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On behalf of Eversource, a proud sponsor of Energize Connecticut, and in partnership with Connecticut Passive House, we are pleased to offer *Passive House Training* 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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Upcoming Webinar

June 9, 2021- Passive House Process: The Path to Certification

presented by

John Loercher

CTPH

CONNECTICUT PASSIVE HOUSE

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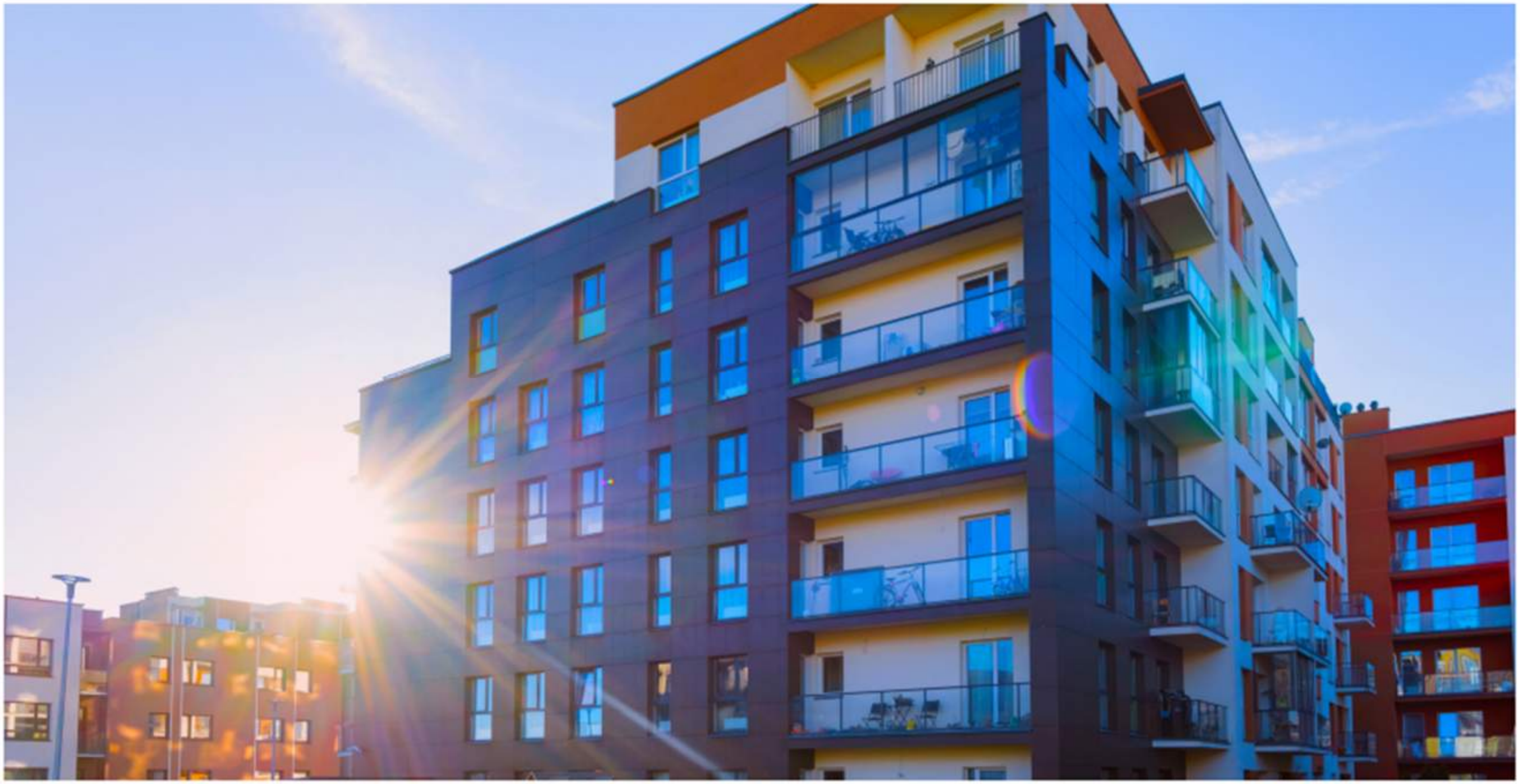
or email PassiveHouseTrainingCT@icf.com

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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Passive House 201

Technical Aspects of Passive House

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

Luke McKneally AIA, LEED AP, CPHC

Account Manager

High Rise & Passive House projects

PH 201 Statement

- **Summary:** This is an introductory course to provide rudimentary knowledge of Passive House design considerations. It assumes familiarity with the PH101 presented by PHCT. It is not a formal training under PHIUS+ or PHI.
- **Audience:** Those interested in why Passive House works, but not yet engaged in a certification course through PHI or PHIUS+
- **Topics:**
  - Basic massing, shading and solar control
  - Air barrier, weather barrier and thermal control layers
  - Balanced ventilation, efficient heating, cooling and domestic hot water systems
  - Modeling used to guide the design

Learning Objectives

1. Learn more about what has been called the most energy efficient building standard in the world, Passive House.
2. Understand how Passive House provides an ideal path to achieving Net Zero Energy / Net Zero Carbon buildings.
3. Understand how the building enclosure design is critical to meeting the Passive House certification criteria.
4. Learn how mechanical systems design can work with envelope design to reduce energy loads.

Why Passive House?

Focus on fundamental principles of building physics to reduce energy loads at their source.

Net-Zero Energy via Passive House

- Total source energy demand is roughly equal to site energy production
- May offset large fossil fuel energy use with renewable source electricity, resulting in high GHG emissions

- Rigorous standard for primary energy reduction (before renewable energy)
- Significant GHG emissions reductions
- Net-Zero energy or net-zero energy ready
- Source-Positive energy capable

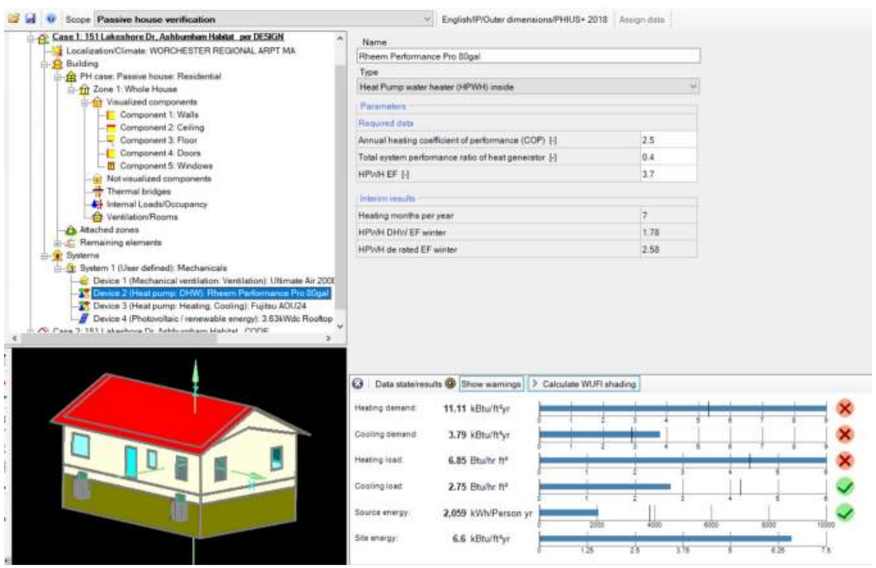
Source Energy Limits

PHIUS+ 2021:	Varies / person / yr
PHIUS+ 2018:	3,840 kWh / person / yr
PHIUS+ CORE:	5,500 kWh / person / yr

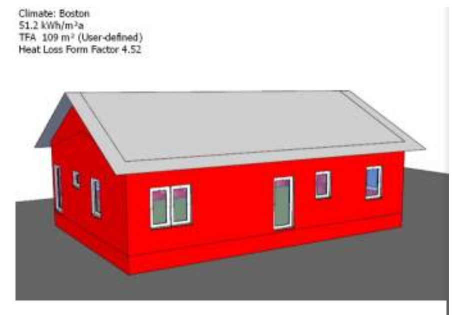
PHI Premium:	9.51 kBTU / sf / yr
PHI Plus:	14.26 kBTU / sf / yr
PHI Classic:	19.02 kBTU / sf / yr

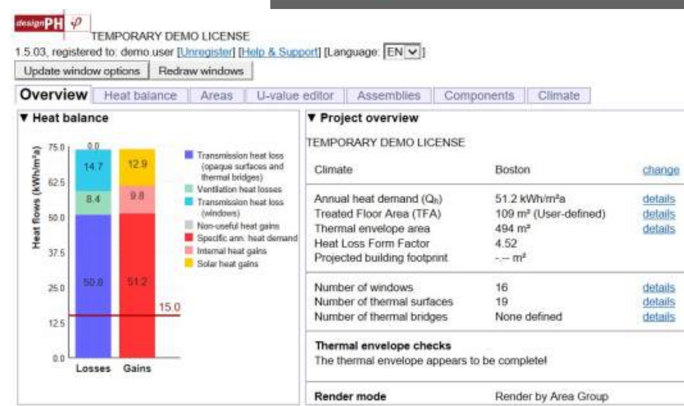
Modeling

WUFI



DesignPH/PHPP

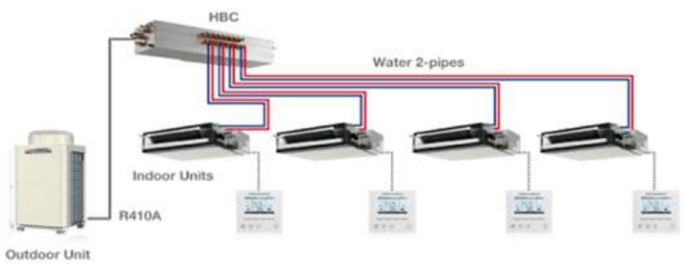




Complementary Programs

Passive House ≠ Products and Technologies



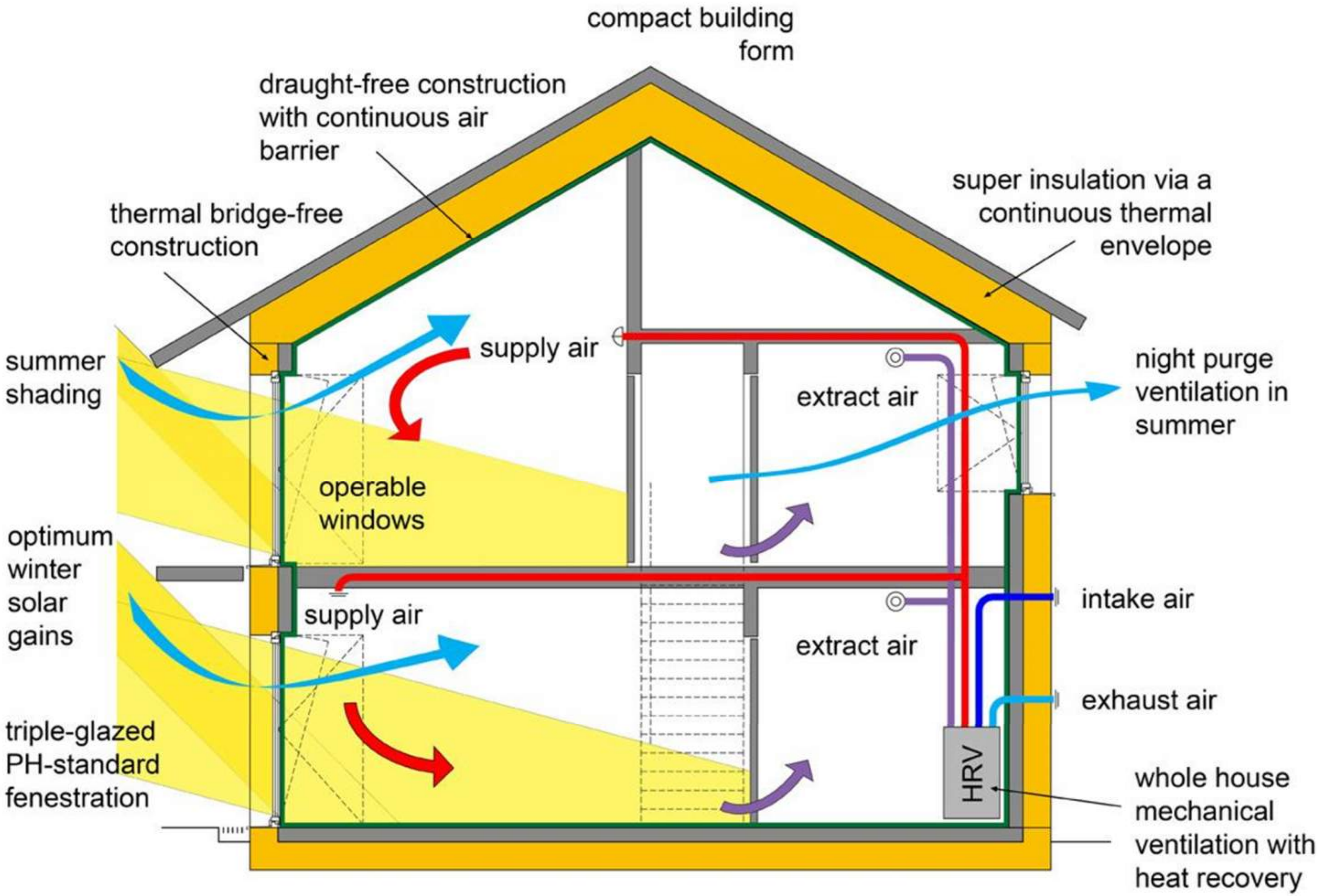

Passive House =
Whole Building Systems Analysis

Energy Flow

Climate & Context

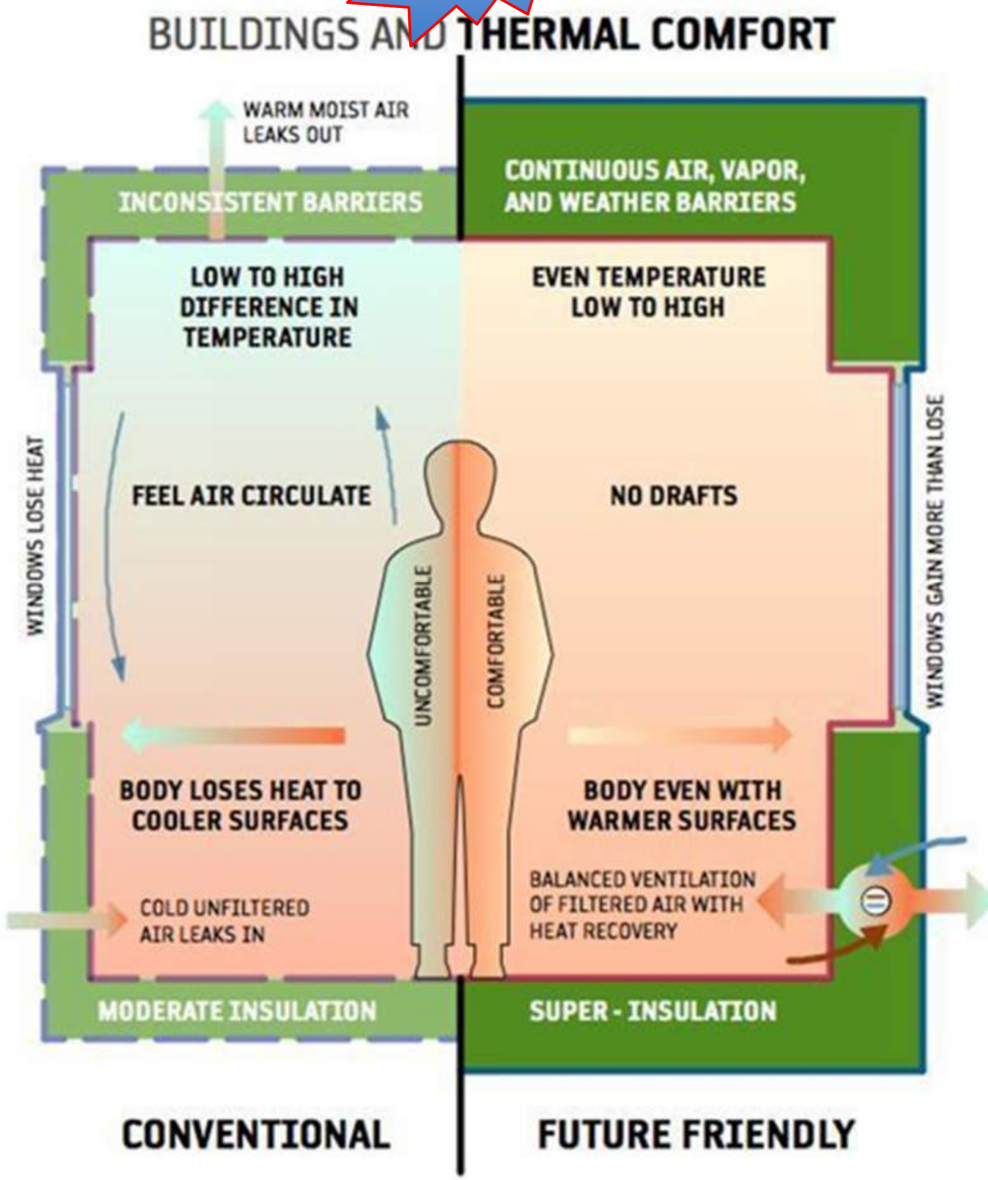
Massing & Envelope

Mechanical, Electrical, & Plumbing



Credit: Createrra

Conventional vs. Passive House



Credit: Jamie Wolf, Wolfworks, Inc.

