Energy Code Compliance: Wood-Frame Buildings and Updates to the Seattle and Washington State Energy Codes

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RDH BUILDING SCIENCE

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Course Description

A growing belief among design and construction professionals is that energy efficiency is crucial in building design. This presentation will provide practical information for designing wood-frame multi-family and mixed-use buildings to avoid common comfort-related pitfalls. Discussion will cover design, detailing and installation of high-performing and energy efficient assemblies. Topics will include design concepts, detailing techniques, assemblies, construction inspections, and lessons learned over years of energy-efficient design. Changes to the Seattle energy code and the effect on both light frame and mass timber construction will be discussed. Attendees can expect to gain a better understanding of energy code requirements, and how to meet or exceed them through proper building design.

Learning Objectives

1. Highlight areas of the building enclosure that are critical to design, detail and install correctly in order to achieve energy code compliance.

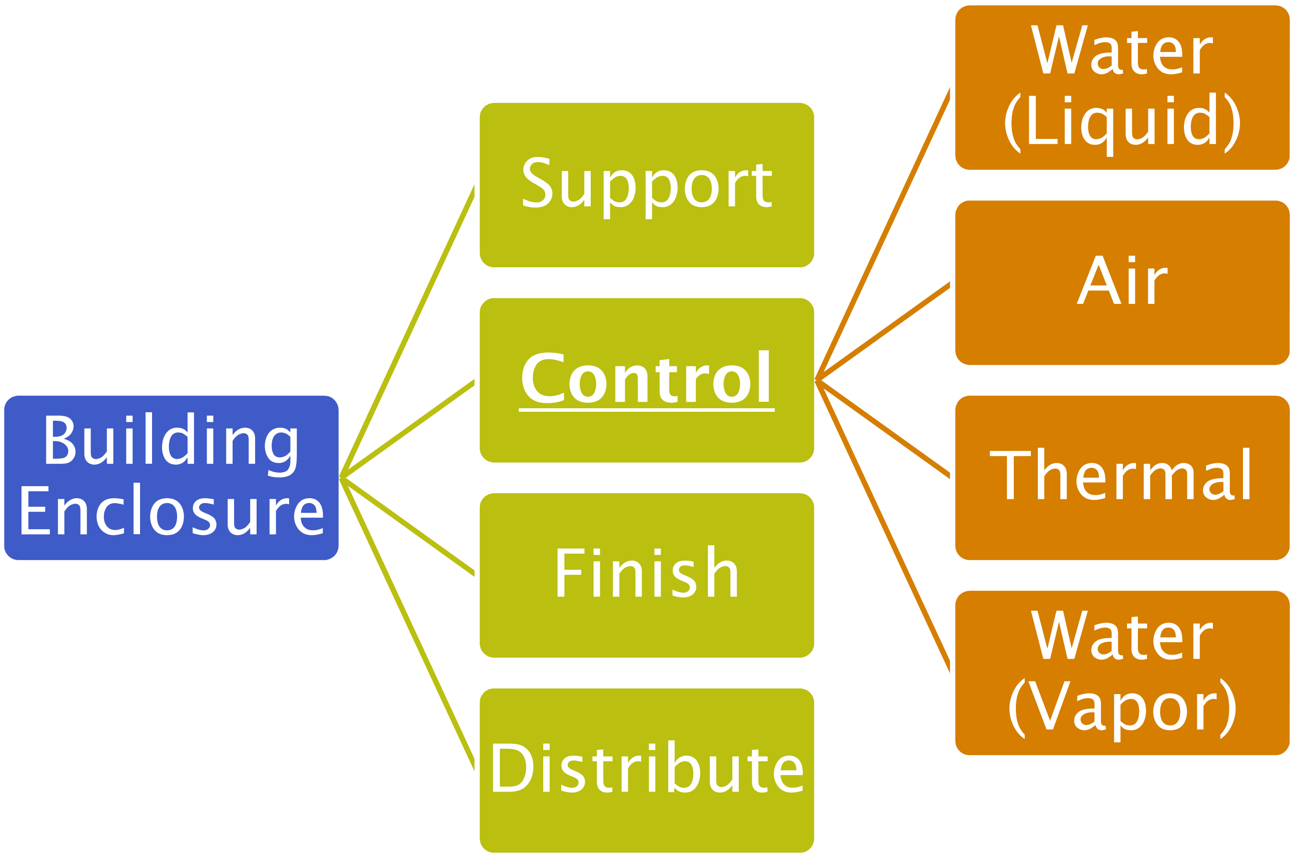
2. Explore effective detailing techniques in building enclosures that minimize thermal bridging and improve energy performance.

3. Discuss energy efficiency requirements of wood-frame buildings constructed in Seattle per the 2018 Seattle Energy Code.

4. Demonstrate options for exceeding energy-efficiency objectives using wood-frame assemblies.

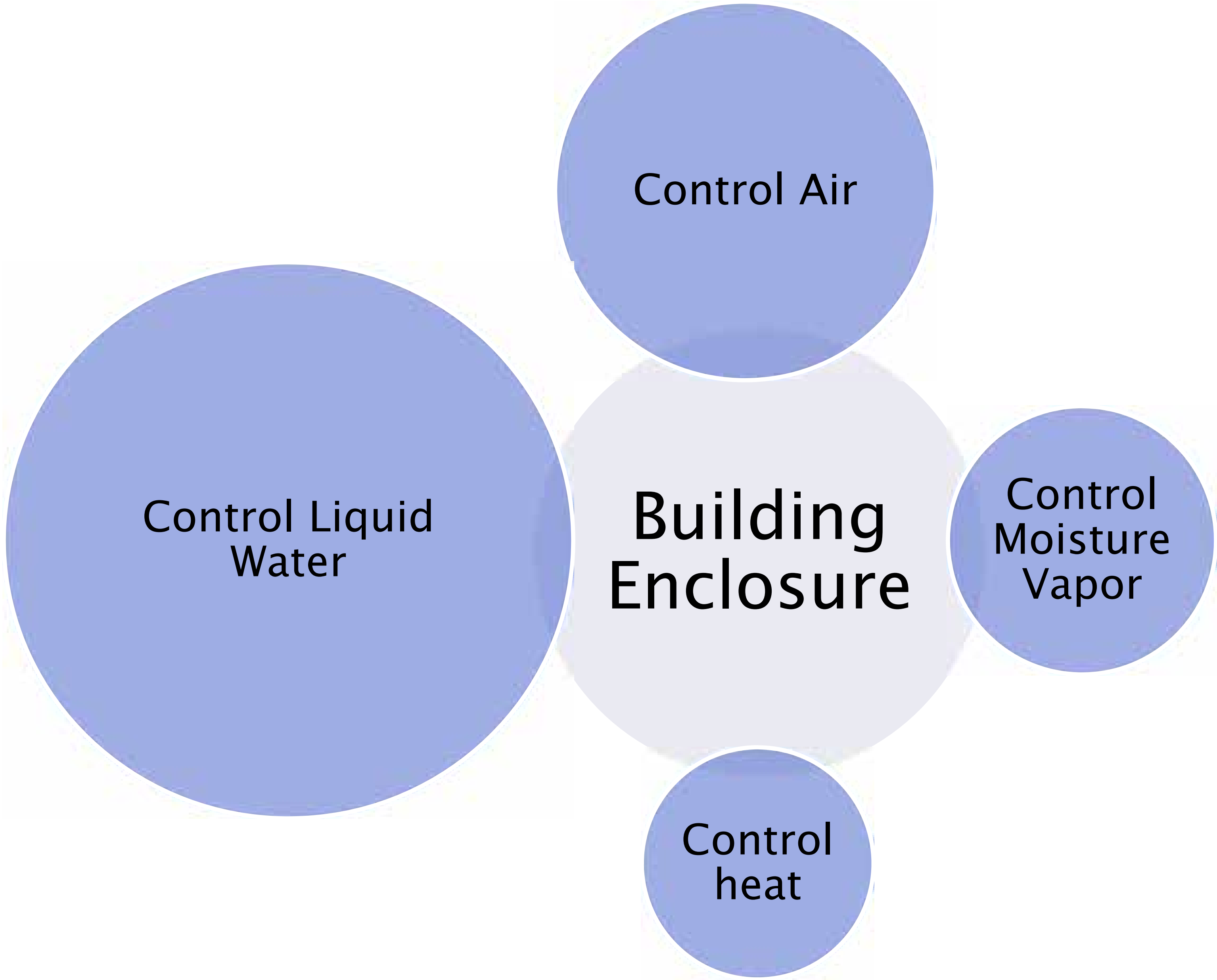
The Building Enclosure System

Control Functions (i.e. loads)

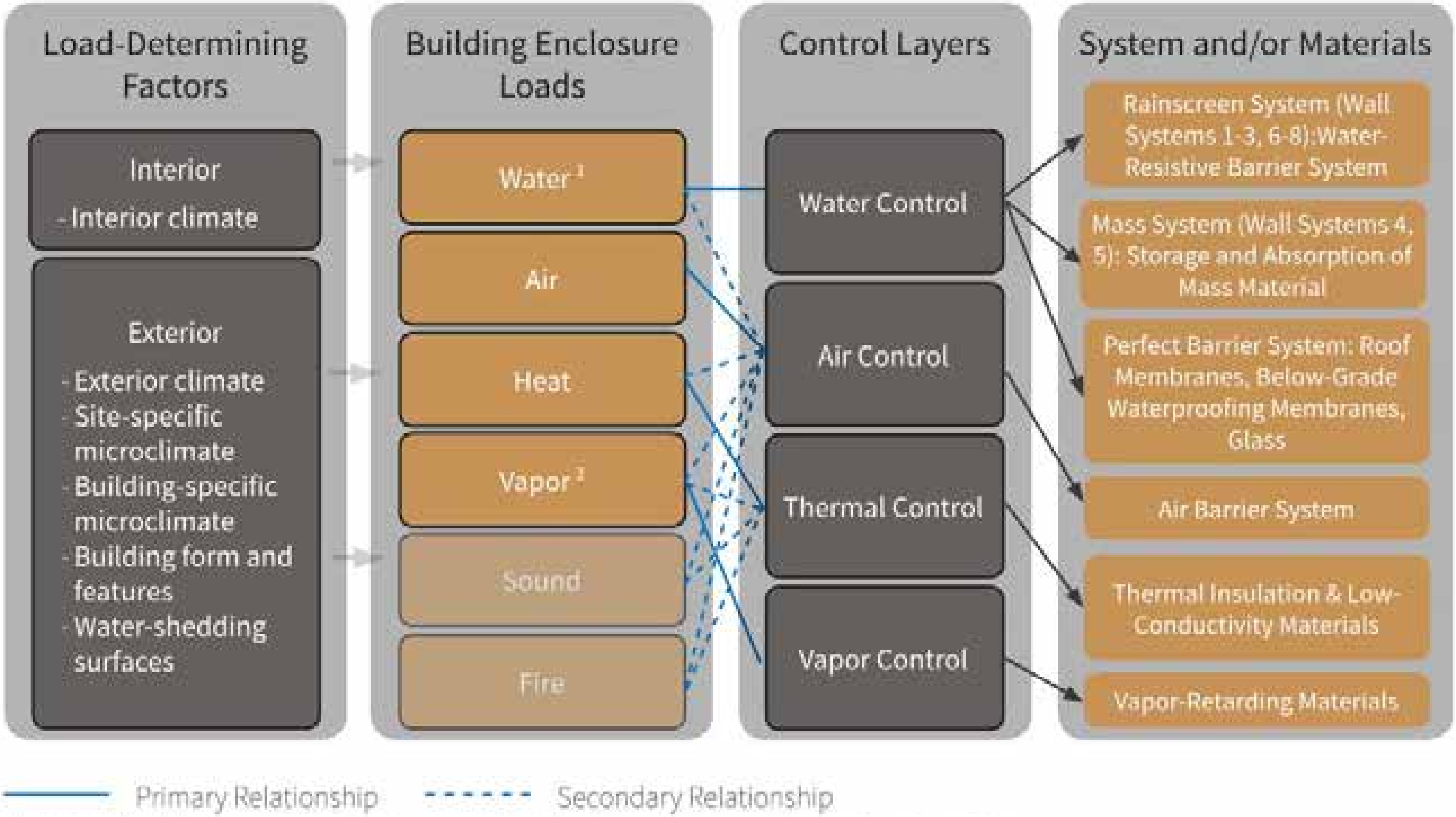


…other control layers include sound, fire, etc.

Relative Importance of Control Function/Loads



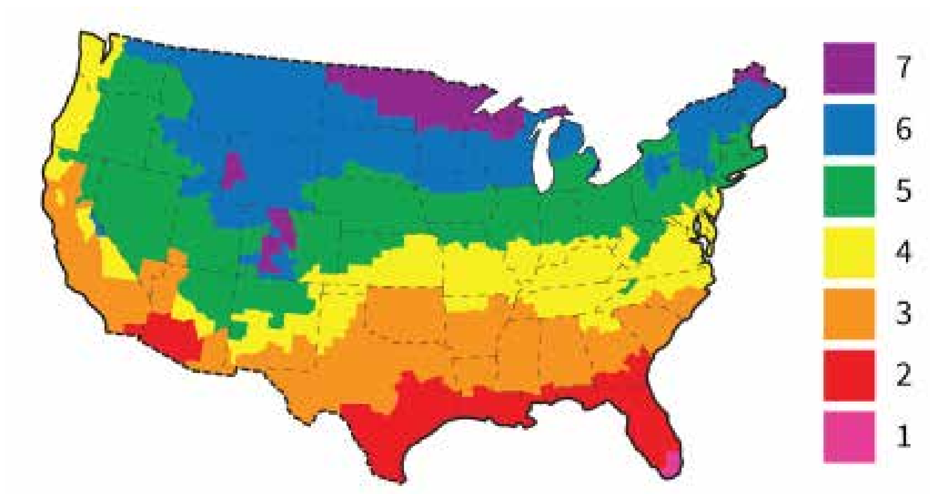
Loads and Layers



[1] Water is defined here as precipitation (rain, snow, hail, etc.) and groundwater as well as condensate moisture.
[2] Vapor is separately defined here as the water vapor in air.

Building Enclosure Loads

ASHRAE Climate Zone Map



Average Rainfall

Fig. i-6 United States total annual rainfall levels.

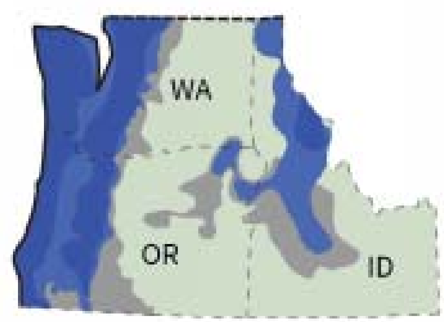


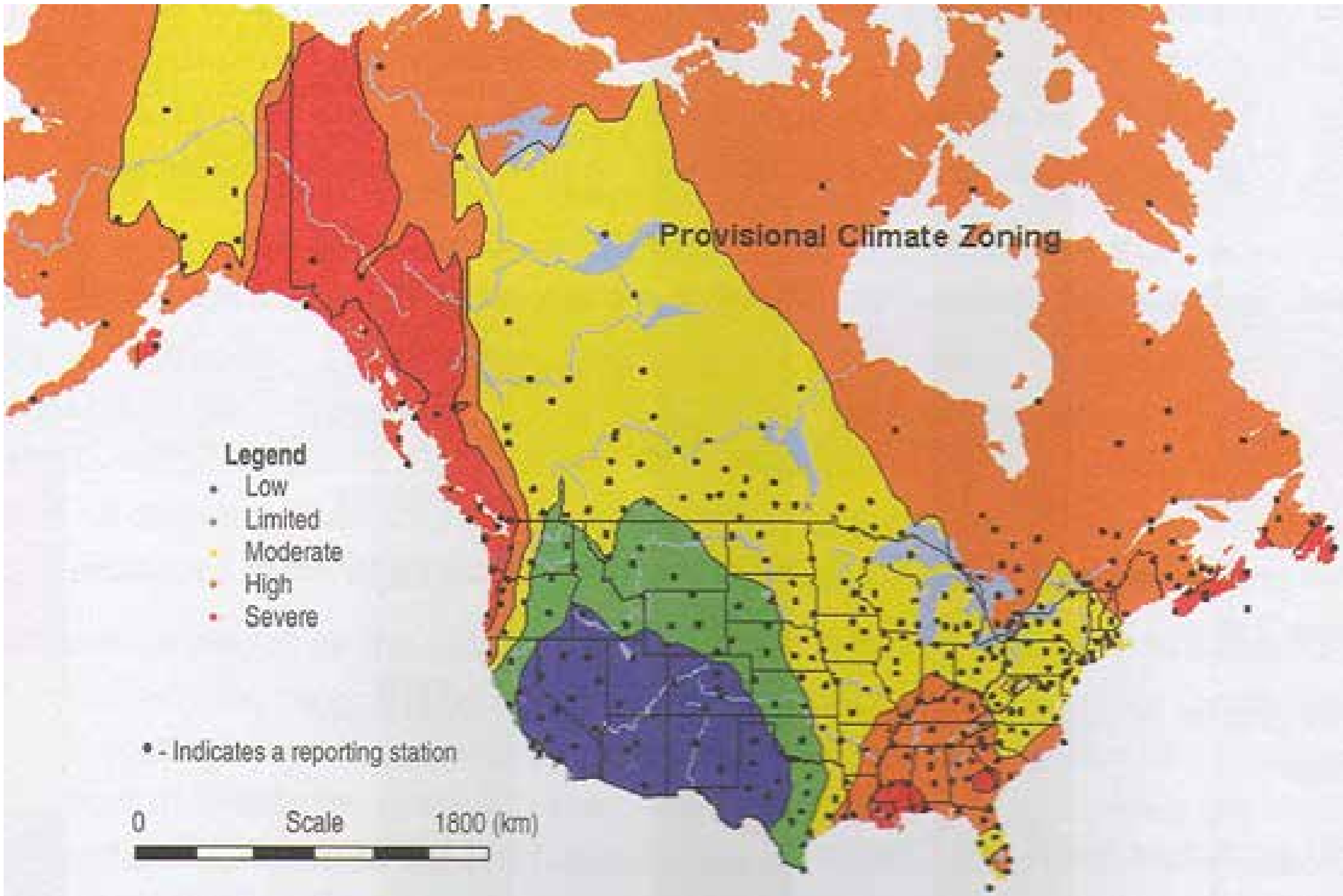
Fig. i-7 Northwest region specific total annual rainfall levels.

Extreme – Over 60"
High – 40" - 60"
Moderate – 20" - 40"
Low – Under 20"

Climate zones 4, 5, 6

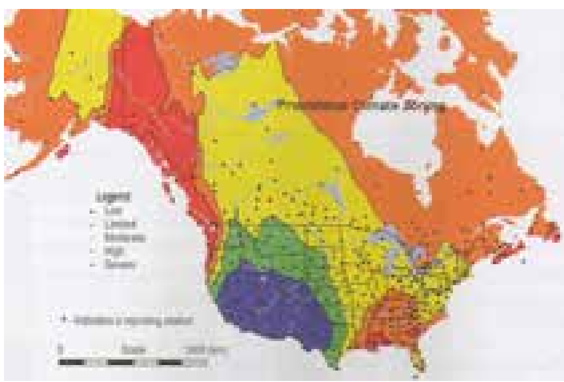
Rain/Snow: from low to extreme

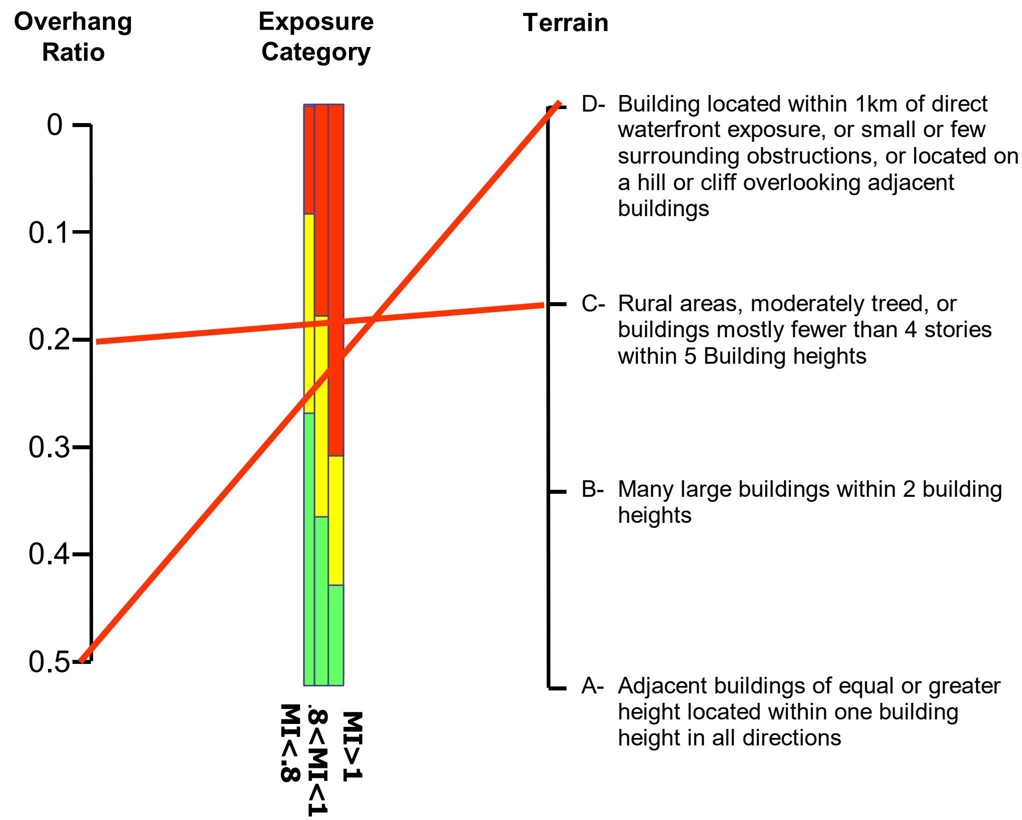
Site Climate - Wetting and Drying Potential



