February 26,2020

Multifamily Air Leakage: Test Methods and Results

Energy Design Conference & Expo

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The Energy Conservatory

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“This educational offering is recognized by the Minnesota Department of Labor and Industry as satisfying 1.5 hours of credit toward Building Officials and Residential Contractors code /1 hour energy continuing education requirements.”

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Agenda

- Commonly used airtightness standards
- Multifamily testing options
- Advantages and disadvantages to each
- Common code and program requirements
- Equipment setup for automated testing
- Low-rise test results

Commonly Used Airtightness Standards

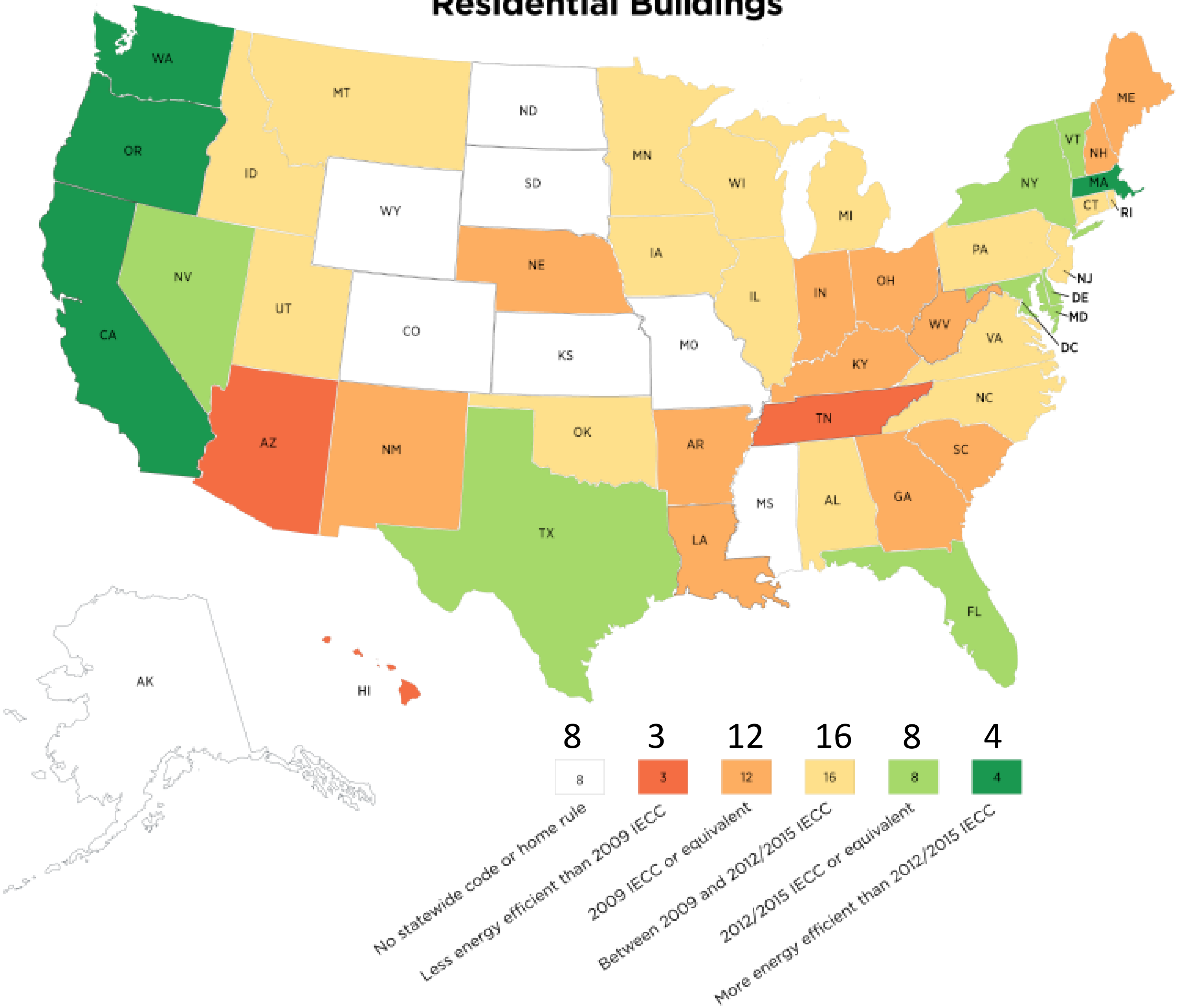
- ASTM E779
- CGSB-149
- RESNET 380

Programs Requiring Testing

Starting with 2012 IECC (3 stories or less)

- All residential buildings must be tested for airtightness and meet the following levels
  - 5 ACH_{50} Climate zones 1 - 2
  - 3 ACH_{50} Climate Zones 3 - 8
- Some states have local amendments
- Enforcement stronger in urban areas

Residential Buildings



Other Testing Requirements

- **Illinois 2019**
  - **0.25** CFM_{50}/ft^2 SA
- **New York State option**
  - More than 7 unit buildings
  - option of 0.3 CFM_{50}/ft^2 SA or 3 ACH_{50}
- **Washington State**
  - **Proposed 0.40** CFM_{50}/ft^2 SA
- **Army Corp of Engineers**
  - 0.25 CFM_{75}/ft^2 enclosure area (0.19 CFM_{50})
  - What is achievable with proper design? 0.11
  - Refers to ASTM E779 -10

Other Programs Requiring Testing

Energy Star for High Rise

- 0.3 CFM_{50} / ft^2 enclosure – adjacent units open to outside
- Blower door test must be conducted (E779-10 or E1827)
- Sampling protocol may be used
- Requires preliminary and final testing
  - Inspect air sealing details during construction
  - Test at least 2 units as soon as they are ready

Other Programs Requiring Testing

LEED Multifamily IEQ PR 2012 - ETS

- 1.25 in^2 leakage area/ 100 ft^2 enclosure area (6 sides)
- 0.23 CFM_{50}/ ft^2 enclosure
- A sampling protocol may be used
- Setup?

Other Programs Requiring Testing

- Washington State – all buildings > 3 stories
- HERS Rating – multifamily units
- State or Utility multifamily programs
- Other multifamily programs?

RESNET

RESNET
RESIDENTIAL ENERGY SERVICES NETWORK

RESNET Guidelines for Multifamily Energy Ratings

These Guidelines were developed by the
Residential Energy Services Network (RESNET)
and adopted by the
RESNET Board of Directors on
August 29, 2014

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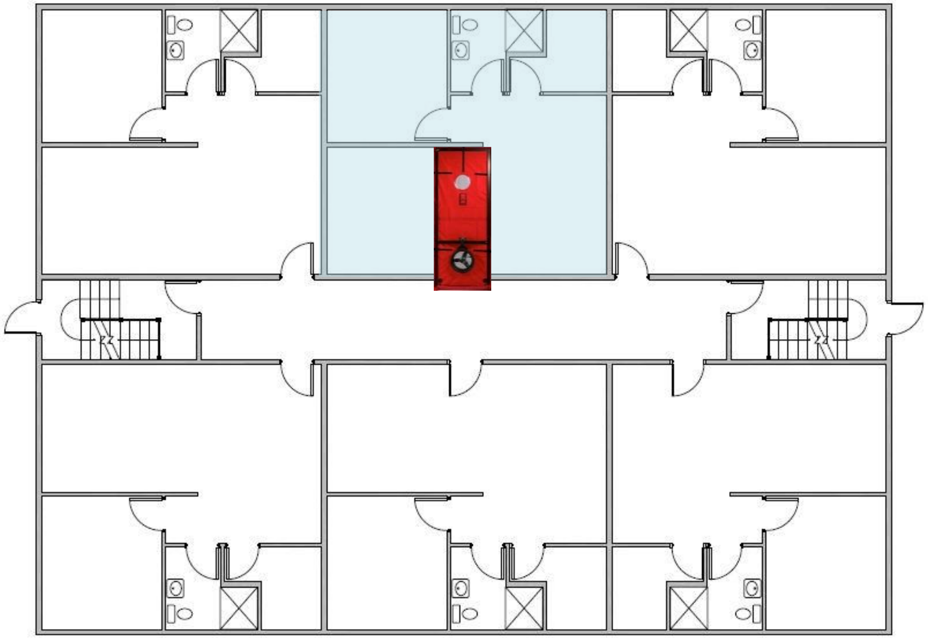
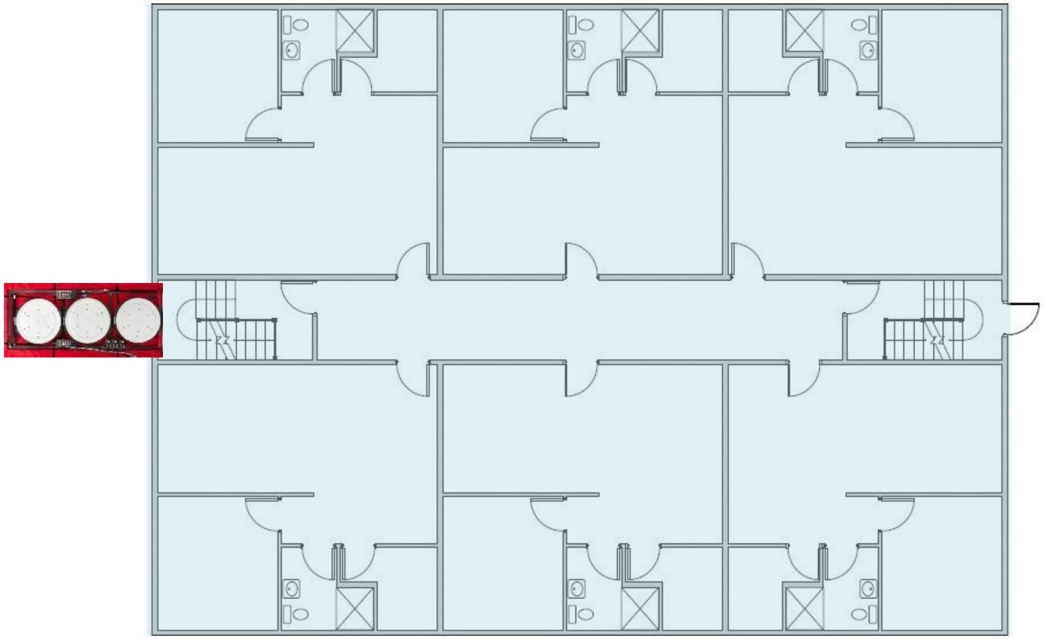
Four Separate Protocols

1. An unguarded *dwelling unit*-level blower door test – “*Compartmentalization*” test



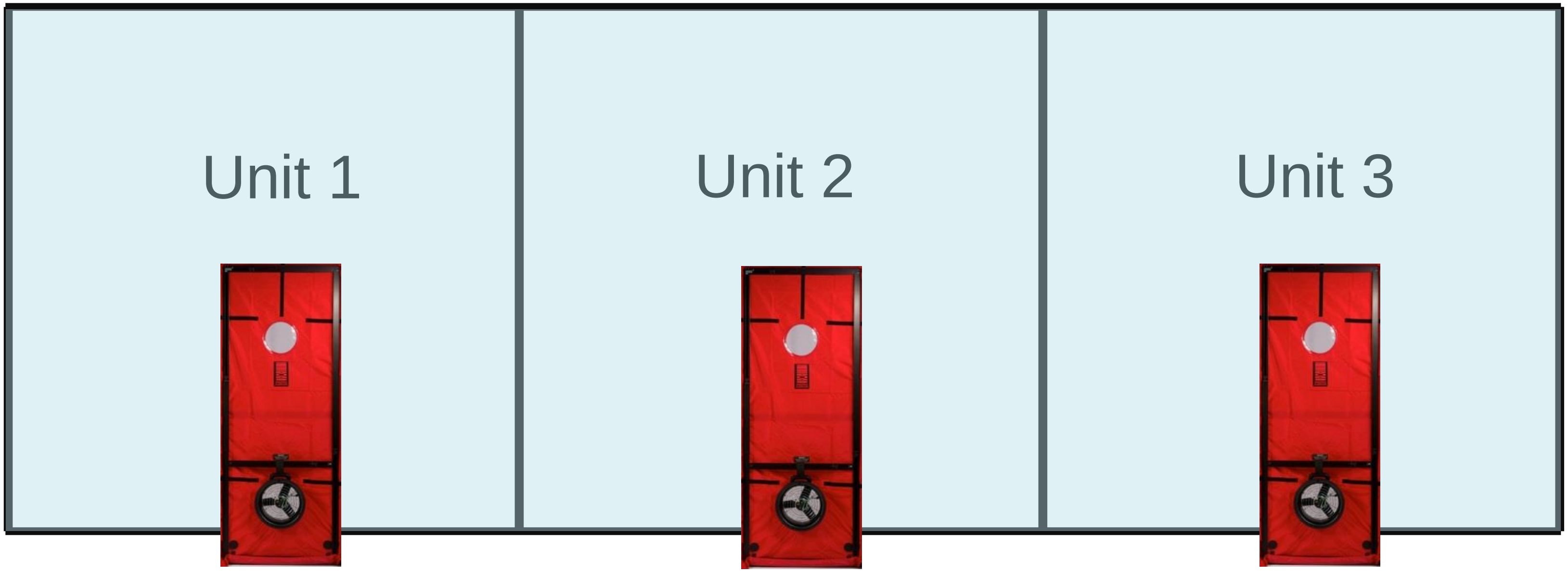
Four Separate Protocols

2. A full building single zone blower door test



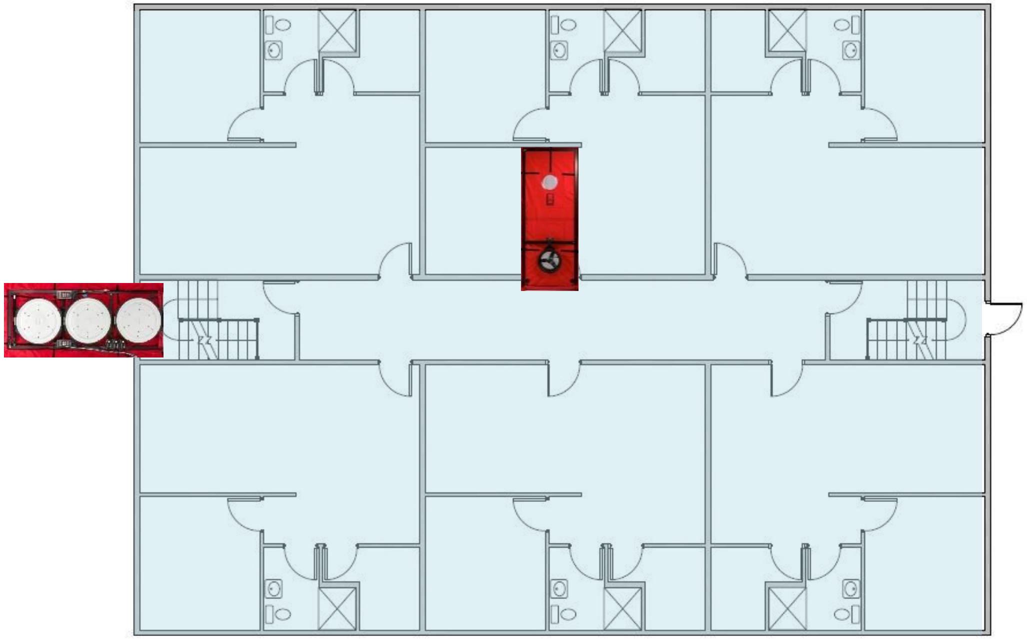
Four Separate Protocols

3. A full building multi zone blower door test



Four Separate Protocols

4. A full building blower door test simultaneously with a target *dwelling unit* test



Advantages of Compartmentalizing Units

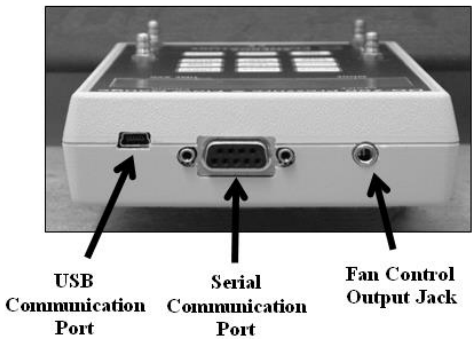
- Reduces sound transfer
- Reduces odor / pollutant transfer (ETS)
- Reduces wind effect
- Reduces stack effect
- Better able to control mechanical ventilation
- New construction
  - Seal plate to floor
  - Seal sheetrock at edges
  - Putty packs or Flanged / gasketed electrical boxes

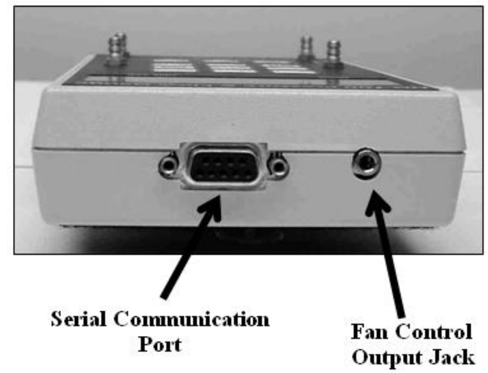
Single Unit vs Leakage to Outside

UNIT	Unguarded CFM50	Guarded CFM50	CFM50 Diff	% Diff
Left	352	339	13	4%
Center	308	178	130	42%
Right	324	197	127	39%
TOTAL	984	714	270	27%

