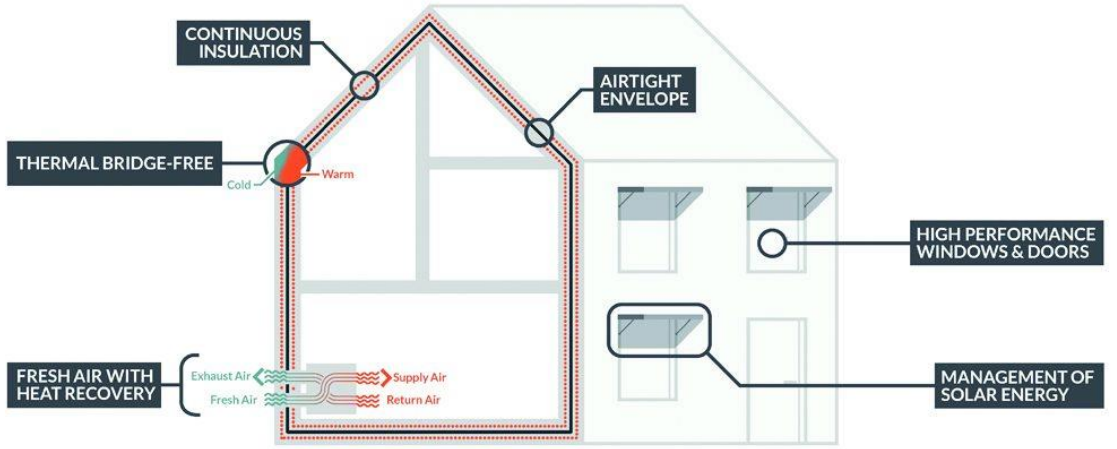
PASSIVE HOUSE BASICS

The Building Envelope



PASSIVEhouse MASSACHUSETTS

www.PHMass.org | Aaron@PassiveHouseMA.org | Twitter @PassiveHouseMA

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The Sponsors of Energize Connecticut, and in partnership with Connecticut Passive House, are pleased to offer *Passive House & All-Electric Homes Initiative* to support workforce development and help transform the energy efficiency and building construction industries in Connecticut.

CTPH

CONNECTICUT PASSIVE HOUSE

For more information, please visit EnergizeCT.com/passive-house
or email PassiveHouseTrainingCT@icf.com

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Take energy efficiency to a new level

Residential New Construction Passive House Multi-family buildings with five units or more

PASSIVE HOUSE INCENTIVE STRUCTURE FOR MULTI-FAMILY (5 UNITS OR MORE)				
Incentive Timing	**Activity**	**Incentive Amount**	**Max Incentive (Per Unit)**	**Max Incentive (Per Project)**
Pre-Construction	Feasibility Study[1]	Up to 100% of Feasibility Study Costs	N/A	$5,000.00
	Energy Modeling[2]	75% of Energy Modeling Costs (Before 90% Design Drawings)	$500.00	$30,000.00
		50% of Energy Modeling Costs (90% Design/50% Construction)	$250.00	$15,000.00
Post Construction	Certification[3]	Up to 100% of Certification Costs	$1,500.00	$60,000.00

1. Feasibility Study will require documentation in the form of a Feasibility Study report and invoice from the Passive House Consultant
2. Incentives will only be awarded prior to 50% Construction Drawings for Passive House projects. No incentives will be granted after 50% Construction Drawing set.
3. Certification may be either through PHIUS, PHI, or EnerPHit certification offerings.

Next steps you can take...
Contact your Energy Efficiency Representative or

Go to EnergizeCT.com or call 1-877-WISE USE for more details.

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	LEVEL 1		LEVEL 2	
	Single Family (Detached Dwellings)	Multifamily (Attached Dwellings)	Single Family (Detached Dwellings)	Multifamily (Attached Dwellings)
Total UA Alternative Compliance or HERS Index Score †	Total UA ≥ 7.5% better than 2021 IECC or HERS Index Score ≤ 55		Total UA ≥ 15% better than 2021 IECC or HERS Index Score ≤ 45	
Heat pump for space heating ††	Required		Required	
Space Conditioning Connectivity & Controls †††	Optional		Required	
Heat pump for water heating	Required	Optional	Required ††††	
Hot Water Distribution †††††	Required		Required	
Envelope Infiltration Rate (ACH)	ACH50 ≤ 2.5	CFA > 850ft2: ACH50 ≤ 4.0 CFA < 850ft2: ACH50 ≤ 5.0	ACH50 ≤ 2.0	CFA > 850ft2: ACH50 ≤ 3.0 CFA < 850FT2: ACH50 ≤ 4.0
Duct Leakage Rate (CFM)	2021 IECC code minimum requirements		All ductwork must be located in conditioned space	
Balanced Ventilation Systems	Optional		Required HRV/ERV (≥70% SRE / ≥40% TRE)	
Induction Cooking	Optional		Required †††††	Optional
Electric Vehicle Readiness †††††††	Required		Required	

ALL-ELECTRIC HOME INCENTIVE STRUCTURE		
	Level 1	Level 2
Single Family	$7,500	$10,000
Single Family Attached	$3,000	$5,000
Multifamily	$1,500	$2,500

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Thank You

For more information, please visit EnergizeCT.com/passive-house
or email PassiveHouseTrainingCT@icf.com








Photo Credit: www.SGBUILD.com

How A Texas Passive House Survived the 2021 Deep Freeze

Monday morning at 1:00 a.m., the power went out, and when they woke that morning, it was 9°F outside and 62°F inside.

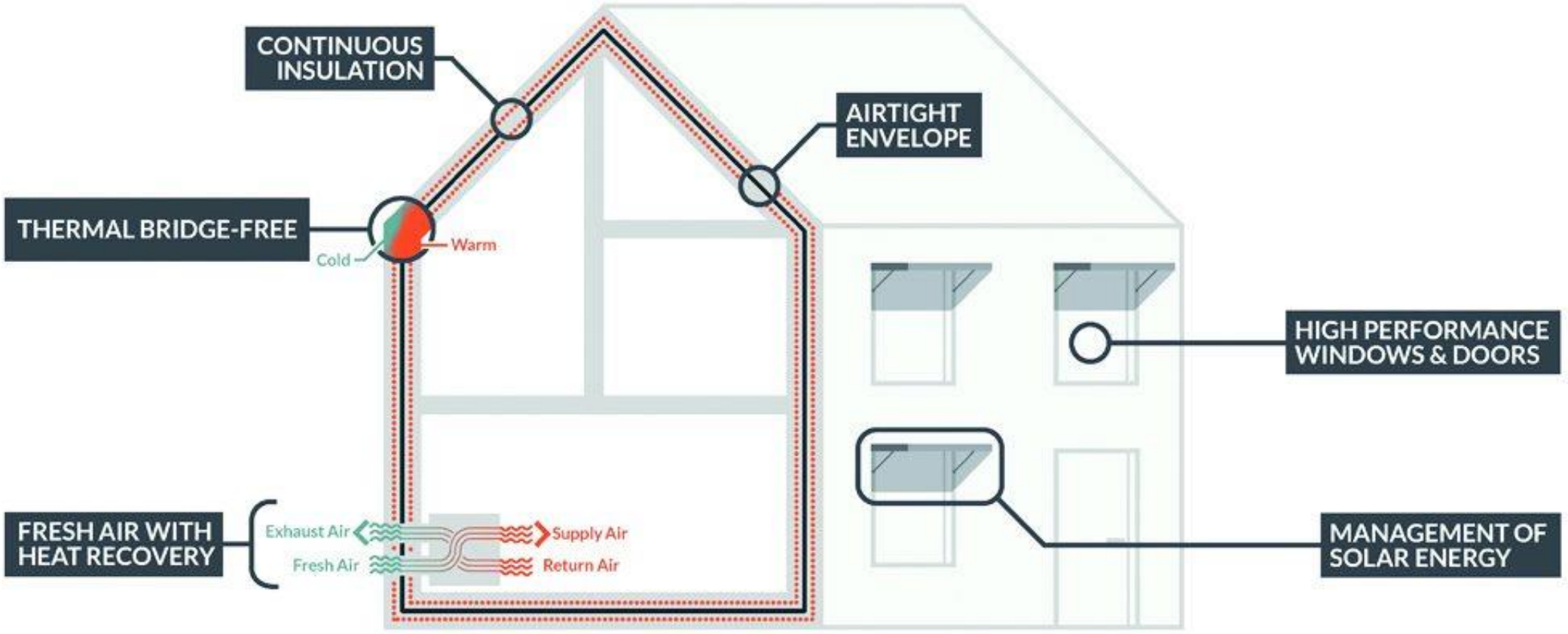
At our neighbor's house, which was identical to ours [before the Passive House retrofit], it was 36°F. They may as well have been living in a tent."

https://www.buildwithrise.com/stories/texas-passive-house-weathered-the-2021-storm

Conventional Building Envelopes

Source: BobVila.com

Passive House Building Envelopes



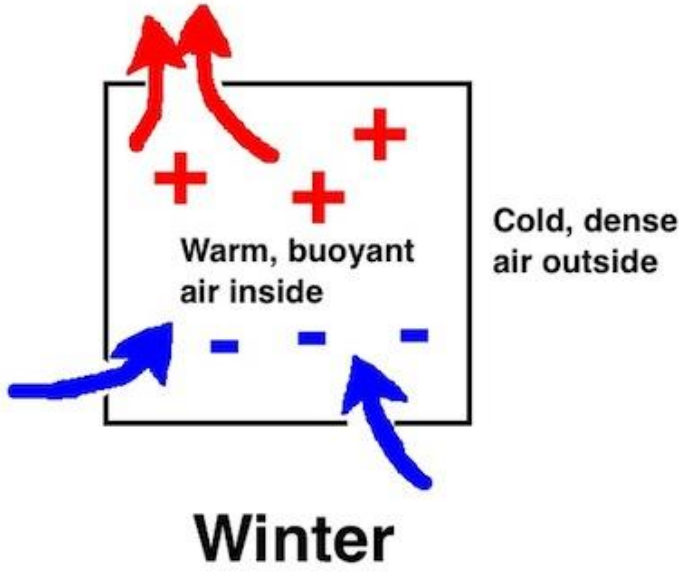
Building Science Basics

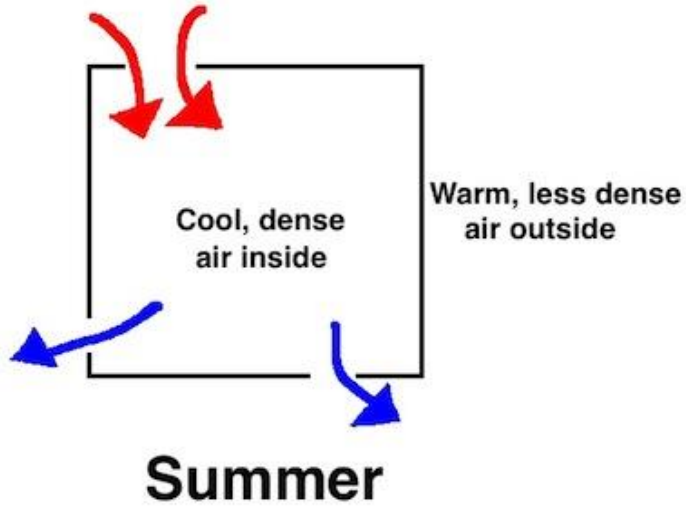
Air Pressure and **Thermal Temperature** want to be in balance

