A Sustainable Future: Understanding Embodied Carbon in Buildings





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



TIME SERIES: 1884 TO 2019

Data source: NASA/GISS Credit: NASA Scientific Visualization Studio



TIME SERIES: 1884 TO 2019

1884

Data source: NASA/GISS Credit: NASA Scientific Visualization Studio

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?

Overview of Greenhouse Gas Emissions in 2018



Total Emissions in 2018 = 6,677 <u>Million Metric Tons of CO₂</u> equivalent. Percentages may not add up to 100% due to independent rounding. Source: Global Alliance for Buildings and Construction. 2018 GLOBAL STATUS REPORT.

- 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





Carbon: Operational vs. Embodied

Embodied Carbon Operational Carbon Total Carbon Emissions of Global New Construction from 2020-2050 Occurs only during occupancy of Occurs during full lifecycle of **Business as Usual Projection** the building & can be reduced over building and is locked-in when time through energy efficiency the building opens. 50% 49% 51% measures. 40% % Carbon Emissions Embodied carbon will be responsible for almost half 109 of total new construction emissions 0% between now and 2050. EMBODIED OPERATIONAL CARBON CARBON © 2018 2030, Inc. / Architecture 2030. All Rights Reserved, Data Sources: UN Environment Global Status Report 2017; EIA International Energy Outlook 2017





AIA Framework for Design Excellence



Measure 6 DESIGN FOR ENERGY

DESIGN FOR WELLNESS

Measure 2 DESIGN FOR COMMUNITY





Measure 7

Measure 4 DESIGN FOR WATER



Measure 5
DESIGN FOR ECONOMY



image credit: AIA COTE

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

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

<u>Zero Waste Guidelines</u>







THE 2030 CHALLENGE FOR EMBODIED CARBON

Buildings, Infrastructure, and Materials



Making a Difference Now, For the Future

COMMITTING TO NET ZERO

We are a community of progressive structural engineers who endorse the global vision of net zero carbon building. Whether you are a structural engineer, architect, contractor, owner or someone in between, we invite you to join us in the movement in promoting, designing and constructing net zero embodied carbon structures by 2050!

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 CO₂e Emissions Associated with Structural Materials Used in New Construction in the United States by Building Sector

Sustainable Structural Design: 4 Approaches



Refine the structural design (design optimization, materials and process specification)

Fabricate with renewable power sources.

Produce or use structural materials more efficiently.

Utilize "carbon offsets" (not ideal)

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

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

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

Refining the Design: Embodied Carbon (EC) in Materials

100%



Baseline WALL-1 TYPICAL PLASTER OVER MTL STUD RAINSCREEN

STANDARD GWB

Proposed WALL-2 OPTIMIZED PLASTER OVER MTL STUD RAINSCREEN

- PAINT

- METAL LATH

- SHEATHING

- MTL STUD

- PLYWOOD

- MINERAL WOOL BOARD

MINERAL WOOL BLANKET

- LOW CARBON GWB

- PLASTER COATS

22% Reduction

Refining the Design: Embodied Carbon (EC) in Materials

The Embodied Carbon of Building Materials

All figures in kg CO2/kg of building material

Aluminum					11.5
Fibreglass				8.1	
Brass			4.5		
Lead		3.2			
Zinc		2.9			
Plastic		2.7			
Steel		2.7			
Copper		2.7			
Viyl		2.6			
Insulation		1.9			
Cement	1.0				
Glass	0.9				
Ceramics	0.7				
Plasterboard	0.4				
Timber	0.3				
Bricks	0.2				
Concrete	0.1				
Straw	0.1				
Stone	1 0.1				

Note: This figure is intended as a beginners guide. Detailed estimation involves considerable complexity for each product. Figures for metals assume virgin material.

Source: Inventory of Carbon & Energy (ICE) database. Download: http://www.circularecology.com/ice-database.html

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.

Refining the Design: EC in Materials



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.

Photo: Chipcity. License: CC BY-SA 3.0.

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					
Charles 1	100% recycled	:	220				
Steel	Virgin	694					
Concrete		:	265				
AL .	100% recycled		532				
Aluminum	Virgin	4,352					

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.



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

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



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 EC 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

The Embodied Carbon of Building Materials

All figures in kg CO2/kg of building material



Note: This figure is intended as a beginners guide. Detailed estimation involves considerable complexity for each product. Figures for metals assume virgin material.

Source: Inventory of Carbon & Energy (ICE) database. Download: http://www.circularecology.com/ice-database.html

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



Change. EXIT

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



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



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		Emissions Considered					Acceptabil	lity for G		
	Analysis	Embodied Emissions	Operational Emissions	Data Regionalized or National Averages	Custom Assemblies for Input	Software Cost	LEED v4 credits	LEED crec		
LCATools 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	6520	ĒÒ			
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			(PAPA		
Whole Building LCA Tools for Use in Conceptual Design, Schematic Design, Design Development, and Construction Document Phases						ECOM ECOM is a simple embodied carbon estimator to calculate the approximate (E)mbodie				
Athena Impact Estimator for Buildings	Detailed robust WBLCA	Yes	Yes	Regionalized	Yes	 (C)arbon (O)rder of (M)agnitude based on your structural material quantities. 				
Taliy	Detailed robust WBLCA	Yes	Yes	National averages	Yes			Calculate Now		
One-Click LCA	WBLCA with regionalized generic data and global EPD library	Yes	Yes	Both	Yes	for estimate	105			

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 (
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	





Who is talking about Embodied Carbon?



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</u> <u>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.