BUILDINGENERGY BOSTON

How to Scale Up High Impact Embodied Carbon Reductions through Projects and Policies

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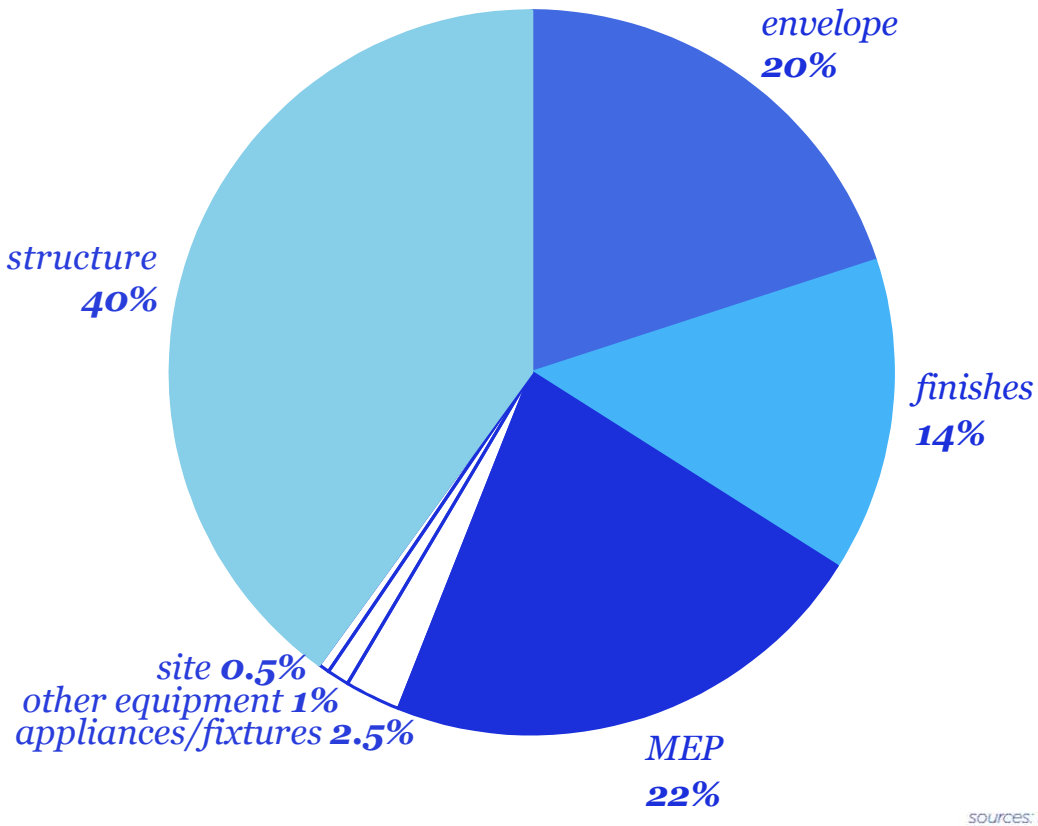
Northeast Sustainable Energy Association (NESEA)
February 28, 2022

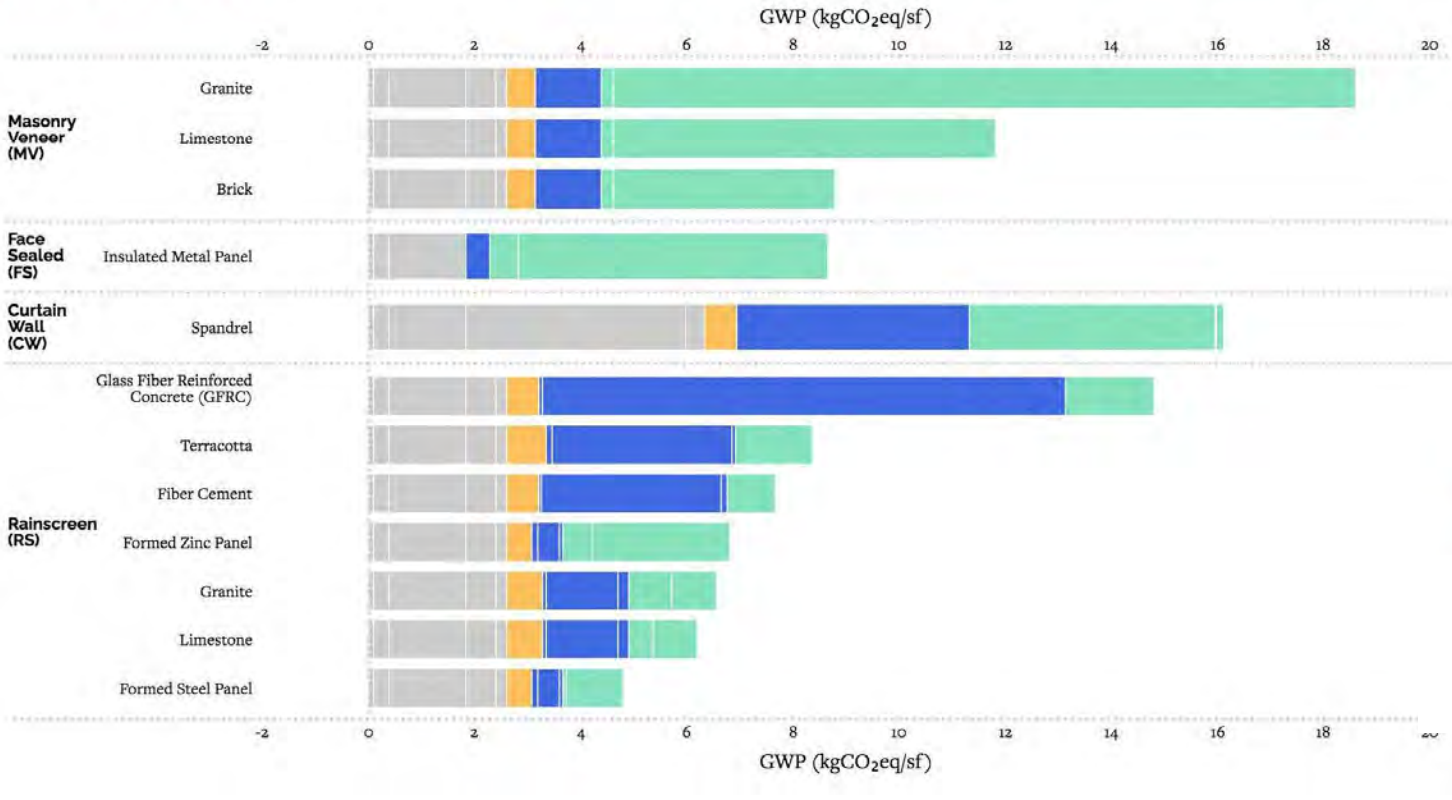
EMBODIED CARBON IN BUILDINGS



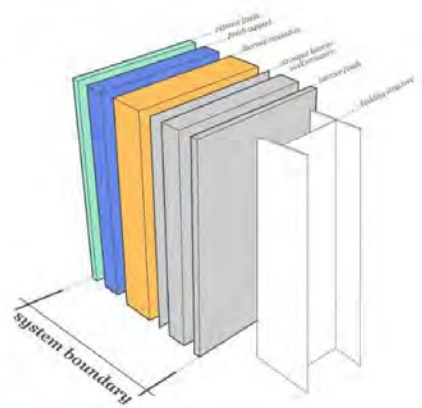
sources: K. Simonen, Testing Whole Building LCA: Research and Practice, 2015

EMBODIED CARBON - FAÇADE SYSTEM SELECTION

Material Breakdown

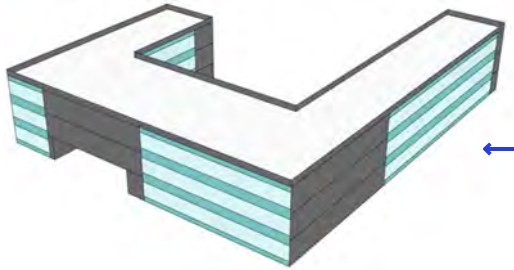


LEGEND

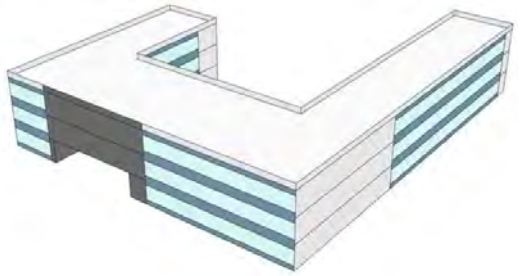


MV - Granite
MV - Limestone
MV - Brick
FS- Insulated Metal

EMBODIED CARBON - FAÇADE SYSTEM SELECTION



← VS. →



ENVELOPE CALCULATOR

◉ Initial Carbon (only Module A) ○ 60 Year (with Module D) ○ 60 Year (no Module D)

Option 1

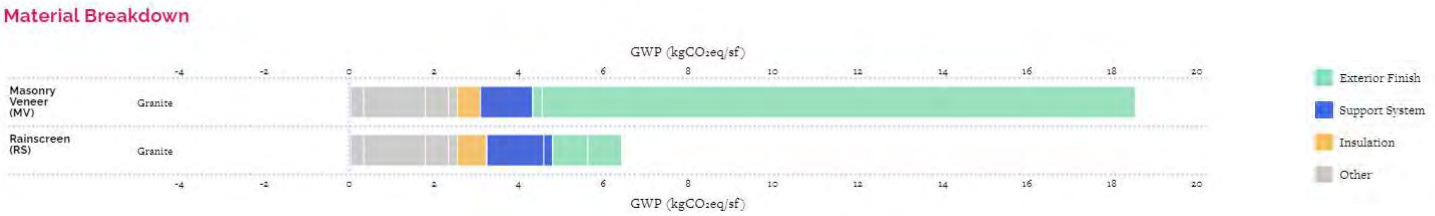
Type	Square Feet	GWP
MV - Granite	15470	286968.50
CW - Spandrel (Alum w/ Backpan)	8665	123822.85
	24,135 ft²	410,791.35 kgCO₂eq

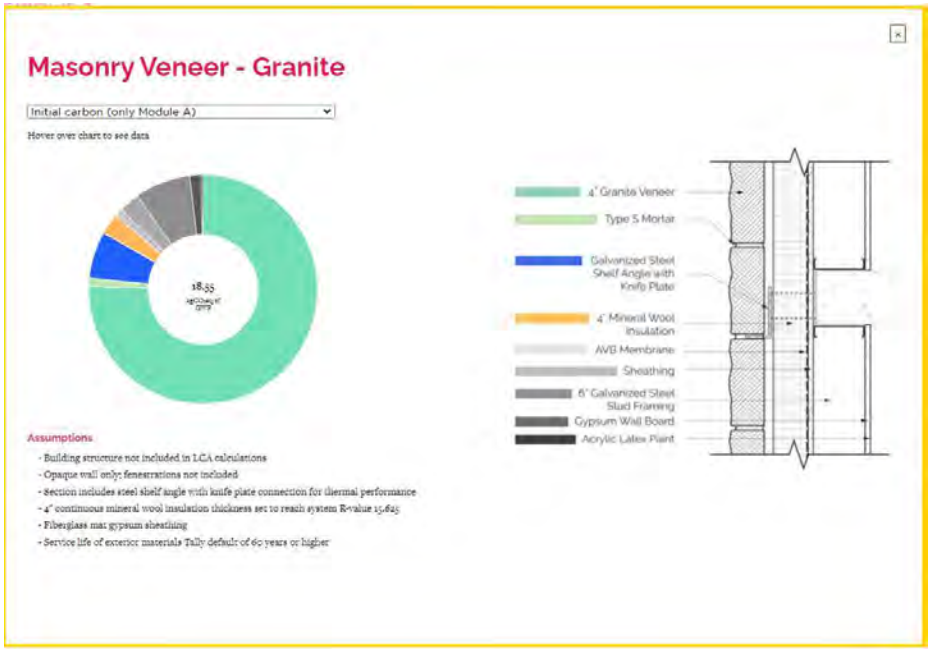
Option 3

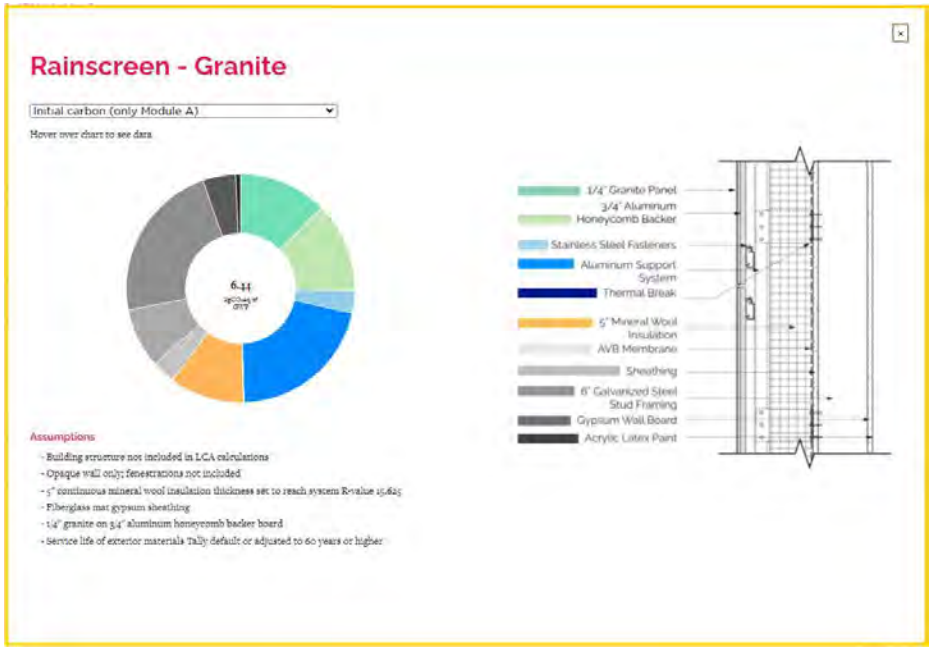
Type	Square Feet	GWP
MV - Granite	2659	49324.45
RS - Granite	12811	82502.84
RS - Formed Zinc Panel	8665	[illegible]
	24,135 ft²	189,449.54 kgCO₂eq

54% reduction in embodied carbon!

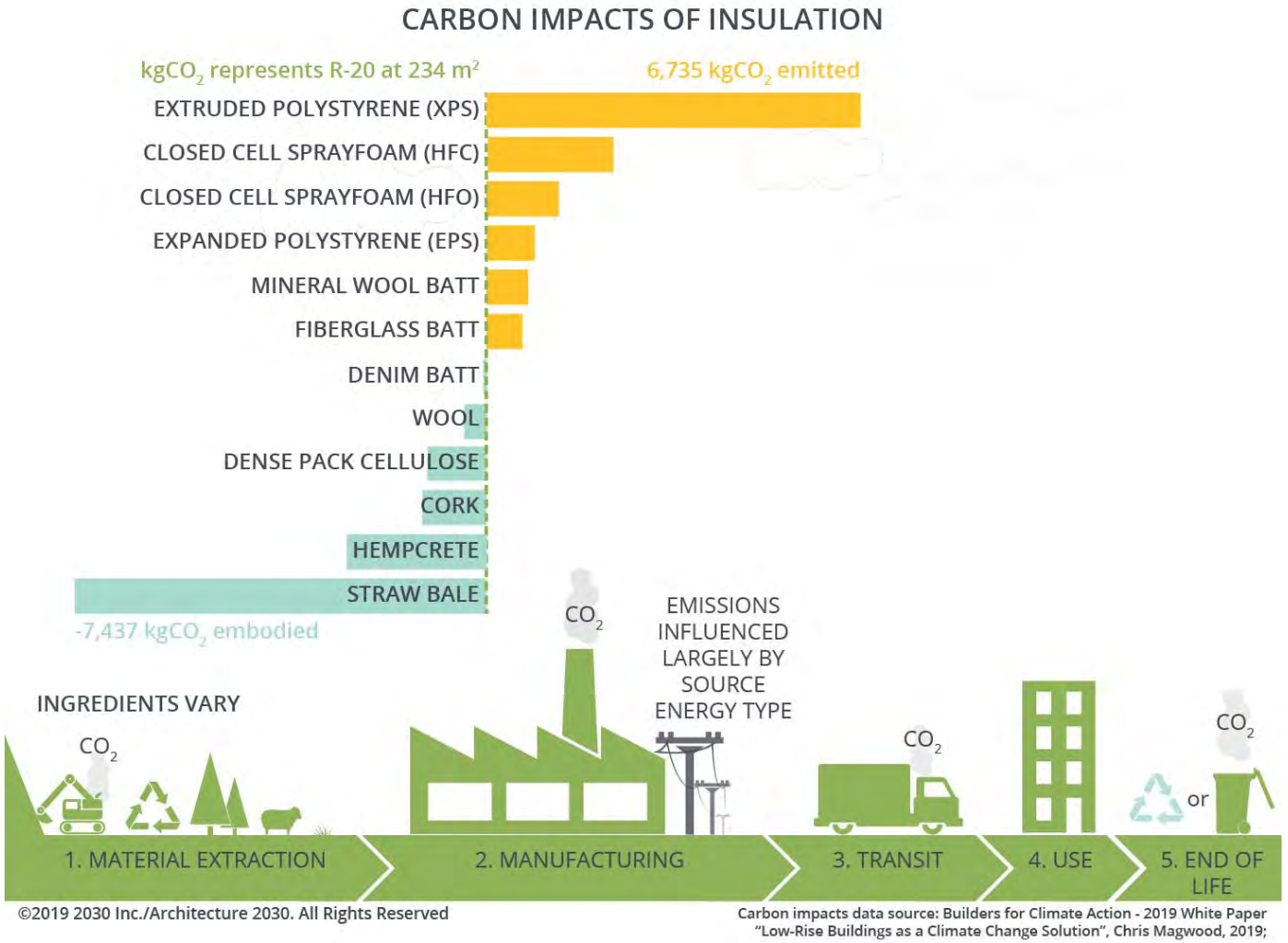
EMBODIED CARBON - FAÇADE SYSTEM SELECTION





