Zoning and Compartmentalization

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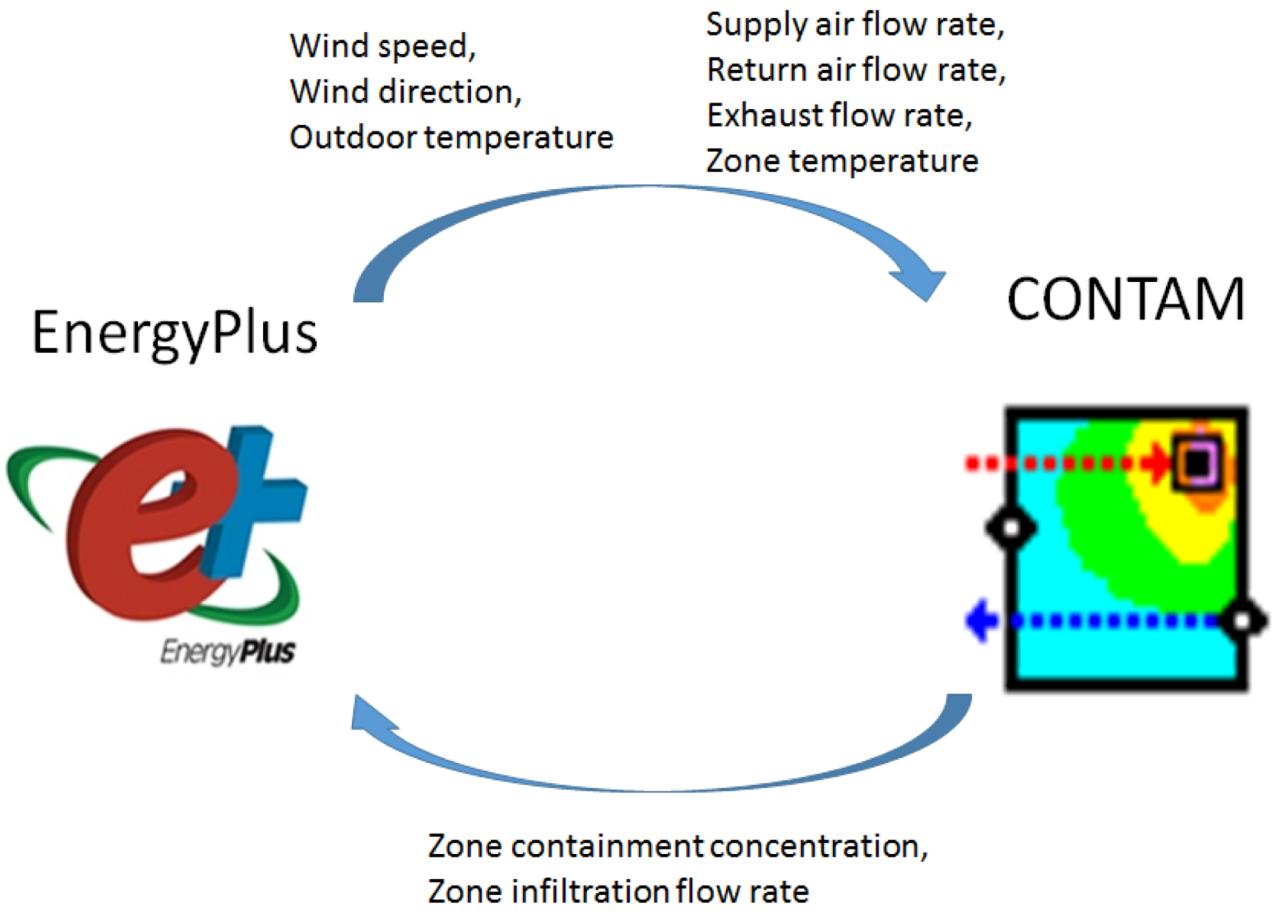
BUILDING TECHNOLOGY & URBAN SYSTEMS DIVISION
Energy Technologies Area

Simulating Zoning Controls



Smart Ventilation Strategies Including Zoning

- Track occupants (assumes we know occupancy)
- Combine with outdoor temperature-based controls
- Zonal Air flow options:
  1. Air flow
     1. Keep total air flow constant. Direct air to to zones that need venting.
     2. Reduce total air flow. Vent each zone that calls for venting at rate proportional to fraction of total floor area.
  2. Number of zones
     1. Four + zones: kitchen, bathrooms, bedrooms and “other” living spaces
     2. Two zones: 1. sleeping & 2. All other spaces

Exposure-based Controls

- Keep relative exposure below 1 when occupied, 5 when vacant
- Match relative exposure to continuously operating non-zoned system
  - Track occupant individual exposure
  - Ventilate at low rate unoccupied, higher when occupied. No real-time exposure calculations
  - Contaminant-based:
    - Vent dwelling if any contaminant in any zone above threshold
    - Vent zone if that zone above threshold
    - Vent zone if occupied and above threshold

Contaminant Emissions

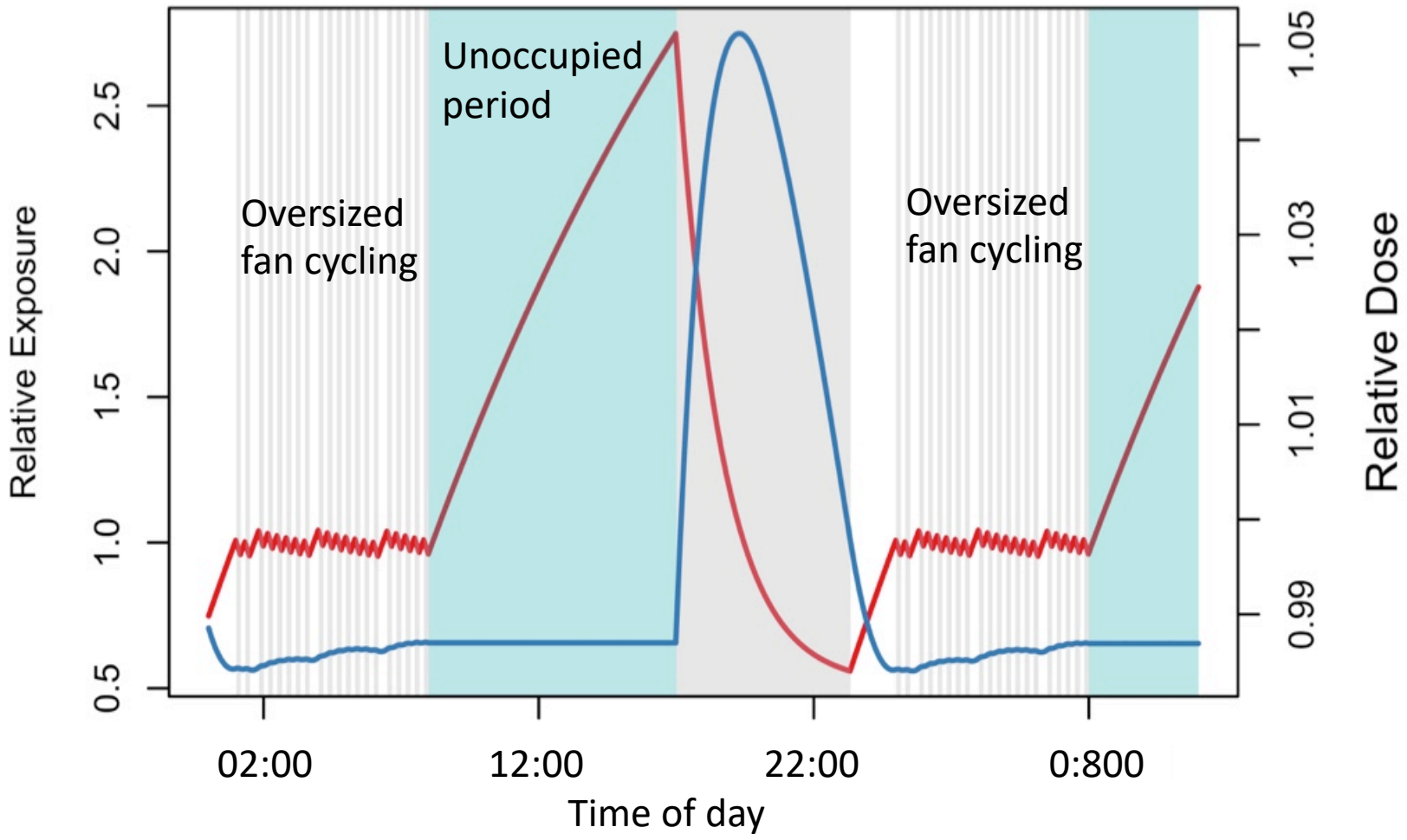
From HENGH field study of 70 California homes

