Embodied Carbon

When it comes to building decarbonization, many professionals are familiar with operational carbon, which refers to the greenhouse gases (GHG) emitted from energy use (electricity and fossil fuels) for building operations. As California State building codes (Title 24) increase building energy efficiency, the relative proportion of a building's embodied carbon will increase compared to operational carbon. Professionals are quickly becoming familiar with embodied carbon as the state legislature has passed bills like Buy Clean California that require limited embodied carbon in building products on state-funded projects.

What is Embodied Carbon?

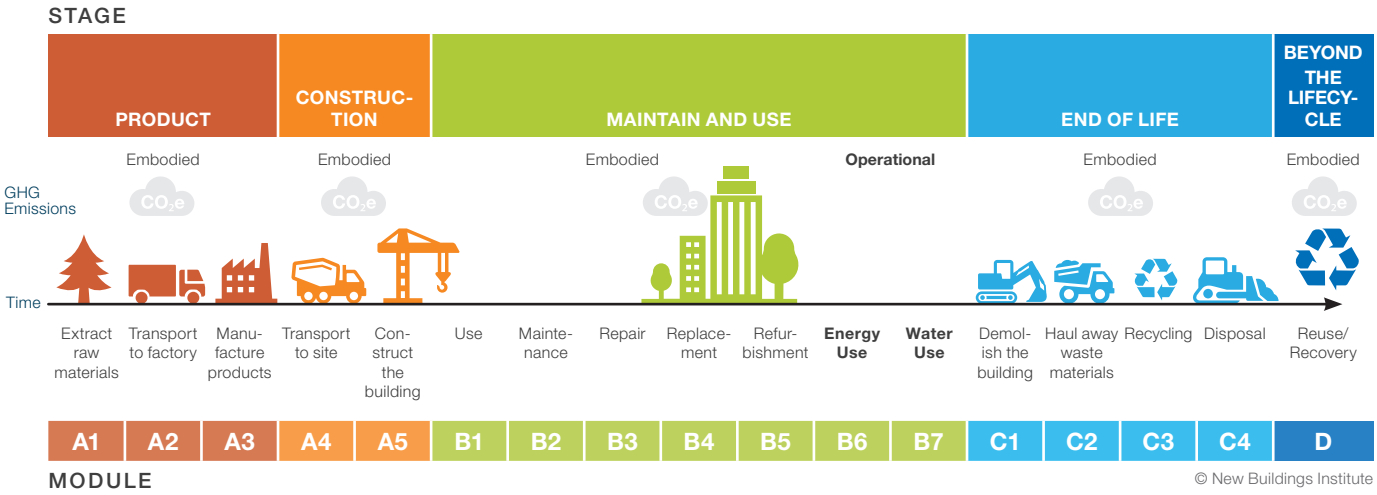
Embodied carbon refers to the GHG emissions from the non-renewable energy associated with raw material extraction, manufacturing, transportation, installation, maintenance, and disposal of building materials. Upfront embodied carbon relates to stages A1-A3 in a product's lifecycle, also called cradle-to-gate (see Figure 1).

Why Focus on Embodied Carbon?

Worldwide, 39% of all emissions come from buildings, with 11% from building materials and construction (embodied carbon), according to the International Energy Agency. Embodied carbon emissions are expected to increase due to a growing global demand for construction to accommodate population growth and the need to replace aging infrastructure. The 2018 United Nations Intergovernmental Panel on Climate Change report states that we must reduce emissions by 45% by 2030 to have a chance of limiting warming to under 1.5°C. In addition, California's goal is to reduce economy-wide emissions by 40% by 2030 from 1990 levels, and 80% by 2050. With these strict timelines to mitigate the impacts of climate change, it becomes imperative to address embodied carbon.

LIFECYCLE STAGES

Data source: BS EN 15978:2011



Most LCAs, WBLCAs, and EPDs focus on stages A1-A3: the extraction of raw materials, transport to the factory, and manufacturing of the products. Stage A has the biggest potential for embodied carbon reduction.

