

# Envelope Improvements in Multifamily Retrofits: Strategies and Examples

Presented By:

Joseph Andracchio

Chet Knaup



## Montgomery County Energy Summit



Since 1972, Steven Winter Associates, Inc. has been providing research, consulting, and advisory services to improve the built environment for private and public sector clients.

Our services include:

- Energy Conservation and Management
- Decarbonization
- Sustainability Consulting
- Green Building Certification
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and  
operation

# Why Buildings?

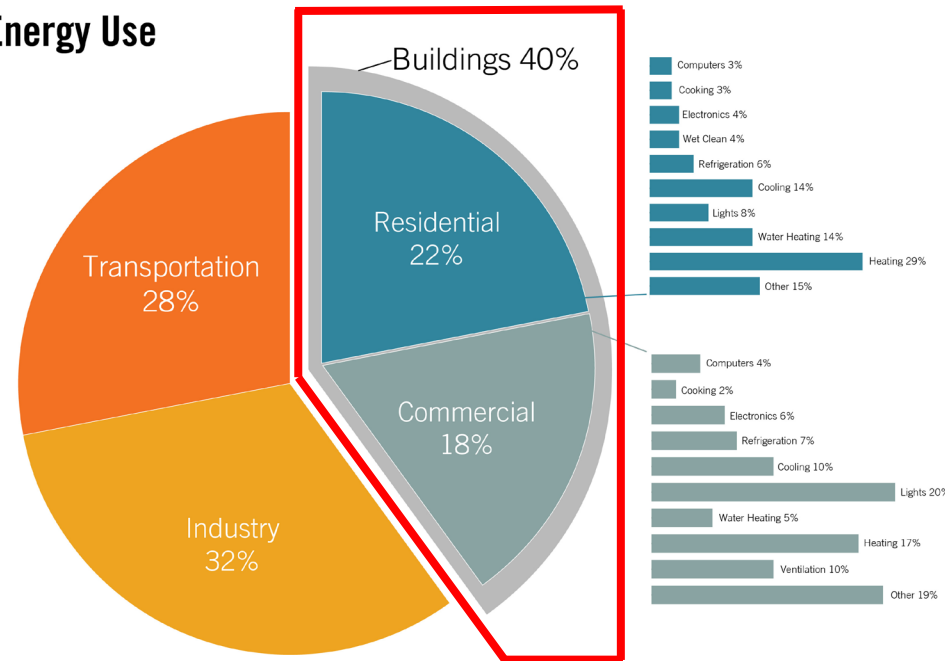
- Buildings are a big part of energy use
- Embodied (retrofit!)
- Operational
- Carbon of both



HISTORICAL

## Buildings & Construction Account For 40% Of Energy-Related CO2 Emissions In Cities

U.S. Energy Use



**40%** Energy-related CO2 emissions

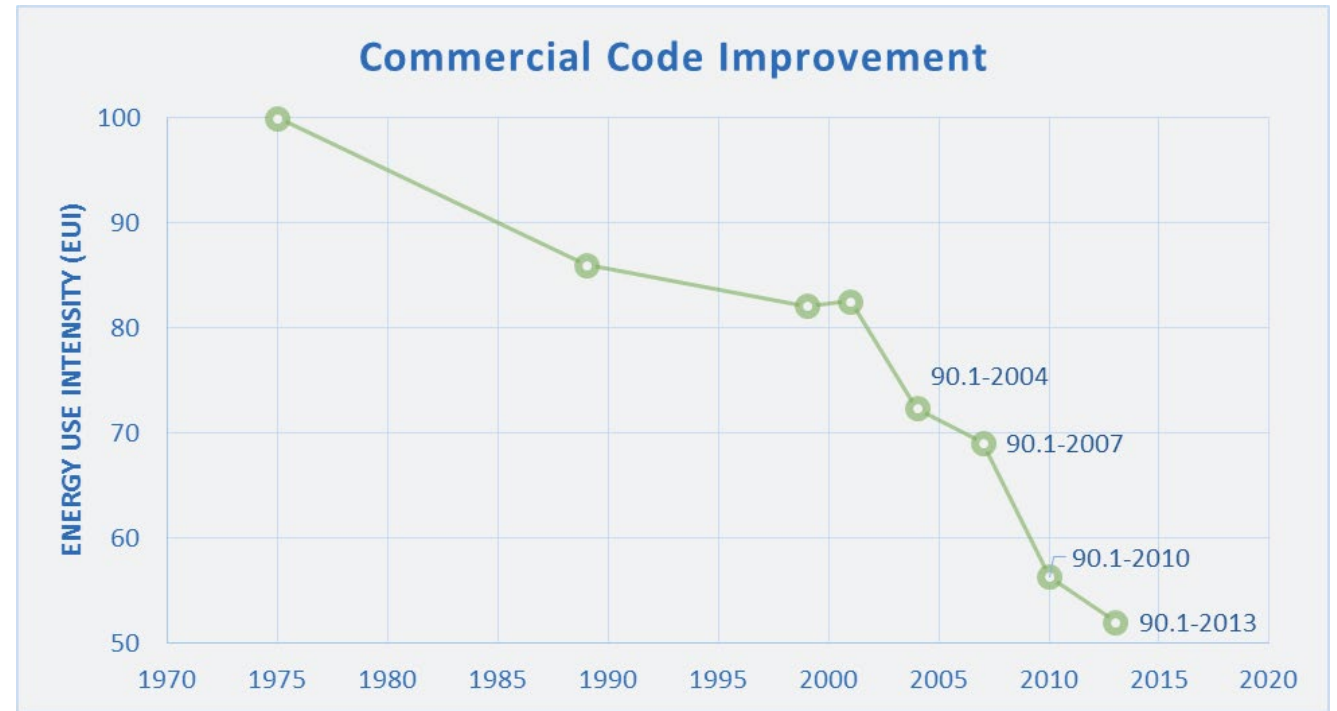
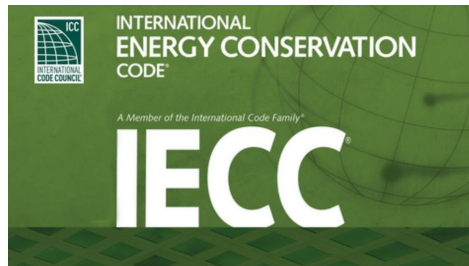
**36%** Final energy

Source: REN21 Renewables in Cities 2019 Global Status Report

# New Construction Efficiency Trends



- Building CODES
  - Energy
  - Green
- More savings every ~3 years



# Large Stock of Existing Buildings

- BIG existing energy use
- Older buildings less efficient
- Reuse = lower carbon
- *Lots of programs!*

## Affordable Multifamily Energy Efficiency Program

[Program Overview](#) | [How to Participate](#) | [Incentive Structure](#) | [Become a Participating Contractor](#) | [Program Roadmap](#) | [Ready to Participate](#) | [Resources & Links](#) | [Related Information](#)

## Energy Savings for Multifamily Properties

🏠 Up to \$6,000 per unit for electrification measures

## Multifamily Retrofit Tools and Workforce Resources

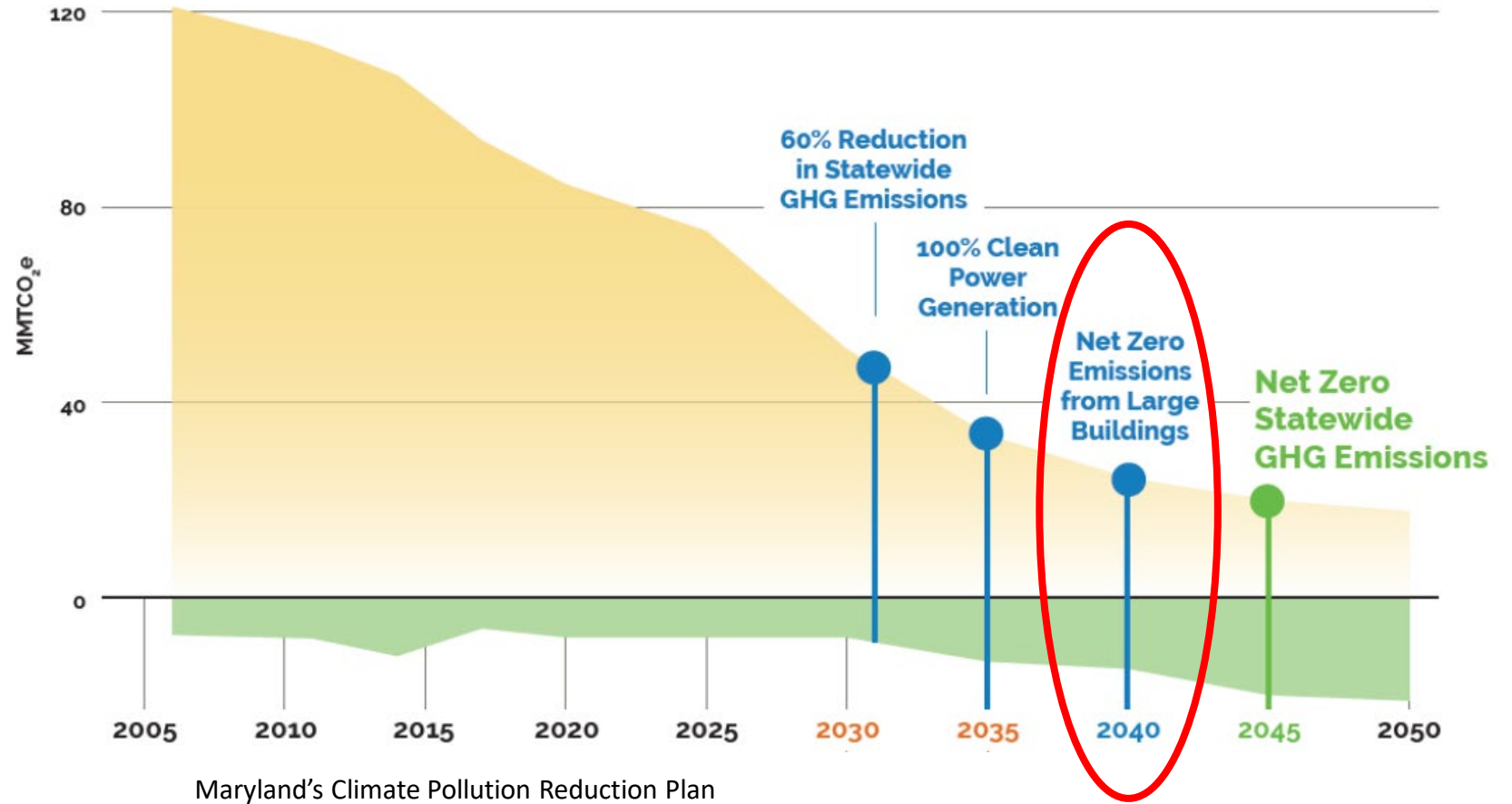
**Building Energy Performance Standards (current)** - Requires certain buildings 35,000 square feet or larger to achieve specific energy efficiency and direct emissions standards, including achieving net-zero direct emissions by 2040.

