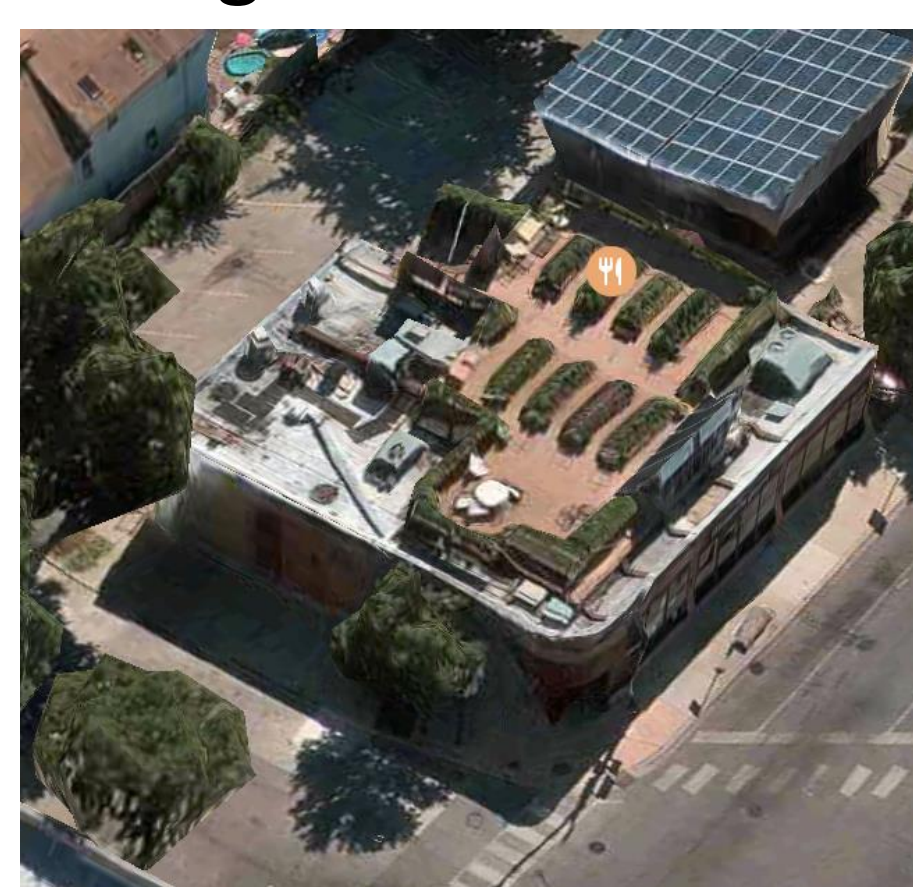


### Abstract

The owner of a local restaurant envisions a modern, sustainable, and cost-effective residential addition above his business. The goal of this project is to design the most energy efficient and sustainable dwelling unit possible with the highest return on investment. In order to accomplish this, the project team designed multiple subsystems for the unit, including its structure, solar energy, indoor water use, rainwater management, ventilation, and thermal regulation. Various design strategies were implemented to reach a final holistic design of all required systems. A risk analysis was conducted in order to iterate the design and provide risk mitigation recommendations. Calculations along with modeling tested the final design to ensure its functionality. This testing resulted in outputs that confirmed the design's structural integrity, energy-efficiency, comfort, sustainability, and financial feasibility.

