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MIT Research: Life Cycle Assessment of Commercial Buildings

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

Methodology

A standardized LCA methodology is critical in order to increase the consistency of LCA for buildings. The MIT research supports standardization by proposing good practices for conducting LCA on buildings. It is important that LCAs use a comprehensive life cycle perspective and provide transparency with regards to the data, scope, boundaries, functional units and other important LCA parameters. Drawing boundaries to include all phases of the building life cycle—materials, construction, use (including operating energy), maintenance and end of life—allows for an accurate representation of cumulative environmental impacts over the life of a building (see figure 1).

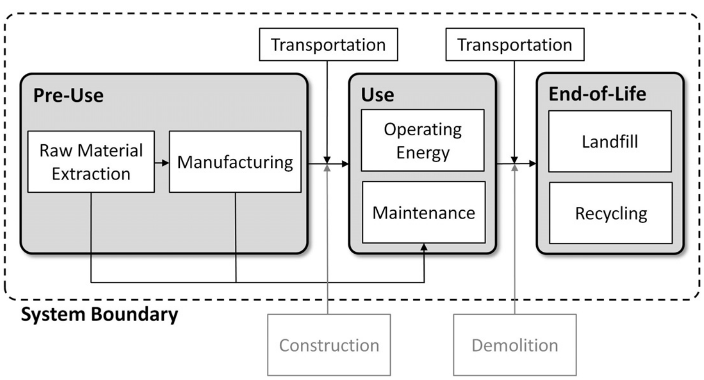

Figure 1. LCA of commercial buildings must identify boundaries of the building life cycle analysis.

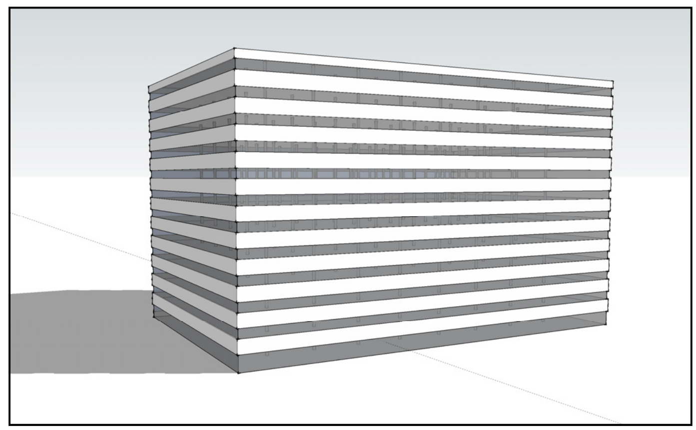

Figure 2. Benchmark 12-story commercial building, with 40% glazing and 60% aluminum rain screen panel cladding.

Benchmarking

These methodologies were applied to a benchmark 12-story, 498,590 ft^2 (46,321 m^2) commercial building (see Figure 2). The building was analyzed for two climates, Phoenix and Chicago, and for two different structural materials, concrete and steel. The annual operating energy, determined using the EnergyPlus building energy analysis software, was conducted for a 60-year life cycle. The Global Warming Potential (GWP) was quantified using CO_2-equivalents (CO_2e) for several purposes, including benchmarking emissions for current construction practices, comparing impacts of concrete versus steel and understanding the relative magnitude of impacts for different life cycle phases.

Impacts

The analysis demonstrated that the greenhouse gas emissions due to operational energy of the benchmark buildings are responsible for 95-96% of life cycle emissions. Compared to the steel structure, the concrete building has approximately the same embodied emissions (pre-use, maintenance and end-of-life phases), but have lower operating emissions (operational phase), which can lead to similar life cycle emissions over time. For all cases considered, the concrete buildings had similar emissions over 60 years as the steel alternatives. The LCA research drew several conclusions, including:

- Concrete and steel commercial buildings have a similar embodied GWP of 42 lbs CO_2e/ft^2 (205 kg CO_2e/m^2);
- Thermal mass of an exposed concrete frame can provide HVAC savings of 7-9% compared to a steel frame. This accounts for 2% savings in annual operating emissions;
- Over a lifetime of 60 years, the CO_2e emissions of the concrete building were slightly lower than the steel alternative (see figure 3); and
- The steel and concrete buildings have very similar emissions over the full life cycle and the choice of structural material does not dramatically influence the total emissions.

Impact Reductions

Finally, several recommendations for reducing life cycle emissions of concrete buildings were presented. In particular, the GWP reduction effects of supplementary cementitious materials (SCMs) in concrete, such as fly ash, were quantified. Additional options for reducing operating emissions were introduced and quantified within the full life cycle. There are a number of potential emissions reduction strategies for concrete buildings and LCA provides guidance for future environmental improvements, including:

- Increasing SCM substitution (such as fly ash) in the concrete building from 10% to 25% can decrease pre-use GWP by 4.3%; and
- Lighting control and low-lift cooling can decrease the operating energy requirements for concrete buildings. Low-lift cooling takes advantage of the high heat capacity of concrete and is effective when building cooling loads are reduced through control of internal and solar heat loads.

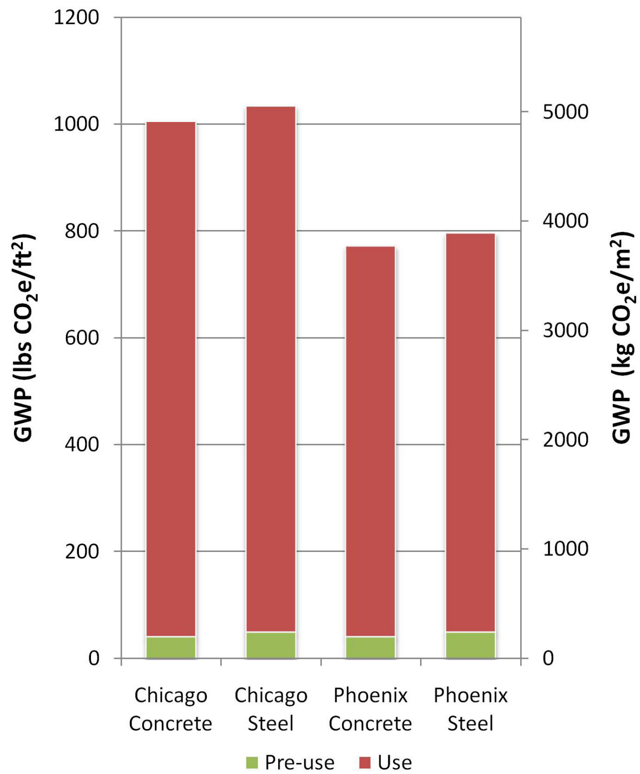

Figure 3. Total Global Warming Potential (GWP) over 60-year lifespan for commercial buildings.

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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