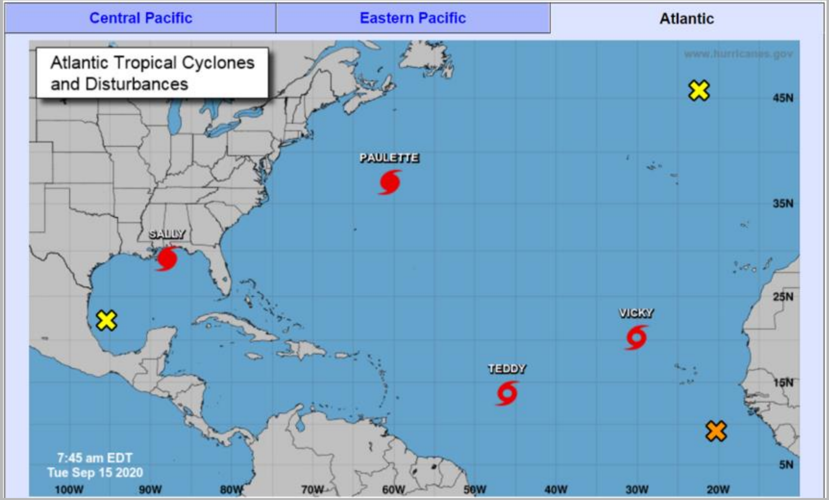
A Sustainable Future: Understanding Embodied Carbon in Buildings

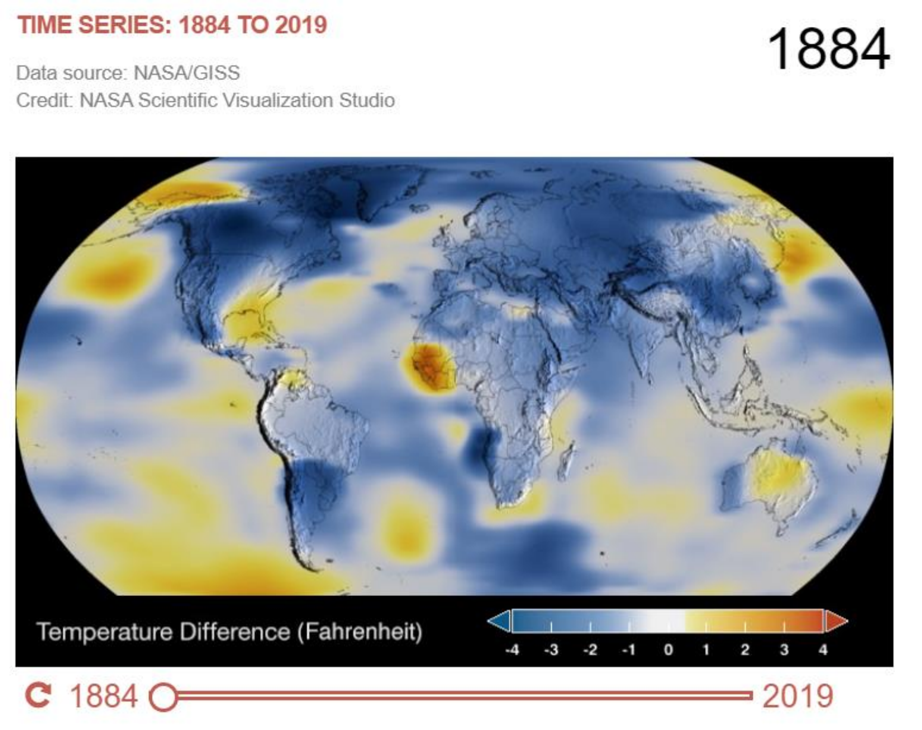
Brian McSweeney, PE
Structural Project Engineer

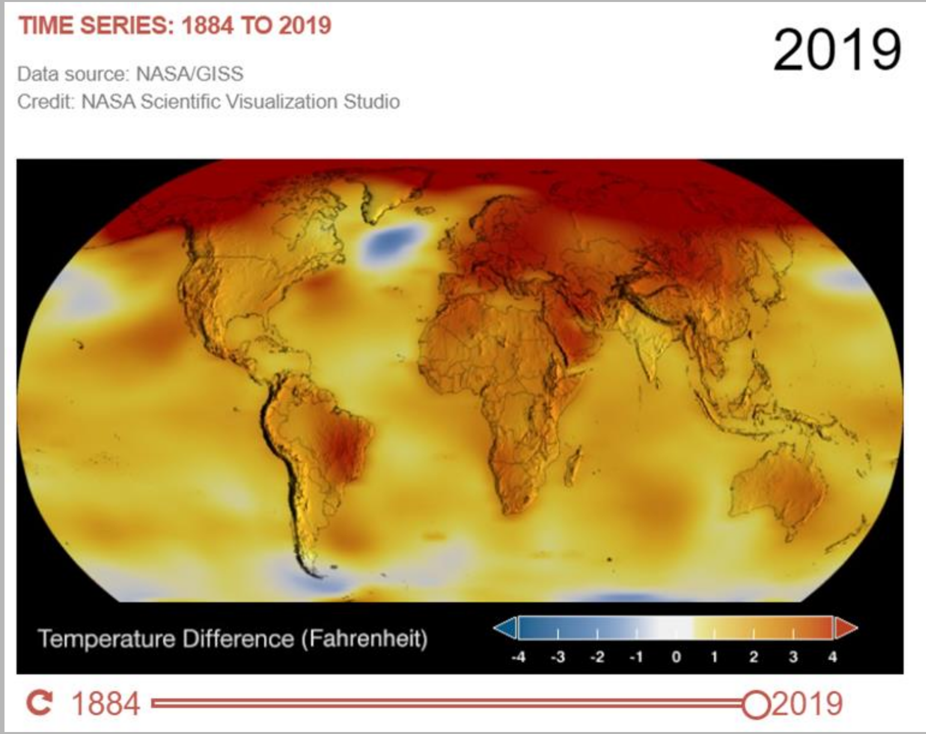
Kristy M. Walson, PE, LEED Fellow, BEMP

TLC ENGINEERING SOLUTIONS



Protesters demonstrate outside of U.S. Bank Stadium on May 31 in Minneapolis. (Salwan Georges/The Washington Post)


TIME SERIES: 1884 TO 2019
1884
Data source: NASA/GISS
Credit: NASA Scientific Visualization Studio
Temperature Difference (Fahrenheit)
-4 -3 -2 -1 0 1 2 3 4
1884
2019


TIME SERIES: 1884 TO 2019
2019
Data source: NASA/GISS
Credit: NASA Scientific Visualization Studio
Temperature Difference (Fahrenheit)
-4 -3 -2 -1 0 1 2 3 4
1884
2019

