Occupant-centric operation of academic buildings

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DBOM

Data-driven Building Operation and Maintenance
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Our objective is to improve **energy efficiency and comfort** in **existing buildings** through **operation, maintenance, and retrofit** decisions informed by **data analytics**.

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Brodie Hobson

Andre Markus

Pedram Nojedehi

Narges Zaeri

Narges Torabi

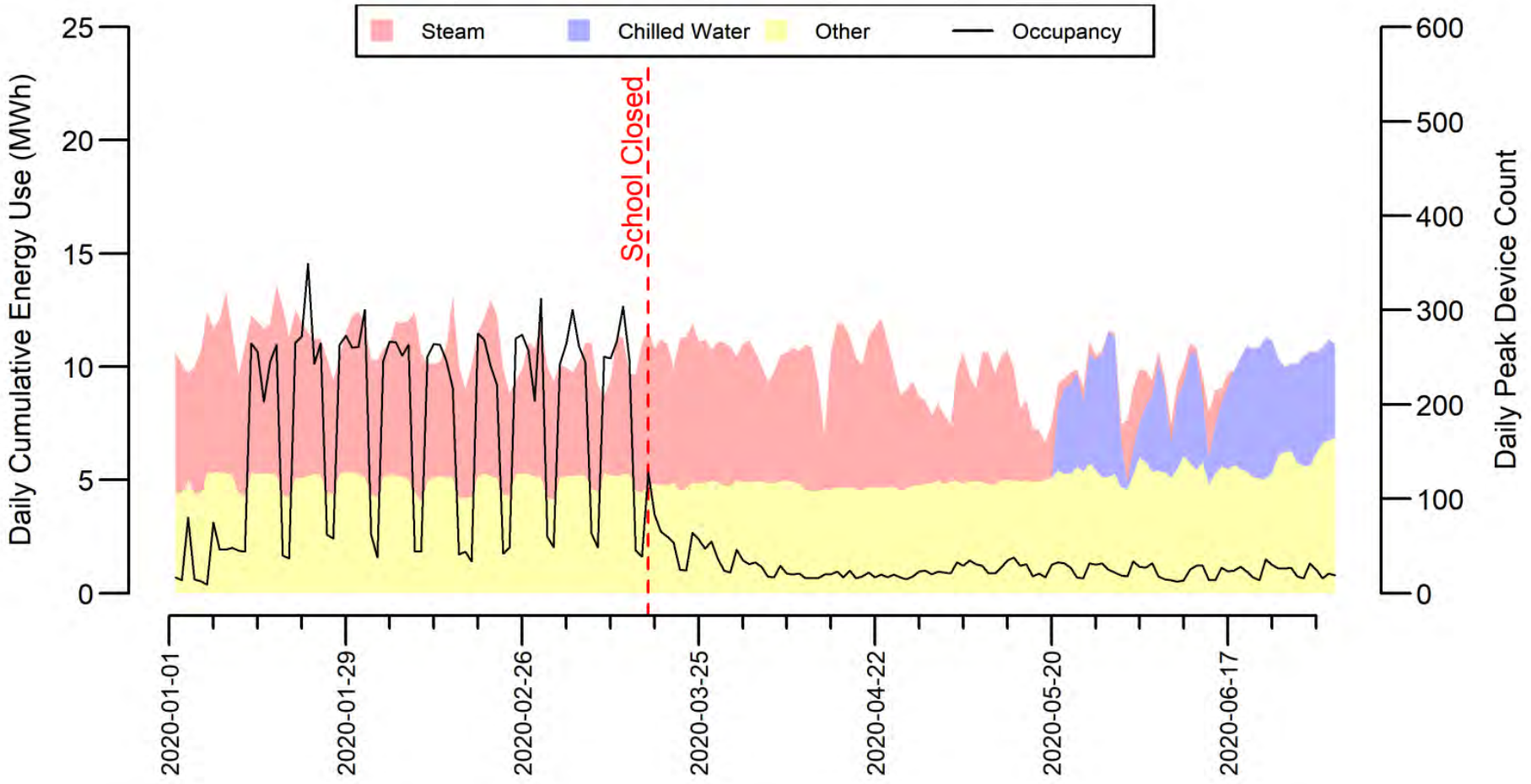
Zina Khorasanizadeh

Shane Ferreira

Hussein Elehwany

Arya Parsaei

- Building energy modelling
  - EnergyPlus
  - Algorithm development sandbox environment
  - Calibrated energy models
- Carleton as a living-lab
  - Densely instrumented floors in Canal & Health Sciences & EDC buildings
  - Submetering at the terminal device level
  - Over ten types of sensors integrated within BAS (e.g., light colour, illuminance, CO_2, PIR, humidity, window contact)
  - Read/write to the BAS
  - Ability add/remove sensors
- Field-scale research
  - Collaborations with NRC, PSPC, DND, Bentall GreenOak, BGIS, etc.
  - Large-scale data analysis and demonstration studies



Hobson, Brodie W., and H. Burak Gunay. "Evaluating the impact sequences of operation have on the implementation of occupant-centric controls." Energy and Buildings 266 (2022): 112121.

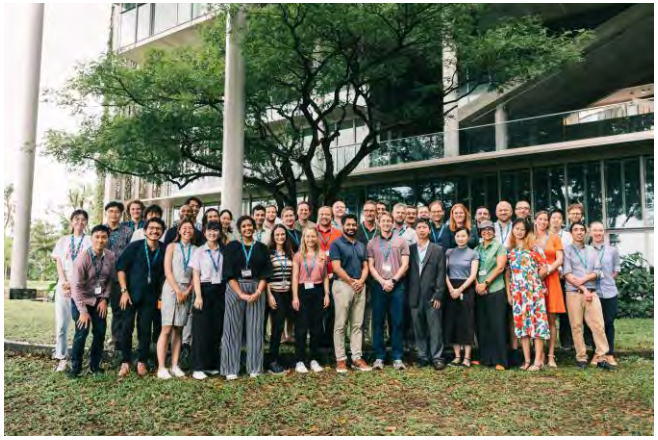
Agenda

- Occupant-centric controls (OCCs)
- Controls-oriented occupant data
- Occupant-centric sequences of operation
  - Using CO_2 sensing and motion detectors for ventilation control
  - Using motion detectors for zone mode of operation control
  - Using window contact sensors for zone-control
- Prerequisites for effective OCCs

Occupant-centric controls

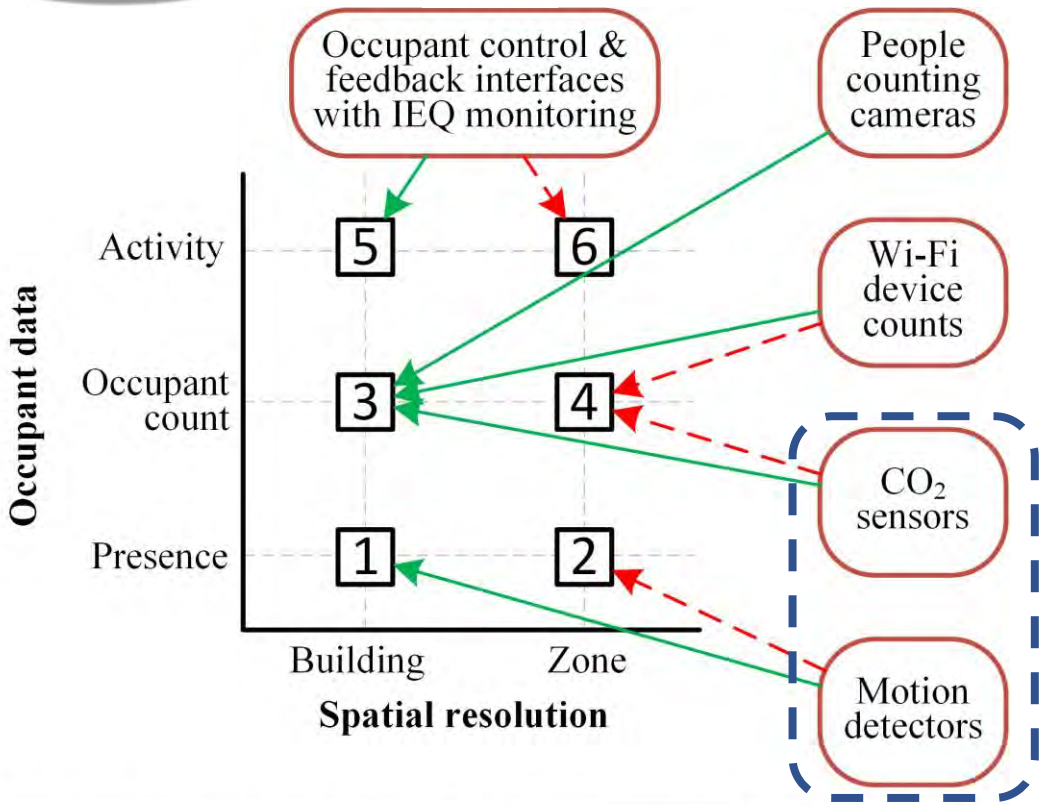
*Occupant-centric controls (OCC) is an **indoor climate control approach** whereby **occupancy and occupant comfort information** are used in the **sequence of operation of building energy systems**.*