Impacts on Users and Co-Benefits

- **Healthy indoor environmental quality**
  - Draft-free
  - Comfortable
  - Surface temperatures well above dew point
  - Reduced mold risk
  - Paired with low VOC, low toxin materials
  - Filtered fresh air
- **Passive survivability**
  - Minimal temperature drift during extreme weather conditions even with system shutdowns or power outages
  - Longer, slower heating and cooling loss times
- **Minimized noise**
  - Insulation

Passive House whole building energy flow

GAINS:

- Solar energy through windows, assemblies
- Occupant heat
- Equipment energy loss inside envelope (lights, computers, misc.)
- Equipment Outputs and Efficiencies
- Renewable energy system inputs if present (PV and Solar Thermal)

LOSSES:

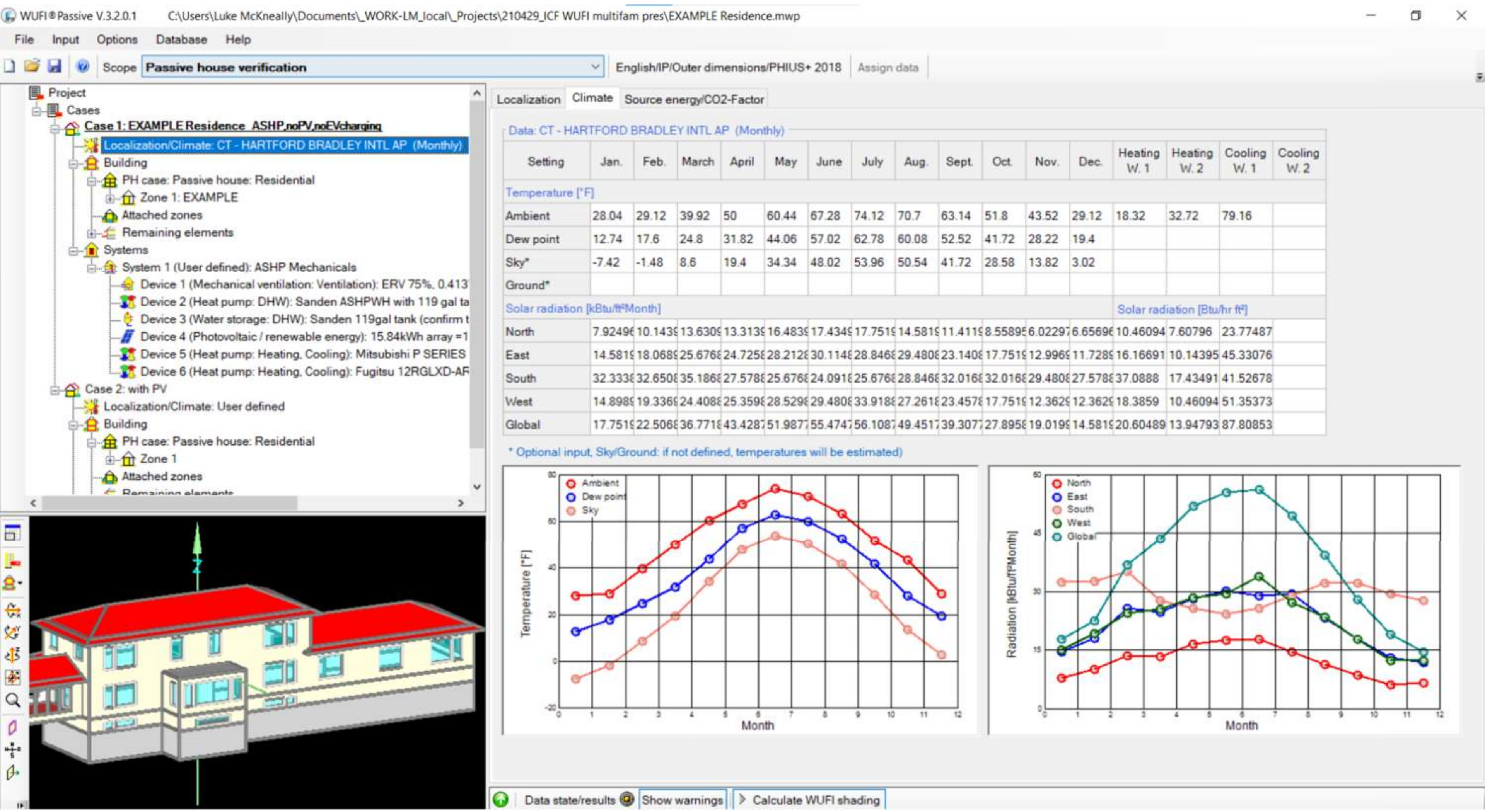
- Thermal & Moisture transfer through:
  - Air Infiltration and Leakage
  - Assemblies and Components
  - Ventilation

Climate Data

USDA hardiness map

Climate Data

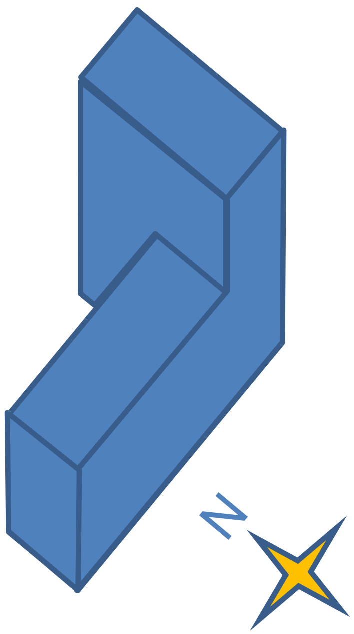
WUFI modelling



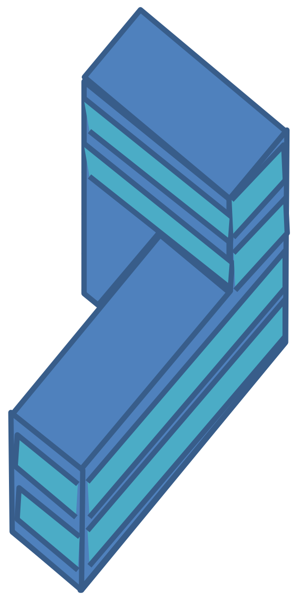
Setting	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Heating W. 1	Heating W. 2	Cooling W. 1	Cooling W. 2
Temperature [°F]																
Ambient	28.04	29.12	39.92	50	60.44	67.28	74.12	70.7	63.14	51.8	43.52	29.12	18.32	32.72	79.16	
Dew point	12.74	17.6	24.8	31.82	44.06	57.02	62.78	60.08	52.52	41.72	28.22	19.4				
Sky*	-7.42	-1.48	8.6	19.4	34.34	48.02	53.96	50.54	41.72	28.58	13.82	3.02				
Ground*																
Solar radiation [kBtu/ft²Month]													Solar radiation [Btu/hr ft²]			
North	7.92496	10.1439	13.6309	13.3139	16.4839	17.4349	17.7519	14.5819	11.4119	8.55895	6.02297	6.65696	10.46094	7.60796	23.77487	
East	14.5819	18.0689	25.6768	24.7258	28.2128	30.1148	28.8468	29.4808	23.1408	17.7519	12.9969	11.7289	16.16691	10.14395	45.33076	
South	32.3338	32.6508	35.1868	27.5788	25.6768	24.0918	25.6768	28.8468	32.0168	32.0168	29.4808	27.5788	37.0888	17.43491	41.52678	
West	14.8989	19.3369	24.4088	25.3598	28.5298	29.4808	33.9188	27.2618	23.4578	17.7519	12.3629	12.3629	18.3859	10.46094	51.35373	
Global	17.7519	22.5068	36.7718	43.4287	51.9877	55.4747	56.1087	49.4517	39.3077	27.8958	19.0199	14.5819	20.60489	13.94793	87.80853	