Climate Change is **Carbon**

...and Global Warming,

and Greenhouse Effect,

and Social Equity,

and Extreme Weather Events,

and Rising Sea Levels,

and Global Pandemics,

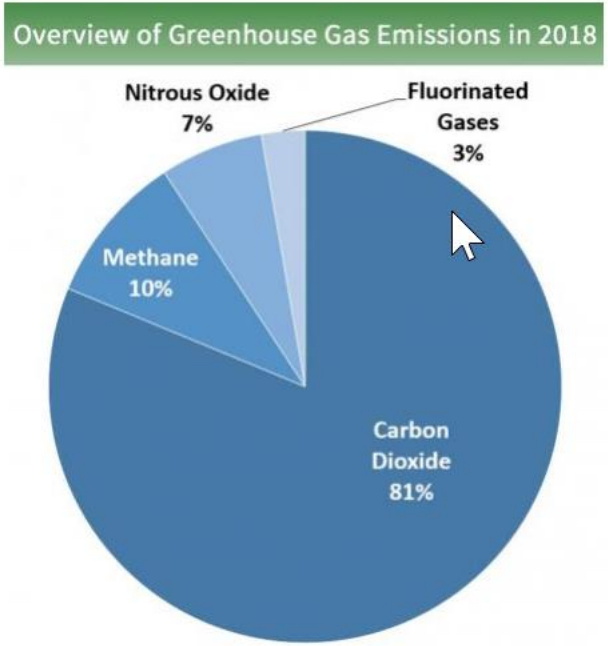
and Melting Glaciers,

and Fossil Fuel Burning,

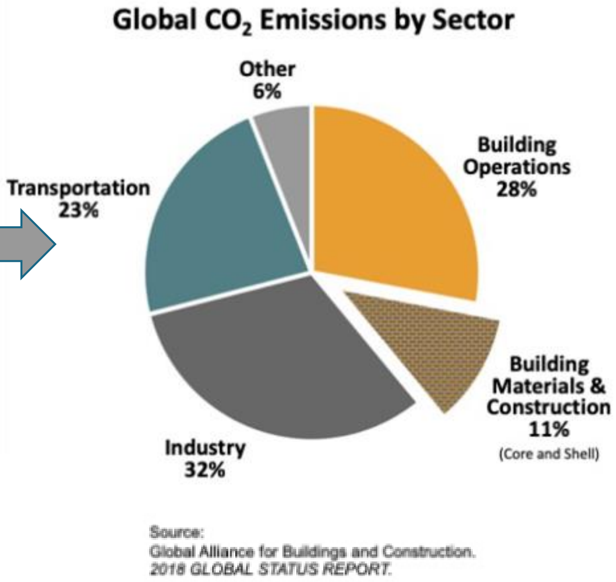
and...

ESA Climate Change Initiative

Carbon: What's the big deal?



Total Emissions in 2018 = 6,677 Million Metric Tons of CO_2 equivalent. Percentages may not add up to 100% due to independent rounding.

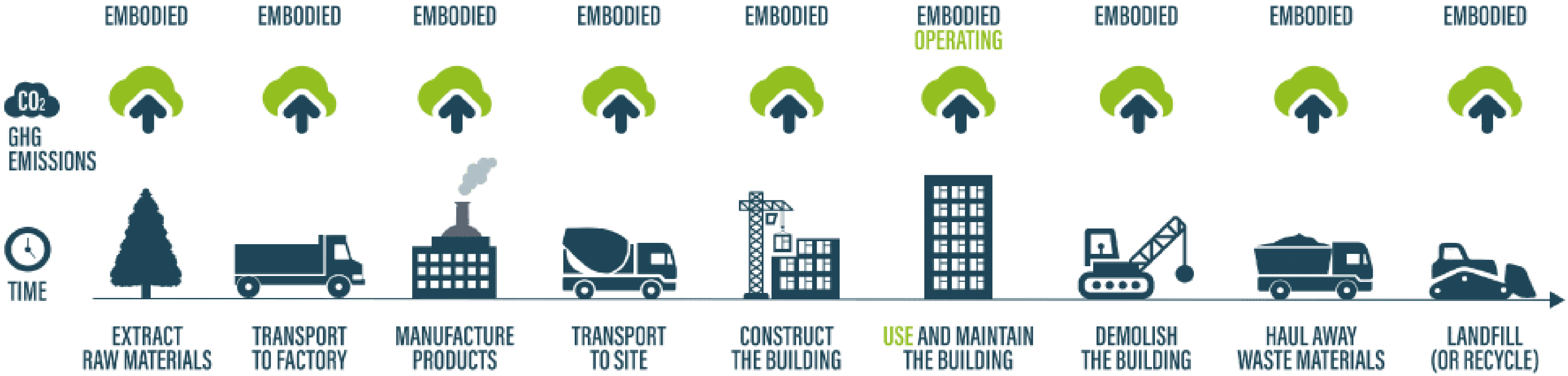


- Excessive trapping of Greenhouse Gases in the Earth's atmosphere leads to Global Warming, which leads to Climate Change.
- Carbon Dioxide accounts for approximately 81% of all Greenhouse Gas Emissions.
- As Building Operations continue to do better, Building Materials will become a larger part of the pie.

Carbon: Operational vs. Embodied

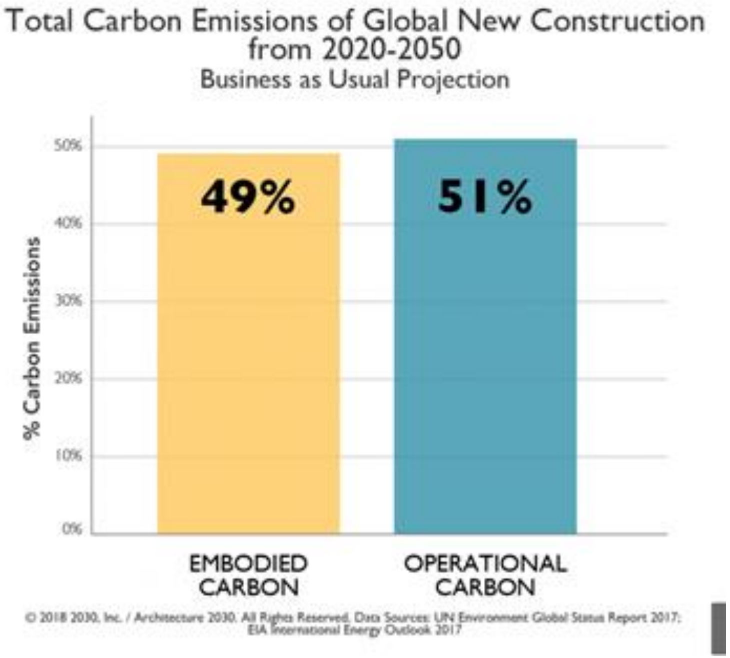
Operational Carbon
The carbon released into the atmosphere as a result of a building's energy consumption. Occurs at the utility plant(s).

Embodied Carbon
The environmental impact associated with extracting, manufacturing, and transporting building materials to the jobsite.



TLC ENGINEERING SOLUTIONS

Carbon: Operational vs. Embodied



Operational Carbon
Occurs only during occupancy of the building & can be reduced over time through energy efficiency measures.

Embodied Carbon
Occurs during full lifecycle of building and is locked-in when the building opens.

AIA

image credit: AIA COTE

- Energy benchmarking & goal setting
- Passive design features / climate responsive design
- Onsite renewables (solar, wind)
- Energy Modeling
- Commissioning
- Net Zero Energy / Net Zero Carbon Building

Resources:

AIA 2030 Commitment

Architect's Guide to Building Performance

- Safer material selection
- Embodied Carbon
- Material Sourcing
- Construction Waste Diversion

Resources:

ILFI Red List

Carbon Smart Materials Palette

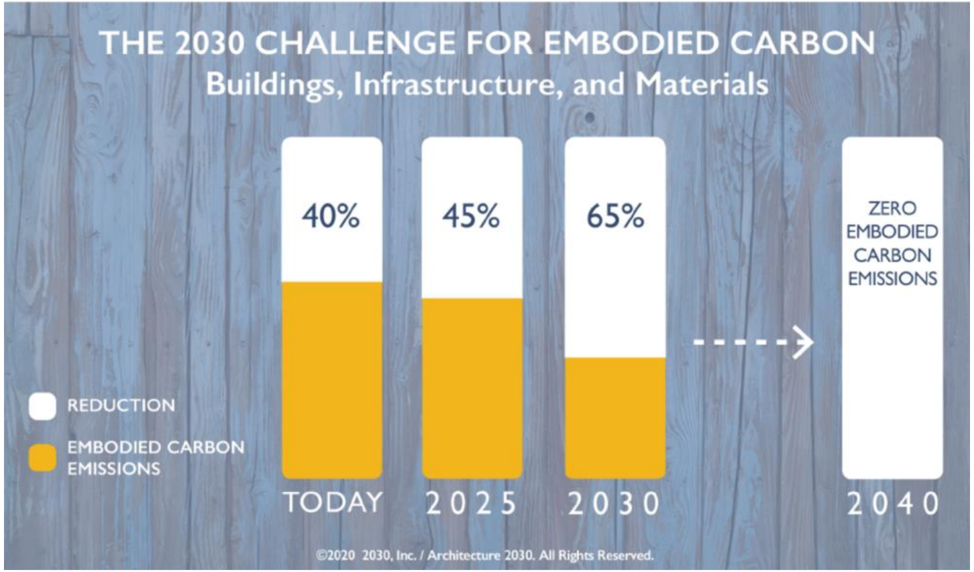
Zero Waste Guidelines

West Branch of the Berkeley Public Library
Berkeley, CA, USA
ARCHITECT **Leddy Maytum Stacy Architects**

