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Compartmentalization and Ventilation System Impacts on Air and Contaminant Transport for a Multifamily Building

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Acknowledgements

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Background

ASHRAE Standard 62.2 and other codes/standards bodies are working to improve ventilation requirements for multifamily dwellings

This paper considers two key questions:

1. Can we recommend a level of compartmentalization that minimizes internal air flows to limit IAQ issues from unit to unit transport of contaminants?
2. Does it matter what ventilation system you have, and are different vent types more or less sensitive to compartmentalization?

Other considerations:

- Are the current ASHRAE 62.2 requirements reasonable?
- What are climate impacts?

Modeling Summary

Use coupled CONTAM and EnergyPlus models to determine air flow and energy use for a year

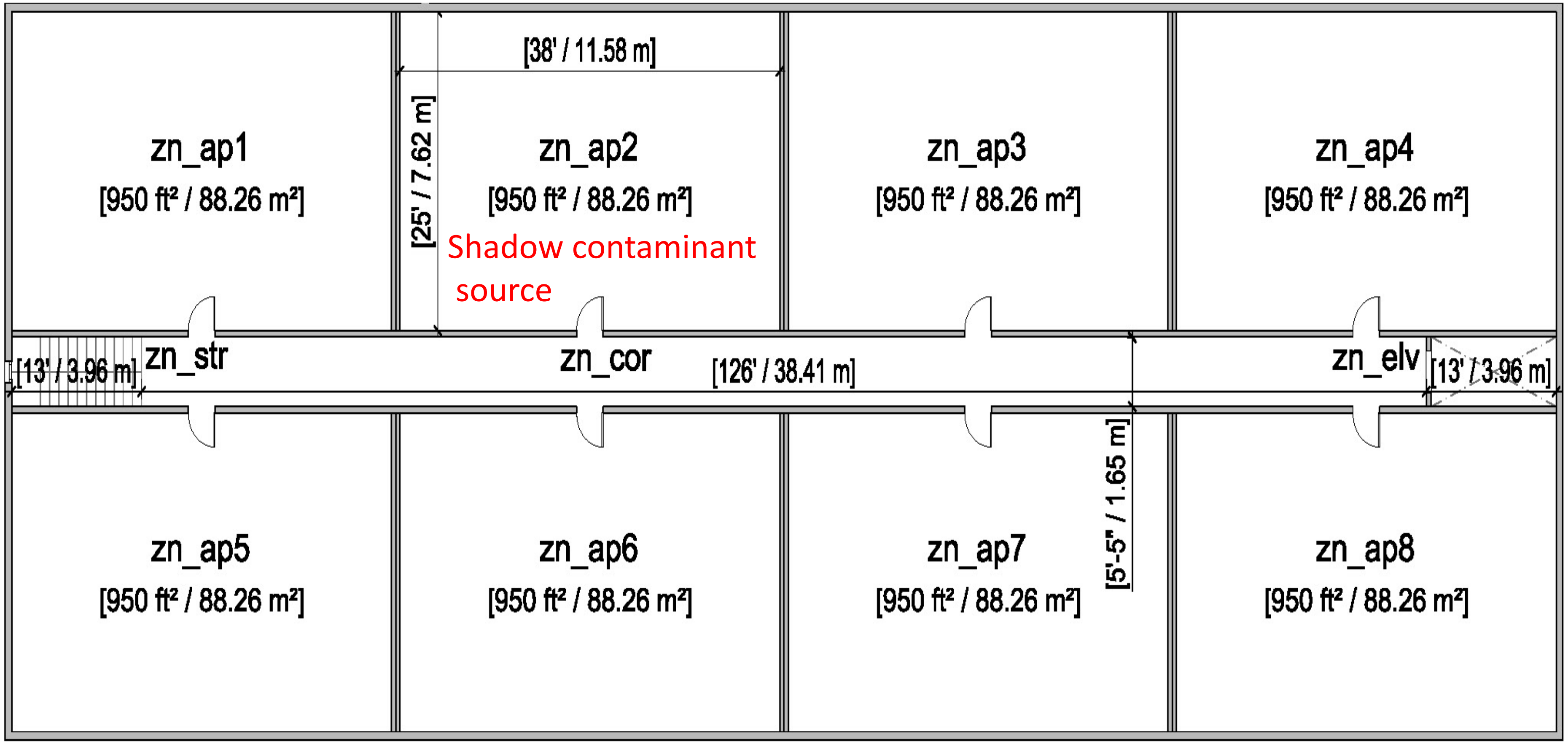
- Using 3 minute timesteps to allow for scheduling of kitchen/bath exhaust fan operation, occupancy schedules and ventilation controls
- CONTAM – air flows and contaminant concentrations
- EnergyPlus – moisture balance and energy calculations
- Mid-rise common corridor prototype based on existing models used in DOE energy code analysis
- Zoning
  - Each dwelling unit is a single zone – assumed a fully mixed dwelling
  - Added stairwell and elevator zones to prototypes

