Life Cycle Assessment of Katerra's Cross-Laminated Timber and Catalyst Building

Summary Document

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By

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EXECUTIVE SUMMARY

Katerra has developed its own cross-laminated timber (CLT) manufacturing facility in Spokane Valley, Washington. This 25,100 m^2 (270,000 ft^2) factory is the largest CLT manufacturing facility in the world, and is capable of producing approximately 187,000 m^3 of CLT per year. Katerra has also established a vertically integrated supply chain to provide the wood for the CLT factory. Production started in 2019. A picture of the factory is shown in Figure 1.

Figure 1. Katerra CLT manufacturing facility in Spokane Valley, Washington (credit: Katerra).

Katerra commissioned the Carbon Leadership Forum (CLF) and Center for International Trade in Forest Products (CINTRAFOR) at the University of Washington to analyze the environmental impacts of its CLT as well as the Catalyst Building in Spokane, Washington. The Catalyst is a 15,690 m^2 (168,800 ft^2), five-story office building that makes extensive use of CLT as a structural and design element. Jointly developed by Avista and McKinstry, Katerra largely designed and constructed the building, and used CLT produced by Katerra's new factory. Performing a life cycle assessment (LCA) on Katerra's CLT will allow Katerra to explore opportunities for environmental impact reduction along their supply chain and improve their CLT production efficiency. Performing an LCA on the Catalyst Building will enable Katerra to better understand life cycle environmental impacts of mass timber buildings and identify opportunities to optimize the environmental performance of mid-rise CLT structures.

CLT LCA

The research team determined that the embodied carbon impact of Katerra's CLT is 130 - 158 kg CO_2e/m^3 (varying depending on modeling assumptions). This result falls at the lower end of the spectrum of the results from other LCA studies of CLT produced in the United States [1]-[3]. This lower impact is likely due to a combination of the use of lighter-weight wood species, higher efficiencies of production processes, higher efficiencies in adhesive use, and a higher waste recovery rate. Based on an analysis of the results, the research team determined that Katerra could further reduce the environmental impacts of its CLT by: 1) reducing long distance transportation impacts by locally sourcing the wood, 2) streamlining the CLT lamstock procurement process to reduce waste, and 3) drying lumber at the sawmill with hogfuel instead of at the manufacturing facility with a natural gas kiln. Additional research work could refine the results by gathering more factory data after a year of operations and explore the effects of varying multiple study parameters.

The cradle-to-gate embodied carbon of Katerra's CLT is

130 - 158 kg CO_2e/m^3,

which falls on the low-end of the range for U.S. CLT products

Catalyst Building LCA

The life cycle assessment of the Catalyst Building, core and shell only, estimated the upfront embodied carbon of the building to be 207 kg CO_2e/m^2. This result is similar to other mass timber buildings and is lower than most other office buildings per unit of floor area, according to the Embodied Carbon Benchmark Study [4]. Additionally, the Catalyst Building stores approximately 204 kg CO_2/m^2 of biogenic carbon, which nearly offsets its upfront embodied carbon. However, a more comprehensive analysis, including end-of-life considerations, should be performed in order to draw more definitive conclusions about the total carbon footprint of the building.

The upfront embodied carbon of the Catalyst Building is approximately

207 kg CO_2e/m^2,

which is similar to other mass timber buildings and lower than most other office buildings per unit floor area. This number does not include the carbon stored in the wood nor the impacts of maintenance and end-of-life.

INTRODUCTION

Katerra is a start-up construction company that has developed a vertically integrated cross-laminated timber (CLT) manufacturing supply chain and facility. Katerra commissioned the Carbon Leadership Forum (CLF) and the Center for International Trade in Forest Products (CINTRAFOR) at the University of Washington to perform a life cycle assessment (LCA) study to understand the environmental impacts and opportunities for impact reduction in Katerra's CLT supply chain and manufacturing process. CINTRAFOR performed an LCA of the CLT supply chain and production process while the CLF performed a whole building LCA of a new building that used CLT produced at Katerra's CLT facility.