	Connectivity		
	Left	Center	Right
Left'		0	0
Center	0		15.2
Right	0	22.9	

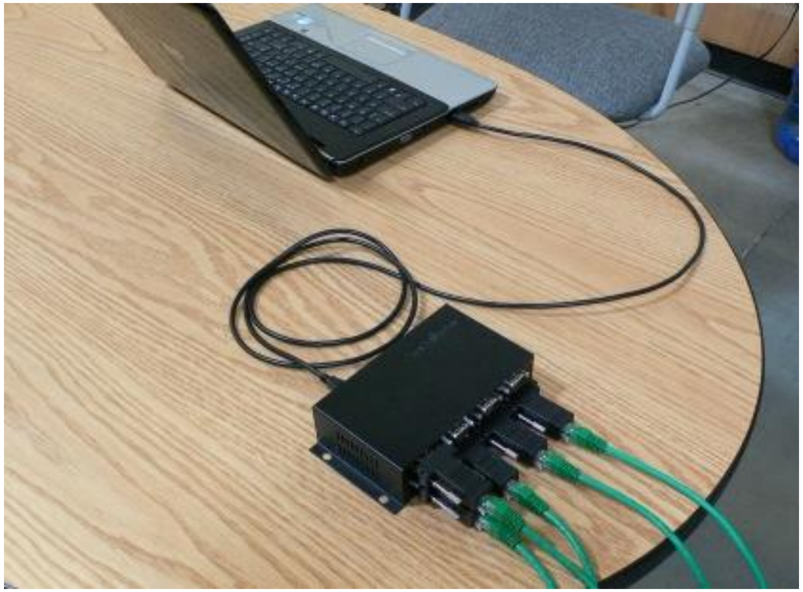
Test Software





Connecting to a Computer with Multiple DG-700s

- Wired connection – 9 pin serial to USB Hub



Connecting to a Computer with Multiple DG-700s

- Wireless connection – router required





Connecting to a Computer with Multiple DG-700s

- Multiple Routers

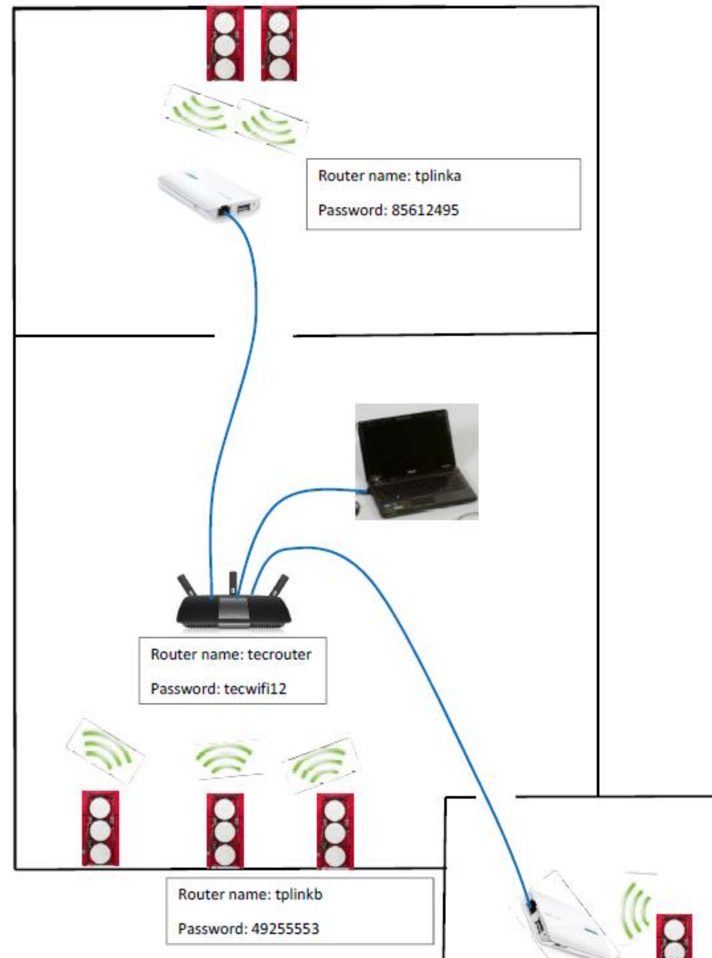
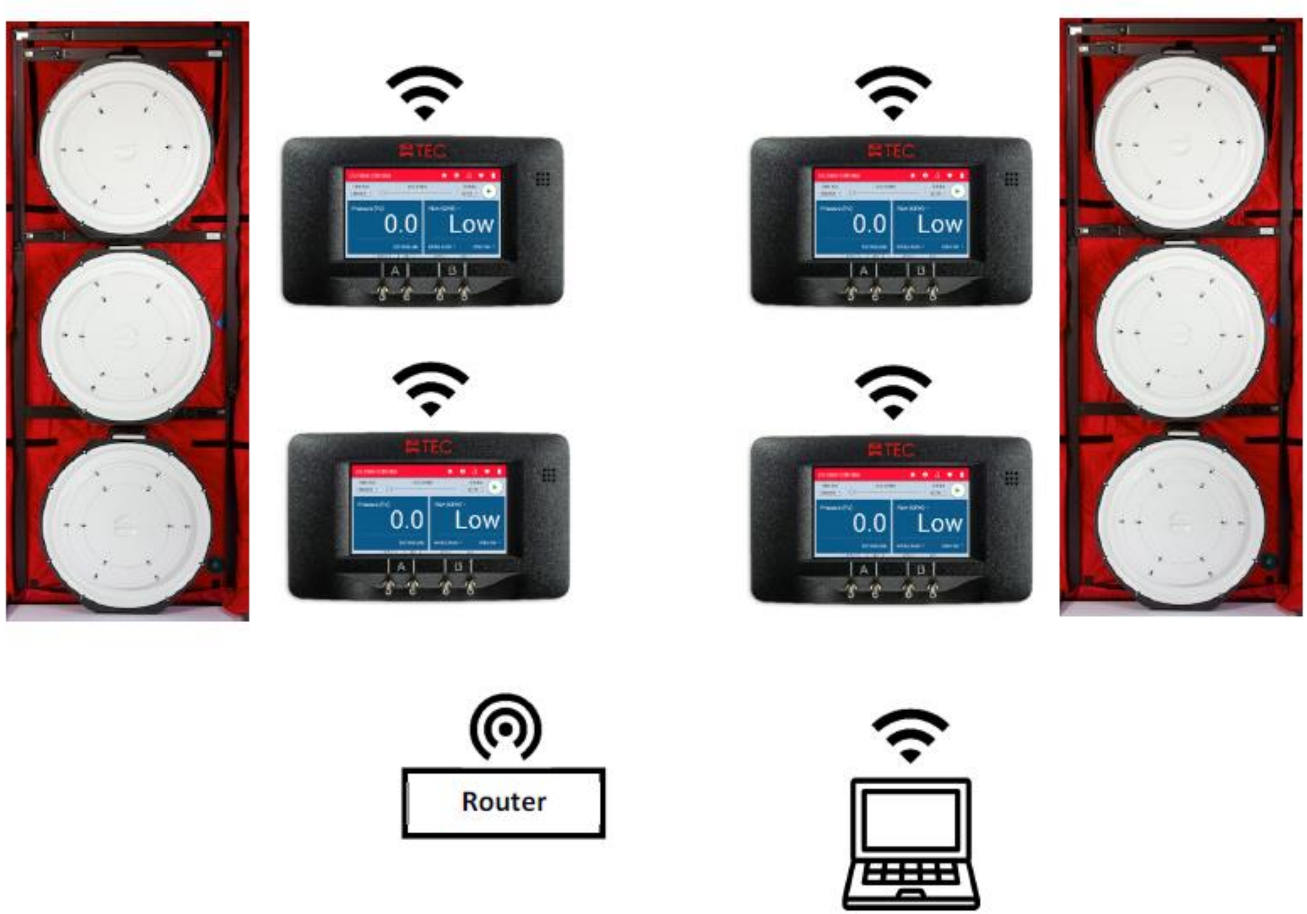


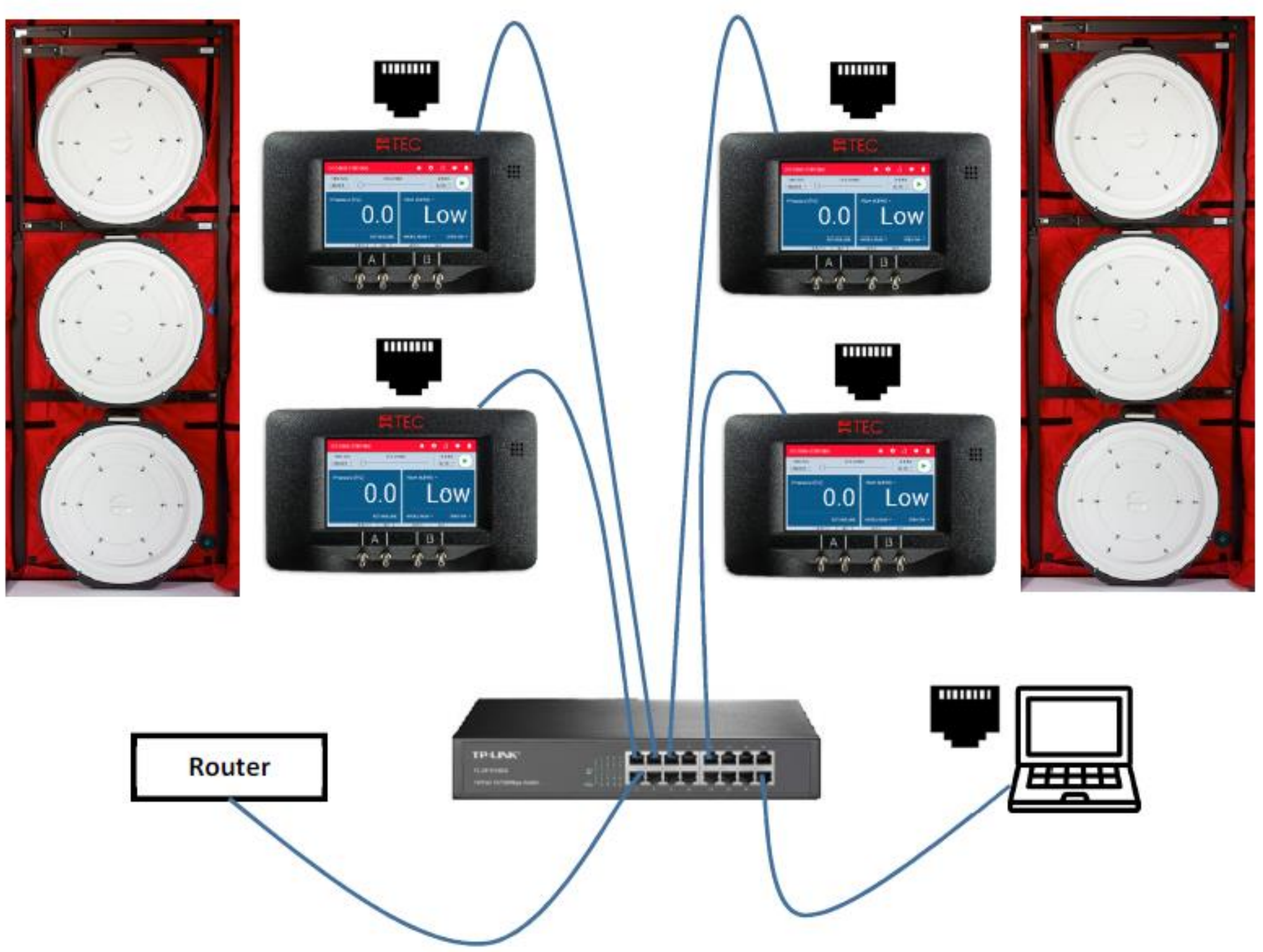
Figure 1

DG-1000 Connection Options

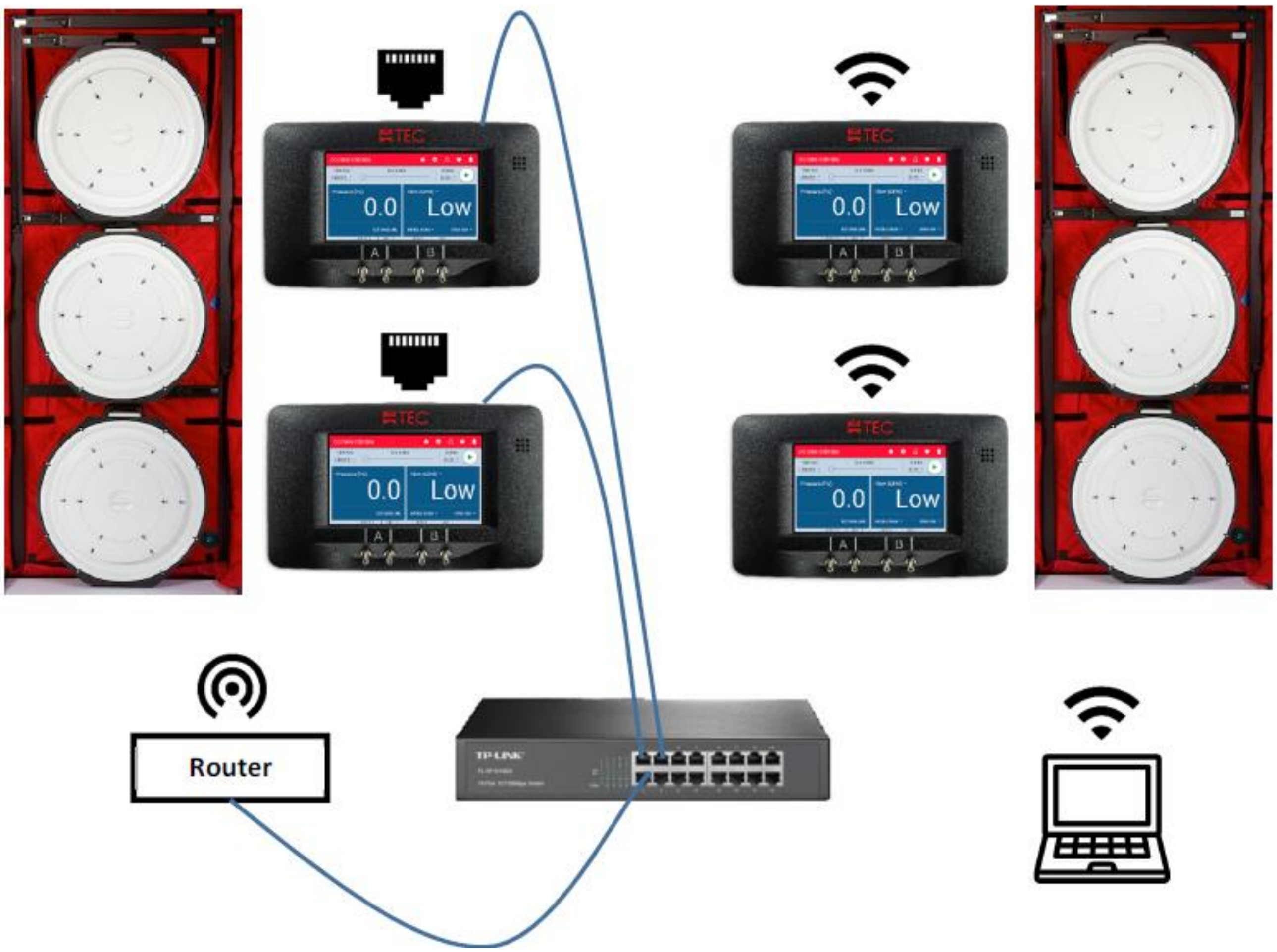
DG-1000 Connection Options



DG-1000 Connection Options



DG-1000 Connection Options



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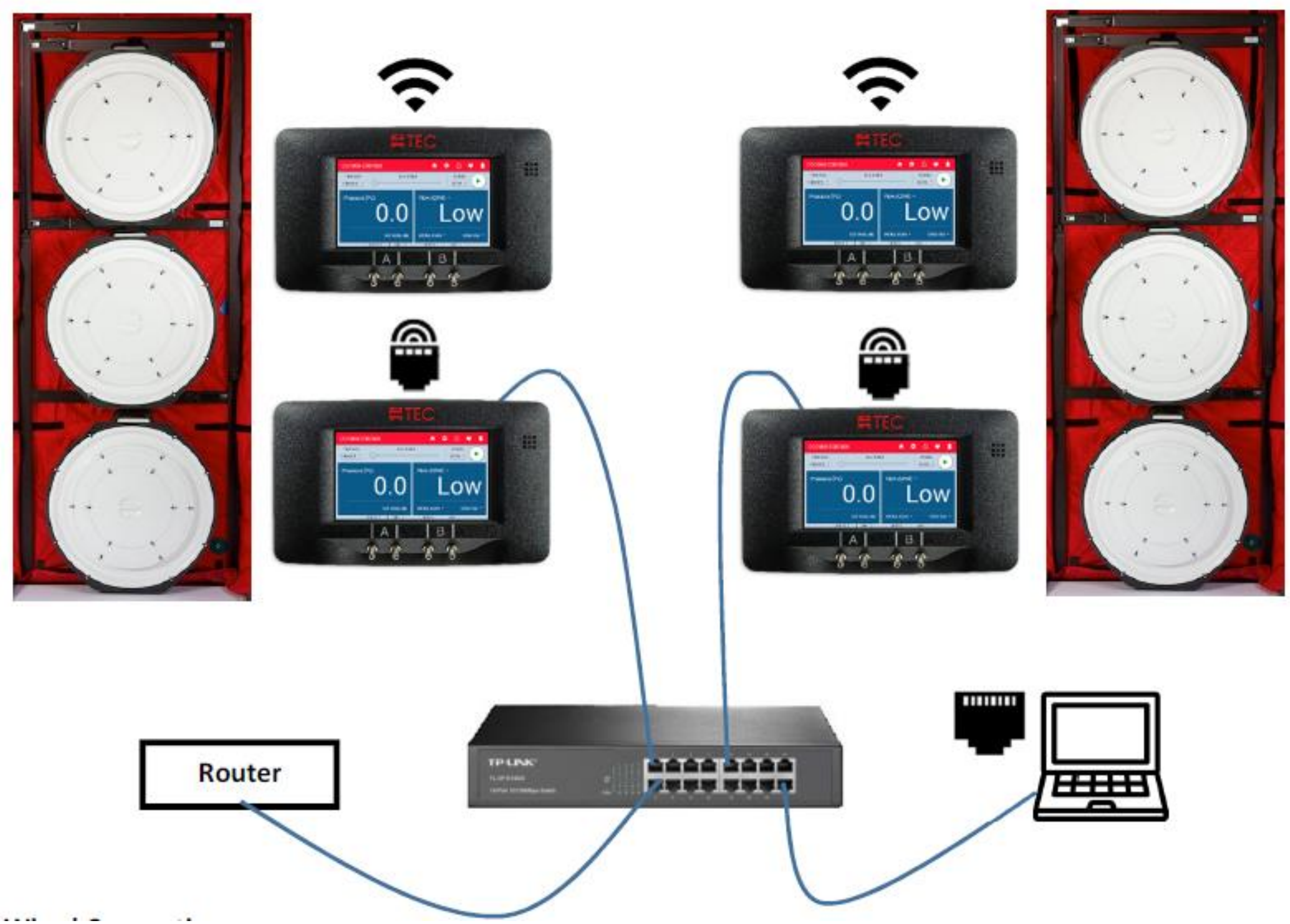


Setup the Fans

Two Gauges and Three Fans

Gauge 1

A: Envelope Press.

B: Bottom Fan

3 Controllers

Gauge 2

A: Middle Fan

B: Top Fan

No open taps on gauges

Fans plugged into separate circuits

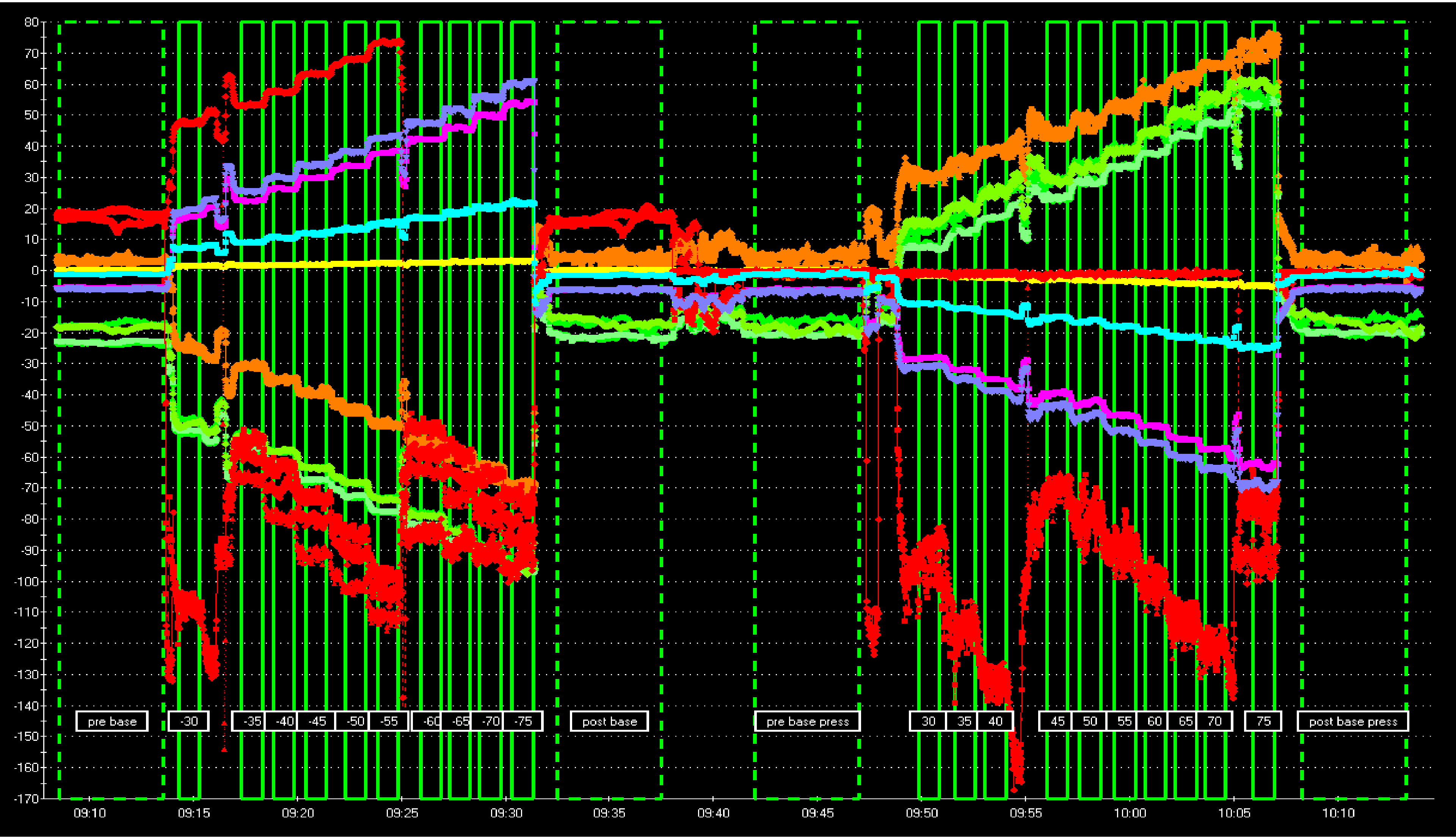
Two Gauges and Three Fans

3 way
Fan Control Splitter

3 Controller
Board

Kill-O-Watt
Meter

TECLOG4 Sample Test
Multipoint – depress and pressurization



DOE Energy Code Field Study

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Assessing Energy Impacts and Air-leakage in Multifamily Buildings

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Center for Energy and Environment

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Energy Conservatory

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Slipstream

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Air Leakage Testing: Goals

- Determine whether relationship exists between tests
  - Whole building vs compartmentalization vs unit exterior
  - Garden-style and common entry
  - How strong is relationship?
  - What variables affect predictive power for energy use?
- Provide envelope air leakage protocol
- Provide guidance for code language
- Assess energy impact of air leakage testing using this protocol

Air Leakage Testing: Test Comparison

- Single Unit Compartmentalization
  - Measures total leakage of unit (exterior + interior of building)
  - Easiest test to implement & most common
- Whole Building
  - Measures exterior leakage of whole building
  - Corresponds most closely to intent of air tightness test in the IECC (??)
- Single Unit Exterior (Guarded)
  - Measures exterior leakage of unit
  - Most complex to implement (two sets of blower doors)

Field Study: Building Types

- Common Entry
  - Closed corridors and common areas
  - Interior entry to units

- Garden Style
  - Open corridors to outside
  - Exterior entry to units

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Garden Style

- Not as many of this building type in the study, mainly because there is not that as many of this building type. (At least in MN)
- Did not get as much participation in WA & OR
- Main difference from common entry to garden style is no common area (corridor or spaces)
- Because of multiple and independent doors, these can be a real challenge.