Five Climate Zones

- 2A (Hot humid, Tampa, FL), 2B (Hot dry, Tucson, AZ), 3C (Warm marine, San Diego, CA), 4A (Mixed humid, New York, NY) and 7 (Very Cold/International Falls, MN).
- Heating from gas furnace (80% AFUE) at 21.1 C
- Cooling from DX cooling coil (nominal COP=3.6) at 24 C

Prototype floor plan

Four floors each with same floorplan
Walk-up and high-rise in next phase of work



Air Leakage

Air Leakage at 50Pa normalized by total envelope area

1. Typical: 5 L/s50/m^2 (1cfm50/ft^2)
2. Current practice (**ASHRAE 62.2 old requirement**): 1.5 L/s50/m^2 (0.3 cfm50/ft^2)
3. Moderate target for better performance (**ASHRAE 62.2 new requirement**): 1 L/s50/m^2 (0.2 cfm50/ft^2)
4. Tight: 0.5 L/s50/m^2 (0.1 cfm50/ft^2)
5. Super tight: 0.25 L/s50/m^2 (0.05 cfm50/ft^2)

Leakage distribution based on field studies using “guarded’ tests

- 2.5% to each party wall
- 10% to each floor or ceiling surface
- 45% to the corridor wall
- 30% to exterior wall surfaces.

Ventilation Systems

11 systems – all with flows fixed to minimally meet ASHRAE 62.2: 27.5 L/s *continuous operation*

1. Balanced HRV
2. Balanced ERV
3. Unit exhaust with corridor supply
4. Six variations of unit exhaust with trickle vents: 2 design pressures (5 and 10 Pa) and three fan and vent sizes: ASHRAE 62.2, ASHRAE 62.2 + 50%, and Double ASHRAE 62.2
5. Unit supply
6. None

With and without MERV 13 filters (90% efficient for PM2.5) on dwelling unit supply ventilation air flows, corridor supply ventilation air flows, and dwelling unit recirculated air flows from the heating and cooling system

Kitchen (50 L/s) , bath (25 L/s) and laundry exhaust (37.5 L/s) on *fixed schedules*

Corridor ventilated to meet ASHRAE 62.1: 19.2 L/s *continuous operation*

Contaminant Sources

Formaldehyde - from field studies

- Outdoors: 2ppb constant
- Indoors: based on temperature and humidity typically 20 µg/h/m^2
- No emission in corridors, stairwells or elevator shafts

Fine Particles – PM2.5 – from field studies

- Outdoors: Hourly data from EPA monitoring sites.
  - Two cases: Averaging 14.8 µg/m3 and 8.1 µg/m3
- Indoors: 0.07 µg/s per occupant, 20.8 µg/s from cooking (assuming a 50% Capture Efficiency range hood)
- Includes interior deposition

Contaminant Sources

Carbon Dioxide: Two adults and two children on fixed schedules

- Adults: 10 mg/s when awake, 6.5 mg/s asleep, and children 6.5 mg/s awake and 4 mg/s asleep
- No CO_2 from cooking
- 400 ppm outdoors constant

Water Vapor – mostly based on ASHRAE Standard 160 and National Institute of Standards and Technology publications 7212 and 6162

- Respiration, cooking, showering, dishwashing from occupancy + background generation
- EnergyPlus Effective Moisture Penetration Depth (EMPD) model

“Shadow” Contaminant Emissions

For tracking of fraction of each contaminant that comes from a specific unit.

