PASSIVE HOUSE 201

PASSIVEhouse MASSACHUSETTS

BROUGHT TO YOU BY

PROUD SPONSORS OF

The Sponsors of Energize Connecticut, and in partnership with Connecticut Passive House and BuildGreenCT, 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.

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

BROUGHT TO YOU BY

EVERSOURCE

CNG SCG UI

Part of the AVANGRID Family

PROUD SPONSORS OF

energize CONNECTICUT CT

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.

BROUGHT TO YOU BY

EVERSOURCE CNG SCG UI

Part of the AVANGRID Family

PROUD SPONSORS OF

energize CONNECTICUT CT

BROUGHT TO YOU BY

EVERSOURCE CNG SCG UI

Part of the AVANGRID Family

PROUD SPONSORS OF

energize CONNECTICUT CT

The future of high-performance, all-electric homes starts here.

	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

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

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

BROUGHT TO YOU BY

Part of the AVANGRID Family

PROUD SPONSORS OF

Thank You

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

PASSIVE HOUSE 201

PASSIVEhouse
MASSACHUSETTS

Your local Passive House group

ctpassivehouse.org

CTPH

CONNECTICUT PASSIVE HOUSE

What did we learn before?

~~PASSIVE HOUSE~~

1. Passive Houses are not all houses
2. Passive House are not all passive

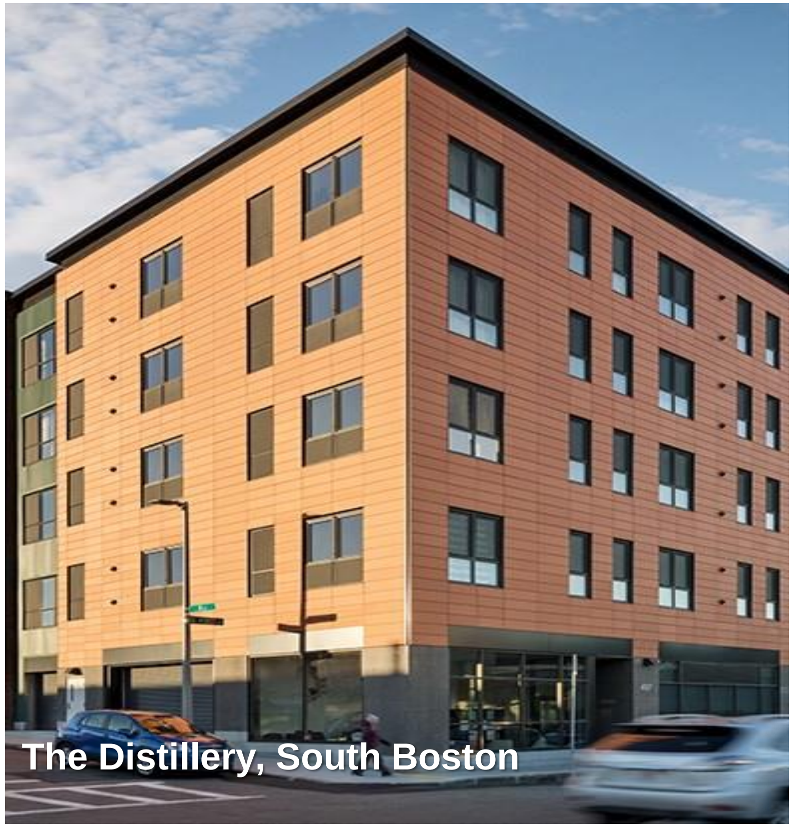
Passive House Building Standards

What is Passive House?

- Passive House is third party building verification program with two options for certification (PHIUS and PHI)
- These certification standards set energy performance and building envelope air-tightness requirements

How do Passive House Buildings Perform?

- Heating loads are reduced by 90% or more compared to a typical building
- Overall energy demand can be reduced by 60% or more
- Significant improvement in Indoor Air Quality and Occupancy Comfort


The Distillery, South Boston

Passive House Building Standards

Passive House's can be any building and any size

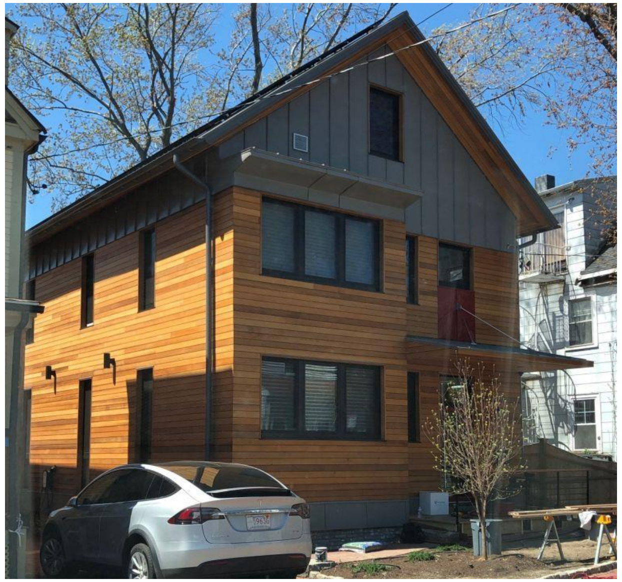
- Residential home, townhouse, multifamily building, commercial office, school, municipal building

Waverly School, Beverly

Single-Family Home, Cambridge

Winthrop Center
Commercial Office, Boston

Which of these buildings is a Passive House?



Passive House Organizations

- Create and Manage the PH Standard
- Define Metrics and Criteria
- Provide Certification for Buildings
- Provide Accreditation for Professionals

Passive House Institute

PHIUS
Passive House Institute US

Passive House Certification Requirements

Performance Criteria

- Heating & Cooling Demand
- Whole Building Airtightness
- Source Energy Demand

Other Criteria

- Ventilation, Moisture Management, Quality Assurance

Passive House Metrics

	PHIUS	PHI
Annual Heating	5.3 kBtu/ft2	15 kWh/m2 (4.8 kbtu/ft2)
Peak Heating	4.4 Btu/ft2	10 watts/m2 (3.2 btu/ft2)
Annual Cooling	2.9 kBtu/ft2-yr	15 kWh/m2-yr (4.8 kbtu/ft2)
Peak Cooling	4.2 Btu/ft2	10 watts/m2 (3.2 btu/ft2)
Source Energy	3840 kWh/person (Residential) 34.8 kBtu/ft2 (Commercial)	60 kWh/m2 (all projects)

*above numbers are for general use only, consult PHIUS/PHI for specific project targets

PHIUS: phius.org/phius-certification-for-buildings-products/project-certification/
PHI: passiv.de/en/03_certification/02_certification_buildings/08_energy_standards/08_energy_standards.html

Phius Certification – RESIDENTIAL CALCULATOR

Phius 2021
Performance Criteria Calculator v3.1

UNITS:	IMPERIAL (IP)
BUILDING FUNCTION:	RESIDENTIAL
PROJECT TYPE:	NEW CONSTRUCTION

STATE/ PROVINCE	MASSACHUSETTS
CITY	BOSTON LOGAN INT ARI

Envelope Area (ft²)	3,750.0
iCFA (ft²)	2,000.0
Dwelling Units (Count)	1
Total Bedrooms (Count)	4

Space Conditioning Criteria

Annual Heating Demand	5.2	kBtu/ft²yr
Annual Cooling Demand	5.7	kBtu/ft²yr
Peak Heating Load	3.9	Btu/ft²hr
Peak Cooling Load	2.7	Btu/ft²hr

Source Energy Criteria

Phius CORE	3725	kWh/person.yr
Phius ZERO	0	kWh/person.yr

INPUT

Building Type

Location

Size

Density

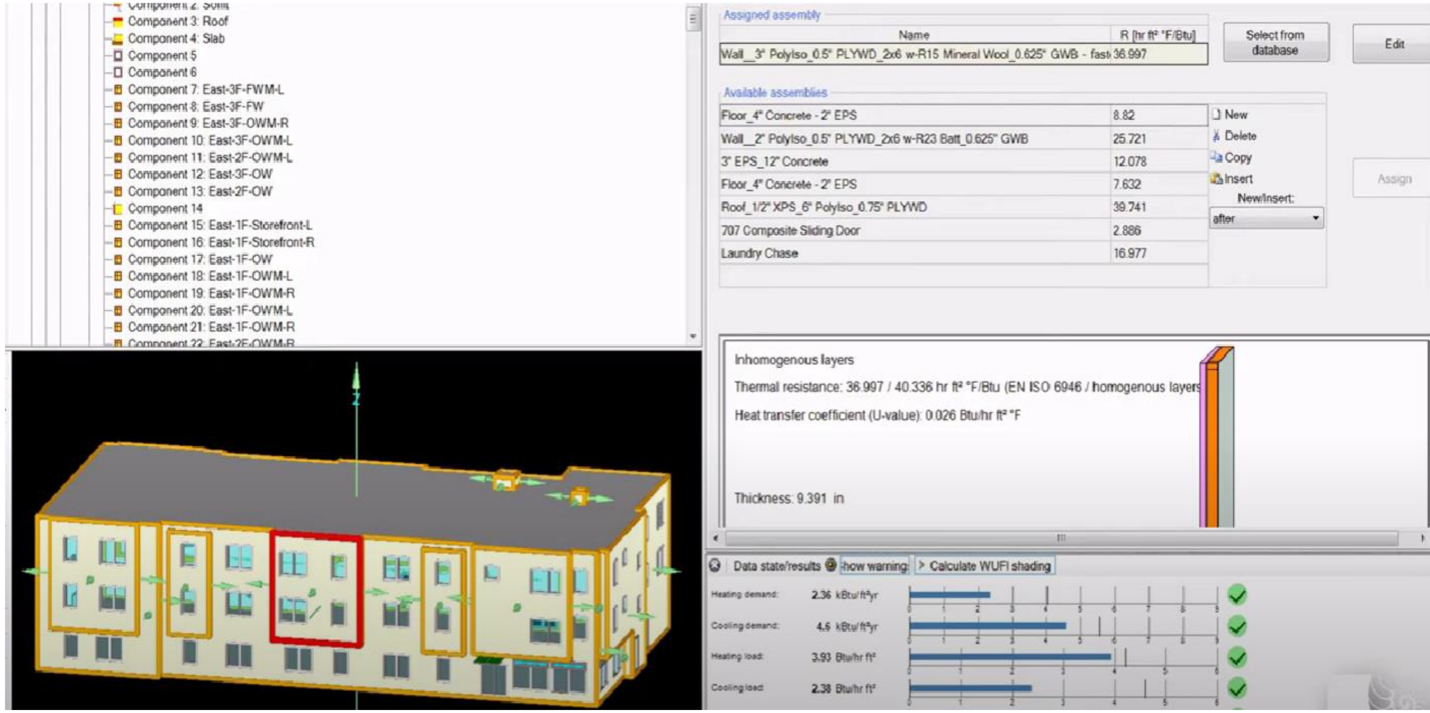
OUTPUT

Metrics

Advanced Energy Modeling

WUFI Passive or PHPP (Passive House Planning Package)

- Model heating and cooling demand, peak load, and total energy demand
- Model hygrothermal interactions between the indoor air and the building envelope
- Calculate the required performance level of individual components such as wall insulation, windows, etc. and their influence on the energy balance
- Account for all building components and systems, local climate data, and building use
- Determine the size and required performance of mechanical systems
- Account for internal and external heat gain sources



Passive House Metrics

Air Tightness Standard

Building Energy Code	Passive House*
3	**0.6**
ACH50	ACH50
(air changes per hour at 50 Pascals)	(air changes per hour at 50 Pascals)
	*Passive House International (PHI)

*above numbers are for general use only, consult PHIUS/PHI for specific project targets

PHIUS: phius.org/phius-certification-for-buildings-products/project-certification/
PHI: passiv.de/en/03_certification/02_certification_buildings/08_energy_standards/08_energy_standards.html

Benefits of Passive House

Financial Benefits

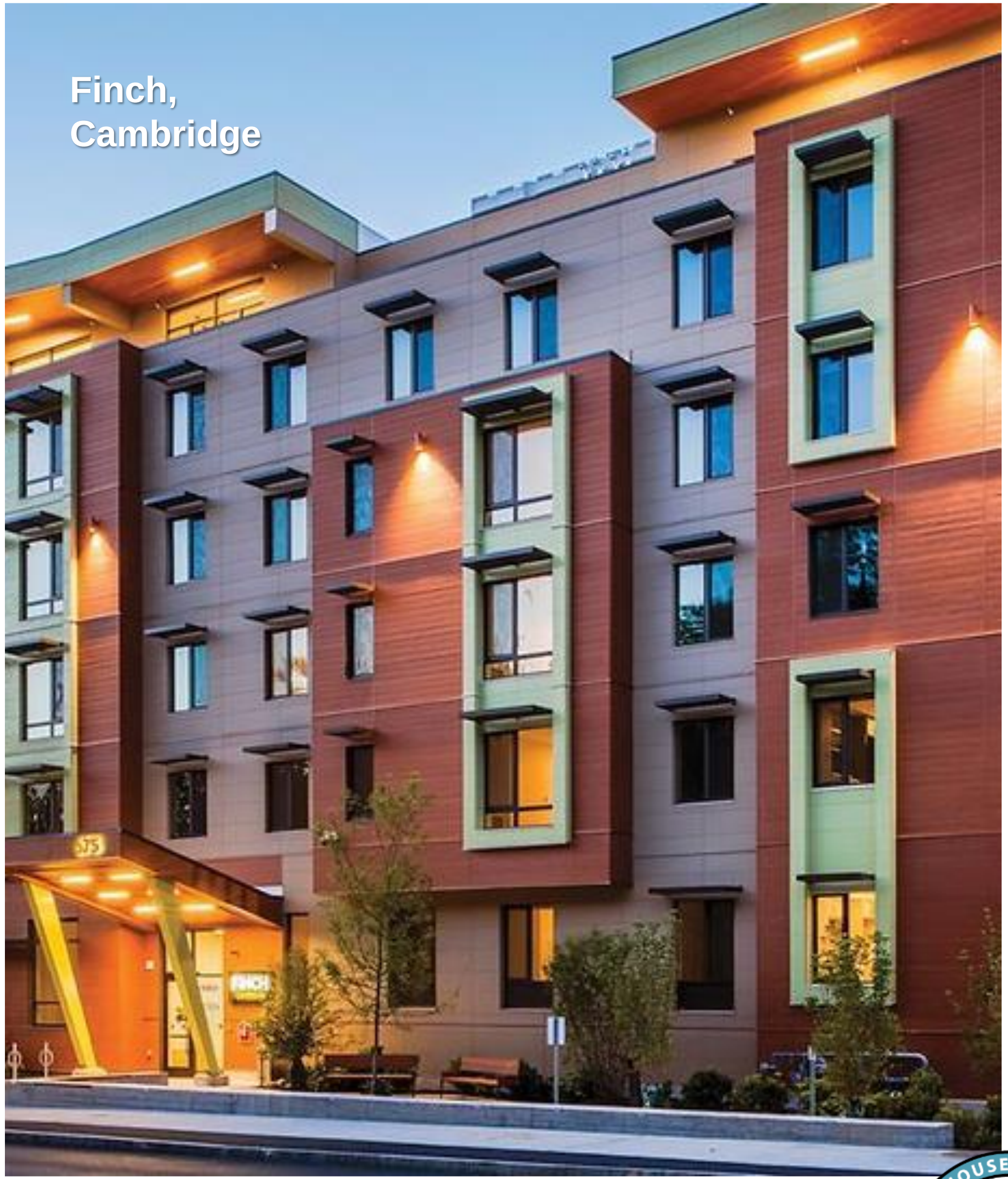
- Reduced energy utility costs
- Reduced equipment maintenance costs
- Longer lasting construction