IEA EBC Annex 79 on Occupant-centric Design and Operation of Buildings



BACnet thermostat

enOcean window contact sensors (with BACnet gateway)

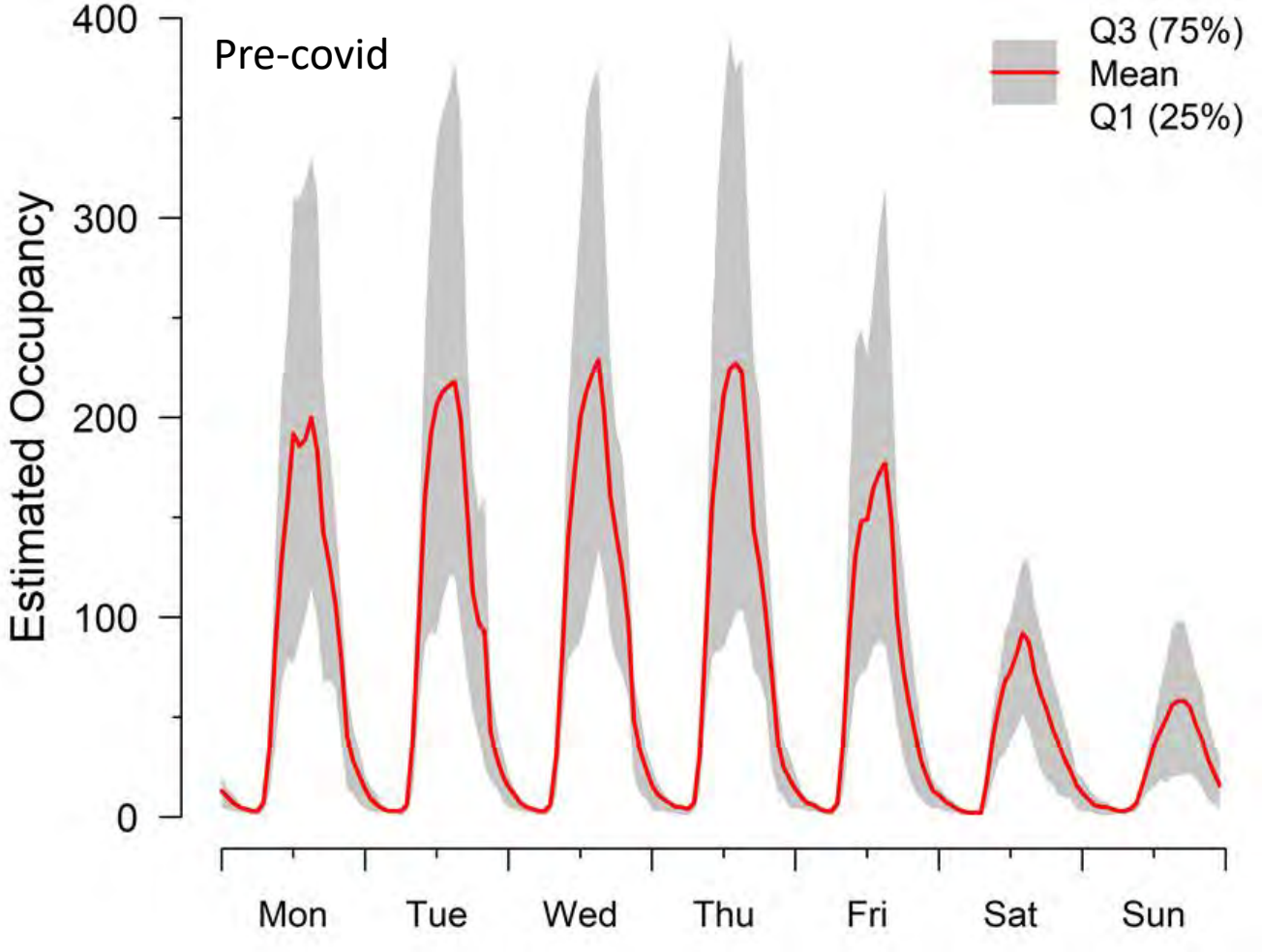


- Red dashed lines require sensor deployment to accommodate zone-level coverage.
- Green solid lines require sensor deployment only at a few locations in a building such as entry points.

Gunay, Burak; Nagy, Zoltan; Miller, Clayton; Ouf, Mohamed; Dong, Bing. ASHRAE Journal; New York Vol. 63, Iss. 5, (May 2021): 30-40.

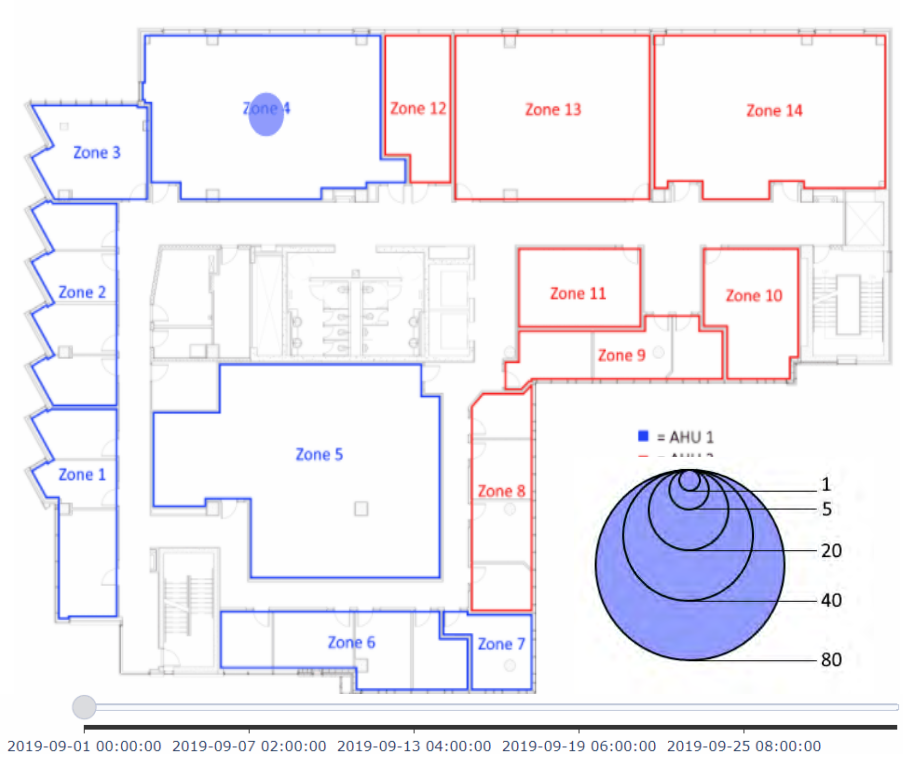
Using CO_2 sensing and motion detectors for ventilation control

Design occupancy was 1000 people!



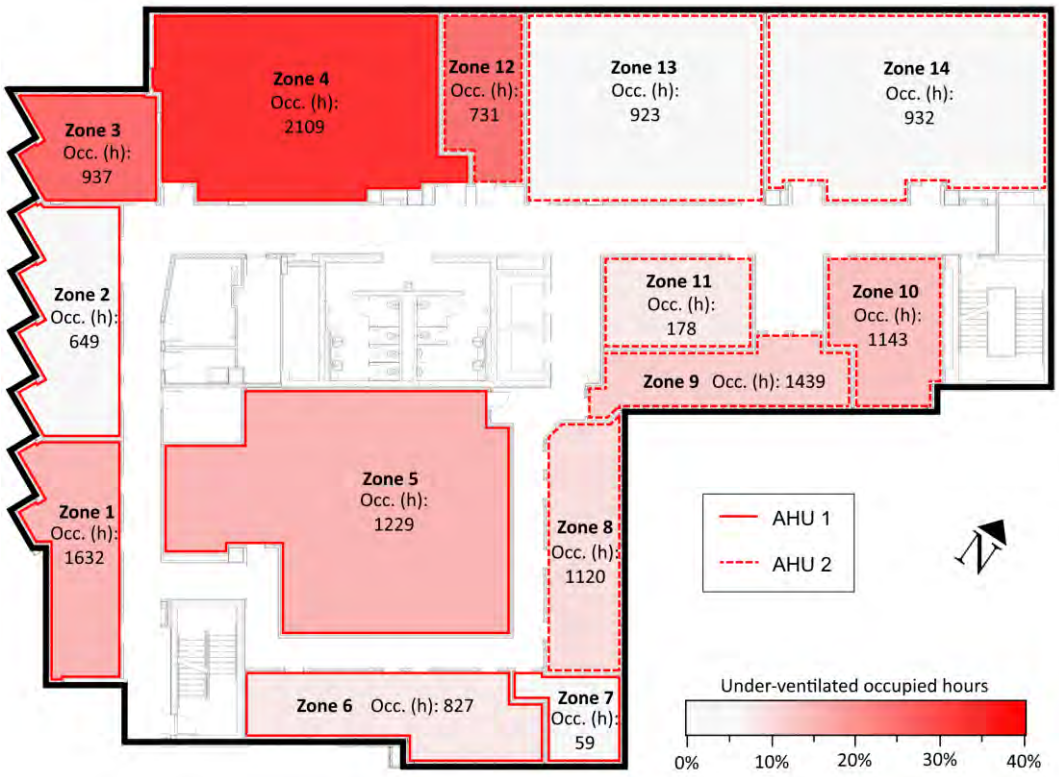
Hobson, Brodie W., et al. "Clustering and motif identification for occupancy-centric control of an air handling unit." *Energy and Buildings* 223 (2020): 110179.