Credit: Fraunhofer IBP

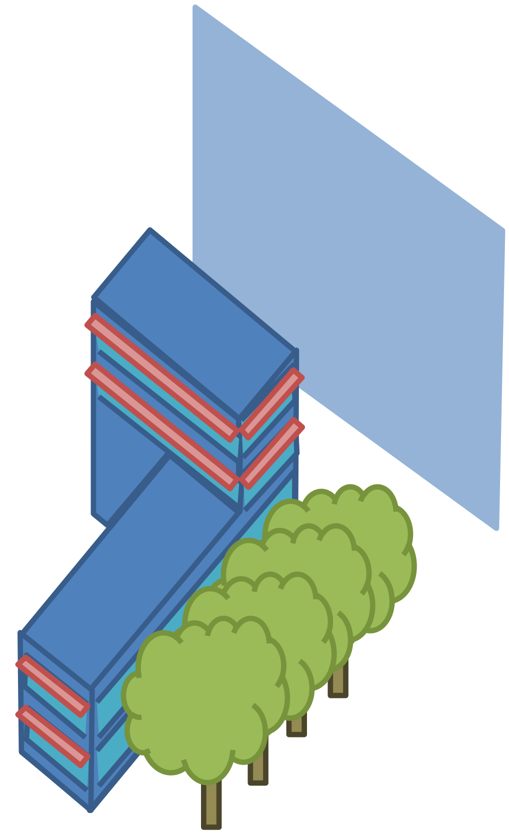
Massing, Orientation, Glazing, Shading



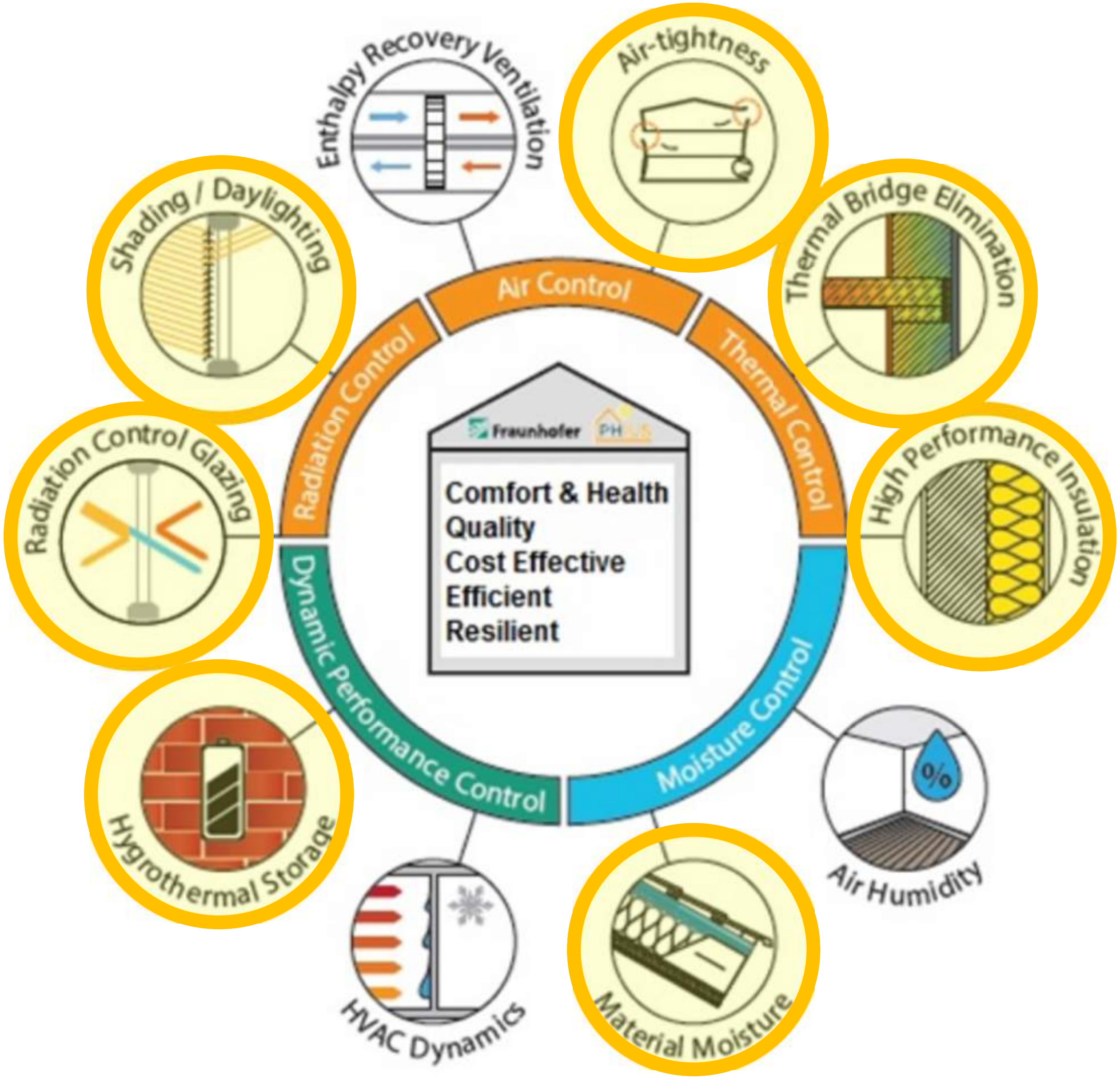
MASSING &
ORIENTATION



WINDOW AREA
& ORIENTATION

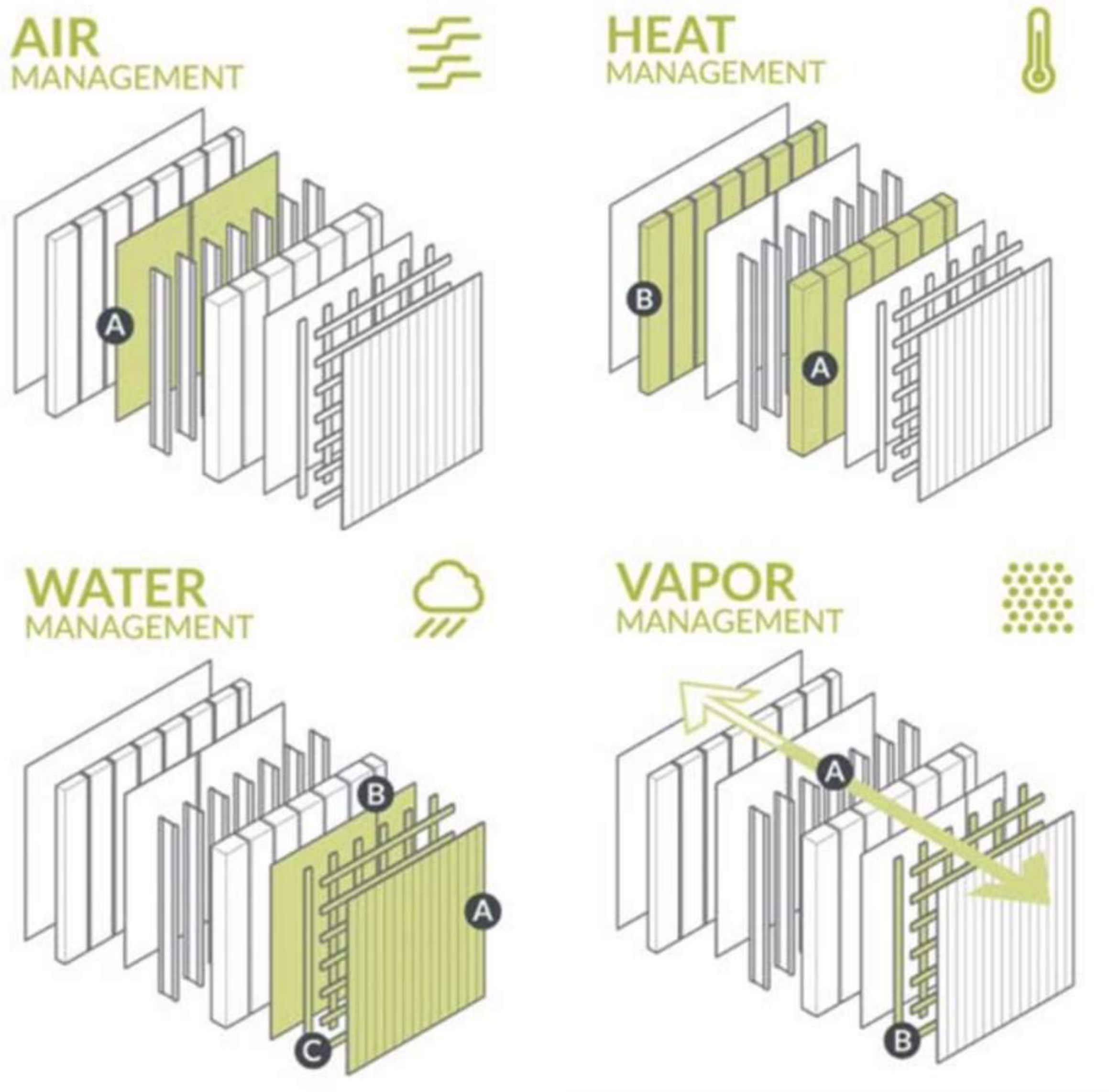


SOLAR EXPOSURE



Credit: PHIUS & Pembina Institute

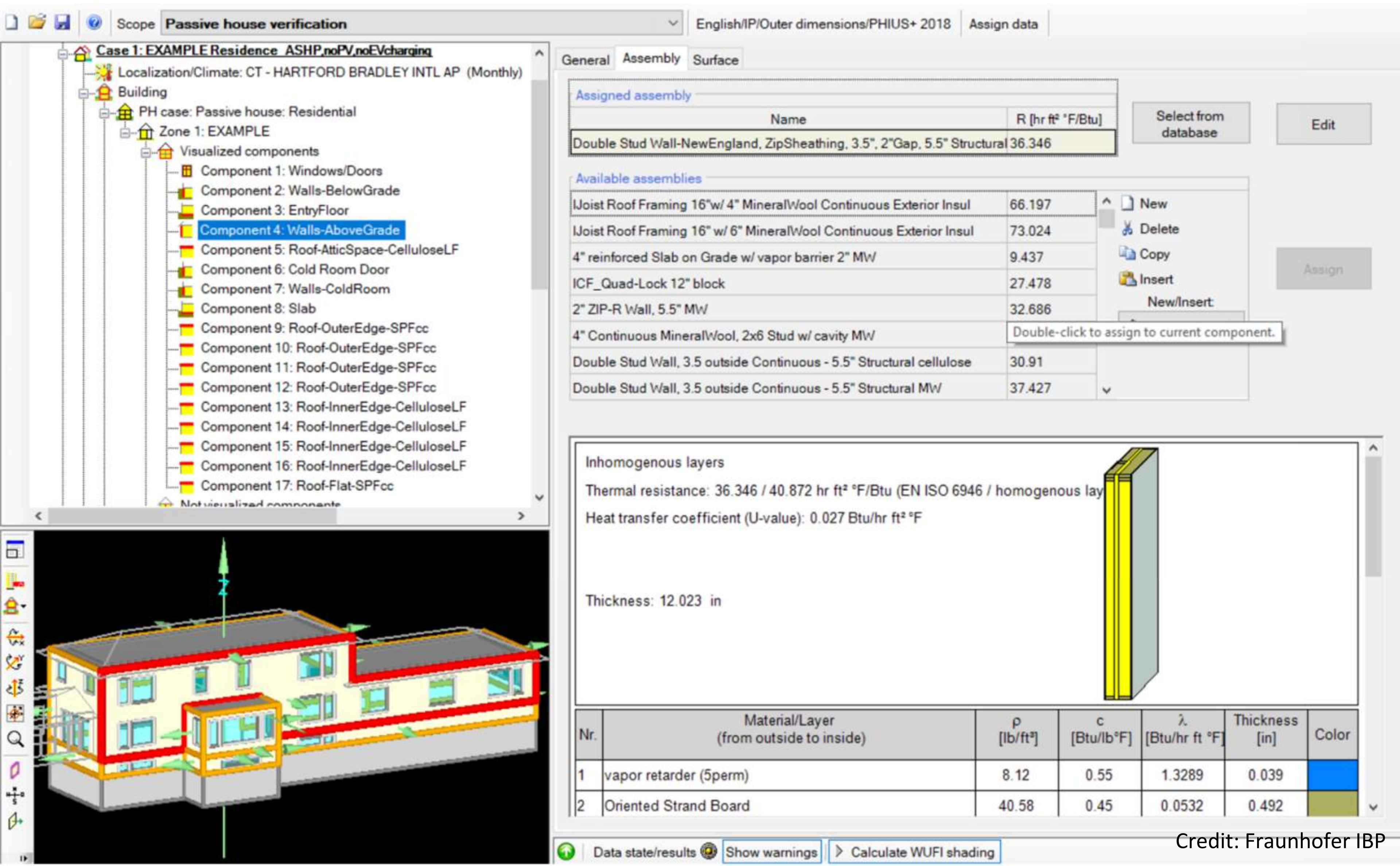
Enclosure



Credit: Hammer & Hand

Assemblies

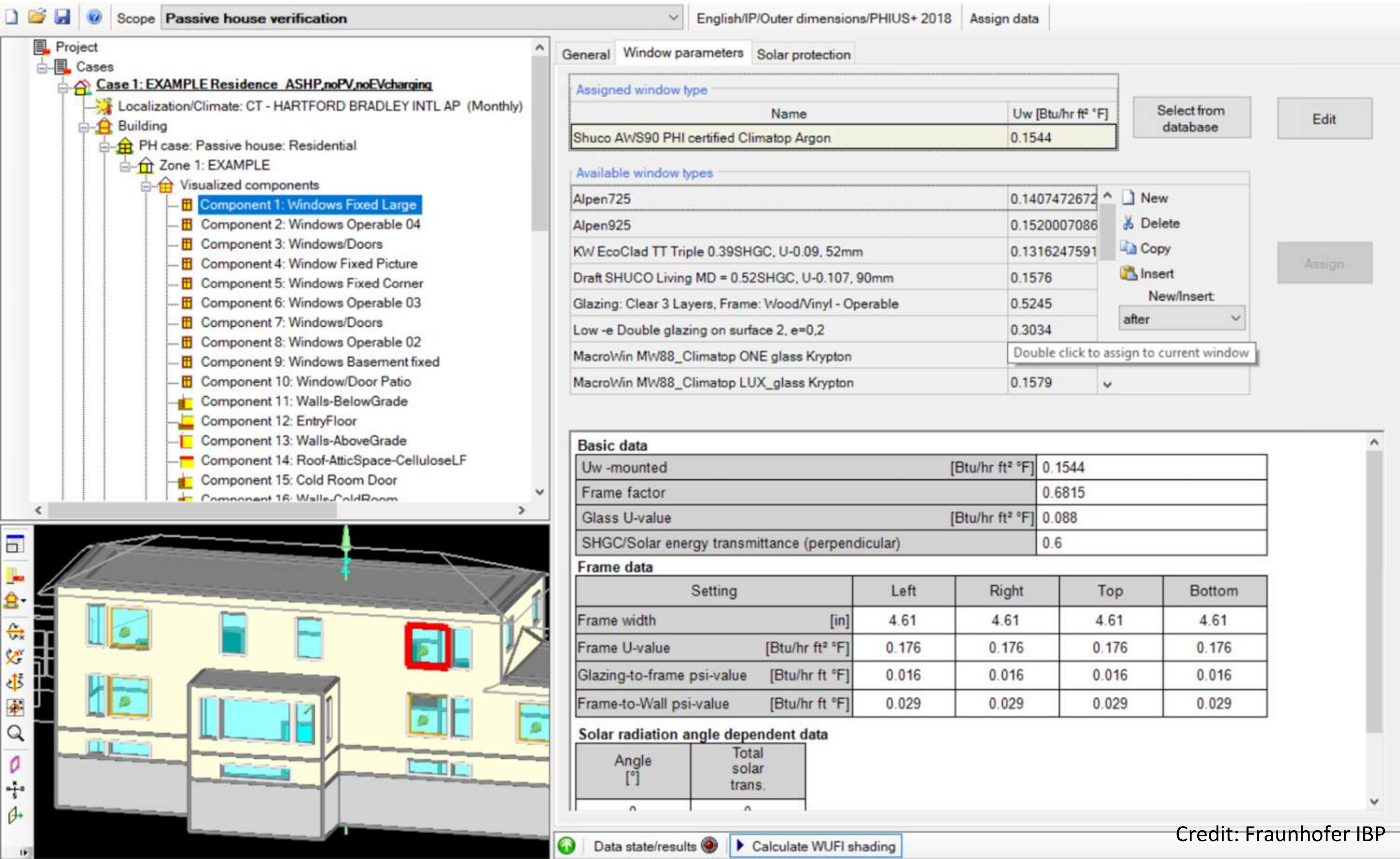
WUFI modelling



Credit: Fraunhofer IBP

Assemblies

WUFI modelling



Credit: Fraunhofer IBP

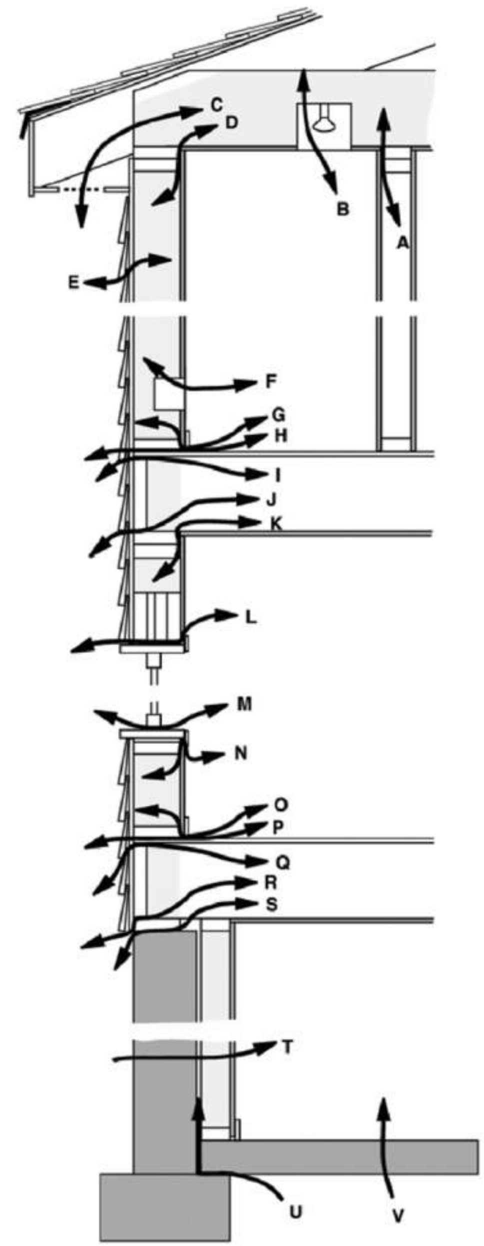
Air Leakage

PHI: 0.6 ACH50
0.033 cfm50 / ft2 for ≥10,000sf

PHIUS: 0.08 cfm75 / ft2 for 1-4 stories
0.11 cfm75 / ft2 for ≥5 stories
0.30 cfm50 / ft2 dwelling units

US Army Corp of Engineers (v3, 2012):
0.25 cfm75 / ft2

Mass Save UDRH 2019 Baseline:
0.4 cfm75 / ft2



Credit: Wolf & Tyler (2013)

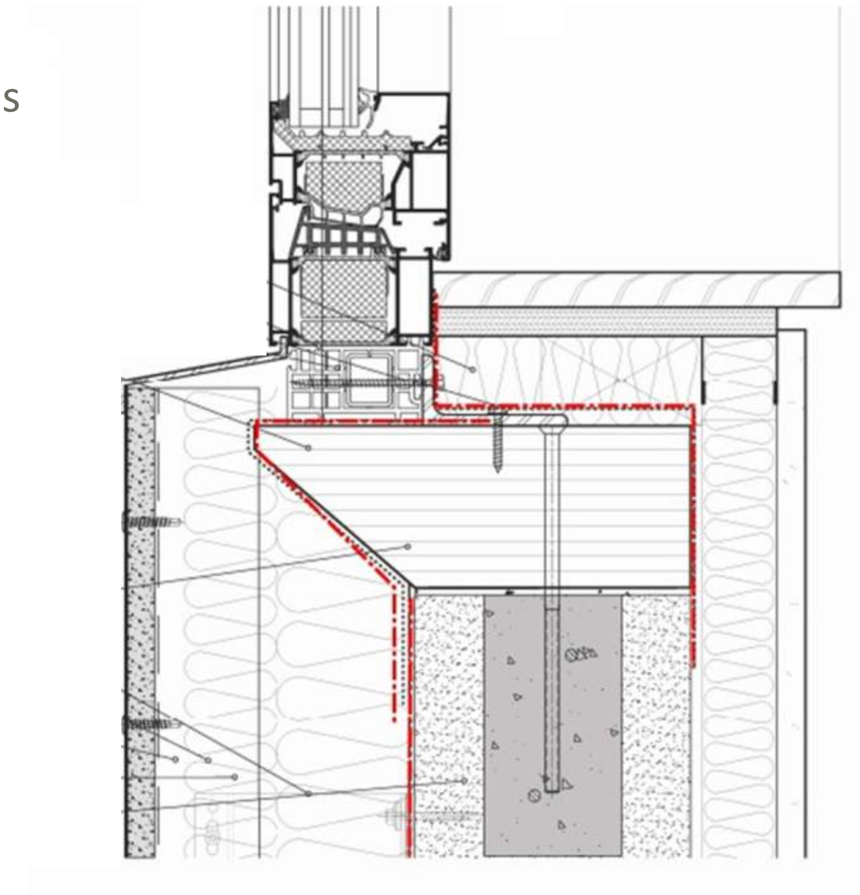
Air Barrier Details

Air barrier continuity

- High attention to all exterior details

Insulation continuity

- Thermal bridge mitigation wherever possible

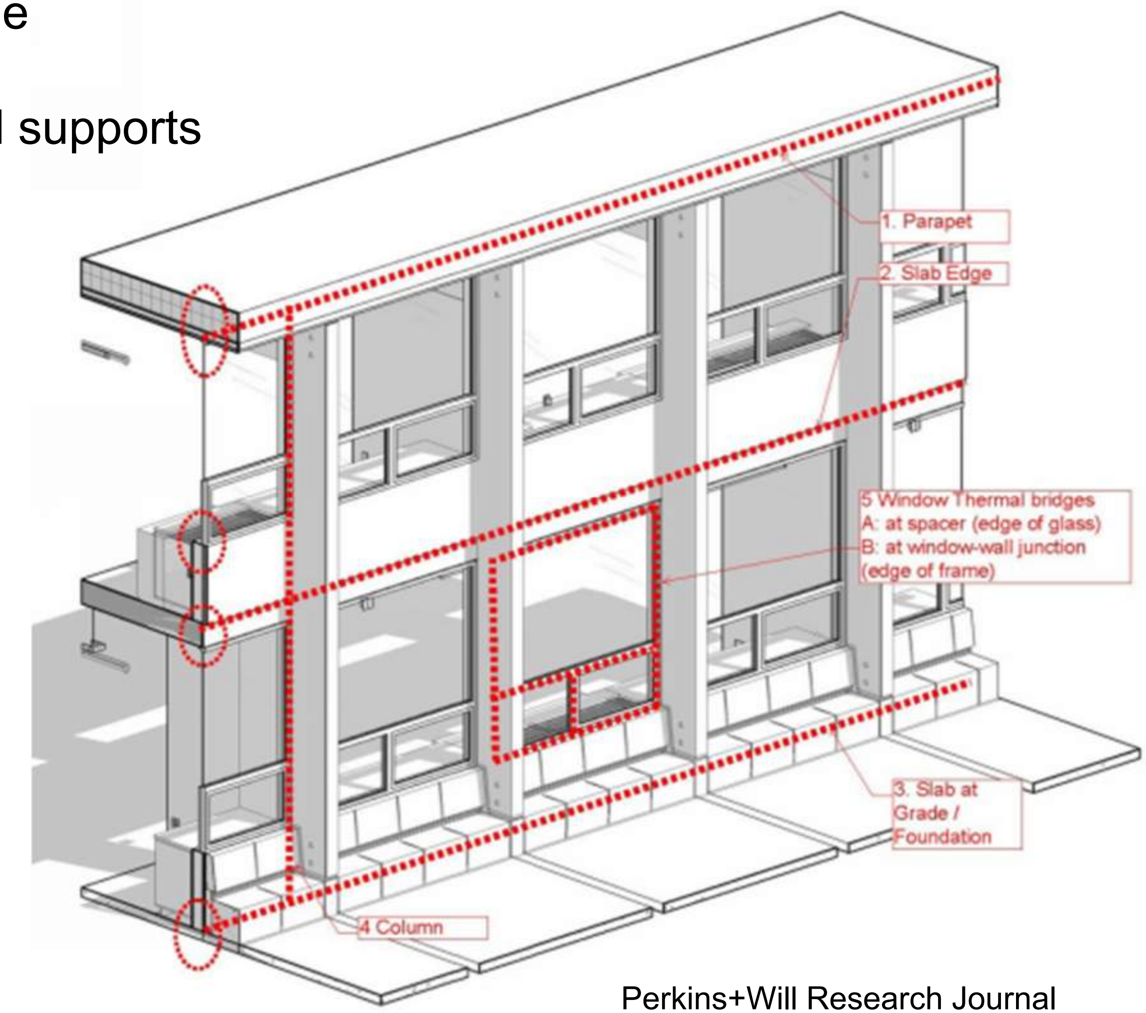


Credit: Steven Winter Associates

Thermal Bridging

Thermal Bridges are common at structural interfaces:

- Columns and beams at facade
- Slab & floor edges at facade
- Window and door frames and supports
- Cantilevers
- Penetrations

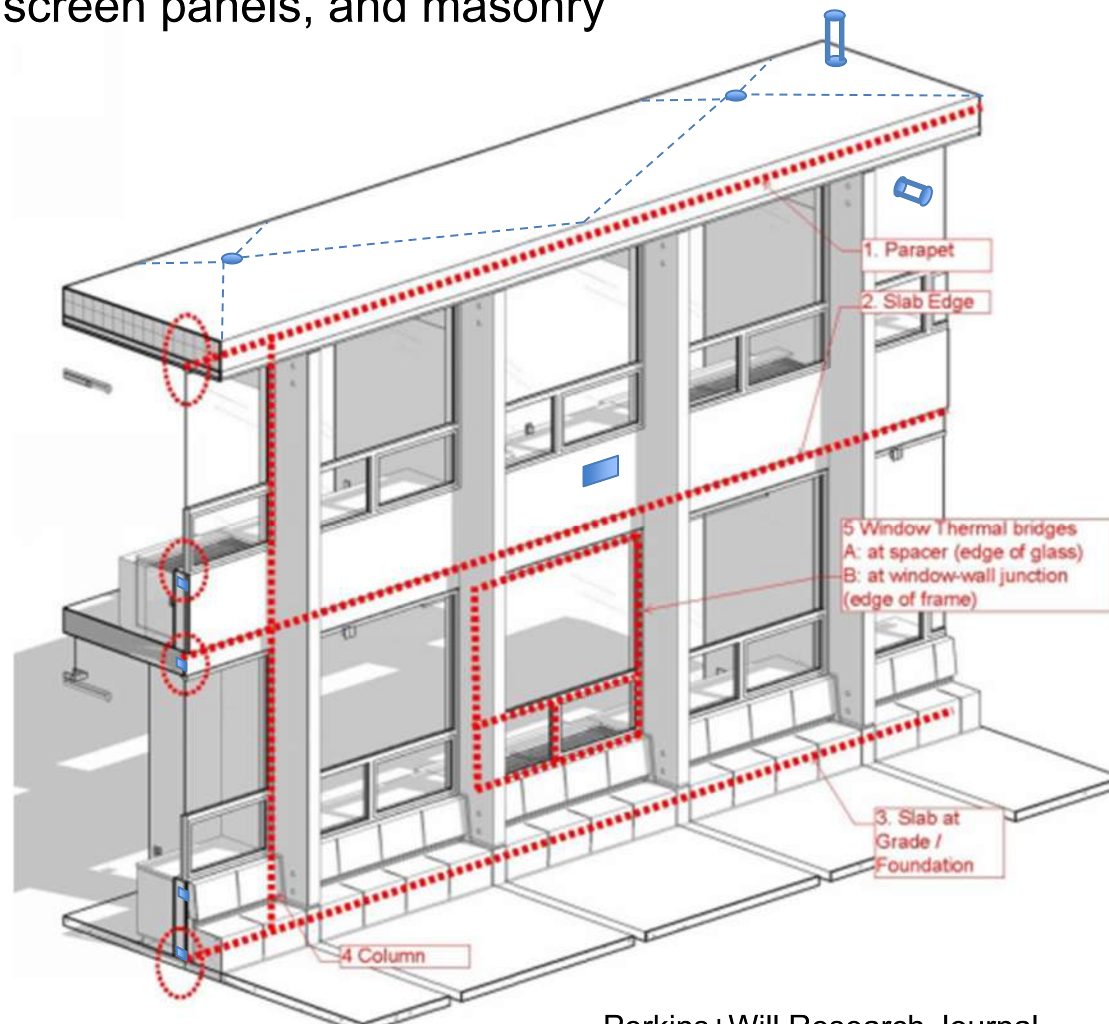


Perkins+Will Research Journal
2017 / VOL 09.01

Thermal Bridging

AND

- Anchors for curtain walls, rain screen panels, and masonry
- Rainwater drains
- Waste pipes
- Electrical
- Ventilation
  - Intakes and exhausts
  - Kitchen extraction hoods
  - Dryer exhaust



Perkins+Will Research Journal
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Thermal Bridge Modeling

PHPP

Passive House planning: **SPECIFIC ANNUAL HEATING DEMAND (monthly method)**

(This page displays the sums of the monthly method over the heating period)

Climate:	NY, New York	Interior temperature:	68 °F
Building:		Building type:	
Spec. Capacity:	19 BTU/(ft²°F)	Treated floor area A_{TFA}:	189,012 ft²

Building assembly	Temperature zone	Area ft²		R-Value hr.ft².F/BTU		Month. red. fac.		G_t F.day/yr		kBTU/yr	per ft² treated floor area
Exterior wall - Ambient	A	91719	* 1/	23.6	*	1.00	*	5673	=	528826	2.80
Roof/Ceiling - Ambient	A	10972	* 1/	34.2	*	1.00	*	5673	=	43631	0.23
Floor slab / Basement ceiling	B	10788	* 1/	3.6	*	1.00	*	708	=	51051	0.27
Windows	A	30[illegible]31	* 1/	4.2	*	1.00	*	5673	=	977446	5.17
Exterior door	A	600	* 1/	28.0	*	1.00	*	5673	=	2917	0.02
Exterior TB (length/ft)	A	18904	*	0.041	*	1.00	*	5673	=	106418	0.56
											kBTU/(ft²yr)
Transmission heat losses Q_T									Total	1710290	9.05

= 6 % of the total heat loss through the envelope.

