ENVIRONMENTAL IMPACT

1. INTRODUCTION

Illinois Solar Decathlon is an interdisciplinary registered student organization at the University of Illinois at Urbana-Champaign seeking to lead innovation in design and construction to advance towards an environmentally sustainable future. We are thrilled to present our latest project, RENU House.

RENU House is a 1,510 SF energy net-zero home. RENU represents the four guiding principles of our design and construction processes: Renewable, Economical, Nourishing, and Universal.

R ENEWABLE
The most important feature of the project is energy net-zero status, but we have also striven to reduce the effect on the surrounding environment in every other aspect of the home.

E CONOMICAL
Sustainable developments must be financially feasible to be adopted. We have prioritized cost efficiency in every design choice to ensure the home remains affordable for our target clients.

N OURISHING
The design seeks to encourage fulfilling lifestyles by prioritizing accessibility for all abilities and emphasizing the mental and physical health of occupants.

U NIVERSAL
This design can be replicated in similar small-town markets across the United States, potentially bringing sustainable innovation to communities throughout America.

RENU House is nestled in the village of Rantoul, Illinois, a town of roughly 12,000 people fifteen miles north of the University of Illinois at Urbana-Champaign. Illinois Solar Decathlon has partnered with the Village of Rantoul Urban Planning Committee and the local Champaign County chapter of Habitat for Humanity for the build, consistently communicating with local stakeholders to ensure the home meets the needs of the occupants while effectively integrating into the small-town community.

RENU House was designed as a family residence, and can accommodate a diverse range of family dynamics such as a single parent or multigenerational household. Upon completion of the Department of Energy Solar Decathlon competition, the home will be fully donated to a local Habitat for Humanity family in need: Elonda, a single mother and intermittent wheelchair user, and her daughter, Monae, who is pregnant with her first child.

2. DESIGN DECISIONS & CONCLUSIONS

When deciding the materials and technologies that would be used to build RENU House, considerable attention was taken to ensure we chose options that maximize sustainability for the production, installation, usage, and end stages of their life cycles. Many of our products come from environmentally conscious companies which reduce the environmental impact of the production of the materials. For example, our heating and ventilation system and many of our appliances are manufactured by LG. LG has shown initiative to lessen their environmental impact through their goal to "reduce greenhouse gasses in the pre- and post-production stages by 150,000 tons and 30,000,000 tons, respectively, by 2020" (LG Sustainability & Environmental Policy). They moved toward this goal in stages by "reducing greenhouse gas emitted during a product's life cycle (including raw materials used in production, distribution, usage and disposal)" (LG Sustainability & Environmental Policy). Therefore, not only are the appliances in our house energy efficient by reducing the emissions produced during the use of these products, but by supporting companies like LG we are inherently also reducing the emissions produced during the manufacturing of our appliances.

Similarly, we have chosen to incorporate other products from companies demonstrating strong sustainability principles, including our cabinets and roofing. Our cabinets are from Marfa Cabinets whose products are made from 100% post-consumer recycled wood (Why Work with Us? Marfa Cabinets). Our roofing is a metal SLR roof from Morin Corp. Morin Corp is a company that greatly values sustainable practices which has allowed them to operate at net zero carbon emissions status since 2020 (About Us. Morin Corporation A Kingspan Group Company).

Beyond greenhouse gas emissions based on the company's choices, we also recognize that emission reductions can be obtained in our choice of suppliers and vendors based on their proximity to our construction site. In order to reduce the transportation emissions, when all else was largely equal (quality and value) we have chosen some products based on their proximity to the construction site. For example, all of our windows and doors were sourced from Jeld-Wen. Jeld-Wen's has a manufacturing warehouse in Rantoul, the same town as RENU House. Therefore, less emissions were produced during the transportation of these products. Another locally sourced product is the aggregate used in the concrete of the house. This aggregate comes from a quarry in Urbana, IL which is only 20 minutes from Rantoul. This resulted in a significant reduction in our transportation emissions.

