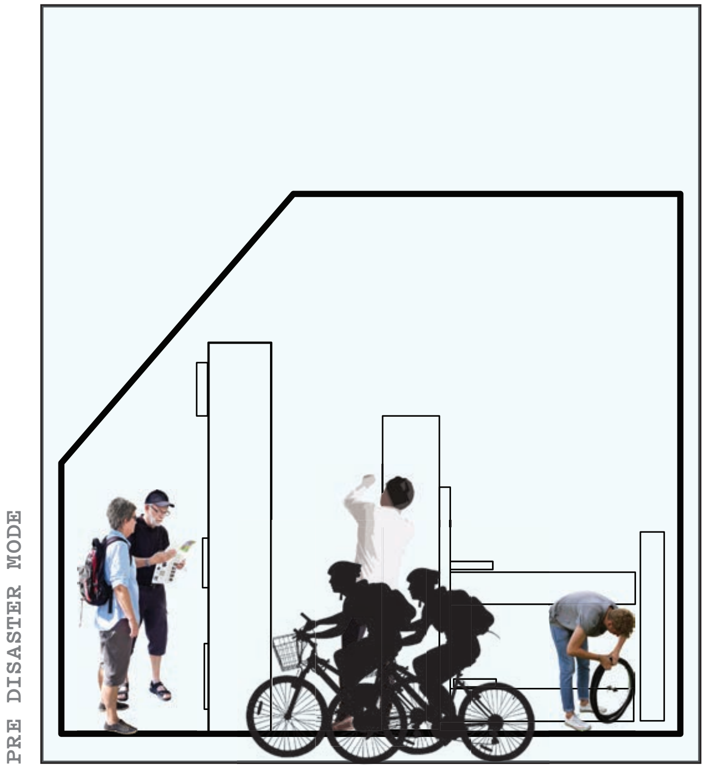

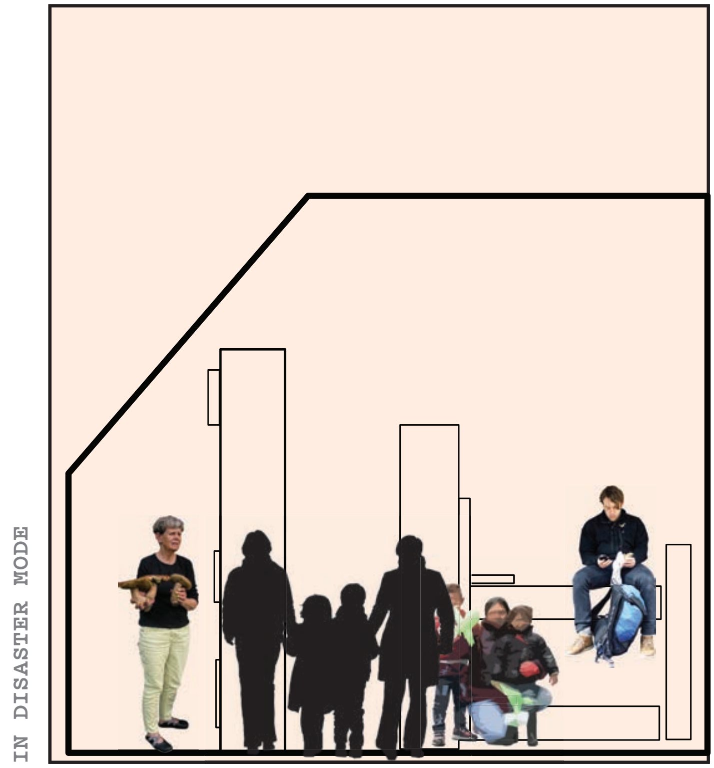

Passive Heating Strategies for Disaster Relief Planning

Winter 2019
Dunes City

Lindsey Naganuma • Alexandra Rempel

Architecture/Environmental Science 400M/500M

University of Oregon
Dunes City
SCI Sustainable Cities Institute
SCYP Sustainable City Year Program

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The author wishes to acknowledge and thank Dunes City for making this project possible, and furthermore for contributing to the goals and requirements for the development of the disaster relief shelters. Additional thanks to Jamie Mills, City Administrator, for her assistance throughout the project.

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About SCI

The Sustainable Cities Institute (SCI) is an applied think tank focusing on sustainability and cities through applied research, teaching, and community partnerships. We work across disciplines that match the complexity of cities to address sustainability challenges, from regional planning to building design and from enhancing engagement of diverse communities to understanding the impacts on municipal budgets from disruptive technologies and many issues in between.

SCI focuses on sustainability-based research and teaching opportunities through two primary efforts:

1. Our Sustainable City Year Program (SCYP), a massively scaled university-community partnership program that matches the resources of the University with one Oregon community each year to help advance that community's sustainability goals; and

2. Our Urbanism Next Center, which focuses on how autonomous vehicles, e-commerce, and the sharing economy will impact the form and function of cities.

In all cases, we share our expertise and experiences with scholars, policymakers, community leaders, and project partners. We further extend our impact via an annual Expert-in-Residence Program, SCI-China visiting scholars program, study abroad course on redesigning cities for people on bicycle, and through our co-leadership of the Educational Partnerships for Innovation in Communities Network (EPIC-N), which is transferring SCYP to universities and communities across the globe. Our work connects student passion, faculty experience, and community needs to produce innovative, tangible solutions for the creation of a sustainable society.

About SCYP

The Sustainable City Year Program (SCYP) is a year-long partnership between SCI and a partner in Oregon, in which students and faculty in courses from across the university collaborate with a public entity on sustainability and livability projects. SCYP faculty and students work in collaboration with staff from the partner agency through a variety of studio projects and service-learning courses to provide students with real-world projects to investigate. Students bring energy, enthusiasm, and innovative approaches to difficult, persistent problems. SCYP's primary value derives from collaborations resulting in on-the-ground impact and expanded conversations for a community ready to transition to a more sustainable and livable future.

About Dunes City, Oregon

Located along the visually stunning coast of Oregon coast east of Highway 101, the city of Dunes City (population 1,325) is a small town surrounded by unique natural features and a variety of recreational opportunities including fishing, hiking, ATV touring, and hunting. Resources include the 515-acre Jessie Honeyman State Park and the 40-mile Oregon Dunes National Recreation Area, which are the largest coastal dunes in the United States. Lakes bordering Dunes City include Woahink Lake and the 3,164 acre-Siltcoos Lake. With 30 miles of shoreline and the Siltcoos River Canoe Trail, Siltcoos is the largest lake on the Oregon Coast and is thought to be named for Siuslaw Indian headman Tsiltcoos.

Dunes City Hall is home to the city's council chambers, community and visitor center, and all city offices. City Hall also serves as the meeting place for commissions and committees that serve the area's residents. Dunes City hosts the annual Oregon Dunes Triathlon and Duathlon, an Olympic-sanctioned event that attracts athletes from all over the world.

Work on this project was supported by funds provided by the JPB Foundation.

Course Participants

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Executive Summary

Three student groups collaborated with city of Dunes City city council and staff to develop passive heating strategies to achieve winter sustainability after the predicted 9.0 magnitude earthquake and accompanying tsunami that will occur just off the Oregon coast.

Students investigated ways to create a shelter outside of the tsunami inundation zone for people to seek refuge after a disaster. The Dunes City city council believes they may be without assistance for an extended time period due to their distance from major highways. It is unknown how much infrastructure will be destroyed in the earthquake so the council assumes that assistance will reach them much later than nearby Florence, Oregon.

The class visited Dunes City and met Jamie Mills, Dunes City city administrator. During the visit the students learned how Dunes City was already preparing for the earthquake and tsunami. City staff have determined that city hall will be their health center during a disaster and picked out select plots of land where they hope to build relief shelters.

Mills also facilitated a visit to both sites. The first site was very sandy and far away from city hall. City staff expressed their concerns about resilience of the structures and the potentially difficult path for citizens travelling to this location. The second site that was a short walk from city hall on a dirt road. The ground on this site was a combination of dirt and sand making it more ideal for disaster relief shelters. At the second site the students performed a site analysis.

After the site visit, the student groups discussed their findings as a class and began deciding how relief shelters could be built. Students adhered to the City's assumptions and goals, including:

- Assume post-disaster conditions (e.g. destroyed infrastructure, debris, etc.)
- Lack of resources (e.g. food, shelter, medicine, etc.) for at least a month
- Lack of services (e.g. electricity, heat, water, etc.) for at least a month
- Create shelters large enough to house the citizens of Dunes City and potential tourists (about 50 people)

Afterwards, the student groups decided how they would achieve the aforementioned goals through different contextual considerations as well as experimentation with software: Climate Consultant 6.0, EnergyPlus, and Window 7.6. This allowed them to visualize design options for disaster relief shelters that could successfully meet specified goals and serve a variety of purposes before and after a disaster.

In conclusion, the student groups determined an ideal site orientation of a variation between south and east. Furthermore, the optimal tilt for any possible glazing system is between 40 and 50 degrees. The student groups experiemented with a variety of different shelter functions for before and after the disaster. Combining adaptible functionality and succesful passive heating strategies, the students show the efficiency and effectiveness of capturing solar resources in a mostly overcast Dunes City.

Introduction

Dunes City partnered with University of Oregon's Sustainable City Year Program to design disaster relief shelters that would provide housing and resources to citizens and visitors in town if a disaster were to occur. This is a high priority problem because of the predicted 9.0 magnitude earthquake that is expected when the Cascadia Subduction Zone shifts.

The city of Dunes City and many other coastal cities in Oregon are trying to improve their disaster readiness. Dunes City's current efforts include making sure that city staff are able and ready to assist if necessary. City employees have been first aid trained so that they would be able to administer different medications that are currently being stored for emergencies. Additionally, the City is establishing a robust tsunami evacuation route with clear directional signage. Staff have also been educating locals about disaster preparedness.

Three student groups, with input from city administrator Jamie Mills, generated a collection of passive heating strategies that could help Dunes City continue to prepare for a disaster and also be functional and useful to their town pre-disaster.

Background

Dunes City is a small coastal city just south of Florence, Oregon. It is about 3.5 square miles in size and sits at an elevation of 39 feet. It is surrounded by the Honeyman State Park sand dunes, the Siuslaw Forest, and two lakes: Woahink Lake and Siltcoos Lake. There are about 1,325 current residents in the city, although this number fluctuates seasonally due to the increased number of summer visitors.

Dunes City's climate is relatively mild. There are only 156 sunny days during the year and on average about 55% cloud coverage on days with overcast conditions. The City typically gets 74 inches of rain and about a half inch of snow per year. The summer winds predominately come from the North at 12 to 16 miles per hour but increase along the dunes. Winter winds vary much more in direction and during intense winter storms can exceed 100 miles per hour. Overall, the summers are relatively comfortable, dry, and clear, while winters are cold, wet, and mostly cloudy.

Dunes City is covered by large sand dunes just off the Oregon coast. While these dunes are an attraction during the summer, they are also a large liability in the event of an earthquake. Sand is highly prone to liquefaction, defined as when the strength and stiffness of sand or soil is reduced by the shaking of an earthquake. This could be a major issue for Dunes City depending on where buildings are located and how deeply they are anchored into the earth.

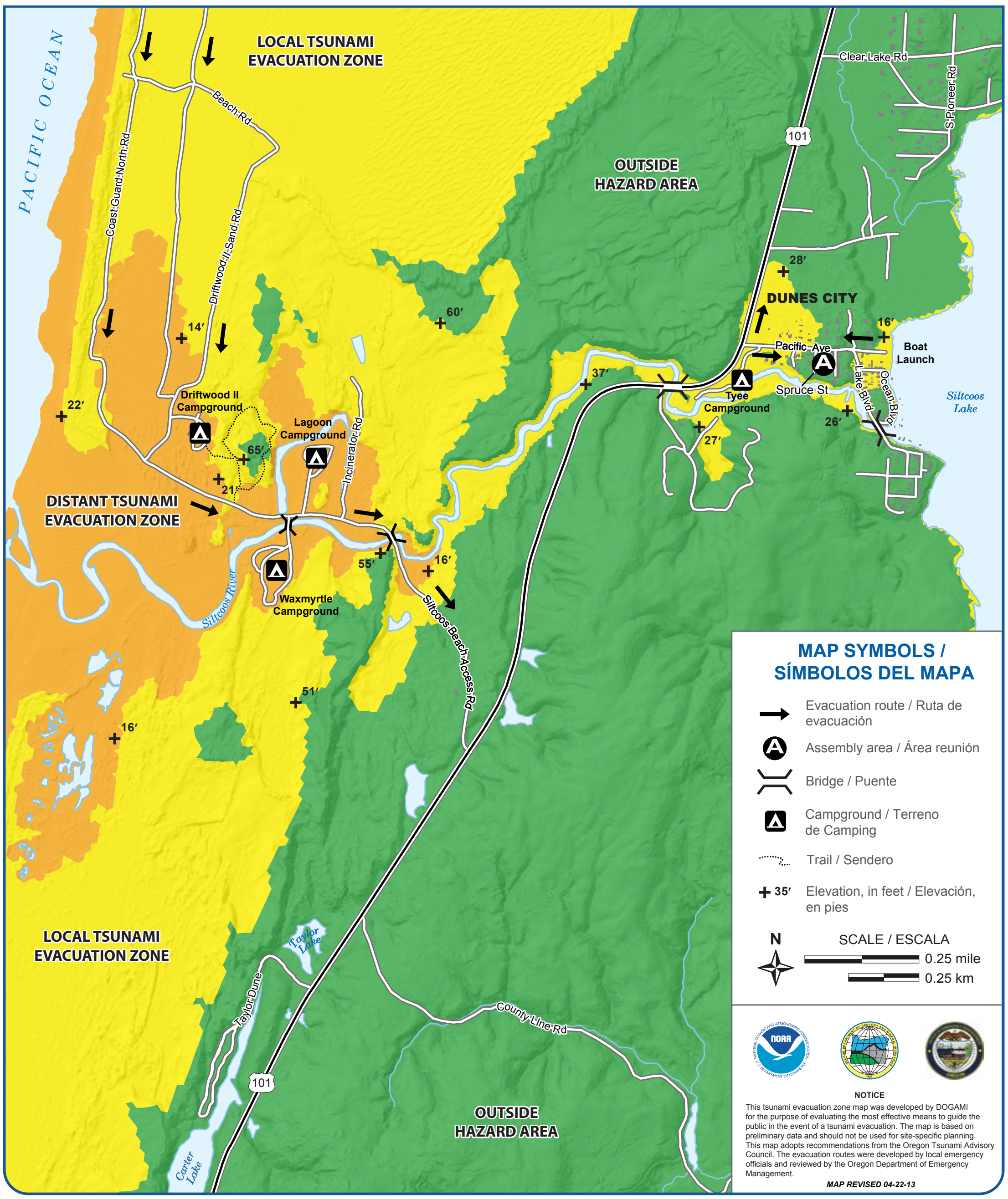
SOLAR SITE SURVEY

The Dunes City climate provides context for the site analysis conducted on the site. A site analysis is important because there could be unique site characteristics that do not directly correlate to Dunes City's overall climate. An analysis of the site allows a more detailed understanding of climatic factors that directly impact the success of passive solar heating.

Overall, the site was very similar to Dunes City climate. It was located on the sand dunes about a ten-minute walk from City Hall, which would serve as the city's medical treatment facility in a post-disaster scenario. Both City Hall and the proposed location for the disaster relief shelter are outside the inundation zone of the predicted tsunami that will hit shortly after an earthquake occurs.

FIG. 1

Map of the predicted inundation zone of the tsunami post-earthquake.



SOLAR ANALYSIS

The first step of the solar site survey was to measure solar exposure on the site. Students took these measurements from many different locations on the site to ensure they picked the area with the most sun exposure.

The angle, path, and strength of the sunlight are some of the most important elements in passive solar heating. In order to make well informed design decisions, it is crucial to develop an understanding of how the sun will move through the sky. Solar pathfinders were used to measure the solar exposure from different positions on the site.

Further analysis using the solar pathfinder data calculated relevant design criteria like optimal tilt, site orientation, space arrangement, and other passive heating strategies. The latitude of Dunes City is about 44° N, which determines the angle that the sun crosses the sky at a given time of day throughout the year. Post-survey solar radiation data was derived from the software Climate Consultant 6.0 and overlaid onto the sun path diagram for 44° N latitude. The sun path data were then combined with the solar pathfinder data to draw conclusions about positioning and building orientation on the site.

FIG. 2

Students on site using the solar pathfinder equipment to measure solar exposure.

FIG. 3

View of Solar Pathfinder on site measuring the amount of sunlight that will reach the site at different times of the year. Photograph by Hannah McKay.

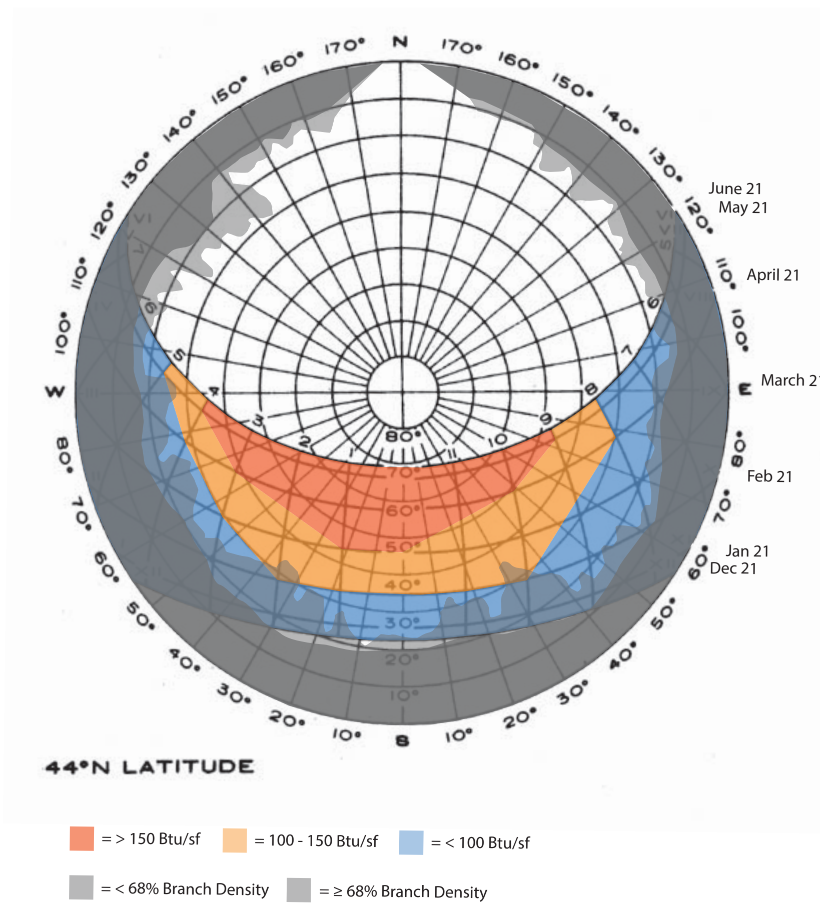


FIG. 4

Diagram of the inclinometer process for measuring shading object heights. Illustration by Lindsey Naganuma.

VEGETATION ANALYSIS

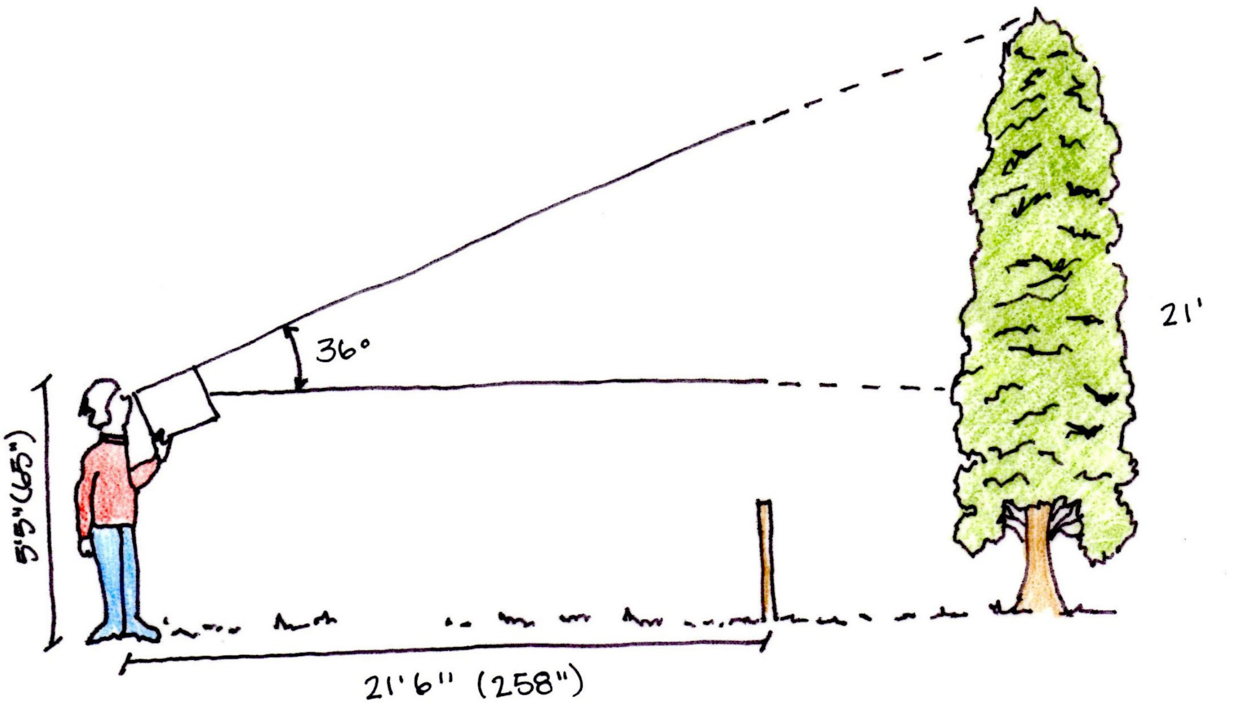
The next step during the solar site survey was to document the surrounding vegetation. This process was completed in two parts. First, students measured the height of a shading object. A student stood at the proposed site location with an inclinometer at eye-level and measured the top of a shading object, while another student recorded the angle displayed on the inclinometer.

In order to complete the height calculation, students measured the position of the object. Students used tape measurers to record the shading object's distance from the proposed site location. Once this information was collected, the height of the shading object was calculated.

For shading objects located off-site, the process was very similar. In this case, distance was measured on-site from the proposed building location to the edge of the site. This gave the relative height of the shading object. While this calculation did not determine the exact object height, it approximated the object height if it were located on the edge of the site. Students used this method because some objects were far away from the actual site location but still created shade. In this scenario the important information is how much shade this object will create at certain times of day.

FIG. 5

Students on site using the inclinometer equipment to measure the angle to the top of the tree.



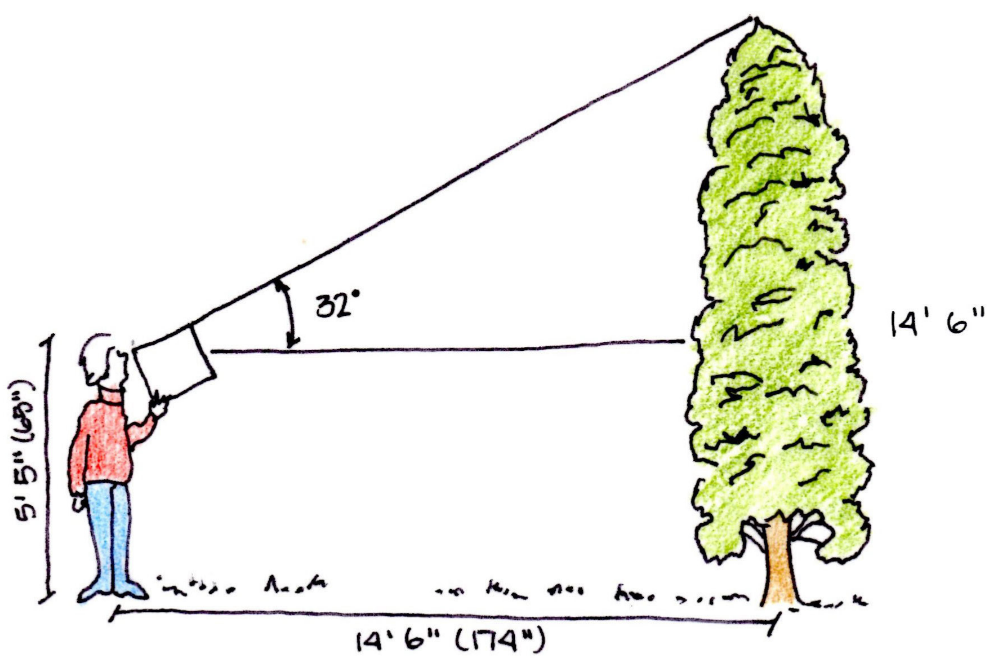
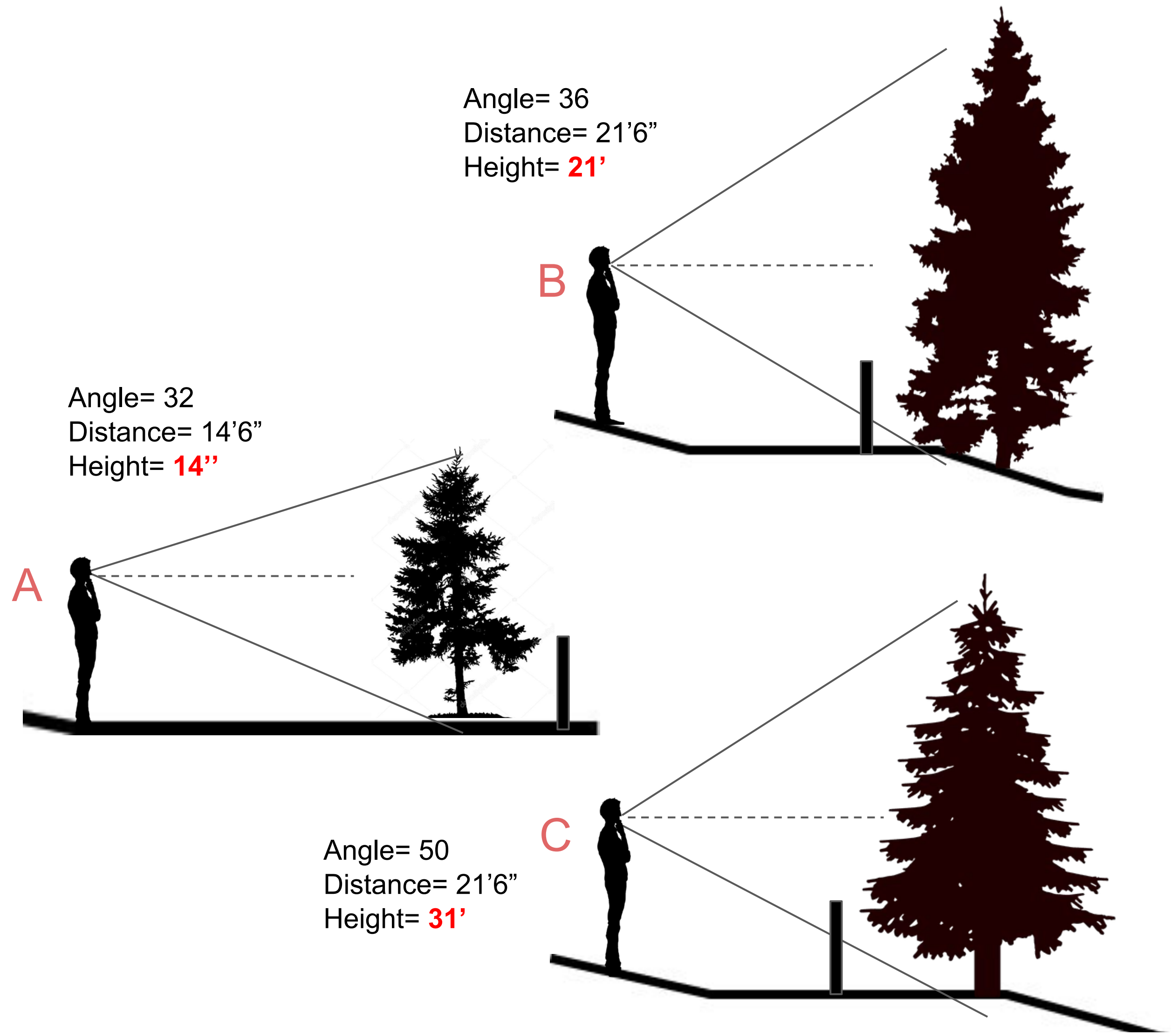


FIG. 6

Diagram of the calculation for measuring the height of shading objects on the site.

FIG. 7

Diagram of the calculation for measuring the height of shading objects on the site.



The second step was to collect tree debris and make note of the existing types of vegetation on site. Students used this information to identify the different vegetation species on site. Knowing types of vegetation species is crucial in understanding what types of sunlight will reach the site. Depending on the species, the density of branches may allow some sunlight to shine on the site even though a shading object has been recorded.

Through the samples collected from the site, photos taken of different vegetation, and notes from the solar site survey, it was determined that the main forest types surrounding the site are Douglas fir and spruce-hemlock. These types of forests commonly include the following tree species: cascara buckthorn (*Rhamnus purshiana*), Douglas-fir (*Pseudotsuga menziesii*), lodgepole pine (*Pinus contorta*), Port Oxford-cedar (*Chamaecyparis lawsoniana*), Sitka spruce (*Picea sitchensis*), and western hemlock (*Tsuga heterophylla*).

Knowing most vegetation on site is an evergreen species simplifies the shade challenges because students can assume these trees will not lose their leaves during winter months.

FIG. 8

Sketches of different tree species displaying different branch densities and shapes.

Passive Heating Strategies

Passive heating strategies vary by climate and function. Because Dunes City lies in an overcast climate in the Northern Hemisphere, examples and recommendations are specific to this type of environment.

Additionally, this climate-based variation means that there is not one "correct" strategy, but instead ane array of different options that Dunes City could successfully implement with their disaster relief shelters.

MOVABLE INSULATION

Selecting the proper movable insulation is as important as determining the best passive heat building strategies. Passive heating has one major trade-off: more glass area increases solar energy, but also increases heat loss when exterior temperatures are low. This trade-off can be lessened with proper movable insulation.

Insulation will reduce the amount of heat lost through glazing surfaces when outside temperatures are low. During the day the insulation can be removed to ensure proper solar energy collection. There are many different types of movable insulation. It can be rigid or soft, exterior or interior, small or large, and automatic or manual. Most solutions are unique to the associated passive heating strategy.

SPACE TYPES

Conventionally, there are three main passive heating strategies: direct gain, indirect gain, and isolated gain. Each strategy creates a different type of space that could serve a different function. It is important to recognize these methods do not need to be used in isolation; a combination could offer a unique solution to a site.

Direct Gain

Direct gain is the simplest strategy for passive heating. The living space of a building, meaning rooms regularly occupied by people, is physically used as a solar collector for heating. The sunlight shines directly through a window and into the room where it heats the space up and keeps occupants warm. A dining room or study in a house could potentially be used as a direct gain space.

