Executive Order 594:

Decarbonizing and Minimizing Environmental Impacts of State Government

To maximize potential GHG emissions reductions, all new construction and substantial renovations, where possible and cost-effective, shall:

- Evaluate and implement strategies to reduce embodied carbon contained in building materials.

Reducing Embodied Carbon in Buildings

Rebecca Esau AIA, Manager, Carbon-Free Buildings, RMI

Mark D. Webster, PE, LEED AP BD+C, Senior Consulting Engineer, SGH

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.

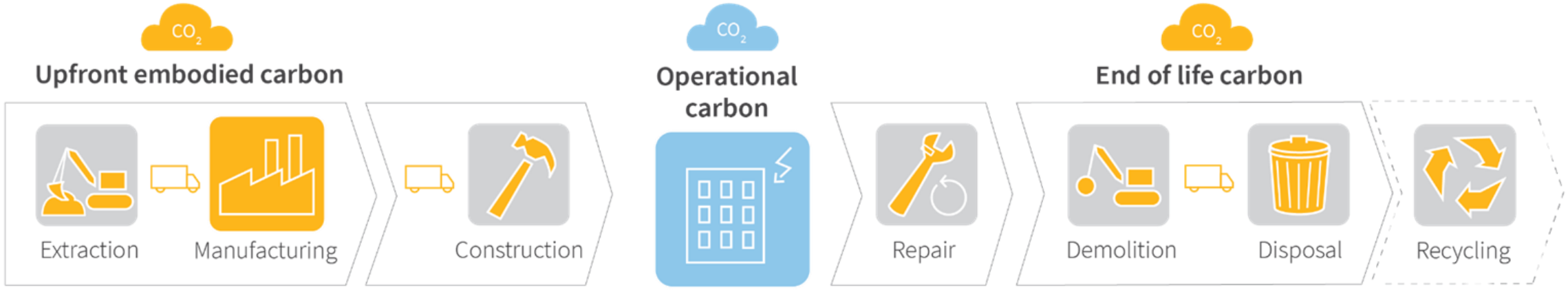

Image Source: *Carbon Leadership Forum, 2020*

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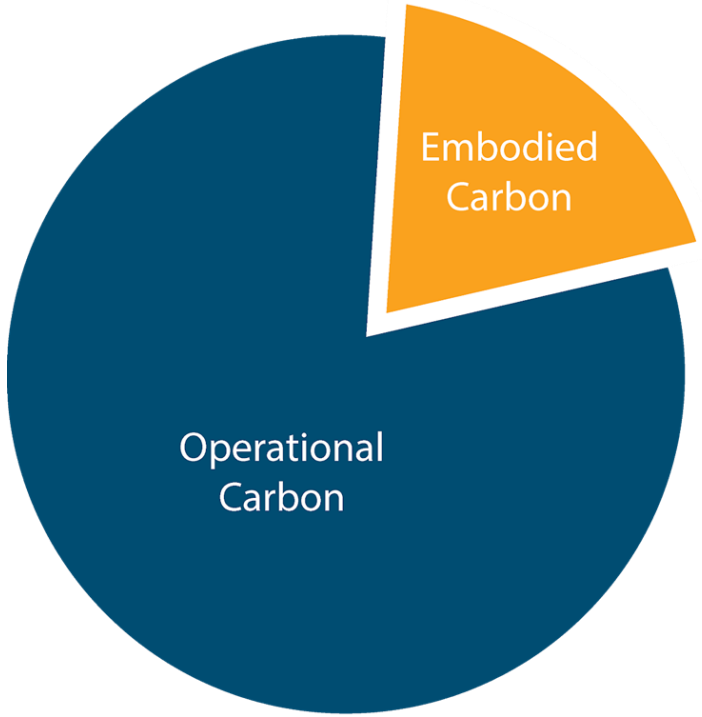
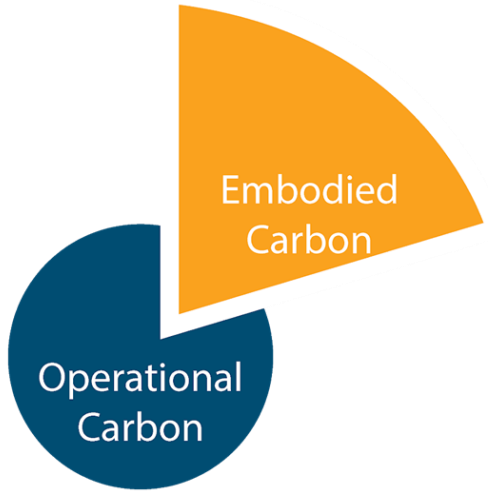
Carbon-Free Buildings
Low-Embodied Carbon Program

