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High-Performance Envelopes in Wood Construction

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RDH

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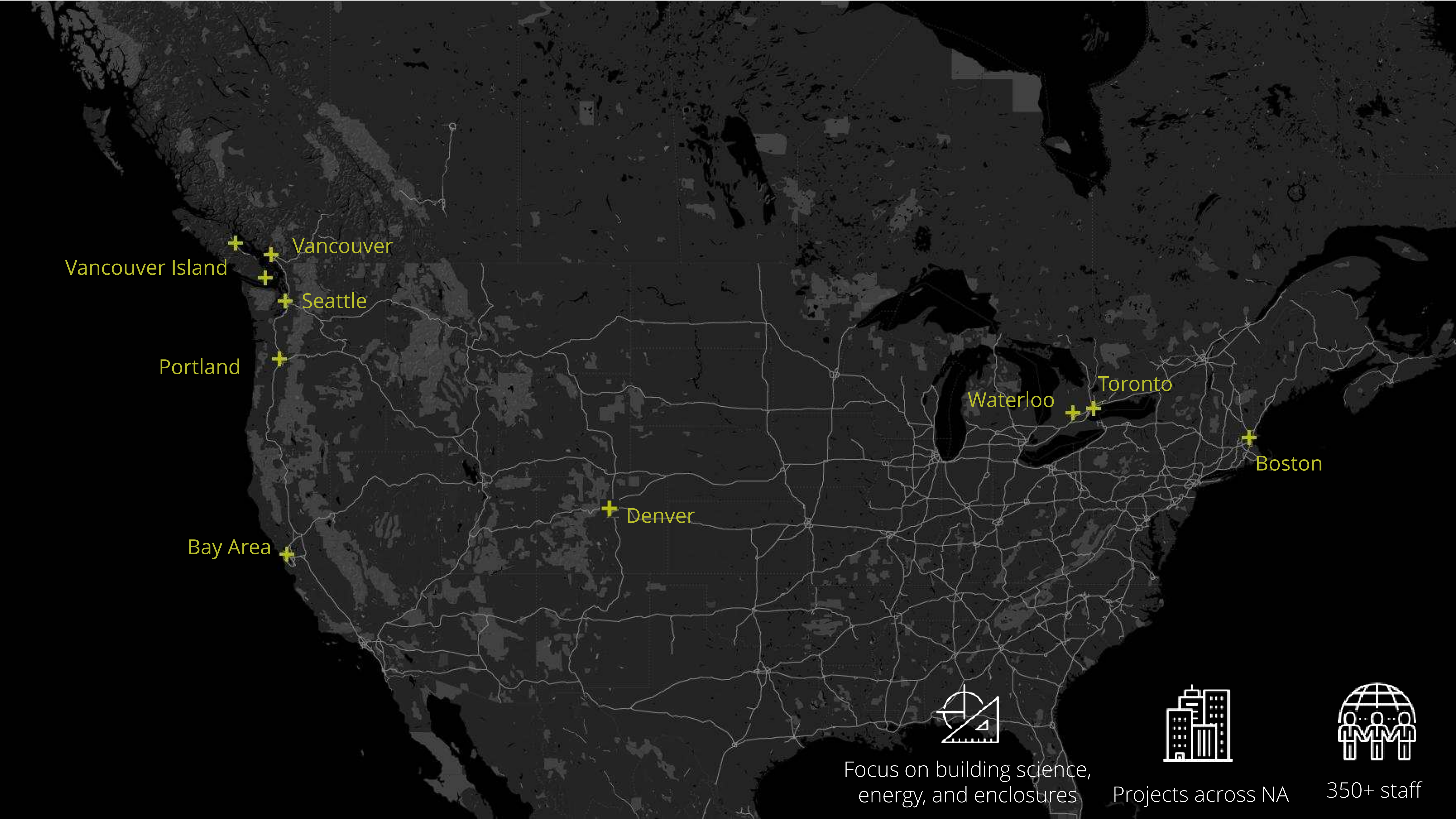
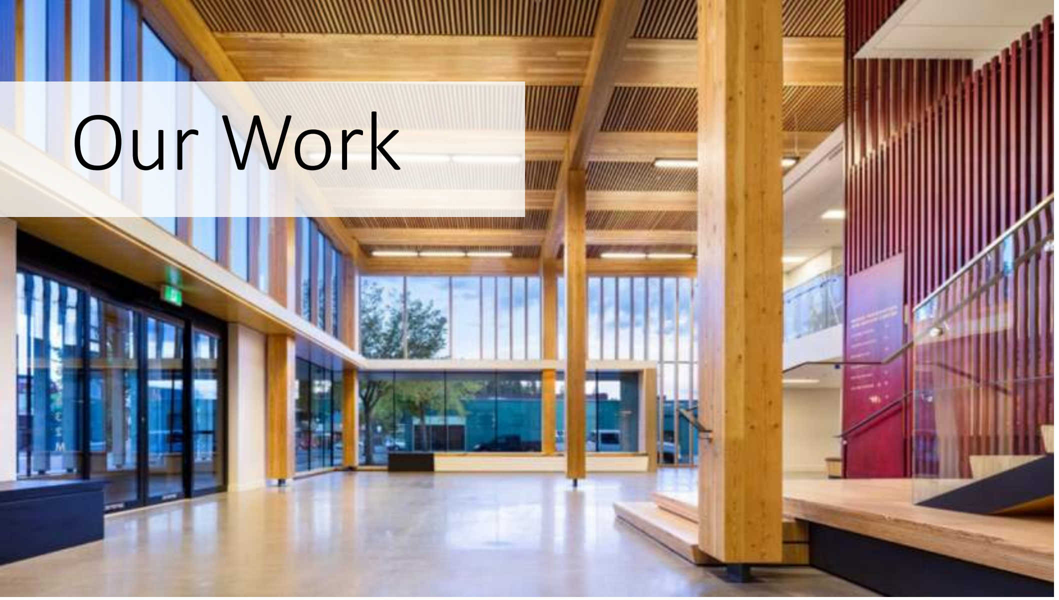


Focus on building science, energy, and enclosures

Projects across NA

350+ staff

Our Work



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Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

AIA Approved Continuing Education

Course Description

This course examines the critical role of envelope design in delivering healthy, safe, and durable buildings, focusing on wood construction—primarily light-frame wood systems. Buildings designed to meet or exceed evolving energy codes and high-performance standards, such as Passive House, are increasingly common in the US. As jurisdictions increasingly adopt aggressive energy performance targets, design teams must adapt envelope assemblies and detailing strategies to achieve greater levels of airtightness, insulation, and moisture control. The session will highlight best practices in coordinating architectural, structural, and MEP systems while addressing challenges like vapor control and constructability specific to wood building systems.

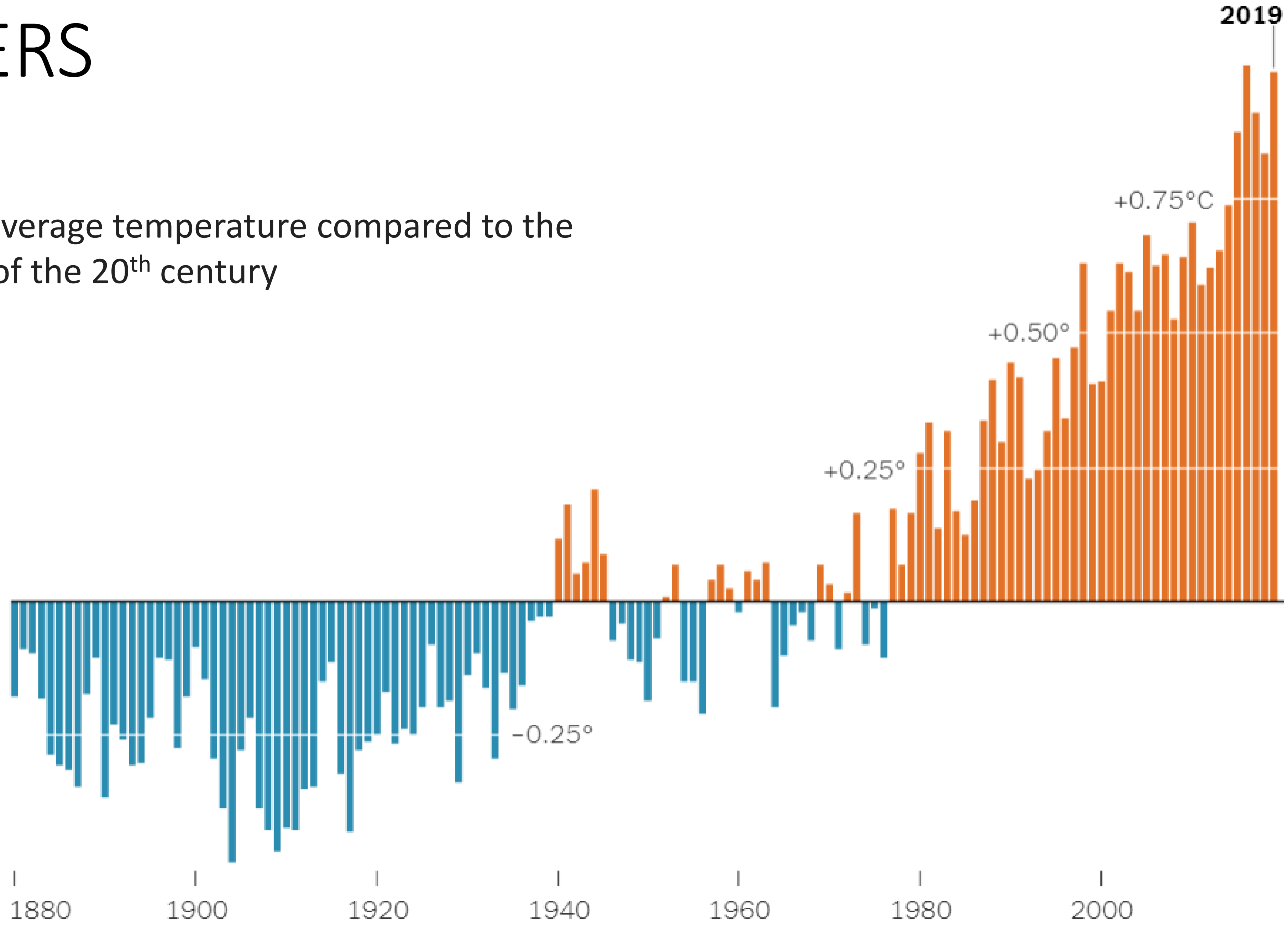
Learning Objectives

1. Explain the current energy code standards under the IECC and how they compare to other energy benchmarks such as Passive House, with an emphasis on their implications for energy efficiency.
2. Analyze how energy performance requirements impact envelope design decisions in wood construction, and the need for coordination strategies across disciplines.
3. Discuss common assemblies and lessons learned from real project examples that create comfortable and healthy living spaces.
4. Evaluate how high-performance envelope strategies, particularly air, vapor, and thermal control in wood construction, contribute to occupant well-being by improving indoor air quality, thermal comfort, and resilience to moisture.

1 Rewind to 2015

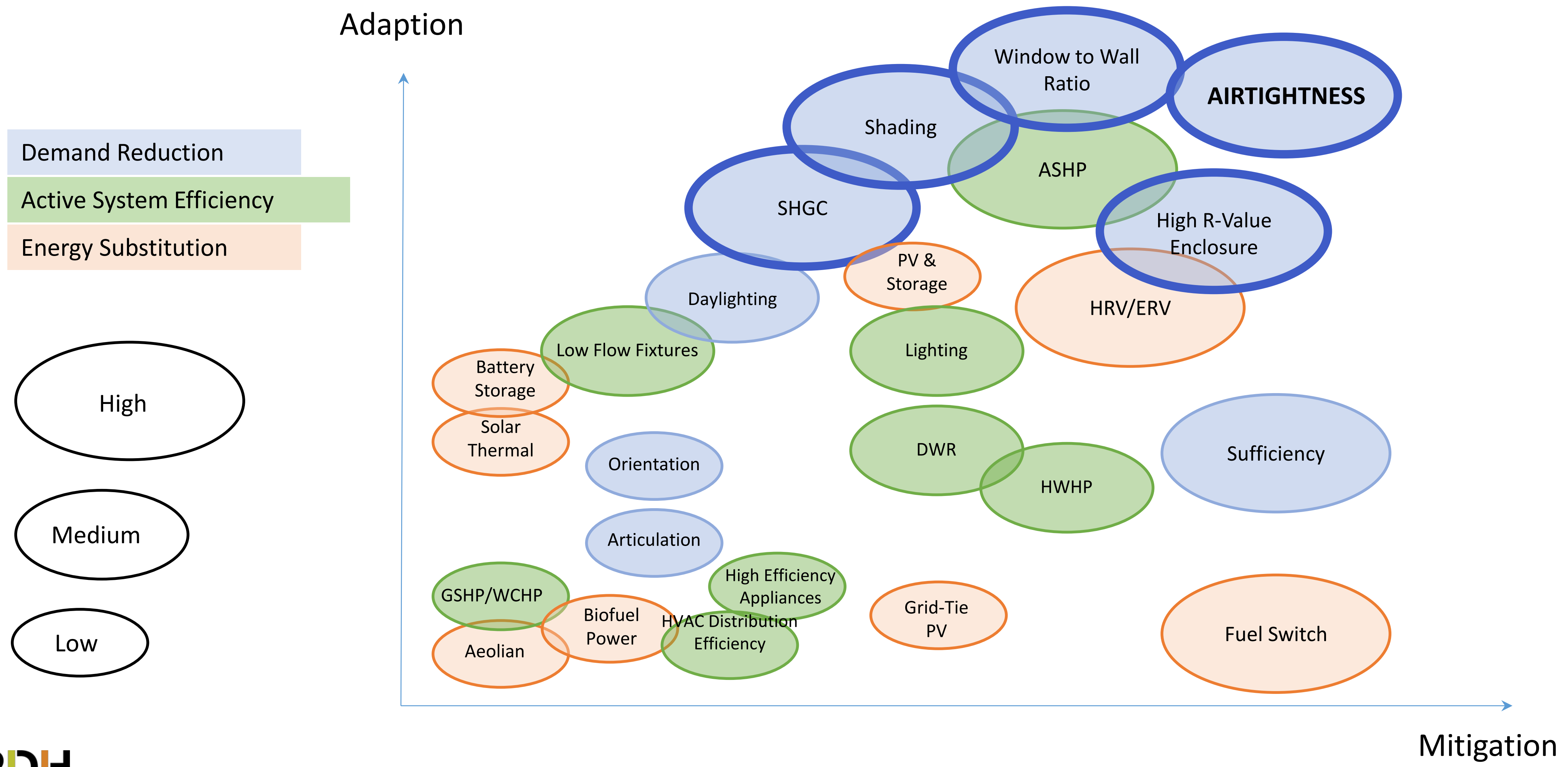
DRIVERS

Global average temperature compared to the middle of the 20th century



Source: NOAA Climate.gov

Demand Reduction – Enclosure Performance



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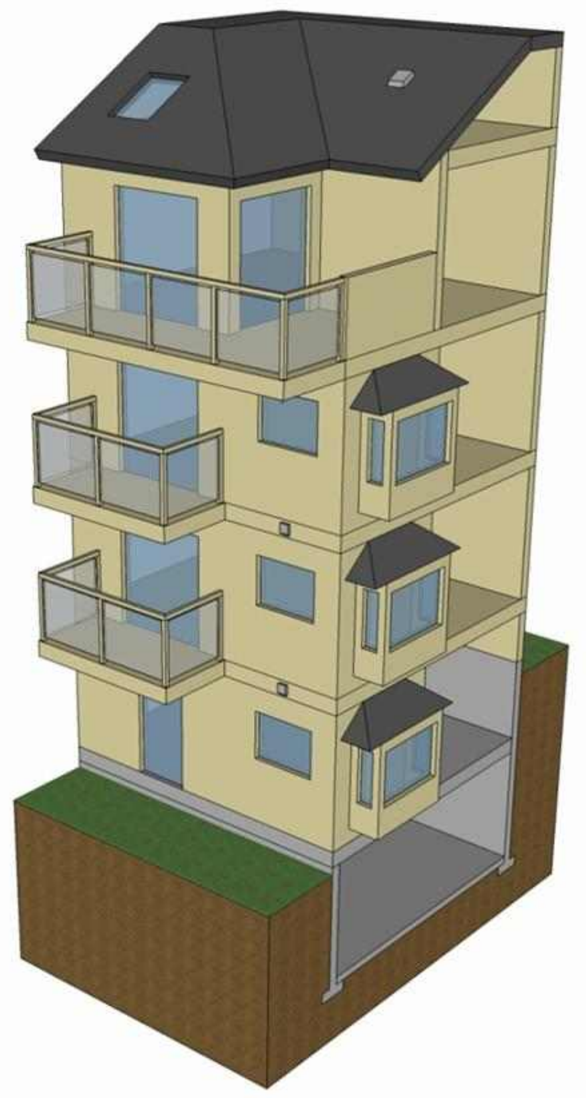
Building Enclosure Design Fundamentals

- Separate indoors from outdoors, by controlling:
  - Heat flow
  - Air flow
  - Vapor diffusion
  - Water penetration
  - Condensation
  - Light and solar radiation
  - Noise, fire, and smoke

- While at the same time:
  - Transferring structural loads
  - Being durable and maintainable
  - Being economical & constructible
  - Looking good!

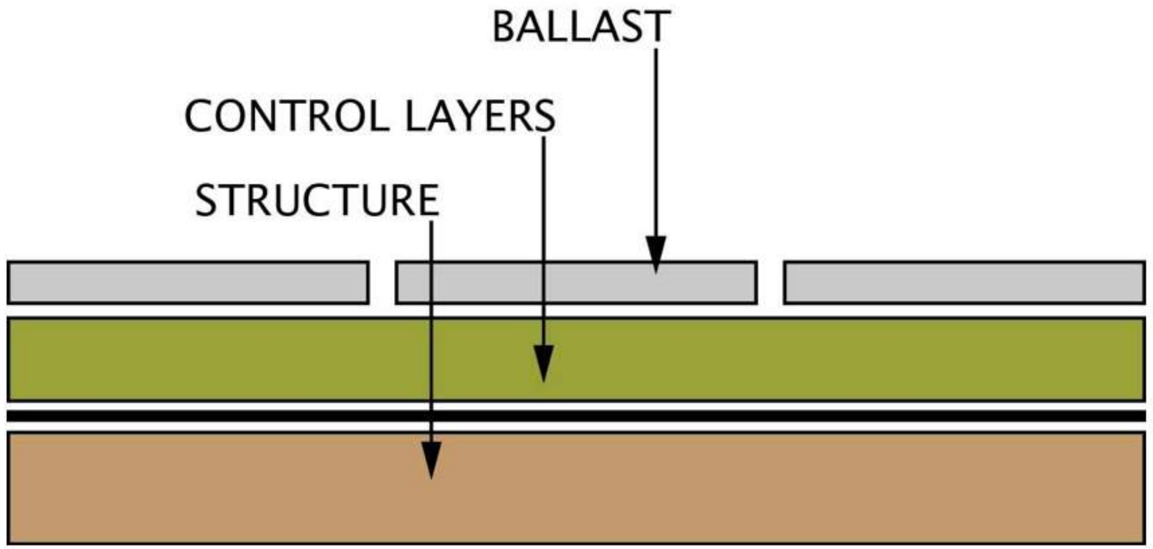


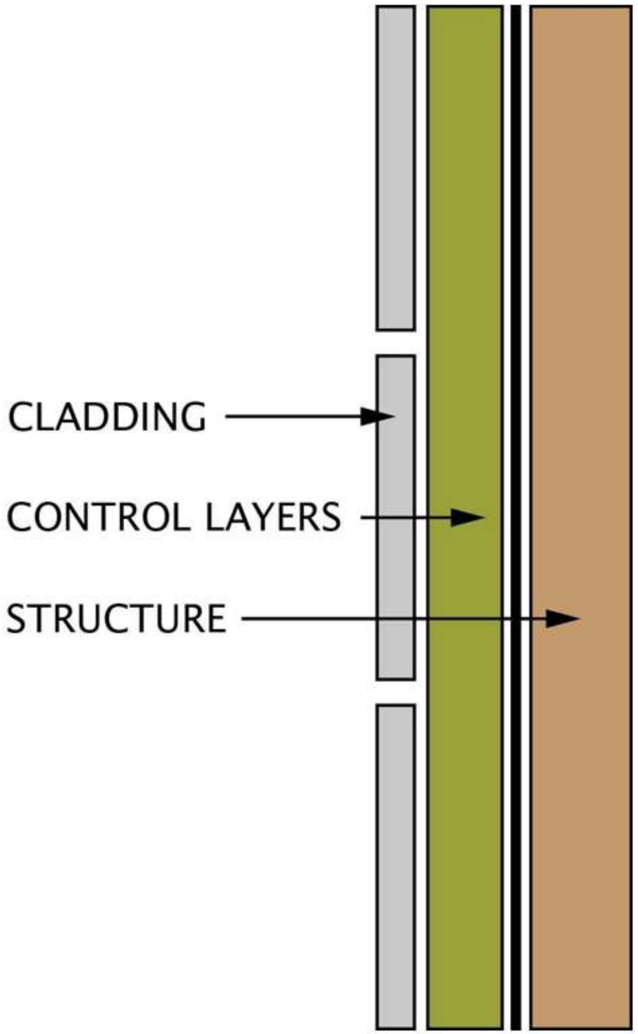
What do we know?

