Airtightness and internal air flows in multifamily buildings

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Why is internal leakage important?

- Contaminant Transport
  - Odours (cooking, tobacco smoke)
  - Moisture
  - Health (particles, airborne pathogens)
- Pest control
  - Insects, mice, rats, etc.
- Heating and cooling energy use
  - Stack and wind effects
- Fire Safety
  - Fire and smoke spread
- HVAC air flow & pressure control

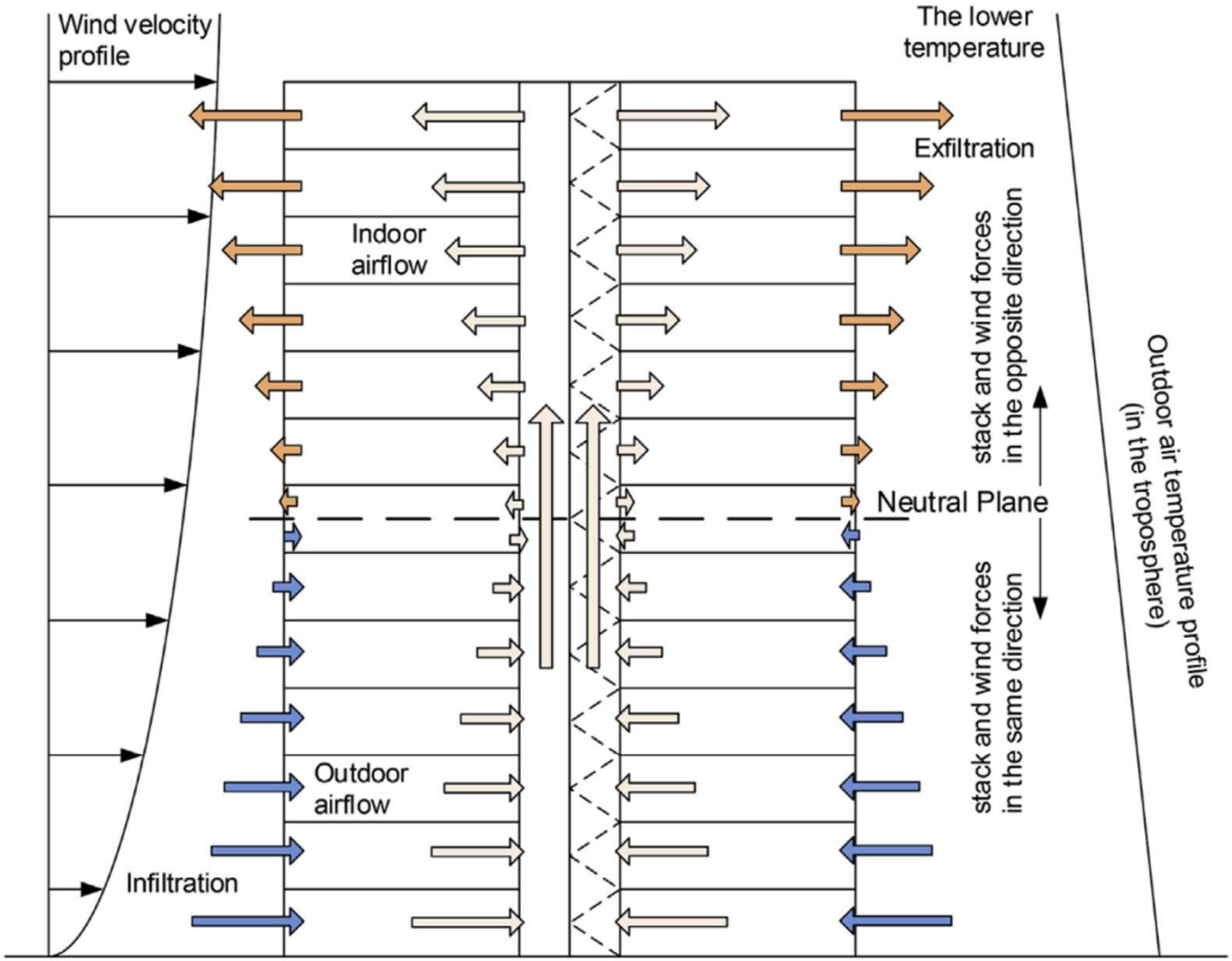
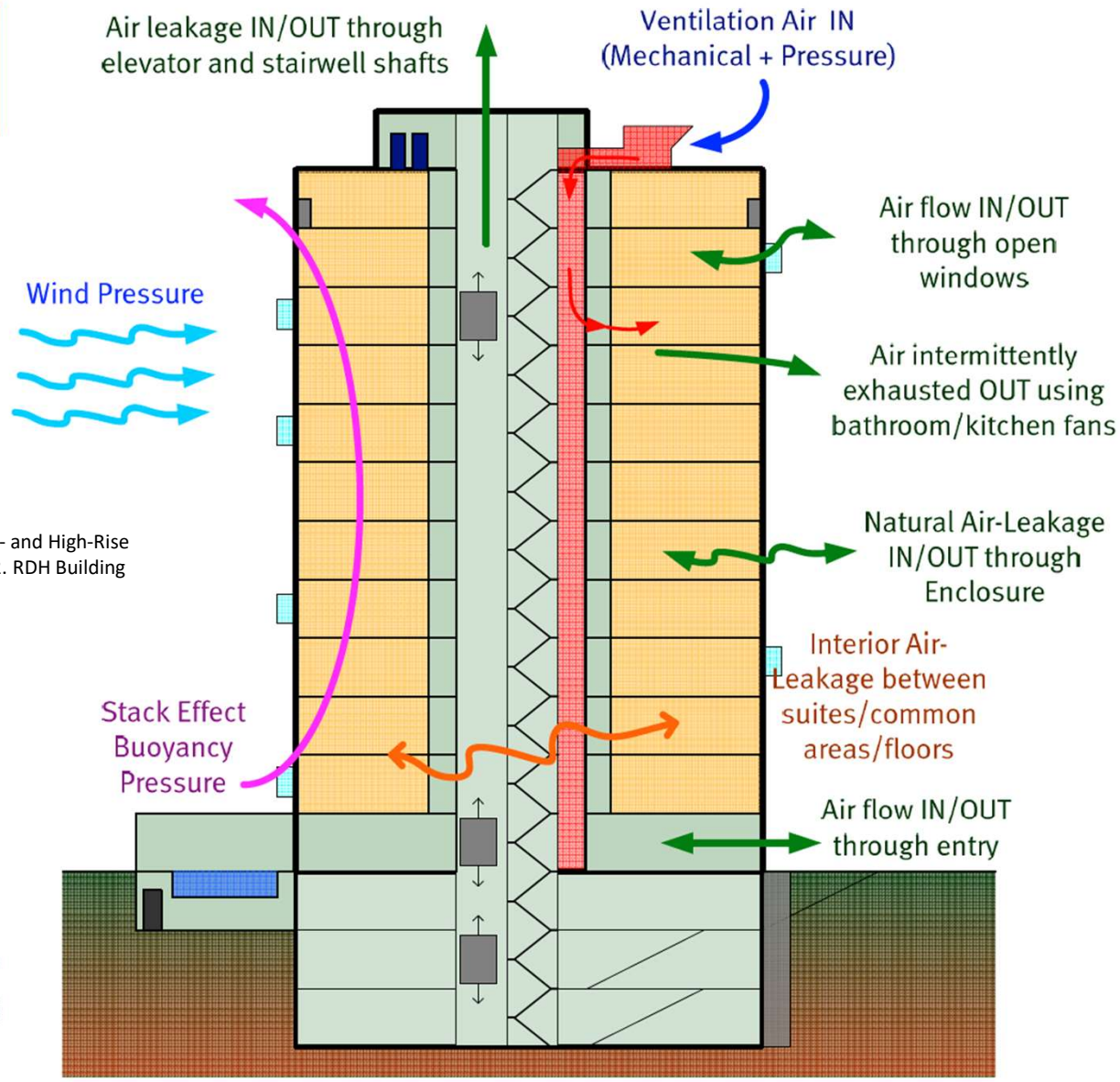
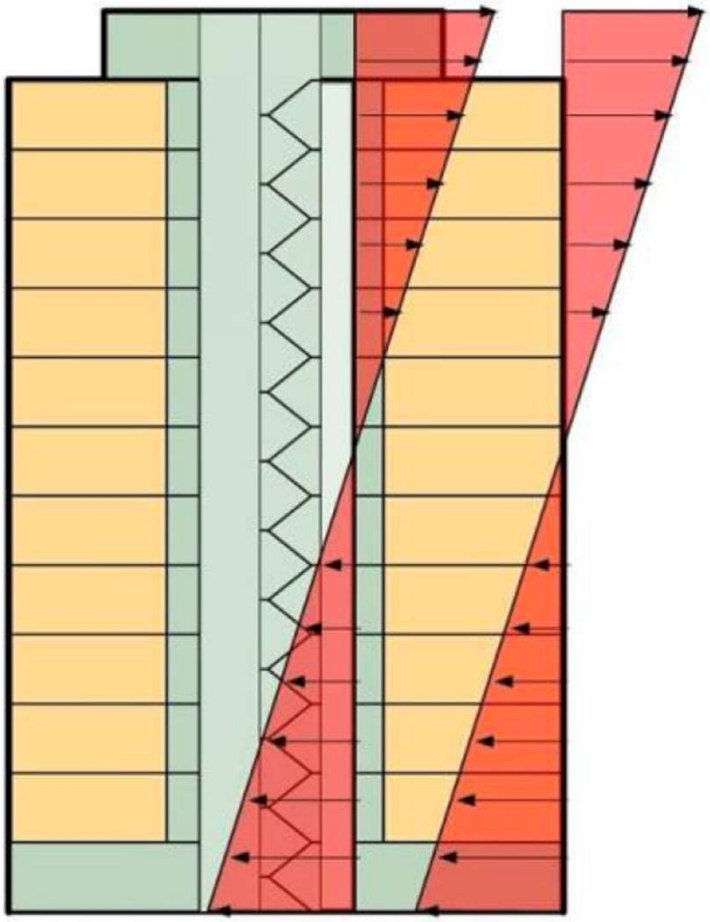


