Emission Omissions:

Carbon accounting gaps in the built environment

IISD REPORT

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Executive Summary

There is a rising interest in Canada about how the choice of building materials may affect future greenhouse gas (GHG) emissions, and whether a preference for a specific building material or combination of materials can help Canada reduce the GHG emissions of the built environment and achieve targeted emission reductions.

Evidence for optimizing the choice of building materials has largely been drawn from life-cycle assessment (LCA) studies that consider the GHG (and other) impacts of products at each phase of their "cradle-to-grave" lifespan (i.e., production, use and end of life). While LCA is the best-available tool for evaluating the GHG performance of alternative building products and designs, policy-makers and building designers should be aware that it also has significant limitations, challenges and uncertainties.

The aim of this research is to identify:

a) Limitations, challenges and uncertainties in existing LCAs and quantify their significance to the current understanding of the relative GHG performance of buildings made alternatively of concrete, steel or wood structural elements.

b) Best practices that could improve the reliability and usefulness of LCA to support effective policies to decarbonize the built environment.

c) Longer-term opportunities to reduce life-cycle emissions in the built environment by supporting decarbonization efforts in the concrete, steel and forestry sectors.

Summary of Key Findings

Existing LCAs produce widely variable results, even for similar buildings, posing challenges for decision-makers.

LCA accounting of the GHG emissions associated with different building materials can vary widely depending on how they handle various assumptions and uncertainties. These assumptions and uncertainties are typically not fully disclosed. Further, sensitivity analyses—or other techniques to identify the importance of assumptions and uncertainties to the results—are rarely conducted. In other words, LCAs rarely assess how their assumptions increase uncertainty around their results and/or how different assumptions could yield significantly different results.

LCAs comparing building materials can exaggerate the importance of embodied impacts when they discount or ignore the contribution of other significant life-cycle emissions.

While many LCA studies focus on the embodied life-cycle GHG emissions associated with different structural elements (typically concrete, steel or wood), they tend to discount or ignore the operational stage emissions as well as the emissions impacts of other building systems (e.g., site preparation, heating and ventilation, supplementary structures, furnishing). This can inflate the relative contribution of the embodied emissions of the structural building elements. Used in isolation, these results can lead to decisions that are too narrow in scope and shift focus away from a more comprehensive picture of emission reduction opportunities in buildings.

Regional variability was found to significantly affect overall life-cycle emissions.

For example, steel production in Canada is mostly split between electric arc furnace (EAF) mills, which use recycled steel feedstock and renewable electricity, and basic oxygen furnace (BOF) mills, which use virgin iron ore. Sourcing steel from EAF mills can decrease embodied emissions by a factor of two to four compared to steel from BOF mills or imported steel from China. Regional markets typically determine the steel that is available. Wood building products' end-of-life emissions are highly dependent on disposal conditions—wood materials that are landfilled at sites that do not have methane recovery or flaring can have end-of-life emissions up to 10 times higher than wood disposed at landfills with landfill gas recovery. Emissions associated with raw material extraction for both steel and concrete were also identified as having high variability.

Biogenic carbon emissions and sequestration related to the production and end-of-life stages of wood building products hold the most significant uncertainty in existing LCAs.

Whereas emissions from the production of concrete and steel are well understood, accounting for emissions and sinks in the biogenic carbon cycle of wood products is complex and requires sophisticated carbon models that can track exchanges between different carbon pools. LCA studies typically do not track biogenic carbon but simply assume that whatever carbon is harvested is replaced sustainably by new forest growth in the future (i.e., carbon neutrality). Criticisms of this assumption include that it ignores significant and measurable GHG emissions from soil disturbance, carbon losses from the conversion of old-growth primary forest and real-world silvicultural success rates than can be significantly less than 100 per cent. Previous studies have also found that as little as 15 per cent of the carbon stored in a standing tree is sequestered in the final wood product. Few LCAs account for the immediate climate change impacts of these carbon losses relative to the small amount of carbon stored, nor do they account for the time required to recapture that carbon and other biogenic carbon losses in new forest growth.

Sensitivity analyses of assumptions related to biogenic carbon suggest that the life-cycle GHG emissions of wood products can be significantly higher than those presented in LCA literature.