Do you have 16 blower doors?

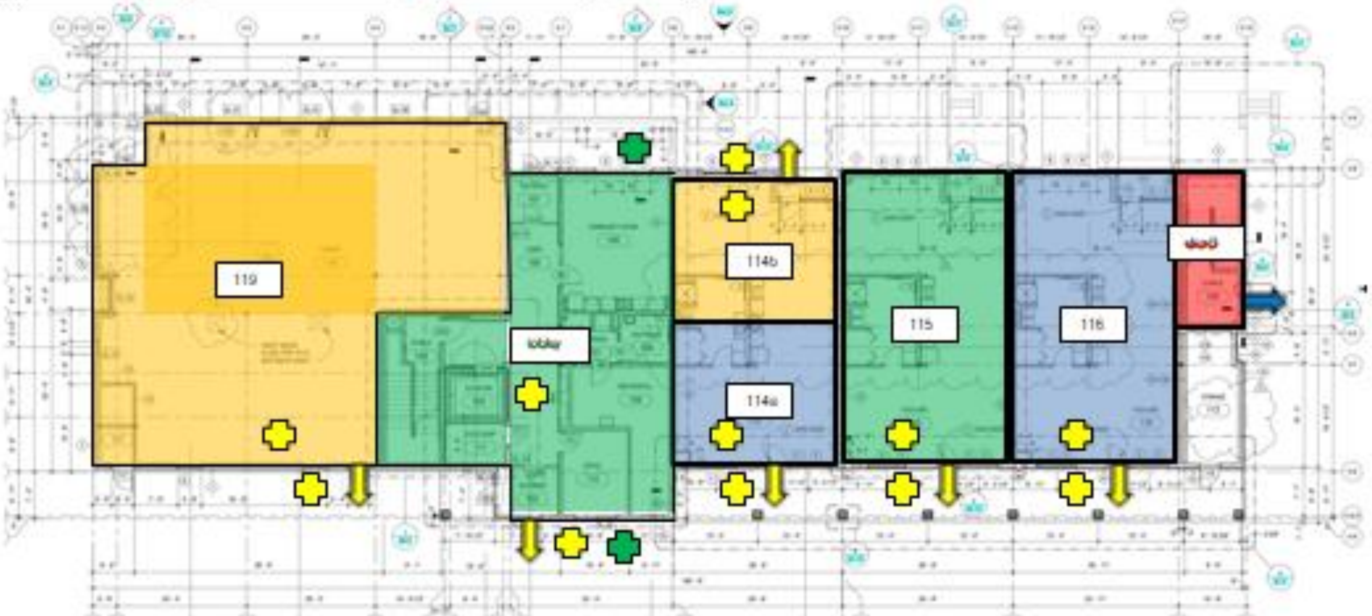
A Blower Door for Every Unit

Extensive Initial Setup

Link All Blower Doors to One Computer

Another Challenge - Mixed Use Building

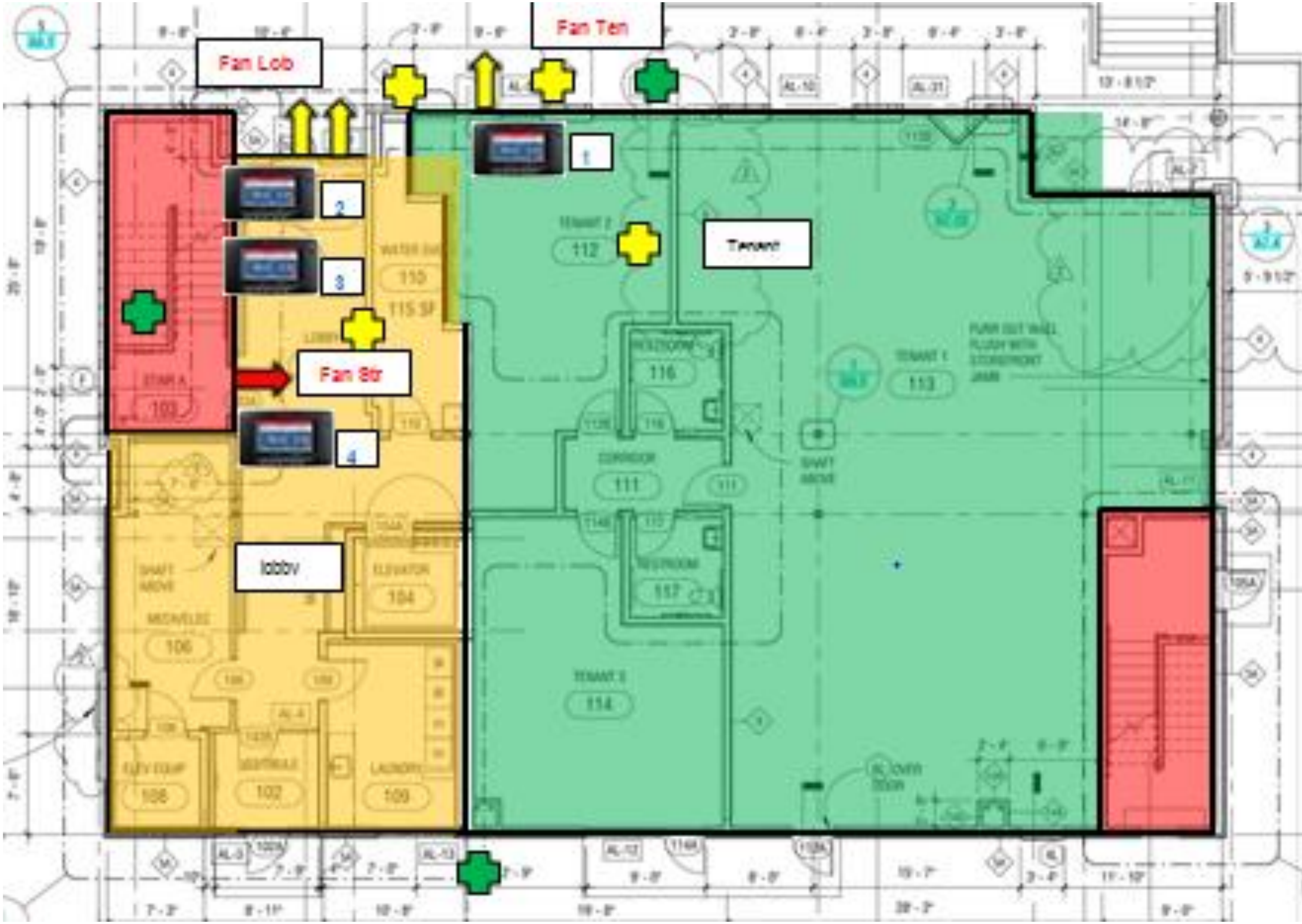
Whole Building Guarded Test Equipment Configuration



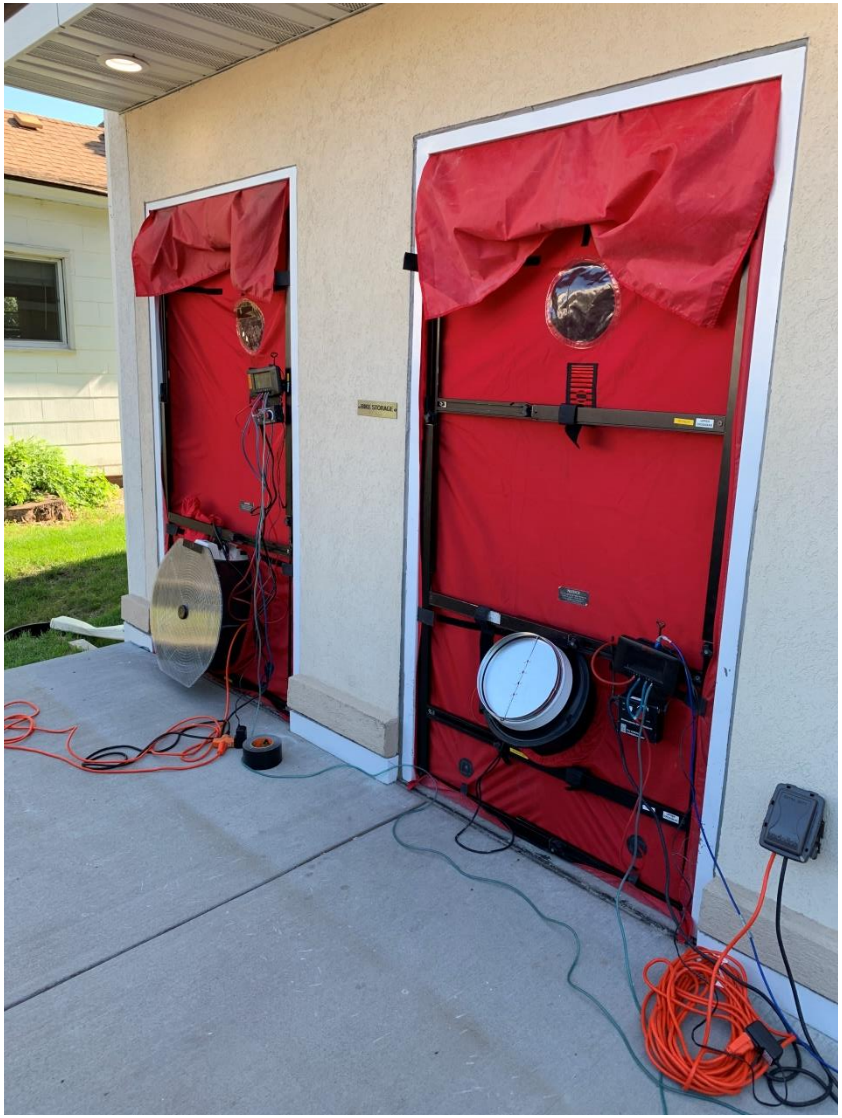
First Floor – Commercial Spaces

Second and Third Floor – Residential Units

Second Mixed Use Building



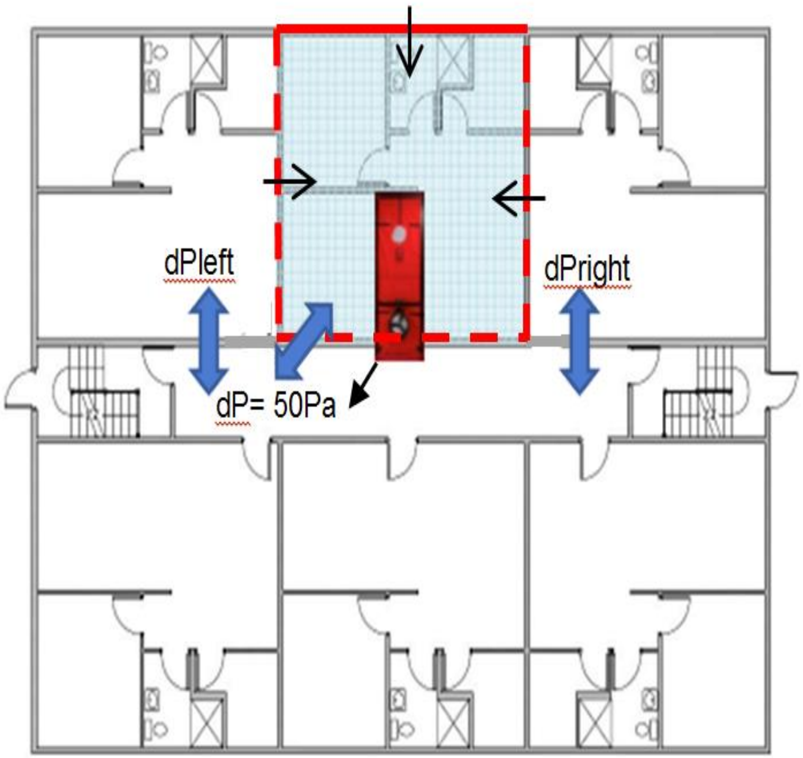
First Floor – Commercial Spaces



Self Closing Flappers – Simplify Baseline Measurements

Common Entry Building

Common Entry: Compartmentalization Test



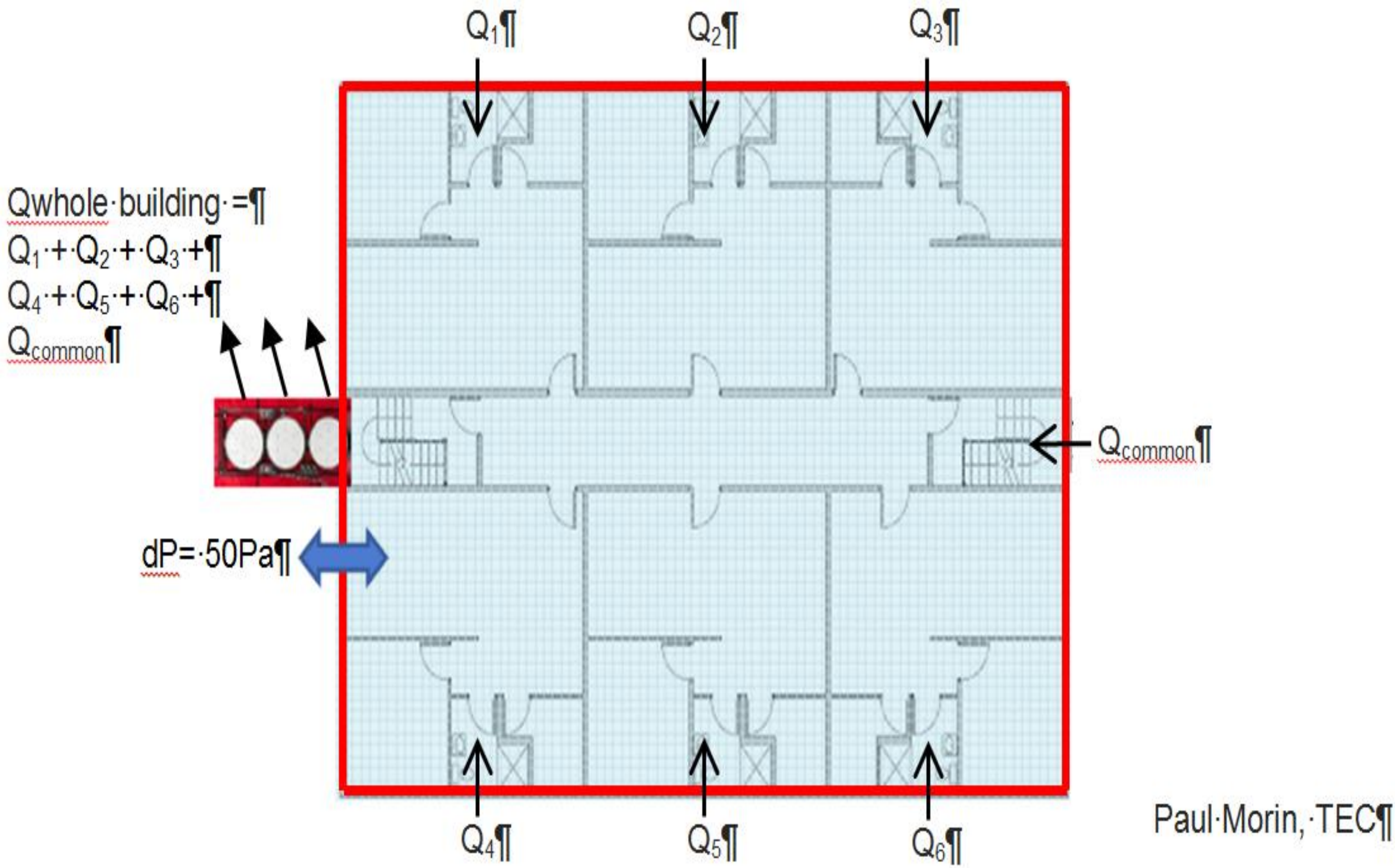
Paul Morin, TEC

When # units > 12, cluster sample
10 to 12 units

- Step 1:
  - Hall doors of all units closed
  - Measure unit/hall dP of immediately adjacent units (horizontal and vertical)
- Step 2:
  - If change in dP of an adjacent unit > 5Pa, open hall door to that unit
  - Repeat total leakage measurement