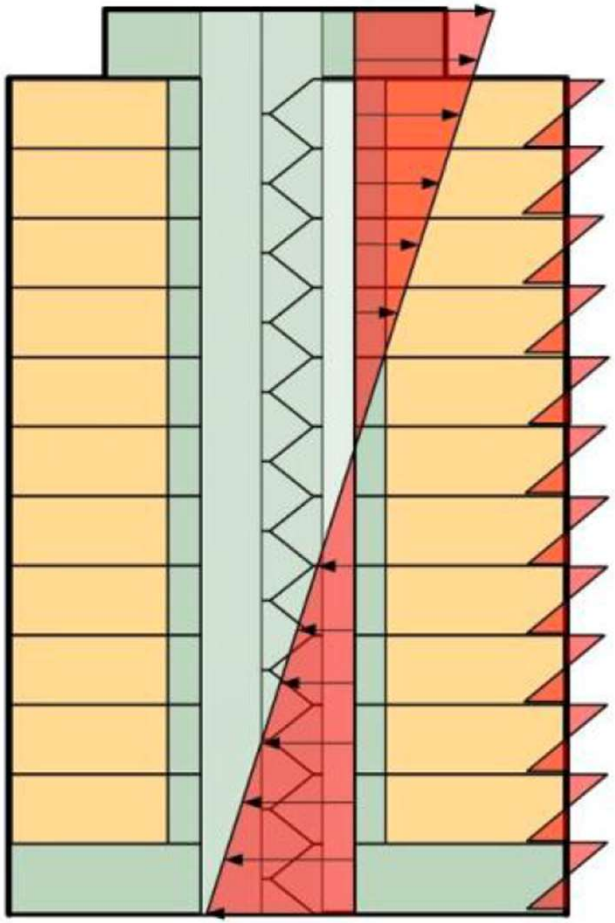
Fig. 1. Airflow in high-rise buildings caused by the stack effect and wind pressure in winter.



"Energy Consumption and Conservation in Mid- and High-Rise Residential Buildings in British Columbia." 2012. RDH Building Engineering.



Stack Effect - Typical Highrise Conditions



Stack Effect - Compartmentalized Floors and Suites

"Energy Consumption and Conservation in Mid- and High-Rise Residential Buildings in British Columbia." 2012. RDH Building Engineering.

Where are the leaks?

Electric wiring

Plumbing

Wall cavities

Images form Rohr et al. 2018. Individual unit and guard-zone air tightness tests of apartment buildings. AIVC Conference Proceedings.

Airtightness Metrics

- Air flows at fixed test pressure of 50 Pa: cfm50/ft^2 or L/s/m^2 or m^3/h/m^2
  - Sometimes 75 Pa is used for high rise applications
- Total leakage: all surfaces ← most common
- Leakage to outside
- Leakage to inside
- Normalization Areas: *boundary areas* or *exterior envelope*
- Can be volume normalized to Air Changes per Hour (ACH)

North America Standardized tests

Tests for exterior envelopes also applied to testing individual units – no standard tests for interior leakage

- CGSB 149.10 – exterior envelope testing
- CGSB 149.15 – uses building HVAC system for envelope leak testing
- ASTM E779 – confirms single zone conditions and has limit on stack effect of 200 ^{o}Cm (building height x temperature difference)
- ASTM E1827 – confirms single zone conditions and has single point testing
- ISO 9972 – exterior envelope testing
- ATTMA Technical Standard L1-2012 & L2-2010 – UK standards for enclosure testing, L2 has guidance for testing large buildings

Testing "row" house

Internal leakage measurement principles:

1. Neutralize unit to unit pressures

2. Subtract "guarded" result from total to get leakage to outside separate from unit to unit leakage

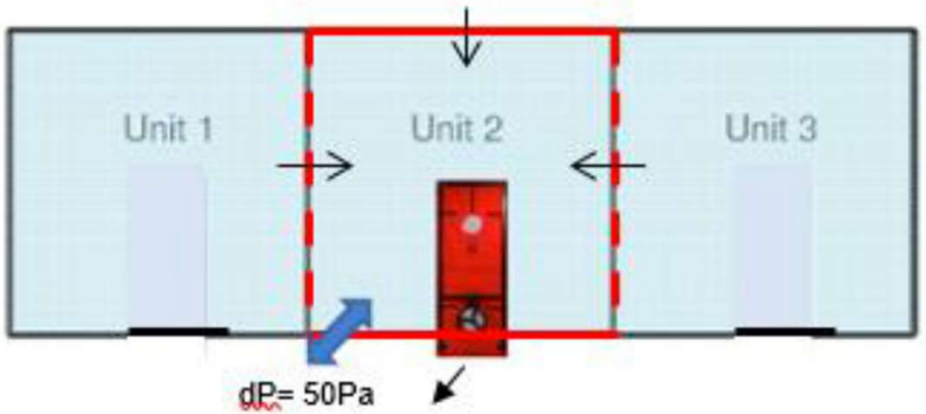


Figure 5. Compartmentalization test of single unit in a garden-style building

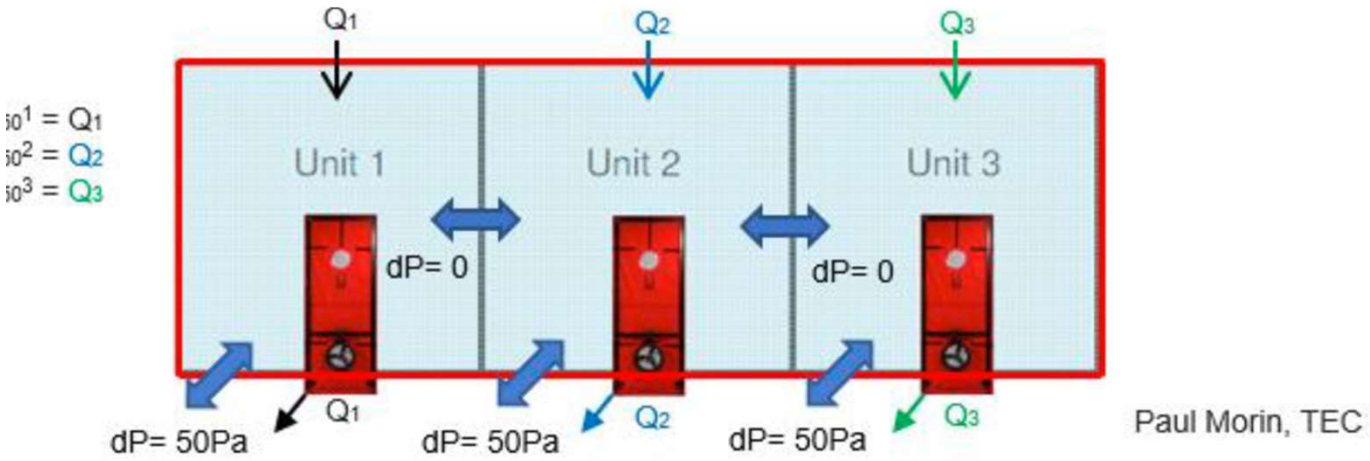
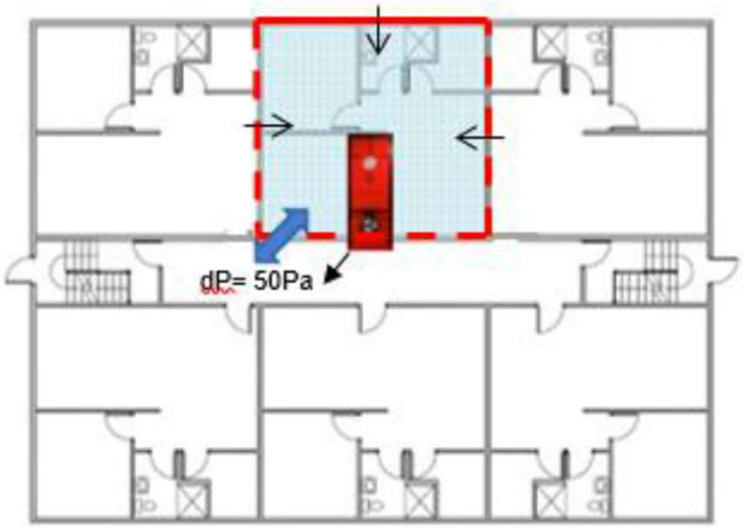


Figure 7. Single-unit exterior test for three units in a single-story garden-style building

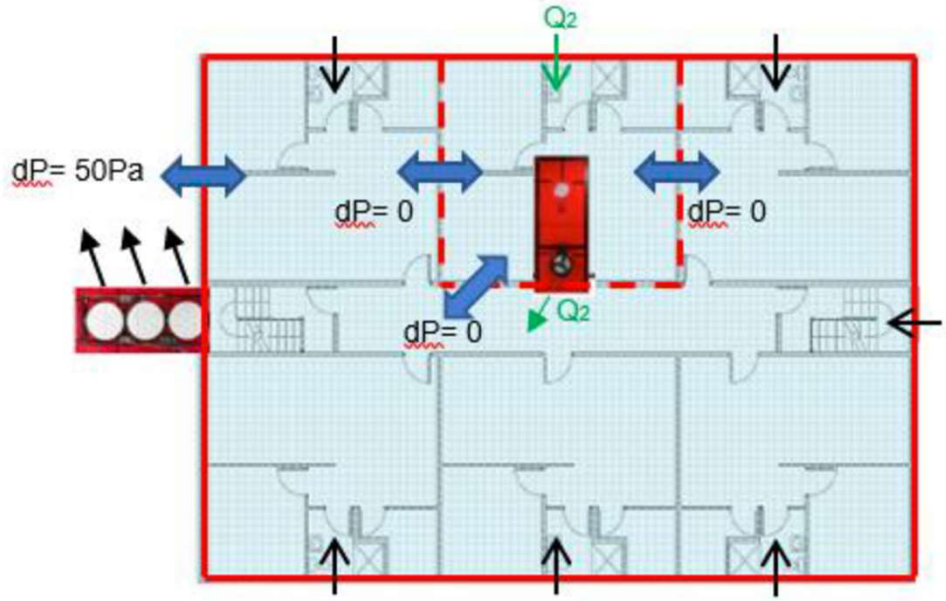
David Bohac, Lauren Sweeney, Robert Davis, Collin Olson, and Gary Nelson. 2020. "Energy Code Field Studies: Low-Rise Multifamily Air Leakage Testing." Washington, DC: US DOE. https://www.mncee.org/sites/default/files/report-files/LRMF_AirLeakageTesting_FinalReport_2020-07-06.pdf.

Testing common–entry buildings



Paul Morin,

Figure 6. Compartmentalization test of single unit in a common-entry bu



Paul Morin, TEC

Figure 8. Single-unit exterior test for a single-story common-entry building with six units

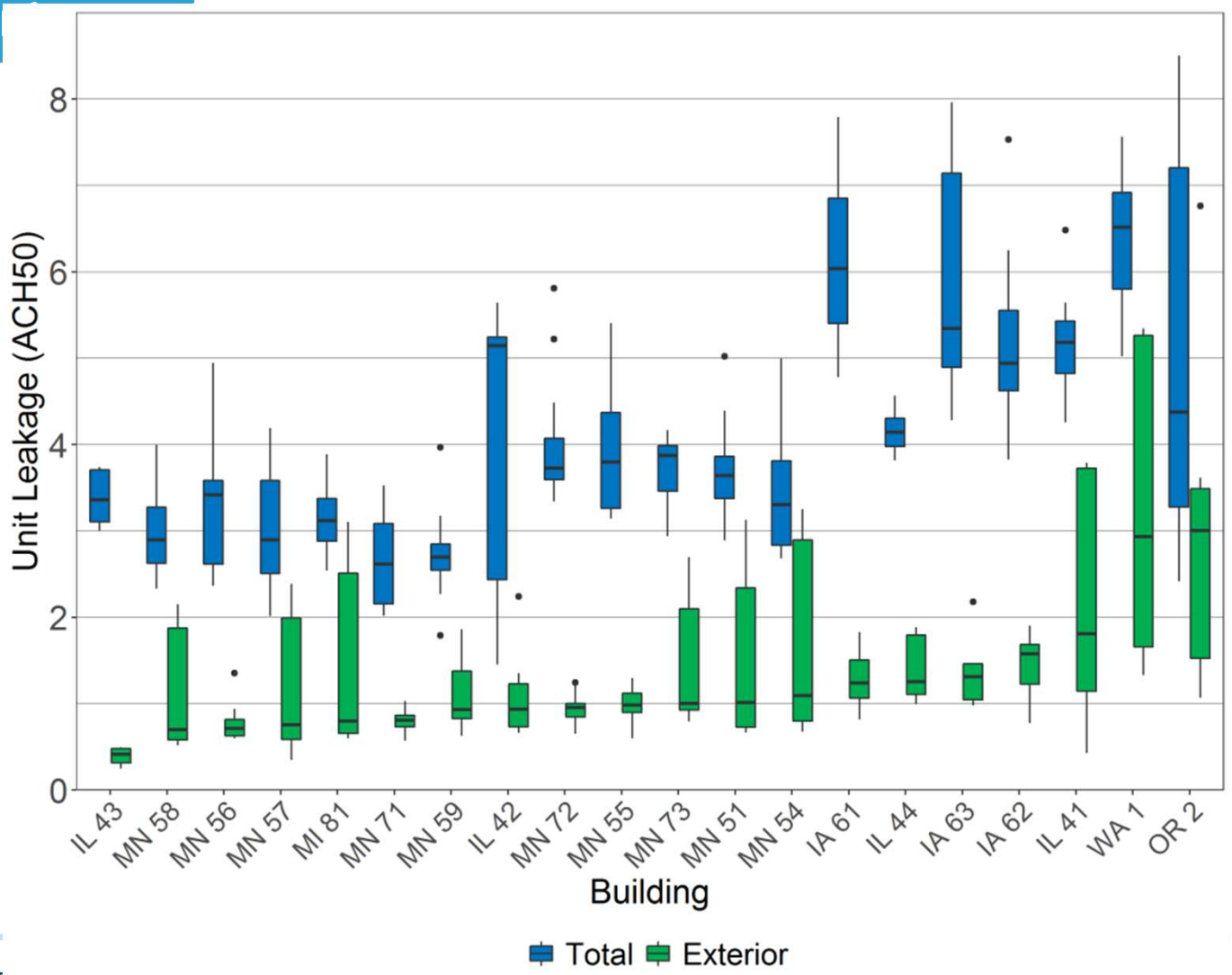
David Bohac, Lauren Sweeney, Robert Davis, Collin Olson, and Gary Nelson. 2020. "Energy Code Field Studies: Low-Rise Multifamily Air Leakage Testing." Washington, DC: US DOE. https://www.mncee.org/sites/default/files/report-files/LRMF_AirLeakageTesting_FinalReport_2020-07-06.pdf.