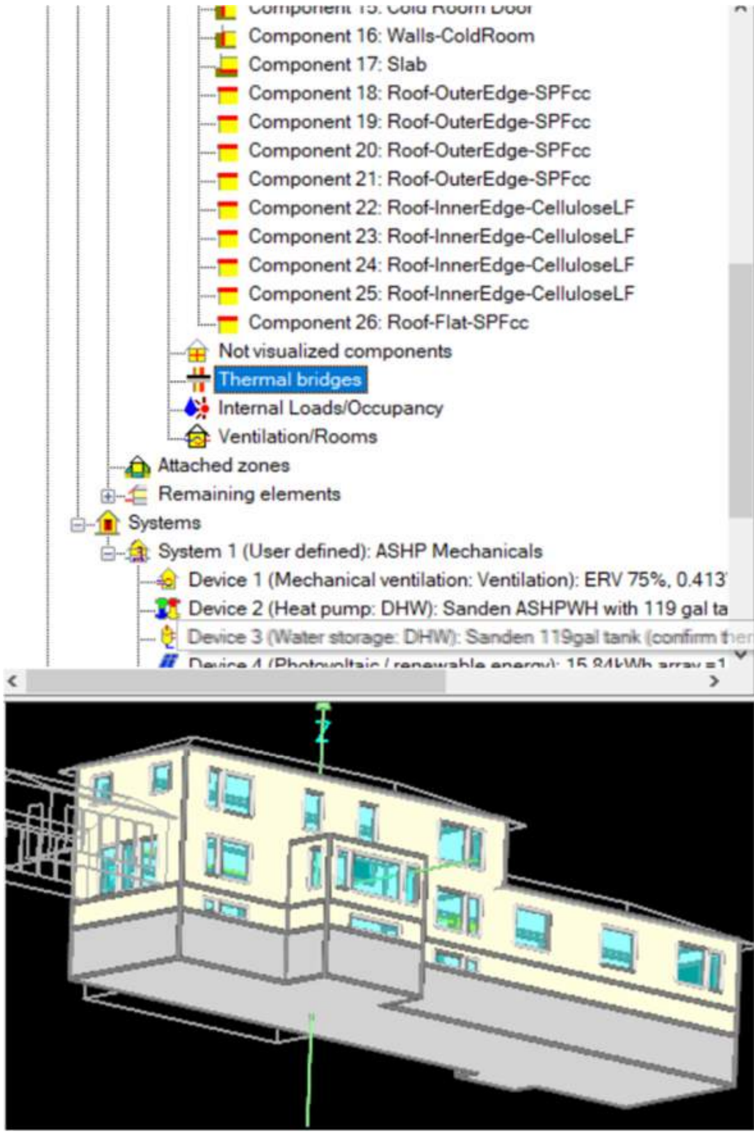
Thermal bridge inputs

Nr.	Thermal bridge description	Group Nr.	Assigned to group	Qty	User deter-mined length [ft]	-	Length ℓ [ft]	Input of thermal bridge heat loss coefficient BTU/hr.ft.F	Ψ BTU/hr.ft.F
6	Wall Panel Bridges					-		Wall Panel Bridges	
7	Panel to panel (H1)	15	Thermal bridges Ambient	1	8131.80	-	8131.80	Panel to panel (H1)	0.072
8	Panel corner	15	Thermal bridges Ambient	2	253.00	-	506.00	Panel corner	-0.038
9	Shallow over Deep (SO	15	Thermal bridges Ambient	1	3949.50	-	3949.50	Shallow over Deep (SO	0.012
10	Deep over shallow (S)	15	Thermal bridges Ambient	1	3949.50	-	3949.50	Deep over shallow (S)	0.015
11	Vertical Joint (V1)	15	Thermal bridges Ambient	1	1828.78	-	1828.78	Vertical Joint (V1)	0.029
12						-			
13	Roof Bridges					-		Roof Bridges	
14	TB1	15	Thermal bridges Ambient	1	7.58	-	7.58	TB1	0.099
15	TB2	15	Thermal bridges Ambient	1	207.22	-	207.22	TB2	0.136
16	TB3	15	Thermal bridges Ambient	1	24.27	-	24.27	TB3	0.072
17	TB4	15	Thermal bridges Ambient	1	24.27	-	24.27	TB4	0.087
18	TB6	15	Thermal bridges Ambient	1	23.84	-	23.84	TB6	0.021
19	TB7	15	Thermal bridges Ambient	1	23.84	-	23.84	TB7	0.130
20	TB8	15	Thermal bridges Ambient	1	70.24	-	70.24	TB8	0.143
					Total : 18,904				

Credit: Steven Winter Associates / PHI

Thermal Bridge Modeling

WUFI



Linear thermal bridges

Nr	Name	Linear thermal transmittance [Btu/hr ft °F]	Length [ft]	Attachment
1	Slab edge	.047	276	Perimeter
2	Porch Roof	0.1	2.5	Ambient

New

Delete

Copy

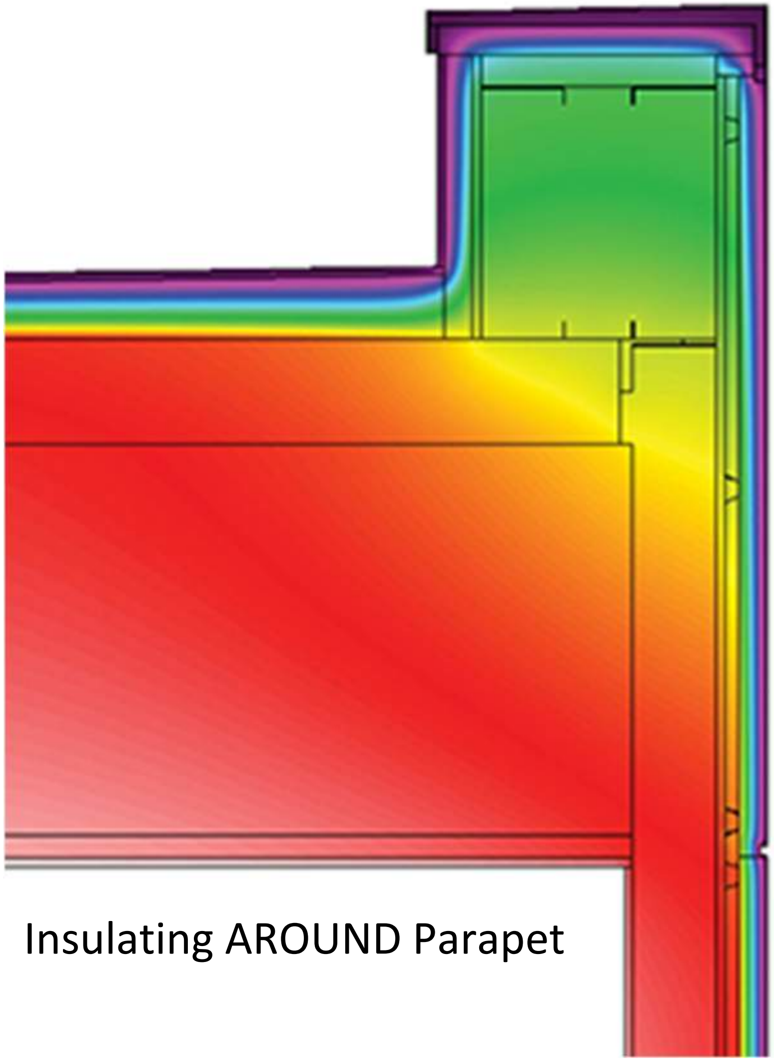
Insert

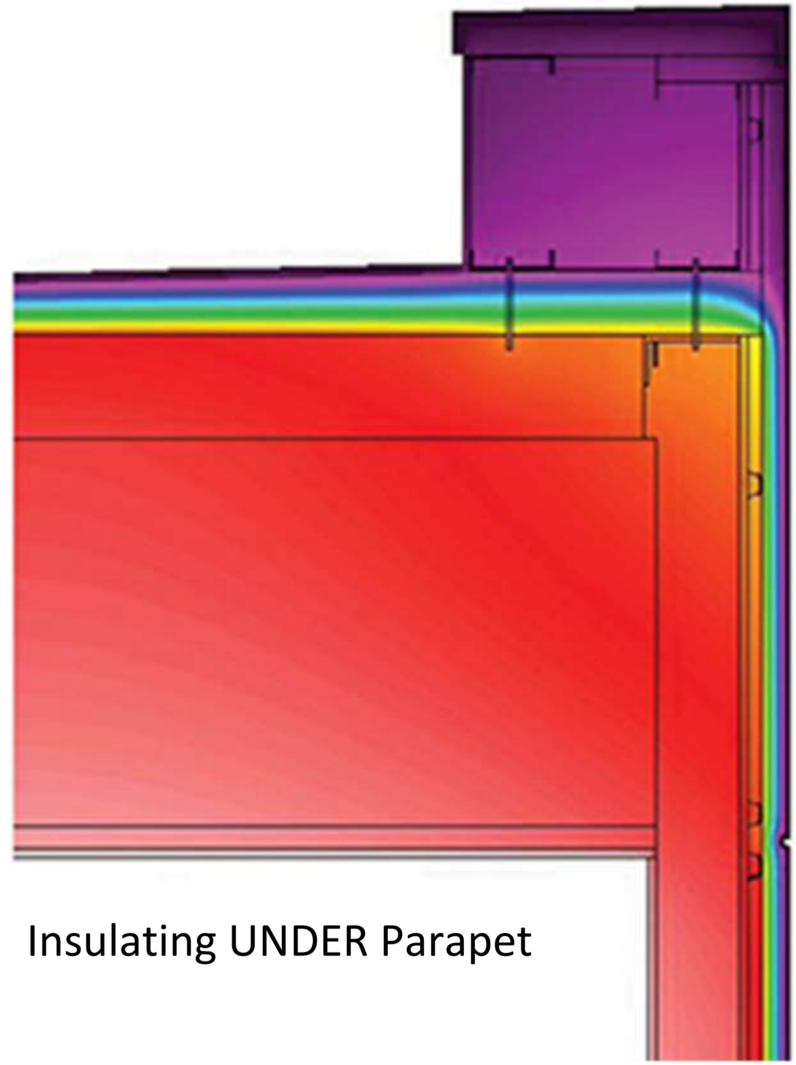
New/Insert:

after

Credit: Fraunhofer IBP

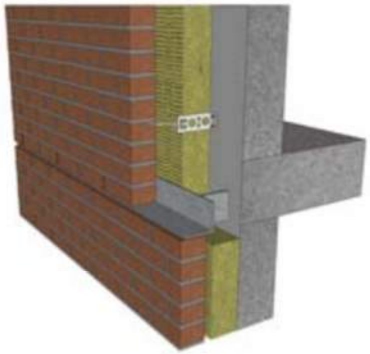
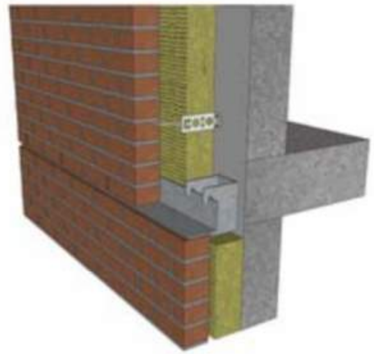
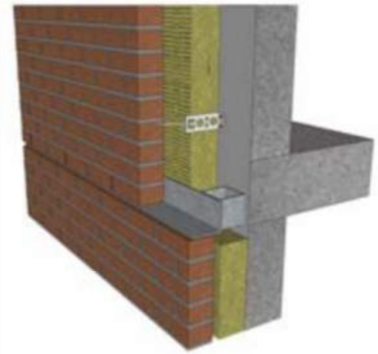
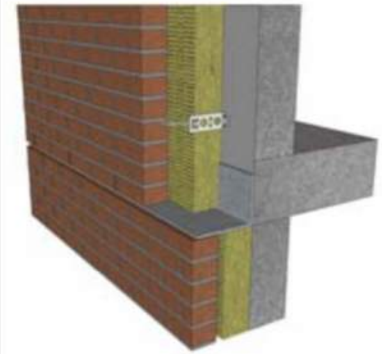
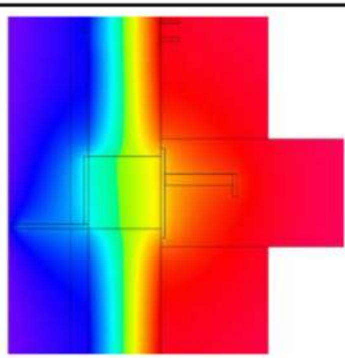
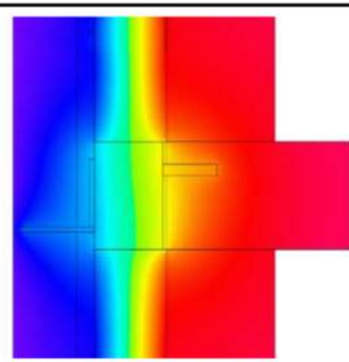
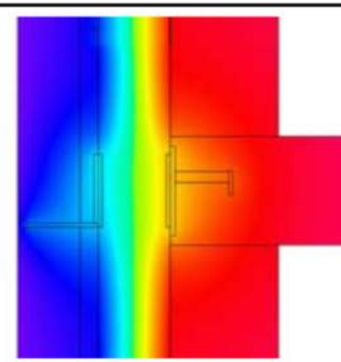
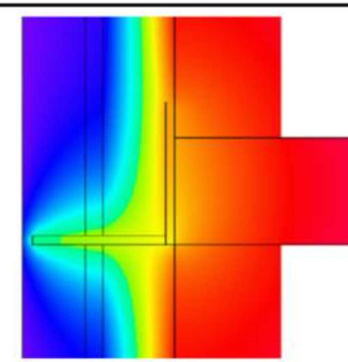
Thermal Bridging