### Introduction

#### Background



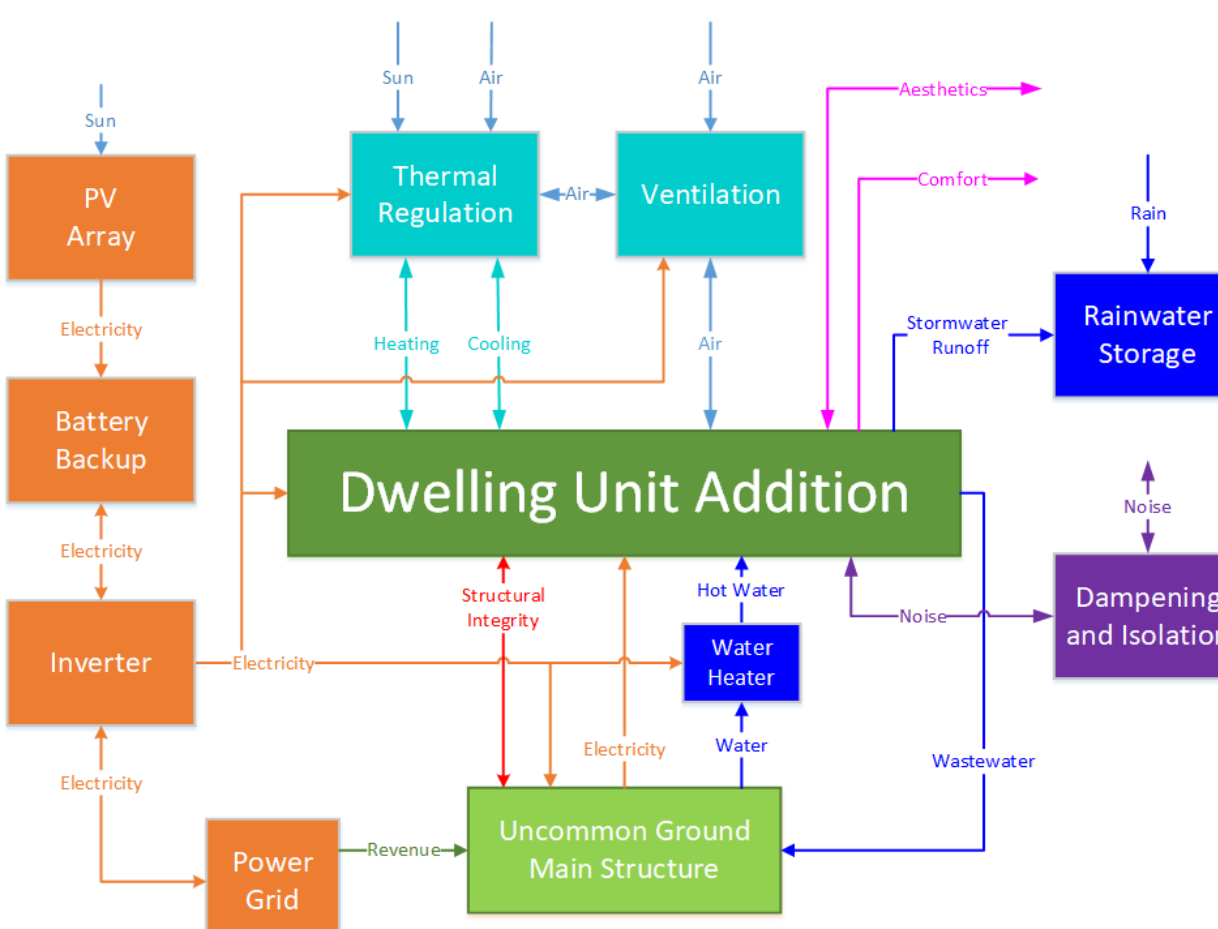
Uncommon Ground is a farm-to-table, organic, restaurant that has won many sustainability awards with locations in Rogers Park and Lakeview, Chicago. The Rogers Park location established itself as the First Certified Organic Rooftop Farm in the United States. Community and environmental sustainability are the two core values that the owners, Michael and Helen Cameron, have incorporated into Uncommon Ground by using reclaimed wood, solar panels, and farm-grown, local food. On the roof of the Rogers Park restaurant, Michael Cameron envisions a modern dwelling unit to be built on the southeast corner of the building.

#### Requirements

The design will accommodate up to 4 people, include a bedroom sized for a queen-sized bed, kitchenette, a sitting area with a sleeper sofa, single bathroom, and patio area overlooking the rooftop garden. The unit will be aesthetically pleasing and stand-out from the rest of the building. All relevant codes and regulations were considered throughout the design process to ensure that the final design will be in compliance when implemented. The design aims to align as closely as possible with LEED building standards.

