Passive House

and the

Shifting Energy Landscape

Westford Symposium
August 7, 2024

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RDH BUILDING SCIENCE

Making Buildings Better ™

Hello From Boston

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Agenda

- →Massachusetts Stretch Energy Code Context
- →Passive House in Existing Buildings
- →Passive House in Non-Residential New Construction
- →Passive House in Multi-family residential
- →Conclusions

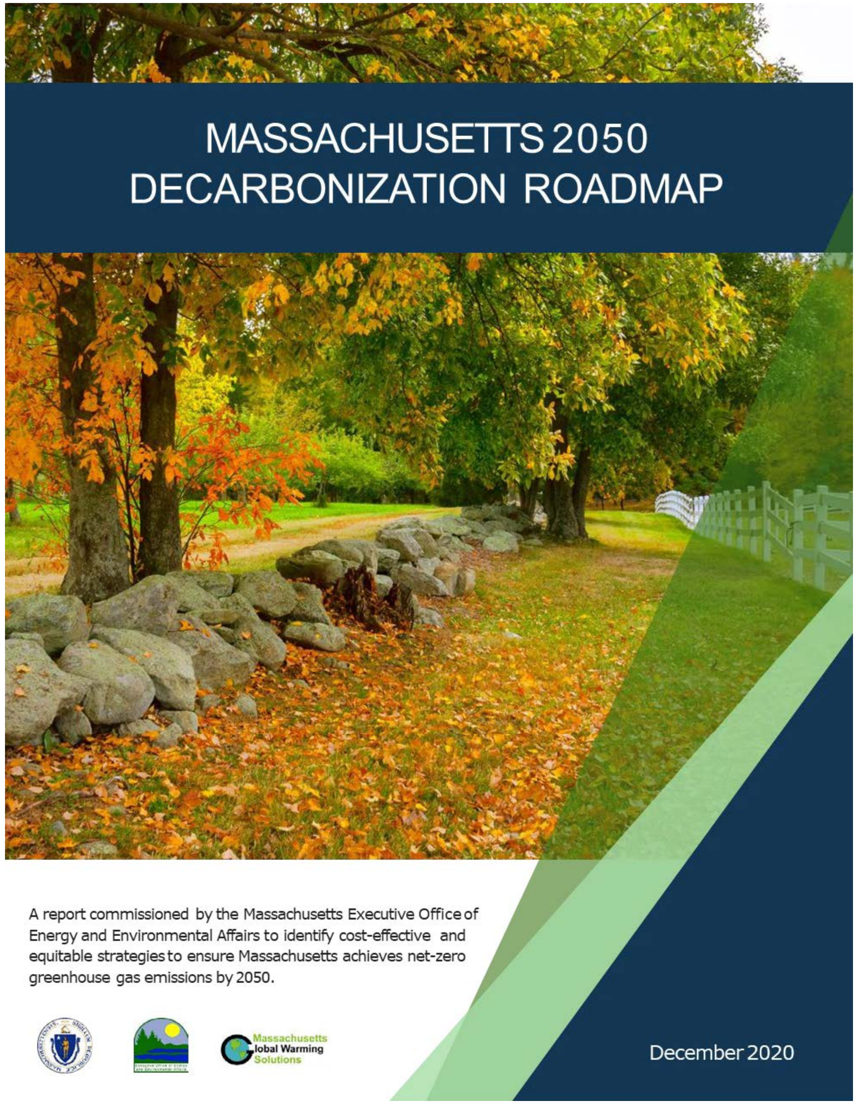
1 Energy Code Context

Decarbonization in Massachusetts

March 26, 2021 Governor Baker signed into law:

→ 50% carbon emissions reduction by 2030
→ 75% carbon emissions reduction by 2040
→ Net Zero carbon emissions by 2050

New Stretch Code and Specialized Opt-In code make meaningful impacts to design practice



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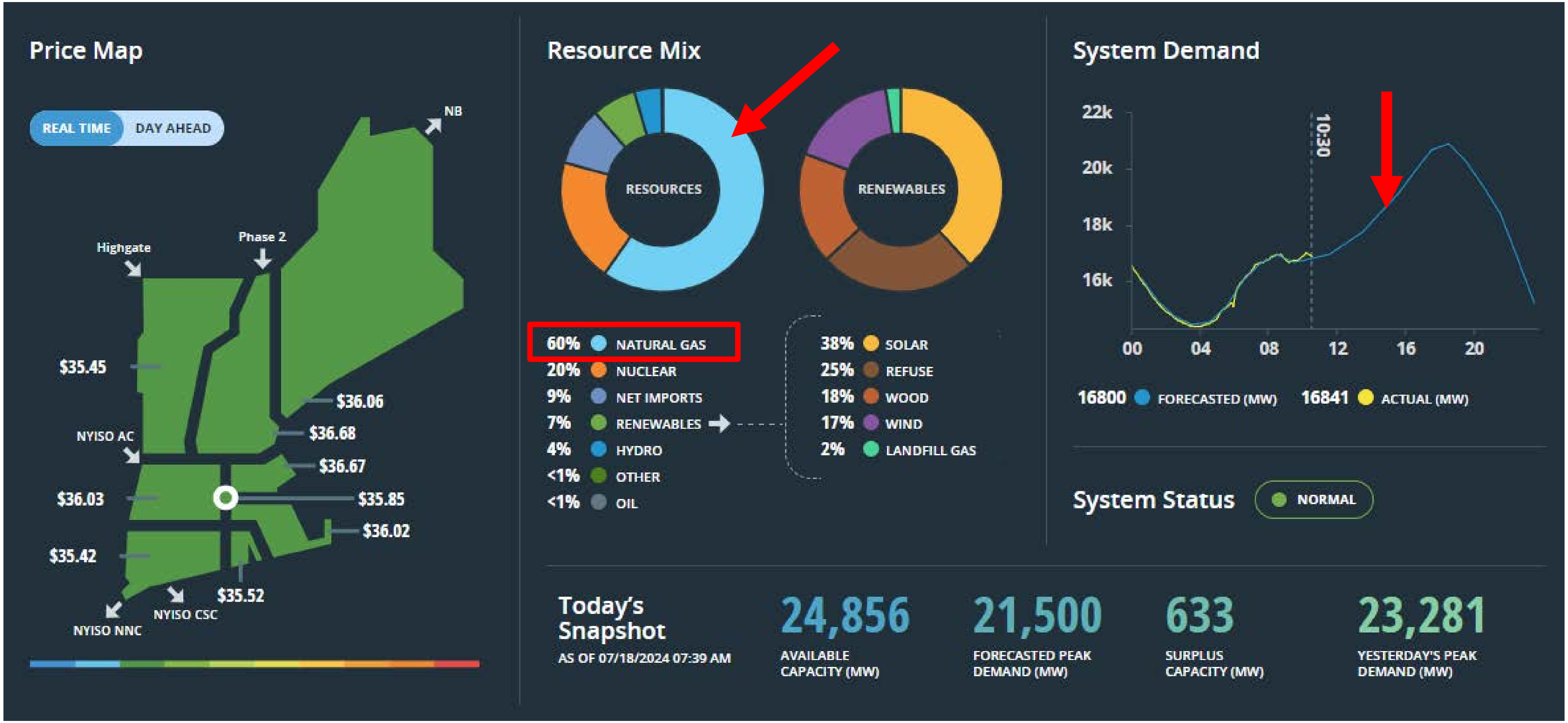
Operational Carbon



Massachusetts Energy Code

Base Code (IECC 2021*)

- New construction in towns & cities not a green community
- **52 communities**

*Expected from BBRS:
July 2023
(current base code is IECC 2018 with MA amendments)

Stretch Code (2023 update)

- New construction in towns & cities that are a green or stretch community
- **299 communities**

Residential : Jan 2023
Commercial: July 2023

Specialized Code (“Net-Zero”)

- New Construction in towns & cities that vote to opt-in to this code
- **Effective date:** Typically 6-11 months after Town/City vote

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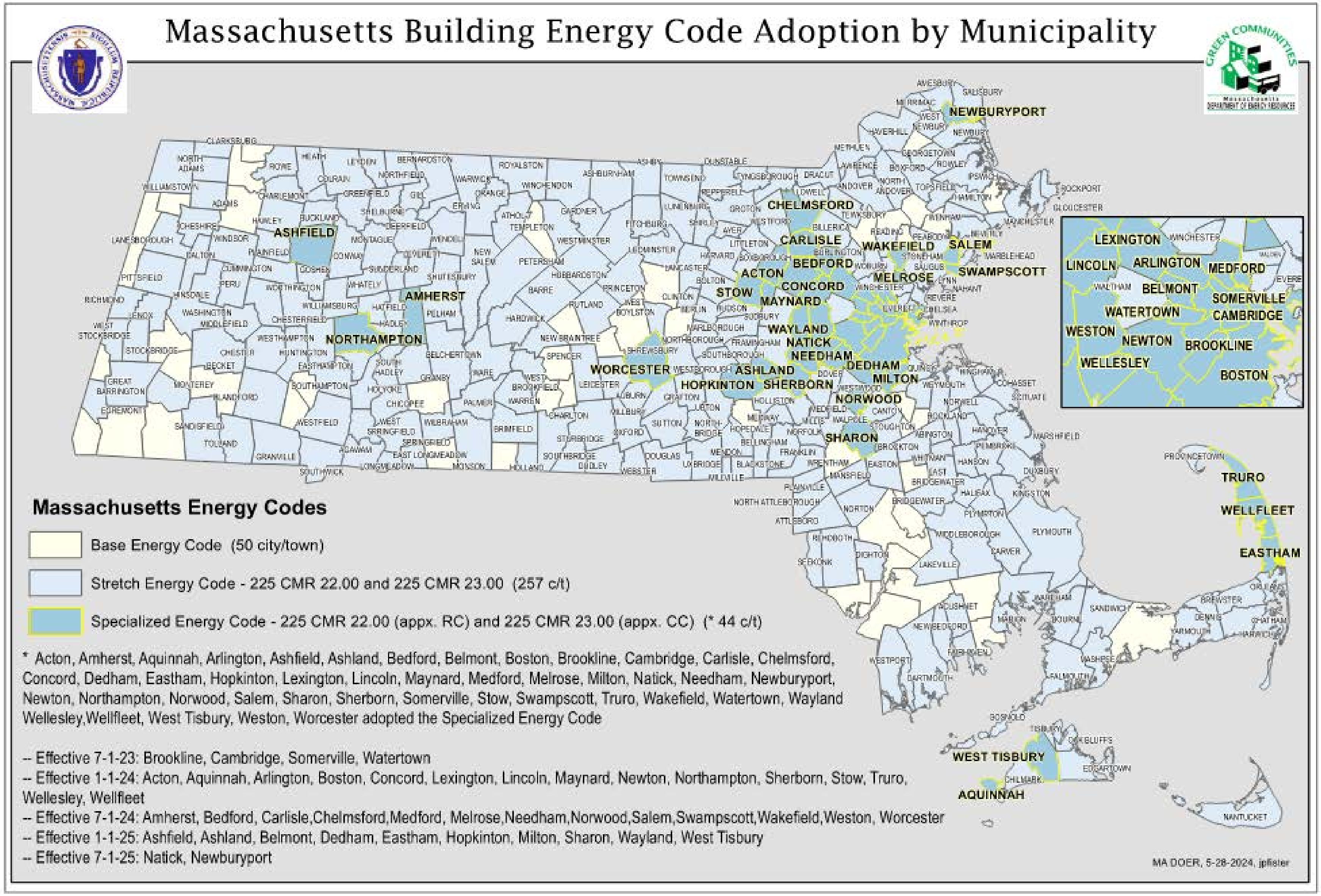
Source: Massachusetts DOER

Massachusetts Stretch Code



Source: Massachusetts DOER

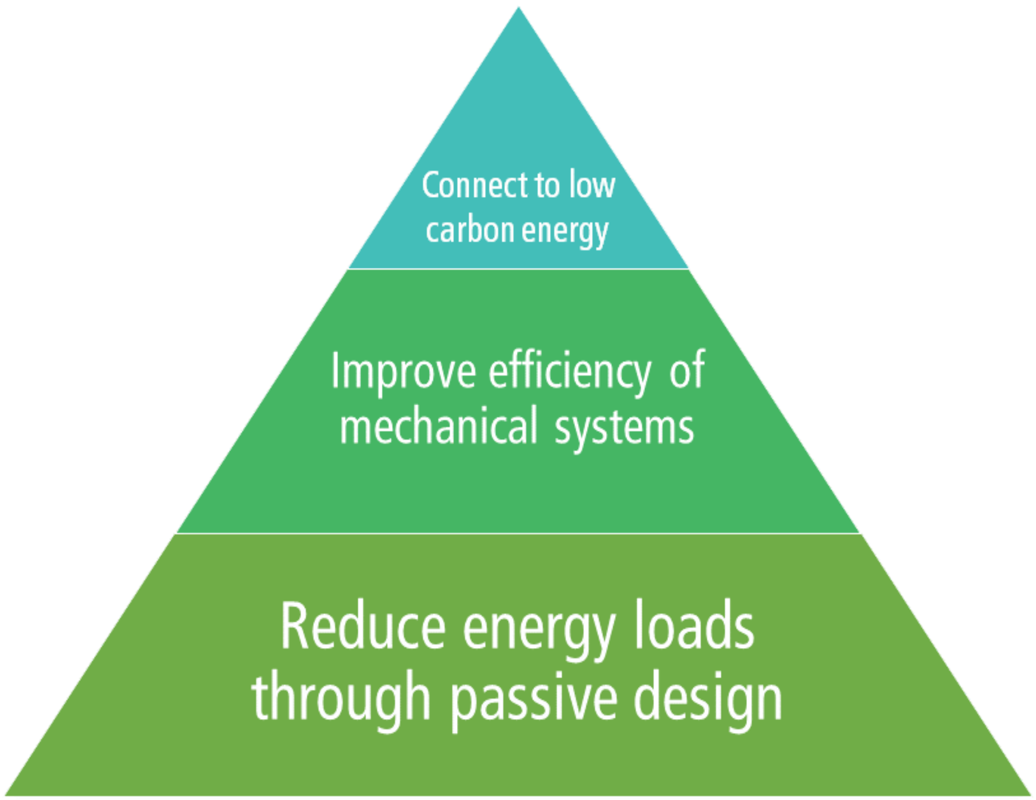
Absolute Performance Metrics

→Passive House

→TEDI

→ASHRAE 90.1 with Performance Energy Index Targets

→HERS



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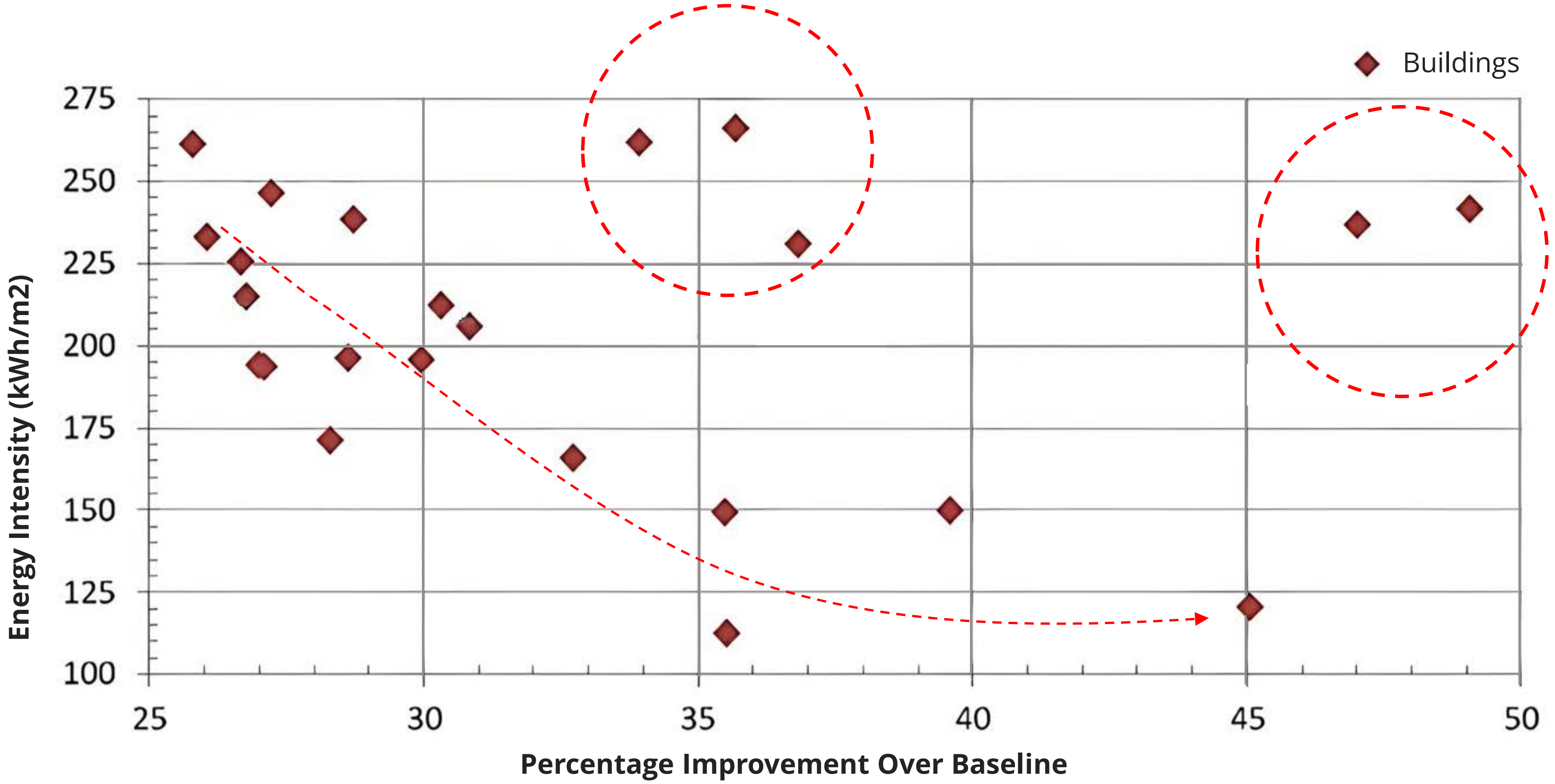
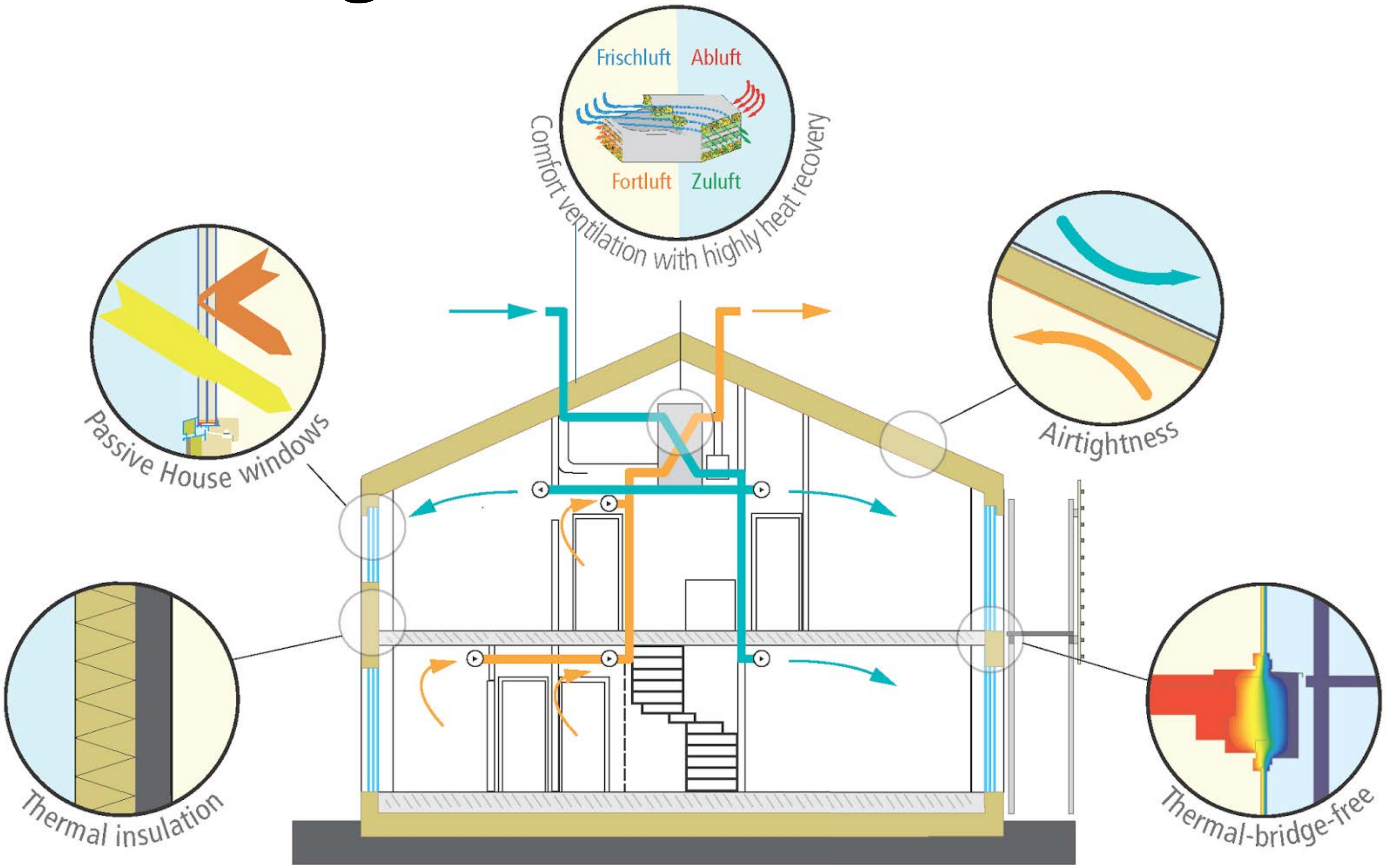
Source: Toronto Zero Emissions Buildings Framework (2017)

Relative Performance – ASHRAE 90.1



→ Some correlation between relative savings and energy use intensity of the building
→ BUT what about all the outliers?

