Passive Heating Strategies for La Pine, Oregon

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UNIVERSITY OF OREGON

LA PINE OREGON

SCI Sustainable Cities Initiative

SCYP Sustainable City Year Program

Acknowledgements

The authors would like to acknowledge and thank the City of La Pine for contributing to the development of this project and providing insight into the possibilities and goals of sustainable development in La Pine. The meetings and information provided by the city made the development of and learning through the project possible. We would like to thank particular people for their contributions to the project.

Dennis Scott - Mayor of La Pine

Cory Misley - La Pine City Manager

In addition, we would like to thank the La Pine's planning department staff who gave us feedback on our work at the final presentation and the community members for welcoming us and showing interest in the project.

About SCI

The Sustainable Cities Initiative (SCI) is a cross-disciplinary organization at the University of Oregon that promotes education, service, public outreach, and research on the design and development of sustainable cities. We are redefining higher education for the public good and catalyzing community change toward sustainability. Our work addresses sustainability at multiple scales and emerges from the conviction that creating the sustainable city cannot happen within any single discipline. SCI is grounded in cross-disciplinary engagement as the key strategy for improving community sustainability. Our work connects student energy, 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.

SCI Directors and Staff

Marc Schlossberg, SCI Co-Director, and Professor of Planning, Public Policy, and Management, University of Oregon

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About La Pine

La Pine is a small Central Oregon community located in Deschutes County. In the foothills of the Cascade Mountains, La Pine is surrounded by open meadows, lakes, and rivers. It has a long history dating back to French fur traders in the 1800s, but it was not until 2006 that the city formally incorporated. The seven square miles of La Pine represent the newest city in Oregon, and are home to a population of around 2,000 residents. According to the La Pine Chamber of Commerce, Deschutes County has experienced the most rapid growth of any county in Oregon over the last decade. La Pine itself is experiencing significant growth in both population and economics. Key industries contributing to this growth include technology and biotech, recreational and outdoor gear manufacturing, brewing and data centers. As an emerging Oregon city, La Pine is in a unique position to develop and enact sustainable practices for its future.

La Pine is the first ever Small City Pilot for the University of Oregon Sustainable Cities Initiative's Sustainable City Year Program (SCYP). Through this partnership, multiple university courses in areas such as journalism, business, architecture, and more have provided tangible recommendations for the city of La Pine to incorporate into its future development plans. As a small city, La Pine balances day-to-day needs and long-range planning, making it an ideal location for the infusion of energy and new ideas.

The SCYP Small Cities Pilot is made possible in part by a grant from The Ford Family Foundation. These initiatives and outcomes from participation with SCYP will help develop ideas that are cost-effective to build and operate, provide safe and convenient access, and achieve sustainability goals while supporting La Pine's projected growth in population

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

Course Participants

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Executive Summary

The City of La Pine partnered with the University of Oregon's Architecture and Environmental Science Departments through the Sustainable City Year Program to develop implementation strategies for passive heating and environmentally conscious design. The City asked students to focus on ideas for a City Center, Balcony Sunspaces and a Community Greenhouse. Seven student teams explored the potential for each project type. Two or more groups were assigned to each project type to generate different design options.

The City Center designs were created by two teams; Team One: Jared Dukes, Zoe Walker-Aparicio and Austin Daich; and Team Two: Courtney Cisler, Khiseth Abramvicka and James Li.

The Community Greenhouse designs were generated by two teams; Team One: Gabe Haug, Zach Bradby, Kyomi Tamura and Kai Miyajima; and Team Two: Renee Dobre, Champe Holbeck and Ryan Mark.

The Balcony Sunspace was the only project with three groups, as the teams were groups of two. Spencer Boragine and Josh Rosenthal worked on a shaded version of this project, as did Achyuthan Ramaswamy and Matt Olney. Pippa Bailey and Rowan Atherley designed ideas for an unshaded version of the project.

All seven teams created site analysis documents, discovered optimal glass tilts, thermal goals, designed the building and movable insulation and calculated the thermal mass and glass sizing requirements. This report explains the specific passive heating strategies for each unique project and how they can be applied to other structures in La Pine.

Introduction

The growing city of La Pine strives to set an example for sustainable city development. As the community grows so does the need for additional infrastructure. This led La Pine explore design options for a City Center, a Community Greenhouse, and prototype Balcony Sunspaces for multi-family housing.

The goal of passive heating is to harness the energy of the sun to heat spaces without the use of electrical heating systems, or to at least significantly reduce the need for them. Through the use of thermal mass, tilted glass, movable insulation, building orientation, and ventilation, a building can reduce its carbon footprint. According to the U.S. Green Building Council, the operation of buildings contributes about 40% of carbon emissions. If cities like La Pine can use sustainable strategies like passive heating, global carbon emissions can be reduced. La Pine is interested in testing these ideas in three different areas of development, with a public City Center, a shared Community Greenhouse, and housing focused Balcony Sunspaces.

After being introduced to the goals of each project type, student teams identified strategies based on site location, sun orientation, shading, and access. Each project type was designed by two or more student groups to provide a wider range of options for La Pine to consider. The focus was on more technical aspects of passive heating to inform the physical designs of each project. This impacted the appearance in regards to glass tilting, roof pitch, movable insulation, shading, user controls, and the depth and/or width of the space. The students used site context to respect the current design preferences of the community and illustrate that sustainable design is not exclusively entwined with modern design.

This report offers design options and recommendations for three different project types and overall strategies for passive heating in La Pine. Along with visual representations of each project, students created energy models to predict the performance of their designs. The research that went into these models was compiled using information gathered in La Pine and with assistance from programs like EnergyPlus™ and Climate Consultant 6.0. This report synthesizes the complex, technical data into concrete applications for current and future development in La Pine.

Background

La Pine's Climate

La Pine is in a mountain plateau area in the middle of Oregon with an elevation of 4,236 feet above sea level. Weather patterns in this area are influenced by the elevation and surrounding mountains. In winter, precipitation is more likely to be snow than rain, compared to its counterparts at lower elevations. It also gets more sun than lower counterparts to the west. July and August are the warmest two months where the average high temperature is just above 80˚F, with June coming up close as the next warmest month. April, May, June, September, and October are cooler than July and August with an average high temperature in the 60˚F and 70˚Fs, but warmer than the coolest months with an average total temperature of between 50˚F and 60˚F. March starts to cool down a bit, getting closer to the coolest months, November through February, which have average total temperatures in the low 30˚Fs. Therefore, the heating season is September through May or June depending on the goal temperature of the space (through June for a higher goal temperature and through May if the goal temperature is a bit lower).

Another element of La Pine's climate is its cloud cover levels. November through March average above 60% cloud cover; April and May above 50%; and June through October is under 50% (as low as an average of 20%). This is just an indicator of how often solar radiation is diffuse versus direct, which does not necessarily have a large effect on the capabilities of passive heating design in La Pine.

A climate characteristic that is important for both heating and cooling, depending on how the design needs to address it, is wind. Winter winds come primarily from the south and summer winds primarily from the northwest. Windspeeds average between 5 and 10 mph throughout the year.

Trees also hold importance for both heating and cooling as they block sunlight. This can be advantageous when sunlight is not desired, but presents challenges in situations where direct sunlight is needed. There are primarily pine trees in the region, which are coniferous trees, meaning they do not lose their leaves. These trees have between about 50 and 75% density, which means that when they are shading a space, they are blocking much of the direct sunlight.

Passive Heating Design Elements

Solar Analysis

The sun is the primary instrument for heating a space passively, which requires many considerations, such as shading elements, solar radiation levels, sun azimuth, and altitude angles throughout the year. All of this information can be used to determine the orientation of a space, the optimal angle of glass, the necessary amount of glass, the type of glass, and glass treatments that are needed throughout the heating months of the year.

First, the orientation of the building, or space, needs to be determined. This is often found to be due south in the Northern Hemisphere, but is also dependent on shading elements around the site and where the most sunlight access is. In order to determine this a pathfinder—a mechanism that reflects the surrounding elements onto a sun path chart—can be used to analyze where and when elements surrounding the site will block the sun (Figure 1). This will lead to an optimized building orientation with the least amount of elements blocking the sun.

Sun altitude, the angle the sun is above the horizon, and azimuth, the angle of the sun along the horizontal ranging between east and west of true south, change throughout the year (Figure 2). Altitudes, along with solar radiation measurements at different tilts (Figure 3), determine the optimal tilt for glass in order to allow the greatest solar access. Solar radiation information that measures both diffuse and direct radiation can be found through universal climate measurement data online or in applications like Climate Consultant. The altitudes for La Pine, measured at noon, range from 22˚ on the winter solstice (December 21) to 70˚ on the summer solstice (June 21). While it is not strictly necessary to tilt the solar-collecting glass for passive design, tilted glass provides the greatest solar energy gain per square foot of glass. In a sunny climate like La Pine's, vertical glass can also be effective if the area is enlarged as described below.

After determining the tilt, the necessary amount of glass can be established. This requires a comparison of the solar radiation gains for each potential glass area to the heating need for that space. The heating need is determined based on the goal for the minimum temperature of the space and how many days need heat to reach this temperature, referred to as the heating degree days (HDD). The ideal glass area can be chosen based on which glass area collects the right amount of solar radiation to cover as much of the heating need as desired. There are reasons, such as cost, lack of insulation on glass and summer heat gain, to choose a smaller glass area that does not necessarily cover all of the heating need but just most of it.

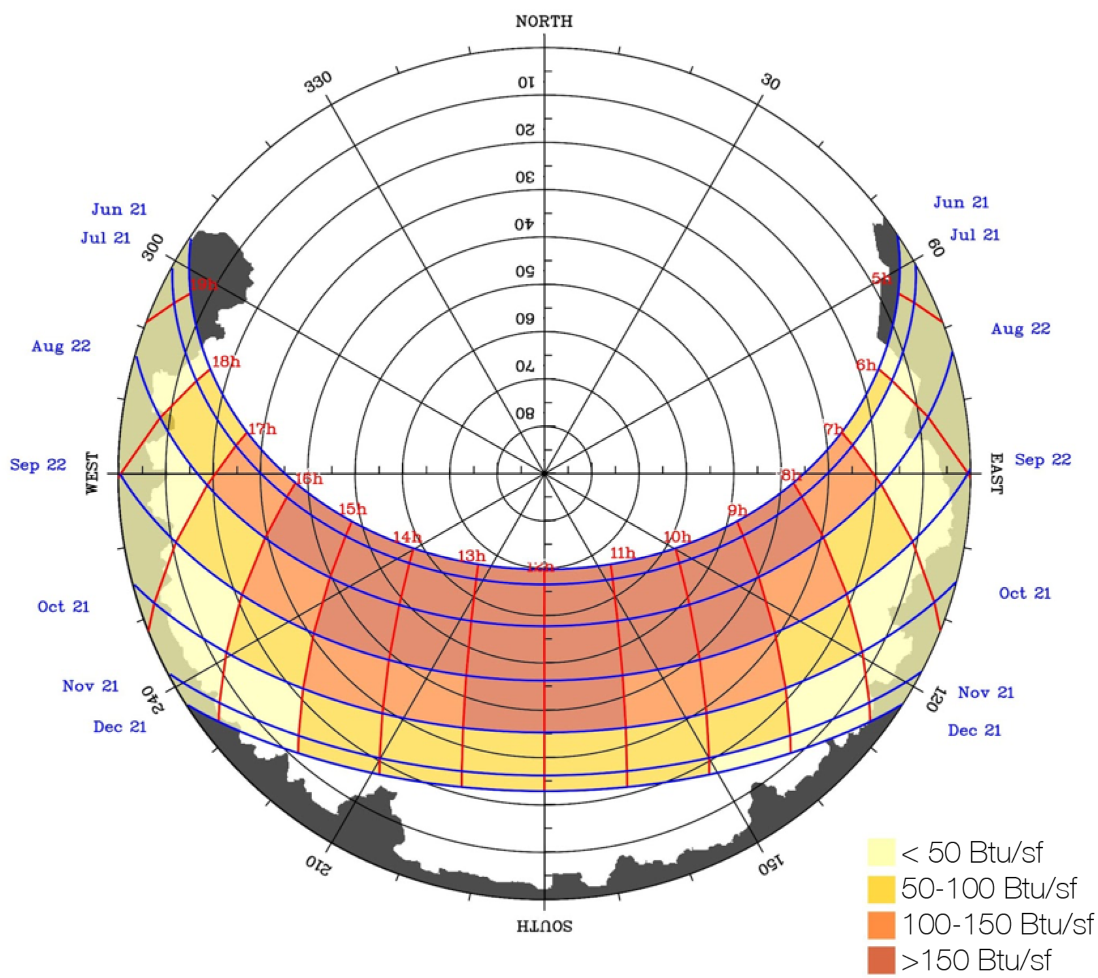


Figure 1: An example of a sun path shading chart for La Pine. The grey represents shading elements and the colors represent solar radiation. This shows that the shading elements are only shading right after sunrise and right before sunset all year.

Another important aspect of passive heating design is the glass type and treatment. Primary considerations for glass type are how much light they let through, transmittance, and how insulating they are. The more insulated they are, typically the less transmittance there is, but these decisions are made based on how much light needs to make it through the glass, particularly for thermal mass systems, and if there is any movable insulation.

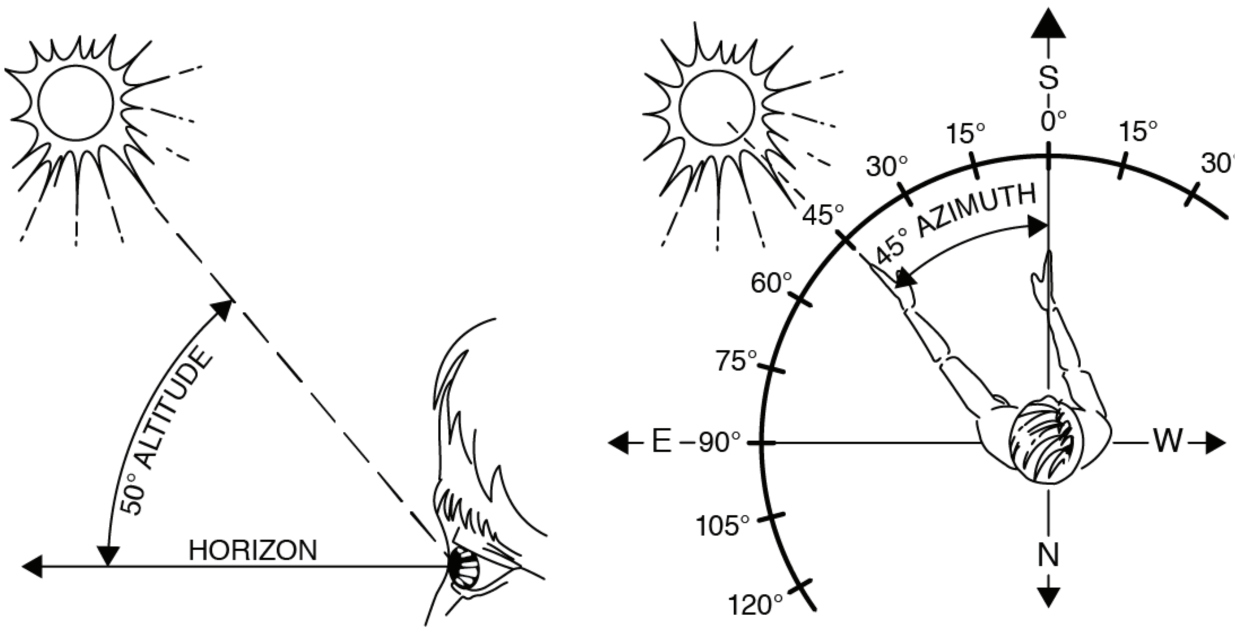


Figure 2: Visualization of azimuth and altitude angles (Grondzik and Kwok, page 175).

Radiation Energy at Tilts (degrees above horizontal)

	90	80	70	60	50	40	30	20	10	0
January	90	94	97	97	94	89	82	73	62	50
February	91	98	103	105	104	101	95	87	77	65
March	113	127	138	145	149	150	147	140	130	117
April	110	129	146	159	169	175	177	174	168	157
May	102	125	147	166	182	194	201	204	202	196
June	96	123	148	171	191	207	218	224	225	222
July	105	133	159	183	203	219	229	235	234	229
August	123	149	172	191	206	215	220	219	213	201
September	136	155	170	180	187	188	185	177	164	147
October	136	148	157	161	162	158	150	138	122	104
November	90	96	99	99	97	92	85	76	65	53
December	90	94	95	94	91	85	77	67	55	42

Figure 3: Solar radiation through glass at each of these angles. The solar radiations of each tilt, for the months that need heat, need to be added up where the tilt with the highest summer solar radiation indicates the optimal tilt.

Movable Insulation

In order to make up for the poor insulative quality of glass, movable insulation can be used. Movable insulation is insulation that can be added and removed to keep heat in the space during the times where it is not gaining heat from solar radiation. These systems vary in style, and can be automated or manual, but all share the common goal of insulating the glass at night. Movable insulation systems have not yet been widely commercialized, so must usually be custom designed. The upside to this is that the system can be designed specifically to the windows in the space, the aesthetic quality desired, and any multiple uses desired. Primary functioning considerations for creating a movable insulation system are the insulative value of the material(s), the way it seals along all edges to the window or surrounding walls, and how it is operated.

Thermal Mass

Thermal masses (Figure 4) are masses of material, typically a floor or wall, that collect and store heat from solar radiation and then radiate this heat back out of the material when it becomes warmer than its surroundings. These can be used as both cooling and heating elements. For cooling, a larger mass is more optimal; for heating, the mass needs to be big enough to heat when and how much is desired, but not too big that it cannot radiate enough heat back out. Thermal mass works best in direct sunlight, but still works under diffuse light. Many different materials, even water walls, where the wall has water inside it, can be used for a thermal mass wall or floor depending on what the goals are for the heating of the space by the wall. Thermal masses can be used to reheat the space they collect from or to heat spaces behind them that are not receiving direct heat. Vents, placed in the thermal mass wall between two spaces, can be used in combination with the mass wall to heat the space that is not receiving solar radiation directly. Vents are placed in a wall to transfer hot air from the warming space to the cool space and cool air back into the warming space. They can be set on a schedule to open depending on temperature in the warming space where the air, in addition to the wall, is heating up from direct solar radiation.

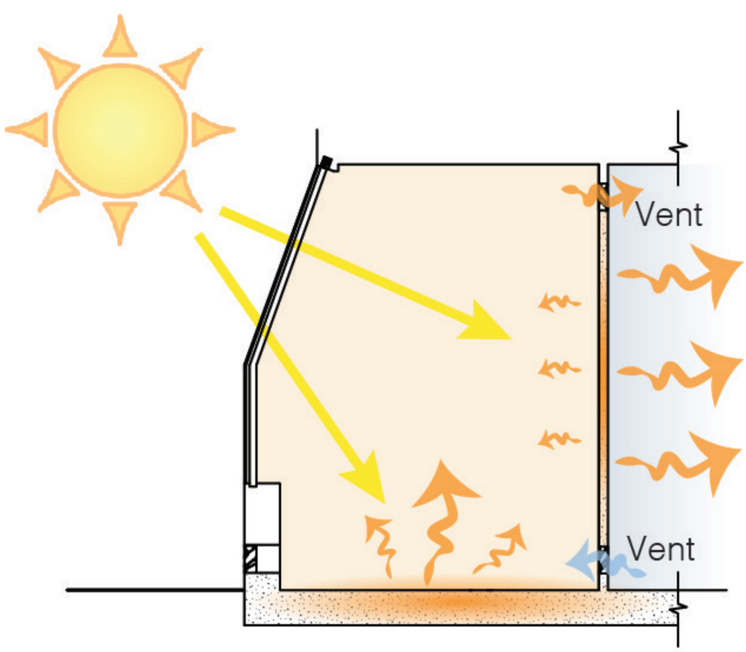


Figure 4: Thermal masses (orange) radiating heat collected from the sun into adjacent spaces. Vents allowing for warm air to travel into cooler space and cool air to be pushed back into the warming up space.

Overheating and Passive Cooling

Many passive heating systems can create spaces that sometimes overheat, particularly in warmer months. Primary strategies to deal with this are shading devices and operable windows for natural ventilation. Movable insulation, overhangs, and deciduous trees can be used to shade the spaces. In addition, windows can be operable, or there can be exterior vents, to either have natural ventilation across the space or stacked ventilation where cool air comes in the bottom and pushes warm air out of openings at the top (Figure 5).

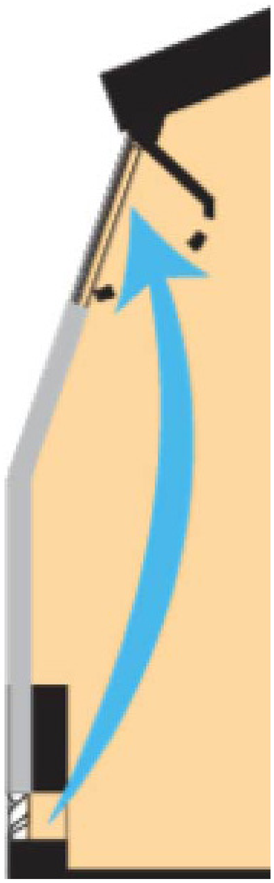


Figure 5: An example of stack natural ventilation where the cool air is coming in a vent at the bottom and, because hot air rises, hot air is being pushed out of an operable window at the top.

Analysis and Recommendations

Balcony Sunspaces

Introduction

Unlike the other project types, the Balcony Sunspaces are a prototype, meaning that these spaces will be designed as potential ways of retrofitting existing living units. The sunspaces are intended to promote passive solar heating in multi-family residential design and to provide additional outdoor-like living space in the cold winter climate. As an example, the Little Deschutes Lodge was chosen as the site and shaded/unshaded conditions were applied to the building. The Balcony Sunspaces will be small in square footage, only about 100-400 square foot per unit, but they will have extensive controls. Mid-State Electric Cooperative is highly interested in this project as it could help reduce energy loads in the growing city of La Pine.

Project Highlights

The Little Deschutes Lodge, a two-story apartment building, enabled the student teams to consider what a stacked sunspace system might look like and how to optimize it. Two of the groups determined that a 40˚angle was the optimal tilt when considering the entire heating season (September-June), while one group used a 70˚ angle as it was optimal for the coldest part of the heating season and reduced the solar gain in the cooling season.

Two of the student groups then used this optimal angle to pull the lower level unit out from above to increase available sunlight.

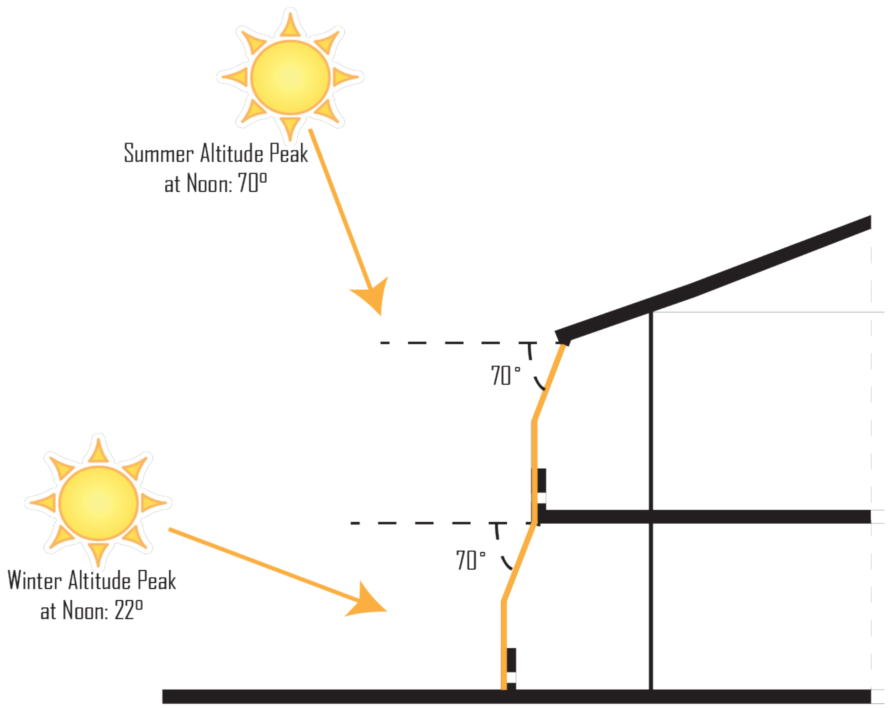


Figure 6: Little Deschutes Lodge with a 70° optimal tilt.

