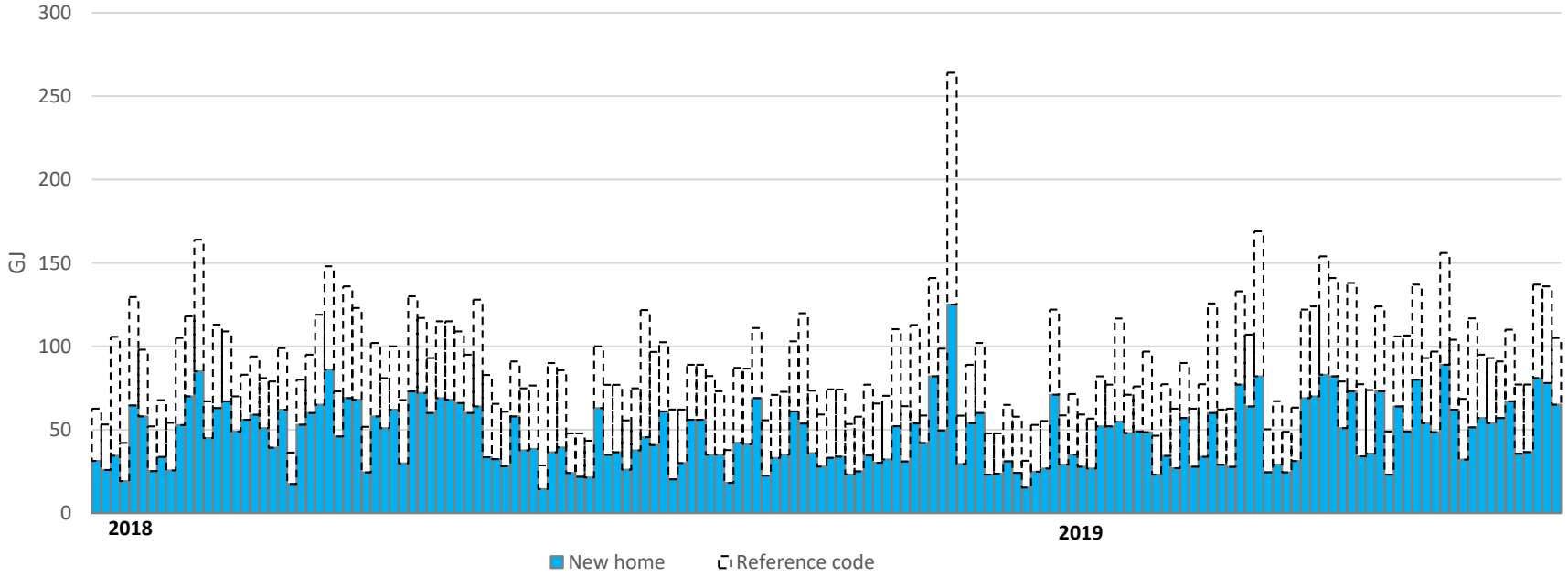
New homes in Yukon built to 50% thermal target



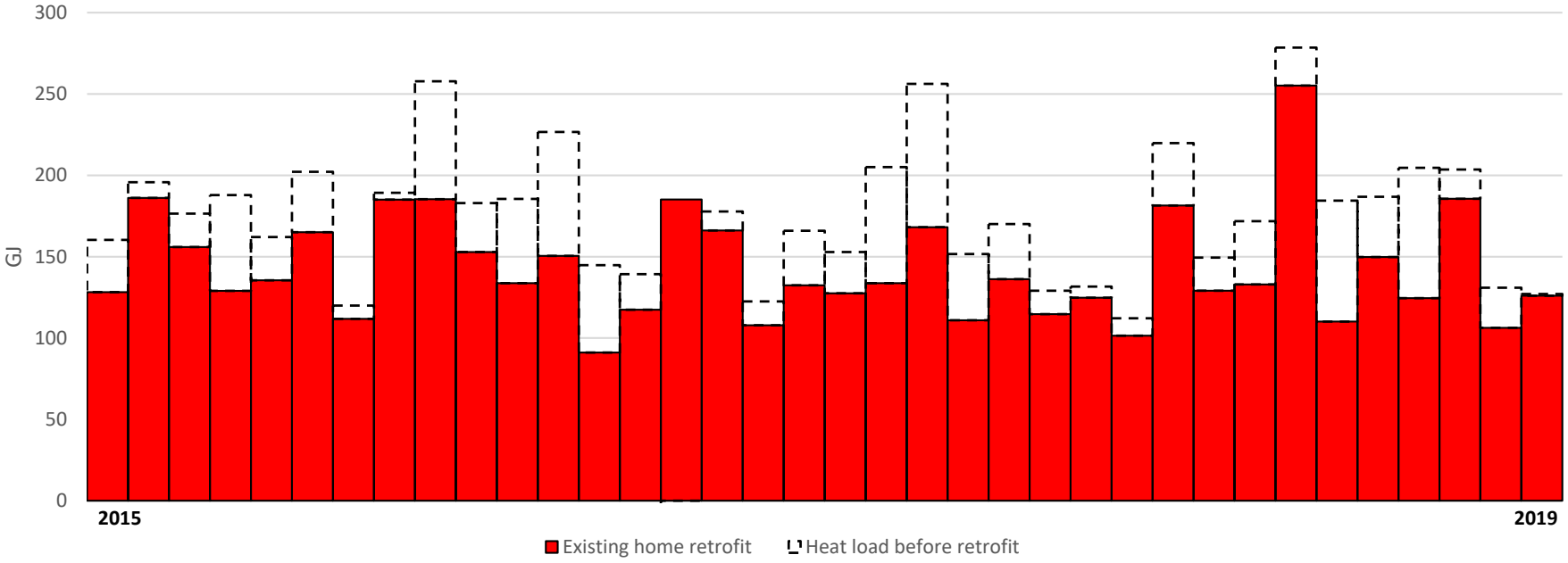
$10,000 rebate for new homes meeting 50% thermal target.

462 homes have met the target since launch of program in 2015.

7,400 GJ in energy savings (2,000,000 kWh) over last year and a half.

Enough energy to heat 141 super-insulated homes.

Energy savings from retrofits



up to $10,000 for adding insulation to existing homes ($2.50 per sf of R20).

36 homes have been retrofitted since launch of program in 2015.

1,200 GJ in annual energy savings (335,000 kWh).

Enough energy to heat 8 retrofits or 26 super-insulated homes.

GOOD ENERGY Commercial program rebates

25% **rebate payment** on costs to complete upgrades in commercial buildings.

CO_{2e} Upgrades must result in **greenhouse gas emissions reductions**.

>$5,000 Projects costs greater than five thousand dollars must be **pre-approved**.

Contact us at **Energy Branch** (393.7063) or energy@gov.yk.ca for additional information or visit us at 206A Lowe Street (opposite Riverside Grocery).

Optimized Energy Retrofits for Yukon Homes

MAY 9, 2019 – WHITEHORSE, YUKON

GRAHAM FINCH, MASC, PENG & MICHAEL WILKINSON, MENG, EIT
RDH BUILDING SCIENCE INC.

RDH BUILDING SCIENCE

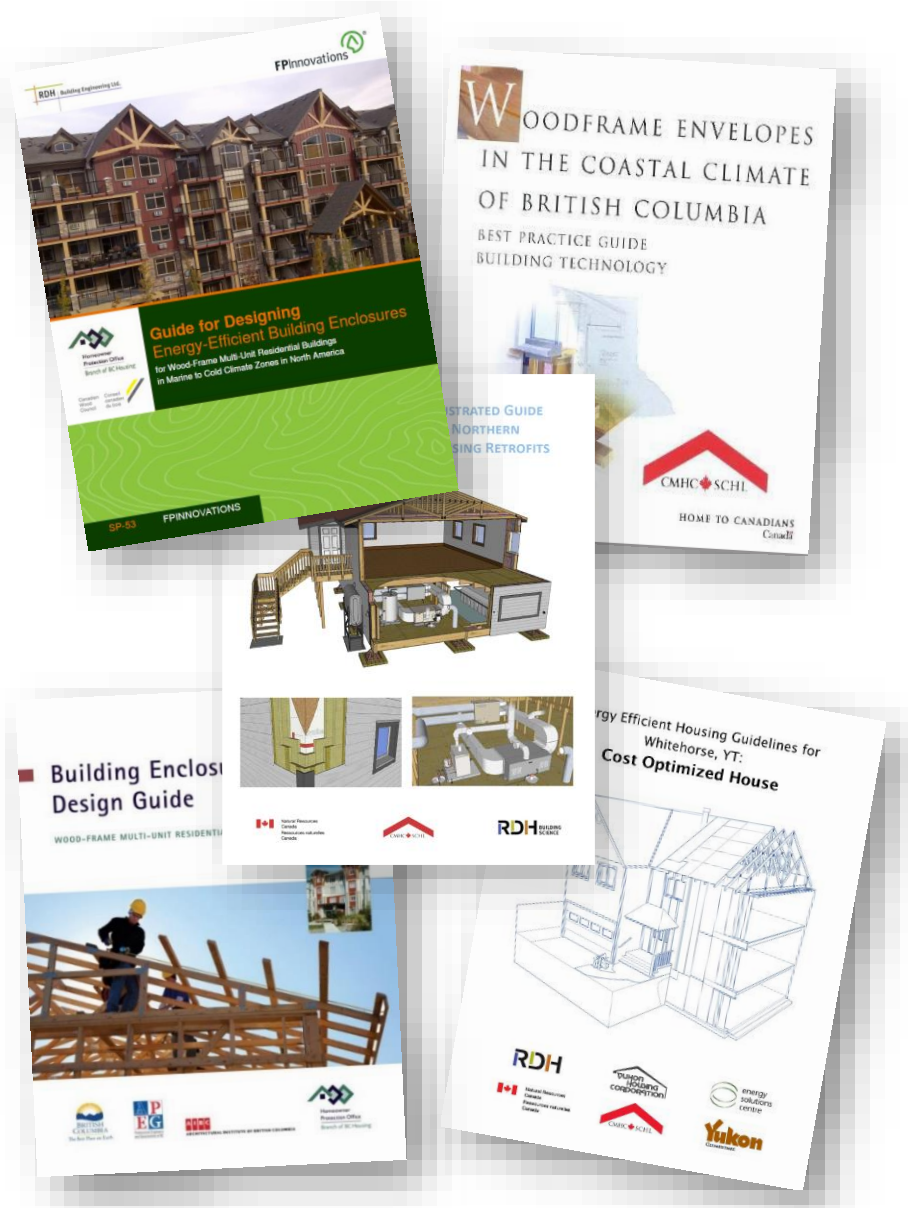
Outline

- → Introduction & Background
- → *Energy Efficient Housing Retrofits for Yukon Guideline*
  - → Building Science Fundamentals
  - → Health & Safety Considerations
  - → Optimal Retrofit Packages for the Yukon
  - → Implementation Considerations
  - → Step by Step Details for Enclosure Retrofits
- → Next Steps & Potential Future Work

RDH BUILDING SCIENCE

Introduction: About RDH

- → **Building Enclosure** Engineering Firm with over 250 staff across 9 offices in Canada & US - Projects North America Wide
- → We are Engineers, Architects, Technologists, Project Managers, Contractors, Researchers
- → We are all about Making Buildings Better
  - → New Construction
  - → Existing Buildings
  - → Forensics
  - → Energy Efficiency & Policy
  - → Practical Research, Education & Guidelines



Background – Why You're Here

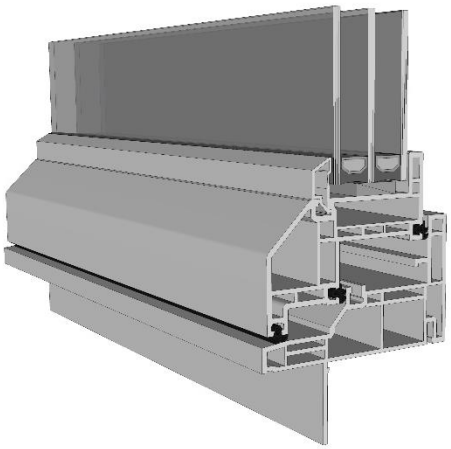
→ No shortage of building enclosure upgrades that are available to improve the energy efficiency of existing homes

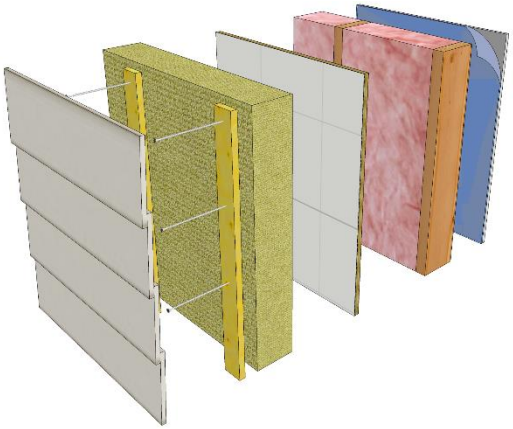
→ Air sealing, insulation upgrades, and more comprehensive retrofits can result in reduced energy consumption, lower utility costs, and improved passive survivability

→ There is a lack of understanding around selecting the best approach

  → What are optimal R-values for assemblies, window performance for existing housing in the Yukon?

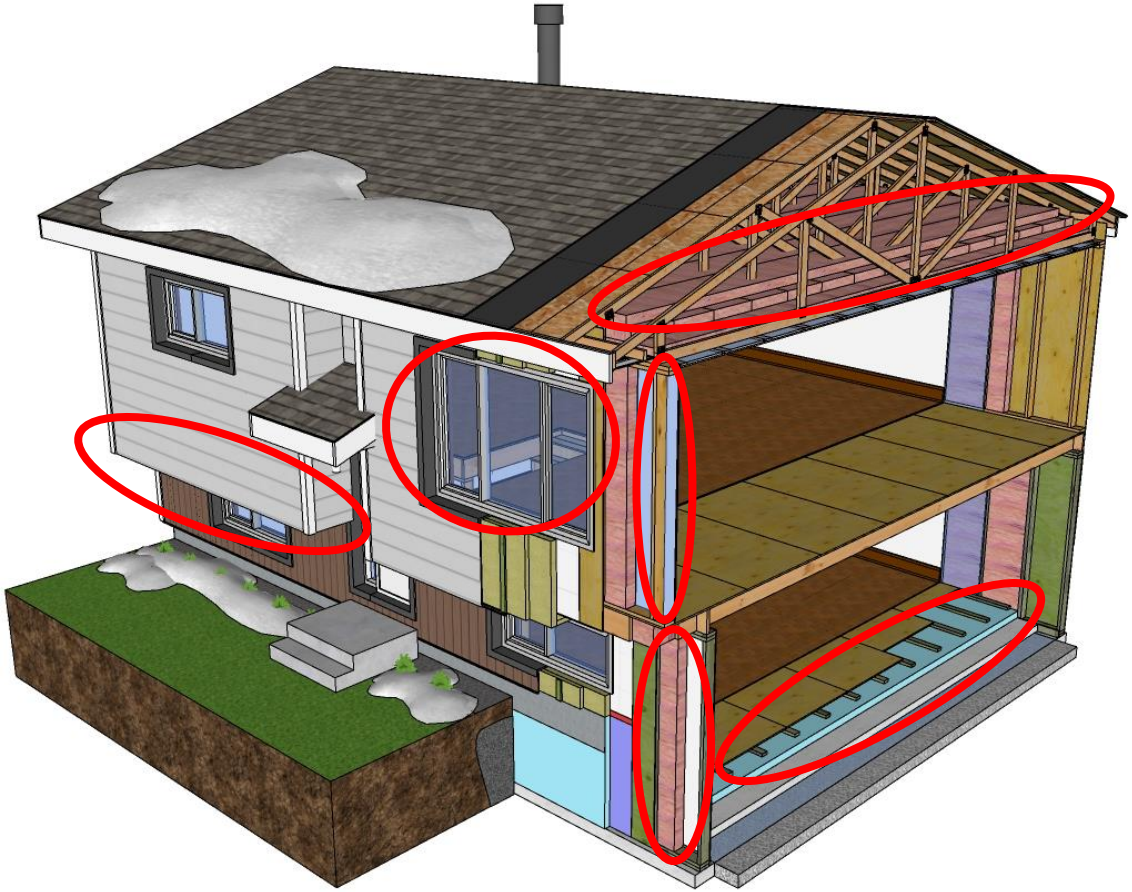
  → What combination of retrofits is the most cost effective or results in the highest energy savings?





Background – Retrofitting Aged Housing Stock

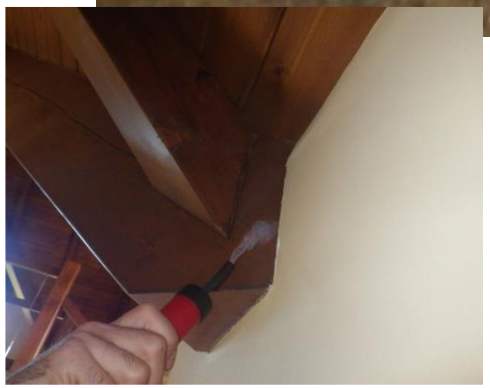
Potential Areas for Building Enclosure Upgrades

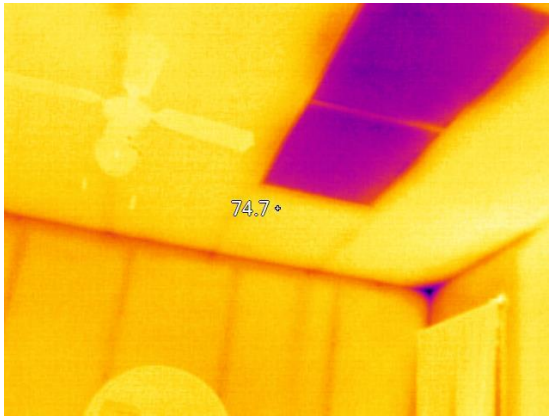


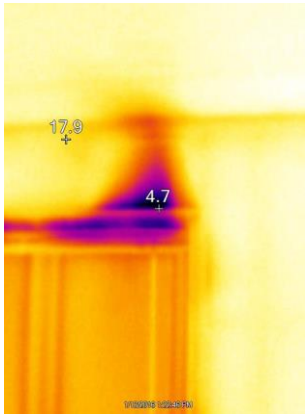
- → Attics – easy and very common
- → Compact roofs/cathedral ceilings – harder to access
- → Walls (cavity fill or exterior insulation during siding retrofits) – more intensive and costly
- → Floor headers, bay windows, exposed floors and other locations of missing insulation – depends on access
- → Windows – expensive but highly impactful
- → Foundations and slab on grade – most challenging and expensive

Identifying Candidate Homes

- → Visual Assessment
- → Infrared Scans
- → Blower door test
- → Prioritize poorly insulated and easy/cost effective accessible locations first
- → Identify very air leaky homes and locate and seal the big holes







Energy Efficient Housing Retrofits for Yukon

Acknowledgements

→ CMHC

→ NRCan

→ CANMET-Energy

→ Yukon Housing Corporation

→ Yukon Government Energy Branch

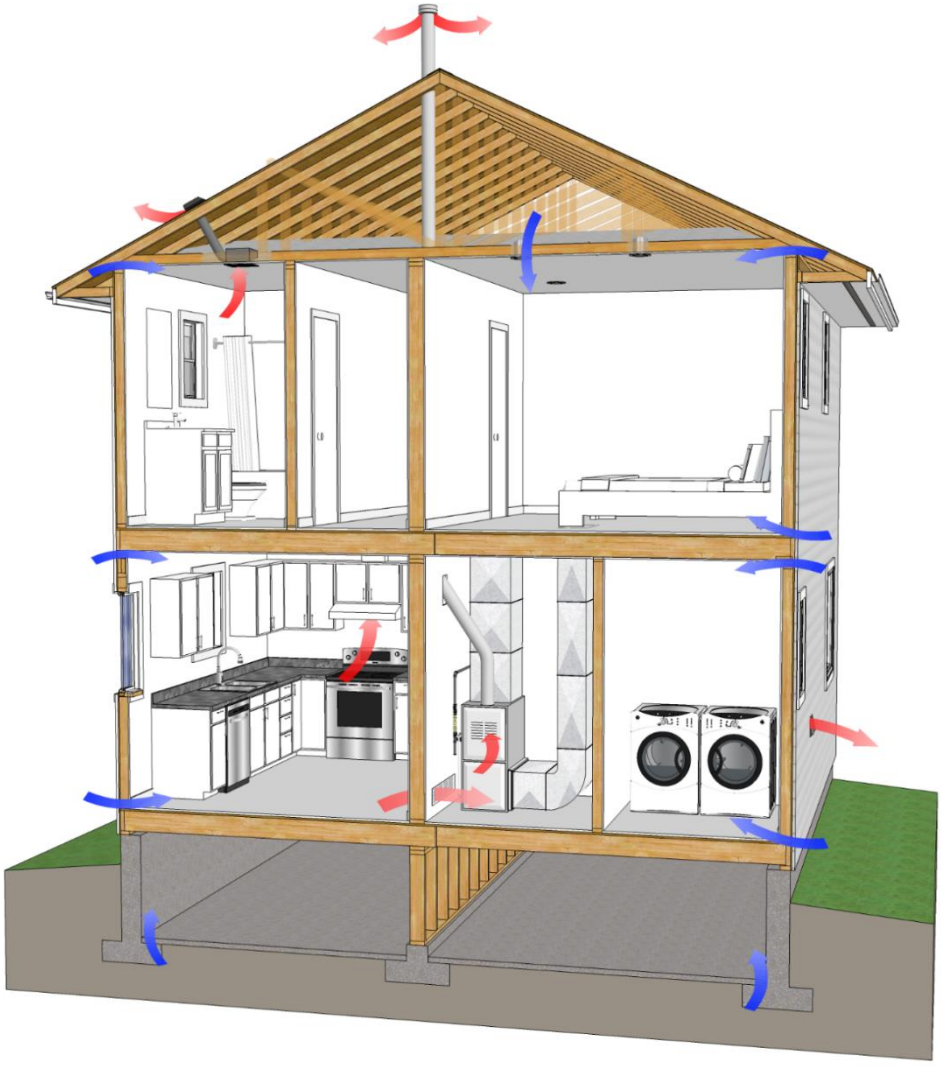
Building Science for Retrofits

- → House as a System
- → The Building Enclosure
- → Yukon Specific Retrofit Considerations
- → Thermal Comfort

RDH BUILDING SCIENCE

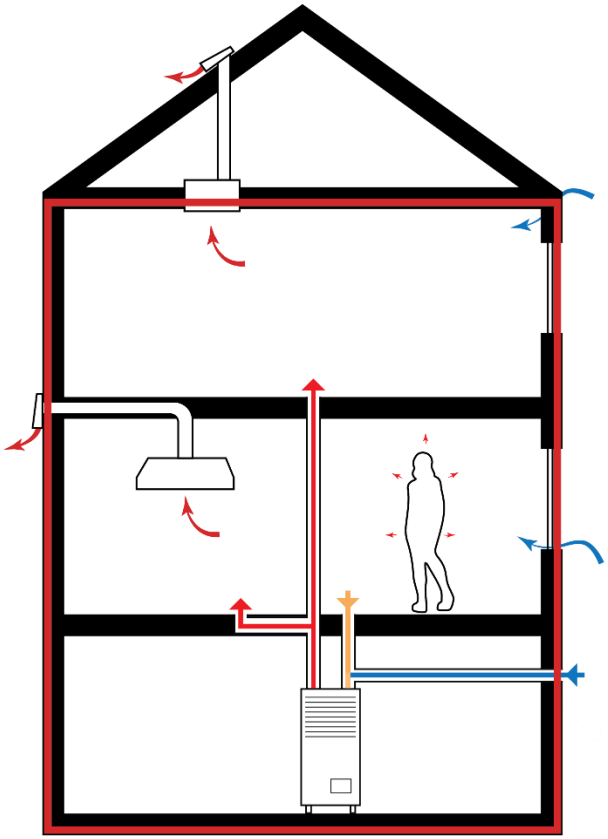
House as a System

- → House is made up of building enclosure, structure, mechanical and electrical equipment, etc.
- → Energy upgrades do not occur in isolation
- → Changes to insulation levels or airtightness improvements may lead to unintended negative consequences including durability and health and safety risks



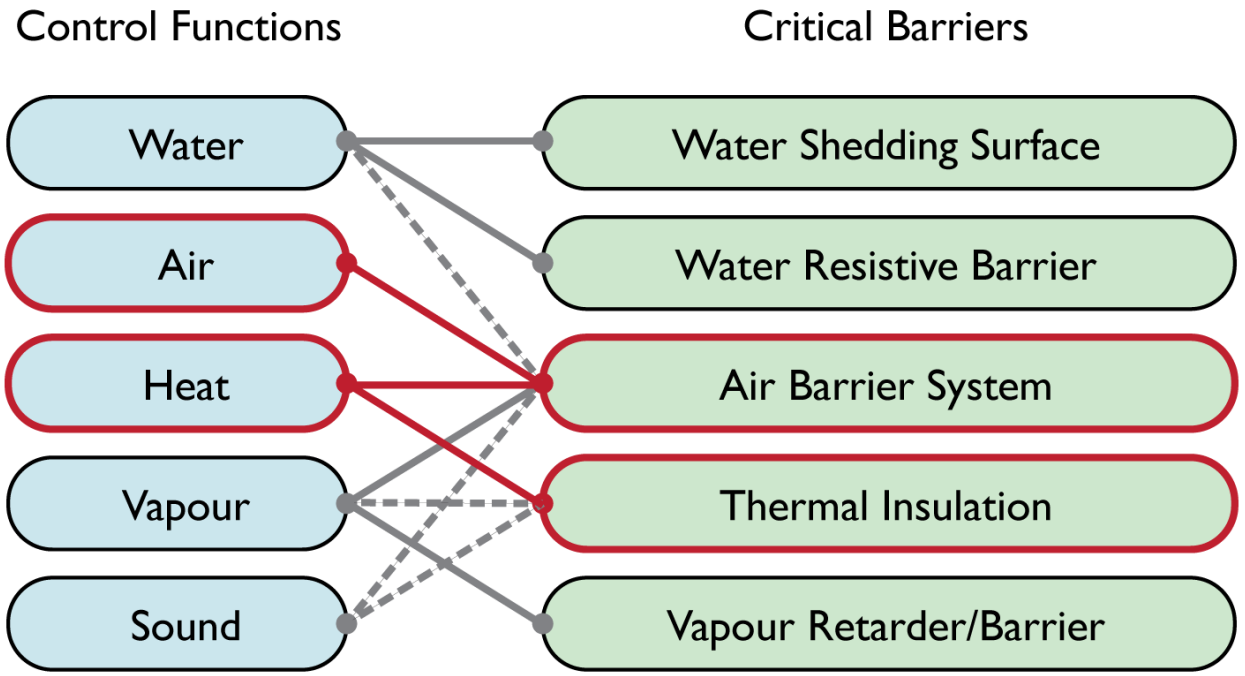
House as a System

- → Air sealing work can reduce drafts and improve occupant comfort but may reduce indoor air quality
- → Airtightness improvements can lead to backdrafting of naturally aspirating furnaces
- → New insulation without commensurate airtightness improvements may lead to building durability issues
- → Improved insulation, thermally efficient windows, and reduced air leakage may reduce loading on space heating equipment



The Building Enclosure

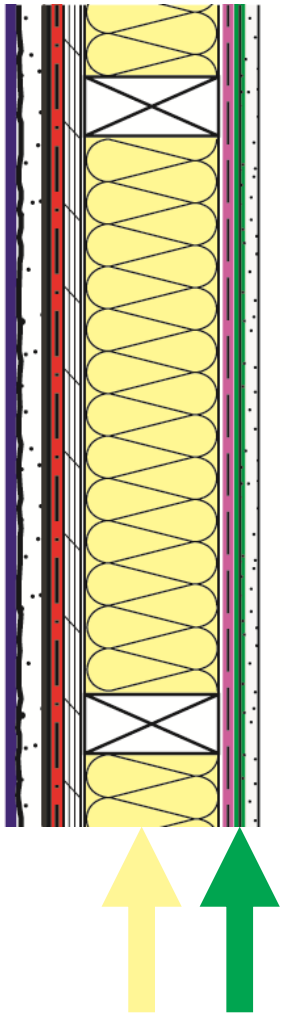
- → Materials and components that separate the exterior from interior environment
- → Increasing building airtightness and insulation levels can improve energy performance, occupant comfort, and building durability



The Building Enclosure

→ Layers of materials and components that control elements

Water Shedding Surface
Water Resistive Barrier
Air Barrier
Vapour Retarder
Thermal Insulation



The Building Enclosure

- Air Barrier
  - Resists airflow between interior and exterior spaces
  - Heat loss occurs when interior conditioned air escapes or when exterior air infiltrates building

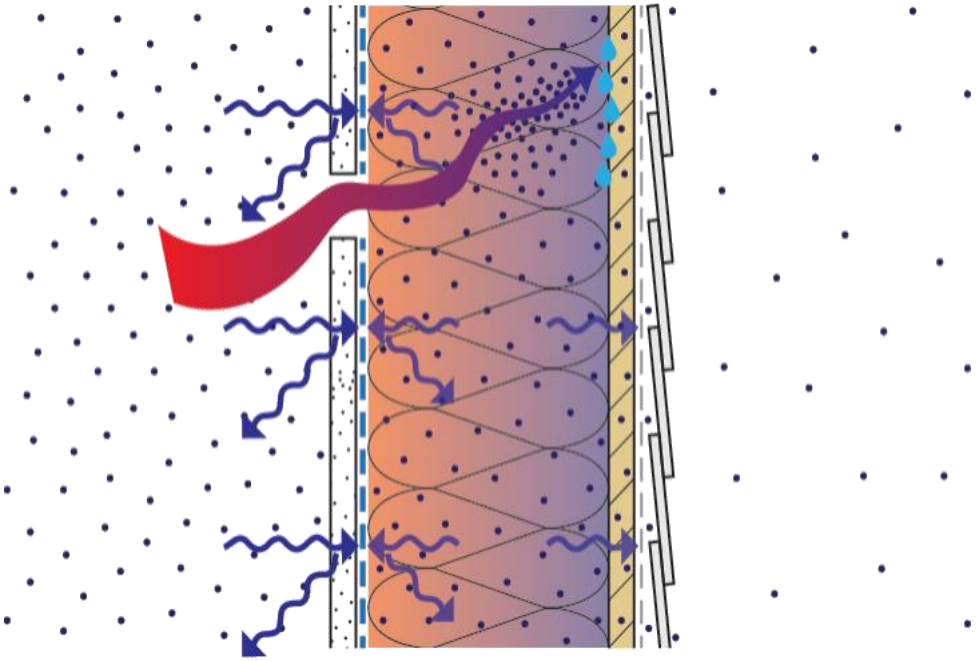
- Thermal Insulation
  - Materials with low thermal conductivity resist heat flow
  - Higher R-value indicates greater resistance to heat flow

Insulation and R-values

- → Insulation is rated by a term called an R-value, which is its rating of thermal resistance. A higher value results in less heat flow.
- → Most insulation has an R-value of between R-3 and R-6 per inch of thickness – though framing and other thermal bridges will reduce the assemblies overall performance
- → Common insulation products include: fiberglass and mineral fibre, cellulose, wood fiber, and various foamed plastics

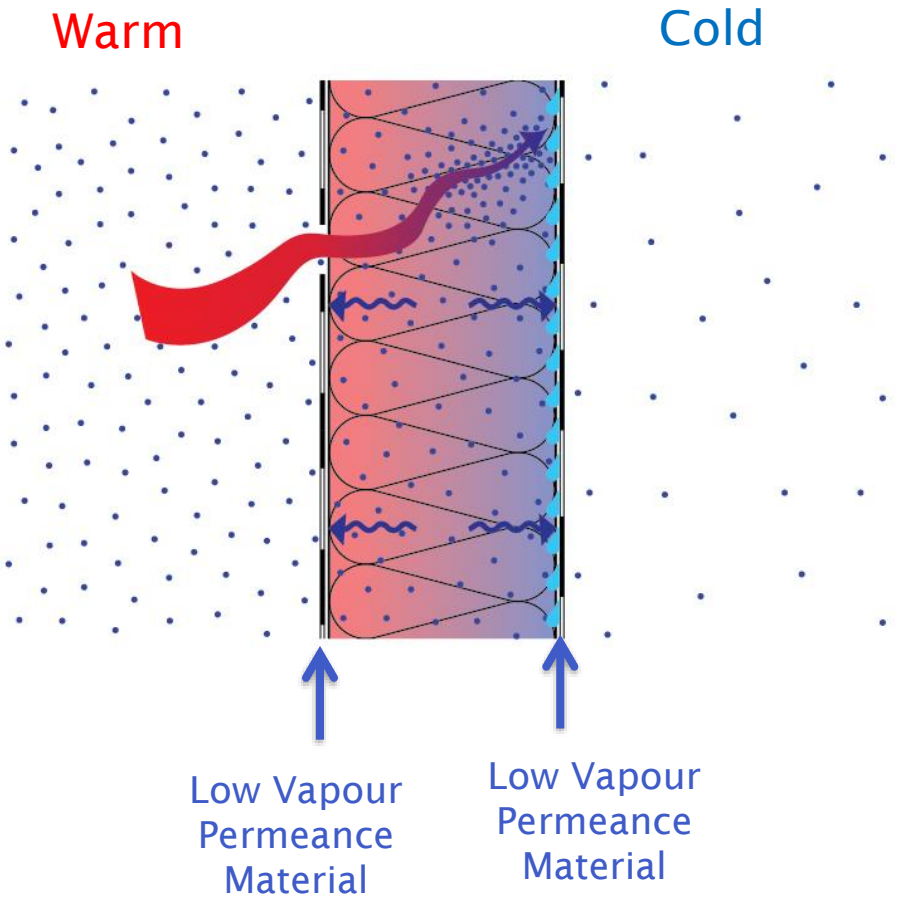
Durability Considerations

- → Air Leakage Condensation
  - → Has the interior air barrier (polyethylene sheet) been compromised?
  - → Has insulation been added without the necessary airtightness improvements?
- → Humid air that bypasses the polyethylene sheet may condense on cold surfaces leading to moisture damage



Durability Considerations

- → Dual Vapour Barriers
  - → A material with low vapour permeance is often desirable on the high vapour pressure side (warm interior side in a cold climate) of a wall assembly to control outward vapour diffusion.
  - → Have vapour impermeable materials been installed on the outside of existing assemblies?
- → Newly added materials with low vapour permeance can create problems by trapping moisture and restricting drying.

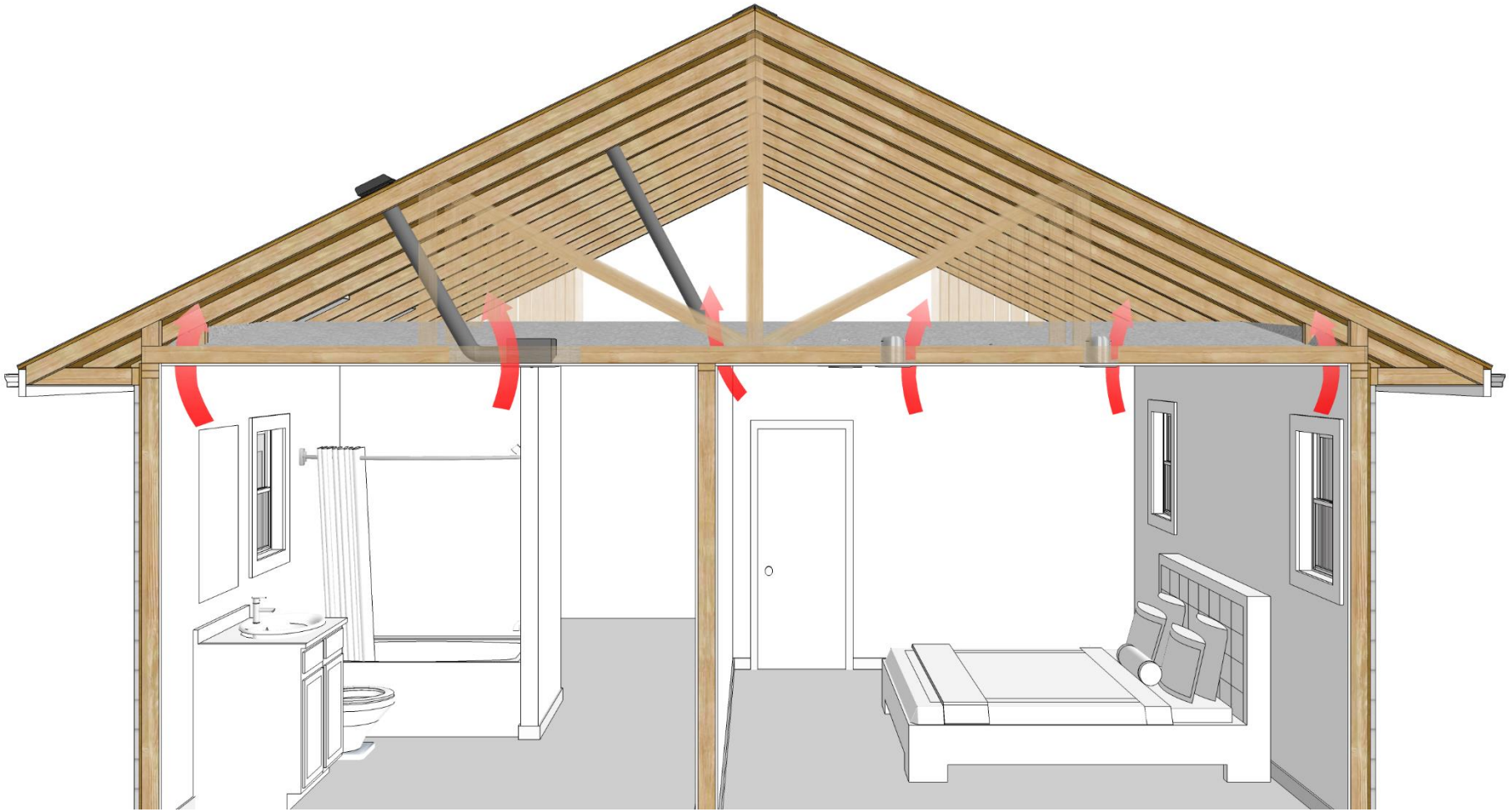


Durability Considerations

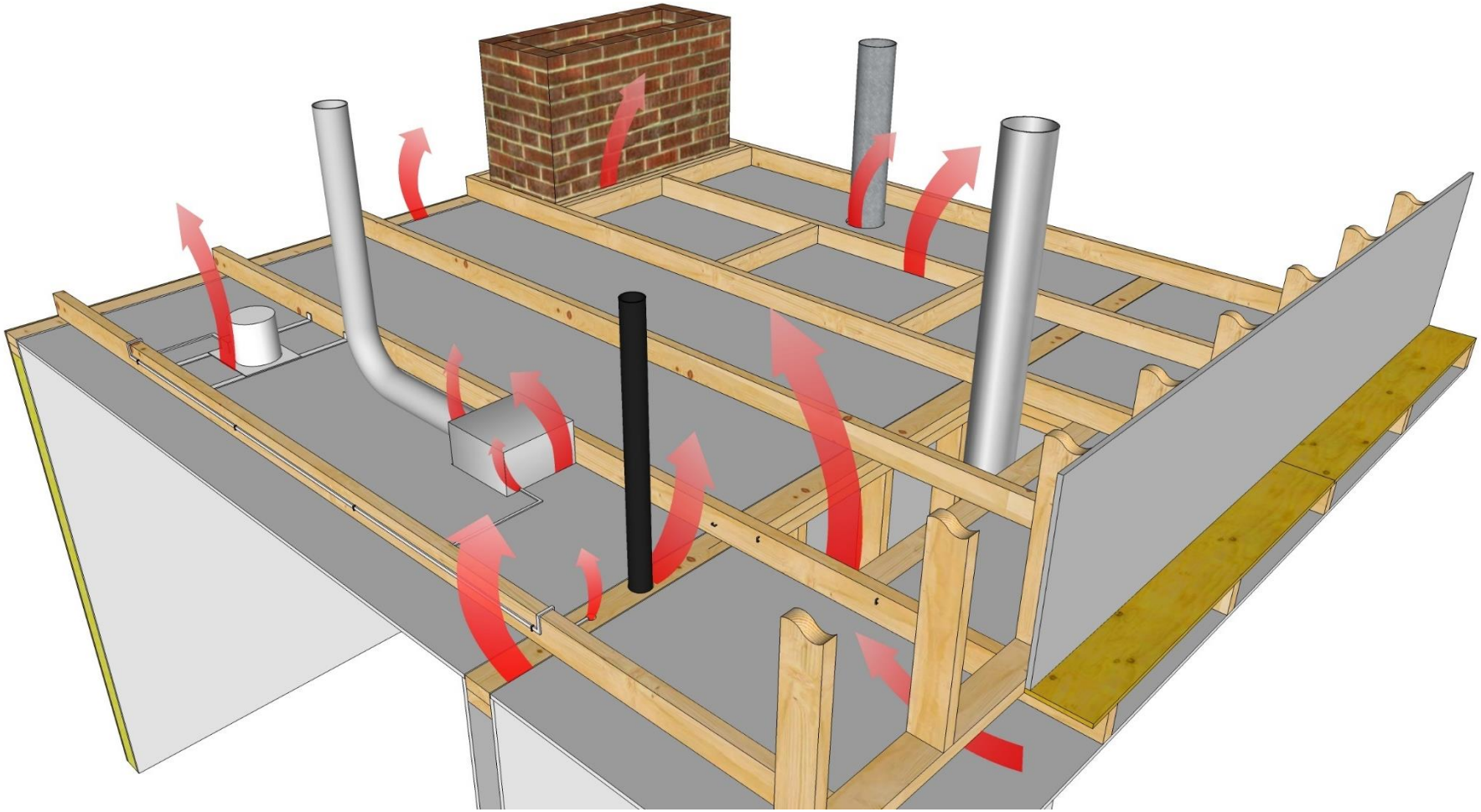
- → Material compatibility
  - → While many materials may work well in isolation, the combination and interaction of different materials is required for building enclosures, and can create issues.
  - → Are the retrofit materials compatible with existing building materials and each other?
- → Reinstall/repair/replace existing components as required
  - → Components that have been removed during the retrofit or that have experienced damaged must be replaced!