- Actual building occupancy is heterogenous.
- Zone use may change over time without changes to the size, configuration, or operation of the HVAC system.



Credit: Tareq Abuimara and Brodie Hobson

- During 41% of occupied hours, at least one (1) thermal zone had per person outdoor airflow below that recommended by ASHRAE for IAQ purposes.



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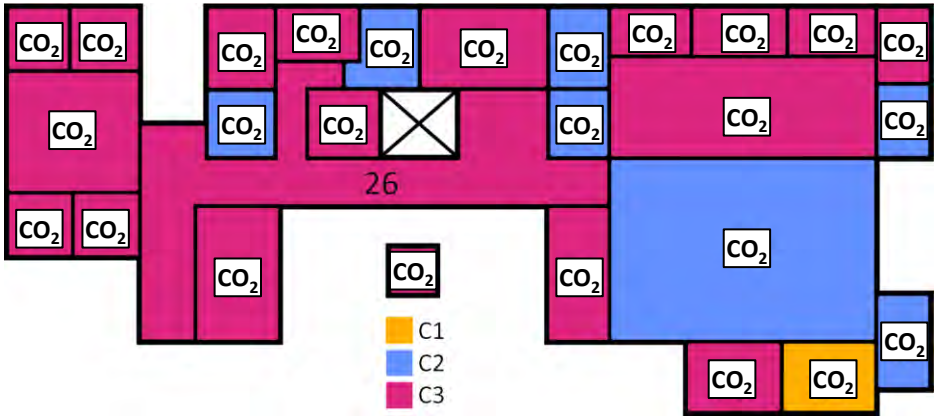
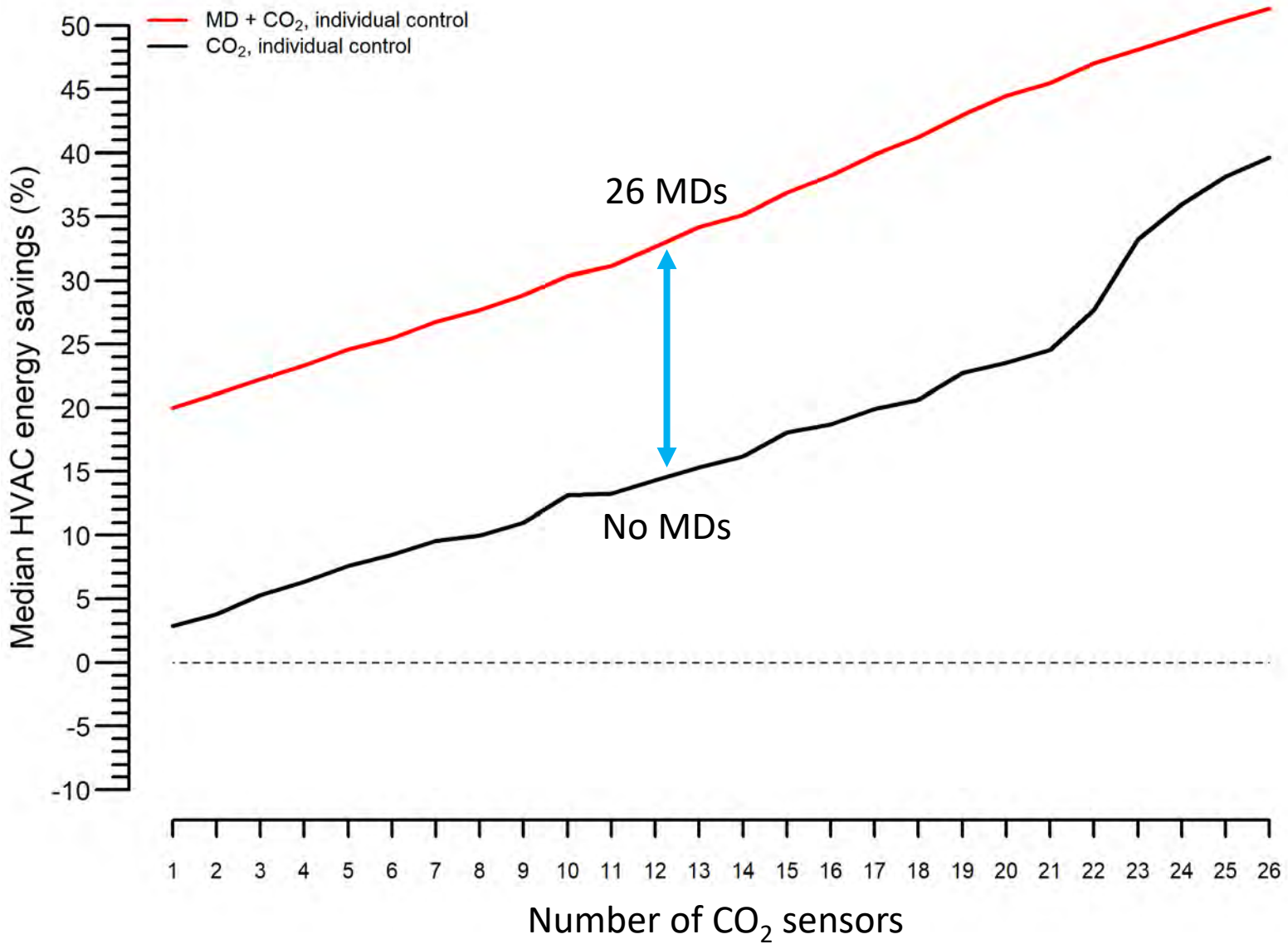


ASHRAE RP-1747 Sequence for Demand Control Ventilation

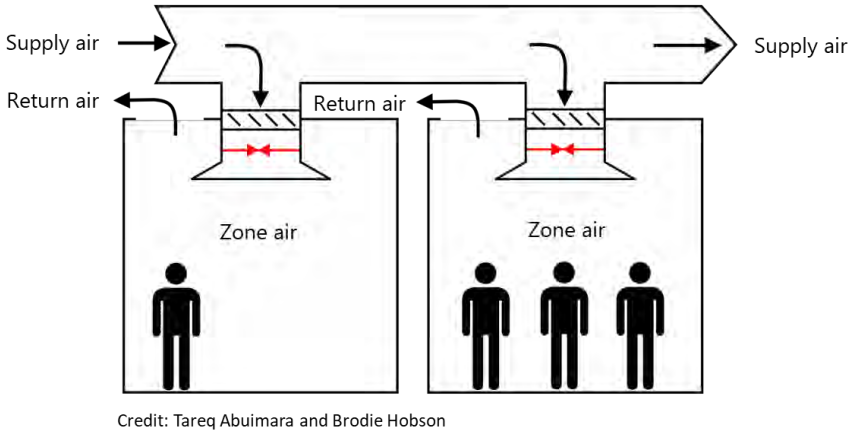
```
if CO2 in zone i is below the setpoint
     reduce VAV i minimum airflow setpoint
elseif CO2 in zone i exceeds the setpoint
     increase VAV i minimum airflow setpoint
     if VAV i damper fully opens
          request AHU to increase outdoor air fraction
     end
end

If motion detector in zone i has been off for one-hour
      set the VAV i minimum airflow setpoint to zero
end
```

Based on EnergyPlus simulations with measured occupancy data & hard-sized HVAC systems to as-built drawings.



- Installation, maintenance, and recalibration cost of CO_2 sensors can limit dense deployments
- Because of air re-circulation & similarities in occupancy patterns, unique CO_2 patterns are usually far fewer than the number of zones.
- If each CO_2 sensor is allowed to control a number of adjacent zones, what would be the ideal sensor density?