Embodied carbon is significant

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



Building as Usual



High Performance Buildings

Image Source: *Carbon Leadership Forum, 2020*

Embodied carbon is urgent

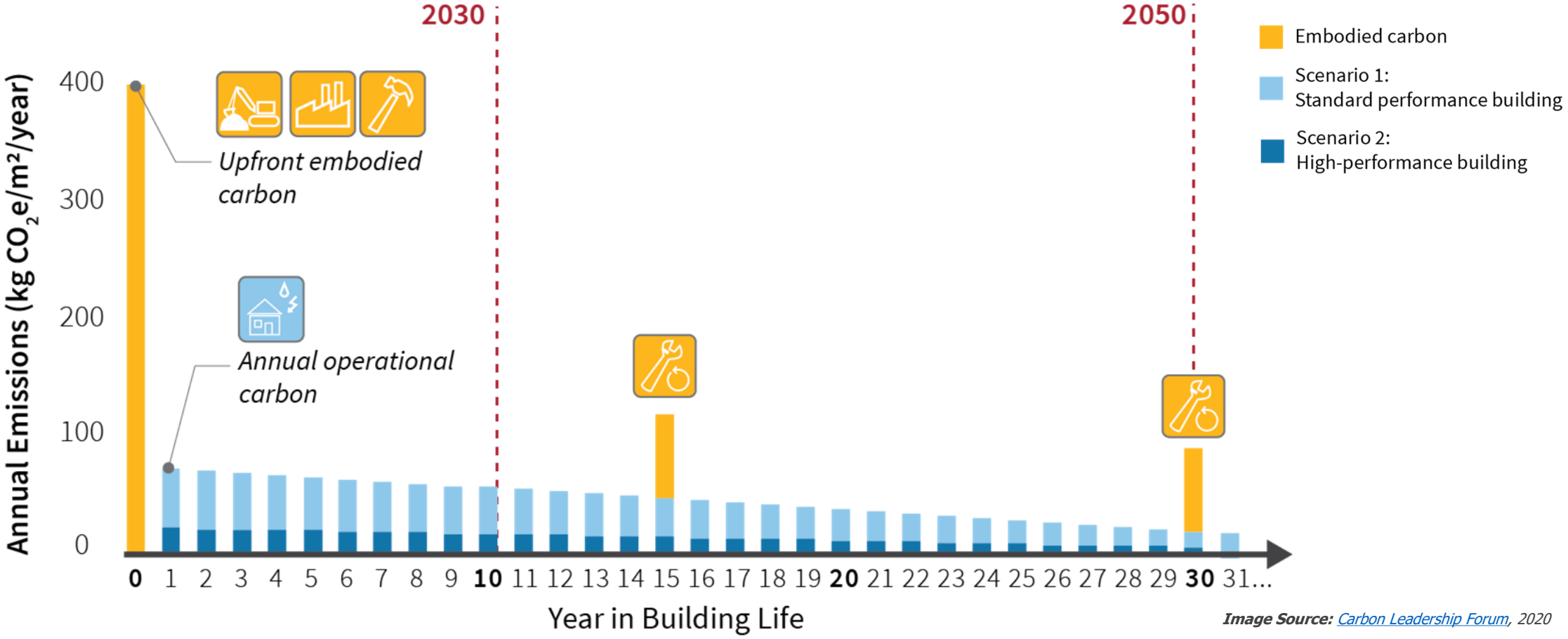


Image Source: *Carbon Leadership Forum, 2020*

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Low-Embodied Carbon Program

Reducing embodied carbon is an opportunity

Benefits to reducing emissions from building materials and construction:

- Improve air quality
- Support regional manufacturing
- Cost-effective solutions:
  - RMI study shows emissions from materials used in buildings can be reduced by up to 46% with no added cost

Strategies to Include Embodied Carbon in Procurement

Carbon-Free Buildings
Low-Embodied Carbon Program

Decision touchpoints for impact

Strategies

- Make design decisions that reduce embodied carbon
  - Example: Use existing buildings

Strategies

- Use alternate, low-carbon materials to do the same job
  - Example: Use timber instead of steel

Strategies

- Specify the carbon limit for a material
  - Example: Specify low-embodied carbon concrete

How to measure embodied carbon

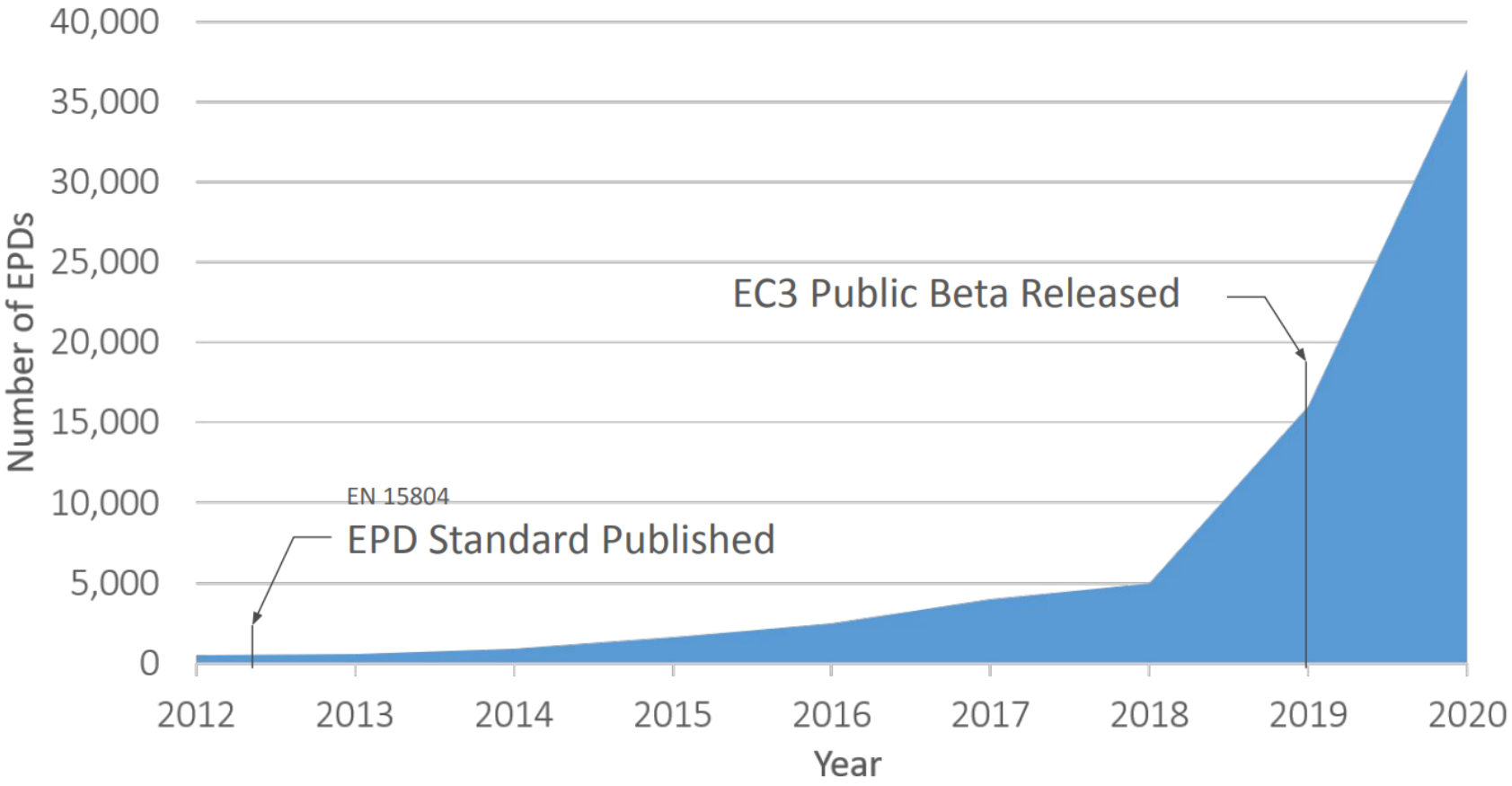
Products and Materials:

- Environmental Product Declarations (EPDs): a nutrition label for materials. Provides a measure of kg CO_2e per functional unit of material.
- A manufacturer would conduct a Life-Cycle Assessment (LCA) to produce an EPD for their product
- An LCA is a standardized method of measuring the environmental impacts of a product throughout its life-cycle

Buildings:

- Whole-Building Life-Cycle Assessment (WBLCA) is the process of approximating the kg CO_2e (embodied or embodied + operating) per unit area for an entire building

The number of EPDs is growing



Data from 2012 – 2018 was adapted from Andersen et al. (2019). Data for 2020 represents number of EPDs in EC3.

