Ventilation in Multi-Family Buildings

19TH ANNUAL WESTFORD SYMPOSIUM ON BUILDING SCIENCE (SUMMER CAMP)

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RDH

I'm Not Going to Talk About This

Intro

I'm Not Going to Talk About This Either

Intro


Ventilation air is heated or cooled by make-up air unit
Stack Effect Driven Exfiltration
Tempered ventilation air supplied to each floor common corridor
Air flow through open windows
Air leakage between adjacent suites
Airflow in Multi-Family Buildings as a System
Air flow in elevator shaft and stairwells
Stack Effect Driven Infiltration
Air leakage between floors
Parking garage exhaust fans
Contaminated Air Infiltration
Pool
Common Areas
Parking Garage
(Typically unheated)

Outline

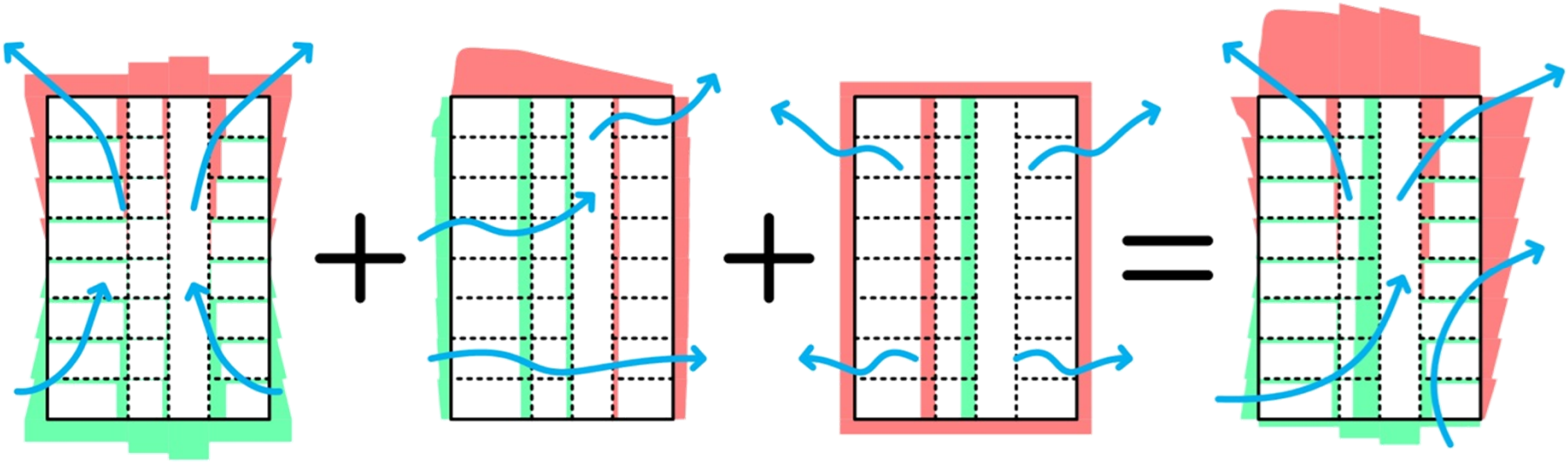
- → A (little) Bit of Science
- → Some Engineering
  - → Corridor Pressurization Case Study
    - › What it Is
    - › Measuring It
    - › Finding Out Why
    - › What it Means
- → A Bit of Context

A (little) Bit of Science

A Bit of Science – Driving Forces

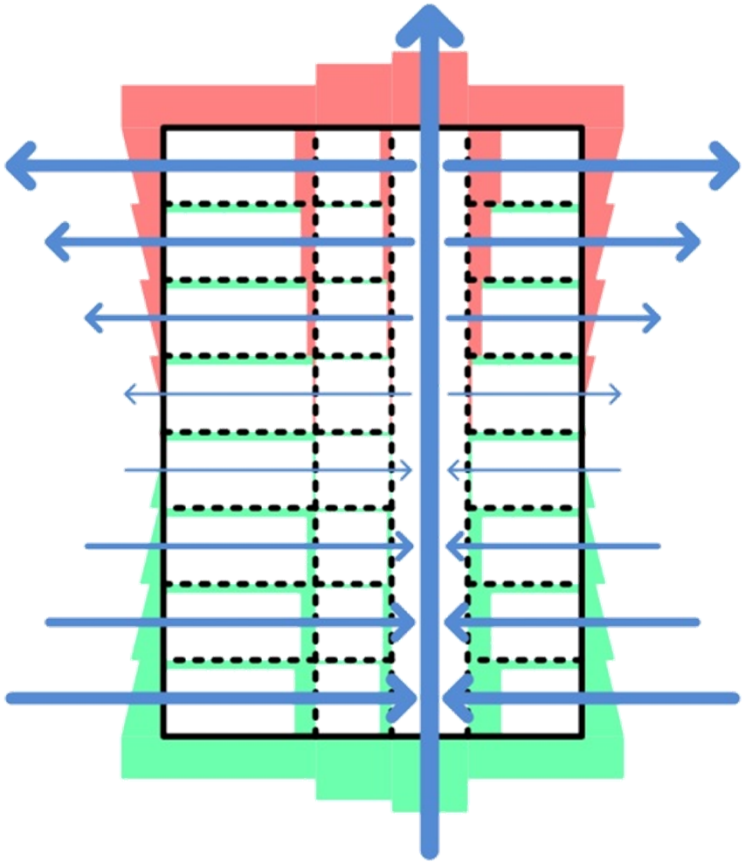
3 *Driving Forces* create pressure differences that drive airflow:

Stack Effect, **Wind**, and **Mechanical Ventilation**



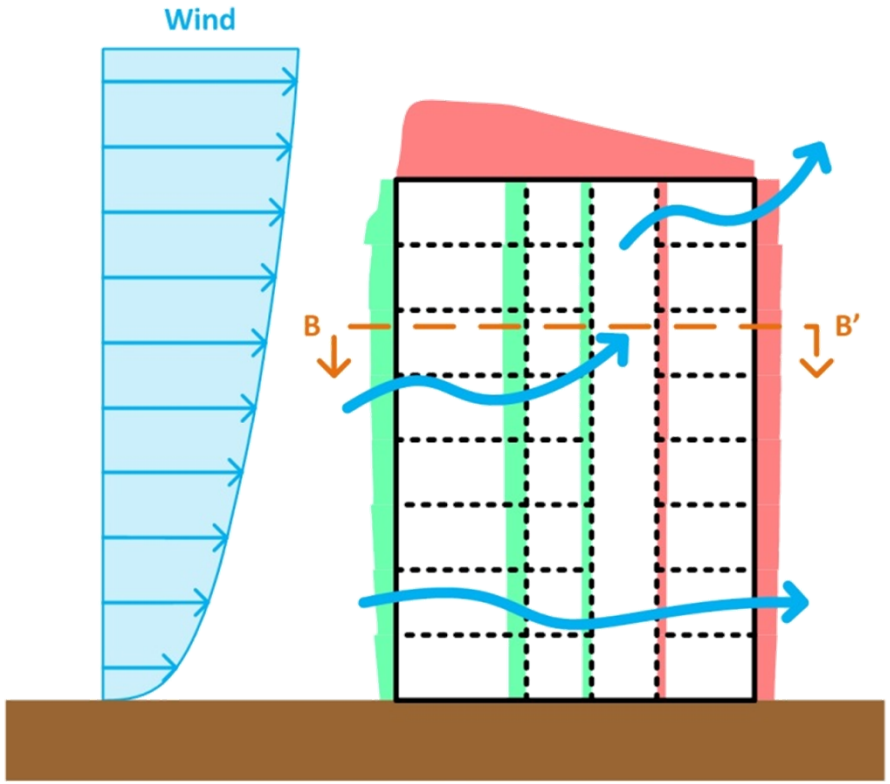
A Bit of Science – Stack Effect

Stack effect caused by the **density difference** between inside air and outside air due to **temperature difference**

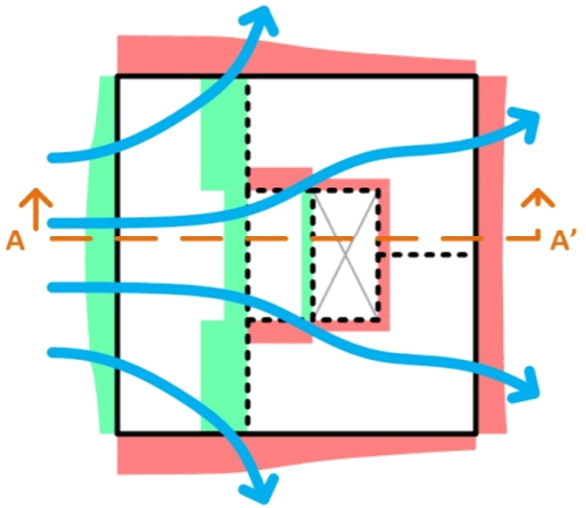


A Bit of Science – Wind

Wind creates pressures on the surface of a building and tends to drive airflow **from windward to leeward**

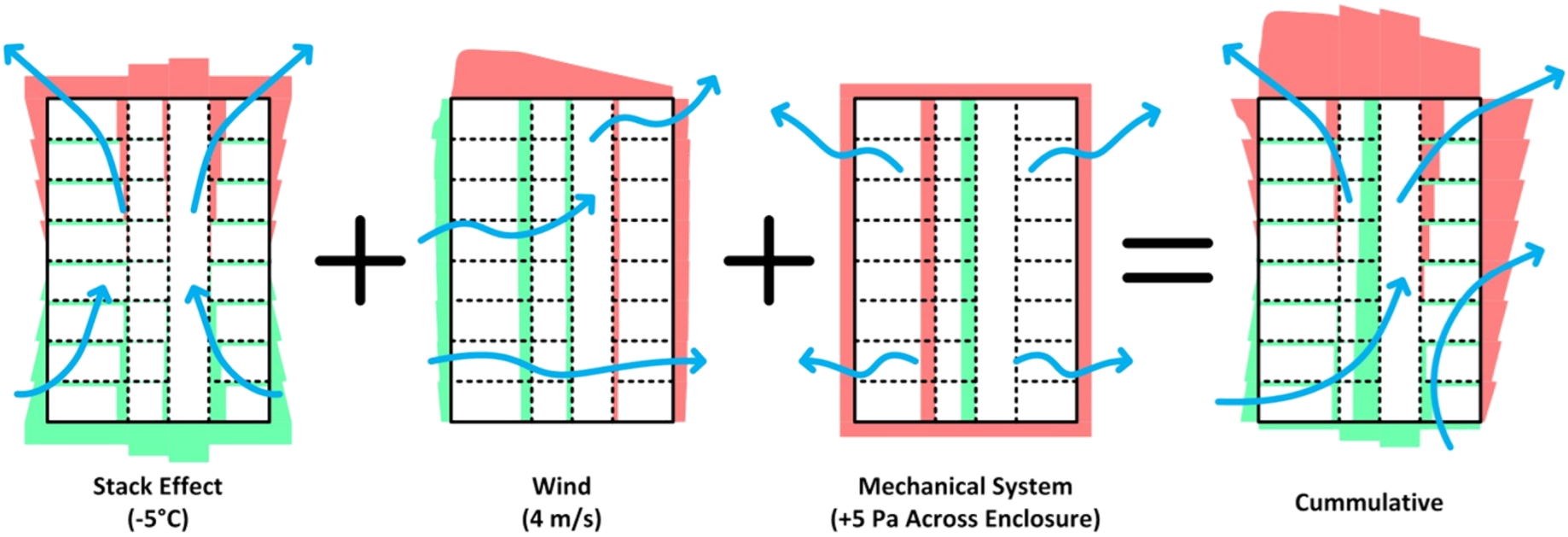


Vertical Cross-Section A-A'



Horizontal Cross-Section B-B'

A Bit of Science – Driving Forces



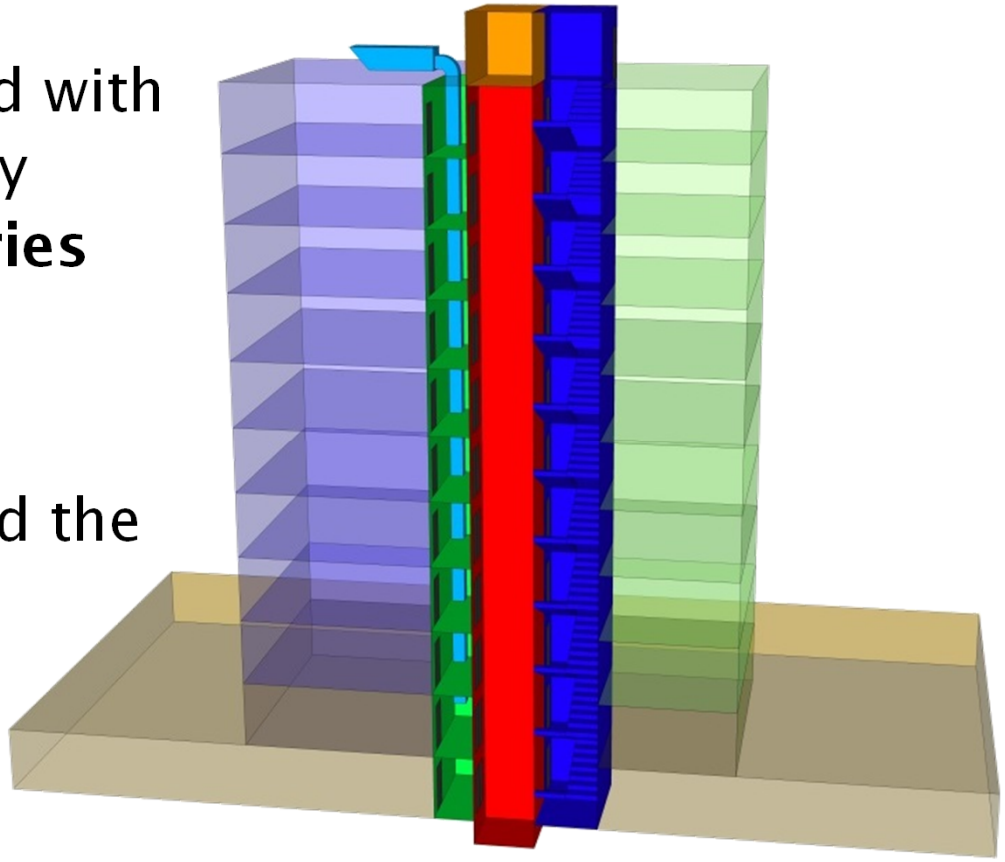
A Bit of Science - Airtightness

Resistance to airflow provided by airtightness of building elements such as walls, windows, doors, etc.

