BUILDINGENERGY BOSTON

# The Balancing Act: Reducing Embodied and Operational Carbon in High-Performance Envelopes

**David Charney, Goody Clancy**
**Felipe Francisco, Studio NYL**
**Rachael Gerry, Goody Clancy**

***Curated by Ilka Cassidy***

**Northeast Sustainable Energy Association (NESEA) | March 24, 2026**

# Presenters

**David Charney, AIA**
Senior Associate
Goody Clancy

**Felipe Francisco, AIA, CPHC**
Principal - Façade Design
Studio NYL, a Lerch Bates Company

**Rachael Gerry, AIA, CPHD**
Associate
Goody Clancy

# Learning Objectives

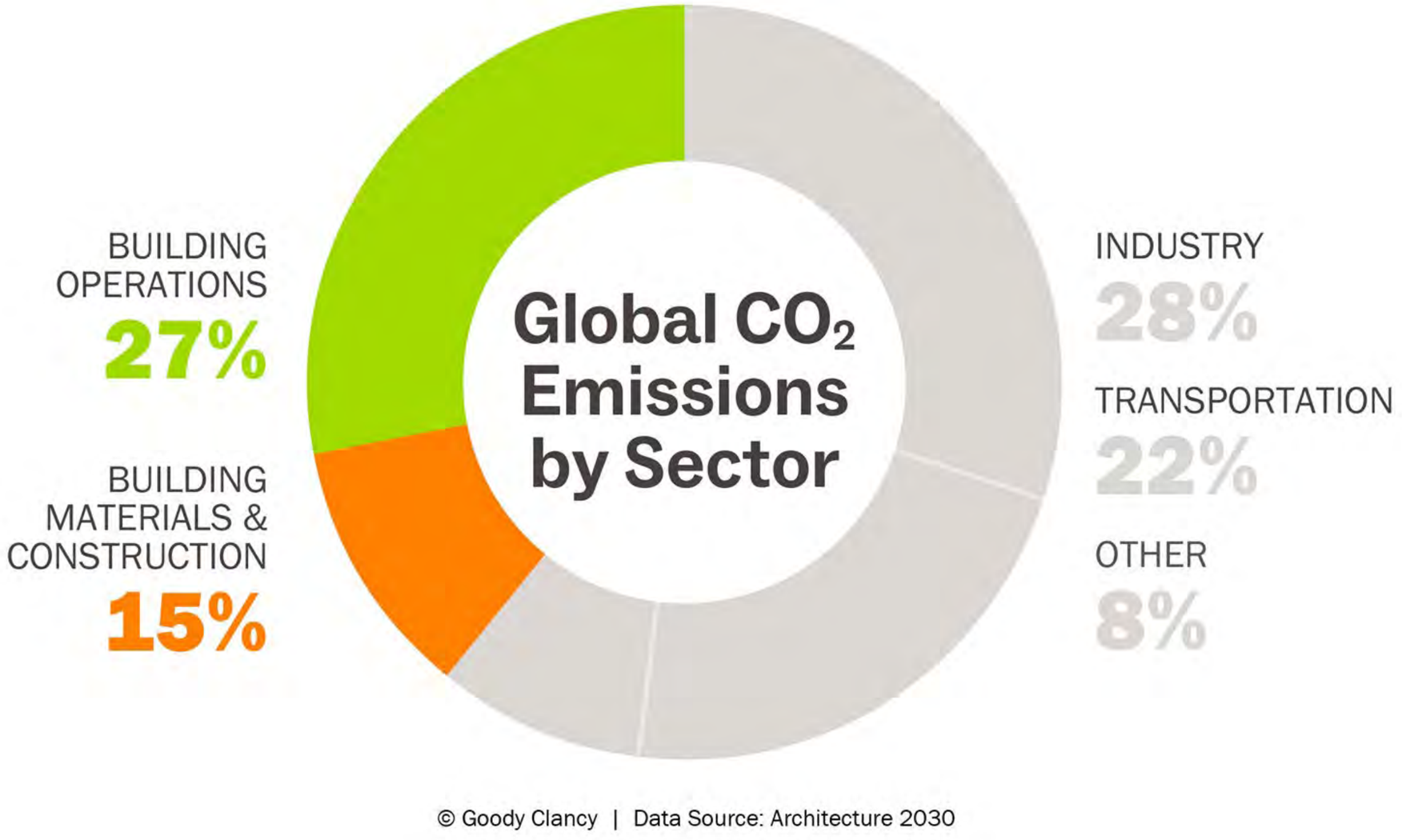
- Identify how evolving energy codes are influencing the design and performance requirements of exterior envelope assemblies.
- Evaluate embodied vs. operational carbon tradeoffs across different project typologies, including existing building retrofits and new construction projects.
- Apply practical strategies for reducing embodied carbon in exterior envelopes, including reducing material use and optimizing backup structures.
- Interpret embodied carbon data from project examples to inform material and assembly choices.

# Why Envelope Embodied Carbon Matters

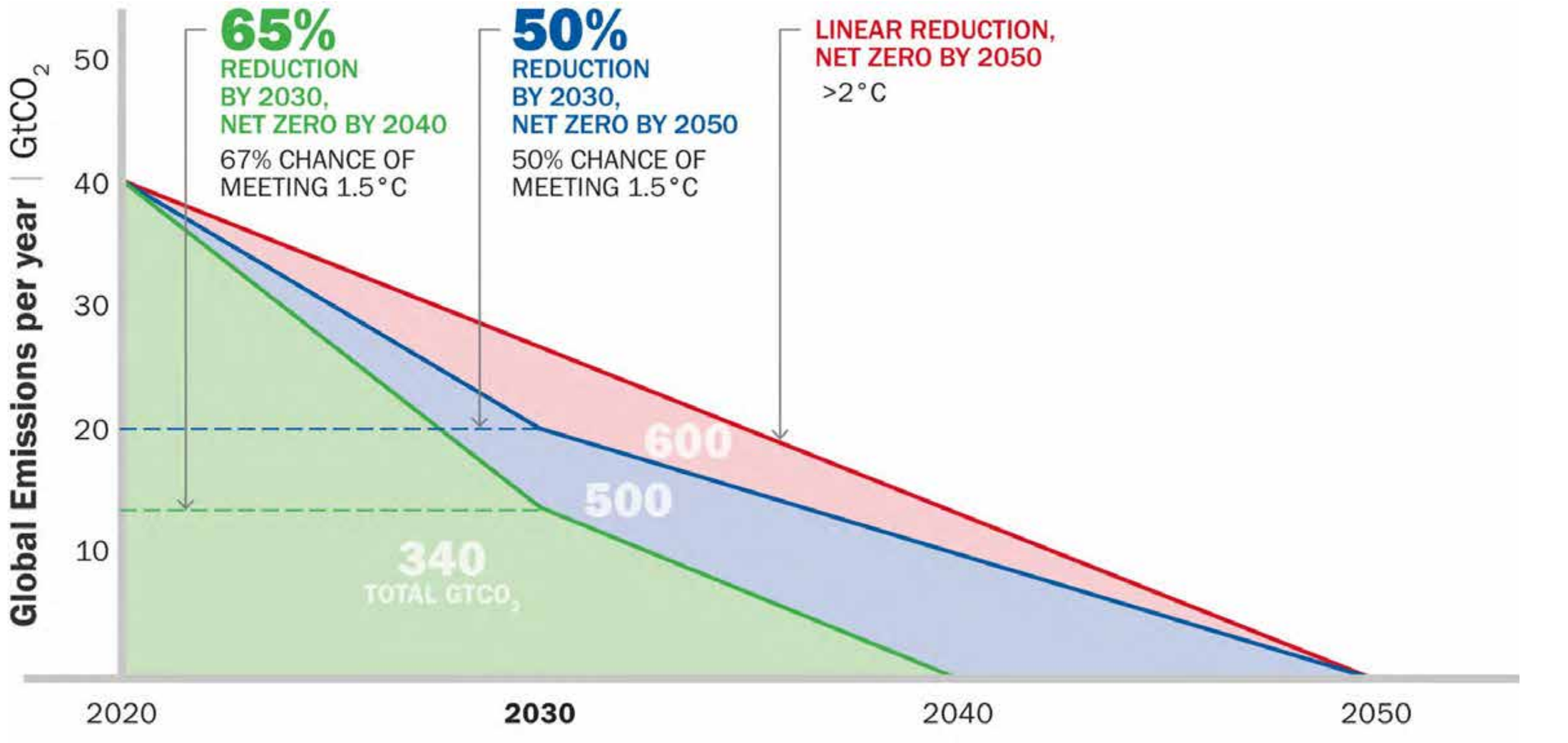
# Global Carbon Emission by Sector

**“The built environment is responsible for about 42% of annual global CO2 emissions.”**

- Architecture 2030



# The Time Value of Carbon



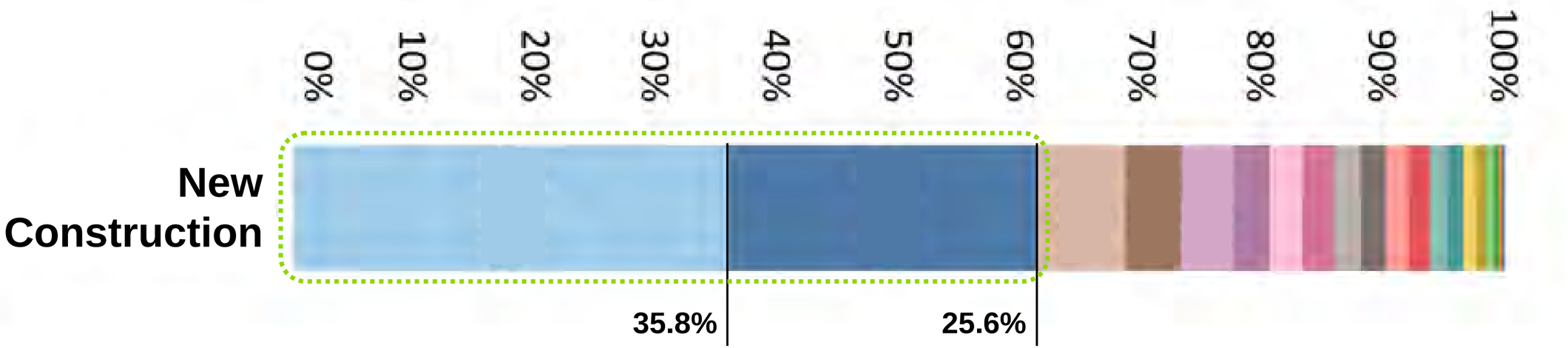


DATA SOURCE: ARCHITECTURE 2030

# Embodied Carbon Impact by Category – New Construction

**Concrete & Steel on average account for over 60% of a building's total embodied carbon**

- Carbon Leadership Forum




SE2050
COMMITTING TO NET ZERO

**Color Legend**

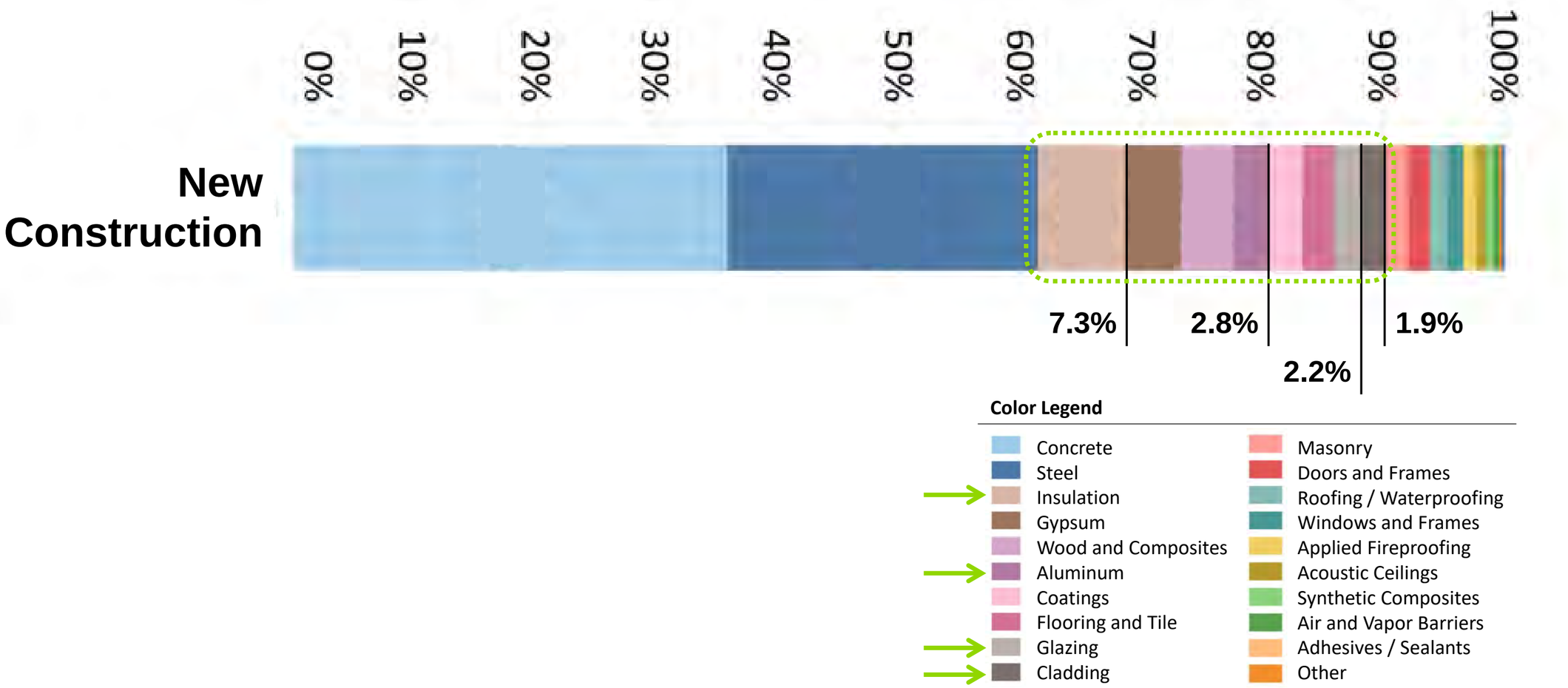
- Concrete
- Steel
- Insulation
- Gypsum
- Wood and Composites
- Aluminum
- Coatings
- Flooring and Tile
- Glazing
- Cladding
- Masonry
- Doors and Frames
- Roofing / Waterproofing
- Windows and Frames
- Applied Fireproofing
- Acoustic Ceilings
- Synthetic Composites
- Air and Vapor Barriers
- Adhesives / Sealants
- Other

Data Source: Carbon Leadership Forum

# Embodied Carbon Impact by Category – New Construction

**Eight material categories on average account for the next 30% of a building's total embodied carbon, including insulation, aluminum, glazing & cladding**

- Carbon Leadership Forum

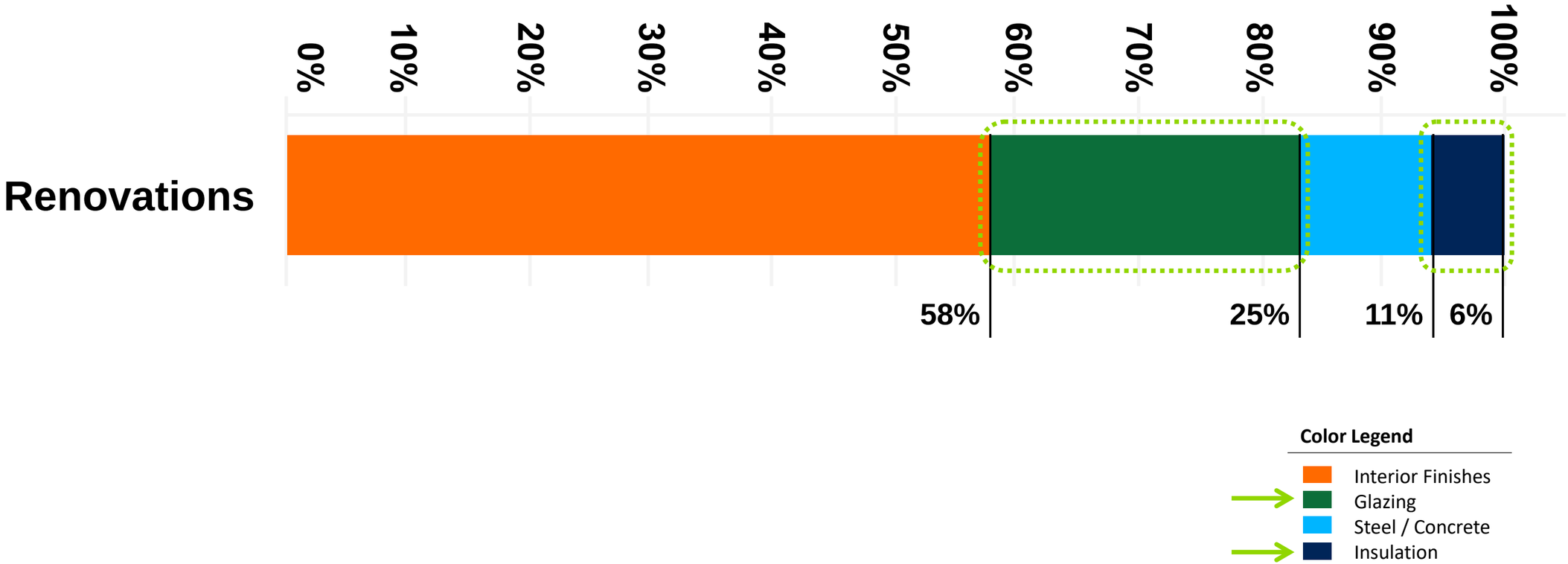



Data Source: Carbon Leadership Forum

# Embodied Carbon Impact by Category – Renovations

**In a renovation project, glazing replacement and roof & wall insulation around for over 30% of the project's total embodied carbon.**

- CARE Tool



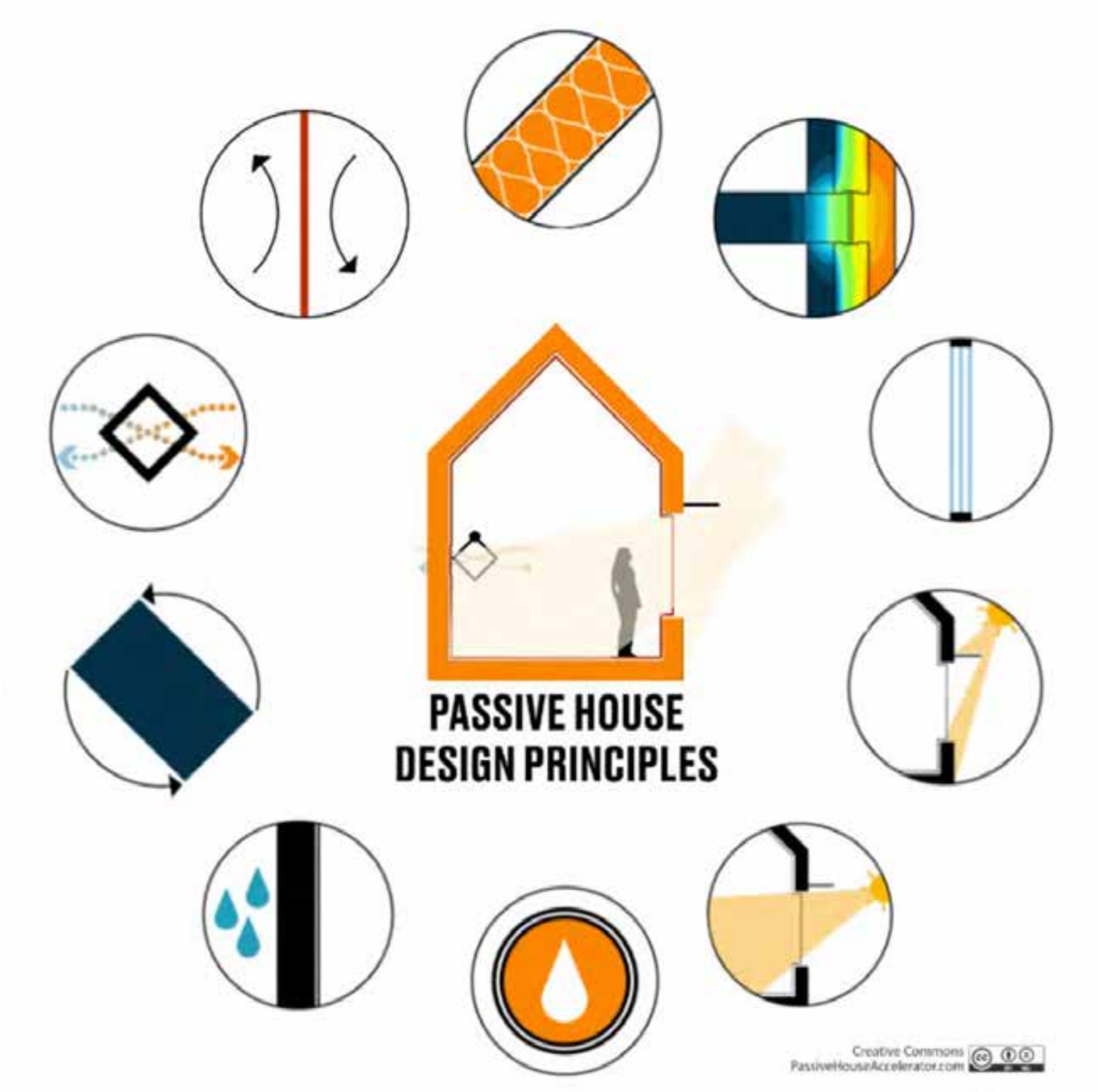


DATA SOURCE: CARE Tool & Carbon Leadership Forum

# Balancing Low-Carbon & High Performance

**The Building Envelope does a lot for a building – controlling air leakage, water infiltration & thermal performance.**

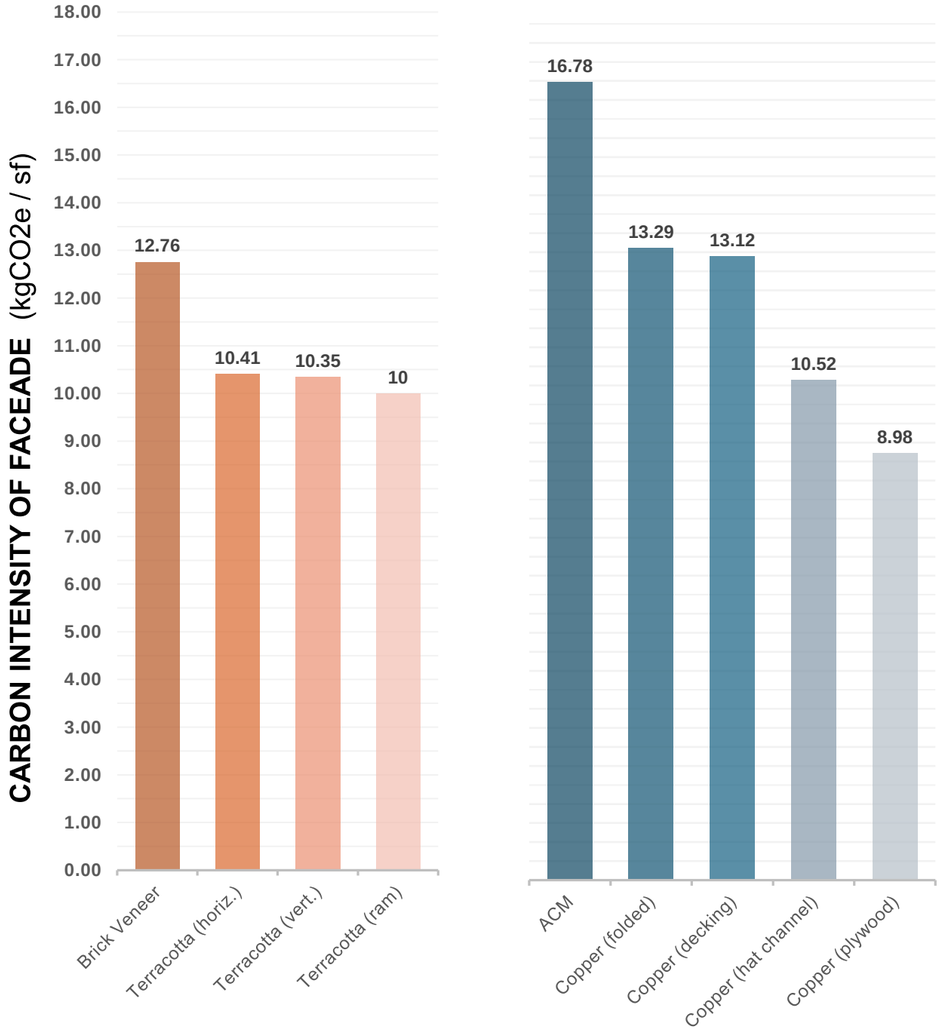
**How do you drive down carbon without sacrificing performance?**



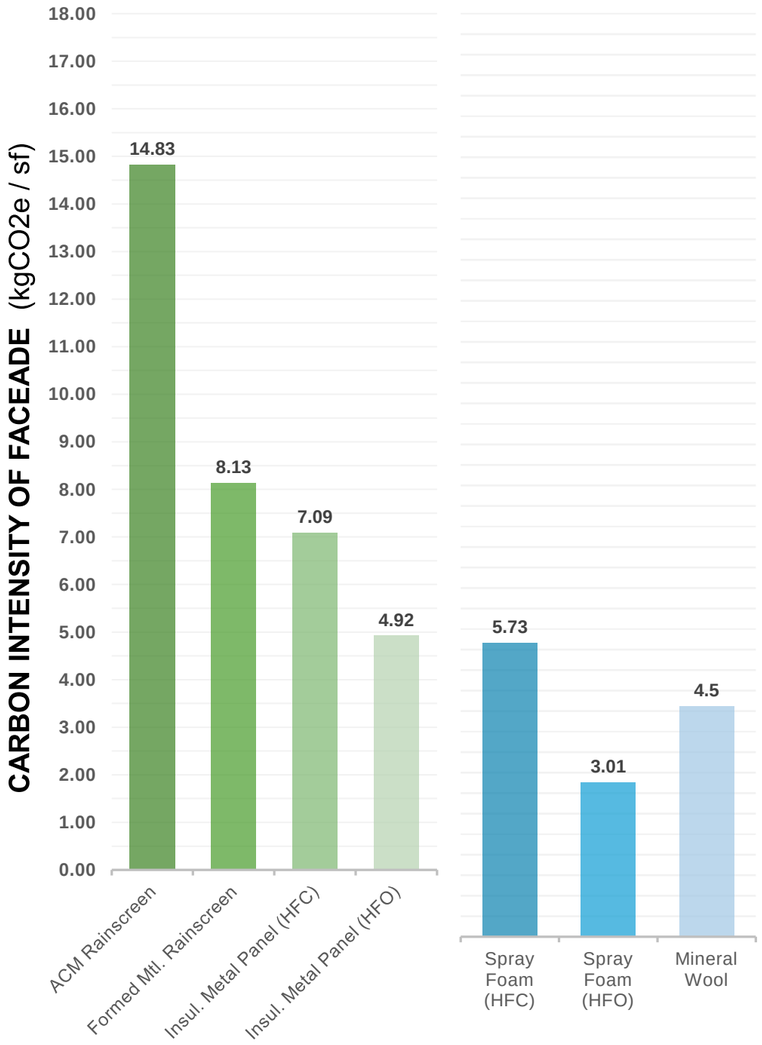
# Importance of Early Analysis

- 2021 IECC Baseline Insulation Value = U-0.055

## NEW CONSTRUCTION ASSEMBLIES




## ENVELOPE RETROFIT ASSEMBLIES





DATA SOURCE: EXTERIOR ENVELOPE

# **The Impact of New Codes**: More Materials, Higher Carbon

# WHAT ARE "PERFORMANCE" BASED CODES?

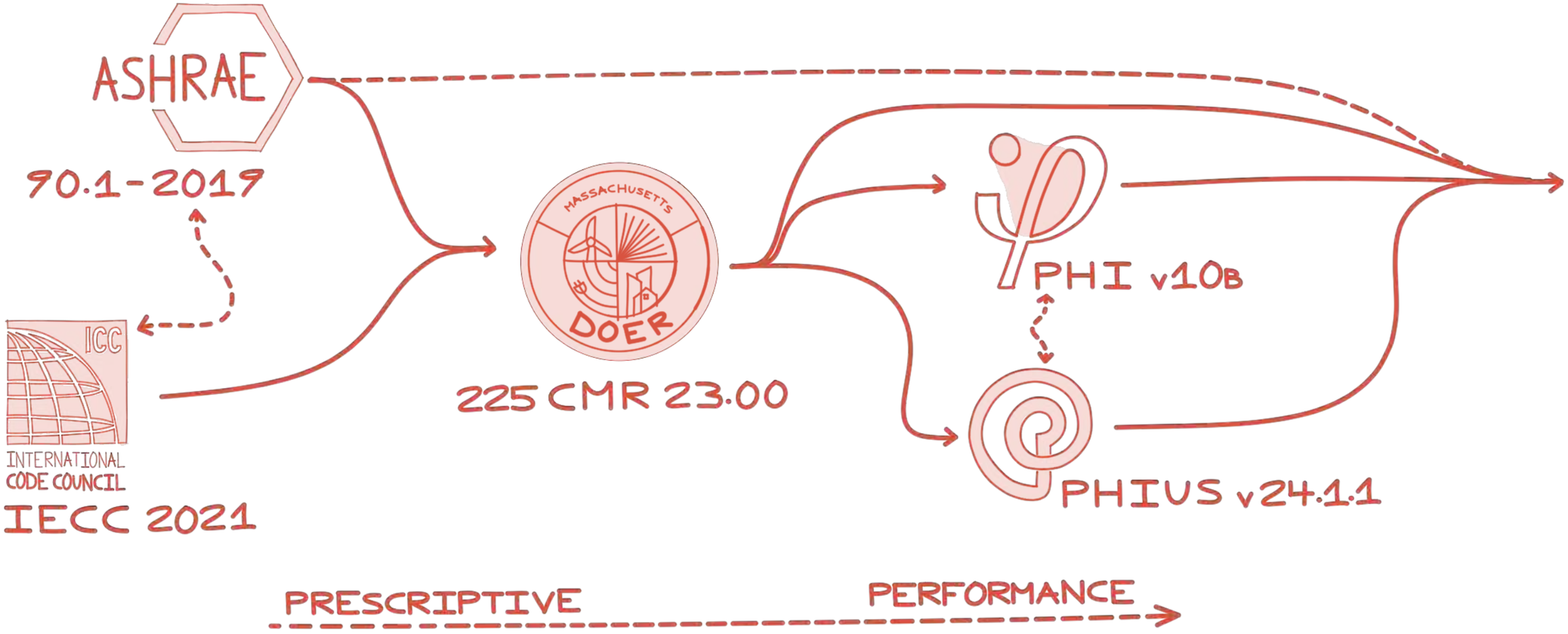

ASHRAE
90.1-2019
ICC
INTERNATIONAL
CODE COUNCIL
IECC 2021
MASSACHUSETTS
DOER
225 CMR 23.00
PHI v10B
PHIUS v24.1.1
PRESCRIPTIVE
PERFORMANCE

**TABLE C402.1.3**
**OPAQUE THERMAL ENVELOPE INSULATION COMPONENT MINIMUM REQUIREMENTS, *R*-VALUE METHOD[a]**

| CLIMATE ZONE | 0 AND 1 | | 2 | | 3 | | 4 EXCEPT MARINE | | 5 AND MARINE 4 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | All other | Group R | All other | Group R | All other | Group R | All other | Group R | All other | Group I |
| **Roofs** | | | | | | | | | | |
| Insulation entirely above roof deck | R-20ci | R-25ci | R-25ci | R-25ci | R-25ci | R-25ci | R-30ci | R-30ci | R-30ci | R-30ci |
| Metal buildings[b] | R-19 + R-11 LS | R-19 + R-11 LS | R-19 + R11 LS | R-19 + R-11 LS | R-19 + R-11 LS | R-19 + R-11 LS | R-19 + R-11 LS | R-19 + R-11 LS | R-19 + R-11 LS | R-19 + R-11 LS |
| Attic and other | R-38 | R-38 | R-38 | R-38 | R-38 | R-38 | R-49 | R-49 | R-49 | R-49 |
| **Walls, above grade** | | | | | | | | | | |
| Mass[f] | R-5.7ci[c] | R-5.7ci[c] | R-5.7ci[c] | R-7.6ci | R-7.6ci | R-9.5ci | R-9.5ci | R-11.4ci | R-11.4ci | R-13.3c |
| Metal building | R-13 + R-6.5ci | R-13 + R-6.5ci | R13 + R-6.5ci | R-13 + R-13ci | R-13 + R-6.5ci | R-13 + R-13ci | R-13 + R-13ci | R-13 + R-14ci | R-13 + R-14ci | R-13 + R-14ci |
| Metal framed | R-13 + R-5ci | R-13 + R-5ci | R-13 + R-5ci | R-13 + R-7.5ci | R-13 + R-7.5ci | R-13 + R-7.5ci | R-13 + R-7.5ci | R-13 + R-7.5ci | R-13 + R-10ci | R-13 + R-10ci |
| Wood framed and other | R-13 + R-3.8ci or R-20 | R-13 + R-3.8ci or R-20 | R-13 + R-3.8ci or R-20 | R-13 + R-3.8ci or R-20 | R-13 + R-3.8ci or R-20 | R-13 + R-3.8ci or R-20 | R-13 + R-3.8ci or R-20 | R-13 + R-3.8ci or R-20 | R-13 + R-7.5ci or R20 + R3.8ci | R-13 + R-7.5ci + R-20 + R-3.8c |
| **Walls, below grade** | | | | | | | | | | |
| Below-grade wall[d] | NR | NR | NR | NR | NR | NR | R-7.5ci | R-10ci | R-7.5ci | R-10ci |
| **Floors** | | | | | | | | | | |
| Mass[e] | NR | NR | R-6.3ci | R-8.3ci | R-10ci | R-10ci | R-14.6ci | R-16.7ci | R-14.6ci | R-16.7c |
| Joist/framing | R-13 | R-13 | R-30 | R-30 | R-30 | R-30 | R-30 | R-30 | R-30 | R-30 |
| **Slab-on-grade floors** | | | | | | | | | | |
| Unheated slabs | NR | NR | NR | NR | NR | R-10 for 24" below | R-15 for 24" below | R-15 for 24" below | R-15 for 24" below | R-20 fo 24" belo |
| Heated slabs[g] | R-7.5 for 12" below + R-5 full slab | R-7.5 for 12" below + R-5 full slab | R-7.5 for 12" below + R-5 full slab | R-7.5 for 12" below+ R-5 full slab | R-10 for 24" below + R-5 full slab | R-10 for 24" below + R-5 full slab | R-15 for 24" below + R-5 full slab | R-15 for 24" below + R-5 full slab | R-15 for 36" below + R-5 full slab | R-15 fo 36" belo + R-5 fu slab |

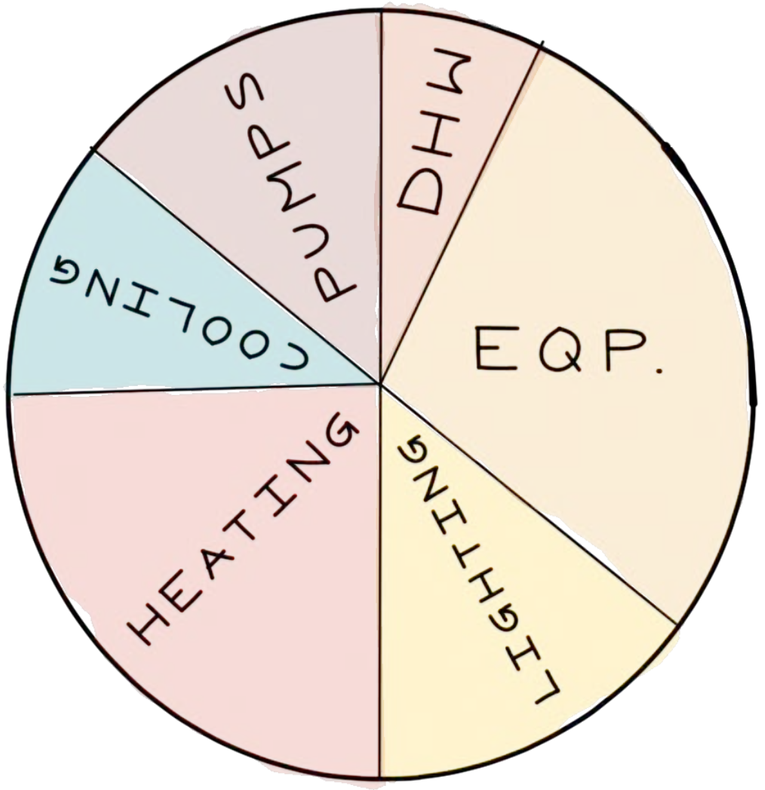
**TABLE C402.1.4OPAQUE THERMAL ENVELOPE ASSEMBLY MAXIMUM REQUIREMENTS, *U*-FACTOR METHOD[a, b]**

| CLIMATE ZONE | 0 AND 1 | | 2 | | 3 | | 4 EXCEPT MARINE | | 5 AND MARINE 4 | | 6 | | 7 | | 8 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | All other | Group R | All other | Group R | All other | Group R | All other | Group R | All other | Group R | All other | Group R | All other | Group R | All other | G |
| **Roofs** | | | | | | | | | | | | | | | | |
| Insulation entirely above roof deck | U-0.048 | U-0.039 | U-0.039 | U-0.039 | U-0.039 | U-0.039 | U-0.032 | U-0.032 | U-0.032 | U-0.032 | U-0.032 | U-0.032 | U-0.028 | U-0.028 | U-0.028 | 0. |
| Metal buildings | U-0.035 | U-0.035 | U-0.035 | U-0.035 | U-0.035 | U-0.035 | U-0.035 | U-0.035 | U-0.035 | U-0.035 | U-0.031 | U-0.029 | U-0.029 | U-0.029 | U-0.026 | 0. |
| Attic and other | U-0.027 | U-0.027 | U-0.027 | U-0.027 | U-0.027 | U-0.027 | U-0.021 | U-0.021 | U-0.021 | U-0.021 | U-0.021 | U-0.021 | U-0.017 | U-0.017 | U-0.017 | 0. |
| **Walls, above grade** | | | | | | | | | | | | | | | | |
| Mass[f] | U-0.151 | U-0.151 | U-0.151 | U-0.123 | U-0.123 | U-0.104 | U-0.104 | U-0.090 | U-0.090 | U-0.080 | U-0.080 | U-0.071 | U-0.071 | U-0.071 | U-0.037 | 0. |
| Metal building | U-0.079 | U-0.079 | U-0.079 | U-0.079 | U-0.079 | U-0.052 | U-0.052 | U-0.050 | U-0.050 | U-0.050 | U-0.050 | U-0.050 | U-0.044 | U-0.039 | U-0.039 | 0. |
| Metal framed | U-0.077 | U-0.077 | U-0.077 | U-0.064 | U-0.064 | U-0.064 | U-0.064 | U-0.064 | U-0.055 | U-0.055 | U-0.049 | U-0.049 | U-0.049 | U-0.042 | U-0.037 | 0. |
| Wood framed and other[c] | U-0.064 | U-0.064 | U-0.064 | U-0.064 | U-0.064 | U-0.064 | U-0.064 | U-0.064 | U-0.051 | U-0.051 | U-0.051 | U-0.051 | U-0.051 | U-0.051 | U-0.032 | 0. |
| **Walls, below grade** | | | | | | | | | | | | | | | | |
| Below-grade wall[c] | C-1.140[e] | C-1.140[e] | C-1.140[e] | C-1.140[e] | C-1.140[e] | C-1.140[e] | C-0.119 | C-0.092 | C-0.119 | C-0.092 | C-0.092 | C-0.063 | C-0.063 | C-0.063 | C-0.063 | 0. |
| **Floors** | | | | | | | | | | | | | | | | |
| Mass[d] | U-0.322[e] | U-0.322[e] | U-0.107 | U-0.087 | U-0.074 | U-0.074 | U-0.057 | U-0.051 | U-0.057 | U-0.051 | U-0.051 | U-0.051 | U-0.042 | U-0.042 | U-0.038 | 0. |
| Joist/framing | U-0.066[e] | U-0.066[e] | U-0.033 | U-0.033 | U-0.033 | U-0.033 | U-0.033 | U-0.033 | U-0.033 | U-0.033 | U-0.027 | U-0.027 | U-0.027 | U-0.027 | U-0.027 | 0. |
| **Slab-on-grade floors** | | | | | | | | | | | | | | | | |
| Unheated slabs | F-0.73[e] | F-0.73[e] | F-0.73[e] | F-0.73[e] | F-0.73[e] | F-0.54 | F-0.52 | F-0.52 | F-0.52 | F-0.51 | F-0.51 | F-0.434 | F-0.51 | F-0.434 | F-0.434 | 0. |
| Heated slabs | F-0.69 | F-0.69 | F-0.69 | F-0.69 | F-0.66 | F-0.66 | F-0.62 | F-0.62 | F-0.62 | F-0.62 | F-0.62 | F-0.602 | F-0.602 | F-0.602 | F-0.602 | 0. |