- Continuous emission:
  - “Generic” contaminant
  - Formaldehyde (depends on Temperature, Humidity and Ventilation Rate)

- Periodic Emission:
  - PM2.5 from cooking
  - CO_2 and H_2O from occupants
  - Occupant schedules

- Use reference exposure limits for chronic exposure:
  - Formaldehyde: OEHHA REL is 9 µg/m^3 for 8-hour and chronic exposures
  - Particles (PM2.5): WHO Chronic level is 10 µg/m^3
  - CO_2 : 1100 ppm
  - Moisture: 60% RH

Fan off when unoccupied: generic VOC exposure

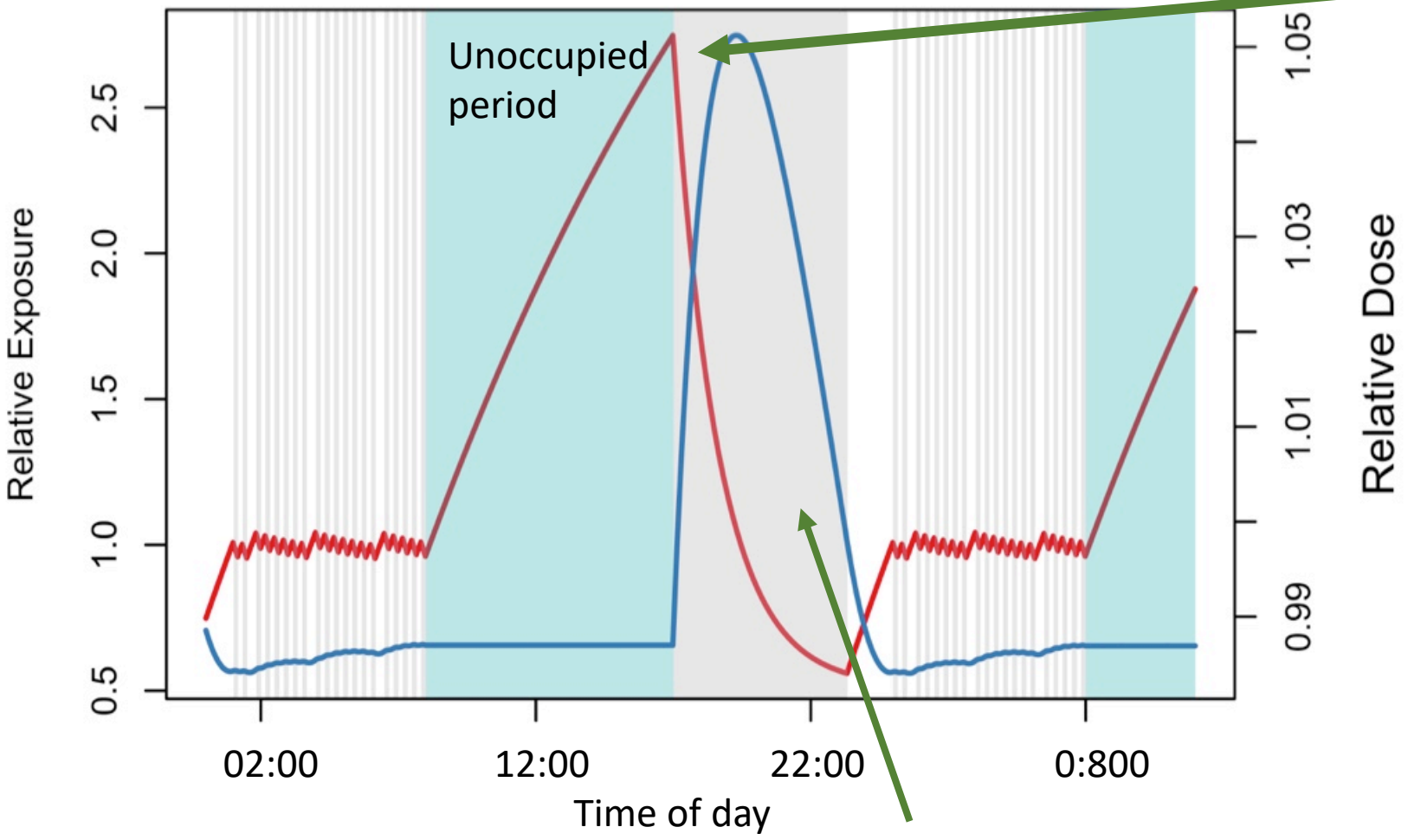


Relative Exposure tracks contaminants at all times: accounts for emissions when vacant

Relative dose based on occupant being exposed – unchanged during unoccupied hours

Fan off when unoccupied: generic VOC exposure

High exposure upon re-entry



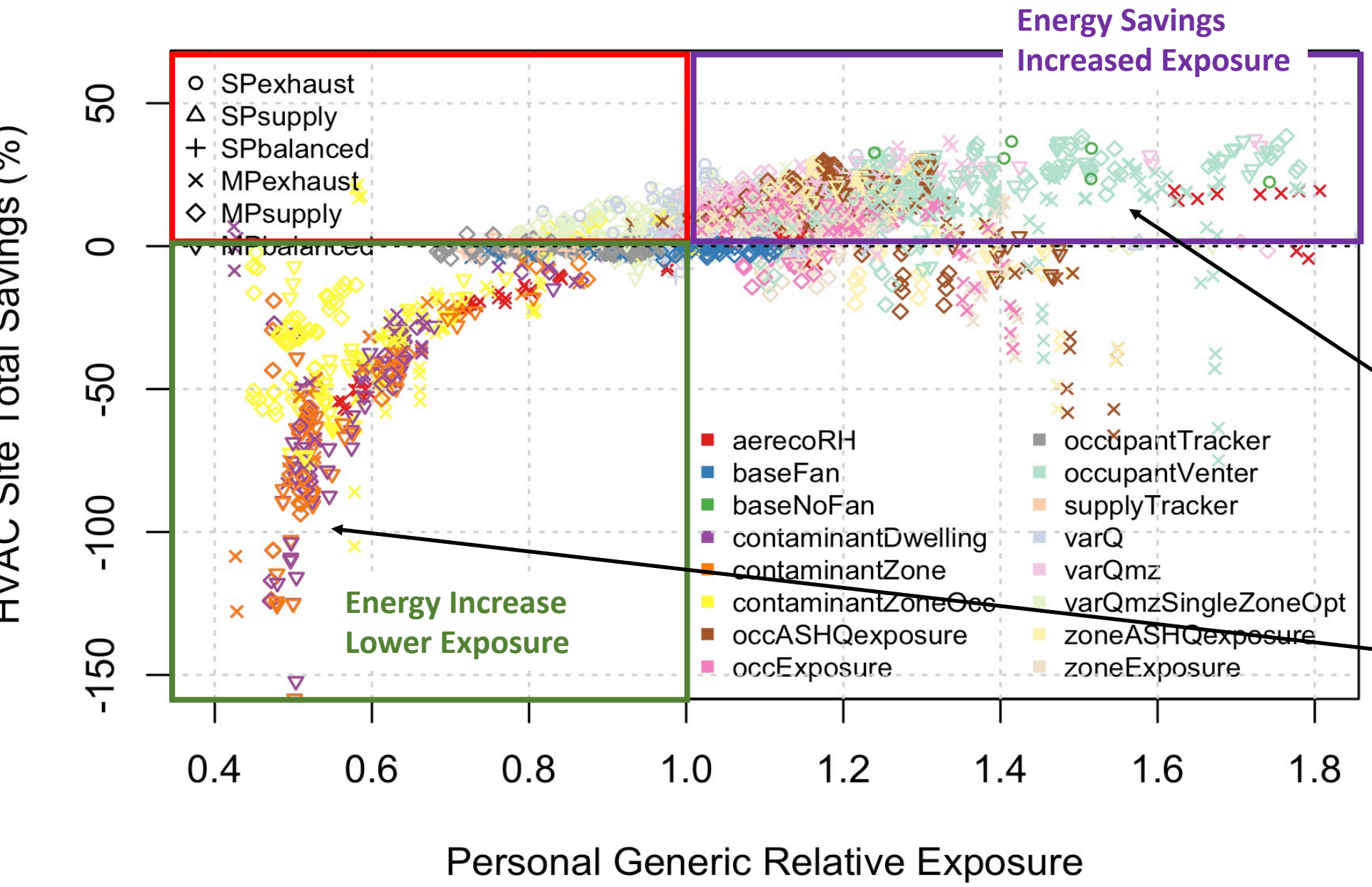
Doubled ventilation rate for many hours

Shifts ventilation to colder hours:

- From 9 am – 5 pm
- To 5 pm - 11 pm

Extra venting means little/no energy savings – in some cases shift to colder hours increases energy use.

Including natural infiltration to limit high exposure: 5% savings (up to 30% for leaky (5 ACH50)) homes

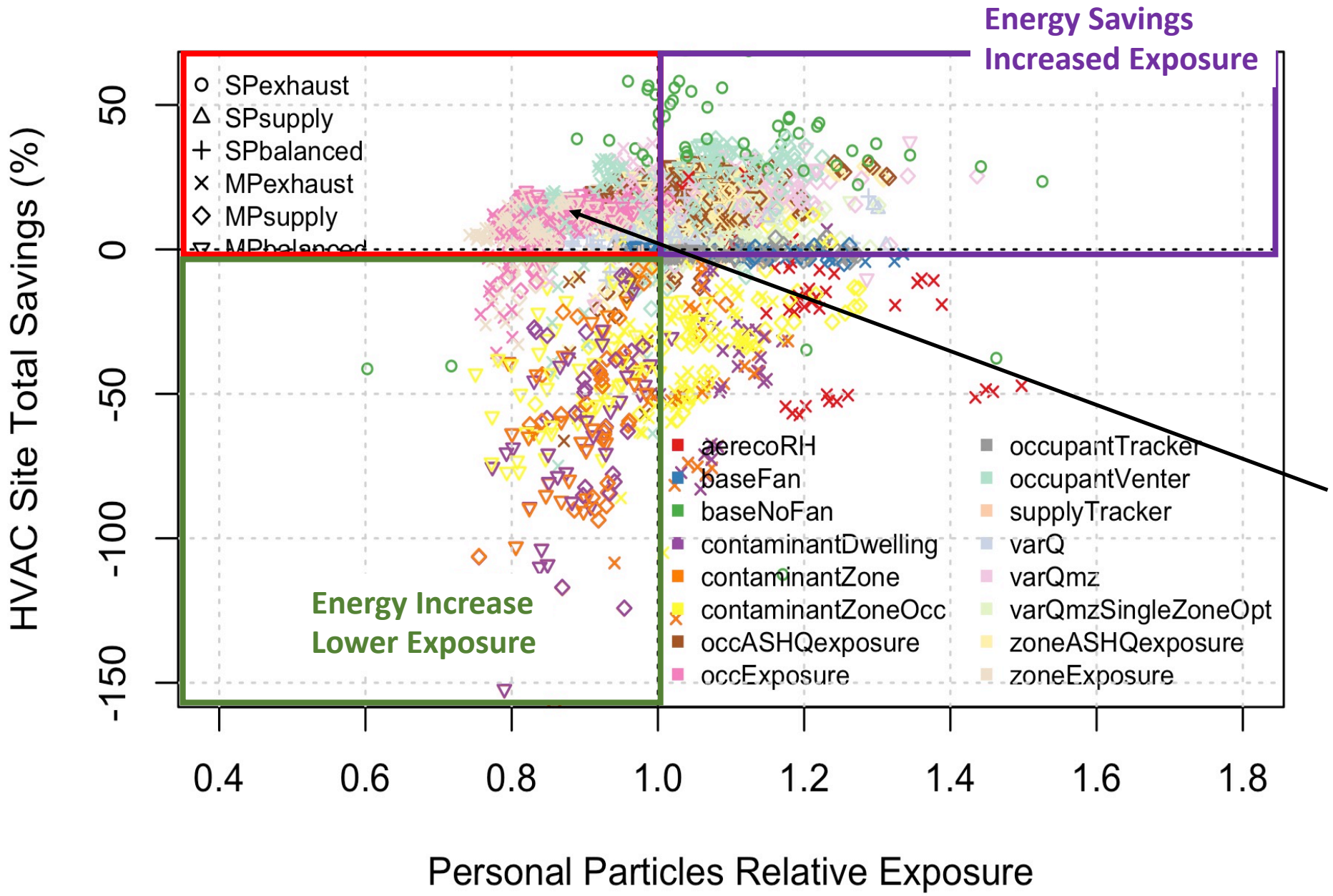


Many controls saved energy but increased exposure OR decreased exposure but used more energy