The benefit of this type of strategy is solar energy traveling directly into the space where heating is required. Less direct methods may have a difficult time transferring the heat to the necessary space. Challenges of this strategy include controlling the solar energy allowed into the space. Since these spaces are physically inhabited by occupants, the temperature may become too hot at certain times of the day in order to remain warm throughout the night. Some direct gain spaces can reach temperatures as warm as to 100°F. Shading and natural ventilation need to be included to keep temperatures manageable in the summer.

The cloudiness in Dunes City winters causes tilted glazing to be much more effective than vertical glazing.

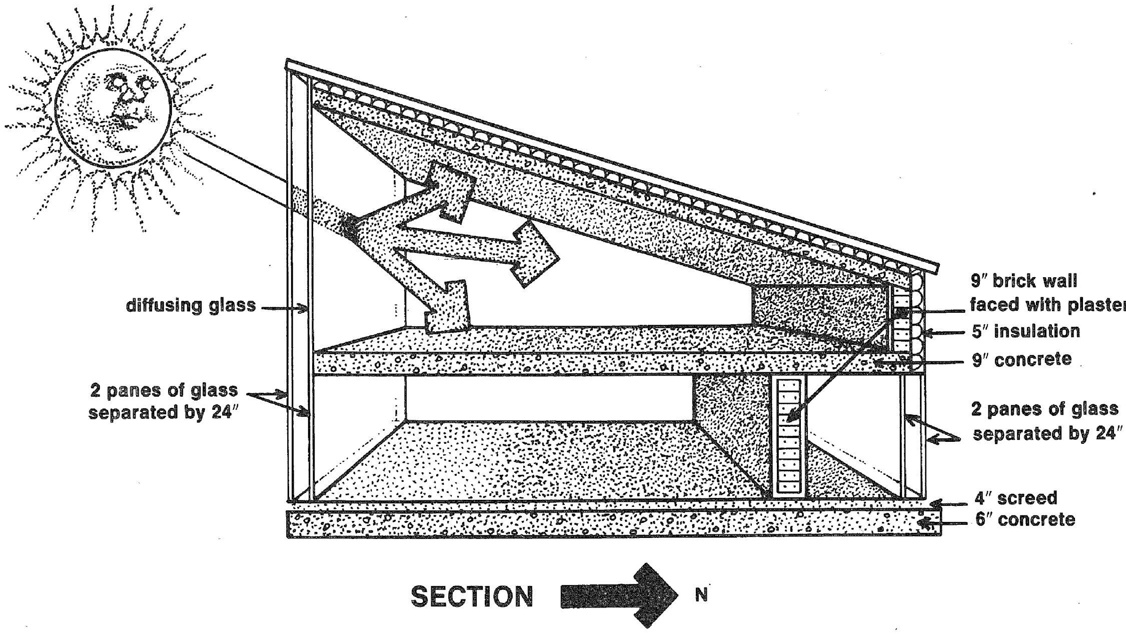


FIG. 9

Diagram of a direct gain space (Marzia, 32).

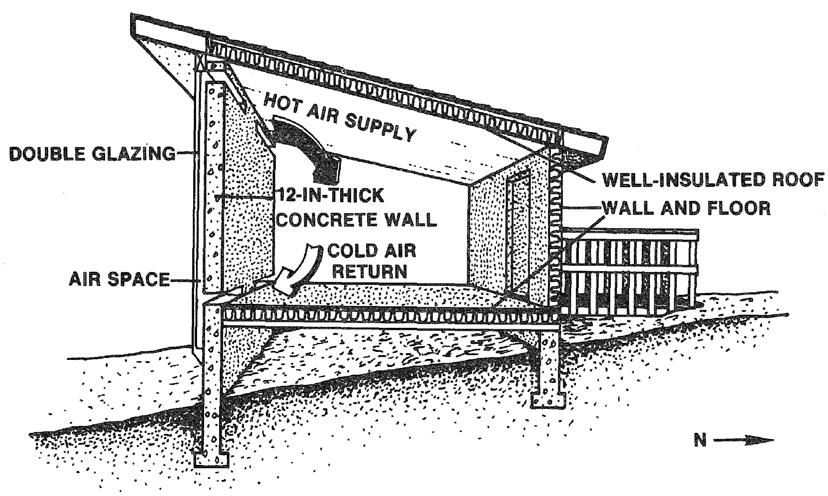


FIG. 10

Diagram of an indirect gain space (Marzia, 45).

Indirect Gain

Challenges of direct gain spaces can be mitigated through indirect gain strategies. There are two main types of indirect gain strategies: thermal storage walls and roof ponds. Seeing as water could be a scarce resource for Dunes City post-disaster, a thermal storage wall is a more viable solution. A thermal storage wall, also known as a Trombe wall, is a wall placed adjacent to a large glazing system. The sun enters through the glazing system and is absorbed by the wall. This wall then stores the solar energy and slowly releases it throughout the day.

This strategy creates a small barrier between the living space and the solar collection space. The small space in between the window and the Trombe wall can heat to uncomfortable temperatures while the living space remains comfortable all day long. The challenge with this method is timing when and how the wall releases heat into the living space. Material and thickness of the Trombe wall is dependent on when and how quickly heat is needed. Sometimes this can be difficult to successfully execute in a predominately overcast climate.

In cloudy climates it is ifficult for vertical walls to efficiently absorb the sun. Cloud cover diffuses the sunlight, altering the optimal angle needed to collect solar heat. On a clear day, the sun's orientation dictates the optimal capture angle, but on a cloudy day the best angle is from directly above. Dunes City's overcast climate makes solar collection more difficult than in clear climates.

Isolated Gain

An isolated gain system uses an external surface that absorbs solar energy that is then transferred to the living space when needed. The benefit of this strategy is that it gives maximum temperature control to the occupant. When the space feels too hot the occupant can vent the space, preventing heat accumulation. In contrast, when a space is too cold the occupant can close the vent and increase the temperature of the space. The main challenge of the strategy is effectively transferring solar energy from the external surface into the living space.

In the case of Dunes City, a viable strategy could be a separate glazed space such as a greenhouse or sun space. This would allow a separate, less inhabited space to heat up to uncomfortable temperatures while the main living space would remain unaffected. Heat in the uninhabited space could then be released into the

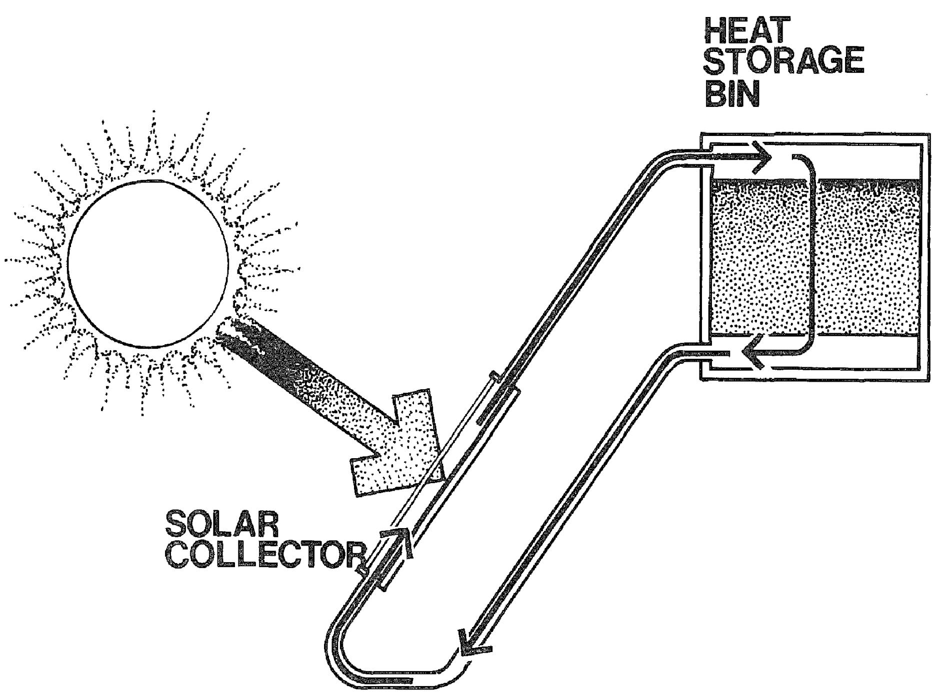


FIG. 11

Diagram of a convective loop (Marzia, 60).

main living space via venting. In the absence of venting, heat can be stored in a greenhouse space throughout the day. The main challenge of this strategy is the insulation requirements. In order to store solar energy through the night, movable insulation will need to be deployed and occupants will need to be educated about the schedule of this operation.

A tilted glazing surface is critical to this strategy's success. Tilting the glass with maximize solar collection on both sunny and overcast days. As mentioned above, overcast weather diffuses the sun's rays and causes the strongest source of solar radiation to come from directly above a surface. Tilted glazing will still be able to collect this solar heat. While vertical glazin is more effective on sunny days, it fails to collect solar resources on overcast days.

THERMAL COMFORT

Thermal comfort is important when considering passive heating options. Often this idea is thought of as the physical comfort an occupant feels when in a space. The main metrics for measuring thermal comfort are relative humidity, humidity level, wet bulb temperature, operative temperature, and clo level, defined as follows:

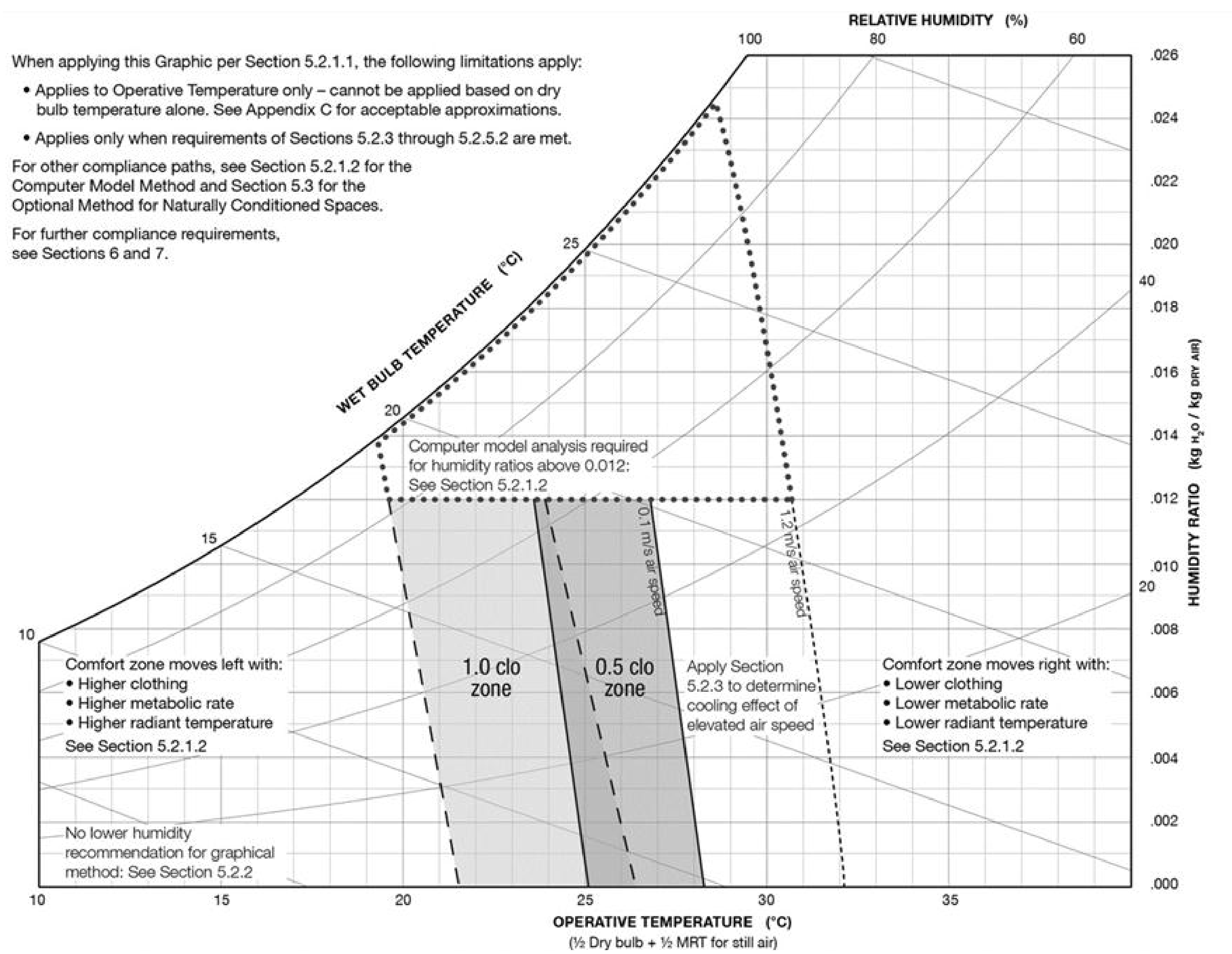


FIG. 12

Psychrometric chart from ASHRAE Standard 55 used to measure thermal comfort in a conditioned space.

- Relative humidity: the percentage of water vapor pressure in the air relative to the amount of water vapor necessary to reach equilibrium.

- Humidity: the amount of water vapor present in the air.

- Wet bulb temperature: the temperature of the air passing over a thermometer wrapped in a wet cloth.

- Operative temperature: a measurement of thermal comfort that is simplified from three different factors: air temperature, mean radiant temperature, and air speed.

- Clo level: a measurement of thermal insulation a person receives from wearing different articles of clothing.

The psychrometric chart combines all of these metrics into one simplified thermal comfort zone.

This chart is specific to conditioned spaces. Specifically, the standard comfort zone measures thermal comfort in conditioned office spaces. For any unconditioned areas, the Adaptive Comfort Zone chart should be referenced.

In the case of Dunes City, no spaces within the disaster relief shelter will be unconditioned due to the relatively cold temperatures in winter months. However, passive heating strategies are more appropriately measured by the Adaptive Comfort Zone. Because heat is generated solely by the sun without mechanical systems, passive heating conditions are similar to an unconditioned space.

Thermal delight is an additional sense to be considered in addition to thermal comfort. Thermal delight refers to the warming sensation an individual feels in response to specific colors, textures, and materials. Keeping thermal delight in mind will be crucial to maintain comfortable disaster relief shelters.

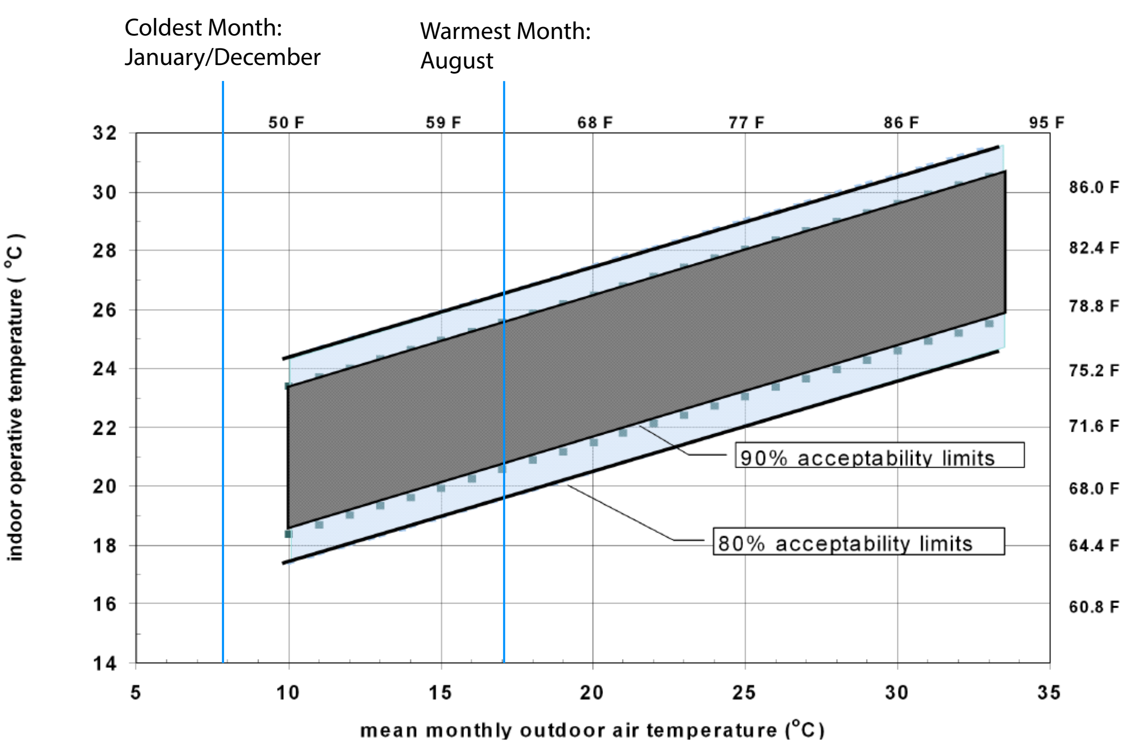


FIG. 13
Adaptive Comfort Zone chart from ASHRAE Standard 55 used to measure thermal comfort in an unconditioned space.

Project 1: Bailey and Martinez Project

This project focused on creating a shelter with year-round comfort and flexibility of public and private spaces. The design intent addressed the thermal comfort goals to maintain steady and comfortable temperature levels, allowing occupants to experience a variety of different temperatures throughout the sheltered space.

INTRODUCTION

The project emphasized year-round comfort with the shelter so it could be usable at any point in the year. The project also drew on direct gain passive heating strategies with effective shading for cooling during warmer months. In terms of flexibility, the group wanted the shelter to have pre-emergency and post-emergency uses. Pre-emergency it could serve as a mechanism to educate the public about earthquake preparation while being an identifiable landmark and communal space. Post-emergency it could serve as a shelter to residents. Furthermore, the shelter will be divided up into multiple spaces: a sunspace, an area with operable windows, and an outdoor thermal mass. This group focused on the conceptual design of a disaster shelter. Each individual living quarter would be built out of a cargo shipping container. This keeps costs low and allow the shelter to be assembled and deconstructed with ease. The design's multi-level component gives more space for larger groups and families without people up. Lastly, a large retaining wall at the north end of the site protects against liquefaction and damage to the shelter.

METHODOLOGY

This group started by examining different tree heights to help determine the shading objects that surround site. They compared the results to solar pathfinder images to determine an ideal building location. The team also calculated the optimal tilt for the location at 40 degrees. Next, they looked at the solar radiation available during different times of the year (see Appendix A for initial analysis).The team chose recycled polycarbonate for window glazing, which is more durable in the event of a disaster. This material is ideal for this design because it has high solar absorbance despite the lower light transmittance.

The group calculated the heating need of the building and solar energy collected through the potential glazing system. Here, they assumed that any excess heat could be mitigated using shading and moveable insulation (see Appendix A for heating need calculations). The team used the EnergyPlus software to test the effectiveness of their movable insulation schedule and found that it works adequately for the passive heating system (see Appendix A for graphs of EnergyPlus results).

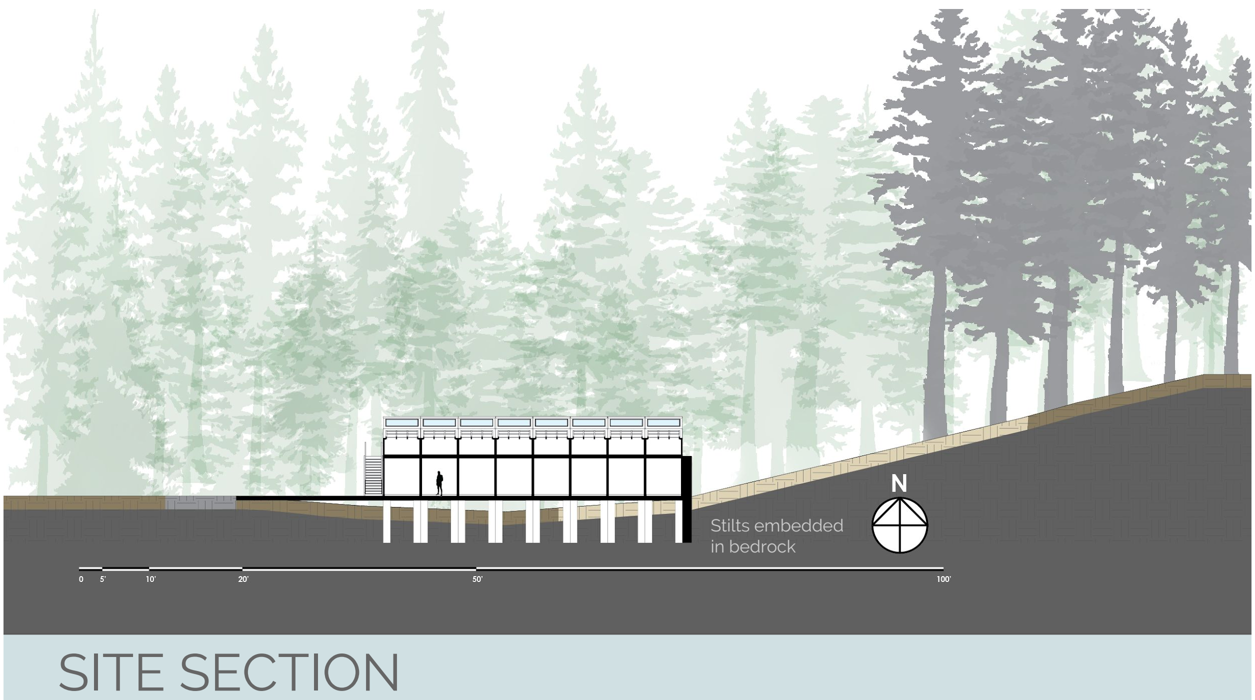
RECOMMENDATIONS

This group recommended placing the building north of the site's access road and orienting it eastward to maximize solar collection. The team recommended using a tiled glazing surface of 40° wherever possible. This will absorb the most solar radiation.

Furthermore, the group recommended a strict moveable insulation schedule. Through this project the team realized that within their passive heating system the moveable insulation, glazing, and thermal mass are all interdependent. These three factors create a well-conditioned space year-round, thus if one factor changes others should as well. For example, improvements to the insulation system should be coupled with increased thickness to the proposed insulation.

FIG. 14

Section of proposed shipping container building with clerestory windows.



Project 2: Blankenberger and Solorzano Project

This project focused on creating a multipurpose and modular disaster relief shelter. The design intent addressed the thermal comfort goals to provide warmth in the winter and relief from hot summer temperatures with programmatic and thermal gradients.

INTRODUCTION

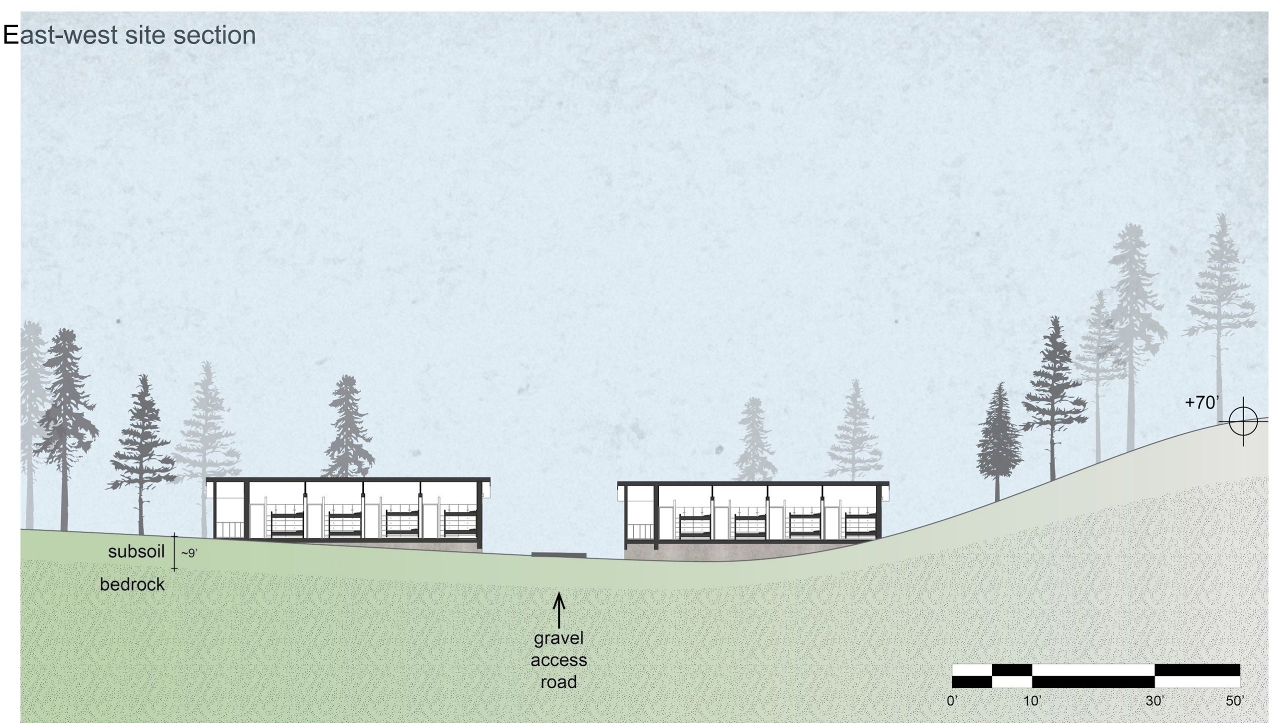
This project was inspired by the idea of one building with two functions: community building and adequate shelter. In terms of modularity, the team wanted to add a level of adaptability. The shelter is constructed of smaller pieces that fit together to create one large shelter depending on how many people need shelter or how big of a community space Dunes City wants to create. This makes it easy to expand the space over time as the City deems necessary. Furthermore, the team incorporated a thermal gradient with warmer public spaces and cooler shelter and storage spaces during the day. Shelter spaces would become warmer during the night. These spaces can be opened up and connected to each other or partitioned off depending on the desired functionality.

METHODOLOGY

The group started by determining the optimal location and orientation of their building. They looked at the solar pathfinder images to see which locations had the best solar radiation and compared this with the shade that

FIG. 15

Section of proposed modular building showing the thermal gradient from the East West view.



would appear on the site from nearby trees. The team also considered views the building would have depending on its position. After combining all the information on a 44° latitude sun path, they placed their shelter's ideal location at either side of the access road oriented east.

Next, the group studied different solar radiations for the optimal tilt of the glazing surface. They decided that 40° was the optimal tilt. This decision was based on heating need and solar radiation potential. They also explored how different sizes of glass effect solar collection. From these calculations they determined that 10 to 15 square meters of glass would provide the necessary solar energy to heat the building. The student group assumed that the extra solar energy collection could be mitigated through other methods.

The group used the Window 7.6 software to choose their glazing type. They chose a double-pane system of clear float glass. This type of glass has very high solar absorbance and visible transmittance, which helps maximize the solar energy collected through the sunspace. The high collection energy required that moveable insulation be applied at night time. The team used EnergyPlus to test the effectiveness of their movable insulation schedule and found that it is adequate for the passive heating system (see Appendix B for graphs of EnergyPlus results).

RECOMMENDATIONS

This group recommended placing the building on either side of the site's access road and orienting it eastward to maximize solar collection. The team recommended using a tiled glazing surface of 40° wherever possible to absorb the most solar radiation. The building should have somewhere between 10 to 15 square meters of solar collection glazing.

Furthermore, the group recommended following a strict moveable insulation schedule. Even with this schedule the sleeping quarters can get quite cool. If improvements were to be made, the team recommends adjusting the thickness of the thermal mass to better insulate the bunk bed areas. Another solution to this issue is to provide an additional personal heat source for occupants while they sleep.

Project 3: Mckay, Naganuma, and Shortall Project

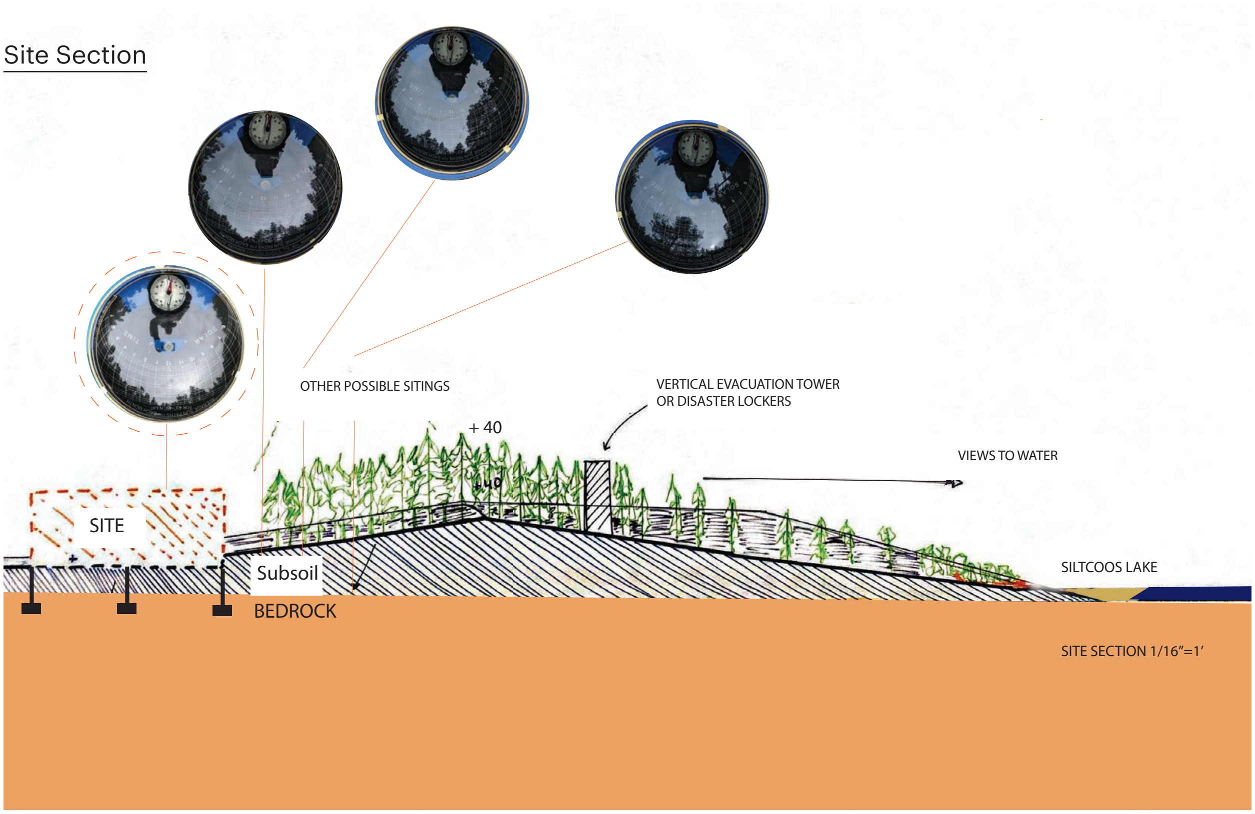
This project focused on creating an adaptable and mixed-use cottage. The design intent addressed the thermal comfort goals of capitalizing on the solar energy available in Dunes City and incorporating the use of colors and textured materials to create thermally delightful spaces.

