AIR LAB
AEROSOL INTRUMENTATION RESEARCH

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Low-Cost Sensors to Optimize Ventilation Systems

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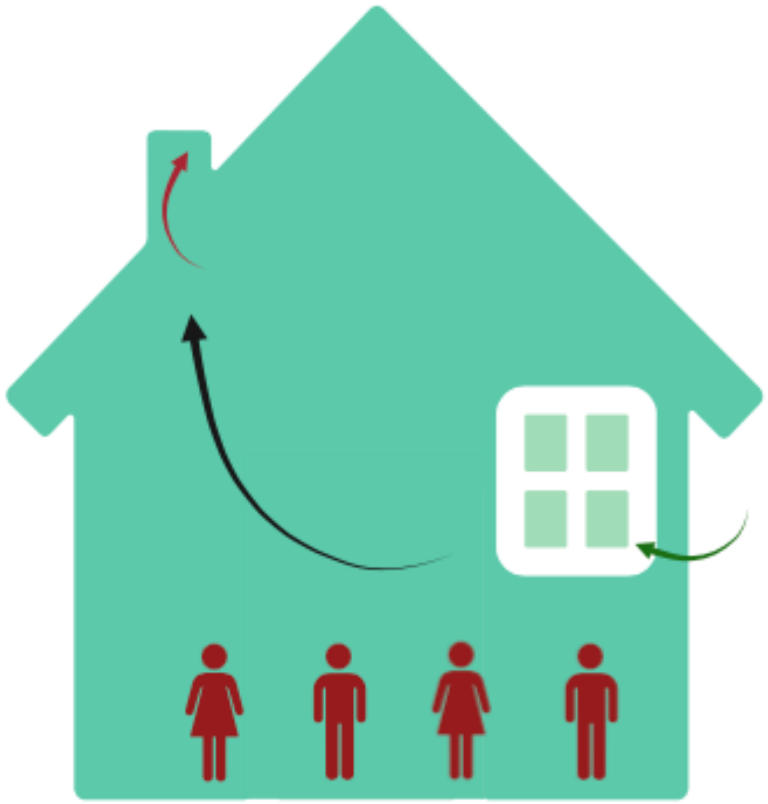
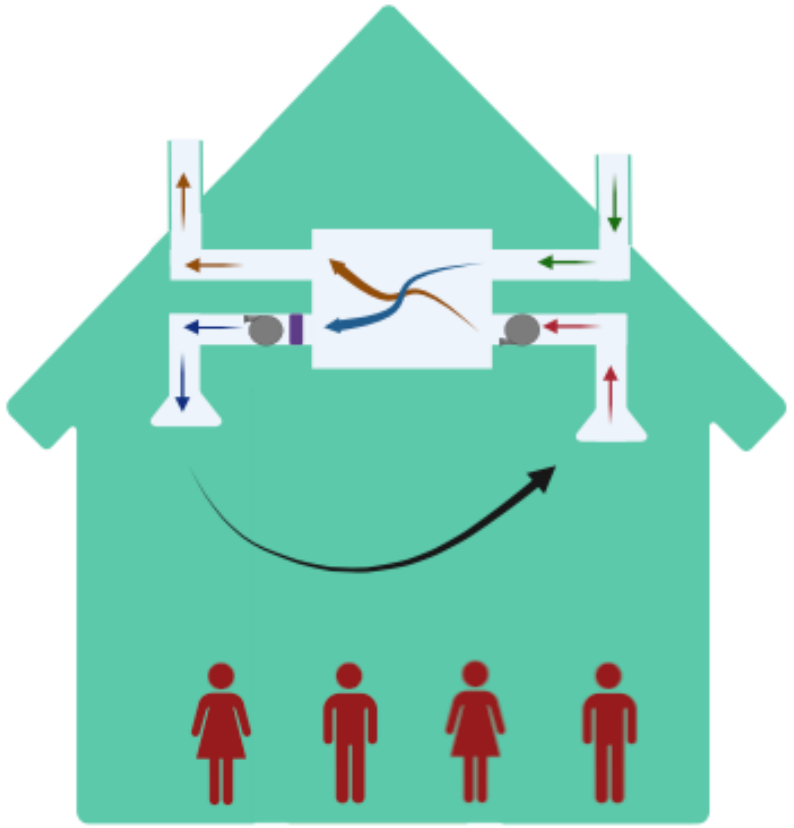
Ventilation – healthy air vs. energy efficiency

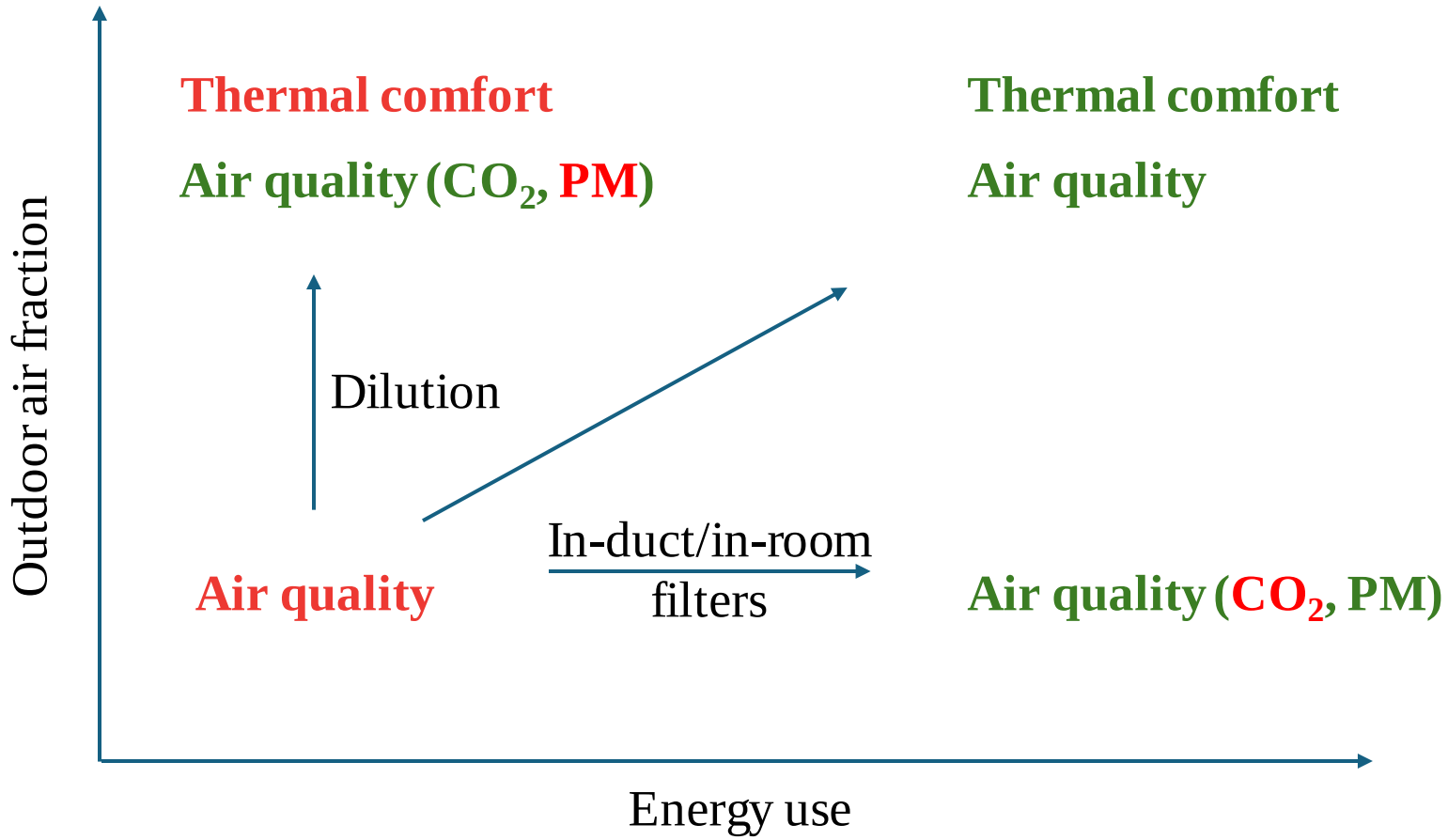
- ASHRAE
  - More outdoor air
  - Dilution – CO_2, airborne particles