A Bit of Science

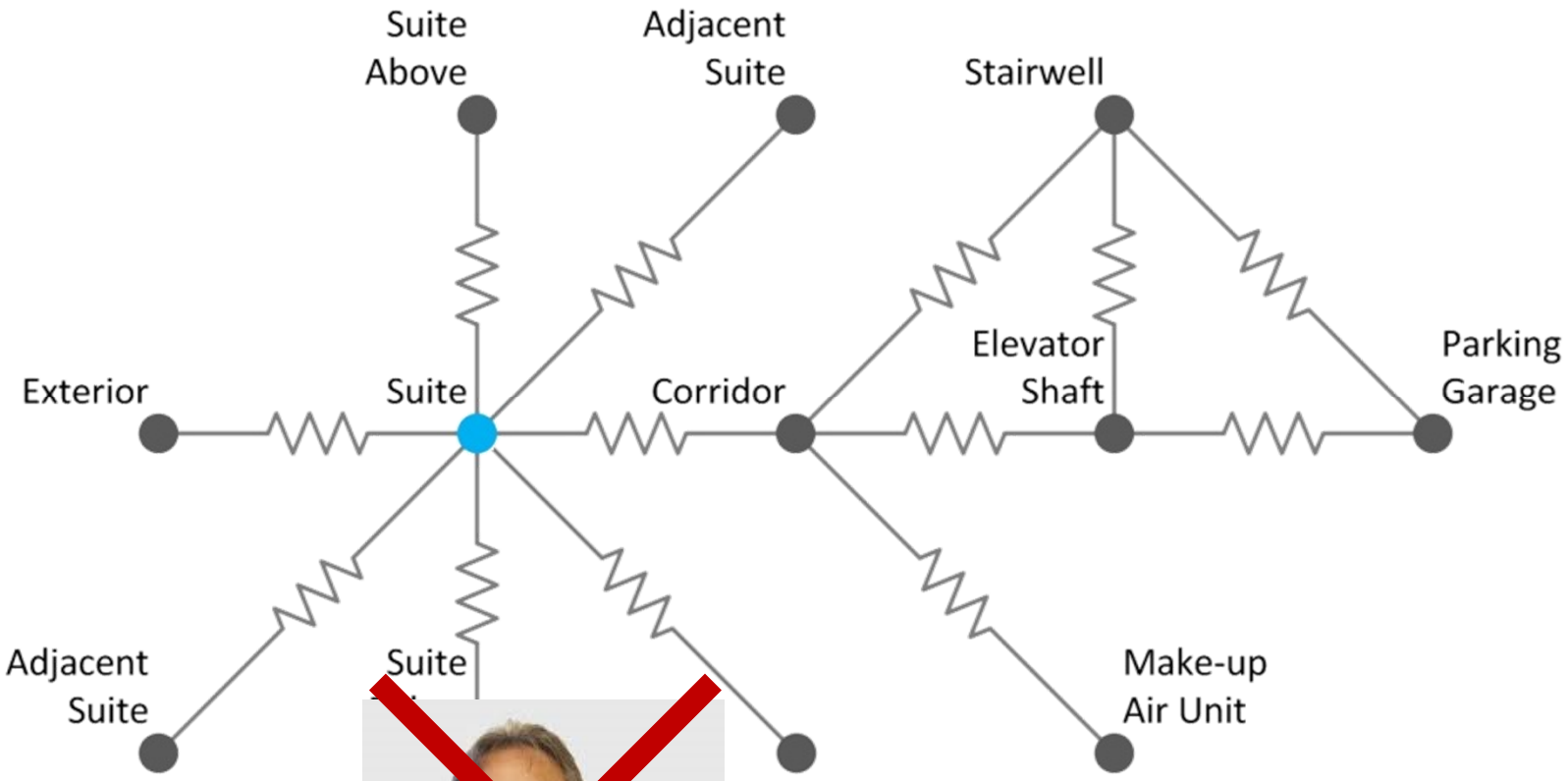
→ Buildings are complicated with many **zones** separated by many **pressure boundaries**

→ Convenient to develop a model to help understand the complex relationships



A Bit of Science

→ Many connected interior spaces…



Interstitial Spaces

A Bit of Science

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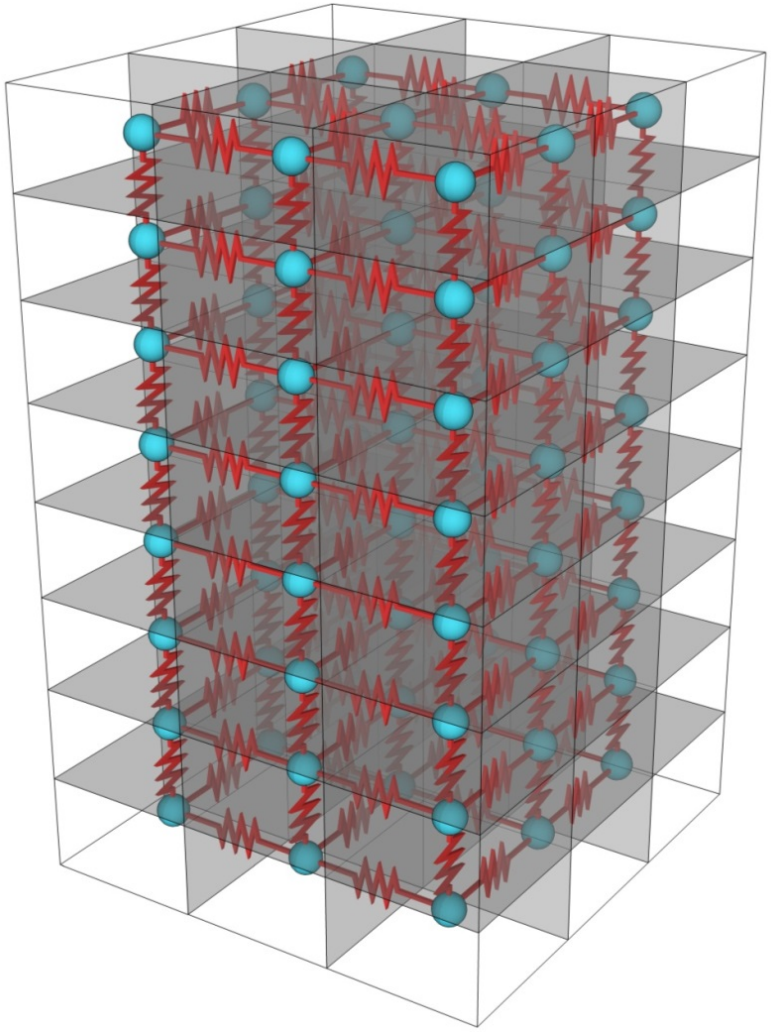
→ It's complicated…



Corridor Pressurization Ventilation Systems

→ A Case Study

Background

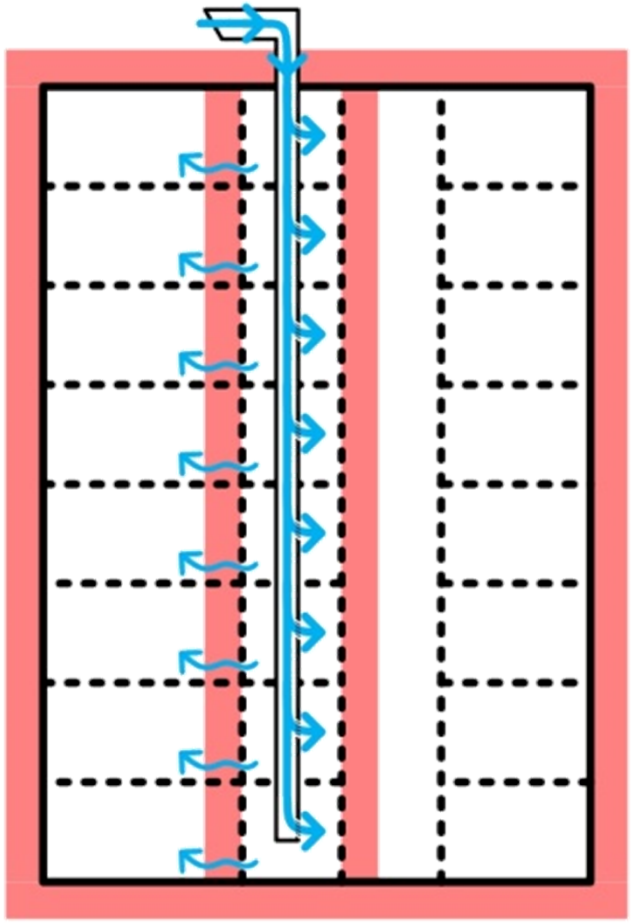
- → Most apartments/condos (multi-family buildings) are ventilated using **pressurized corridor systems**

- → **Decades of anecdotal evidence** indicates that this system likely does not work very well
  - → Still most common system

- → Particularly relevant now, as newer more airtight buildings have **less tolerance for poorly performing ventilation systems**
  - → Less infiltration and exfiltration to supplement ventilation

Pressurized Corridor Ventilation System

- → Design Intent
  - → **Provide ventilation** air to all zones
  - → **Control flow of air contaminates** between zones
- → How
  - → **Provides air to corridors** directly via a vertical shaft which **pressurizes the corridor**
  - → Corridor pressurization forces air **into suites via intentional gaps** under the entrance doors



Case Study Building

- → **13-story** multi-family building in Vancouver, Canada with **37 residential suites**
- → Constructed 1986
- → Enclosure renewal 2012
- → Below grade parking garage located under the building
- → Ventilated using **pressurized corridor ventilation system** by a single make-up air unit

Overall, is **typical** of high-rise multi-family buildings

Measured Ventilation Rates

Perfluorocarbon (PFT) Testing

Two component system:

→ **PFT Sources** (7 distinct types)

→ Capillary absorption tube samplers **(CATS)**

→ Sources release **distinct PFT tracer gasses in different zones** and use **CATS to sample the concentrations**

Sources

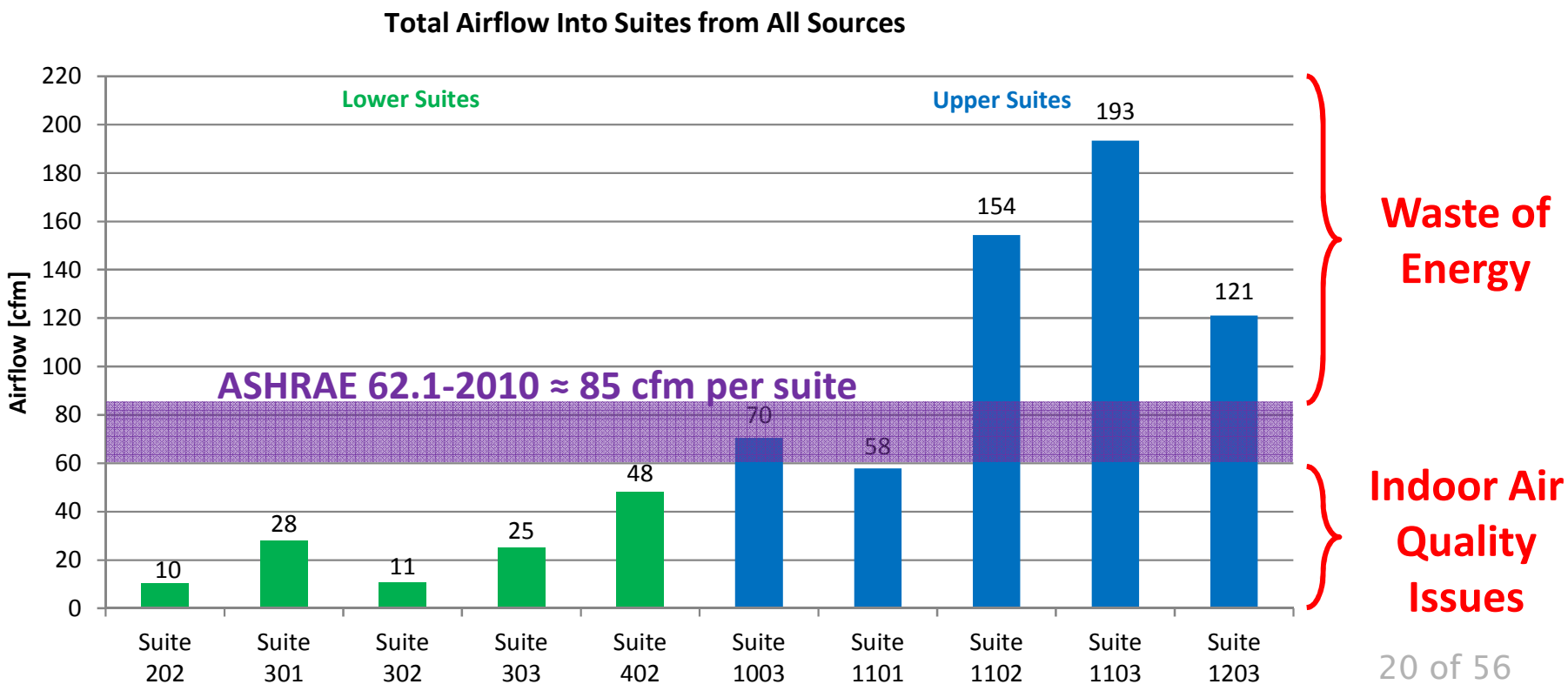
CATS

Measured Ventilation Rates

→ Order of magnitude variation in the ventilation rates

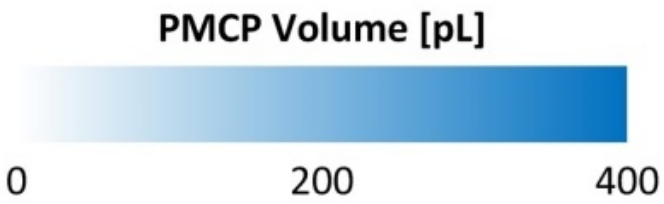
→ Significantly higher rates for upper suites than lower suites