Health & Comfort Benefits

- Improved indoor air quality
- Reduced air drafts
- Quieter acoustics

Environmental Benefits

- Reduced carbon emissions
- Climate resilient building
- Platform for electrification and net-zero



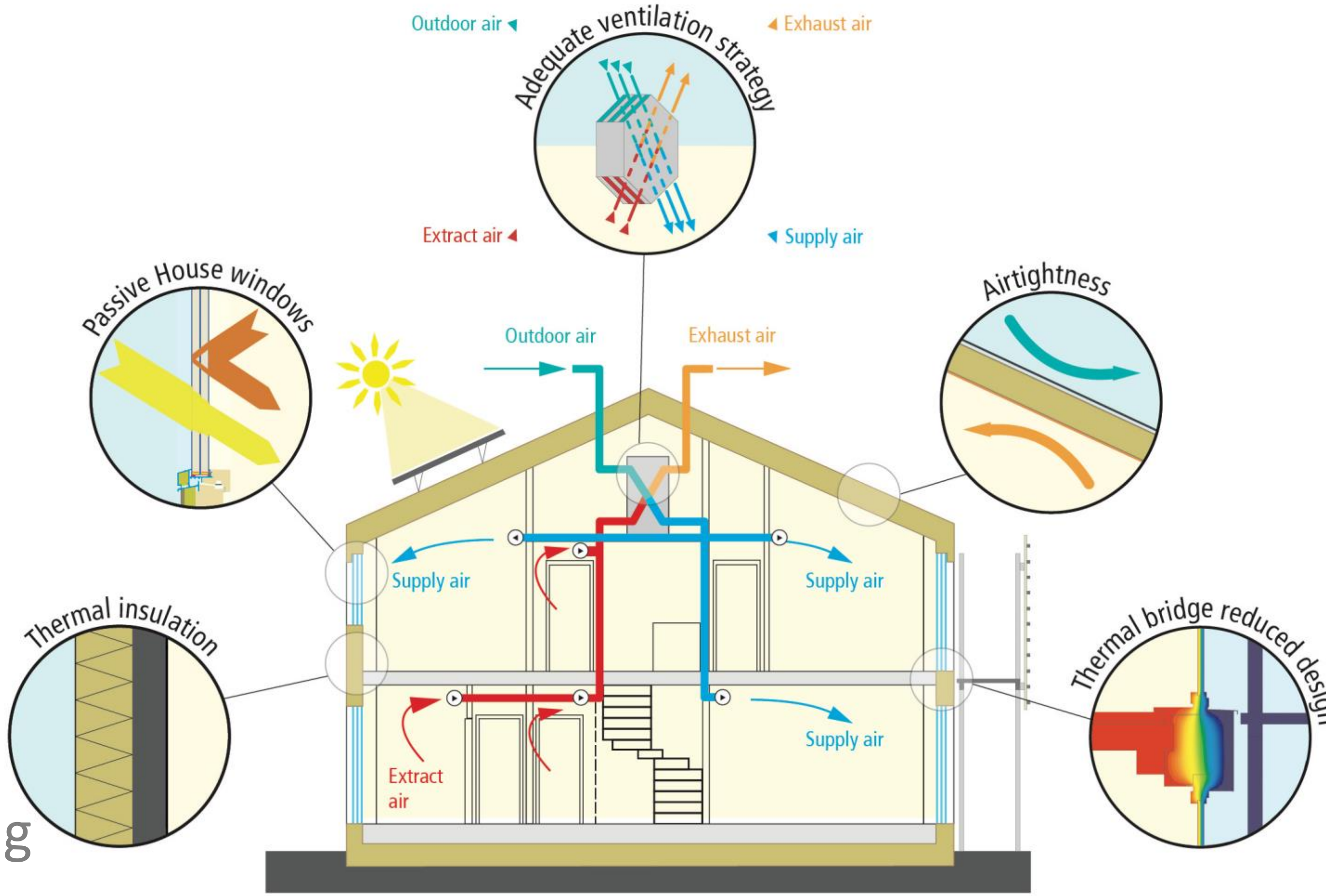
Features of Passive House Buildings

Building Envelope:

- Continuous Thermal Insulation
- Air-Tight Building Envelope
- Thermal Bridge Mitigation
- High-Performance Windows & Doors
- Optimized Solar Heat Gain

Mechanical Systems:

- Balanced & Continuous Ventilation with Heat Recovery
- Efficient & Minimized Heating & Cooling
- Efficient Water Heating & Distribution

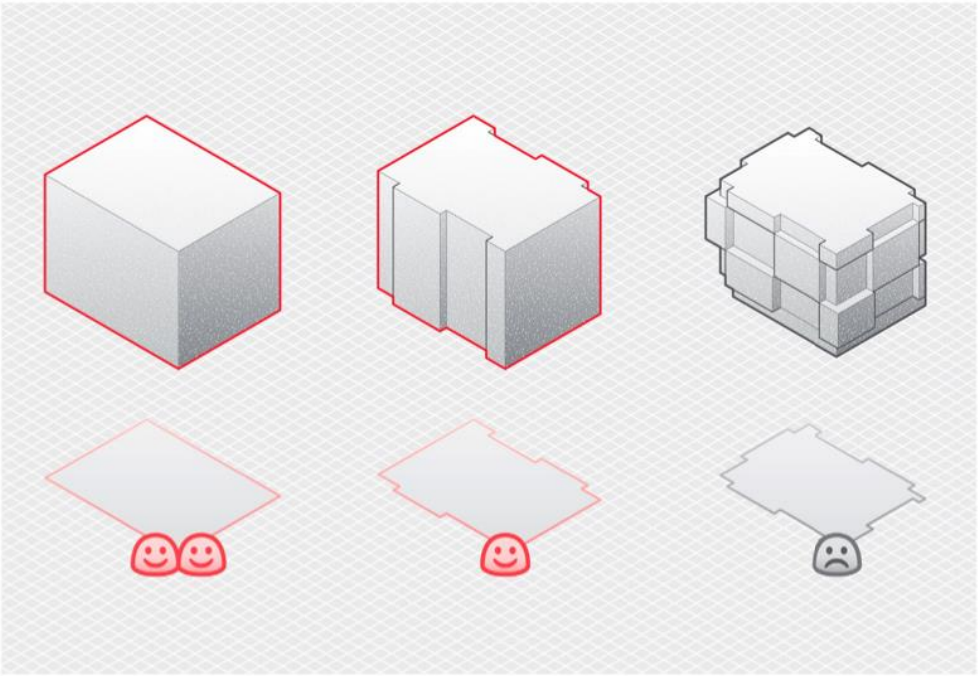


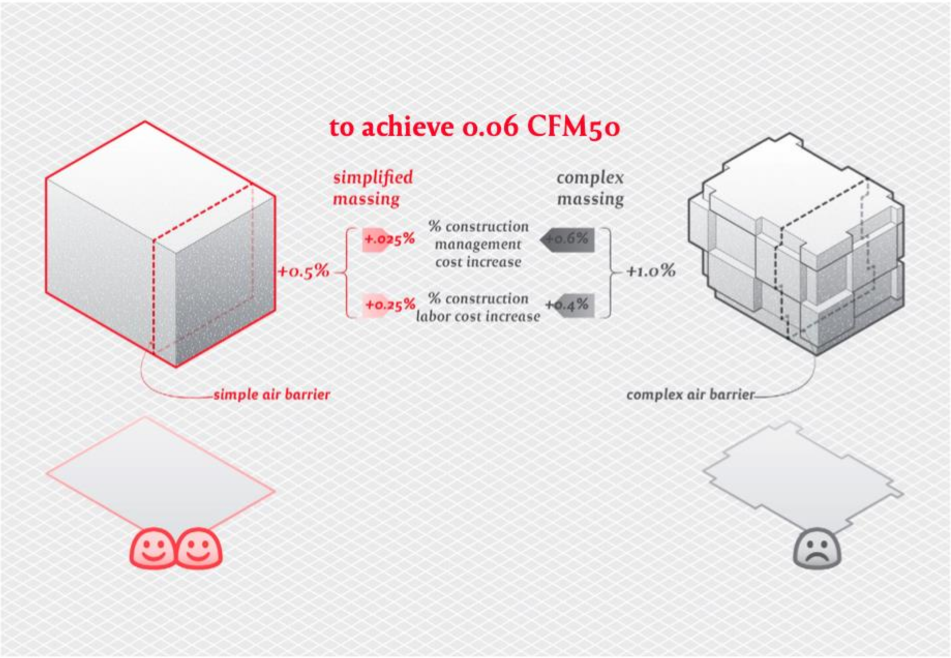
Passive House Institute, *principles of passive house*

General Design Strategies

Massing and Form

- The more complicated the from, the more challenging it is to achieve air-tightness and thermal bridging reductions

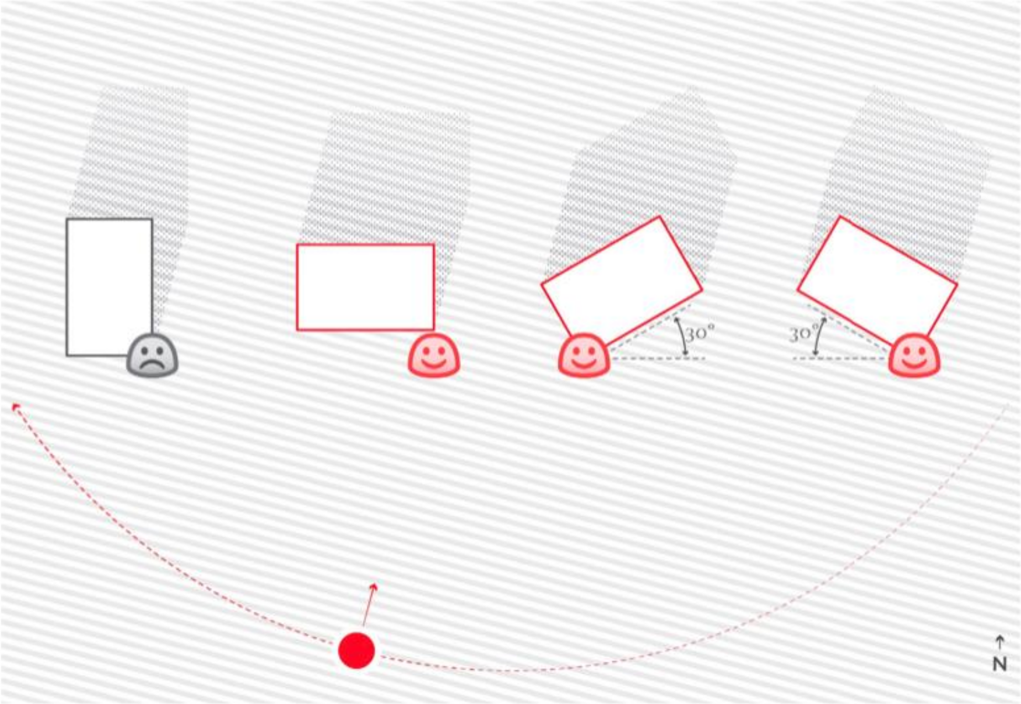


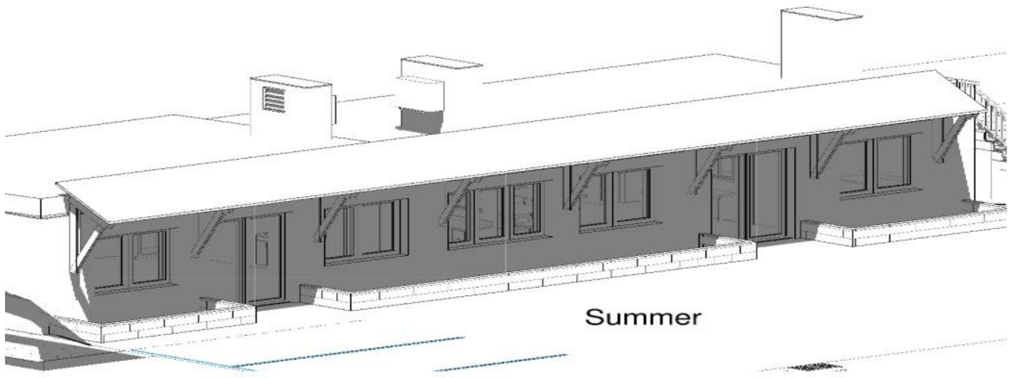


General Design Strategies

Building Orientation and Siting

- Long face towards sun exposure
- Beware of trees and other buildings

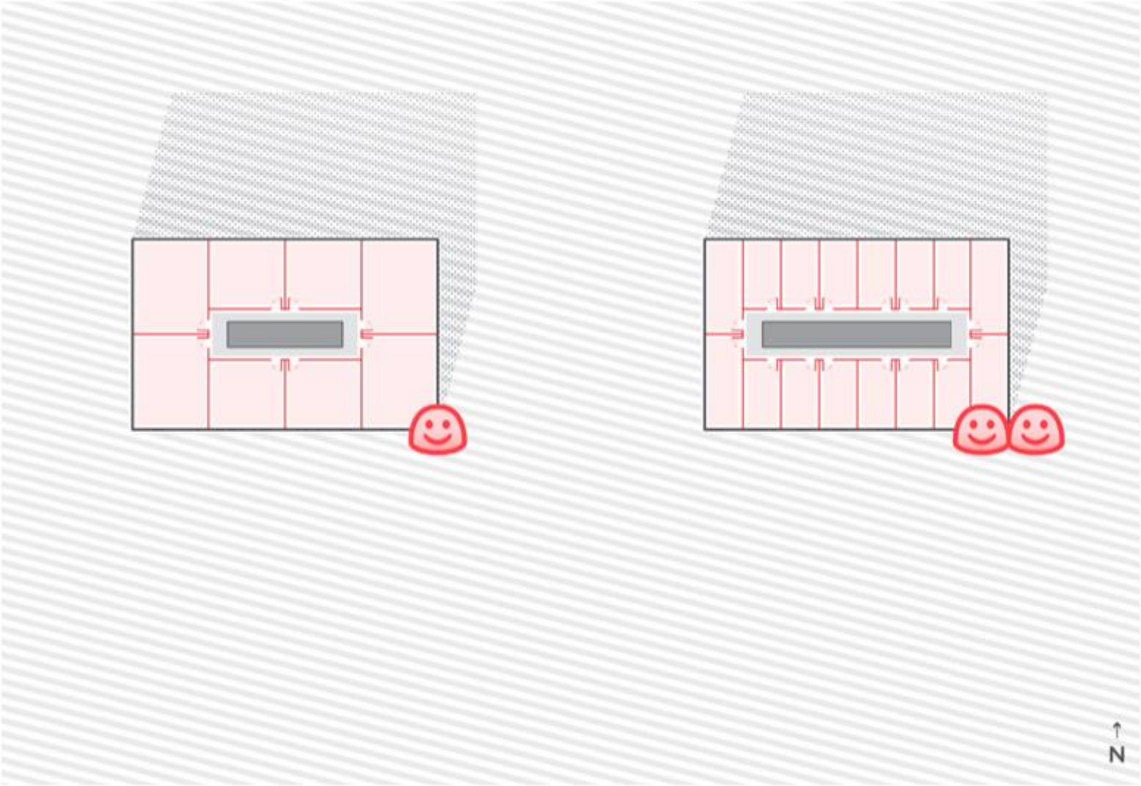




General Design Strategies

Increased Density

- More heat sources inside (people, appliances, etc)