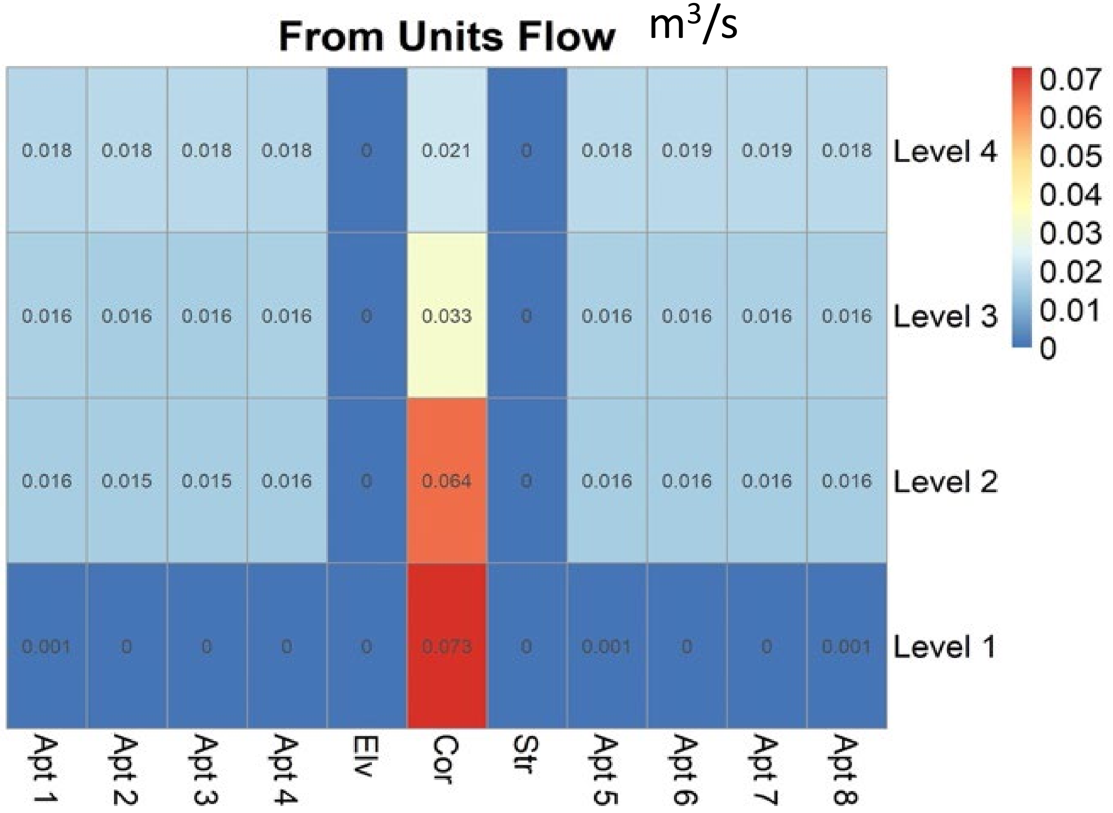
Unit #2 on floors 1, 3 and 4.

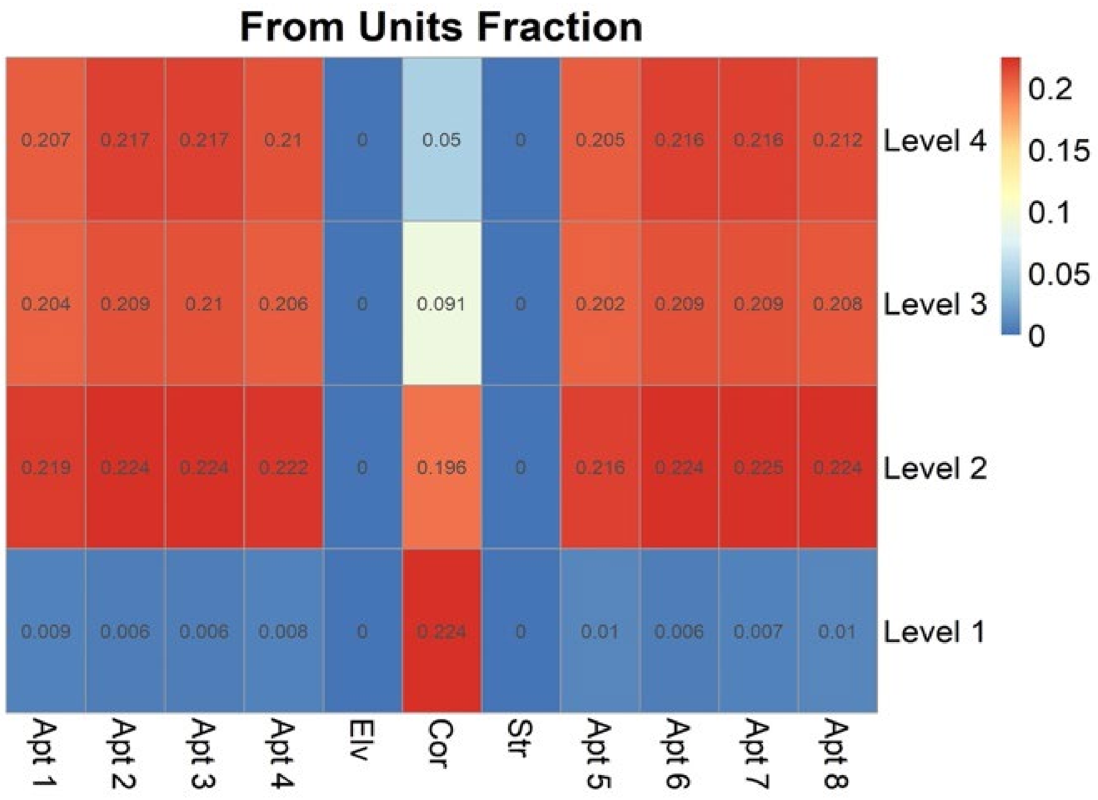
Same contaminants and emission rates but tagged and separately tracked.

