BUILDINGENERGY BOSTON

Beyond Anthropocentrism: Practical Design for Resilient Building Enclosures

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Northeast Sustainable Energy Association (NESEA) | March 19, 2024

Beyond Anthropocentrism

Practical Design for Resilient Building Enclosures

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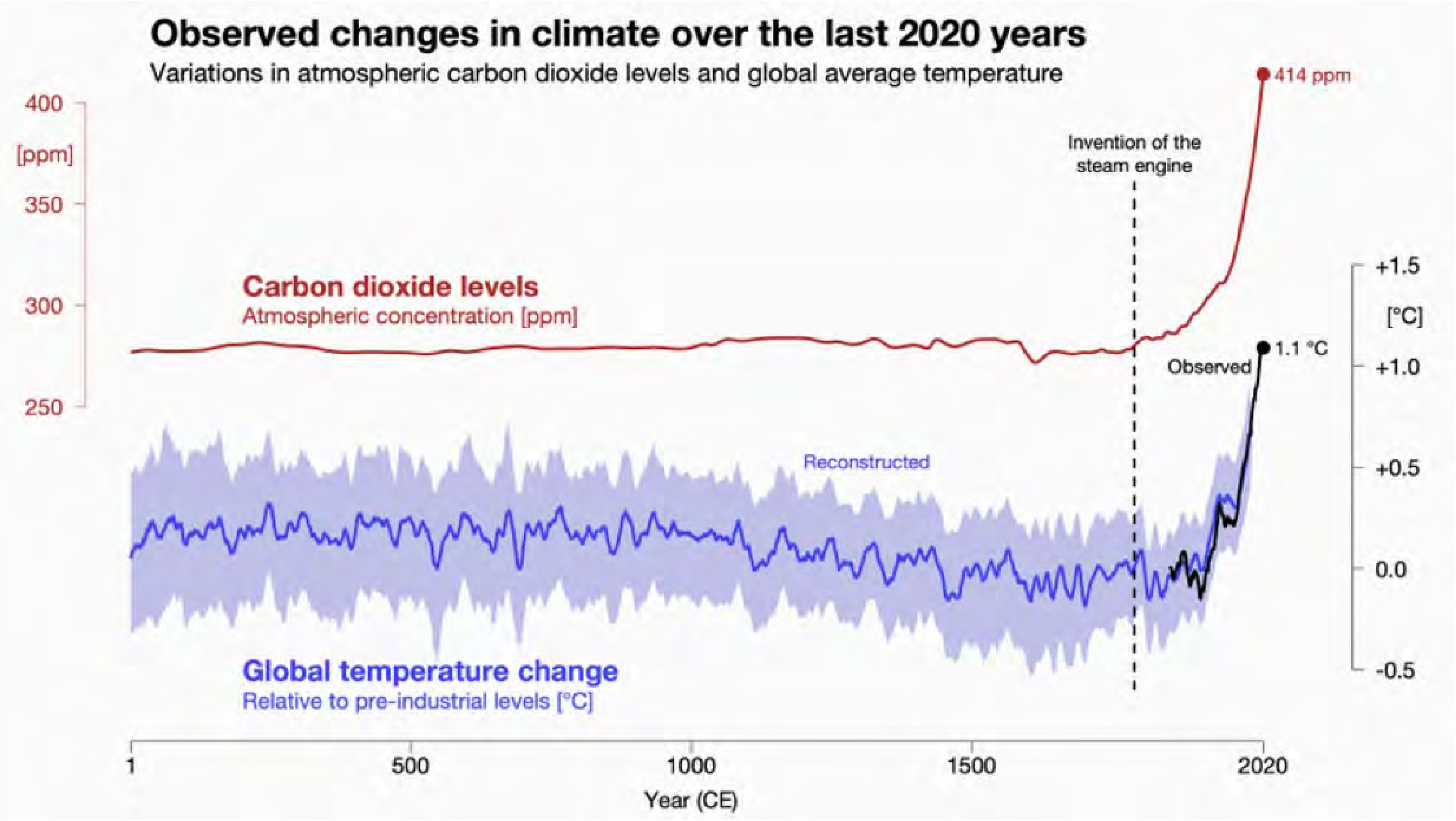
RDH BUILDING SCIENCE
Making Buildings Better ™

Carbon Emissions + Human Centered Design



"Humans caused global warming, not sea turtles." *-Timothy Morton in Being Ecological*

Ecological Thought

Instead of imagining that everything is useless and that the apocalypse has come – so there's no point anyway – and instead of thinking that we have to completely reimagine how to do things (we'll never get going with those attitudes), it would be better to start where we are and use some of the inadequate and broken tools we have, and see how they get modified by working at scales and with lifeforms that are unfamiliar to us, for which the tools were not designed. In that process, the tools might undergo some changes.

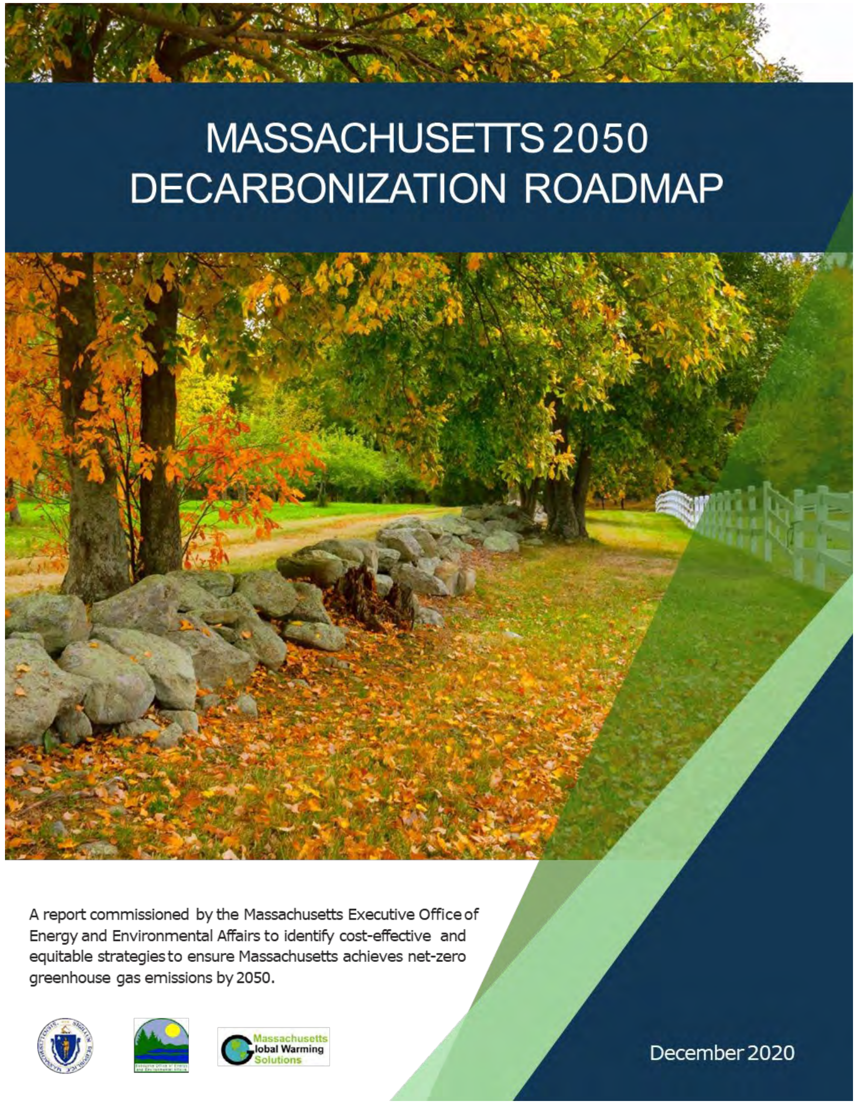
-Timothy Morton in Being Ecological

Decarbonization in Massachusetts

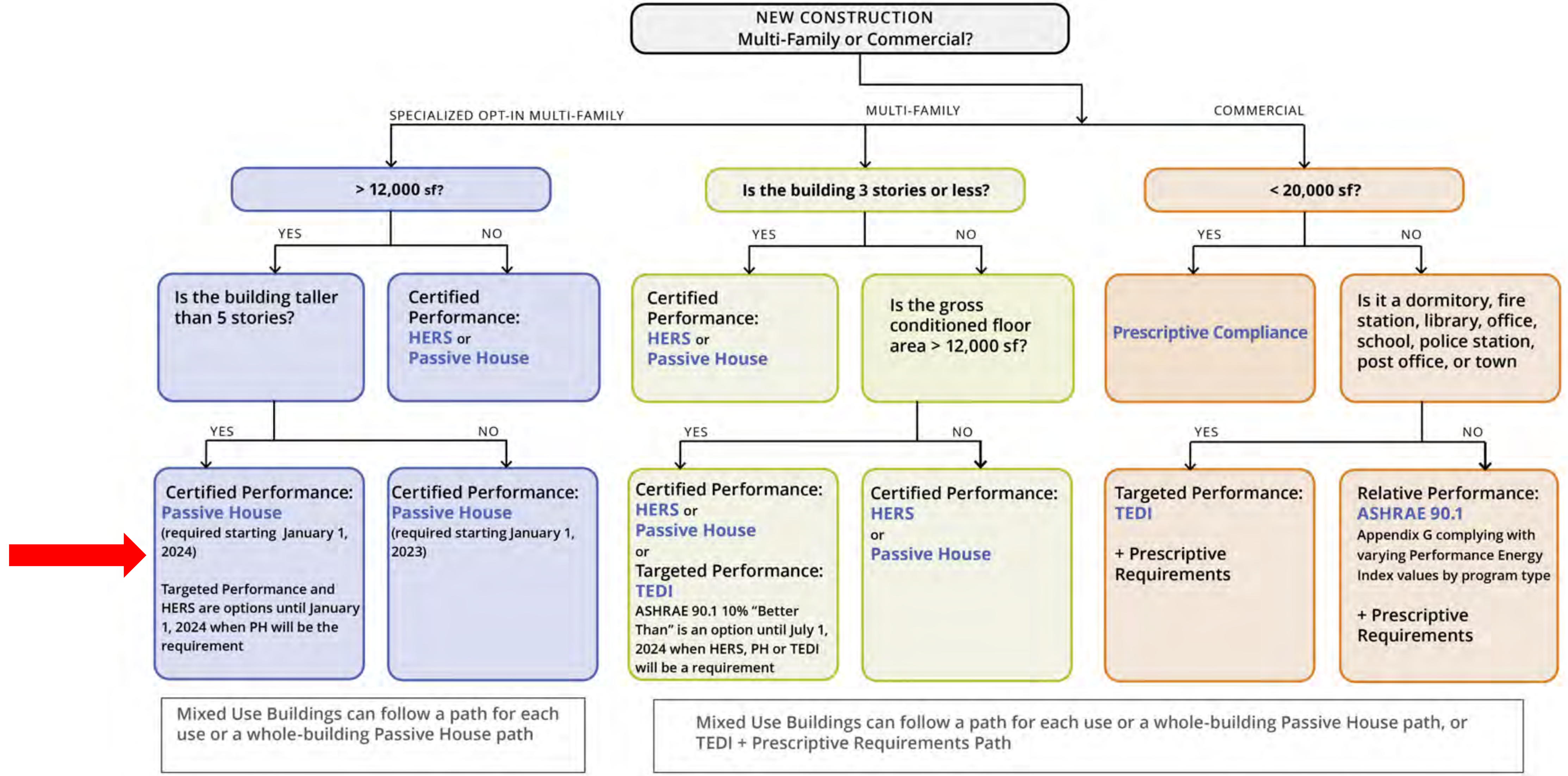
March 26, 2021 Governor Baker signed into law:

→ 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 advancements towards these mandated targets and include **Passive House** requirements for code compliance!

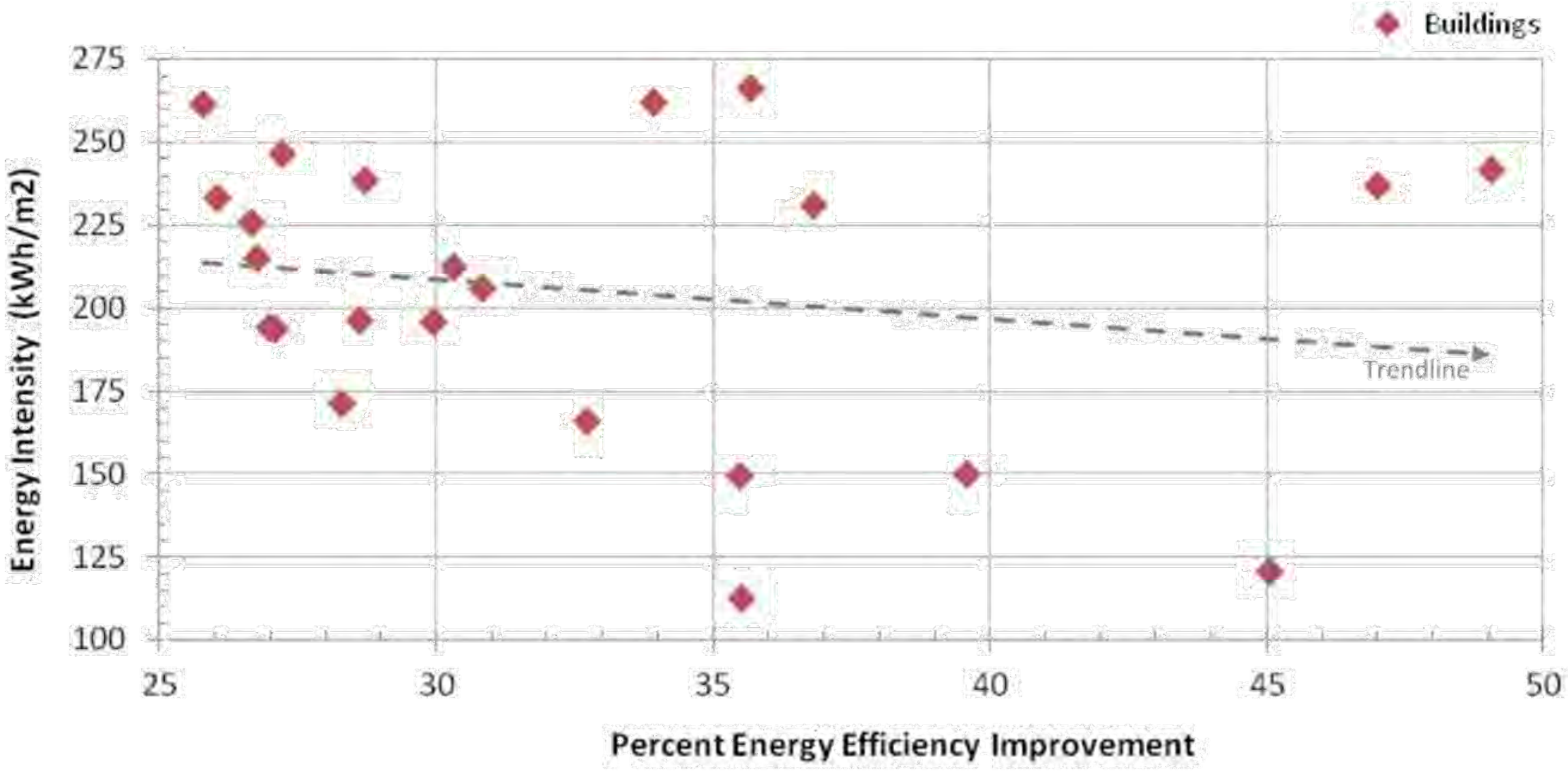


MA Stretch + Specialized Opt-In Code



PASSIVE HOUSE IS A CODE COMPLIANCE PATH OPTION FOR ANY BUILDING

Relative Performance – ASHRAE 90.1



→ Lack of correlation between relative savings and energy use intensity of the building

Case Study + Targets

TABLE 2 KEY DESIGN CHARACTERISTICS					
	100% SD Set	**Current Design***	**Current @15% WWR**	**Option 1:** Improve CW, higher WWR	**Option 2:** CW with lower WWR
Above Grade Walls	R-35	R-15 Opaque CW	R-15 Opaque CW	R-20 Opaque CW	R-20 Opaque CW
Below Grade Walls	R-30	R-30	R-30	R-30	R-30
Roof	R-50	R-50	R-50	R-50	R-50
Window to Wall Ratio	25%	35%	15%	35%	30%
Windows (vision glazing)	Punched windows U-0.16	Curtainwall U-0.22	Curtainwall U-0.22	Curtainwall U-0.19	Curtainwall U-0.22
Balconies	None	4/floor with point connections	4/floor with point connections	4/floor with point connections	4/floor with point connections
Ventilation	70% SRE, high fan power	70% SRE, high fan power	85% SRE, low fan power	85% SRE, low fan power	85% SRE, low fan power
Heating	ASHP COP 1.8	ASHP COP 1.8	ASHP COP 1.8	ASHP COP 1.8	ASHP COP 1.8
Cooling	COP 2.3	COP 2.3	COP 2.3	COP 2.3	COP 2.3
DHW	COP 2.6	COP 2.6	COP 2.6	COP 2.6	COP 2.6
Lighting	25% or more below ASHRAE 90.1	25% or more below ASHRAE 90.1	25% or more below ASHRAE 90.1	25% or more below ASHRAE 90.1	25% or more below ASHRAE 90.1
Appliance & Plug Loads	PHIUS Default	PHIUS Default	Best In Class Energy Star	Best In Class Energy Star	Best In Class Energy Star

* Current Design based upon "Volpe R1 Client Design Review presentation Dated 16 November 2022.

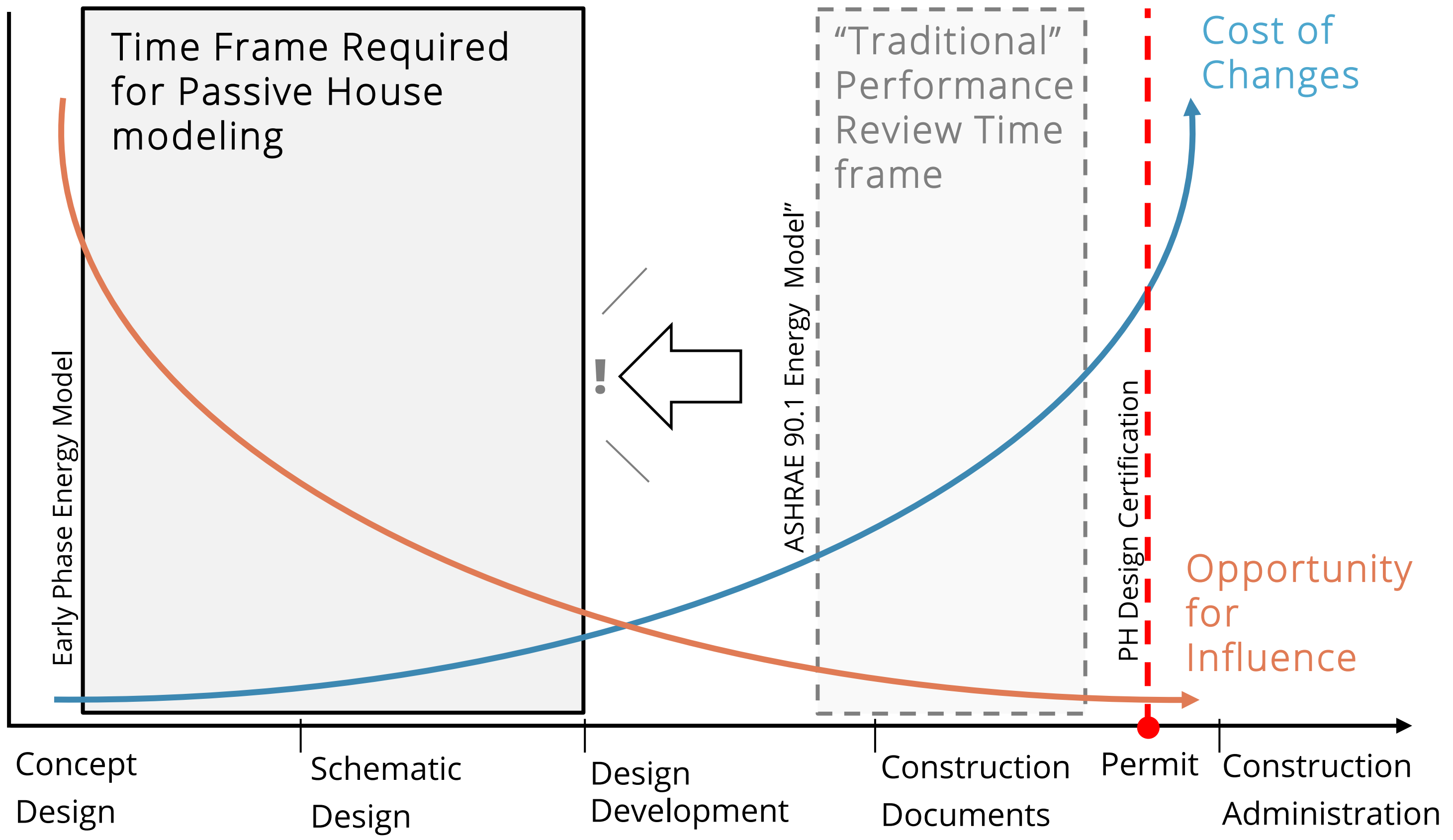
Front-loaded Design Process

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

→ Energy Model + Set performance targets early

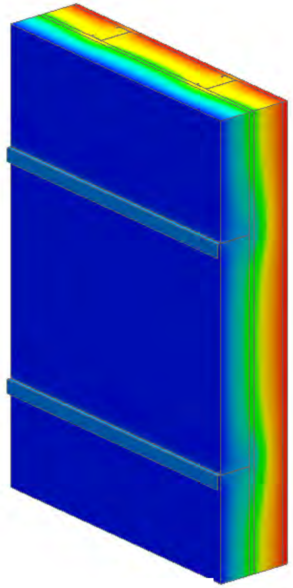
→ Design accordingly with whole team

→ Update modeling and check design through subsequent phases



Calculating Thermal Performance

Clear Field

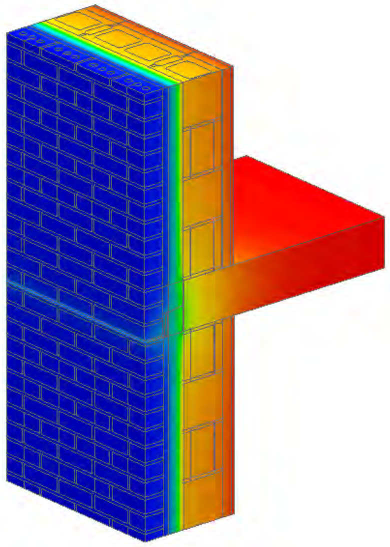


U_o

heat loss per area

Any repeating elements in the wall assembly: cladding attachment, panel joints, through wall flashing

Linear

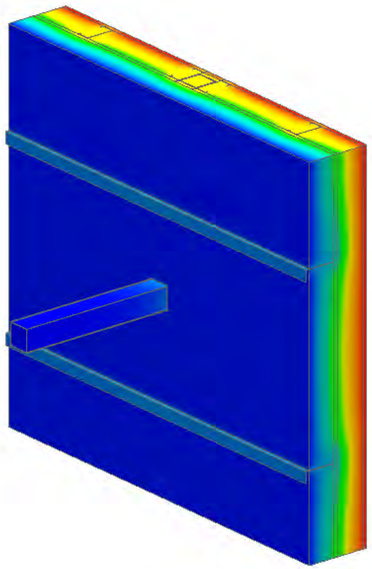


Ψ

additional heat loss per length

Continuous structural elements like slab edges that penetrate thermal boundary

Point



χ

additional heat loss per point

Point structural elements like beam penetrations through the thermal boundary

For Phius these typically go into the WUFI Passive Model separately and are not counted in the Clear Field R-value.

