IAQ 2020: Indoor Environmental Quality Performance Approaches

Analysis of Zoned Residential Ventilation Controls

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Learning Objectives

- Knowledge of optimized residential ventilation system design for zoning
- Understanding of the impact of ventilation zoning on energy use
- Understanding of the impact of ventilation zoning on indoor air quality
- Understanding of the limitations of ventilation zoning

Acknowledgements

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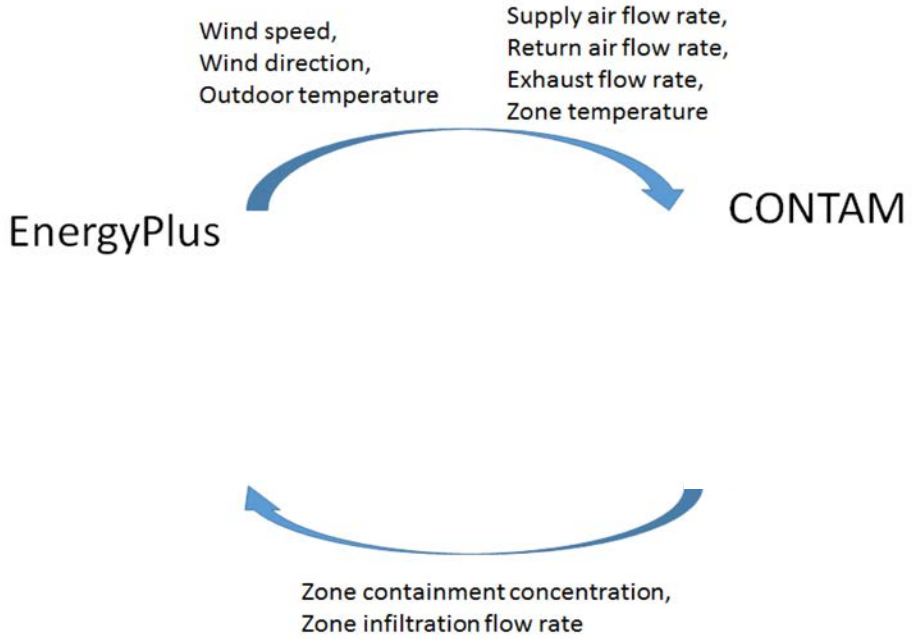
Simulation Background



- New California code compliant homes:
  - single family with envelope leakage of 0.6, 2 and 3 ACH50
  - Apartment, 3 ACH50
- Central forced air for non-zoned and distributed zonal heat pumps for zoned systems

