Ecologically based Life Cycle Assessment of Building Materials

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Abstract

Conventional LCA techniques inadequately account for product's natural capital consumptions. Doing so would allow for more complete inter- and intra-sector comparisons of the life-cycle impacts of building materials such as wood, concrete and steel.

The EcoLCA method has recently arisen to address the challenge of providing comprehensive resource accounting in LCA and standardizing a unit for resource aggregation. To address the issue above, the proposed research seeks to accomplish the following objectives: (1) Compare life-cycle performance of common building materials, like wood, concrete, and steel, using the EcoLCA technique and (2) use hybrid EcoLCA to characterize the environmental profile of current research on engineered wood based building materials.

Use EcoLCA tool to estimate the environmental impact of structural beams manufactured from three materials: concrete, engineered wood, and steel. Early results suggest that the concrete beams have the highest aggregated resource consumption when measured using ECEC, ICEC, Mass Flow, and Energy Consumption. Results do not yet exist for the hybrid EcoLCA study of specific materials under development at the University of Maine's Advanced Engineered Wood Composites.

Background

Building industry:
- -Major contributor to GHG's and natural resource consumption
  - -38%CO_2 emissions (U.S.)[1]
  - -39% Energy (U.S.)[2]
  - -40% Raw Materials (global)[3]

Green Building Materials
- -Need to develop products with low to no environmental impact
- -Understanding such impacts is difficult due to lack of:
  - -sufficient & complete data
  - -fully developed methodology

LCA of Wood Building Products:
- -As a renewable bio-based resource, research suggests that wood products result in lower, even negative, net CO_2 emissions and consume a relatively low amount of energy[4]
- -However, other factors should be considered:
- -increased land use intensification[5]
- -wood products often less durable[6]
- -can emit significant levels of VOCs[7-8]
- -wood products less recyclable than other building products like steel
- -LCA methods that consider these factors should be explored in light of the wood industry

Ecologically based LCA[9]:
- -Method and publicly available web tool for LCA
- -Augments Input-Output LCA methods with extensive accounting for ecosystem goods and services
- -Allows for analysis at the economic sector level via NAICS categories
- -Permits resource aggregation via Ecological and Industrial Cumulative Exergy Consumption (ECEC & ICEC), Mass Flow, and Energy Consumption

Methodology

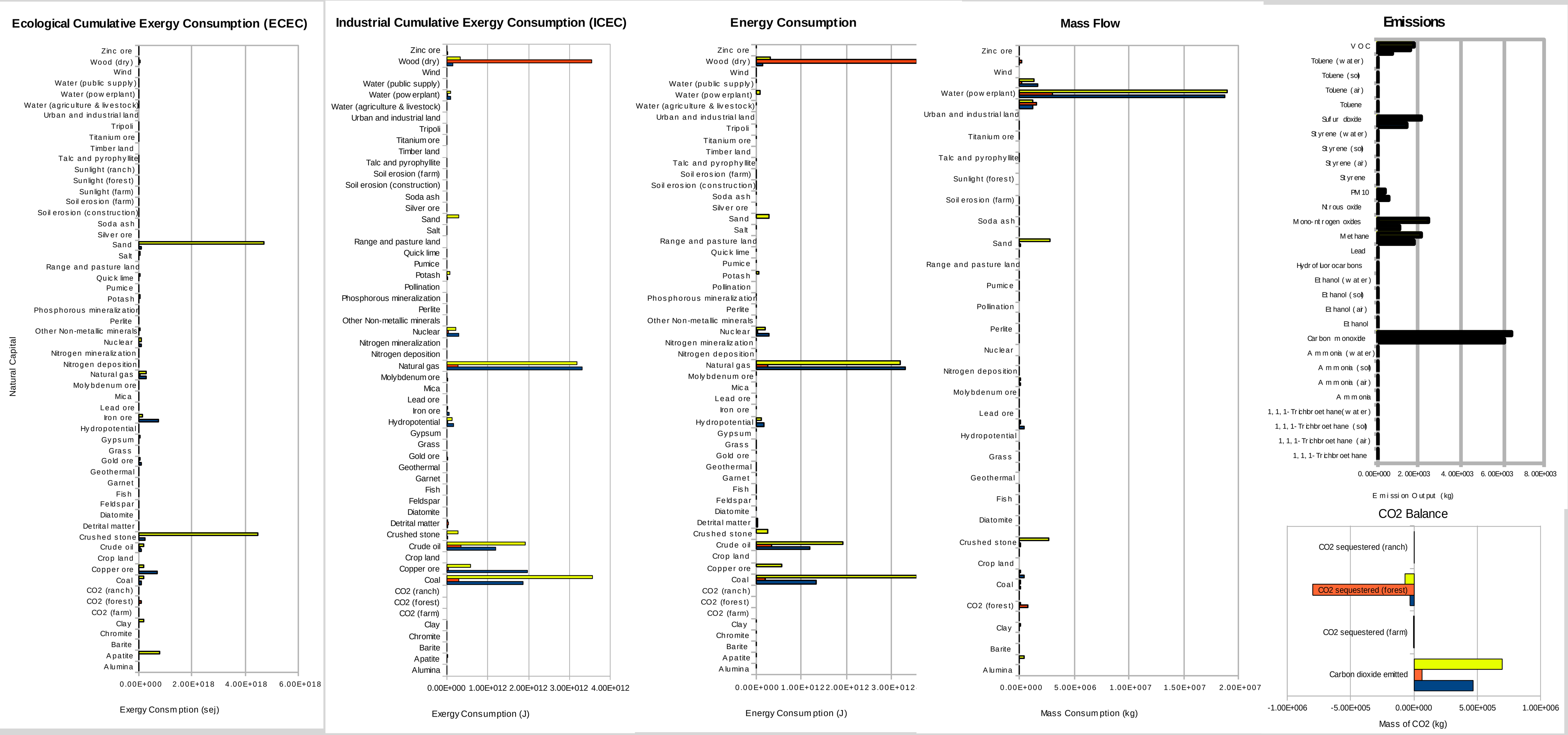
EcoLCA of Common Building Materials by Economic Sector:

-Use EcoLCA tool to estimate the environmental impact of three 'functionally similar' beams manufactured from different materials: concrete, engineered wood, and steel

Sector Name	NAICS Code	Rep. Matrl	Cost per 20' [10]
Wood Product Manufacturing Engineered Wood Member and Truss Manufacturing	321 32121B	Glulam Beams 1 3/4" wide x 18" deep	$139
Nonmetallic Mineral Product Manufacturing Other Concrete Product Manufacturing	327 327390	Prefab, rect. beams 20' span, 12" x 20"	$670
Fabricated Metal Product Manufacturing Architectural and Structural Metal Manufacturing	332 332312	Wide flange 12in (depth) x 35 (lb/ft)	$730

- -Representative materials were selected based on a preliminary attempt to create a 'functionally similar' beam
- -Cost of beam calculated using *Building Construction Cost Data, 2005*
- -Input to EcoLCA based on value of 1000 beams (arbitrary scaling factor)
- -Resource consumption aggregated using ECEC, ICEC, Mass Flow and Energy Consumption
- -Compare differences in results based on available aggregation techniques

Preliminary Results



Total Values by Sector

	ECEC (sej)	ICEC (J)	Energy (J)	Mass (kg)	CO2 (kg)	Land (ha)	Water (L)
332312	2.53E+18	9.21E+12	6.46E+12	2.29E+07	4.32E+05	2.19E+01	2.16E+07
32121B	2.87E+17	4.62E+12	4.47E+12	5.94E+06	-7.37E+05	4.76E+02	4.86E+06
327390	1.15E+19	1.07E+13	1.07E+13	2.84E+07	6.17E+05	4.70E+01	2.17E+07

Note:
'Sunlight' categories removed from results due to disproportionately high values

Discussion

Analysis:
- -Concrete beams show highest aggregated resource consumption when measured using ECEC, ICEC, Mass Flow, and Energy Consumption
- -Steel beams show second highest in above categories
- -Glulam beams show largest land use impact
- -Glulam beams show negative CO2 emissions due to carbon sequestration
- -Concrete beams show highest emissions outputs (e.g. VOCs, CO, SOx, CH3, except for PM10
- -Steel beams often show comparable emissions outputs to concrete
- -Glulam beams show high VOC emissions

Uncertainty & Limitations:
- -Functionally similar is not functionally equivalent, thus comparisons should be made cautiously
- -Economic sector data is an average of many types of products
- -Low price of glulam beams could underestimate total environmental impact; moreover, scaling by 1,000 could exaggerate this issue

Conclusions

These results are preliminary and subject to the uncertainties and limitations listed above. Thus, further research should be conducted before conclusions are drawn.

Next Steps:
- -Combine process level data specific to beams with EcoLCA results in a hybrid LCA study
- -Define 'functionally equivalent' beams based on mechanical and physical properties
- -Explore issues related to scaling and cost estimation via sensitivity analyses

References

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