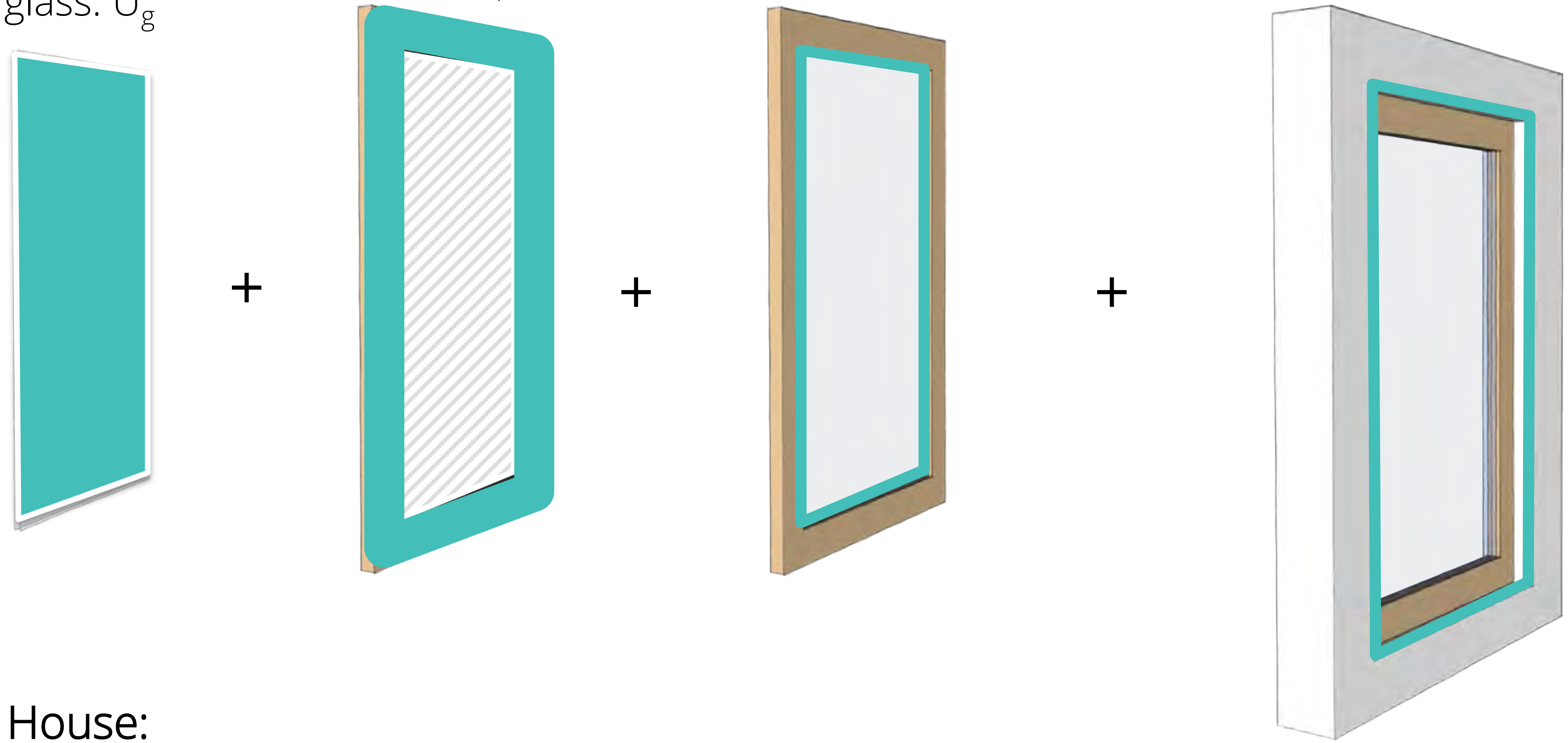
Calculating Enclosure Thermal Performance

Glazing
U-Value of the glass: U_g

Frame
U-Value of the frame: U_f

Spacers
Ψ-Value of the spacer: Ψ_{spacer}

Installation
Ψ-Value of the installation: $\Psi_{installation}$

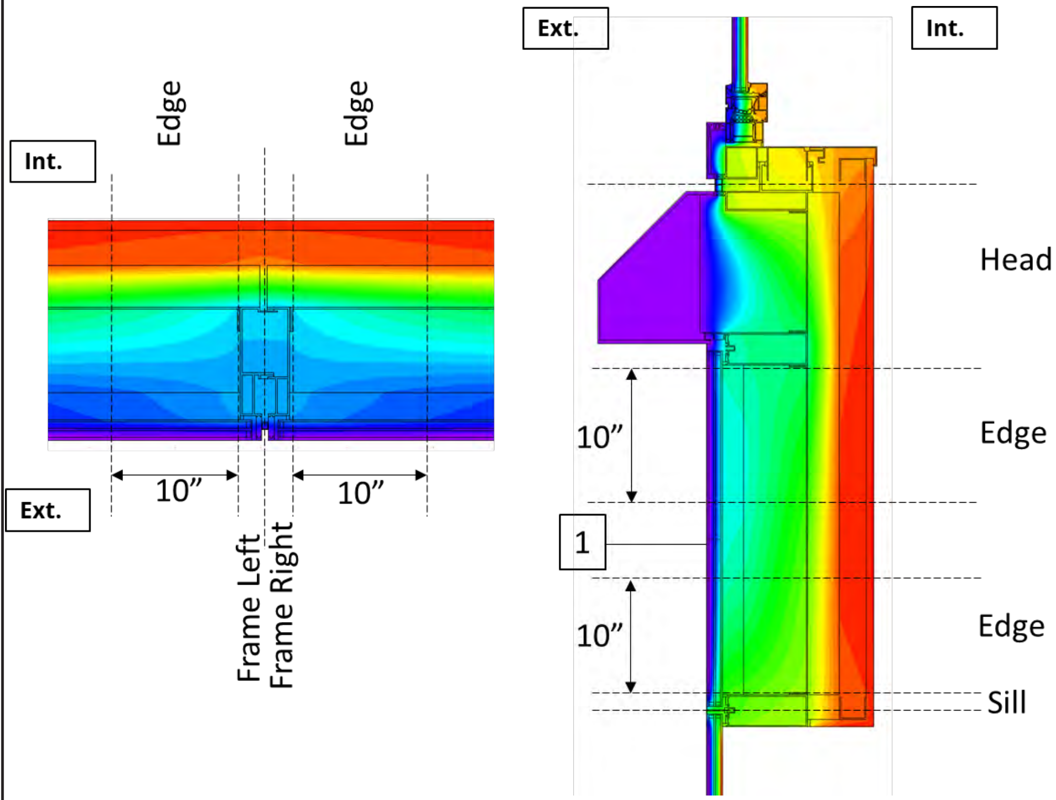


For Phius window perimeter thermal bridging (Psi Install) typically go into the WUFI Passive Model separately and are not counted in the Clear Field R-value.

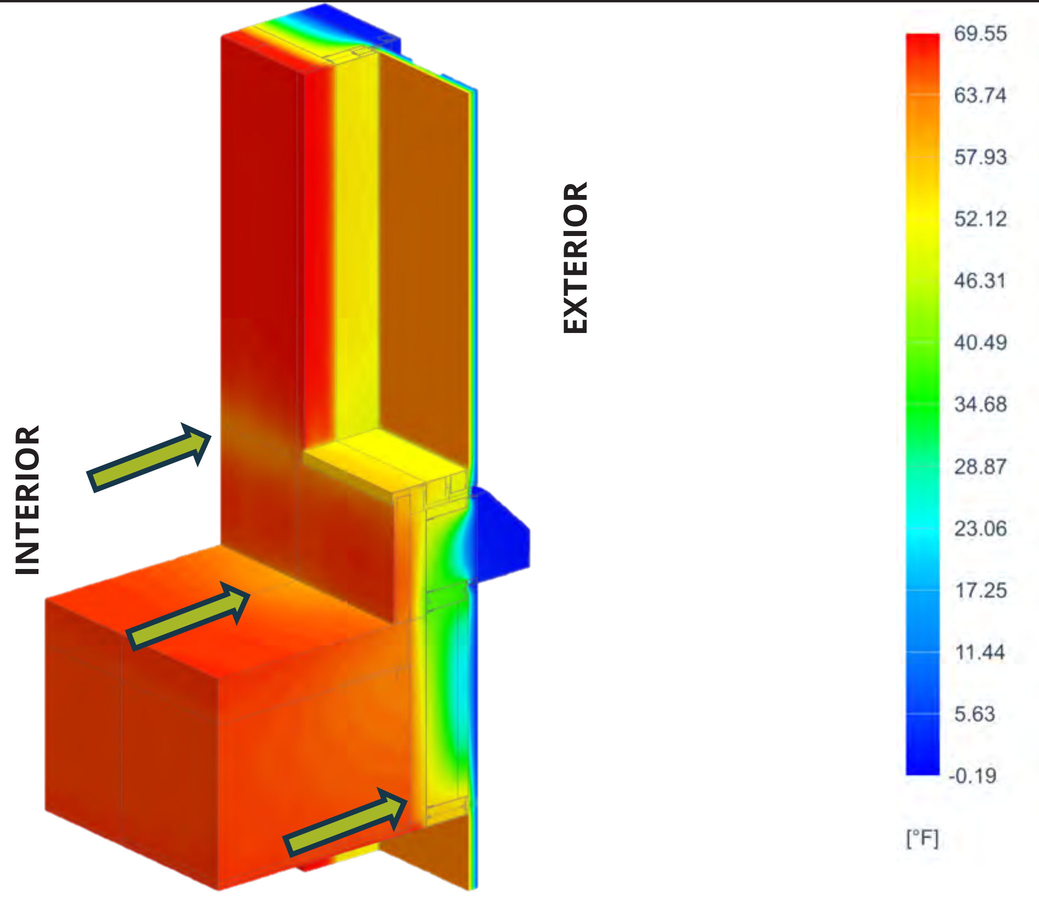
Passive House:

Window U-value: $U_{w\text{-}installed}$ accounting for glass + frame + spacers + installation

2D vs. 3D Finite Analysis



Spandrel R-25.2 per NFRC 100-2020 (2D Finite Analysis)

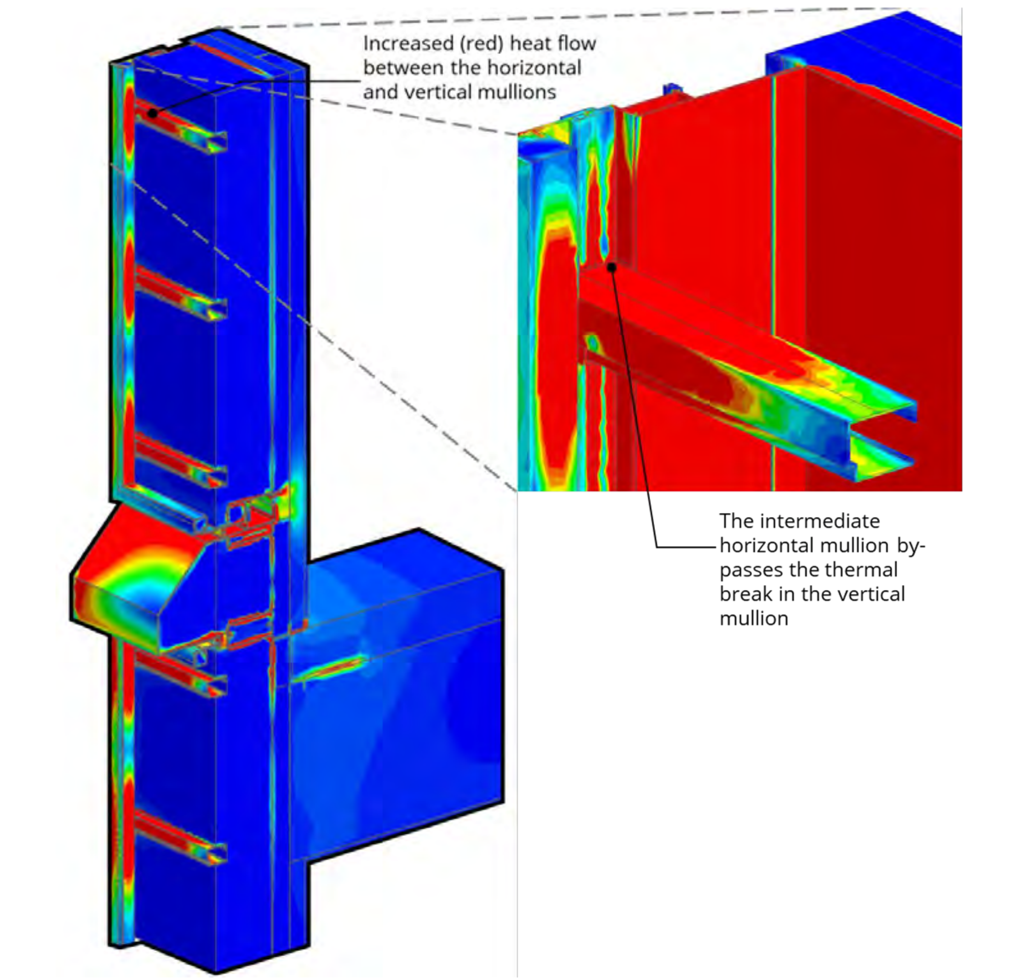


Same spandrel R-8.5 per CSA Z5010 (3D Finite Analysis)

Not including Psi-install of vision glazing – entered separately into WUFI Passive

Consequences of not Accounting Accurately

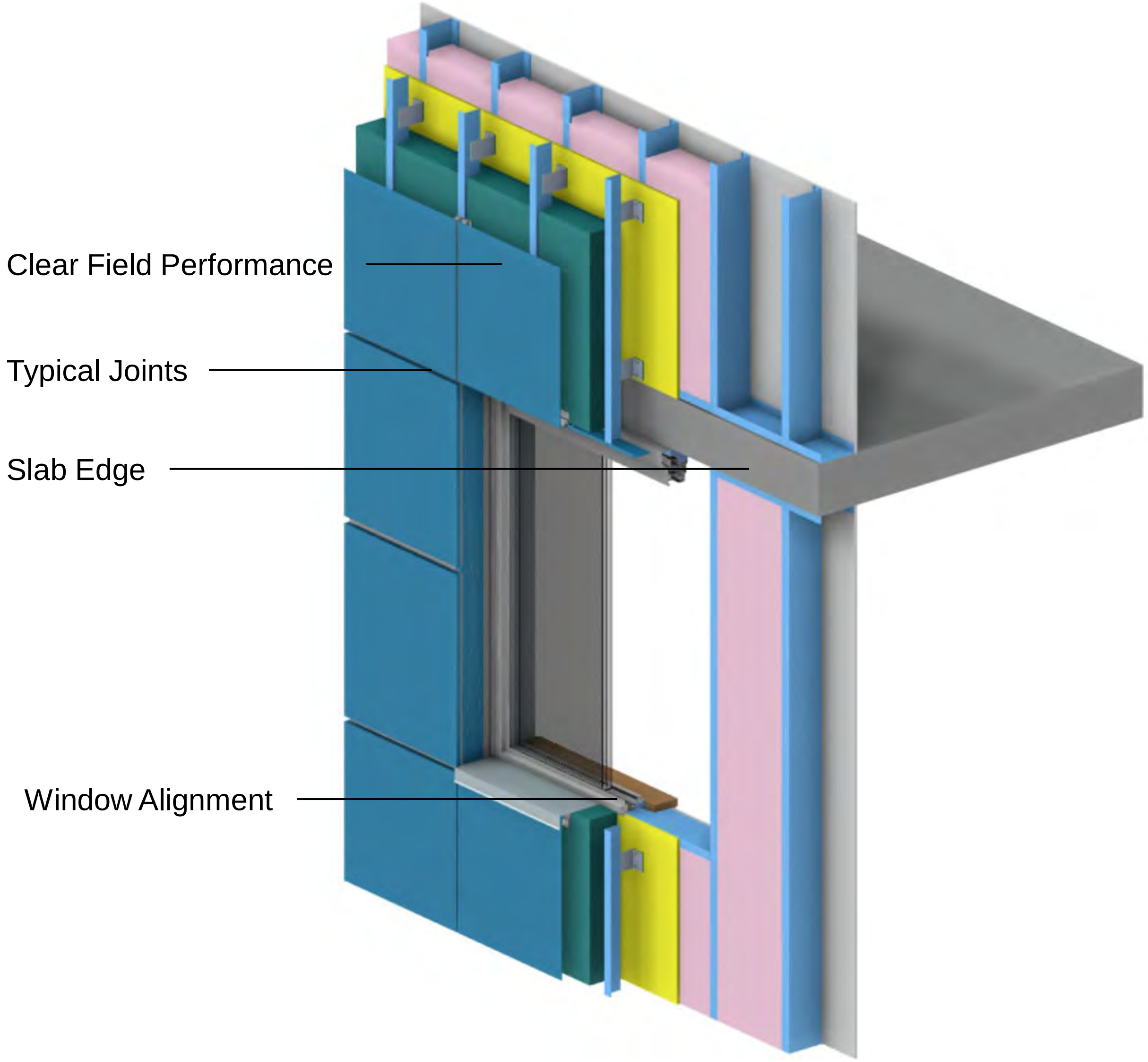
- Overly optimistic assessment of U-value can lead to:
  - An actual Energy Use Intensity higher than what was modeled (Performance Gap)
  - Under-sizing of mechanical systems
  - Condensation risks, impacts on occupant comfort, durability of materials
  - More expensive utility bills
- Performance gap is a disservice to the goals of Passive House



Multi-planar heat flow example in unitized curtain wall

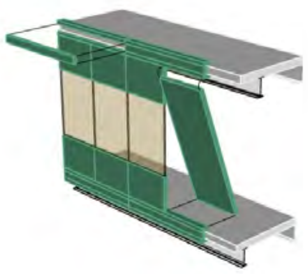
Design Optimization

- **Account** for the performance of each component
- **Understand** the holistic influences of structural, architectural and other disciplines on thermal design.
- **Determine** the relative impact of each component on the thermal performance to know where to best focus design efforts
- **Confirm** through thermal modeling



PANELIZED WALL SYSTEMS

Wall Systems – Early Phase Discussions



1 Window Wall (high performance fiberglass)

Opaque area ~R-19
Slab by-pass ~ R-8
Vision ~ 0.24

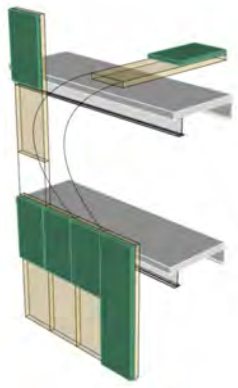
Thermally broken aluminum or fiberglass frame with high performance glazing

+ Less costly than unitized or panelized systems

- Thermal performance not in range of target values

- Less efficient installation process, field QAQC

- Unlike unitized curtainwall, no known customized window wall systems to accommodate additional insulation.



2 Unitized Curtainwall

Opaque area ~R-6-8
Vision ~ 0.26 (improved with vacuum insulated glass)

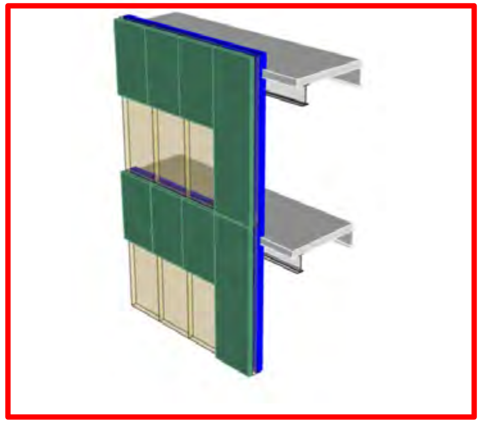
Thermally broken aluminum frame with high performance glazing.

+ Efficient installation process

+ Pre-tested system with factory QAQC

- Thermal performance not in range of target values

- Limited capacity to structurally support cantilevering elements (fins, overhangs)



3 Unitized Curtainwall with warm-side insulation

Opaque area ~R-9-11

Vision ~ 0.26 (improved with vacuum insulated glass)

Thermally broken aluminum frame with high performance glazing.