California Climate Zone	HDD	CDD
1	2400	5
3	1700	70
10	950	950
16	2800	250

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

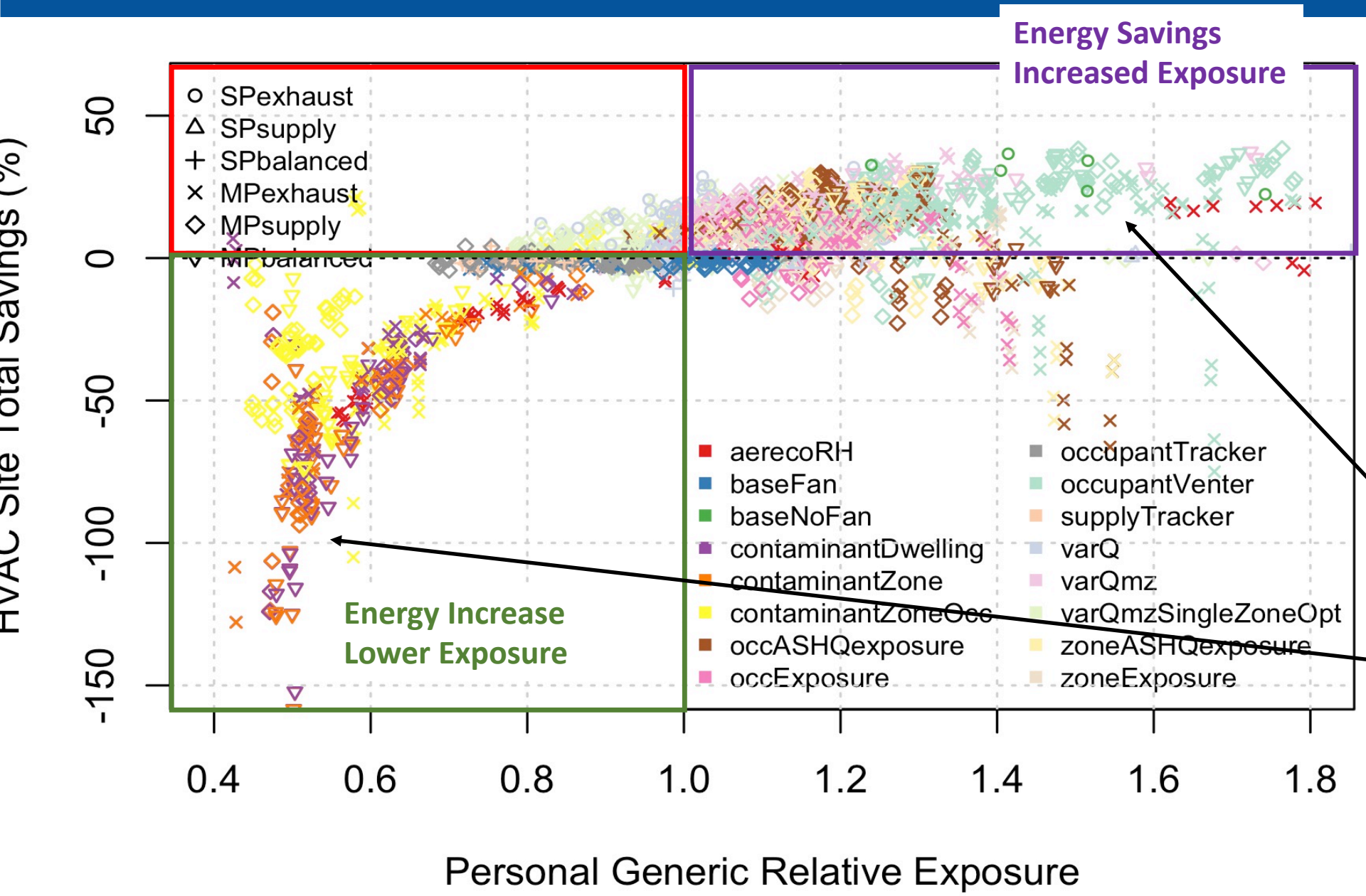
- Use reference exposure limits for chronic exposure:
  - Formaldehyde: OEHHA REL is 9 µg/m^3 for 8-hour and chronic exposures
  - Particles (PM2.5): WHO Chronic level is 10 µg/m^3
  - CO_2 : 1100 ppm
  - Moisture: 60% RH

Smart Ventilation Strategies

- Track occupants (assumes we know occupancy)
- Combine with outdoor temperature (shift to milder conditions)
- 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 system
- Track occupant individual exposure
- Ventilate at low rate unoccupied, higher when occupied. No 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
  - Control RH between 30% and 60%