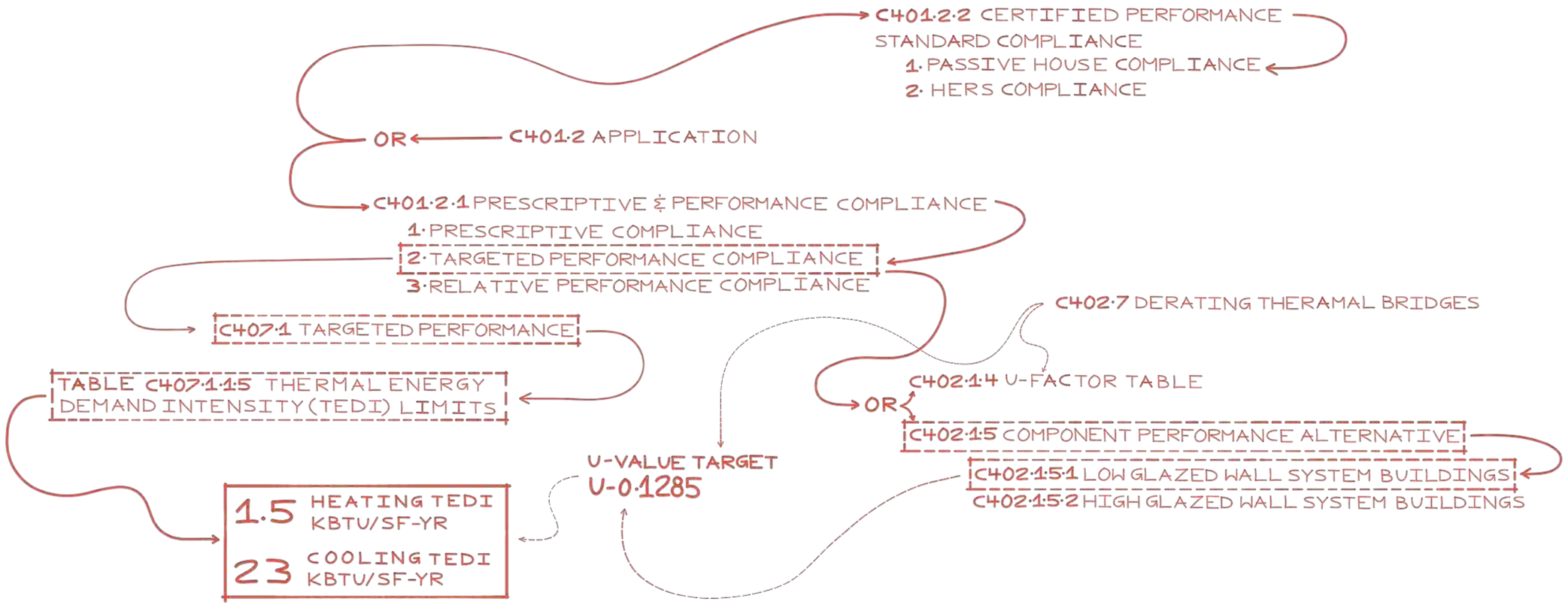
# ASHRAE 90.1-2019
APPENDIX-G

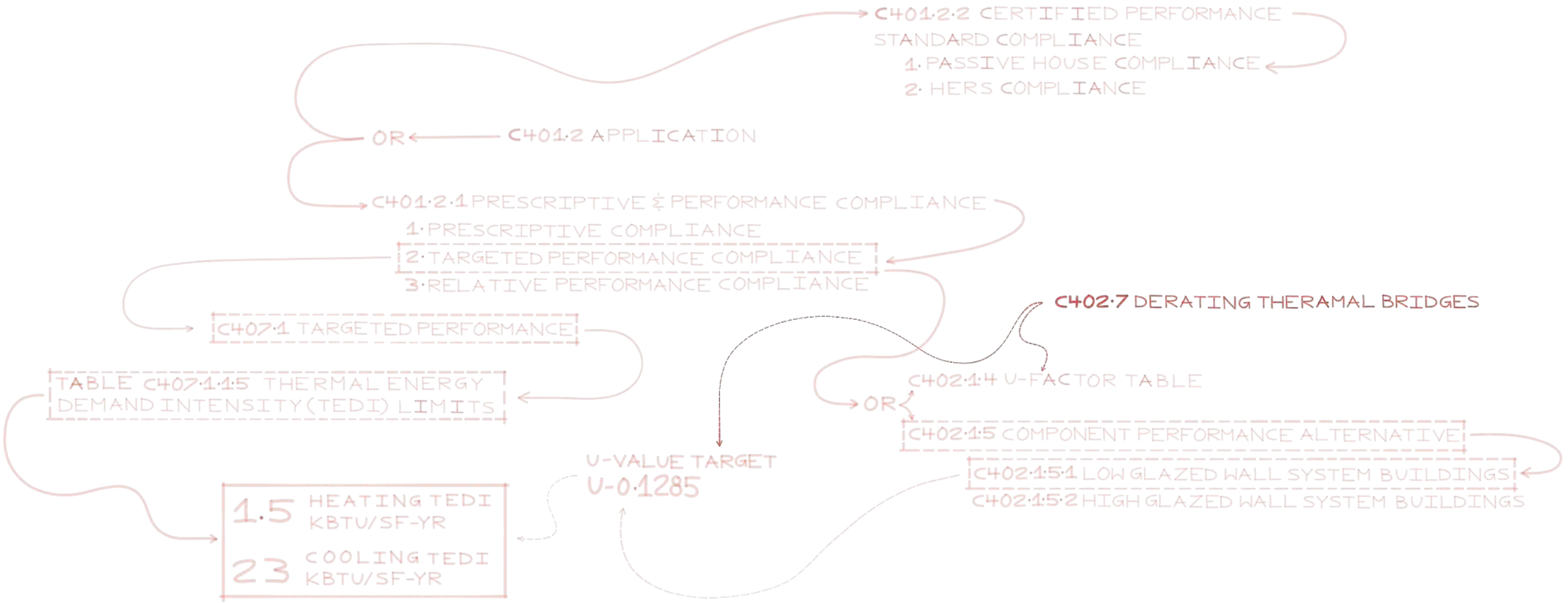
## ENERGY
## USE
## INTENSITY

(EUI) KBTU/SF-YR



225 CMR 23.00 v2025


C401.2.2 CERTIFIED PERFORMANCE
STANDARD COMPLIANCE
1. PASSIVE HOUSE COMPLIANCE
2. HERS COMPLIANCE
OR
C401.2 APPLICATION
C401.2.1 PRESCRIPTIVE & PERFORMANCE COMPLIANCE
1. PRESCRIPTIVE COMPLIANCE
2. TARGETED PERFORMANCE COMPLIANCE
3. RELATIVE PERFORMANCE COMPLIANCE
C407.1 TARGETED PERFORMANCE
TABLE C407.1.1.5 THERMAL ENERGY DEMAND INTENSITY (TEDI) LIMITS
1.5 HEATING TEDI KBTU/SF-YR
23 COOLING TEDI KBTU/SF-YR
U-VALUE TARGET
U-0.1285
C402.7 DERATING THERAMAL BRIDGES
C402.1.4 U-FACTOR TABLE
OR
C402.1.5 COMPONENT PERFORMANCE ALTERNATIVE
C402.1.5.1 LOW GLAZED WALL SYSTEM BUILDINGS
C402.1.5.2 HIGH GLAZED WALL SYSTEM BUILDINGS


C401.2.2 CERTIFIED PERFORMANCE STANDARD COMPLIANCE
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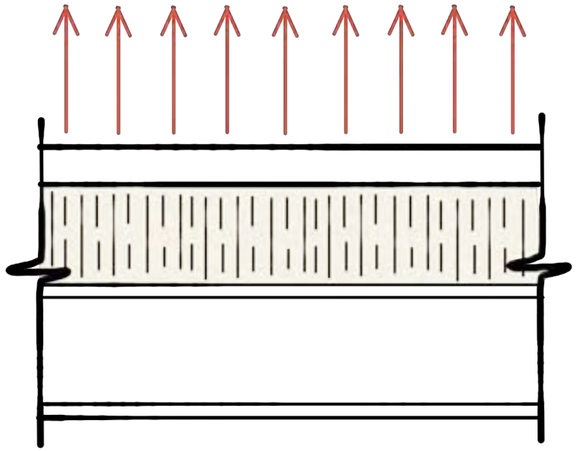
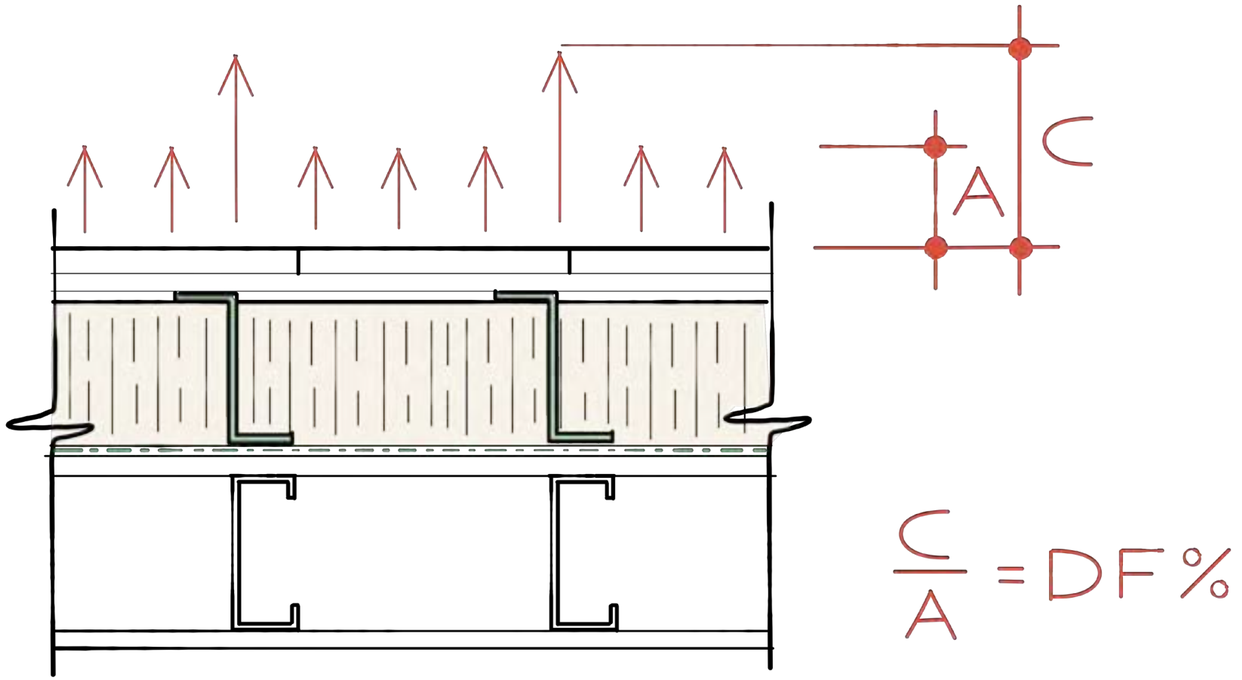
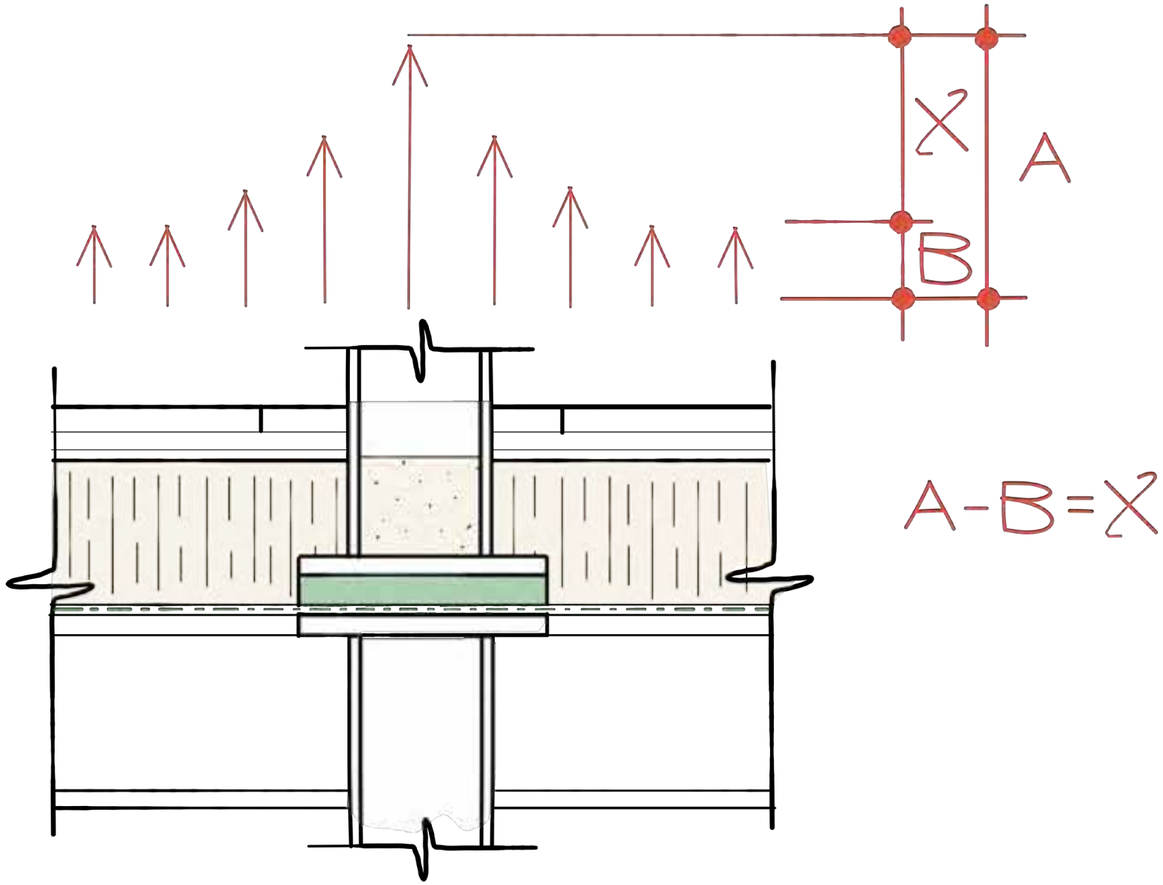


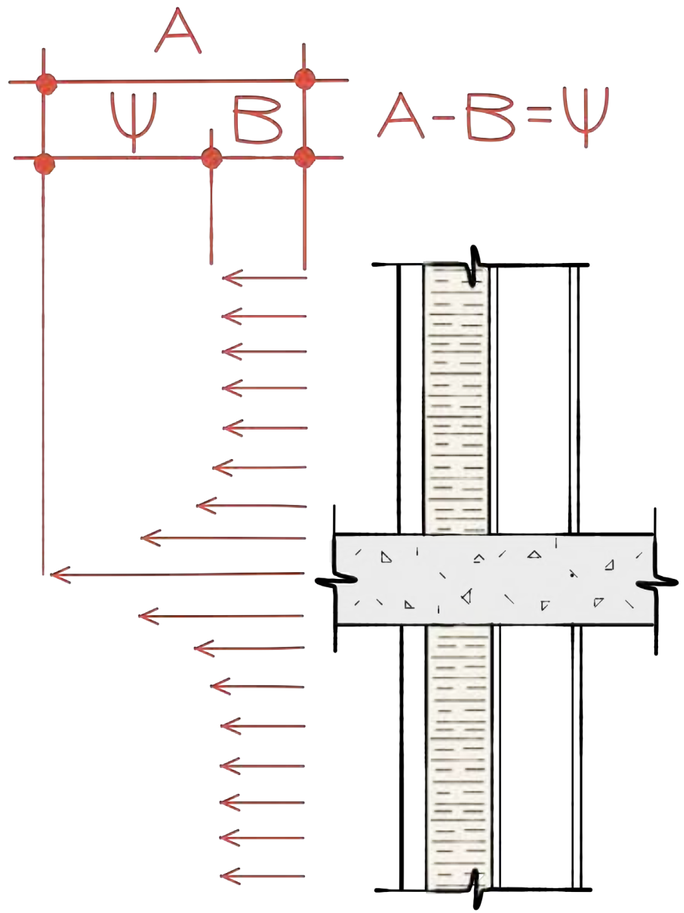
$Btu/(h.ft^2.°F)$

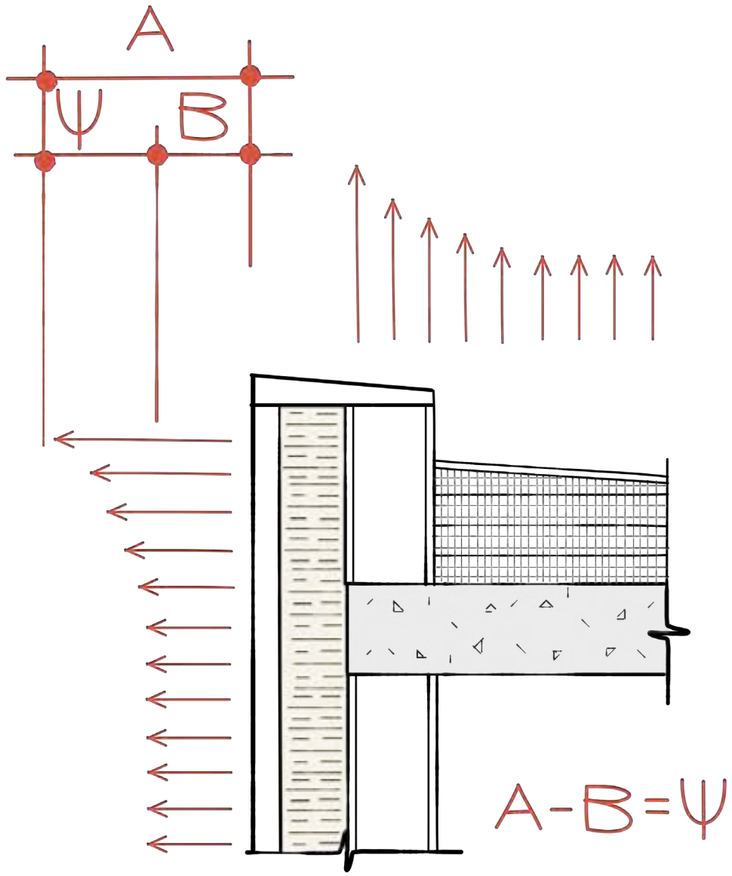
OR

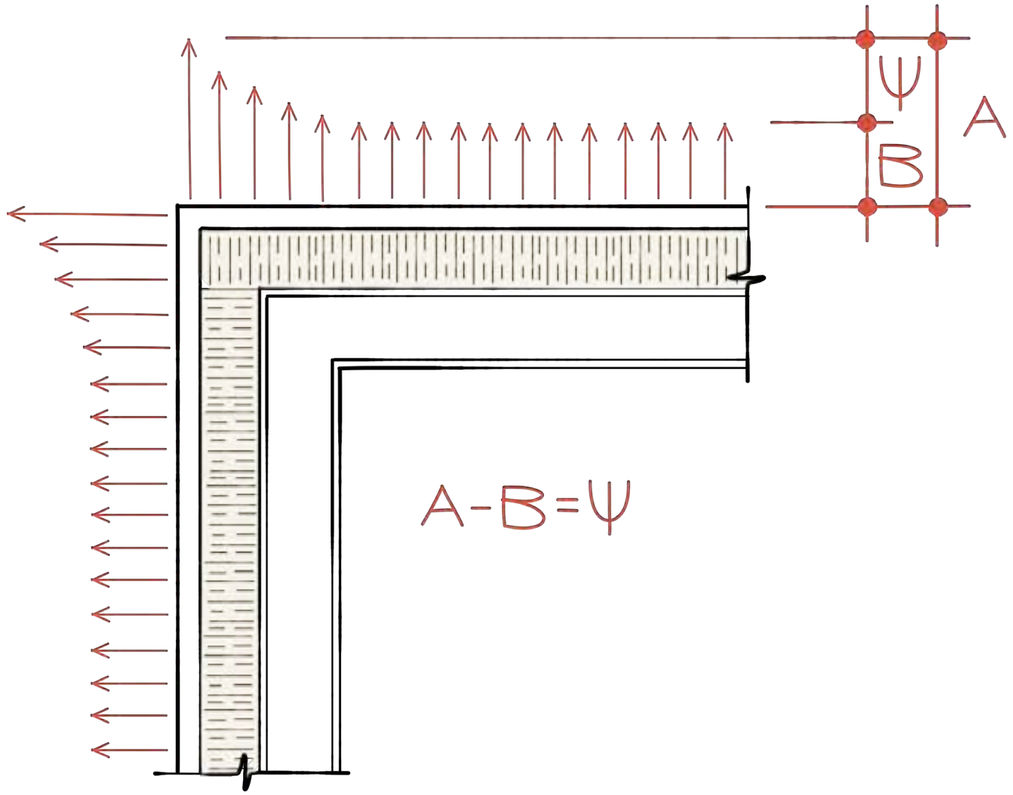
U-VALUE

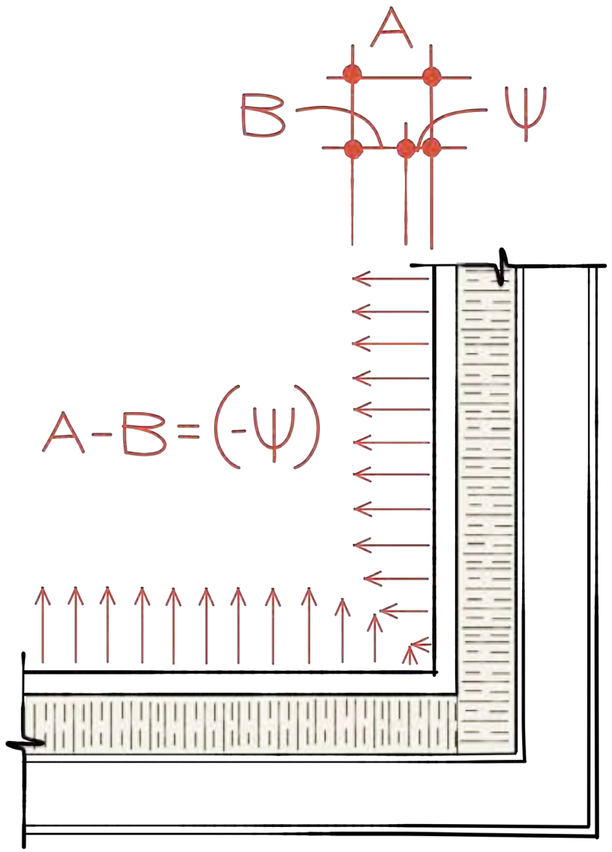

A
C
C/A = DF%

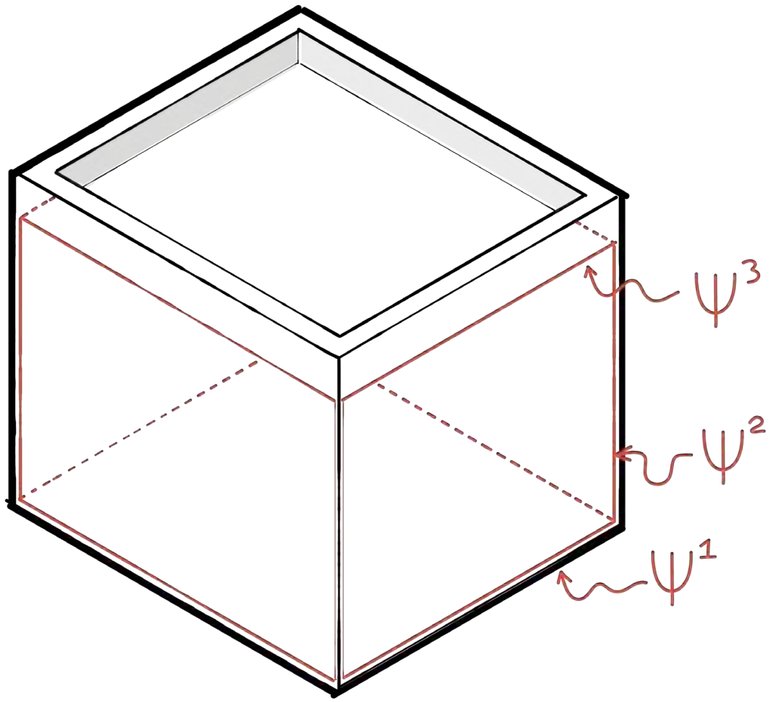

X
A
B
A-B=X

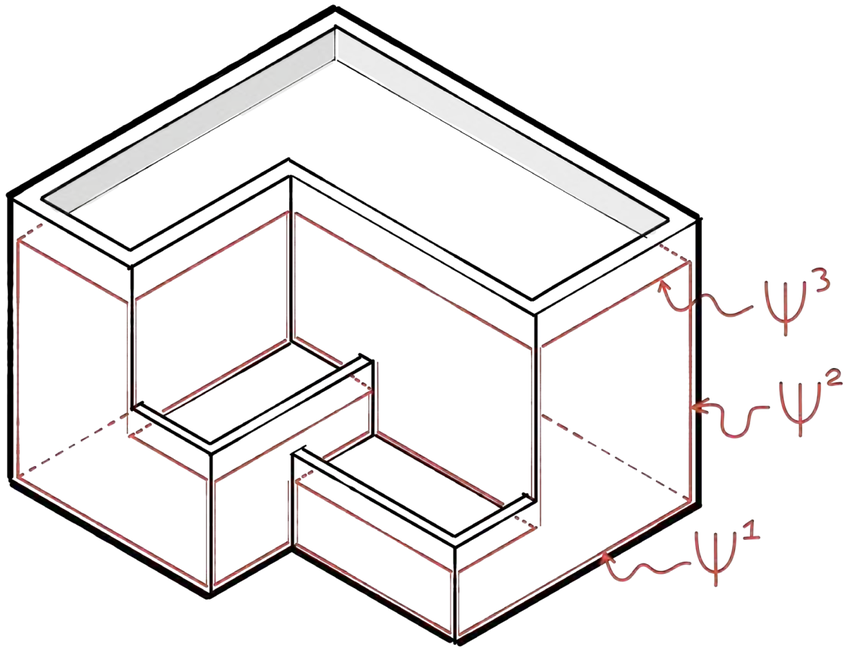

A
Ψ
B
A-B=Ψ

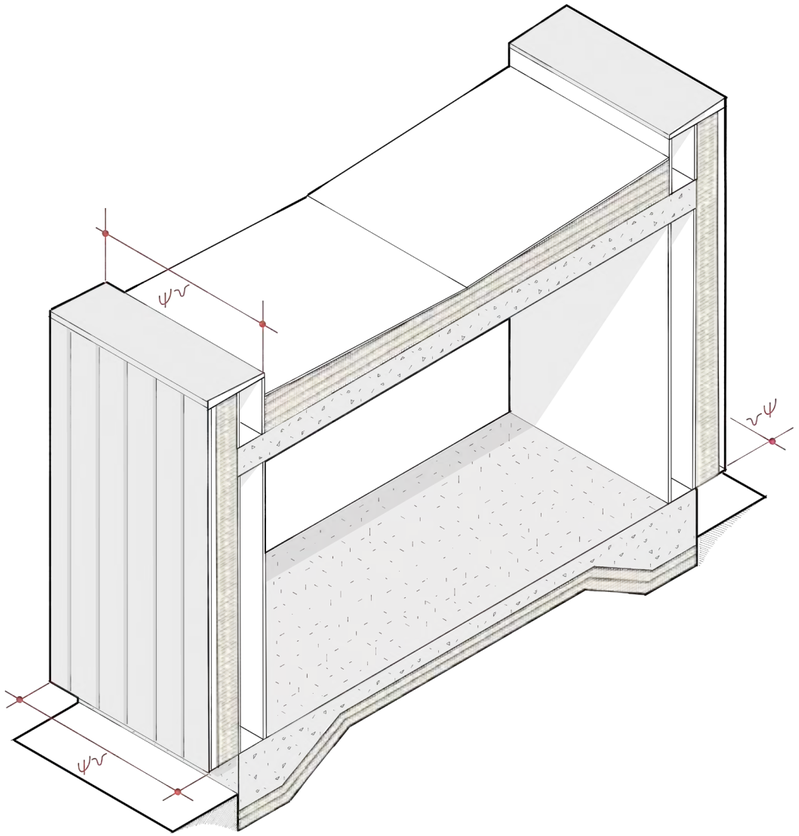

A
Ψ
B
A-B=Ψ

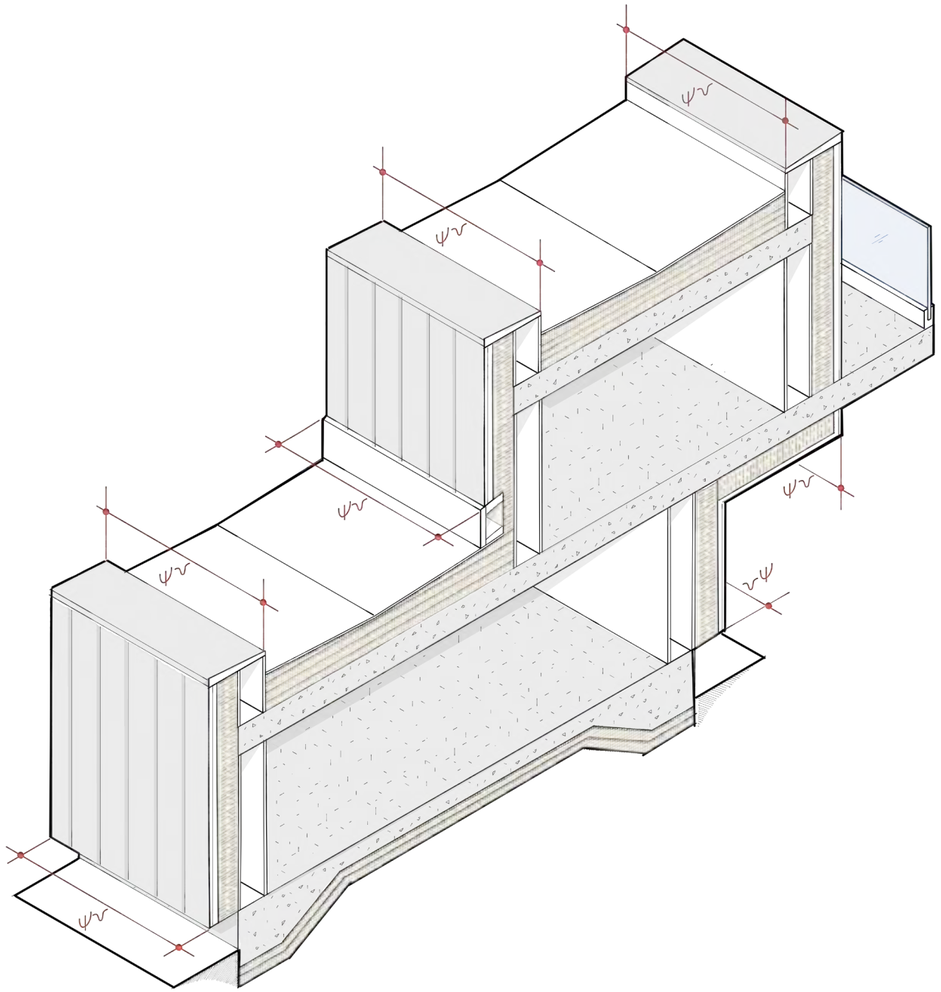

Ψ
A
B
A-B=Ψ

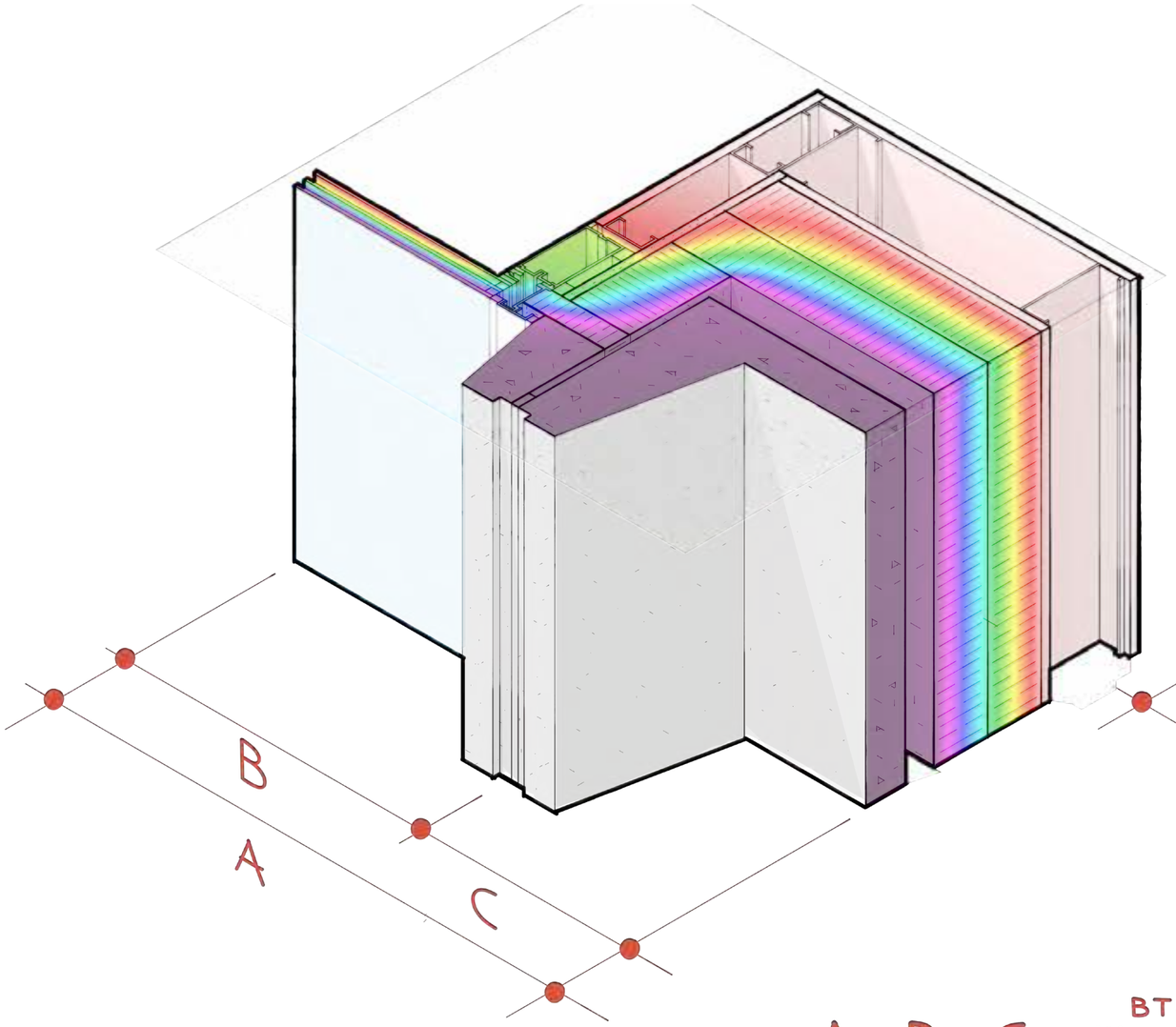

A
B
Ψ
A-B=(-Ψ)