architecture 2030

SEI ASCE STRUCTURAL ENGINEERING INSTITUTE

SE2050 COMMITTING TO ZERO



In Our Future: Sustainable Structural Design

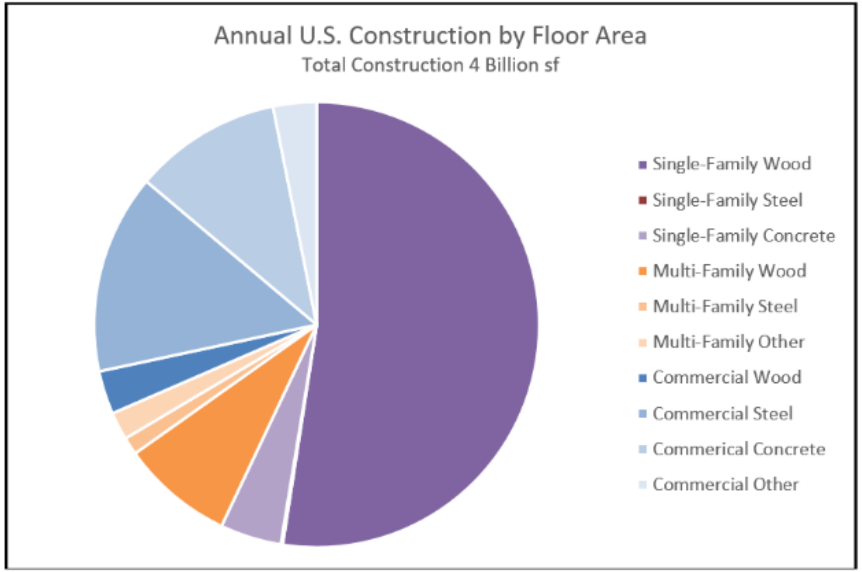


Figure 1-2: Annual New Construction in the United States by Building Type and Type of Structural Frame

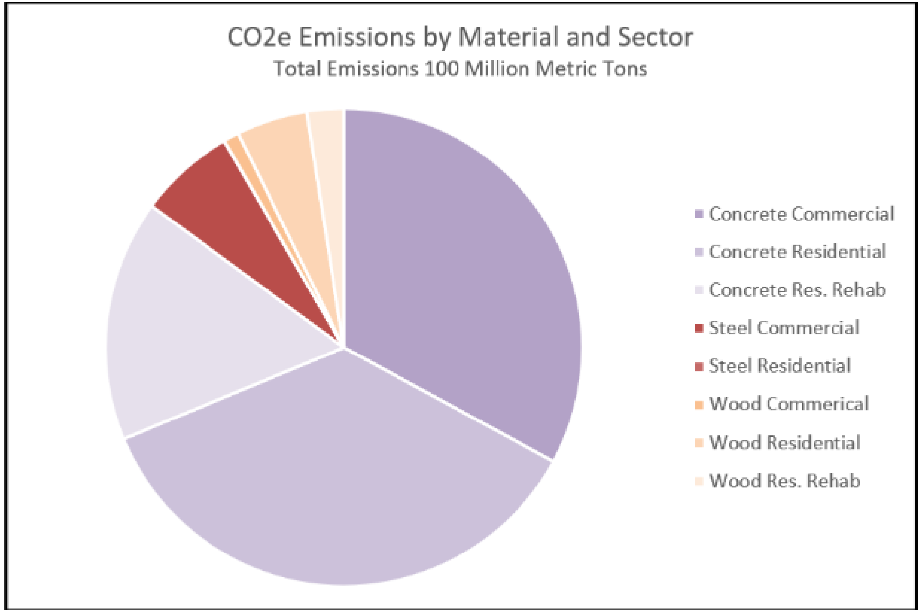


Figure 1-3: Annual CO_2e Emissions Associated with Structural Materials Used in New Construction in the United States by Building Sector

Sustainable Structural Design
4 Approaches

1. **Refine the Structural Design**
   a. Design optimization, materials and process specification
2. **Fabricate with Renewable Power Sources**
3. **Produce or Use Structural Materials More Efficiently**
4. **Employing "Carbon Offsets" (not ideal)**

Source: Achieving Net Zero Embodied Carbon in Structural Materials by 2050, SEI Sustainability Committee / Mark D. Webster, March 2020

1. Refining the Structural Design

We can *sharpen our pencils* in structural design. What might this include?

- Lighter structure (caution: the devil is in the details!)
- Optimization with architectural coordination
- Performance-Based Design (PBD):
    - Intensive coordination to develop objectives/requirements
    - Freedom in the “how”
- Resilient structure (longevity)

Potential: 10%-25% estimated emissions reduction

Source: Achieving Net Zero Embodied Carbon in Structural Materials by 2050, SEI Sustainability Committee / Mark D. Webster, March 2020

1. Refining the Structural Design (cont.)

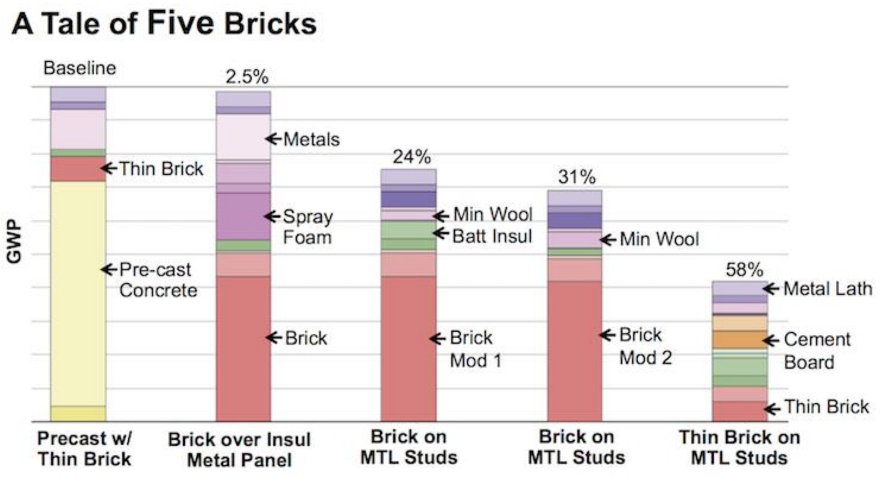
We can *sharpen our pencils* in the specifications also. What else might this include?

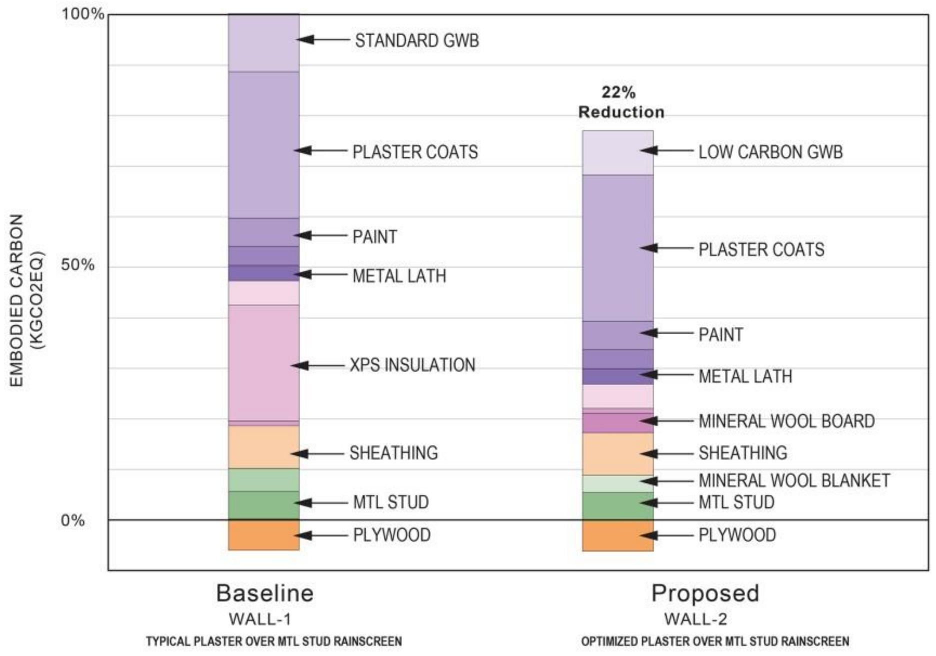
- The usual “percent recycled content” and “local sourcing”...but this alone is not enough
- Specifying better material additives and manufacturing processes (requires Design Team / Owner buy-in!) - i.e., blended cements
- Requiring modular / panelized construction (less waste)
- EDUCATION: working with Owners, Architects, and Suppliers to understand availability and benefits / costs to specifications

