KNOWLEDGE HIGHWAY:
The Critical Path to Advance Embodied Carbon Building Codes

The climate crisis requires an all-out effort to reduce energy use and related emissions throughout the economy. Buildings need to be a serious part of this effort. Our new research, though, reveals critical gaps in our understanding of how to track and quantify the carbon embodied in buildings—from the materials themselves to their manufacture, transport, use, and disposal.

To cut heat-trapping emissions, we need to close these knowledge gaps. The construction of buildings accounts for 5% of global energy use and 10% of global greenhouse gas emissions. A main source of these emissions is the manufacture of construction materials such as steel, cement, and glass, so we must reduce the energy and carbon that go into making them.

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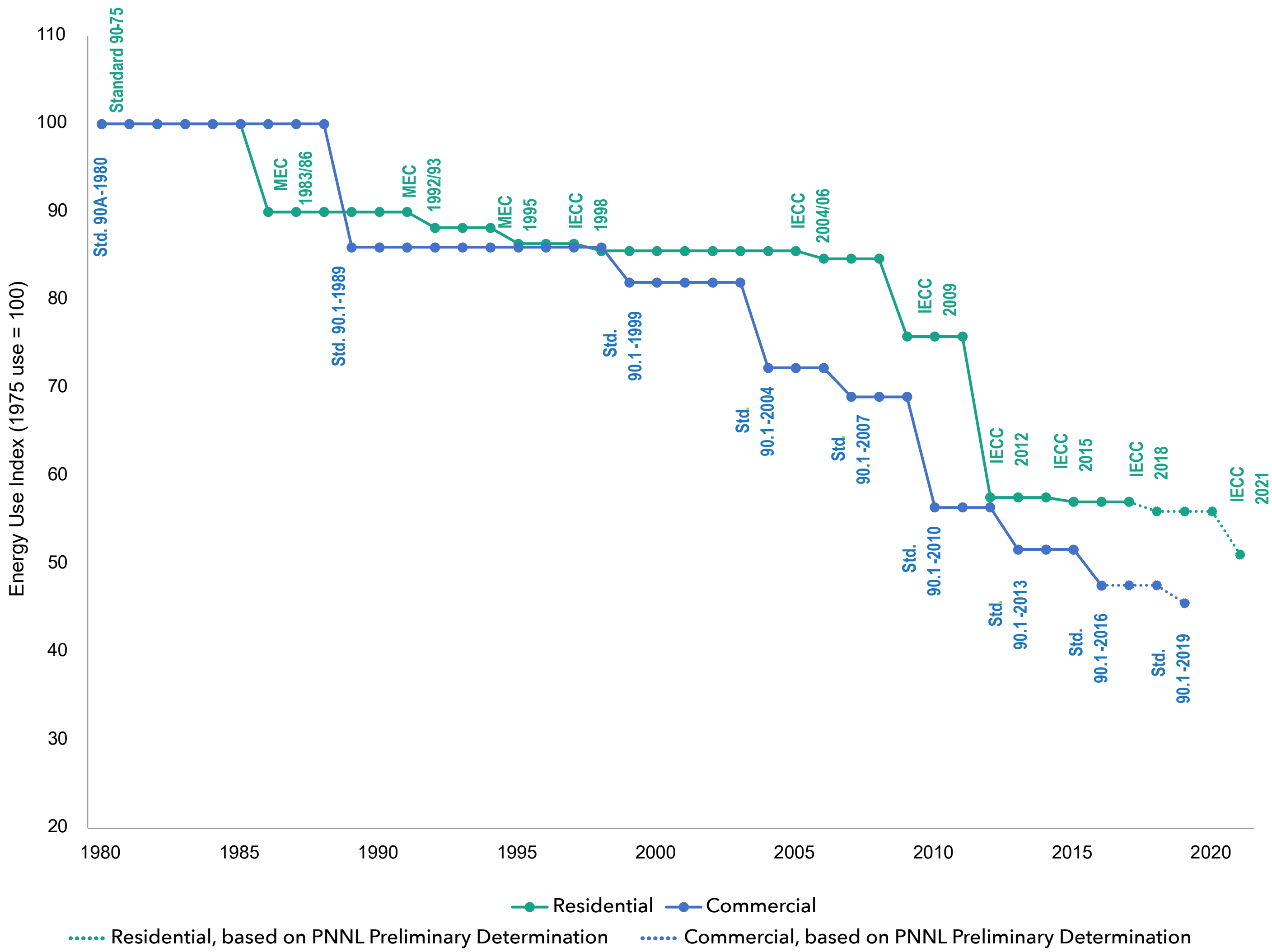
The good news: we have a window of opportunity to address this issue. Consumer preference for lower-carbon products is expected to grow rapidly, creating market-pull for these products. In the United States, the federal government and some cities are increasingly interested in Buy Clean policies, which require government agencies to buy low-carbon construction materials. An aggressive push for new building energy codes that advance net-zero-energy and net-zero-carbon operations is also emerging. By influencing general practices in the building industry, such codes and standards can accelerate the shift to low-embodied-carbon buildings. Since 1980, as the figure below shows, codes have spurred dramatic reductions in energy use in both homes and commercial buildings.