Occupancy-based systems without exposure control lead to high exposures

Contaminant controls operate a lot – driven by need to control formaldehyde

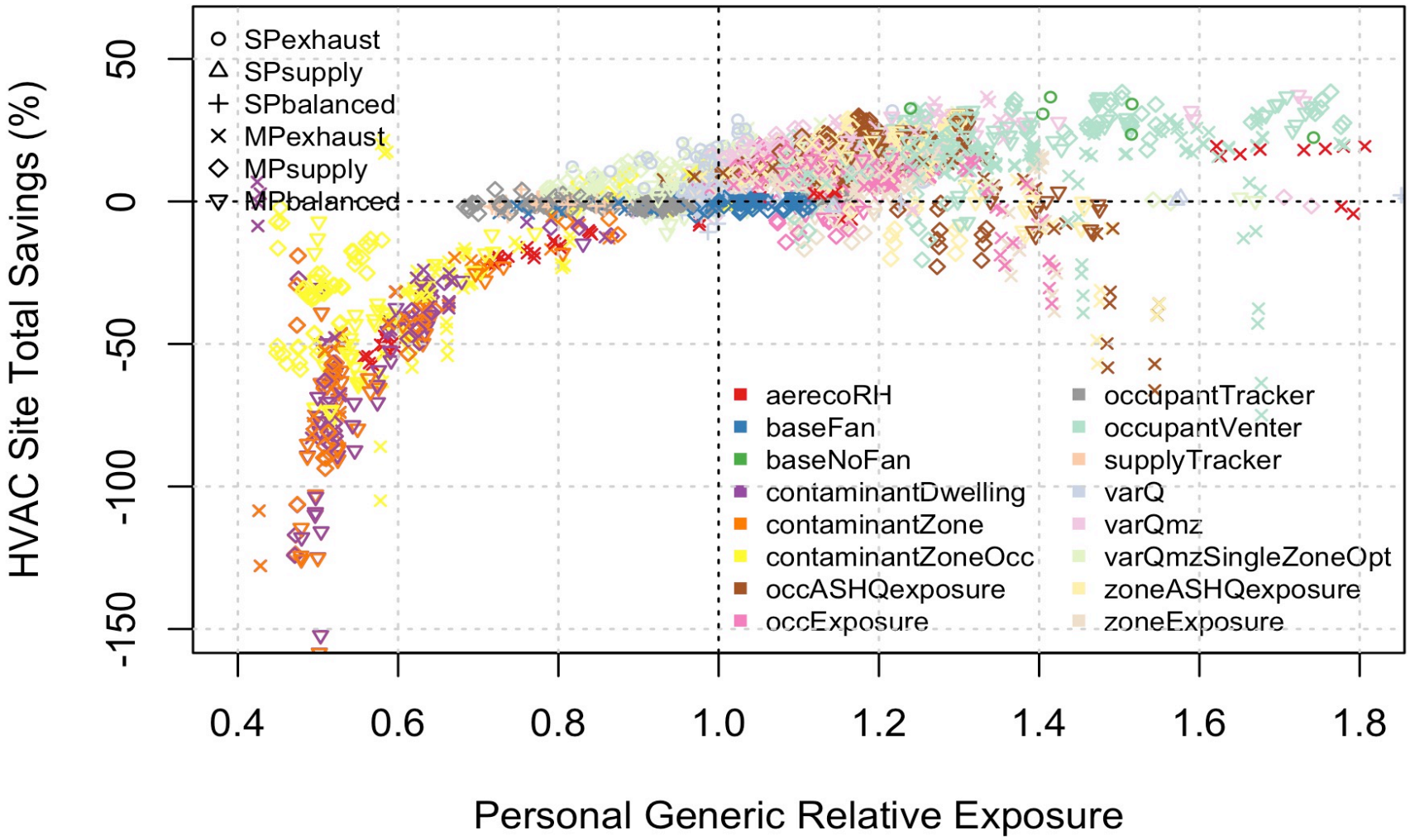
Zoning not a clear advantage



Best performance was for exhaust systems

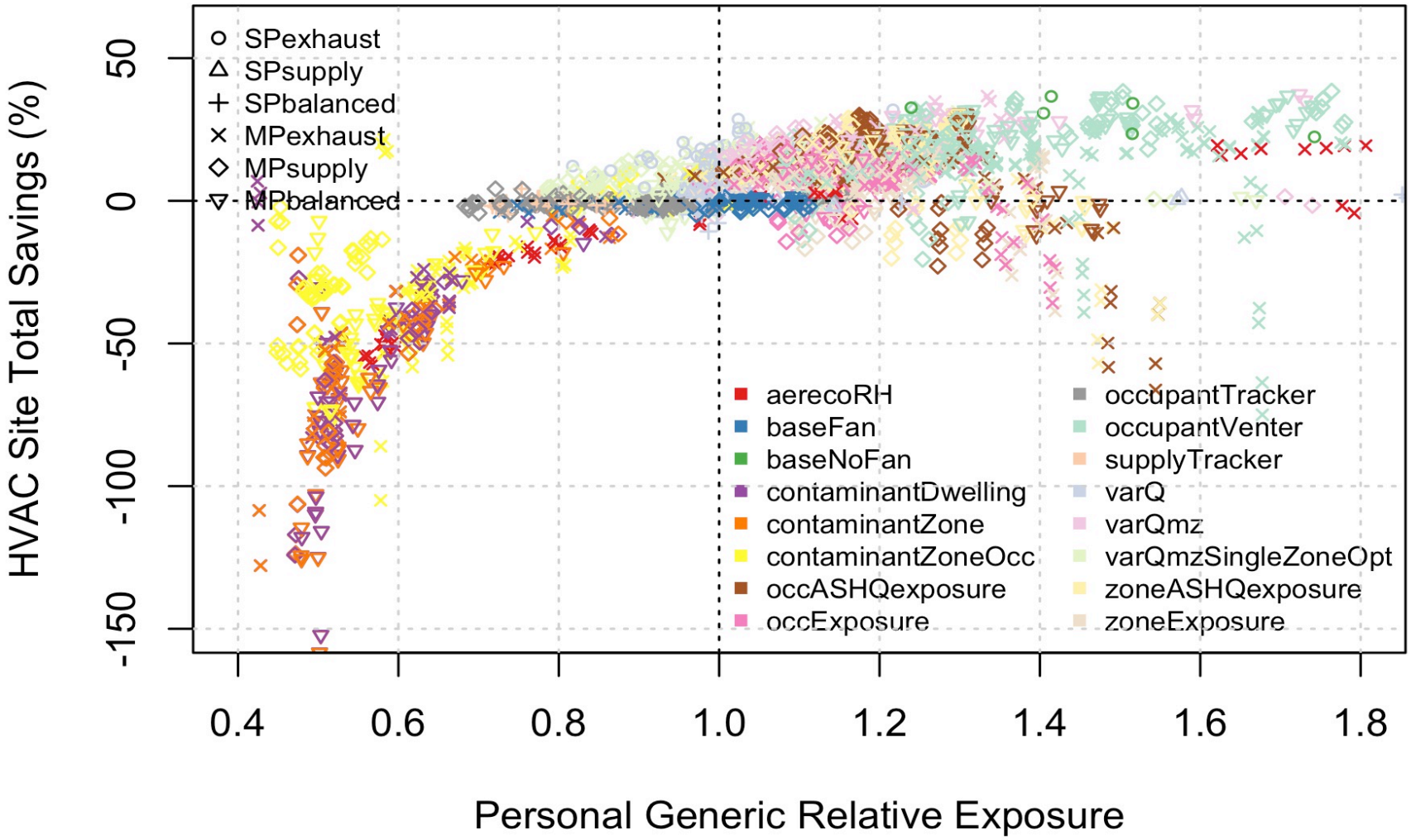
Zoning using occupancy controls looks OK

Zonal Control



Best controllers saved 10-25% of ventilation energy compared to about 7% for non-zoned versions

Zonal Control

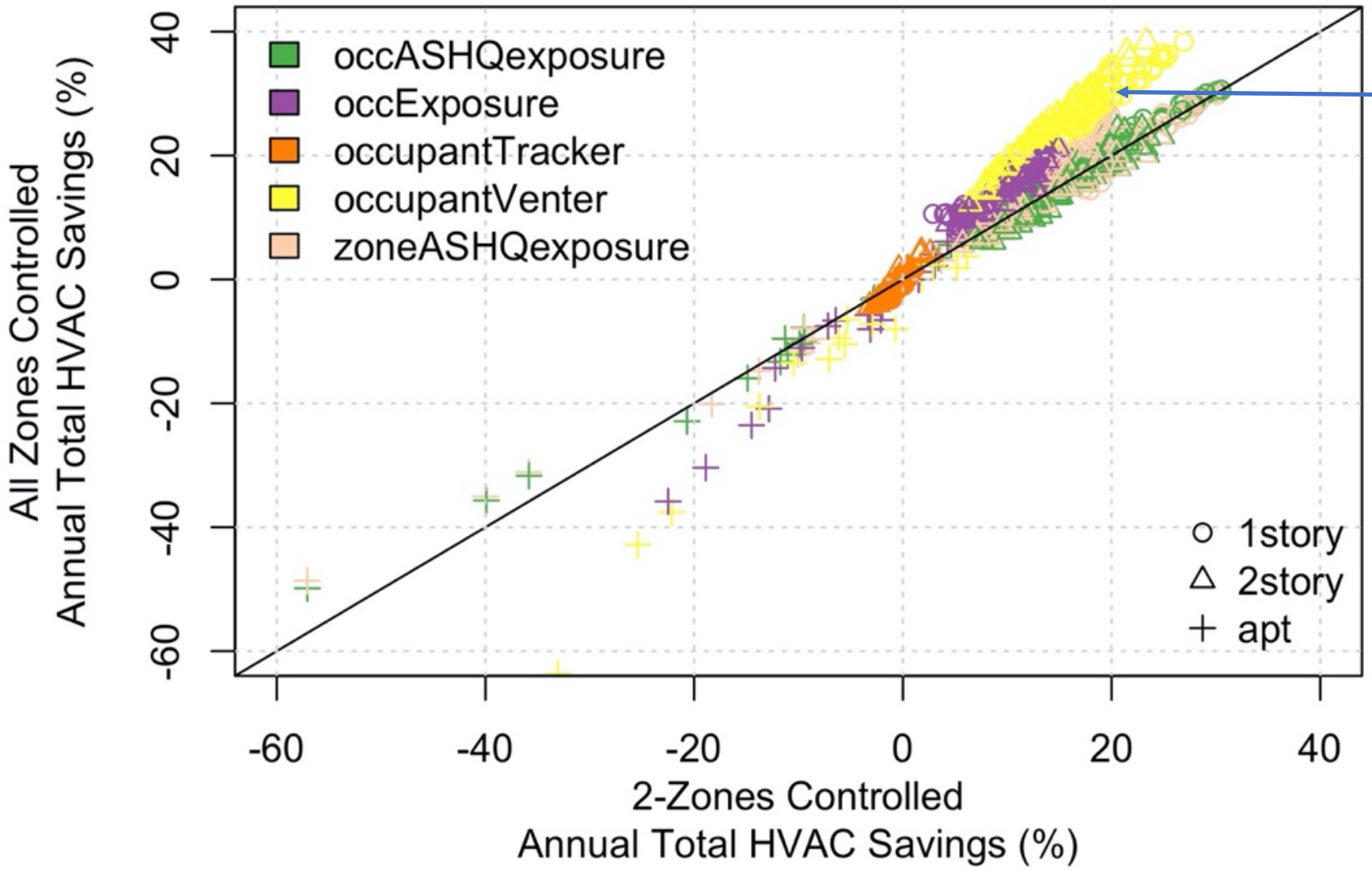


BUT.. increased contaminant concentrations for at least one contaminant:

- diversity of sources: continuous vs. periodic vs. outdoors
- diversity of removal mechanisms: outside air ventilation, deposition, filtration

People move from zone to zone – same problem as occupancy with contaminant build-up

More zones does not necessarily mean more savings

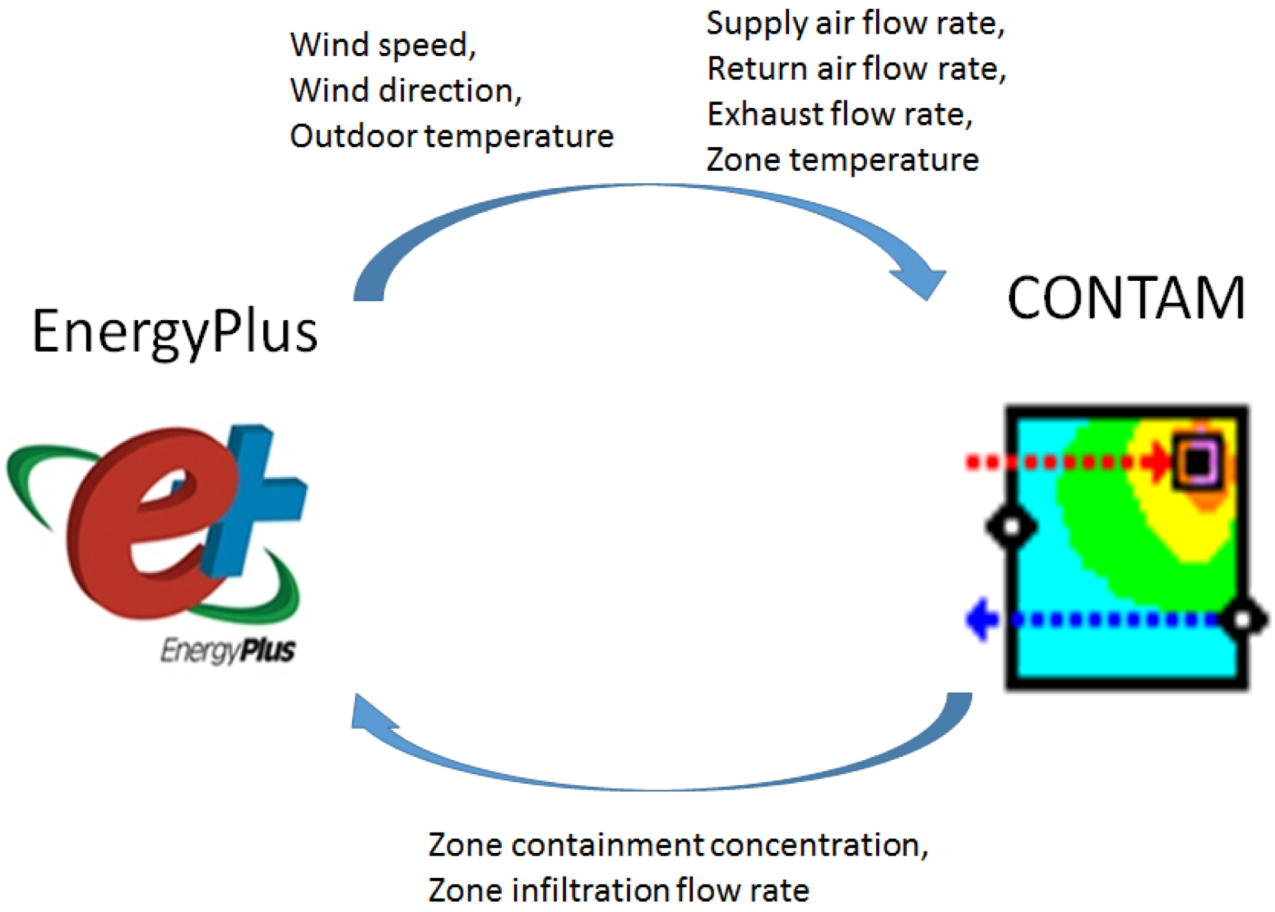


Additional energy saving BUT higher exposure

Zoning

- Zone control compared to non-zoned:
  - reduced IAQ when point-source contaminant emissions (e.g., cooking, breathing, bathing) were aligned with the location of the non-zoned fan
  - improved IAQ when contaminant sources (e.g., CO_2 in bedrooms with closed doors) are NOT aligned with the location of the non-zoned fan
  - improved IAQ when non-zoned systems did not evenly serve the dwelling. E.g., two-story dwellings, where first and second levels are ventilated at substantially different rates by non-zoned systems
  - More zones not necessarily better in homes:
    - sleeping and non-sleeping split seems optimal
    - For multistory homes – advantage to extra zones to ensure good ventilation of all floors