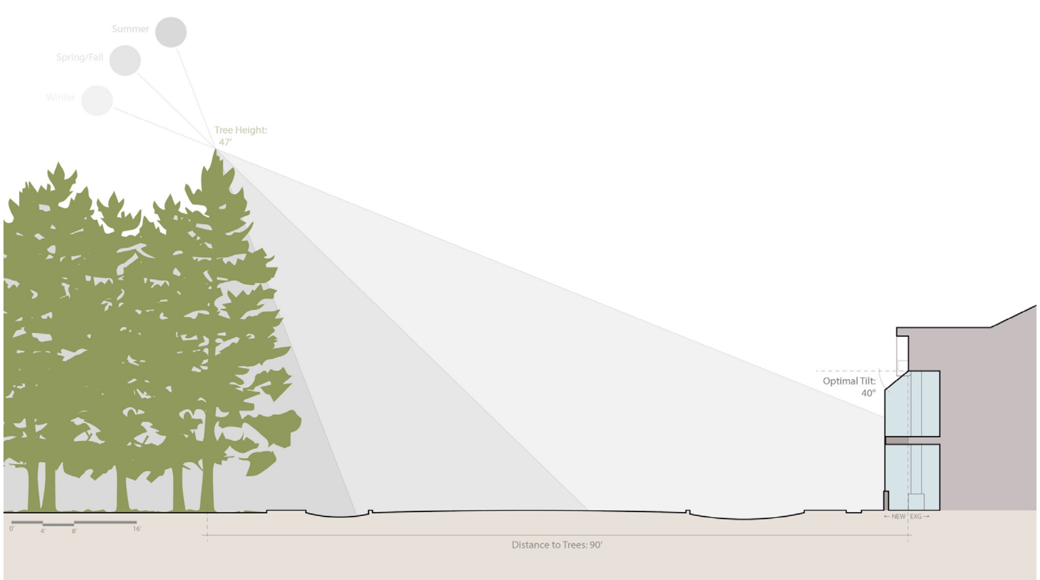


Figure 7: Little Deschutes Lodge with a 40° optimal tilt.

In order to provide shading in the summer and reduce heat loss in the winter, movable insulation shoulder be used with these sunspaces. Movable insulation is often custom made per project in order to guarantee the best fit for the site. As these sunspaces are attached to dwellings, each individual sunspace's insulation can be controlled by the user as necessary. The thickness of the insulation is dependent on the thermal abilities of the chosen material. Two of the groups created rolling movable insulation shades, while another offered a louvered panel design. This cooling mechanism will give occupants control of their environment and allow them to use the sunspaces as additional square footage in their units.

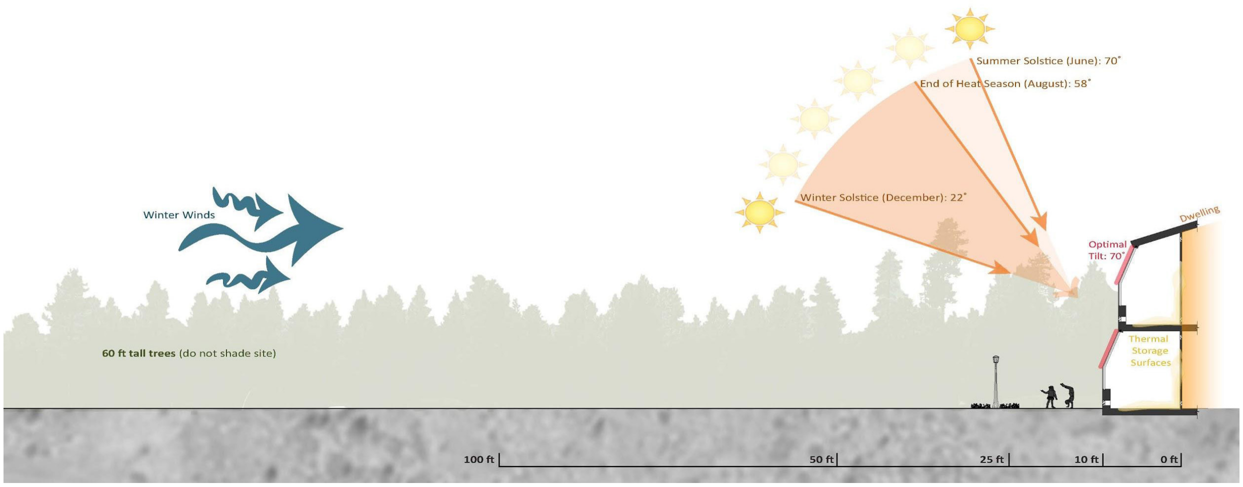


Figure 8: Cooling mechanisms for a 70° optimal tilt design.

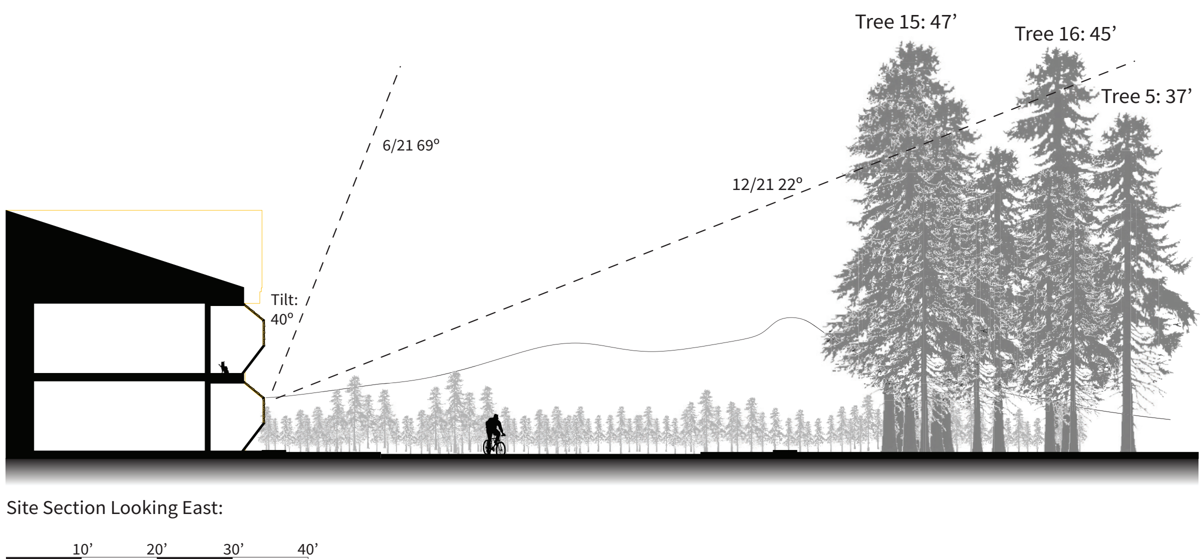


Figure 9 Cooling mechanisms for a 40° optimal tilt design.

Another method to control the temperature of the space is thermal massing. Based on the surface area of the sunspace, the concrete thermal mass will need to be approximately three inches thick. This will release heat in the evening as temperatures outside drop. The volume of the sunspace overall is quite small, only 100-400 square feet, which means that the thermal mass can be placed very near to the windows, preferably less than ten feet. Venting in the form of physical vents or operable windows, will be used to release heat in the summer and pull heat into the dwelling zone in the winter.

Recommendations for Balcony Sunspaces

- Pull lower levels out further than levels above to give them more access to sunlight.
- Have a concrete thermal mass of around three inches and locate it close enough to the windows (no more than 10') that it gets a reasonable amount of direct solar radiation to heat the dwelling behind the sunspace.

Community Greenhouse

To strengthen an existing community gathering space and to support the city's interest in growing food, La Pine asked the University of Oregon to produce ideas for a Community Greenhouse. For this project a site was chosen at the corner of Morson and Main Street, across from the La Pine Library and directly behind the La Pine Community Center. This section will explain the project in detail and provide specific recommendations.

Introduction/Explanation

In order to support sustainable living and promote community involvement, La Pine expressed interest in a Community Greenhouse. The site for this project is an existing, under-utilized gathering space that could improve with the addition of a greenhouse. Additional gardens could surround the greenouse, with casual seating to create a welcoming environment. Within approximately 1,000 square feet of space the minimum temperature will be 40 °F while the spring/fall temperatures will be controlled to prevent overheating. This Community Greenhouse is a high priority for La Pine as they continue to support community interest in growing food.

Project Highlights

Both teams determined that the greenhouse should be at least partially underground to take advantage of the consistent temperature and thermal qualities of the earth.

In addition to being subterranean, movable insulation will be required at night and during the winter seasons to prevent heat loss through the glass. The double pane glass will allow the ideal amount of solar heat gain through while also reducing the overall heat loss. Due to the optimal glass tilt existing between 50° and 60°, and the tailored nature of passive heating, the insulation system will need to be custom made. The team of Gabe, Kyomi, Kai, and Zach proposed a spring arm system that would allow the insulation to spread across the entire expanse of glass.

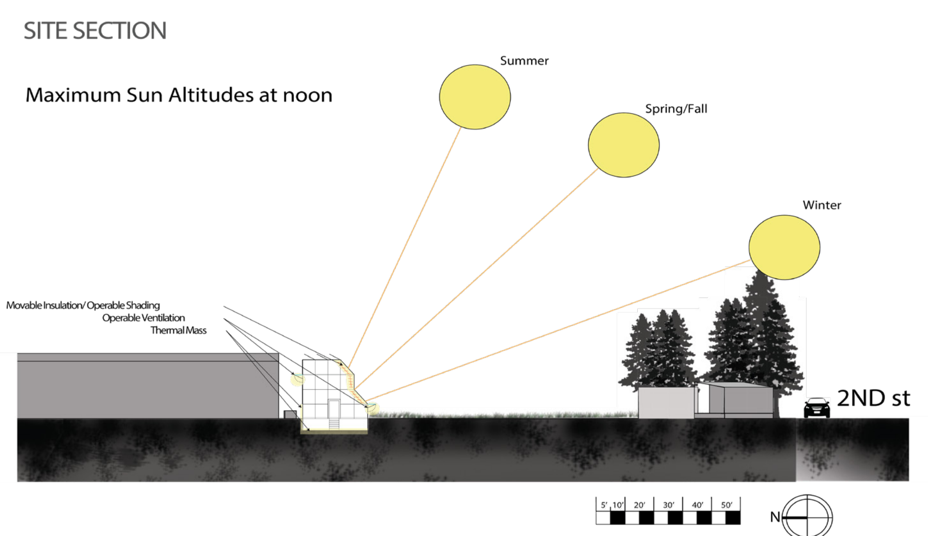


Figure 10: Maximum sun altitudes at noon throughout the year.

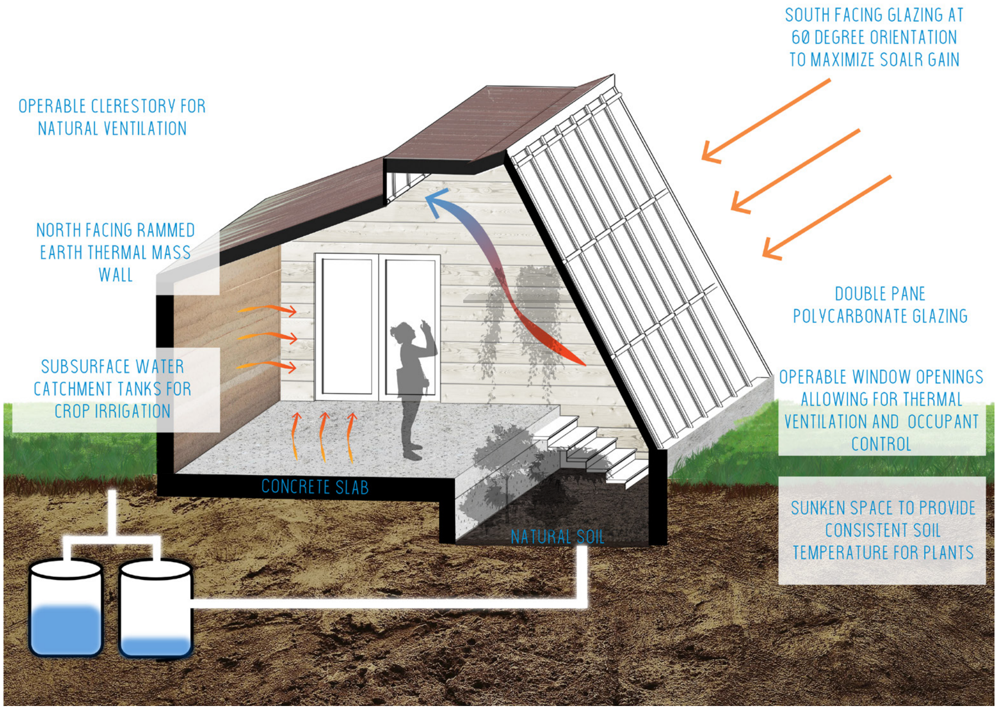


Figure 11: Passive heating methods that could be implemented in a La Pine community greenhouse.

The team of Renee, Ryan, and Champe proposed a louvered unit system that could be used to bring light further back into the space when needed.

The movable insulation only prevents heat loss; the thermal mass is required to absorb and retain energy until it is needed. Both teams discovered that with the subterranean floors, only approximately three inches of concrete thermal mass would be required and it does not need to cover the entire area of the greenhouse floor.

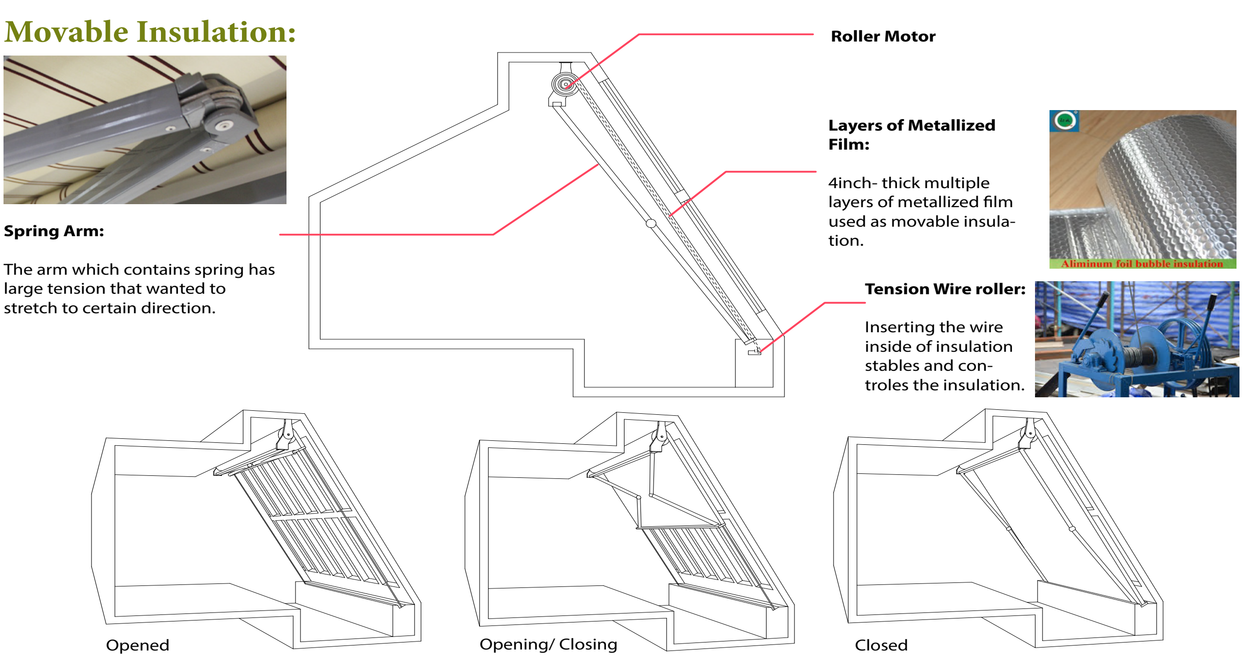


Figure 12: The spring arm system for movable insulation proposed by the team of Gabe, Kyomi, Kai, and Zach.

Venting through operable glass panels will be used to cool the greenhouse in the summer. This will enhance the comfort for users and keep the plants at an appropriate temperature.

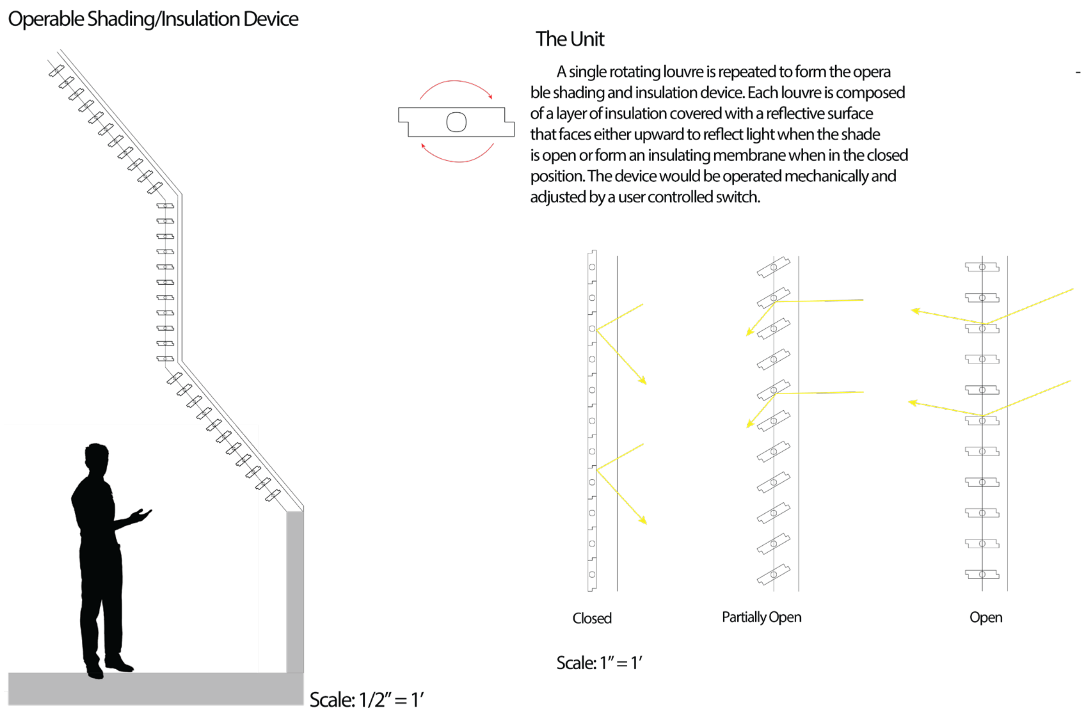


Figure 13: The louvered unit system for movable insulation proposed by the team of Renee, Ryan, and Champe.

Information about thermal mass		
Loamy moist soil		
Density	1600	kg.m^3
Heat Capacity	0.89	KJ/kgk
Solar absorbtance	0.7	
Total Surface area	118.916	m^2

February solar radiance		
Monthly (60)	105	Kwh/m^2
Daily	3.5	Kwh/m^2
Glazing cut	2.0755	Kwh/m^2
Total	80.98186	KWh
Convert	291534.7	KJ

February Temperature		
Warmest	12.7	C
Coolest	-8.9	C
Change	21.6	C

Glazing Information		
Area	600	ft^2
	55.74	m^2
Transmittance	0.407	

1. Total Solar radiance:

60 degree tilt Daily solar energy x Total glazing area x Transmittance

= 80.9

Conversion:

80.9 x 3600KJ

=291,534.7KJ

2. Desired temperature

Warmest - Coolest

= 21.6C

3. Thermal Mass thickness

{(1/Heat Capacity) x Solar Radiation}
Desired Temperature increase

= 15165.14 kg

15165.14 / Density / Total surface area

=0.08m

= 3.14 inch thickness

Figure 14: Solar radiance and thermal mass calculations for the community greenhouse.

Recommendations for Community Greenhouses

- Have a thin concrete thermal mass on at least part of the floor to radiate heat into the space at night.
- Have a portion of the greenhouse below grade to provide a consistent temperature from the ground.

City Center

Every developing city could utilize a central gathering space in the heart of their downtown. La Pine asked the University of Oregon to develop ideas for their proposed City Center. This site is bound by Huntington Road, 4th Street, and Dalles-California Highway. The city would like this project to act as a transportation hub and a social hub. This section will explain the project in detail and provide specific recommendations for designing a City Center on this site.

Introduction

La Pine is a growing city and as a part of this expansion the city is focused on connecting to the more developed cities nearby by promoting bus and shuttle transportation to Bend, Redmond, and Sisters. The City Center will serve as a town hub and open market with market booths, small eateries, and outdoor space. An enclosed building space of approximately 1,000 square feet will provide an area for commuters and visitors as they wait for the next bus. The site will need to include parking and landscaping to invite visitors to the center of La Pine. This project is of great importance to La Pine as they hope it will act as inspiration for other green design.

Highlights of Projects

The two teams generated different concepts for La Pine's City Center. Both teams came to a similar conclusion that the angle of the tilted glass should be between 50° and 60° and it should be double pane. This will create a warm, welcoming space for visitors while minimizing heat loss. The team of Courtney, Khiseth, and James proposed a sawtooth roof with skylights to help create natural feeling divisions throughout the building. The team of Jared, Zoe, and Austin proposed a series of pop-up skylights that would remain relatively unnoticed as they filter light through.

Because a City Center is not an ideal place for tilted glass, a significant portion of vertical glass was used in both designs. This inspired deep overhangs and custom movable insulation systems.

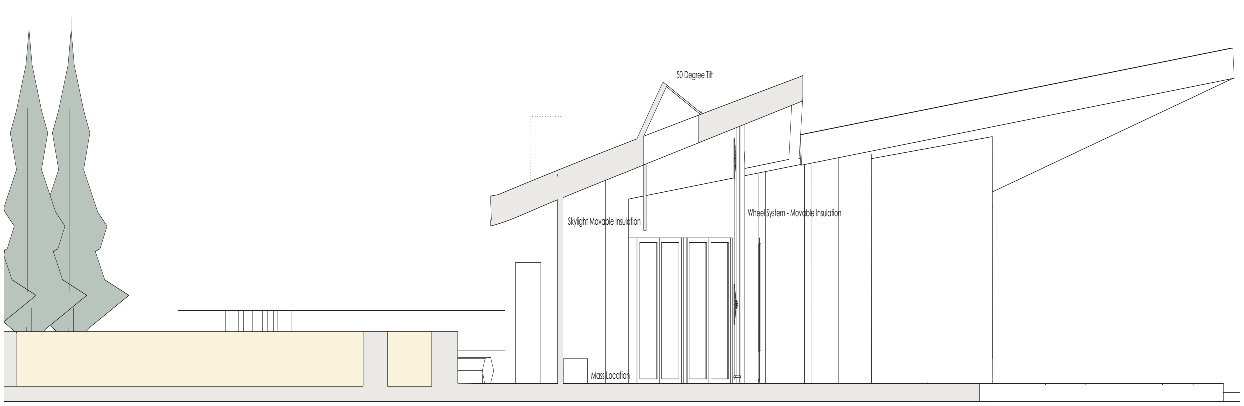


Figure 15: Partial section of La Pine City Center, including 50° tilted glass, skyliight movable insulation, and wheel system movable insulation.