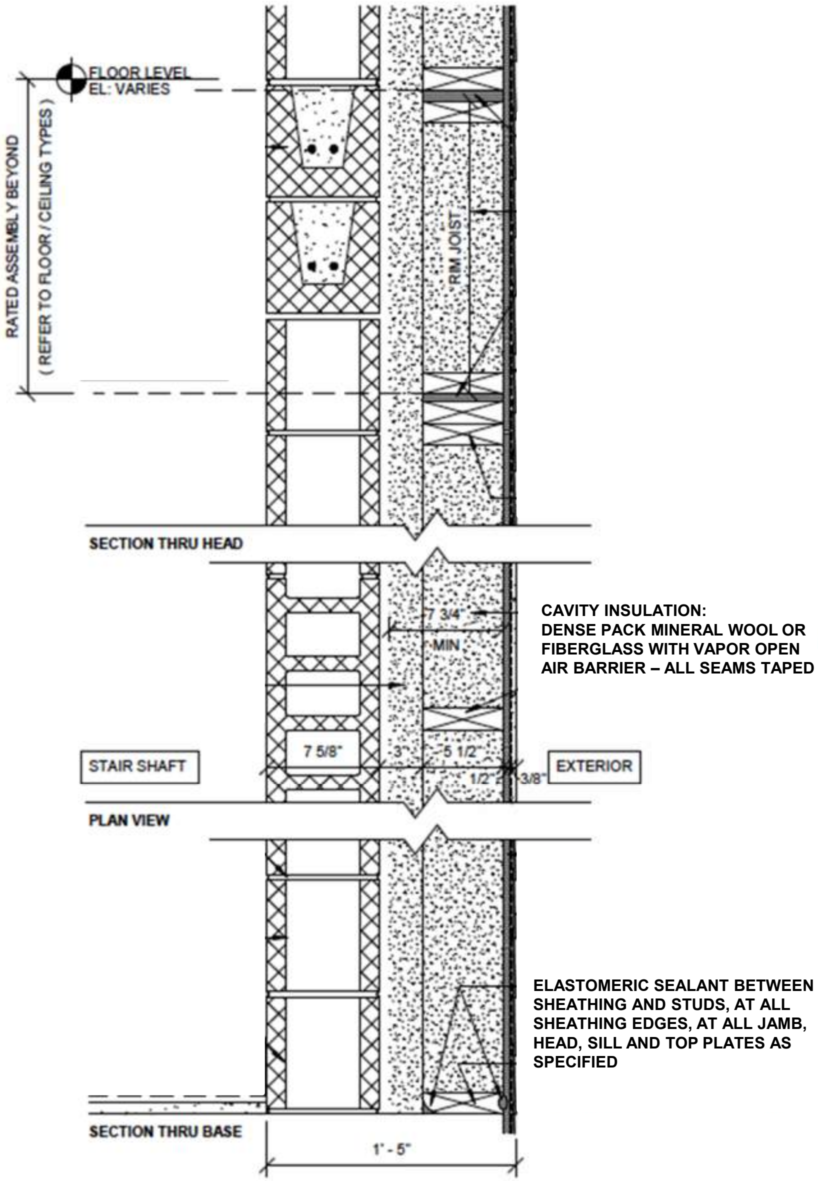
Credit: Meip Keller, Payette 2015

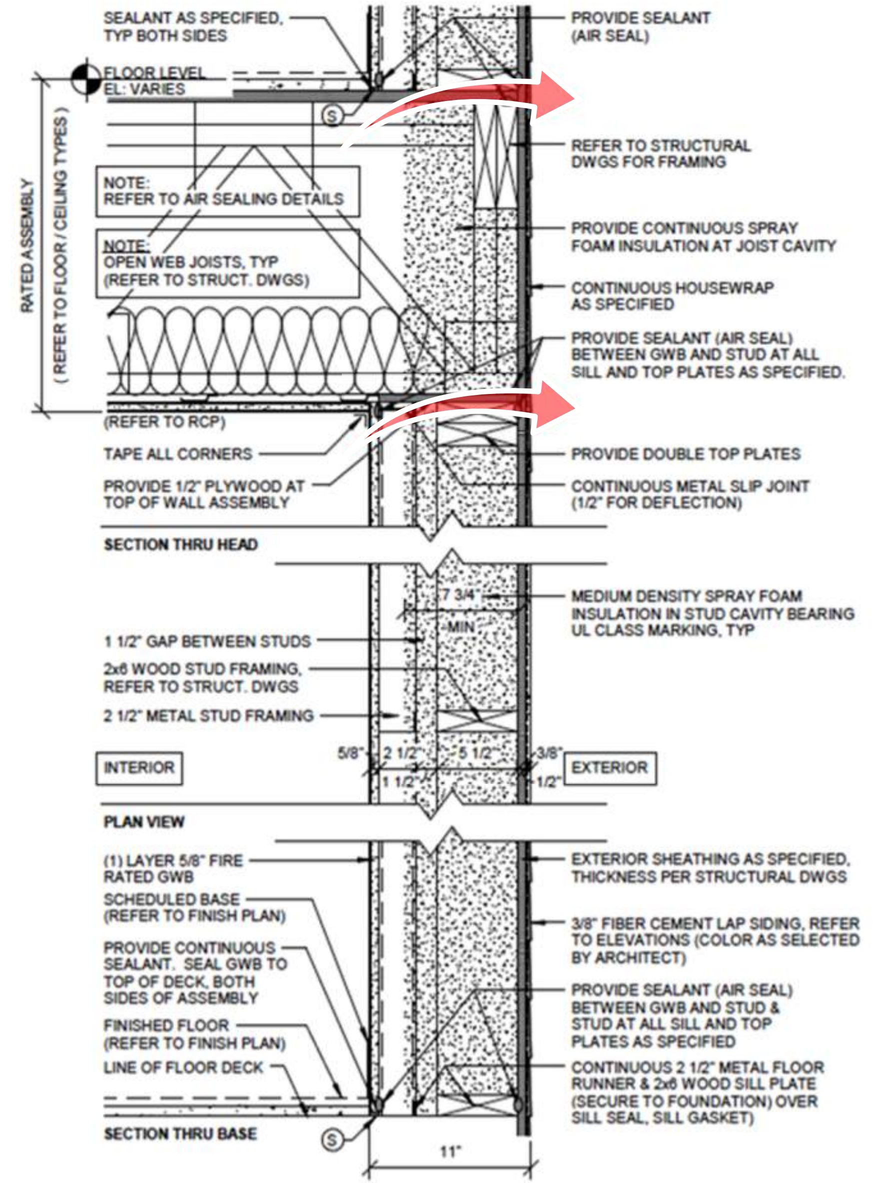
Thermal Bridging

	Knife Plate	Fero FAST System	HSS Section	Large Angle
				
				
Effective Assembly R-Value	R-16.4 (RSI 2.89)	R-16.3 (RSI 2.87)	R-16.1 (RSI 2.84)	R-10.6 (RSI 1.87)
Effective Reduction	14.0%	14.6%	15.7%	43.0%