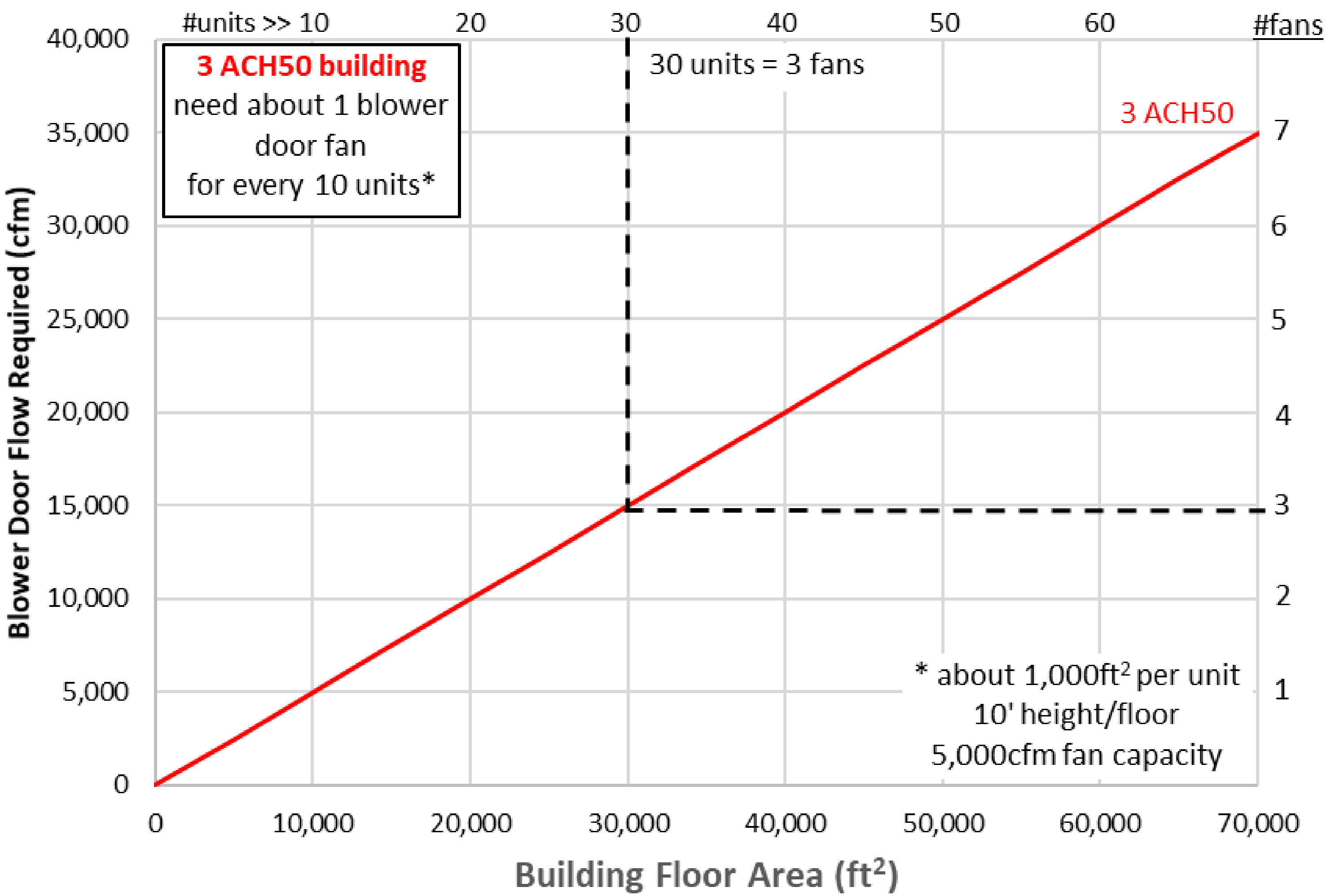
Total Leakage of Individual Units

Common Entry: Whole Building Test

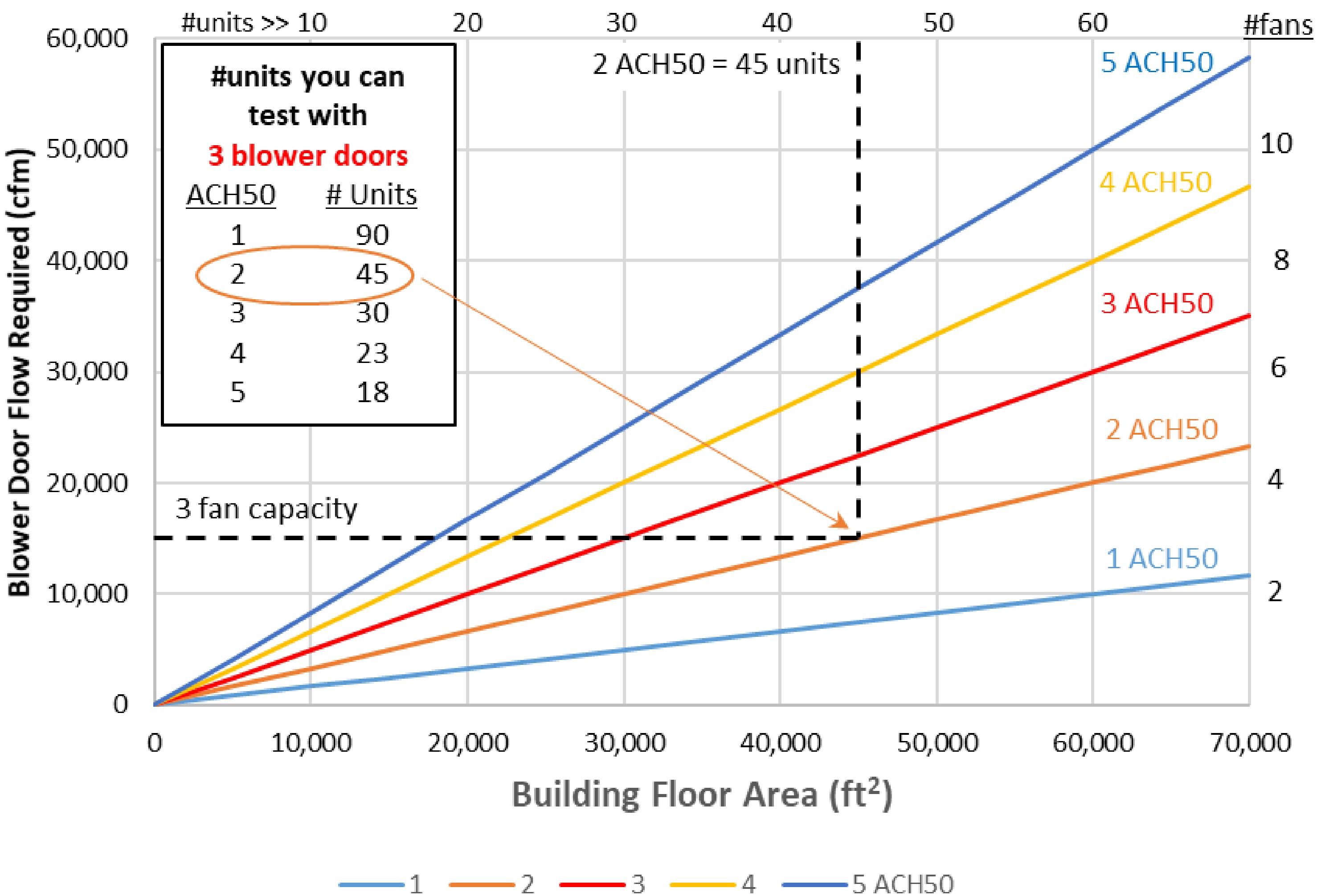


Exterior Leakage- Whole Building

Whole Building: How many blower doors?

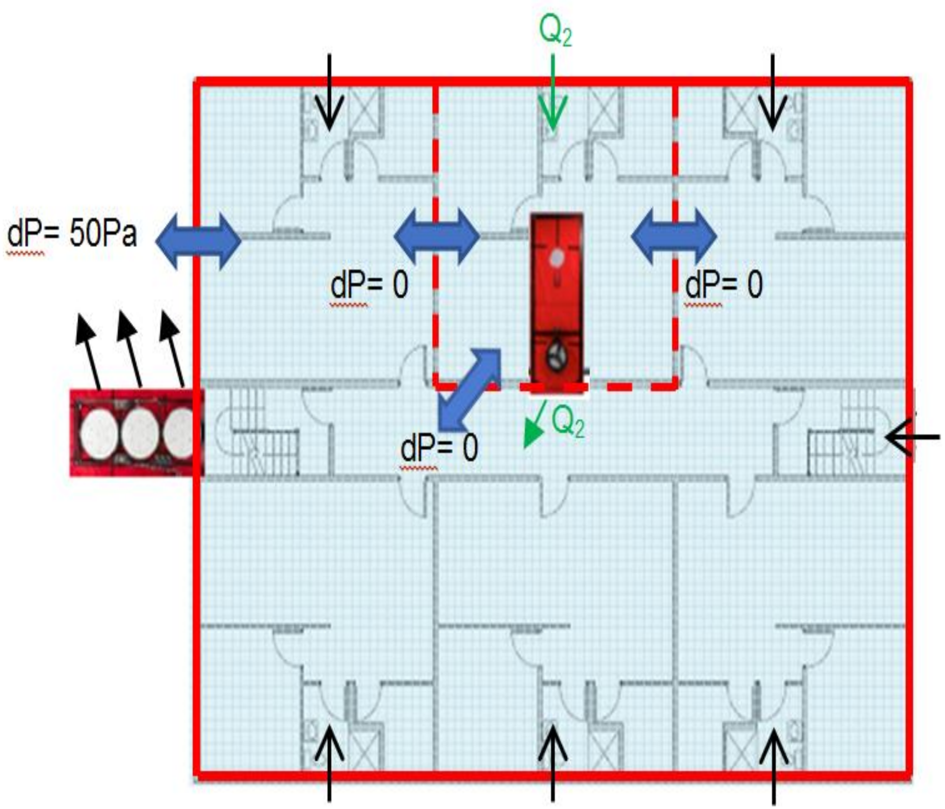


Whole Building: How many blower doors?



Easier to test tighter buildings

Common Entry: Guarded Test



Paul Morin, TEC

When # units > 12, same cluster sample as compartmentalization tests

- Step 1:
  - Hall doors of all units open
  - Unit measurement (Q_2) = exterior leakage
- Step 2:
  - Immediately adjacent units – close hall door and open window
  - Unit measurement (Q_2) = (exterior + adjacent) leakage

Exterior Leakage- Individual Units

Three Tests to Breakdown Unit Leakage

1. Compartmentalization = total leakage

2. Guarded Unit = exterior leakage
   - Total – exterior = interior leakage

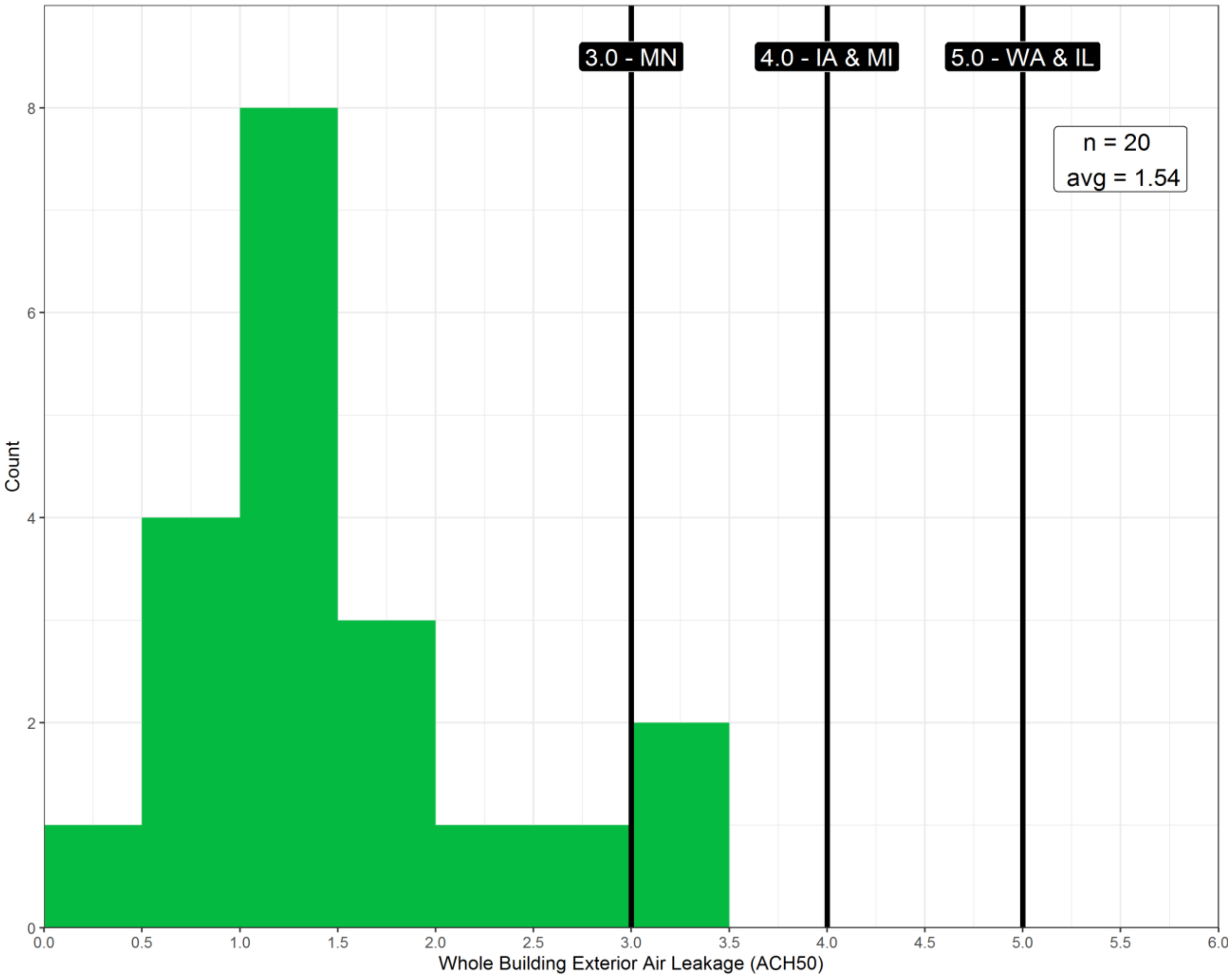
3. Guarded Unit with adjacent units open to exterior = exterior + adjacent leakage
   - Total – (exterior+adjacent) = common space/hall leakage
   - (Exterior+adjacent) – exterior = adjacent unit leakage

20 Common Entry Test Buildings

- 6 states
  - Minnesota= 10
  - Illinois= 4
  - Iowa= 3
  - Michigan, Oregon, Washington = 1
- # stories
  - three-story= 19*, two-story= 1
- # units
  - average= 31, min= 6, max= 60
- Floor area
  - average= 33,000sf, min= 6,700sf, max= 72,700sf

* 2 buildings had two residential floors over one commercial floor

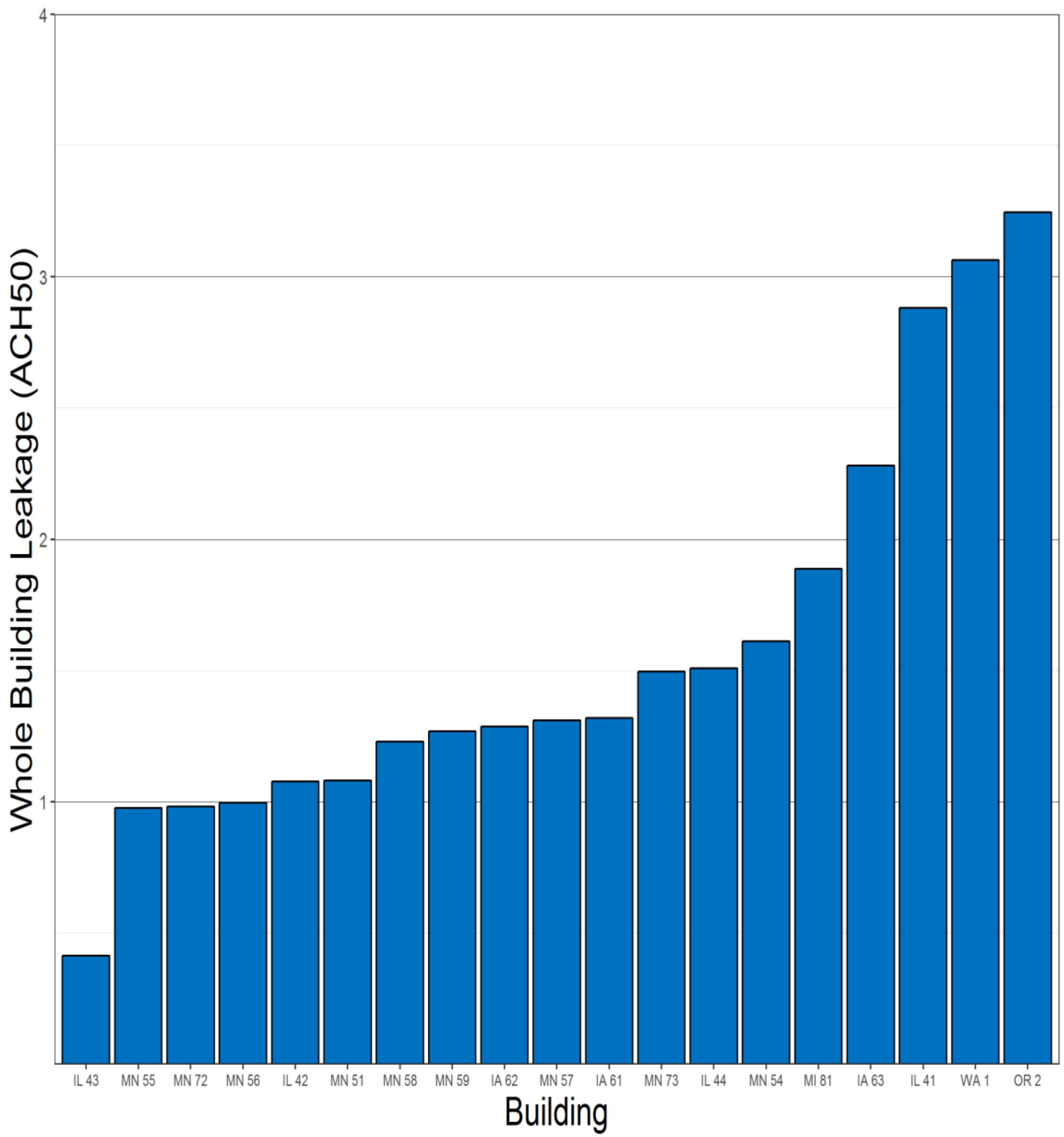
Whole Building Leakage: ACH_{50}



- Summary
  - Average= 1.54
  - Median= 1.30
  - Min= 0.41 (IL PH)
  - Max= 3.25
- State averages
  - MN= 1.19
  - IL= 1.47 (1.82 w/o PH)
  - IA= 1.63
  - MI= 1.89
  - OR/WA= 3.16

- All of the buildings were at least 39% below the leakage required by code for their state
- On average the buildings were 61% below the code-required leakage

Whole Building Leakage: ACH_{50}



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Building & Design Characteristics That Could Impact Envelope Leakage

- State air leakage code requirement/enforcement?
  - Test type and max acceptable
- Energy program requirement for air leakage test
  - Program, test type, max acceptable (target or requirement)
- Ceiling-roof
  - Flat roof
  - Vented attic
- Space below lowest level
  - Slab
  - Garage
  - Basement
- Air barrier design approach
  - Exterior, above grade walls
  - Demising walls
  - Ceiling-roof
- Common Entry or Garden Style

Building & Design Characteristics
That Could Impact Envelope Leakage

- Code leakage requirement and attic type explained 80% of variation in leakage
- Lower code requirement = lower actual leakage
- Vented attics 30% to 100% leakier than flat roofs
- Energy efficiency program >> no impact
- Space below the bottom floor >> little impact
- Wall air barrier >> not enough to determine impact

