U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

New Residential Construction Carbon Emissions

This fact sheet will help homebuilders better understand the largest sources of carbon emissions in constructed homes and see the comparative impact of those sources on overall emissions.

Background

As of 2022, U.S. climate goals include reductions in greenhouse gas (GHG) emissions economy-wide by more than 50% by 2030, a zero-emissions power sector by 2035, and a net-zero emissions economy by 2050 (White House 2021). Currently, carbon emissions from commercial and residential buildings account for 36% (EPA 2022) of total U.S. emissions—with residential buildings representing just over half of this amount. As residential homebuilders respond to these challenges, there is a need to understand and assess current home performance against carbon reduction goals to enable informed decision making.

To help with this process, this fact sheet demonstrates the carbon emissions associated with a typical single-family detached home constructed to current standards. This information is based on the results of a case study by IBACOS and published by the U.S. Department of Energy (DOE 2023). Separately, the material choices and outcomes described are based on work produced by Builders for Climate Action (Magwood et al. 2021).

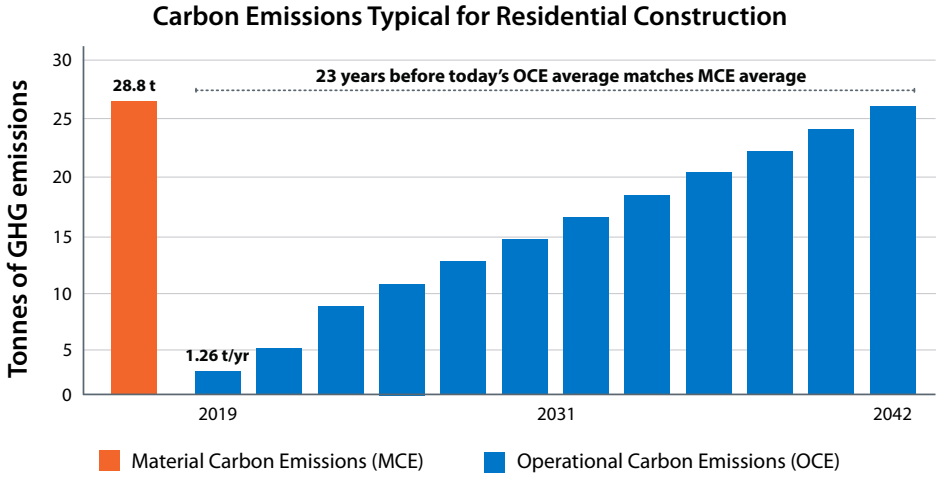

Figure 2. This graph illustrates the importance of addressing material carbon emissions, showing that it will take 23 years before the cumulative operational carbon emissions equal the amount of material carbon emissions associated with the house by the time it is first built. *Based on a case study in British Columbia from Builders for Climate Action using the Material Carbon Emissions (MCE2) estimator tool.*

Carbon Emissions in Homes

Embodied carbon emissions refer to the greenhouse gas emissions that result from the extraction of raw materials that go into building products, manufacturing of the products, transportation to a job site, construction of a building, the maintenance and repair of that building, and the eventual disposal of the building products. Operational carbon emissions refer to the greenhouse gas emissions associated with the heating, cooling, energy, and water use of the building. The combination of these two categories, operational and embodied carbon, can be considered in the assessment of net-zero carbon goals. Figure 1 demonstrates the chronology of each of these categories and how they can compare to each other. Figure 2 demonstrates the time-based relationship between embodied and operational carbon.

Embodied Carbon Emissions Breakdown

Figure 3 shows embodied carbon emissions associated with the same model home plan in a cold and warm climate. Primary differences between the two houses include foundation type (basement versus slab on grade) and insulation levels. Interior materials and finishes, and exterior cladding materials are similar. Mechanical, electrical, plumbing (MEP) and other systems have not been included in this analysis since standardized emissions product

Figure 1. This figure demonstrates the chronology of each of these categories and how they can compare to each other. *Figure from Carbon Leadership Forum (2020).*