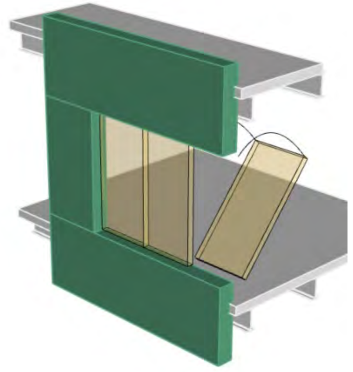
Continuous interior insulated wall behind spandrel

+ Benefits of unitized curtainwall apply

- Additional trade coordination and QAQC for interior wall

- May require limitations on interior RH conditions to limit condensation risks

- Limited capacity to structurally support cantilevering elements



4 Traditional Stick Built Wall

Opaque area ~R-20 +,

Window ~ 0.15 – 0.20

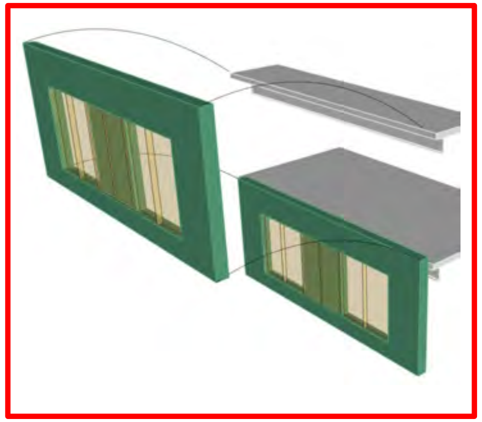
Traditional stud framed wall on slab with high performance windows

+ Continuous AVB and insulation leads to less heat loss through joints

- Less efficient installation process

- Additional trade coordination and field QAQC

Cost comparison TBD (labor)



5 Mega-panel

Opaque area ~R-20 +

Window ~ 0.15 -0.20

Large format panel with high performance windows

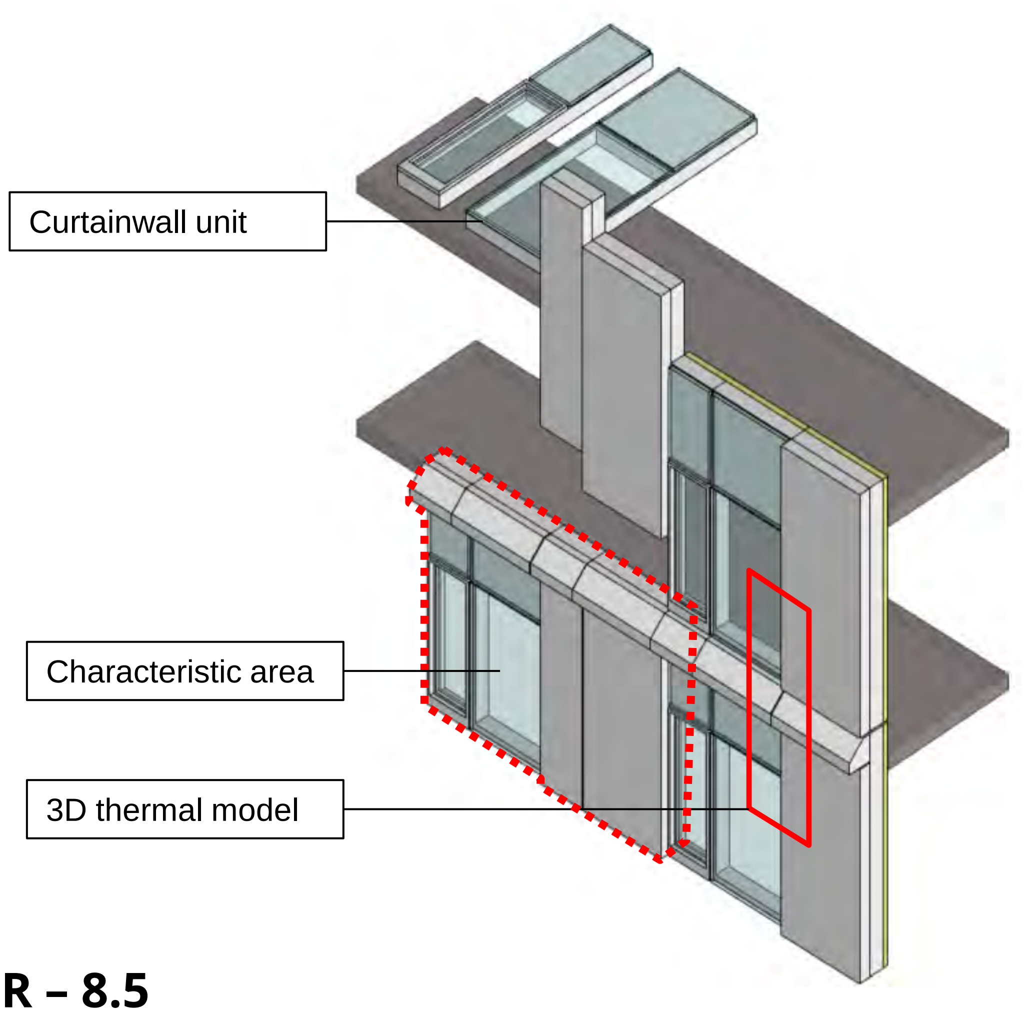
+ Pre-tested system with factory QAQC

+ Performance criteria baked into one panel

- Limited number of vendors

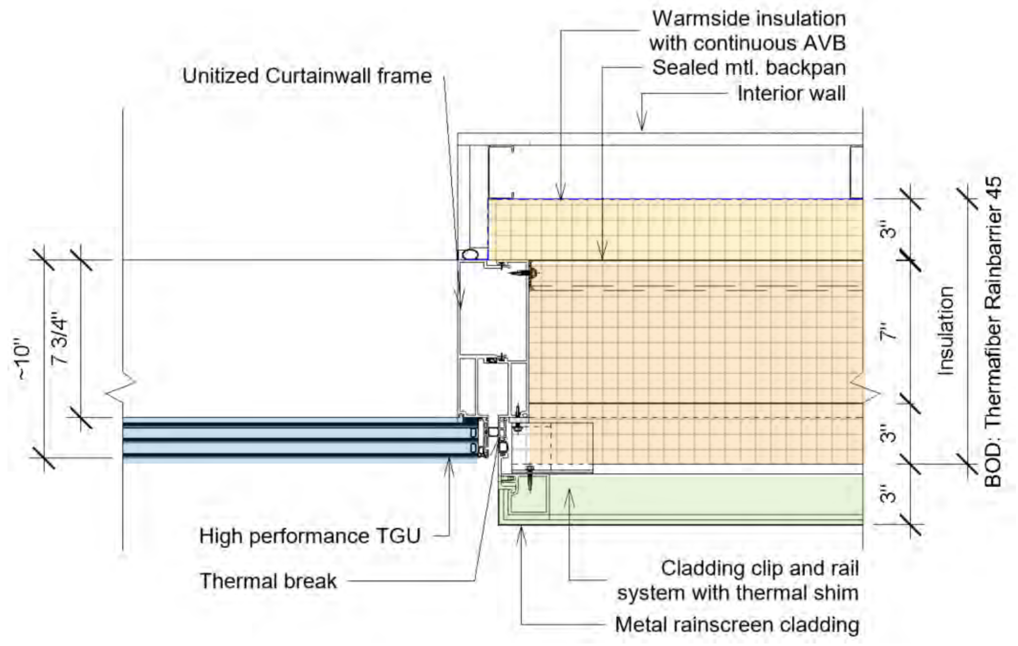
- Complex site logistics

Unitized Curtainwall

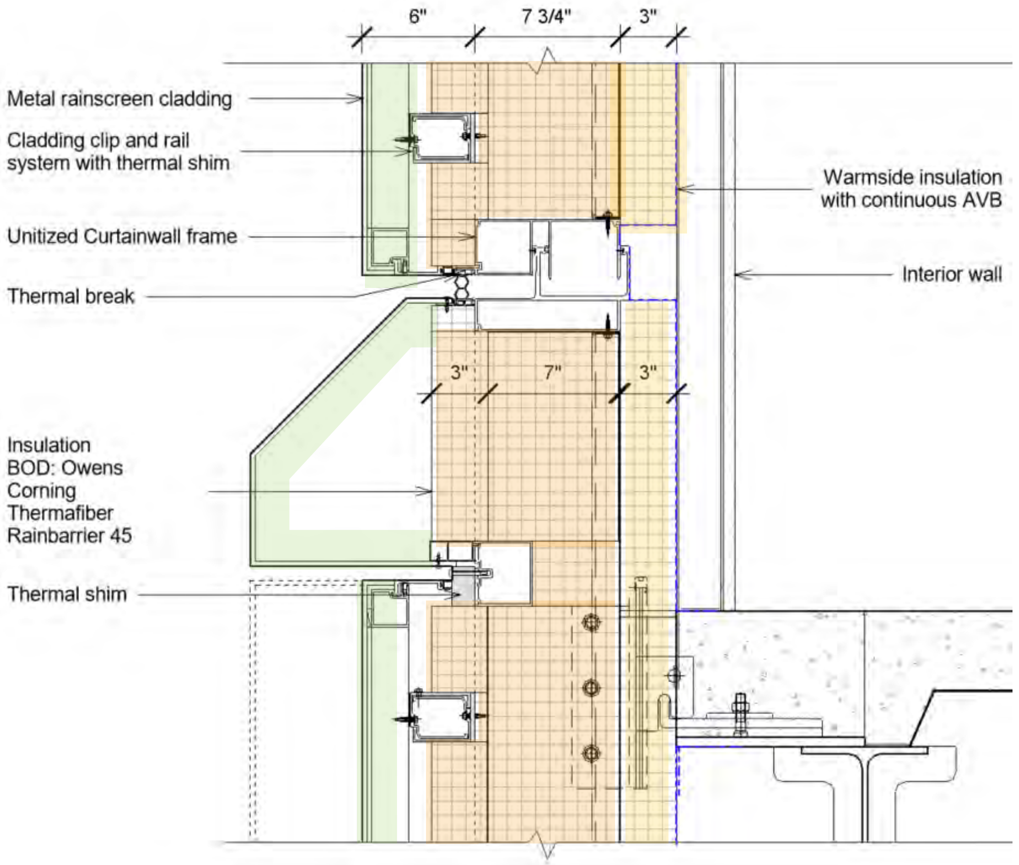


ID	Description	Quantity	Baseline from PH Model	Curtainwall Results
	Opaque			
1	Glazed Spandrel	23.7 sq ft	NA	U-0.12 BTU/hr.ft².F
2	Metal Clad Spandrel	73.5 sq ft	NA	U-0.09 BTU/hr.ft².F
3	Opaque Linear Transmittance	8.2 ft		Ψ-0.02 BTU/hr.ft.F
4	Anchors	2	*(Thermal Bridge Free)*	*(Thermal Bridge Free)*
	Clear Field (Opaque)	97.15 sf	**U-0.05 BTU/hr.ft².F (R-20)**	**U-0.12 BTU/hr.ft².F (R-8.5)**
	Transparent			
5	Vision Glazing	24.0 sq ft	U-0.20 BTU/hr.ft².F	U-0.20 BTU/hr.ft².F
5.1	Vent Glazing	12.8 sq ft	U-0.20 BTU/hr.ft².F	U-0.20 BTU/hr.ft².F
6.1	Window-to-wall Interface Fixed (PSI)	13.9 ft	Ψ-0.035 BTU/hr.ft.F	Ψ-0.10 BTU/hr.ft.F
6.2	Window-to-wall Interface Vent (PSI)	10.38 ft	Ψ-0.035 BTU/hr.ft.F	Ψ-0.06 BTU/hr.ft.F
	Average Overall Installed Window U-value	NA	**U-0.22 BTU/hr.ft².F**	**U-0.26 BTU/hr.ft².F**
	Average Overall Installed Window U-value, vent	NA	**U-0.22 BTU/hr.ft².F**	**U-0.25 BTU/hr.ft².F**
	Misc. Thermal Bridges			
7	TB04: Intermediate floors	12.75 ft	Ψ-0.040 BTU/hr.ft.F	<0.01 *(Thermal Bridge Free)*
	Overall (Opaque + Transparent)		U-0.11 BTU/hr.ft².F (R-9.1)	U-0.16 BTU/hr.ft².F (R-6.5)