Credit: Meip Keller, Payette 2015

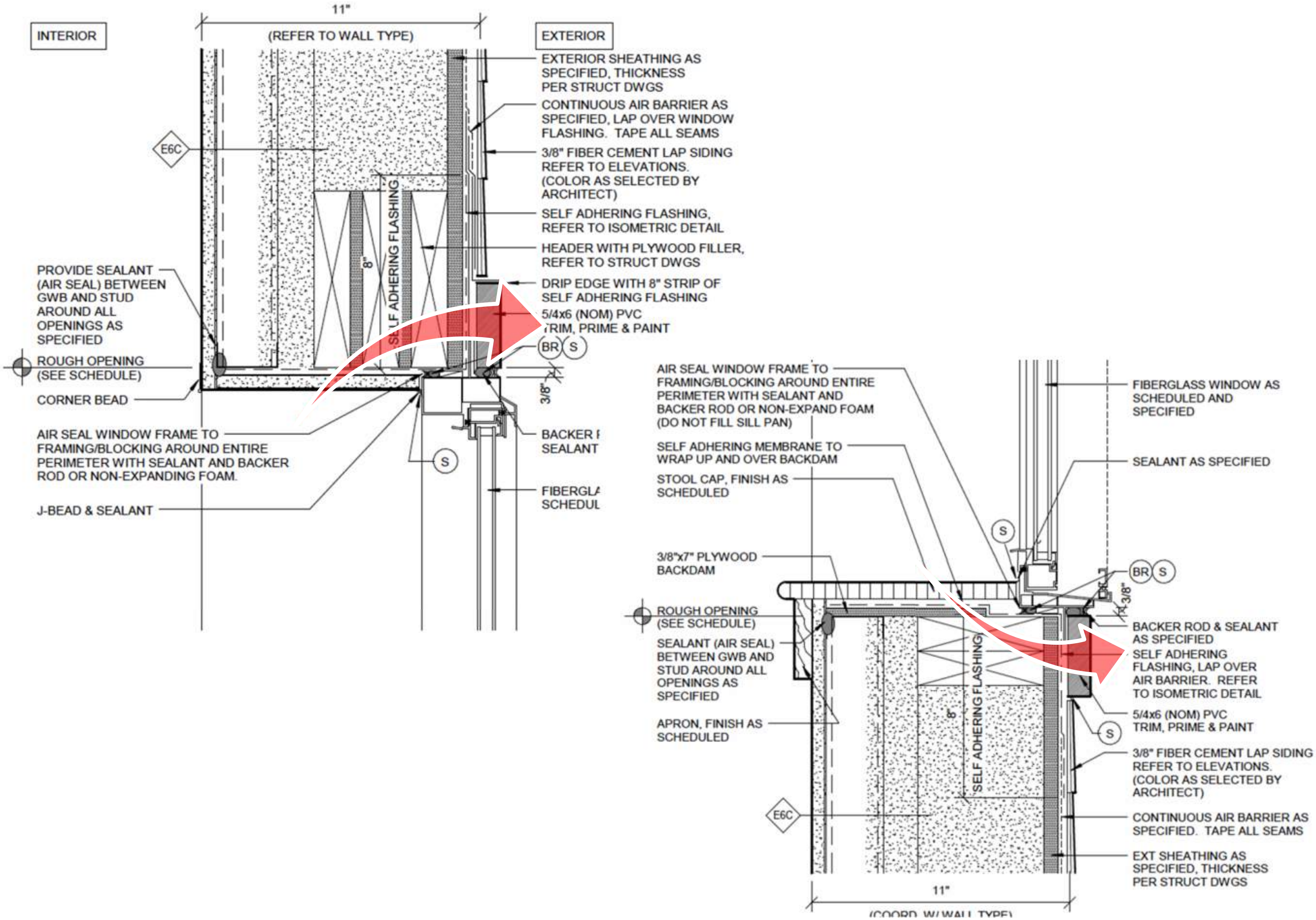
Enclosure - Walls





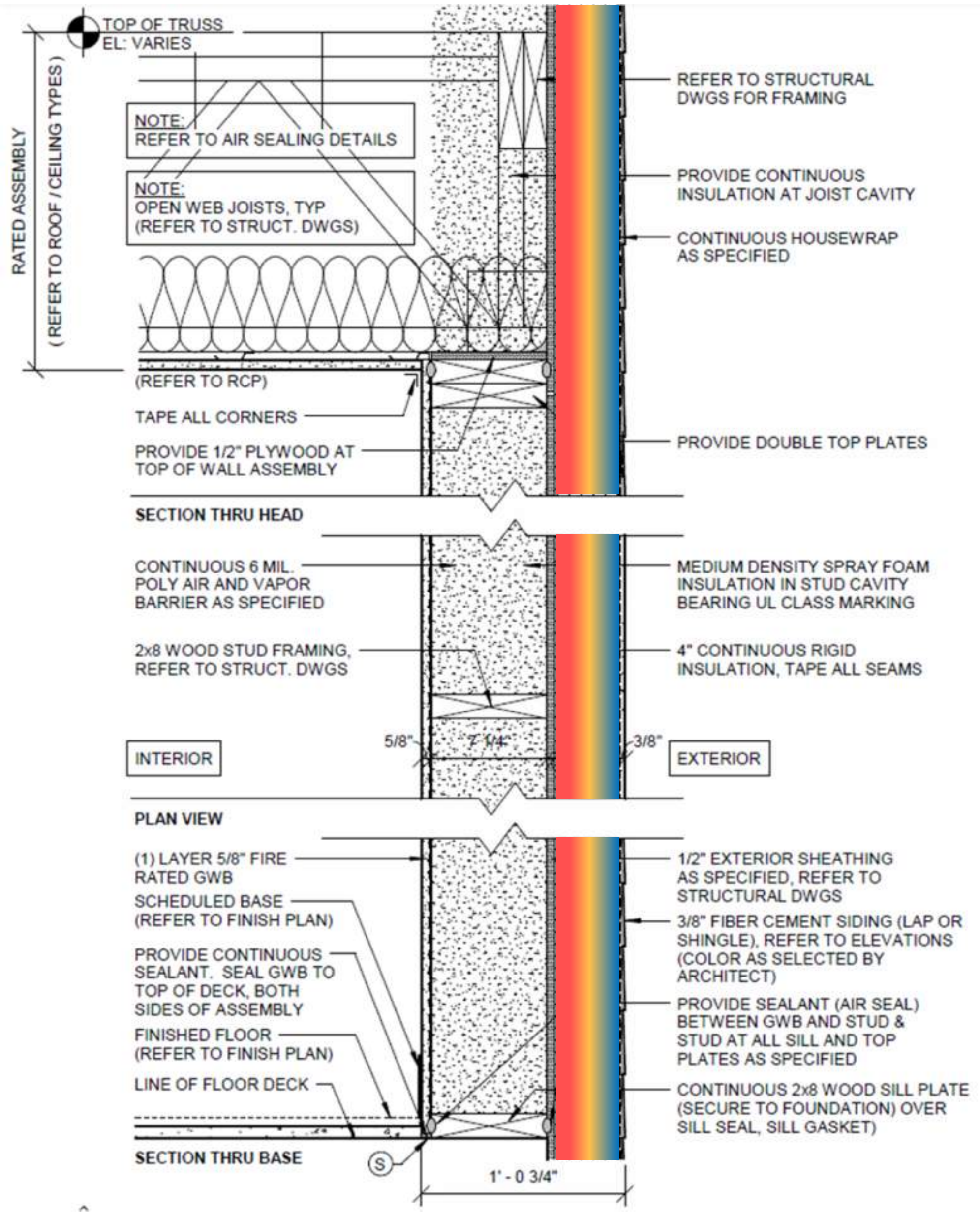
Credit: The Architectural Team

Enclosure – Windows & Doors



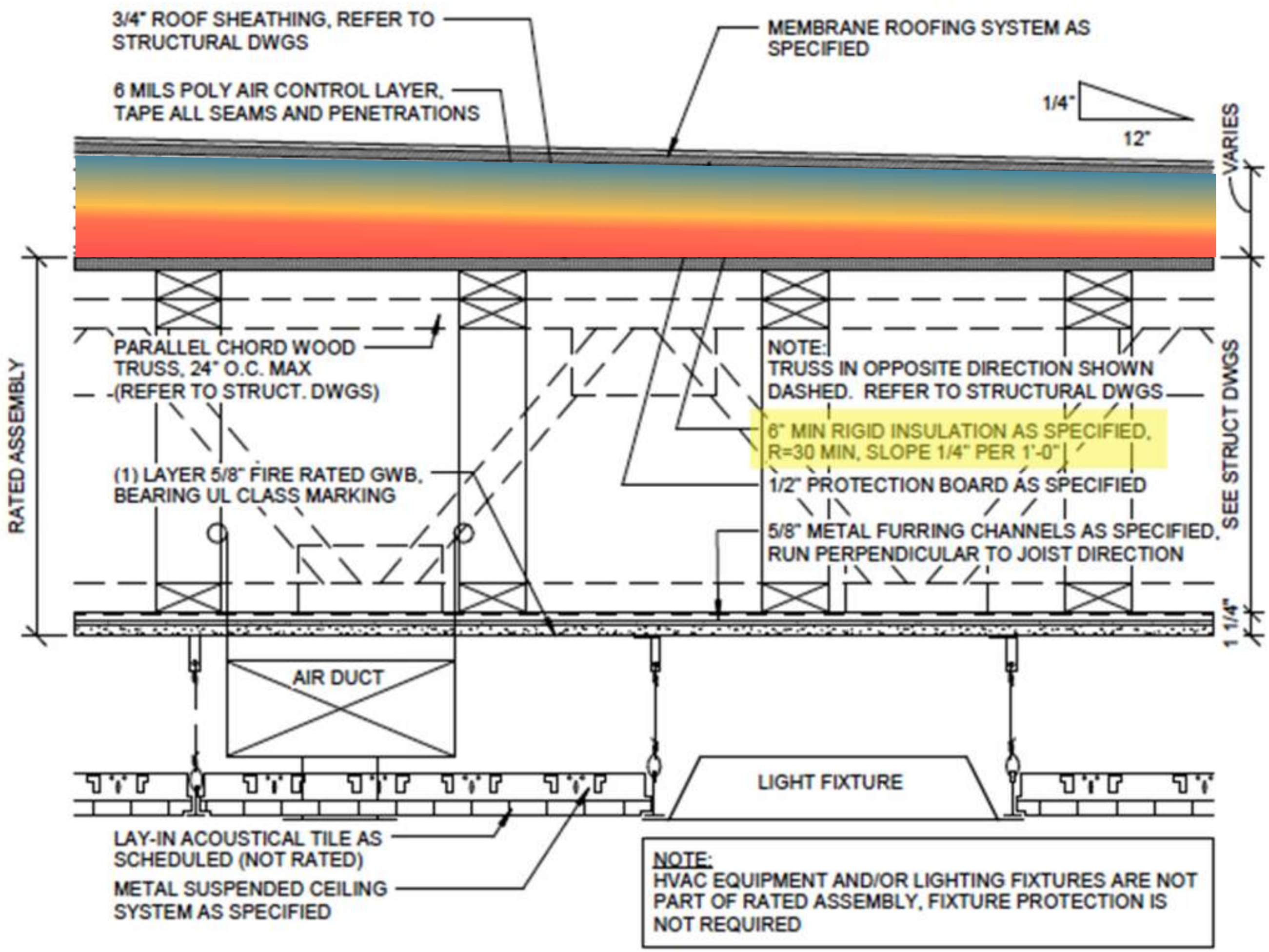
Credit: The Architectural Team

Enclosure - Walls



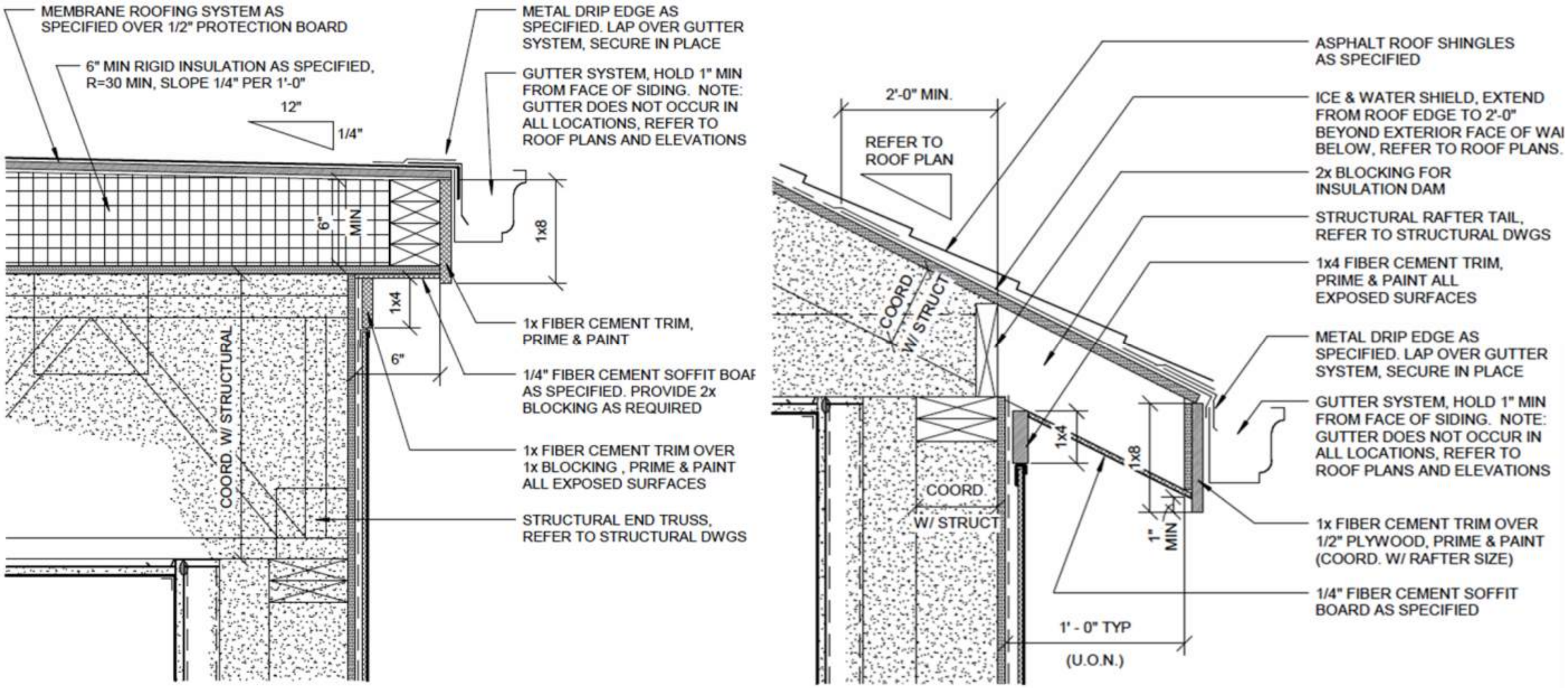
Credit: The Architectural Team

Enclosure - Roof



Credit: The Architectural Team

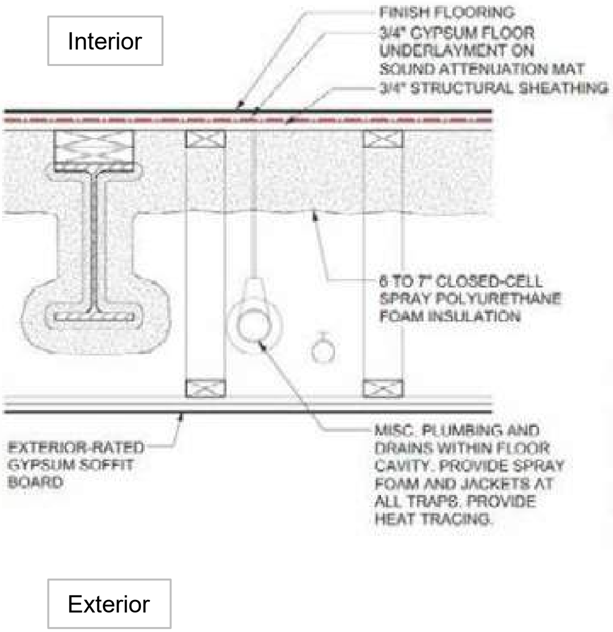
Enclosure – Wall to Roof



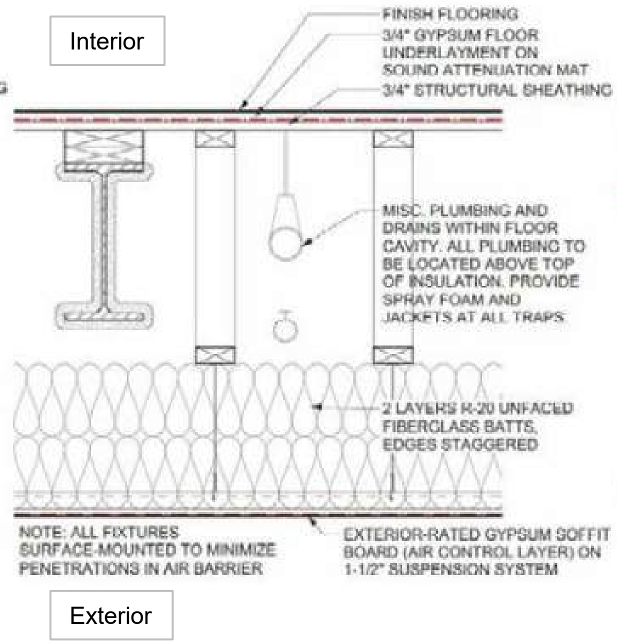
Credit: The Architectural Team

Enclosure – Interior over Exterior

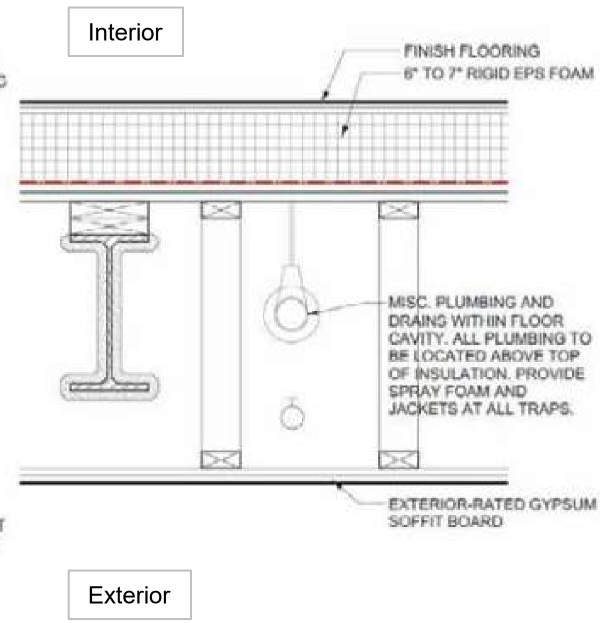
Insulation Under Deck



Insulation At Ceiling



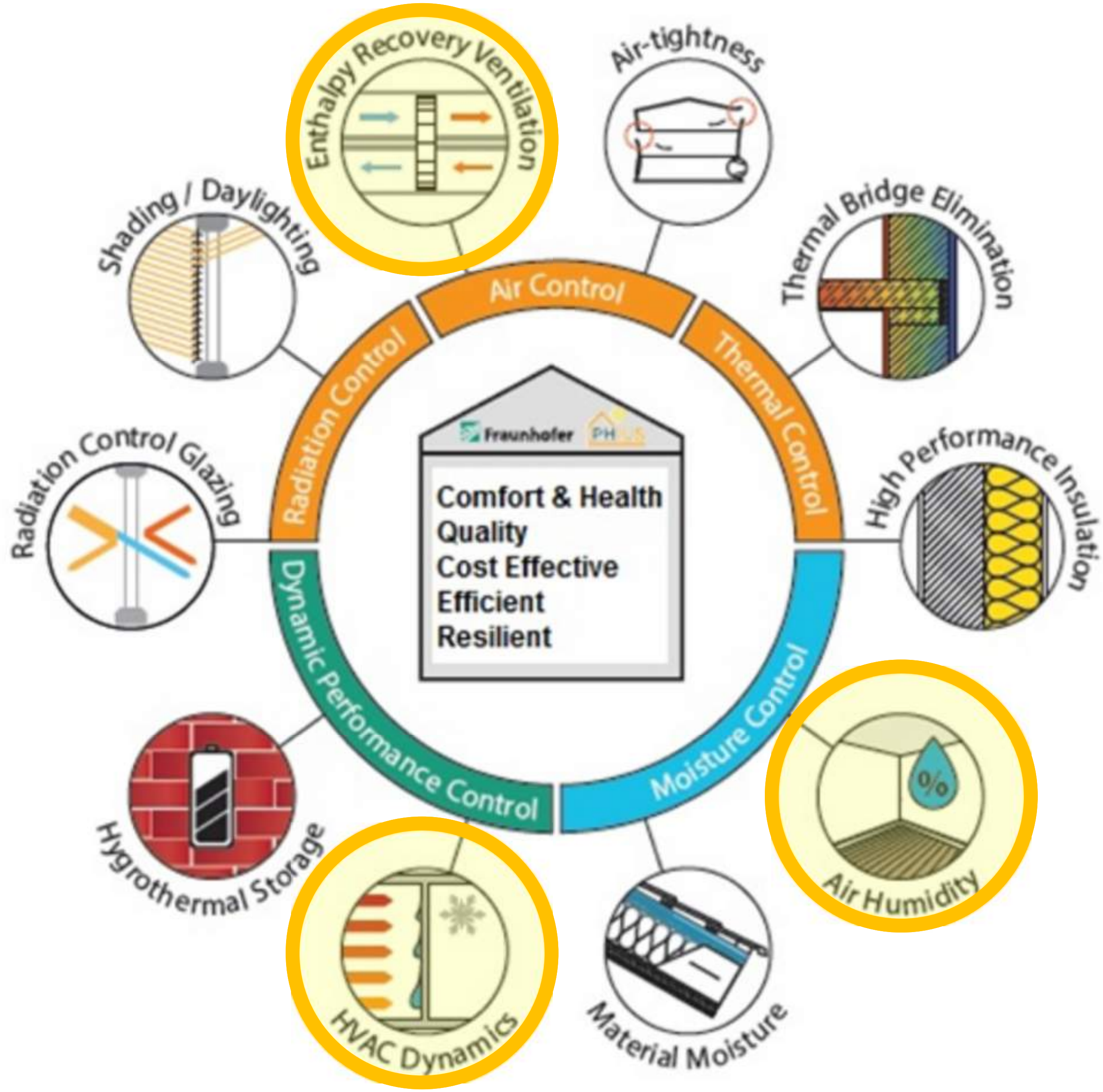
Insulation Above Deck



Challenges

- Heat Tape for plumbing
- Access to plumbing traps
- Inspection of insulation for effectiveness, codes, and PH compliance
- Managing moisture risks at interior spaces
- Location / control of Air Barrier

Credit: Utile Inc.

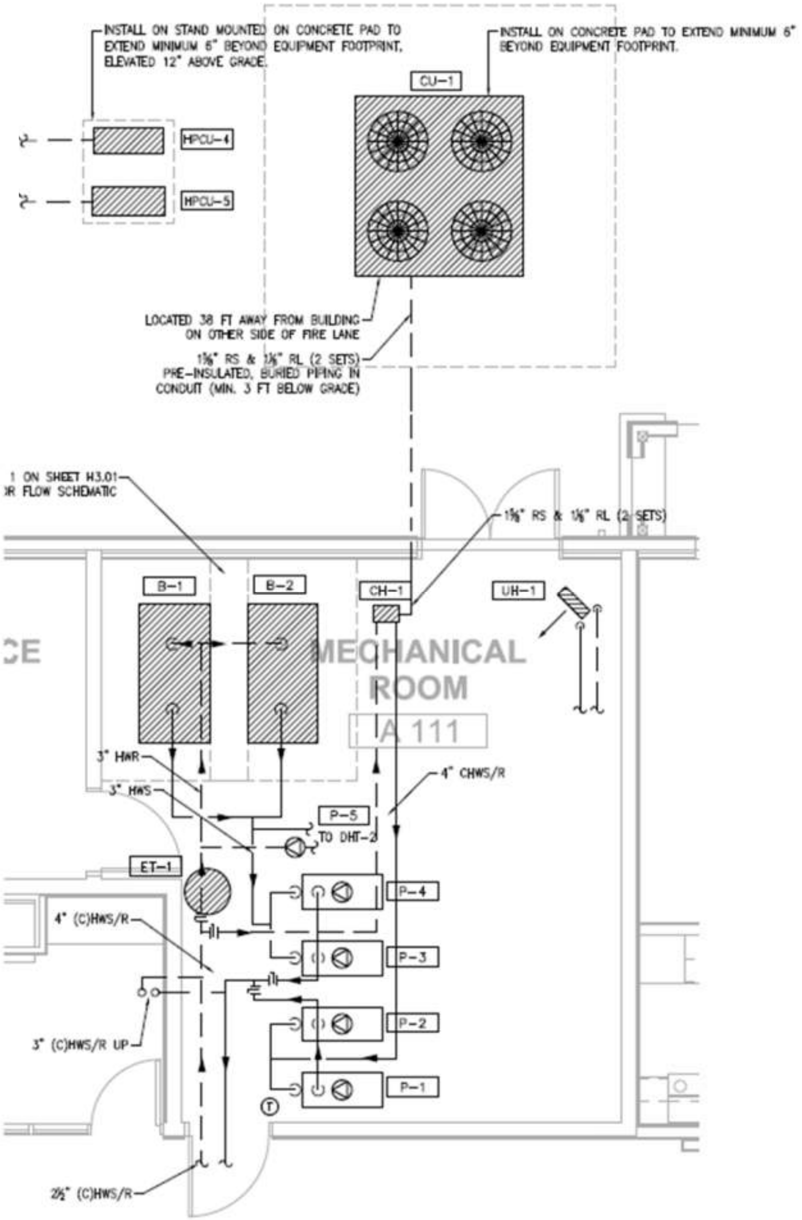


Credit: PHIUS & Pembina Institute

Mechanical Systems

	Central	Semi-Central	Unit-Based
Ventilation (ERV/HRV)		x	
Heating			x
Cooling			x
Domestic Hot Water	x		

Mechanical Systems – Central Heating/Cooling

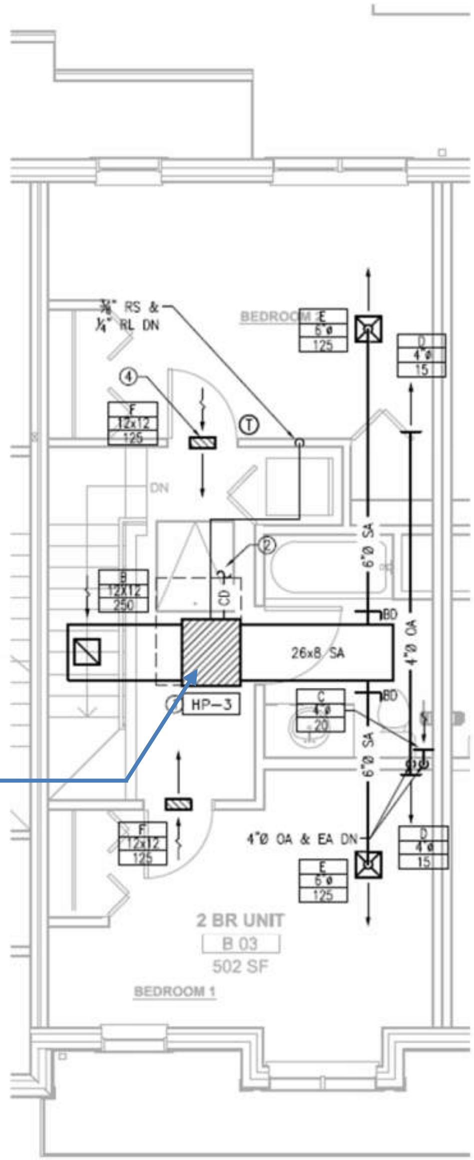


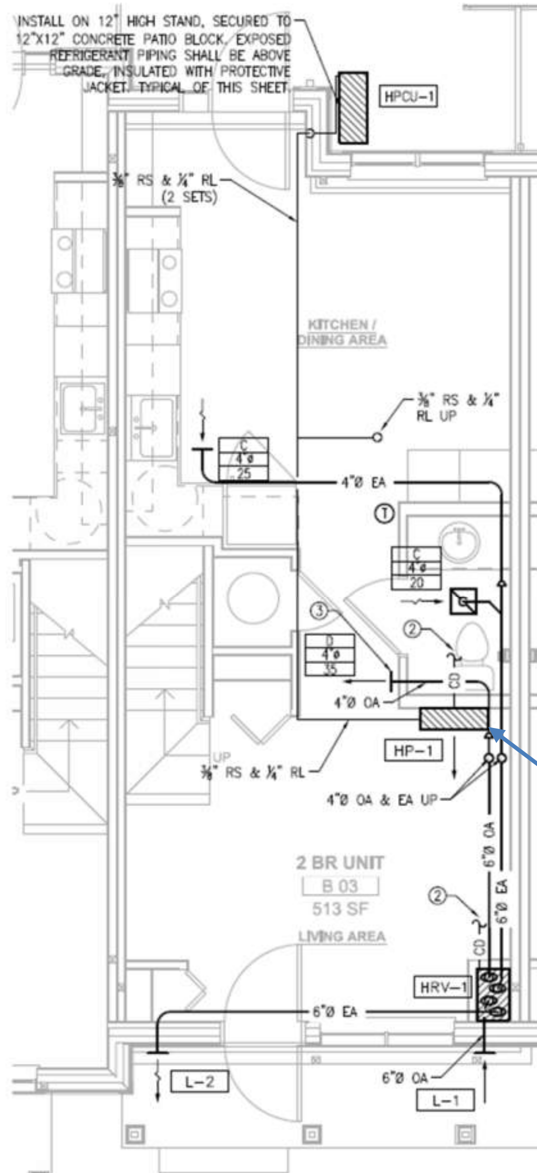
Credit: Petersen Engineering Inc.

Mechanical Systems – Individual HVAC

ASHP

Ducted Units





Wall Units

Credit: Petersen Engineering Inc.