- Thermal energy moves due to temperature differences (from hot to cold)
- Air moves due to pressure differences (high to low) and density

In a building (in winter):

- Hot air will rise and move outside through gaps in the attic, roof, and top floors
- Cold air will then be drawn through gaps in the basement and lower floors
- At the same time heat will conduct through materials with low thermal resistance





Building Science Basics

The building envelope **provides air and thermal barriers** to reduce this movement

- Some materials can provide thermal resistance (insulation)
- Others act as thermal conductors/bridges (studs)
- Gaps in the envelope or in the material themselves allow air to move through
- R-Value is the measure of a material or envelope's thermal resistance (higher is better)
- R-Value *does not* measure air movement

Liquid Water and **Water Vapor**

- Liquid Water moves primary by gravity (flows down)
- Water can also be moved by suction forces from materials (like a sponge)
- Water Vapor moves by diffusion from high pressure to low pressure
- Some materials can be barriers to liquid water while being open to diffusion of vapor
- Perm Rating is a measure of a materials vapor permeability (lower is less permeable)

Four Control Layers

Thermal (Heat):

Reduces thermal conduction of heat through materials by using insulation and thermal bridge mitigation (the sweater over the building)

Air:

Reduces uncontrolled movement of heat, water, and pollutants in the air through holes and gaps in the envelope (the wind breaker?)

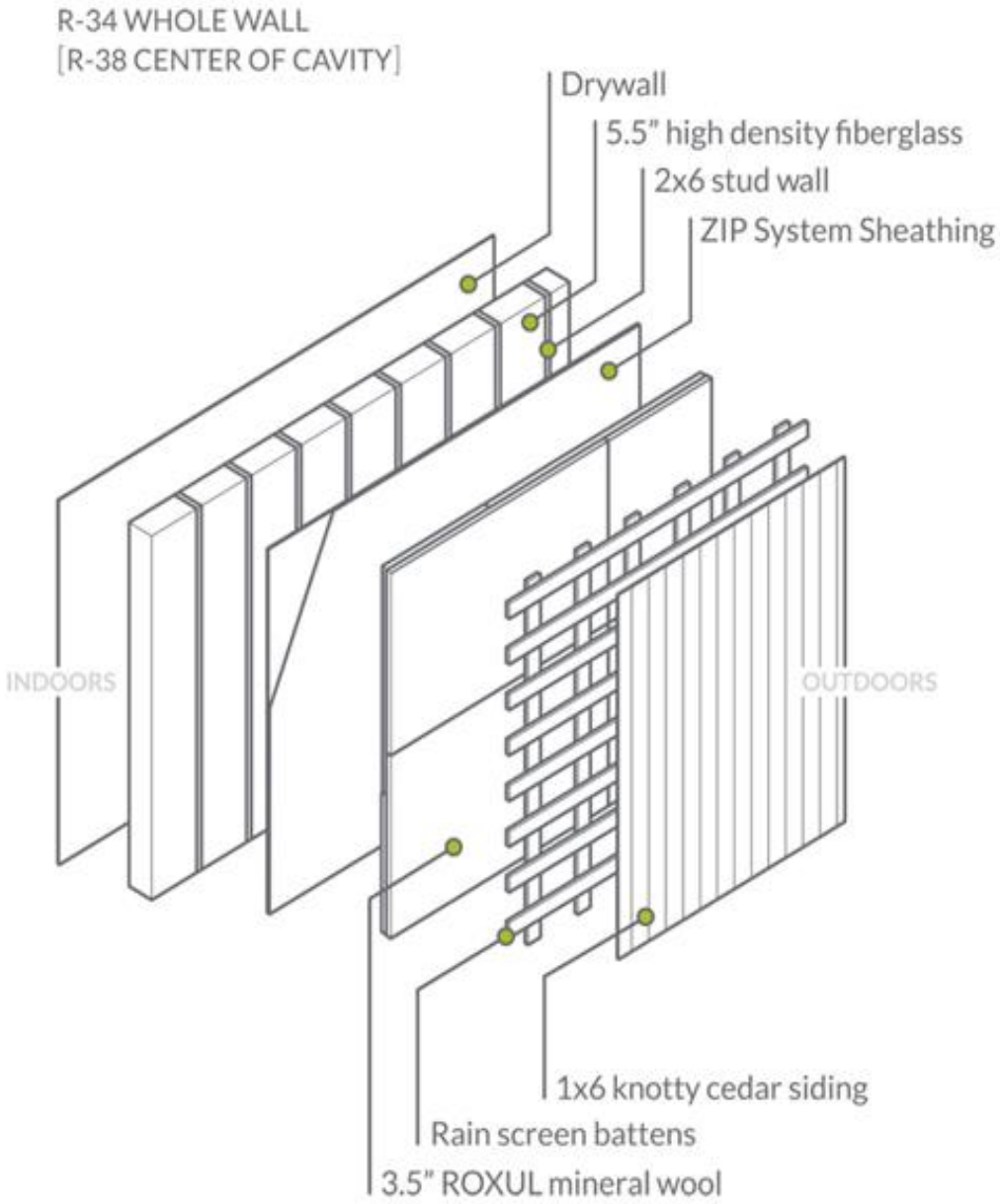
Vapor:

Manages how water vapor moves through the envelope and keeps from being trapped inside the assembly

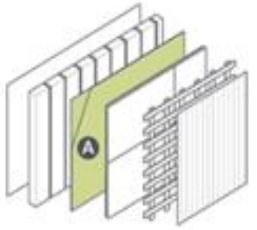
Water:

Keeps the building dry and, when it does get wet, allows it to dry out

Four Control Layers

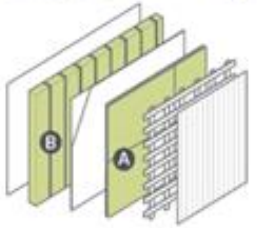


AIR MANAGEMENT



Ⓐ ZIP Sheathing

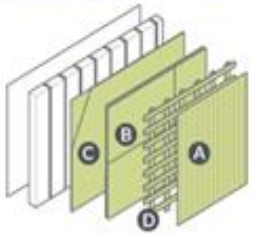
HEAT MANAGEMENT



Ⓐ 3.5" of exterior mineral wool insulation (R-14)

Ⓑ 5.5" of high density fiberglass insulation (R-23)

WATER MANAGEMENT



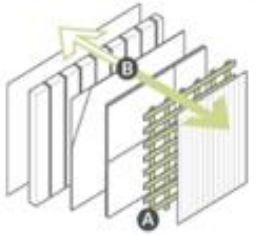
Ⓐ Primary barrier: Siding

Ⓑ Secondary barrier: ROXUL mineral wool

Ⓒ Final barrier: ZIP Sheathing

Ⓓ Rain screen allows bulk water to drain away

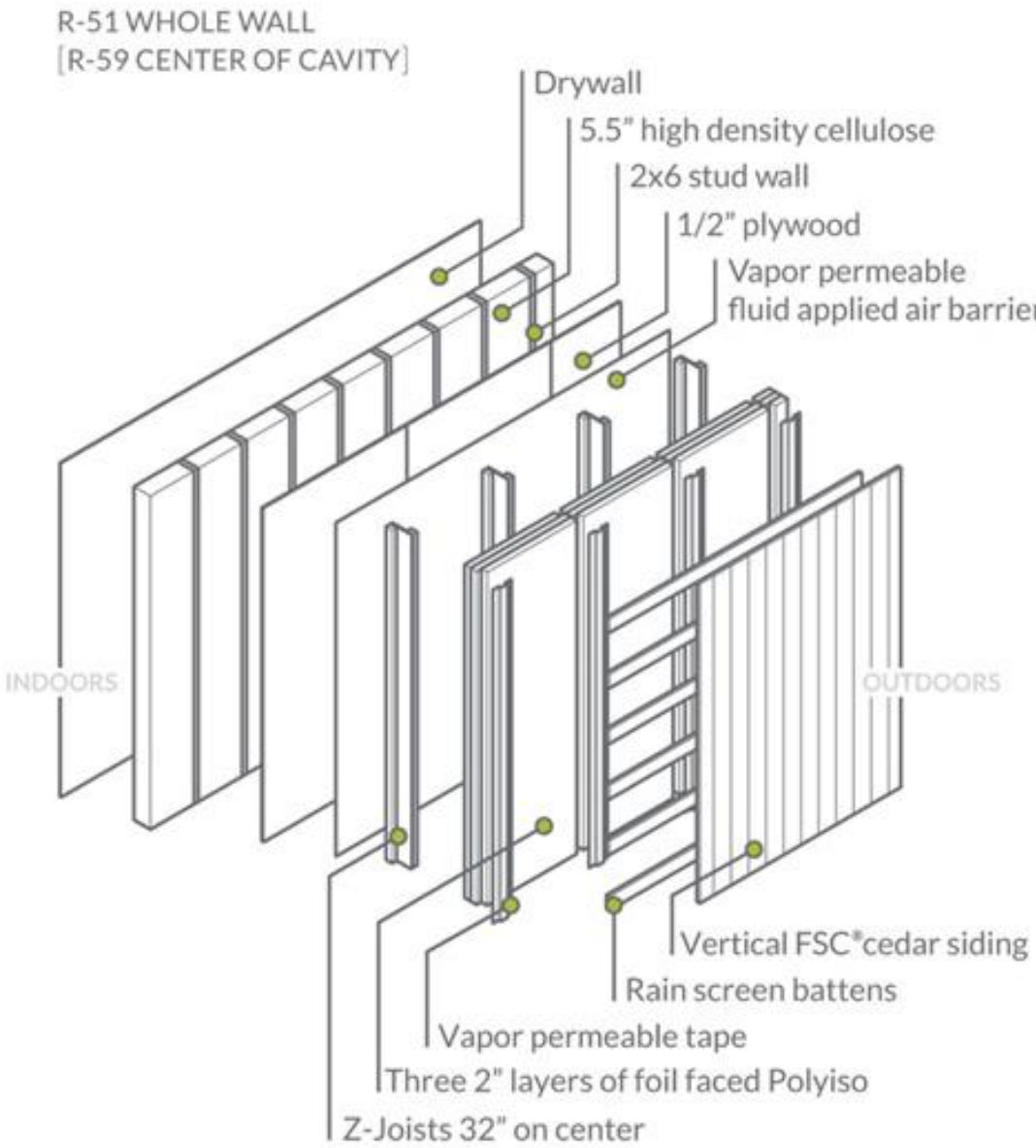
VAPOR MANAGEMENT



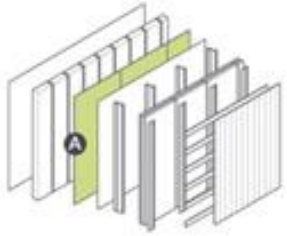
Ⓐ Rain screen dries cladding and the assembly

Ⓑ The assembly is vapor open in both directions; though the ZIP Sheathing is a vapor retarder, slowing vapor movement from interior into assembly. Mineral wool also warms sheathing, which encourages vapor diffusion.

