Embodied Carbon and Water in Building Construction

Introduction

Most building and energy codes measure and regulate operational carbon and operational water. The term "operational" is related to the carbon dioxide emissions equivalent and the water usage in the daily functions of a building. In contrast, "embodied" carbon and water refers to the carbon dioxide emissions equivalent and water that was used in the full life-cycle of the building. Embodied carbon has been largely ignored in regulations to date, and is sometimes dismissed as insignificant relative to operational carbon. In fact, embodied carbon contributes significantly to greenhouse gas emissions, and embodied water uses large quantities of a precious resource. We can't afford to ignore them any longer.

Embodied Carbon

Nearly 40 percent of global greenhouse gas emissions are attributable to the construction and buildings sector.[1] Eleven percent of these emissions come from embodied carbon, which refers to the greenhouse gases released during the extraction of raw materials for the products that will be used in the building, transportation of these materials to the factory, manufacture of the products, transportation of the products to the site, construction of the building, and final deconstruction and demolition of the building. The final step includes transportation and recycling of parts of the building, as well as sending waste to the landfill. In contrast, 28 percent of building emissions come from operational carbon. These are emissions caused by operating the building throughout its lifetime, such as heating spaces and running appliances.

Measuring Global Warming Potential

The global warming potential of material is reported in kilograms of carbon dioxide equivalence ($kgCO_2e$). The total life-cycle carbon footprint of a building is measured in $kgCO_2e$ per square foot of gross floor area per year. CO_2e measures all greenhouse gases, converted to their equivalence in carbon dioxide. For example, one kilogram of methane is expressed as having a global warming potential (GWP) of 25 $kgCO_2e$.

Embodied Water

According to the United Nations Environmental Program, 30 percent of fresh water that is globally available is consumed by the building sector.[2] The embodied water in a building is equal to the water used to extract and produce the materials in the building, plus the water used in the process of construction. Conversely, the operational water includes daily use such as water used to wash hands and flush toilets. A study in Australia

[1] Architecture 2030. 2021. "Why The Building Sector?" Architecture 2030." Accessed November 8, 2021, https://architecture2030.org/why-the-building-sector/.

[2] Rivero-Camacho, C. et al. 2022. "Water Footprint of the Life Cycle of Buildings: Case Study in Andalusia, Spain." *Advances of Footprint Family for Sustainable Energy and Industrial Systems*. ed. Ren, J. Cham: Springer International Publishing. https://doi.org/10.1007/978-3-030-76441-8_7.

estimated that it would take an average Australian household 15 years of daily operational water consumption to equal the embodied water consumption used during the lifecycle of the house.[3] Some studies have shown that embodied water over the lifecycle of the building can be equal to operational water over the same period of time.[4]

Emissions from Embodied Carbon are Growing

The global population is estimated to be near 10 billion by 2050, and global building stock will double in that same timeframe.[5] All of this construction, combined with renovations of existing aging building stock, leads to estimates that by 2050 emission levels caused by operational carbon and embodied carbon will be equal.[6] Overall, renovation is much more sustainable than new construction, but we must measure the embodied carbon inherent in the task, and choose our materials wisely. Together, the embodied carbon of only three materials: concrete, steel, and aluminum make up 23 percent of total global emissions.

Methods of Reducing Embodied Carbon[7]

- Renovating and reusing existing buildings
- Using low-carbon concrete mixes, for instance, by integrating fly-ash, slag, or calcined clays
- Limiting carbon-intensive materials such as aluminum, plastics, and foam insulation
- Choosing lower-carbon alternatives
- Choosing carbon sequestering materials, such as wood, or hemp insulation
- Using salvaged materials, such as brick, or reclaimed wood
- Using high-recycled content materials, such as recycled steel
- Maximizing structural efficiency to reduce material use
- Using fewer finish materials, by using structural materials as finish materials
- Minimizing waste by designing according to the common sizes of materials

[3] Choudhuri, I. et al. 2018. "Embodied Water in Building Construction - A Review." All India Seminar on Innovative Trends in Civil Engineering organized by Institute of Engineers India and Rajarambapu Institute of Technology. https://www.researchgate.net/publication/352374641_EMBODIED_WATER_IN_BUILDING_CONSTRUCTION_-A_REVIEW

[4] Choudhuri, I. et al.

[5] World Green Building Council. 2021. "Embodied Carbon Call to Action Report." World Green Building Council. Accessed November 4, 2021, https://www.worldgbc.org/embodied-carbon.

[6] SPOT. 2020. "Embodied vs Operational Carbon." SPOT (blog). August 16, 2020. https://spot.ul.com/blog/embodied-vs-operational-carbon/.

[7] Strain, L. "10 Steps to Reducing Embodied Carbon." American Institute of Architects. Accessed November 15, 2021, https://www.aia.org/articles/70446-ten-steps-to-reducing-embodied-carbon.

Buy Clean Colorado Act

One example of an enacted policy that addresses embodied carbon is Colorado's HB21-1303 Global Warming Potential for Public Project Materials. It limits the maximum global warming potential for materials, such as asphalt, cement, glass, steel, and structural wood, used in certain public projects. While HB21-1303 was enacted on July 6, 2021, the state has until January 2025 to set the maximum global warming limits of these materials. Buy Clean policies are also underway in California and Washington.

What's Next?

If we are going to reduce the carbon and water footprints of buildings, we must enact policies that address the issue of embodied carbon and water emissions and their global warming potential. Most current energy policies address only operational carbon and operational water, but awareness is growing. Change has been slow and more progress is necessary.