Potential: An additional 15-35% estimated emissions reduction

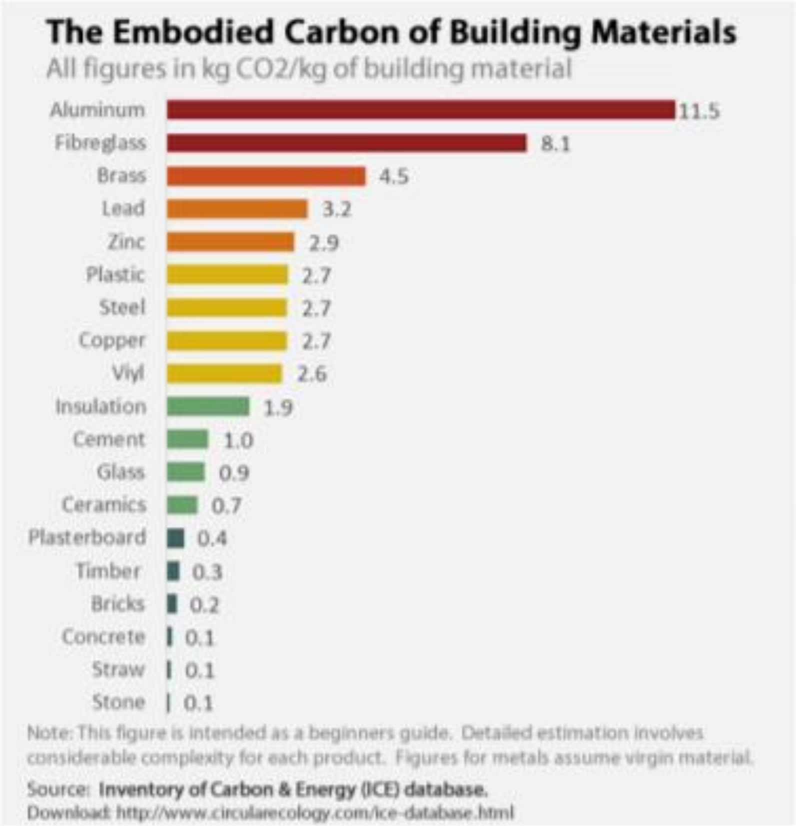
Source: Achieving Net Zero Embodied Carbon in Structural Materials by 2050, SEI Sustainability Committee / Mark D. Webster, March 2020

1. Refining the Design: EC in Materials





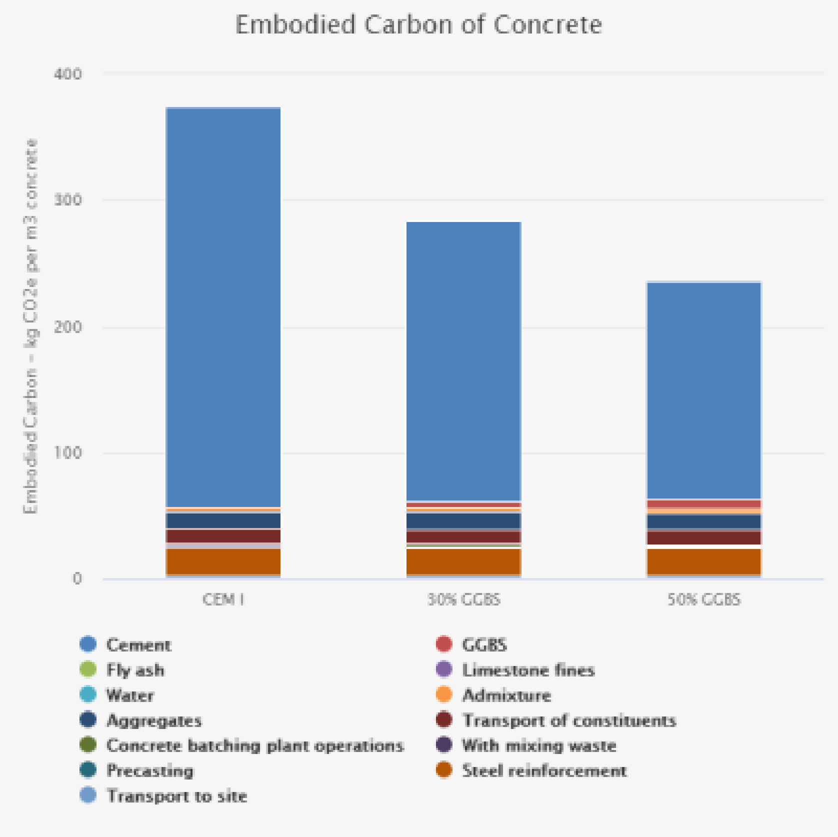
1. Refining the Design: EC in Materials

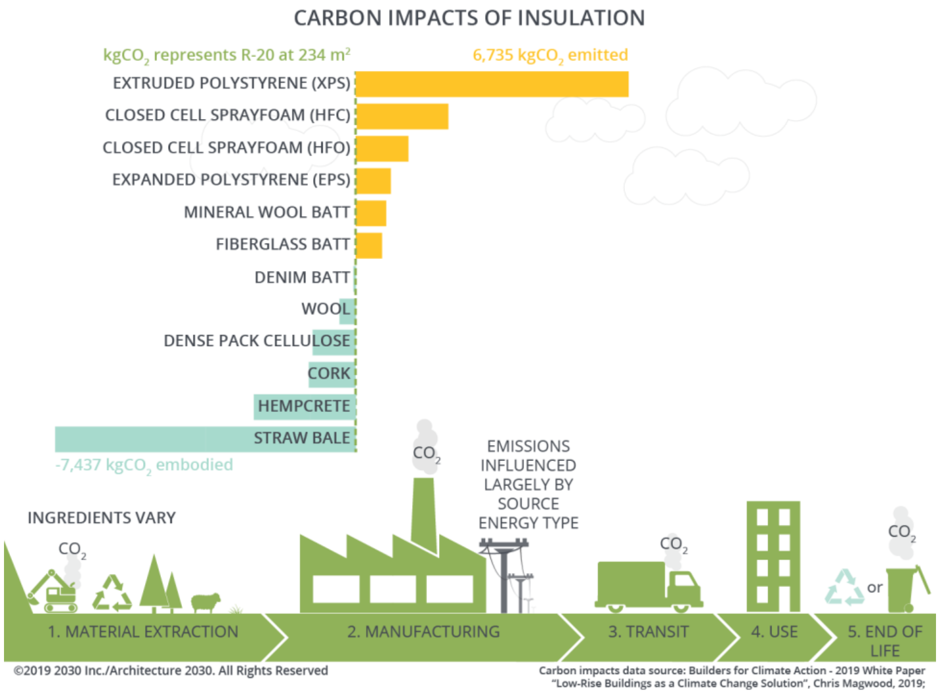


From BuildingGreen's "*The Urgency of Embodied Carbon and What You Can Do about It*":

- Structural systems almost always comprise the largest source of embodied carbon in the building—up to 80%, depending on the building type when looking at gross tonnage.
- The first goal when looking to reduce the embodied carbon of a project is to target the structural system.
- **Concrete** and **Steel** combined account for 11% of global CO2 emissions. Combustion during manufacturing process and cleanliness of the supporting energy grid contribute to embodied carbon.

1. Refining the Design: EC in Materials





1. Refining the Design: EC in Materials

The eight-mile-long, three-mile-wide Hull–Rust–Mahoning open pit iron mine in Hibbing, Minnesota was established in the late 1800s and is still producing iron ore.