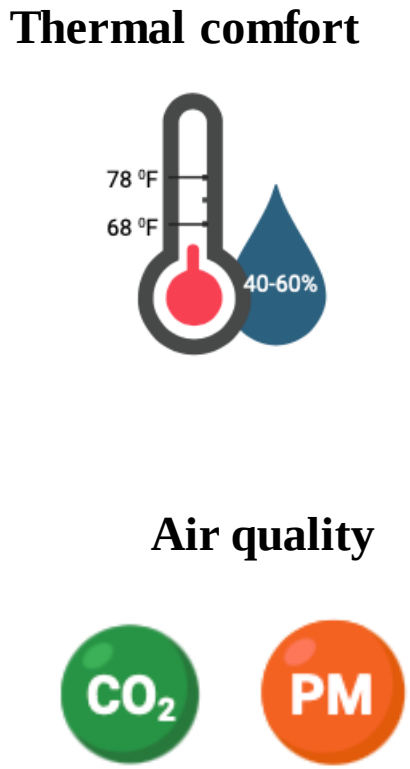


- U.S. DOE
  - More air recirculation
  - Energy saving



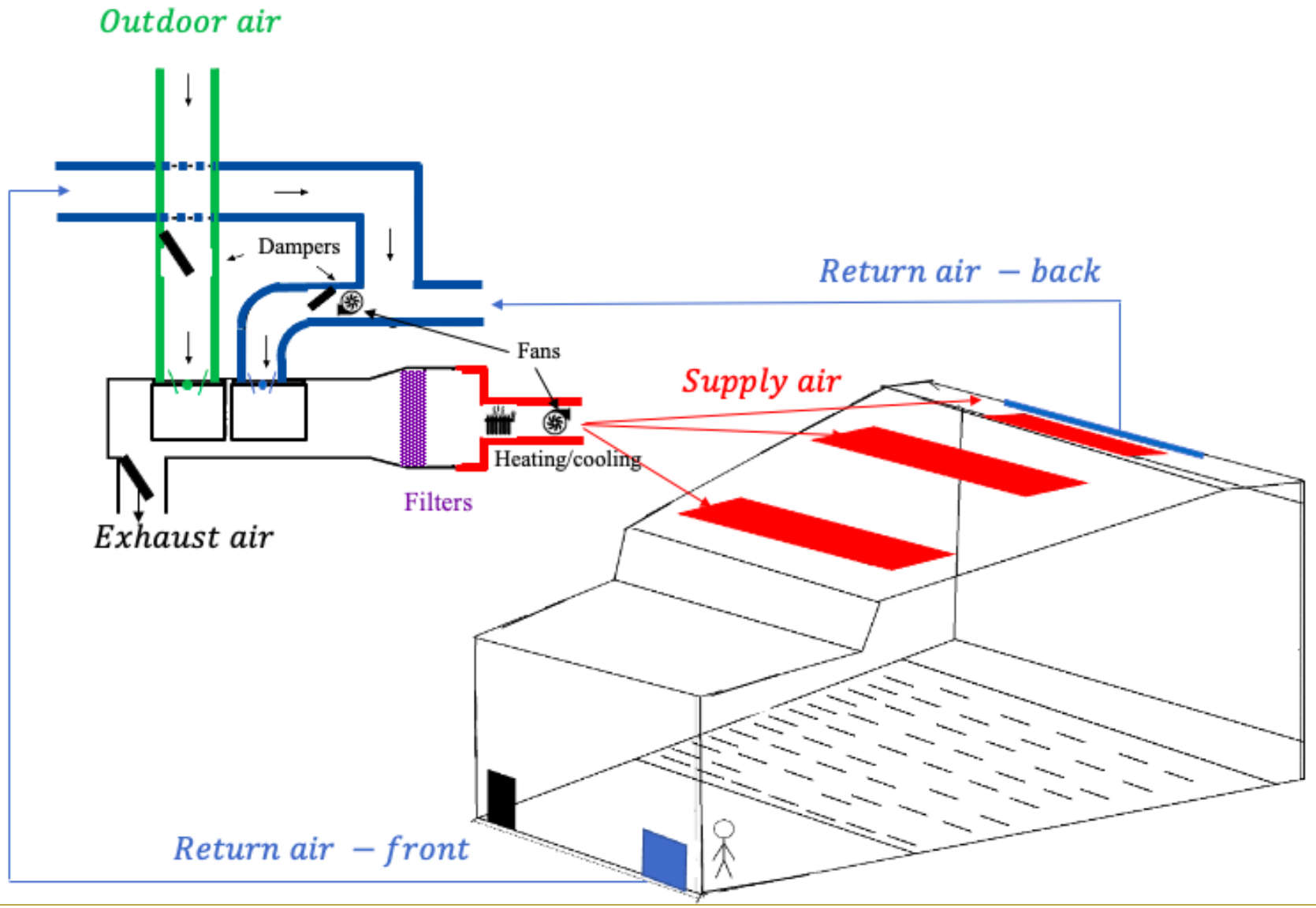
Ventilation systems: current state of the art