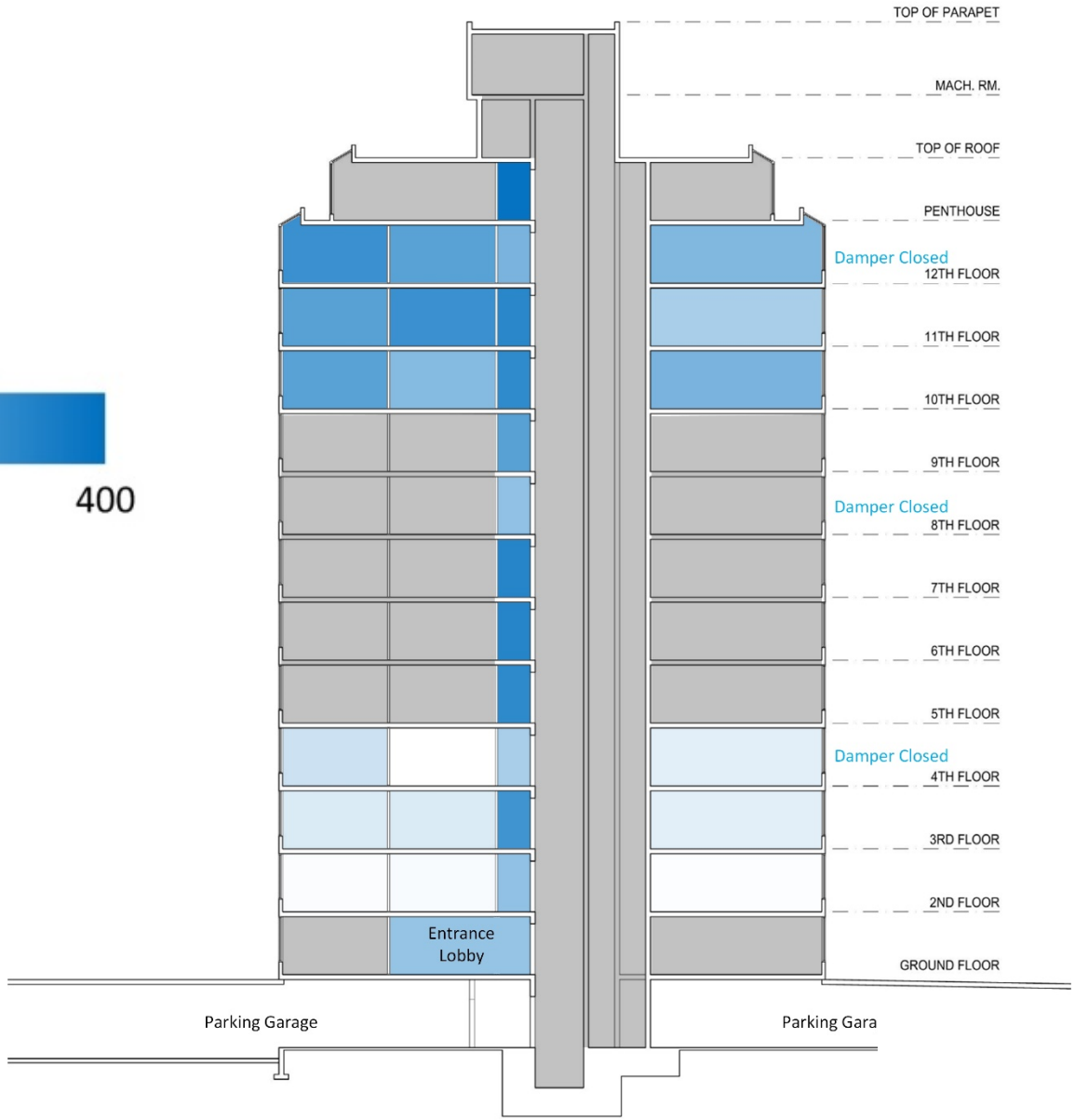
→ Most suites under-ventilated or over-ventilated



Measured Ventilation Rates

PMCP Released in MAU

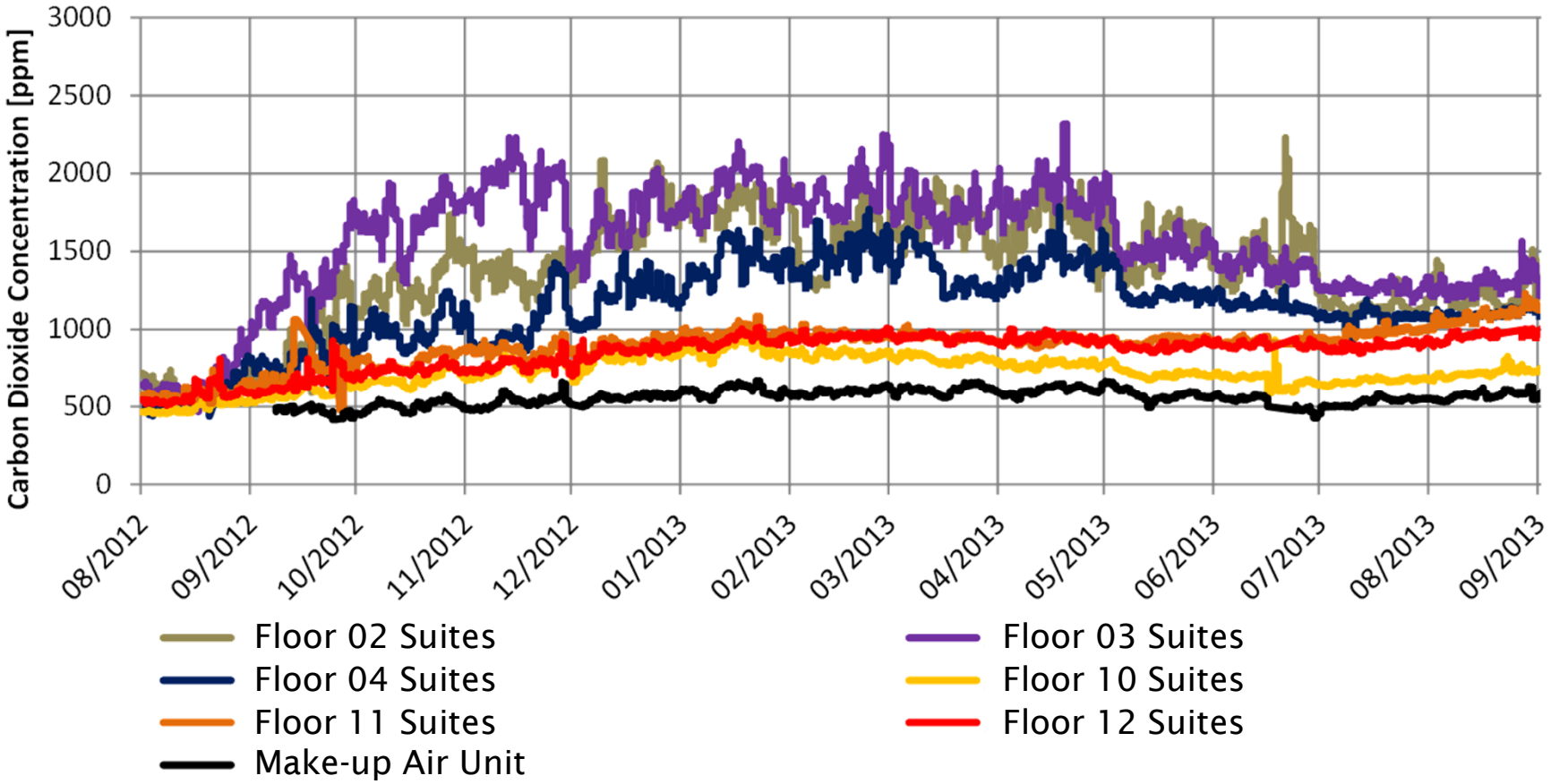




Measured CO_2 Concentrations

→ Carbon dioxide concentrations were monitored as an indicator of indoor air quality (IAQ)

→ Significantly **higher concentrations in the lower suites**



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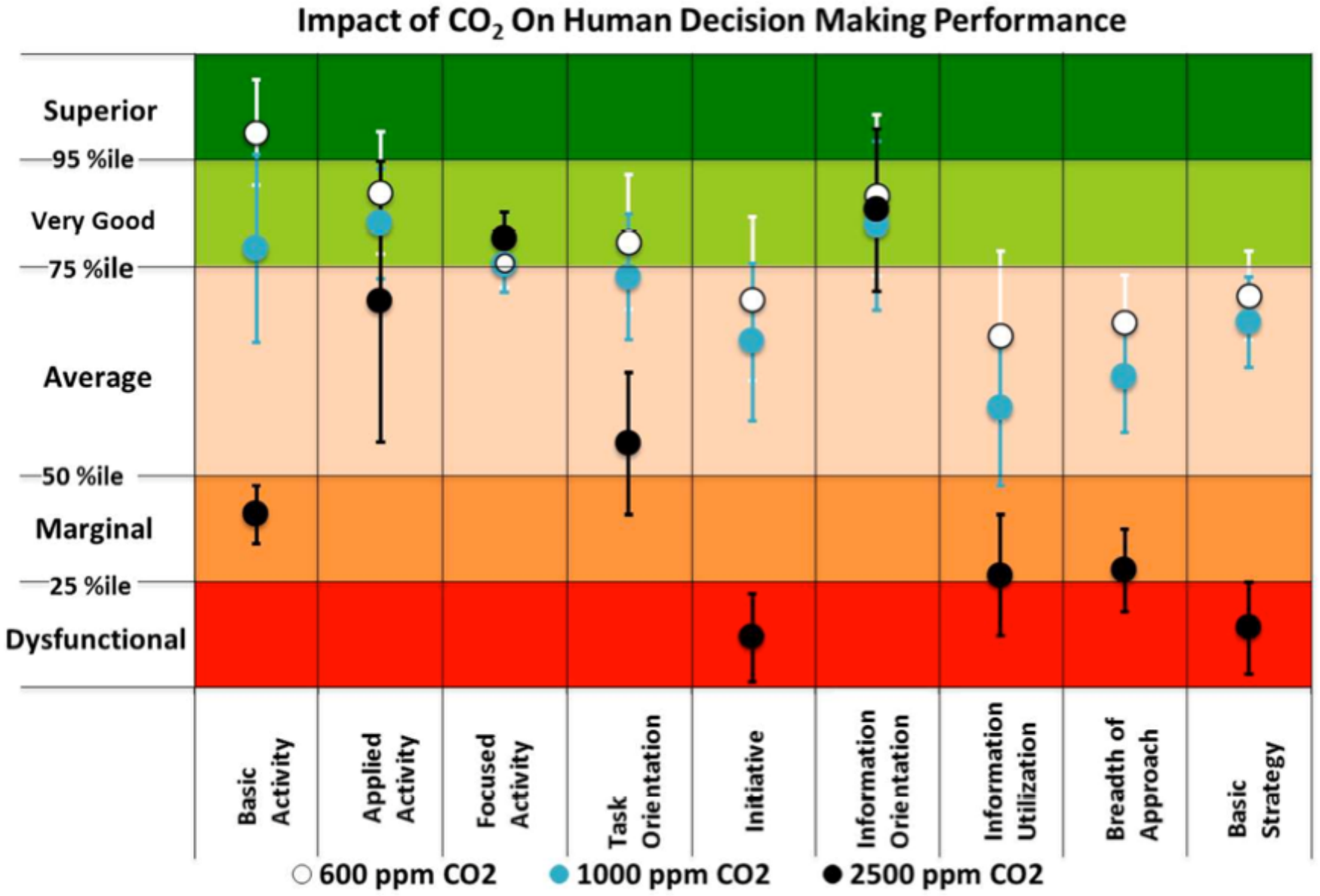
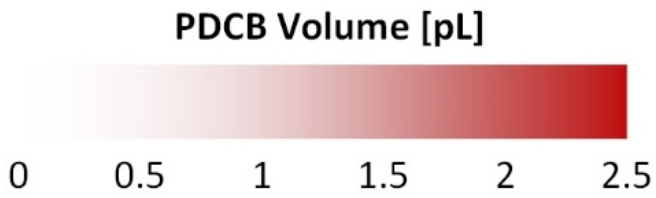


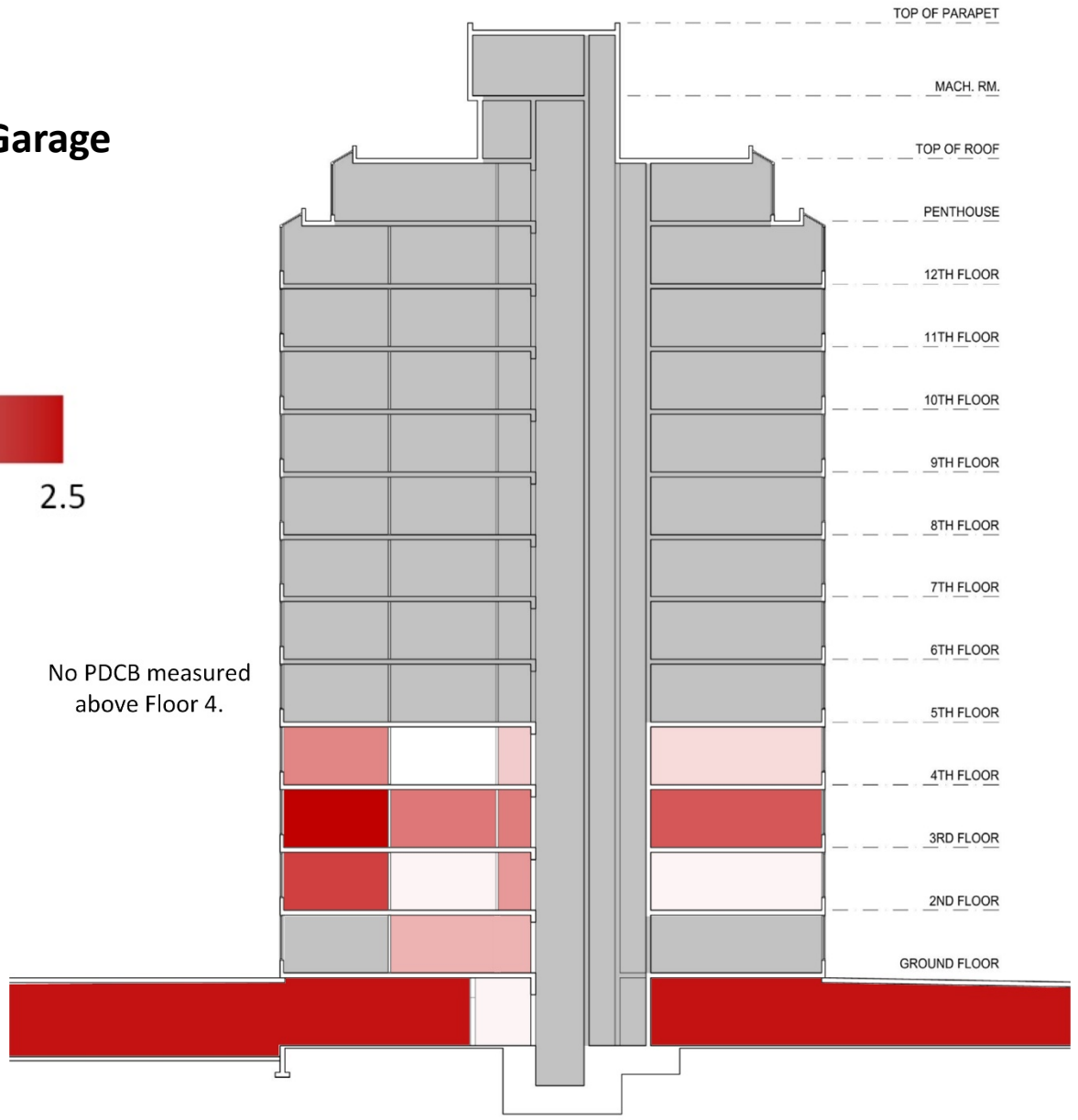
(Fisk et al, 2013)

Infiltration from Parking Garage

PDCB Released in Parking Garage



No PDCB measured above Floor 4.



Measured Ventilation Rates

- Summary:
  - Over ventilation and under ventilation of most suites
  - Higher ventilation rates in upper suites than lower suites
  - Better indoor air quality in upper suites than lower suites

Why is this happening?

Cause of Ventilation Rates - MAU

Maybe the MAU isn't working correctly?