- **Control Rain** – Rainwater penetration causes most problems - poor details (e.g. lack of, poorly implemented, wrong materials)
- **Control Air** – Air leakage condensation can cause serious problems – especially in pressurized buildings in colder-climates and energy
- **Control Vapor** – Vapor diffusion can cause wetting – but more importantly is critical to drying after construction and in-service
- **Control Heat** – But do so smartly – place insulation on the outside of structural elements, warmer materials are drier materials

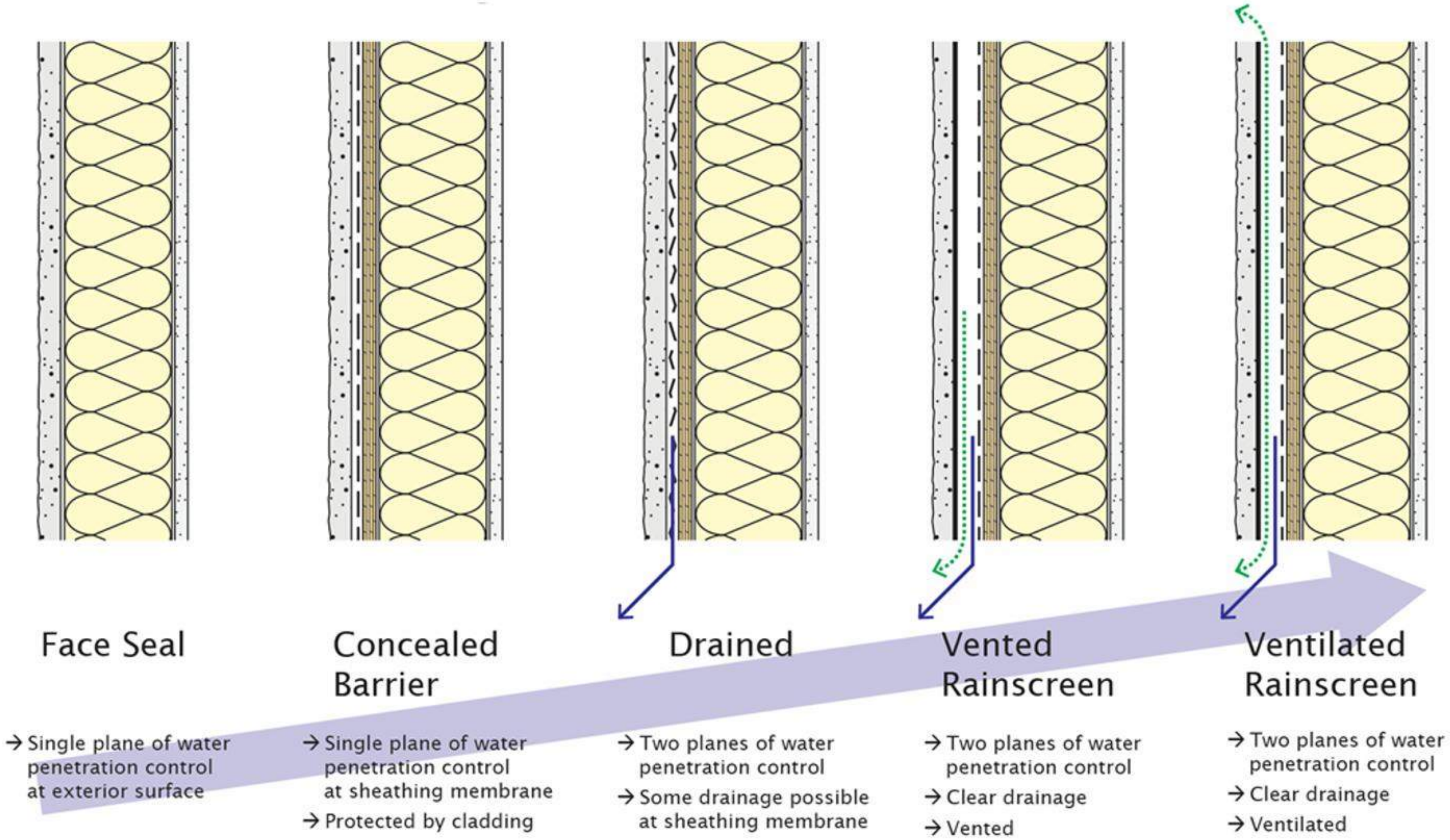
The 'Perfect' Assembly

- → Rain penetration control: rainscreen cladding over water barrier
- → Air leakage control: robust air barrier system
- → Heat control: continuous insulation layer
- → Locate all barriers **exterior** of structure
  - → Keep structure warm and dry
- → 50+ year old concept!





Water Penetration Control Strategies



Types of Air Barrier Systems

Loose Sheet Applied Membrane – Taped Joints & Strapping

Sealed Gypsum Sheathing – Sealant Filler at Joints

Liquid Applied – Silicone sealants and silicone membrane at Joints

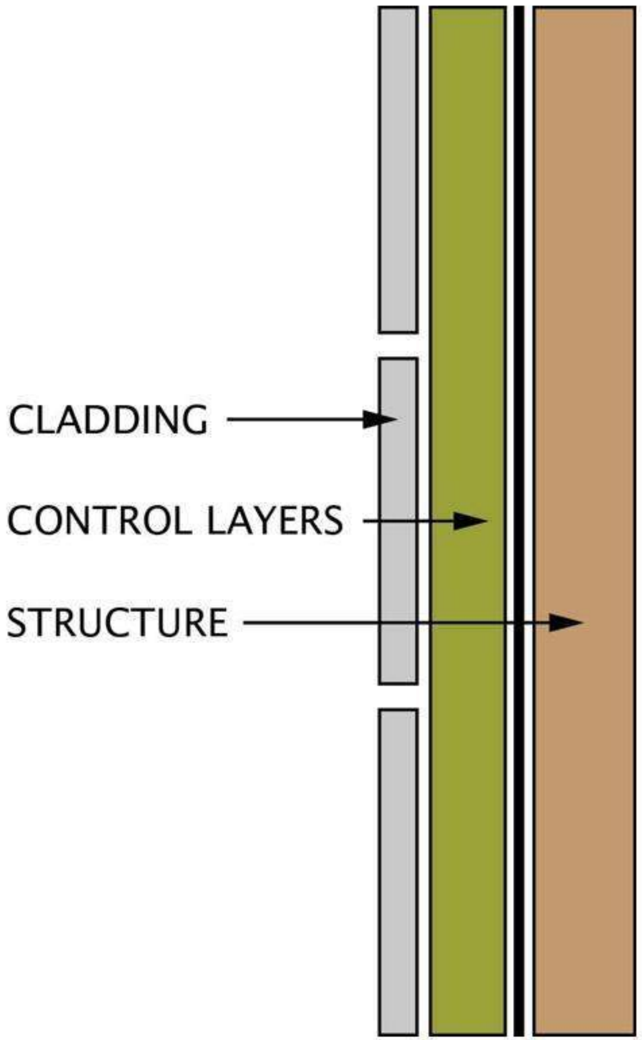
Sealed Plywood Sheathing – Sealant & Membrane at Joints

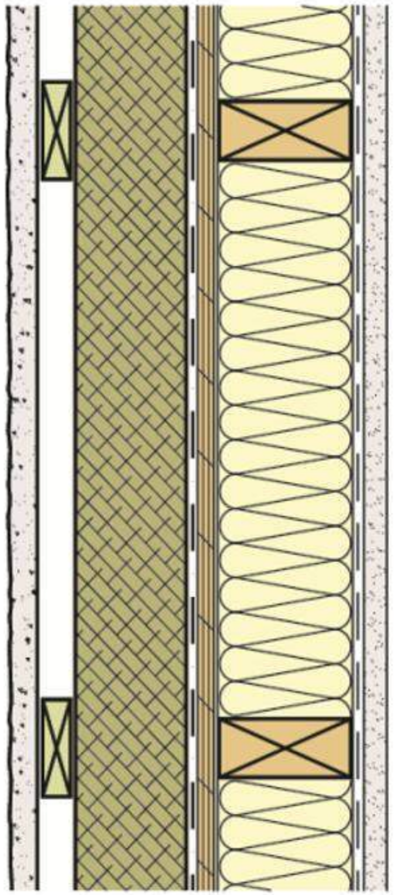
Sealed Sheathing – Membrane at Joints

Self-Adhered vapor permeable membrane

Plywood sheathing with taped joints (good tape)

Wood-Frame Assemblies – 'Perfect' Wall





EXTERIOR

- Cladding
- Airspace (ventilated)
- 1x3 wood strapping, screwed through Insulation
- Rigid, mineral-fibre insulation (thickness to meet R-value requirement)
- Vapour-permeable sheathing membrane
- Sheathing (plywood or OSB)
- 2x4 or 2x6 wood framing with batt insulation
- Polyethylene film (cold climates only)
- Gypsum board and paint

INTERIOR

Trends in Building Enclosure Design

- Trend towards more energy efficiently building enclosures
- Air barriers now required in 2012 IECC and 2013 CEC
- Continuous insulation becoming more common
  - Seeing more new building materials, enclosure assemblies and construction techniques

- **More insulation = less heat flow to dry out moisture**
  - “Marginal” assemblies that worked in the past may no longer work
  - Amount, type and placement of insulations matters, for vapor, air and moisture control

- **Need to fully understand the science and interaction of design parameters**


Tyvek
COMMERCIALWRAP


Tyvek

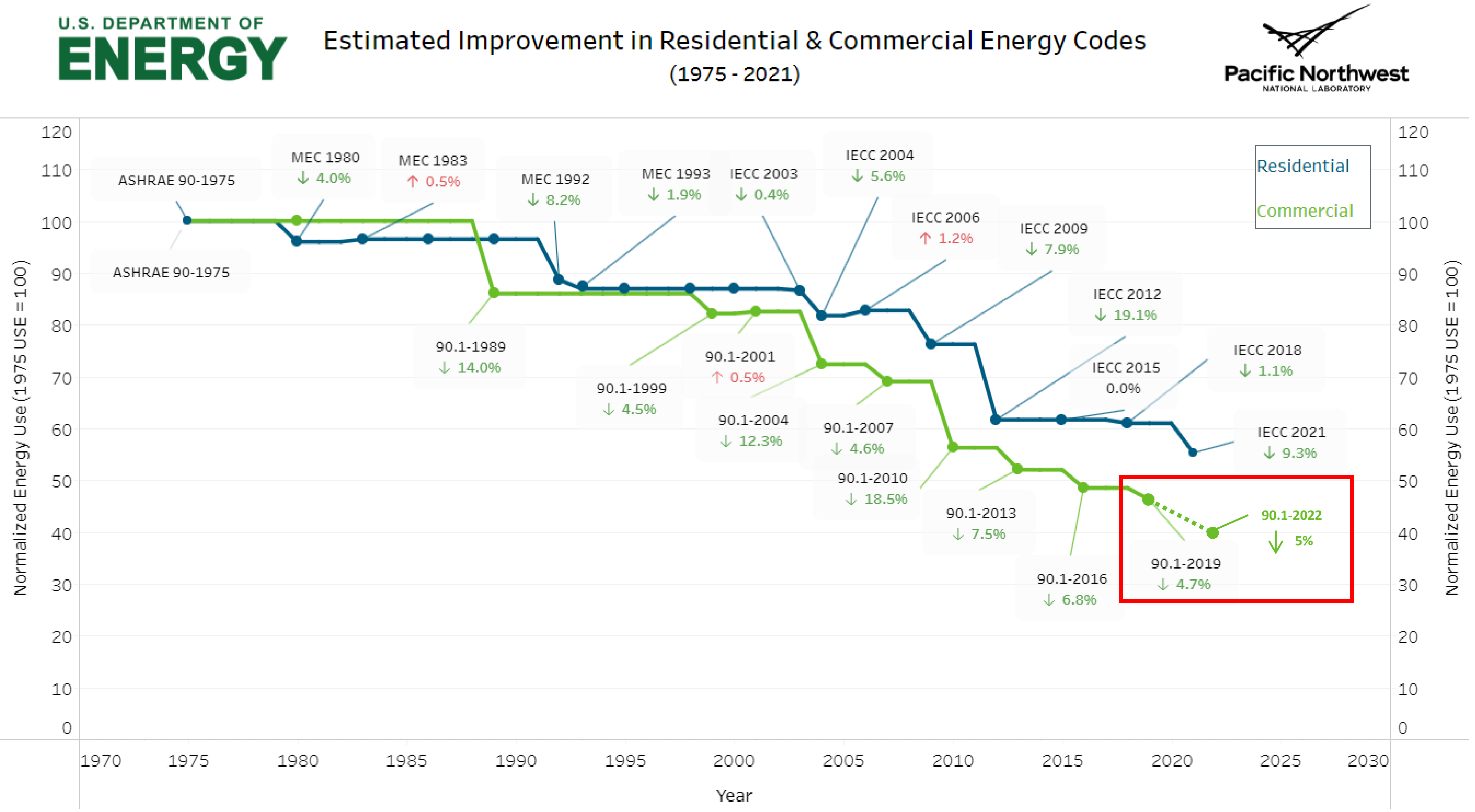

Tyvek

2 Recent Trends

Now vs. Then

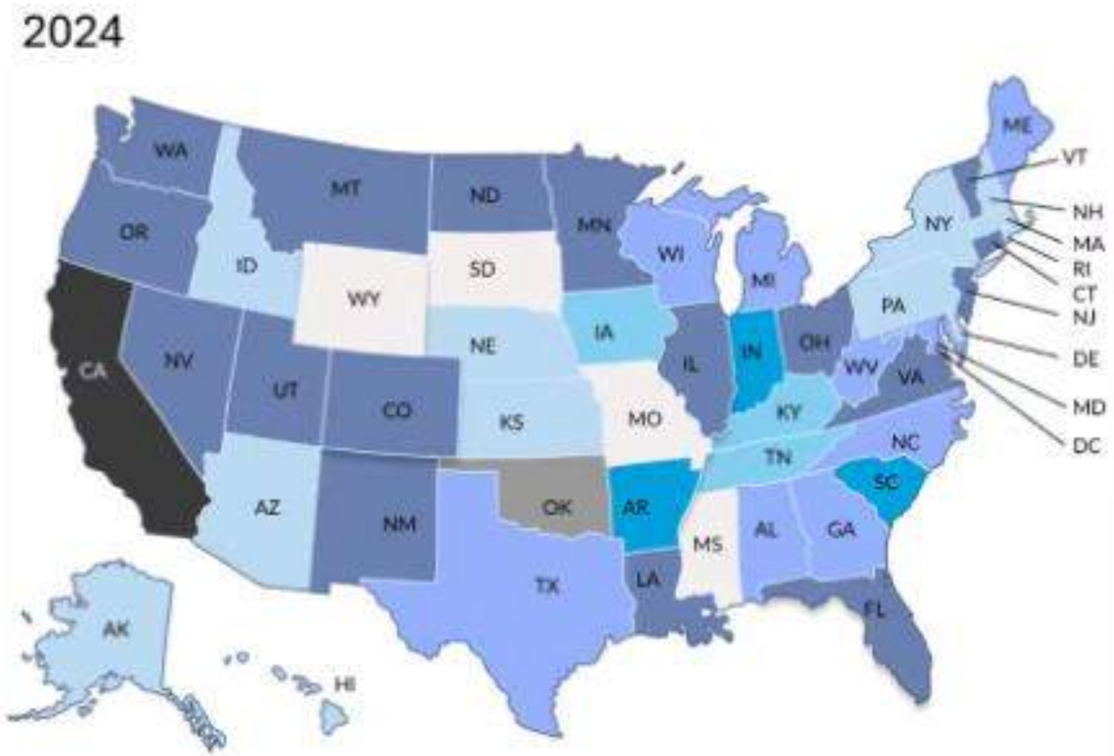
- Control Rain:
  - Then: focus on WRB continuity, flashing details, integration
  - Now: Drainage provisions updated over time by climate
- Control Air:
  - Then: Air barriers requirements emerging in Energy Codes; testing requirements in leading jurisdictions
  - Now: Requirements spreading quickly across regions
- Control Vapor:
  - Adjustments, largely do consider the use of exterior insulation
- Control Thermal:
  - Incrementally stricter targets over time
  - More focus on thermal bridging