Four Control Layers

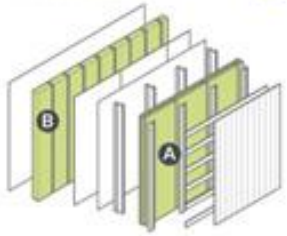


AIR MANAGEMENT



Ⓐ Air barrier: Fluid applied air barrier on plywood

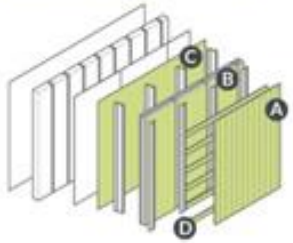
HEAT MANAGEMENT



Ⓐ Three layers of Polyiso exterior insulation (R-36)

Ⓑ High-density cellulose in stud cavity (R-21)

WATER MANAGEMENT



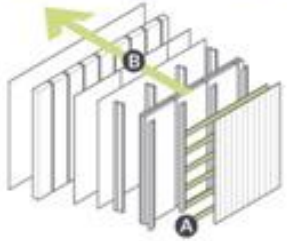
Ⓐ Primary barrier: Siding

Ⓑ Secondary barrier: Foil face of Polyiso

Ⓒ Final barrier: Face of fluid applied air barrier

Ⓓ Rain screen allows bulk water to drain away

VAPOR MANAGEMENT



Ⓐ Rain screen dries cladding and interrupts capillary action into the assembly

Ⓑ The assembly is vapor-open to the inside. The sheathing is kept warm by thick layer of Polyiso, preventing moisture accumulation.

Elements of the Building Envelope

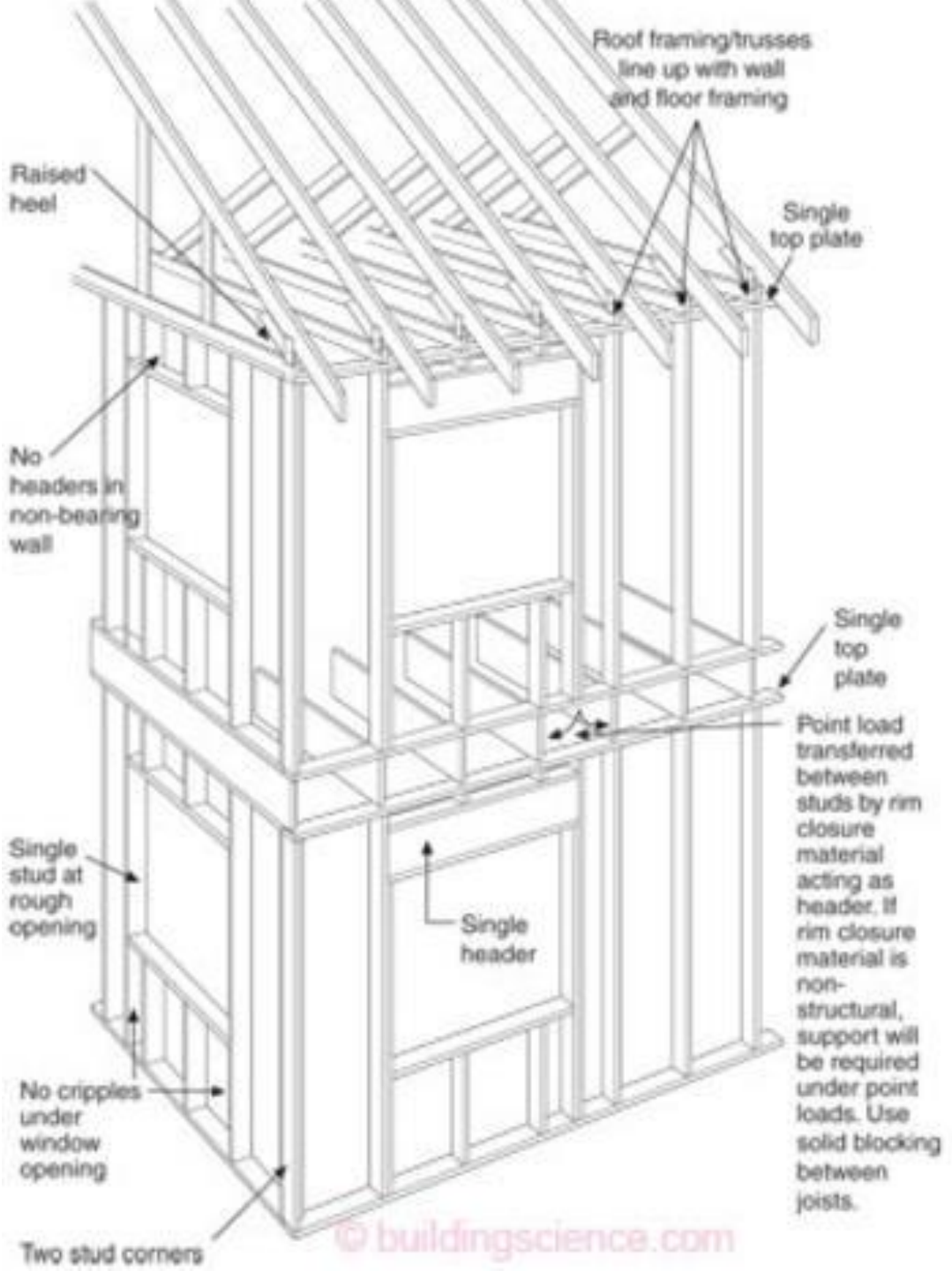
- Advanced Framing
- Cavity Insulation
- Exterior Insulation
- Air Tight Barrier
- Thermal Bridge Mitigation
- Water and Vapor Control

Advanced Framing

Main Goals:

- Reduce thermal bridging from wall studs, headers, etc.
- Create more space for cavity insulation

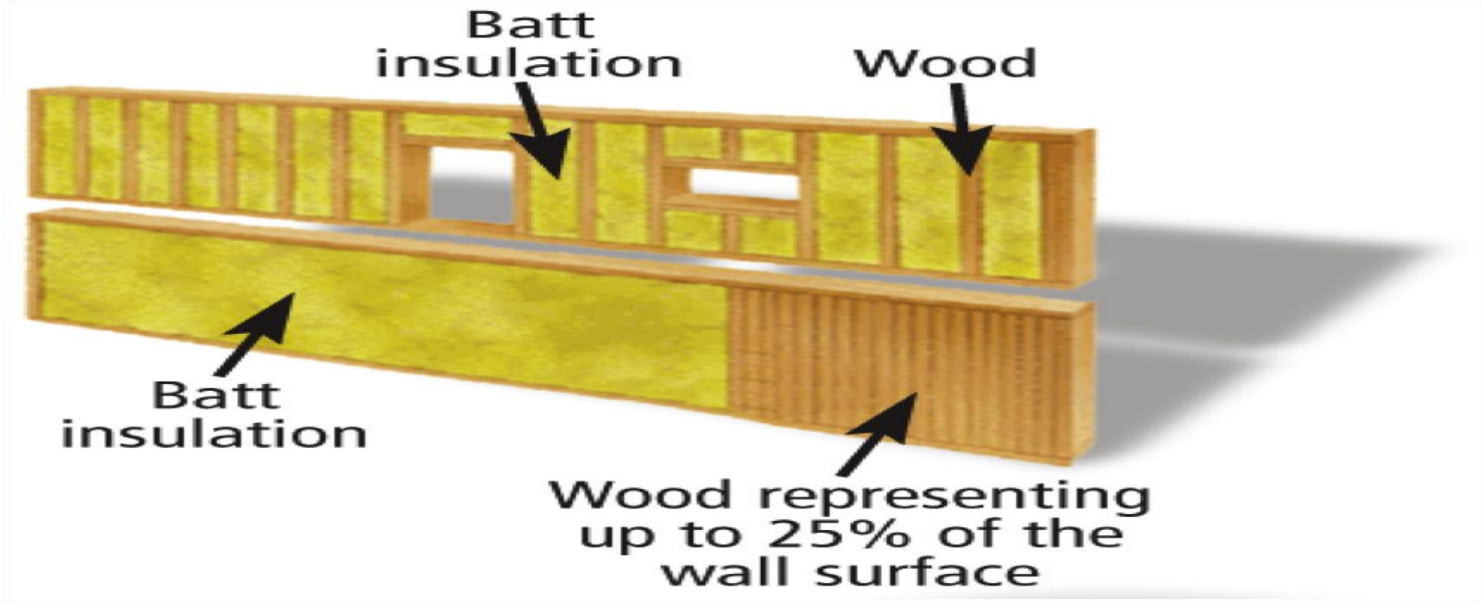
Bonus: can reduce costs by reducing lumber usage



Advanced Framing

Studs

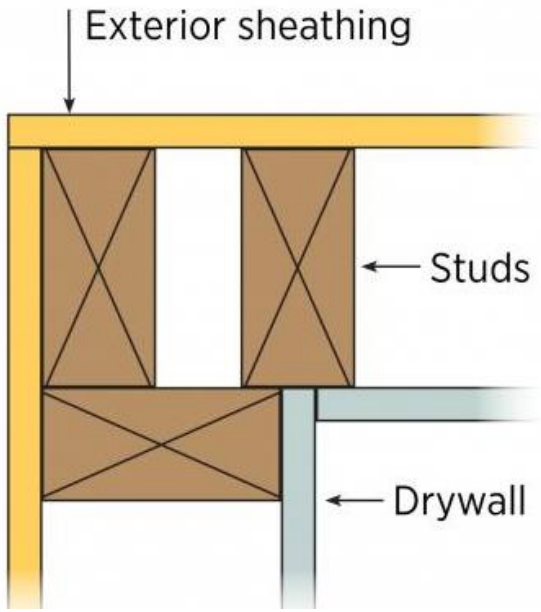
Frame wall studs (plus joists and rafters) at 24” on center (vs 16”)