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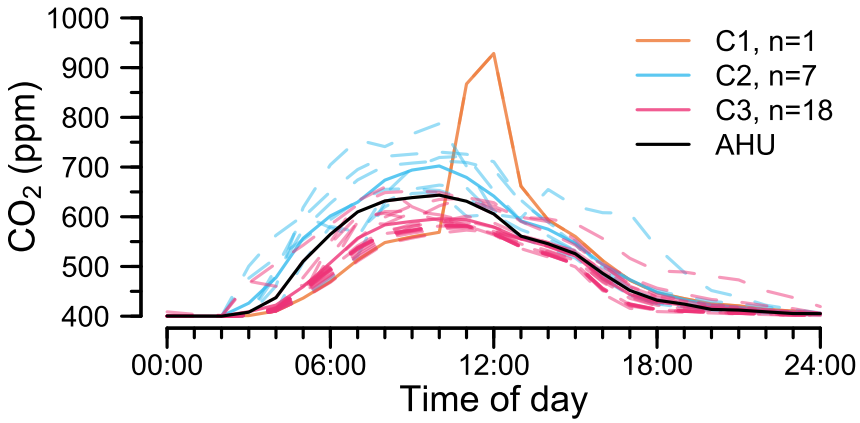
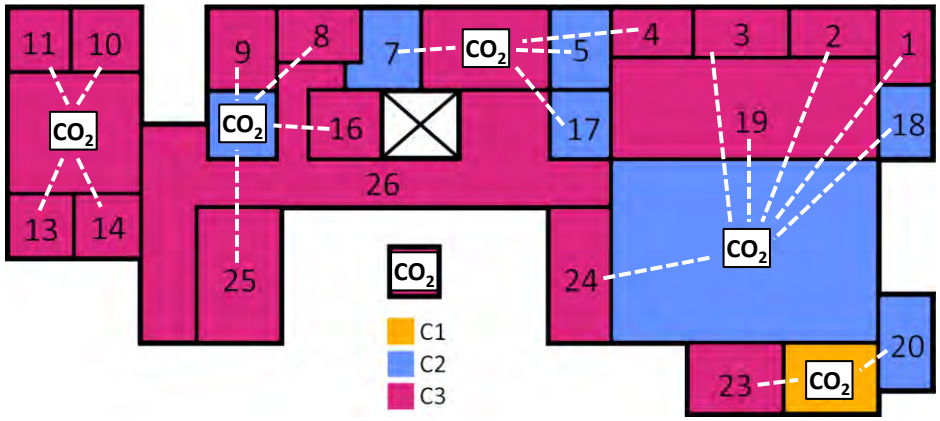
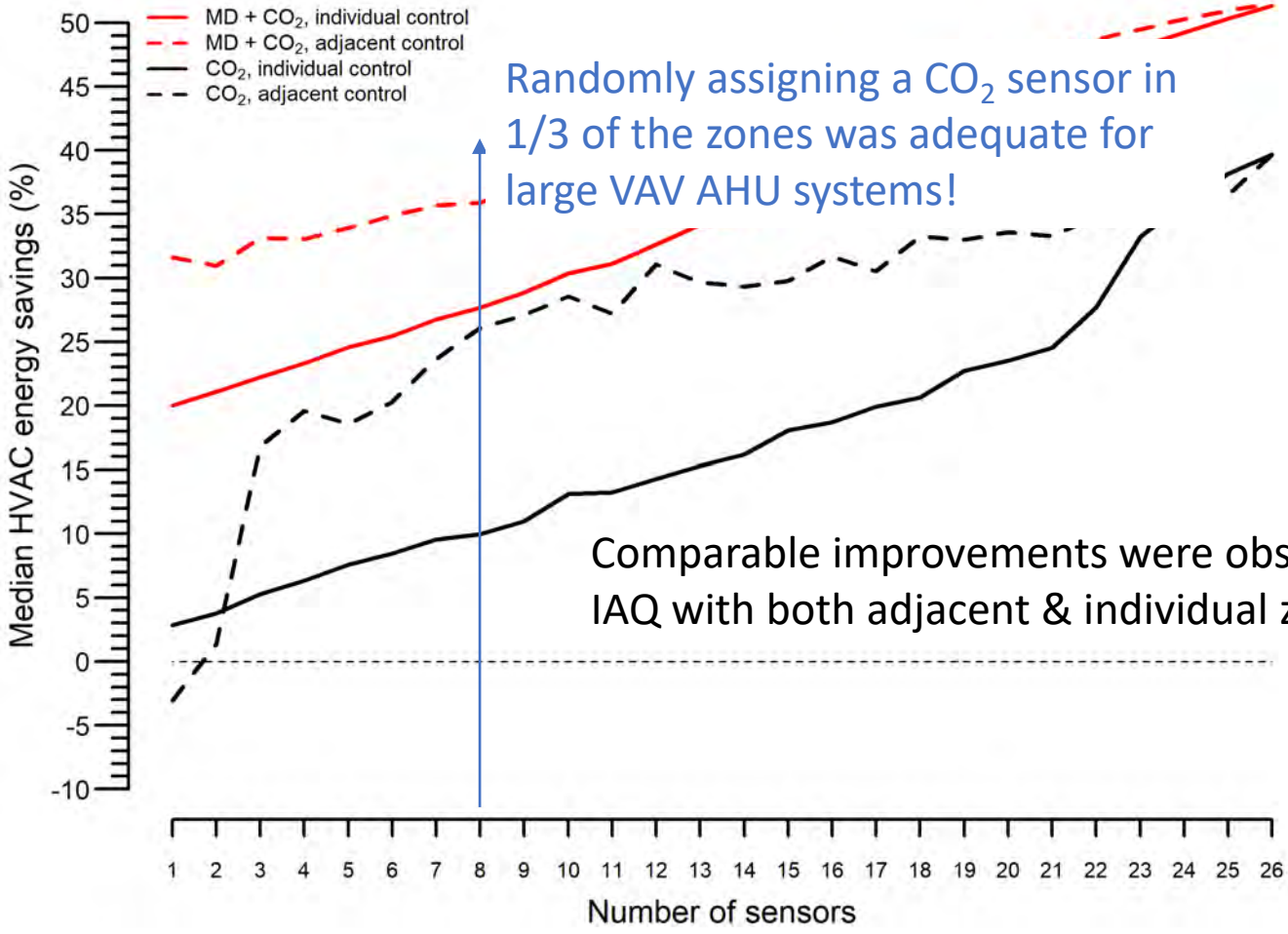




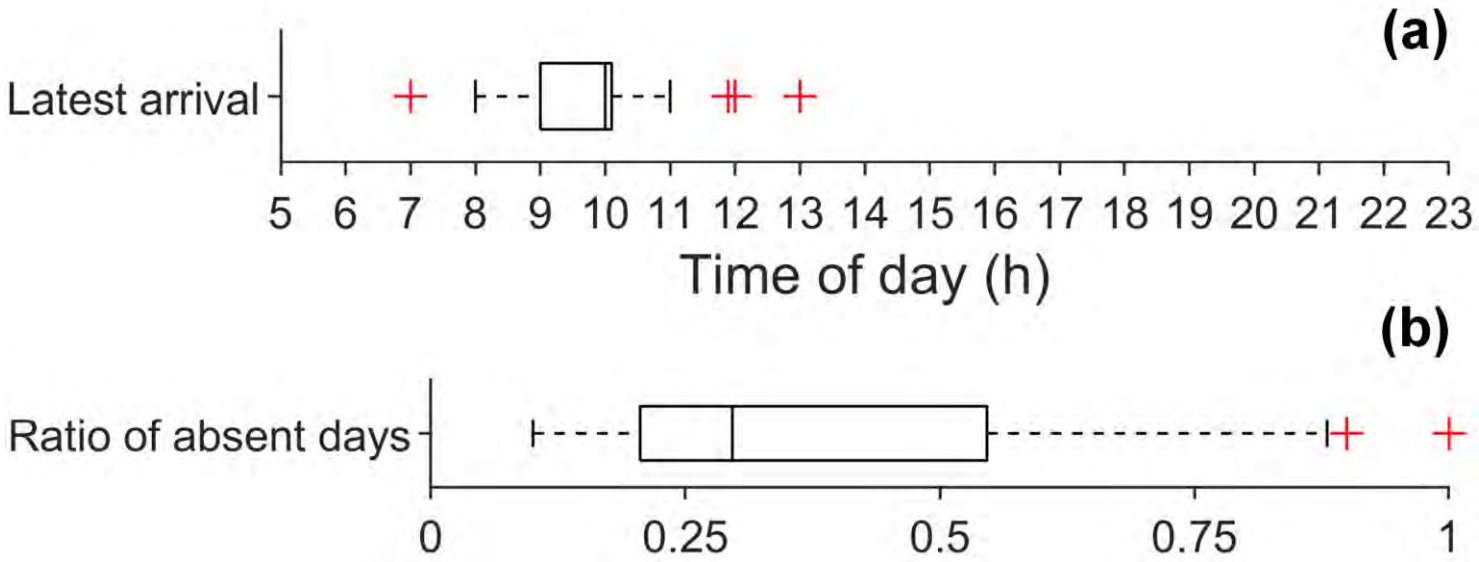


Randomly assigning a CO_2 sensor in 1/3 of the zones was adequate for large VAV AHU systems!

Comparable improvements were observed with IAQ with both adjacent & individual zone control.