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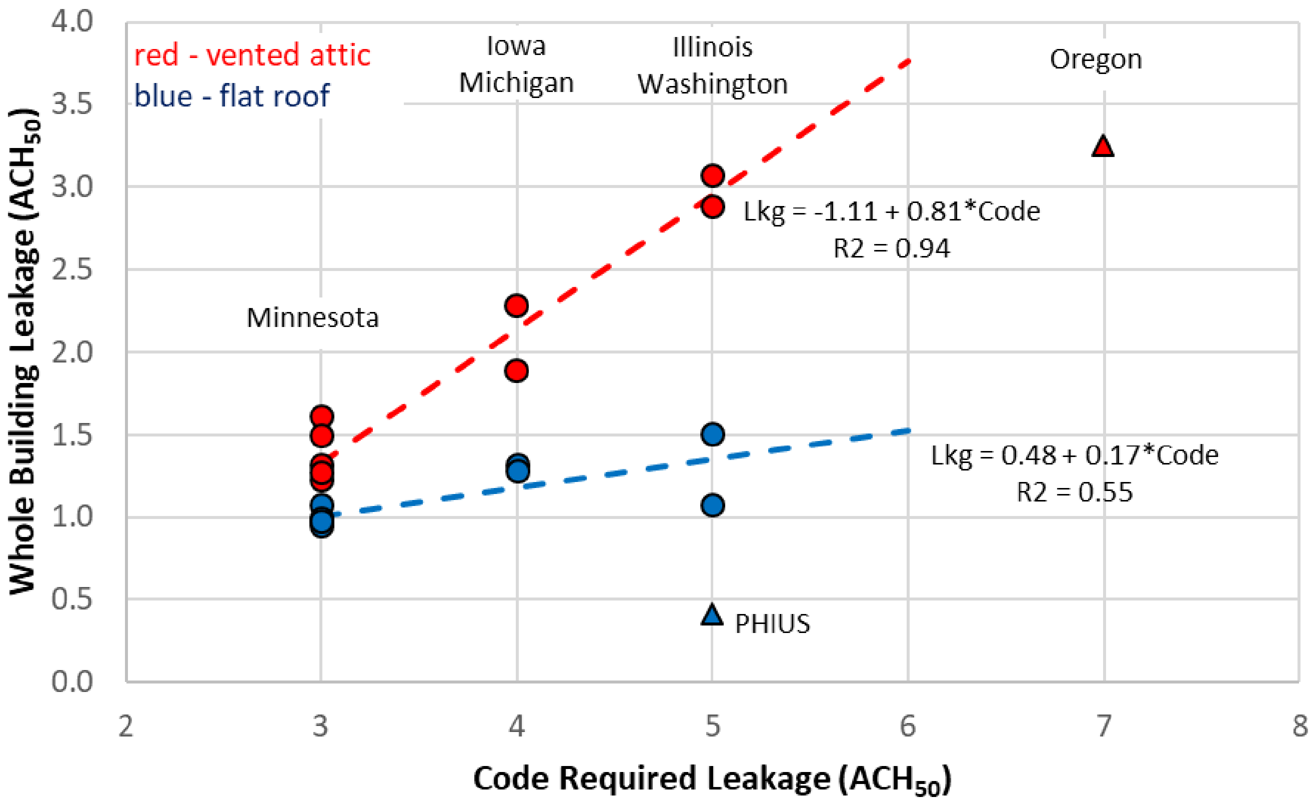
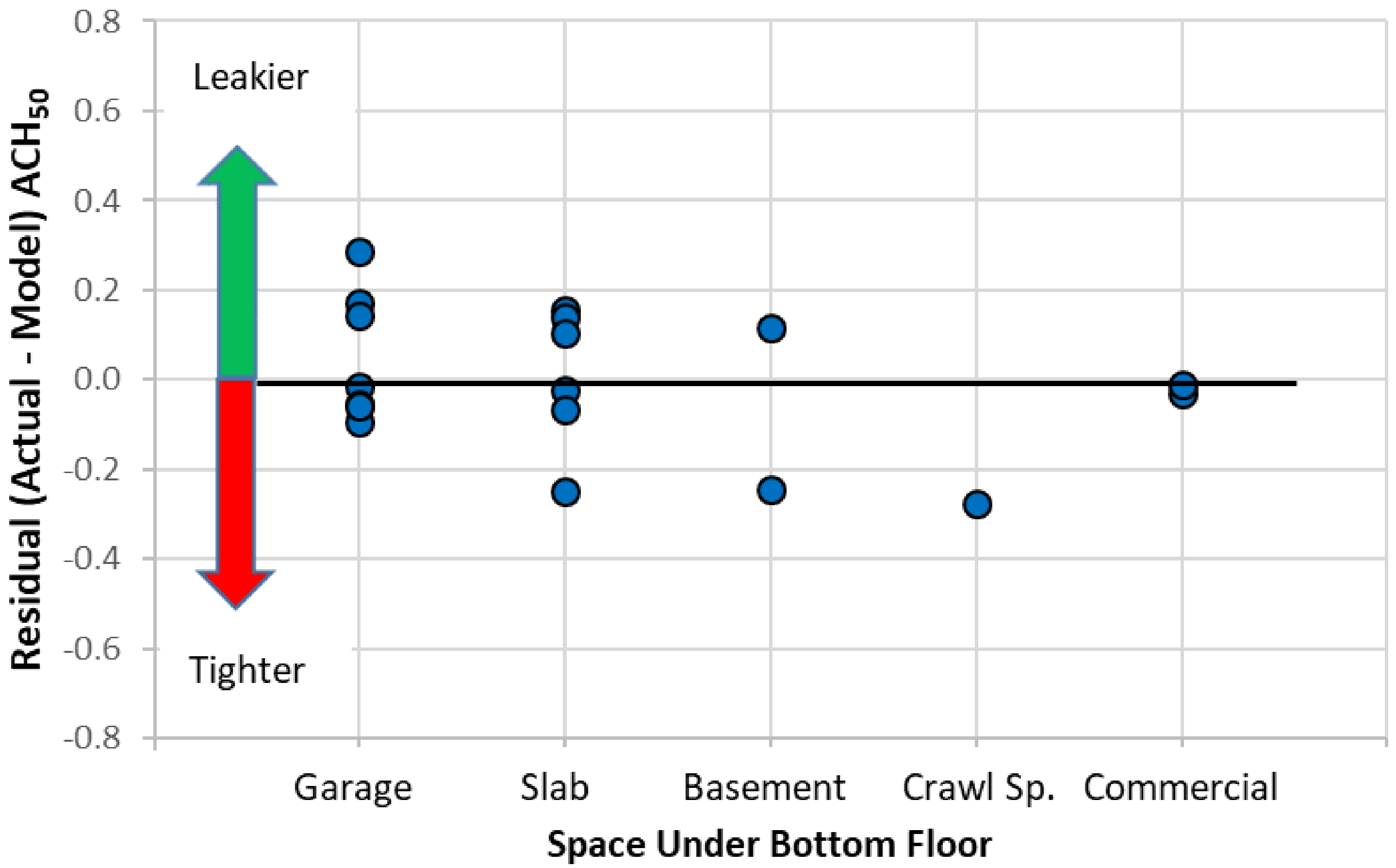
Impact of Code & Attic Type



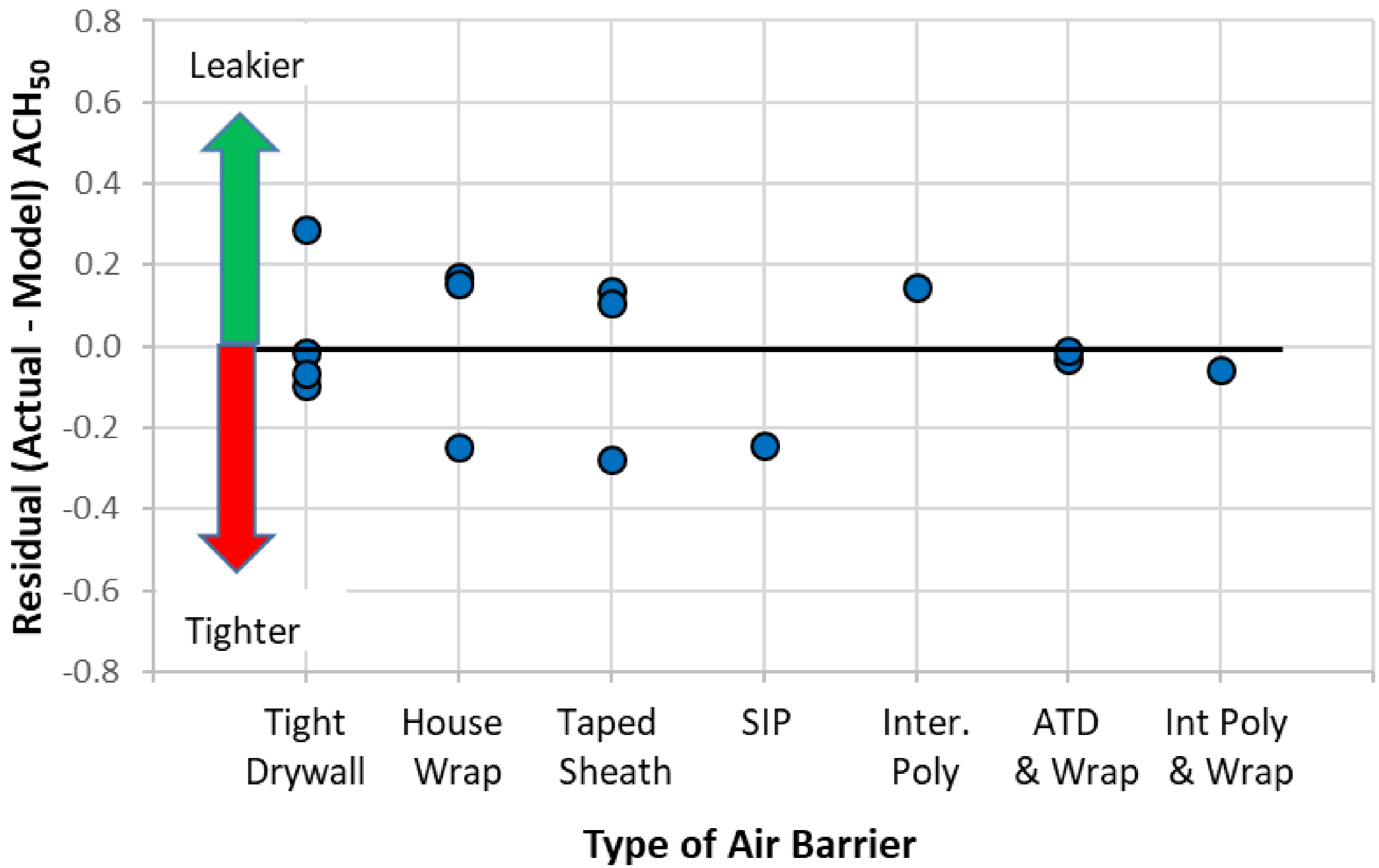
- Code leakage requirement and attic type explained 80% of variation in leakage
- Participation in energy efficiency program didn't impact leakage
- Vented attics 30% to 100% leakier than flat roofs

Impact of Space Under Bottom Floor



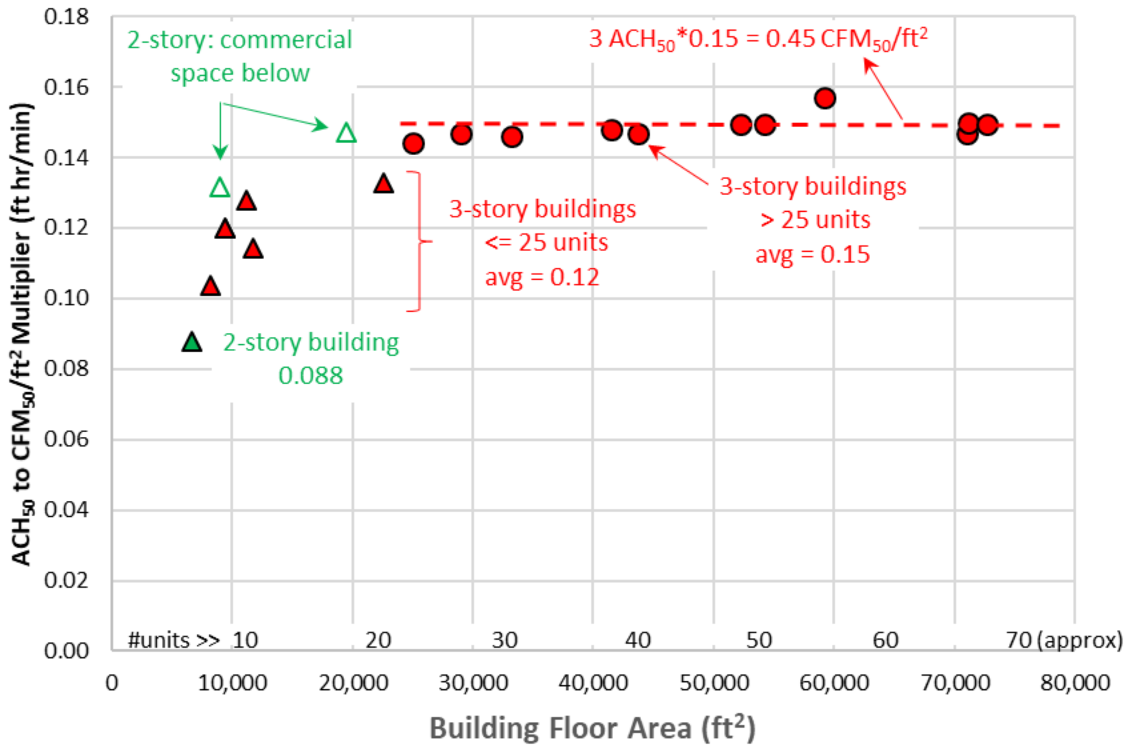
- Type of space below the bottom floor does not seem to affect the building leakage

Impact of Exterior Wall Air Barrier



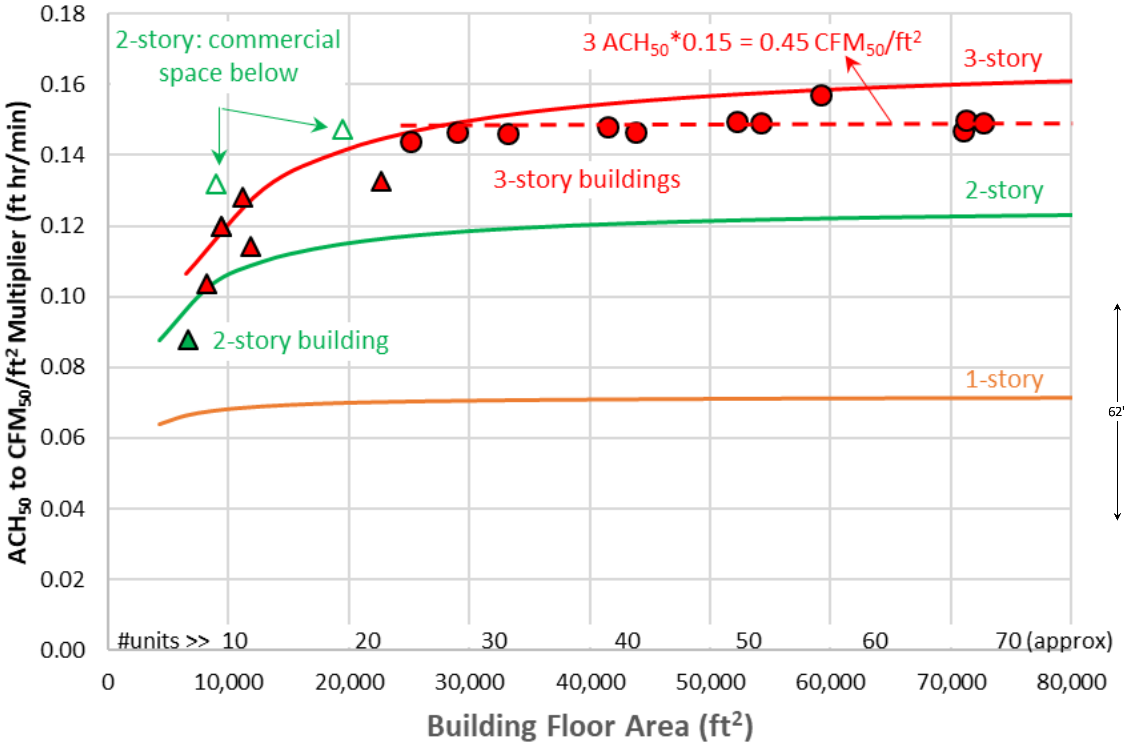
- No strong trends in building leakage by type of wall air barrier (too many types – small sample for each)
- All can work well with good application?

Convert ACH_{50} to CFM_{50}/ft^2

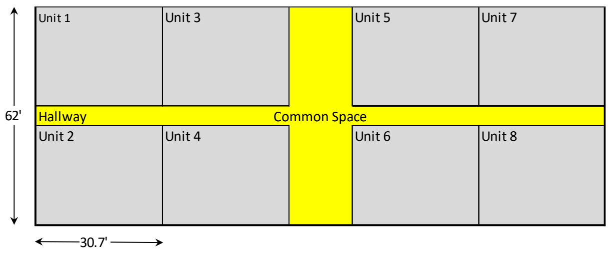


- Can we use two criteria interchangeably?
  - 3-story with #units > 25: $3.0\ ACH_{50} = 0.45\ CFM_{50}/ft^2$
  - 3-story with #units <= 25: $3.8\ ACH_{50} = 0.45\ CFM_{50}/ft^2$
  - 2-story, 10 units: $5.1\ ACH_{50} = 0.45\ CFM_{50}/ft^2$
- Easier for smaller buildings to pass CFM_{50}/ft^2

Convert ACH_{50} to CFM_{50}/ft^2

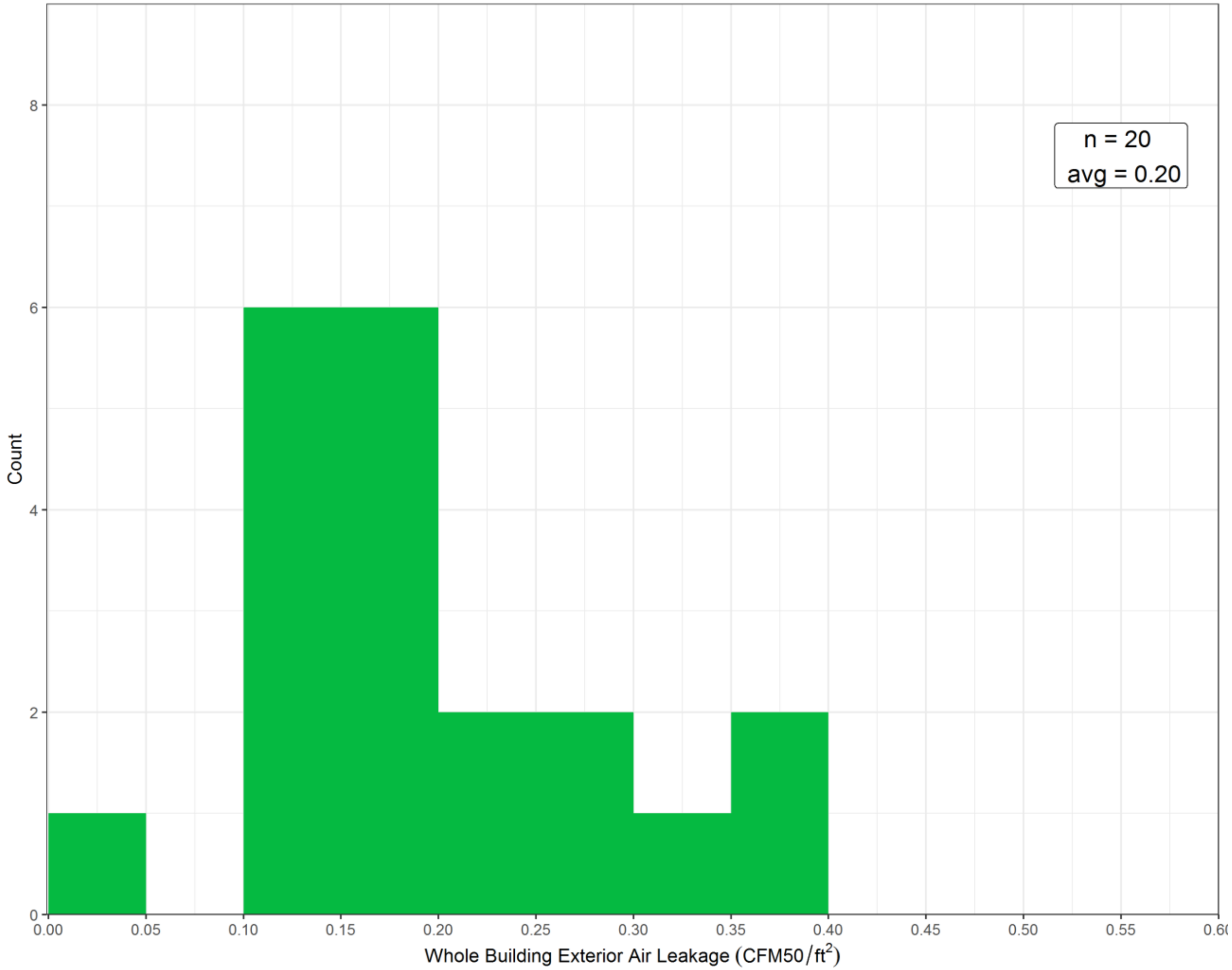


Prototype Building



- Calculations with simple prototype building
  - 3-story: 2.8 ACH_{50} = 0.45 CFM_{50}/ft^2
  - 2-story: 3.7 ACH_{50} = 0.45 CFM_{50}/ft^2
  - 1-story: 6.3 ACH_{50} = 0.45 CFM_{50}/ft^2
- Easier for 1-story buildings to pass CFM_{50}/ft^2