Testing with corridors

Figure 6.5: Balanced Fan Pressurization/Depressurization Method Schematic (Finch, 2007)

Finch, G, Straube, J., & Genege, C. (2009) *Air Leakage Within Multi-Unit Residential Buildings: Testing and Implications for Building Performance*. Proceedings of 12th Canadian Conference on Building Science and Technology. Montreal: National Building Envelope Council. 529-544.

Results vary building to building and unit to u



Bohac et. al. (2020) (Report) LRMF study. Center for Energy and Environment MN

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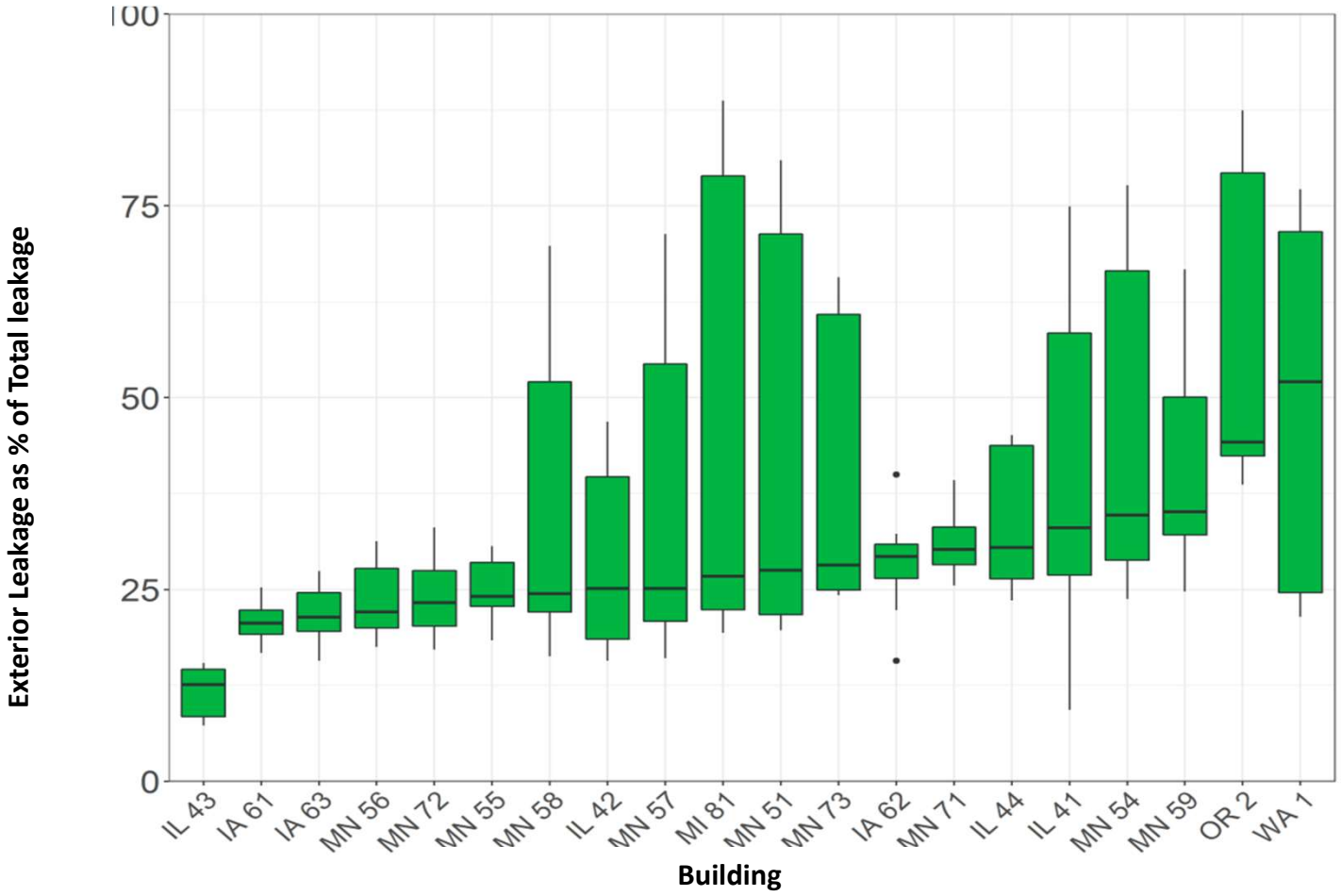
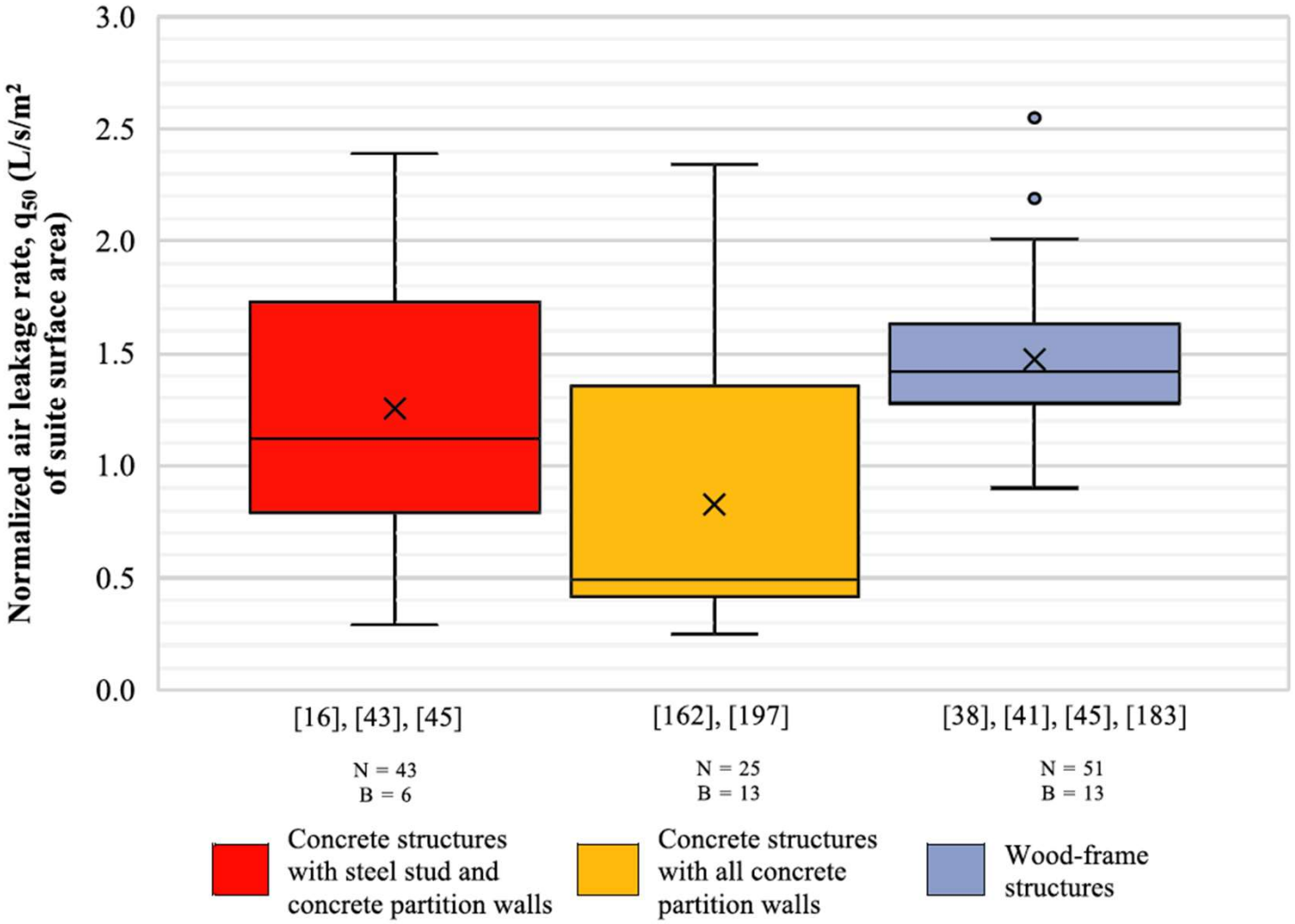
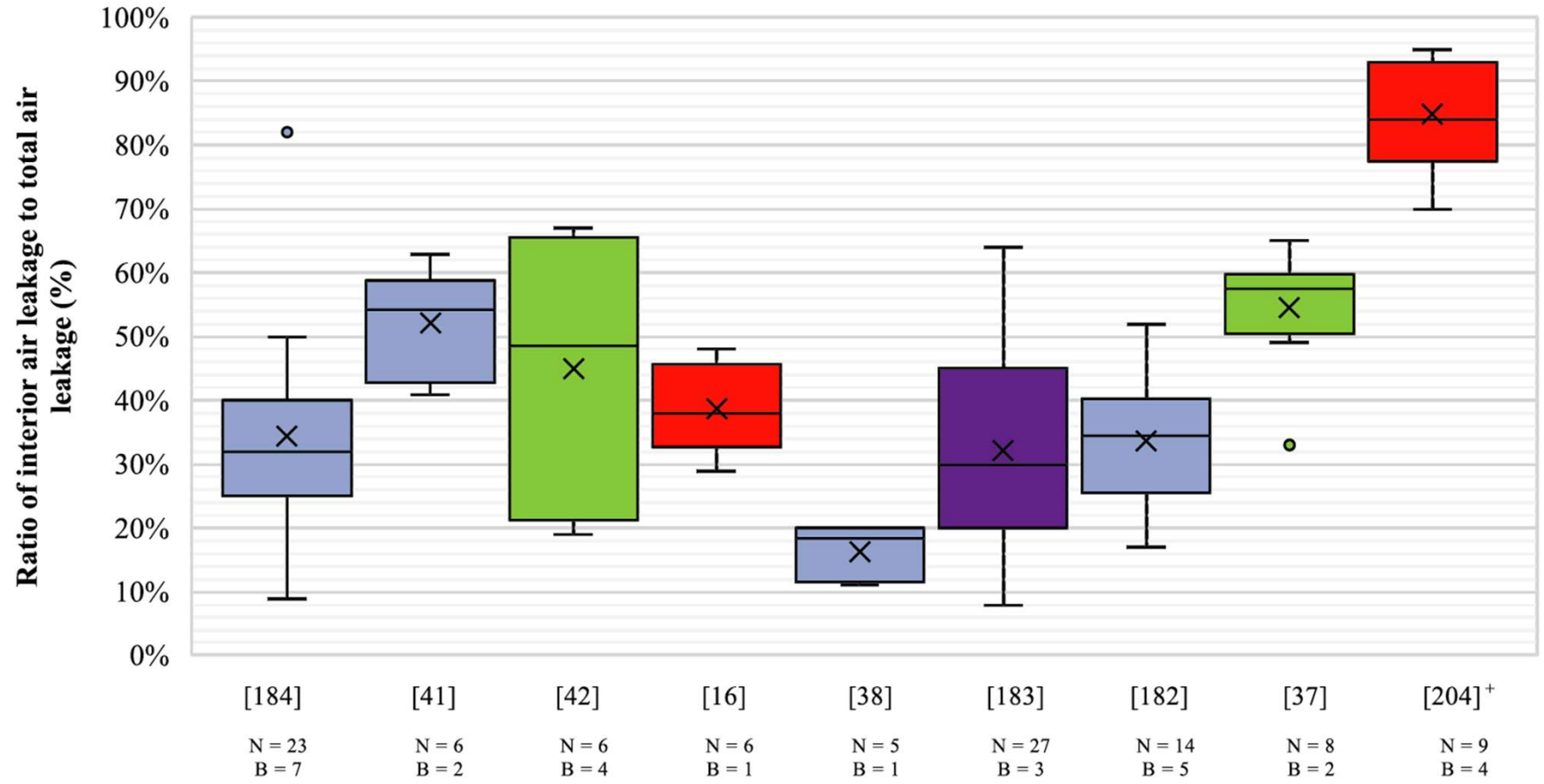