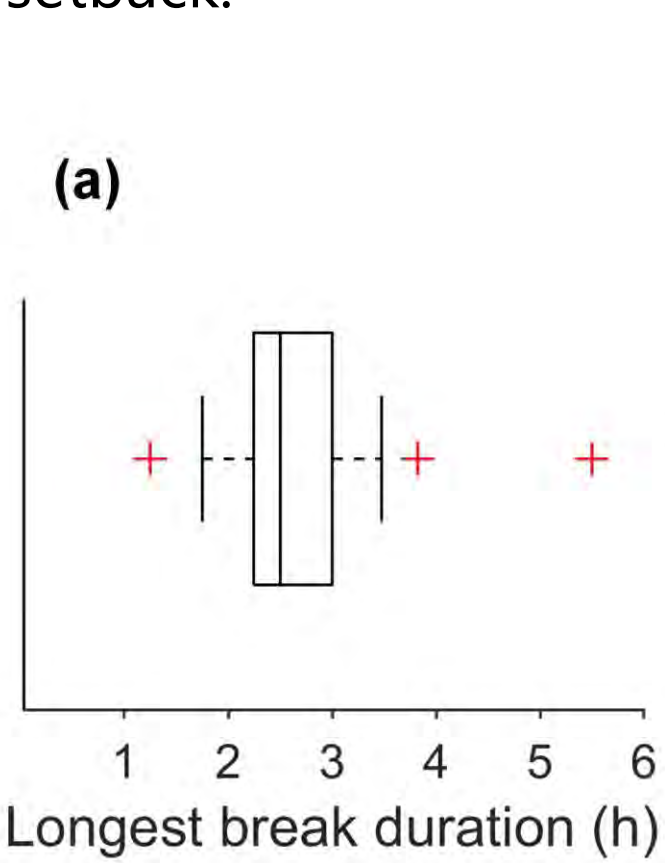
Using motion detectors for zone mode of operation control

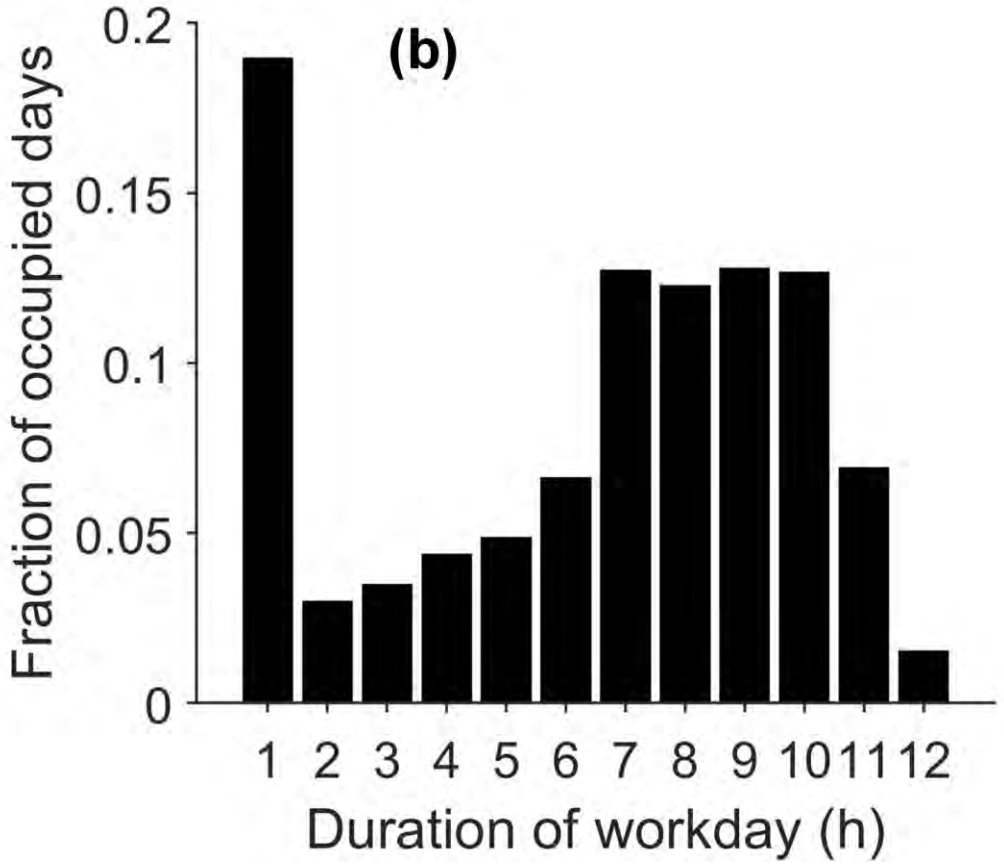
- Some zones in a building can be frequently empty.



- A simple, yet very effective sequence can exploit this:
  - If a **motion detector** has not been triggered until noon, the space will likely remain empty for the rest of the day.
  - Revert to zone to unoccupied mode & apply a 2-3°C temperature setback

- On many days, occupants drop in for brief periods – just for meetings, pick up a delivery, etc.
- If the motion detector in a room hasn't been triggered for longer than the four hours, apply a 2-3°C temperature setback.





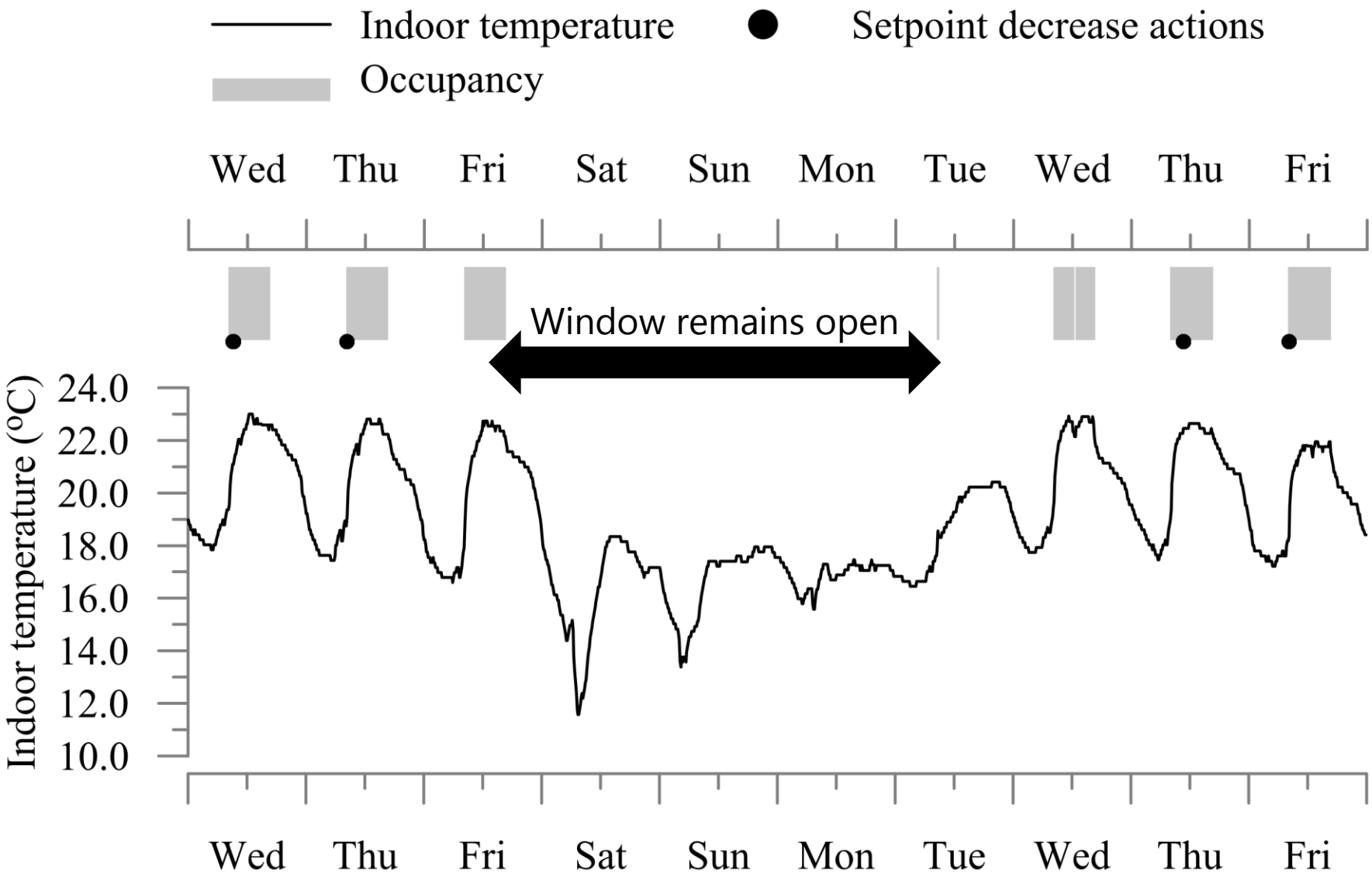
Using window contact sensors for zone-control