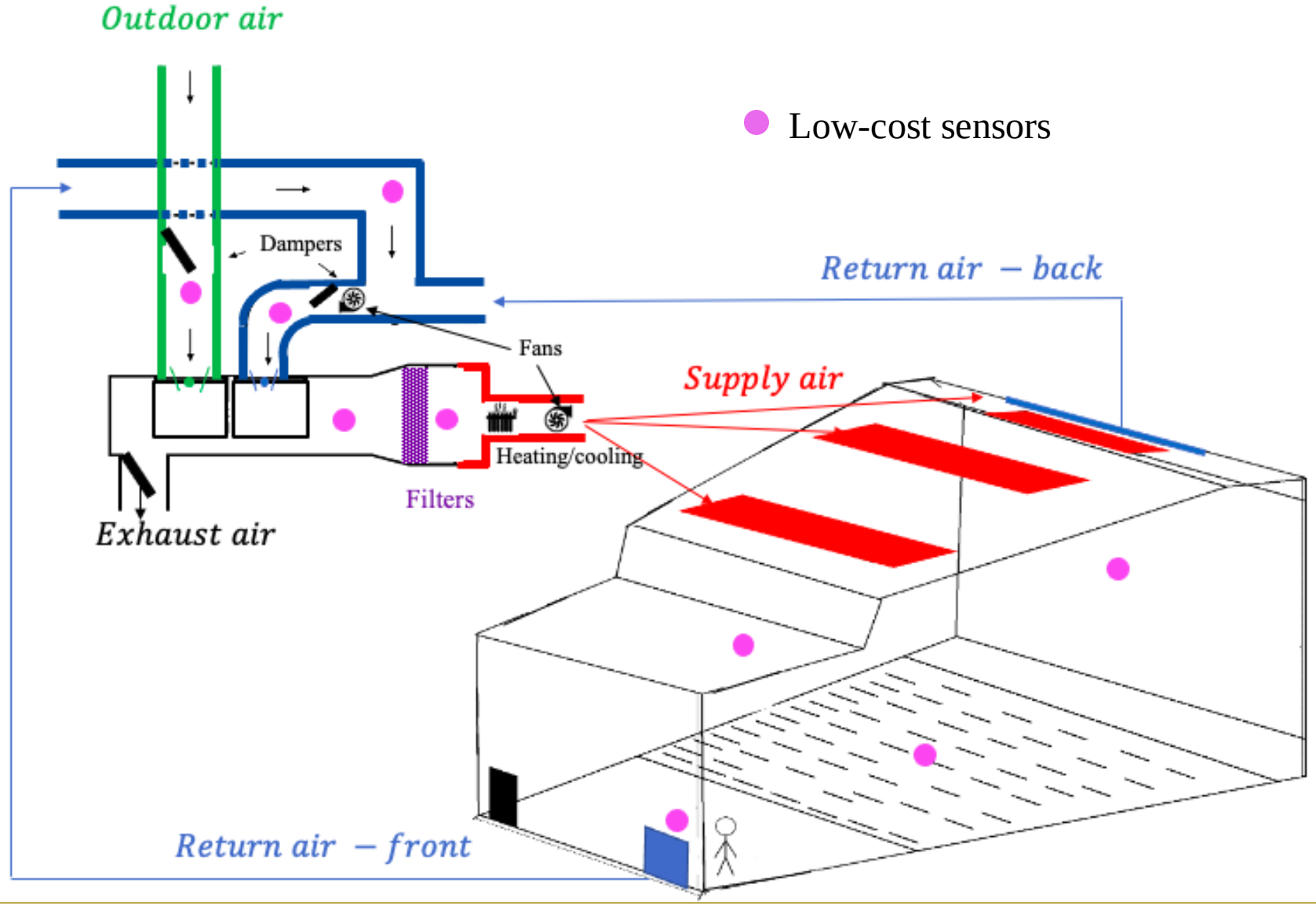
Responsive ventilation system - driven by extensive measurements