#### System Description

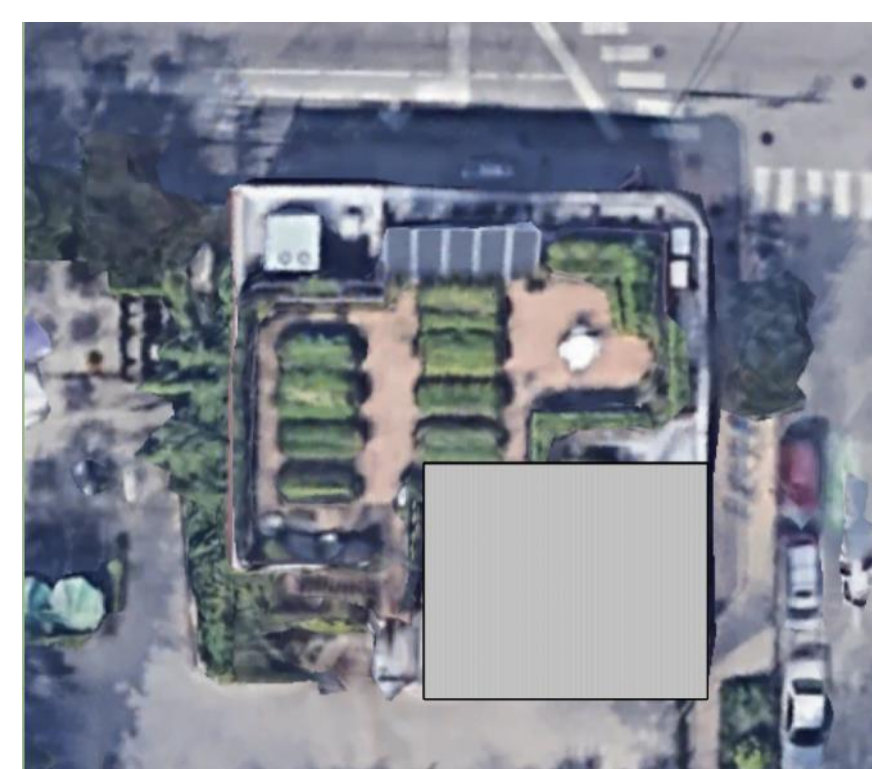
The system boundary encapsulates the dwelling unit addition, its relationship with the Uncommon Ground restaurant's main structure, and the surrounding environmental factors such as sun, wind, and rain. Subsystems culminate in the holistic design of the dwelling unit and are represented in the system diagram. Each box in the diagram describes a subsystem or process. Inputs and outputs are described with headed arrows.



### Methods

#### Passive Design

The goal of passive design is to design a building to heat and cool naturally. It is best way to reduce a building's energy consumption. The residential unit was designed for the sun's altitude angles at 1401 W Devon to shade the summer sun for cooling and capture winter sun to warm the space. A long, south-facing façade filled with windows is incorporated in our design because the sun faces that way. The unit has a long, east to west direction to absorb the most solar energy. Different shading devices and overhangs will be incorporated depending on the cardinal direction of the exterior and the kind of daylighting desired.



Exhaust openings should have a high inlet, and low inlets for intake to maximize stack effect. The clerestory windows located on the roof and the high windows on the north façade are high exhaust openings. Building occupants or building owner would want to have one set open at a time, while opening either the south windows, or the doors on the north façade. Windows have been placed across the room and offset from each other to maximize the mixing while minimizing the obstructions to airflow.

#### Energy System Sizing

Energy loads for the system were calculated using estimated usage times for various appliances and devices. The electricity usage per day was converted to usage per month in kWh/month to allow for sizing of an adequate solar system.

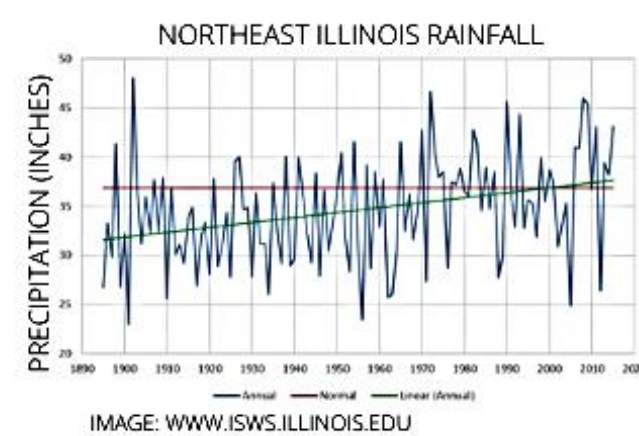
#### Water Calculations

In order to ensure indoor water use efficiency, low flow fixtures were implemented in the design and calculations were performed in order to specify the amount of gallons used and determine the sizing of a tankless electric water heater. To comply with ordinances and align with LEED standards, the anticipated stormwater runoff of the roof was calculated to determine the volume of rain that should be captured by the design. Stormwater management solutions such as rain barrels and stormwater planters were then sized.

250+ gallons of rainwater will be stored, detained, and delayed to comply with Chicago's Stormwater Ordinance.