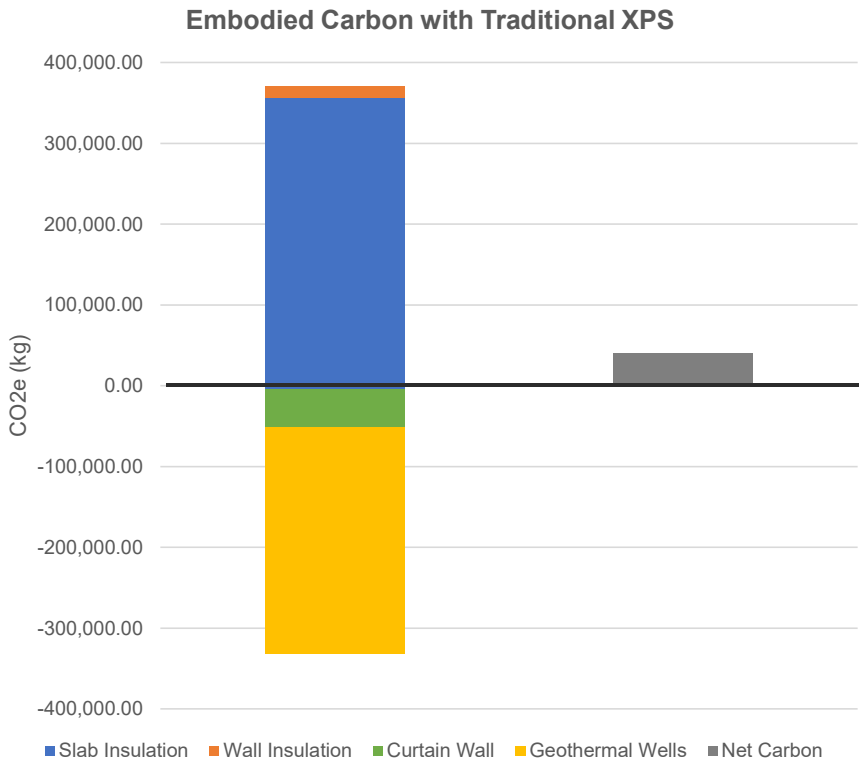


REDUCING EMBODIED CARBON - MATERIAL CHOICES

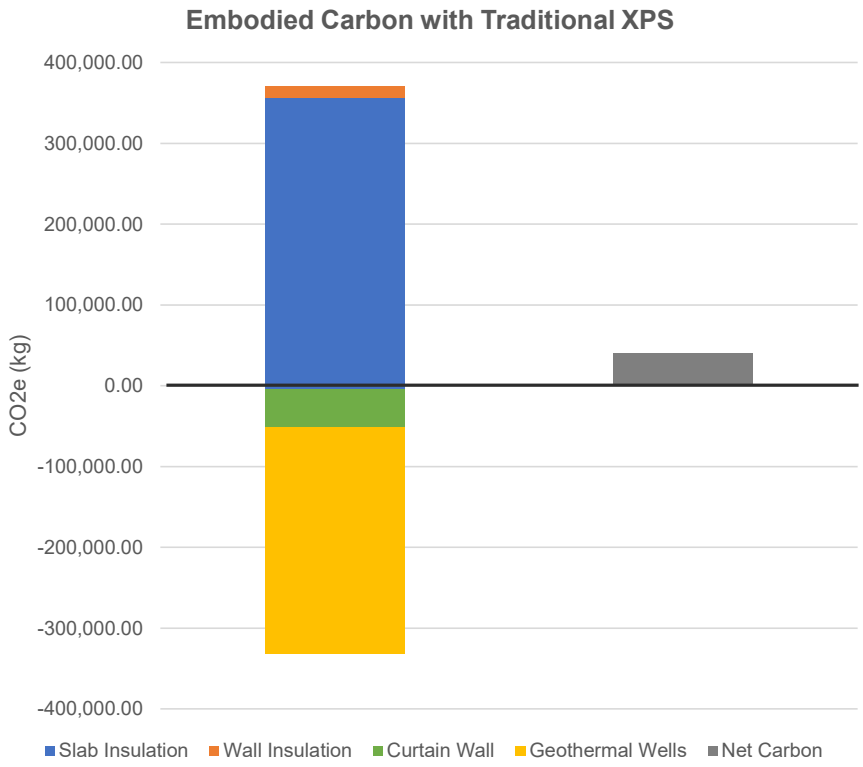


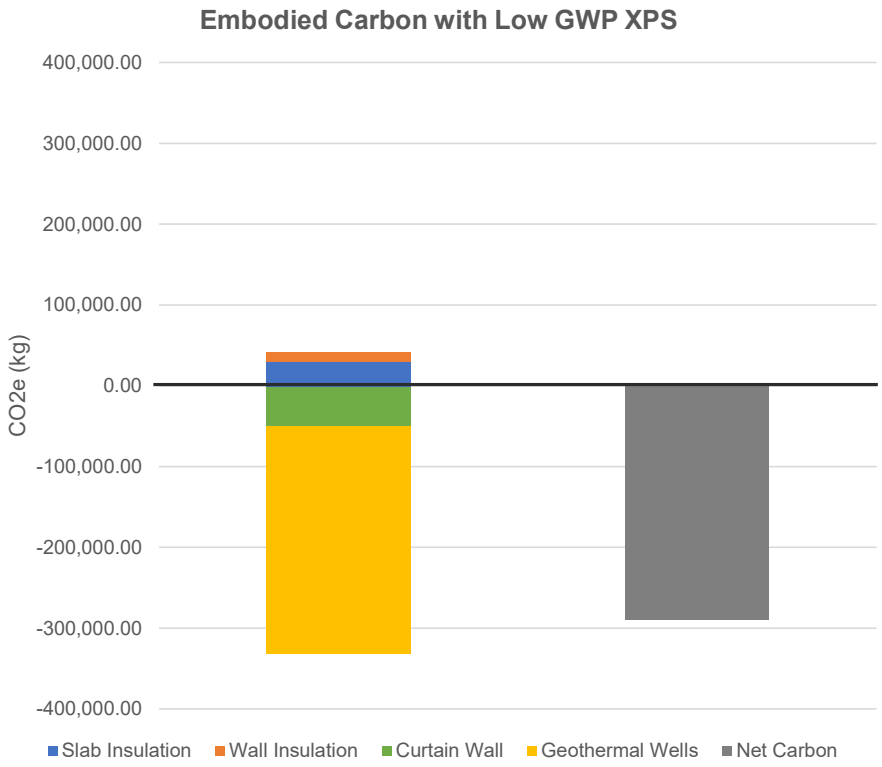
Carbon impacts data source: Builders for Climate Action - 2019 White Paper "Low-Rise Buildings as a Climate Change Solution", Chris Magwood, 2019;

REDUCING EMBODIED CARBON – MATERIAL SELECTION



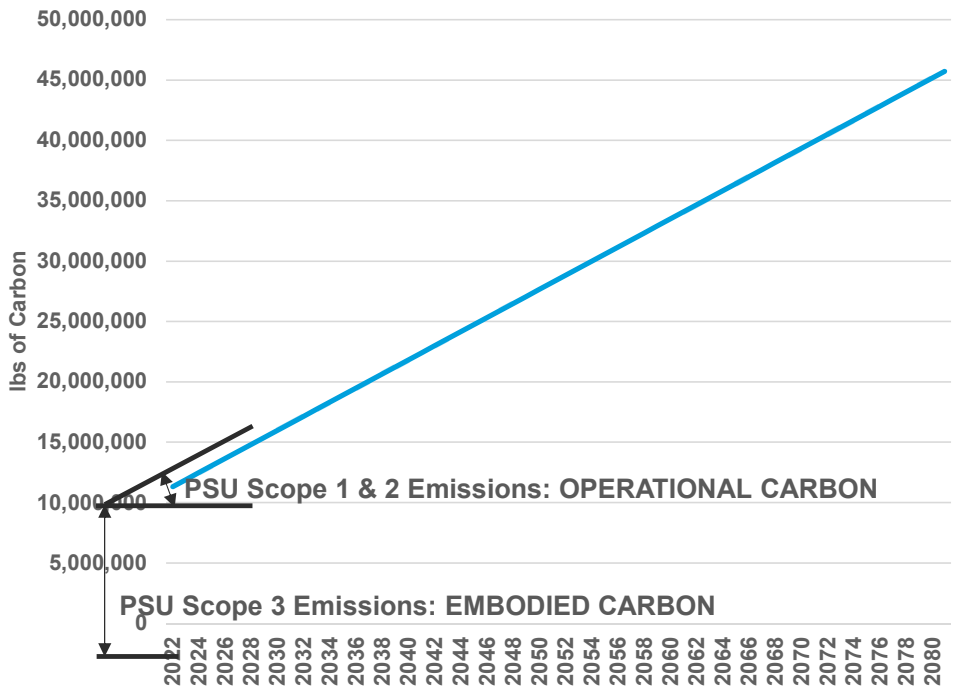
REDUCING EMBODIED CARBON – MATERIAL SELECTION



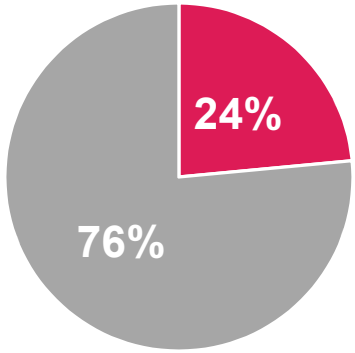


EMBODIED CARBON TIME VALUE | PSU Commitment

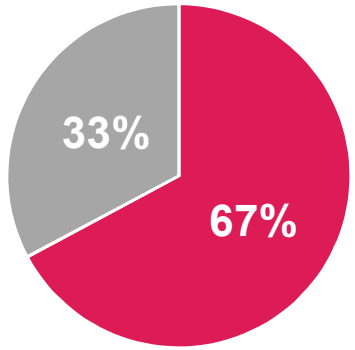
- Goal of 35% reduction in greenhouse gas emissions by 2020
  - Have reduced by 18% already from 2005 levels
  - Ultimate goal of 80% reduction from 1990 levels by 2050
- PSU Scope 1, 2, & 3 Emissions