Corner vs. middle
Unit size
Construction variability

Construction Type



Lozinsky, Cara H., and Marianne F. Touchie. 2020. "Inter-zonal Airflow in Multi-unit Residential Buildings: A Review of the Magnitude and Interaction of Driving Forces, Measurement Techniques and Magnitudes, and Its Impact on Building Performance." Indoor Air 30 (6): 1083–1108. https://doi.org/10.1111/ina.12712.



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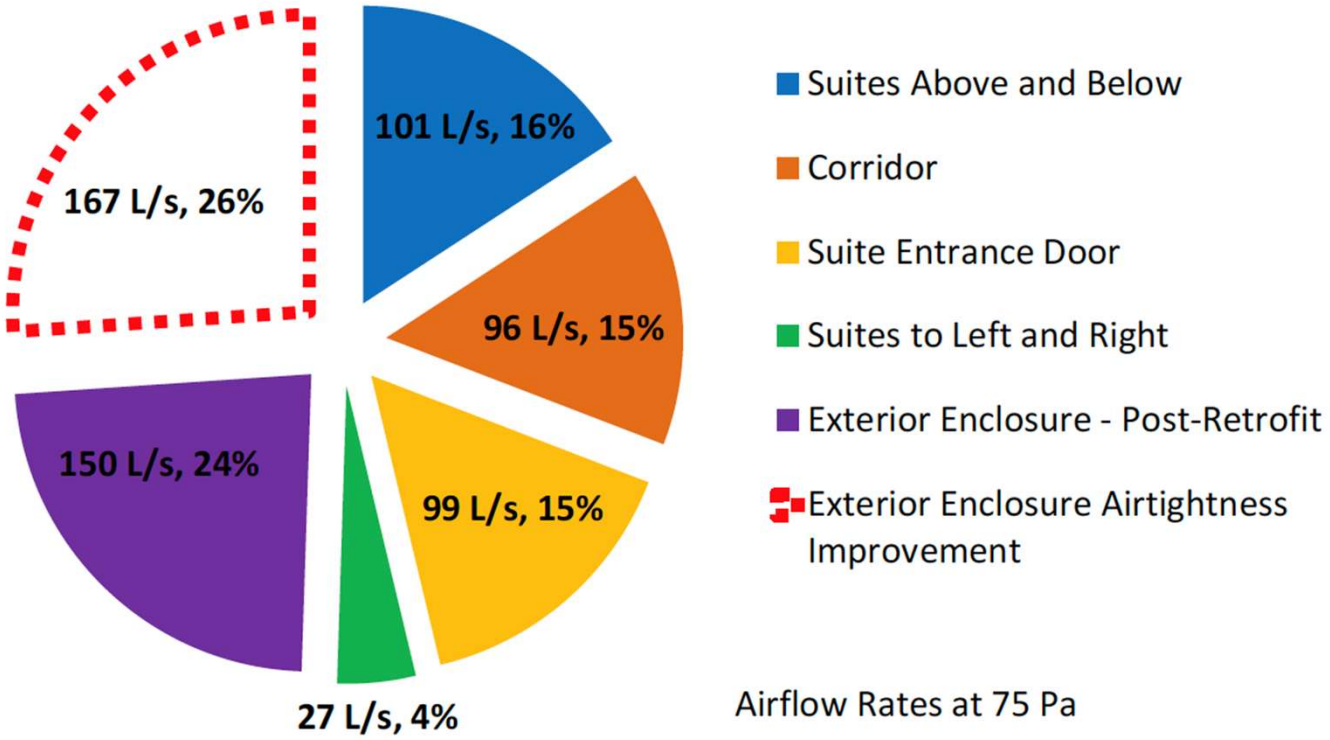
Apartment leakage breakdown