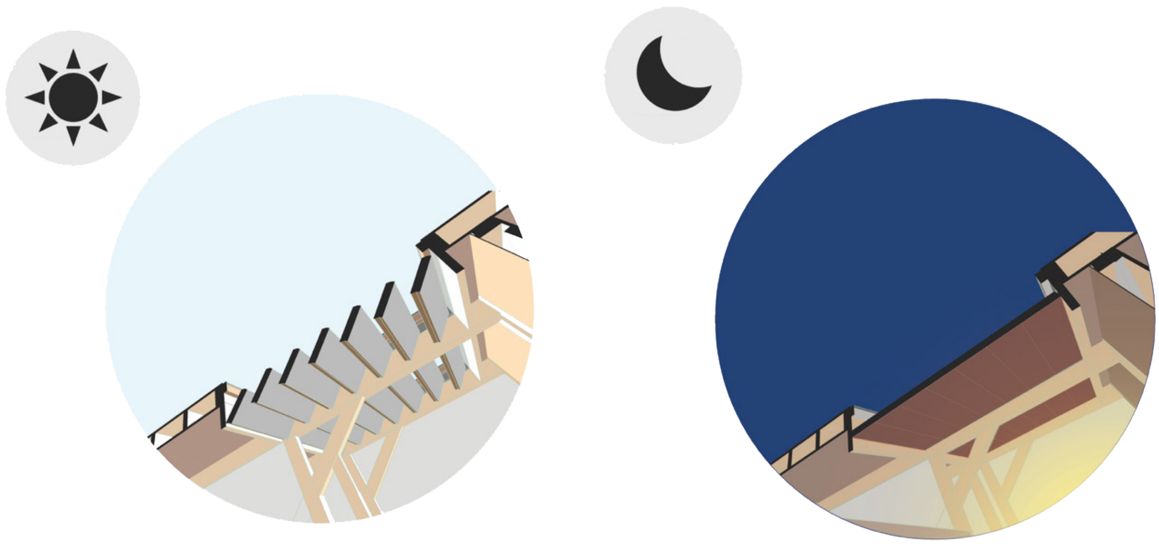


Figure 16: A sawtooth skylight design can be used to adjust solar heating and insulation throughout the day.

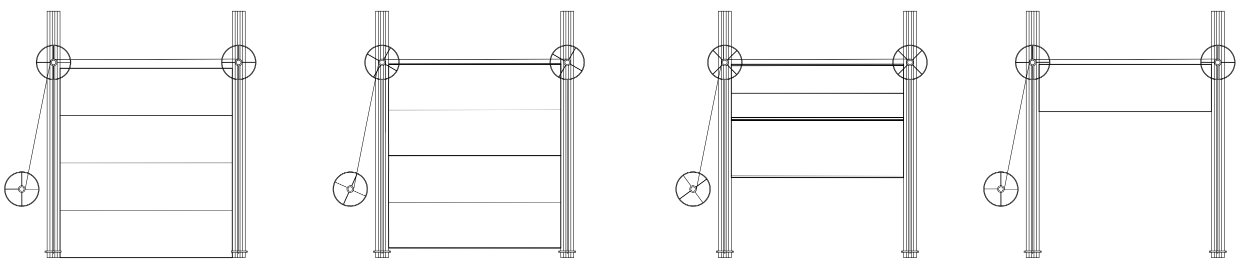


Figure 17: The wheel system of movable insulation is one potential mechanism that can be used to adjust insulation throughout the day.

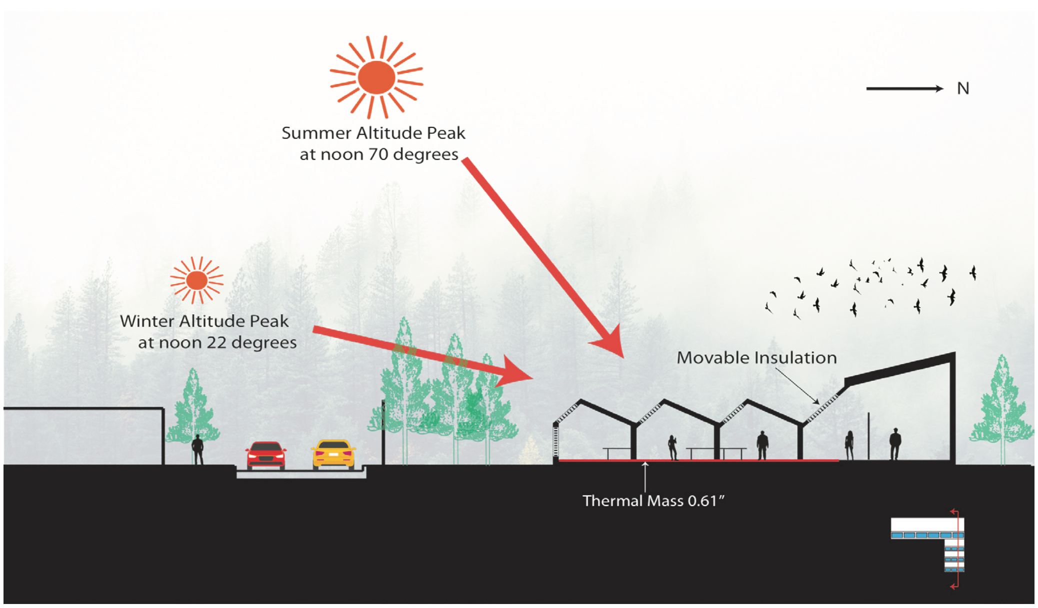


Figure 18: Sun altitude peaks throughout the year.

Due to the large square footage of the overall building, the City Center only requires about an inch of concrete thermal mass. This provides a quick release of heat and it will allow the building to maintain a relatively constant temperature. In addition to this, operable doors and windows were designed to act as a ventilation system and a way for visitors to appreciate the views of La Pine.

Recommendations for City Center

- Movable insulation system should be automated so that it works efficiently in a large, public place.
- Have a thin concrete thermal mass (around one inch, depending on the surface area of the mass) on the floor.
- Place large overhangs where appropriate for sheltering bus station areas and to shade the interior for the warmer summer months.

General Recommendations for Passive Heating Projects

Tilt glass between 50˚ and 70˚ (depending on cooling strategies and aesthetics) as the optimal tilt for gaining enough solar radiation in the coldest months while gaining less in the warmest months.

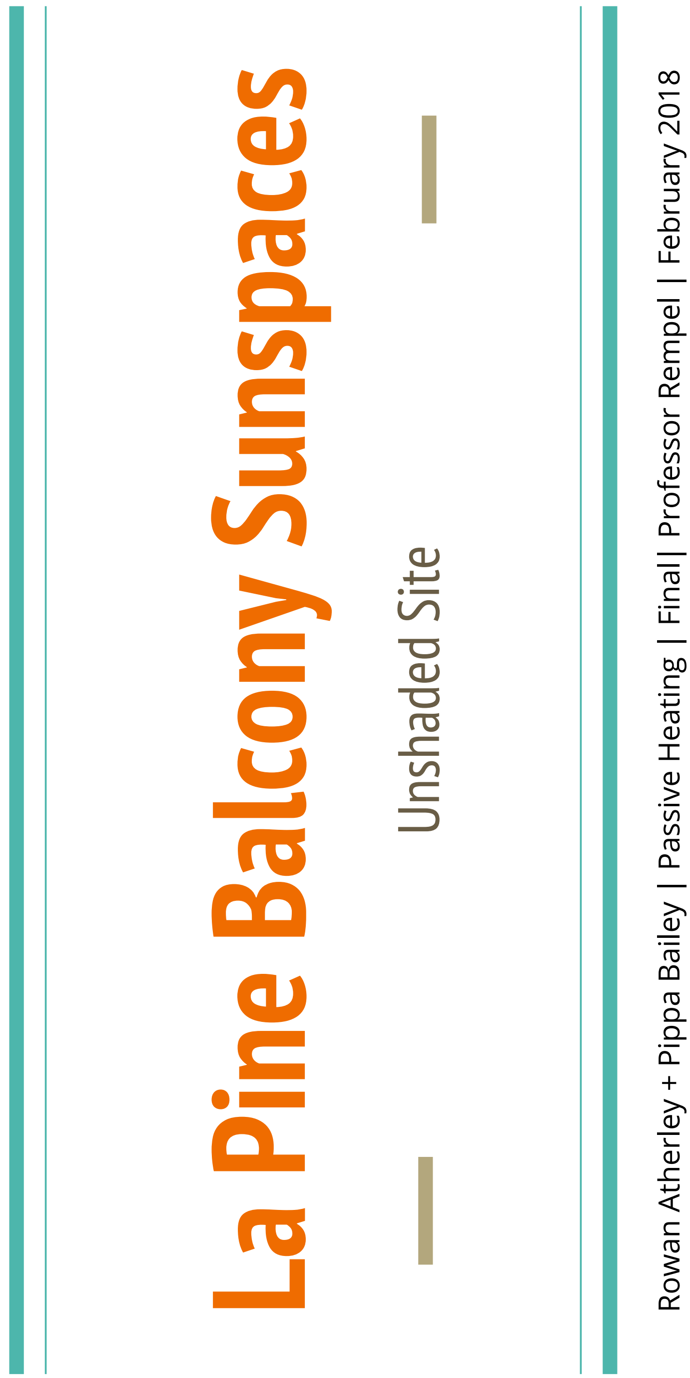
- Use a combination of double pane glass and movable insulation to insulate the windows when the space is not gaining heat, and manipulate movable insulation to act as shading when space is gaining too much heat.
- Use operable windows and vents, either across the space from each other or stacked on top of each other, to cool the space when it overheats (in winter and summer) and to give occupants more control over the environment.

Figure 19: Rendering of a possible design for the La Pine City Center.

Conclusion

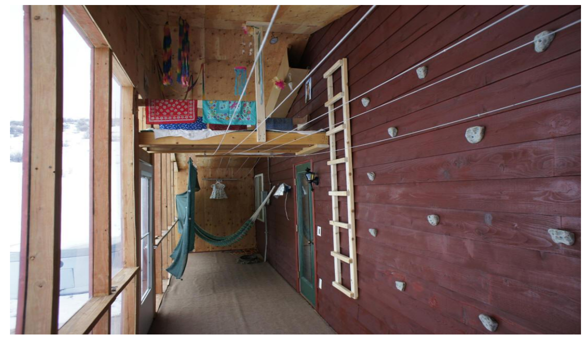
The City of La Pine is an ideal climate for passive heating strategies. Passive heating is a simple way for cities to reduce their carbon footprint and limit their need for electrical heating systems. By researching project types that include public and private spaces, La Pine can gain a sense of what is required to alter existing buildings or build new structures. For any future passive house project in La Pine, the research reveals that glass should be double pane, and tilted between 50˚ and 70˚, with custom movable insulation systems, venting and thermal mass appropriate for the square footage. Through thoughtful design, the City of La Pine has the potential to inspire other developing cities to make sustainable design a priority.

Appendix A: Balcony Sunspaces Presentations



Design Intent: Precedents

Mike's Low Thermal Mass, Many Purpose Sunspace (in the Colorado Mountains)



http://www.builditsolar.com/Projects/Sunspace/MikeSunspace/MikeSunspace.htm

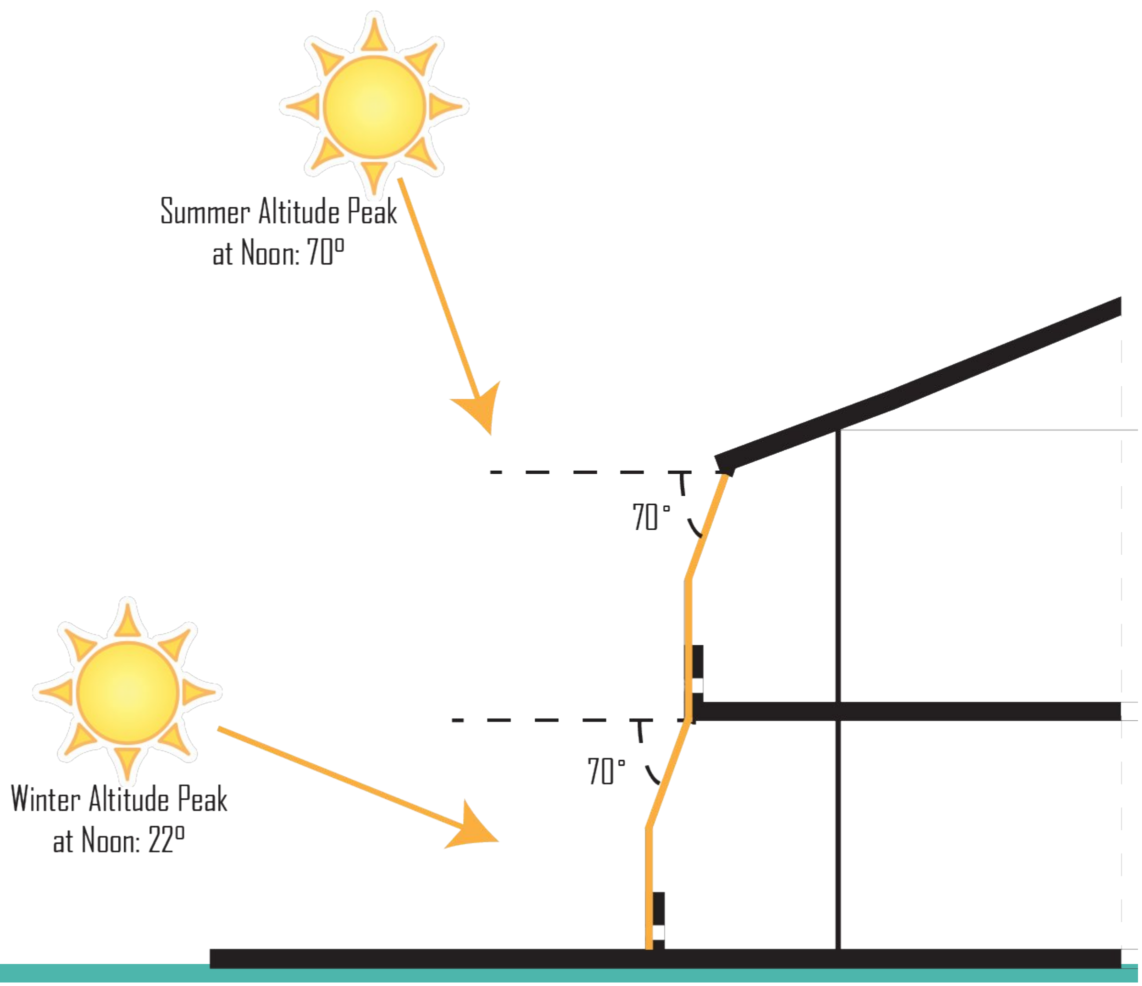
Design Intent: Precedents

functional balcony indoor/outdoor space

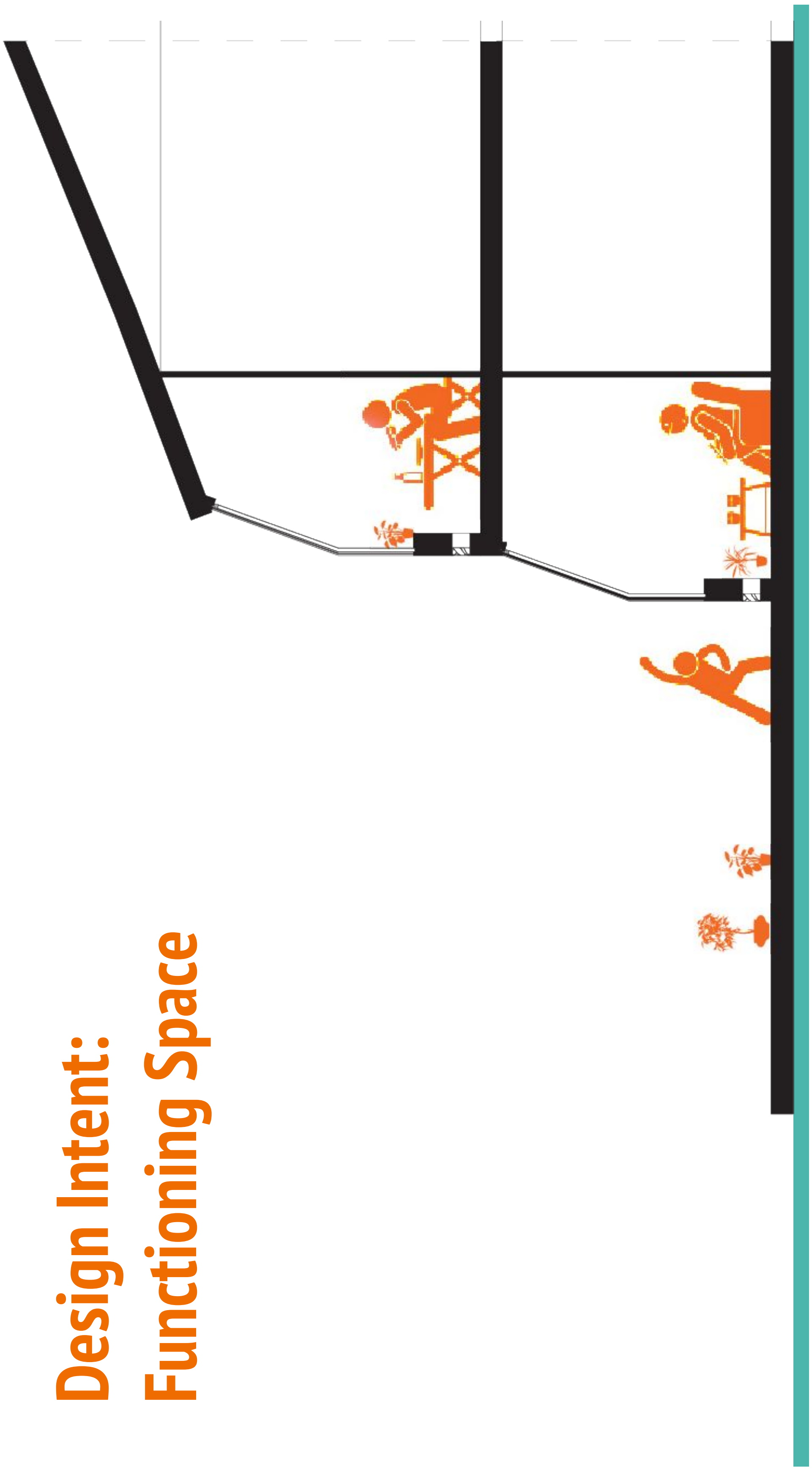
stacking sunspaces for access to light on both levels

interior space with **primarily glass wall and roof**

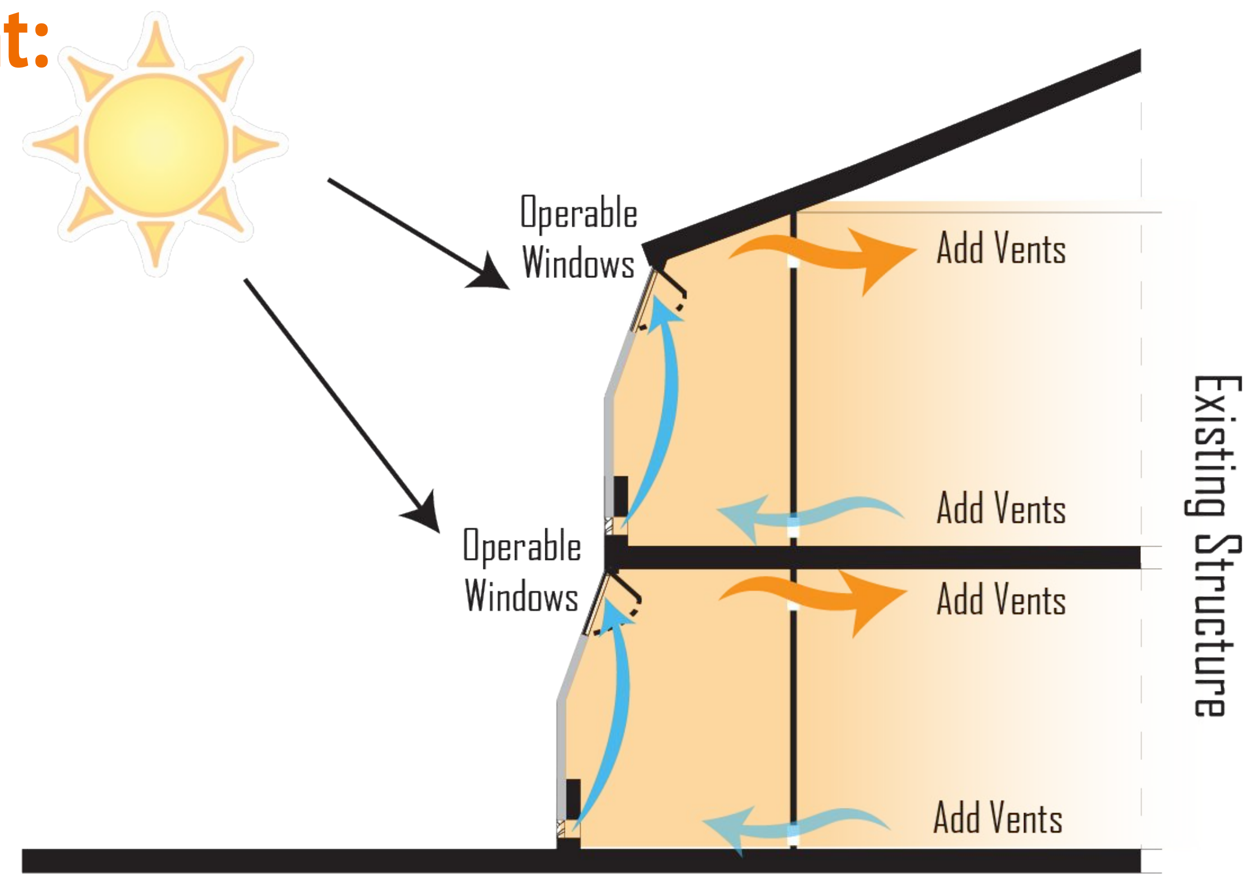
Design Intent: Form Generated by Sun Angles



Design Intent: Functioning Space

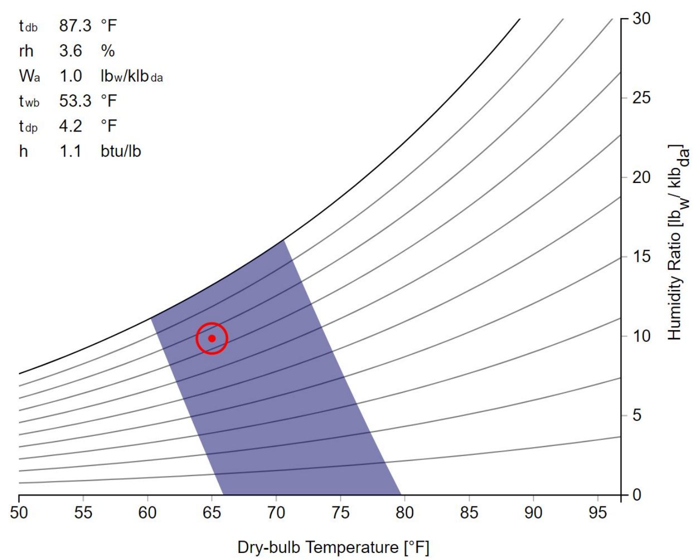


Design Intent: Heat Flow



Design Intent: Goals for Thermal Comfort

- To create an indoor space that feels like an outdoor space
  - A warm space (with direct sunlight) in the winter
  - A cool space (with a breeze) in the summer
  - Easy for user to adjust
- Thermal Delight:
  - Operable Windows
  - Shading Devices
- Considerations:
  - Movable Insulation
  - Solar Resources Available for 1st Level Residences
  - Heat needs to penetrate back to dwellings