# Planning for Lower Emissions



- State Planning
- Including buildings

Figure 1: Major Milestones on Maryland's Decarbonization Timeline

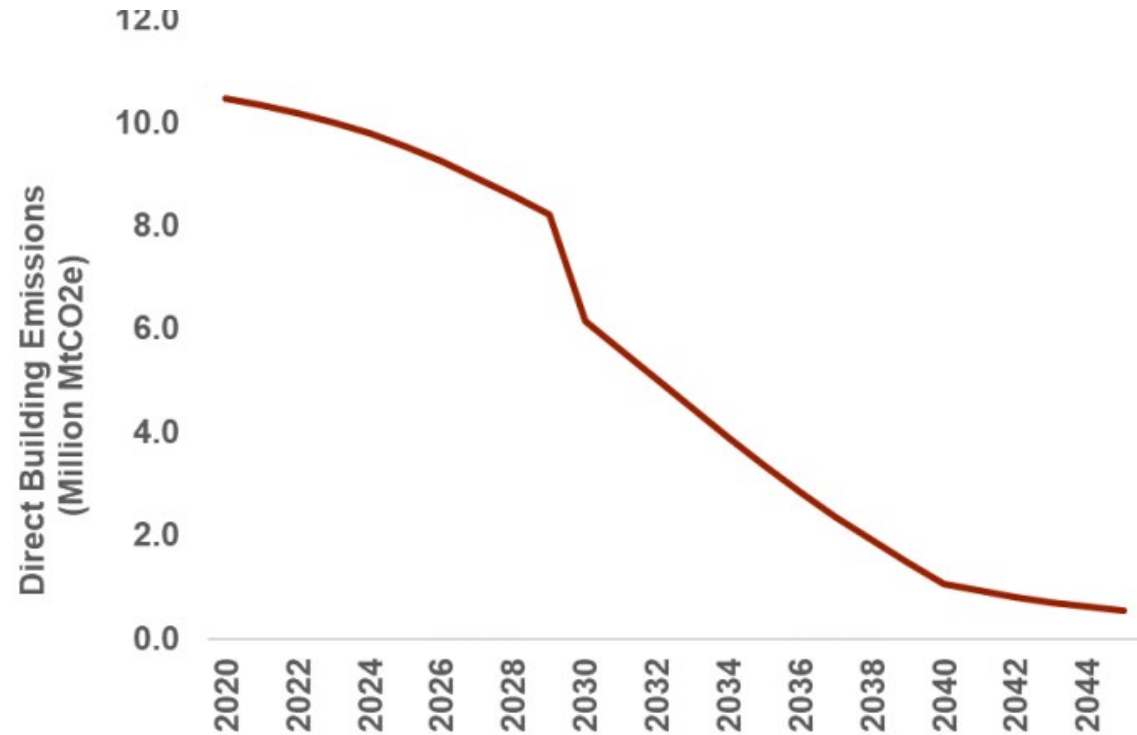


# Lowering Building Energy Use



- Maryland taking it seriously
- Studies for all sectors
- Bldgs: It can be done!

Overall, E3 estimates that residential and commercial building emissions could decrease around 95 percent by 2045 including offsets from the alternative compliance program.

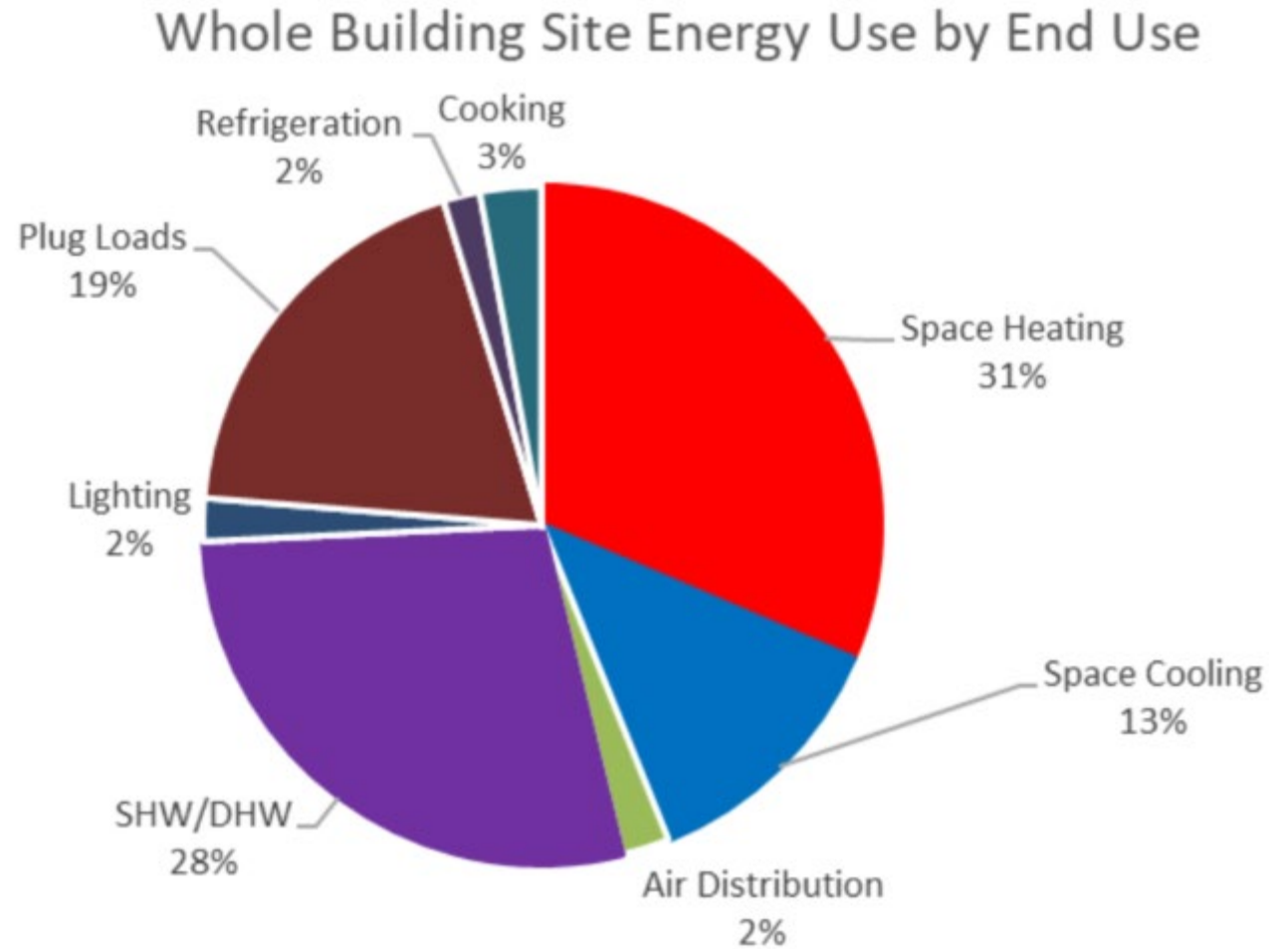


MD Commission on Climate Change  
Building Energy Transition Plan  
Energy + Environmental Economics (E3)

# Buildings: Where is That Energy?



- Get Data
- Evaluate Bldg: Heating and Cooling
- Analyze
- Plan for Upgrades



Example from 2023 multifamily retrofit analysis

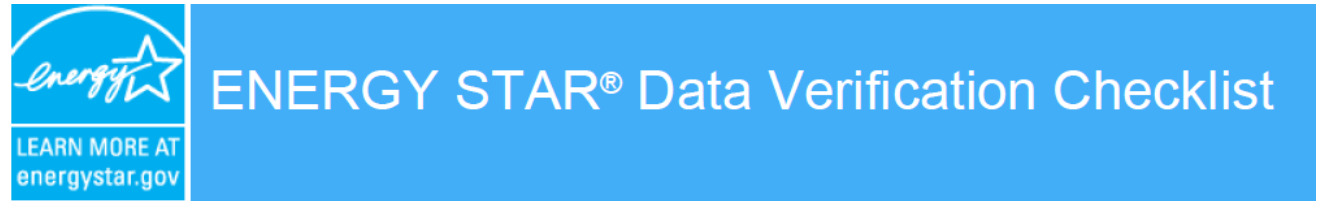


# Get Data: Benchmarking



- Need to HAVE data to improve Get
- “You can’t improve what you don’t measure.”
- Which building have most impact?

## Benchmarking Law Compliance



**51**

ENERGY STAR®  
Score<sup>1</sup>

**St. Paul on 4th St**

Registry Name: St. Paul on 4th St  
Property Type: K-12 School  
Gross Floor Area (ft<sup>2</sup>): 101,523  
Built: 1914

For Year Ending: Dec 31, 2023  
Date Generated: Mar 5, 2024

# Existing Building Stock

- Many shapes and sizes
- Heating and cooling:
  - What impacts this the most?



