

EMBODIED CARBON 101

PRESENTATION TO ZONING &
PLANNING COMMITTEE

April 11, 2022

Climate & Sustainability Team

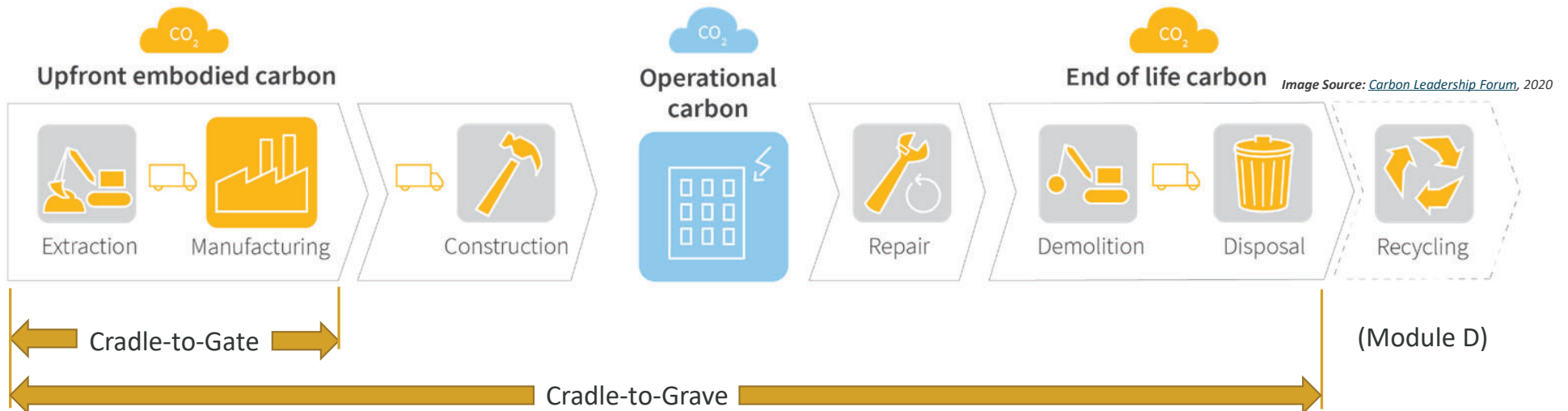
Embodied Carbon Working Group



What is embodied carbon in the built environment?

Embodied carbon refers to the greenhouse gas (GHG) emissions associated with the manufacturing, transportation, installation, maintenance, and disposal of building materials.

Upfront embodied carbon focuses on the GHG emissions released before a building is constructed. These can also be thought of as supply chain emissions.



Note: some content courtesy of Rebecca Esau of RMI

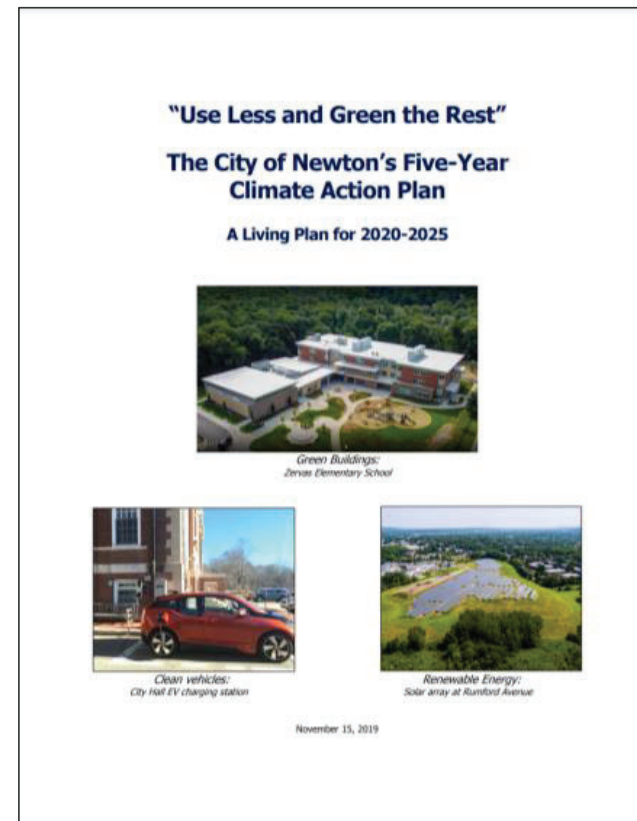
Background

Climate Action Plan, 2019

- “Neither this Climate Action Plan nor the NCCE Plan directly addresses embodied energy. Embodied energy will need to be addressed in the future, as accounting methodologies and mitigation strategies continue to be developed.”