Mechanical Systems – Central / Semi-Central HVAC

VRF

Wall unit

Ducted Ceiling Units

Performance

- + Ventilation ductwork minimized
- + Heat recovery option allows for simultaneous heating and cooling

Design

- - Extra piping required

Wall Units

- + No additional ceiling space required
- - Additional power for each unit per room
- - No units on market for very small loads

Ducted Units

- + Hidden equipment
- - Requires additional ceiling space
- - Requires sealing of ducts

Credit: Steven Winter Associates

Ventilation

Continuous Balanced Ventilation:

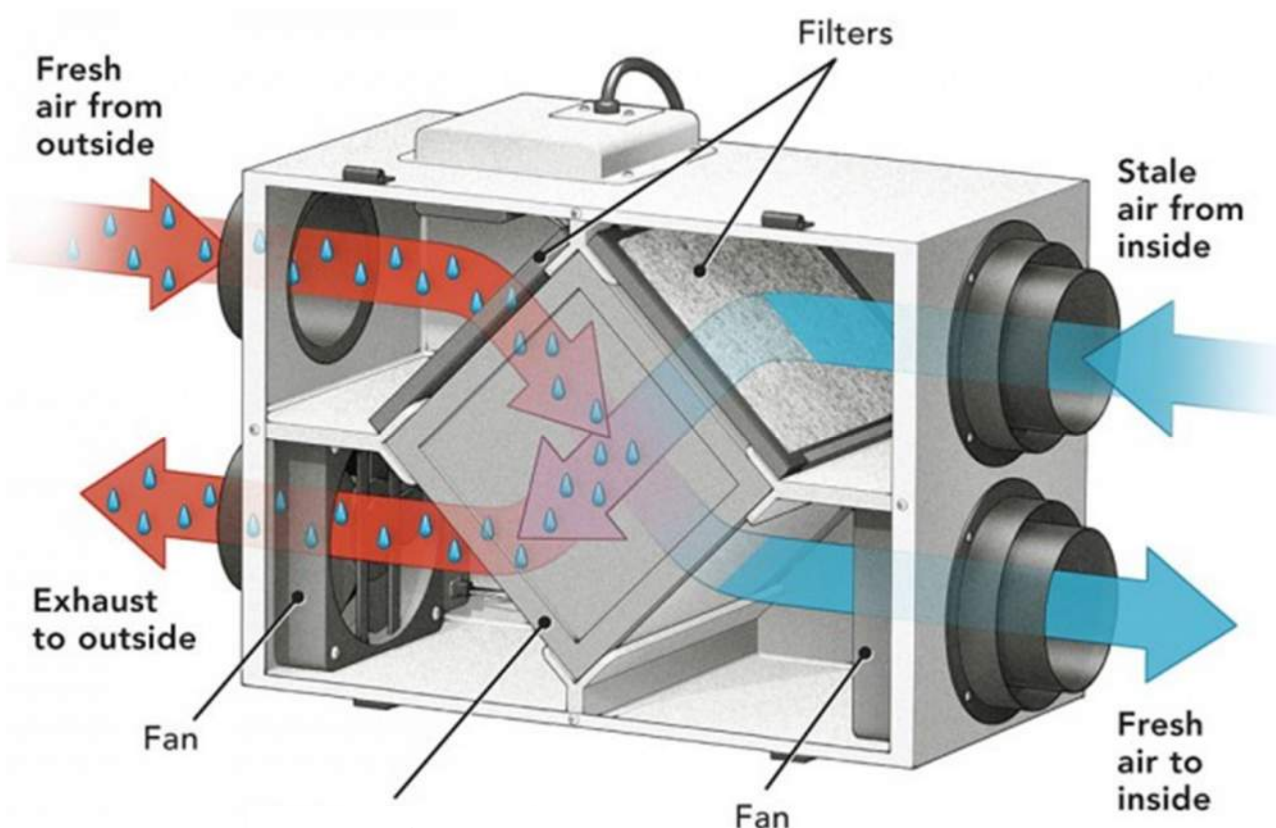
– Exhausting Stale Air
from point sources (kitchen, bathroom ...)

+ Intake and Filtering of Fresh Air
to living areas (bedrooms, living room ...)

With Heat / Energy Recovery

Sensible and Latent Energy Transfer

> 50-70% efficiency

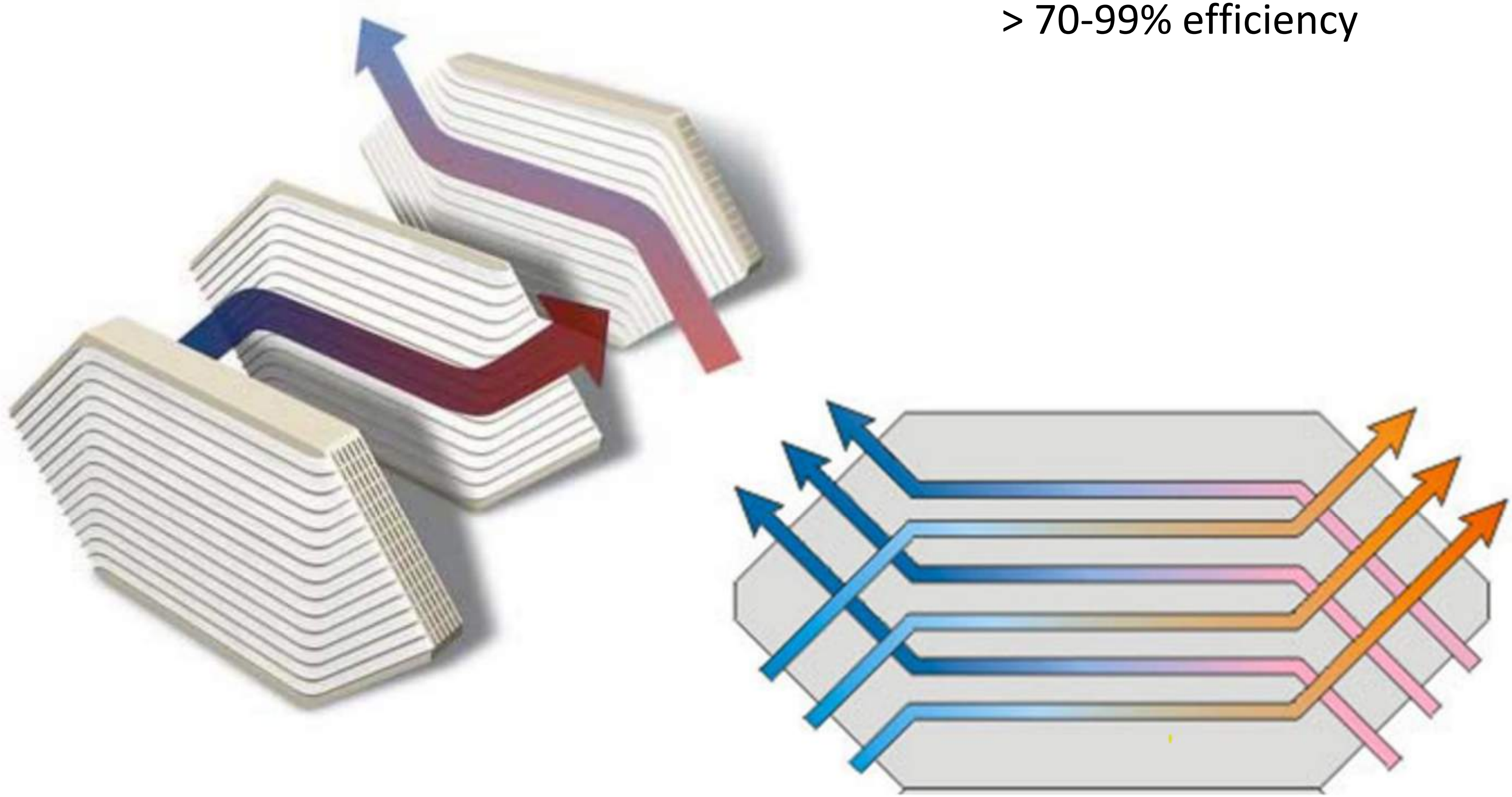


Cross Flow Heat or energy recovery core

Credit: SummerAire

Sensible and Latent Energy Transfer

> 70-99% efficiency

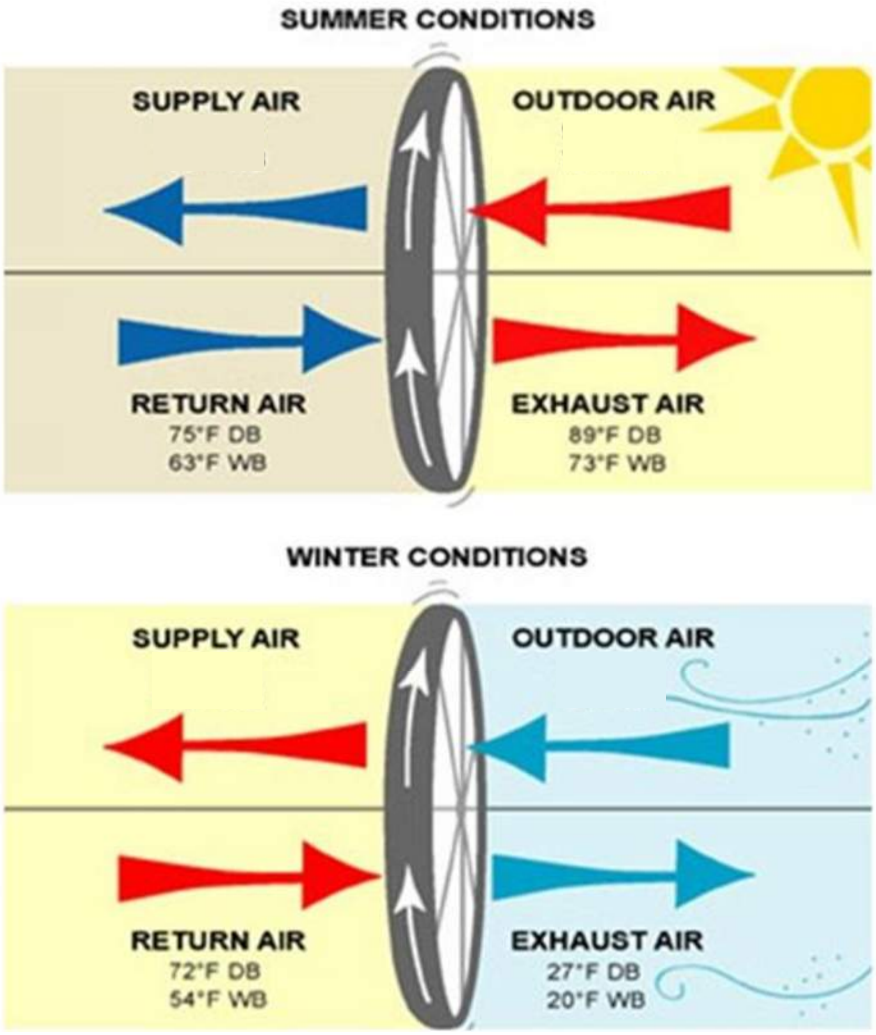


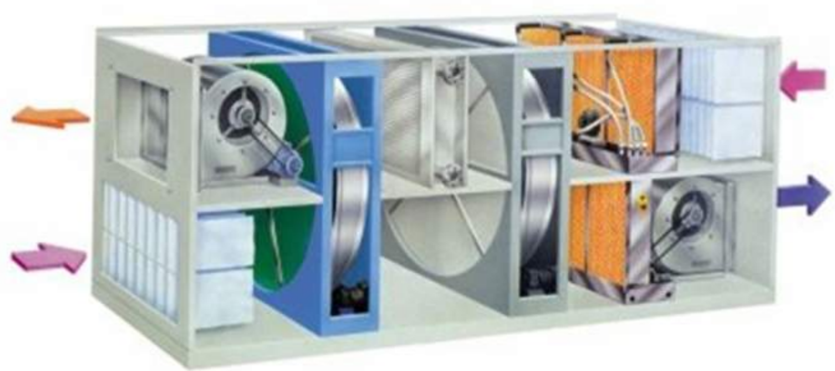
Counter Flow Heat
or energy recovery core

Credit: Michael LeBeau & Barry Stevens

Sensible and Latent Energy Transfer

> 60-80% efficiency

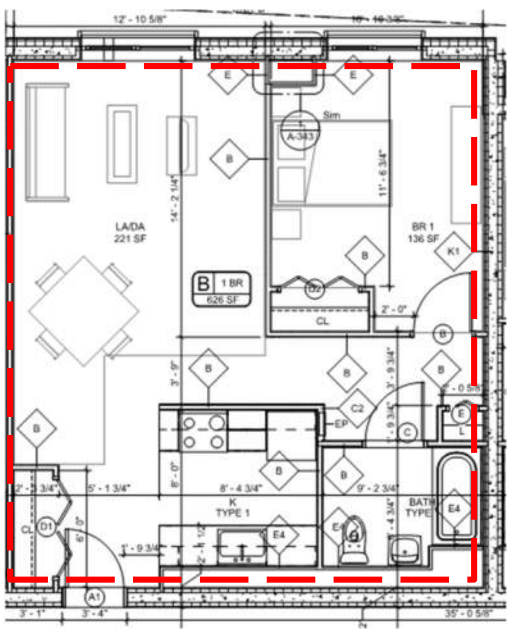




Credit: doas-radiant.psu.edu

Mechanical Systems – Balanced Ventilation

Heat/Energy Recovery Ventilator



Centralized

One ERV ventilates several apartments

Decentralized

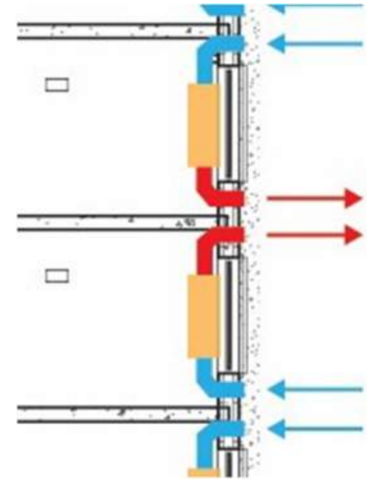
Each unit has their own ERV

Credit: Steven Winter Associates

Mechanical Systems – Balanced Ventilation

Heat/Energy Recovery Ventilator

Design / Constructability



<u>Centralized</u>

Benefits

- Less horizontal duct > Less ceiling depth
- No exterior through wall penetration

Challenges

- Loss of floor space for vertical shafts
- Large floor and roof penetrations
- Fire rated shafts & dampers needed
- Critical to seal duct
- Higher floor to floor at horizontal distribution floor requires coordination

<u>Decentralized</u>

Benefits

- No floor and roof penetrations
- Better apartment compartmentalization

Challenges

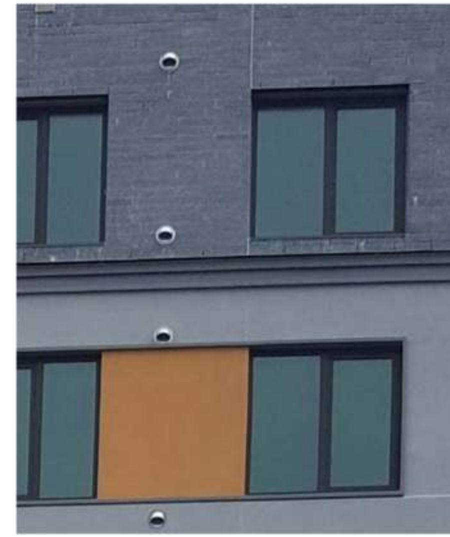
- Sealing 2 penetrations per apartment
- Horizontal duct at every apartment requires detailed coordination and increases ceiling depth

Credit: Steven Winter Associates

Mechanical Systems – Central vs Distributed

Heat/Energy Recovery Ventilator

Maintenance and Operation



Centralized

Benefits
- Fewer units to maintain
- ERV more accessible to maintenance

Challenges
- Cost of ventilation on owner

Decentralized

Benefits
- Power for ERV on tenant panel

Challenges
- Filters need to be replaced in every apartment every 3 months
- Requires access to exterior louvers for cleaning

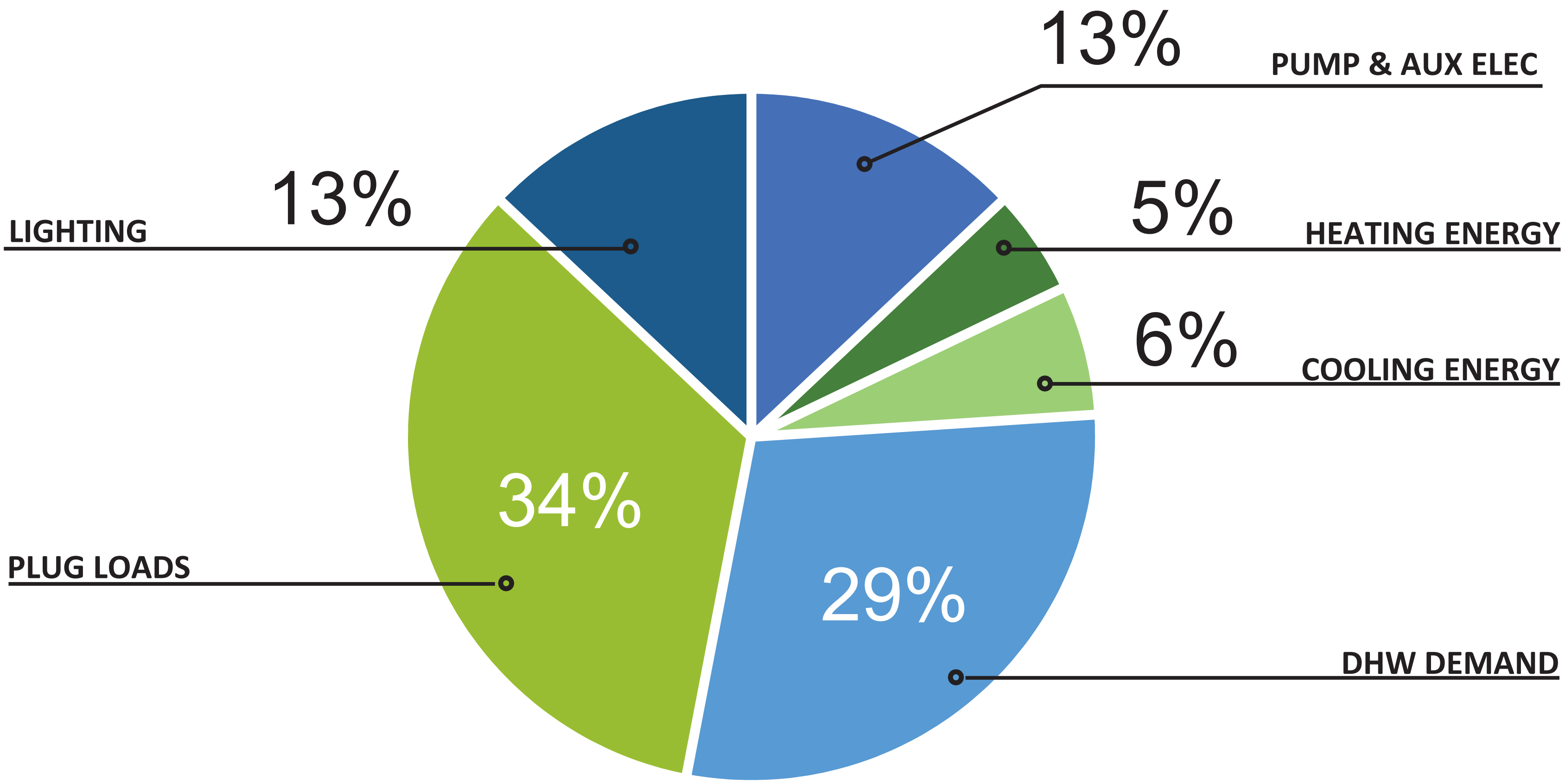
Credit: Steven Winter Associates

Domestic Hot Water

- Hot water used for drinking, food prep, sanitation, and personal hygiene
- NOT for heating, swimming pools, commercial cooking, etc.