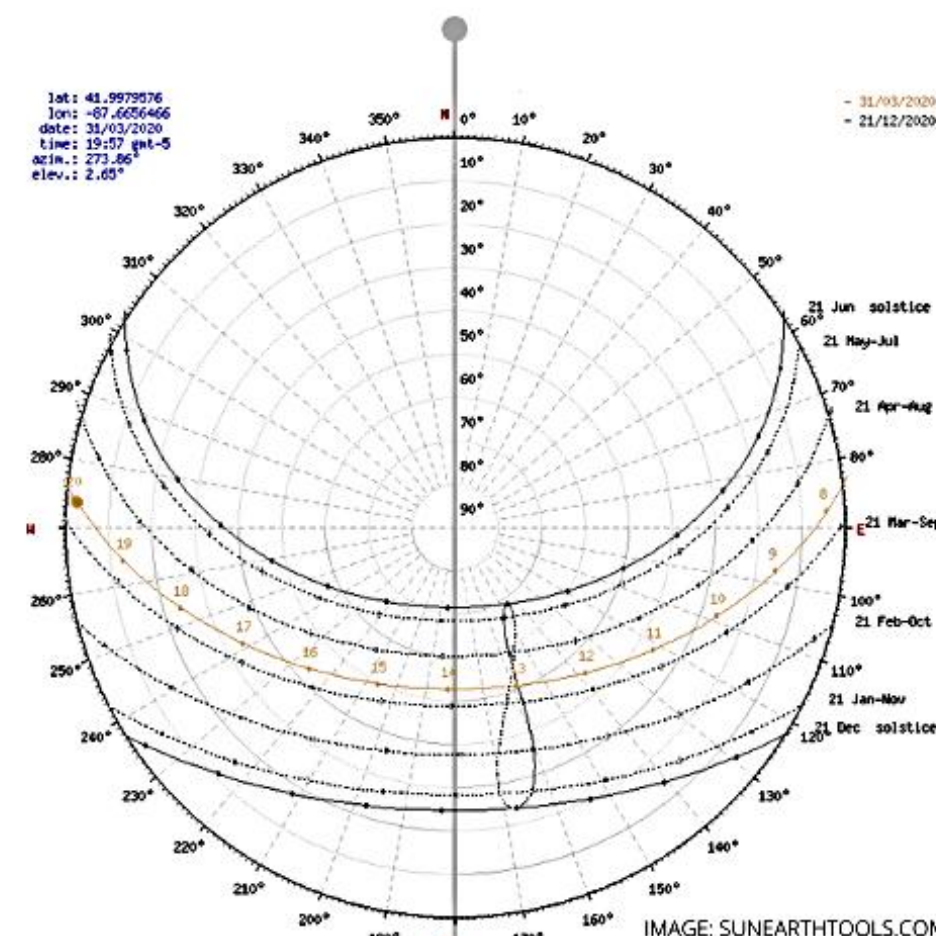
The system will align with LEED, manage the community's CSOs, and minimize stormwater flooding.

