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MIT Research: Life Cycle Assessment of Residential Buildings

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Life cycle assessment (LCA) offers a comprehensive approach to evaluating and improving the environmental impacts of residential buildings. Recent research at the Massachusetts Institute of Technology (MIT) explored and advanced key areas relevant to the field of LCA: methodology, benchmarking and impact reduction opportunities.

Methodology

A standardized LCA methodology is essential in order to increase the accuracy and consistency of the LCA approach. This MIT research supports standardization by proposing good-practice concepts for conducting LCA on residential buildings. Regardless of a project's goal and scope, good practice stipulates that LCAs use a comprehensive life cycle perspective and provide an adequate level of transparency with regards to the data, scope, boundaries, functional units and other important LCA parameters. Including all phases of the building life cycle—materials, construction, use (including operating energy), maintenance and end of life—allows for accurate representation of cumulative environmental impacts over the life cycle.

Benchmarking

The general methodology was applied to benchmark structures used in residential building applications. Both Insulated Concrete Form (ICF) construction consisting of concrete walls encased in expanded polystyrene (EPS) insulation and typical light-frame wood construction were studied. For all buildings, the roof, partitions and floors are designed in the same manner. Design of the exterior walls and foundations vary between the different buildings. Two types of residential buildings were considered (see figure 1):

1. Two-story, 2400 ft^2 (223 m^2) single-family building.
2. Four-story multi-family apartment building with a total square footage of 33,763 ft^2 (3,137 m^2).

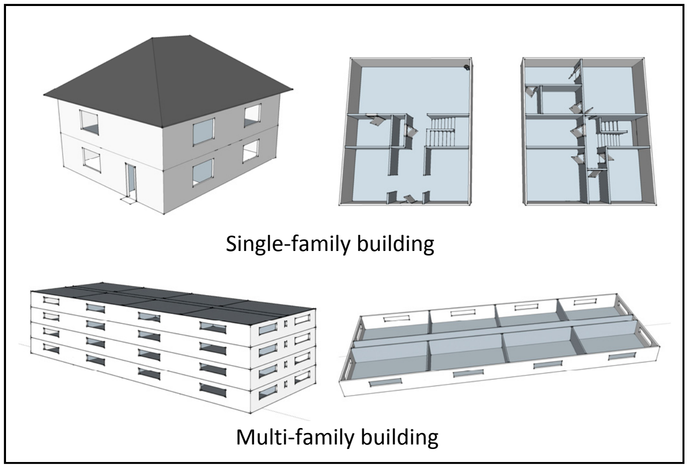

Figure 1. Benchmark 2-story single-family and 4-story multi-family buildings studied by MIT.

All LCAs were carried out for two different cities in the U.S. to model regional and climatic differences: Chicago, representing a cold climate, and Phoenix, representing a hot, dry climate. The annual operating energy, determined using the EnergyPlus building energy analysis software, was conducted for a 60-year life cycle. Benchmark single-family houses are designed and modeled based on the Building America House Simulation Protocol (BAHSP).

The resulting Global Warming Potential (GWP) was then quantified using CO_2-equivalents (CO_2e) for a number of purposes, including benchmarking emissions for current practices, comparing concrete with wood and understanding the relative importance of different phases of the life cycle. In particular, their work demonstrates that there are measureable differences between various construction materials and that concrete structures can provide unique benefits compared to other materials over an operating life cycle.

The MIT study quantified the carbon emission impact of building systems over its complete life cycle. Information on system boundaries and processes allocation was clearly outlined and peer reviewed. The strength of the MIT research lies in its detailed and transparent methodology of the analysis of the harvested raw materials, construction, operating (or use) phases of the life cycle of the building.

Impacts

By considering the buildings' entire operational life, the MIT research uncovered concrete's ability to offer a highly resilient structure while providing thermal mass benefits resulting in energy savings. According to the report:

- Concrete homes have a higher *embodied* GWP in the pre-use phase—but this phase accounts for only about 2-12% of the overall GWP for the life of the home;
- For a cold climate, such as Chicago, the energy savings of an ICF house built from average to tight levels of air infiltration saves 23% of total operating energy; and
- Over a 60-year life cycle, the lower (5%-8% for single family, 4.4%-6.2% for multifamily) *operating* GWP outweighs pre-use emissions (see figure 2).

Impact Reductions

The MIT study offered a number of opportunities for reducing GWP of concrete residential buildings. The following provides a summary of recommendations to reduce GWP:

- Moving from a 6 in (15.2 cm) to a 4 in (10.2 cm) concrete core is both cost effective and reduces emissions;
- Using ICFs with thicker insulation panels, increasing air tightness, and using thinner concrete walls can reduce GWP at prices lower than current market prices of carbon; and
- Increasing SCM substitution from 10% to 50% in the ICF walls reduces the pre-use GWP by 12% to 14%.

Cost Considerations

The report found ICF construction has higher initial cost than light-frame wood construction but offers lower energy costs.

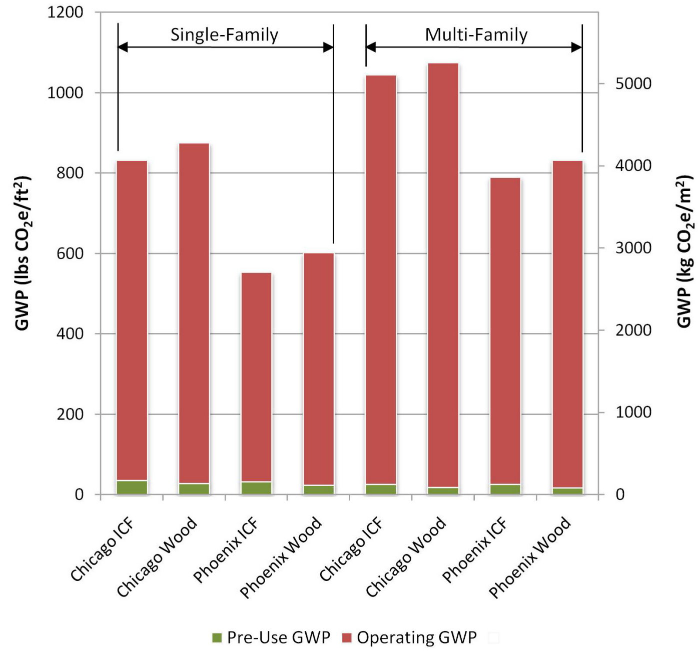

Figure 2. Pre-use and operating GWP over 60-year lifespan for single-family and multi-family residential buildings.

The relative life cycle costs for ICF construction is +$2.36 to +$4.09/ft^2 (+$25 to +$44/m^2) of wall area in Chicago and –$0.08 to +$4.15/ft^2 (–$1 to +$45/m^2) of wall area in Phoenix. Over the entire life cycle, ICF construction increases the price of a house by less than 5%.

More Information

The full report titled *Methods, Impacts, and Opportunities in the Concrete Building Life Cycle* can be downloaded from the MIT Concrete Sustainability Hub Web site at http://web.mit.edu/cshub. The Concrete Sustainability Hub is a research center at MIT that was established by the Ready Mixed Concrete (RMC) Research & Education Foundation and the Portland Cement Association (PCA). Both organizations are committing significant effort and resources with the goal of accelerating emerging breakthroughs in concrete science and engineering and transferring that science into practice. NRMCA is providing technical input to the research program and helping transfer the research results into practice.

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