Sustainable, Resilient Buildings

August 2019

An Overview of CSHub Buildings Research

Buildings both contribute to and are vulnerable to climate change. In the U.S., the heating, cooling, and operation of buildings and homes account for more than 40% of carbon dioxide emissions each year—more emissions than are produced by either transportation or industry. Meanwhile, the damage to property by the increasing number and intensity of hurricanes, tornadoes, and endangers lives and costs billions.

Any strategy for mitigating the effects of climate change must decrease energy usage and emissions from the building sector, as well as make structures more hazard-resistant. These measures will have substantial environmental, financial, and safety benefits for companies and individuals.

Research at the MIT Concrete Sustainability Hub (CSHub) supports the development of sustainable and resilient buildings by quantifying their energy use and hazard resistance. CSHub is developing streamlined methods for quantifying the environmental and economic impacts of different materials and construction systems.

Resilience and Life Cycle Cost Analysis

While most disaster relief organizations tend to focus on disaster response, CSHub research finds that investments in disaster mitigation reduce disaster costs and shorten recovery time. This preemptive approach is referred to as resilience.

CSHub research aims to make buildings and communities more resilient by informing homeowners of the

long-term cost benefits of hazard resistant construction. To do this, researchers use an approach called life cycle cost analysis (LCCA). LCCA calculates initial construction costs along with operational costs, including those associated with energy consumption and hazard repair, to estimate the total lifetime cost of a structure.

Using LCCA approaches, researchers have found that hazard repair costs can be significant over the lifetime of a building—even exceeding those of initial construction (see figure below). While resilient construction has only slightly higher initial costs it has long-term cost benefits because it can reduce the damages inflicted by disasters over the life of a building. Often it involves solutions like increasing the nail size in roof panels and installing windows with higher thickness. In Charleston, South Carolina, for instance, researchers found that expenditures on these higher

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construction standards were offset within five years due to the frequency of hazards like hurricanes.

To inform homeowners and builders of these cost benefits, CSHub has developed the Break-Even Mitigation Percentage. This tool displays the amount that can be invested upfront in resilient construction while still breaking even over the course of a building's lifespan.

To learn more about CSHub building resilience and LCCA research, visit https://cshub.mit.edu/buildings/LCCA

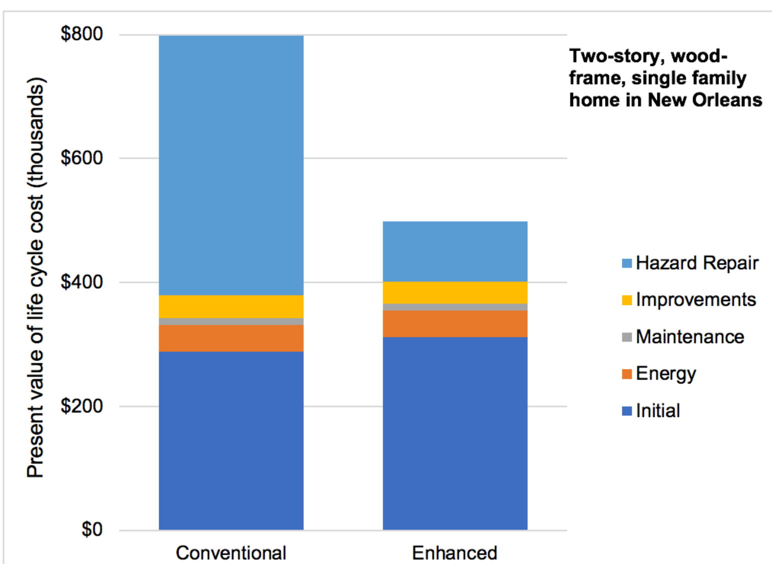
To view the Break-even Mitigation Dashboard, go to https://cshub.mit.edu/bemp-dashboard

Building Life Cycle Assessment

Building life cycle assessment (LCA) is an approach used by builders and developers to measure the lifetime environmental impacts of a building design. Much like LCCA, LCA examines a building's life cycle, including a building's materials, construction, operation, and demolition. CSHub has found that the operational impacts, also known as use phase impacts, represent the greatest proportion of a building's total environmental impact.

While vital for sustainable construction, LCA tools are rarely integrated into the building design process since they are time and data-intensive. However, the Building Attribute to Impact Algorithm (BAIA) developed by CSHub researchers streamlines building LCA so that developers can incorporate it early into the design process where it can have the greatest impact.

To learn more about CSHub building LCA research, visit https://cshub.mit.edu/buildings/lca



The lifetime costs of conventional and enhanced (hazard resistant) building designs in New Orleans. The enhanced design has slightly higher initial costs than the conventional design but a significantly lower life cycle cost due to lower hazard repair costs.