Exposure – Combining the Variables

- 🟥 **High exposure - Rainscreen Strategy**
- 🟨 **Moderate Exposure – Some judgment required in conjunction with assessment of other factors such as detailing, level of dependency on maintenance and renewals, tolerance for risk etc.**
- 🟩 **Low Exposure – Less robust assemblies can be considered, such as those utilizing a barrier strategy**





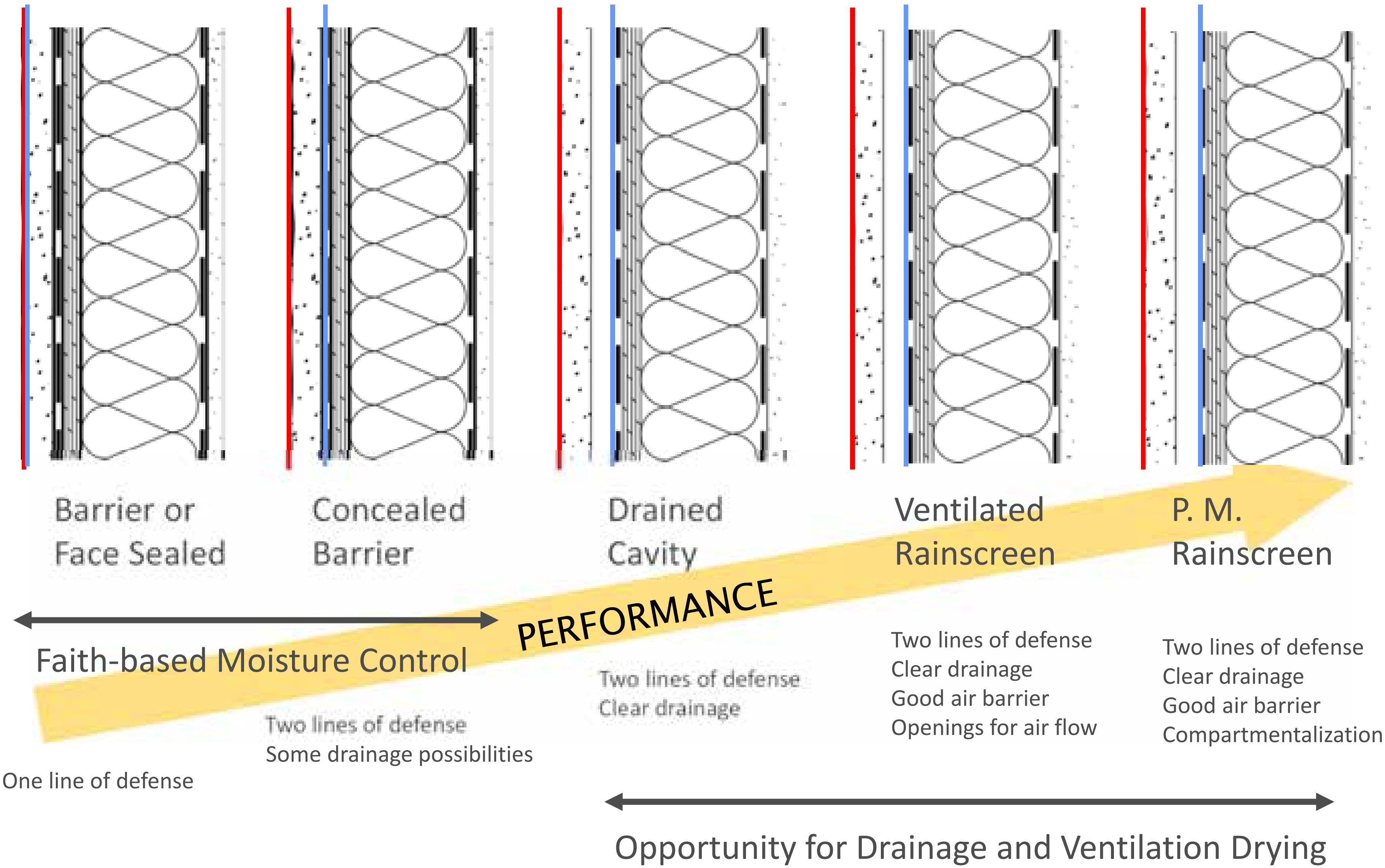
Overhang Ratio = Overhang Width / Wall Height

Where: Wall Height is the height above the lowest affected element (sill of window if considering a window)

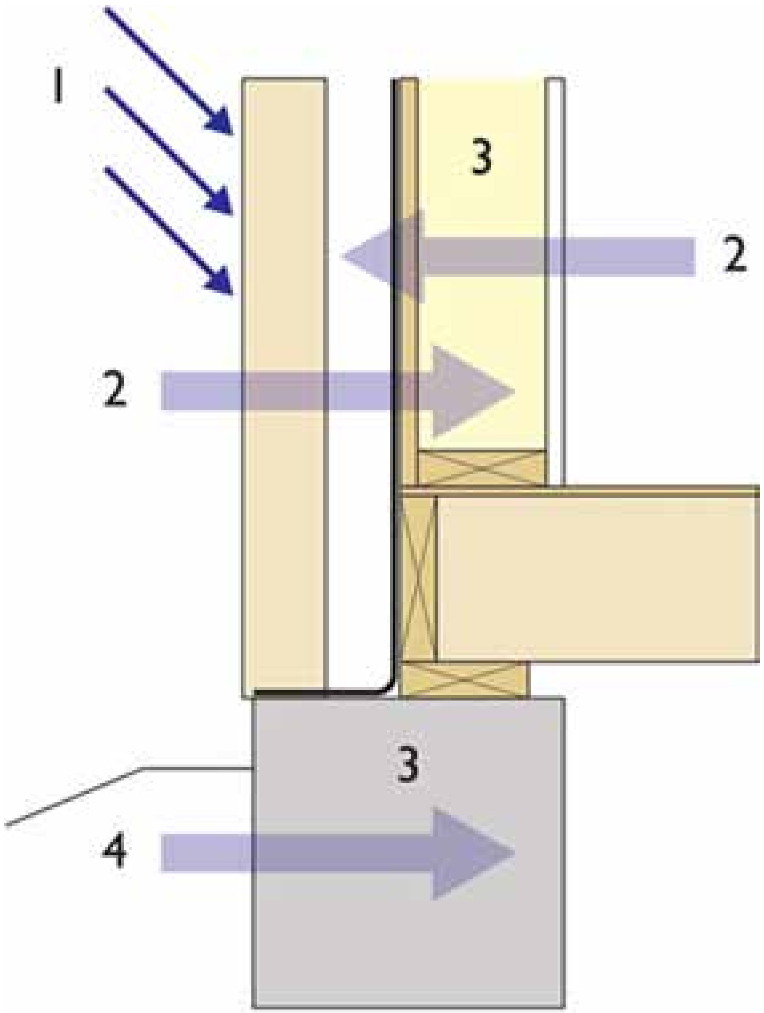
Overhang Width is the horizontal distance between the outer surface of the cladding or window and the outer surface of the overhang

Water (Liquid) Control

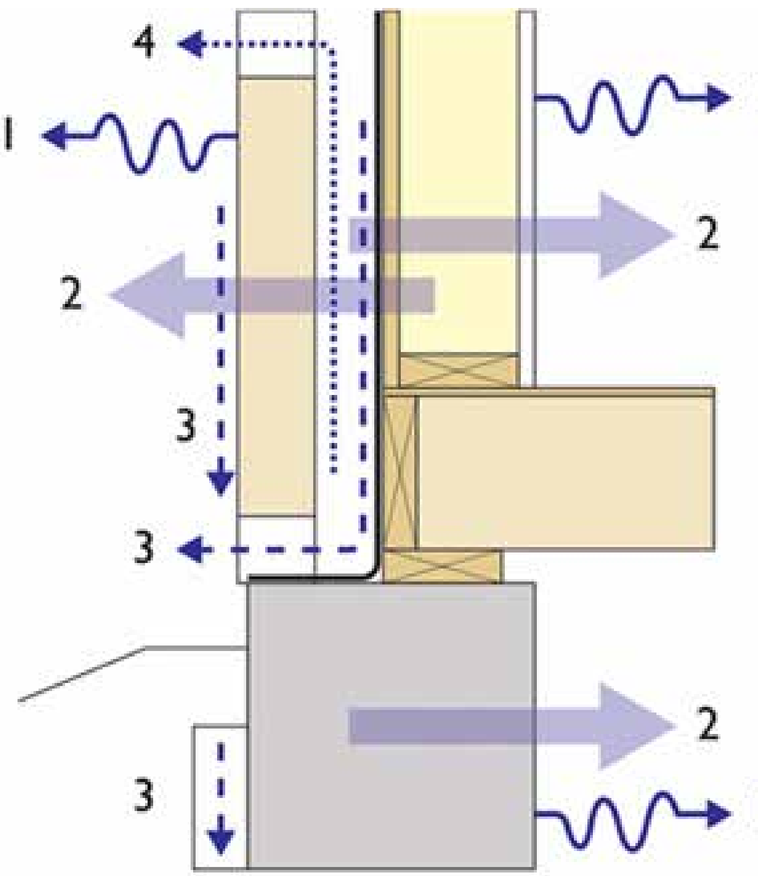
Continuum of MC Strategies for Framed Walls



How do Walls get Wet and Dry?

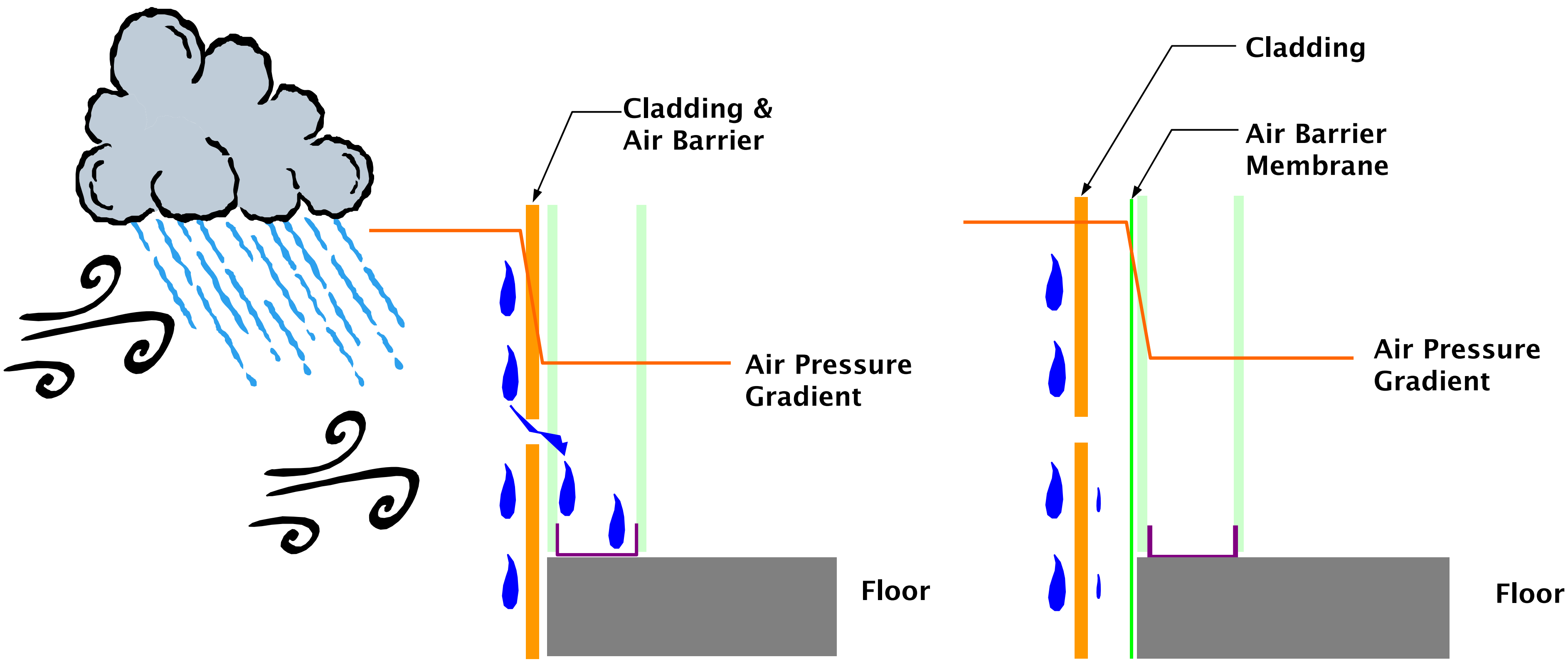


1. Precipitation (rain or snow)
2. Water vapor transported by diffusion and/or air movement (outward or inward)
3. Built-in construction moisture
4. Groundwater



1. Evaporation of water at surfaces
2. Water vapor transport by diffusion and/or air movement (outward or inward)
3. Drainage
4. Ventilation drying by air exchange

Physics of Water Penetration Control



Air Barrier System

Air Penetration Control – Why?

→ Code requirement

→ Moisture

  → Air holds moisture that can be transported and deposited within assemblies.

→ Energy

  → Unintentional airflow through the building enclosure can account for as much as 50% of the space heat loss/gain in buildings.

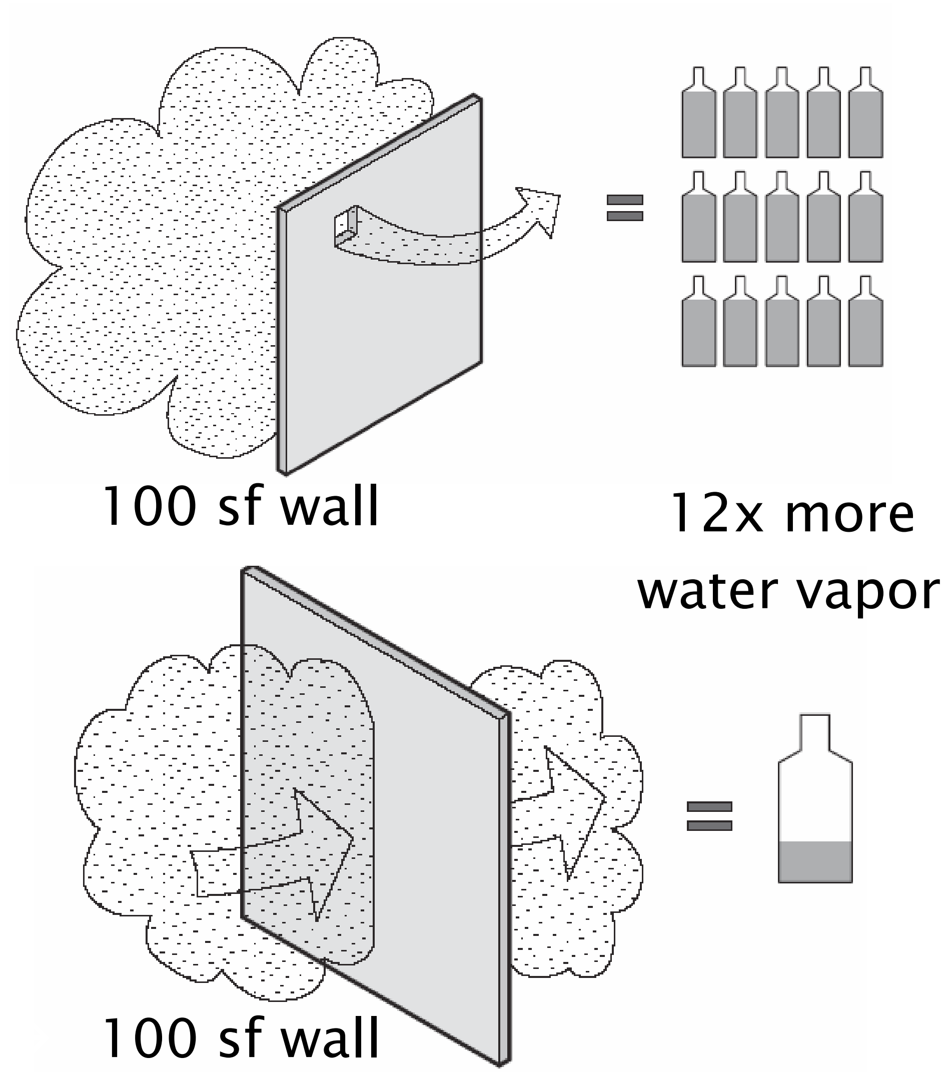
Air Leakage vs. Diffusion

Air Transport

- Flow through Hole: 38 cfm
- Air Tightness: 2.3 ACH in 1000 cf room
- Water Vapor Transmission: 48 tsp/hr (1 cup/hr)

Vapor Diffusion

- Vapor Permeance: 20 Perm
- Water Vapor Transmission: 4 tsp/hr



Air Leakage Condensation

Penetrations?

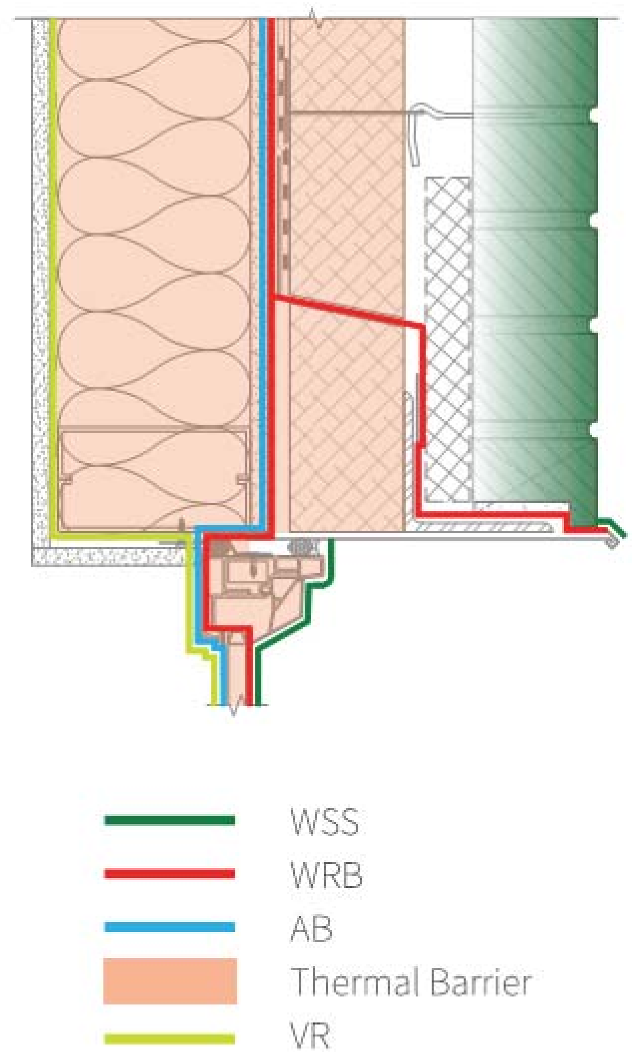
Water (Vapor) Control

Vapor Control Layer

Vapor Retarder (VR)

→ Primary relationship: vapor control

→ The element (or elements) that is (or are) designed and installed in an assembly to control the movement of water by vapor diffusion.



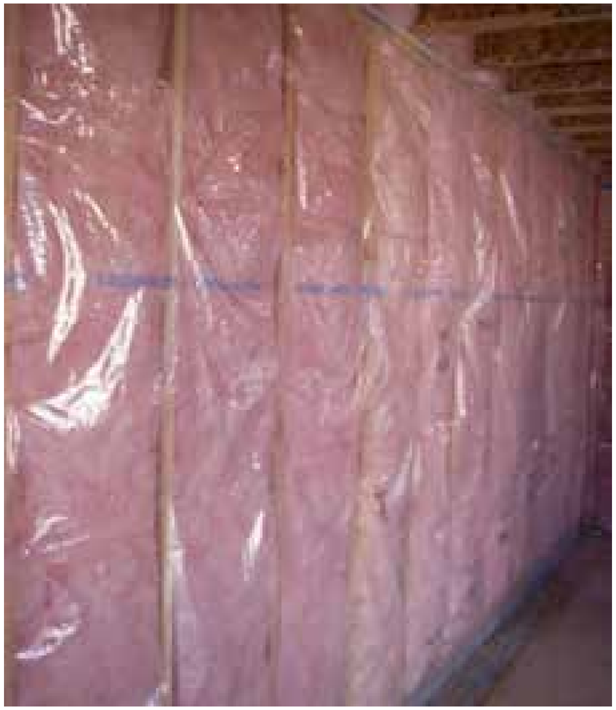
Vapor Retarder

Vapor Retarder Classification

- Class I: ≤ 0.1 perm
- Class II: > 0.1 perm, < 1.0 perm
- Class III: >1.0 perm, < 10 perm
- Class IV: > 10 perm

Common VR Products:

- Polyamide Film
- Polyethylene Membrane
- Asphalt-Coated Kraft Paper
- Polyvinyl Acetate (PVA) Vapor-Retarding Primer



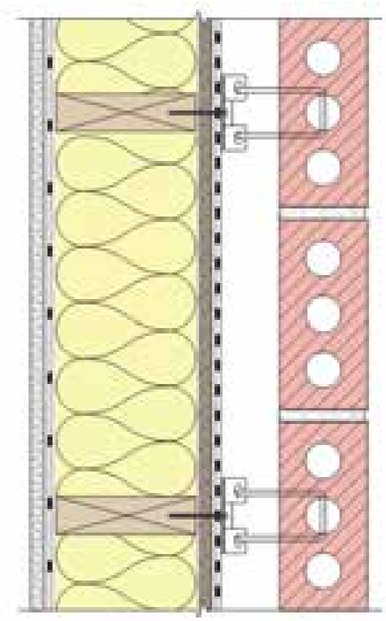
Vapor Retarder

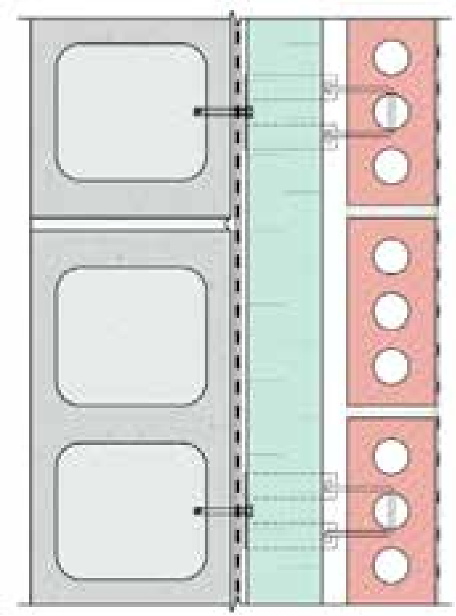
Placement is Important

→ Will vary with wall structure and rain control strategy

→ Warm side of the insulation (warm or high vapor pressure side) in the Pacific Northwest

→ Where walls are fully insulated exterior of the WRB/AB, a vapor impermeable WRB/AB membrane is commonly used as the vapor barrier





Thermal Control

2015 SEC Compliance Pathways

→ **Prescriptive Path**

- → C402.1.3: Insulation Component R-value method
- → C402.1.5: Component U-Factors and F-Factors

→ **Total Building Performance Path**

- → C407: Proposed building energy model consumes 87-93% of Reference building energy model

→ **Target Performance Path**

- → C401.3: Proposed building energy model and occupied, completed building meet energy consumption targets established by the City of Seattle.

