PART I:

Introduction to embodied carbon

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Introduction

As building designers, we have already put significant efforts into reducing the environmental footprint of buildings. We have improved operational energy efficiencies and made progress towards the widespread electrification of buildings.

However, this is not enough. In order to avoid the catastrophic impacts of climate change and to have any chance of reaching the decarbonization targets set by the Paris Agreement, we have to do more. We have to tackle embodied carbon, which encompasses the greenhouse gas emissions associated with materials over the full life cycle of buildings.

The most recent report from the world's leading experts on climate change—the Intergovernmental Panel on Climate Change (IPCC)—warns of observed changes in weather extremes such as heat waves, heavy precipitation, droughts, and tropical cyclones.[1, 2] The report also clearly finds that the human influence on these weather events has strengthened. Based on the current trajectory, global temperatures are expected to exceed 1.5°C.[3]

In order to prevent global temperatures from exceeding 1.5°C, global net anthropogenic CO_2 emissions must decline by about 45% from 2010 levels by 2030 and reach net zero by 2050.[4] This means that we have until 2030 to radically decarbonize the building industry.

The good news is that we already have strategies that can make a difference, and architects can lead the way.

What is embodied carbon?

Broadly speaking, there are two ways of categorizing the greenhouse gas (GHG) emissions associated with buildings: (1) operational carbon, the emissions associated with energy used to operate a building; and (2) embodied carbon, the emissions associated with materials and construction processes over the whole life cycle of a building.

Greenhouse gases are substances in the atmosphere, such as carbon dioxide, methane, and nitrous oxide that contribute to global warming. Carbon dioxide (CO_2) makes up roughly 76% of global emissions.[5] For this reason, "carbon" is often used as shorthand for greenhouse gases.

Embodied carbon

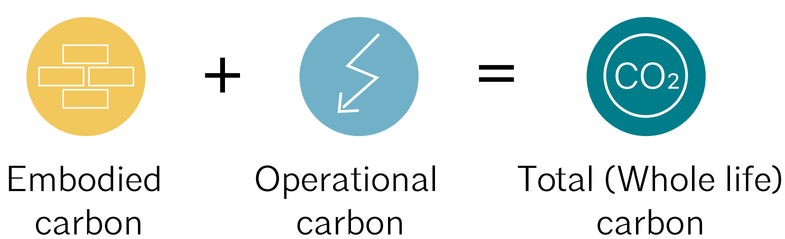
Embodied carbon emissions are generated by the manufacturing, transportation, installation, maintenance, and disposal of construction materials used in buildings, roads, and other infrastructure. Upfront embodied carbon (also known as upfront carbon) refers to the greenhouse gas emissions released before a building or infrastructure starts being used, which are largely from manufacturing impacts. This is particularly important for reaching 2030 climate targets because these emissions will be "frontloaded" in the next 10 years, unlike annual operating emissions or end-of-life emissions, which will occur later and/or gradually over time. According to the World Green Building Council, upfront carbon will be responsible for "half of the entire carbon footprint of new construction between now and 2050, threatening to consume a large part of our remaining carbon budget."[6]

Operational carbon

Operational carbon emissions are generated by fuel consumption for heating/cooling, supplying fresh water, ventilation, and power over the course of a building's lifetime.

The total carbon or whole life carbon of a building is the sum of both embodied and operational carbon. To reach net-zero total carbon, a building must minimize both the operational and embodied carbon over the building's life cycle and offset any remaining carbon with carbon offsets.