Unitized Curtainwall

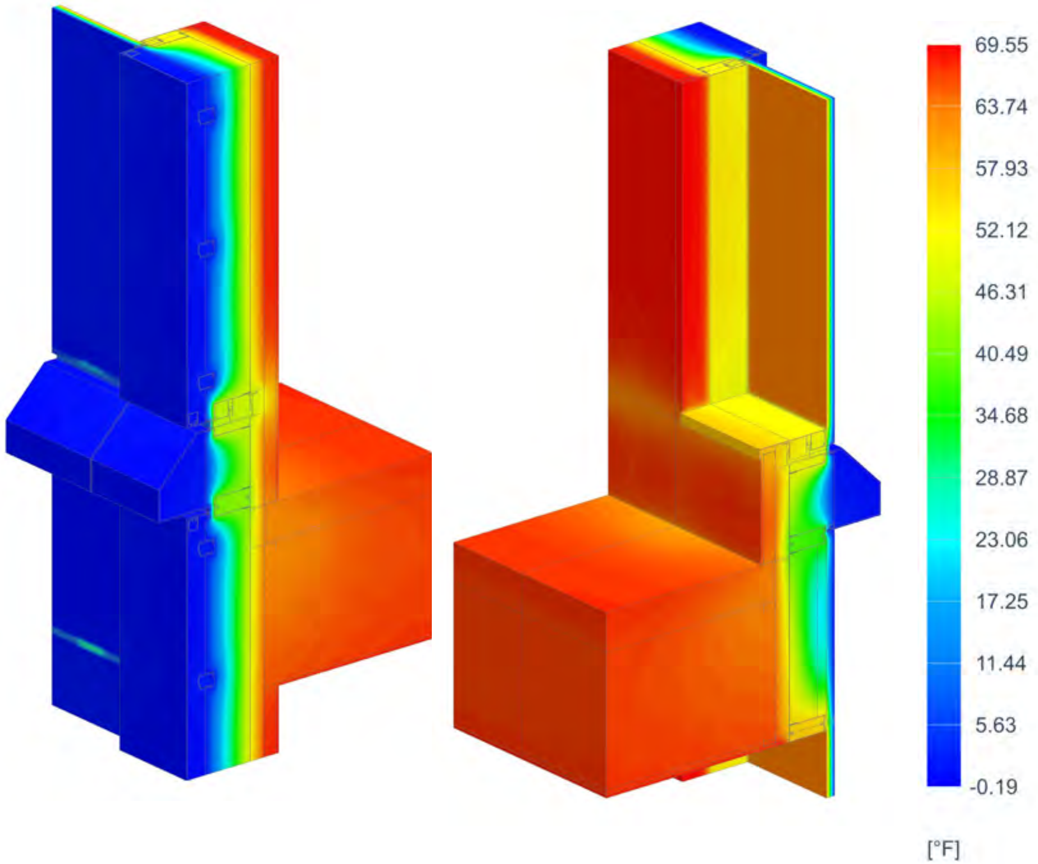


PLAN
Vision to metal clad spandrel

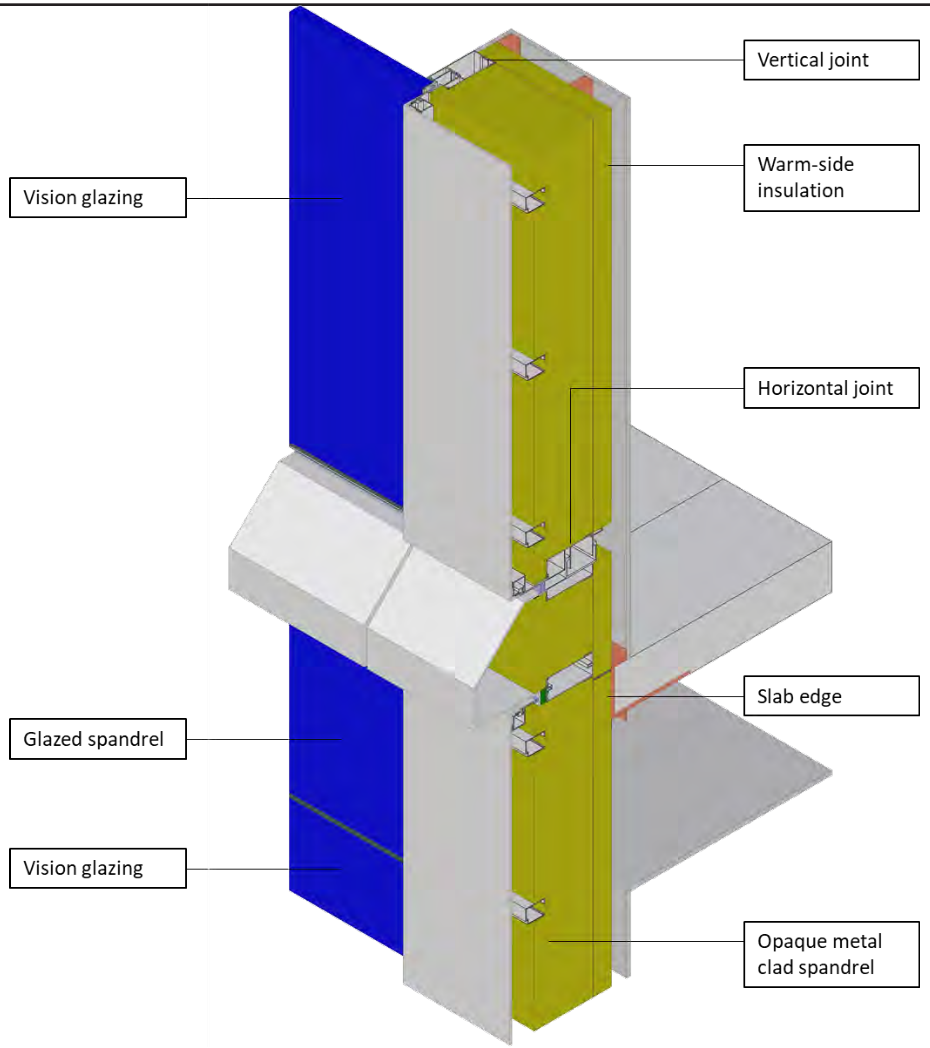


SECTION
Metal clad spandrel stack joint

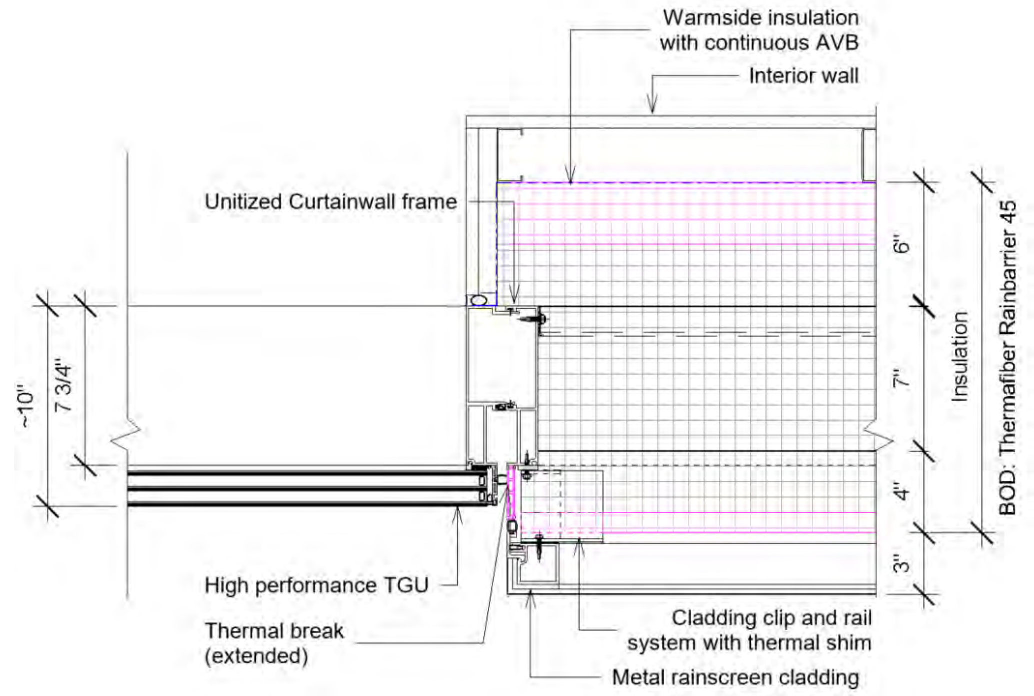
Unitized Curtainwall



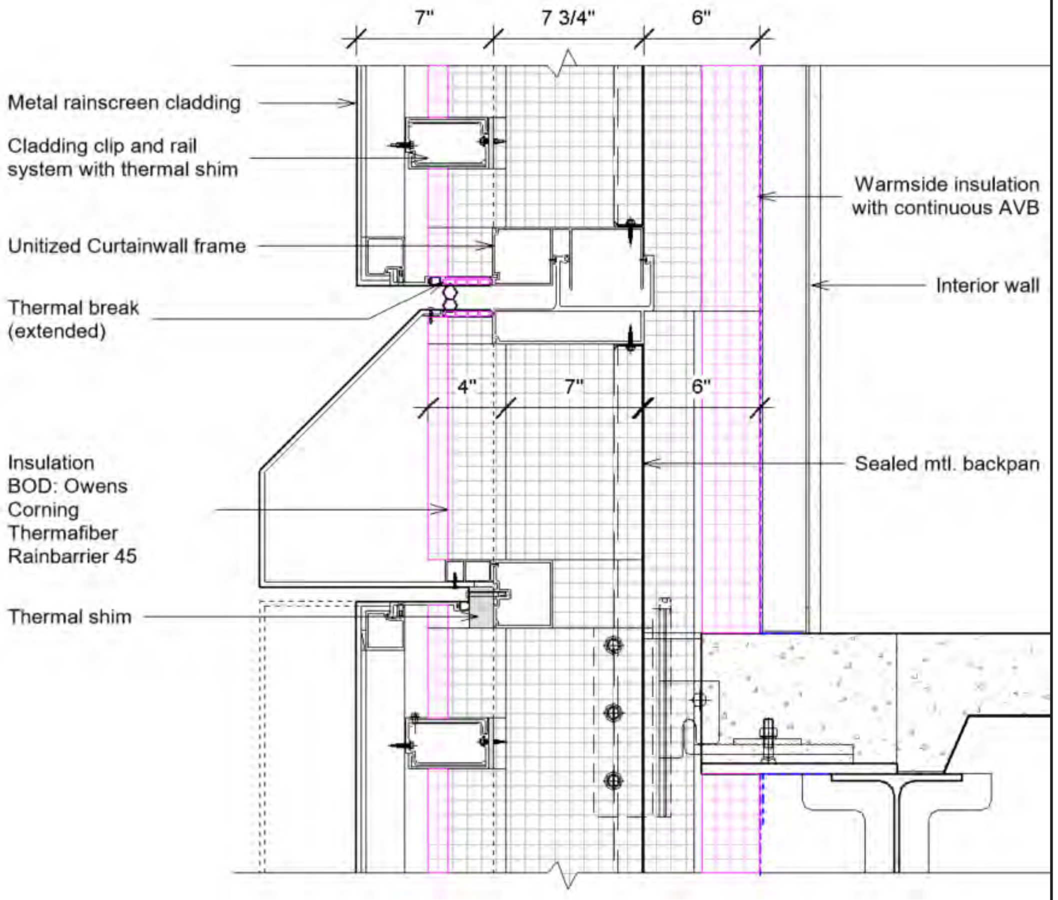
R – 8.5



Unitized Curtainwall - Improved



Plan: Opaque R-Value improved to R-17

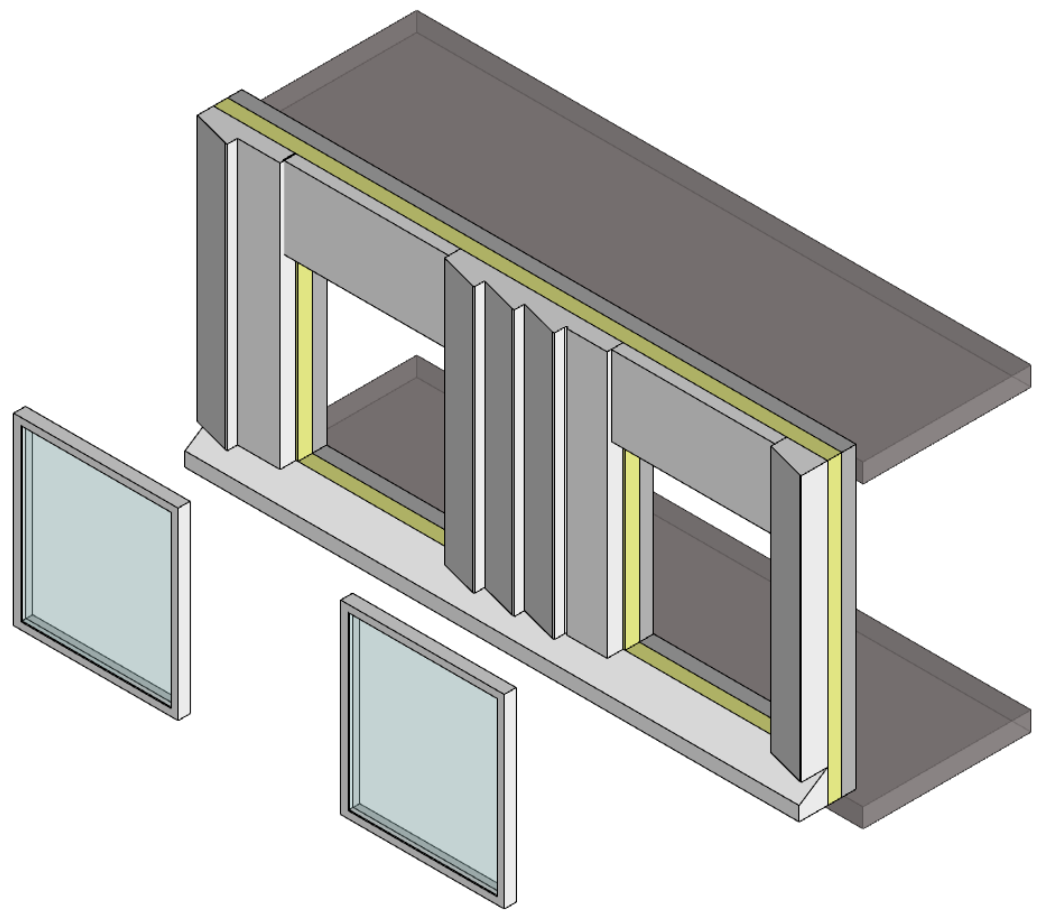


Section: Opaque R-Value improved to R-17

Unitized Curtainwall Conclusions

- It can be complicated to make unitized curtainwall do what is necessary.
- Stop designing 100% glass towers.
- To achieve the required thermal performance, a very high R-value opaque assembly, in addition to curtainwall, is required to balance the traditional thermally inefficient unitized curtainwall
- Requires specific design limitations and careful engineering
- Likely the most expensive system, potentially cost prohibitive
- Requires further industry innovation towards lowering system U-value to remain a viable option in our market

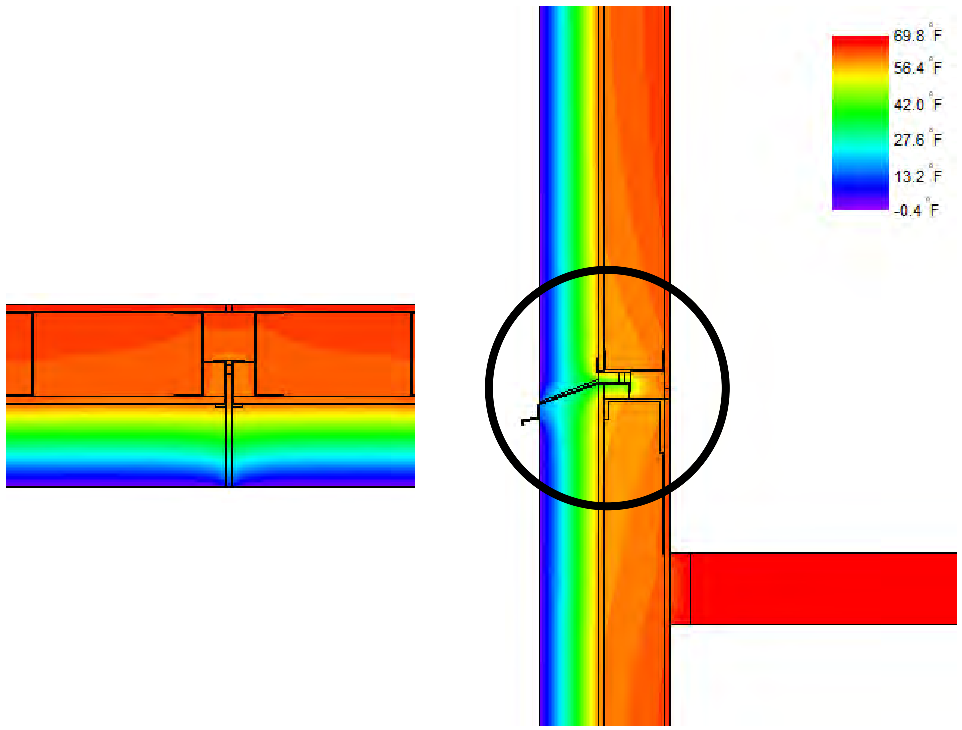
Mega Panel



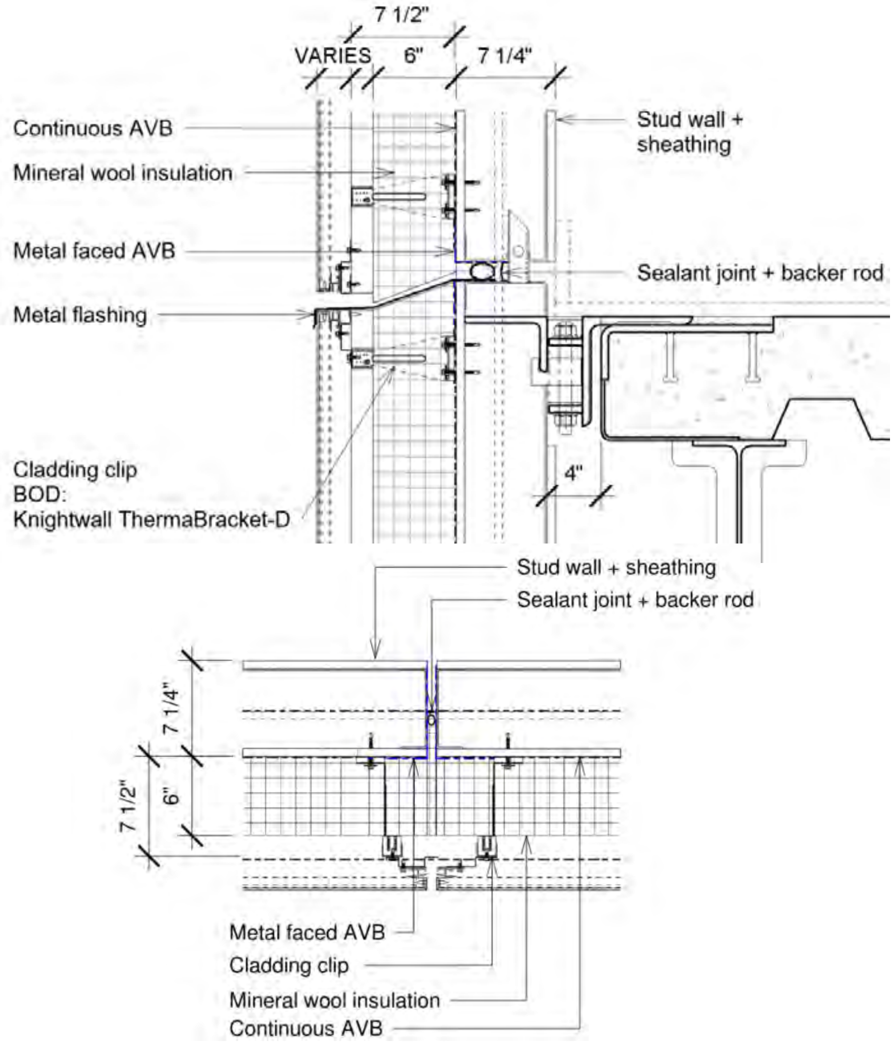
R – 23.2

ID	Description	Quantity	Baseline Input	Mega Panel Results
	Opaque			
1	Center of Panel	152 sq ft	NA	U-0.041 BTU/hr.ft².F
2	Vertical Panel Joint	10.5 ft	NA	Ψ-0.022 BTU/hr.ft².F
3	Horizontal Panel Joint	21.6 ft	NA	Ψ-0.004 BTU/hr.ft².F
4	Anchors	2	*(Thermal Bridge Free)*	*(Thermal Bridge Free)*
Clear Field (Opaque)		152 sq ft	**U-0.05 BTU/hr.ft².F (R-20)**	**U-0.043 hr.ft².F/BTU (R-23.2)**
	Transparent			
5	Windows	76 sf	U-0.20 BTU/hr.ft².F	U-0.20 BTU/hr.ft².F
6	Window-to-wall Interface (PSI)	49 ft	Ψ-0.035 BTU/hr.ft.F	Ψ-0.022 BTU/(hr·ft·F)
Average Overall Installed Window U-value		NA	**U-0.22 BTU/hr.ft².F**	**U-0.21 BTU/hr.ft².F**
	Misc. Thermal Bridges			
7	TB04: Intermediate floors	21.58 ft	Ψ-0.040 BTU/ft.F.hr	<0.01 *(Thermal Bridge Free)*
	Overall (Opaque + Transparent)		U-0.110 BTU/hr.ft².F (R-9.1)	U-0.099 BTU/hr.ft².F (R-10.1)

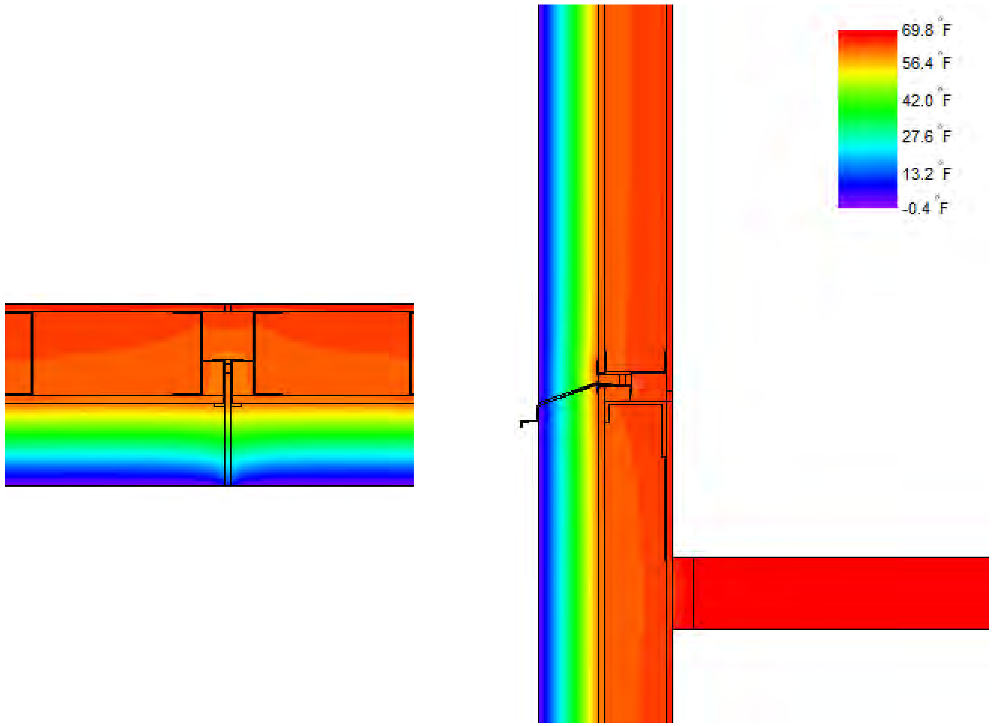
Mega Panel



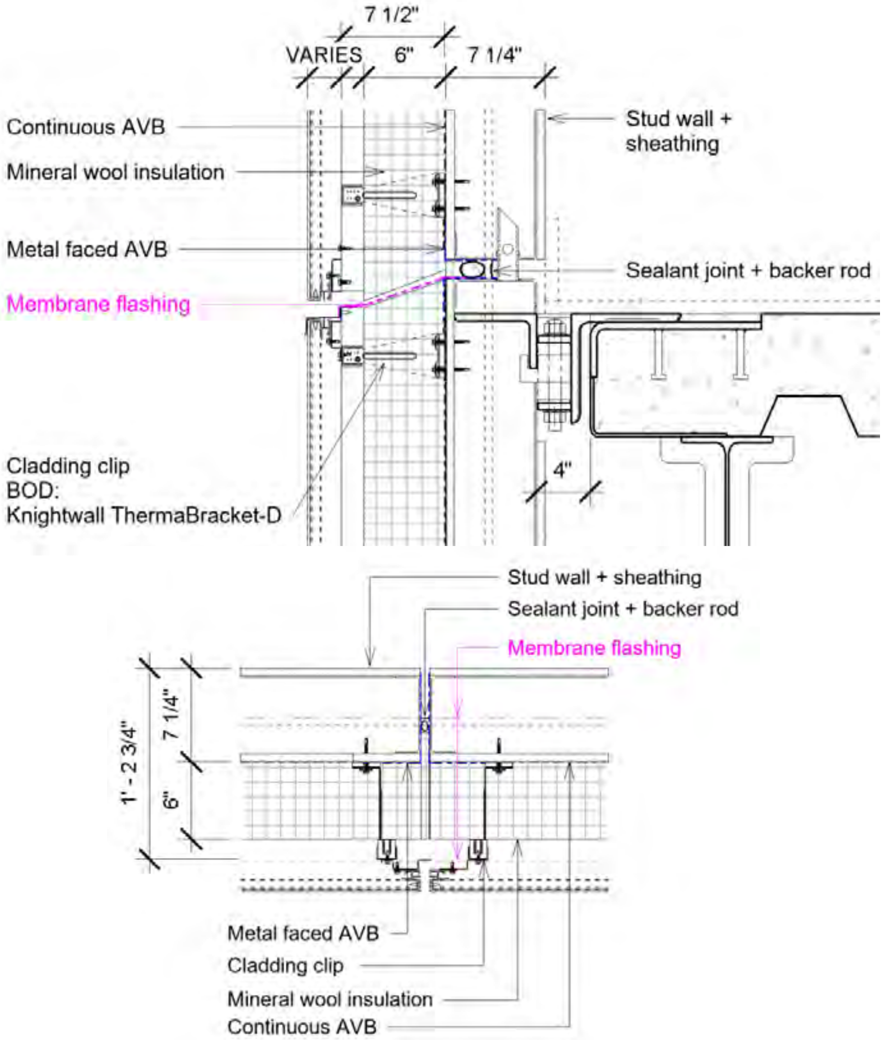
R – 15.7



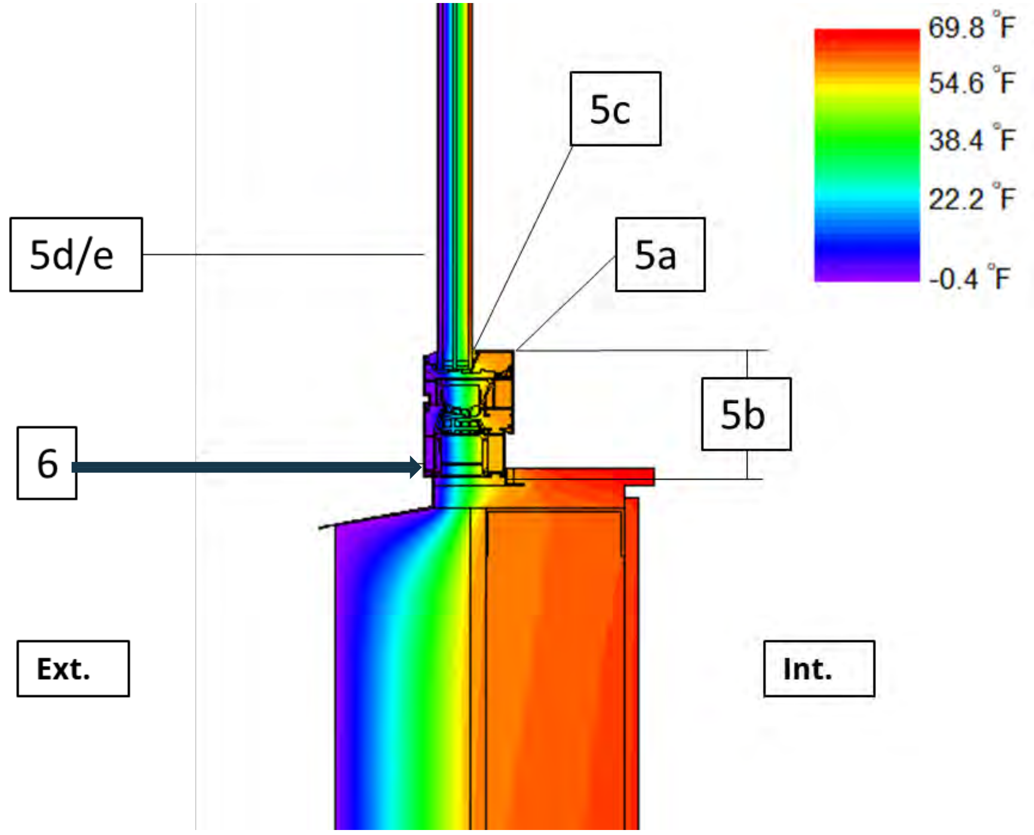
Mega Panel



R – 23.2

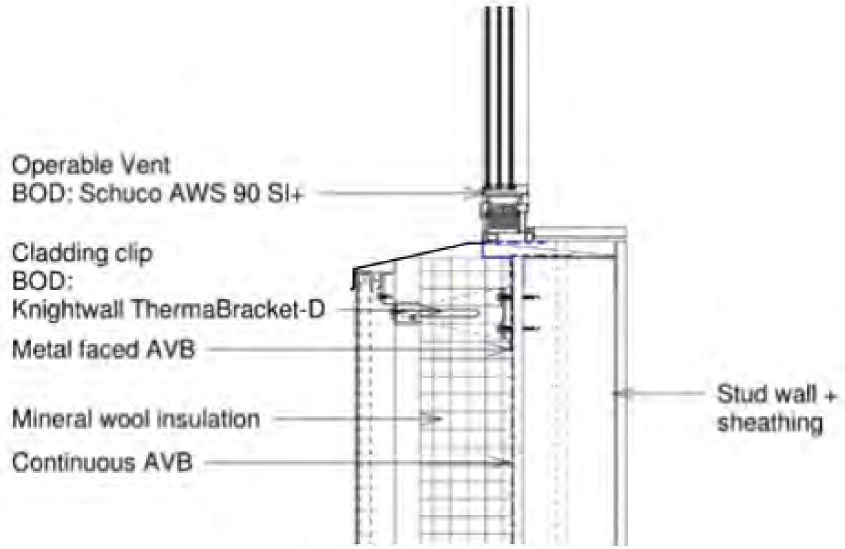


Mega Panel – Window

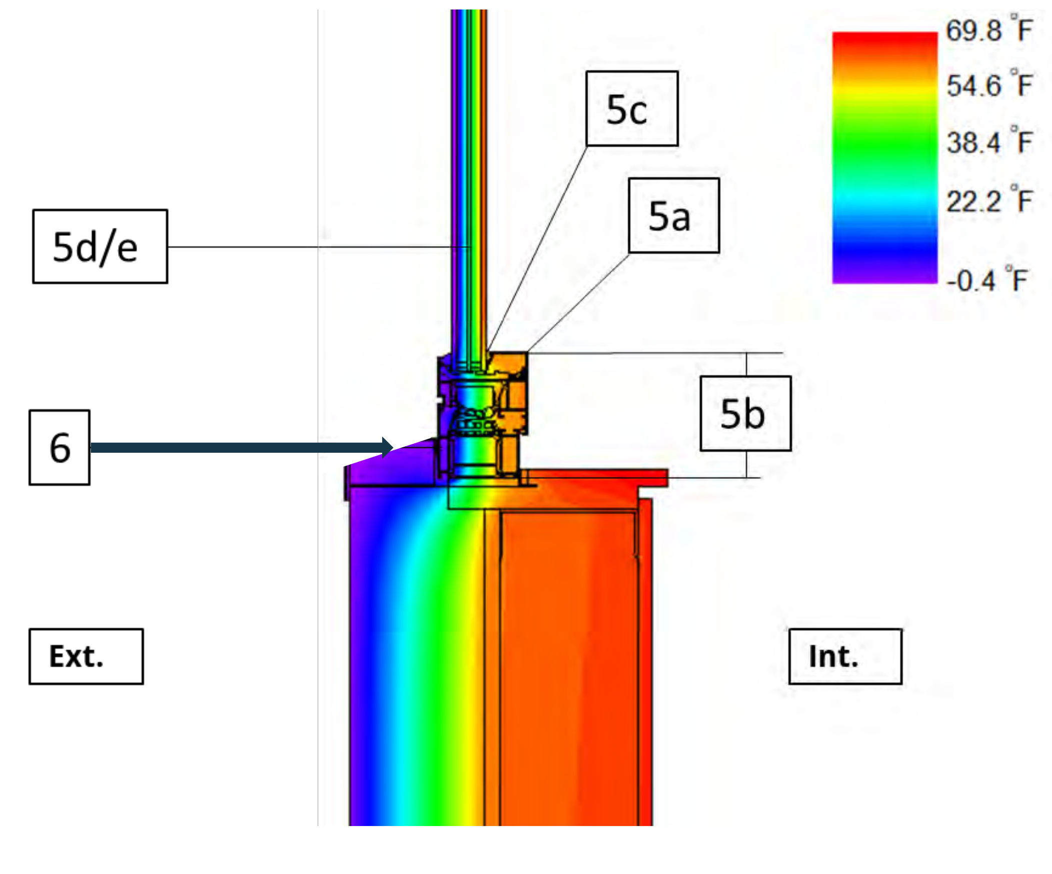


Ψ-0.057 BTU/hr·ft·F

ID	Description	BOD	Model Results
5	Operable Vent	**Schuco AWS 90 SI+**	
5a		Frame performance, Uf	U-0.14 BTU/hr·ft²·F
5b		Frame Width	4.8 in
5c		Glazing edge thermal bridge	Ψ-0.03 BTU/hr·ft·F
5d		Glazing COG U-value	U-0.12 BTU/hr·ft²·F
5e		Glazing COG SHGC	0.40
6		**Window-to-wall Interface (PSI)**	**Ψ-0.057 BTU/hr·ft·F**