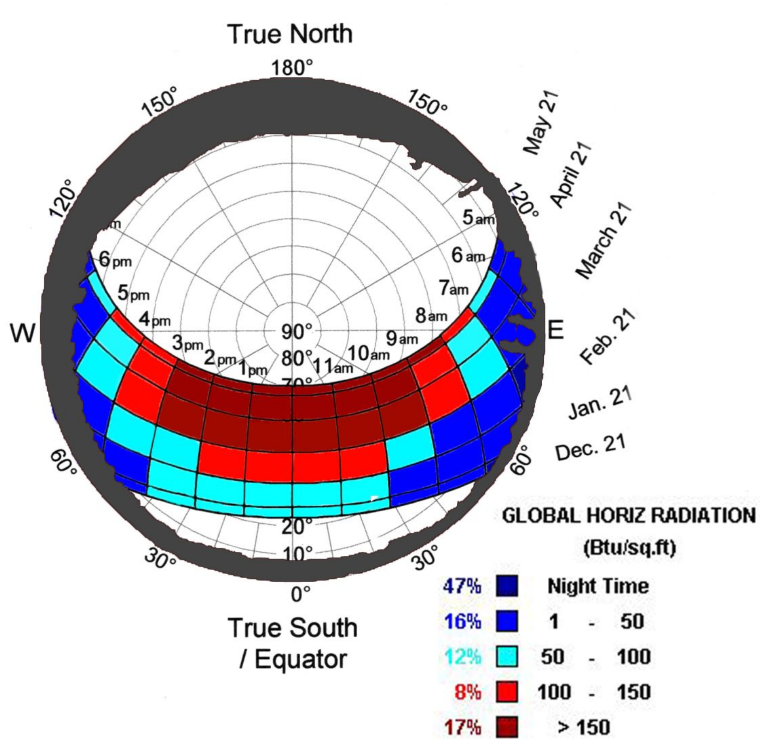


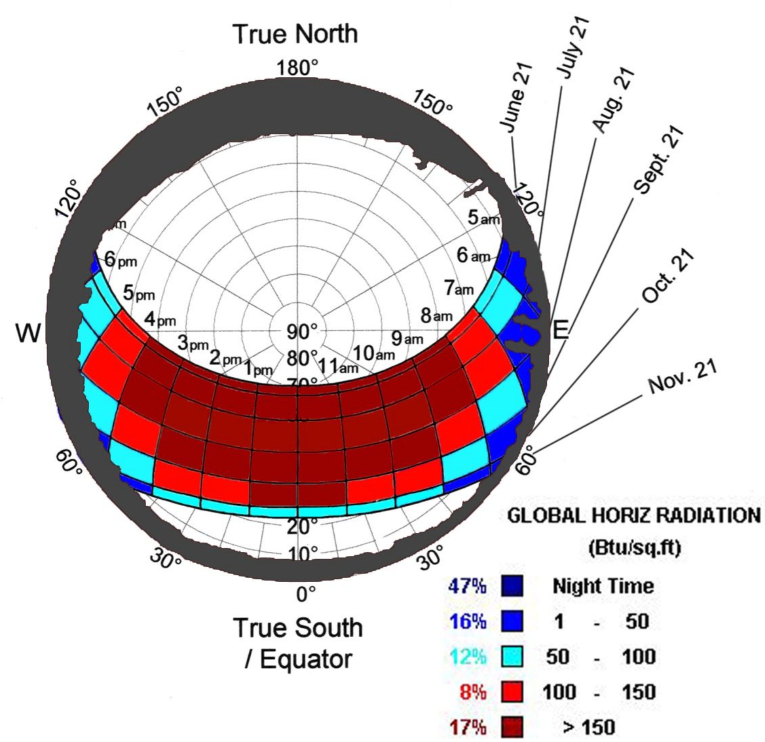
Design Intent: Goals for Heat Delivery Patterns

- **Sunspace is warm in morning,** because air starts heating up with sunrise, while **dwelling is still cold in morning**
- Heat delivered to dwelling through thermal mass starting mid-day, but primarily in **late afternoon and evening,** which means:
  - getting wall temperature to between ~ 100℉ - 120℉
  - material with fairly high conductivity
  - fairly thin thermal mass
- Movable insulation will be automated to come on around sunset (when space starts losing heat) and come off around sunrise (when space starts gaining heat)

Solar Site Survey: Pathfinder

Solar Site Survey: Solar Resources + Shading



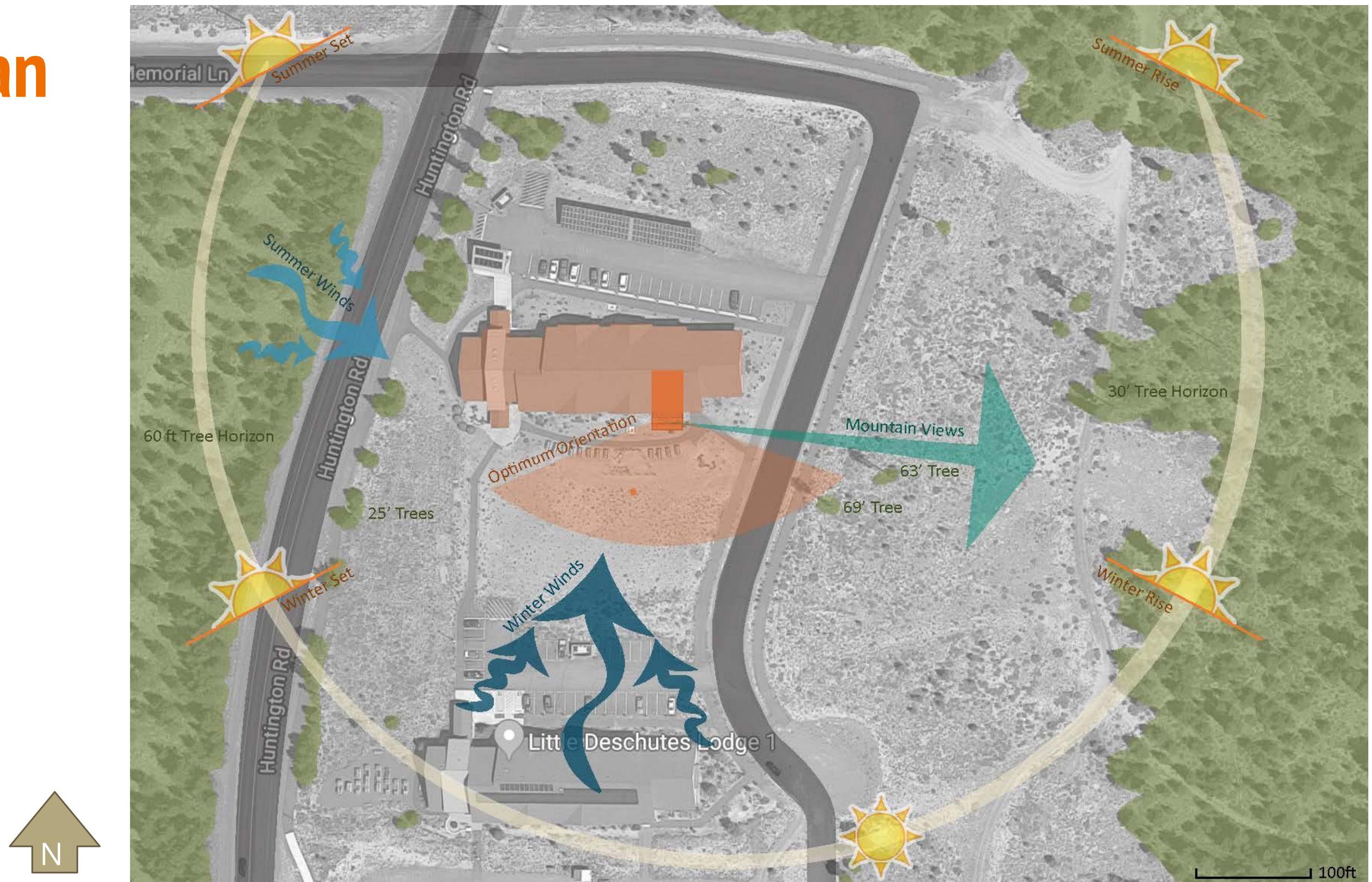


Solar Site Survey: Trees

Lodgepole Pine
Coniferous
50-60% density

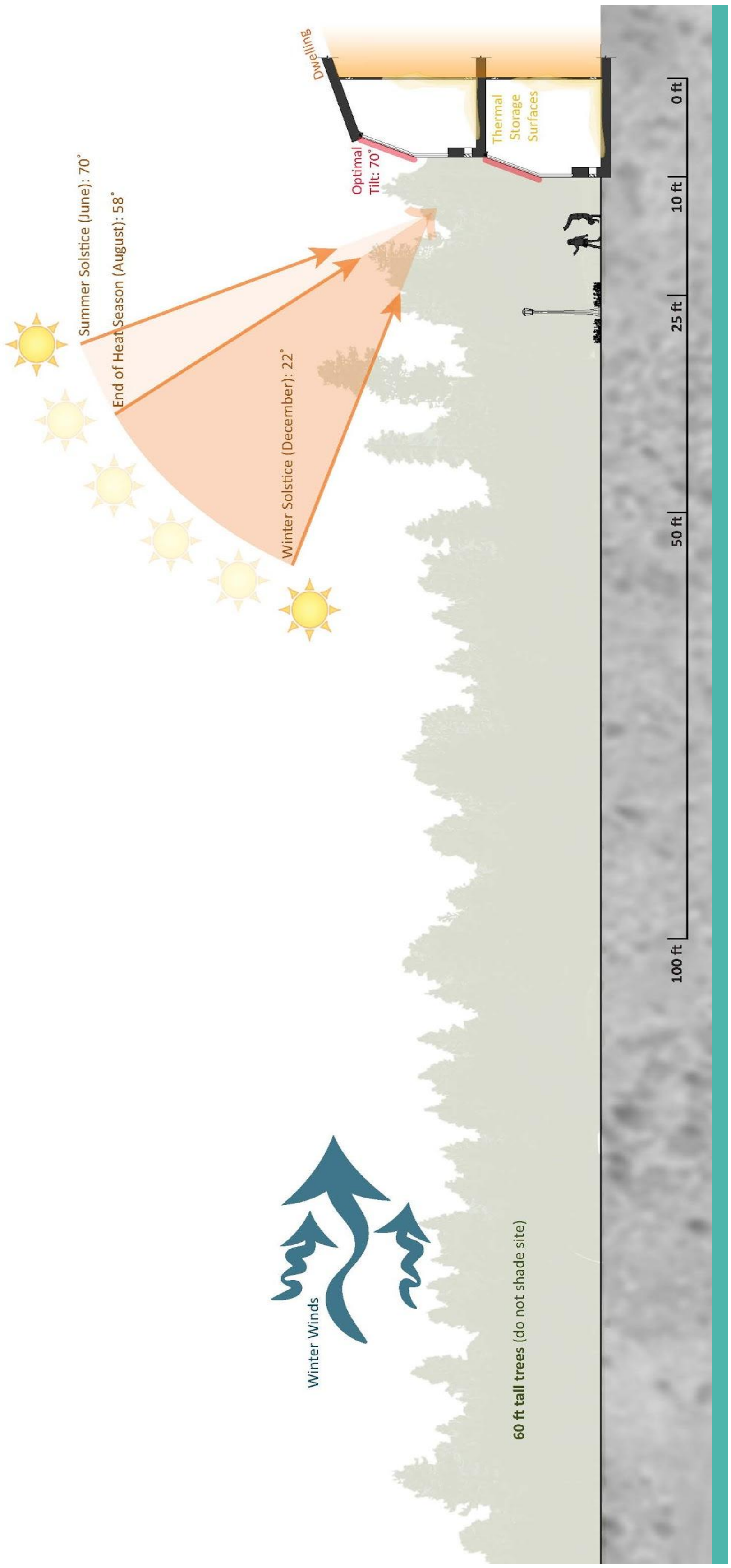
Scotch Pine
Coniferous
70-80% density

Site Plan

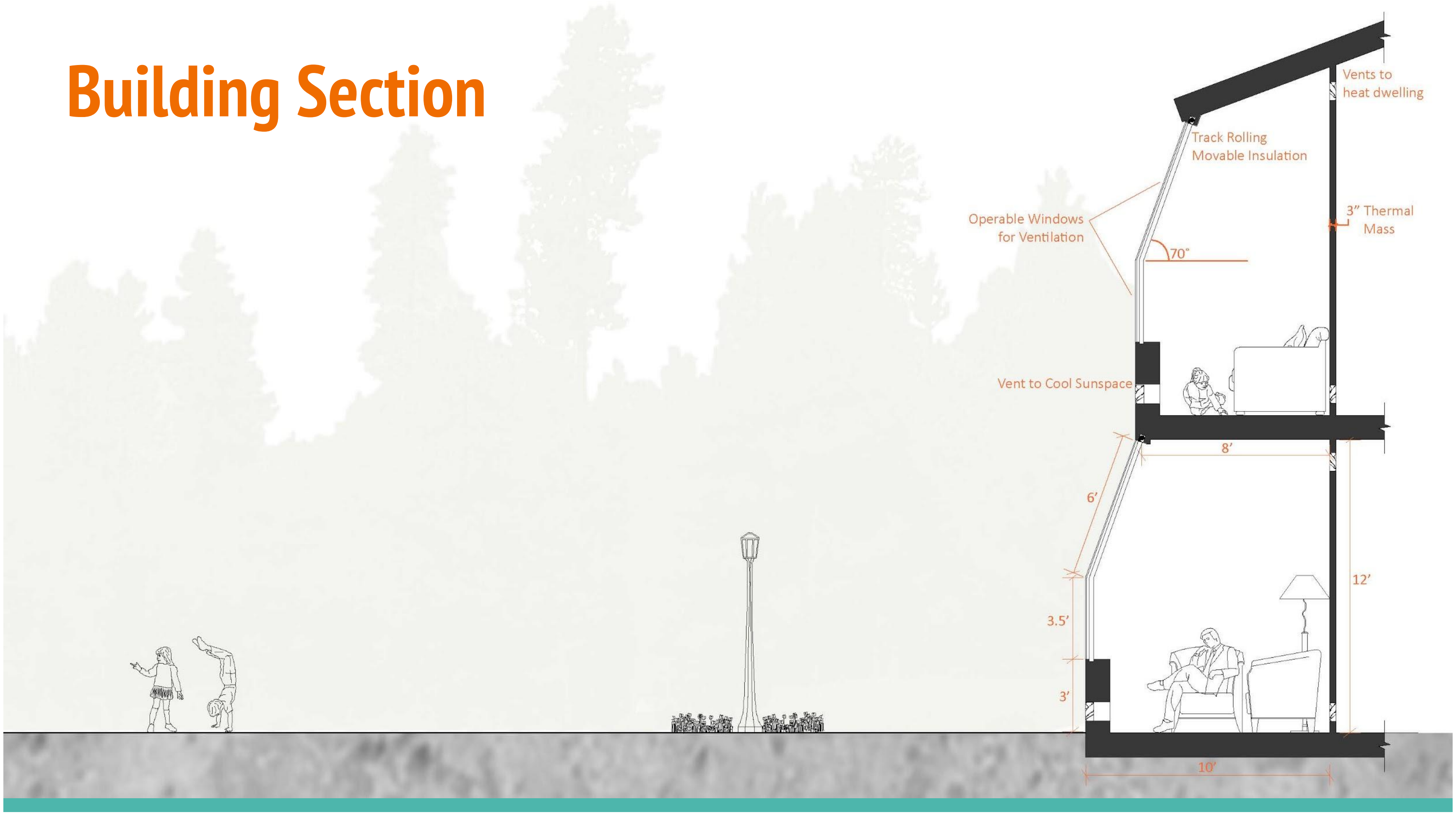


Summer Set
Summer Rise
Winter Set
Winter Rise
Memorial Ln
Huntington Rd
Huntington Rd
Huntington Rd
Summer Winds
Winter Winds
60 ft Tree Horizon
30' Tree Horizon
25' Trees
63' Tree
69' Tree
Mountain Views
Optimum Orientation
Litt e Deschutes Lodge 1
100ft
N

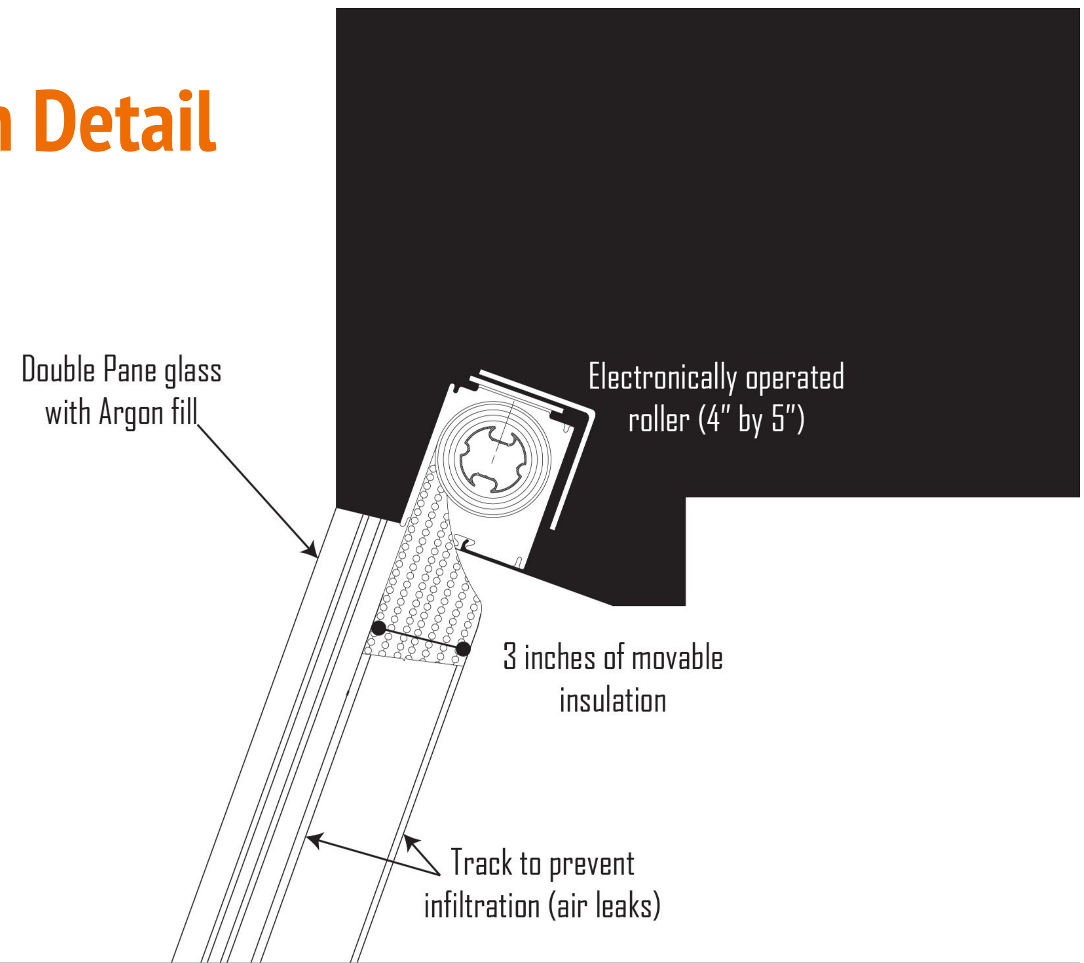
North-South Site Section



Building Section

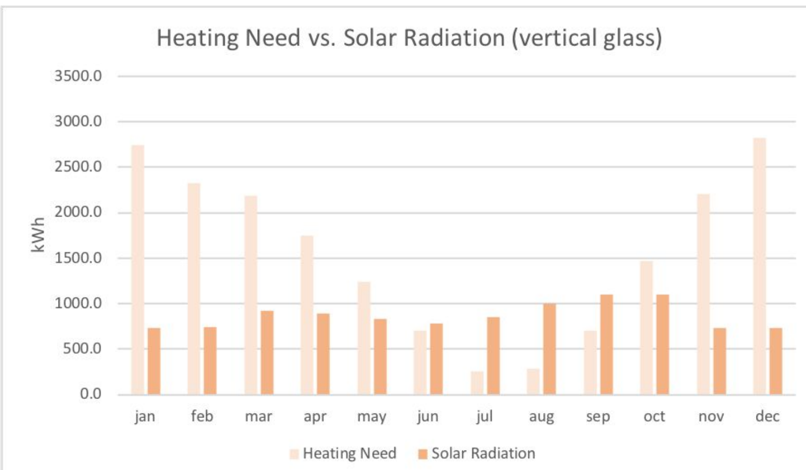


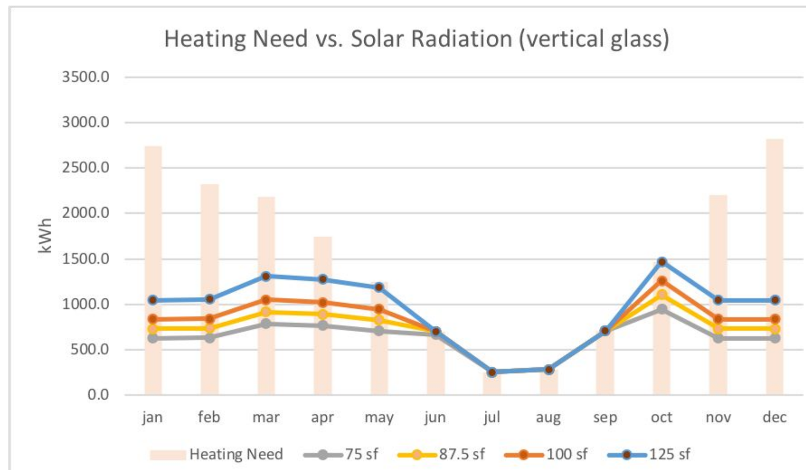
Movable Insulation Detail



Glass Sizing for Vertical Glass

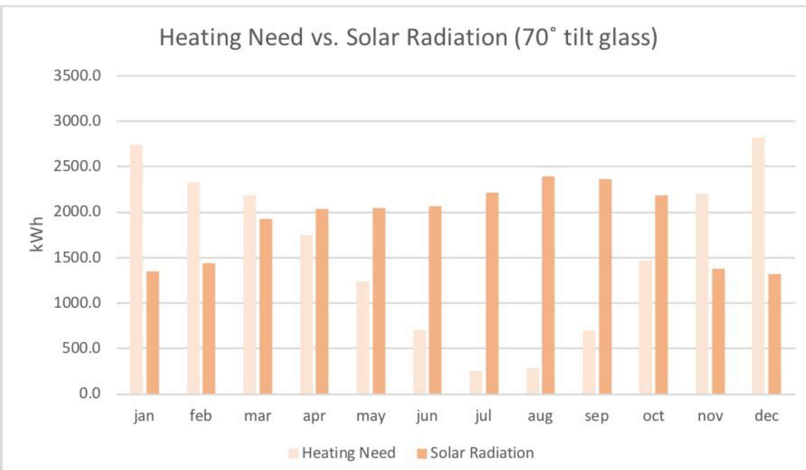
- Vertical wall to allow the space to be inhabited comfortably
- Amount of glass on vertical surface determined primarily on **aesthetics and views**
- **87.5 sf** (3.5′ tall window) of glazing on just over half the total south-facing wall surface

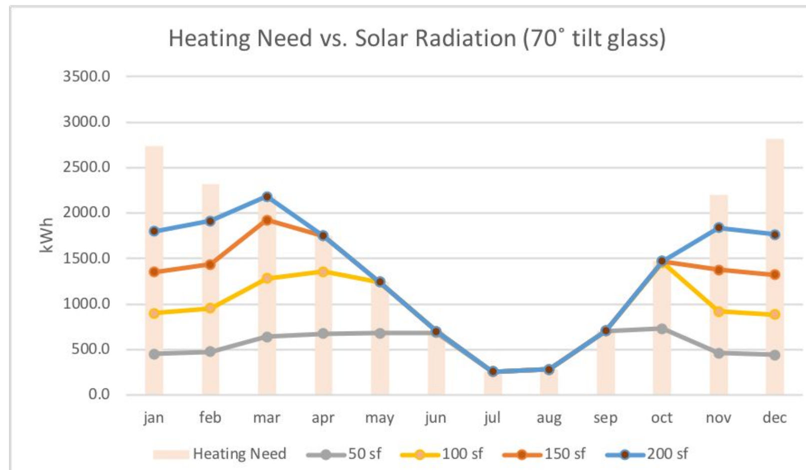




Glass Sizing for Tilted Glass

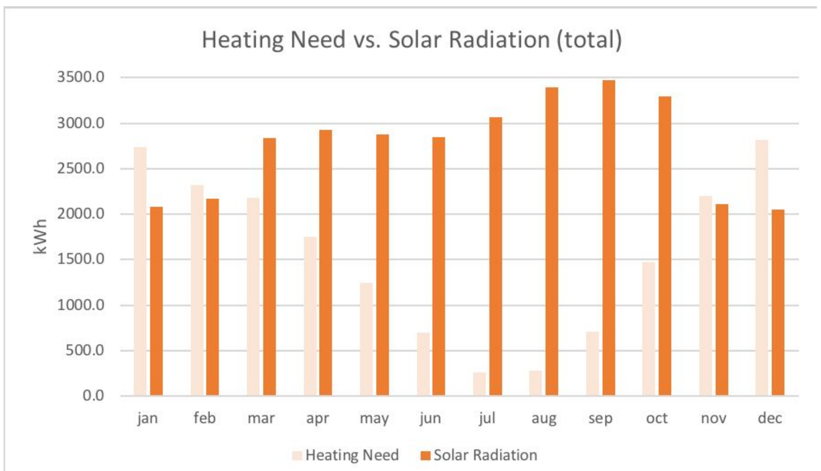
- **Optimal tilt** for most intense part of heating season: **70°**
- Tilted surface glass determined by heating need and direct solar radiation onto the thermal mass surface additional to what is provided by vertical windows
- **150 sf** (6' tall window) of glazing on tilted surface