Testbed



- Average occupancy: 65
- Total volume: 660 m^3
- Floor area: 110 m^2

Testbed



Low-cost sensors

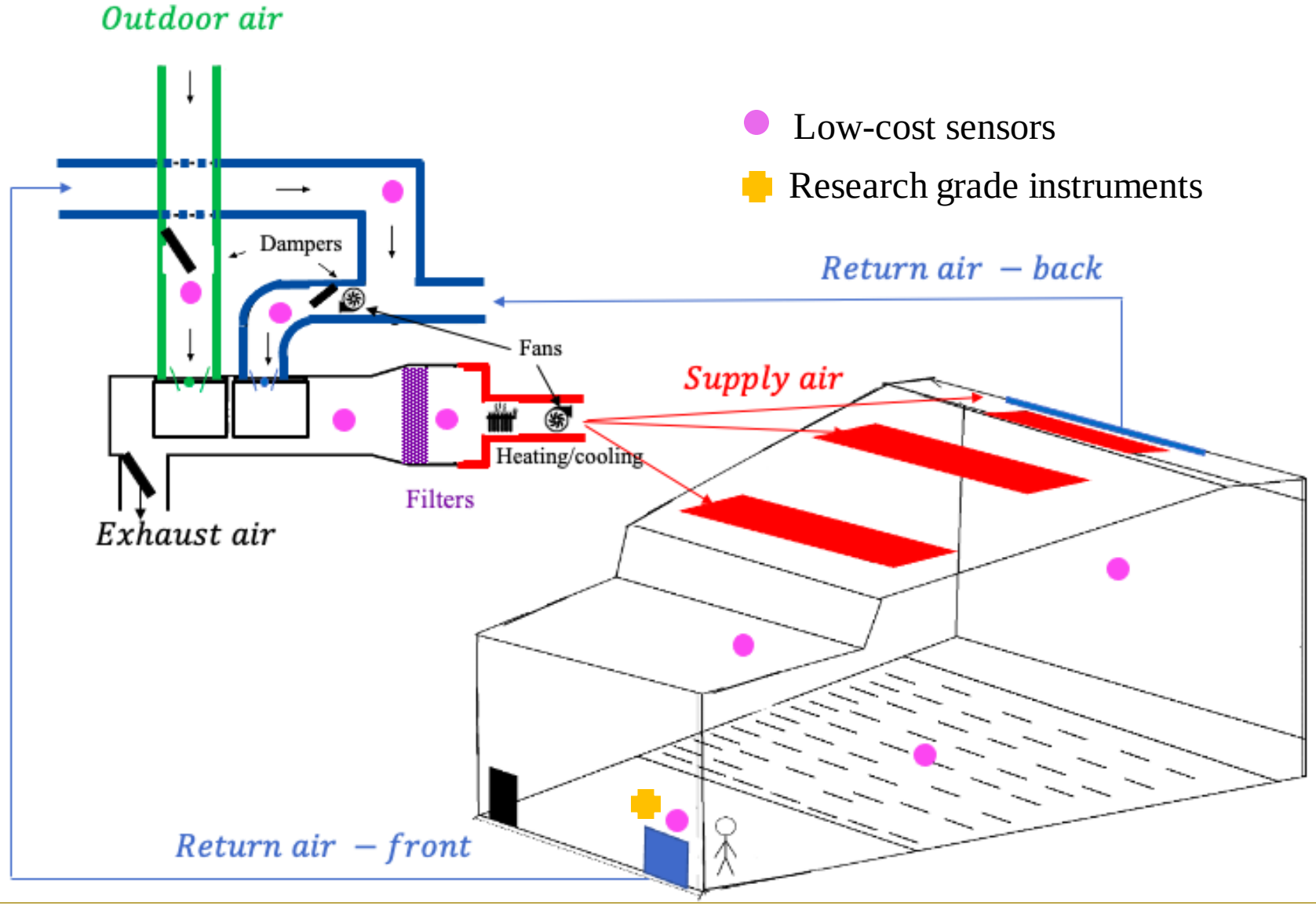
CO_2, T and RH

SCD 41

PM levels

PMS5003

Testbed

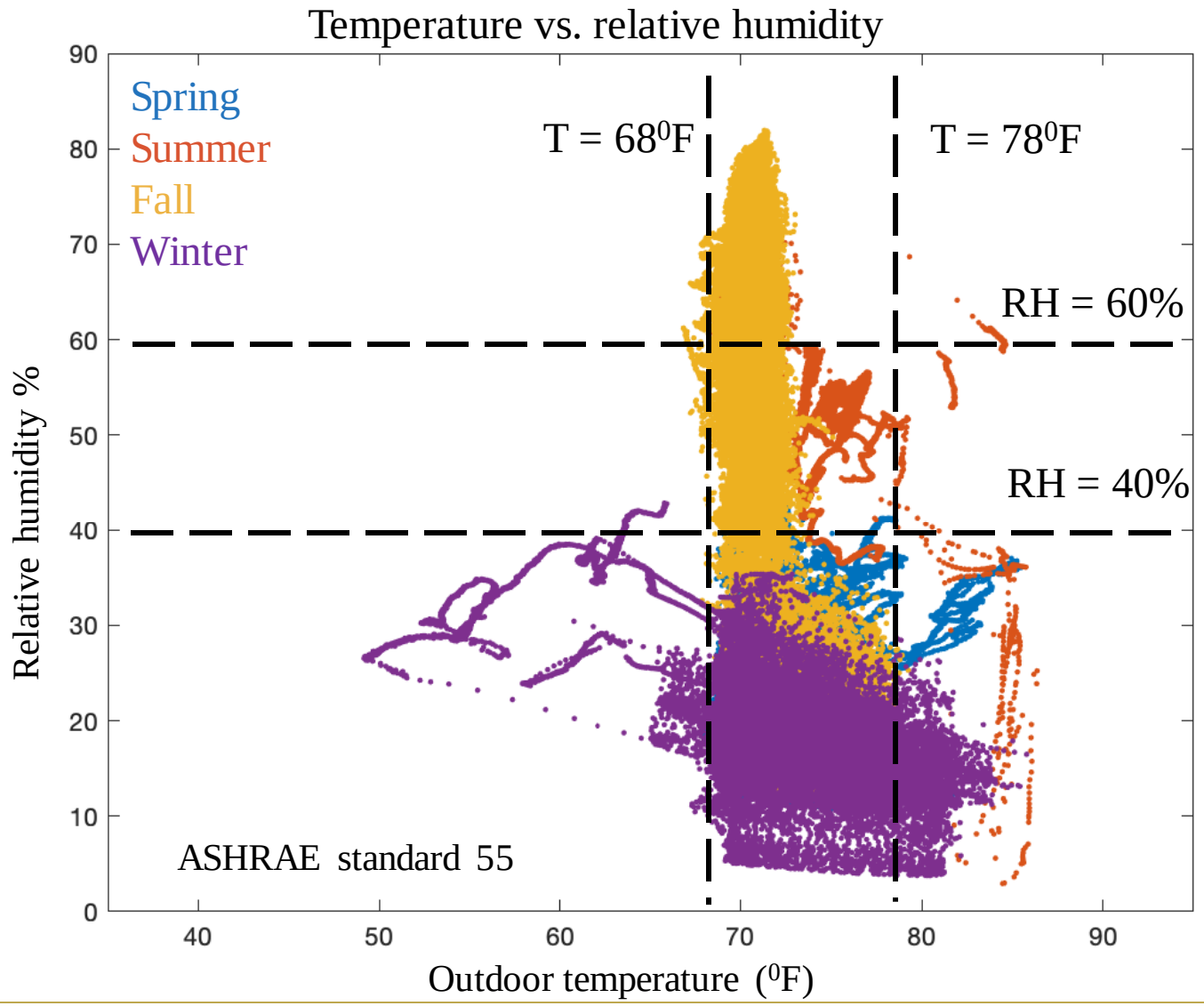


UHSAS (DMT)

APS(TSI)

SMPS(TSI)