FIGURE 1:
Total (whole life) carbon



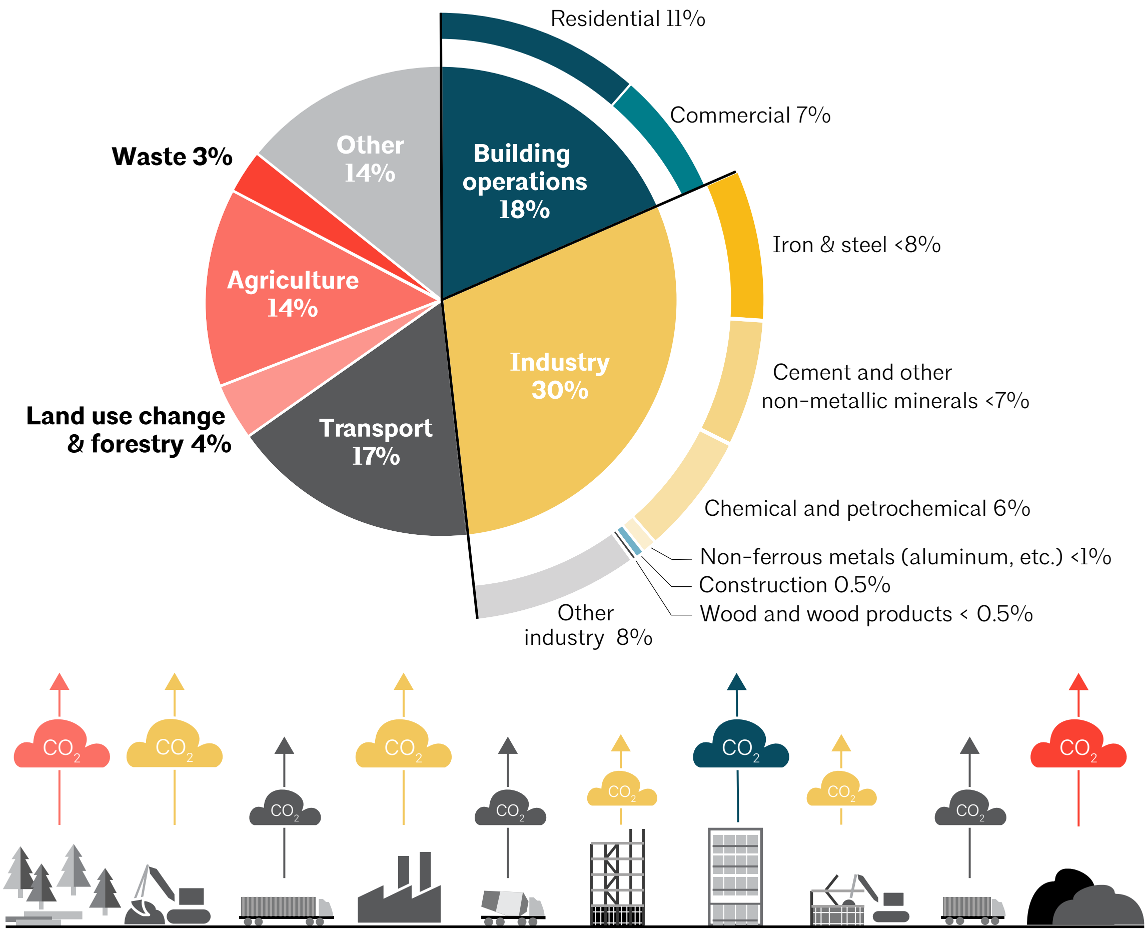
Why architects?

Buildings are a top contributor to global climate change.

When considered over the full life cycle—including embodied carbon—the impacts of the built environment are spread across nearly every sector of the economy (see figure 2). Many of the materials we use in construction, such as concrete and steel, make up large proportions of industrial emissions. When building materials are shipped to processing facilities, construction sites, or landfills, those emissions are tracked as transportation emissions. The production of building materials contributes to agriculture and land use change due to the growth and harvest of wood and other bio-based building products. Finally, when buildings are demolished, much of the building ends up in landfills or incinerators, where their decomposition or combustion is tracked as waste emissions. For this reason, it can be hard to untangle and estimate the true global impact of embodied carbon and buildings as whole.

The largest contributor to global emissions by end use is the industrial sector, contributing 30% of global emissions (see figure 2). Building materials are one of the largest sources of industrial emissions, which means that they are potential drivers to reducing emissions from this sector. The top two industrial sectors alone—steel and cement—are each individually responsible for more emissions than all of commercial building energy use each year (see figure 2). A significant portion of the materials are used in buildings and other infrastructure.

FIGURE 2:
Global greenhouse gas emissions and the Life Cycle of Buildings
Emissions data from IEA and WRI Climate Watch (2016 GHG emissions data)



When considered over their full life cycle, the building industry influences nearly every major sector of global GHG emissions.

In addition to being the largest sector, industry is also frequently cited as the sector with the "hardest-to-abate" emissions for two key reasons:

1. Many key industrial processes require high-temperature heat that can't reliably be replaced by clean energy yet.[7]

2. Process emissions from industrial and fuel transformation processes release CO_2 and other pollutants directly into the air. For example, approximately 60% of emissions from cement production are process emissions that can't be reduced through fuel switching.

For these reasons, industrial emissions can't be reduced only through a transition to clean power and electrification.

Architects, in collaboration with other designers, builders, and clients, are perfectly placed to help push for solutions to global emissions from manufacturing and other sectors by:

» Minimizing the need for high-carbon materials and processes through building design and system selection; and

