Curb Your Carbon!

The objective of this challenge is to develop an innovative solution that will reduce carbon emissions from U.S. buildings (residential, commercial, new, or existing). Student problem statements can focus on embodied carbon, carbon sequestration and storage, and/or operational carbon emissions. Innovative solutions should lead to significant reductions in carbon emissions, and fewer inequalities in obtaining new technologies for identified stakeholder groups.

Background

Buildings account for about 40% of energy-related carbon emissions worldwide.[1] **Carbon emissions** generally refer to carbon (primarily carbon dioxide—CO_2) that is released into the atmosphere, contributing to greenhouse gases that trap heat and warm the planet.[2] Energy-related carbon emissions come from a variety of sources including the emissions related to energy consumption in buildings (both electricity and fossil fuels), known as **operational carbon emissions**, as well as carbon emissions related to material manufacturing and all other construction processes, known as **embodied carbon**. Residential and commercial buildings in the United States match global trends, with annual operational carbon emissions totaling 29% of all U.S. emissions when the CO_2 emissions from the generation and distribution of electricity are factored in.[3]

The United States has committed to significantly reducing carbon emissions by 2030.[4] A unique characteristic of buildings—when compared to other carbon-emitting sectors such as personal vehicles and transportation—is that buildings have a comparatively slower turnover rate. The average age of U.S. homes and commercial buildings is around 45 years old,[2] with projected life expectancies anywhere from 75 to 100 years or more.[5] Additionally, the U.S. population is projected to grow 20%–25% between now and 2060,[6] which will continue to increase demand for housing and commercial floor space. As with any multifaceted and complex problem, there are many opportunities for solutions addressing carbon reductions in our buildings—both operational and embodied.

The architectural and design community has been focused on employing strategies and processes to reduce embodied carbon for many years. Examples include design practices focused on renovation and reuse of existing buildings and materials, selecting building products that have minimal carbon emissions during manufacturing, and locally sourcing materials when possible, to further minimize emissions related to transporting the materials for construction.[7] More recent advancements in materials are unlocking opportunities for carbon sequestering or capturing. For example, concrete

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[1] World Green Building Council. 2022. "Bringing Embodied Carbon Upfront." https://www.worldgbc.org/embodied-carbon.
[2] United States Environmental Protection Agency. 2022. "Sources of Greenhouse Gas Emissions." https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions.
[3] Leung, Jessica. 2018. "Decarbonizing U.S. Buildings." Climate Innovation 2050. https://www.c2es.org/document/decarbonizing-u-s-buildings/
[4] The White House. 2021. "President Biden Sets 2030 Greenhouse Gas Pollution Reduction Target Aimed at Creating Good-Paying Union Jobs and Securing U.S. Leadership on Clean Energy Technologies." https://www.whitehouse.gov/briefing-room/statements-releases/2021/04/22/fact-sheet-president-biden-sets-2030-greenhouse-gas-pollution-reduction-target-aimed-at-creating-good-paying-union-jobs-and-securing-u-s-leadership-on-clean-energy-technologies/.
[5] O'Connor, Jennifer. "Survey on Actual Service Lives for North American Buildings." Presented at Woodframe Housing Durability and Disaster Issues conference, Las Vegas, October 2004. https://cwc.ca/wp-content/uploads/2013/12/DurabilityService_Life_E.pdf.
[6] Vespa, Jonathan, Lauren Medina, and David M. Armstrong. 2020. *Demographic Turning Points for the United States: Population Projections for 2020 to 2060.* The United States Census. P25-1144. https://www.census.gov/library/publications/2020/demo/p25-1144.html.
[7] Strain, Larry. "10 steps to reducing embodied carbon." 2022. https://www.aia.org/articles/70446-ten-steps-to-reducing-embodied-carbon.

blocks are becoming available that are made without the use of cement as a binding ingredient and have CO_2 directly injected into the product, thereby permanently sequestering it.[8,9]

There are multiple pathways to reducing operational carbon, including energy efficiency and electrification, as well as smart devices and equipment that enable connectivity between devices, buildings, and the electric grid to optimize energy consumption and minimize carbon emissions from the electric grid.[2]

