The Environmental Benefits of Wood Construction

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Summary

Life-cycle assessment (LCA) has convincingly demonstrated the environmental advantages of wood-based construction systems compared to alternatives in steel or concrete. However, concerns in North America and in Europe over forest management have led to confused public opinion regarding wood. This has resulted in some sustainable design guidelines that don't acknowledge wood's LCA performance, and marketing efforts by the steel and concrete industries that imply those materials are environmentally preferable to wood. In addition to emotional responses to harvesting, wood's environmental image also suffers from perceptions that North American wood-framing practice inefficiently uses the resource; that wood product manufacturing is stuck in the past; and that wood buildings have shorter life spans than buildings made from other materials. This paper presents results of new LCA studies on wood within the context of these image problems, and discusses mechanisms for reclaiming wood's premier environmental status among construction materials. This includes highlighting the unique role of wood products in the earth's carbon cycle, an environmental benefit currently under-appreciated in the context of global warming.

Keywords: LCA, sustainable design, advanced framing, service life, carbon sequestration.

1. Introduction

Environmental awareness in the design and construction sector has rapidly escalated in recent years around the globe. Considered for decades to be a mere niche interest area in the U.S. and Canada, "sustainable design" is now a relevant force in mainstream non-residential construction. The environmental movement has expanded both in reach and in scope – originally focused almost exclusively on energy efficiency, sustainable design is now additionally concerned with ecological impacts of product manufacturing, embodied energy in products, construction waste and other broad issues.

At first glance, this architectural environmental movement would seem good news for structural wood products, which enjoy the unique advantages of renewability and clean manufacturing. However, end users of wood products are often conflicted in their environmental perception of wood, due to discomfort with forest management, misunderstandings about wood's longevity, and misinformation about environmental improvements in both harvesting and manufacturing.

Concerns about the forest are strongly based on emotions, which indicates a delicate and difficult communications effort. This is a critical task, but is outside the scope of this paper. Here we discuss how to address the technical image problems for wood in the environmental arena, by providing data to support wood's superior environmental status as a construction material.

2. Life-cycle Assessment of Wood Framing

2.1 LCA as a design tool

Life-cycle assessment is a formal process of quantifying the environmental effects of a product through its entire life, from raw resource or material acquisition through manufacture, use, and ultimate disposal. Instead of a single-attribute analysis of a material's environmental impact, such as its recycled content, LCA takes a holistic approach to the overall impact.

The application of LCA to decision-making in building design is fairly new and not yet broadly practised. LCA is complex enough to tax the time and knowledge of a typical designer. In addition, few LCA design tools exist, and each is regionally specific. In North America, the only whole-building LCA tool is the Athena™ Environmental Impact Estimator [1]. While North American designers are slowly becoming more aware of LCA and the benefits of a performance-based approach to sustainable design, most designers rely instead on highly prescriptive guidelines such as the popular LEED™ program. The shortcomings of these guidelines are already recognised, and there is movement to integrate LCA into them [2]. Until this happens, wood may be somewhat disadvantaged by most prescriptive sustainable design programs, as these tend to reflect popular misunderstandings about the environmental profile of various construction products [3].

2.2 LCA results on wood

Anticipating an increase in environmental scrutiny of wood products, Forintek Canada Corp., with support from Natural Resources Canada, in 1991 began gathering life cycle inventory data on wood and other construction products [4]. This work subsequently led to the formation of the independent Athena™ Sustainable Materials Institute (www.athenasmi.ca), an international leader in LCA for buildings.

Life-cycle assessment has since been used to credibly and scientifically demonstrate the true environmental profile of wood construction products in Canada [5] and the U.K. [6]. In the U.K., these results have led to rewards for the use of wood in BREEAM, an environmental rating system for buildings [7].

The Canadian Wood Council recently commissioned another study, using the Athena™ LCA package, to more thoroughly examine the environmental picture for a typical North American house built of wood versus competing structural materials [8]. In Canada and the United States, most single-family and low-rise multi-family construction is wood-frame. Both the steel and the concrete industries are actively seeking more share of the residential market by promoting the environmental benefits of each material while raising consumer alarm about loss of forest. In the case of steel, an emphasis is placed on its recycled content, while for concrete the stress is on durability and the thermal benefits of the insulated concrete form system.