While a building's operational carbon can be reduced throughout its lifetime via energy efficiency improvements and retrofits, most of the embodied carbon of a building is already emitted once it has been constructed. Not much can be done to reduce its embodied carbon after construction. For highly efficient buildings, embodied carbon accounts for over 50% of a building's total emissions, further strengthening the case for mitigating embodied carbon.

How is Embodied Carbon Measured and Represented?

Each building product has a specific amount of embodied carbon, which is measured by the product's **global warming potential (GWP).** The GWP is represented by kg of CO_2-equivalent (kg-CO_2e) per weight or area of the product and per embodied carbon module (See Figure 1).

A product-level **life cycle assessment (LCA)** is a study that uses a preapproved analysis (ISO 14040) to determine the environmental impacts. Similarly, measuring the impact of an entire building is referred to as a **whole building life cycle assessment (WBLCA).** A **product category rule (PCR)** defines (as detailed by International Organization for Standardization (ISO) 14025) how a product's LCA data will be communicated in the easier-to-read format developed by a third-party professional, known as an **environmental product declaration (EPD).**

EPDs quantify the environmental impact of a product, including GHG emissions. EPDs can be for a product's industry average GWP (industry-wide EPD), the product from one company (product-specific EPD), or the product from a particular factory (facility-specific EPD). EPDs are growing in number as third-party rating systems and policies that aim to reduce embodied carbon emissions are requiring Type III EPDs.

How Do Designers Select Low Carbon Materials?

RMI's Reducing Embodied Carbon in Buildings report showed a potential 46% whole building embodied carbon reduction with less than a 1% total cost premium, illustrating that cost-effective, low-carbon solutions exist today to reduce construction emissions. The table on the next page summarizes the emissions reduction potential per product and the total-project cost premium of using low-carbon versions of various building materials.

Studies show that cost-effective, low-carbon solutions exist today to reduce construction emissions. Using less product, recycled content, and selecting low-carbon alternatives are some of the easiest and most effective ways to reduce building embodied carbon emissions.

What can Building Professionals Do?

Building professionals informed about the strategies and resources available to reduce embodied carbon will be better prepared to meet the changing market trends and policies while helping us collectively achieve our climate and environmental goals.

Everyone on the building design and construction team has an opportunity to reduce the total embodied carbon footprint. Low-carbon decisions are best made early in the design process with an integrated design approach.

Owners:

Ask about embodied carbon, how to reduce it, and set total GWP per square foot goals. Require building and material reuse.

Architects:

Minimize materials and specify recycled and low carbon materials. Set an embodied carbon budget based on WBLCAs of similar types of buildings. Design buildings for resiliency, longevity, and reuse. Request EPDs from manufacturers and set GWP limits for materials used in high quantities.

Structural engineers:

Efficiently design structural systems for material efficiency, longevity, and flexibility for future reuse.

Contractors:

Procure lower-carbon products, reuse materials from previous projects, and minimize fossil fuels on-site.

Mechanical engineers:

Select heat pump systems that use low-GWP refrigerants and minimize duct and pipe runs.

Cost-effective, Low Carbon Product Selection

Concrete

Actions to Reduce Carbon
Substitute cement with alternative cementitious materials (ACM). Choose recycled aggregate. Select structural shapes and sizes that use less material while keeping the same structural integrity.

Emissions Reduction Potential
14-33%

Cost Premium
No to low

Structural Steel

Actions to Reduce Carbon
Specify CA or U.S.-made steel and steel with high recycled content. Prioritize electric arc furnace (EAF) production over basic oxygen furnace (BOF) production.

Emissions Reduction Potential
1-10%

Cost Premium
1%

Rebar

Actions to Reduce Carbon
Use 97% or higher recycled content rebar. Select a structural concrete design that uses less material while keeping the same structural integrity.

Emissions Reduction Potential
4-10%

Cost Premium
No to low

Insulation

Actions to Reduce Carbon
Replace foam (especially XPS) will lower-carbon materials, like cellulose and mineral wool batt.

Emissions Reduction Potential
16%

Cost Premium
No

Glazing

Actions to Reduce Carbon
Select low-carbon window frame materials. Specify no more than two panes of glazing.