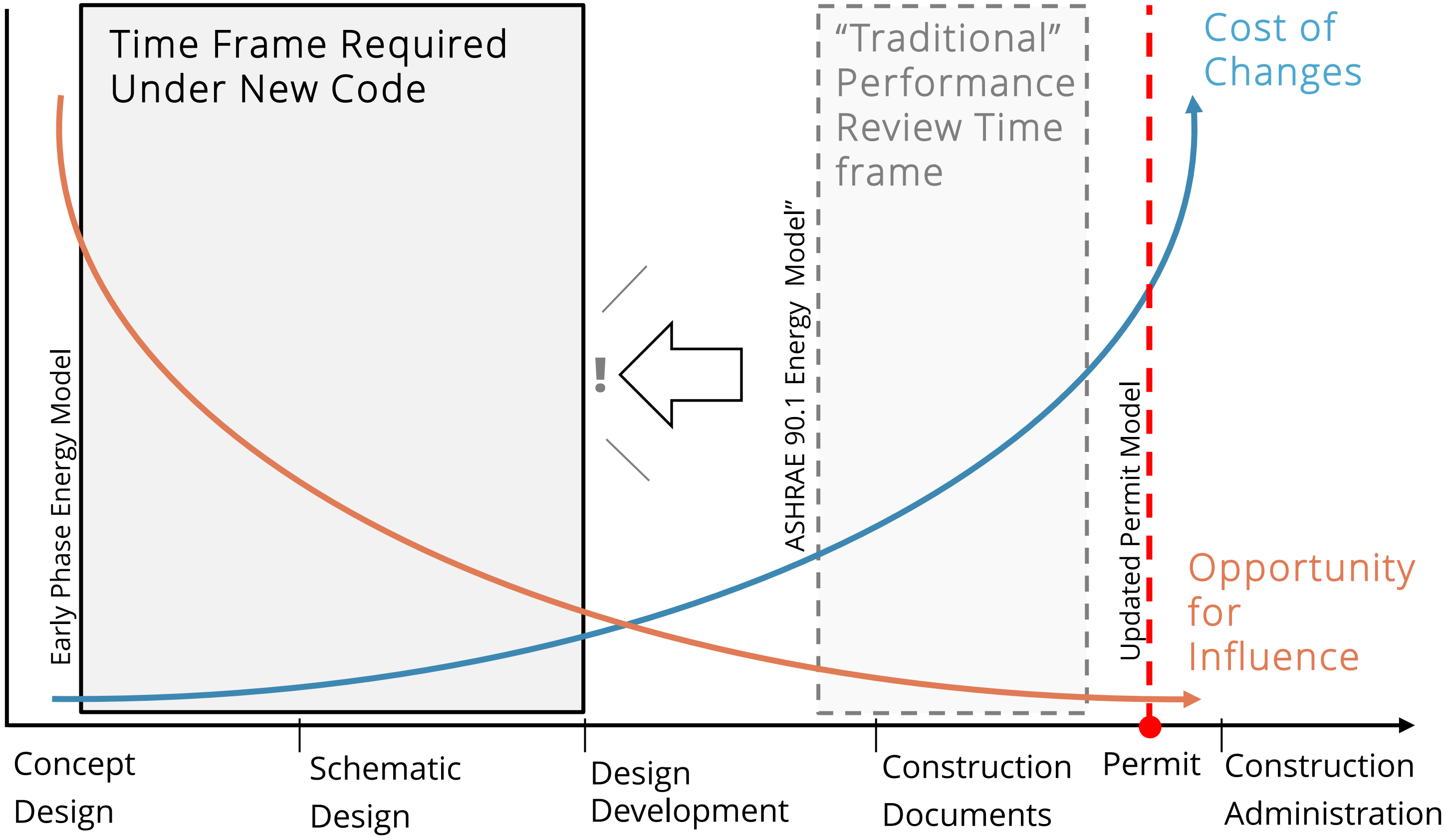
Whole Building Performance



Front-loaded Design Process

Most cost-effective approach to delivering buildings =
make the right decisions early

- Energy Model + Set performance targets early
- Design accordingly with whole team
- Update modeling and check design through subsequent phases



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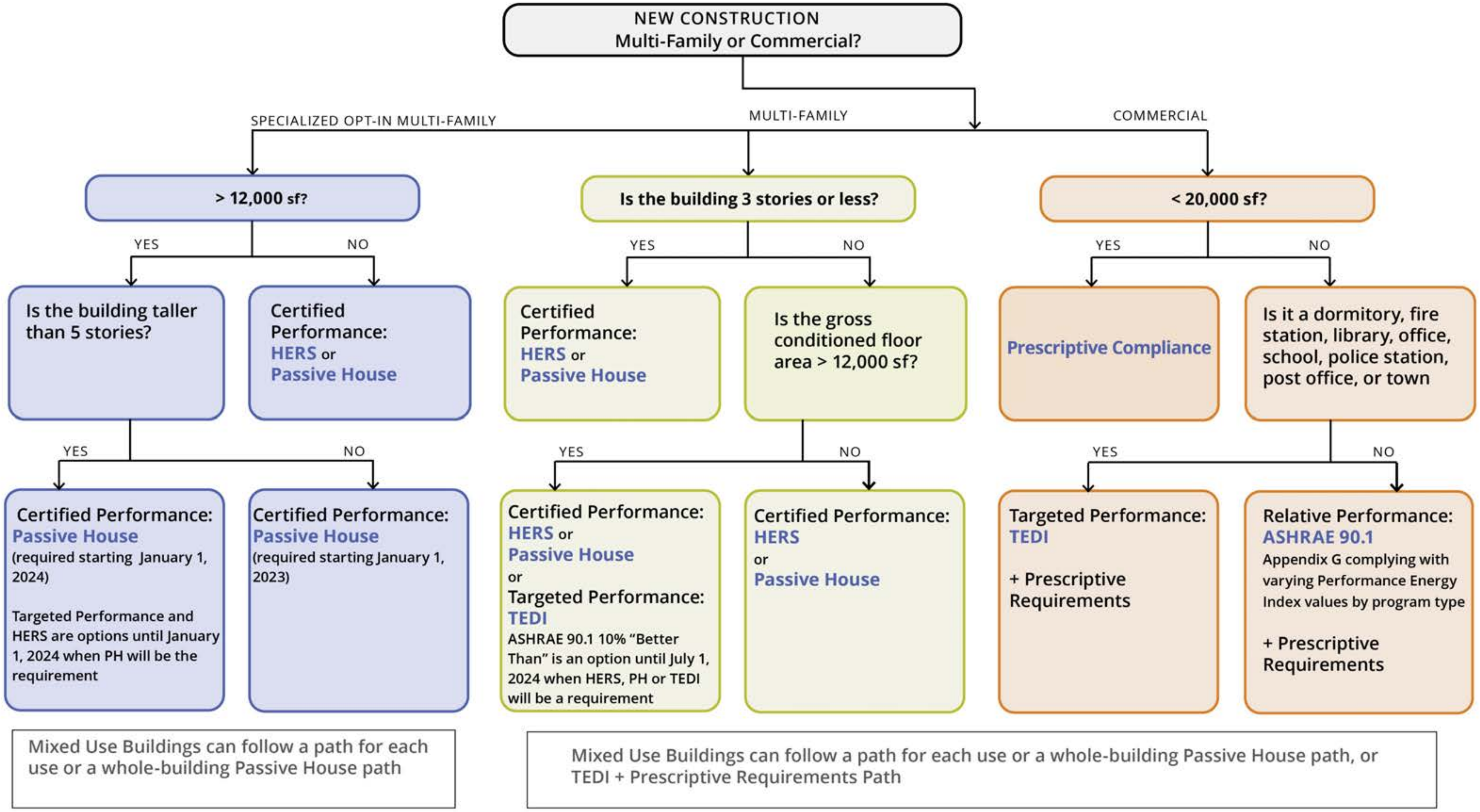
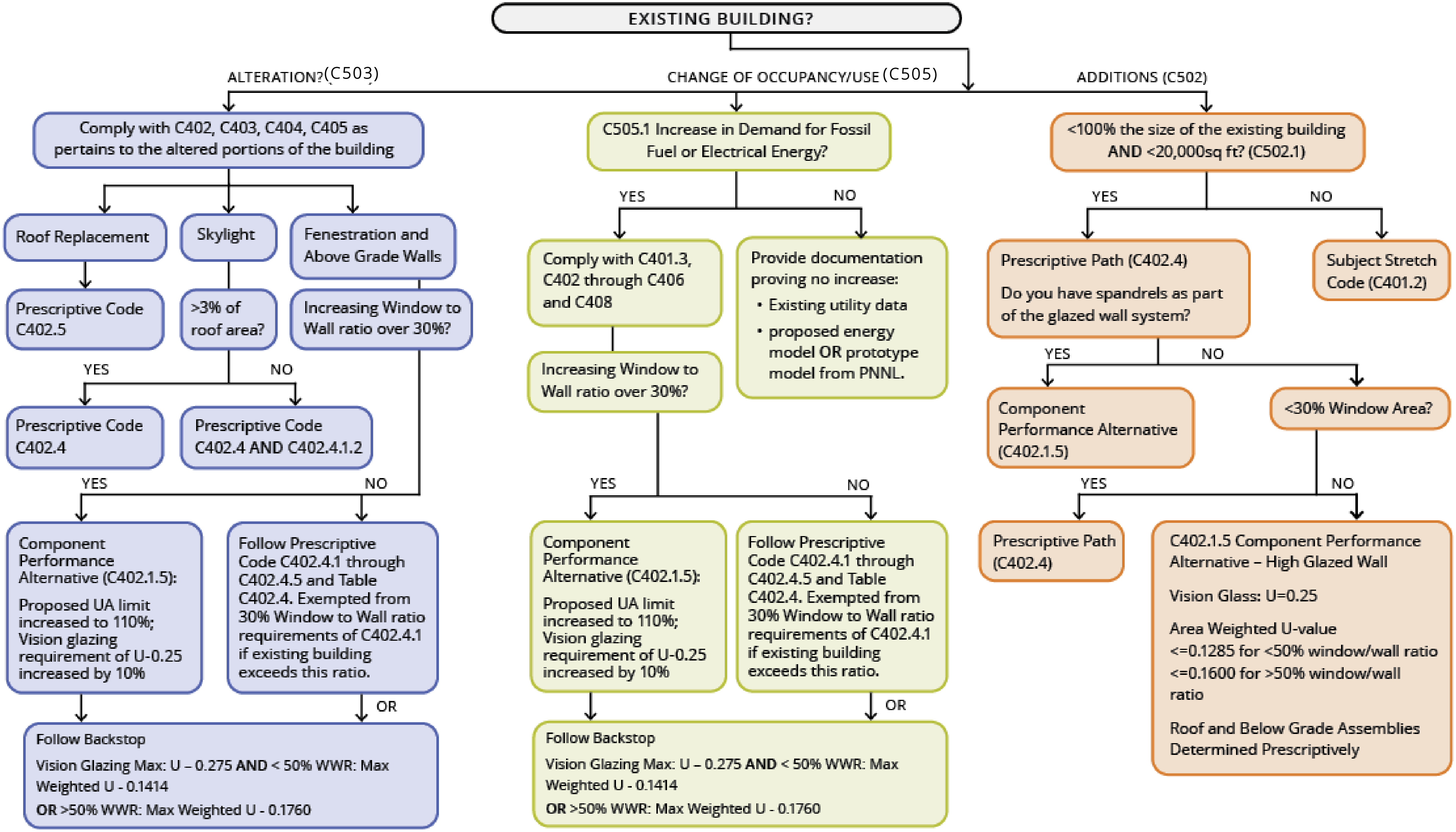
Stretch + Specialized Opt-In Code



PASSIVE HOUSE IS A CODE COMPLIANCE PATH OPTION FOR ANY BUILDING

Existing Buildings Stretch Code



Stretch Code + Specialized Opt-In Code

PATHWAY

- Prescriptive
- "Targeted" performance
- "Relative" performance
- Passive House
- HERS

ADDITIONAL MANDATORY STRETCH CODE PROVISIONS

Prescriptive, "Targeted" performance, "Relative" performance:

→ Envelope Derating (C407.2)
→ Airtightness (C402.5)
→ EV Readiness (CC101.5)
→ PV Readiness (CB103)
→ Additional Efficiency (C406.1)
→ Partial Electrification for High Ventilation (C401.4.1)
→ Envelope Backstop (C402.1.5) with Derating (C407.2) (Except for Prescriptive)

Passive House, HERS:

→ EV Readiness (CC101.5)
→ PV Readiness (CB103)

SPECIALIZED OPT-IN

Pick One (CC101.3):

→ Net Zero (CC 103)
→ All-Electric (CC 104)
→ Mixed Fuel (CC 105)

→ +PH for MF Residential over 12,000 sf (CC101)

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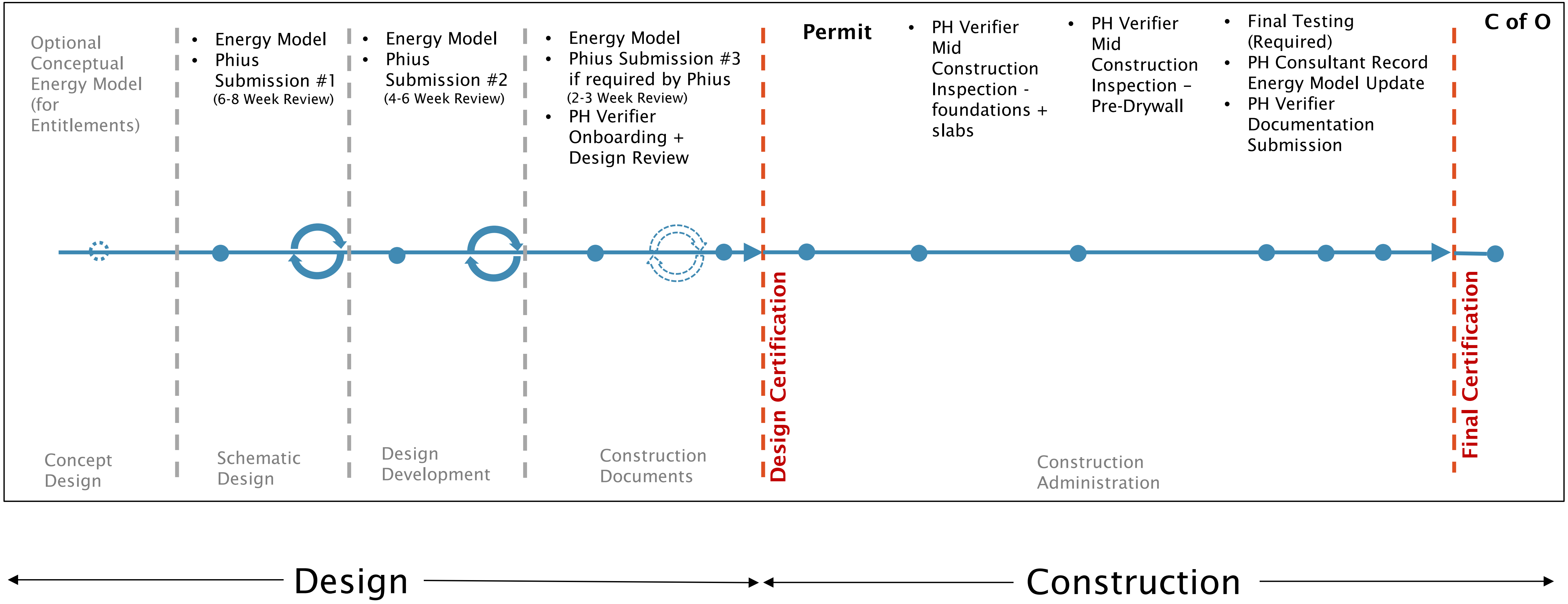
Design+Phius Certification Process



2 PH in Existing Buildings

The project you are about to see is a PHI project.
The names have been changed to protect the innocent.