# Example Case Study: Existing Affordable Multifamily



- Reviewing energy efficiency masures (EEMs)
  - Modeled savings for upgrades

EEM #	EEM Name	Site EUI Savings (%)	Measure Cost / SF
<b>Low-Cost Recommendations</b>			
1	ENERGY STAR Refrigerator	<1%	\$0.53
2	Lighting Upgrade	1%	\$0.26
3	Plumbing Upgrade	<1%	\$0.38
<b>TOTALS (Low-Cost Measures)</b>		<b>1.5%</b>	<b>\$1.17</b>
<b>Potential Capital Recommendations</b>			
1	Envelope and Air Sealing	34%	\$21.48
2	HVAC Systems Upgrade	28%	\$16.21
3	DHW Heater Upgrade	18%	\$15.38
4	Cooking Fuel Conversion	<1%	\$2.82
<b>TOTALS (Capital Measures)</b>		<b>80%</b>	<b>\$55.59</b>
<b>TOTALS (All Measures)</b>		<b>81.5%</b>	<b>\$57.06</b>

## Envelope: 34% Savings

- Thermal (insulation)
- Air Sealing

# Main Envelope Components



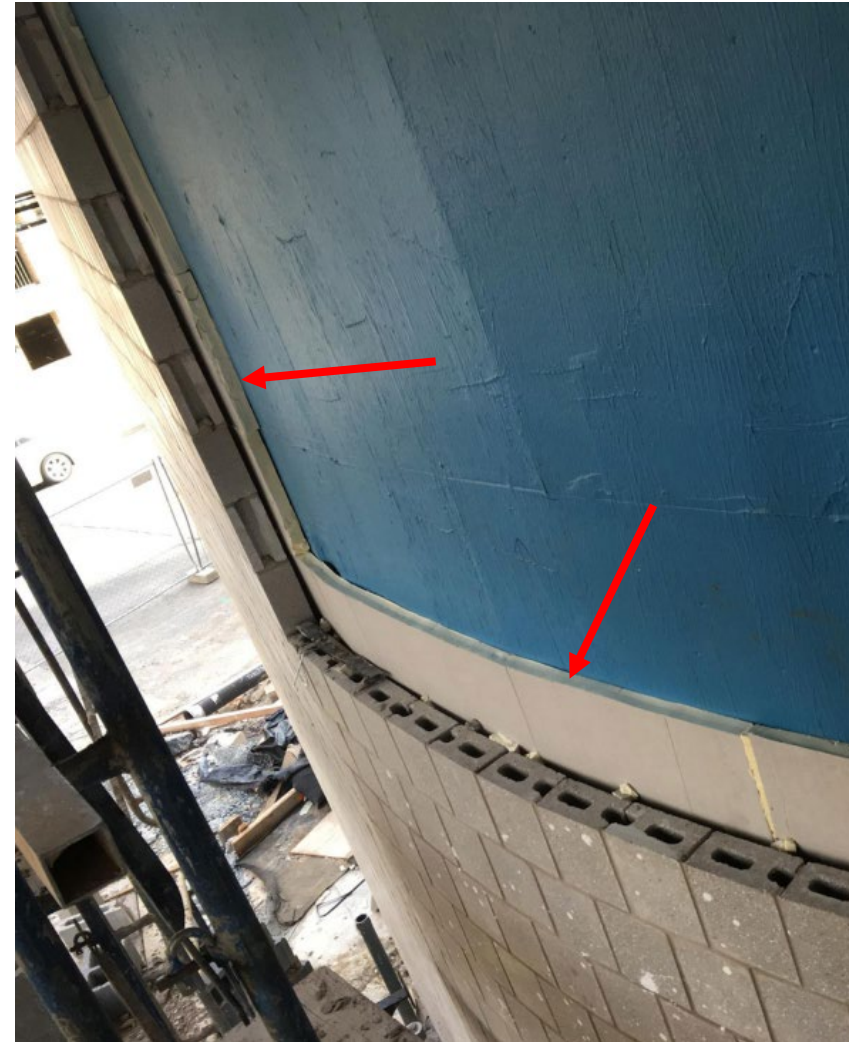
- Thermal Envelope (Insulation)
- Air Barrier:
  - Whole Building
  - Compartmentalization



# Thermal Envelope: Insulation



- Cavity: Between Framing
- Continuous



# Only Cavity Insulation



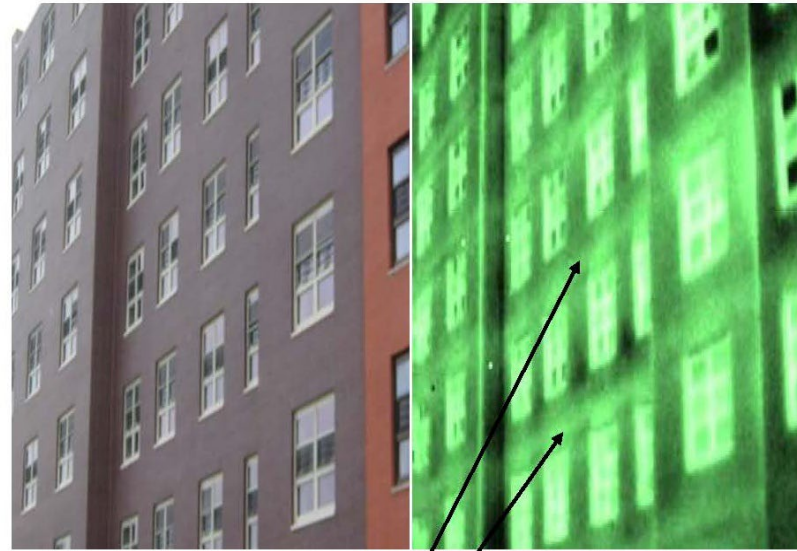
- Thermal Bridging
- Framing 'blocks' insulation cover
- Significant energy loss
- Why we want continuous



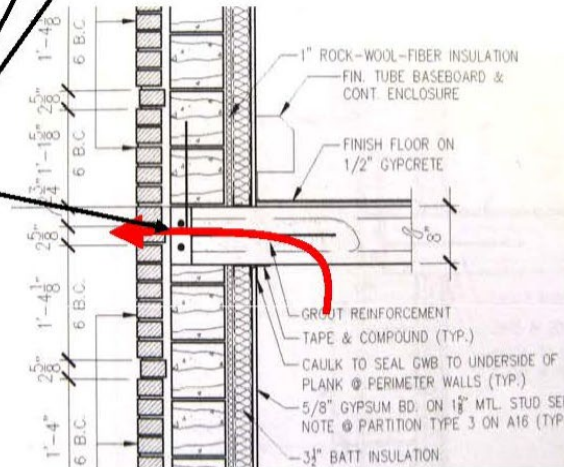
Source: Dryvit Systems, Inc. and The Dow Chemical Company

# Thermal Bridging

- Masonry Buildings Also

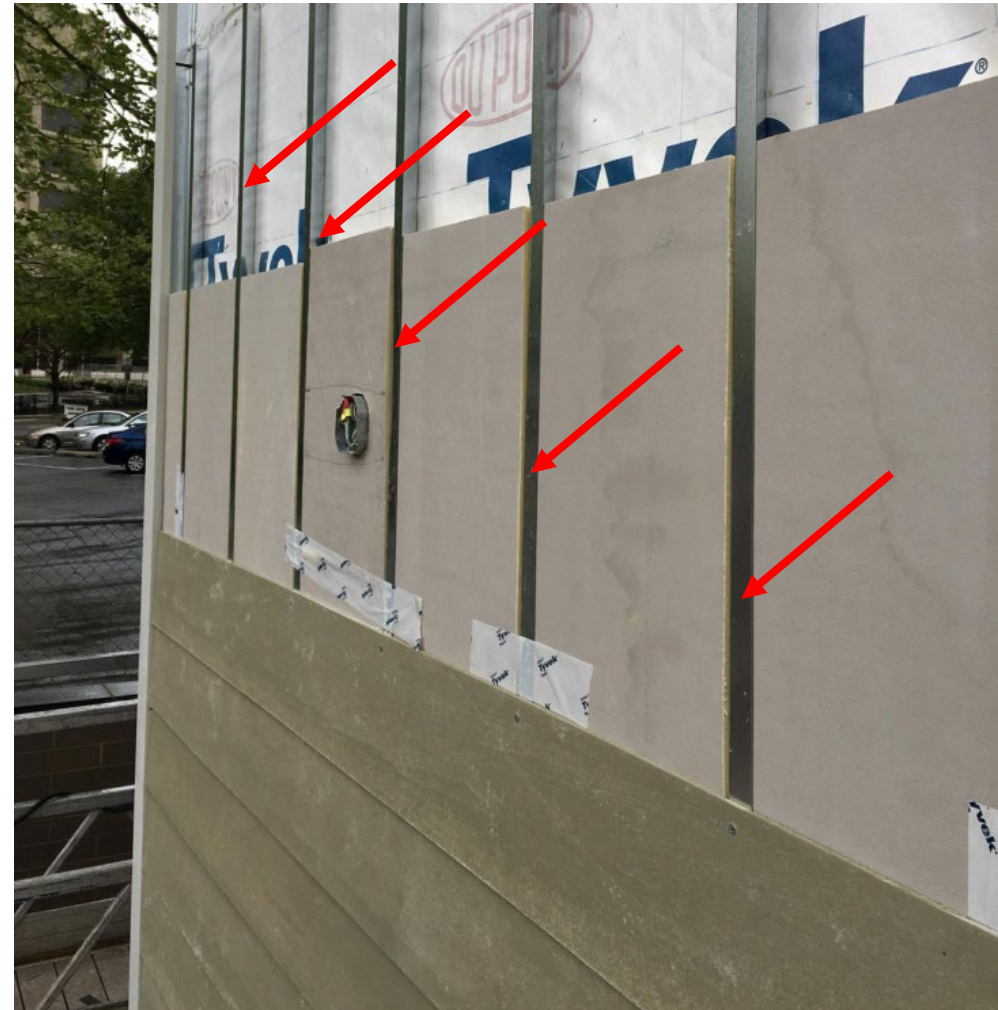


Heat is lost through the thermal bridges at the slab edges.



# Thermal Bridging

- Exterior Insulation Solves the Issue?
- How is it designed/installed?