INTRODUCTION

The project was inspired by the idea of a livable solar collecting space. Because of uncertain circumstances surrounding the disaster relief shelter, it was crucial that the space be adaptable with a mix of uses. In terms of adaptability, the group wanted to incorporate social gradients as well as thermally contrasting spaces. By creating a livable solar collection space, occupants have the option of inhabiting a very warm, bright space or a cooler, darker space. Furthermore, having adaptable functions is also a major design element. The site location is very close to Highway 101, a major road for long distance bikers. Pre-disaster, this space can act as a temporary overnight shelter for bikers to safely stop and rest. Post-disaster it will become a shelter for residents.

FIG. 16

Section of proposed site positioning based on solar resource measurements.



METHODOLOGY

This student group started by looking at the different solar pathfinder images to see which areas on the site had the most solar exposure. Since Dunes City's climate is relatively overcast, it is important to ensure that solar radiation is maximized. The team chose an area just north of the site's access road.

After choosing a proposed building location, the team looked at daily radiation levels and their variation throughout the year. These data came from the software Climate Consultant 6.0 and weather data from Florence, Oregon. The Florence weather data station is the closest weather station to the site in Dunes City. By pairing these data with the shade measures from the site visit, the group determined they would orient the building to the southwest.

Next, the passive heating strategy needed to be determined. This was done by defining the heating season, or the months of the year that heating is necessary to keep indoor temperatures comfortable. The group used heating degree days (HDDs) to determine the heating season. An HDD is a unit that measures the amount of energy necessary to heat the building. They also used weather data from Climate Consultant to rule out the summer months of June through August.

To ensure the most accurate heating season possible, the group examined the solar radiation collected based on the glazing surface tilt. To see the impacts that different heating seasons would have on the amount of energy collected through the glazing surface they did a variety of calculations (see Appendix C for calculations). The group found that no matter how the heat season was defined the optimal tilt was either 40° or 50°. In order to determine optimal tilt, they graphed the heating need verses the solar radiation. They found that a tilt of 50° gave more heat in colder winter months and less heat in hotter summer months (see Appendix C for graph). The team decided that the heating season would exclude June, July and August with an optimal tilt of 50°.

The student group used Window 7.6 to select their glazing material. They chose an acrylic glass that would be more resistant to shattering in an earthquake but also has high absorbance of solar radiation. This high absorbance requires movable insulation to keep the heat in during cool evening hours. The team used EnergyPlus to test the effectiveness of their movable insulation schedule and found that it works adequately for the passive heating system (see Appendix C for graphs of EnergyPlus results).

RECOMMENDATIONS

This group recommended placing the building just site's access road and orienting it to the southwest to maximize solar collection. The team recommended using a tiled glazing surface of 50° wherever possible. This will absorb the most solar radiation.

Furthermore, the student group recommended following a strict moveable insulation schedule. If improvements were to be made to the insulation system, they recommended increasing edge sealing around the window and potentially leaving the moveable insulation on longer in morning hours (Dunes City temperatures do not warm up until later in the morning).

Conclusion

Dunes City is a challenging place for passive solar design due to the relatively overcast climate. However, through a variety of calculations and measurements, student groups determined that solar energy is a reliable and plentiful heating source post-disaster when access to other resources is limited. Researching different passively heated space types and movable insulation strategies reveals a variety of plausible solutions for disaster relief shelters.

Overall conclusions that can be drawn from research include that the ideal orientation on the site is at some variation between south and east. Additionally, the optimal tilt for glass surfaces to collect the most solar heat is between 40° and 50°. There are also many ways to occupy the space pre-disaster and many different strategies that are equally effective at capturing solar energy post-disaster.

In terms of the glazing material, most teams decided to use a non-glass material. Materials like acrylic or recycled polycarbonate have similar properties to glass but are resistant to the effects of an earthquake.

Potential functions for the disaster relief shelter pre-disaster include but are not limited to a community center, a public landmark, or an overnight shelter for Highway 101 bikers. The City will have to decide post-disaster if the shelter will return to a pre-disaster function or serve another purpose.

In conclusion, there are many ways to achieve a successful passive heating strategy. Properly locating and orienting the building, determining the correct glazing material, and ensuring adequate moveable insulation are critical to the system's success. Other important factors include the building's heating needs and solar energy collection of the glazing system. We recommend that Dunes City consider these factors when designing its passively heated disaster relief shelter.

References and Resources

ASHRAE Standard: Thermal Environmental Conditions for Human Occupancy. American Society of Heating, Refrigerating and Air-Conditioning Engineers, 2010. PDF.

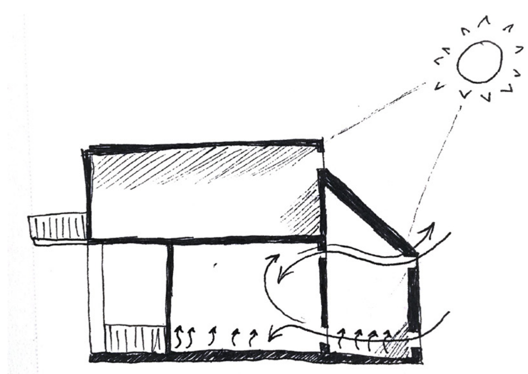
Mazria, Edward. *The Passive Solar Energy Book*. Rodale Press, 1979. p28-65. Print.

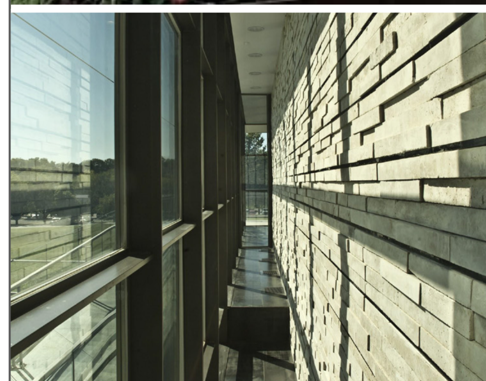
Appendix A

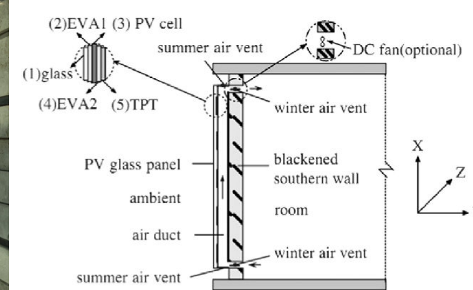
Project 1: Virginia Bailey and Francisco Martinez Final Presentation

IDEA #1 Year-Round Comfort

This shelter could be used at any point in the year, depending on when the Cascadia Subduction Zone finally reaches its breaking point, and so it is important for it to be comfortable during any time. Strategies that will provide this comfort include **sufficient direct gain and storage** during heating months and **shading strategies** in the cooling months to prevent excessive heating.

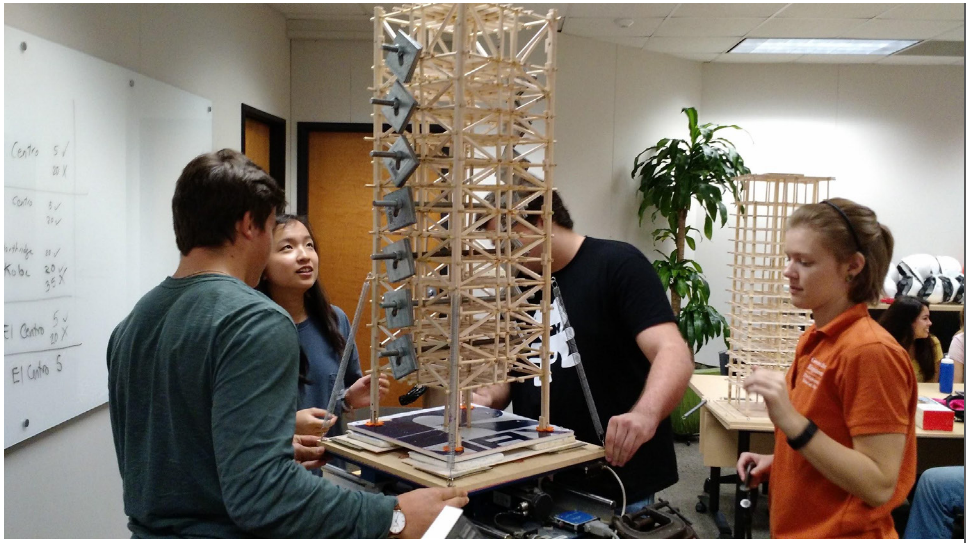




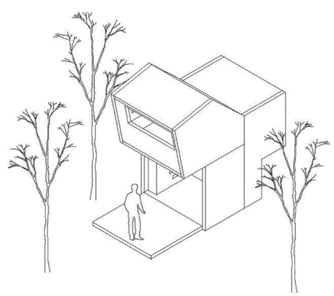


PROGRAMMATIC IDEAS / PRECEDENTS

PROGRAMMATIC IDEAS / PRECEDENTS



University of Texas earthquake education activities



Height and projections of buildings used to create a strong identity

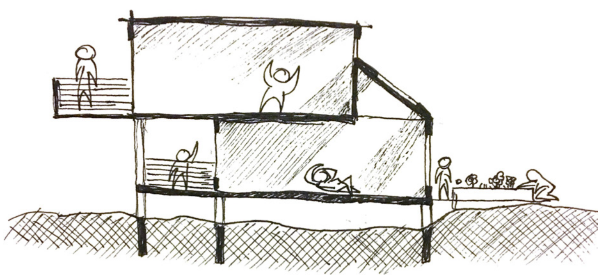
IDEA #2 Flexible Functional Use

Not only should the structure be usable **pre-emergency**, but also be a usable area **post-emergency**. The opportunity to create a space that engages the general populace regularly, would serve as mechanism to **educate and remind the citizens** of Dunes City of space that can be easily accessed in a post-emergency situation. Whether it becomes a **landmark or communal space** that **actively engages with the public**, the structure would become a well known and **identifiable** area for support in the event of a disaster.

IDEA #3 Transition Spaces

If the shelter is divided into **multiple spaces**, it can aid in **flexibility of use** and temperature depending on the time of day or year.

- A **sunspace** can be used as a direct heat gain space, which some people may enjoy as a warm space to reside in during the early morning or winter season
- An area with **operable windows** can be used to create a cooler zone for those needing to cool down, but can also be closed off in order to seal up the space for security.
- Outdoor **thermal masses** can create more of a transition to the outdoors in order to create a comfortable area that is not always indoors but may still provide some protection post-emergency. This outdoor space could also be used as a plaza or public garden space.



PRECEDENT STUDIES

House Liray

The house is comprised of five corten steel shipping containers (1,200 square feet) transformed into an **earthquake-proof** home near Santiago, Chile. The shipping containers provide **strength, durability, and stackability** which allows flexibility of use for the future. It also allows for beautiful **views** of the mountains, not sacrificing aesthetics for functionality.

Important Concepts:

The cargo containers are **cheap but also durable** and, if used from recycled containers, good for the environment. The durability helps with the climate and the potential for disaster. The stackability helps with the **flexible design** goal (additions).

The posts raising the containers off the ground are secured into the bedrock to be **earthquake resistant**. This idea of creating stilts is a creative way of **securing the building** and avoiding possible issues with liquefaction.

PROGRAMMATIC IDEAS / PRECEDENTS

PRECEDENT STUDIES

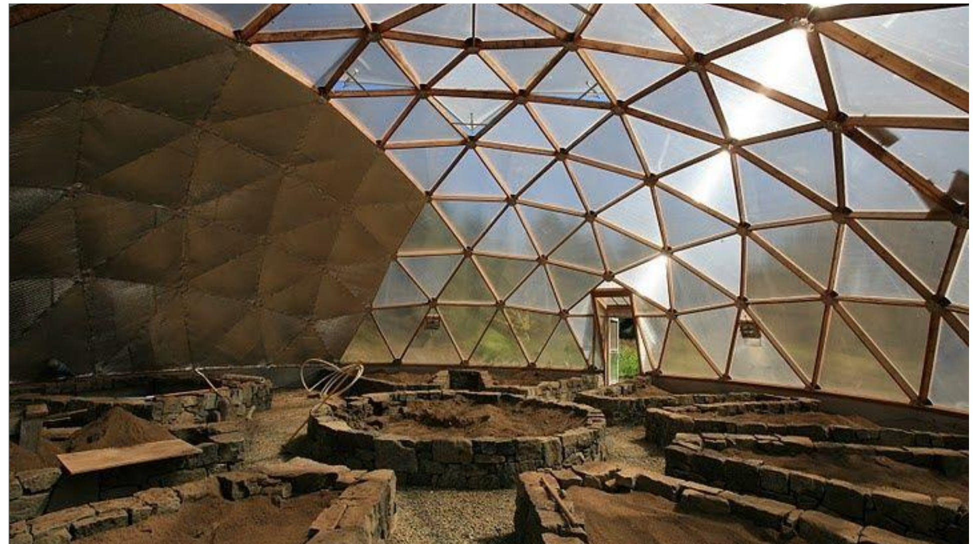
Geodesic Domes

These **earthquake proof** shelters, located atop the seismically active Great Syrian-African Rift, are constructed utilizing **straw bales**. They are unique in that they use a **safe** and **environmentally sound** construction as opposed to other buildings in the area that use reinforced concrete, an expensive and less effective material. The domes themselves hold roughly four tons and slide around and don't collapse due to their structural integrity. They are primarily heated from sunlight and thus use **60% less energy** for **heating** and **cooling** and work well in particularly **cold climates**.

Important Concepts:

The space can be small or large to accommodate both **private and public spaces.**

The material is extremely cheap and **easy to build/replicate** and the glazing would naturally have **tilts** that would allow for more **solar energy collection**.



PROGRAMMATIC IDEAS / PRECEDENTS

DESIGN INTENT

1. Provide both public and private spaces by creating a shared building for public uses (food, medicine, games, etc.) as well as individual units for smaller groups or families.
2. Cargo containers used as a cost effective but durable solution.
3. Sunspace as a "warm zone" for heat gain that can be ventilated into the space for added warmth.
4. Multi-level with access (more space for larger groups and families so that people aren't too split up but also don't feel cramped in one big room)
5. Public garden and walkway for protected outdoor space.
6. Retaining wall to protect from potential liquefaction/soil movement during the initial earthquake. This also allows all units to be at the same level.

PROGRAMMATIC IDEAS / PRECEDENTS

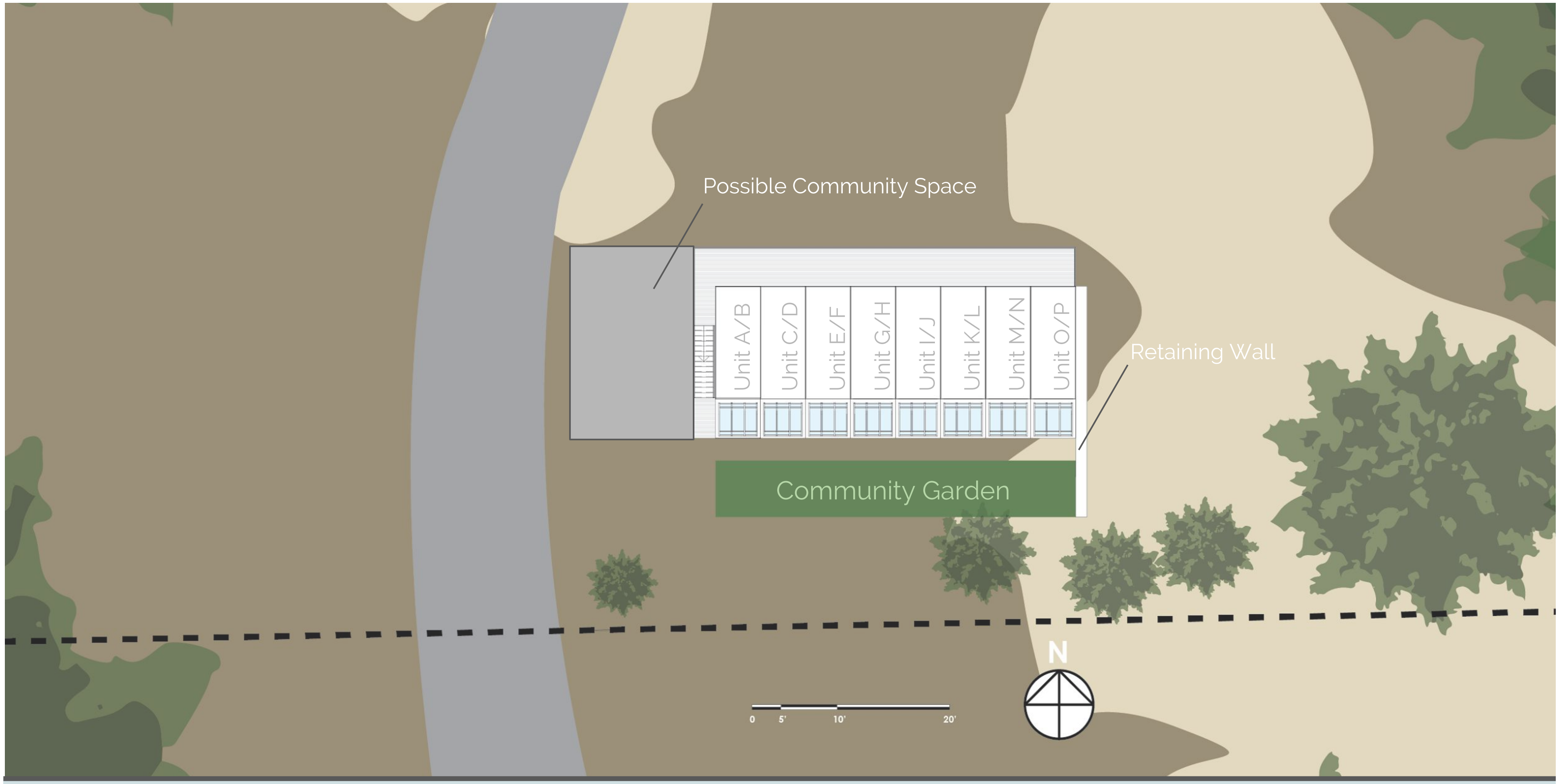
Goals:

1. Create a conditioned environment that not only offers immediate support for a post-emergency scenario but that can be utilized as a shelter space for individuals that lack properly conditioned spaces for living. This can be achieved through increased insulation that can be implemented differently during the day depending on the weather at that time. It will help the space to maintain a more even temperature so that the standard comfort zone can still be met.

2. Freedom to experience a variety of different temperatures throughout the sheltered space. The sunspace can have a much higher temperature than the rest of the interior spaces (up to 85 degrees Fahrenheit) in order to provide warmth for those seeking it, or even allow for a garden space.

3. Offer opportunities for the user to feel a sense physical thermal comfort by avoiding temperature swings of over 20 degrees Fahrenheit and maintaining a temperature range within the ASHRAE standard of 68 degrees to 77 degrees. Operable windows allowing for night flushing will help reduce interior air temperature at night during summer months, while thermal masses will absorb needed heat during winter days to reradiate at night and maintain the warmth of the space.

THERMAL COMFORT GOALS


Possible Community Space
Unit A/B
Unit C/D
Unit E/F
Unit G/H
Unit I/J
Unit K/L
Unit M/N
Unit O/P
Retaining Wall
Community Garden
N
0
5'
10'
20'

SITE PLAN

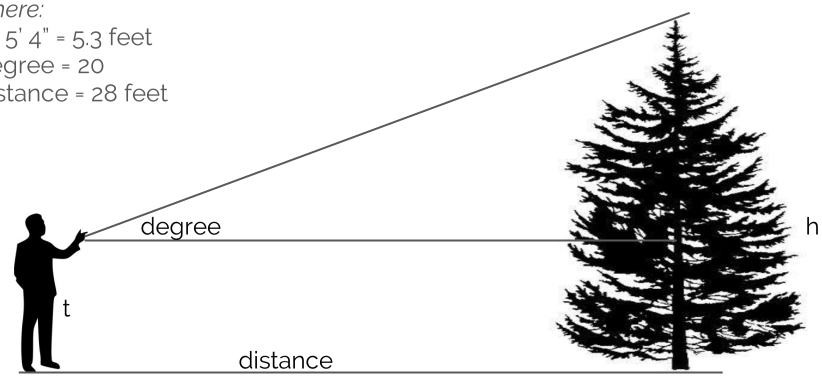
Small

Species: Douglas Fir

Height: 15.5'

tan(20) = (h-5.3')/28' = 15.5'

where:
t = 5' 4" = 5.3 feet
degree = 20
distance = 28 feet



TREES

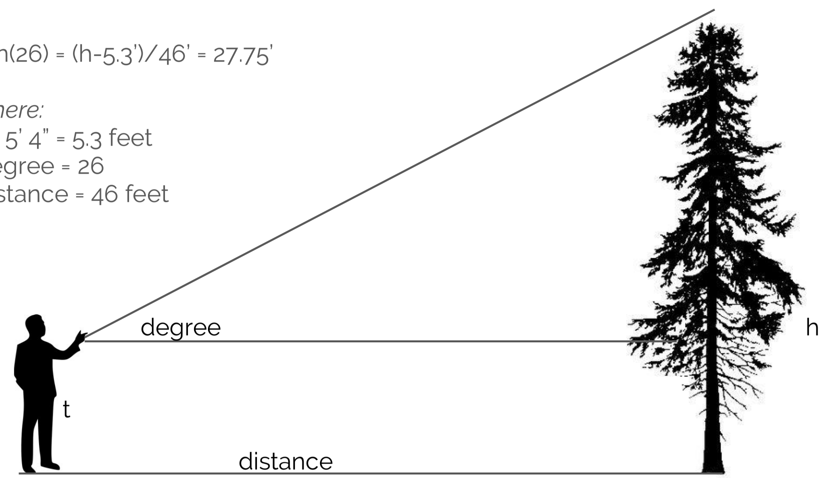
Medium

Species: Douglas Fir

Height: 27.75'

tan(26) = (h-5.3')/46' = 27.75'

where:
t = 5' 4" = 5.3 feet
degree = 26
distance = 46 feet



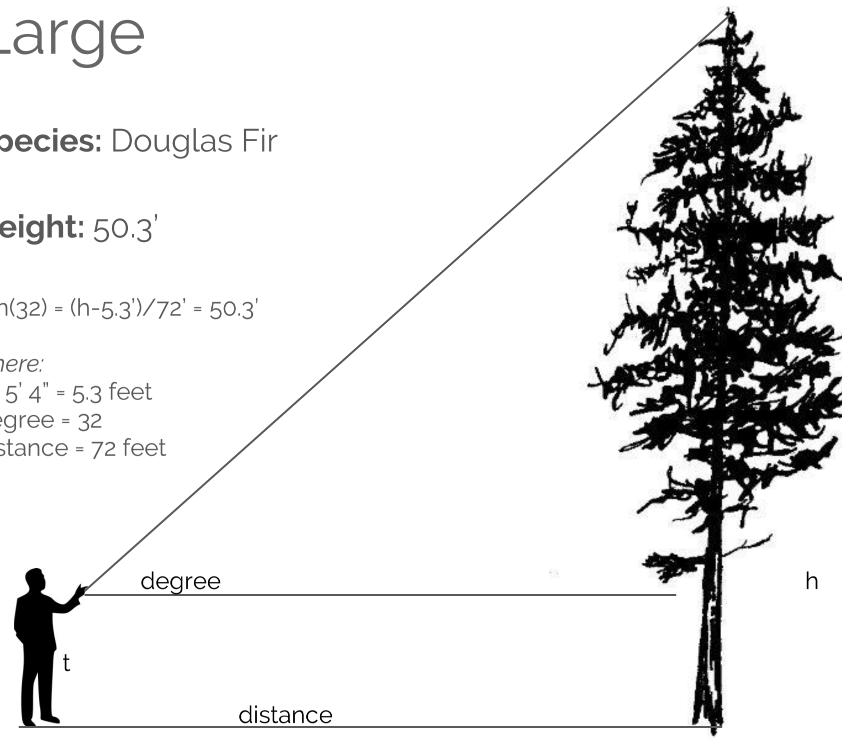
Large

Species: Douglas Fir

Height: 50.3'

tan(32) = (h-5.3')/72' = 50.3'

where:
t = 5' 4" = 5.3 feet
degree = 32
distance = 72 feet



Vegetation

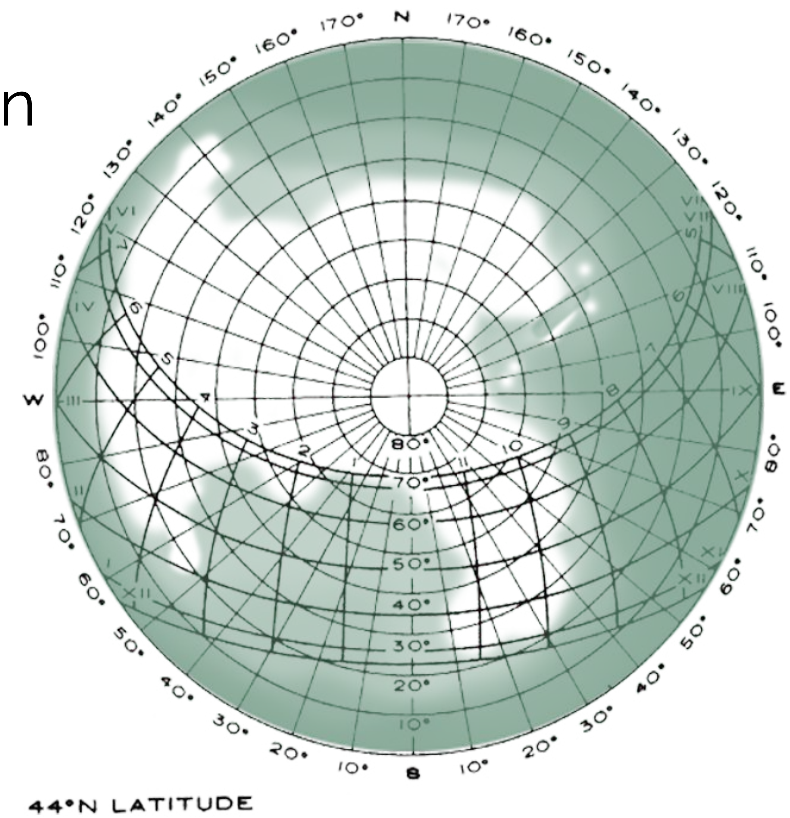
and other things found on-site

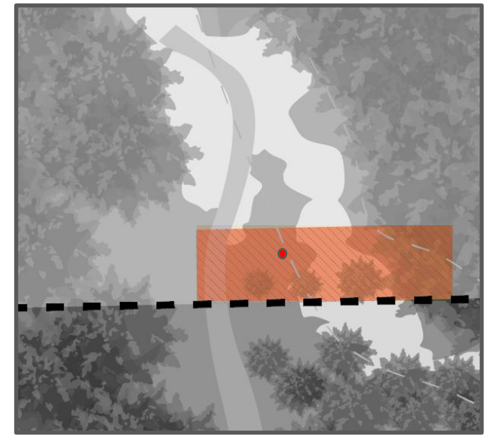
- Sand
- Fir Needles
- Bearberries (red berries)
- Broken clay pigeons and shot gun shells
- West Coast moss

Western Location

The westernmost part of the site seems to be the most flat and open, and has the lowest tree coverage in the area.

According to the solar pathfinder findings, the early mornings and late afternoons will be shaded almost year round from 7am to 6pm. There are still two hours (11am-1pm), even during the winter solstice where there will still be some direct sunlight potential.



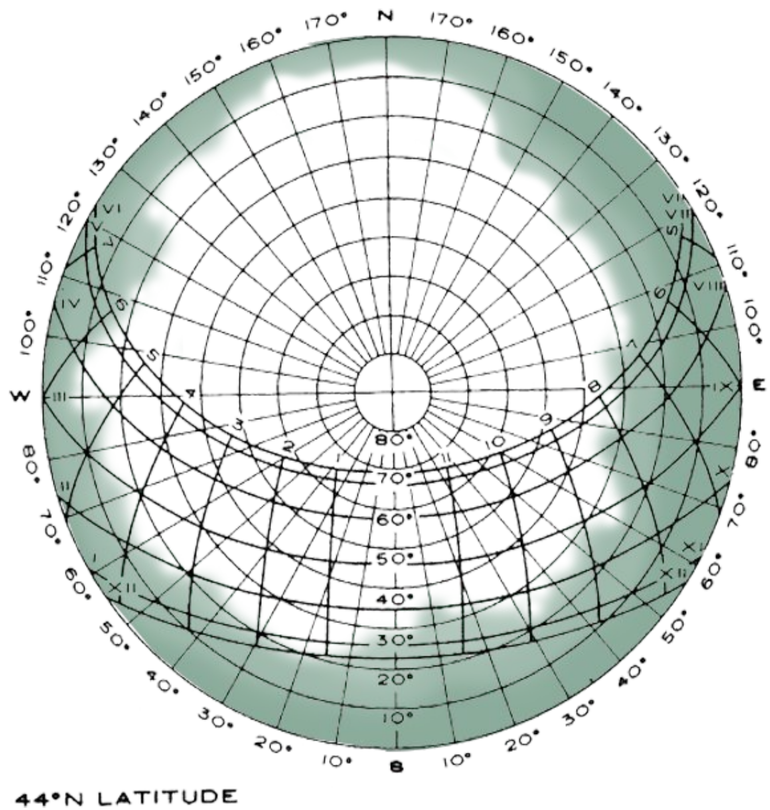


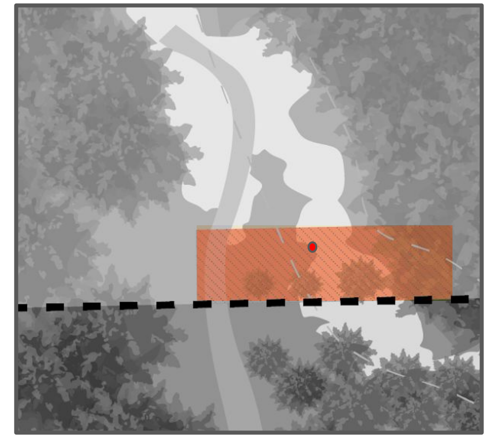
SOLAR PATHFINDER FINDINGS

Central Location

The central part of the site begins to slope up, but it remains relatively clear as well, All locations are clear on the north side, although that is unhelpful for lighting. Moving east adds shading slowly.

Much of the solar pathfinder findings are the same, although now in the winter solstice, it is the first couple hours of the afternoon that remain in the direct sun. There are also more obstructed hours in the morning.