Academic Admin. Building, Boston, MA

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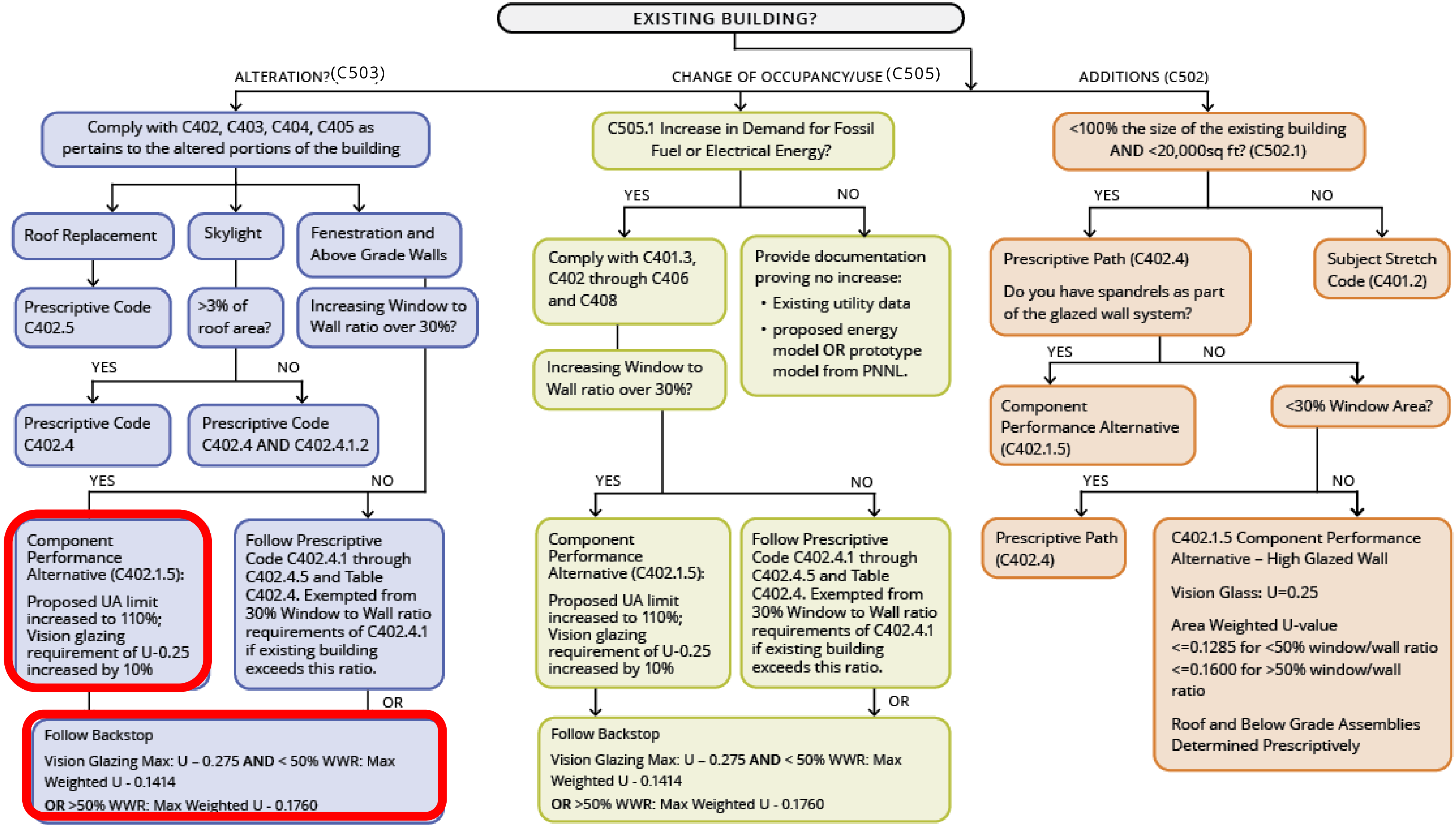
Existing Buildings Stretch Code



EnerPHit is an alternate existing building code compliance path

Proposed Vertical Enclosure Backstop

4” Mineral Wool with U-0.22 Windows

							Totals	751.2	100%
Transmittance Type	**Include**	**Transmittance Description**	**Area, Length or Amount Takeoff**	**Units**	**Transmittance Value**	**Units**	**Source Reference**	**Heat Flow (BTU/hr°F)**	**%Total Heat Flow**
Clear Field	☑	AGW1 Block wall with stucco	2519.83	ft2	0.051 R-20	BTU/ hr ft² °F	Parallel Path R-value Method	128.5	17%
Clear Field	☑	AGW2 Block wall with brick	1850.32	ft2	0.052 R-19	BTU/ hr ft² °F	Parallel Path R-value Method	96.2	13%
Clear Field	☑	Windows (all window types)	984.79	ft2	0.220 R-4.5	BTU/ hr ft² °F	Parallel Path R-value Method	216.7	29%
Clear Field	☑	Opaque Exterior Door	22.82	ft2	0.400 R-2.5	BTU/ hr ft² °F	Parallel Path R-value Method	9.1	1%
Linear Interface Detail	☑	Punch Window & Glazed Door installation - Top	185.53	ft	0.086	BTU/ hr ft °F	BETBEG 7.3.8	16.0	2%
Linear Interface Detail	☑	Punch Window & Glazed Door installation - Left/Right	539.69	ft	0.079	BTU/ hr ft °F	BETBEG 7.3.8	42.6	6%
Linear Interface Detail	☑	Punch Window & Glazed Door installation - Sill	185.53	ft	0.088	BTU/ hr ft °F	BETBEG 7.3.8	16.3	2%
Linear Interface Detail	☑	Exterior Wall Corner	80.38	ft	0.000	BTU/ hr ft °F	PHI TB Catalogue V3	0.0	0%
Linear Interface Detail	☑	Foundation Wall to Slab	160.17	ft	0.376	BTU/ hr ft °F	PHI TB Catalogue V3	60.2	8%
Linear Interface Detail	☑	Typical intermediate floors	320.34	ft	0.376	BTU/ hr ft °F	BETBG 7.2.18	120.4	16%
Linear Interface Detail	☑	Wall to Roof Transition	273.49	ft	0.162	BTU/ hr ft °F	PHI TB Catalogue V3	44.3	6%
Linear Interface Detail	☑	Opaque door perimeter	20.08	ft	0.040	BTU/ hr ft °F	RDH Initial Assumption	0.8	0%
Point Interface Detail	☐			#	0.000	BTU/ hr °F		0.0	0%

Overall Wall & Glazing Thermal Performance	
Opaque U-Value (BTU/hr ft2 oF)	0.140 ✓
Effective R-Value (hr ft2 oF/BTU)	7.2

Target: < U-0.141

→ This starts to look like EnerPHit

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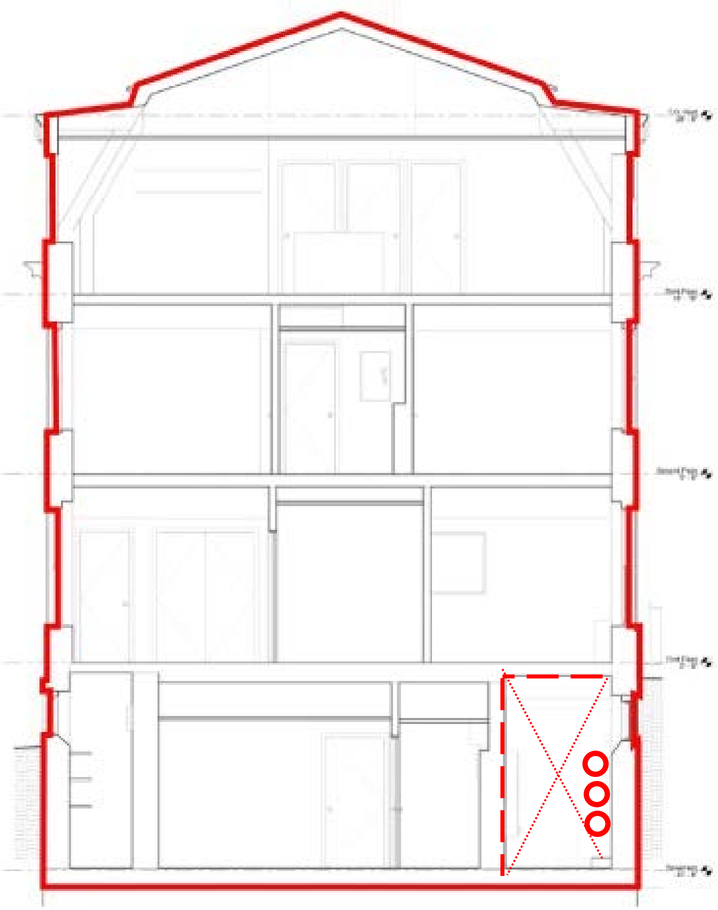
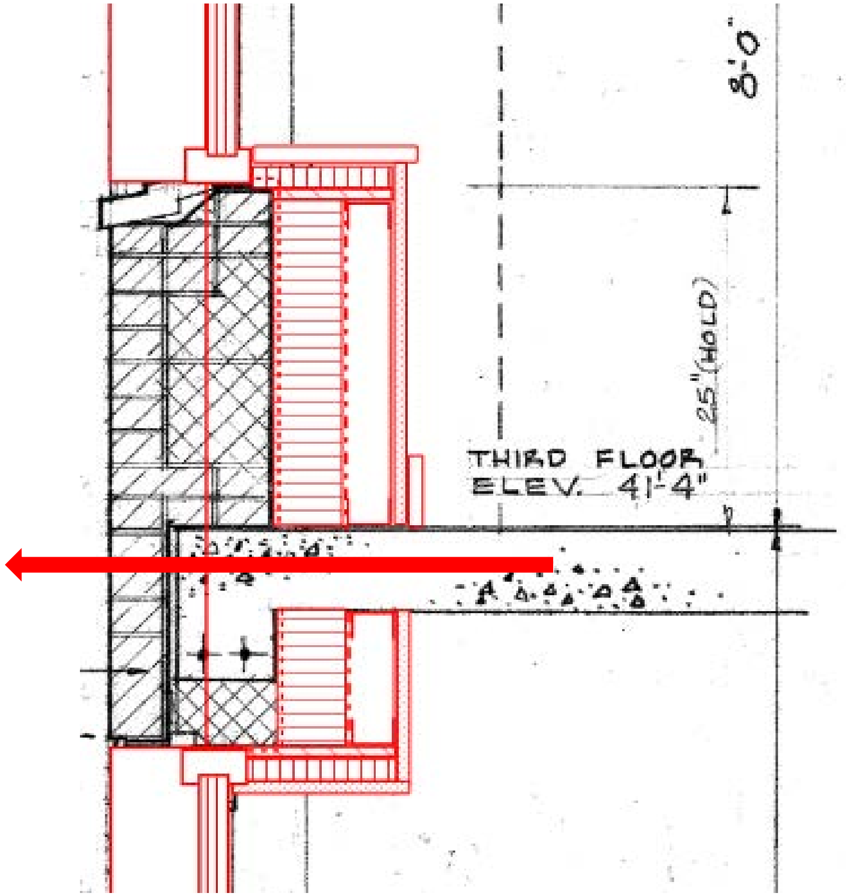
Proposed Above Grade Wall Modifications





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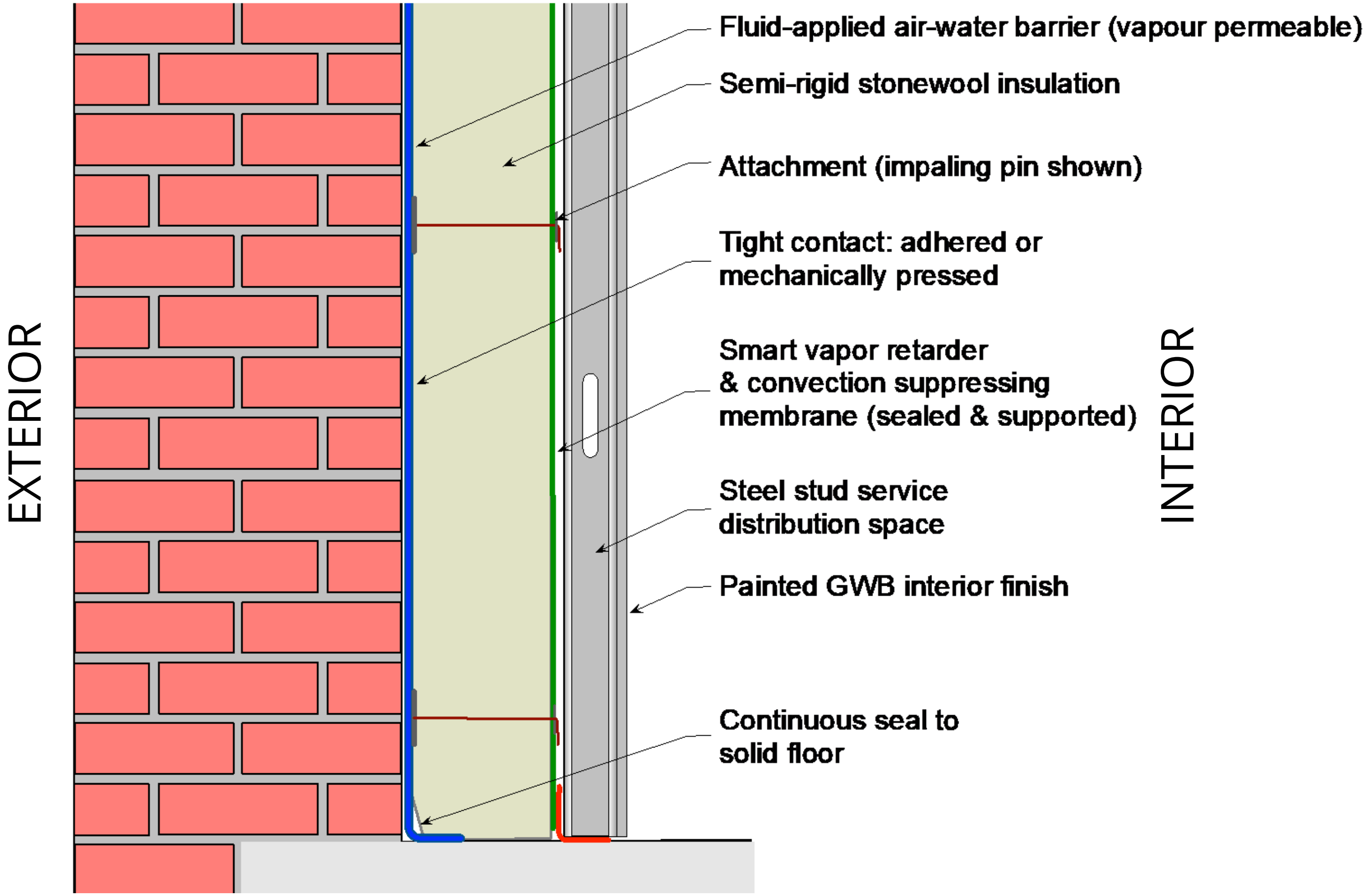
Existing wall – Interior Insulation



