



Embodied Carbon Emissions in Buildings

Presented by

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Firm Profile | DEEP GREEN ENGINEERING LEADERSHIP



- 100+ NET ZERO ENERGY PROJECTS
- 110+ LEED PLATINUM & GOLD CERTIFIED
- 10 AIA COTE TOP TEN BUILDINGS
- 10+ LIVING BUILDING PROJECTS
- 5+ PASSIVE HOUSE PROJECTS



Understanding Carbon



Embodied Carbon

Manufacture, transport and installation of construction materials

Operational Carbon

Building Energy Consumption

Embodied Carbon | DEFINITION

Carbon emissions associated with materials and construction processes throughout the whole lifecycle of a building or infrastructure. Embodied carbon therefore includes: material extraction, transport to manufacturer, manufacturing, transport to site, construction, use phase (eg concrete carbonation but excluding operational carbon), maintenance, repair, replacement, refurbishment, deconstruction, transport to end of life facilities, processing, disposal. - **WorldGBC**

Embodied carbon is the sum impact of all the greenhouse gas emissions attributed to the materials throughout their life cycle (extracting from the ground, manufacturing, construction, maintenance and end of life/disposal).
- **Embodied Carbon Network**

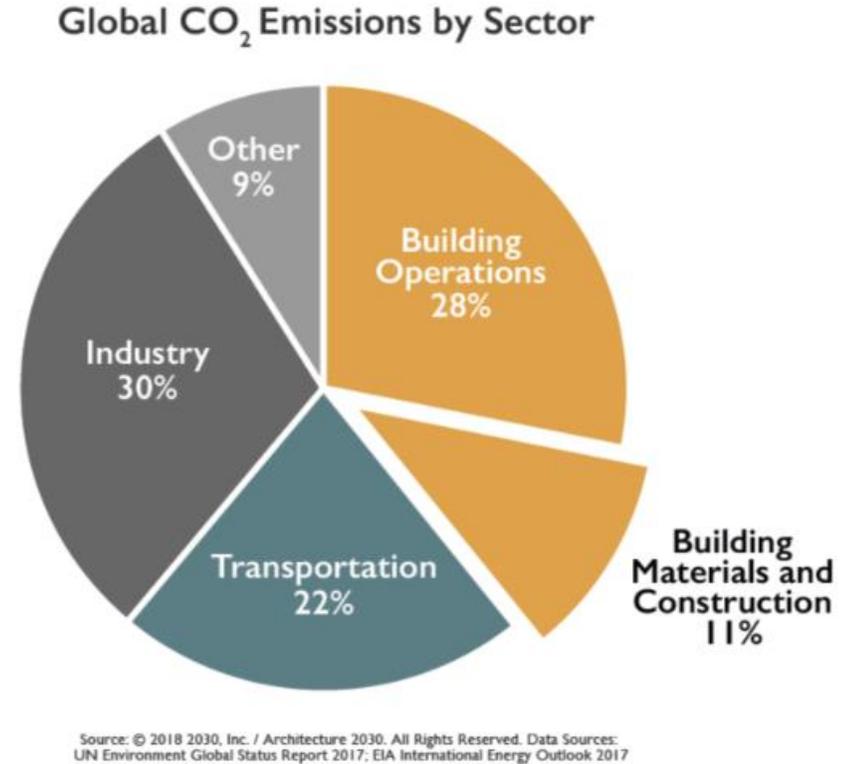
Embodied carbon is the carbon footprint of a material. It considers how many greenhouse gases (GHGs) are released throughout the supply chain and is often measured from cradle to (factory) gate, or cradle to site (of use). - **Circular Ecology**

By 2060, the world is projected to add 230 billion m² (2.5 trillion ft²) of buildings, or an area equal to the entire current global building stock*. This is the equivalent of adding an entire New York City to the planet every 34 days for the next 40 years.

****UN Environment, Global Status Report 2017***

Embodied Carbon | WHY FOCUS ON EMBODIED CARBON?

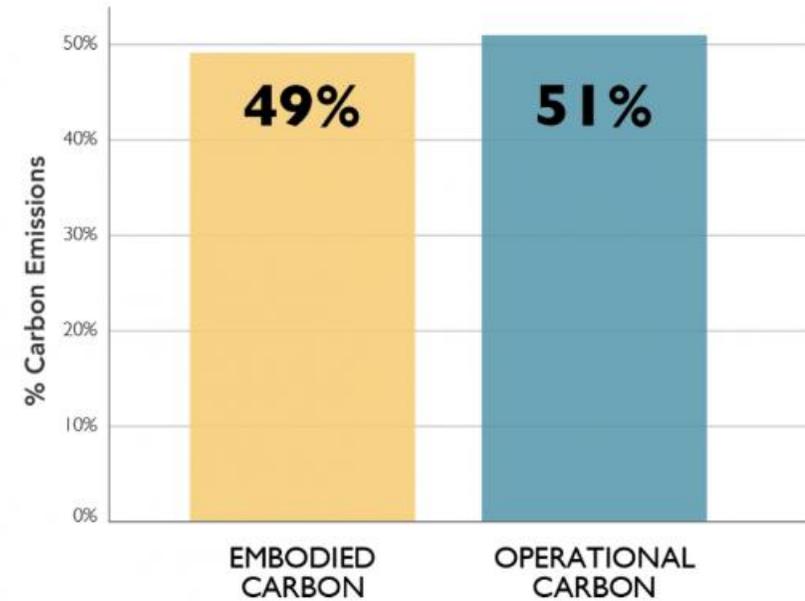
- Embodied carbon emissions from the building sector are responsible for **11% of annual global GHG emissions**.
- Embodied carbon will be responsible for almost **50% of total new construction emissions between now and 2050**.



Embodied Carbon | WHY FOCUS ON EMBODIED CARBON?

- **Operational carbon** can be reduced with building energy efficiency projects.
- **Embodied carbon** is locked in place as soon the building is built.

Total Carbon Emissions of Global New Construction
from 2020-2050
Business as Usual Projection



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Embodied Carbon | WHY FOCUS ON EMBODIED CARBON?

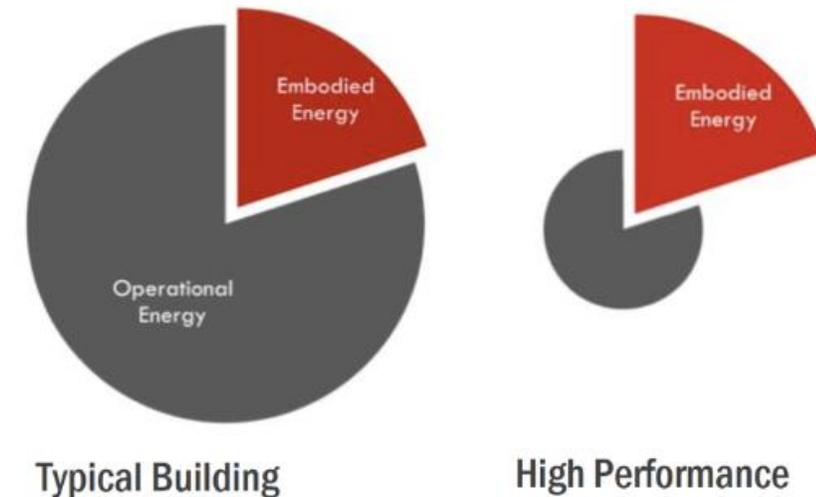
Achieving Net Zero

More recently the building and construction sector has focused on reducing operational carbon in buildings through increased energy efficiency and renewable energy deployment.

Moving Beyond Operational Carbon

Until now, embodied carbon has been largely overlooked, but as operational carbon is reduced, embodied carbon will grow in importance as a proportion of total emissions.

Figure 3: Embodied Energy in Typical and High Performing Buildings



Source: [West Coast Climate Forum](#)

Embodied Carbon | WHY FOCUS ON EMBODIED CARBON?

Rating Systems

- LEED v4
- Living Building Challenge: Materials petal/zero carbon certification

Industry Challenges

- 2030 Challenge for Products
- Structural Engineers 2050 Challenge
- AIA Materials Pledge