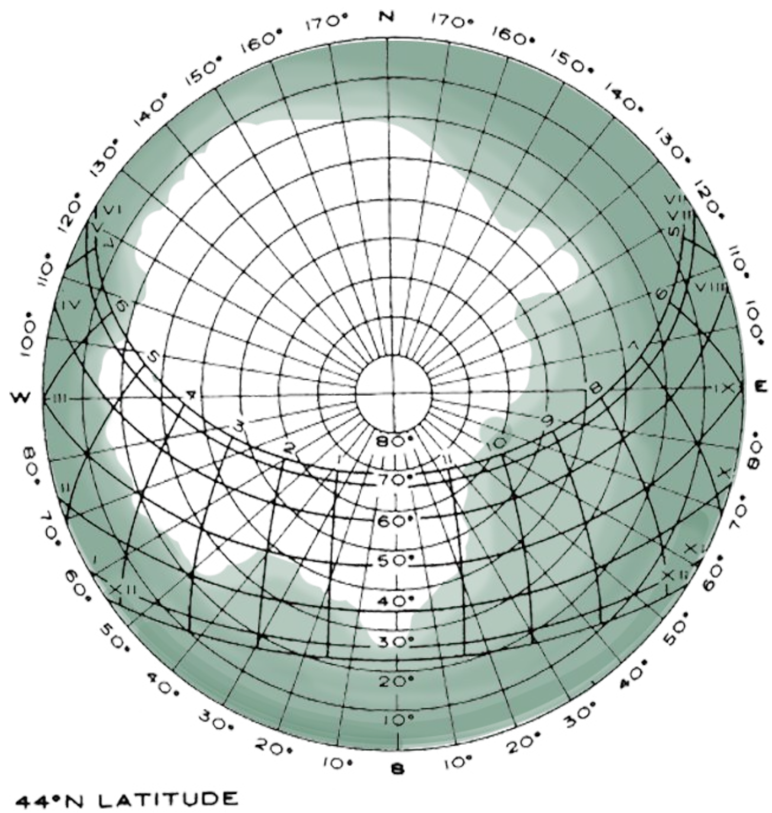


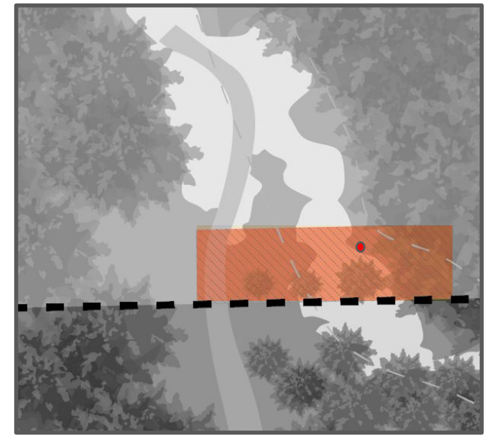
SOLAR PATHFINDER FINDINGS

Eastern Location

We chose to move even further east to see how much it would impact the direct sunlight. Any further east, and almost the entire area would be shaded.

As you can see in on the solar pathfinder, there are only short periods where there is direct solar access throughout the year (10am-12pm approximately). In the afternoon between the equinox and the summer solstice, the hours between 3pm and 6pm will be in the sun.





SOLAR PATHFINDER FINDINGS

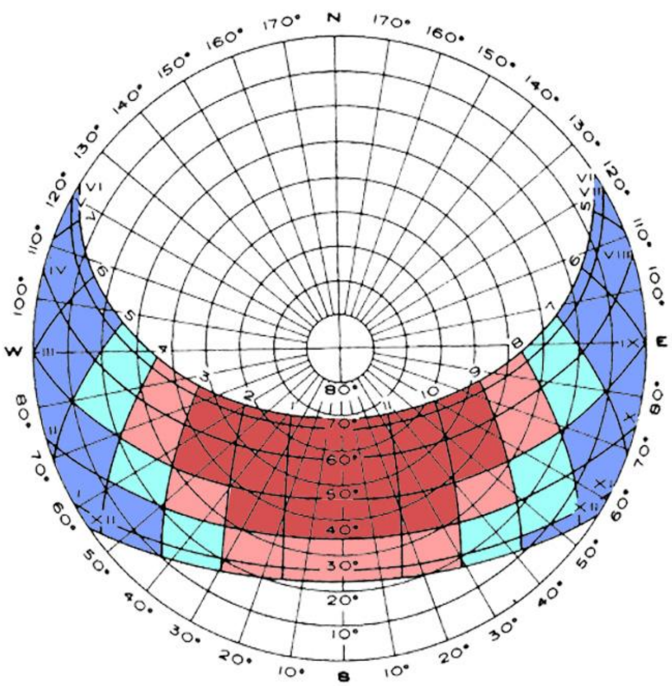
Glazing Tilt

Using the data from the North Bend, OR TMY3 file, we drew the 40-degree tilt energy information for a 1 square meter surface area. From this data, in combination with other Heating Degree Day data and the 2.0 kWh heating need for the area, we checked to determine approximately how much tilted (40-degree) area would be needed to achieve the proper amount of heating for the area.

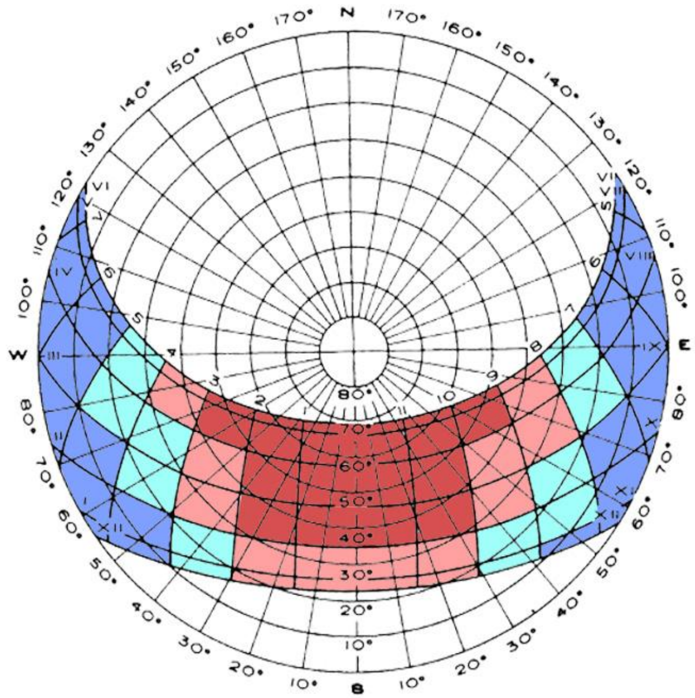
Monthly energy (kWh) on **1 m^2** surface of specified tilt: North Bend, OR TMY3 file											
Date	Days	90	80	70	60	50	40	30	20	10	0
January	31	76.4	81.1	83.7	84.3	82.9	79.4	74.0	66.9	58.2	48.3
February	28	74.9	81.0	85.3	87.5	87.7	85.8	81.9	76.1	68.6	59.6
March	31	100.4	112.5	122.1	128.8	132.5	133.0	130.4	124.6	116.0	104.7
April	30	95.3	111.8	126.0	137.7	146.3	151.7	153.6	152.1	147.1	138.8
May	31	89.5	110.3	129.4	146.2	160.0	170.3	176.8	179.4	177.9	172.3
June	30	81.2	102.7	123.4	142.3	158.5	171.6	181.0	186.4	187.7	184.8
July	31	95.3	120.3	143.7	164.5	181.9	195.4	204.5	208.8	208.2	202.8
August	31	101.0	122.7	142.1	158.5	171.4	180.3	184.9	185.2	181.1	172.7
September	30	111.5	127.7	140.9	150.8	157.0	159.4	157.8	152.4	143.3	130.8
October	31	111.3	122.1	130.0	134.6	135.9	133.7	128.2	119.5	107.9	93.8
November	30	81.3	86.6	89.8	90.8	89.5	86.0	80.3	72.8	63.5	52.8
December	31	89.5	93.8	95.7	95.1	92.0	86.6	78.9	69.2	57.8	45.1
						1595.6	**1633.1**	1632.4			

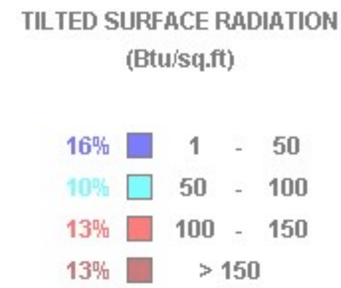
Heating Degree Days	
Month	**65**
January	676
February	575
March	587
April	495
May	393
June	275
July	209
August	196
September	228
October	396
November	558
December	699
Summary	5287

Fall



Spring





Finding the tilt of the glazing depended on what the goal of that glazing was mostly for, which, referring back to our goals of optimal winter heating, we decided that finding a tilt that provided higher surface radiation in the winter months would be preferred. The charts above show the overlay of surface radiation in this particular area.

SOLAR SURFACES

THERMAL MASS CALCULATIONS

Transmitted Solar Radiation		Solar Absorptance		Solar Radiation Taken Up
87794.404 Btu	x	0.71	=	62,334.0268 Btu

Warmest Daily Temp (March)	Coldest Daily Temp (March)		Temp Increase In Wall
67.325 F	32.675 F	=	34.65 F

Heat Capacity		Solar Radiation Taken Up		Temp Increase In Wall		Mass Needed
[$\frac{1}{0.215 \text{ BTU/lb F}}$	x	62,334.0268 Btu]	÷	34.65 F	=	8,367.264 lb

Mass Needed	Density	Mass Wall Surface Area		Thermal Mass Thickness
8,367.264 lb	149.8 lb /ft^3	115 SF	=	0.48 ft -> 5.76 inches ~ 6 inches

Material Properties:

Heat Capacity: 0.215105163 Btu/lb* F
Solar Absorptance: 0.71
Density: 149.8 lb /ft^3

Environment Properties:

Transmitted Solar Radiation: 62,334.268 Btu
Wall Surface Area: 115 SF
Warmest Temp (March): 67.325 F
Coldest Temp (March): 32.675 F

Heating Need

These charts outline not only the heating need per month (defined by the 2.5 kWh multiplied by the Heating Degree Days) but also the possible levels of glazing to meet those requirements. The last column shows the specific amount of glazing (in square meters) that we have per unit. In the following slide, we will show the combined information, as well as how much it will need to be mitigated by movable insulation / shading to avoid overheating in the non-heating months.

Date	Heating Need per month (2.5kWh*HDD)	90-degree tilt surface radiation (kWh) on 1 sm	90-degree tilt surface radiation on 10sm (kWh)	90-degree tilt surface radiation on 20sm (kWh)	90-degree tilt surface radiation on 30sm (kWh)	on 10.3 sm (kWh)
January	1690	76.4	764.3	1528.6	2292.8	787.2
February	1437.5	74.9	749.3	1498.5	2247.8	771.8
March	1467.5	100.4	1004.1	2008.3	3012.4	1034.3
April	1237.5	95.3	953.4	1906.7	2860.1	982.0
May	982.5	89.5	895.5	1791.0	2686.5	922.4
June	687.5	81.2	811.6	1623.3	2434.9	836.0
July	522.5	95.3	953.3	1906.5	2859.8	981.9
August	490	101.0	1010.1	2020.3	3030.4	1040.5
September	570	111.5	1115.4	2230.7	3346.1	1148.8
October	990	111.3	1112.9	2225.8	3338.7	1146.3
November	1395	81.3	812.6	1625.2	2437.8	837.0
December	1747.5	89.5	894.9	1789.8	2684.7	921.8
Average	1101.46	92.3	923.1	9231.1	92311.0	11409.6

per day 33.36369

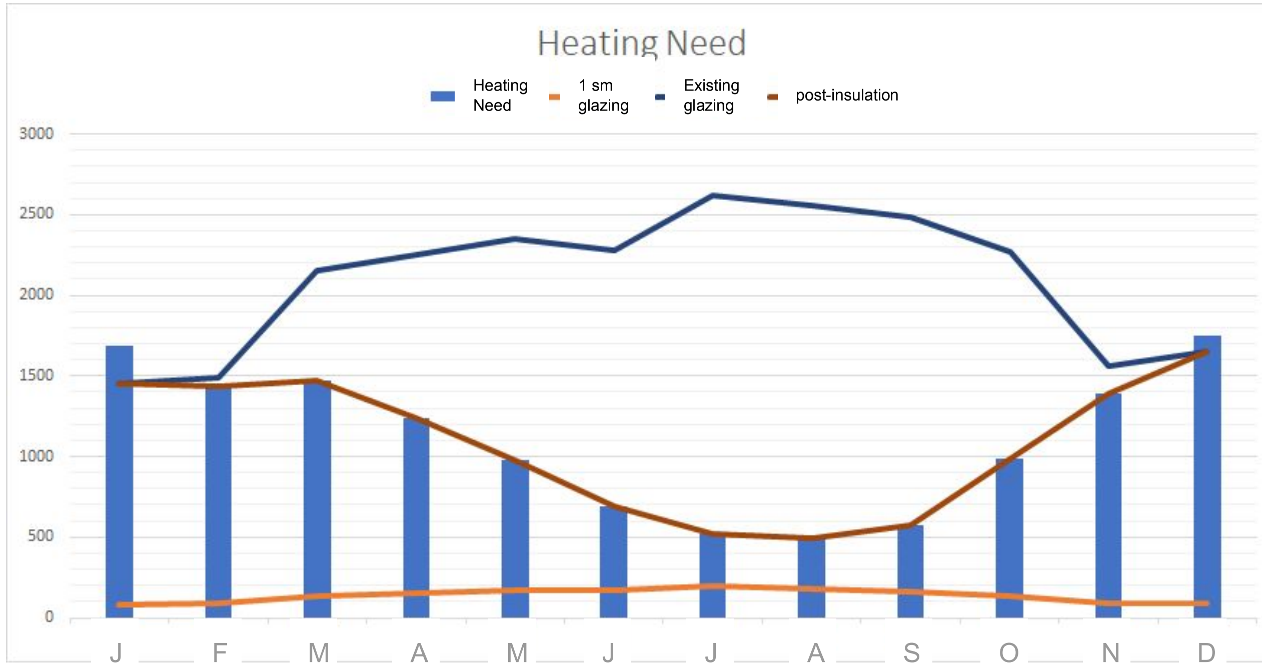
heating month

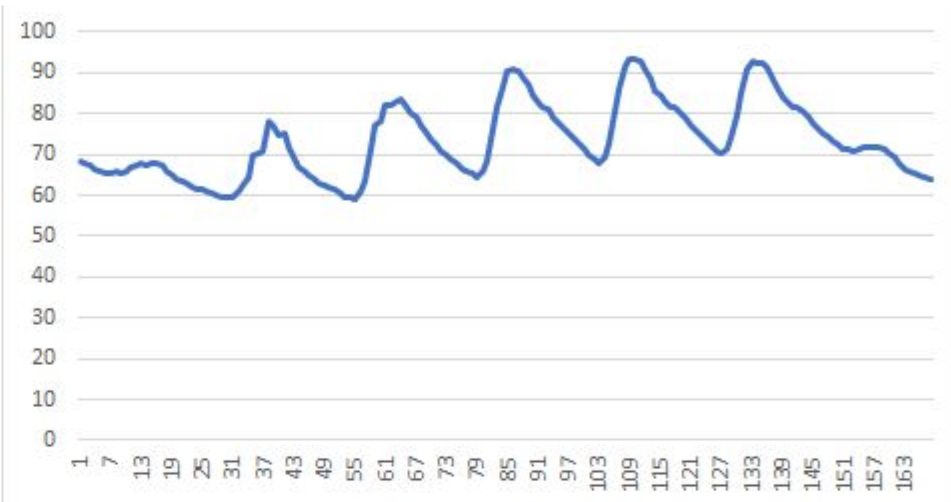
Date	Heating Need per month (2.5kWh*HDD)	40-degree tilt surface radiation (kWh) on 1 sm	40-degree tilt surface radiation on 10sm (kWh)	40-degree tilt surface radiation on 20sm (kWh)	40-degree tilt surface radiation on 30sm (kWh)	on 8.4 m2 (kWh)
January	1690	79.4	794.1	1588.2	2382.3	667.0
February	1437.5	85.8	858.1	1716.2	2574.4	720.8
March	1467.5	133.0	1330.1	2660.3	3990.4	1117.3
April	1237.5	151.7	1516.9	3033.9	4550.8	1274.2
May	982.5	170.3	1702.7	3405.4	5108.1	1430.3
June	687.5	171.6	1716.0	3431.9	5147.9	1441.4
July	522.5	195.4	1954.2	3908.4	5862.6	1641.5
August	490	180.3	1802.8	3605.6	5408.4	1514.3
September	570	159.4	1593.5	3187.0	4780.5	1338.5
October	990	133.7	1337.3	2674.7	4012.0	1123.4
November	1395	86.0	859.8	1719.5	2579.3	722.2
December	1747.5	86.6	865.7	1731.4	2597.1	727.2
Average	1101.46	136.1	1360.9	13609.4	136093.7	13718.2

per day 36.04274

Heating Need

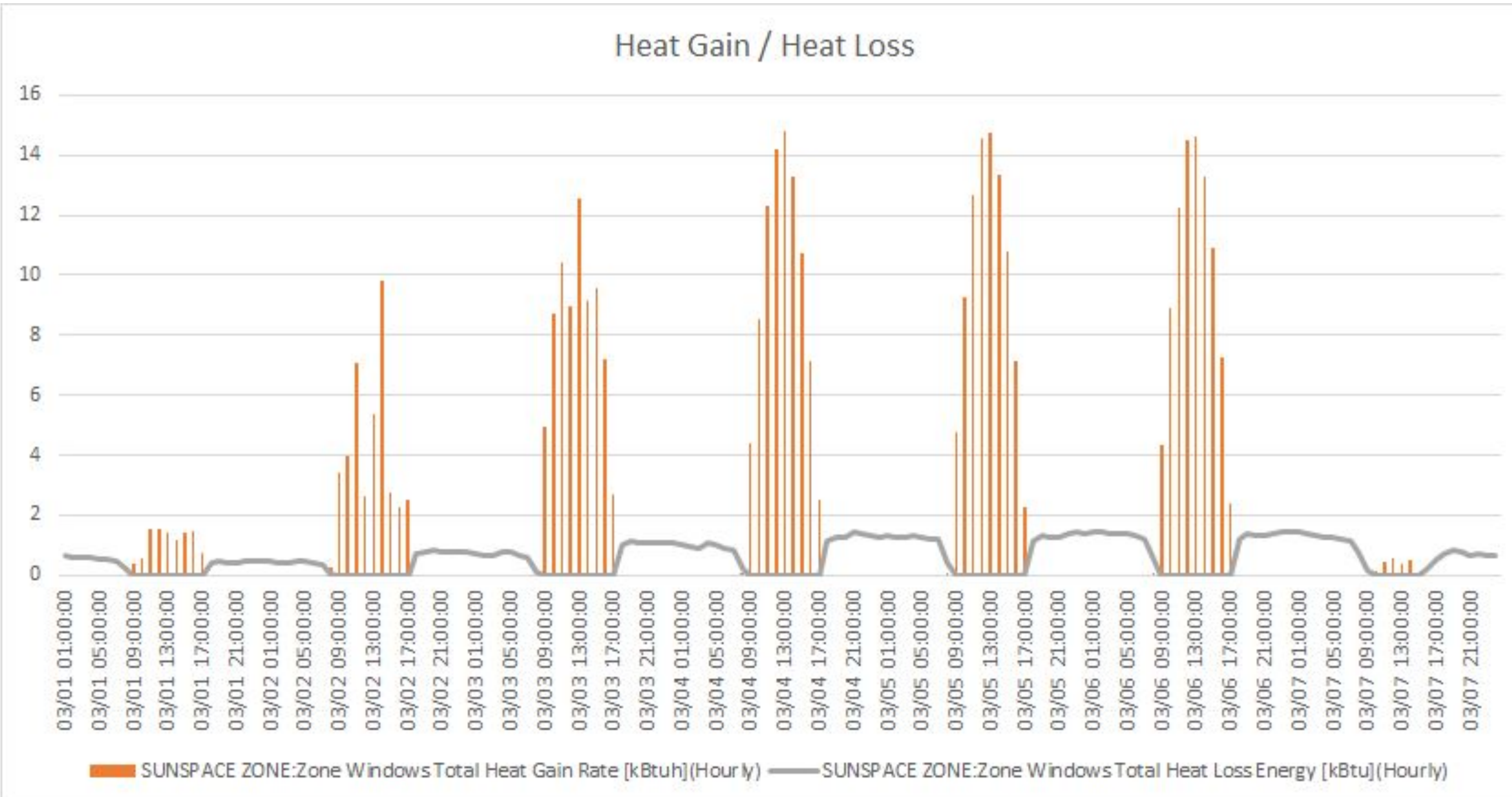
combined	heating need	glazing need	glazing area (sm) insulated
1454.2	1690.0	max	none
1492.6	1437.5	16.8	1.9
2151.6	1467.5	11.0	7.7
2256.2	1237.5	8.2	10.5
2352.6	982.5	5.8	12.9
2277.4	687.5	4.0	14.7
2623.4	522.5	2.7	16.0
2554.8	490.0	2.7	16.0
2487.4	570.0	3.6	15.1
2269.6	990.0	7.4	11.3
1559.2	1395.0	16.2	2.5
1648.9	1747.5	max	none



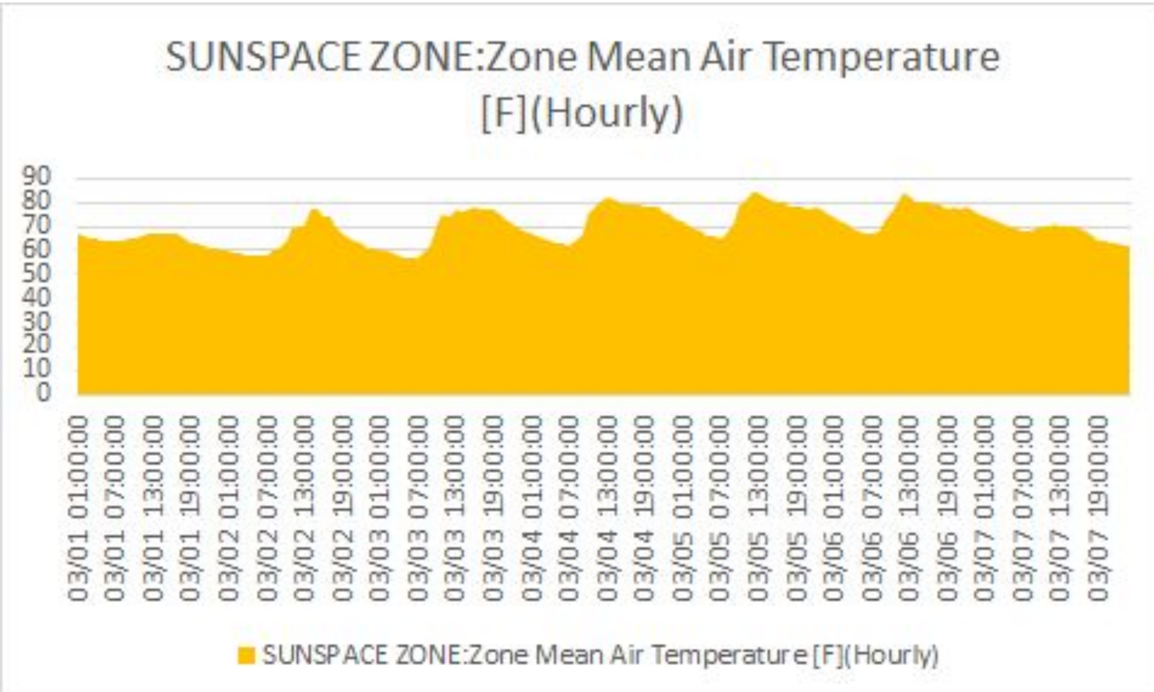


- Over the course of a week long observation, beginning with the first week of March, we were able to meet the base temperature was set at 65 F.
- Although the chart only depicts the initial first week of March, the sunspace also follows and meets the said base points throughout the year.

HOURLY OPERATIVE TEMPERATURES



HEAT GAIN / LOSS


SUNSPACE ZONE:Zone Mean Air Temperature [F](Hourly)
90
80
70
60
50
40
30
20
10
0
03/01 01:00:00
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03/06 19:00:00
03/07 01:00:00
03/07 07:00:00
03/07 13:00:00
03/07 19:00:00
SUNSPACE ZONE:Zone Mean Air Temperature [F](Hourly)

SUNSPACE

Glazing Selection

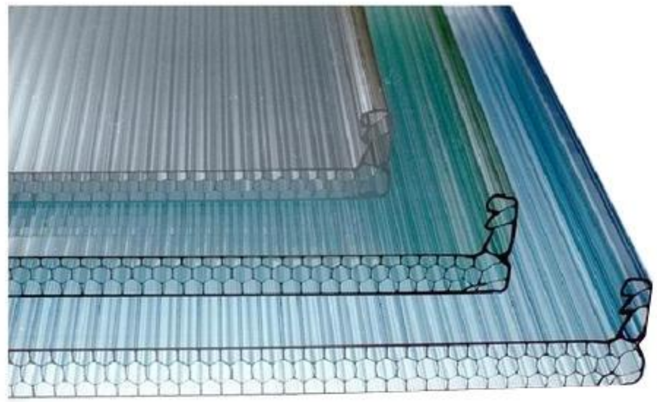
After exploring various options using Windows7, we found an alternative material in **recycled polycarbonate**. The material not only was tested to be more durable in the event of a disaster (200x stronger than glass), but it also proved to have high light transmittance with low u-values.

SHGC: 0,71

U-Value: 0.56

Heat gain: *100 Btu/sf-h x 0.71 SHGC x 1 sf =* 71 Btu/hr/sf

Heat loss: *0.56 x 1 sf x 60 F =* 33.6 Btu/hr



Aerogel	Insulated Glass Unit	Standard 25mm Panel	Aerogel Filled 25mm Panel
Thermal (R-Value)	R 2.85	R 2.94	R 6.25*
Acoustic (STC Value)	na	20	24
Light Transmission	74%	72%	49%*
Solar Heat Gain Coefficient	.71	.57	.54*

*Values verified by NFRC Testing for 25mm filled panel

SOLAR SURFACES

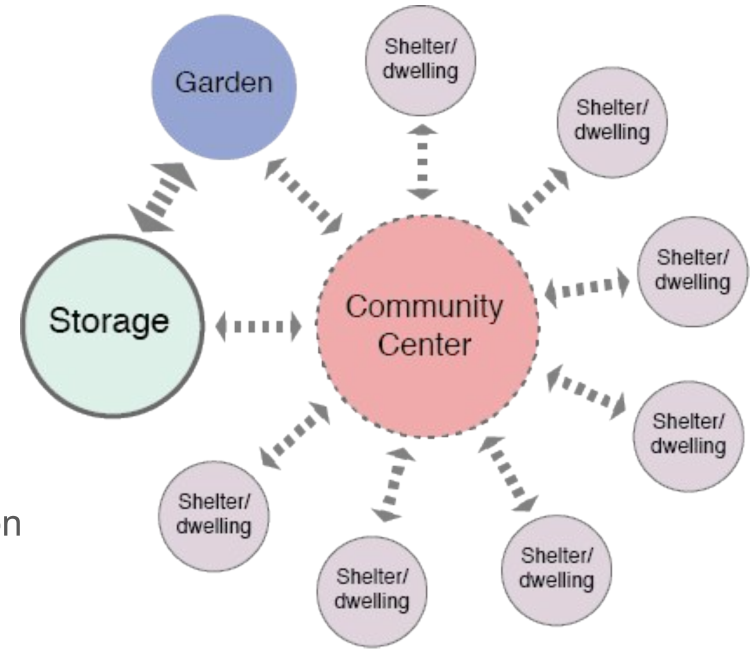
Appendix B

Project 2: Denise Blankenberger and Estefania Solorzano Final Presentation

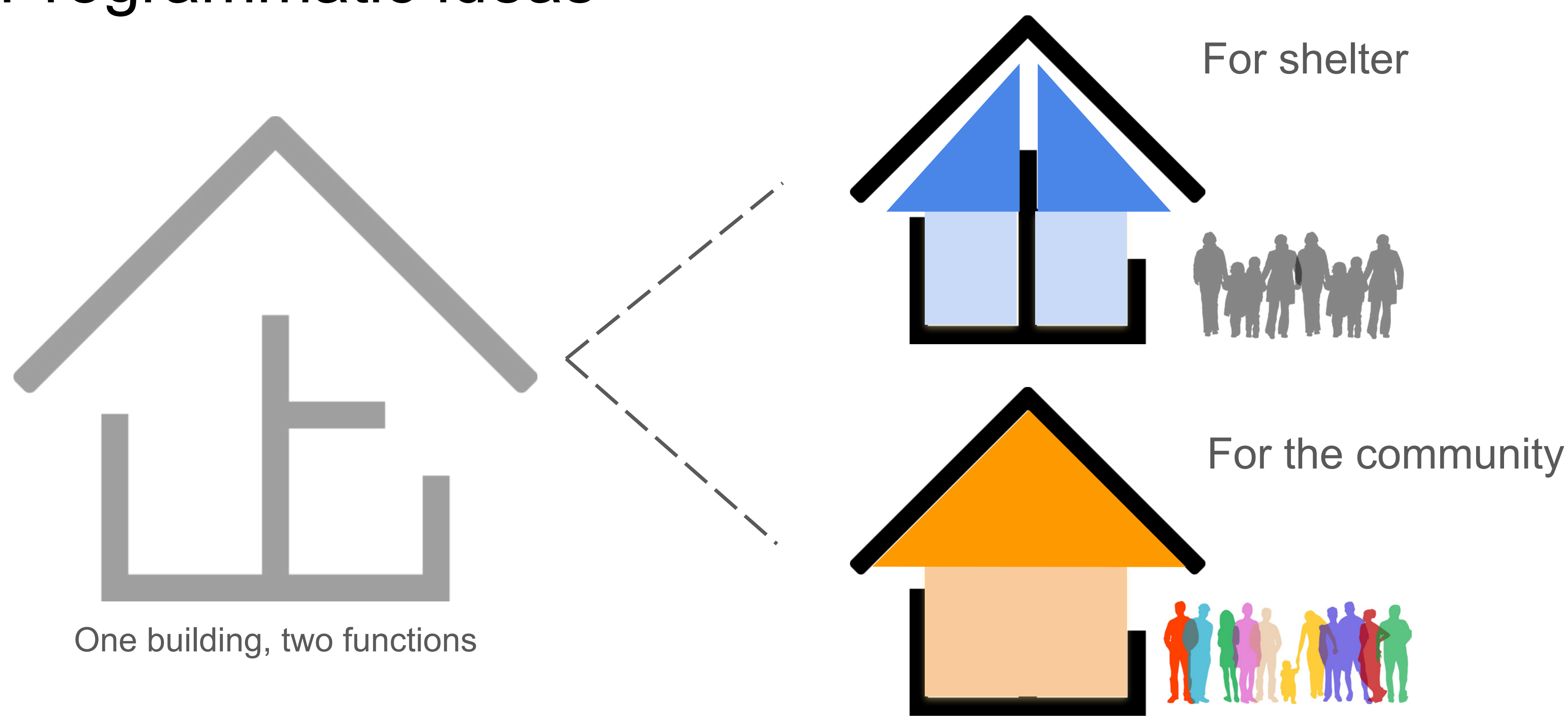
Design Criteria

- Must be able to withstand earthquake and aftershocks
- Must be fully passive
- Must be able to accommodate ~50 people
- Must be designed for modularity
- Must allow flexibility, functionally and structurally
- Must be multipurpose

- Should provide nourishment
- Should encourage community engagement
- Should be a shared commodity and source of satisfaction