Life Span of the Building

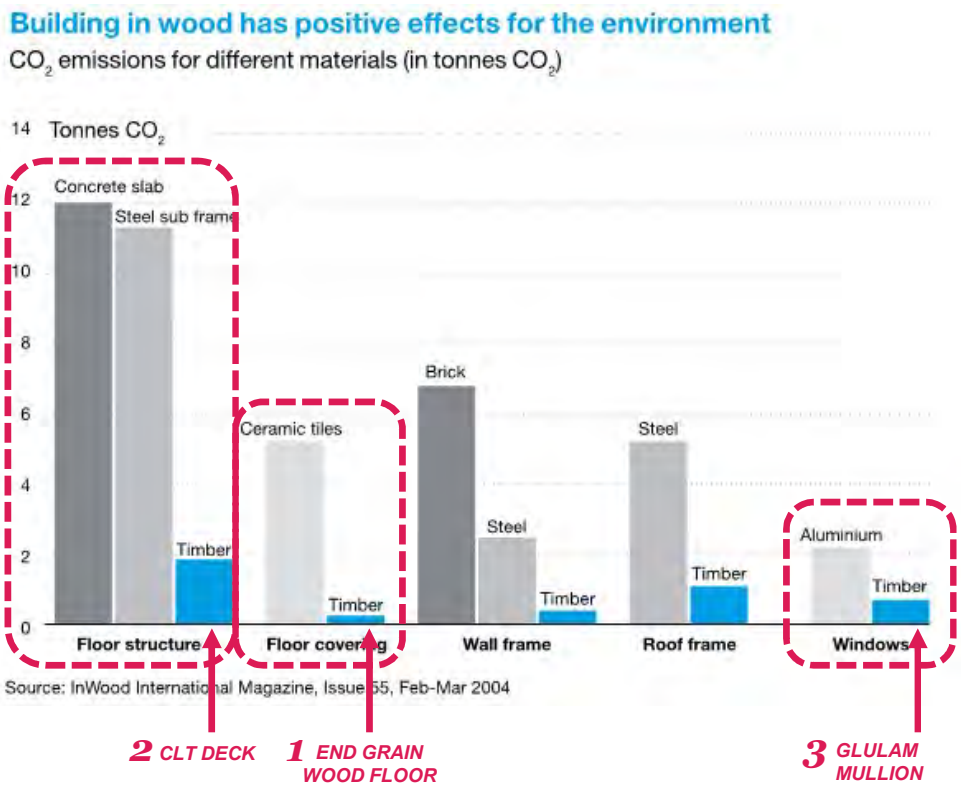


Between now and 2030

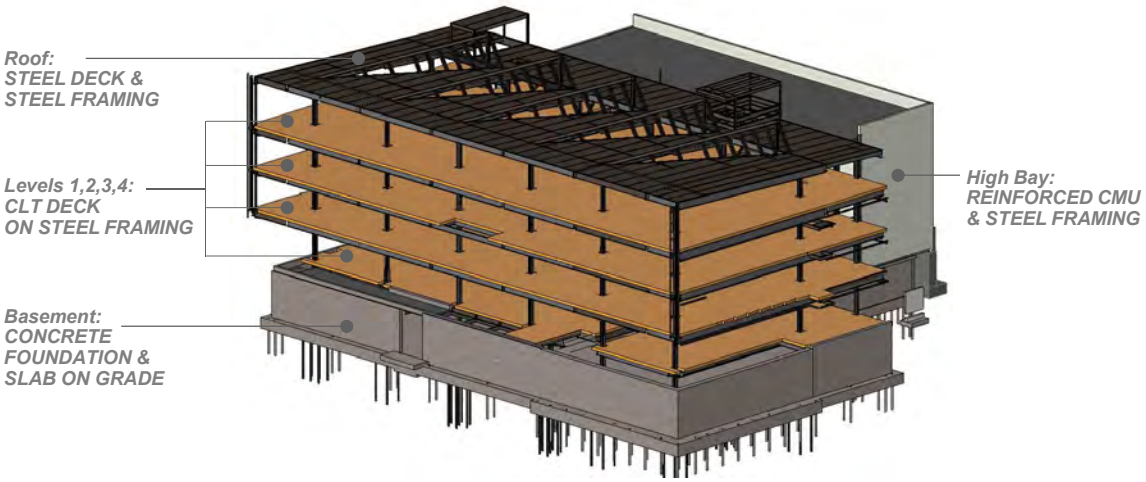


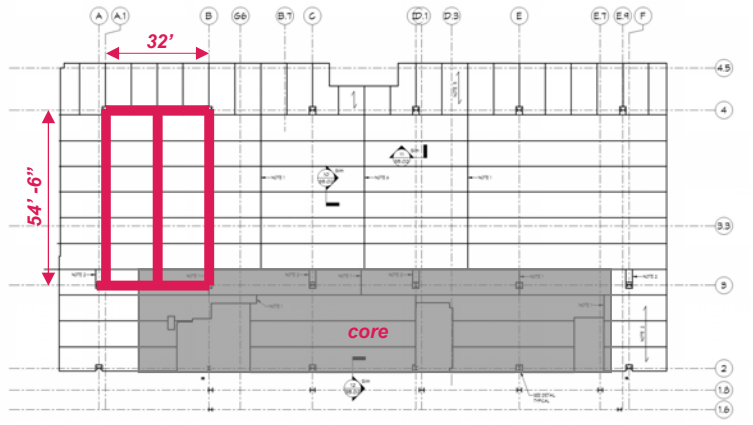
Embodied Carbon Operational Carbon

reducing embodied carbon on projects

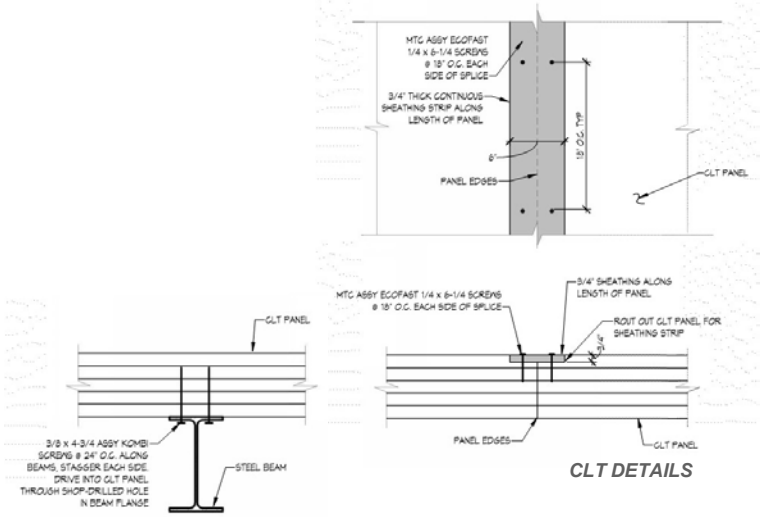


hybrid structure | CLT decking and steel frame





CLT PANEL LAYOUT



CLT DETAILS

end grain wood block flooring

Fir Strip tongue and groove with spline

Level 0

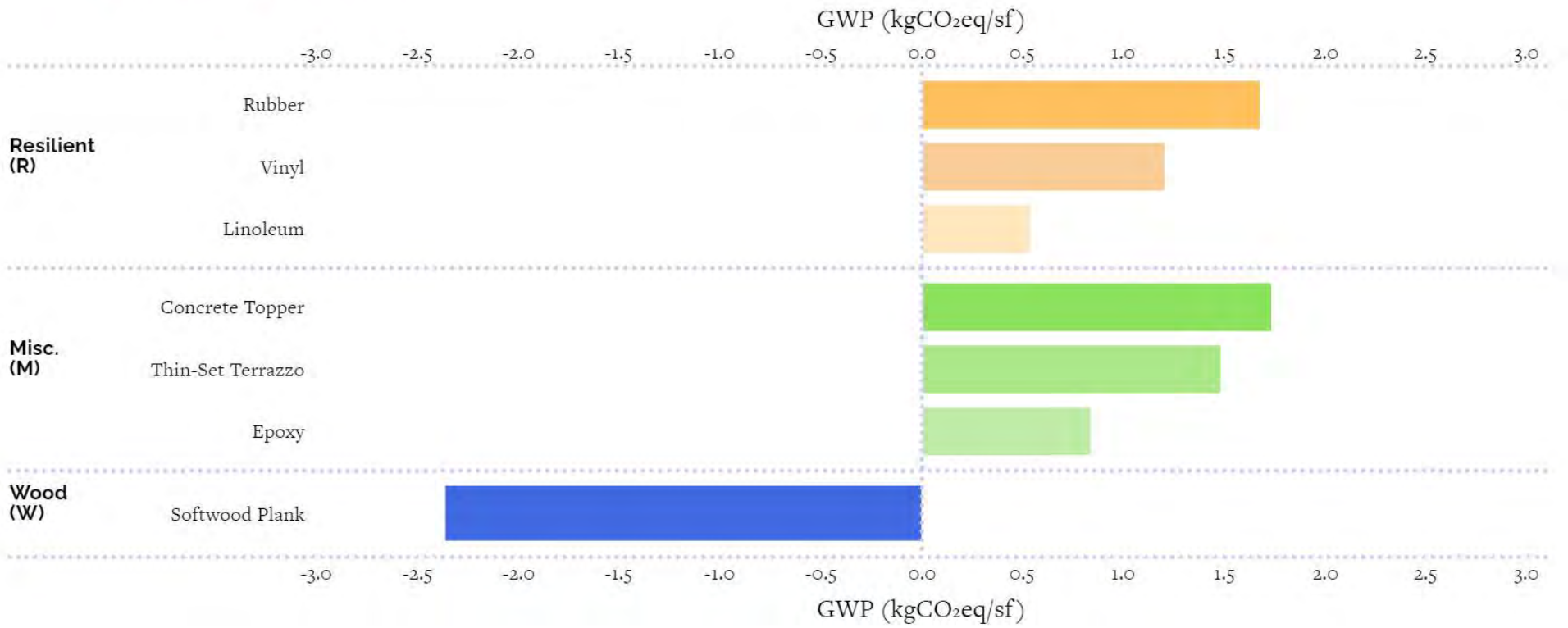
Level 1

Level 2/3

Level 4

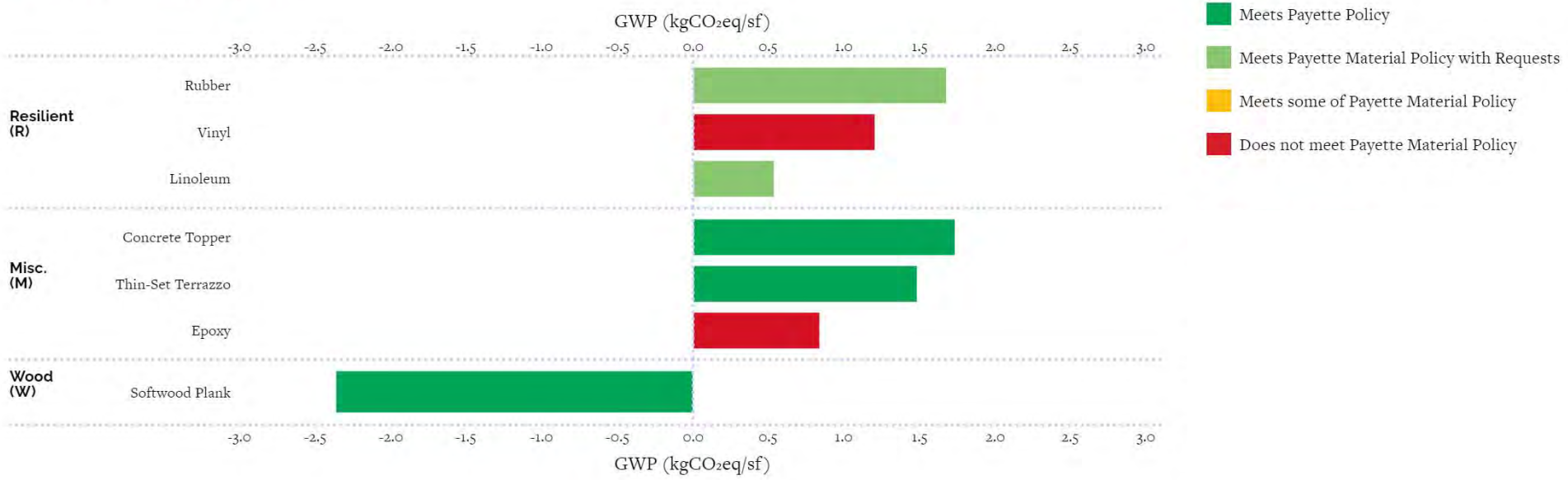
reducing embodied carbon on projects

Global Warming Potential

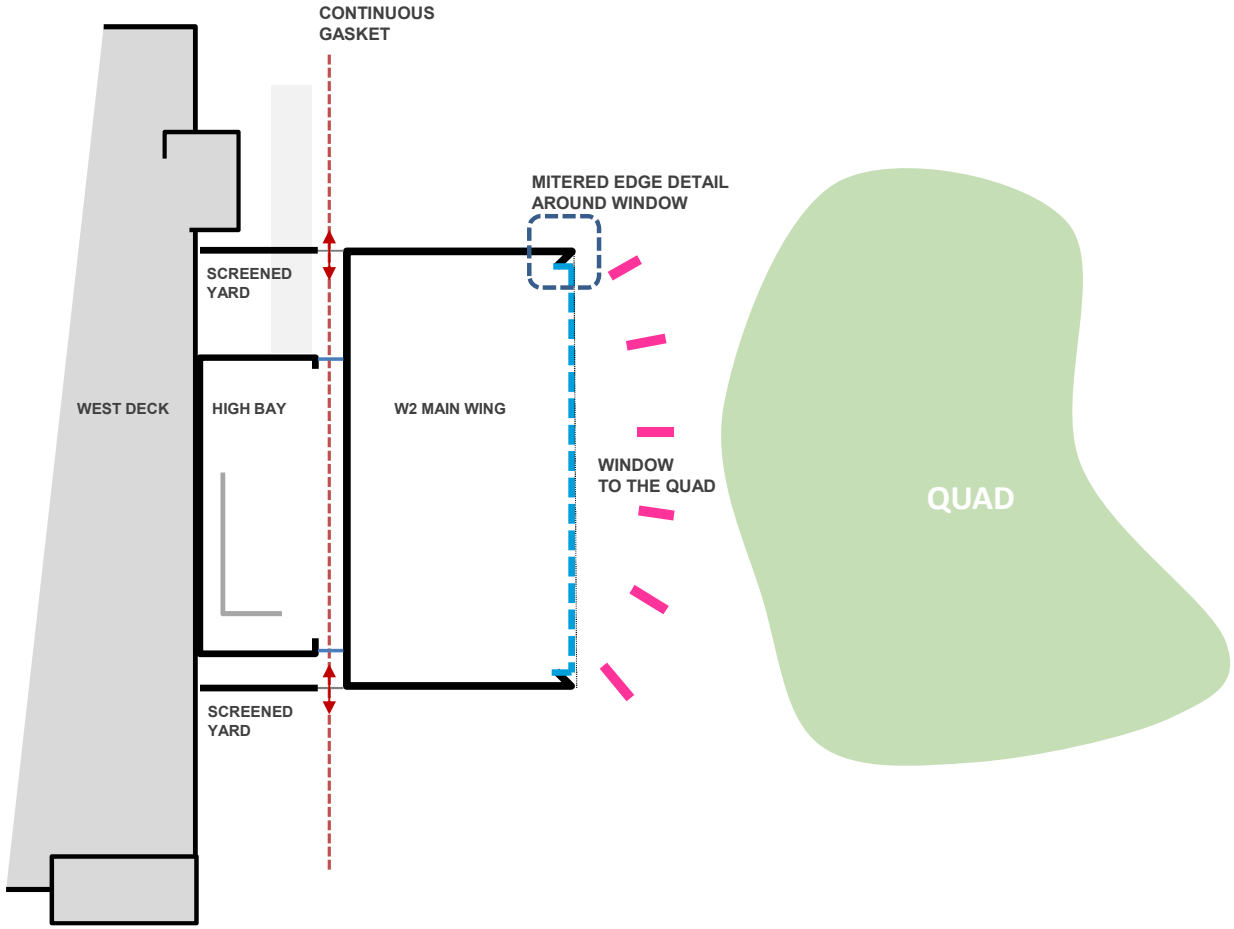


reducing embodied carbon on projects

Material Health Impact



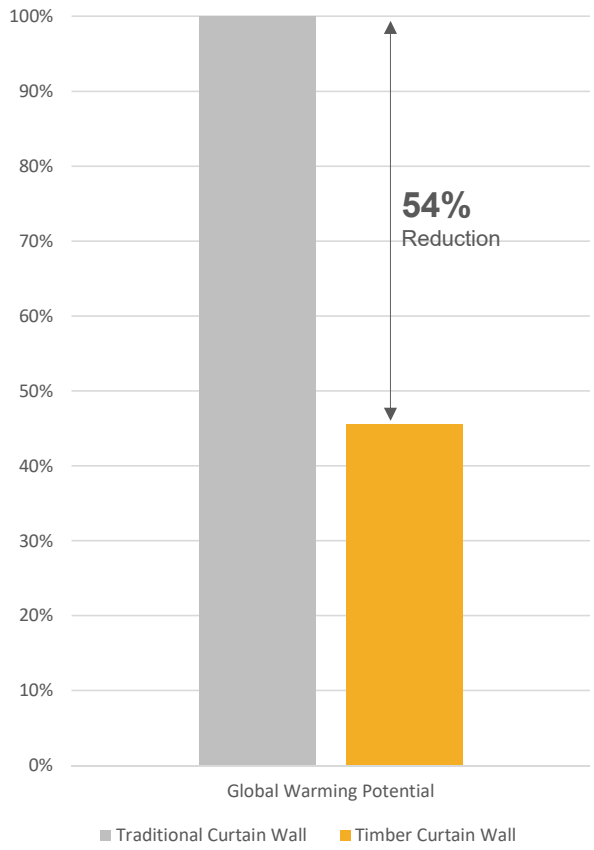
An "Open Book"


CONTINUOUS
GASKET
MITERED EDGE DETAIL
AROUND WINDOW
SCREENED
YARD
WEST DECK
HIGH BAY
W2 MAIN WING
WINDOW
TO THE QUAD
QUAD
SCREENED
YARD

Timber Curtain Wall| *Glulam*

- Natural wood interior, Durable aluminum exterior
- Thermal properties of wood insulate for higher energy efficiency than aluminum curtain wall
- Reduced Carbon Footprint
- Occupant Well-Being
- Meets visibility goals & desire to bring warmth to façade

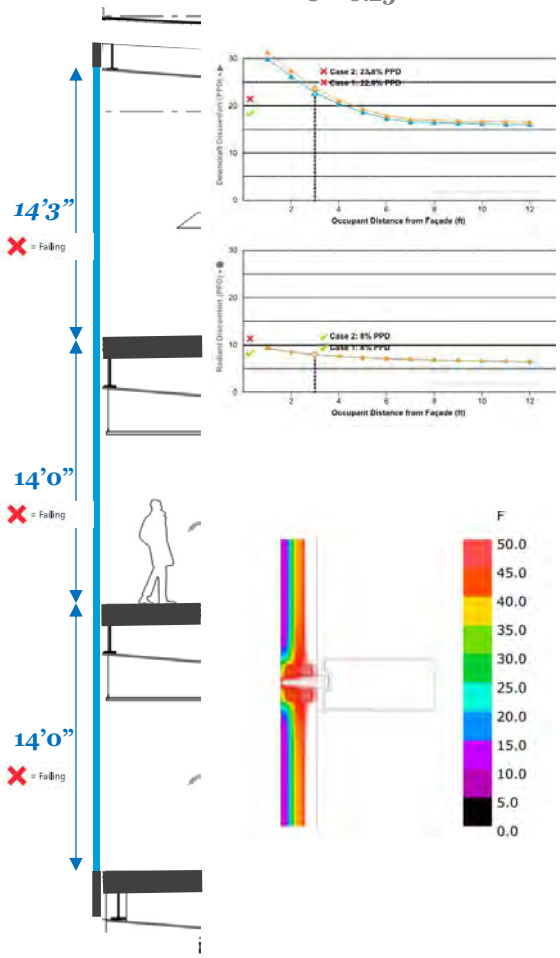
embodied carbon reduction



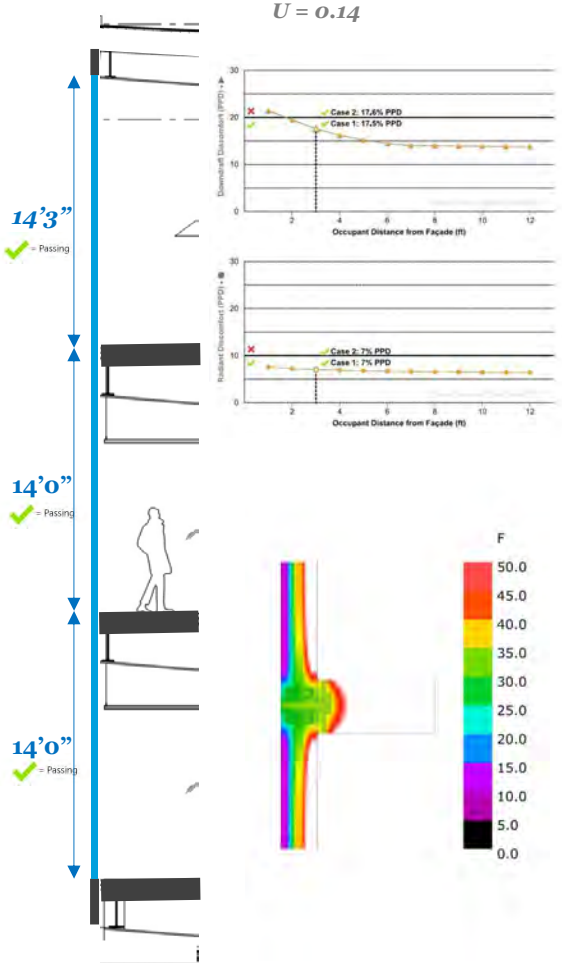
EMBODIED CARBON: in design

Curtain wall comparison| *Glazing comfort tool + Therm*

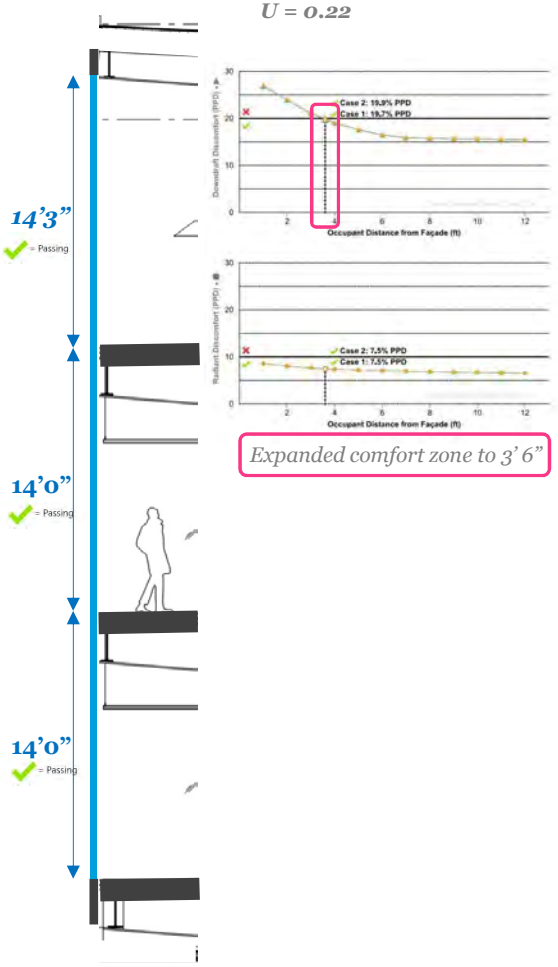
ALUMINUM + TRIPLE GLAZING
U = 0.25



TIMBER + TRIPLE GLAZING
U = 0.14



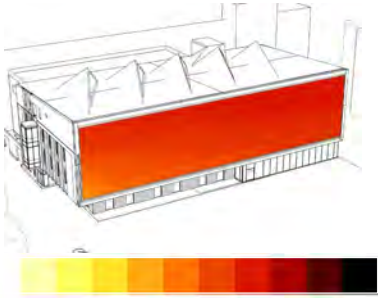
TIMBER + DOUBLE GLAZING
U = 0.22

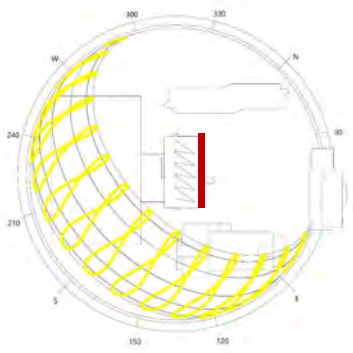


Expanded comfort zone to 3’ 6”