History of U.S. building codes, 1980–2021. Source: Data from Pacific Northwest National Laboratory and U.S. DOE Building Codes Program, unless otherwise noted.

The bad news: we do not yet know enough to effectively use codes to reduce embodied carbon. Our research shows that we need to learn more about embodied carbon in building materials and design before we can develop, adopt, and implement national model building codes that can limit this major source of carbon emissions.

The study screened more than 5,000 recent articles on life-cycle assessment (LCA).[1] This process, combined with an extensive review of 44 articles focused on U.S. buildings, found 6 major knowledge gaps:

U.S. standards and protocols. Well-established international and European standards exist to guide the development of methodologies to assess embodied carbon in the built environment. However, the United States does not have, but will need, an industry-wide standard and set of implementation protocols to ensure credible and consistent results.

Robust and complete data. Existing data focus mostly on materials and the manufacturing process. But the transportation involved in constructing a building and the construction process itself have carbon footprints. To enable more-complete life-cycle analyses, we need data on these aspects of buildings. Data collection and reporting guidelines are also needed for supply-chain-specific and facility-specific data to enable more-accurate counting and fair comparisons.

Transparent and accessible databases. Many tools are available to facilitate embodied carbon analysis. However, the databases' inconsistent quality, lack of transparency, and substitution of foreign data for missing U.S. information can cause significant disparities in results and hamper the credibility of LCAs. Guidelines for data standardization and transparency are needed.

Whole-building benchmarking. In the United States, the largest knowledge gap exists at the whole-building level. The lack of publicly accessible building-level data and lack of guidelines to establish reference cases are obstacles to reaching consensus on how to baseline or benchmark the life-cycle embodied carbon of a building. Better data and consensus are needed.

Integration with building operation and resilience. The trade-offs between operational carbon (from building energy use) and carbon embodied in a building should be considered in whole-building evaluations. The lack of information on the durability of alternative materials and products may also introduce conflicts between resilience and embodied carbon. These are all critical components that must be addressed to combat climate change.

Manufacturers' participation. Manufacturers, construction companies, and building owners will need to participate in developing guidelines and standards for collecting data on embodied carbon. Their ability to meet reporting and disclosure requirements must be considered. Business cases should be developed to motivate manufacturers to invest in low-carbon products. Building decarbonization policies should align with industrial decarbonization to send a consistent message to the market and the industry.

[1] LCA is a method of assessing the environmental impacts of a product or service throughout its entire life cycle. The LCA method is standardized by the International Organization for Standardization (ISO) in ISO 14040 and 14044. Global warming potential (GWP) is one output of LCA. Embodied carbon quantification is usually derived from the GWP output, which measures a multitude of greenhouse gas emissions (such as methane, nitrous oxide, and chlorofluorocarbons) in CO_2 equivalents.

We can and must do more to reduce embodied carbon in the built environment. To make the leap from voluntary standards adopted by industry leaders to building codes guiding general practice, we need to build adequate knowledge infrastructure. Efforts so far have created momentum and provided important pieces of the puzzle, but multilayer solutions are needed to implement successful practices across complicated supply chains.

Our current knowledge gaps do not mean we should hold off on developing embodied carbon building specifications and code components. There are opportunities for action today.

Our study provides a basis for governments, academia, industry, and other entities to fill in the identified gaps.

As the first step, we recommend U.S. federal agencies (e.g., the Department of Energy, Environmental Protection Agency, and National Institute of Standards and Technology), work with standard-developing organizations (e.g., ASHRAE and the International Code Council), local code officials, research institutes, and advocacy groups to develop an agreed-upon roadmap for the longer-term adoption of embodied carbon building codes.

In addition, we recommend that U.S. federal agencies take two immediate actions to address two major gaps: (1) facilitate the development of U.S.-applicable LCA standards for buildings based on the international and European standards, and (2) fund the collection and organization of the data inputs that go into analyzing LCA. With more-robust U.S. standards and LCA data inputs, baselines to evaluate embodied carbon in buildings can be established.

The federal agencies noted above and the federally funded research and development centers should also lead the way in establishing embodied-carbon-reduction targets for whole buildings over their entire life cycles, while considering the impact on operational energy use and carbon emissions.

Can we pave a pathway together?