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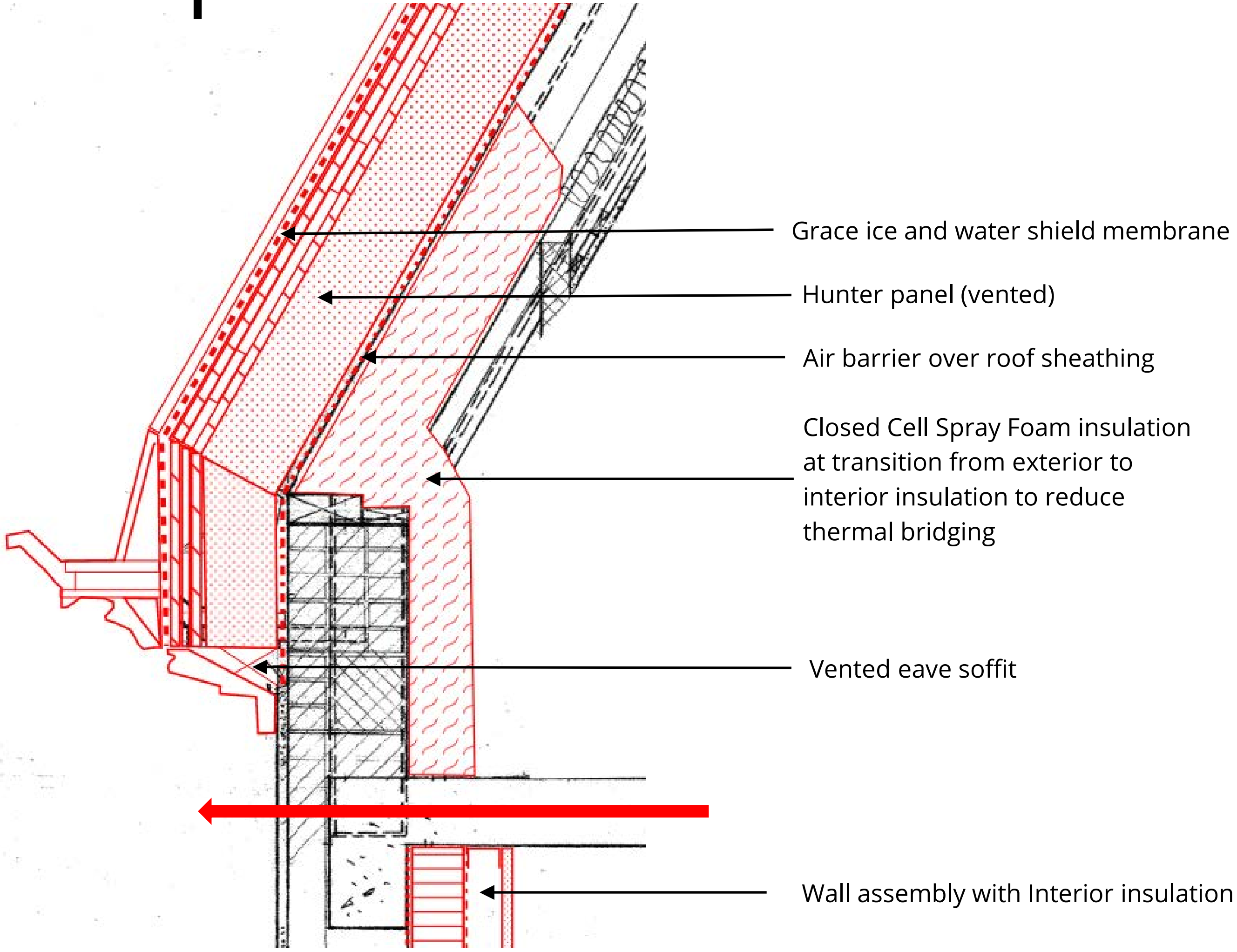
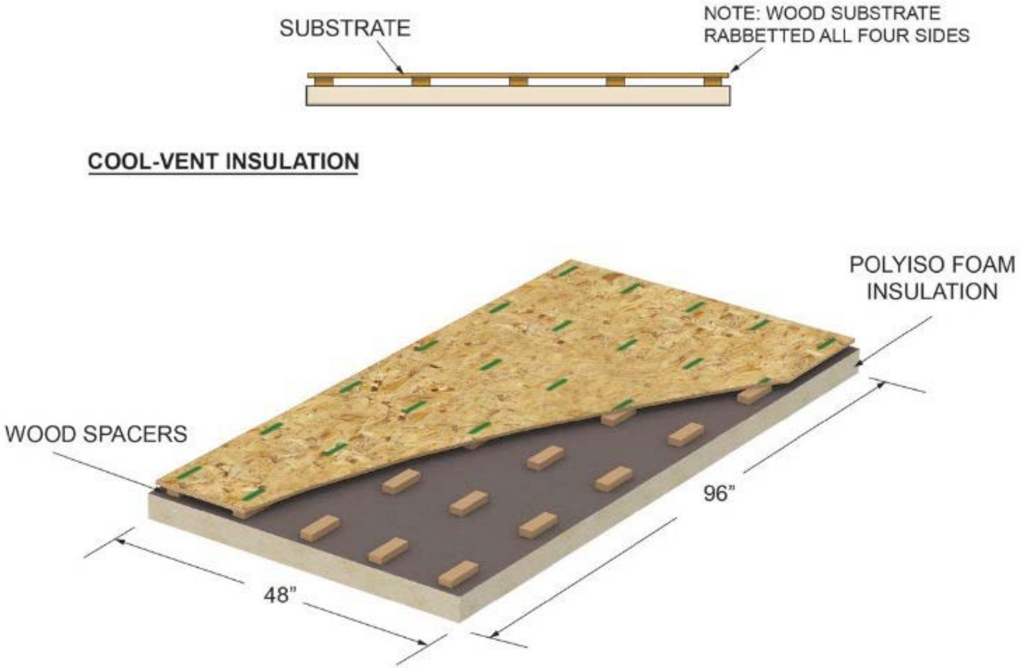
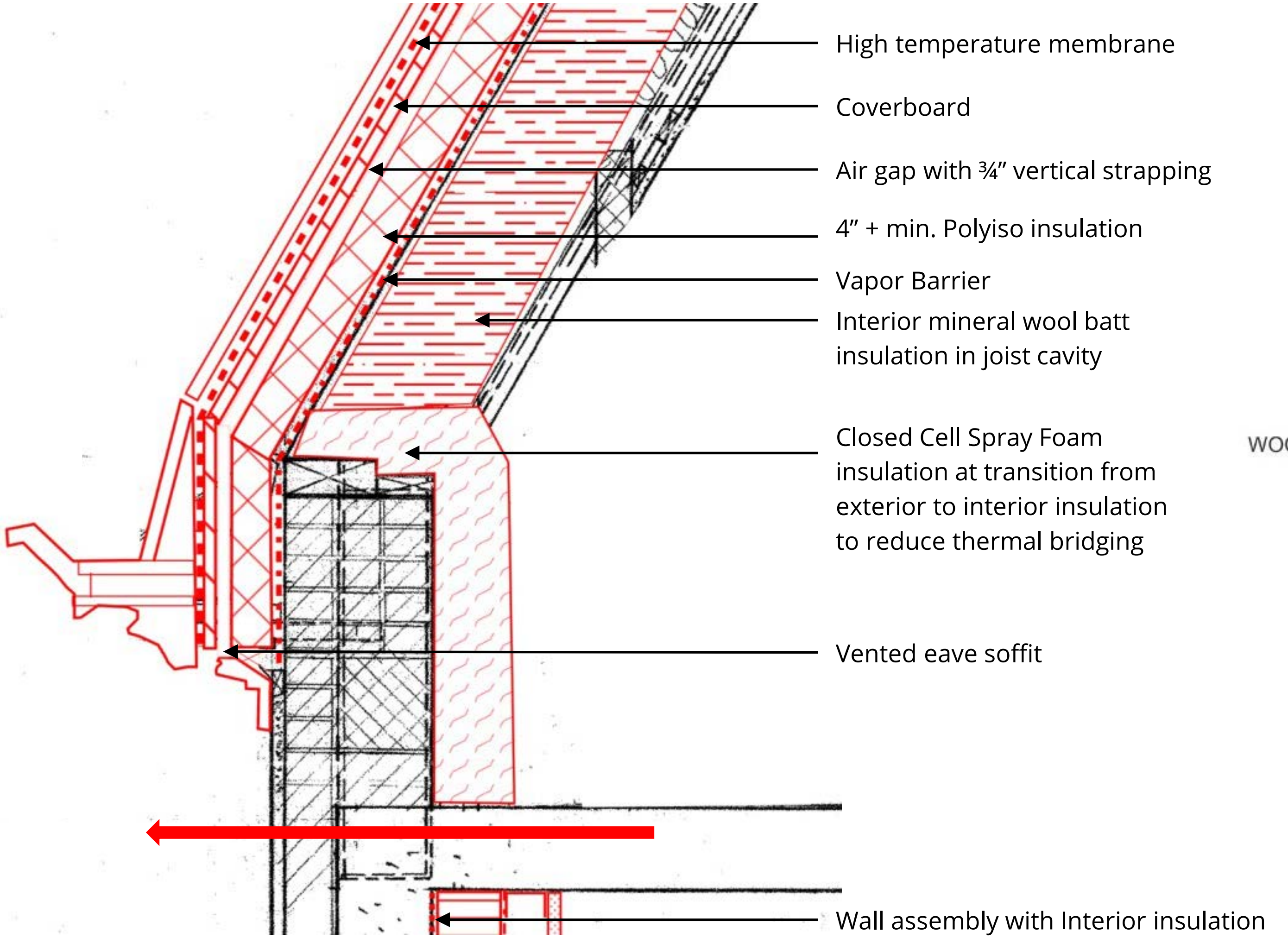
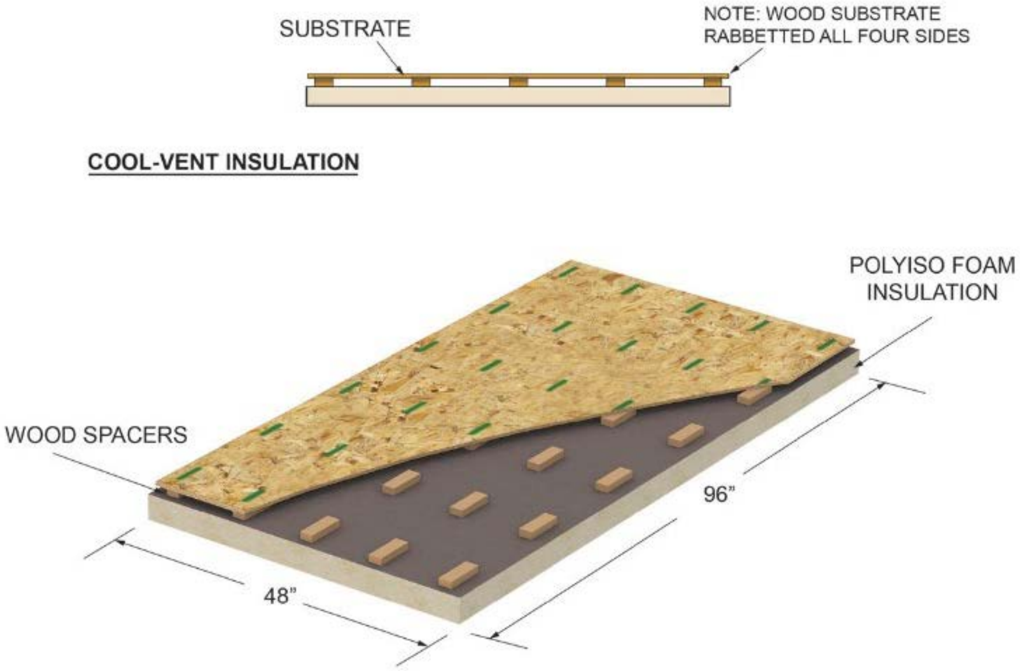
Proposed Roof Modifications – Exterior





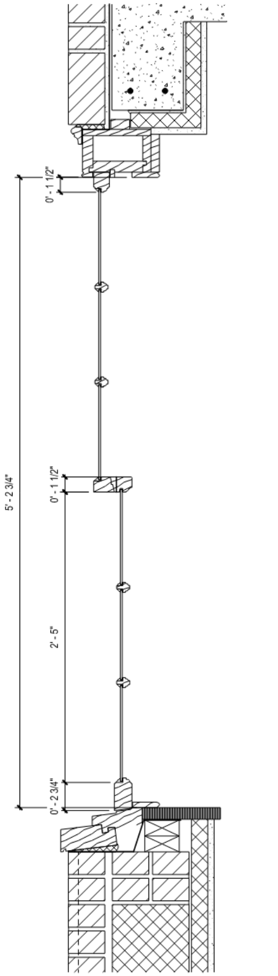
Proposed Roof Modifications – Split Insulation



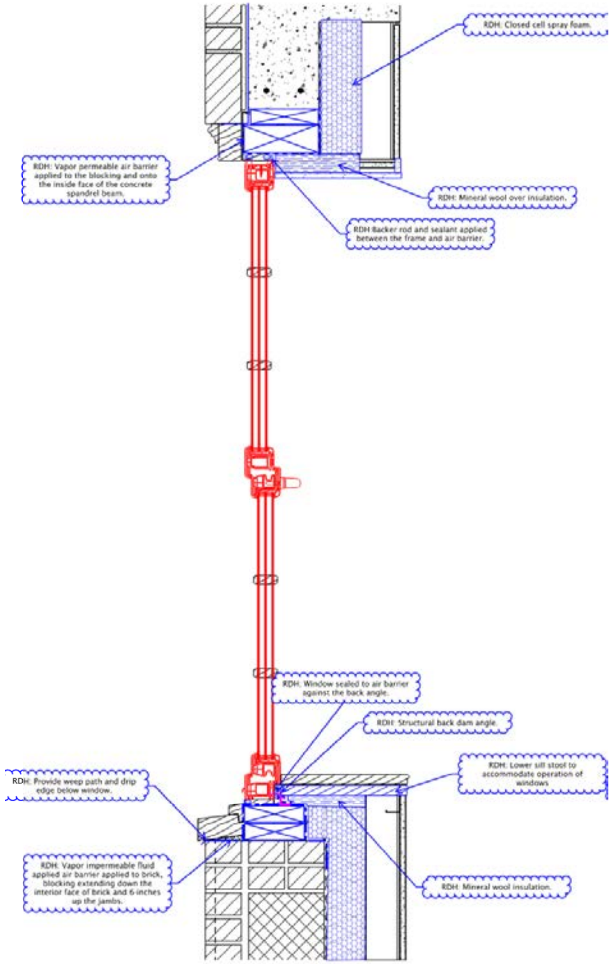


SIM.

Windows



1 Dillon House Existing Window Profile
1 1/2" = 1'-0"



4 Supera 74 Fixed Hopper
1 1/2" = 1'-0"

EnerPHit Energy vs Component Method

EnerPHit energy demand criteria

Climate zone according to PHPP	Heating	Cooling
	Max. heating demand	Max. cooling + dehumidification demand
	[kWh/(m²a)]	[kWh/(m²a)]
Arctic	35	equal to Passive House requirement[1]
Cold	30	
Cool-temperate	25	
Warm-temperate	20	
Warm	15	
Hot	15	
Very hot	15	

EnerPHit component criteria

Climate zone according to PHPP	Opaque envelope[1] against...				Windows (including exterior doors)					Ventilation	
	...ground	...ambient air			Overall[4]			Glazing[5]	Solar load[6]		
	Insulation	Exterior insulation	Interior insulation[2]	Exterior paint[3]	Max. heat transfer coefficient ($U_{D/W,installed}$)			Solar heat gain coefficient (g-value)	Max. specific solar load during cooling period	Min. heat recovery rate[7]	Min. humidity recovery rate[8]
	Max. heat transfer coefficient (U-value)			Cool colours							
	[W/(m²K)]			-	[W/(m²K)]			-	[kWh/m²a]	%	
Arctic	Determined in PHPP from project specific heating and cooling degree days against ground.	0.09	0.25	-	0.45	0.50	0.60	$U_g - g*0.7 \le 0$	100	80%	-
Cold		0.12	0.30	-	0.65	0.70	0.80	$U_g - g*1.0 \le 0$		80%	-
Cool-temperate		0.15	0.35	-	0.85	1.00	1.10	$U_g - g*1.6 \le 0$		75%	-
Warm-temperate		0.30	0.50	-	1.05	1.10	1.20	$Ug - g*3.2 \le -0.6$		75%	-
Warm		0.50	0.75	-	1.25	1.30	1.40	-		-	-
Hot		0.50	0.75	Yes	1.25	1.30	1.40	-		-	60 % (humid climate)
Very hot		0.25	0.45	Yes	1.05	1.10	1.20	-		-	60 % (humid climate)

Minimum Requirements vs. PH

4” Mineral Wool with U-0.22 Windows

Component	Stretch Code Design	EnerPHit Component Method
Above Grade Walls	**R-20 (U-0.051)** 4” mineral wool at interior face of brick	**R-20** 4” Mineral wool at interior face of brick ✓
Below Grade Walls + Slab	**R-19** 4” Mineral Wool at interior face of foundation wall	**Same as Stretch Code** ✓
Roof	**R-32** Split Insulation approach to achieve Prescriptive R-value	**R-38** Same with an additional 1”+ of insulation ↑
Windows	Simulated Double-Hung Tilt-Turn windows (**U-0.275 max**).	**TBD** EnerPHit requirement U-0.15 BTU/hr.ft2.F
Airtightness	0.35 cfm/ft^2 75 (**+/- 3.0 ACH50**)	+/- 0.1 cfm/ft^2 75 (~**1.0 ACH50**) ↑
Ventilation	**75% efficient heat recovery** with demand control ventilation.	**PHI-certified HRV/ERV** ↑
Heating & Cooling	**Existing District Energy Systems**	**Same as Stretch Code** ✓
Lighting	All lighting controls **automatic**. All spaces with occupancy or vacancy sensors with override switches and dimming.	**Same as Stretch Code** ✓
Appliance + Plug Load	At least 50% of installed receptacles shall be controlled via **Automatic Receptacle control** requirements.	**Same as Stretch Code** ✓

Stretch Code U-values are derated per Enclosure Backstop

EnerPHit Energy vs Component Method

Specific building characteristics with reference to the treated floor area							
	Treated floor area m²		371.0		Criteria	Alternative criteria	Fullfilled?[2]
Space heating **<25 required**	Heating demand	kWh/(m²a)	75	≤	-	-	-
	Heating load	W/m²	38	≤	-	-	
Space cooling	Cooling & dehum. demand	kWh/(m²a)	7	≤	-		-
	Frequency of overheating (> 25 °C)	%	-	≤	-		-
	Frequency of excessively high humidity (> 12 g/kg)	%	1	≤	10		Yes
Airtightness	Pressurisation test result n_{50}	1/h	1.0	≤	1.0		Yes
Moisture protection							
	Smallest temperature factor $f_{Rsi=0.25\ m^2K/W}$	-	0.70	≥	0.87	0.74	No
Thermal comfort	All requirements fulfilled?	-					No
	U-value	W/(m²K)		≤	0.82		
	U-value	W/(m²K)		≤	0.98		
	U-value	W/(m²K)		≤	1.07		
	U-value	W/(m²K)		≤	0.45		
Non-renewable Primary Energy (PE)	PE demand	kWh/(m²a)	219	≤	-		-
Primary Energy Renewable (PER)	PER demand	kWh/(m²a)	102	≤	151	151	Yes
	Renew. energy generation (in rel. to projected building footprint area)	kWh/(m²a)	0	≥	-	-	

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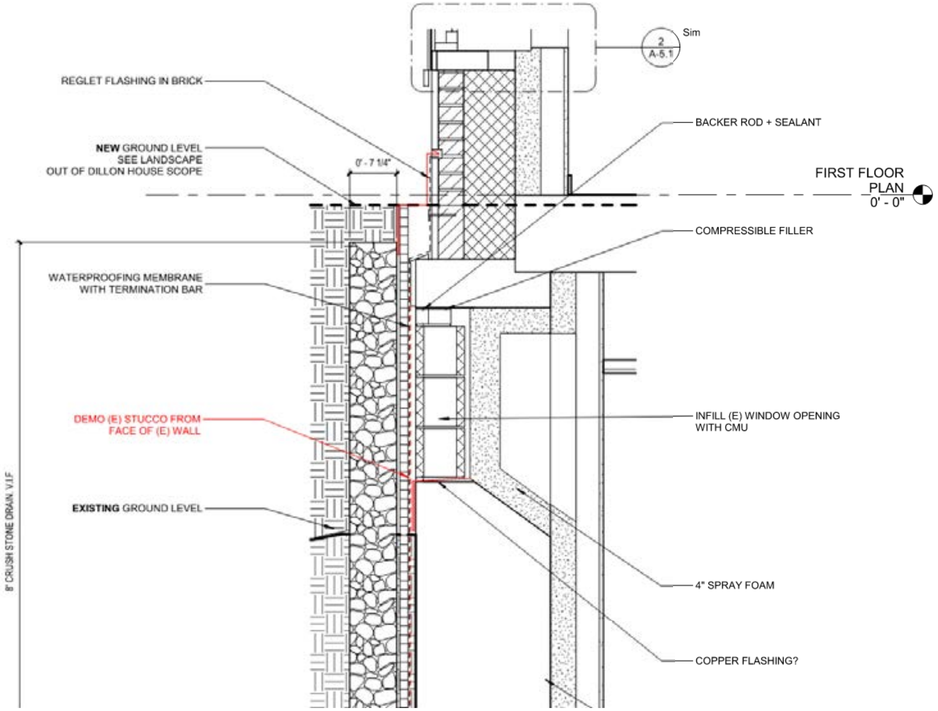
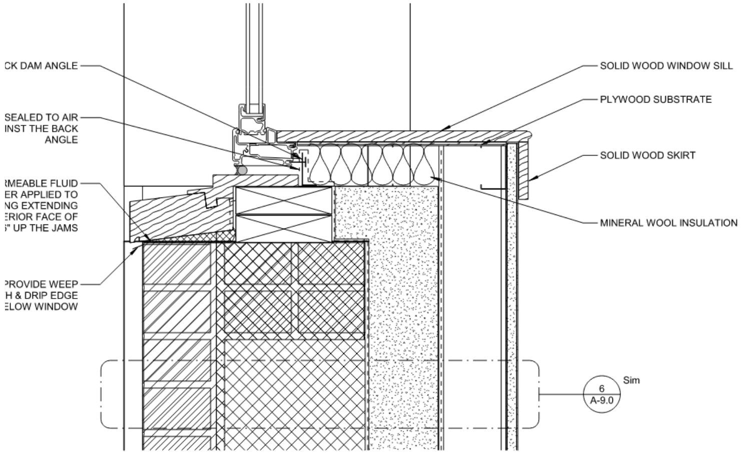
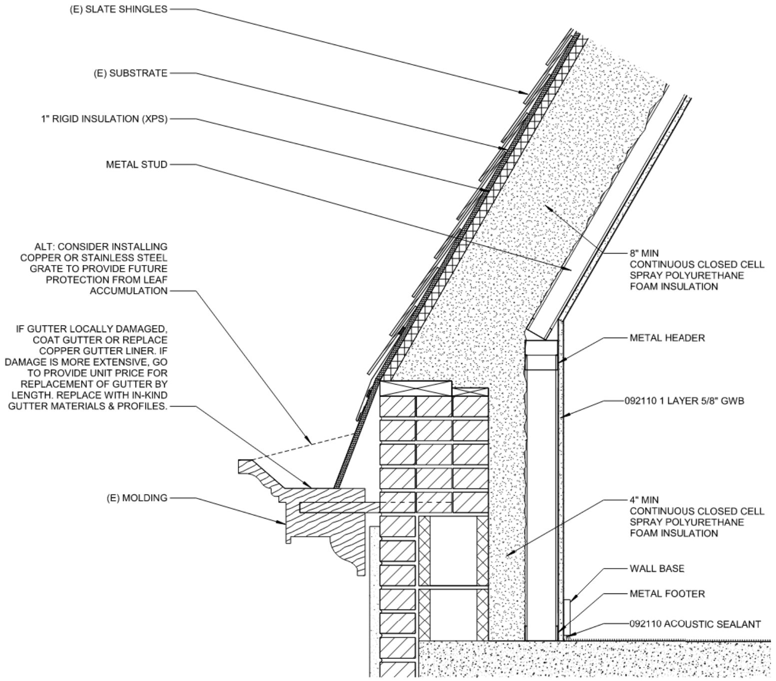
Evolving Enclosure