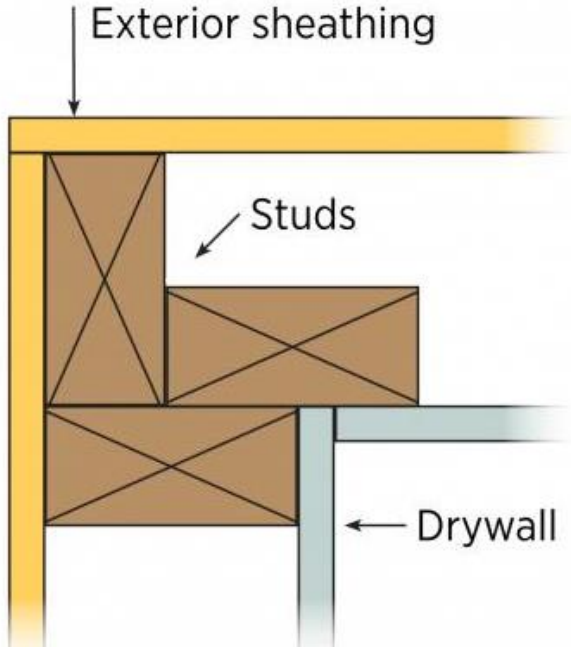
In a house traditionally framed 16” on-center with R-19 insulation in walls, the actual effective R-value would only be R-12 at best after factoring in R-1 wood studs and supports

Advanced Framing

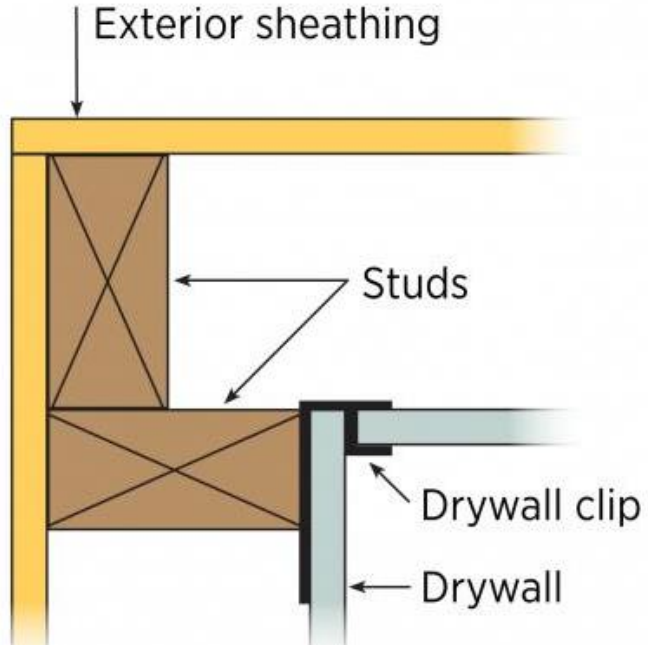
Corners



Typical Framing



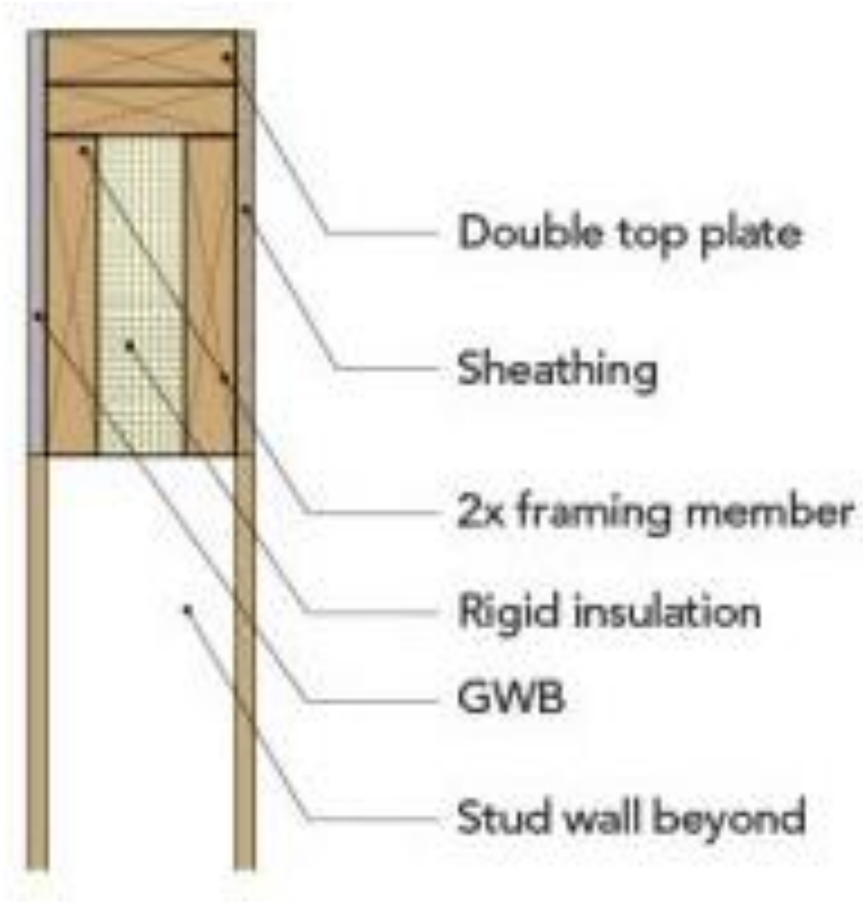
Advanced Option 1

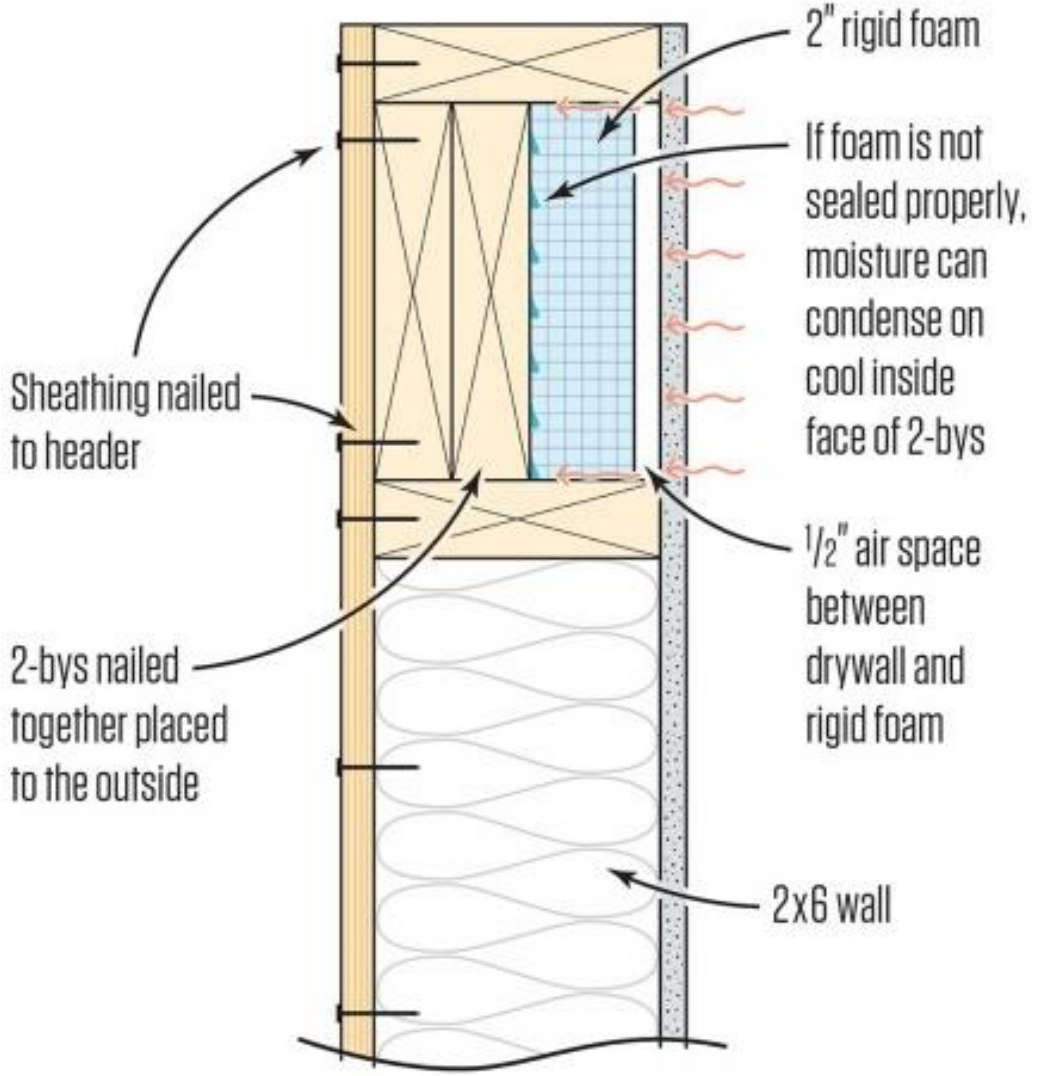


Advanced Option 2

Advanced Framing

Headers





https://www.greenbuildingadvisor.com/article/better-energy-efficiency-with-insulated-headers

https://www.jlconline.com/how-to/insulation/insulated-headers_o

Cavity Insulation

Main Goal:

- Provide part of the thermal barrier of the building (along with exterior insulation)

Cavity Insulation

Fiberglass

Mineral Wool

Cellulose

Spray-Foam

Cavity Insulation

Proper installation is critical:

- Dense-packed insulation will settle if installed at a lower density than required
- Batts must be sized currently for the cavity to gaps at sides
- Looser insulation can get compressed during install, reducing performance
- Spray foam may not expand to desired thickness

Exterior Insulation

Main Goals:

- Provide part of thermal barrier (along with cavity insulation)
- Reduce impact of thermal bridges within the assembly

Exterior Insulation

Mineral Wool Boards

Polyiso

Wood Fiber Boards

EPS/XPS Foam

Exterior Insulation

Before continuous insulation

After continuous insulation

Finch Cambridge

Exterior Insulation

- Type of insulation will be driven by costs, familiarity, and project goals (such as reducing embodied carbon)
- Amount of insulation will be determined with energy modeling (WUFI or PHPP) and will take into account internal heat loads, thermal bridging, and other factors

Distillery
- 3” Mineral Wool

Finch Cambridge
- 2” Mineral Wool

Wheaton College
- 5” Mineral Wool

Air Barrier

Main Principles:

- Continuous air barrier around building
- Eliminate air gaps, holes, etc. in barrier
- Taped seems, penetrations, etc
- Target metric is measured with blower door test

Finch Cambridge
Siga Majvest 500 (blue) and tape (white)

Air Barrier

Taped Sheathing

Membrane Sheet

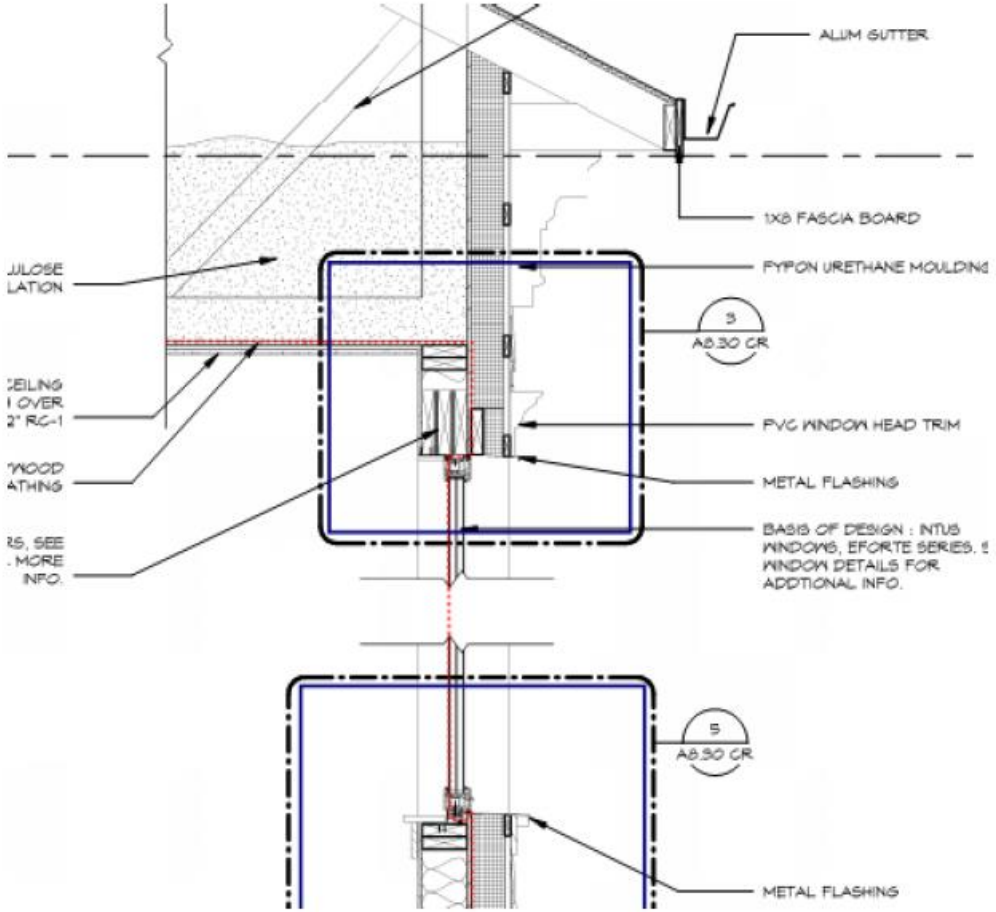
Fluid-applied

Vaporized Sealant

Air Barrier

Air Barrier needs to be continuous!

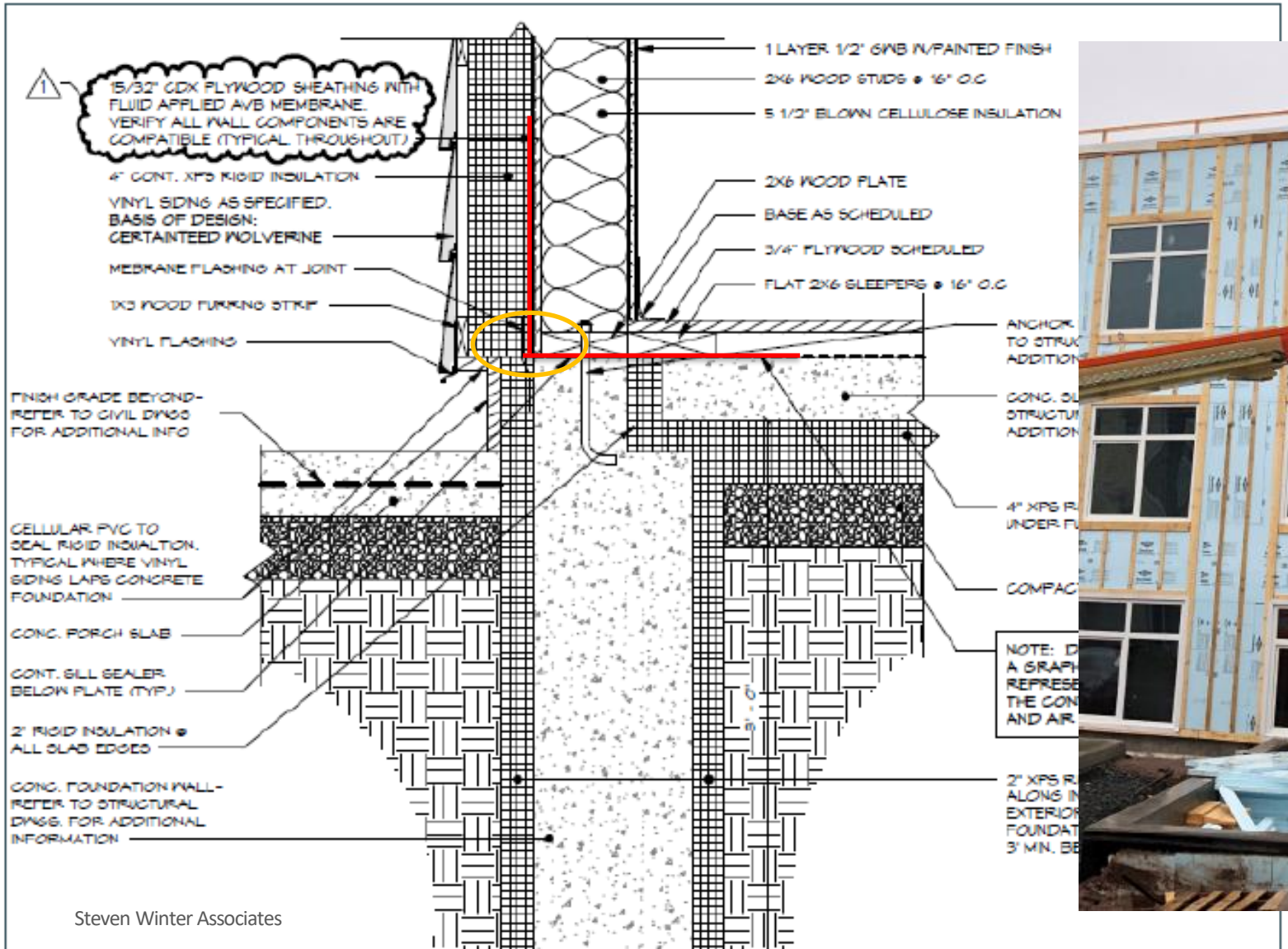
- Red Line Test – can you follow the air barrier without lifting your pencil?



Air Barrier

Continuous Air Barrier

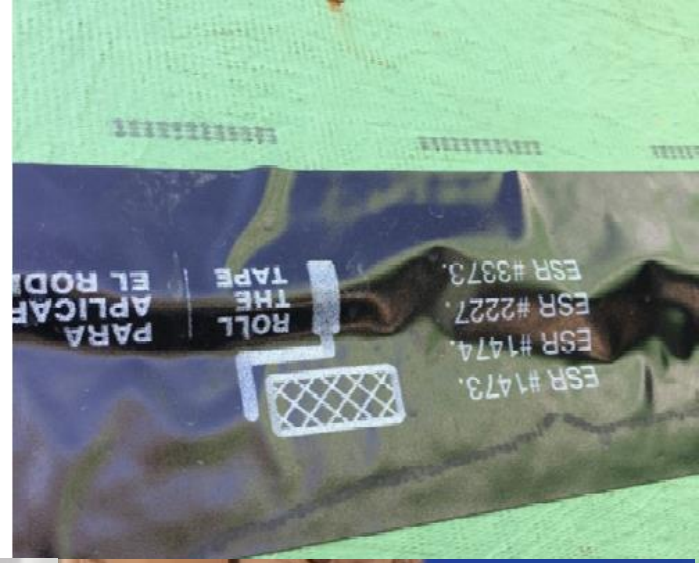
- Watch the critical connections (floor to wall, etc.)



Steven Winter Associates

Air Barrier

- Watch out for penetrations, transitions, and proper taping



Finch Cambridge
Air sealing around windows and penetrations, taped seams

Air Barrier

- Use recommended products including tapes and seals

Air Barrier

- Pay attention to install sequencing and proper layering of the air barrier

Air Tightness Standard

Building Energy Code

3

ACH50

(air changes per hour at 50 Pascals)

Passive House*

0.6

ACH50

(air changes per hour at 50 Pascals)

*Passive House International (PHI)

Air Tightness Standard

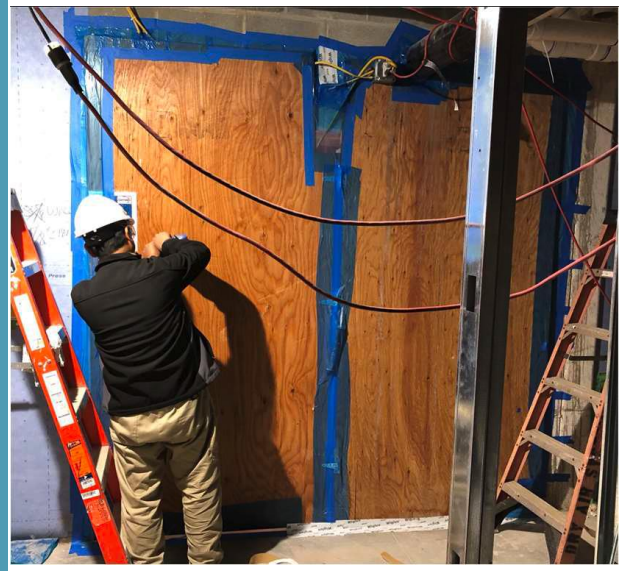
Conduct ***blower door tests*** early and often

- At minimum:
    1. Full envelope test once windows and doors are in
    2. After sheetrock is up and walls are closed
    3. Pre-occupancy for final numbers