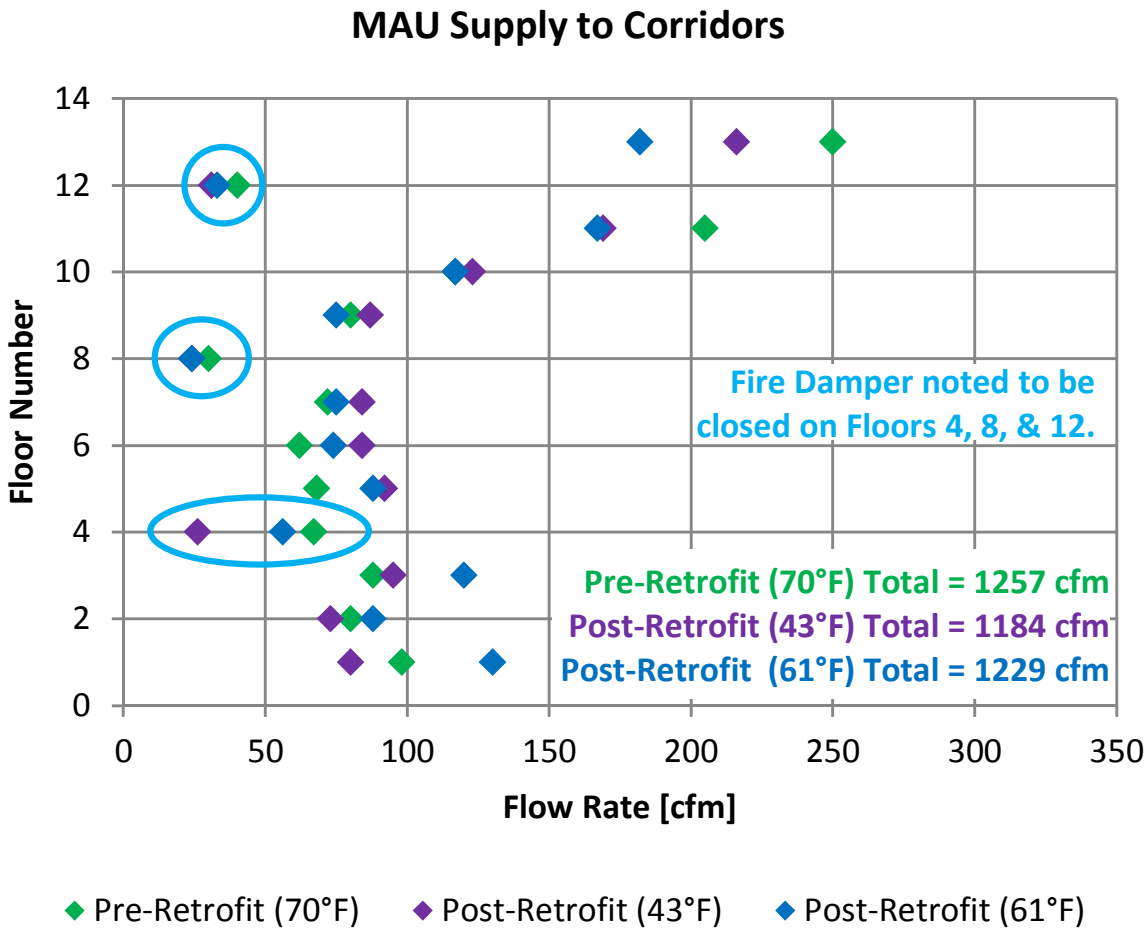
→ Powered flow hood used to measure intake flow rate

→ MAU airflow **approximately the same** as design flow rate (3,300 cfm)

Cause of Ventilation Rates – Duct Leakage

Maybe the ventilation air isn't reaching the corridors?

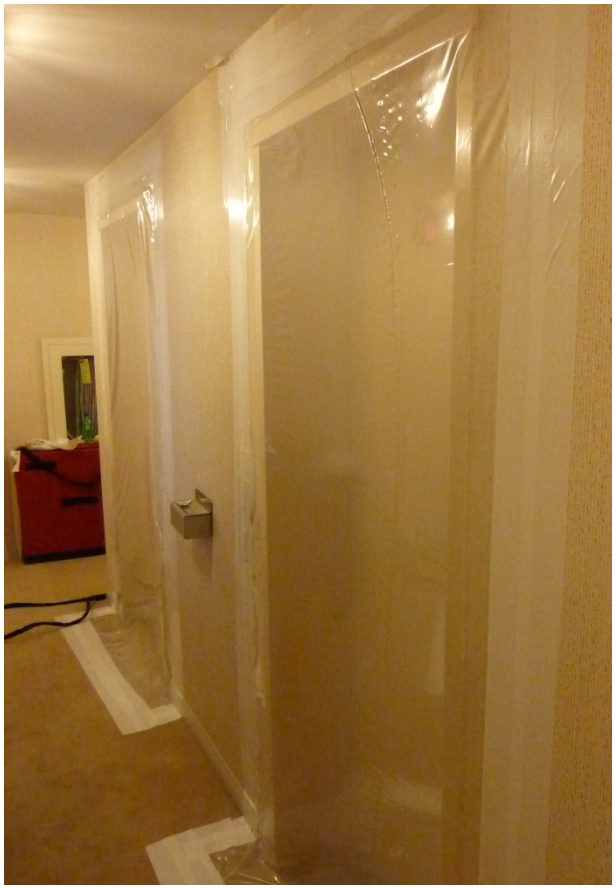
→ Only **40%** of intake flow reaches the corridors directly



Cause of Ventilation Rates – Corridor Leakage

Maybe the air isn't reaching the suites from the corridors?

→ Airtightness tested corridors and found significant flow paths other than to the suites through the suite entrance doors.



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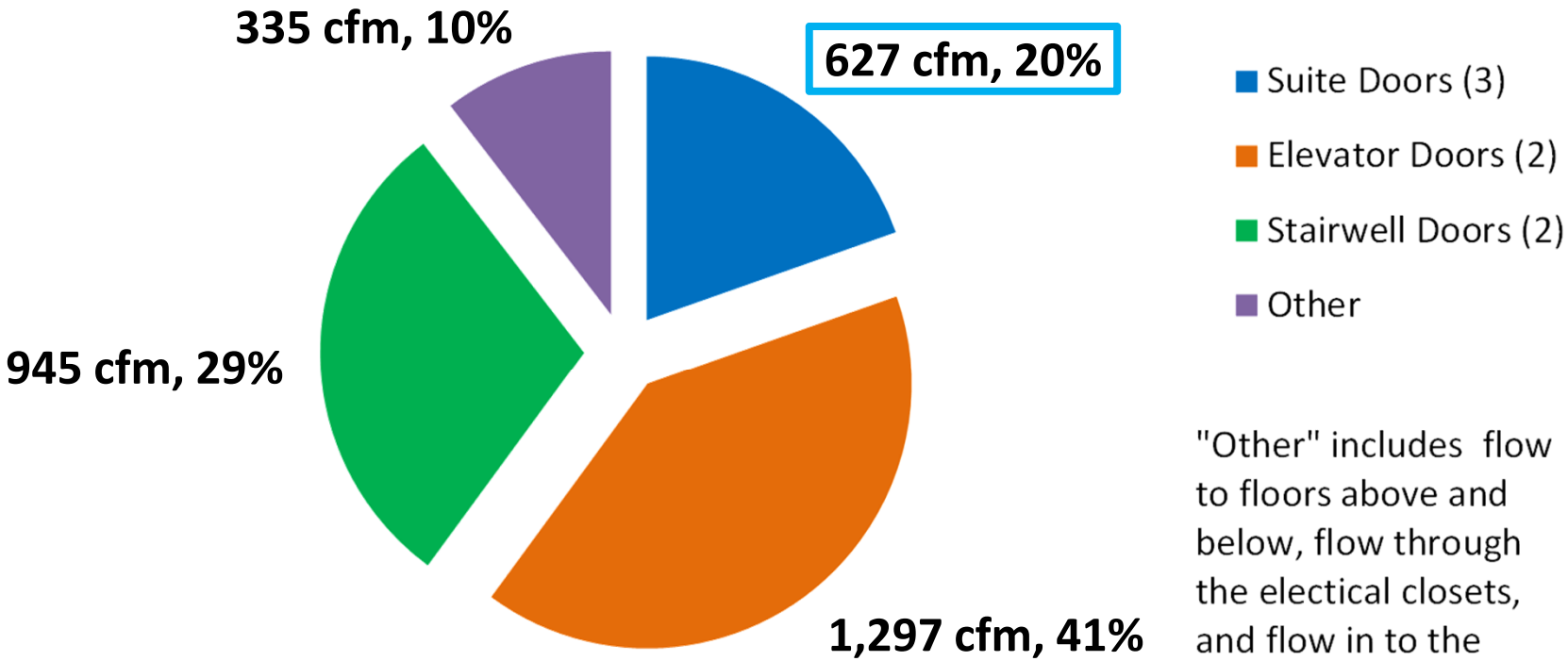


Airflow Rates at 75 Pa

"Other" includes flow to floors above and below, flow through the electical closets, and flow in to the garbage chute.

Cause of Ventilation Rates – Leakage

→ If only 40% of the flow rate reaches the corridors
And, only 20% of that air reaches the suites…

$$\mathbf{40\% \times 20\% = 8\%}$$

→ Theoretically, only **8%** of intended ventilation actually goes where it is supposed to! Waste of ventilation air, and the energy needed to move and condition it.

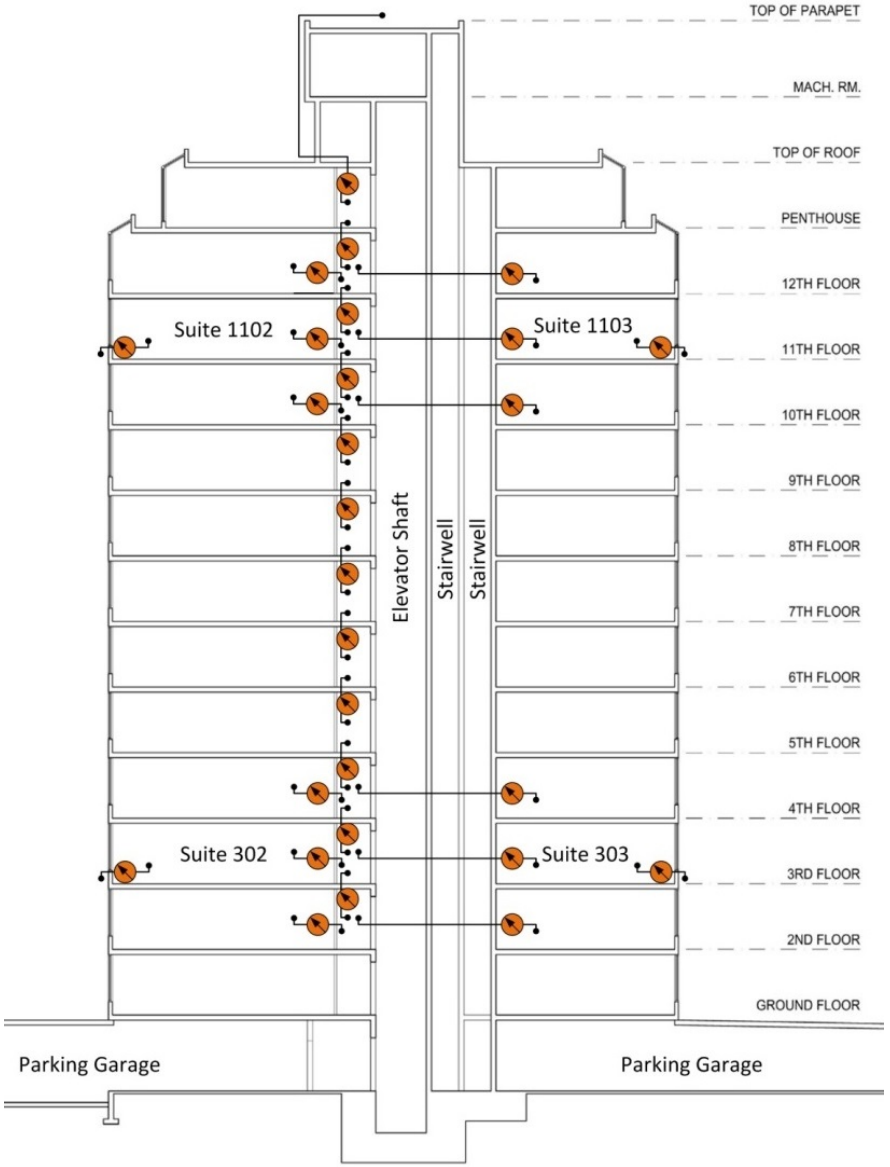
Leakage of air along ventilation flow path is a major issue.

Cause of Ventilation Rates – Pressure Differences

Maybe pressure differences are an important factor?

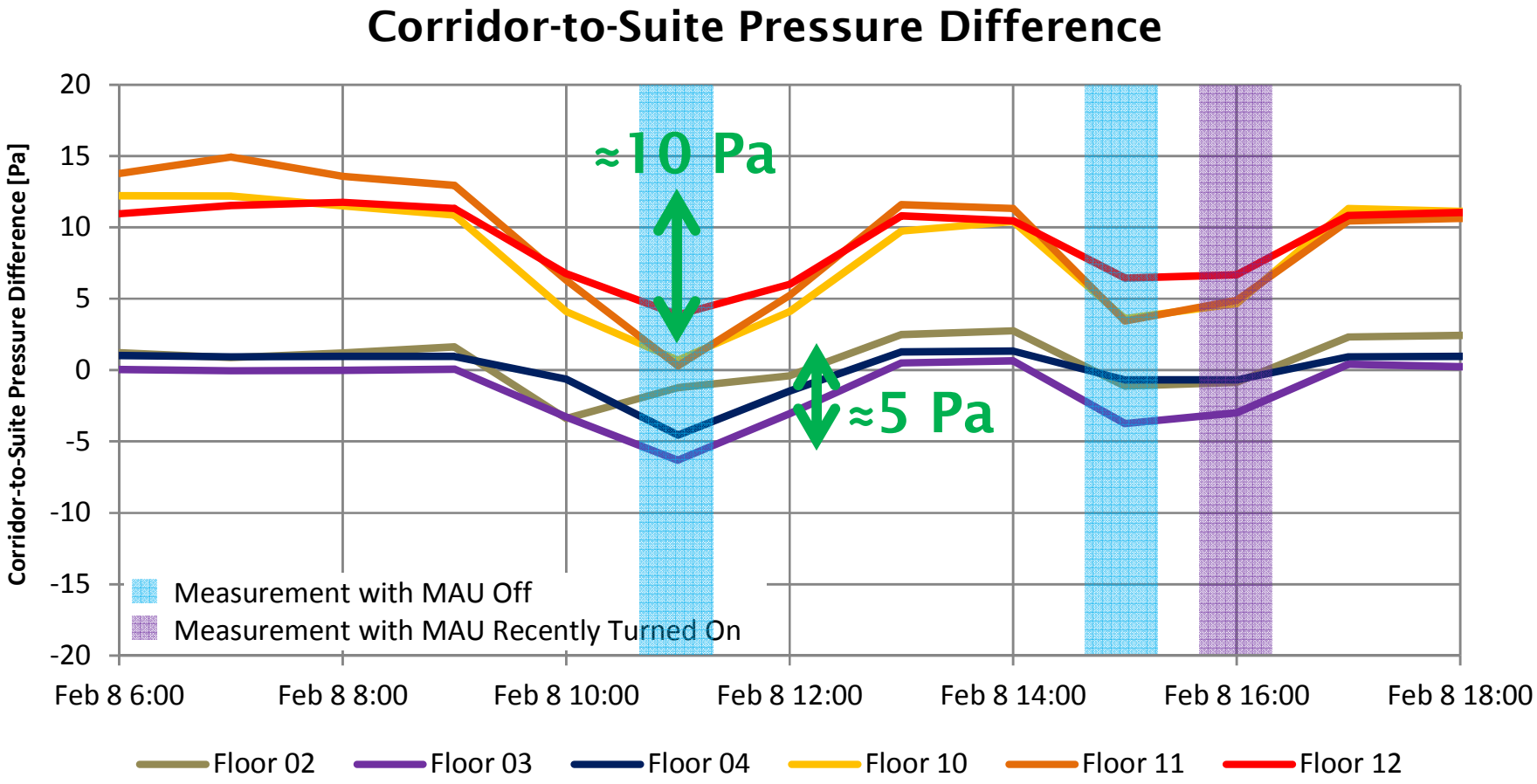
→ Pressure differences were monitored with a focus on an upper floor and a lower floor (Floors 11 & 3)

