Life Cycle Assessment of Earthen Construction Materials

Victor Font Bartumeus, University of Illinois at Urbana-Champaign
Alena Raymond and Alissa Kendall, University of California, Davis

Project Overview

Motivation: The construction industry consumes large quantities of energy and resources and has significant impacts on the environment. Due to growing concerns over climate change and resource depletion, we must examine the life cycle impacts of conventional concrete-based construction materials and methods and explore opportunities for future sustainable development.

Background: Researchers at New Mexico State University (NMSU) are investigating the use of sisal fiber to increase the tensile strength of adobe bricks, making them a more viable alternative to concrete masonry units (CMUs) in structural applications. However, the impacts of adobe versus CMUs have not yet been examined.

Figure 1. Sisal fiber-reinforced adobe bricks prior to drying at NMSU.

Project Objective: A life cycle assessment (LCA) was performed to evaluate and compare the environmental impacts of an adobe wall against those of a CMU wall.

Methods

System Definition ("functional unit"): 12-foot tall by 1-foot wide wall section with a structural capacity ≥ 34,000 lbs.

Data Collection:

- The materials required for each wall type were estimated with the help of NMSU researchers.
- Energy consumption and associated emissions from fuel and electricity use of vehicles/equipment were estimated.
- The emissions tracked include greenhouse gases (GHGs) and criteria air pollutants, among others.

LCA Calculations:

- Emissions were assigned to various impact categories and translated, using characterization factors, into indicators that represent potential environmental impacts.

$$I^i = \sum_x CF_x^i \times M_x$$

I^i = potential impact to a specific impact category of concern (i)
CF_x^i = characterization factor of chemical (x) for impact category (i)
M_x = mass of chemical (x)

Results

The life cycle of each wall system:

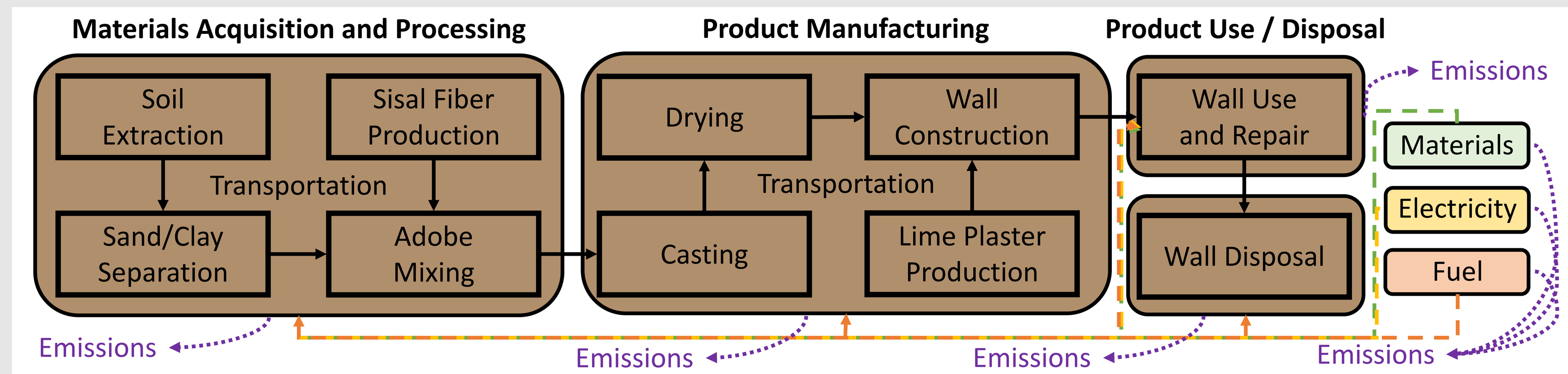

Figure 2. Flow diagram for the adobe wall system.