Sustainable Development Design, 2019

- Section 5.13 of the Zoning Ordinance adopted
- 5.13.4.D: Embodied Carbon [reserved]



Recent Steps

Formation of Working Group, Fall 2021

- Mark Webster
 - Structural Engineer, SGH
- Russel Feldman
 - Architect, President of AIA Massachusetts
- Beverly Craig
 - Project Manager, MassCEC

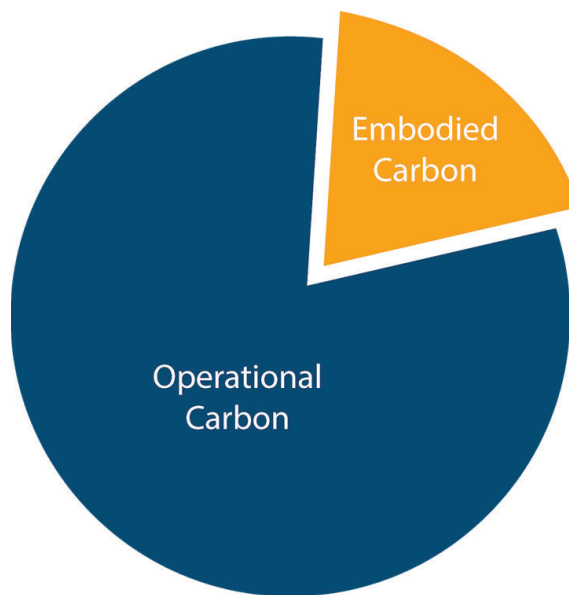
In conversation with:

- Climate & Sustainability Team
- Planning Department
- Councilor Deb Crossley

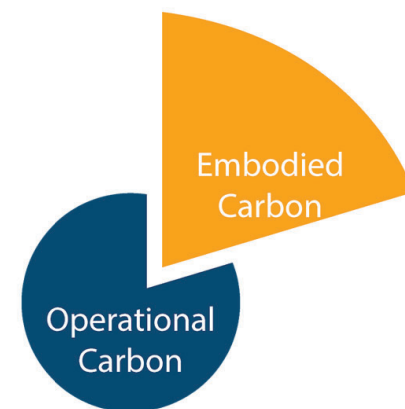
Embodied carbon is significant

Energy efficiency and grid decarbonization efforts will decrease operational carbon over time.

Embodied carbon contributes a higher proportion of life-cycle emissions in more energy-efficient buildings.