It is also important to consider how carbon emissions are accounted for throughout the lifetime of a building. Embodied carbon emissions are released due to the construction or renovation of a building, whereas operational carbon emissions are released continuously. For example, 38% of all carbon emissions over the first 10 years for a typical new construction building built in 2020 will be the embodied carbon released due to construction—the remaining 62% are carbon emissions from operating the building.[10] However, when we compare typical new construction to high-performance construction, the story changes. Two-thirds of all carbon emissions over the first 10 years for a high-performance building will be the embodied carbon released due to construction.[10] The primary reason for this is the significant reduction in operational carbon emissions from energy efficiency measures taken as part of the high-performance design. In either case, the key take away is that solutions for both embodied and operational carbon are needed.

Additional research has studied the relationship between carbon emissions and socioeconomic status. Some data suggest that high socioeconomic status may disproportionately contribute to energy-driven carbon emissions related to consumption patterns, and at the same time substantial financial resources of high socioeconomic people can influence emissions and climate change policy and mitigation efforts—not always in positive ways.[11] Related research has also shown that although high socioeconomic status may lead to higher consumption rates, these consumption patterns are often related to transport emissions, and lower socioeconomic status people are more likely to contribute to carbon emissions related to households.[12] In either case, careful consideration needs to be taken in approaching carbon reduction solutions for specific stakeholder groups—especially vulnerable and historically excluded, underserved, and frontline communities.

The Challenge

This challenge asks student teams to develop an innovative solution that will reduce carbon emissions in buildings. Students can focus on any aspect related to carbon emissions, including but not limited to embodied carbon, carbon sequestration and capture, and operational carbon emissions. Teams should first develop a focused problem statement for a specific stakeholder group and then develop a technical solution or process.

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[8] CarbiCrete. 2022. https://carbicrete.com.
[9] Echohome. 2021. "Carbon Negative Concrete Goes into Pioneering 'Green' CMU Blocks – Quebec Leads the Way!" https://www.ecohome.net/news/1514/carbon-negative-concrete-cmu-blocks-quebec-leads-the-way/.
[10] Carbon Leadership Forum. 2022. "Introduction to Embodied Carbon." https://carbonleadershipforum.org/toolkit-1-introduction/.
[11] Nielsen, K.S., K.A. Nicholas, F. Creutzig, et al. 2021. "The Role of High-Socioeconomic-Status People in Locking In or Rapidly Reducing Energy-Driven Greenhouse Gas Emissions." *Nature Energy* Volume 6: Pages 1011–1016. https://doi.org/10.1038/s41560-021-00900-y.
[12] Büchs, Milena, Sylke V. Schnepf. 2013. "Who emits most? Associations Between Socio-Economic Factors and UK Households' Home Energy, Transport, Indirect and Total CO_2 Emissions." *Ecological Economics* Volume 90: Page 114–123. https://www.sciencedirect.com/science/article/pii/S0921800913000980.

Suggestions for student teams include (but are not limited to) the following:

- Create innovative design strategies and practices specifically aimed at reducing embodied carbon.
- Develop new materials or manufacturing processes that reduce or eliminate carbon emissions, as well as potentially capture and store CO_2.
- Present solutions with advanced controls that optimize building operation and minimize carbon emissions.

Student submissions should:

- Describe the scope and context of the chosen problem.
- Identify affected stakeholders, making sure to consider socioeconomically vulnerable and historically excluded, underserved, and frontline communities (communities at the "front line" of pollution and climate change[7]).
- Develop a technical solution to the chosen problem for the targeted stakeholder group. The solution may also include policy solutions, supply chain and manufacturing processes, economic solutions, or other aspects critical to identified stakeholder barriers, but a technical solution must be proposed.
- Discuss appropriate and expected impacts and benefits of the proposed solution. This should include a cost/benefit analysis, a market adoption analysis, and should also consider non-economic costs and benefits, such as occupant health, productivity, well-being, and others.[8]
- Develop a plan that describes how the team envisions bringing its idea to scale in the market, including sales or distribution channels, outreach mechanisms, stakeholder engagement, and other relevant details.