Assessing the environmental impact of construction material using Life Cycle Analysis (LCA)

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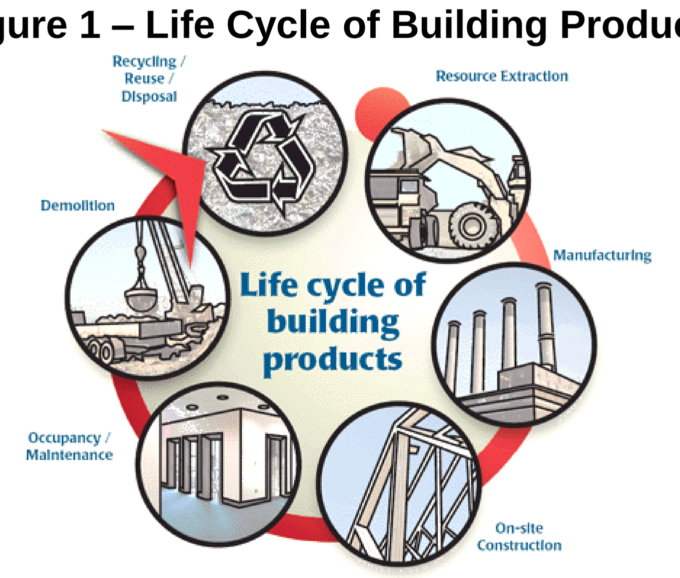
Introduction

Sustainability has become an important consideration for civil engineers during the design process of buildings using Building Information Modeling software (BIM). LCA offers a cradle-to grave method of evaluating the environmental impact of a building material. Athena Institute's EcoCalculator software uses a LCA approach that displays the environmental impact in terms of:

- fossil fuel consumption (FFC),
- weighted resource use (WRU),
- global warming potential (GWP),
- acidification potential (AP),
- human health respiratory effects potential (REP),
- eutrophication potential (EP),
- ozone depletion potential (ODP), and
- smog potential (SP).

Figure 1 below provides a summary of the stages of the materials "life" that are accounted for during LCA.

Figure 1 – Life Cycle of Building Products



Objectives

The objective of this study was to use EcoCalculator to estimate the environmental impact of three building models constructed out of steel, concrete, or wood that are otherwise identical. The viability of incorporating EcoCalculator into BIM software was also investigated.

Methodology

Three different versions of the EcoCalculator software – EcoCalculator for Residential Assemblies, EcoCalculator for Commercial Assemblies (low-rise), and EcoCalculator for Commercial Assembles (high-rise) – were each used to simulate the life cycle of three buildings constructed out of solely steel, concrete, or wood that are otherwise identical. Upon completion of the aforementioned simulations, the viability of integrating EcoCalculator into BIM software was investigated by performing an exhaustive analysis of the procedures and design of EcoCalculator.

Results

Upon completion of the LCA of the models used, the figures below were constructed to depict the impact of the models (in percent relative to the impact of the wood building) in the seven different criteria EcoCalculator estimates. The buildings constructed from wood performed significantly better in all three tests than those made out of concrete or steel.