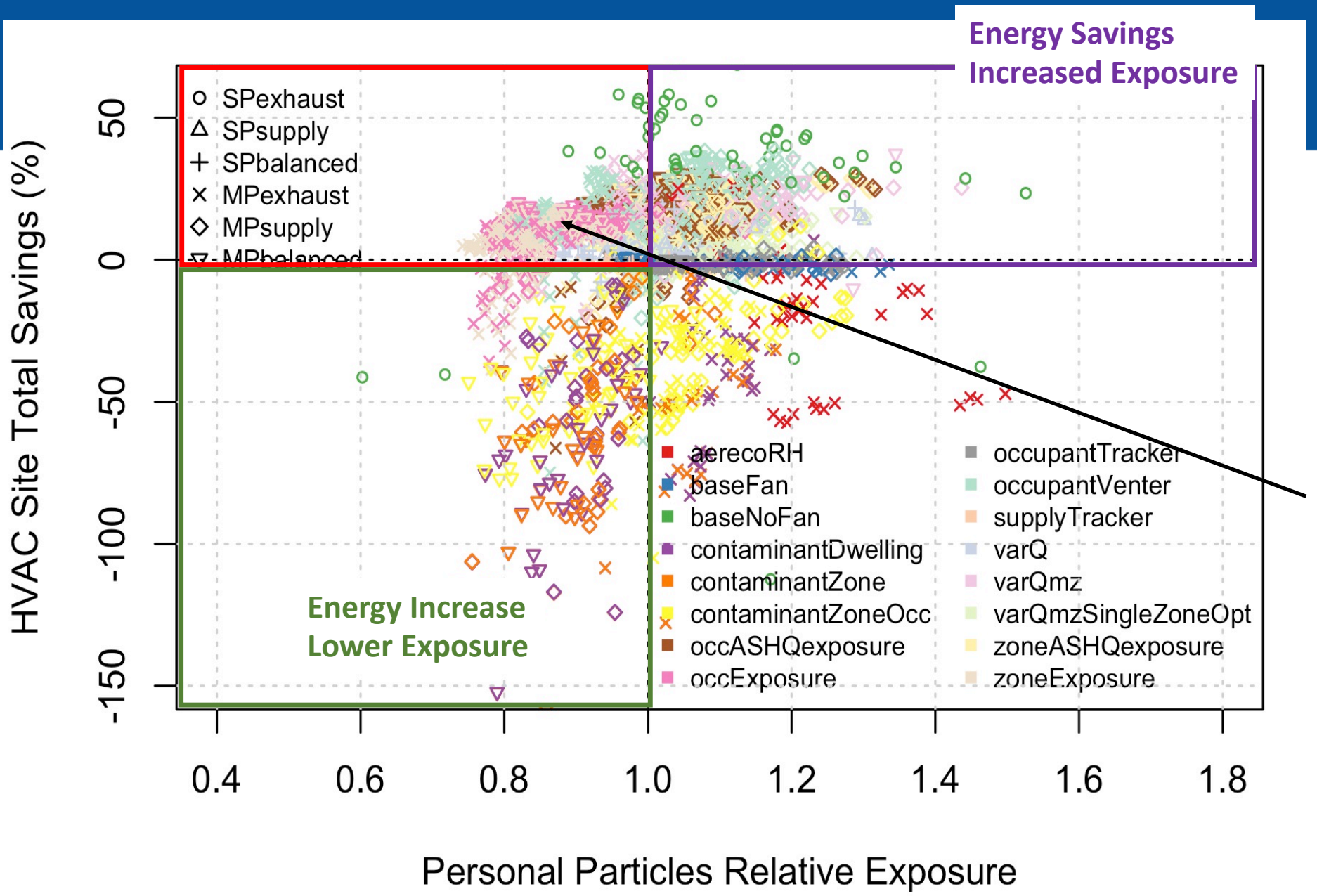


Many controls saved energy but increased exposure OR decreased exposure but used more energy