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Buildings use a lot of materials

Most of a building's embodied carbon is attributable to structural materials, building envelope materials, and certain finishes.

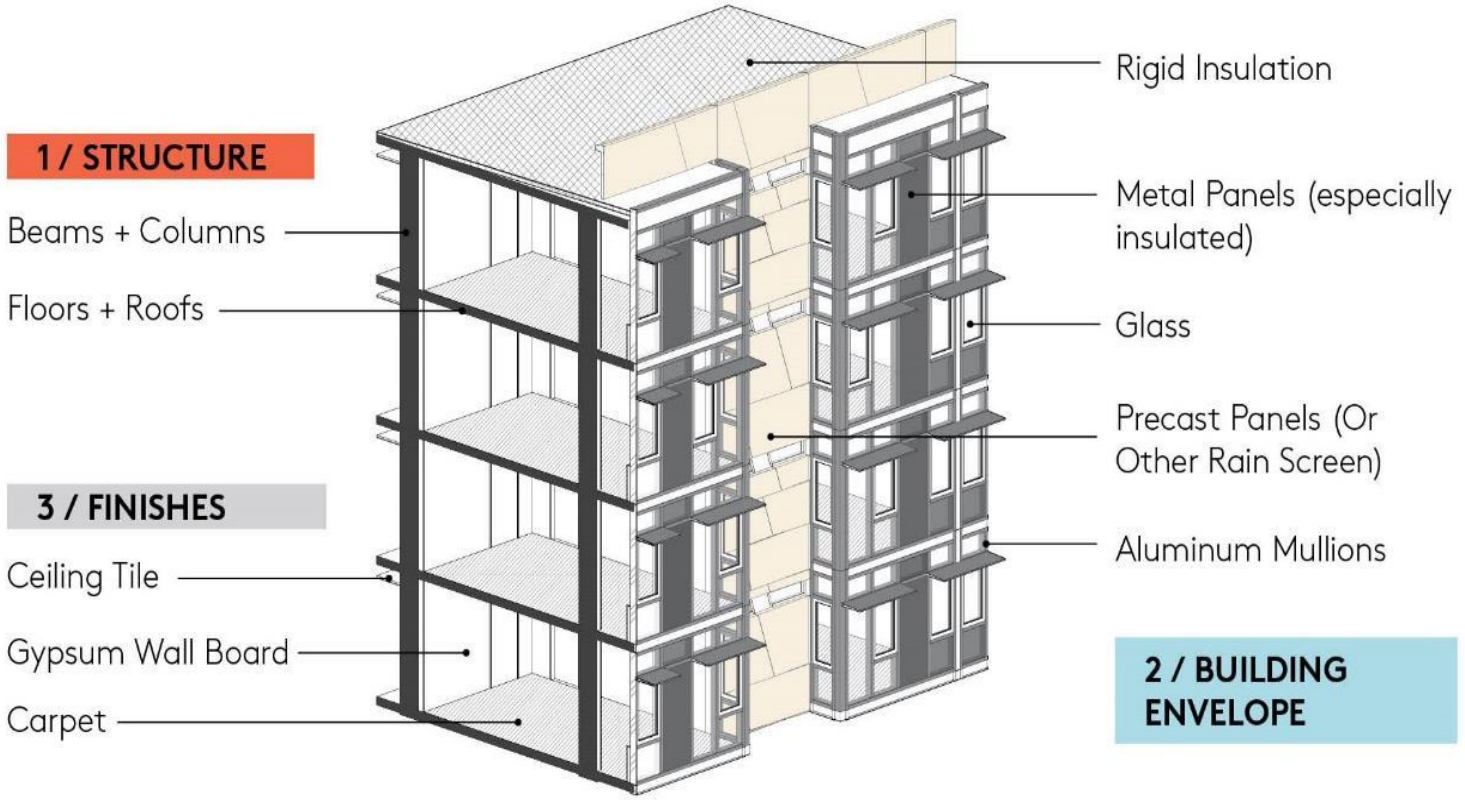


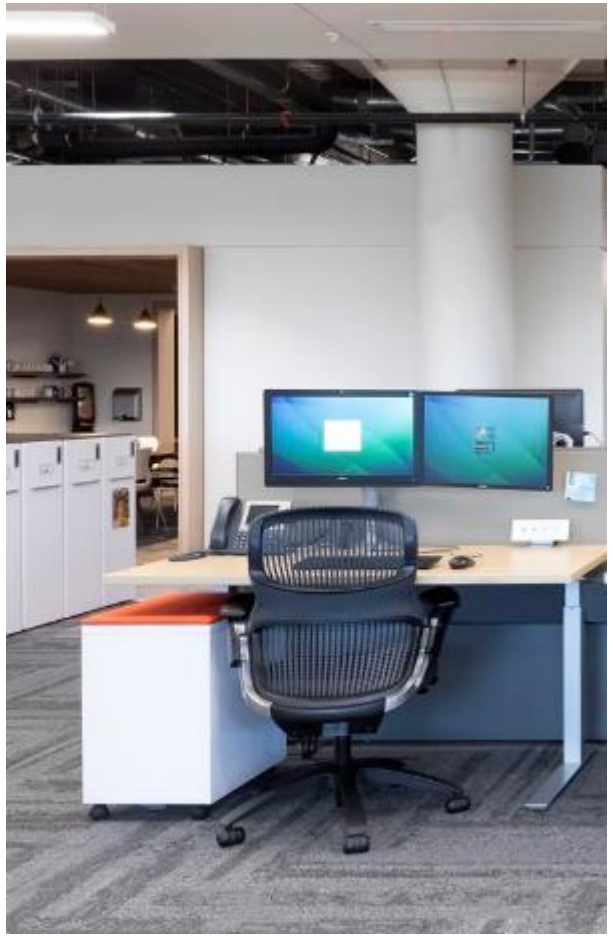
Image Source: *Mithun*

Build new vs building reuse

Structural components of a commercial office building can represent 60-67% of the building's total embodied carbon

"The greenest building is the one that's already built"
–Carl Elefante

Tenant fit-outs are a major opportunity



Significant embodied carbon reduction opportunities exists in building renovations

- Embodied carbon impacts of retrofits add up over the lifecycle of a building
  - Assumed to be equal to initial embodied carbon expended during new construction (CLF 2019)
- Finish materials like ceiling tiles, drywall, and carpet, are materials with some of the highest embodied carbon
- Strategies and tools used for reduction are identical to new construction