→ Assessed relationship of stack effect and wind to ventilation system performance



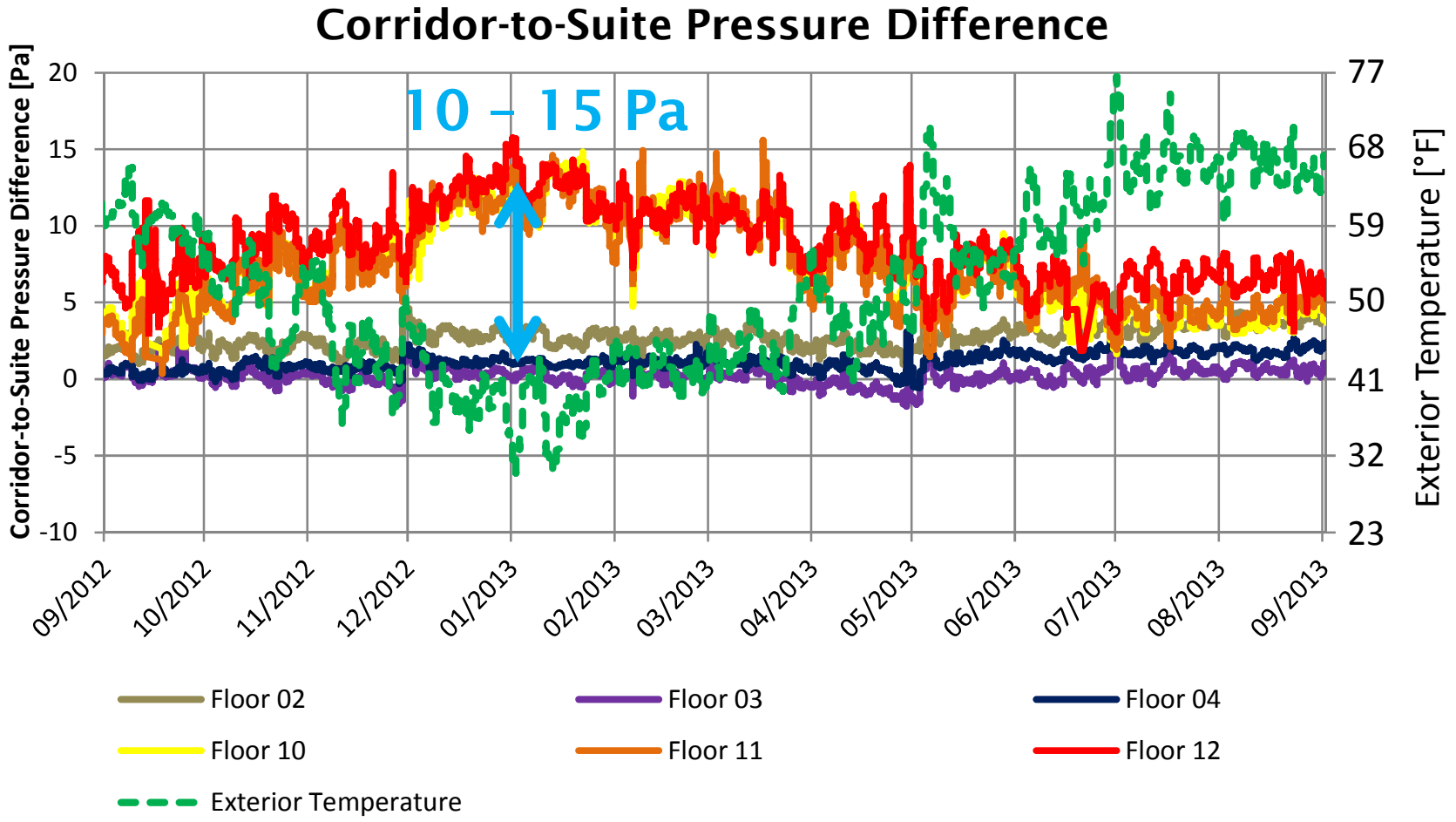
Cause of Ventilation Rates – Pressure Differences

→ Mechanical ventilation system creates pressure of **5 to 10 Pa**



Cause of Ventilation Rates – Pressure Differences

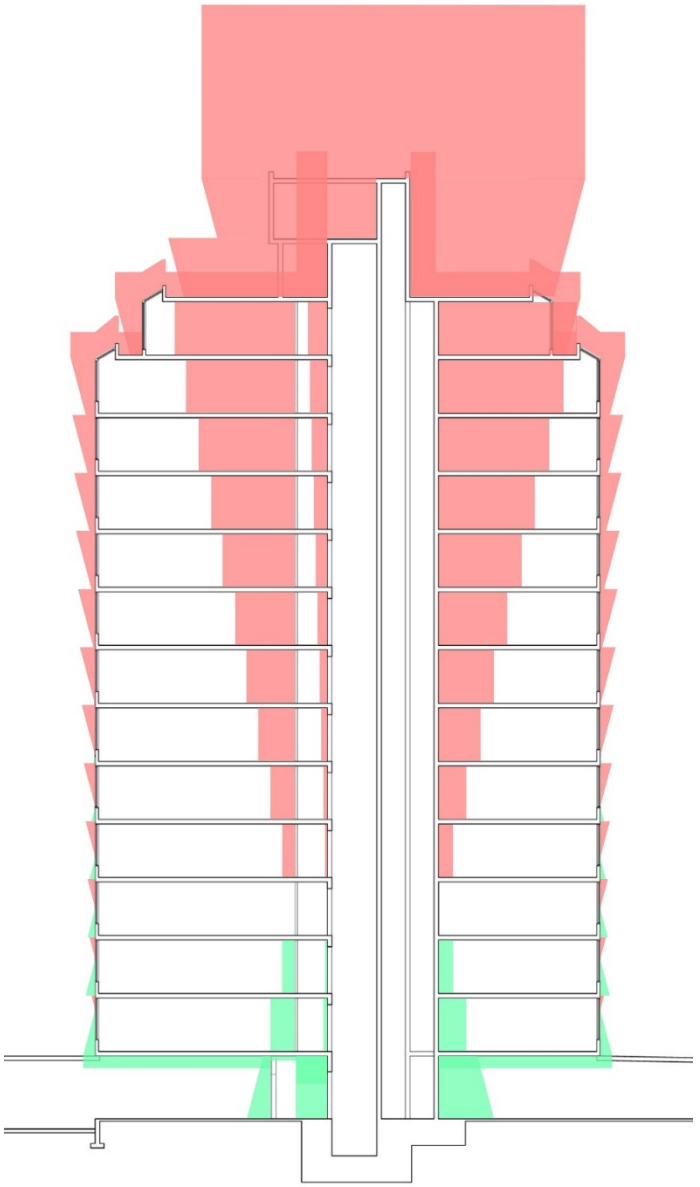
→ Pressures created by stack effect found to be of similar magnitude (10 to 15 Pa) as mechanical pressures



Cause of Ventilation Rates – Pressure Differences

→ Stack effect pressures found to distribute **69% at corridor-to-suite** boundary and only **9% at exterior** enclosure

→ Stack effect pressure **acts primarily in the same location as mechanical pressures** intended to provide ventilation and control contaminate flow



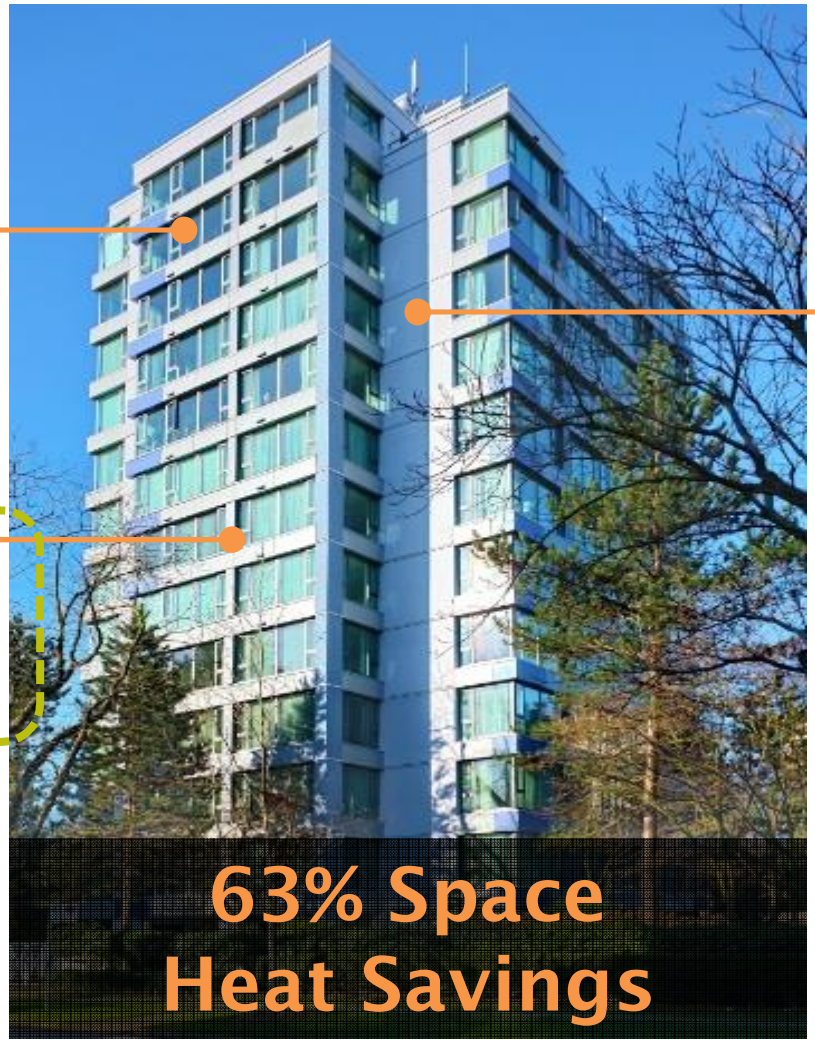
Cause of Ventilation Rates – Enclosure Retrofit

Maybe the enclosure retrofit negatively impacted the ventilation system performance?

Enclosure Retrofit - After

Installed More Insulative Windows
R-1.8 upgrade to R-5

Improved Air-Sealing
Reduced air leakage by 53%

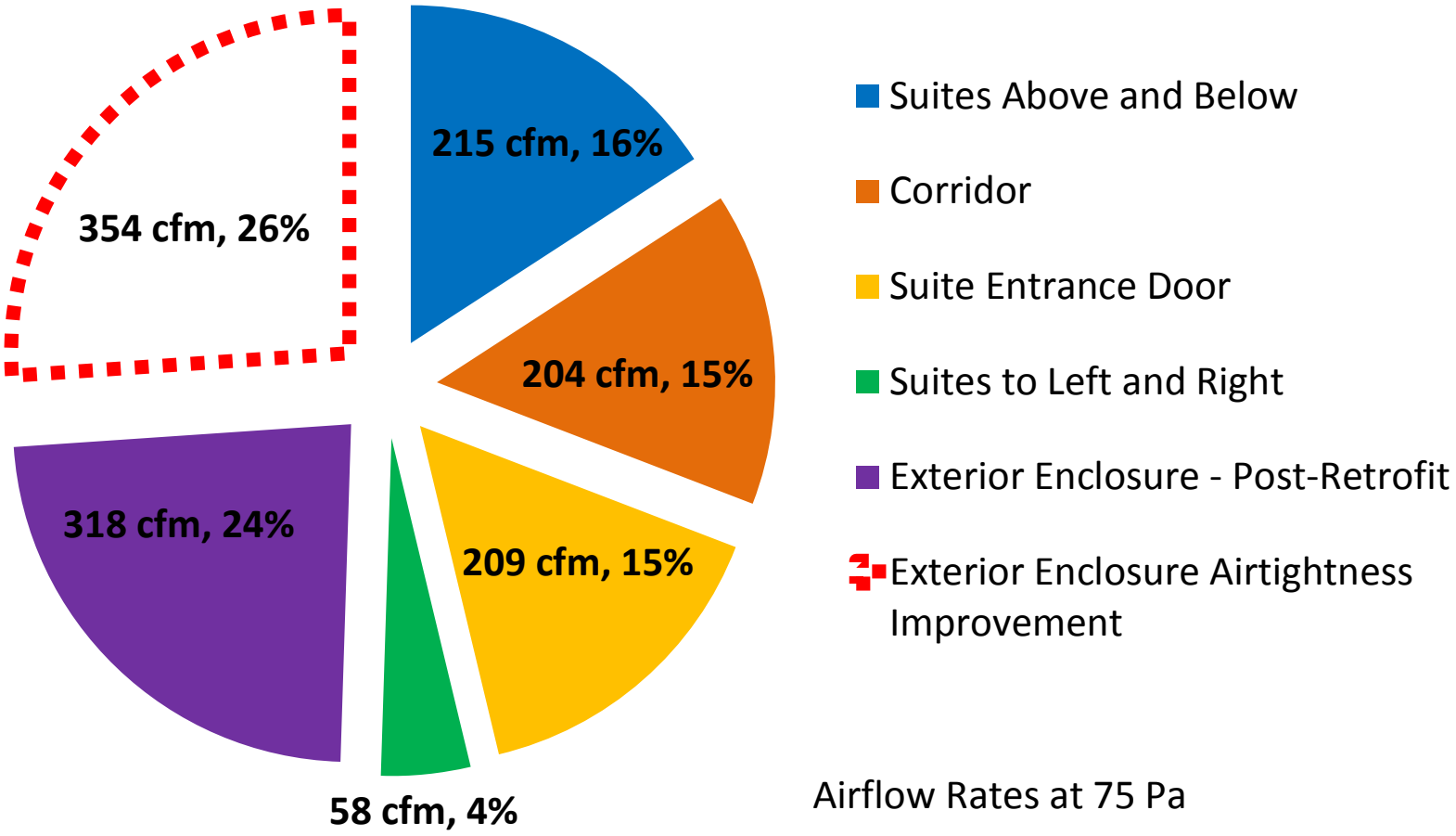


Added Insulation to Exterior Walls
R-4 upgraded to R-16

Improvements:
- → Quieter
- → More comfortable
- → Reduced electricity and gas consumption