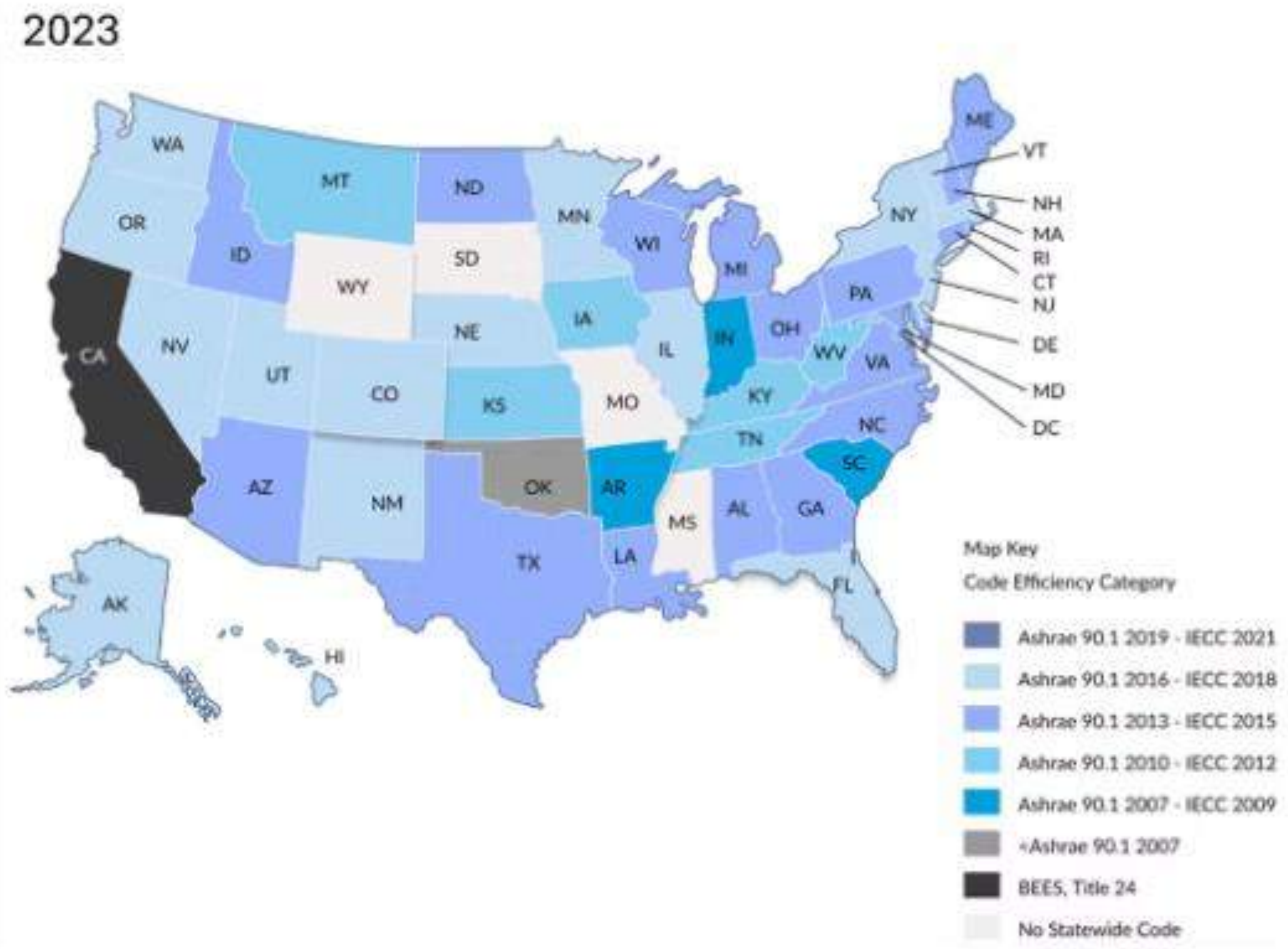
Energy Code Trends



ving Codes

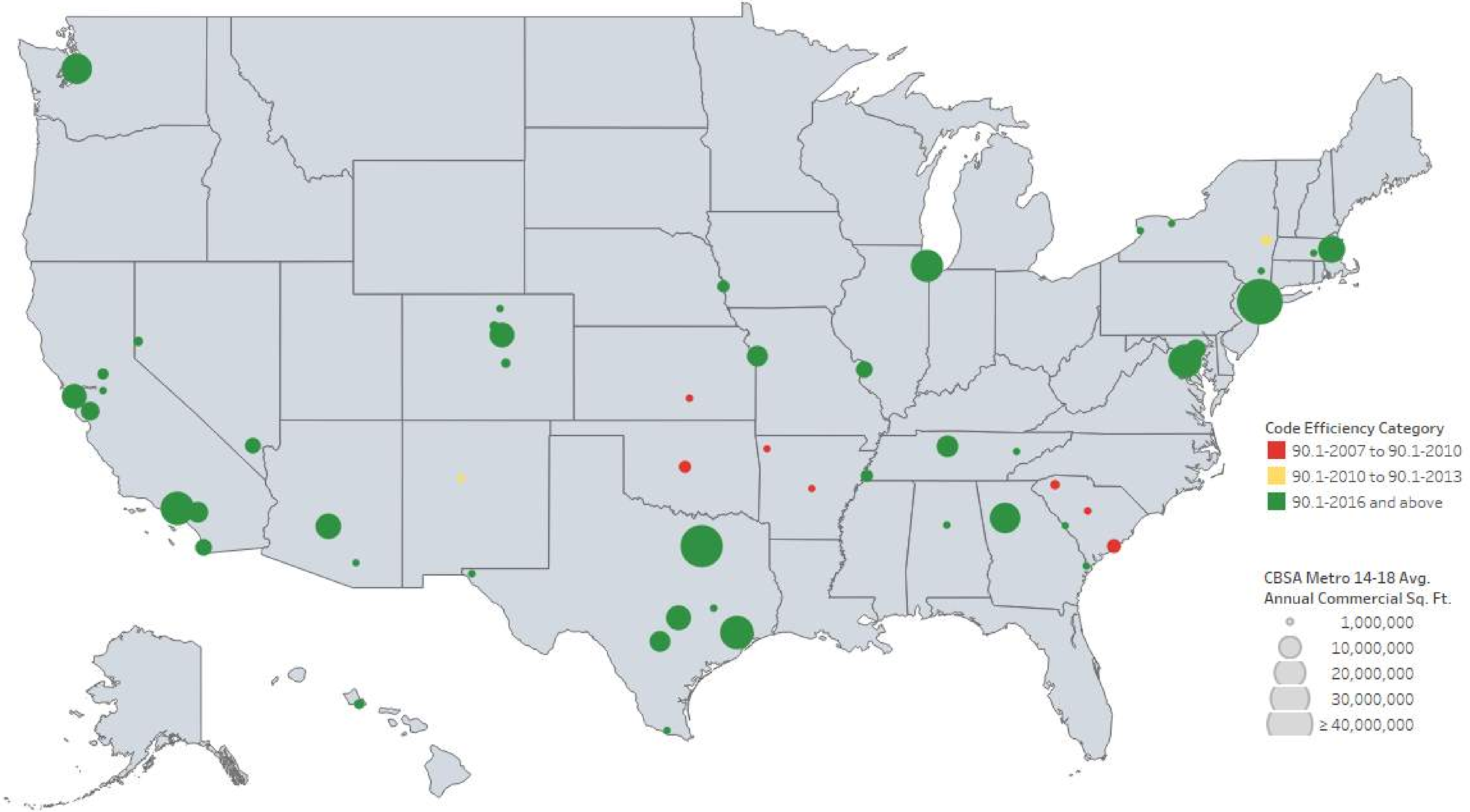
IECC Adoption





City Commercial Energy Code Efficiency

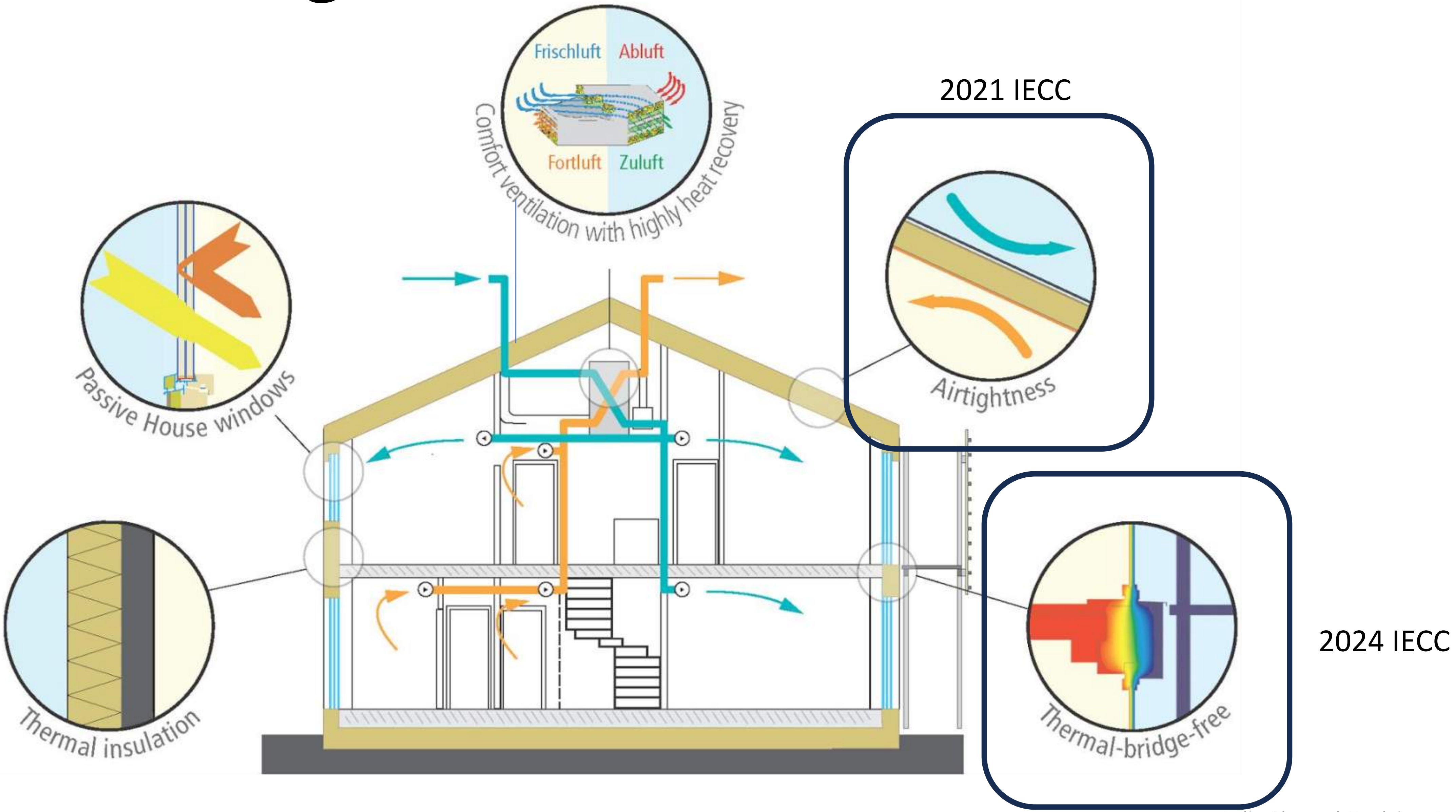
(with Authority to Adopt)



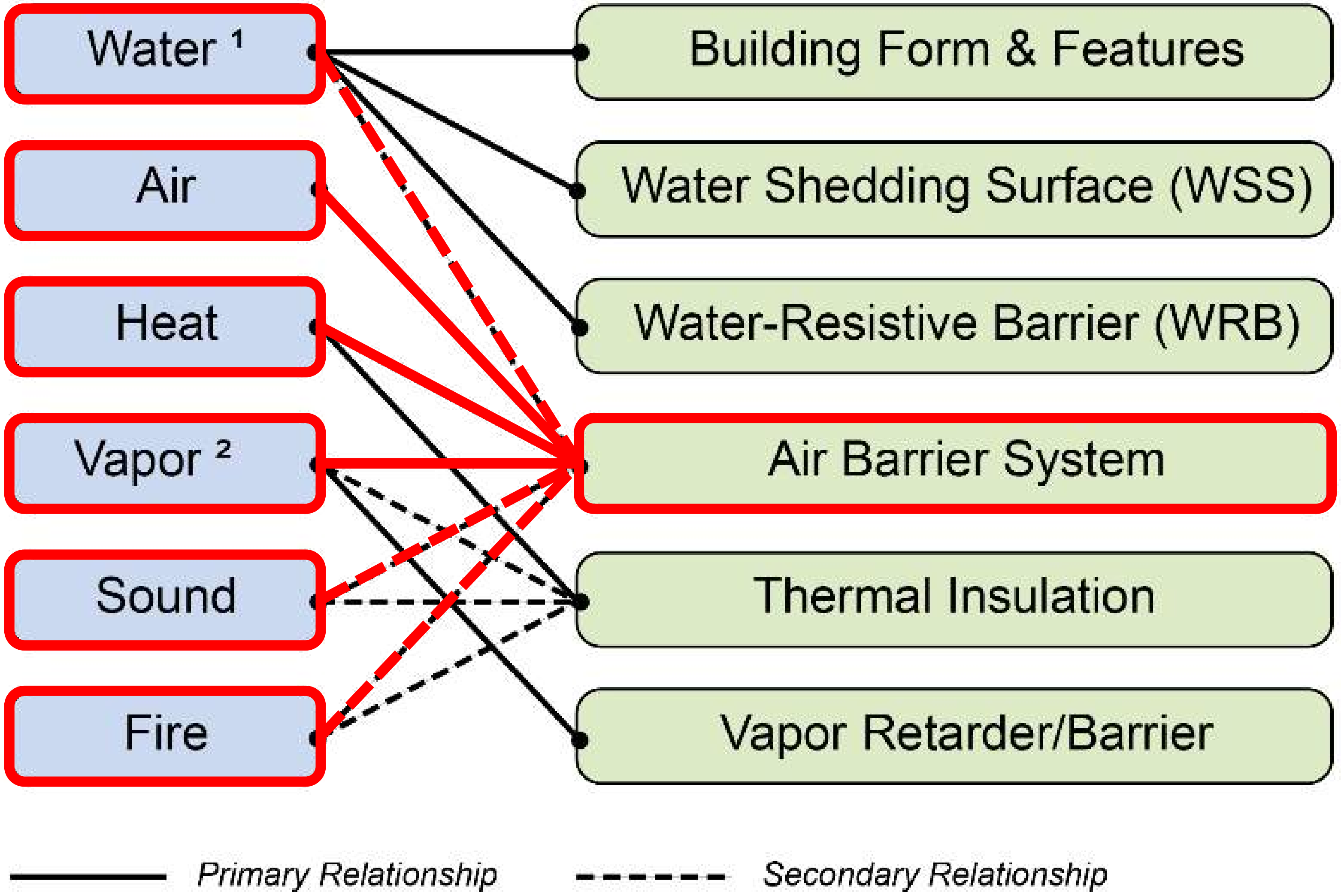
Commercial Floor Area: 2014-2018 Dodge Data
Updated as of 06/28/24

Evolving Codes

Whole Building Performance



Control Layer Concepts and Systems



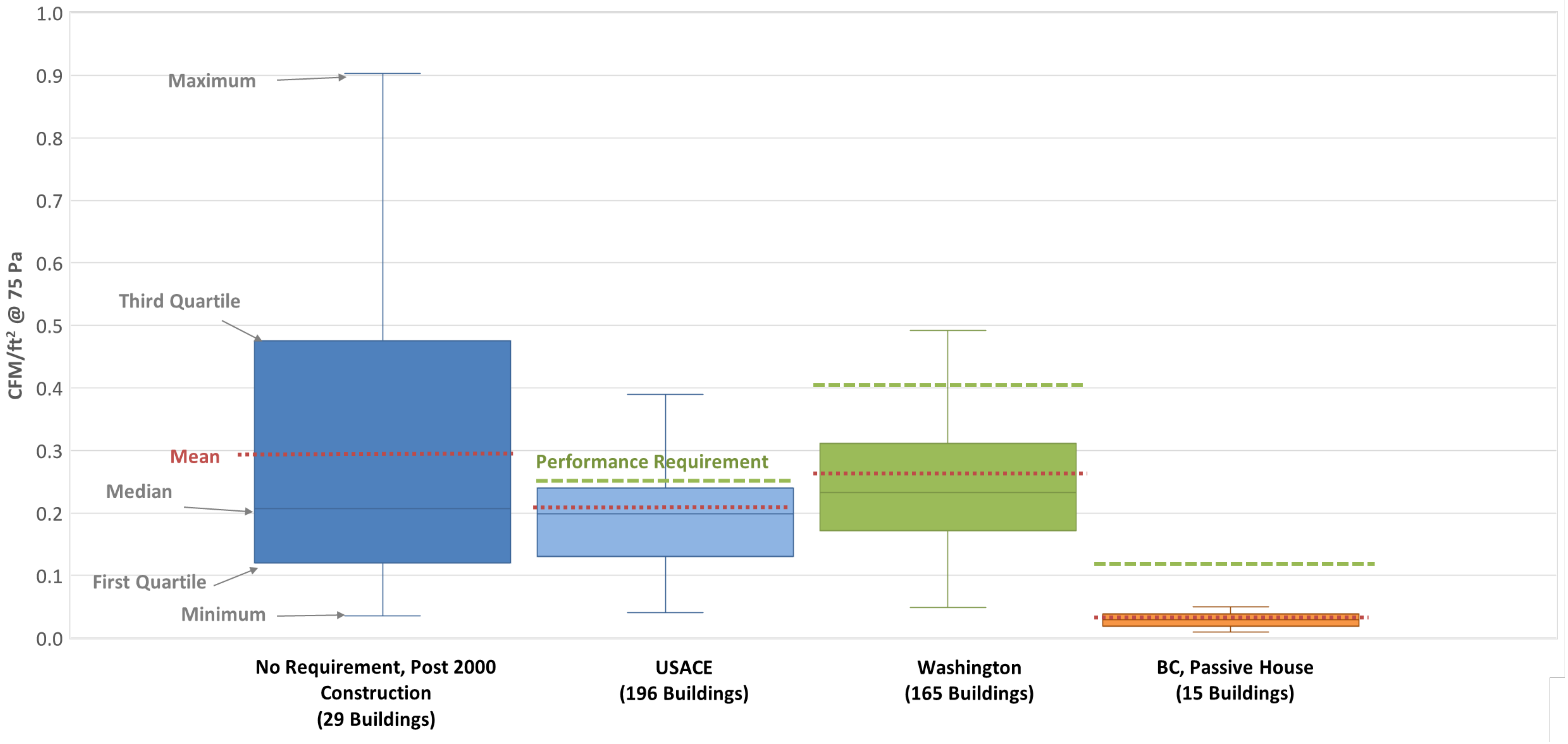
1 – Water is defined here as precipitation (rain, snow, hail, etc.) and ground water

2 – Vapor is separately defined here as the water vapor in air, as well as condensate moisture

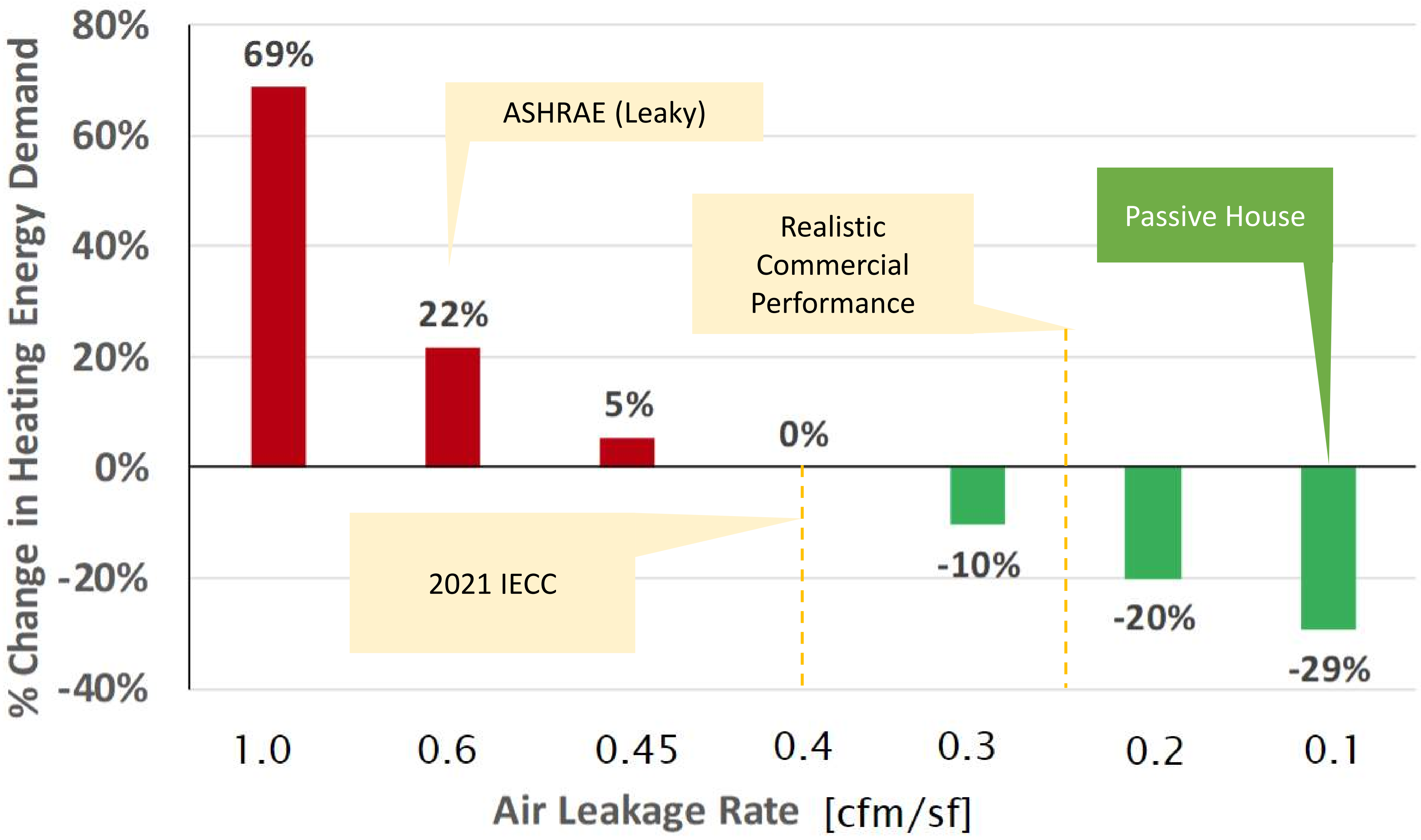
Seattle & Washington

- <2006: You have to seal the building
- 2009: You have to have a continuous air barrier and test the building (0.4 cfm/sf target)
- 2012: You “have to” pass the test (0.4 cfm/sf)
- 2015: You “have to” pass the test (0.3 cfm/sf)
- 2018: You “have to” pass the test (0.25 cfm/sf)