Top building material categories for reducing embodied carbon

Concrete

14-33% reduction
No to low cost premium

Rebar

4-10% reduction
No to low cost premium

Insulation

16% reduction
No cost premium

Glazing

3% reduction
10% cost premium

Finish Materials

5% reduction
No to low cost premium

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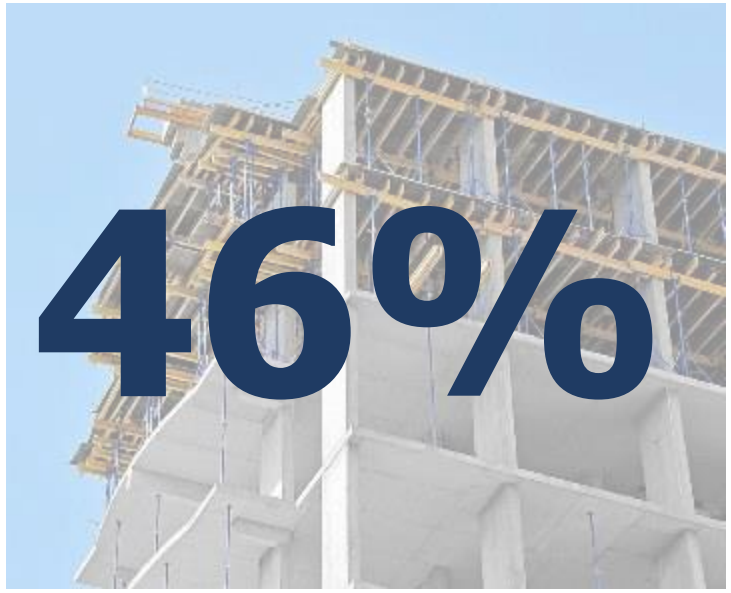
Low-Embodied Carbon Program

Case studies in embodied carbon reductions

Embodied carbon reductions:



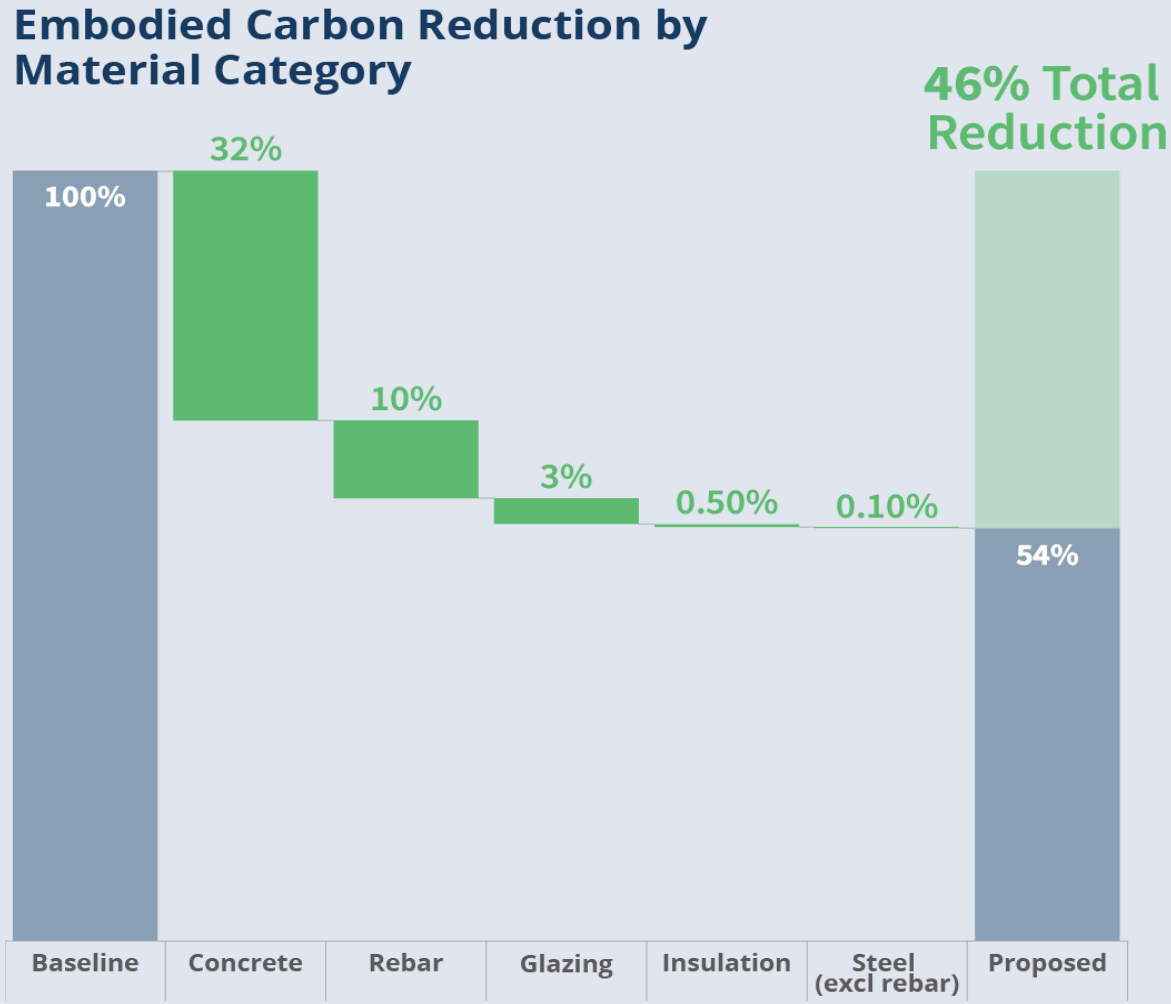
Steel reinforced concrete slab

Wood-framing with concrete slab

Tilt-Up concrete

Case study 1: Mid-Rise Concrete & Steel

Up-front embodied carbon reduction from baseline	Cost premium of low-embodied-carbon measures	CO_2e reduced (metric tons)
46%	< 0.5% Of Total Budget	2,228



Carbon impacts of insulation

- Insulation products vary widely in embodied carbon
- Some insulation products naturally sequester carbon