Testing before and after exterior envelope sealing



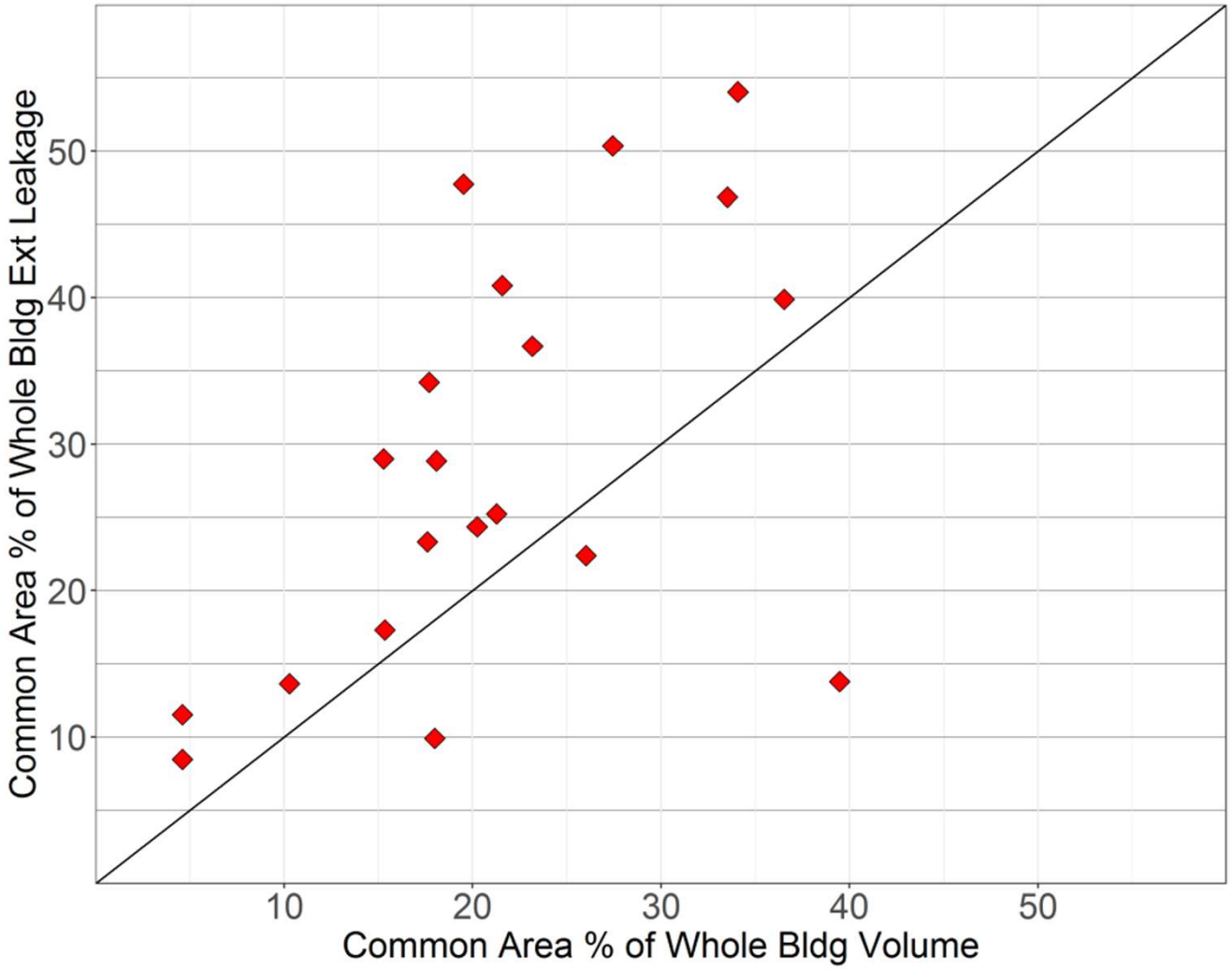
Ricketts, L, and J Straube. 2014. "A Field Study of Airflow in Mid to High-Rise Multi-Unit Residential Buildings." In , 1414th Canadian Conference on Building Science and Technology - Toronto, Ontario 2014

US New Construction Leak Breakdown Summary

- High rise/common corridor
  - 2-3% to each unit to each side
  - 10-15% to each unit above or below
  - 20-35% to corridor
  - 30-55% to outside
- Midrise/walkup – no corridor
  - 2-3% to each unit to each side
  - 10-15% to each unit above or below
  - 75% to outside

Air Leakage of Common Areas

Common areas can be more leaky than dwellings



How much air flow?

Pressure differences are lower than across envelope therefore air flows much lower

Tracer gas studies: typically 4% … but sometimes 40%

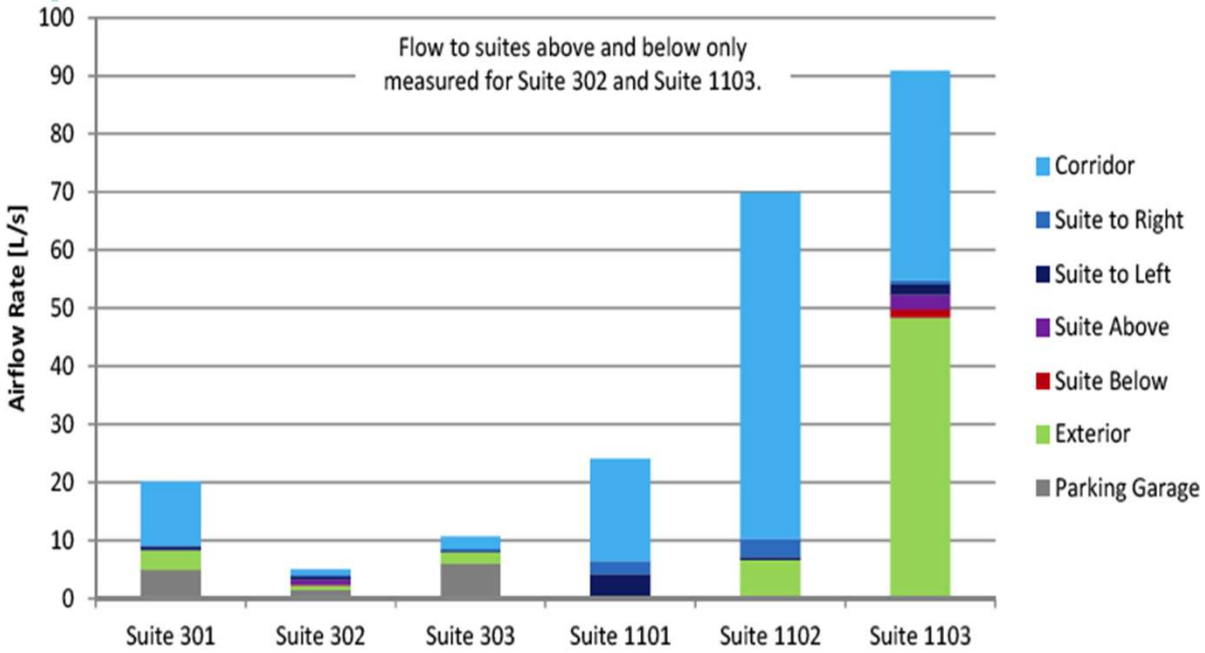


FIGURE 2: Chart showing source of airflow into suites for six suites at the case study building