Building as Usual



High Performance Buildings

Image Source: Carbon Leadership Forum, 2020

Note: some content courtesy of Rebecca Esau of RMI

Embodied carbon is urgent

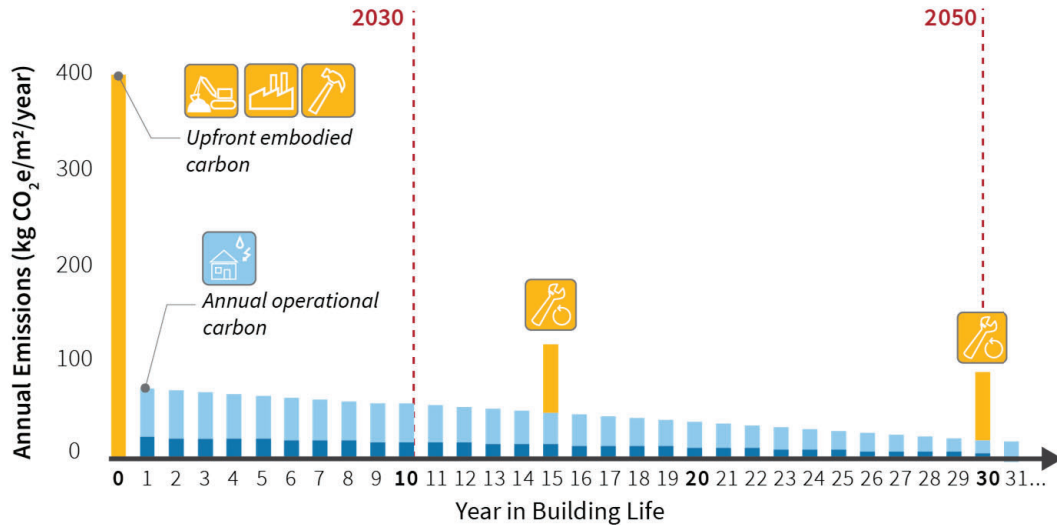
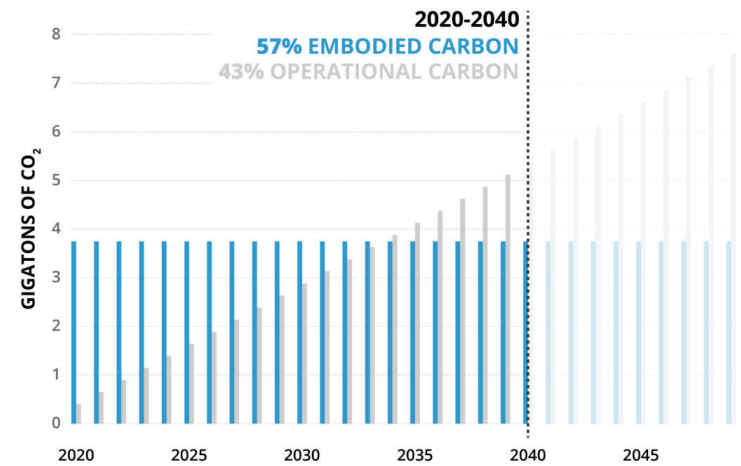


Image Source: [Carbon Leadership Forum](#), 2020

- Embodied carbon
- Scenario 1: Standard performance building
- Scenario 2: High-performance building

Total Carbon Emissions of **Global New Construction** with no building sector interventions



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Data Sources: UN Environment Global Status Report 2017; EIA International Energy Outlook 2017

Note: some content courtesy of Rebecca Esau of RMI

WHY FOCUS ON STRUCTURAL MATERIALS?

- Structural materials account for over half of building embodied carbon for most projects.
- Design decisions such as choice of materials and procurement decisions such as concrete mix requirements can have a big influence on emissions.