Timber Curtain Wall| *Direct Annual Sun after 8am*

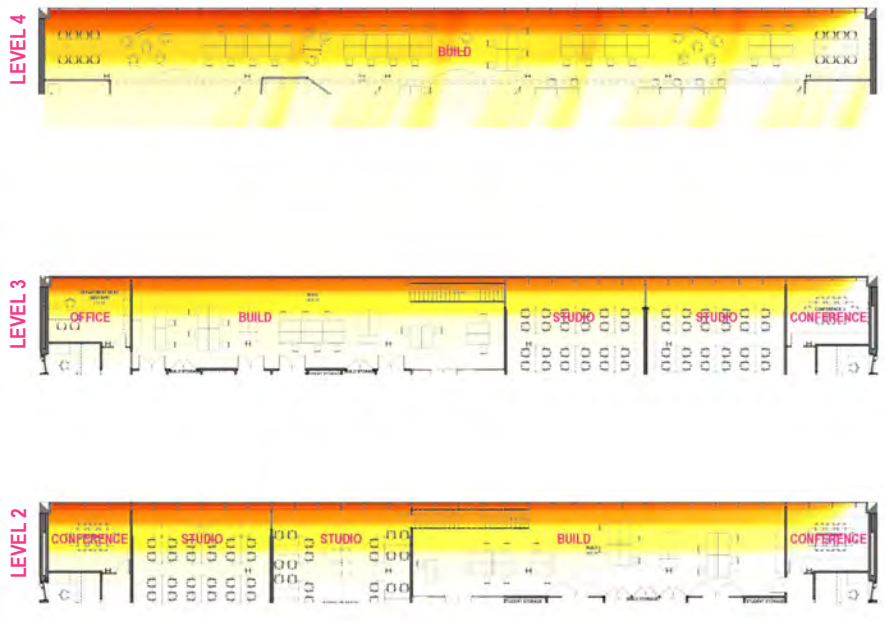
- No interior shades needed

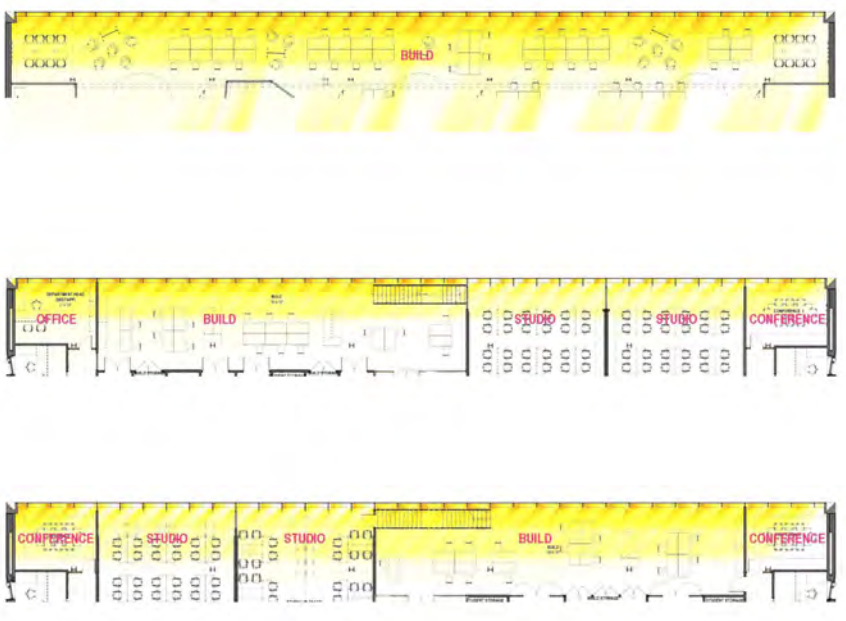




WITHOUT CONSIDERING MULLION DEPTH

DEEPER TIMBER MULLIONS






87%
reduction in energy usage

Conclusions

- *you don't need permission . . . there is a lot we can do now*
- *make a part of your design process from the beginning*
  ...and your consultants
- *bring LCA results to internal + external design discussions*
- *compare operation and embodied carbon*
- *reuse: the item with the lowest embodied carbon already exists*
- *reduce: look to materials that have lower embodied carbon*
  ...or could the material be eliminated?
- *consider the lifespan*

TOBIN MONTESSORI & VASSAL LANE UPPER SCHOOLS

OVERVIEW

Cambridge, MA

275,000 SF
New Construction

Preschool to 8th grade

INTEGRATED APPROACH

ENERGY METERING

MAXIMIZE ON-SITE RENEWABLE

LOW-FLOW PLUMBING FIXTURES & HEAT PUMPS

EMBODIED CARBON

ZERO ON-SITE GREENHOUSE GAS EMMISSION

ON-SITE STORMWATER MANAGEMENT

LOW ENERGY LED LIGHTING

SOLAR SHADING

EDUCATION

LEED GOLD

HYBRID STRUCTURAL SYSTEM

HIGH-PERFORMANCE BUILDING ENVELOPE

LOW-CARBON IMPACT MATERIALS

ENERGY RECOVERY SYSTEMS

TO KEEP OR NOT TO KEEP?

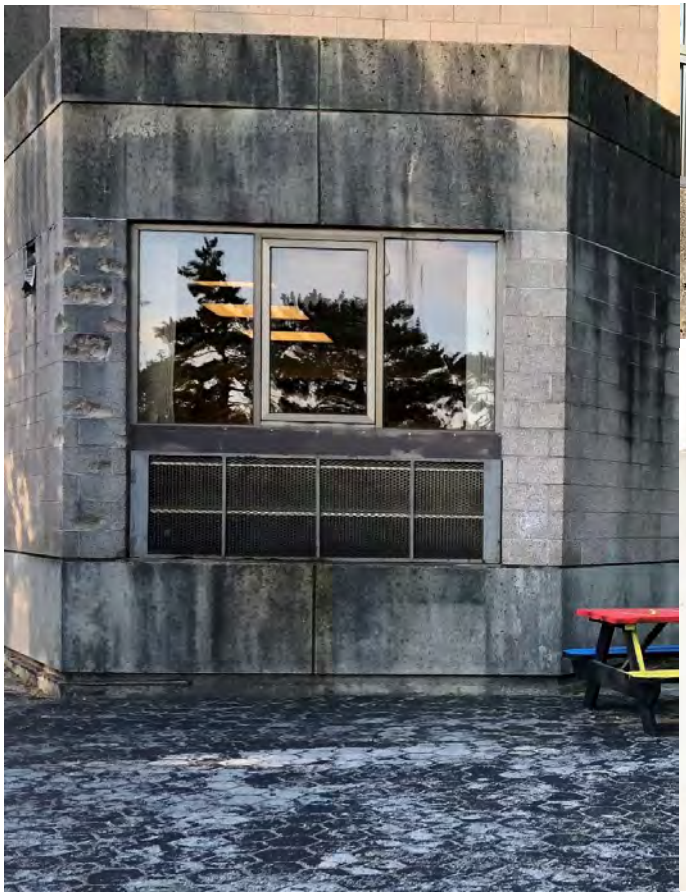
RENOVATION/ADDITION VS. NEW CONSTRUCTION

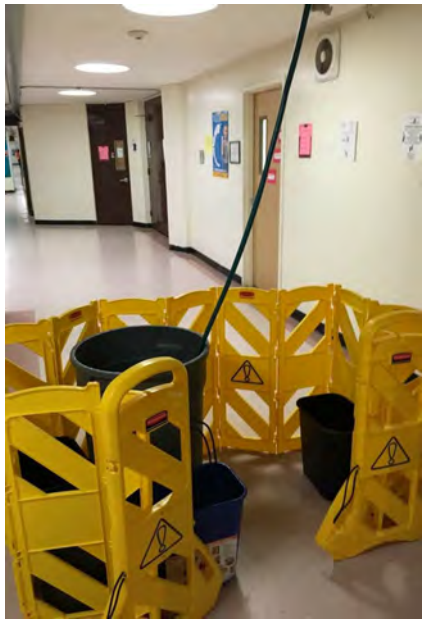
- Design Option Matrix utilized to compare all options in Feasibility Study
- Embodied Carbon was studied for Design Goal ranking
- **The Initial Assumption:** The Renovation + Addition option would have less Global Warning Potential (GWP) than any of the new construction options.

	RENOVATION/ADDITION	WINGS	PAVILIONS	REPLACEMENT
Design Goals				
Resilience	0 ▼	3 ▲	2 –	2 –
Sustainability, ZNE	1 –	3 ▲	3 ▲	2 –
Education Principles				
Identity & Arrival	1 –	2 –	3 ▲	3 ▲
Heart of School	1 –	2 –	1 –	3 ▲
Efficient Sharing	0 ▼	2 –	2 –	3 ▲
Open Space Diversity	1 –	3 ▲	2 –	3 ▲
Direct Outdoor Access	3 ▲	2 –	3 ▲	2 –
Community Partner				
Traffic and Parking	0 ▼	2 –	1 –	3 ▲
Contiguous Open Area	1 –	2 –	1 –	2 –
Building Size/Footprint	0 ▼	2 –	1 –	3 ▲
Site Circulation	0 ▼	2 –	1 –	3 ▲
Total	**8**	**25**	**20**	**29**

EXISTING CONDITIONS

A BUILDING BEYOND ITS USEFUL LIFE



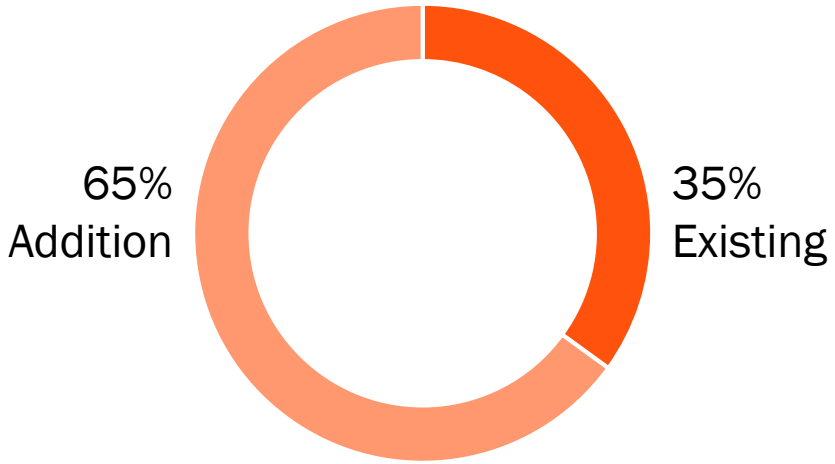


TO KEEP OR NOT TO KEEP?

RENOVATION/ADDITION VS. NEW CONSTRUCTION

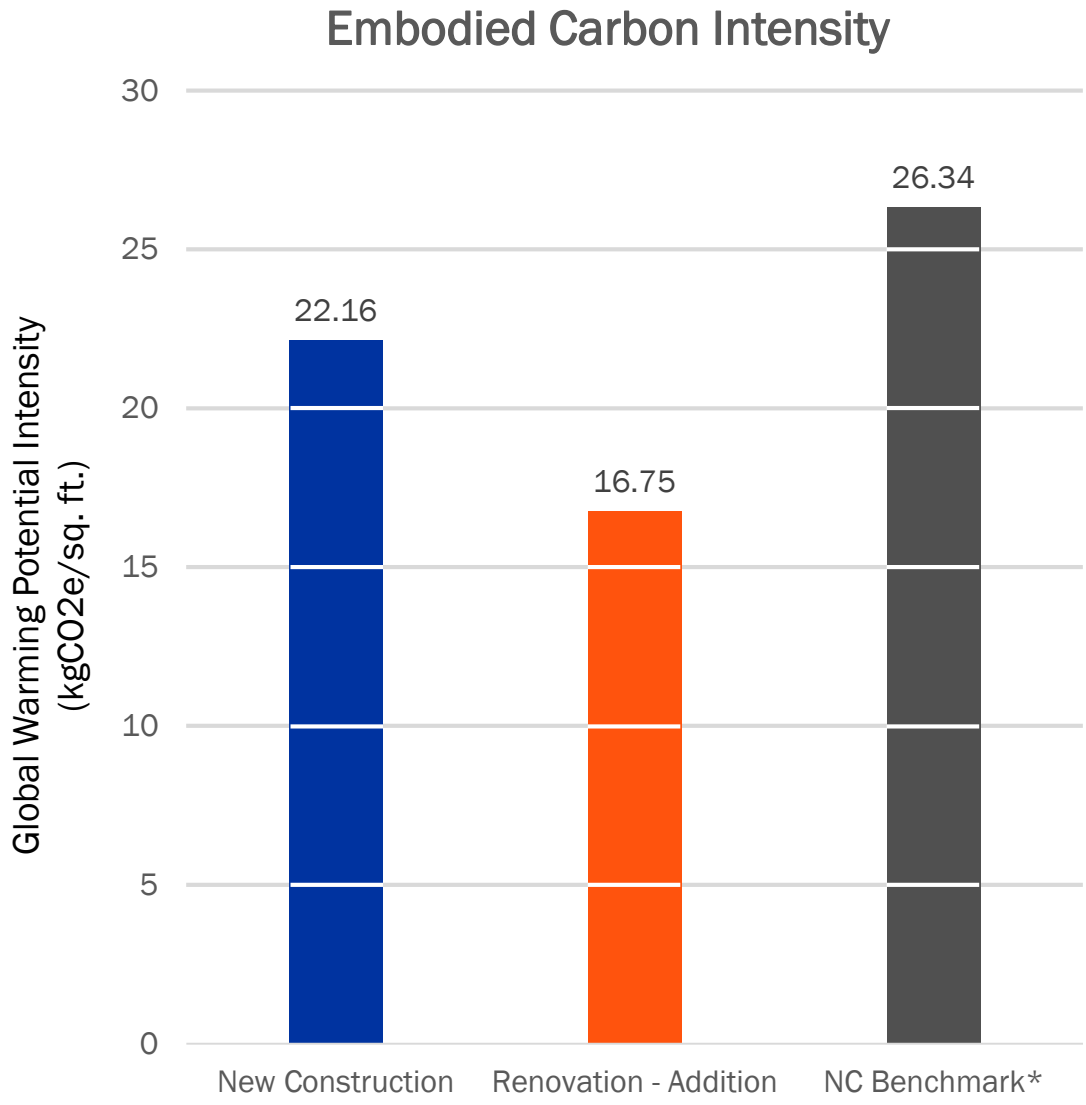
Renovation + Addition:

- Structure could be salvaged with significant seismic reinforcement
- Square footage breakdown:



New Construction:

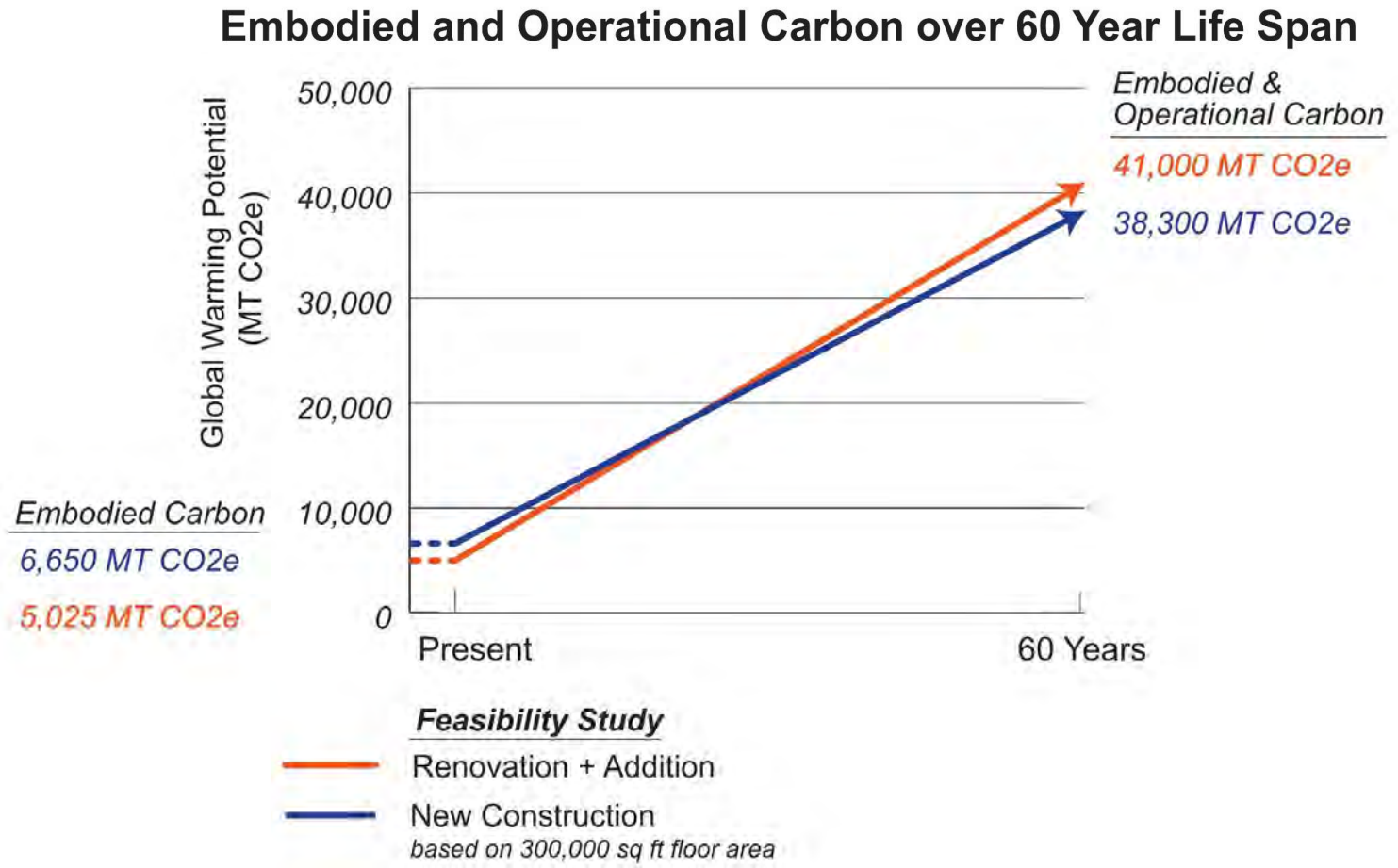
- Building pEUI set to match Reno+Addition
- On-site renewals were not included



**Benchmark based on Carbon Leadership Forum 2017 Embodied Carbon Benchmark Research, data for educational buildings in North America, new construction, 200k-500k sq. Ft.*

TO KEEP OR NOT TO KEEP?