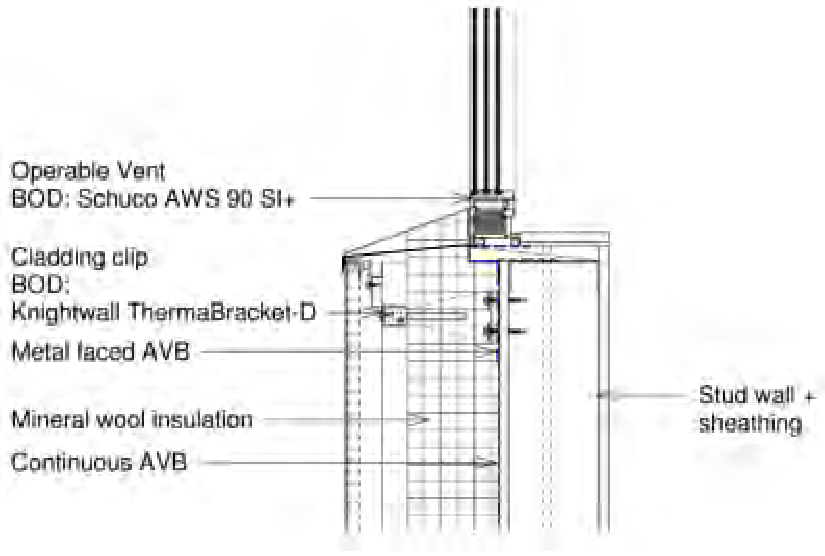


Mega Panel – Window Improved



Ψ-0.022 BTU/hr·ft·F

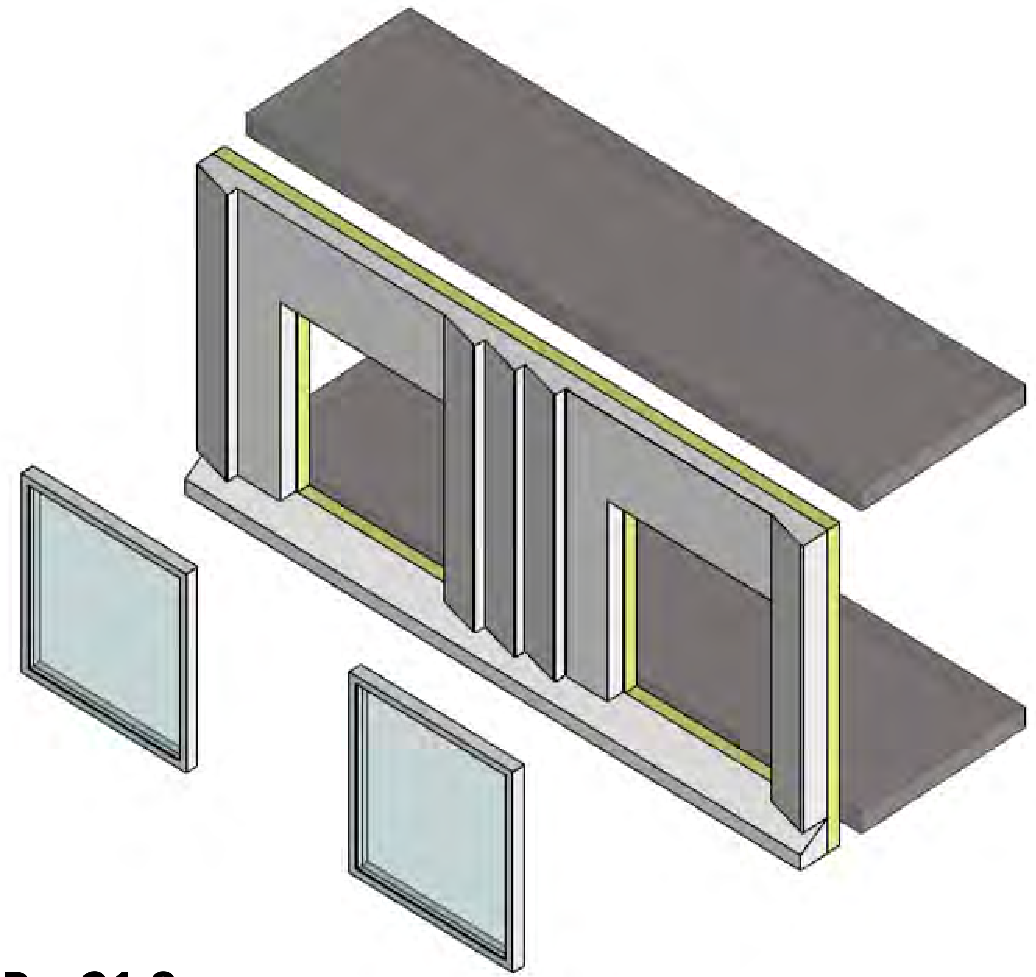
ID	Description	BOD	Model Results
5	Operable Vent	**Schuco AWS 90 SI+**	
5a		Frame performance, Uf	U--0.14 BTU/hr·ft²·F
5b		Frame Width	4.8 in
5c		Glazing edge thermal bridge	Ψ-0.03 BTU/hr·ft·F
5d		Glazing COG U-value	U-0.12 BTU/hr·ft²·F
5e		Glazing COG SHGC	0.40
6		**Window-to-wall Interface (PSI)**	Ψ-**0.022 BTU/hr·ft·F**



Mega Panel Conclusions

- Details matter
- This is our preferred option
- Control layers are in the right places – “perfect wall”
- Even within this system, careful attention needs to be paid to things like through-wall flashing and window details.
- Mega Panel designs can be proprietary by manufacturers and may have varying thermal results depending on system detailing.

Precast Concrete

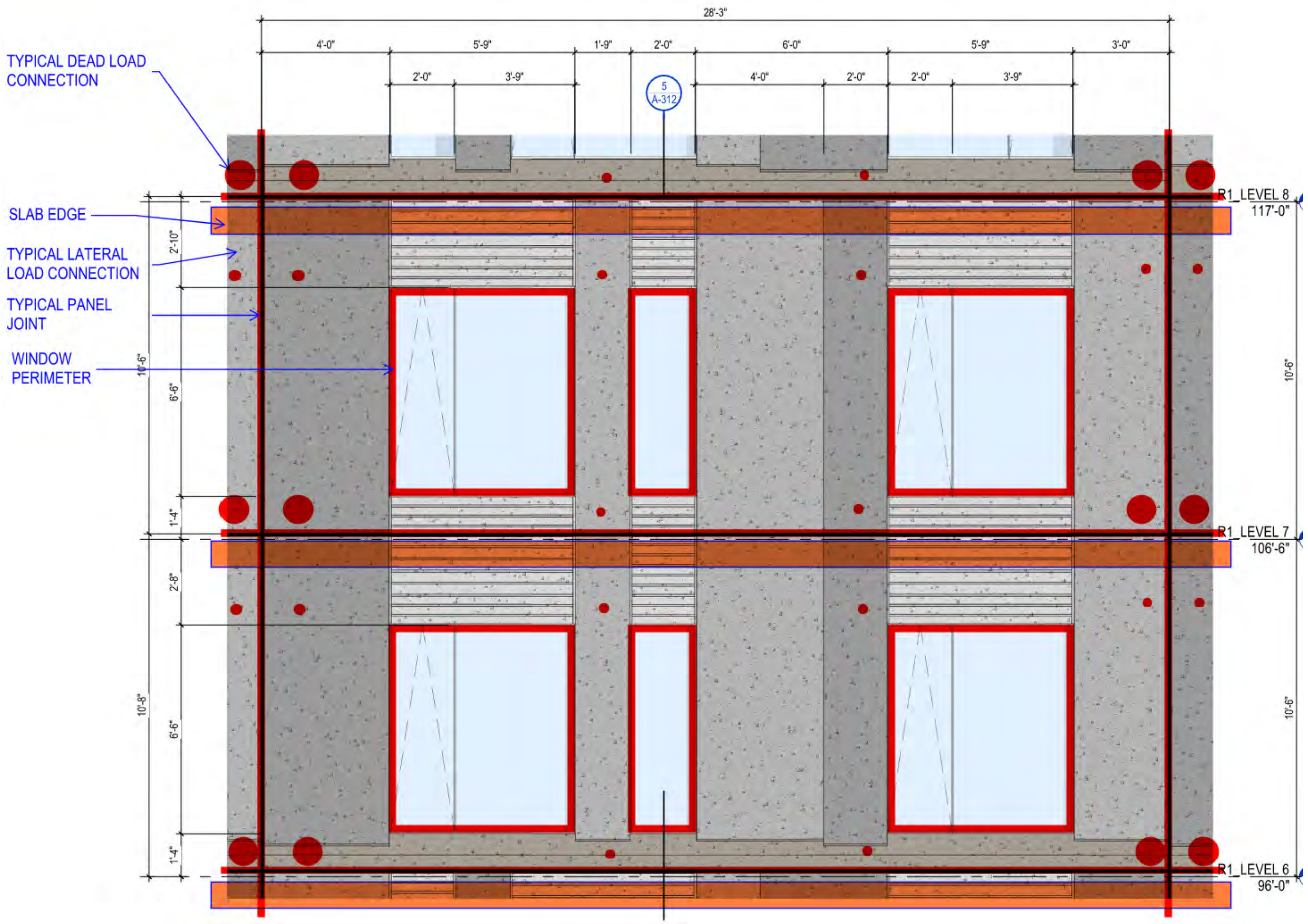


R – 21.8 (in this exact configuration)

ID	Description	Quantity	Baseline from PH Model	Precast Results
	Opaque			
1	Center of Panel	152 sq ft	*no break out value*	U-0.038 BTU/hr.ft^2.F
2	Vertical Panel Joint	10.5 ft	*no break out value*	Ψ-0.013 BTU/hr.ft.F
3	Horizontal Panel Joint	21.6 ft	*no break out value*	Ψ-0.009 BTU/hr.ft.F
4.1	Dead Load +Wind Load Anchor	2	*(Thermal Bridge Free)*	*X*-0.166 BTU/hr.F
4.2	Lateral Load + Wind Load Anchor	1	*(Thermal Bridge Free)*	*X*-0.522 BTU/hr.F
	Clear Field (Opaque)	152 sq ft	**U-0.05 BTU/hr.ft^2.F (R-20)**	**U-0.046 BTU/hr.ft^2.F (R-21.8)**
	Transparent			
5	Windows	76 sq ft	U-0.197 BTU/hr.ft^2.F	U-0.197 BTU/hr.ft^2.F
6	Window-to-wall Interface (Ψ)	49 ft	Ψ-0.035 BTU/hr.ft.F	Ψ-0.035 BTU/hr.ft.F
	Average Overall Installed Window U-value	NA	**U-0.22 BTU/hr.ft^2.F**	**U-0.22 BTU/hr.ft^2.F**
	Misc. Thermal Bridges			
7	TB04: Intermediate floors	21.6 ft	Ψ-0.040 BTU/hr.ft.F	Ψ- 0.014 BTU/hr.ft.F
	Overall (Opaque + Transparent)		**U-0.110 BTU/hr.ft^2.F (R-9.1)**	**U-0.105 BTU/hr.ft^2.F (R-9.5)**

Precast Concrete – Panel Layout Options

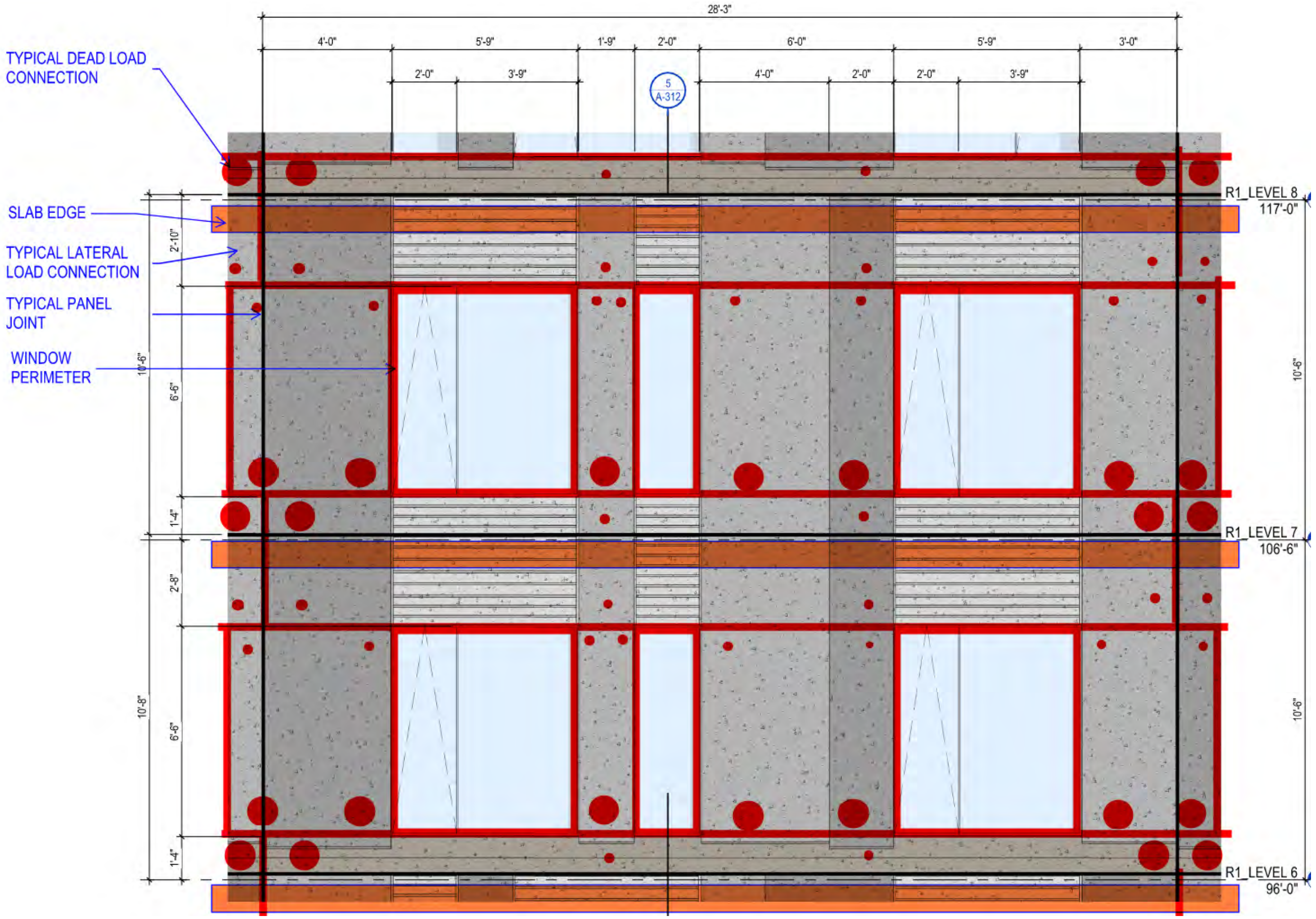
- Consider panel layouts that will allow for the minimum number of gravity, lateral and wind load anchors
- Minimize number of penetrations through insulation.
- Façade articulation through texture and color in a relatively “flat” panel
- This is the most optimal Precast layout



“Double Doughnut - optimal layout + anchor arrangement

Precast Concrete – Panel Layout Options

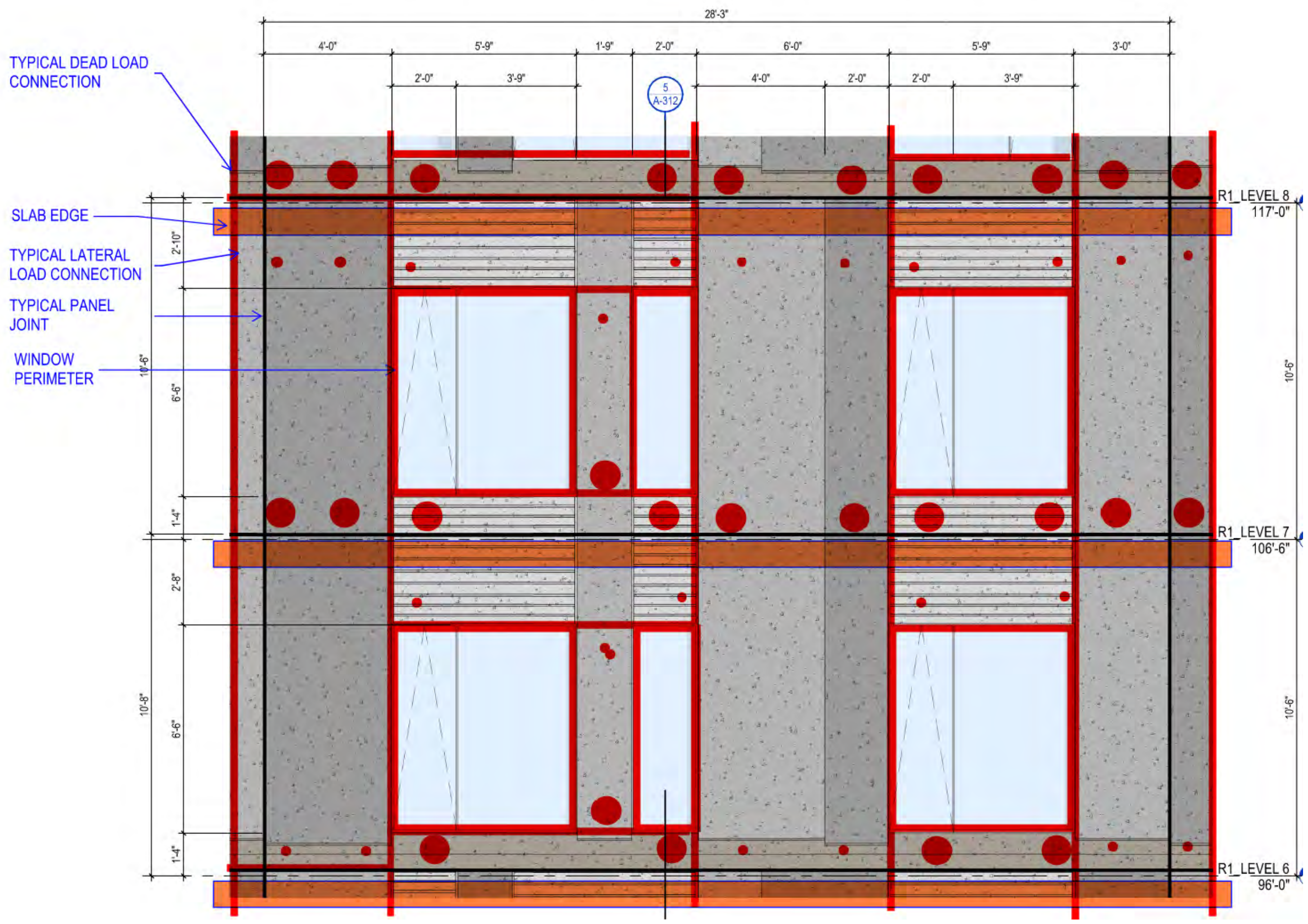
- Consider panel layouts that will allow for the minimum number of gravity, lateral and wind load anchors
- Minimize number of penetrations through insulation.
- Possible to articulate the façade more finely with larger number of different panels.
- Many more anchors in this type of layout, challenging clear field R-values required.