50% removal rate for PM2.5 for flow through interior (and exterior) walls

Results – Air flows from other units

Worst case to best illustrate differences between units: Highest leakage, In-unit Exhaust with corridor supply, CZ7



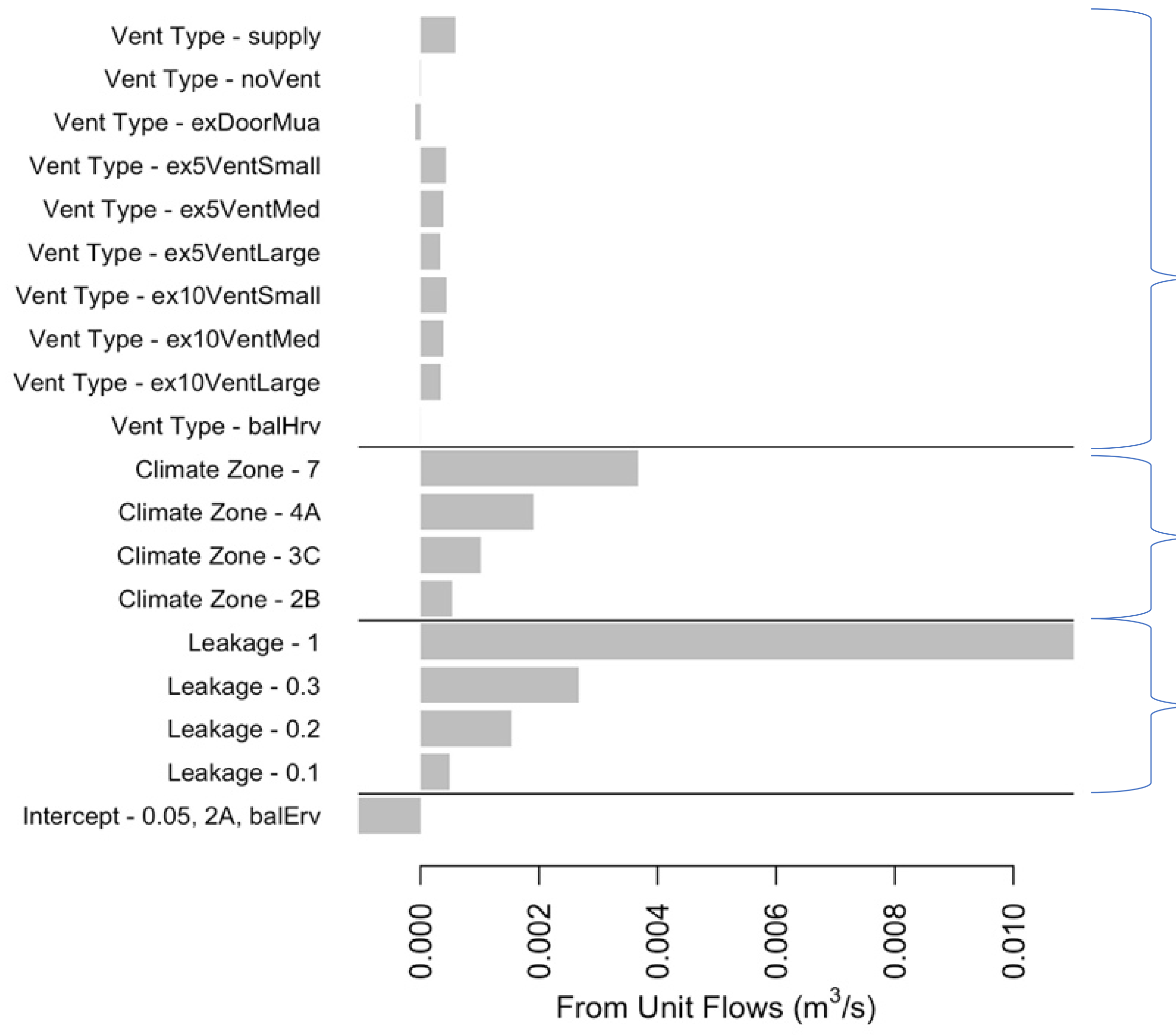


Flows are mostly vertical – lower floor has almost no flow from other units

Worst case is about 18 L/s or 22% of total air flow into the unit is from other units