Whole Building Leakage: CFM_{50}/ft^2



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  - Median= 0.19
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- State averages
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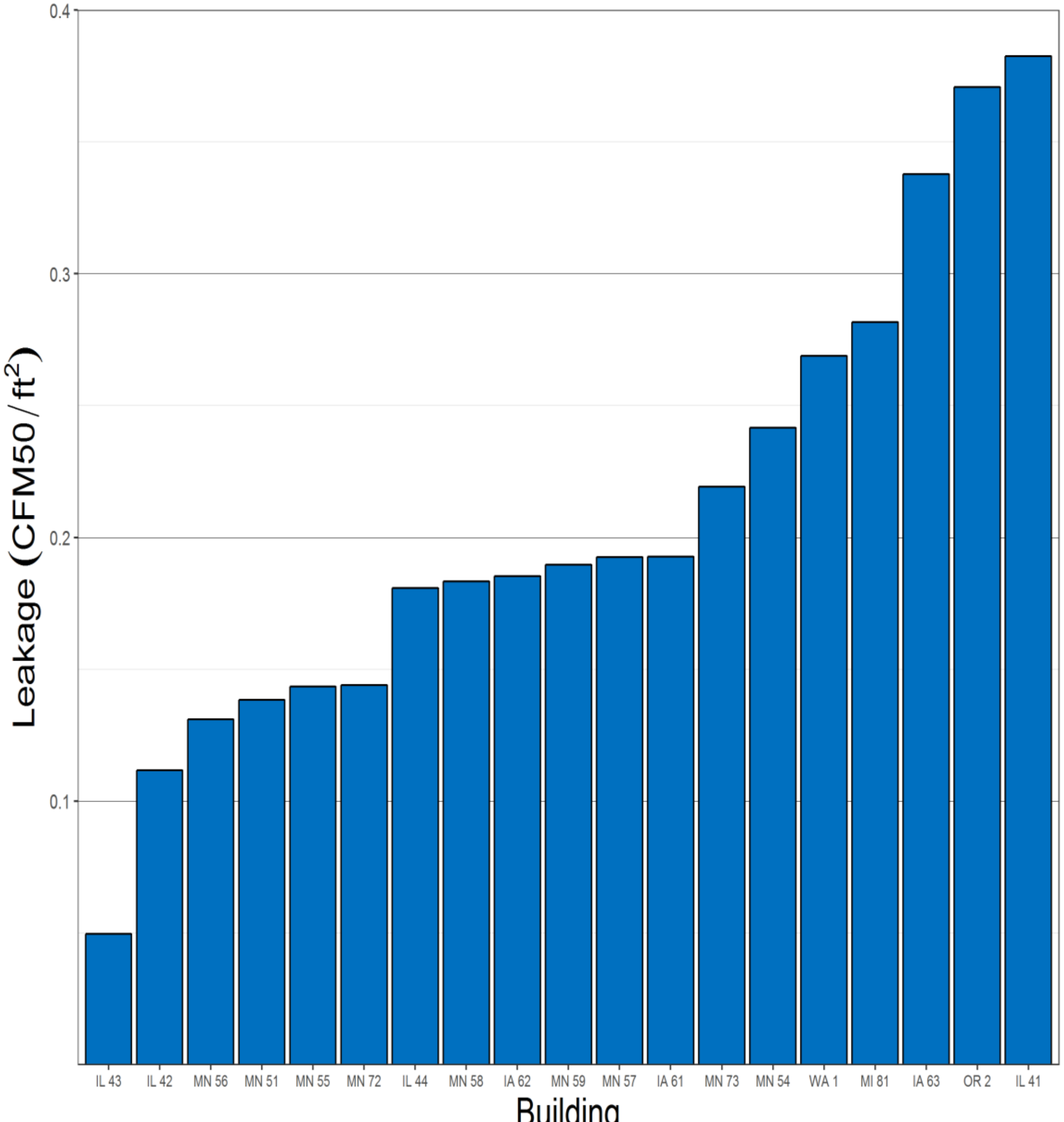
  - IA= 0.24
  - MI= 0.28
  - OR/WA= 0.32

CFM_{50} x 1.3 = CFM_{75} (n=0.65)

0.25 CFM_{75}/ft^2 = 0.19 CFM_{50}/ft^2

Whole Building Leakage: CFM_{50}/ft^2



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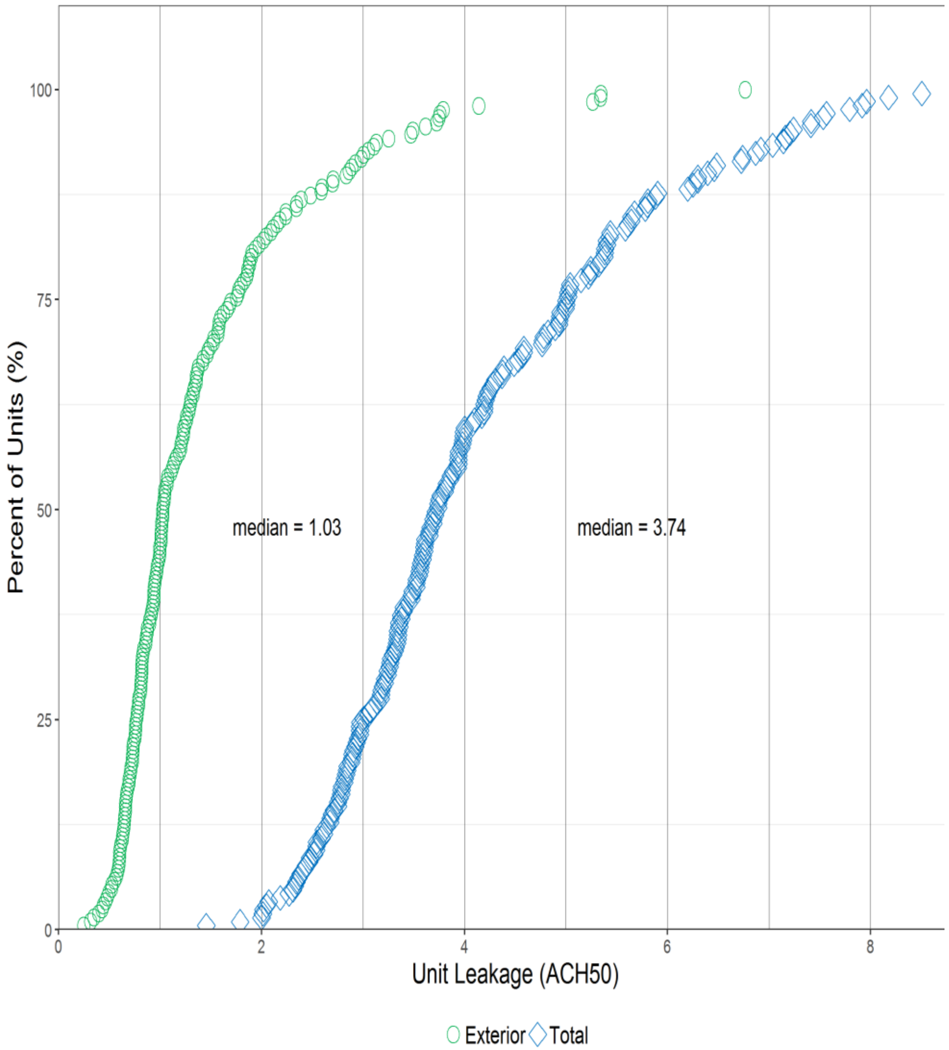
CFM_{50} x 1.3 = CFM_{75} (n=0.65)