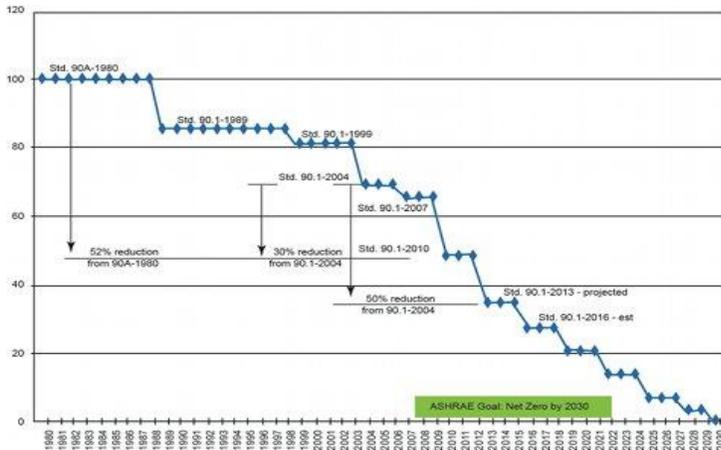
Policy Initiatives

Embodied Carbon | CODE AND POLICY LANDSCAPE



LEED Zero

ASHRAE DRIVING TOWARDS NET ZERO

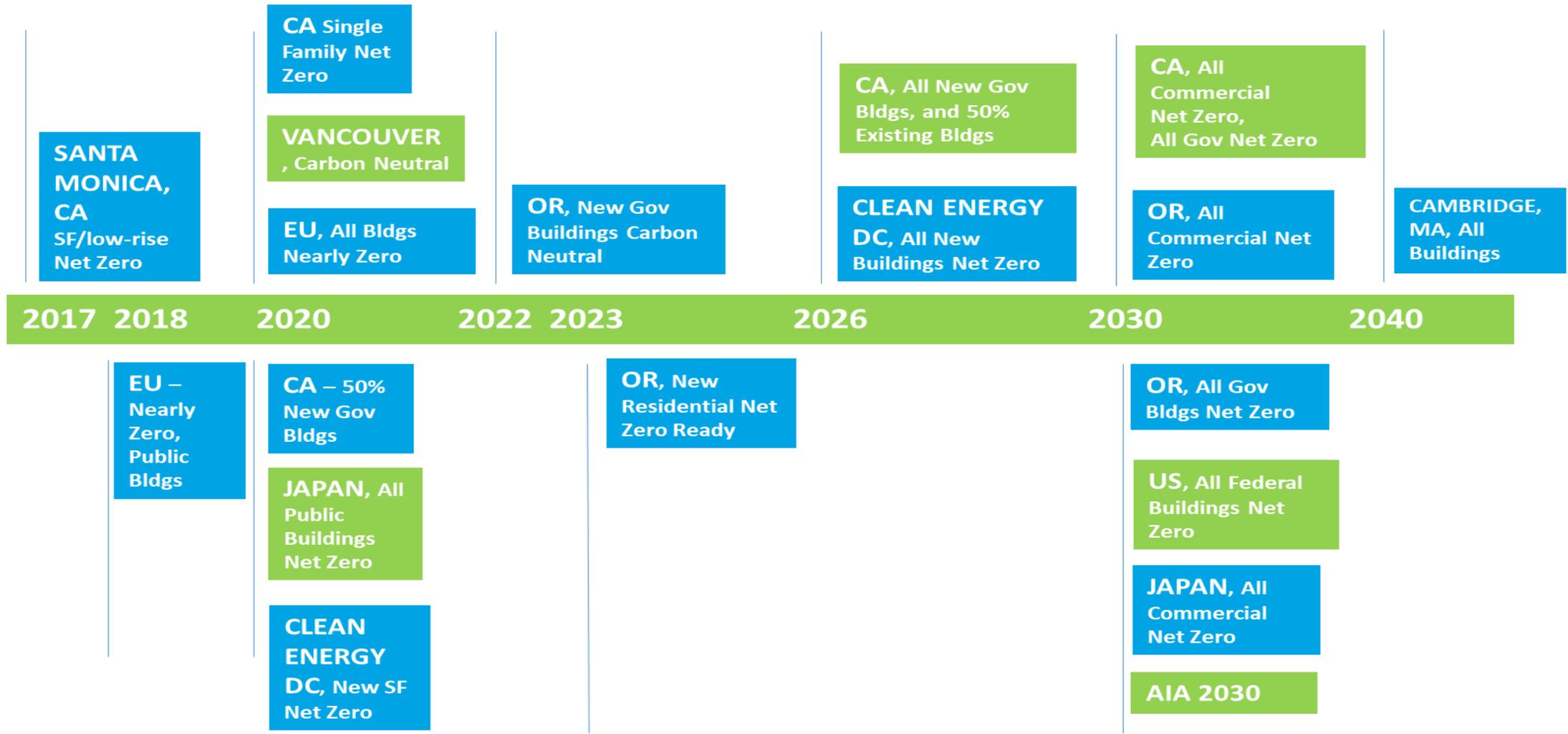


World Green Building Council

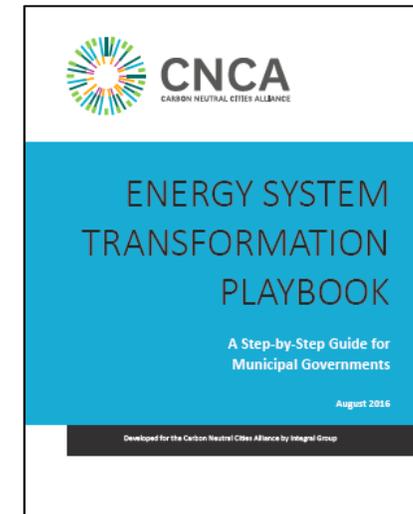
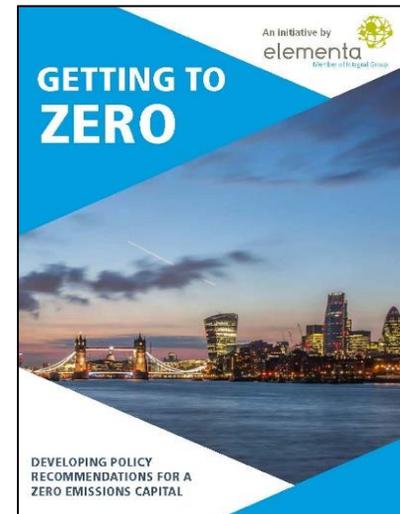
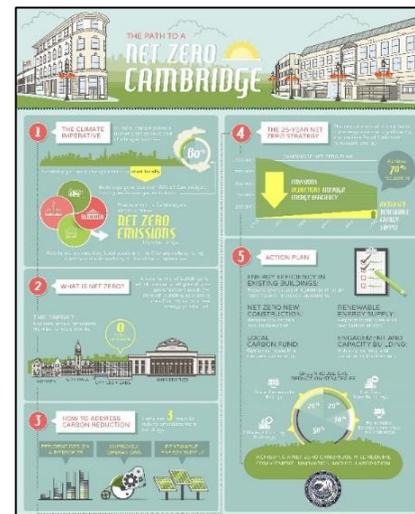
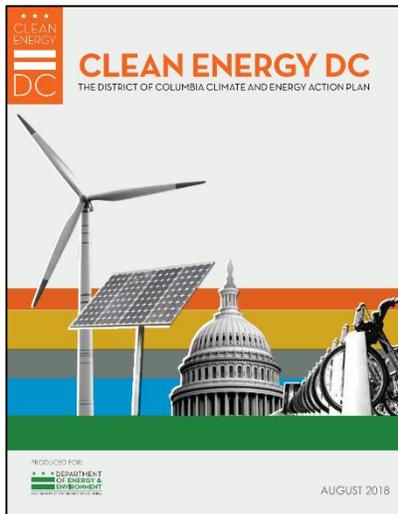
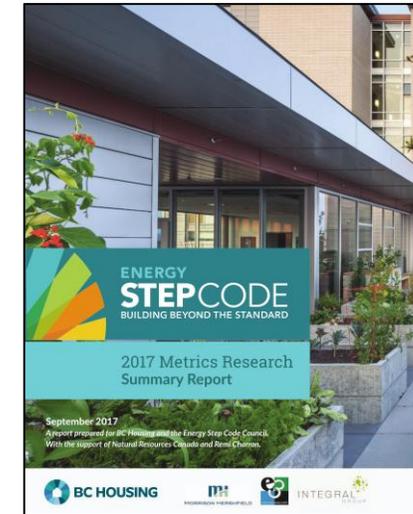


Target:
All buildings zero carbon by 2050

Embodied Carbon | CODE AND POLICY LANDSCAPE



Embodied Carbon | STANDARDS AND PLANS



Embodied Carbon | CANADA ZERO CARBON BUILDING STANDARD



- Focused on performance
- Requires a zero carbon balance in operations and has TEDI target
- Additional reporting requirements for EUI, peak demand, and embodied carbon (reporting only, but likely moving to requirements in next version)

Embodied Carbon | VANCOUVER ZERO EMISSIONS BUILDINGS PLAN



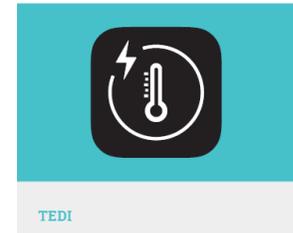
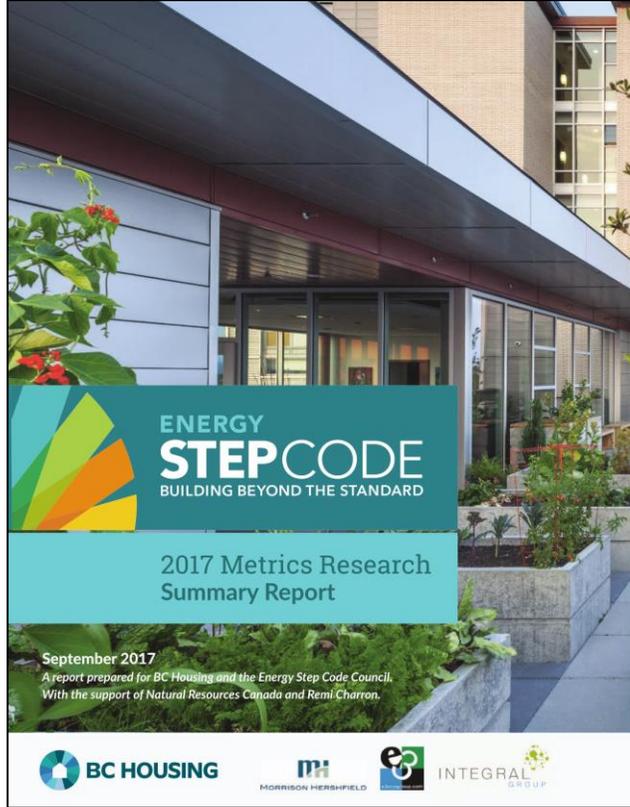
- Establishes limits for carbon emissions, TEDI and EUI
- Offers a Passive House alternative compliance path
- Requires airtightness testing and enhanced compliance, metering infrastructure and benchmarking
- Some limits on embodied carbon (e.g. spray foam)

Embodied Carbon | TORONTO ZERO EMISSIONS BUILDINGS FRAMEWORK



- Establishes stepped GHG & energy targets to Zero Emissions by 2030
- Includes a set of prescriptive requirements
- Plus: Climate Change Resilience Checklist
- Integral working on Existing Buildings Plan for Toronto now, and Embodied Carbon may be a part of the new plan