Average across all simulations is 3 L/s or 5%, and less than 3% for current ASHRAE 62.2 leakage limit

Results – Sensitivity of Air Flows from Other Units to Simulation Parameters



Multivariate linear regression to estimate the sensitivity to each simulation parameter
Relative of a base case of lowest leakage, Climate Zone 2A and balanced ERV

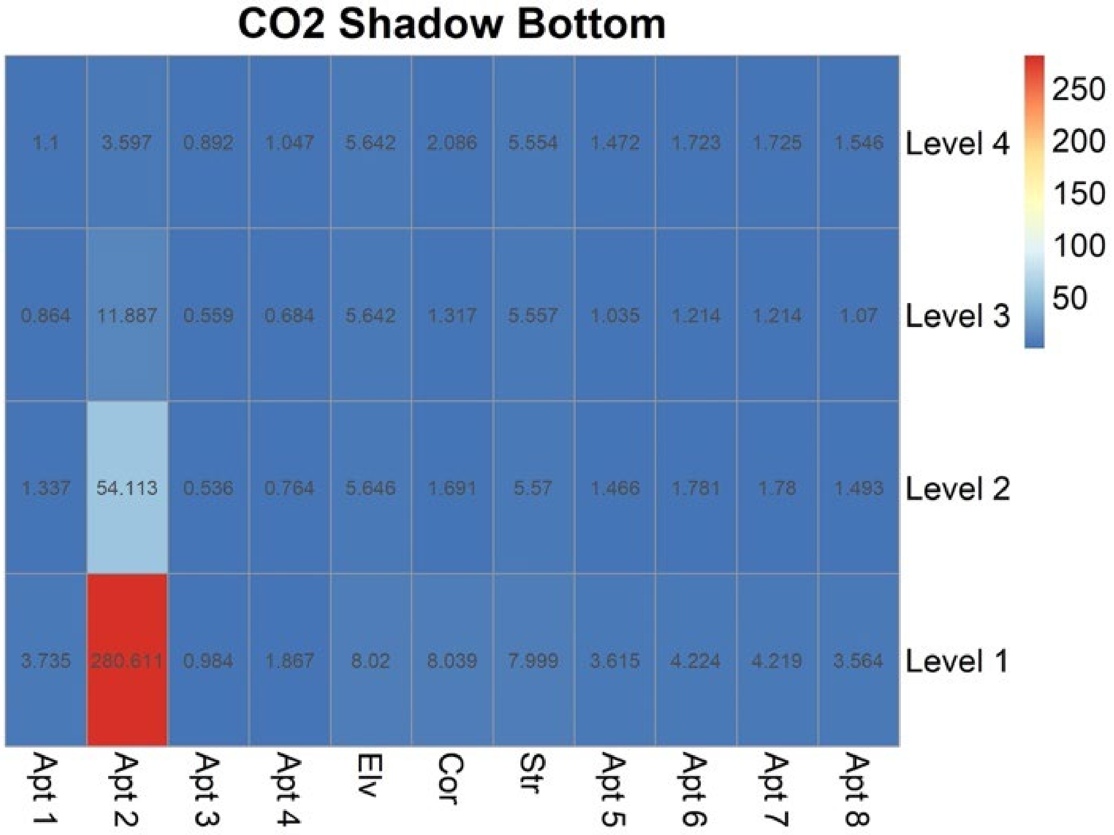
Ventilation system type has almost no effect: <2%