Proposed Enclosure Backstop Update

4” Closed Cell Spray Foam with U-0.275 Windows

					Totals	691.4	100%
Transmittance Description	**Area, Length or Amount Takeoff**	**Units**	**Transmittance Value**	**Units**	**Source Reference**	**Heat Flow (BTU/hr°F)**	**%Total Heat Flow**
AGW1 Block wall with stucco	2519.83	ft2	0.031	BTU/ hr ft² °F	Parallel Path R-value Method	78.1	11%
AGW2 Block wall with brick	1850.32	ft2	0.037	BTU/ hr ft² °F	Parallel Path R-value Method	68.5	10%
Windows (all window types)	984.79	ft2	0.275	BTU/ hr ft² °F	Component Performance Alternative C402.1.5	270.8	39%
Opaque Exterior Door	22.82	ft2	0.370	BTU/ hr ft² °F	Prescriptive Req. C402.1.4	8.4	1%
Punch Window & Glazed Door installation - Head	185.53	ft	0.083	BTU/ hr ft °F	BETBEG 7.3.8	15.4	2%
Punch Window & Glazed Door installation - Jambs	539.69	ft	0.083	BTU/ hr ft °F	BETBEG 7.3.8	44.8	6%
Punch Window & Glazed Door installation - Sill	185.53	ft	0.083	BTU/ hr ft °F	BETBEG 7.3.8	15.4	2%
Foundation Wall to Slab	160.17	ft	0.367	BTU/ hr ft °F	BETBG 7.2.18	58.8	9%
Typical intermediate floors	320.34	ft	0.367	BTU/ hr ft °F	BETBG 7.2.18	117.6	17%
Wall to Roof Transition	273.49	ft	0.050	BTU/ hr ft °F	BETBG 8.4.3	13.7	2%
		#	0.000	BTU/ hr °F		0.0	0%

Overall Wall & Glazing Thermal Performance	
Opaque U-Value (BTU/hr ft2 oF)	**0.129** ✓
Effective R-Value (hr ft2 oF/BTU)	**7.8**

Target: < U-0.141

→ The client chose this option as the project evolved, prior to committing to EnerPHit

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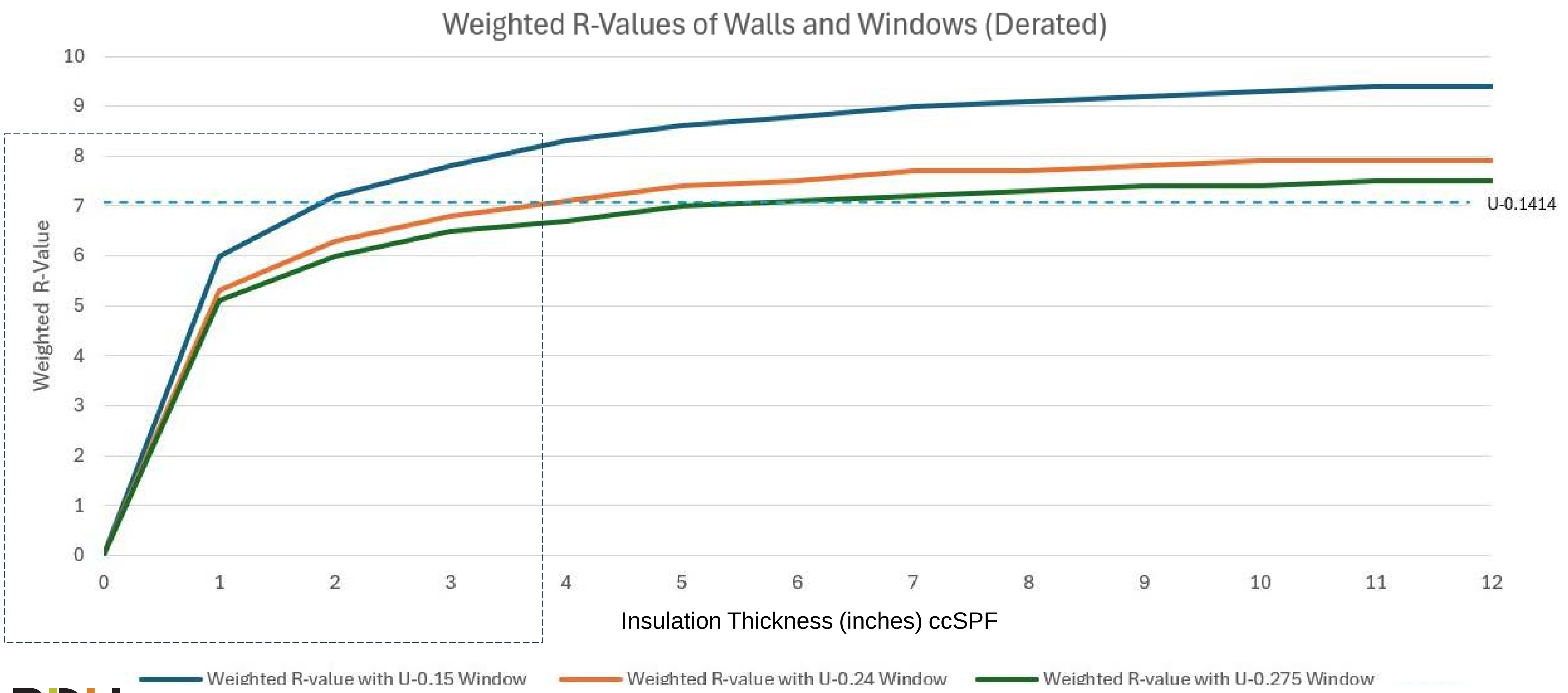
Higher U-value windows vs More Wall Insulation



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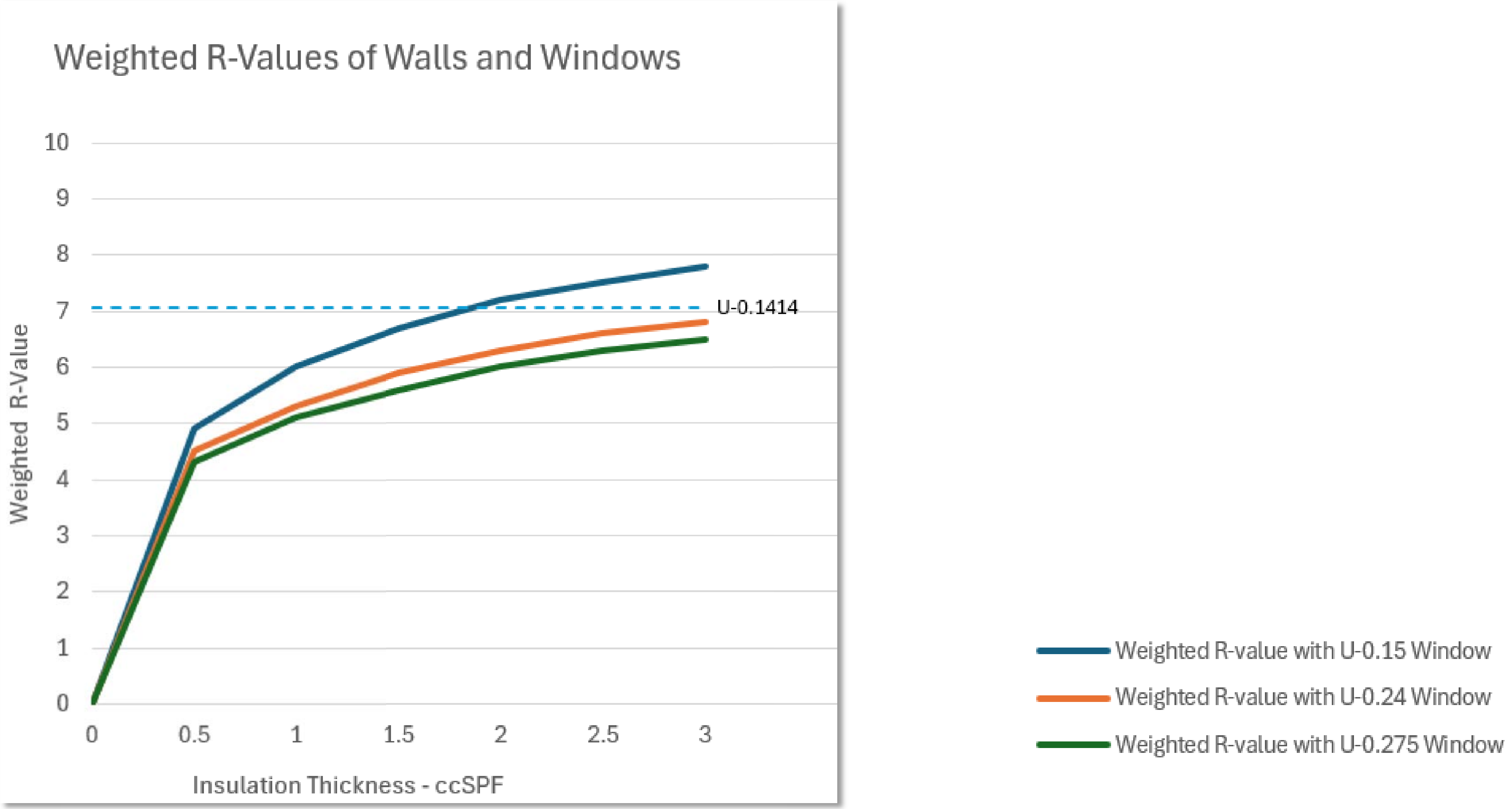

Weighted R-Values of Walls and Windows
Weighted R-Value
10
9
8
7
6
5
4
3
2
1
0
0
0.5
1
1.5
2
2.5
3
Insulation Thickness - ccSPF
U-0.1414
Weighted R-value with U-0.15 Window
Weighted R-value with U-0.24 Window
Weighted R-value with U-0.275 Window

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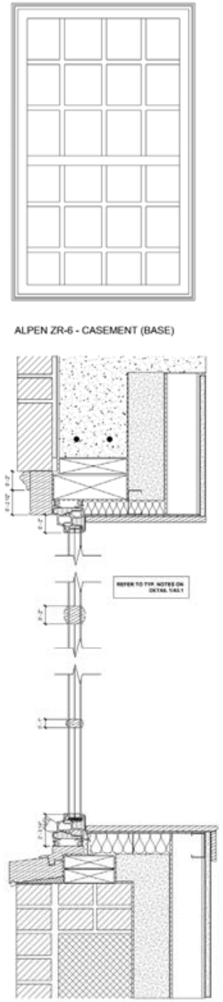
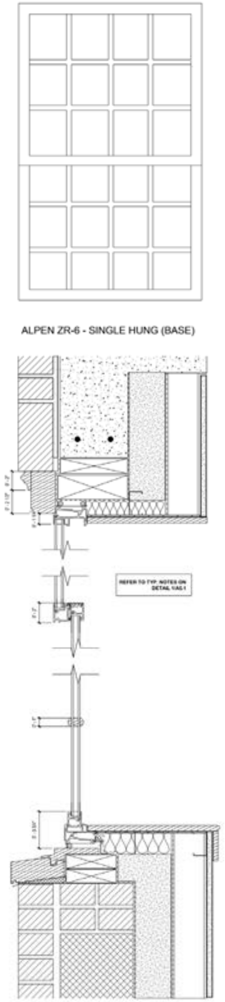
Windows



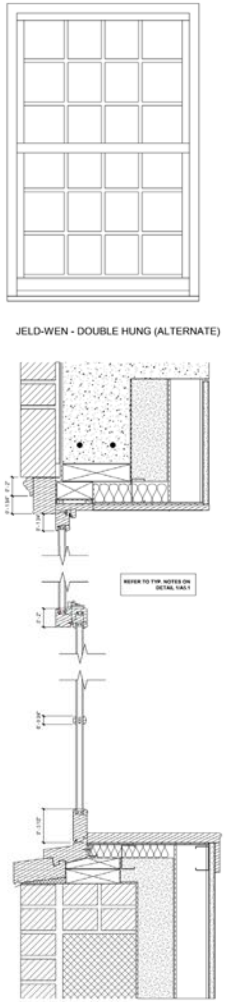
Alpen Zenith ZR 6 Casement

MATERIAL: FIBERGLASS
COLOR: CUSTOM
PROFILE: TO MATCH EXISTING
U-VALUE: 0.2
INFILTRATION: <0.1



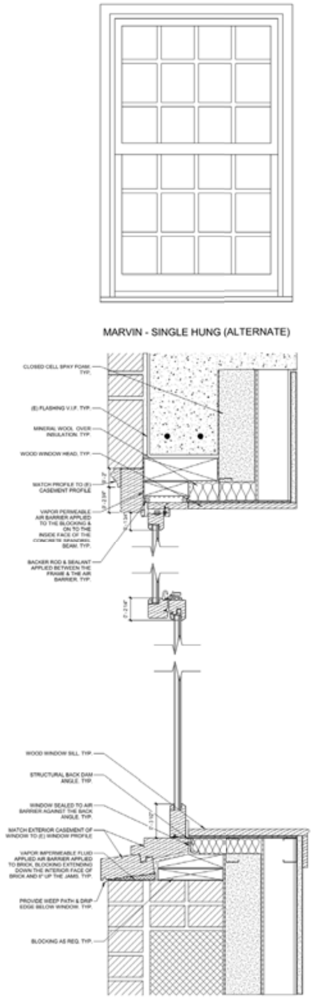
Alpen Zenith ZR 6 Single Hung

MATERIAL: FIBERGLASS
COLOR: CUSTOM
PROFILE: TO MATCH EXISTING
U-VALUE: 0.2
INFILTRATION: <0.1



Jeld Wen Custom Wood Double Hung

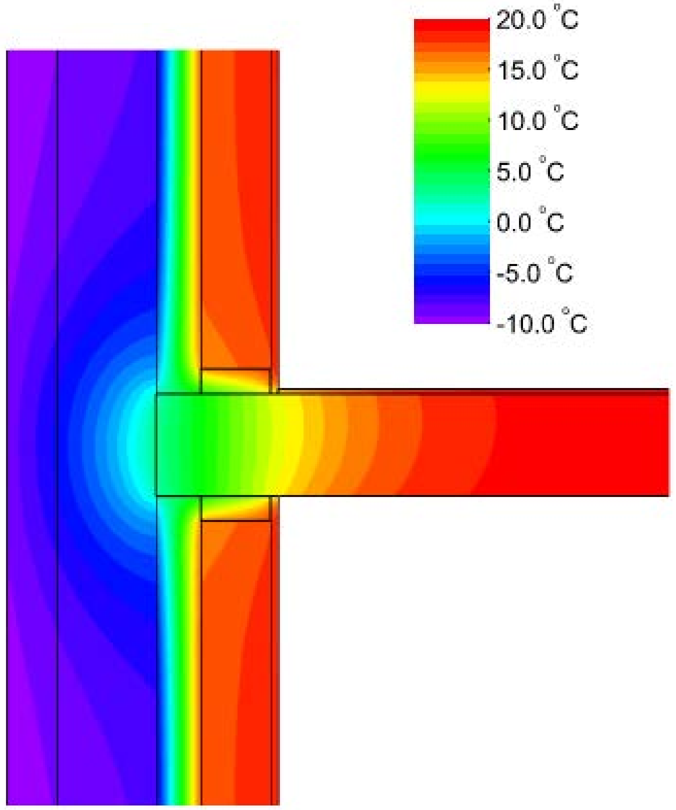
MATERIAL: WOOD (FSC) (SAPELE)
COLOR: PTD
PROFILE: TO MATCH EXISTING
U-VALUE: 0.27
INFILTRATION: <0.3

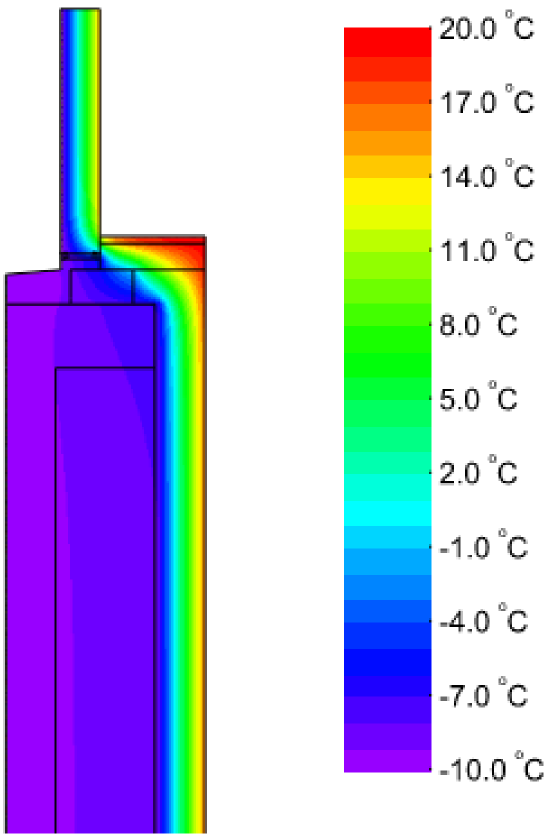


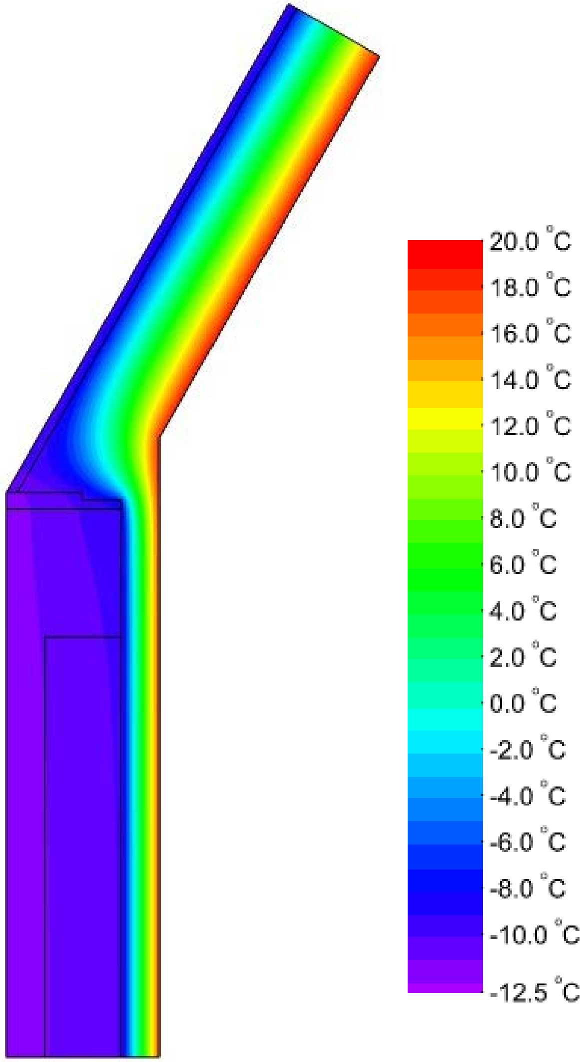
Marvin Ultimate Wood Double Hung

MATERIAL: WOOD (NOT FSC) (MAHOGANY
COLOR: PTD
PROFILE: TO MATCH EXISTING
U-VALUE: <0.2
INFILTRATION: 0.03

Evolving Enclosure







Updated Design for EnerPHit

Component	Modified Stretch Code + EnerPHit Compliant Design	
Above Grade Walls	**R-32 (U-0.031)** 4" CCSPF at interior face of brick	✓
Below Grade Walls + Slab	**R-32 (U-0.031)** 4" CCSPF at interior face of foundation	✓
Roof	**R-38** Split Insulation approach to achieve Prescriptive R-value	✓
Windows	Simulated Double-Hung Tilt-Turn windows (**U-0.18 max for worst case window, pending historic exception from Certifier**).	✓
Airtightness	+/- 0.1 cfm/ft^2 75 (**~1.0 ACH50**)	✓
Ventilation	**PHI-certified HRV/ERV**	✓
Heating & Cooling	**Existing District Energy Systems**	✓
Lighting	All lighting controls **automatic**. All spaces with occupancy or vacancy sensors with override switches and dimming.	✓
Appliance + Plug Load	At least 50% of installed receptacles shall be controlled via **Automatic Receptacle control** requirements.	✓

Stretch Code U-values are derated per Enclosure Backstop

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Next Steps

- → Design Stage Review in progress with Certifier
- → Detailed mechanical design coordination with MEP Engineer
- → Brick testing ongoing
- → Ongoing enclosure design coordination including thermal bridge evaluation and modelling
- → Construction scheduled for Spring, 2025

Conclusions

- Backstop requirements are similar to what EnerPHit component method requires.
- If achieving PH Certification is a goal, it's not a heavy lift beyond minimum code requirements.
- Potential for Phius Revive to make similar existing building considerations.
- Use low U-value windows to achieve thermal comfort and minimize condensation risk, in addition to reducing the required amount of wall insulation, potentially satisfying multiple project considerations.
- Passive House also encourages this.