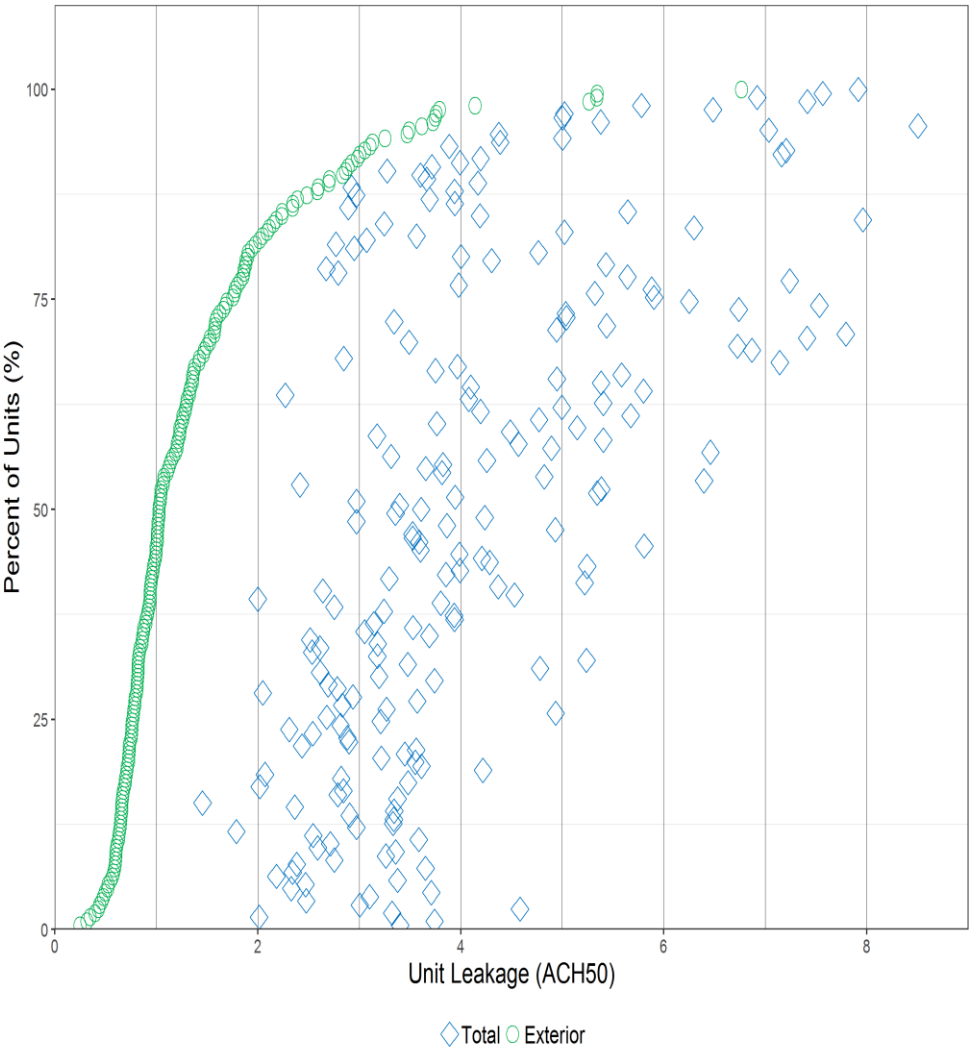
0.25 CFM_{75}/ft^2 = 0.19 CFM_{50}/ft^2

Individual Unit Leakage: ACH_{50}

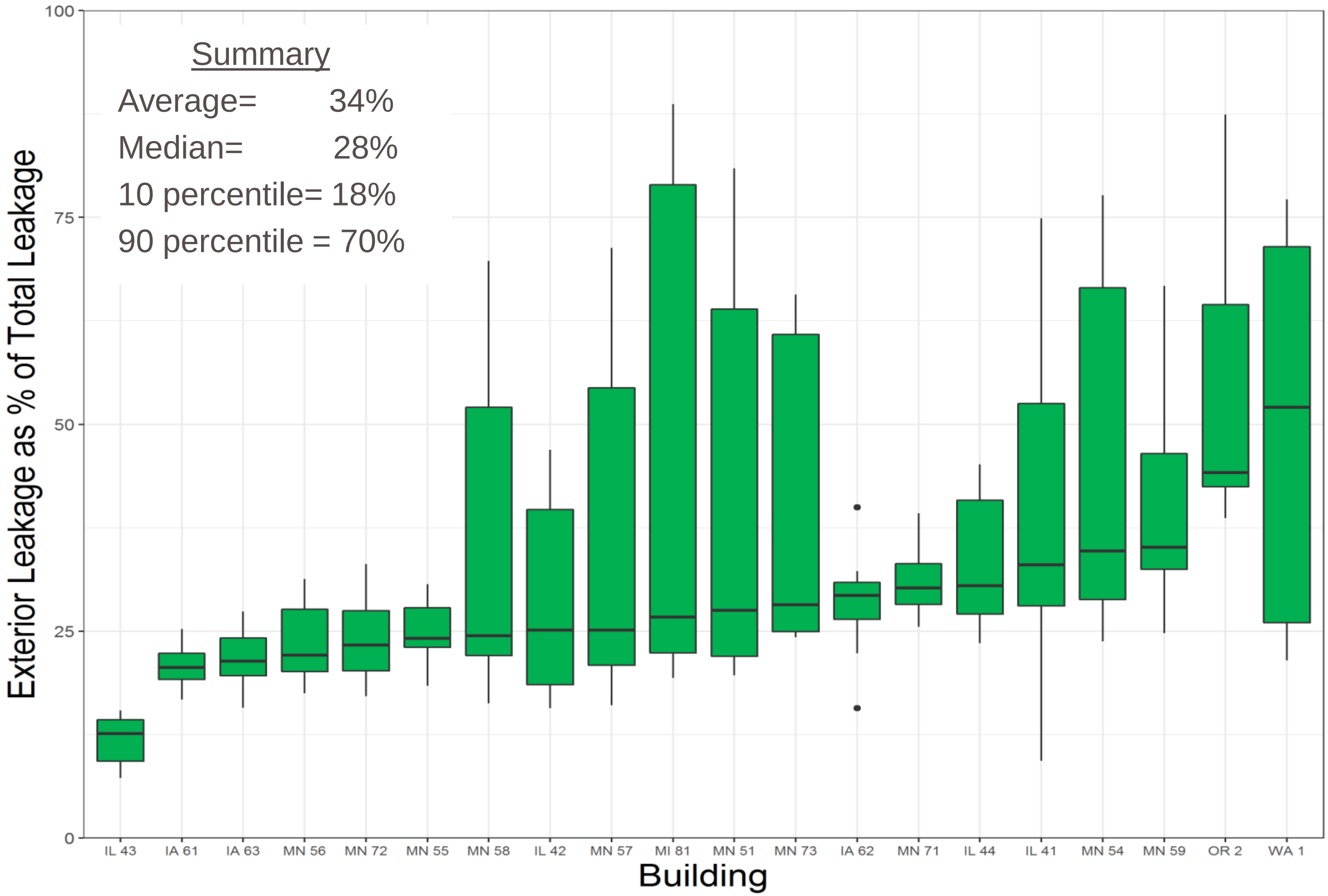
Total and exterior sorted separately



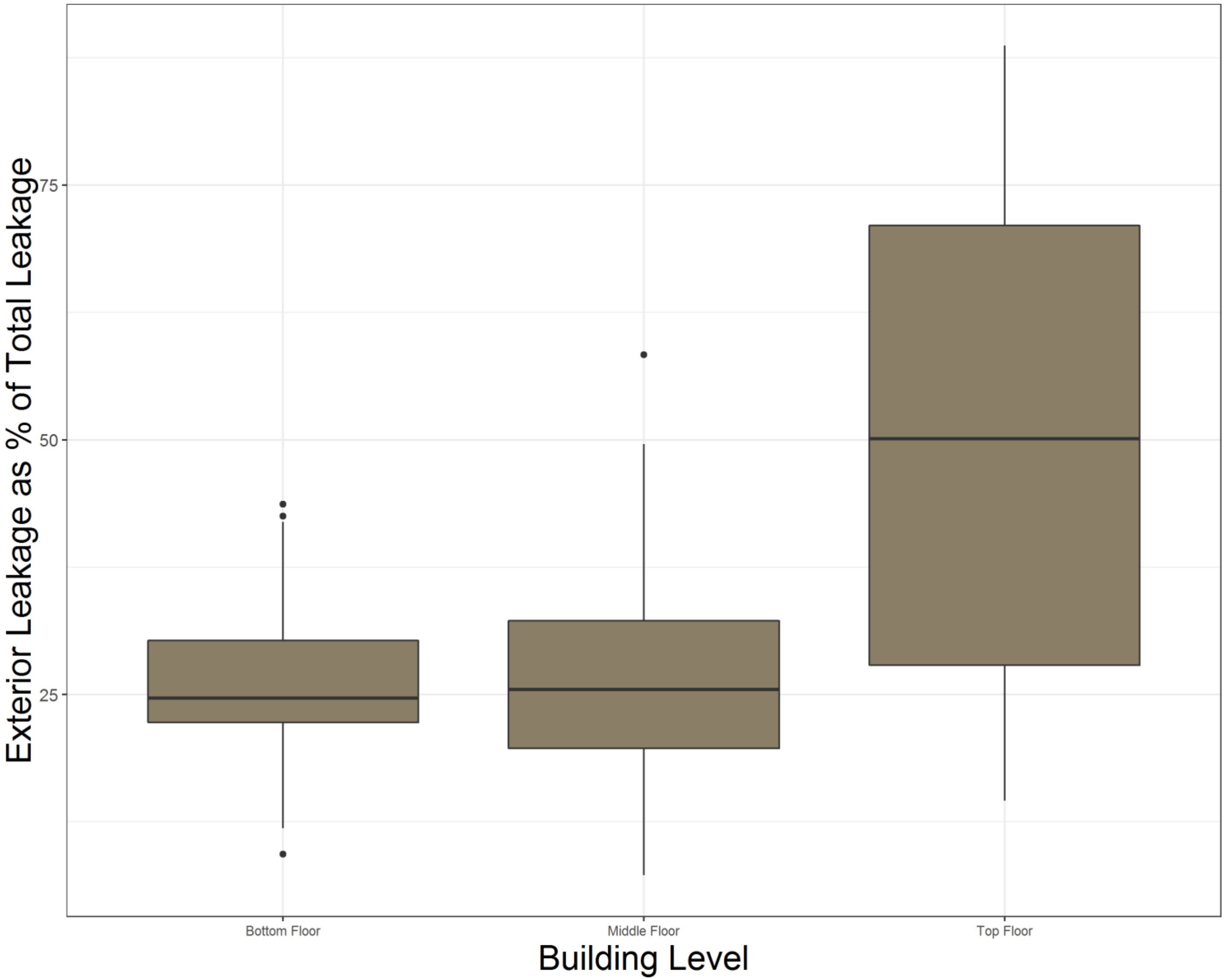
Total paired with exterior



Individual Unit Leakage: Exterior as % of Total

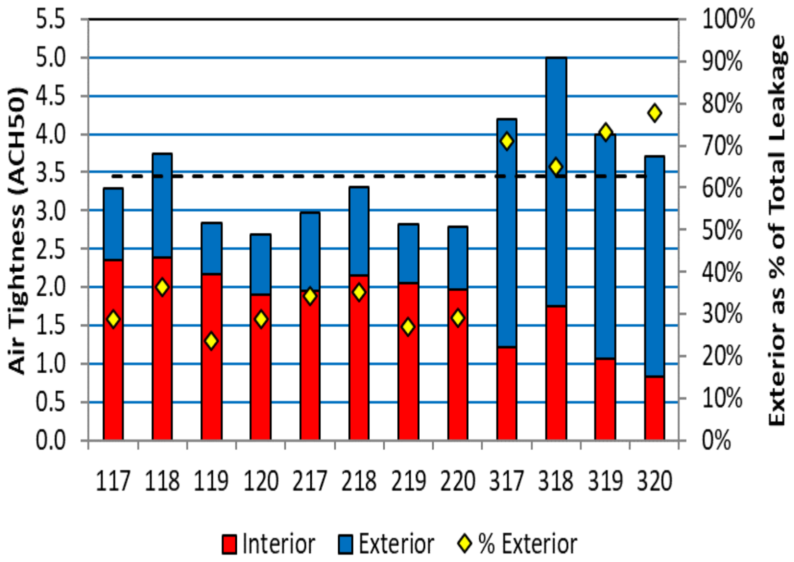


Unit Leakage: Exterior as % of Total

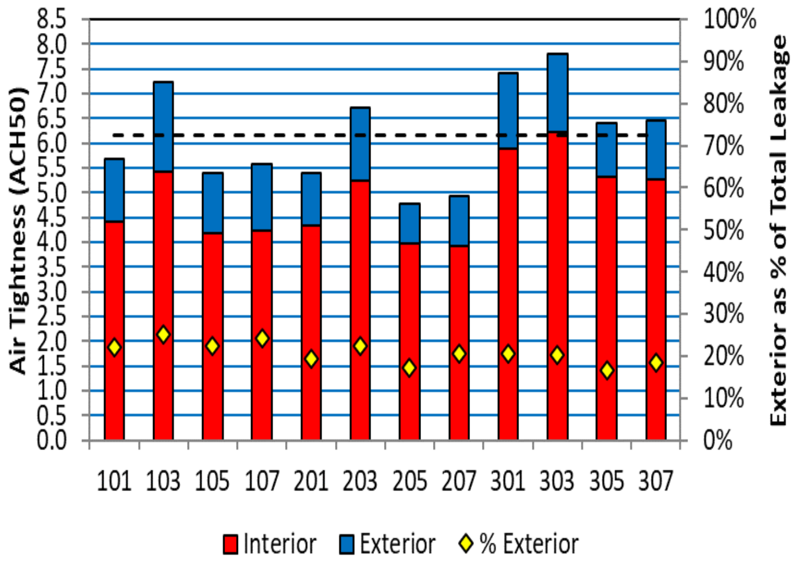


Unit Leakage: Exterior as % of Total

MN 54



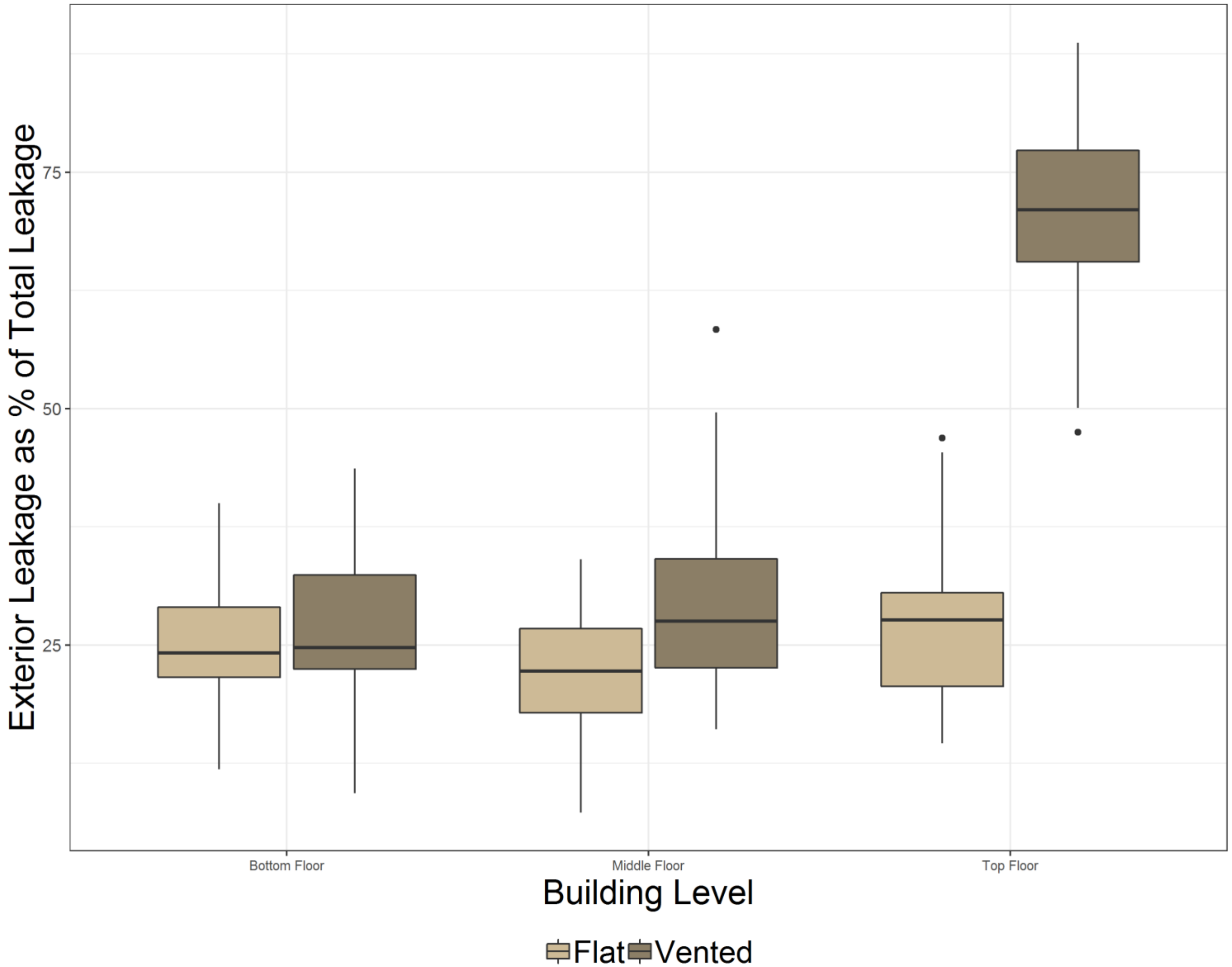
IA 61



Yellow diamonds = percent exterior leakage.

Which building has a vented attic space?

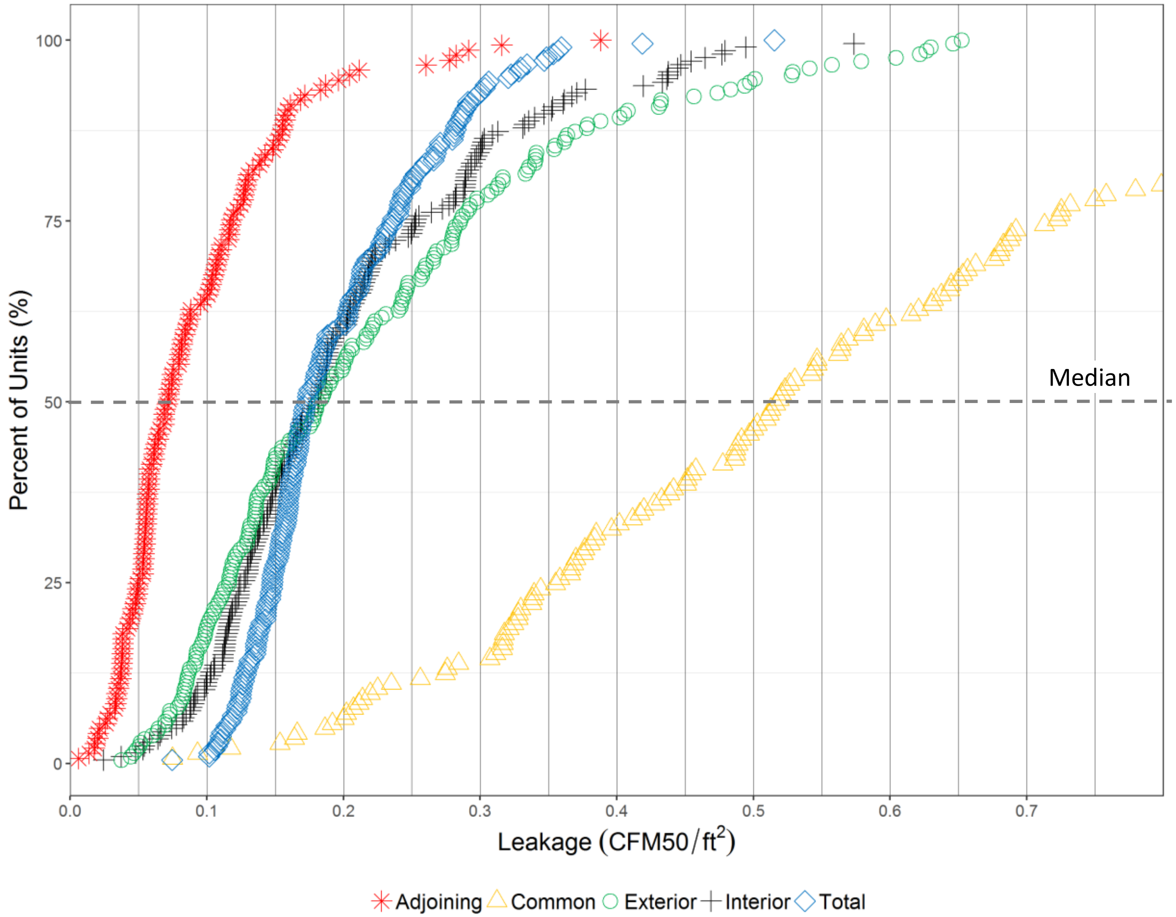
Unit Leakage: Exterior as % of Total



Top floor of vented attics

Unit Leakage: Adjoining Units & Common Area

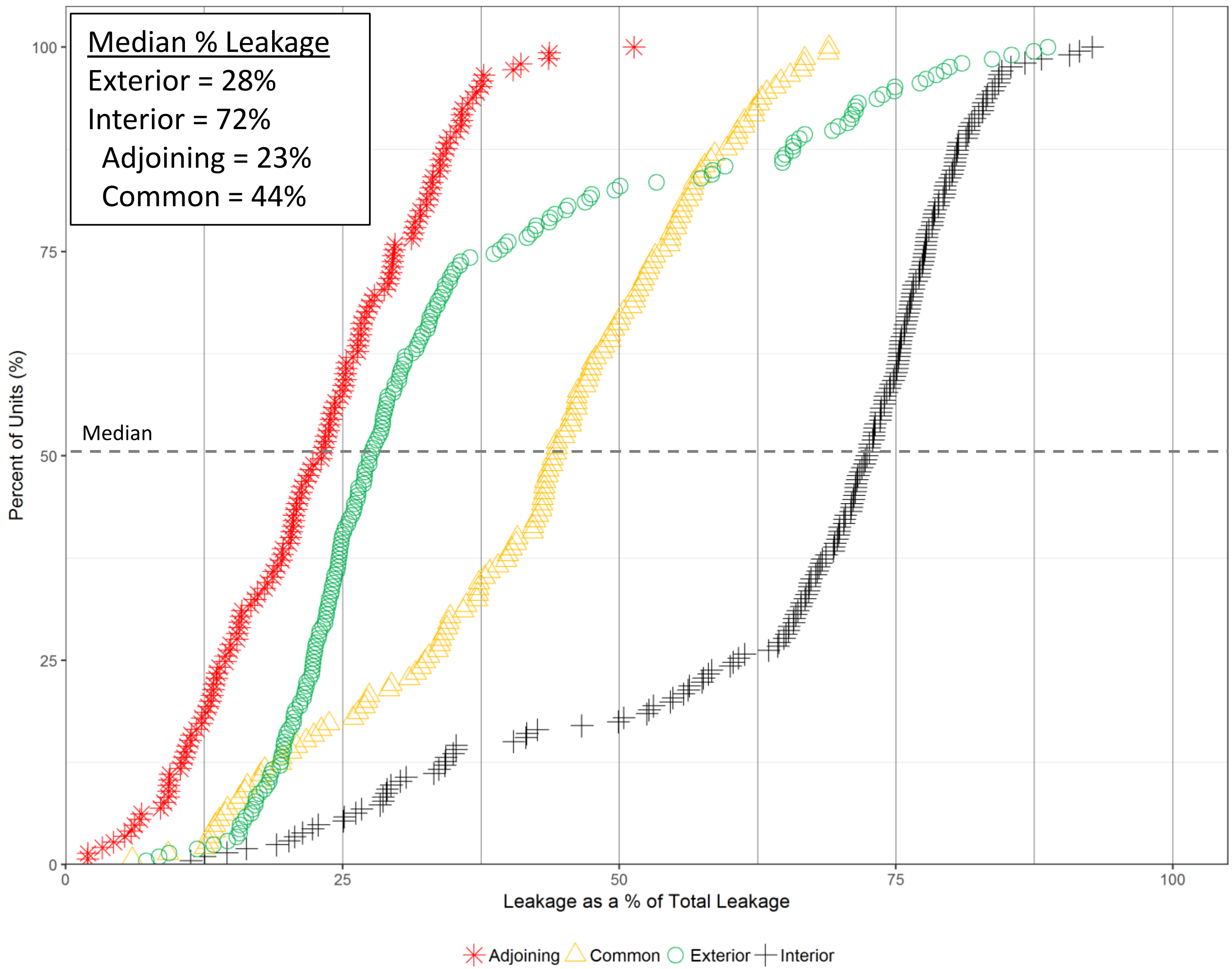
Surface Area Normalized Leakage



- Surface area normalized leakage is similar for exterior and interior
- Leakage to common space is much greater than leakage for any other portions of envelope (almost 10x greater than leakage to adjoining units)

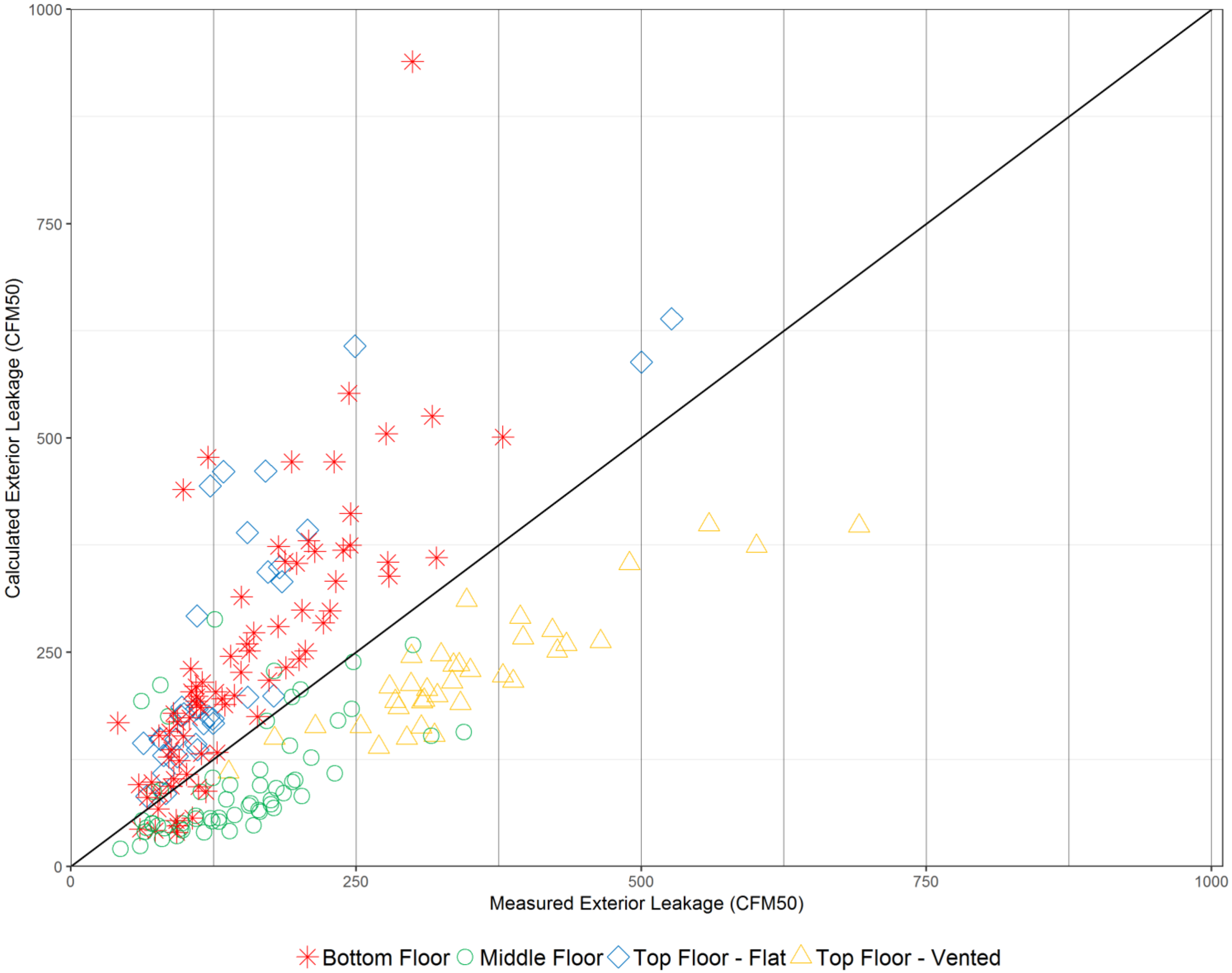
Unit Leakage: Adjoining Units & Common Area

Leakage as % of Total

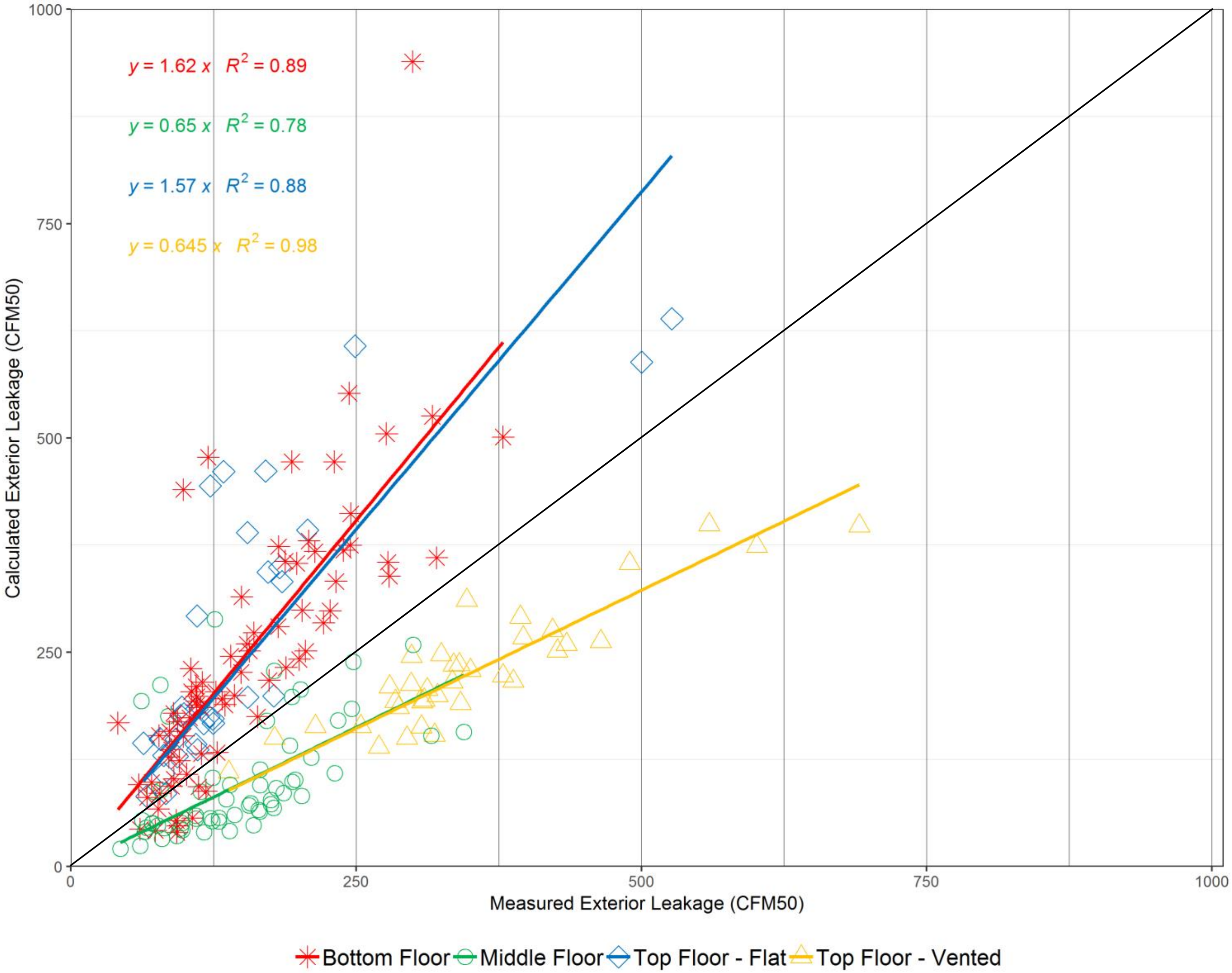


Adjoining + common medians don't add to 72% because those measurements were only conducted for a subset of the buildings