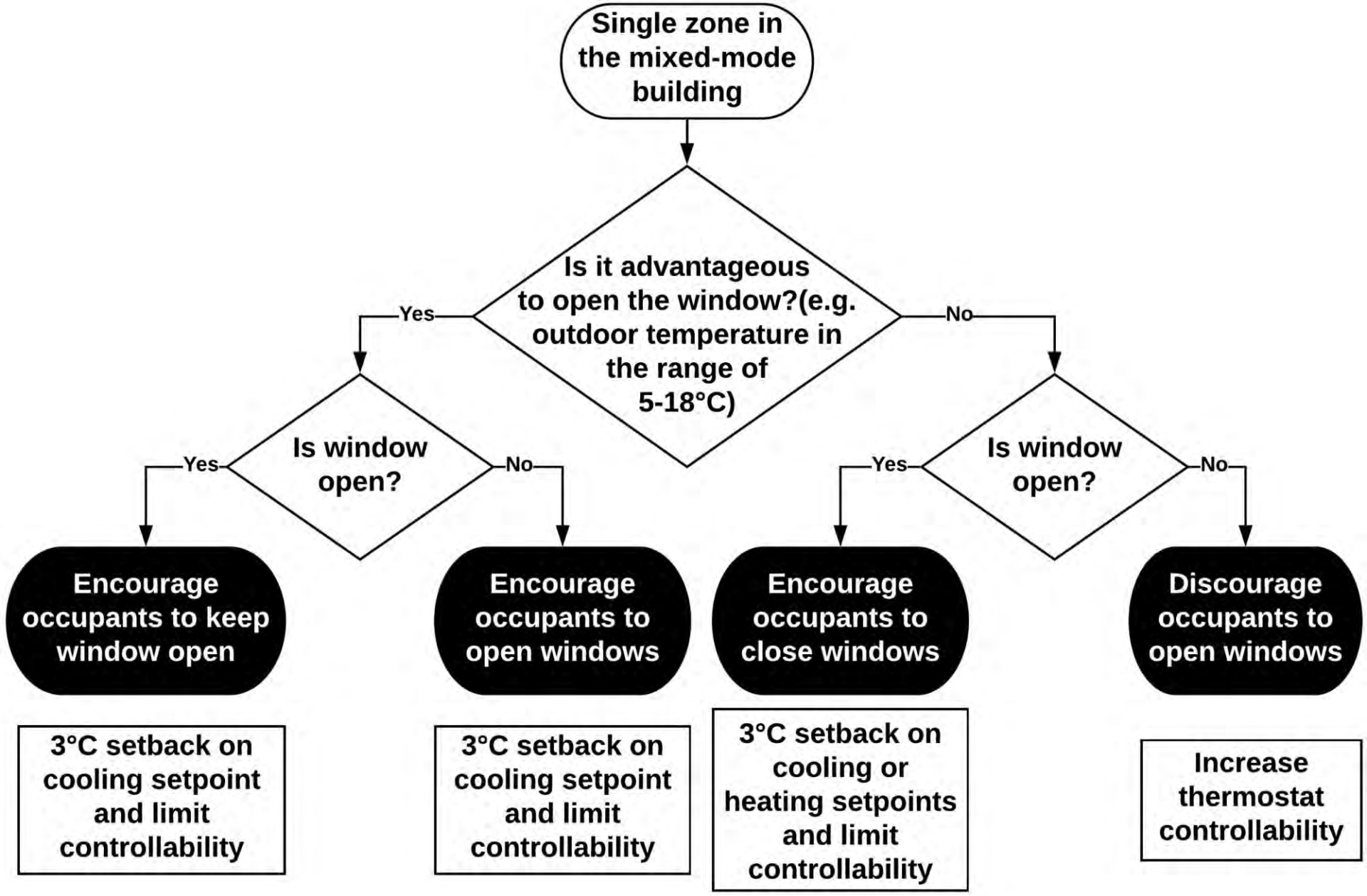
Mixed mode buildings

- Potential to reduce cooling energy
- Improve occupant comfort & satisfaction
- Risks to increase heating and cooling energy use due to inappropriate occupant behaviour
- Risk of frost damage!
- 30+ wireless window contact sensors integrated into the BAS at Carleton

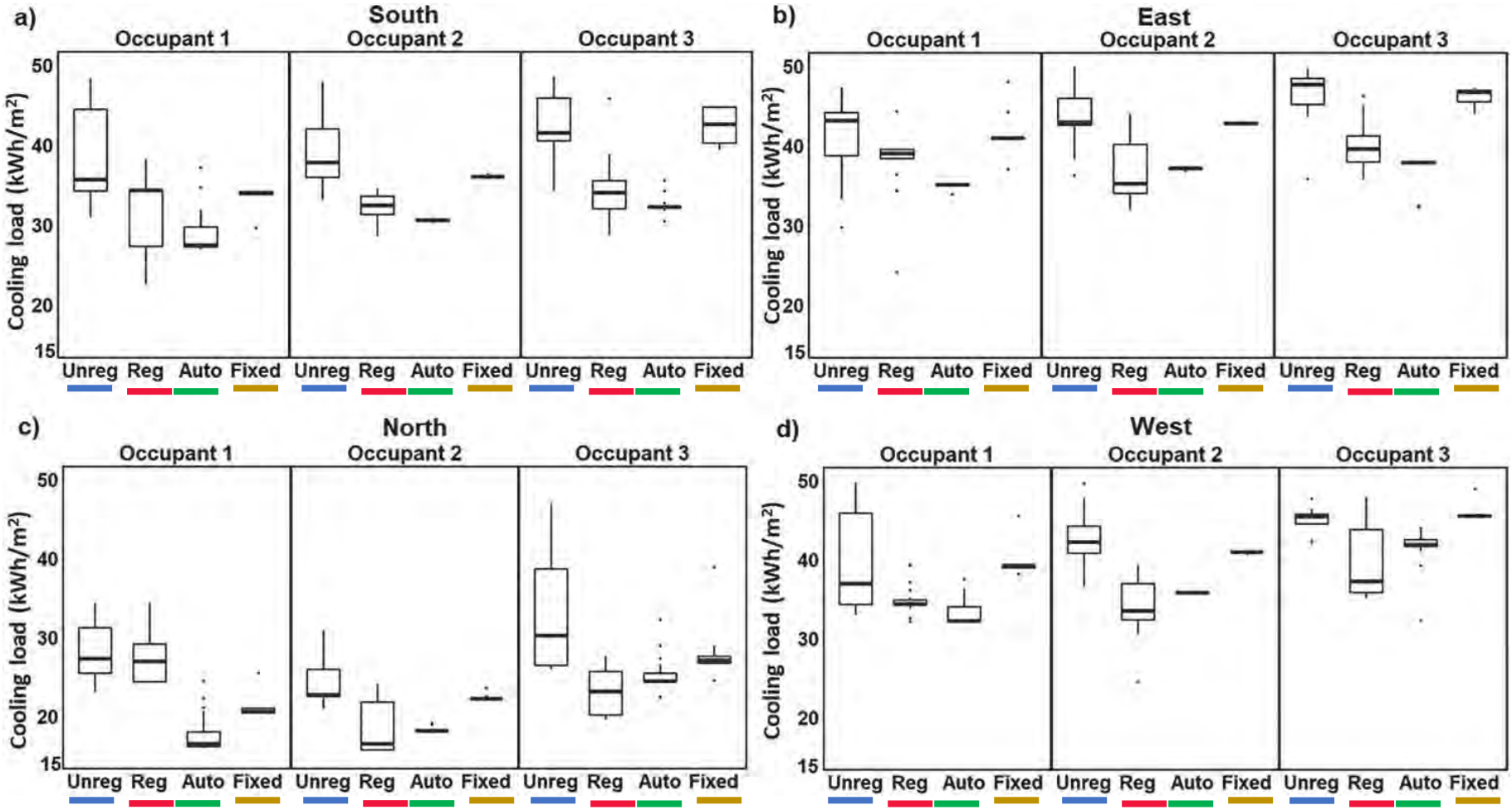
Delta enOcean to BACnet gateway

Echoflex enOcean contact sensors


Indoor temperature
Setpoint decrease actions
Occupancy
Wed
Thu
Fri
Sat
Sun
Mon
Tue
Wed
Thu
Fri
Window remains open
Indoor temperature (°C)
24.0
22.0
20.0
18.0
16.0
14.0
12.0
10.0
Wed
Thu
Fri
Sat
Sun
Mon
Tue
Wed
Thu
Fri


Single zone in the mixed-mode building
Is it advantageous to open the window?(e.g. outdoor temperature in the range of 5-18°C)
Yes
No
Is window open?
Yes
No
Is window open?
Yes
No
Encourage occupants to keep window open
Encourage occupants to open windows
Encourage occupants to close windows
Discourage occupants to open windows
3°C setback on cooling setpoint and limit controllability
3°C setback on cooling setpoint and limit controllability
3°C setback on cooling or heating setpoints and limit controllability
Increase thermostat controllability

Unreg: Temperature setpoints do not change based on window state.
Reg: Temperature setpoints are adapted based on window state.
Auto: If we have automated window actuators, opening/closing the windows optimally.
Fixed: Fixed (non-operable) windows.