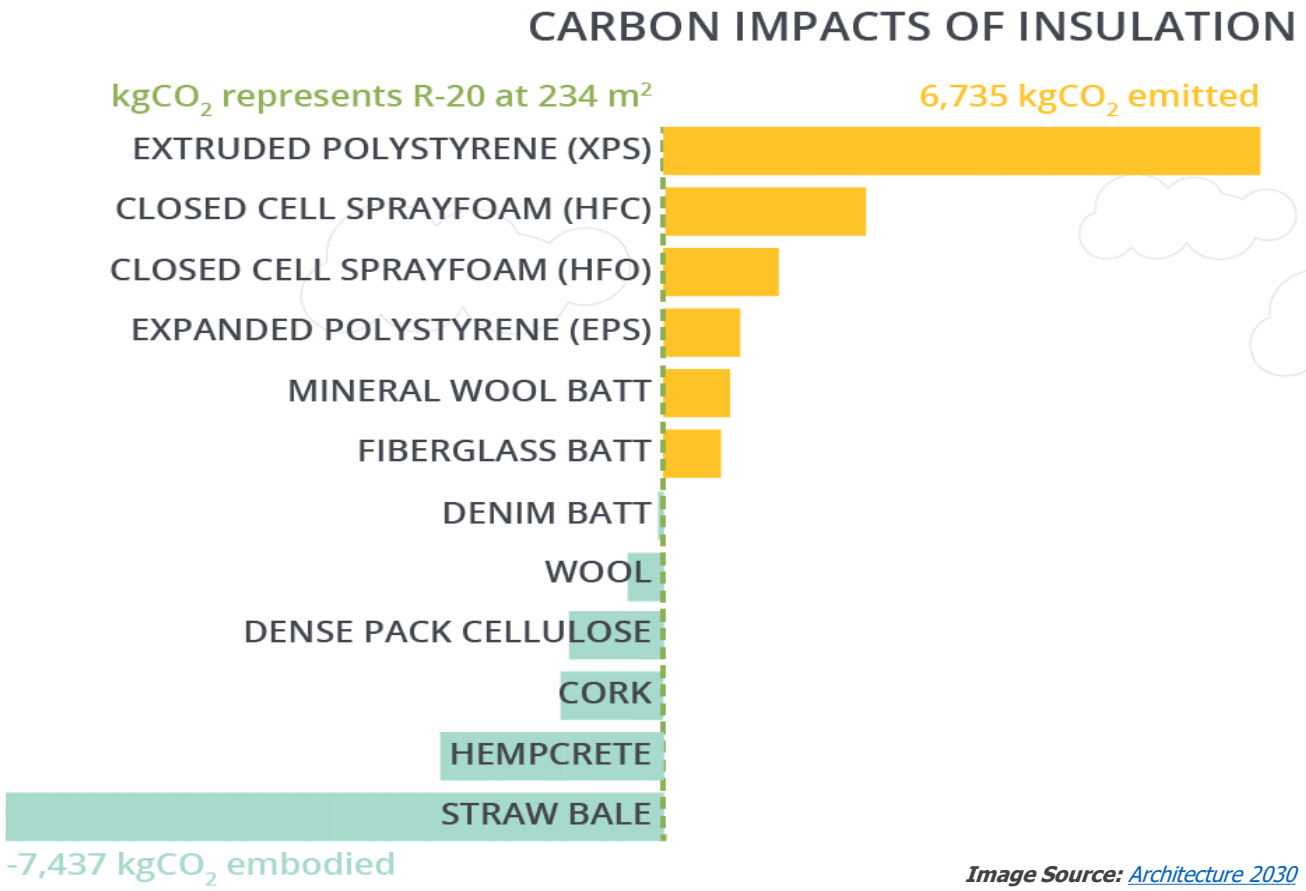


Image Source: *Architecture 2030*

EMBODIED CARBON

STRUCTURAL MATERIALS

Mark D. Webster

Senior Consulting Engineer

1 February 2022

WHY FOCUS ON STRUCTURAL MATERIALS?

- Structural materials account for over half of building embodied carbon for most projects.
- Design decisions such as concrete mixes and type of lateral system can have a big influence on emissions.

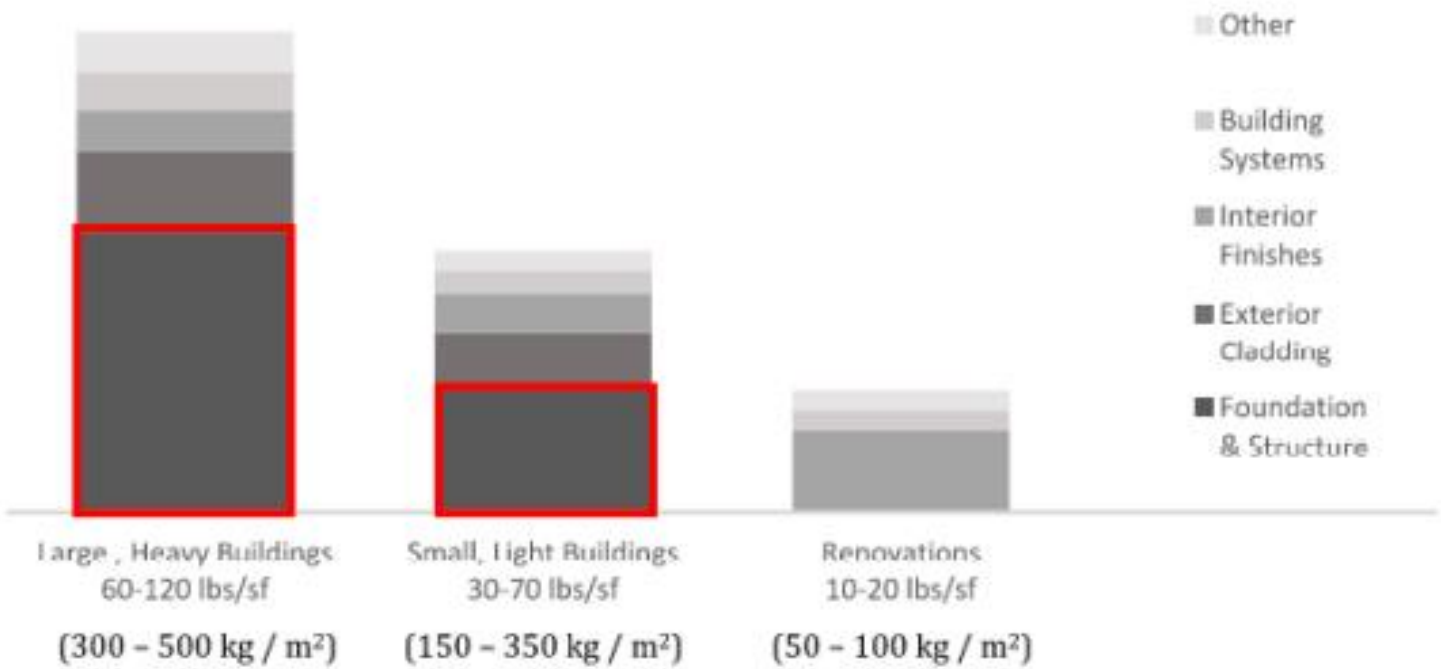
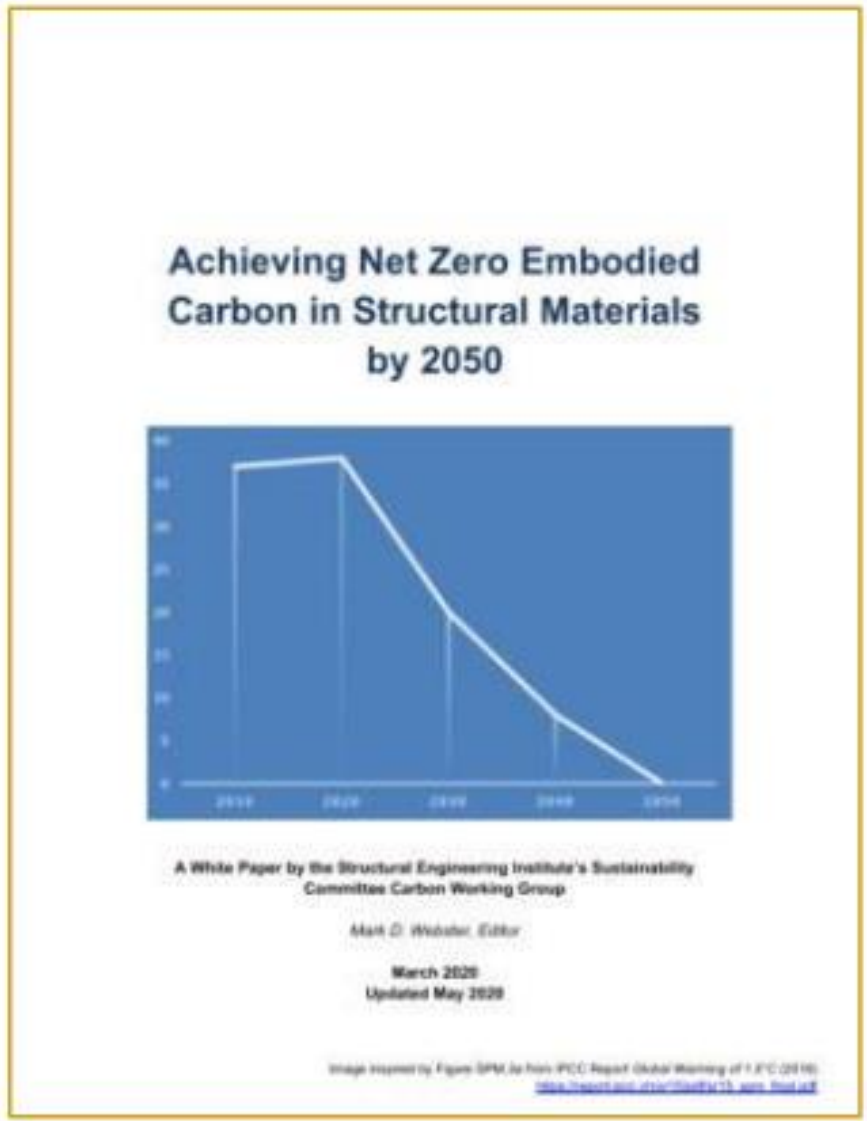