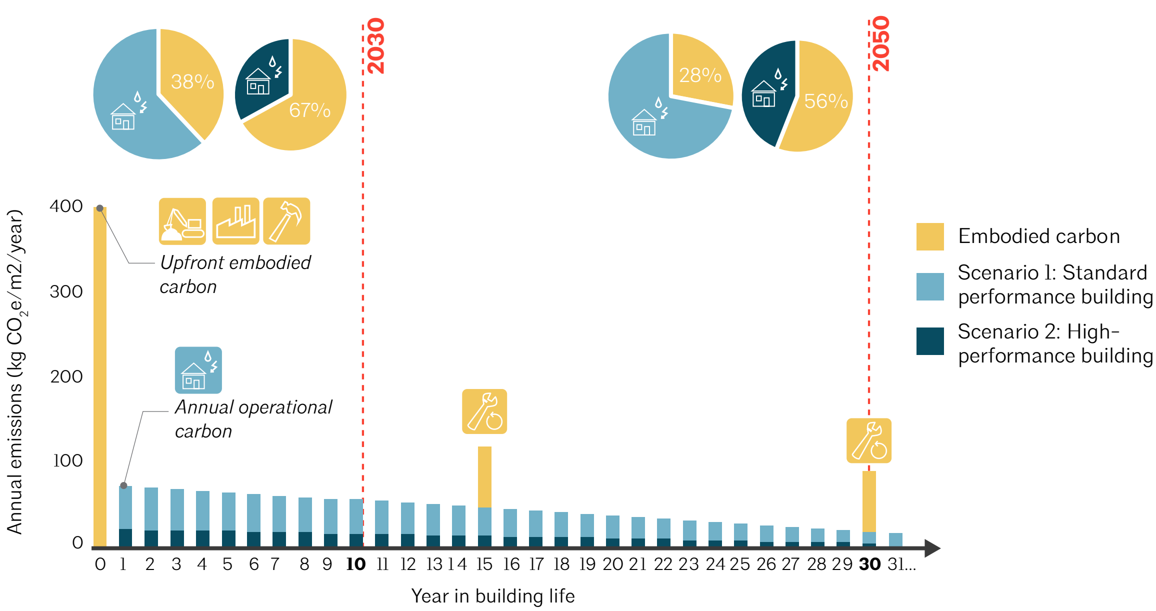
» Creating demand for clean manufacturing practices by selecting and specifying products from suppliers that have improved their operations and supply chains.

Why now?

We need to reduce embodied carbon now, before new buildings are built, in order to reach climate targets that allow us to avoid catastrophic climate change.

Emissions released now are more critical than emissions released later because (1) emissions will accumulate in the atmosphere; and (2) there is limited time remaining before the tipping point of the climate crisis—this idea is known as "carbon lock-in."[8] This means that in the near-term, action to reduce embodied carbon is as important as—or more important than—operational carbon.

FIGURE 3:
Embodied carbon lifetime emissions
Data Sources: Embodied Carbon Benchmark Study and Commercial Buildings Energy Consumption Survey (CBECS), assuming a medium-sized commercial office building. Assumes gradual grid decarbonization to zero by 2050.



Once upfront carbon emissions are released into the atmosphere, we can't take them back (at least not directly nor immediately). In contrast, operational carbon generated from the daily operations of a building can be decreased over time thanks to ongoing energy efficiency and grid decarbonization efforts.

Approximately two-thirds of the total carbon for a high-performance building constructed in 2020 is from embodied carbon in the first 10 years of a building's life (by 2030). By 2050, approximately half of a building's lifetime emissions are from embodied carbon (see figure 3).

Additionally, many of the most impactful decisions related to embodied carbon happen in the early stages of a design project (learn more in the section "Design Strategies"). For large projects with long project schedules, early design choices made today will lock in emissions for a building that may not open for another 5 to 10 years.

If we wait to tackle embodied carbon until after we have "fixed" operational carbon, we will be too late. Architects and the building industry as a whole need to act now.

Just & healthier materials & supply chains

Embodied carbon is inherently connected to climate justice and issues of public health and equity.

Embodied carbon disproportionately impacts frontline communities.

Frontline communities are groups of people who are directly affected by climate change and inequity at higher rates than people who have more power in society. For example, people of color, people who are low-income, who have disabilities, etc., have fewer advantages and access to resources in our society than other people.

The historical and present inequities that impact frontline communities exacerbate the negative impacts of climate change have the same root causes.[9] For example, systemic racism in the U.S. has widened the racial wealth gap and caused disinvestment in Black and brown communities.[10] This has pushed communities of color into areas that are more at risk of increasingly frequent extreme weather events, and made it less likely that there is a safety net to recover from those events.

Building materials also have a direct local impact on community health because material supply chains rely on manufacturing facilities and power plants, both of which are associated with negative health impacts for adjacent communities through the release of heavy metals, toxic chemicals, and particulate matter into the water, air, and food sources of nearby communities, causing short-term and long-term health problems.

Therefore, supporting low-carbon and non-toxic building materials can reduce impacts on frontline communities on two fronts: (1) acting to mitigate the global systemic impacts of climate change, such as extreme weather events; and (2) decreasing the local environmental and health impacts from industrial pollution.

Solutions to embodied carbon and modern slavery both require supply chain transparency.

Building materials are one of the highest-risk industries for modern slavery in the world. According to the International Labor Organization, the construction industry ranks as the second-highest sector in terms of risk of forced labor (after domestic labor),[11] with exploitation occurring at the construction site as well in the material supply chain.

In order to address modern slavery in construction materials, supply chains must be better tracked and better understood. Tackling embodied carbon requires a similar approach: better supply chain transparency and traceability. This will be a challenge because the construction sector is "the largest industrial sector in the world, the most disaggregated, and the least modernized."[12] But scrutinizing supply chains will allow us to both address greenhouse gas emissions and human rights violations hidden in construction material supply chains around the world.

Supply chain transparency is a first step in working towards accountability across just and ethical supply chains and should be seen as a core responsibility of design teams.

Endnotes

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