Distillery, 2017
- 28 units
- Wood framed
- 3” Mineral Wool

Finch, 2021
- 98 units
- Wood framed
- 2” Mineral Wool

General Design Strategies

Glazing Percentage and Placement

- More than 25% glazing to wall ratio can present more challenges
- Too little glazing, or incurrent placement, can negatively impact solar heat gain

Finch Cambridg

Building Envelope

Provide a *thermal barrier* around the entire building

- Dense-packed frame cavity insulation
- Continuous insulation layer
- Reduction of thermal bridging

Create an *air-tight barrier* around the entire building

- Continuous air-barrier system
- Taped and sealed penetrations
- Elimination of air gaps

The Distillery

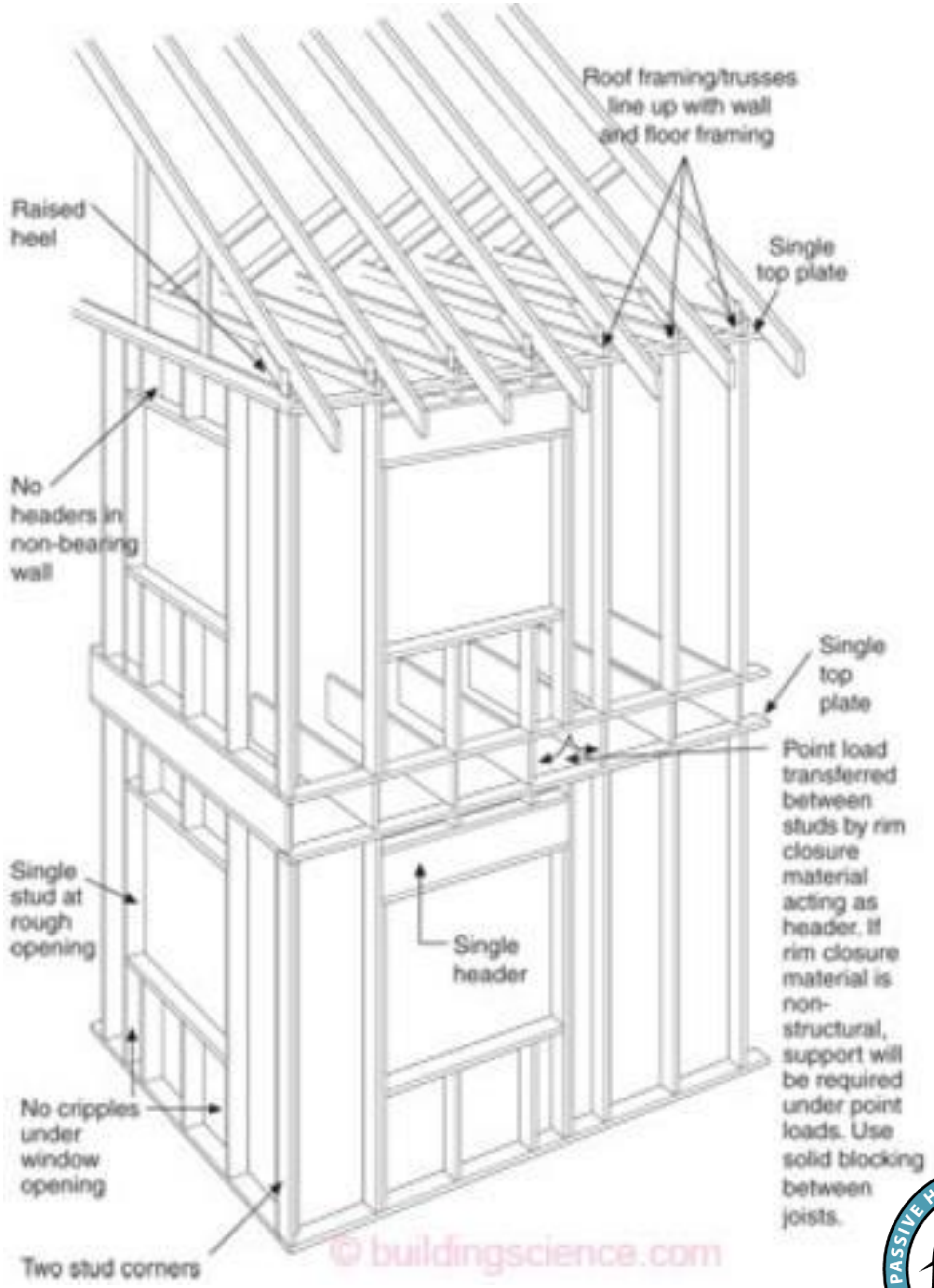
Advanced Framing

Main Goals:

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

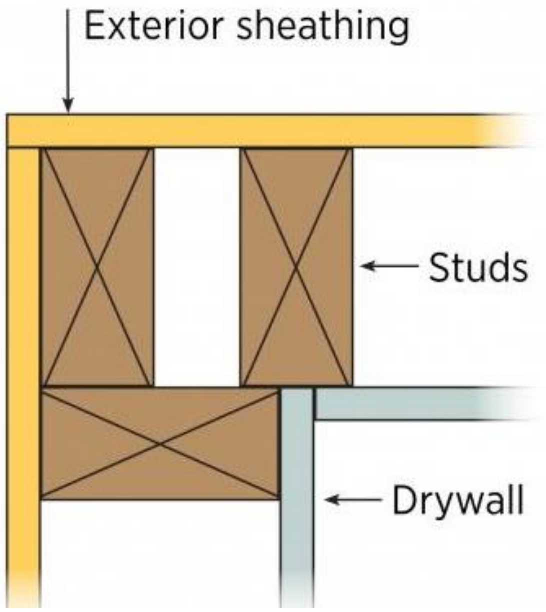
Focus Areas:

- Stud Spacing (24” on-center)
- Corners
- Headers

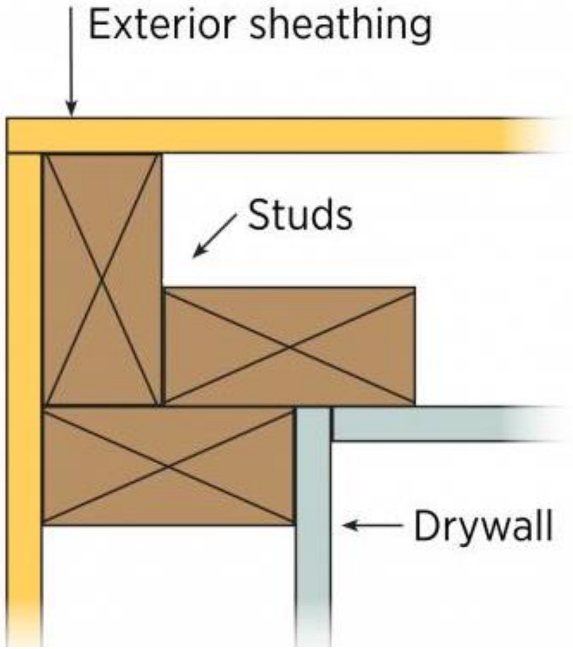


Advanced Framing

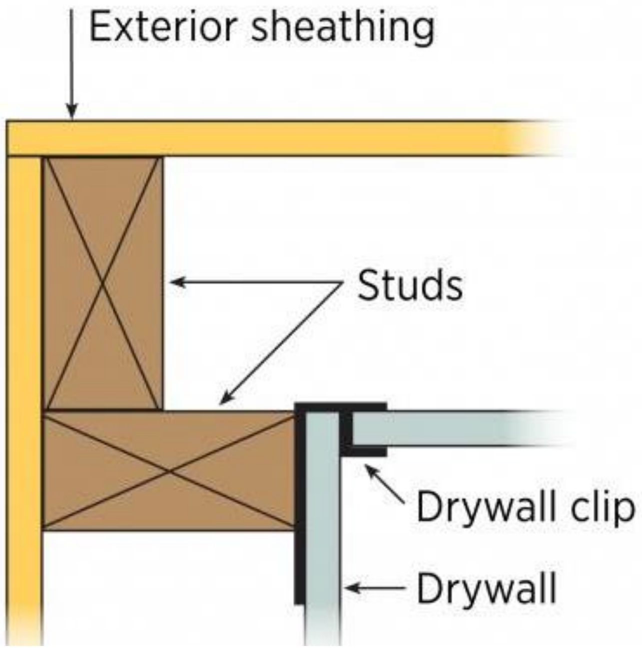
Corners



Typical Framing



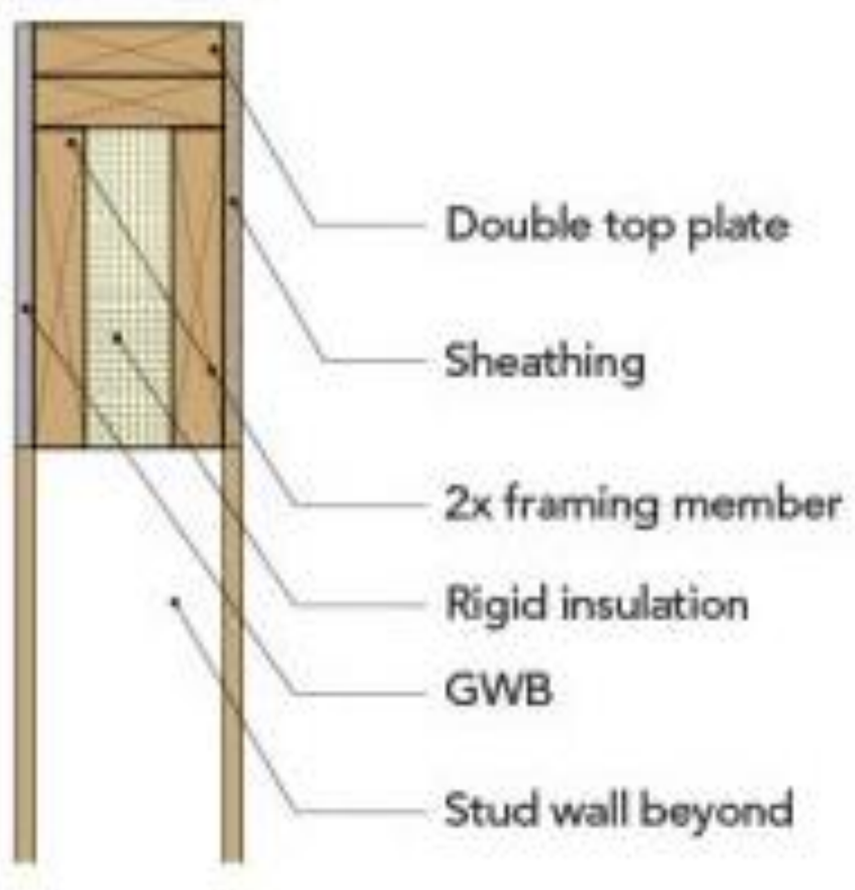
Advanced Option 1

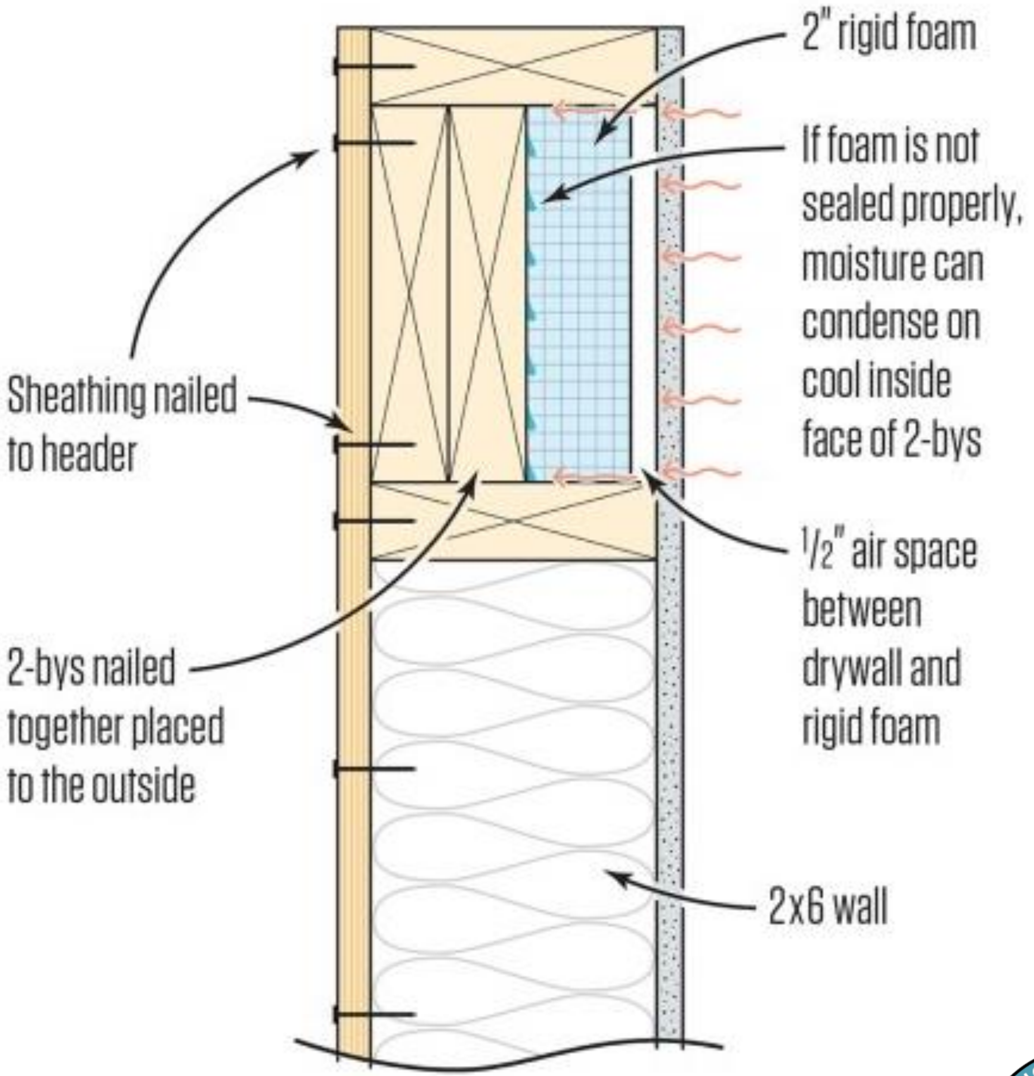


Advanced Option 2

Advanced Framing

Headers





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

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

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

Mineral Wool Boards

Polyiso

Wood Fiber Boards

EPS/XPS Foam

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

Finch Cambridge
- 2" Mineral

Wheaton College
- 5" Mineral

Exterior Insulation

Before continuous insulation

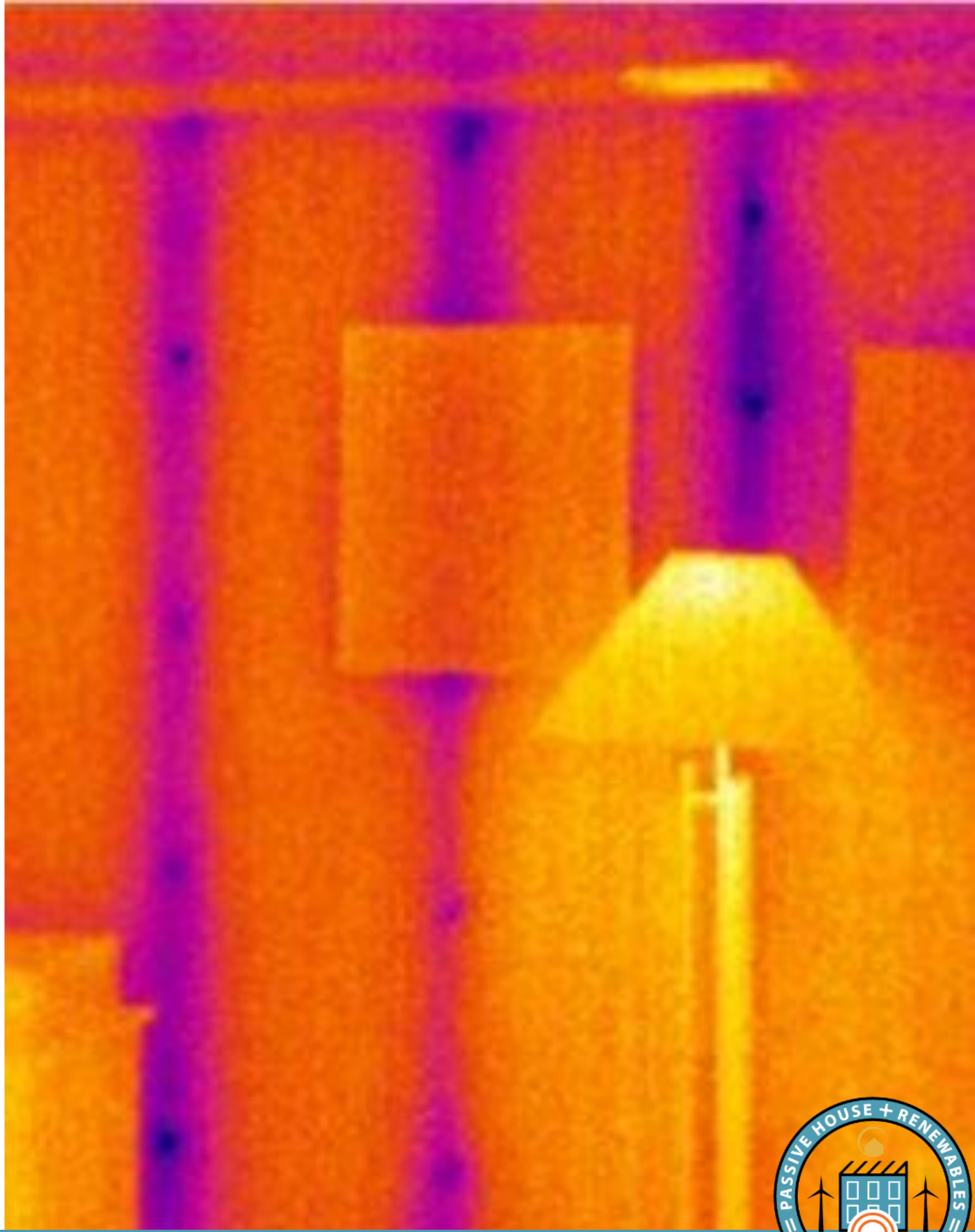
Finch Cambridge

After continuous insulation

Thermal Bridging

Thermal Bridges

- Heat transfers through materials with higher thermal conductivity (wood , metal, concreate, etc.)
- Passive House requires focus on reducing the amount of, and mitigating the impact of , thermal bridges through the envelope



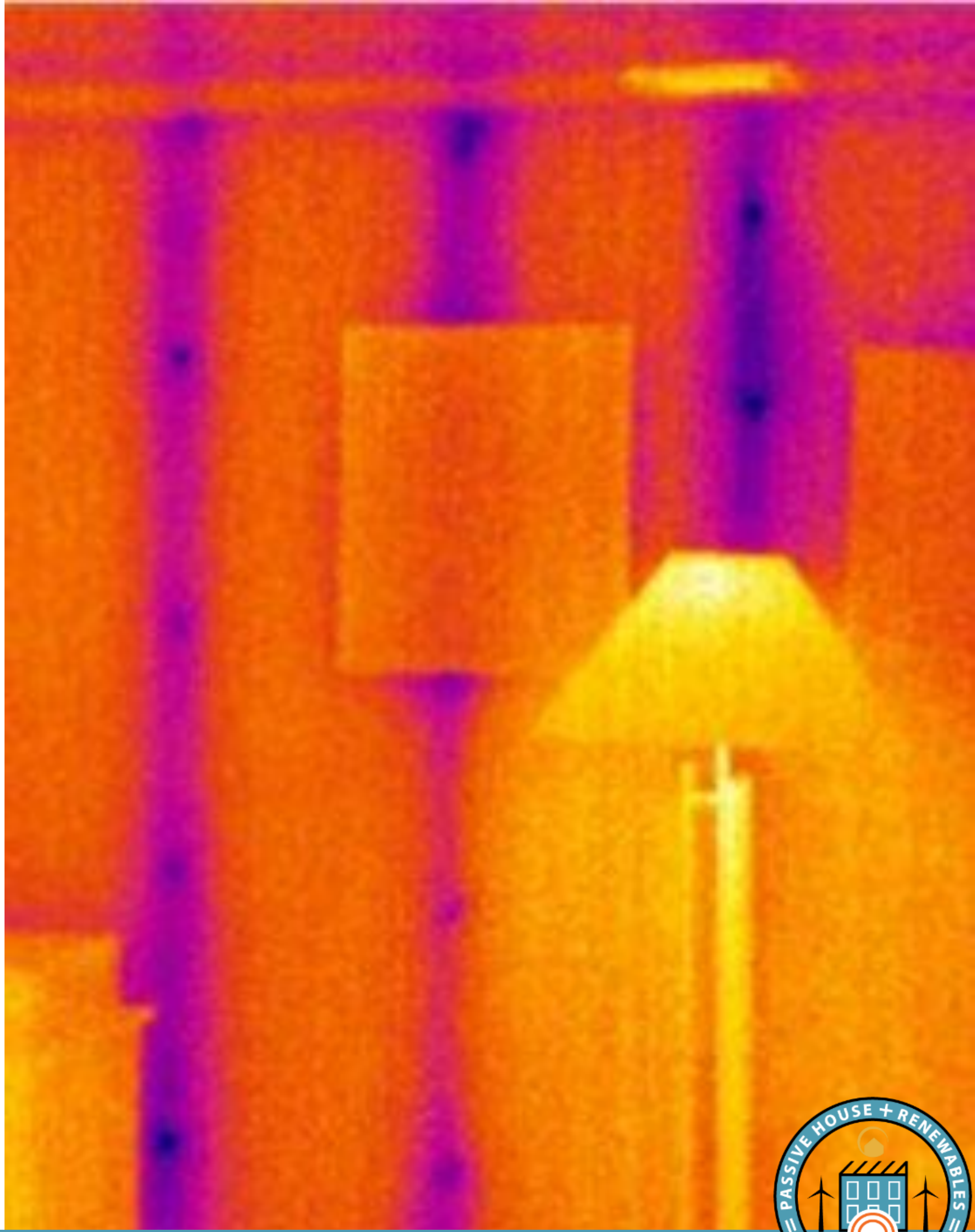
Thermal Bridging

Thermal Bridges lead to:

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

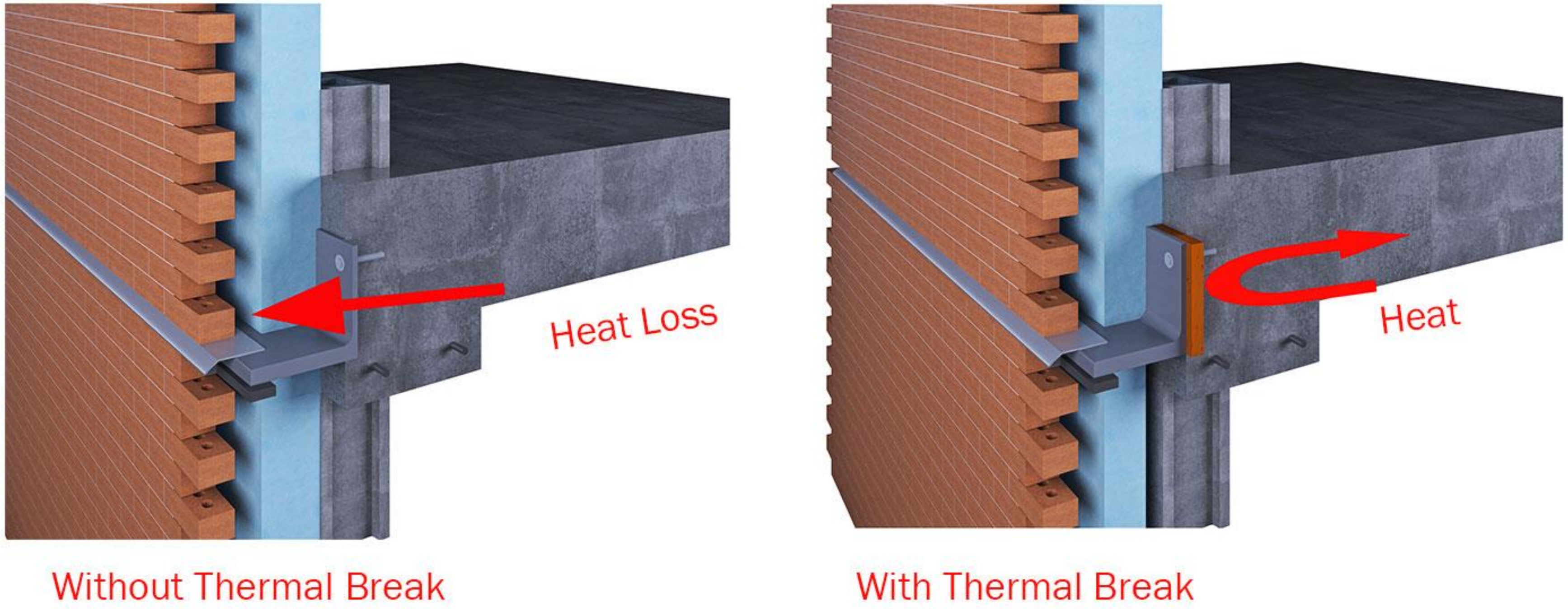
Areas of Concern:

- 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



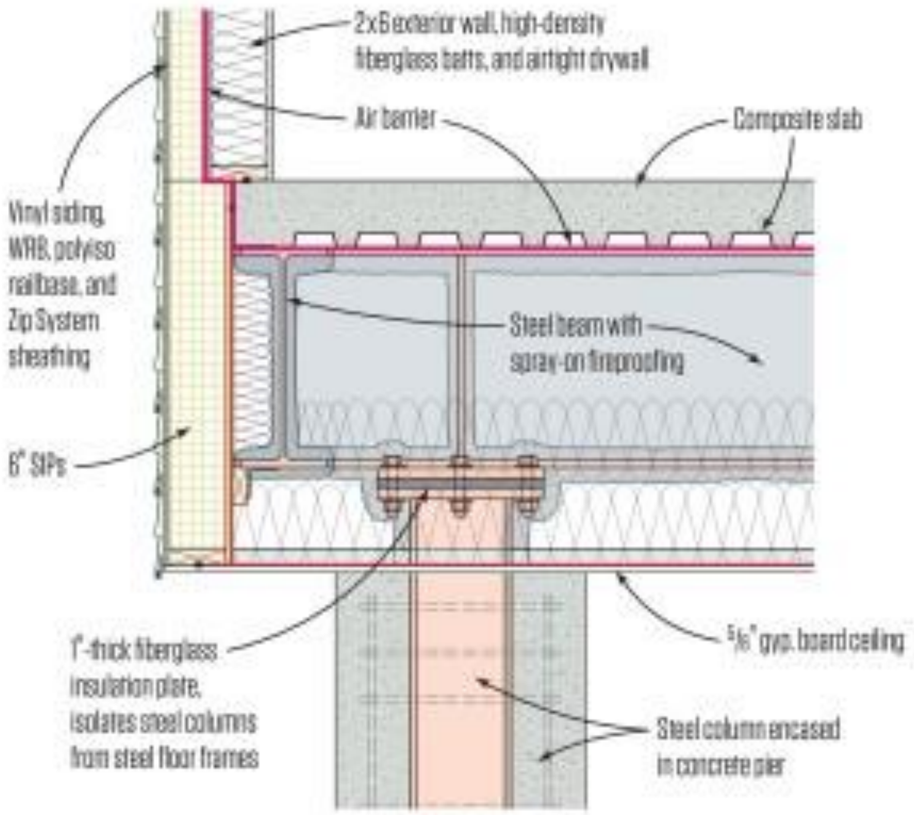
Thermal Bridging

Thermal Breaks



Thermal Bridging

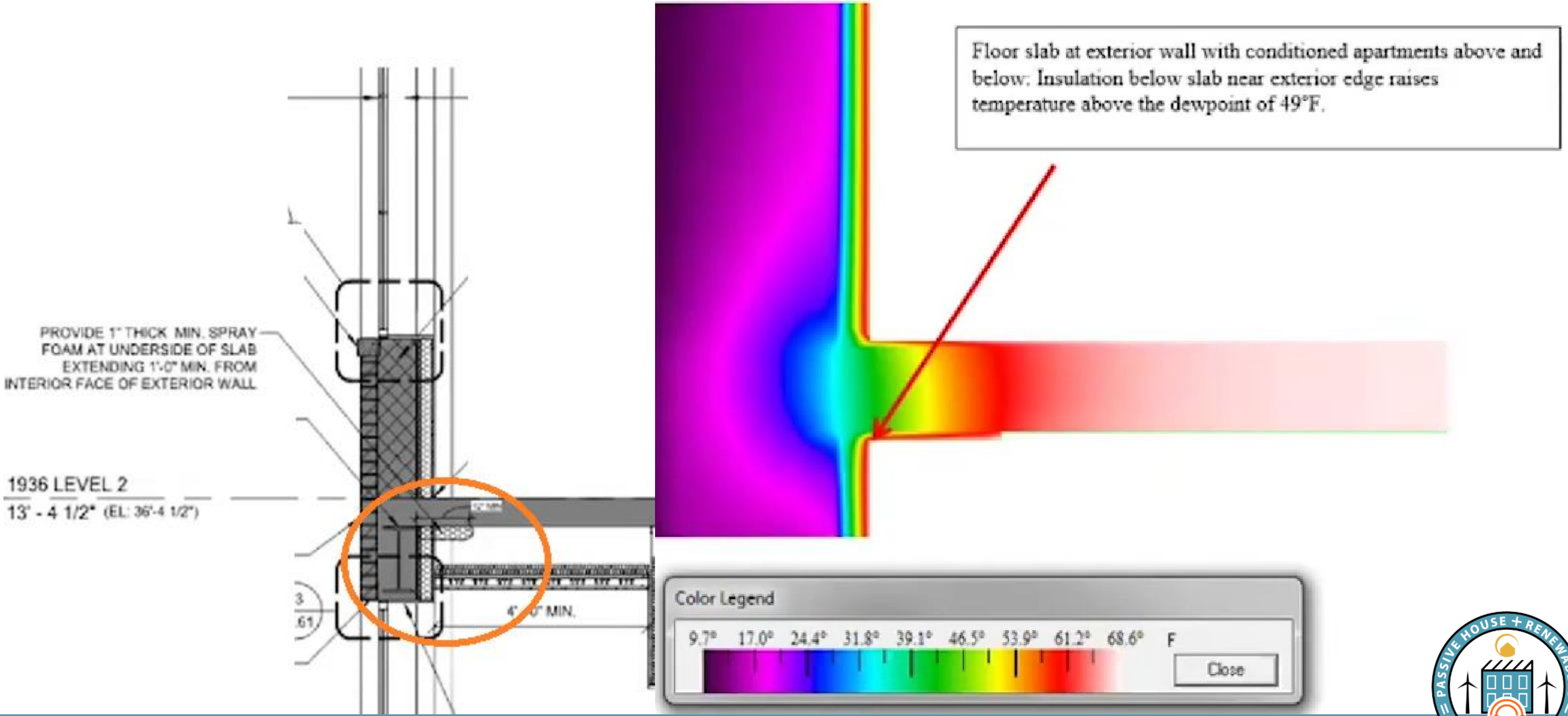
Thermally Broken Steel Support



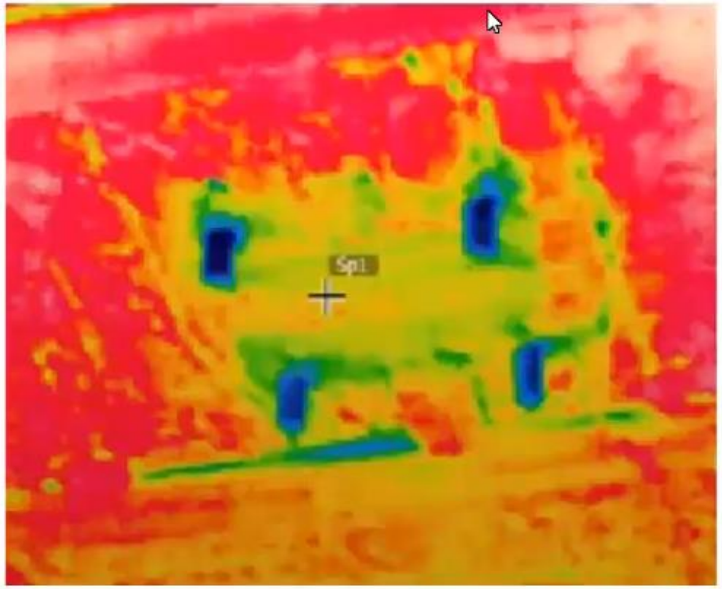
Elm Place (VT)