RENOVATION/ADDITION VS. NEW CONSTRUCTION



SITE REMEDIATION

CONCRETE

- Reduce soilcrete wall by over 60% to align with material and cost goals

Proposed

Reduced

SITE REMEDIATION

URBAN TREE CANOPY

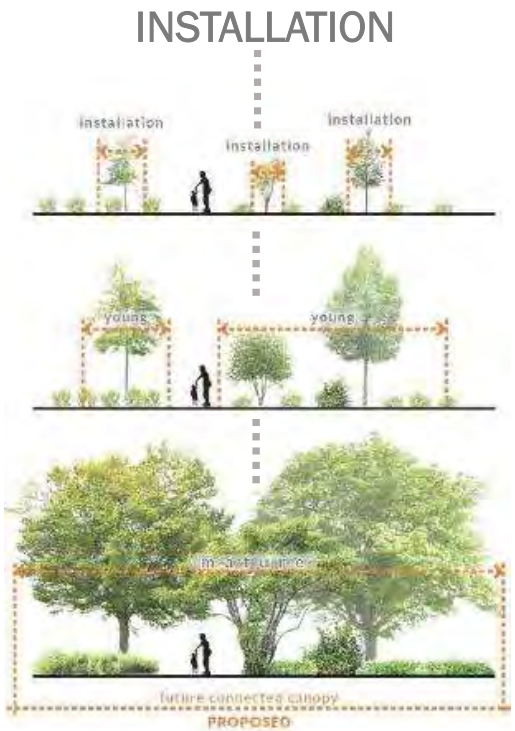
2021 **PRE CONSTRUCTION**

141 total (83 ≥6" cal)
34 protected
107 removed (49 ≥6" cal)

*family 33 removed by city

2025 **POST CONSTRUCTION**

408 total
34 protected
374 new



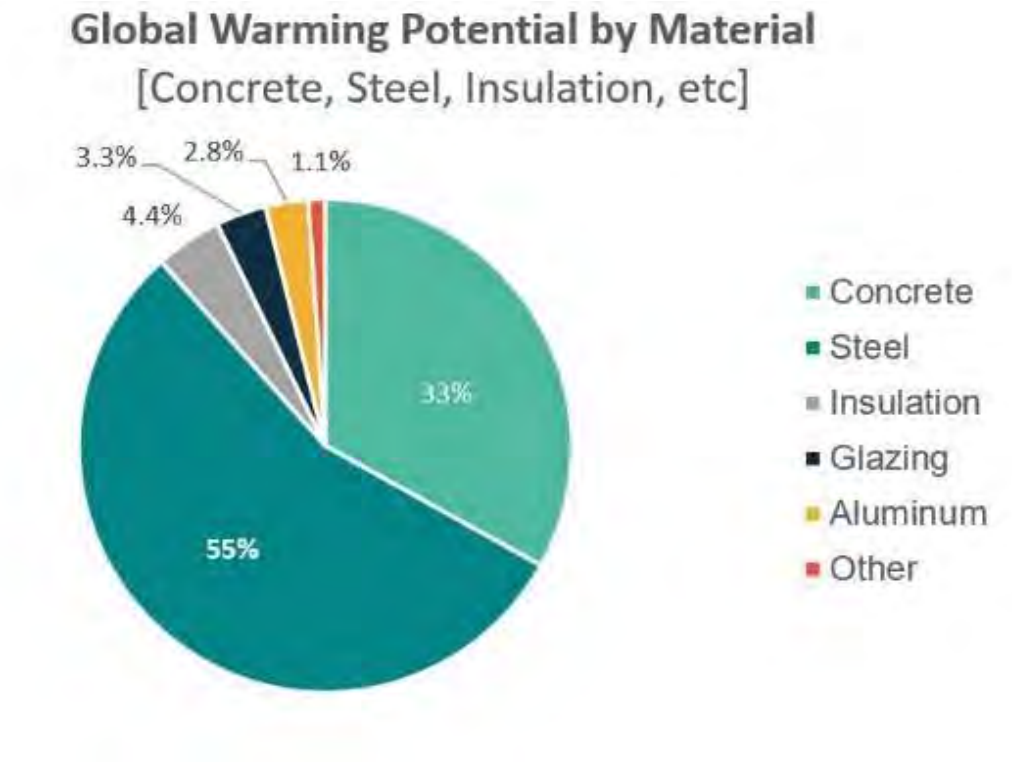
PRE + POST CONSTRUCTION COMPARISON

Tobin Montessori + Vassal Lane Upper Schools

BIG PICTURE – STRUCTURE

MATERIAL IMPACTS

- A preliminary embodied carbon study conducted at the outset of Schematic Design
- Steel and Concrete were primary targets



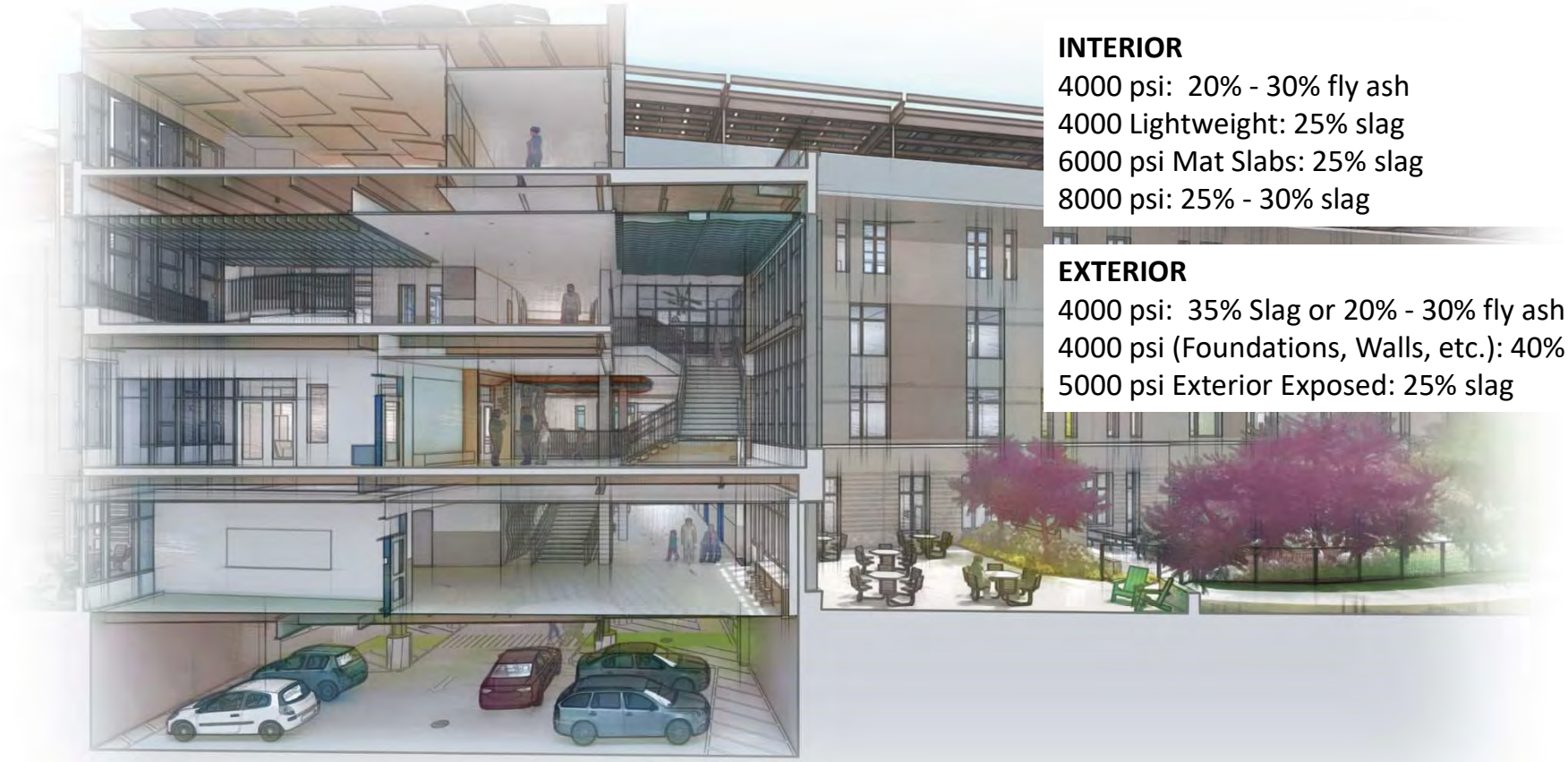
BIG PICTURE – STRUCTURE

MATERIAL IMPACTS

ALTERNATIVES	QUANTITY cy	A1-A3 kgCO2e	CHANGE %
Total Project Concrete (Baseline)	8994	2.72 MILLION	
20% Fly Ash in 30% of concrete	8994	2.60 MILLION	-4.41%
20% Fly Ash in 100% of concrete	8994	2.32 MILLION	-14.71%
30% Fly Ash in 30% of concrete	8994	2.54 MILLION	-6.62%
30% Fly Ash in 100% of concrete	8994	2.10 MILLION	-22.79%
Based on NRMCA industry average			
Inject CO2 in 30% of concrete	8994	2.67 MILLION	-1.80%
Inject CO2 in 100% of concrete	8994	2.56 MILLION	-6.00%
Based on average 6% reduction in GWP from CarbonCure documentation (carboncure.com)			

BIG PICTURE – STRUCTURE

MATERIAL IMPACTS



INTERIOR

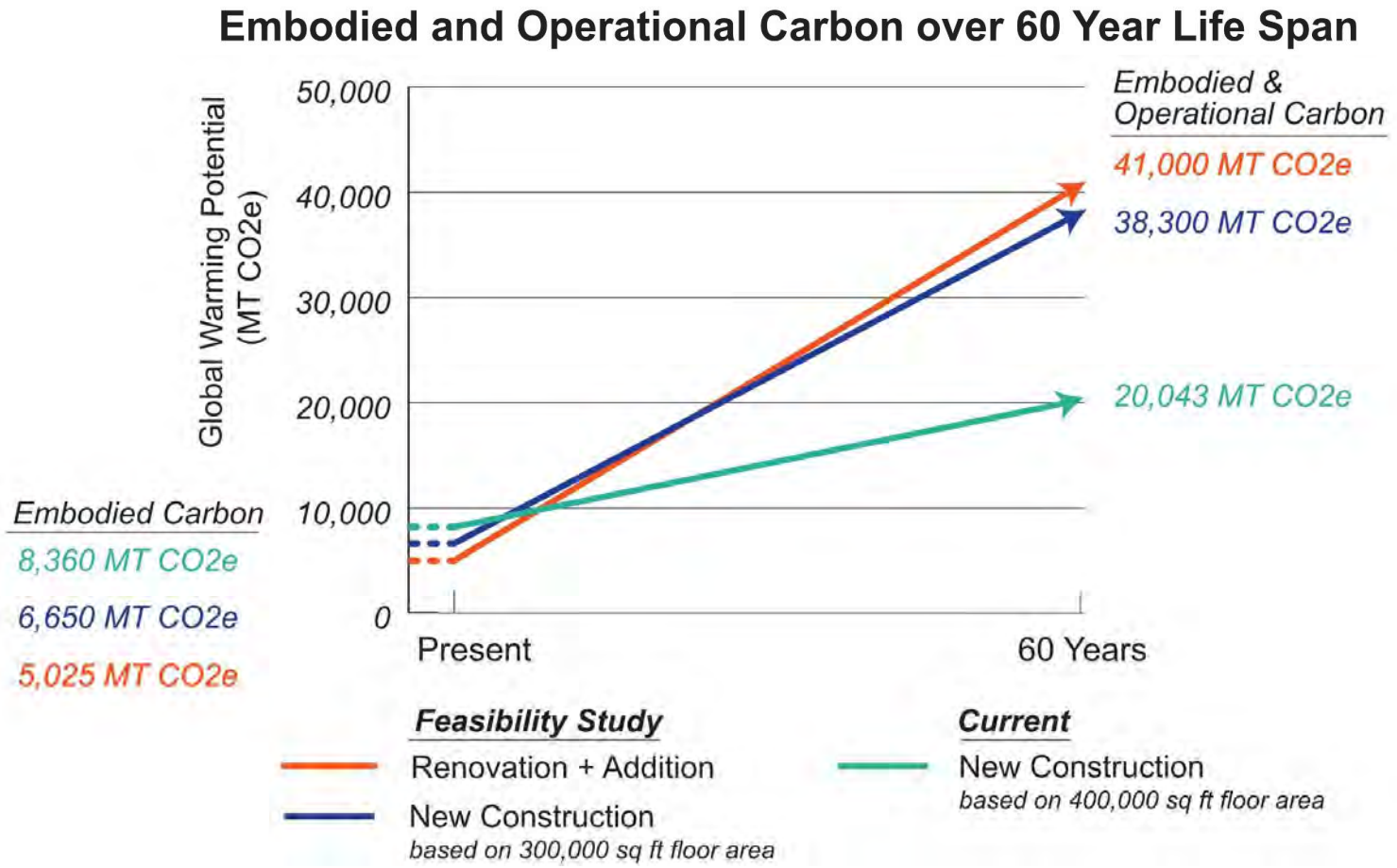
4000 psi: 20% - 30% fly ash
4000 Lightweight: 25% slag
6000 psi Mat Slabs: 25% slag
8000 psi: 25% - 30% slag

EXTERIOR

4000 psi: 35% Slag or 20% - 30% fly ash
4000 psi (Foundations, Walls, etc.): 40% slag
5000 psi Exterior Exposed: 25% slag