Embodied Carbon | BC ENERGY STEP CODE

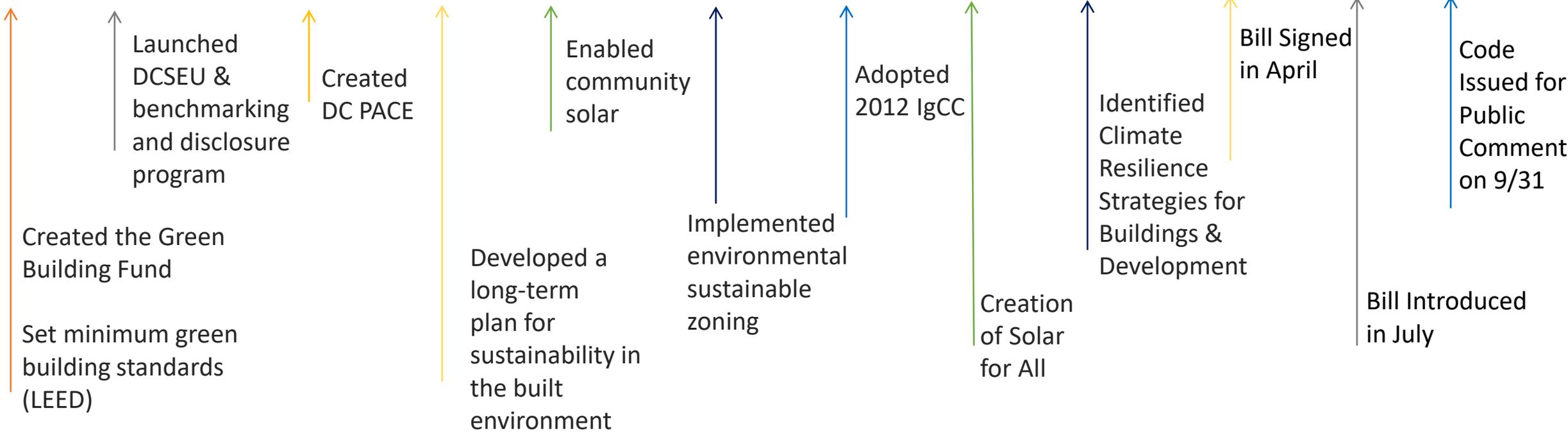


PATHWAY TO 2032: PART 3 (WOOD-FRAME RESIDENTIAL)

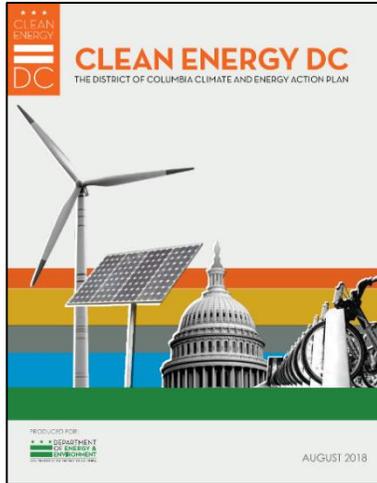


Embodied Carbon | DC POLICY HISTORY

2006 2008 2010 2012 2013 2014 2016 2018



Embodied Carbon | DC ZERO ENERGY CODE



- Net Zero Code for Residential – 2021
- Net Zero Code for Commercial – 2026
- Proposed DC 2019 Energy Code includes Appendix Z: Net-Zero Pathway for Commercial Buildings
- DC easing the path for adoption/structural incentives
- DC also beginning to offer some financial Incentives (DC SEU, DCRA, DOEE, DC Green Bank)

MEDIAN EUI FOR BUILDINGS IN DC

62.4

kBtu/SF/yr

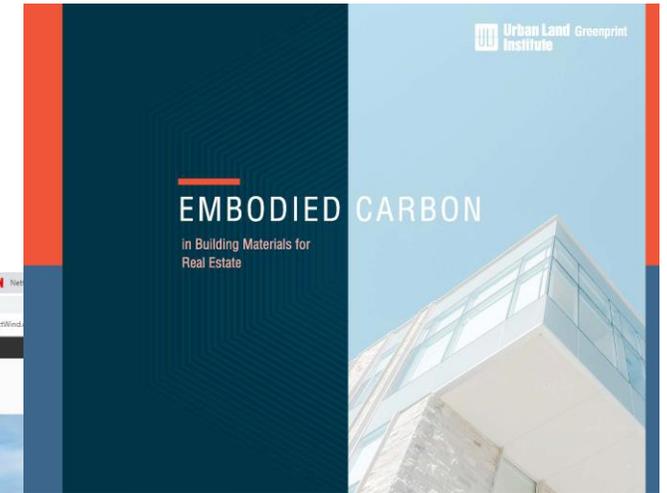
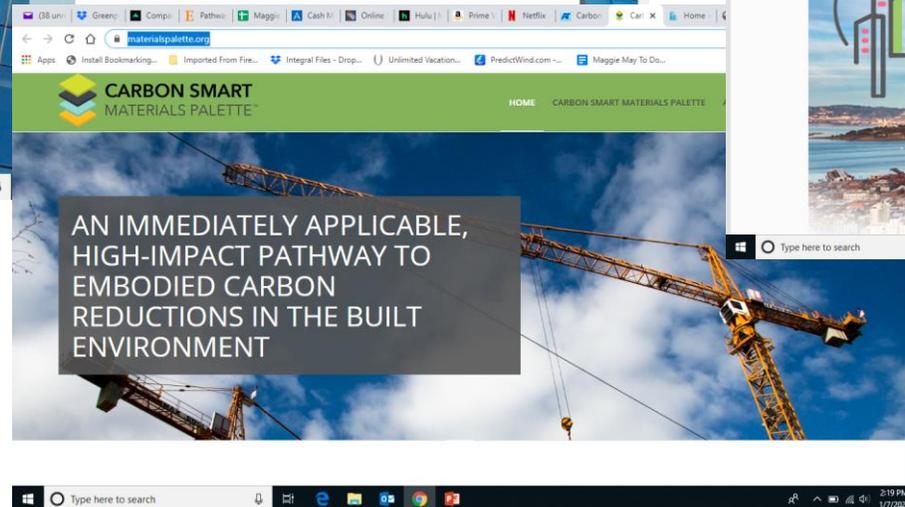
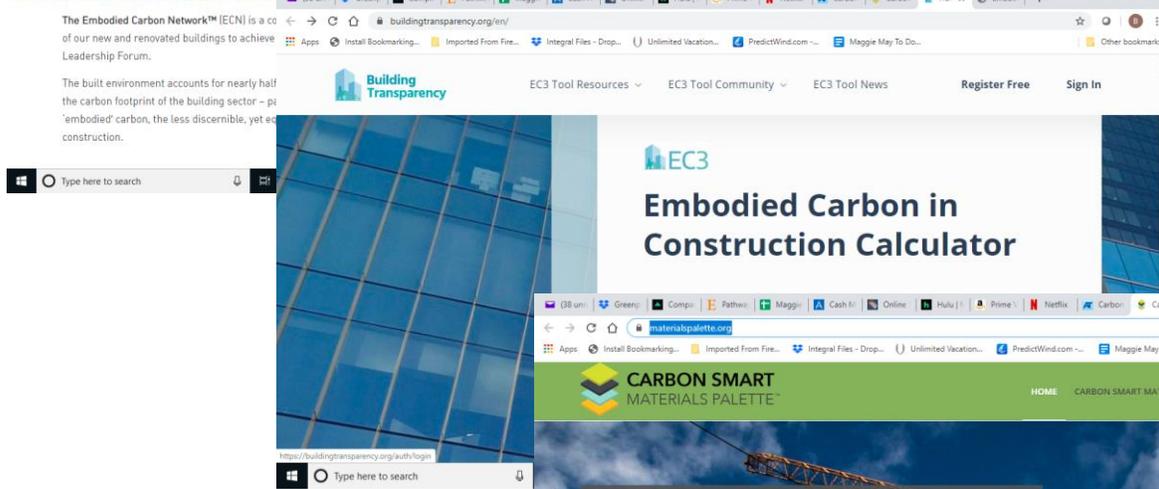
	Assumed Incremental Cost	ECM only			Net Zero with ECM			Net Zero without ECM		
		NPV	SPB	ROI	NPV	SPB	ROI	NPV	SPB	ROI
Office New Construction	\$3,790,218	-\$396,476	11 yrs	9.1%	\$2,672,413	3.0 yrs	33.8%	\$2,508,026	3.3 yrs	30.3%
Multifamily New Construction	\$4,608,518	-\$1,772,741	17.7 yrs	5.7%	\$3,192,398	3.0 yrs	33.1%	\$2,943,543	3.4 yrs	29.3%
Office Renovation	\$3,464,015	-\$137,039	8.1 yrs	12.3%	\$1,260,704	2.7 yrs	36.8%	\$3,008,046	3.4 yrs	29.2%

MEDIAN EUI FOR NET ZERO BUILDINGS

22.6

kBtu/SF/yr (source: NBI)

Embodied Carbon | RAPIDLY CHANGING LANDSCAPE



Embodied Carbon | TOOLS

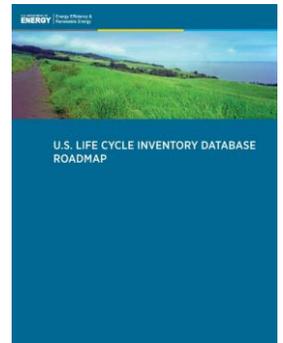
BUILDING LCA TOOLS



Athena
Sustainable Materials
Institute



DATABASES



INDUSTRY DATA



Environmental Product Declarations –

Show Transparency Like Food Labeling

Nutrition Facts	
Serving Size 2/3 cup (55g)	
Servings Per Container About 8	
Amount Per Serving	
Calories 230	Calories from Fat 40
	% Daily Value*
Total Fat 8g	12%
Saturated Fat 1g	5%
Trans Fat 0g	
Cholesterol 0mg	0%
Sodium 160mg	7%
Total Carbohydrate 37g	12%
Dietary Fiber 4g	16%
Sugars 1g	
Protein 3g	