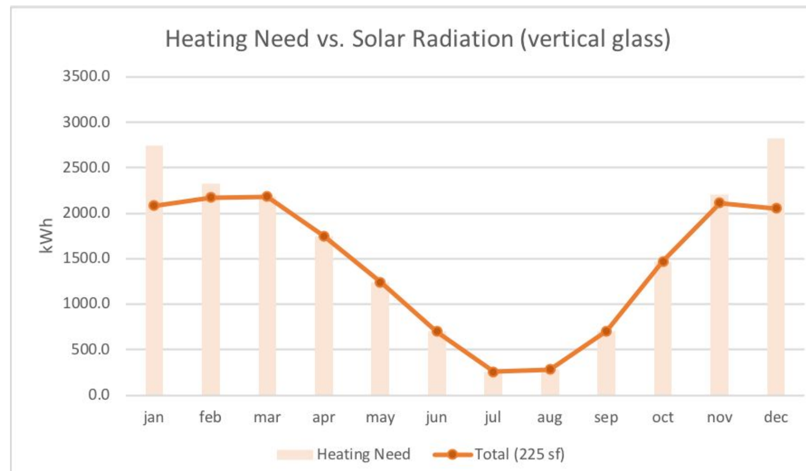




Glass Sizing Total

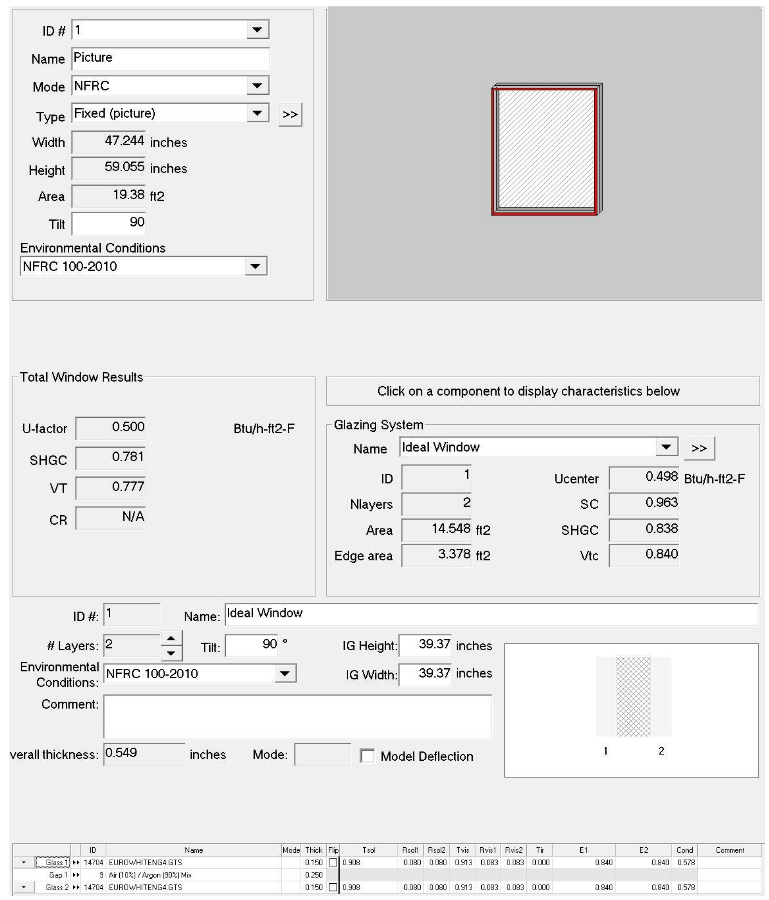
- Provides solar radiation for *at least ¾* of the heating need in the winter
- After analyzing model in EnergyPlus, this amount of glass was needed to keep dwelling at a base temperature of 65℉ most of the time
- Primary problem of **cooling sunspace in summer and parts of heating season**





Glazing Assembly

- Considerations:
  - Transmitting sun to thermal mass
  - Minimizing heat loss, particularly overnight
- Results:
  - High Solar Heat Gain Coefficient (SHGC)
  - High Visual Transmittance (VT)
  - Movable insulation overnight (u-factor not as important)
  - Double pane glass, with argon in gap



Thermal Mass Sizing

Material Properties:		Environment Properties:	
density:	140 lb/ft^3	warmest temp:	120 ˚F
conductivity:	0.925 Btu/h*ft*˚F	coldest temp:	50 ˚F
solar absorptance:	0.6	transmitted solar radiation:	200,000 Btu
heat capacity:	0.215 Btu/lb*˚F	wall surface area:	237.5 sf

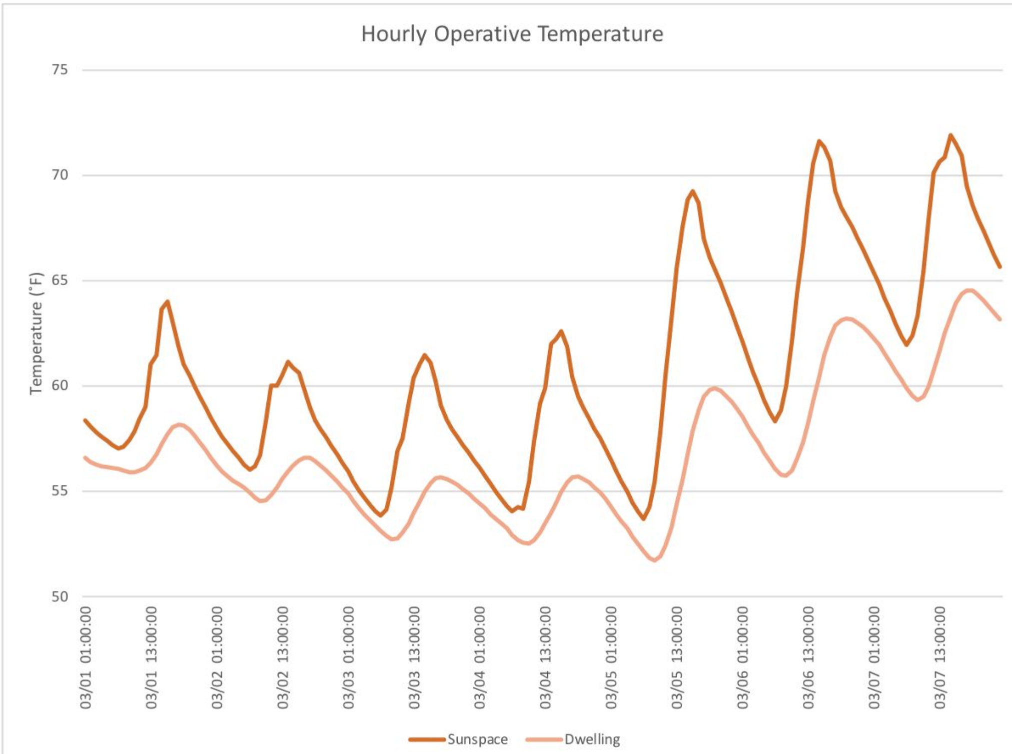
transmitted solar radiation		solar absorptance		solar radiation taken up
200000 Btu	X	0.6	=	120000 Btu

warmest daily temp		coldest daily temp		temp increase in wall
120 ˚F	X	50 ˚F	=	70 ˚F

heat capacity		solar radiation taken up		temp increase		mass needed
0.215 Btu/lb*˚F	X	120000 Btu	÷	70 ˚F	=	7973.4 lb

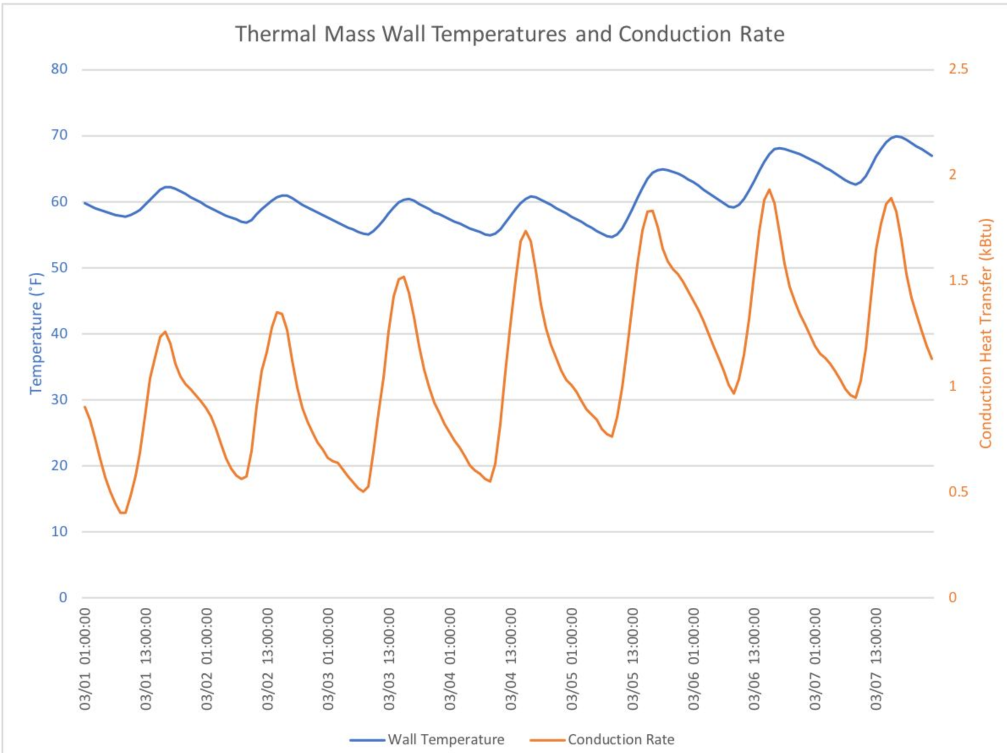
mass needed		density		mass wall surface area		thickness		
7973.4 lb	X	140 lb/ft^3	÷	237.5 sf	=	0.2 ft	=	**2.9 in**

Hourly Operative Temperatures



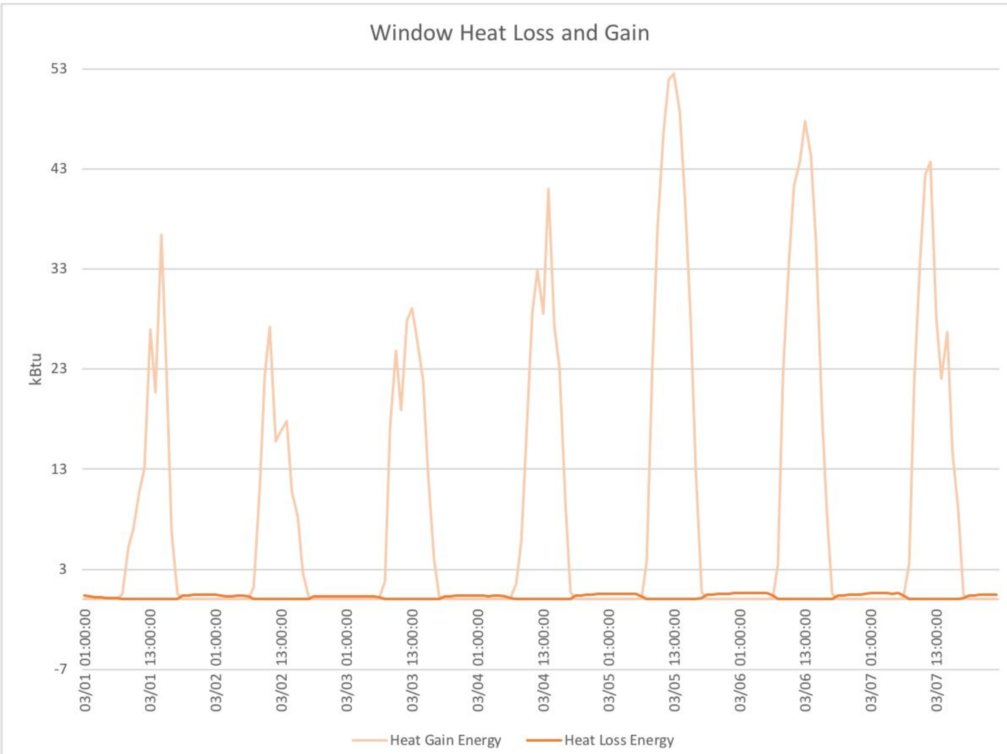
- Base temperature is 65˚F
- During the week of March 1st-7th it was able to meet this goal on three days
- Throughout the year (not shown) the sunspace meets the ASHRAE 55 standards majority of the time

Thermal Mass Effectiveness



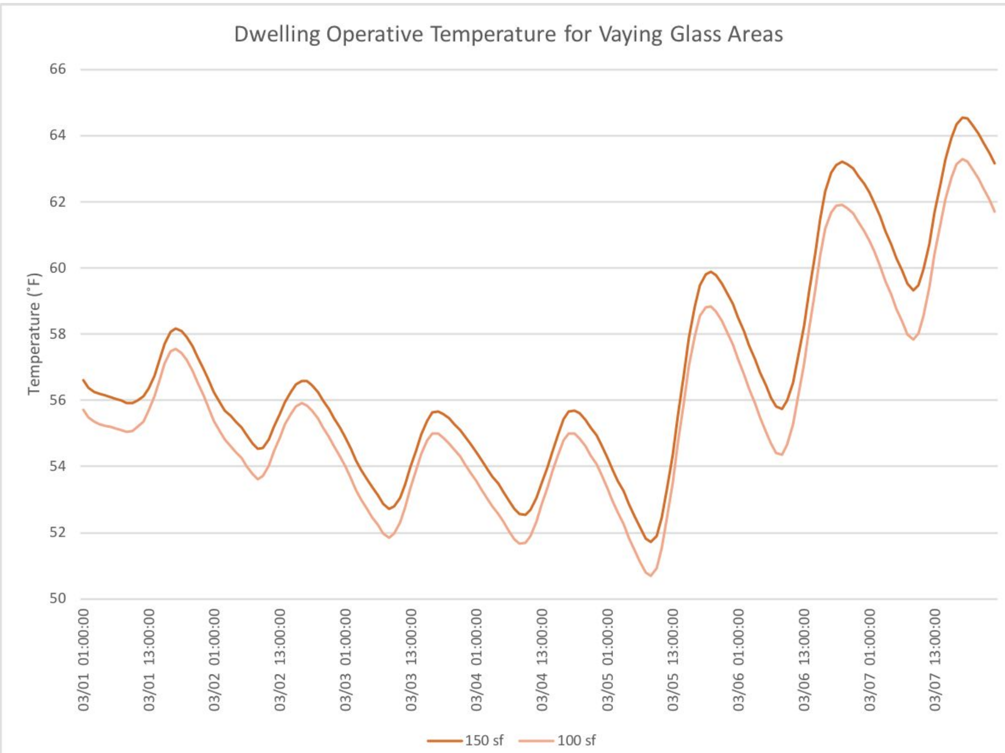
- Thermal mass resized to find the most effective mass for base temperature of 65°F
- Mass intended to provide heat to the dwelling zone in the evening
- Conductive heat transfer rate peaks in early afternoon and releases heat in evening (as seen in the peaks and valleys of the orange line)

Windows Heat Gain and Loss



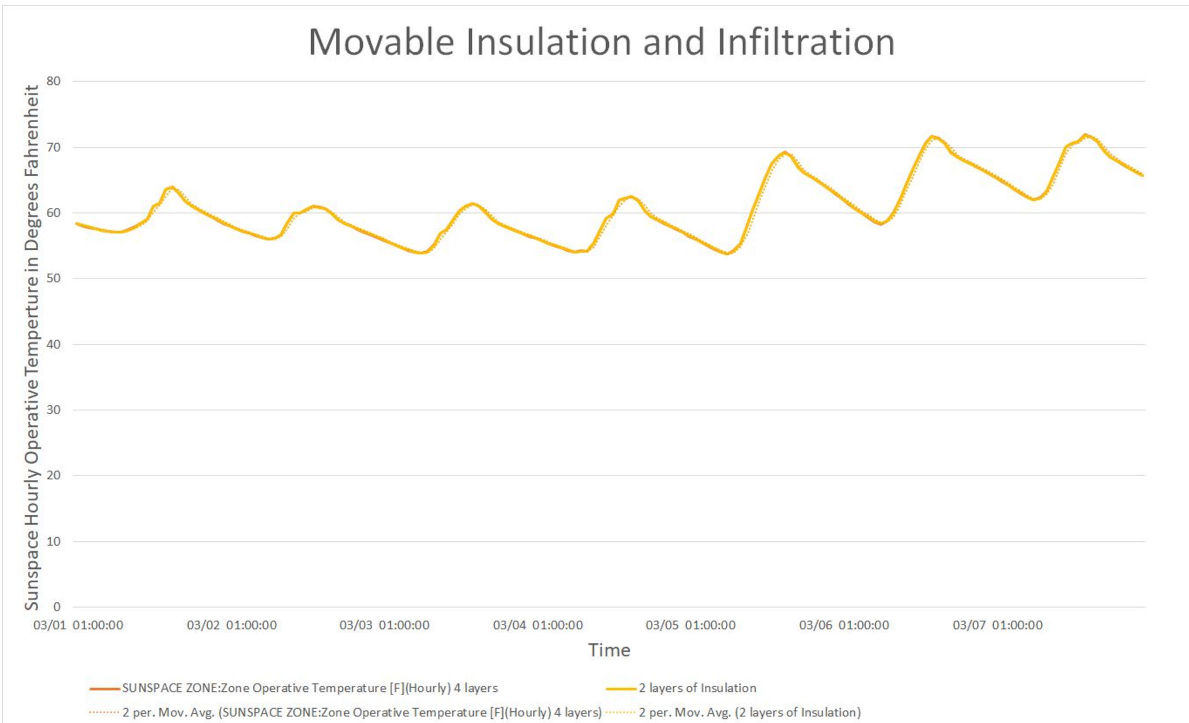
- Double pane glass with argon gas to reduce heat loss while still allowing a significant amount of solar energy through
- Heat loss energy successfully remains close to zero kBtu due to movable insulation
- Spikes in graph are due to increased solar energy available

Changing Area of Tilted Glass



- Increasing tilted glass area allowed for thermal mass to receive more direct sunlight
- Particularly helped in deeper winter months (January and February)
- In first week of March, it increased temperature by 1˚F

Changing Movable Insulation Materials



- In an attempt to see the difference between the thickness of the movable insulation I cut the insulation in half
- There were negligible changes in the temperature overnight, even with half as thick insulation and increased infiltration

PASSIVE HEATING

MATT OLNEY
ACHYUTHAN RAMASWAMY

DESIGN INTENT

Precedents

Creating a visually continuous facade, that blends with the overall design.

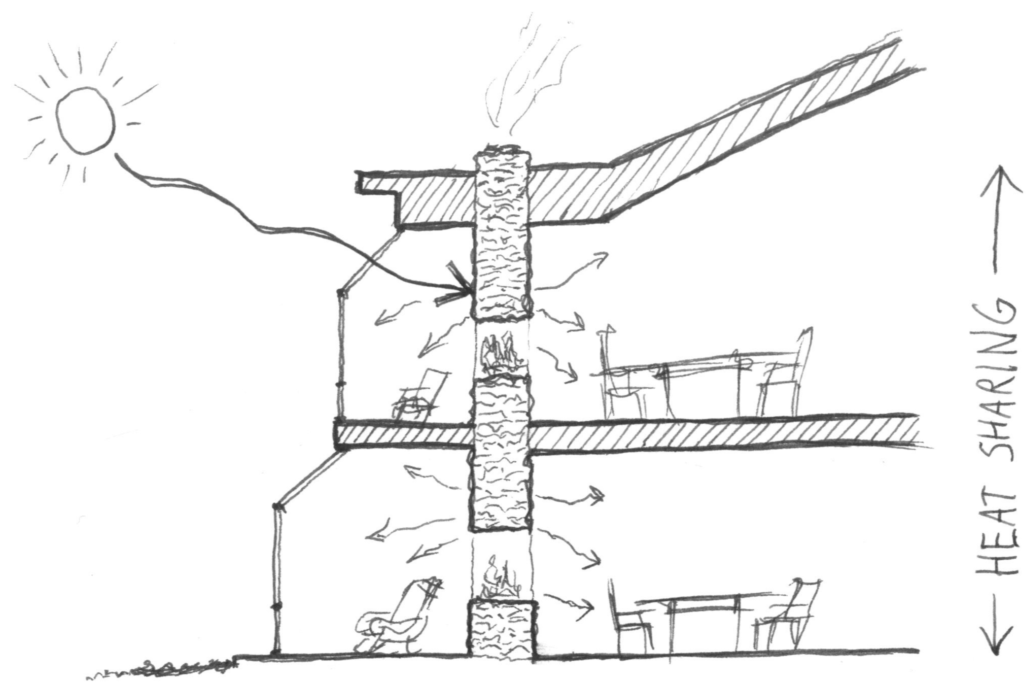
Sunspace as an extension of the dwelling unit rather than a stand alone addition.

Quality of space that can extend into creating an experience for the users.

