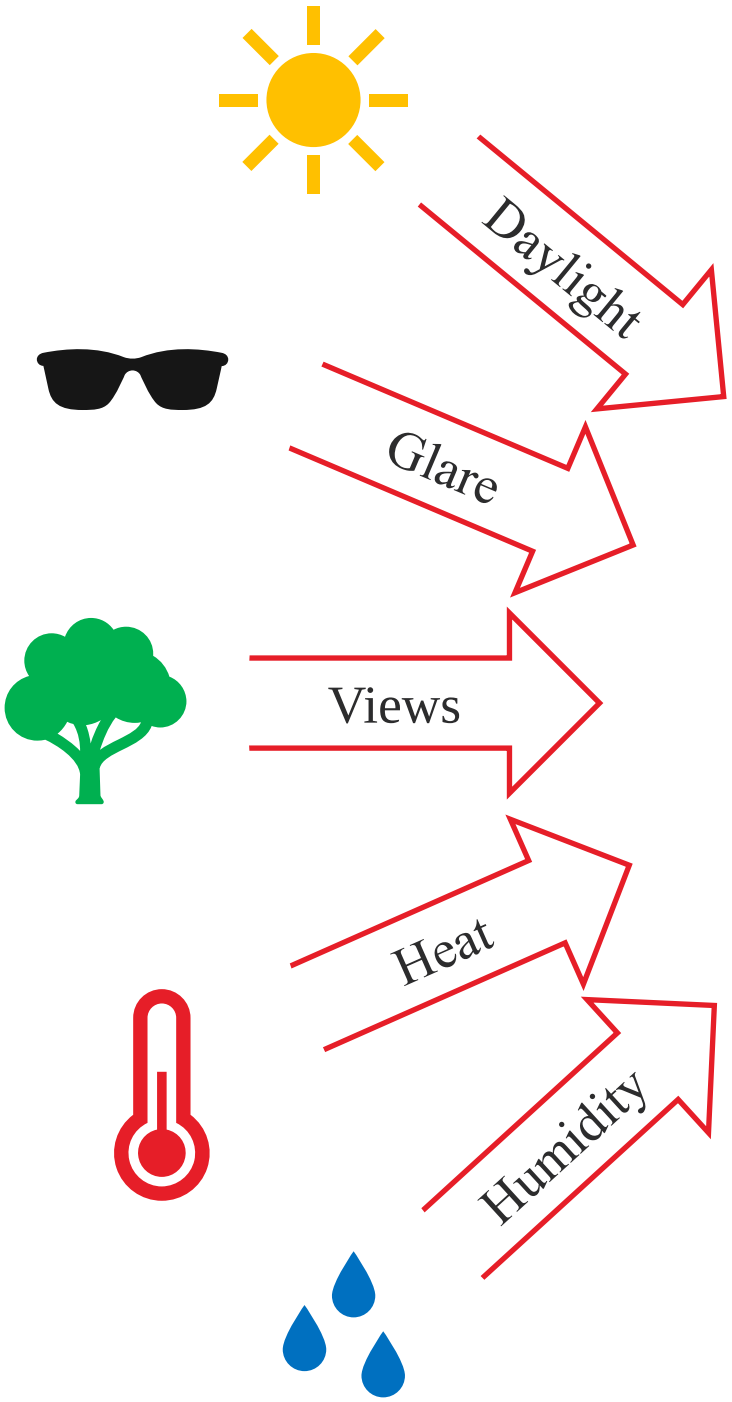
Designing indoor air quality for lab occupants



- [x] Filtering HVAC system
- [x] Low emission materials
- [x] Monitoring
- [x] Space use
- [x] Occupants



Questions?

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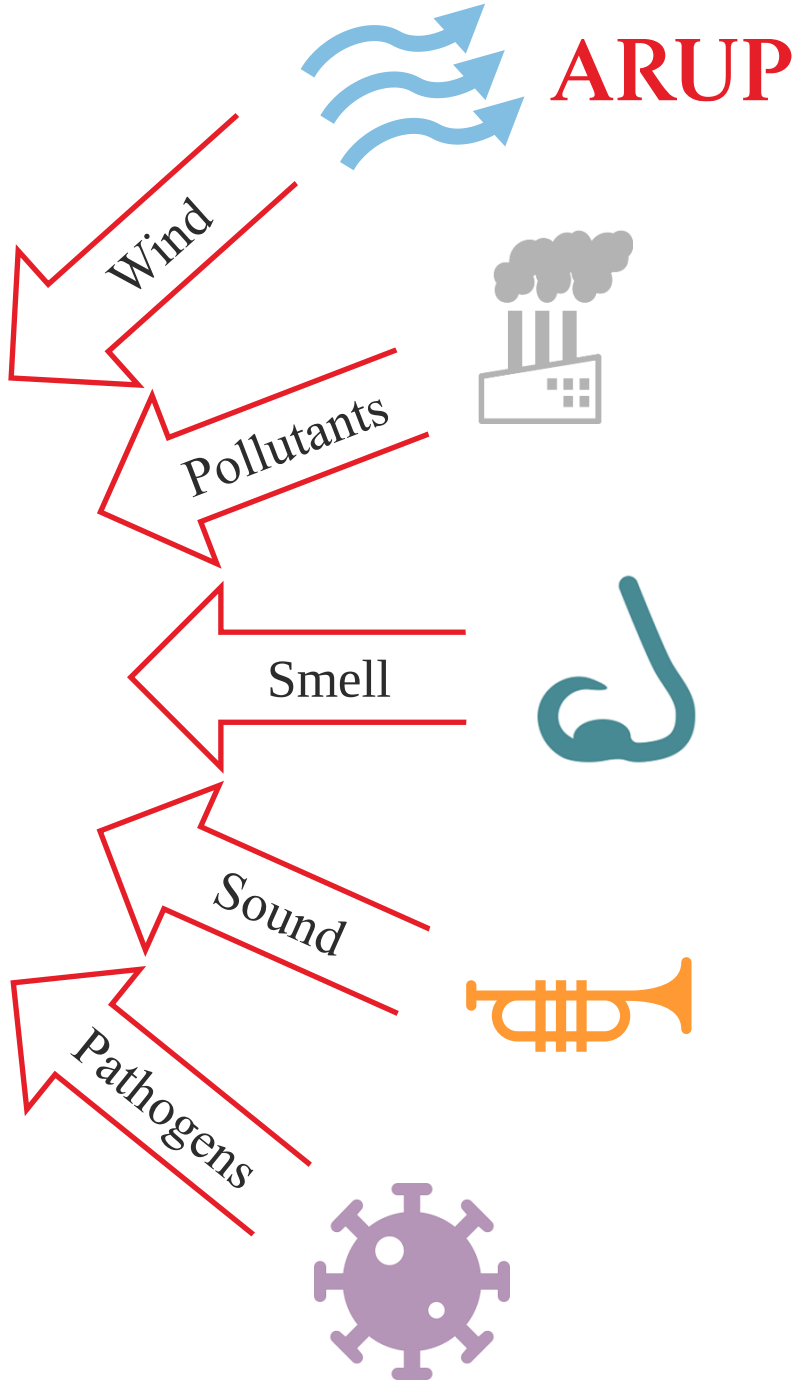

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