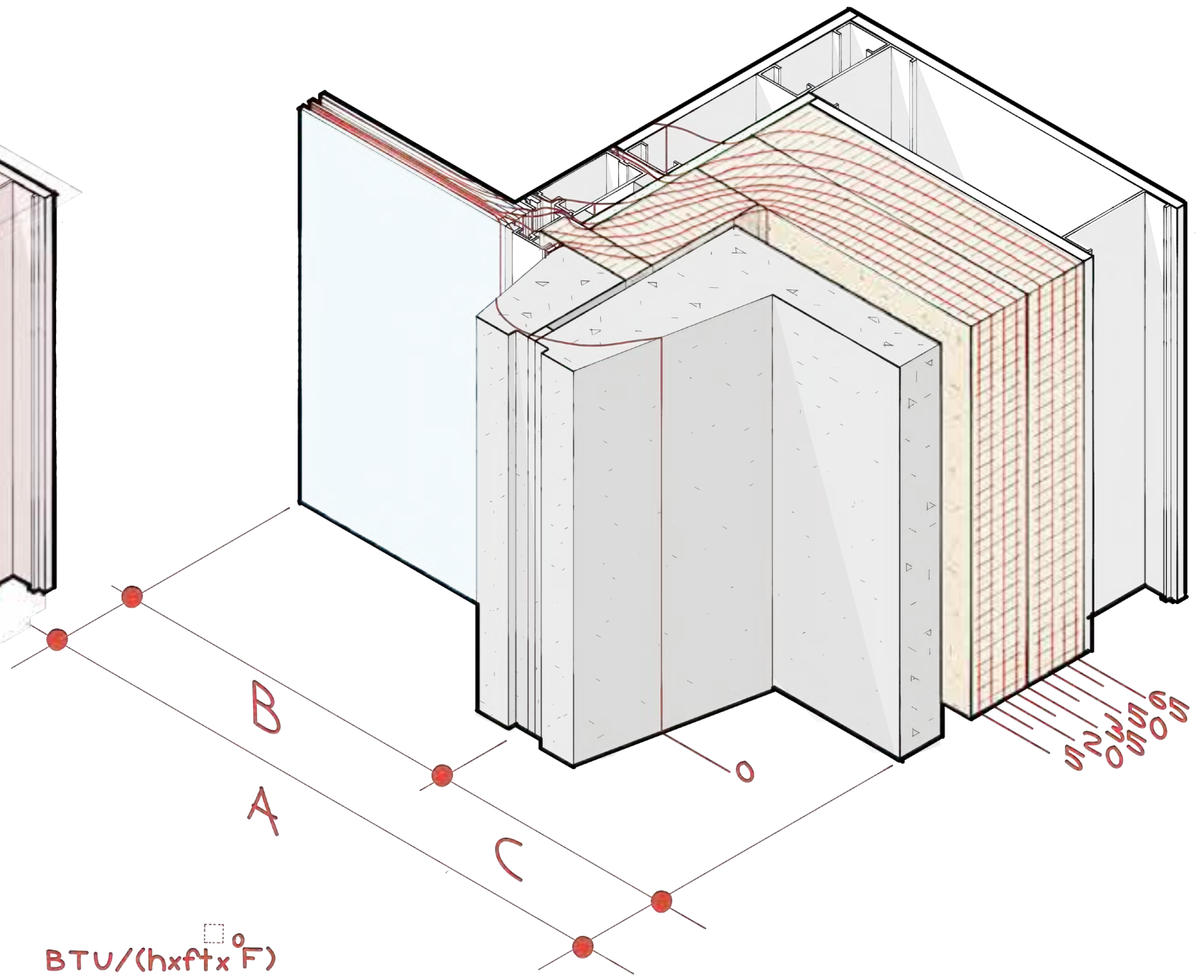

ψ3
ψ2
ψ1


ψ3
ψ2
ψ1

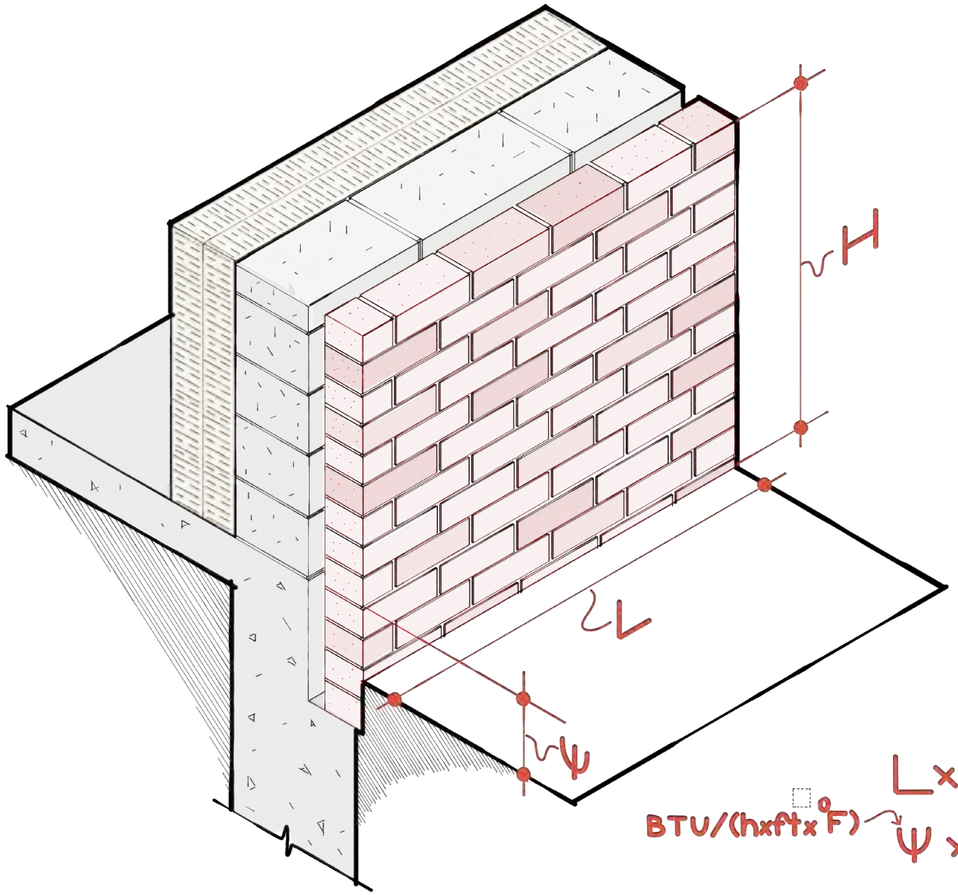

ψ
ψ
ψ

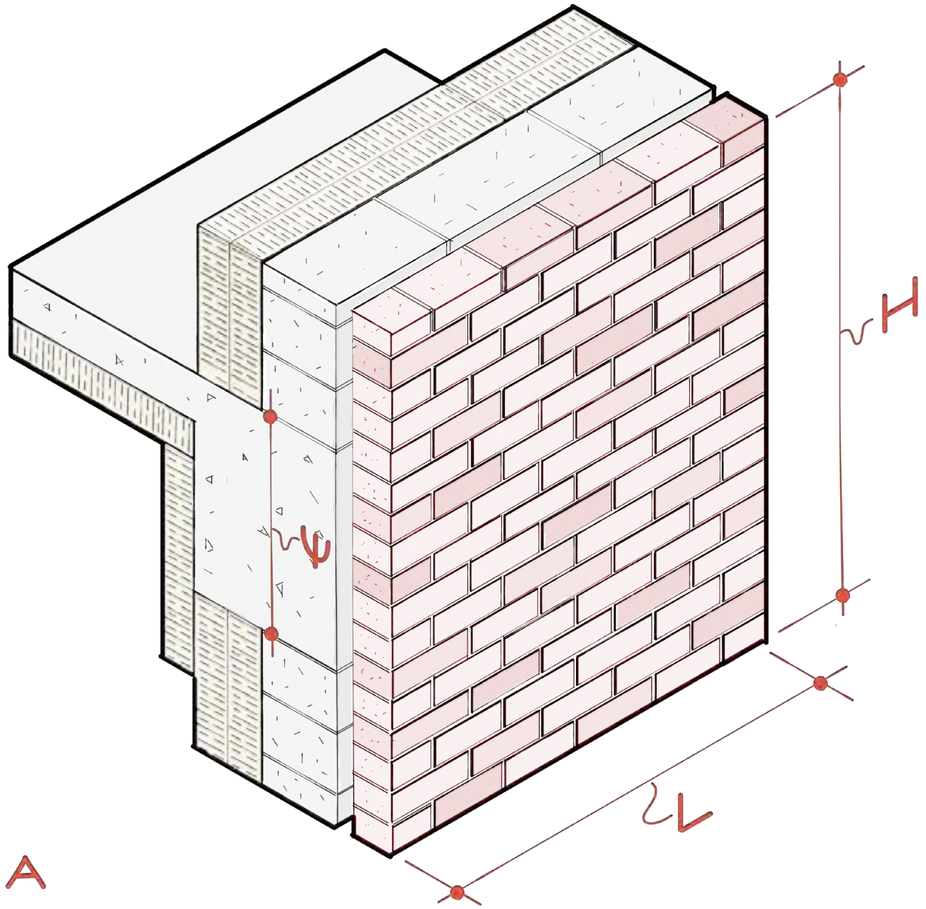

ψ
ψ
ψ
ψ
ψ
ψ




$$A - B - C = \Psi \; \mathrm{BTU/(hxftx\,{}^{0}F)}$$



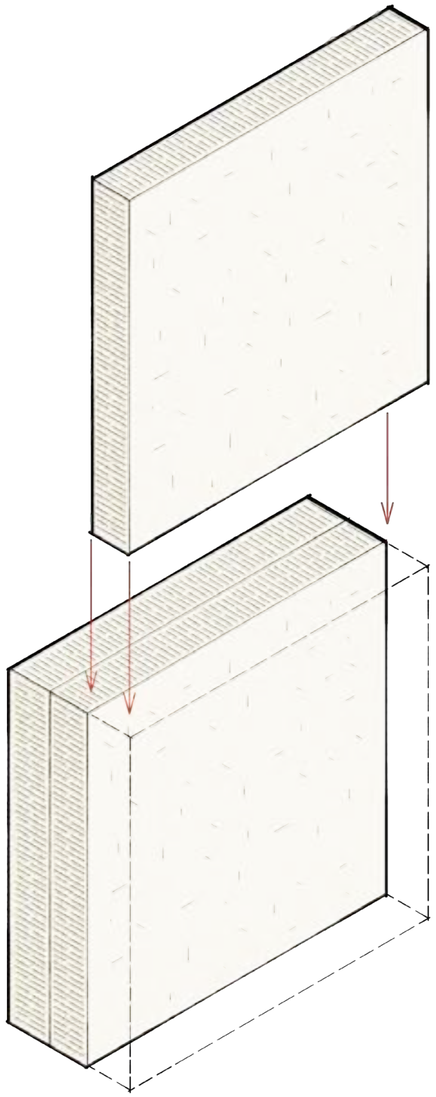



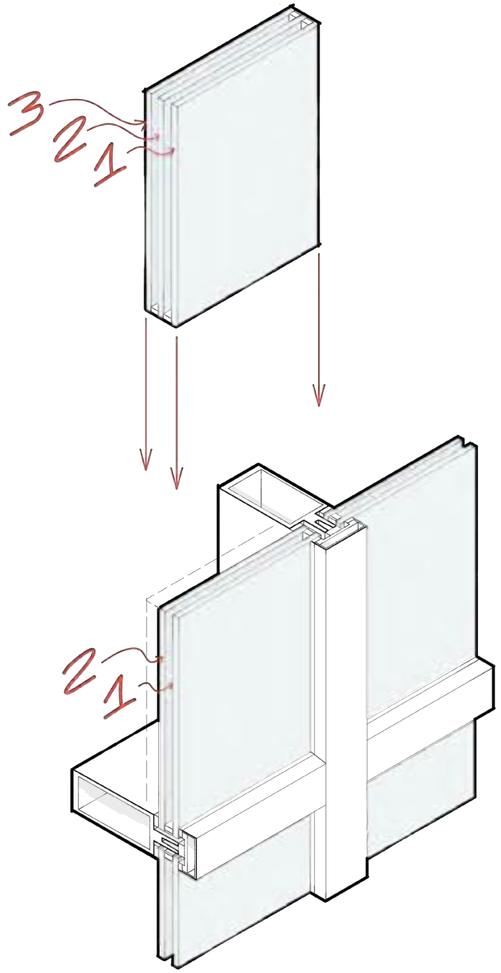

$L \times H = A$

$\psi \times L = \psi_L$ BTU/(hxftx°F)

$\psi_L \% A = U_{ADD}$ BTU/(hxft²x°F)

$U + U_{ADD} = U_{TOT}$

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2
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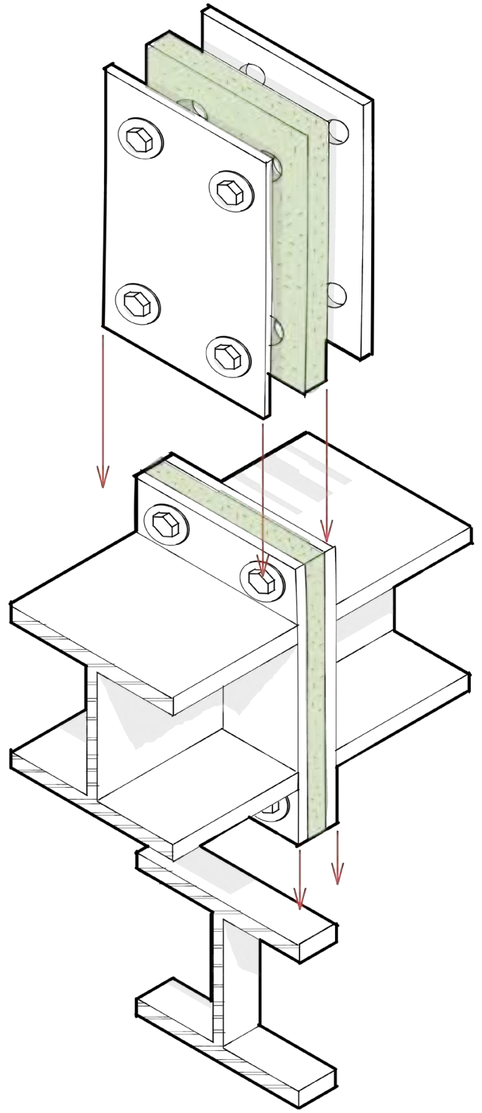
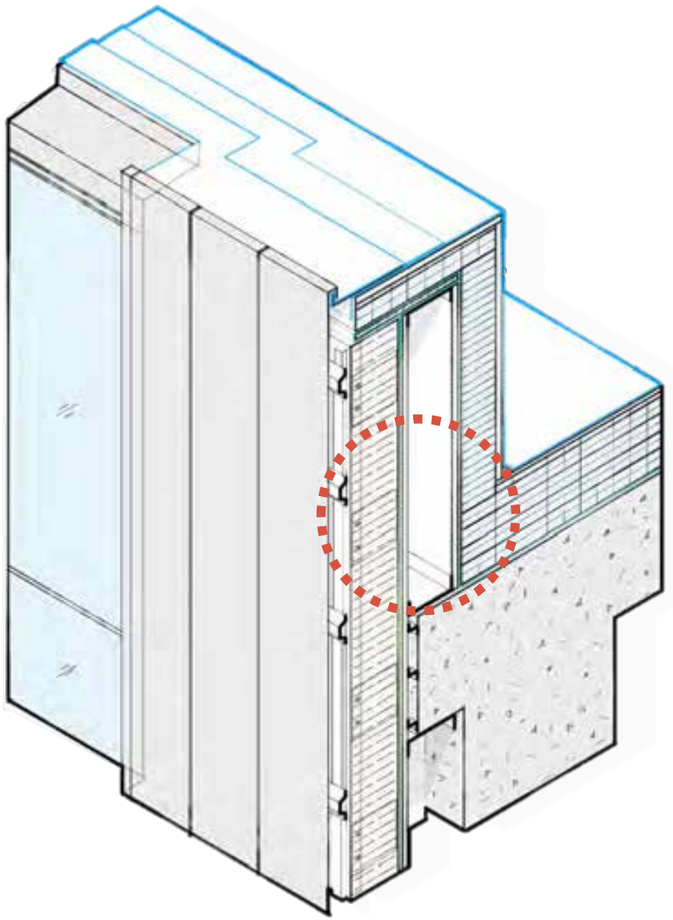
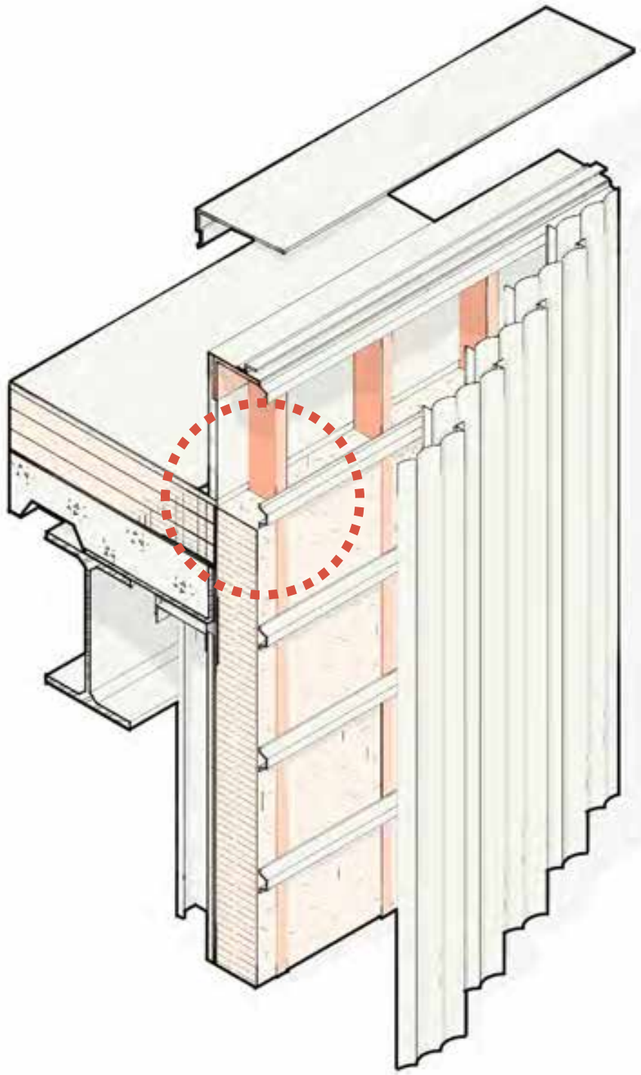
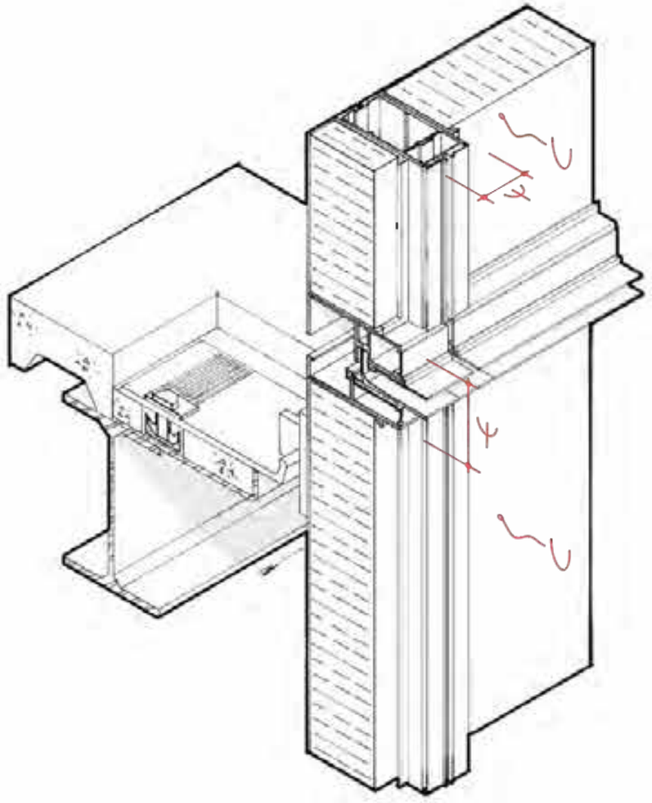
2
1

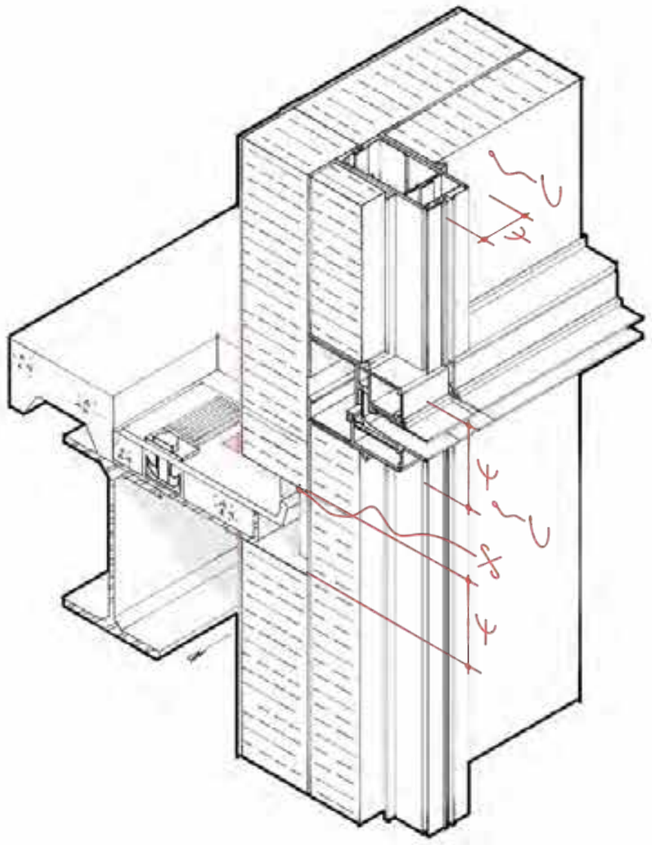




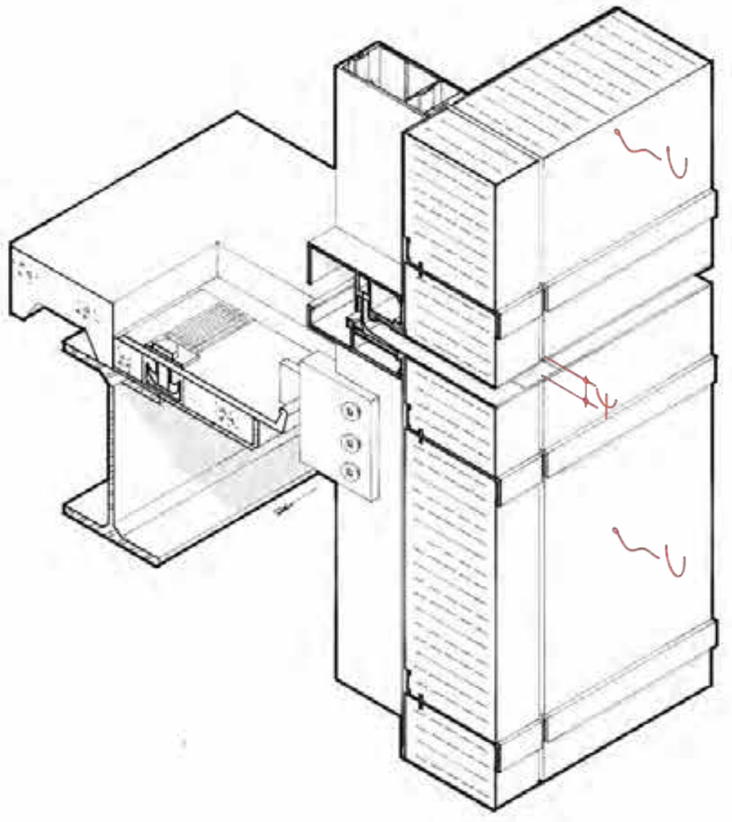




$$V_D = \left(\frac{\Psi \times \text{LENGTH}}{A_{TOTAL}}\right) + \left(\frac{\Psi \times \text{LENGTH}}{A_{TOTAL}}\right) + V_O$$

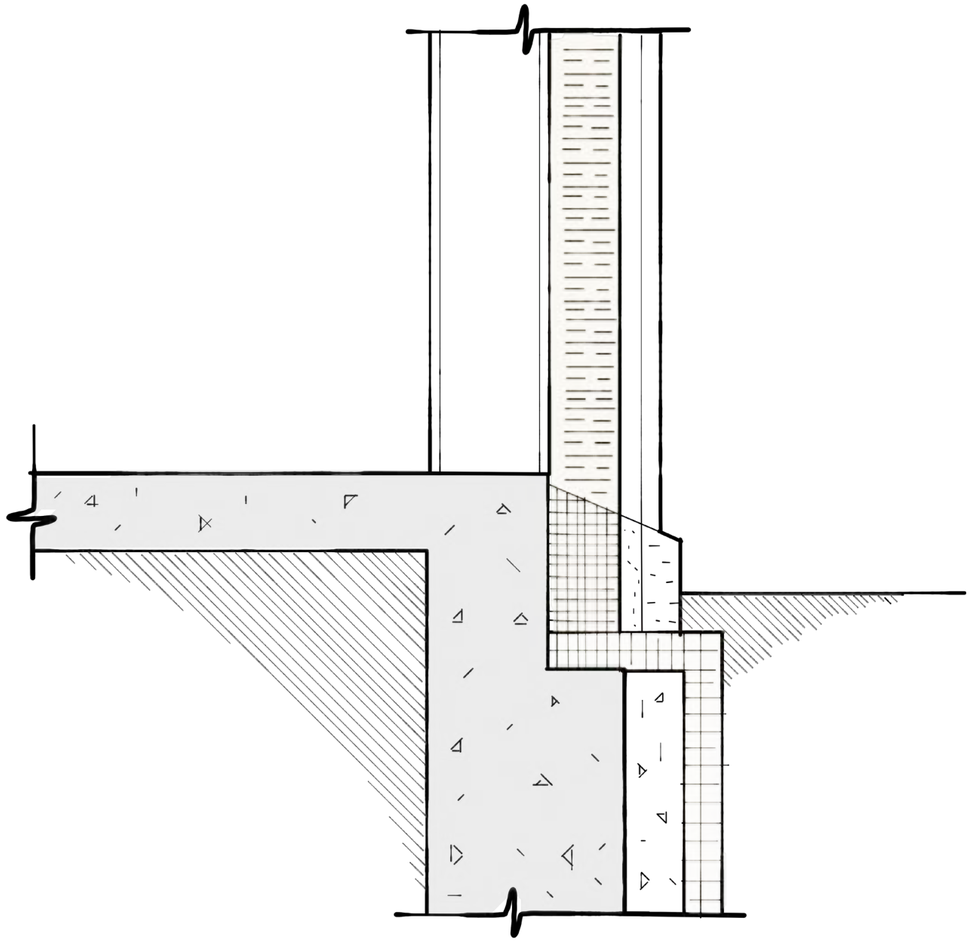


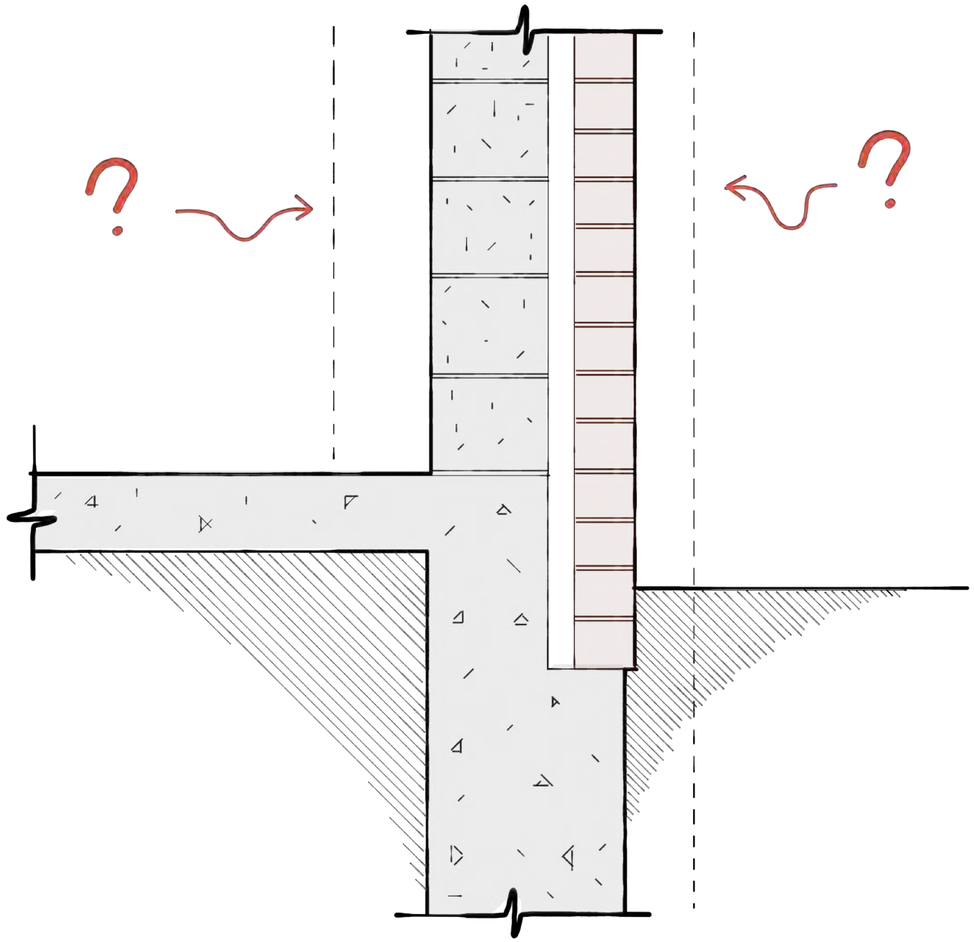
$$V_D = \left(\frac{\Psi \times \text{LENGTH}}{A_{TOTAL}}\right) + \left(\frac{\Psi \times \text{LENGTH}}{A_{TOTAL}}\right) + \left(\frac{\Psi \times \text{LENGTH}}{A_{TOTAL}}\right) + S + V_O$$