Emissions Reduction Potential
3%

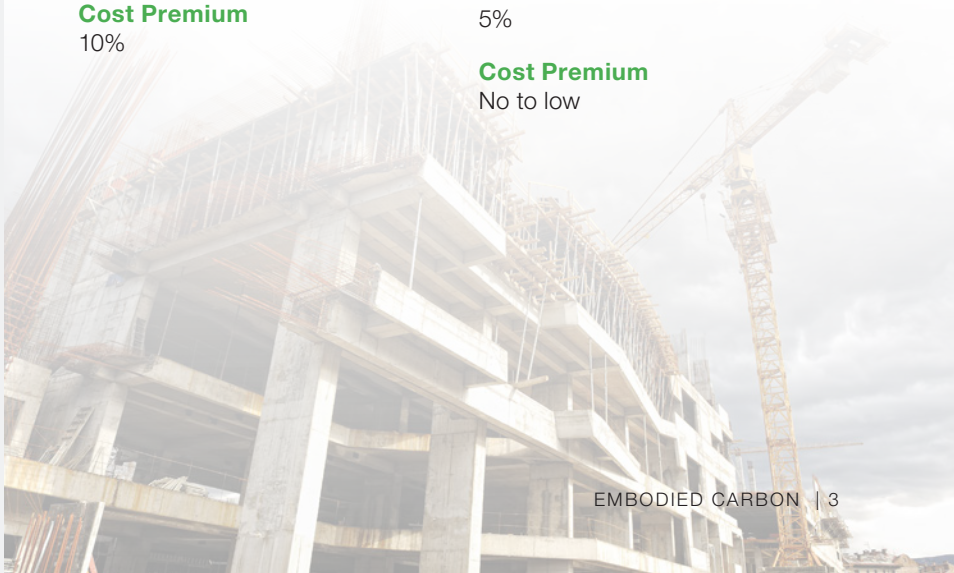
Cost Premium
10%

Finish Materials

Actions to Reduce Carbon
Select low-carbon and durable finish materials. Reuse materials and design for deconstruction and reuse for future tenant improvements.

Emissions Reduction Potential
5%

Cost Premium
No to low



Embodied Carbon Policies

Policies to address embodied carbon are underway in climate action plans, buy clean procurement policies, and product GWP limits in building and reach codes. The Buy Clean California Act (BCCA) requires the Department of General Services (DGS) to create GWP limits for four materials used in public works projects: structural steel (hot-rolled sections, hollow structural sections, and plate), concrete reinforcing steel, flat glass, and mineral wool board insulation. **San Francisco** and **Oakland climate action plans** mention efforts to curb embodied carbon. **San Francisco** and **Los Angeles** signed C40's Clean Construction Declaration, which aims to reduce embodied emissions by at least 50% for all new buildings, major retrofits, and all infrastructure projects by 2030. **Marin County** was the nation's first low-carbon concrete code. On a national scale, in December 2021, President Biden signed Executive Order 14057 that includes a net zero emissions requirement for federal procurement no later than 2050, including a buy clean procurement policy to promote the use of construction materials with lower embodied emissions.

Key Resources:

Architect's Embodied Carbon Toolkit

Lifecycle Assessment Case Studies

Where do we Stand? Case studies

Lifecycle GHG Impacts in Building Codes

Resources

NBI maintains a collection of ZNE resources, including case studies, research, and tools and guides for getting your project to ZNE. Visit gettingtozeroforum.org.

CALIFORNIA ENERGY CODES & STANDARDS
A STATEWIDE UTILITY PROGRAM

The Codes & Standards program is designed to improve compliance with the state's building and appliance energy codes and standards. The program aims to advance the adoption and effective implementation of energy efficiency measures and building practices to lock in long-term energy and GHG savings to meet California's ZNE, decarbonization and climate goals. The program recognizes that codes and standards are one of the most effective pathways to ensuring sustained market transformation—and that key to making them work well are well-informed industry professionals and consumers.

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New Buildings Institute (NBI) is a nonprofit organization driving better energy performance in commercial buildings. We work collaboratively with industry market players—governments, utilities, energy efficiency advocates and building professionals—to promote advanced design practices, innovative technologies, public policies and programs that improve energy efficiency. We also develop and offer guidance and tools to support the design and construction of energy efficient buildings.

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