#### WATER



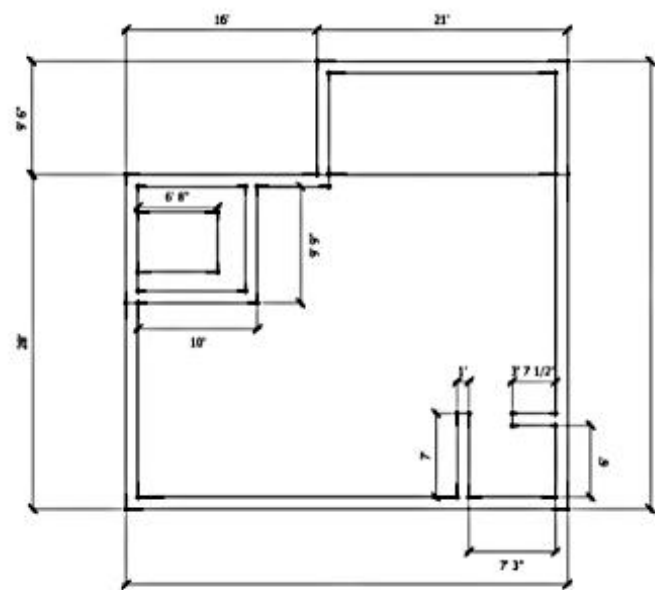
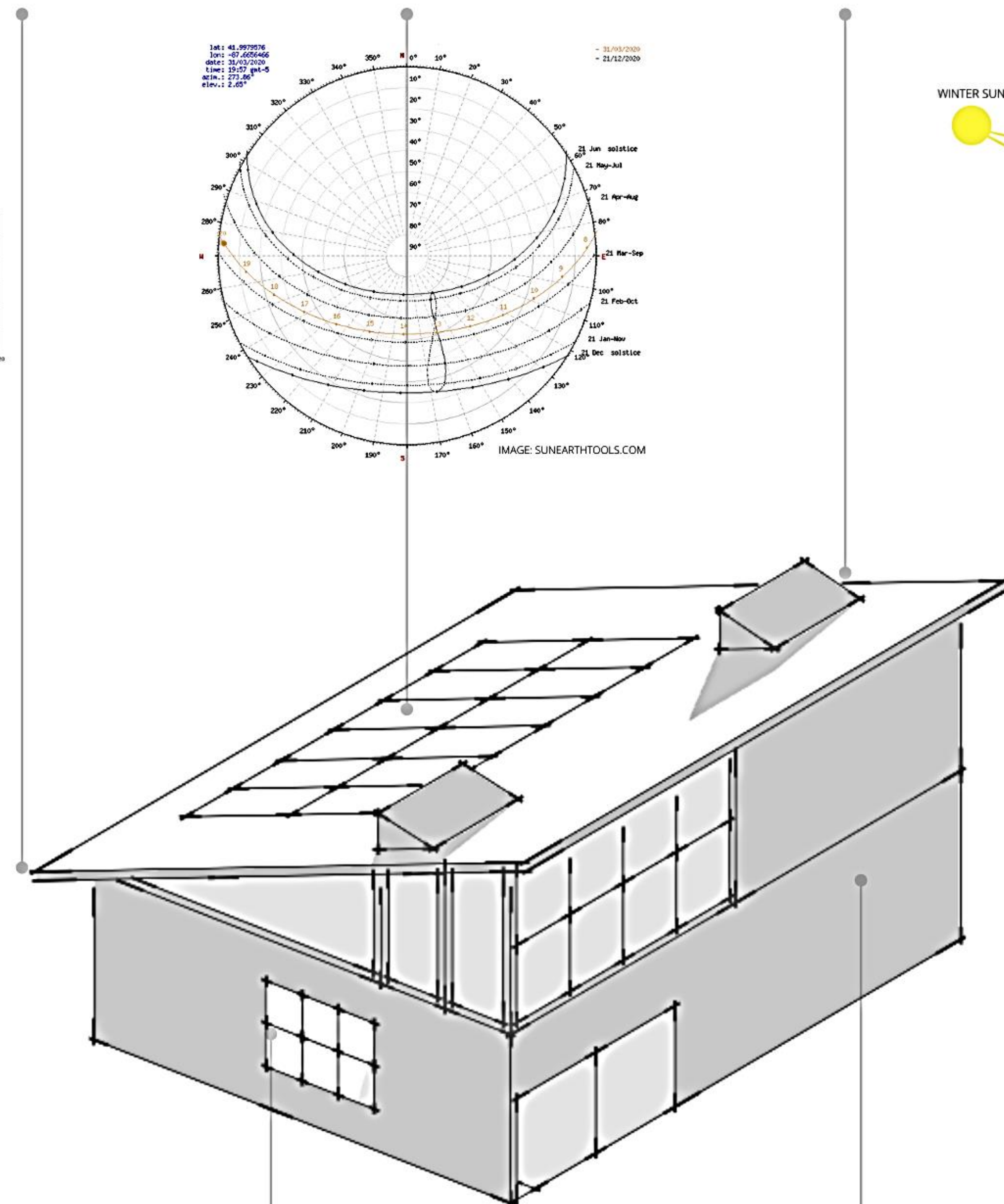
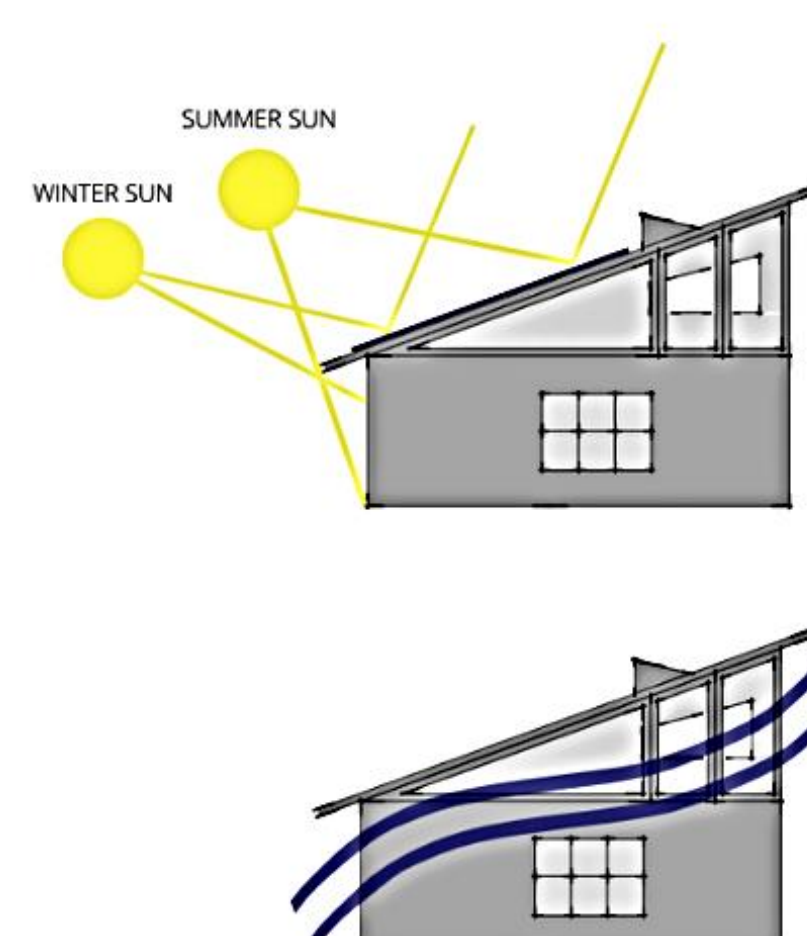
Electricity will be generated with solar panels. The system has the potential to be entirely self sufficient with battery backup. It will incorporate a tie-in to the electric grid for days where there isn't adequate sunlight and reverse metering to receive energy bill credits.