Thermal Bridging

The Tyler
Floor slab to exterior wall connections



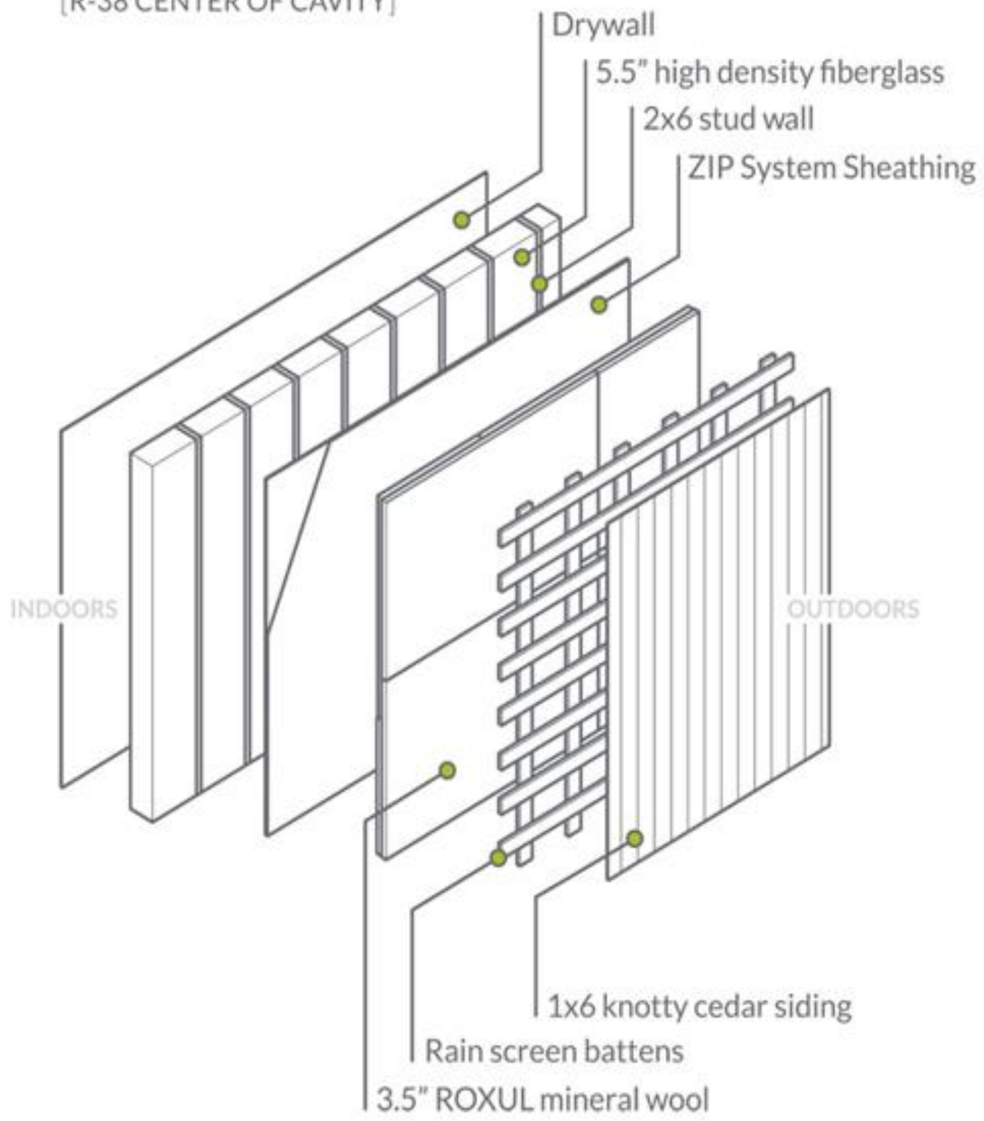
Thermal Bridging



Finch Cambridge

Building Envelope Layers

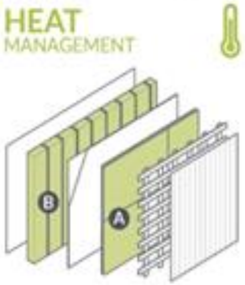
R-34 WHOLE WALL
[R-38 CENTER OF CAVITY]



AIR MANAGEMENT

- A ZIP Sheathing

HEAT MANAGEMENT



- A 3.5” of exterior mineral wool insulation (R-14)
- B 5.5” of high density fiberglass insulation (R-23)

WATER MANAGEMENT

- A Primary barrier: Siding
- B Secondary barrier: ROXUL mineral wool
- C Final barrier: ZIP Sheathing
- D Rain screen allows bulk water to drain away

VAPOR MANAGEMENT

- A Rain screen dries cladding and the assembly
- B 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.

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

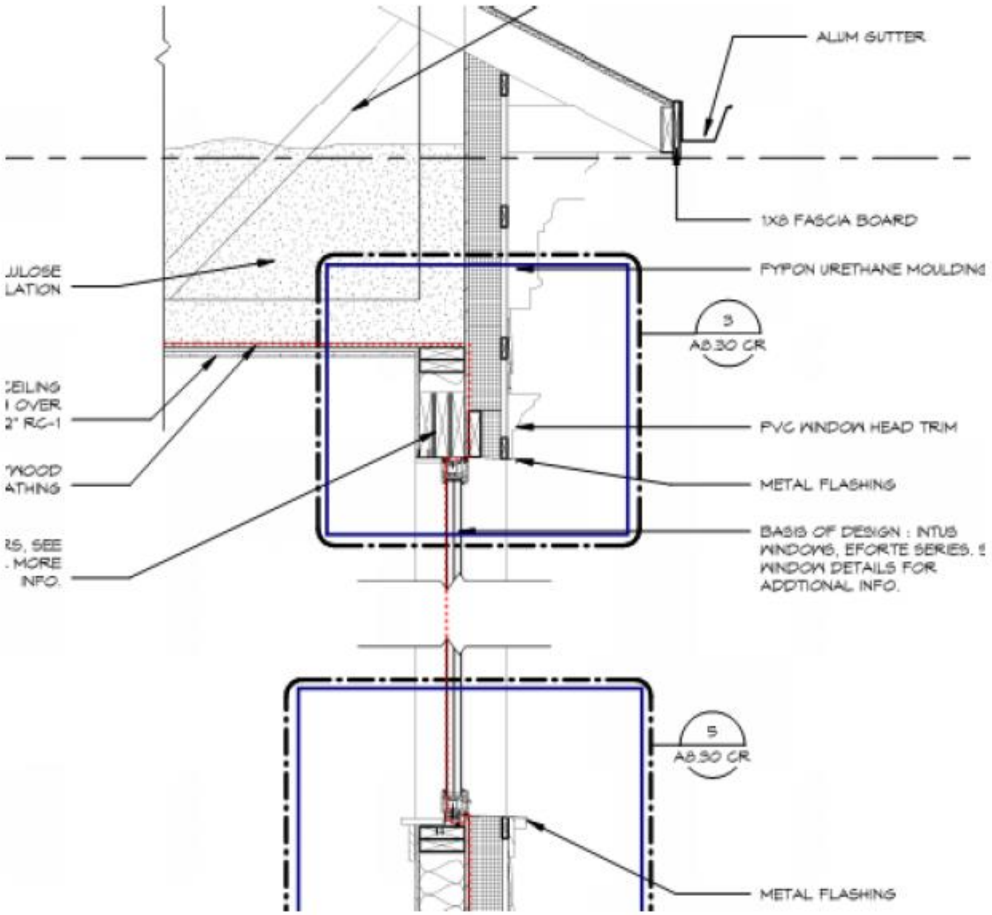
Fluid-applied

Vaporized Sealant

Air Barrier

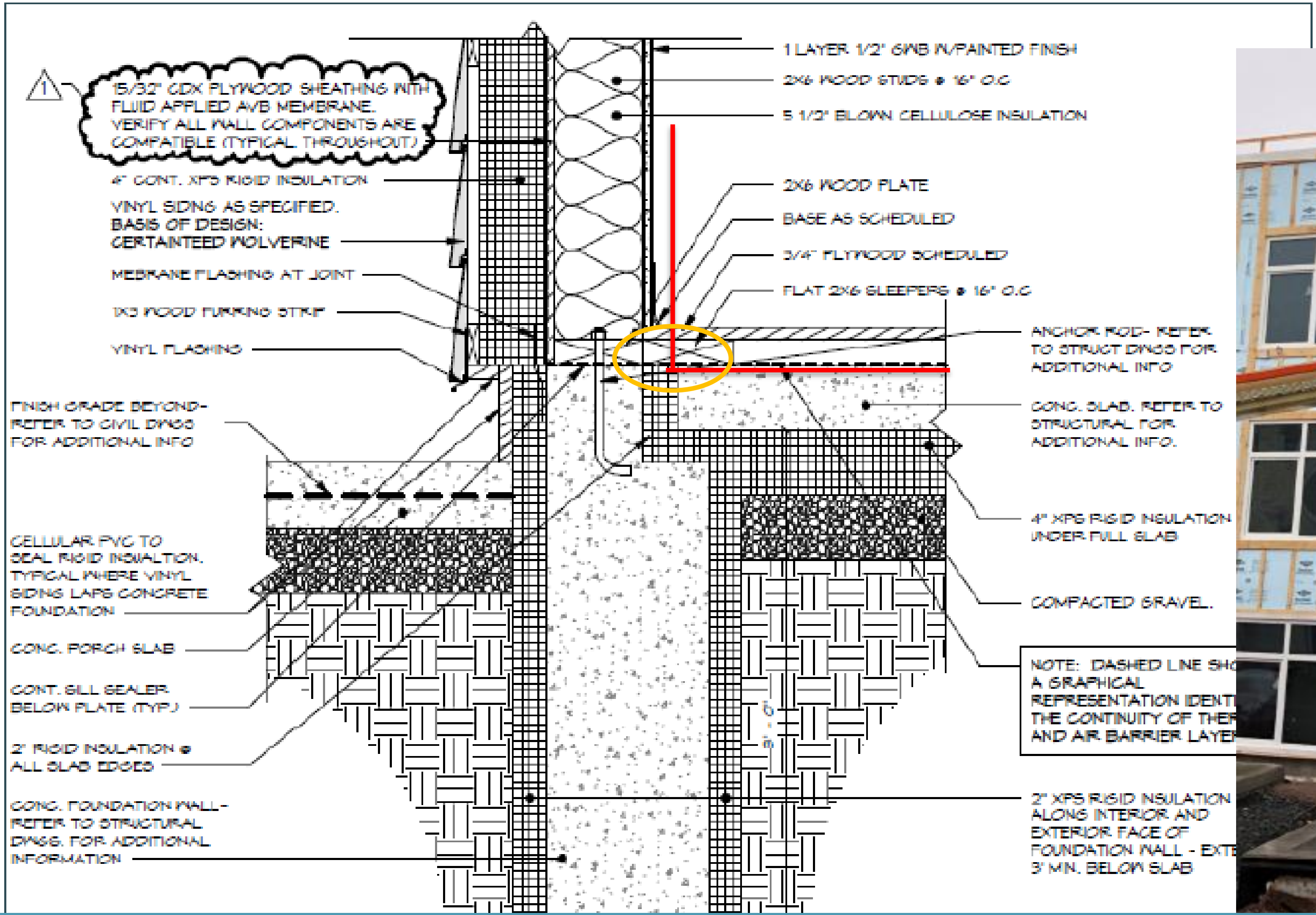
Air Barrier needs to be continuous!