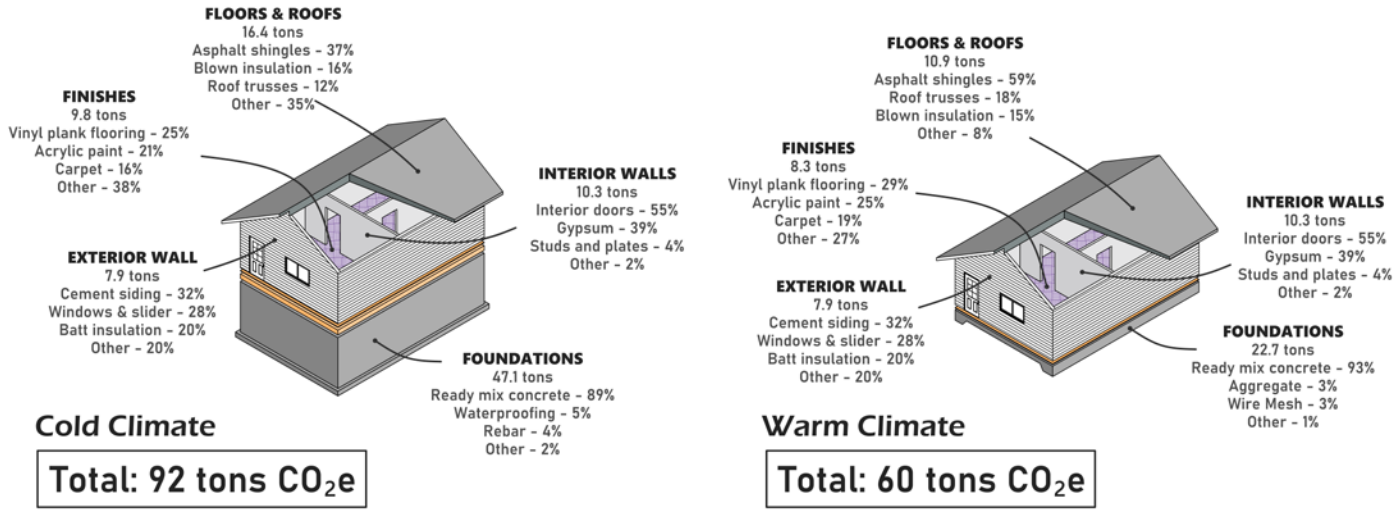

Figure 3. Upfront embodied carbon emissions associated with the construction of a new production home in a cold (left) and warm (right) climate, by building assembly and material. Based on a case study by IBACOS (DOE 2023; note that MEP systems have been excluded)

declaration documents are not currently available for these materials.

As shown in this figure, the same floor-plan built in a cold climate has higher total embodied carbon emissions than in a warm climate, due largely to the larger volume of concrete used in the foundation and to the increased insulation levels in the thermal enclosure.

Material Selection Impact

Multiple studies have shown that the highest impact materials for material carbon emissions are insulation, cladding (wall/roof), and concrete. Emissions can be reduced by using lower-emitting versions of these materials, but they remain important categories to address. Detailed material takeoffs are needed to accurately determine overall upfront embodied carbon emissions, but adjustment to these three areas offer the greatest impact, and the greatest opportunity to understand cost influences. There are cost-neutral material substitutions that can be made immediately that result in substantial reductions in embodied material carbon, and there are substitutions that may be available in the next five-to-10 years that have even greater carbon benefit (Magwood et al. 2021).

Conclusions

Builders can consider taking several important actions right now to reduce the carbon emissions associated with their homes. With nearly 1.6 million units being constructed in the U.S. each year,[1] the biggest immediate impact a builder can having on meeting U.S. climate goals is to select the materials and construction practices that reduce upfront embodied carbon emissions. Additionally, building energy efficient homes such as homes that comply with the U.S. Environmental Protection Agency's Energy Star Residential New Construction[2] program or the U.S. Department of Energy's Zero Energy Ready Home[3] program, will provide ongoing reductions to operational carbon emissions that will continue to lower as utilities adopt cleaner sources of energy. ■

Citations

Carbon Leadership Forum. 2020. Embodied Carbon 101.

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EPA. 2022. Sources of Greenhouse Gas Emissions. U.S. Environmental Protection Agency.

Magwood, Chris, et al. 2021. *Achieving Real Net-Zero Carbon Emission Homes: Embodied Carbon Scenario Analysis of the Upper Tiers of Performance in the 2020 Canadian National Building Code.* Passive Buildings Canada and Builders for Climate Action.

White House. 2021. ICYMI: President Biden Signs Executive Order Catalyzing America's Clean Energy Economy Through Federal Sustainability. December 13, 2021.

Learn More

Technical Report: https://www.nrel.gov/docs/fy23osti/84227.pdf

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1 For more information, see: https://www.census.gov/construction/nrc/index.html
2 For more information, see: https://www.energystar.gov/newhomes
3 For more information, see: https://www.energy.gov/eere/buildings/zero-energy-ready-home