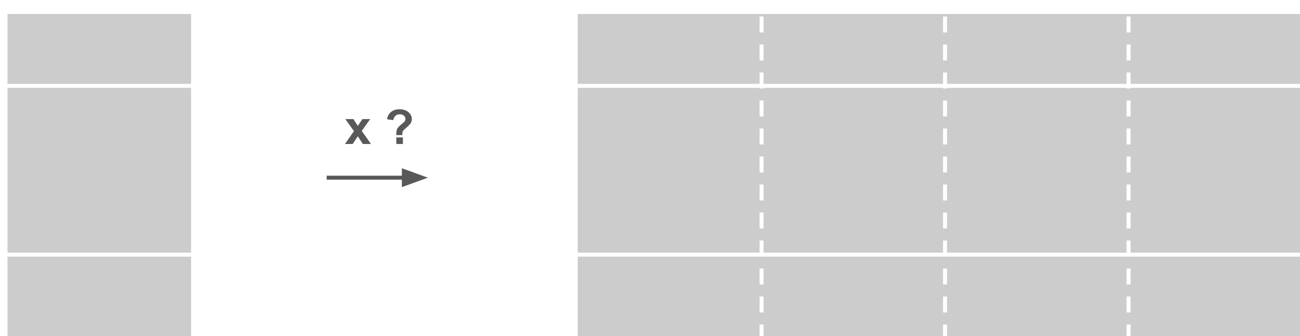


Programmatic ideas



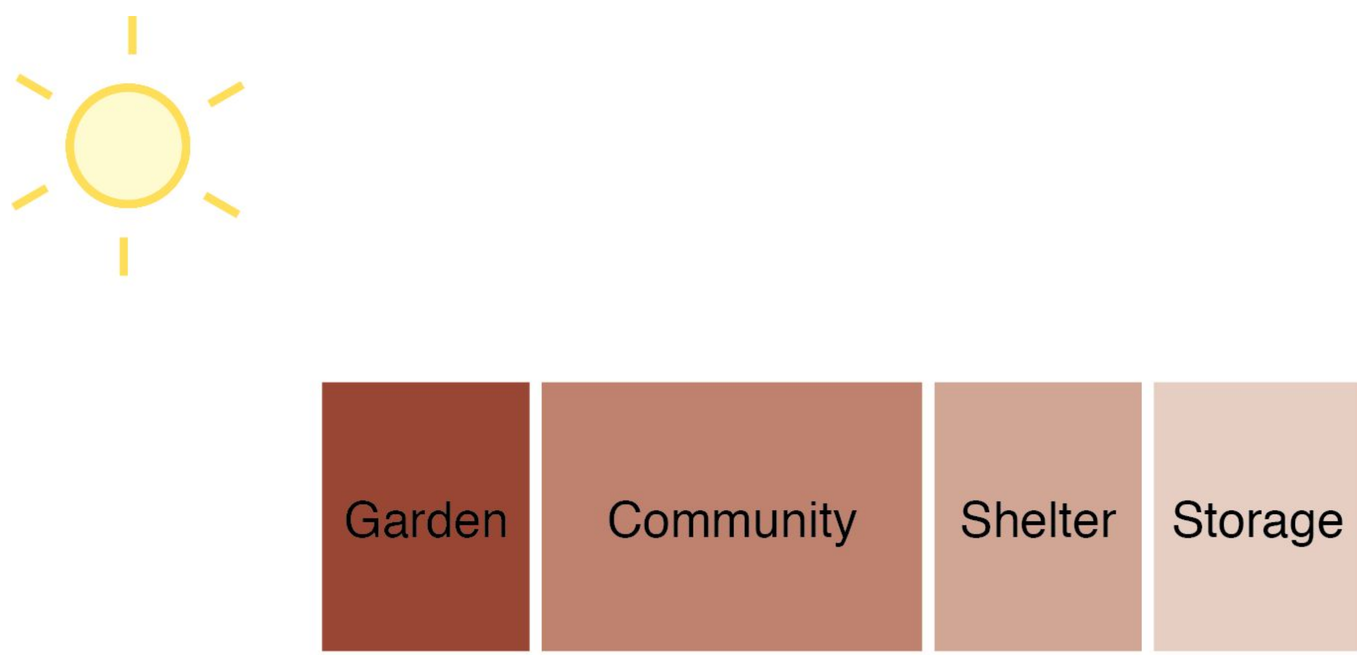
Programmatic ideas

Adaptable and modular



Programmatic ideas

Thermal and programmatic gradient

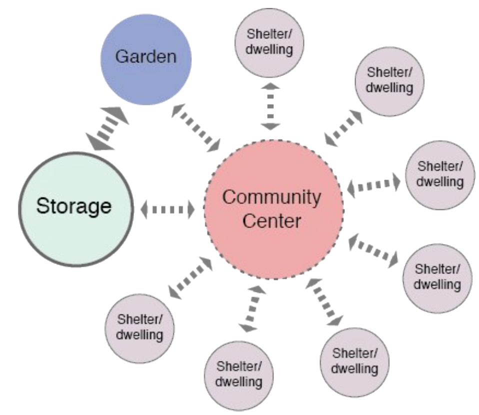


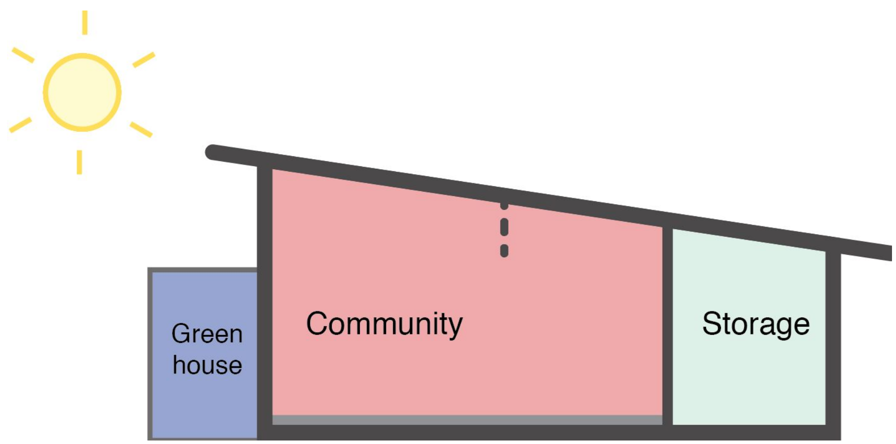
Programmatic ideas

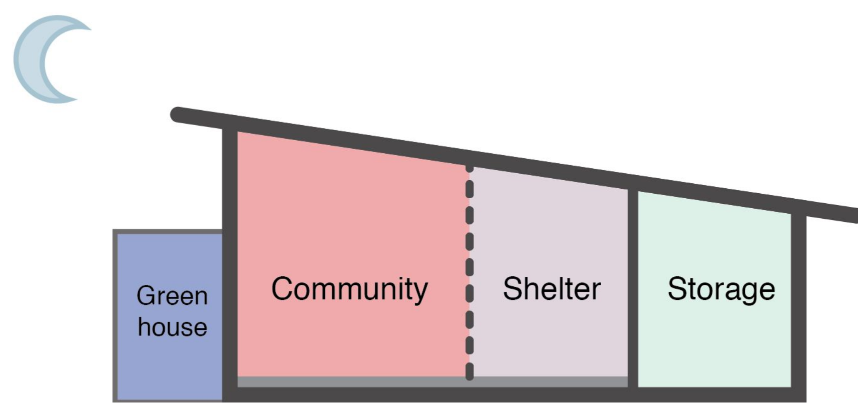
Thermal and programmatic gradient

Programmatic ideas

Thermal and programmatic zones







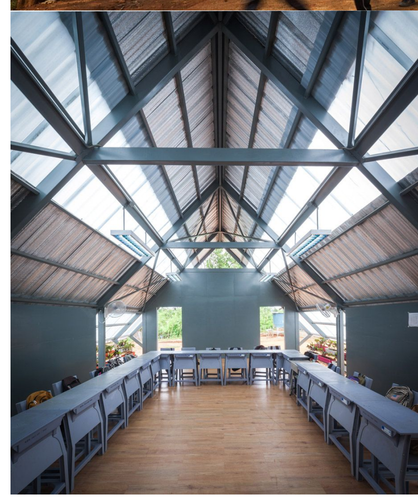
Earthquake-resistant school

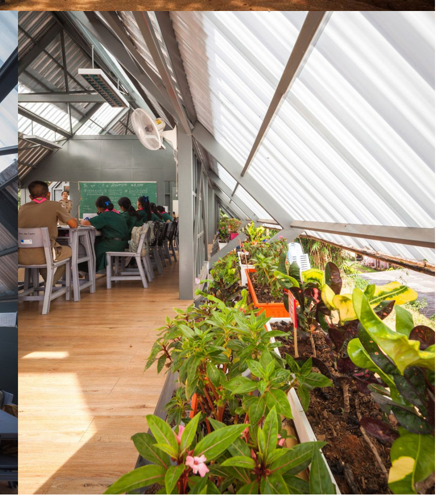
Baan Huay Sarn Yaw School - Chiang Rai, Thailand

Vin Varavarn Architects

Why we like it:

- Passive
- Operable elements
- Natural materials
- Elevated
- Modular
- Elegant
- Integration of plant life



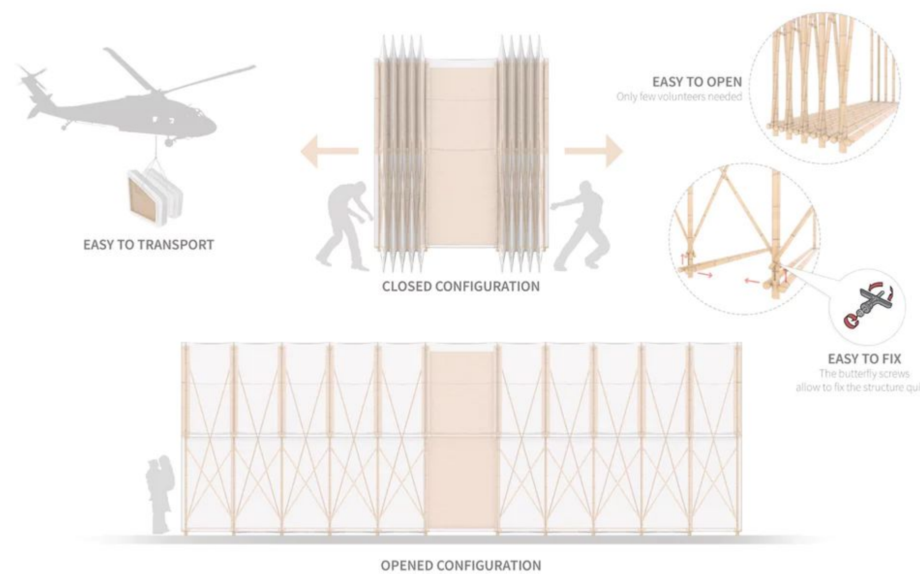


Concertina-like disaster shelter

Barberio Colella ARC firm - Nepal

Why we like it:

- Expandable structure
- Local materials (bamboo)
- Waterproof membrane
- Modular
- Rainwater catchment
- Solar panels
- Insulation layers with recyclable materials (woolen clothing)



Low-cost hexagonal shelter

Minnesota-based Architects for Society

Why we like it:

- Compactable size (430 sf)
- Modular (SIPs)
- Scalable design
- Low cost ($17,000 each)
- Allows multiple rearrangements
- Units can be combined
- Natural ventilation

Goals for thermal comfort

To provide **warmth**:

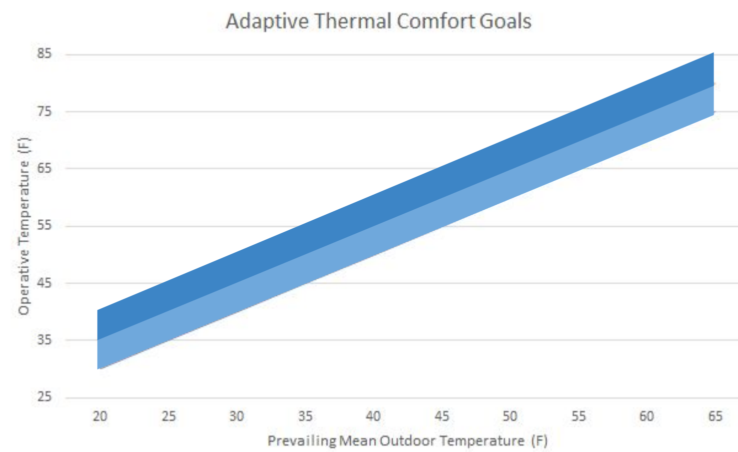
- not only thermal **warmth** to keep away the evening / winter chill…
- but to kindle interpersonal **warmth** by fostering community

To provide relief:

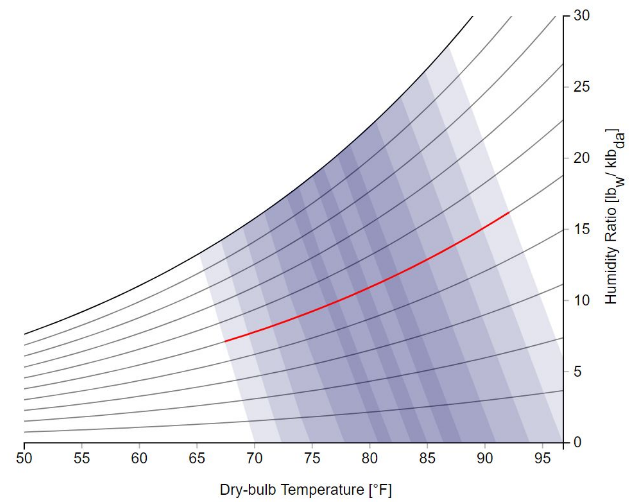
- not only cooling from the potentially hot and stifling summer heat…
- but to offer peaceful air movement for comfortable cooling effects

Goals for thermal comfort

- In winter months (Oct - May), the indoor operative temperature should be 10°F-15°F greater than the outdoor prevailing temperature



- In summer months (June - Sept), the indoor operative temperature should remain between 65°F and 82°F.



Goals for heat delivery patterns

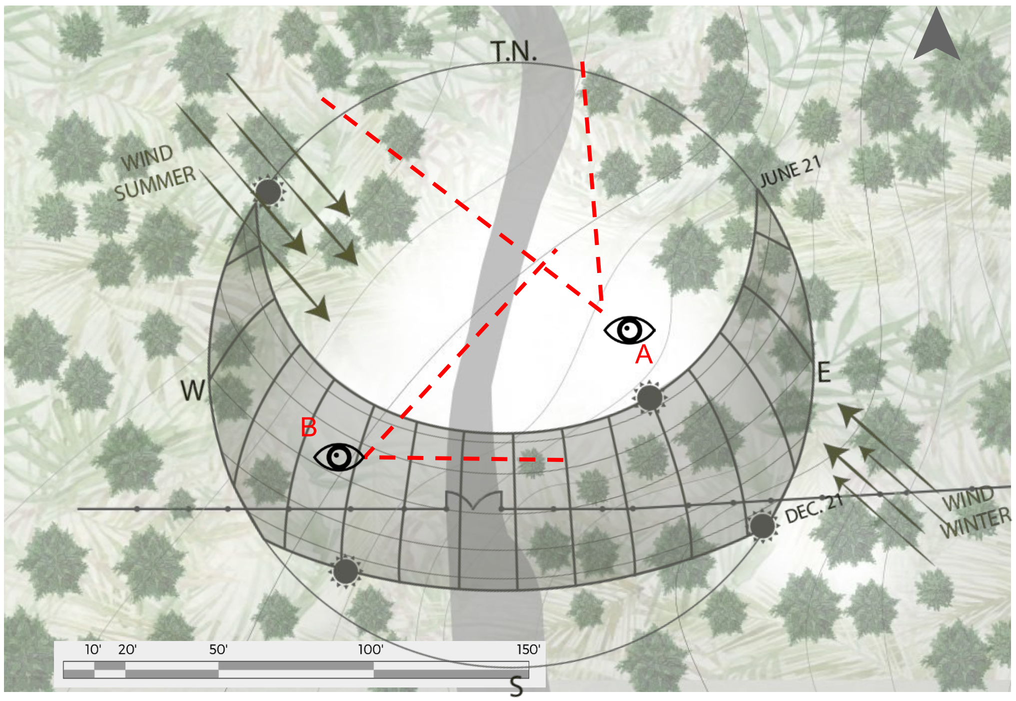
During the daytime, the greenhouse acts as the solar collection space. The community space, adjacent to the greenhouse, accepts its surplus heat. (~8:00am - 6:00pm)

During the evening hours, movable insulation covers the greenhouse, and its heat is released to the occupied spaces. The community space is subdivided into individual shelter spaces. In this way, the heat moves its way down the thermal gradient. (~6:00pm - 8:00am)

The thermal mass should be sized to collect enough heat during the daytime hours that it can release the heat during the evening hours: accomplished by a 6” thermal mass floor in the sunspace and a 6” concrete wall shared (with a window to control heat transfer) between the sunspace and occupied space.

SITE

T.N.
WIND
SUMMER
JUNE 21
W
E
DEC. 21
WIND
WINTER
10'
20'
50'
100'
150'
OPTIMAL
ORIENTATION


T.N.
WIND
SUMMER
JUNE 21
W
E
A
B
DEC. 21
WIND
WINTER
10'
20'
50'
100'
150'
S

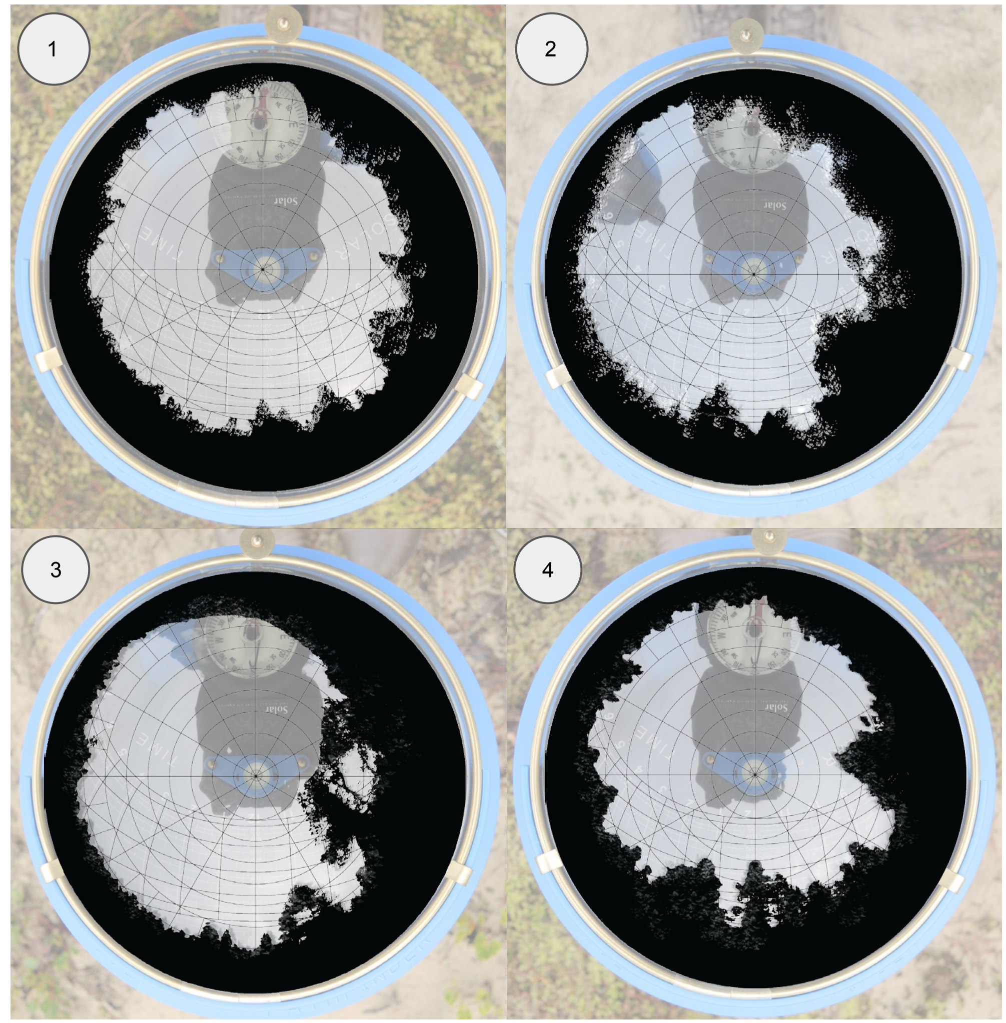
SITE VIEWS


A


B

Site solar survey

Most solar exposure →



TREES

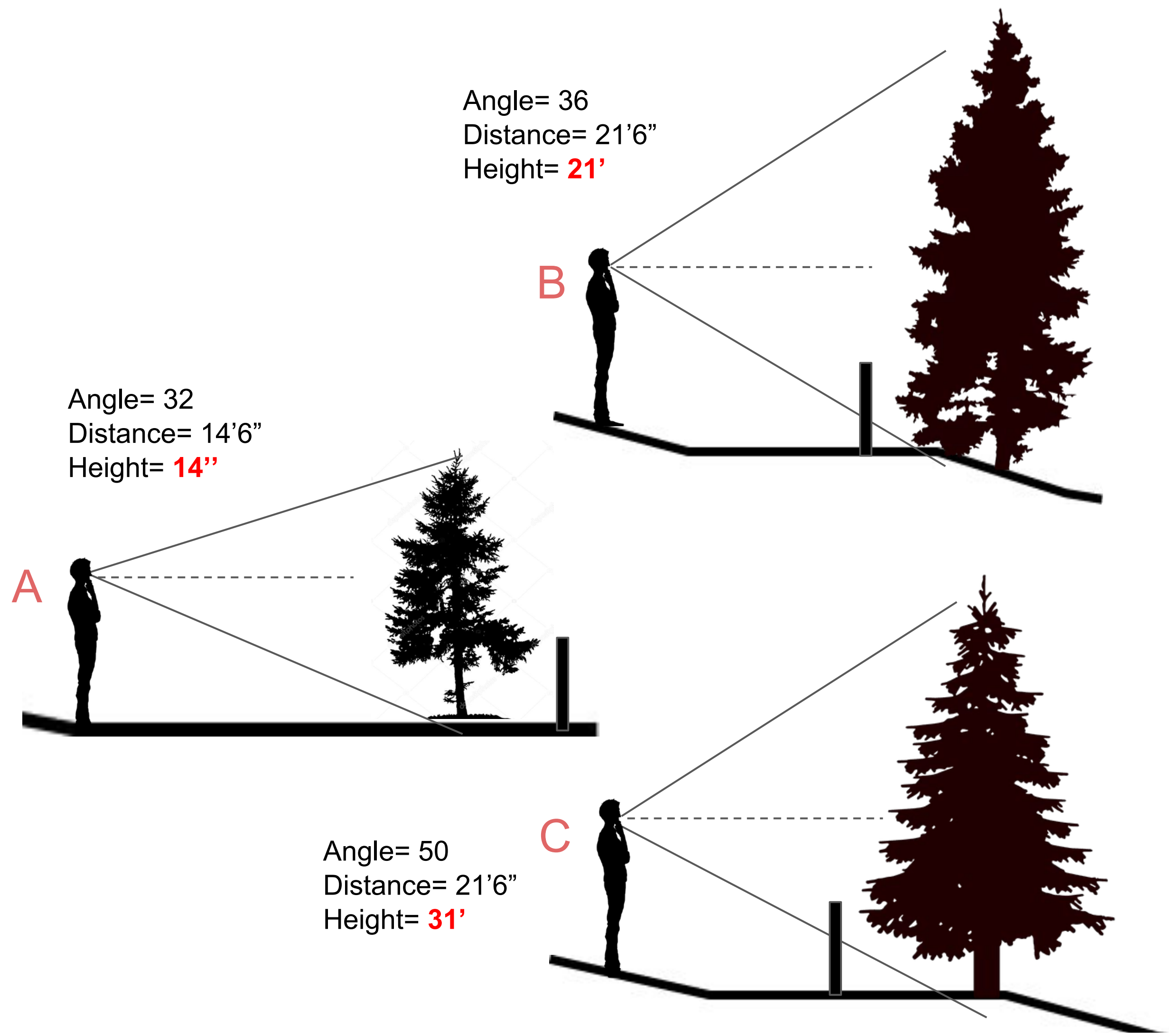
Western Larch

(*Laris Occidentalis*)

GROUND
VEGETATION

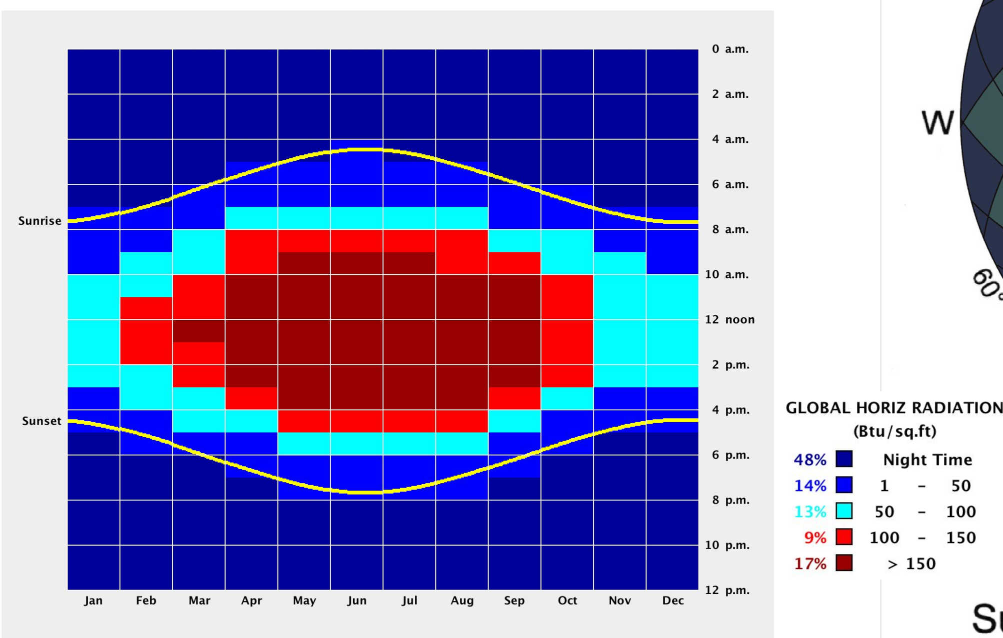
Tree IDs

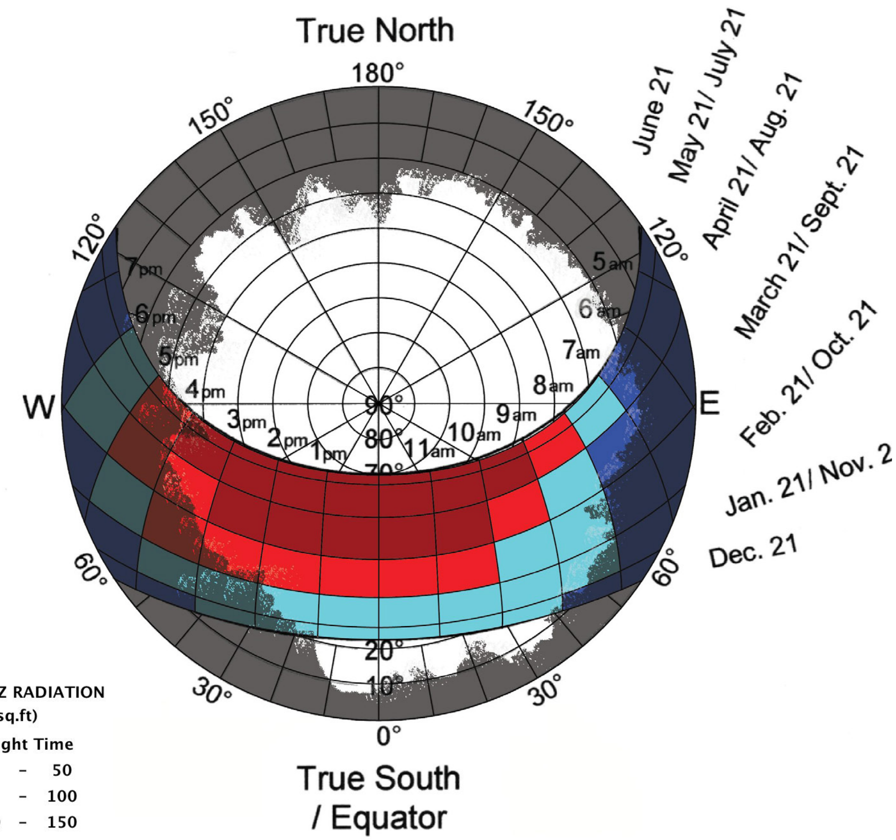

A
B
C


B
Angle= 36
Distance= 21'6"
Height= **21'**
A
Angle= 32
Distance= 14'6"
Height= **14''**
C
Angle= 50
Distance= 21'6"
Height= **31'**

Site solar survey

Optimal orientation: 0° to 30°S

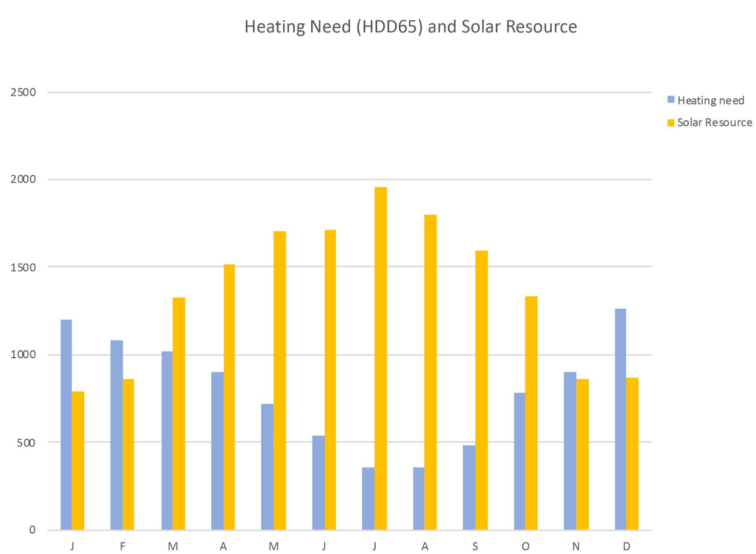


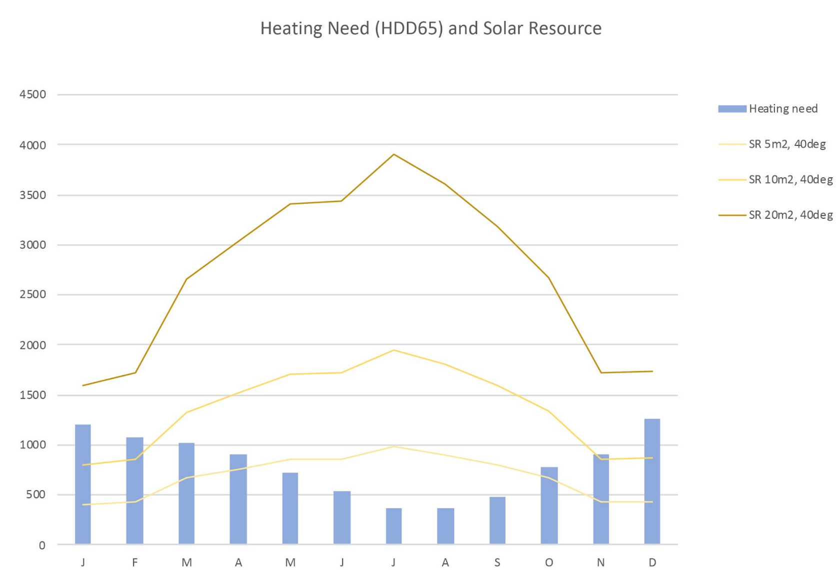


Sun Path Diagram, 44° N Latitude

Graphs + sizing elements

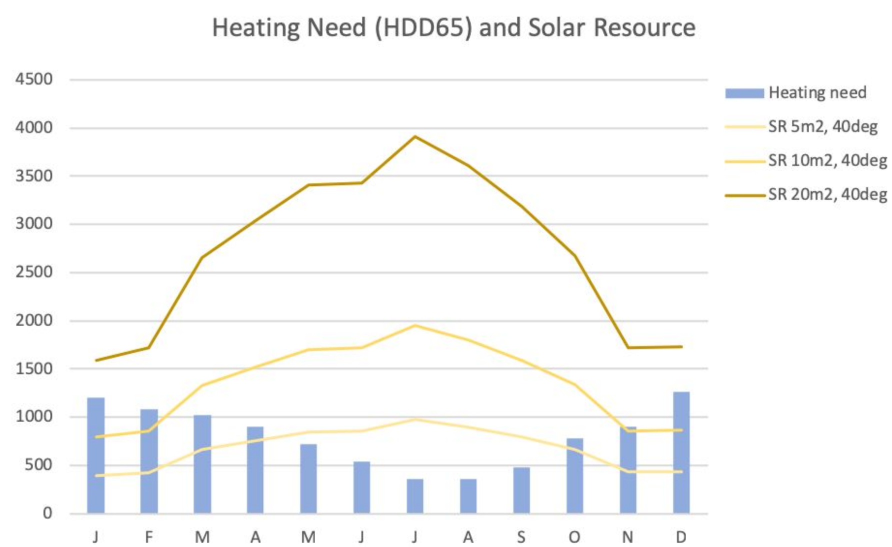
Optimum tilt: 40°
Glass size: $10m^2$
Base temperature: 65°F

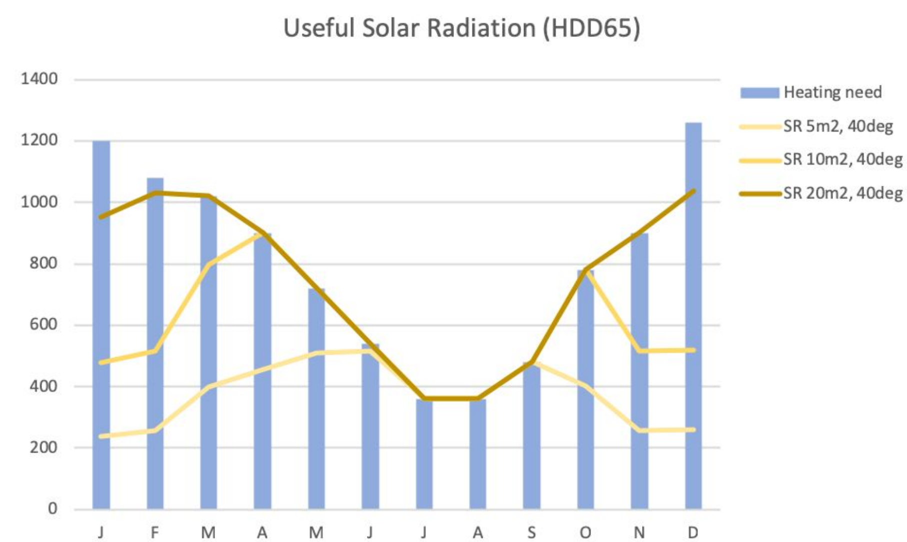




Graphs + sizing elements

Based on winter months, 20m^2 of glass meets nearly all our heating needs, but this requires a great deal of insulation. With our modular design, we may not need to heat as large of a surface area, so 10m^2 - 15m^2 might suffice.