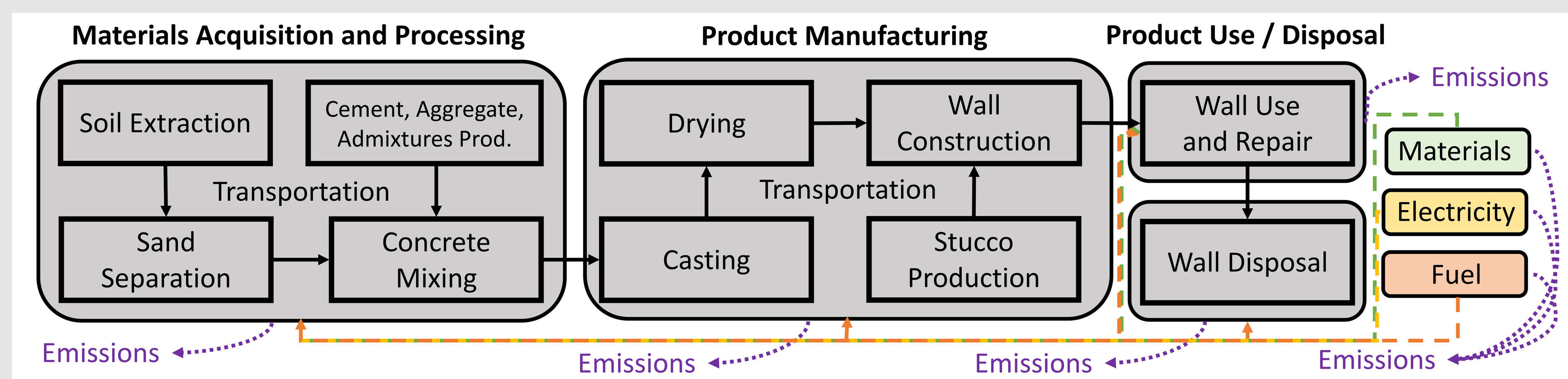

Figure 3. Flow diagram for the CMU wall system.

Environmental Indicator Results:

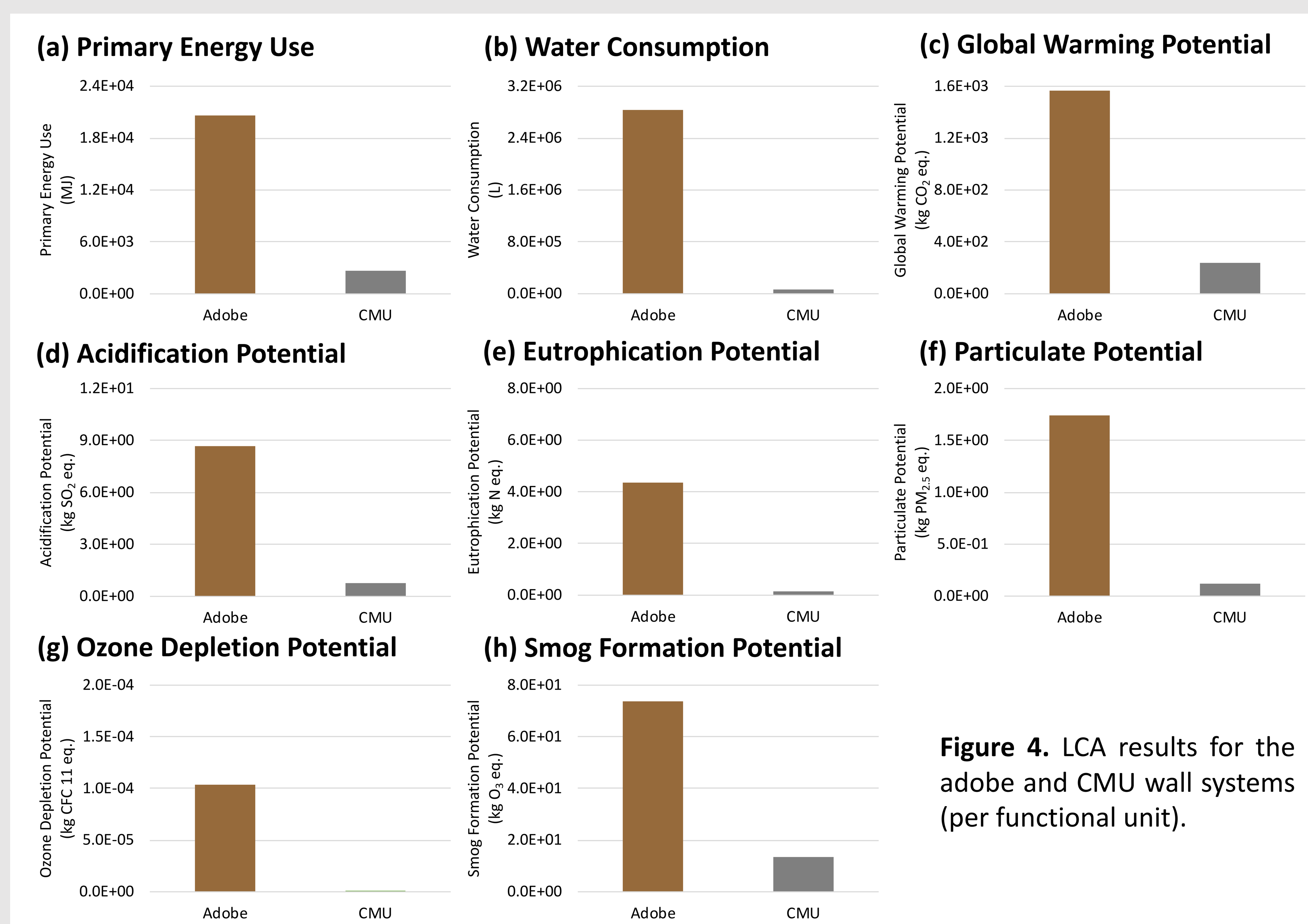

Figure 4. LCA results for the adobe and CMU wall systems (per functional unit).

Interpretation

- The potential impacts associated with the adobe wall exceed those of the CMU wall for all impact categories.
- For the adobe wall, most impacts stem from sisal fiber production (88% for GWP), primarily due to the large quantity of nitrogen fertilizer required for sisal cultivation.
- For the CMU wall, most impacts stem from production of the CMU bricks (45% for GWP).
- Without sisal, the adobe wall would have lower impacts than the CMU wall by about 28%, on average. However, excluding sisal may affect the structural integrity of adobe.

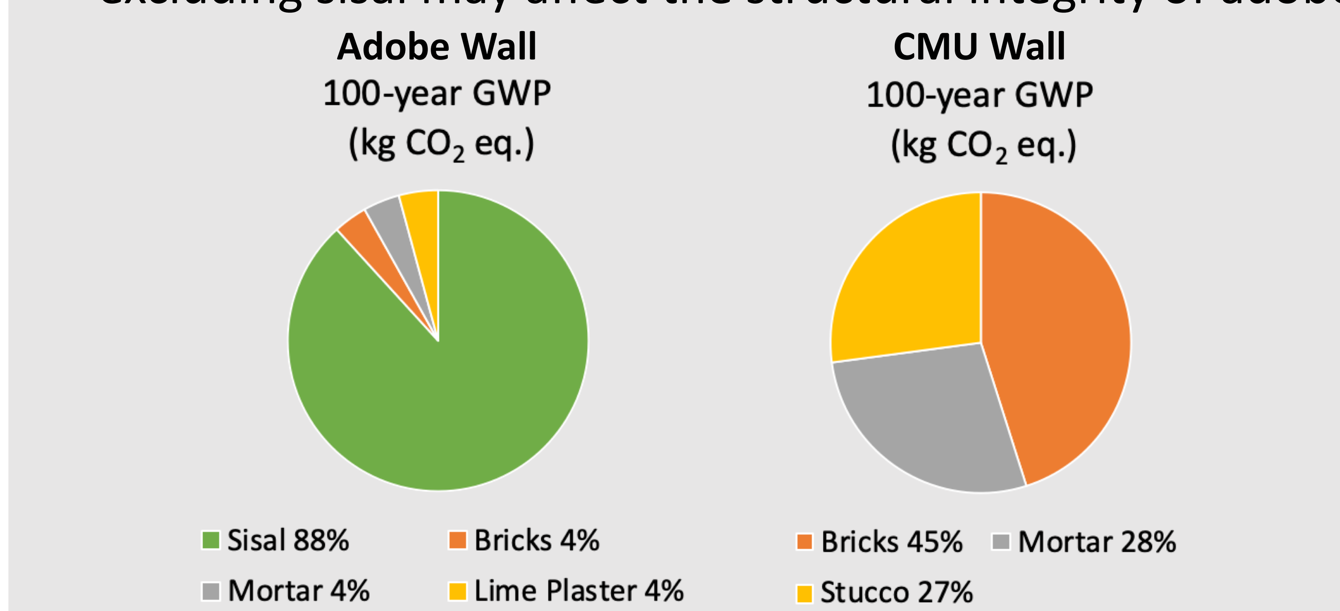

Figure 5. Breakdown of GWP impacts for the adobe wall system (left) and the CMU wall system (right).

Conclusions

- Sisal-reinforced adobe has higher potential environmental impacts than CMUs, assuming fully-industrialized product manufacturing processes for both technologies.
- Improved data for sisal cultivation should be sought, given its importance in these findings.
- Replacing sisal with an alternative fiber could yield lower environmental impacts compared to CMUs.
- Future work should quantify the impacts from the use and end-of-life phases of the life cycle and incorporate them in the LCA results.

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