Compartmentalization in Multifamily Buildings



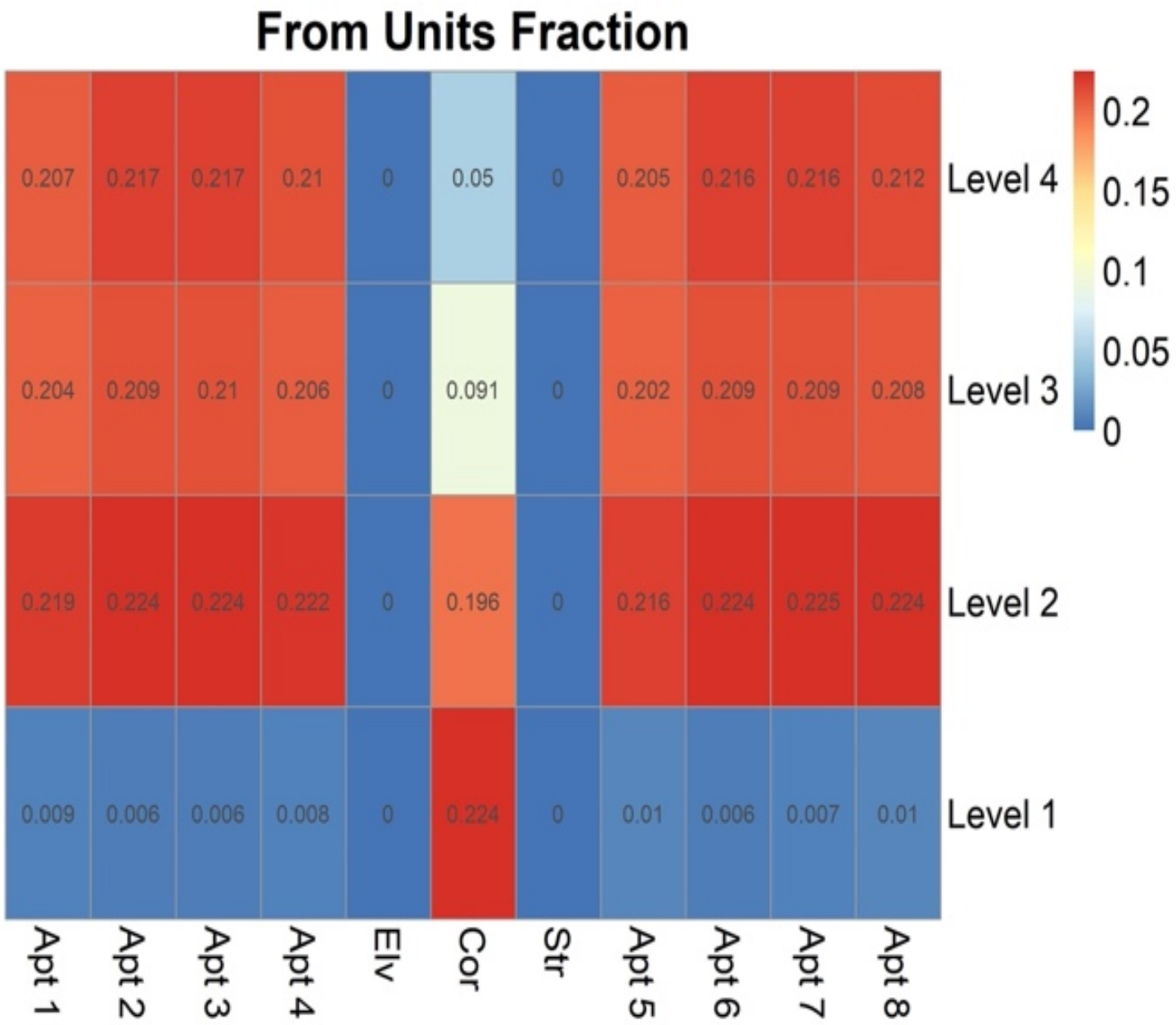
Combined CONTAM/EnergyPlus Simulations

- 4 stories, 8 apts per story
- Balanced, supply and exhaust ventilation systems
- Five whole dwelling unit leakage scenarios were simulated:
  - Typical (5 L/s/m^2)
  - Current practice (1.5 L/s/m^2)
  - Moderate target for better performance* (1 L/s/m^2)
  - Tight (0.5 L/s/m^2) and Super tight (0.25 L/s/m^2)

*Current requirement in US Ventilation Standard ASHRAE 62.2

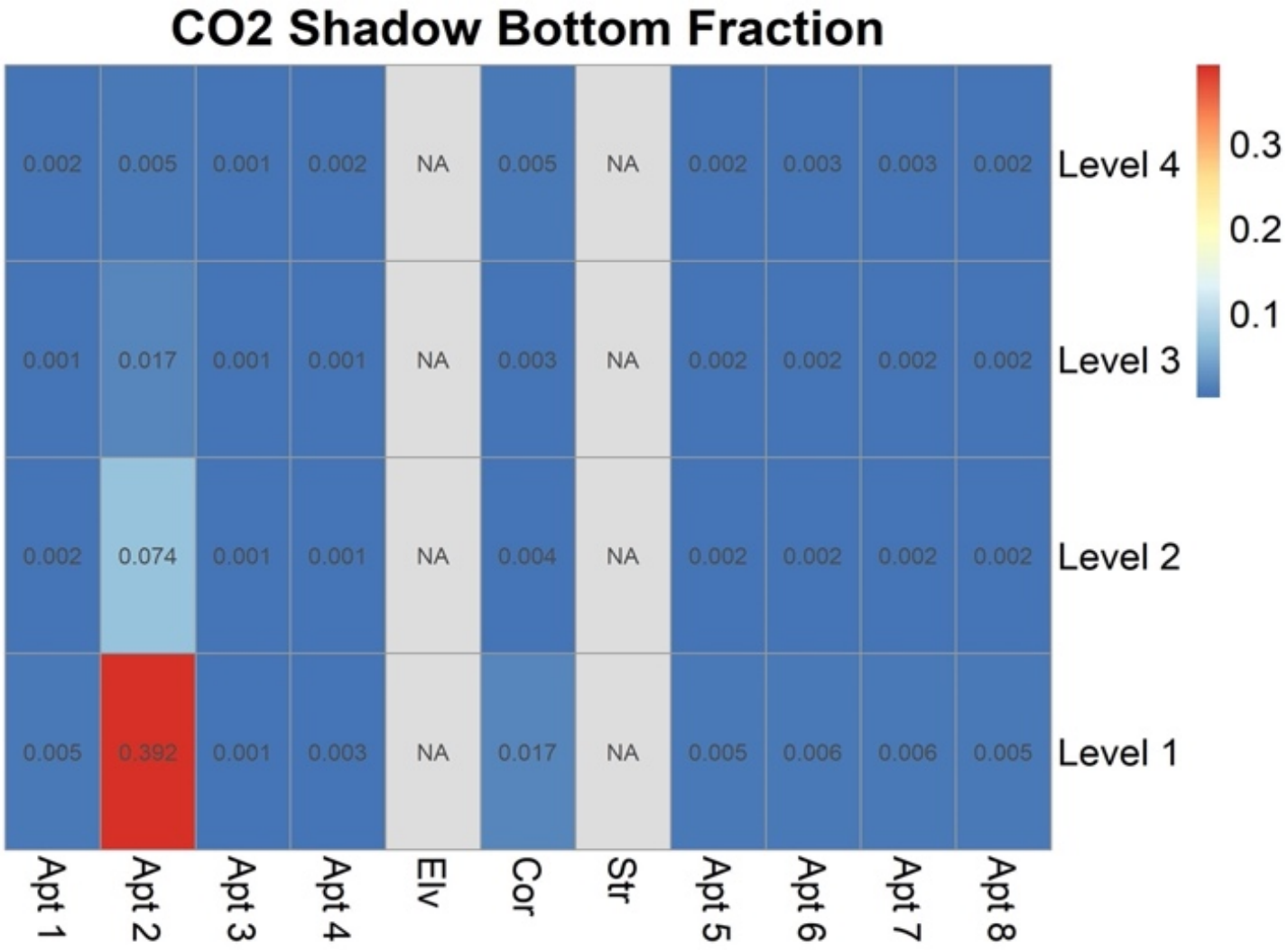
Air Flow Results

- Dwelling exhaust + corridor supply
- Worst case shown here
- Typical fractions 0.05 (5%) or less