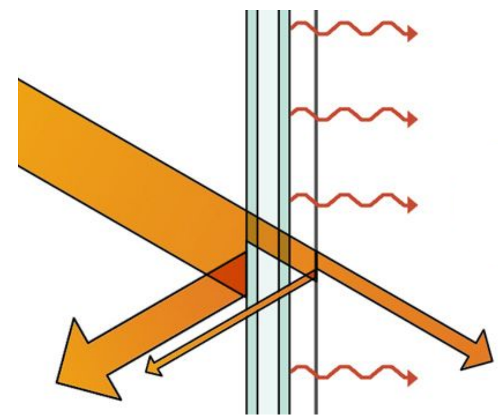
Thermal mass sizing

Target month: March

Solar radiation = 3600kJ solar radiation x 0.7 solar absorptance = **2,520 kJ ptl uptake**

Temperature:

- Coolest expected night mass temperature = **50°F** (10°C)
- Desired warmest daytime temperature = **110°F** (43°C)
- 43°C - 10°C = **33°C**



Mass wall:

- Solar absorptance = **0.6**
- Heat capacity = **0.96 kJ/kgK**
- Density = **2000kg/m^3**
- (1/0.96) kg*K/kJ * 2,520 kJ ÷ Δ33°C = **79kg mass**

Thickness:

- 79kg mass * 1m^3/2000kg = 0.04 m^3 volume ÷ 10m^2 area = 0.004m = **4cm thick (~2")**

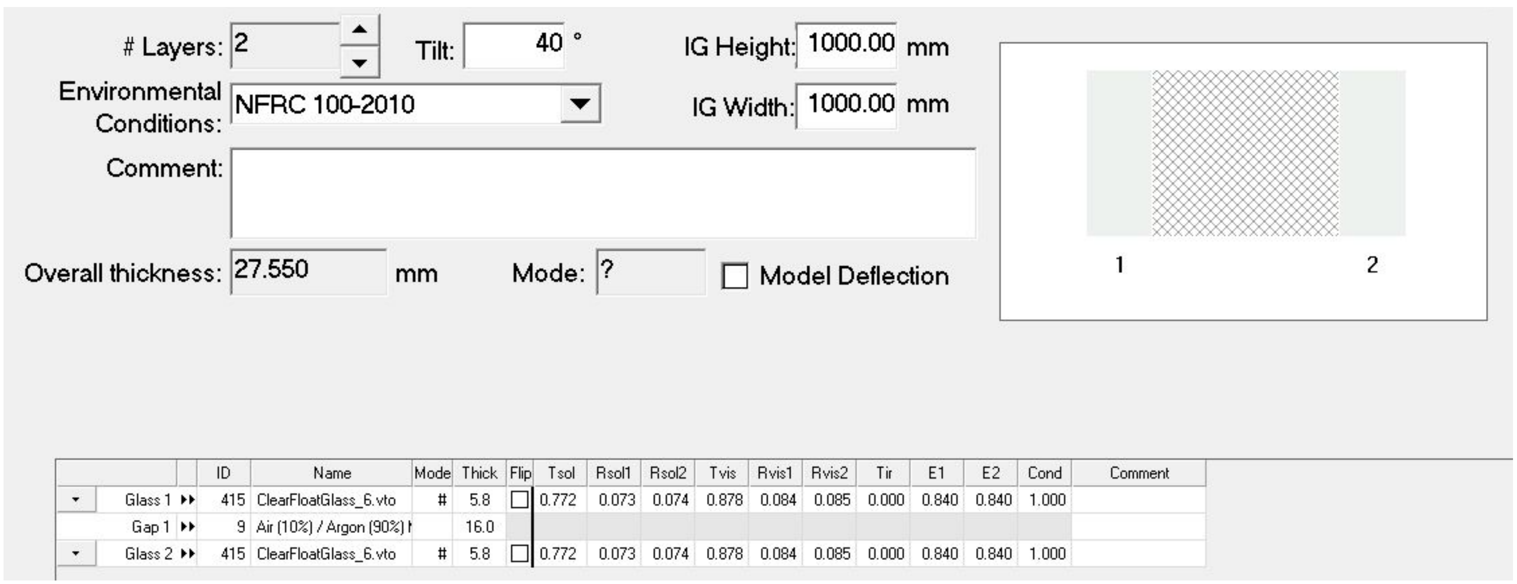
Graphs + sizing elements

Clear Float Glass

SHGC: 0.772

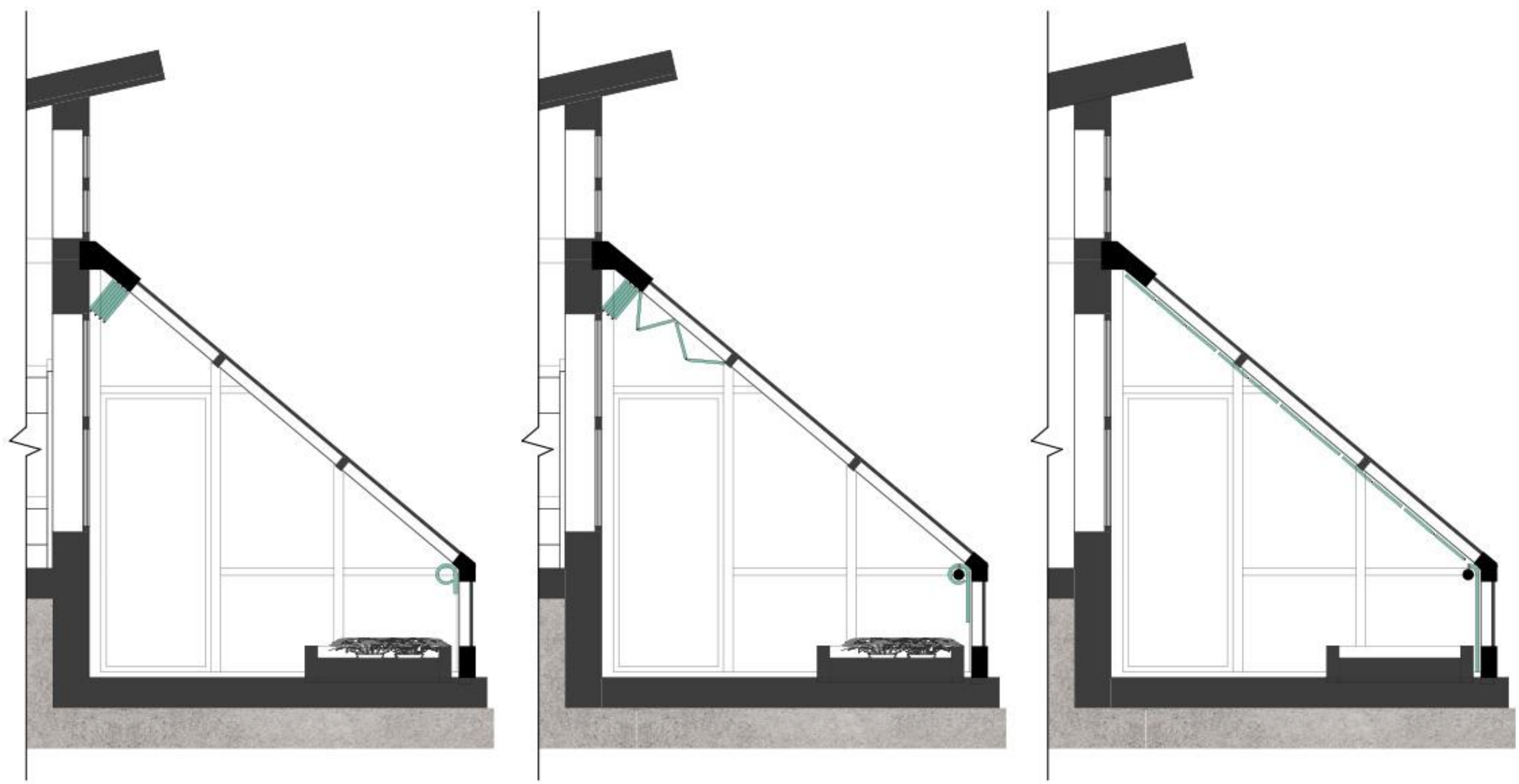
Visible transmittance: 0.878

We chose a double-pane glazing for the sunspace. The glass of choice has a high Solar Heat Gain Coefficient and high Visible Transmittance to allow as much solar radiation during the day as possible. It will then be imperative to cover it with insulation overnight; otherwise, there will be a significant amount of heat loss.

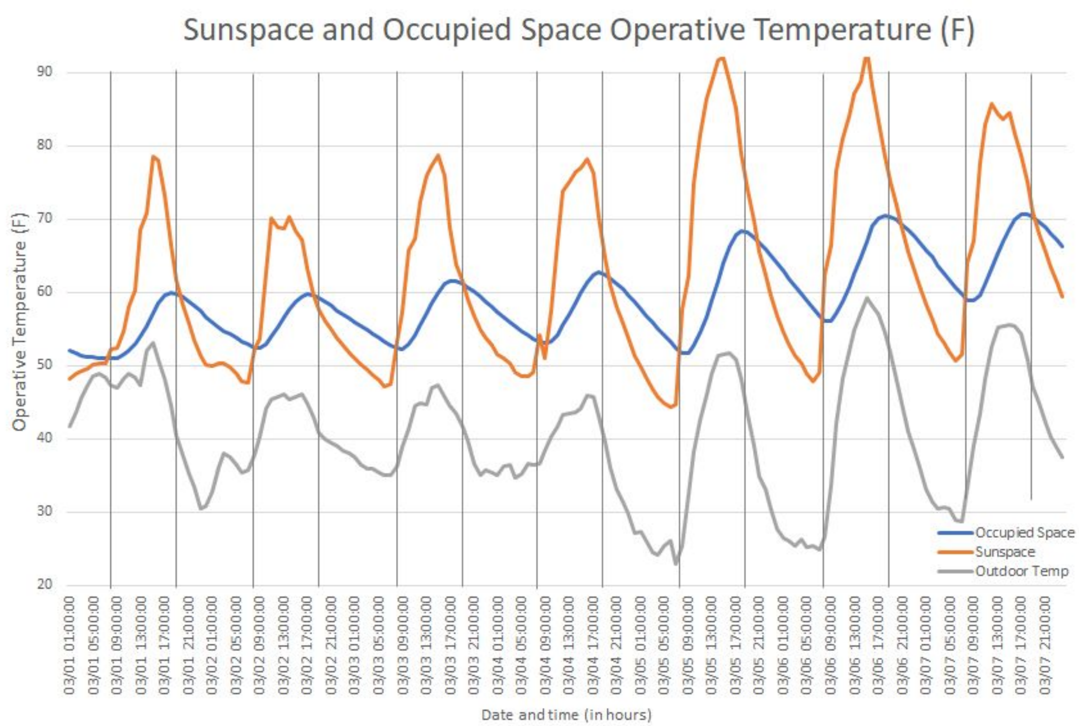


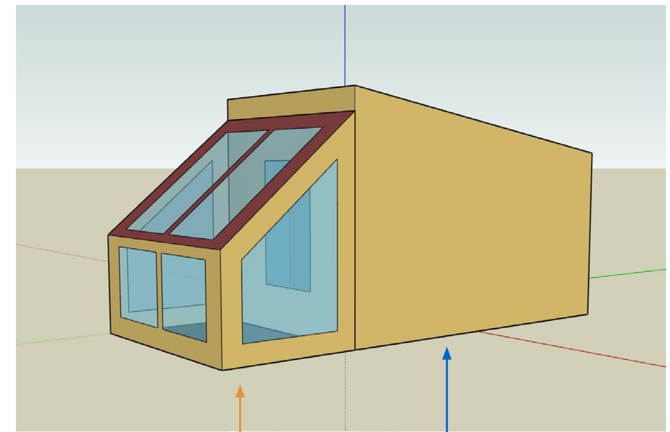
	ID	Name	Mode	Thick	Flip	Tsol	Rsol1	Rsol2	Tvis	Rvis1	Rvis2	Tir	E1	E2	Cond	Comment
Glass 1	415	ClearFloatGlass_6.vto	#	5.8	☐	0.772	0.073	0.074	0.878	0.084	0.085	0.000	0.840	0.840	1.000	
Gap 1	9	Air (10%) / Argon (90%)		16.0												
Glass 2	415	ClearFloatGlass_6.vto	#	5.8	☐	0.772	0.073	0.074	0.878	0.084	0.085	0.000	0.840	0.840	1.000	

Movable insulation details



Performance - Operative Temperature



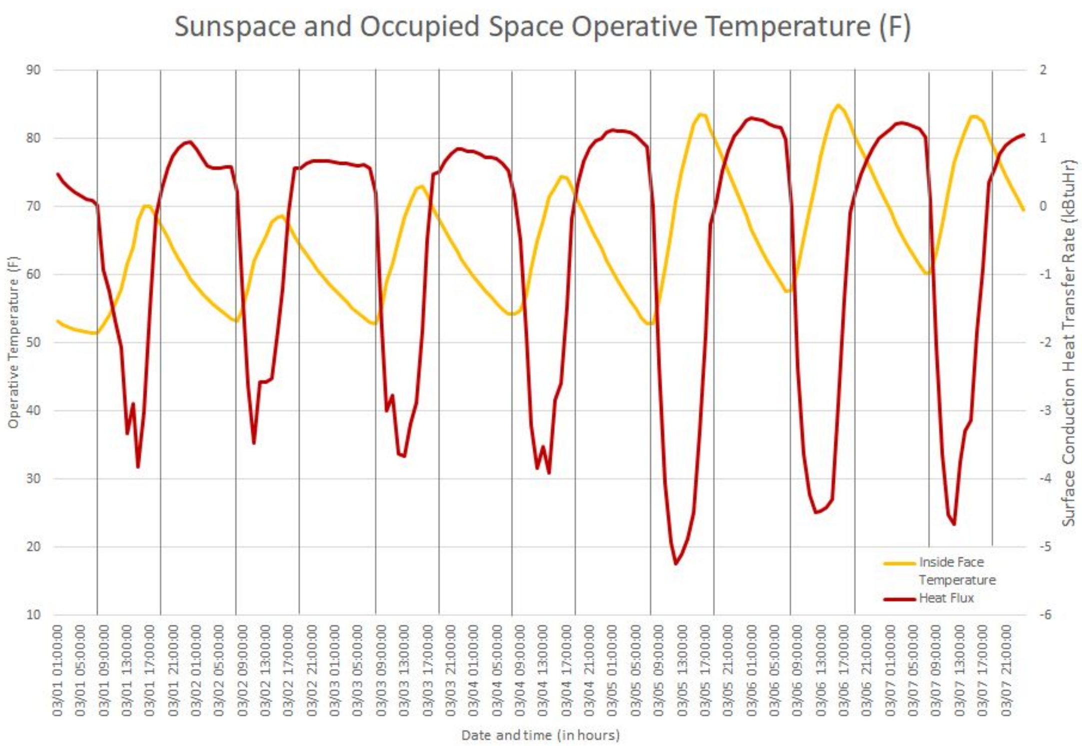


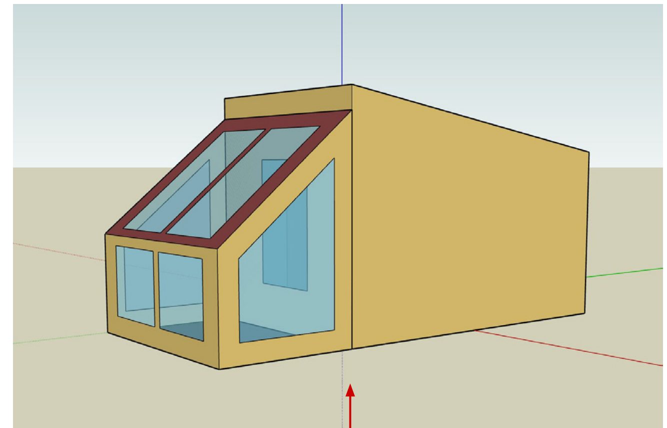
Sunspace

Occupied Space

The occupied zone stays about 10°F warmer than the outdoor temperature except in the early hours of the morning. This means that our thermal mass is not buffering the cool evening hours as much as we would like. We could improve this with more thermal mass or choose a material with a higher conductivity.

Performance - Heat Flux

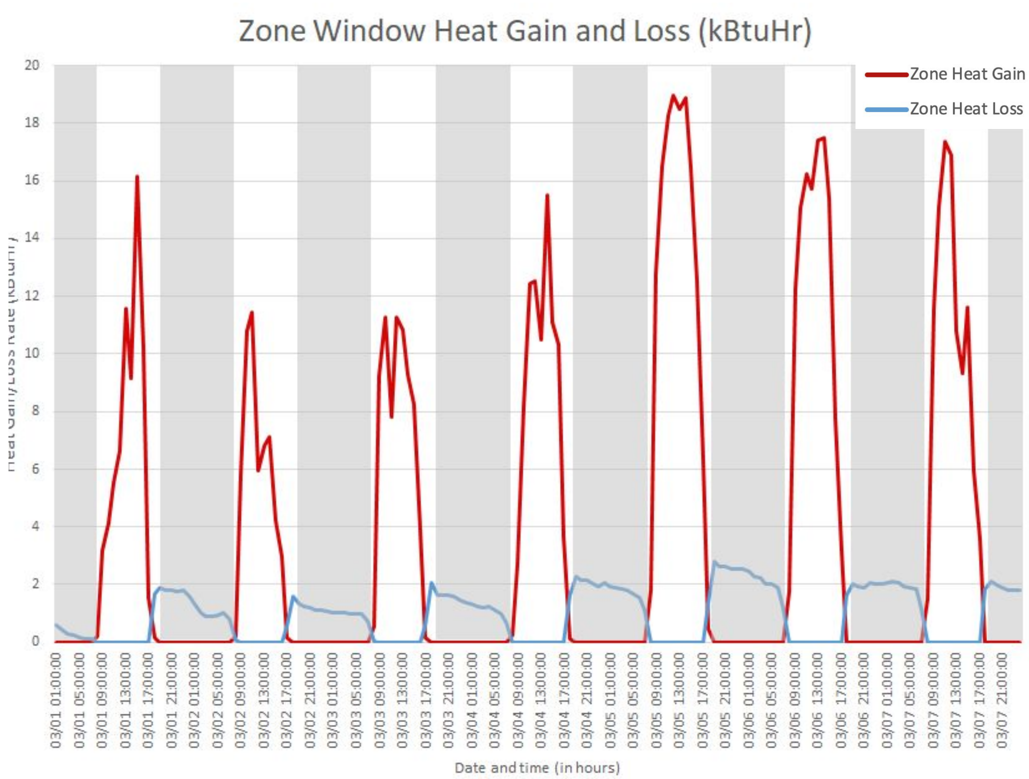


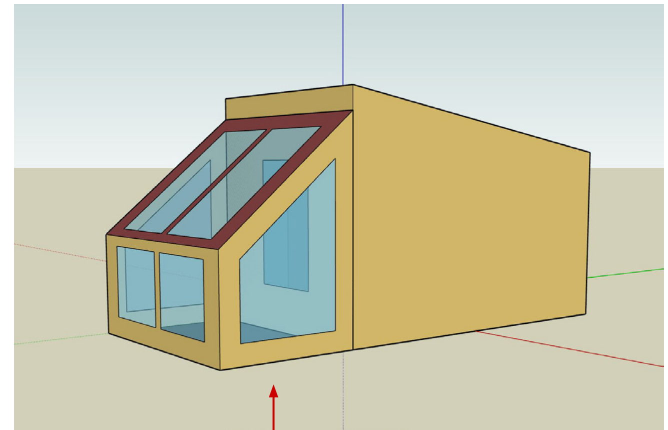


Thermal mass (6” concrete wall)

The thermal mass in the sunspace performs really well for heat flux: it rapidly shares its heat with the surrounding environment when the insulation is deployed, but the inside face temperature never gets significantly hot - that would indicate that the thermal mass has reached its maximum load. We could actually size ours down a bit so that it releases more heat during cool hours.

Performance - Window Heat Gain/Loss





Sunspace Zone

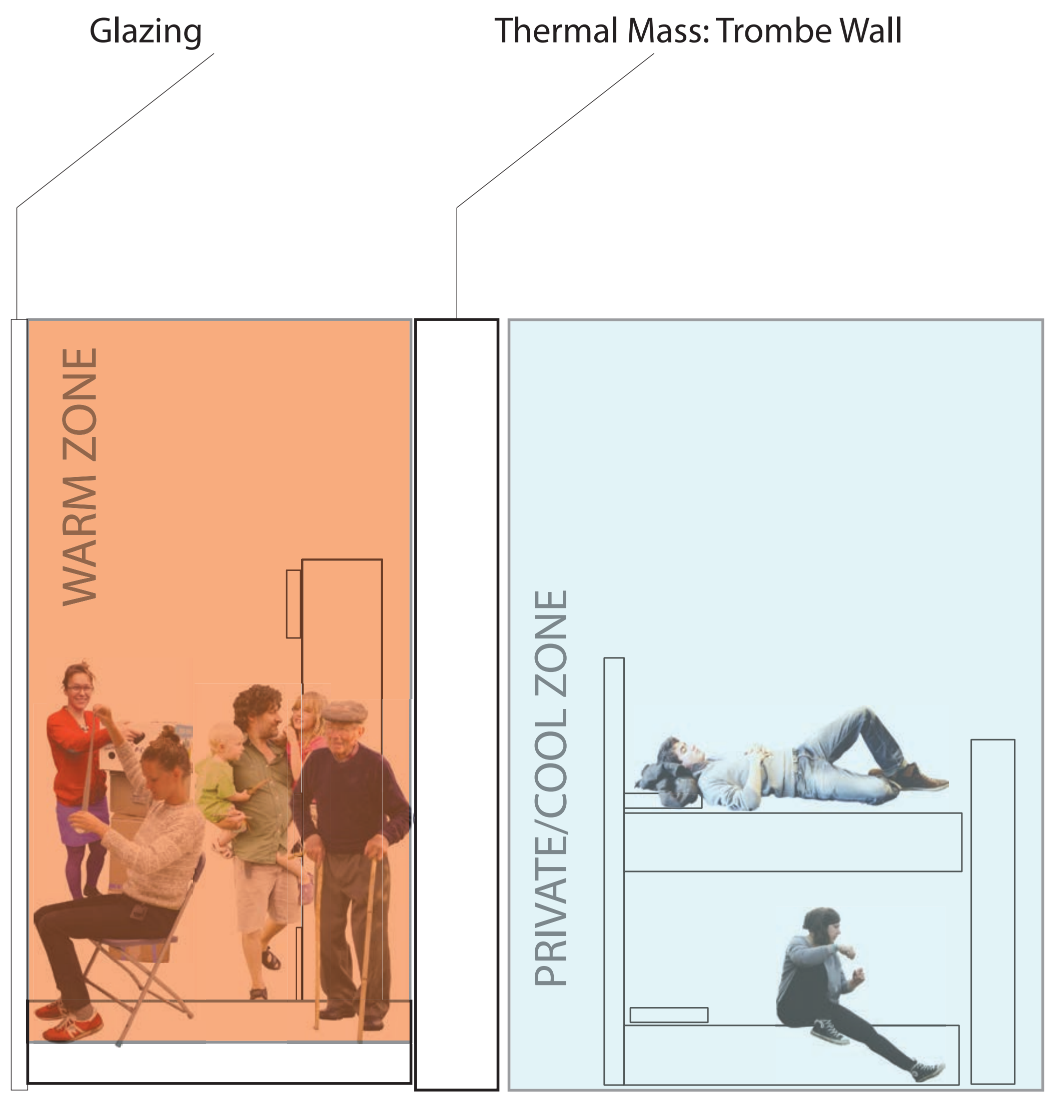
The sunspace does an excellent job of gaining heat during desired hours, and the moveable insulation also performs very well to mitigate heat loss during the evening hours. The chart shows that during the uncovered hours, the glazing allows a huge amount of solar radiation, but during the covered hours (gray bars), there is very little heat loss (blue line).