"Spandrel and Column Covers" – less optimal layout + anchor arrangement

Precast Concrete – Panel Layout Options

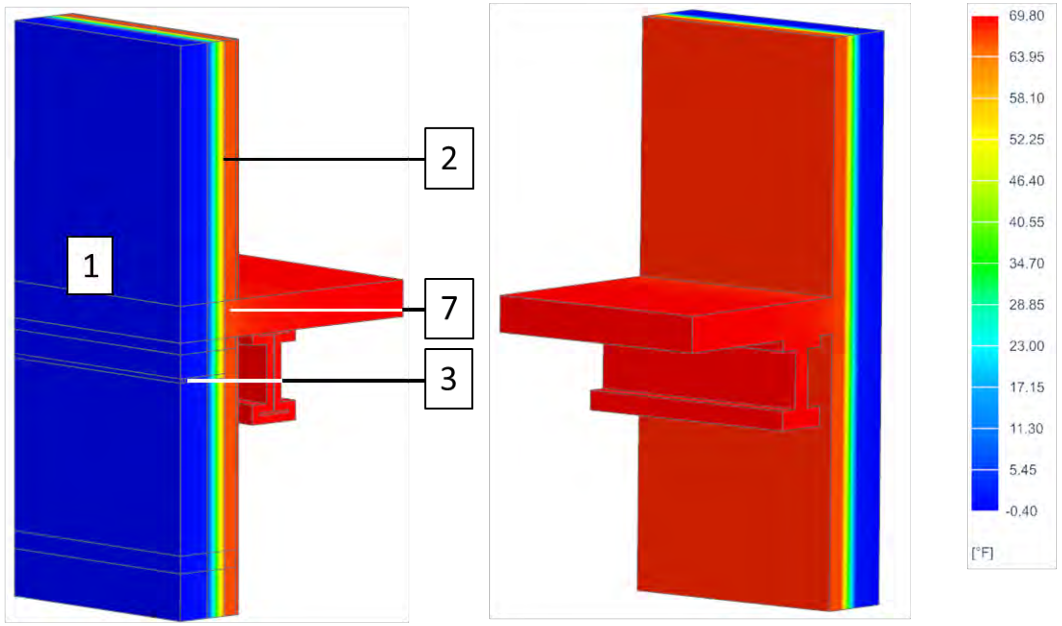
- Consider panel layouts that will allow for the minimum number of gravity, lateral and wind load anchors
- Minimize number of penetrations through insulation.
- Still more anchors than “Double Doughnut”

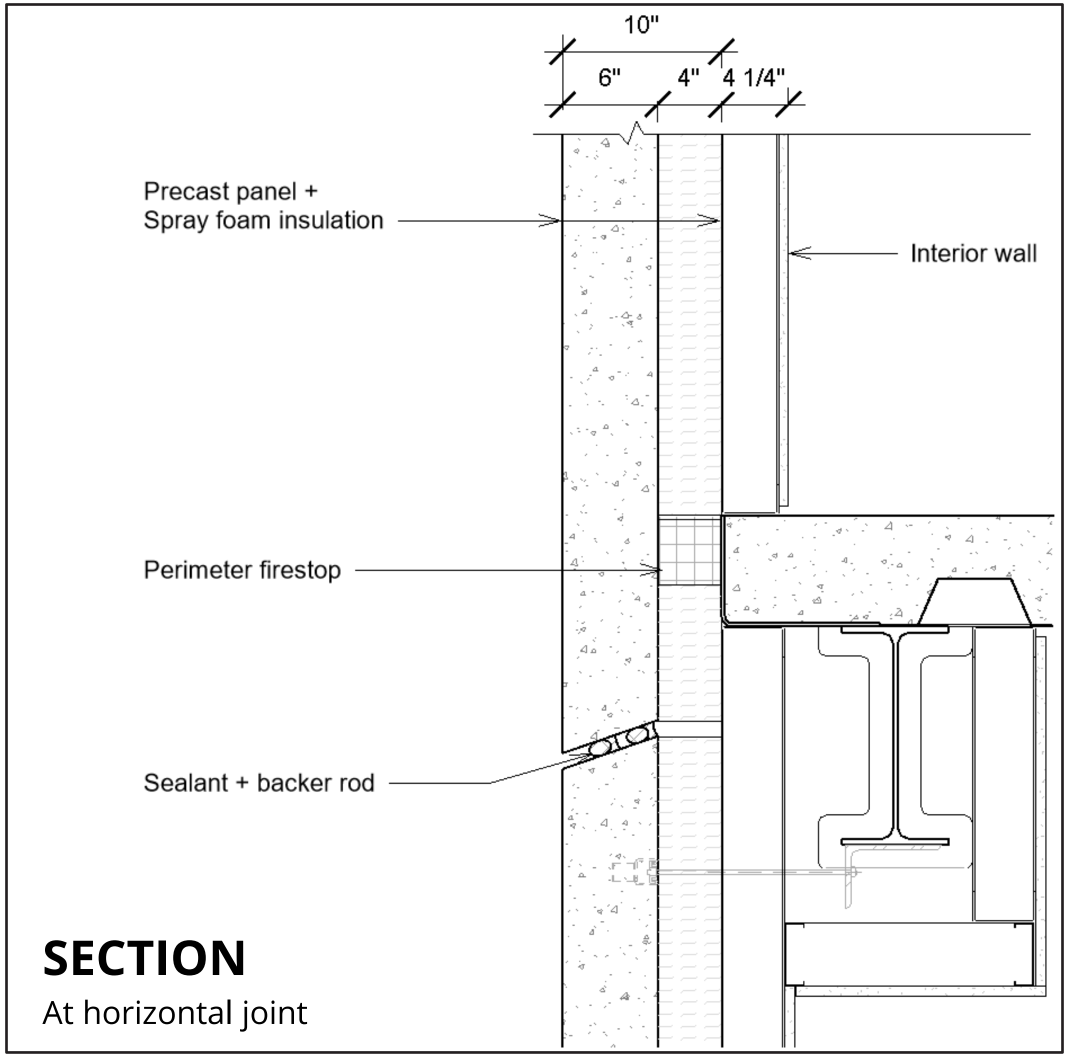


“Hybrid” –
less optimal layout + anchor arrangement

Precast Concrete – Clear Field (w/o Anchors)

ID	Description	Quantity	Model Results
	Opaque		
1	Center of Panel	152 sq ft	U-0.038 BTU/hr.ft².F
2	Vertical Panel Joint	10.5 ft	Ψ-0.013 BTU/hr.ft.F
3	Horizontal Panel Joint	21.6 ft	Ψ-0.009 BTU/hr.ft.F
7	TB04: Intermediate floors	21.6 ft	Ψ-0.0137 BTU/hr.ft.F

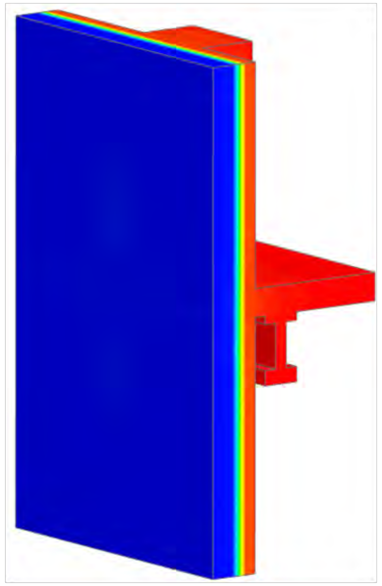


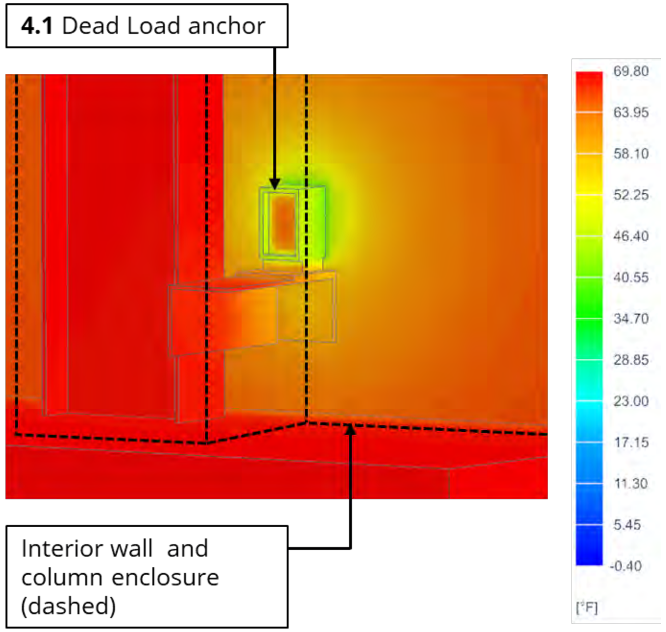


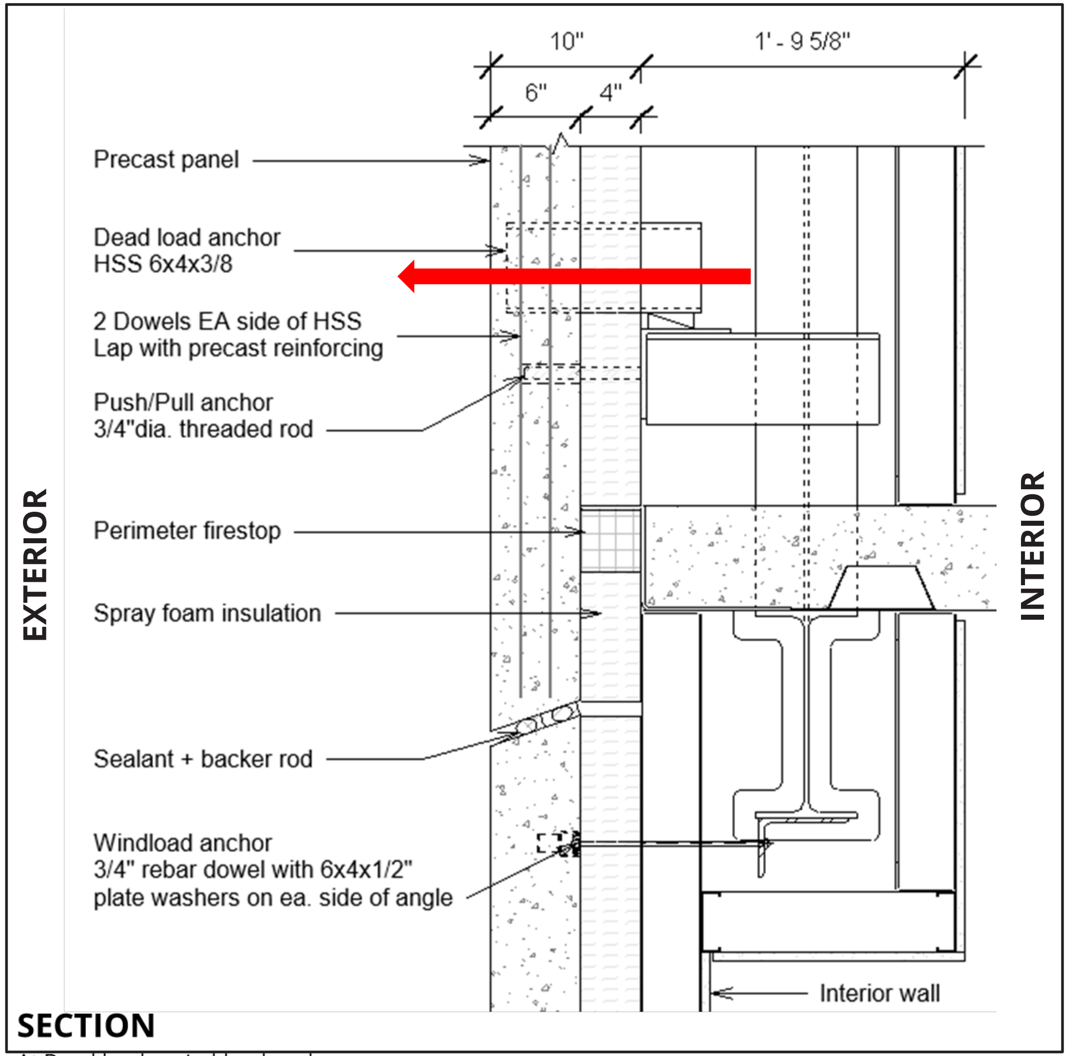
SECTION
At horizontal joint

Precast Concrete – Dead Load Anchors

ID	Description	Quantity	Model Input
	Opaque		
4.1	Dead Load + Wind Load Anchor with interior wall and column cover	2	*X*-0.166 BTU/hr.F



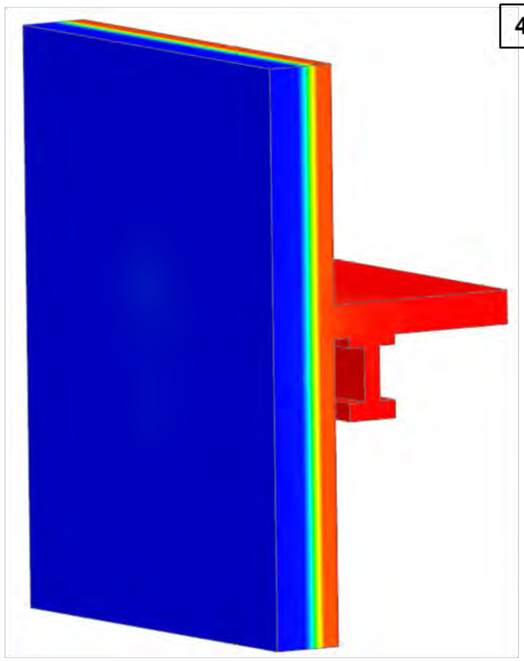


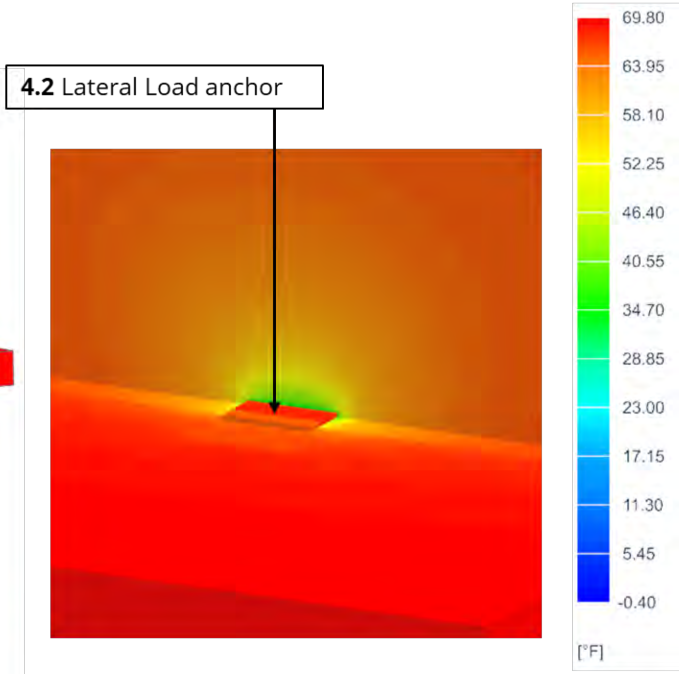


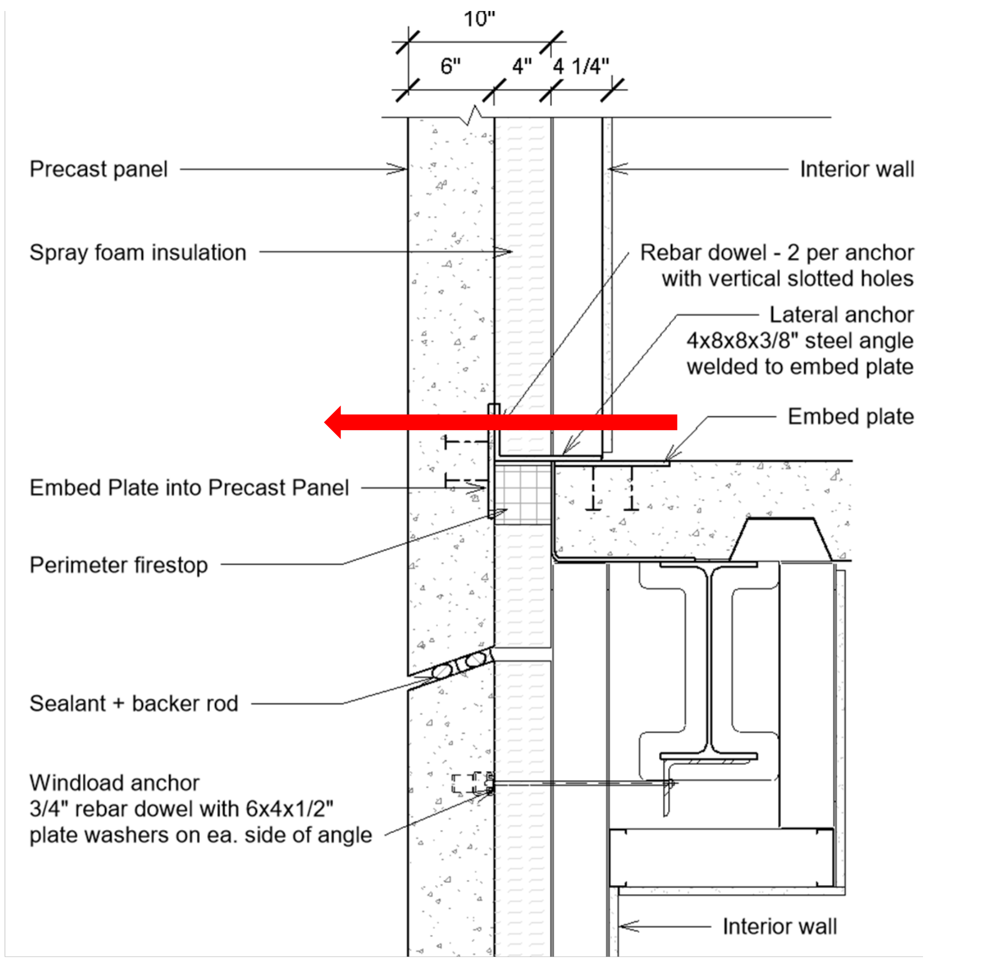
At Dead load + wind load anchor

Precast Concrete – Lateral Load Anchors

ID	Description	Quantity	Model Input
	Opaque		
4.2	Lateral Load + Wind Load Anchor	1	*X*-0.522 BTU/hr.F