The Impact of Test Requirements

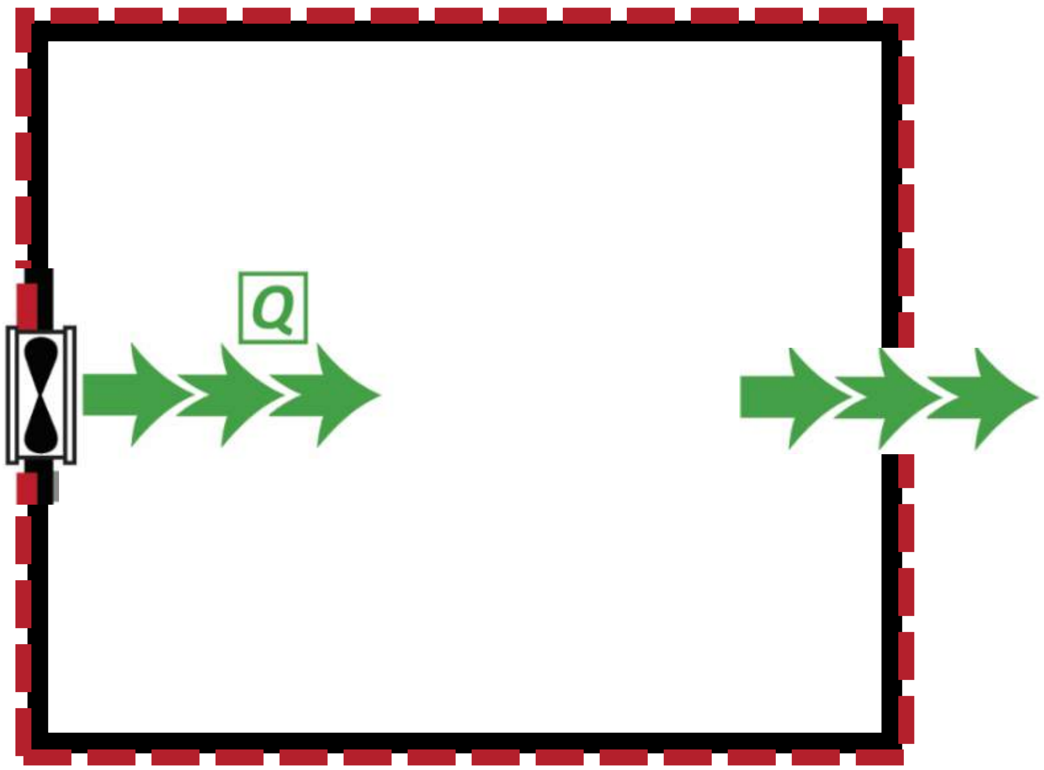


Air Leakage and Energy Savings



IECC 2021 Airtightness Testing

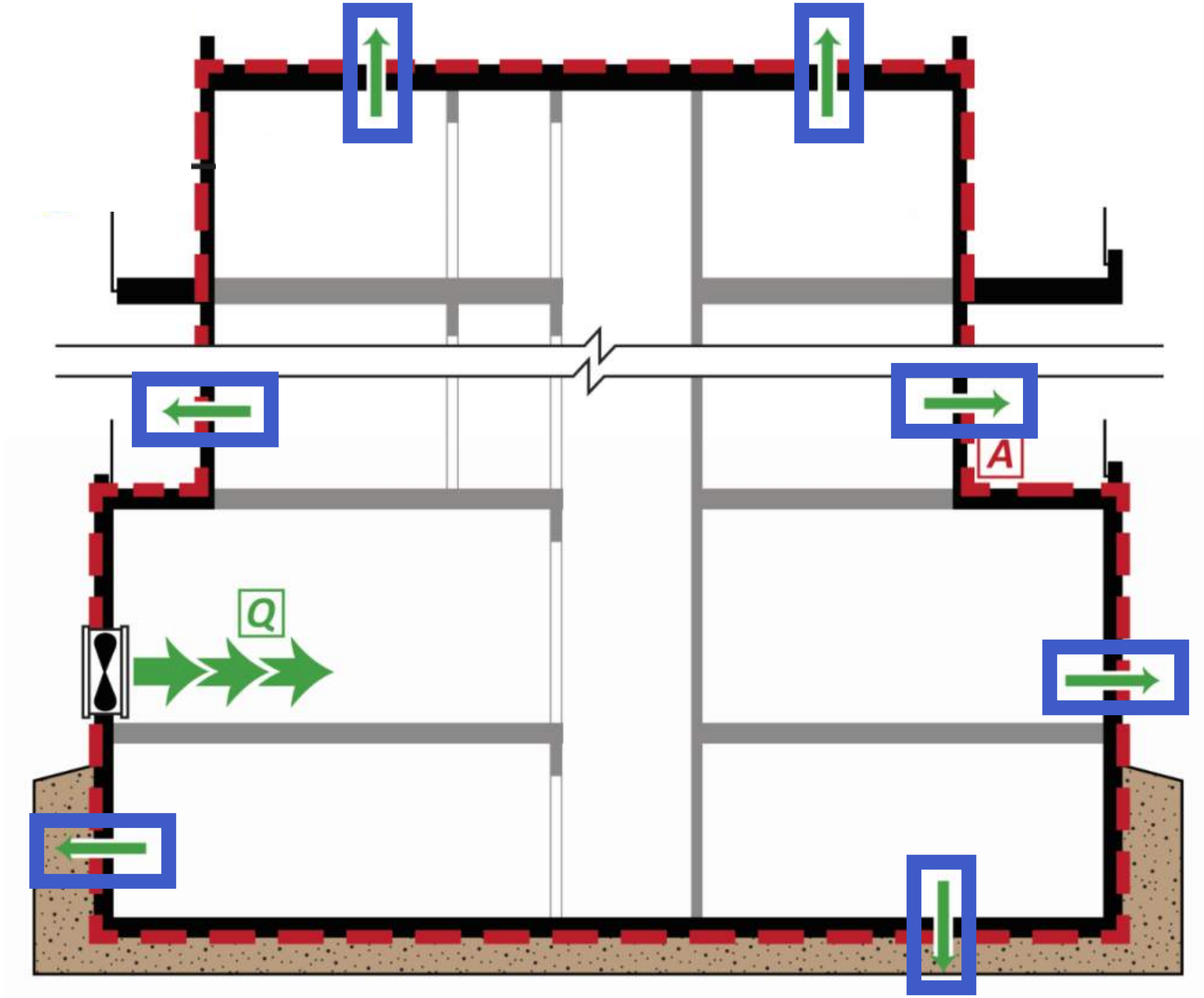
Airflow In = Airflow Out



Airtightness Testing

Airflow In = Airflow Out

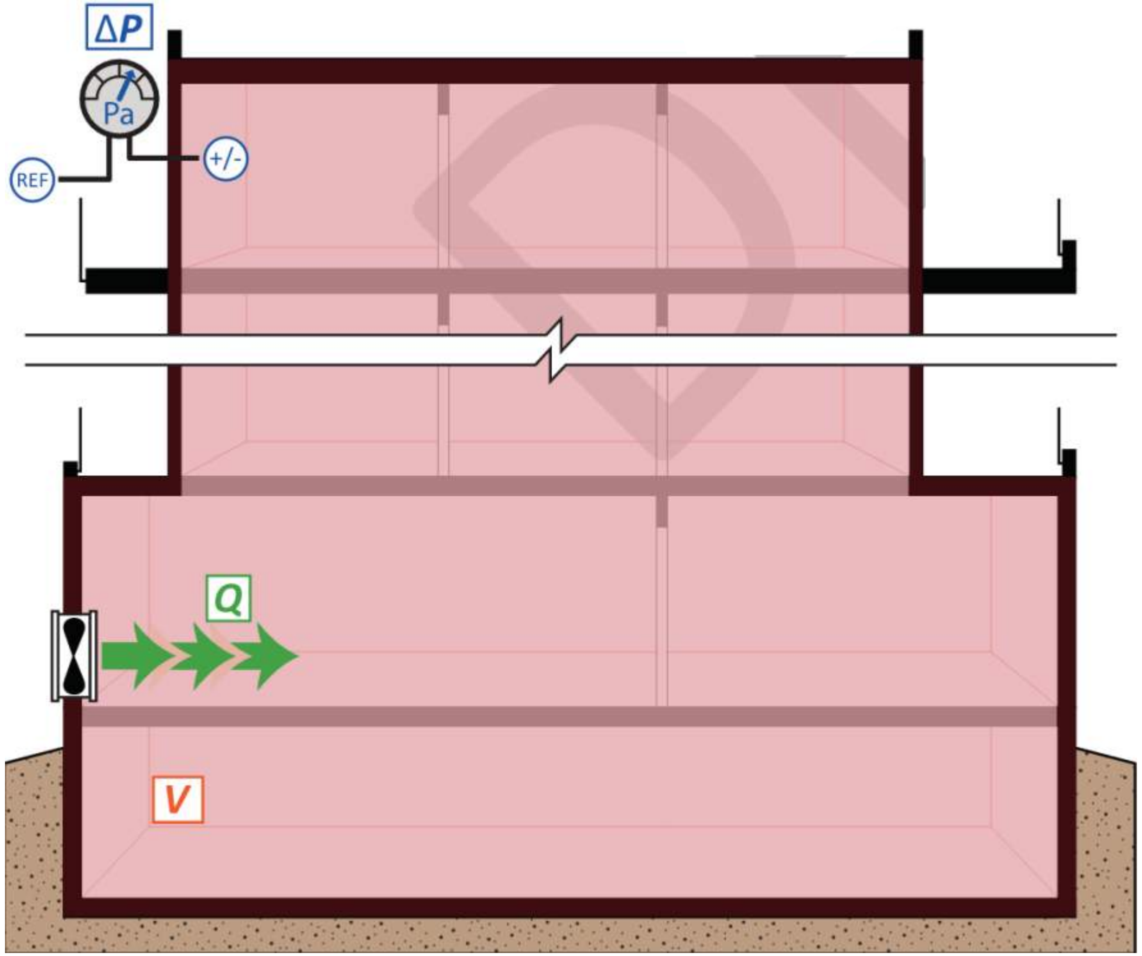
Air Leakage Rate (L/s•m², cfm/sf)



Airtightness Metrics

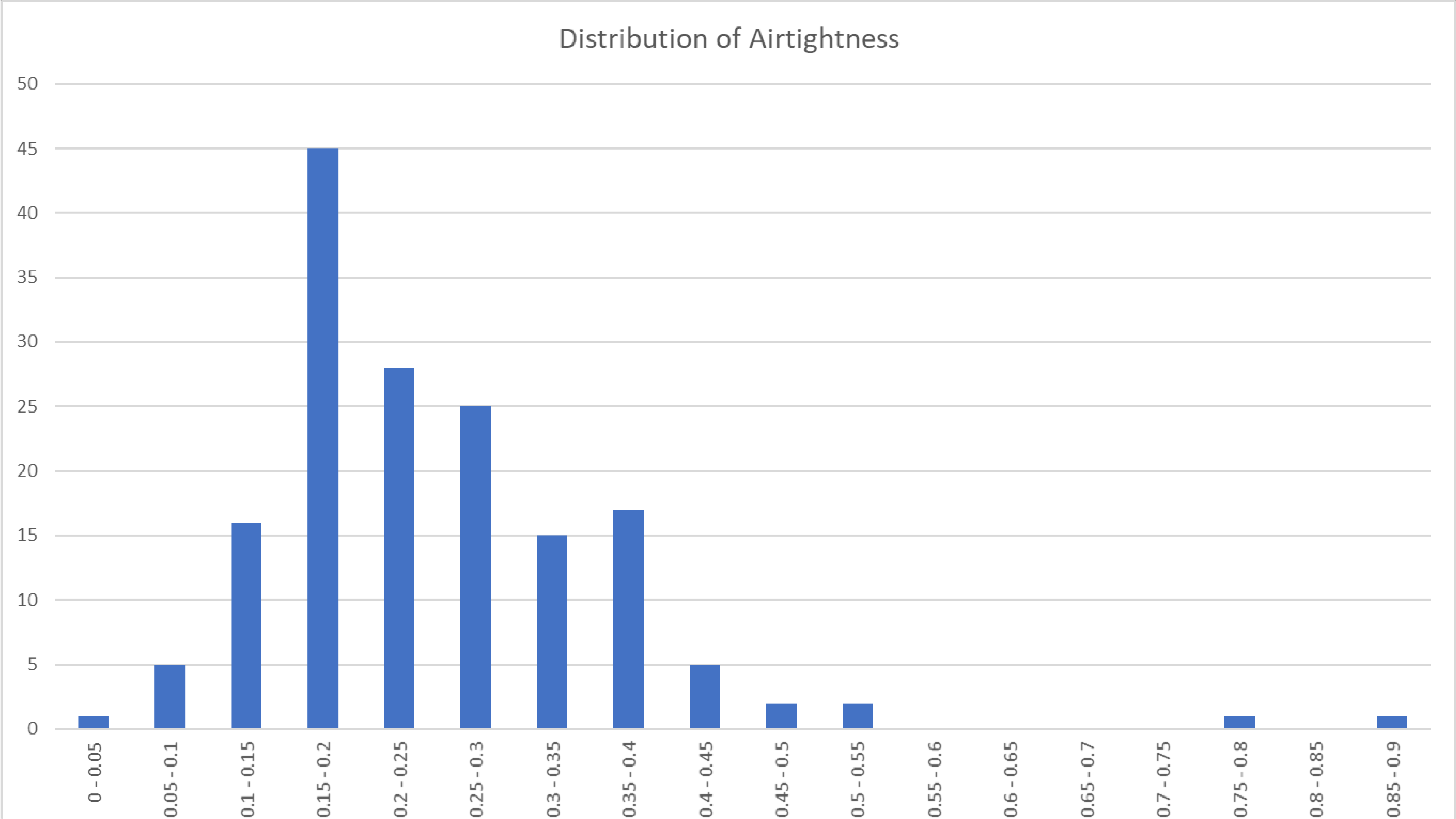
Air Change Rate

$$ACH_{\Delta P} = \frac{Q_{\Delta P}}{V}$$

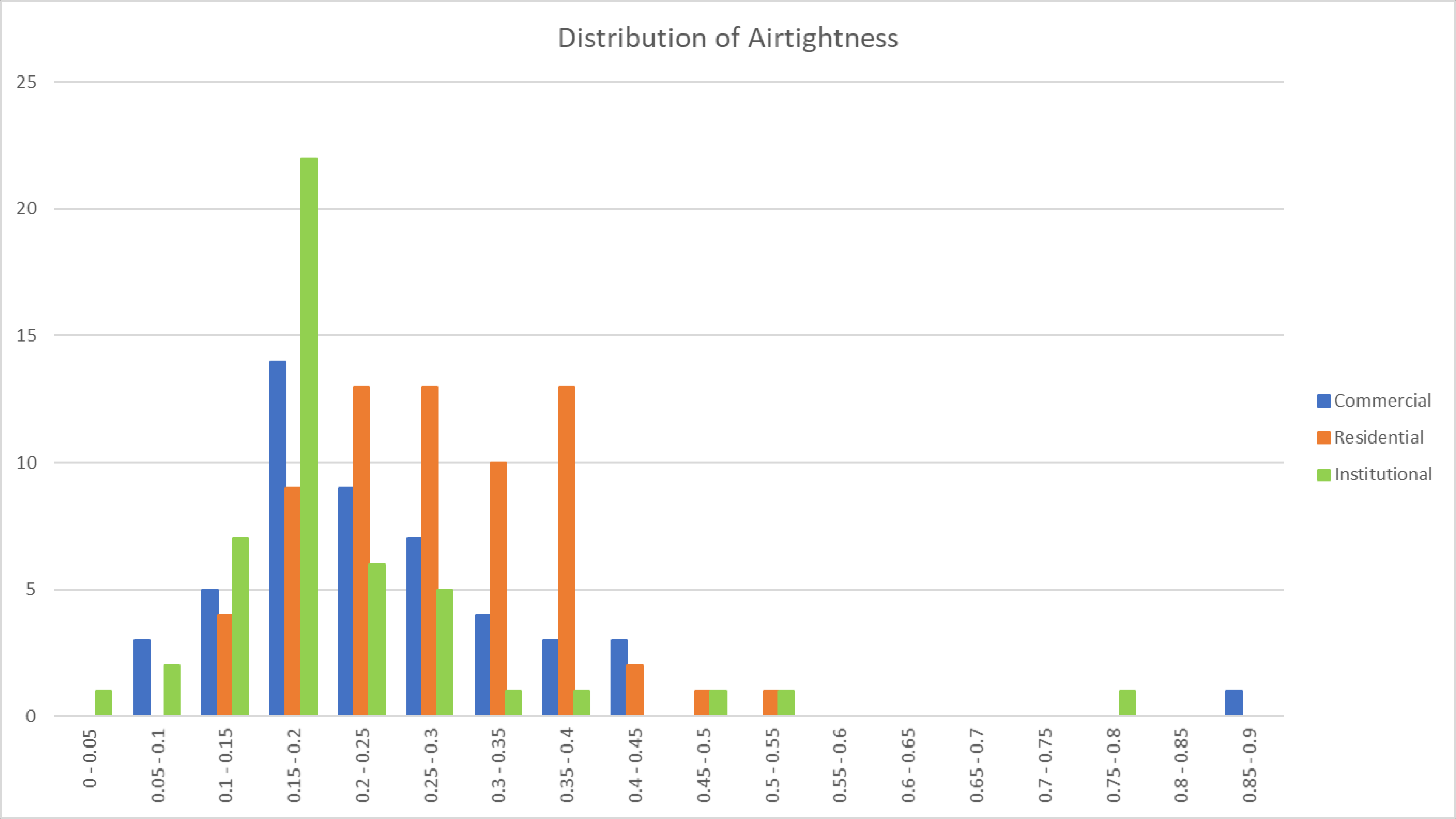


How have we been doing?