Attic Considerations

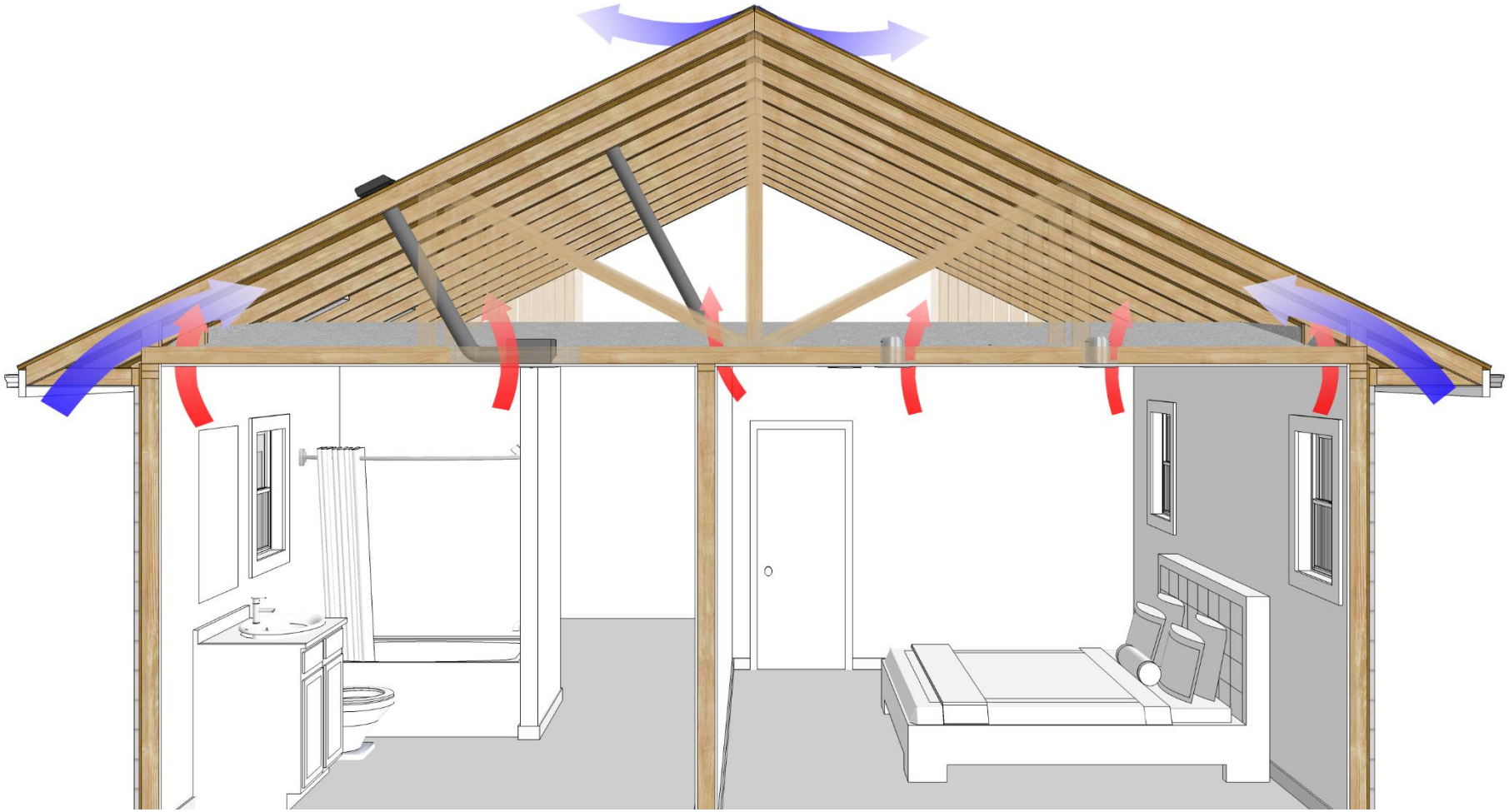
Attics- Air Leakage



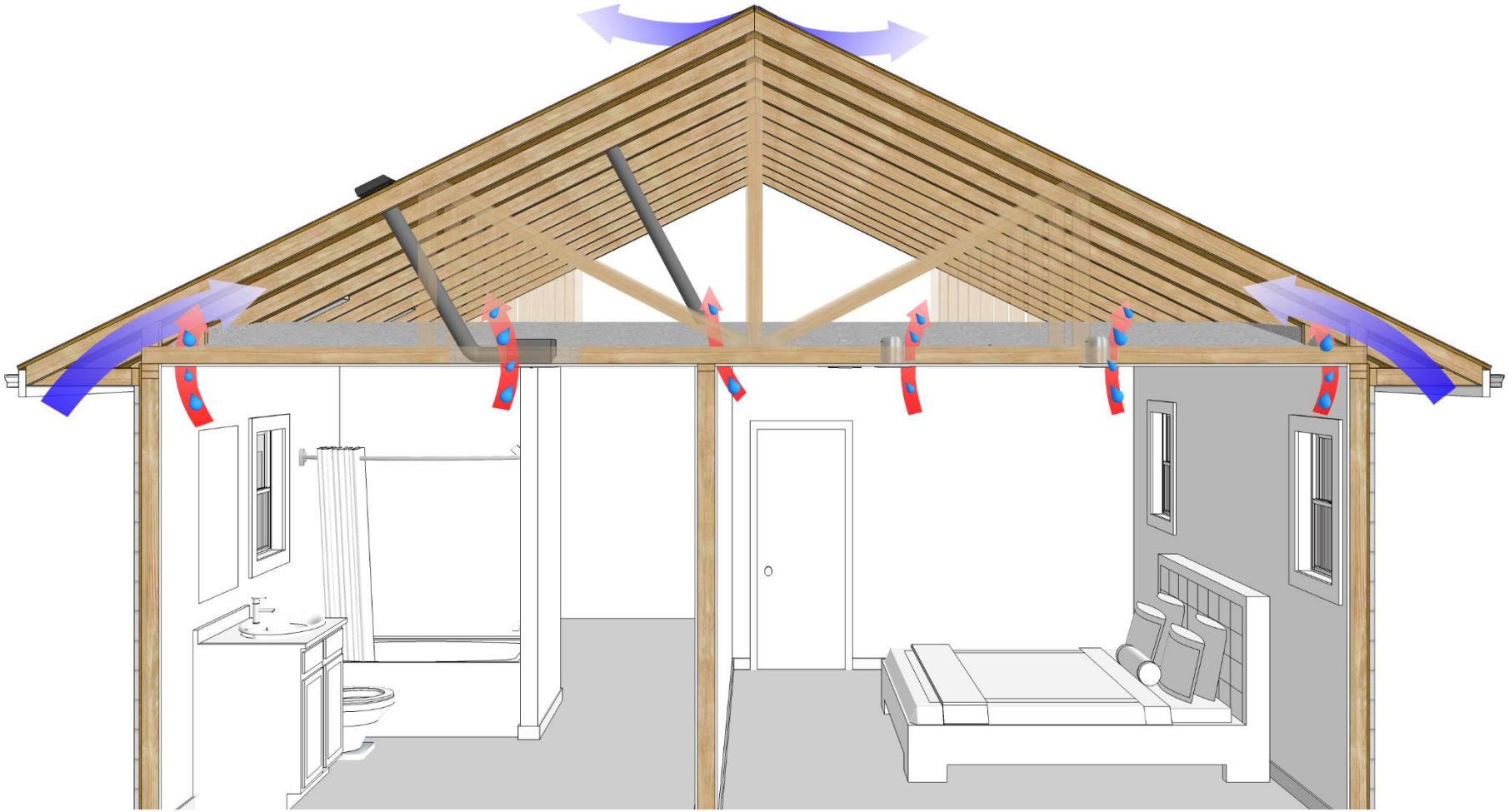
Attics – Many Sites of Air Leakage



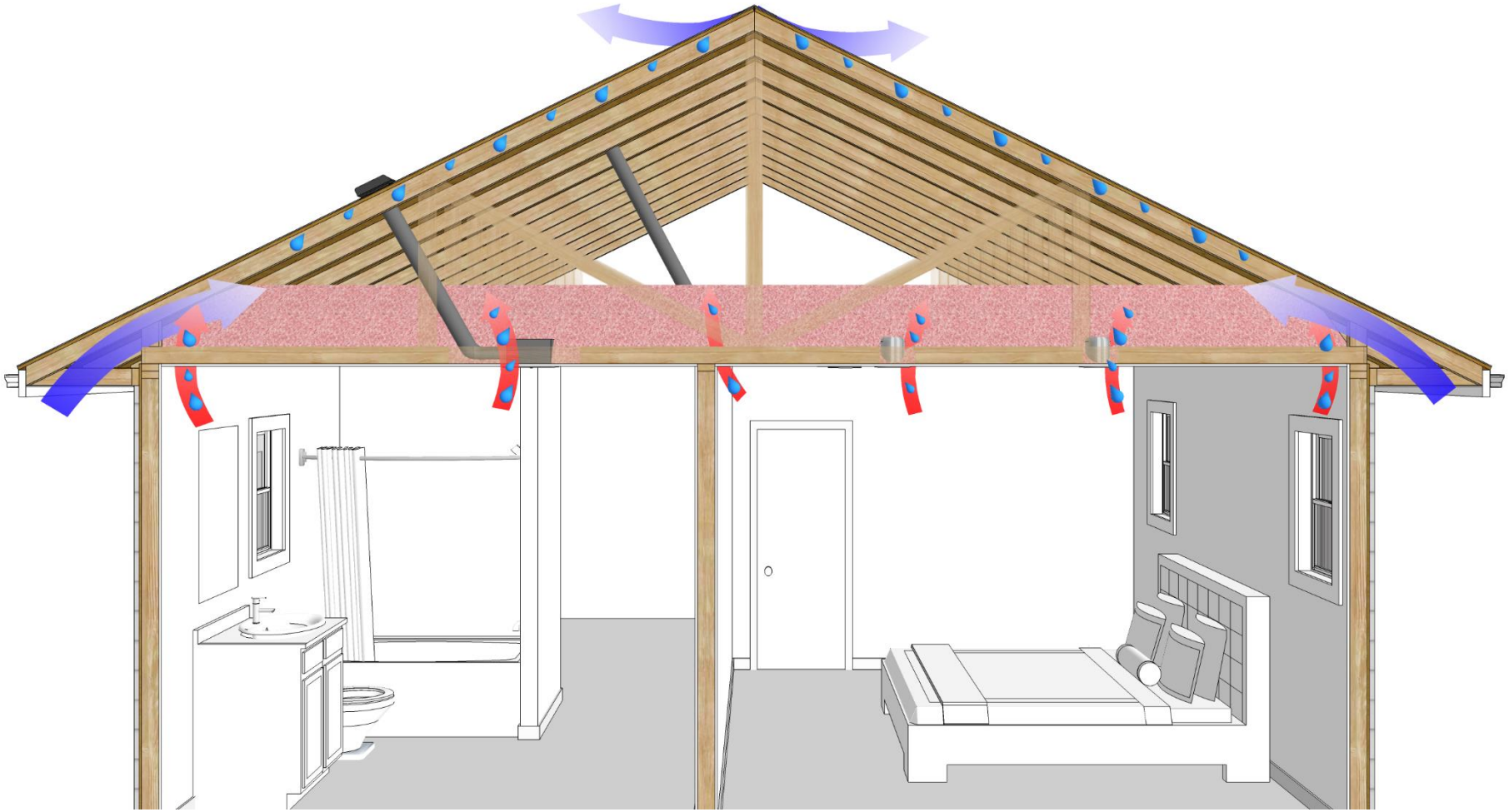
Attics - Ventilation



Attics – Moisture Sources

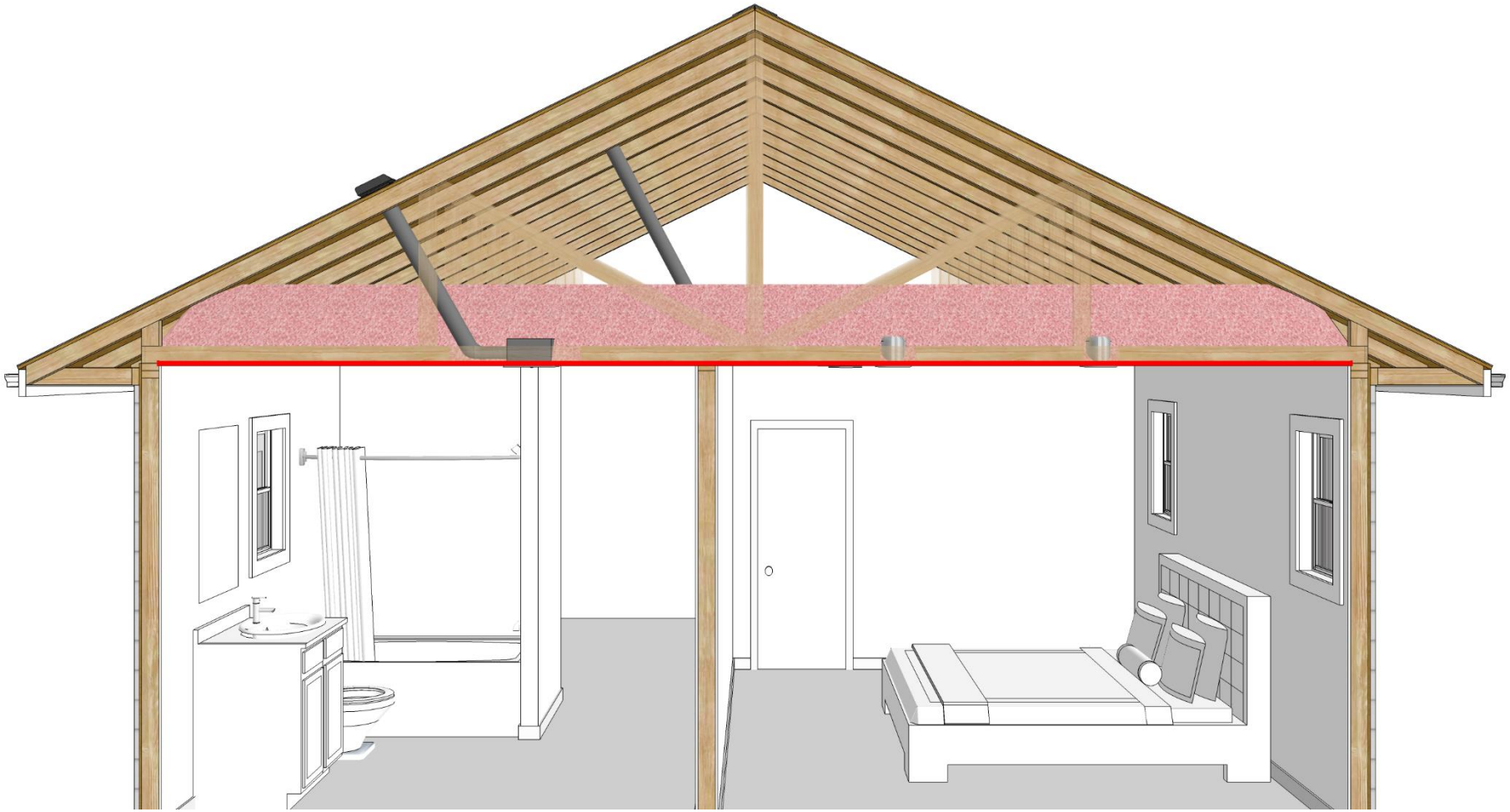


Attics – Insulation & Moisture Risks



Attics – Insulation & Moisture Risks

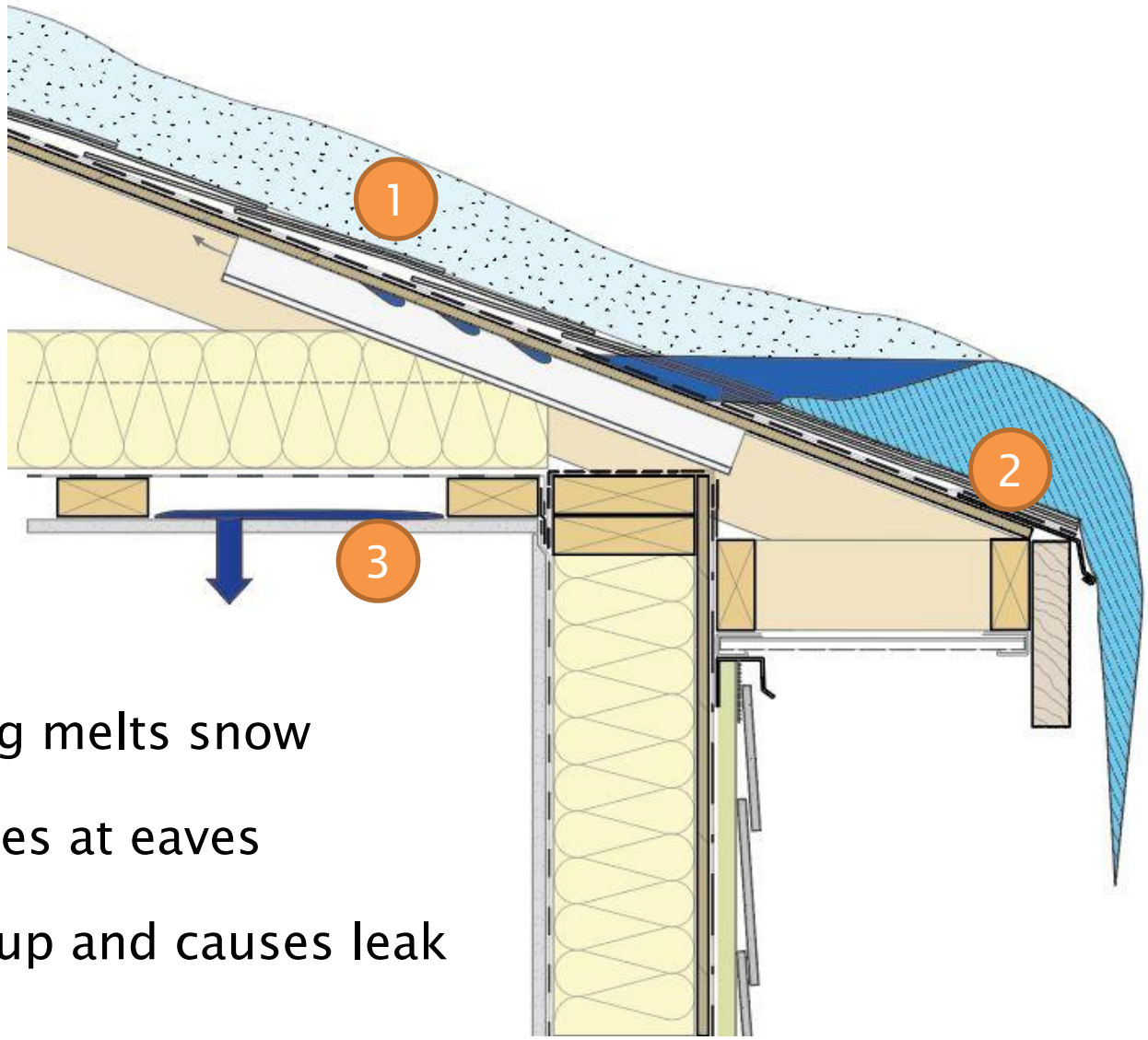
Attics – Air Sealing & Insulation



Yukon Specific Retrofit Considerations

- → Ice damming
  - → Areas of roof receive unintentional heat from the interior or are exposed to differing exterior conditions
  - → Snow melts and refreezes as ridges of ice on roof eaves that impede roof drainage
  - → Can lead to water leakage and damage to roof sheathing and structural members

Yukon Specific Retrofit Considerations



1. Local warming melts snow
2. Water refreezes at eaves
3. Water builds up and causes leak

Yukon Specific Retrofit Considerations

- → Cause
  - → Discontinuous insulation or localized areas with reduced insulation thickness
  - → Leakage of warm interior air into the attic
  - → Uninsulated heat sources in the attic
  - → Differences in solar exposure and snow thickness
- → Prevention
  - → Increased attic insulation levels applied continuously
  - → Airtight ceiling plane
  - → Removal of heat sources in attic where possible insulate where not
  - → Improved attic ventilation
  - → Install waterproof membrane from the eaves extending up the roof

Yukon Specific Retrofit Considerations

→ Soil Freezing and Frost Heave

- → As water in soil freezes it can experience a dramatic volume change causing soil displacement
- → This soil displacement or **frost heave** can cause significant damage to basement foundations and slabs
- → Frost heave acts in the direction of heat transfer

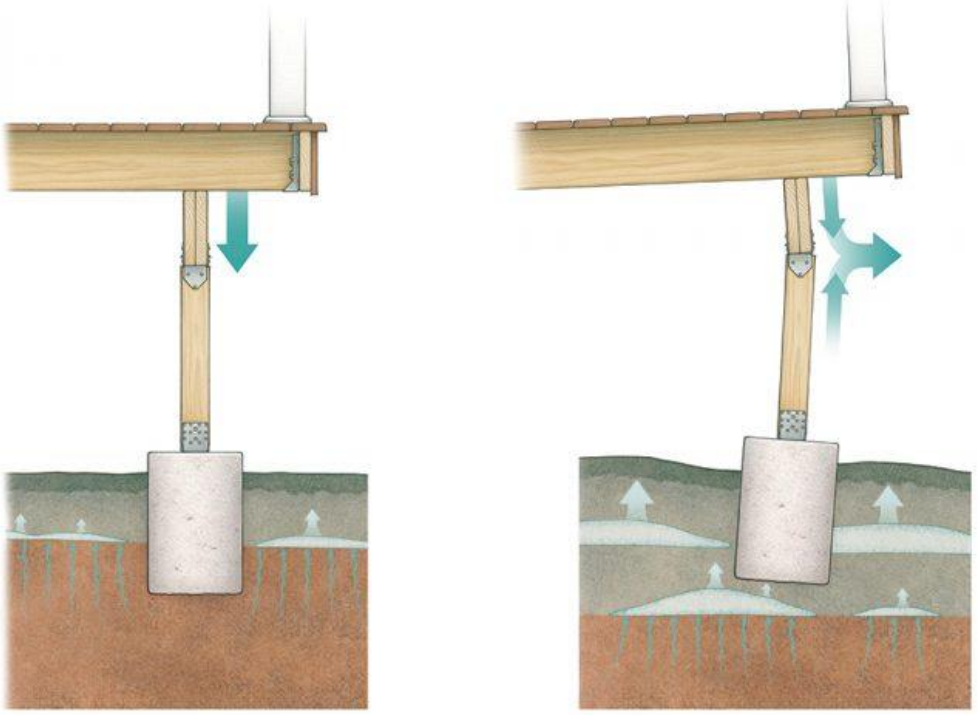
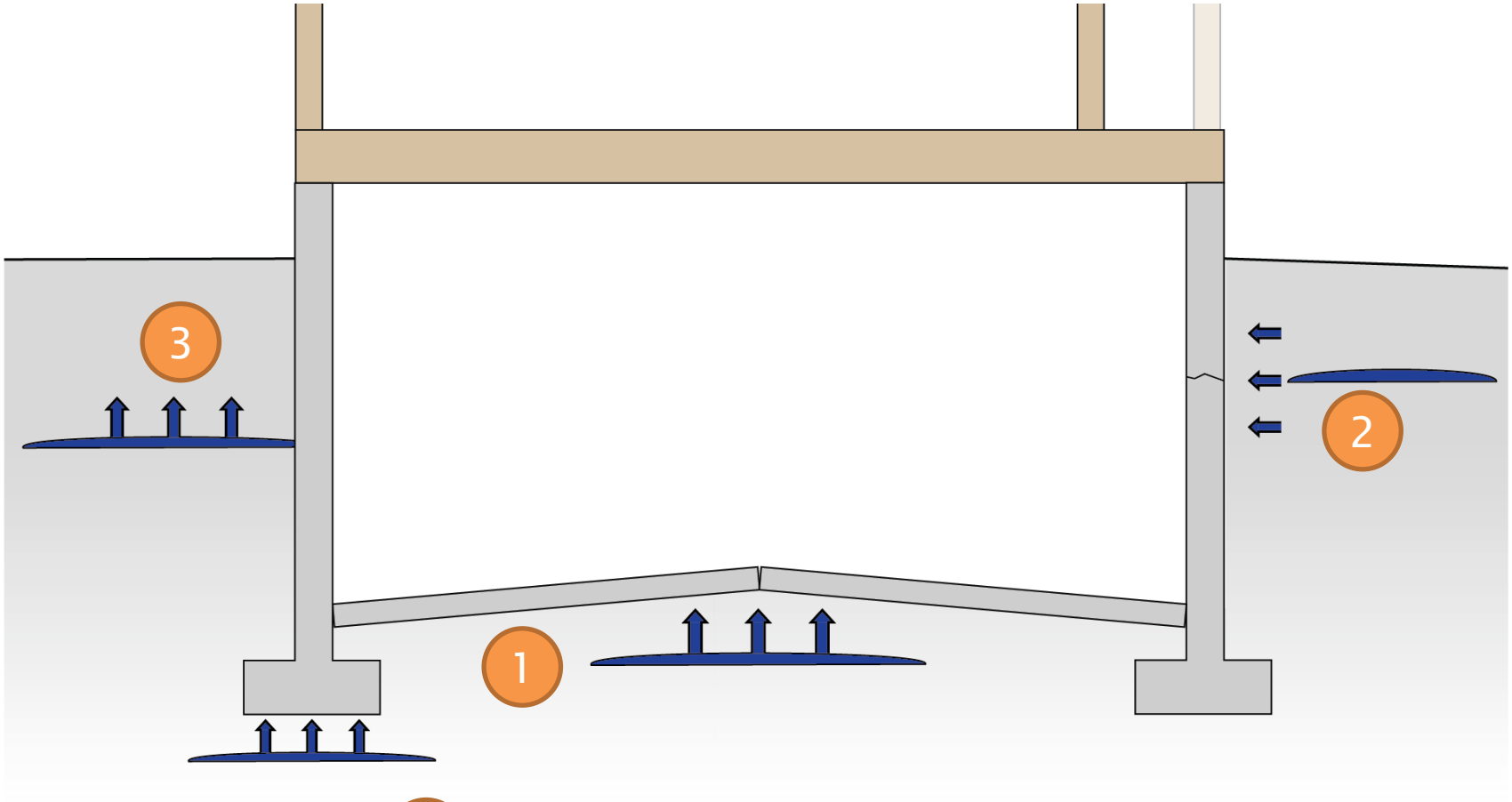


Image courtesy of Fine Homebuilding

Yukon Specific Retrofit Considerations



1. Upward frost heave beneath slab and footings
2. Inward frost heave at foundations
3. **Adfreezing** displaces foundations upwards

Yukon Specific Retrofit Considerations

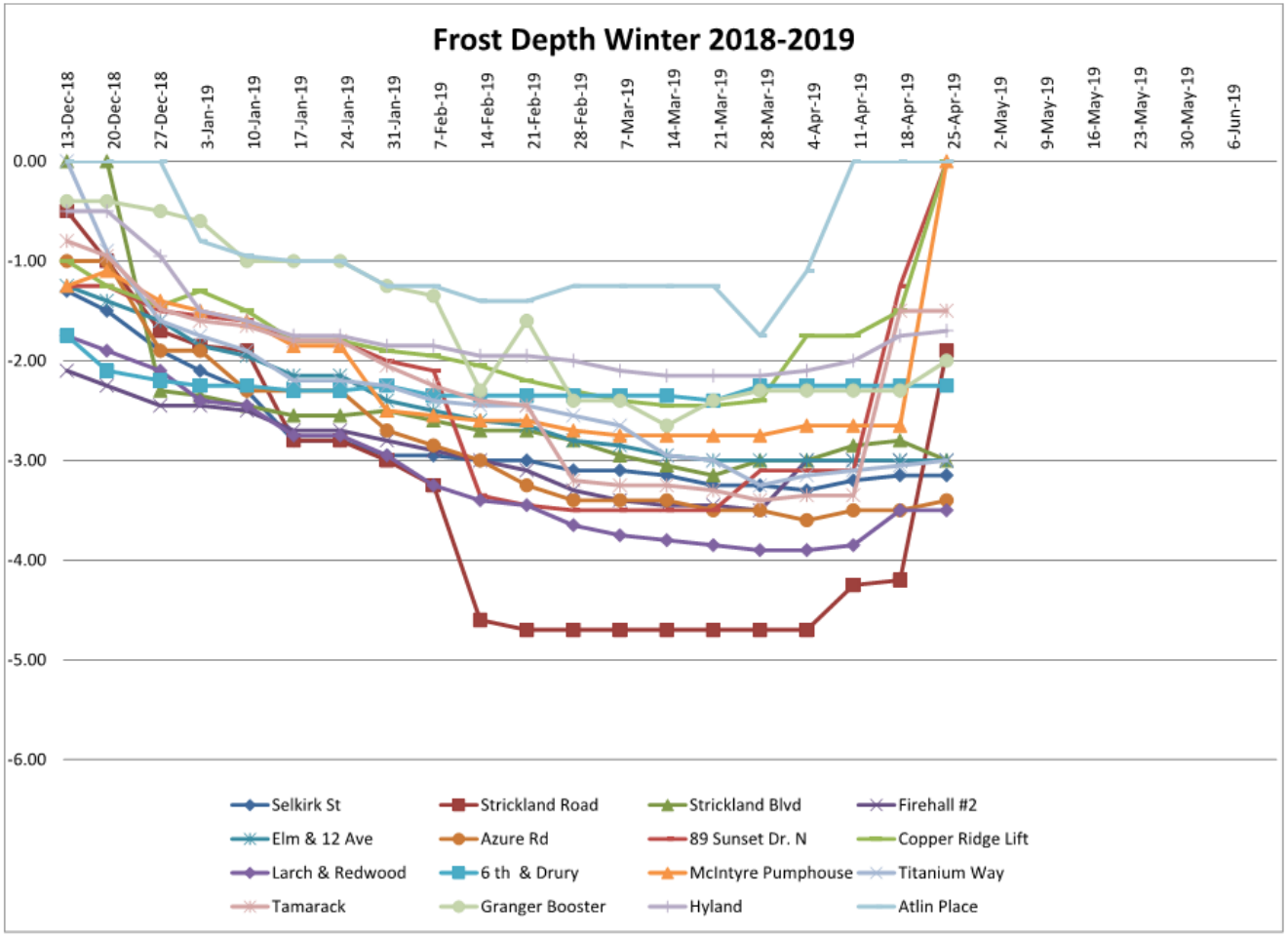
→ Cause

- → Building surrounded by frost susceptible soils (loamy and silty soil)
- → Water present in the soil
- → Freezing temperatures

→ Prevention

- → Remove frost susceptible soils
- → Remove ground water adjacent building (drainage)
- → Increase ground temperatures around basements
  - › Heat basement / crawlspace
  - › **Insulation skirt** to reduce heat loss from soil adjacent foundations – insulation thickness and width dependent on local conditions (frost depth, freezing degree days)

Yukon Specific Retrofit Considerations

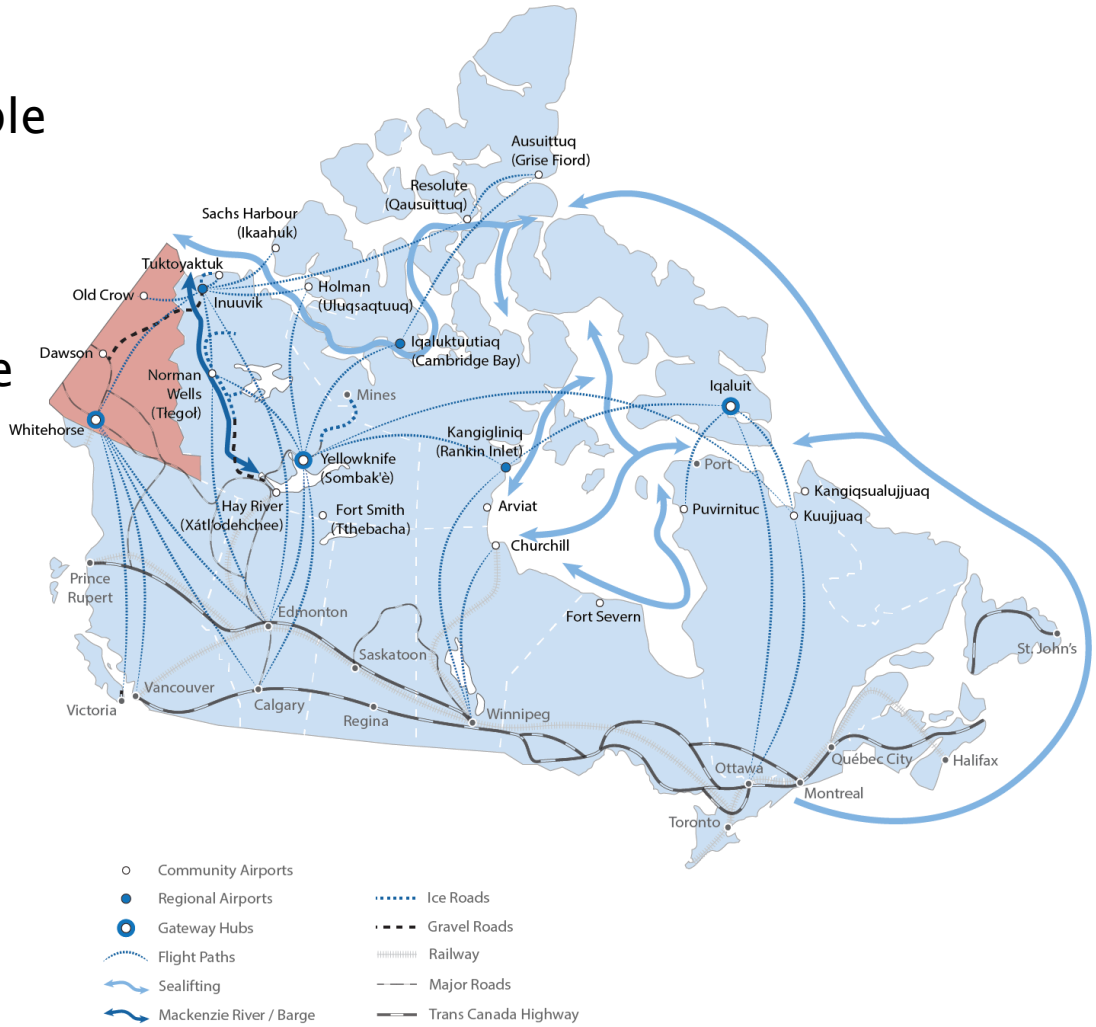


Frost depth over 4m (13 ft) at some locations in Whitehorse!

Yukon Specific Retrofit Considerations

→ Material Availability

- → Many materials available in the South are not readily available in the North or are prohibitively expensive
- → Material weight has a large impact on cost when leaving gateway hubs such as Whitehorse



Yukon Specific Retrofit Considerations

→ Material Durability

→ Many common construction materials behave differently during installation and in-service in the North due to extreme cold

- Sealants
- Liquid-applied membranes
- Peel and Stick membranes
- Vinyl cladding and membranes
- Fibre-cement cladding

Thermal Comfort

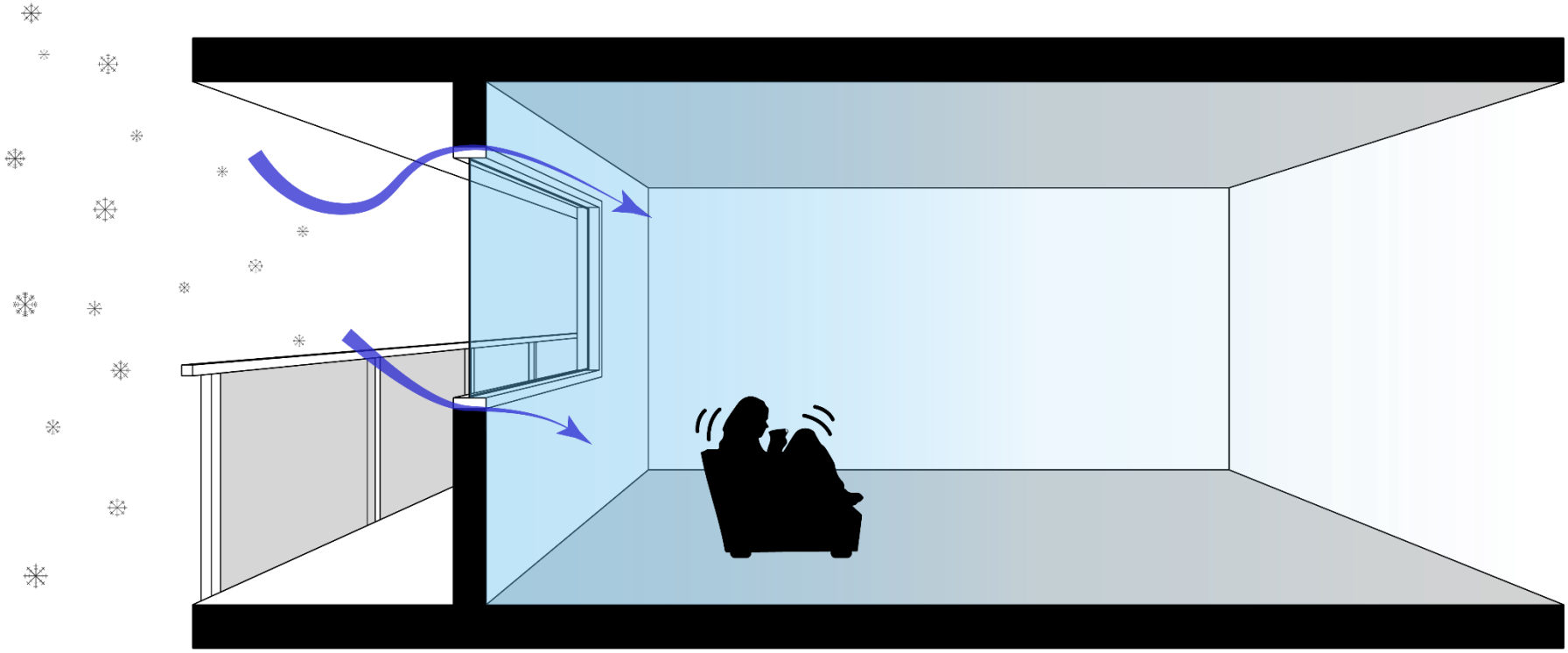
→ Occupant thermal comfort is impacted by interior ambient temperatures and surface temperatures

→ Highly insulated assemblies (windows, opaque assemblies, etc.) tend to have warmer interior surface temperatures

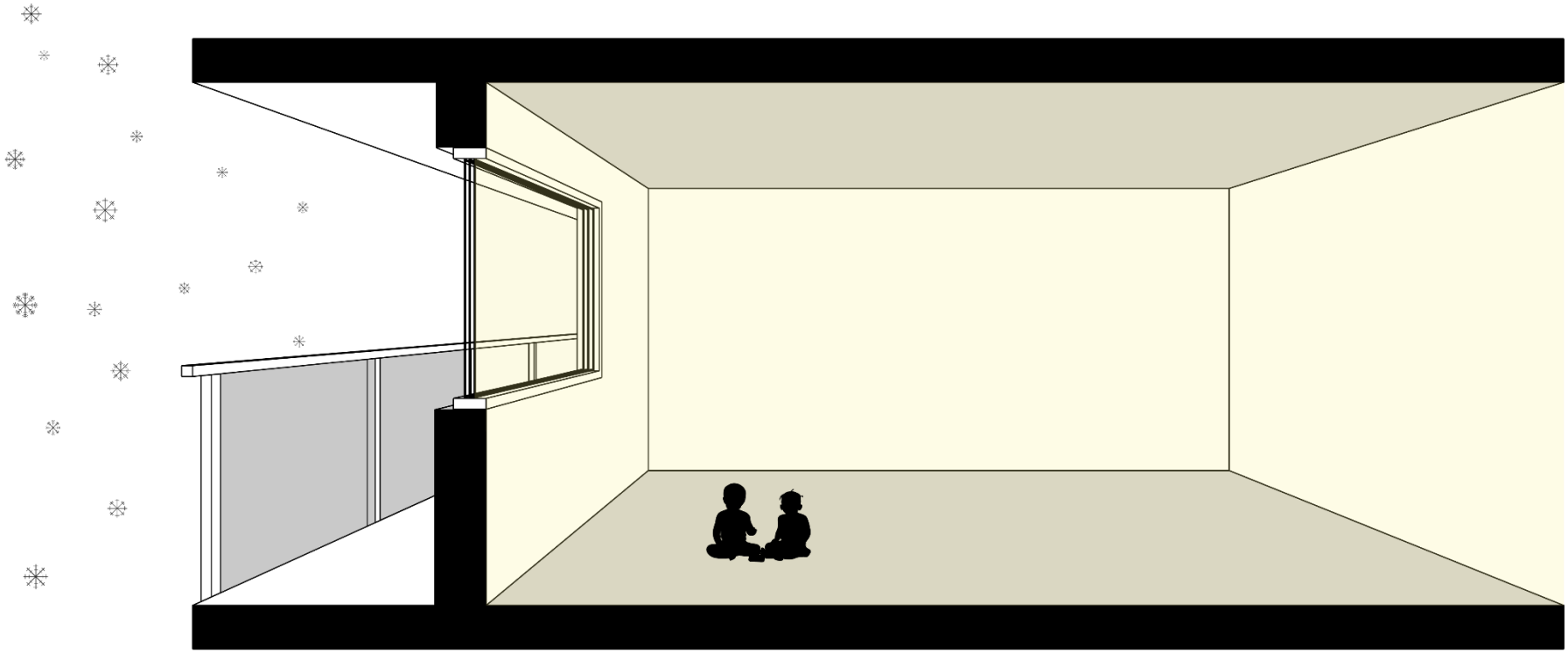
→ Airtight buildings limit uncontrolled air leakage leading to heat loss via air leakage and uncomfortable cold drafts

→ **Improving occupant thermal comfort should be a primary motivator for building enclosure retrofits!**

Thermal Comfort



Thermal Comfort



Health & Safety Considerations for Retrofits

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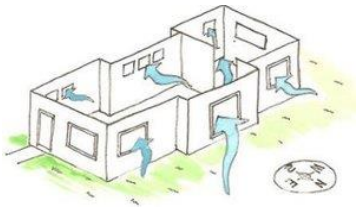
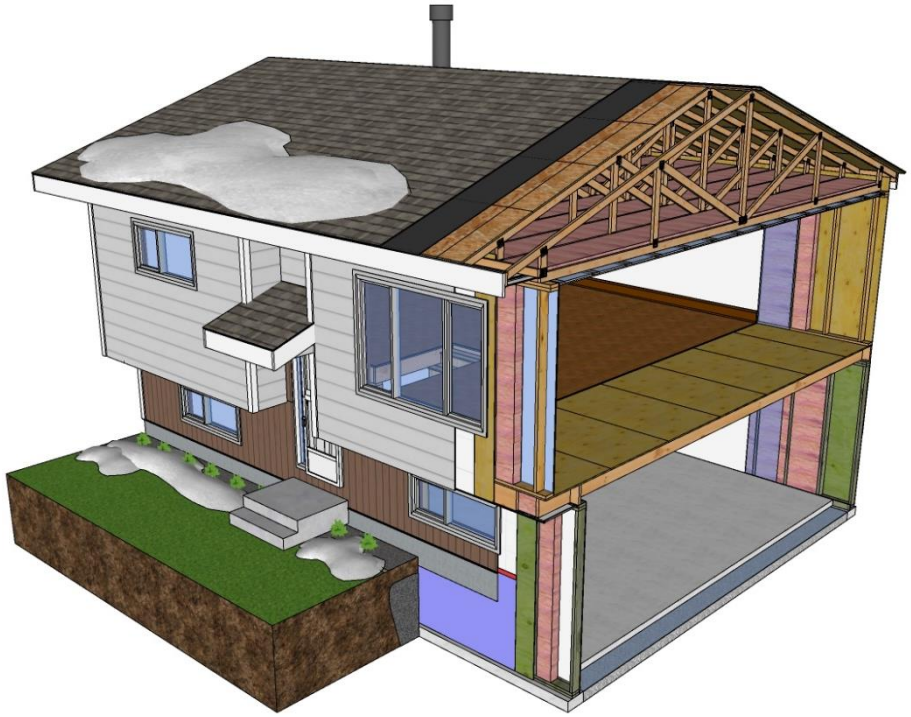
Health & Safety Considerations for Retrofits

Ventilation

- → Chemicals & VOCs
- → Temporary ventilation fans
- → Windows/doors open
- → Full respirator equipment

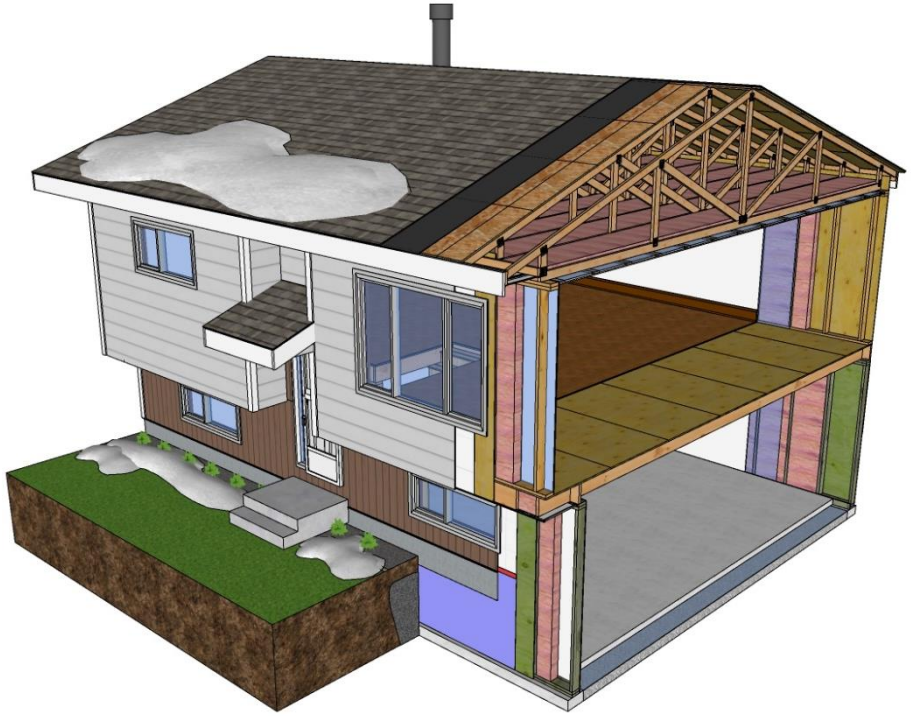




Health & Safety Considerations for Retrofits

Homeowner Safety

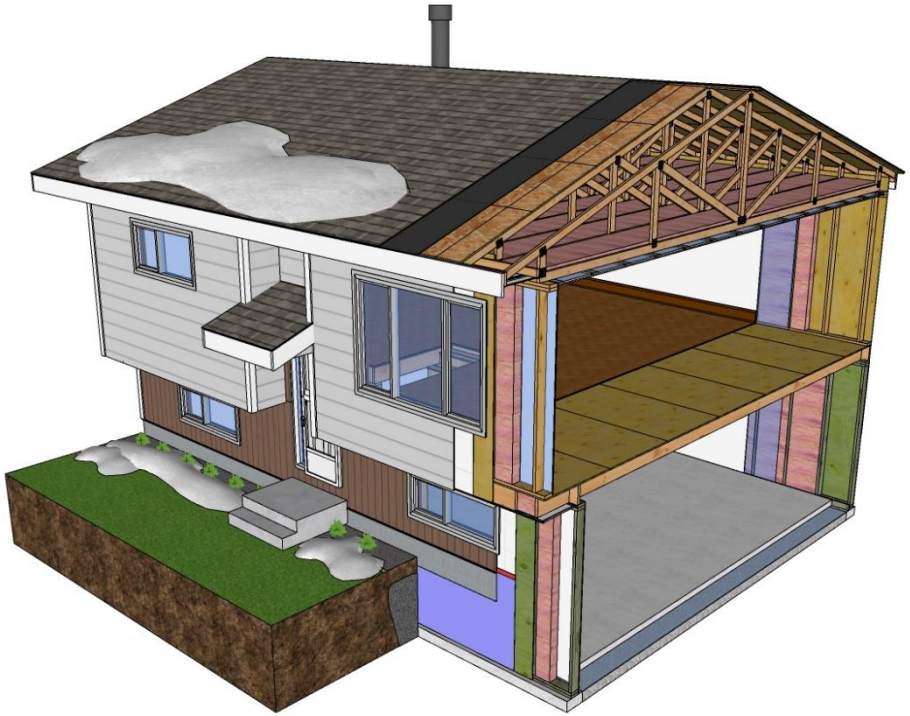
- → Block off access to hazardous areas
- → Lock-out equipment
- → Beware of children
- → Warn of dust
- → Don't block exits



Health & Safety Considerations for Retrofits

Electrical Wiring

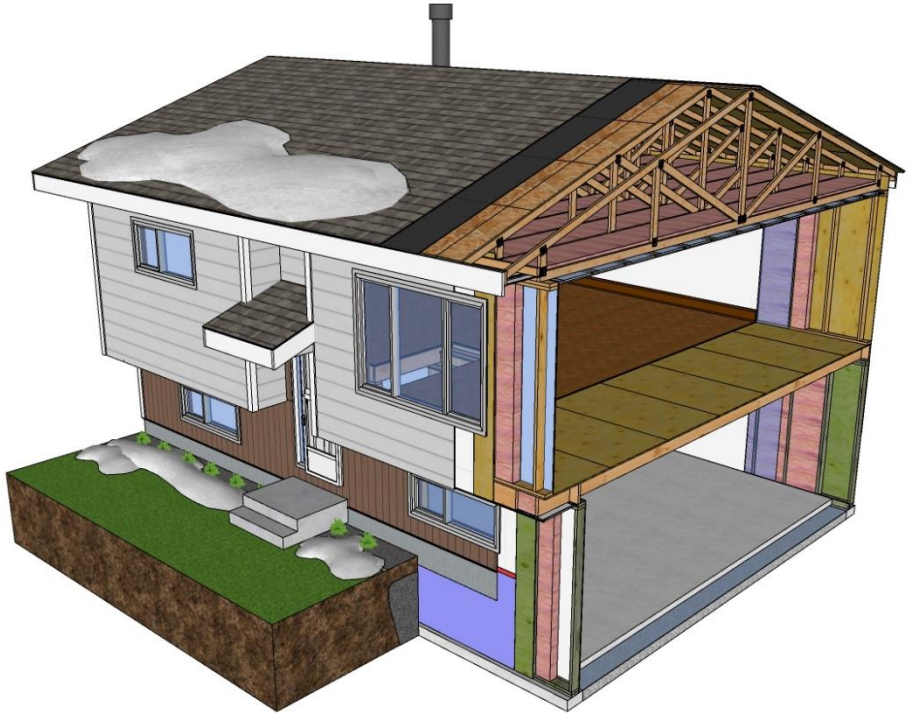
- → No contact with bare wires
- → Hire an electrician
- → Disconnect heating devices
- → Knob and tube wiring = no-go



Health & Safety Considerations for Retrofits

Ladders

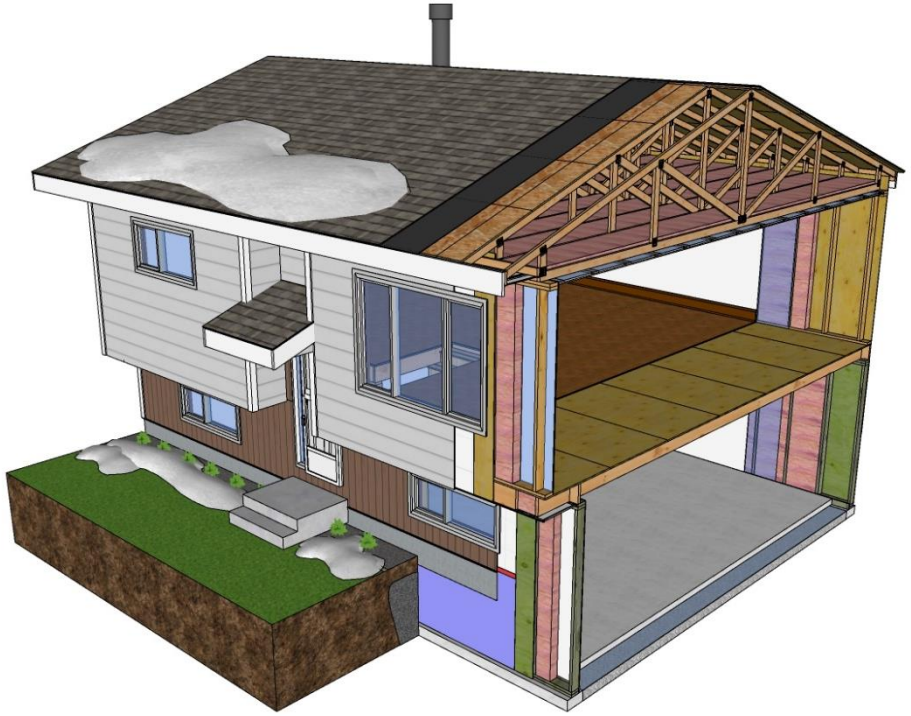
- → Grade 2 or better
- → Three points of contact
- → Solid ground
- → Face the ladder
- → Use tie offs



Health & Safety Considerations for Retrofits

Structural Elements

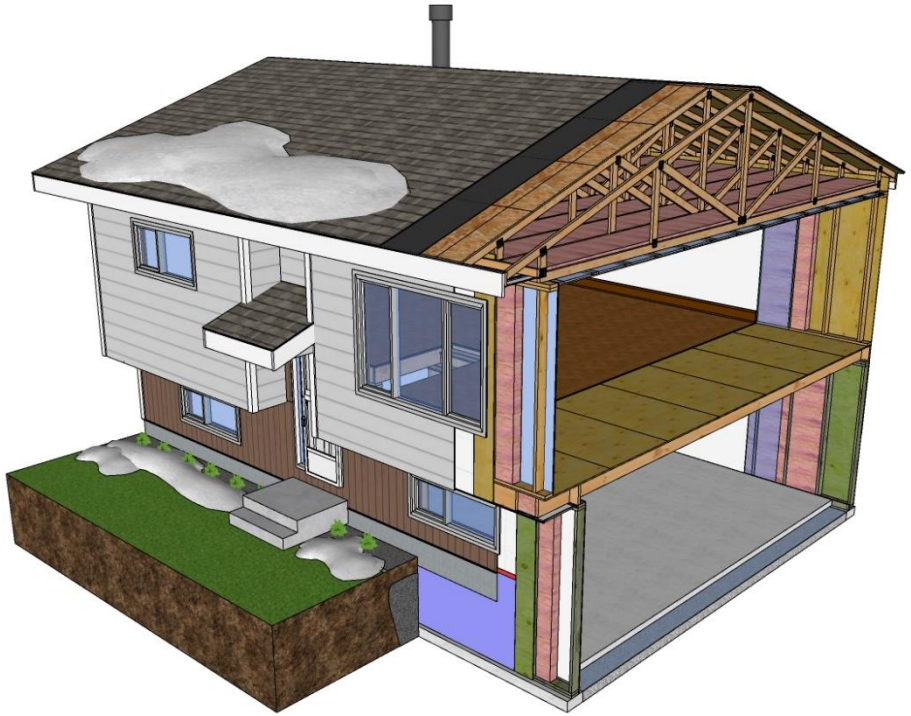
→ No modifications to structural elements without structural engineer!