Figure 2 - Environmental Impact of Residential Buildings

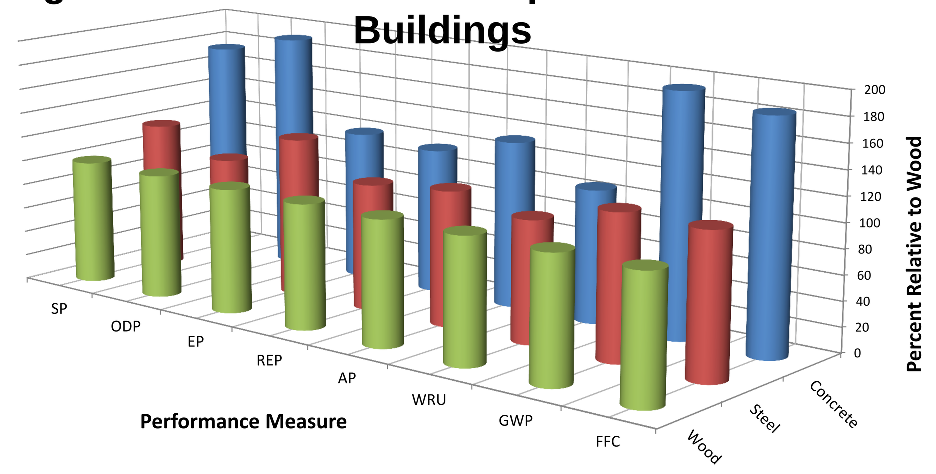


Figure 3 - Environmental Impact of Low-Rise Commercial Buildings

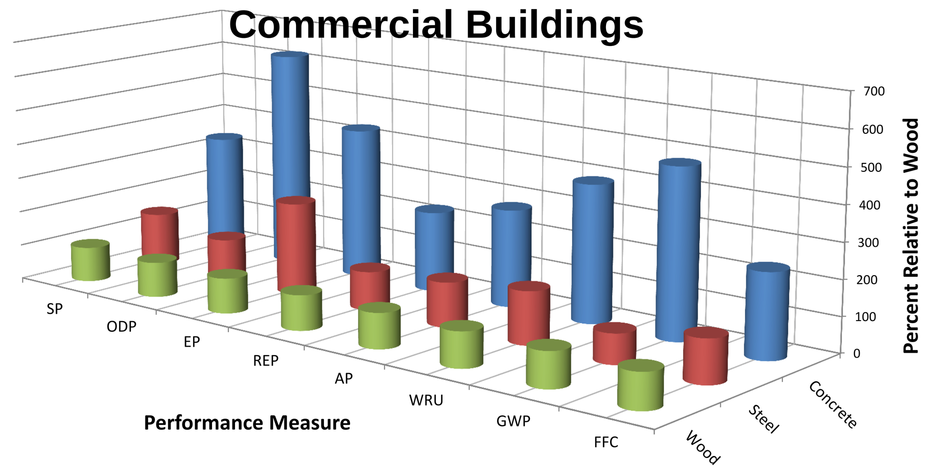
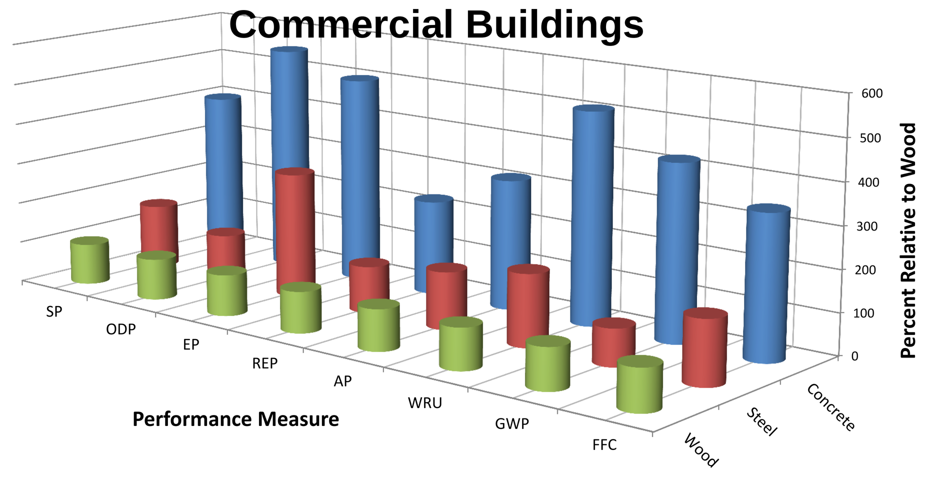


Figure 4 - Environmental Impact of High-Rise Commercial Buildings

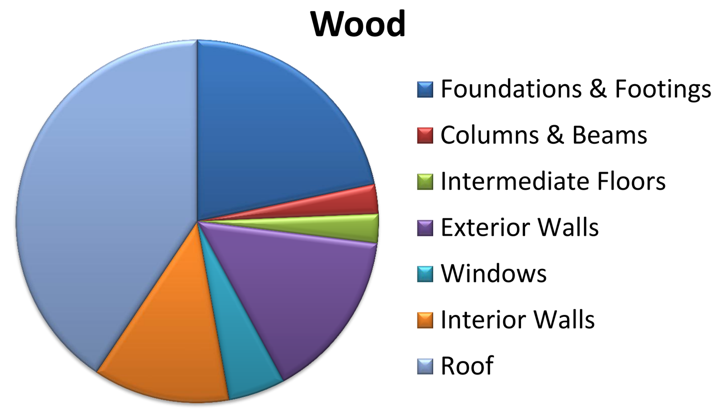


It was discovered that there is no feature in EcoCalculator that allows the user to specify functional requirements of the building or to verify that the assemblies selected will meet their predetermined functional requirements (e.g. bearing capacity, durability under specific conditions, etc.). Since it requires users to base design decisions on environmental impact alone, it is less useful as a standalone application but could be linked to other programs to develop a more thorough analysis of the building models.

Additionally, EcoCalculator is inconsistent in the liberty it gives its users to personalize their building designs. In many cases, the user must choose out of a limited selection of products. For example, the *Foundations and Footings* section of the program provides basic options that allow the user to specify dimensions of the foundation wall, slab, and footing, but it excludes other foundation options, like monopile foundations, foundation reinforcements using non-concrete materials, slab-on-grade, or rubble trench foundations.

Inherent assumptions in the design of EcoCalculator decrease the overall accuracy of the program. Particularly, it assumes constant concrete strength over all of the concrete elements is uses, and specific element dimensions and orientation (e.g. stud width and spacing, in the case of the *Interior Walls* section). Figure 5 below examines the fossil fuel consumption of the wood residential model.

Figure 5 – Fossil Fuel Consumption of a Residential Building Constructed from Wood



If the building model used stronger concrete than the program assumes, the contribution of this concrete to the total fossil fuel consumption is not truly represented by the graphs produced.

Conclusions and Recommendations

The results of the LCA performed by EcoCalculator suggest that wood is the optimal building material to minimize environmental impact of residential or commercial assemblies. However, EcoCalculator makes assumptions that compromise the accuracy of its results. Moreover, EcoCalculator lack of functions and assembly options suggest that it should be combined with others software before being considered for integration into BIM software. Other software, such as Athena Institute's Impact Estimator, could also be investigated and analyzed in a similar fashion.

References

1. Athena Institute. (2012). *EcoCalculator Quickstart*. Retrieved from Athena Software.
2. Athena Institute. (2012). *Inner Workings Synopsis.* Retrieved from Athena EcoCalculator for Assemblies.

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