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

Exposures and Ventilation Rates – no contaminant controls

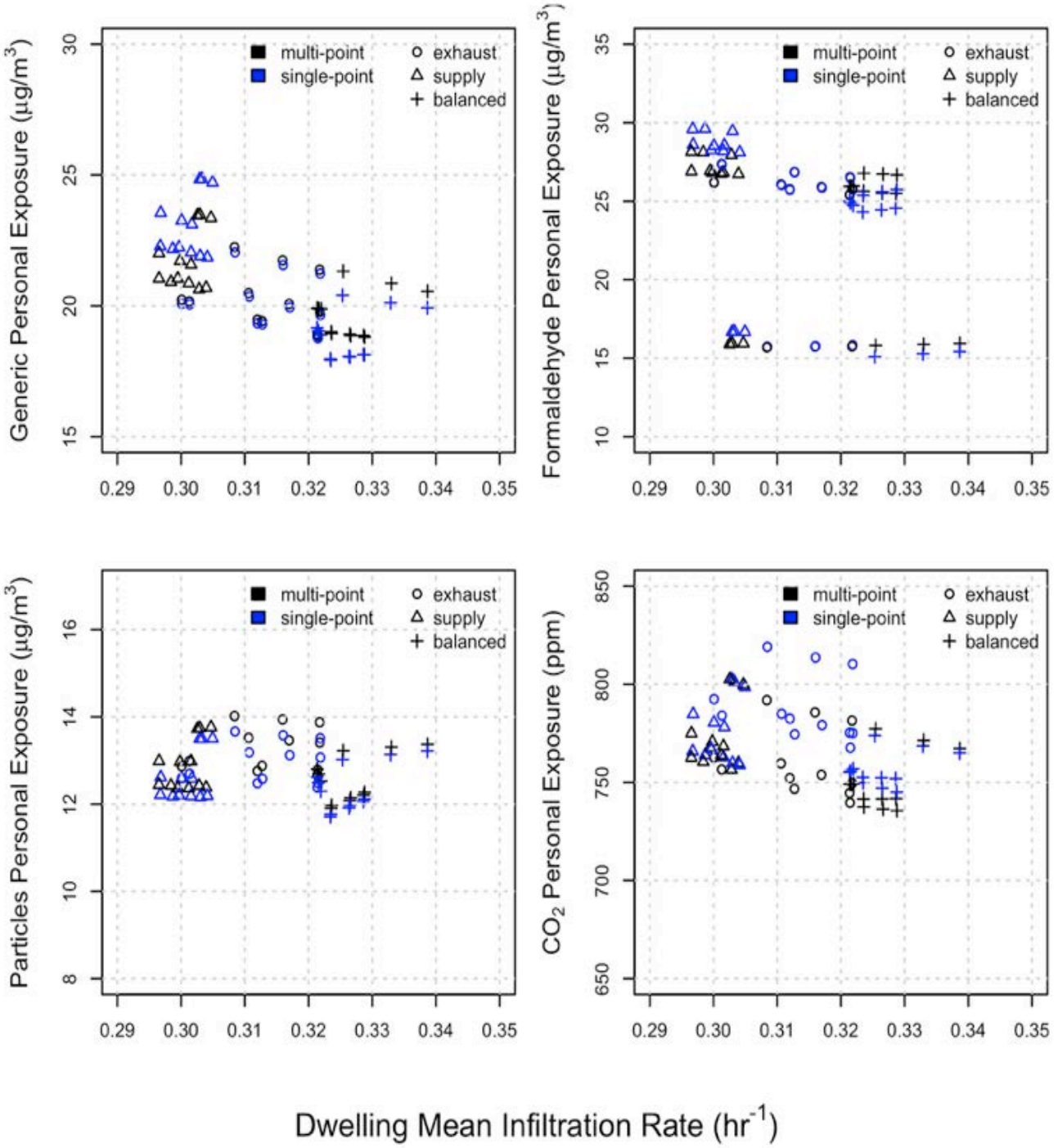
Zoning can:

increase exposure

- For particles
- For generic and formaldehyde exposure

decrease exposure

- For most CO_2 cases



Zoning Exposure Results for VarQ controller (best energy performance) with contaminant controls