- Since 2009 code implementation
  - 250+ tests
  - 20,000,000 sf of enclosure area tested
- Overall average: 0.249 cfm/sf
- Tightest: 0.0485 cfm/sf
- Leakiest: 0.860 cfm/sf
- Sortable by:
  - Test date
  - Occupancy type
  - Air barrier type (at opaque walls)
  - Enclosure area
  - Pressurization or depressurization results



Distribution of Airtightness
50
45
40
35
30
25
20
15
10
5
0
0 - 0.05
0.05 - 0.1
0.1 - 0.15
0.15 - 0.2
0.2 - 0.25
0.25 - 0.3
0.3 - 0.35
0.35 - 0.4
0.4 - 0.45
0.45 - 0.5
0.5 - 0.55
0.55 - 0.6
0.6 - 0.65
0.65 - 0.7
0.7 - 0.75
0.75 - 0.8
0.8 - 0.85
0.85 - 0.9



Distribution of Airtightness
25
20
15
10
5
0
0 - 0.05
0.05 - 0.1
0.1 - 0.15
0.15 - 0.2
0.2 - 0.25
0.25 - 0.3
0.3 - 0.35
0.35 - 0.4
0.4 - 0.45
0.45 - 0.5
0.5 - 0.55
0.55 - 0.6
0.6 - 0.65
0.65 - 0.7
0.7 - 0.75
0.75 - 0.8
0.8 - 0.85
0.85 - 0.9
Commercial
Residential
Institutional

Takeaways: Missing Details

- It's usually not the details you have that get you in trouble…it's the details you don't have

3 What’s Next

21 -> 24 IECC - Oregon

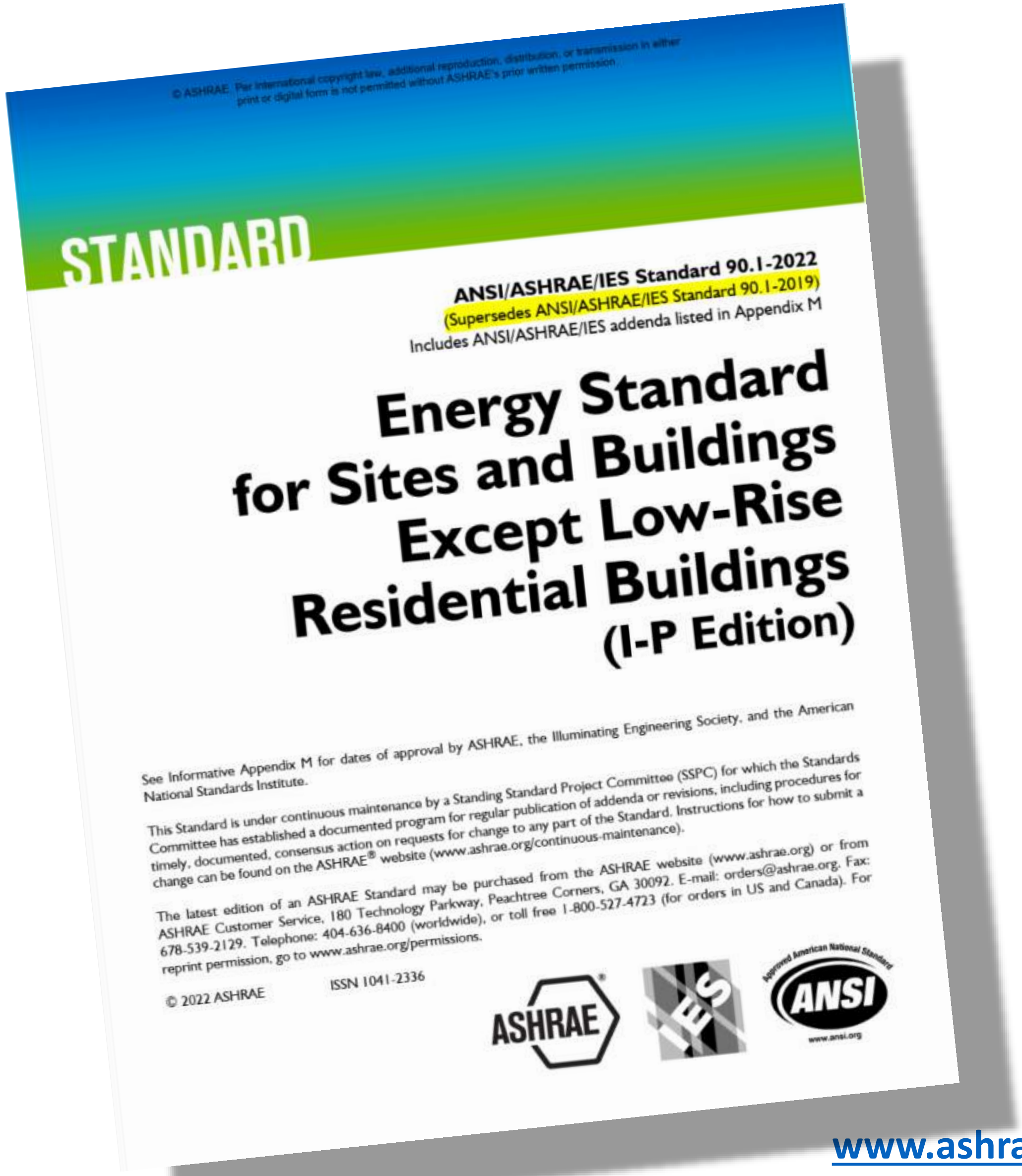
2021 OEESC Air Testing Requirements:

- Current air leakage pressurization test reported with a rate less than 0.40 cfm/ft^2 @ 75Pa
- **Exception 3:** Air leakage testing not required if continuous air barrier is designed and installation is verified by 3rd party, which is a requirement

2024 OEESC Air Testing Requirements:

- Air leakage rate drops to 0.35 cfm/ft^2 @ 75Pa.
  < 10,000ft^2 mandatory air leakage testing.
- > 10,000ft^2 *Design & Verification* required
- Test result between 0.35 cfm/ft^2 and 0.45 cfm/ft^2
  Seal what you can and inform AHJ
- > 0.45 cfm/ft^2 – seal and retesting required

ASHRAE 90.1-2022 Energy Standard


STANDARD

ANSI/ASHRAE/IES Standard 90.1-2022
(Supersedes ANSI/ASHRAE/IES Standard 90.1-2019)
Includes ANSI/ASHRAE/IES addenda listed in Appendix M

Energy Standard for Sites and Buildings Except Low-Rise Residential Buildings
(I-P Edition)

See Informative Appendix M for dates of approval by ASHRAE, the Illuminating Engineering Society, and the American National Standards Institute.

This Standard is under continuous maintenance by a Standing Standard Project Committee (SSPC) for which the Standards Committee has established a documented program for regular publication of addenda or revisions, including procedures for timely, documented, consensus action on requests for change to any part of the Standard. Instructions for how to submit a change can be found on the ASHRAE® website (www.ashrae.org/continuous-maintenance).

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2024 OEESC Effective January 1, 2024
with 6-month grace period

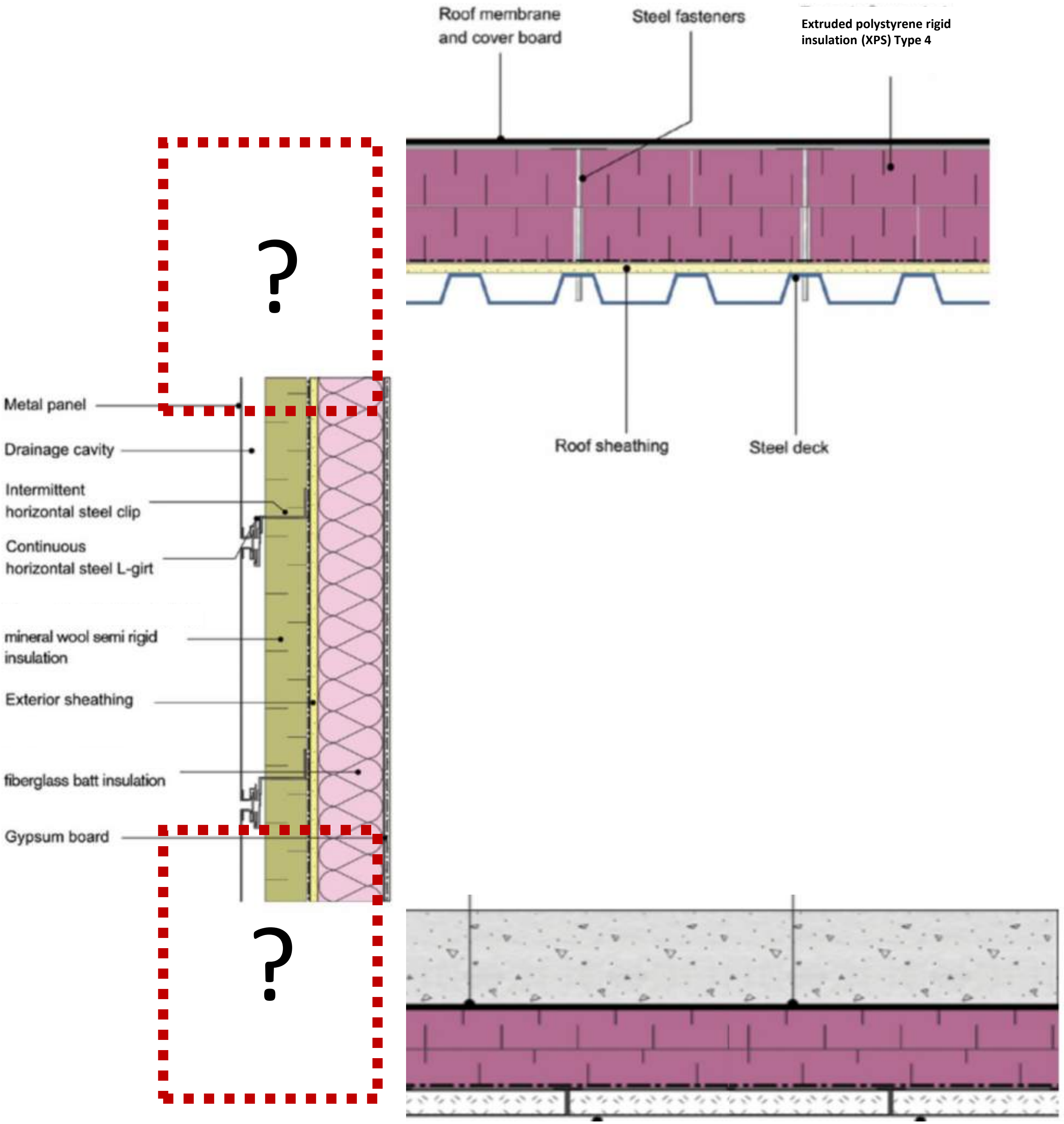
- What's New (Enclosure)
- Chapter 5 – Building Envelope
  - *5.5.5 – Linear and Point Thermal Bridging*
  - *Whole Building Air Leakage Testing < 25,000ft²*
- *Section 10.5 – Renewable Energy Resources*
- *Chapter 11 – Additional Efficiency Requirements (New)*
- Appendix A – Thermal Performance calculations
  - *Reformatted for clarity*
  - *Table A10.1 psi- and chi-factors (New)*
- *Appendix K – Thermal Bridges (New)*

www.ashrae.org

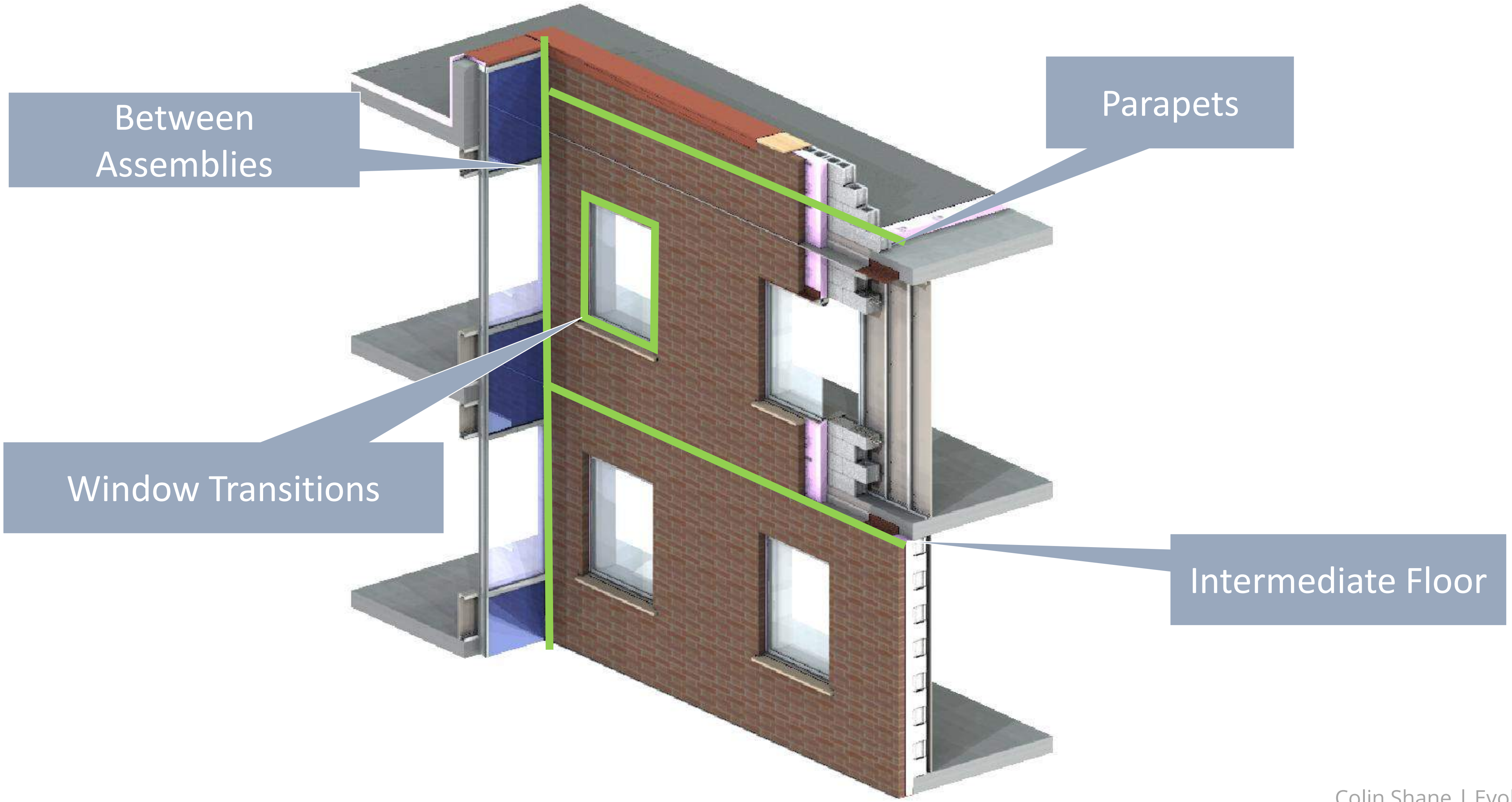
What About Interfaces?

- The way that enclosure assemblies interface can greatly impact the actual heat flow through a building enclosure

- Is more impactful for non-combustible buildings than wood-frame due to thermal bridging



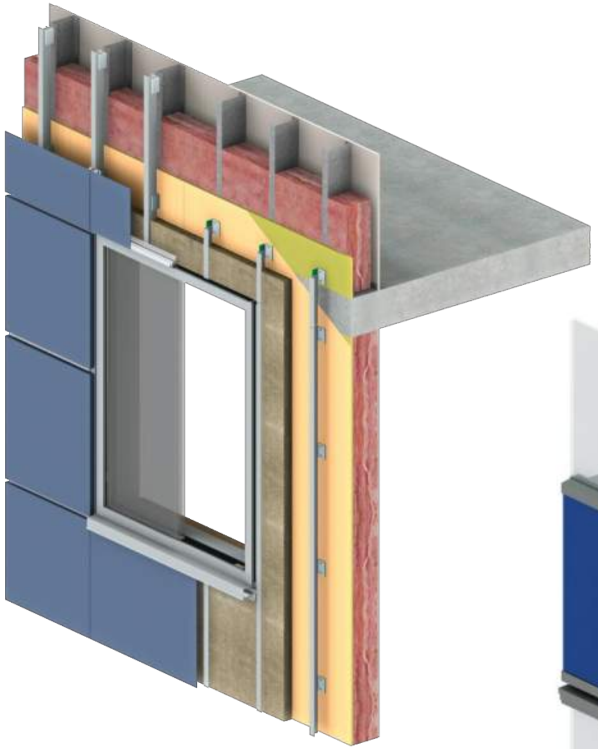
Wall Assembly is Just One Part of the System

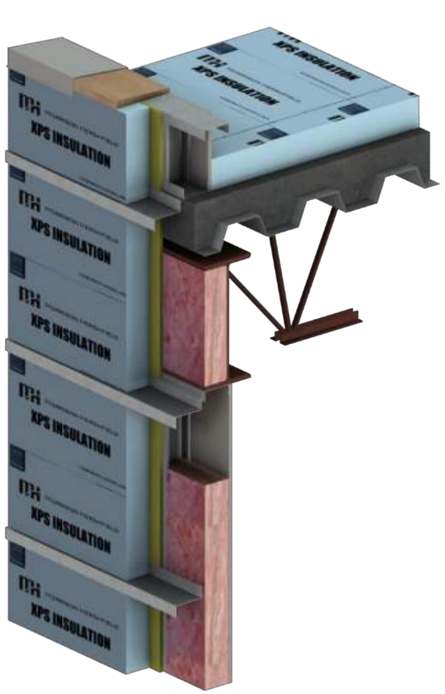


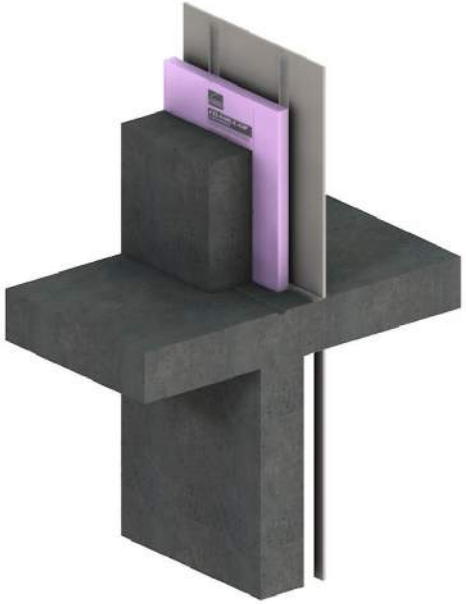
BC Hydro Building Envelope Thermal Bridging Guide (BETBG) – MH

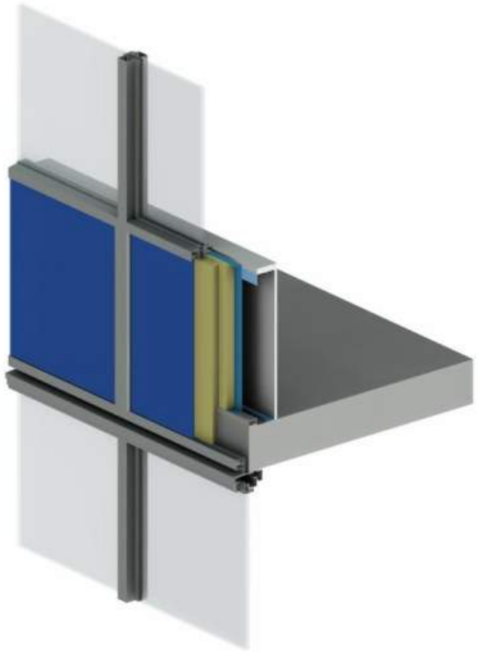
Interface Assemblies

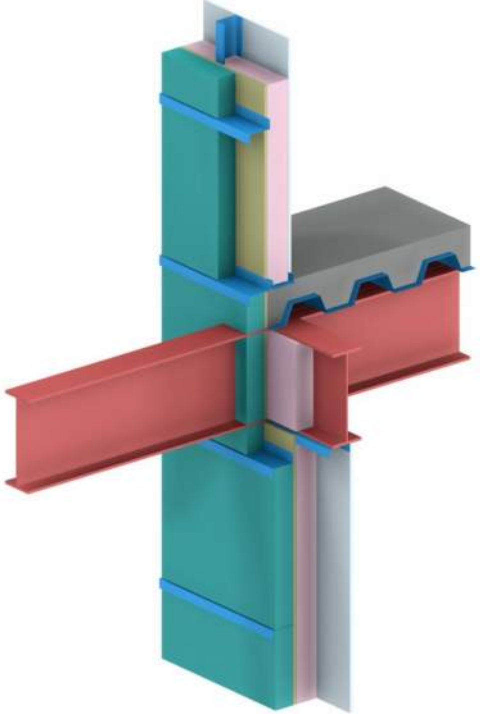
- **Geometric Bridges**
  - Corners
  - Parapets
- **Transitions**
  - Window-wall interfaces
  - Wall to roof
- **Penetrations**
  - Balconies
  - Beams





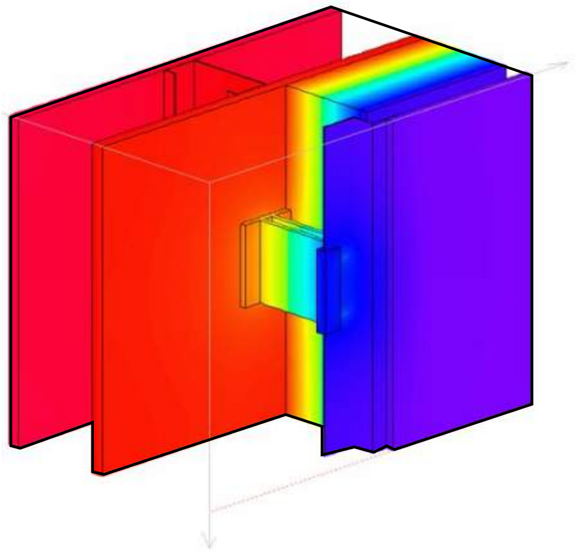






Accounting for Interfaces (By Length + By Each)