GOAL

The goal of this study was to understand the environmental impacts of Katerra's CLT and highlight opportunities for impact reduction. To do so, the research team performed the following activities:

- The CINTRAFOR team performed an LCA of Katerra's CLT, taking into account the source of lumber (British Columbia, Canada), the species mix (Spruce-Pine-Fir), the location of the manufacturing facility (Spokane Valley, Washington), and the manufacturing process of producing the CLT.
- The CLF research team performed a whole building LCA (WBLCA) of a 5-story, commercial mixed-use building that was largely designed and constructed by Katerra. This building is named the Catalyst Building and is located in Spokane, Washington. The building was under construction at the time of this writing.

METHODOLOGY

Environmental impacts assessed

Five environmental impact measures were evaluated and characterized using the Tool for the Reduction and Assessment of Chemical and other Environmental Impacts (TRACI) 2.1. Primary energy consumption was also assessed using the Cumulative Energy Demand (CED). These impact measures were [with units of measurement in brackets]:

- Global warming potential (GWP) in kilograms of carbon dioxide equivalent [kg CO_2e]
- Acidification potential (AP) in kilograms of sulfur dioxide equivalent [kg SO_2e]
- Eutrophication potential (EP) in kilograms of nitrogen equivalent [kg Ne]
- Ozone depletion potential (ODP) in kilograms of trichlorofluoromethane (CFC11) equivalent [kg CFC11e]
- Smog formation potential (SFP) in kilograms of ozone equivalent [kg O_3e]
- Primary energy consumption [MJ]

The in-depth analysis of the results focuses on GWP, since this is a primary impact measure of concern in the building industry.

System boundary

The system boundary of the CLT LCA is shown in Figure 2 (next page). The system boundary of the building LCA was limited to core and shell (structure and enclosure only). Interior fit-out and tenant improvements, i.e. interior finishes, partitions, mechanical, electrical, and plumbing, were not included. The specific components included in the building LCA are later shown in Figure 4 in the Results and Discussion section.

Life cycle scope

Generally, the CLT LCA covered the following life cycle stages:

- A1: Forestry operations and lumber production
- A2: Transportation from sawmills to CLT manufacturing facility
- A3: Onsite CLT manufacturing

The building LCA covered the following life cycle stages:

- A: Product and construction process stages
    - A1: Raw material extraction
    - A2: Transportation of materials from material supply to the manufacturing facility
    - A3: Product and material processing/manufacturing
    - A4: Transportation of materials from manufacturing facility to the building site
    - A5: Construction and installation
- B: Use stage
    - B6: Operational energy use only
- D: Benefits and loads beyond the system boundary
    - Biogenic carbon storage