WHERE WE ARE

FROM FEASIBILITY TO REALITY



WHERE WE ARE

FROM FEASIBILITY TO REALITY

Waste Management from Demolition and Construction

Optimization

Material Selections

TAKEAWAYS

Carbon is everywhere

Recognizing **Scale** is Key

Once Carbon is spent, it is gone.
Therefore, let's **spend it wisely.**

First united Methodist Church

embodied carbon case study

nesea building energy boston

Mark D. Webster

Senior Consulting Engineer

Simpson Gumpertz & Heger

1 March 2022

project team

Design Team

Owner: First United Methodist Church

Architect: Maple Hill Architects

Structural Engineer: Simpson Gumpertz & Heger

MEP Engineer: Norian/Siani Engineering

Civil Engineer: Samiotes Consultants

Landscape Architect: Suzanne Hopkins McDonough

Construction Team

General Contractor: ACS Group

Concrete Subcontractor: Stashis Property Maintenance

Ready-Mix Supplier: Dauphinais Concrete

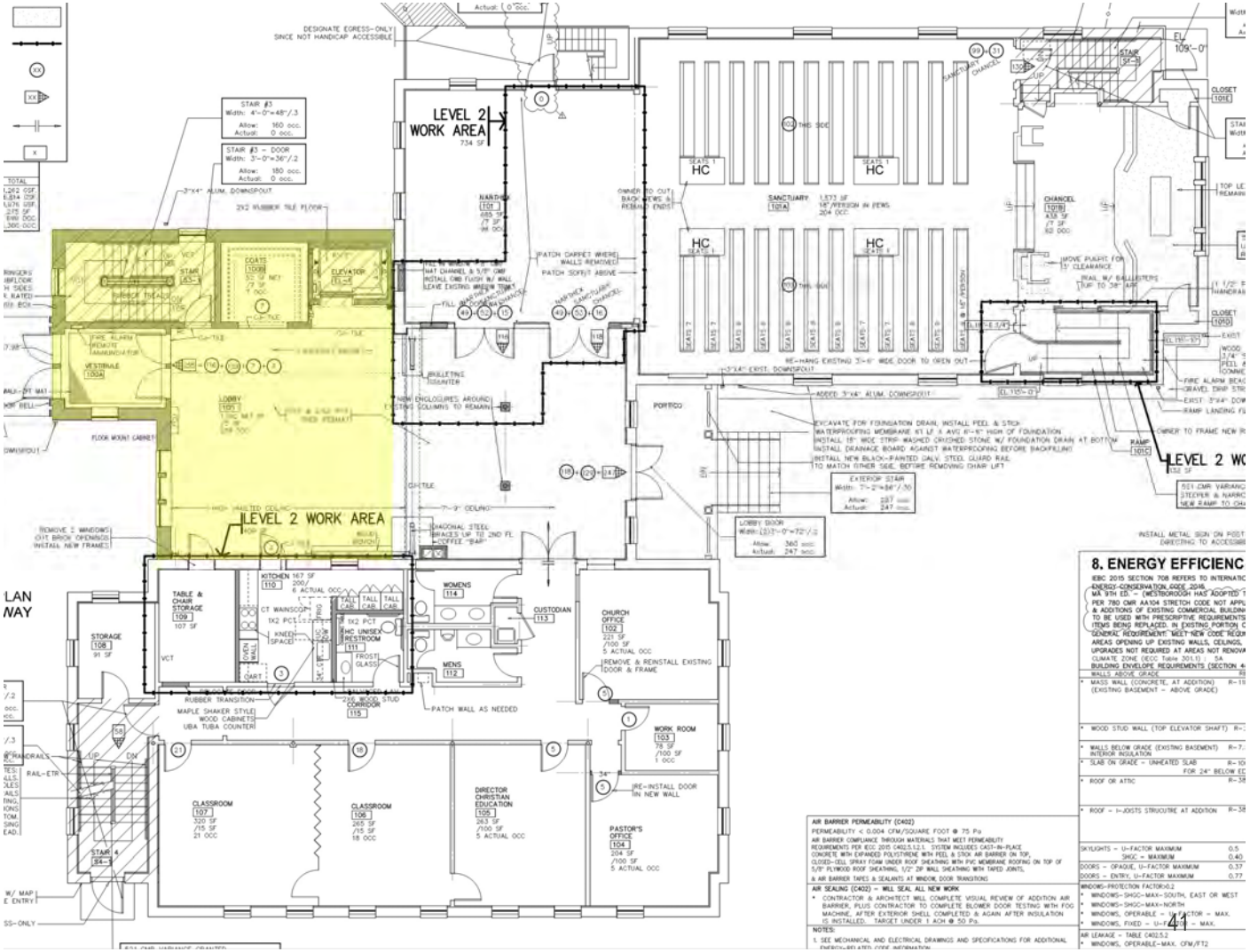
fumc facts

Existing

- built around 1967
- masonry exterior walls
- steel framing and bar joists
- wood-framed roof

Addition

- basement + two stories
- 2800 sf
- ICF walls
- wood-framed floors and roof



construction

16 December 2019

construction

2 March 2020

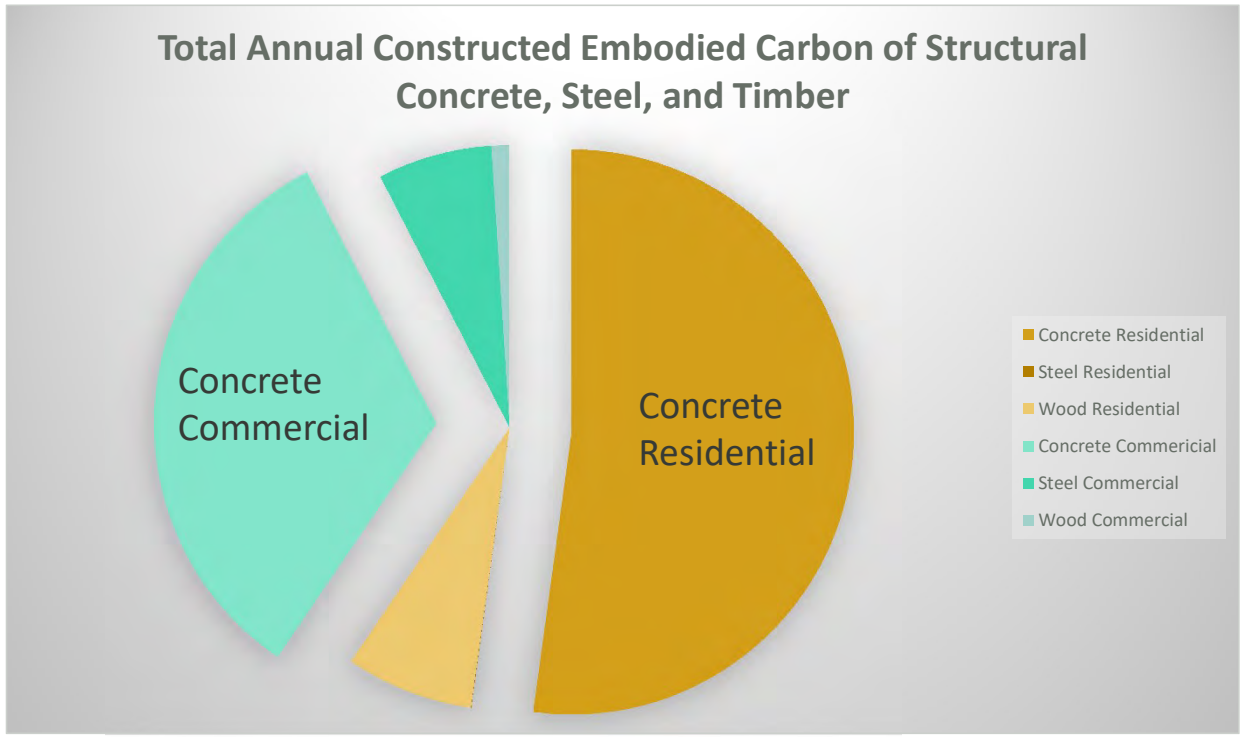
construction

15 May 2020

construction

24 October 2021
(Dedication Ceremony)

concrete drives structural embodied carbon



Achieving Net Zero Embodied Carbon in Structural Materials by 2050
(https://seisustainability.files.wordpress.com/2020/05/how-to-get-to-zero-200525.pdf)

specifying low carbon concrete

Element	56-Day Strength	28-Day Strength	Max. Aggregate	Max. Portland Cement	Min. Cementitious
Foundations	4,000 psi	3,000 psi	3/4”	300 lb/cy	585 lb/cy
ICF Walls	4,000 psi	3,000 psi	3/8”	350 lb/cy	600 lb/cy

We specified a cap on the Portland cement content. The ready-mix supplier could decide how to meet the strength requirement. In this case, they opted to use slag to replace cement. Other materials could also serve this purpose, including Pozzotive, a finely ground glass product.

procurement strategies for reducing embodied carbon

Concrete

Environmental Product Declarations

This graphic shows just how much change we need to make happen here in Massachusetts!

TABLE C: NUMBER OF COMPLYING EPDS PER CONCRETE STRENGTH CLASS PER STATE

State	2499 psi	2500 psi	3500 psi	4500 psi	5500 psi	6500+ psi
AL	1	6	5	4	0	0
CA	569	4237	6012	5427	2041	785
CO	2	30	113	214	28	36
DC	1	4	4	3	3	4
FL	3	11	67	16	14	9
GA	8	115	135	75	22	11
IA	2	10	55	21	0	0
IL	0	6	70	52	32	15
MA	0	0	15	12	5	2
MD	5	25	20	15	16	20
NC	1	92	107	71	4	6

Image Source: NBI

concrete performance

Day of Placement	Mix	Tested 28-Day Strength	Notes
11/19/19	Foundations 0% slag	6000 psi	Wrong Mix Delivered
12/23/19	Foundations 50% slag	9100 psi	
1/24/20	Foundations 20% slag	7600 psi	Contractor concerned about cold weather (low temp that night in the high 20s)
2/21/20	Foundations 50% slag	7400 psi	Much colder than 1/24 (temp in low teens that night).
3/11/20	ICF walls 44% slag	7700 psi	
4/22/20	ICF walls 44% slag	6800 psi	

Life cycle assessment

Athena Environmental Impact Estimator

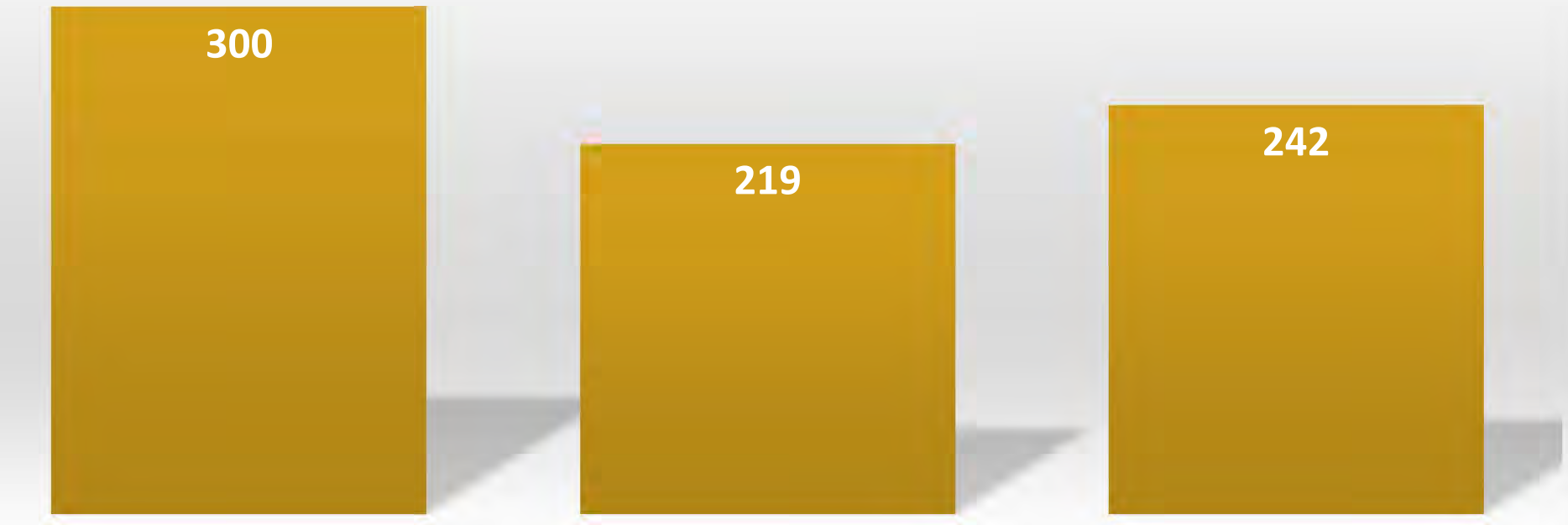
Athena
Sustainable Materials
Institute

- Free LCA software.
- Includes wide range of materials with A-C life cycle (cradle-to-grave) and Module D option (beyond building life).
- Includes a concrete mix calculator.
- Input options:
  - Select from pre-designed systems
  - Input bill of materials
  - Combination of the above

defining the concrete baseline mix

- NRMCA Eastern Regional Benchmark for 4000 psi concrete has 21% cement replacement.
- 20% cement replacement common in our region if no special provisions.
- Dauphinais provided a 20% slag mix when concerned about the cold weather.
- I used the Dauphinais mix for my baseline mix.

Embodied Carbon of Concrete Mixes
(kg CO2e/cy)

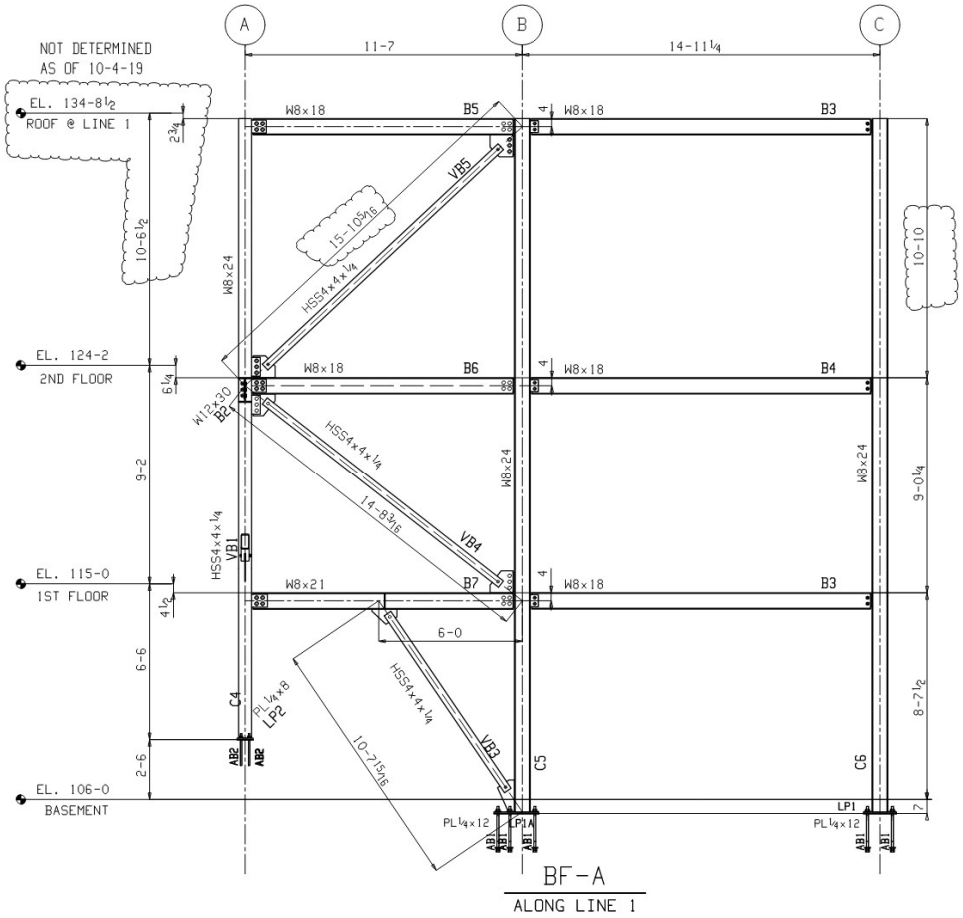


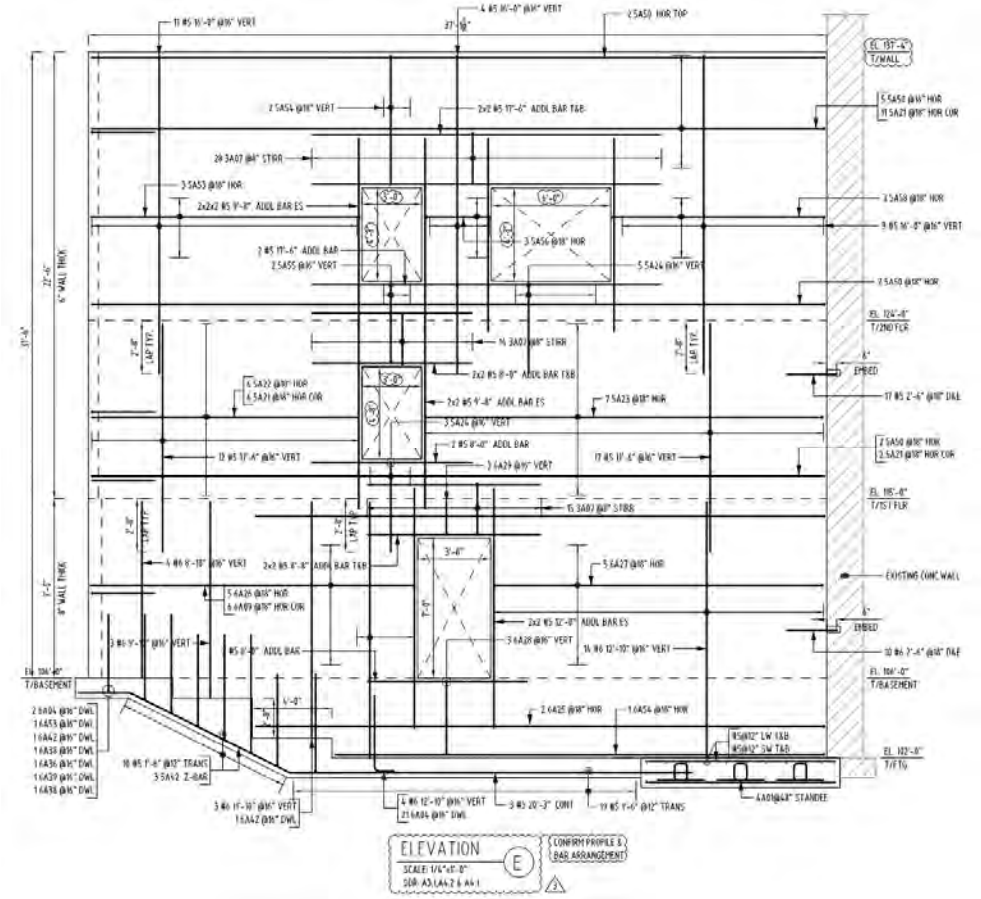
Estimated Using Athena Custom Concrete Mix Tool

What if Building Had Been Constructed Like the Original Building?