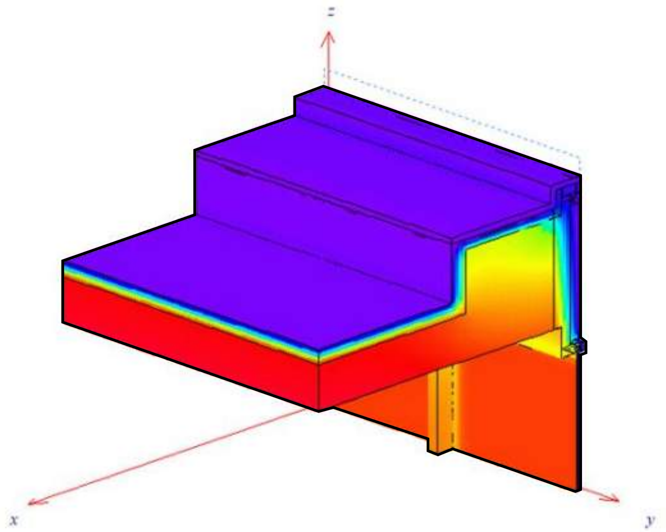
Clear Field Assemblies



U_o

heat loss per area

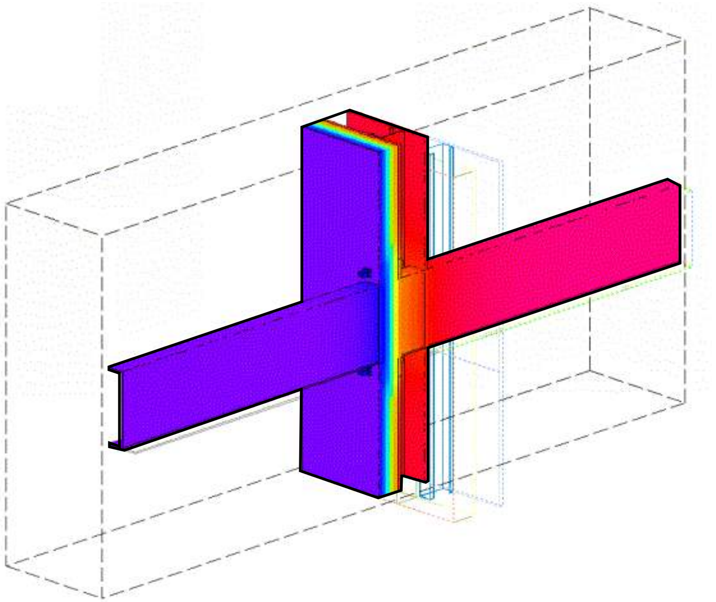
+Linear



Ψ

Psi, additional heat loss per length

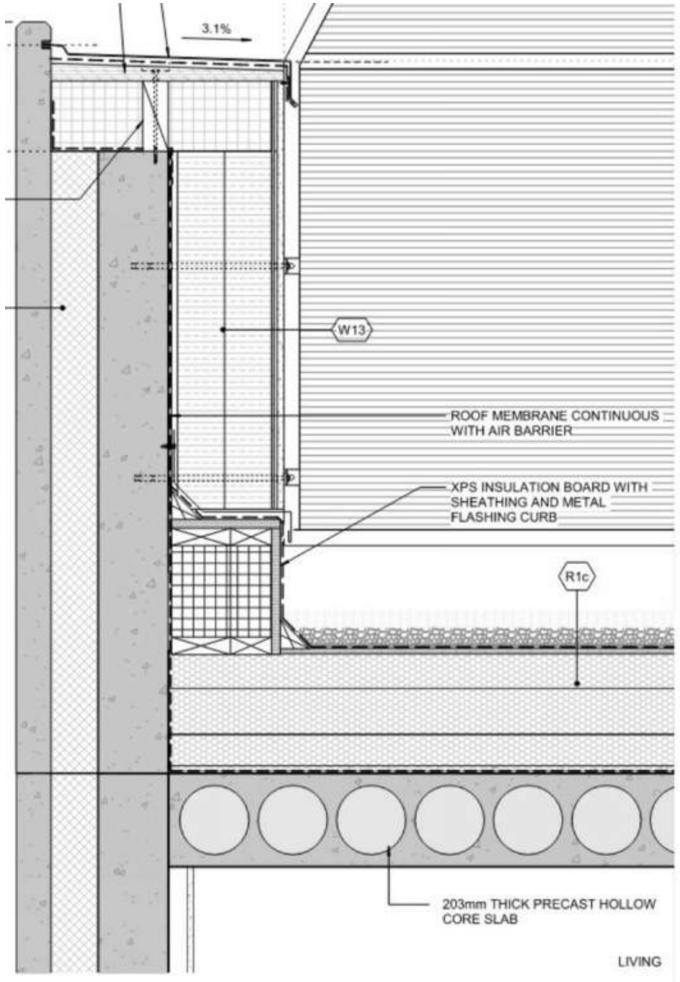
+Point

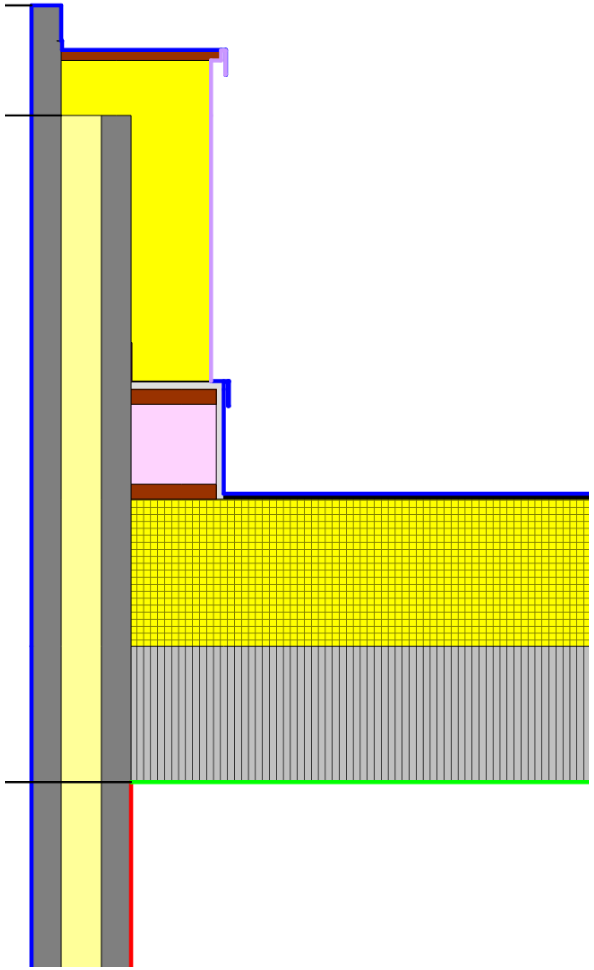


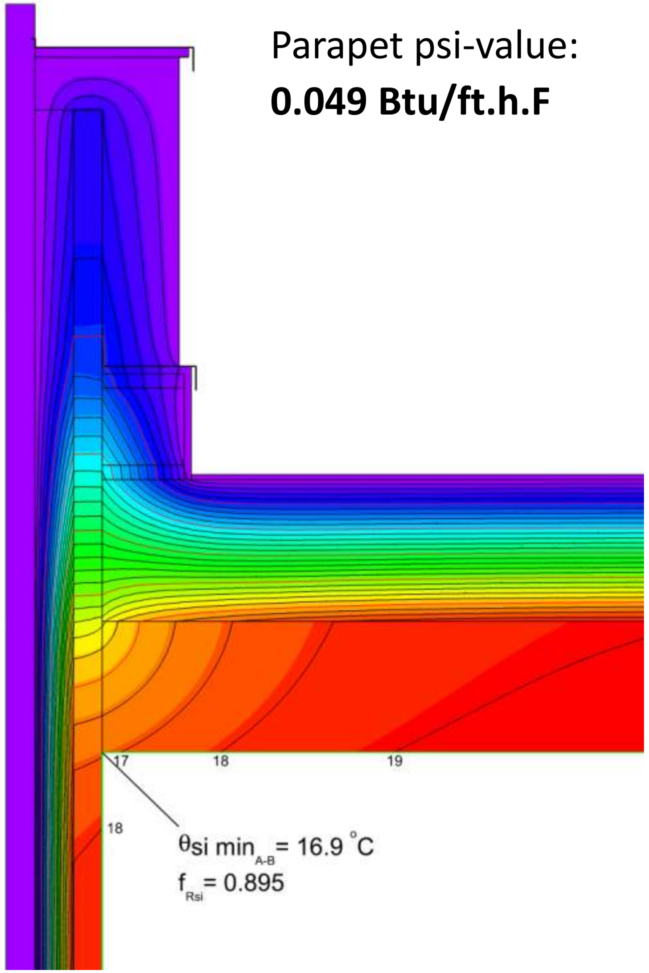
χ

Chi, additional heat loss per point

Example Linear Thermal Bridges







Parapet psi-value:

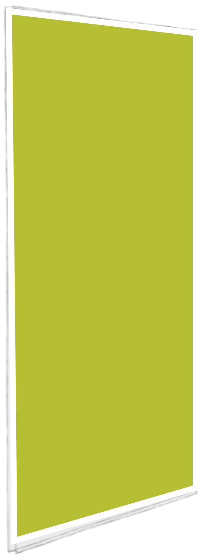
0.049 Btu/ft.h.F

Window U-values Are Very Complicated

Overall Glazing Product Performance value

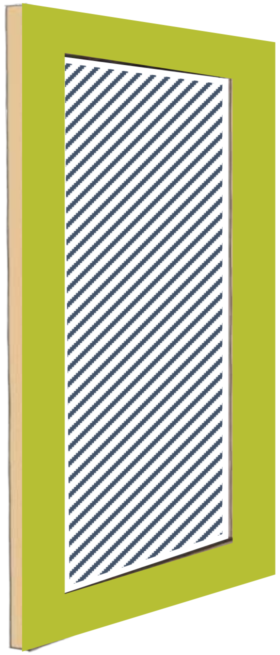
Glazing

U-Value of the glass: U_g



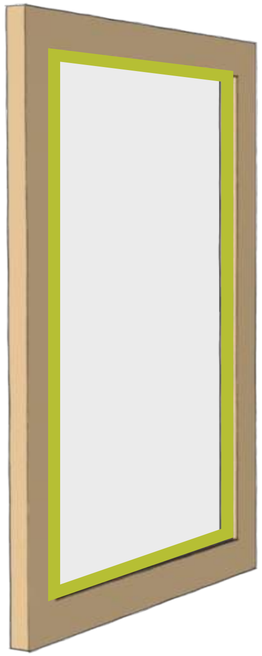
Frame

U-Value of the frame: U_f



Spacers

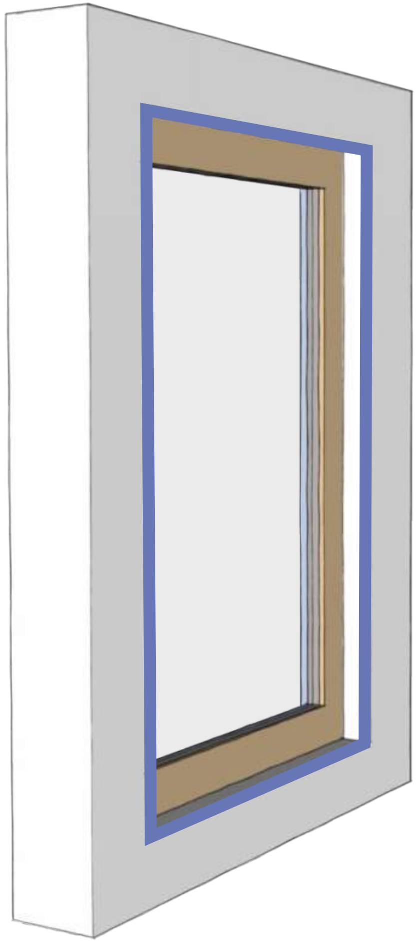
Ψ-Value of the spacer: Ψ_{spacer}



Window Product U-value: $U_{w\text{-uninstalled}}$ accounting for glass + frame + spacers

Installation

Ψ-Value of the installation: $\Psi_{installation}$

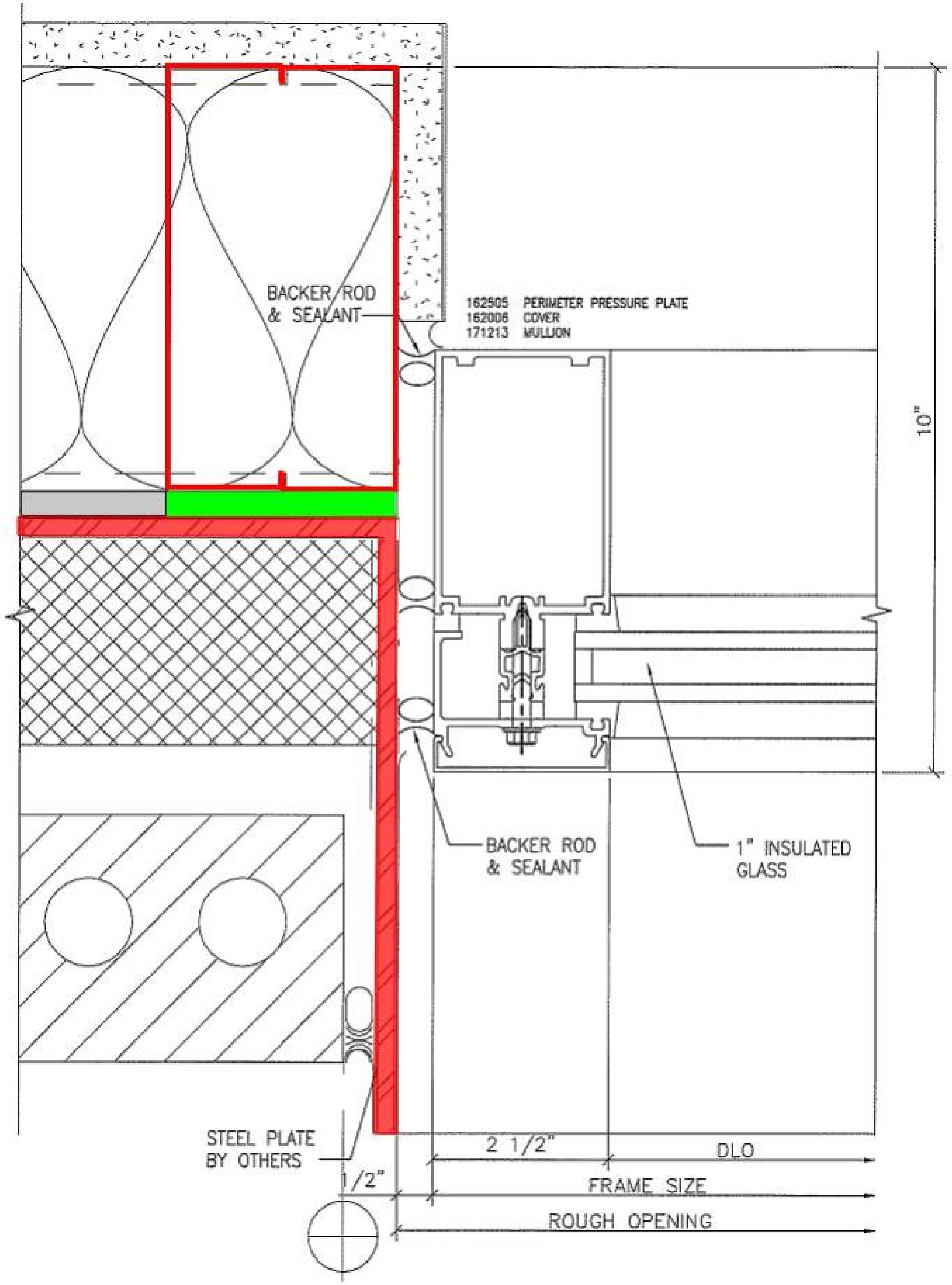


Installed window U-value: $U_{w\text{-installed}}$ accounting for glass + frame + spacers + installation