Additionally, all of our construction workers and tradespeople are from the surrounding area. This reduces all of their travel emissions each time they come to work on site. Considering the construction has taken place over the course of about half a year with many trips to the site, reducing transportation emissions each time adds up significantly. Additionally by using locally sourced labor we are helping the circular economy and will further our goal to help revitalize Rantoul.

We also made design decisions to utilize materials that will increase RENU House's sustainability and/or durability. The first example of this is the siding and flooring. Both our siding and flooring is made from bamboo products which is advantageous because almost all industrial bamboo products are CO2 negative making it one of the most environmentally friendly construction materials on the market. This is because of variations in carbon

sequestration and bioenergy production during end-of-life (van der Lugt, P.). Additionally with our bamboo siding there is no periodic upkeep because of its high temperature resistance and stability. Traditional housing siding requires a lot of upkeep, like painting, which is why bamboo completely avoids this resulting in longer durability.

We also decided to have a metal roof as opposed to a traditional asphalt roof. Although asphalt roofs are commonly found on single family homes in the Rantoul area, they require periodic maintenance and replacement. On the other hand, metal roofs are more durable and whose lifetime is four times that of a typical roof with little to no upkeep, which reduces environmental impact and stress for the homeowners. Additionally, metal can be 100% recycled at the end of the roof's lifetime. The recycling aspect, along with the fact that we sourced our roofing panels from Morin, a net zero company, makes our roof an environmentally friendly choice.

Another material that was chosen for environmental reasons is our PEX plumbing pipes. PEX has a significantly lower embodied energy than alternative piping because it does not extract natural resources. PEX only results in 1.57 kg of CO2 per kg of PEX whereas PVC and copper pipes result in about 2.6 kg of CO2 per kg of material. Additionally, PEX piping requires fewer repairs, resulting in fewer downstream costs to both transportation and future depletion (and associated costs) of mining and natural metals resources. Some of the many additional benefits of PEX are that it can withstand higher and colder temperatures than PVC pipes and PEX has a lower thermal conductivity rate than copper. As a result, PEX pipes can help keep hot water hotter for longer periods of time (Materials Selection in Mechanical Design).

Lastly, the construction activity that had the largest impact on our LCA was creating a concrete foundation. We recognize that concrete is very CO2 intensive and results in a large portion of our LCA. However, after our analysis, we made this decision to increase the durability, longevity and structural integrity of RENU House. According to the Southeast Concrete Masonry Association a concrete foundation lasts over 100 years compared to alternatives such as wood that only last a couple decades and need continuous upkeep. Since our house is being donated through Habitat for Humanity to a family who will be calling it home for years, it was very important that RENU home was structurally sound and remains that way for years with minimal required upkeep, vigilance, or future financial burden on part of the homeowner.

3. LIFE CYCLE ASSESSMENT

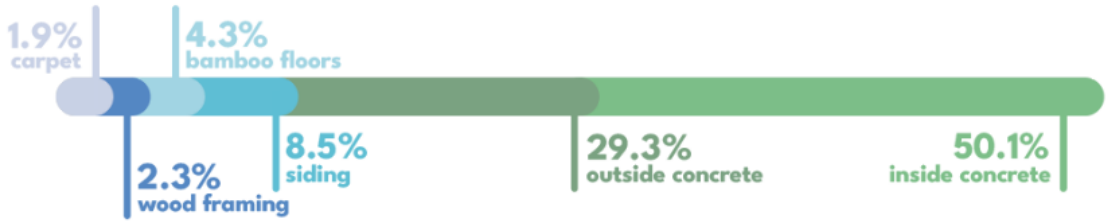
To conduct a comprehensive Life Cycle Assessment of the RENU House, we first divided the home into fifteen key building components to accurately measure the materials used. Our analysis encompassed the entire production-to-usage cycle. Using Ecoinvent, an immense LCA database, we compiled data on the overall quantities of CO2, SO2, NOx, and PO4 which can be seen in the second table. From the assessment the house was estimated to release 484 kg of SO2, 146,553 kg of CO2, 509 kg of NOx, 172 kg of PO4 in the production-to-usage cycle (seen in the first table). According to the US Environmental Protection Agency this amount of CO2 is the equivalent to 744,455 MJ, which is the embodied energy of RENU House. Notably, the production of concrete for both the interior and exterior of the house, including driveways and walkways, emerged as the largest contributor to all emissions, particularly in CO2. In addition to concrete, the siding, crafted from the sustainable material, bamboo, emerged as the

third-largest emitter across all categories. However, the sheer square footage covered by the bamboo siding accounts for this high emission. Also, this life cycle only takes into account the CO2 from production. So bamboo's emissions would be a lot lower if we took into account that it reduces carbon during its production part of the materials lifecycle.