In this study, three equivalent 216 square metre houses were analysed over a 20-year lifetime in Toronto, Canada. One house is wood-frame, one is light gauge steel, and one is made from insulated concrete forms. The results address all embodied environmental effects for the structures plus all heating and cooling environmental effects over 20 years, and clearly indicate that wood has the lowest values in all six environmental measures calculated by Athena™ (Table 1).

Structural System	**Primary Energy** (Gigajoules)	**Global Warming Potential** (Equiv. kg CO_2)	**Air Pollution** (Critical Vol.)	**Water Pollution** (Critical Vol.)	**Resource Use** (kg)	**Solid Wastes** (kg)
Light-frame wood	3313	158192	58793	32	397690	24318
Light-frame steel	3713	182251	64751	122	425918	25882

Insulated conc. forms	3942	203061	65423	105	597514	28140

Table 1: Summary of 20-year comparative environmental results for three houses in Toronto.

3. Wood Framing Efficiency

Some sustainable design advocates claim that standard North American residential wood-frame practice uses wood inefficiently and creates too much waste. It is felt that the environmental profile of a wood house would be improved through the implementation of a more careful design approach known as advanced framing or optimum value engineering. Some typical examples of advanced framing include alignment of openings with the framing module and vertical alignment of framing elements to eliminate headers, elimination of three-stud corners, and adjustment of roof slope to best use standard panel sizes without trimming.

Forintek commissioned an LCA study comparing a current best-practice Canadian house with one using advanced framing principles [9]. The houses are spatially identical (2 stories, 207.4 m^2) and both are wood-frame, however the house with advanced framing is designed to minimize the volume of wood. The conventional house is modelled with 38 x 140 mm lumber studs spaced at 400 mm, single bottom plates, double top plates, 3-stud corners, and exterior OSB sheathing. The advanced framing house uses 38 x 89 mm studs at 600 mm spacing, single plates, 2-stud corners, window and door alignment with the framing, metal cross-strapping to replace exterior sheathing, and exterior rigid insulation to compensate for the loss of cavity insulation thickness due to the smaller studs.

The advanced framing house uses 50% less wood volume than the conventional house, saving on average $2000 in labour, material and debris disposal costs (2003 Canadian dollars). However, the environmental implications of this are insignificant (or even negative), as shown in Table 2. This is because the removal of wood elements requires the addition of less environmentally benign components such as polystyrene insulation and metal strapping.

Framing Method	**Primary Energy** (Megajoules)	**Global Warming Potential** (Equiv. kg CO_2)	**Air Pollution** (Critical Vol.)	**Water Pollution** (Critical Vol.)	**Resource Use** (kg)	**Solid Wastes** (kg)
Conventional framing	736546	17615	8970	21	35206	175366
Advanced framing	751781	17256	8962	21	36064	171620

Table 2: Comparative embodied LCA summary results for conventional versus advanced framing.

4. Maximising Renewable Content

In the advanced framing study discussed above, it is clear that minimising wood in a structure does not have significant environmental benefits. On the contrary, *maximising* the use of renewable construction materials has been demonstrated to have significant benefit when compared to either a conventional or an advanced wood-framed house [9]. Conventional construction was compared to a version using 38 x 140 mm studs (to maximize cavity space), replacement of fibreglass batt insulation with cellulose, single plates, 2-stud corners, exterior plywood sheathing, window and door alignment with framing, and wood siding replacing vinyl. As shown in Figure 1, the maximum renewable house embodied 30% less energy, emitted 25% less greenhouse gases, 35% less air pollutants, 1% less water effluents, 25% less solid waste and used 4% less raw resources.