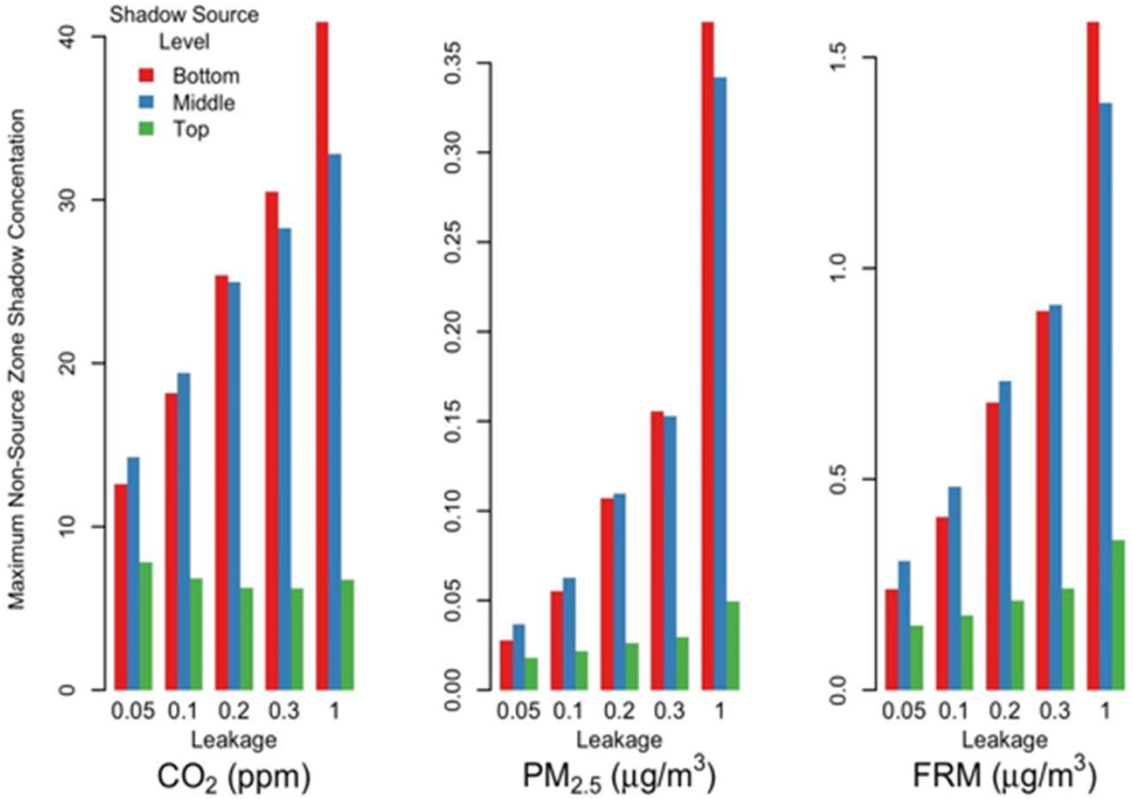
Bohac, D. L., M. J. Hewett, S. K. Hammond, and D. T. Grimsrud. 2011. "Secondhand Smoke Transfer and Reductions by Air Sealing and Ventilation in Multiunit Buildings: PM and Nicotine Verification: Secondhand Smoke Transfer and Reductions by Air Sealing and Ventilation." *Indoor Air* 21 (1): 36–44. https://doi.org/10.1111/j.1600-0668.2010.00680.x.

Ricketts, L and Straube, J, 2014. A field study of Airflow in Mid to High-Rise Multi-Unit Residential Buildings. 14th Canadian Conference on Building Science and Technology, Toronto, ON. http://rdh.com/wp-content/uploads/2015/01/CCBST-2014-A-Field-Study-of-Airflow-in-High-Rise-Multi-Unit-Residential-Buildings-LR-JS.pdf

Contaminant Concentrations

CONTAM Modeling Study

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

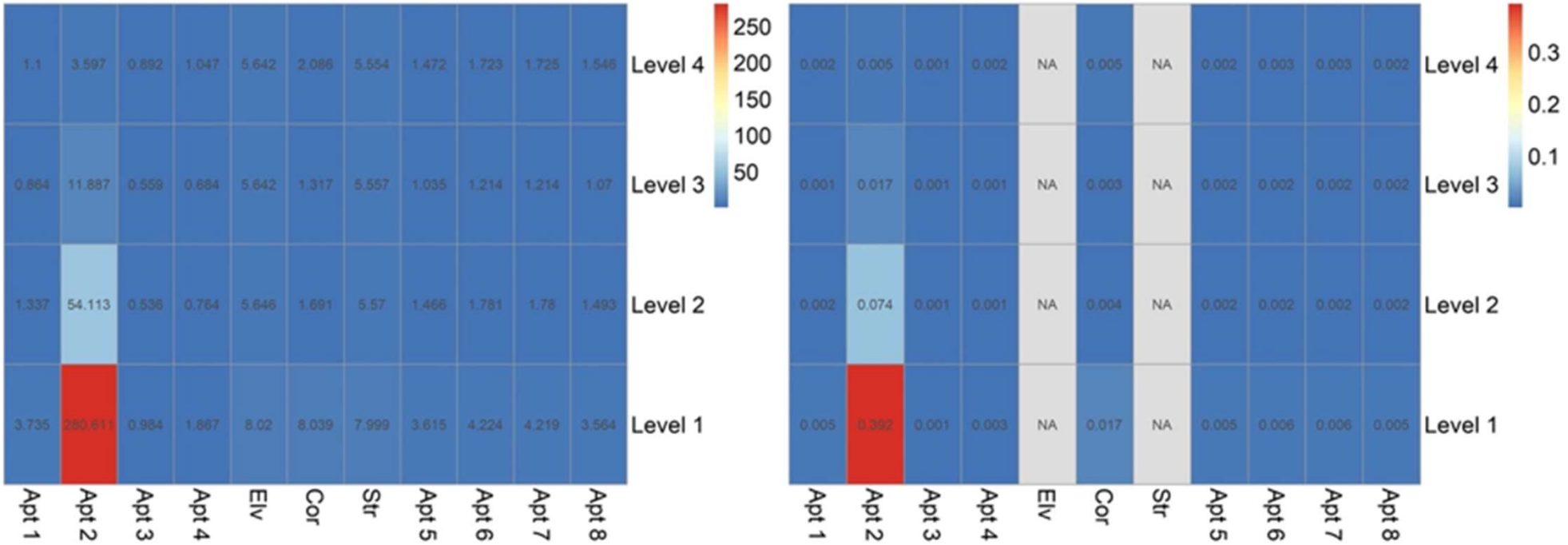
PM and Formaldehyde more sensitive to leakage due to deposition mechanisms

Measured contaminant transport in ”tight construction”: CO_2 (0-3%), PM2.5 (unmeasureable)

Modera, M., Adler, S., Harrington, C., Bennett, D., Moran, R. and Goebes, M. 2023. Final Report Improving Indoor Air Quality, Energy Efficiency, and Greenhouse Gas Reductions Through Multifamily Unit Compartmentalization. Calfornia Air Resources Board TEREport.