Figure 5. Carbon Emissions by Building Type and Building Element
Source: Embodied Carbon Benchmark Project, Carbon Leadership Forum, and review of multiple embodied energy and carbon studies

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

ACHIEVING NET ZERO EMBODIED CARBON



- White Paper published in March 2020
- This paper addresses the first question many engineers ask about eliminating embodied carbon in construction:
- *How is that even possible??*

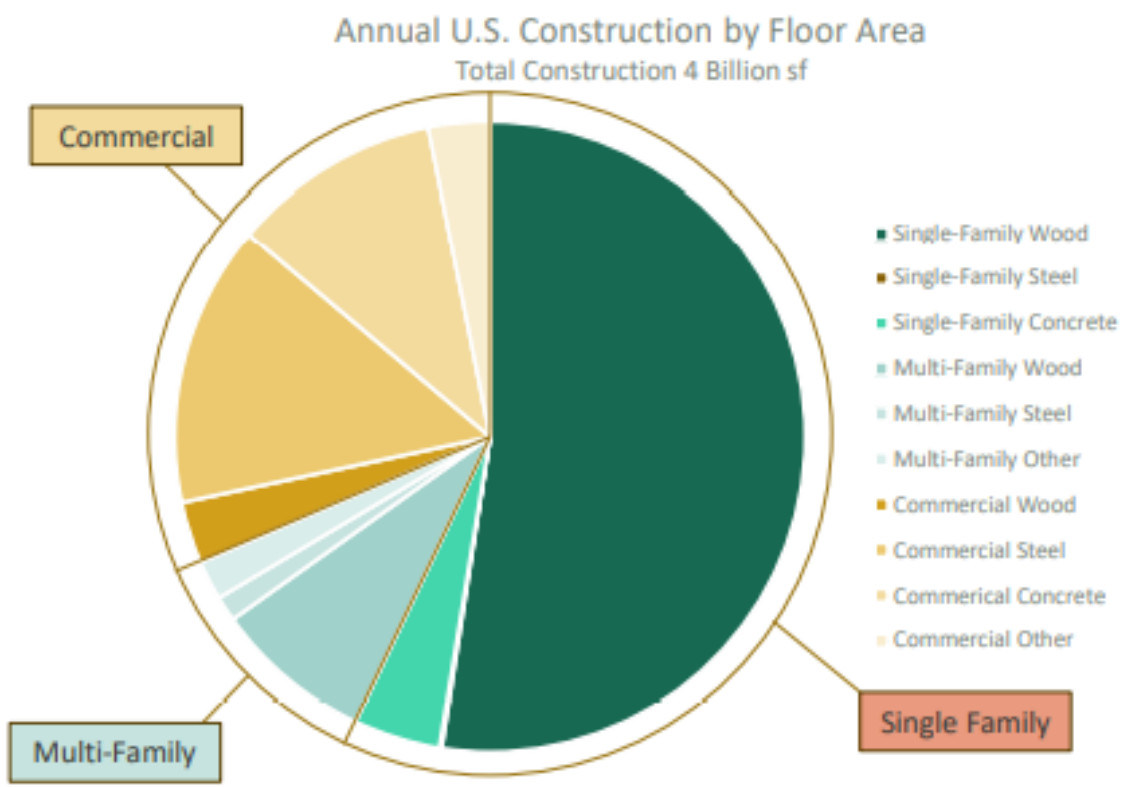
https://seisustainability.files.wordpress.com/2020/05/how-to-get-to-zero-200525.pdf