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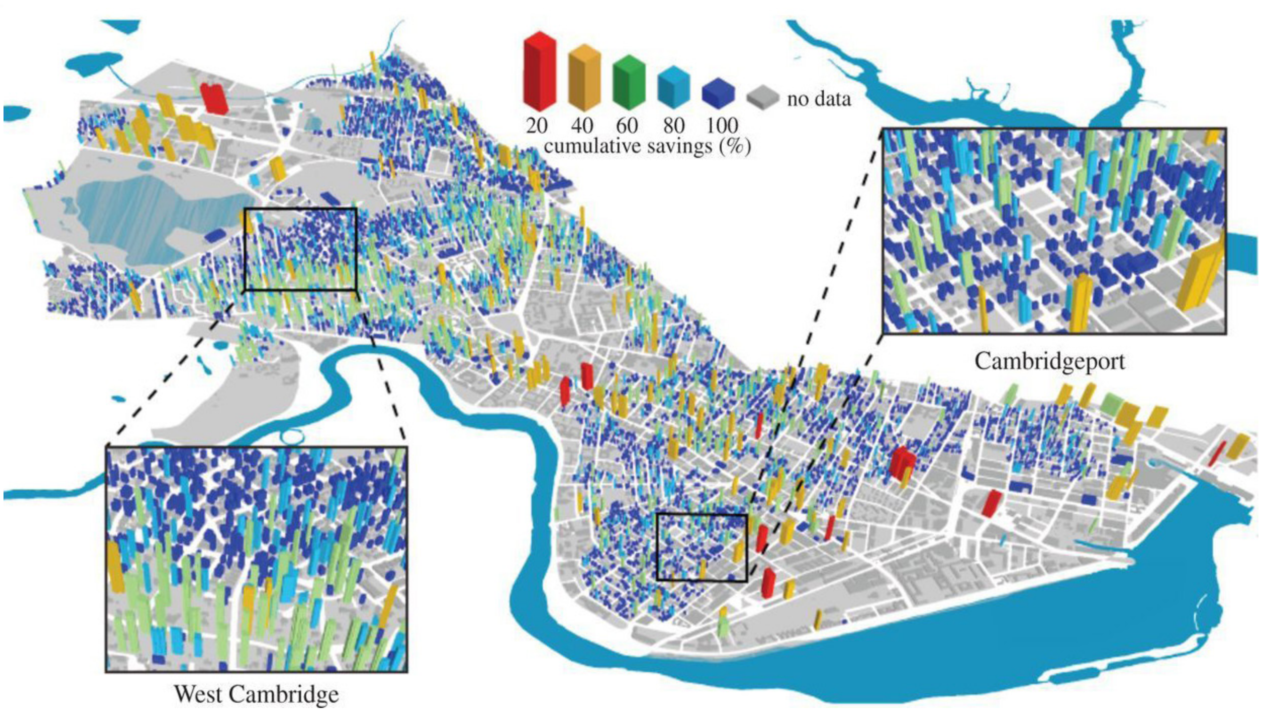

A map of Cambridge with colors representing the retrofittability potential of buildings for energy savings.

Urban Physics

Increasing urbanization means that policies enacted in cities are critical to mitigating the effects of climate change, urban heat island (UHI) effects, and natural or man-made disasters. CSHub research analyzes the economic, environmental, and hazard resistance impacts of building configuration and design in urban environments.

Using techniques from materials science, CSHub researchers have begun to characterize the layout of urban streets and buildings to predict the severity of urban heat islands and hurricane wind loads.

This research offers stakeholders ways to better understand and address urban resilience. For existing urban spaces, their model can mitigate the impacts of UHIs and wind loads by identifying particularly vulnerable areas for retrofit. The model also fills gaps in wind and heat flow simulations by offering more localized and streamlined results.

To learn more about CSHub urban physics research, visit https://cshub.mit.edu/buildings/urban-physics

City and Building Energy Consumption

CSHub research seeks to reduce emissions and energy consumption of buildings by examining which design choices have the greatest environmental impact.

Many of these design decisions are dictated by building energy codes, which specify the design and construction of buildings with regards to energy use and conservation. CSHub research investigates the long-term benefits of these codes.

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Researchers have also sought to lower the emissions of buildings generated during materials extraction and construction phases—also known as embodied carbon. They investigated the use of supplementary cementitious materials (SCMs), or substitutes for the carbon-intensive portland cement typically used in concrete mixtures, and found that through the adoption of the latest codes and use of SCMs, the emissions of U.S. office buildings would fall by 12%.

However, for many buildings, the use phase, or operational life, contributes most to lifetime emissions. To inform builders of how to lower these use phase emissions, CSHub researchers measure which building parameters contribute most to long-term energy consumption.

They have also applied this approach to the city-scale. Since older, often inefficient, buildings can compose much of a city, investigations have been conducted to find which buildings should be targeted for retrofit for the most effective overall reduction of emissions in a city. When applying their model to just 16% of the building stock of the city of Cambridge, researchers saw a 40% reduction in the city's overall gas consumption (see figure on the previous page).

To learn more about CSHub city and building energy consumption research, visit https://cshub.mit.edu/buildings/urban-energy

References

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