$$V_D = \left(\frac{\Psi \times \text{LENGTH}}{A_{TOTAL}}\right) + V_O$$

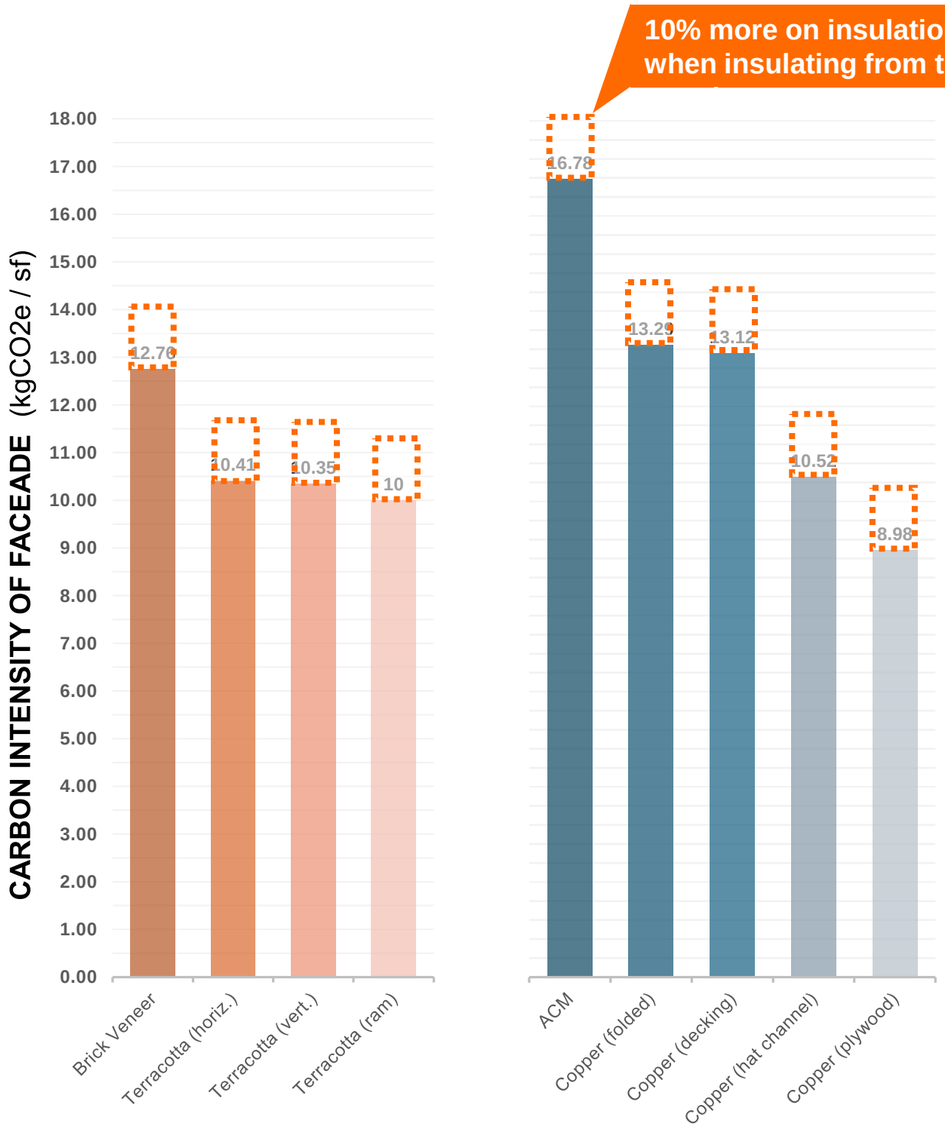
# IMPACT OF NEW CODES



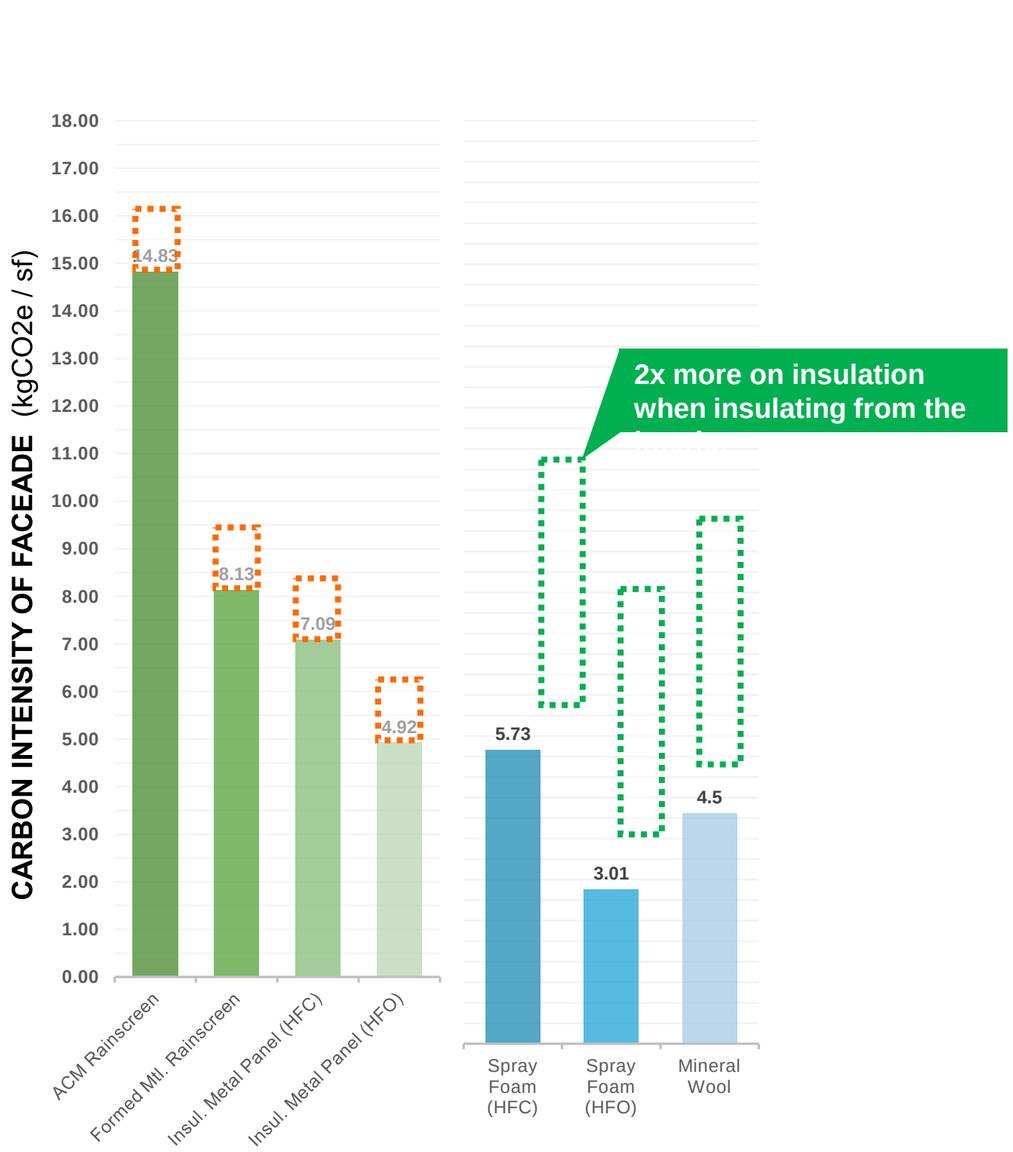


# Impact of MA Stretch Code on ECI

## NEW CONSTRUCTION ASSEMBLIES




## ENVELOPE RETROFIT ASSEMBLIES

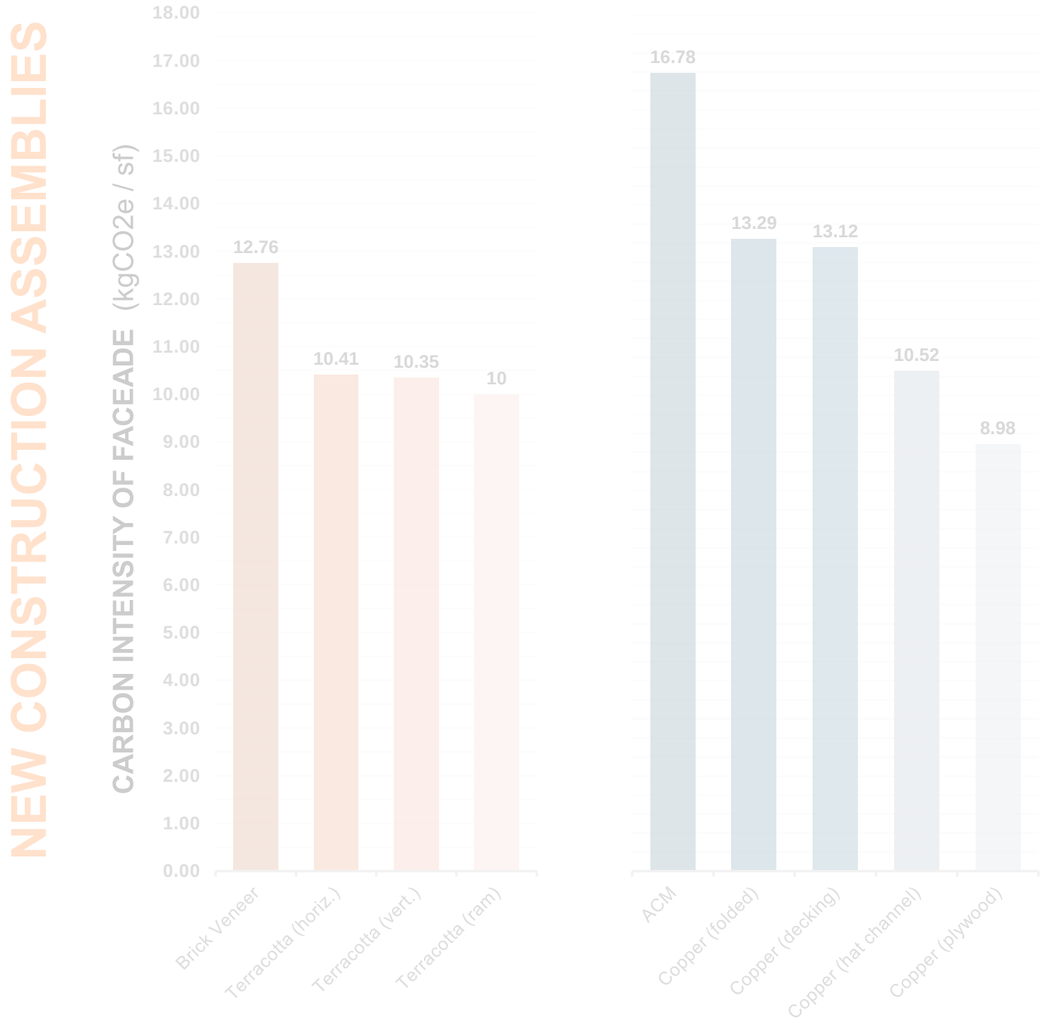


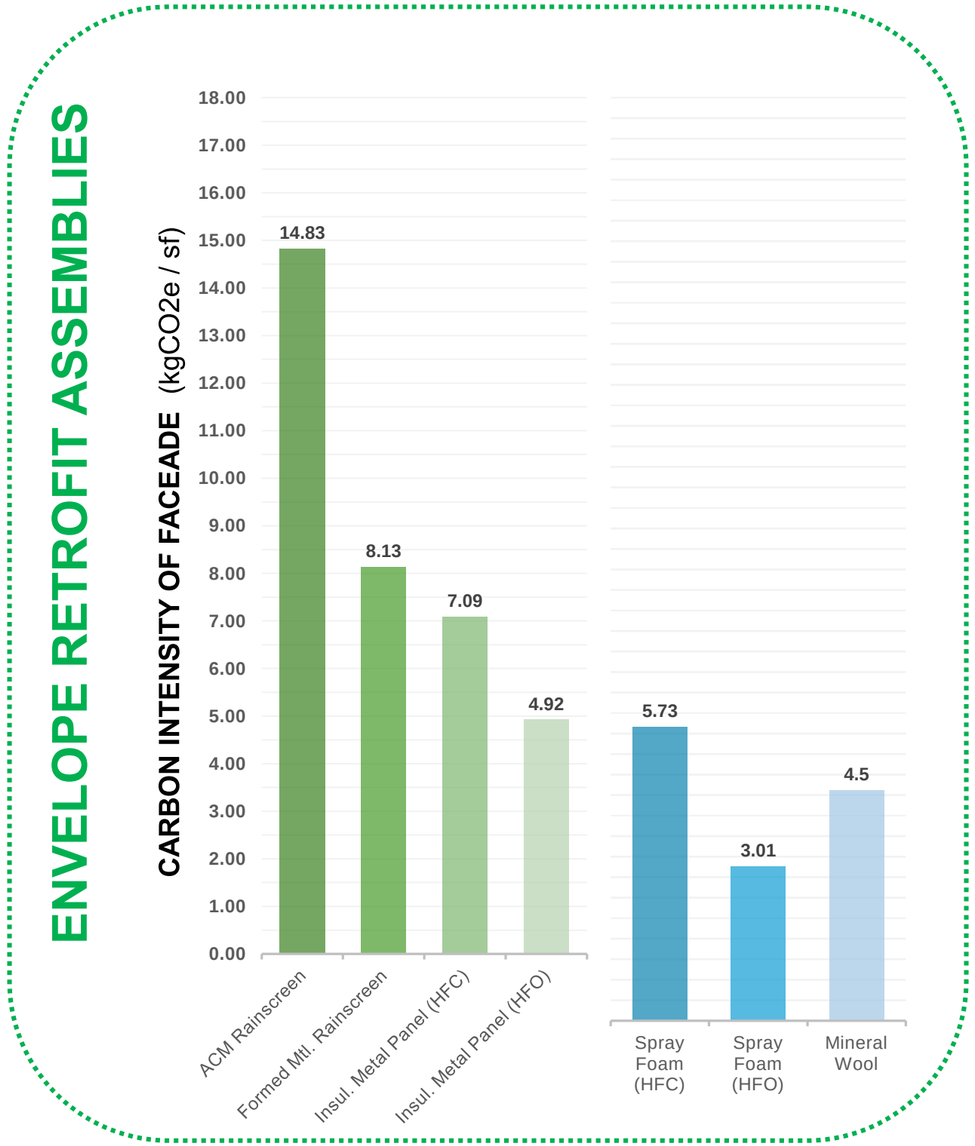


DATA SOURCE: EXTERIOR ENVELOPE

# **Case Studies:** Strategies for Success

# **Strategies for Driving Down ECI:** Envelope Retrofits

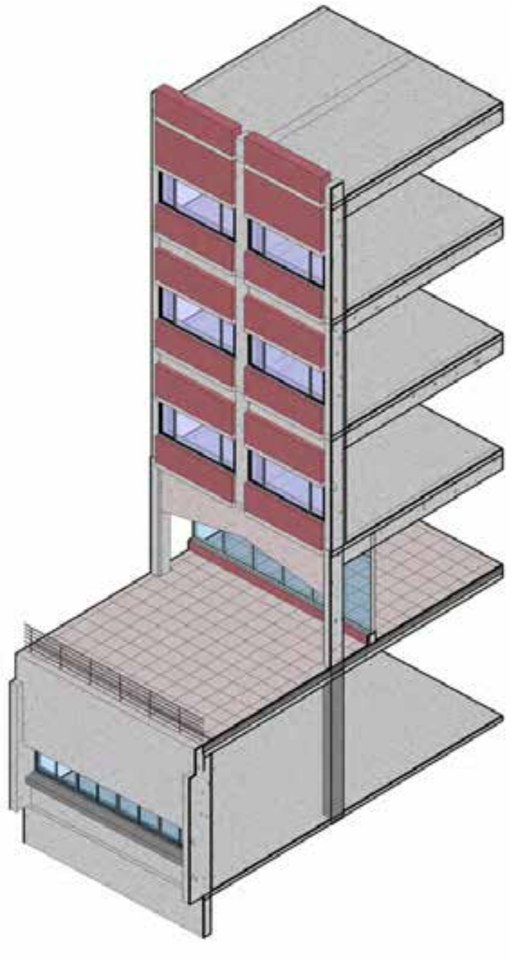


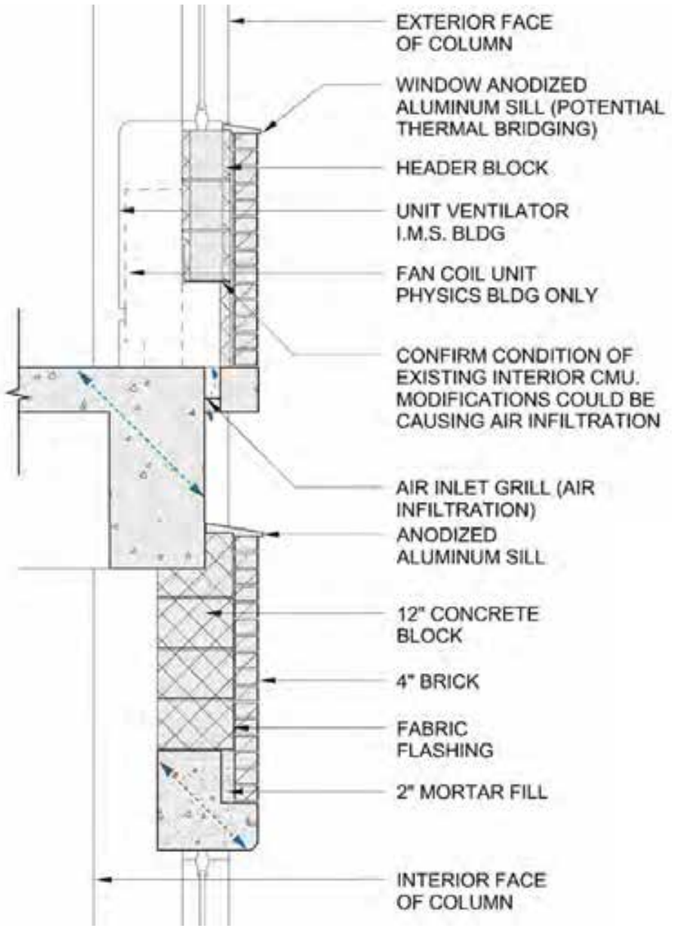



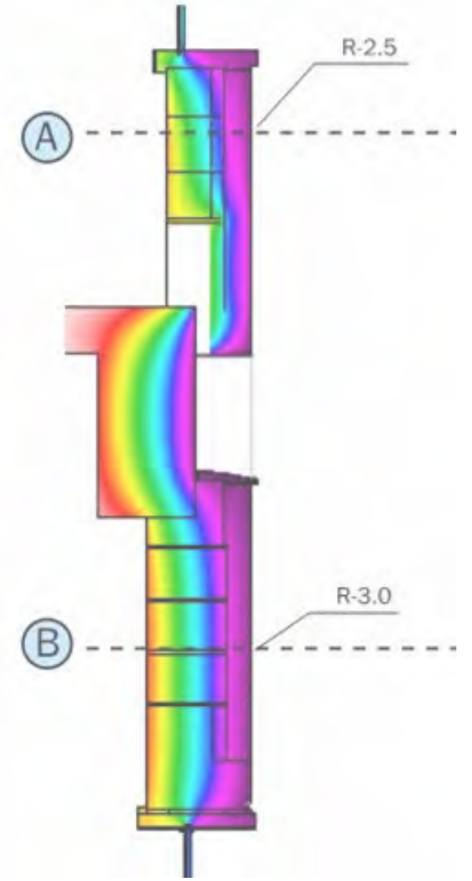


DATA SOURCE: EXTERIOR ENVELOPE

# Case Study #1 Midcentury Lab Building

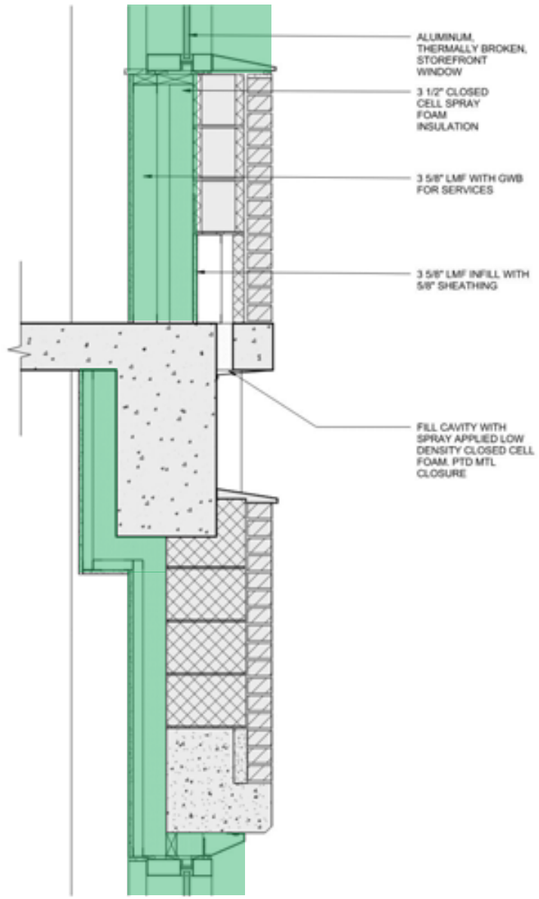


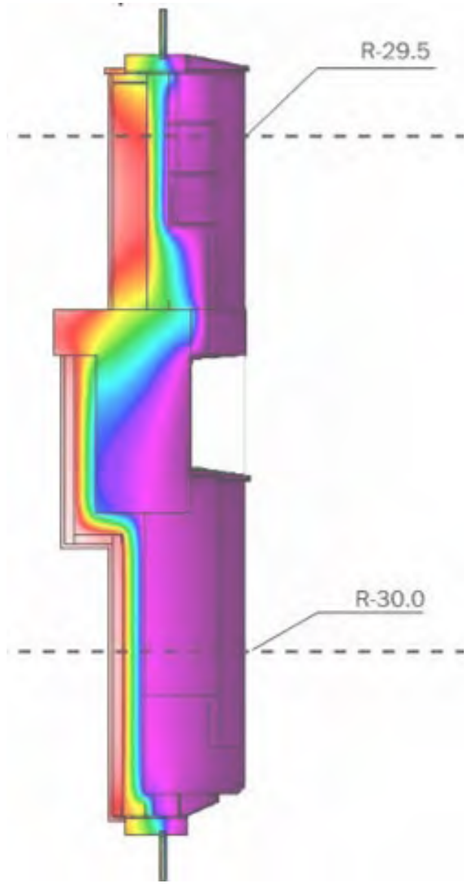


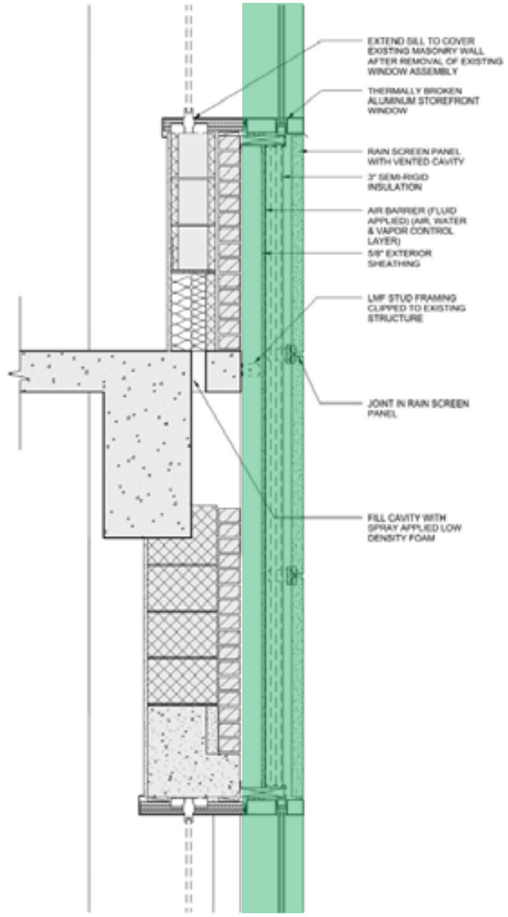

**Gant Science Complex,** University of Connecticut

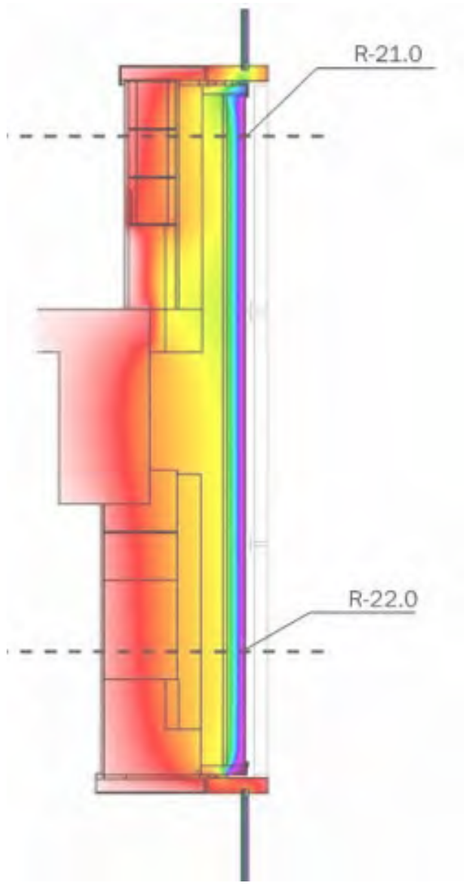
# Interior Insulation vs. Overcladding



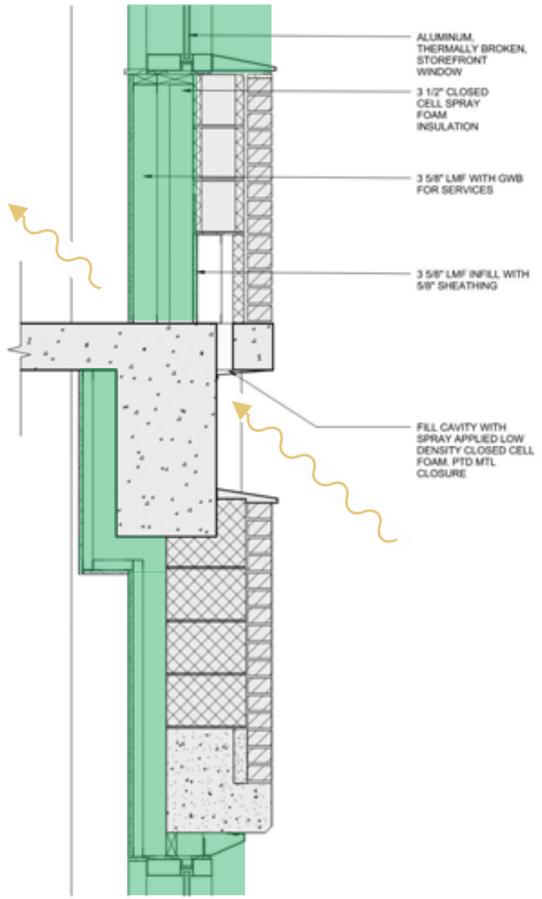

**Interior Insulation**
**3 ½” Spay Foam**

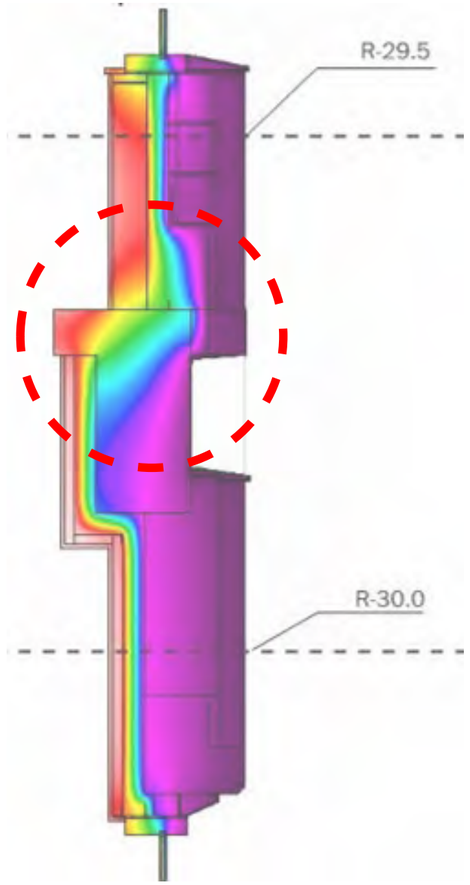


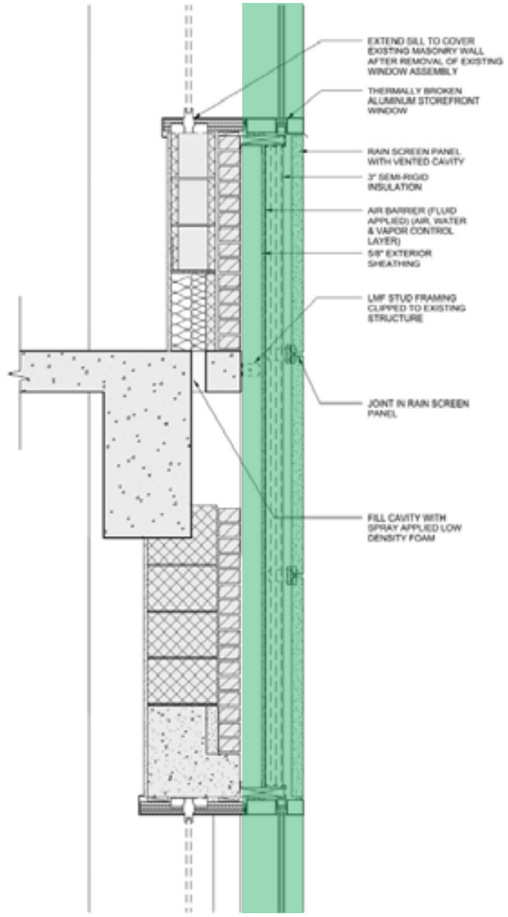

**Over-Cladding**
**3” Semi-Rigid Insulation**

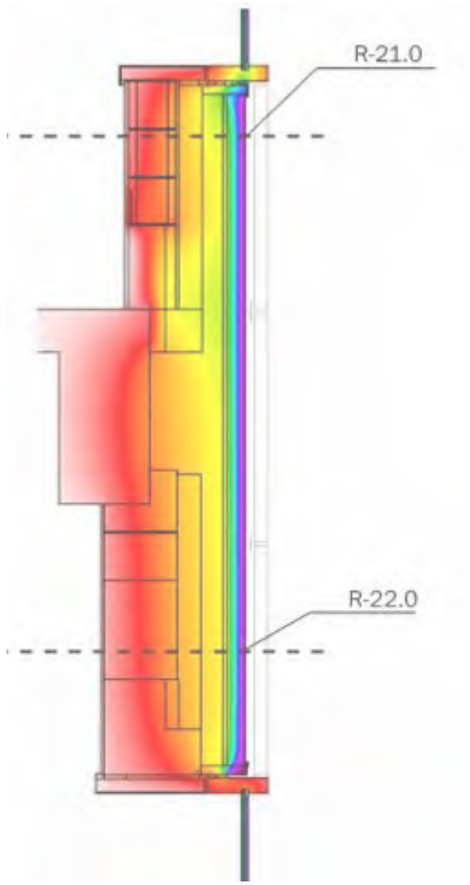
# Interior Insulation vs. Overcladding




**<u>Interior Insulation</u>**
**3 ½” Spay Foam**

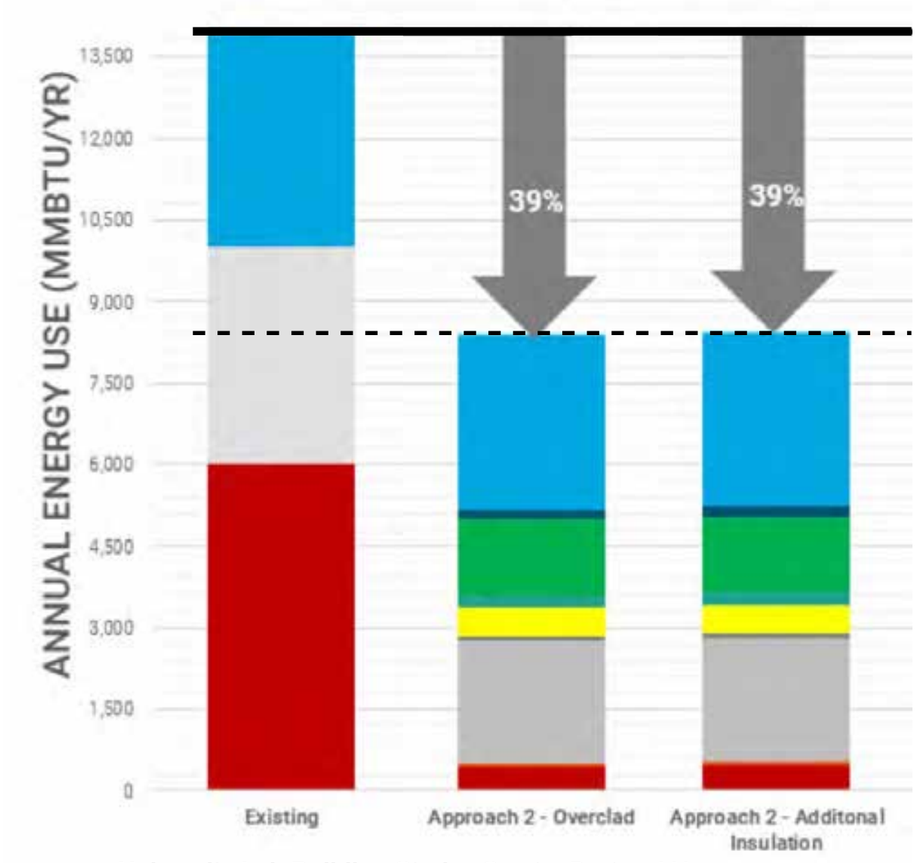


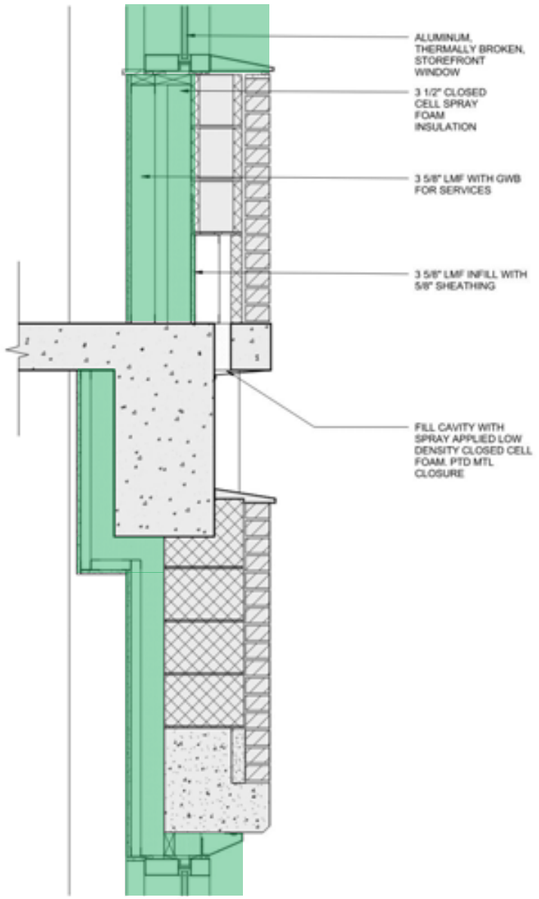

**<u>Over-Cladding</u>**
**3” Semi-Rigid Insulation**

# Comparable Operational Carbon Savings

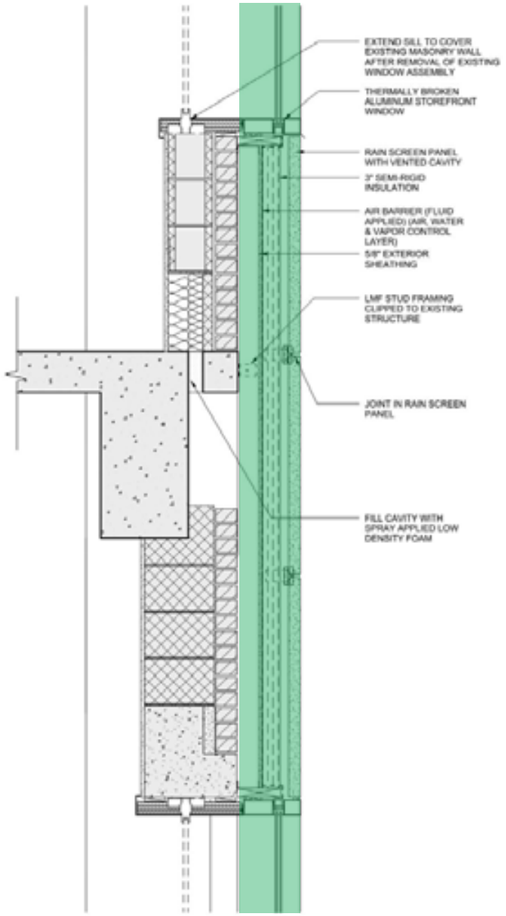
- Overclad resulted in **no additional** energy savings




**University Lab Building Study,** Greater Boston, MA



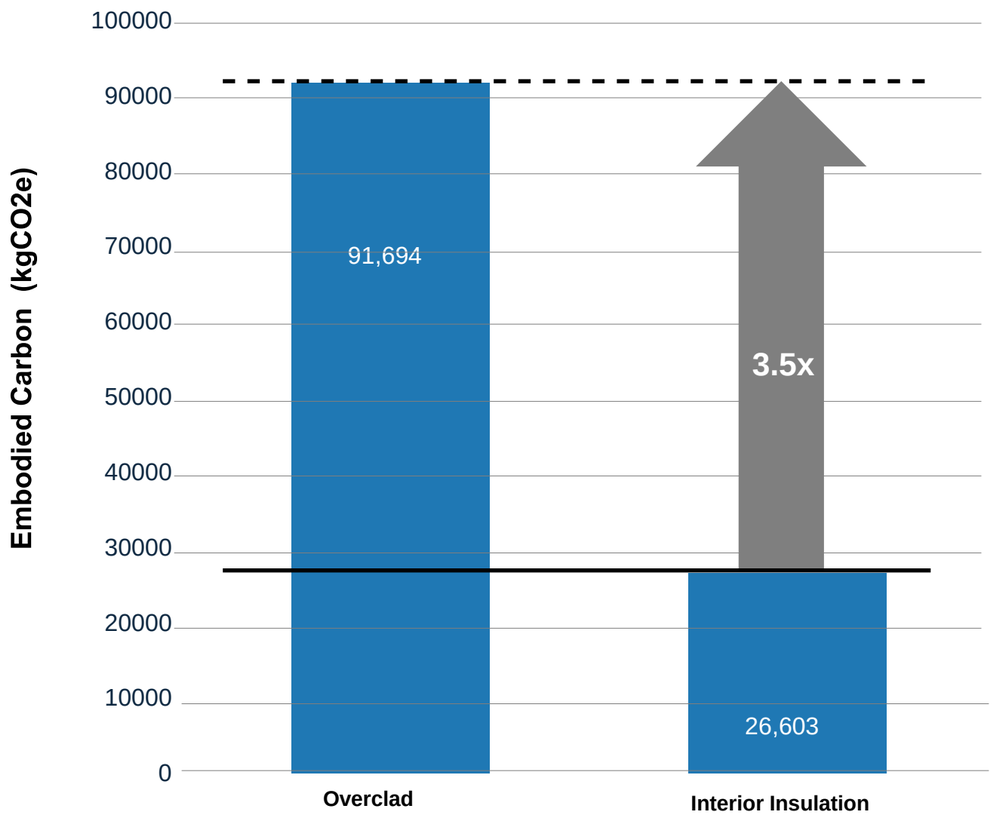

**Interior Insulation**
**3 ½” Spay Foam**



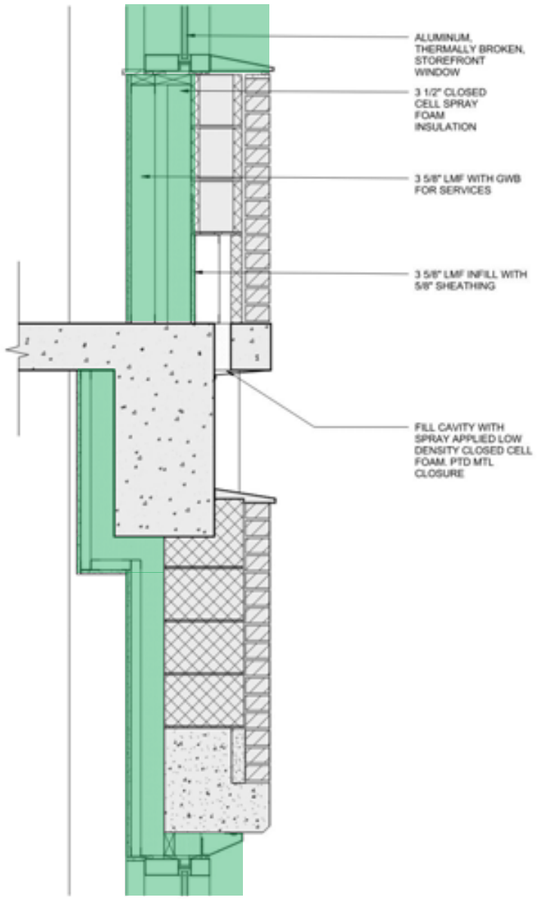

**Overcladding**
**3” Semi-Rigid Insulation**

# Higher Embodied Carbon Impact

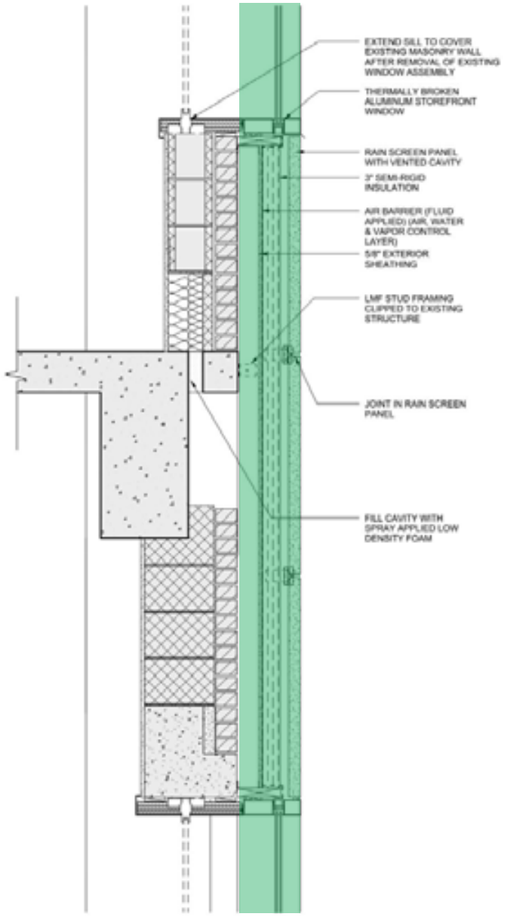
- **3.5x** Higher Embodied Carbon
- Carbon Payback Period = **33 years**




**University Lab Building Study,** Greater Boston, MA




**Interior Insulation**
**3 ½” Spay Foam**




**Overcladding**
**3” Semi-Rigid Insulation**

# Higher Initial Costs, Minimal Cost Payback

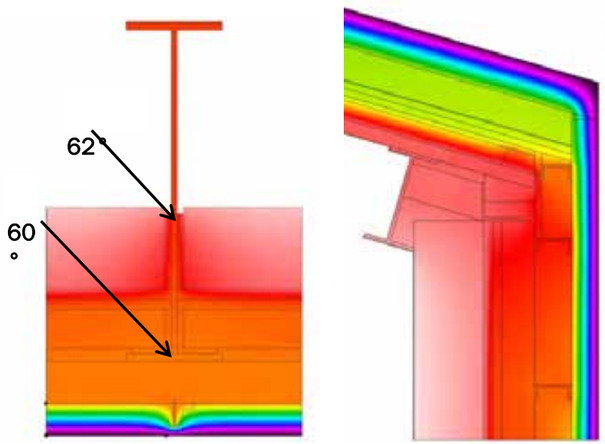
- **4% Higher Costs over first 30 years ⟶ < 1% Annual Energy Cost Savings**


**University Lab Building Study,** Cambridge MA

| Results | | Additional Insulation | Overclad |
|---|---|---|---|
| *Total Electricity Consumption* | MMBtu/yr | 4,593 | 4,590 |
| *Total Natural Gas Consumption* | MMBtu/yr | 2 | 2 |
| *Total Steam Consumption* | MMBtu/yr | 674 | 634 |
| *Total Chilled Water Consumption* | MMBtu/yr | 3,187 | 3,194 |
| *Renewable Energy Generation* | MMBtu/yr | 12 | 12 |
| *Net Energy Consumption* | MMBtu/yr | 8,444 | 8,408 |
| *Total Operational Emissions* | kg $CO_2$eq/yr | 469,000 | 467,000 |
| *Total Energy Cost* | $/yr | 323,000 | $321,000 |
| *Building Energy Use Intensity (without renewables)* | kBtu/sf-yr | 190 | 189 |

# Case Study #2 Adaptive Reuse of Existing Athletic Facility

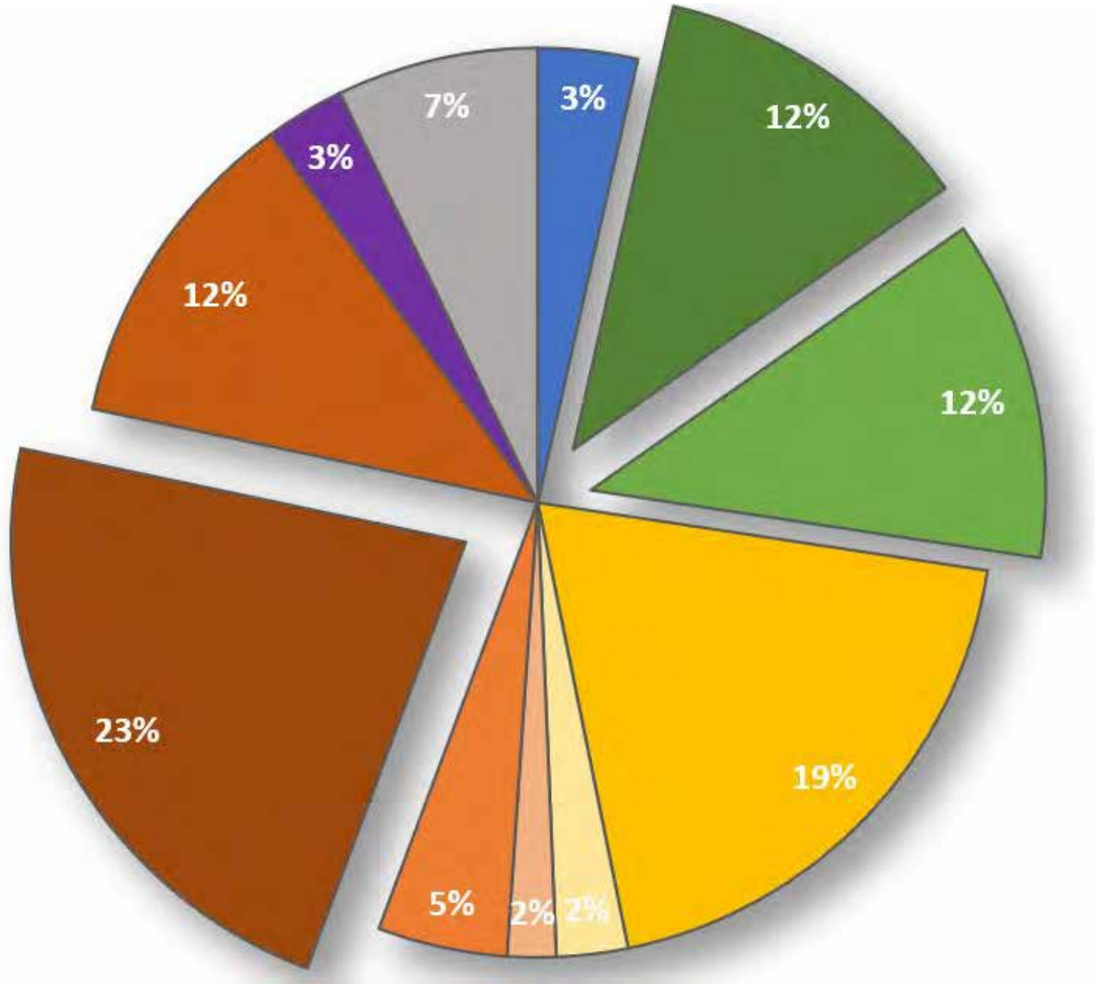
- Quinsigamond Community College – IQ Center
  - $26.8m // $550/sf
  - 55,000 gsf
  - Program:
    - Multipurpose rooms
    - Classrooms
    - Maker space
    - Nutrition Lab + Café
    - Student Life spaces
    - Recreation + Fitness




