Embodied Carbon Emissions in Buildings

Presented by

Bill Updike
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 (e.g., concrete carbonation but excluding operational carbon), maintenance, repair, replacement, refurbishment, deconstruction, transport to end of life facilities, processing, disposal. - **WorldGBC**

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 m$^2$ (2.5 trillion ft$^2$) 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.

![Global CO₂ Emissions by Sector](chart.png)

Embodyed 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.
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**
ASHRAE DRIVING TOWARDS NET ZERO

Target:
All buildings zero carbon by 2050
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)
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)
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)

2017

1. BC BUILDING CODE
   - Enhanced Compliance

2. INCENTIVES
   - 20-40% better

3. INCENTIVES AND/OR REQUIREMENTS
   - 50% better

4. NET ZERO READY
   - New Construction

2032

imagine | accelerate | perform | sustain

INTEGRAL
Revolutionary Engineering
Embodied Carbon | DC POLICY HISTORY

2006:
- Green Building Act
- Created the Green Building Fund
- Set minimum green building standards (LEED)

2008:
- Clean Affordable Energy Act
- Created DC PACE

2010:
- Energy Efficiency Financing Act
- Launched DCSEU & benchmarking and disclosure program

2012:
- Sustainable DC Plan
- Enabled community solar

2013:
- Community Renewables Act
- Developed a long-term plan for sustainability in the built environment

2014:
- Green Area Ratio
- Green Codes
- Implemented environmental sustainable zoning

2016:
- RPS Update
- Climate Ready DC
- Adopted 2012 IgCC
- Identification of Solar for All

2018:
- Green Bank
- Clean Energy DC
- Net Zero Code
- Identified Climate Resilience Strategies for Buildings & Development
- Creation of Solar for All
- Bill Signed in April
- Code Issued for Public Comment on 9/31
- Bill Introduced in July
Embodied Carbon | DC ZERO ENERGY CODE

- Net Zero Code for Residential – 2021
- Net Zero Code for Commercial – 2026
- DC easing the path for adoption/structural incentives
- DC also beginning to offer some financial Incentives (DC SEU, DCRA, DOEE, DC Green Bank)

<table>
<thead>
<tr>
<th>Tabular Data</th>
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</thead>
<tbody>
<tr>
<td>Assumed Incremental Cost</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Office New Construction</td>
</tr>
<tr>
<td>Multifamily New Construction</td>
</tr>
<tr>
<td>Office Renovation</td>
</tr>
</tbody>
</table>

MEDIAN EUI FOR BUILDINGS IN DC
62.4 kBtu/SF/yr

MEDIAN EUI FOR NET ZERO BUILDINGS
22.6 kBtu/SF/yr (source: NBI)
Embodied Carbon | RAPIDLY CHANGING LANDSCAPE

Imagine | accelerate | perform | sustain
Embodied Carbon | TOOLS

BUILDING LCA TOOLS

- tally
- Athena Sustainable Materials Institute
- EC3

DATABASES

- GaBi Database Content
- European Commission
- QUARTZ
- ecovent

INDUSTRY DATA

- EUROFER The European Steel Association
- FEFCO European Federation of Corrugated Board Manufacturers
- Worldsteel Association
- International Aluminium Institute
Embodied Carbon | EPDs

Environmental Product Declarations – Show Transparency Like Food Labeling
Embodied Carbon | EC3 TOOL

EC3
Embodied Carbon Calculator for Construction

Tower #2, California, 2021
Embodied Carbon | TALLY TOOL

Acoustical Tile Ceiling (ACT)  
Existing

Gypsum Board Ceiling  Existing
Embodied Carbon | CARBON SMART MATERIALS PALETTE
Embodied Carbon | MATERIALS

Source: Simpson, Gumpertz & Heger
• 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
Concrete Accounts for ~6-7% of All GHG Emissions Globally

China used more cement in the last three years than the U.S. used in the entire 20th century.

Sources: USGS, Cement Statistics 1900-2012; USGS, Mineral Industry of China 1990-2013
Supplementary Cementitious Materials Can Replace 50% (and Sometimes More) of the Portland Cement in Concrete
ZERO/NEGATIVE CARBON CONCRETE IS COMING!
Embodied Carbon | STEEL

ZERO CARBON STEEL IS COMING!

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

In the small town of Luleå in northern Sweden, SSAB has teamed up with Vattenfall and LKAB to build a pilot plant for the world’s first fossil-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
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

- Extruded Polystyrene (XPS): 6,735 kgCO₂ emitted
- Closed Cell Sprayfoam (HFC): kgCO₂ represents R-20 at 234 m²
- Closed Cell Sprayfoam (HFO)
- Expanded Polystyrene (EPS)
- Mineral Wool Batt
- Fiberglass Batt
- Denim Batt
- Wool
- Dense Pack Cellulose
- Cork
- Hempcrete
- Straw Bale
- -7,437 kgCO₂ embodied

INGREDIENTS VARY

1. Material Extraction
2. Manufacturing
3. Transit
4. Use
5. End of Life

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
During photosynthesis, plants capture gaseous carbon from the atmosphere. That carbon is stored in the plants themselves, as well as in the soil.
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.
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!
How do you compare different insulation products’ avoided CO₂ emissions in the use phase?

\[
\text{Emissions Delta} = \text{GHG Emissions baseline (initial R)} - \text{GHG Emissions (upgraded R)}
\]

**Key Variables**
- Initial R of base external wall
- Added R from insulation
- Climate
- HVAC Technology
- Fuel/Electricity Sources

**Operational Savings**
GHG Savings Model from Reduced Heating and Cooling Load
Global Warming Potential (GWP) in kgCO2e; Functional unit: 1m2 of foam 4” thick

**Perceived best choice**

<table>
<thead>
<tr>
<th></th>
<th>4” EPS (R=3.8/in)</th>
<th>4” PolyIso (R=6.5/in)</th>
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<tbody>
<tr>
<td><strong>Cradle to Gate</strong></td>
<td>7.04e0</td>
<td>18.4e0</td>
</tr>
<tr>
<td><strong>Construction</strong></td>
<td>3.47e-1</td>
<td>6.50e-1</td>
</tr>
<tr>
<td><strong>Building Use</strong></td>
<td>Not Included</td>
<td>Not Included</td>
</tr>
<tr>
<td><strong>End of Life</strong></td>
<td>1.02e-2</td>
<td>2.19e-2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>7.40e0</td>
<td>19.1e0</td>
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Global Warming Potential (GWP) in kgCO2e; Functional unit: 1m2 of foam 4” thick

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<tr>
<td><strong>Building Use</strong></td>
<td>442 SAVED</td>
<td>504 SAVED</td>
</tr>
<tr>
<td><strong>End of Life</strong></td>
<td>1.02e-2</td>
<td>2.19e-2</td>
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<tr>
<td><strong>Total</strong></td>
<td>435 SAVED</td>
<td>485 SAVED</td>
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**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

Better choice: 4” Polyliso (R=6.5/in)
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 → LCA MODELING → DESIGN DEVELOPMENT → LCA MODELING → 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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