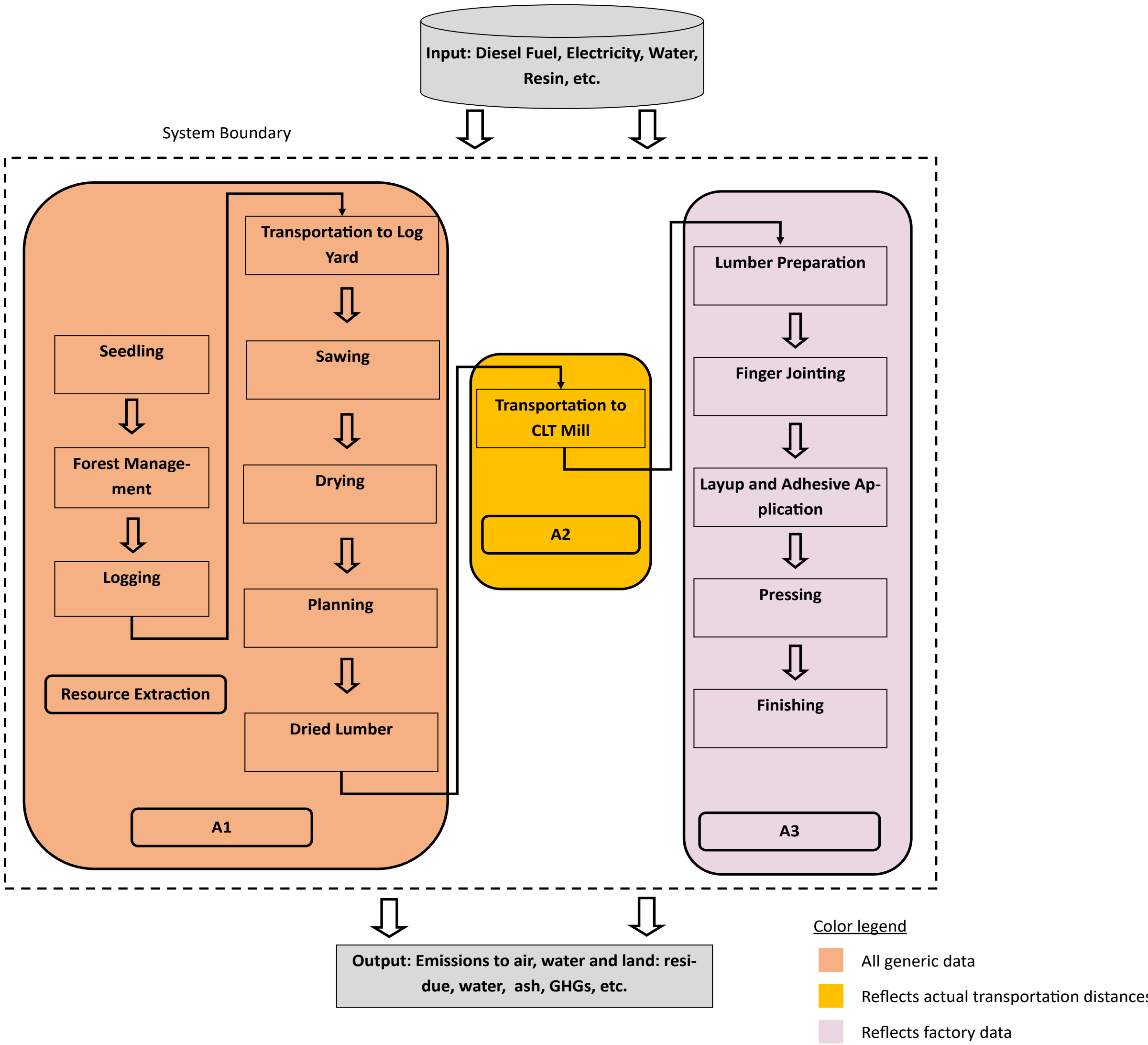

Figure 2. System boundary for CLT production.

Method

The LCA of the CLT supply chain and manufacturing process was performed using SimaPro version 9. The LCA impacts were characterized using TRACI 2.1. Primary energy consumption was characterized using the CED method. The data used in the CLT LCA included primary and secondary data, meaning that some data were collected from the manufacturing facility and some data were collected based on LCA research. Specifically, the LCA data for life cycle stage A1 was taken from an LCA for Canadian lumber production [5], while the LCA data for life cycle stages A2-A4 were based on actual transportation distances and manufacturing processes. This study treated biogenic carbon in accordance with the North America Product Category Rule [6] and the default TRACI impact method. Under the carbon neutrality assumption of wood products, TRACI does not account for CO_2 emitted through woody biomass consumption toward the final global warming impact but accounts for all other emissions other than CO_2.

The LCA of the Catalyst Building was performed based on material quantities provided by Katerra. Background LCA data were taken from Athena Impact Estimator version 5.2, using life cycle stage A impacts only. Some EPDs were needed to provide the LCA impacts of certain materials or products that were not available in Athena. Concrete LCA data were based on actual mix design submittals provided by Katerra, entered into Athena's custom concrete mix design module. For operational energy, the energy use intensity (EUI) for the final design of the building was provided by the mechanical contractor.

RESULTS AND DISCUSSION

Due to space constraints, only the results for the global warming potential (GWP) for life cycle stage A, also known as embodied carbon, are shown in this summary document. The full project report with more detailed results is available.[1]

CLT LCA

The full analysis had considered a baseline model and a conservative model. The overall GWP result from the baseline model is 130 kg CO_2e/m^3, and overall GWP result from the conservative model is 158 kg CO_2e/m^3. Figure 3 presents a contribution analysis for the conservative model. This figure shows that of the four processes, onsite CLT manufacturing has the greatest impact, followed by lumber production, lumber transport, then CLT transportation. The top three subprocesses are lumber manufacturing, lumber infeed, then panel finishing.