# Balance of Envelope and Mechanical System

**Trophy Point's Latest Estimate**

| | | SCHEME 1 | | |
|---|---|---|---|---|
| | | | 48,077 SF | |
| | | Subtotal Trade | Total | $ /SF |
| **A** | **SUBSTRUCTURE** | | **$408,528** | $ 8.50 |
| | A10 Foundations | $408,528 | | |
| **B** | **SHELL** | | $3,806,154 | $ 84.78 |
| | B10 Superstructure | $1,350,603 | | |
| | B20 Exterior Enclosure | $1,056,830 | | |
| | B30 Roofing | $1,398,720 | | |
| **C** | **INTERIORS** | | **$2,054,561** | $ 42.73 |
| | C10 Interior Construction | $928,666 | | |
| | C20 Stairs | $130,000 | | |
| | C30 Interior Finishes | $995,896 | | |
| **D** | **SERVICES** | | **$4,864,767** | $ 101.19 |
| | D10 Conveying | $185,000 | | |
| | D20 Plumbing | $529,480 | | |
| | D30 HVAC | $2,609,289 | | |
| | D40 Fire Protection | $195,762 | | |
| | D50 Electrical | $1,345,237 | | |
| **E** | **FITTINGS & FIXED EQUIPMENT** | | **$292,057** | $ 6.07 |
| | E10 Equipment | $25,000 | | |
| | E20 Fixed Furnishings / Millwork | $267,057 | | |
| **F** | **SPECIAL CONSTRUCTION & DEMOLITION** | | **$825,882** | $ 17.18 |
| | F20 Selective Building Demolition | $825,882 | | |
| **G** | **SITEWORK** | | **$327,372** | $ 6.81 |
| | G10 Site Preparation | $81,650 | | |
| | G20 Site Improvements | $193,222 | | |
| | G30 Site Mechanical Utilities | $52,500 | | |
| | G40 Site Electrical Utilities | $0 | | |
| | **TOTAL DIRECT COST** | | | |
| | Design Contingency 17.50% | | $2,249,000 | |



ASHRAE 90.1 (Appendix G 2013) Baseline - Estimated

EO 594 - Pathway 1, 20% Better than ASHRAE 90.1 (App G 2013) - Estimated

EO 594 - Pathway 2, 20% Better than ASHRAE 90.1 (2016) IECC 2018 - Estimated

2023 Base Code IECC (2021) – Estimated
Plus MA Additional Commercial Amendments

**TARGET EUI RANGE**

2023 Stretch Code, IECC (2021)
+ MA Stretch Code Amendments

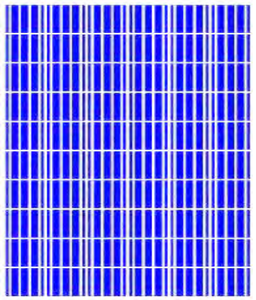
**92**
Energy Use Intensity kBtu/sf/yr

**66**

**58**

**42**

EUI:
**34**



## BASELINE BUILDING

- Typical student life / classroom building in Climate Zone 6A

## ENVELOPE

- Limited amount of glass
- Optimize insulation levels
- Low solar heat gain
- Exterior shading

## REDUCED LOADS

- LED lighting
- Smart outlets
- Occupancy sensors
- Daylight sensors

## HVAC

- De-couple ventilation from conditioning
- Energy recovery
- Load sharing
- Performance monitoring

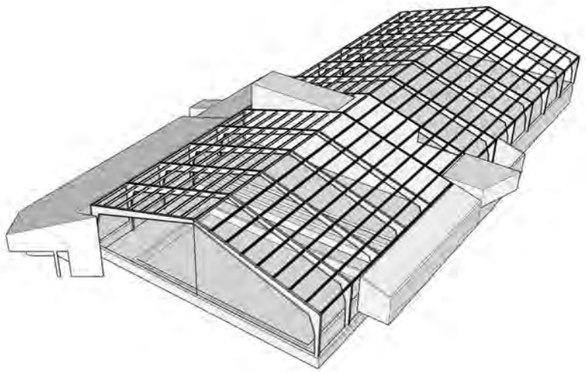
## OCCUPANT ENGAGEMENT

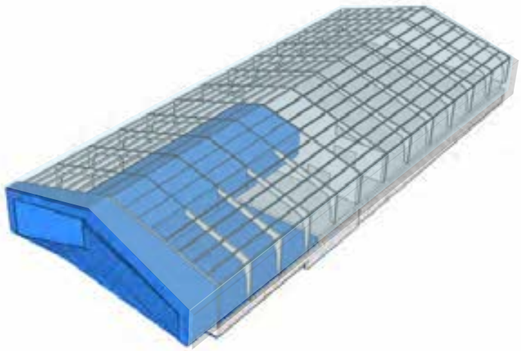
- Sub-metering
- Training
- Wider set points

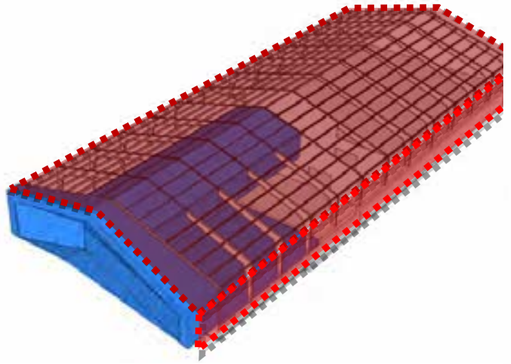
## ELECTRIFY

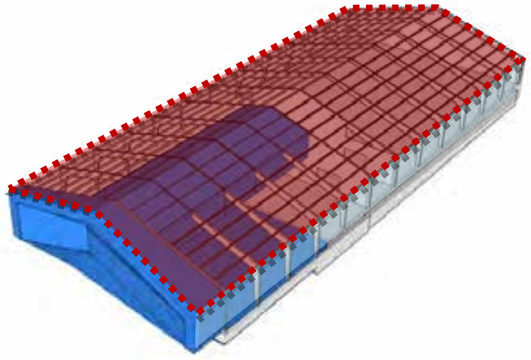
- On-site PVs
- Clean energy purchase
- Heat pump

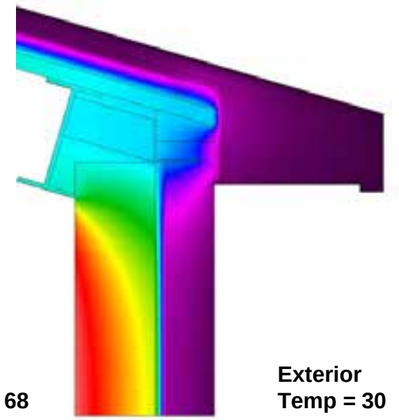
# Interior Insulation vs. Overcladding

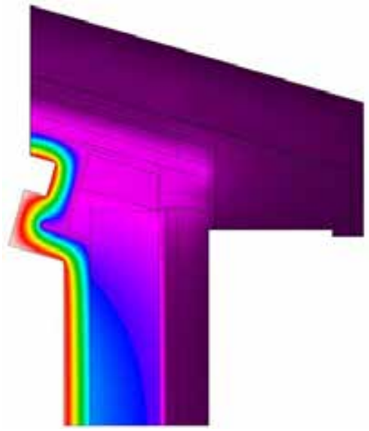


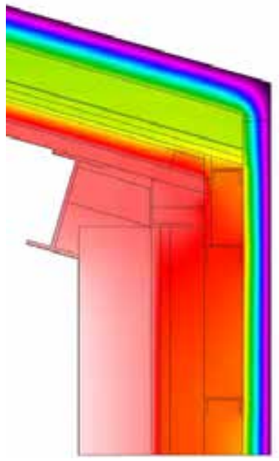


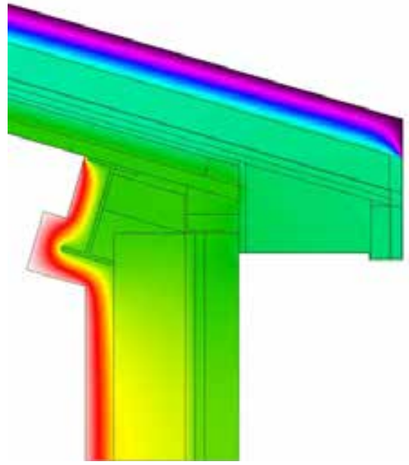










Existing

**Effective R-4**

Interior Spray foam

**Effective R-12 ci**

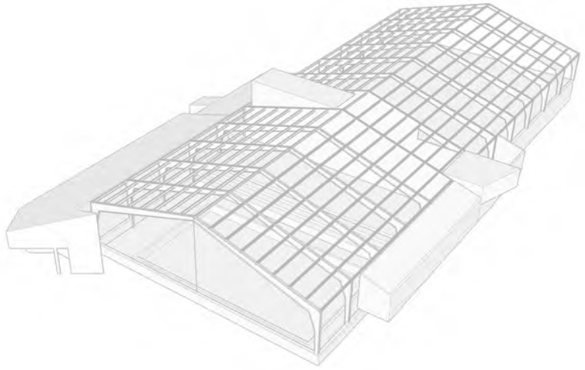
Exterior Overclad

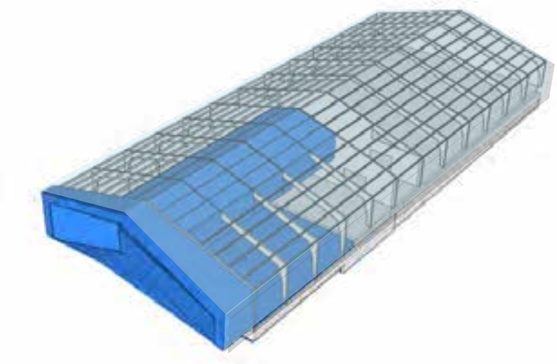
**Effective R-24 ci**

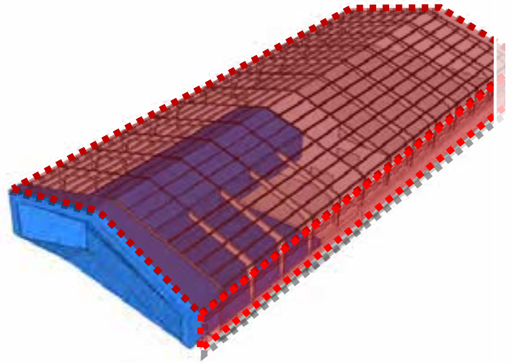
Interior Spray +
Roof Overclad

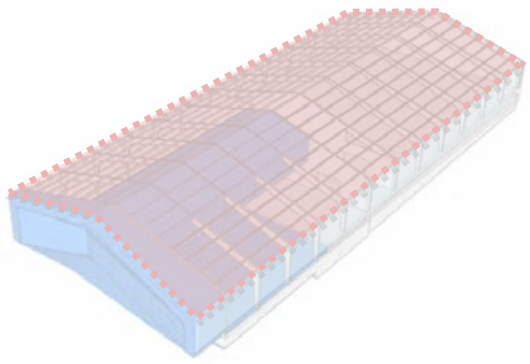
**Effective R-24 (not cont.)**

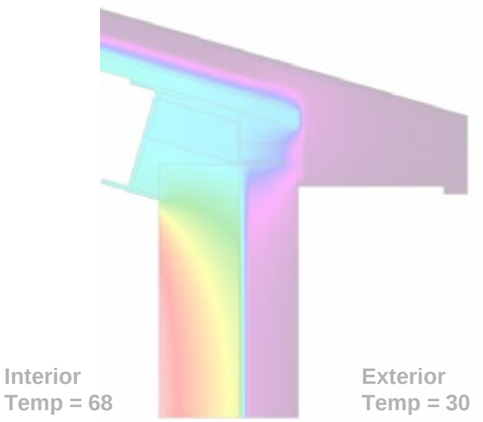
# Interior Insulation vs. Overcladding

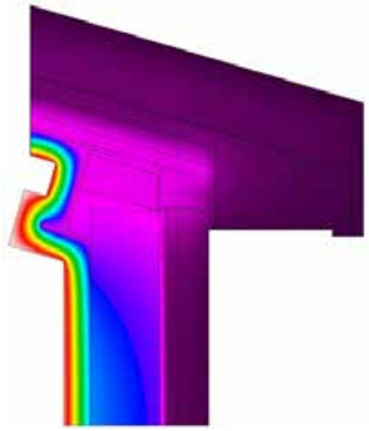


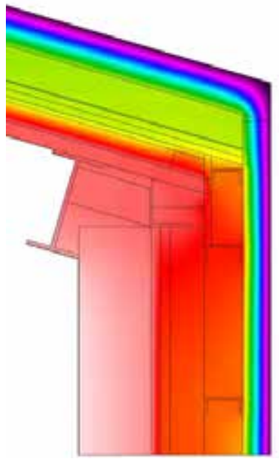


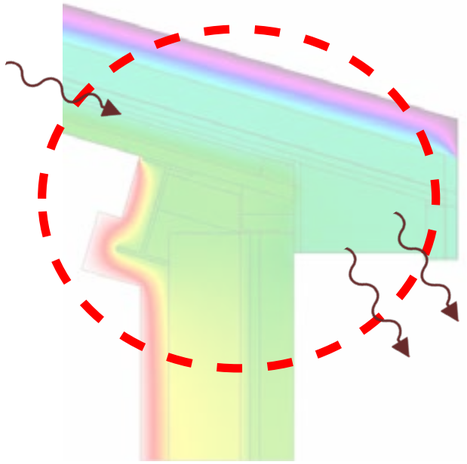










Existing

**Effective R-4**

Interior Spray foam

**Effective R-12 ci**

Exterior Overclad

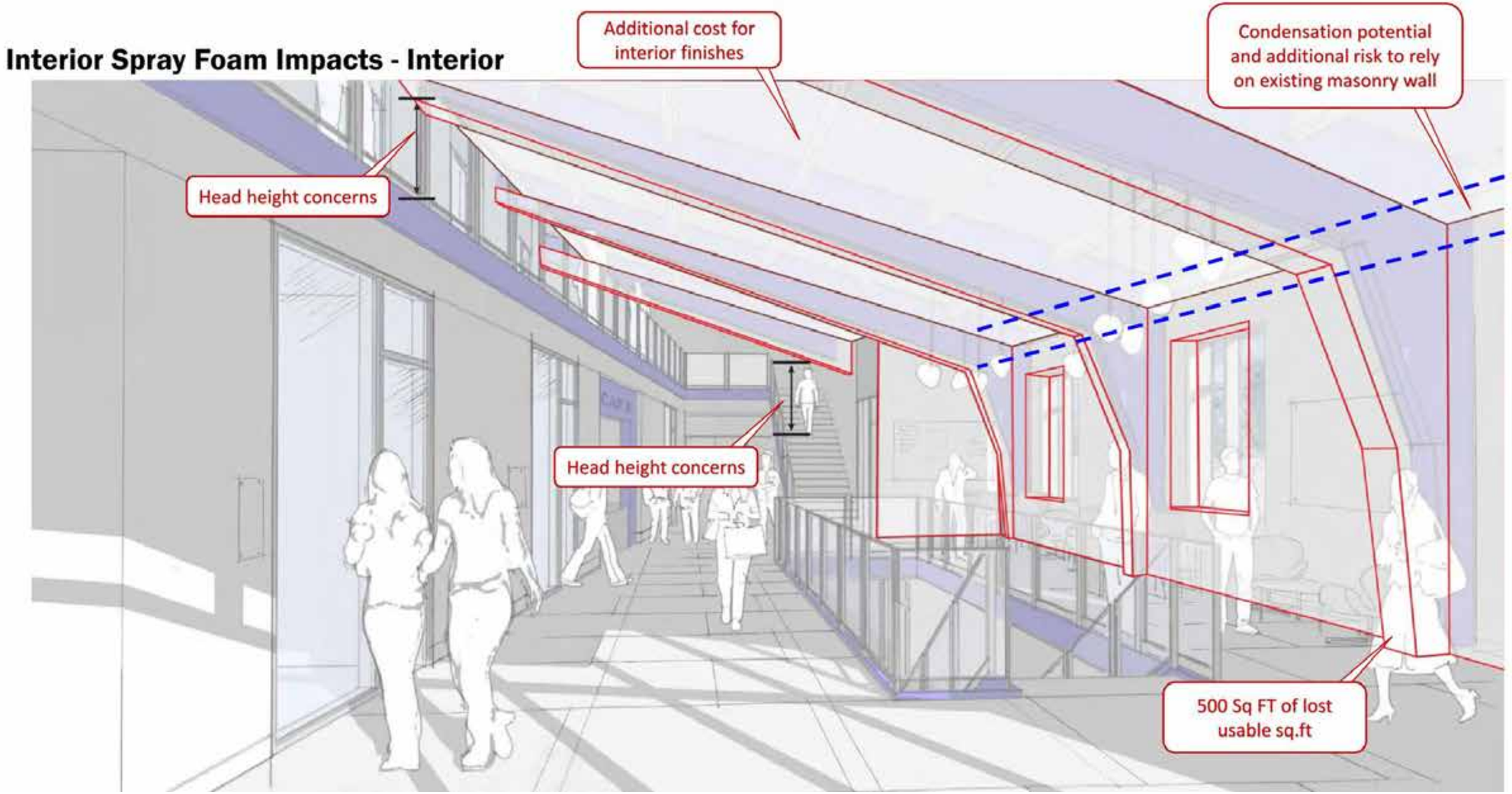
**Effective R-24 ci**

Interior Spray +
Roof Overclad

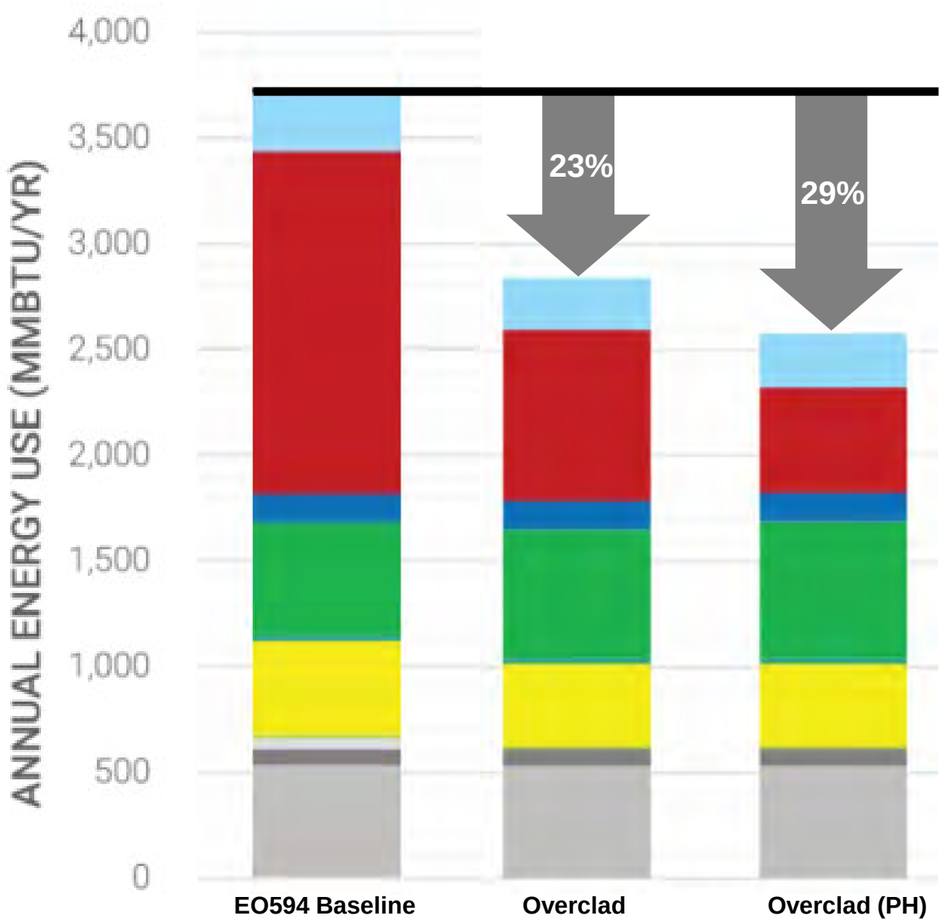
**Effective R-24 (not cont.)**

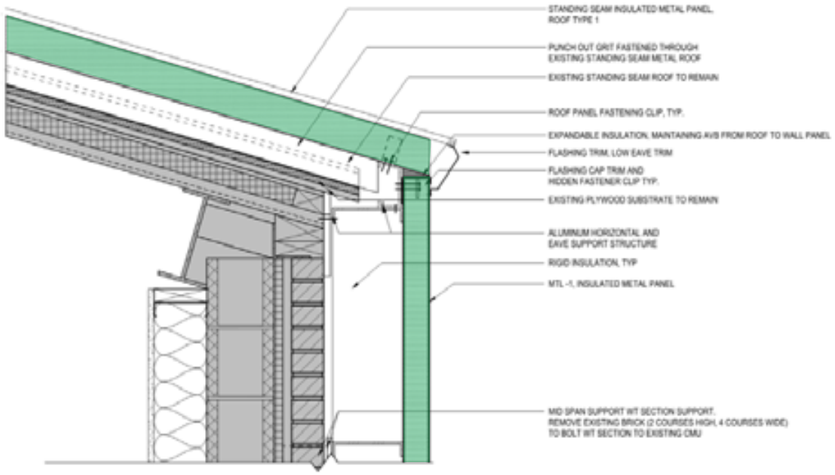
# **Why Overclad:** Protect Exposed Structure


# **Why Overclad:** Preserve Interior Space

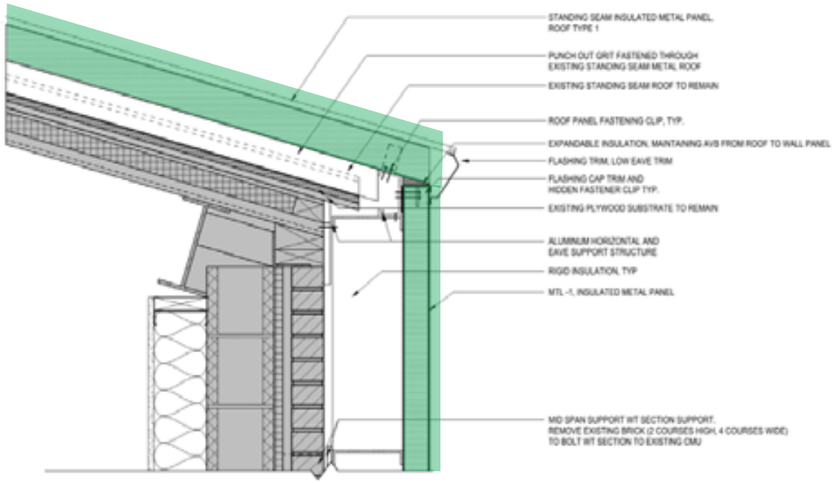


# Passive House vs. Code Min. Envelope



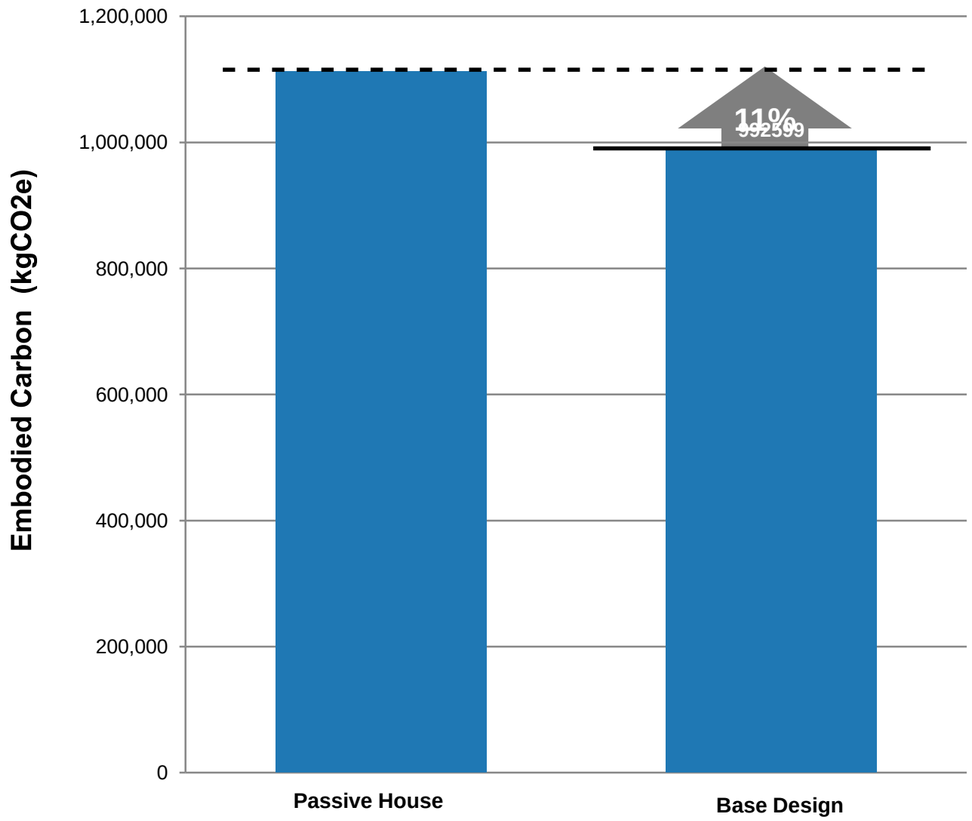

**<u>Overcladding</u>**
**3” IMP Panel (Wall) // 4” IMP Panel (Roof)**

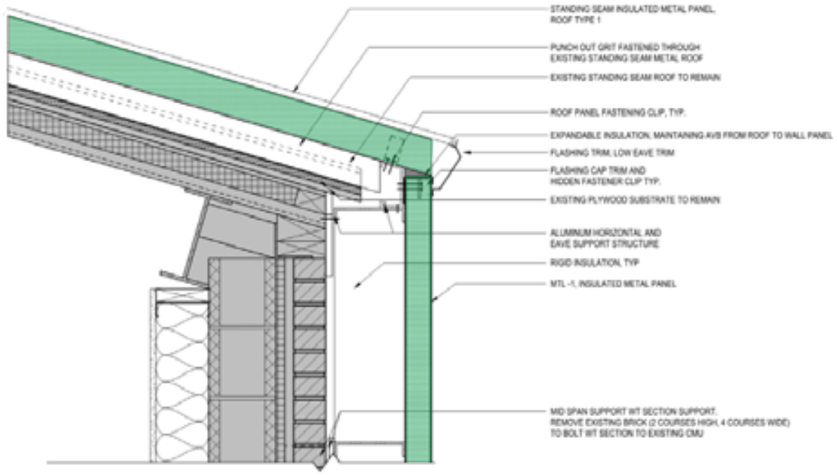



**<u>Overcladding</u>**
**4” IMP Panel (Wall) // 6” IMP Panel (Roof)**

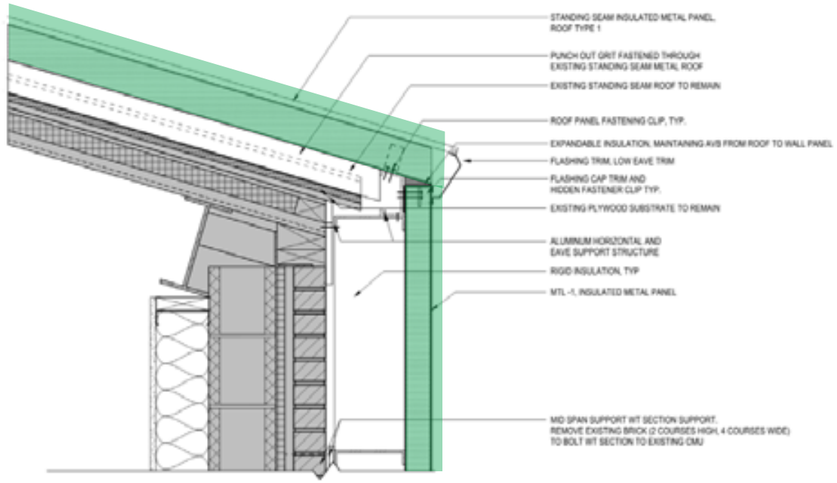
# Passive House vs. Code Min. Envelope

- **11%** Higher Embodied Carbon
- Carbon Payback Period = **5 years**



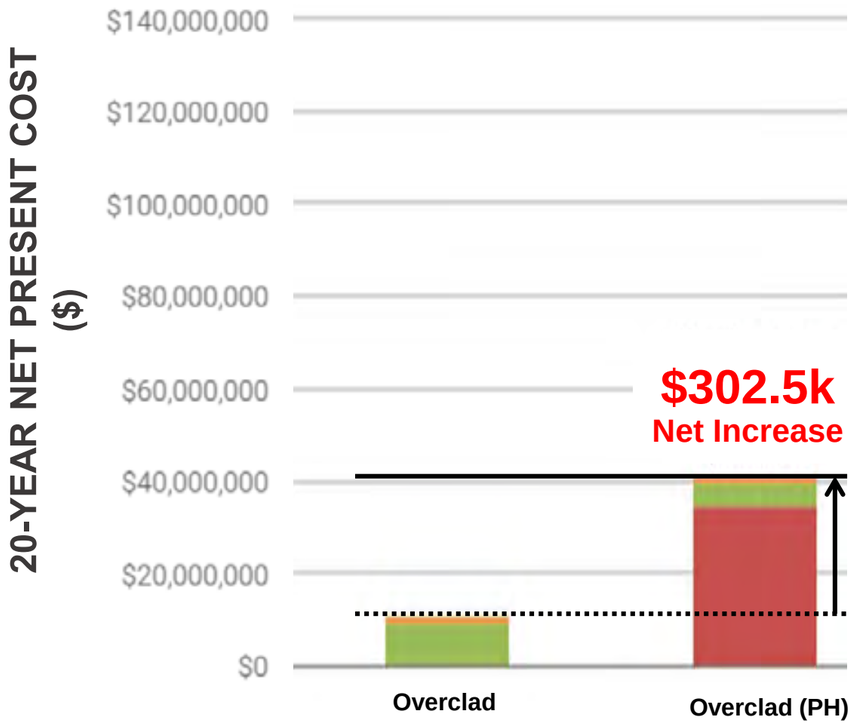

**Overcladding**
**3” IMP Panel (Wall) // 4” IMP Panel (Roof)**




**Overcladding**
**4” IMP Panel (Wall) // 6” IMP Panel (Roof)**

# Passive House vs. Code Min. Envelope

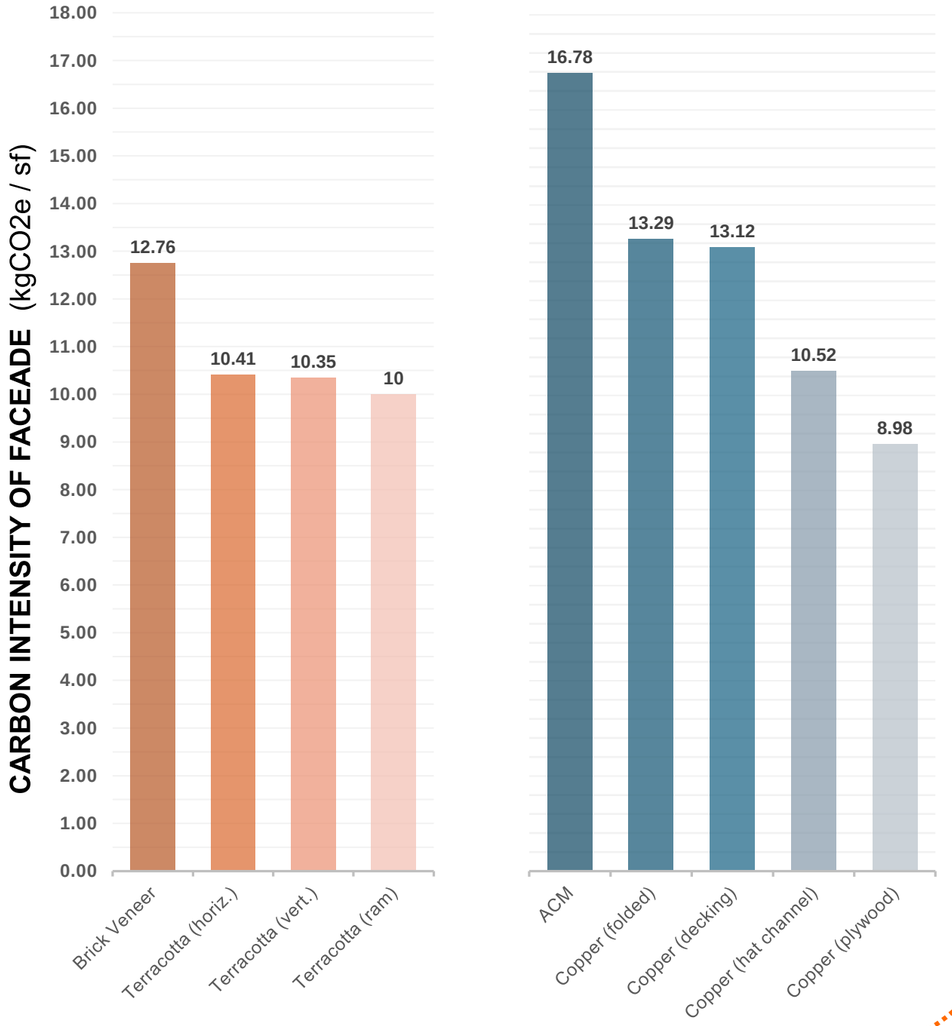
- **300% Higher Costs over first 20 years** ⟶ **2% Annual Energy Cost Savings**



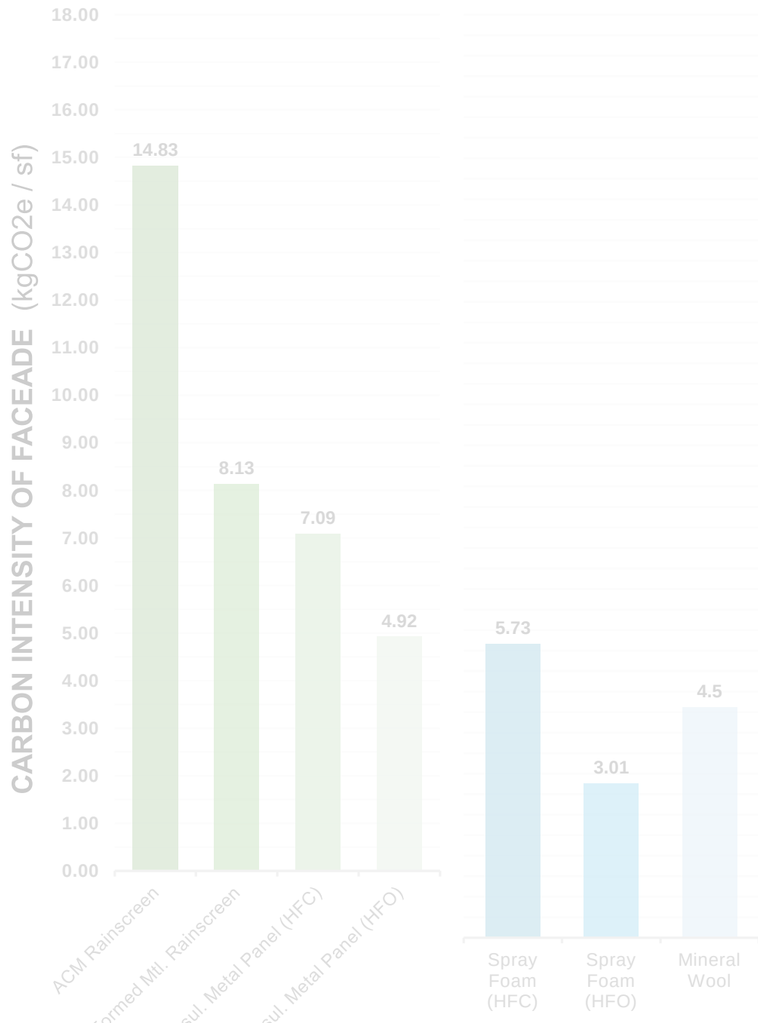

| SUMMARY | OPTION 1D.1 Gas Boiler Air Cooled Chiller Full Overclad | OPTION 1D.1 PH Gas Boiler Air Cooled Chiller Passive House |
|---|---|---|
| CONSTRUCTION COSTS | $23,491,920 | $24,057,358 |
| ANNUAL ENERGY COST | $128,622 | $126,161 |
| ANNUAL MAINTENANCE COST* | $13,369 | $13,369 |
| UTILITY INCENTIVE | $6,000 | $24,000 |

# Strategies for Driving Down ECI: New construction

## NEW CONSTRUCTION ASSEMBLIES




## ENVELOPE RETROFIT ASSEMBLIES





DATA SOURCE: EXTERIOR ENVELOPE

# Academic Brick Campuses


Emmanuel College | Dartmouth University | Vanderbilt University | William and Mary | Uni. of New Hampshire | Harvard Business School | Notre Dame

# Types of Masonry Assemblies

**MASS MASONRY**

MULT WYTHE GRAVITY LOADED ASSEMBLY

**TRANSITIONAL MASONRY**

HISTORIC TILES WITH STEEL BACKUP AND ORNATE CHARACTER

**BRICK VENEER**

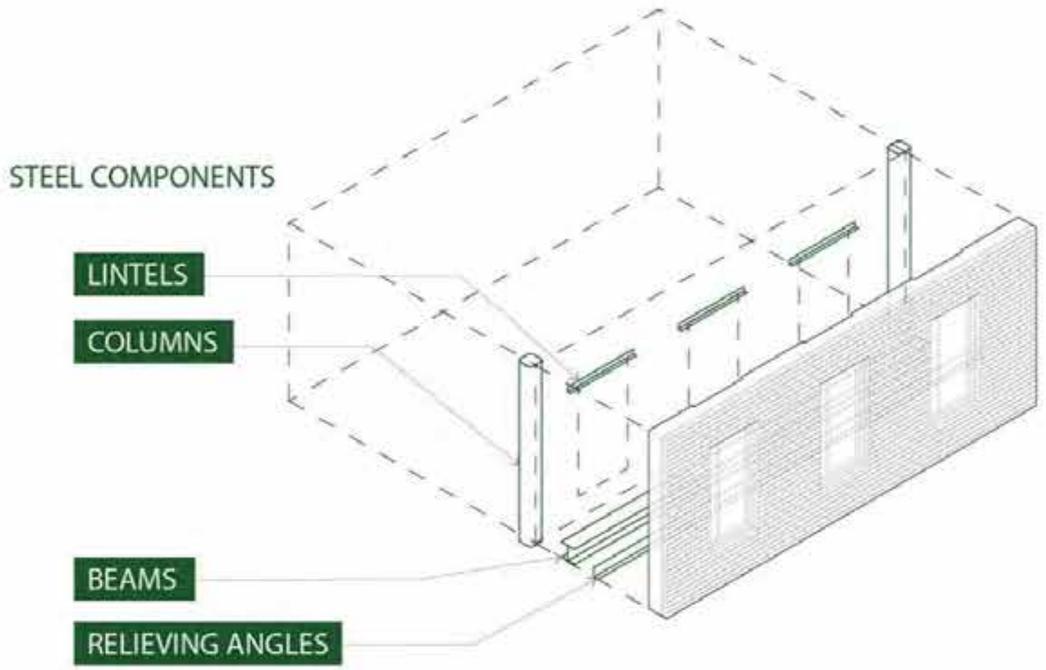
SINGLE WYTHE HUNG ASSEMBLY WITH STEEL REINFORCING

**TERRA COTTA RAINSCREEN**

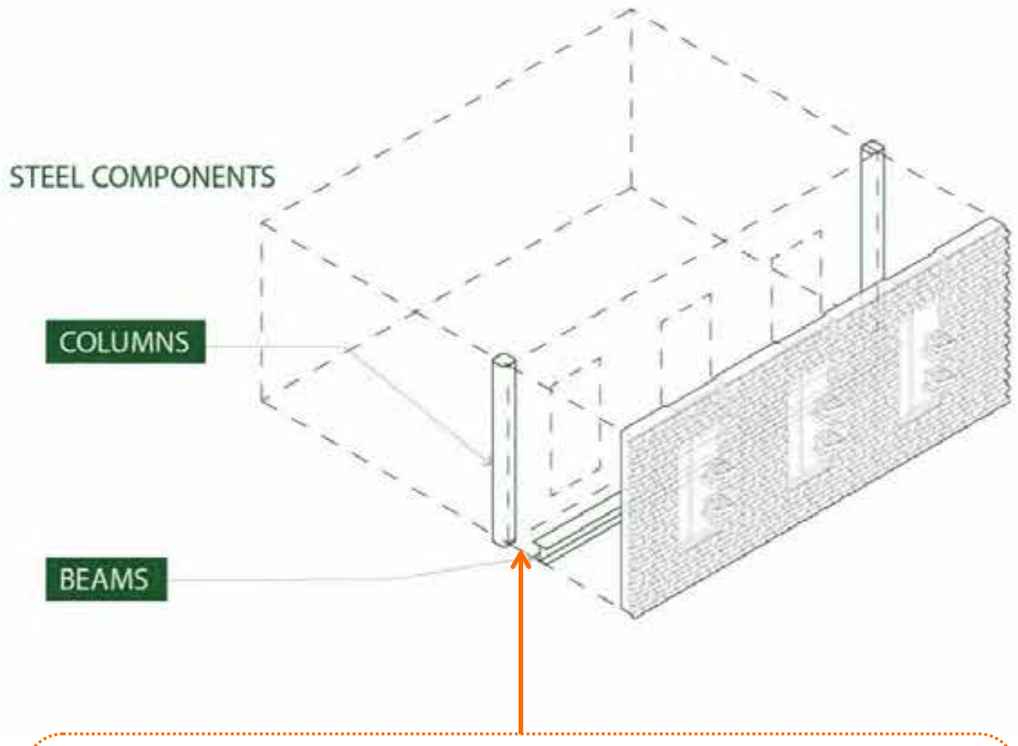
TERRA COTTA PANEL WITH ALUMINUM SUBSTRUCTURE

# Reduction in Structure

TYPICAL BRICK FACADE




TESSELATED TERRACOTTA FACADE




Lighter structural steel members due to decreased weight of wall assembly.