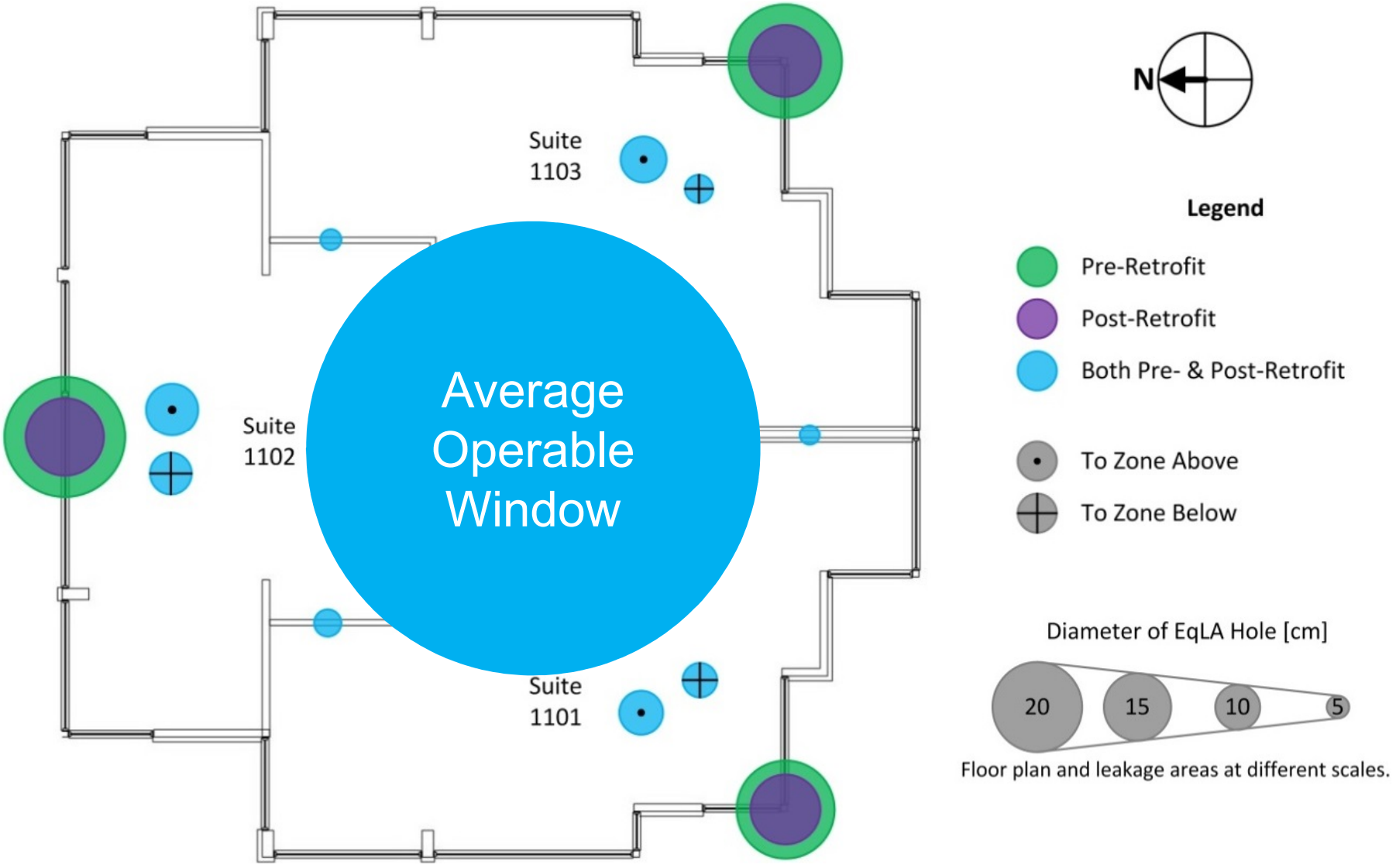
Cause of Ventilation Rates – Enclosure Retrofit

→ Overall measured average enclosure airtightness improvement of approximately 53%