Prescriptive Code Compliance

→ **C402.1.3: Insulation Component R-value method**

→ **Each assembly must meet required U-value or prescribed insulation R-value**

- *Simple approach*
- *No flexibility for poorly performing assemblies*
- *Path rarely taken*

→ **C402.1.5: Component U-Factors and F-Factors**

- *U-value * Area calculation*
- *Very difficult to achieve code compliance when window-to-wall ratio exceeds 40%*

→ **Section C406: Requires selection of two additional efficiency package options.**

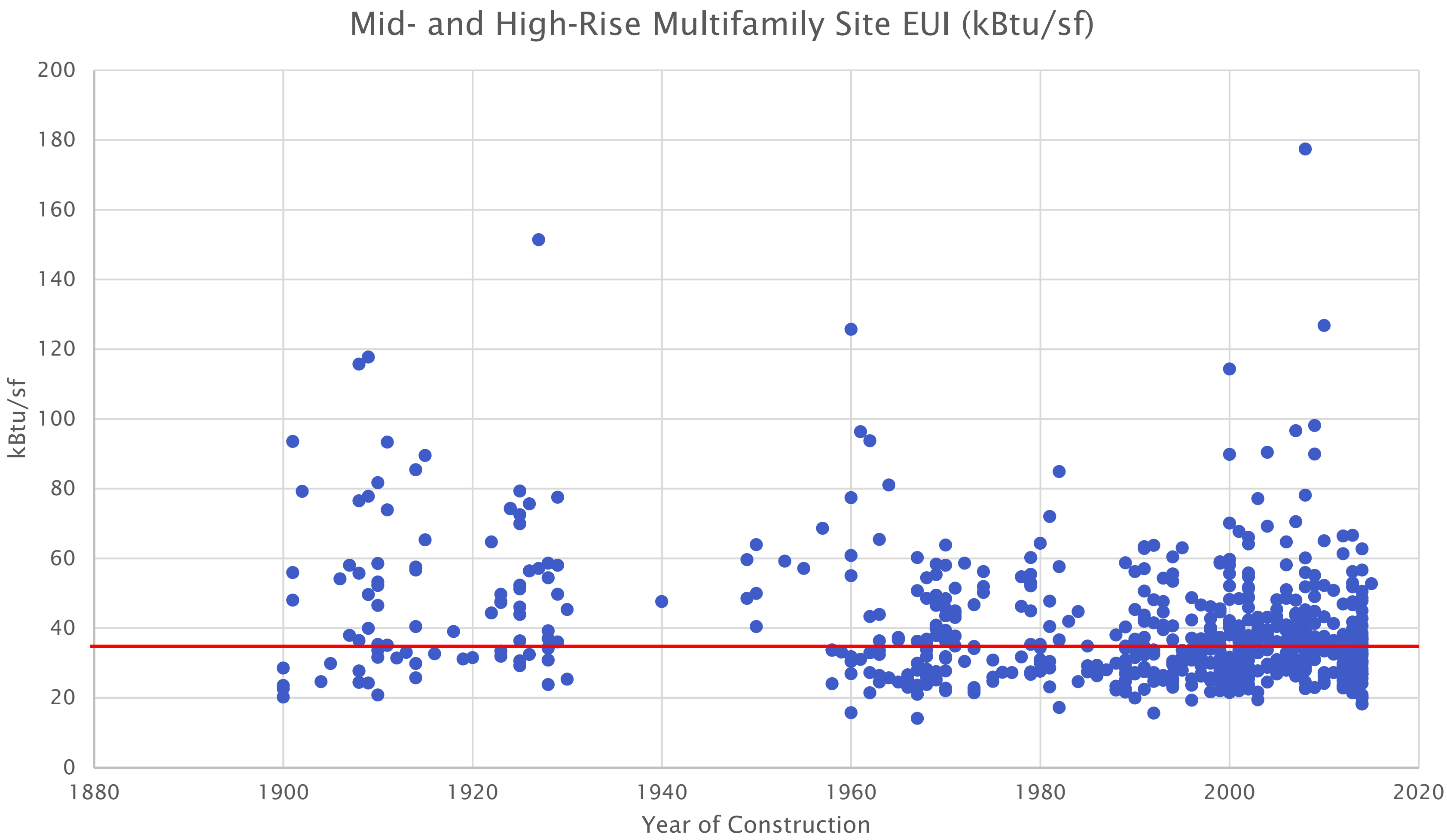
Target Performance Path

→ Proposed energy model must show conformance with Seattle's energy use targets.

→ Building must meet Energy Use Intensity (EUI) target established in code after occupancy.

- Not included in WSEC.
- No reference model required.
- Must submit operating energy use for 3 to 4 years after building completion
- Owner shall provide financial security to be used as a penalty for failing to achieve targets. Penalty of $1/sq ft - $4/sq ft.
- Not popular

Target Performance Path: Comparison to 2015 Seattle Benchmarking Data



C407: Total Building Performance Path

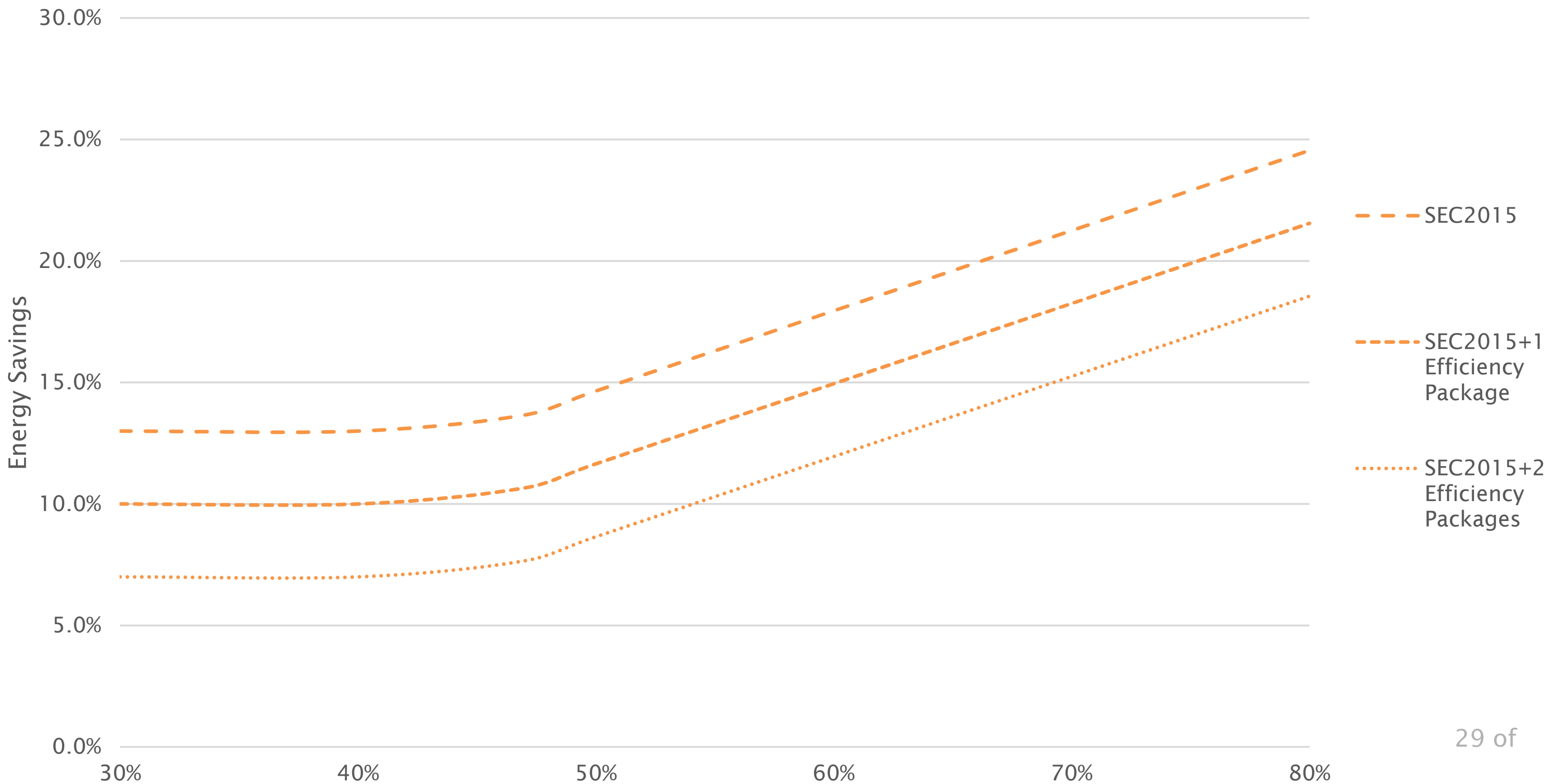
→ 2 Models: Reference and Proposed

Comparison to Prescriptive Compliance
Account for savings from high efficiency mechanical systems and lighting.
Requires electrical, mechanical permits submitted with building permit.
Increased flexibility.
More complexity and more time required to complete analysis

Changes from 2012 to 2015 Seattle Energy Code

Section C406: Additional Efficiency Options

- → Enhanced Envelope Performance
- → Reduced Air Infiltration
- → More efficient HVAC equipment
- → Dedicated Outdoor Air System (DOAS)
- → High efficiency service water heating
- → Reduced Lighting Power Density
- → Enhanced Lighting Controls
- → On-Site Renewable Energy



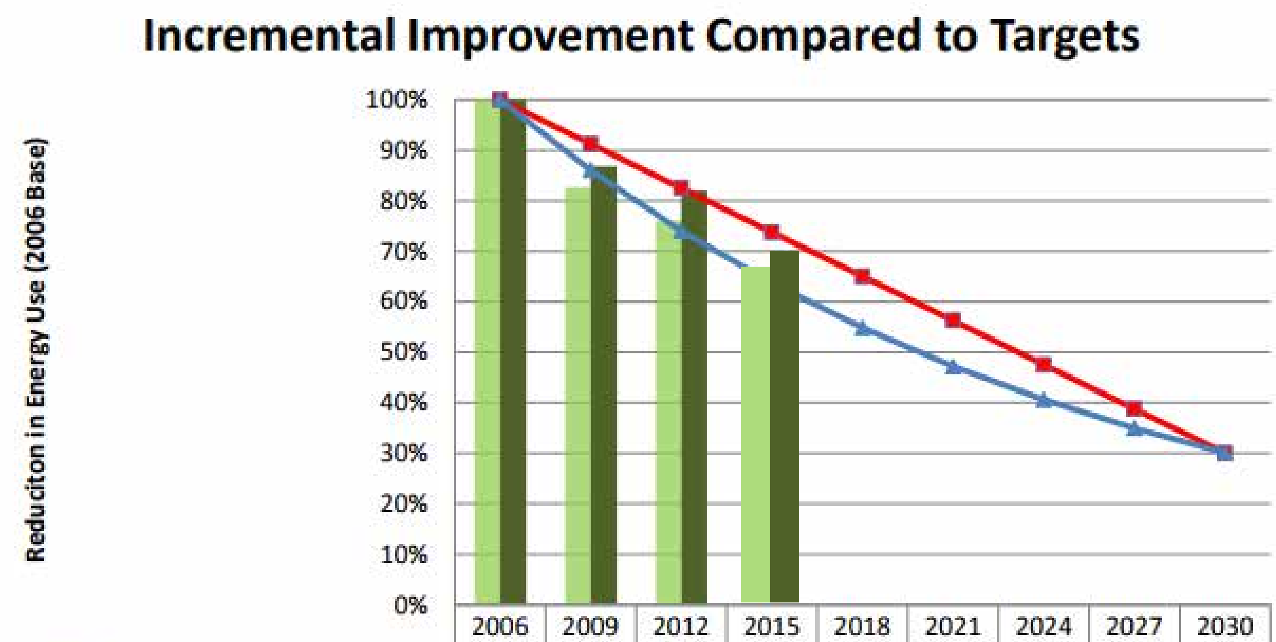
Seattle Code U-Values and R-values

	2009	2015
Wood-Framed	0.054 (R19)	Commercial/Group R .051/0.054 (R19)
Metal-Framed	0.057(R17)	0.055(R18)
Mass Wall	0.09(R11)	0.057(R17)
Attic Roof	0.027(R37)	0.021(R48)
Insulation above the Deck	0.031(R32)	0.027(R37)
Non-Metal Glazing	0.32	0.28
Metal Glazing	0.40	0.34

	2009	2015
Wood-Framed	R-13 + R-7.5 (Commercial) R-21 Intermediate framing (Group R)	R-13 + R-7.5 (Commercial) R-21 Intermediate framing (Group R)
Metal-Framed	R-19 + R-8.5CI	R-19 + R-8.5CI
Mass Wall	R-16 CI or R-13 + R-6CI	R-16 CI or R-13 + R-6CI
Attic Roof	R-49	R-49
Insulation above the Deck	R-38CI	R-38CI

Where we're going

Incremental Improvement Compared to Targets



	2006	2009	2012	2015	2018	2021	2024	2027	2030
Residential	100%	82.7%	76.1%	69%					
Commercial	100%	86.8%	82.0%	75%					
Target: 8.75 % savings compared to the 2006 WSEC	100%	91%	83%	74%	65%	56%	48%	39%	30%
Target: 14% savings compared to each previous code	100%	86%	74%	64%	55%	47%	41%	35%	30%

Credit: Washington State Building Code Council
with 2015 values input by RDH

Conductive Heat Loss Control

- → Insulation between studs is most common heat control strategy
- → Need to consider effective R-values
- → Wood ± R-1 per inch
- → "Continuous insulation" may be required in some climate zones per IECC

Thermal Anatomy 101 – Wood Frame House

- → R-20 Insulation in walls
  - → R-16 accounting for studs
- → R-40 Attic Insulation
  - → R-36 accounting for trusses
- → R-2 Windows, 20% Wall Area
  - → Wood or vinyl frames, non-low-e glass, air-fill

Using R-4 windows instead of R-2 improves overall R-value to R-13.0, an overall improvement of R-4.1 (46%)

U-overall = 1/16 * 0.54 + 1/36 * 0.32 + 1/2 * 0.14

= 0.112 --> **R-overall =8.9** **63% Heat Loss through windows**

Thermal Anatomy 101 –Wood Frame Low-Rise

- → R-12 Insulation in walls
  - → R-9 accounting for studs
- → R-20 Roof Insulation
- → R-1.7 Windows, 40% Wall Area
  - → Aluminum frames, non-low-e, air fill

R-4 windows instead of R-1.7 improves overall R-value to R-6.8, an overall improvement of R-2.4 (55%) (8.3 with R-4 ext. insul.)

U-overall = 1/9 * 0.42 + 1/20 * 0.30 + 1/1.7 * 0.28

= 0.23 --> **R-overall =4.4** **73% Heat Loss through windows**

Thermal Anatomy 101 – High-rise

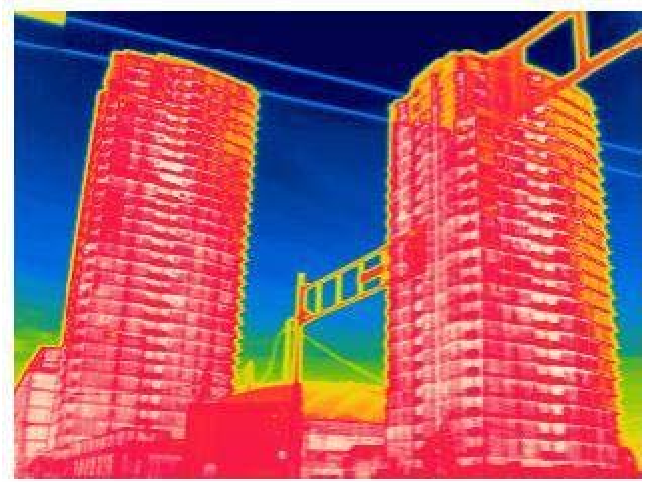
→ R-12 Insulation in walls

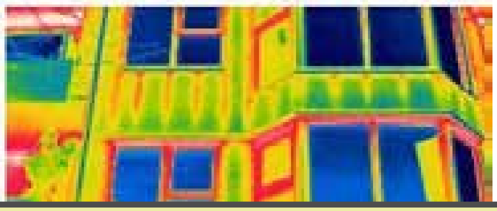
  → R-5 accounting for steel studs

→ R-20 Roof Insulation

→ R-1.8 Windows, 60% Wall Area

  → Aluminum window wall, hard-coat low-e, air fill





180,000 sq.ft.

R-4 windows instead of R-1.8 improves overall R-value to R-4.5, an overall improvement of R-1.9 (73%)

U-overall = 1/5 * 0.38 + 1/20 * 0.06 + 1/1.8 * 0.56

= 0.39 --> **R-overall =2.6** **80% Heat Loss through windows**

R-value Comparisons

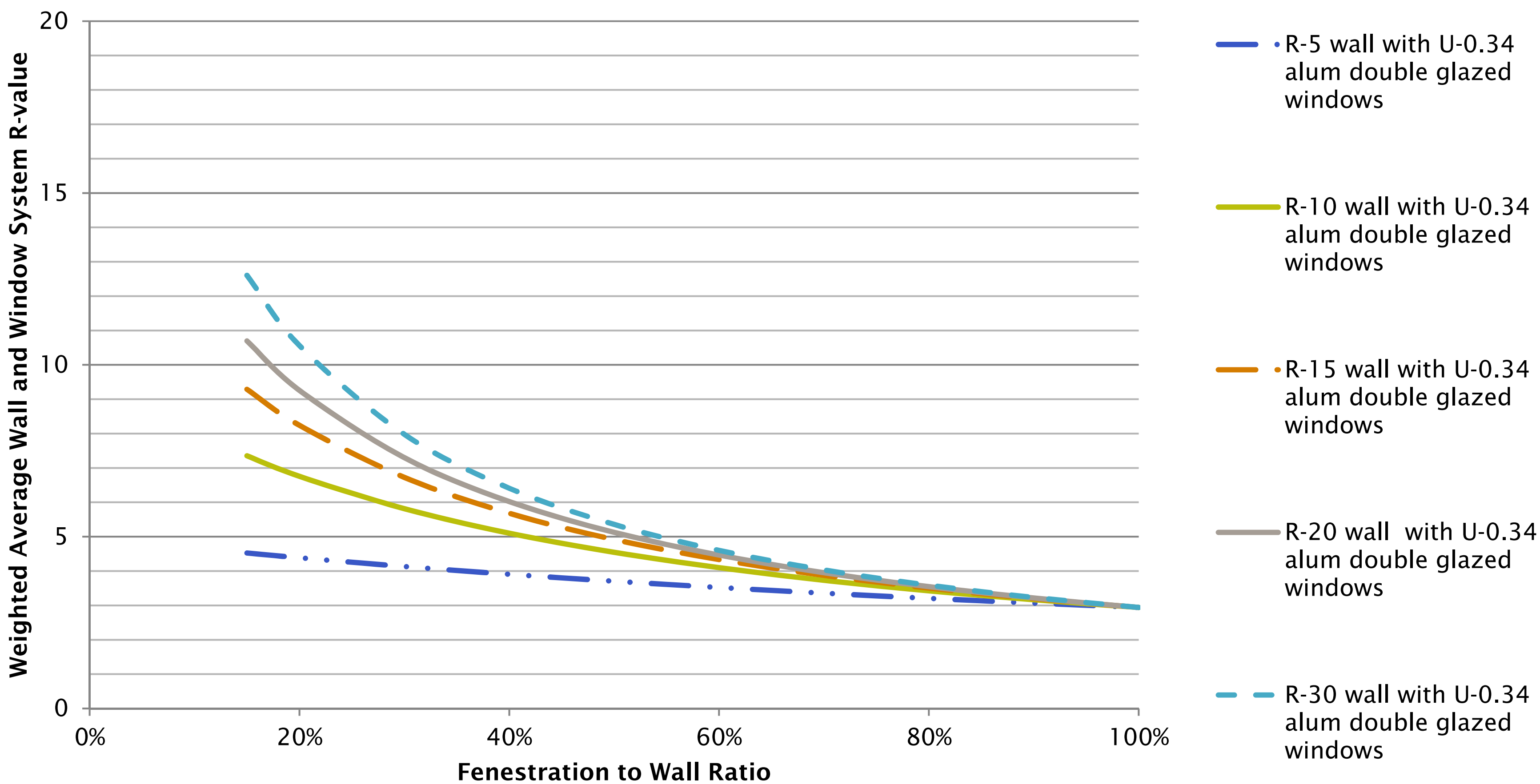
- → An overall R-value of R-2 to R-3 is small – and is directly related to the energy loss through the building envelope
- → For Comparison:
  - → 1" of fiberglass insulation is ~R-4
  - → ½" of extruded polystyrene foam insulation is R-2.5