Net Carbon Emissions of Common Construction Materials

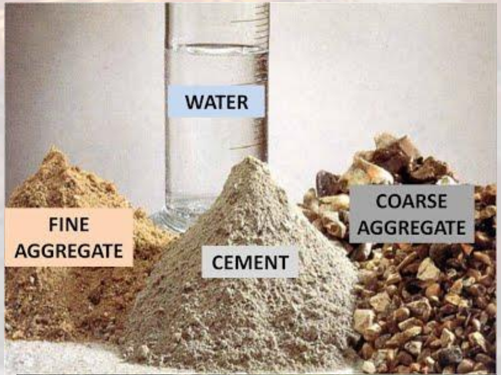
Material		Net carbon emissions (kilogram carbon/ton)	Near-term net carbon emissions, including carbon storage within material (kilogram carbon/ton)
Framing lumber		33	–457
Brick		88	
Glass		154	
Steel	100% recycled	220	
	Virgin	694	
Concrete		265	
Aluminum	100% recycled	532	
	Virgin	4,352	

2. Using Renewable Power in Fabrication

Partnering with the industry in a broader sense - materials manufacturers, suppliers, and so forth - is critical!

Selecting any part of the construction process, especially energy-intensive fabrication steps, that is on a green power source will noticeably impact the Embodied Carbon content of a project.

3. Producing Materials More Efficiently



When it comes to materials production, we have options!

- Cement processing via kiln
  - Alternative cement types (low-lime calcium silicate cement)
- Steel blast furnace type
  - Electric Arc or Energy-Optimized, vs. Coal-fired (“Blast furnace blast oxygen furnaces”, or BF-BOF)
- Wood harvesting
  - Sustainable forests certified by the FSC

3. Using Materials More Efficiently

How about adaptive reuse? It’s like “recycling” a building!

- Minimizes virgin material use (less new Embodied Carbon)
- May be eligible for historic tax credits
- Can reduce construction time and overall energy expenditure (again, less new EC)

Potential: 5%-15% estimated emissions reduction (adaptive reuse) , 5%-10% for salvaged material use

4. Employing Carbon Offsets

What is a "Carbon Offset"? The SEI Sustainability Committee defines it in their *White Paper on Net Zero by 2050* as:

"Investments in actions that reduce carbon emissions."

Combining Approaches for Embodied Carbon Reduction

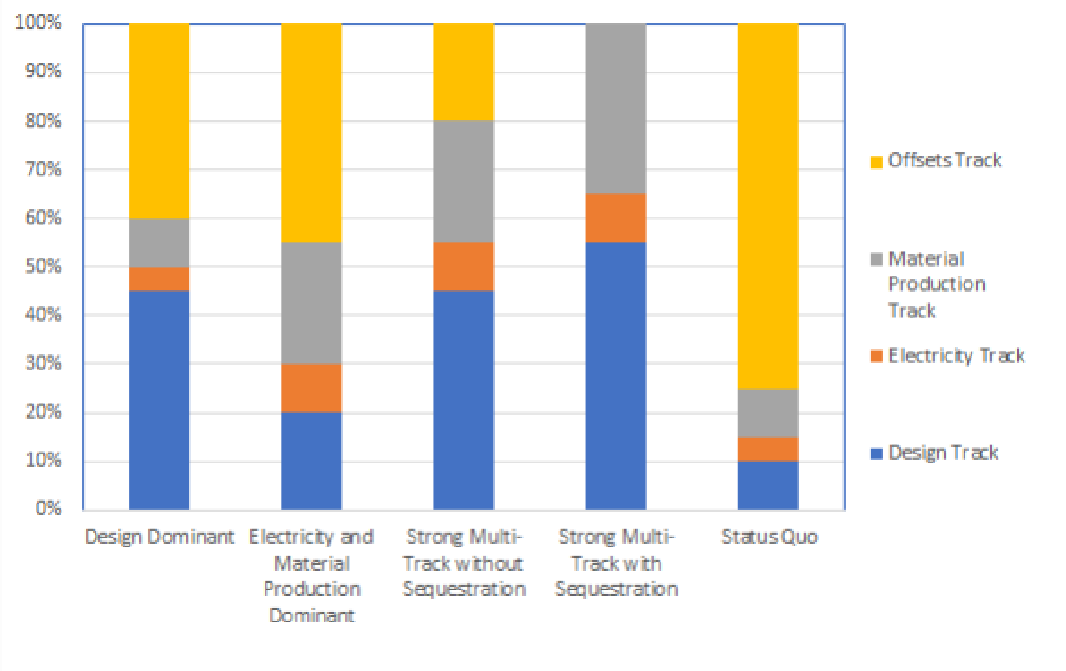
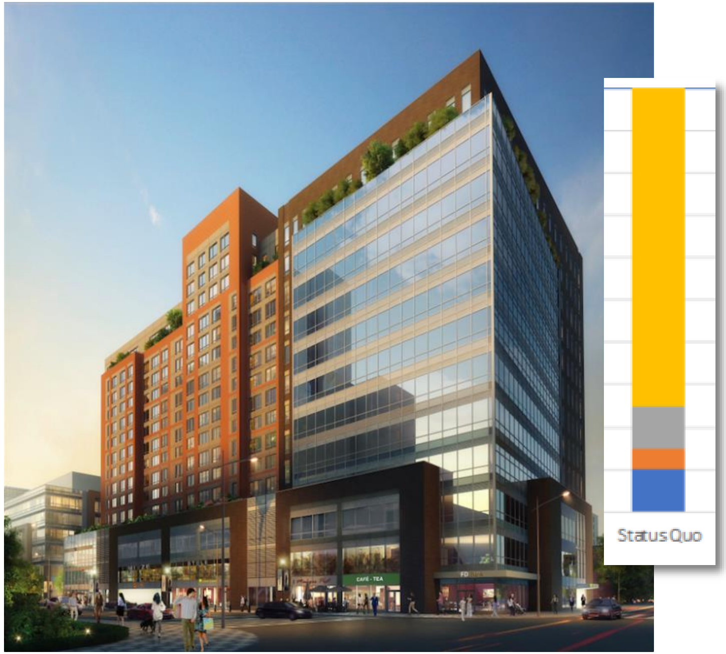


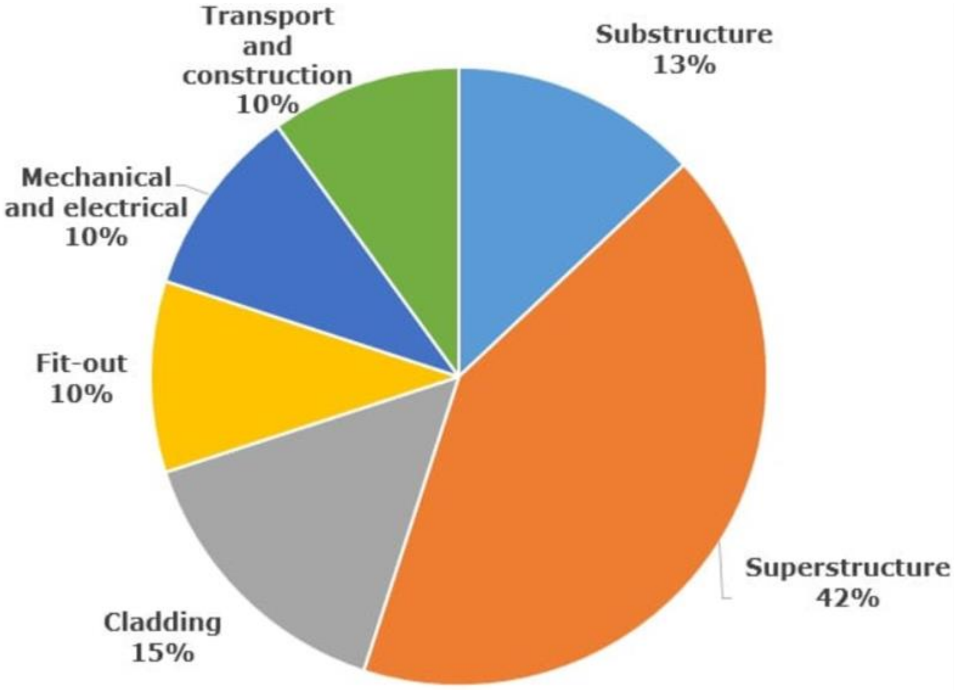
Figure 1-1: Some of the Possible Paths to Net Zero Embodied Carbon by 2050. Each bar represents different combinations of the four available reduction tracks.