Airflow Rates at 75 Pa

Cause of Ventilation Rates – Enclosure Retrofit



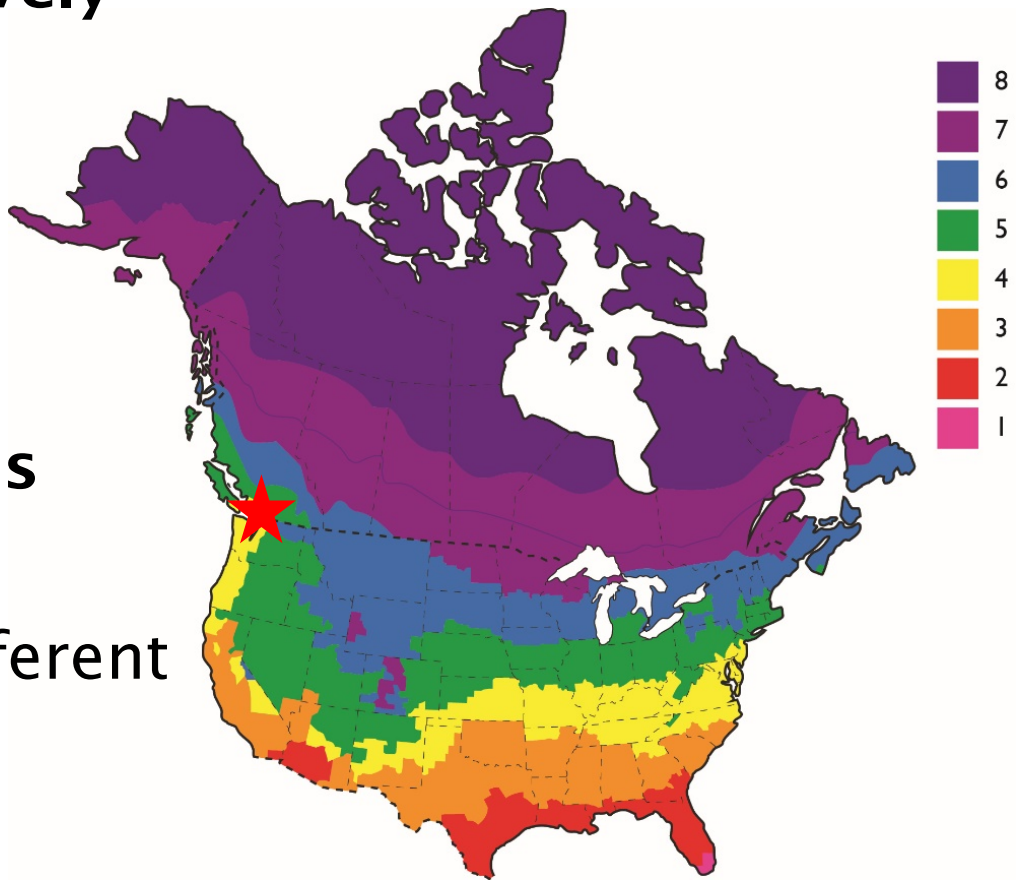
Extension of Study Findings

→ **Vancouver is a relatively moderate climate**

→ Should consider other climates

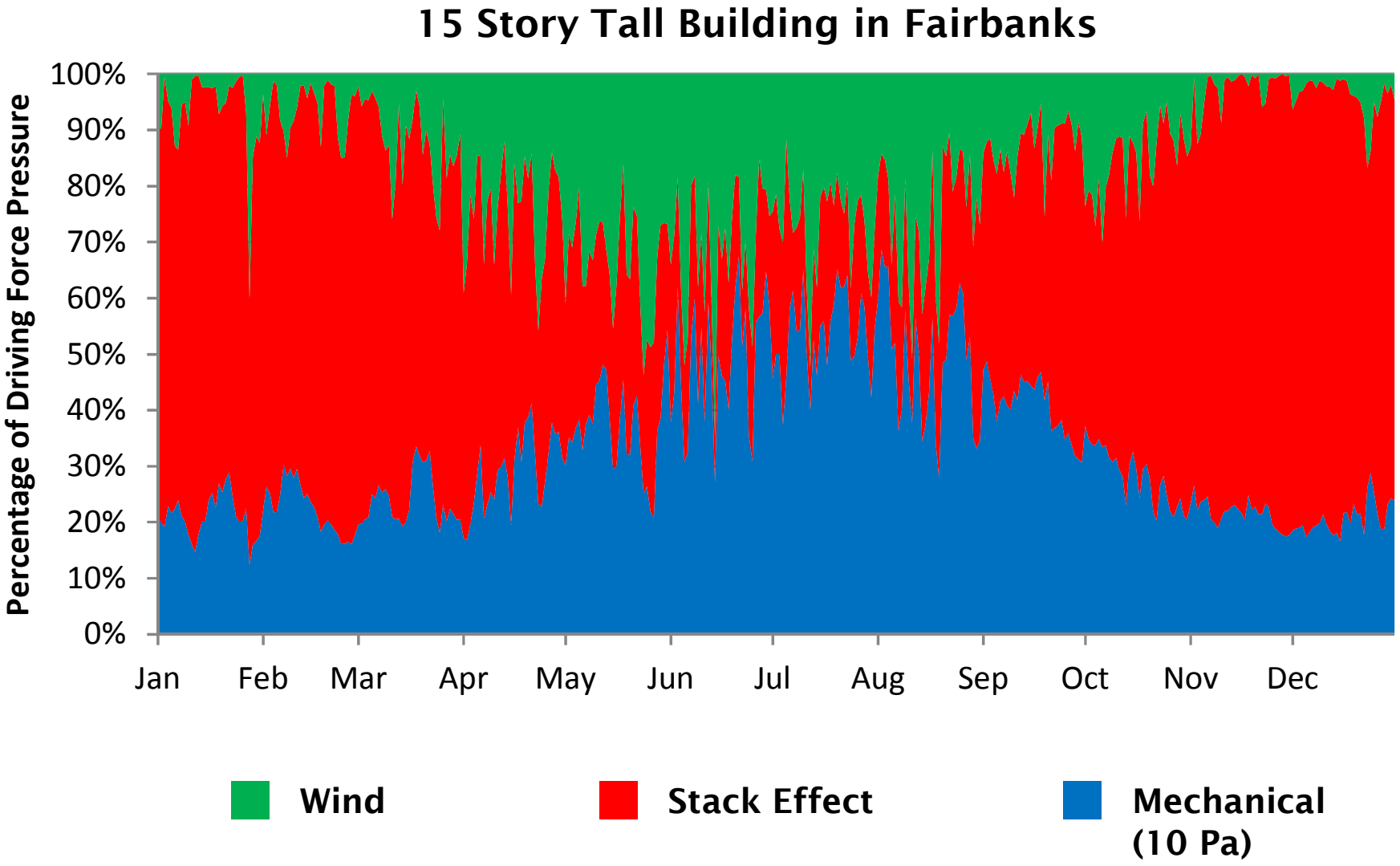
→ **Case study building is 13 stories**

→ Should consider different building heights



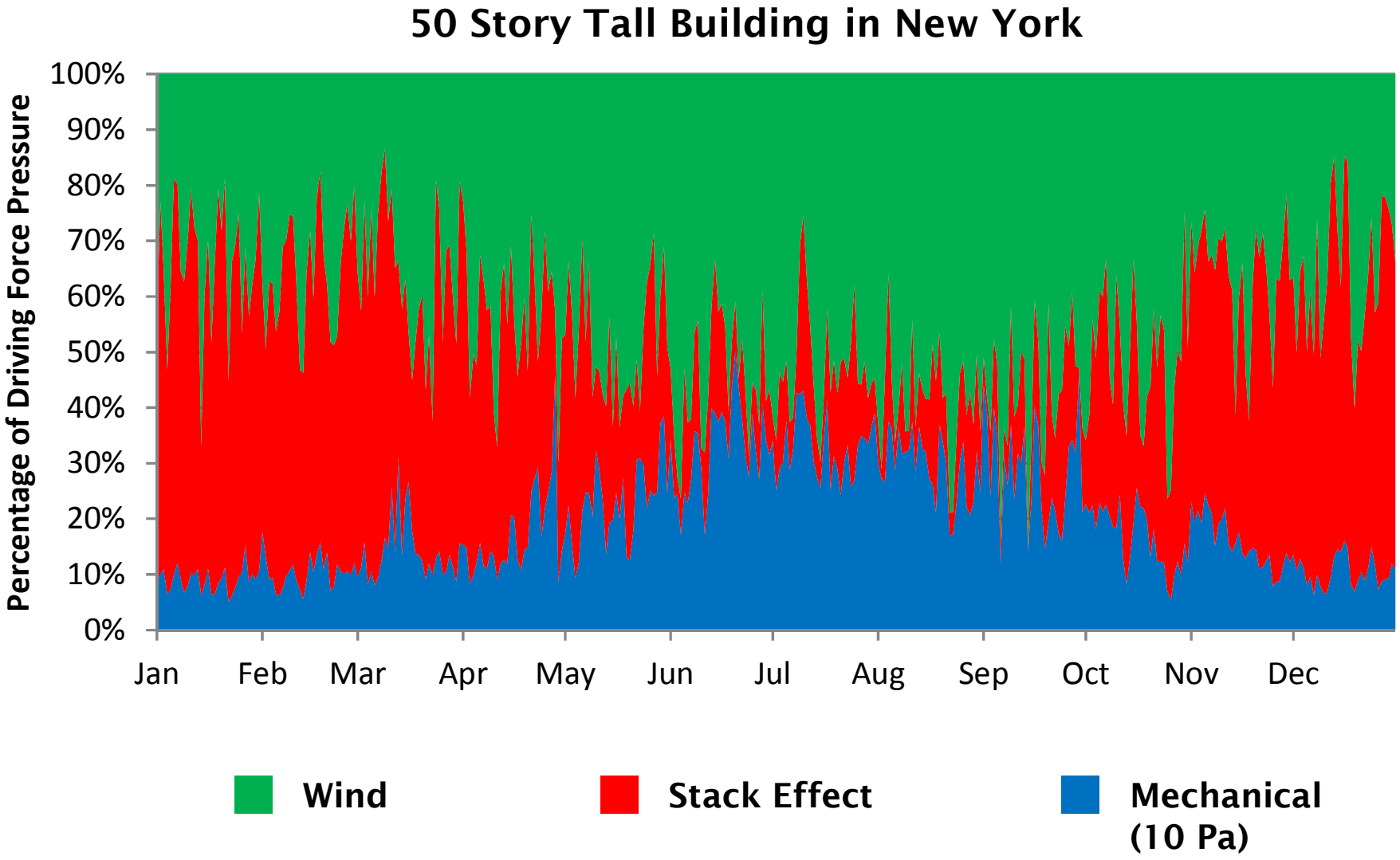
Extension of Study Findings

→ Climate



Extension of Study Findings

→ Building Height

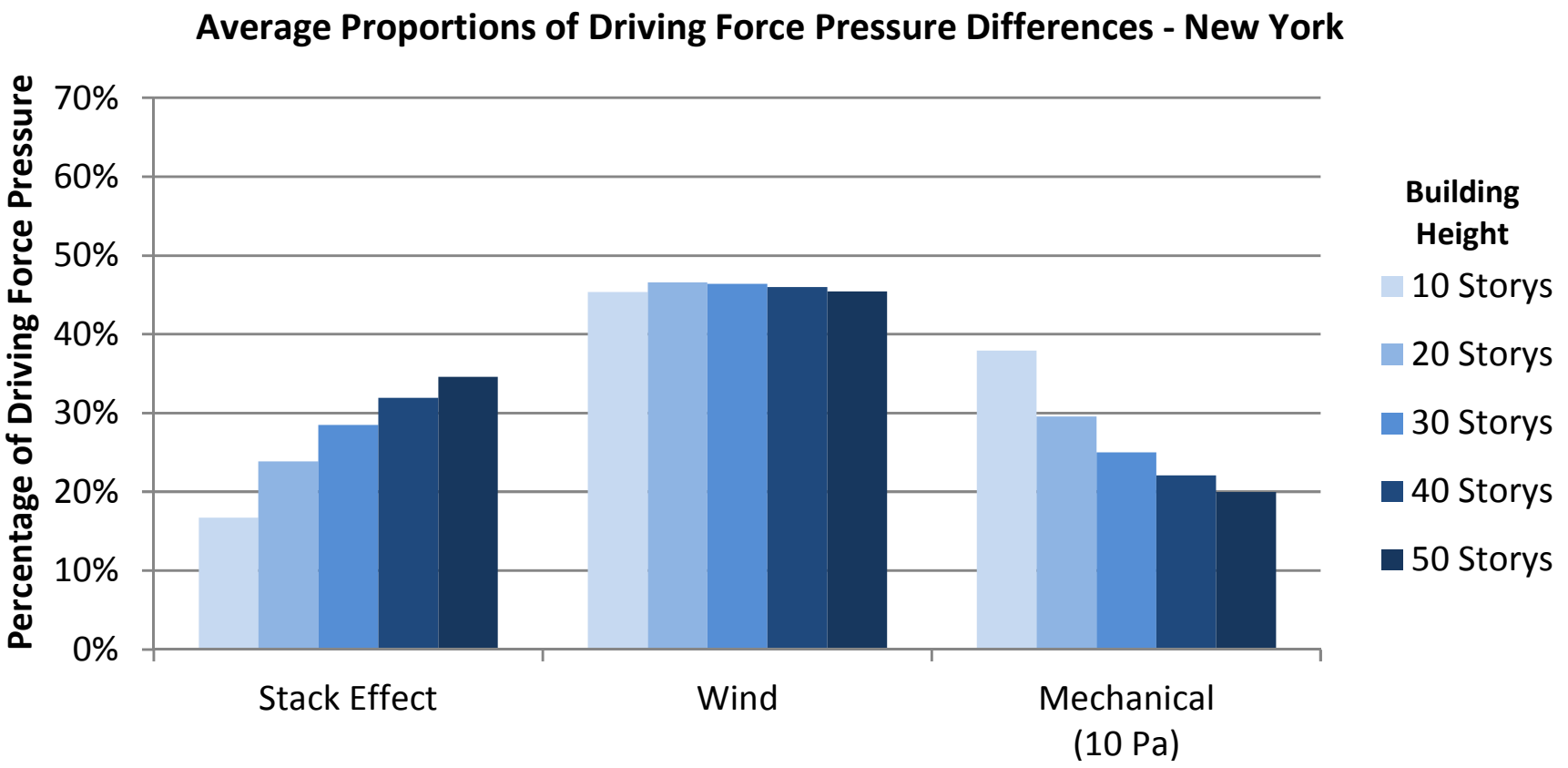


Extension of Study Findings

→ Stack effect is more significant in taller buildings

→ Proportion of wind pressures remains relatively the same

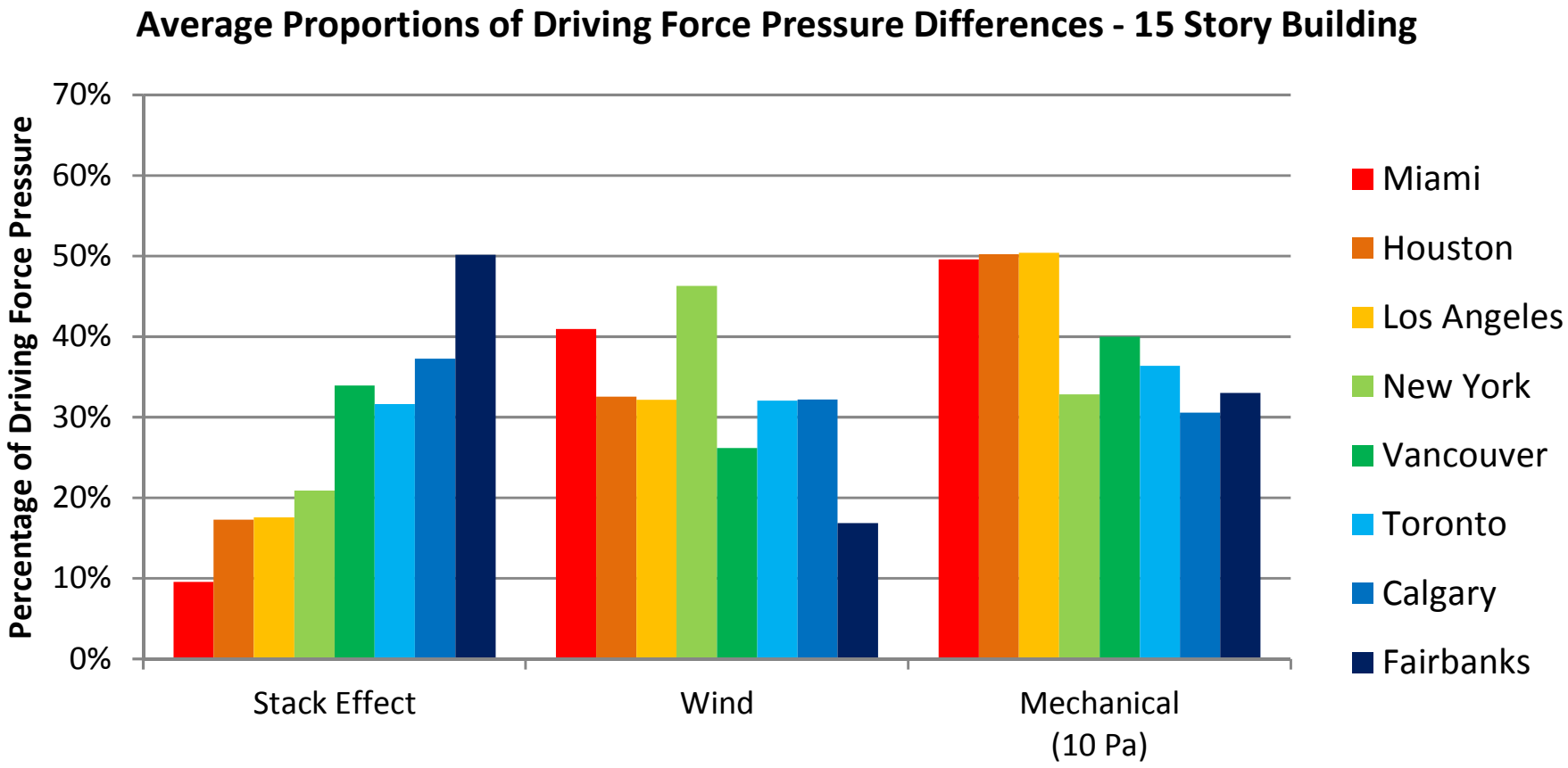
→ Relative magnitude of mechanical pressures decreases as height increases



Extension of Study Findings

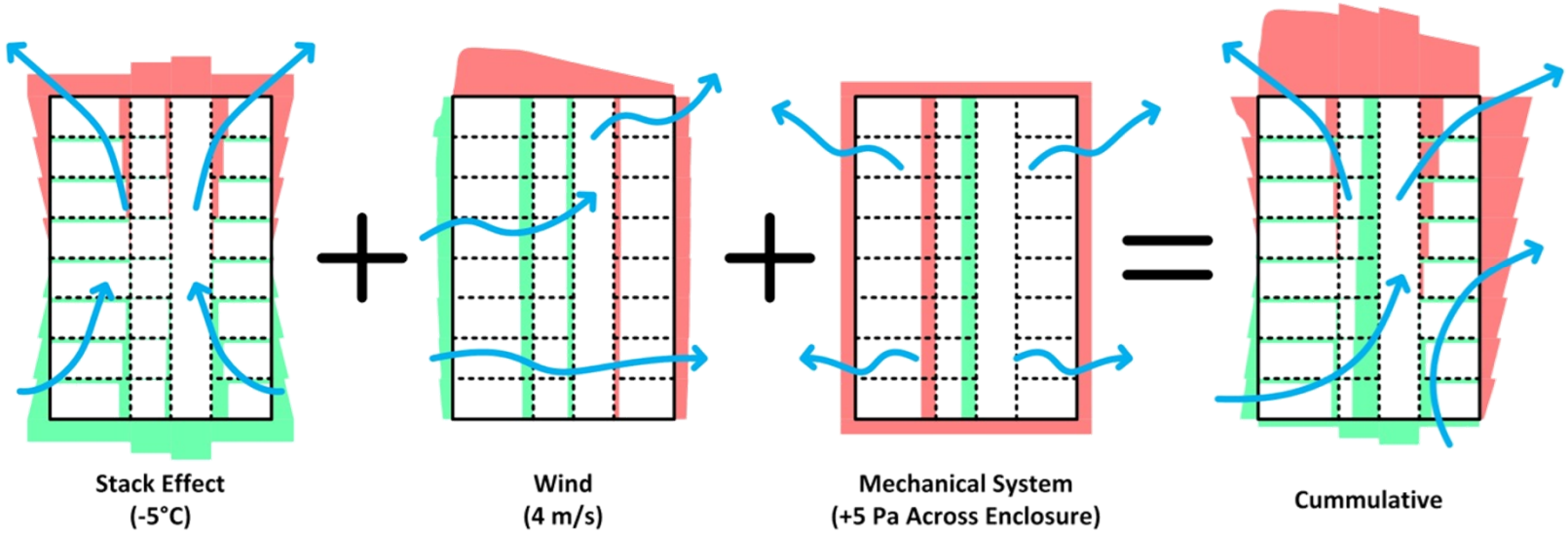
→ Stack effect more significant in cold climates

→ Wind highly variable, but typically more significant in warm climates



Comparison of Driving Forces

- Since all of the pressure differences created by the driving forces (stack effect, wind, & mechanical systems) are of similar magnitude, it is possible that **any one could dominate**
- This is exaggerated for buildings located in more extreme climates than Vancouver



Ventilation system can not practically overwhelm nature.

What it Means

- Corridor pressurization **does not provide intended ventilation rates** to a large number of suites
  - Some significantly over ventilated while others significantly under ventilated
- Significant **leakage along the ventilation air flow path** from the duct and the corridor (wasted ventilation)
  - Uncontrolled airflow wastes energy and provides poor ventilation
- Stack effect and wind pressures are often similar or greater than mechanically-induced pressures
  - **Ventilation system can not practically overwhelm nature**

What it Means

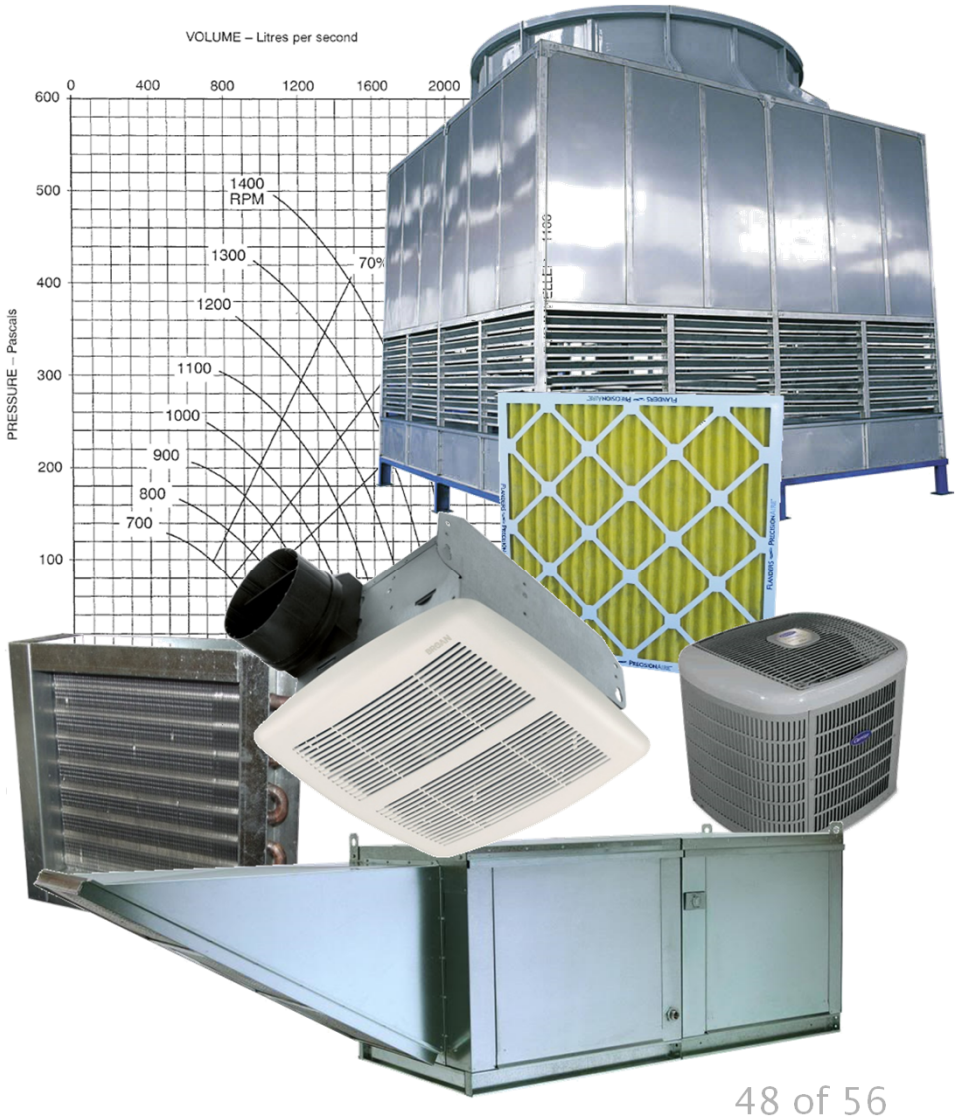
→ Ventilation air should be **directly supplied** to suites to limit the potential of loss along the flow path and of the system being overwhelmed by stack effect and wind

→ The **exterior enclosure should be airtight**, and suites and vertical shafts should be **compartmentalized** (airtight) to limit the impact of wind and stack effect on ventilation

A Bit of Context

A Bit of Context - Efficiency

How can we talk about equipment efficiency when system efficiency is **8%**?