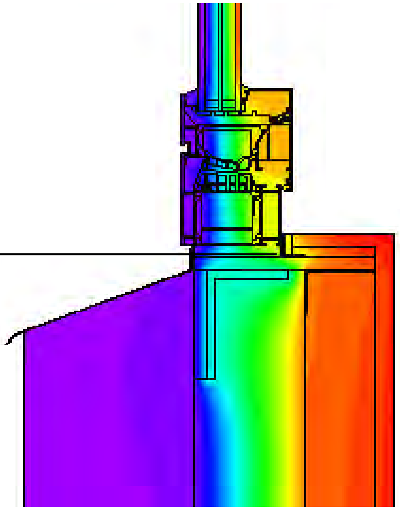


SECTION

At Lateral load + wind load anchor

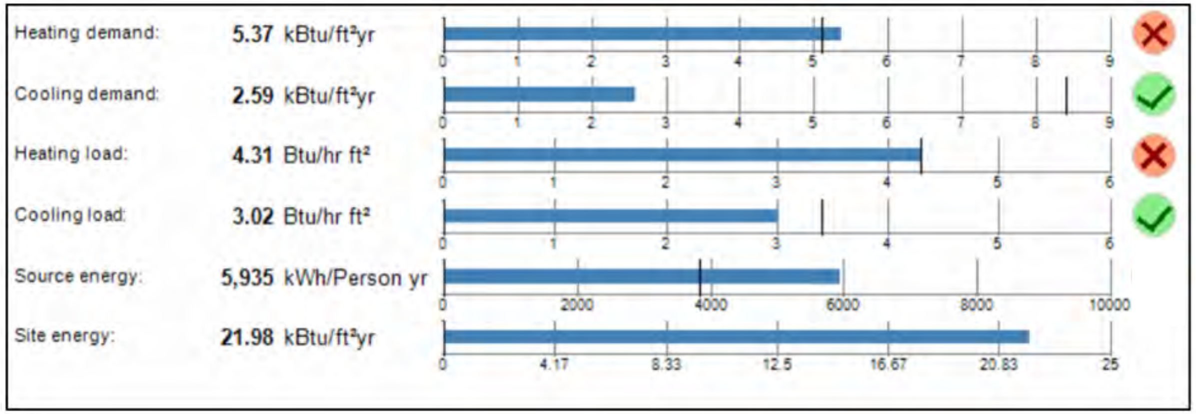
Window Details

Window Sill

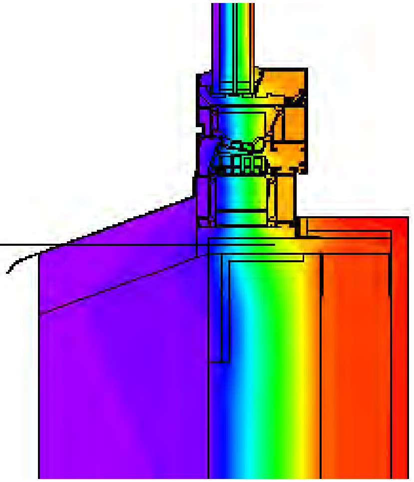


Ψ-**0.086** BTU/hr·ft·F

With this detail the WUFI Passive Model fails

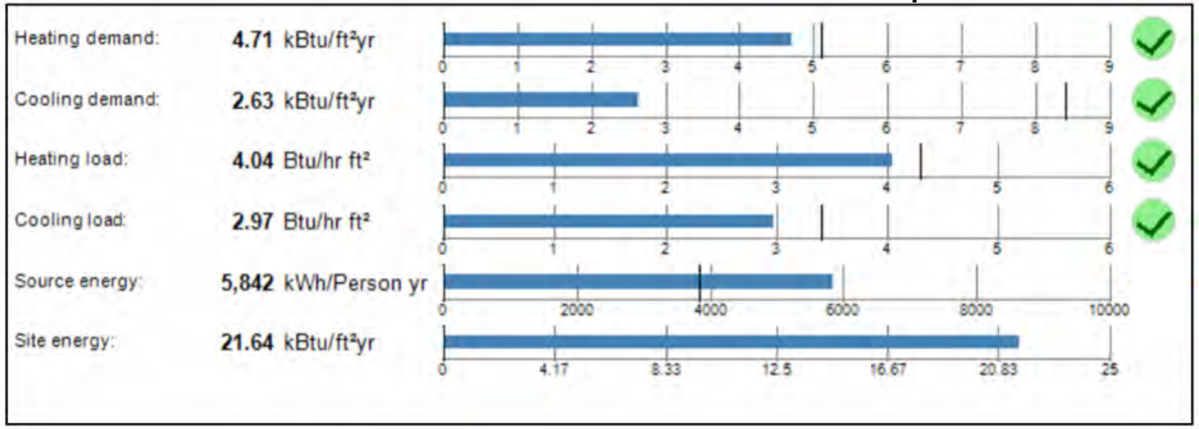


Improved Over-Insulated Window Sill

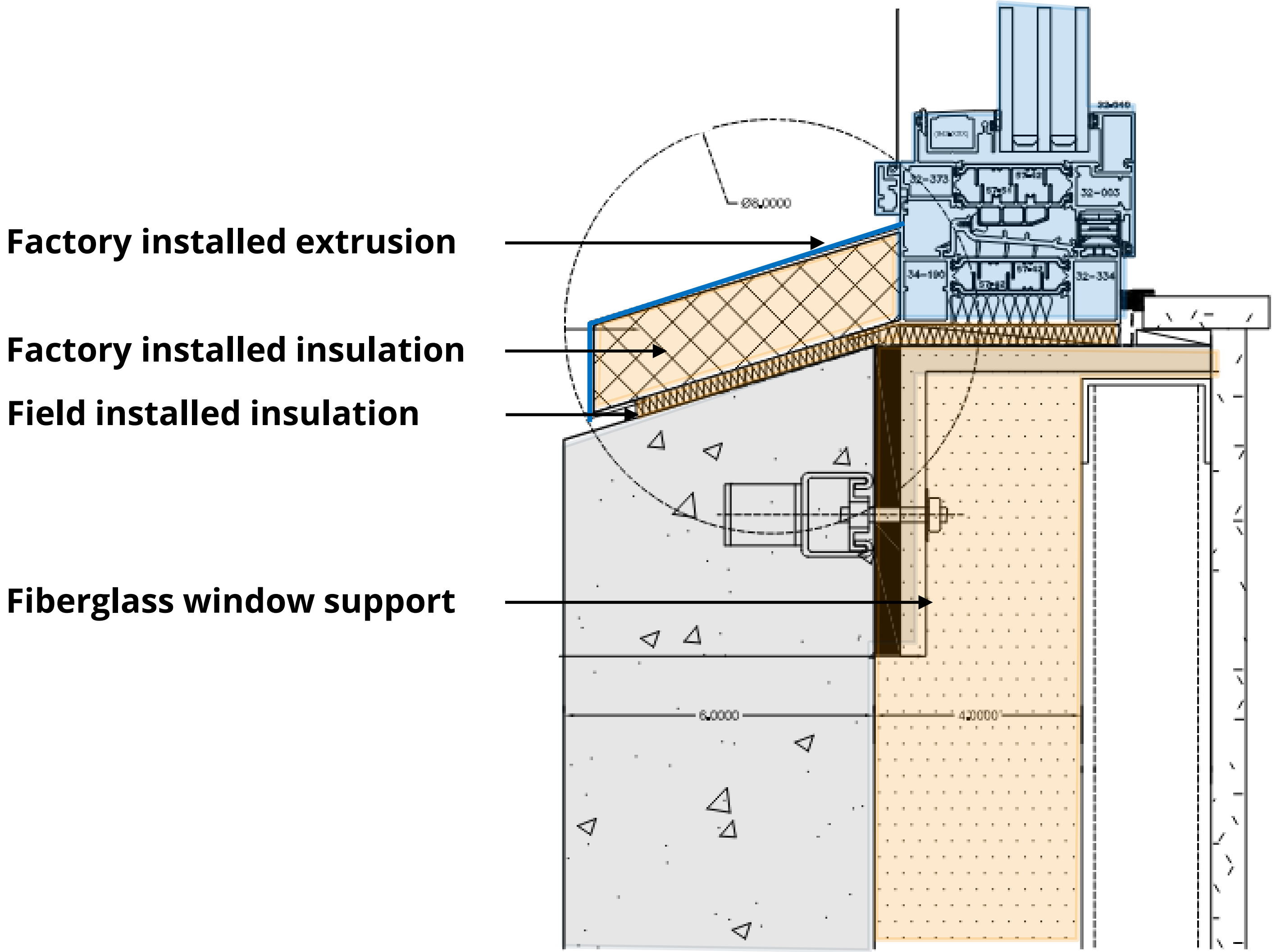


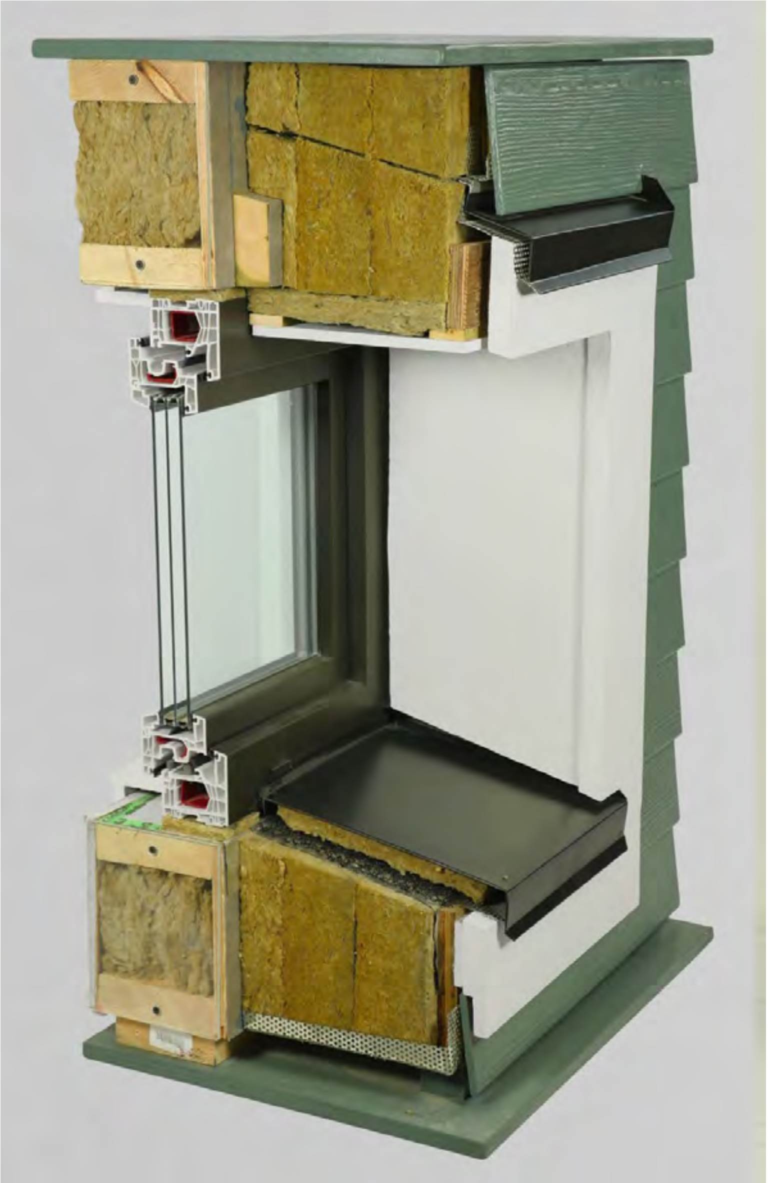
Ψ-**0.035** BTU/hr·ft·F

With this detail the WUFI Passive Model passes



Window Details

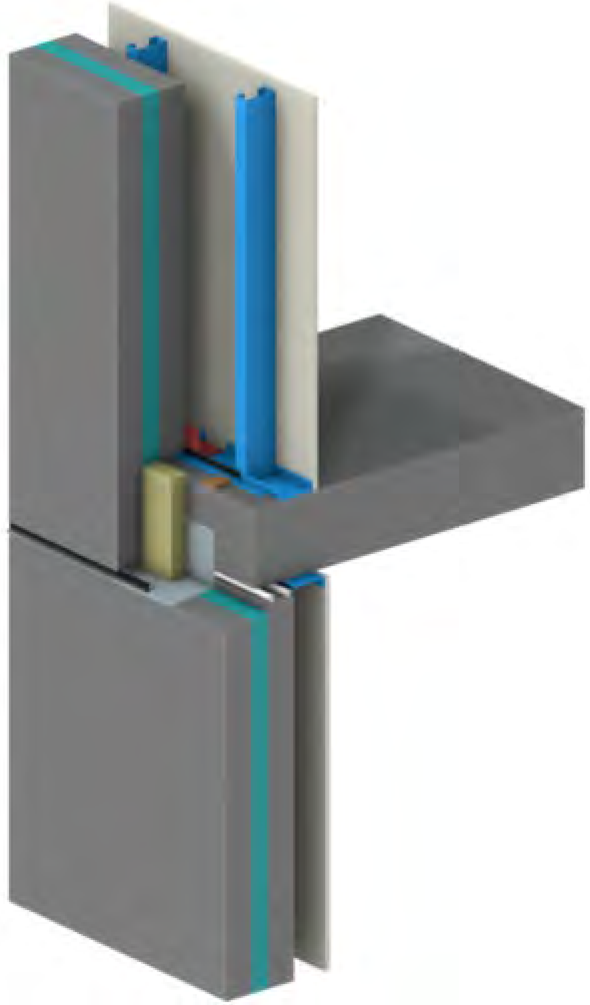




Precast Conclusions

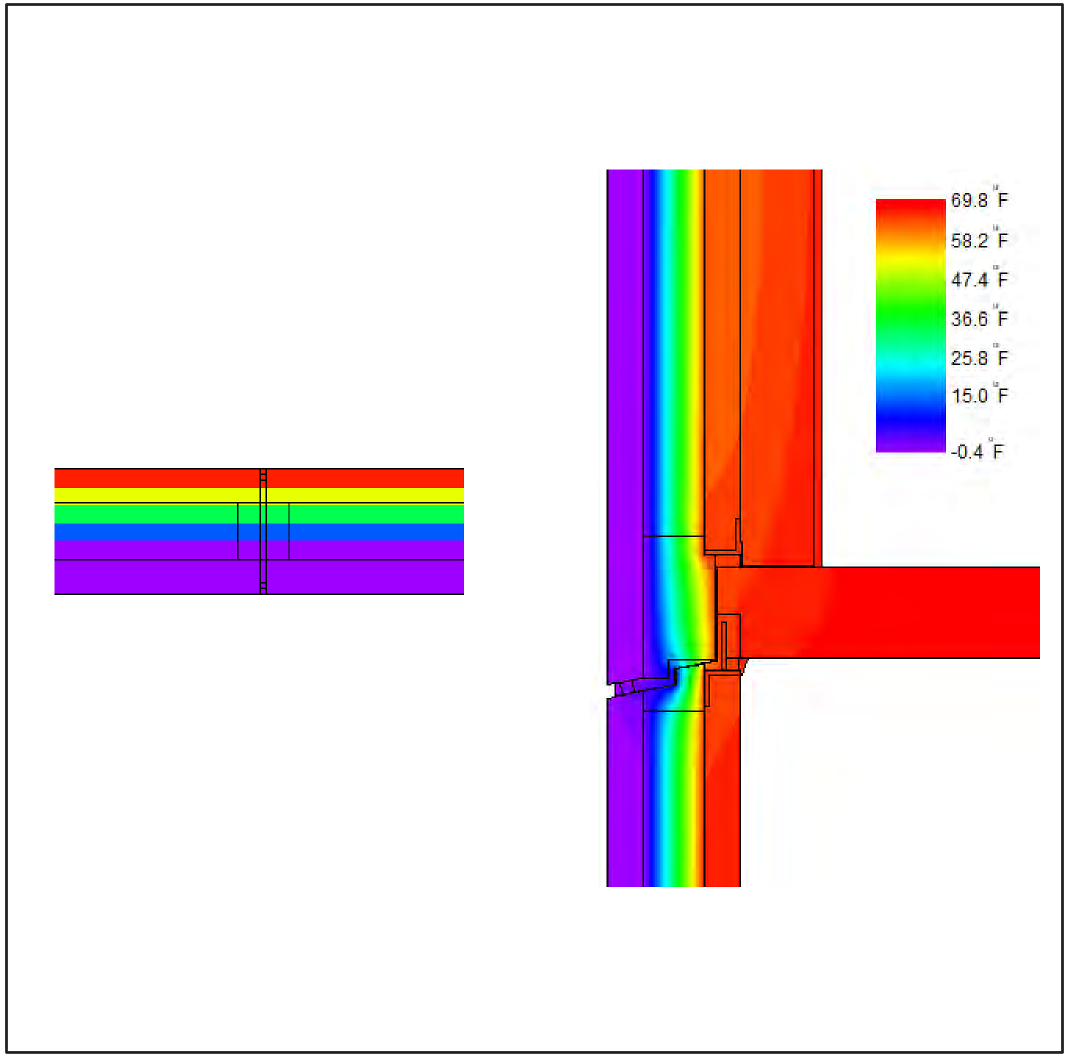
- → With the optimized “Double Doughnut” large panel layout, with minimum number of anchors, it is possible to achieve the necessary R-20.
- → Other layouts will result in lower clear field R-values.
- → Slab edges MUST be held back minimum 4” from inside face of panel with deep mineral wool firestop. This requires design and structural coordination.
- → With 2” lifts on closed cell spray foam, thickness adds up quickly if requiring more R-value.
- → 4” of CCSPF in this case remains feasible, but there are diminishing returns on insulation thickness when ability to mitigate other thermal bridges is limited.
- → Limits to how much spray foam insulation we can put on the inside face of panels before it imposes on usable square footage of building and the structural system.
- → Have to design it “just right” to make the system work.

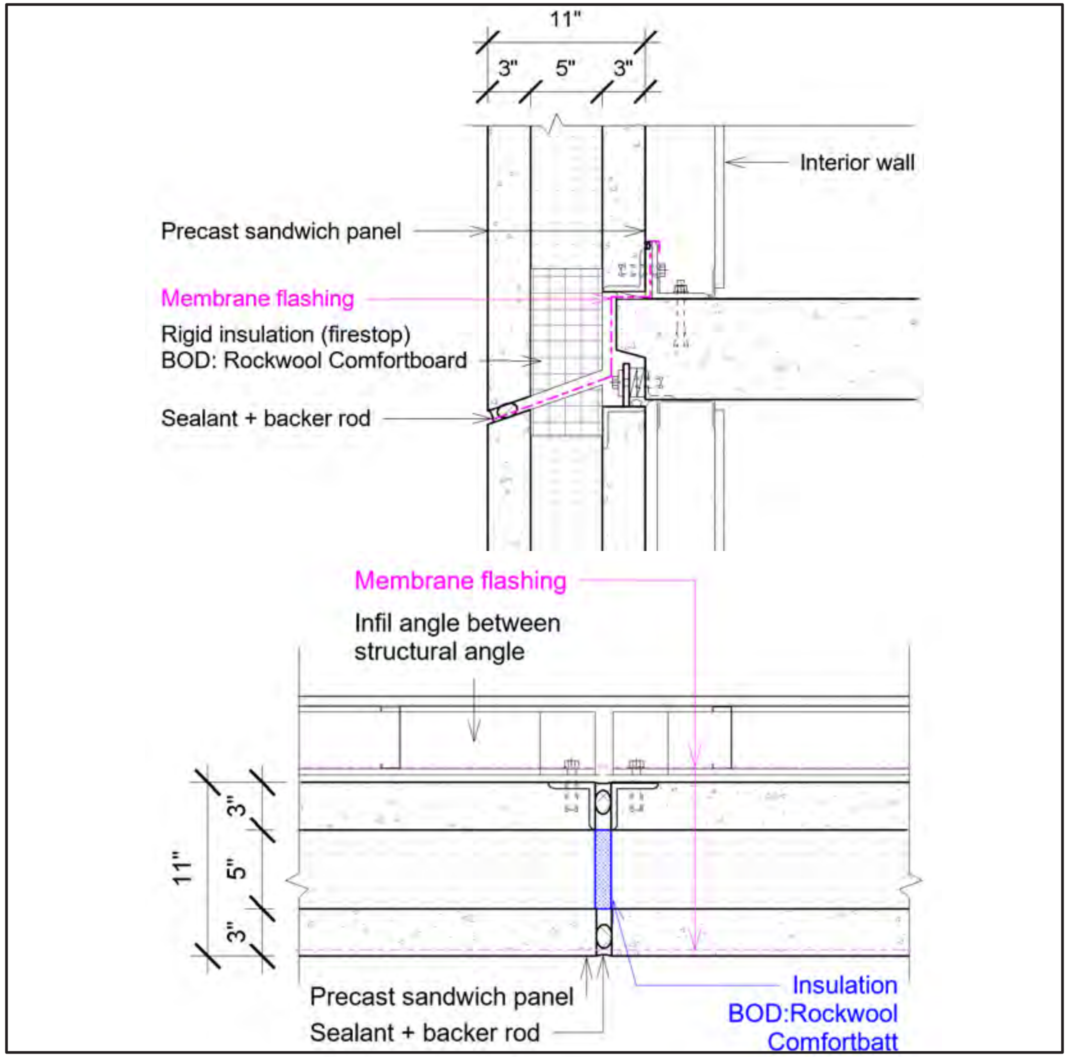
Precast Concrete Sandwich Panel



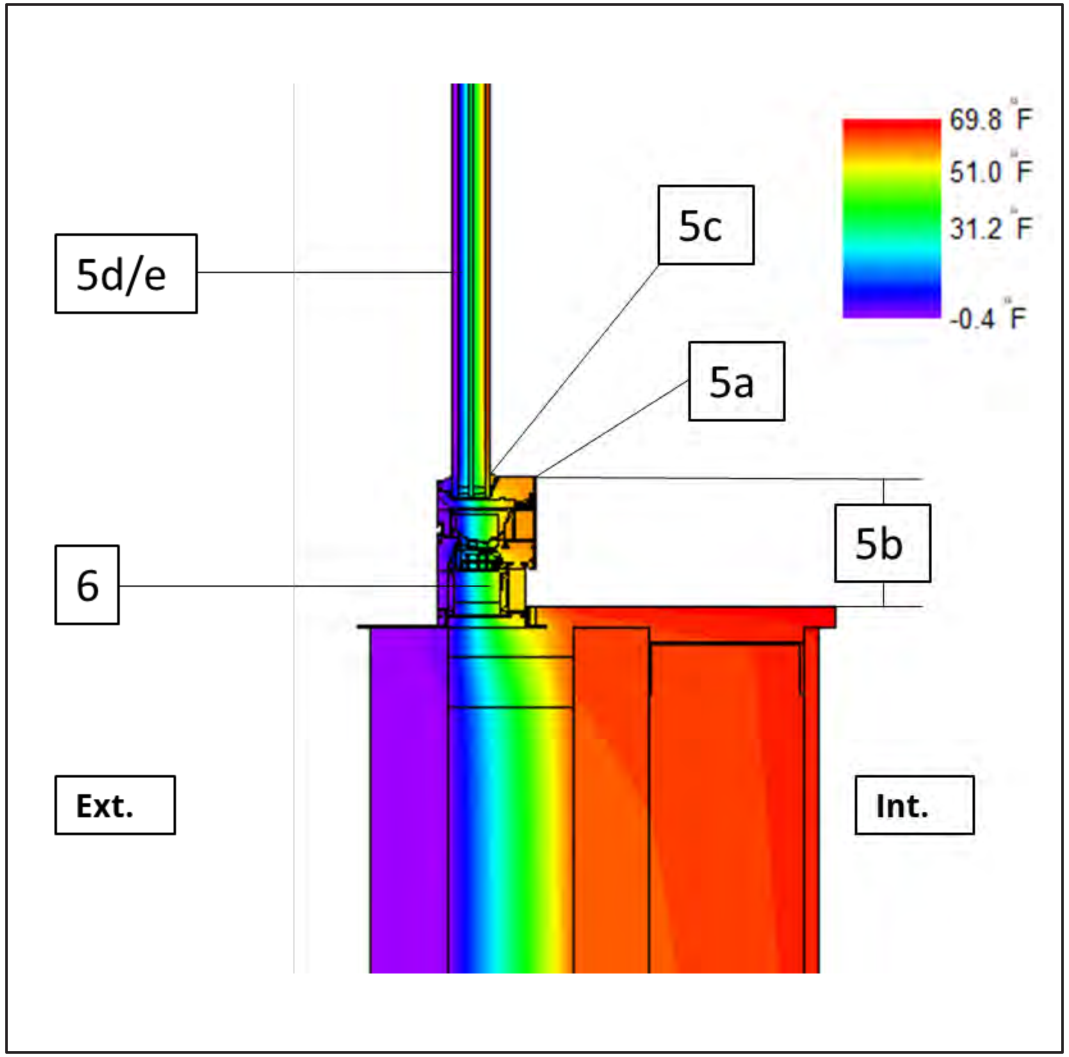
ID	Description	Quantity	Baseline from PH Model	Precast Sandwich Results
	Opaque			
1	Center of Panel	152 sq ft	*no break out value*	U-0.047 BTU/hr·ft^2·F
2	Vertical Panel Joint	10.5 ft	*no break out value*	*(Thermal Bridge Free with insulated vertical joint)*
3	Horizontal Panel Joint	21.6 ft	*no break out value*	Ψ-0.018 BTU/hr·ft·F
4	Anchors	2	*(Thermal Bridge Free)*	*(Thermal Bridge Free)*
Clear Field (Opaque)		152 sq ft	**U-0.05 BTU/hr.ft^2.F (R-20)**	**U-0.050 BTU/hr·ft^2·F (R-20.0)**
	Transparent			
5	Windows	76 sf	U-0.197 BTU/hr.ft^2.F	U-0.197 BTU/hr.ft^2.F
6	Window-to-wall Interface (PSI)	49 ft	Ψ-0.035 BTU/hr.ft.F	PSI-0.036 BTU/hr.ft.F *(marginally above target)*
Average Overall Installed Window U-value		NA	**U-0.22 BTU/hr.ft^2.F**	**U-0.22 BTU/hr.ft^2.F**
	Misc. Thermal Bridges			
7	TB04: Intermediate floors	21.6 ft	Ψ-0.040 BTU/hr.ft.F	<0.01 *(Thermal Bridge Free)*
	Overall (Opaque + Transparent)		**U-0.110 BTU/hr.ft^2.F (R-9.1)**	**U-0.107 BTU/hr·ft^2·F (R-9.4)**

Precast Concrete Sandwich Panel

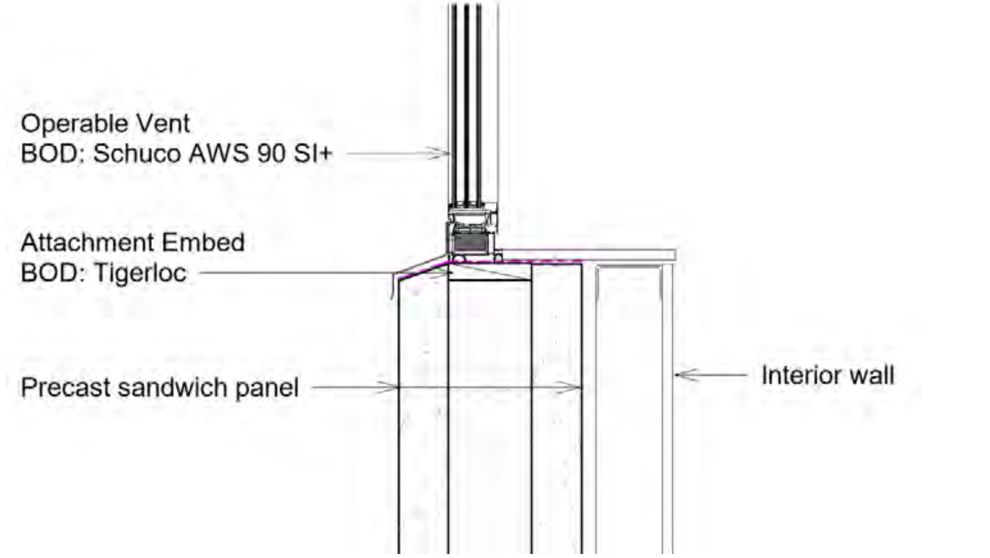




Precast Concrete Sandwich Panel - Windows



ID	Description	BOD	Model Results
5	Operable Vent	**Schuco AWS 90 SI+**	
5a		Frame performance – Operable Threshold	U-0.14 BTU/hr·ft²·F
5b		Frame Width - threshold	4.8 in
5c		Glazing edge thermal bridge	Ψ-0.028 BTU/hr·ft·F
5d		Glazing COG U-value	U-0.12 BTU/hr·ft²·F
5e		Glazing COG SHGC	0.4
6		**Window-to-wall Interface (PSI)**	Ψ-**0.036 BTU/hr·ft·F** *(marginally above target)*



Precast Sandwich Conclusions

- Mitigates thermal bridging at:
  - Floor plates
  - Wall anchors
  - Rough openings

- Limitations on depth of outer wythe of concrete, requires design that does not use deeper concrete for façade articulation.
- Still novel for many Precasters