Savings of 1.75 pounds per sq.ft

## DESIGN PROMPT

**Innovate beyond the contextual vernacular, creating a facade that dialogues with the past while looking toward the future.**

- Lightweight Rainscreen
- Sculptural & Figural
- Facade Transformation from Plane to Object
- Cost Effective
- Thermally Capable
- Decreased Global Warming Potential

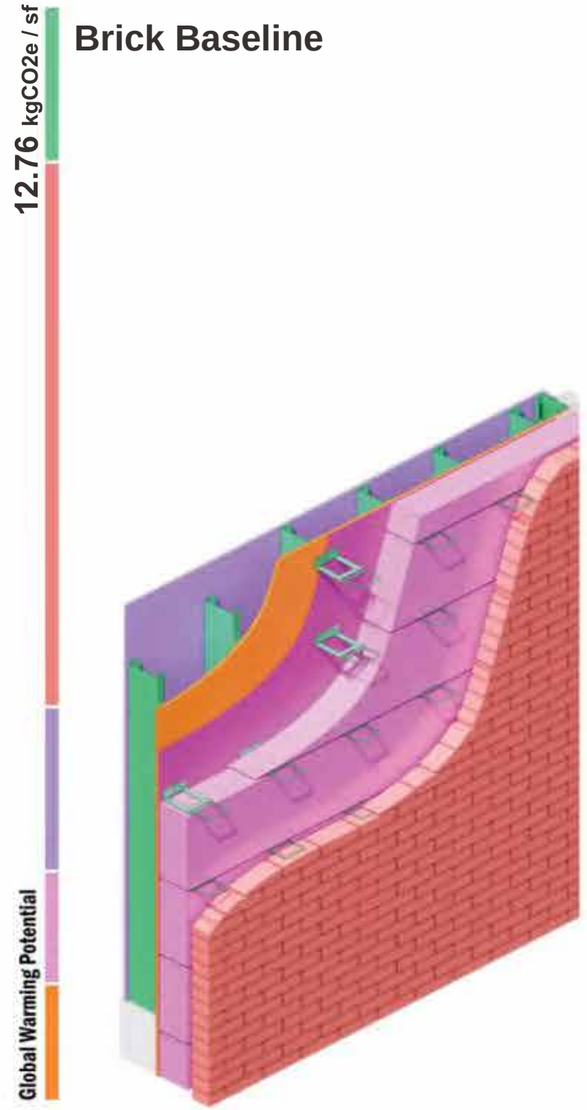
# Terracotta Carbon Accounting

20% reduction in aluminum
31% reduction in masonry

Reduced GWP compared to baseline

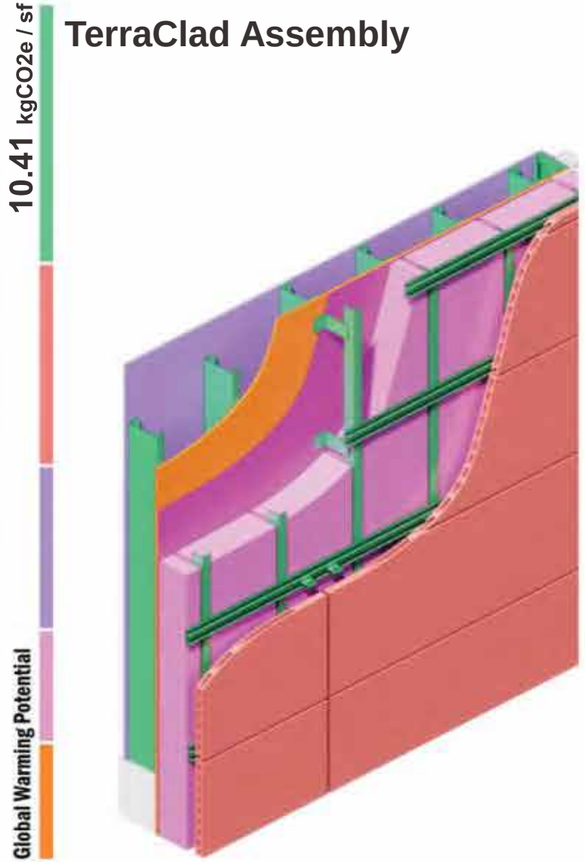
## Brick Baseline

12.76 kgCO2e / sf



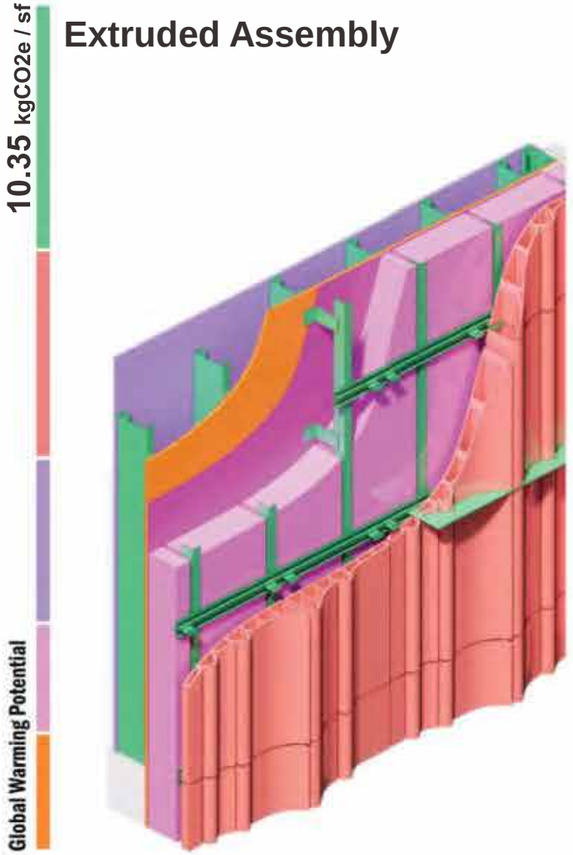

## TerraClad Assembly

10.41 kgCO2e / sf



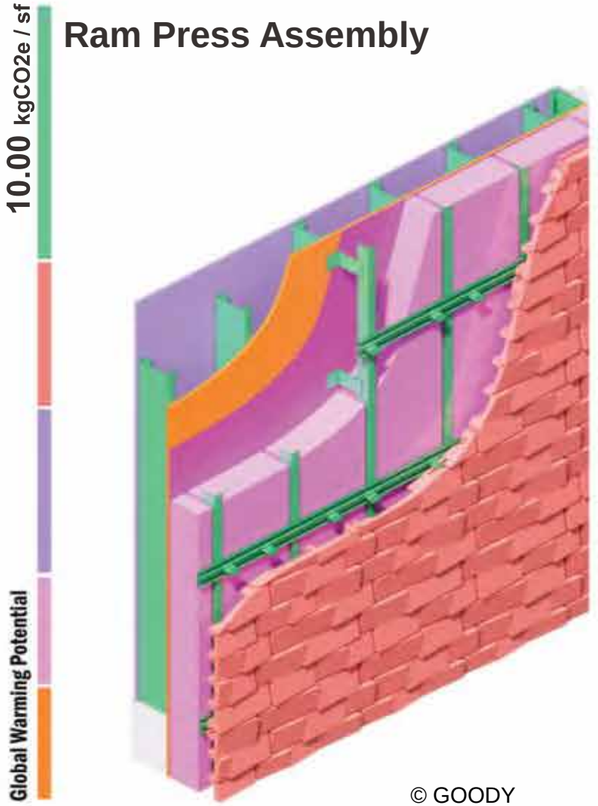

## Extruded Assembly

10.35 kgCO2e / sf




## Ram Press Assembly

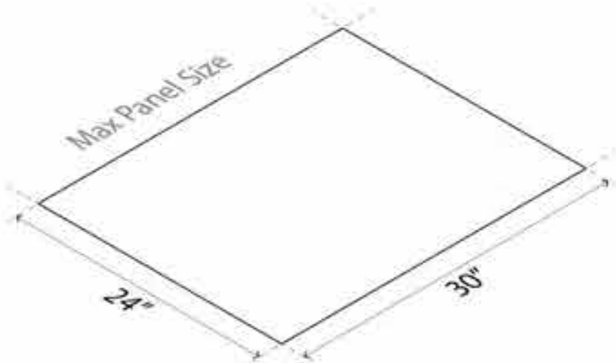
10.00 kgCO2e / sf

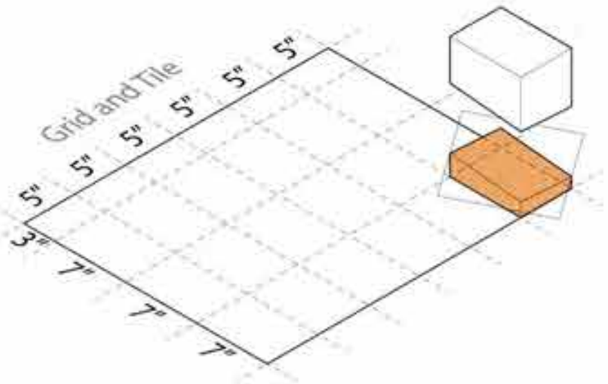


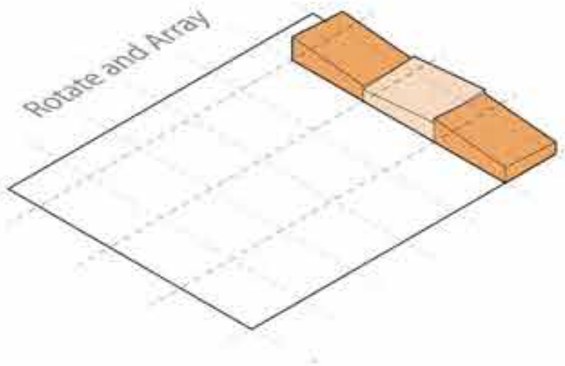


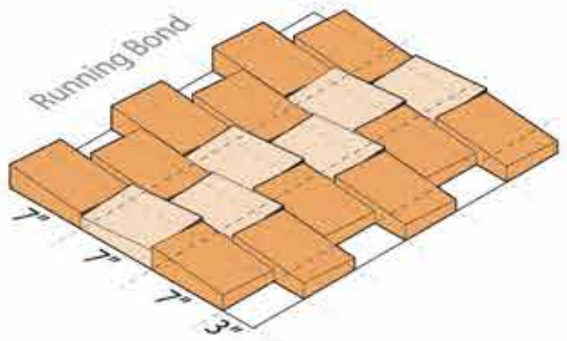

DRIVING DOWN THE EMBODIED CARBON

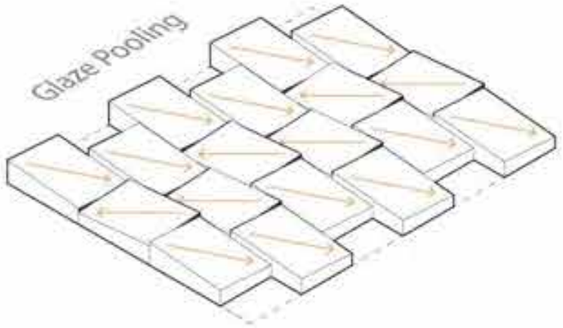
# Tessellation Strategy

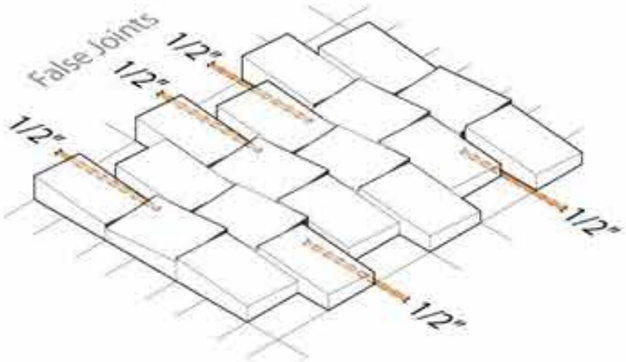


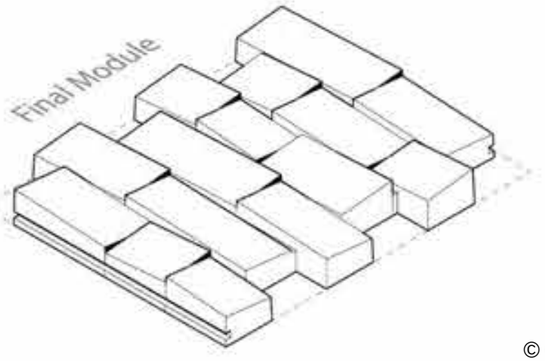



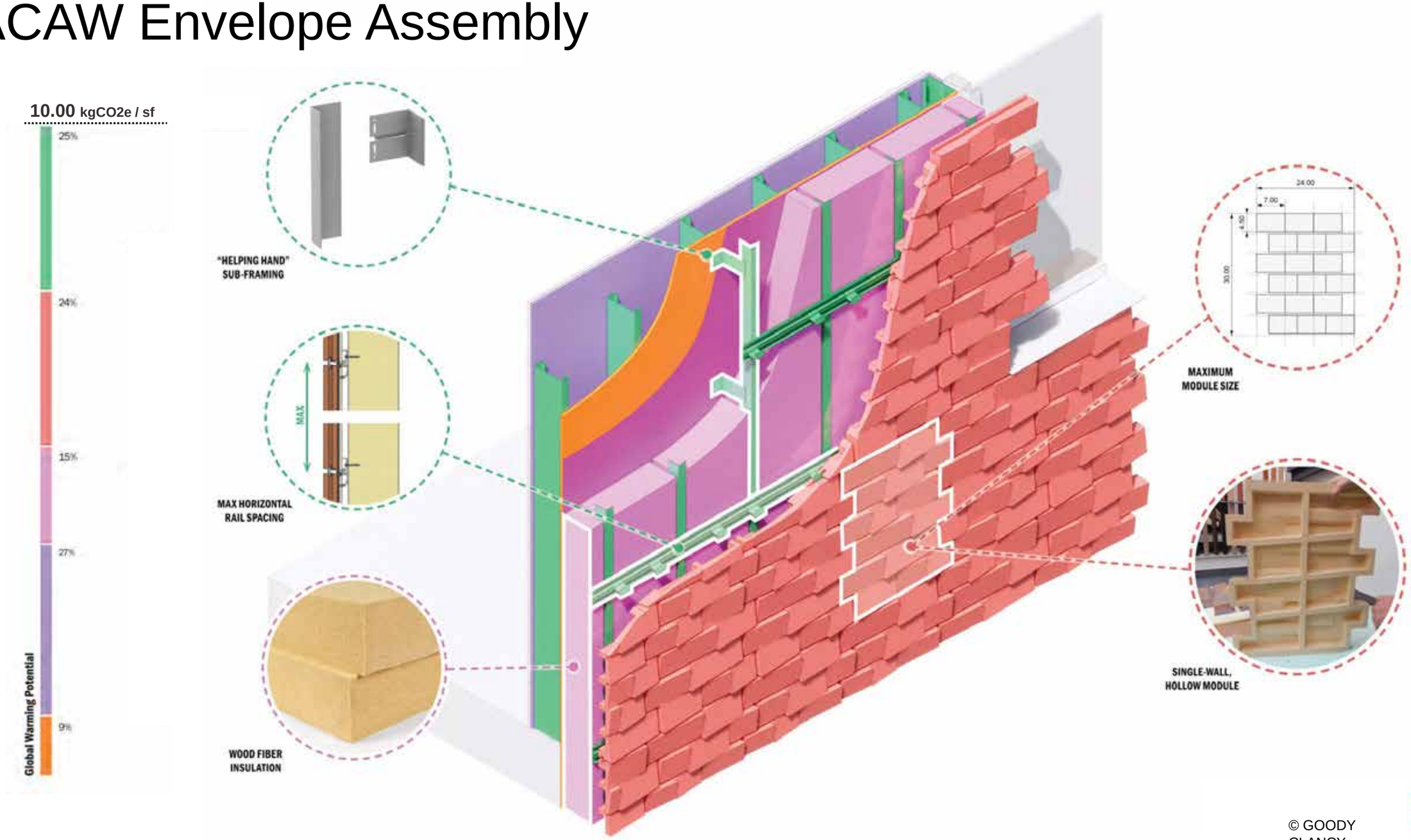



# ACAW Envelope Assembly



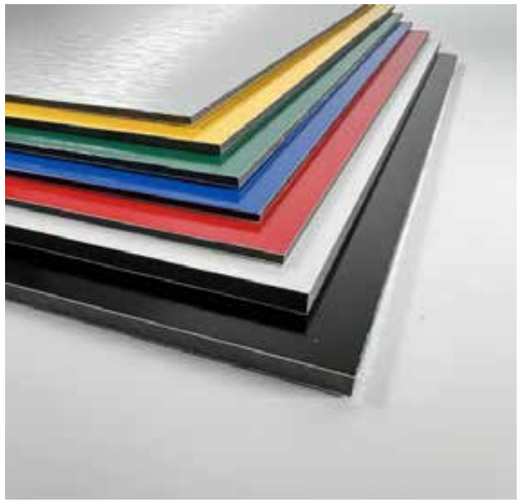
# Mock-up Assembly


GOODYCLANCY
ARCHITECTURE / PLANNING / PRESERVATION

# Case Study #3 Addition to Workhorse Lab Building

- UMass Lowell – Olney Science Center Addition
  - $103m
  - 53,000 gsf (addition)
  - 53,000 gsf (renovation)
  - Program:
    - 12 New Teaching Labs
    - 9 Renovated Classrooms (Traditional & Active Learning)
    - New “Knowledge Commons”

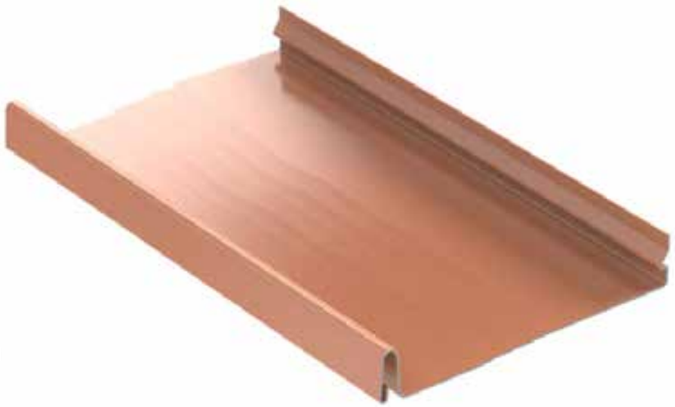
# Reducing ECI of Cladding Material



**Aluminum Composite Panels**
ECI = **16.78** kgCO2e / sf

**Aluminum Plate Panels**
ECI = **16.70** kgCO2e / sf

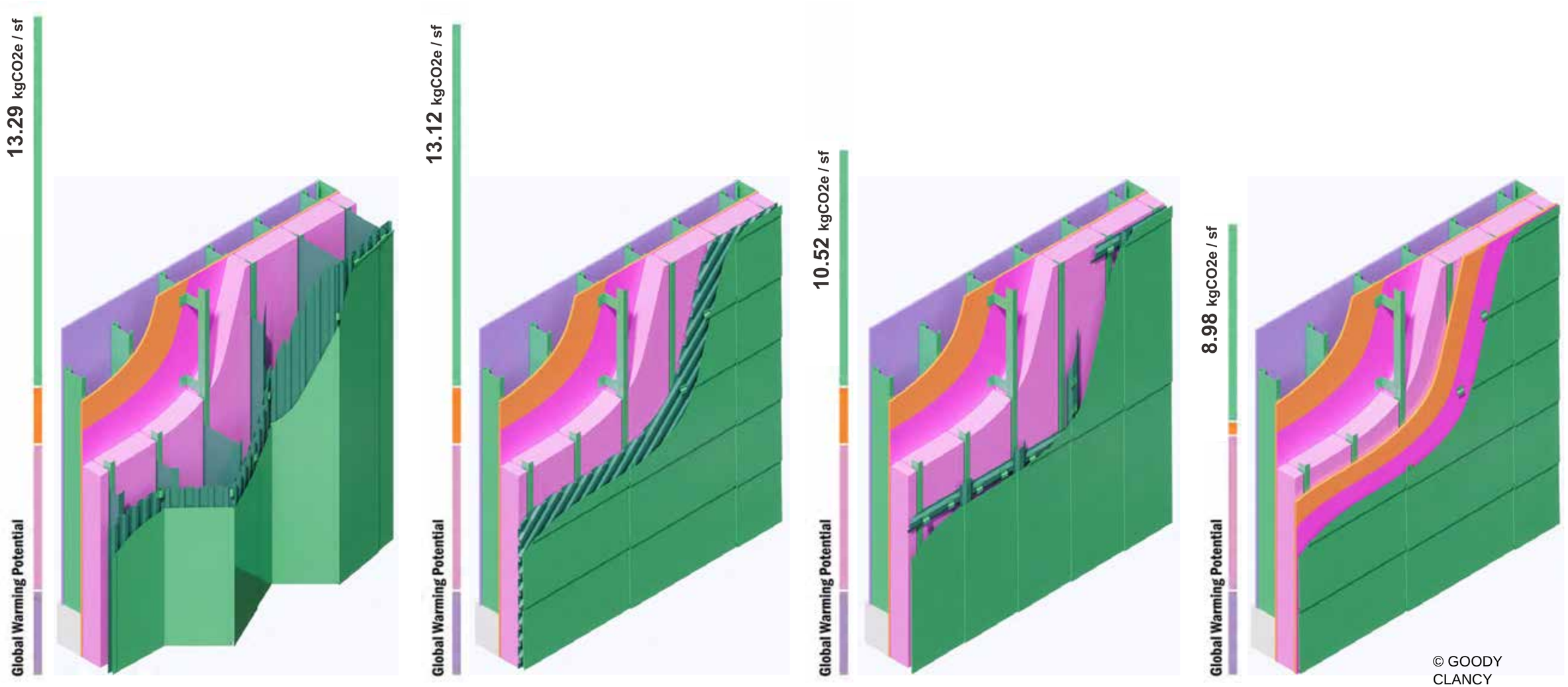
**Formed Aluminum Panel**
ECI = **9.43** kgCO2e / sf



**Formed Copper Panel**
ECI = **8.29** kgCO2e / sf

DRIVING DOWN THE EMBODIED CARBON

# Reducing ECI of Support Structure




**Steel Decking with Articulations**

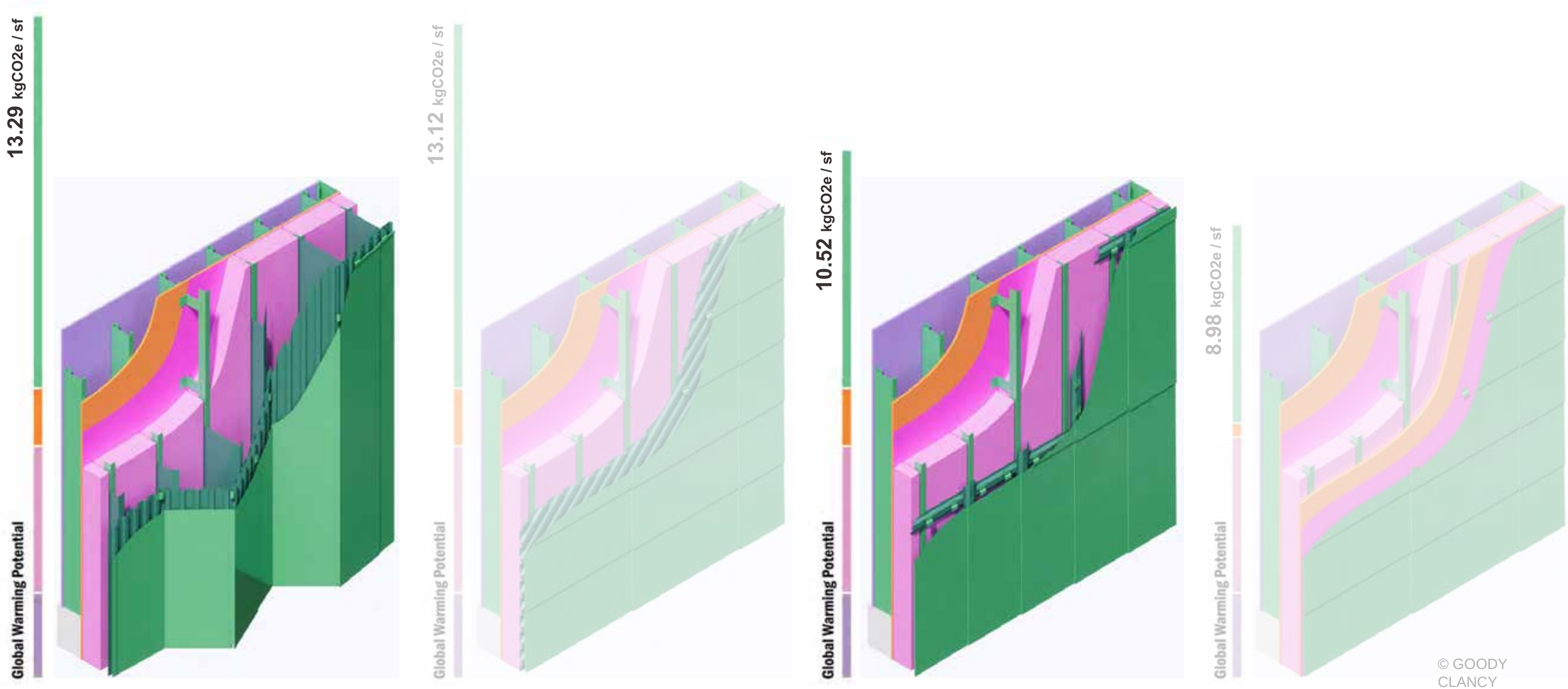
**Steel Decking**

**Horizontal & Vertical Rails**

**Plywood Back-up**

DRIVING DOWN THE EMBODIED CARBON

# Reducing ECI of Support Structure




**Steel Decking with Articulations**

**Steel Decking**

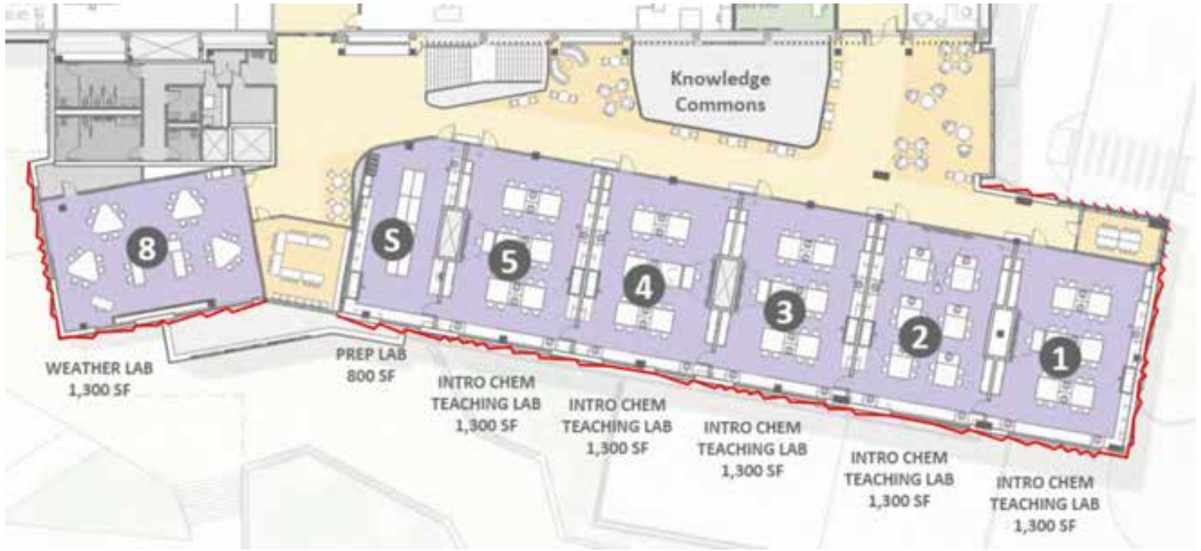
**Horizontal & Vertical Rails**

**Plywood Back-up**

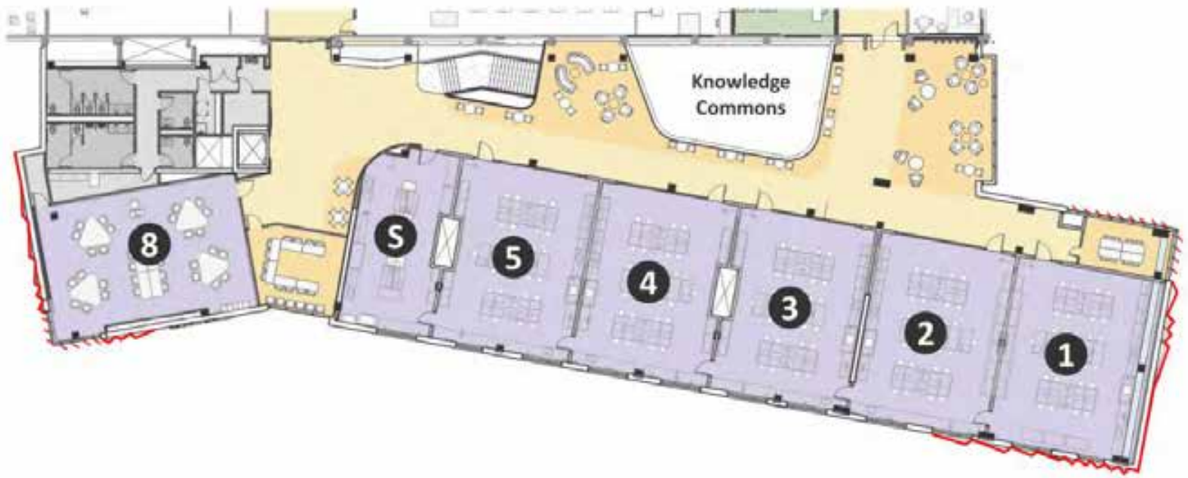
DRIVING DOWN THE EMBODIED CARBON

# Optimizing Articulations for Maximum Impact

**Façade Articulations - DDs**




**Façade Articulations - CDs**




50% Reduction in Façade Articulations


OLNEY SCIENCE CENTER
LIFANG

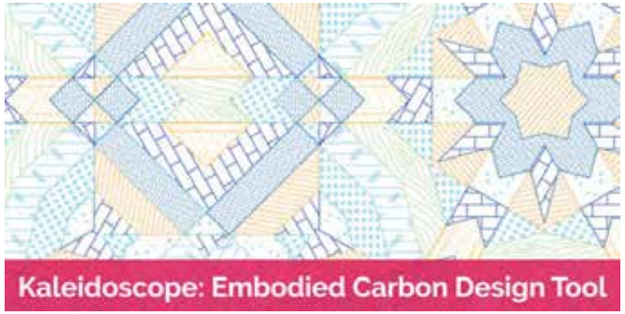

OLNEY SCIENCE CENTER
LIFANG


OLNEY SCIENCE CENTER
LIFANG

# **Tools & Workflows:** Filling and Industry Gap

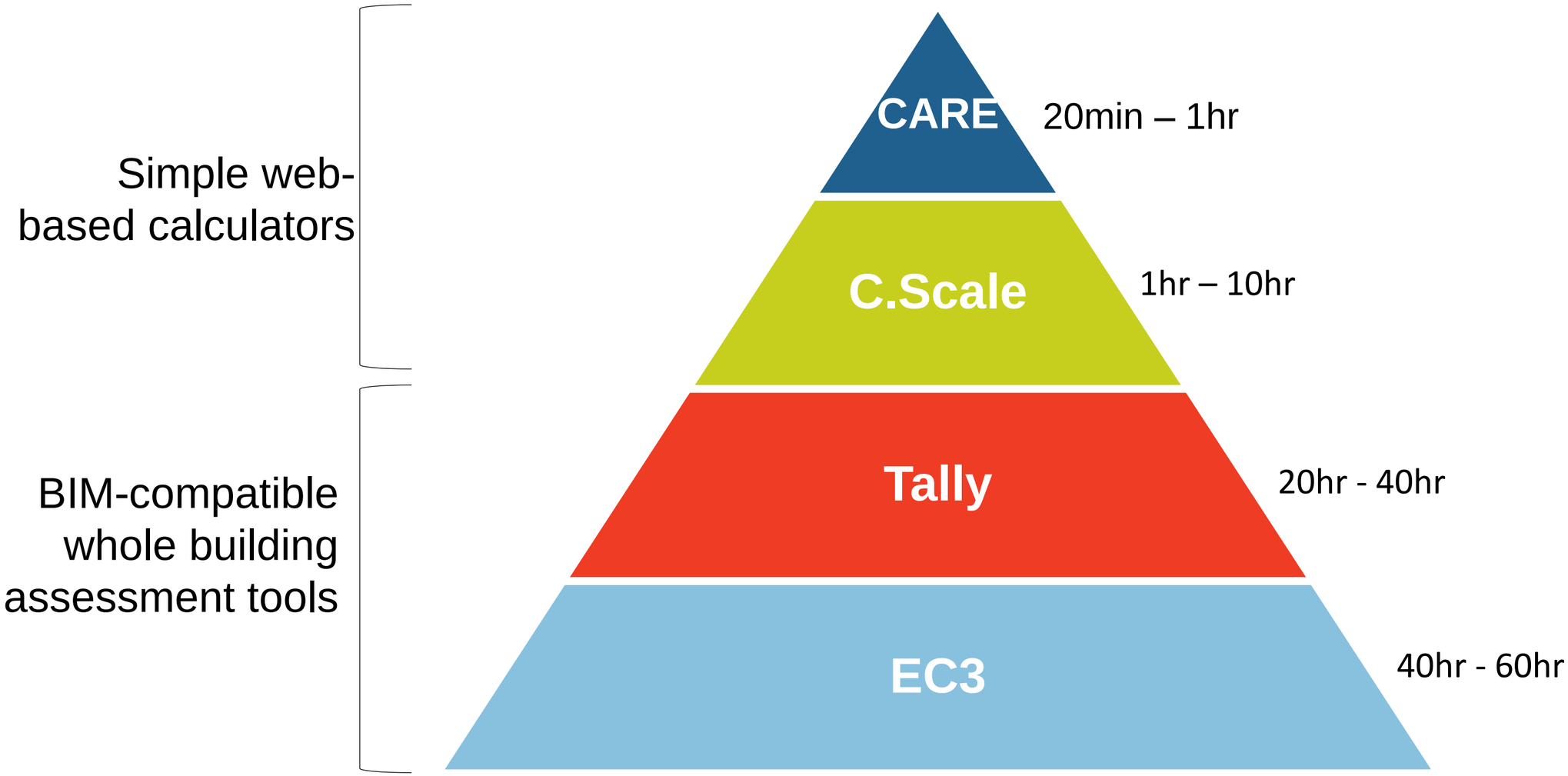
# Tools for Architects, by Architects



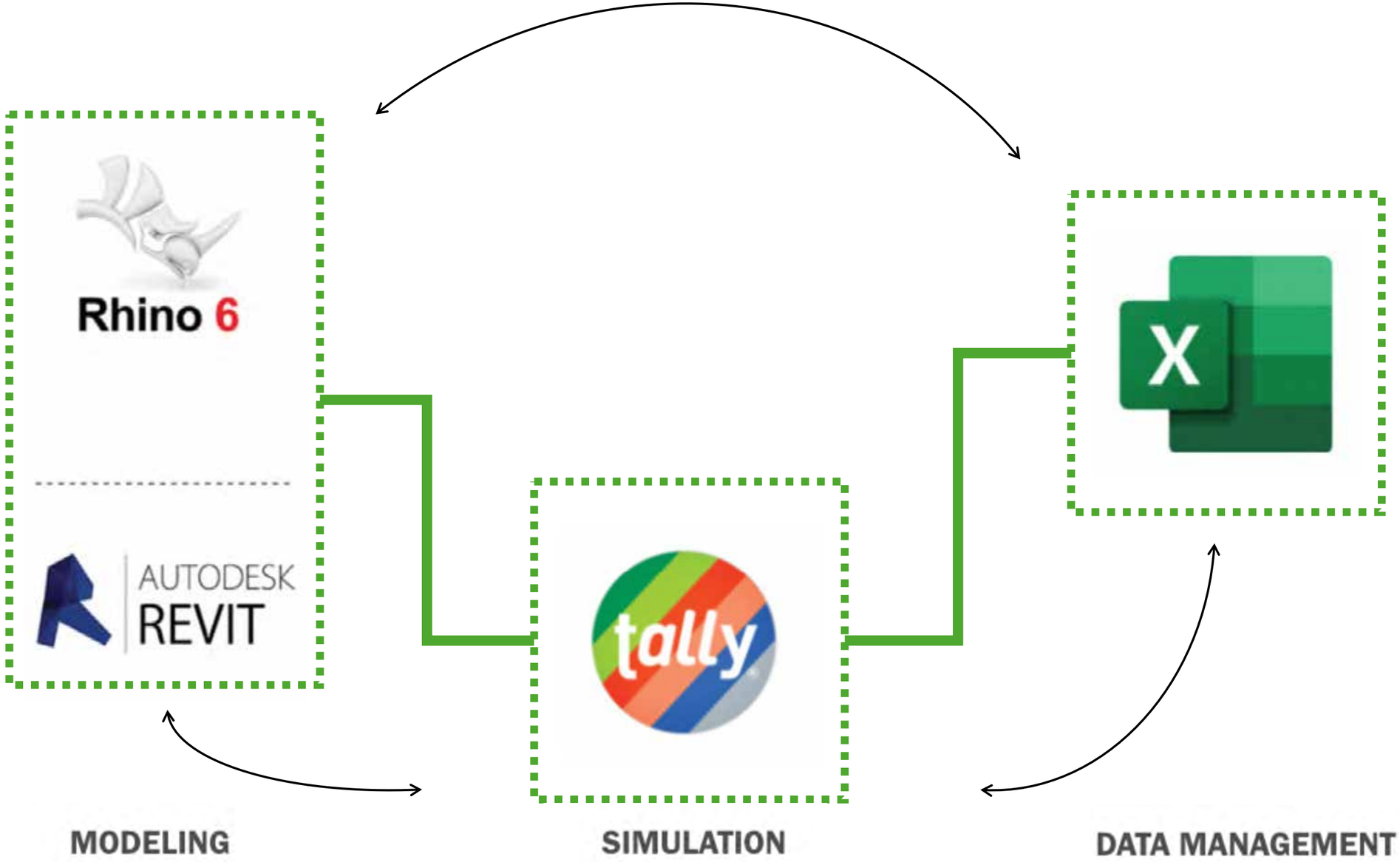





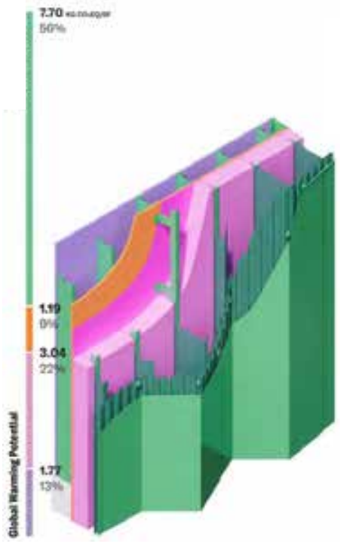
# Effort and Complexity in Using the Tools