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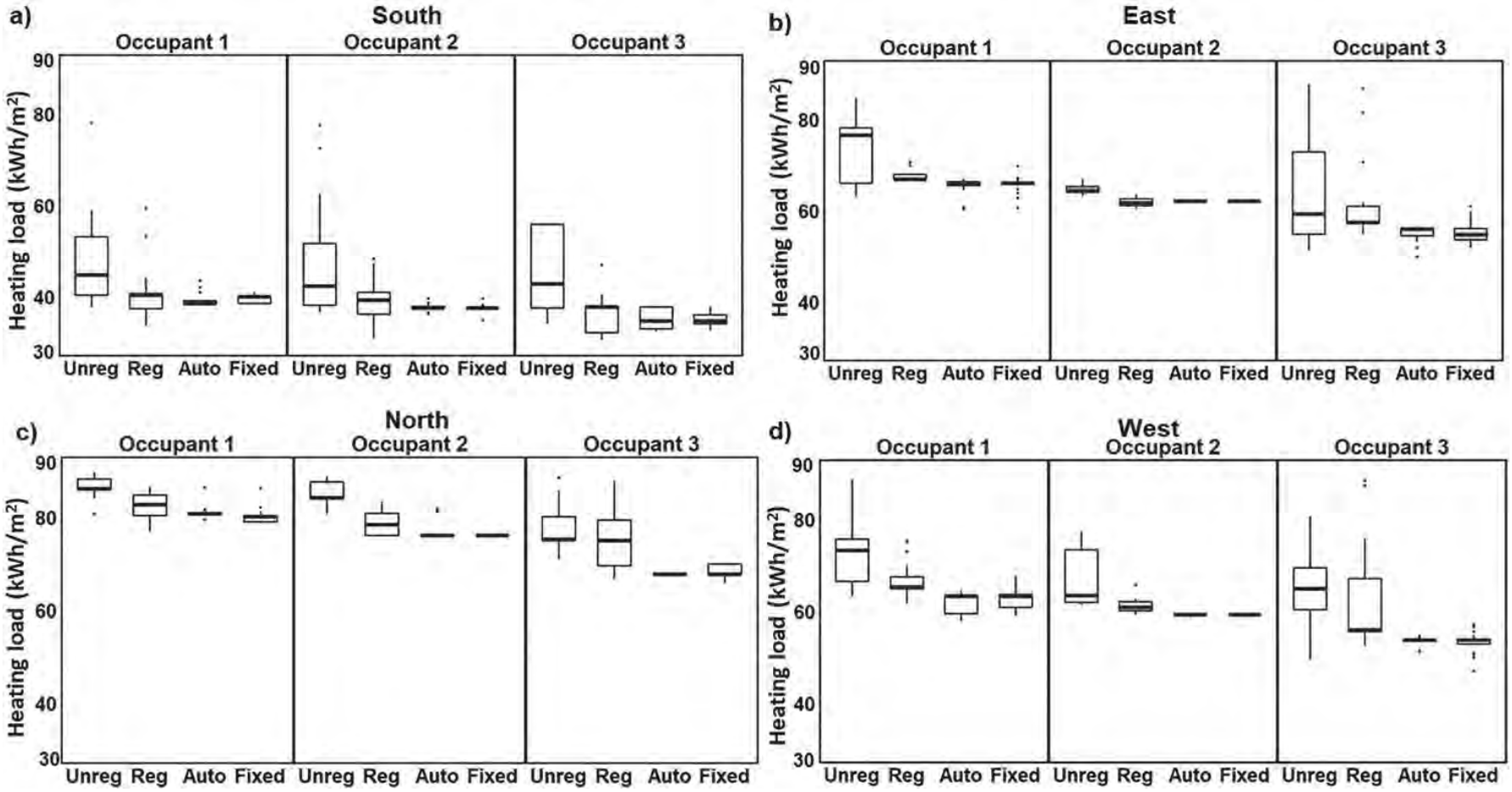
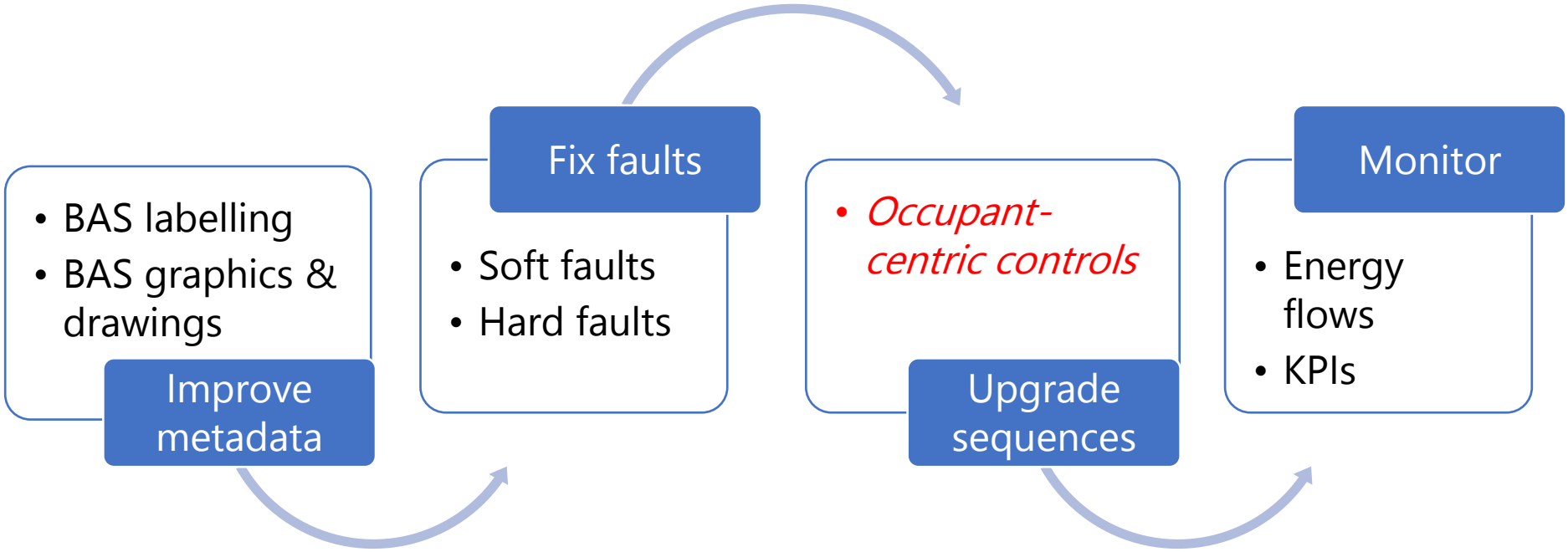


Prerequisites for effective occupant-centric controls

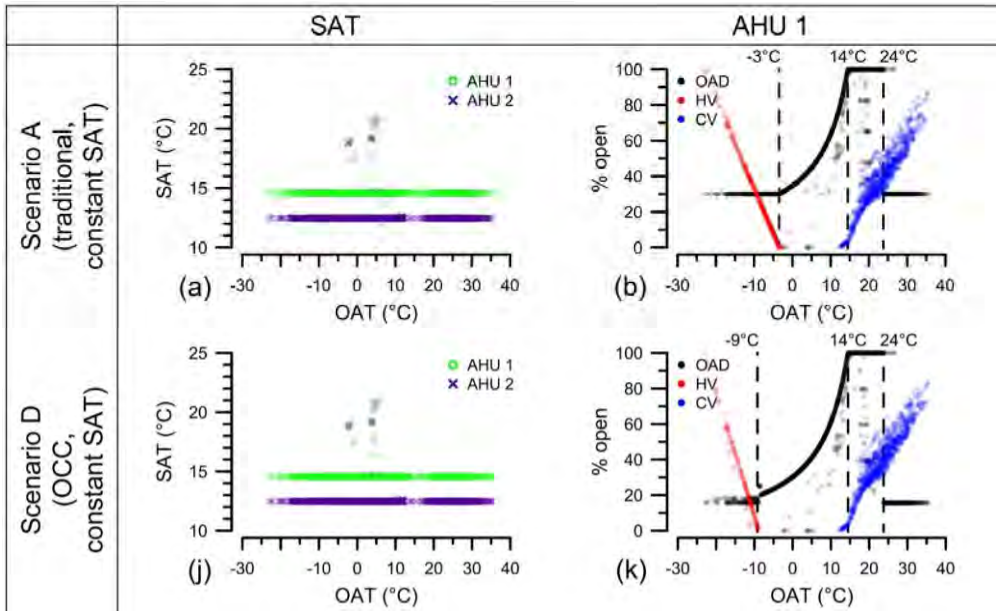


Order of addressing these operational issues is critical!

- Detecting faults without metadata is quite difficult.
- Upgrading sequences without fixing faults is not possible.
- Making sense of KPIs and end-uses with operational problems is quite challenging.