Air Tightness Standard

Blower Door Tests – Early and Often

Harbor Village example



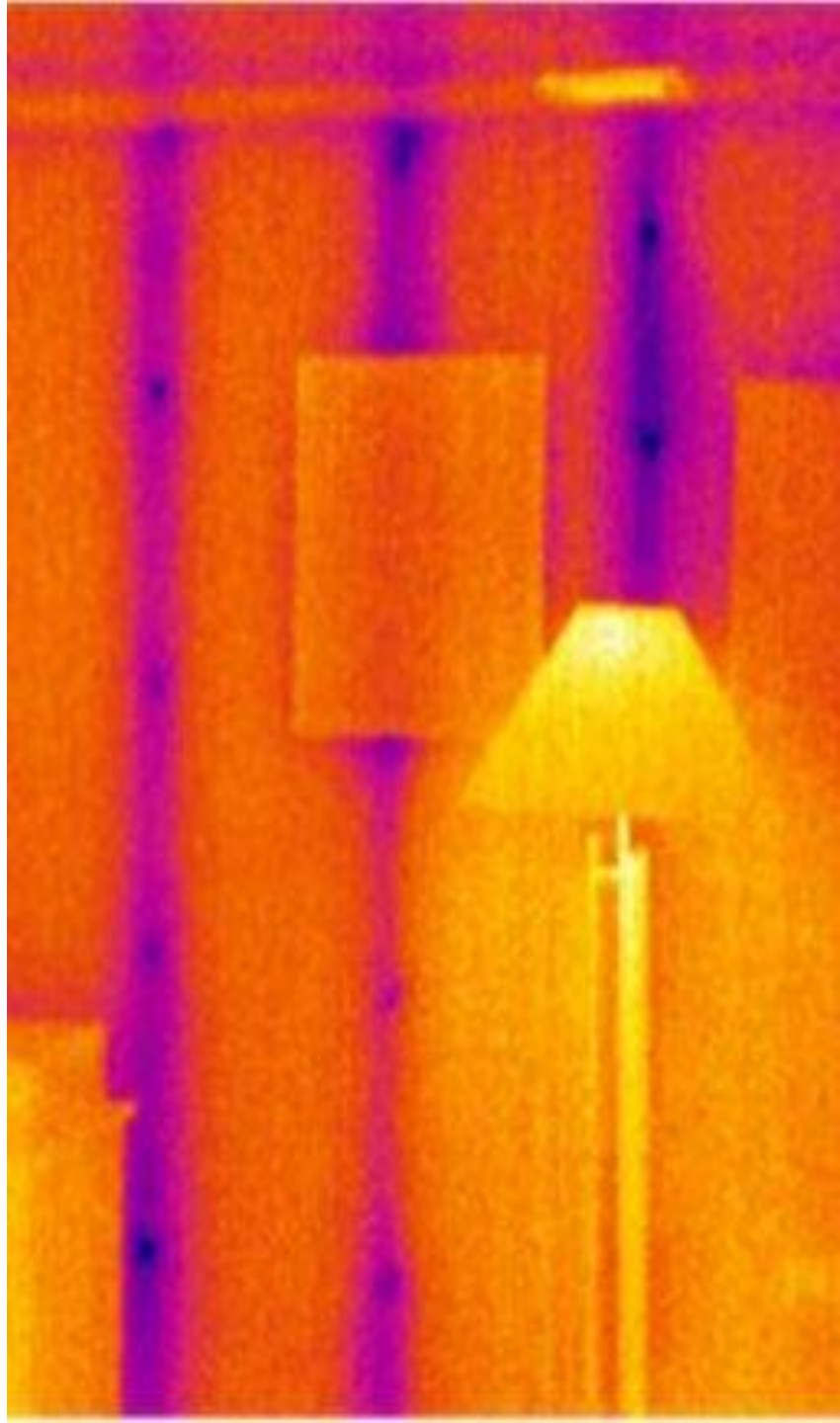
Midpoint Test 2

Photos from New Ecology, Inc

Thermal Bridging

Main Principle:

- Heat transfers through materials with higher thermal conductivity (wood studs, steel, metal fasteners, plumbing lines, etc)
- These materials create a *bridge* through the assembly between outside and inside or between other materials
- Thermal brides need to be mitigated or removed



Thermal Bridging

Thermal Bridges lead to:

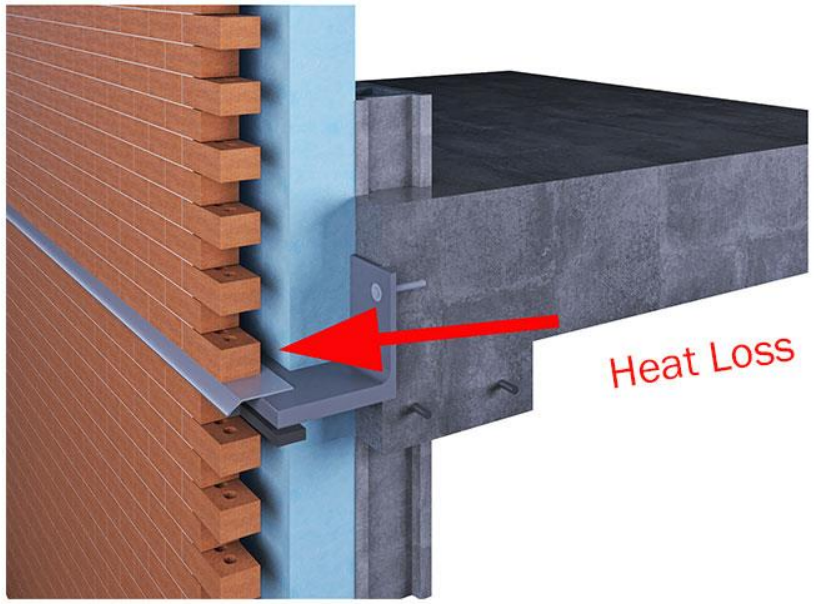
- Heat loss
- Low surface temps
- Impaired thermal comfort
- Risk of condensation
- Risk of mold growth

Areas of Concern:

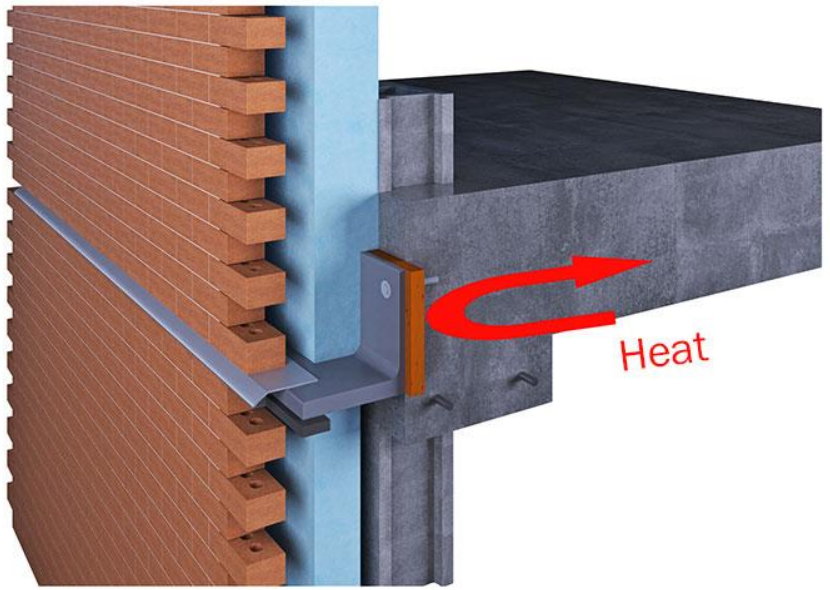
- Weak points in insulation (studs)
- Wall penetrations (plumbing, electrical)
- Beams that meet or pass through a wall
- Outside features attached to wall (balcony, awning)
- Corners
- Window frames