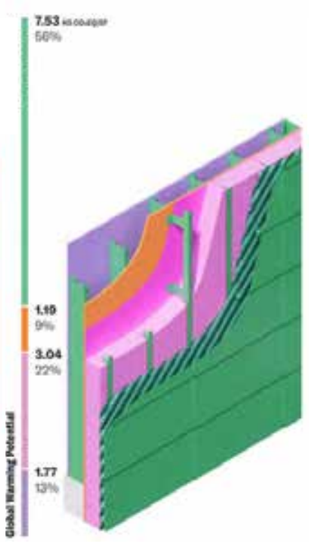
# Envelope Embodied Carbon Accounting Workflow



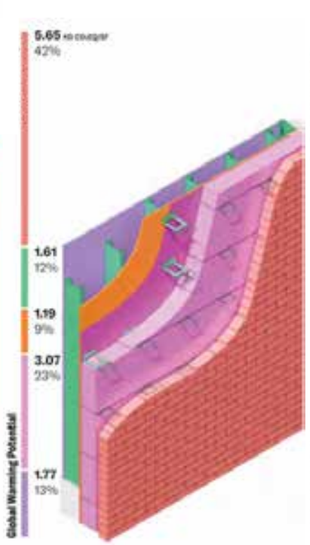
# All Assemblies – In house office resource



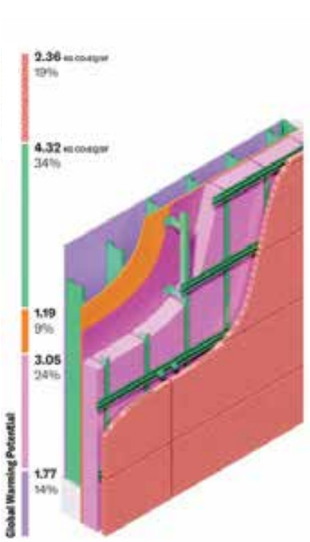

**Copper**
Steel Decking w/ Articulations



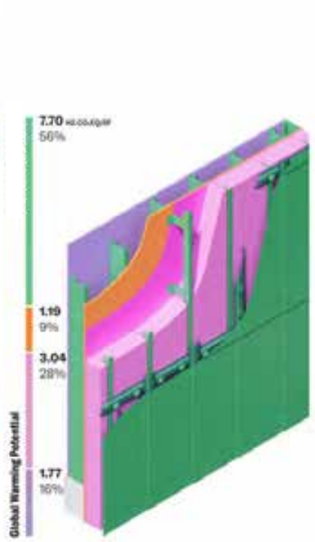

**Copper**
Steel Decking



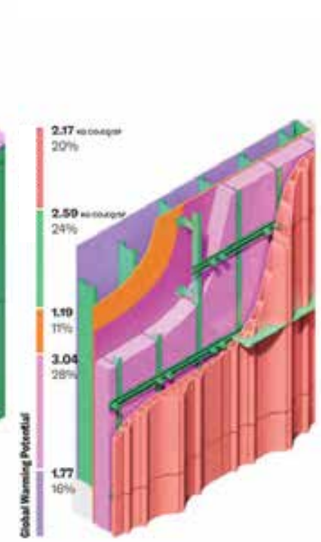

**Brick**
Typical Assembly



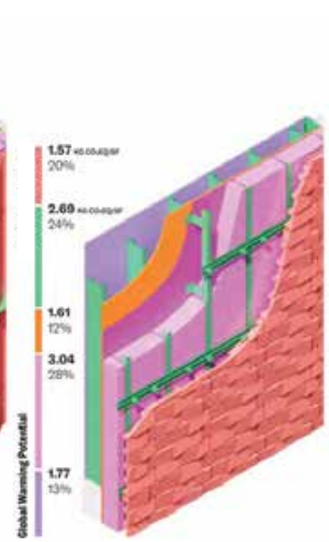

**Terracotta**
TerraClad Assembly



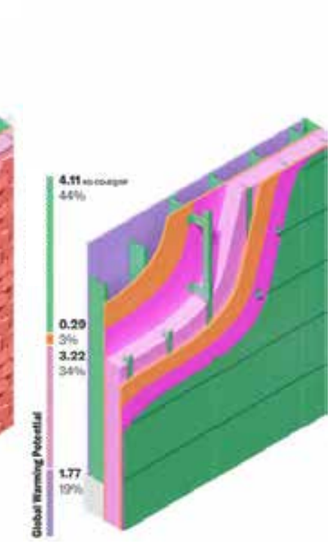

**Copper**
Horizontal & Vertical Rails




**Terracotta**
Extruded Assembly



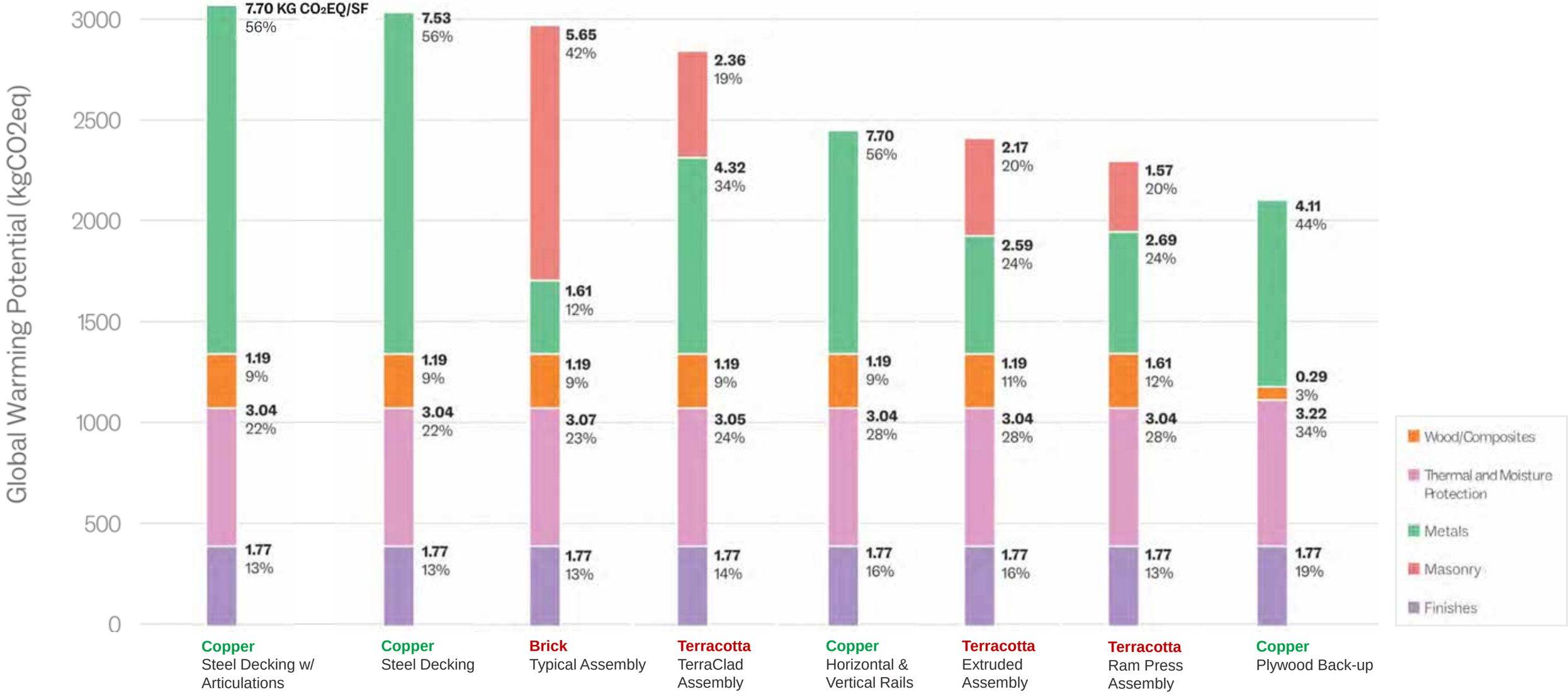

**Terracotta**
Ram Press Assembly

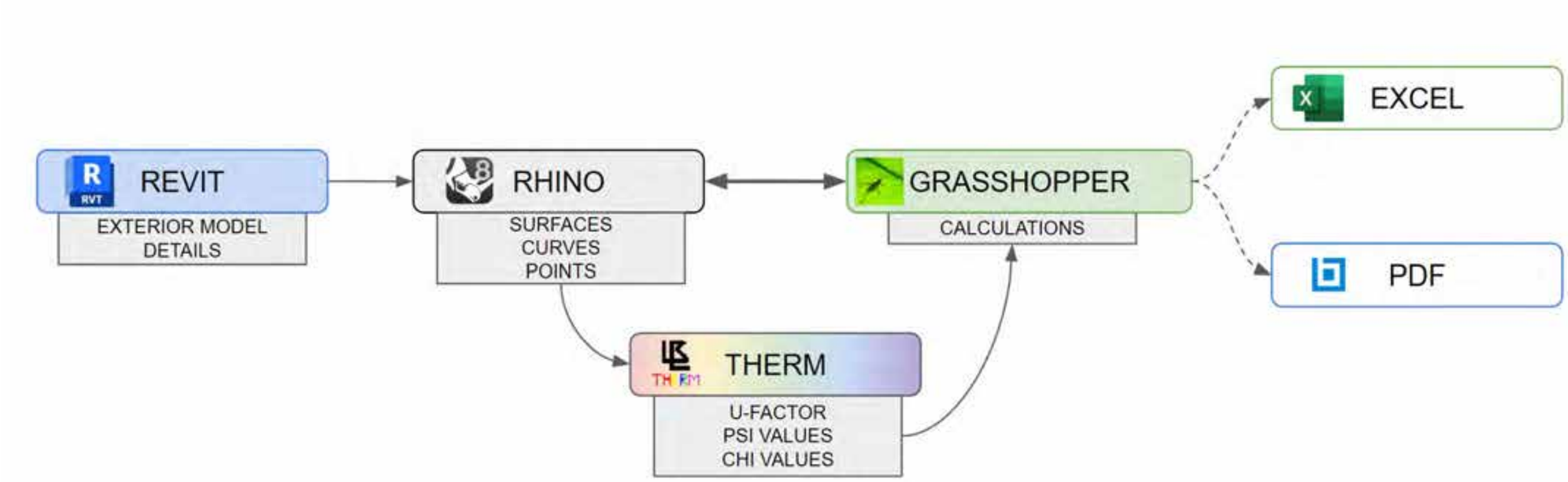


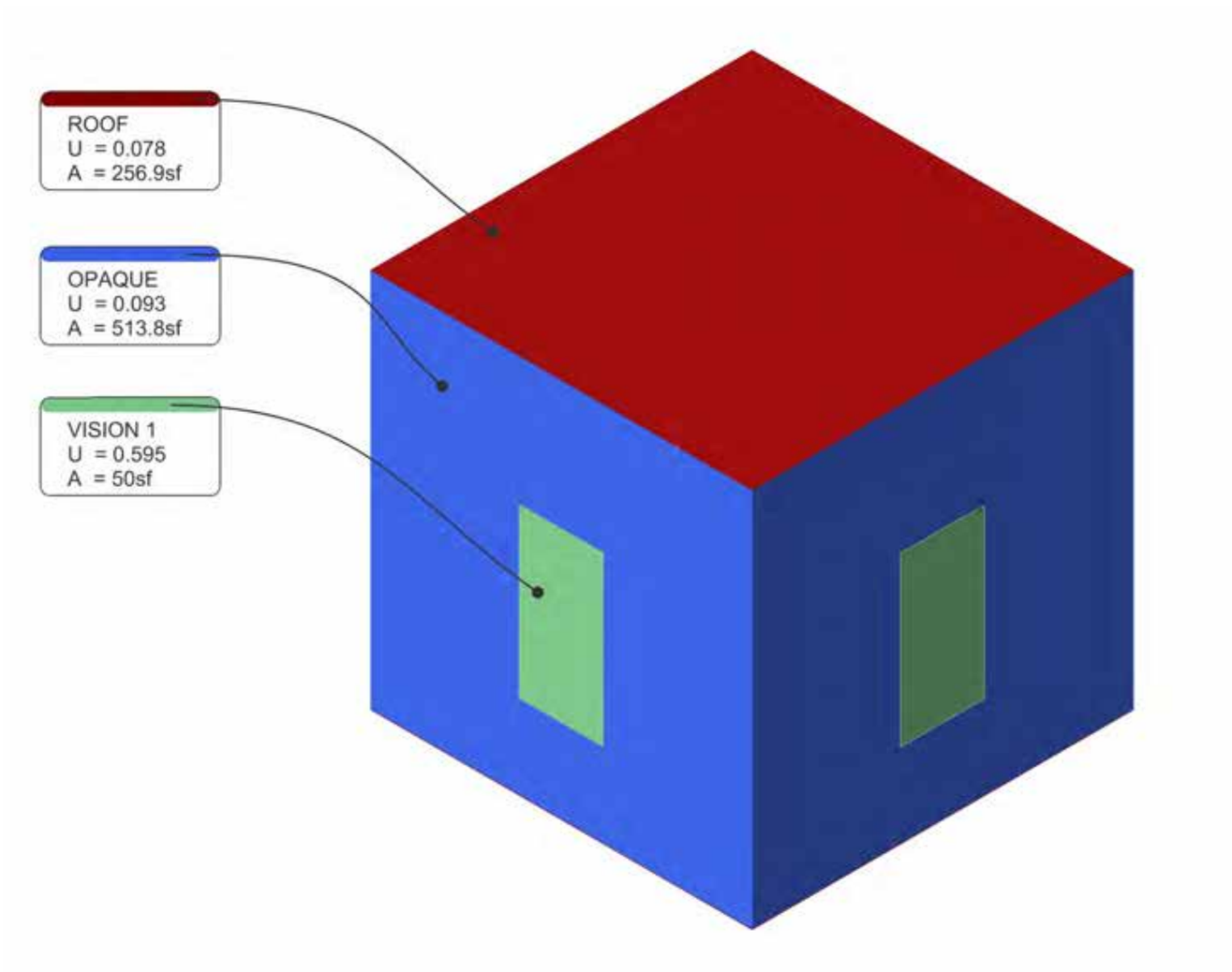

**Copper**
Plywood Back-up

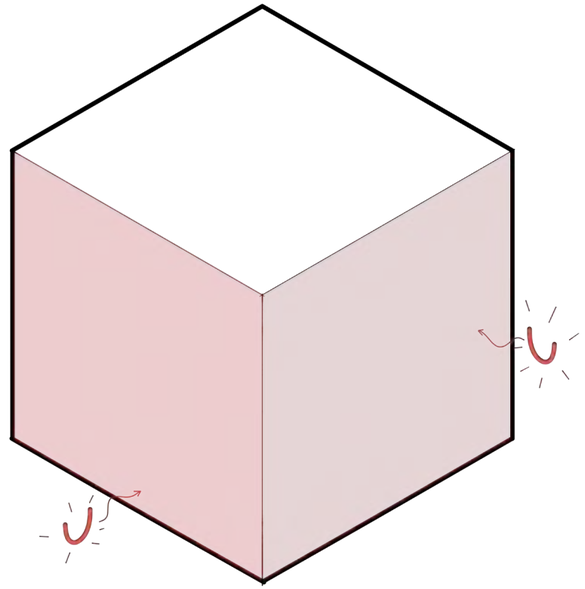
DRIVING DOWN THE EMBODIED CARBON

# Carbon Accounting by Material




REVIT
EXTERIOR MODEL
DETAILS
RHINO
SURFACES
CURVES
POINTS
GRASSHOPPER
CALCULATIONS
EXCEL
PDF
THERM
U-FACTOR
PSI VALUES
CHI VALUES



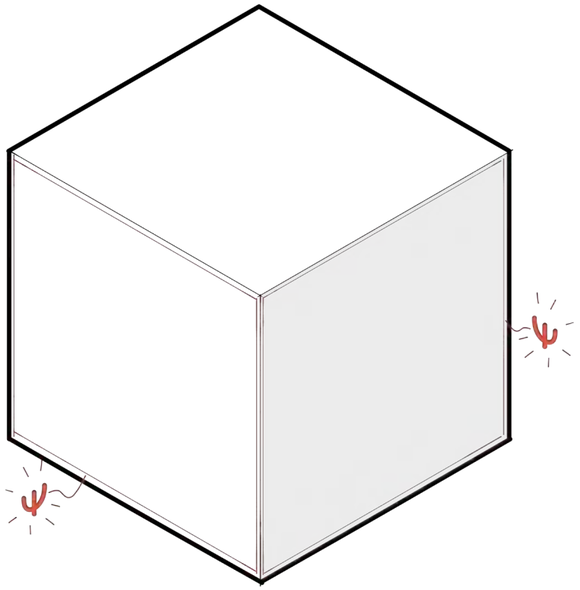



$$L \times H = A$$

$$\Psi \times L = \Psi_L$$

$$\Psi_L \% A = U_{ADD}$$

$$U + U_{ADD} = U_{TOT}$$

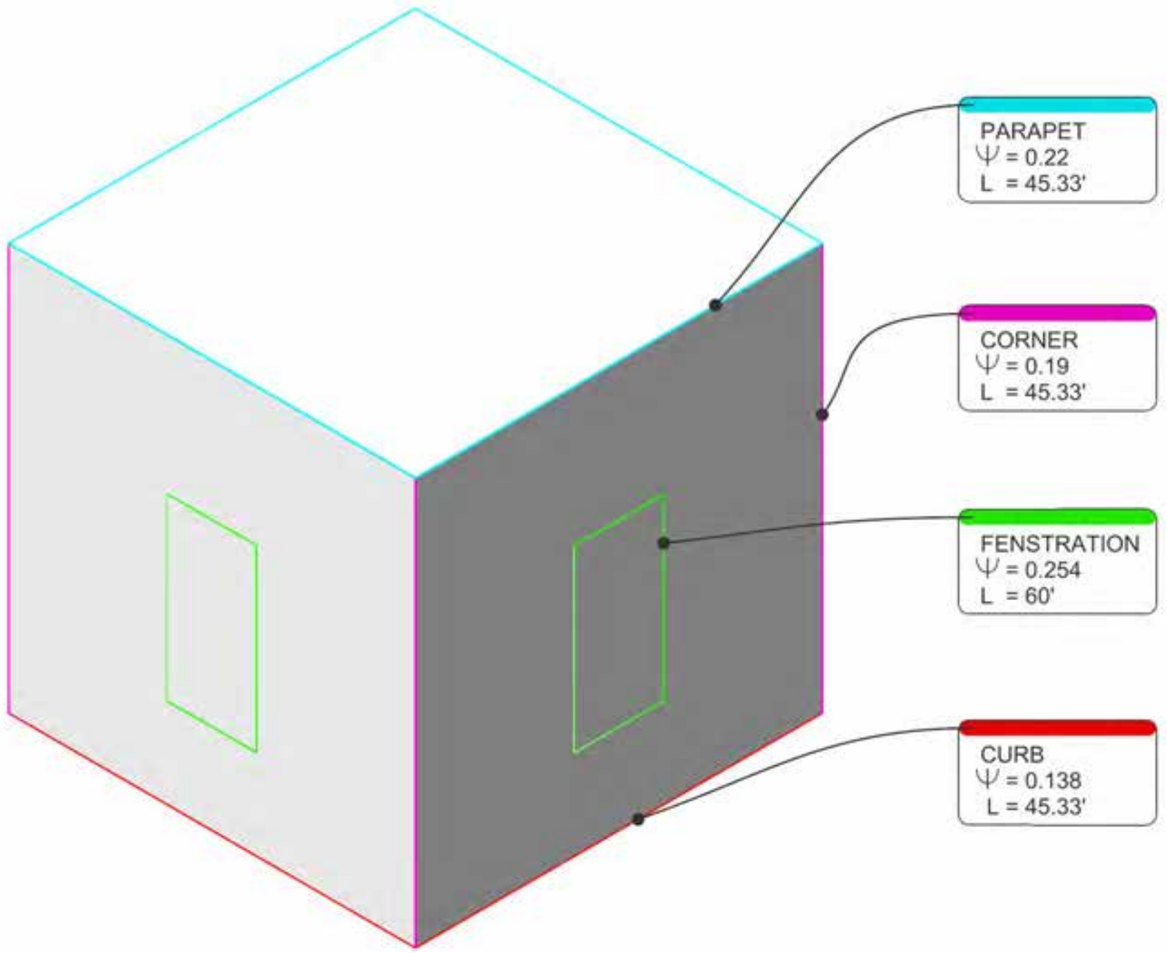


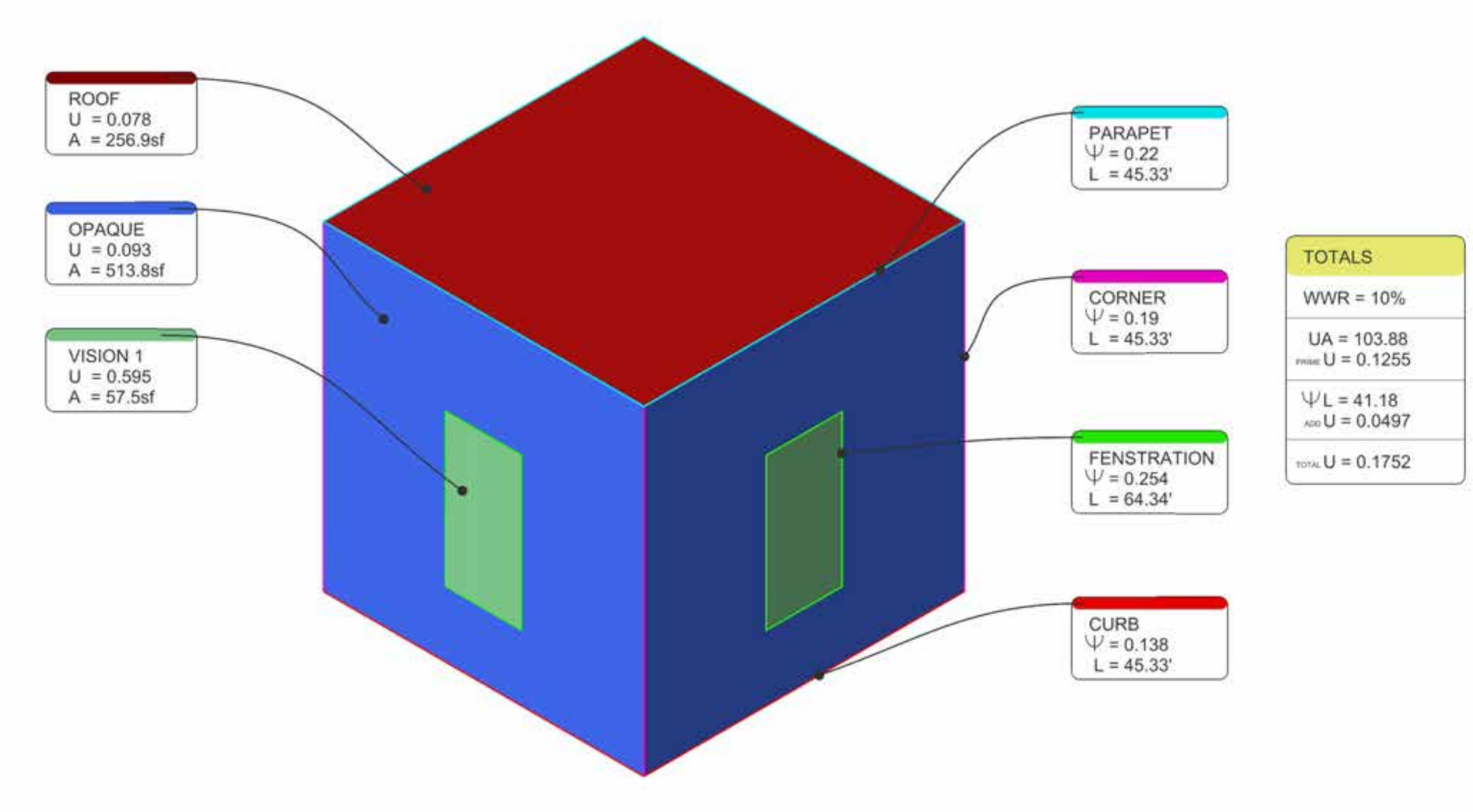

$$L \times H = A$$

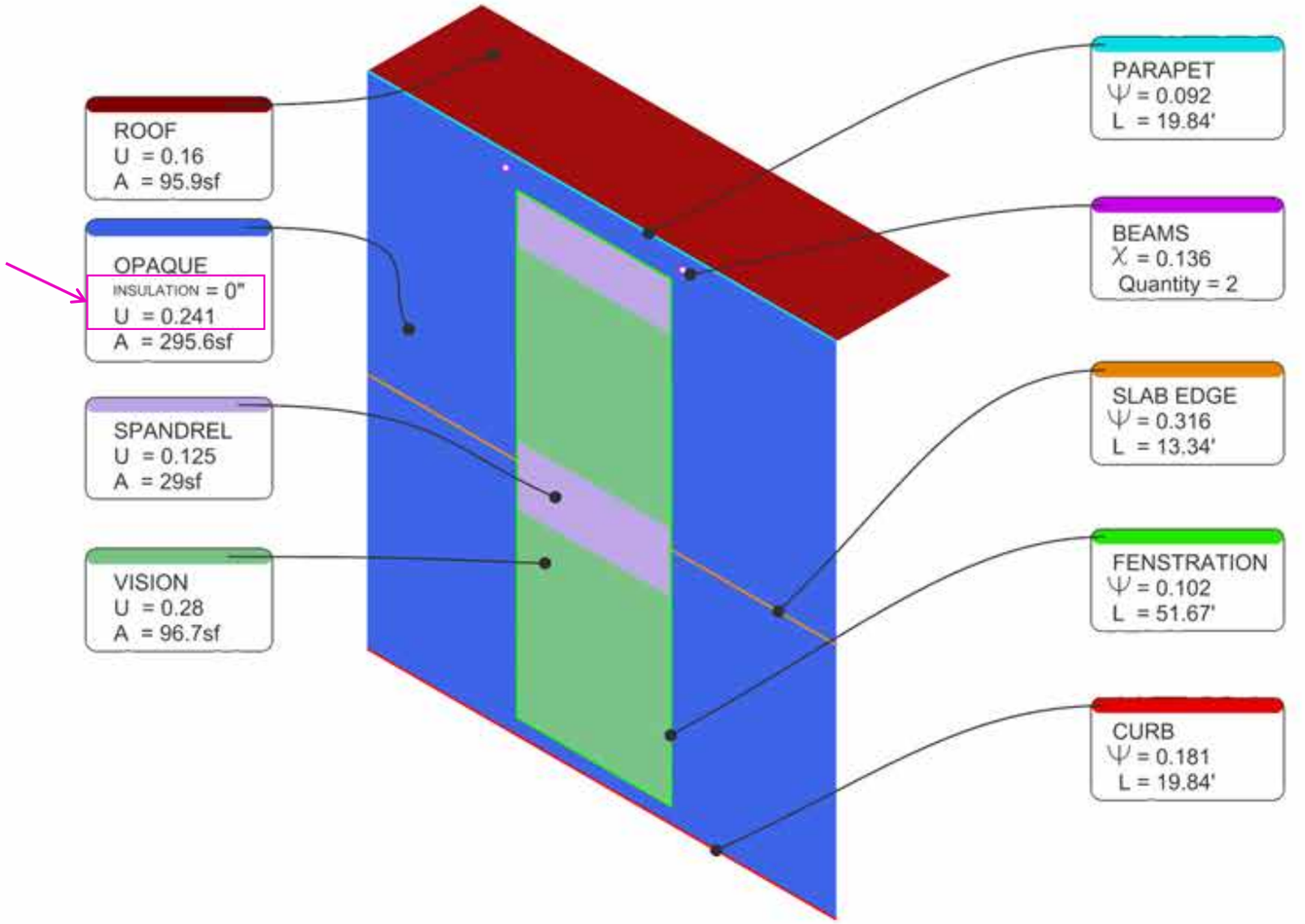
$$\Psi \times L = \Psi_L$$

$$\Psi_L \% A = U_{ADD}$$

$$U + U_{ADD} = U_{TOT}$$

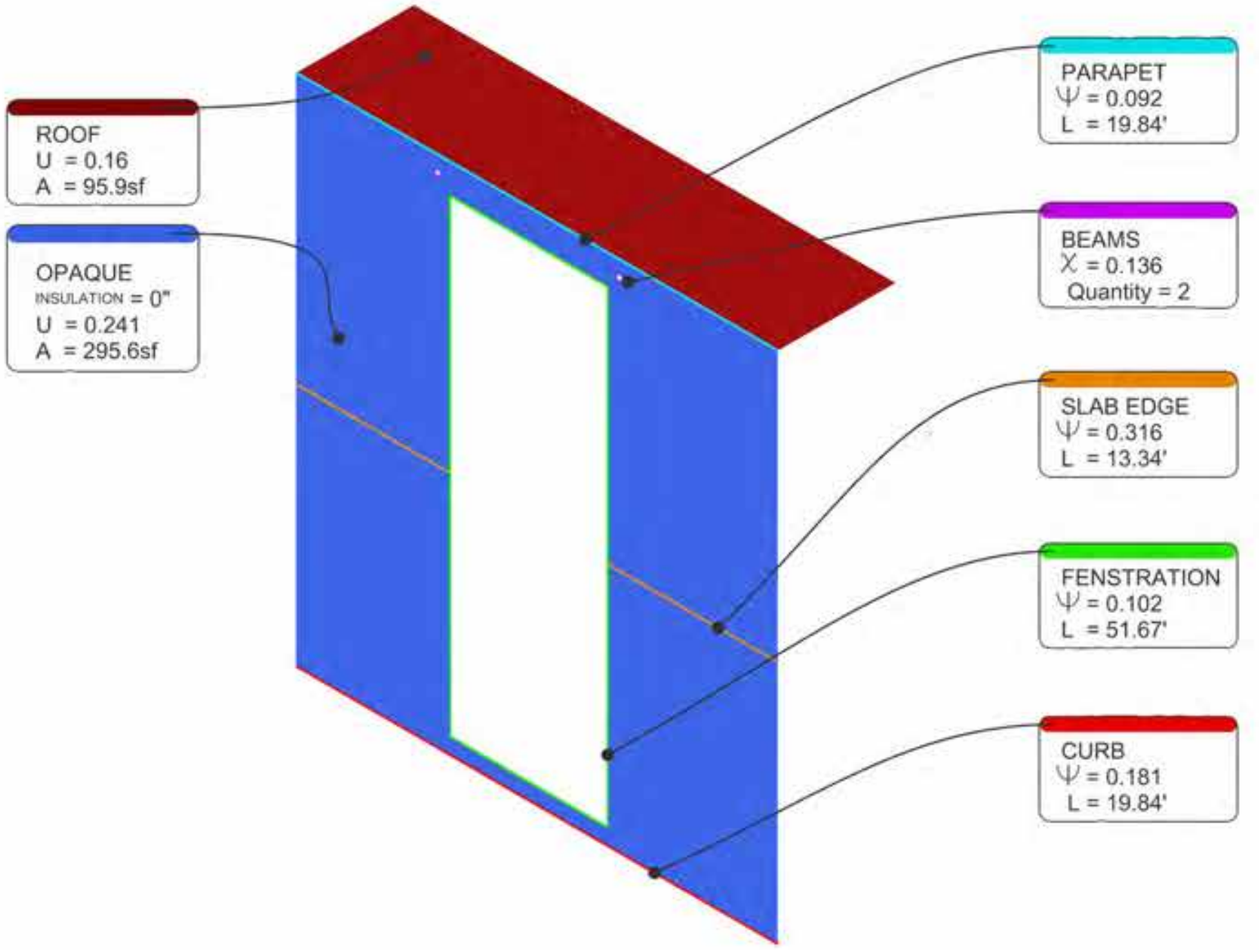



ROOF
U = 0.078
A = 256.9sf
OPAQUE
U = 0.093
A = 513.8sf
VISION 1
U = 0.595
A = 57.5sf
PARAPET
Ψ = 0.22
L = 45.33'
CORNER
Ψ = 0.19
L = 45.33'
FENSTRATION
Ψ = 0.254
L = 64.34'
CURB
Ψ = 0.138
L = 45.33'
TOTALS
WWR = 10%
UA = 103.88
PRIME U = 0.1255
ΨL = 41.18
ADD U = 0.0497
TOTAL U = 0.1752




| TOTALS |
| --- |
| WWR = 30% |
| UA = 118.27 |
| PRIME U = 0.2809 |
| ΨL = 14.91 |
| χ Q = 0.272 |
| ADD U = 0.0361 |
| TOTAL U = 0.317 |