3 PH in Non-Residential New Construction

Pierce Elementary School, Brookline, MA

1. New Construction School (C-407.1)

→TEDI path with Enclosure Backstop (C402.1.5)

→TEDI modeling may supersede requirements of the Enclosure Backstop

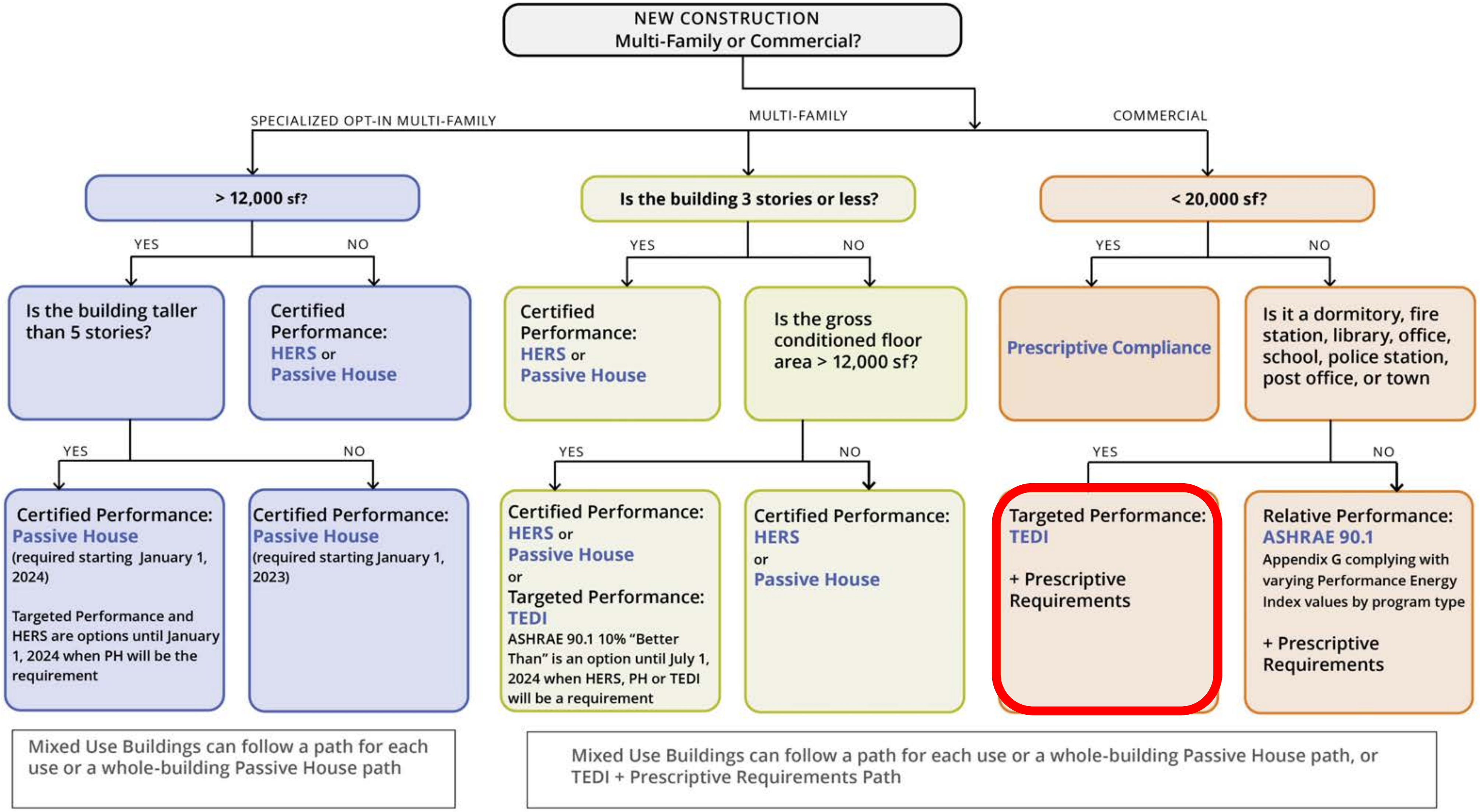
2. Existing Building Alteration (C-503)

→Prescriptive derating for opaque assemblies being altered is preferred over Backstop as the plan is to leave existing windows (following backstop would mean replacing all the windows)

3. Existing Building Addition (C-502)

→Following Enclosure Backstop, using same assemblies as the new construction school

Stretch + Specialized Opt-In Code



Passive House is a code compliance path for any building

TEDI requirements

Schools larger than 125,000 sf:

→ TEDI targets are more stringent than Passive House

→ Heating TEDI: 2.2 kbtu/sf/yr (7 kWh/m2a)

→ Cooling TEDI: 12 kbtu/sf/yr (38 kWh/m2a)

→ Different from TEDI in BC or Toronto

→ Some elements modelled prescriptively (ie no credit for demand control ventilation)

Table C407.1.1.5
Thermal Energy Demand Intensity (TEDI) Limits

Use Type	Heating TEDI (kBtu/sf-yr)	Cooling TEDI (kBtu/sf-yr)
Office, fire station, library, police station, post office, town hall >= 125,000-sf	1.5	23
Office, fire station, library, police station, post office, town hall between 75,000 and 125,000-sf	4 — 0.00002 * Area (sf)	18 + 0.00004 * Area (sf)
Office, fire station, library, police station, post office, town hall <= 75,000-sf	2.5	21
K-12 School >= 125,000-sf	2.2	12
K-12 School between 75,000 and 125,000-sf	2.7 — 0.000004 * Area (sf)	32 - 0.00016 * Area (sf)
K-12 School <= 75,000-sf	2.4	20
Residential multifamily and dormitory >= 125,000- sf	2.8	22
Residential multifamily and dormitory between 75,000 and 125,000-sf	3.8 — 0.000008 * Area (sf)	4.5 + 0.00014 * Area (sf)
Residential multifamily and dormitory <= 75,000-sf	3.2	15
All other >= 125,000-sf	1.5	23
All other between 75,000 and 125,0000-sf	4 — 0.00002 * Area (sf)	18 + 0.00004 * Area (sf)
All other <= 75,000-sf	2.5	21

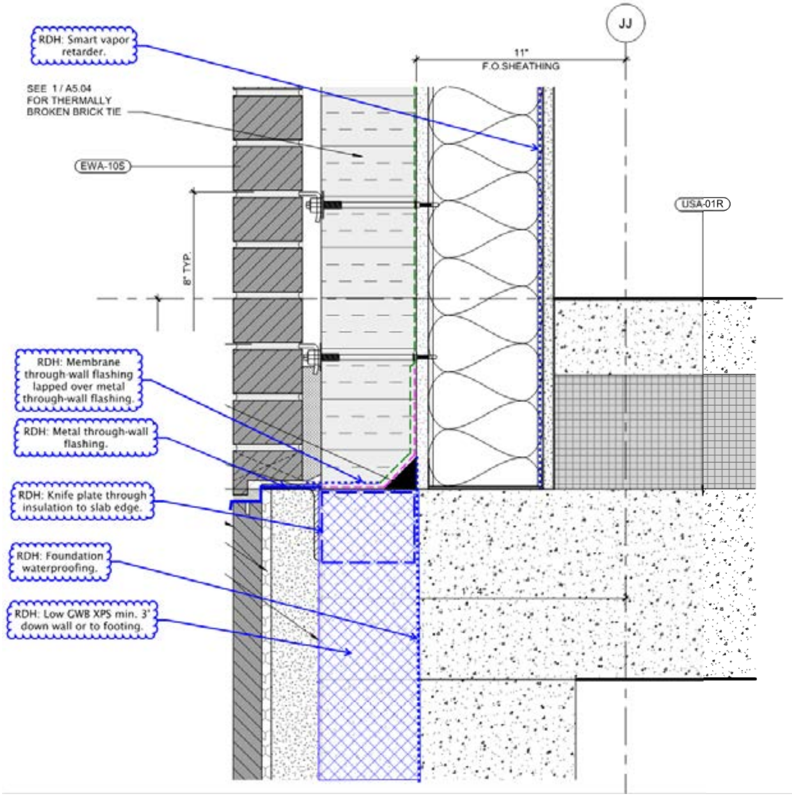
Calculating Enclosure Thermal Performance

Transmittance Description	Area, Length or Amount Takeoff	Units	Transmittance Value	Units	Source Reference	Heat Flow (BTU/hr°F)	%Total Heat Flow
					Totals	7915.1	100%
Brick on CFMF	31461.00	ft^2	0.037 (R-27)	BTU/ hr ft^2 °F	RDH Masonry Guide	1165.2	15%
Brick on CMU	3615.00	ft^2	0.045 (R-22)	BTU/ hr ft^2 °F	RDH Masonry Guide	164.3	2%
Brick on Concrete	1525.00	ft^2	0.045	BTU/ hr ft^2 °F	RDH Masonry Guide	69.3	1%
Slate/Granite shingle on CFMF backup	3804.00	ft^2	0.037	BTU/ hr ft^2 °F	RDH Masonry Guide	140.9	2%
Standing seam/Metal Panel on CFMF	14267.00	ft^2	0.037	BTU/ hr ft^2 °F	RDH Masonry Guide	528.4	7%
Slate shingle on CMU	1683.00	ft^2	0.045	BTU/ hr ft^2 °F	RDH Masonry Guide	76.5	1%
Spandrels (large openings)	1494.00	ft^2	0.168	BTU/ hr ft^2 °F	4.1.2	251.0	3%
Spandrels (small openings)	1040.00	ft^2	0.168	BTU/ hr ft^2 °F	4.1.2	174.7	2%
Kawneer 1600-UT System 2 (large)	11169.00	ft^2	0.190	BTU/ hr ft^2 °F	Kawneer Data	2122.1	27%
Kawneer 1600-UT System 2 (small)	7025.00	ft^2	0.210	BTU/ hr ft^2 °F	Kawneer Data	1475.3	19%
Wood on CFMF	923.00	ft^2	0.037	BTU/ hr ft^2 °F	RDH Masonry Guide	34.2	0%
Wood on CMU	531.00	ft^2	0.045	BTU/ hr ft^2 °F	RDH Masonry Guide	24.1	0%
CMU Wall @ Garage Interface	2542.50	ft^2	0.043	BTU/ hr ft^2 °F	RDH Masonry Guide	110.5	1%
Shelf angles/slab edge/intermediate floor	2186.00	ft	0.118	BTU/ hr ft °F	RDH DER TB Guide	257.9	3%
Window Perimeter	7757.00	ft	0.047	BTU/ hr ft °F	5.3.13	364.6	5%
Slab to Garage Transition	1286.77	ft	0.350	BTU/ hr ft °F	RDH DER TB Guide	450.4	6%
Wall to Roof Transition	1540.00	ft	0.210	BTU/ hr ft °F	RDH DER TB Guide	323.4	4%
Low parapet	867.47	ft	0.210	BTU/ hr ft °F	RDH DER TB Guide	182.2	2%

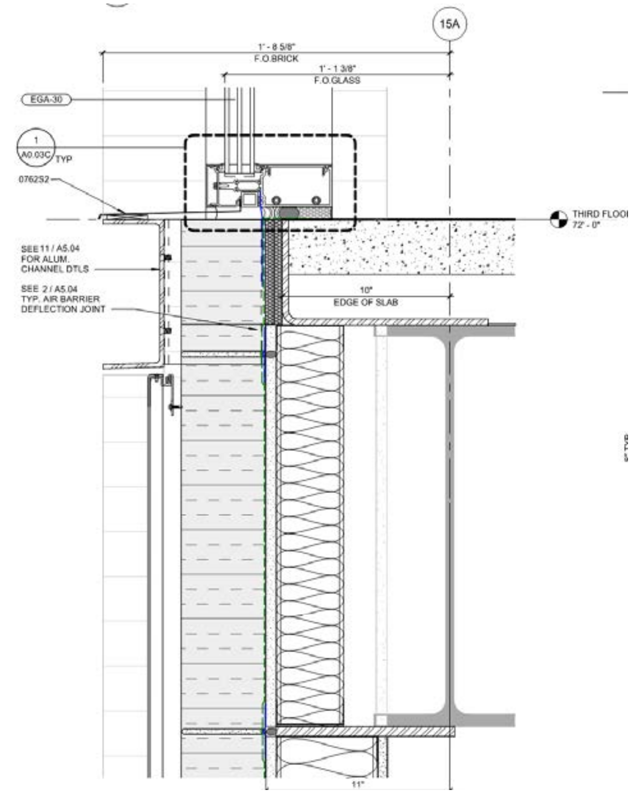
Overall Wall & Glazing Thermal Performance	
U-Value (BTU/hr ft^2 °F)	0.098 ✓
Effective R-Value (hr ft^2 °F/BTU)	10.2

Target: < U-0.1285

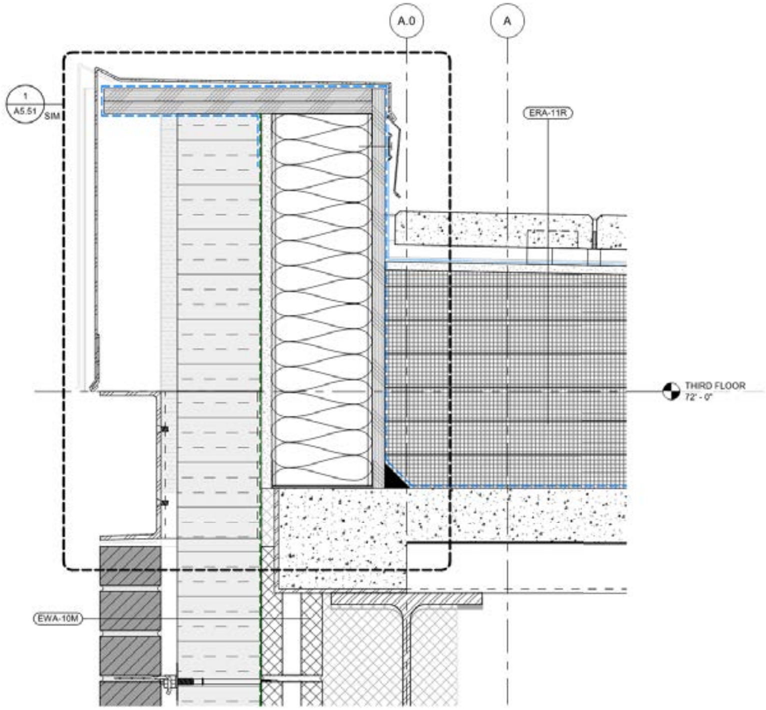
Assemblies



RDH: Smart vapor retarder.
SEE 1 / A5.04 FOR THERMALLY BROKEN BRICK TIE
EWA-10S
JJ
11" F.O.SHEATHING
USA-01R
8" TYP.
RDH: Membrane through-wall flashing lapped over metal through-wall flashing.
RDH: Metal through-wall flashing.
RDH: Knife plate through insulation to slab edge.
RDH: Foundation waterproofing.
RDH: Low GWB XPS min. 3" down wall or to footing.



15A
1' - 8 5/8" F.O.BRICK
1' - 1 3/8" F.O.GLASS
EGA-30
1 A0.03C TYP
0762S2
THIRD FLOOR 72' - 0"
SEE 11 / A5.04 FOR ALUM. CHANNEL DTLS
SEE 2 / A5.04 TYP. AIR BARRIER DEFLECTION JOINT
10" EDGE OF SLAB
11"

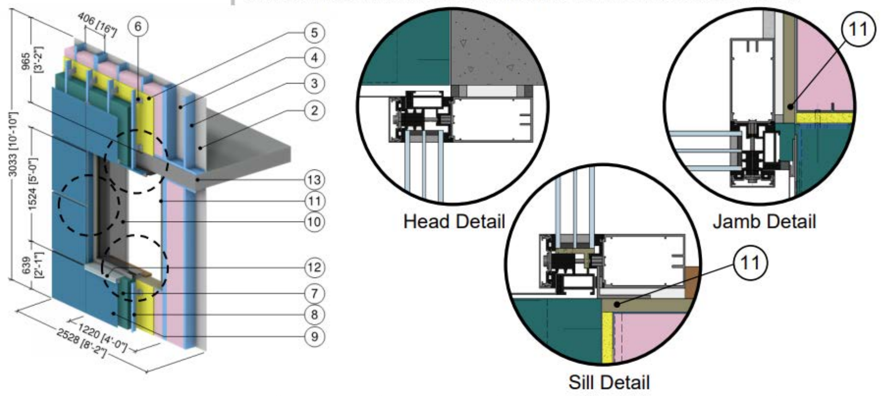


A.0
A
1 A5.51 SIM
ERA-11R
THIRD FLOOR 72' - 0"
EWA-10M

Reference Detail

Detail 5.3.13

Exterior and Interior Insulated 6" x 1 5/8" Steel Stud (16" o.c.) Wall Assembly with Thermally Isolated Vertical Brackets and Rail System (24" o.c.) Supporting Metal Cladding and R-19 Batt Insulation in Stud Cavity – Triple Glazed Aluminum Curtain Wall & Intermediate Floor Intersection with Window Thermal Break Positioned in the Exterior Insulation

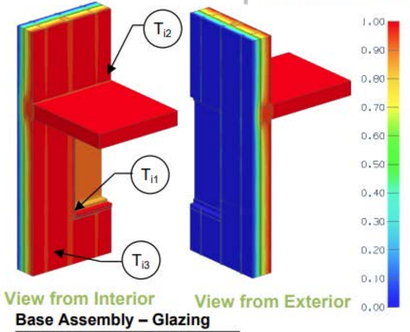


ID	Component	Thickness Inches (mm)	Conductivity Btu·in / ft²·hr·°F (W/m K)	Nominal Resistance hr·ft²·°F/Btu (m²K/W)	Density lb/ft³ (kg/m³)	Specific Heat Btu/lb·°F (J/kg K)
1	Interior Film[1]	-	-	R-0.6 to R-1.1 (0.11 RSI to 0.20 RSI)	-	-
2	Gypsum Board	1/2" (13)	1.1 (0.16)	R-0.5 (0.08 RSI)	50 (800)	0.26 (1090)
3	6" x 1 5/8" Steel Studs (16" o.c.) with Top and Bottom Tracks	18 Gauge	430 (62)	-	489 (7830)	0.12 (500)
4	Fiberglas Batt Insulation	6" (152)	0.32 (0.046)	R-19 (3.35 RSI)	0.9 (1.1)	0.17 (710)
5	Exterior Sheathing	1/2" (13)	1.1 (0.16)	R-0.5 (0.08 RSI)	50 (800)	0.26 (1090)
6	Thermally Isolated Aluminum Bracket	0.09" (2.2)	1110 (160)	-	171 (2739)	0.21 (900)
7	Exterior Insulation	Varies	-	R-10 to R-25 (1.76 RSI to 4.40 RSI)	1.8 (28)	0.29 (1220)
8	Vertical Aluminum L-girt	0.09" (2.2)	1110 (160)	-	171 (2739)	0.21 (900)
9	Generic Cladding with 1/2" (13mm) vented air space is incorporated into exterior heat transfer coefficient					
10	5' (1.5m) x 4' (1.2m) Aluminum curtain wall (Passive House certified): triple glazed & thermally broken[2], IGU U_{IGU} = 0.14 BTU/hr.ft².°F (0.81 W/m²K)					
11	Wood Liner	1/2" (13)	0.69 (0.10)	-	31 (500)	0.45 (1880)
12	Aluminum Flashing	14 Gauge	1110 (160)	-	171 (2739)	0.21 (900)
13	Concrete Floor Slab	8" (203)	12.5 (1.8)	-	140 (2250)	0.20 (850)
14	Exterior Film[1]	-	-	R-0.2 (0.03 RSI) to R-0.7 (0.12 RSI)	-	-