Health & Safety Considerations for Retrofits

Attic Fall Hazards

- → Wires, nails, wood blocking
- → No capacity on gypsum
- → Use good lighting

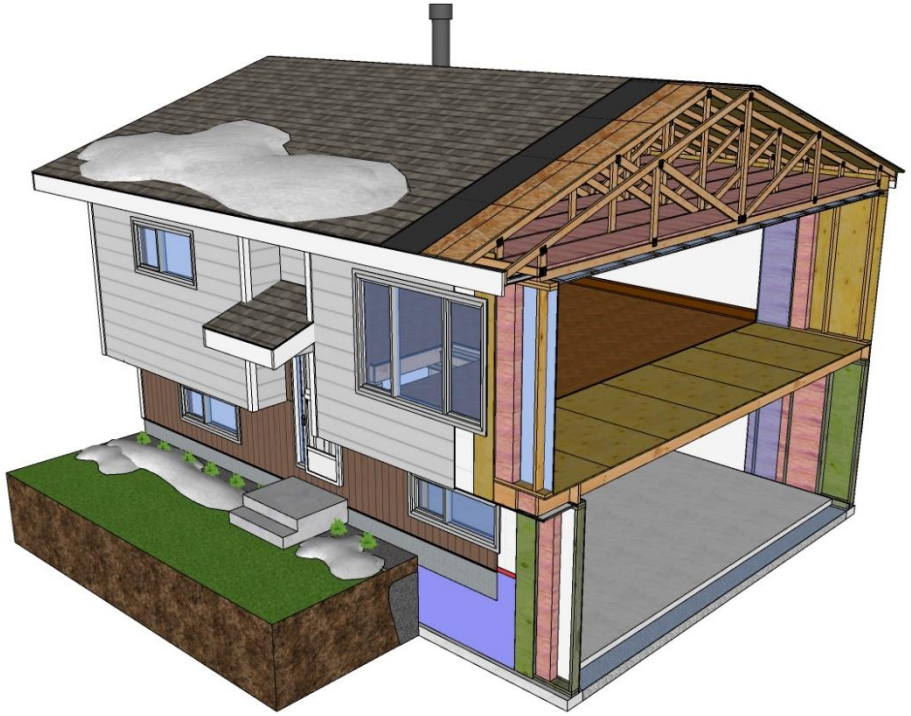


Health & Safety Considerations for Retrofits

Fungal Growth

→ Mould growth should be addressed by remediation

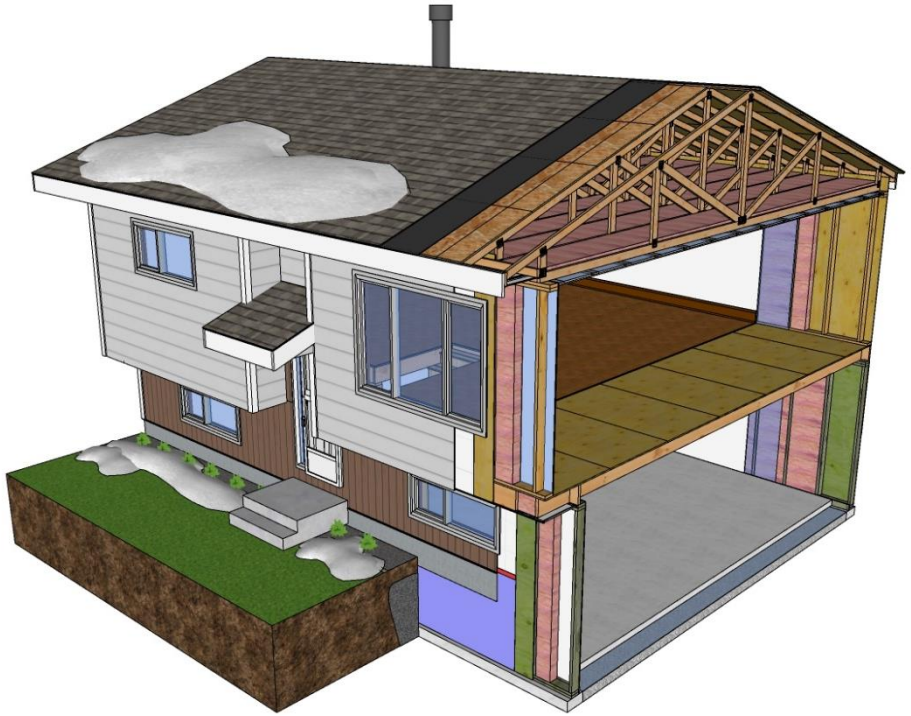
→ Cleaned and removed with PPE



Health & Safety Considerations for Retrofits

Asbestos

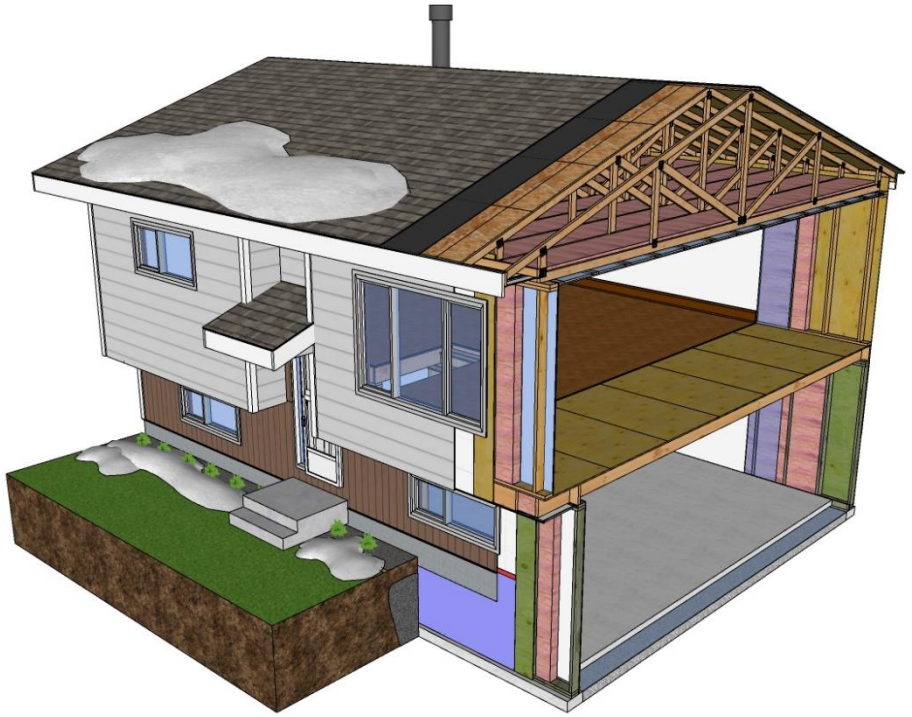
- → Vermiculite insulation = no-go
- → Old pipes, adhesives, window caulking, GWB and tape
- → Complete environmental assessment if doing major work



Health & Safety Considerations for Retrofits

Spray Foam

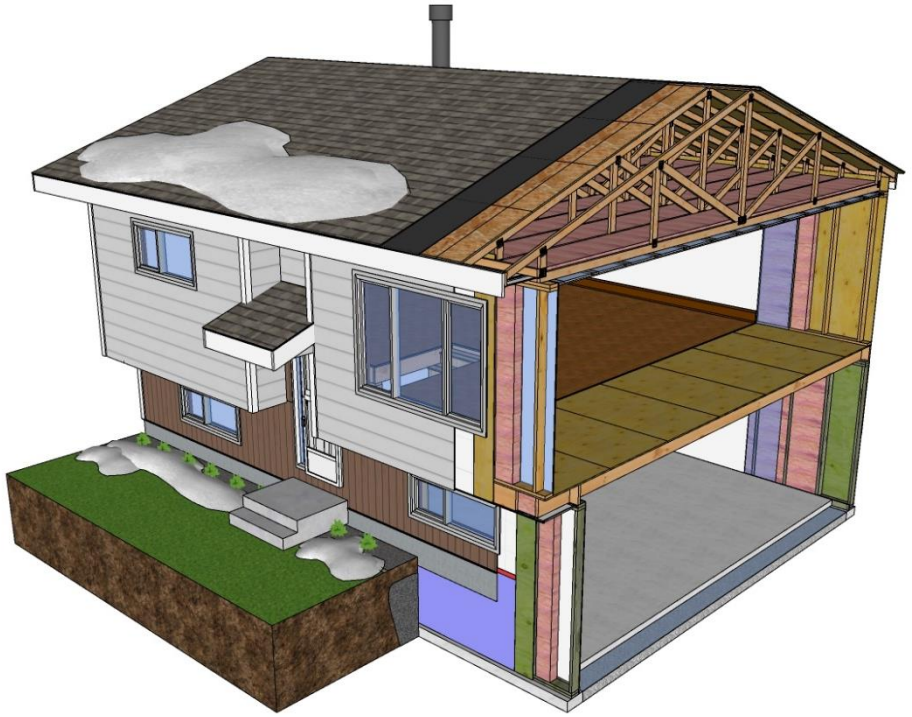
- → Large amounts installed by trained contractor
- → Use respirator
- → Will need to vacate home while installing/curing



Health & Safety Considerations for Retrofits

Solvents & VOCs

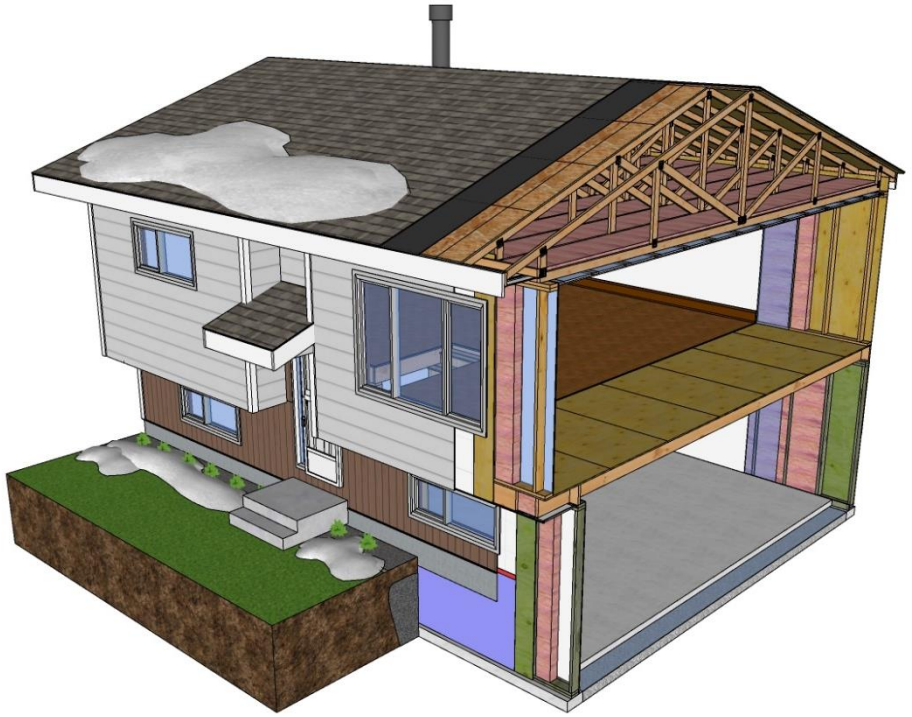
- → Check SDS for all chemicals, sealants, insulations
- → Use low-VOC products where possible



Health & Safety Considerations for Retrofits

Lead Paint

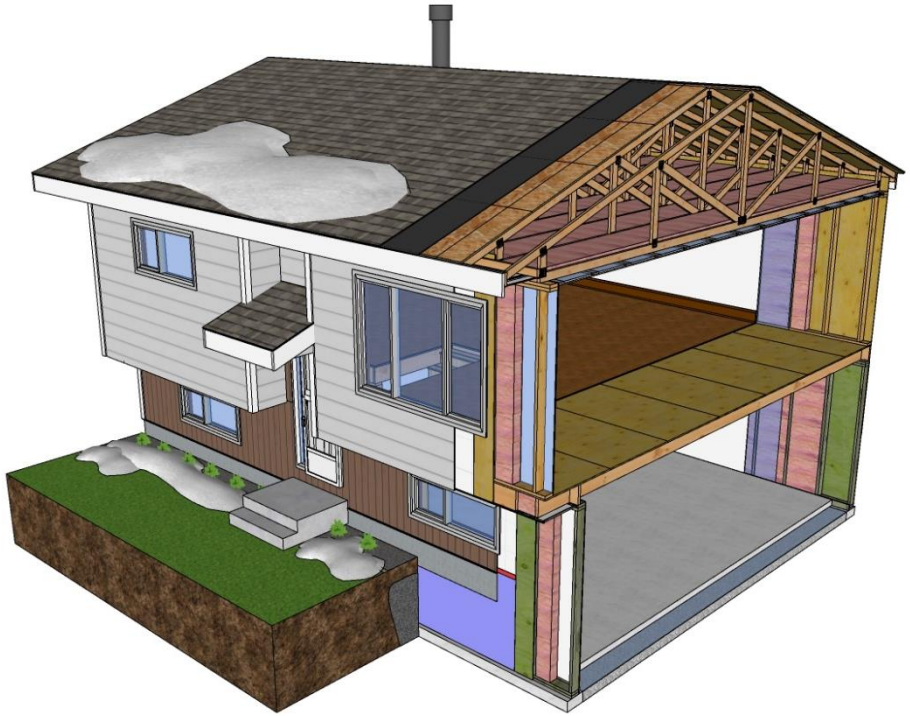
- → Used until 1980s
- → Not a hazard if left intact
- → Requires special removal measures if damaged or being removed



Health & Safety Considerations for Retrofits

Combustion Safety

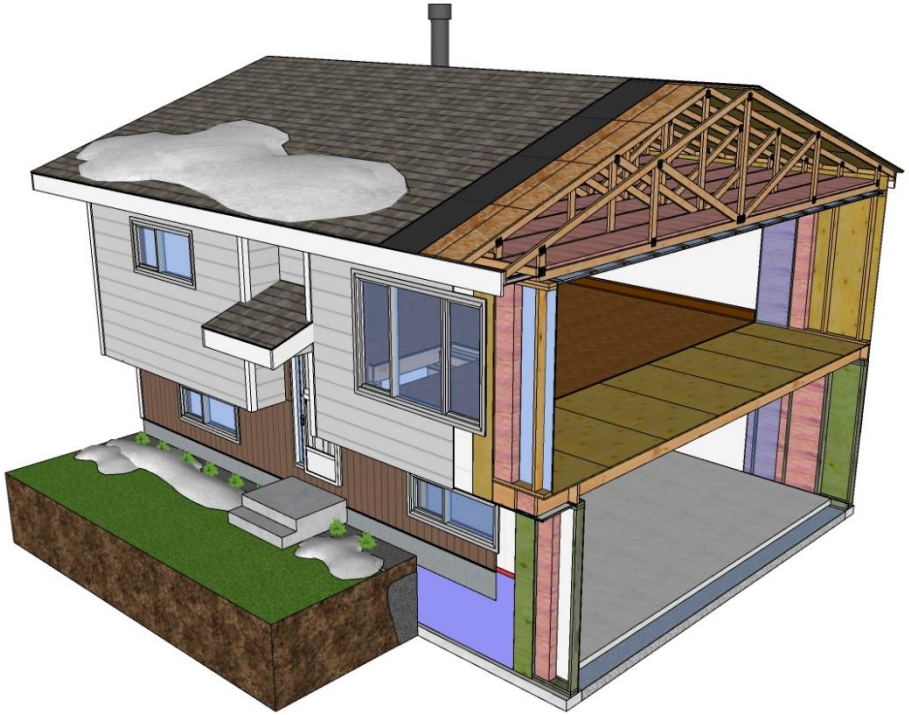
- → Air sealing may affect combustion equipment access to air
- → Direct vent or makeup air inlet may be required
- → Removal of fireplaces may be warranted
- → Depressurization test required if largescale air sealing retrofits completed – discuss with homeowner

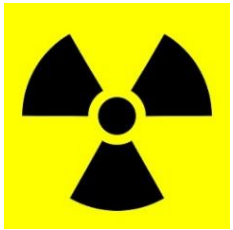


Health & Safety Considerations for Retrofits

Radon Gas

- → Test home for radon
- → Notify homeowner to address this before beginning retrofit
- → Always complete sealing of basement or crawlspace before doing other work.
- → Use retrofit opportunity to address radon!





Optimal Retrofit Packages for Yukon

- → Archetype Home
- → Optimization Process
- → Optimization Results
- → Retrofit Packages
- → How to Prioritize Retrofits?

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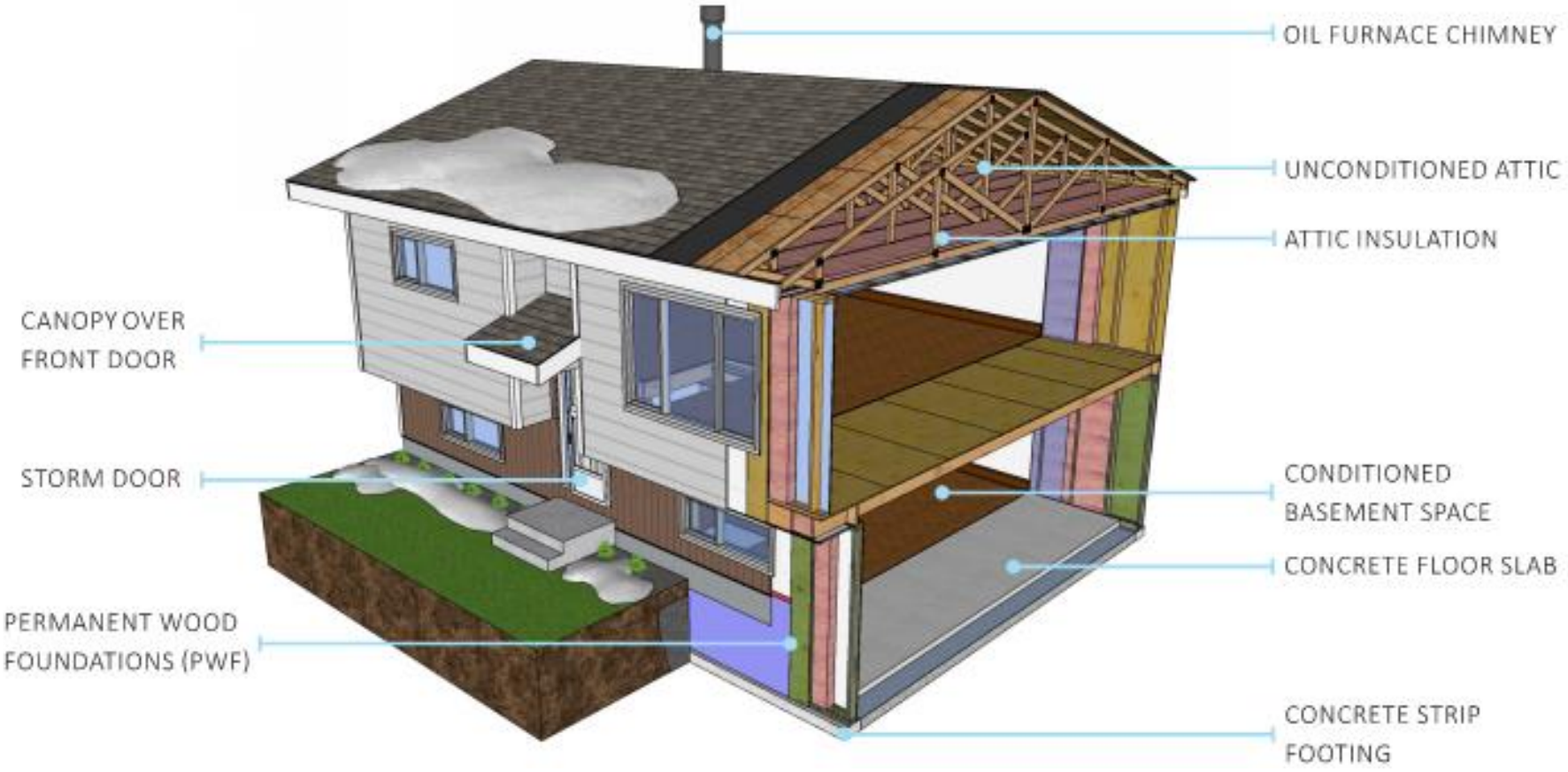
Archetype Home – Whitehorse, YK

- 1-storey detached house w/ finished basement, ~1550 sq.ft located in Whitehorse:
  - Attic – Raised heel truss w/ batts
  - Foundation - 2x6 PWF w/ batts Uninsulated concrete slab
  - Main floor is cantilevered at front of house – 2x10 joists w/ batts
  - AG Wall - 2x4 wood stud w/ batts
  - Casement windows (double glazed, clear, air fill)
  - Oil furnace and electric hot water heater
  - Energy Use – 164 GJ/year

Archetype Home – Whitehorse, YK

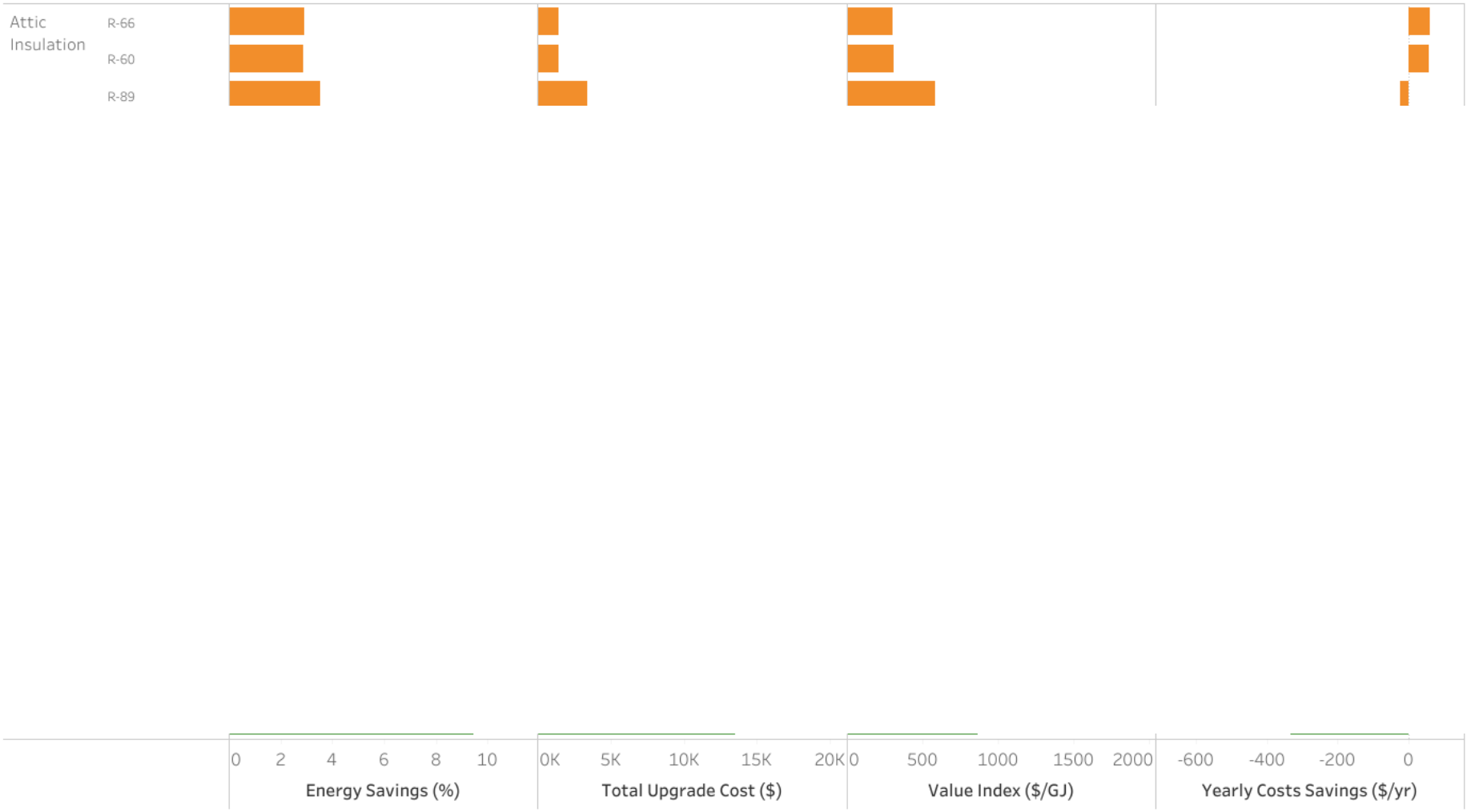


Optimization Process

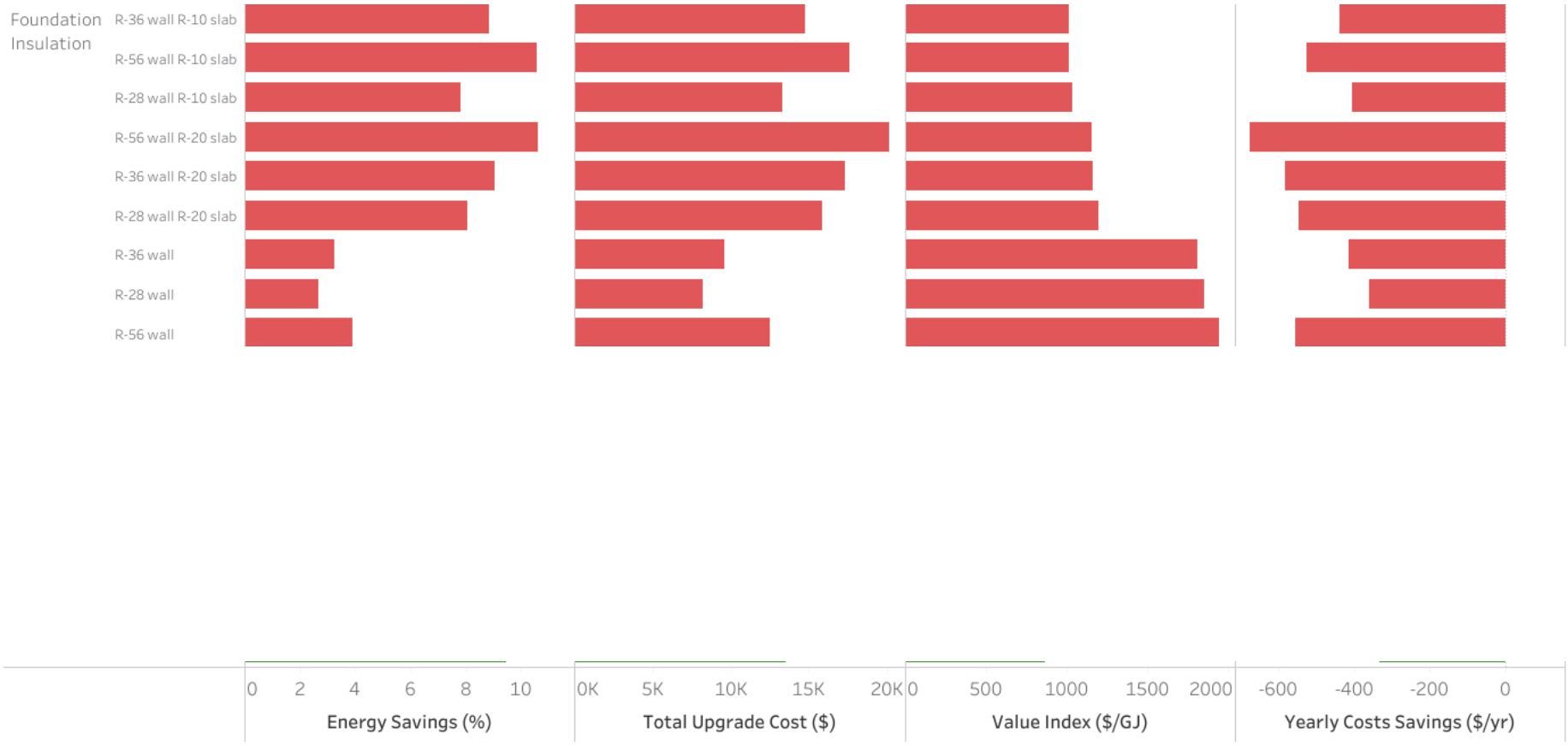
- → Thousands of simulations run in HOT2000 by NRCan/CANMET-Energy
- → Labour and material costs provided by YHC
- → Several building enclosure retrofits simulated:
  - → Building enclosure assembly R-values
    - › Walls, foundation, floor slab, roof
  - → Airtightness levels
  - → Window replacement (improved U-Values)
  - → No mechanical retrofits for now
- → Interaction of all components in system considered
- → Retrofit capital costs, utility costs, mortgage carrying costs all considered – cost to build & cost to operate

Optimization Process

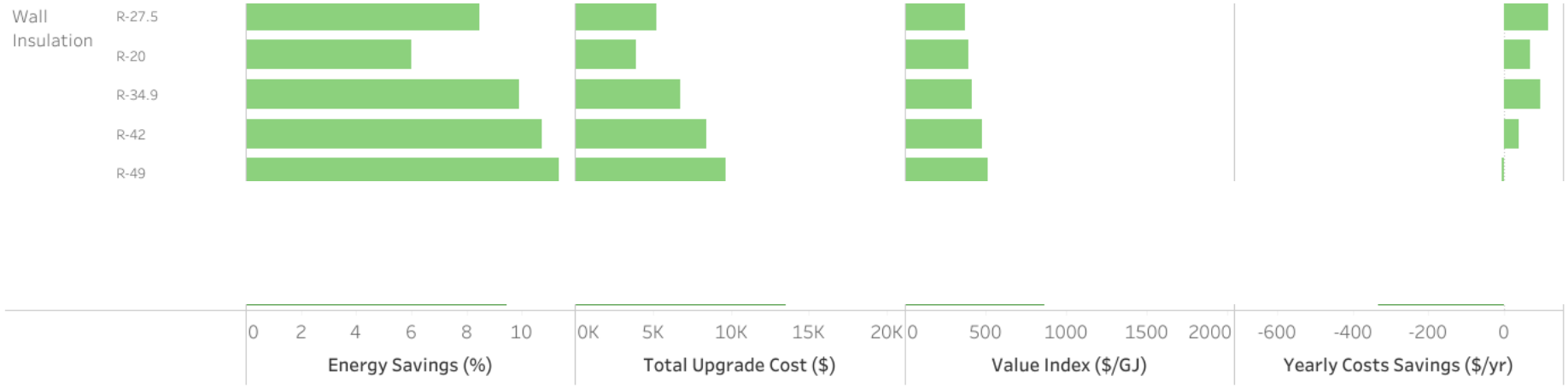
Optimization Process



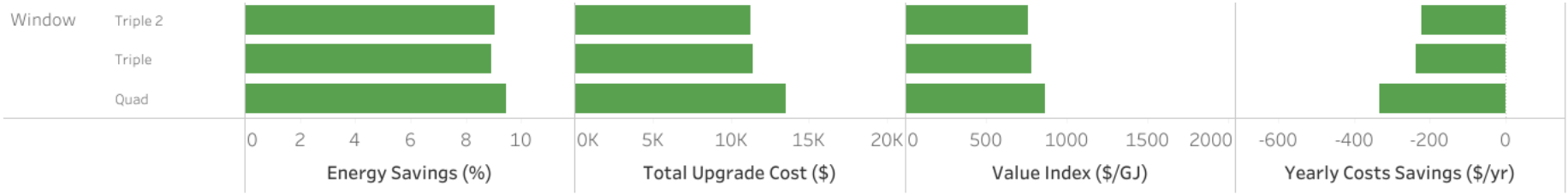
Optimization Process



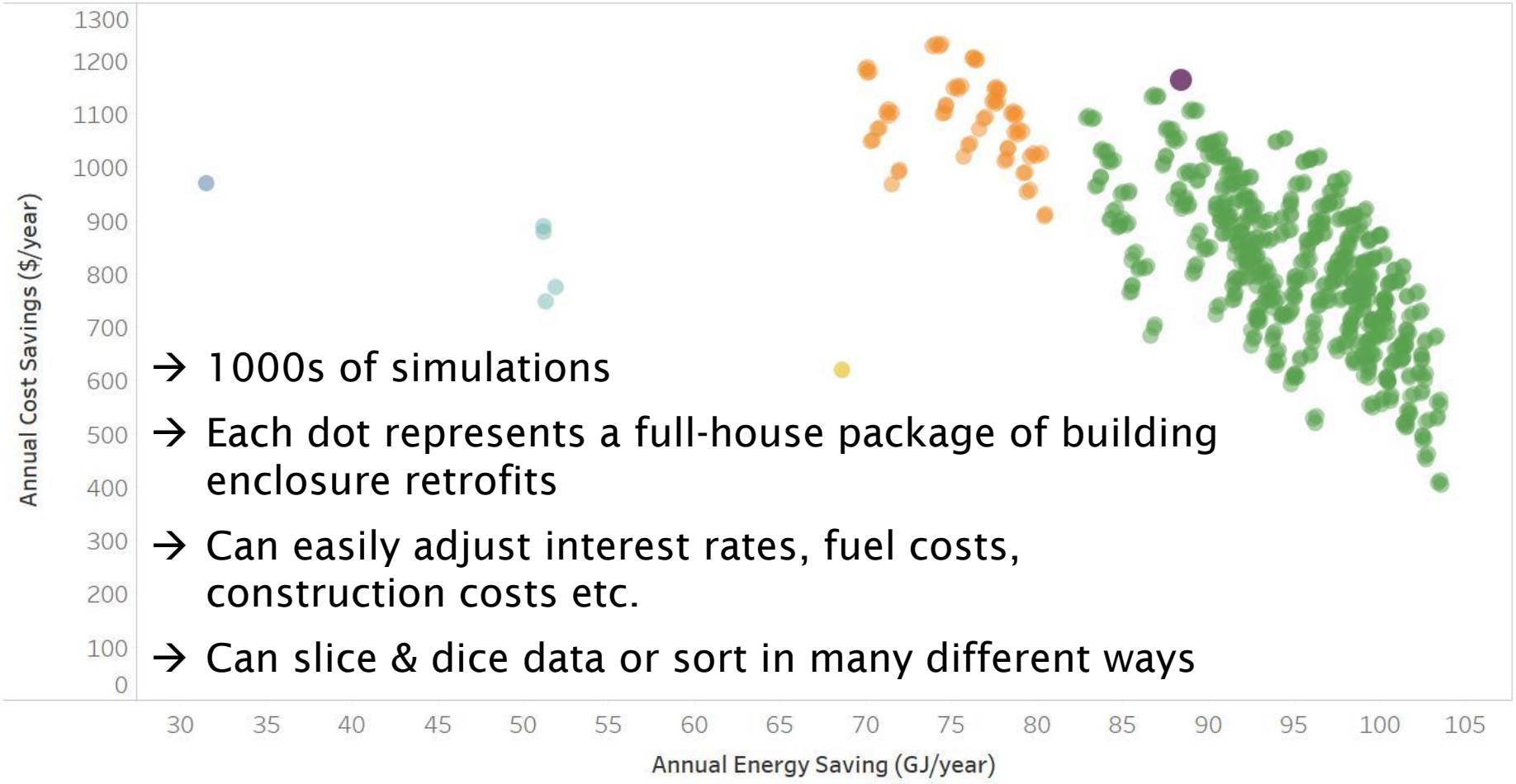
Optimization Process



Optimization Process



Optimization Results



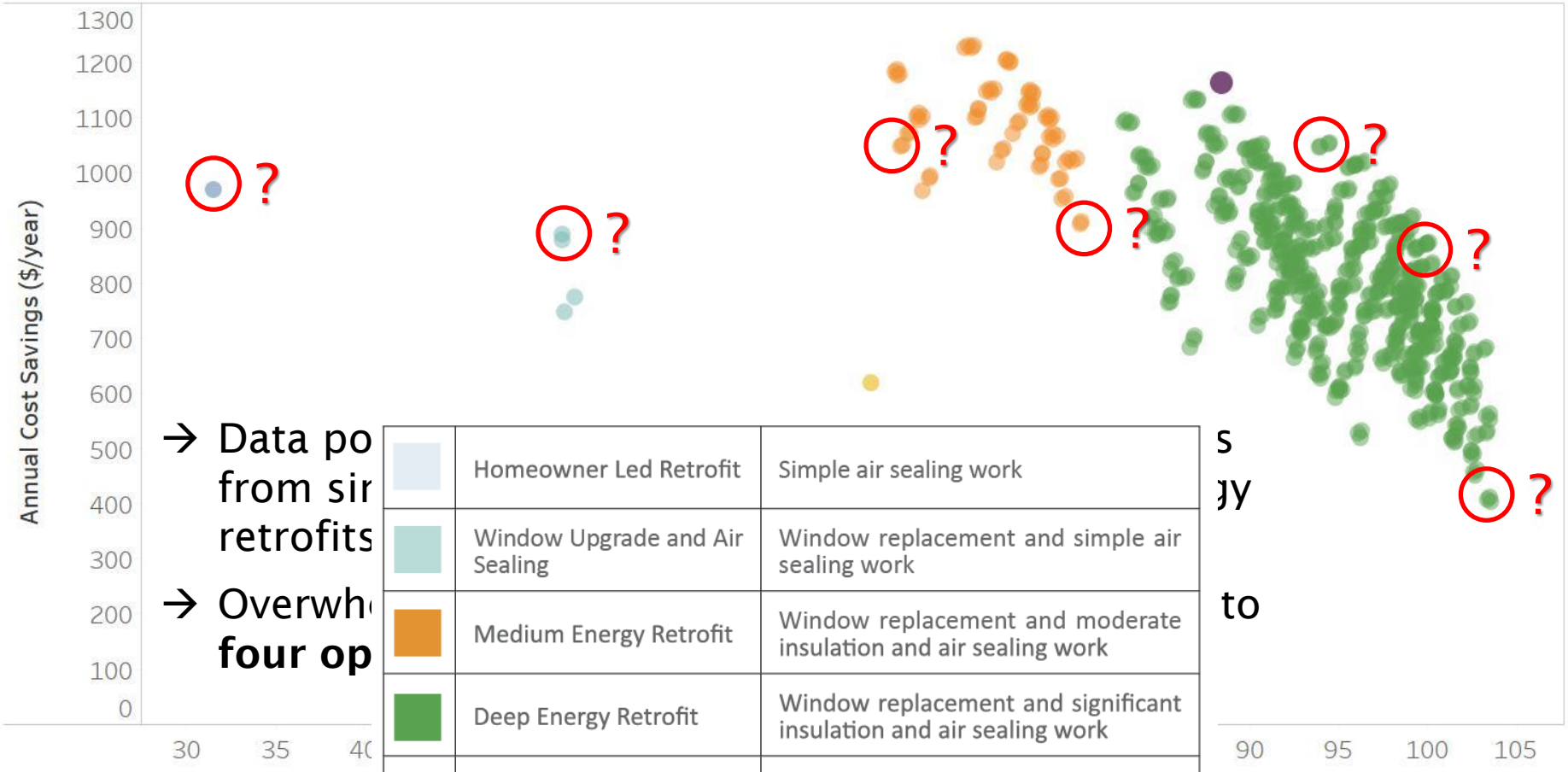
→ 1000s of simulations

→ Each dot represents a full-house package of building enclosure retrofits

→ Can easily adjust interest rates, fuel costs, construction costs etc.

→ Can slice & dice data or sort in many different ways

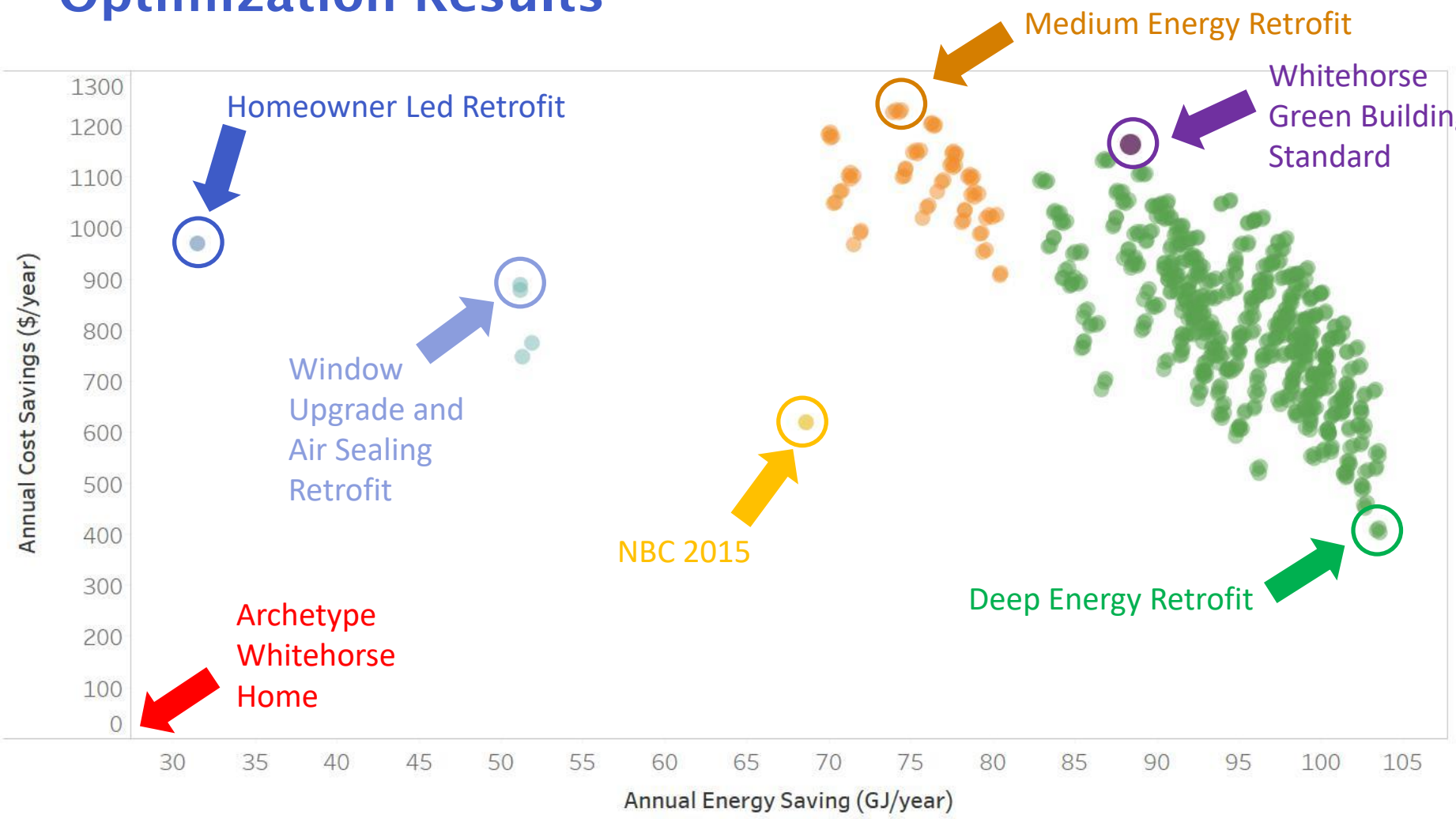
Optimization Results



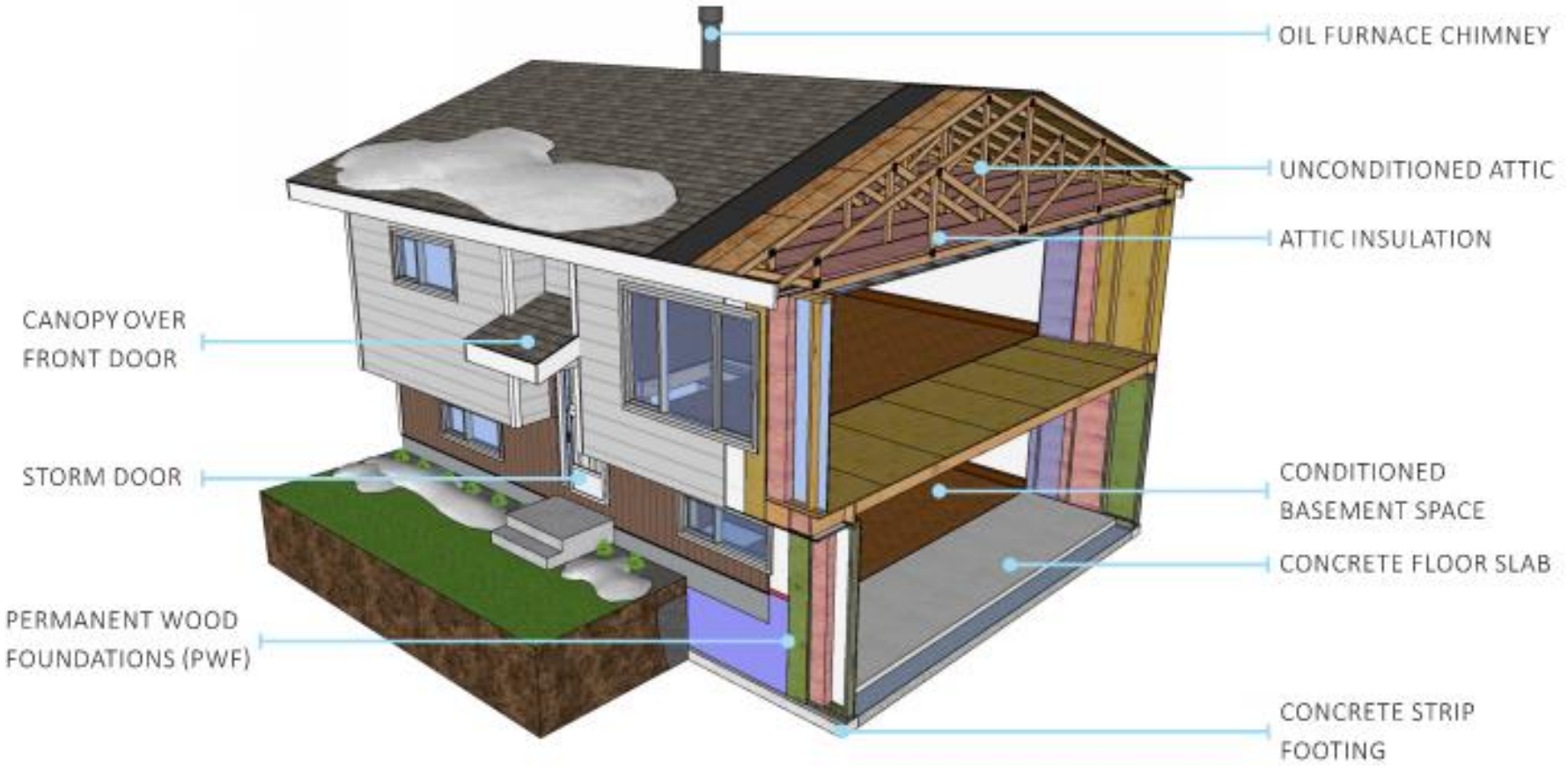
→ Data po s
from sir gy
retrofits
→ Overwh to
four op

	Homeowner Led Retrofit	Simple air sealing work
	Window Upgrade and Air Sealing	Window replacement and simple air sealing work
	Medium Energy Retrofit	Window replacement and moderate insulation and air sealing work
	Deep Energy Retrofit	Window replacement and significant insulation and air sealing work
	2015 National Building Code (Section 9.36)	Prescriptive Code requirements met
	Whitehorse Green Building Standard	Prescriptive Code requirements met