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



Air Barrier

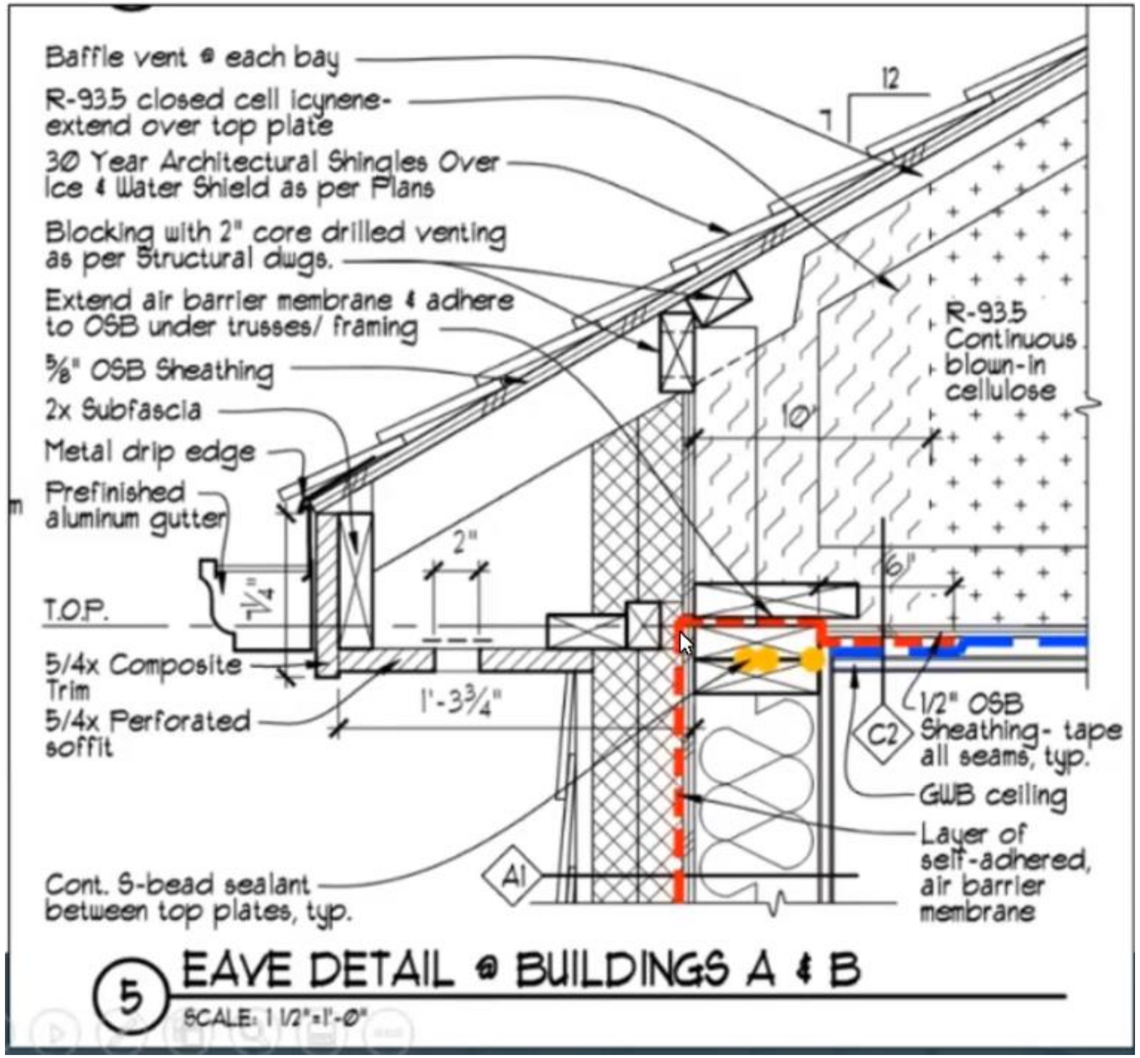
Continuous Air Barrier --- Watch the critical connections (floor to wall, etc.)



Air Barrier

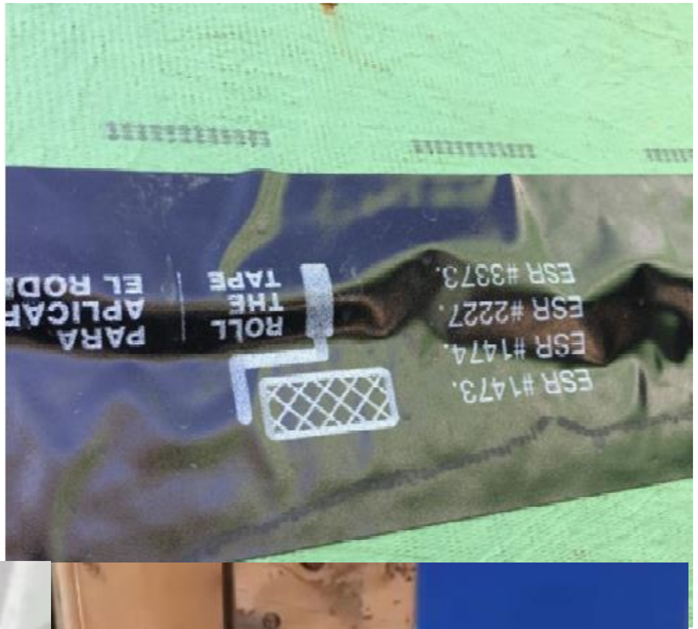
Continuous Air Barrier

- Watch the critical connections



Steven Winter Associates

Air Barrier



Continuous Air Barrier

- Watch for penetrations, tapping details, etc

Finch Cambridge

Air Barrier

Continuous Air Barrier

- Use recommended products including tapes and seals

Air Barrier

Continuous Air Barrier

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

Air Barrier

Continuous Air Barrier

- Pay attention location of penetrations and sealing methods

Pipe location does not leave enough room for seal

Air Tightness Testing

Blower Door Test Times (Minimum Recommendation)

1. Full envelope test once windows and doors are installed – ideally after mechanicals are installed and sealed off)
2. After sheetrock, test individual apartments/units for compartmentalization
3. Pre-occupancy whole building test

Tips

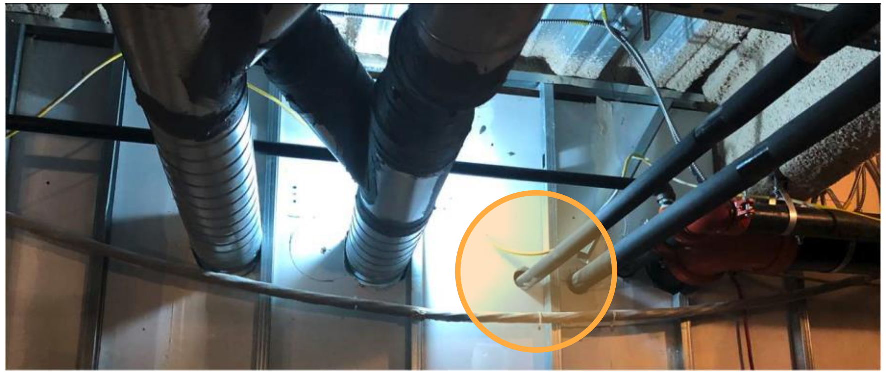
- Isolate the trouble zones (for Harbor Village this was the lobby)
- Use smoke testing to “follow the leaks”
- Have contractor there for as many tests as possible

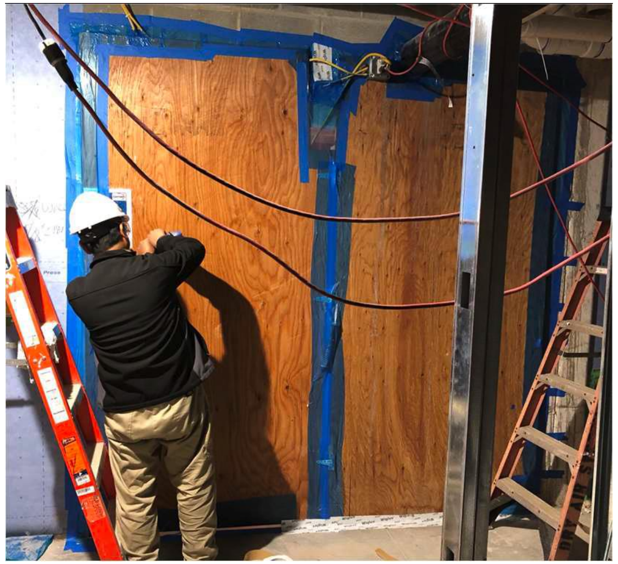
Source: Black Mountain Architects

Air Tightness Testing

Blower Door Tests – Early and Often - Harbor Village example

Midpoint Test 1





Midpoint Test 2

Photos from New Ecology, Inc

Water Control Layers

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

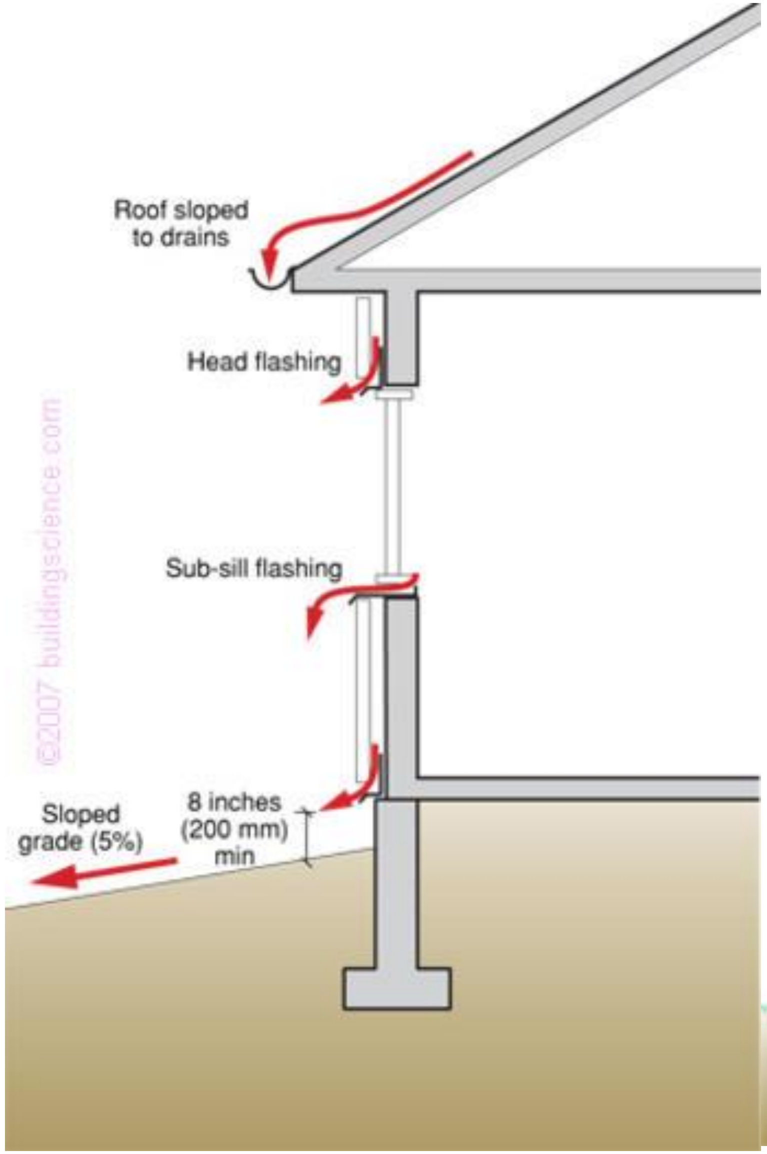
Water Control Layers

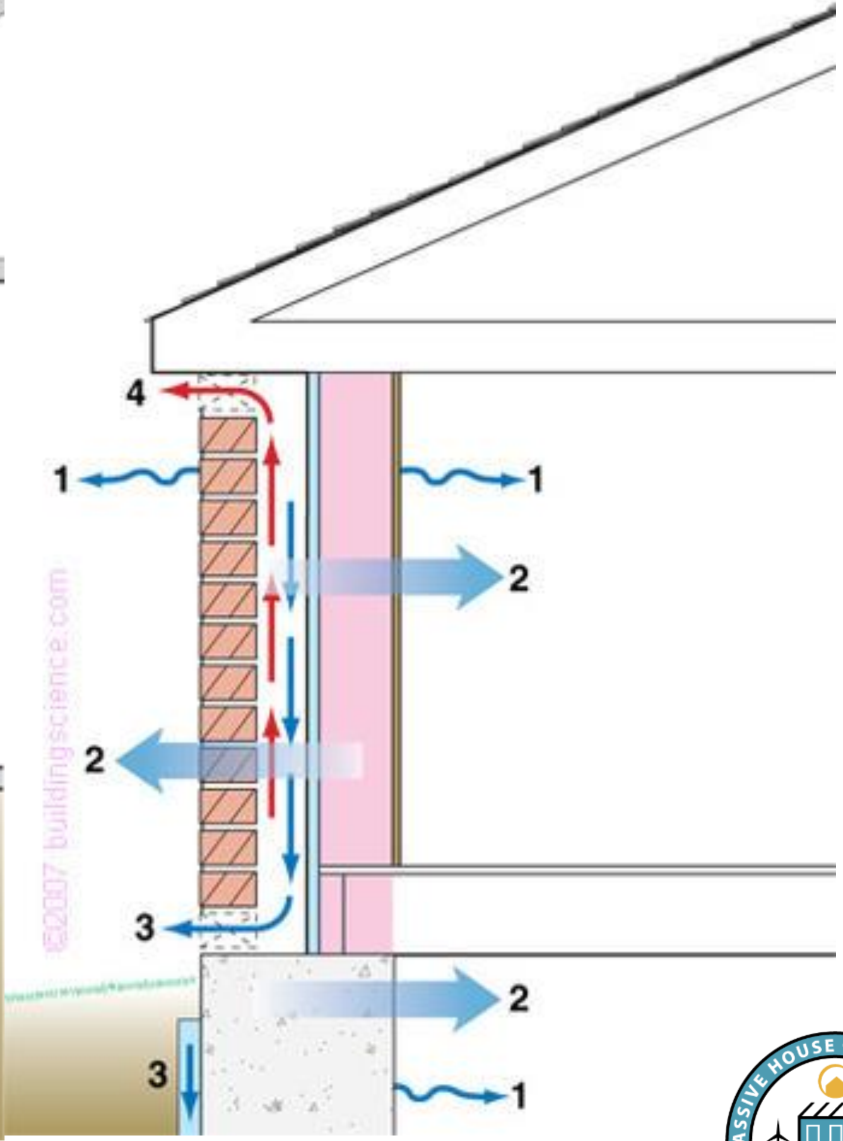
Water needs a path to follow - *and plan for it to fail:*

1. Flow off the shingles and siding and gutters

2. Drip out weeps and off sills

3. Dry out from the inside





Water Control Layers

Drainage Mats

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

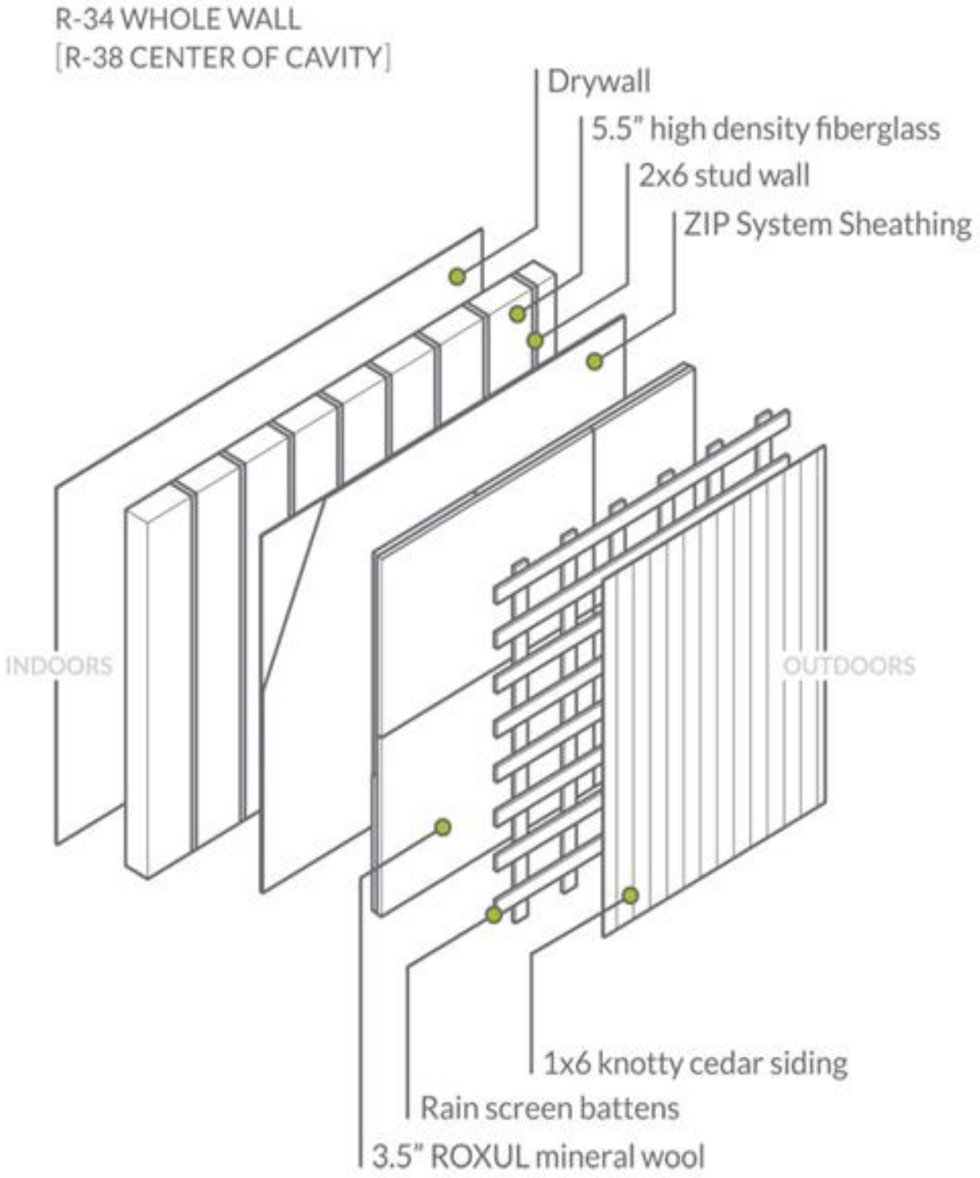
Vertical or Horizontal Battens

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

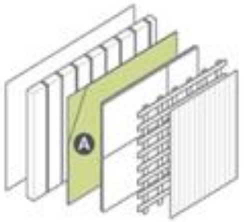
Water Control Layers

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

Building Envelope Layers

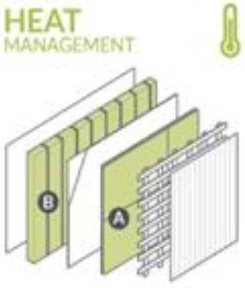


AIR MANAGEMENT



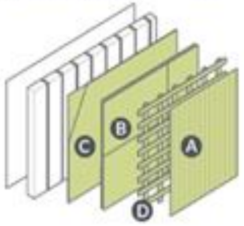
- A ZIP Sheathing

HEAT MANAGEMENT



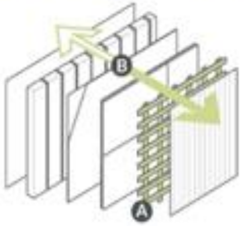
- A 3.5" of exterior mineral wool insulation (R-14)
- B 5.5" of high density fiberglass insulation (R-23)