Appendix C

Project 3: Hannah McKay, Lindsey Naganuma and Bryce Shortall Final Presentation

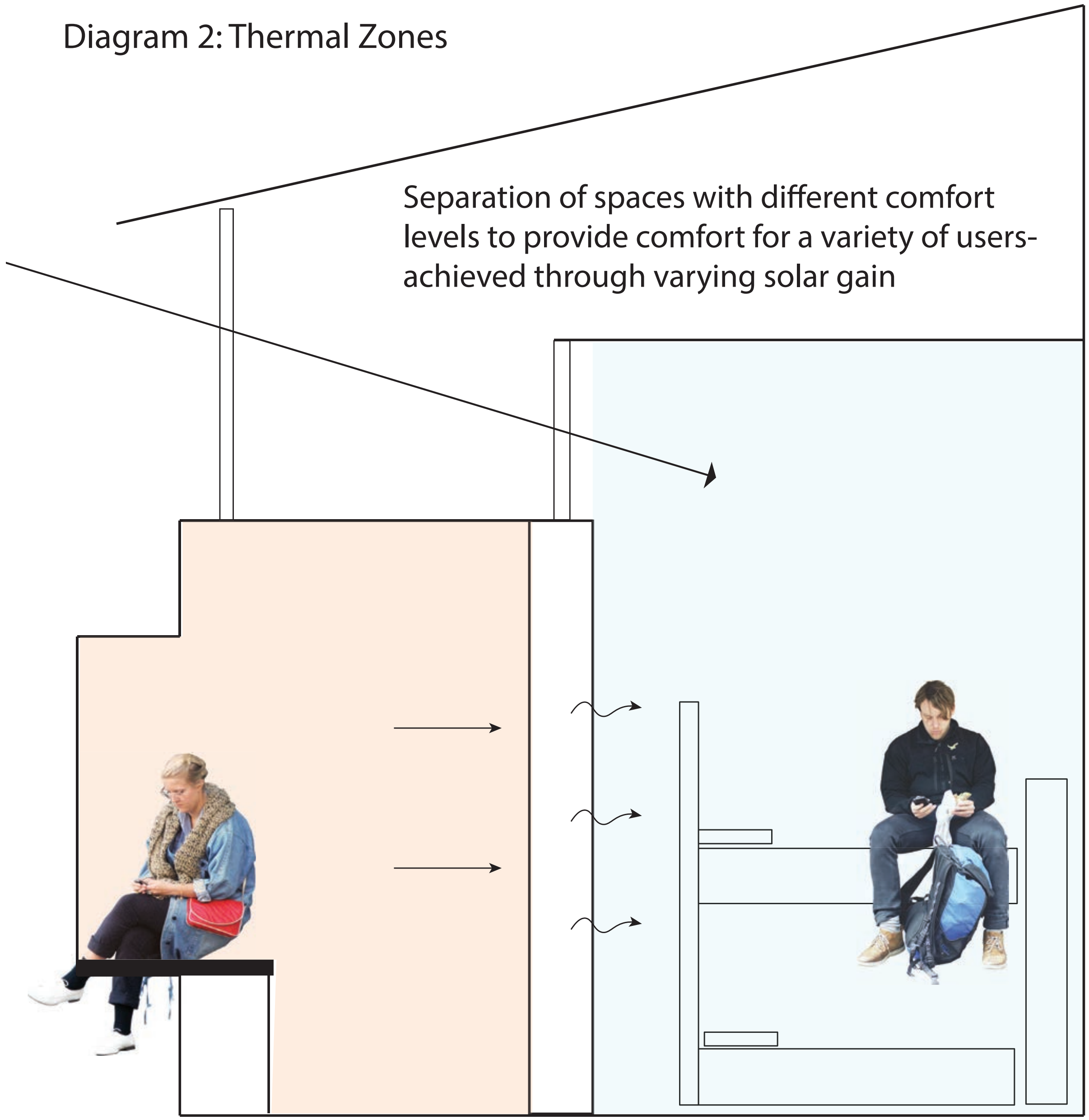
Diagrams: Conceptual ideas for Dunes City

Livable Solar Collecting Space



Diagrams: Conceptual ideas for Dunes City

Diagram 2: Thermal Zones



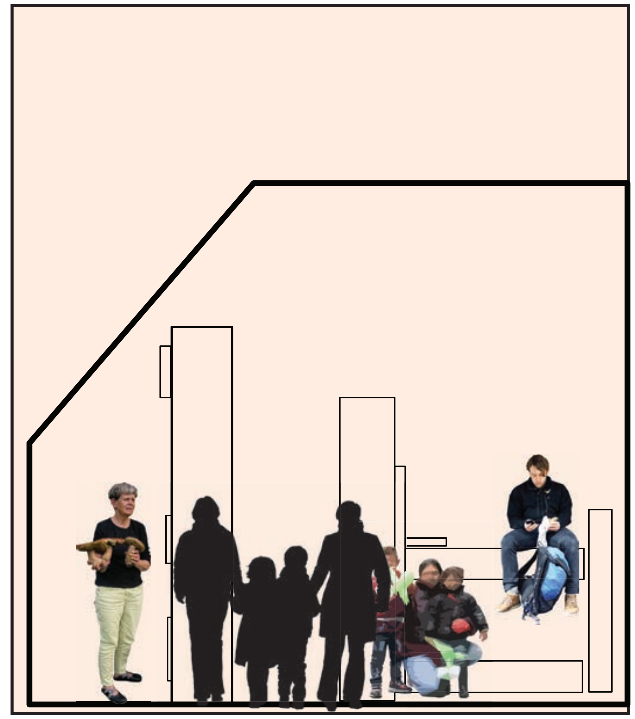
Diagrams: Conceptual ideas for Dunes City

Diagram 3: Transformative and Adaptive Uses

PRE DISASTER MODE

Amenities:
Bunks for Traveling Bikers
Library stocked with biking maps and helpful traveling hints
Small Kitchen Nook
First aid supplies for as needed basis
Shelter
Bathrooms
Lockers

IN DISASTER MODE



Amenities:
Bunks for displaced families
Library stocked with foraging information and helpful survival skills
Small Kitchen Nook
First aid supplies for use in small emergencies
Shelter
Bathrooms
Lockers

Precedents: Livable Solar Collecting Space

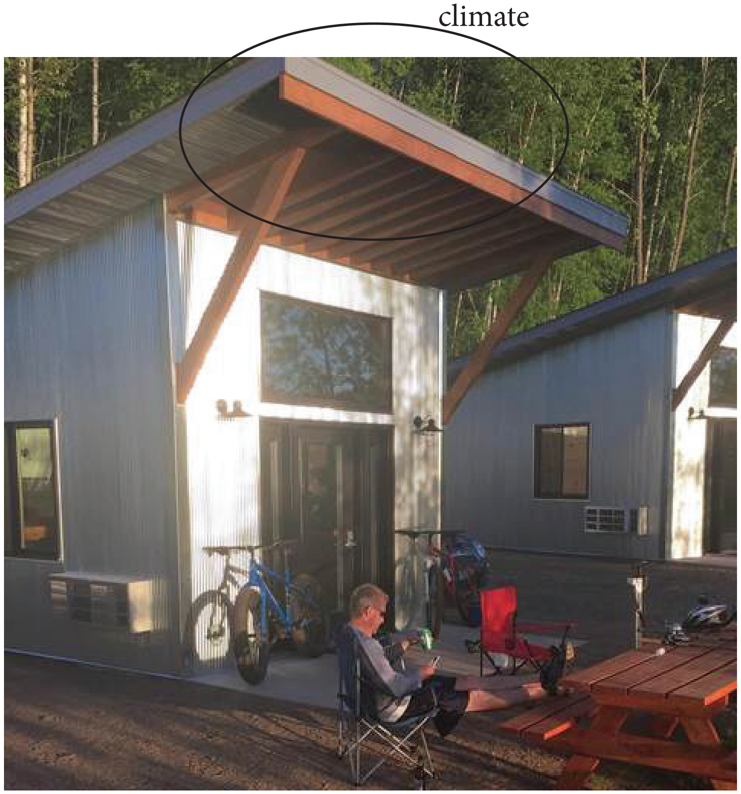
Context: Kickapoo Mud Creek Nature Conservancy- Conservatory Building in Oregon Illinois
Shown: Use of a trombe wall to create a visually stimulating and thermally warm (or sometimes hot) space
Climate: High precipitation throughout year, on average 189 days of sun, 90* in summer, 12* in winter

Context: House in Aberdeenshire- Renovated from an existing farm building to have improved thermal performance
Shown: Intermediate space between tilted glazing and granite wall acting as trombe wall
Climate: High Precipitation, colder climate, cloudy climate

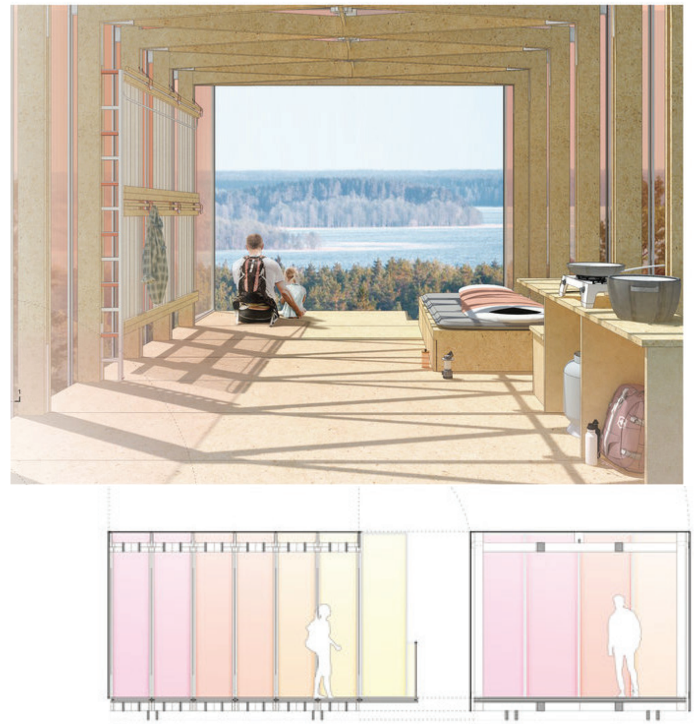
We like these precedents for the shelter in Dunes City because they provide inhabitable solar collecting spaces. They are not designed to be comfortable at all times, but to allow for users to choose when this space is right for them. Provides privacy through window seating.

Precedents: Central and Private Spaces

Note: Overhangs would not be appropriate in our cloudy climate



Context: True North Basecamp Biker Cabins
A precedent for our ideas of having smaller individualized spaces, and also of our desire to house bikers from the 101

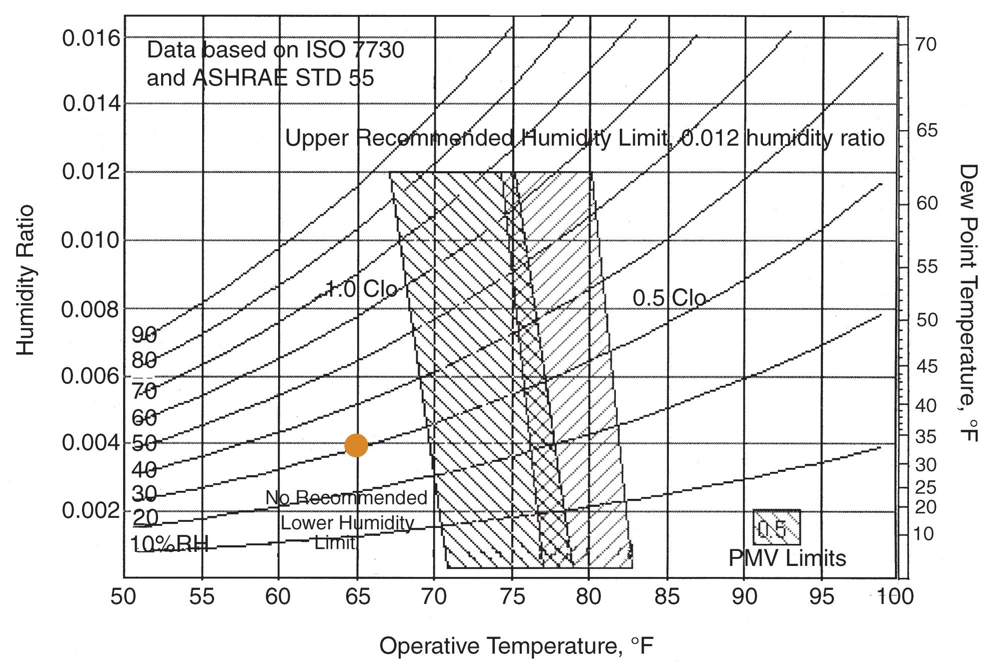


Context: Amber Road Trekking Cabins Competition-Sparano and Mooney Architecture
A precedent for our ideas of colored glass or plexiglass to enhance the feeling of thermal comfort in the space. Also a precedent for having a communal space.

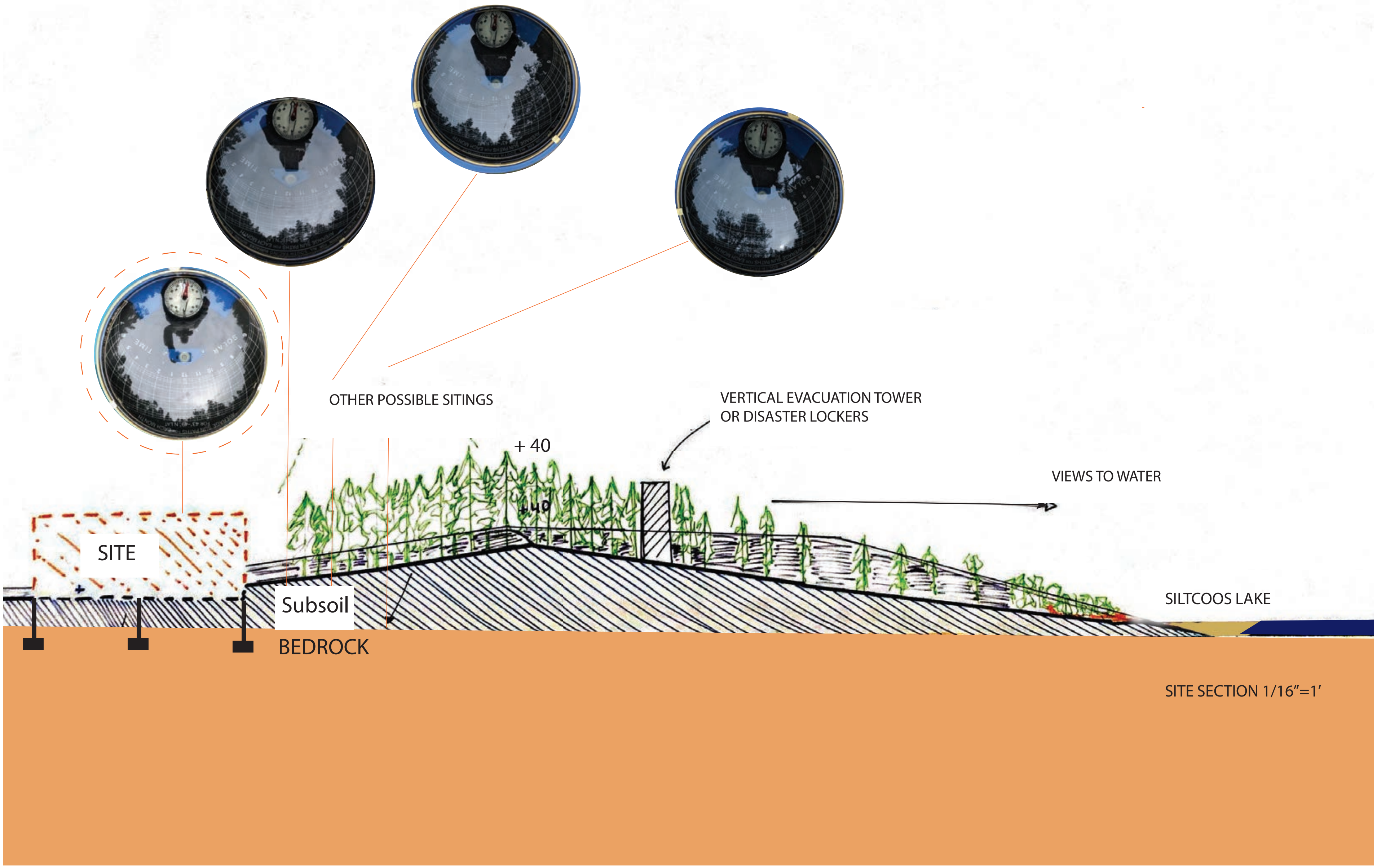
We like these precedents for our ideas of having a communal space for gathering, with more private and separate living quarters off of this. We want to incorporate colored glass or plexiglass to diffuse light and create a "warm" environment.

DESIGN INTENT: THERMAL COMFORT GOALS

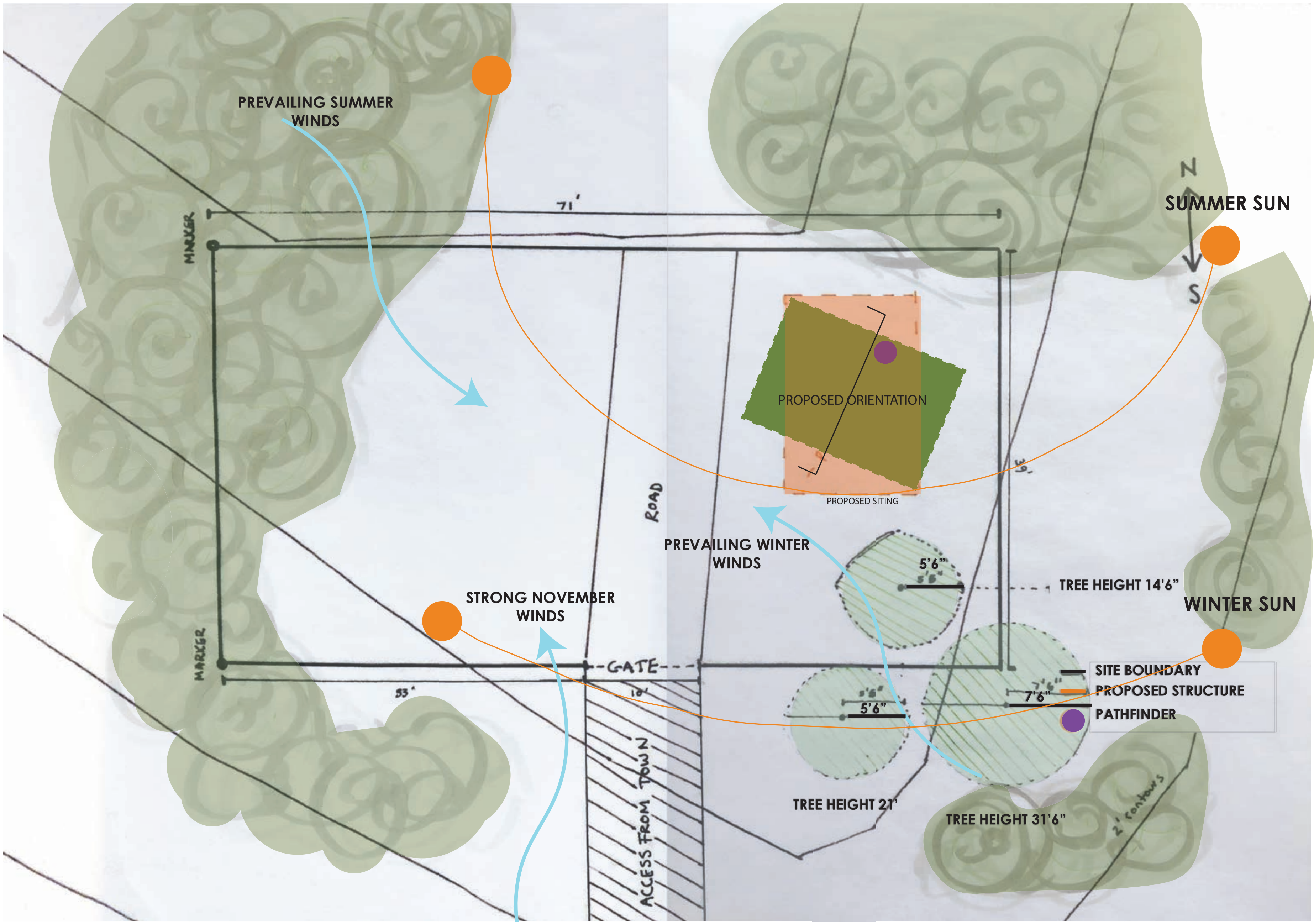
- Incorporate warm interior color through use of colored paneling
- Operable windows easily accessible allow for ease of cooling
- Give operable window access to everyone in order to implement adaptive comfort zone
- Establish a minimum interior temperature standard of 60º
  - Solar gain from clerestory during the day
  - Trombe wall radiation for the evenings



Site Section

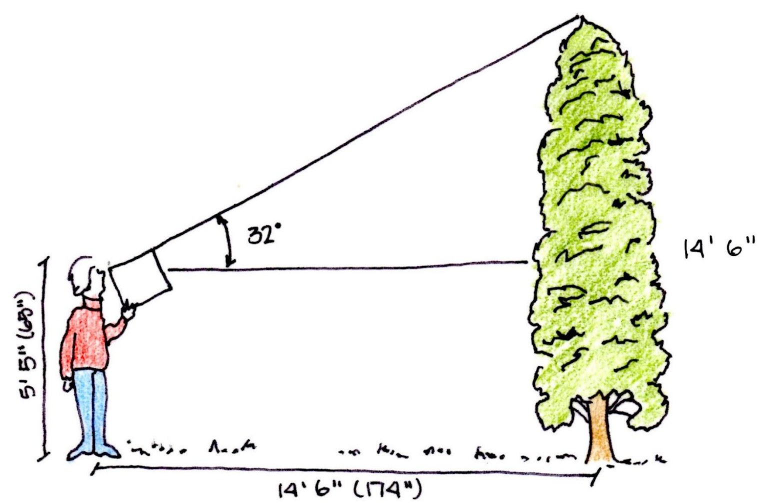


Zoomed in Site Plan

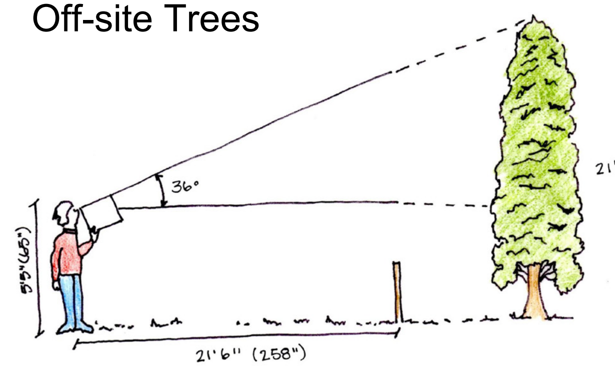


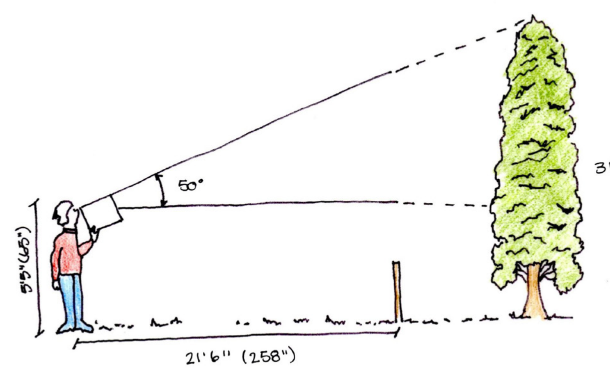
SOLAR SITE SURVEY: TREE HEIGHTS

On-site Tree



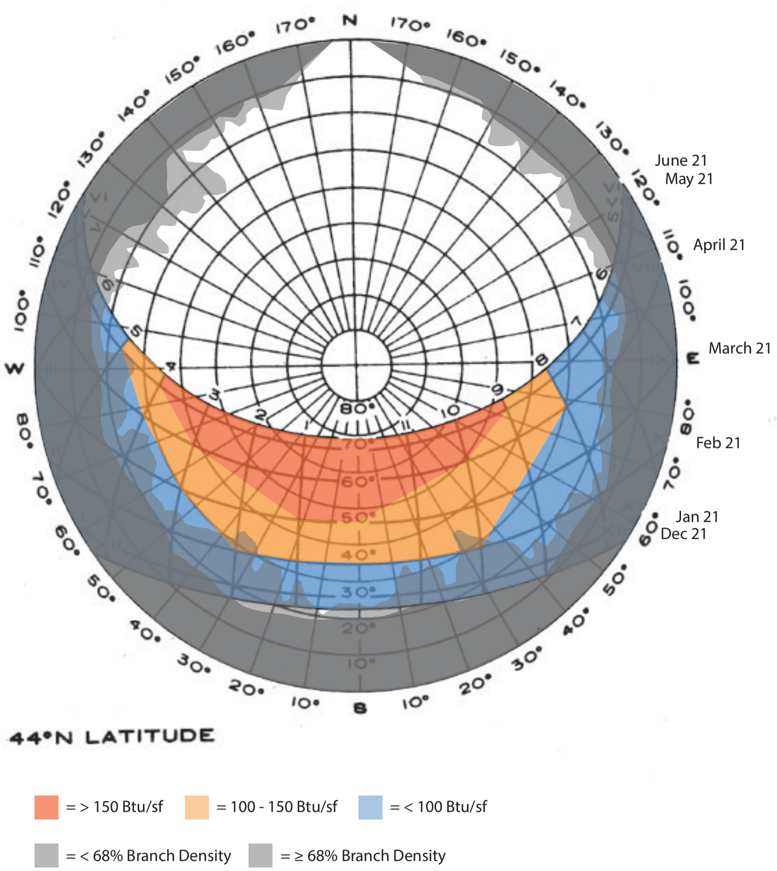
Off-site Trees

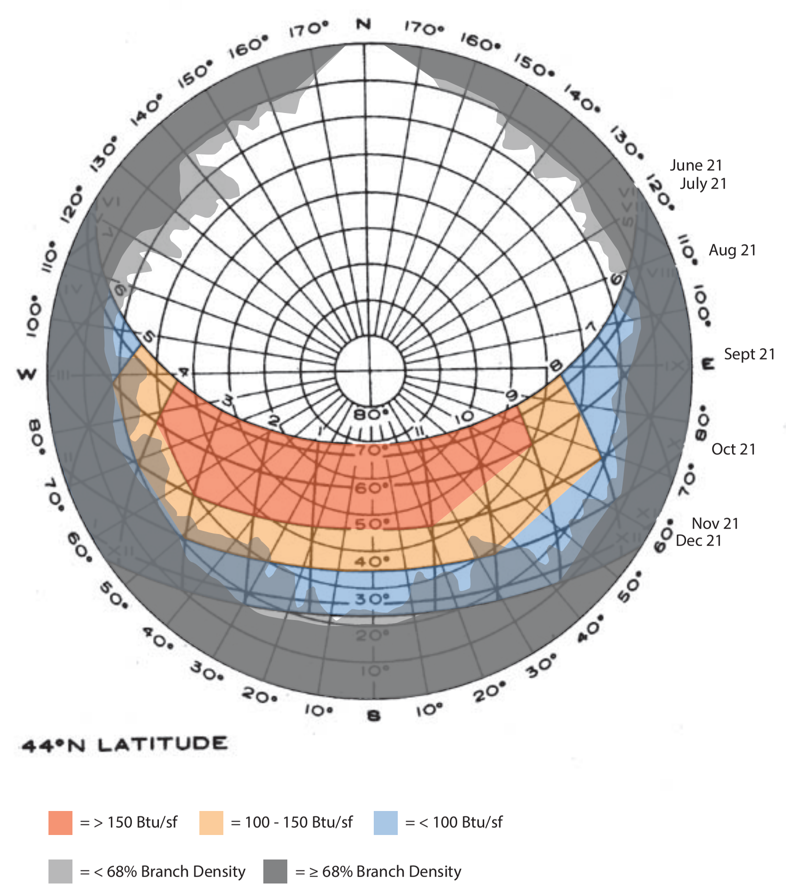




*Relative heights

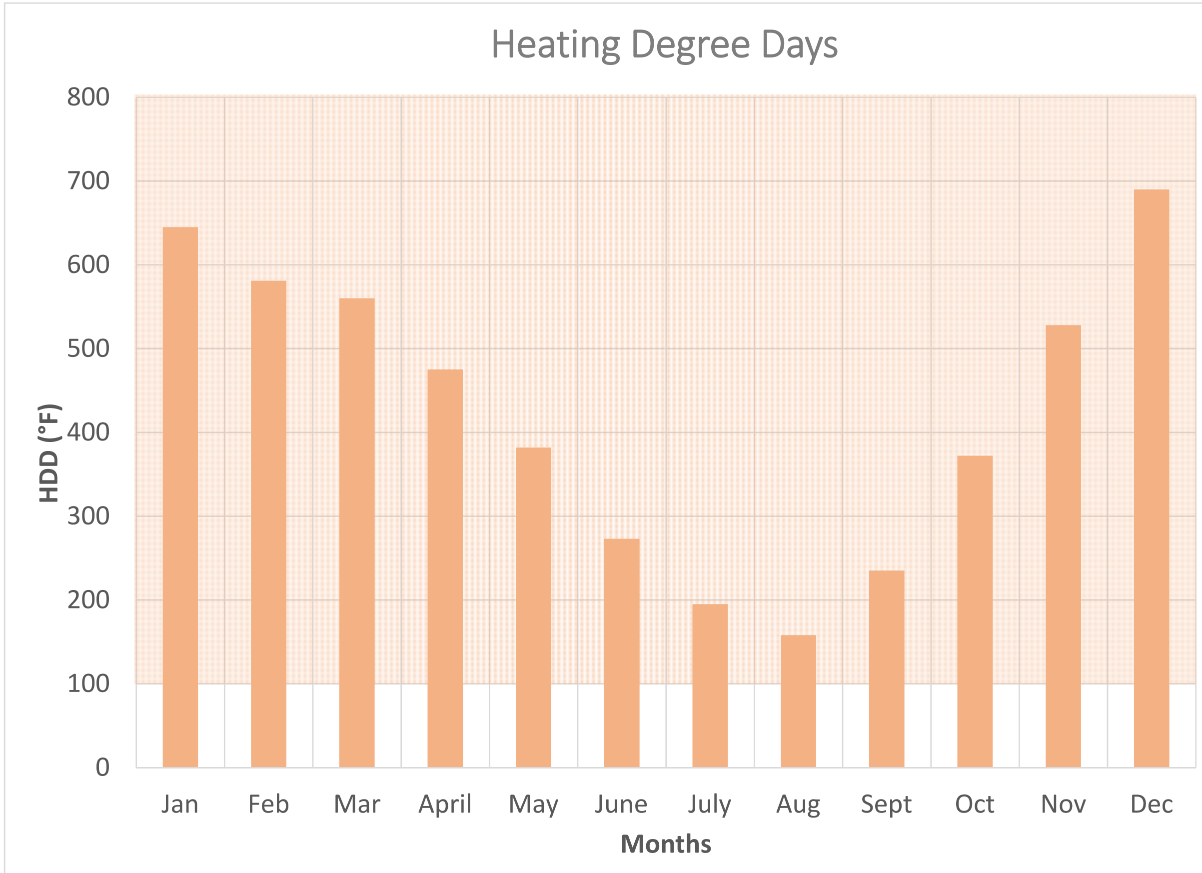
[SOLAR SITE SURVEY]





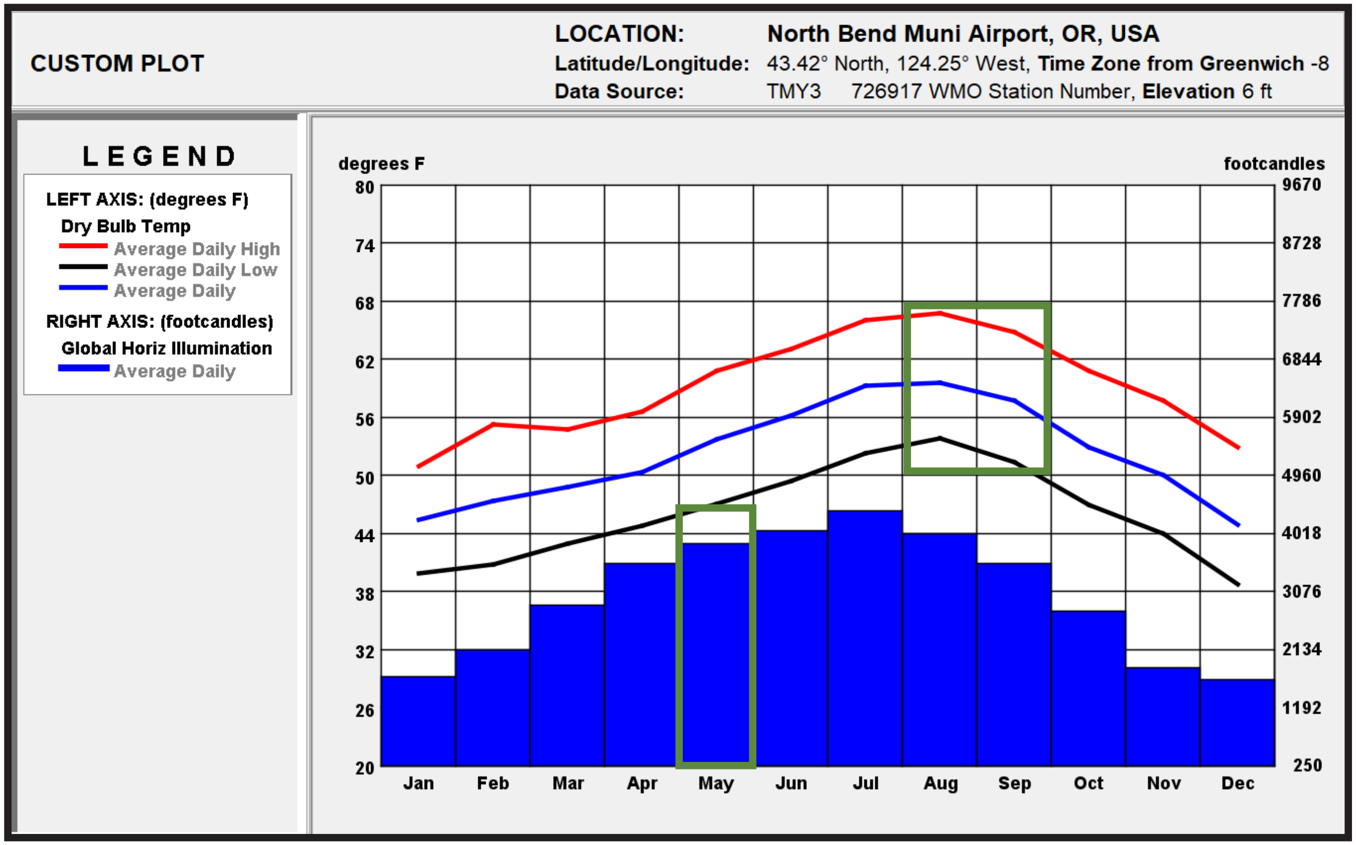
- More intense solar radiation comes from the southwest portion of the site
- Tree canomy in the southwest and southeast portions of the site are mostly less than 68% density
- The southwest portion of the site has the least amount of tree canopy and the most solar radiation