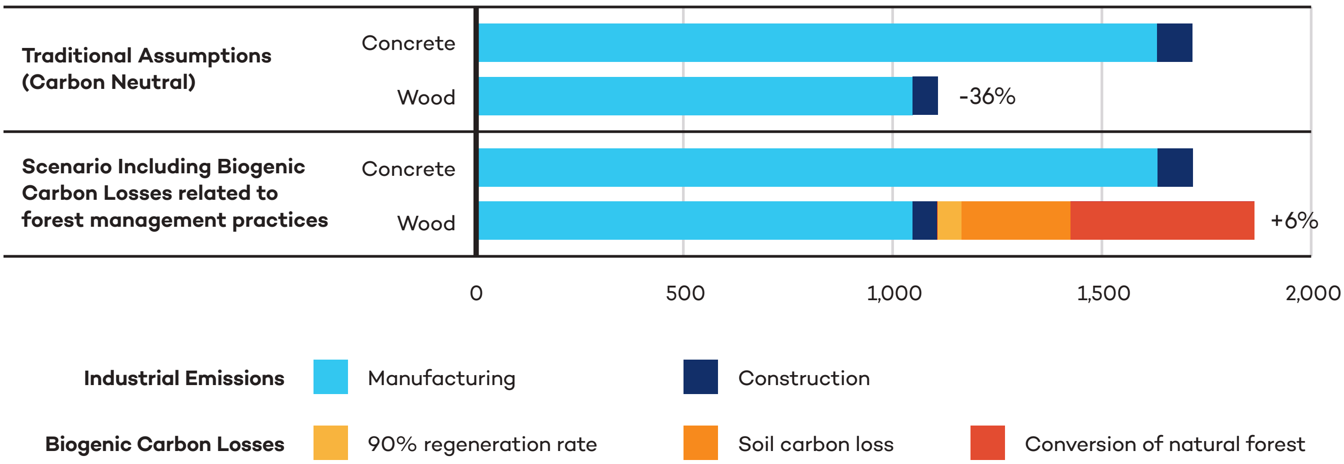
Based on a typical LCA study, it is possible to test the overall LCA impacts of wood building construction against a concrete building, controlling for the GHG impacts of three different forest management scenarios: a silvicultural success rate of 90 per cent, a net permanent loss of soil carbon attributed to a clear-cut harvest and carbon losses from the conversion of primary forest to secondary managed forest.[1] Compared to a baseline that assumes biogenic carbon emissions are zero over the building life cycle, cradle-to-gate life-cycle emissions for wood buildings increased between 5 and 72 per cent depending on the scenario. Aggregating these impacts suggests that a wood building could have greater embodied emissions than a concrete building (see Figures ES1 and ES2).

In an energy-efficient, long-service-life structure, the GHG impacts of building material choice remain negligible, suggesting that embodied emission reductions should not be pursued at the expense of operational efficiency.

While the LCA GHG impacts of materials relative to the overall life cycle of a building vary slightly depending on regional climatic conditions and energy mix as well as the energy efficiency and longevity of the structure, these impacts are small for most buildings in Canada and emphasize the continued importance of prioritizing energy efficiency and designing long-lived low or net-zero-energy buildings. Material choices need to be made on a building-by-building basis, driven by the role they play in enhancing the structure's environmental strategies and performance.