WATER MANAGEMENT



- A Primary barrier: Siding
- B Secondary barrier: ROXUL mineral wool
- C Final barrier: ZIP Sheathing
- D Rain screen allows bulk water to drain away

VAPOR MANAGEMENT



- A Rain screen dries cladding and the assembly
- B 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.

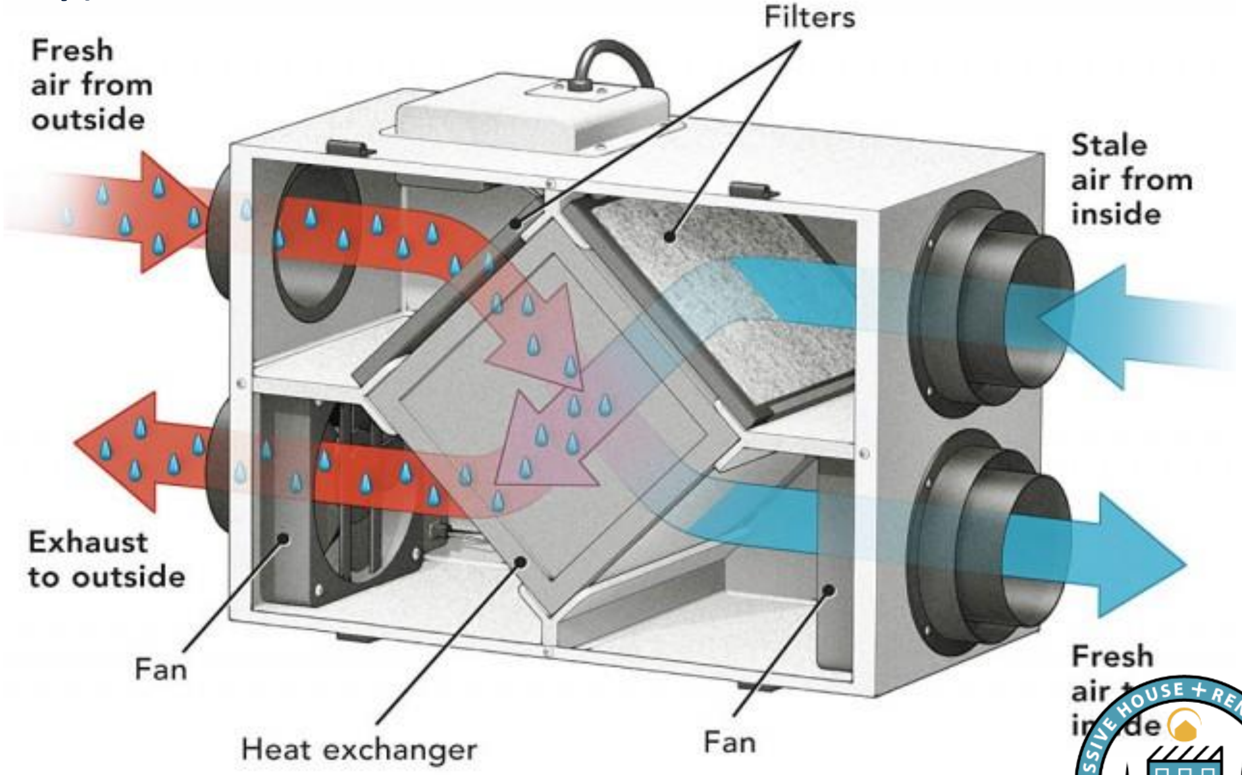
Mechanical Systems

Provide heating, cooling, ventilation, and hot water

- Balanced & Continuous Ventilation with Heat Recovery
- Efficient & Minimized Heating & Cooling
- Efficient Water Heating & Distribution

Energy Recovery Ventilators (ERV and HRV)

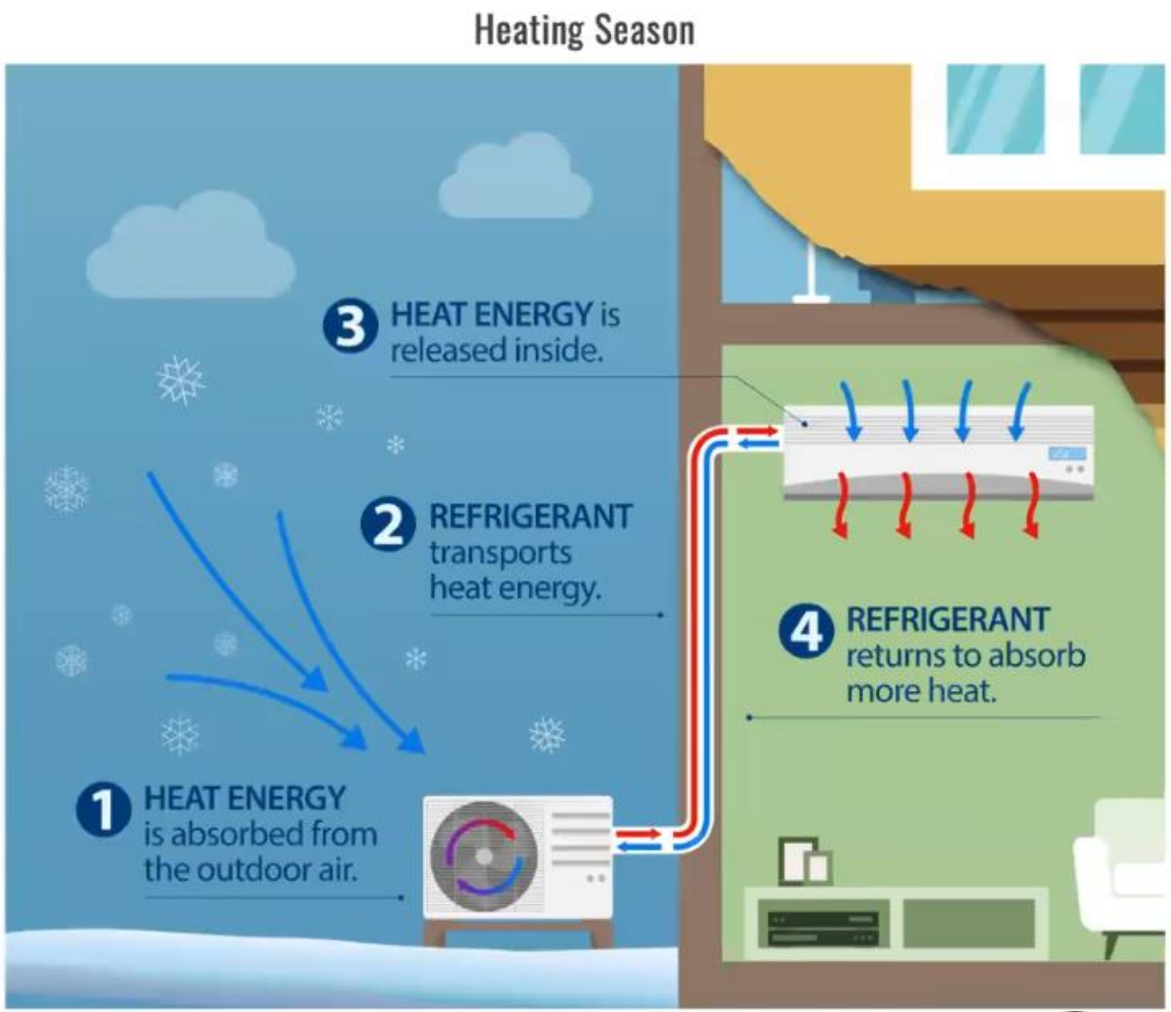
- Continuously running ventilation system (with variable fan speeds)
- Provides fresh ***filtered*** air into building while completely exhausting dirty air
- Recovers heat from outgoing air (~80% efficiency)
- Does not mix incoming and outgoing air
- ERVs also provide (some) humidity control



Air-Sourced Heat Pumps and VRF Systems

- All-Electric system
- Provide both heating and cooling
- Operate at 200%-400% efficiency

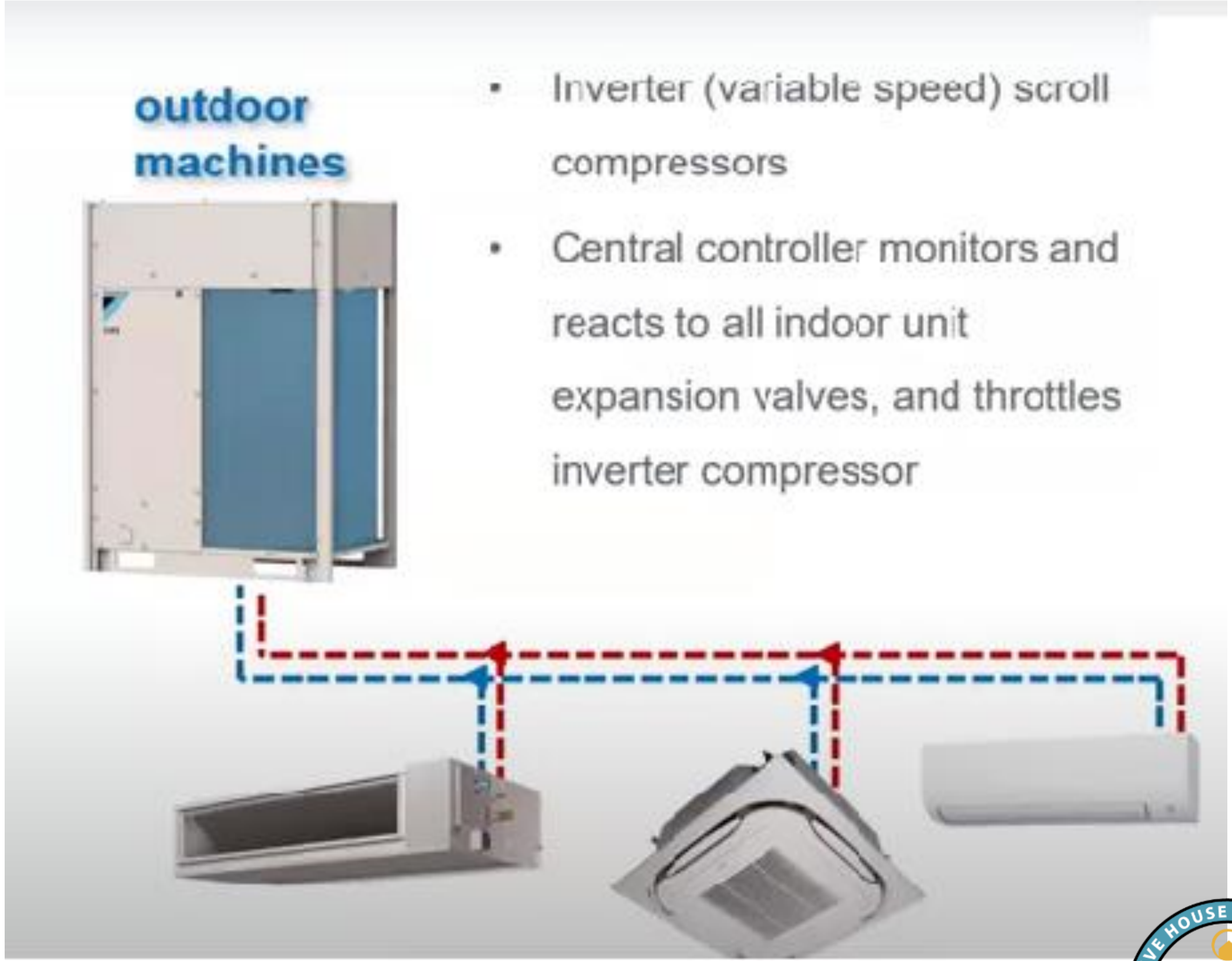
  Can be undocked (aka mini-split system) or use tradition (but better sealed) air ducts
- Cold climate models remain effective in below zero temperatures



Air-Sourced Heat Pumps and VRF Systems

Variable Refrigerant Flow (VRF)

- All-electric solution for larger buildings
- Heat-Recovery versions can provide heating and cooling within the same zone at the same time
- Non-Heat Recovery versions are in either heat or cool mode



- Central VRF

Mechanical System Sizing and Selection

Finch Cambridge

- VRF condensers on roof connect to heat pump heads in each unit
- 13 rooftop condensers supply 149 indoor units