Source: Achieving Net Zero Embodied Carbon in Structural Materials by 2050, SEI Sustainability Committee / Mark D. Webster, March 2020

Side-by-Side Visual for Multi-Tracks 3 and 5

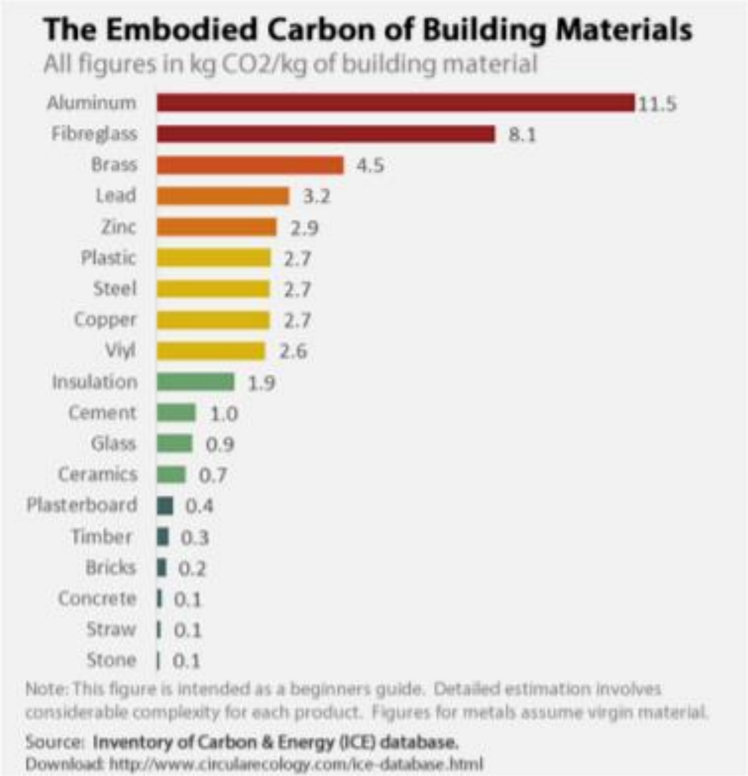


Embodied Carbon in MEP Systems



- MEP systems account for approximately 10% of the embodied carbon in new construction.
- MEP's contribution relies heavily on the type of building.
- 10% may not seem like a large chunk, but it doesn't tell the whole story
- Extremely important to analyze both MEP's *direct* and *indirect* contributions to the embodied carbon content of a building.

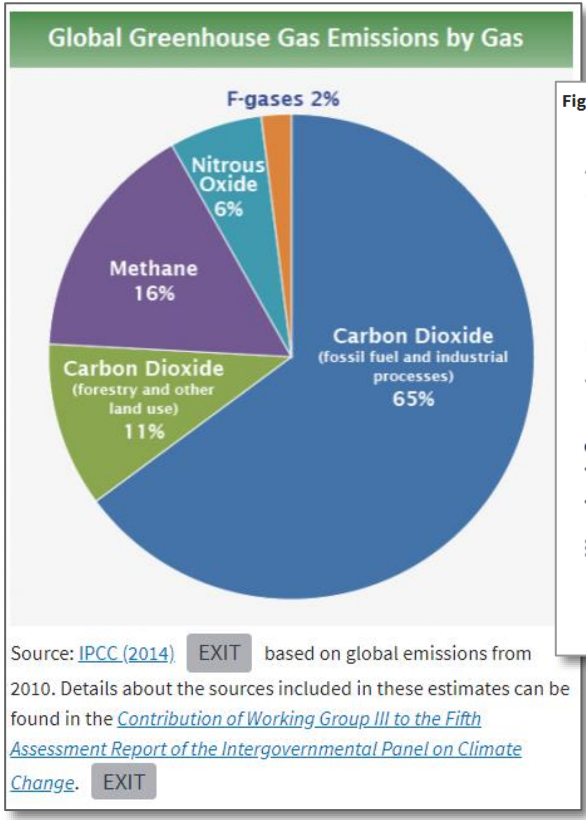
Embodied Carbon in MEP Systems:
Direct Impacts

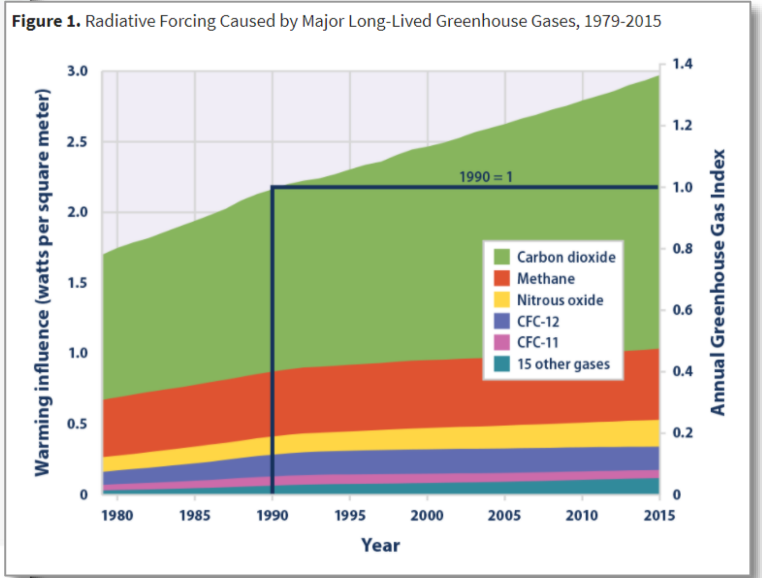


MATERIALS

- Primary materials used in MEP systems include:
    - Galvanized Steel & Aluminum (ductwork)
    - Insulation
    - Copper (wiring, piping)
    - Plastic (piping, wire sheathing)
- These materials have a high embodied carbon content.
- Groups like *Building Green* are pushing for more transparency from equipment manufacturers by asking for EPDs and point of origin on components used.

Embodied Carbon in MEP Systems:
Direct Impacts



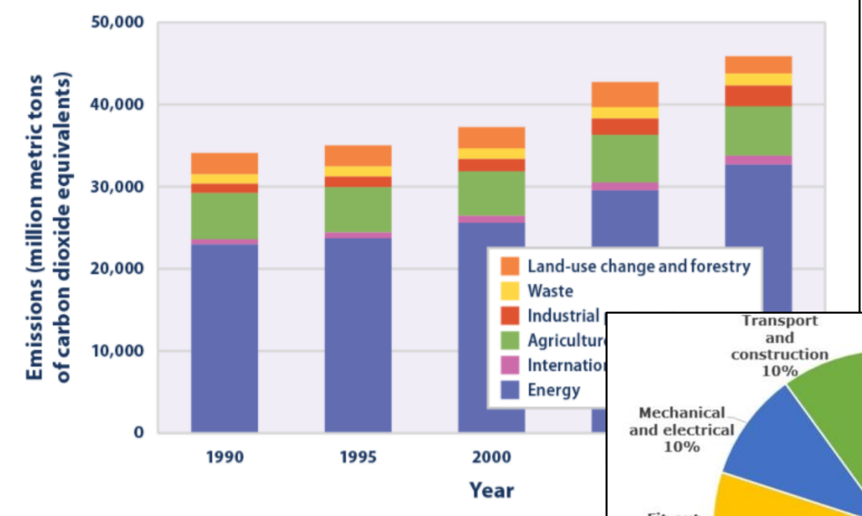


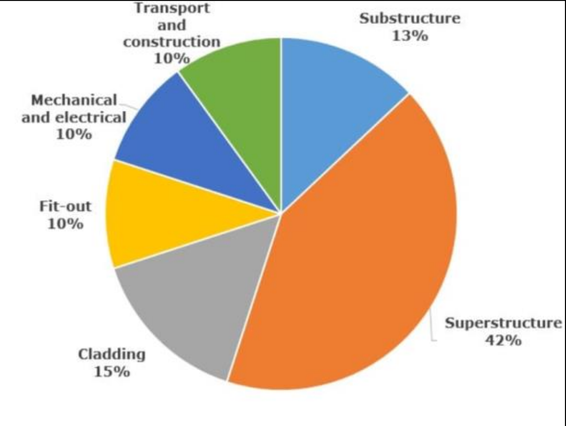
REFRIGERANTS

- Refrigerants' contribution to greenhouse gases is small, but still worth keeping in mind.
- As codes phase-out more harmful refrigerants, the overall contribution starts to level out.
- Radiative impacts need to be considered.
- Is there a future where cooling can be accomplished with harmless refrigerants?

