Iowa State University

Natural Resource Ecology and Management

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Comparison of environmental impacts from production of wood, concrete, and steel construction materials using a life cycle analysis approach

Background

Concern regarding the environmental impacts of material production and use has increased in recent years, especially in the construction industry. This study capitalizes on that increased interest by examining and comparing the environmental and human health impacts of producing 1 m^3 of wood, concrete, and steel. Comparison was made using a holistic study approach known as life cycle analysis or LCA which follows standards set by ISO 14040 protocols. My hypothesis is wood creates the least impacts due to its biological origins.

Impacts Examined

Impact	Units
Abiotic Depletion (ADP)	kg Sb eq
Acidification (AP)	kg SO_2 eq
Eutrophication (EP)	kg PO_4 eq
Climate Change (GWP)	kg CO_2 eq
Ozone Depletion (ODP)	kg CFC-11 eq
Human Toxicity (HTP)	kg 1,4-DB eq
Terrestrial Ecotoxicity (ETP)	kg 1,4-DB eq
Photo-Oxidant Formation (POCP)	kg C_2H_4 eq

Figure 1. Environmental and human health impacts examined

Methods

- A LCA method was used to determine the impacts outlined in Figure 1.
- Impacts were established by product category rules (PCR) which are defined in ISO 14040.
- A system boundary, known as a cradle-to-grave approach, was established to focus analysis on five life cycle stages outlined in Figure 2.
- Impact values were obtained from peer-reviewed literature. Values were converted accordingly to obtain a uniform kg/m^3 unit of measure.
- A functional unit of 1 m^3 of wood, concrete, and steel was examined.
- Impact values were compared and interpreted.
- An informative brochure was produced to educate the public on the impacts of their construction material choices.

Data Collection

Data was collected from peer reviewed articles and publications from CORRIM[1], Athena[2], and other national LCA organizations. Each publication used different approaches and units in their analyses. Values were converted to kg/m^3 based on the assumption a linear relationship exists. Outliers were removed in the data collected.

Table 1. Results of LCA comparison of wood, concrete, and steel.

Impacts	Units	Wood (kg/m^3)	Concrete (kg/m^3)	Steel (kg/m^3)
ADP	kg Sb eq	--	5.95E-07	6.25E-08
AP	kg SO_2 eq	-97.9	4.08	1.74E-05
EP	kg PO_4 eq	-0.00504	0.919	2.89E-07
GWP	kg CO_2 eq	-1690	273.8	0.002638
ODP	kg CFC-11 eq	-0.00000422	3.13E-05	3.21E-12
HTP	kg 1,4-DB eq	3.78	2.54E-05	0.000204
ETP	kg 1,4-DB eq	0.00206	4.41E-07	5.40E-08
POCP	kg C_2H_4 eq	14.6	0.101	1.81E-06