At the time of conducting this research, the CLT facility was not operating at full capacity, but this capacity is expected to increase in the future. At full capacity, this facility is expected to be more efficient than smaller facilities, potentially leading to lower environmental impacts per unit volume of CLT produced.

After performing the LCA of Katerra's CLT, the research team made the following key observations and recommendations that could further increase production efficiency and reduce environmental impacts:

1. Currently, the average distance between Katerra's CLT facility and the sawmills is approximately 328 km. If Katerra could source the lumber within a 100-km radius, the overall GWP of the CLT could be reduced by as much as 10%.
2. Currently, the lumber purchased by Katerra is round-edged, which requires additional cutting to square the edges before CLT can be produced, leading to additional waste. Material loss can be reduced significantly if the CLT lamstock procurement process can be streamlined.
3. Currently, to reduce the moisture content from 19% to 12%, the lumber is dried at Katerra's CLT facility using a natural gas kiln (note that in Figure 3, this drying step occurs under "Onsite CLT Manufacturing" > "Lumber Infeed"). An alternative method for reducing the environmental impact of drying would be to dry the lumber at the sawmill using hog fuel, which is a waste product of lumber production.

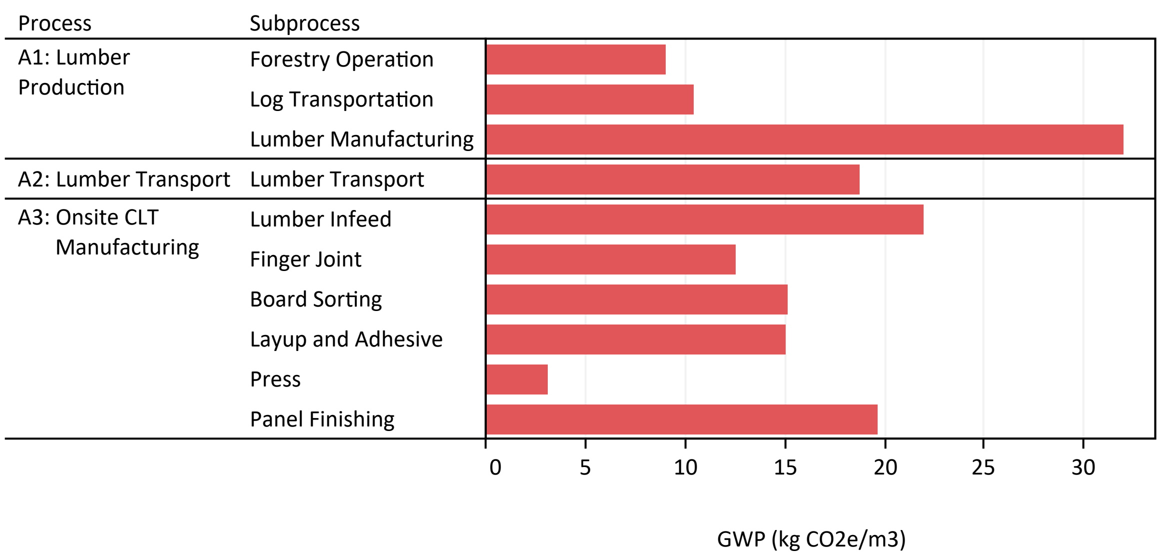

Figure 3. GWP results of CLT LCA (conservative model) per cubic meter of CLT produced.

[1] The full project report can be found at www.katerra.com and www.carbonleadershipforum.org/projects/katerra

Catalyst Building LCA

Figure 4 presents the GWP results of the Catalyst Building by building component, color-coded by material category. Overall, the structure has a greater impact than the enclosure, as is typical in buildings. Within the structural system, the gravity system has the greatest proportion of impacts, followed by subgrade, foundation, then lateral system. Within the enclosure, the wall system has the greatest proportion of impacts, followed by roof then subgrade. By item type, the highest-impact items in the building are:

1. CLT structural slabs (not including topping slabs)
2. Glulam beams and columns
3. Acoustic underlayment, topping slab, and mat foundation (concrete-type products)