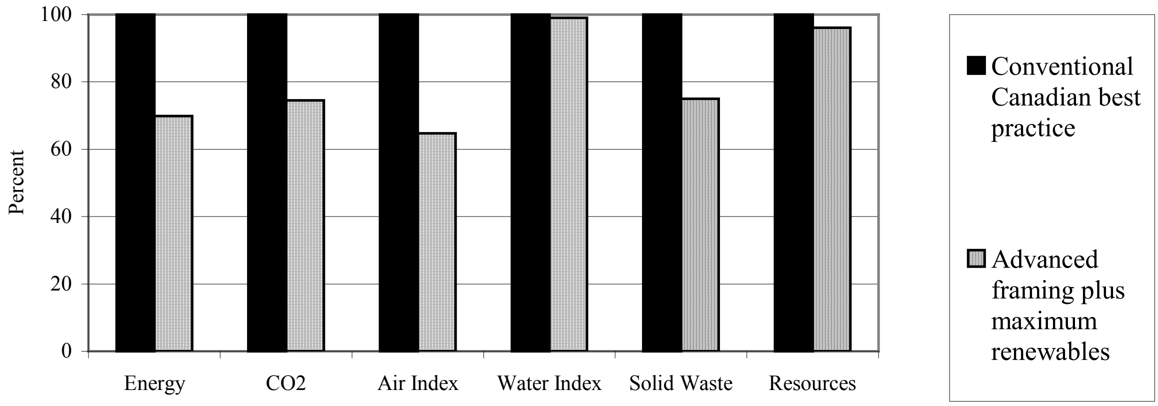

Figure 1: Comparative embodied LCA results for advanced framing with renewable siding and insulation versus a conventional house (the baseline).

5. Service Life of Wood Buildings

Life cycle assessment requires an estimate of a building's useful life span. Survey data from building industry practitioners in Canada and the U.S. show a widespread belief that wood buildings have greatly shorter service lives than buildings made from other structural materials [10]. A short service life has a negative effect on LCA results, as the impact of a replacement building will be included in the calculation. Forintek commissioned a demolition survey in the U.S. to explore any potential correlation between structural material and service life, after finding virtually no published documents with this data. Information was gathered for 227 buildings demolished in the city of Minneapolis/St. Paul from 2000-2003 [11]. As expected, reasons for demolition were largely related to changing land values, lack of suitability of the building for current needs, and lack of maintenance of various components. Only eight buildings identified a specific structural failure, and only one of these was wood decay.

A few previous studies indicate that service lives of most buildings are probably far shorter than their theoretical maximum lives. For example, a large study of U.K. residential buildings found 46% of demolished structures fell in the 11-32 year age class [12]. Another large study, of office buildings in Japan, found the typical life span to be between 23 and 41 years [13]. It is reasonable to assume that, for the vast majority of demolished buildings in the world, the structural material is likely intact, but the building is no longer serving its intended purpose or is no longer delivering the best value for the land.

While wood is thought to have a short life expectancy due to risk of fire or biodegradation, our results surprisingly showed that wood buildings have the *longest* life spans (Figure 1). The majority of demolished wood buildings were older than 75 years, while over half of all the demolished concrete buildings fell into the 26-50 year category.

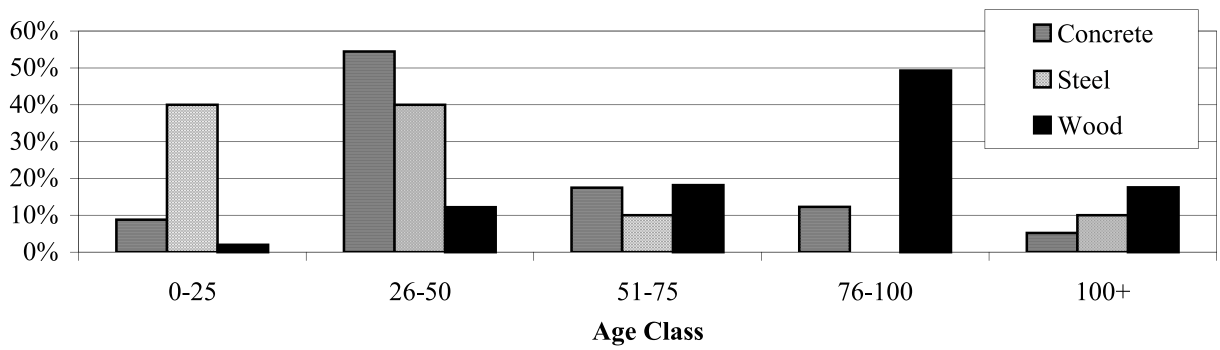

Figure 2: Distribution of demolished buildings over age classes, by structural material.