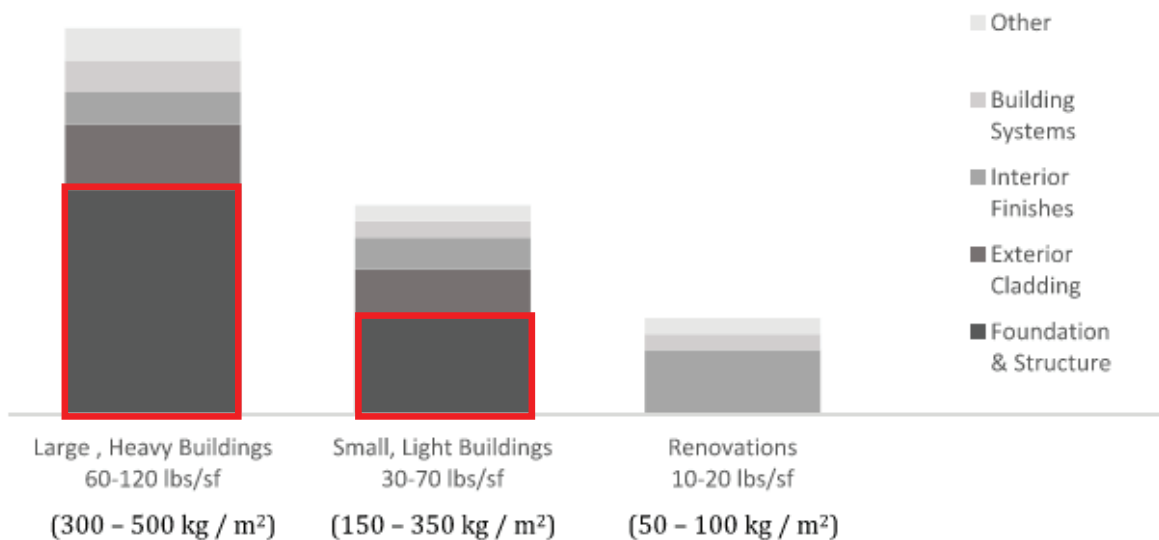
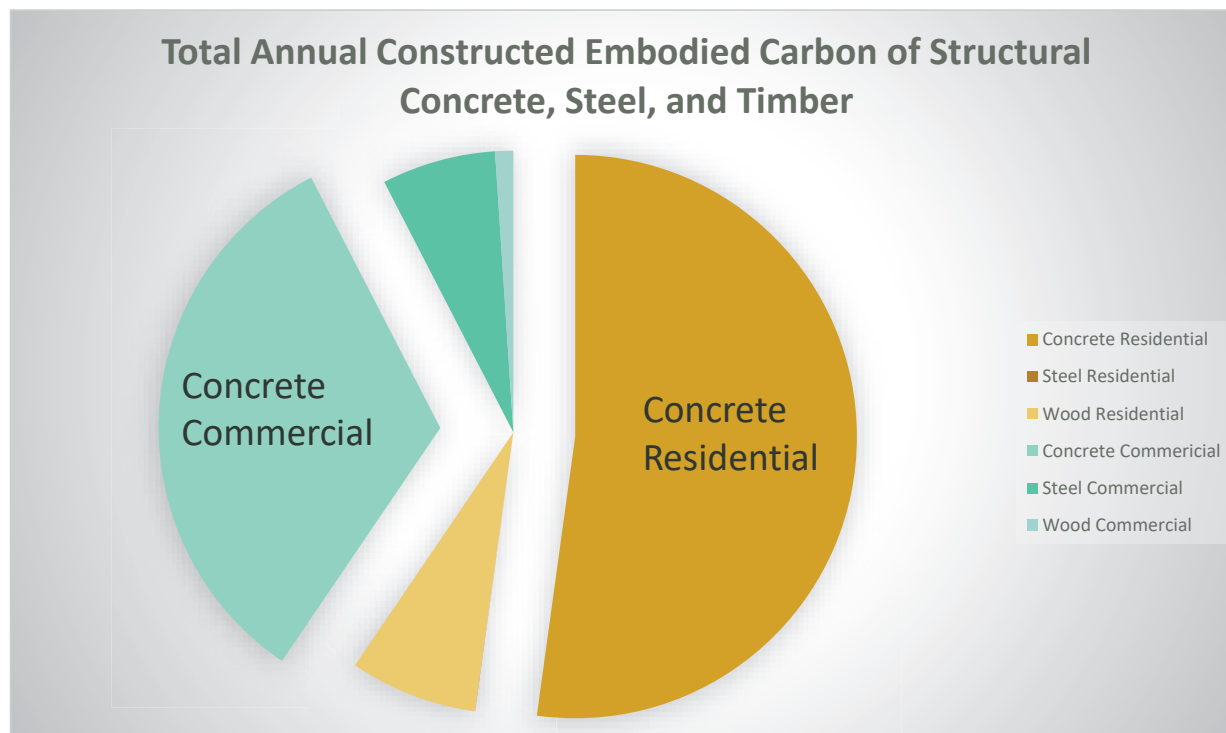


Figure 5. Carbon Emissions by Building Type and Building Element

Source: Embodied Carbon Benchmark Project, Carbon Leadership Forum, and review of multiple embodied energy and carbon studies

Source: CLF "Time Value of Carbon" (2017)

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>)

EMBODIED CARBON ESTIMATION TOOLS

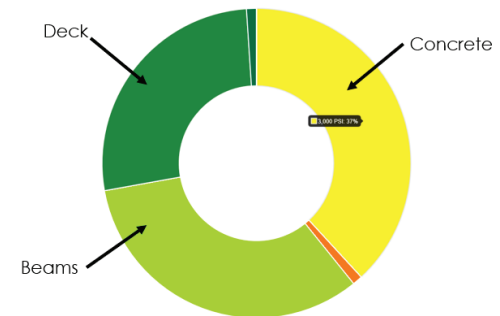


Athena
Impact Estimator
for Buildings



tallyTM

SE 2050 – ECOM



REDUCING EMBODIED CARBON IN STRUCTURAL DESIGN

Design vs. Procurement Strategies

Design strategies relate to the form of the building:

- Renovation vs. New Construction
- Form: how tall, how deep into the ground, how many irregularities such as column offsets
- Bay Size: widely spaced columns increase structural framing sizes significantly
- Choice of Materials (e.g. steel vs. concrete vs. timber framing)
- Designers can use embodied carbon tools to optimize these options

Procurement strategies relate to how the materials are specified after design:

- Cement limits for concrete
- Embodied carbon limits for materials
- Certified wood

PROCUREMENT STRATEGIES FOR REDUCING EMBODIED CARBON

Concrete

- Specify cement replacement
 - slag, fly ash
 - Pozzotive
- Specify cement or GWP limits
- Carbon mineralization (CarbonCure)
- Blended cements
- Performance-based specifications



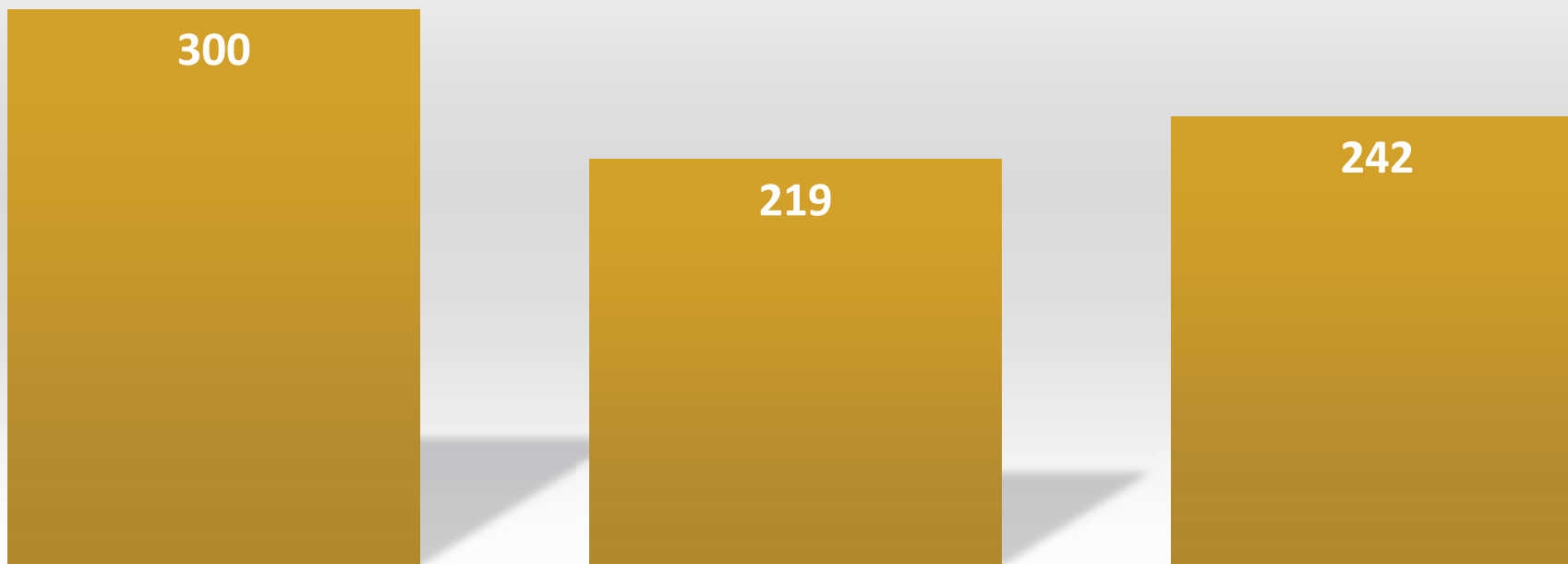
ADDITION PROJECT

Westborough Church
Project (opened 2021)



Embodied Carbon of Concrete Mixes (kg CO₂e/cy)

Note: Embodied Carbon of concrete mix with no cement replacement = 327 kg/cy (NRMCA EPD).