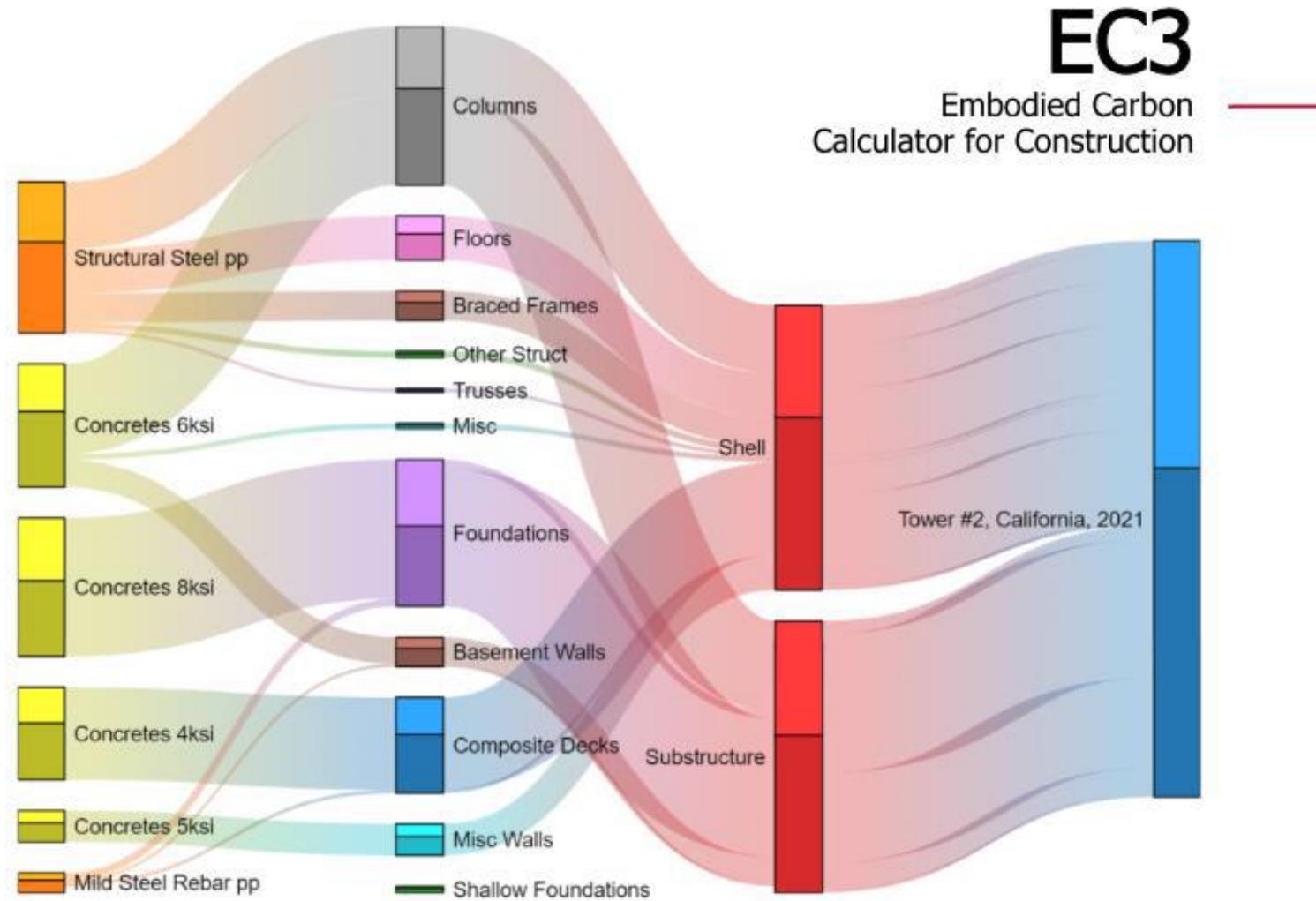


Life Cycle Impact Results (per m³)

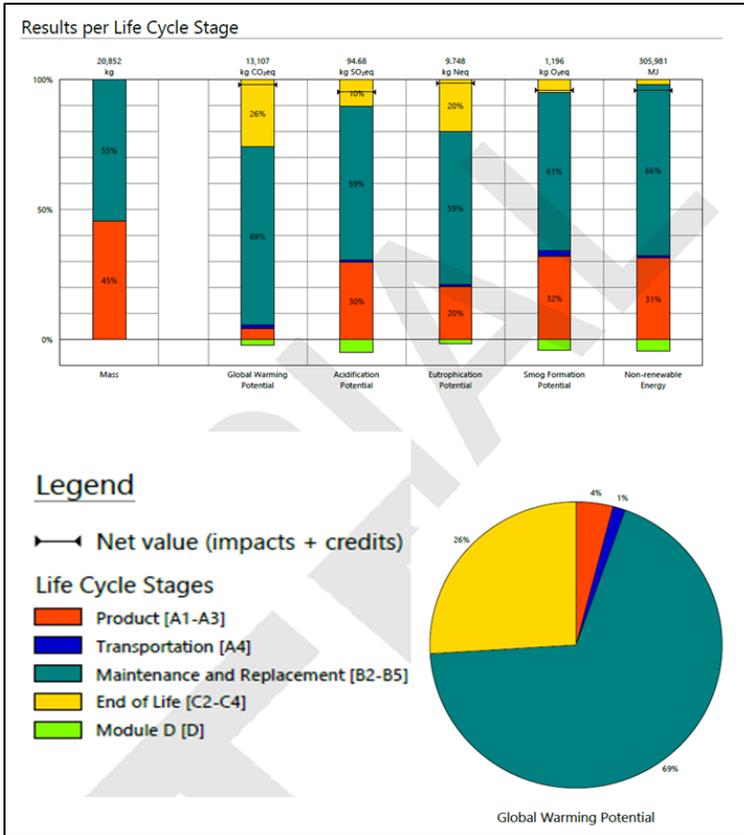
Declared Unit: 1 m³ of 10,000 psi concrete at 28 days

OPERATIONAL IMPACTS	PerformX™ PECC10K
Plant Operating Energy (MJ)	38.6
On-Site Plant Fuel Consumption (MJ)	11.1
Concrete Batch Water (m ³)	1.68E-01
Concrete Wash Water (m ³)	1.91E-02
On-Site Waste Disposal (kg)	0.0
ENVIRONMENTAL IMPACTS	
Total Primary Energy (MJ)	3,017
Climate Change (kg CO ₂ eq)	445
Ozone Depletion (kg CFC 11 eq)	1.31E-08
Acidification Air (kg SO ₂ eq)	2.96
Eutrophication (kg N eq)	0.09
Photochemical Ozone Creation (kg O ₃ eq)	0.61

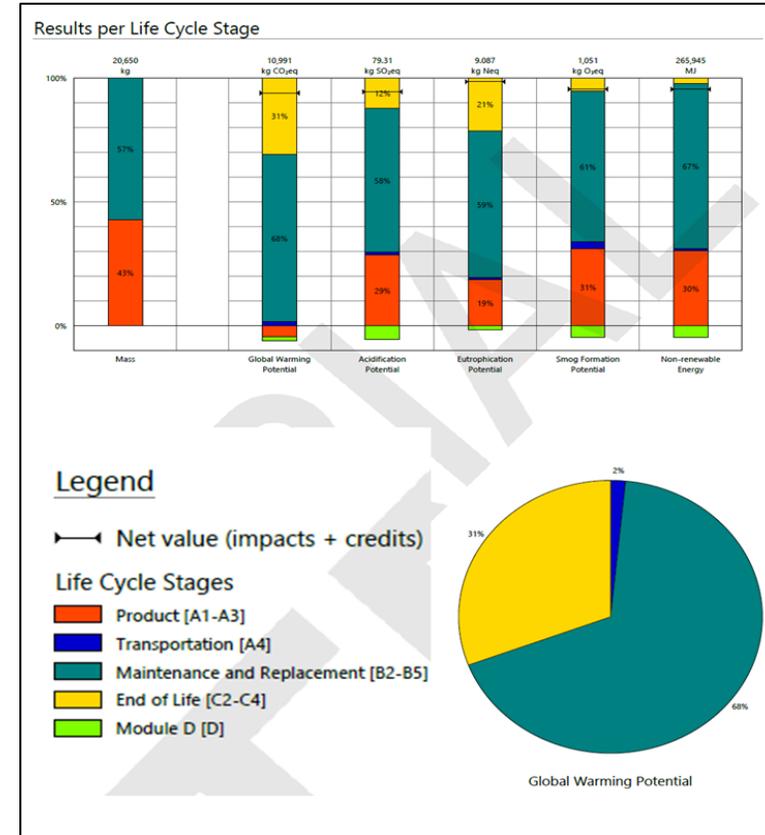
Embodied Carbon | EC3 TOOL



Embodied Carbon | TALLY TOOL



Acoustical Tile Ceiling (ACT)
Existing



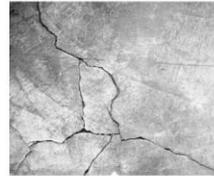
Gypsum Board Ceiling Existing

Embodied Carbon | CARBON SMART MATERIALS PALETTE



HIGH-IMPACT MATERIALS

Predominant building materials with high-impact potential for emissions reductions