Steel Angle at Jamb Example

- Insert Thermal Bearing Pad

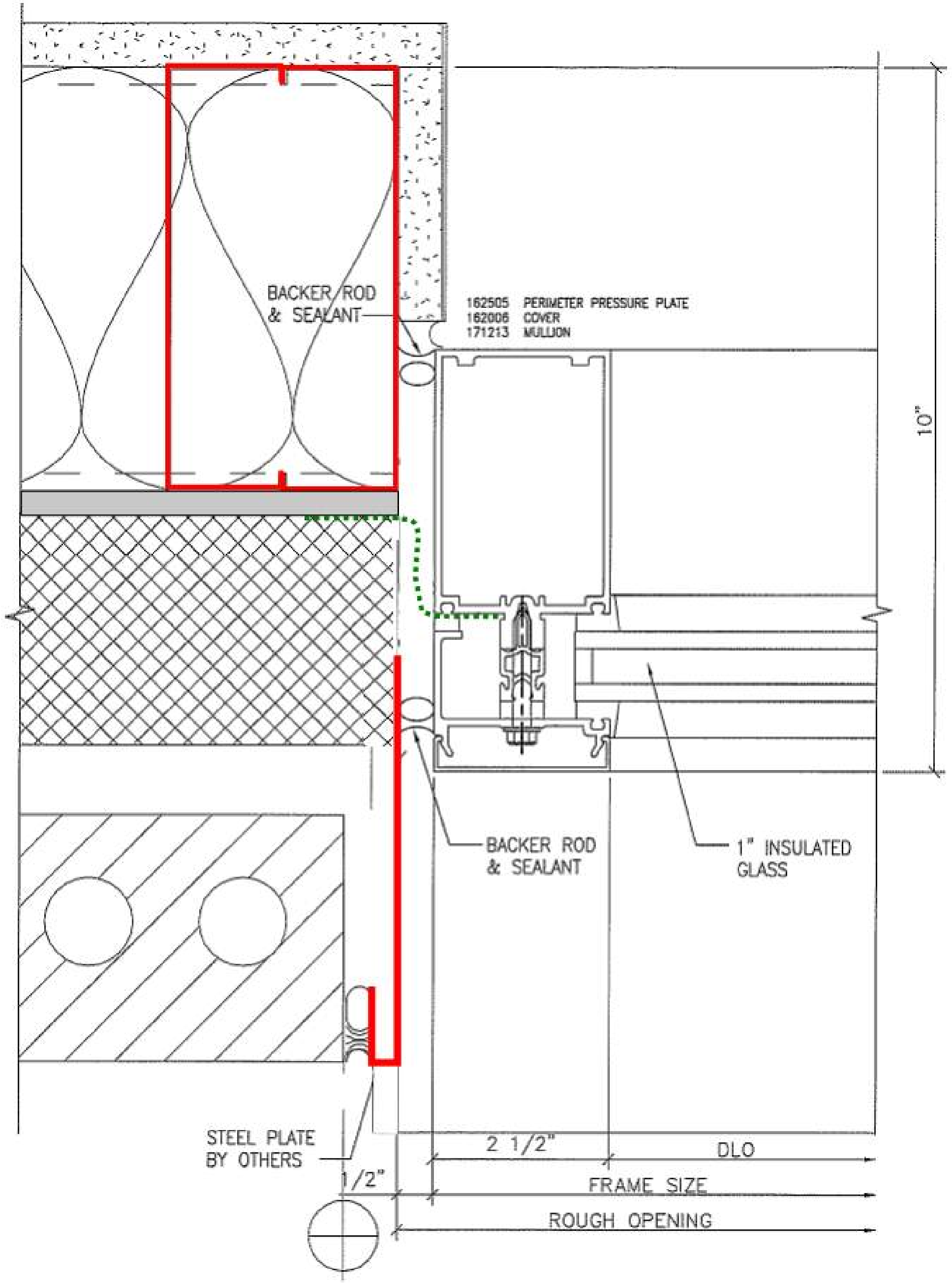
$$\Psi = 0.314 \text{ Btu/(h·ft·F)}$$



Steel Angle at Jamb Example

- Replace steel angle with flashing

$$\Psi = 0.045 \text{ Btu/(h·ft·F)}$$



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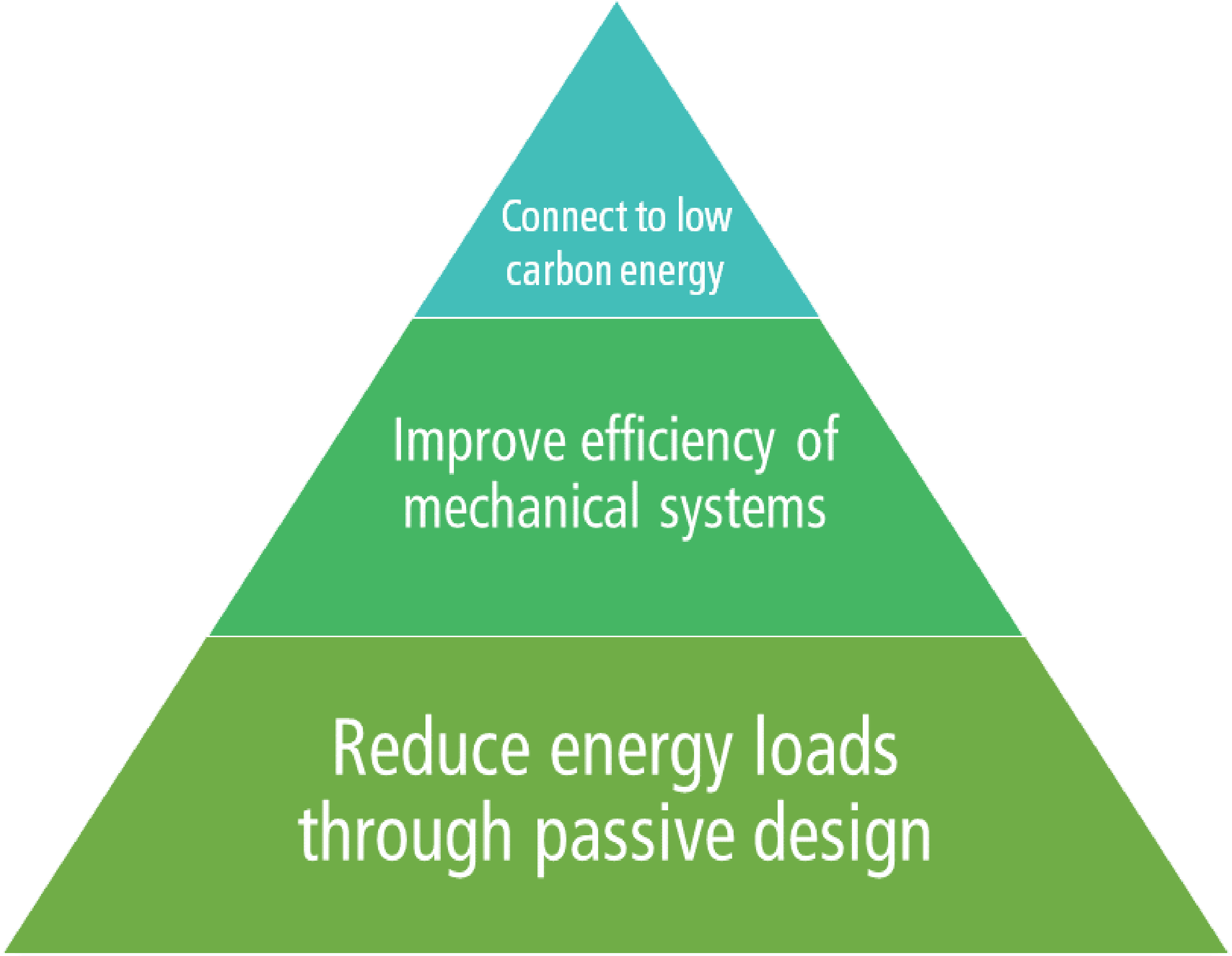
4 Further Forward

Absolute Performance Metrics

- →PHIUS
- →TEDI
- →ASHRAE 90.1 with Performance Energy Index Targets
- →HERS



Massachusetts Energy Code

Base Code (IECC 2021*)

- New construction in towns & cities not a green community
- **52 communities**

*Expected from BBRS: **July 2023**

(current base code is IECC 2018 with MA amendments)

Stretch Code (2023 update)

- New construction in towns & cities that are a green or stretch community
- **299 communities**

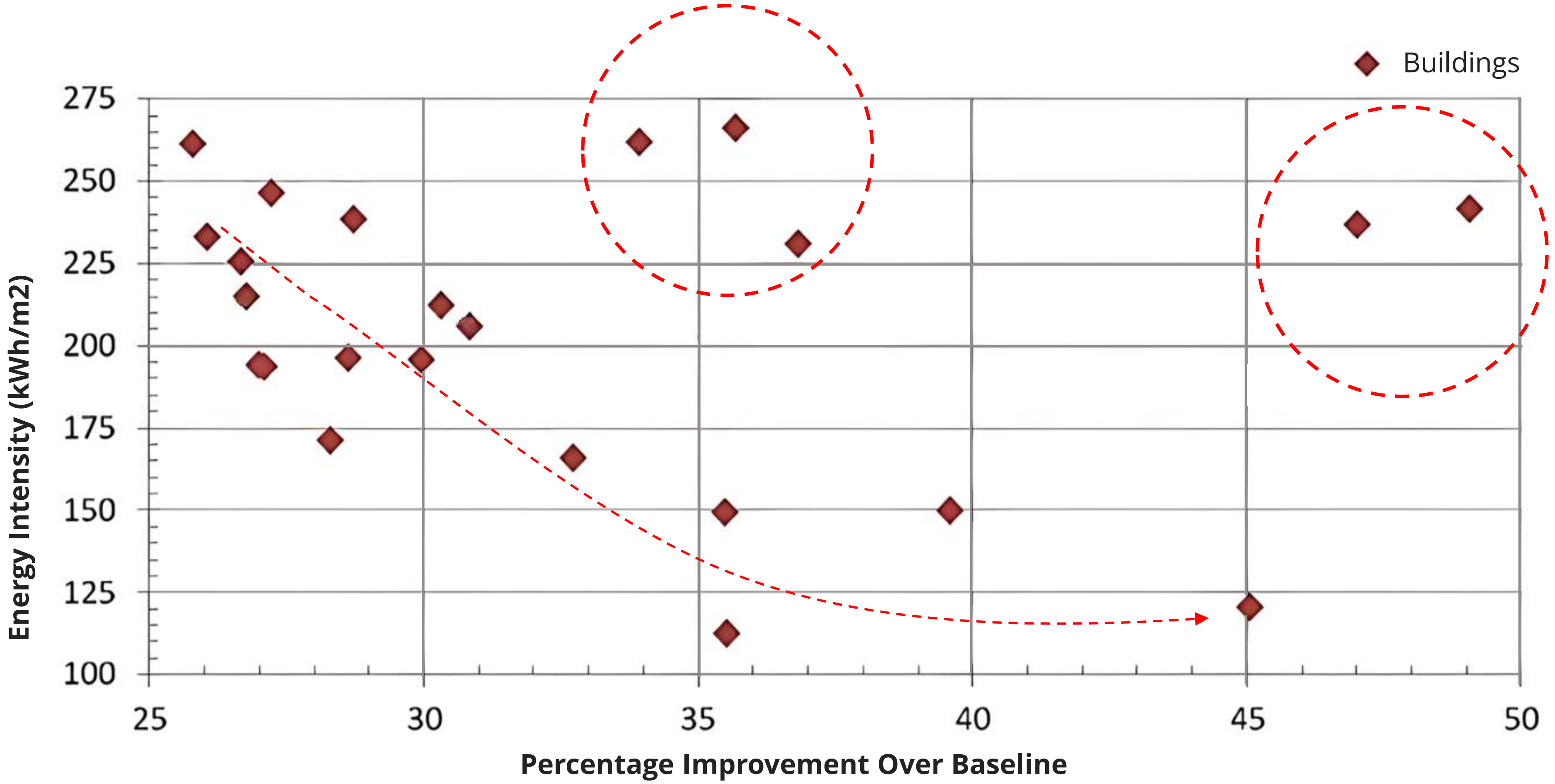
Residential : Jan 2023
Commercial: July 2023

Specialized Code (“Net-Zero”)

- New Construction in towns & cities that vote to opt-in to this code
- **Effective date:** Typically 6-11 months after Town/City vote

Source: Massachusetts DOER

Relative Performance – ASHRAE 90.1



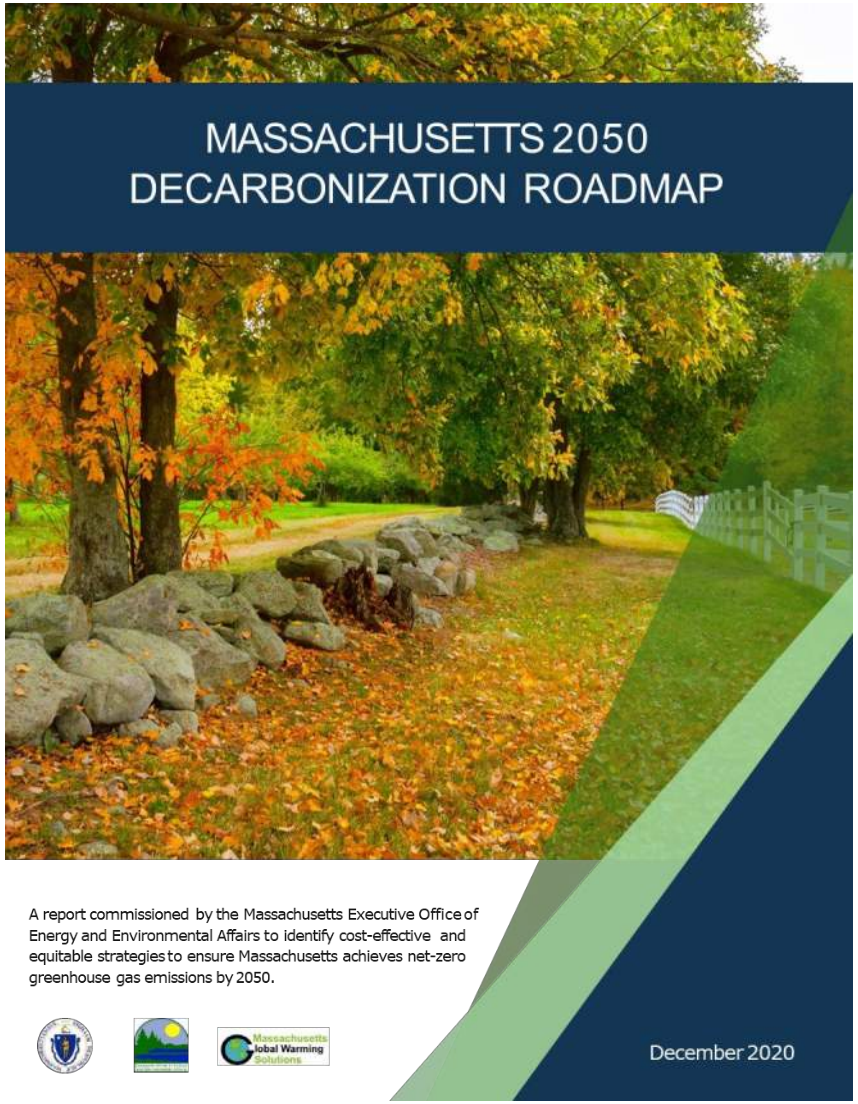
→ Some correlation between relative savings and energy use intensity of the building
→ BUT what about all the outliers?

Decarbonization in Massachusetts

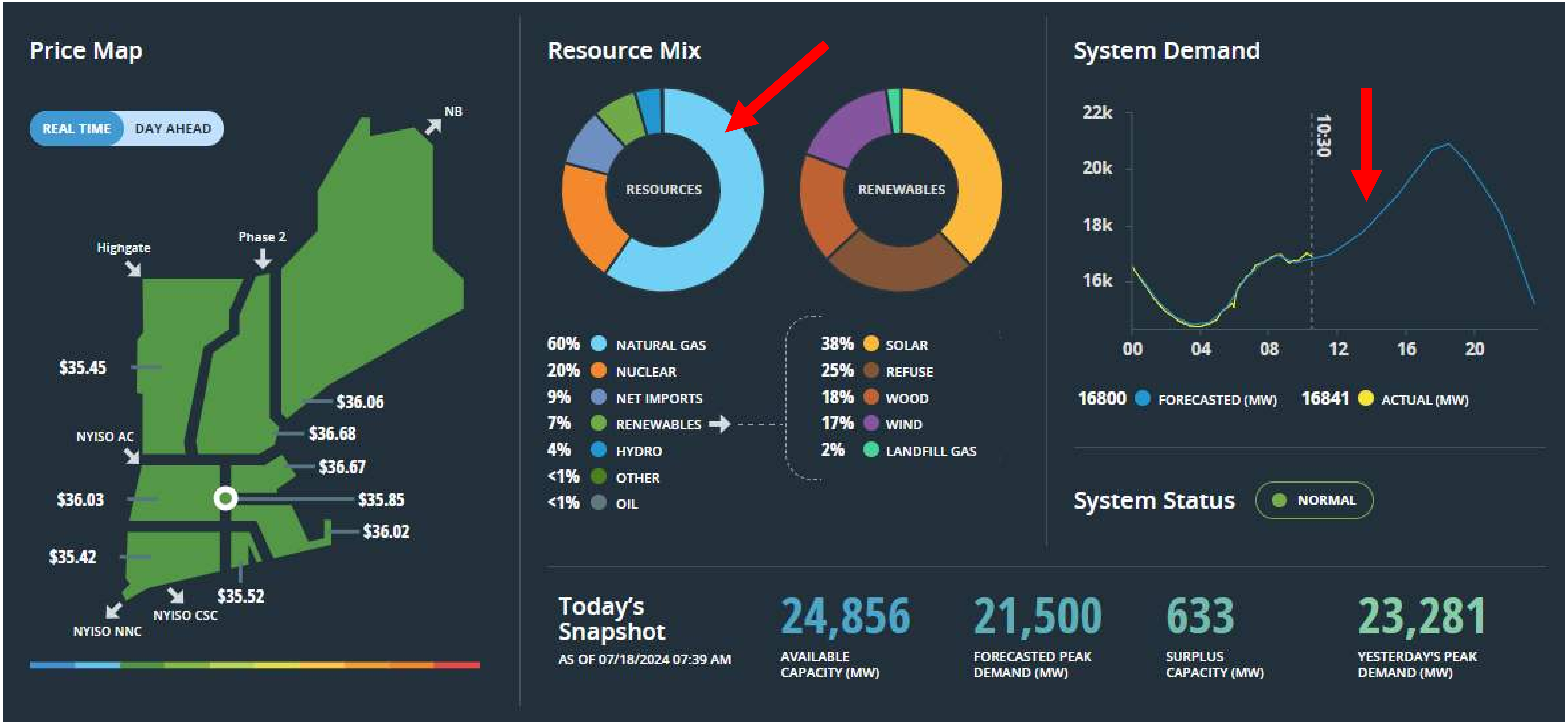
March 26, 2021 Governor Baker signed into law:

→ 50% carbon emissions reduction by 2030
→ 75% carbon emissions reduction by 2040
→ Net Zero carbon emissions by 2050

New Stretch Code and Specialized Opt-In code make meaningful impacts to design practice



Operational Carbon



Whole Building Performance

TABLE 1 WUFI®PASSIVE MODEL RESULTS*								
Absolute Targets**		**Current Design** ***	**Alt 1:** 0.25 SHGC at South Elevations	**Alt 2:** 25% WWR + 0.3 SHGC for all glazing	**Alt 3:** 28% WWR + 0.3 SHGC for all glazing	**Alt 4:** 4" Wall Insulation	**Alt 5:** Direct Electric Water Heater
HEATING DEMAND KBTU/FT^2-YR	**≤ 5.2**	3.68	4.29	3.66	3.62	4.28	3.68
HEATING LOAD BTU/H-FT^2	**≤ 4.4**	2.88	3.04	2.89	2.92	3.12	2.88
COOLING DEMAND KBTU/FT^2-YR	**≤ 8.2**	1.44	1.32	1.54	1.66	1.42	2.72
COOLING LOAD BTU/H-FT^2	**≤ 3.4**	2.31	2.23	2.39	2.5	2.35	2.89
SOURCE ENERGY Based on 228 Dwelling Units and 294 Bedrooms	**4,900 kWh/ occ**	3,972	4,055	4,148	4,160	4,064	4,512
AIRTIGHTNESS CFM/FT^2 @ 75 pa	**≤0.08**	0.08 (assumed)	0.08 (assumed)	0.08 (assumed)	0.08 (assumed)	0.08 (assumed)	0.08 (assumed)

*Area-normalized metrics are calculated using iCFA in accordance with PHIUS requirements

**Criteria based on PHIUS+ 2021 for Boston, MA

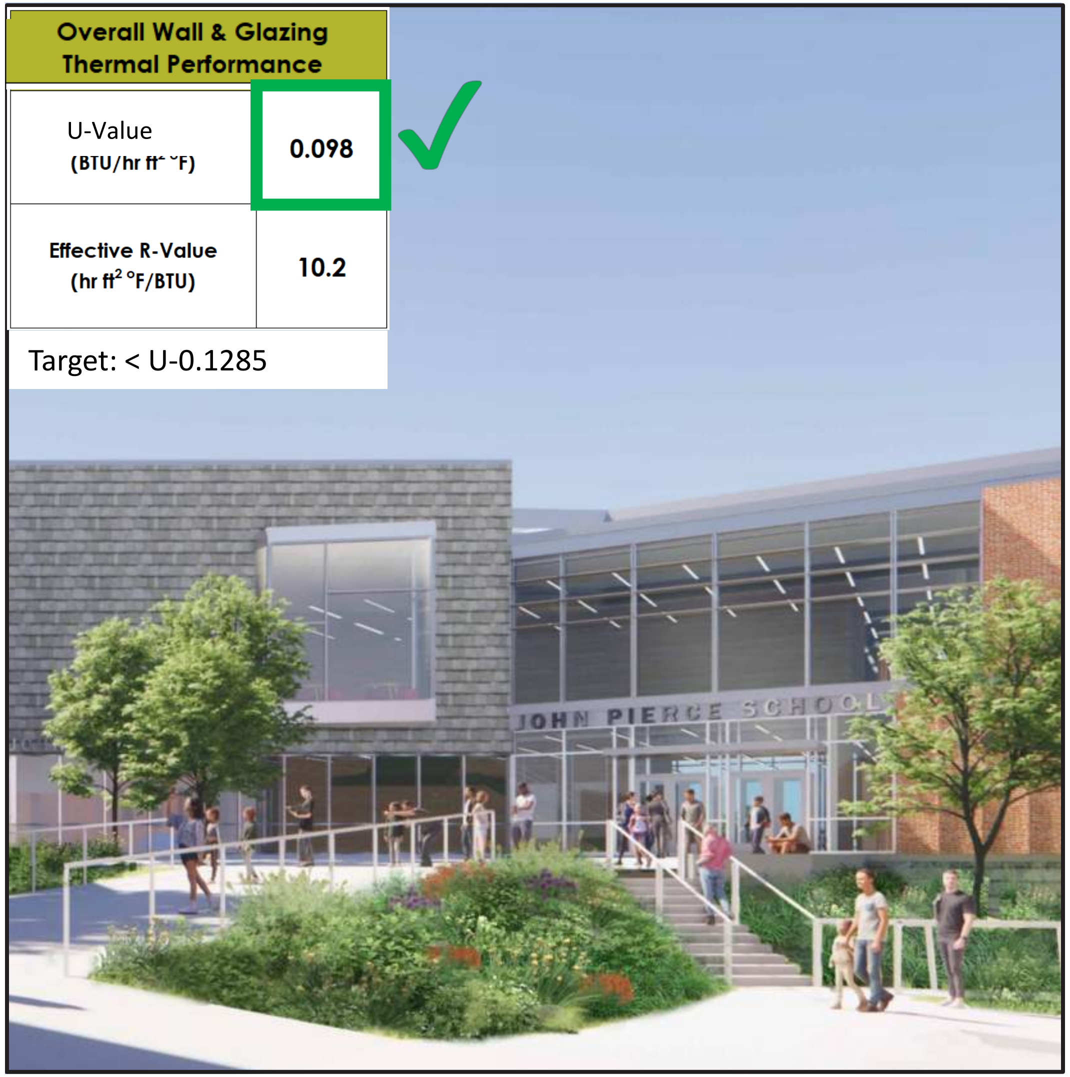
***Current Design based upon documentation listed above and assumptions noted in Table 2