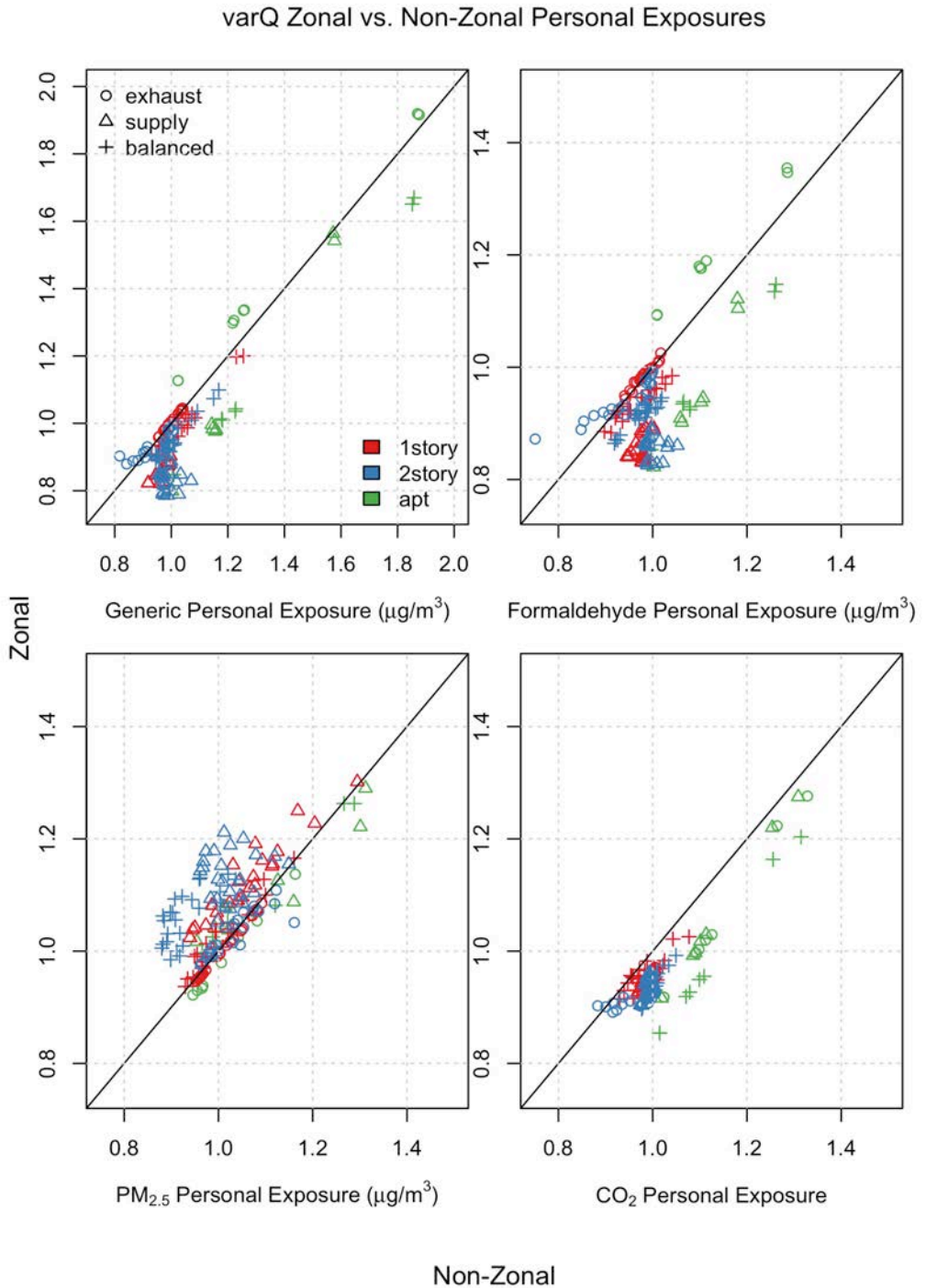
Zonal controls can either ***increase*** or ***decrease*** exposure:

Biggest ***decrease***: consistently better for CO_2

- because occupants are source

Biggest ***increase***: consistently poor for $PM_{2.5}$ supply & balanced systems