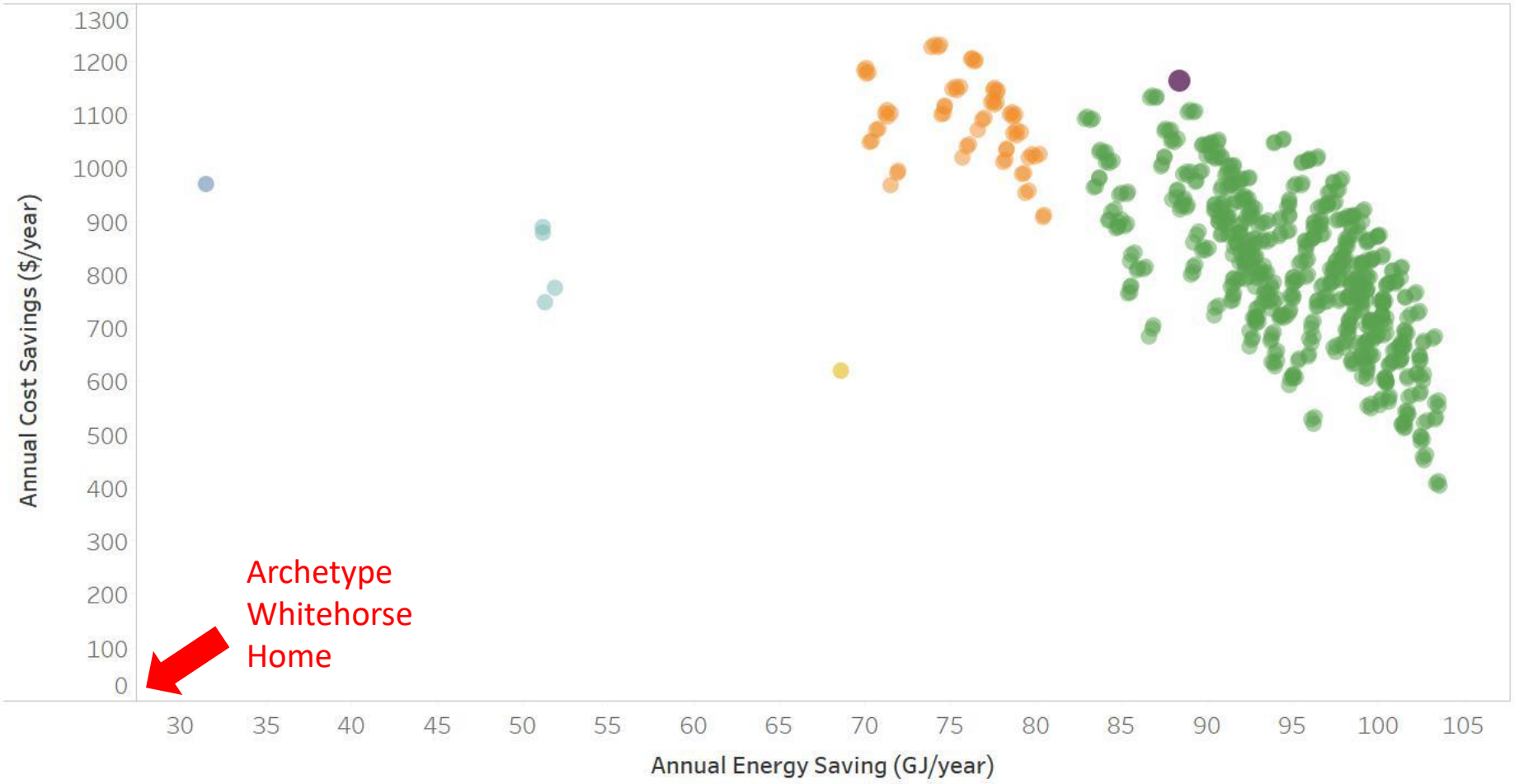
Optimization Results



Base Case House



Base Case House

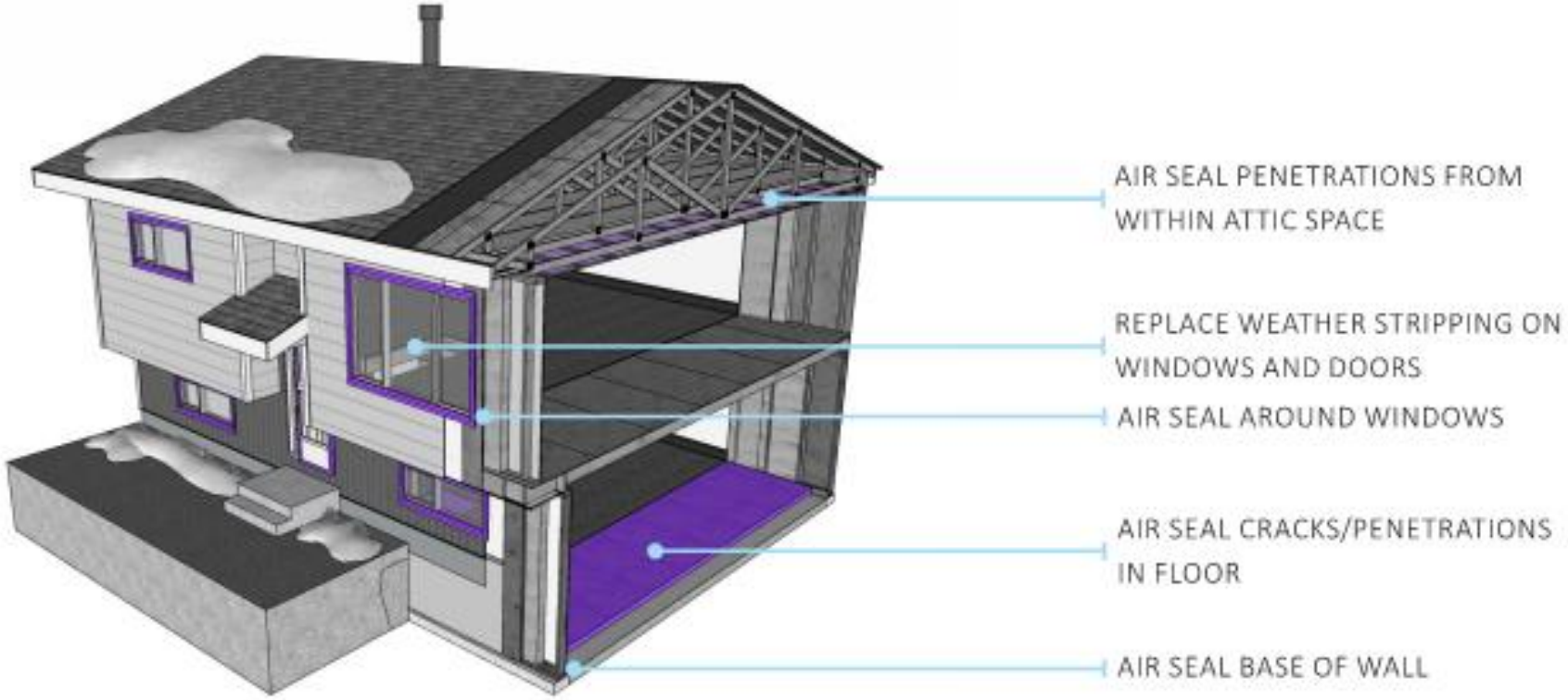


Base Case House

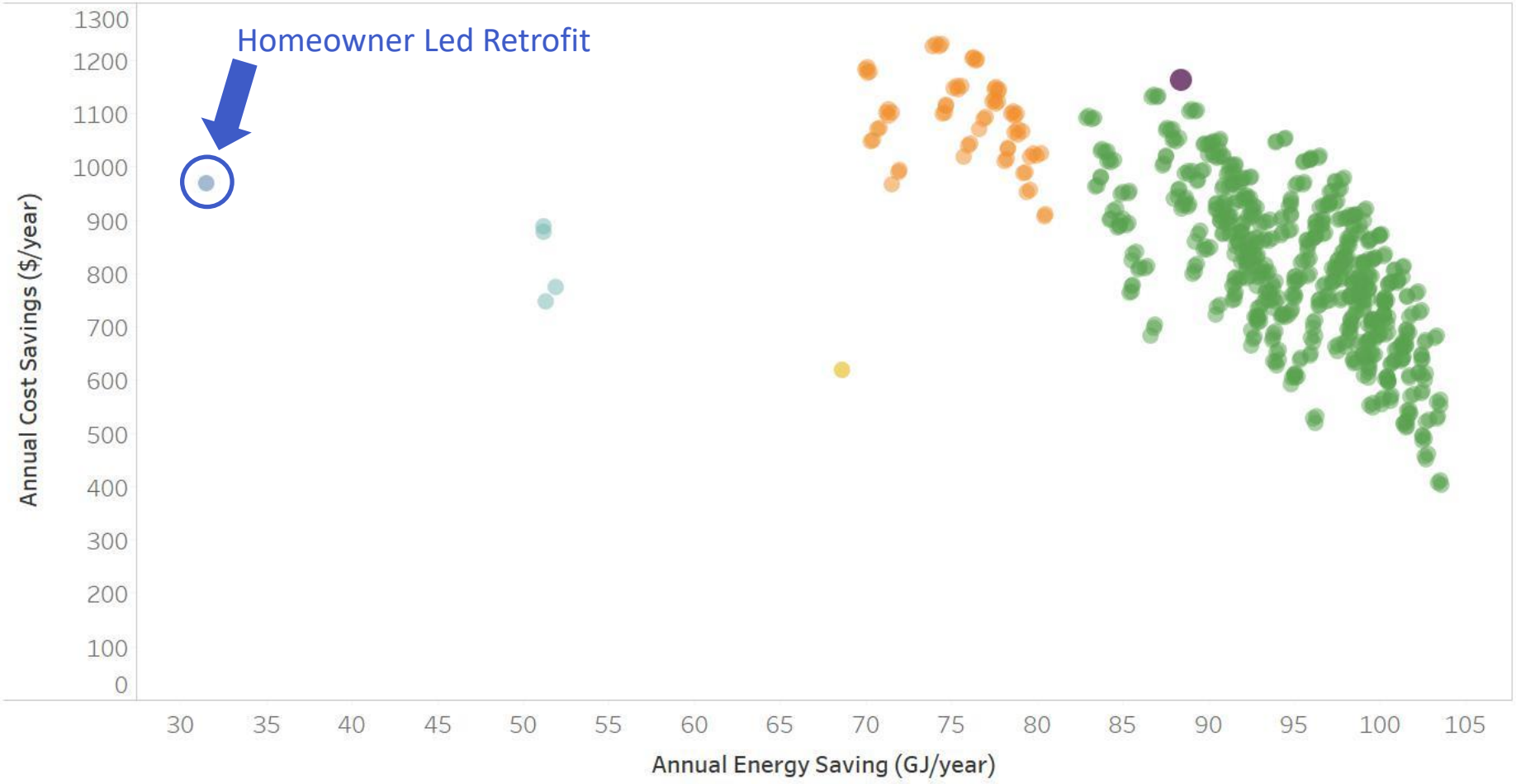
Basement Slab	Uninsulated concrete slab
Foundation/Basement Wall	2X6 PWF @ 406mm (16") O.C. with batt insulation, RSI-2.7 (R-15)
Above Grade Wall	2x4 Wood stud @ 406mm (16") O.C. with batt insulation, RSI 2.2 (R-12)
Exposed Floor	2X10 Joists @ 406mm (16”) O.C. with batt insulation, RSI-4.0 (R-23)
Attic	Raised heel truss @ 610mm (24") O.C. with batt insulation, RSI-5.5 (R-31)
Air Tightness	8.17 ACH (air changes per hour)
Casement Windows	Double-glazed, clear, air fill, USI-2.94 (U-0.52), SHGC 0.60

Retrofit Packages

→ Homeowner Led Retrofit



Retrofit Packages



Retrofit Packages

Basement Slab	Uninsulated concrete slab
Foundation/Basement Wall	2X6 PWF @ 406mm (16") O.C. with batt insulation, RSI-2.7 (R-15)
Above Grade Wall	2x4 Wood stud @ 406mm (16") O.C. with batt insulation, RSI 2.2 (R-12)
Exposed Floor	2X10 Joists @ 406mm (16") O.C. with batt insulation, RSI-4.0 (R-23)
Attic	Raised heel truss @ 610mm (24") O.C. with batt insulation, RSI-5.5 (R-31)
Air Tightness	5.0 ACH (air changes per hour)
Casement Windows	Double-glazed, clear, air fill, USI-2.94 (U-0.52), SHGC 0.60
Annual Energy Savings	31 GJ/year
Annual Operating Cost Savings*	$969/year

* Savings on energy bills – Payments on principal and interest

What is Annual Operating Cost Savings?

Example:

→ Borrow/Mortgage, $25,000 to buy new windows, insulation and air-sealing

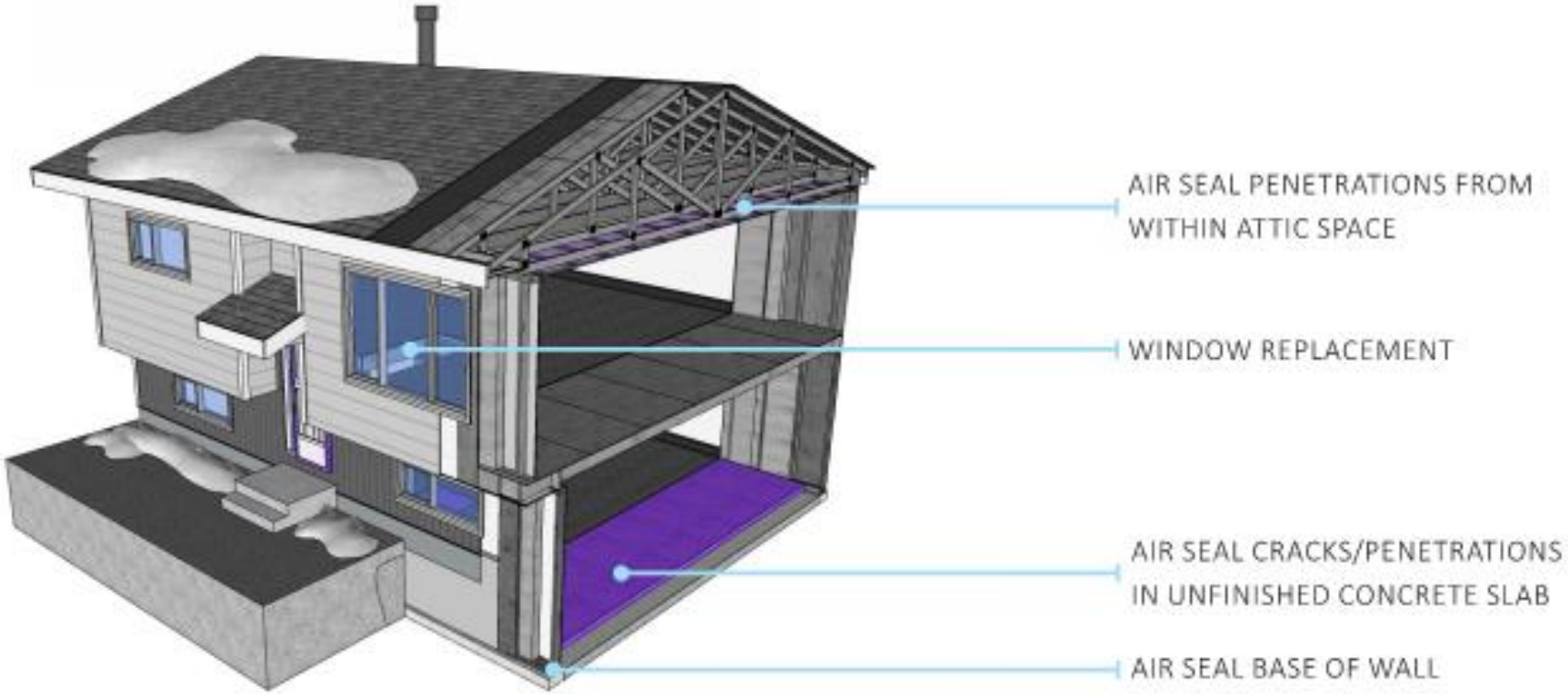
→ This costs homeowner $2000/year

→ But the energy cost savings are $2800/year

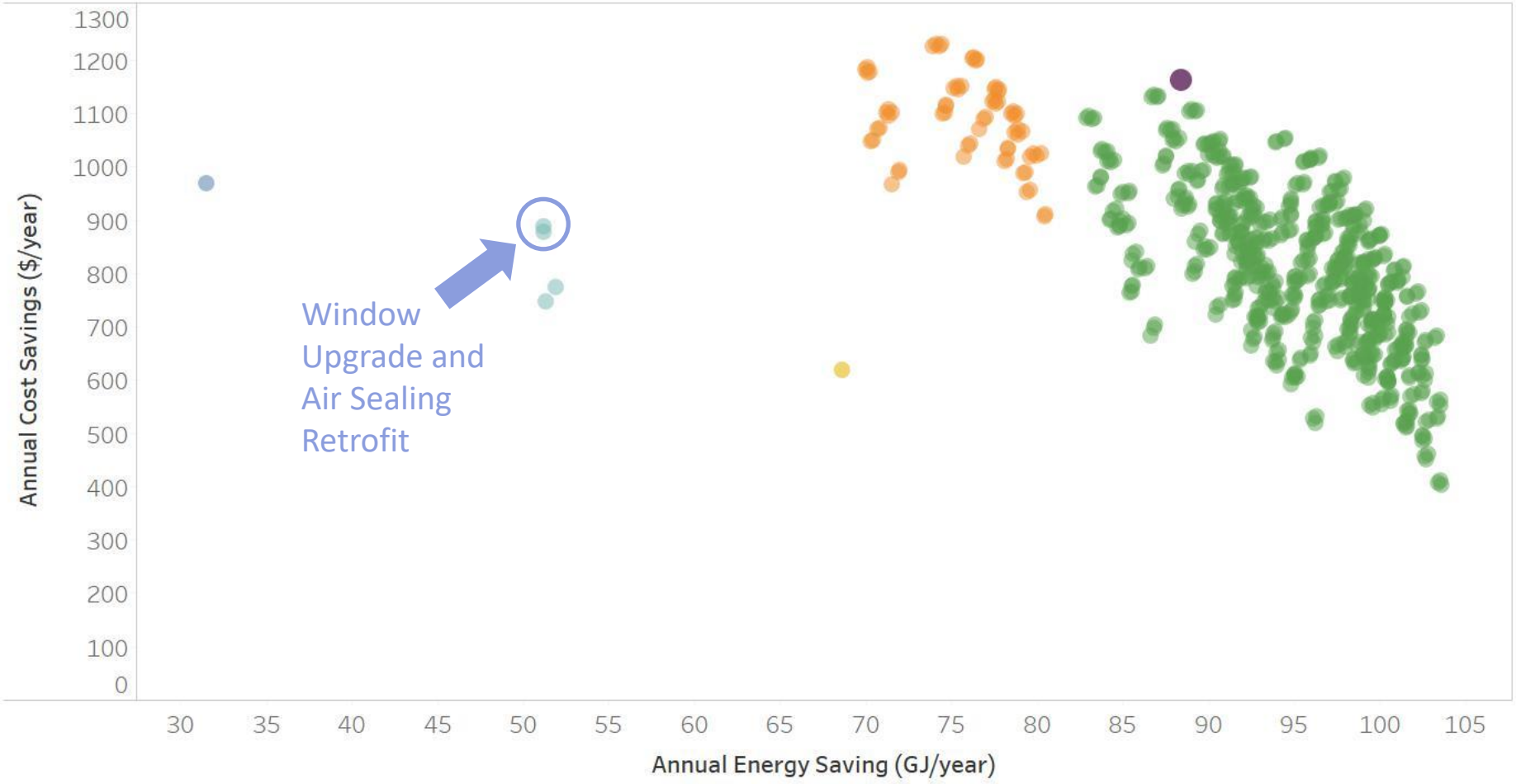
→ Net benefit is $800/year (less if not mortgaged w/ interest)

Retrofit Packages

→ Window Upgrade and Air Sealing Retrofit



Retrofit Packages



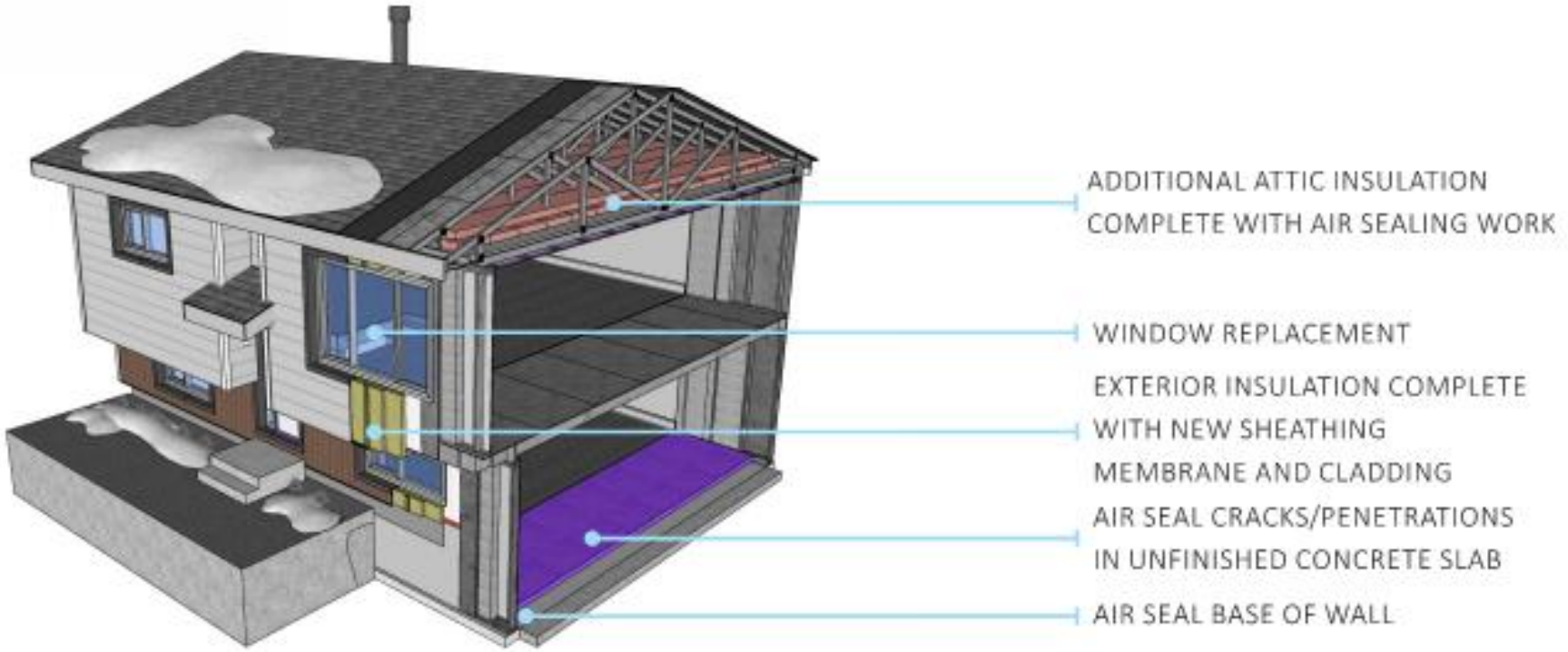
Retrofit Packages

Basement Slab	Uninsulated concrete slab
Foundation/Basement Wall	2X6 PWF @ 406mm (16") O.C. with batt insulation, RSI-2.7 (R-15)
Above Grade Wall	2x4 Wood stud @ 406mm (16") O.C. with batt insulation, RSI 2.2 (R-12)
Exposed Floor	2X10 Joists @ 406mm (16") O.C. with batt insulation, RSI-4.0 (R-23)
Attic	Raised heel truss @ 610mm (24") O.C. with batt insulation, RSI-5.5 (R-31)
Air Tightness	4.0 ACH (air changes per hour)
Casement Windows	Triple-glazed, 1 low-e coating, argon gas fill, USI-1.17 (U-0.21), SHGC 0.28
Annual Energy Savings	51 GJ/year
Annual Operating Cost Savings*	$889/year

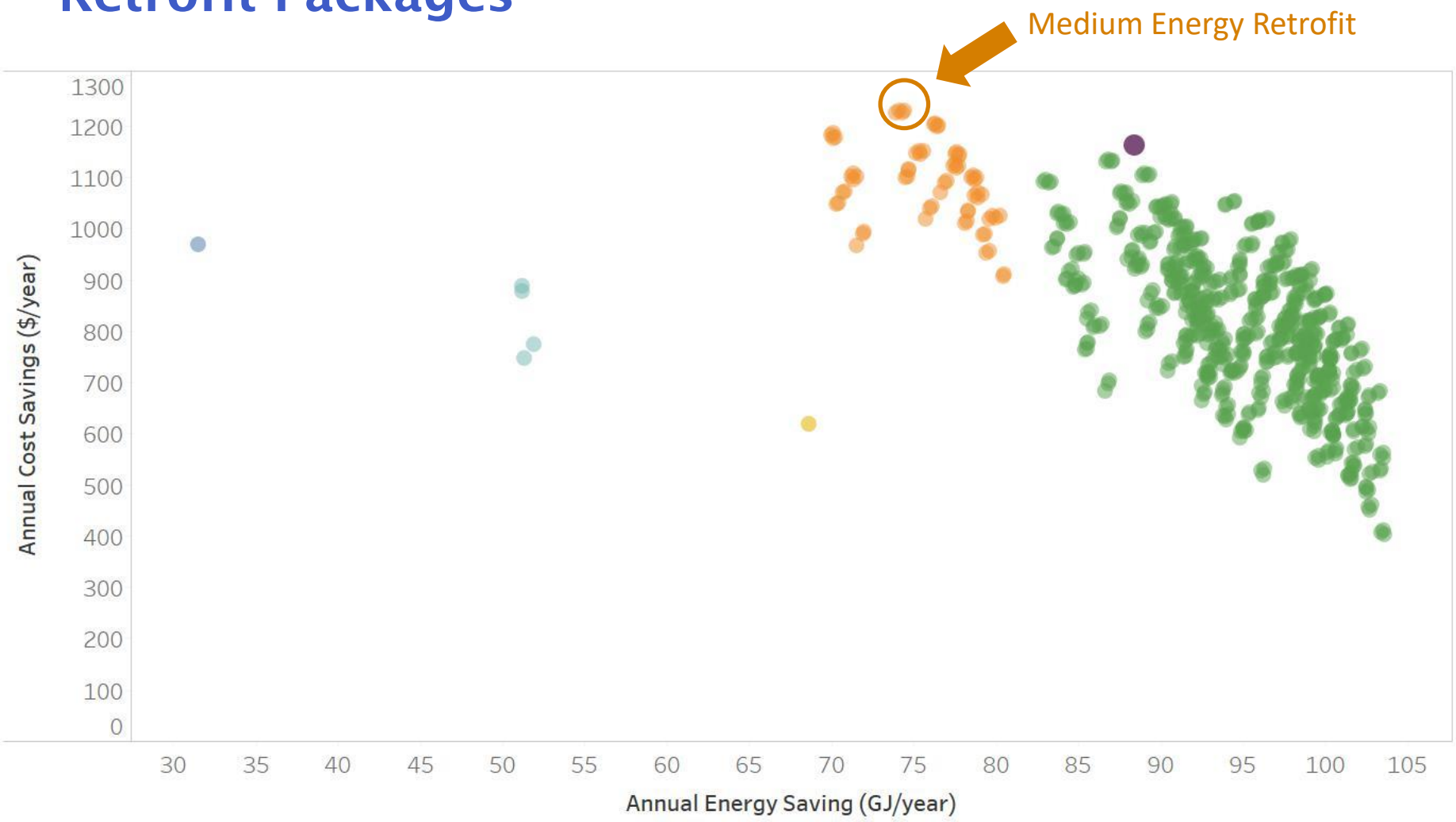
* Savings on energy bills – Payments on principal and interest

Retrofit Packages

→ Medium Energy Retrofit



Retrofit Packages



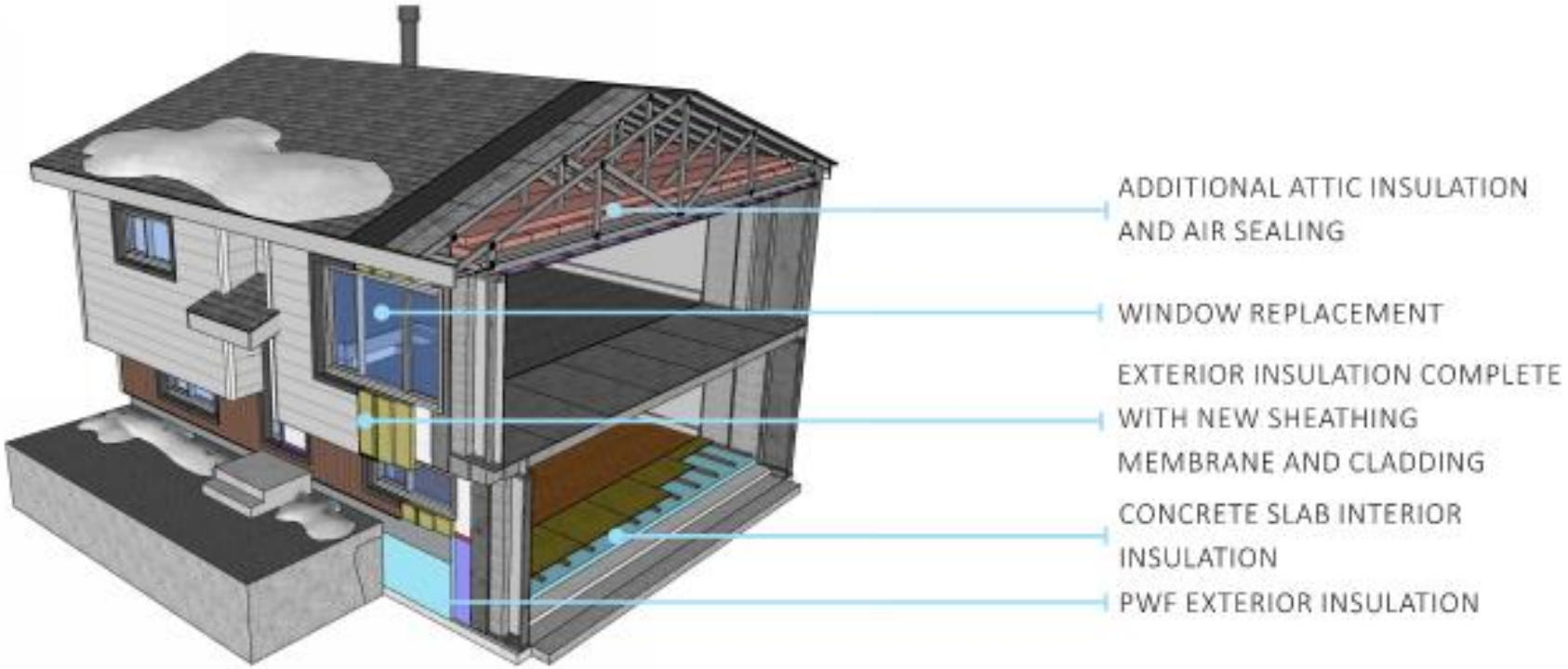
Retrofit Packages

Basement Slab	Uninsulated concrete slab
Foundation/Basement Wall	2X6 PWF @ 406mm (16") O.C. with batt insulation, RSI-2.7 (R-15)
Above Grade Wall	2x4 Wood stud @ 406mm (16") O.C. with batt insulation, new 102mm (4") exterior insulaton, RSI 4.9 (R-28)
Exposed Floor	2X10 Joists @ 406mm (16") O.C. with batt insulation, new 102mm (4") exterior insulaton, RSI 6.5 (R-37)
Attic	Raised heel truss @ 610mm (24") O.C. with additional batt insulation, RSI 11.6 (R-66)
Air Tightness	3.0 ACH (air changes per hour)
Casement Windows	Triple-glazed, 1 low-e coating, argon gas fill, USI-1.17 (U-0.21), SHGC 0.28
Annual Energy Savings	74 GJ/year
Annual Operating Cost Savings*	$1230/year

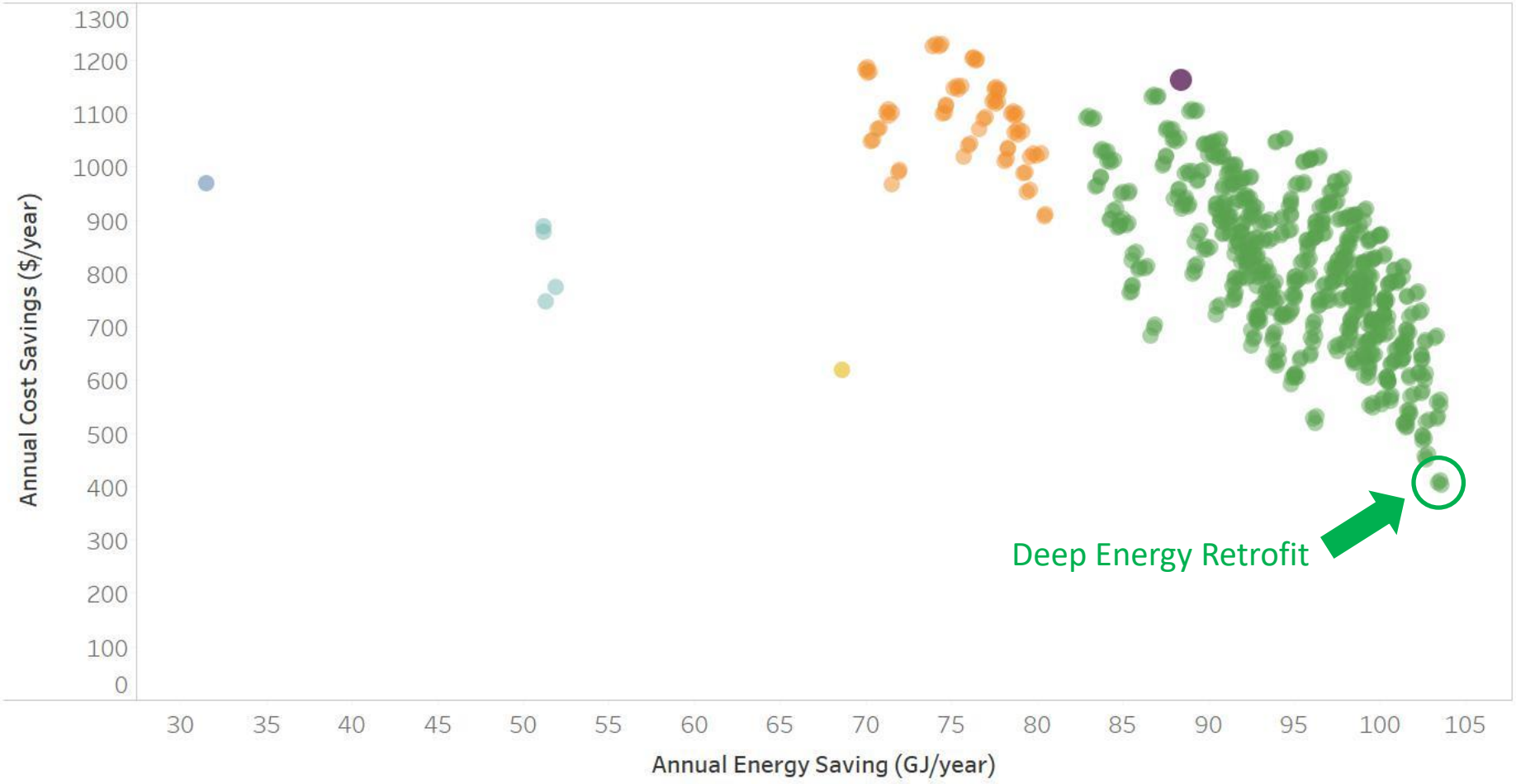
* Savings on energy bills – Payments on principal and interest

Retrofit Packages

→ Deep Energy Retrofit



Retrofit Packages

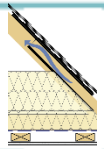


Retrofit Packages

Basement Slab	Concrete slab, new 102mm (4") interior XPS insulation, RSI-3.5 (R-20)
Foundation/Basement Wall	2X6 PWF @ 406mm (16") O.C. with batt insulation, new 203mm (8") exterior XPS insulation, RSI 9.9 (R-56)
Above Grade Wall	2x4 Wood stud @ 406mm (16") O.C. with batt insulation, new 254mm (10") exterior insulaton, RSI 8.6 (R-49)
Exposed Floor	2X10 Joists @ 406mm (16") O.C. with batt insulation, new 254mm (10") exterior insulaton, RSI 10.2 (R-58)
Attic	Raised heel truss @ 610mm (24") O.C. with additional batt insulation, RSI 15.7 (R-89)
Air Tightness	1.0 ACH (air changes per hour)
Casement Windows	Quad-glazed, 2 low-e coatings, argon gas fill, USI-0.88 (U-0.15), SHGC 0.18
Annual Energy Savings	104 GJ/year
Annual Operating Cost Savings*	$402/year

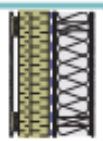
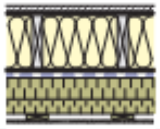
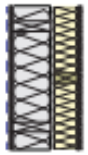
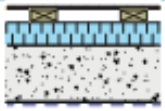
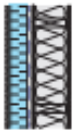
* Savings on energy bills – Payments on principal and interest

How to Prioritize Retrofits?

Air Sealing (Interior/ Exterior)		Air seal with spray foam, tapes, membranes and sealant throughout the home. Sealing all the large holes in the house will have the largest effect. Service penetrations not intended for airflow or venting should be sealed where possible. Consider replacing the weatherstripping on windows and doors. Air sealing can improve the thermal comfort of the home, and decrease heating costs. For further information on homeowner air sealing techniques refer to *Best Practice Guide: Air Sealing and Insulation Retrofits, published by BC Housing**.
Accessible Attic (Interior/ Exterior)		Air seal from within the attic space and install additional batt or loose blown insulation.
Windows and Doors (Exterior)		Remove existing windows and replace with high performance triple or quad glazed windows. Install windows according to best practices and over-insulate frames where possible. For further info refer to *Best Practices: for Window and Door Replacement in Wood-Frame Buildings, published by The Fenestration Association of BC and BC Housing***.

Least Comprehensive & Costly

How to Prioritize Retrofits?

Above-Grade Walls (Exterior)		Remove existing cladding and building paper. Repair the existing sheathing and framing as necessary. Install new sheathing membrane and detail as the air barrier. Install exterior insulation with new strapping and exterior cladding.
Exposed Floors (Exterior)		Remove existing soffit material. Repair the existing framing and install new sheathing. Install new sheathing membrane and detail as the air barrier. Install exterior insulation with new strapping and vented soffit panels.
Unfinished Below-Grade Walls (Interior)		Remove the existing basement interior finishes and polyethylene vapour retarder. Repair/ replace existing framing and batts as necessary. Install an additional insulated stud wall on the interior side of the existing PWF wall complete with a new smart vapour retarder. This approach is less durable than adding exterior insulation to the foundation wall; however this retrofit is significantly easier to execute.
Unfinished Floor Slab (Interior)		Install rigid insulation on the interior surface of the floor slab complete with sealed board joints. Above the insulation, install a new subfloor (sleepers and sheathing) and flooring. Finished basements will require additional work and cost.
Below-Grade Walls (Exterior)		Excavate around existing PWF walls and remove any existing waterproofing, drainage mat and protection board. Install new waterproofing, rigid insulation, drainage mat and protection board.

Most Comprehensive & Costly

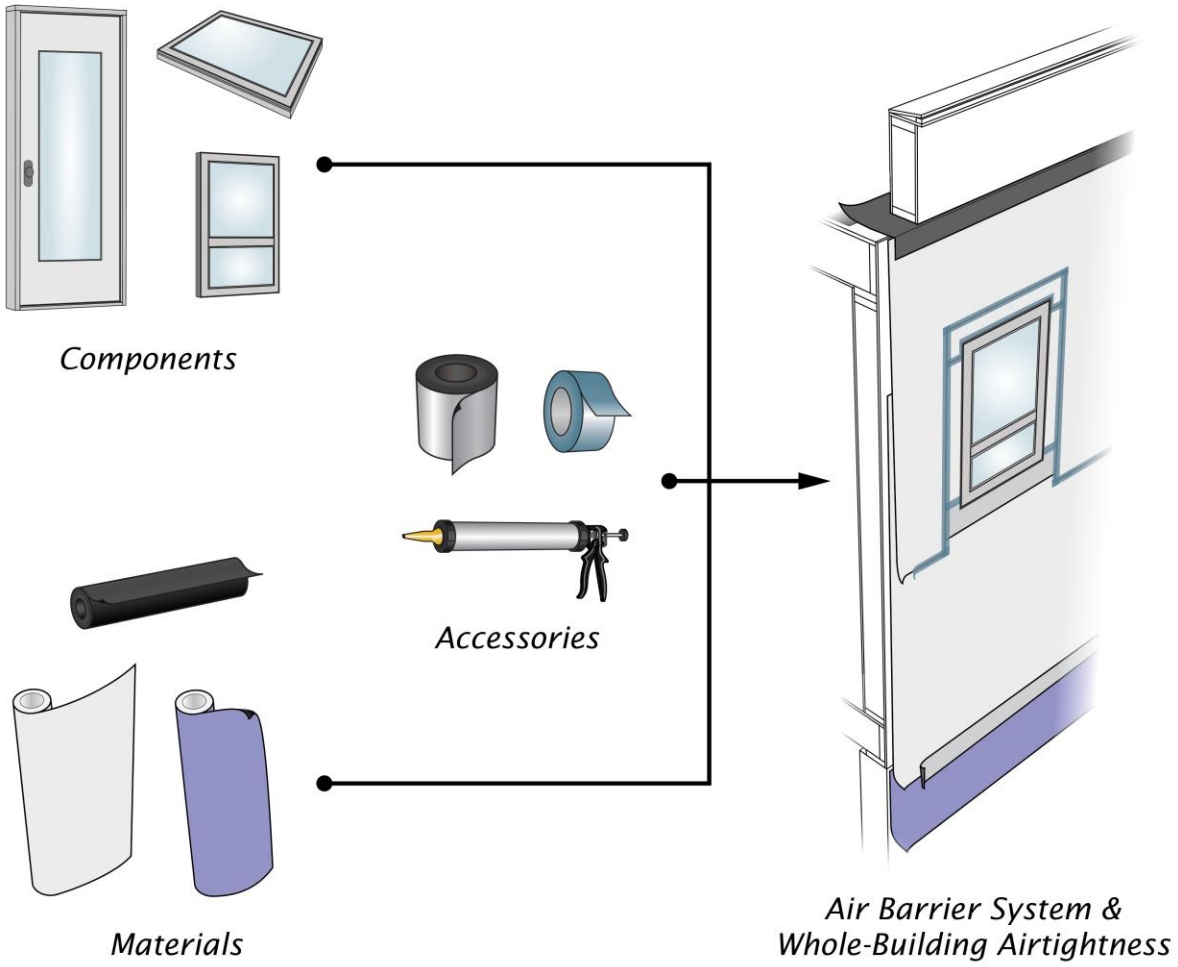
Implementation Considerations

- → Retrofit Air Barrier Strategies
- → Exterior Insulation Retrofits
- → Window Selection

RDH BUILDING SCIENCE

Retrofit Air Barrier Strategies

→ More comprehensive building enclosure retrofits provide an opportunity to improve the **air barrier system.**



Retrofit Air Barrier Strategies

- → Air barrier improvements should include materials/components that are:
  - → Continuous across building enclosure elements (new and existing)
  - → Air impermeable
    - › Air barrier materials - less than 0.02 L/s·m² (0.004 cfm/ft²) @ 75 Pa
    - › Air barrier systems - less than 0.2 L/s·m² (0.04 cfm/ft²) @ 75 Pa
  - → Durable under environmental loading (temperature, UV, etc.)
  - → Strong (wind and other building loads)
  - → Rigid / fully supported

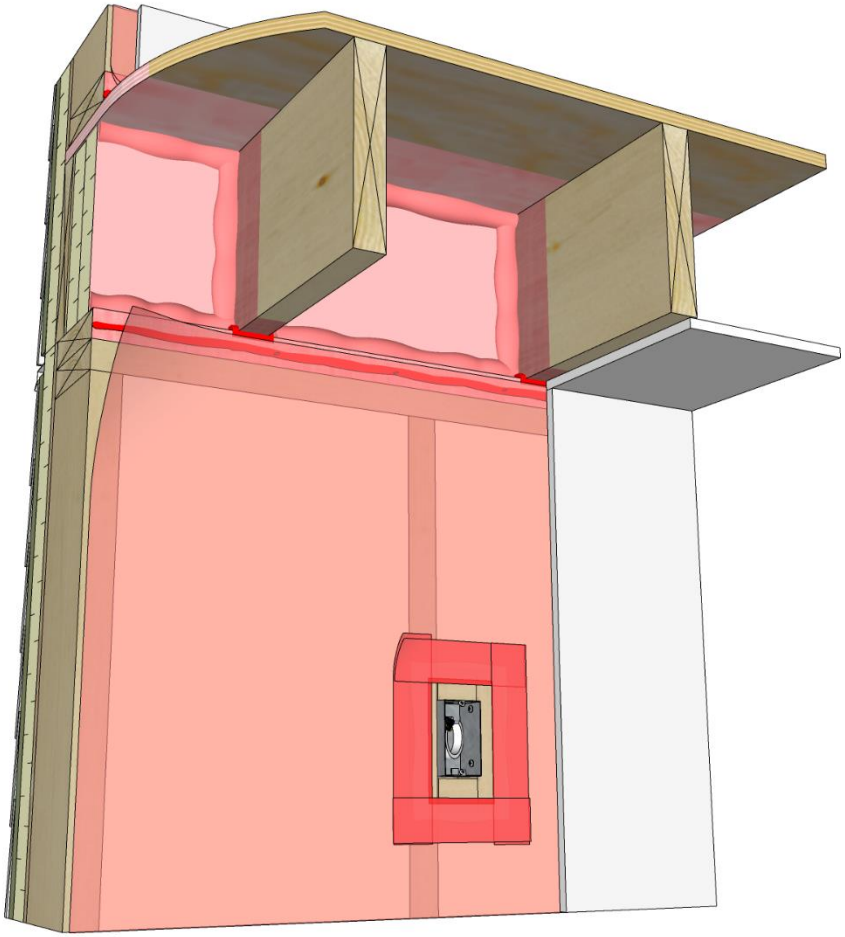
Sealed Interior Polyethylene Retrofit

→ Typically existing air barrier (and vapour retarder)

→ Improvements can include air sealing existing penetrations such as electrical outlets or adding new interior vapour retarder in some cases

→ Access to existing polyethylene sheet is limited without removing interior finishes – ceiling is the exception

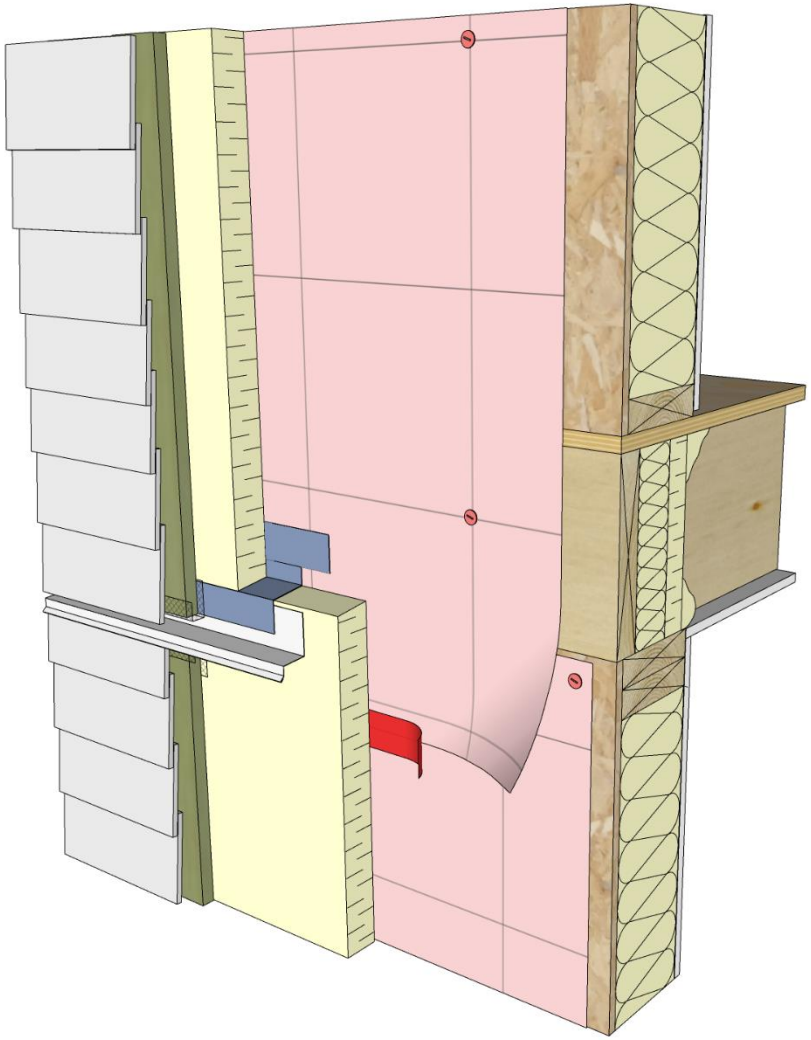
Sealed Interior Polyethylene Retrofit



Exterior Sheathing Membrane Retrofit

- → New sheathing membrane installed in conjunction with exterior insulation retrofit
- → Different types of sheathing membranes:
  - → Mechanically attached house wrap with taped laps
  - → Peel and stick (permeable)
- → Exterior application makes detailing easier
- → Also functions as the water control layer – replaces building paper

Exterior Sheathing Membrane Retrofit

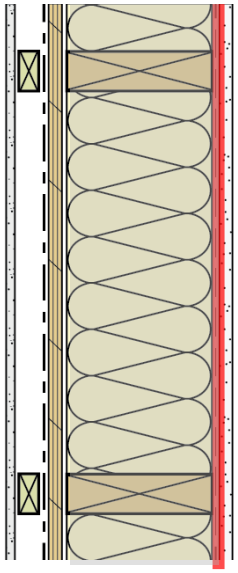


Exterior Insulation Retrofits

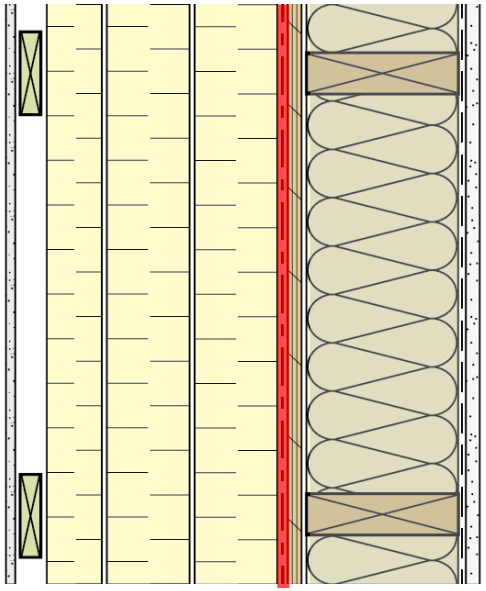
- → Why install exterior insulation?
  - → Interior finishes can remain in place (in most cases)
  - → Thermally efficient with good cladding attachments
  - → Moisture durability!
- → Things to consider:
  - → Exterior insulation selection
    - › Mineral wool
    - › Plastic foams (EPS, XPS)
  - → Structural cladding attachment
    - › Long screws
    - › Clips

Exterior Insulation Retrofits

Existing assembly - cavity insulated, interior air barrier?