5/8" ceiling tile ~R-2

Down Jacket R3-R5

Energy Efficiency Fundamentals

→ The enclosure has the longest lifespan of all building components



Energy Efficiency Fundamentals

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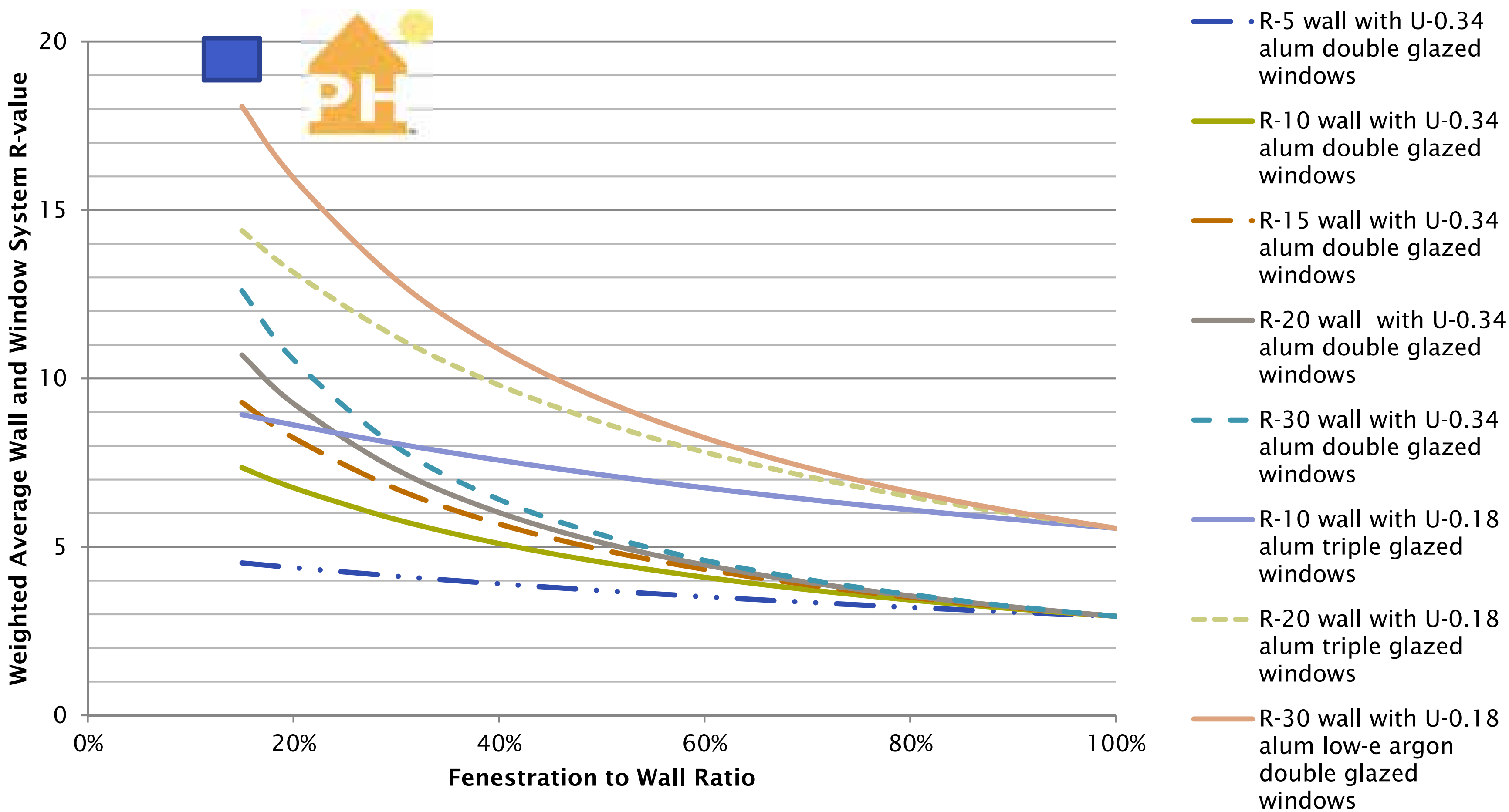
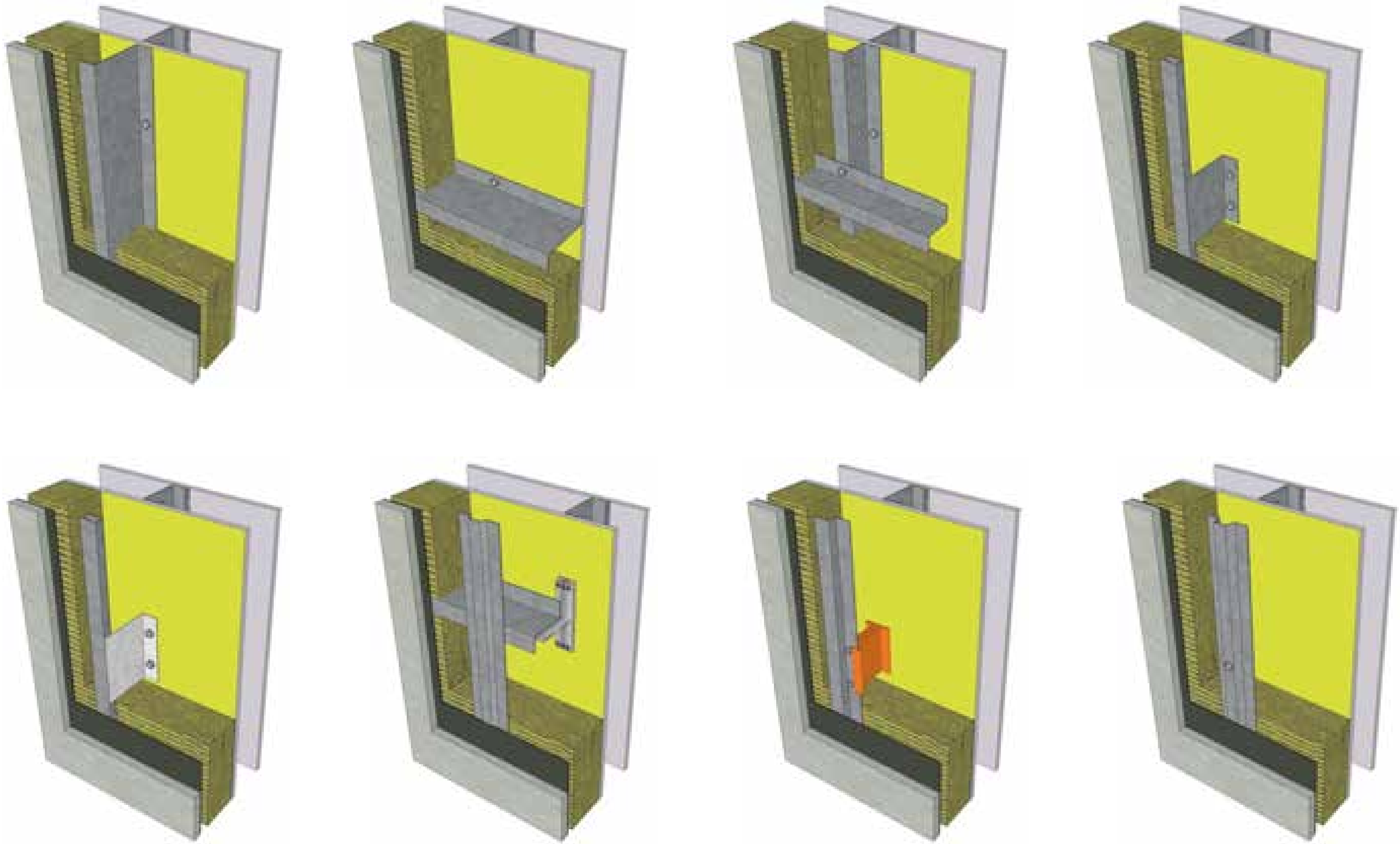
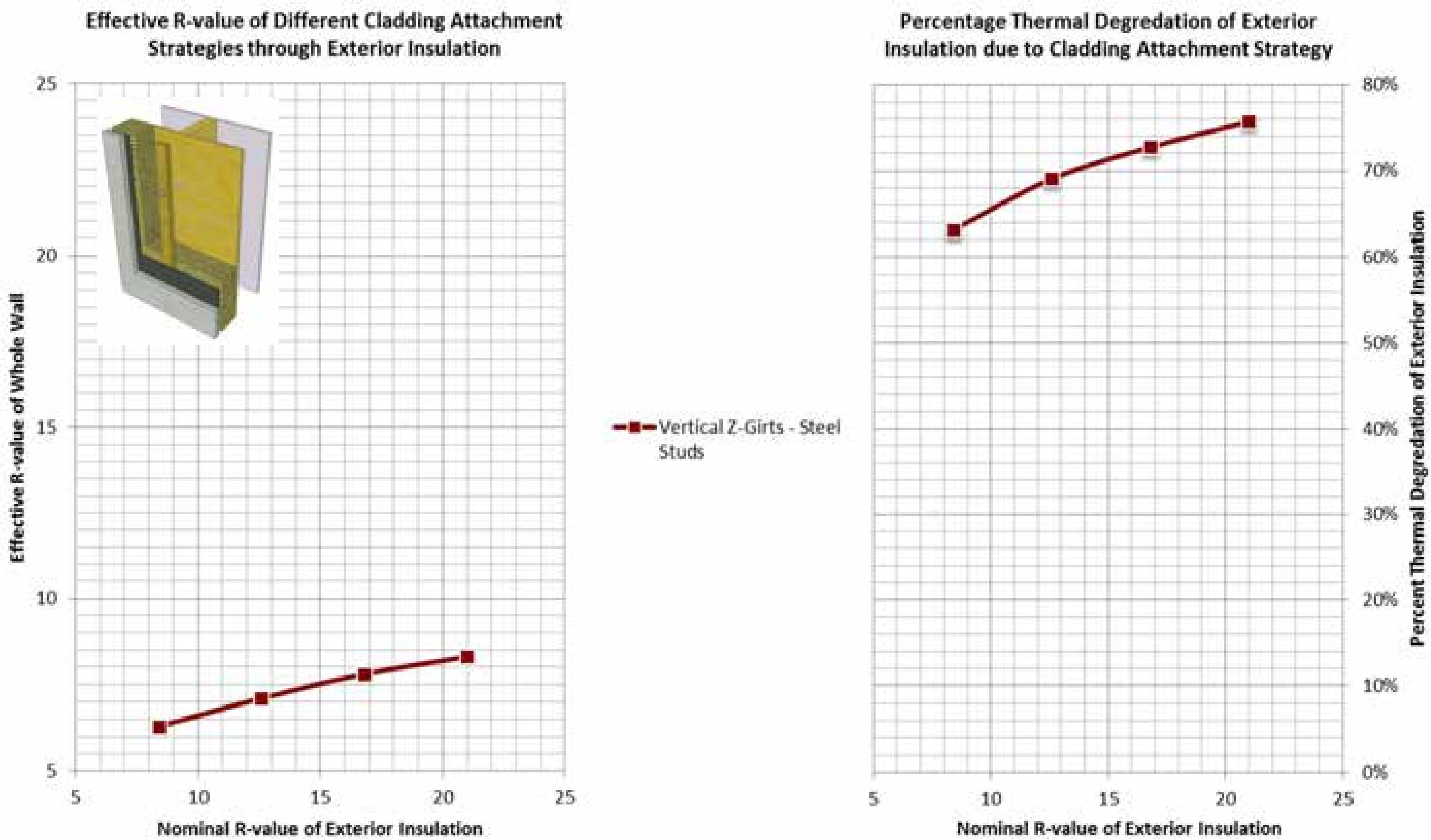


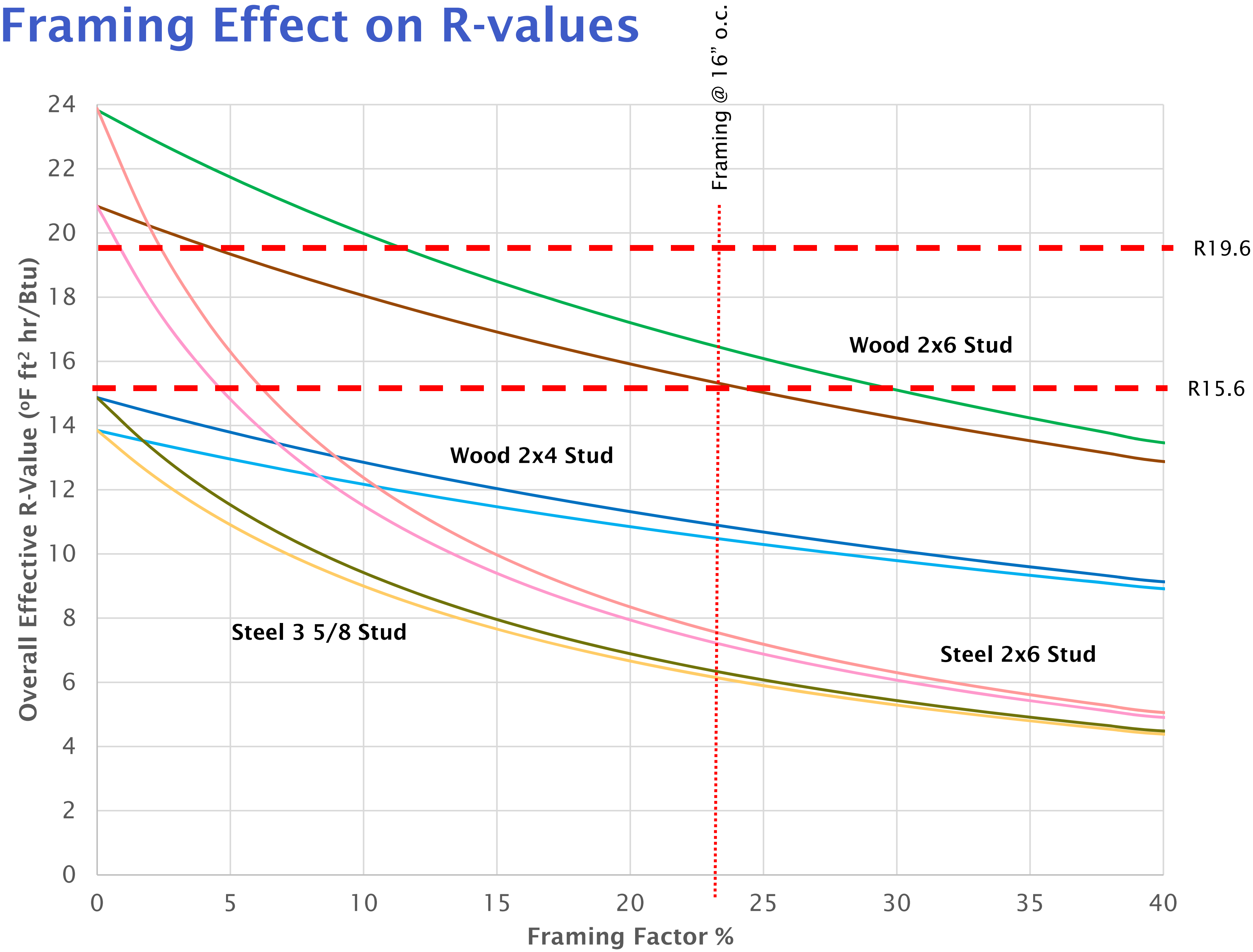
Many Attachment Options



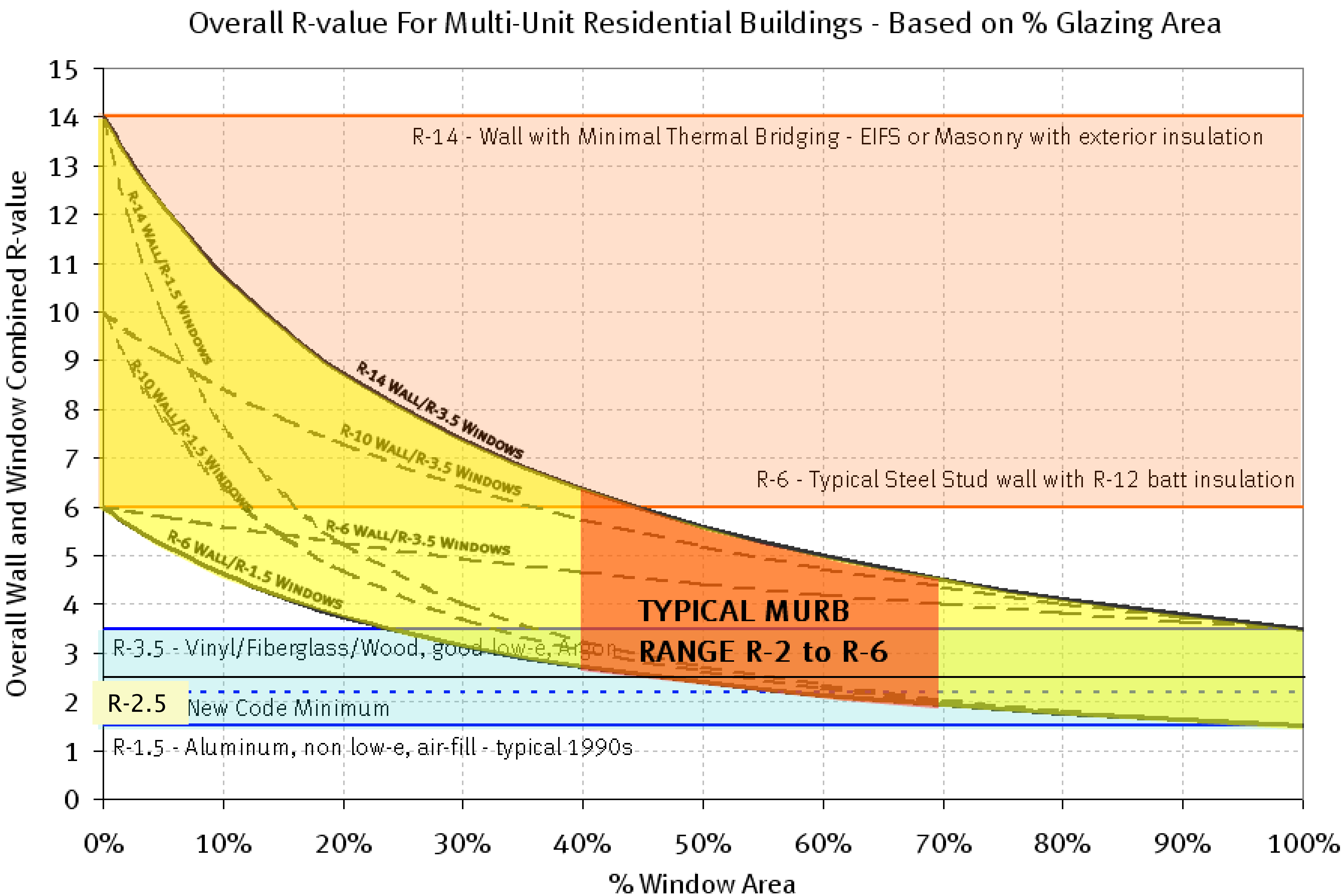
Thermal Comparison of Options



Framing Effect on R-values



Effect of Window Area on Overall Building R-value



The Standard Approach

→ Assembly

  → ½" gyp

  → 2x6 @ 16" o.c.