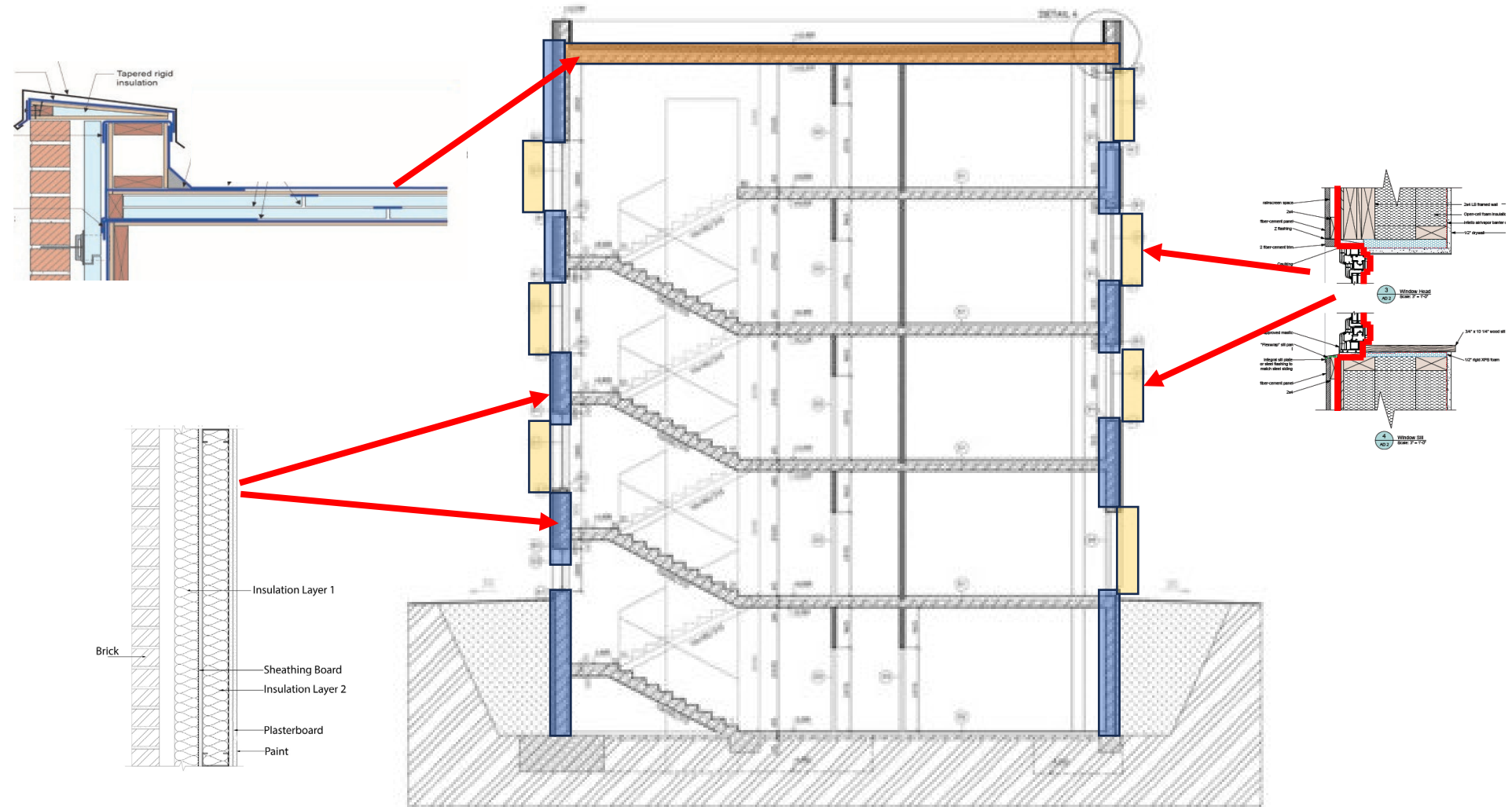




# Thermal Envelope – Main Components

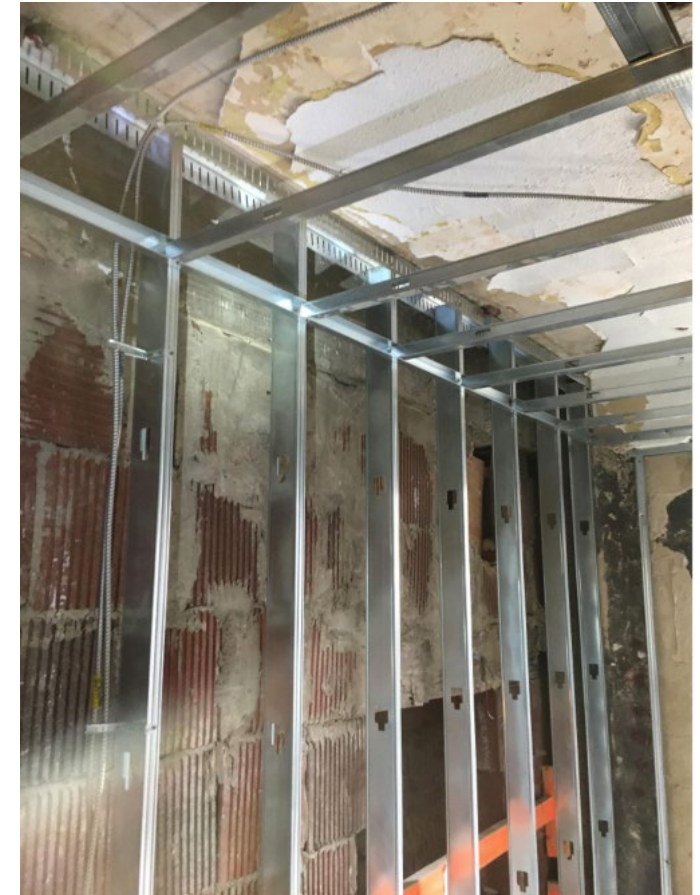


- Roof
- Walls
- Windows



# Envelope: Walls

- Cannot Touch?
- Existing Studs?
- Frame Out Interior?



# Envelope: Walls



- Insulate Cavity
- Insulate Behind Cavity?
  - Continuous thermal break

GAP between stud and masonry



Spray foam fills the gap



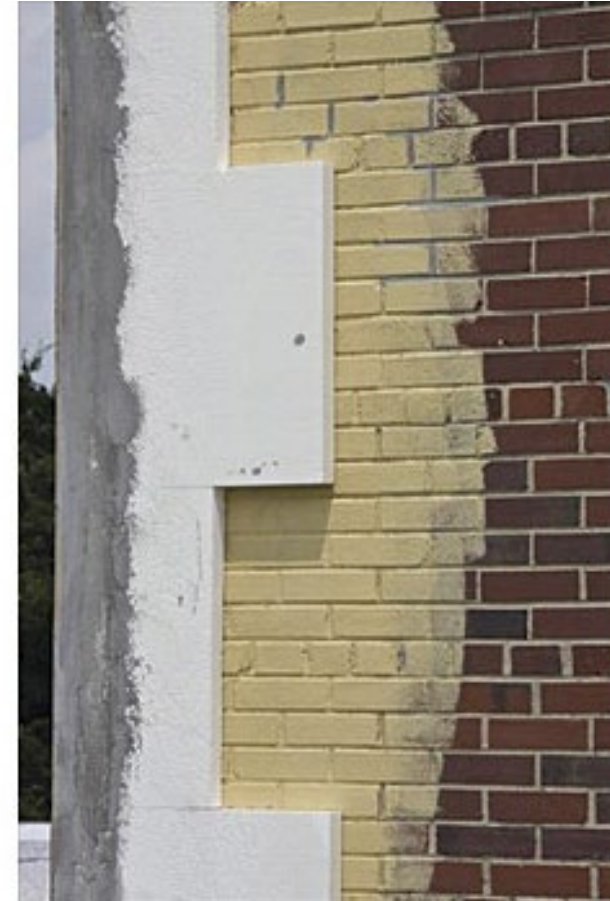
# Envelope: Walls



- Add Exterior?
- Retrofit EIFS?
- Significant Savings
  - \$\$\$?

The main components of the work are as follows:

- Apply EIFS to all exterior walls.
- Increase flat roof insulation to R-38
- Install new ENERGY STAR windows and exterior doors
- Minimize envelope air leakage using a comprehensive air barrier continuity plan



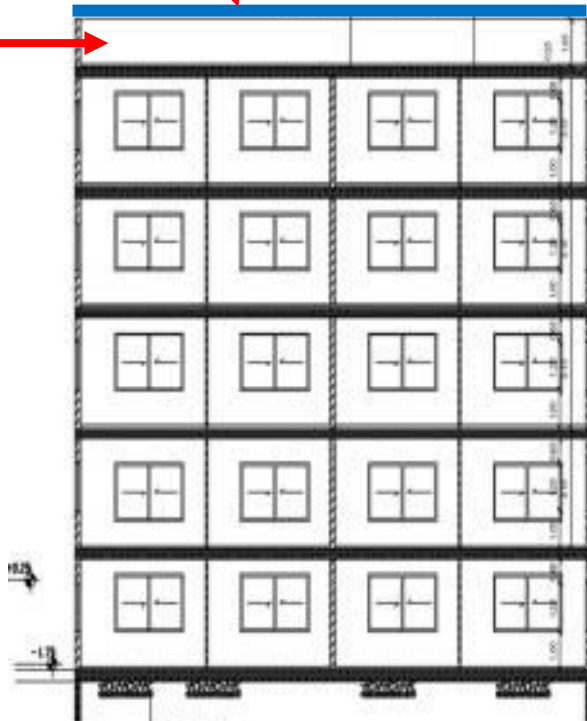
wconline.com

# Envelope: Roof



Deck: Full Replace?

- What is Existing?
  - Roof Deck Insulation
  - “Attic” Cavity?



# Envelope: Roof



- What is Existing?
  - Roof Deck Insulation
  - “Attic” Cavity?



Vented: Look Inside?