Goals:

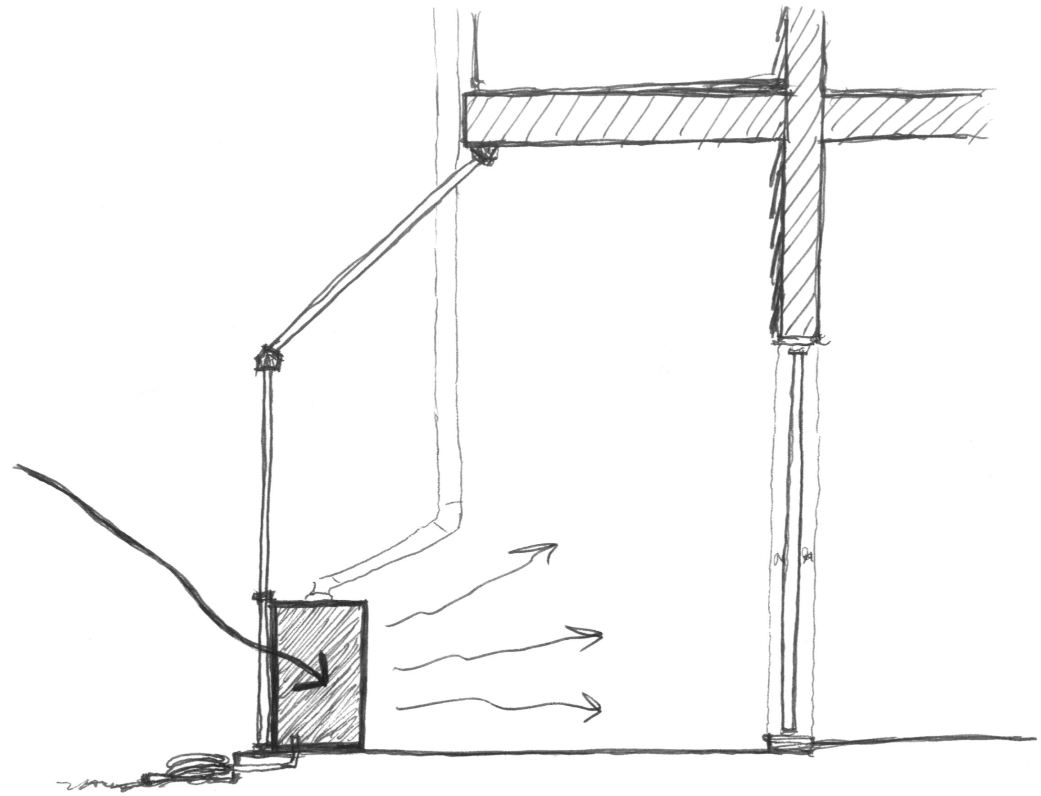
- Thermal Comfort - Maximising the comfort in the living spaces at the same time not compromising upon the potential utility of the sun space during colder months.
- Thermal + Architectural Delight - A visual connection to the outdoor environment by making the sun space more utilitarian rather than just a thermal buffer.
- Constructional Feasibility
- Easy Retrofit for an Existing Building

Program Ideas



Hearth as thermal mass
- Heated by sun or by fireplace
- Warmth is transferred vertically
- Attractive architectural feature

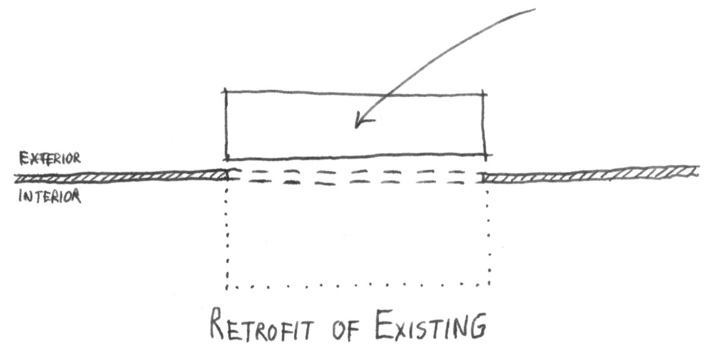
Program Ideas

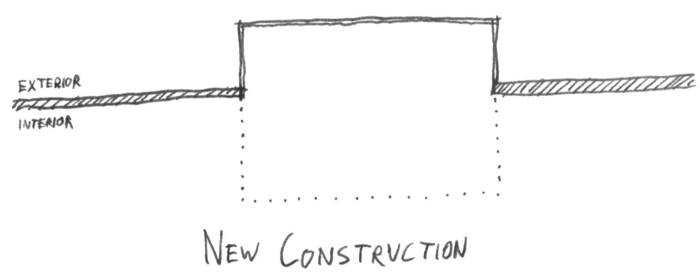


Rainwater as thermal mass

- Collects water for landscape use
- Tank sits against sunspace glass (effectively a trombe wall)
- Leakage is not as much of an issue in what is already an outdoor space

Program Ideas

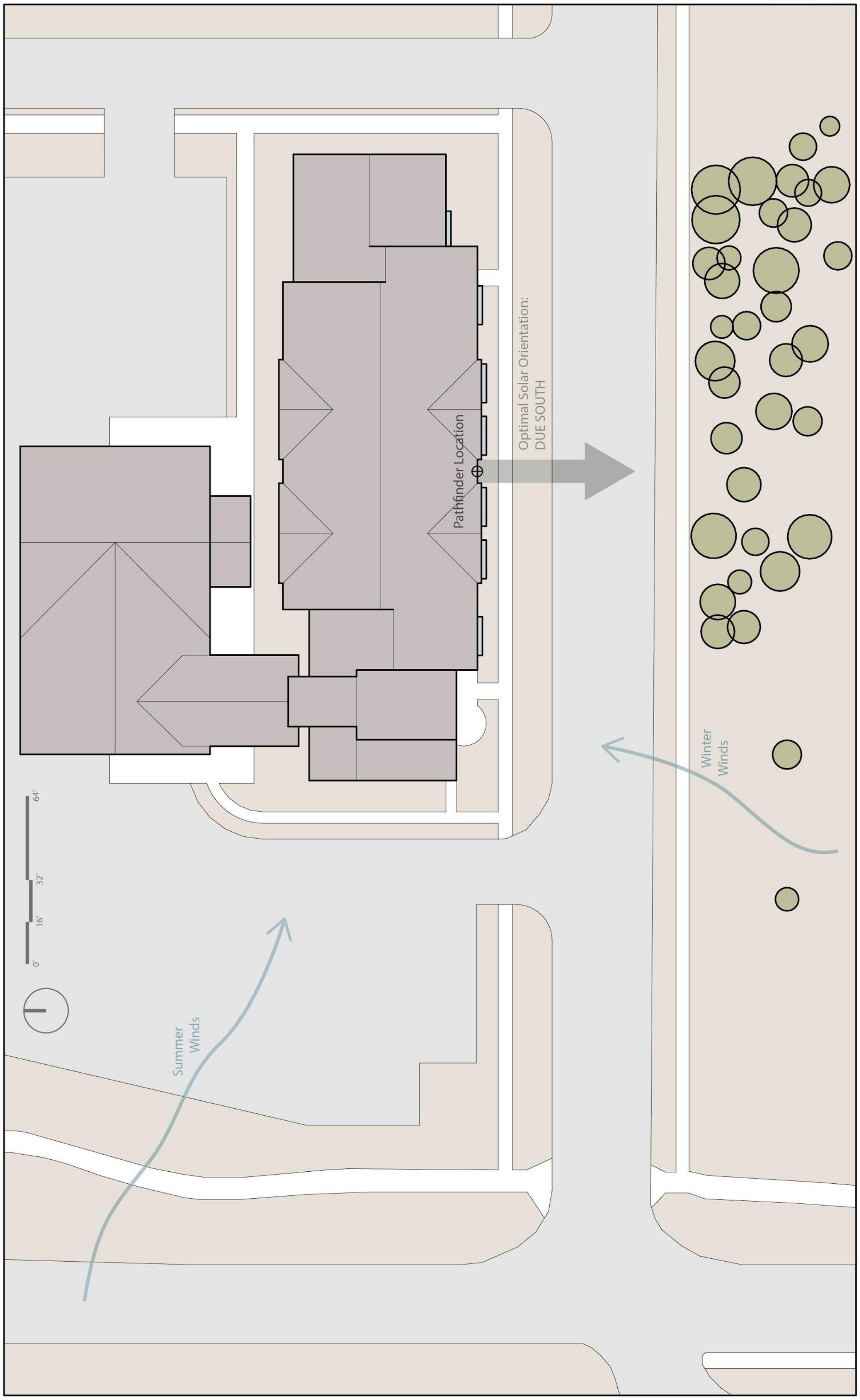




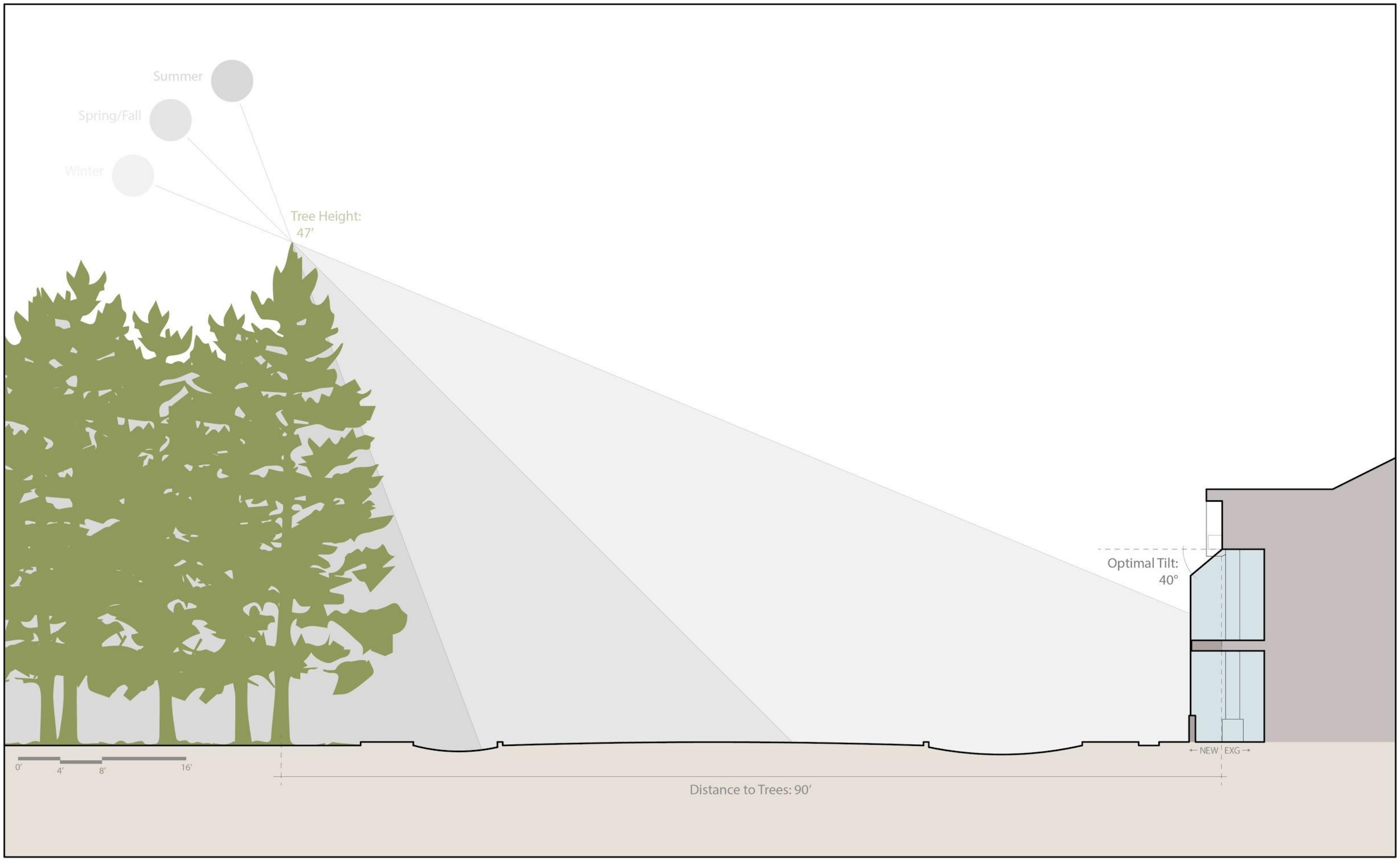
Adaptability
- A single design that can be adjusted accordingly to work with both existing and future construction in La Pine.

SOLAR SITE SURVEY

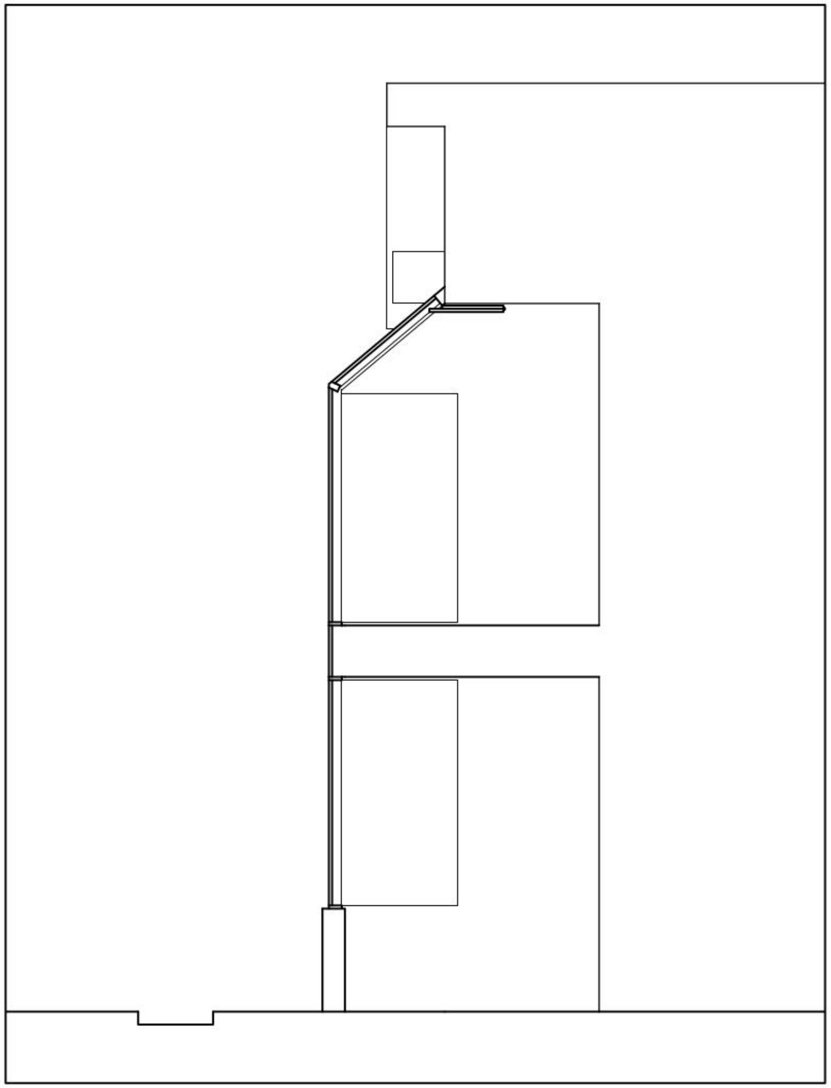
Site | Plan

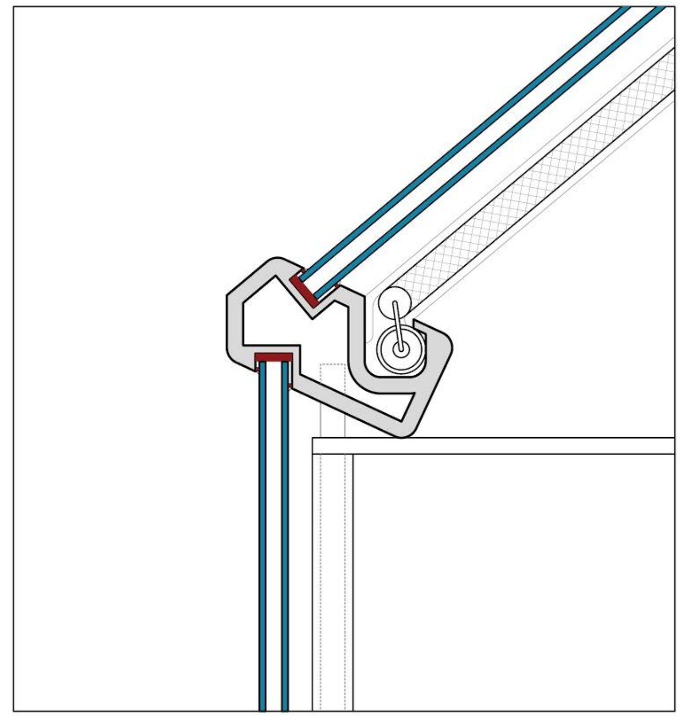

Pathfinder Location
Optimal Solar Orientation:
DUE SOUTH
Winter
Winds
Summer
Winds
0'
16'
32'
64'

Site | Section

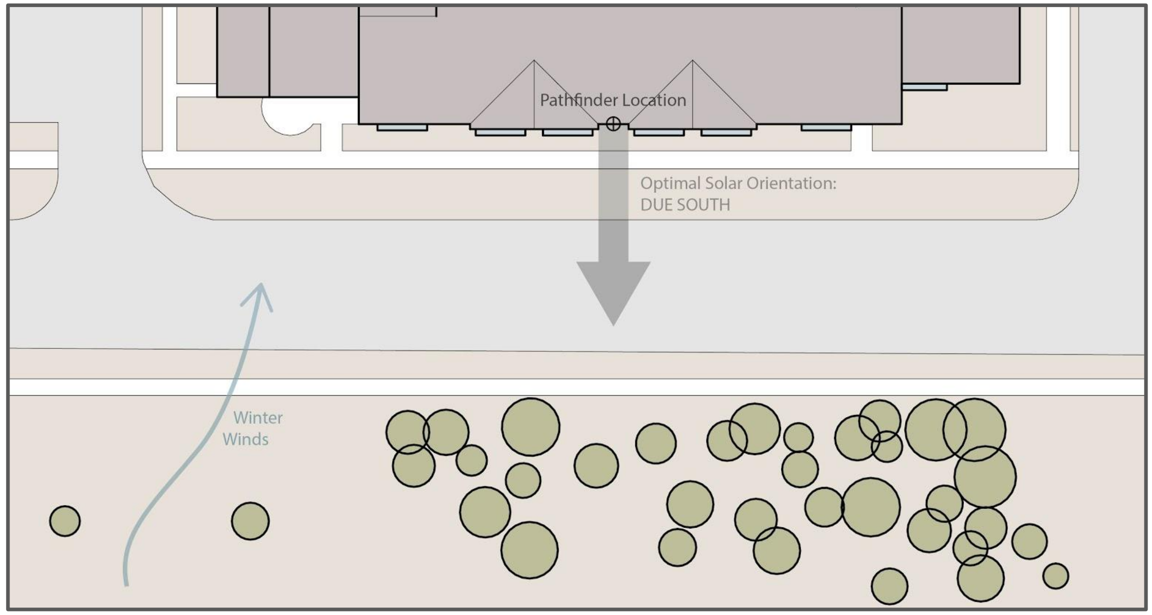


Building | Section & Movable Insulation Detail





Tree Types

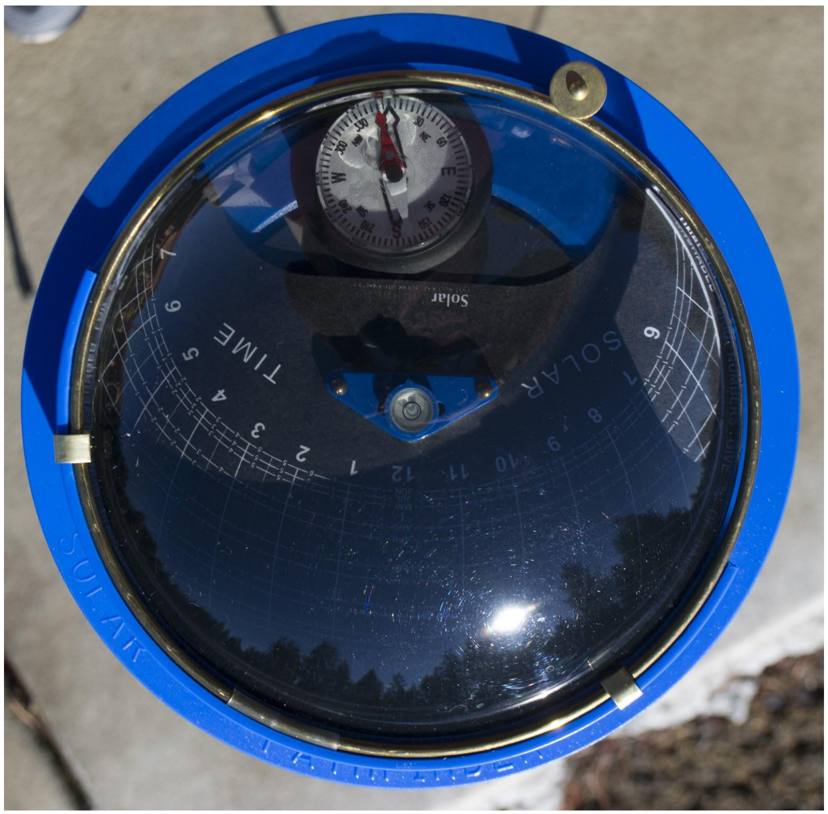


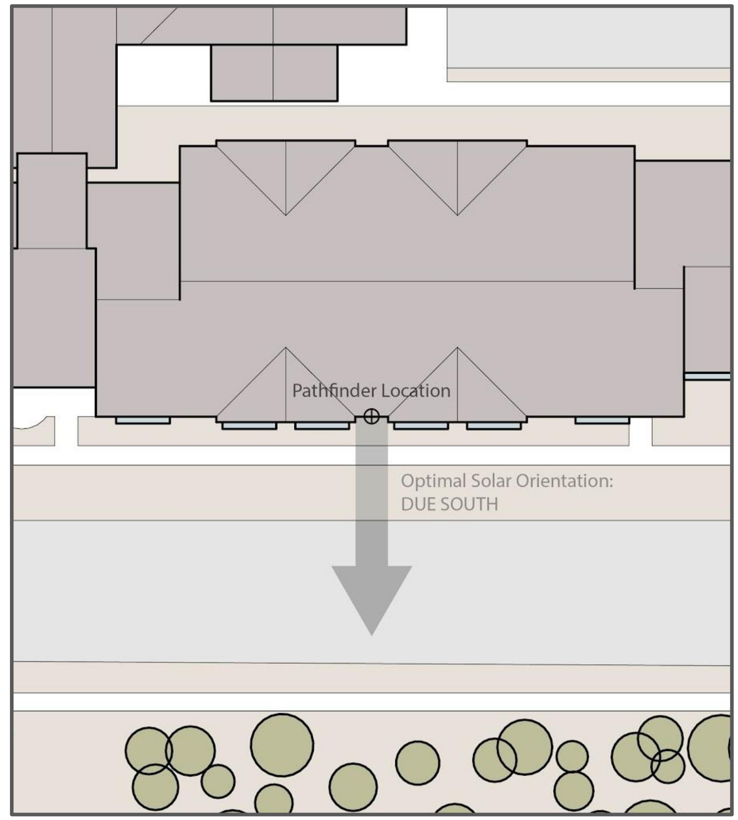
Predominantly evergreen **Lodgepole pines** and younger **Douglas fir**