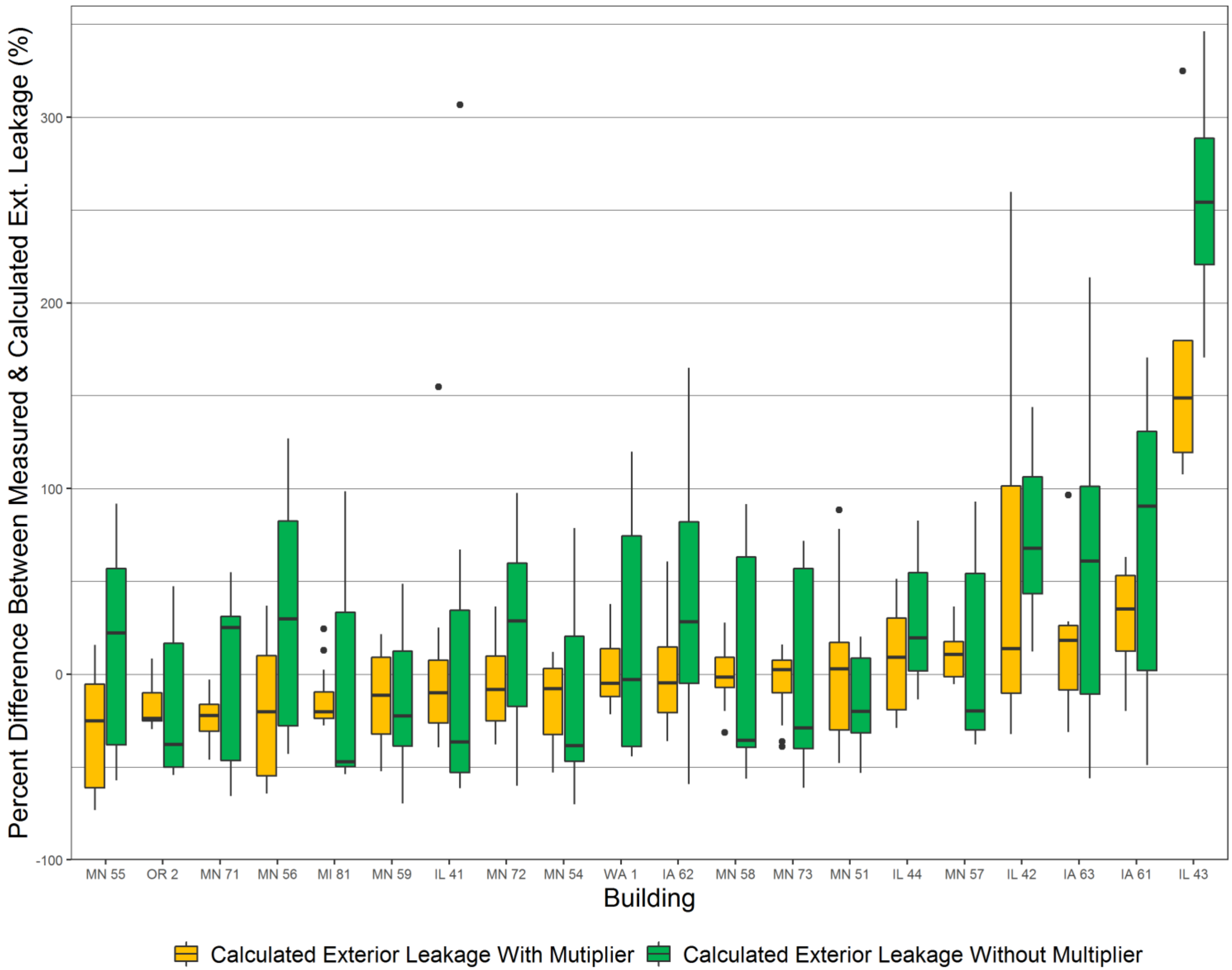
Using Total Leakage to Predict Exterior: By Ratio of Exterior to Total Surface Area



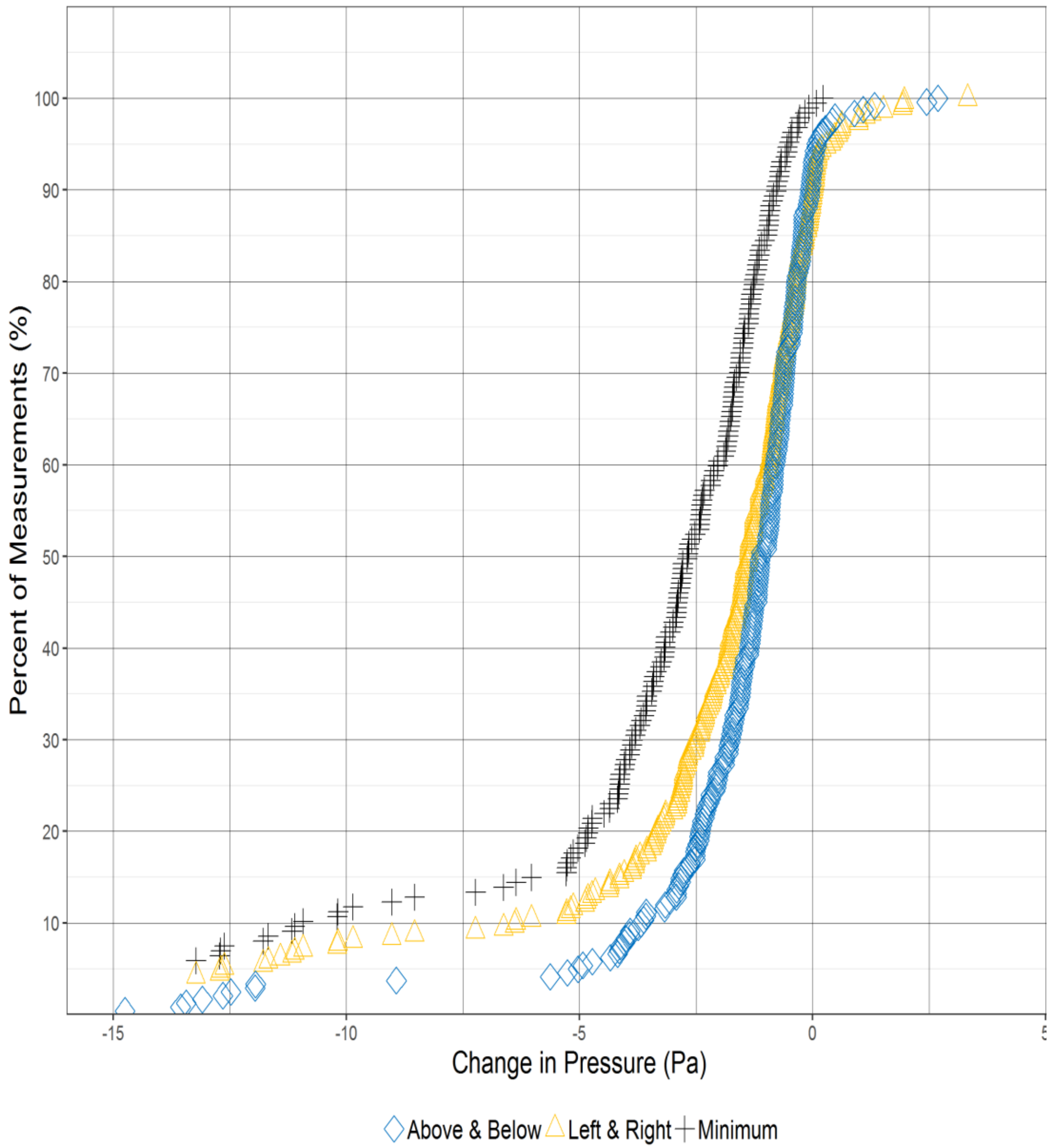
Using Total Leakage to Predict Exterior: By Ratio of Exterior to Total Surface Area

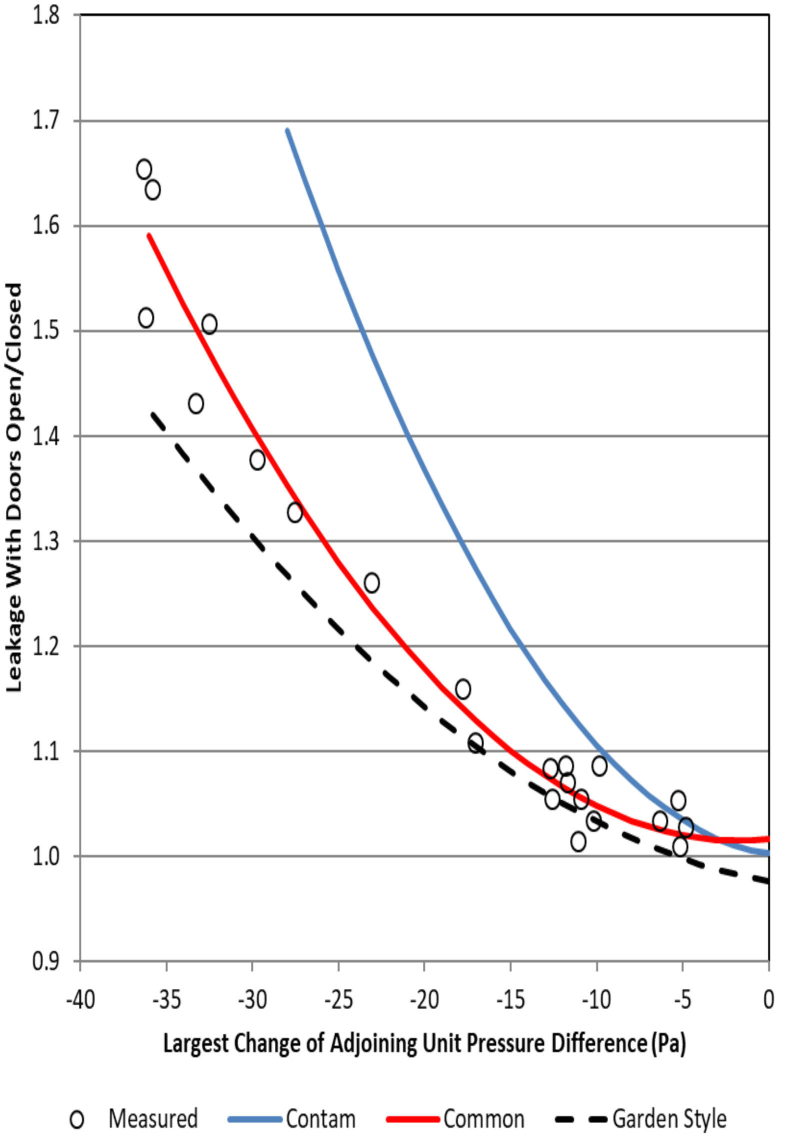


Using Total Leakage to Predict Exterior: By Ratio of Exterior to Total Surface Area

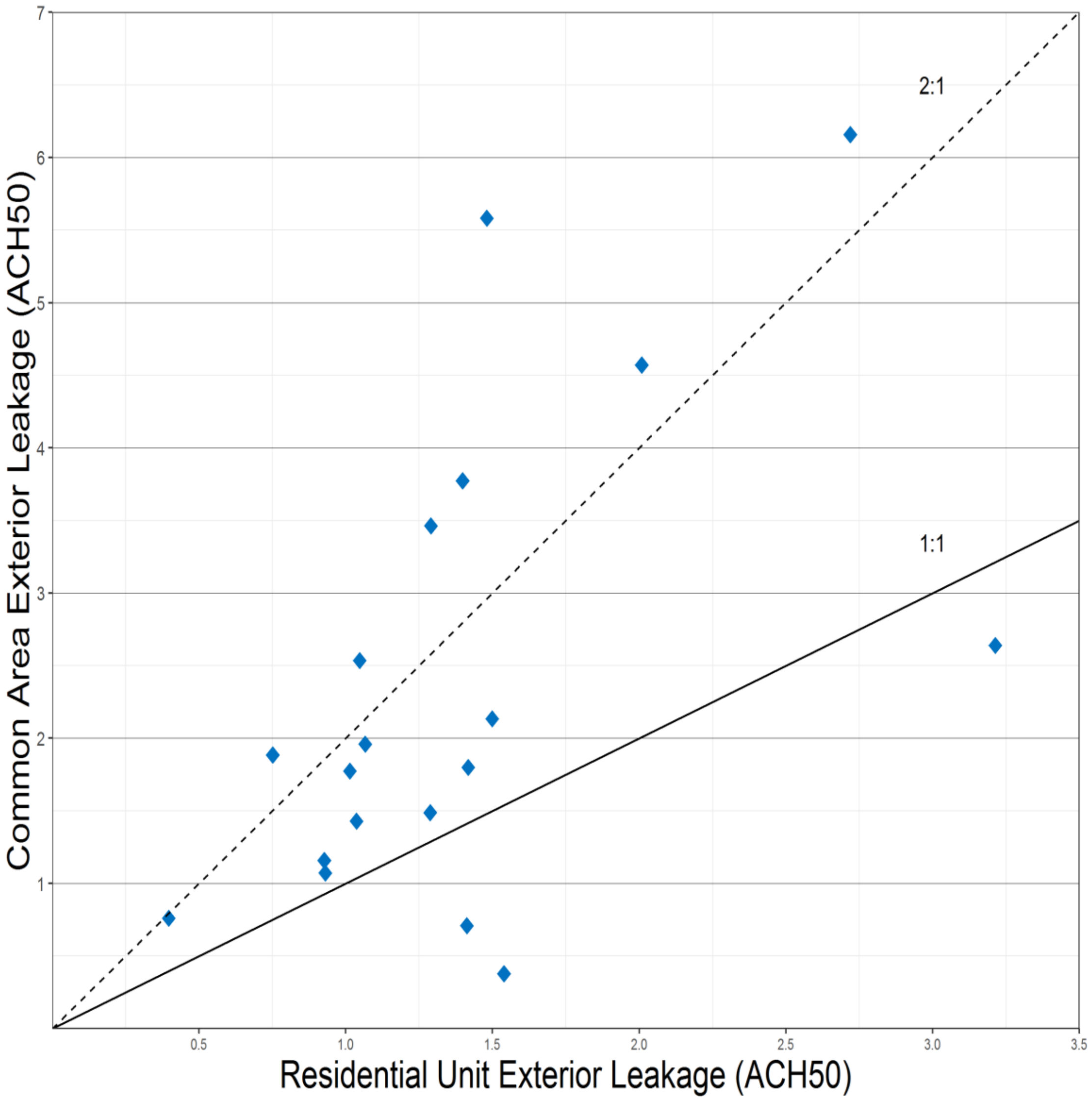


Adjacent Unit Pressures



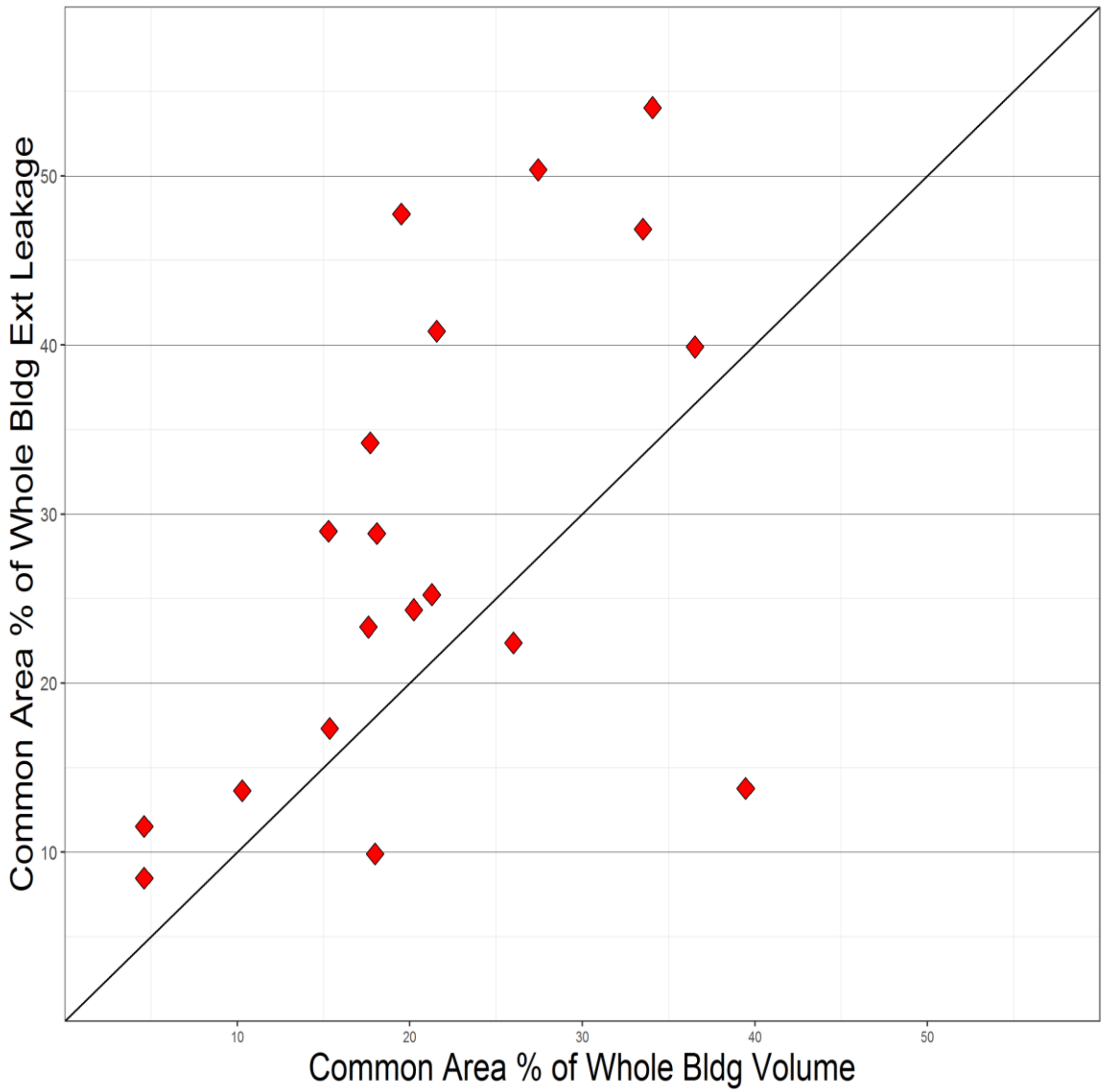


Whole Building Exterior Leakage: ACH_{50}



- Residential Units
  - Average= 1.39
  - Median= 1.29
  - Min= 0.40
  - Max= 3.21
- Common Area
  - Average= 2.38
  - Median= 1.89
  - Min= 0.38
  - Max= 6.16

Impact of Common Area Leakage on Whole Building



Summary and Main Takeaways

- Average whole building = 1.54 ACH50 (61% below code).
- 1 ACH_{50} 90 unit apartment building >> test with only 3 blower door fans.
- Code leakage requirement and attic type explained 80% of variation in leakage.
- Floor level has big impact on how leaky a unit is and where the leaks are located (vented attics >> leakier).
- When using exhaust only ventilation strategy, where is that air coming from (only 28% leakage is to outside)?
- Don’t forget the common spaces in air sealing details.

Questions

THANK you!

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