  → R-20 high density insulation

  → ½" sheathing

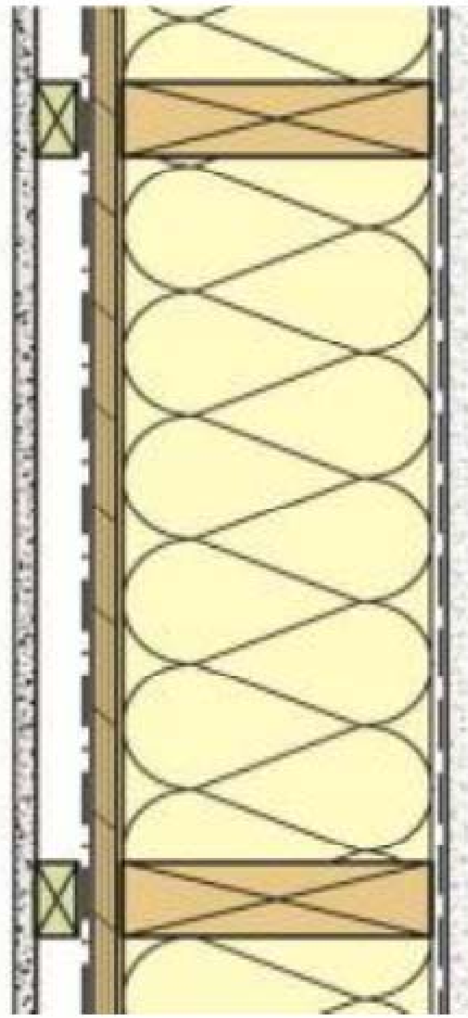
  → WRB/furring/cladding

→ Standard framing factor

  → 77% cavity, 23% framing

→ U-0.064

→ R-15.6



Higher R-Values - Option #1

→ Assembly

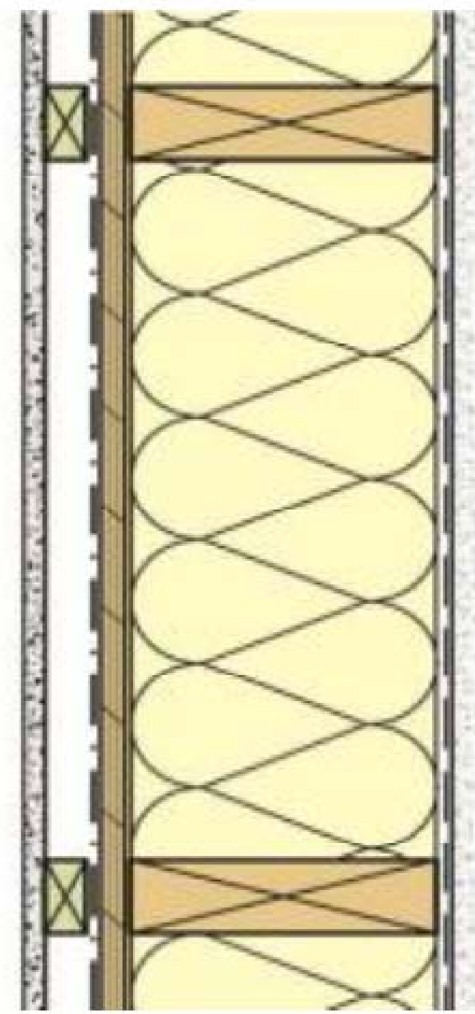
- → ½" gyp
- → 2x8 @ 16" o.c.
- → R-30 high density insulation
- → ½" sheathing
- → WRB/furring/cladding

→ Standard framing factor

- → 77% cavity, 23% framing

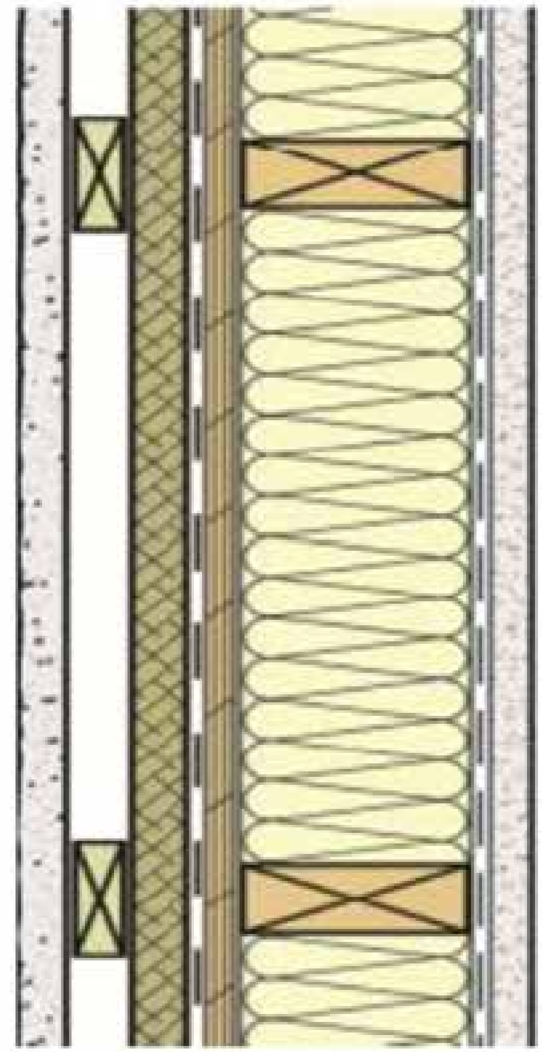
→ U-0.045

→ ± R-22.0



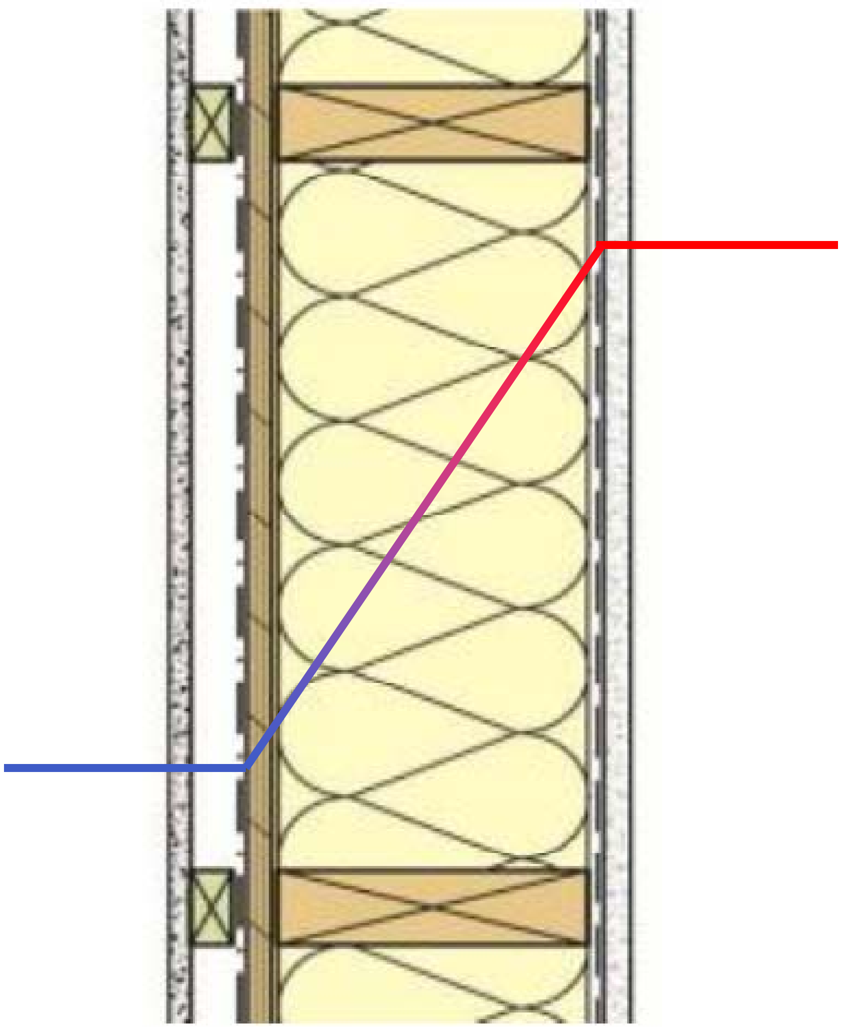
Higher R-Values - Option #2

- → Assembly
  - → ½” gyp
  - → 2x6 @ 16” o.c.
  - → R-21 high density insulation
  - → ½” sheathing / WRB
  - → 1” insulation (R-4.2 cont.)
  - → Furring/cladding
- → Standard framing factor
  - → 77% cavity, 23% framing
- → U-0.046
- → ± R-22

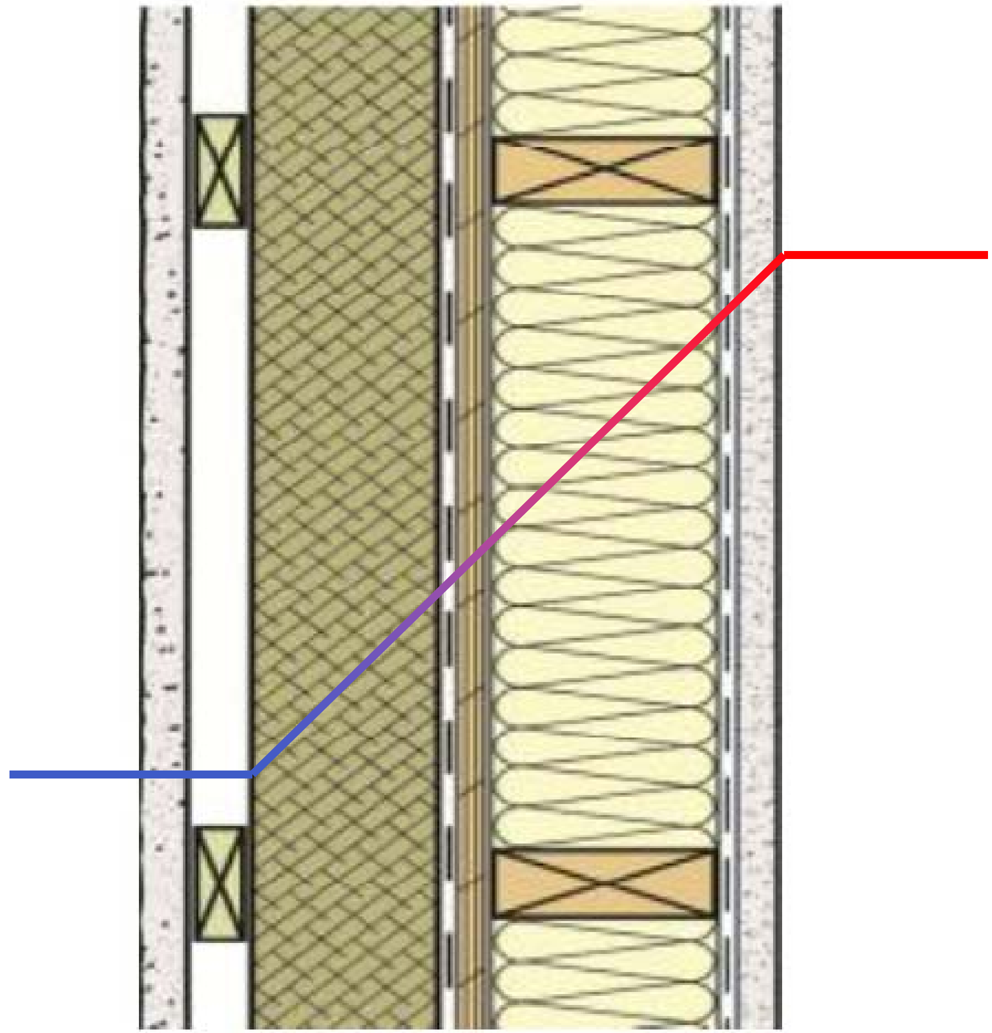


So, What's the Difference?

R-22



R-22



Exterior Insulation Selection (Vapor Control)

→ Rigid exterior foam insulations (XPS, EPS, Polyiso, closed cell SPF) are vapor impermeable

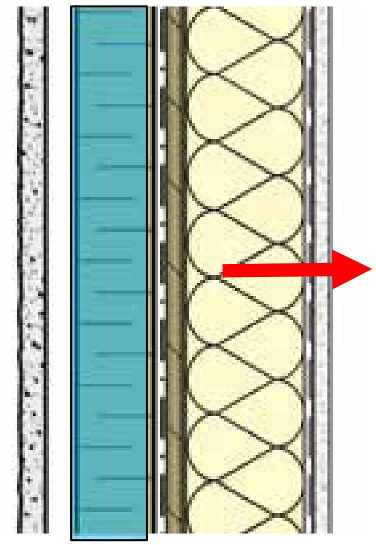
  → Rules of thumb: Vapor barrier on 'warm' side

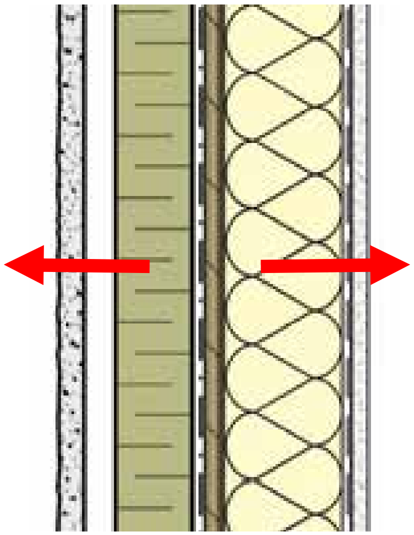
→ Fibrous insulations (mineral fiber / glass fiber) are vapor permeable

  → Allows drying to the exterior

  → Often safer in cold and mixed climates

→ Vapor permeance properties of WRB/air barrier membrane is also very important





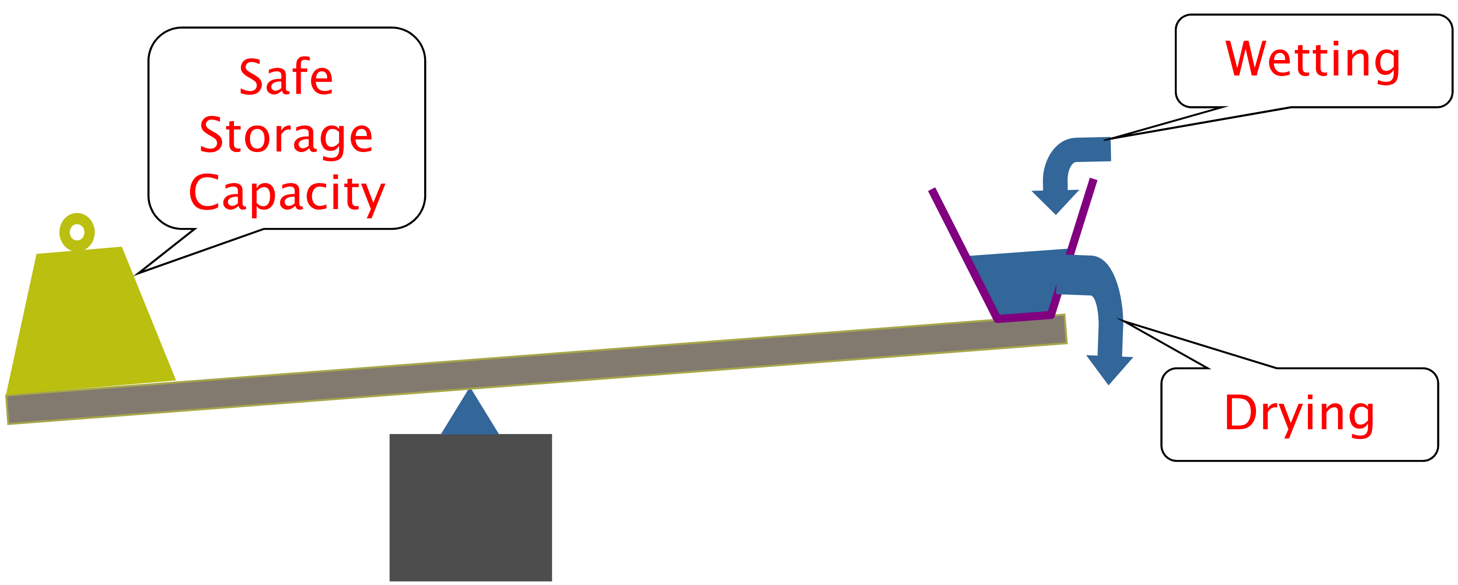
Building Science: Wetting and Drying

→ How can we keep the sheathing and other materials dry?

→ Don't let them get as wet

→ Create air space to promote drainage and drying

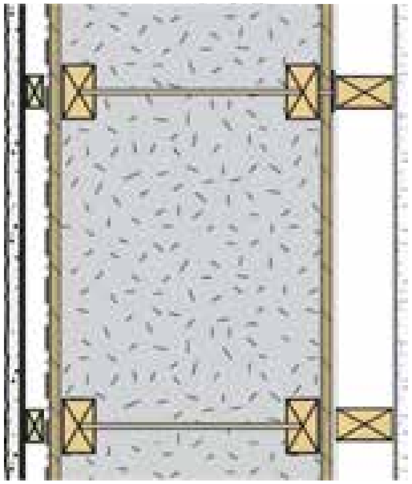
→ Design for vapor diffusion drying



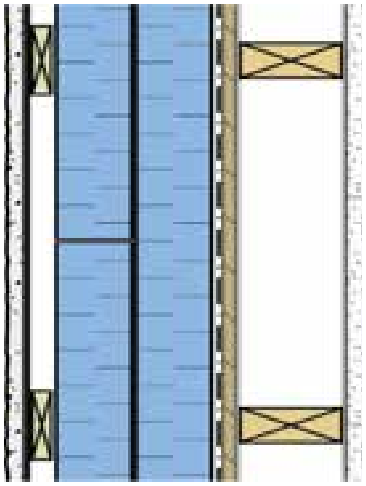
The Future of Insulation: Hybrid Insulation/Split Insulated Assemblies

How to Insulate More

Stuff It?



Wrap It?



Ext. Insul. & Cladding Attachment Considerations

- → Cladding weight & gravity loads
- → Wind loads
- → Seismic loads
- → Back-up wall construction (wood, concrete, steel)
  - → Attachment from clip/girt back into structure (studs, sheathing, or slab edge)
- → Exterior insulation thickness
- → Rigid vs semi-rigid insulation
- → R-value target, tolerable thermal loss?
- → Ease of attachment of cladding – returns, corners
- → Combustibility requirements

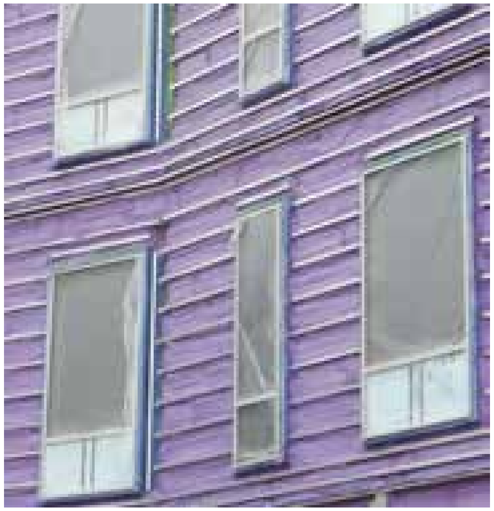
Cladding Attachment & Exterior Insulation

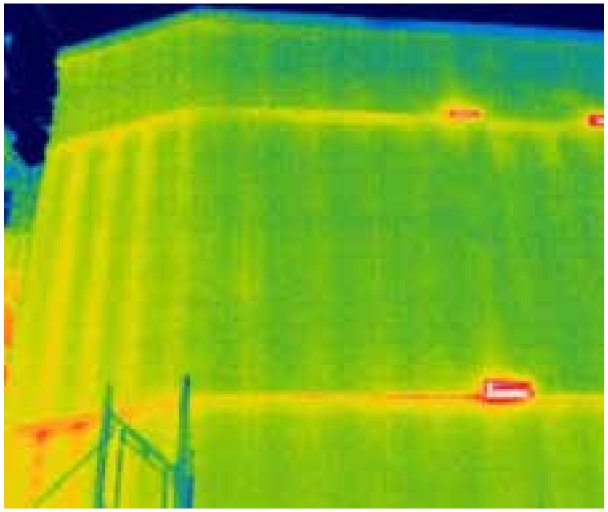
→ Exterior insulation is only as good as the cladding attachment strategy

→ What attachment systems work best?

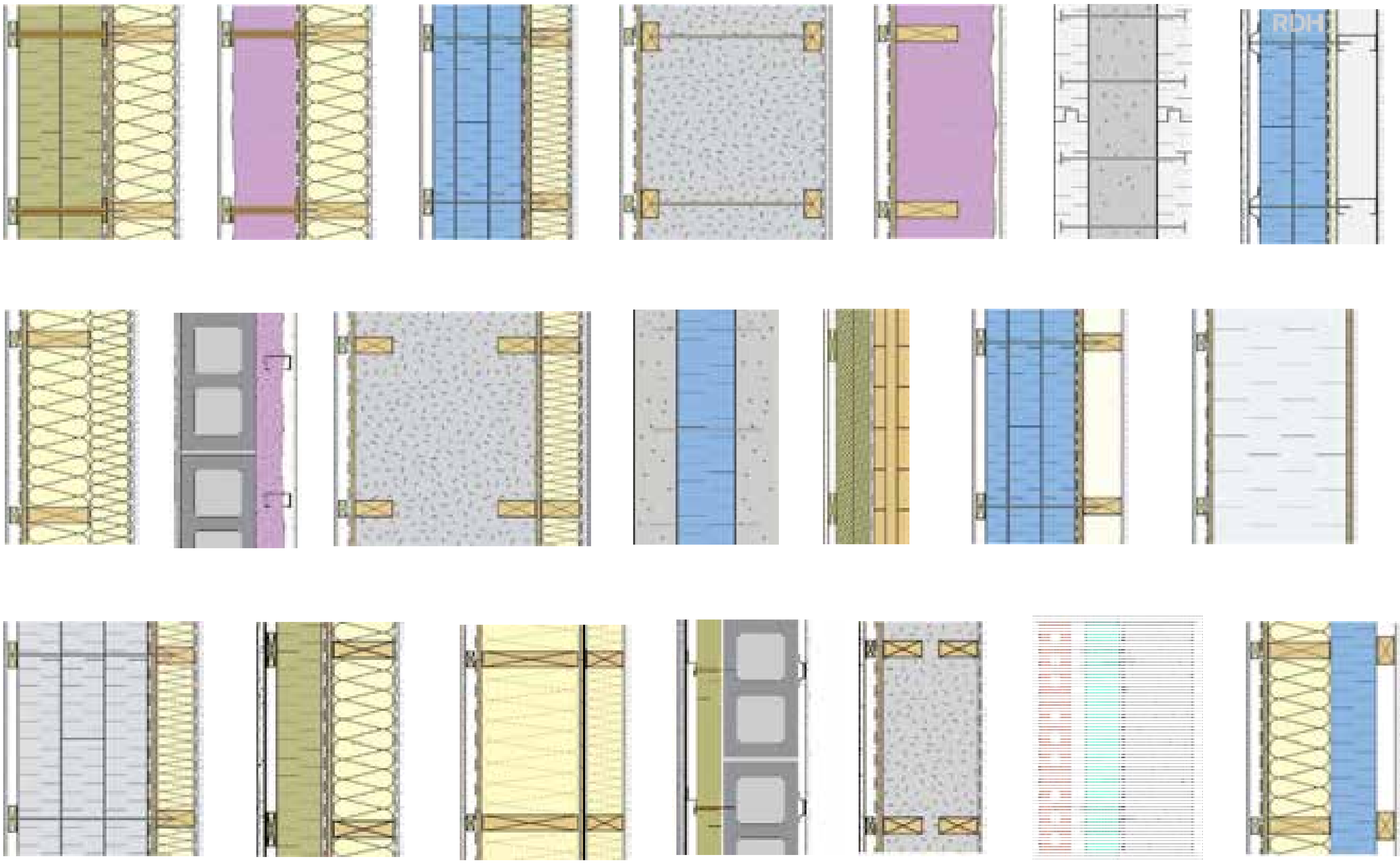
→ What is and how to achieve true continuous insulation (ci) performance?