[1] Value selected from table 1, p. 26.1 of 2009 ASHRAE Handbook – Fundamentals depending on surface orientation
[2] The thermal conductivity of air spaces within framing was found using ISO 100077-2

Detail 5.3.13

Exterior and Interior Insulated 6" x 1 5/8" Steel Stud (16" o.c.) Wall Assembly with Thermally Isolated Vertical Brackets and Rail System (24" o.c.) Supporting Metal Cladding and R-19 Batt Insulation in Stud Cavity – Triple Glazed Aluminum Curtain Wall & Intermediate Floor Intersection with Window Thermal Break Positioned in the Exterior Insulation



Thermal Performance Indicators

Assembly 1D (Nominal) R-Value	R_{1D}	R-21.3 (3.75 RSI) + exterior insulation
Transmittance / Resistance without Anomaly	U_w, R_w, U_g	"clear wall" U- and R-value: w = wall without intermediate floor g = glazing
Transmittance / Resistance	U_{floor}, R_{floor}, U_t, R_t	U and R-values for: floor = wall + intermediate floor t = combined wall + floor + window
Surface Temperature Index[1]	T_i	0 = exterior temperature 1 = interior temperature
Linear Transmittance	ψ	Incremental increase in transmittance per linear length

[1]Assumptions and limitations for surface temperatures identified in ASHRAE 1365-RP

Base Assembly – Glazing

$U_{centre\ of\ glass}$ Btu/ft² ·hr ·°F (W/m² K)	U_g Btu/ft² ·hr ·°F (W/m² K)
0.142 (0.81)	0.199 (1.13)

Nominal (1D) vs. Assembly Performance Indicators

Base Assembly – Steel Stud Clear Wall

Exterior Insulation 1D R-Value (RSI)	R_{1D} ft²·hr·°F / Btu (m² K / W)	R_w ft²·hr·°F / Btu (m² K / W)	U_w Btu/ft² ·hr ·°F (W/m² K)
R-10 (1.76)	R-31.3 (5.51)	R-19.2 (3.38)	0.052 (0.30)
R-15 (2.64)	R-36.3 (6.39)	R-21.8 (3.83)	0.046 (0.26)
R-20 (3.52)	R-41.3 (7.28)	R-24.8 (4.37)	0.040 (0.23)
R-25 (4.40)	R-46.3 (8.15)	R-27.6 (4.86)	0.036 (0.21)

Intermediate Floor Linear Transmittance

R_{floor} ft²·hr·°F / Btu (m² K / W)	U_{floor} Btu/ft² ·hr ·°F (W/m² K)	Ψ_{floor} Btu/ft² ·hr ·°F (W/m² K)
R-16.1 (2.83)	0.062 (0.35)	0.071 (0.122)
R-18.5 (3.26)	0.054 (0.31)	0.056 (0.098)
R-21.3 (3.75)	0.047 (0.27)	0.046 (0.080)
R-23.9 (4.21)	0.042 (0.24)	0.040 (0.068)

Window Transition Transmittance

Exterior Insulation 1D R-Value (RSI)	R_t ft²·hr·°F / Btu (m² K / W)	U_t Btu/ft² ·hr ·°F (W/m² K)	Ψ_{Head} Btu/ft ·hr ·°F (W/m K)	Ψ_{Sill} Btu/ft ·hr ·°F (W/m K)	Ψ_{Jamb} Btu/ft ·hr ·°F (W/m K)	Ψ_{Total} Btu/ft ·hr ·°F (W/m K)
R-10 (1.76)	R-8.1 (1.43)	0.123 (0.70)	0.036 (0.063)	0.028 (0.048)	0.046 (0.080)	0.042 (0.073)
R-15 (2.64)	R-9.1 (1.60)	0.110 (0.62)	0.040 (0.069)	0.031 (0.053)	0.047 (0.081)	0.043 (0.074)
R-20 (3.52)	R-9.9 (1.74)	0.101 (0.58)	0.044 (0.076)	0.033 (0.058)	0.048 (0.083)	0.047 (0.082)
R-25 (4.40)	R-10.5 (1.85)	0.095 (0.54)	0.048 (0.083)	0.033 (0.058)	0.047 (0.082)	0.050 (0.086)

Temperature Indices

	R10	R15	R20	R25	
T_{i1}	0.76	0.76	0.76	0.75	Min T on window frame, at bottom corner at edge of glass
T_{i2}	0.76	0.79	0.82	0.84	Max T on interior surface of sheathing, along bottom track
T_{i3}	0.41	0.44	0.48	0.51	Min T on interior surface of sheathing, between studs

RDH

Failed TEDI vs. PH Model Inputs

Component	TEDI Model	Passive House
Above Grade Walls	**R-22 to R-27**, cladding-dependent 6" Cavity mineral wool, 5" Exterior mineral wool	**Same as TEDI Model** ✓
Below Grade Walls	**R-25** 5" XPS	**Same as TEDI Model** ✓
Roof	**R-50** 10" Polyiso	**Same as TEDI Model** ✓
Parking Garage Slab	**R-30** 6" Concrete with 6" XPS above	**R-18 at gymnasium, R-30 elsewhere** 3" XPS at gymnasium, 6" XPS elsewhere ✓
Windows	**~1.1 W/m2K whole-window** Kawneer 1600 UT	**Same as TEDI Model** ✓
Airtightness	**0.08 cfm/ft2 (~0.45 ACH50)**	**Same as TEDI Model** ✓
Ventilation	**~75,000 m3/h @ 75% heat & energy recovery** (44,526 cfm, per MA TEDI Guidelines)	**~88,000 m3/h @ 75% heat & energy recovery** (51,650 cfm) ✓
Heating & Cooling	**Electric boiler & water-cooled chiller** (per MA TEDI Guidelines)	**GSHP** w/ radiant panels & hydronic fan coils ✓
Lighting	**264,502 kWh/yr** (per MA TEDI Guidelines)	**Same as TEDI model** ✓
Appliance + Plug Load	**463,690 kWh/yr** (per MA TEDI Guidelines)	**347,161 kWh/yr** (per equipment schedules w/ ASHRAE usage patterns, and standard value per meal prepared) ✓

RDH

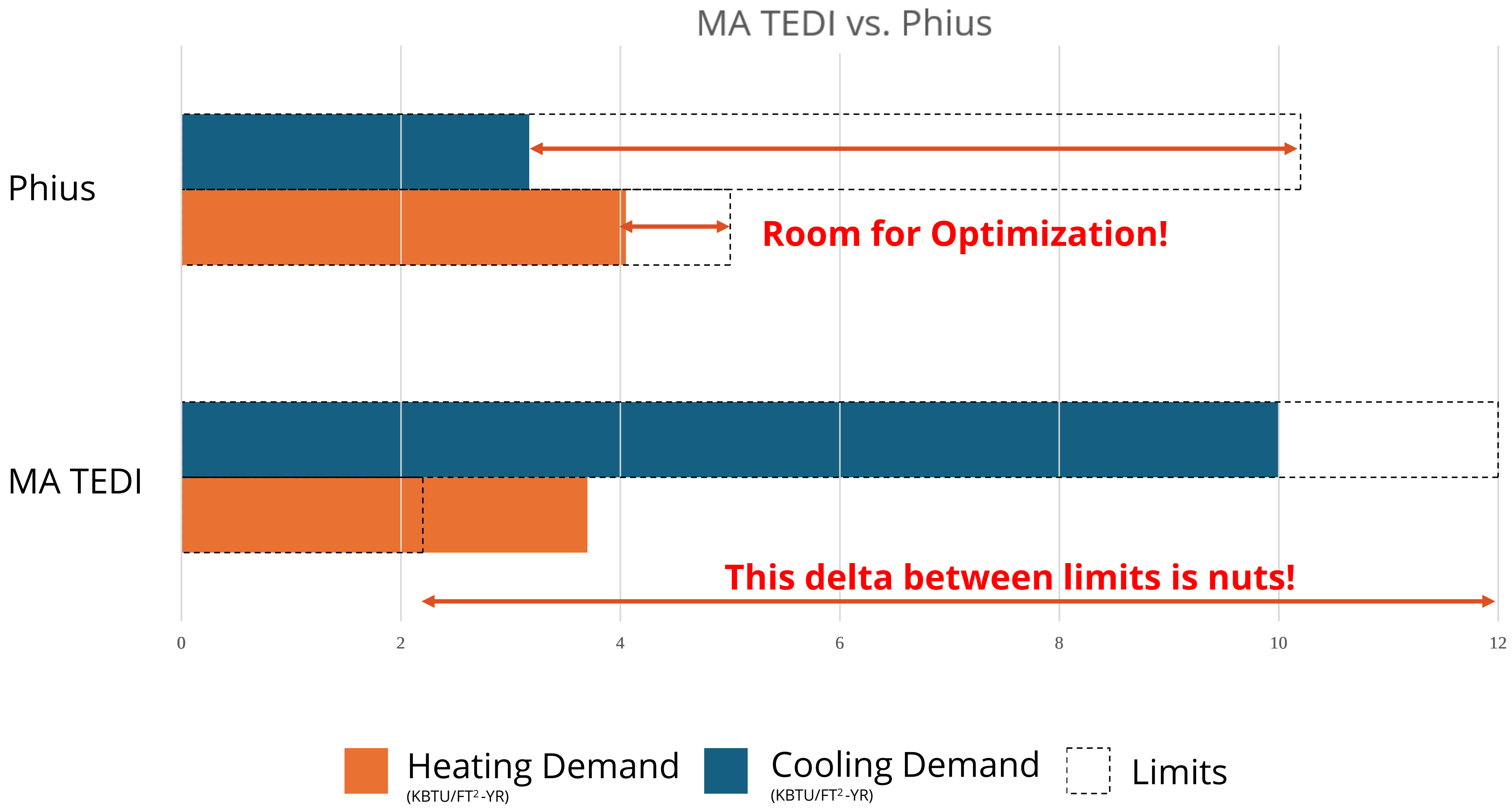
TEDI vs. Passive House Results

	TEDI Target	TEDI Results*	Phius Targets	Phius Results
Heating Demand ($KBTU/FT^2$-YR)	≤ 2.2	3.7 ✗	5	4.05 ✓
Heating Load ($BTU/HR\text{-}FT^2$)	-	7.7	5.8	4.42 ✓
Cooling Demand ($KBTU/FT^2$-YR)	≤ 12	10 ✓	10.2	3.17 ✓
Cooling Load ($BTU/HR\text{-}FT^2$)	-	17.6	4.3	3.33 ✓
Source Energy ($KBTU/FT^2$-YR)	-	32.1	30.35	24.06 ✓
Airtightness (CFM/FT^2-75)	≤ 0.35	**0.08** (assumed) ✓	0.08	**0.08** (assumed) ✓

TEDI Results are based on RDH's corrected version of the eQuest model originally provided by GGD.
TEDI results based on MA Guidelines for "Default" method modeled in eQuest.
Area-normalized metrics are calculated using iCFA in accordance with PHIUS requirements.
Criteria based on PHIUS+ 2021 for Boston, MA .

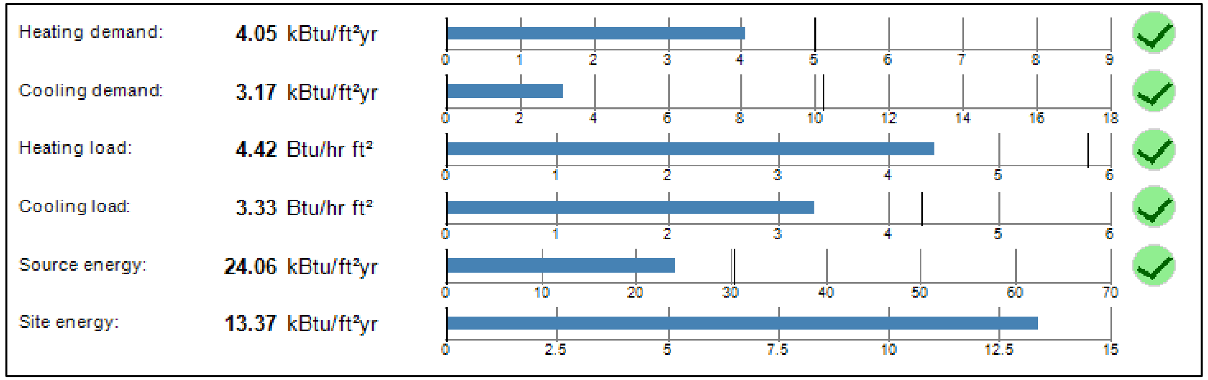
RDH

TEDI vs. PH Model Results



Passive House Optimization

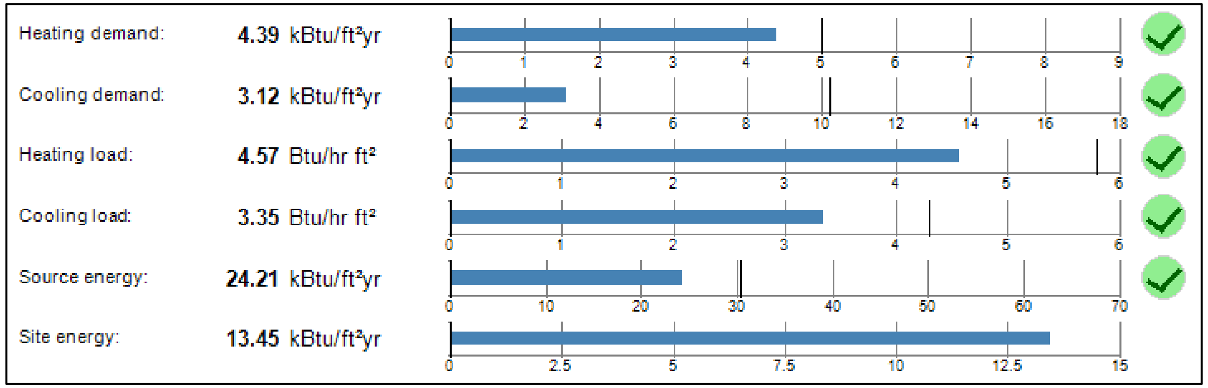
Reduce under-slab insulation from 6” to 3”



OR

Increase the COG U-value from U-0.111 to U-0.14

→ Opens possibility of more IGUs

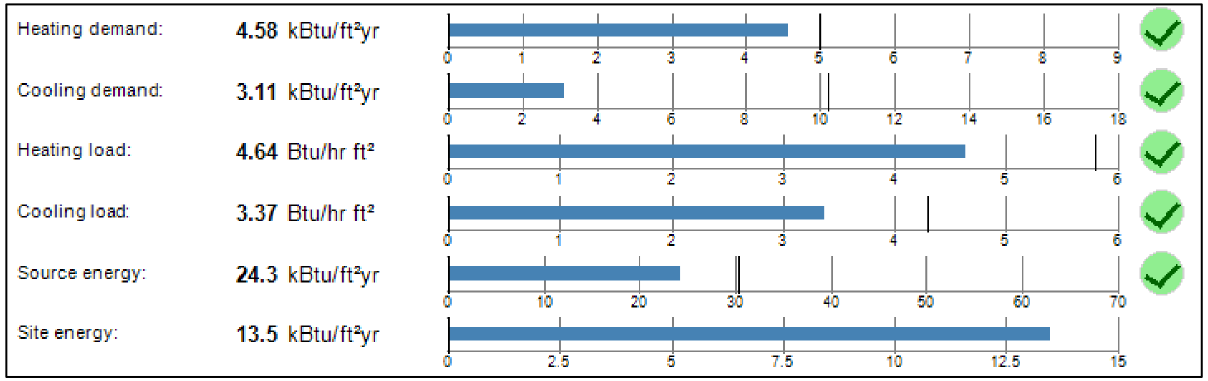


OR

Reduce wall clear field R-value from ~R-26 to R-18

→ Remove stud cavity insulation and maintain 5” mineral wool outboard of sheathing **OR**

→ Keep stud cavity insulation and reduce to ~3” mineral wool outboard of sheathing



RDH

Next Steps

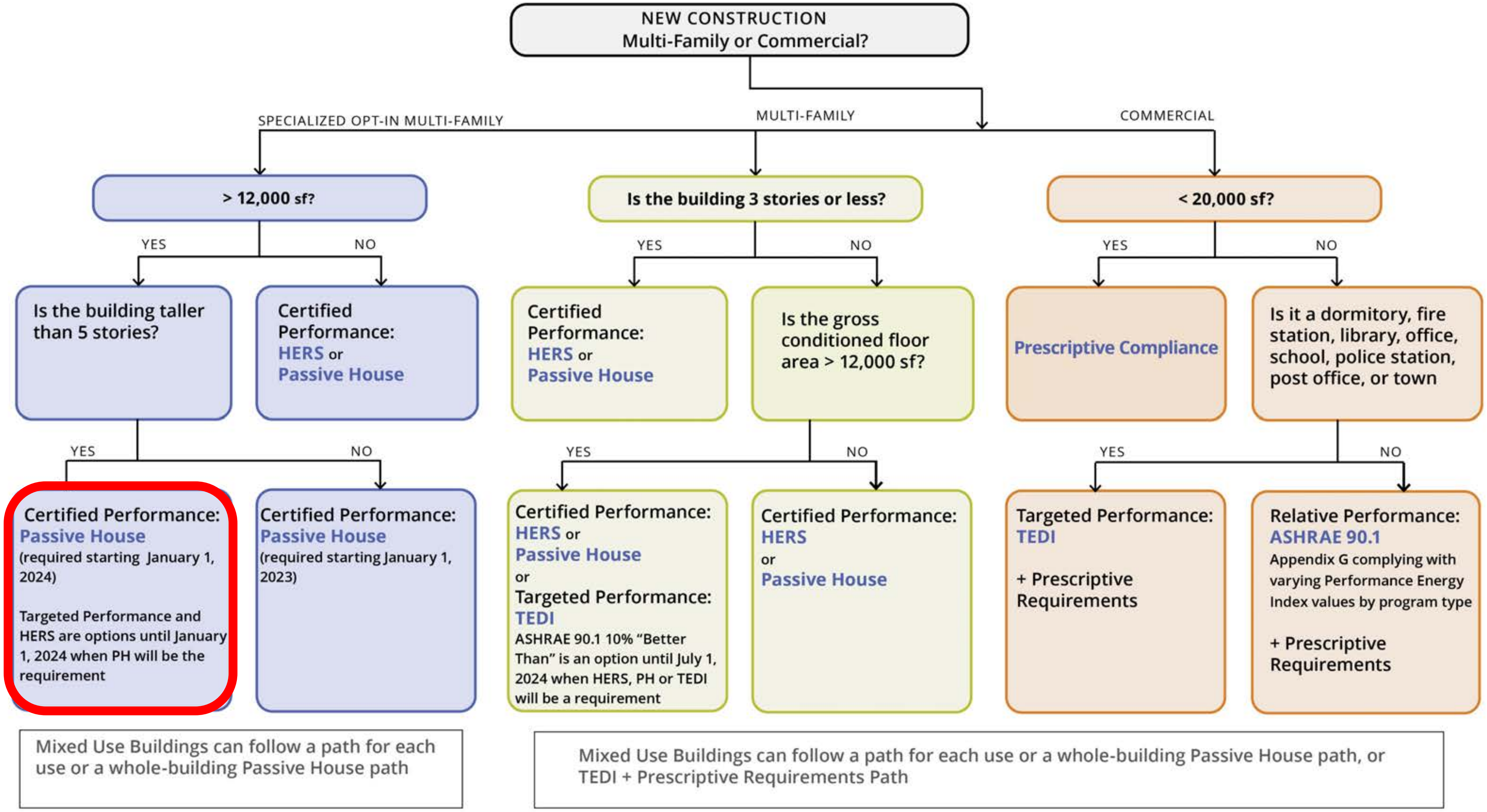
- → Project is continuing with TEDI as a path forward with “As Designed” modeling.
- → Project team was already too far down the road on TEDI path to want to switch metrics and incur additional soft costs of PH consulting and Verification
- → Ideally the project would have started off targeting Passive House instead – it is feasible and at this point a better defined, better proven and more familiar process

TEDI Conclusions

- → TEDI modeling targets and guidelines need to be updated by DOER.
- → Modeling per “Default” TEDI guidelines does not work.
- → First generation of projects is testing the system, and identifying the “bugs”
- → PH is feasible for non-residential buildings including schools and allows optimization.
- → Consider Passive House Certification from the outset on projects where TEDI is the minimum code required path.