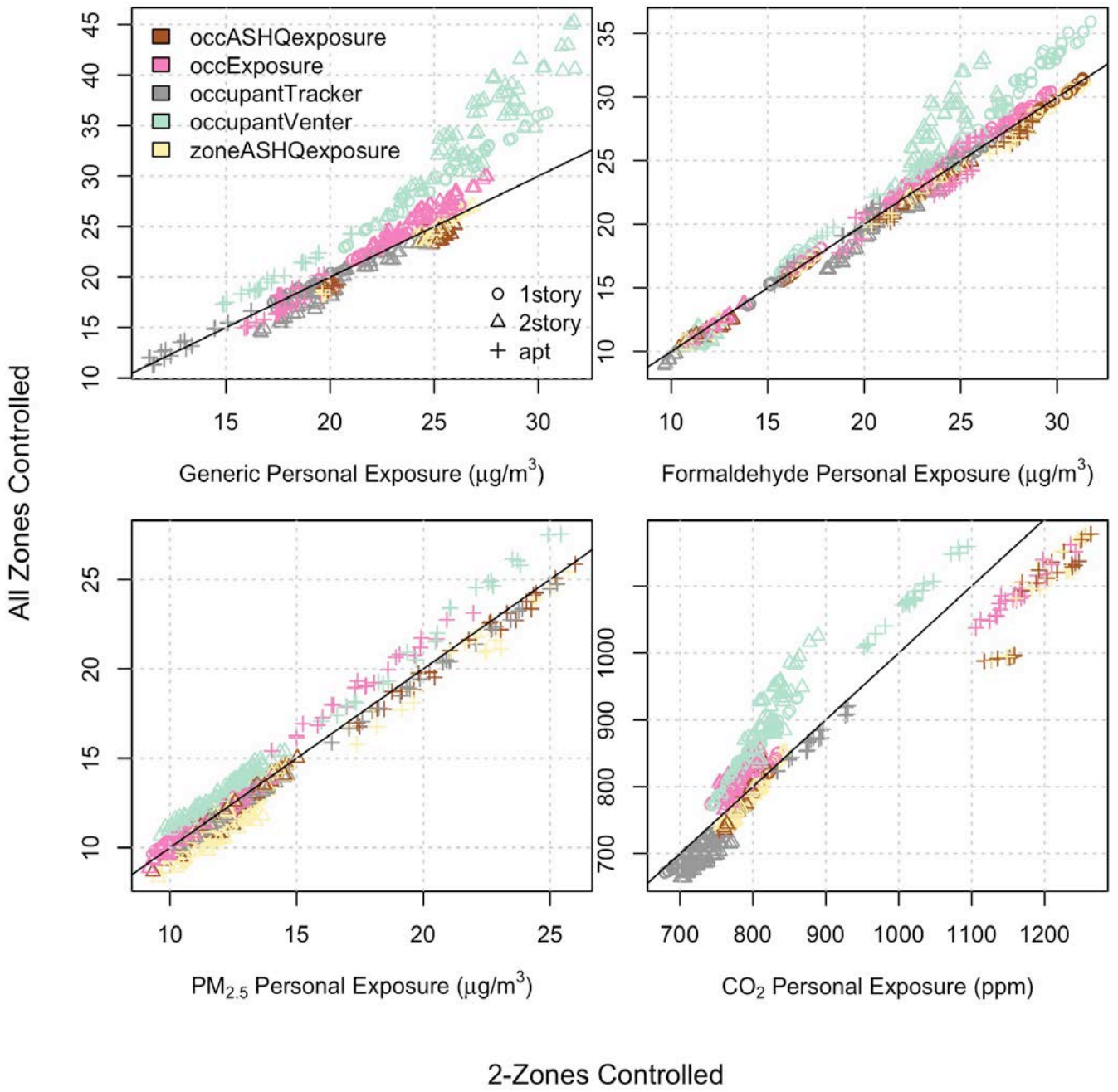
- Exhaust more effective at concentrated contaminant removal



Are more zones better for contaminants?