Thermal Bridging

Thermal Breaks



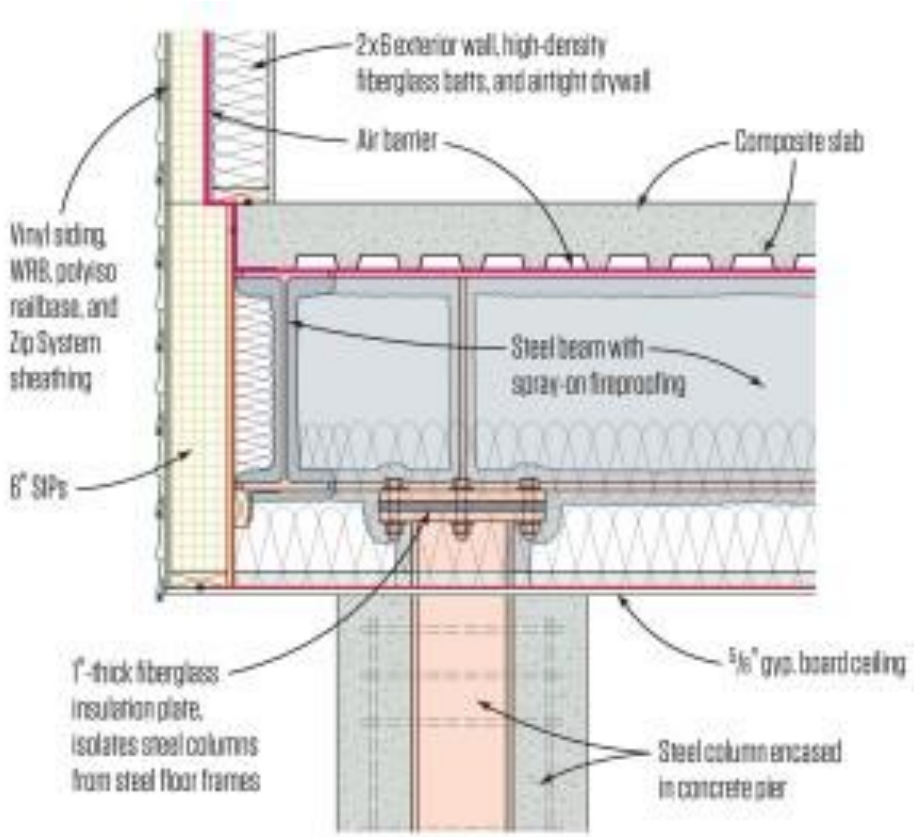
Without Thermal Break



With Thermal Break

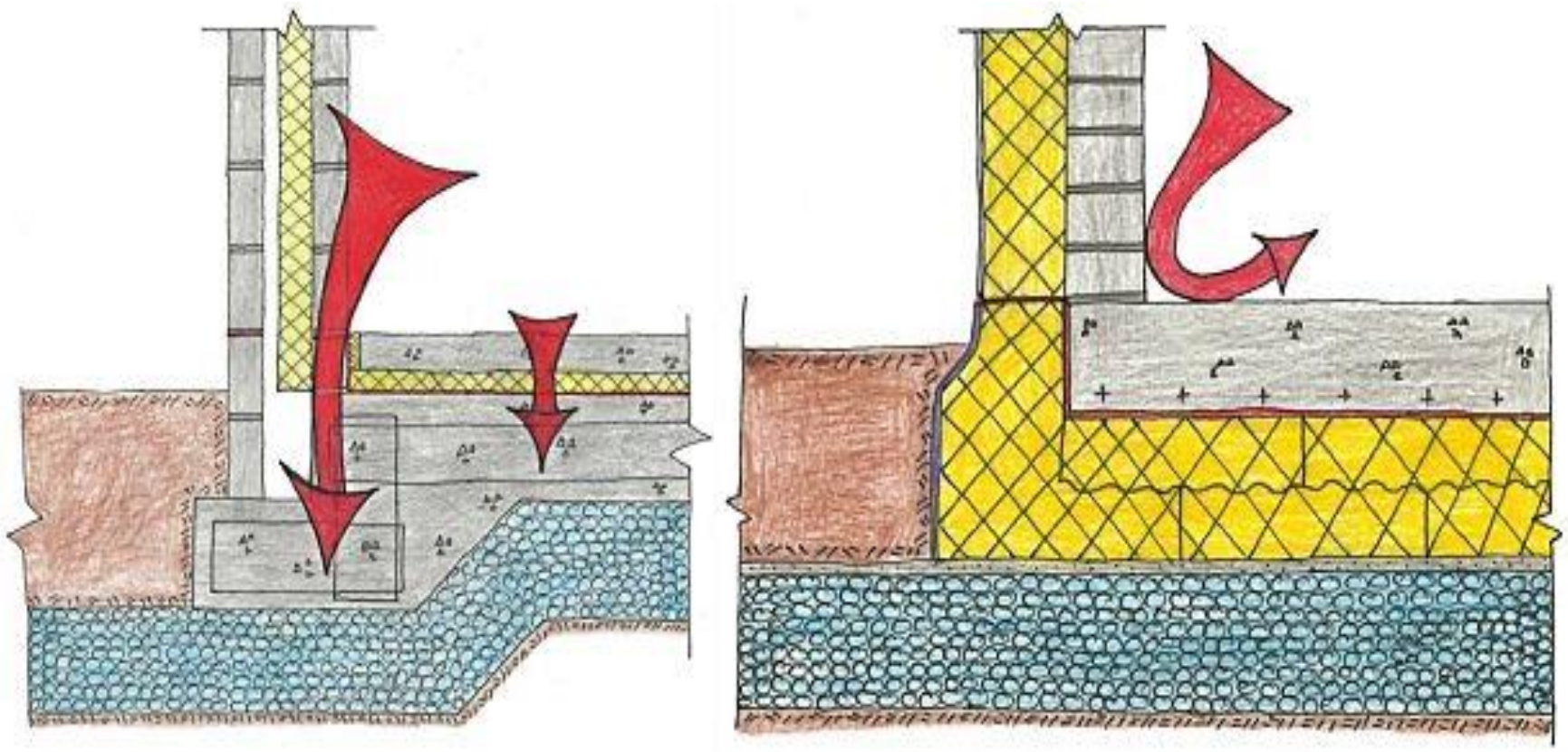
Thermal Bridging

Elm Place
Thermally Broken Steel Support



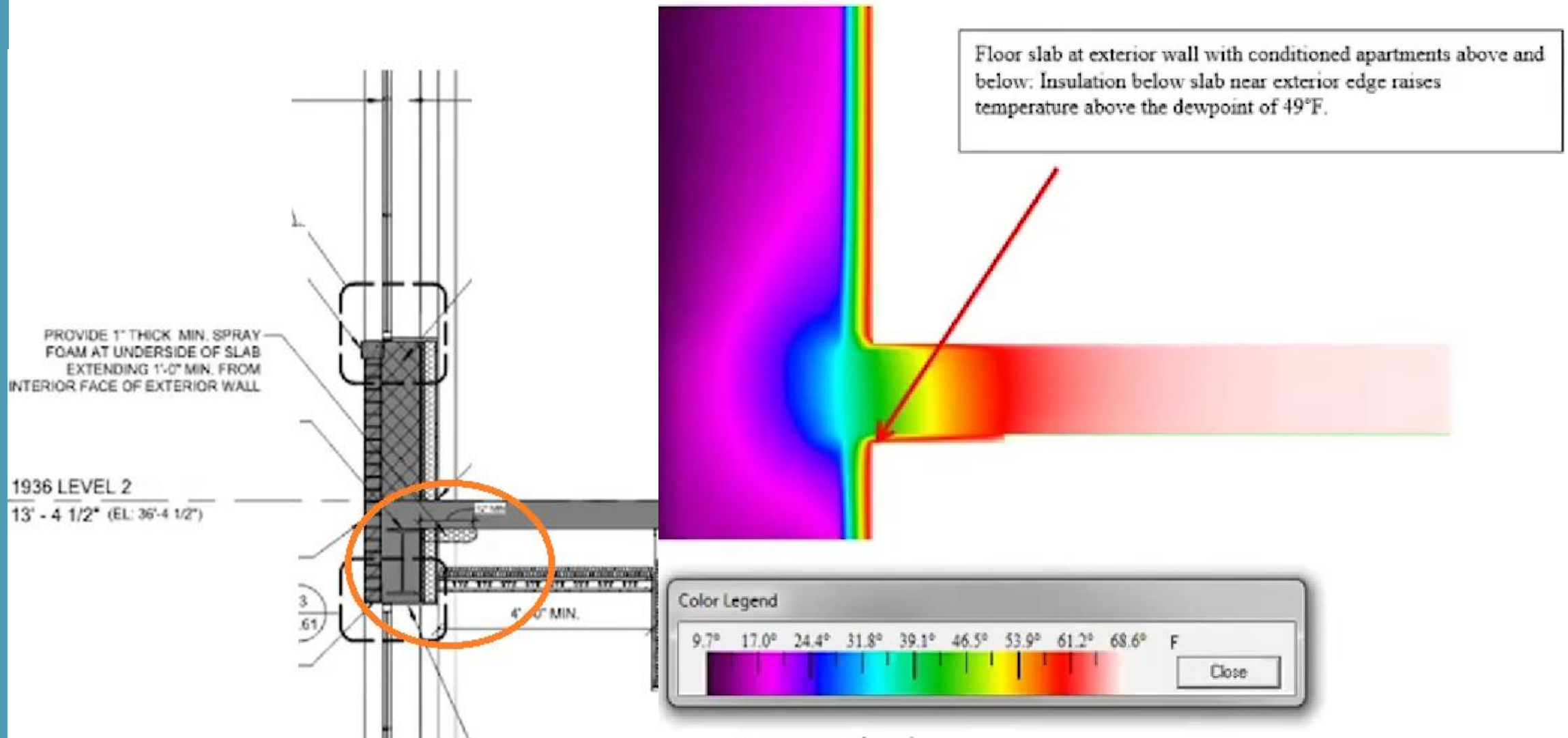
Thermal Bridging

Floor slab and foundations

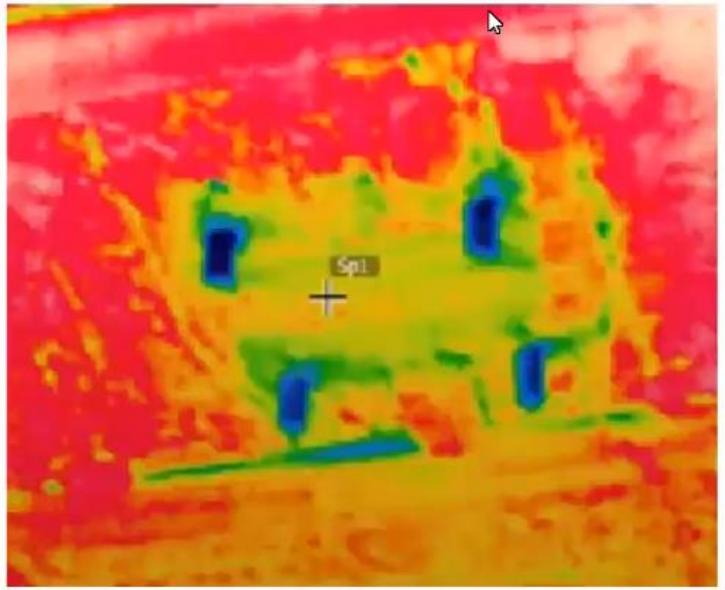


Thermal Bridging

The Tyler
Floor slab to exterior wall connections



Thermal Bridging



Finch Cambridge

Water Control

Water Always Finds A Way:

1. Bulk water
2. Capillaries
3. Air
4. Vapor diffusion

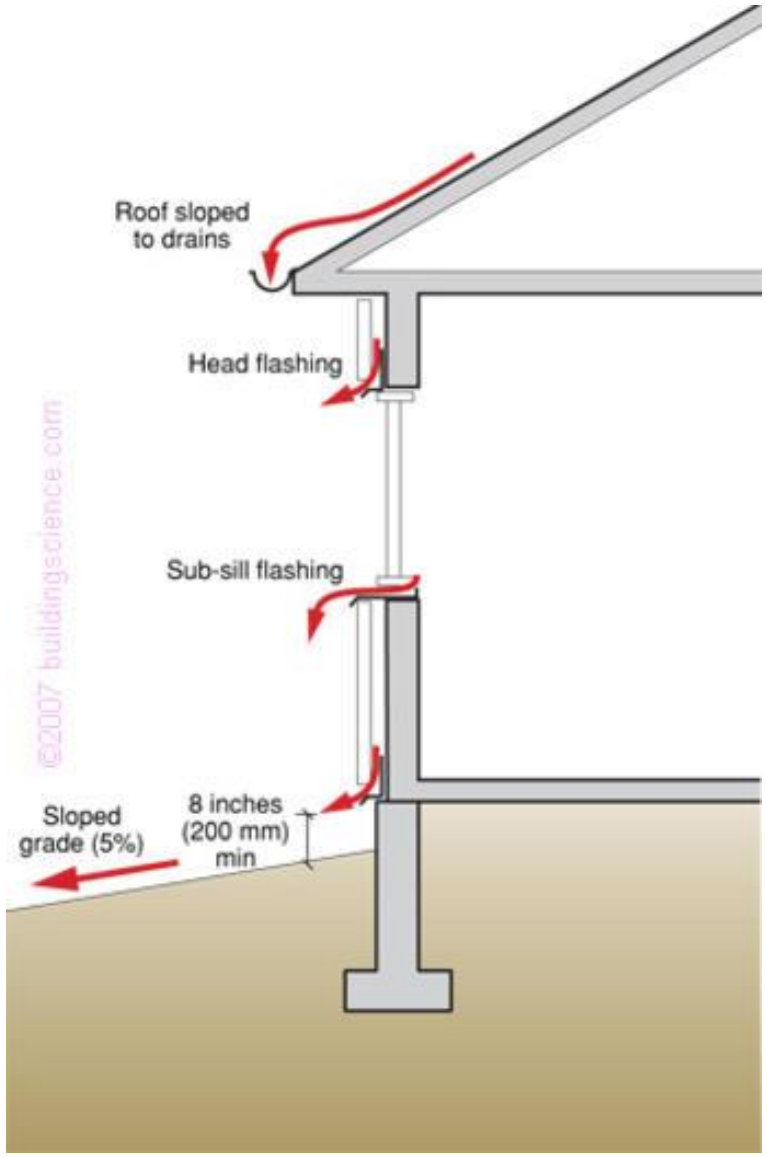
Water Control

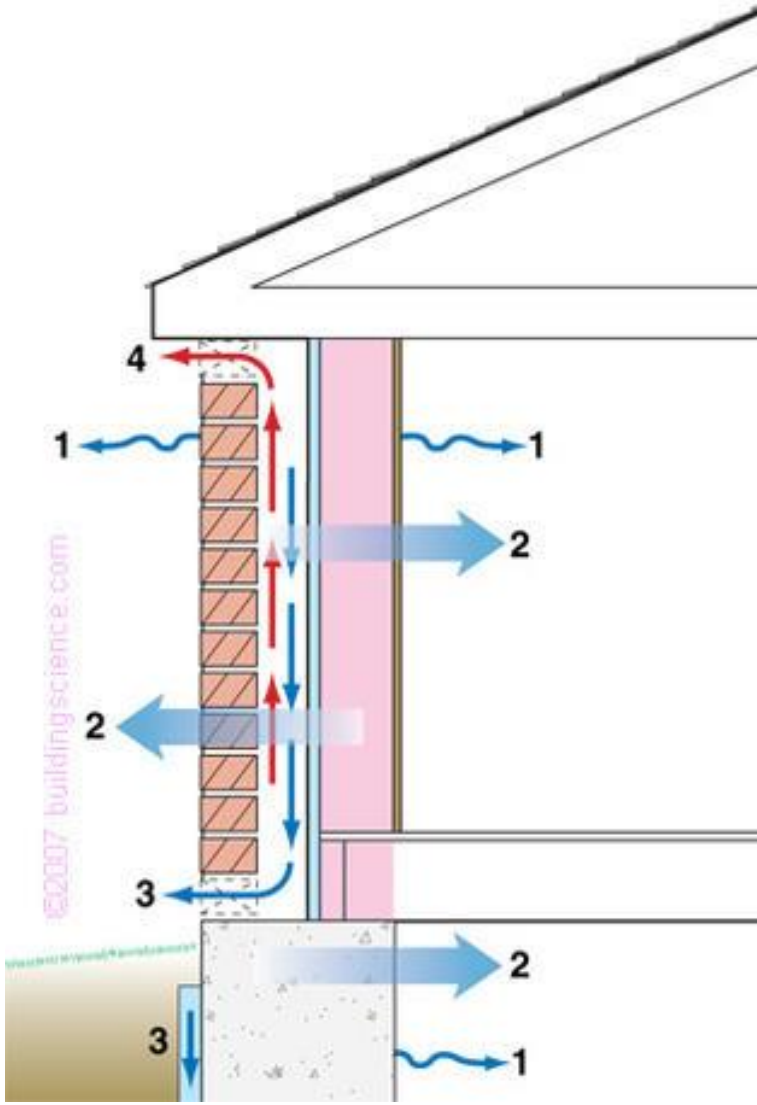
So we give it a path to follow - *and plan for it to fail:*

1. Flow off the shingles and siding and gutters

2. Drip out weeps and off sills

3. Dry out from the inside





Rainscreens

A ***rainscreen*** is a system that creates a gap ***between the siding and the water-resistive barrier*** (or exterior insulation) and promotes ***drainage*** and ***airflow*** within the wall assembly

Rainscreen with vertical strapping and coravent at top and bottom of wall

Rainscreens

Drainage Mats

Homeslicker by Benjamin Obdyke provides ¼" gap for water to drain

Vertical or Horizontal Battens

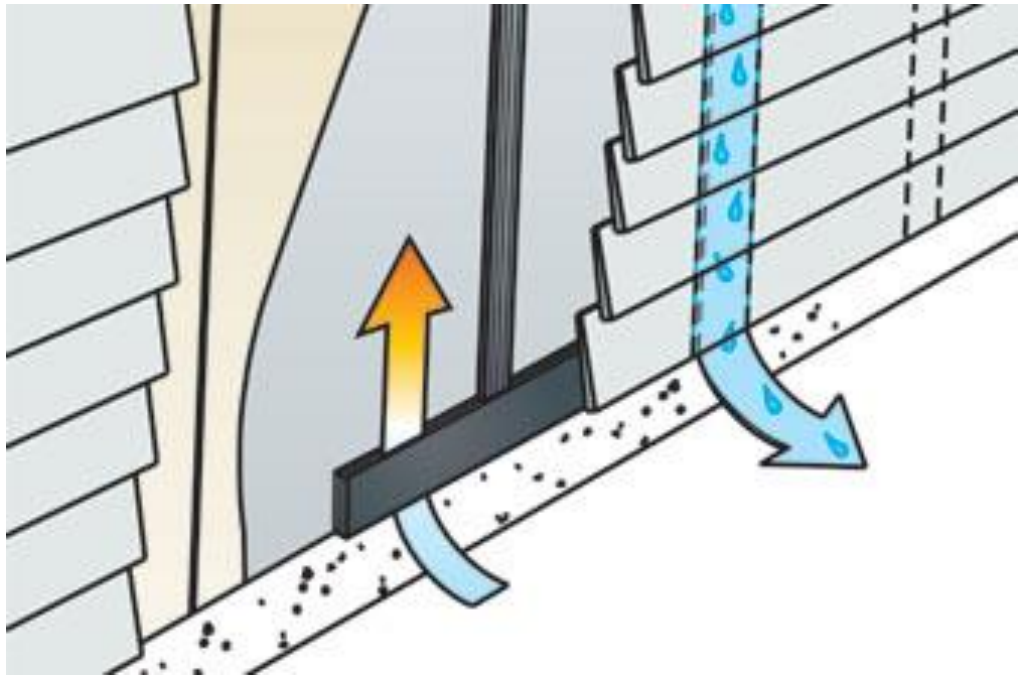
Rainscreen w/ 1x3 strapping provides ¾" drainage and ventilation gap

Rainscreens

Finch Cambridge - Cascadia Clips
The Loop – Knight Wall System
Both provide rainscreen and thermally broken siding connections

Rainscreens

- Vents are needed to allow draining and air flow



Vapor Control

- Think of steam (water vapor) in a boiling pot of water with the lid on. The water vapor under the lid is under high pressure (high relative-humidity) and the air in the room is under low pressure (low relative humidity).

- Remove the lid and the vapor immediately diffuses (or moves) from the high-pressure area to the low-pressure area

- Now imagine the lid has tiny holes that allow the water vapor in the pot (steam) to pass through it. The amount of steam that can pass through the lid is the lid's permeability. The more steam that can pass through the lid, the higher the lid's perm rating

Vapor Control

Water vapor diffuses through permeable materials from the warm (humid) side toward the cold (dry) side

Perm Ratings

Class 1 - Vapor Impermeable
0.1 perms or less

Class 2 – Vaper Semi-Impermeable
0.1 perms to 1 perm

Class 3 – Vaper Semi-Permeable
1 perm to 10 perms

Vapor Permeable (Open)
greater than 10 perms

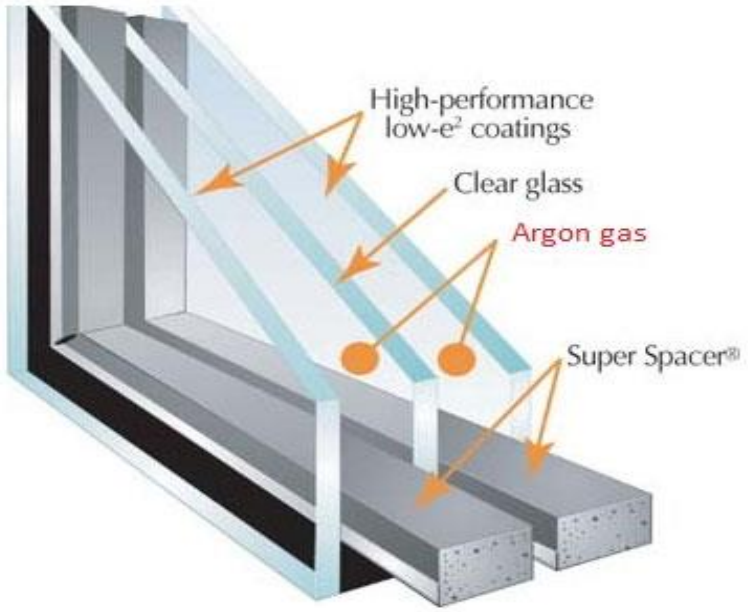
Stegohome is a Vapor Impermeable Barrier (perm <.01)

Vapor Control

- ***Smart Vapor Barriers*** are membranes with pores that expand in the high humidity and contract in low humidity, changing permeability based on the conditions
- The pores close in the winter, preventing water vapor from entering the wall assembly and condensing or “wetting” on cold surfaces (like cold sheathing)
- In the humid summer months, the pores open and allow water vapor to leave the wall-assembly to the inside where mechanical equipment can regulate humidity

Windows

- Double or Triple-glazed and gas filled between panes
- High-performance glass coating
- Spacers between glass
- Full thermal break within frame
- Weep holes for water to drain out of window assembly



Winthrop Center Curtain Wall

Winthrop Center Curtain Wall

Unitized Curtain Wall System

- Manufactured by Sotawall with Karas and Karas Glass installers
- 5-foot modules hung on inside wall
- Triple pane glass
- Vision section 0.220 U-value
- Opaque section 0.055 U-value

The Loop at Mattapan Station

Harbor Village: Dense Foam insulation over Siga Airbarrier system

Four Control Layers

Thermal (Heat):

Reduces thermal conduction of heat through materials by using insulation and thermal bridge mitigation (the sweater over the building)

Air:

Reduces uncontrolled movement of heat, water, and pollutants in the air through holes and gaps in the envelope (the wind breaker?)

Vapor:

Manages how water vapor moves through the envelope and keeps from being trapped inside the assembly

Water:

Keeps the building dry and, when it does get wet, allows it to dry out

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