Tree Density

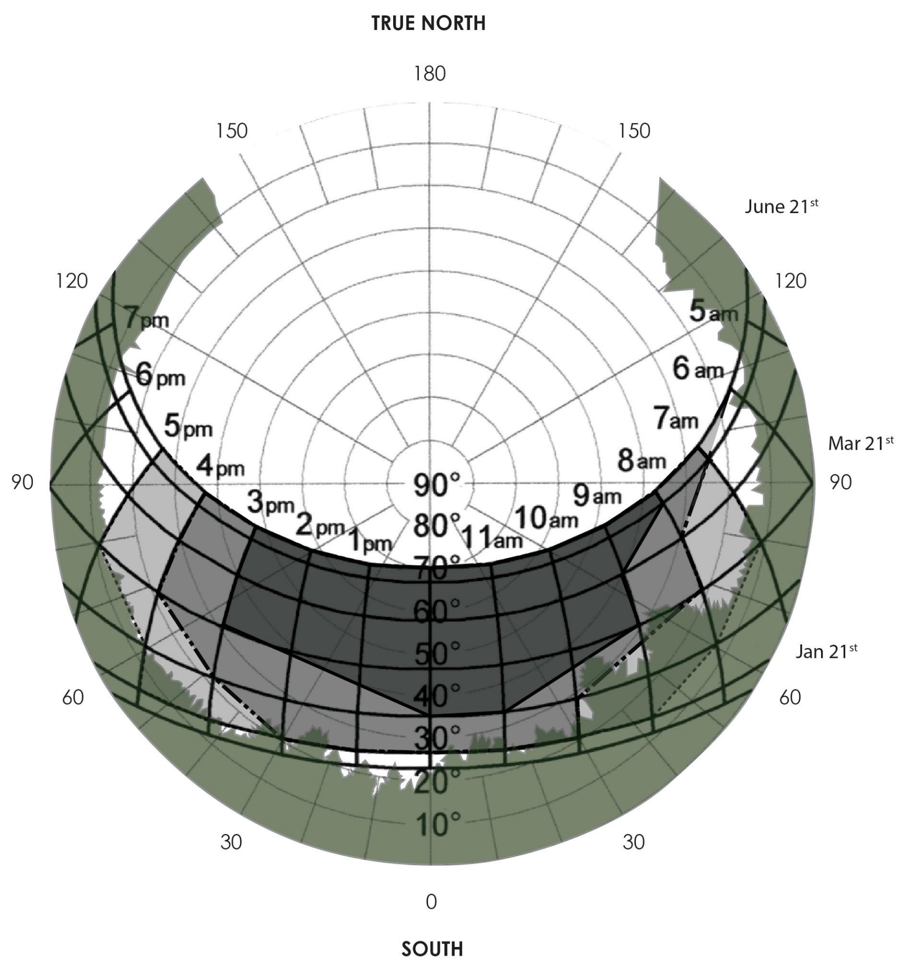
TREE DENSITY ~37% - 55%

Pathfinder Photo





Solar Resources

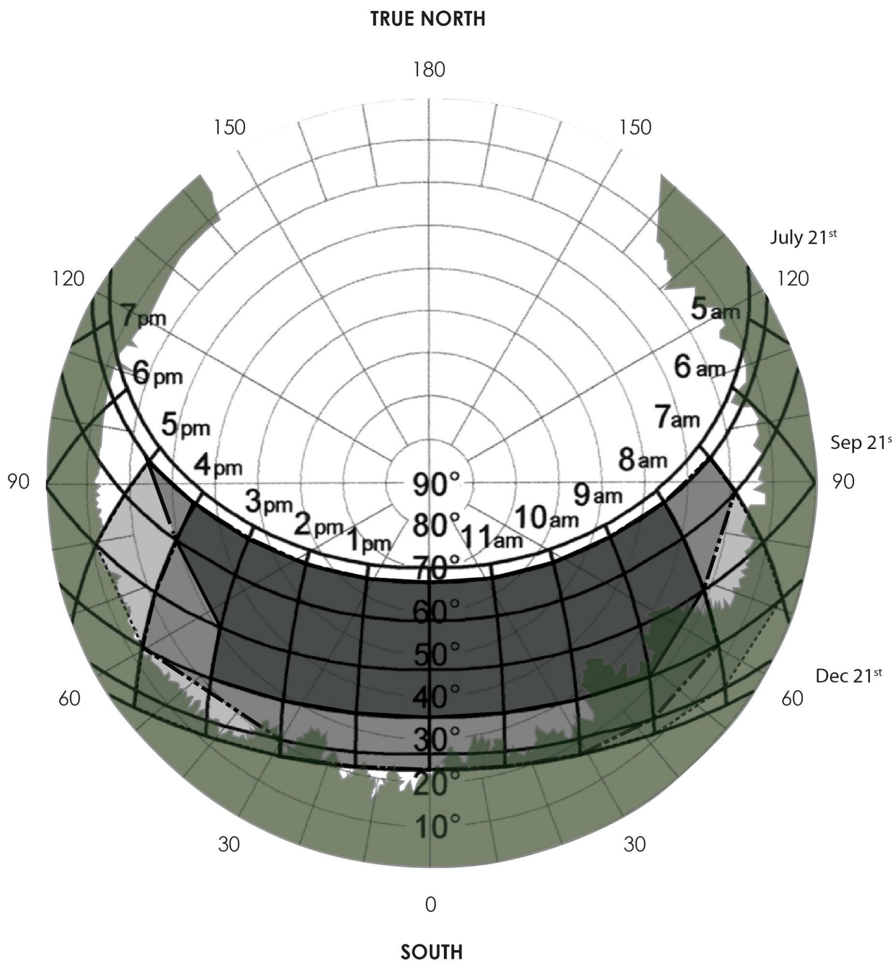


January - June

Swatch Legend

- > 150 Btu/SFT
- 100-150 Btu/SFT
- 50-100 Btu/SFT
- 1-50 Btu/SFT

Solar Resources



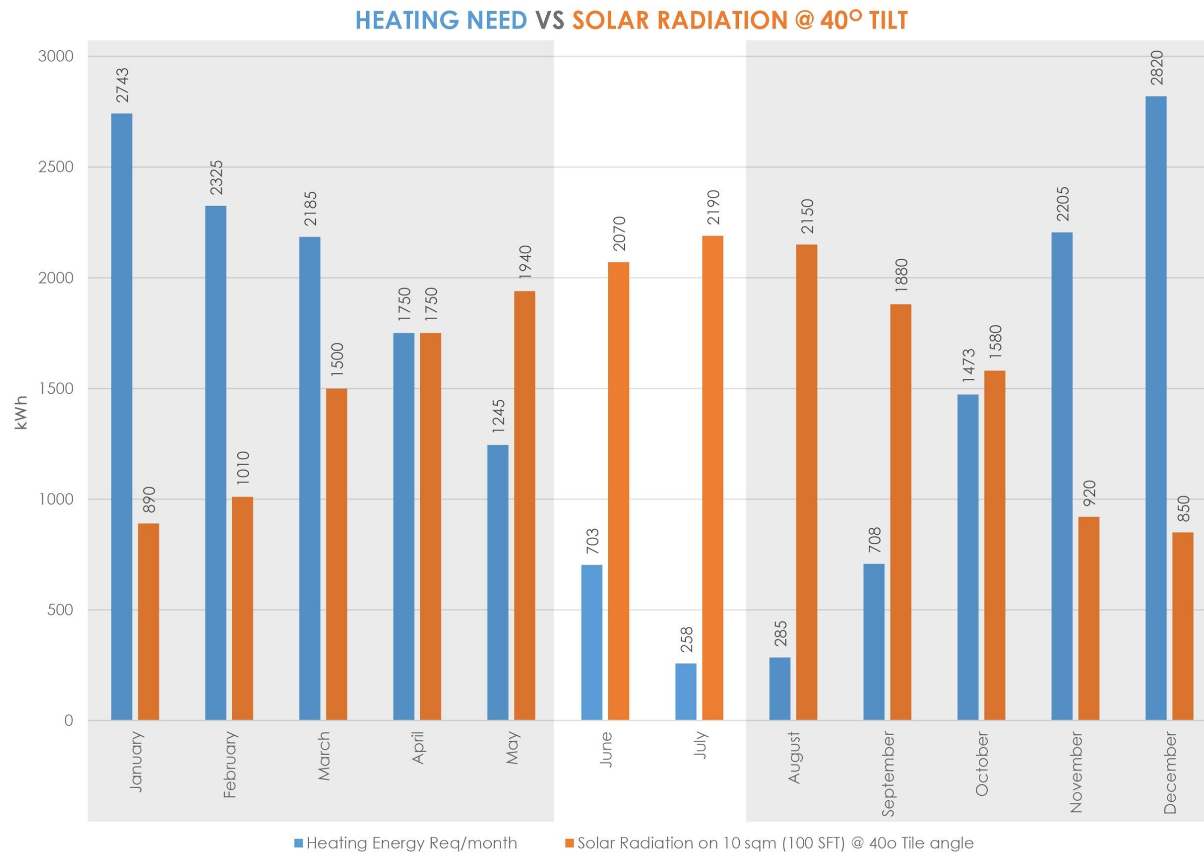
July - December

Swatch Legend

- > 150 Btu/SFT
- 100-150 Btu/SFT
- 50-100 Btu/SFT
- 1-50 Btu/SFT

GRAPHS | SIZING ELEMENTS

Heating Needs



- **HDD 65** considered as baseline, so as to have comfortable utility for sunspaces similar to balconies
- Shaded Region indicates the probable heating season
- The plot compares the heating need of an average dwelling unit (shown in blue) against the solar radiation incident on 10 sqm (100 sf) of glazing tilted @ 40° above horizontal (shown in orange)
- There is a **requirement for shading devices** to prevent the unit from overheating in the hotter seasons
- **Movable insulation** will also be important for retaining heat during the cooler nights

Month	No. of Days	HDD_{65}/Month	HDD_{65}/Day	Heating Energy Req/day	Heating Energy Req/month	Solar Radiation @ 40° Tile angle	Solar Radiation on 10 sqm @ 40° Tile angle
			Base-BPT(°F)	2.5kWh/HDD_{65}			
January	31	1097	35.39	88.47	2742.50	89	890
February	28	930	33.21	83.04	2325.00	101	1010
March	31	874	28.19	70.48	2185.00	150	1500
April	30	700	23.33	58.33	1750.00	175	1750
May	31	498	16.06	40.16	1245.00	194	1940
June	30	281	9.37	23.42	702.50	207	2070
July	31	103	3.32	8.31	257.50	219	2190
August	31	114	3.68	9.19	285.00	215	2150
September	30	283	9.43	23.58	707.50	188	1880
October	31	589	19.00	47.50	1472.50	158	1580
November	30	882	29.40	73.50	2205.00	92	920
December	31	1128	36.39	90.97	2820.00	85	850

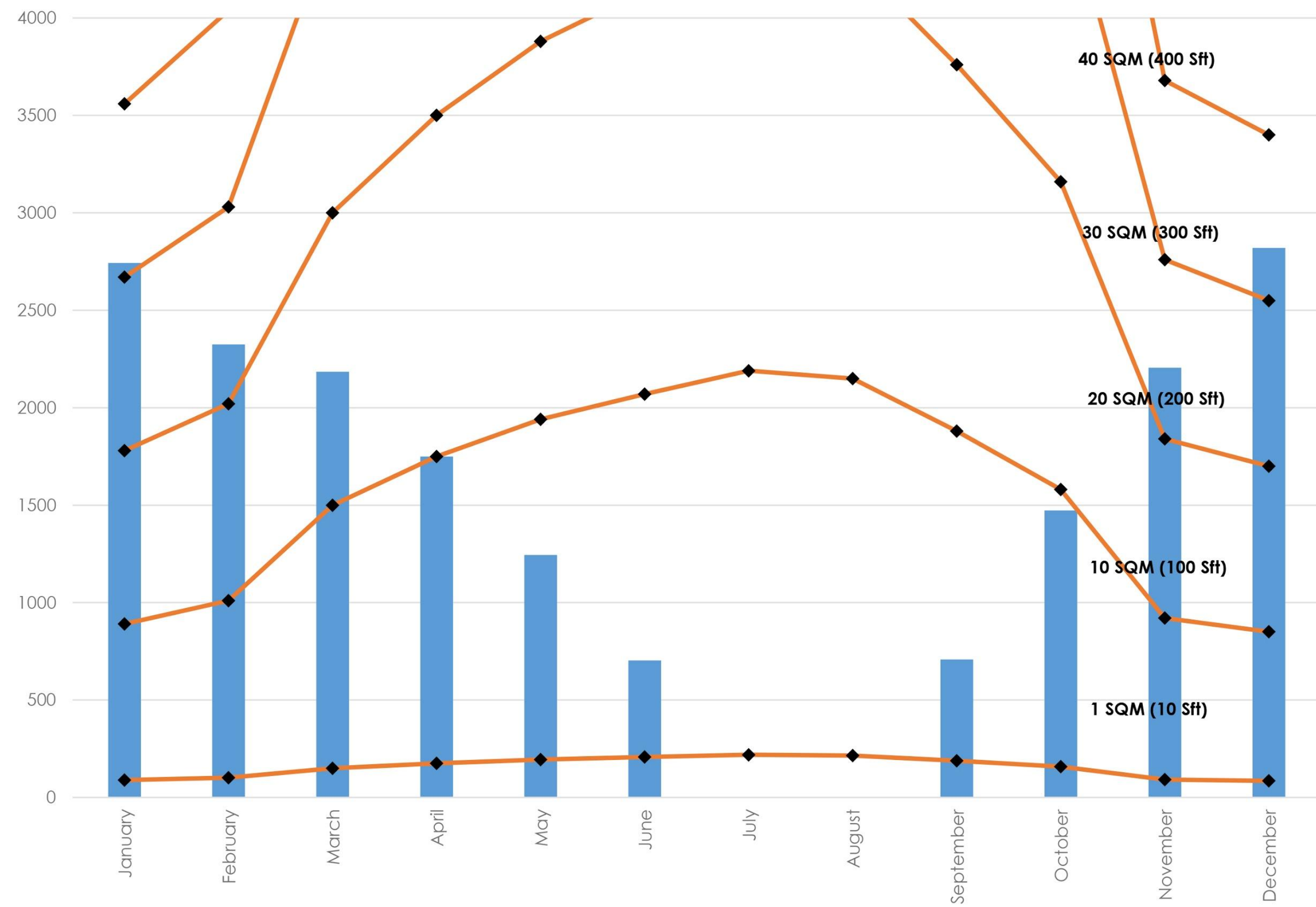
Plotted on the graph
Heating Season

This side has the results in total kWh/m2 on each tilted surface for the corresponding month.

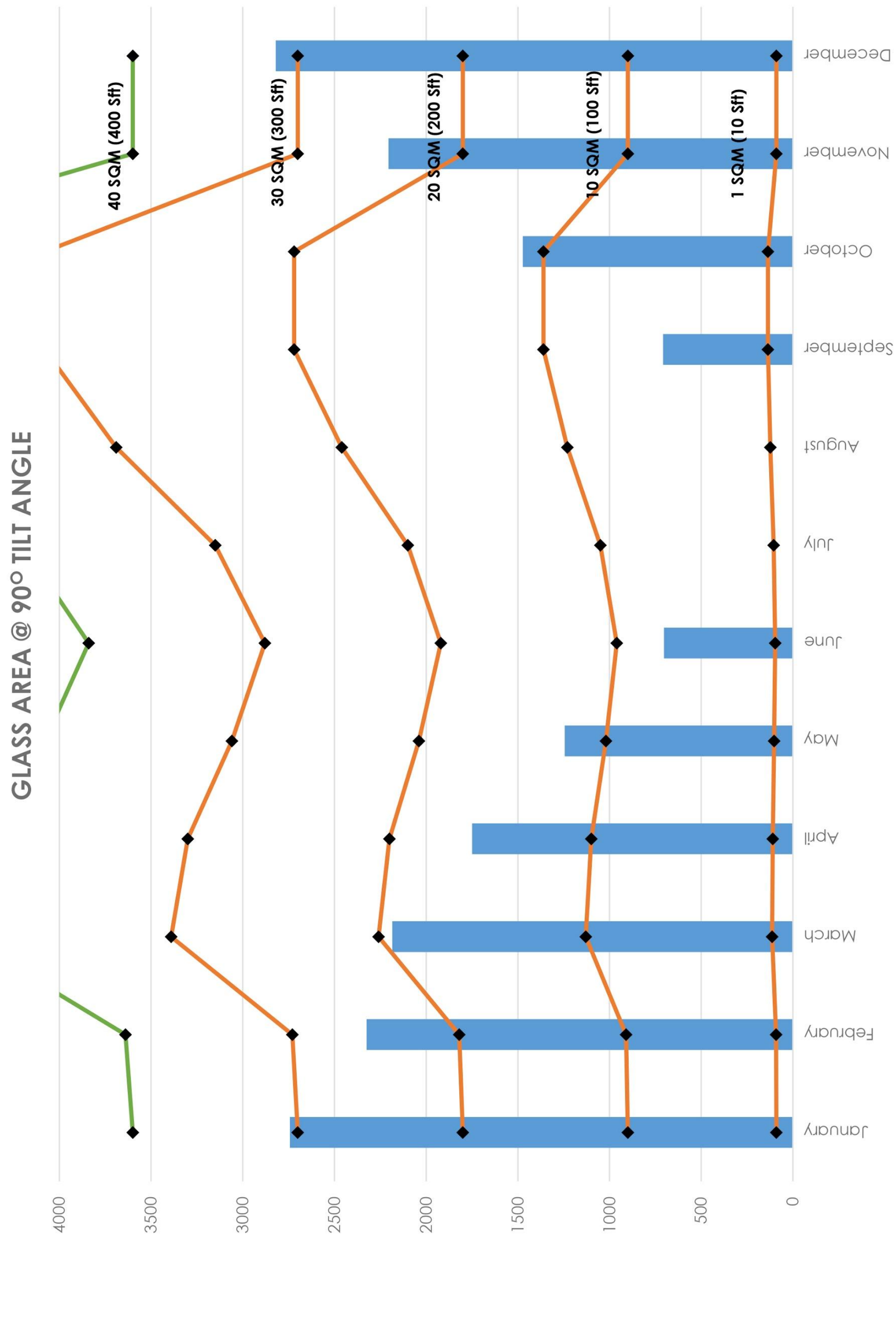
	Tilt (degrees above horizontal)									
Month	**90**	**80**	**70**	**60**	**50**	**40**	**30**	**20**	**10**	**0**
January	90	94	97	97	94	89	82	73	62	50
February	91	98	103	105	104	101	95	87	77	65
March	113	127	138	145	149	150	147	140	130	117
April	110	129	146	159	169	175	177	174	168	157
May	102	125	147	166	182	194	201	204	202	196
June	96	123	148	171	191	207	218	224	225	222
July	105	133	159	183	203	219	229	235	234	229
August	123	149	172	191	206	215	220	219	213	201
September	136	155	170	180	187	188	185	177	164	147
October	136	148	157	161	162	158	150	138	122	104
November	90	96	99	99	97	92	85	76	65	53
December	90	94	95	94	91	85	77	67	55	42
Heating Needs/sqm (Heating Season)	**1053**	**1188**	**1298**	**1378**	**1425**	**1438**	**1416**	**1360**	**1271**	**1153**

Glass Sizing

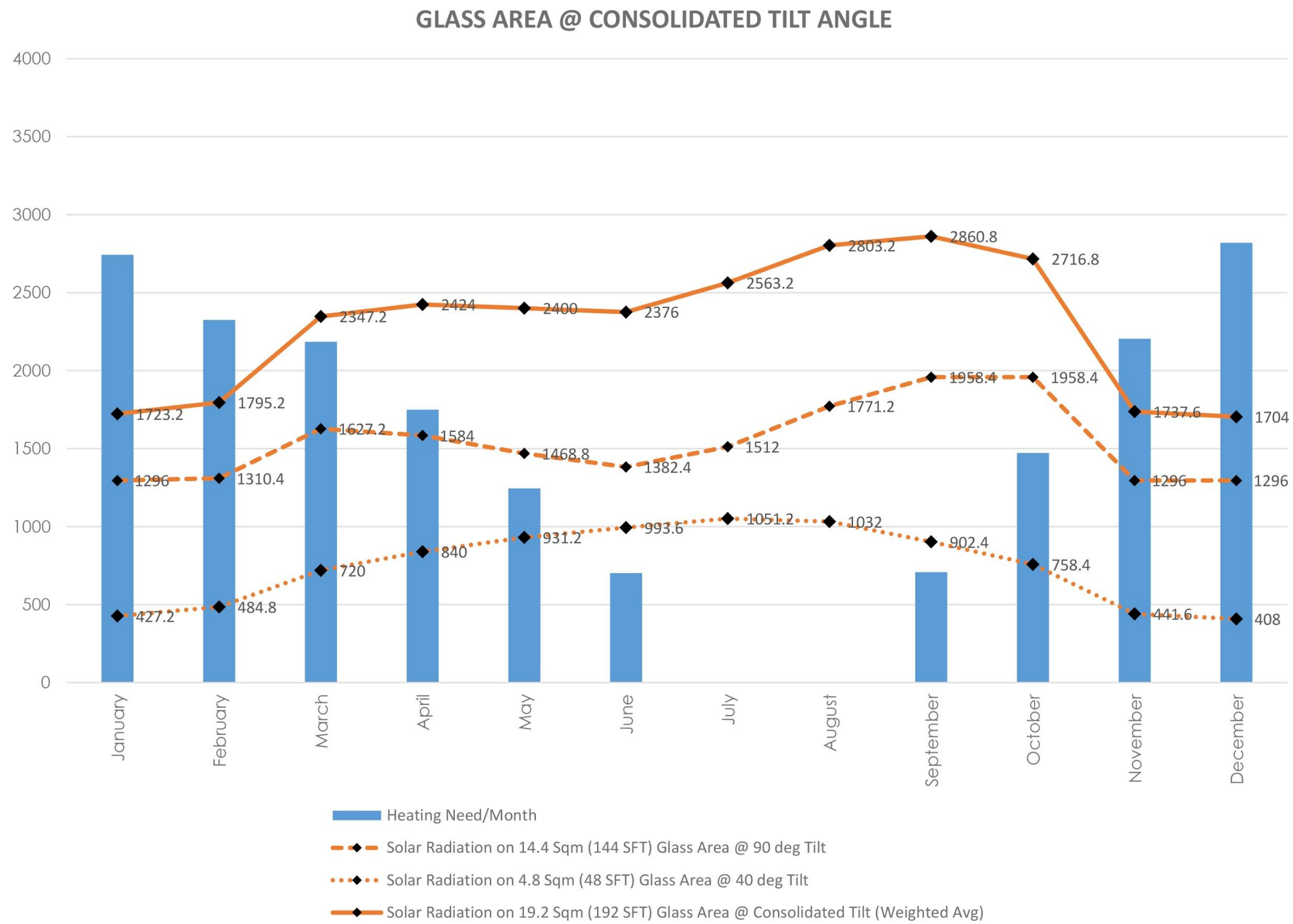
GLASS AREA @ 40° TILT ANGLE



Glass Sizing



Glass Sizing



Note: Incedent Solar Radiation for consolidated glass area calculated [144 Sft (75%) of 90 deg tilt and 48 Sft (25%) of 40 deg Tilt] for an overall of 192 Sft glass area

Glass Choice

- To maximize the passive heating potential within our limited footprint, we evaluated potential glass choices based on SHGC values above 0.6 with significant visible light transmittance and lower u-value to arrest heat loss in colder seasons.

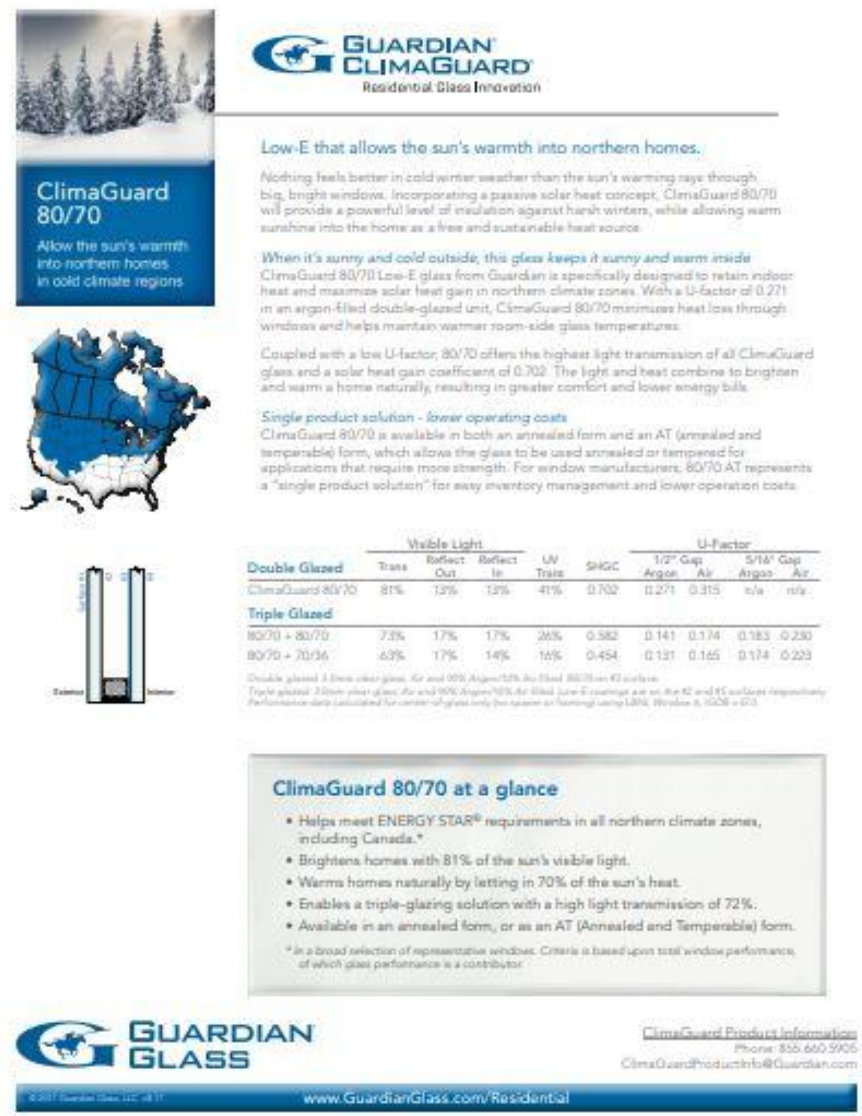
- Basis of Design: Guardian Climaguard 80/70 (double glazed)

  SHGC: 0.702
  U-Value: 0.271
  VLT: 81%

Total Window Results

U-factor	0.417	Btu/h-ft2-F
SHGC	0.575	
VT	0.662	
CR	N/A	

(Assembly values from WINDOW 7)



Low-E that allows the sun's warmth into northern homes.

Nothing feels better in cold winter weather than the sun's warming rays through big, bright windows. Incorporating a passive solar heat concept, ClimaGuard 80/70 will provide a powerful level of insulation against harsh winters, while allowing warm sunshine into the home as a free and sustainable heat source.