Controlling more zones is sometimes good, some times not for *CONTAMINANTS*

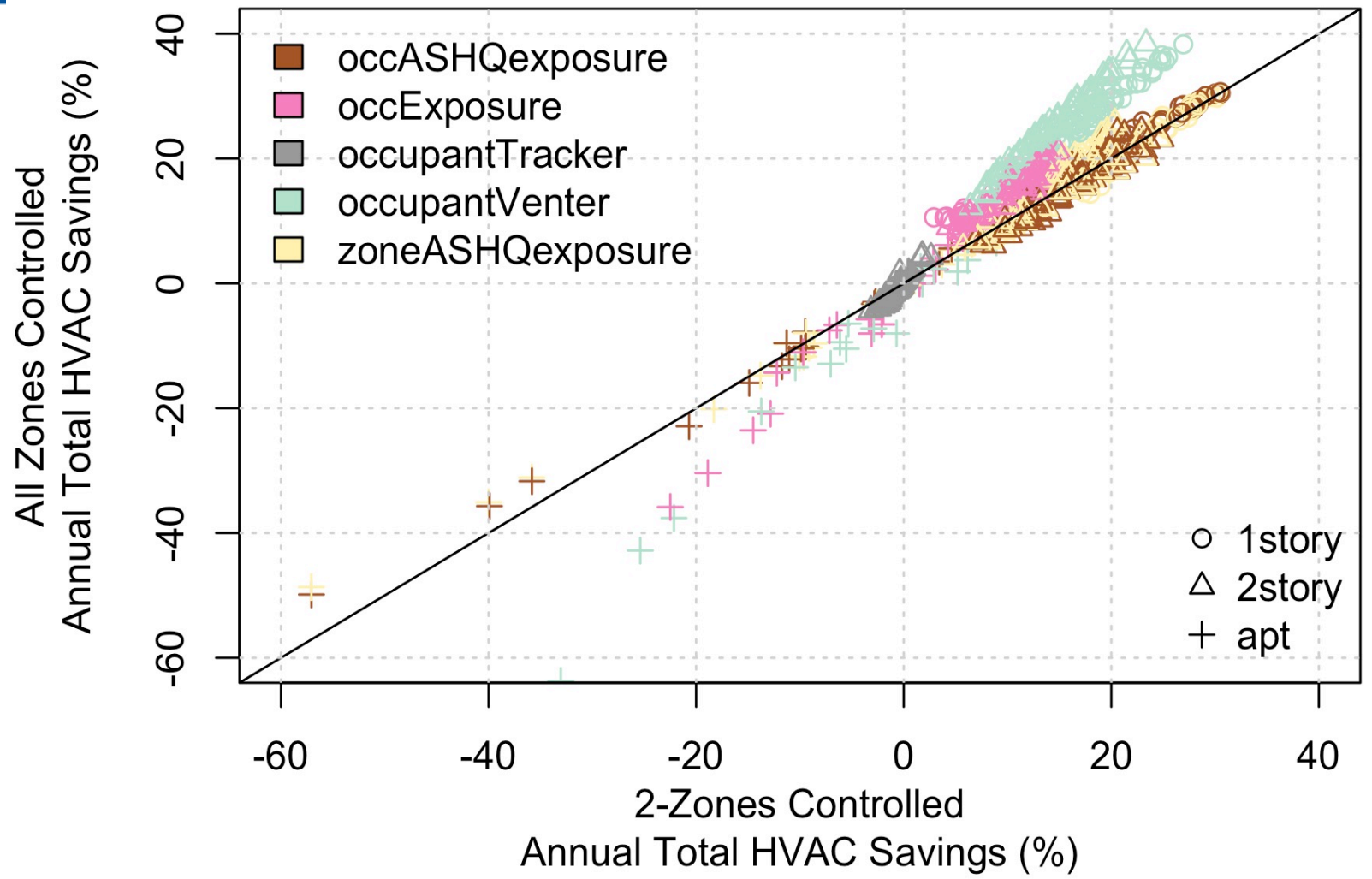
As occupants move from zone to zone they are exposed to higher contaminant levels upon entry to a zone that was previously under-ventilated.



Are more zones better for energy savings?

Sometimes good: SF homes

Sometimes not: apartment



Other observations

- Direct contaminant control
  - Can't vent enough to control formaldehyde – even at double the ASHRAE 62.2 minimum required rate
  - Future work will need to allow for much higher formaldehyde – is this OK?
- Exhaust systems:
  - Least zonal (but still good for bedroom CO_2 control)
  - Most consistent contaminant control
- Supply systems
  - More effective zoning – lowest total ventilation
  - Higher power fans mean bigger energy use… but also bigger savings when controlled
  - Not so good for particles: more from outside + not as good at removing particles from cooking
- Balanced systems
  - Effective zoning – highest total ventilation but also highest fan power. Had the biggest energy savings from smart controls

Conclusions

- Few control strategies saved energy without increasing exposure
- Hard for zonal ventilation to control all contaminants
- Exhaust systems most consistently saved energy
- Effective zoning limited by:
  - Open doors
  - Occupant movement (continually entering less ventilated space)
  - Zoning effect depends on contaminant
    - Particles increased, CO_2 decreased, HCHO/generic source up or down
- Direct contaminant controls were ineffective due to the inability to control formaldehyde below chronic levels
- Adding extra zones beyond sleeping/other ineffective

Bibliography

Walker, I.S., Less, B.D, Lorenzetti, D. and Sohn, M. 2022. Analysis of zoned ventilation systems. Presented at IAQ 2020. Athens, Greece. May 6th2022.

Additional details in:

Less, B., Walker, I., Lorenzetti, D., Mills, E., Rapp, V., Dutton, S., Sohn, M., Li, X., Clark, J. and Sherman, M. 2020. Smart Ventilation for Advanced California Homes. LBNL-2001342. https://doi.org/10.2172/1635274

Less, B., Walker, I., Lorenzetti, D., and Sohn, M. (2021), SVACH - Development of advanced smart ventilation controls for residential applications, Dryad, Dataset, https://doi.org/10.7941/D1WK8M

Questions?

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Thank you!