Reference Mix (20% Replacement)

50% Replacement

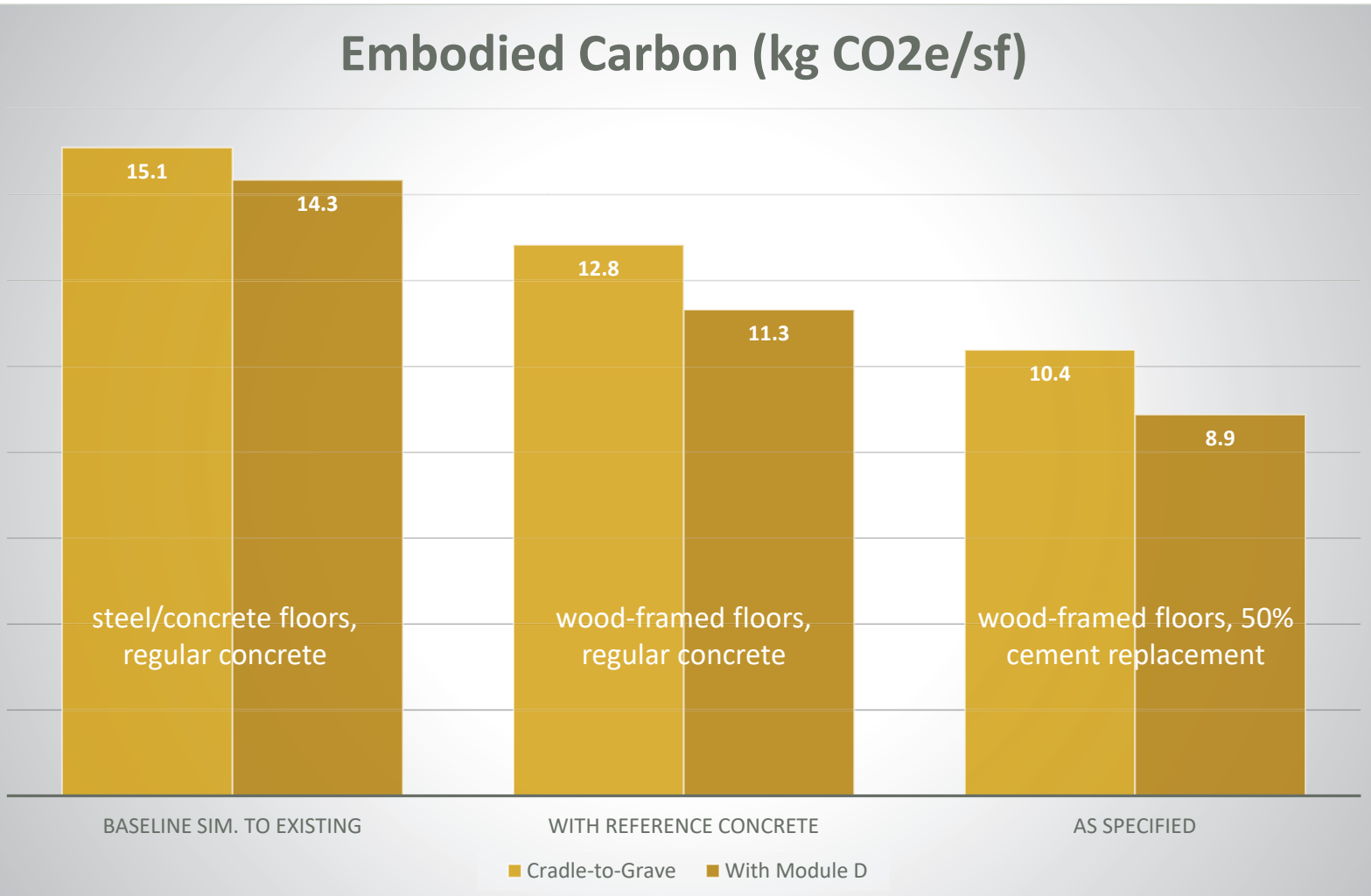
44% Replacement

“Replacement” refers to the percentage of cement in mix replaced by alternative low-carbon cementitious materials.