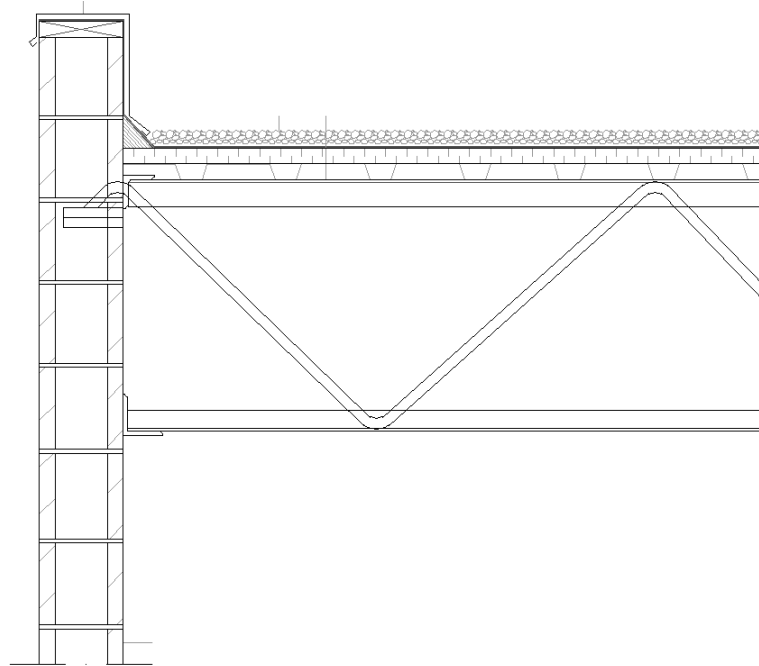
~2ft Cavity with No Insulation



# Envelope: Roof



- Filling Cavity
- Access from Above?
  - Blown-in
- Access from Below?
  - Batt or other?
- *Air Seal Same Time!*



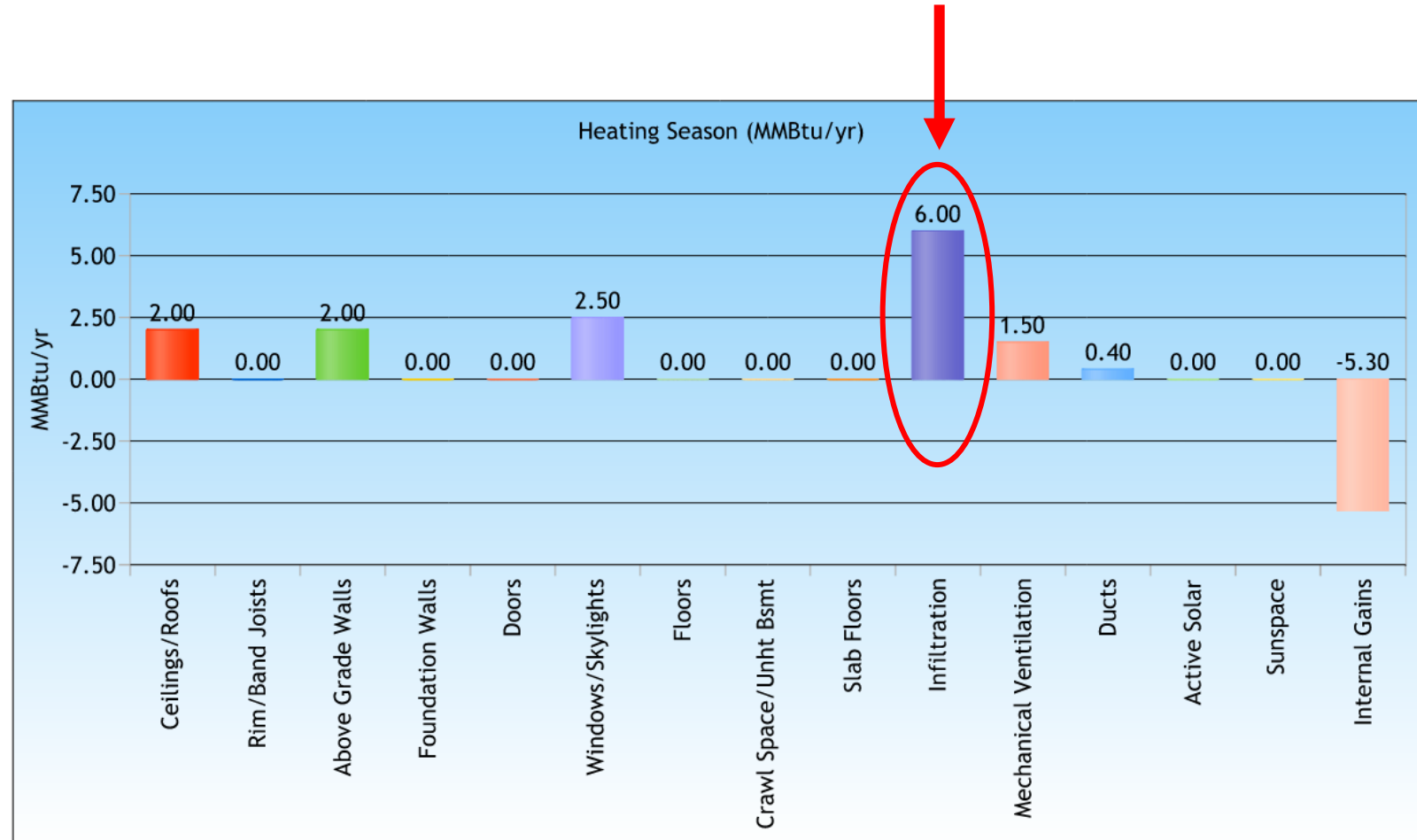
# Air Sealing



## Envelope Air Leakage

Energy Model Dwelling Unit

- Leakage can be important





# Testing Requirements

- Whole building AND unitized
- Updates to codes
- Residential and Commercial

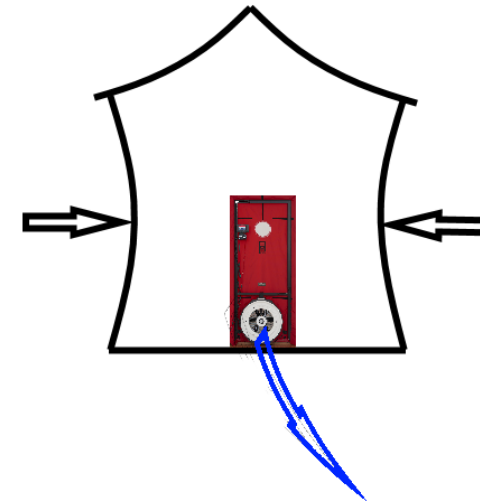


Codes / I-Codes / 2021 International Energy Conservation Code (IECC) ▾

## Chapter 4 [CE] Commercial Energy Efficiency

**C402.5.2 Dwelling and sleeping unit enclosure testing.**

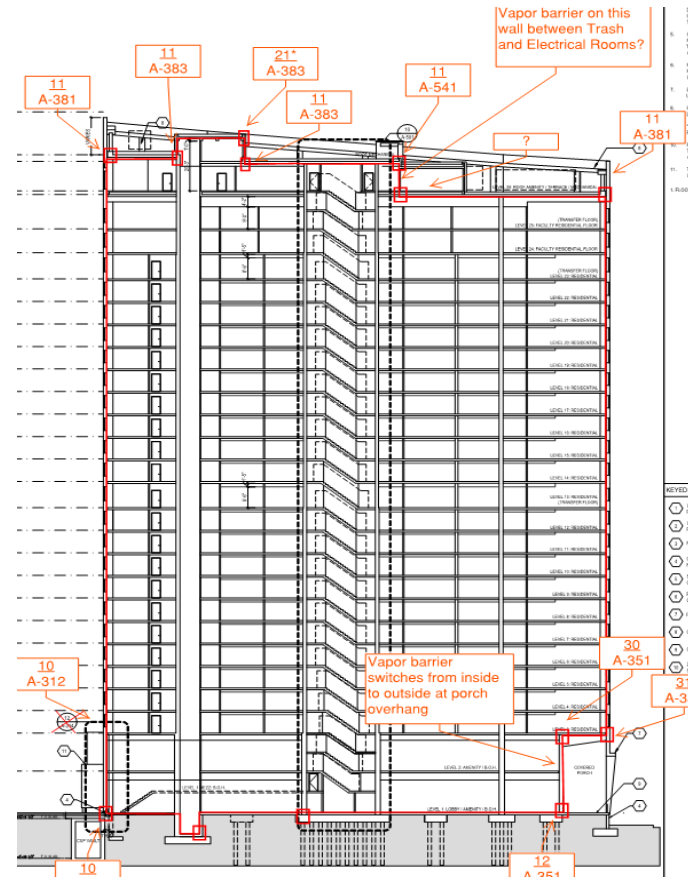
**C402.5.3 Building thermal envelope testing.**