A Bit of Context – Current Codes/Standards

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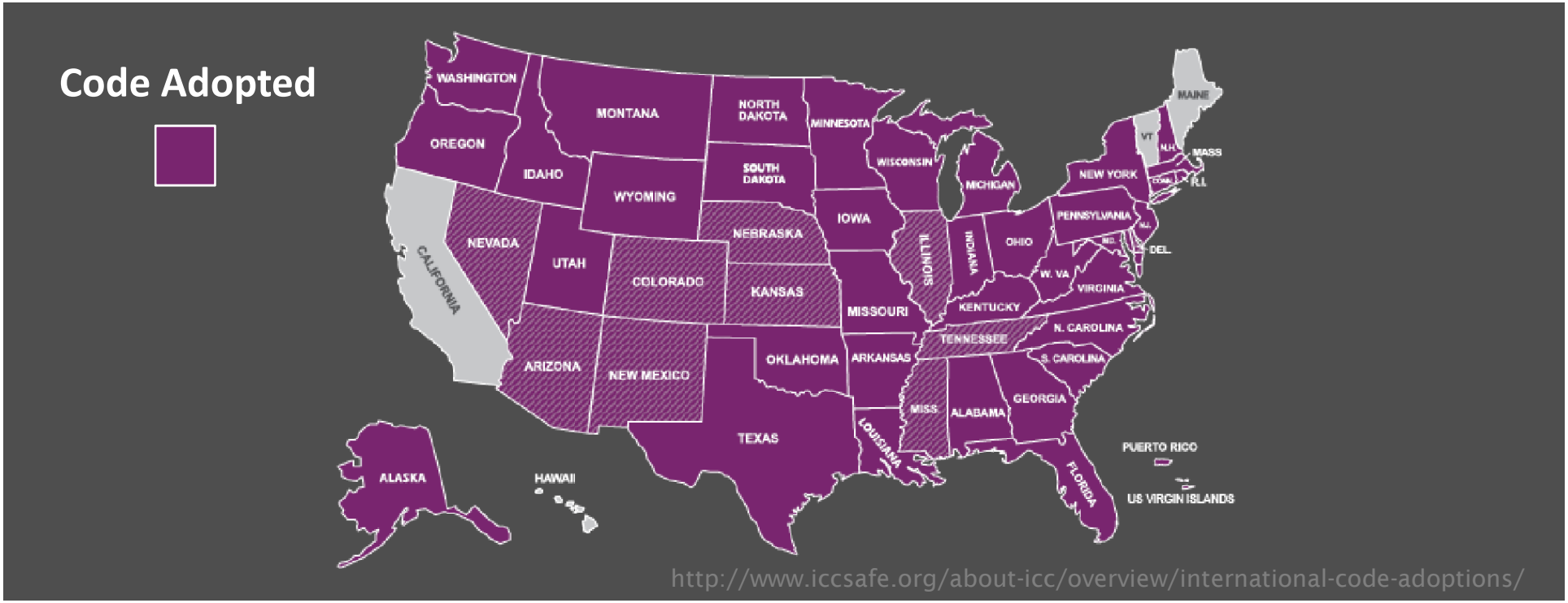
→ International Mechanical Code 2012

→ *601.2 Air movement in egress elements.*
*Corridors **shall not serve as** supply, return, exhaust, relief or ventilation air **ducts**.*

→ Something similar in code since at least **1996**



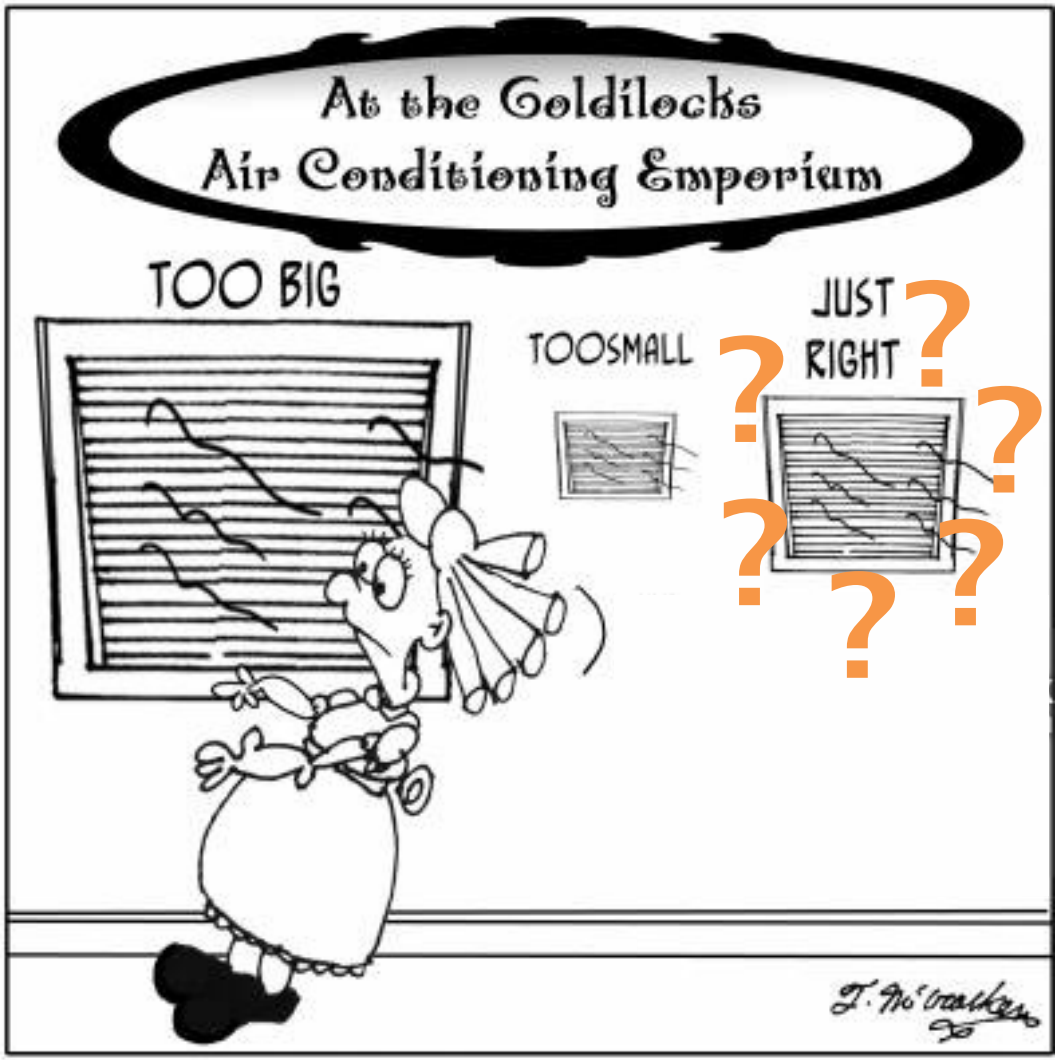
A Bit of Context – Current Codes/Standards

→ CaGBC LEED Credit EQp1 Interpretation (#1126)

- → *Supply of ventilation air from corridor is unlikely to meet the referenced ASHRAE 62.1 requirements for distribution*
- → *Likely to conflict with ETS and fire separation*

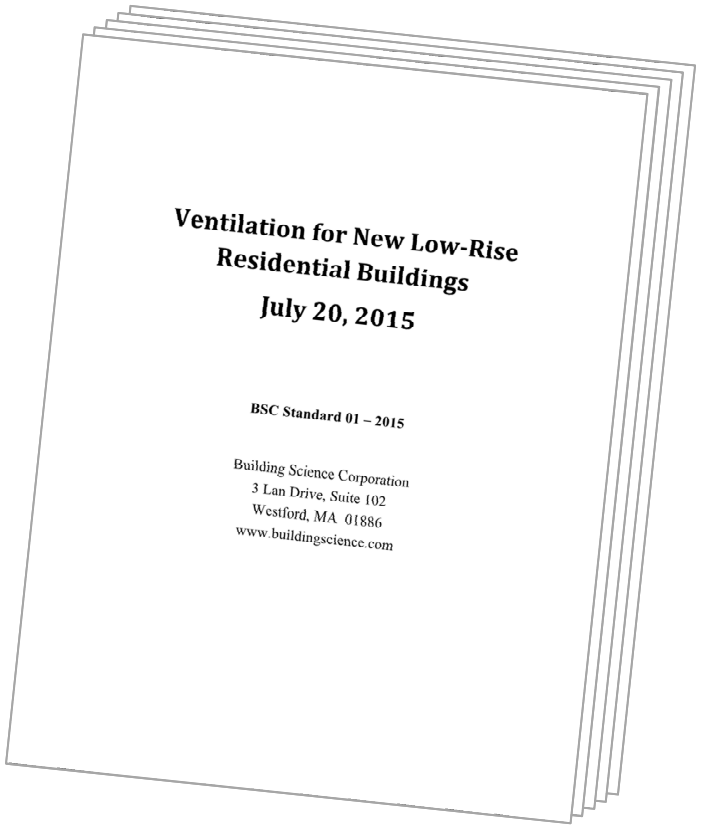
A Bit of Context – How much air?

How do we set a ventilation rate if we don't know what we are going to get?



A Bit of Context - Are All Systems Equal?

→ *BSC Standard 01* takes a first crack at adjusting ventilation rate based on system effectiveness

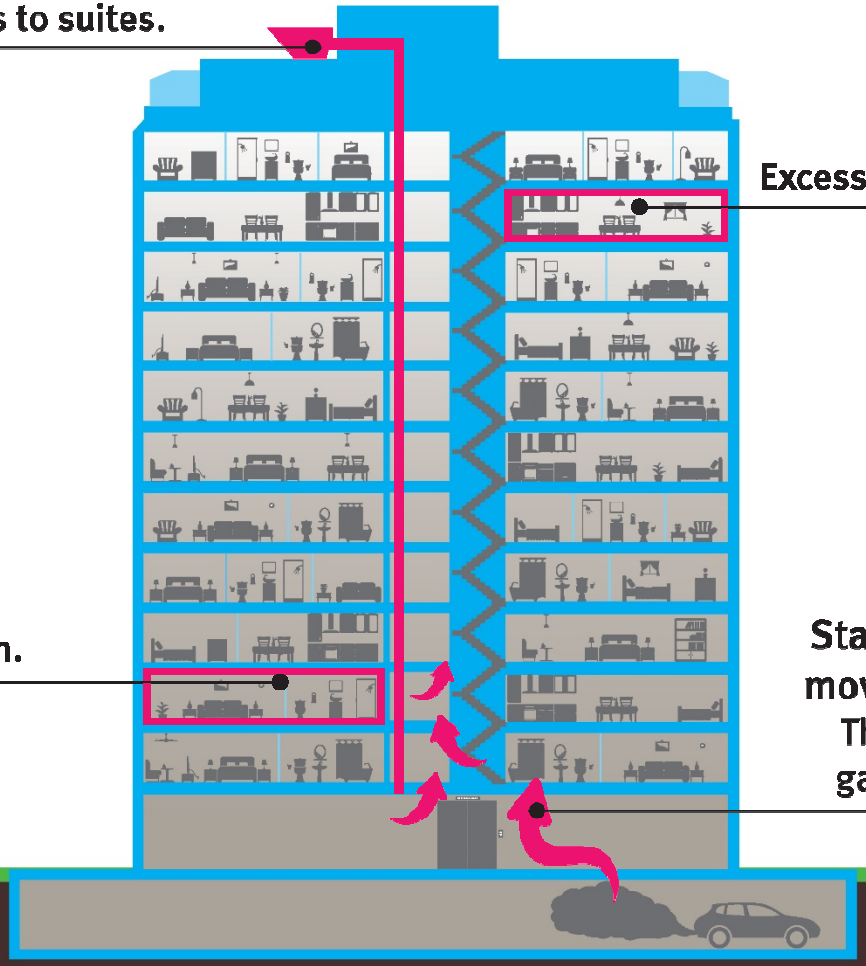


System Type	Distributed	Not Distributed
Balanced or Mixed	0.75	1.0
Not Balance or Mixed	1.0	1.25

One more thing…

Current Situation…

Ventilation system very inefficient.
Only 8% of ventilation air gets to suites.



Upper suites significantly over ventilated.
Excessive ventilation wastes energy.

Lower suites significantly under ventilated.
CO_2 concentration › 1000 ppm.

Stack effect causes upward air movement within the building.
This causes fumes from parking garage to infiltrate the building.

Ventilation Issues Remain

The Plan

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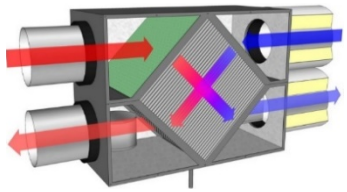
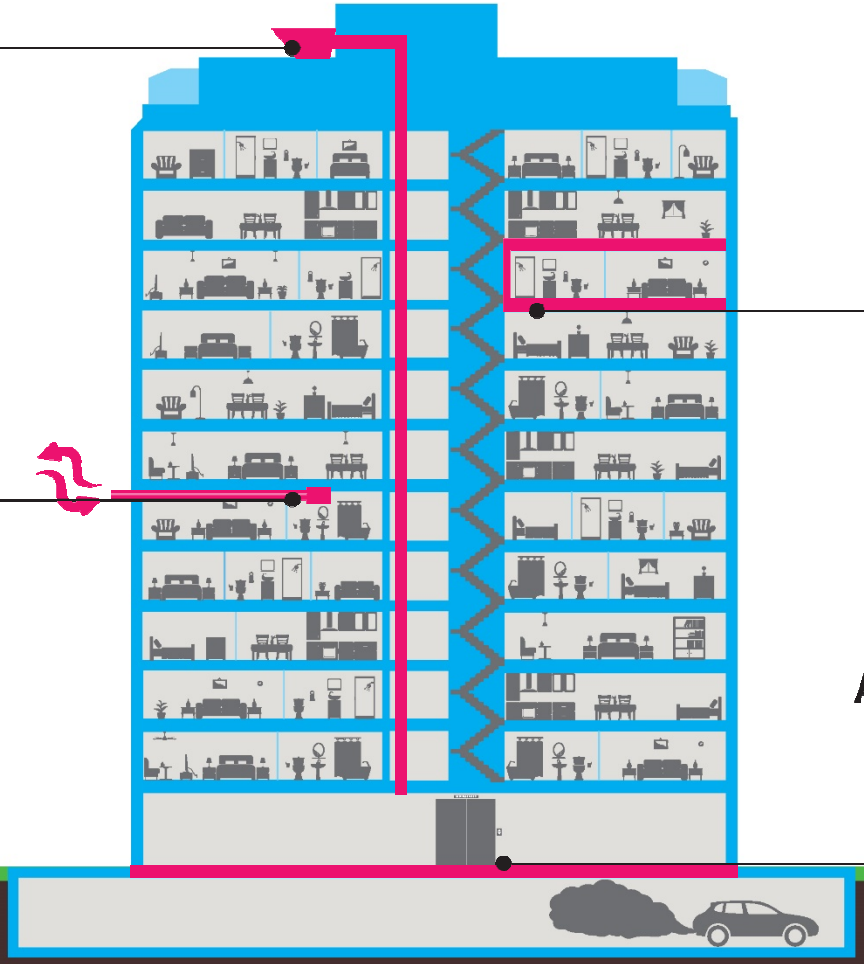
Central Ventilation Size Reduced
Only ventilates corridors.

Heat Recovery Ventilators Installed in Each Suite
Direct ventilation and heat recovery.



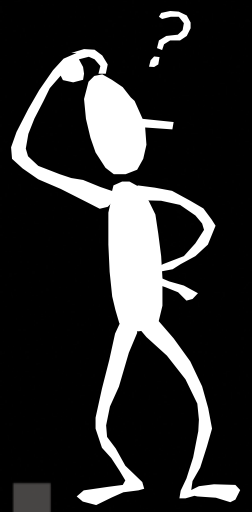


Air Sealing Between Suites
Reduced internal transfer of contaminates and energy.

Air Sealing Between Parking Garage and Inside
Reduced infiltration of harmful contaminates.

Additional Energy Savings & Improved Air Quality

Questions?



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