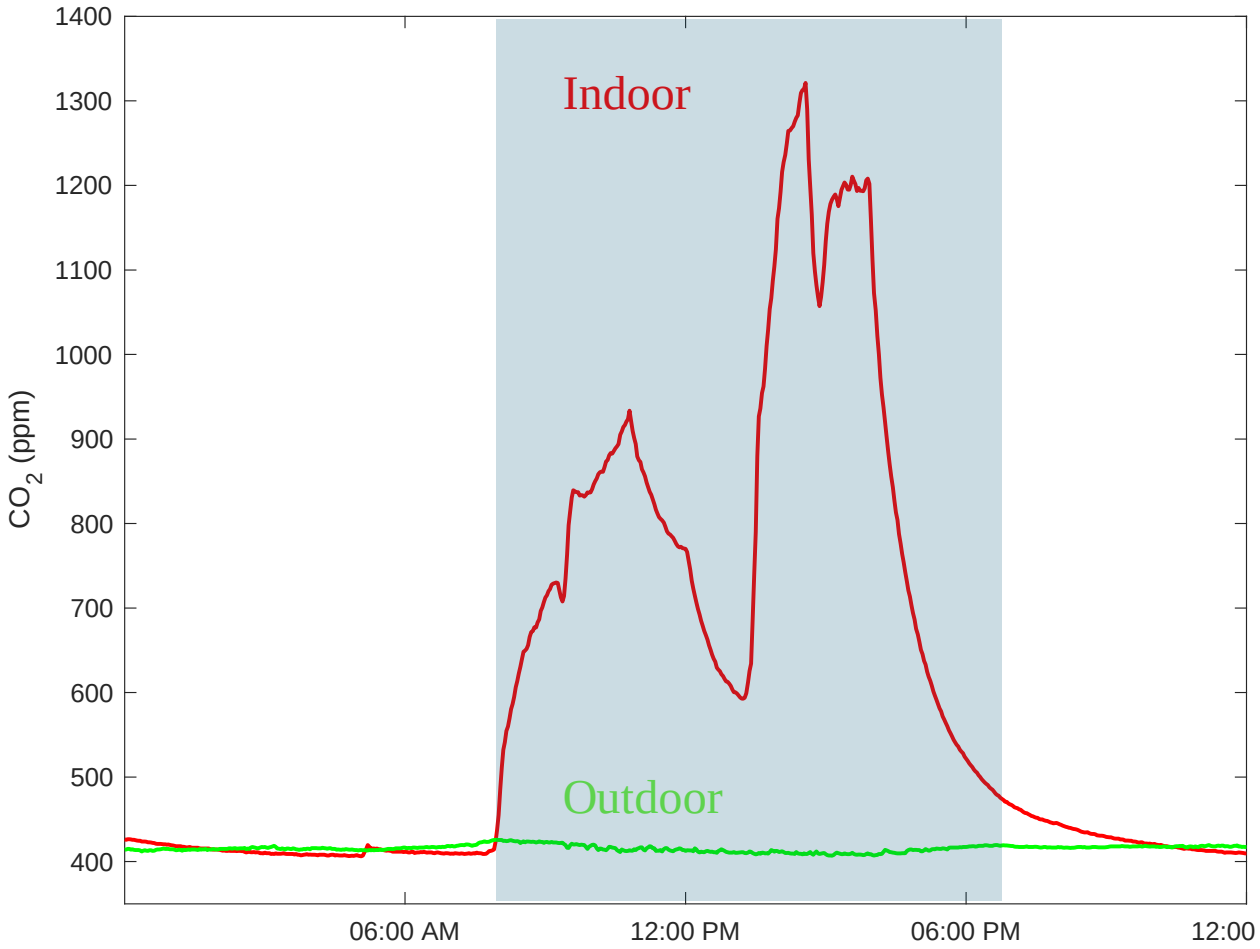
Thermal comfort



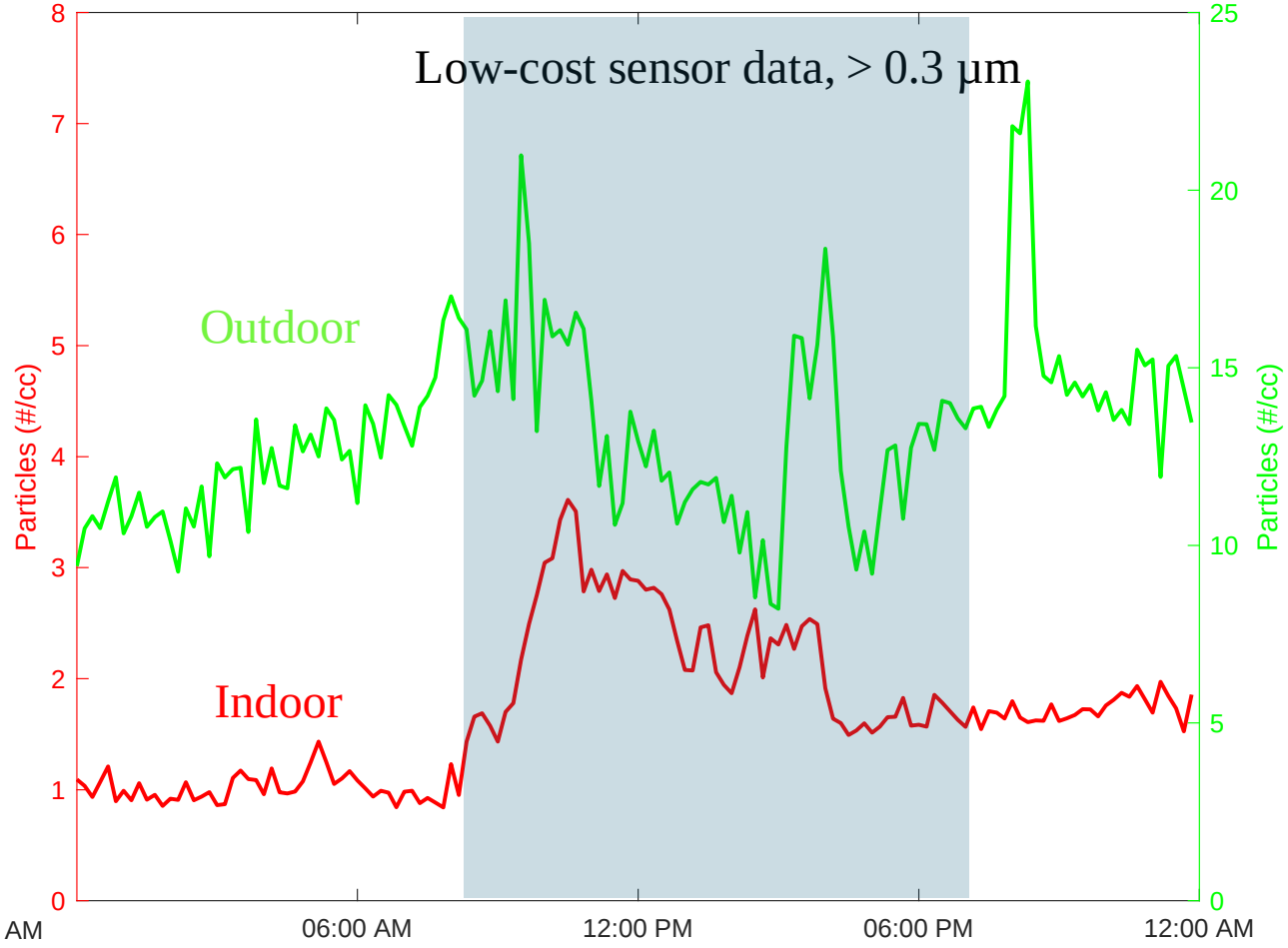
- Temperature regulated within a tight range
- Relative humidity lower than recommended, especially in spring and winter
  - Air heating in spring makes air dry
  - No humidifying/dehumidifying of air