# Whole Building Air Barrier

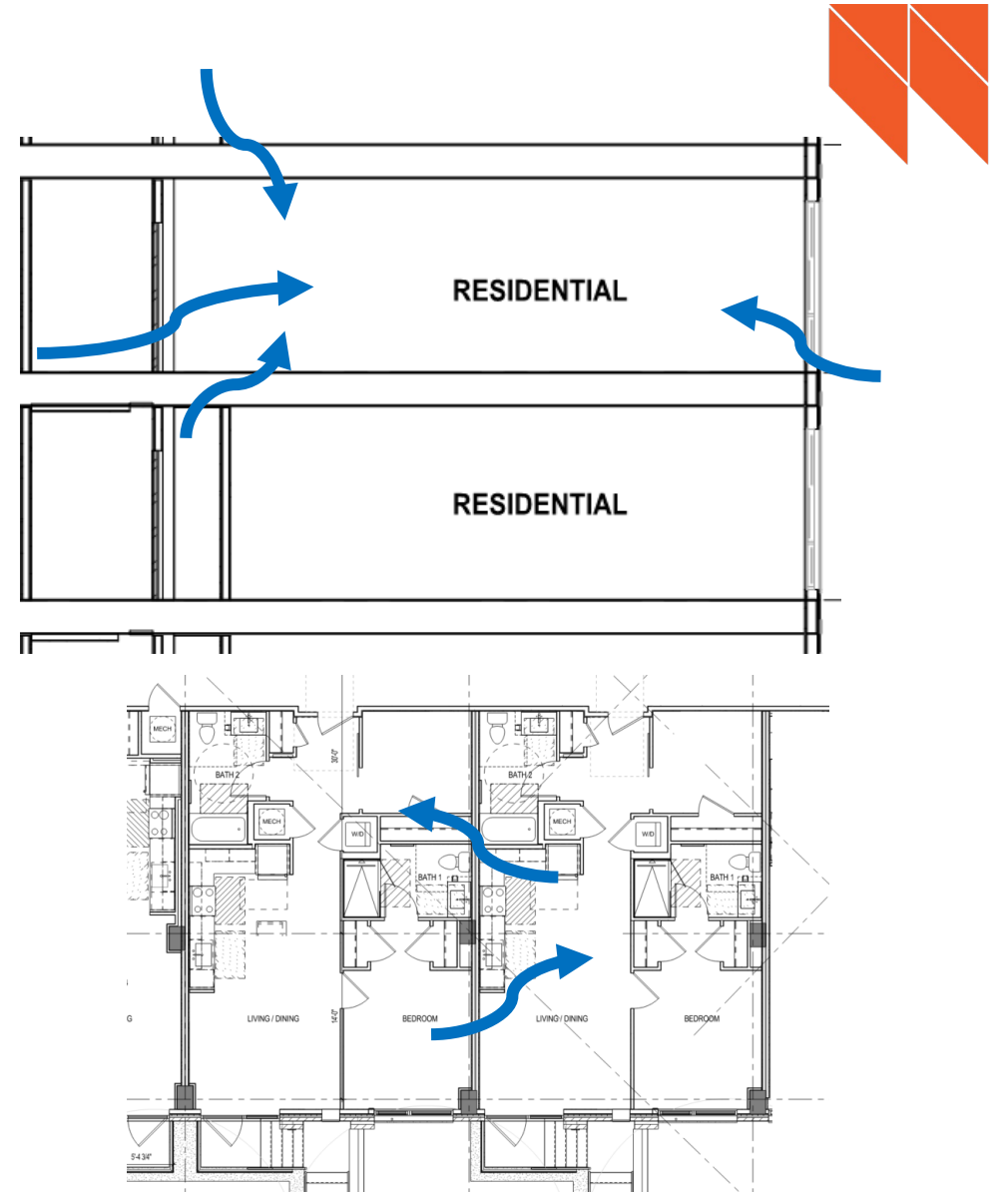
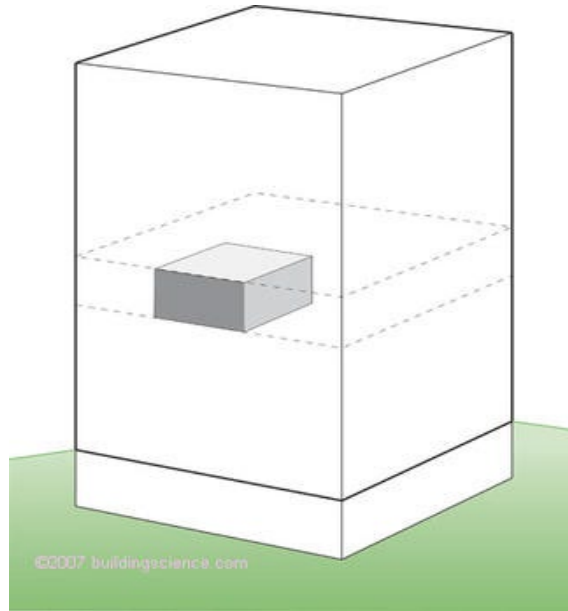


- Whole Envelope
- Find Weak Points
- Continuity



# Compartmentalization Air Barrier

- Between Dwelling Units
- Energy?
- Cooking, pests, smoke, sound, etc.



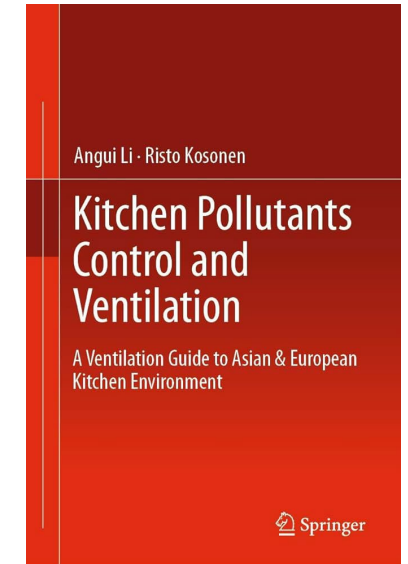
# Indoor Air Quality!



- Very Important
  - Interacts with energy efficiency
  - Seal a building – need fresh air
- Get out pollutants (Kitchen!)
- Get out moisture (Bath!)
- Low VOC materials



## How to Find Indoor airPLUS Compliant Low-Emission Products



ULTRA LOW VOC

# Seal Tight – Ventilate Right

- Get pollutants out

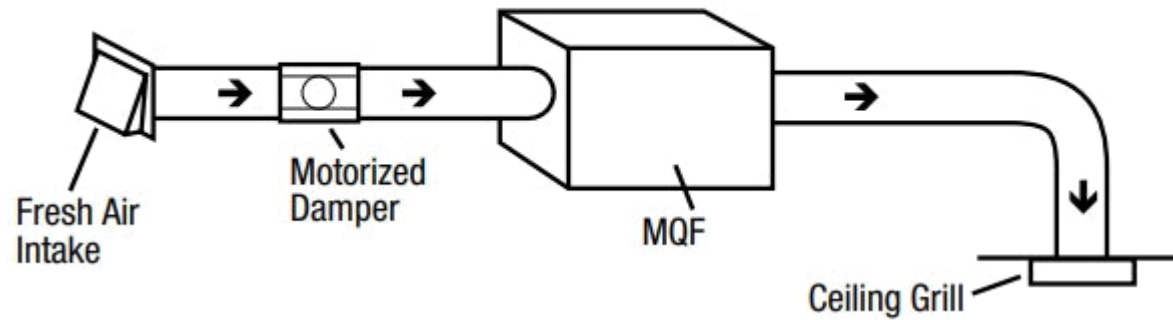


## Energy Savings Plus Health

Indoor Air Quality Guidelines for Multifamily Renovations

- Bring Fresh Air In

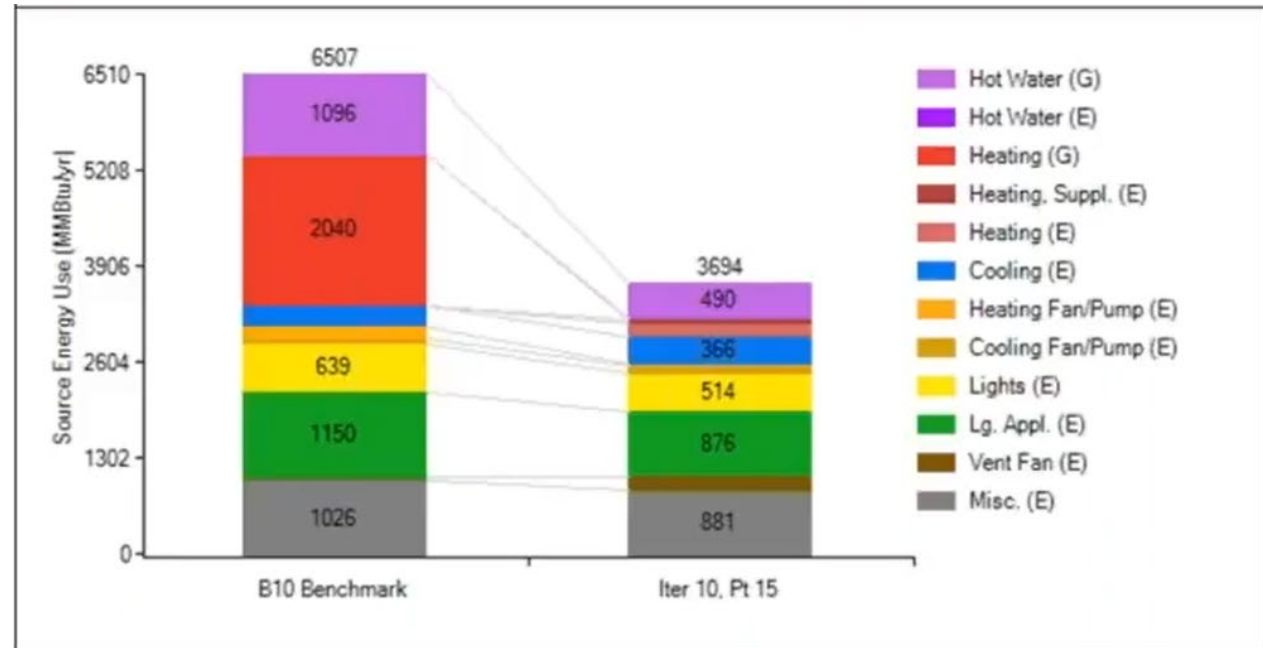
### DIRECT TO DWELLING



# Envelope

- Insulate Where You Can
- Air Sealing While You Insulate
  - Air Seal Other Areas
- Ventilate for Fresh Air
- Efficient, healthier, happier

EEM #	EEM Name	Annual Owner Energy Cost Savings (\$/yr.)	Site EUI Savings %
1	<b>Envelope Insulation and Air Sealing</b> Increase roof insulation to R-38, install R-20 exterior wall insulation, replace windows and sliding doors with U-value 0.30 and SHGC 0.40, air seal all penetrations to reduce infiltration by 20% to <=0.46 CFM50/SF enclosure.	28,400	19.6%



©2018 Passive House Institute US |



# Building Testing - Results in Better Buildings

# Existing Buildings

## Typical Testing Procedures:

- Blower Door Testing
- Thermal Imaging
- Combustion Testing



# Blower Door Testing

## What is Blower Door Testing?

- Sealing openings in a space, then applying pressurization on the space to determine the rate of air leakage.

## Why conduct Blower Door Testing?

- To determine how much Infiltration\Exfiltration occurs in a space.