.1413 COMLIANCE TARGET




TOTALS

WWR = 30%

UA = 87.56

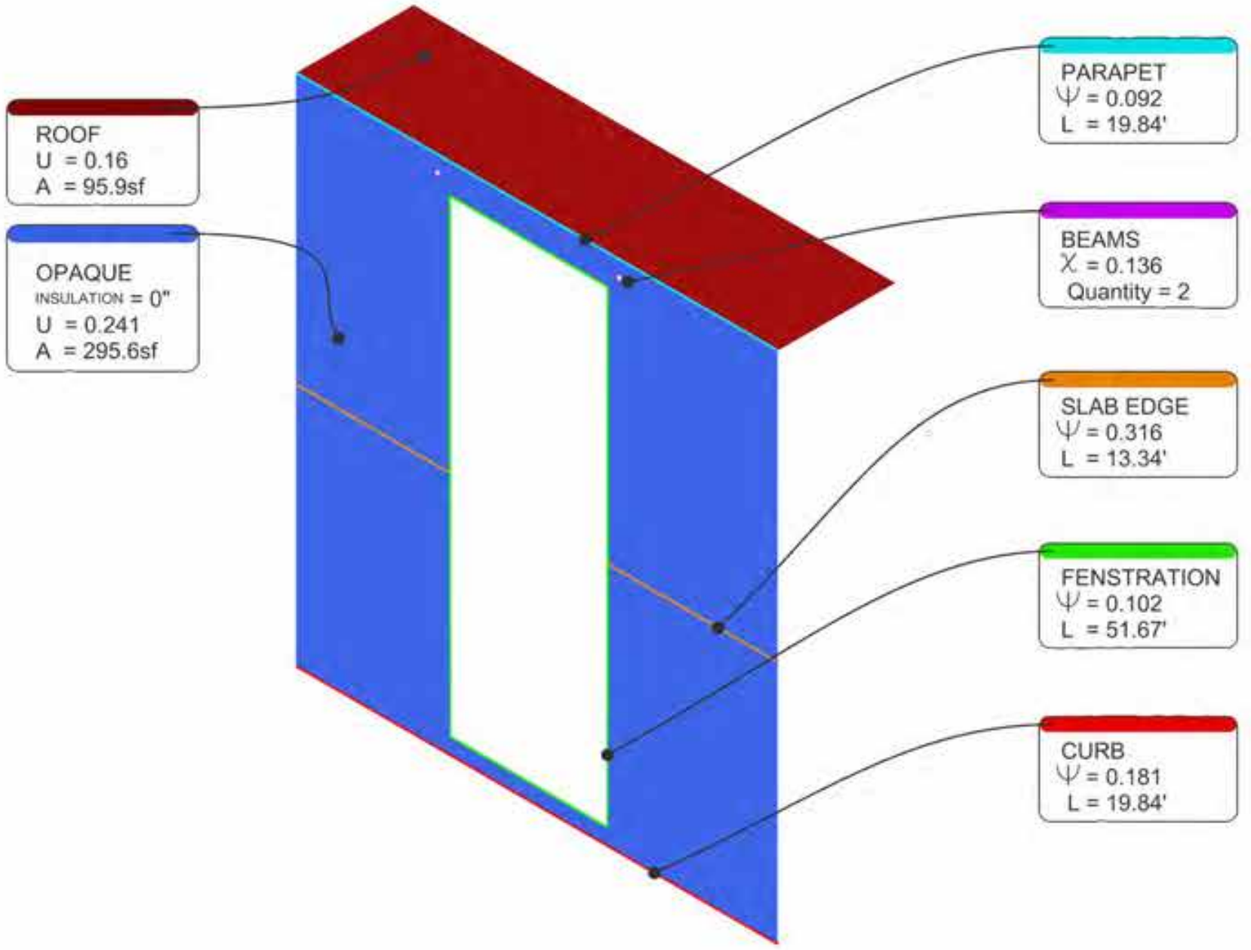
$_{PRIME}U = 0.2958$

ΨL = 14.91

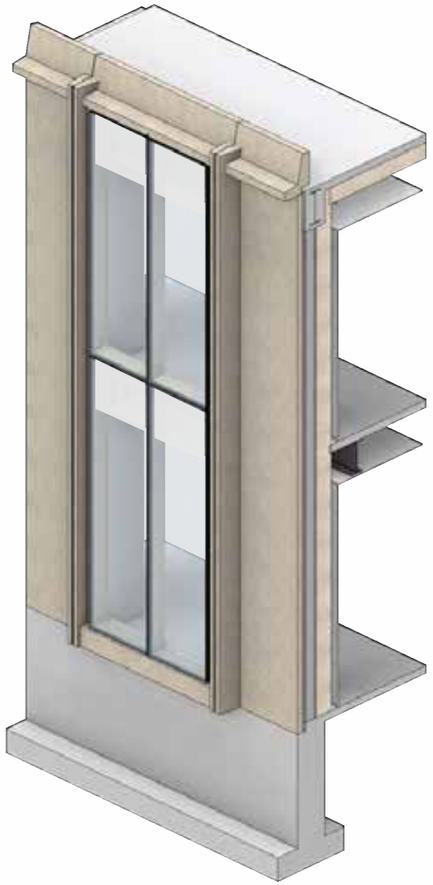
χ Q = 0.272

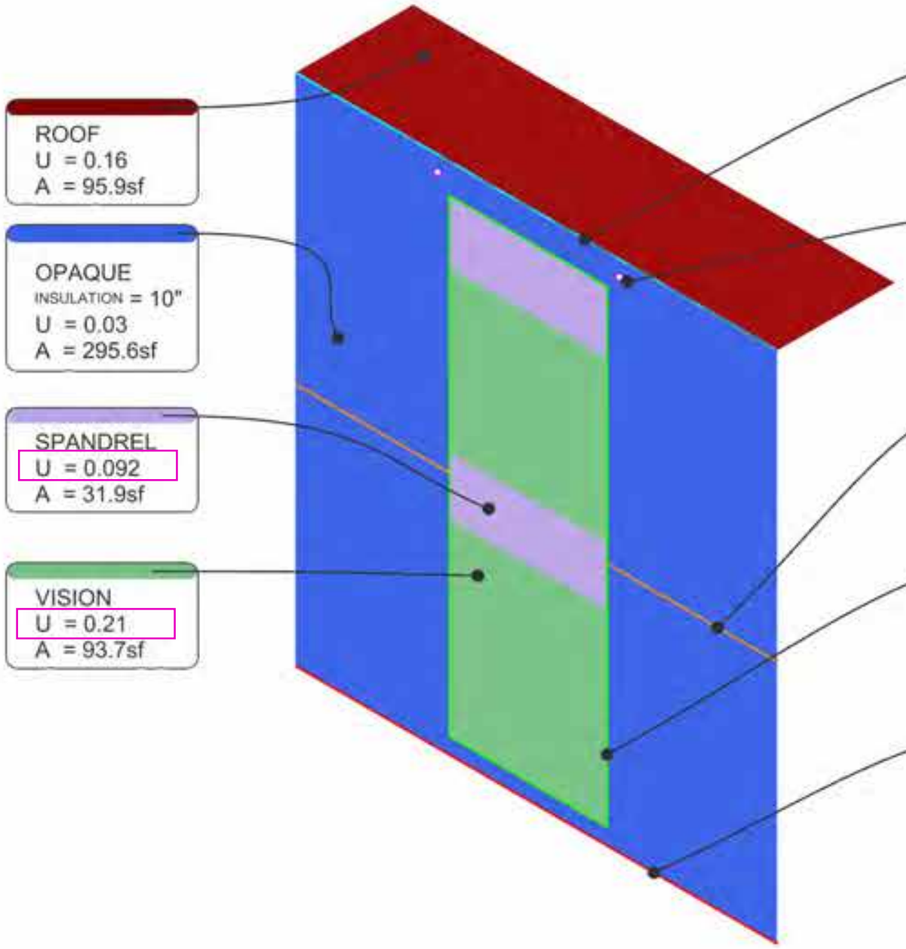
$_{ADD}U = 0.0513$

$_{TOTAL}U = 0.3471$




| TOTALS |
| --- |
| WWR = 0% |
| UA = 87.56<br>PRIME U = 0.2958 |
| ΨL = 14.91<br>χ Q = 0.272<br>ADD U = 0.0513 |
| TOTAL U = 0.3471 |






-0.033

-0.070

-0.069

TOTALS

WWR = 30%

UA = 47.8

PRIME U = 0.1135

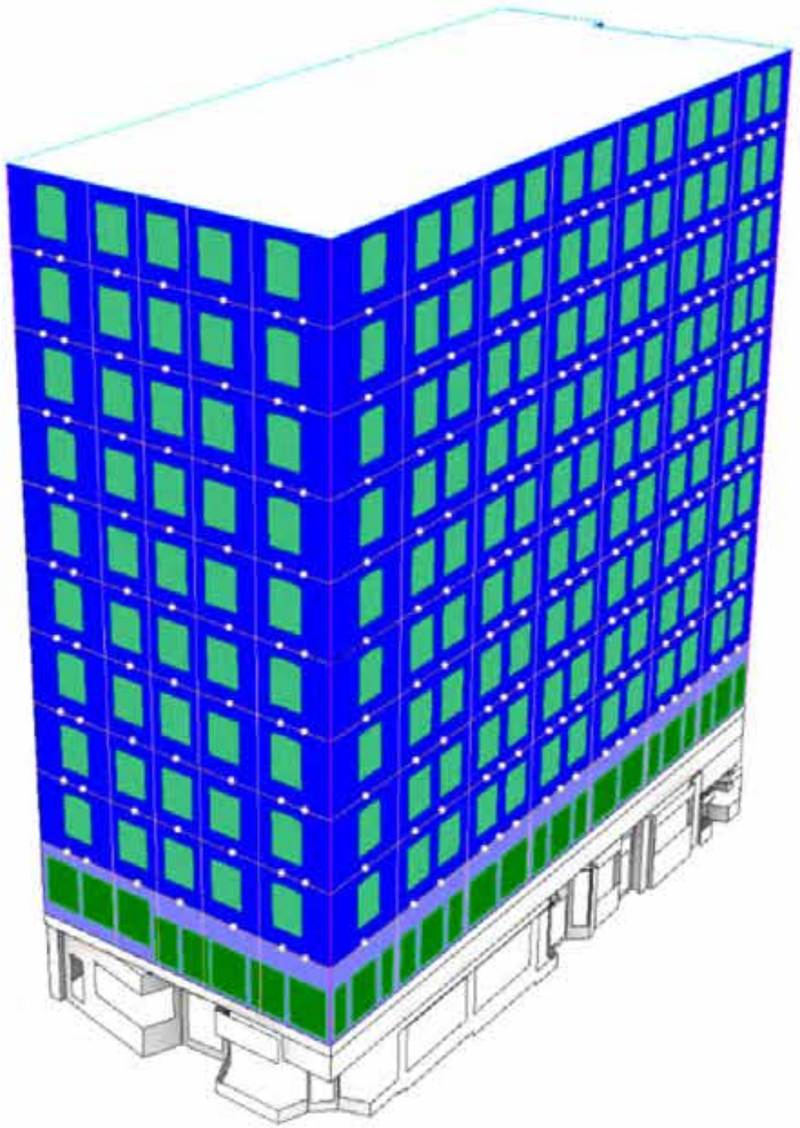
ΨL = 11.35

χ Q = 0.272

ADD U = 0.0276

TOTAL U = 0.1411

.1413 COMLIANT



INPUT
Opaque 1 U-Value, 0.021
Insulation Thickness, 8
R-Value per Inch, 6
Opaque 2 U-Value, 0.021
Insulation Thickness, 8
R-Value per Inch, 6
Vision 1 U-Value, 0.25
Vision 2 U-Value, 0.25

Thermal Bridging
(PSI) Beams, 0.1108
Columns, 0.1108
Corner, 0.0336
Fenestration, 0.1725
Parapet, 0.1108
(CHI) XBeams, 0.7438

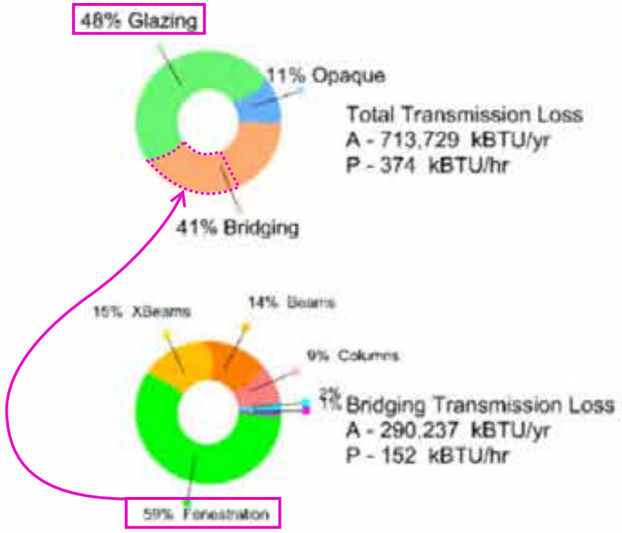
**TOTALS**

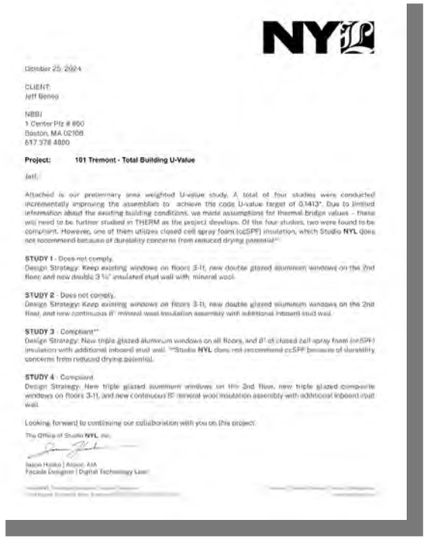
WWR = 27%

UA = 2998
$_{PRIME}U = 0.082$

$\Psi L = 2055$
$\chi Q = 301$
$_{ADD}U = 0.057$

$_{TOTAL}U = 0.139$
$_{TARGET}U = 0.1413$





October 25, 2024

CLIENT:
Jeff Benno

NBBJ
1 Center Plz # 850
Boston, MA 02108
617 378 4800

**Project:** **101 Tremont - Total Building U-Value**

Jeff,

Attached is our preliminary area weighted U-value study. A total of four studies were conducted incrementally improving the assemblies to achieve the code U-value target of 0.1413*. Due to limited information about the existing building conditions, we made assumptions for thermal bridge values – these will need to be further studied in THERM as the project develops. Of the four studies, two were found to be compliant. However, one of them utilizes closed cell spray foam (ccSPF) insulation, which Studio **NYL** does not recommend because of durability concerns from reduced drying potential**.

**STUDY 1** - Does not comply.
Design Strategy: Keep existing windows on floors 3-11, new double glazed aluminum windows on the 2nd floor, and new double 3 ½" insulated stud wall with mineral wool.

**STUDY 2** - Does not comply.
Design Strategy: Keep existing windows on floors 3-11, new double glazed aluminum windows on the 2nd floor, and new continuous 8" mineral wool insulation assembly with additional inboard stud wall.

**STUDY 3** - Compliant**
Design Strategy: New triple glazed aluminum windows on all floors, and 8" of closed cell spray foam (ccSPF) insulation with additional inboard stud wall. **Studio **NYL** does not recommend ccSPF because of durability concerns from reduced drying potential.

**STUDY 4** - Compliant
Design Strategy: New triple glazed aluminum windows on the 2nd floor, new triple glazed composite windows on floors 3-11, and new continuous 8" mineral wool insulation assembly with additional inboard stud wall.

Looking forward to continuing our collaboration with you on this project.

The Office of Studio **NYL**, inc.

Nabila Hudda | Assoc. AIA
Façade Designer | Digital Technology Lead

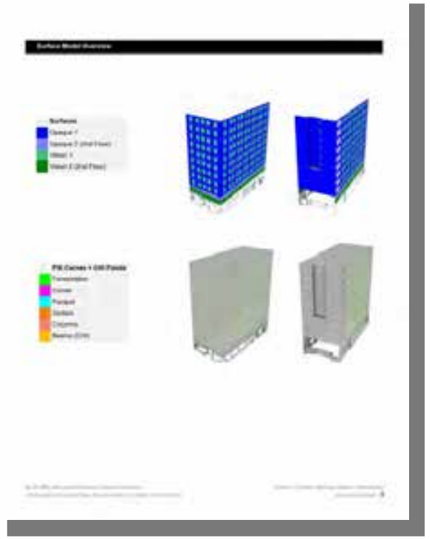
**1: General Notes**

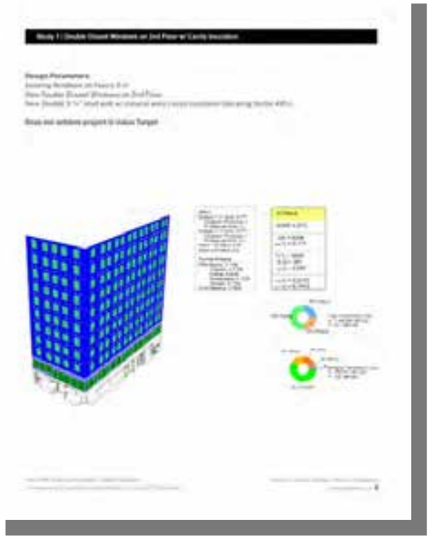
This is a preliminary report based on the limited information of the existing building conditions. As the project develops additional information will be required about the existing mass masonry walls and surrounding construction build-up in order to model the thermal bridging values. Reasonable performance values have been used on typical glazing assemblies.

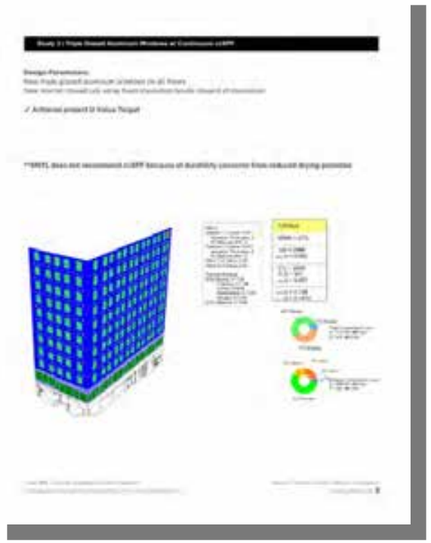
*The assumed energy code compliance pathway for the project is section C402.1.5 Component performance alternative, subsection C402.1.5.1 Low glazed wall system buildings. This section requires an area-weighted average of all above grade wall systems to be less than or equal to 0.1285. As per section C503.1 Alterations, Exception 3 "Where the component performance alternative in Section 402.1.5 is used to comply with this section, the proposed UA shall not be greater than 110 percent of the target UA." This allows for the area-weighted u-value to be increased to 0.1413 to all alterations to existing buildings.

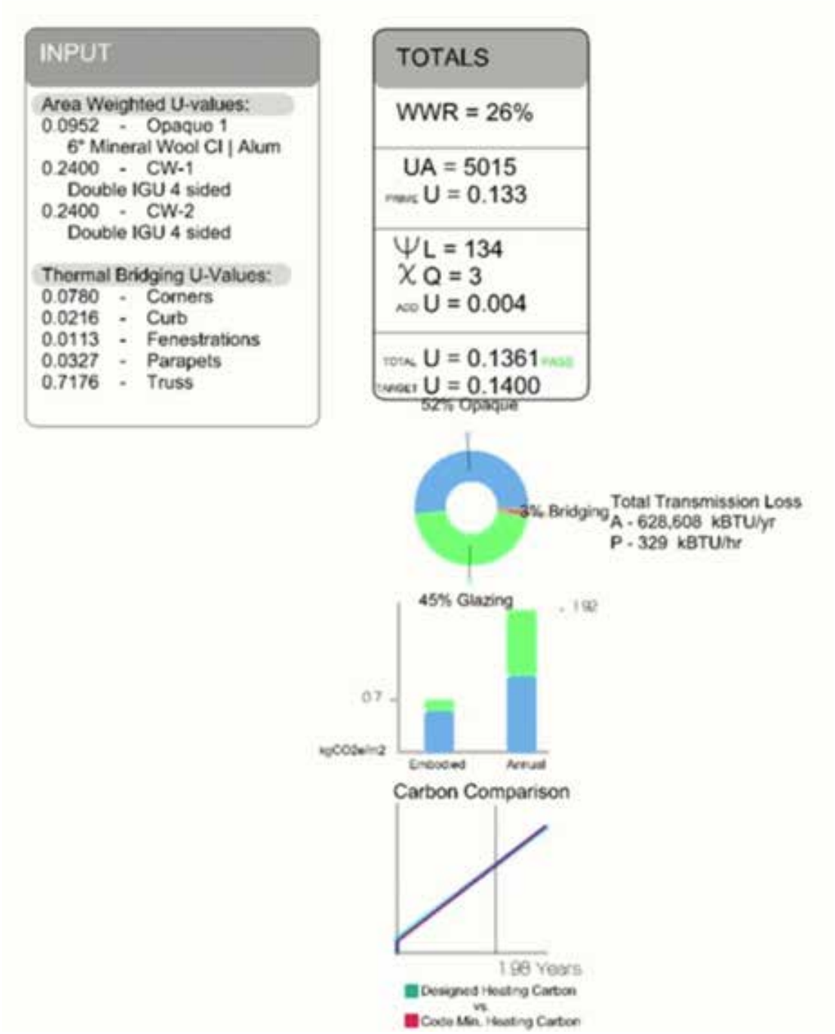
**2: Formulas and Units**

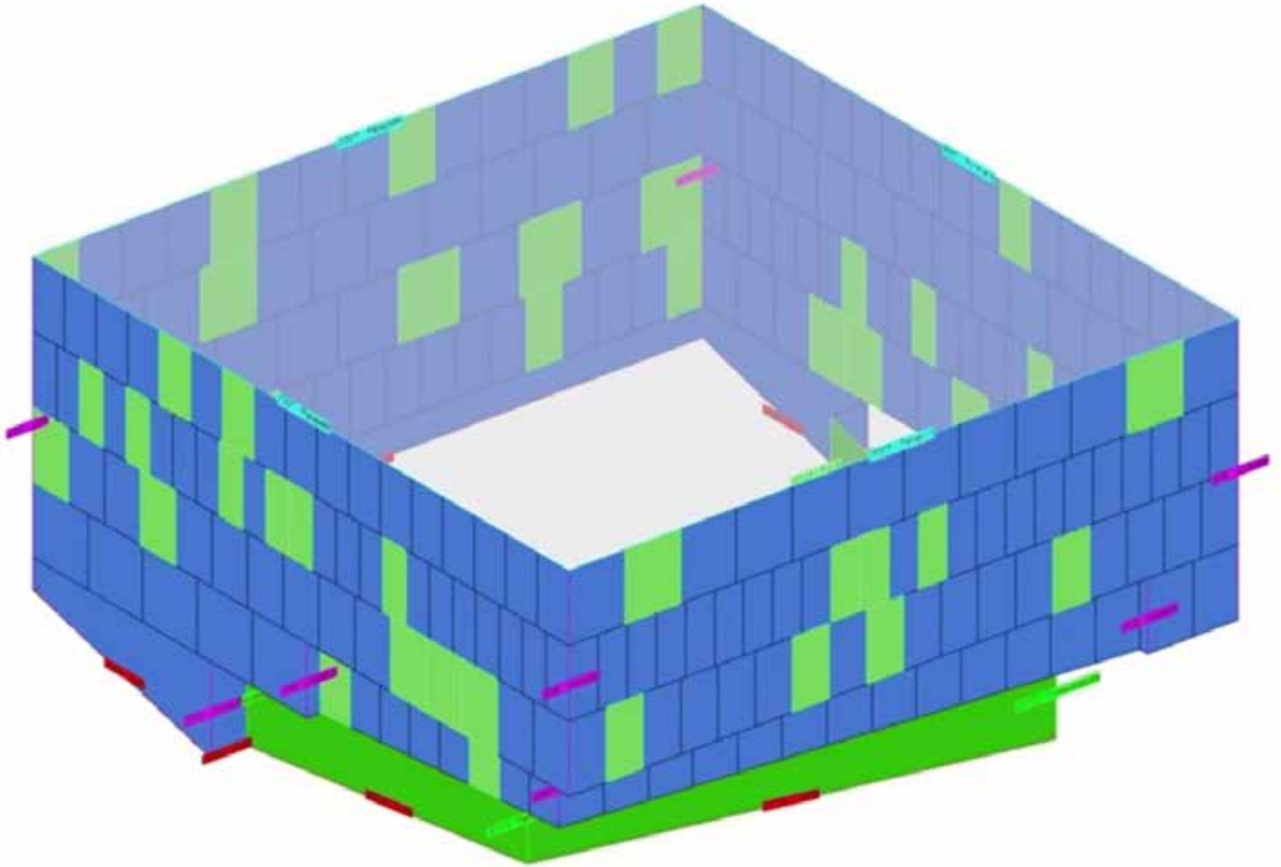
U-Value : BTU/(ft. ft2. °F)
R-Value : ft2.°F.h/BTU
UA = Area weighted U-value
$u_{wall} = (U_{1.1} * A_{1.1}) / \text{Total Area}$
$u_{sill} = (P_{fill\,1.1} * L_{1.1}) + (HSS_{fill\,1.1} * L_{1.1}) / \text{Total Area}$
$u_{all} = u_{wall} + u_{sill}$

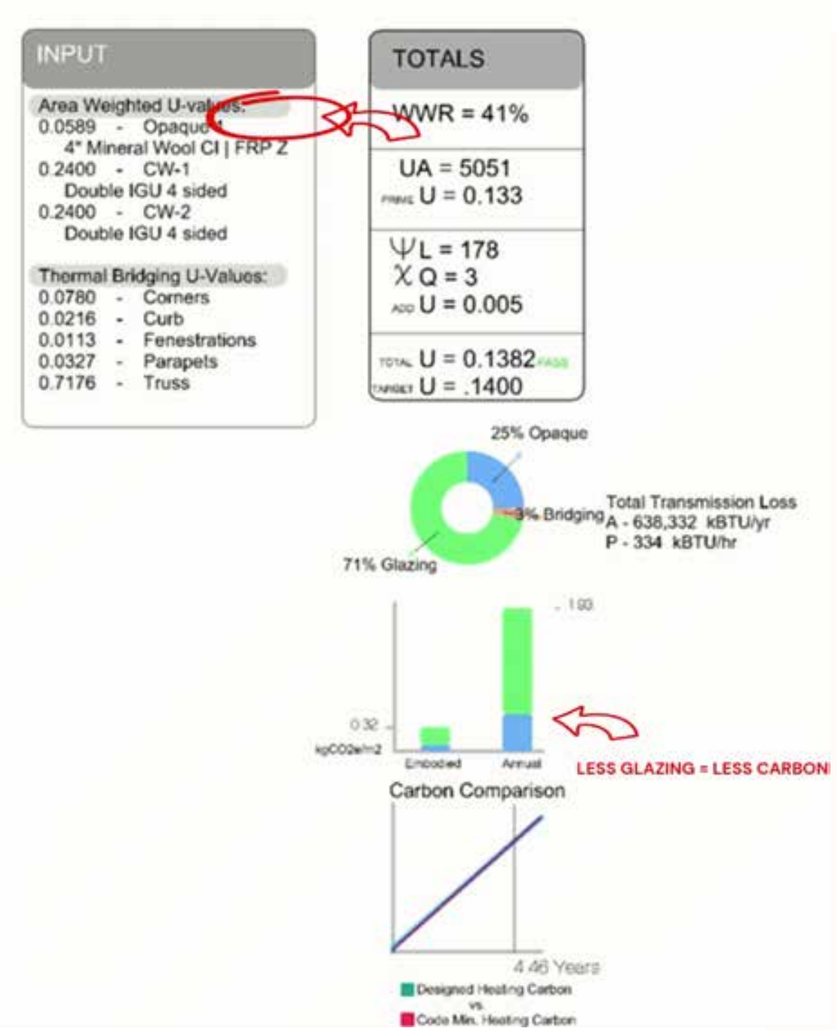


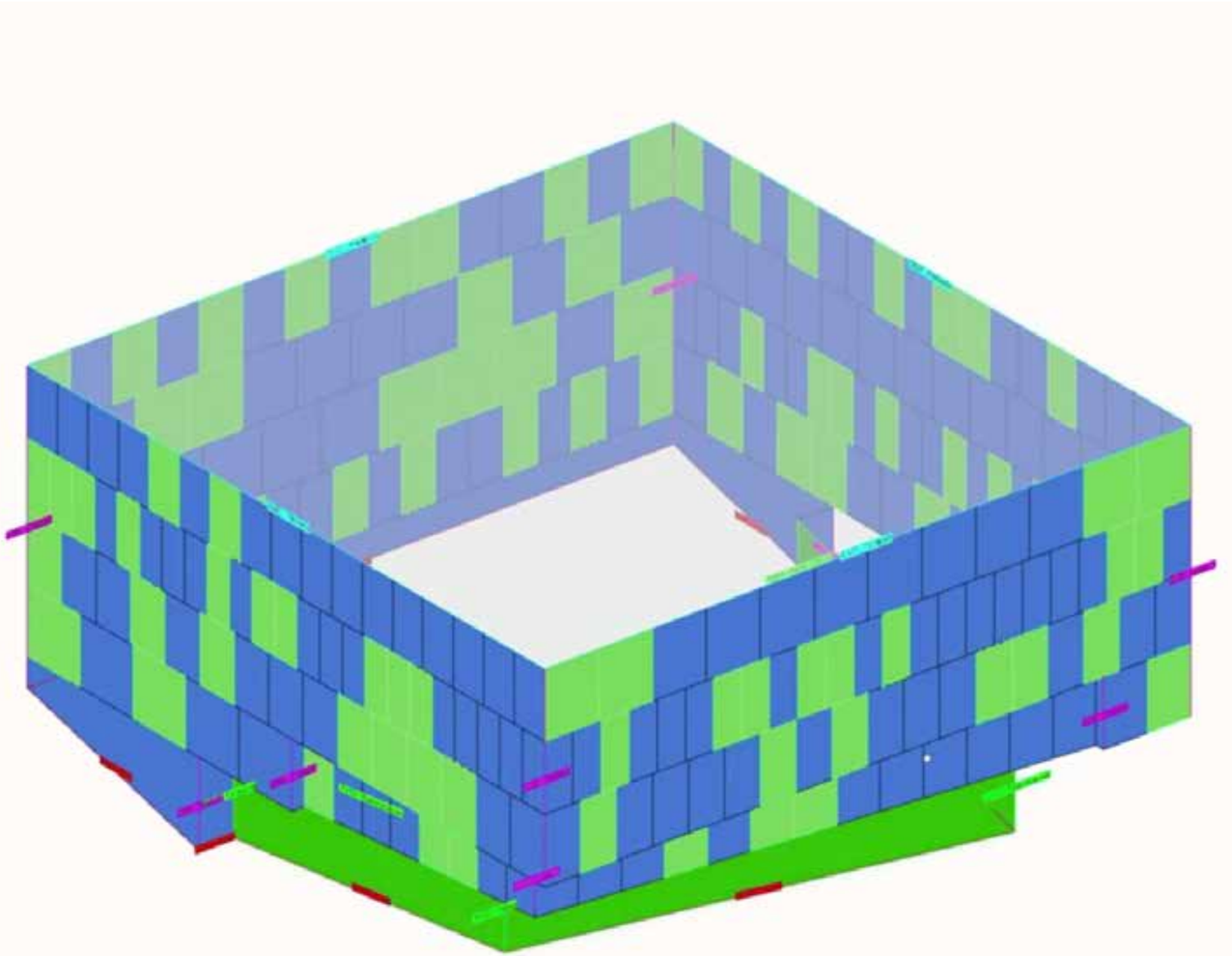





INPUT
Area Weighted U-values:
0.0952 - Opaque 1
6" Mineral Wool CI | Alum
0.2400 - CW-1
Double IGU 4 sided
0.2400 - CW-2
Double IGU 4 sided
Thermal Bridging U-Values:
0.0780 - Corners
0.0216 - Curb
0.0113 - Fenestrations
0.0327 - Parapets
0.7176 - Truss
TOTALS
WWR = 26%
UA = 5015
FINAL U = 0.133
ΨL = 134
χQ = 3
ADD U = 0.004
TOTAL U = 0.1361 PASS
TARGET U = 0.1400
52% Opaque
3% Bridging
Total Transmission Loss
A - 628,608 kBTU/yr
P - 329 kBTU/hr
45% Glazing
0.7
kgCO2e/m2
Embodied
Annual
Carbon Comparison
198 Years
Designed Heating Carbon
vs.
Code Min. Heating Carbon




INPUT
Area Weighted U-values:
0.0589 - Opaque
4" Mineral Wool CI | FRP 2
0.2400 - CW-1
Double IGU 4 sided
0.2400 - CW-2
Double IGU 4 sided
Thermal Bridging U-Values:
0.0780 - Corners
0.0216 - Curb
0.0113 - Fenestrations
0.0327 - Parapets
0.7176 - Truss
TOTALS
WWR = 41%
UA = 5051
FRAME U = 0.133
ΨL = 178
χQ = 3
ADD U = 0.005
TOTAL U = 0.1382 PASS
TARGET U = .1400
25% Opaque
4% Bridging
71% Glazing
Total Transmission Loss
A - 638,332 kBTU/yr
P - 334 kBTU/hr
.190
0.32
kgCO2e/m2
Embodied
Annual
LESS GLAZING = LESS CARBON
Carbon Comparison
4.46 Years
Designed Heating Carbon
vs.
Code Min. Heating Carbon



# Takeaways

- The building industry must reduce **embodied carbon** now, to avoid catastrophic global warming.
- After structural systems, the **building envelope** is one biggest contributors to a building's overall embodied carbon impact.
- However, building envelopes also play a key role in reducing the **operational carbon** required to heat and cool a building.
- New energy codes focus on reducing **operational carbon**, at the expense of driving up the **embodied carbon** of the envelope assembly.
- Designers need to find a **balance** between operational and embodied carbon savings to achieve the lowest Whole Life Carbon impact.
- To achieve the lowest Whole Life Carbon impact, it is critical to **study** envelope embodied carbon **early & often.**
- **Carbon accounting tools** are not yet nuanced enough to account for the complexities of building enclosures - as an industry we need to work together to develop new tools to study this important metric.

# Thank you!

**David Charney, AIA**
Senior Associate
Goody Clancy
david.charney@goodyclancy.com

**Felipe Francisco, AIA, CPHC**
Principal - Façade Design
Studio NYL, a Lerch Bates Company
felipe.francisco@lerchbates.com

**Rachael Gerry, AIA, CPHD**
Associate
Goody Clancy
rachael.gerry@goodyclancy.com

# BUILDINGENERGY BOSTON

## Please fill out an evaluation for this session

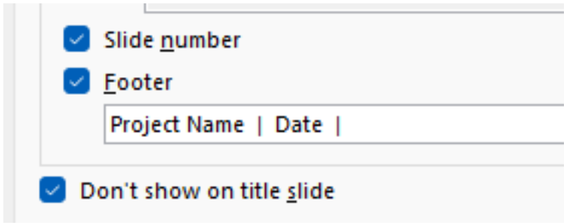

or: *nesea.org/eval*

Northeast Sustainable Energy Association (NESEA)

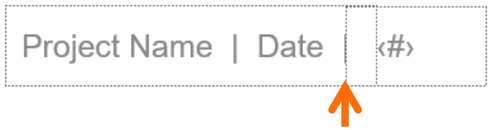
# PowerPoint Tips

Updating the **footer**:

1. Go to the main master slide (top)
2. Go to **Insert** in the top menu.
3. Press **Header & Footer**.
4. Type new text in the **Footer** field. [Project Name] Double space | Double space [Date] Double space |




5. Check **Don’t show on title slide**.
6. Press **Apply to All**.
7. On the main master slide (top), adjust the width of the footer text box so everything fits on one line.
8. Align left edge of slide number box to | at the end of the footer.




Adding **section headers**:

1. Go to **View** / **Slide Master.**
2. Scroll down to master slide with green section header.
3. Change text to section name.
4. Rename slide accordingly.
5. Repeat for each section.
6. **Close Master View** to return to **Normal View**.

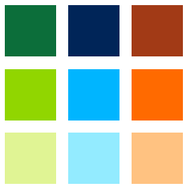
**Agenda and section dividers**:

1. There are two options for the agenda and divider slides: green and gray.

For **consistent spacing** between headline and bullets, align the top edge of the bottom text box to the base line of the headline.


Use the **eyedropper tool** and the click the color swatches below if they don’t appear in **Recent Colors**.

Primary color palette

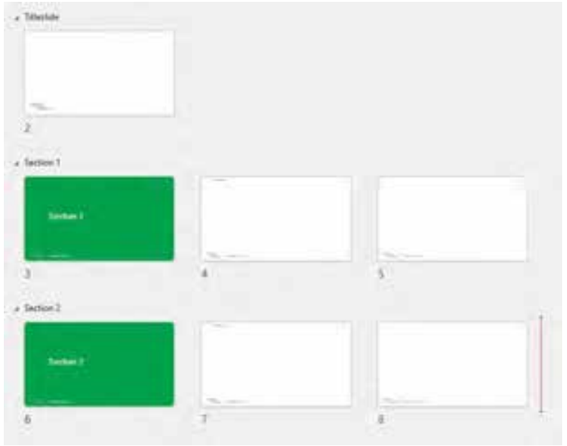


Secondary color palette

# PowerPoint Tips

Organize slide deck by **Sections**.

1. View **Slide Sorter**.
2. Select range of slides.
3. Right-click, select **Add Section**, and name section accordingly.



**Reformatting an existing presentation**:

1. Go to **Insert** in the top menu.
2. Press **Reuse Slides**.
3. In the panel on the right, press Browse and navigate to your presentation.
4. Select file and press **Choose Content.**
5. Uncheck **Use source formatting**.
6. Either press **Insert All** or **click on each slide** you would like to import into new presentation.
7. Go to **View** / **Slide Master** and duplicate master slide with green section headers and change text to each section name. Rename slides accordingly.
8. **Close Master View** to return to **Normal View**.
9. In left panel, select slides in each section and apply the appropriate master slide.
10. Adjust text and images as necessary.

# PowerPoint Tips

Sample table style

| Address | Use | Area* (GSF) | Fire Prot | MAAB Entry** | Beds Grad Apt (400 NSF avg) | Beds UG Apt (220 NSF avg) | Beds Traditional (125 NSF avg) | Recommended Configuration | Notes |
|---|---|---|---|---|---|---|---|---|---|
| 63 BSR | B | 7,717 | UP | Rear | 8 | 16 | 22 | Grad Apt | Proximity with other Grad |
| 67 BSR | B | 7,181 | SP | Rear | 7 | 14 | 19 | Grad Apt | Proximity with other Grad |
| 121 BSR | B | 12,547 | Unknown | Rear | 9 | 19 | 28 | Business | Connected to OGC |
| 126 BSR | B | 6,224 | UP | Rear | 8 | 16 | 23 | UG Apartment | |
| 152 BSR *** | B | 11,157 | UP | Side/Rear | 6 | 12 | 25 | Traditional | Silber Way entry |
| 154 BSR *** | B | 9,383 | UP | Rear | 9 | 17 | 28 | Traditional | |
| 156 BSR *** | B | 5,143 | UP | Rear | 6 | 12 | 18 | Traditional | |
| 165 BSR | R | 7,065 | SP | Rear | 8 | 16 | 23 | Traditional | Leverage configuration |
| **Totals** | | | | | **61** | **122** | **186** | | |

# IMPACT OF NEW CODES

# IMPACT OF NEW CODES