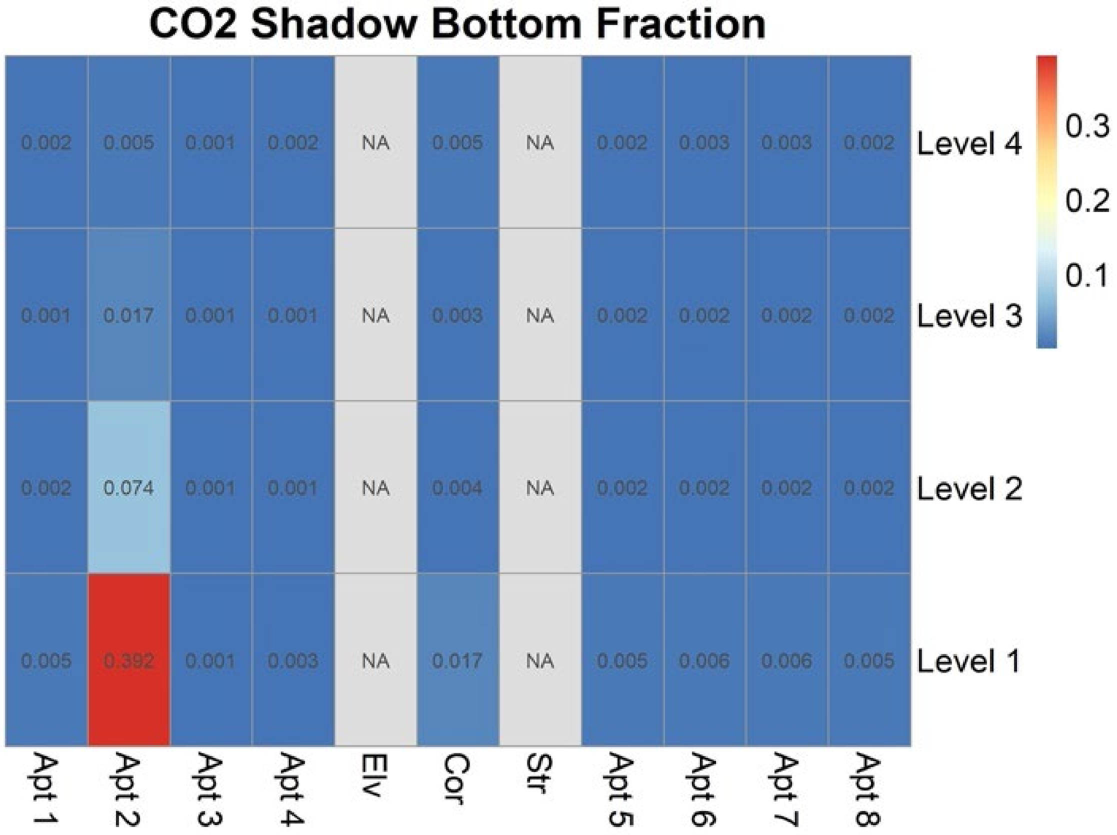
Climate is more important – colder climates have more transfer between units: up to 5% of total flows

Leakage is the dominant factor – good justification for liming this in ventilation standards

Results – Shadow Contaminants

Annual mean shadow CO_2 concentration ppm (left) and concentration fraction (right) sourced from Apartment 2 on Level 1 of the building. Highest leakage, In-unit Exhaust with corridor supply, CZ7