Daily variations of CO_2 and particles

CO_2 concentration



Particle concentration



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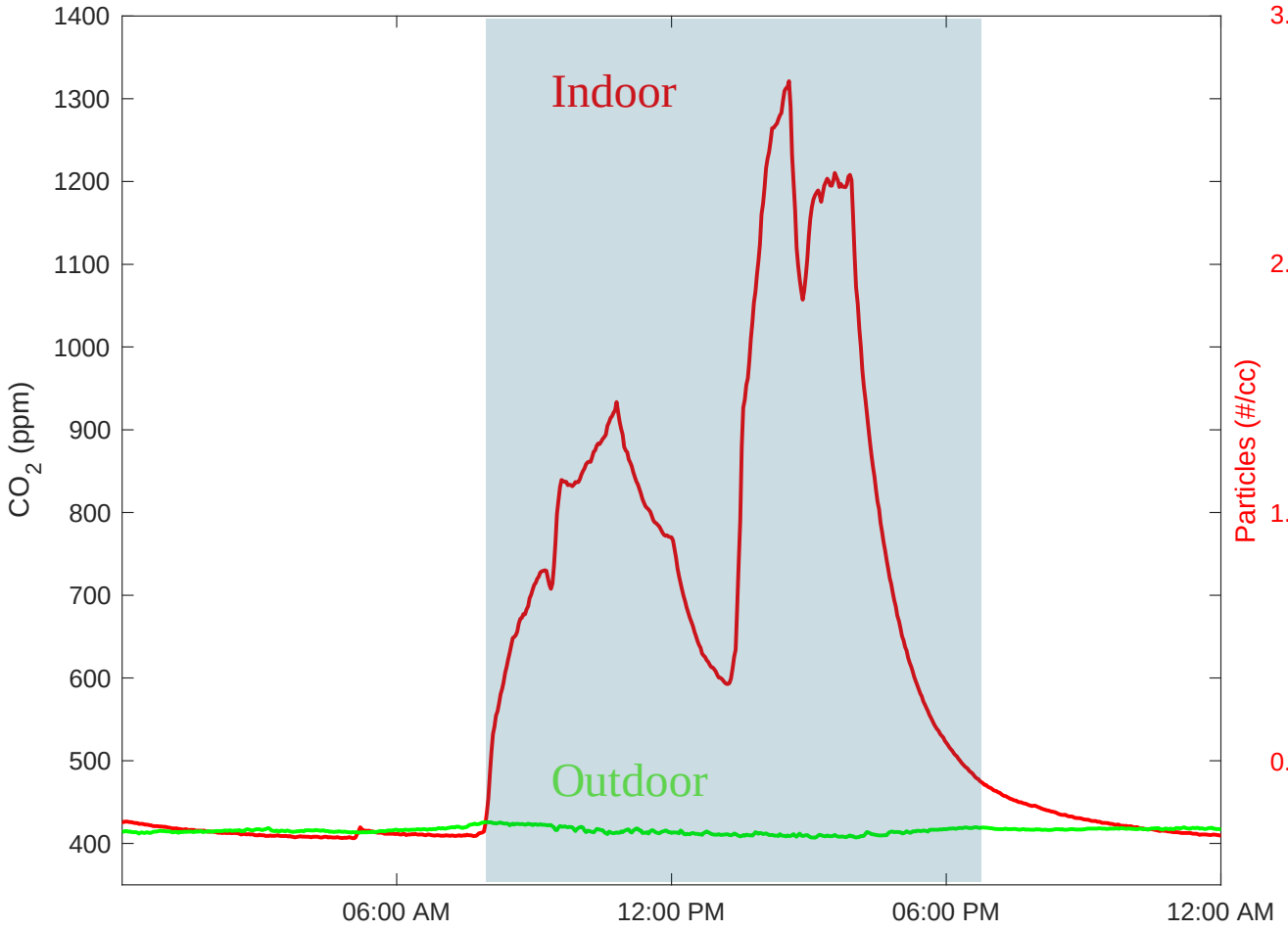
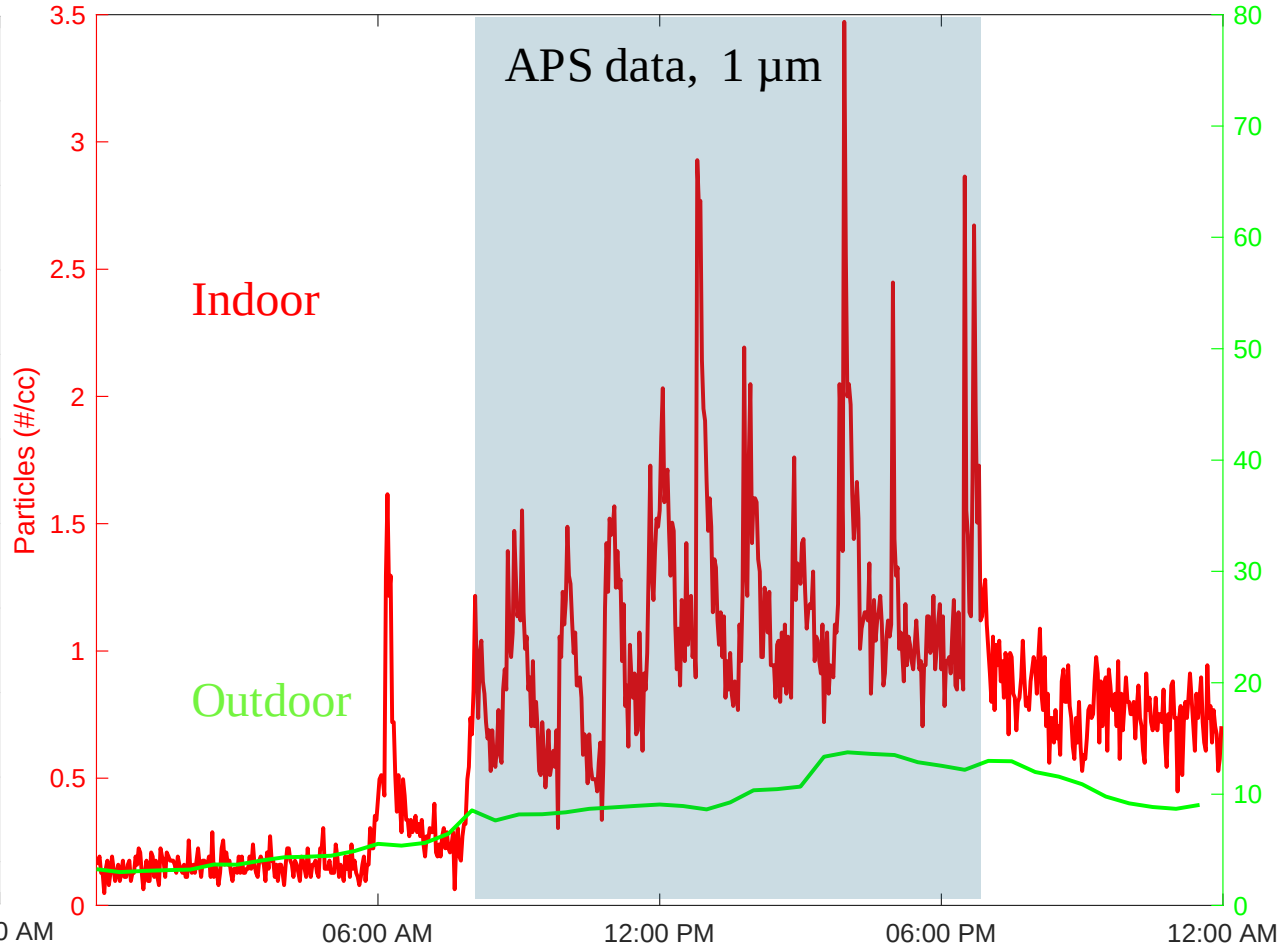
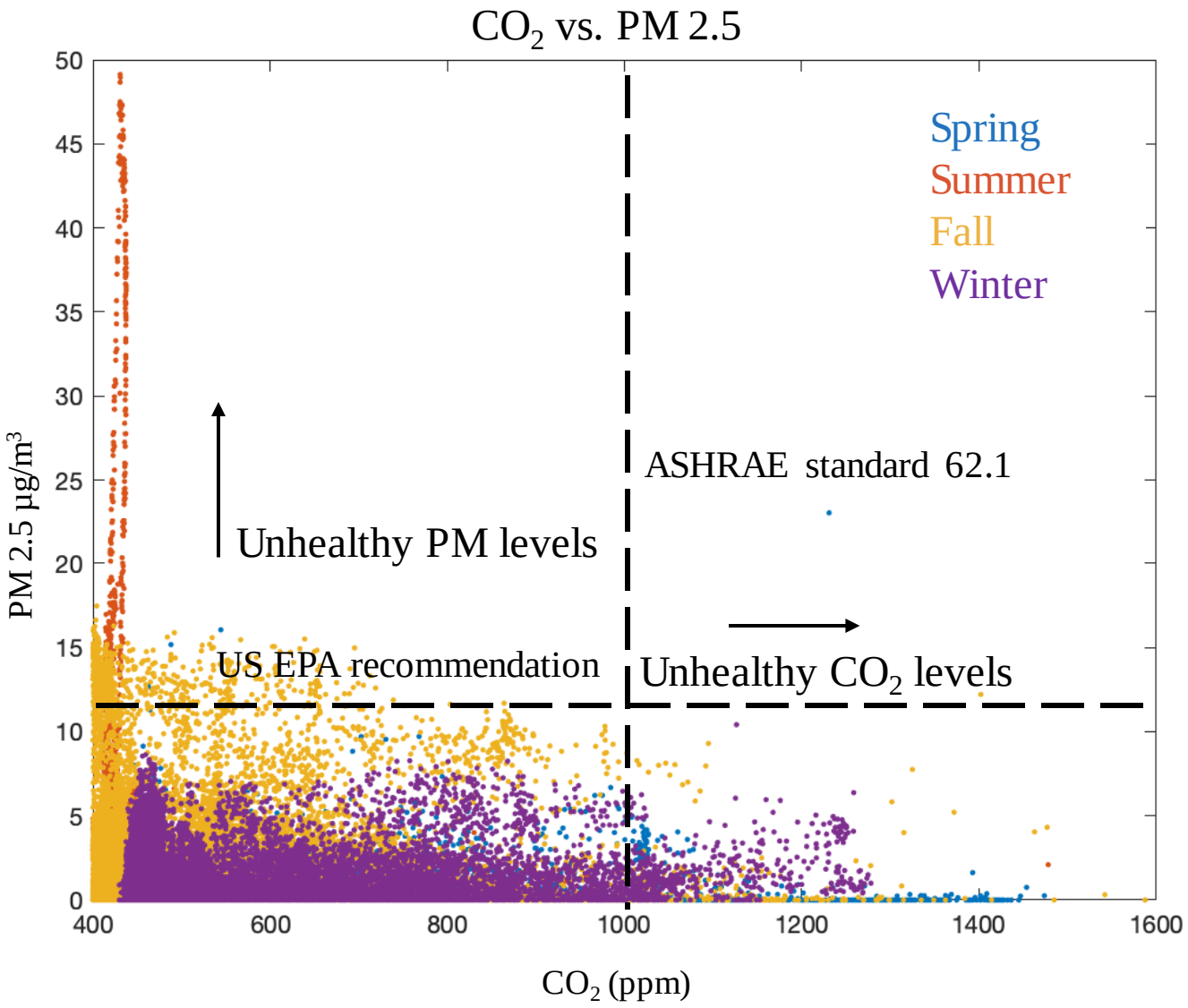