Retrofit assembly – split insulated, exterior air barrier



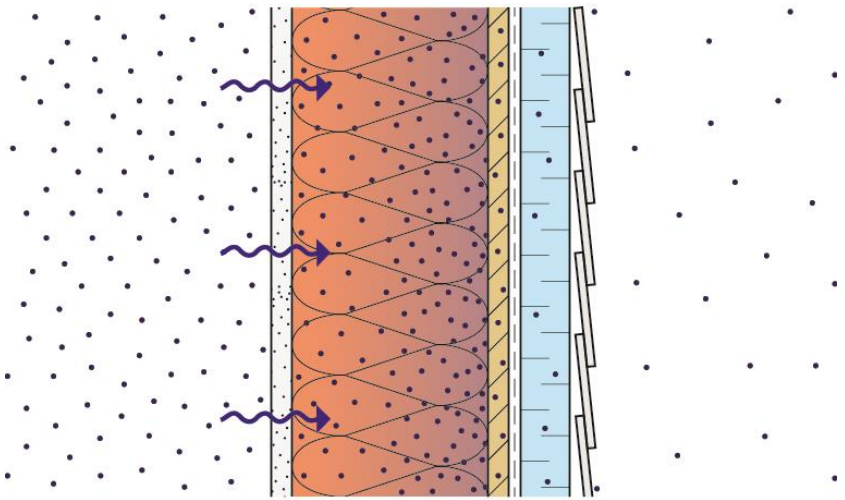
Insulation Selection

→ Various exterior insulation types can be used

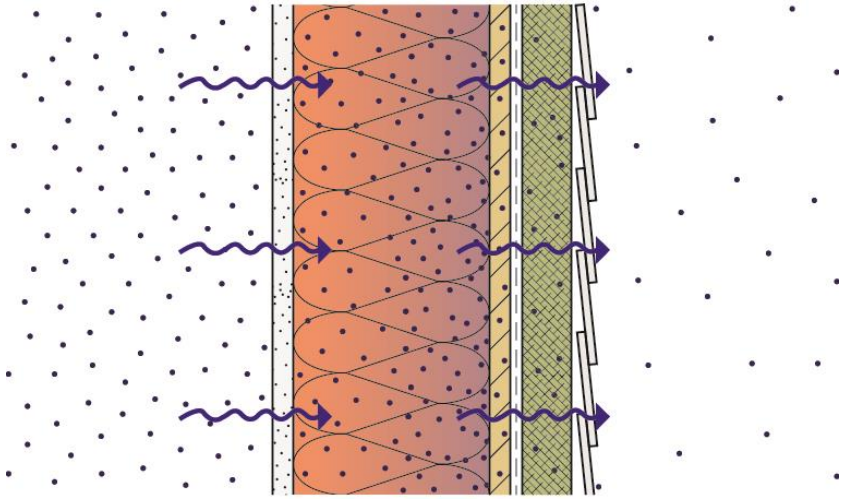
→ Permeable: Mineral Wool or Rigid Fiberglass

→ Impermeable: XPS, EPS, Polyiso, Closed-Cell Sprayfoam

→ BUT, permeable insulations allow for outward drying and are typically less risky in retrofit situations



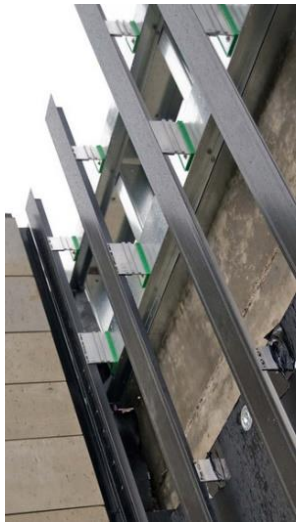
Vapour impermeable
= restricted flow



Vapour permeable
= flow through

Structural Cladding Attachment





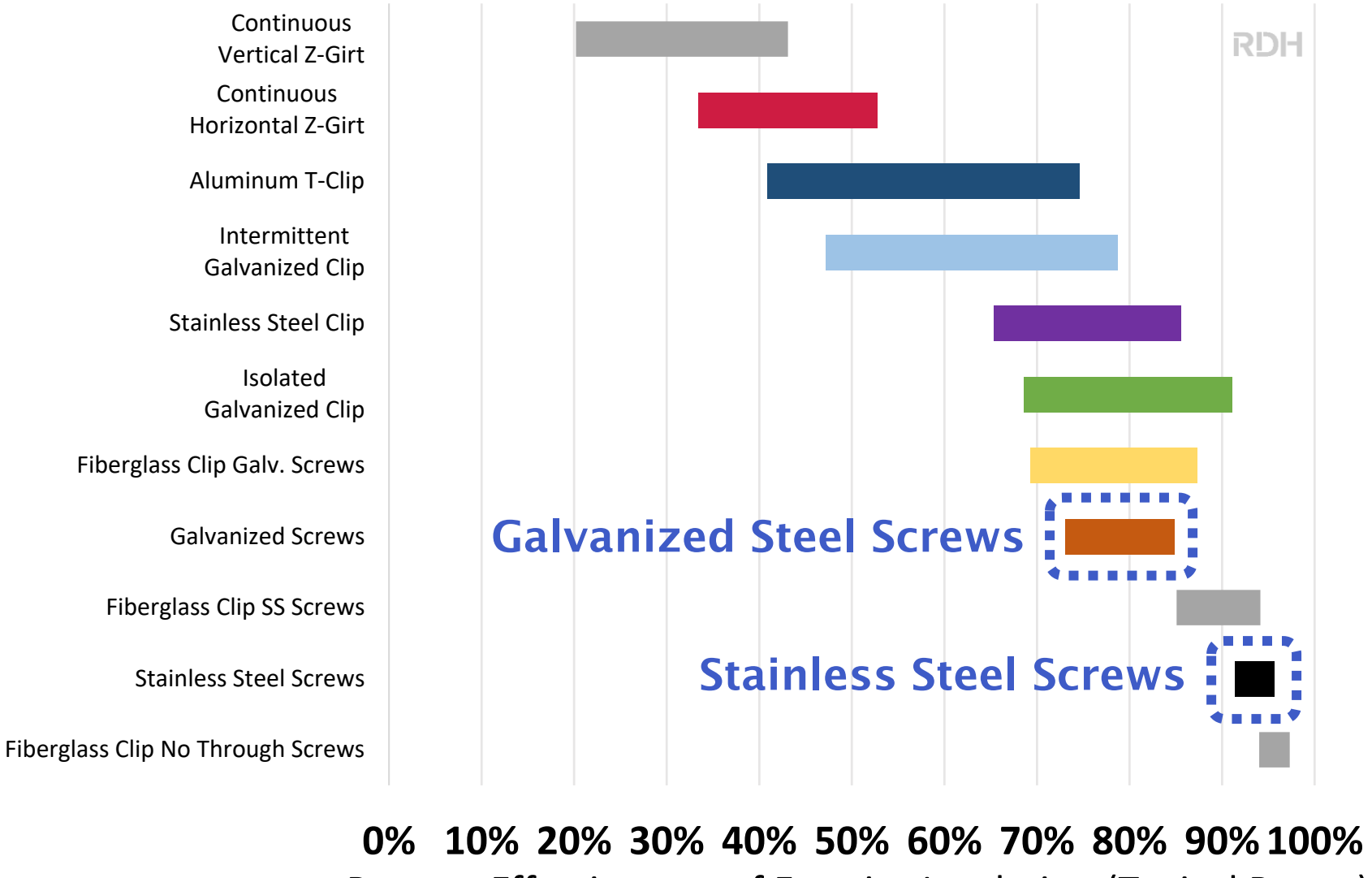


Cladding Attachment: Screws through Insulation

~5-10% loss in R-value for wood-framing, fastener dependent

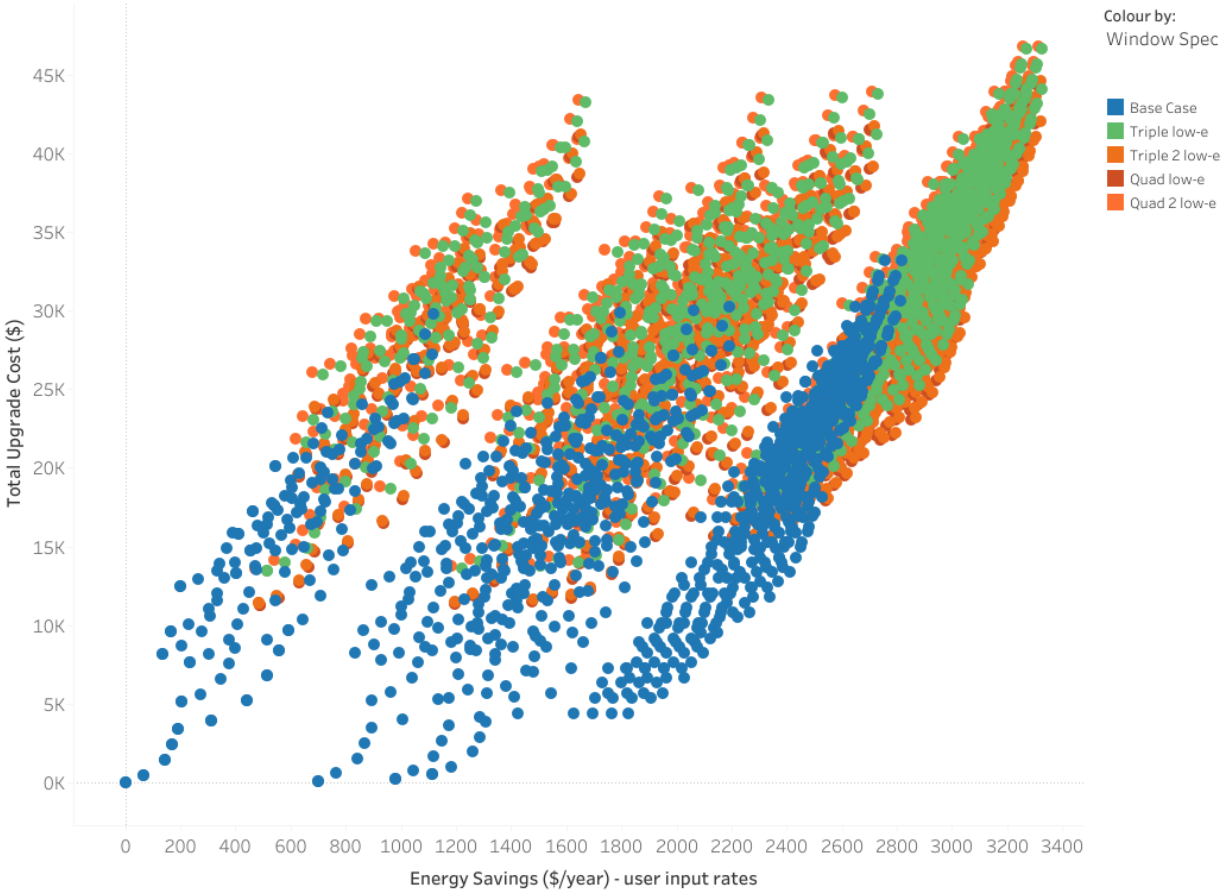
Cost effective compared to clip systems & works well in wood-framed walls!

Screws Through Insulation are Highly Effective



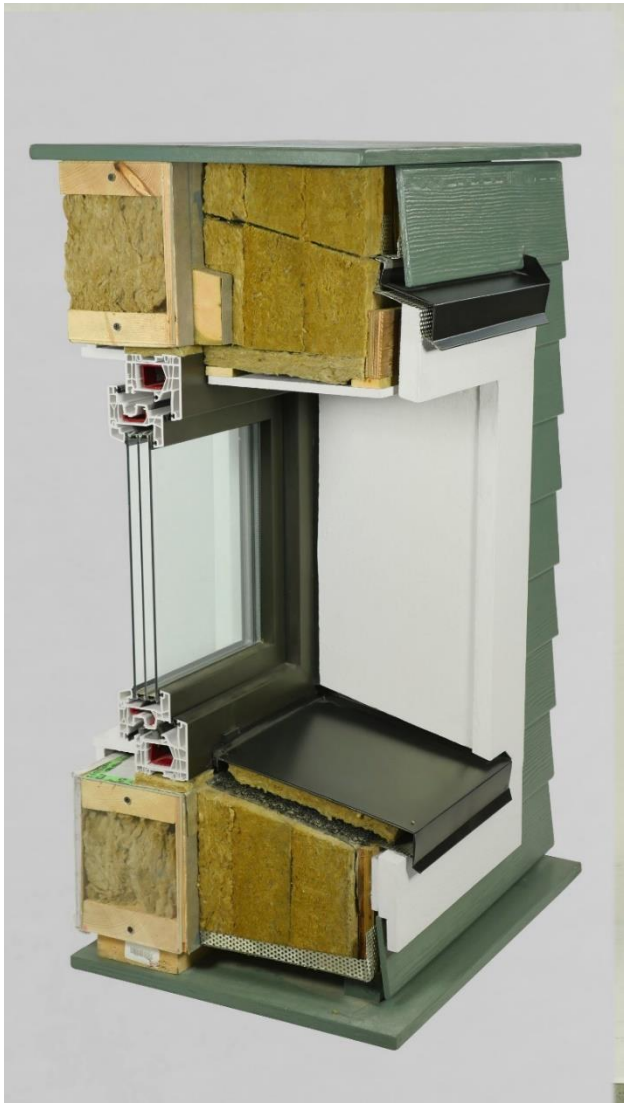
Window Selection

→ High performance windows are critical to achieve deep energy retrofits



Window Selection

- → High performance windows typically include the following:
  - → Low conductivity frames (wood, vinyl, etc.)
  - → Triple- or quad-glazed (3-4 pane) insulated glazing units (IGUs)
    - › 1-3 low-emissivity coatings
    - › Noble gas fill (argon, krypton)
    - › Low conductivity spacer bars
    - › Low U-value, relatively low solar heat gain coefficient (SHGC)
- → Choosing between triple- and quad-glazed windows can be a nuanced decision



Step by Step Details for Enclosure Retrofits

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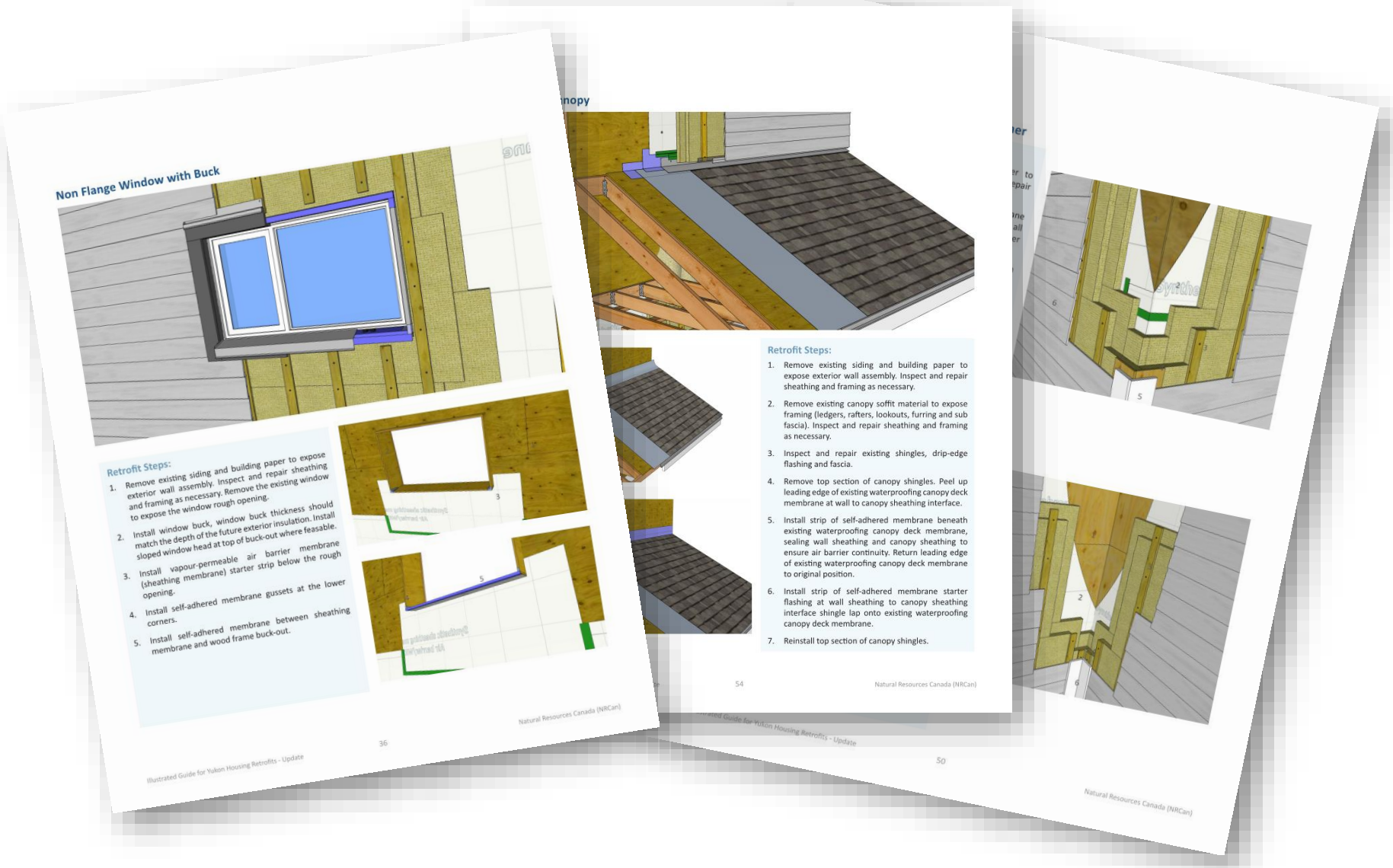
Attic Retrofits

Above Grade Wall Retrofits



Foundations and Slab Retrofits

Next Steps & Potential Future Work

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Next Steps & Potential Future Work

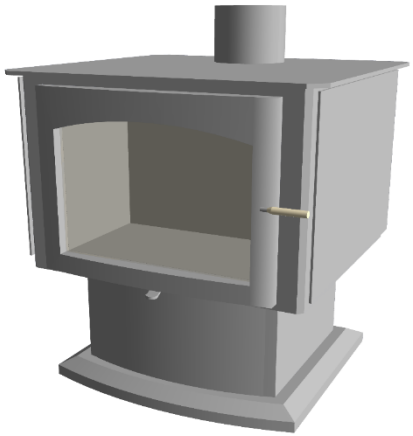
→ Collection of industry feedback & improvements

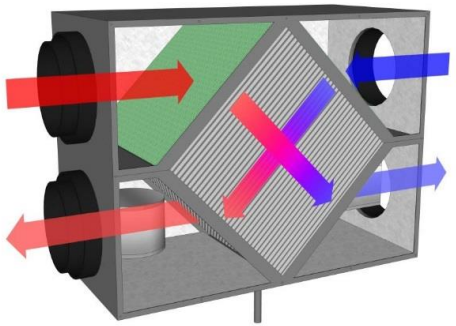
→ Potential Micro-optimization – understand & articulate the cost/energy implications of tweaking components

  → What is the impact of housing archetype modifications?

  → What is the impact of mechanical upgrades on enclosure retrofits?

→ Include additional construction details





Energy Efficient Housing Retrofits for Yukon

Draft Available - Will be Finalized & Published Soon after industry Feedback Received (YHC)

Discussion + Questions

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→ rdh.com

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Getting into the Details: Optimized Energy Retrofits for Yukon Homes

MAY 9, 2019 – WHITEHORSE, YUKON

GRAHAM FINCH, MASC, PENG & MICHAEL WILKINSON, MENG, EIT
RDH BUILDING SCIENCE INC.

RDH BUILDING SCIENCE

Outline

- → Latest Building Science Research & Building Enclosure Design Trends in the Far North
  - → Membrane Products: What do they do? What Properties Matter?
  - → Exterior Insulation Selection
  - → Long Screw Cladding Attachment
- → Retrofit Tools and Materials
- → Retrofit Installation Details

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Membrane Products: What do they do? What Properties Matter?

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Spot the Problem…

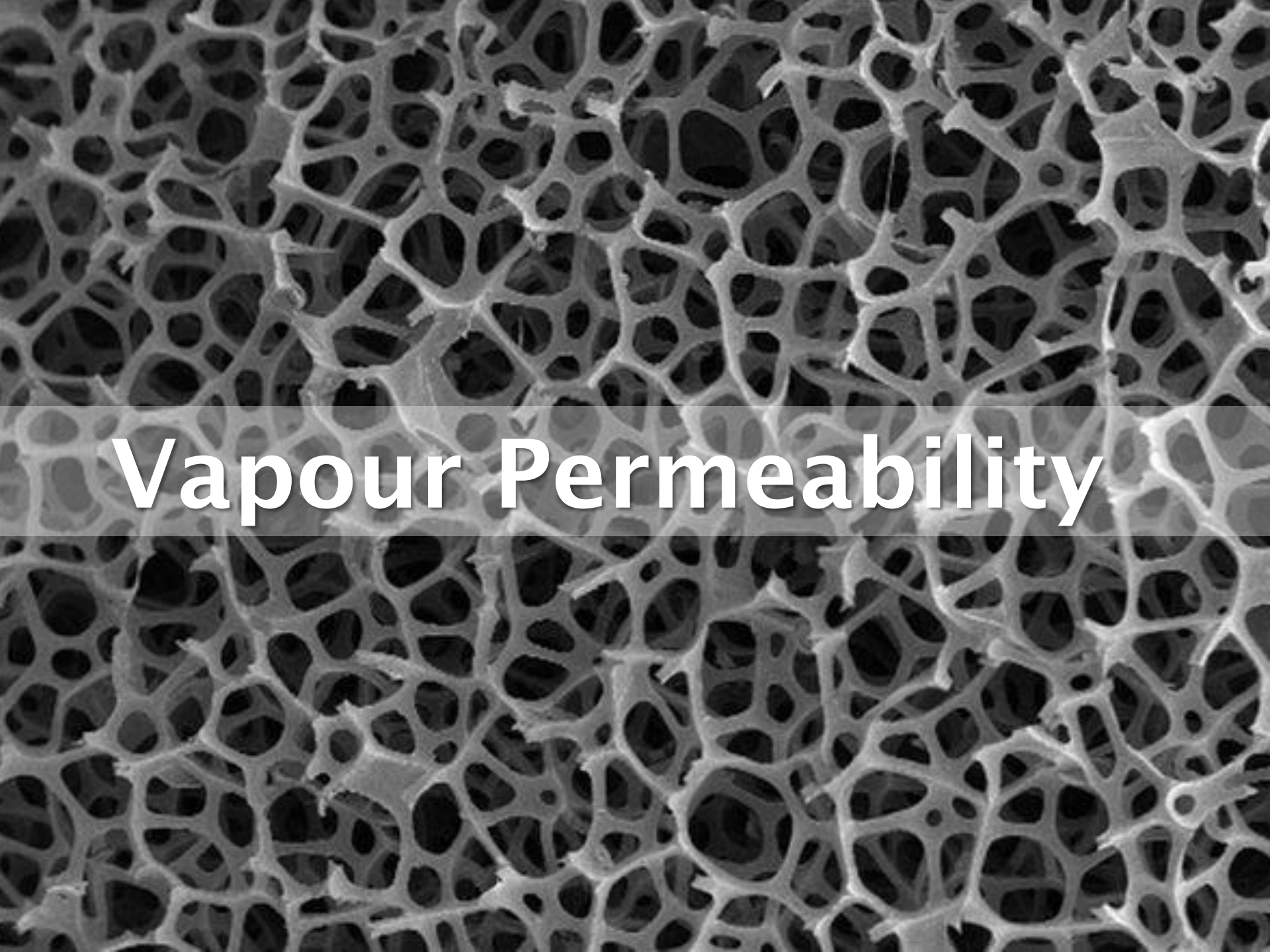
Uses of Building Enclosure Membranes

- → Roofing
- → Waterproofing
- → Water Resistive Barrier
- → Air Barrier
- → Vapour Retarder/Barrier

Types of Membranes

- → Sheet
  - → Self-Adhered
  - → Adhered
  - → Torch/Heat-Applied
  - → Mechanically Attached
  - → Loose-Laid
- → Liquid/Fluid
  - → Roller Applied
  - → Spray Applied
  - → Brush Applied
  - → Trowel Applied
  - → Injection

Key Properties of Membranes Which We Typically Care About



Vapour Permeability


Air Permeability

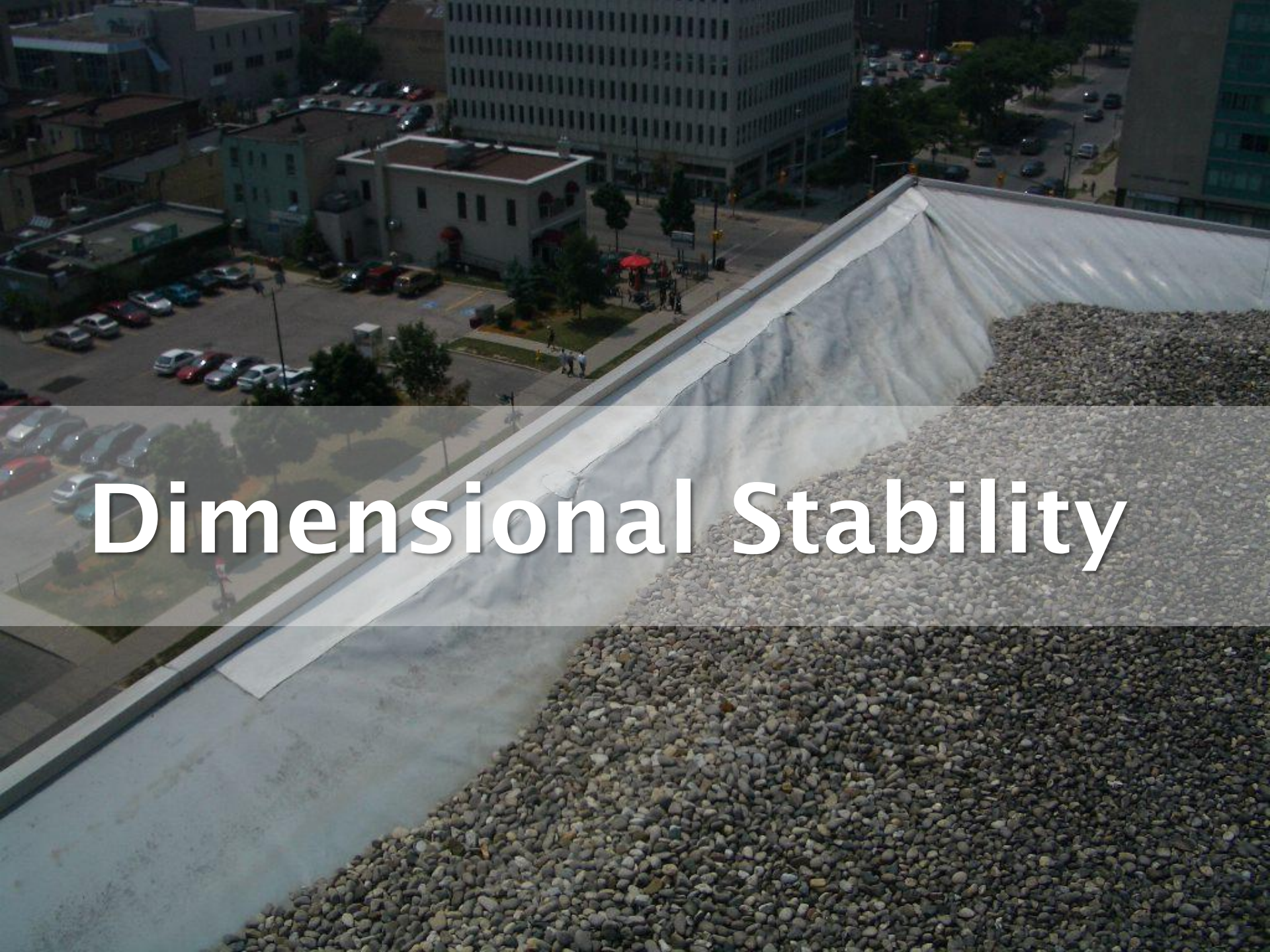

Water
Repellency/Resistance


Physical Properties

Gap/Crack Bridging

Resistance to UV


Resistance to Heat



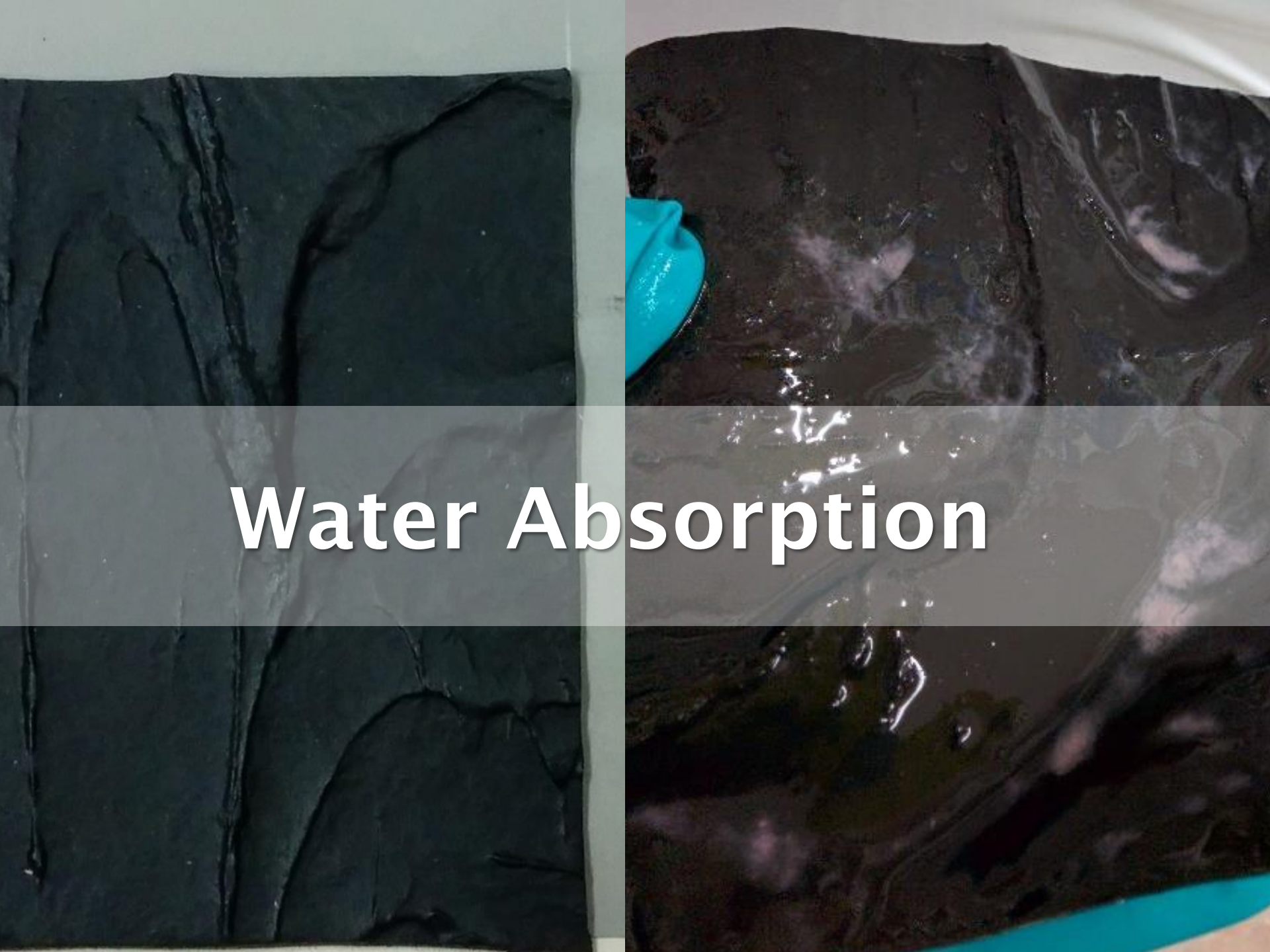
Dimensional Stability

Thermal Expansion/Contraction Properties

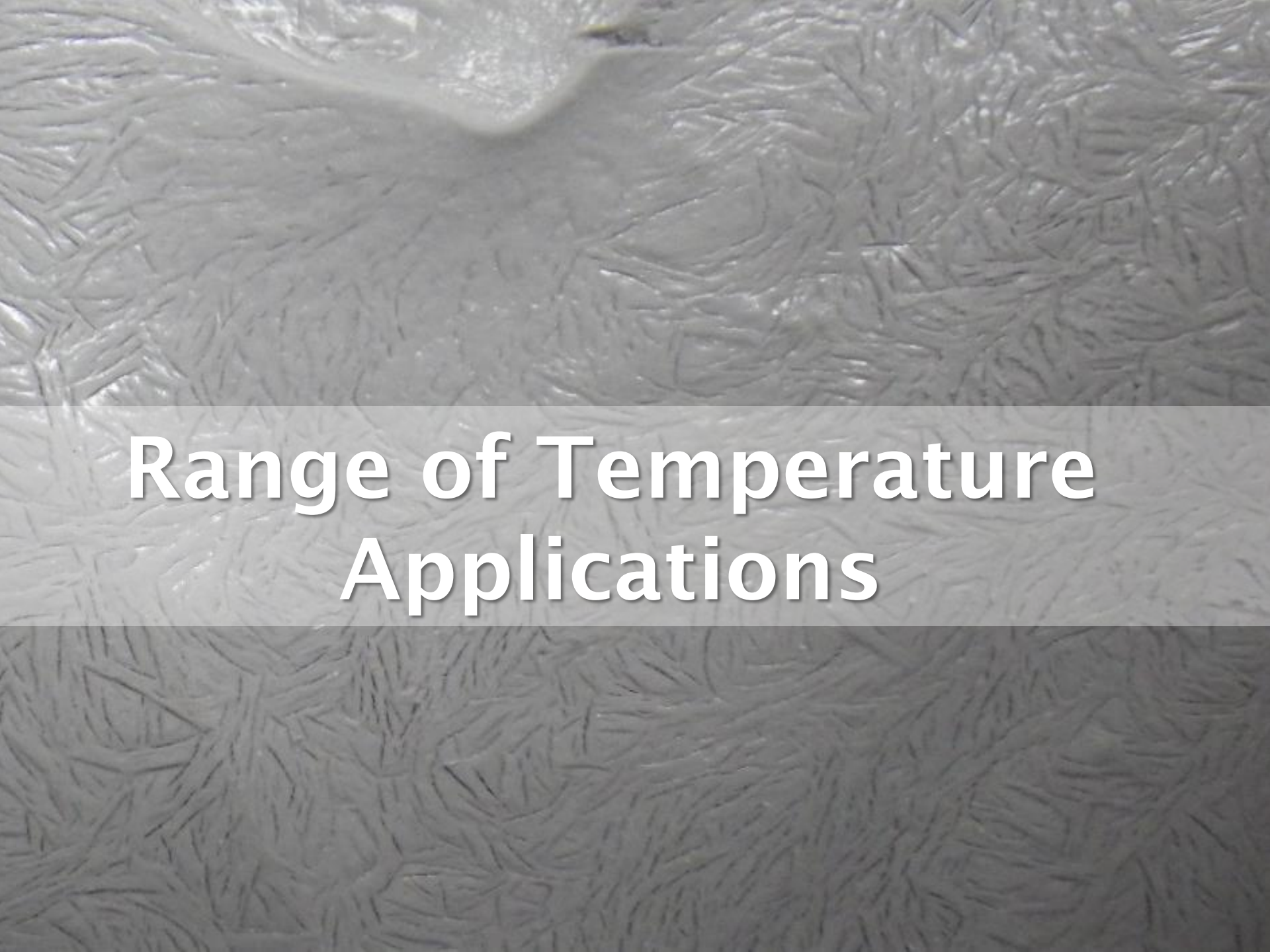
Material Compatibility

Adhesive Characteristics

Water Resistance



Water Absorption



Range of Temperature Applications

Rigidity

Fungal Resistance

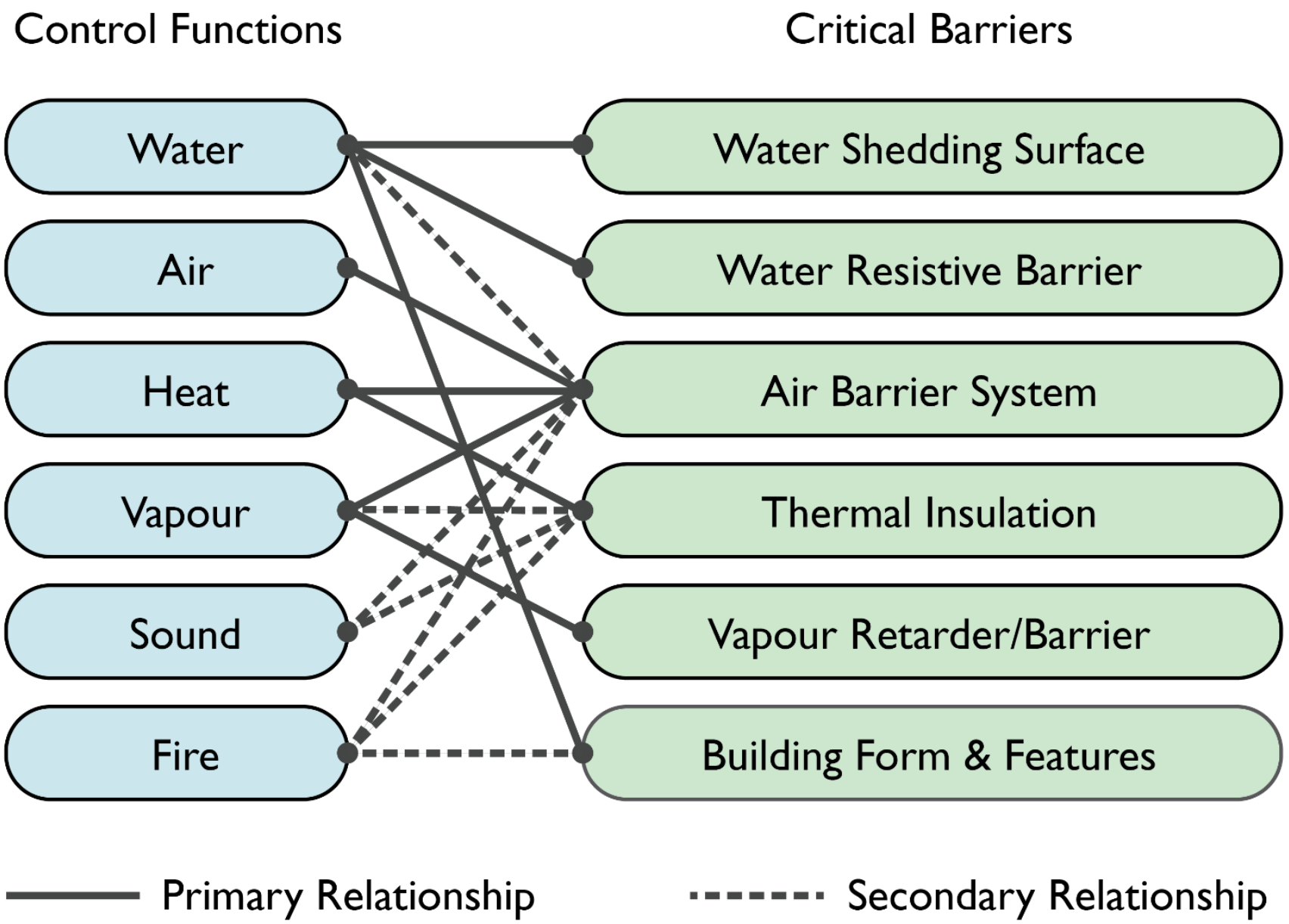

Combustibility

Lap & Joint Details

Air & Water Self-Sealing Abilities


Others?

Selecting the Right Membrane for the Job


Control Functions
Critical Barriers
Water
Air
Heat
Vapour
Sound
Fire
Water Shedding Surface
Water Resistive Barrier
Air Barrier System
Thermal Insulation
Vapour Retarder/Barrier
Building Form & Features
Primary Relationship
Secondary Relationship

Function Combinations

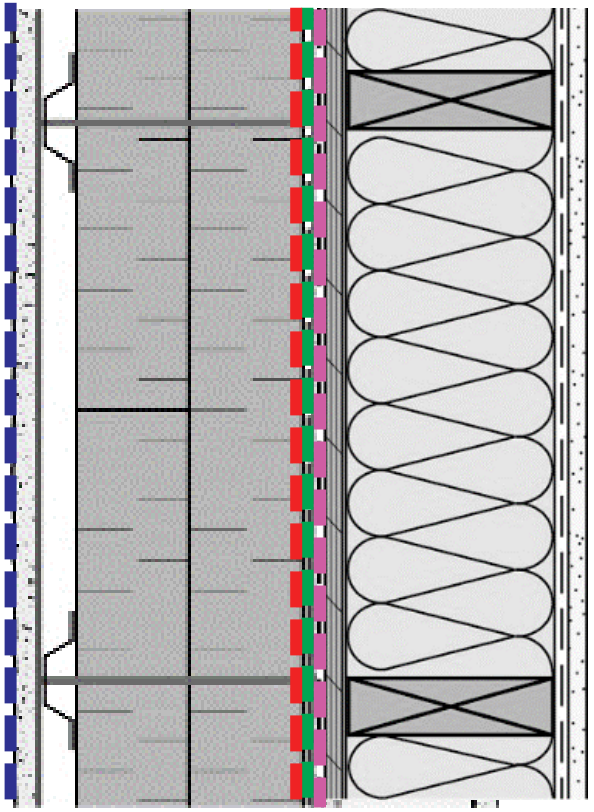
→ Air Barrier/Water Resistive Barrier (AB/WRB)

→ Air Barrier/Vapour Barrier (AB/VB

→ Air Barrier/Vapour Barrier/Water Resistive Barrier (AB/VB/WRB)

→ Vapour Barrier/Water Resistive Barrier (VB/WRB)

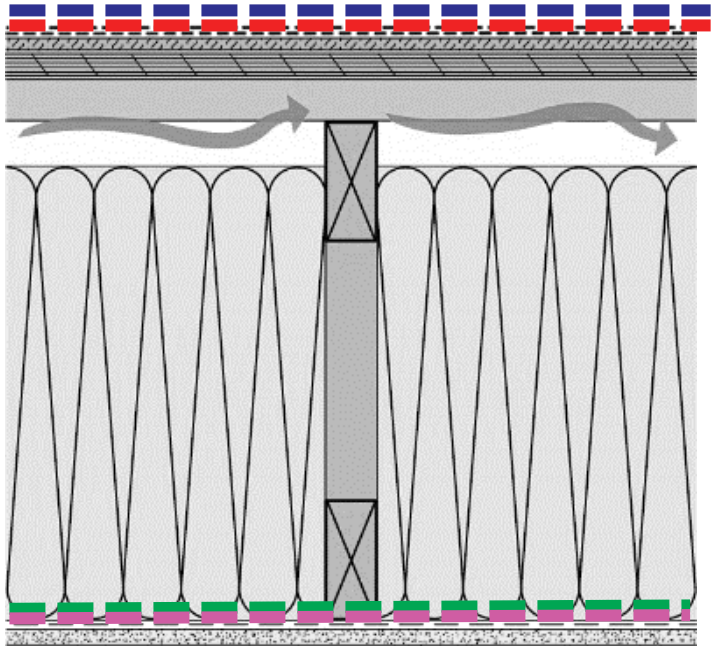
Example – Exterior Insulated Wall



Water Shedding Surface **(WSS)**
Water Resistive Barrier **(WRB)**
Air Barrier **(AB)**
Vapour Retarder **(VR/VB)**

→ *What properties of the combo AB/WRB/VB might be most important here?*

Example – Vented Roof Assembly



Water Shedding Surface **(WSS)**
Water Resistive Barrier **(WRB)**
Air Barrier **(AB)**
Vapour Retarder **(VR/VB)**

→ *What are the key attributes to select for the air barrier membrane/system?*

Detailing Considerations - Compatibility

Something isn't Right Here..

Detailing & Material Specification?

SBPO Housewrap

"Special Silicone"

Foil faced SAM

Below grade Granulated SBS membrane

Concrete Foundation wall

Silicone membrane over plywood

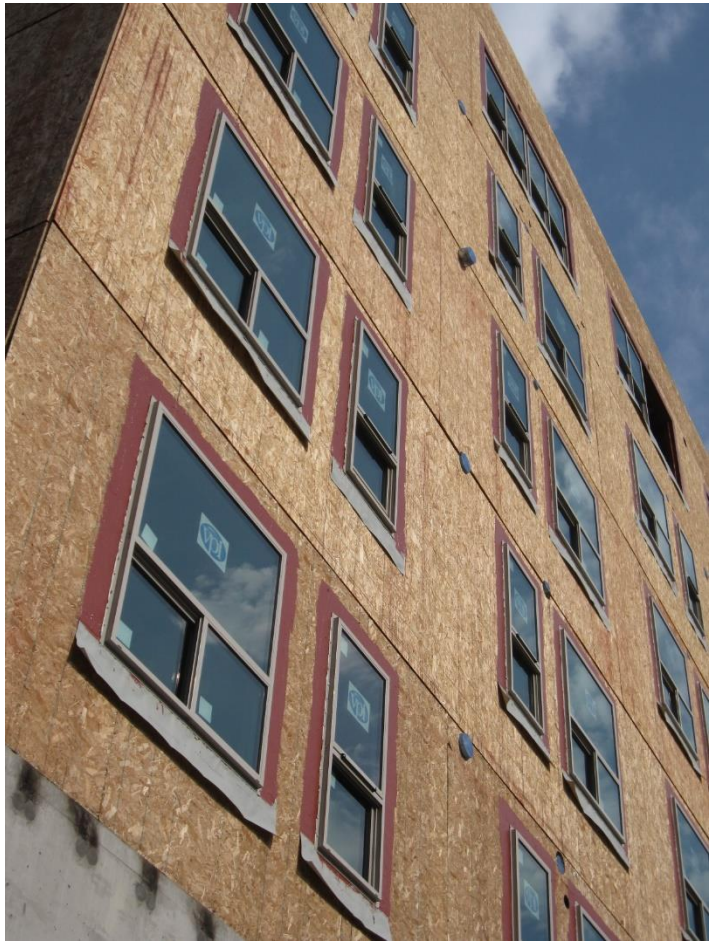
Silicone sealant at joints and fastener holes

Foil-faced SBS

Below grade SBS over Concrete Foundation

Cement board over XPS

Transition Membranes



Joints

Membrane Sample Discussion

Exterior Insulation Selection

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Exterior Insulation Selection for Retrofits

→ Rigid exterior foams are vapour impermeable

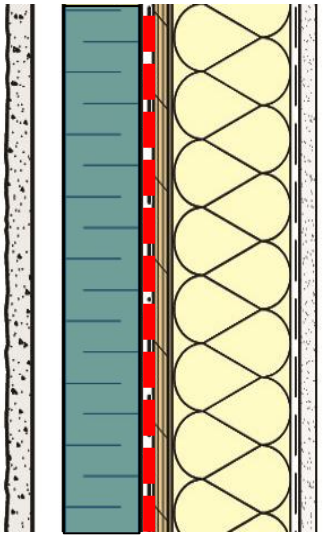
  → Does the wall have two vapour barriers with original poly, can it dry?