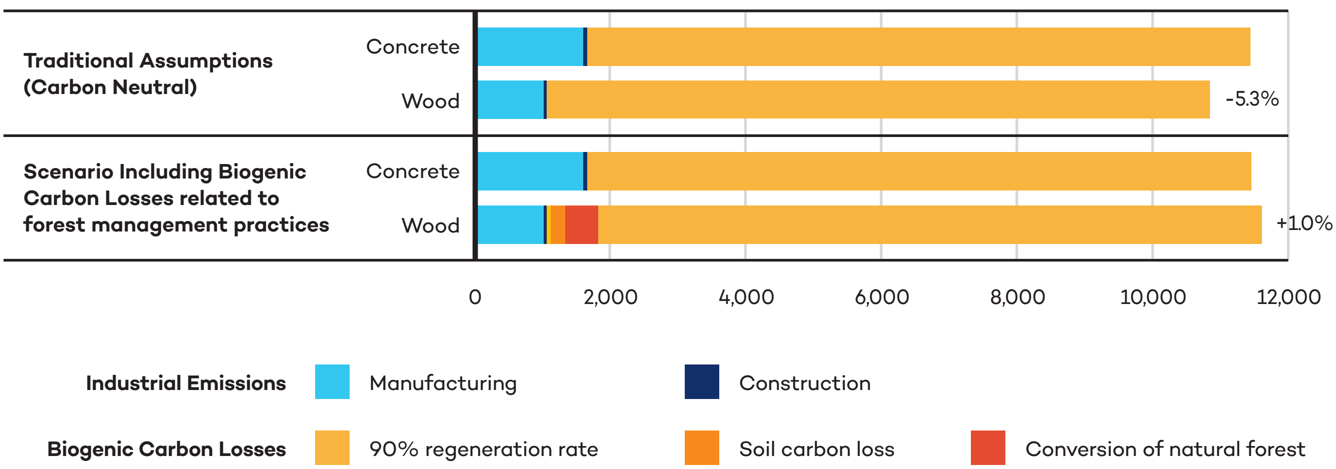
[1] The three scenarios are supported by forestry research and represent reasonable possible ranges of impacts that reflect identified uncertainties. However, they do not represent probabilistic outcomes or average or specific conditions for any given managed forest in Canada. More research and regional modelling are required to determine the probability of impacts.

Figure ES1. Cradle-to-grave building embodied emissions (tCO_2e)



When combined factors such as forest regeneration rates, soil carbon loss and primary-to-new-growth-forest-conversion are all accounted for, the cradle-to-grave embodied emissions for a wood building could be 6 per cent greater than for a concrete building.

Figure ES2. Building embodied and use emissions (tCO_2e)



When adding use phase emissions to the embodied emissions, the carbon impact of a wood building could be 1 per cent greater than for a concrete building.

Summary of Key Recommendations

Building efficiency and longevity should be the priority for decarbonizing the built environment.

In the short to medium terms, improvements in energy efficiency and developing new low- or net-zero-energy buildings offer the highest mitigation potential from the built environment sector. Effective carbon pricing and complementary policies that cover the manufacturing sector will also work to decarbonize embodied emissions of building materials, albeit likely at a slower rate than the decarbonization of building use. In addition, policies should promote building longevity, durability and service efficiency improvements as well as rehabilitation and remodelling to extend service life, all of which have significant GHG emission reduction benefits.

LCA is the right approach, but more data, transparency and robust standards are needed, especially with respect to biogenic carbon.

Policy-makers and building professionals looking to decarbonize buildings should exercise caution when making decisions that prefer one building material over another. Uncertainties, assumptions and omissions in LCA studies, particularly with respect to the biogenic carbon emission of wood products, suggest that comparisons across building materials are fraught with complexity. Far more transparency, consistency and rigour in LCA data and methodologies are needed to render material comparisons meaningful, especially for policy development. As a start, the federal government should invest in up-to-date regionalized, national life-cycle inventories, including a meaningful carbon accounting for wood products that considers regional biogenic carbon impacts against net carbon sequestered.

To address embodied GHG emissions in buildings, policy-makers and building professionals need to focus equally on material efficiency and incenting decarbonization across all material manufacturing sectors.

Each building is unique in design and, while a given building design may substitute wood, steel or concrete elements to some degree, each of these three materials is typically prominent in varying proportions in all construction. In addition, there are varying strategies, technologies and policy levers that can incent GHG reductions in each material sector, all of which should be identified and equally incentivized as part of a robust built environment decarbonization strategy. When it comes to material selection, climate policy and low-carbon building design are best focused on material efficiency and supporting low-carbon innovation across all material sectors. For concrete and steel, this means rewarding low-carbon producers and driving the adoption of best-available technologies, such as the use of lower-carbon alternative fuels. For wood products, there is evidence that market-ready solutions in forestry management and regeneration can significantly enhance emission sinks in Canadian forests and contribute to reaching Canada's emission reduction targets. Deep emission reductions on the order of 60–80 per cent that are in line with Canada's long-range emission reduction targets will require large-scale investment in new low-carbon technologies, such as carbon capture utilization and storage as well as significant changes to forest management practices (e.g., avoidance of slash burning, enhanced silvicultural practices) focused on optimizing and preserving biogenic carbon pools.