- Concrete Foundation Walls
- CMU Exterior Walls
- Concrete Slabs on Steel Deck and Bar Joists
- Wood-Framed Roof

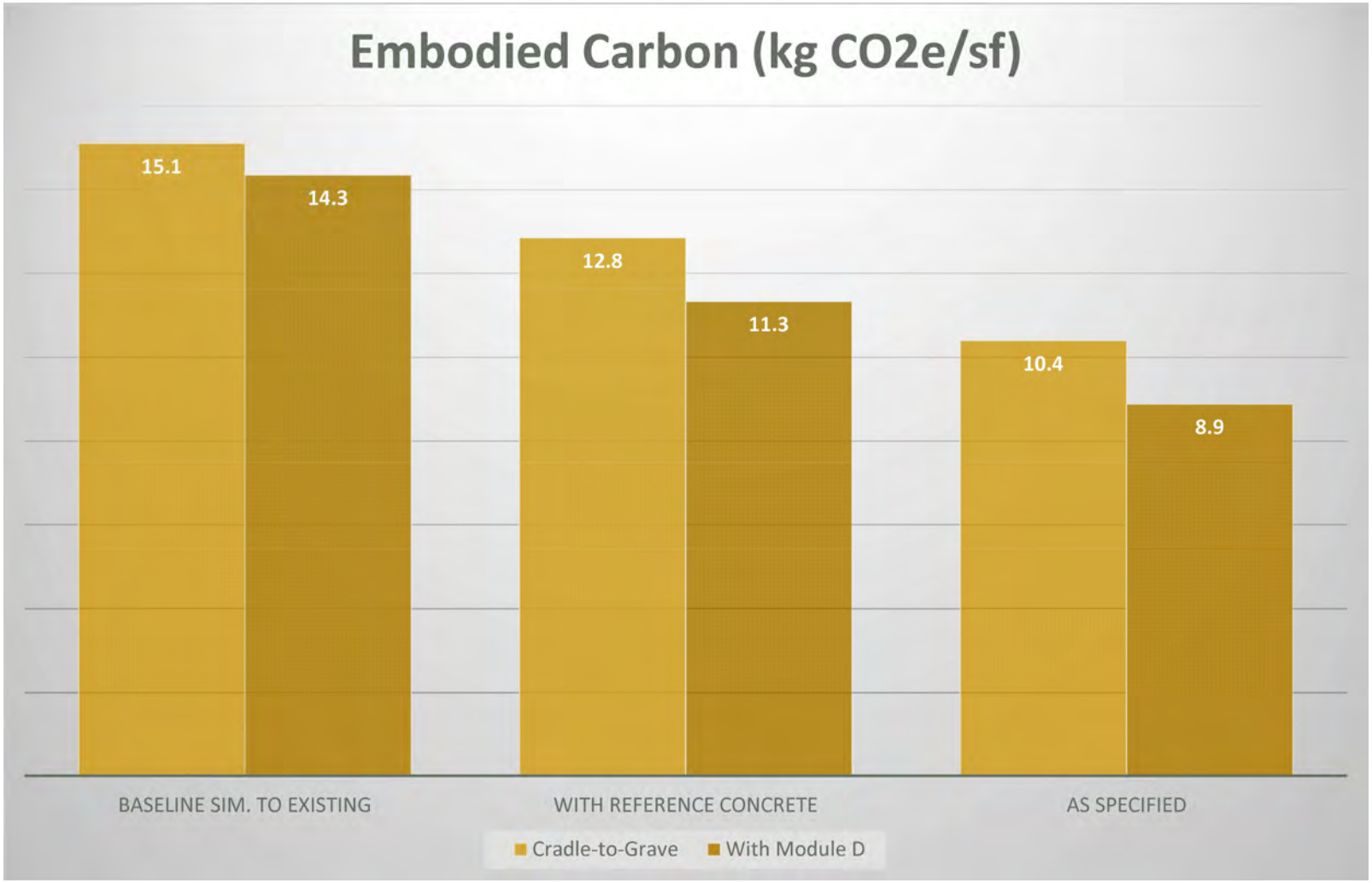
calculating material quantities





Structural Steel and Rebar Shop Drawings

results for the addition

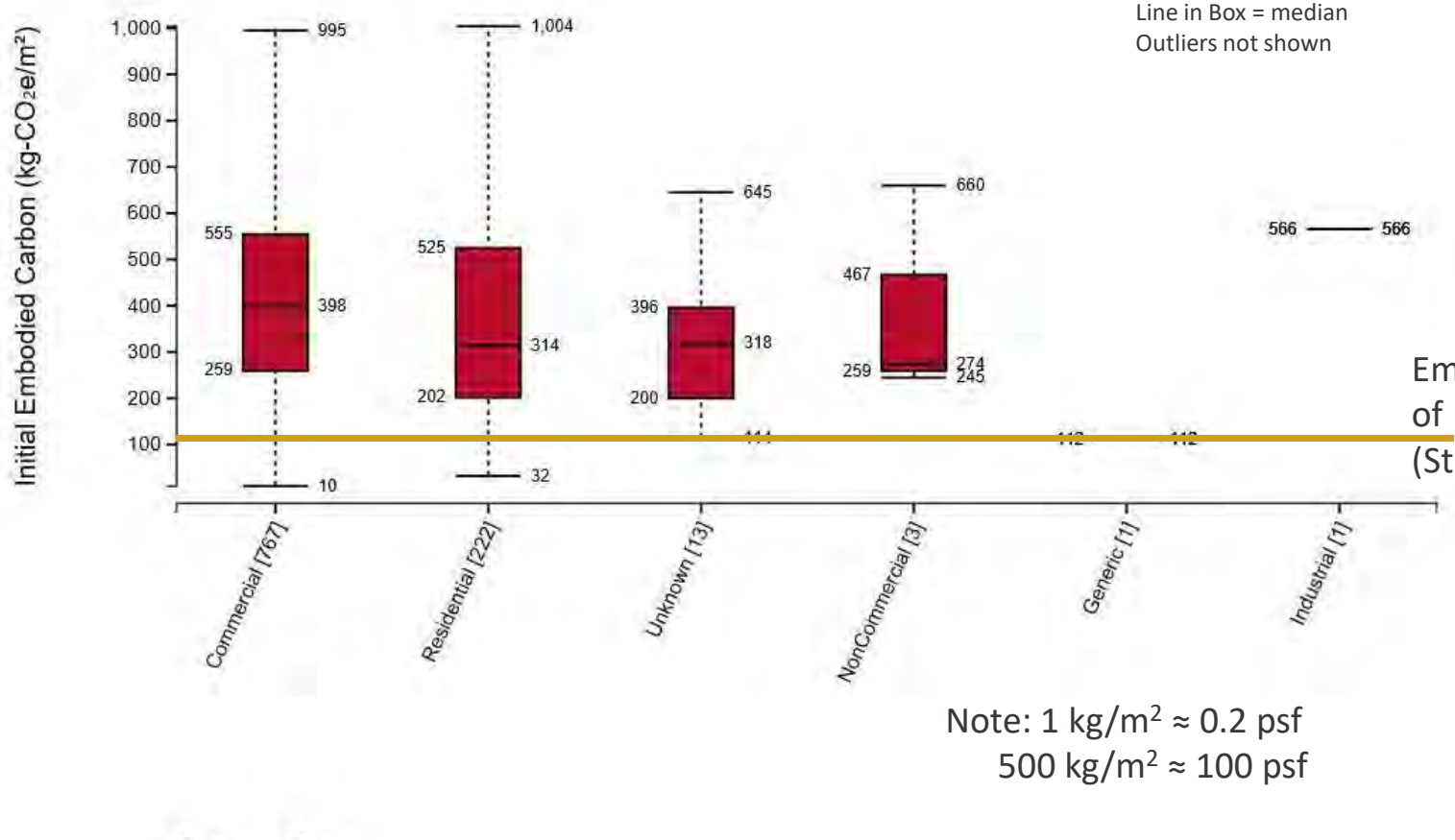


With Module D:
38% reduction from baseline building
22% reduction from reference concrete

Cradle-to-Grave:
31% reduction from baseline building
19% reduction from reference concrete

CLF embodied carbon benchmark study

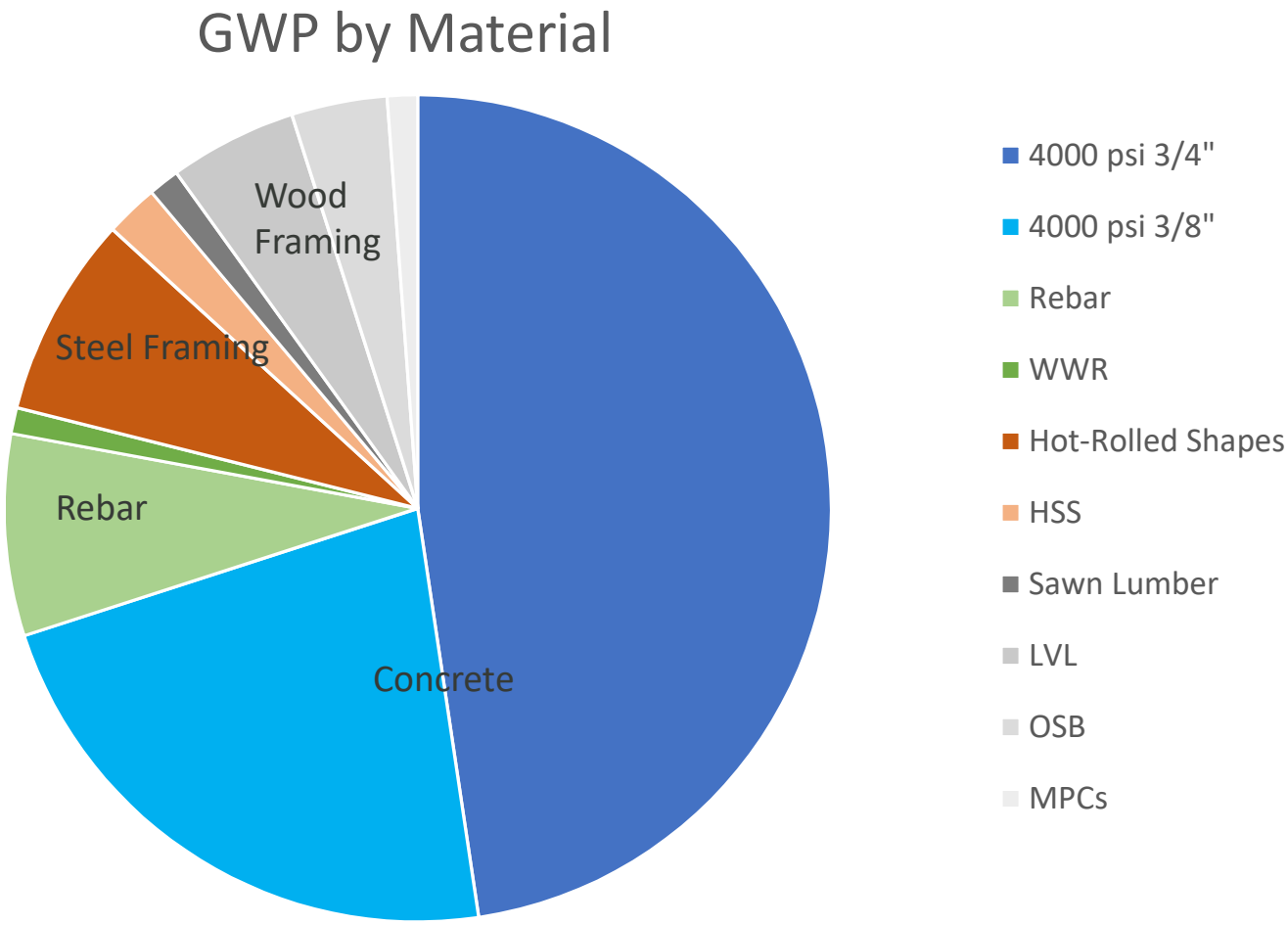
Whisker Plots:
Box = +/- quartiles
Line in Box = median
Outliers not shown



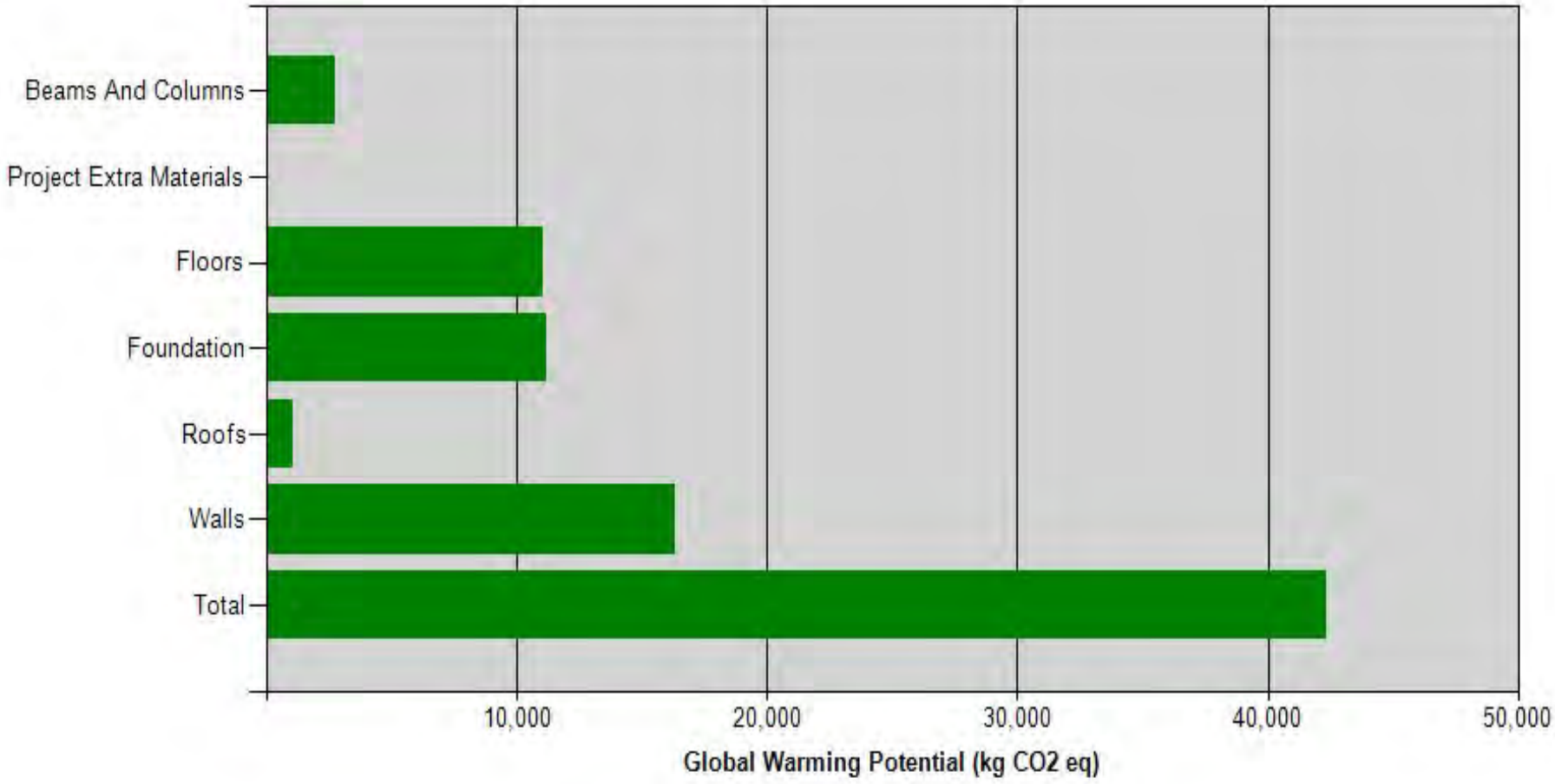
Embodied Carbon of FUMC Project (Structure Only)

Note: 1 kg/m^2 ≈ 0.2 psf
500 kg/m^2 ≈ 100 psf

Embodied carbon by material (as designed, no sequestration)



Embodied carbon by system (baseline cmu building)



lessons learned

- We can easily do useful embodied carbon calculations for our small projects using free LCA tools such as Athena.
- 50% replacement concrete mixes provided ample strength at 28 days and performed well in cold weather.
- Make sure the contractor understands the mix requirements and delivers the approved mixes.

some useful embodied carbon resources for structure

- Structural Engineering (SE) 2050 Commitment (se2050.org/)
- Achieving Net Zero Embodied Carbon in Structural Materials by 2050 (seisustainability.files.wordpress.com/2020/05/how-to-get-to-zero-200525.pdf)
- Athena Institute “About Whole-Building LCA and Embodied Carbon” (athenasmi.org/wp-content/uploads/2019/09/About_WBLCA.pdf)

Current MA Policies that Address Building-related Energy/Carbon

OPERATING ENERGY/CARBON

MA State-level:

- Energy Code- updated every 3 years, next Jan 2023
- Stretch Energy Code- last updated 5 years ago, next Jan 2023
- EO 594 Leading by Design- LEED+ for state facilities
- MassSave Incentives for energy reductions and Passive House

City/Town-level:

- Green building standards/requirements-
  - Boston- Article 37 LEED Certifiable and net zero study; BERDO for existing buildings
  - Cambridge- Article 22 LEED Gold; BEUDO
  - Newton- Special Permit Sustainability Ordinance- LEED or Passive House
  - And many others

EMBODIED ENERGY/CARBON

MA State-level:

- SEVERAL IN DEVELOPMENT…

City/Town-level:

- SEVERAL IN DEVELOPMENT…

Policy *Types* that Address Building-related Embodied Carbon

EMBODIED ENERGY/CARBON

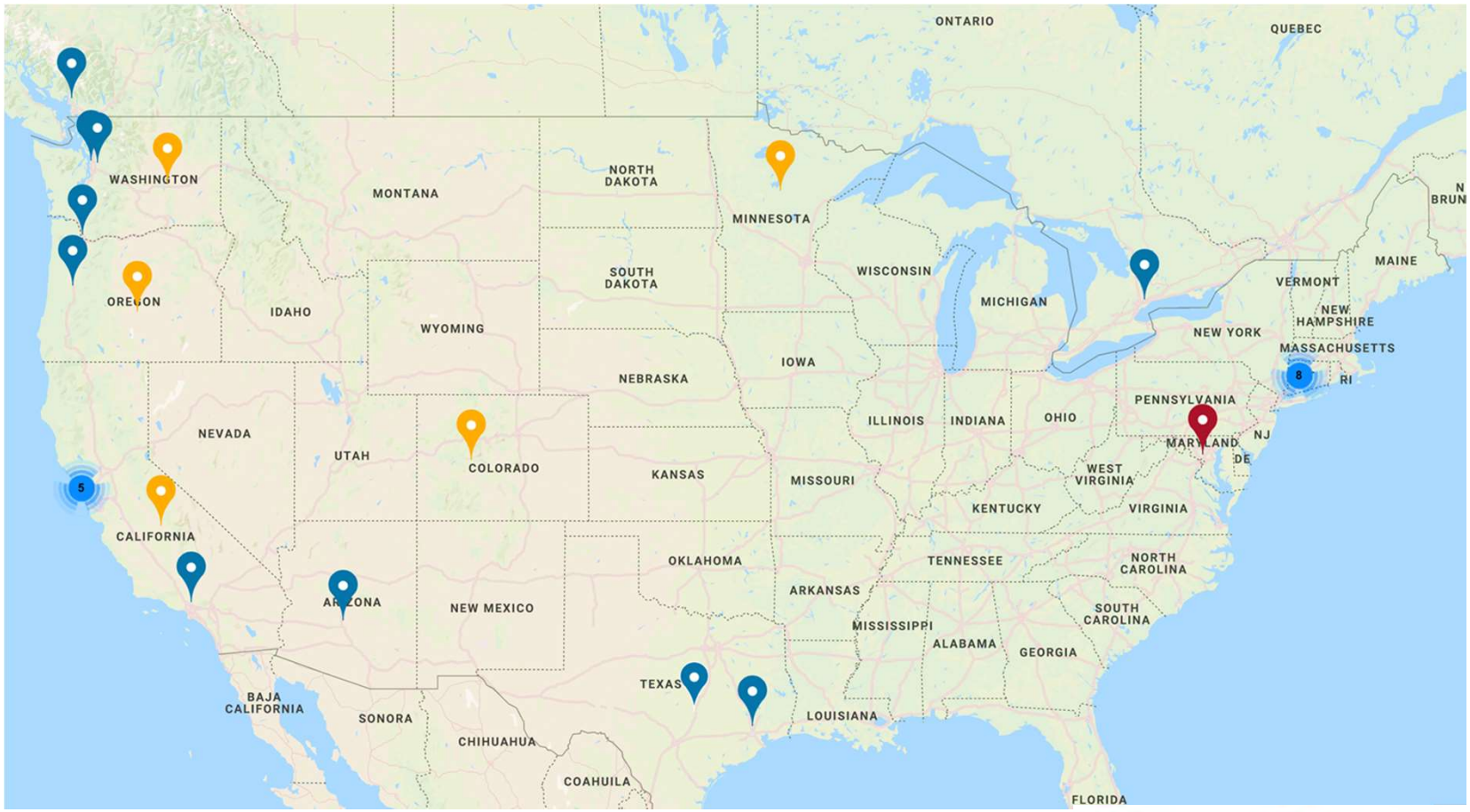
State/County-level:

- Executive Orders
- Procurement Requirements – 'Buy Clean' Policies for specific materials
- Building and Energy Codes

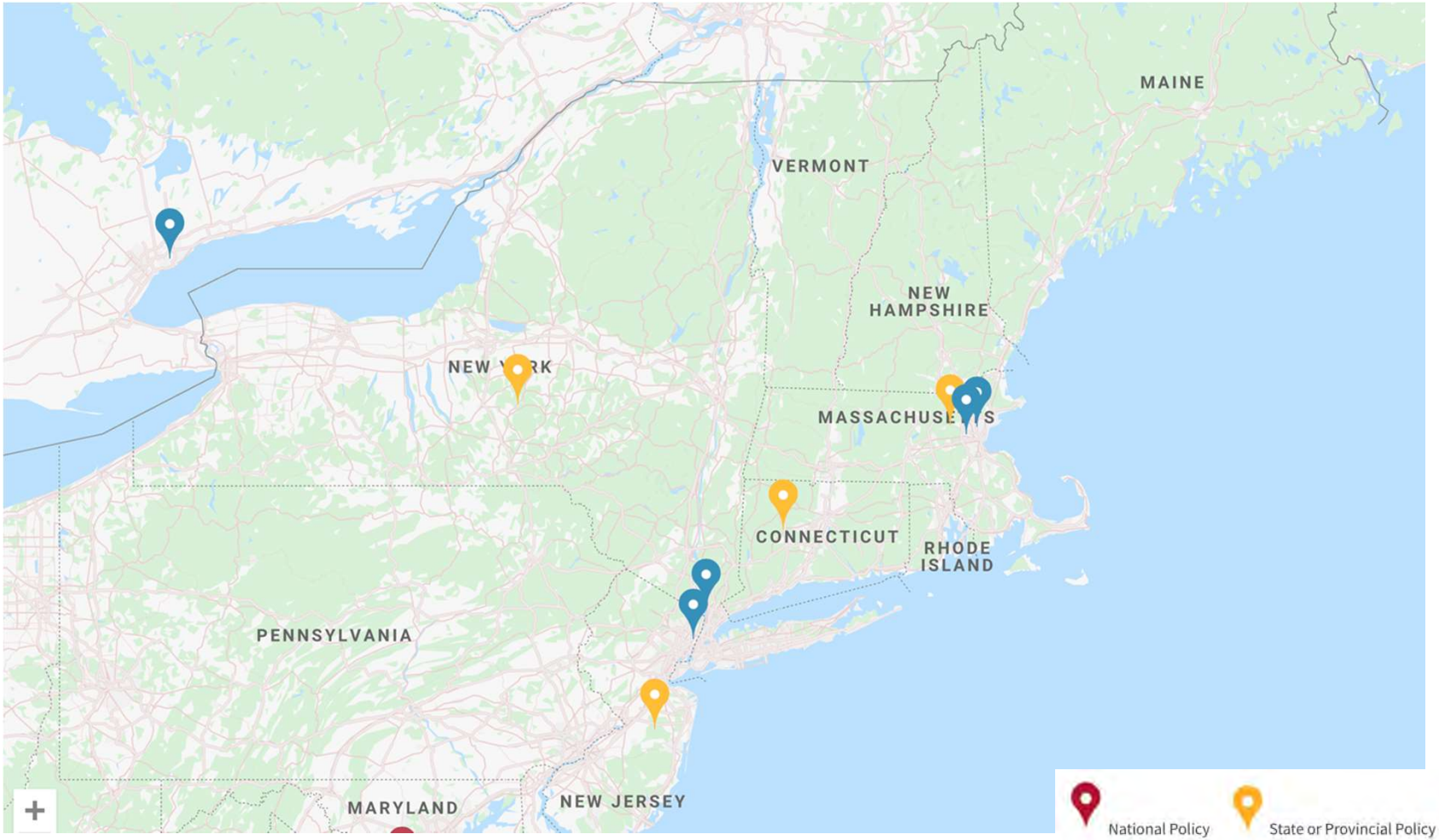
City/Town-level:

- Climate Action Plans
- Zoning/Permitting
- Building Reuse/Deconstruction Ordinances
- Incentives

Embodied Carbon Policies – US and Canada



Embodied Carbon Policies - Northeast



MA Policies *In Development* that Address Building-related Energy/Carbon

EMBODIED ENERGY/CARBON

MA State-level:

- MA Executive Order 594
- MA DOER Net Zero Stretch Energy Code- *PROPOSED*

City/Town-level:

- Boston
- Cambridge
- Newton
- Somerville

Massachusetts State Policy *Enacted*

MA Executive Order 594, *Leading by Example: Decarbonizing and Minimizing Environmental Impacts of State Government*

- Issued April 2021 by Governor Baker
- Section 3: “Evaluate and implement strategies to reduce embodied carbon contained in building materials, where possible and cost-effective.”

Massachusetts State Policy *Proposed/In Development*

Proposed MA DOER Net Zero Stretch Energy Code-

- Pathway: For commercial buildings/large scale multi-family *only*
  - For curtainwall buildings *only*- must demonstrate embodied carbon reduction from menu of options:
    - Low carbon concrete
    - Carbon sequestering materials (wood fibre, mass timber)
    - Recycled materials
    - Reused materials/building reuse
- Timeline for adoption- spring/summer public comment and revisions; Fall 2022 final draft; in effect January 2023

MA Local Policy *Proposed/In Development*

CITY OF BOSTON

1. Zero Net Carbon (ZNC) Zoning, Embodied Carbon Technical Advisory Group (TAG) Recommendations

2. Mass Timber Accelerator Grants

3. Boston Environment Dept. Building Reuse/Deconstruction Pilot

City of Boston - Article 37 and Zero Net Carbon Update Recommendations

Low Carbon Buildings
On-site Renewable Energy
Renewable Energy Procurement
Embodied Carbon

boston planning & development agency

October 20, 2021

Embodied Carbon TAG – 12 Recommendations

POLICY	PRACTICE	AWARENESS
[01] Climate Action Plan: Update with embodied carbon goals and strategies	[06] Pilot Programs / Demonstration Projects	[9] Recognition for Best Practices
[02] Building reuse and deconstruction ordinance(s)	[07] Incentives	[10] City Capacity and Expertise
[03] Require LEED embodied carbon-related/LCA Credits	[08] Professional Advisory Group to the City	[11] Workforce Development
[04] Require whole-building LCA in zoning/permitting process		[12] AEC Industry Resources
[05] Municipal & State collaboration		

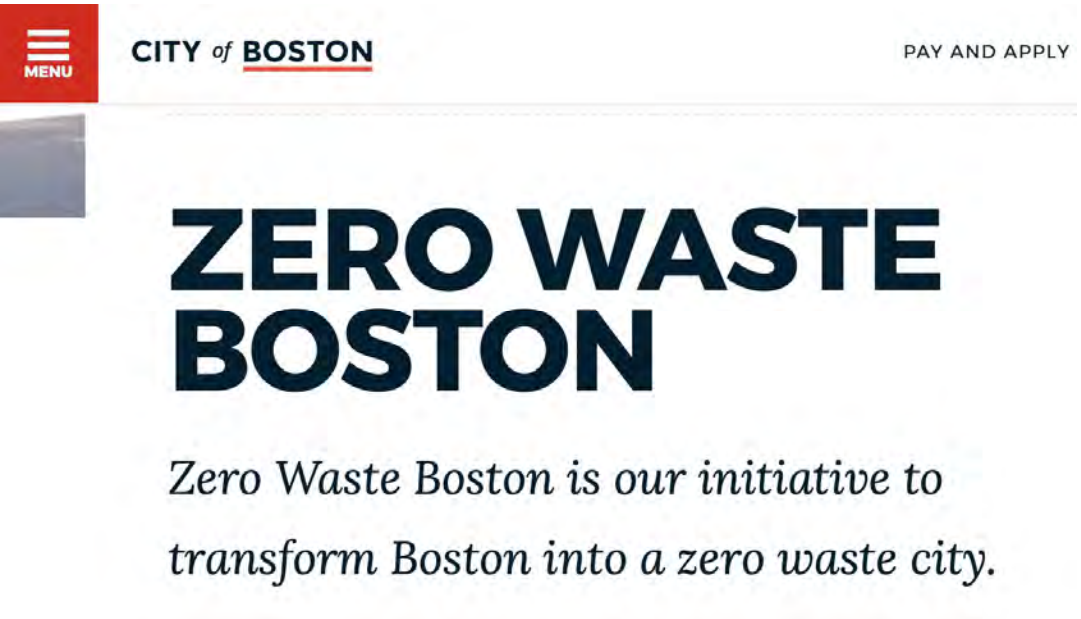
BOSTON MASS TIMBER ACCELERATOR

Provide development teams with technical assistance and funding grants to assess and integrate low carbon mass timber building practices into their projects.

Partners:

- BPDA, BSA, WoodWorks, USDA Forest Service, Softwood Lumber Board, ClimateWorks Foundation

boston planning & development agency



Boston Building Deconstruction Pilot Program

- Identified 5 projects to pilot demonstration

- City with RecyclingWorks providing technical assistance to identify opportunities for deconstruction and recycling or reuse

Cambridge Net Zero Action Plan 2021

2015 NZAP	Recommended Adjustments for the 2021 NZAP Update
Action 1 Energy Efficiency	Action Area 1: Energy Efficiency in Existing Buildings
1.1.1 Custom Retrofit Program	Action 1.1 Custom Retrofit Program for Residential (up to 50 units) and Small Commercial
1.1.2 Additional BEUDO Requirements	Action 1.2 BEUDO Requirements
1.1.3 Upgrades at Time of Renovation	Action 1.2.1 BEUDO Performance Requirements
1.1.4 Operation and Maintenance Plans for New Const.	Action 1.2.2 BEUDO Resource Hub
Action 2 Net Zero New Construction	Action 1.3 Upgrades at Transaction Points
2.1 Net Zero New Construction	Action Area 2: Net Zero New Construction
2.2 Net Zero Incentives	Action 2.1 Net Zero Requirements for New Construction
2.2.1 Market-based Incentives	Action 2.2 Address Embodied Carbon through Green Building Requirements *NEW*
2.2.2 Height and FAR Bonus	Action 2.3 Net Zero Requirements for Municipal Buildings
2.3 Increase Green Building Requirements	Action Area 3: Low Carbon Energy Supply
2.4 Net Zero New Construction for Municipal Buildings	Action 3.1 Carbon Free Thermal Energy
2.5 Removal of Barriers to Increased Insulation	Action 3.2 On-site Renewable Electricity Access
Action 3 Energy Supply	3.2.1 Rooftop Solar Requirement
3.1 Low Carbon Energy Supply	3.2.2 Community Solar Access *NEW*
3.2 Rooftop Solar Ready Requirement	Action 3.3 Off-site Renewable Electricity Access *NEW*
3.3 Develop a MOU with Local Utilities	Action Area 4: Financing and Capacity Building
Action 4 Investigate Local Carbon Fund	Action 4.1 Local Carbon Fund and Community Aggregation
Action 5 Engagement and Capacity Building	
5.1 Communications Strategy	
5.2 Develop Ongoing Capacity to Manage the NZAP	
5.3 Net Zero Lab Standards	

Cambridge 2.2 Address Embodied Carbon Through Green Building Requirements

Short Term (1-2 Years)

1. Adopt embodied carbon narrative for new construction.
2. Assess LEED alternative pathways and zero carbon certification
3. Design and develop policy to prioritize re-use
4. Design carbon intensity targets
5. Develop toolkit / templates
6. Perform technical assessment of carbon impacts
7. Participate in peer learning sessions with other cities

Medium Term (3-5 Years)

8. Adopt Life Cycle Analysis/carbon reduction requirements
9. Implement and monitor performance

Long Term (5+ Years)

10. Adopt enhanced LCA/carbon reduction requirements

Newton Sustainability Ordinance

Sustainable Development Requirements, Adopted December 2019

Applies to any new proposed development > 20,000 sf that requires special permit

- "The Petitioner's design teams will utilize the best available information to **assess embodied carbon** in building materials and **incorporate that information** into the design process so that low embodied carbon materials can be incorporated when cost, availability and performance is feasible."

Newton *PROPOSED* Zoning Requirement for Embodied Carbon

1. Owner/developer must notify design team embodied carbon reductions are a priority
2. Design team must estimate embodied carbon of the project
   - Projects < 50,000 sf, only structural materials
   - Projects > 50,000 sf, structural and enclosure materials and demonstrate a 10% embodied carbon reduction
   - For projects > 50,000 sf, must also consider the embodied carbon of at least three enclosure systems and justify selection of system that does not have lowest embodied carbon.
3. The embodied carbon of concrete used for the project must be capped
4. The design team must consider various means of reducing embodied carbon and prepare a narrative summary

Projects where at least 50% of the floor area comprises re-use of a pre-existing structure are not subject to these provisions.

MA Local Policy *Proposed/In Development*

OTHER MUNICALITIES

- Somerville
- Amherst
- Others

Thank You!

Boston Society for Architecture (BSA), Embodied Carbon 101 Webinars and Impact Series
architects.org/embodied-carbon-101

Carbon Leadership Forum (CLF)
carbonleadershipforum.org

CLF Boston/Northeast Hub- join us!
architects.org/knowledge-communities/clf-boston

Architecture 2030 - architecture2030.org
Carbon Smart Materials Palette

Rocky Mountain Institute
Report- Reducing Embodied Carbon in Buildings
https://rmi.org/insight/reducing-embodied-carbon-in-buildings/

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