  → Can I remove the interior vapour barrier? Not without removing exterior sheathing

→ How much foam insulation should be put outside of the sheathing?

→ Semi-rigid/rigid vapour permeable insulation simplifies retrofit considerations

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

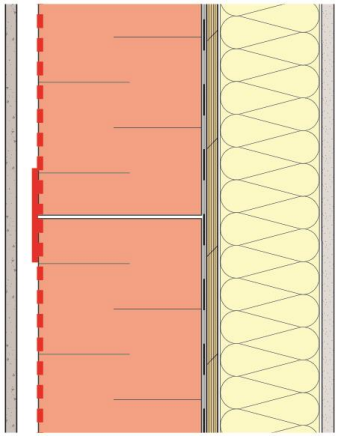


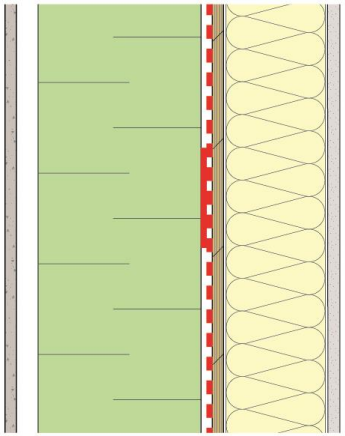
Exterior Insulation Vapour Permeance

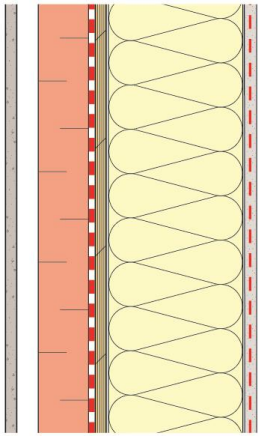
Dry Cup Permeance (US Perms)

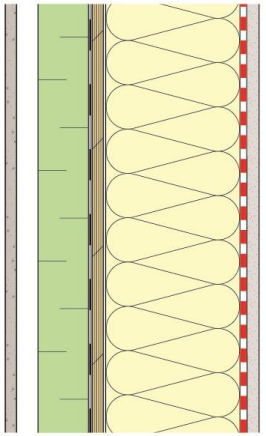
Insulation Type	1"	2"	3"	4"	5"	6"	7"	8"
XPS	0.9	0.4	0.3	0.2	0.2	0.1	0.1	0.1
Closed Cell Sprayfoam	1.7	0.9	0.6	0.4	0.3	0.3	0.2	0.2
Polyiso with Paper Facers	2.0	1.0	0.7	0.6	0.4	0.4	0.3	0.3
Polyiso with Foil Facers	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
EPS (Type 1) w/o facers	3.5	1.8	1.2	0.9	0.7	0.6	0.5	0.4
Wood Fiber Board	9.1	4.6	3.0	2.3	1.8	1.5	1.3	1.1
Open Cell Sprayfoam	60.2	30.1	20.1	15.1	12.0	10.0	8.6	7.5
Rigid Mineral Wool	88.8	49.5	29.6	22.2	17.8	14.8	12.7	11.1
Cellulose	92.3	46.1	30.8	23.1	18.5	15.4	13.2	11.5
Rigid Fiberglass	145.1	72.5	48.4	36.3	29.0	24.2	20.7	18.1

Considerations for Air Barrier Placement

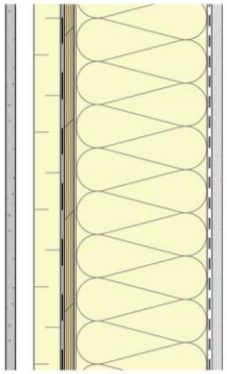


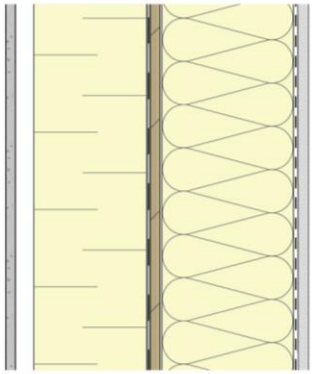


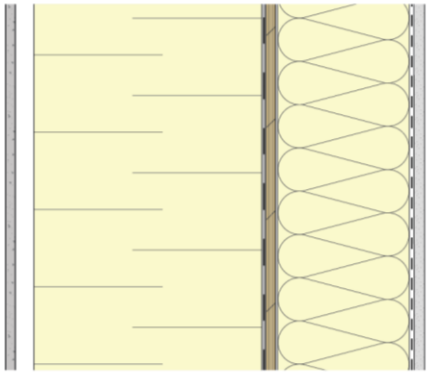




Exterior Insulation Ratios







Safe Insulation Ratios for Flexibility of Air Barrier Placement & Vapour Control

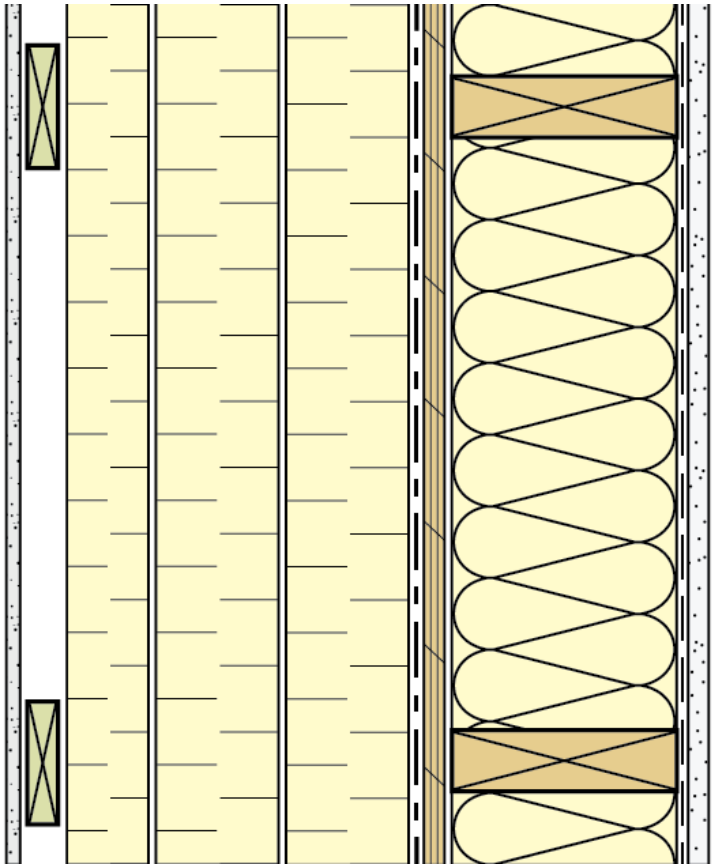
Recommended Ratio of Outboard to Total Thermal Resistance to Limit Condensation Risk

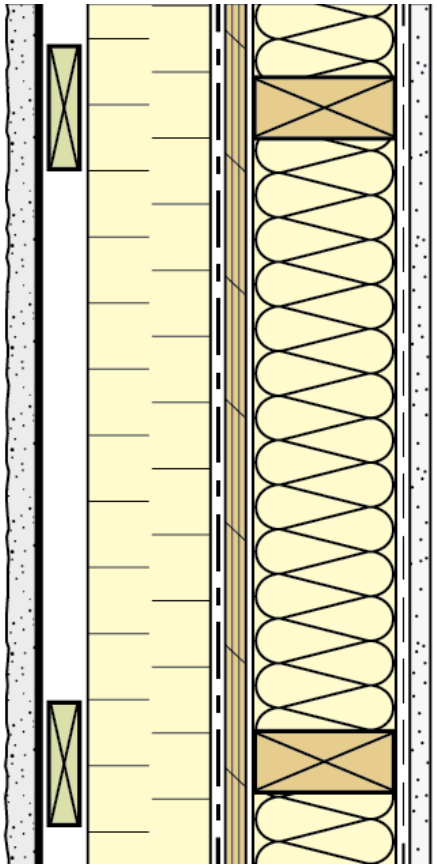
Winter Design Temperature	Indoor Wintertime Relative Humidity				
	20%	30%	40%	50%	60%
0	0.00	0.12	0.32	0.47	0.60
-10	0.23	0.40	0.54	0.64	0.73
-20	0.41	0.55	0.65	0.73	0.80
-30	0.53	0.64	0.72	0.78	0.84
-40	0.66	0.70	0.76	0.82	0.86

Note: Ratios assume no interior vapour control layer and allow for any type of exterior insulation, sheathing or WRB on the exterior of the cavity, as they raise the temperature of the sheathing above the indoor dewpoint and lower the risk of vapour diffusion/air leakage condensation

Assess at Average Wintertime conditions and expected indoor RH levels

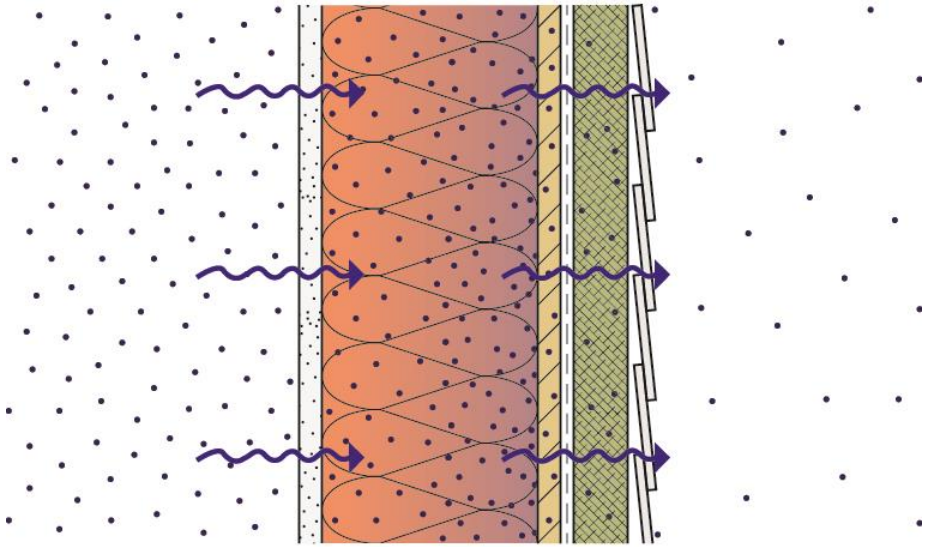
Deep vs Medium Retrofit Considerations



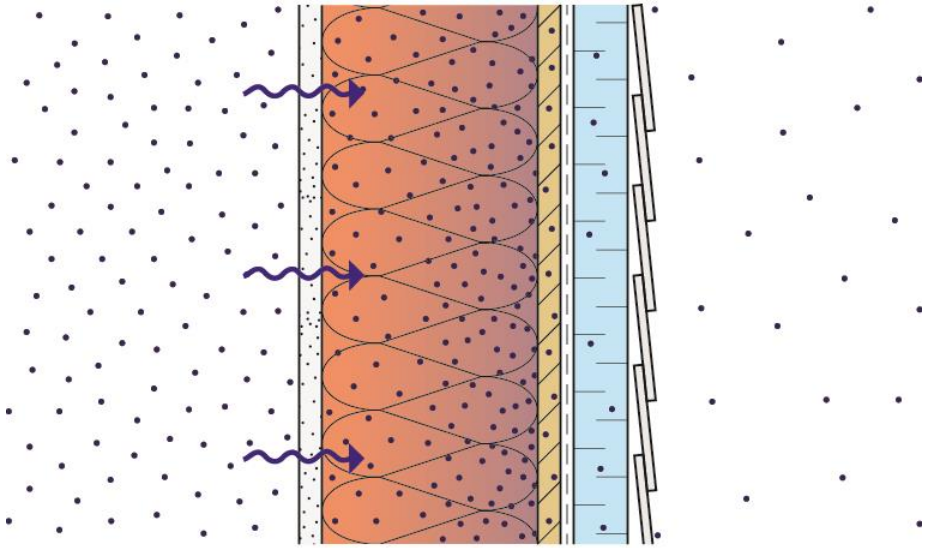


Why is Vapour Permeable Insulation Safer for Retrofits?

*Vapor diffusion **drying** allowed through vapour open mineral wool, fiberglass or cellulose insulation on exterior*



*Vapor diffusion **drying** restricted by foam plastic insulation on exterior – even if enough insulation is installed to prevent condensation*

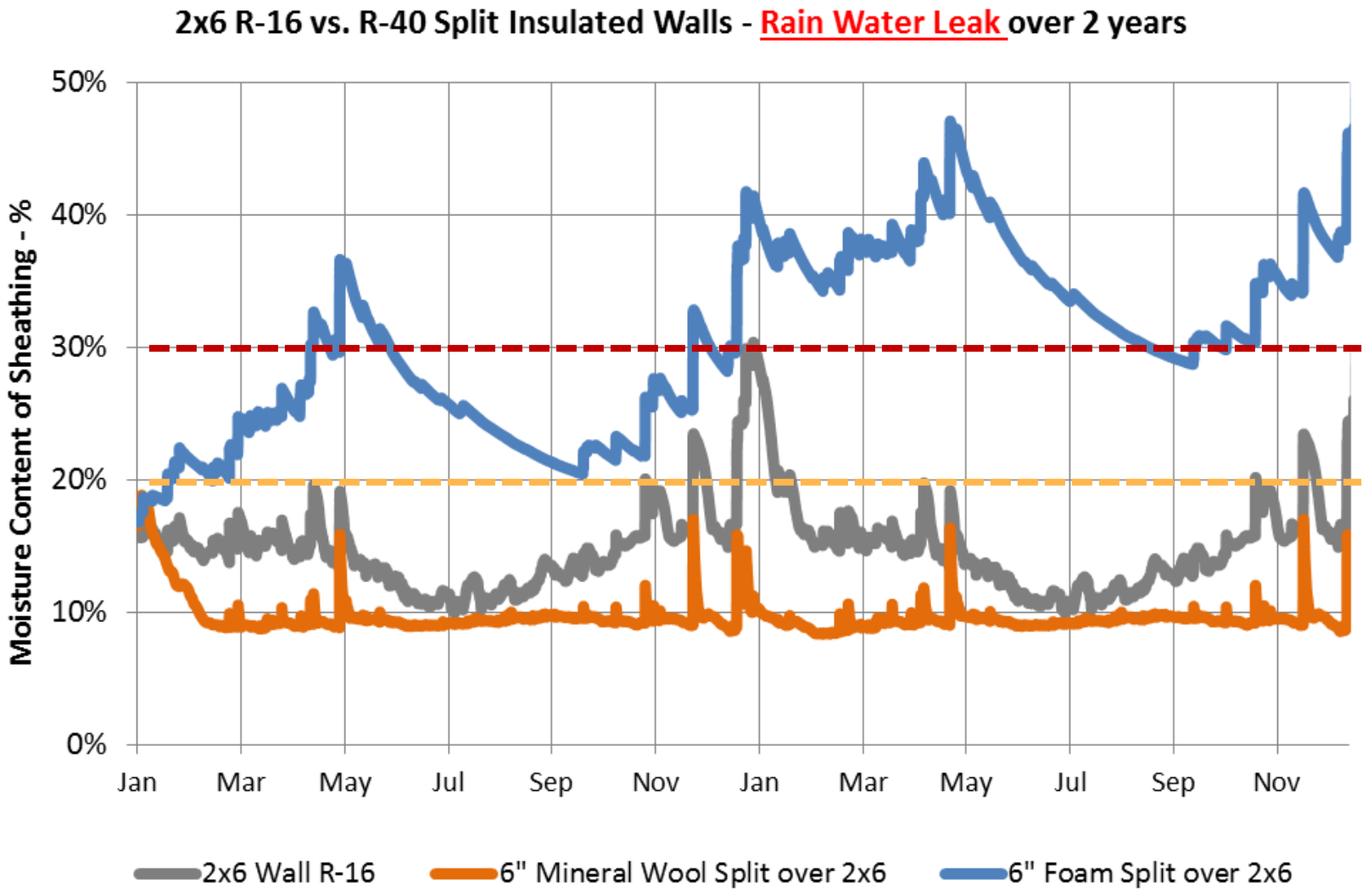


Side by Side Drying Test – Vapour Open vs Closed Exterior Insulation

Plywood Behind XPS – wet for 8 weeks

Plywood Behind Mineral Wool – dried within 8 weeks

Split Insulated Performance



Long Screw Cladding Attachment

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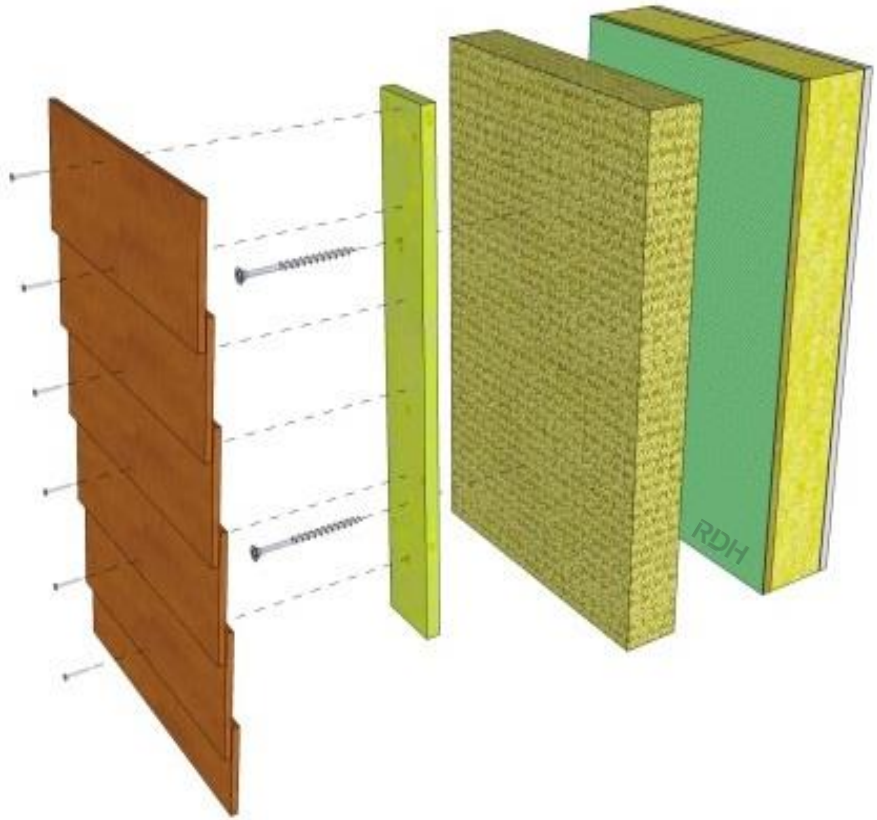
Screws Through Insulation

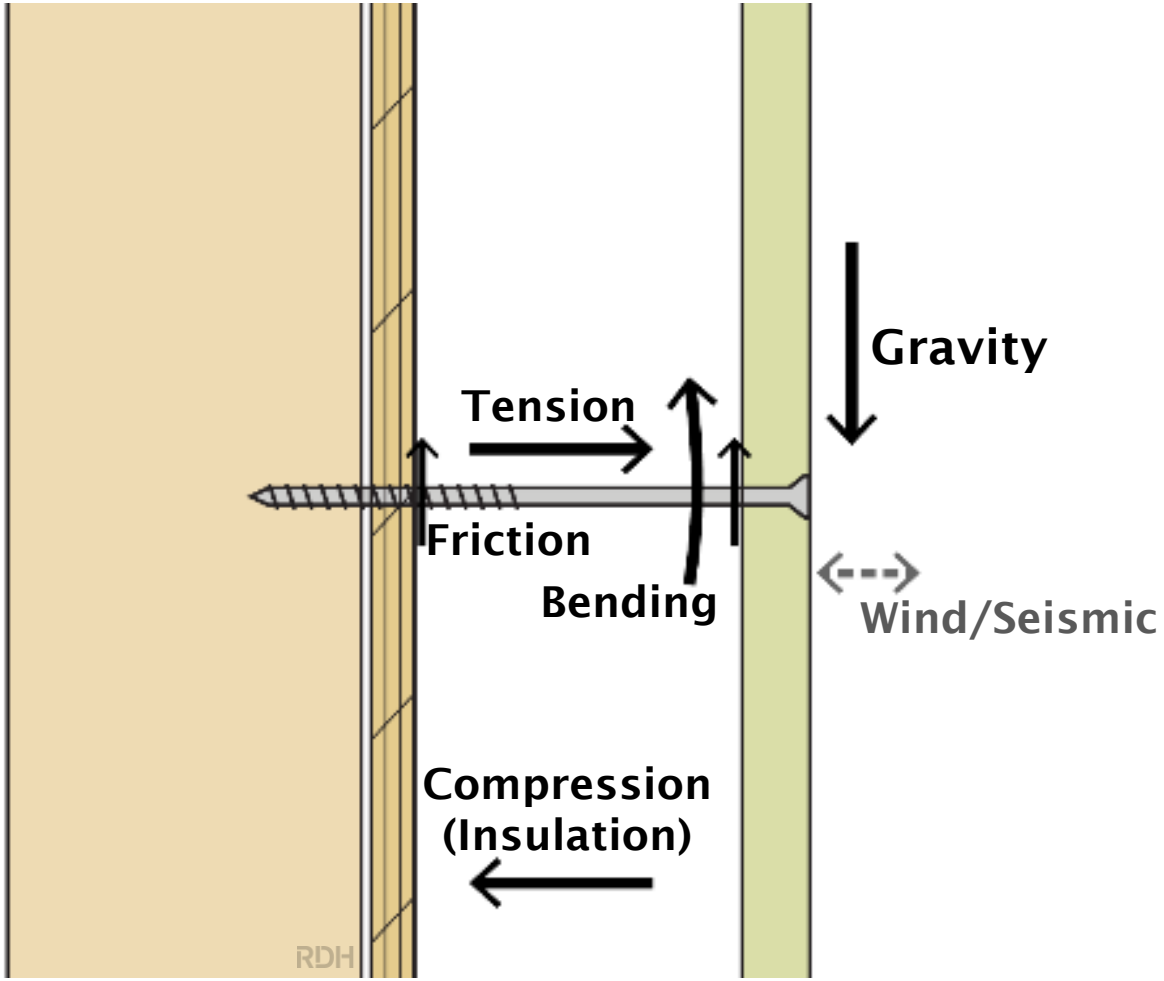
→ Rapidly gaining popularity to meet increasing R-value requirements

→ Uncertainty about:

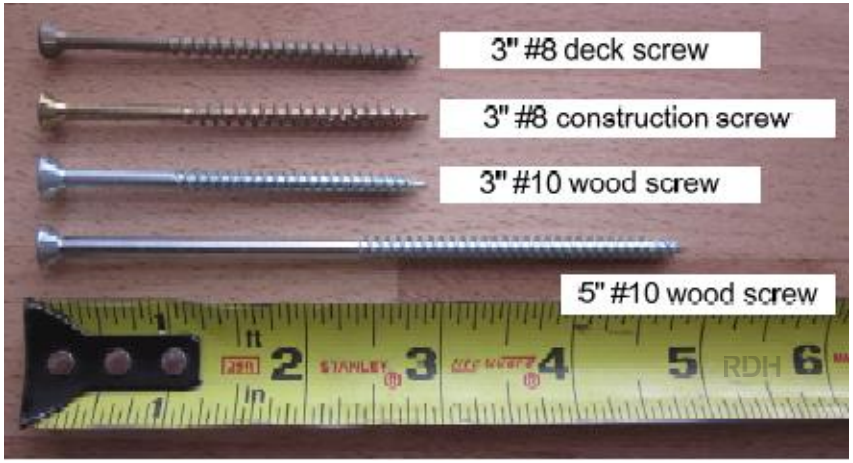
- → How to do it
- → Allowable loads
- → Fastener types
- → Fastener spacing
- → Angle of installation
- → Deflection



Design & Forces



Testing – Initial Testing



Testing

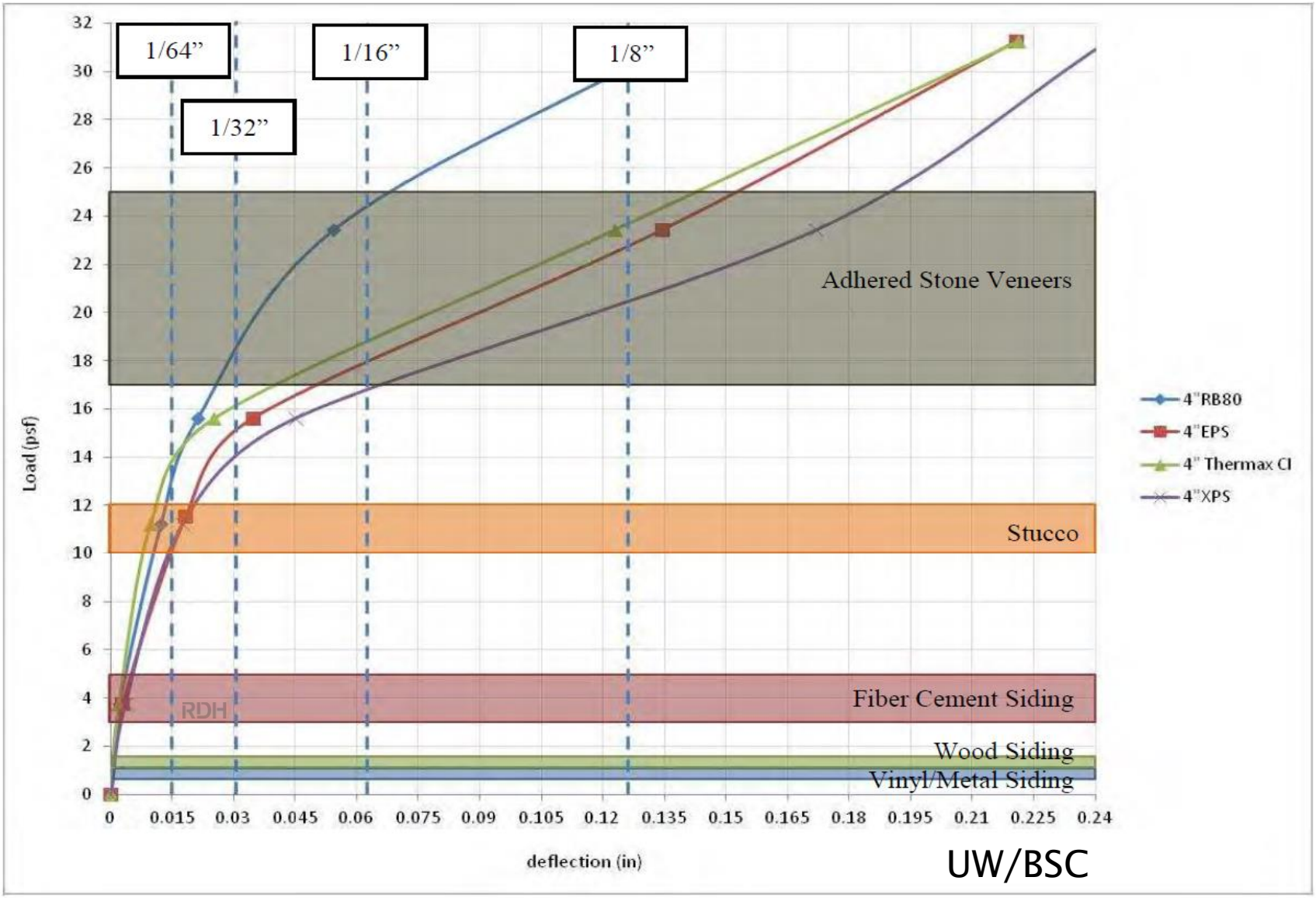
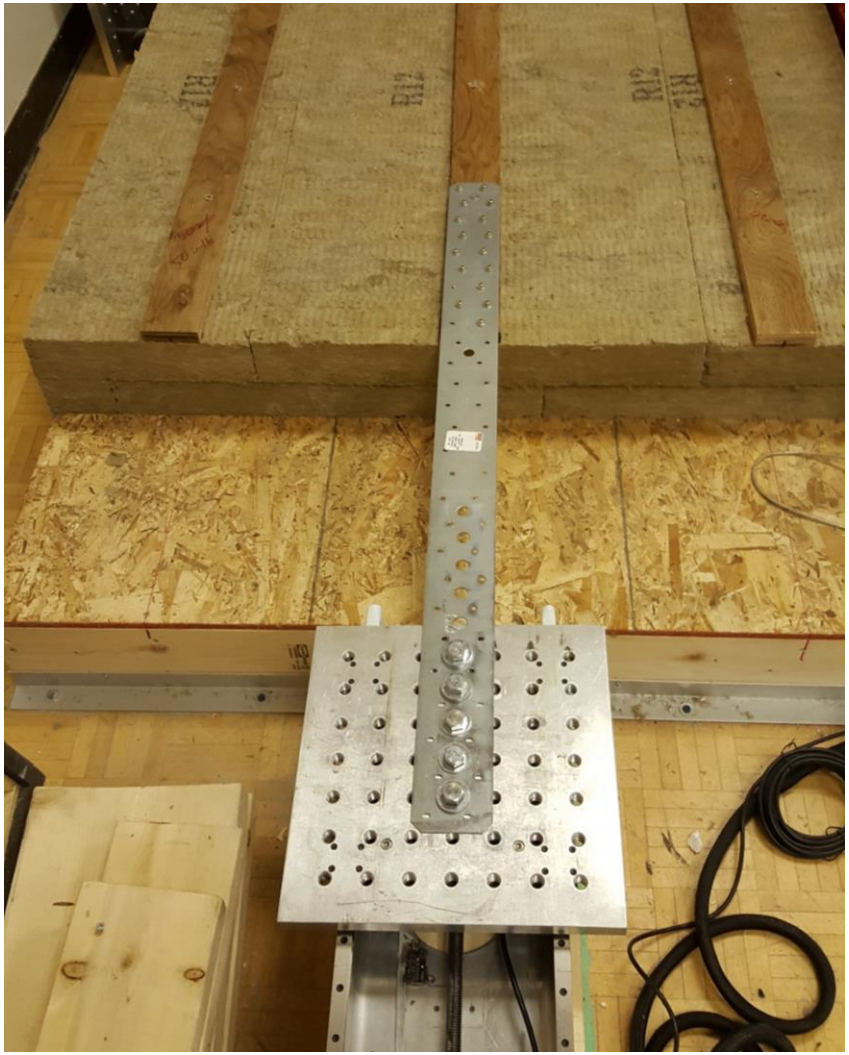


Figure 9: Short term deflection testing results (4” thick insulation)

Testing



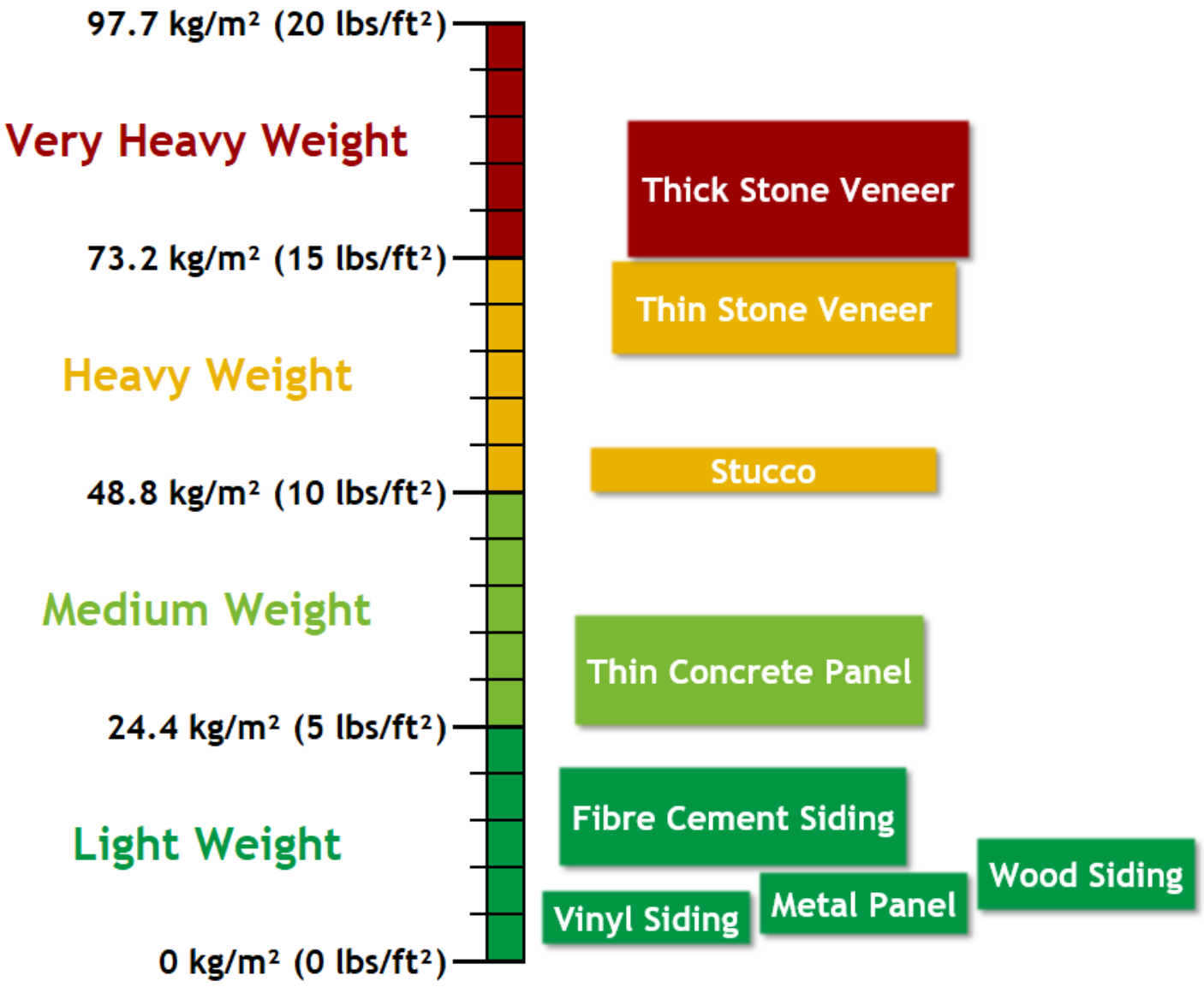
Testing

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

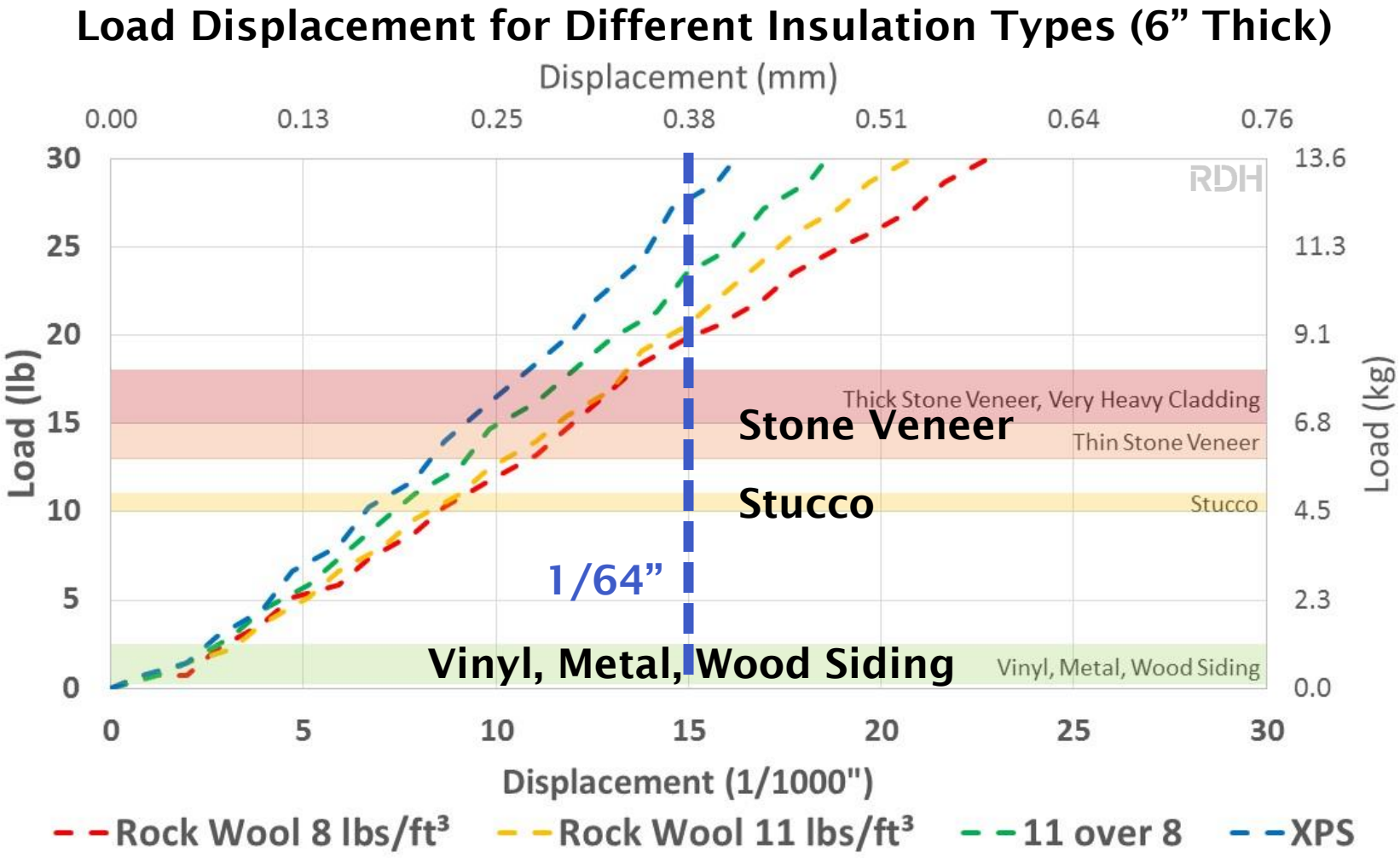
→ Different insulation types (mineral wool and XPS) and different compressive strengths

→ Different screw head types (pan and countersunk)

Cladding Weights

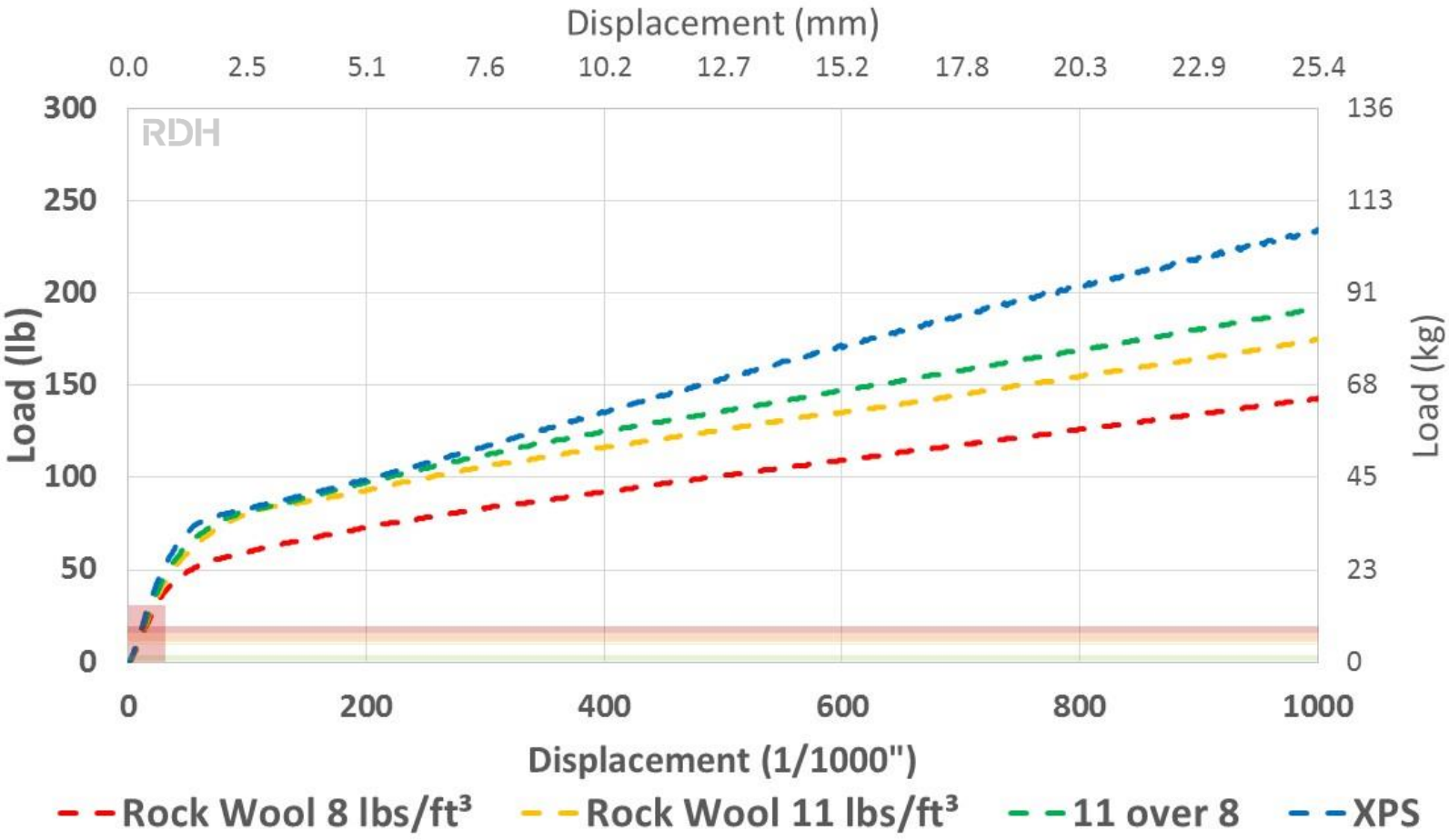


Testing – Insulation Type

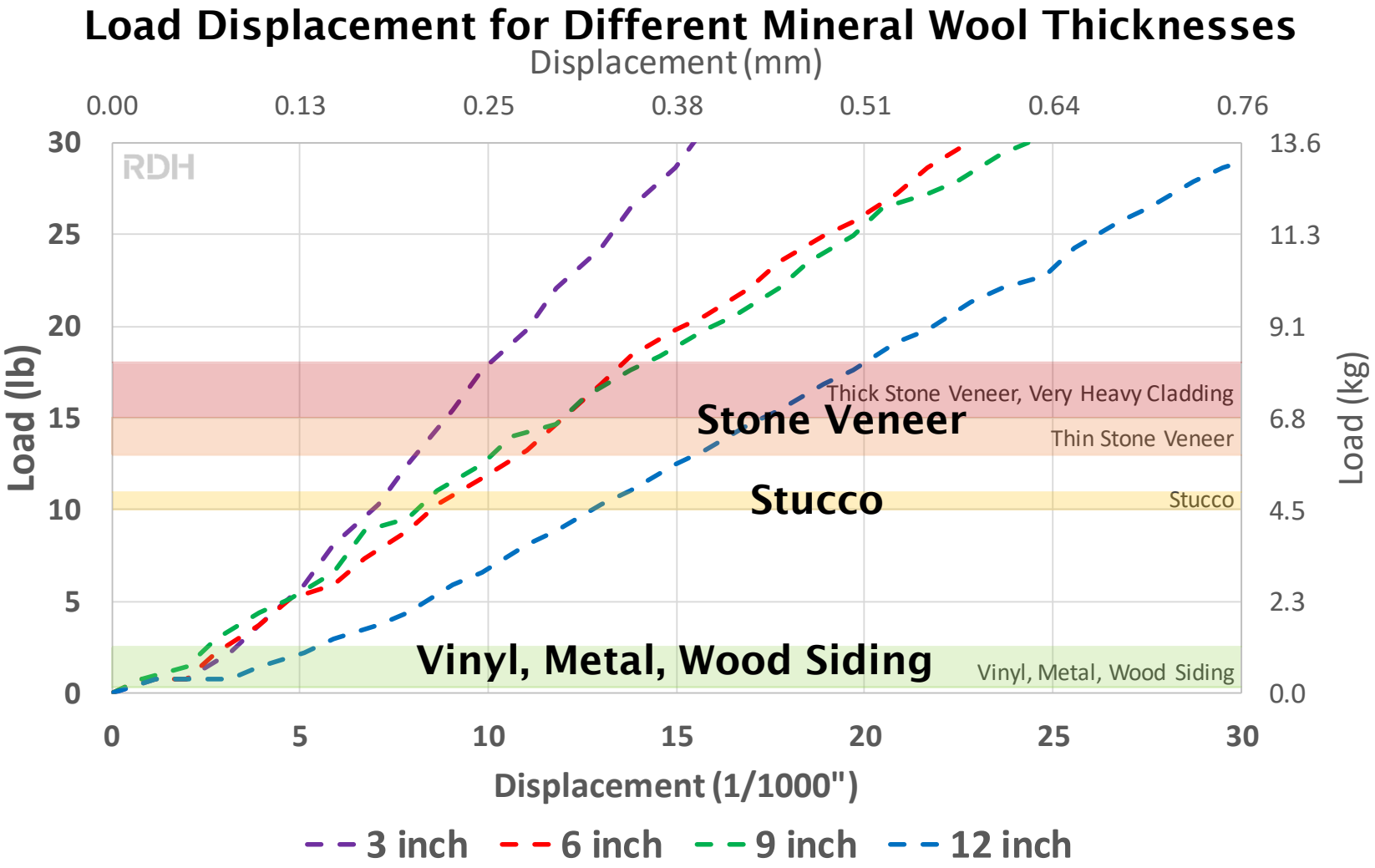


Testing – Insulation Type

Load Displacement for Different Insulation Types (6” Thick)



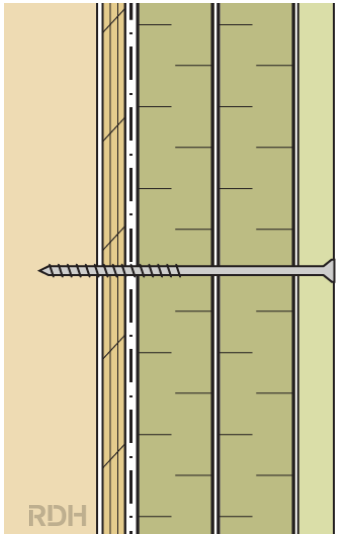
Testing – Insulation Thickness



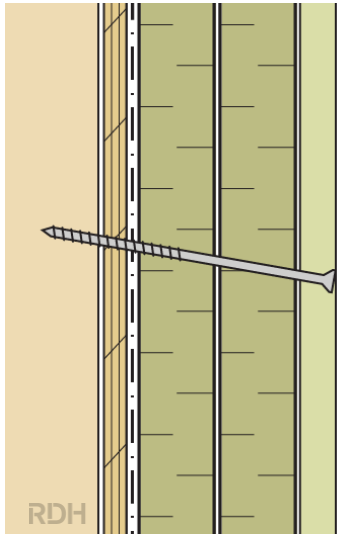
Testing – Insulation Thickness

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

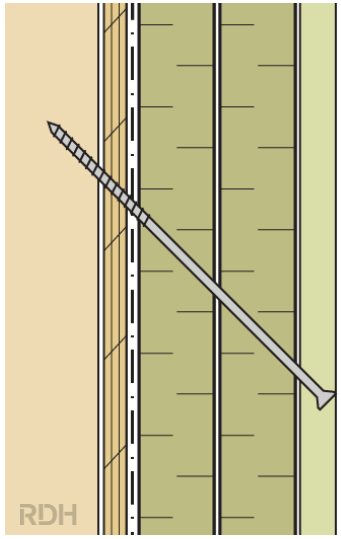
Testing – Different Fastener Arrangements



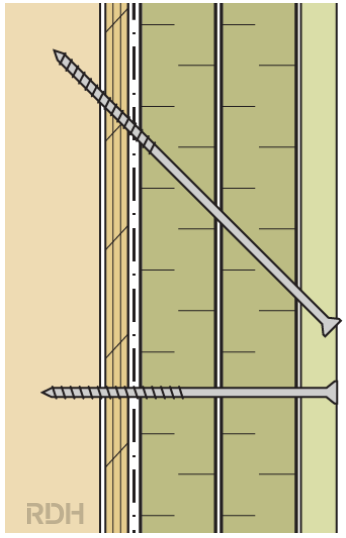
Horizontal (90°)



1:6 (80.5°)

