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Improved buildings could make a big dent in climate change

New MIT report on concrete buildings shows many areas for major reductions in their lifetime carbon footprint.

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August 31, 2011

The construction and operation of buildings accounts for approximately 40 percent of all U.S. emissions of greenhouse gases. The most-used building material in the world, concrete, is used to construct many of the nation's homes and office buildings — but a new MIT report says a variety of measures could drastically reduce, and ultimately even eliminate, the carbon footprint of most new concrete buildings, as well as some older ones.

The new report outlines some of those measures, analyzing buildings' energy use and carbon emissions over their entire life cycle of construction, use and eventual demolition. The report is one of two issued this month by the MIT Concrete Sustainability Hub, a multidisciplinary research collaboration funded by the cement and concrete industries. The researchers say the report provides the most detailed and open accountings ever undertaken of the full life cycle of buildings.

The report reflects nearly two years of work by the MIT team, says lead author John Ochsendorf, associate professor of civil and environmental engineering and architecture. His group's life-cycle analysis extends "all the way down to details of where the components come

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from, and how were they transported." In doing so, researchers were able to "quantify emissions and potential savings, and also put a cost on them," he says.

Not only are there significant savings possible in the energy use of buildings and their associated emissions, but some of these are cost-free: "There are steps to reduce carbon emissions that save money, that pay back owners," Ochsendorf says.

Typically today, concrete is used in construction purely for its structural properties, but by harnessing concrete's thermal properties for passive solar storage, the material could greatly reduce a building's energy needs. For example, by designing windows and overhangs so concrete is exposed to sunlight during the winter, the material can effectively store heat during the day and release it at night. In addition, pipes embedded in concrete floors, walls and ceilings can be used for both heating and cooling, providing greater efficiency as well as greater comfort than systems that rely on heating the air in the room, the report says.

"Life-cycle assessment of buildings is still a relatively new field," Ochsendorf says. Yet governments around the world are already starting to set up requirements for significant reductions in buildings' carbon footprints, and the Intergovernmental Panel on Climate Change has identified buildings as the most cost-effective sector for implementing policy to reduce greenhouse gas emissions. But, Ochsendorf says, in order to show that real reductions are taking place, first you need a reliable assessment of the emissions associated with existing buildings, and a methodology for comparing those with newer ones. The new MIT report provides that, he says.

While many people have attempted to carry out life-cycle analyses, the process is far more complex than it may appear, explains Concrete Sustainability Hub Director Hamlin Jennings. "A great deal of life-cycle analysis is based on opinion," he says — not necessarily because the data are uncertain, but because some decisions on what to factor in are inherently subjective.

For example, when analyzing the impact of adding fly ash (a waste product from coal-fired powerplants) to concrete, do you include the energy used to transport it, or do you omit that because the material would have been transported anyway in order to dispose of it? "That kind of question enters into everything," he says. "How one fairly and justly accounts for these things is, unfortunately, a matter of opinion and politics."

Another example is the fuel used for kilns that make cement — whose use, in many cases, actually provides an environmental benefit. "It turns out that often a significant amount of that fuel might otherwise be waste material, and some of it even toxic waste," Jennings says. "The kiln operates at a very high temperature and decomposes it. So do we just not consider it? All these fuzzy areas have to be looked at carefully."

The MIT report, he says, attempts to provide a more complete approach than others have: "All the boundaries were looked at carefully, and we included the cradle-to-grave analysis in one package." The team "produced a model that is transparent and can be tested by others," he adds.

Already, the American Institute of Architects has embraced an initiative, called the 2030

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Challenge, to spur dramatic reductions in buildings' energy use and emissions; many cities and organizations have already agreed to its goals, which call for a 60 percent reduction in emissions (compared to the existing average) right away, and a 100 percent reduction by 2030. In other words, by then buildings should have no net energy consumption at all — which, amazingly, is already feasible today, Ochsendorf says.

"There have been zero-energy schools built in the last five years," he says, as well as other types of buildings (including the new zero-net-energy headquarters of the National Renewable Energy Laboratory in Colorado). These primarily rely on tight construction and good insulation, and compensate for their remaining energy use by installing solar arrays or other energy-producing systems.

For reducing total life-cycle energy use, "the real opportunities are in operation of buildings, rather than in their initial construction," Ochsendorf says. For many consumer goods such as computers, the energy used over their operating lifetime is about equal to that used for their manufacture, he says, but "for buildings, [energy for] operation is about 10 times that of their construction."

Since concrete is so widely used in construction, it's especially important to "find ways to optimize the use of concrete in a given building," he says. And indeed, it turns out there is a great deal of low-hanging fruit in that area, he says, as outlined in the new report.

Stephen Buonopane, associate professor of civil and environmental engineering at Bucknell University, who was not involved in this work, says the report is "very important and significant." What stands out about it, he says, is the way it combines a life-cycle analysis based on producing materials as well as assembling them, and also includes an analysis of their life-cycle costs and of the energy use of the building over its lifetime. Most analyses, if they include energy use during the occupancy of the building at all, use a simple average of overall use rather than the detailed breakdown offered by this study, he says.

"The other thing I was impressed with," he says, "was the focus on methodology and transparency," making it possible for others to draw on the information and use it to do their own detailed analyses of particular buildings in a specific location. "They did a great job in laying out all the assumptions and all the data" so that others can build on their work, Buonopane says.

The Concrete Sustainability Hub is funded by the Portland Cement Association and the Ready Mixed Concrete Research & Education Foundation.

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