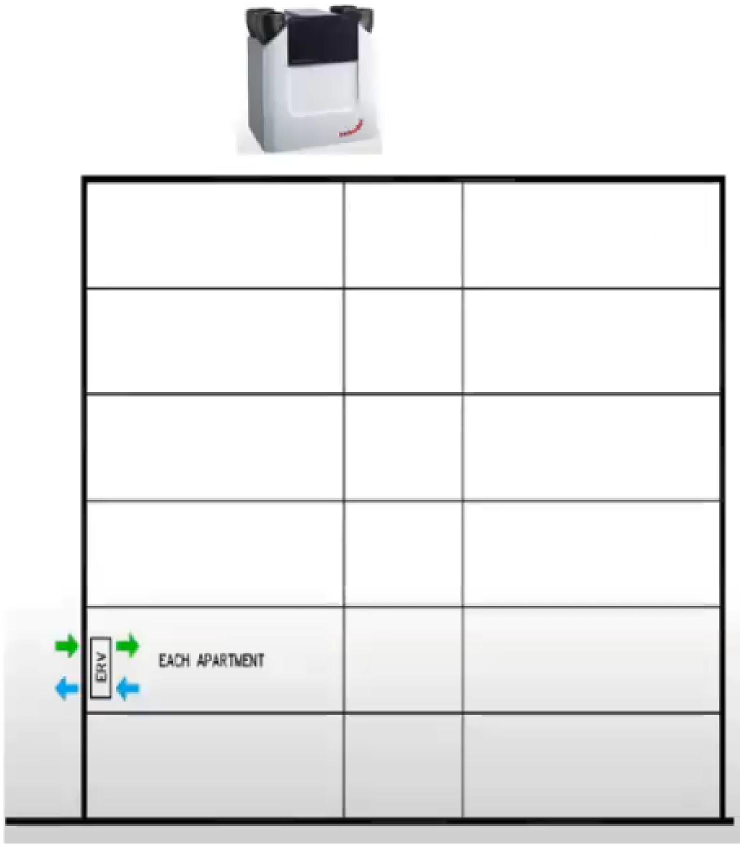
Distillery

- Individual heat pump systems for each unit
- One heat pump head per unit ducted to rooms

Mechanical System Sizing and Selection

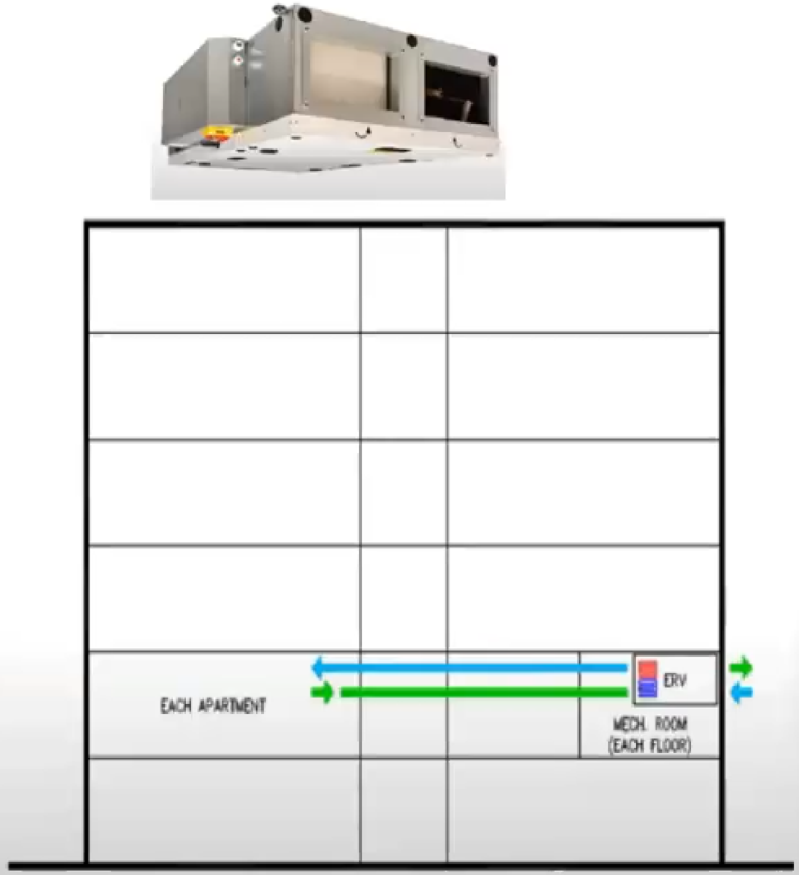
Unitized/Local

Ex: Distillery



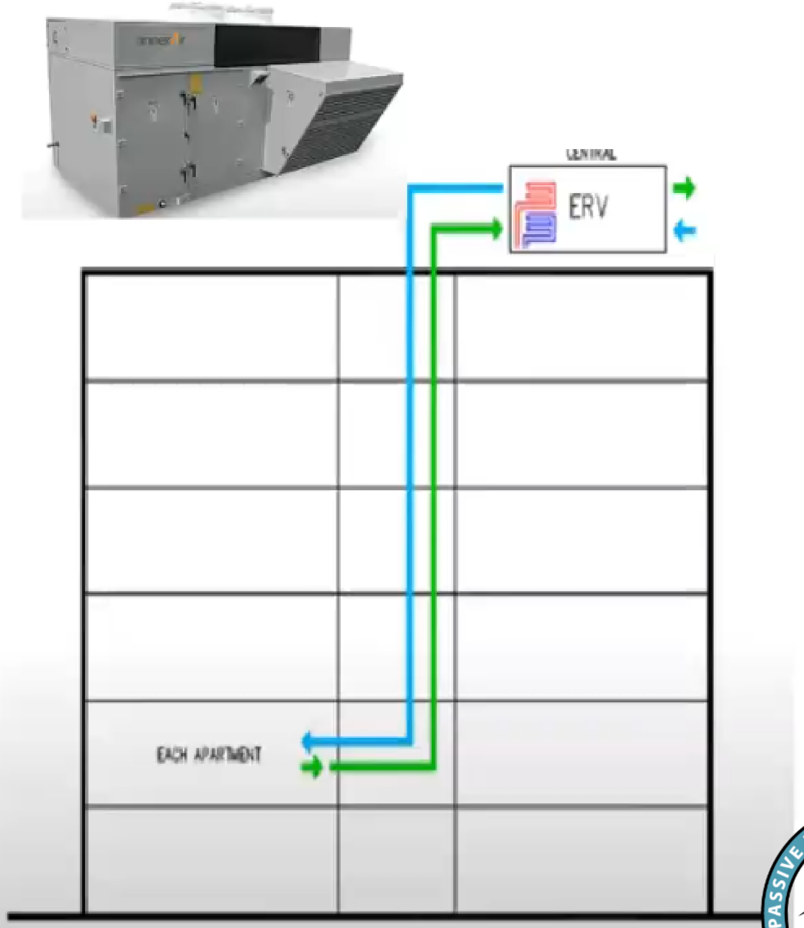
Hybrid/Floor

Ex: Mattapan Station



Centralized

Ex: Finch



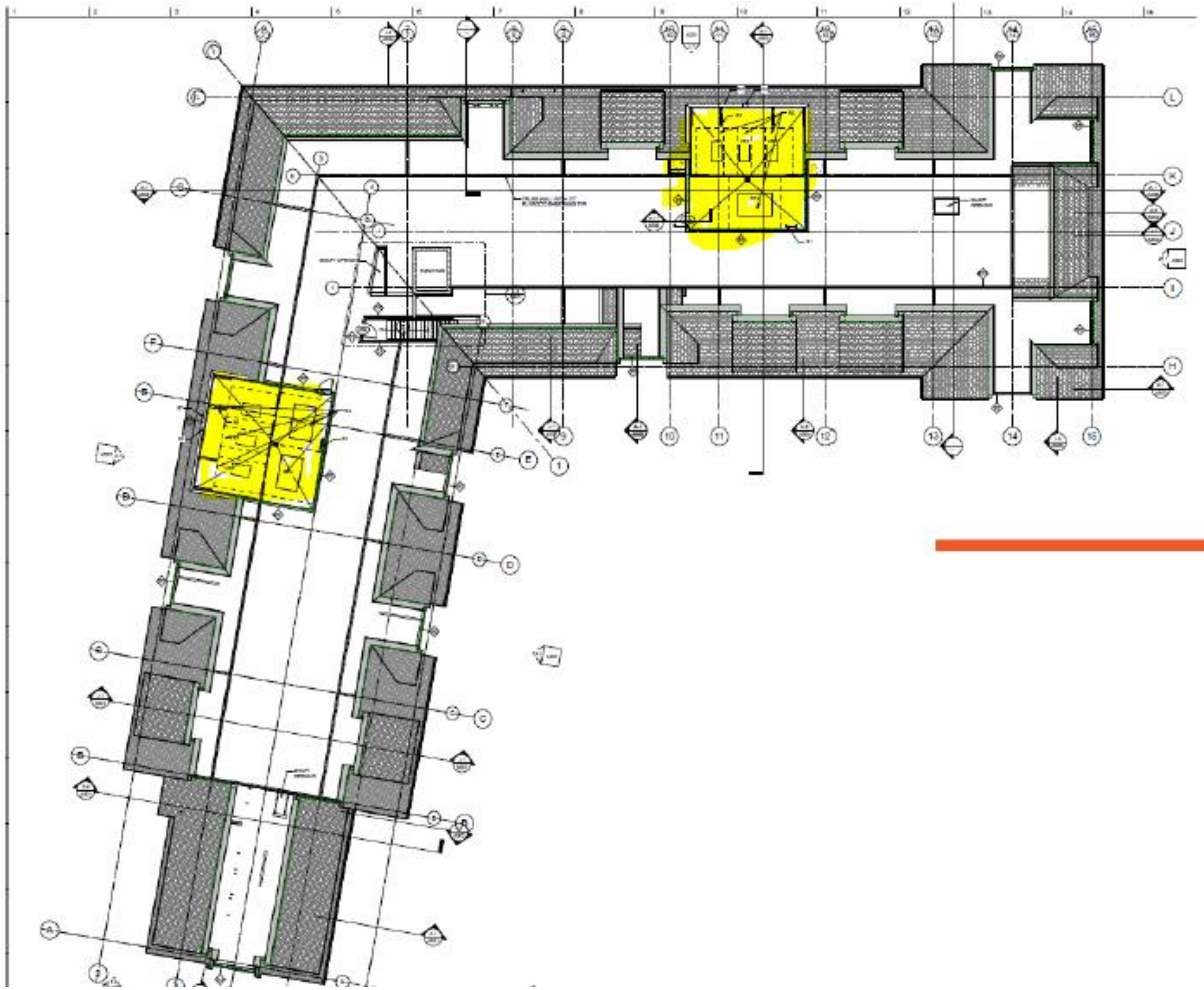
Petersen Engineering

Mechanical System Sizing and Selection

Wall Penetrations

Central vs. Unitized: Wall penetrations from in-unit ERVs

Roof Space



Mechanical Systems (on not!?)

Rocky Mountain Institute Innovation Center

- No central heating or cooling system
- Relies on solar heat gain, thermal mass (concrete floors), and interior heat sources (i.e. people)

Lessons Learned: Design Phase

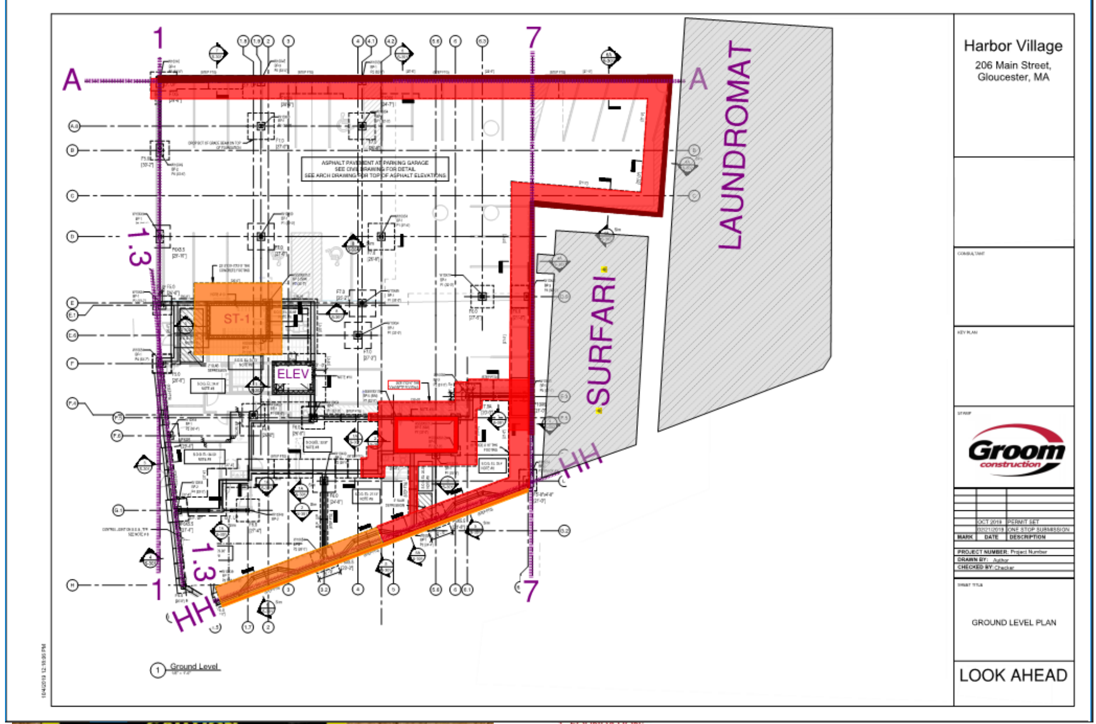
- Bring together your ***integrated team*** early and often to coordinate the project
  - Get your PH Rater/Verifier/Certifier on-board early as well as the CPHC/D
- Continuity of ***critical barriers*** is essential – air, thermal, water, vapor
  - Schematic/shop drawings should all highlight where these are – use color!
- Work with a ***mechanical engineer*** experience with low-energy buildings
  - You do not want to oversize equipment
- Consult with ***GC and trades*** during the design process
  - Focus on constructability and sequencing
- Plan for ***apartment compartmentalization*** from the beginning
  - This is required for Energy Star within Phius+2021
- Pay attention to ***solar heat gain*** and overheating in summer months
  - Shade systems are important on south facing sides (and some east/west)

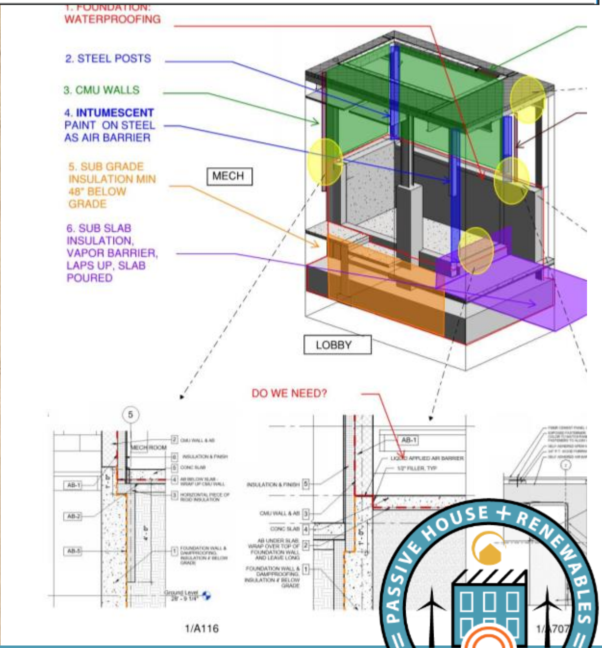
Lessons Learned: Construction Phase

- Hold ***kickoff meetings*** onsite with associated trades
  - Helpful to make sure everyone is on the same page with PH details
- Build ***mock-ups*** onsite that show installation details and provide training opportunities
- Invite ***manufacture reps*** to answer questions and demonstrate recommendations
- Know your ***air barrier*** and clearly label it everywhere
  - Assign an onsite air barrier manger to double-check
- 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

Lessons Learned: Project Management

- Communication is key!
- Highlight PH details on all schedules – in color!
- Review details and sequencing with GC/trades/subs
- Post *Airtight Building* signs for the duration of project
- Assign responsibility for air barrier to specific people
- Plan schedule for multiple blower door tests and walkthroughs





Questions?

BROUGHT TO YOU BY

PROUD SPONSORS OF

Thank You

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