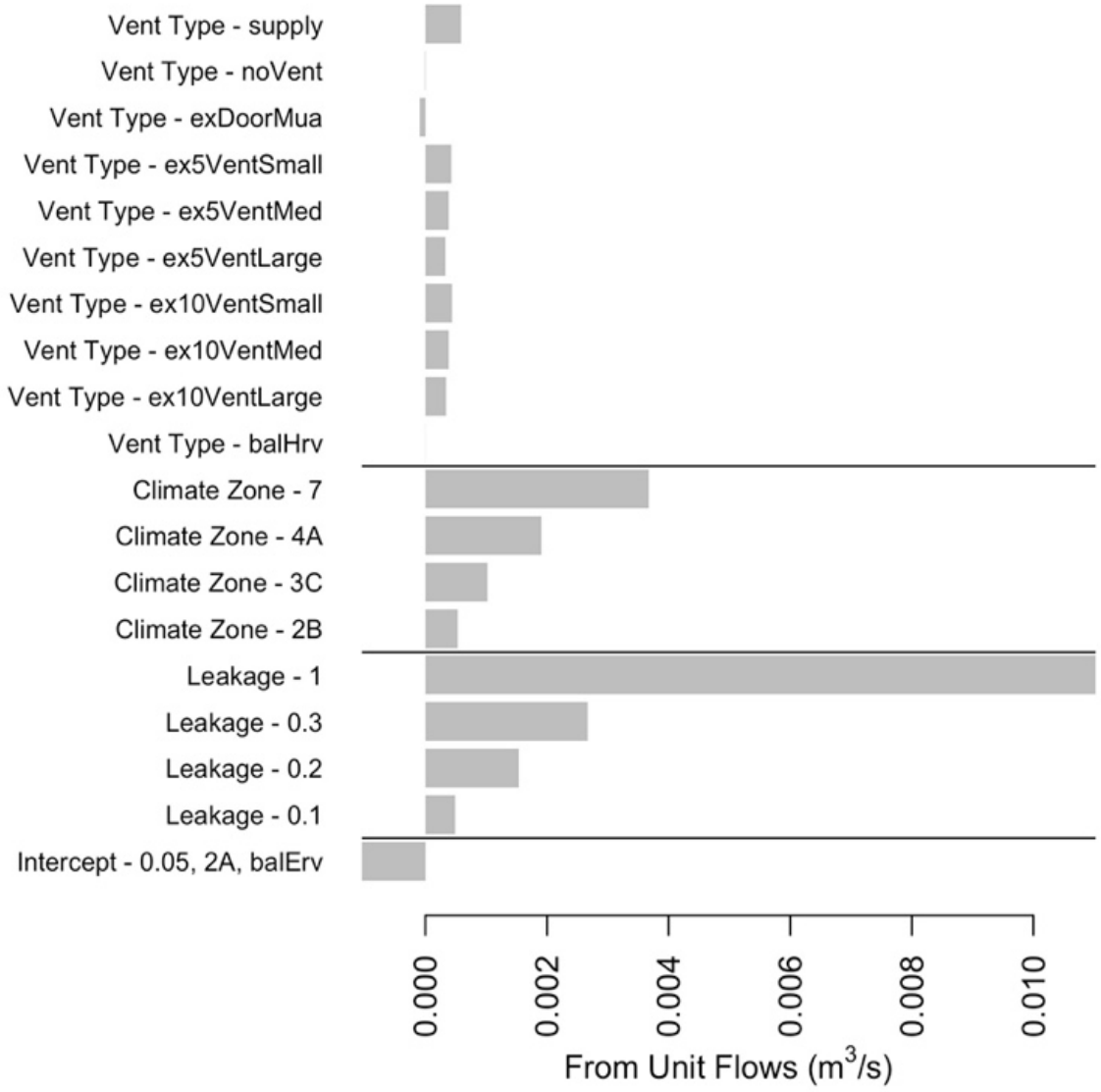
Results: ”shadow” contaminants

- Only significant in dwelling immediately above source unit



Results – parameter sensitivity

- Ventilation system type did not change the results very much – particularly at tighter levels.
- Climate matters
- Leakage dominates



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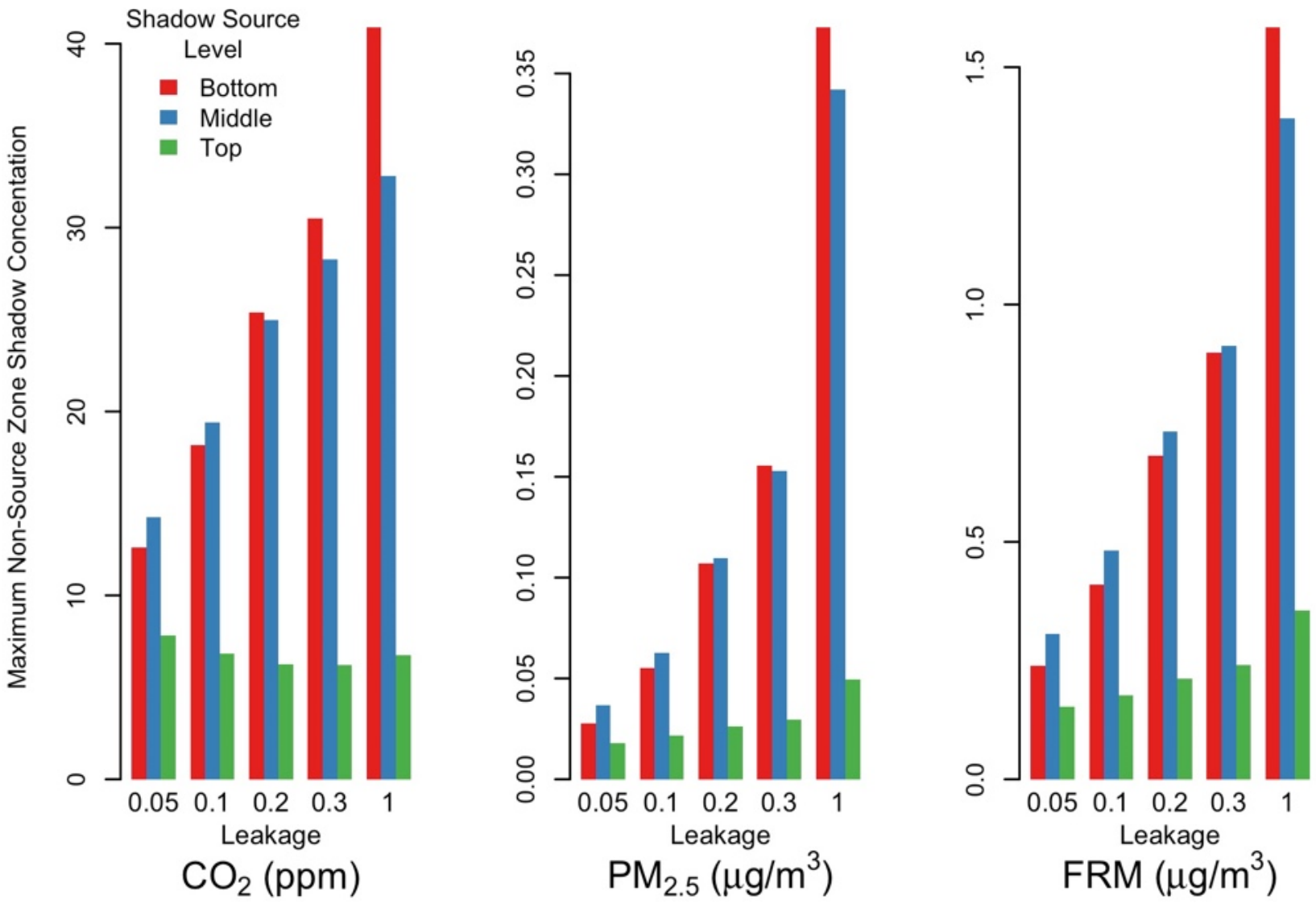