Credit: Steven Winter Associates

Source Energy



PASSIVE HOUSE
HIGH RISE: NYC

Credit: Steven Winter Associates

Mechanical Systems - DHW

Domestic Hot Water – Central

Benefits

- Reduced pumping power
- Can use gas boilers
- Potential to switch to HP in future
- Could utilize demand controlled to reduce recirc loop losses

Challenges

- Loss of floor space
- On owner's meter

Credit: Steven Winter Associates

Mechanical Systems - DHW

Domestic Hot Water – Semi-Central

Per Floor

Benefits

- Heat Pump-ready now
- Reduced pumping power
- Beneficial electrification
- Could utilize demand control to reduce recirculation loop losses

Challenges

- Loss of roof area
- On owner's meter

Credit: Nyle Systems, Colmack Waterheat

Domestic Hot Water – De-centralized

Per Unit

Benefits

- Heat Pump-ready now
- Can easily meet PH criteria
- Beneficial electrification
- Could utilize demand control to reduce recirculation loop losses
- On tenant meter

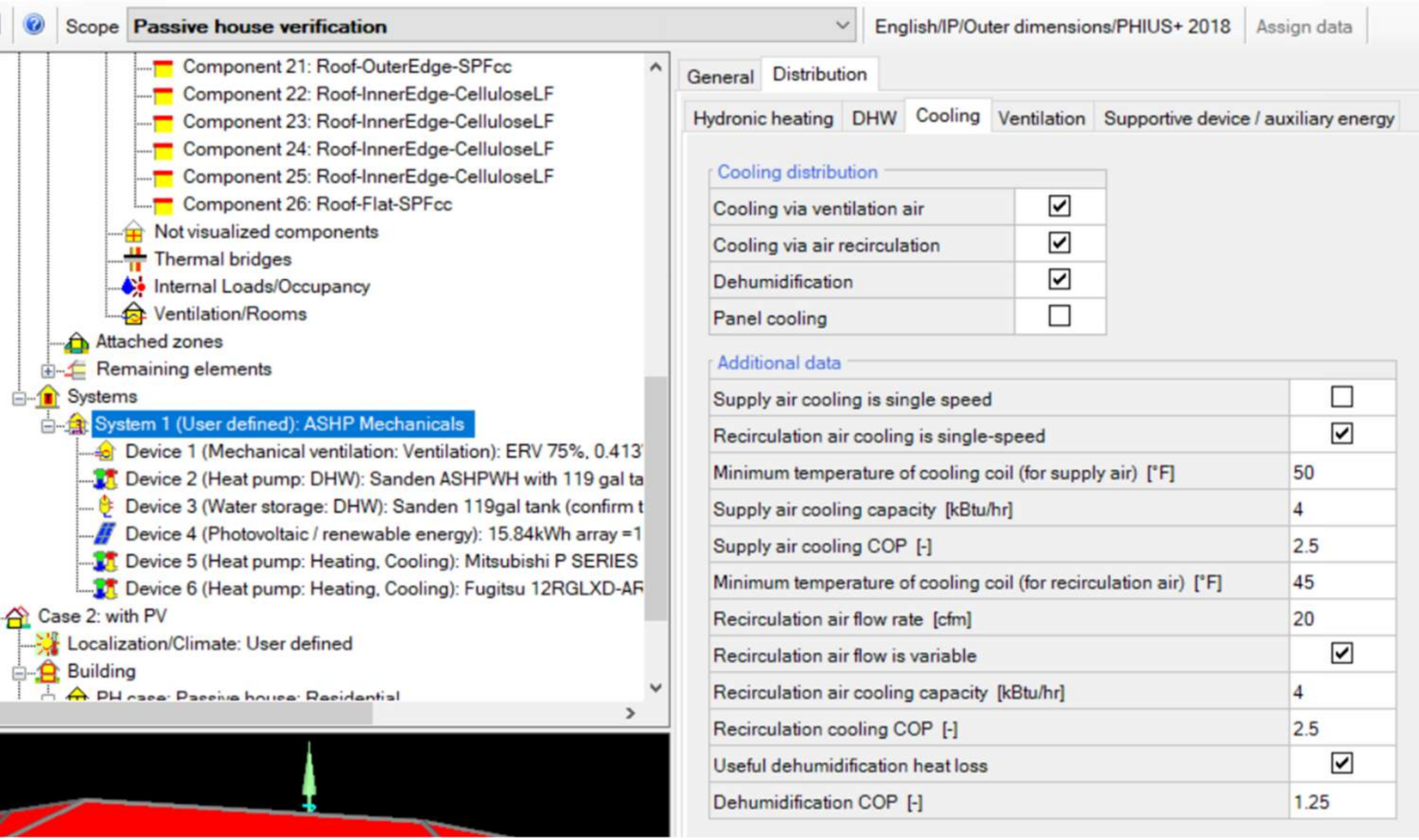
Challenges

- Requires maintenance closet
- Hybrid units require venting
- Split units require outdoor area

Credit: Sanden, Rheem

Mechanical Systems

WUFI modelling



Credit: Fraunhofer IBP

PH Pre-certification

Reviewing Reports

BUILDING INFORMATION

Category:	**Residential**
Status:	**Under construction**
Building type:	**New construction**
Year of construction:	**2021**
Units:	**1**
Number of occupants:	**6 (Design)**
Occupant density:	**1,065.4** ft²/Person

Boundary conditions

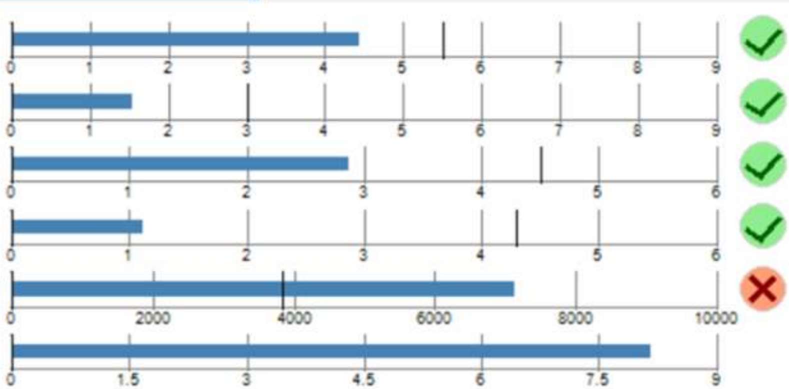
Climate:	**CT - HARTFORD BRADLEY INTL AP (Monthly)**
Internal heat gains:	**0.5** Btu/hr ft²
Interior temperature:	**68** °F

Building geometry

Enclosed volume:	**65,539.2** ft³
Net-volume:	**49,809.8** ft³
Total area envelope:	**12,840.2** ft²
Area/Volume Ratio:	**0.2** 1/ft
Floor area:	**6,392.4** ft²

Data state/results | Show warnings | Calculate WUFI shading

Heating demand:	**4.43** kBtu/ft²yr
Cooling demand:	**1.54** kBtu/ft²yr
Heating load:	**2.86** Btu/hr ft²
Cooling load:	**1.11** Btu/hr ft²
Source energy:	**7,132** kWh/Person yr
Site energy:	**8.16** kBtu/ft²yr



Credit: Fraunhofer IBP

Construction Phase Support

3rd Party Verification

- Engaged during Design
- Verification Team should understand & comment on the design prior to start of construction
- Responsible for enforcing implementation of Design during Construction
- Must have authority through Owner / Architect
- Critical to Passive House performance and certification

Commissioning & Verification

- Testing Assemblies
- Checking critical connections
- Verifying specs
- Documenting issues
- Suggesting resolutions

Credit: Steven Winter Associates

Quality Control

Credit: 475 Building Supply

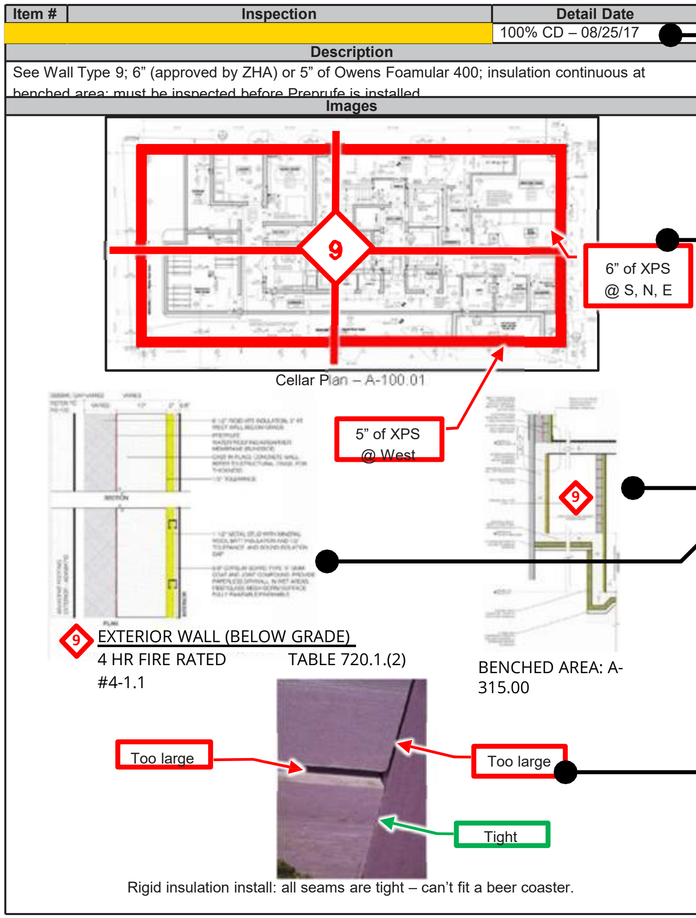
Site Inspection Checklist

The following items must be inspected and/or tested before being made inaccessible:

Phase	Description
BELOW GRADE	Sub-Slab Insulation
	Sub-Slab Air/Vapor Barrier
	Below Grade Wall Insulation
	Below Grade Air/Vapor Barrier
	Gas Meter Room - penetrations
	Trash Room
	Laundry Room
	Waste / Misc. penetrations
ABOVE GRADE	Perimeter conditions at Grade
	Building Corners, Expansion Joints
	Canopies - 1st inspection
	Above Grade Wall Insulation
	Above Grade Air/Vapor Barrier Transitions
	Trash Chute Doors
	Roof Surfaces - Insulation
	Roof Surfaces - Air/Vapor Barrier Transitions
TOP OUT	Mechanical Bulkhead - Insulation
	Mechanical Bulkhead - Air/Vapor Barrier
	Elevator Shaft - Smoke Dampers
	Storefront - Air Sealing
	Canopy - Final Inspection
	Mezzanine - Final Inspection

Credit: Steven Winter Associates

Site Inspection Checklist: Unique Conditions



Checklist developed during construction documents

Instructions provided to inspector for items to inspect

Details provided to assist on-site inspection

Photos annotated to help guide visual inspection

Credit: Steven Winter Associates

Mid-Point Testing

- Whole Building / Guarded blower door test
  - focus on one floor
- Individual apartment blower door tests
- Individual components & Unique Conditions

Credit: Steven Winter Associates

Final Blower Door Test

PHIUS - Pressurize whole building / zones

0.11 cfm75 / ft2   ≥ 5 stories

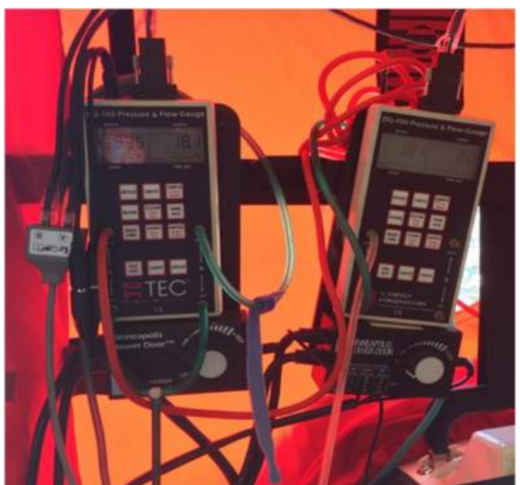
0.08 cfm75 / ft2   all others

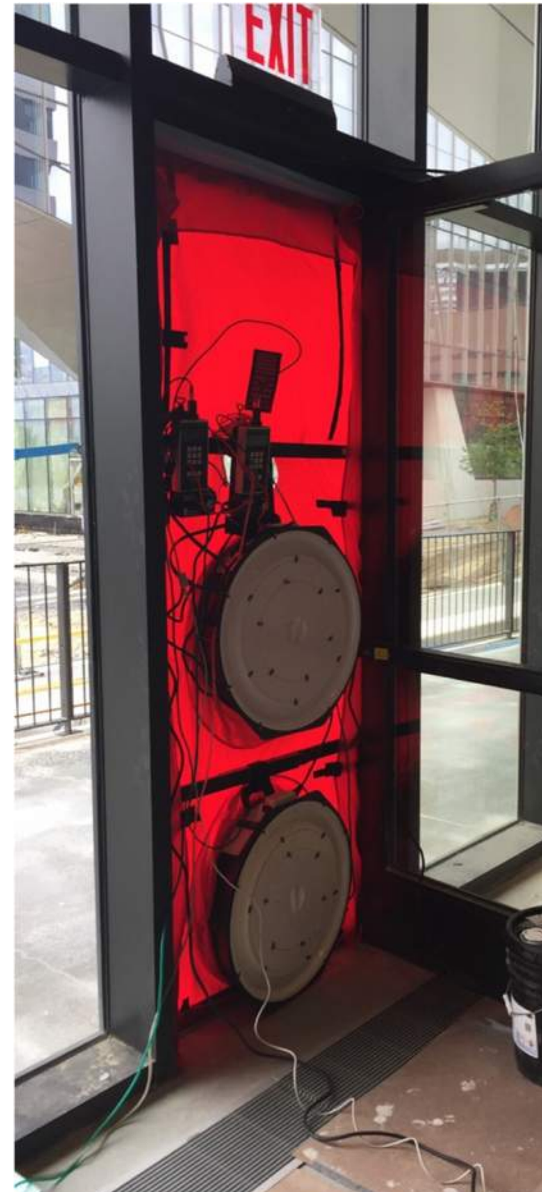
PHIUS - Pressurizing dwelling

0.3 cfm50 / ft2

PHI - Pressurize whole building

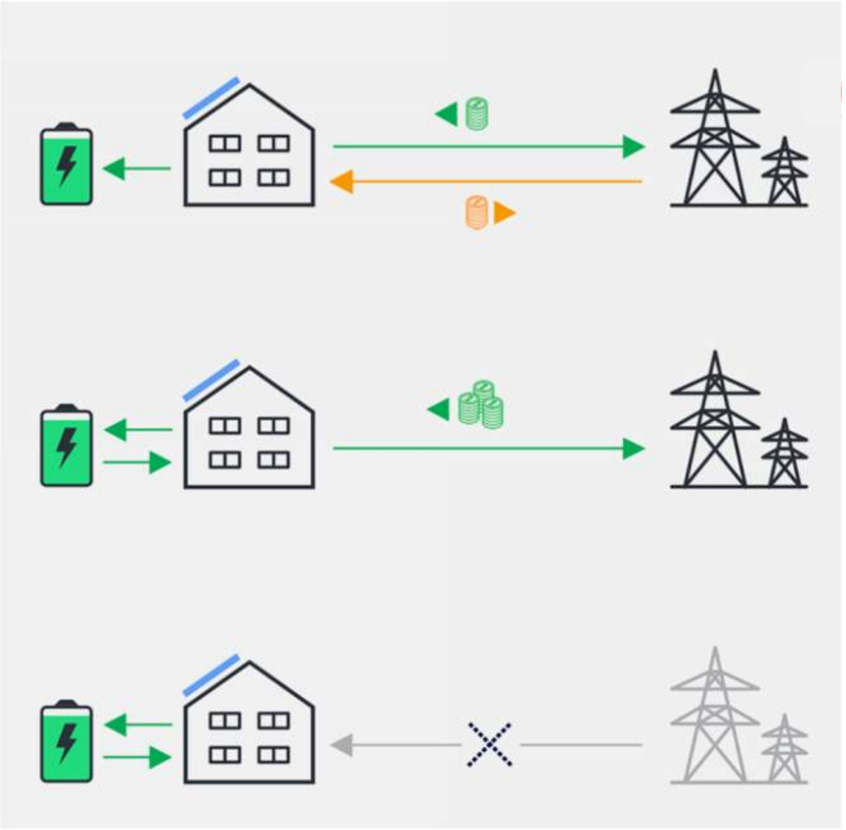
0.033 cfm50 / ft2





Credit: Steven Winter Associates

Passive House + Renewables = "Net Zero"



Renewable Energy Systems
plus storage

- Reduce source energy
- May contribute heat (reduce heating loads, increase cooling loads)

Credits: PHMA, AleSpa, SolarEdge

It CAN be done

Zero Energy Design
Tighthouse Passive House,
Brooklyn

Kaplan Thompson
Bayside Anchor, Portland
Portland Housing Authority (PHA) and Avesta Housing

Christine Benedict
Knickerbocker Commons
RiseBoro Community
Partnership

Icon Architecture
Finch Cambridge
HomeOwner's Rehab, Inc.


It IS BEING done!
Handel Architects
Cornell Tech Residences
Roosevelt Island
Cornell University

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Questions & Further Discussion

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