[SOLAR SITE SURVEY]



- First step determine heating season
- Rule of thumb: any month with more than 100 heating degree days (HDD) will be a part of the heating season
- For Dunes City this is every month, need another method

[SOLAR SITE SURVEY]



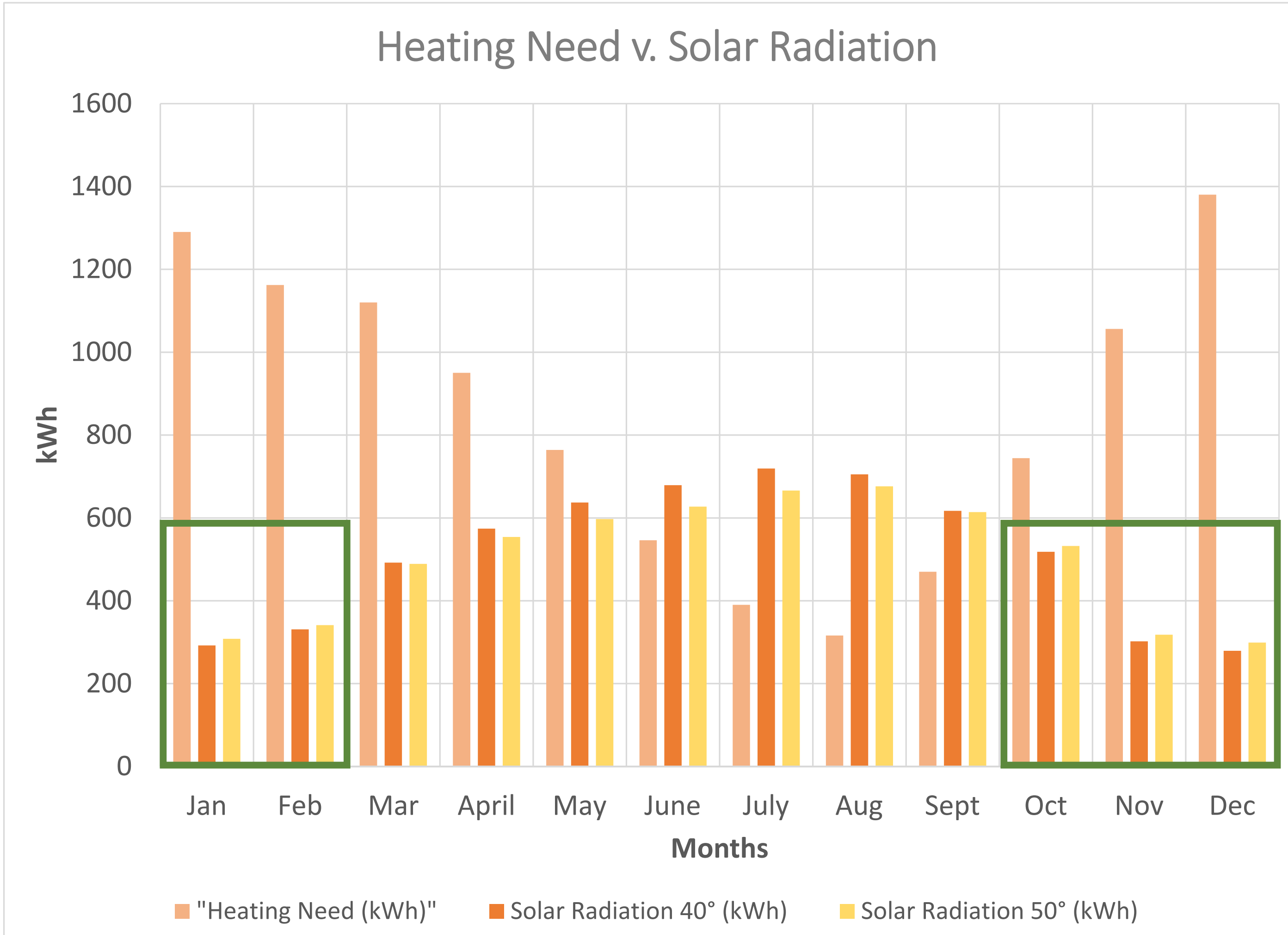
- Source: Climate Consultant
- August and September have similar temperatures to June and July
- May has similar solar radiation levels June and July
- Potential to exclude these months from the heating season

[SOLAR SITE SURVEY]

		Solar Radiation									
Month	# of Days	90°	80°	70°	60°	**50°**	**40°**	30°	20°	10°	0
Jan	31	295	308	318	318	308	292	269	240	203	164
Feb	28	299	322	338	345	341	331	312	285	253	213
March	31	371	417	453	476	489	492	482	459	427	384
April	30	361	423	479	522	554	574	581	571	551	515
May	31	335	410	482	545	597	637	659	669	663	643
June	30	315	404	486	561	627	679	715	735	738	728
July	31	345	436	522	600	666	719	751	771	768	751
Aug	31	404	489	564	627	676	705	722	719	699	659
Sept	30	446	509	558	591	614	617	607	581	538	482
Oct	31	446	486	515	528	532	518	492	453	400	341
Nov	30	295	315	325	325	318	302	279	249	213	174
Dec	31	295	308	308	308	299	279	253	220	180	138
Total		4207.0	4827.0	5348.0	5746.0	6021.0	**6145.0**	6122.0	5952.0	5633.0	5192.0
Total w/o June + July		3547.0	3987.0	4340.0	4585.0	4728.0	**4747.0**	4656.0	4446.0	4127.0	3713.0
Total w/o May + June + July		3212.0	3577.0	3858.0	4040.0	**4131.0**	4110.0	3997.0	3777.0	3464.0	3070.0
Total w/ o June + July + Aug		3143.0	3498.0	3776.0	3958.0	**4052.0**	4042.0	3934.0	3727.0	3428.0	3054.0
Total w/o June + July + Aug + Sept		2697.0	2989.0	3218.0	3367.0	**3438.0**	3425.0	3327.0	3146.0	2890.0	2572.0
Total w/o May + June + July + Aug		2808.0	3088.0	3294.0	3413.0	**3455.0**	3405.0	3275.0	3058.0	2765.0	2411.0

- Optimal tilt depends on the heating season
- Intuitively June and July should not be include in heating season
- Climate data makes it unclear whether or not to include May, August and September
- Optimal tilt could be either 40° or 50°

[SOLAR SITE SURVEY]



- 50° is the optimal tilt for Dunes City
- Warmer in the cold winter months and require less cooling in the hot summer month

SOLAR SITE SURVEY: GLASS TYPE

- Double glazing clear acrylic glass to increase area for daytime solar radiation capture
- Durable aluminum framing for window reinforcement and longevity
- Product example: SGG STADIP
- Reinforced glass strengthened with acrylic core

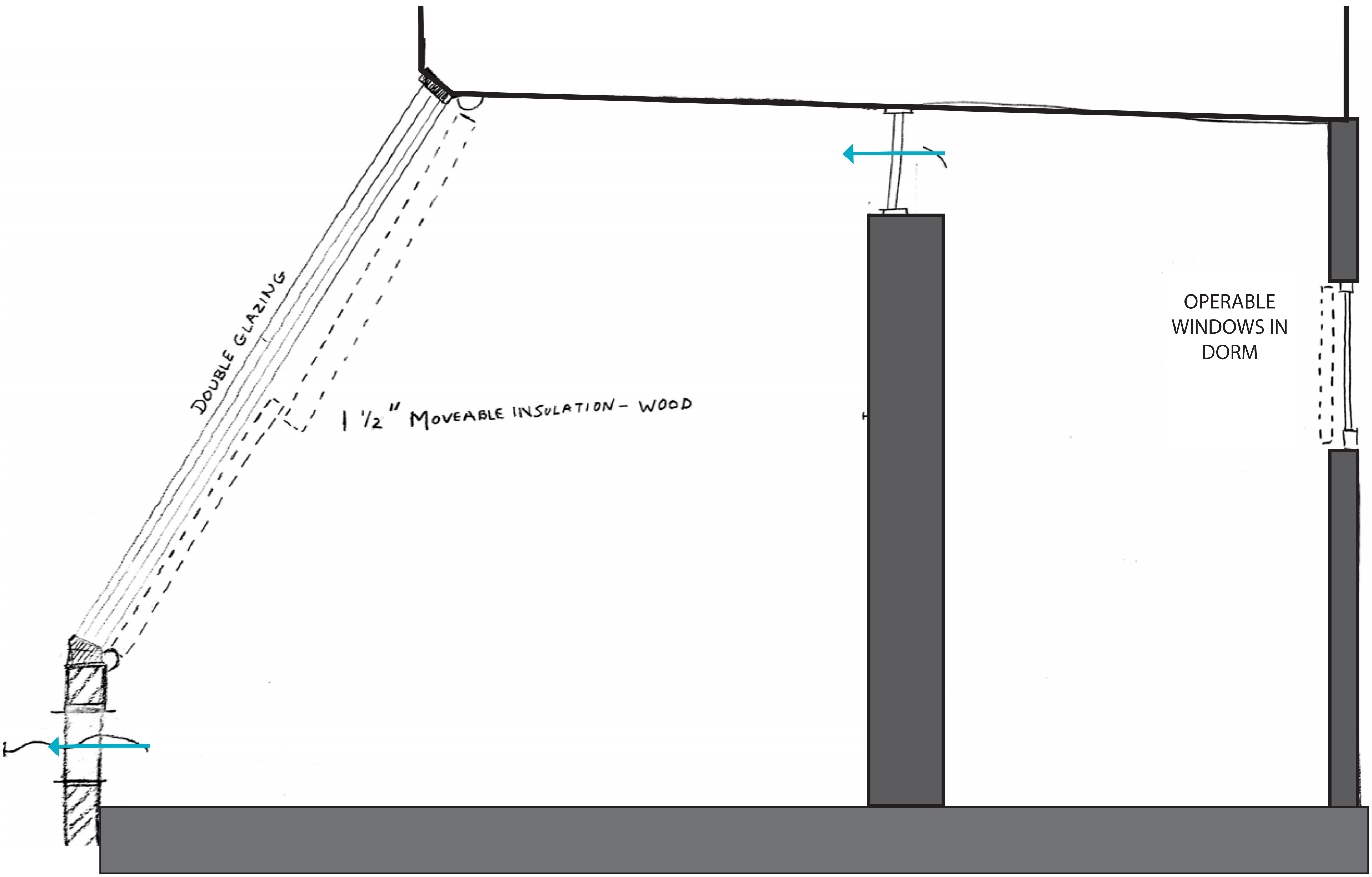
Heat Delivery Options

Afternoon: Direct gain, livable solar collecting space may be uncomfortable

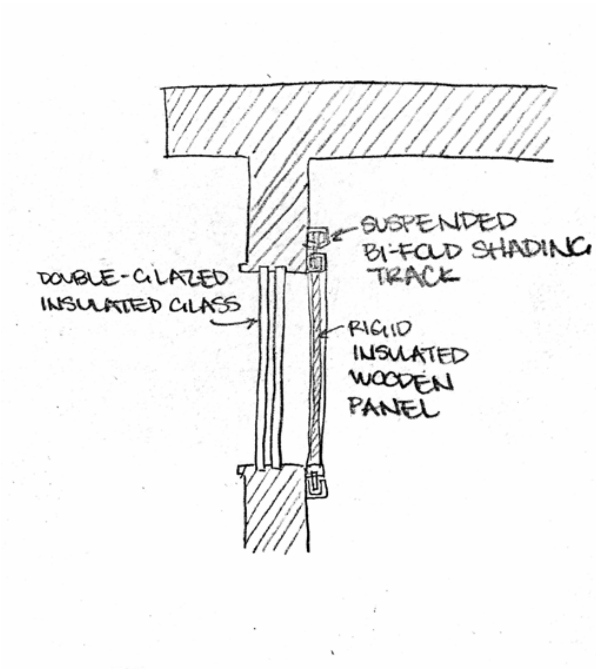
Evening: Thermal mass radiates into both spaces, movable insulation applied in solar collecting space

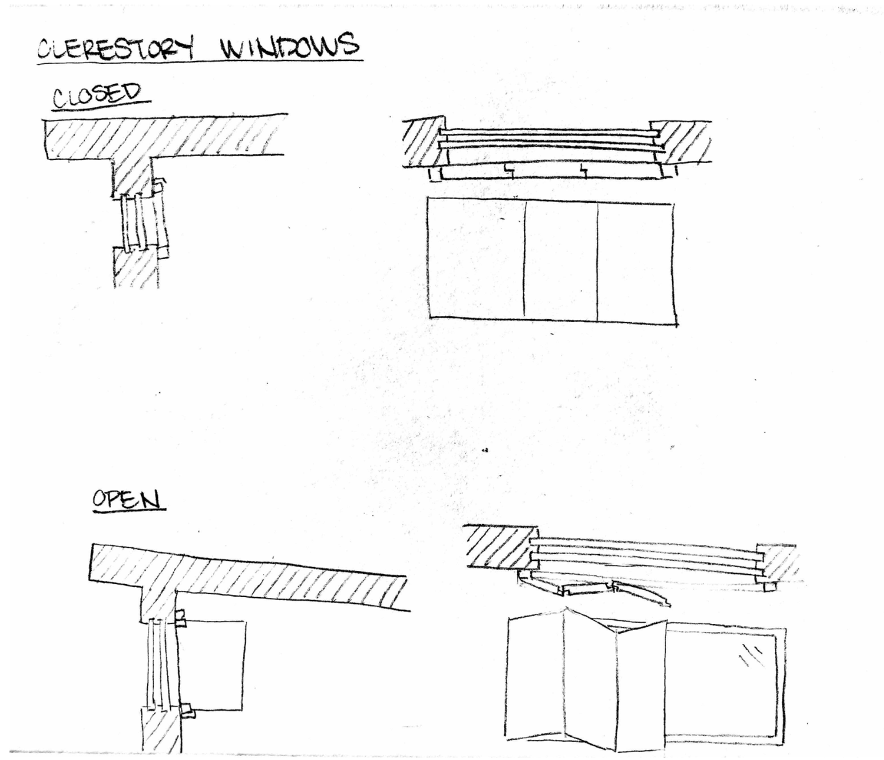
All night: Thermal mass maintains thermal comfort goal, movable insulation is applied throughout night until a couple hours after sunrise

Sizing: Relatively large thermal mass in order to slowly release heat to adequately maintain thermal comfort goals, but sized appropriately to accommodate the low solar radiation levels of Dunes City

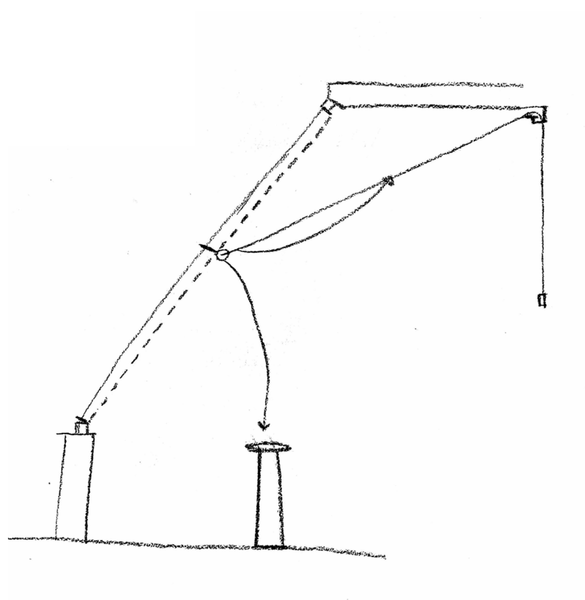

DOUBLE GLAZING
1 1/2" MOVEABLE INSULATION - WOOD
OPERABLE
WINDOWS IN
DORM

Moveable Insulation Detail: Clerestory

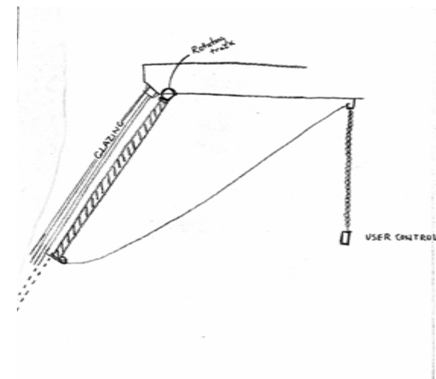


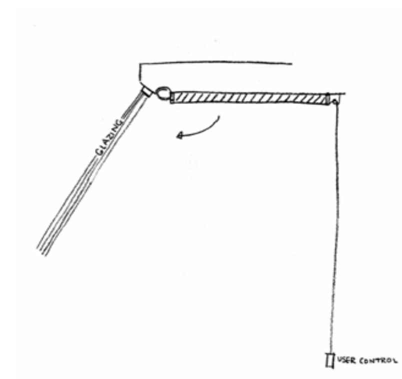


Moveable Insulation Detail: Solar Collecting Space

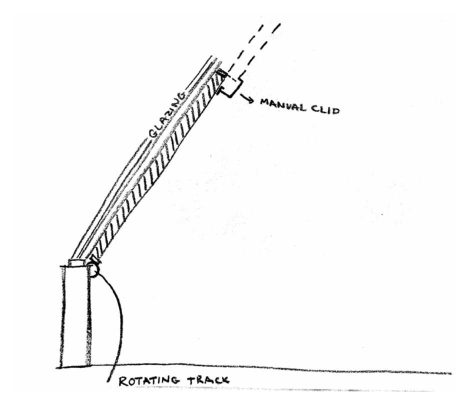


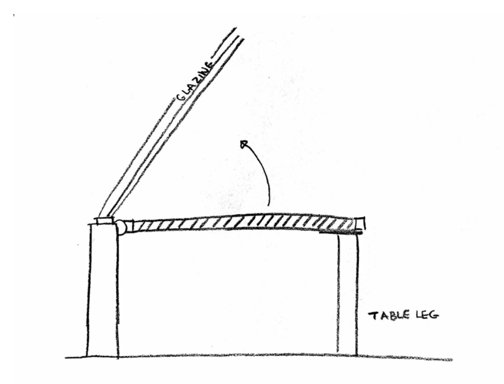
Swings Up to be removed from space on ceiling





Swings Down to become table





Thermal Mass Sizing: Hand Calculation

Step ONE: Choose a material based on Thermal Goals.
Cloudy and cold climate= Thinner Mass
Evening Heat Delivery= High Temperature of 120* F (49* C)
Higher Heat Return Intensity for Cool climate
Moderate to High Thermal Conductivity
Medium to High Solar absorptivity

Material Choice: Concrete! (due to above criteria, cost, and material availability)

Step TWO: Identify Material Properties
Specific Heat Capacity: .88 kj/kg*K (engineering toolbox)
Density: 2400 kg/m^3 (NRMCA)
Thermal Conductivity: .4 W/m*K (engineering toolbox)
Solar Absorptance: .6 fraction (engineering toolbox)

Step THREE: Calculate size of Thermal Mass

Identify Solar Radiation: 3600 kj (1KWH) of solar radiation available per day
Use of daily value in the month of February
3600 kj * .6 solar absorptance= 2160 kj PTL uptake

Identify Temperature Difference: *Warmest Daily Mass Temp* 49* C- *Coolest Daily Mass Temp* 15*C=
34K Temp Difference

How Much Mass is Needed:
*Heat Capacity: .88 kj/kg*K*
*1/.88 kj/kg*K multiplied by 2160 kJ divided by 34K=*
72.2 kg of thermal mass needed

If we have 10 m^2 of mass?
72.2 kg of mass* 1 m^3/2400 kg=
.03m^3 volume/ 10 m^2= 3 cm of mass needed

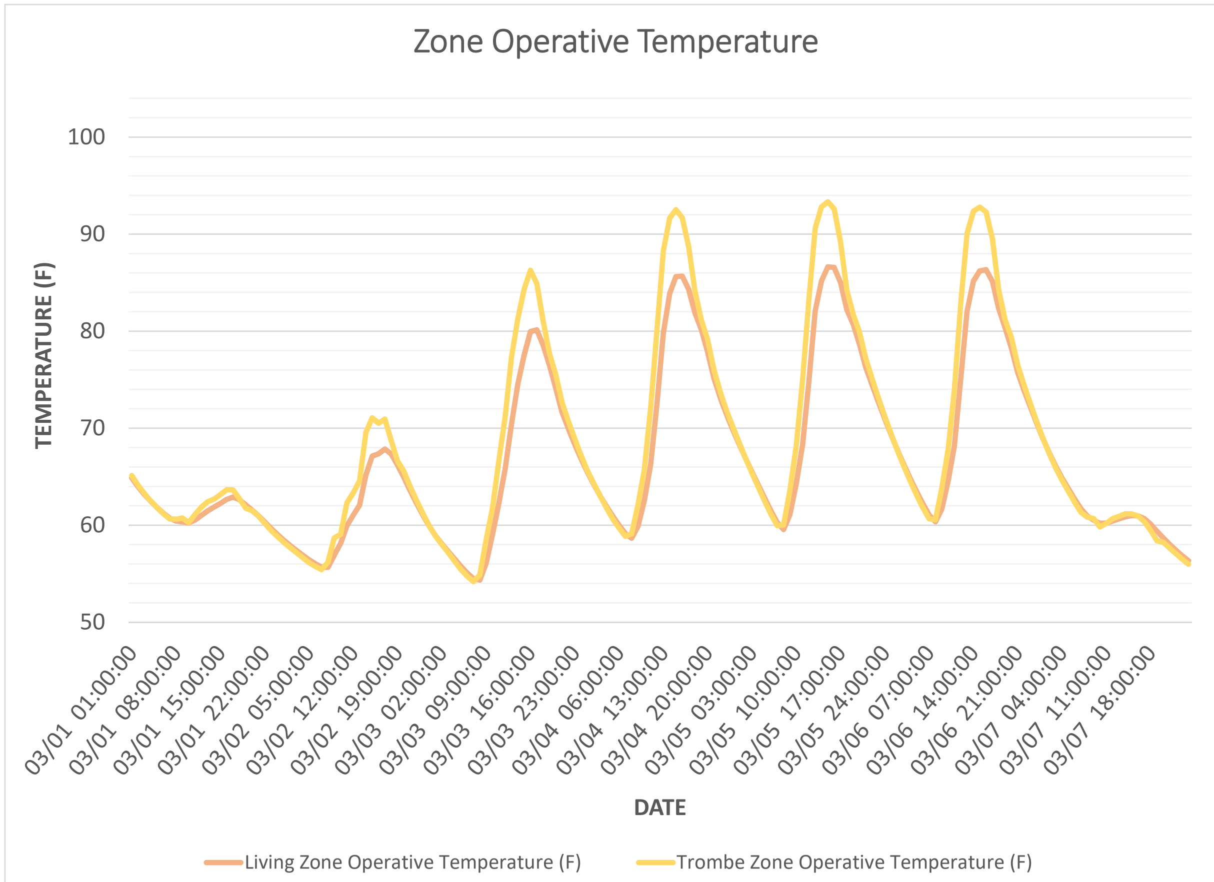
These calculations give us a proposed thickness of thermal mass. However to maintain structural integrity of our wall we are proposing it be at least 2 in (5 cm) thick. We do need it to be thick enough to accomodate rebar for seismic safety.

Extra Thickness Calcs:

.03m^3 volume/ 30m^2= 1 cm of mass needed

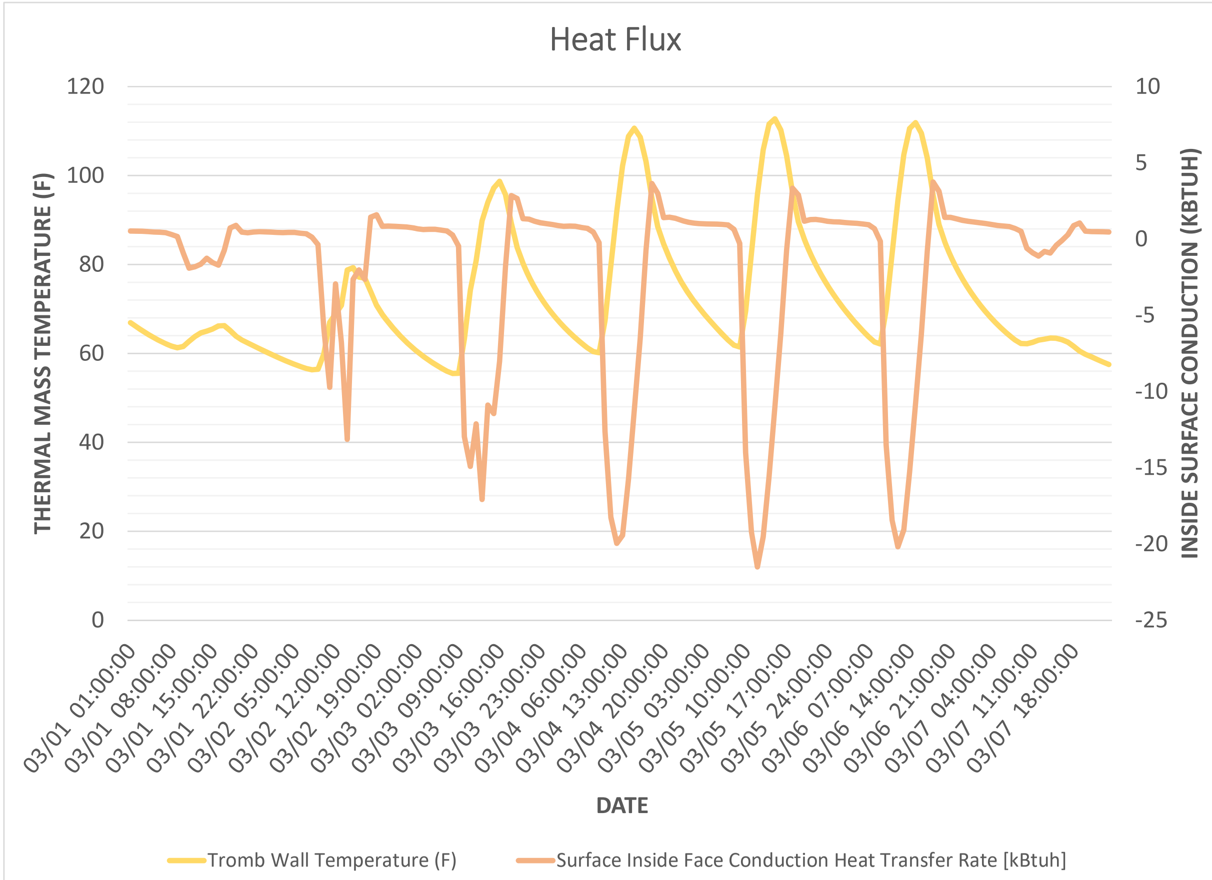
.03m^3 volume/ 5m^2= **6 cm of mass needed**

[ENERGY MODEL]



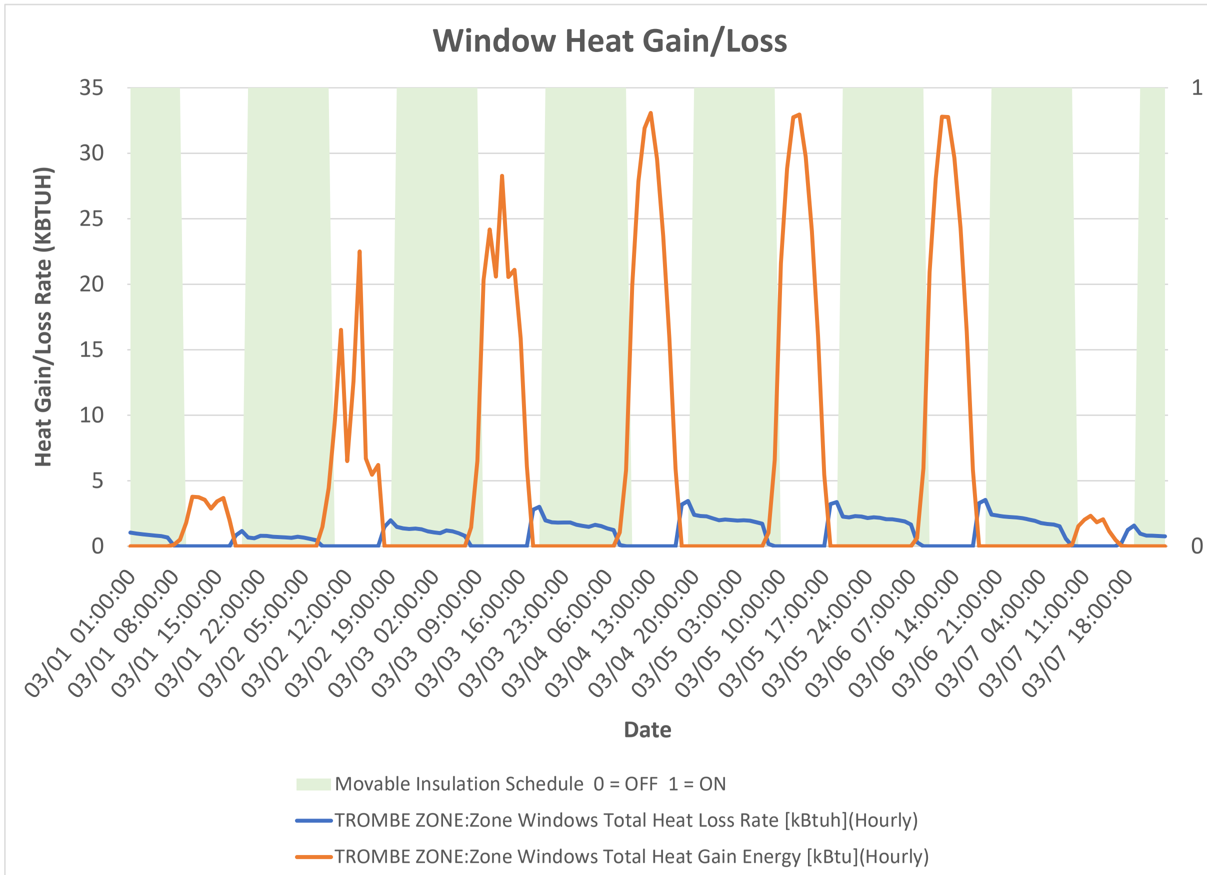
- The trombe wall rapidly absorbs heat throughout the day
- Then the heat is released during the evening when people are still awake and outdoor temperatures begin to drop
- Throughout the night temperatures sometimes drop below 60°F, but this is when people are sleeping and are bundled up

[ENERGY MODEL]



- The trombe wall heat transfer is highest during late afternoon to early evening
- The trombe wall continues to transfer heat consistantly throughout the evening and night
- During the day when solar radiation and temperatures are higher the trombe wall is absorbing heat instead of releasing it to the space

[ENERGY MODEL]



- Green area shows when movable insullation is deployed
- The heat gain is maximized during the day when temperatures and solar radiation are higher
- Due to infiltration and losses of efficiency some heat will be lost during the nighttime.

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