#### SOLAR



The residential unit was designed to work with the environment, for the building occupants and to reduce energy consumption. Overhangs and exterior shading were designed for the sun's path. Window placements were chosen to optimize airflow and daylighting.

#### PASSIVE DESIGN



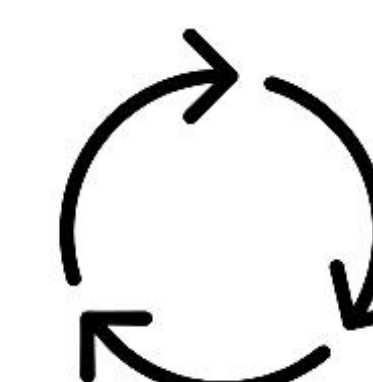
The structure involved designing a platform to raise it off the restaurant's HVAC units. The design ties into the existing steel beams on the restaurant roof to maximize strength and minimize cost. The design complies with Chicago and ICC Residential Building Codes.

#### STRUCTURE

Sustainable, cost-effective, and long-lasting materials were chosen to align with the project's design goals.

As the structure is on a raised platform on top of a restaurant, lightweight materials were chosen without compromising strength.

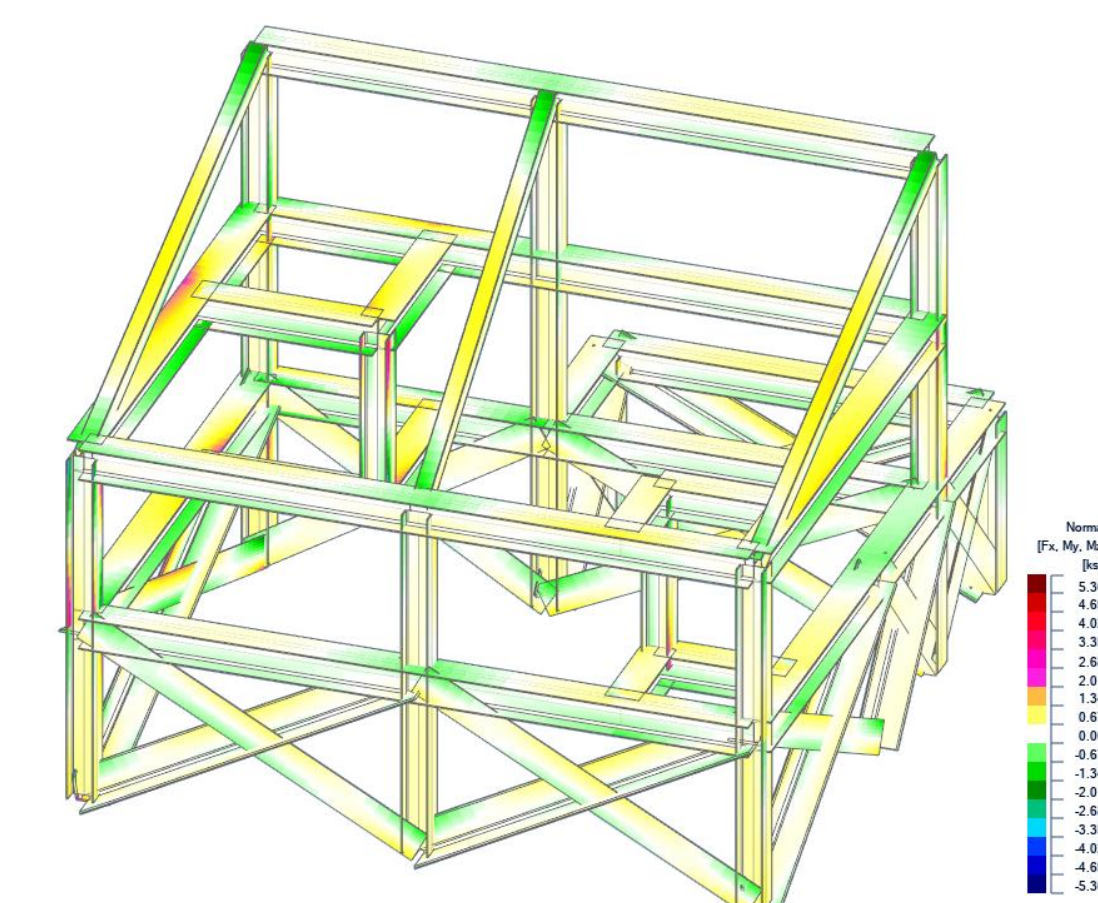
#### MATERIALS



### Results

#### Structural Integrity

The stress maps for the structure show where the most force would be experienced in each member. The members we used were W8x31 for columns, HP10x42 for Beams, LP10x10x0.7 for Bracings, and HSRE6x5x0.1 for the roof bracings. Our robot results showed that our model followed the US Licensing Standards (ULS) for ANSI/AISC, and that all the members were optimized for weight.