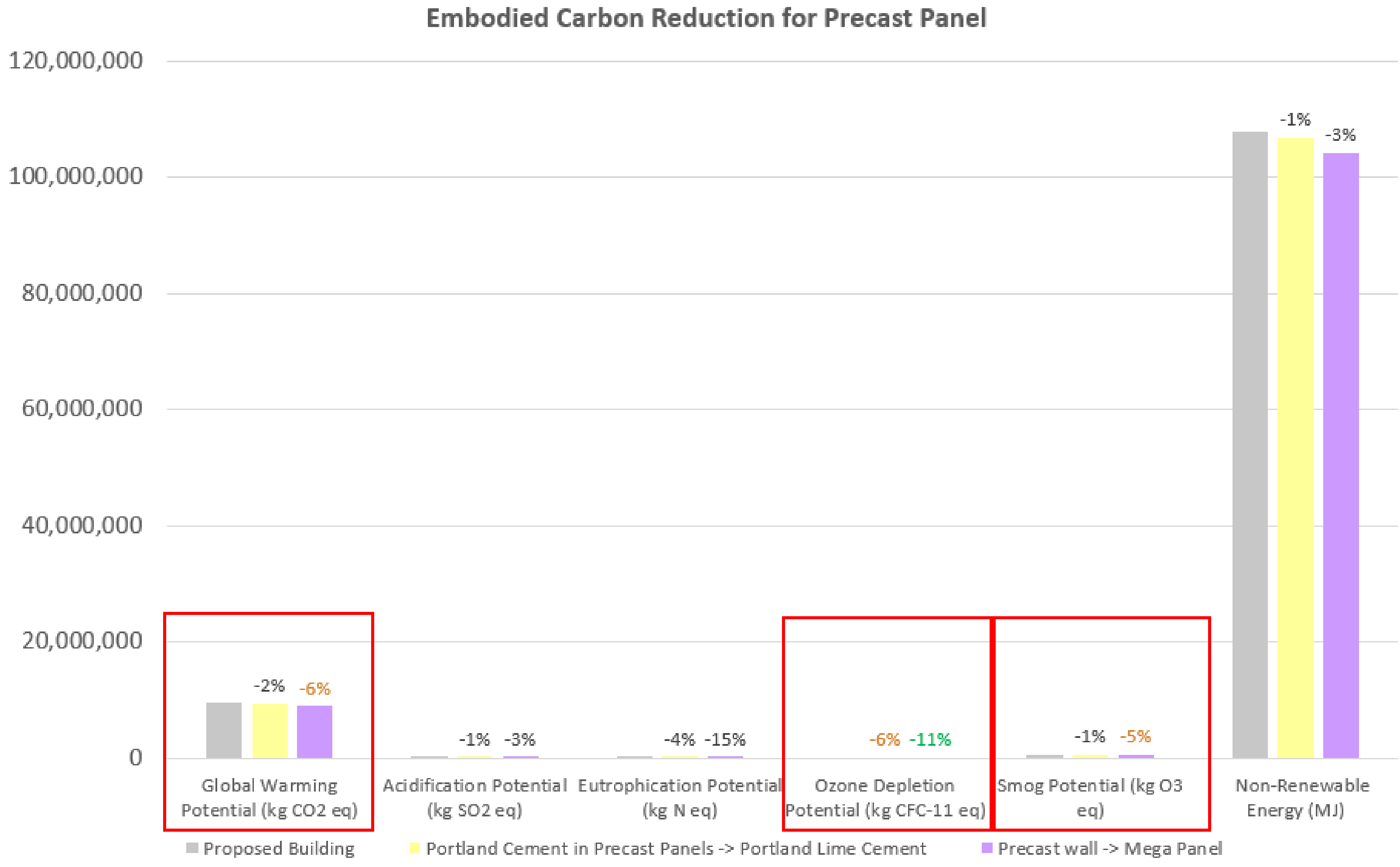
Embodied Carbon

Precast Panel

Proposed Building:

Substitute the conventional concrete mixture in the **Precast Panels** of the proposed model with a **15% fly ash (FA) Portland Lime cement (GUL)** concrete blend, while maintaining the same strength.

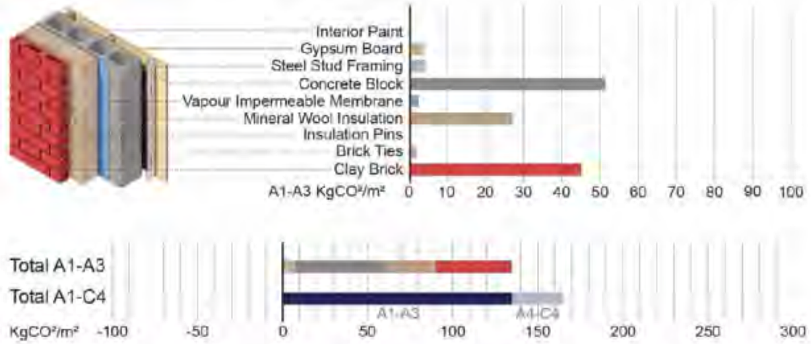
Replace the **Precast Panel Wall Assembly** of the proposed model with a **Mega Panel Wall Assembly** with equivalent thermal performance.



Embodied Carbon

W01: Results Summary

Metrics	Results
Description	**Exterior Insulated CMU with Brick Veneer**
Effective R-value	RSI-4.6 m^2K/W | R-26 $ft^2 \cdot °F \cdot h/BTU$
Embodied Carbon per m^2 of Enclosure (A1-A3)	136.3 $kgCO_2/m^2$
Biogenic Carbon per m^2 of Enclosure	0 $kgCO_2/m^2$



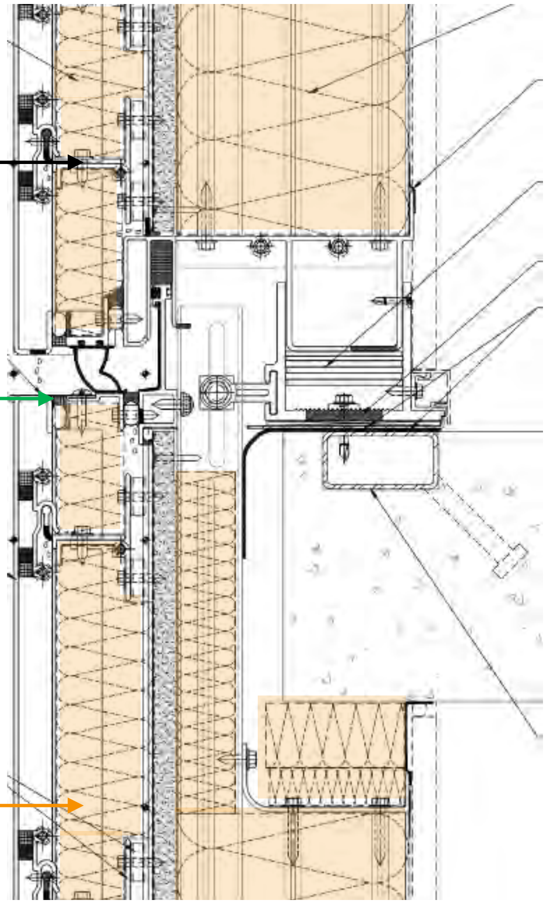
W01: Assembly Effective R-value Calculation

Description	d	t	k	C (USI)	$RSI_{effective}$	$R_{effective}$	$R_{nominal}$
Units	mm	in	W/m·K	W/m^2K	m^2K/W	$ft^2 \cdot °F \cdot h/BTU$	$ft^2 \cdot °F \cdot h/BTU$
Interior Film					0.12	0.68	
Interior gypsum board	12.7	0.50	0.16	27.0	0.04	0.21	
Steel stud-framed wall	63.5	2.50	0.49	7.75	0.13	0.73	
Single-wythe CMU wall	203	8.00	1.18	5.81	0.17	0.98	
Self-adhered sheet-applied air, vapour, and water-resistive barrier (AVB/WRB) membrane	1.00	0.03	-	-	-	-	
Semi-rigid mineral fiber exterior insulation with intermittent stainless steel masonry veneer anchors	152	6.00	0.04	0.24	4.09	23.2	25.8
Air cavity	25.0	0.98	0.03	-	-	-	
Anchored masonry veneer	90.0	3.54	0.79	8.78	-	-	
Exterior air film					0.03	0.17	
TOTALS	**548**	**21.6**			**4.6**	**26.0**	**25.8**

https://www.rdh.com/blog/embodied-carbon-resources-for-building-enclosures/


FAÇADE INNOVATIONS

Glazed Wall Systems– Further Improvement

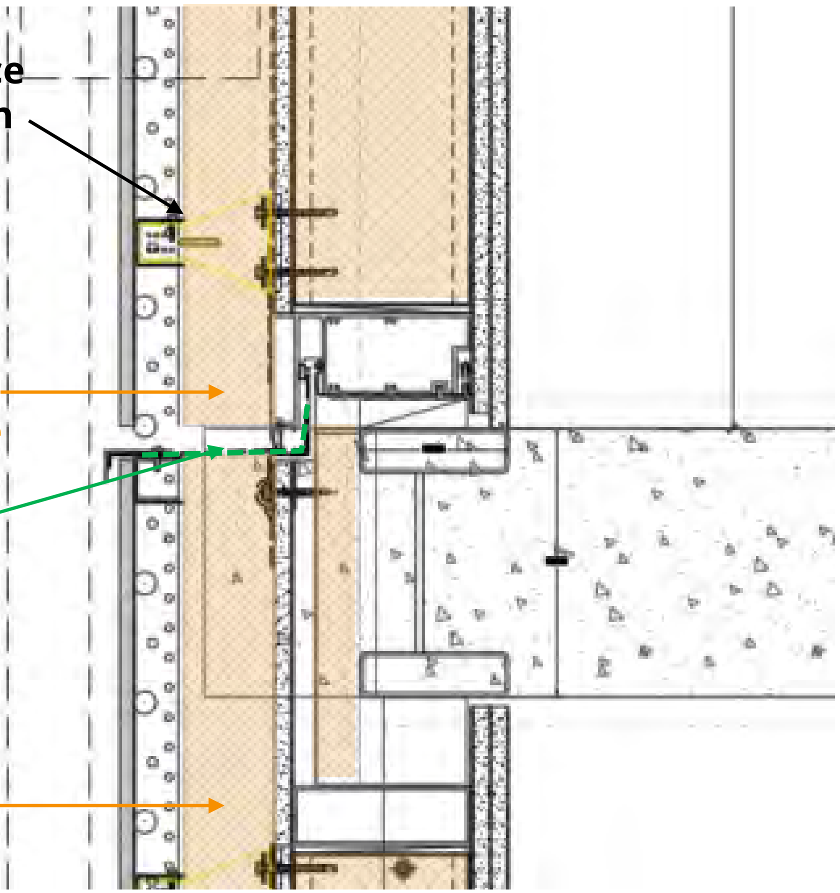


Continuous aluminum rail on thermal shims

Thermally broken Aluminum girt

6” stud wall with insulation between studs. 3” mineral wool insulation outboard of AVB

Base Section Detail



High performance thermally broken clip system (rail outboard of insulation)

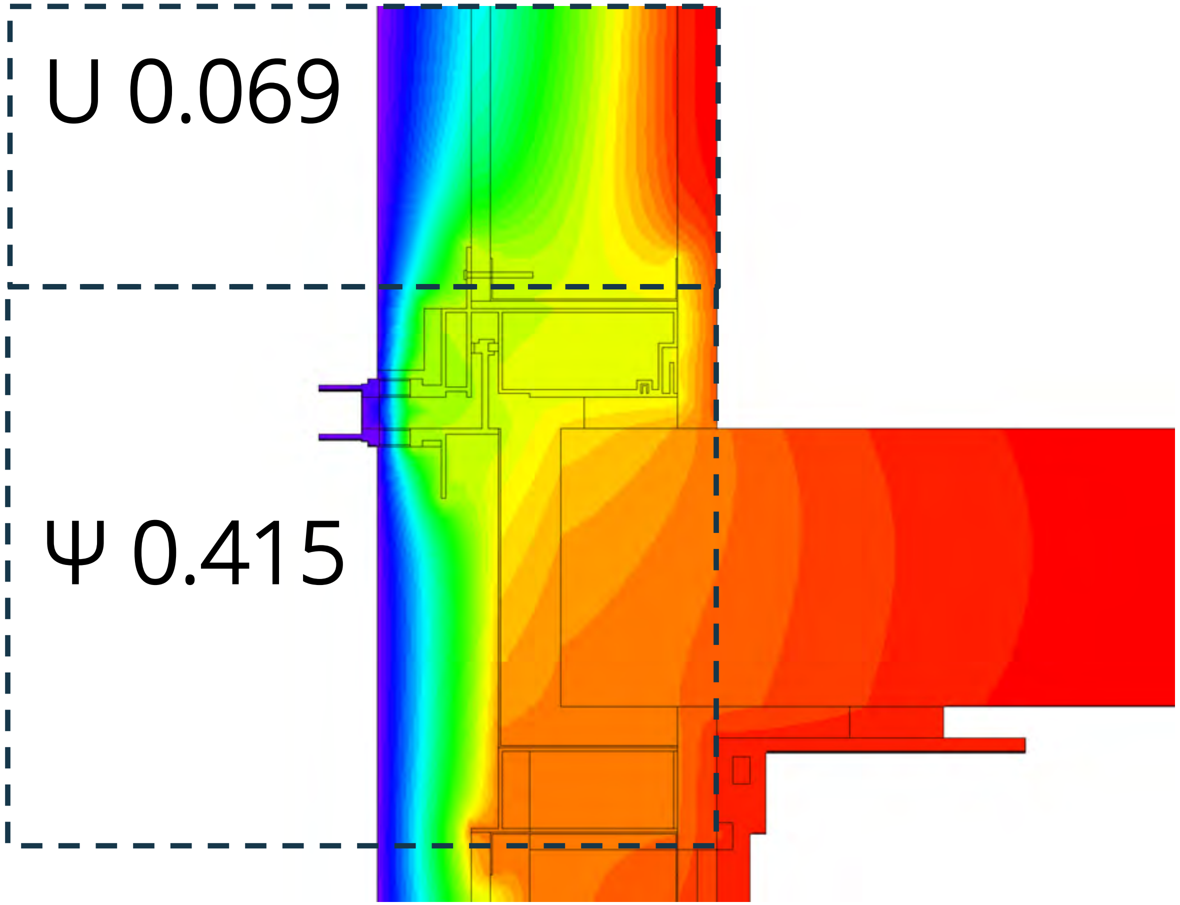
Continuous insulation over aluminum frame

Membrane flashing

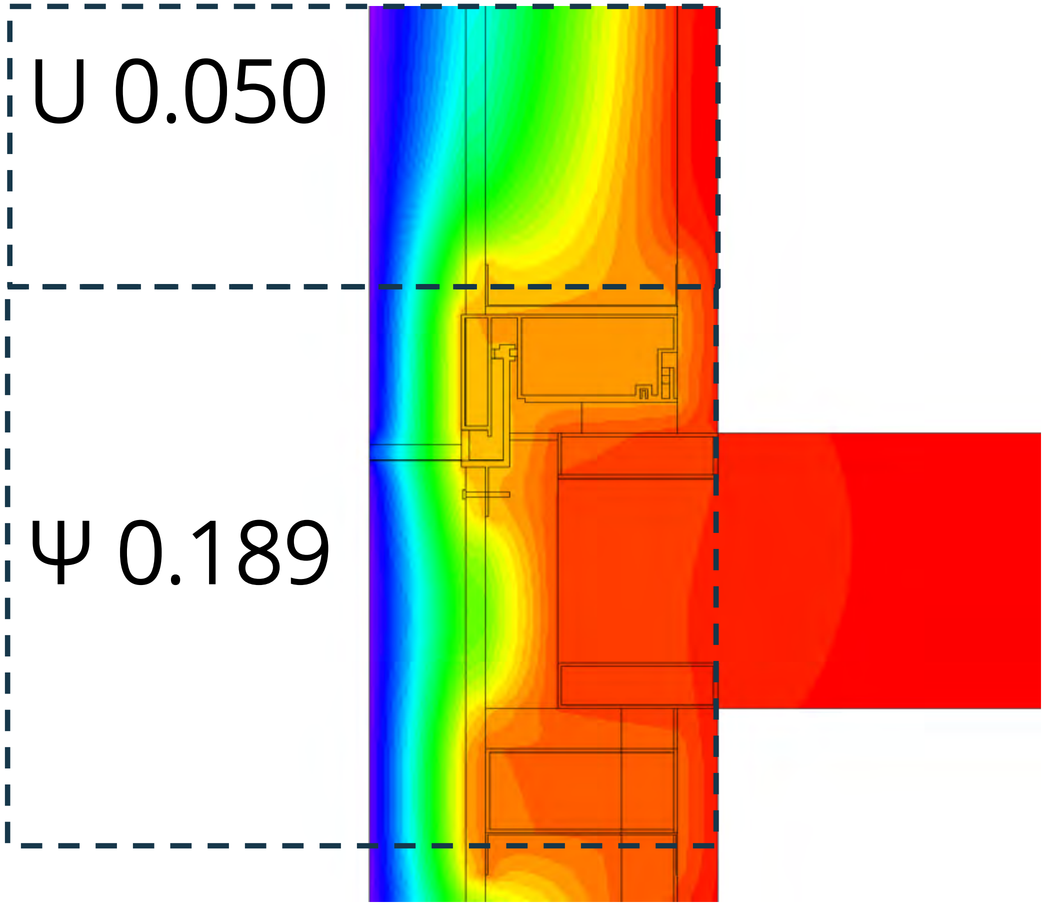
6” stud wall with insulation between studs. 3” mineral wool insulation outboard of AVB

Improved Section Detail

Glazed Wall Systems– Further Improvement



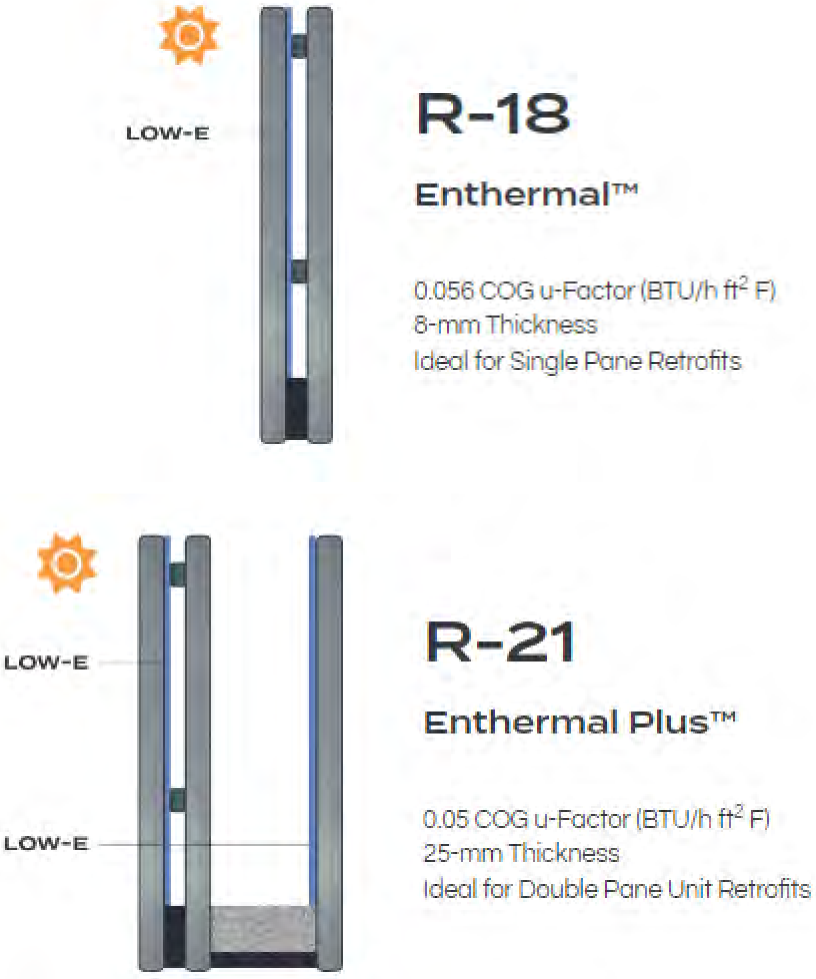
Overall: U 0.086 (R11.6)



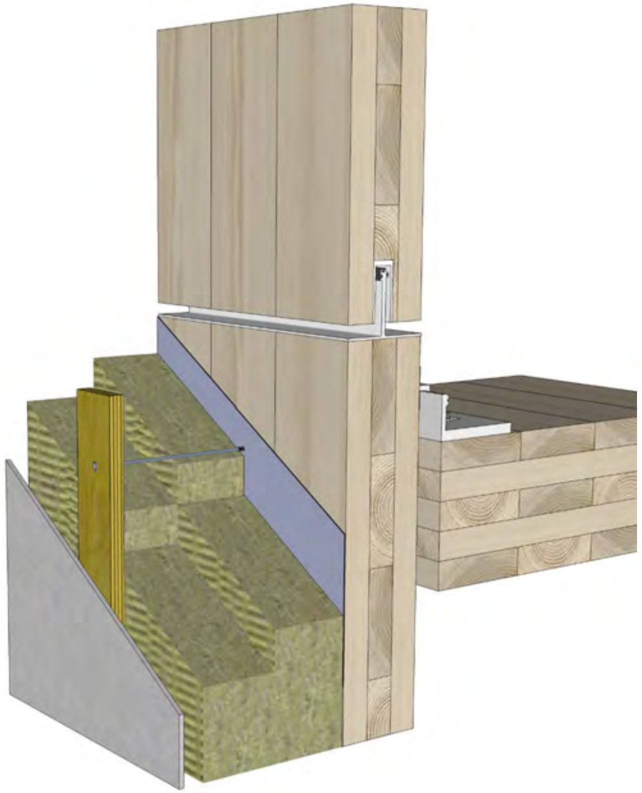
Overall: U 0.055 (R18.2)

Fiberglass frames

Vacuum Insulated Glazing



Mass Timber Facades



Conclusions

- Achieving PH required R-values in conventional large-scale panel systems can be achieved but can be challenging and requires careful design consideration and engineering.
- It is necessary to understand the specific limitations of any system being considered.
- Design phase requires accurate enclosure thermal accounting to minimize performance gap, ensuring that buildings will perform as designed.
- Follow a process where:
  - Account for the performance of each component
  - Understand the holistic influences of structural, architectural and other disciplines on thermal design.
  - Determine the relative impact of each component on the thermal performance to know where to best focus design efforts
  - Confirm through thermal modeling
- Early Phase coordination is required from all stakeholders for both Passive House and Panelization

Thank You.

Image: IFAW

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