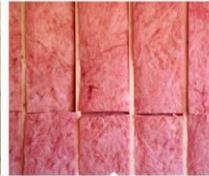
CONCRETE



STEEL



WOOD



INSULATION

CARBON-SMART MATERIALS

Low carbon/carbon sequestering materials



HEMPCRETE



SHEEP'S WOOL



STRAW-BALE



WOOD

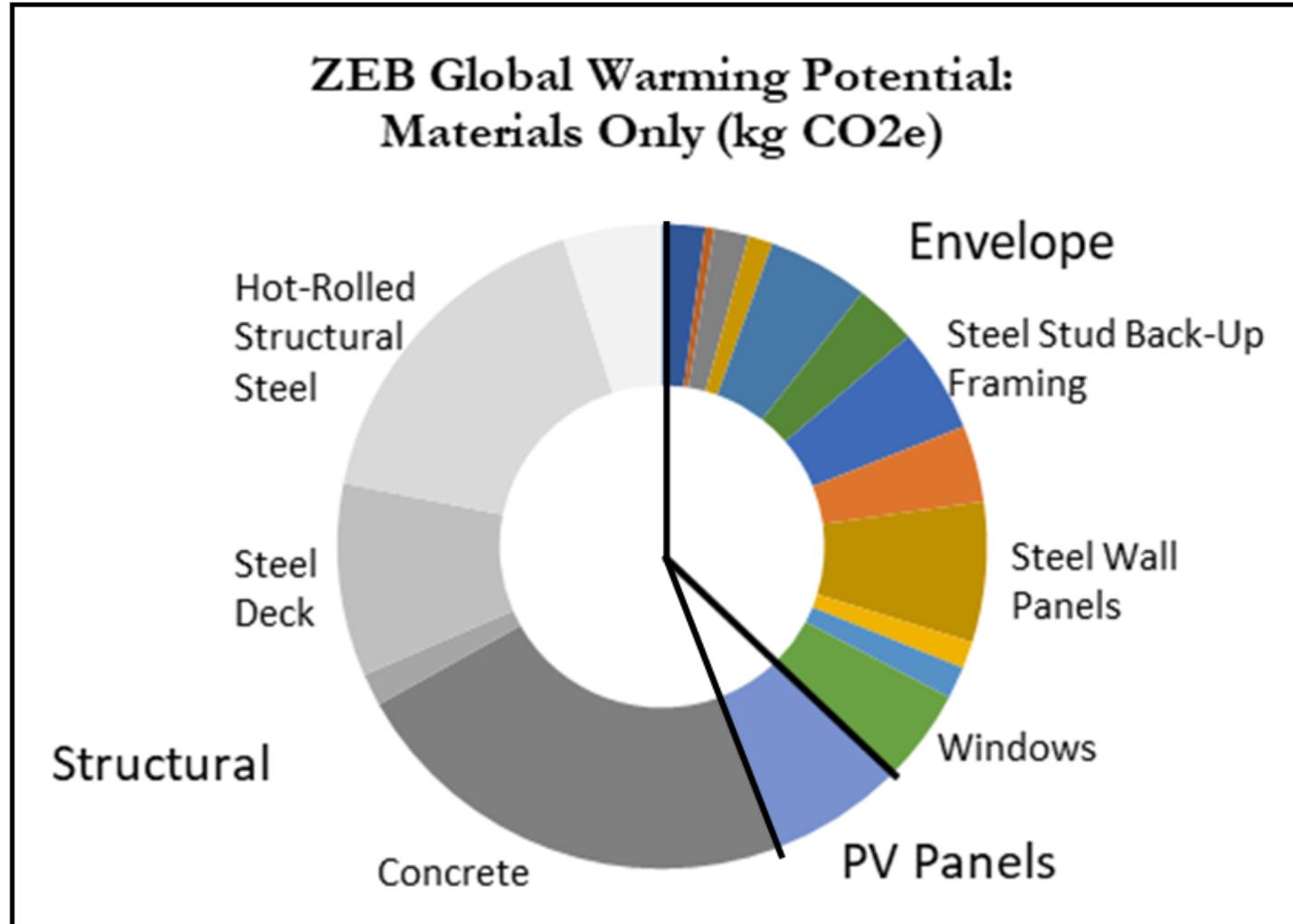
WHOLE BUILDING

Whole building approaches to emissions reductions



WHOLE BUILDING

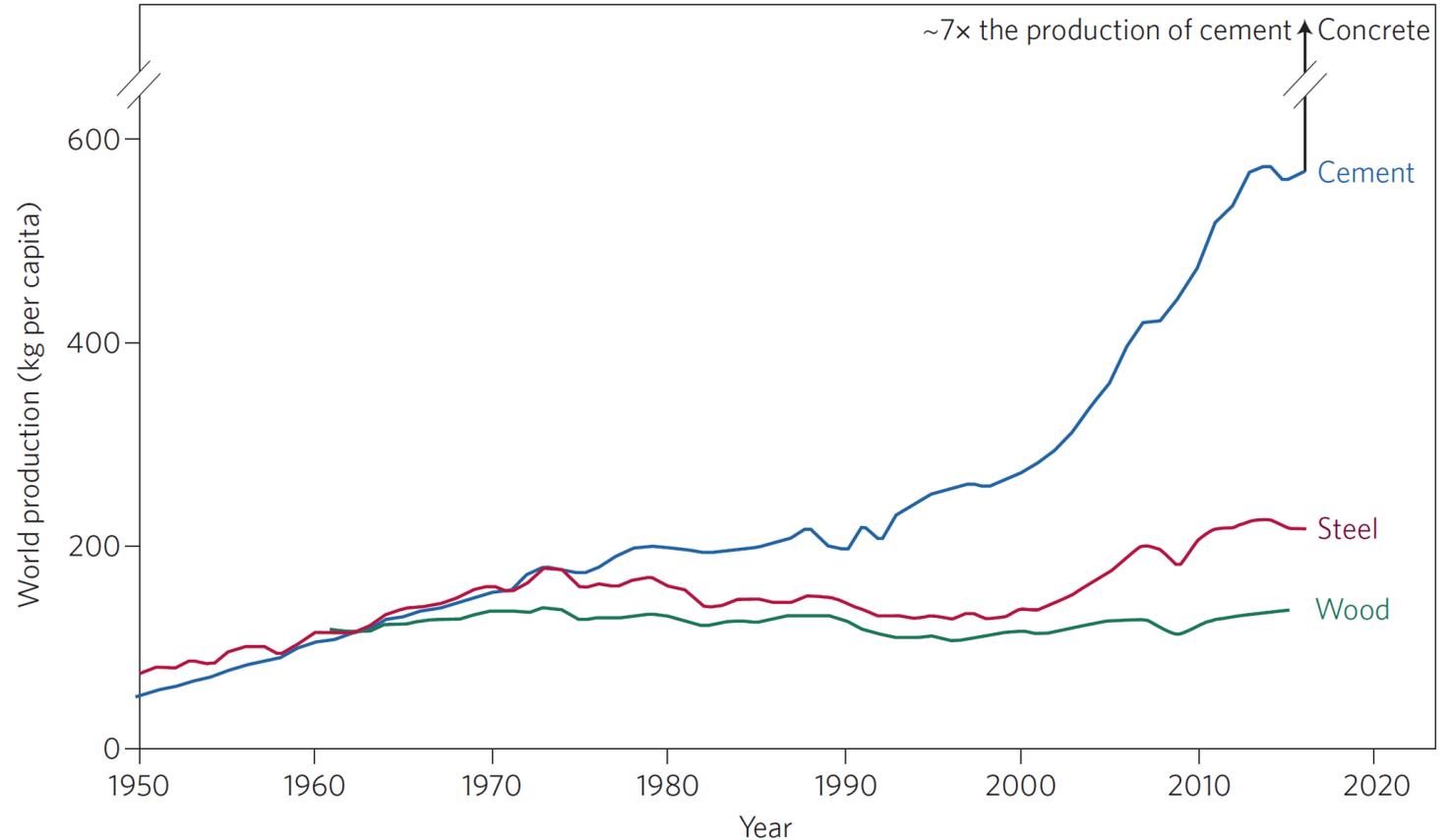
Embodied Carbon | MATERIALS



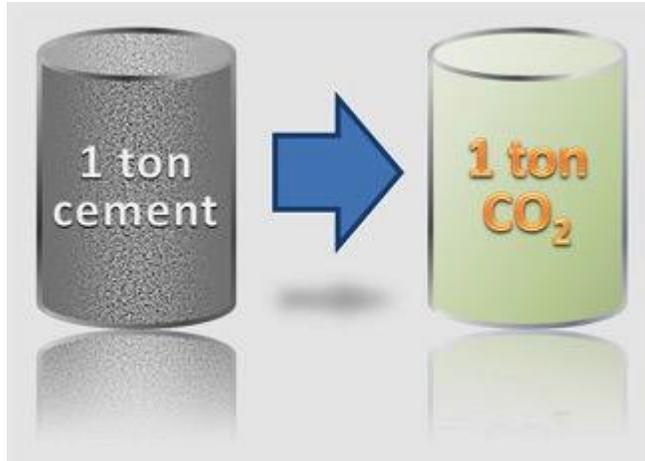
Source: Simpson,
Gumpertz & Heger

Embodied Carbon | MATERIALS

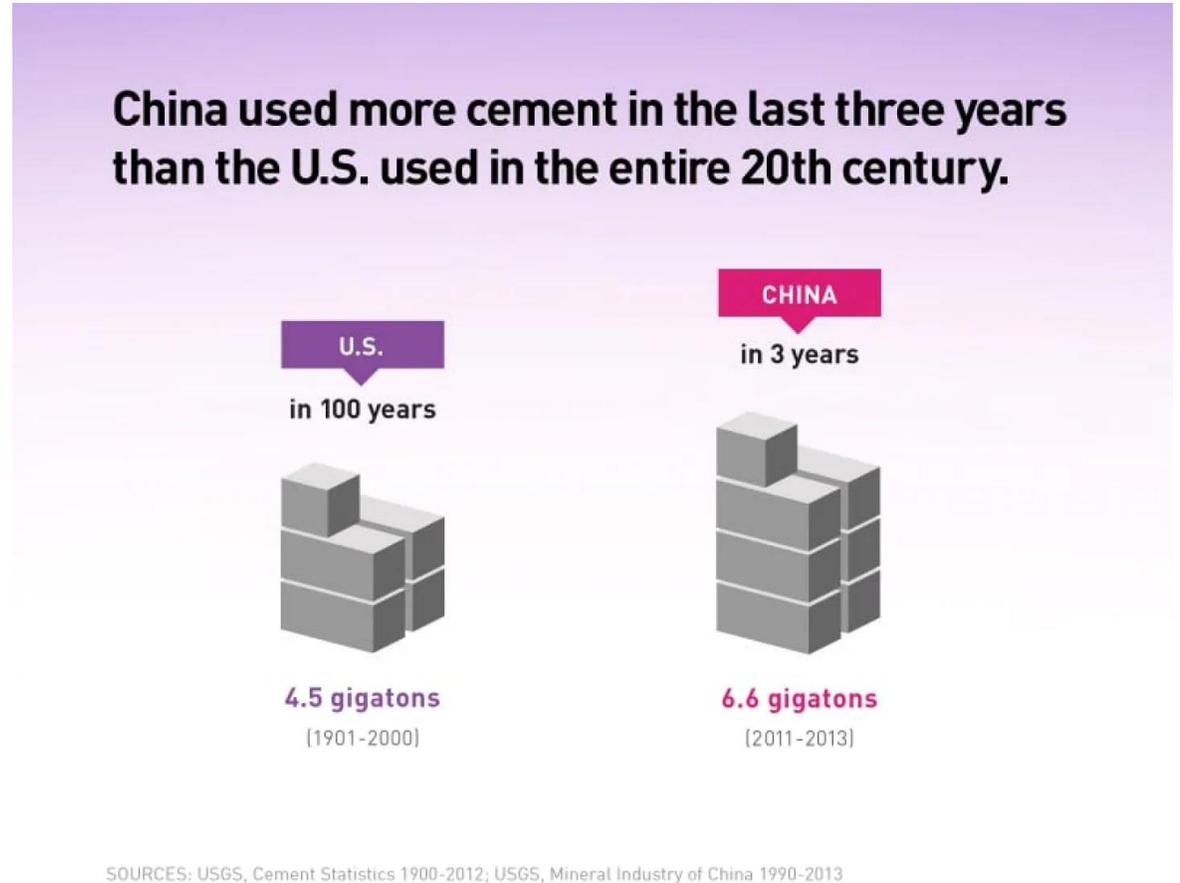
- 80% of GHG Emissions in Concrete from Cement – specify alternatives
- Steel from Electric Arc Furnaces Produce ½ GHG Emissions of Basic Oxygen Steel (EAF uses 93% recycled steel versus 25% in BOS)
- EAFs also use electricity and have potential for decarbonization (BOS uses coal or natural gas)
- Specify wood from sustainably harvested forests



Embodied Carbon | CONCRETE



**Concrete Accounts
for ~6-7% of All GHG
Emissions Globally**



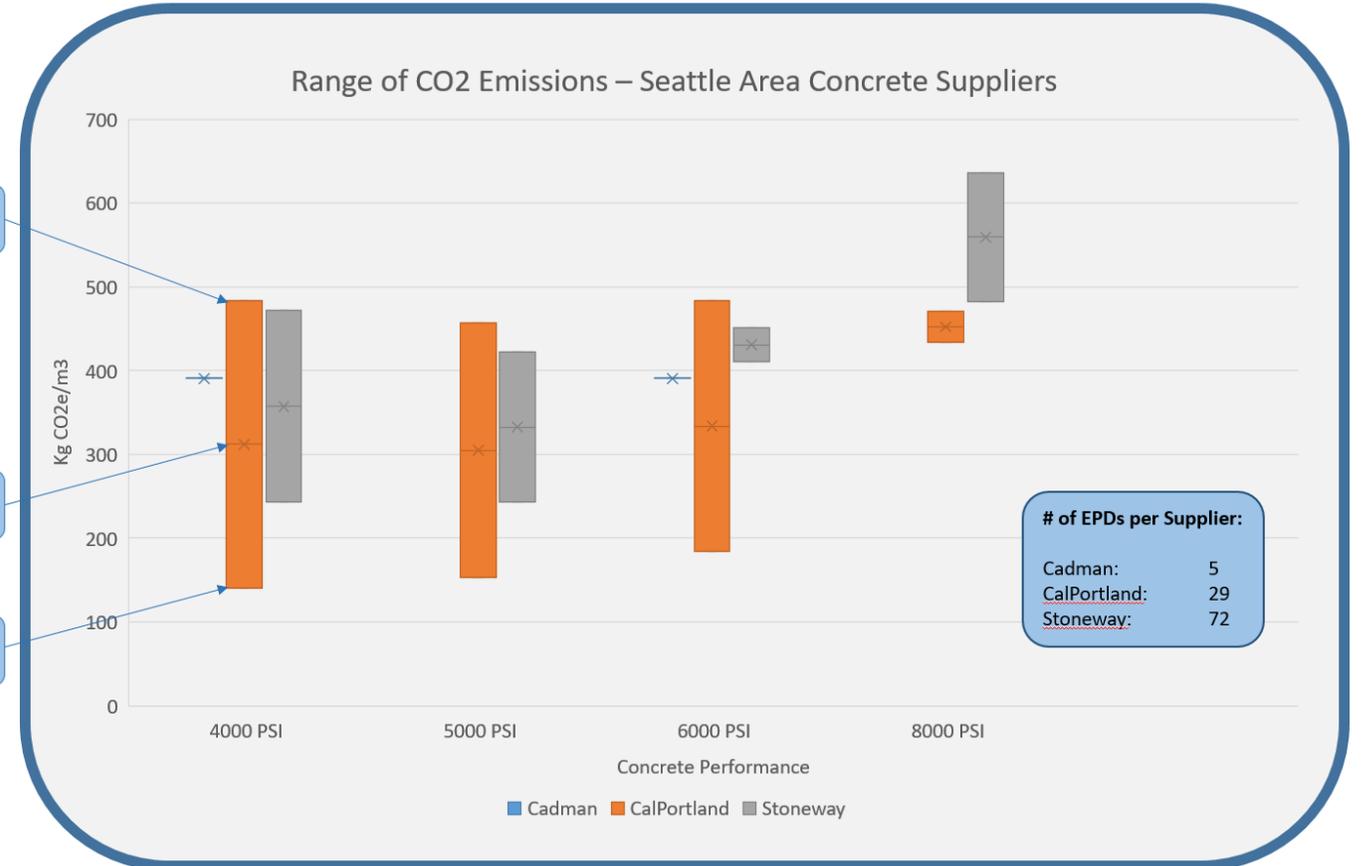
Embodied Carbon | CONCRETE

- **Supplementary Cementitious Materials Can Replace 50% (and Sometimes More) of the Portland Cement in Concrete**

Typical 28 day cure time
Minimal SCM's

Typical 28 day cure time
Some SCM's.

56 day cure time
More SCM's



Embodied Carbon | CONCRETE

ZERO/NEGATIVE CARBON CONCRETE IS COMING!



CarbiCrete



Embodied Carbon | STEEL

ZERO CARBON STEEL IS COMING!