Enclosure Backstop Requirements

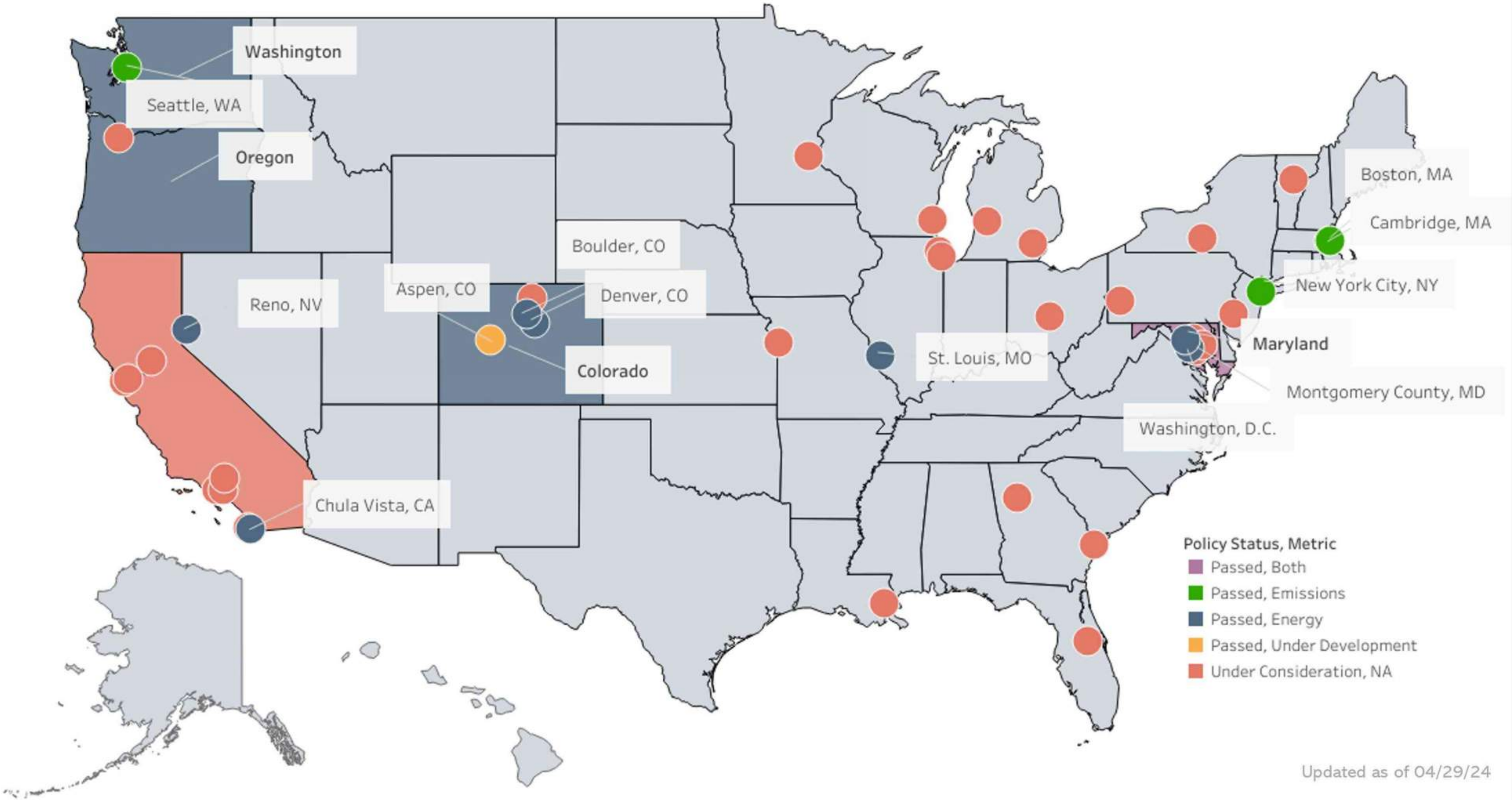
Transmittance Description	Area, Length or Amount Takeoff	Units	Transmittance Value	Units	Source Reference	Heat Flow (BTU/hr°F)	%Total Heat Flow
					Totals	7915.1	100%
Brick on CFMF	31461.00	ft²	0.037 (R-27)	BTU/ hr ft² °F	RDH Masonry Guide	1165.2	15%
Brick on CMU	3615.00	ft²	0.045 (R-22)	BTU/ hr ft² °F	RDH Masonry Guide	164.3	2%
Brick on Concrete	1525.00	ft²	0.045	BTU/ hr ft² °F	RDH Masonry Guide	69.3	1%
Slate/Granite shingle on CFMF backup	3804.00	ft²	0.037	BTU/ hr ft² °F	RDH Masonry Guide	140.9	2%
Standing seam/Metal Panel on CFMF	14267.00	ft²	0.037	BTU/ hr ft² °F	RDH Masonry Guide	528.4	7%
Slate shingle on CMU	1683.00	ft²	0.045	BTU/ hr ft² °F	RDH Masonry Guide	76.5	1%
Spandrels (large openings)	1494.00	ft²	0.168	BTU/ hr ft² °F	4.1.2	251.0	3%
Spandrels (small openings)	1040.00	ft²	0.168	BTU/ hr ft² °F	4.1.2	174.7	2%
Kawneer 1600-UT System 2 (large)	11169.00	ft²	0.190	BTU/ hr ft² °F	Kawneer Data	2122.1	27%
Kawneer 1600-UT System 2 (small)	7025.00	ft²	0.210	BTU/ hr ft² °F	Kawneer Data	1475.3	19%
Wood on CFMF	923.00	ft²	0.037	BTU/ hr ft² °F	RDH Masonry Guide	34.2	0%
Wood on CMU	531.00	ft²	0.045	BTU/ hr ft² °F	RDH Masonry Guide	24.1	0%
CMU Wall @ Garage Interface	2542.50	ft²	0.043	BTU/ hr ft² °F	RDH Masonry Guide	110.5	1%
Shelf angles/slab edge/intermediate floor	2186.00	ft	0.118	BTU/ hr ft °F	RDH DER TB Guide	257.9	3%
Window Perimeter	7757.00	ft	0.047	BTU/ hr ft °F	5.3.13	364.6	5%
Slab to Garage Transition	1286.77	ft	0.350	BTU/ hr ft °F	RDH DER TB Guide	450.4	6%
Wall to Roof Transition	1540.00	ft	0.210	BTU/ hr ft °F	RDH DER TB Guide	323.4	4%
Low parapet	867.47	ft	0.210	BTU/ hr ft °F	RDH DER TB Guide	182.2	2%

Overall Wall & Glazing Thermal Performance	
U-Value (BTU/hr ft² °F)	0.098 ✓
Effective R-Value (hr ft² °F/BTU)	10.2

Target: < U-0.1285

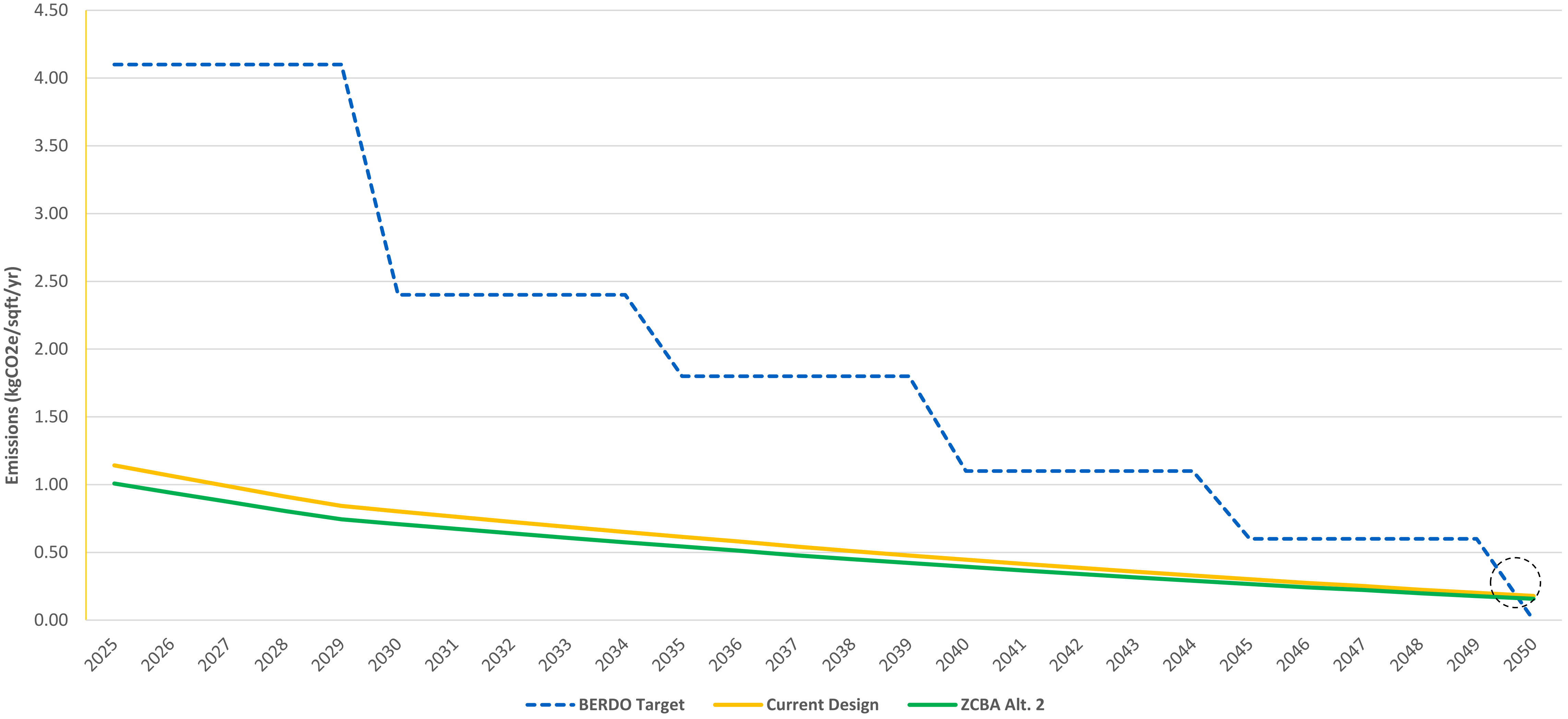


State and Local Building Performance Standards



Updated as of 04/29/24

Phius vs. BERDO 2.0 – Multi-Family Residential Example



BERDO 2.0 (Stick)

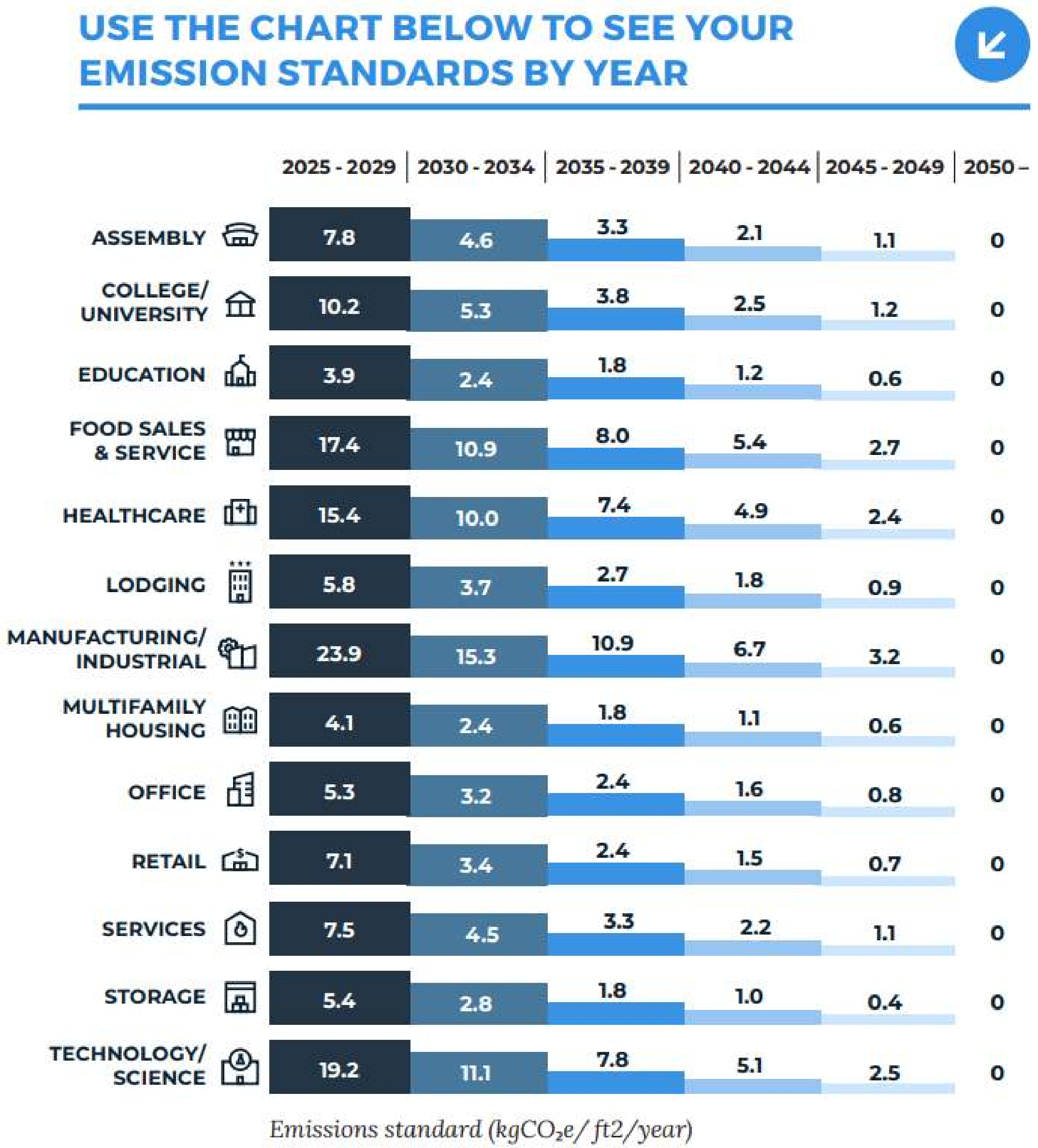
If a building is not complying:

- Make a Compliance Plan implemented the following year

  OR
- Buy Renewable Energy

  OR
- Take alternate compliance path and pay $234 / metric ton over limit

  OR
- Apply for Flexibility Measures that adjust the limit, make allowance for hardship, or allow blended emissions between program types in building or buildings in a portfolio.



Penalty Fees:

- $150-$300 / day failure to comply w reporting
- $300-$1,000 / day failure to comply w emission standards
- $1,000-$5,000 failure to accurately report information

Incentives

→ Multi-Family Residential Buildings with 5+ Units

→ Certification through PHI or Phius

300 Unit Example:

Feasibility: **$5,000**

Energy Modeling: **$20,000**

Pre-Certification: **$225,000**

Certification: **$900,000**

\+ **Total: $1,150,000**

Passive House Incentive Structure for Multi-Family (5 units or more)			
Incentive Timing	**Activity**	**Incentive Amount**	**Max. Incentive**
Pre-Construction	Feasibility Study	Up to 100% Feasibility costs	$5,000
	Energy Modeling	75% of Energy Modeling costs	$500/unit, max. $20,000
	Pre-Certification	$750/unit	N/A
Post-Construction	Certification	$3,000/unit	

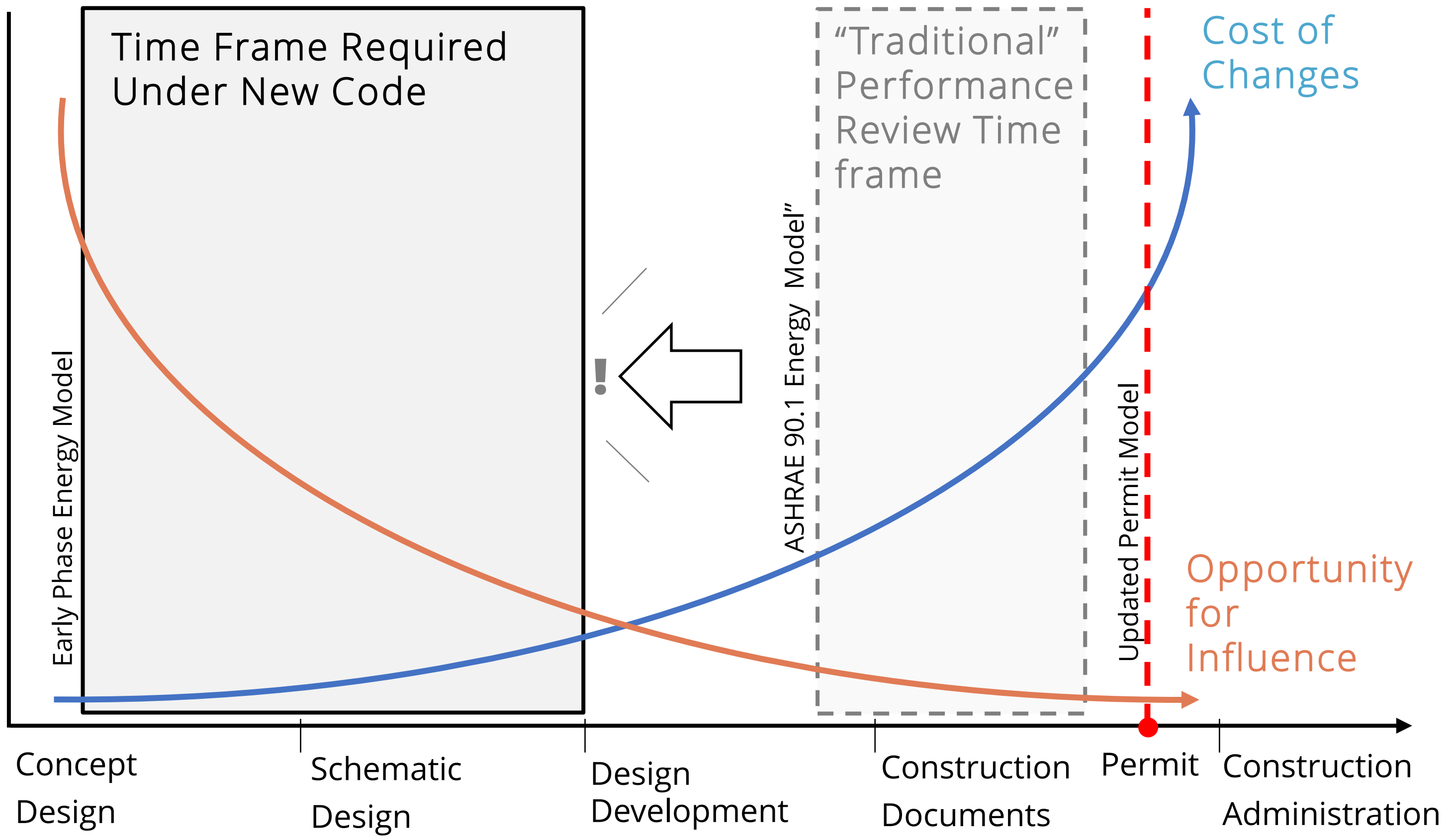
Front-loaded Design Process

Most cost-effective approach to delivering buildings =
make the right decisions early

→ Energy Model + Set performance targets early

→ Design accordingly with whole team

→ Update modeling and check design through subsequent phases



This concludes The American Institute of Architects Continuing Education Systems Course

Making Buildings Better

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THANK YOU!
Questions?

June 2025

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