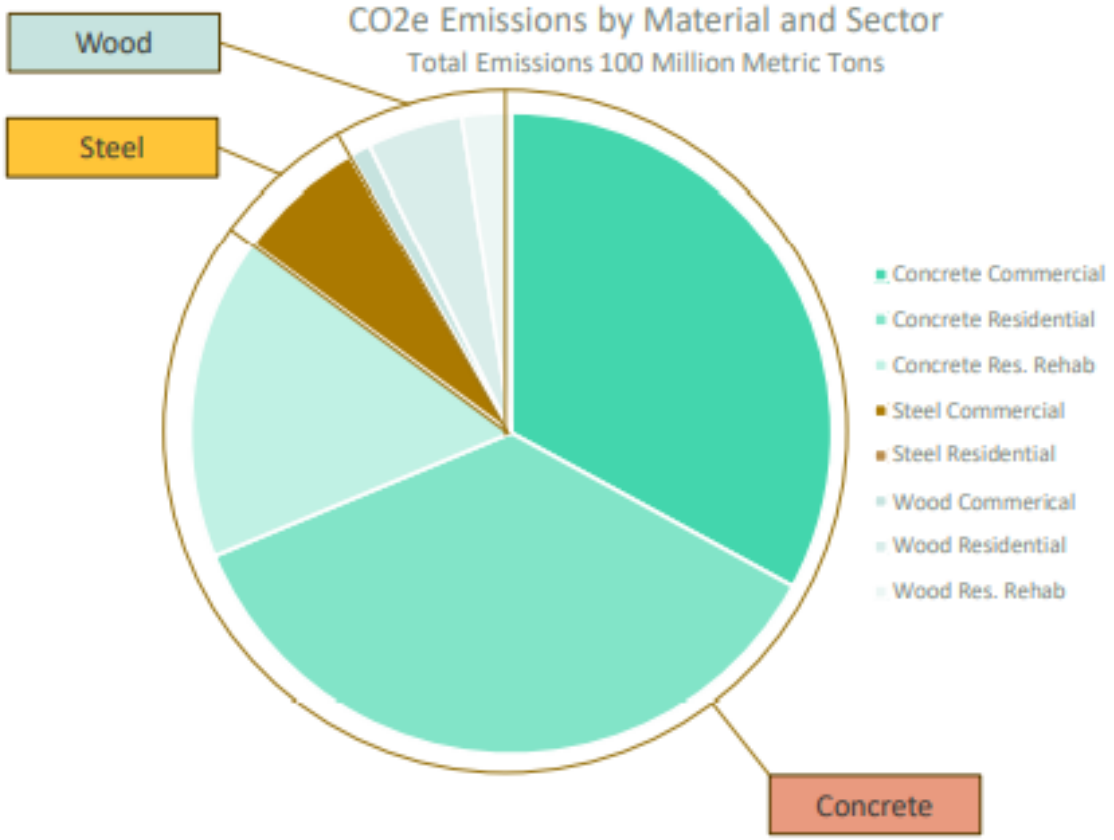
ACHIEVING NET ZERO EMBODIED CARBON

- Defining the Challenge

Takeaways:

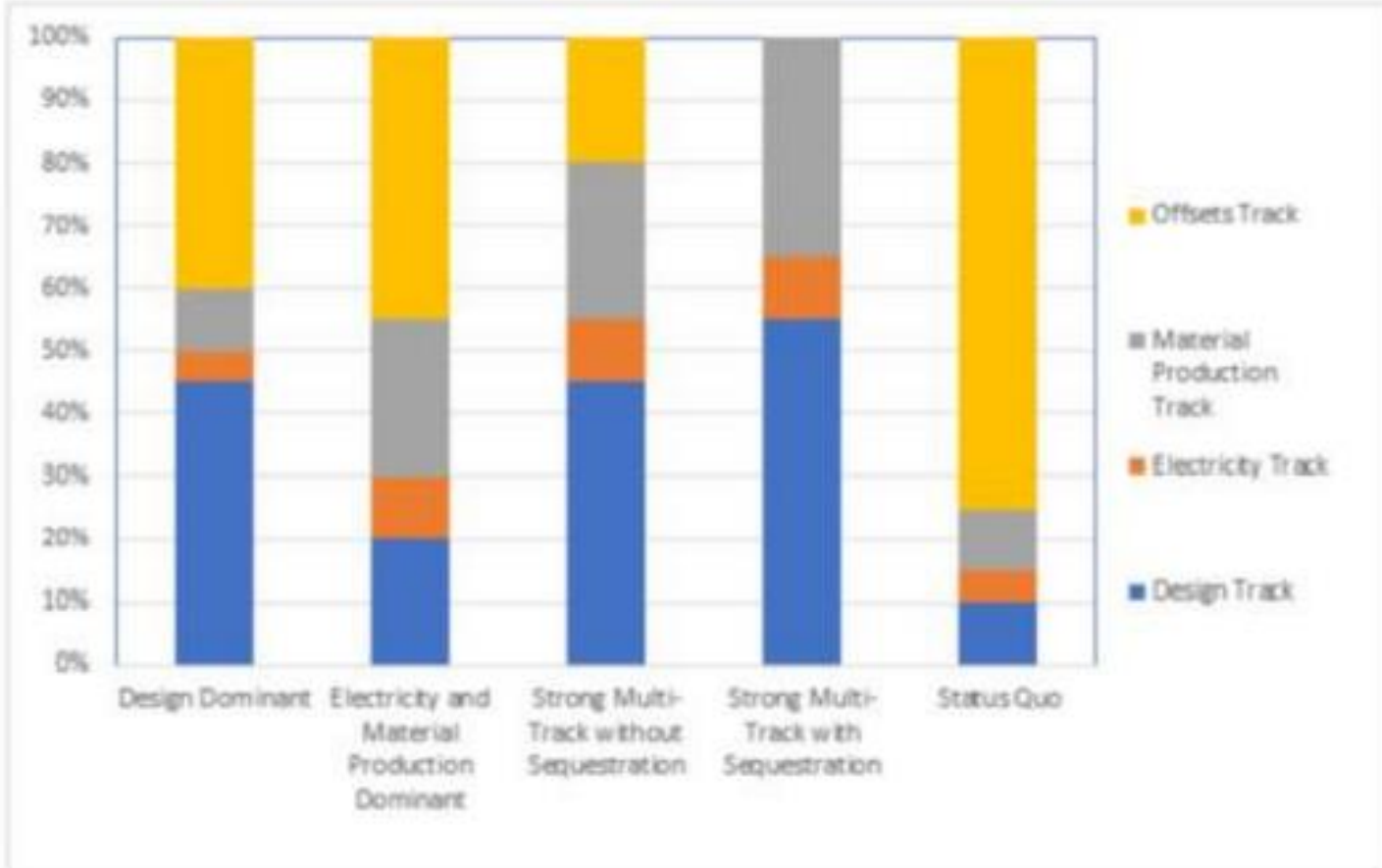
- Residential must be part of the solution.
- Concrete demands the most attention.





ACHIEVING NET ZERO EMBODIED CARBON

- Four Tracks:
  1. Design improvements implemented by engineers and architects.
  2. Greening the electrical grid.
  3. Improving material production.
  4. Carbon offsets.