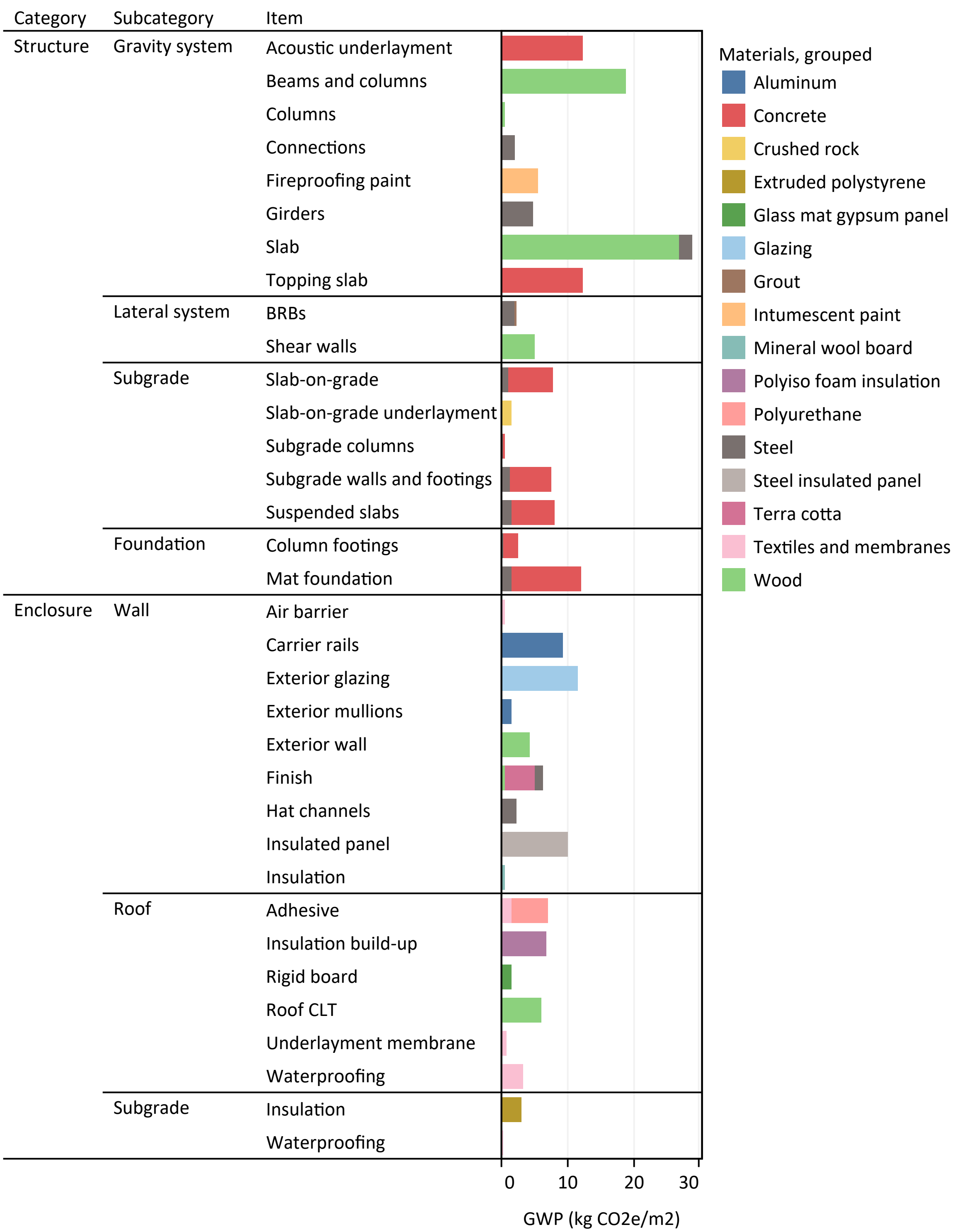

Figure 4. GWP results (life cycle stage A) of Catalyst Building LCA, normalized by total floor area of the building.

Figure 5 presents the GWP results, masses, and volumes of the material groups within the Catalyst Building ranked in descending GWP impact. Note that in the volume analysis, the volumes of membranes and liquids (textiles and membranes, polyurethane, and intumescent paint) were omitted due time constraints and lack of readily-available information. However, the volumes of these items are likely to be insignificant in the context of the whole building.