→ What type of insulation?





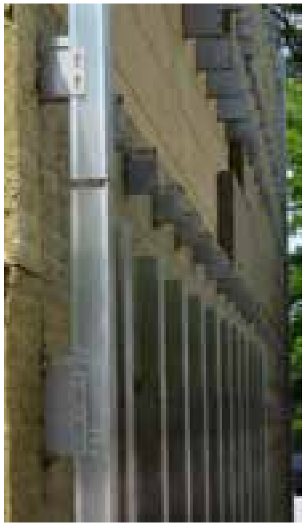
More than one way to get there…



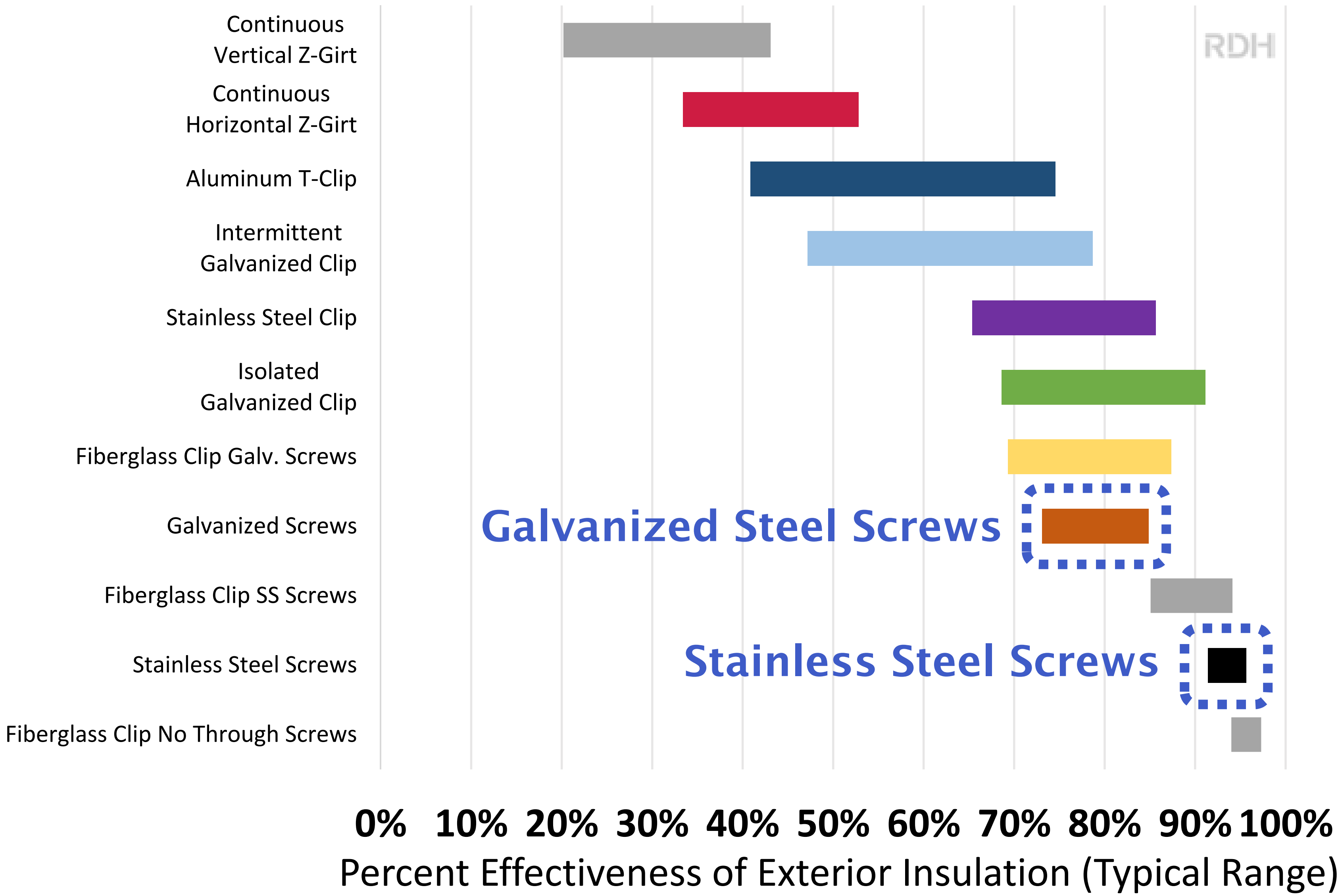
Exterior Insulation Approaches



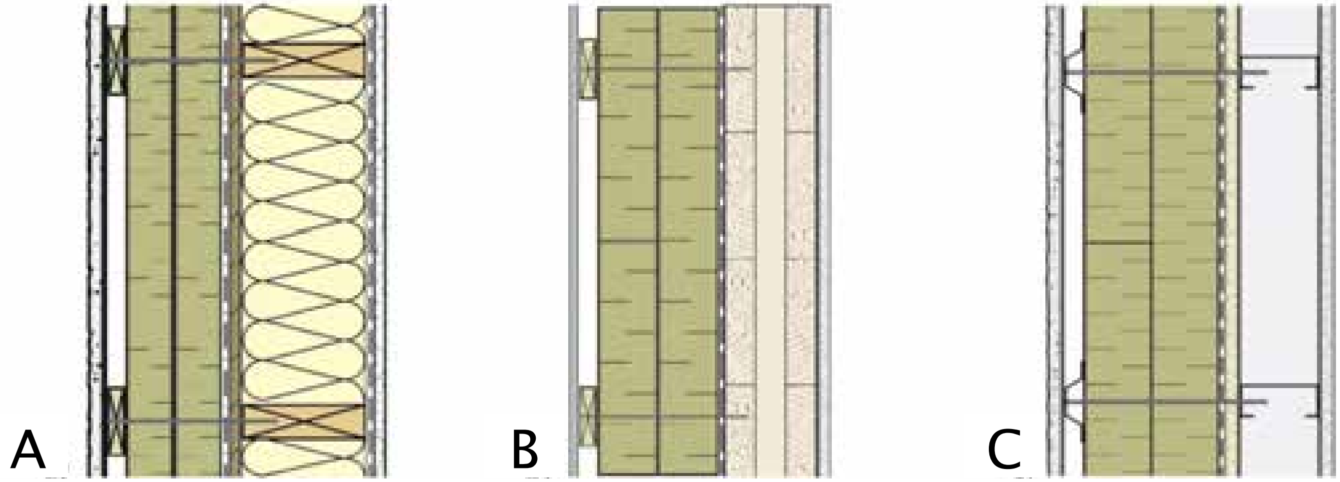


Screws Through Insulation Highly Effective



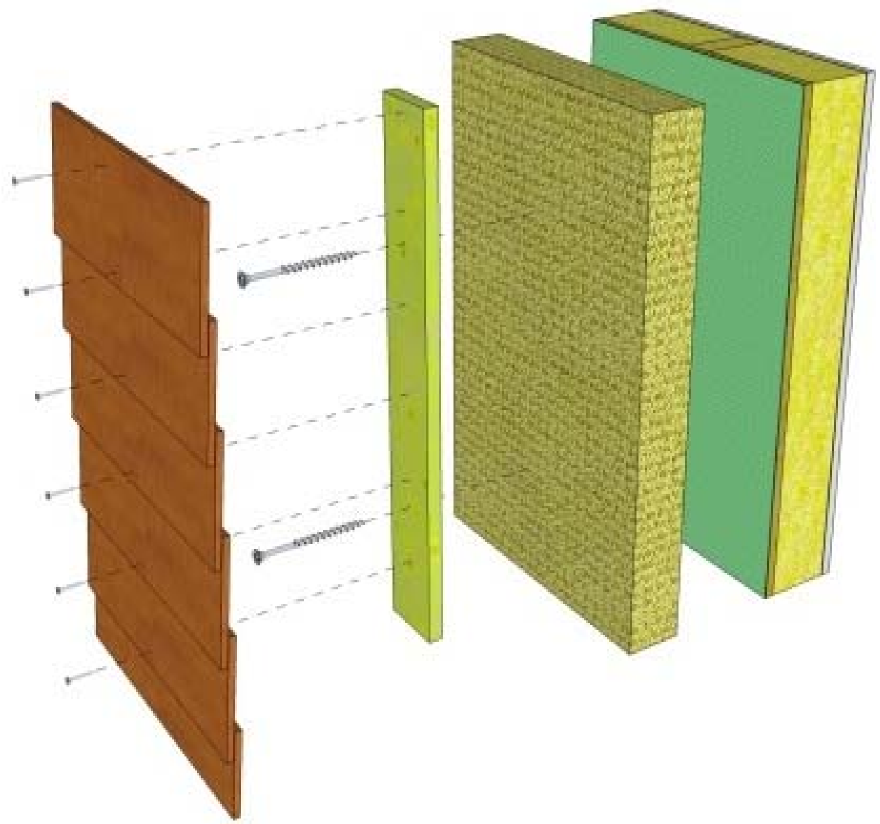
Screws through Insulation – Optimal Chi-Values



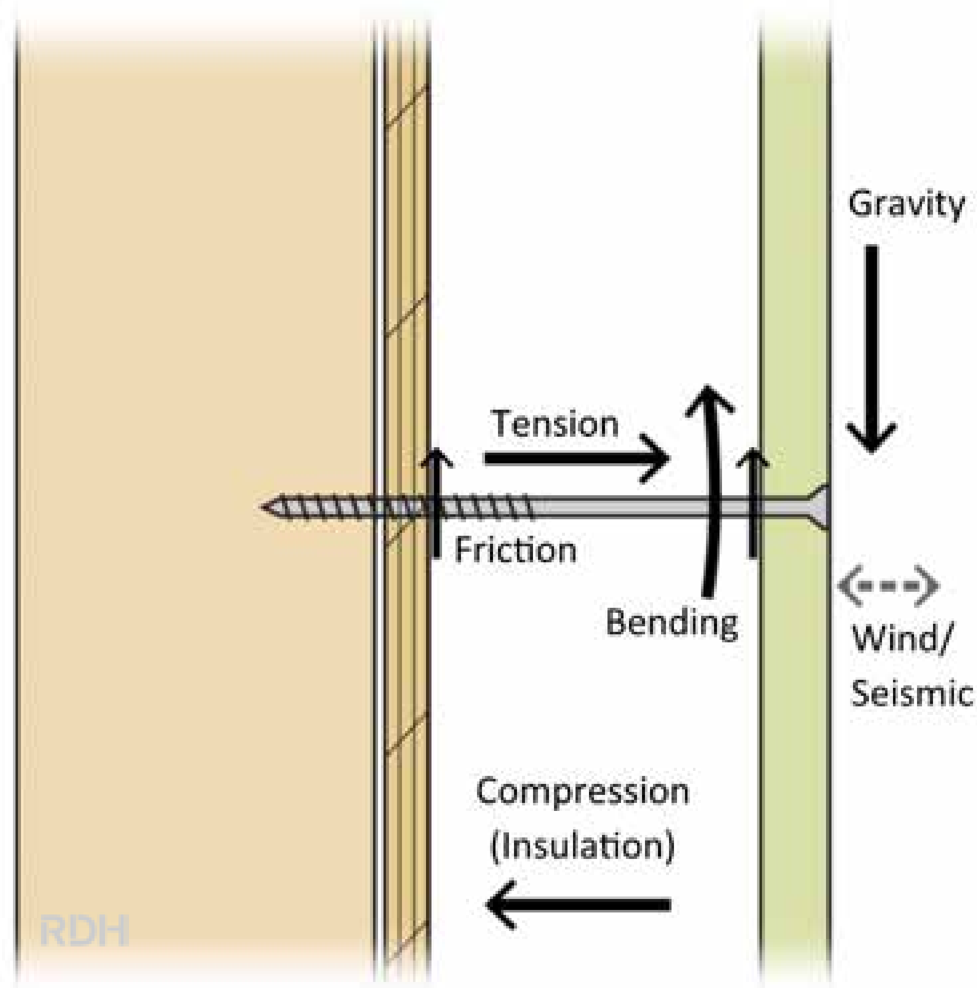
R_{SI}-Value Ext. Insulation (m^2K/W)		Nominal R_{SI}-Value Wall (m^2K/W)	Chi (W/K)	Chi/Area (W/m^2K)			Effectiveness of Exterior Insulation (%)		
				12"x16"	16"x16"	24"x16"	12"x16"	16"x16"	24"x16"
a) 2x6 Exterior Insulated Wood Framed Wall with R_{SI} 3.87 Cavity Fill, #10 screws									
4"	2.82	6.71	0.0010	0.0082	0.0062	0.0041	98%	98%	99%
8"	5.64	9.51	0.0012	0.0098	0.0074	0.0049	94%	96%	97%
12"	8.45	12.33	0.0013	0.0103	0.0078	0.0052	91%	93%	95%
b) 7" Cross Laminated Timber (CLT) Exterior Insulated, #12 screws									
10"	7.04	8.84	0.0018	0.0145	0.0109	0.0072	90%	92%	95%
c) 3 5/8" Steel Stud Wall no Cavity Fill, #10 screws									
4"	2.82	3.44	0.0076	0.0613	0.0460	0.0306	82%	86%	91%

Screws Through Insulation

- → Rapidly gaining popularity to meet increasing R-value requirements
- → Uncertainty about:
  - → How to do it
  - → Allowable loads
  - → Fastener types
  - → Fastener spacing
  - → Angle of installation
  - → Deflection

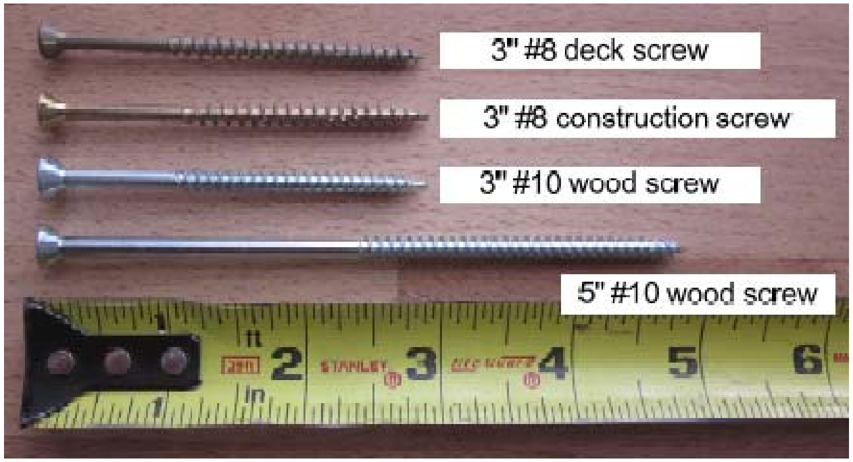


Design and Forces



Service Load State
(Section View)

Testing – Initial Testing



Testing

Cladding Weights

→ Most claddings are “light weight” with only a few products being heavier

Testing

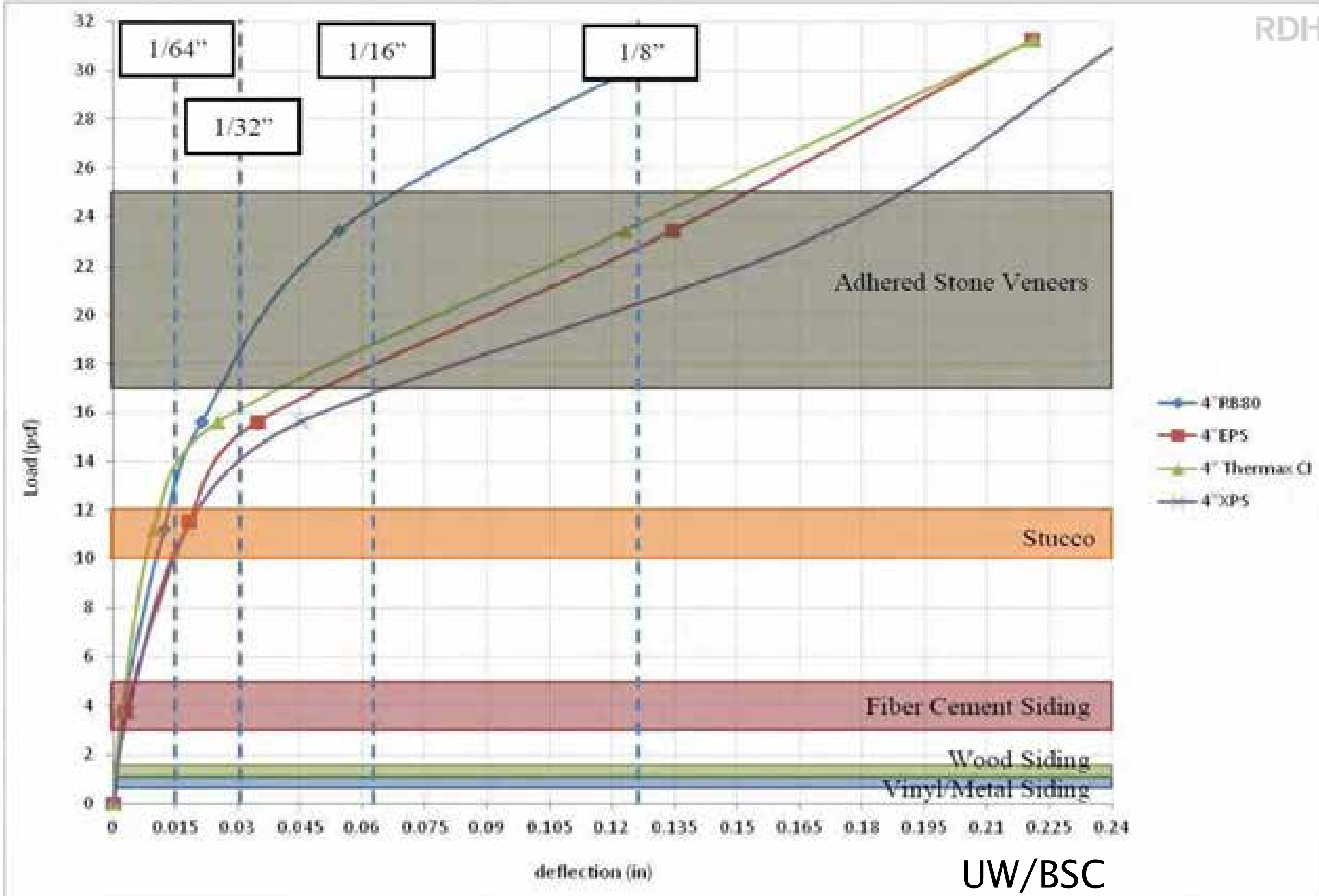


Figure 9: Short term deflection testing results (4" thick insulation)