#### Sustainability

One of our design goals is to align with as many LEED Platinum criteria as possible to ensure our design is energy efficient and has a low environmental impact. Our focus was on the categories of Location & Transport, Sustainable Sites, Water Efficiency, Energy & Atmosphere, Materials & Resources, and Indoor Environmental Quality.

The following is what criteria we know we have met so far. Other criteria is still subject for validation but we plan on achieving all possible credits for most categories.

✓ Renewable Energy	✓ Envelope Insulation	✓ Building Orientation for Passive Solar
✓ Water Efficiency	✓ High efficiency appliances	✓ Community Resources
✓ Windows	✓ Efficient hot water distribution	✓ Location and Transport
✓ Lighting	✓ Energy and Atmosphere	

#### Financial Feasibility

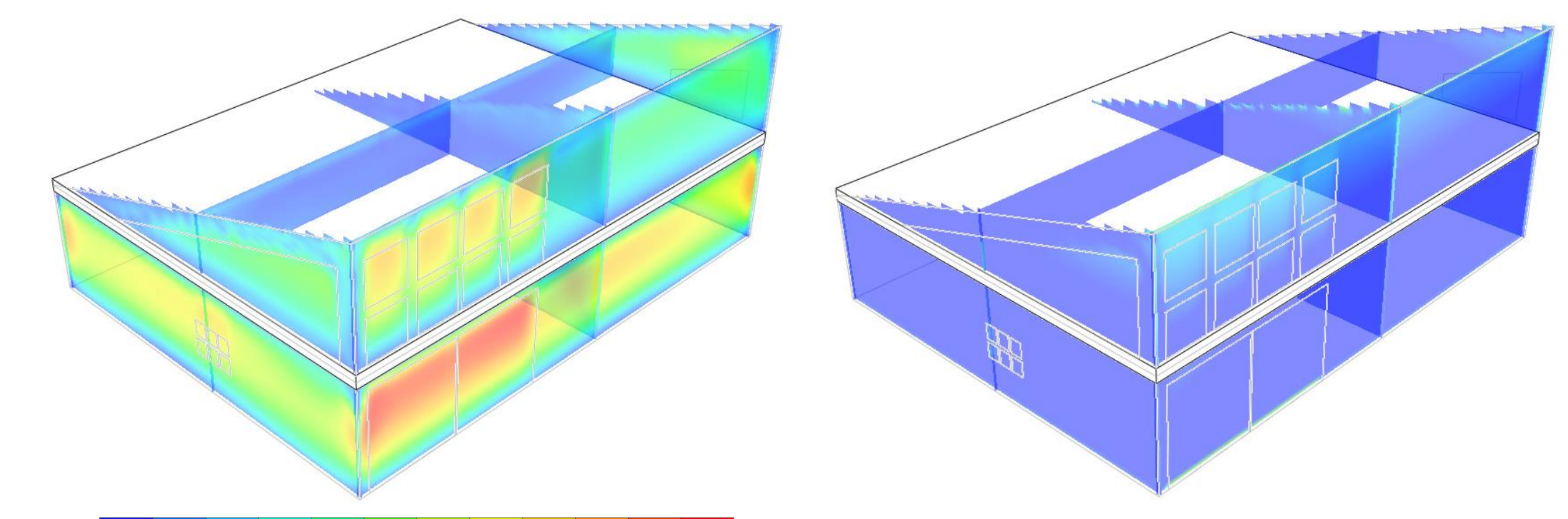
For our revenue calculations, we assumed the average visitor would be a 4 person family. We created 3 revenue scenarios based on Airbnb's data, before taxes:

- High: \$200/night at 75% occupancy with a 3% Airbnb service fee = \$53,110/year
- Medium: \$122/night at 52% occupancy with a 3% Airbnb service fee = \$22,460/year
- Low: \$80/night at 40% occupancy with a 3% Airbnb service fee = \$11,330/year

We estimated the cost of our building to be around \$135,000 and average maintenance costs to be \$4,000. Using these as a baseline, we calculated the ROI for three revenue scenarios. At high revenue, ROI would be 194% with a payback period of 2 years and 5 months. At medium revenue, ROI was 80%, with a payback period of 6 years and 3 months. At low revenue, ROI was 39% with a payback period of 15 years.