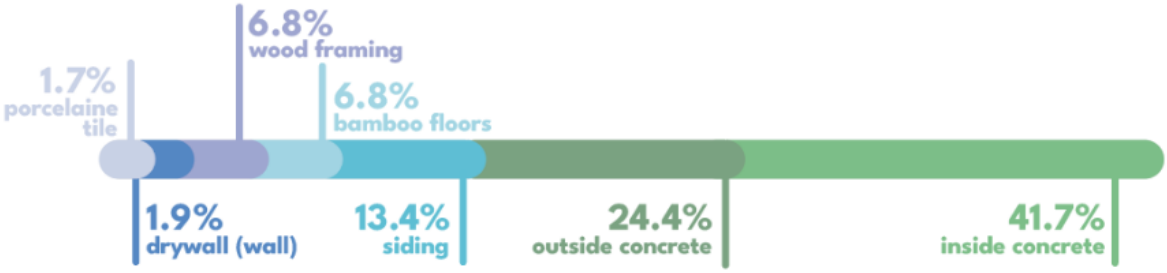
Emission Type	Quantity
CO2	146,553 kg
SO2	484 kg
NOx	509 kg
PO4	172 kg
Embodied Energy	744,455 MJ

Material	Unit of Material	CO2 Value (kg/unit)	SO2 Value (kg/unit)	NOx Value (kg/unit)	PO4 Value (kg/unit)
Wood Framing	m^3	366.8	3.568	4.492	0.915
Concrete	m^3	351.8	0.967	1.142	0.298
Cellulose Insulation	kg	0.3106	0.0017	0.0011	0.0004
Drywall	kg	0.3901	0.002	0.0014	0.0005
Window Glass	kg	1.195	0.0095	0.0064	0.0012
Window Trim	m^2	767.5	3.712	2.105	0.9356
Exterior Doors	m^2	113.0	0.757	0.8112	0.2002
Interior Doors	m^2	48.34	0.275	0.1816	0.0907
Bamboo Siding/ Floors	kg	0.5362	0.0028	0.0019	0.0016
Carpet	kg	11.42	0.0302	0.0232	0.0068
Porcelain Tile	kg	0.806	0.0035	0.0023	0.001