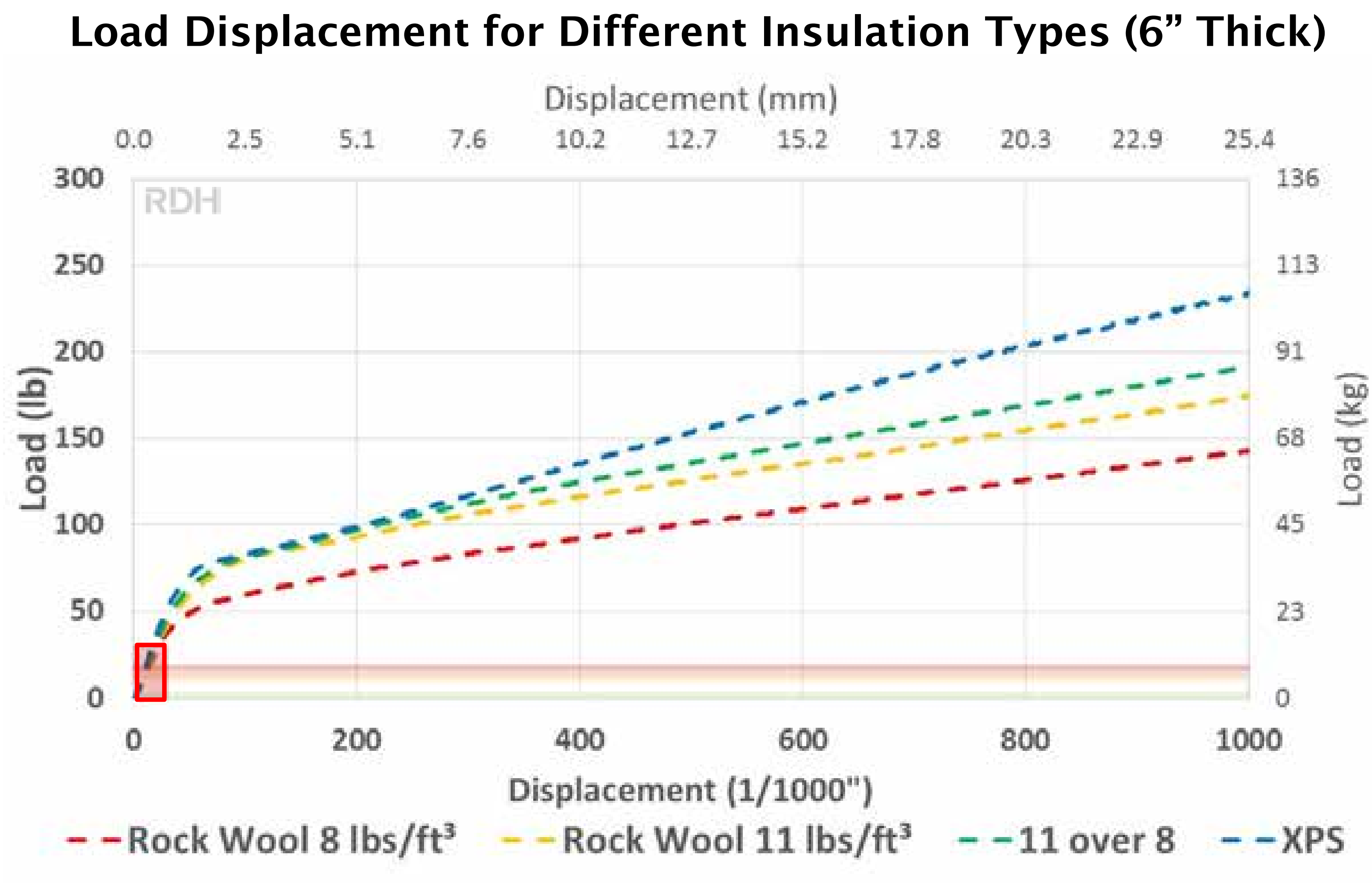
Testing

→ 3", 6", 9" and 12" thicknesses of insulation

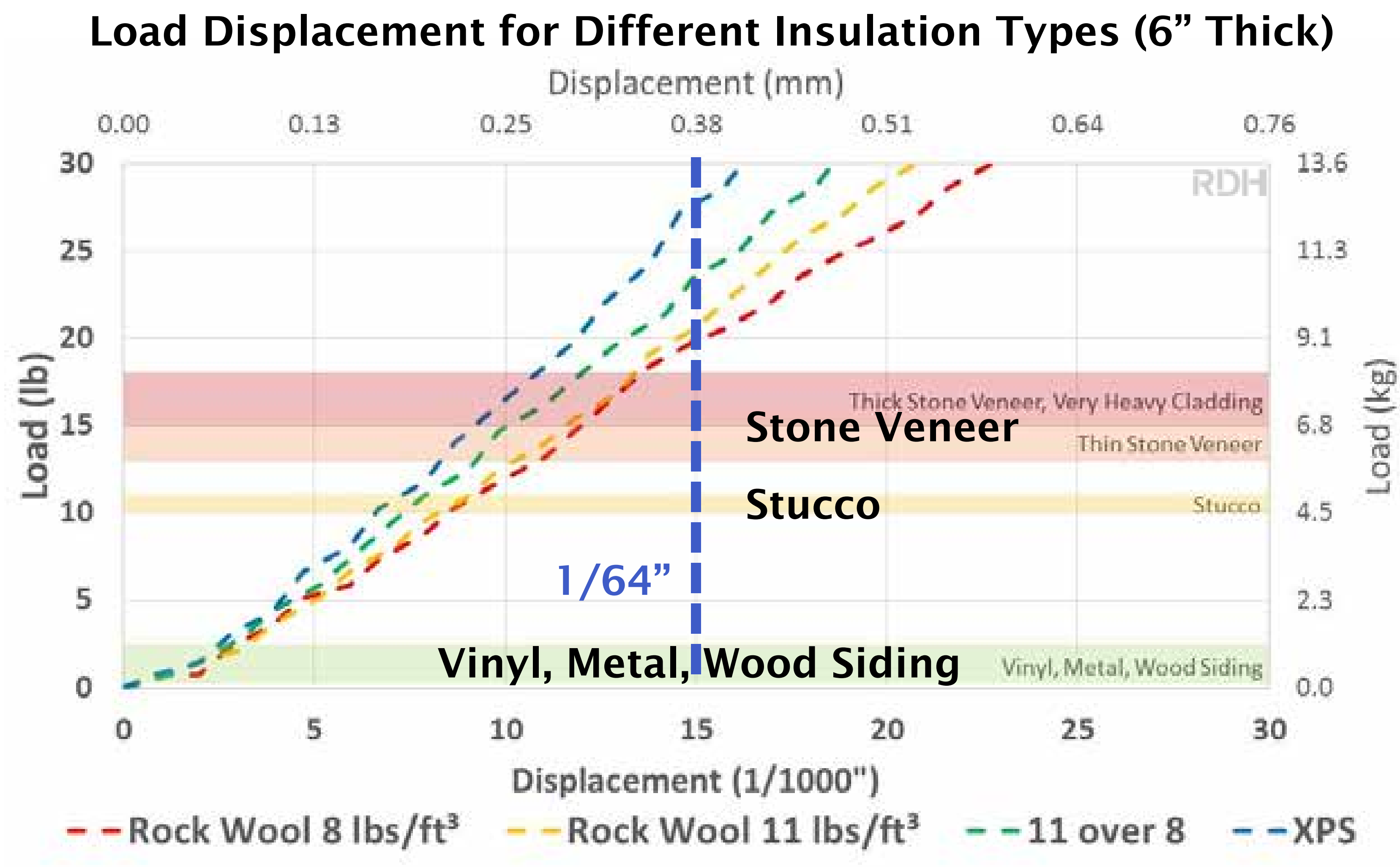
→ Different insulation types (mineral wool and XPS) and different compressive strengths

→ Different screw head types (pan and countersunk)

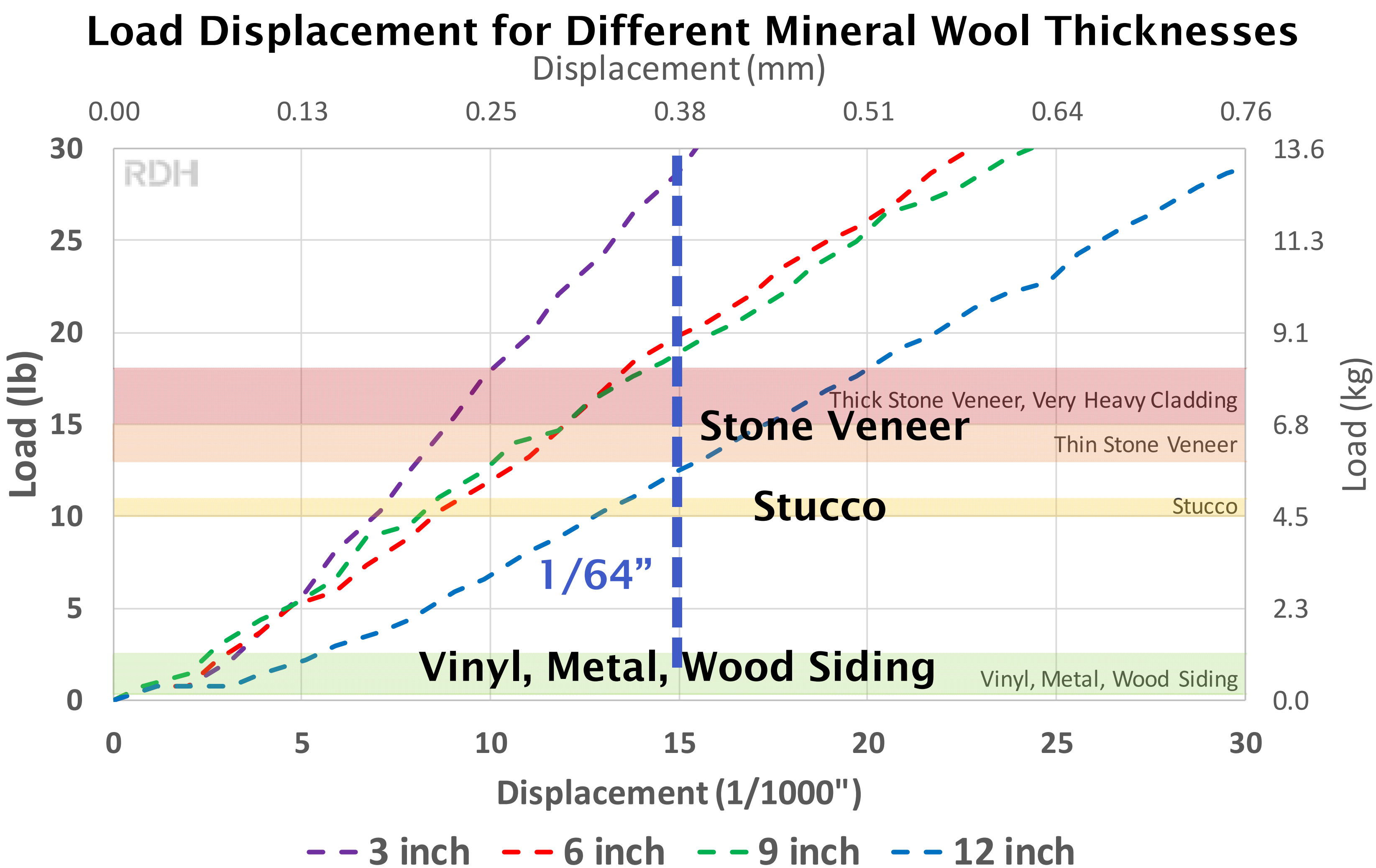
Testing – Insulation Type



Testing – Insulation Type



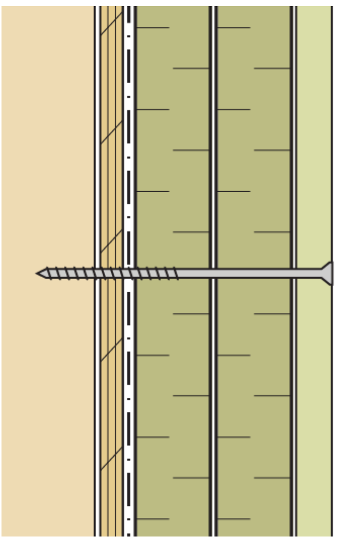
Testing – Insulation Thickness



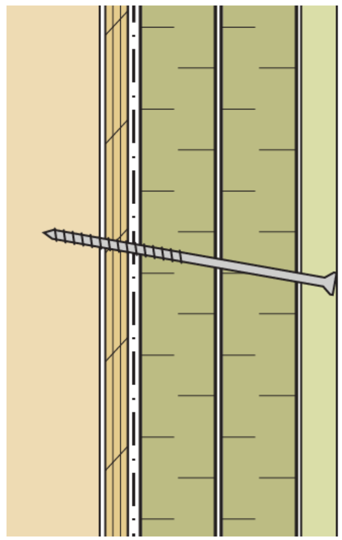
Testing – Insulation Thickness

→ For the record, this is what 12” of insulation looks like…

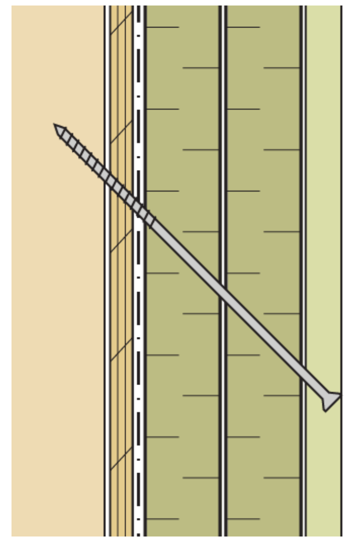
Testing – Different Fastener Arrangements



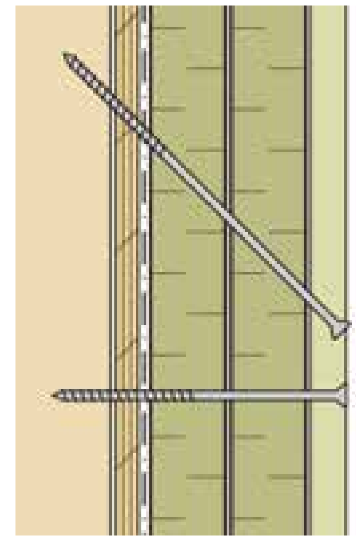
Horizontal (90°)



1:6 (80.5°)

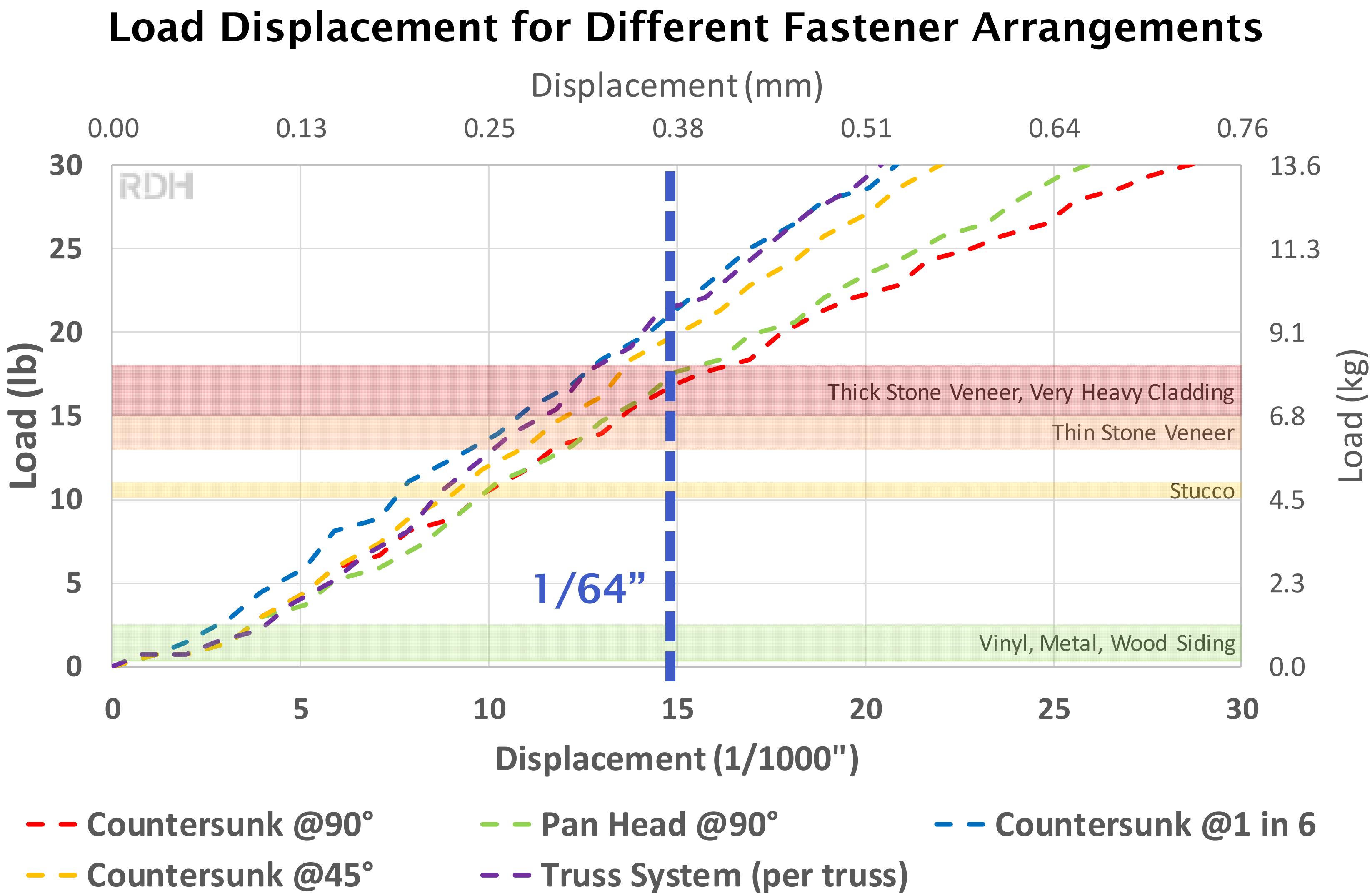


45°

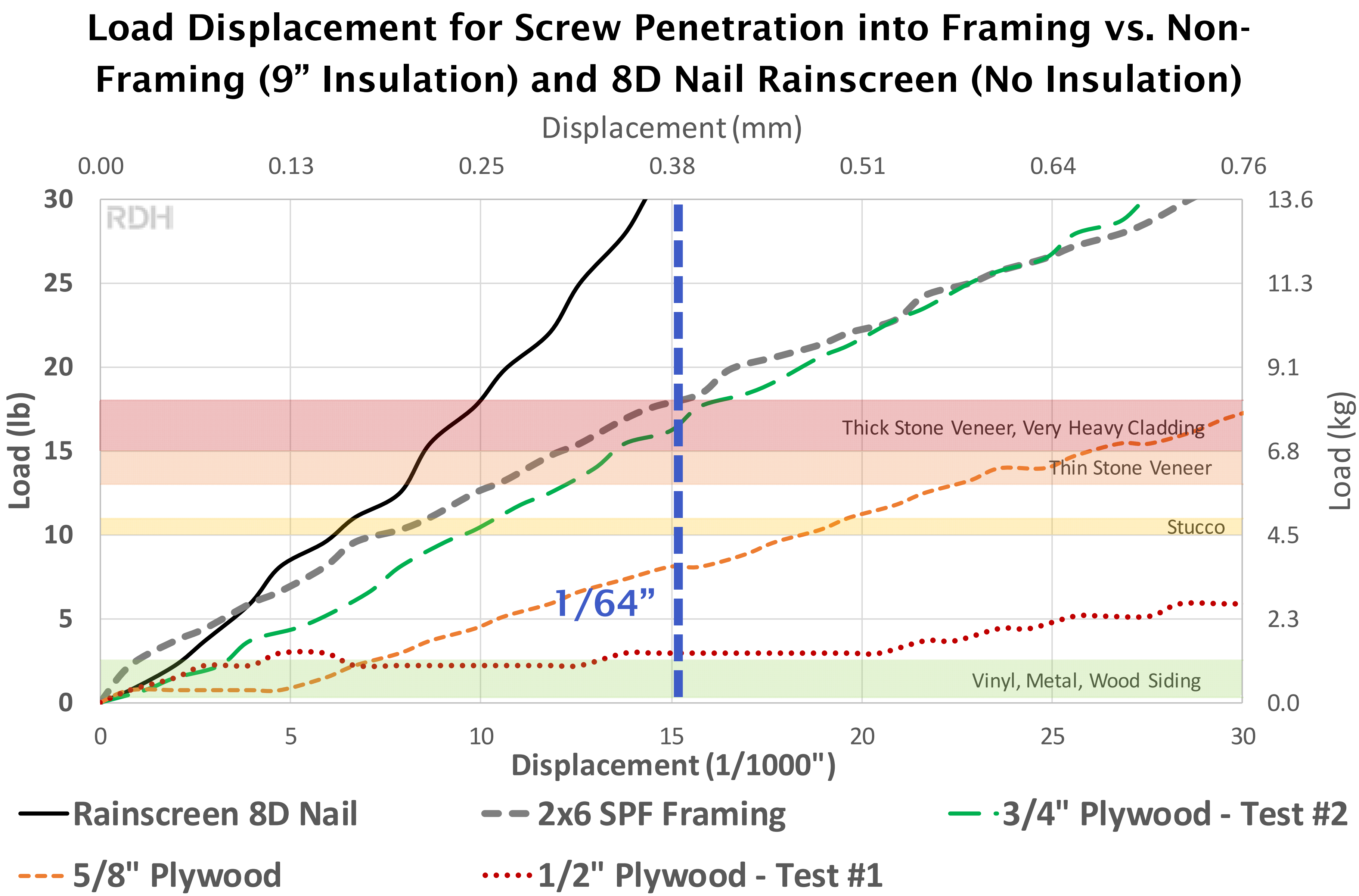


Truss (90° + 45°)

Testing – Fastener Arrangements



Testing – What if we miss the stud?

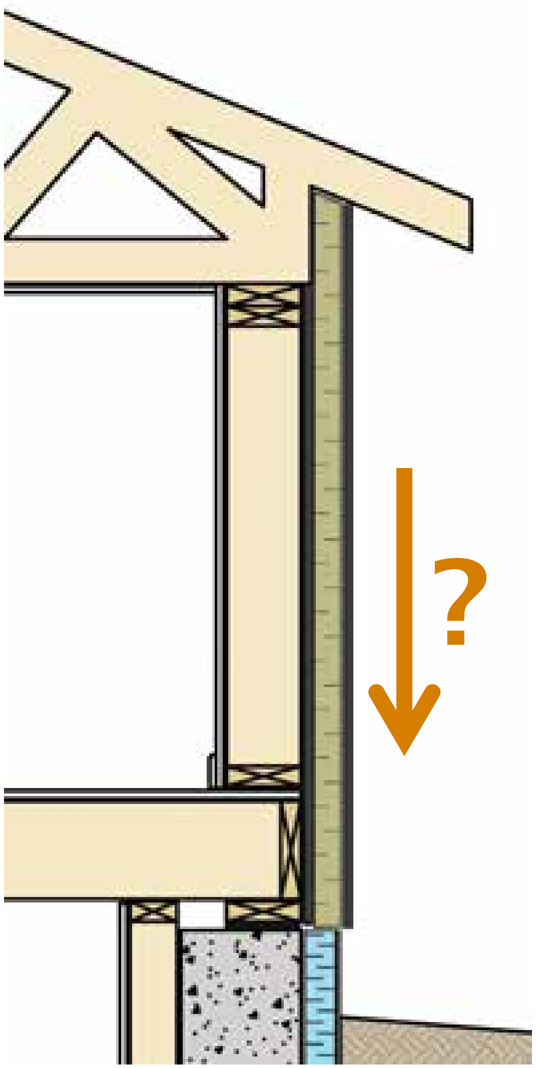


Deflection - How much is too much?