## When to use Blower Door Testing?

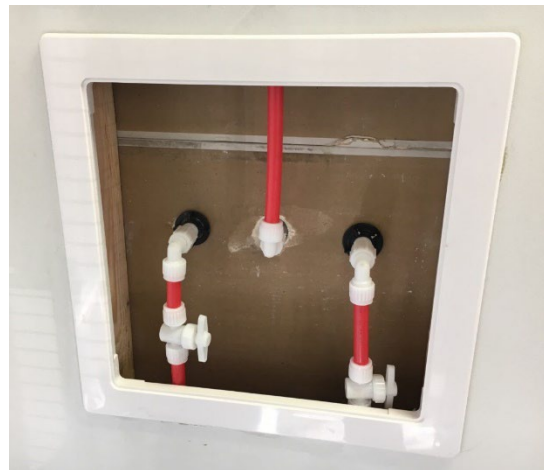
- Tenants have thermal comfort complaints.
- Space has moisture issues.
- Corrosion issues on pipes or equipment.
- Energy consumption is excessive.

# Blower Door Testing



# Blower Door Testing

- Common places for leakage:
  - Doors and windows
  - Plumbing penetrations
  - Access Panels
  - Ductwork penetrations
  - Electrical penetrations
  - Electrical outlet boxes



# Blower Door Testing

## The Process:

1. Test Conducted: One-Point Airtightness Test (CFM50)
2. Created a building energy model based on building geometry, construction, equipment efficiencies and 12 months of utility bills.
3. Applied the measured leakage to the baseline.
4. Changed leakage for proposed leakage savings.
5. Calculated savings.

# Blower Door Testing

## DC Apartment Building #1:

- Average Unit Leakage = 202 CFM
- Acceptable Leakage = 97 CFM
- Potential Leakage Savings = 105 CFM (52%)

Measures: Seal and make airtight wall & floor penetrations, exterior doors, egress doors, windows, baseboards and access hatches.

ESTIMATED ENERGY SAVINGS:						
Annual Energy Cost Savings (\$/yr)	Electric Savings (kWh/yr)	Annual Energy Use Savings (MMBtu)	Total Emissions Savings (Tons CO2/Yr)	Install Cost	Measure Life (years)	Simple Payback (Years)
\$33,747.70	233.60	67.45	4.21	\$75,000	10	2.22

# Blower Door Testing

## DC Apartment Building #2:

- Average Unit Leakage = 227 CFM
- Acceptable Leakage = 118 CFM
- Potential Leakage Savings = 109 CFM (48%)

Measure: Seal and make airtight wall & floor penetrations, exterior doors and access hatches.

ESTIMATED ENERGY SAVINGS:						
Annual Energy Cost Savings (\$/yr)	Electric Savings (kWh/yr)	Annual Energy Use Savings (MMBtu)	Total Emissions Savings (Tons CO2/Yr)	Install Cost	Measure Life (years)	Simple Payback (Years)
\$7,073.44	17,688	494.35	31.0	\$69,812	20	9.87

# Blower Door Testing

## DC Apartment Building #3:

- Average Unit Leakage = 241 CFM
- Acceptable Leakage = 99 CFM
- Potential Leakage Savings = 142 CFM (59%)

Measure: Seal and make airtight wall & floor penetrations, exterior doors and access hatches.

ESTIMATED ENERGY SAVINGS:						
Annual Energy Cost Savings (\$/yr)	Electric Savings (kWh/yr)	Annual Energy Use Savings (MMBtu)	Total Emissions Savings (Tons CO2/Yr)	Install Cost	Measure Life (years)	Simple Payback (Years)
\$2,580.35	2,655	263	15	\$41,635	20	16.1

# Thermal Imaging

## What is Thermal Imaging?

- Specialized camera which detects temperature differential and uses colors to show variance.

## Why use Thermal Imaging?

- It is a non-invasive method for locating problem areas.

## When to use Thermal Imaging?

- Complaints of hot or cold surfaces.
- Visible mold or moisture on surfaces.
- Best to do when conducting a Blower Door Test.

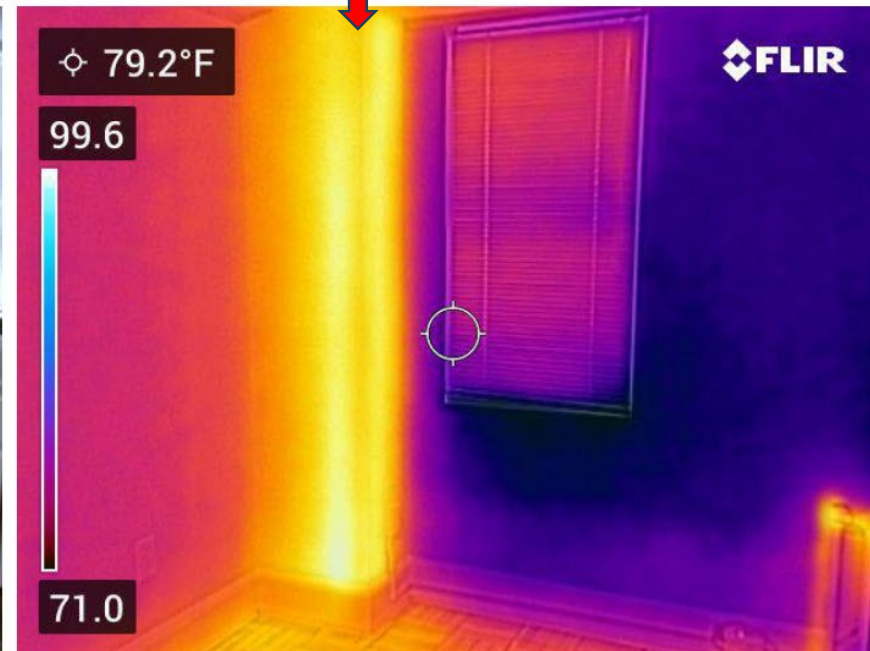


# Thermal Imaging – Pipe Insulation

Using proper testing devices and procedures help identify hard to detect building deficiencies.

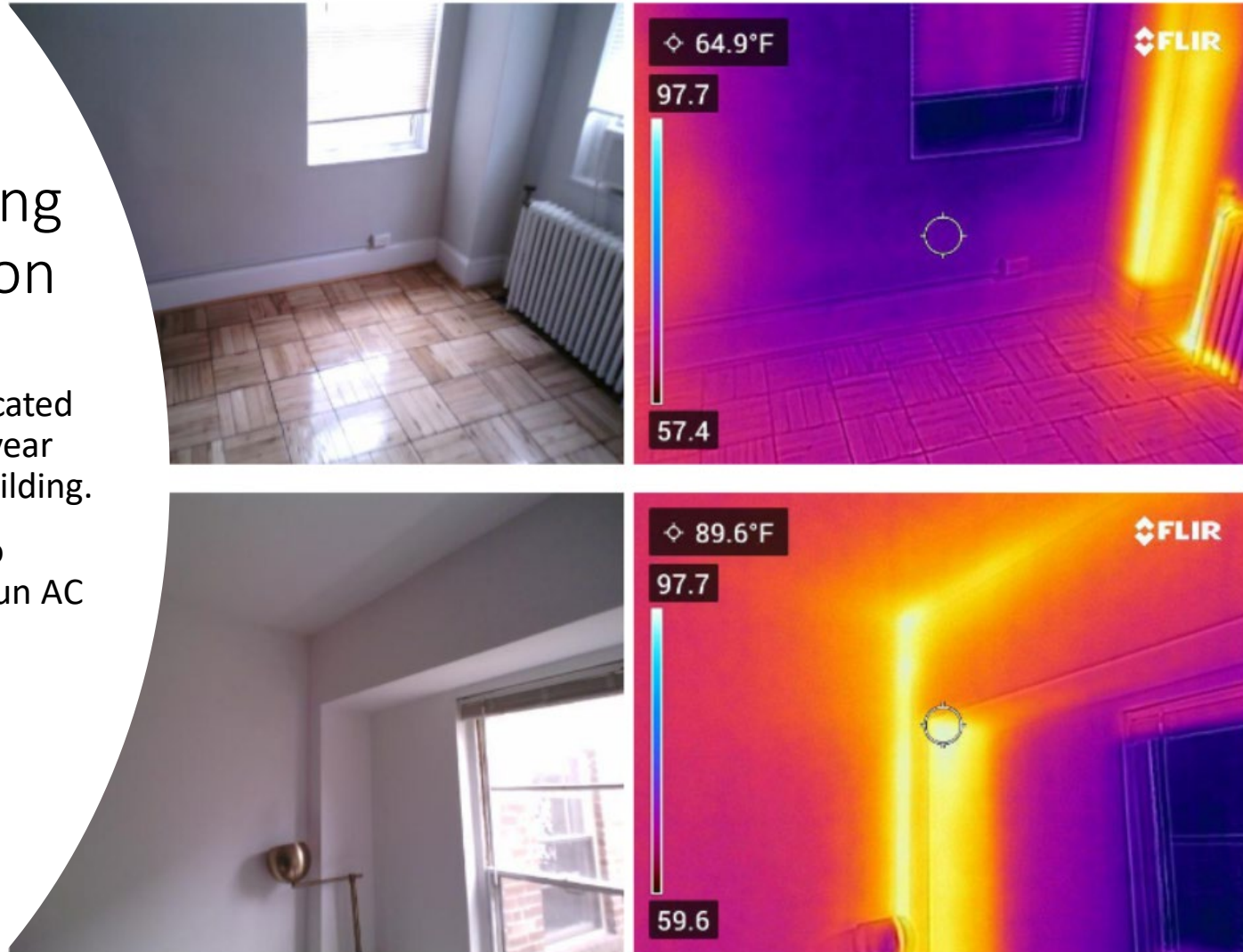
Imaging shows piping heat losses in the wall cavity.

**BENEFIT: NON-INVASIVE**



## Thermal Imaging – Pipe Insulation

- Tenants surveyed indicated that 6-months of the year walls are hot in the building.
- Tenants must resort to opening windows or run AC units to manage the **Overheating** of their apartments.