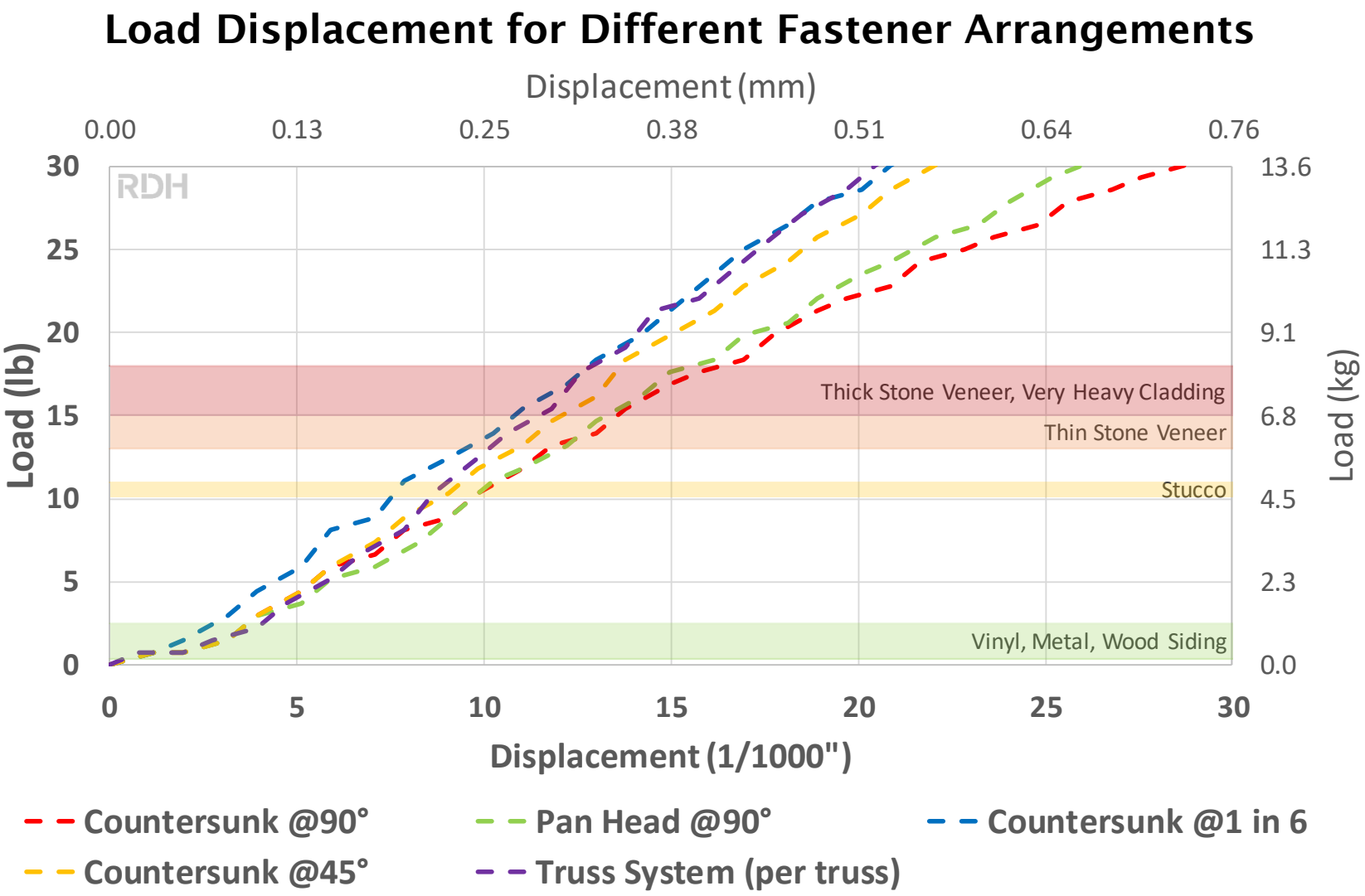


45°

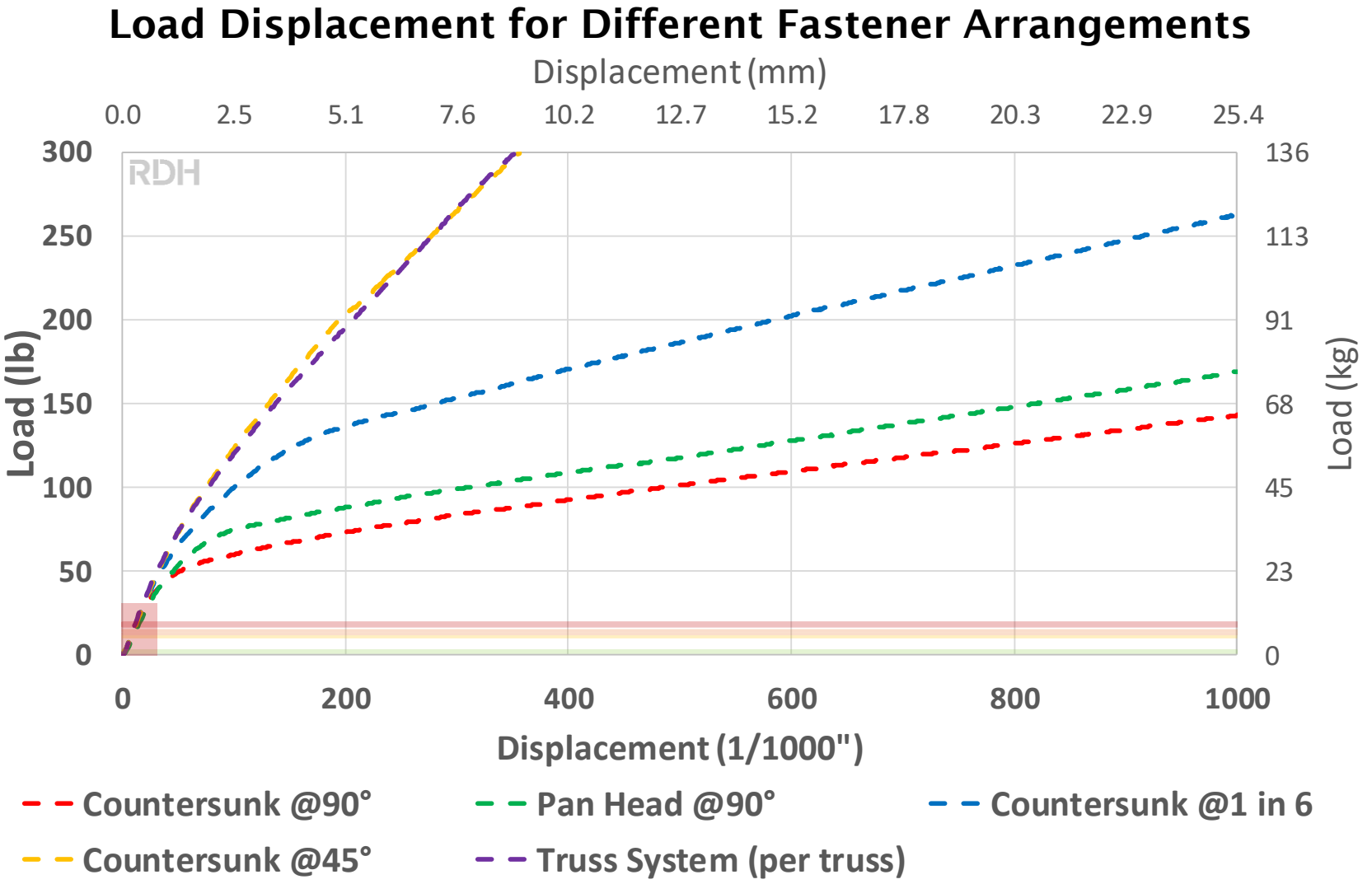


Truss (90° + 45°)

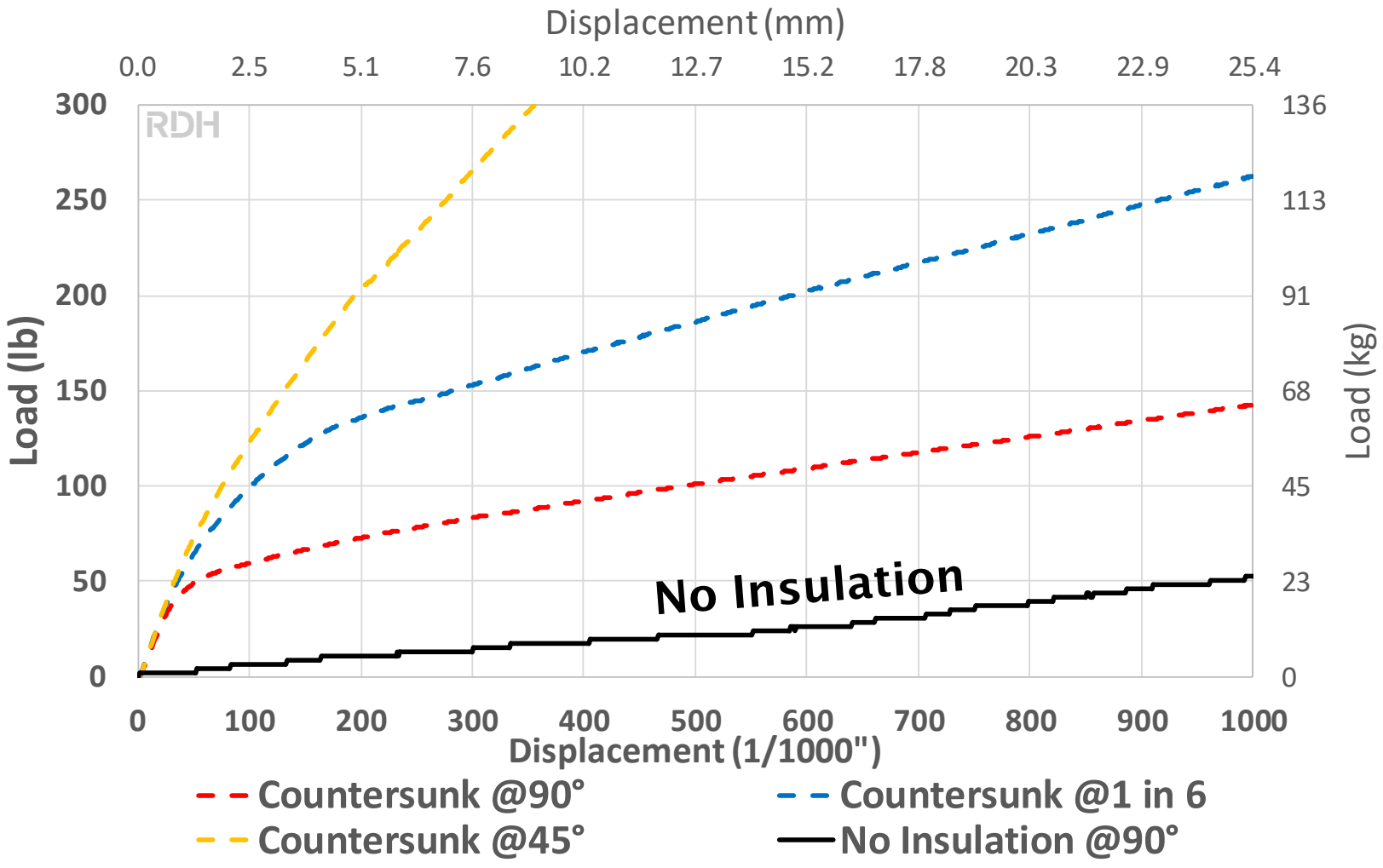
Testing – Fastener Arrangements



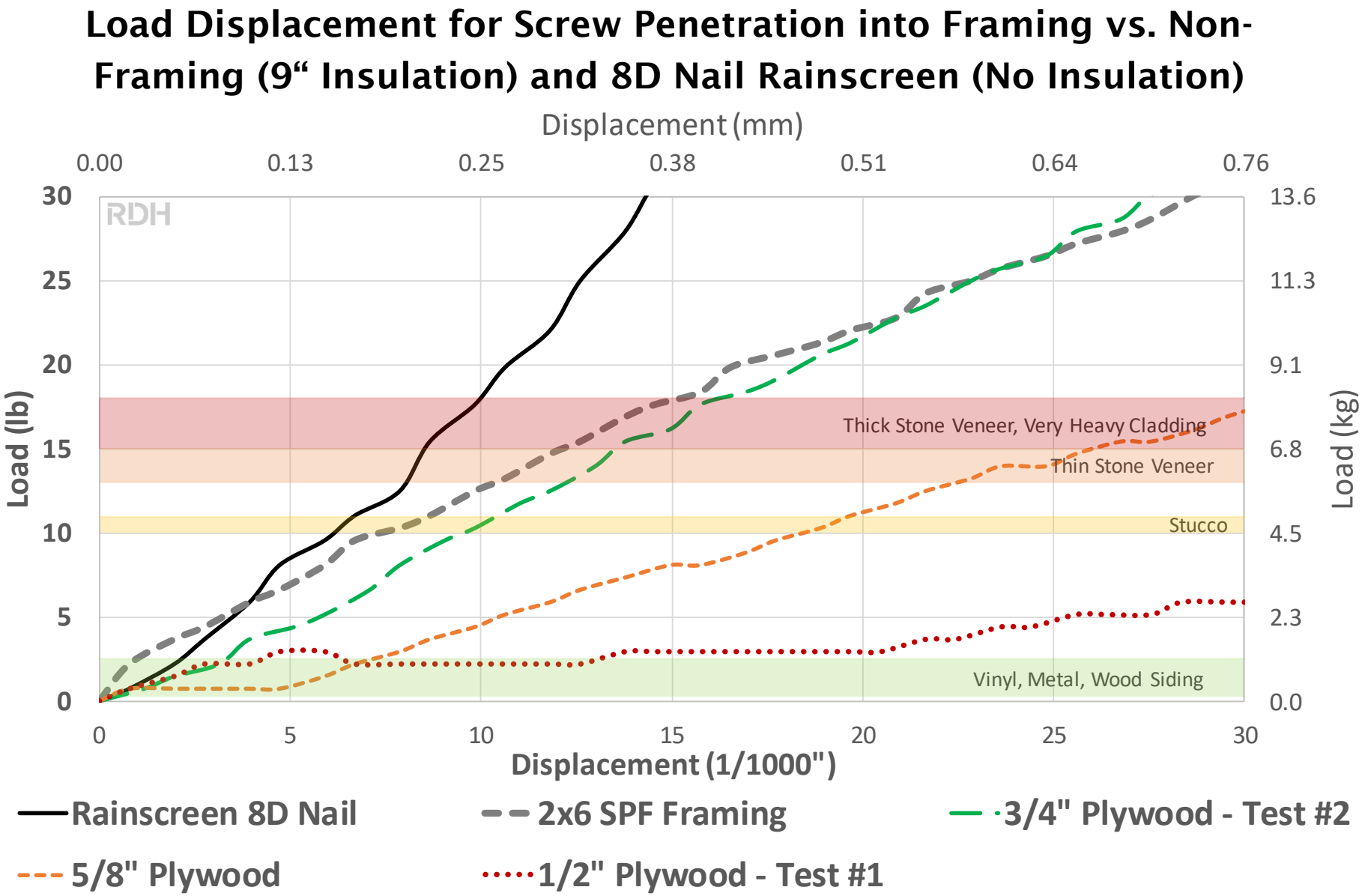
Testing – Fastener Arrangements



Testing – Is this just the fastener?



Testing – What if we miss the stud?

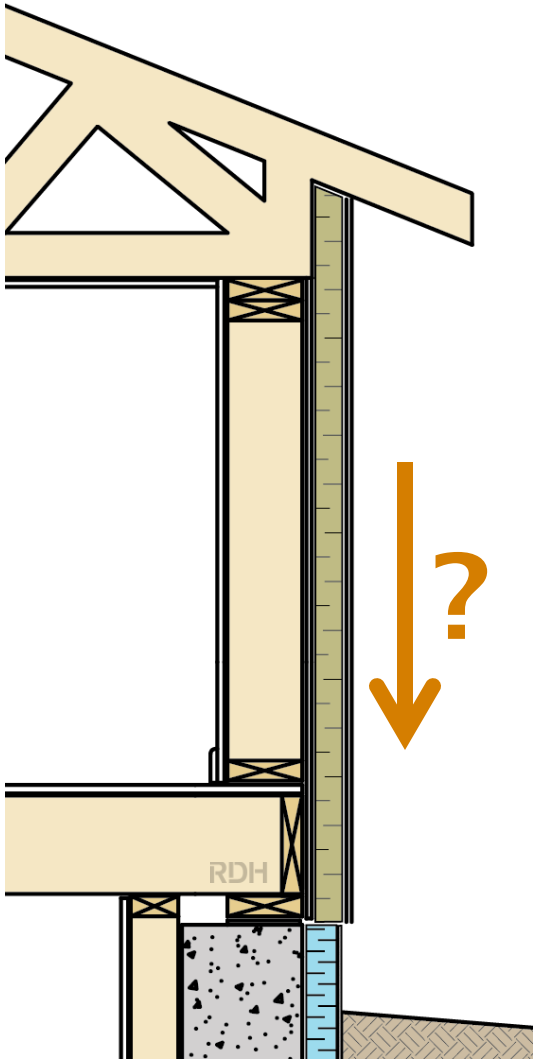


Deflection - How much is too much?

→ 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

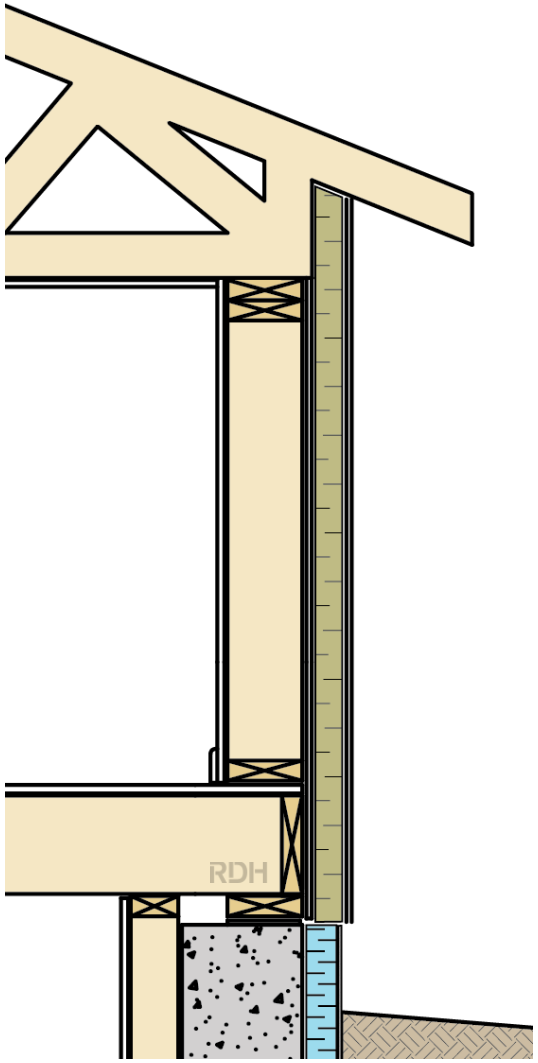
→ Can see it is different than strapping direct to sheathing, but not much



Deflection - How much is too much?

→ Comparison: Wood Shrinkage

- → One wood-frame storey: 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
- → Approximately **3/8” (375mil, 10mm)** shrinkage in one storey height
  - › **Roughly 10x** more than measured deflection in test for any arrangement



Retrofit Tools and Materials

→ Samples of materials/tools

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Tools and Materials – Air Sealing

- → Basic hand/power tools
- → Basic construction materials
- → Polyurethane/silicone/acoustical sealant
- → Tapes
- → Two-part polyurethane spray foam
- → One-part spray foam with dispensing nozzle gun

Tools and Materials - Insulation

- → Rigid/batt/blow-in insulation
- → Insulation baffles

Tools and Materials - Membranes

- → Vapour retarders
- → House wraps
- → Peel and Sticks

Retrofit Installation Details

- → Attic Air Sealing & Insulation
- → New Sheathing Membrane & Exterior Insulation
- → Foundation & Slab on Grade Insulation

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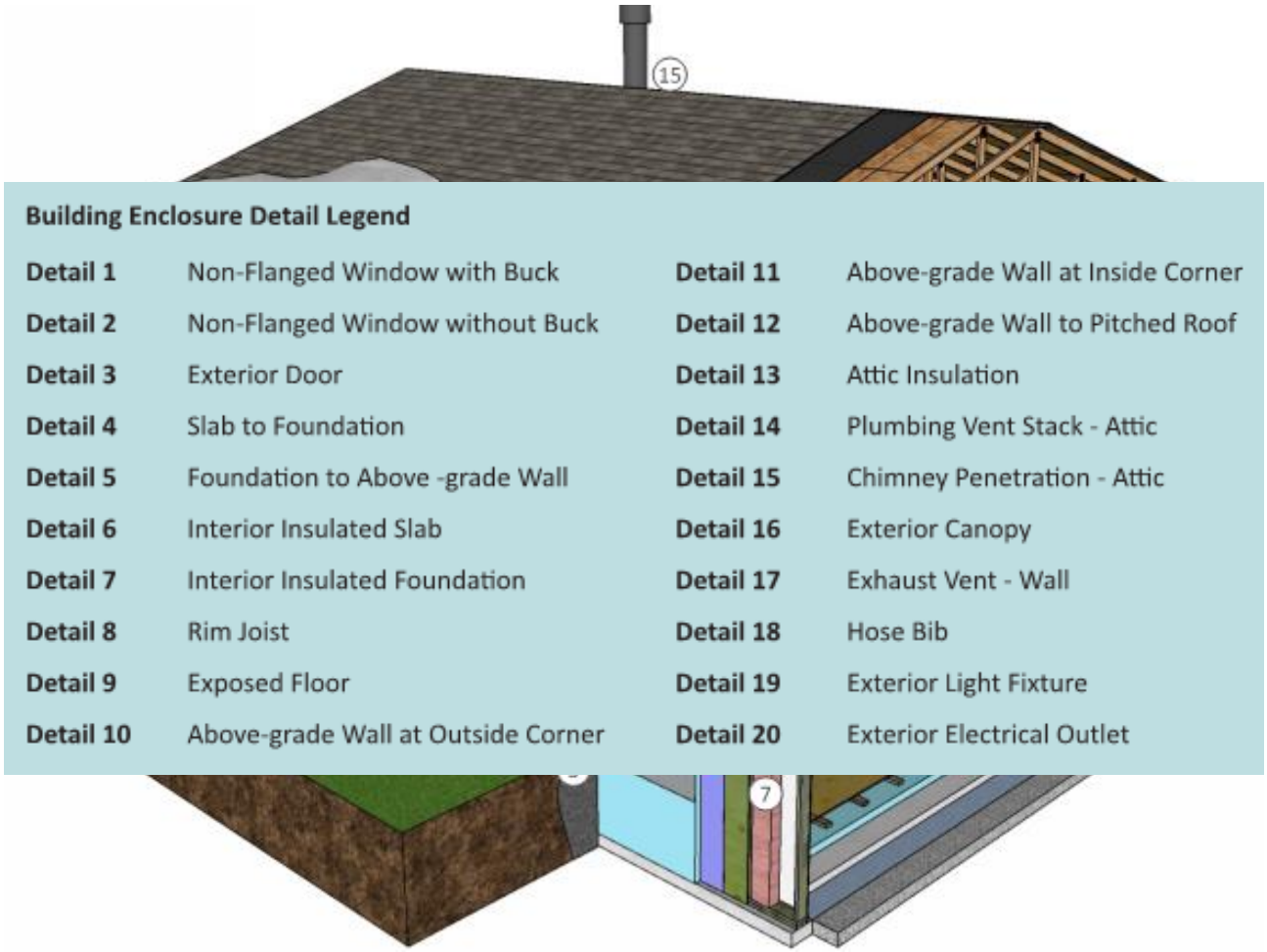
Details in Version 1 of Guide

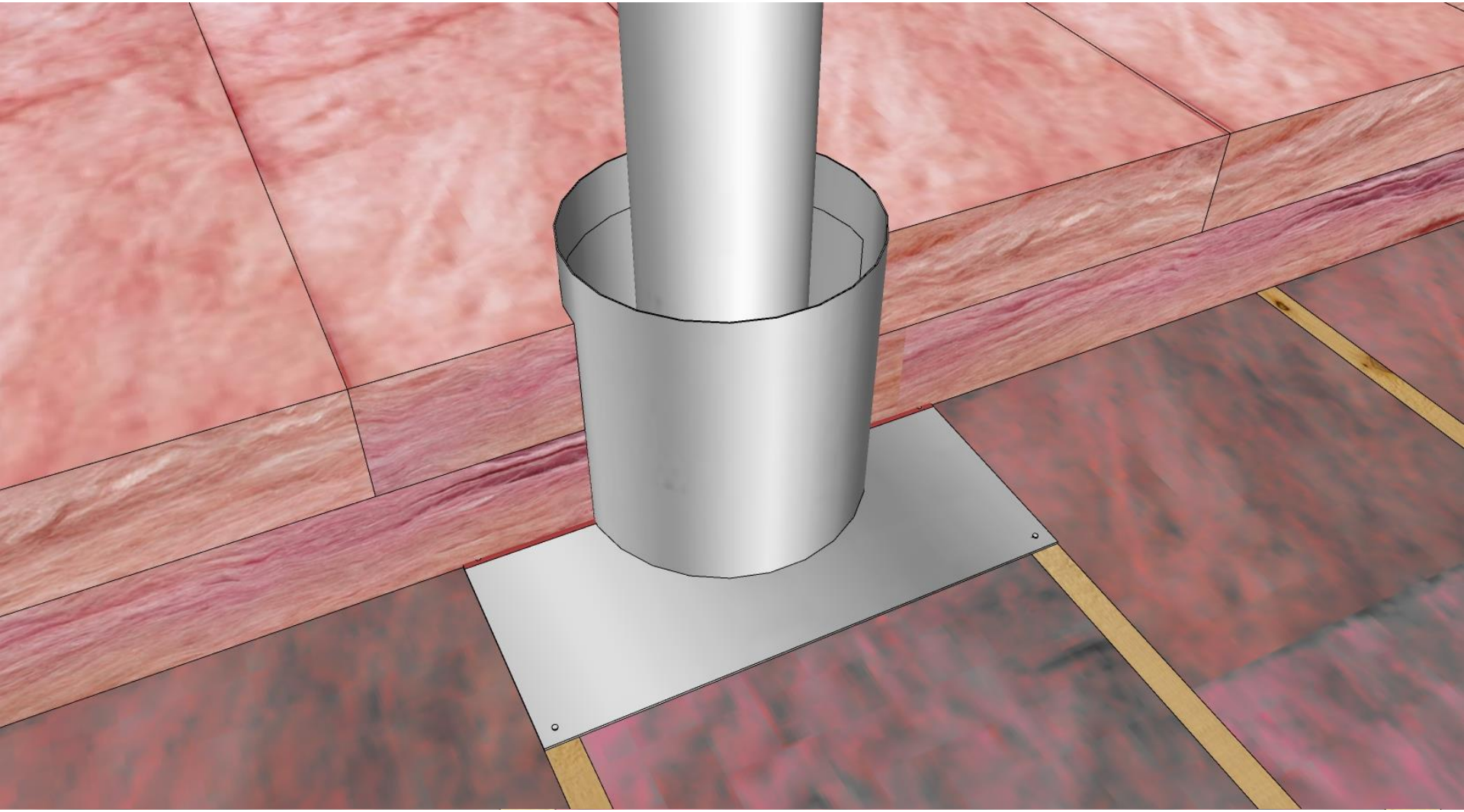


Building Enclosure Detail Legend

Detail 1	Non-Flanged Window with Buck	**Detail 11**	Above-grade Wall at Inside Corner
Detail 2	Non-Flanged Window without Buck	**Detail 12**	Above-grade Wall to Pitched Roof
Detail 3	Exterior Door	**Detail 13**	Attic Insulation
Detail 4	Slab to Foundation	**Detail 14**	Plumbing Vent Stack - Attic
Detail 5	Foundation to Above -grade Wall	**Detail 15**	Chimney Penetration - Attic
Detail 6	Interior Insulated Slab	**Detail 16**	Exterior Canopy
Detail 7	Interior Insulated Foundation	**Detail 17**	Exhaust Vent - Wall
Detail 8	Rim Joist	**Detail 18**	Hose Bib
Detail 9	Exposed Floor	**Detail 19**	Exterior Light Fixture
Detail 10	Above-grade Wall at Outside Corner	**Detail 20**	Exterior Electrical Outlet