→ Difficult to define precise deflection limit but many claddings can easily accommodate 1/8” (125 mil, 3mm) deflection

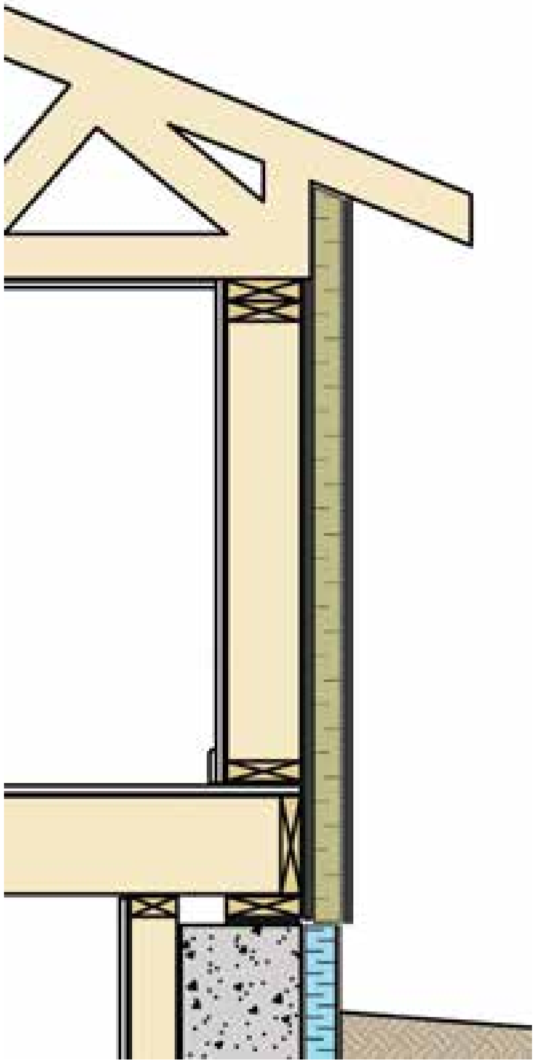
→ Staged loading of the support system helps to “pre-deflect” the strapping prior to cladding completion

→ Can see it is different than rainscreen furring direct to sheathing, but not much

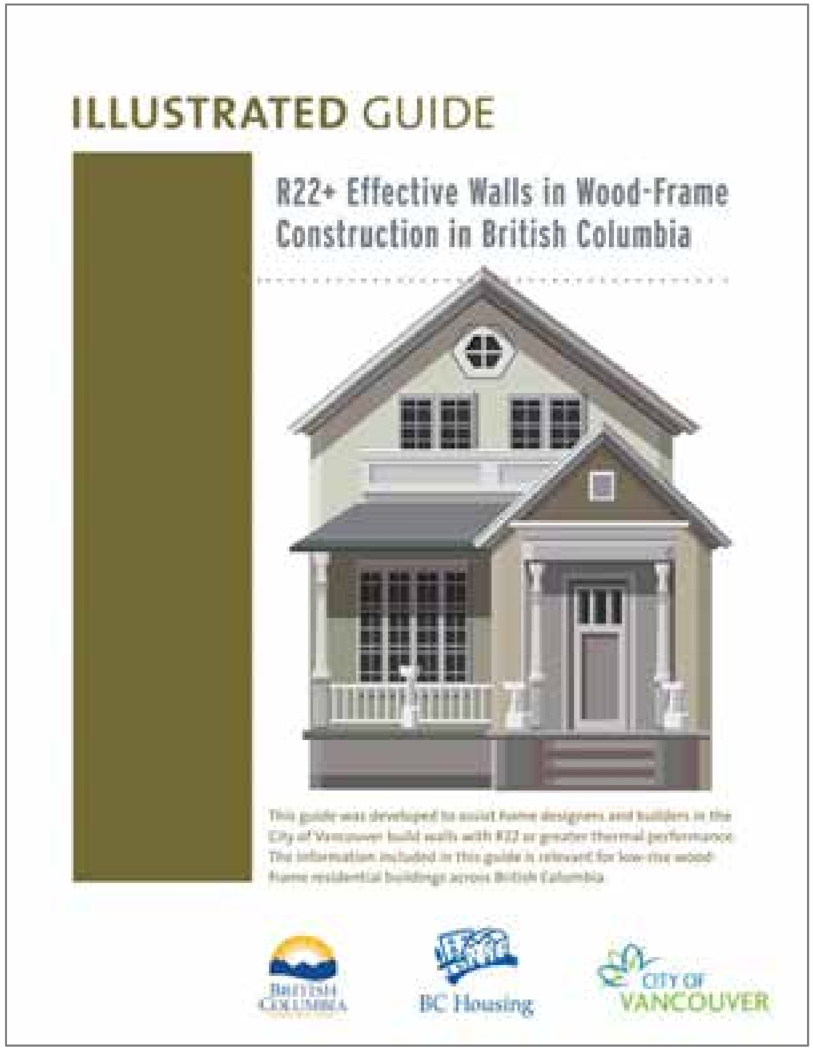


Deflection - How much is too much?

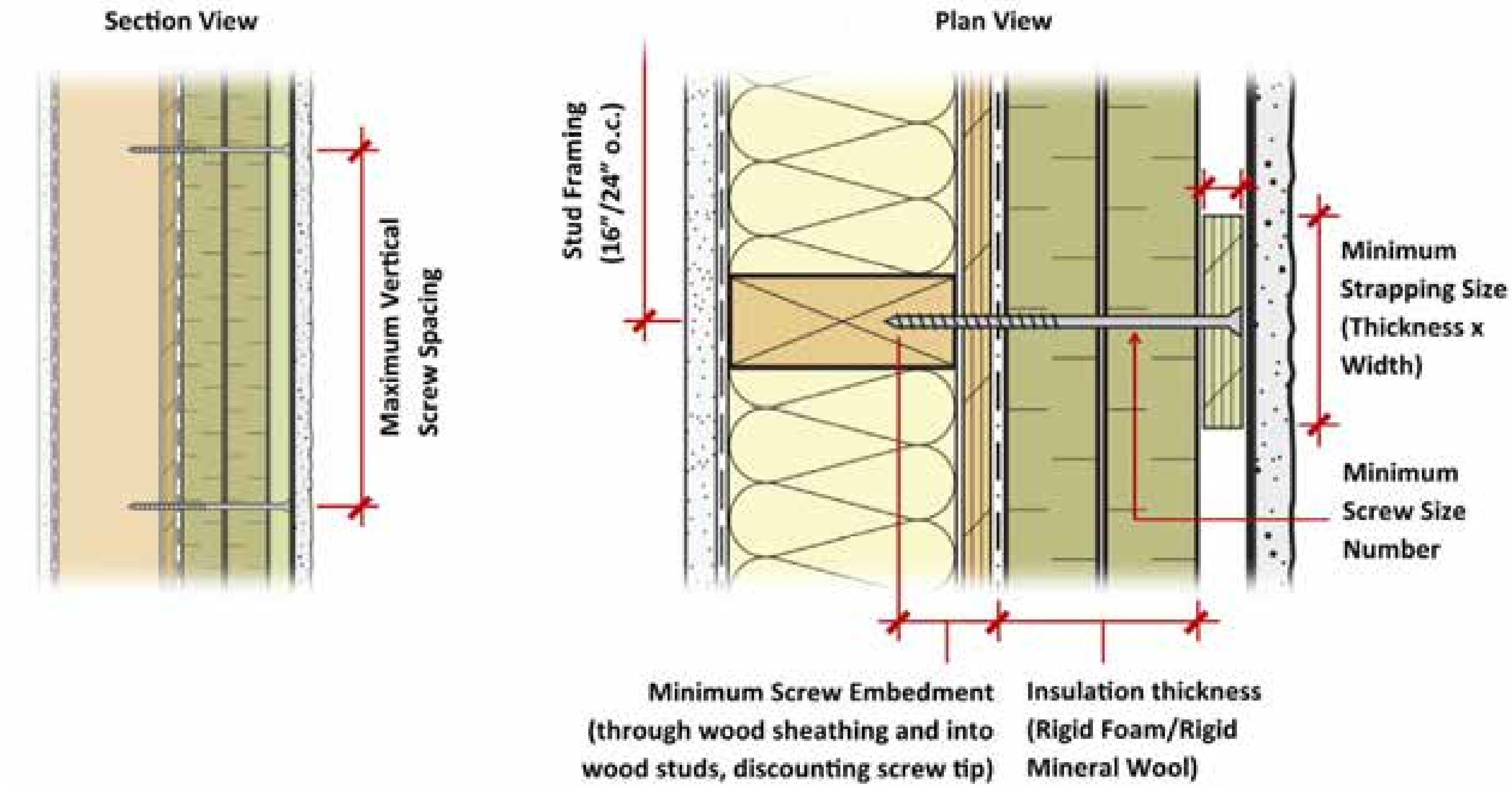
- → Comparison: Wood Shrinkage
  - → One wood-frame story: Double top plate, single bottom plate, 8' ceilings, rim joist
  - → Assume 19% initial MC and 10% final MC at equilibrium with interior
  - → Wood shrinkage due to drying
    - › 0.25%/MC across grain
    - › 0.0053%/MC with grain
  - → Up to **3/8" (375mil, 10mm)** shrinkage in one story height
    - › **Roughly 10x** more than measured deflection in test for any arrangement



R22+ Wall Guide Update



Design Tables

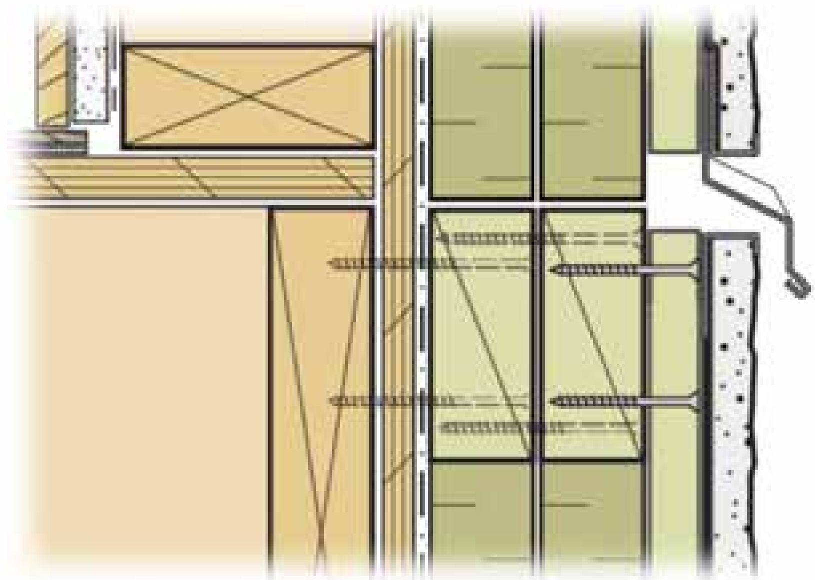


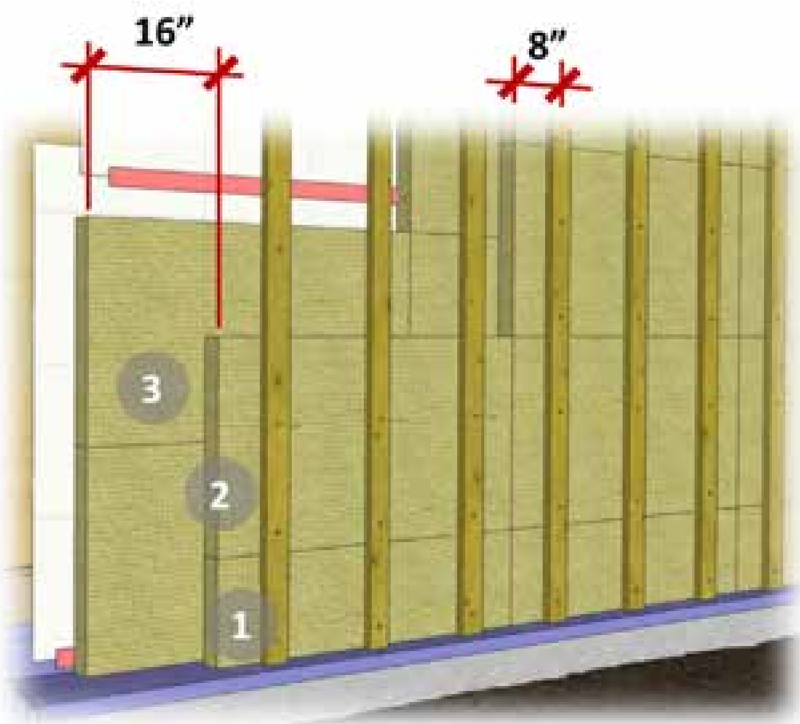
Design Tables

Fastener/Strapping Installation Requirements—Light Weight Cladding					
Thickness of Exterior Insulation	Maximum Vertical Screw Spacing	Minimum Screw Size	Minimum Screw Embedment	Minimum Strapping Size	
				Rigid Foam	Rigid Mineral Wool
Light Weight Cladding Below 5 lbs/ft² - 16" o.c. Stud Framing					
1" to 2" *	24"	#10	1"	3/8" x 1-1/2"	3/8" x 2-1/2"
>2" to 8"	16"				
Light Weight Cladding Below 5 lbs/ft² - 24" o.c. Stud Framing					
1" to 2" *	16"	#10	1"	3/8" x 2-1/2"	3/8" x 2-1/2"
>2" to 8"	12"				

Additional Guidance

Deflection Block →





← Installation Methods

Air and Weather Barriers

Weather Resistive Barriers (WRBs)

- → Types:
  - → Sheet Applied – Vapor Impermeable/permeable
  - → Self Adhered – Vapor Impermeable/permeable
  - → Liquid Applied – Vapor Impermeable/permeable
- → Uses:
  - → Control movement of water (liquid and vapor)
  - → Can be used as the air barrier
  - → Rainscreen or not, open joint or not
- → Installation Considerations
  - → Seams or seamless
  - → UV exposure
  - → Exterior insulation

Types of Air Barriers (and WRBs in some cases) [redacted]

Loose Sheet Applied Membrane – Taped Joints & Strapping

Sealed Gypsum Sheathing – Sealant Filler at Joints

Liquid Applied – Silicone or hybrid sealants (STPE) and membrane

Sealed Plywood Sheathing – Sealant & Membrane at Joints

Sealed Sheathing – Membrane at Joints

Self-Adhered vapor permeable membrane

Plywood sheathing with taped joints (good tape)

Controlling Air Flow – The Air Barrier System

- → To control air flow within buildings – need an Air-Barrier System
  - → Needed in **ALL** building types and climate zones
  - → Is a system of **many materials & components** which are interconnected and **continuous** through the entire building enclosure – sealed airtight
  - → **Details, ease of installation, and material compatibility** are primary design and construction considerations
  - → Can by placed anywhere within the enclosure
    - › Should be protected yet serviceable (if possible)
    - › With design consideration for the potential for condensation & convection bypassing stud cavity insulation
    - › May or may not be combined with vapor & water control functions
    - › Redundancy is useful

The 5 Requirements for Air Barrier Systems

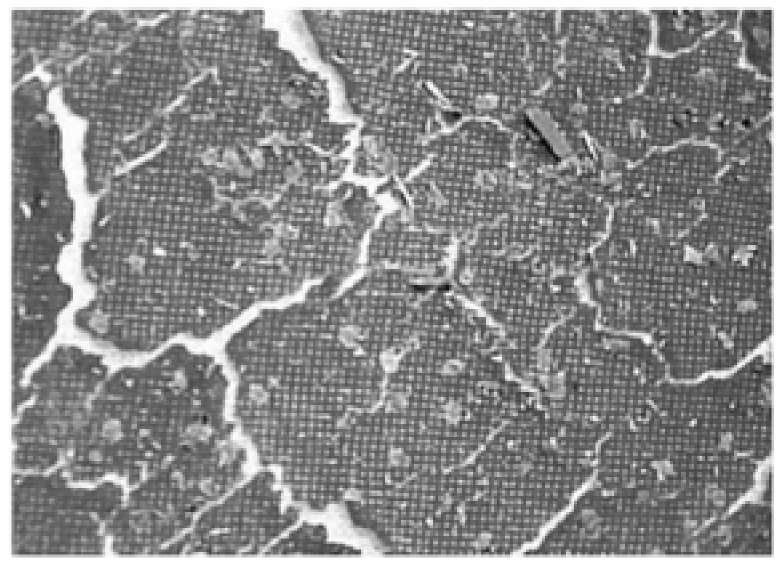
#1: **Continuity** (through all adjacent material – draw a line all the way around the building without lifting your pen)

#2: **Air Impermeability** (code defines)

#3: **Durability** (must last as long as the building and survive the construction phase)

#4: **Strength** (goes with #3)

#5: **Stiff** (either self-supported or supported by adjacent materials)



Unproven air barrier membrane product from Europe – failed due to heat aging effects in roof assembly

Additional Considerations for Air Barrier Systems

- → Air barrier materials should be selected carefully so that when installed their properties will not negatively affect durability or assembly drying ability
- → Watch vapor permeance of air barrier materials on "cold" side of insulation in assemblies
- → Growing appreciation for vapor permeable products on more sensitive substrates

Additional Considerations for Air Barrier Systems

→ Material Compatibility

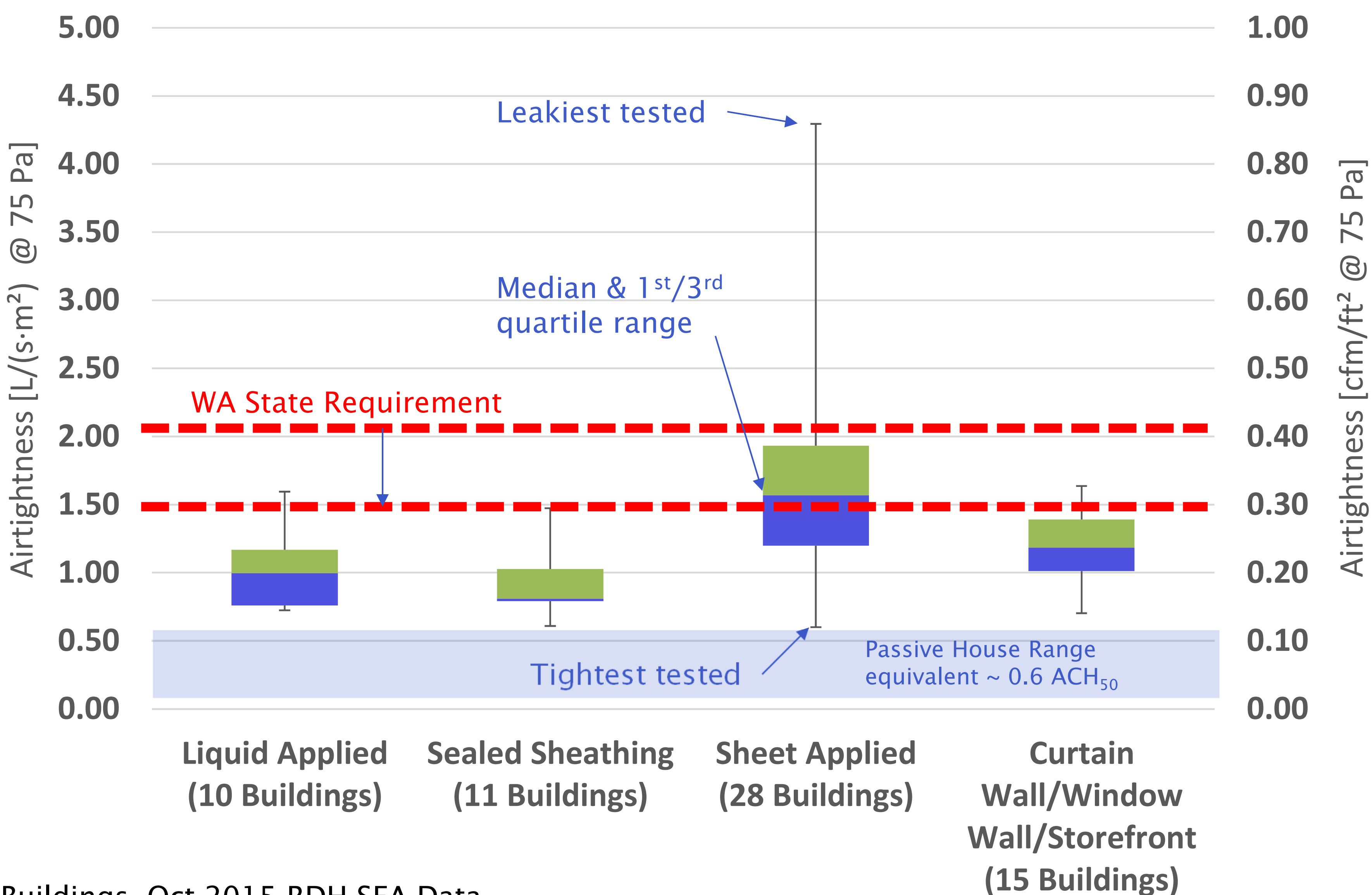
Industry Trends & New Air Barrier Systems

- → Big innovations are being seen in the wall air barrier system market
- → Shift towards "exterior air barrier" systems on framed walls applied to exterior gypsum/wood sheathing
- → **Combined air barrier/water resistive barrier** functions
- → **Vapor permeable AB/WRB** membranes are growing in popularity due to split insulation/exterior insulation wall designs
- → Fire code (NFPA 285) requirements driving material choices in some jurisdictions

Industry Trends & New Air Barrier/WRB Systems

- → Many new cladding attachment systems & resulting penetrations for supports & exterior insulation
- → Combined WRB/Air Barrier behind exterior insulation
- → Self-sealing properties desirable – though can be a practical challenge
- → Current ASTM test standards have not fully caught up with real-world applications (huge range of possible penetrations)

How Well Is the Industry Doing – WA State



54 Buildings, Oct 2015 RDH SEA Data

QUESTIONS?

This concludes The American Institute of Architects Continuing Education Systems Course

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