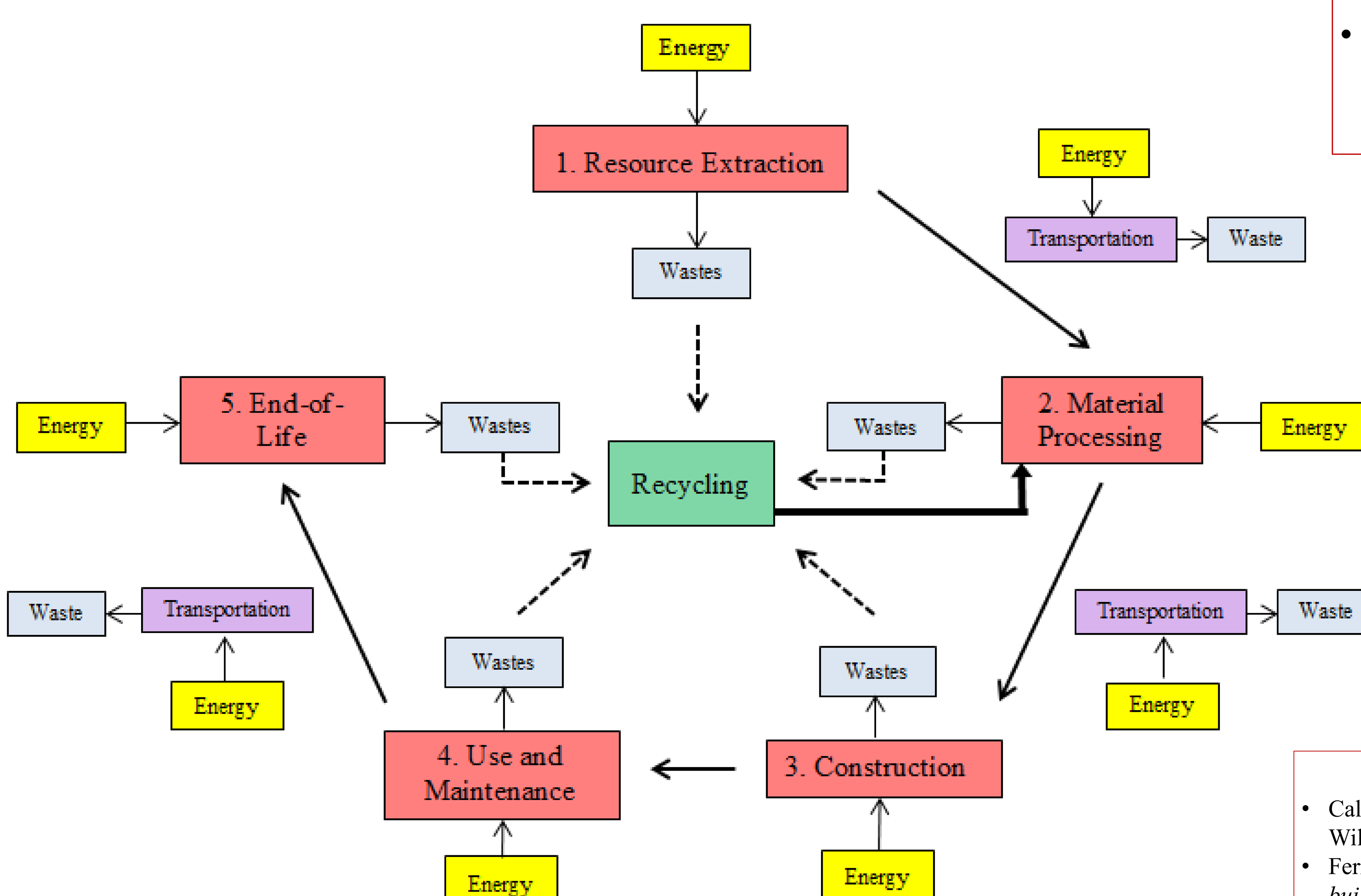

Figure 2. Five stages of a material's life cycle

Results and Interpretation

- Collection of data from different sources proved difficult. Different sources used varying methods and units to obtain impact values.
- Impact values for wood did not include disposal impacts, whereas, impact values for steel and concrete include the entire life cycle process as seen in Figure 2.
- Wood has negative values of selected metrics. Negative values mean the product is absorbing rather than releasing those emissions.
- Concrete had the greatest GWP due to the chemical processes releasing CO_2 during manufacturing.
- Overall, wood had the least air impacts, but greatest land and water impacts. This may be caused by improper land management practices
- Concrete and steel had similar impacts for ADP, HTP, and ETP, but concrete had considerably greater impacts to air.
- Greatest impacts throughout entire life cycle were during manufacturing due to energy use and emissions.

Conclusions

This study has supported my hypothesis. However, challenges of collecting comparative data for wood, concrete, and steel render definitive conclusions illusive. Methods between sources varied greatly which may have caused errors in the data presented. In the future, directly researching impacts of a specific construction component rather than a specific volume of material might reduce variability in impact values.

References

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[1] CORRIM (Consortium for Research on Renewable Industrial Materials) www.corrim.org
[2] Athena – Non-profit research collaborative connecting LCA analysis with construction materials www.athenasmi.org