The screenshot shows a web browser window displaying a CNN Business article. The browser's address bar shows the URL: [cnn.com/videos/business/2019/12/13/steel-sweden-carbon-dioxide-emissions-ssab-vattenfall-lkab-stewart.cnn](https://www.cnn.com/videos/business/2019/12/13/steel-sweden-carbon-dioxide-emissions-ssab-vattenfall-lkab-stewart.cnn). The page features the CNN Business logo and navigation links for Markets, Tech, Media, Success, Perspectives, and Videos. A 'LIVE TV' button and an 'Edition' dropdown are also visible. The main content area is titled 'THE GLOBAL ENERGY CHALLENGE' and includes a BP logo with the text 'IN ASSOCIATION WITH BP'. A video player shows a worker in a steel mill, with the headline 'Company aims to produce world's first fossil fuel-free steel'. The article text states: 'In the small town of Lulea in northern Sweden, SSAB has teamed up with Vattenfall and LKAB to build a pilot plant for the world's first fossil fuel free steel-making process, which will replace coking coal with hydrogen, and if successful can reduce Sweden's total carbon emissions by 10%.' The source is cited as CNN. The Windows taskbar at the bottom shows the search bar, task view, and various application icons, with the system clock displaying 10:38 AM on 1/8/2020.

THE GLOBAL ENERGY CHALLENGE

IN ASSOCIATION WITH BP 

Company aims to produce world's first fossil fuel-free steel

In the small town of Lulea in northern Sweden, SSAB has teamed up with Vattenfall and LKAB to build a pilot plant for the world's first fossil fuel free steel-making process, which will replace coking coal with hydrogen, and if successful can reduce Sweden's total carbon emissions by 10%.