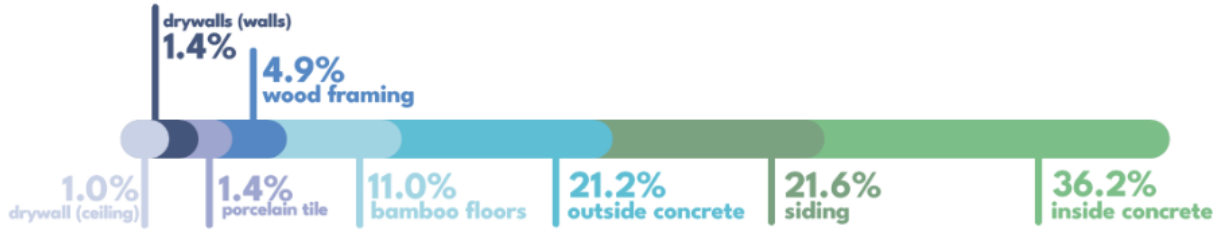
Total CO2



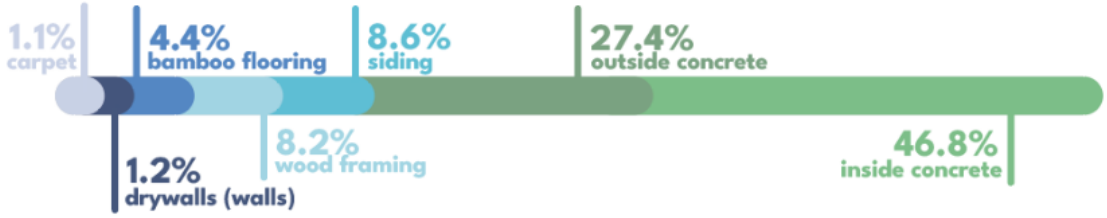
Total SO2



Total PO4



Total NOx



When analyzing the overall impact of RENU House, we made sure to achieve a proper balance between not just choosing materials with the least emissions in their life cycle, but materials that would achieve our goal of producing a durable and long lasting home. Reflecting on our life cycle assessment, we see that for all emissions, our "outside/inside concrete" contributes to over 50% of emissions. In fact, concrete consumes up to 79.4% of our total CO2 emissions. Following our goal to minimize any maintenance needed in the future, concrete has a long lifespan and ensures durability, as it will increase time "between reconstruction, repair and maintenance and the associated environmental impact." (Ashley, *Journal of Green Building* (2008)). Additionally, concrete provides an impermeable foundation to weather and resistance to fire.

The choice to use bamboo in such large quantities in the home will also contribute to being low maintenance, as mentioned before. The surface is easy to refinish by sanding it down and applying a new coating seal, and it is naturally resistant to blemishes from falling objects, compared to other materials that require more upkeep. The material itself has a low carbon footprint because of its ability to grow within a seven year cycle. Bamboo also doesn't require replantation after harvesting like other hardwoods and absorbs more CO2 than other hardwoods. In the production phase itself, bamboo waste such as leaves and wood scraps may be left to rot or used to heat up boilers in the processing stage, thus all waste has a purpose (Design Life-Cycle). For the recycling stage, the material can be removed and ground into mulch. Or, as MOSO states, "it can be chipped to make particle board or burned in a biomass energy plant, creating green electricity and further reducing the use of fossil fuels".

Other materials such as our cellulose insulation have a minimal environmental impact. Cellulose insulation is made from 85% recycled material and sources local materials,"using low-energy manufacturing and reducing the need for long-haul transportation" (Green Fiber). During use, its high density provides great insulation and requires less electricity for heating/cooling.

4. INNOVATION (CIRCULAR ECONOMY AND RE-X OPERATIONS)

Circular economy principles are an essential aspect of the RENU House's construction. By using locally sourced materials and labor, the RENU House reduces the carbon footprint associated with transportation, supports the local economy, and promotes a circular economy. The doors and windows, for example, are sourced from a local factory just an 8-minute drive away. This local sourcing reduces the environmental impact of transportation and supports local jobs, while also promoting the circular economy by keeping resources circulating within the local community.

Additionally, the RENU House utilizes a net-zero metal roof, which is a circular and sustainable product. The metal used in the roof is recyclable, meaning that at the end of its life cycle, it can be melted down and used again. Furthermore, the net-zero aspect of the roof means that it produces as much energy as it consumes, which reduces the overall carbon footprint of the house. Metal roofs also do not require continuous repair which also promotes re-x operations. According to State Farm when compared to asphalt shingles that only last 12-20 years, metal roofs can last 40-70 years.

The use of bamboo for siding and floors is another innovative feature that prioritizes the circular economy and re-x operations. Bamboo is a renewable resource that can be harvested without killing the plant, making it a sustainable alternative to hardwood. Additionally, bamboo is highly durable and moisture-resistant, which makes it an ideal material for siding and floors and does not need a lot of upkeep.

The use of energy-efficient appliances and energy monitoring systems is another innovative feature that promotes the circular economy. By choosing appliances that use less energy, the RENU House reduces its overall carbon footprint and saves on energy costs. These savings can then be spent elsewhere in the community, improving the economy. Furthermore, the energy monitoring system encourages residents to be mindful of their energy consumption, which can lead to significant energy savings.

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