6. Carbon Storage in Wood Buildings

The role of wood products in the earth's carbon cycle is unappreciated by most building industry practitioners, although this is an area of keen interest within some scientific circles. Trees convert atmospheric carbon dioxide (CO_2), the most important contributor to global warming, into wood. This carbon remains stored until the wood decays or burns. Thus, standing forests, forest soil, and long-lived solid wood products such as furniture and structural materials are sequestering substantial amounts of carbon and therefore offsetting greenhouse gas emissions due to the combustion of fossil fuels [14].

Carbon sequestration in wood products and in forests is a complex and controversial area of study from the perspective of estimating and modelling world carbon flows, a critical component in current international activities related to global warming. Although the accounting methods for exact measurements are not yet resolved, there is no question that wood products are unique among the major structural materials in that they sequester more carbon than is released during their production.

The structural wood components in a typical 216 m^2 North America house contain a total of 7,770 kg of carbon. The atmospheric CO_2 equivalent of this is 28,516 kg. If we assume a small light duty car burns 8.5 L of gasoline for every100 km travelled, and gasoline has an energy content of 34.66 Mj /L and emits about 68 g of CO_2/ Mj of gasoline burned, the car emits about 20 kg of CO_2 every 100 km traveled. Hence, 28.5 tonnes of CO_2 sequestered in the house is equivalent to the CO_2 released by driving the car a total of 142,341 km. If we assume the average family car typically travels about 20,000 km/yr, the CO_2 sequestered in the house is equivalent to seven years of car operation.

7. Discussion and Conclusions

With a rising interest in environmental responsibility in the building sector, designers understandably are seeking simplified decision-making tools. The most popular of these in the U.S. and Canada is a guideline and rating system known as LEED™. Designers earn points for a building by incorporating various measures assumed to be environmentally beneficial. Because many of these measures are prescriptive, in particular with respect to material selection, they reflect current beliefs and biases. For example, the LEED™ guideline reflects mixed feelings about wood due to discomfort around forest management, and rewards the use of steel for its recycled content.

Although architects and others typically view wood as a "natural" material, many still feel some environmental guilt when specifying wood products. This is a source of frustration in the wood products sector, given that current scientific data clearly indicate wood has the lightest environmental footprint among its competitors.

The primary mechanism for ensuring that materials are judged objectively is life-cycle assessment. Design guidelines and rating systems should replace subjective and prescriptive measures with LCA-based performance measures. The LEED™ program is already proceeding in this direction. Because this program is the current North American standard-bearer, its adoption of LCA will accelerate the dissemination of LCA through the design world and among other environmental design programs.

A number of image problems for wood can be swept away through an information campaign within the building industry now that data exist which correct life span misconceptions about wood, environmental misconceptions about advanced framing, and the assumed environmental impact of minimising the use of wood products. Forest management assurances also need to be broadly communicated, as these concerns currently function as a screen preventing designers from rationally considering the scientific LCA data that would put their minds at rest about wood.

The benefits of wood products in sequestering carbon have also been under-published. Even though carbon sequestration in wood construction isn't yet credited in any environmental design program or carbon trading scheme, architects can still be influenced in choosing wood if they have a better understanding of the global warming benefits inherent in wood construction.

Some aspects of the environmental performance of wood still need addressing. Wood recovery from construction and demolition waste for re-use or recycling is not yet commonly practiced in North America. Technical advances in wood product processing may not be well-understood by specifiers, many of whom view wood as an outdated material and assume it to be less environmentally attractive than more "modern" materials on that basis alone. Product emissions (formaldehyde, for example) are becoming important in sustainable design, and specifiers are asking many questions about composite wood products. These are important issues for further study.

8. Acknowledgements

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