Source: CNN



It's how we developed

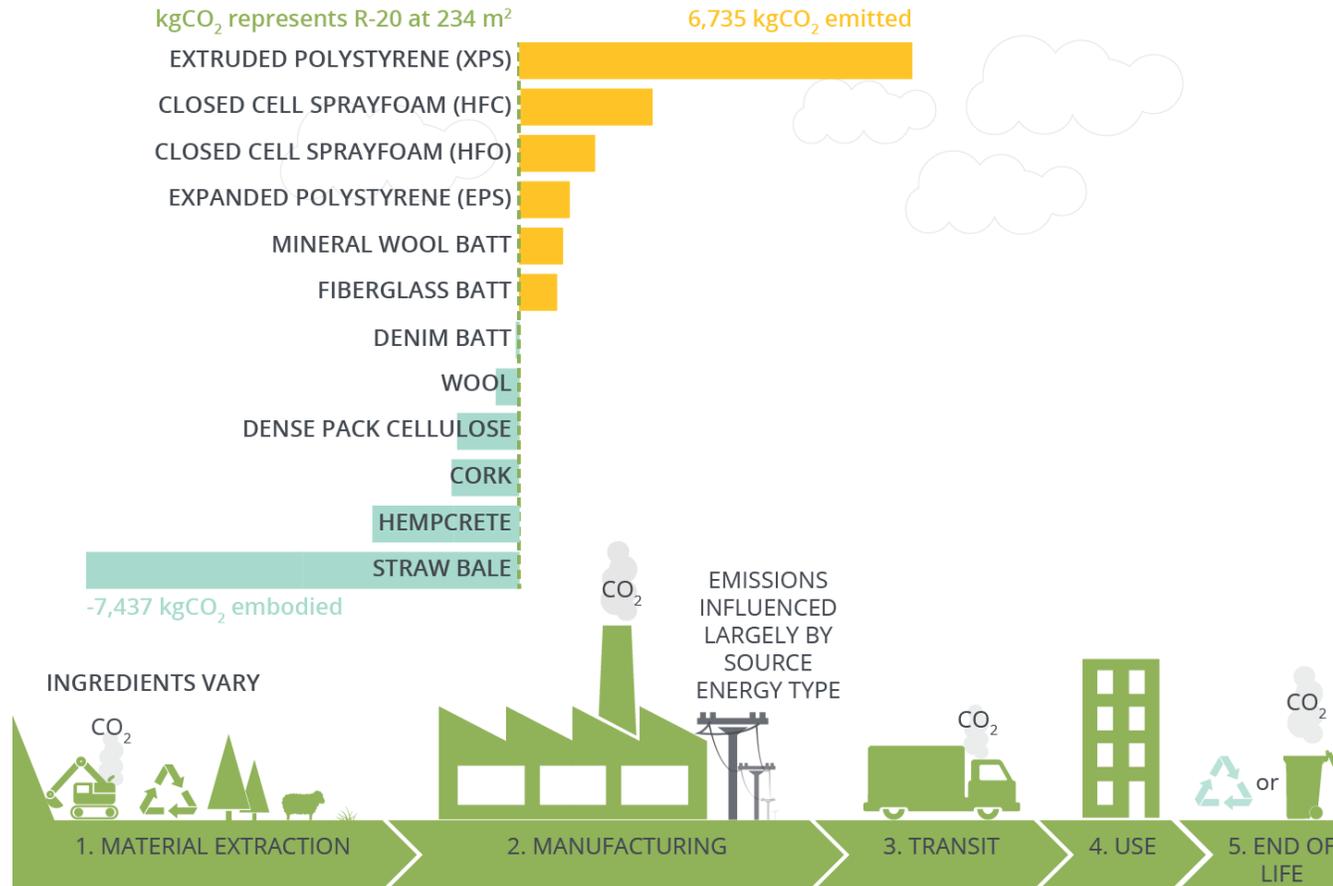
2021 ICC CODE TO INCLUDE NEW PROVISIONS FOR MASS TIMBER



- ❖ **Type IV-A** – Maximum 18 stories, with gypsum wallboard on all mass timber elements.
- ❖ **Type IV-B** – Maximum 12 stories, limited-area of exposed mass timber walls and ceilings allowed.
- ❖ **Type IV-C** – Maximum 9 stories, all exposed mass timber designed for a 2-hour fire resistance.

Embodied Carbon | INSULATION

CARBON IMPACTS OF INSULATION

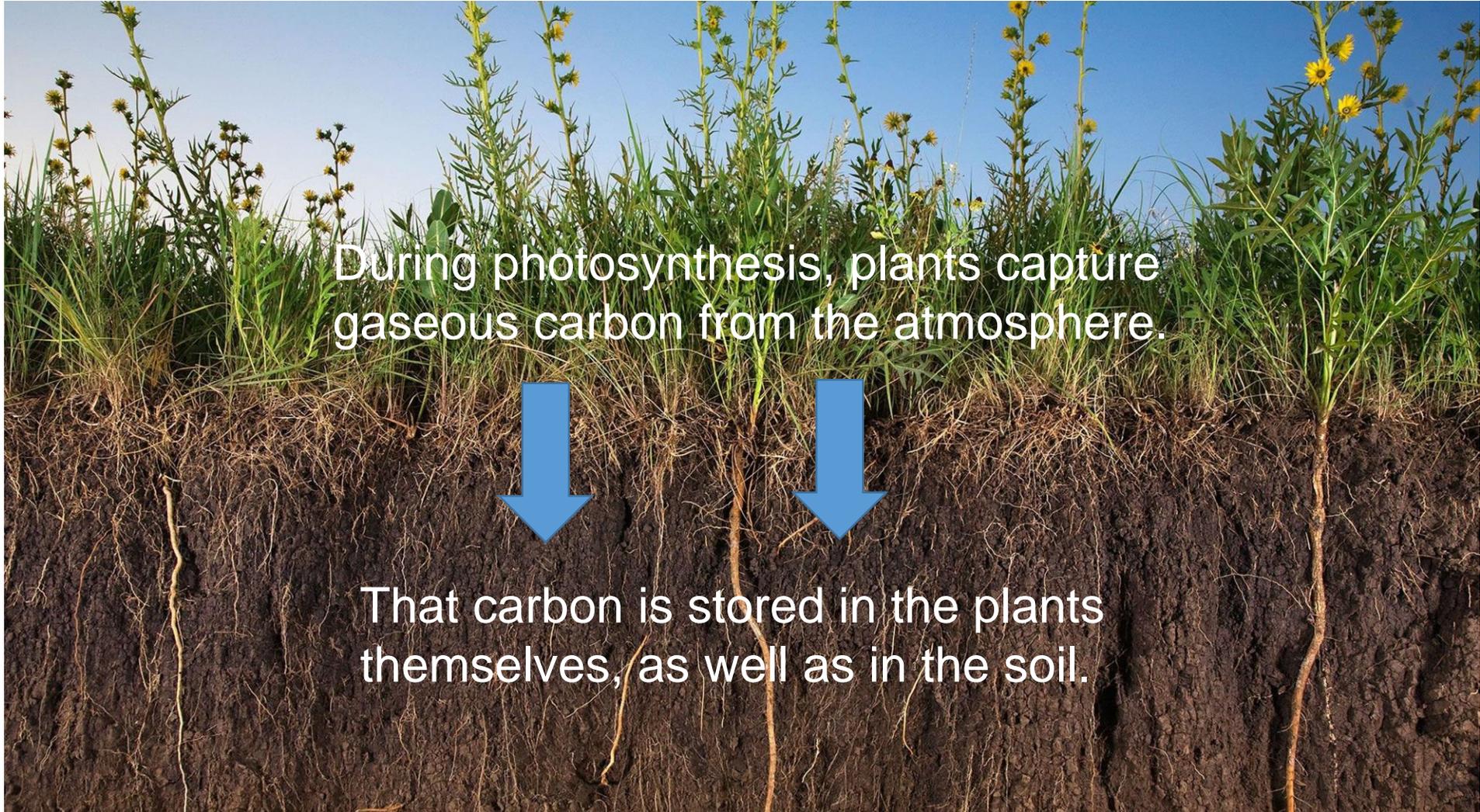


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Carbon impacts data source: Builders for Climate Action - 2019 White Paper "Low-Rise Buildings as a Climate Change Solution", Chris Magwood, 2019;

***Embodied CO₂e of Foundation Wall Insulation R-20**

Embodied Carbon | INSULATION



During photosynthesis, plants capture gaseous carbon from the atmosphere.

That carbon is stored in the plants themselves, as well as in the soil.

Embodied Carbon | MATERIALS

2.16 billion tons of grain straw were grown globally in 2016. That's enough carbon storage to **offset all current transportation GHG emissions** and more than **replace all current insulation materials.**