The left-most chart in this figure shows that wood and concrete have the highest GWP impacts and that their contributions are nearly equal. In comparison, the center and right-most charts in this figure show that concrete has a significantly higher overall mass than wood but a lower overall volume on this project. Generally, this figure shows that GWP impacts of materials in a building are not necessarily correlated with mass or volume.

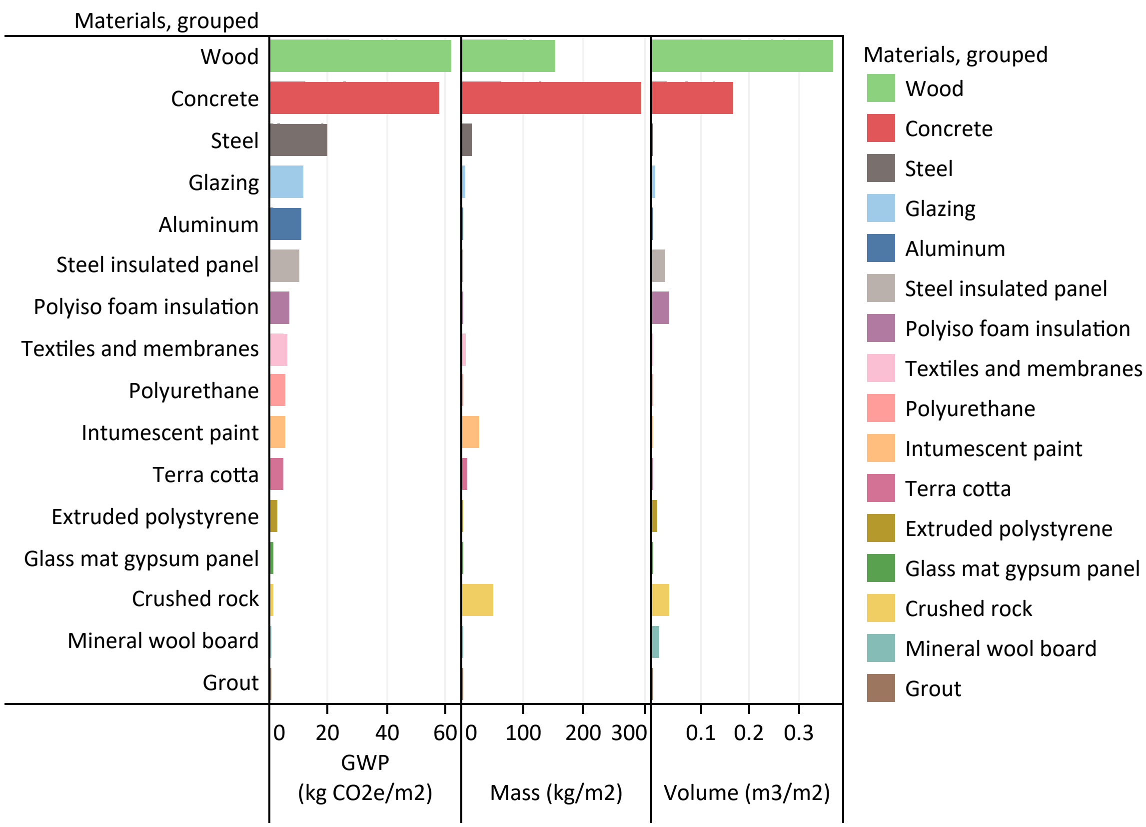

Figure 5. GWP results (life cycle stage A), masses, and volumes of the Catalyst Building LCA, ranked by the overall impact of material groups, normalized by total floor area of the building.

Figure 6 (next page) presents a plot of GWP vs mass, providing a sense of carbon intensity per kilogram in the quantities seen in the building. Note that carbon intensity per unit of mass is not an indication of carbon intensity per functional unit of material. Items that have relatively high carbon intensity per unit mass (in the upper left portion of the graph) are:

- Exterior glazing (glass)
- Insulated metal panel (steel and polyiso)
- Carrier rails (aluminum)

One item that has relatively low carbon intensity (low GWP but high mass) is slab-on-grade underlayment, which is essentially rock. Both concrete and wood have fairly high GWP and masses on the project, which is reasonable because they form the primary structure of the building.