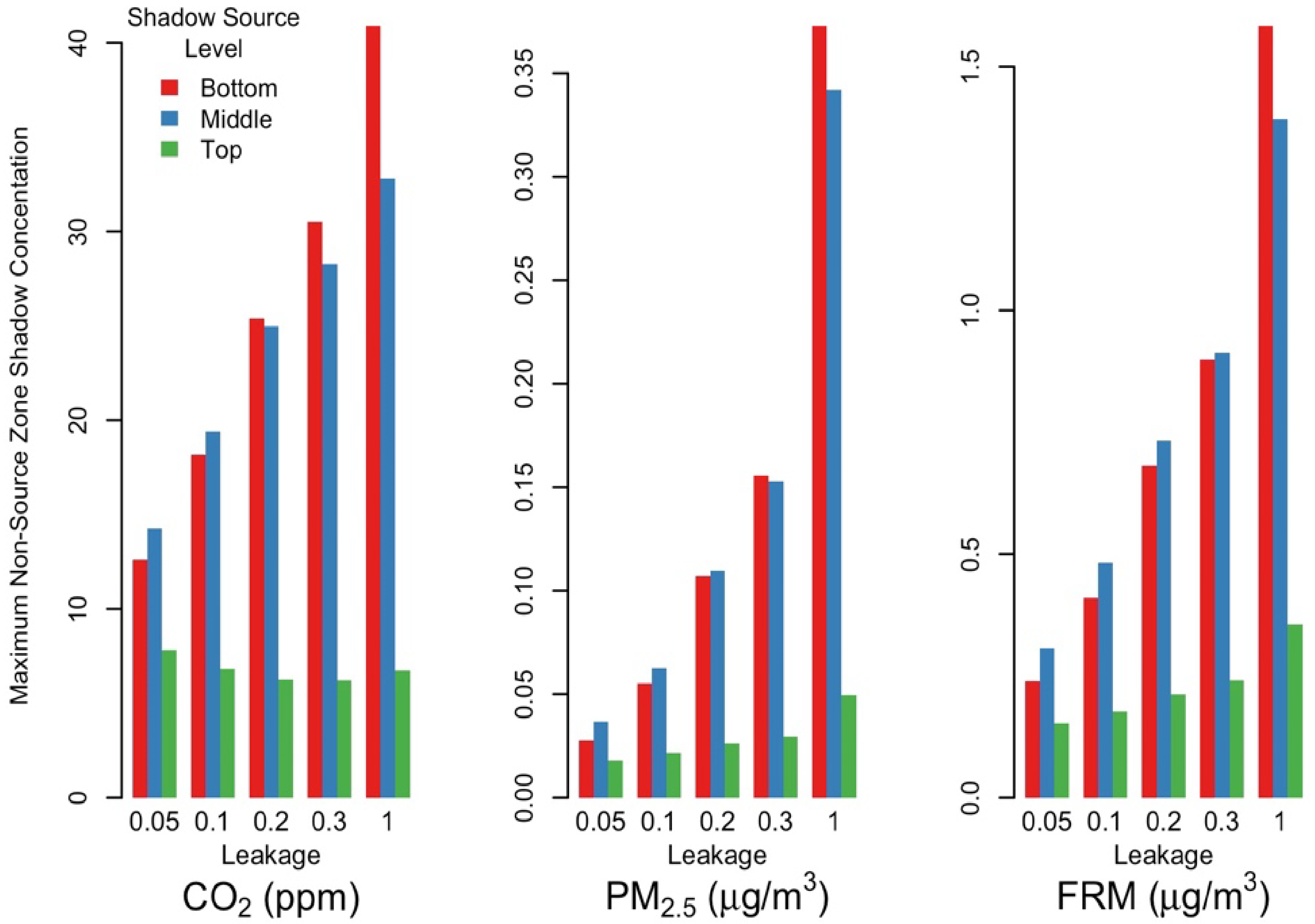


Transport is vertical in almost all cases the highest concentration of shadow contaminant is in unit directly above the source

In this worst case – 7% of CO_2 from source unit in unit directly above

Results – Shadow Contaminants

Worst-case annual concentration of shadow contaminants found in non-source zone



Worst case contributions at 62.2 leakage level:

- CO_2 25ppm (~4%)
- PM2.5 0.1 μg/m^3 (~2.5%)
- Formaldehyde 0.7 μg/m^3 (~3%)

Typical contribution from other units at is about fifty times lower than the worst case

Bottom and middle level sources transport much more to other units

PM and Formaldehyde more sensitive to leakage due to deposition mechanisms

Conclusions

General:

- Leakage is dominant factor – good justification for liming this in ventilation standards
- Climate also matters –colder climates – more transfer between units up to 5% of total flows
- Ventilation system type has almost no effect
- Flows from other units are dominated by vertical transport
- For reasonable leakage limits flows and contaminant transport are low (<5%)

ASHRAE 62.2 Compartmentalization leakage requirement:

- Leads to low air and contaminant transport (<5%) between units in the building.

Conclusions

Future work:

- Analyze energy use results
- Low rise walk up – no corridor
- High-rise – 10 Story

Bibliography

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. Proc. Thermal Performance of the Exterior Envelopes of Buildings XV. Clearwater Beach, FL. ASHRAE.

Questions?

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