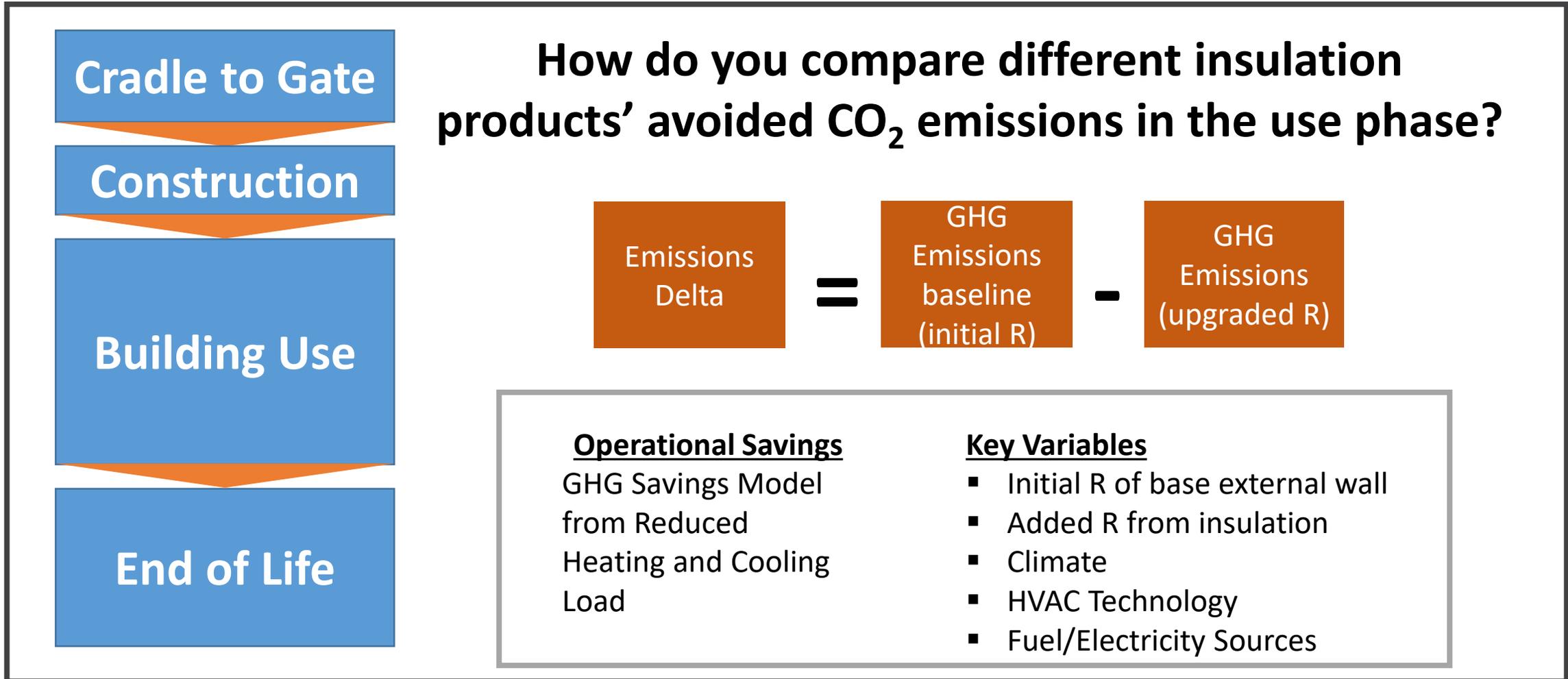
Embodied Carbon | INSULATION

There are lots of plant-based, carbon-storing building materials

- Timber Cellulose
- Bamboo / BamCore
- Wood Fiber Board
- Straw
- Coconut Coir
- Cork
- Mycelium Hemp OSB ReWall
- Rice Hulls
- Waste Textiles
- + More

And few or **no red list** chemicals!





Embodied Carbon | INSULATION

Global Warming Potential (GWP) in kgCO₂e ; Functional unit: 1m² of foam 4" thick

Perceived best choice

	4" EPS (R=3.8/in)	4" PolyIso (R=6.5/in)
Cradle to Gate	7.04e0	18.4e0
Construction	3.47e-1	6.50e-1
Building Use	Not Included	Not Included
End of Life	1.02e-2	2.19e-2
Total	7.40e0	19.1e0

Embodied Carbon | INSULATION

Global Warming Potential (GWP) in kgCO₂e ; Functional unit: 1m² of foam 4" thick

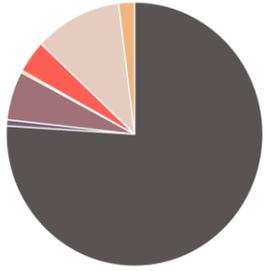
	4" EPS (R=3.8/in)	4" PolyIso (R=6.5/in)
Cradle to Gate	7.04e0	18.4e0
Construction	3.47e-1	6.50e-1
Building Use	442 <i>SAVED</i>	504 <i>SAVED</i>
End of Life	1.02e-2	2.19e-2
Total	435 <i>SAVED</i>	485 <i>SAVED</i>

Better choice

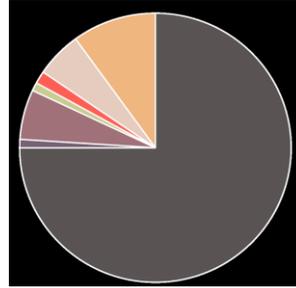
Variables that Impact Use Phase

- Insulation with higher R value
- More extreme climates (HDD) will see largest impact
- Type of energy grid ('dirty' /high FEF vs 'clean' /low FEF)
- If two products are close in R-value, detailed calculation might be helpful

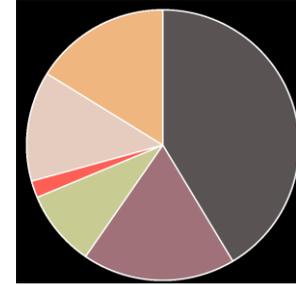
Embodied Carbon | MATERIALS



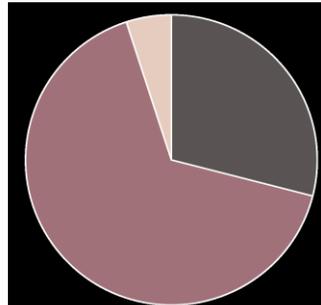
6 story mixed-use residential concrete structure



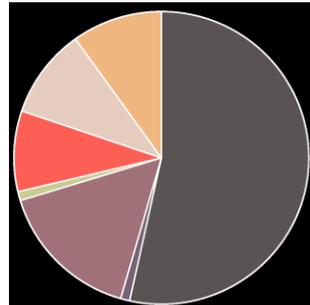
3 story (55,000 GSF) lab+research facility concrete structure



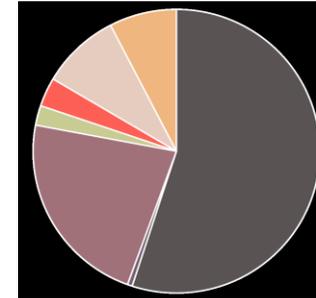
6 story residential mixed concrete and wood structure



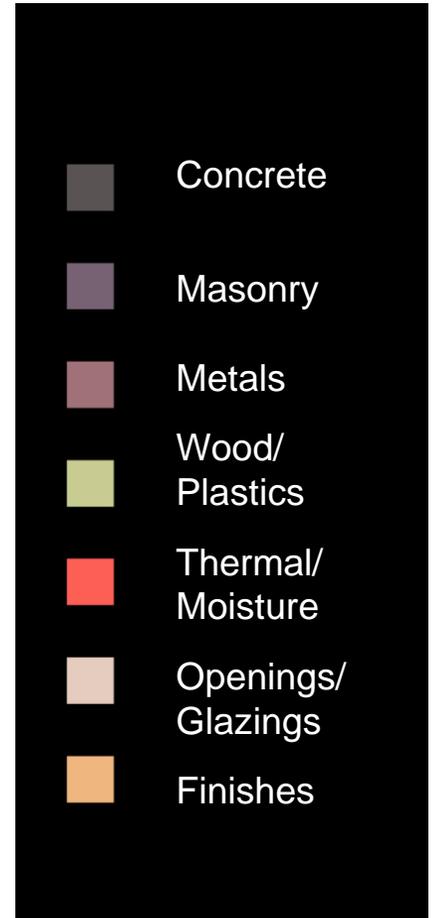
800k GSF commercial concrete and steel structure



4 story (140k GSF) academic use concrete structure



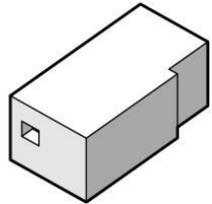
Averaged



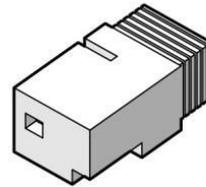
*Source: Architecture 2030

Embodied Carbon | DESIGN PROCESS

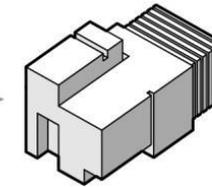
TYPICAL WORKFLOW



SCHEMATIC DESIGN



DESIGN DEVELOPMENT

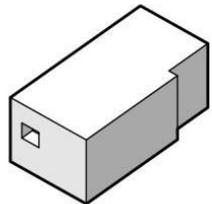


CONSTRUCTION DOCUMENTS

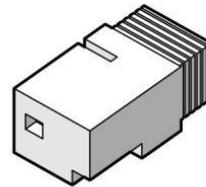
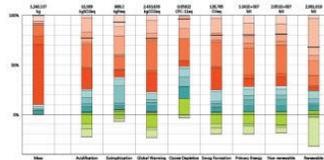


LIFE CYCLE ASSESSMENT

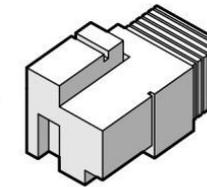
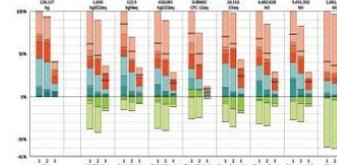
TALLY WORKFLOW



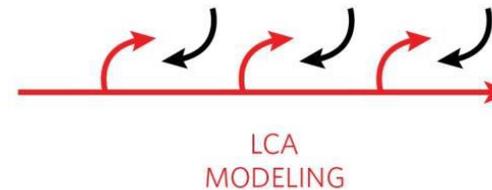
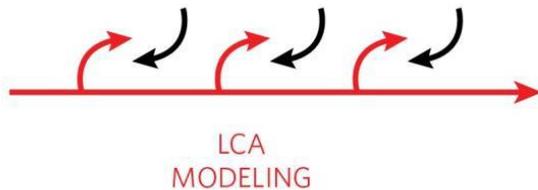
SCHEMATIC DESIGN



DESIGN DEVELOPMENT



CONSTRUCTION DOCUMENTS



1. EARLY-PHASE WHOLE BUILDING LCA

Part to whole, Rough, focus on typologies, assemblies and materials, not products

2. DESIGN OPTION MODELS

Targeted design questions, detailed comparisons

3. END-OF-PROJECT BENCHMARKING

Construction documentation, Project narratives How did we do?

Embodied Carbon | RESOURCES

- Carbon Leadership Forum – Embodied Carbon Network
 - <http://www.carbonleadershipforum.org/embodied-carbon-network/>
- Architecture 2030 – Carbon Smart Materials Palette
 - <https://materialspalette.org/>
- Carbon Smart Building Collective
 - <https://carbonsmartbuilding.org/>
- Athena Sustainable Materials Institute
 - <http://www.athenasmi.org/>
- EC3 Tool
 - <https://www.buildingtransparency.org/en/>
- Tally Tool
 - <https://choosetally.com/>

Questions?

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