Particle concentration

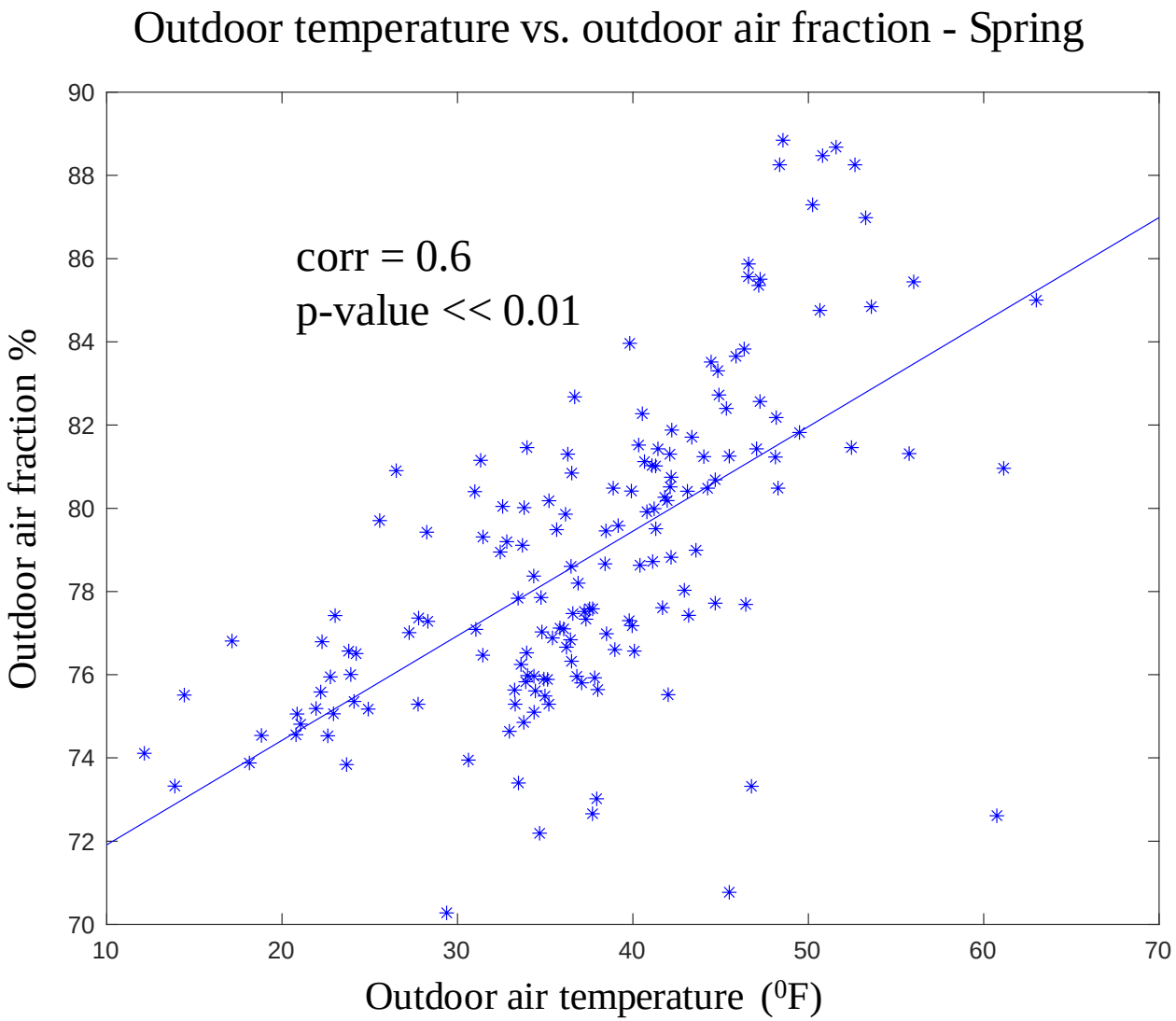


Air quality



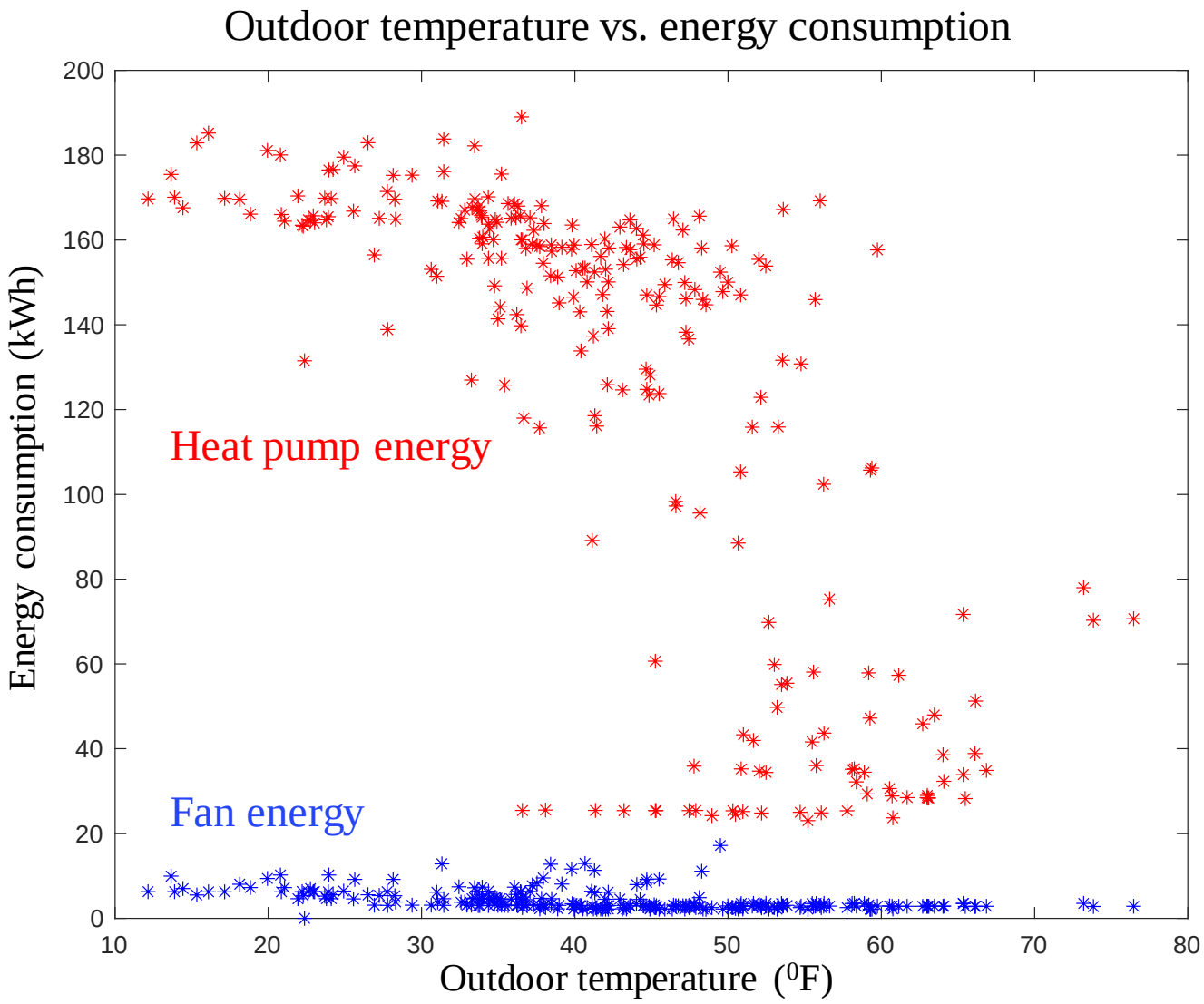
- CO_2 exceeds > 1000 ppm when outdoor air is less (spring and winter)
- PM level stay within healthy limits, except for high outdoor air periods

How outdoor air fraction is decided?