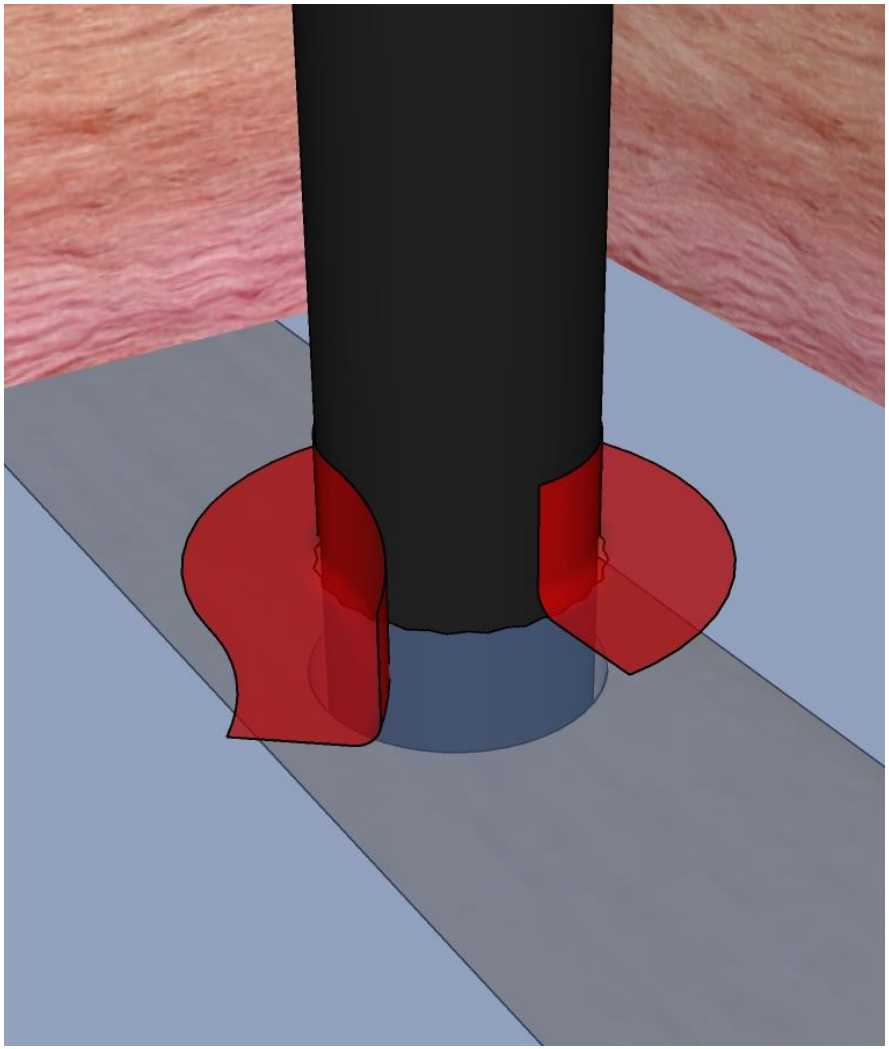
Attic Air Sealing & Insulation

Chimney

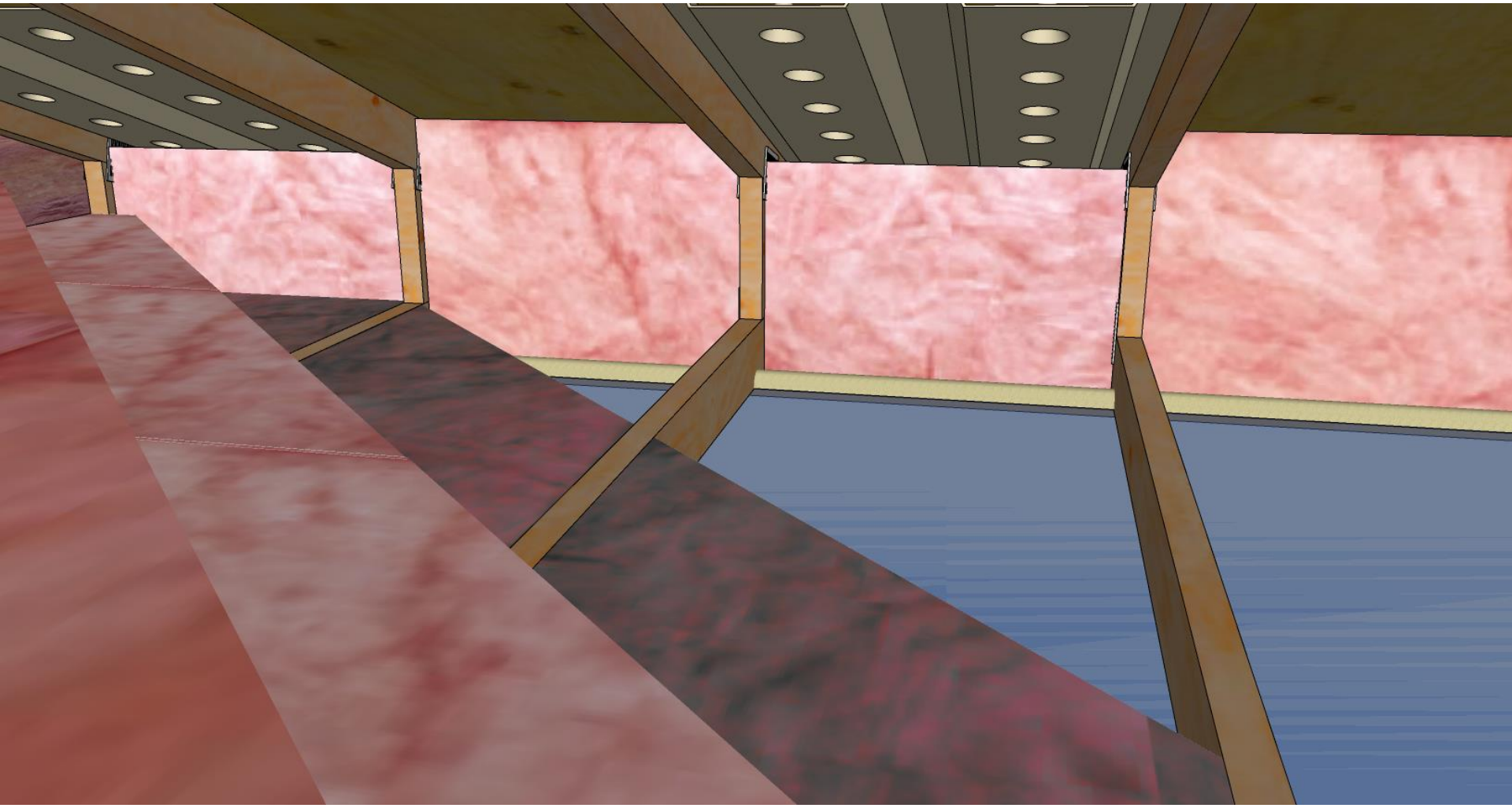


Chimney

Vent Stack



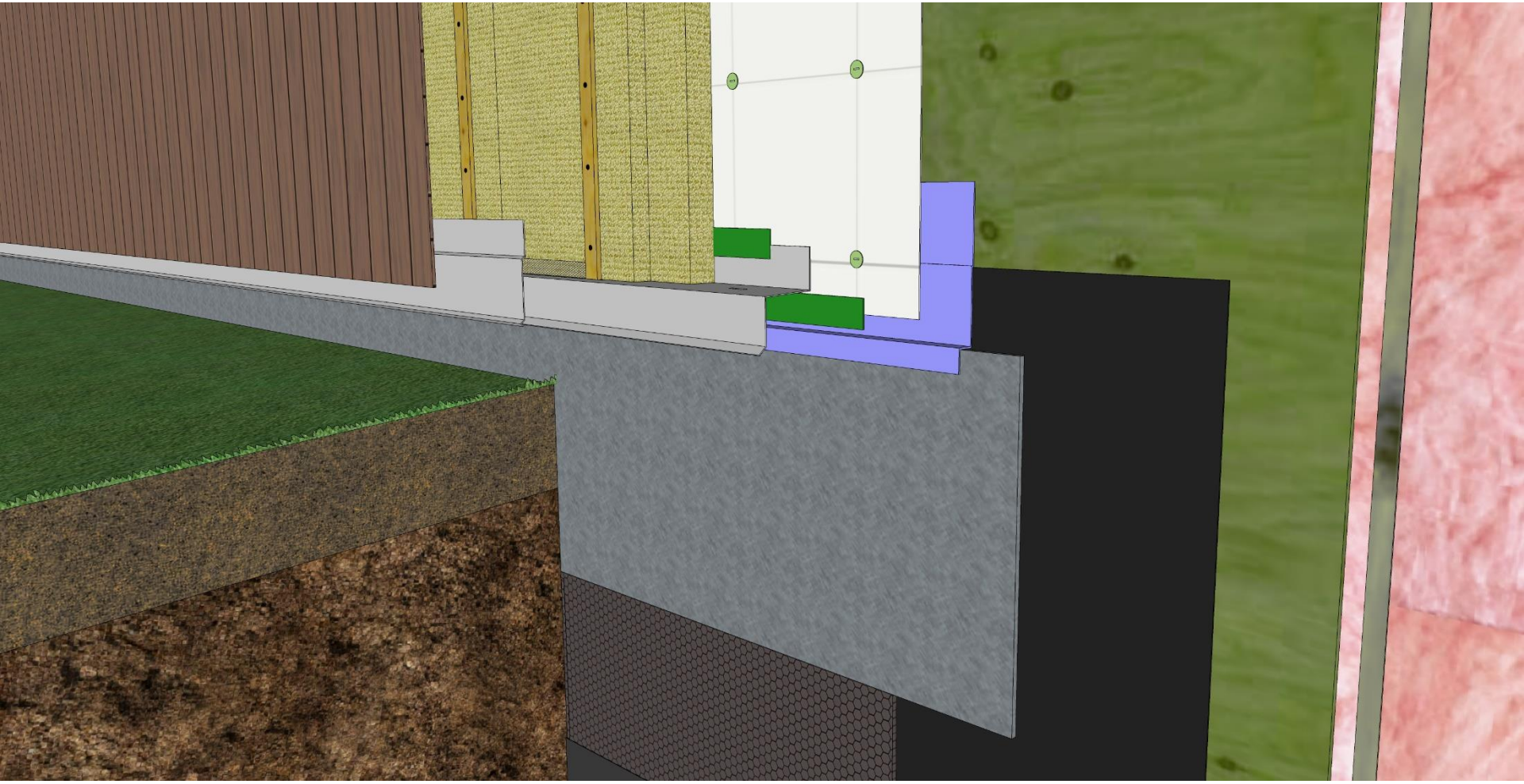
Attic Insulation Top Up



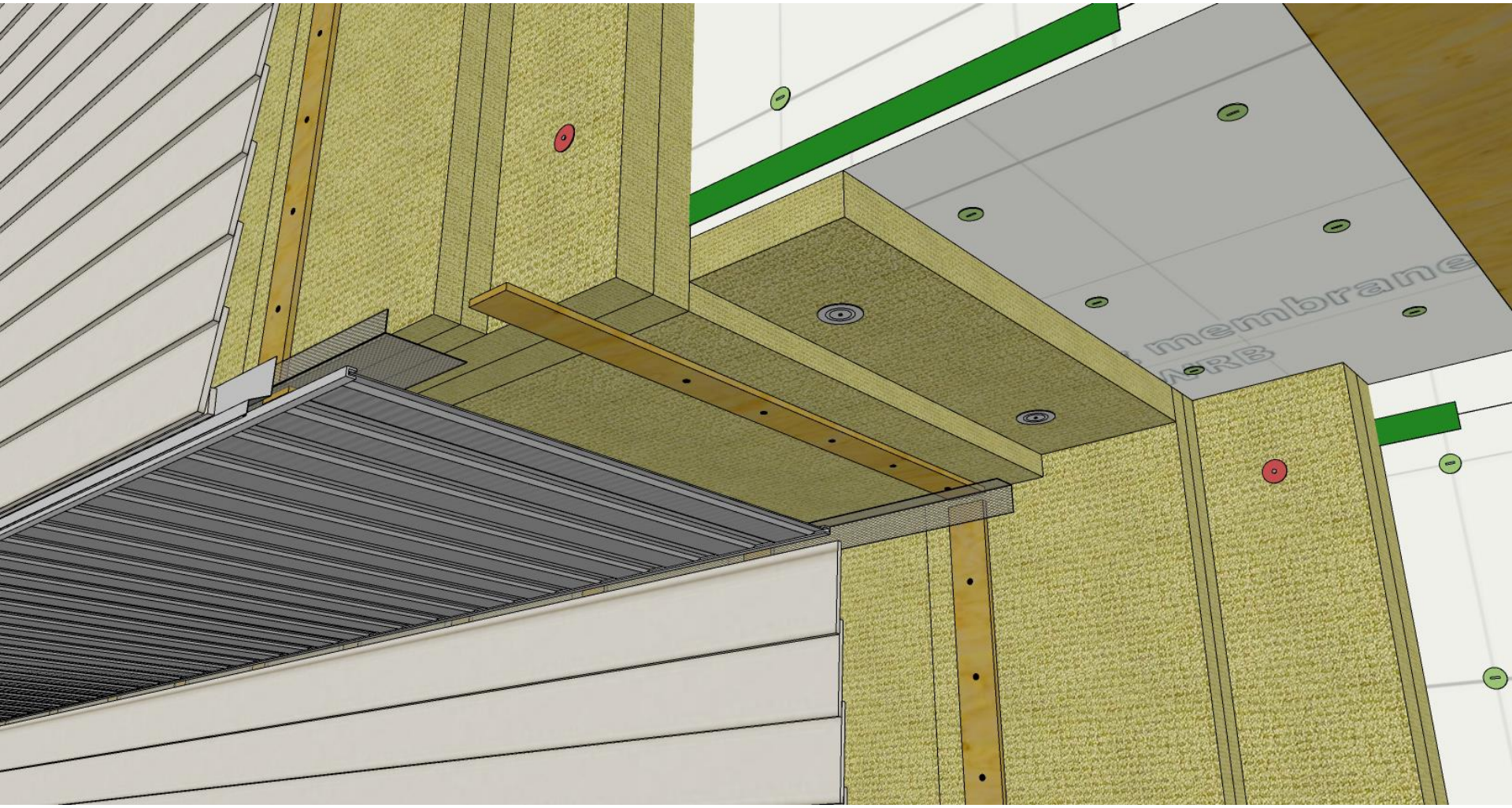
Attic Insulation Top Up

New Sheathing Membrane & Exterior Insulation

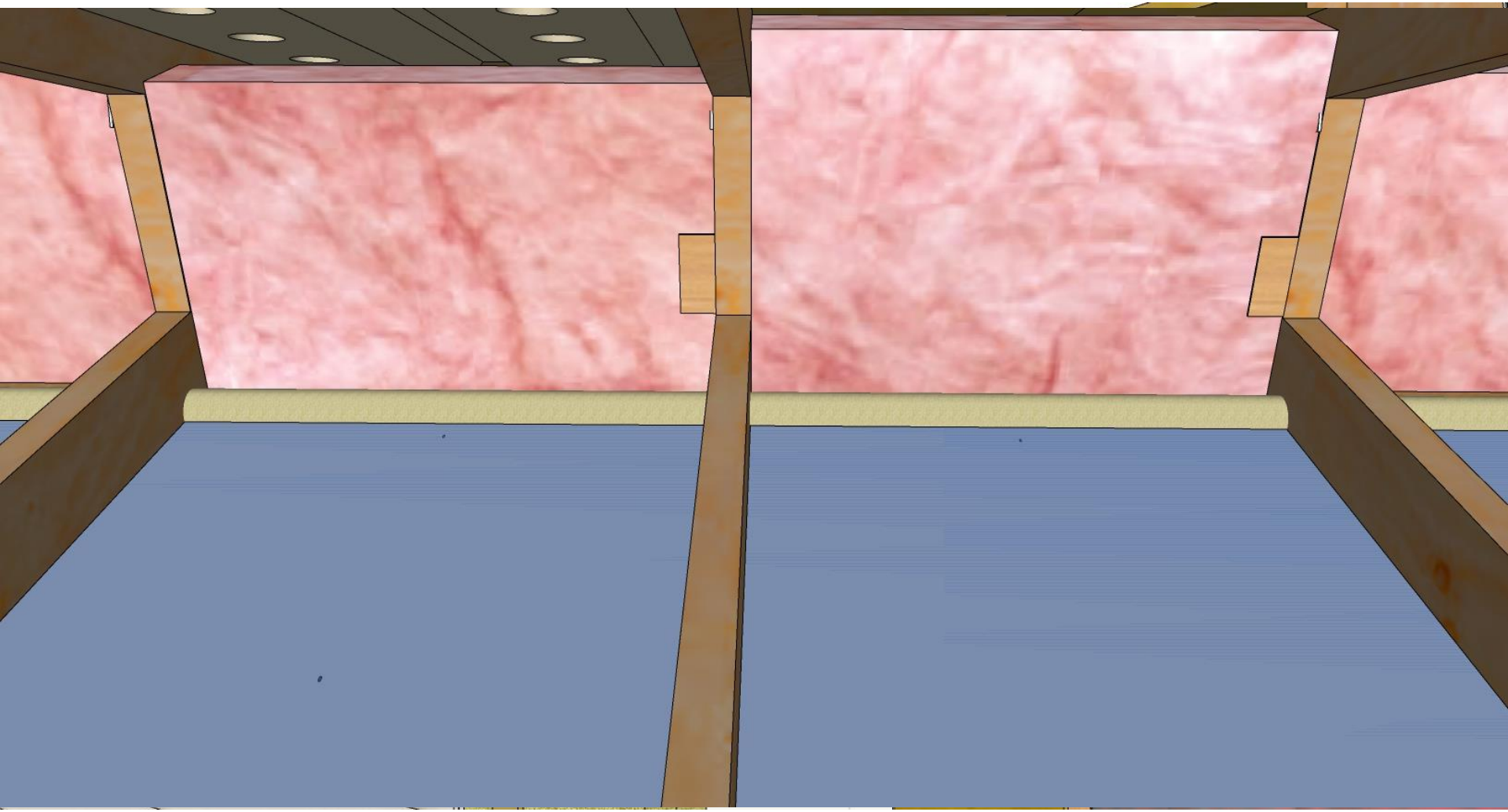
Foundation to Wall Interface



Exposed Floor

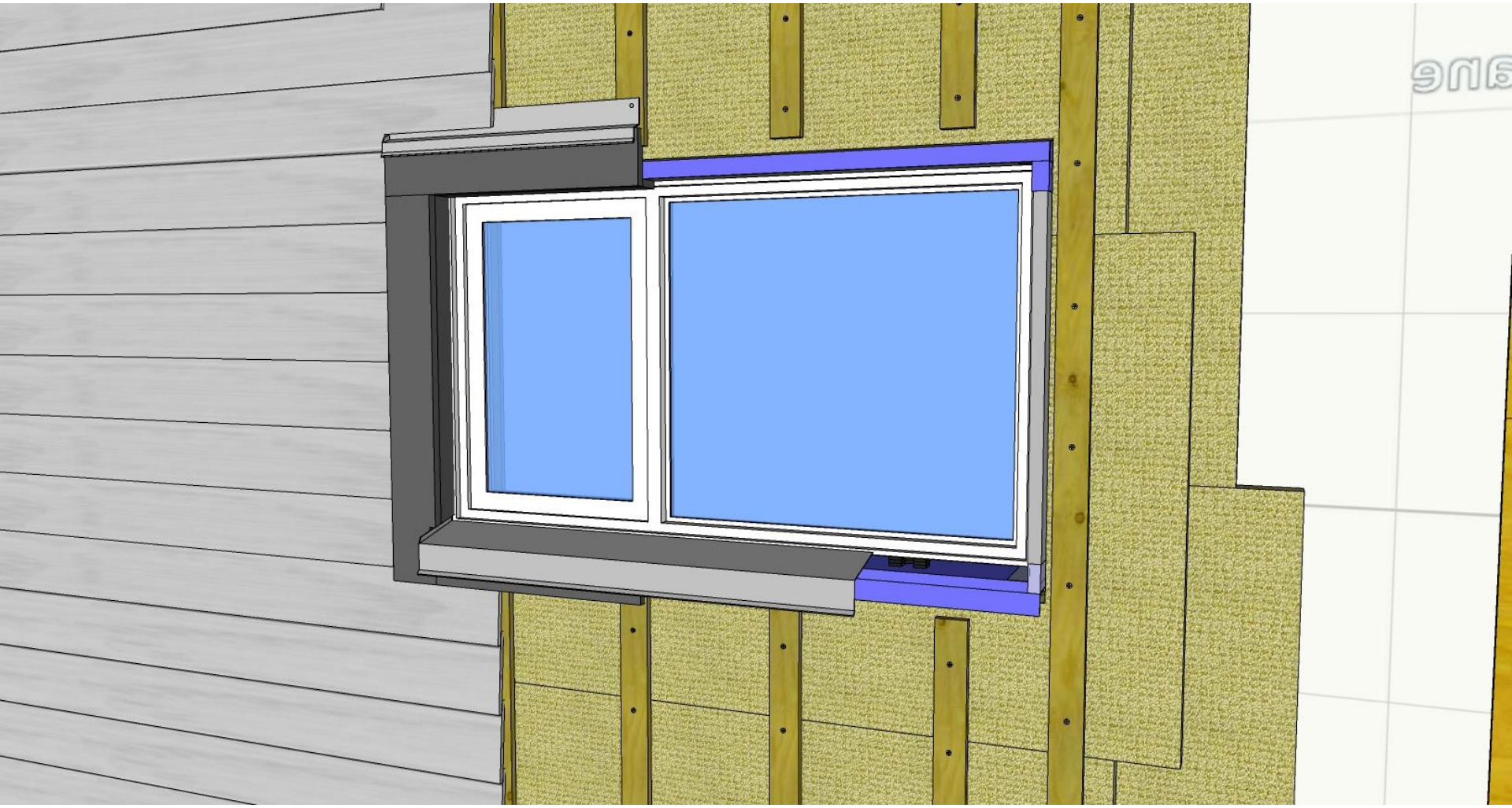


Roof to Wall Interface

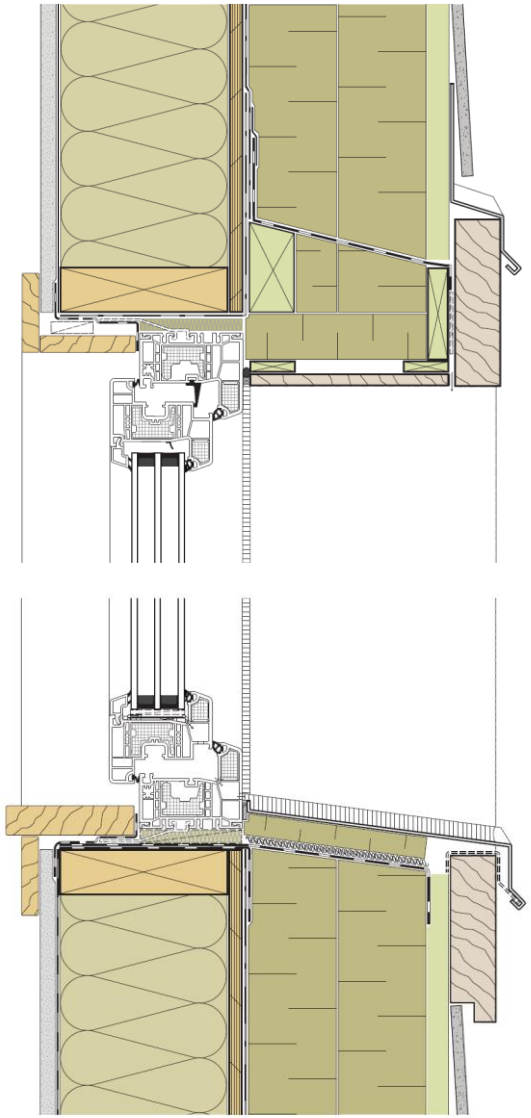


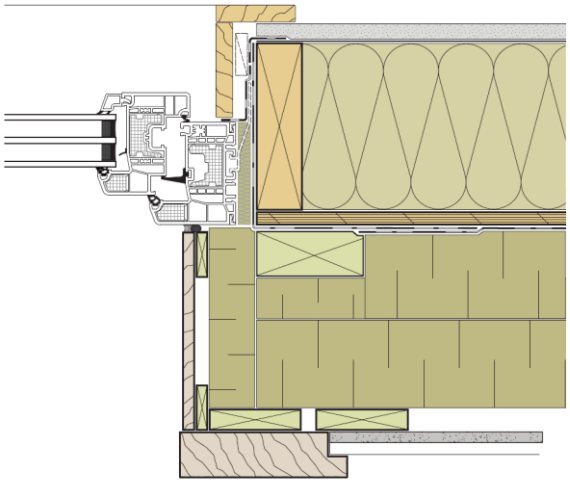
Outside Corner

Non-Flanged Window w/ Buck

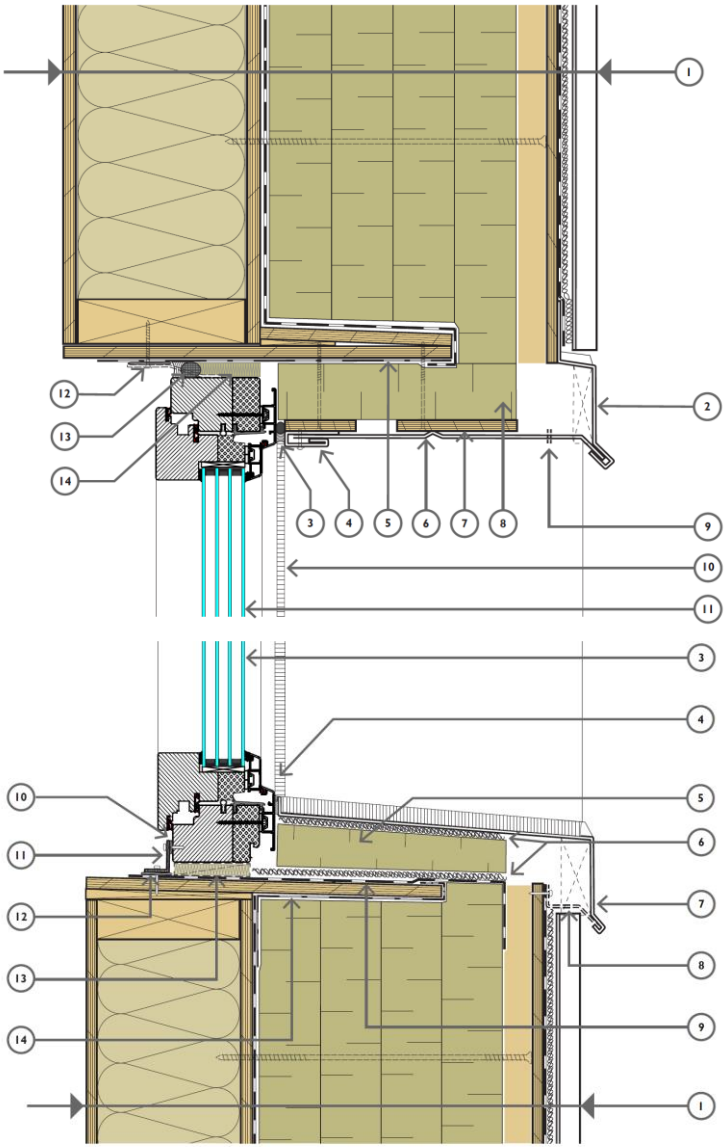


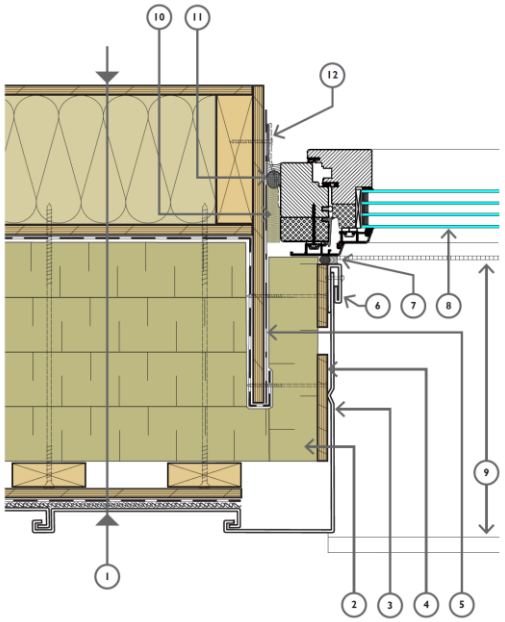
Flashing Improvements & Overinsulation of Window Frames





Quad Window Overinsulated in R60+ Wall

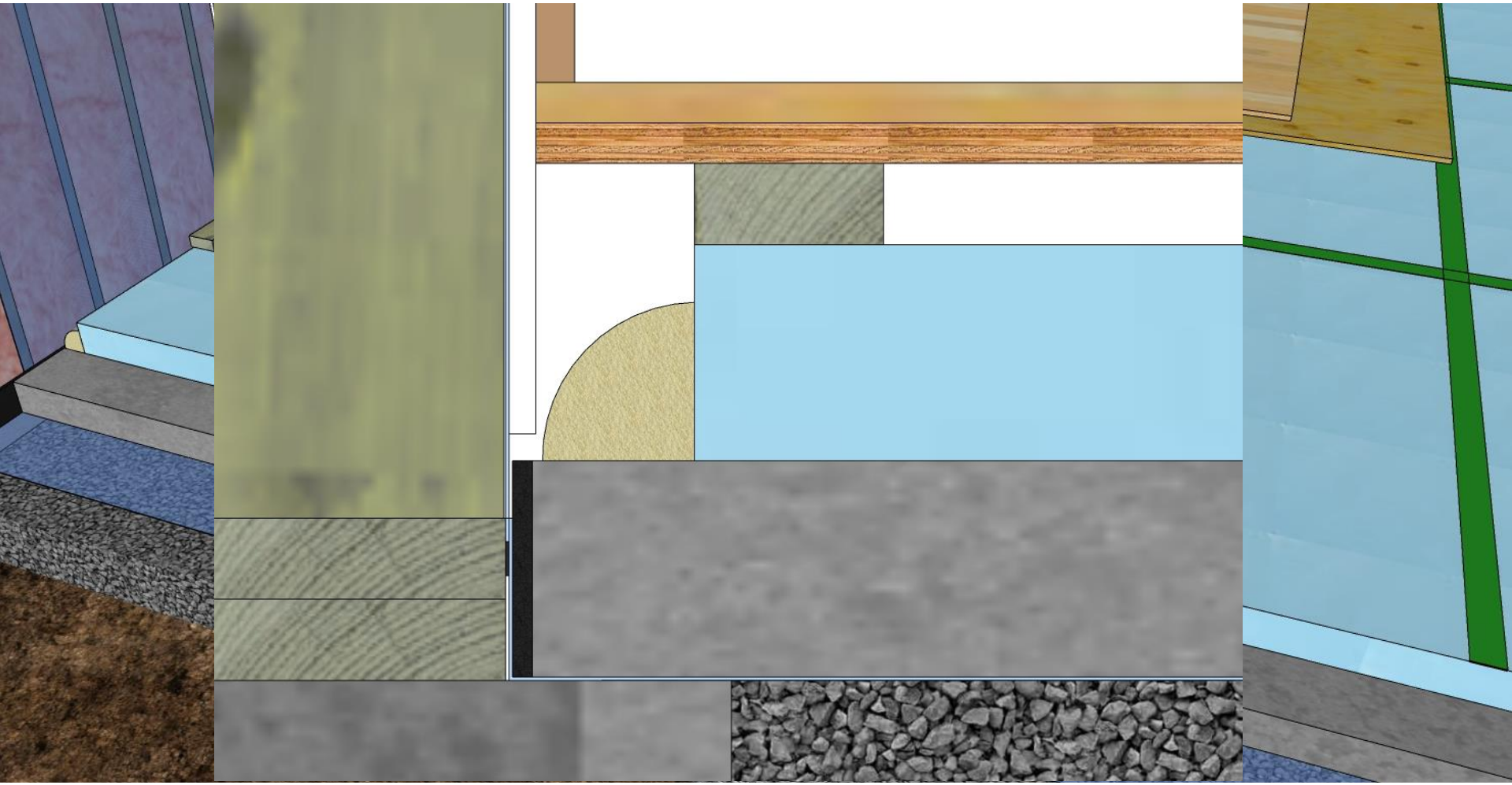




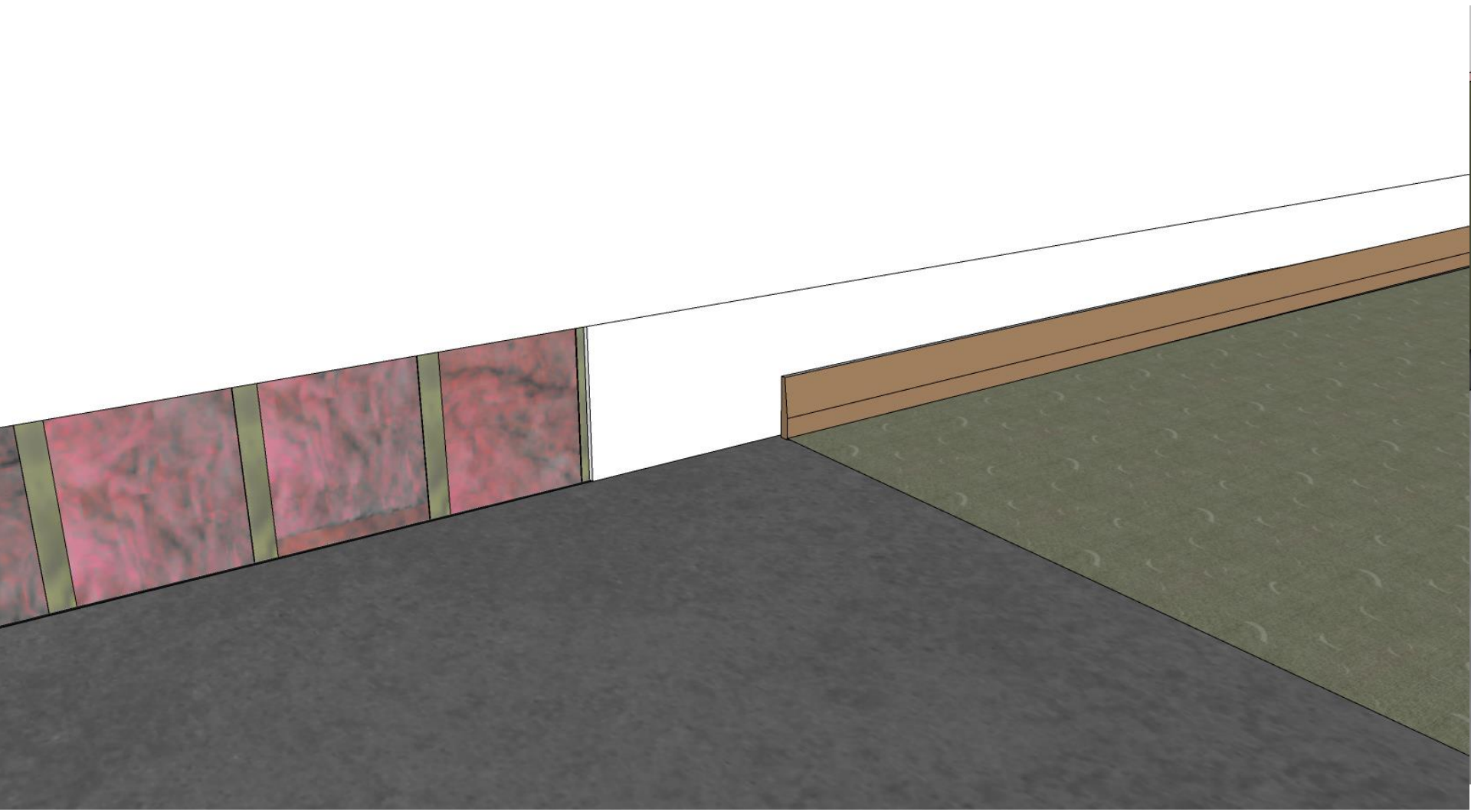
Flashing Improvements & Overinsulation of Window Frames

Foundation & Slab on Grade Insulation

Slab on Grade Insulation

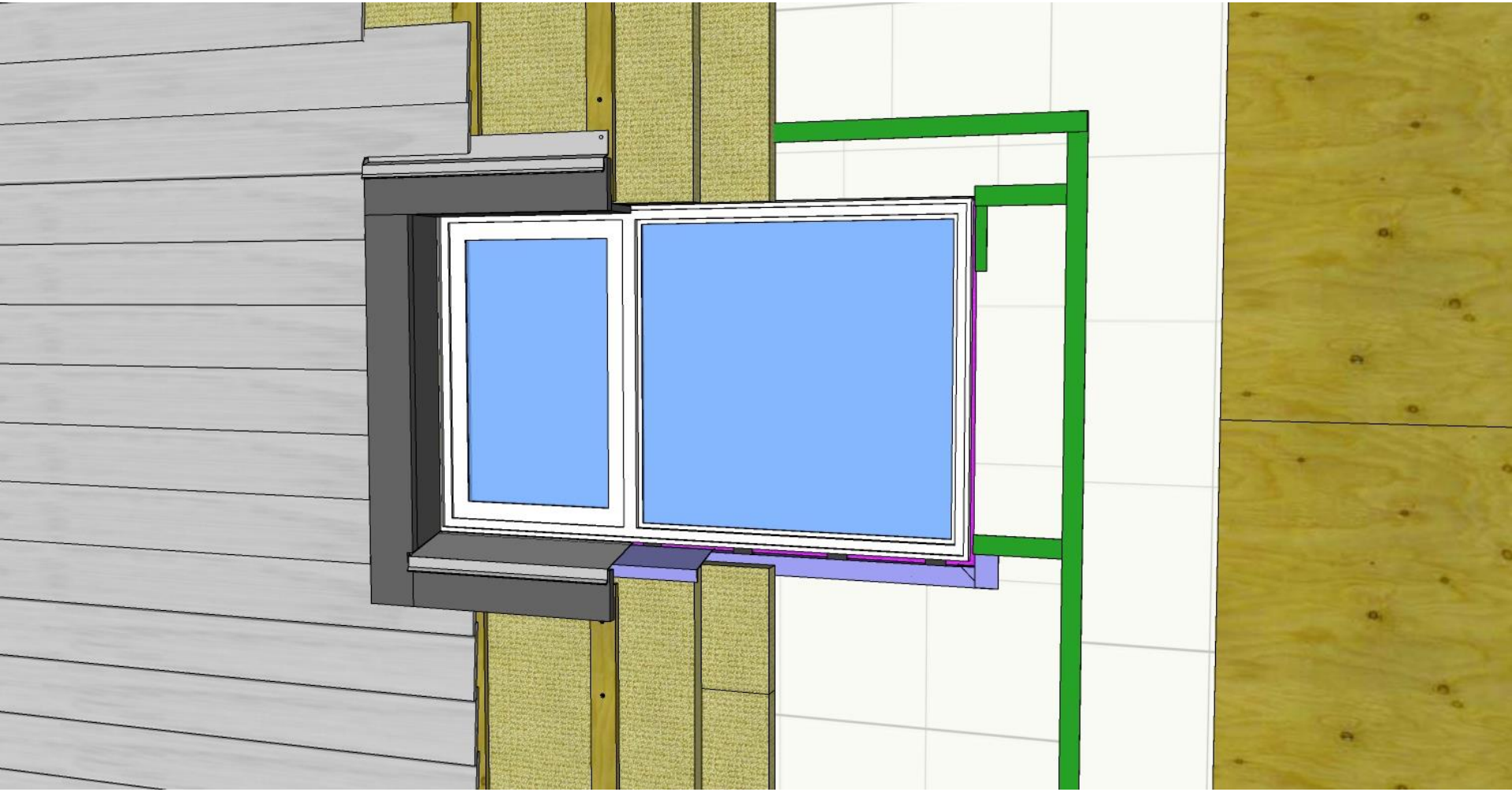


Exterior Insulation and New Waterproofing on PWF

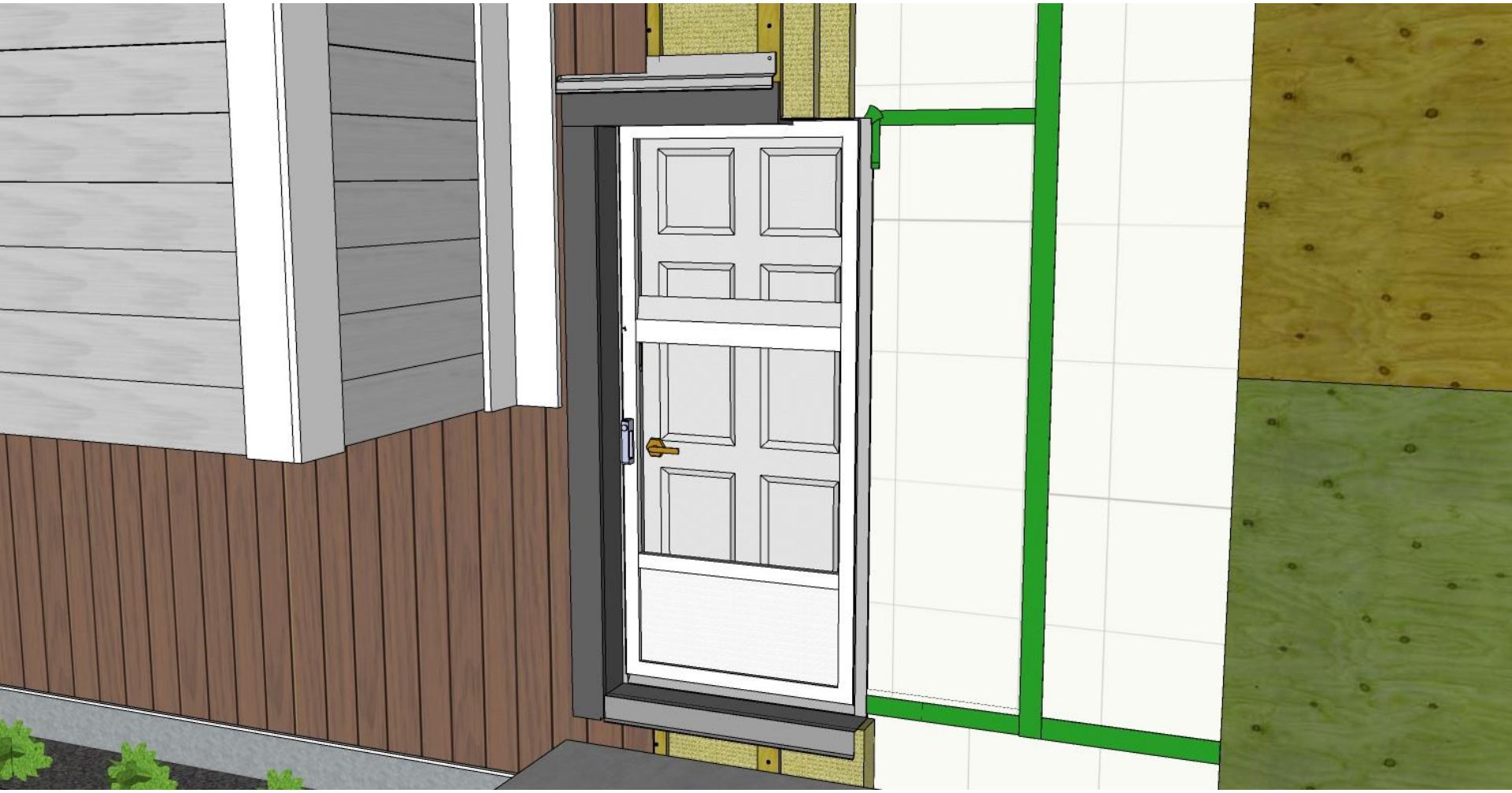


Additional Details

Non-Flanged Window (No Buck)

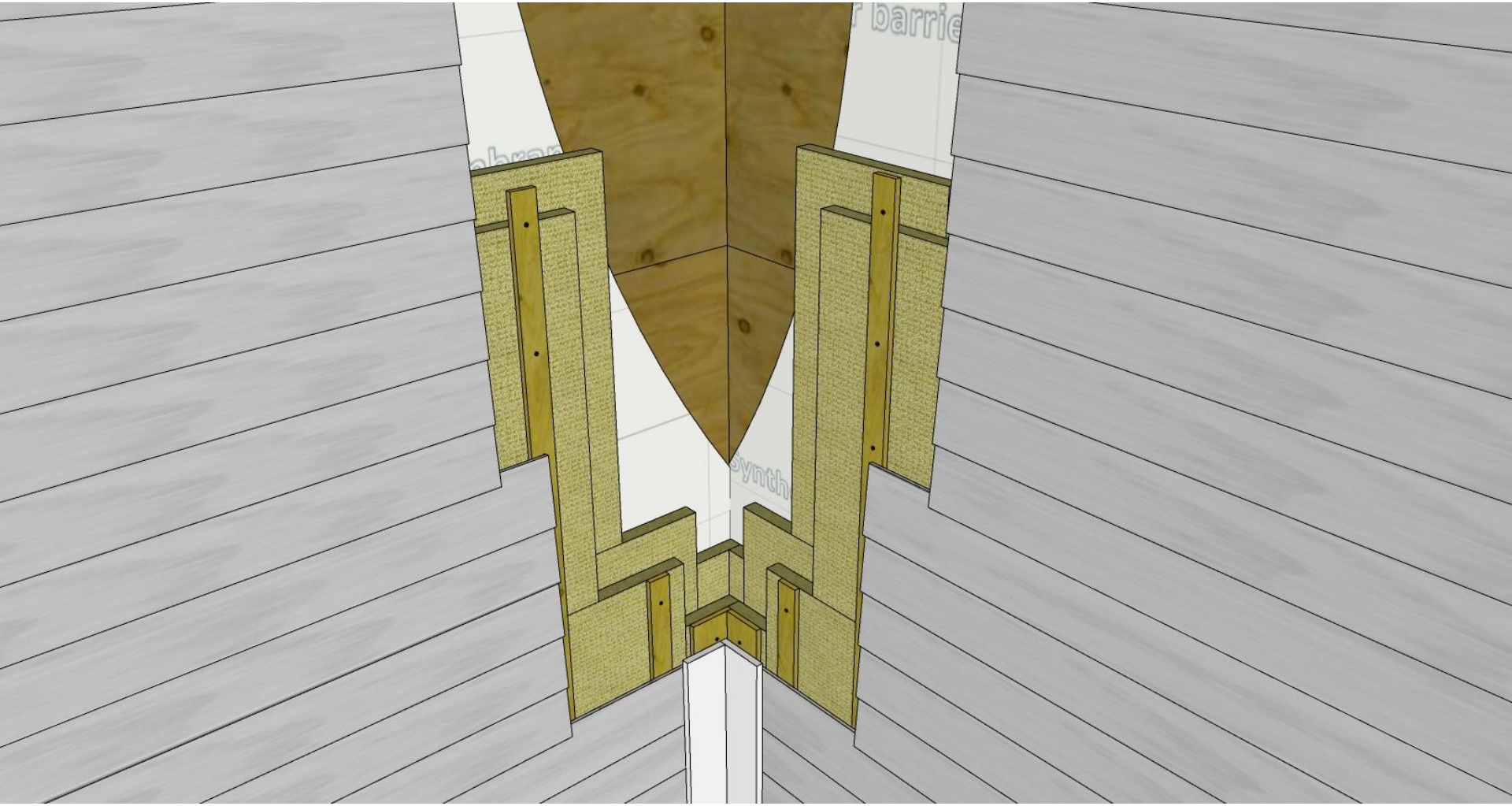


Exterior Door

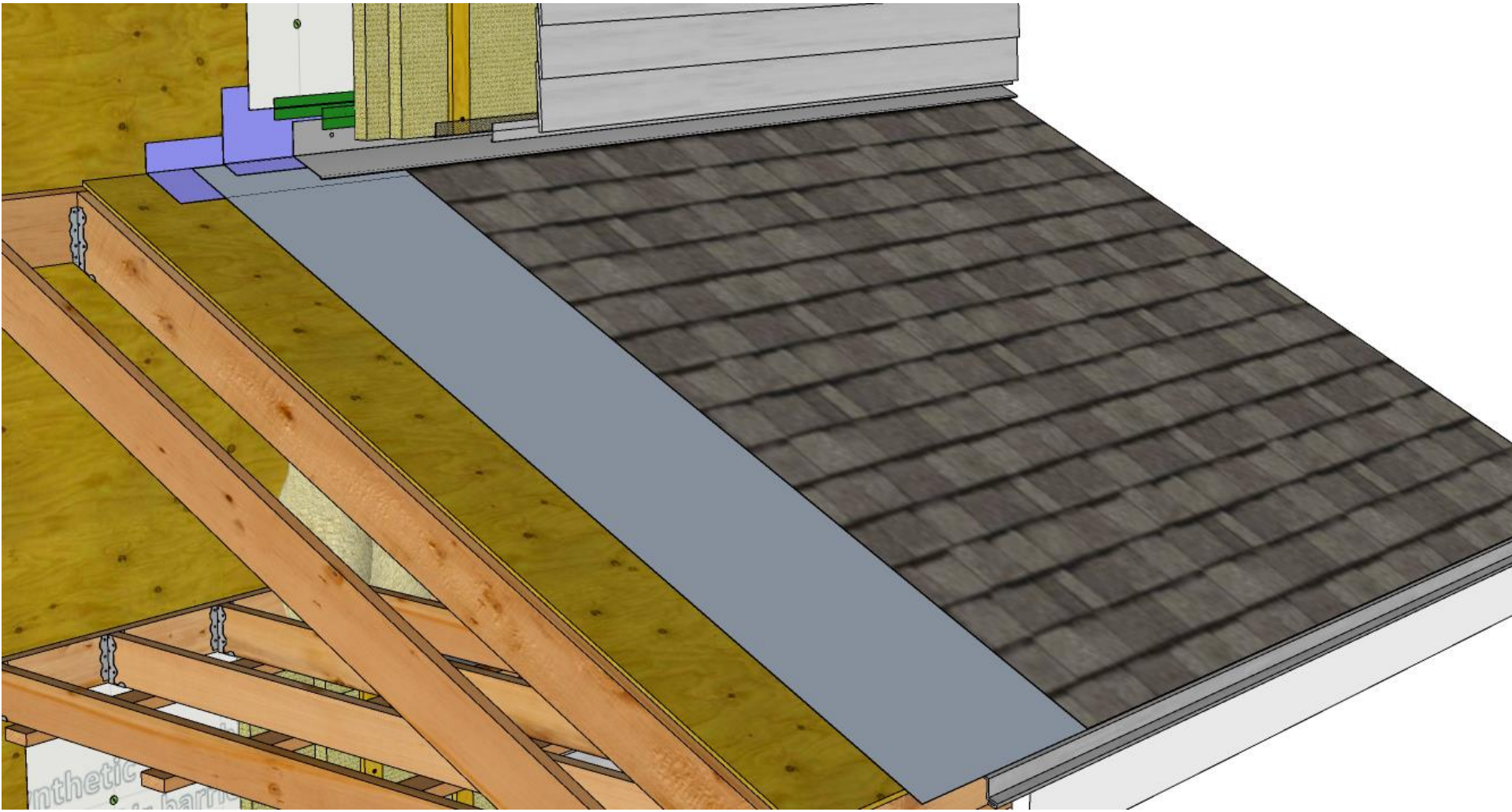


Rim Joist

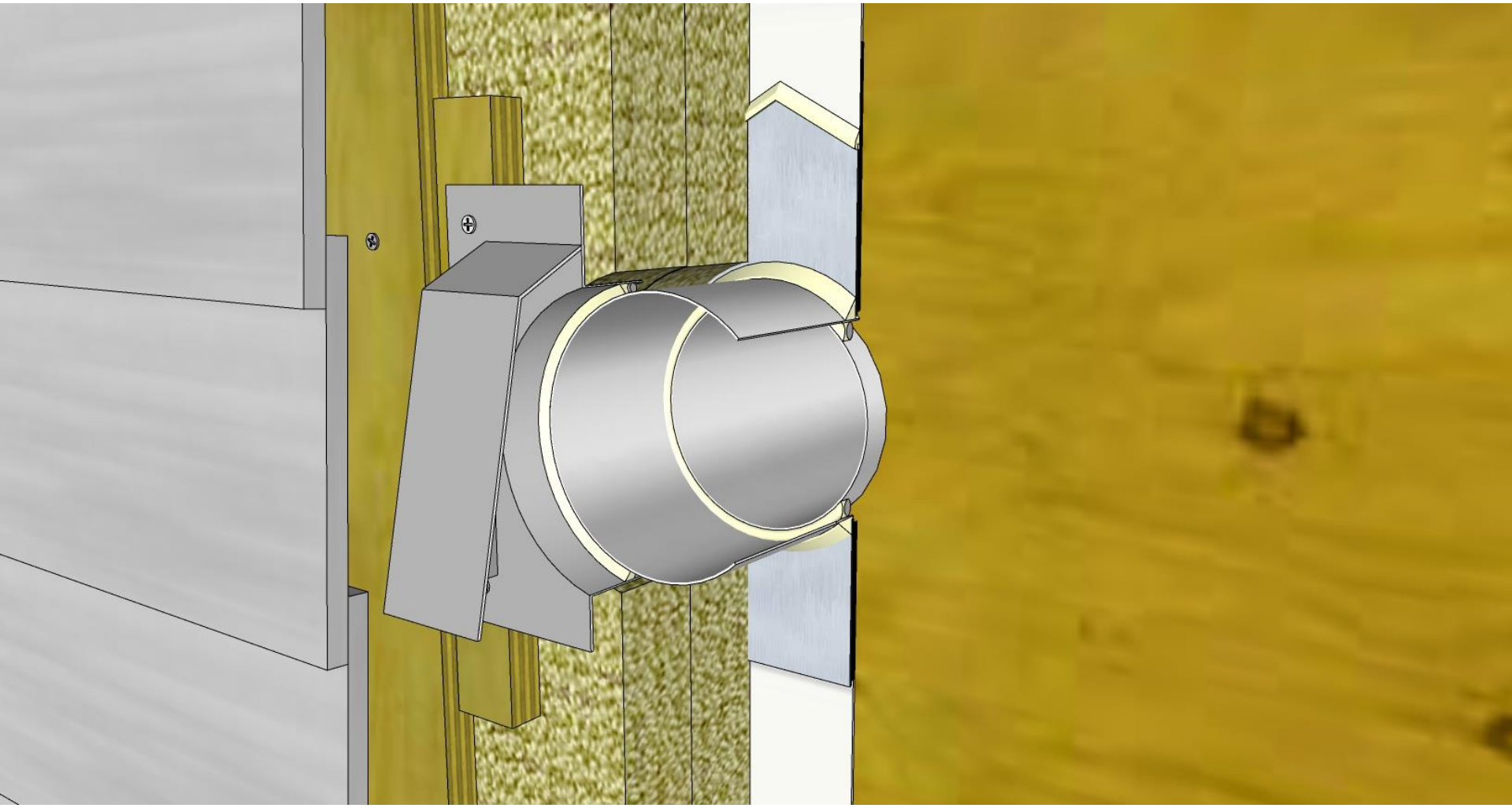
Above Grade Wall at Inside Corner



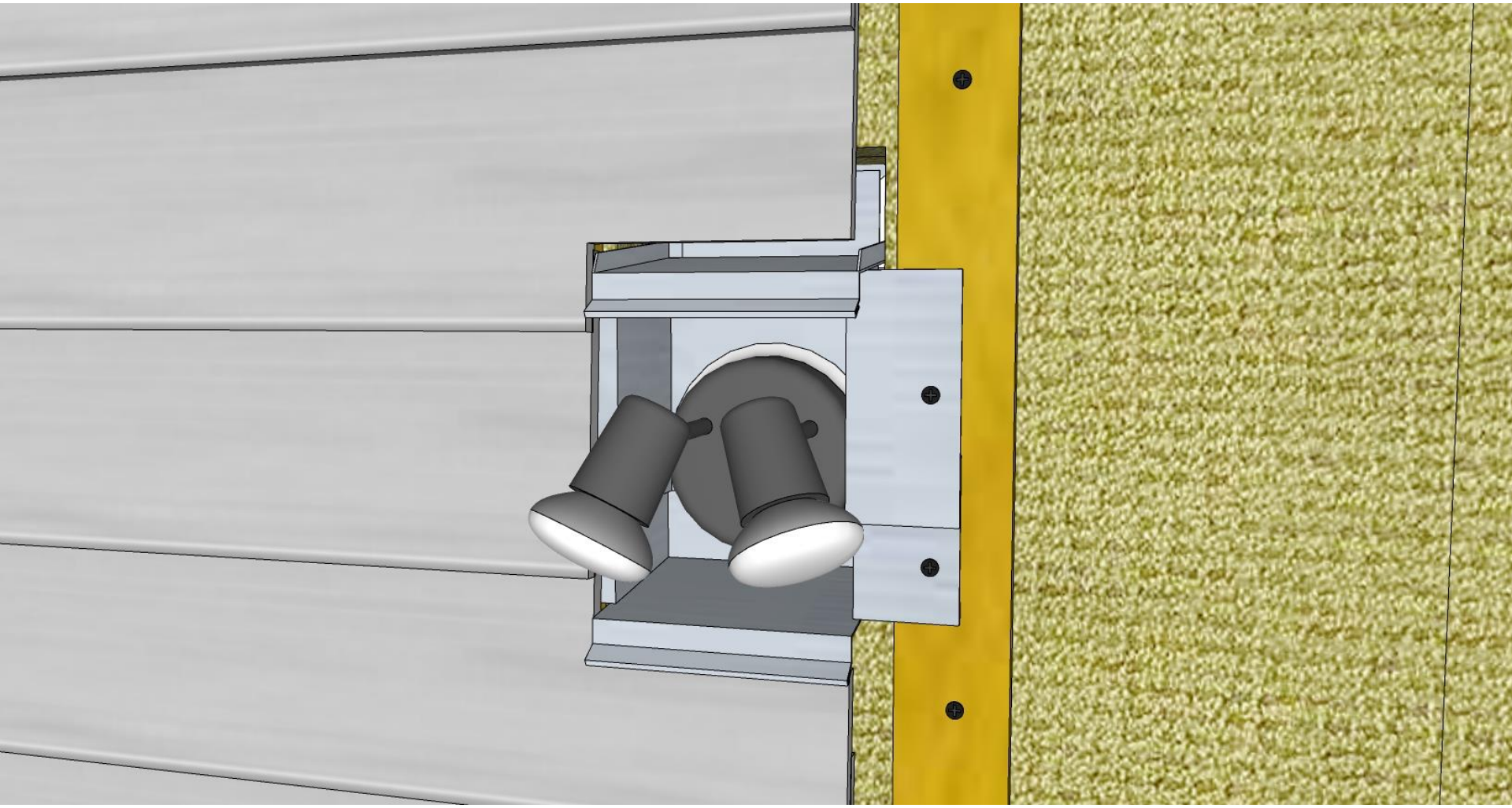
Canopy



Exhaust Vent

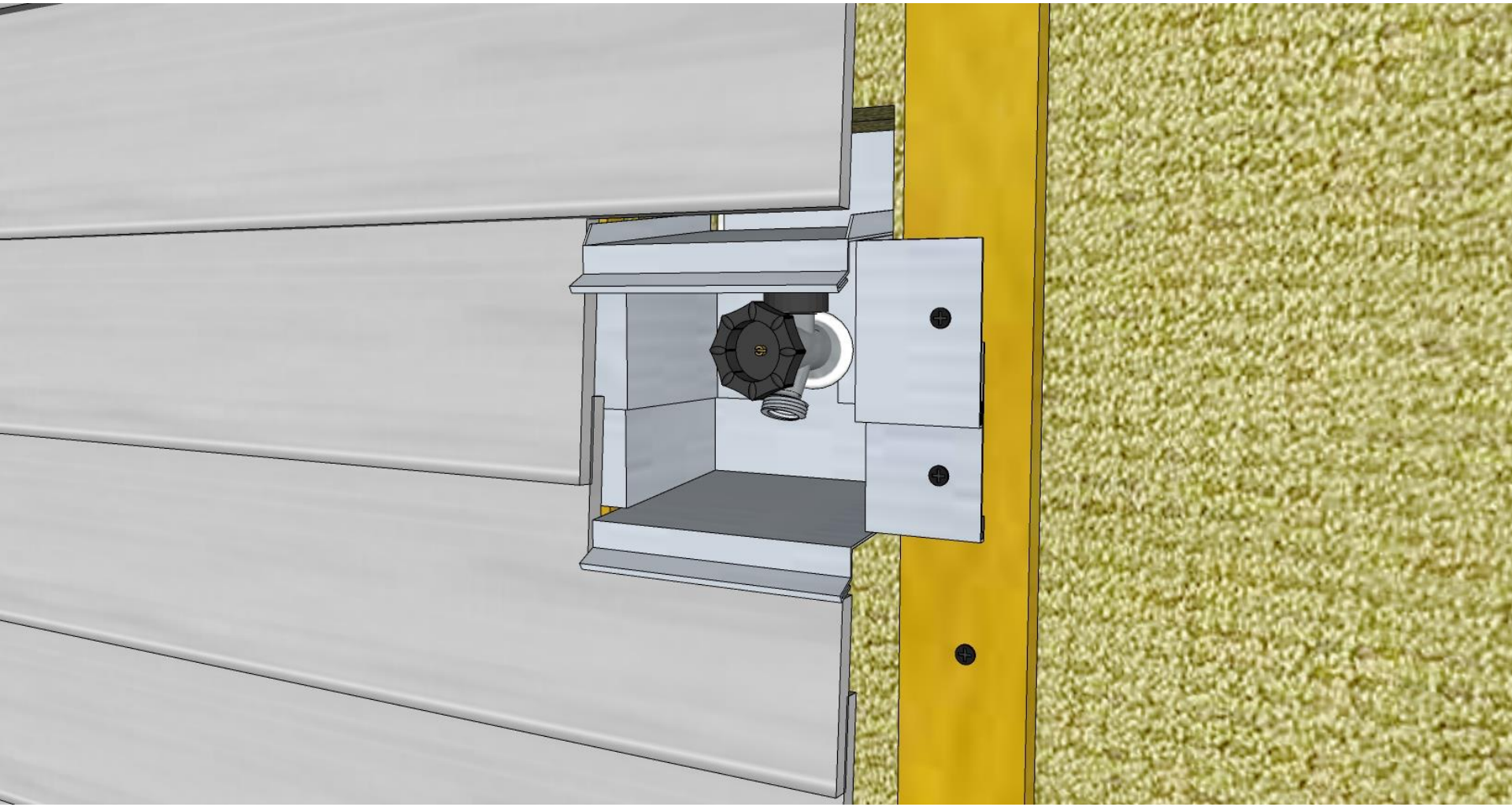


Exterior Light Fixture

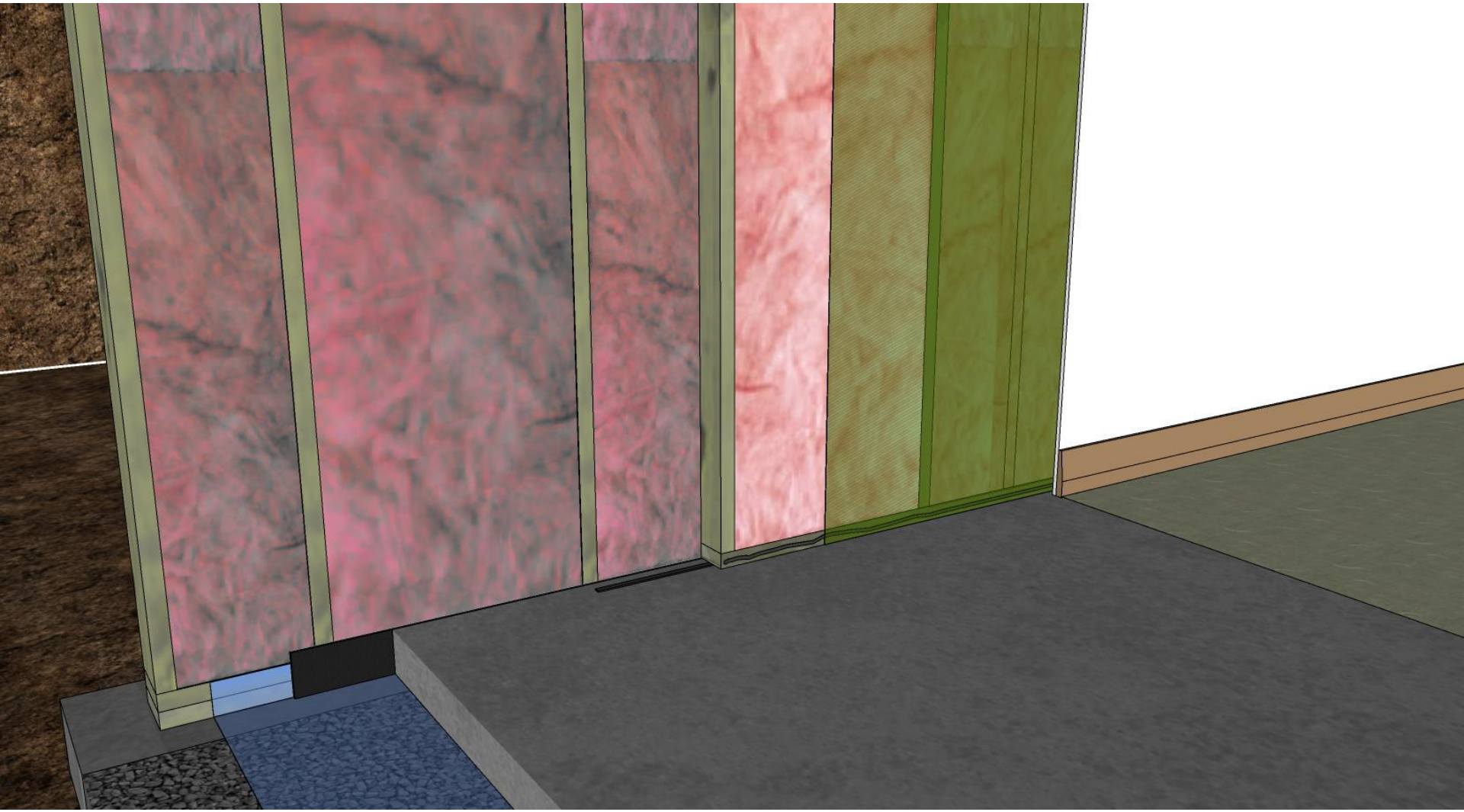


Exterior Electrical Outlet

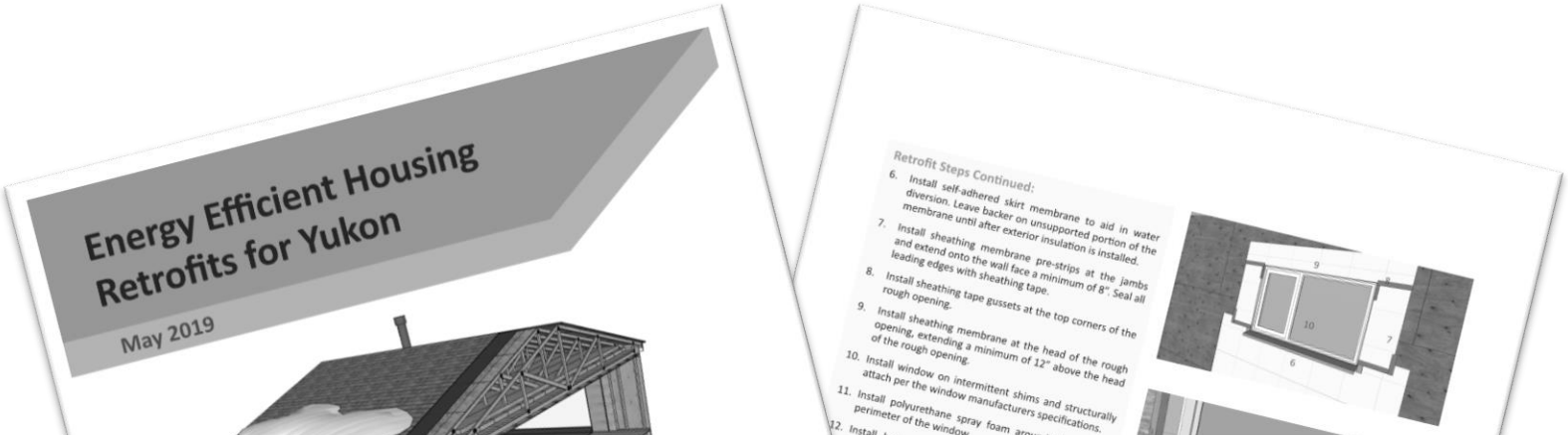
Hose Bib



Interior Insulated Foundation



Energy Efficient Housing Retrofits for Yukon



WE LOOK FORWARD TO YOUR FEEDBACK

Discussion + Questions

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