#### Comfort & Energy Efficiency

Using the energy and thermal analysis software IESVE, we were able to model out structure with all construction materials and see how it behaves in real world weather conditions.



The above image is the velocity profile for summer months demonstrating how air flows through our design. This demonstrates how our strategy for ventilation is implemented.

The above image is the temperature gradient for our design. Even in the summer months where temperatures are 80-90 °F, our system still maintains a comfortable inside temperature of around 72 °F thanks to our passive design strategies.

### Thermal Regulation

Passive design strategies are utilized as much as possible to heat and cool the unit in the most energy-efficient manner. In order to ensure occupant comfort, a mechanical heating and cooling system such as a ductless mini-split or other air source heat pump was considered in the design. Calculations were done to assess the solar heat gain and heat transfer of material components of the house (roof, windows, exterior walls, etc.) and the subsequent heating and cooling loads imposed on the unit's mechanical thermal regulation system.

### Structural Analysis

For the structural analysis of the design, we used the Load and Resistance Factor Design (LRFD) equations built into the Autodesk Robot structural analysis software and consistent with ASCE standards. We used LRFD alternative Allowable Strength Design (ASD) because the latter only account for allowable strength and don't take into consideration overdesign, whereas the LRFD allows us to use more efficient members that are still strong enough.

First, we determined where columns could be placed in our design with respect to the existing UG structure. This was done with the help of Dr. Moshiri, a structural engineering professor at IIT. Then, we took the building geometry we had created, sketched it, and created a 3D model in Robot. Afterwards, we ran calculations with the software and made minor adjustments to make sure the model was an accurate representation of our design. Then, we used the software's in-built ANSI/AISC code verification tool to verify that our structural members held up to the LRFD standards. The software also notified us of whether we had under-designed or over-designed, and offered an optimal member to use.

### Models

#### IES-VE

Integrated Environmental Solutions Virtual Environment (IESVE) software that is capable of accurate energy modeling and thermal load analysis. The program allows the user to select constructions, materials, and time frames for simulations. We used IESVE to model our system with appropriate passive design strategies and to validate our design.

#### Robot

Autodesk® Robot™ Structural Analysis Professional software is Building Information Modeling (BIM) software for engineers to perform structural analysis. It integrates different materials, calculations, and codes to allow engineers to accurately simulate buildings and analyze structures accordingly. We used Robot to ensure that the frame for our model and the platform it stood on could be made structurally sound. The emphasis of the modeling was to show the feasibility of the design rather than to provide a final and accurate design. The steel and structural design must be completed by a licensed structural engineer and approved, as this is beyond the scope of this project.

### Discussion

The testing implemented was able to demonstrate the design's functionality. The designed unit is able to perform as intended for each requirement that was specified. The proposed design is a structurally sound residential addition that ties in effectively with the main restaurant's structure. Since our structural simulations were run solely for the platform and frame, more sturdy members may have to be substituted in order to account for weights like furnishings, sheathing, roofs, and solar panels. The emphasis of the modeling was to show the feasibility of the design rather than to provide a final and accurate design. The steel and structural design must be completed by a licensed structural engineer and approved, as this is beyond the scope of this project. With the modeling we've done in IESVE, we're able to see how effective our passive design strategies are in order to regulate the temperature and air quality of the unit. The focus of this modelling was to detail the validity of our design decisions and how they react to real world conditions. We expect medium and high revenue streams to be probable for this residential addition. As shown by the calculations, the medium and high revenues will result in profit for Uncommon Ground or at least in a break-even scenario. Therefore, we can say that it is likely that the unit can fully payback its initial investment within a period of 5 years after construction. So far, the project's goal to align with LEED Platinum criteria by being energy efficient and sustainable is feasible. Next steps to be taken could include further analyzing details of each of the individual systems and comparing them to the LEED baselines.

### Acknowledgements

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- Igor Seryapin, *Energy Modeler and Engineer*
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- Afshin Faramarzi, *Structural Engineer*
- Dr. Ali Moshiri, *Structural Engineer*
- Krista Wayne, *Mechanical Engineer*
- Kristin Gatzendorfer, *Architect*
- Shona O'Dea, *Building Performance Engineer*
- Marzia Sedino, *Environmental Engineer*