- Our ventilation system can adjust the outdoor air fraction based on outdoor temperature
- Minimum setting: 10%

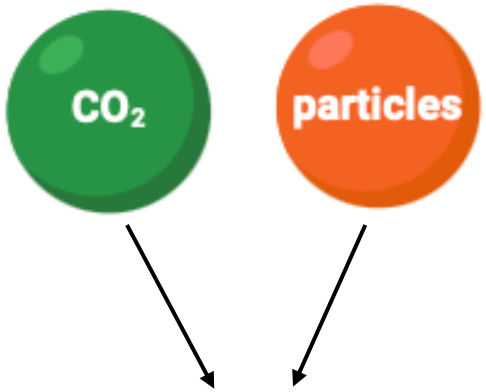
Energy implications



- Fan energy < 20 kWh
- Heating energy is the biggest portion
- Saving energy used for heat pump should be the goal

Air quality index

Air quality

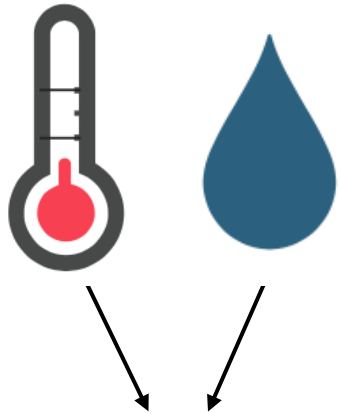


Air quality Index (AQI)

AQI	0 - 50	51-100	101-150	150-200	201 - 300
CO_2 (ppm)	0 - 800	801 - 1000	1001 - 1200	1201-1400	1401 - 1600
Particles (#/l)	0 - 1000	1001 - 2000	2001 - 3000	3001 - 5000	5001 – 100000

Comfort index

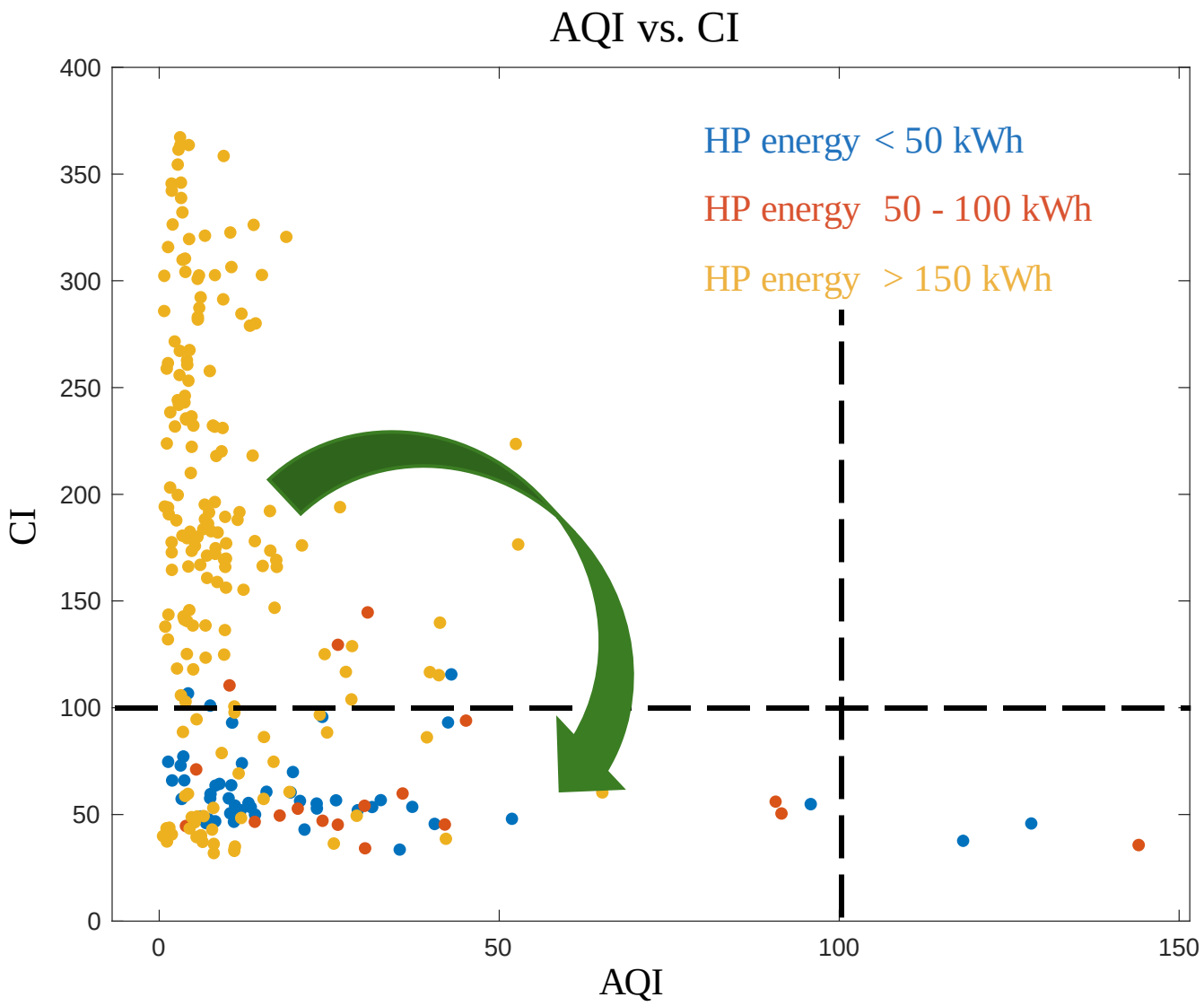
Thermal comfort



Comfort Index (CI)

CI	51 - 500	0 - 50	51 - 500
Temperature (^{0}F)	23 - 67	68 - 78	79 - 122
Relative humidity (%)	0 - 29	30 - 60	61 - 100

AQI vs. CI



- AQI is in healthy levels
- High energy is consumed for heating
  - CI (relative humidity) is compromised

Our goal: Reduce the energy used, stay in the acceptable air quality region

Summary

- Indoor air quality control requires minimizing both air quality (CO_2, PM) and thermal comfort (temperature, relative humidity).
- Our study shows that the approaches to optimize these two are often in contradiction with each other.
- Typical ventilation systems cannot provide a 3-way balance between energy efficiency, indoor air quality and thermal comfort.
- Given changing outdoor conditions and indoor needs, an AI/ML based ventilation control system can help achieve the 3-way balance.

Thank you

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