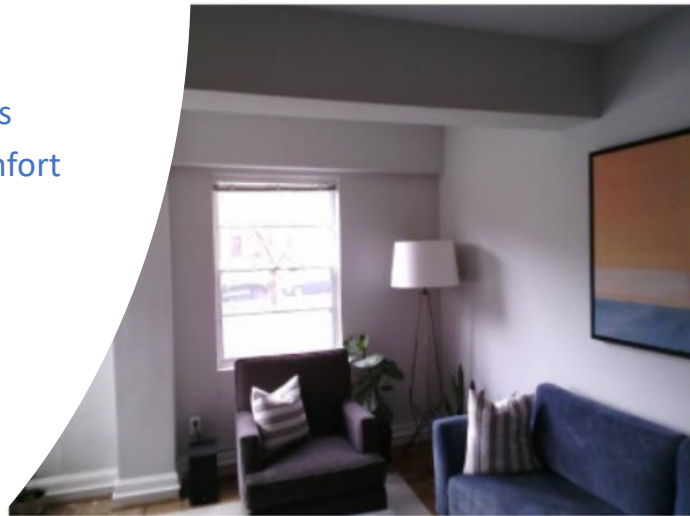
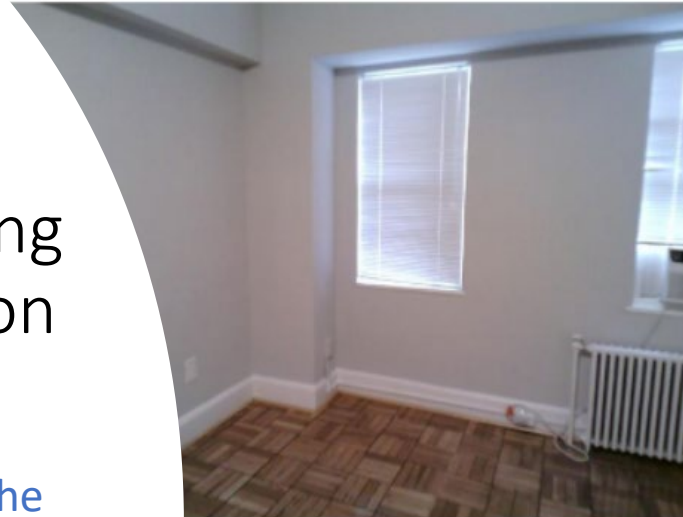


## Thermal Imaging – Pipe Insulation

- **Resolving** the issue requires insulating the piping.

### Benefits:

- Reduced energy bills
- Better Thermal Comfort
- Happier Tenants



# Heat Losses

## 3" HW Riser Pipe:

- Losses 1,764 BTU/hr/floor
- Assuming 13 floors
- Total Loss = 22,932 Btu/hr or 0.229 therm

## Boiler:

- Assume 80% Efficient Natural Gas
- Consumption = 0.229 therm / 0.80
- Consumption = 0.286 therm

## Building Consumption:

- Assume 12 risers in building
- Consumption = 0.286 therm \* 12
- Consumption = 3.432 therm

## Annual Consumption:

- Assume 12 hrs/day of heating
- Assume 120 day of heating
- Consumption = 3.432 therm \* 12 \* 120
- Consumption = 4,942 therm/yr

## Annual Cost:

- Assume = \$1.60/therm
- Cost = 4,942 \* 1.60
- **Cost = \$7,907**

# Thermal Imaging – Window Frames

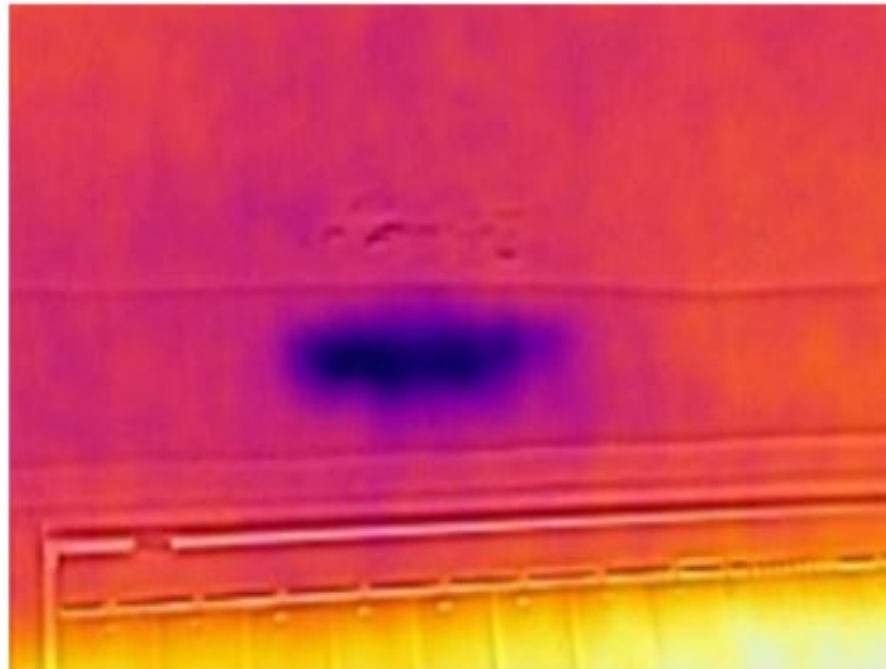
Substantial heat transfer through Non-Thermal  
Break window frames

**BENEFIT: IDENTIFIES PROBLEM AREAS**



# Thermal Imaging

Condensation can result from Uninsulated piping, which leads to mold growth.



# Thermal Imaging

## Resolutions to most issues:

- Insulate pipes, ducts, voids, etc...
  - Seal cracks with caulk, weatherstripping or sealants.
  - Replace with thermal break frames.
  - Create a thermal break layer to separate hot\cold conditions.
- 
- Best to address both air and vapor (moisture) barriers.
  - Key is to eliminate conditions where condensation occurs.

# Thermal Imaging

## Benefits:

- Locate uninsulated pipes, ducts, walls, etc...
- Locate areas of air infiltration due to poor or no air/vapor sealing.
- Reduce energy consumption & costs
- Reduce potential for mold, dry rot and building deterioration.



# Combustion Testing

## Opinion | Natural gas in homes is dangerous

January 26, 2024 at 5:00 p.m. EST



A gas explosion leveled a Southeast D.C. convenience store on Jan. 18. (Omari Daniels/The Washington Post)

Beyond Gas DC found 389 leaks, including 14 at or above the lower explosive limit of 5 percent methane. Burning gas produces pollutants including nitrogen dioxide, a powerful pulmonary irritant that aggravates a host of health conditions. A child living in a home with a gas stove has a 42 percent greater likelihood of asthma.

Image and Text taken from The Washington Post

## What Are the Adverse Health Effects of Gas Stoves?

Go to: ▶

Cooking-related emissions vary with the type of energy used. Some pollutants, such as fine particulate matter with an aerodynamic diameter  $\leq 2.5 \mu\text{m}$  ( $\text{PM}_{2.5}$ ), are released during cooking, regardless of fuel type. The primary pollutant of health concern emitted uniquely by gas (and not electric) cooking is nitrogen dioxide ( $\text{NO}_2$ ), but products of incomplete natural gas combustion include polycyclic aromatic hydrocarbons, formaldehyde, carbon monoxide, and ultrafine particles (4). Nitrogen oxides are irritant gases that can cause bronchoconstriction, airway hyperresponsiveness, and airway inflammation with increased risk of asthma exacerbations, bronchitis, and wheezing (2).

Article taken National Library of Medicine

Research, Cities & Society, Climate

## Climate and health impacts of natural gas stoves

Natural gas stoves release methane – a potent greenhouse gas – and other pollutants through leaks and incomplete combustion. Stanford researchers estimate that methane leaking from stoves inside U.S. homes has the same climate impact as about 500,000 gasoline-powered cars and the stoves can expose people to respiratory disease-triggering pollutants.

Article from Stanford University

# Combustion Testing

## Gas Analyzed and Threshold Required

Equipment	Gas Analyzed	Passing Threshold	Timing requirements
Natural Gas Range	Carbon Monoxide (CO)	Below 25 PPM	after 5 minutes of operation
	Hydrogen Sulfide (H <sub>2</sub> S)	Below 35 PPM	after 5 minutes of operation
Natural Gas Oven	Carbon Monoxide (CO <sub>AS-READ</sub> )	Below 225 PPM	after 15 minutes of operation
	Carbon Monoxide (CO <sub>AIR-FREE</sub> )	Below 800 PPM	after 15 minutes of operation
	Hydrogen Sulfide (H <sub>2</sub> S)	Below 35 PPM	after 15 minutes of operation
Natural Gas Boiler	Carbon Monoxide (CO <sub>AS-READ</sub> )	Below 35 PPM	after 10 minutes of operation
	Carbon Monoxide (CO <sub>AIR-FREE</sub> )	Below 400 PPM	after 10 minutes of operation
	Hydrogen Sulfide (H <sub>2</sub> S)	Below 35 PPM	after 10 minutes of operation
Natural Gas Domestic Hot Water Generator	Carbon Monoxide (CO <sub>AS-READ</sub> )	Below 120 PPM	after 5 minutes of operation
	Carbon Monoxide (CO <sub>AIR-FREE</sub> )	Below 200 PPM	after 5 minutes of operation
	Hydrogen Sulfide (H <sub>2</sub> S)	Below 35 PPM	after 5 minutes of operation
Natural Gas Dryer	Carbon Monoxide (CO <sub>AS-READ</sub> )	Below 25 PPM	after 5 minutes of operation
	Carbon Monoxide (CO <sub>AIR-FREE</sub> )	Below 400 PPM	after 5 minutes of operation
	Hydrogen Sulfide (H <sub>2</sub> S)	Below 35 PPM	after 5 minutes of operation

Spectrum Commissioning used RESNET Mortgage Industry National Home Energy Rating Systems Standards Chapter 8, Building Performance Institute Technical Standards for the Multifamily Building Analyst Professional, ANSI/BPI-1200, and the DC Weatherization Assistance Program as standards to develop the means and methods for executing the combustion safety testing.

# Combustion Testing

- Common equipment to be tested:
  - Range
  - Water Heater
  - Oven
  - Boiler
  - Dryer



# Combustion Testing

## Benefits:

- Improved health and safety
- Better Indoor Air Quality
- Better energy efficiency

# Combustion Testing

## Results from multiple buildings tested:

- Recommended professional adjustment of boilers and DHW Heaters, due to excess air.
- Recommended professional adjustment of ranges and ovens, due to unbalanced combustion.