Embodied Carbon in MEP Systems:
Indirect Impacts

Figure 2. Global Greenhouse Gas Emissions by Sector, 1990–2010

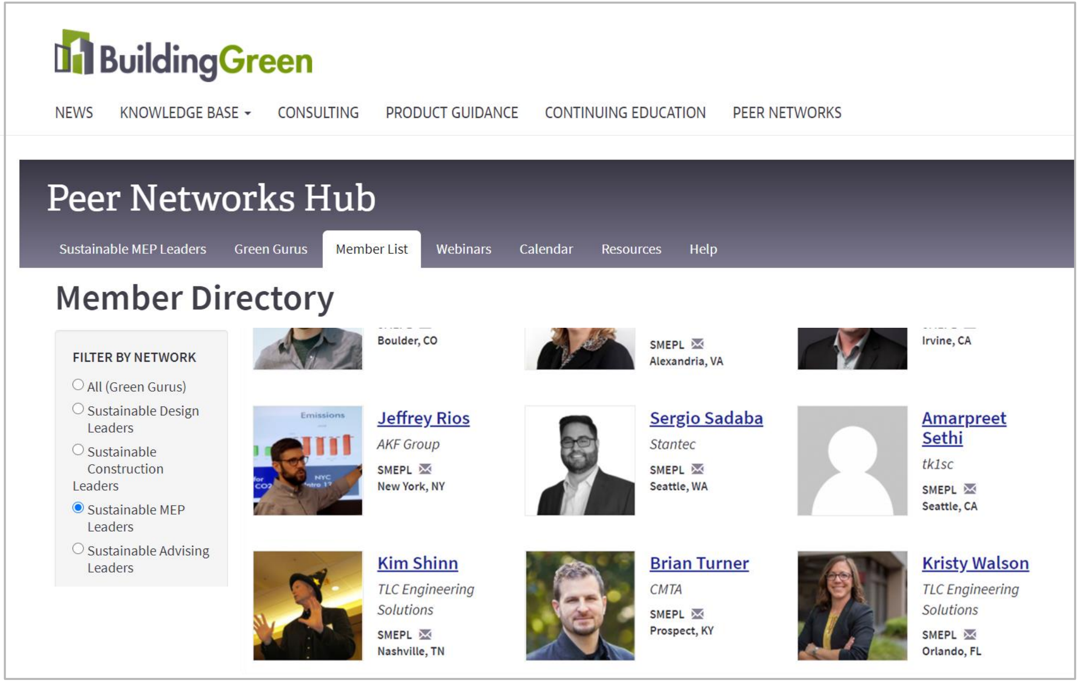




STRUCTURE

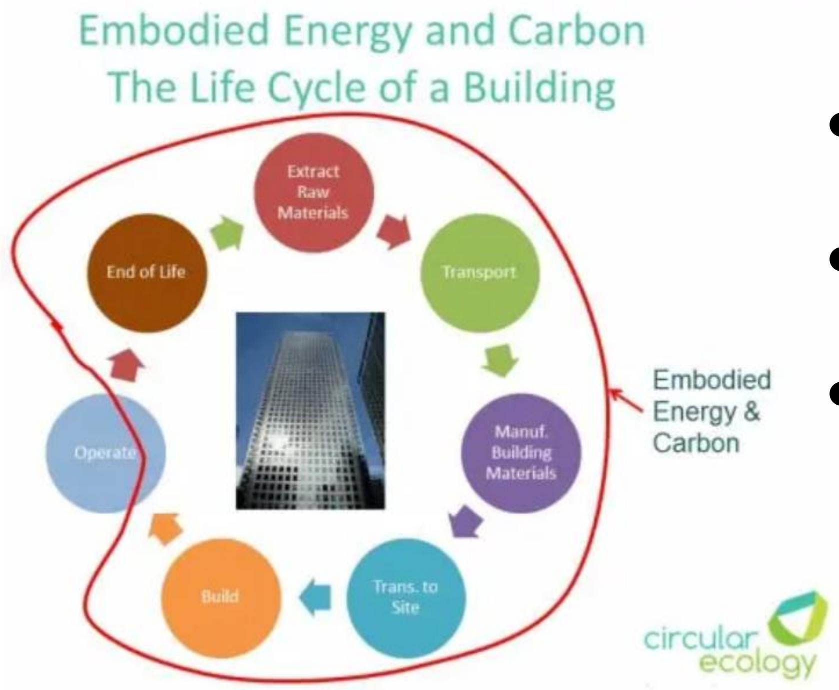
- While MEP’s main carbon impact is during operation, it’s still important to analyze MEP’s embodied carbon.
- Conscious sizing and locating of MEP equipment has a big impact on structure.
- Using the age-old practice of reducing heat loads in the building to decrease mechanical equipment sizes can also reduce structure size.
- Discuss options for locating equipment on grade aids in structure sizing reductions.

Embodied Carbon in MEP Systems:
Building Green Sustainable MEP Leaders



- Embodied Carbon Sub-Committee for MEP Systems
- Reviewing initial embodied carbon counts for standard equipment (source: UK)
- Crafting letter to MEP equipment manufacturer’s asking for EPDs and embodied carbon transparency
- Discussing if EPDs are the best “ask”.

Material End of Life Considerations



- LCA’s consider the *whole* life cycle of each product
- Inventory of Carbon & Energy (ICE) Database
- Beware of depending on recycling for end-of-life

Reducing Embodied Carbon during Design

Reduce, Reuse, Recycle
Utilize existing structures,
Use less material,
Reuse materials

Hold final design <u>accountable</u> for meeting target

01

02

03

04

Whole-Building Life-Cycle Analysis Tool
&
Databases like ICE

Set project Embodied Carbon target early in design

Where there traditionally has not been a significant role for structural engineers in the world of sustainability, they can now step into the forefront as pioneers towards decarbonizing the built environment.

Reducing Embodied Carbon during Design

LCA Tools and Carbon Calculators

	Analysis	Emissions Considered: Embodied Emissions	Emissions Considered: Operational Emissions	Emissions Considered: Data Regionalized or National Averages	Emissions Considered: Custom Assemblies for Input	Emissions Considered: Software Cost	Acceptability for G: LEED v4 credits	Acceptability for G: LEED cre
LCA Tools for Use in Pre-Design and Conceptual Design Phases								
Athena EcoCalculator for Commercial Assemblies	Early estimate simplified LCA (Note: software updates are no longer maintained, so data is somewhat out of date)	Yes	Yes	Regionalized	No			
Carbon Designer (One-click LCA add-on tool)	Early estimate simplified LCA with regionalized generic data	Yes	Yes (with add-on Life Cycle Carbon Tool)	National averages	Yes			
Whole Building LCA Tools for Use in Conceptual Design, Schematic Design, Design Development, and Construction Document Phases								
Athena Impact Estimator for Buildings	Detailed robust WBLCA	Yes	Yes	Regionalized	Yes			
Tally	Detailed robust WBLCA	Yes	Yes	National averages	Yes			
One-Click LCA	WBLCA with regionalized generic data and global EPD library	Yes	Yes	Both	Yes	for estimate		
Other Carbon Calculators								
EC3 (Beta Version)	EPD database, sortable by upfront embodied carbon enabling comparisons of products within like categories; roll-up into total building carbon footprint	Yes	No	Based on product-specific EPDs (currently national averages for wood products)	No	Free	Pilot credit	Pilot c
WoodWorks Carbon Estimator	Rough estimate based on wood building type (wood structure only)	Yes	No	National averages for wood products	No	Free	No	N
WoodWorks Carbon Calculator	Detailed estimate based on wood products used (wood structure only)	Yes	No	National averages for wood products	No	Free	No	N

SE2050 COMMITTING TO ZERO

ECOM

ECOM is a simple embodied carbon estimator to calculate the approximate (E)mbodied (C)arbon (O)rder of (M)agnitude based on your structural material quantities.