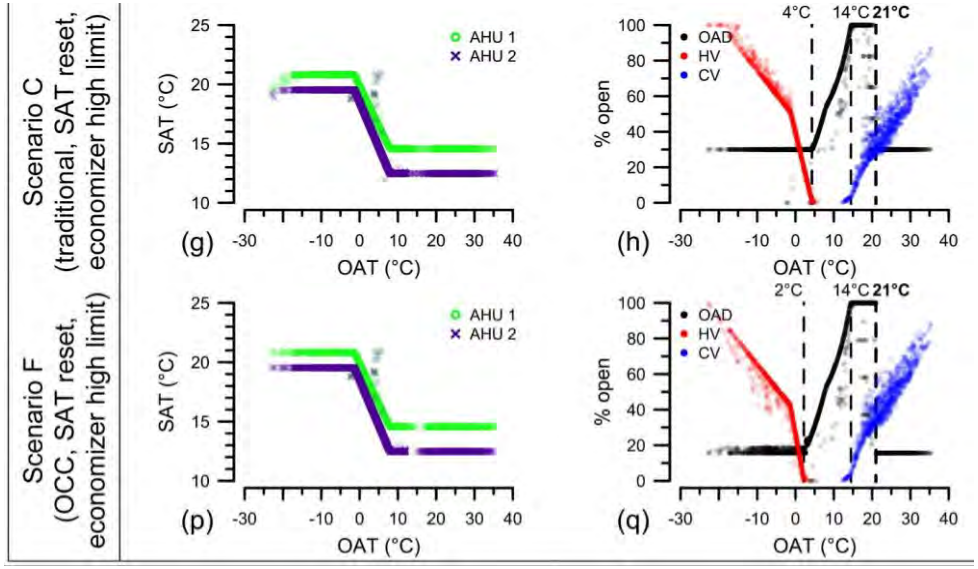
With incorrect AHU SAT reset, OCC yields:

- 4% reduction in cooling
- 4% reduction in heating



With correct AHU SAT reset, OCC yields:

- 6% reduction in cooling
- 19% reduction in heating



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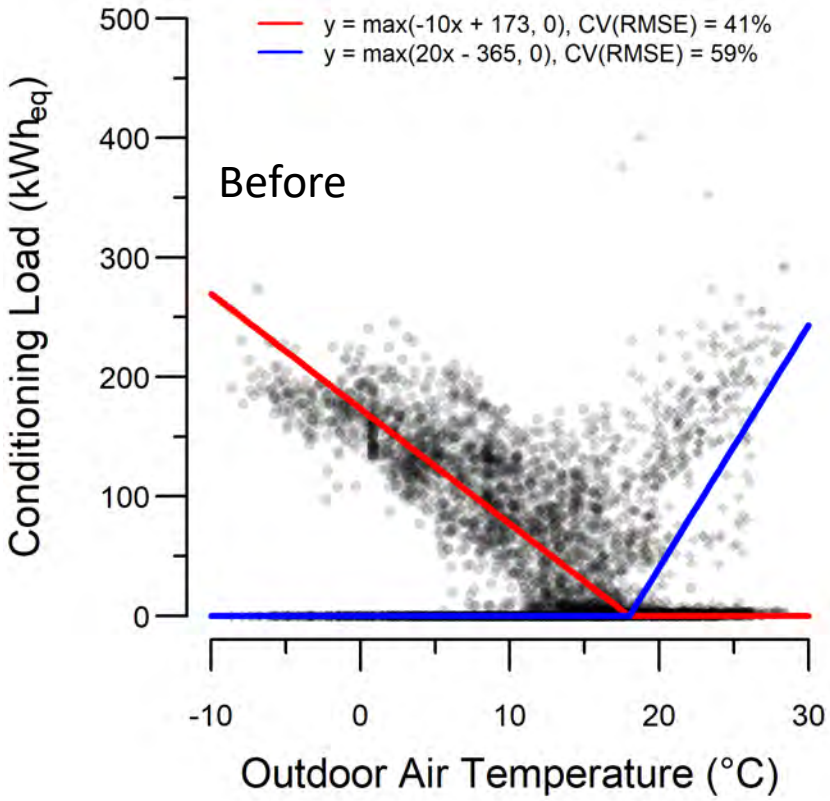
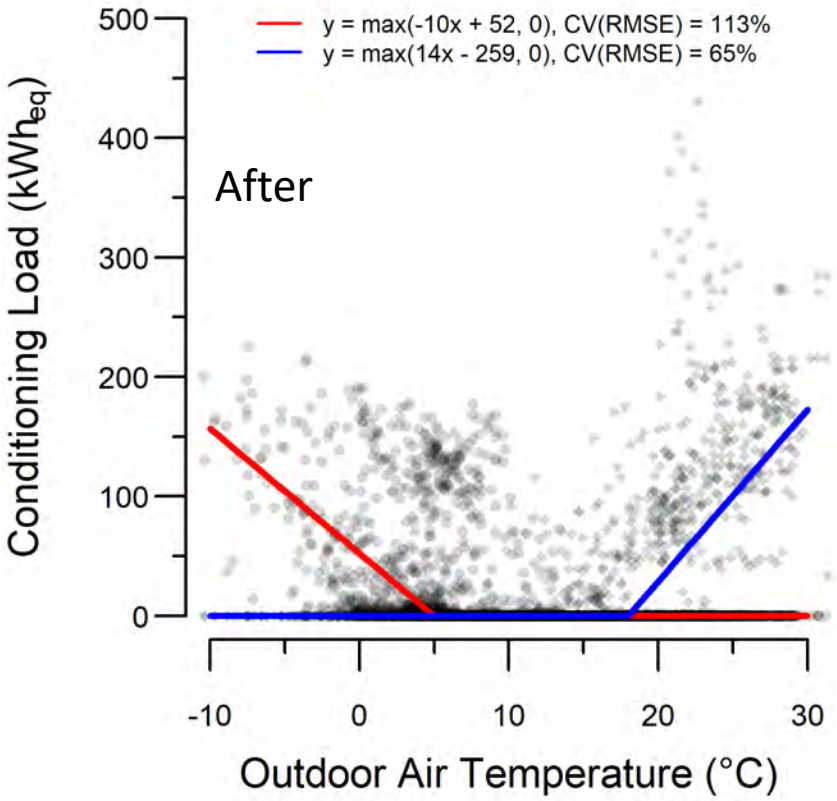
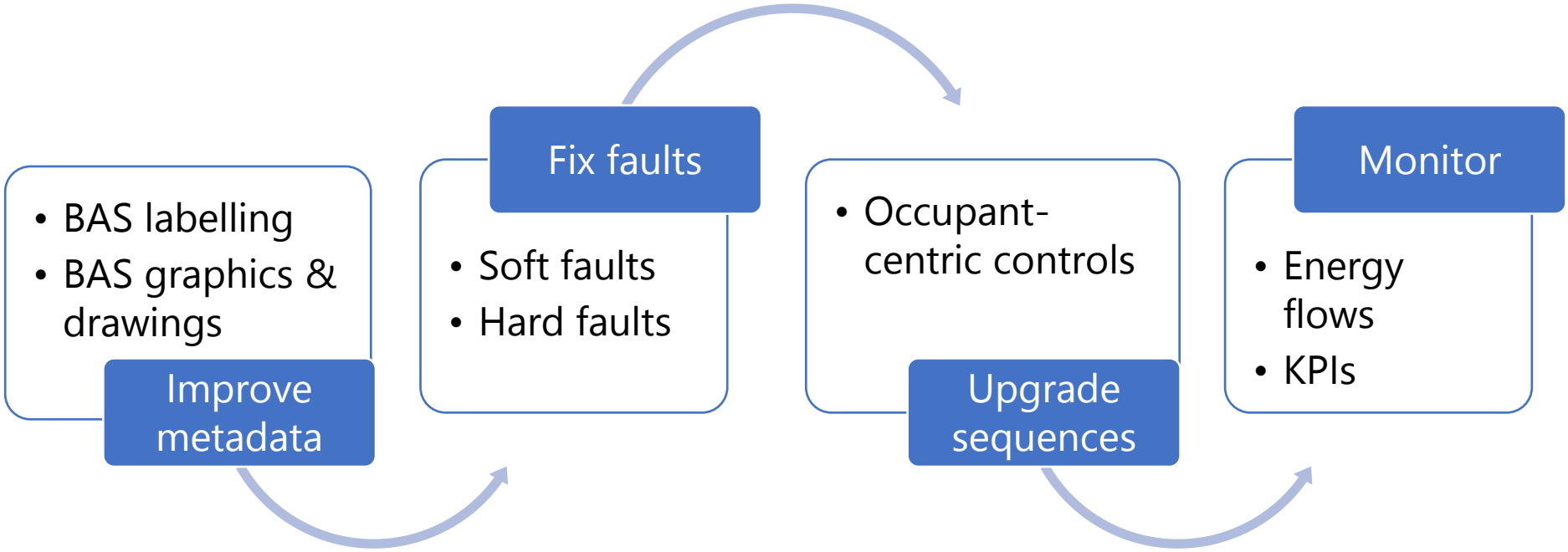
Three years ago, Canal Building was using 292% more heating and cooling energy than it is now!

- We did not change the envelope;
- We did not upgrade a single equipment;
- We did not adversely affect the indoor environmental quality.





Credit: Brodie Hobson


• BAS labelling
• BAS graphics & drawings
Improve metadata
Fix faults
• Soft faults
• Hard faults
• Occupant-centric controls
Upgrade sequences
Monitor
• Energy flows
• KPIs

DBOM
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BPRC
Building Performance Research Centre
Carleton University

Questions:

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