References

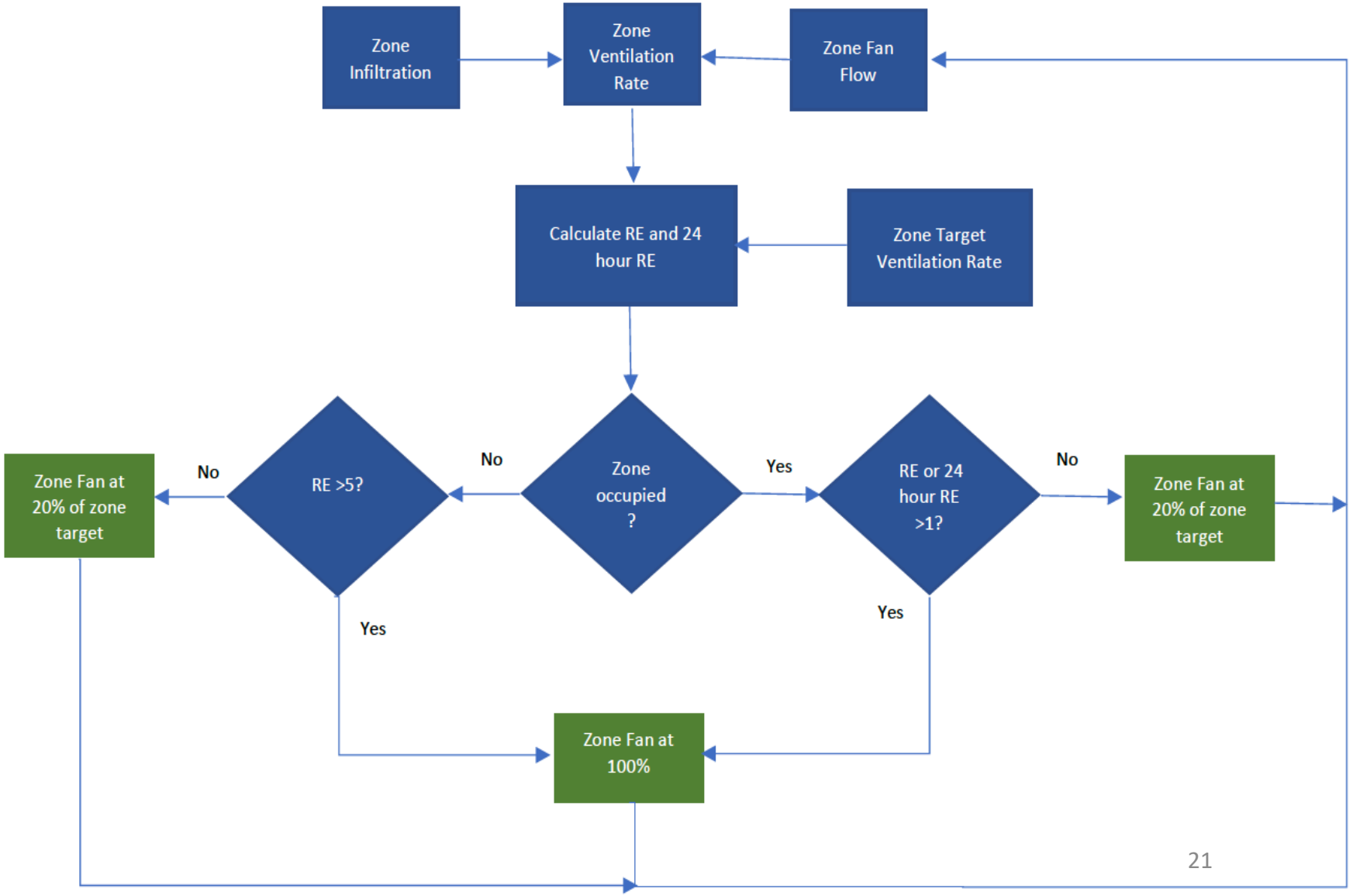
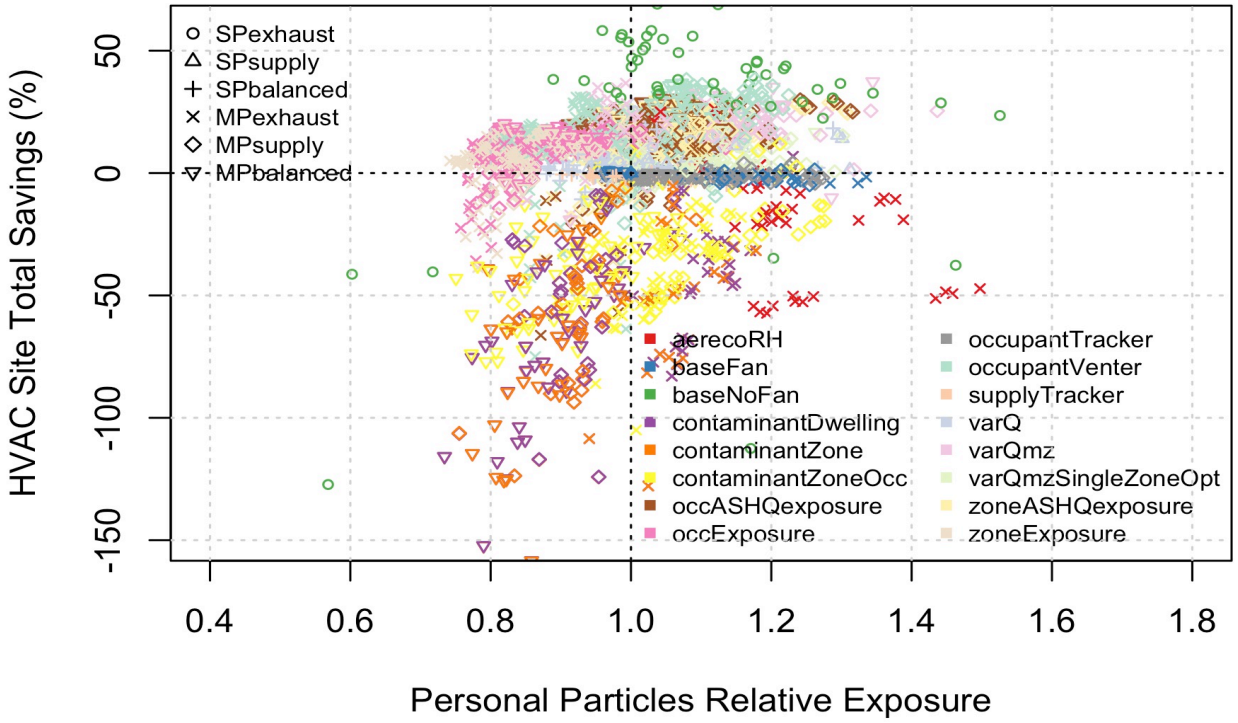
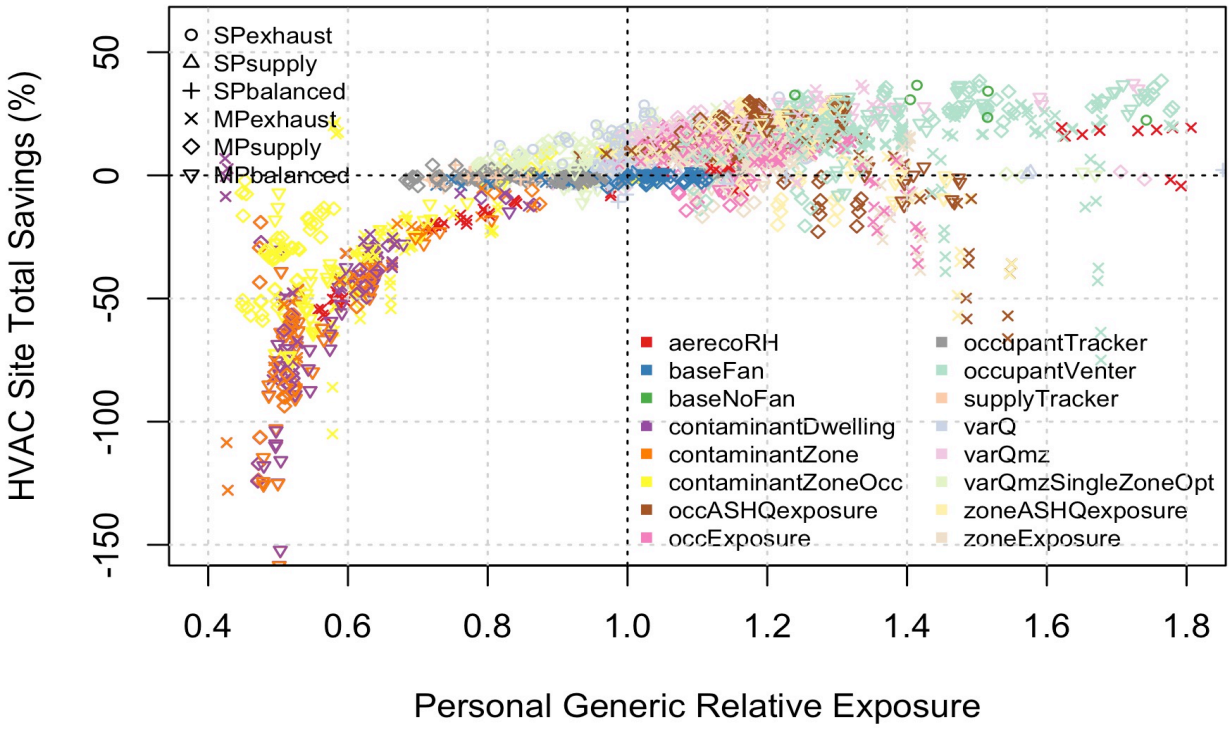
Walker, I., Less, B., Lorenzetti, D., Sohn, M. and Casquero-Modrego, N. 2022. Compartmentalization and Ventilation System Impacts on Air and Contaminant Transport for a Multifamily Building. Submitted to ASHRAE/DOE/BTECC Buildings XV conference.

Walker, I. Less, B. Lorenzetti, D. Sohn, M. (2022). Analysis of Zoned Ventilation Controls. Proc AIVC/ASHAEA IAQ 2020 Conference, Athens, Greece.

Example controller flowchart for a real-time zonal exposure controller

This control process is for a single zone and is repeated for each zone in the dwelling.

"RE" is the relative exposure calculated for an individual zone.



Zonal Control - Different results for different contaminants