Contaminant Concentrations

CONTAM Modeling Study



Most transport is vertical

Energy Saving Example

M. Carlsson, M. Touchie and R. Richman / Energy & Buildings 199 (2019) 20–28

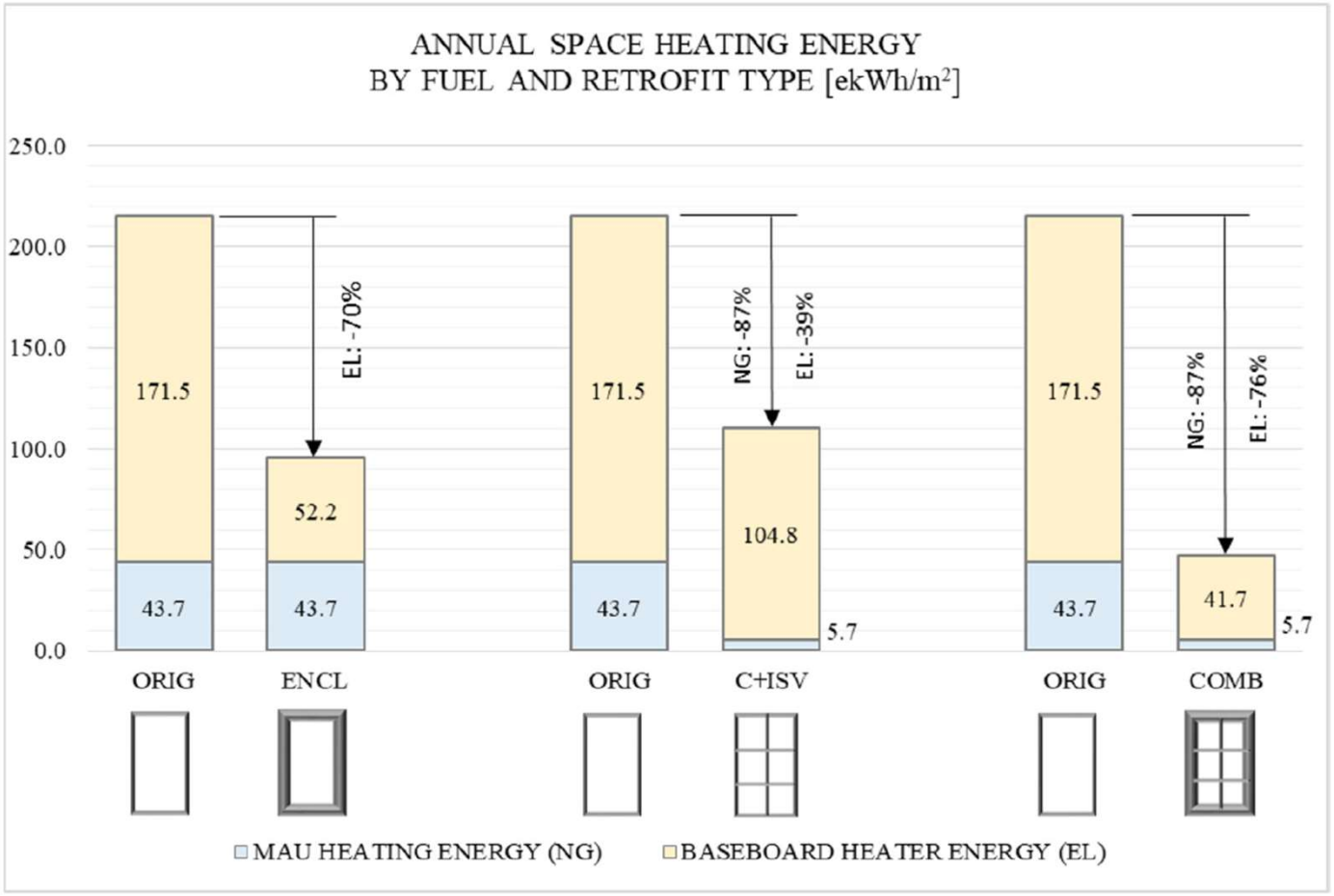
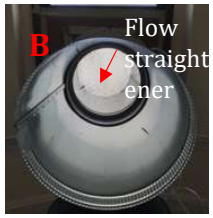
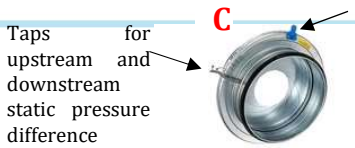


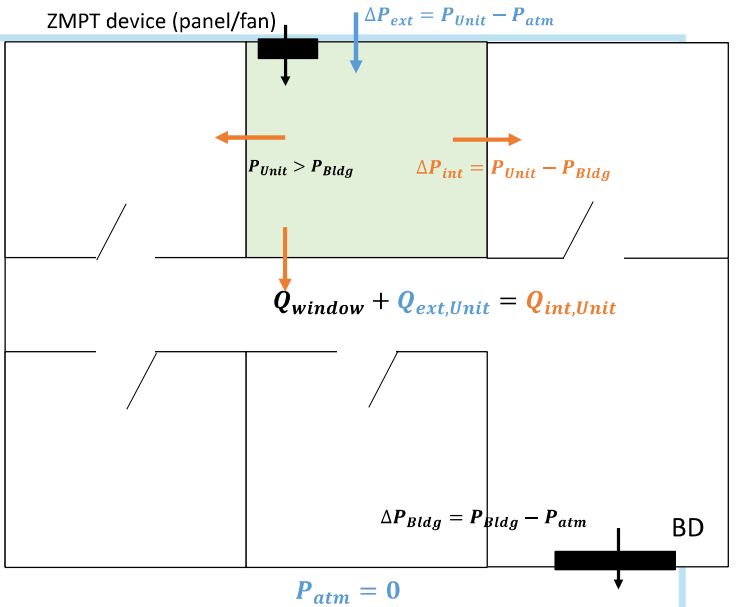
Fig. 2. Simulated annual space heating energy by fuel and retrofit type.

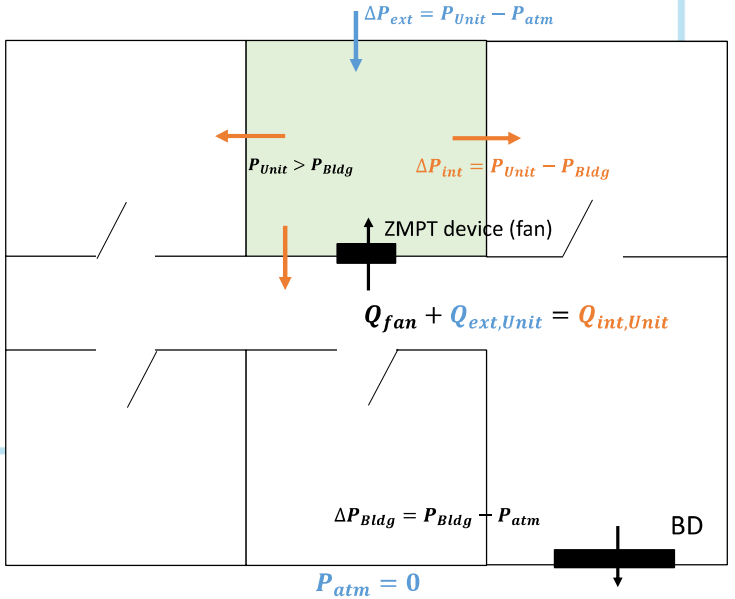
Recent Advances

- New test methods to save time and improve accuracy of separating internal and external leakage
- Use a second flow measuring and modulating device
- Manipulate and record a range of pressures and flows
- Multipoint fitting (c/w fixed 50 Pa test) – more accurate representation of lo flow/pressure behaviour









Jayarathne. 2023. Advancing Building Air Leakage Measurement and Modeling: New Measurement Methods And Experimental Analysis Of Crack Flow Behavior. PhD. Thesis, Boston University

Tightness Standards

- ASHRAE 62.2: 0.2 cfm50/ft^2 (100 L/s/100 m^2)
  - Was 0.3 cfm50/ft^2 (150 L/s/100 m^2) – standards are getting tighter
- LEED certification by the US Green Building Council: up to 2 points for certification rating based on different tightness levels between 0.0675 to 0.195 cfm50/ft^2
- Passive House (exterior envelope):
  - 0.08 cfm50/ft^2 (40 L/s/100m^2) for more than 5 stories
  - 0.06 cfm50/ft^2 (30 L/s/100m^2) 5 stories and under

Questions/comments

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