May be combined in different proportions.

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)
- Use LCA and other 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

Ask for EPDs

- Even if material manufacturers don't have EPDs, asking for them will encourage them to develop them.
- EPD availability will drive market change, since specifiers will be able to competitively source materials and products on the basis of embodied carbon.
- Manufacturers with high emissions will need to find ways to reduce their emissions to compete.

Material-Specific Strategies

- Concrete: Biggest impact of structural materials, also most options to reduce impacts because each mix can be tailored for project.
- Structural Steel: Fewer strategies because fewer producers and suppliers, and domestic producers use similar production methods.
- Timber: Carbon impacts hard to quantify due to complex forest carbon cycles.

PROCUREMENT STRATEGIES FOR REDUCING EMBODIED CARBON

SGH

Concrete

- EPDs
  - This graphic from Rebecca 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

PROCUREMENT STRATEGIES FOR REDUCING EMBODIED CARBON

Concrete

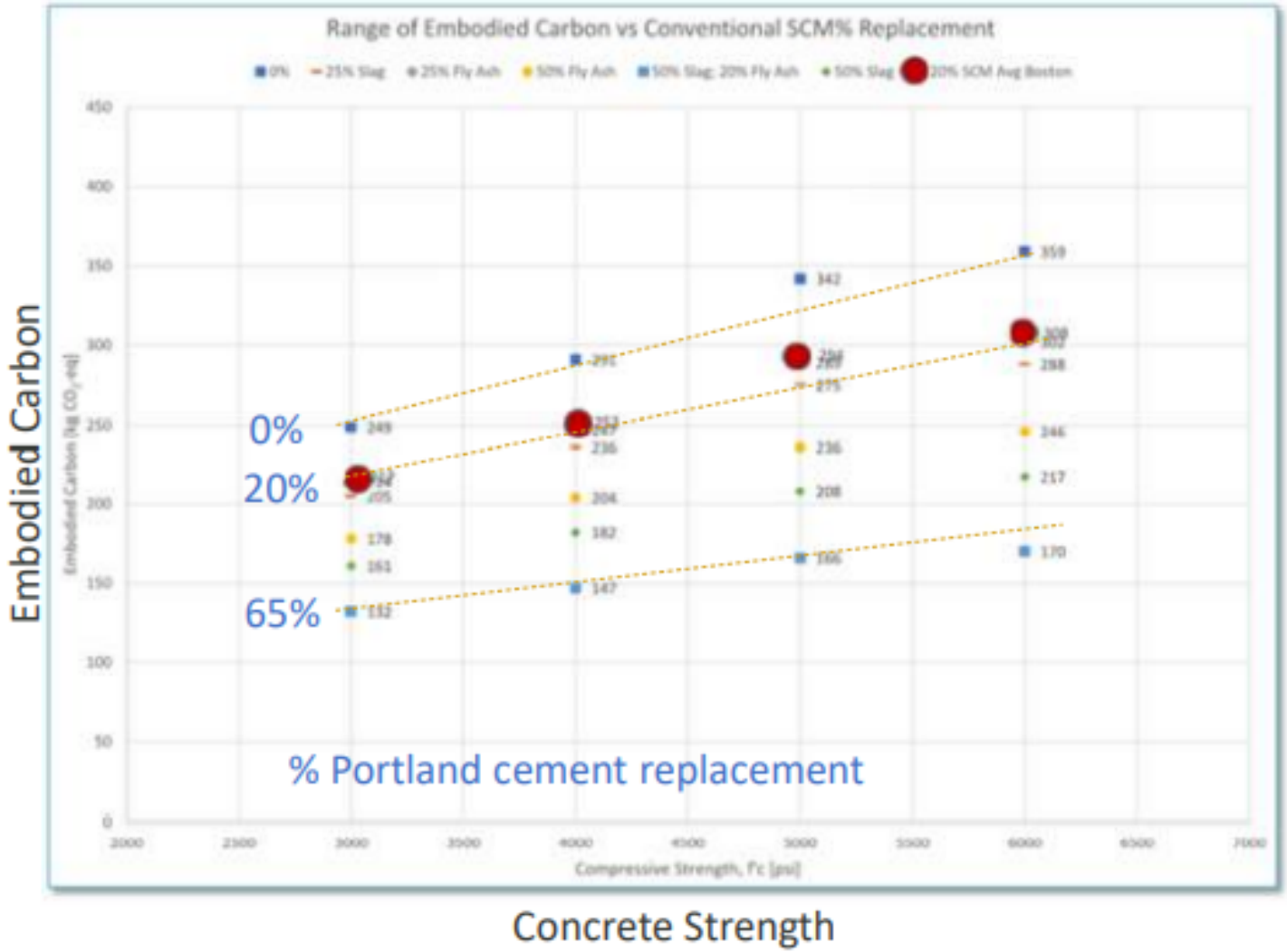
- Specify cement replacement
  - slag, fly ash
  - Pozzotive
- Specify cement or GWP limits
- Carbon mineralization (CarbonCure)
- Blended cements
- Performance-based specifications

FUMC Addition: 50% slag concrete

Reduced embodied carbon of structure by 19%

Reduction in Embodied Carbon Today

- 65% portland replacement
  - ≈ 30%-40% reduction
- 20% portland replacement (Eastern US average)
  - ≈ 10%-15% reduction
- Portland replacement rates contingent on performance requirements



courtesy of Michael Gryniuk, LeMessurier

PROCUREMENT STRATEGIES FOR REDUCING EMBODIED CARBON

Steel

- Domestic steel
- Electric Arc Furnace (EAF) vs. Basic Oxygen Furnace (BOF)

Wood

- Certified and local wood from well-managed forests
- Plywood instead of OSB

CMU

- SCMs in mortar, grout, and block
- Specified compressive strength method instead of volume method to proportion grout

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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_2e/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.

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

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

EMBODIED CARBON POLICY

Federal Executive Order 14057 (8 Dec 2021):

"Catalyzing Clean Energy Industries and Jobs Through Federal Sustainability"

Sustainable Procurement and Supply Chains

Supplier Emissions

- Requirements to disclose GHG and climate risk, and set science-based targets
- Implemented via Federal Acquisition Regulation – pending case

Sustainable Products and Services

- Buy EPA-recommended labels to maximum extent practicable
- CEQ and EPA working on new categories including PFAS and potentially, food

Buy Clean Program

- Reduce embodied carbon via lower-carbon construction materials
- Interagency Buy Clean Task Force to provide detailed recommendations

Integrate across other components within the White House

Boston area examples

Boston, Cambridge, and Newton are all working on embodied carbon requirements.

Thank You!

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