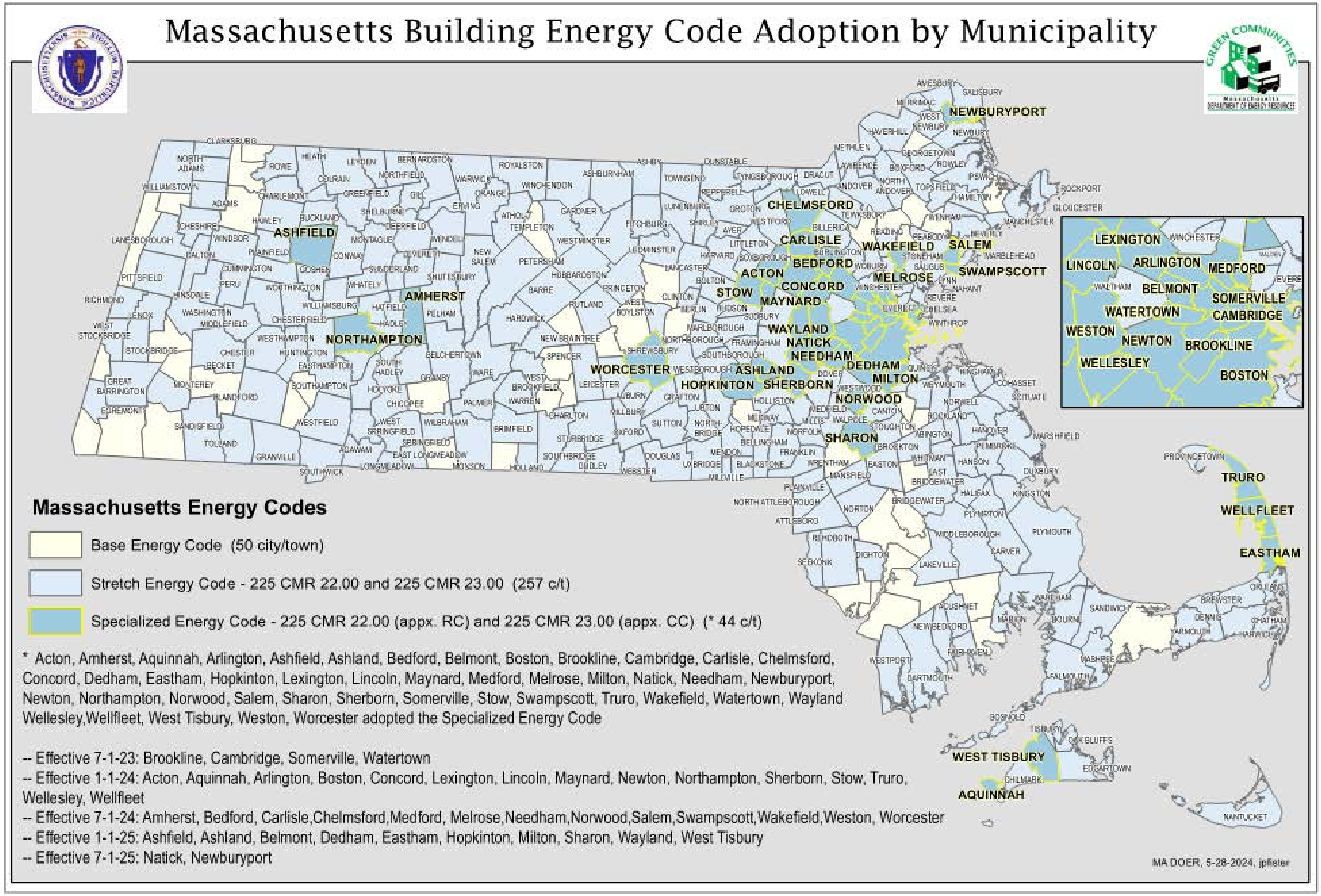
4 PH in Multi-family

Stretch + Specialized Opt-In Code



Passive House is a code compliance path for any building

Massachusetts Stretch Code



Source: Massachusetts DOER

Bunker Hill Building M – Charlestown, MA

- Multi-family Residential
- +/- 90,000 gsf
- 102 units
- CLT Floors
- CFMF Load Bearing Panelized Walls

Bunker Hill Building M, Charlestown, MA. Stantec.

Volpe Parcel R1, Cambridge

- Multi-Family Residential Student Housing
- 2 floors commercial program
- +/- 200,000 gsf
- 212 units

Rendering, Stantec

600 Rivers Edge, Medford

- Multi-family Residential
- +/- 275,000 gsf
- +/- 220 units
- Terrace pool over above-grade first floor parking

Rendering, Gensler

RDH

78 Crafts Street, Newton

- Multi-family Residential
- 4 buildings – 4-6 stories
- +/- 400,000 gsf
- Chapter 40B
  - 20% at 50% AMI
- 307 units

Rendering, TAT

RDH

Multi-family in Cambridge

- Multi-family Residential
- +/- 250,000 gsf
- +/- 250 units

Rendering, Hacin

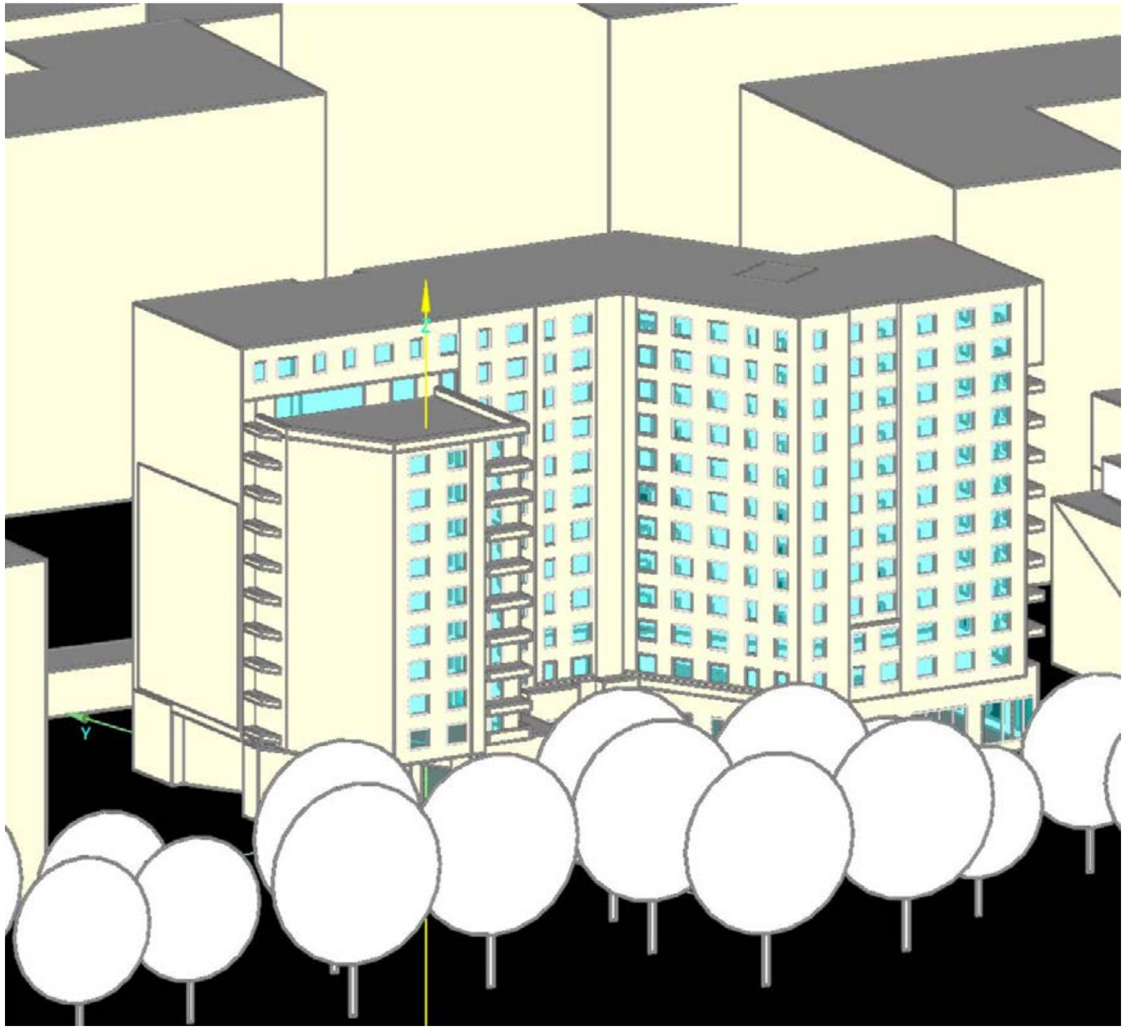
Multi-family in Cambridge

TABLE 1 WUFI®PASSIVE MODEL RESULTS*								
PHIUS Targets**		**Current Design** ***	**Alt 1:** 0.25 SHGC at South Elevations	**Alt 2:** 25% WWR + 0.3 SHGC for all glazing	**Alt 3:** 28% WWR + 0.3 SHGC for all glazing	**Alt 4:** 4" Wall Insulation	**Alt 5:** Direct Electric Water Heater
HEATING DEMAND KBTU/FT²-YR	**≤ 5.2**	3.68	4.29	3.66	3.62	4.28	3.68
HEATING LOAD BTU/H-FT²	**≤ 4.4**	2.88	3.04	2.89	2.92	3.12	2.88
COOLING DEMAND KBTU/FT²-YR	**≤ 8.2**	1.44	1.32	1.54	1.66	1.42	2.72
COOLING LOAD BTU/H-FT²	**≤ 3.4**	2.31	2.23	2.39	2.5	2.35	2.89
SOURCE ENERGY Based on 228 Dwelling Units and 294 Bedrooms	**4,900 kWh/ occ**	3,972	4,055	4,148	4,160	4,064	4,512
AIRTIGHTNESS CFM/FT² @ 75 pa	**≤0.08**	0.08 (assumed)	0.08 (assumed)	0.08 (assumed)	0.08 (assumed)	0.08 (assumed)	0.08 (assumed)

*Area-normalized metrics are calculated using iCFA in accordance with PHIUS requirements

**Criteria based on PHIUS+ 2021 for Boston, MA

***Current Design based upon documentation listed above and assumptions noted in Table 2



Mass Save Incentives (Carrot)

- → Multi-Family Residential Buildings with 5+ Units
- → Certification through PHI or Phius

Bunker Hill Example, 102 Units:

Feasibility: **$5,000**

Energy Modeling: **$20,000**

Pre-Certification: **$51,000**

\+ Certification: **$255,000**

Total: **$331,000**

Passive House Incentive Structure for Multi-Family *(5 units or more)*			
Incentive Timing	**Activity**	**Incentive Amount**	**Max. Incentive**
Pre-Construction	Feasibility Study	Up to 100% of Feasibility costs	$5,000
	Energy Modeling	75% of Energy Model cost	$500/unit, max. $20,000
	Pre-Certification	$500/unit	N/A
Post-Construction	Certification	$2,500/unit	
	Net Performance Bonus	$0.75/kWh	
		$7.50/therm	

The Net Performance Bonus is calculated by determining the final pay for savings incentives and subtracting the pre- and final certification incentives. The result is the Net Performance Bonus.

Projects that pre-certify but do not achieve certification are eligible for the pre-certification incentive and Net Performance Bonus.

Projects over 100 units must be pre-approved by the applicable Sponsors of Mass Save.

BERDO 2.0 (Stick)

If a building is not complying:

- Make a Compliance Plan implemented the following year

  OR

- Buy Renewable Energy

  OR

- Take alternate compliance path and pay $234 / metric ton over limit

  OR

- Apply for Flexibility Measures that adjust the limit, make allowance for hardship, or allow blended emissions between program types in building or buildings in a portfolio.

Penalty Fees:

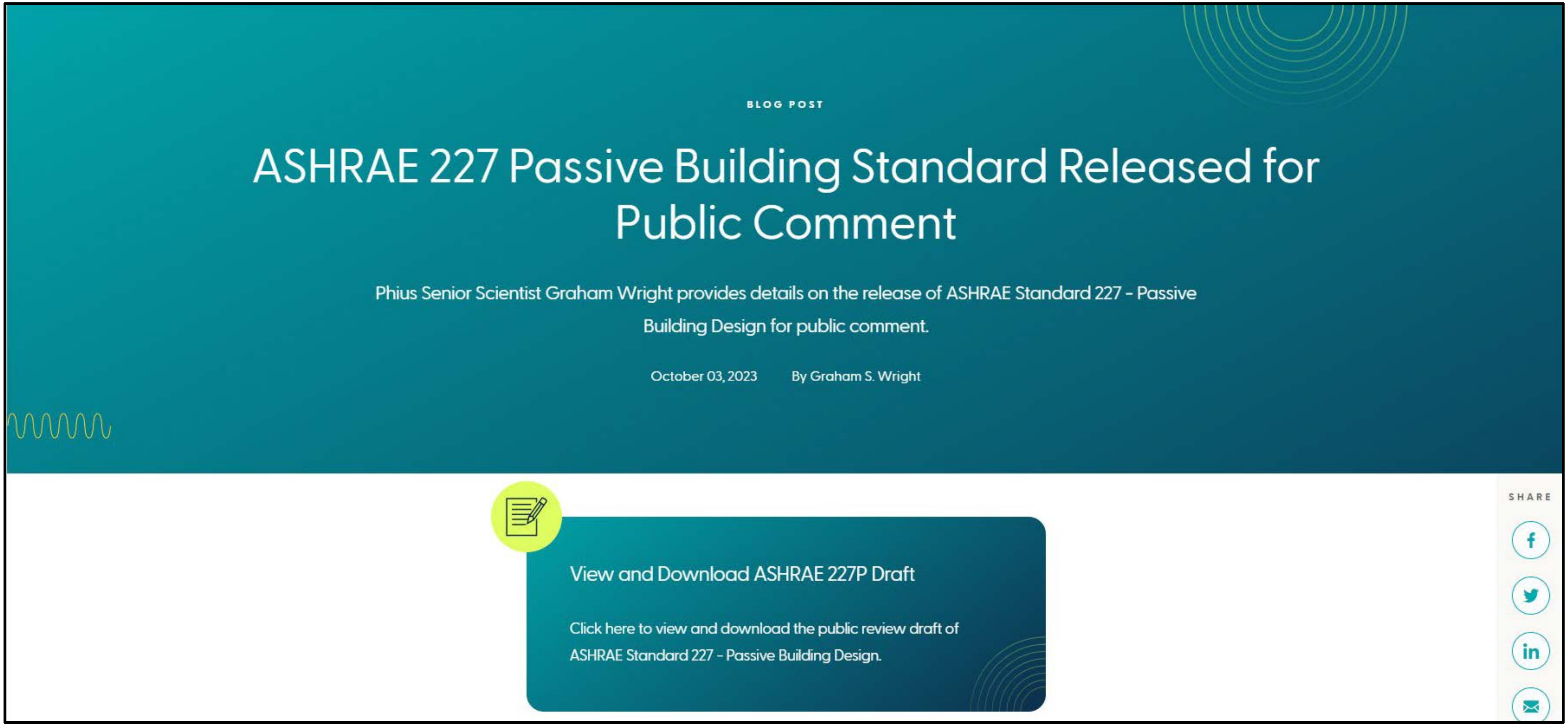
- $150-$300 / day failure to comply w reporting
- $300-$1,000 / day failure to comply w emission standards
- $1,000-$5,000 failure to accurately report information

USE THE CHART BELOW TO SEE YOUR EMISSION STANDARDS BY YEAR

	2025 - 2029	2030 - 2034	2035 - 2039	2040 - 2044	2045 - 2049	2050 –
ASSEMBLY	7.8	4.6	3.3	2.1	1.1	0
COLLEGE/ UNIVERSITY	10.2	5.3	3.8	2.5	1.2	0
EDUCATION	3.9	2.4	1.8	1.2	0.6	0
FOOD SALES & SERVICE	17.4	10.9	8.0	5.4	2.7	0
HEALTHCARE	15.4	10.0	7.4	4.9	2.4	0
LODGING	5.8	3.7	2.7	1.8	0.9	0
MANUFACTURING/ INDUSTRIAL	23.9	15.3	10.9	6.7	3.2	0
MULTIFAMILY HOUSING	4.1	2.4	1.8	1.1	0.6	0
OFFICE	5.3	3.2	2.4	1.6	0.8	0
RETAIL	7.1	3.4	2.4	1.5	0.7	0
SERVICES	7.5	4.5	3.3	2.2	1.1	0
STORAGE	5.4	2.8	1.8	1.0	0.4	0
TECHNOLOGY/ SCIENCE	19.2	11.1	7.8	5.1	2.5	0

Emissions standard ($kgCO_2e$/ ft2/year)

Does PH Certification eventually go away?



BLOG POST

ASHRAE 227 Passive Building Standard Released for Public Comment

Phius Senior Scientist Graham Wright provides details on the release of ASHRAE Standard 227 - Passive Building Design for public comment.

October 03, 2023 By Graham S. Wright

SHARE

View and Download ASHRAE 227P Draft

Click here to view and download the public review draft of ASHRAE Standard 227 - Passive Building Design.

Conclusions

- Energy Codes and Building Science principles, like those made familiar by Passive House, are converging.
- Passive House is a recognized absolute metric for operational energy reduction that can be used towards operational decarbonization.
- Passive House has provided a framework for non-technically oriented people to discuss building science that improves buildings. This empowers building owners to make decisions.
- Passive House is a viable code compliance option for existing or new construction buildings of varying program types.
- In many cases PH is a preferable compliance path to meet the requirements of the Stretch Code, especially in the case of MA TEDI.
- OR...For Now....

JUST DO PH.

Thank You.

RDH

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