The research team also performed a basic calculation of biogenic carbon storage and found that the carbon stored in the wood components of the building is approximately 204 kg CO_2/m². This nearly offsets the total embodied carbon impact of the building, which is 207 kg CO_2e/m². However, a more comprehensive analysis, including end-of-life considerations, should be performed in order to draw more definitive conclusions.

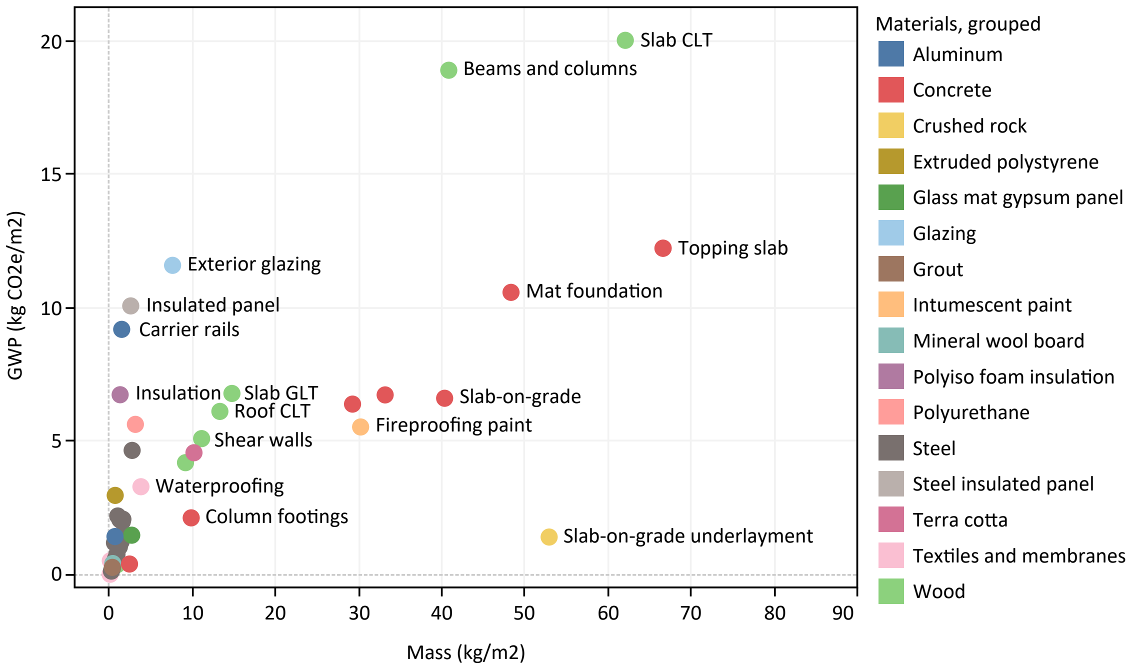

Figure 6. Plot of GWP results (life cycle stage A) versus mass in the Catalyst Building LCA. Only select items are labeled due to space constraints.

POTENTIAL FUTURE WORK

After conducting this study, the research team noted additional opportunities to refine this analysis of Katerra's CLT. Possible future work includes:

- Collect more data from the factory after a year of operations. The factory had just begun production when this study was performed, and additional data would lead to a more accurate LCA model.
- Develop more supply-chain specific LCA data for the softwood lumber production of the CLT LCA.
- Develop LCA estimates for CLT panels of varying panel widths.
- Develop LCA estimates for locally-sourced wood species.
- Explore improving the lamstock procurement plan, based on specific CLT requirements (e.g. specific moisture content, panel width, mechanical property specifications, etc.)
- Incorporate the local electricity grid data into energy calculations. The research team used generalized eGrid data to model electricity impacts, as this is common and widely-accepted practice in LCAs. However, with more time and data, the research team could refine the model to reflect the local electricity grid.

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Cover photo credit: Andrew Giammarco

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Interior of Catalyst Building under construction. Photo credit: Andrew Giammarco.