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CONCRETE SUSTAINABILITY HUB

Research Brief

June 2014

Streamlined Energy Modeling of Residential Buildings

OVERVIEW

Use-phase energy consumption is a key contributor to the environmental impact of residential buildings, but quantifying this energy consumption typically requires a detailed building design and time-consuming energy modeling simulations. In addition, use-phase energy is typically not included in most current life-cycle assessment tools, making it harder to evaluate the environmental tradeoffs of different design options. As a part of our streamlined life-cycle assessment methodology (the Building Attribute to Impact Algorithm, or BAIA), the CSHub has been developing a model that can estimate the use-phase energy consumption based on schematic or "underspecified" building attributes, rather than requiring a comprehensive design and in-depth energy modeling. This Attribute to Activity Model (AAM) for use-phase energy consumption will be used in conjunction with similar models to estimate the life-cycle inventory or "bill of activities" for a building based on parameters that are known early in the design process, thus allowing comparisons of environmental impacts at a point when this information is more likely to affect the building design.

APPROACH

In order to develop the AAM and establish a simplified mathematical relationship between building attributes and use-phase energy consumption, simulations were run with BEopt, an energy modeling tool from NREL that uses EnergyPlus as its simulation engine. Emphasis was placed on building attributes that are relevant to use-phase energy consumption and that are either known or decided upon early in the design process (such as dimensions, window areas, window types, and general wall systems). These parameters were varied randomly using a Monte Carlo approach, with 1,000 simulations in each of 6 climates spanning a range of heating and cooling requirements (from Miami to Anchorage). Least squares regression was then used to relate the building attributes to the resulting use-phase energy consumption, with a separate regression model for each climate.

FINDINGS

Our regressions have an average R^2 value of approximately 0.8, indicating good fit in the model. This means that it is possible to estimate the use-phase energy consumption of a residential building with reasonable accuracy without a fully developed building design, and also without running a full energy use simulation, provided that the building parameters fall within the ranges used to develop the model.

The simulated use-phase energy consumption results can also be grouped by underspecified building attributes to assess how the distribution of energy consumption changes based on high-level design options. For example, Figure 1 shows the distribution of use-phase energy for various wall systems for a residential building in Atlanta. In each of these box plots, the only fixed parameters are the climate (Atlanta) and the indicated wall system category; the distribution in energy consumption shown is due to variation in the other parameters. Plots like this could be used to choose building attributes with lower median energy consumption (or a smaller range for greater certainty). Moving forward, these energy consumption values will be coupled with results from other life-cycle stages to understand the tradeoffs between, for example, use-phase and embodied environmental effects.

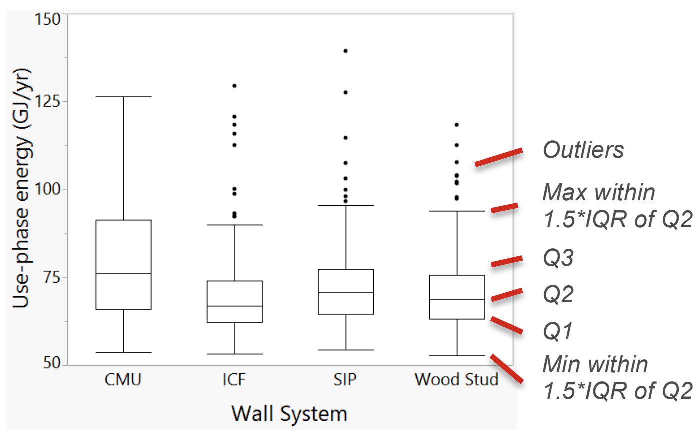

Fig. 1: Results for the 1,000 energy simulations in Atlanta, grouped by underspecified wall systems

IMPACT

The Attribute to Activity Model allows the efficient estimation of use-phase energy consumption based on early design parameters. Rather than requiring a fully developed building design and computationally expensive building energy simulations, this model can be used by designers to gain insight about the environmental effects of different options at a point when this insight has a greater capacity to affect the final building design.

This research was carried out by CSHub@MIT with sponsorship provided by the Portland Cement Association, the Ready
This research was carried out by CSHub@MIT with sponsorship provided by the Portland Cement Association, the Ready
Mixed Concrete Research & Education Foundation and Schlumberger. CSHub@MIT is solely responsible for content.
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