Estimated Using Athena Custom Concrete Mix Tool

EMBODIED CARBON RESULTS FOR THE WESTBOROUGH CHURCH PROJECT

Embodied Carbon (kg CO2e/sf)



With Recycling:
38% reduction from baseline building
22% reduction from reference concrete

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

EMBODIED CARBON POLICY

Marin County Low-Carbon-Concrete Code

Table 19.07.050 Cement and Embodied Carbon Limit Pathways

	Cement limits for use with any compliance method 19.07.050.2 through 19.07.050.5	Embodied Carbon limits for use with any compliance method 19.07.050.2 through 19.07.050.5
Minimum specified compressive strength f_c , psi (1)	Maximum ordinary Portland cement content, lbs/yd ³ (2)	Maximum embodied carbon kg CO ₂ e/m ³ , per EPD
up to 2500	362	260
3000	410	289
4000	456	313
5000	503	338
6000	531	356
7000	594	394
7001 and higher	657	433
up to 3000 light weight	512	578
4000 light weight	571	626
5000 light weight	629	675

Notes

- (1) For concrete strengths between the stated values, use linear interpolation to determine cement and/or embodied carbon limits.
 (2) Portland cement of any type per ASTM C150.

EMBODIED CARBON POLICY

Buy Clean California Act

- ▶ The Buy Clean California Act (BCCA) ([Public Contract Code Sections 3500-3505](#)), states that the Department of General Services (DGS) is required to establish and publish the maximum acceptable Global Warming Potential (GWP) limit for select construction materials. The BCCA targets carbon emissions associated with the production of structural steel (hot-rolled sections, hollow structural sections, and plate), concrete reinforcing steel, flat glass, and mineral wool board insulation. These materials must have a GWP that does not exceed the limit set by DGS.

<https://www.dgs.ca.gov/PD/Resources/Page-Content/Procurement-Division-Resources-List-Folder/Buy-Clean-California-Act>

EMBODIED CARBON POLICY



State of California Buy Clean

GWP limits for eligible structural materials

Eligible material	Maximum acceptable GWP limit (unfabricated) (MT CO ₂ eq./MT)	Value in industry-average EPD (MT CO ₂ eq./MT)
Hot-rolled structural steel sections	1.01	1.08
Hollow structural sections	1.71	1.71
Steel plate	1.49	1.59
Concrete reinforcing steel	0.89	0.92

REQUIREMENTS FOR ALL FEDERAL PROJECTS

Effective 17 March 2022

2. The [prime contractor] shall provide **low embodied carbon concrete** that meets the global warming potential (GWP) limits of the table below, for concrete of the mix type and strength class.

Specified compressive strength (f'c in PSI)	Maximum Global Warming Potential Limits for GSA Low Embodied Carbon Concrete (kilograms of carbon dioxide equivalent per cubic meter - CO ₂ e kg/m ³)		
	Standard Mix	High Early Strength	Lightweight
up to 2499	242	326	462
2500-3499	306	413	462
3500-4499	346	466	501
4500-5499	385	519	540
5500-6499	404	546	N/A
6500 and up	414	544	N/A

These numbers reflect a 20% reduction from GWP (CO₂e) limits in proposed code language: "[Lifecycle GHG Impacts in Building Codes](#)" by the New Buildings Institute, January 2022.

BOSTON AREA



- Town of Brookline: Town must use low carbon concrete (10% less than average) for town-owned projects and encourage developers to do the same.
- City of Cambridge: On path to require measurement and reduction of embodied carbon through Zoning Ordinance.
- City of Boston: Working to implement recommendations of the Embodied Carbon Technical Advisory Group, including measurement and reduction.
- Municipalities share goal of coordinating efforts.

TAKEAWAYS

- Embodied Carbon represents the climate change emissions associated with construction.
- During the critical period between now and 2030 when we need to cut emissions by half, the embodied carbon of new buildings will exceed the energy-related emissions from occupying those buildings.
- Structural materials, especially concrete, tend to dominate embodied carbon.
- The embodied carbon of concrete can be easily reduced with little or no construction cost impact.
- Building reuse in place of new construction is a great embodied carbon strategy.
- Design decisions such as material selection also can make a big difference in embodied carbon.
- Embodied carbon reduction requirements and incentives are happening at all levels of government.

NEXT STEPS

- Feedback/questions
- Discussion with EDC, Chamber of Commerce Real Estate Committee
- Refining draft ordinance language, for presentation at future ZAP meeting