Calculate Now

Who is Responsible for Embodied Carbon?


VT
VS
V

Who is talking about Embodied Carbon?

BuildingGreen

LEED
LEADERSHIP IN ENERGY & ENVIRONMENTAL DESIGN

CLF Carbon Leadership Forum

LIVING BUILDING CHALLENGE

architecture 2030

SEI STRUCTURAL ENGINEERING INSTITUTE ASCE

SE2050 COMMITTING TO ZERO

circular ecology

CALL TO ACTION

- Embodied Carbon science is still *new* and *evolving*. Don't let the uncertainties keep you from doing *something.*
- Tools exist and are readily available to start carbon accounting on your next project.
- Focusing on only the structural materials can have a significant impact.
- Set goals early, make decisions that support these goals, and <u>hold the final project accountable</u> for meeting the goal.
- With the success of high performance design, embodied carbon's environmental impact will soon surpass operational carbon's.

THINK. LISTEN. CREATE.®

Resiliency vs. Low Embodied Carbon

Brian & Kristy Meeting Notes

- Don’t let the uncertainties and disagreements on this topic keep you from doing *something.*
- Differentiate between **conventional lumber** and **mass timber**.
- Distinction between **concrete** and **cement**.
- Cannot have **concrete** without **steel**.
- Architecture *matters!!!!* Both in operational & embodied. - *Include this as a statement, not a slide.*
- We’ve already been down this road with operational carbon and we are succeeding. Take the lessons learned from the operational carbon journey to make the embodied carbon journey quicker and just as successful.
- We know a few things because we’ve seen a few things. A successful project needs trust between consultants.
- Show parallel between Arch2030 and SE2050 programs
- Mechanical & Structural Engineers need to talk **<u>MORE</u>**. Provide added value for each and for our clients.
- If VT vs. UVa Grads can work together, so can architects & engineers.

Learning Objectives

1. Participants will be able to define what constitutes "embodied carbon" and the important role design can play in reducing embodied carbon content in our buildings with respect to Architecture 2030 and the SE 2050 Challenge. **BRIAN & KRISTY**

2. Participant will be able to identify options in the "road map" for reducing the embodied carbon content and global warming potential of our buildings through sustainable structural design, with an examination of framing systems, project specifications, and architectural influences. **BRIAN**

3. Participants will understand the various "levers we can pull" in design for the mechanical, electrical, and plumbing systems of a building so as to have a sustainable impact on the embodied carbon content and global warming potential of the final building product, with a focus on refrigerants. **KRISTY**

- **HVAC plays a large role in operational carbon**
- **Mechanical systems effect structural systems. Can we put this eqp on the ground instead of the roof? Reduce structural sizing.**
- **SMEPL Embodied Carbon Subcommittee - Focusing on asking manufacturers to build the data**
- **Refrigerant is trending downward**
- **Science is still catching up**
- **Can't forget about MEP!**

4. Participants will be able to apply the challenges presented to their design teams so they consider the impact that Owners and Architects can have in facilitating the reduction of EC in their buildings. They will leave equipped to communicate the benefits of early discussions with technical experts, setting embodied carbon targets, and evaluating the

Course Description

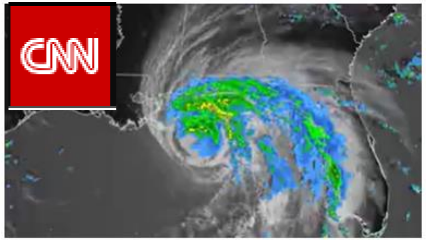
Sustainable buildings are crucial to the future of the human race and societies at large. The embodied carbon (EC) content of buildings in their structures and systems can be a tremendous contributor to the Global Warming Potential (GWP) of a building as a final product. There are numerous decision points in the process of visioning and designing a building at which the EC content can be reduced dramatically, enabling us to build with far less impact on global warming than is currently the case.

As firm believers in this, Kristy Walson and Brian McSweeney of TLC Engineering Solutions will be engaging the design and ownership community to raise their awareness of the action steps they can take with their buildings and designs to provide a sustainable future. They will lay out the definition of EC and the sources of EC in buildings from a structural engineering and mechanical, electrical, and plumbing systems perspective. This presentation will also cover recent research in the field of buildings and embodied carbon, with an eye to increasing our sustainability in design.

Kristy and Brian will then demonstrate the many ways in which engineers, architects, and owners can leverage their role and the available tools in the industry to reduce the embodied carbon content of their buildings. They will examine in detail the options available to design teams for EC reduction and discuss the contributions of Architecture 2030 and the SE 2050 challenge to making it possible to build sustainably.

September 15, 2020 Headlines

CNN



A crawling Hurricane Sally is threatening a 'historic rainfall event'

- Tracking Sally's path
- **Live updates:** Hurricane Sally went into rapid intensification. Here's what that means.

MSNBC

West Coast Wildfires

California official who challenged Trump on climate denial 'Perfect...

As the West Coast burns from massive wildfires, Trump thinks he knows...

Oregon governor: If we don't t... collective action, wildfires 'wi...

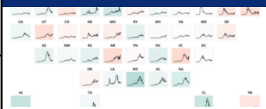
FOX NEWS 10:25 AM

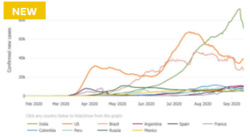
Trump says COVID vaccine weeks away as Dems express concerns over safety

Coronavirus knocks banks off M&A radar: Bank CEO

CEO of largest vaccine maker says world won't have total inoculation until this date... at best

JOHNS HOPKINS UNIVERSITY & MEDICINE | CORONAVIRUS RESOURCE CENTER





NEW CASES OF COVID-19 IN US STATES

Have states flattened the curve?

See if new cases are rising or declining as states reopen.

TESTING TRENDS TOOL

Track trends in COVID-19 cases and tests

See an overview of key testing metrics in each U.S. state

NEW CASES

Have countries flattened the curve?

Daily confirmed new COVID-19 cases for the 20 most affected countries over time.

Why Israel's peace deals with Gulf states matter

Gulf states see opportunities for trade while Israel lessens its isolation, writes Jeremy Bowen.

15h Middle East

Poisoned Navalny 'will return to Russia'

The opposition figure posted on Instagram, announcing that he was breathing free of ventilation.

3m Europe

LIVE **UK government under pressure over lack of tests**

7m Warning over Test and Protect phone scam

17m Can the UK testing shortage be solved?

23m The Netherlands 'sees record daily rise'

'My children's classroom is our car'

Meet the resilient mother who oversees "school" near a wi-fi hotspot because they lack internet at home.

16h US & Canada

Fire erupts in shopping centre near Beirut's port

2h World

US nurse alleges 'hysterectomies on migrant women'

2h US & Canada

Hong Kong's dolphins make pandemic comeback

5h China

The New York Times

Account

Tuesday, September 15, 2020

Today's Paper

Gulf Coast Prepares for Deluge From Hurricane Sally

Officials urged people to prepare for "life-threatening" flash floods, torrential rains and strong winds. "This is the real deal," Mississippi's governor said.

Live

Don Robin made sure an oyster boat was secure as the water rose on Monday in St. Bernard Parish, La.
Chris Granger/The Advocate, via Associated Press

The Washington Post

Democracy Dies in Darkness

September 15, 2020

Edition: U.S. & World | Regional

Election 2020

Devastating fires inject climate change into presidential campaign

Joe Biden attacked President Trump on his environmental record while the president again shrugged off the science behind global warming.

By Seung Min Kim and Brady Dennis