When it's sunny and cold outside, this glass keeps it sunny and warm inside
ClimaGuard 80/70 Low-E glass from Guardian is specifically designed to retain indoor heat and maximize solar heat gain in northern climate zones. With a U-factor of 0.271 in an argon-filled double-glazed unit, ClimaGuard 80/70 minimizes heat loss through windows and helps maintain warmer room-side glass temperatures.

Coupled with a low U-factor, 80/70 offers the highest light transmission of all ClimaGuard glass and a solar heat gain coefficient of 0.702. The light and heat combine to brighten and warm a home naturally, resulting in greater comfort and lower energy bills.

Single product solution - *lower operating costs*
ClimaGuard 80/70 is available in both an annealed form and an AT (annealed and temperable) form, which allows the glass to be used annealed or tempered for applications that require more strength. For window manufacturers, 80/70 AT represents a "single product solution" for easy inventory management and lower operation costs.

	Visible Light					U-Factor			
						1/2" Gap		5/16" Gap	
Double Glazed	Trans	Reflect Out	Reflect In	UV Trans	SHGC	Argon	Air	Argon	Air
ClimaGuard 80/70	81%	13%	13%	41%	0.702	0.271	0.315	n/a	n/a
Triple Glazed									
80/70 + 80/70	73%	17%	17%	26%	0.582	0.141	0.174	0.183	0.230
80/70 + 70/36	63%	17%	14%	16%	0.454	0.131	0.165	0.174	0.223

ClimaGuard 80/70 at a glance

- Helps meet ENERGY STAR® requirements in all northern climate zones, including Canada.*
- Brightens homes with 81% of the sun's visible light.
- Warms homes naturally by letting in 70% of the sun's heat.
- Enables a triple-glazing solution with a high light transmission of 72%.
- Available in an annealed form, or as an AT (Annealed and Temperable) form.

* In a broad selection of representative windows. Criteria is based upon total window performance, of which glass performance is a contributor.

GUARDIAN GLASS

ClimaGuard Product Information
Phone: 855.660.5905
ClimaGuardProductInfo@Guardian.com

www.GuardianGlass.com/Residential

Thermal Mass Sizing

This side has the results in total kWh/m2 on each tilted surface for the corresponding month.										
	Tilt (degrees above horizontal)									
Month	**90**	**80**	**70**	**60**	**50**	**40**	**30**	**20**	**10**	**0**
January	90	94	97	97	94	89	82	73	62	50
February	91	98	103	105	104	101	95	87	77	65
March	113	127	138	145	149	150	147	140	130	117
April	110	129	146	159	169	175	177	174	168	157
May	102	125	147	166	182	194	201	204	202	196
June	96	123	148	171	191	207	218	224	225	222
July	105	133	159	183	203	219	229	235	234	229
August	123	149	172	191	206	215	220	219	213	201
September	136	155	170	180	187	188	185	177	164	147
October	136	148	157	161	162	158	150	138	122	104
November	90	96	99	99	97	92	85	76	65	53
December	90	94	95	94	91	85	77	67	55	42
Heating Needs/sqm (Heating Season)	**1053**	**1188**	**1298**	**1378**	**1425**	**1438**	**1416**	**1360**	**1271**	**1153**

Daily Incident Radiation: 101 kWh/m^2 (February Total) x 28 days x 20 m^2 (Glass Area) x 3600 kJ/kWh = **259,200 kJ**

Energy Uptake: 259,200 kJ x 0.6 (Glass Transmittance) x 0.6 (Absorptance of Concrete) = **93,312 kJ**

Desired Temperature Difference: 45 °C (Expected Max.) - 5 °C (Expected Min.) = **40 K**

Recommended Concrete Mass: (1/0.9) kg-K/kJ (Specific Heat of Concrete) x 93,312 kJ ÷ 40 K = **2,592 kg**

Recommended Thickness: 2,592 kg x (1/2,400) m^3/kg (Density of Concrete) ÷ 15.6 m^2 (Floor Area) = **0.069 m**

(approximately 3 inches)

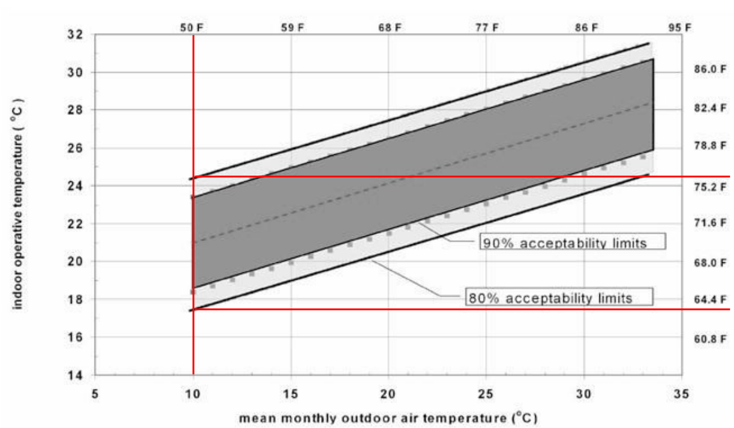
PERFORMANCE

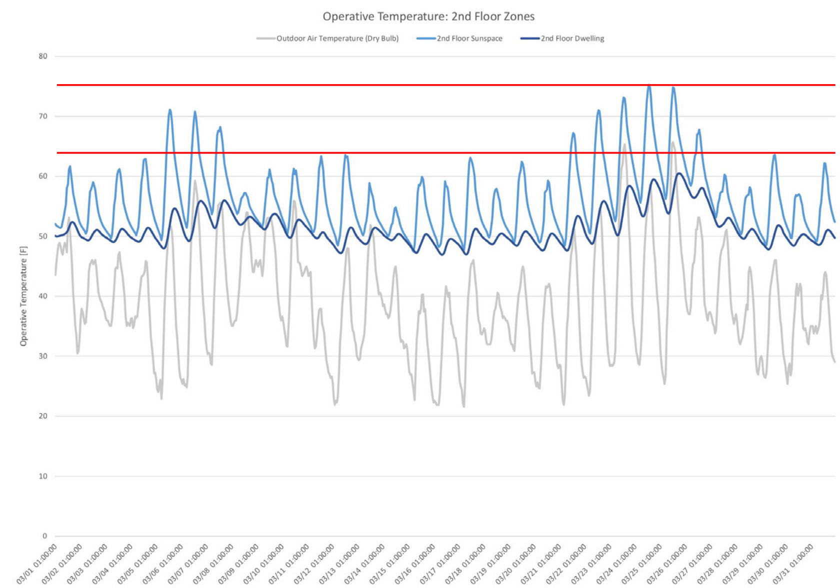
Operative Temperature

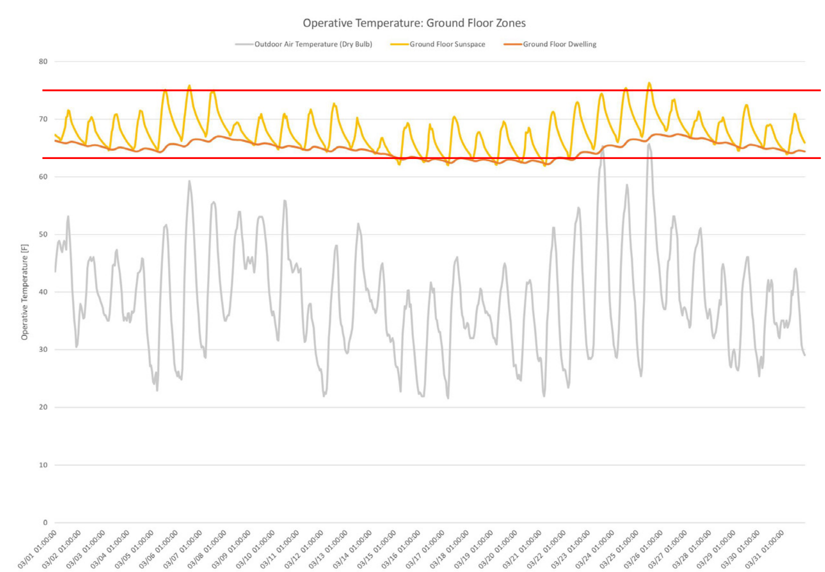
- During the simulation period the 2nd floor sunspace was rarely within the 80% acceptability range of the adaptive comfort model.

- The ground floor sunspace, meanwhile, was within 80% acceptability for nearly the entire period.

- We hypothesize that this difference is due to the lower zone borrowing heat from the upper zone's floor slab. While the lower zone has thermal mass above and below it, the upper zone only has thermal mass below.

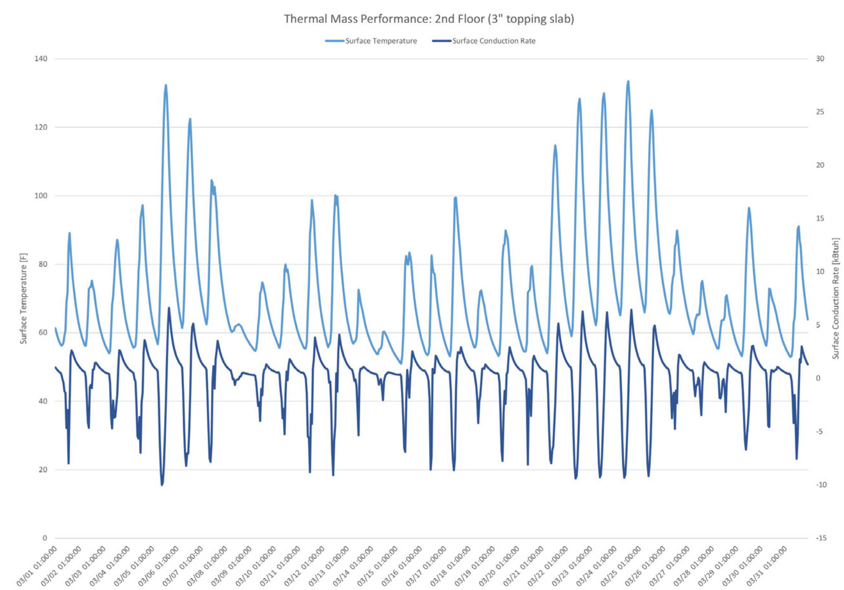


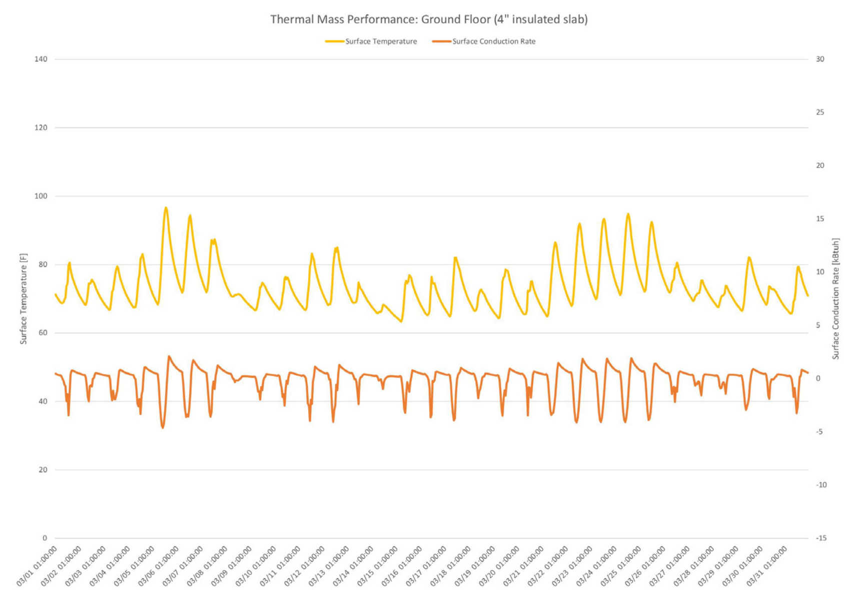




Thermal Mass Performance

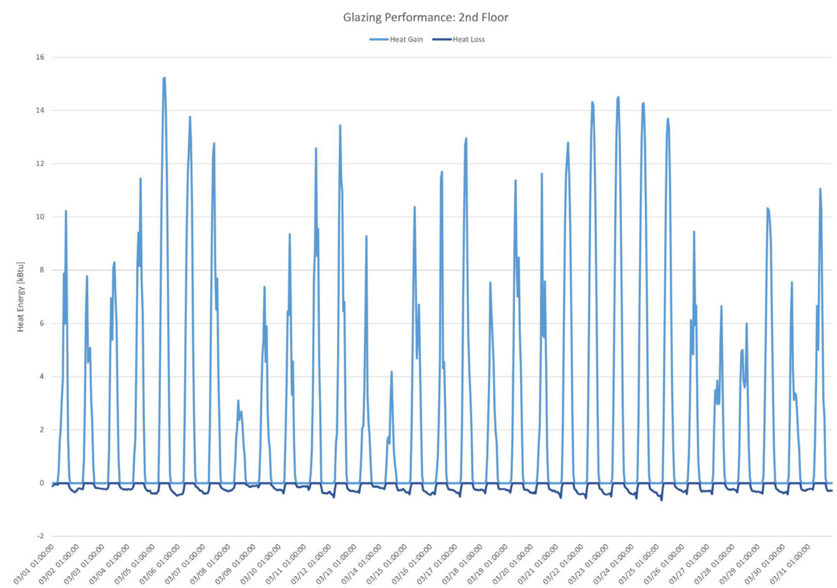
- A similar discrepancy was observed on the surfaces of the thermal mass; the upper slab saw much greater fluctuation in both temperature and convection rate than the lower one.

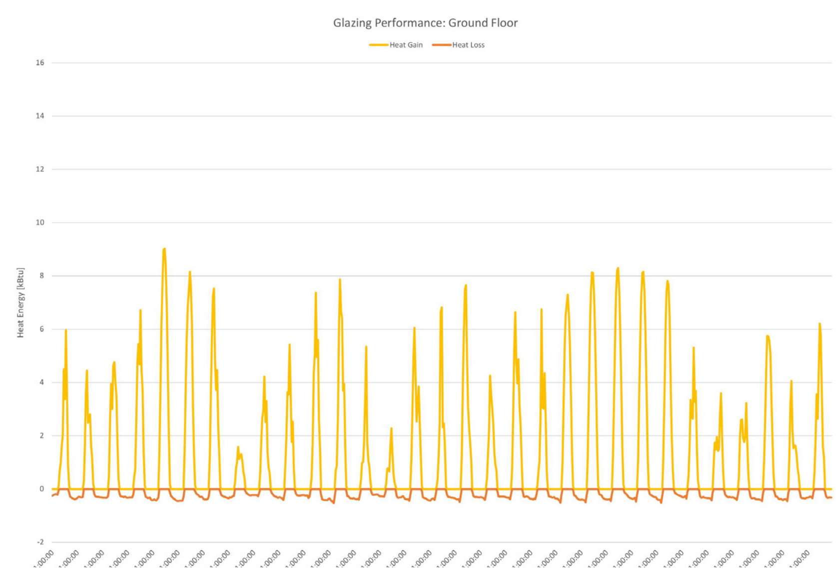




Glazing & Insulation Performance

- Lastly, the glazing on the upper floor (with its larger area and tilted section) gained more energy than that of the ground floor (roughly double).

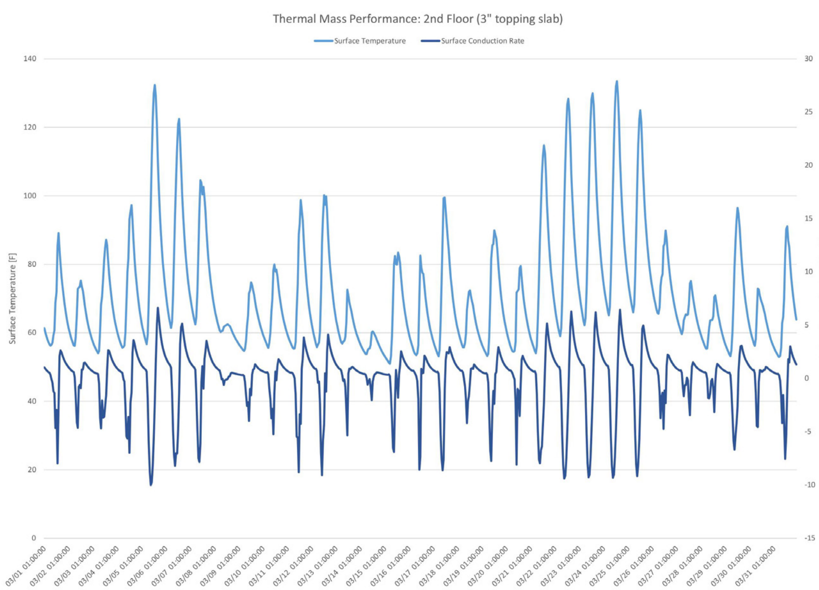


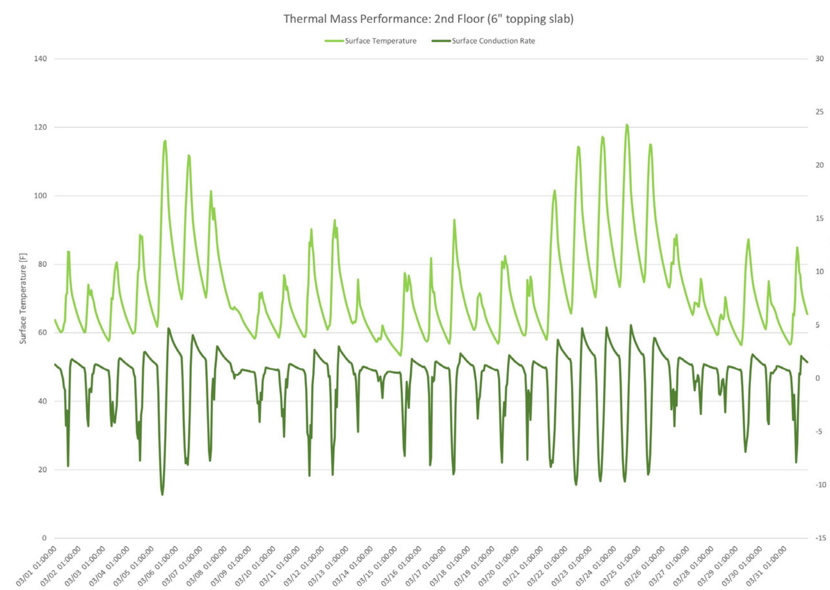


Variation: Increased Thermal Mass

- To find out how much of an effect the sizing of thermal mass had on this discrepancy, we ran another simulation with a 6" topping slab on the 2nd floor instead of the original 3" one.

- Surprisingly, doubling the mass only had a marginal effect on the temperature and rate of convection at its surface

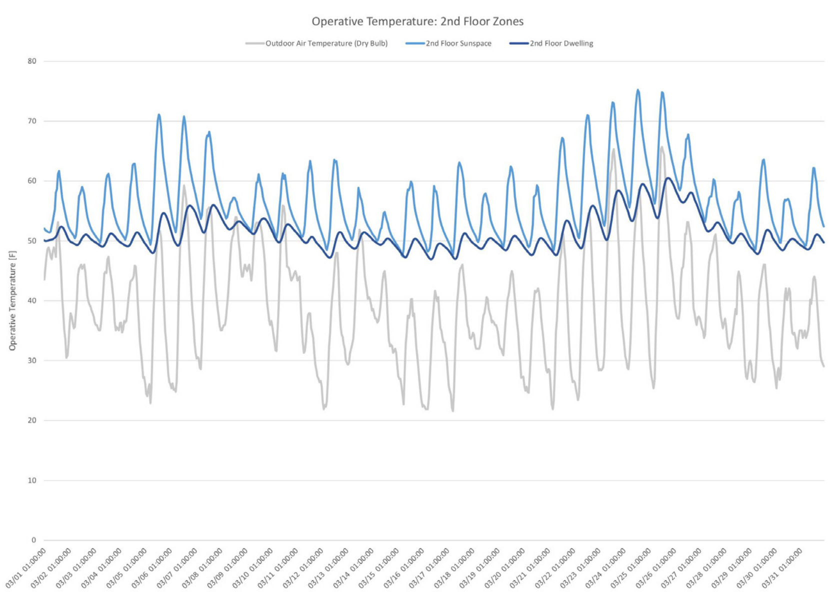


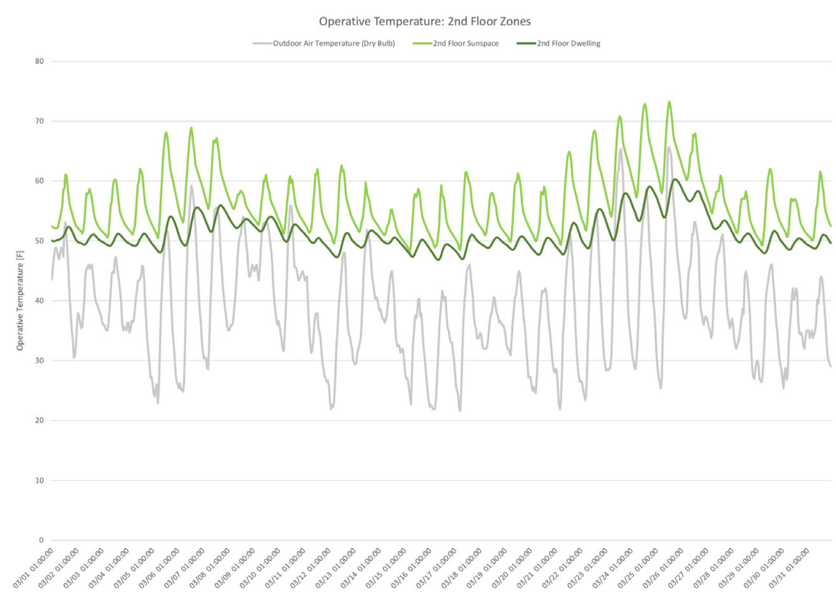


Variation: Increased Thermal Mass

- The effect of doubling the 2nd floor mass on the operative zone temperature was negligible.

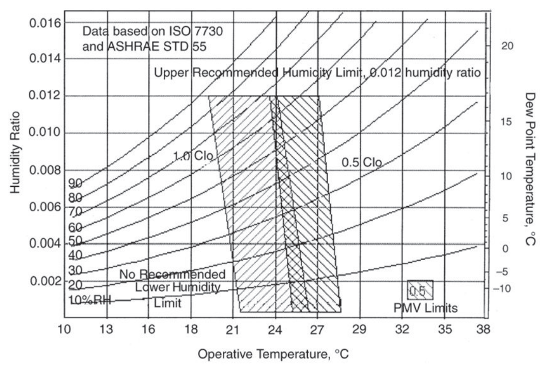
- This suggests that the initial mass sizing calculations were indeed adequate and that other factors (such as glazing area and mass placement) were more important to the thermal characteristics of the upper zone.





the right angle

goals for thermal comfort:



(*Source: ASHRAE Standard 55-2004)

- Using the standard comfort zones, we would like to keep the sunspace within the 1 Clo. acceptability marks for the highest use times, and swing to the 0.5 Clo. acceptability marks during probably low-use times.

- Standard comfort zones allow for an acceptable range of operative temperature, dew point temperature, and humidity ratio, based on the average level of comfort per amount for clothing. Therefore, seasonal changes in attire will contribute to the comfort zones we aim for.

- Comfort goals are made with the understanding that during times of no use, such as 1-6 am, the temperature of the sunspace can swing slightly below the 1 Clo. comfortable range, as long as there is potential to heat up with the sunrise.

- In the same way, the sunspace is also allowed to heat up above the 0.5 Clo. comfortable range during peak sun collecting hours, in order to store heat in thermal mass to disperse into the dwelling for later use. These times will likely have little use, as they are typically during working hours.

- While the standard comfort zone does not address air speed and its contribution to comfort, so we will design for ample air flow through the space when it is needed to help cool down.

- In general, we should like to create a warm, sunny space during cold winter months, as well as a space that is well ventilated and shaded for a cool space during the summer heat.

design intent

goals for thermal delight:

- In colder months, the brightness of the space will be delightful because of the sense of increased warmth, even with relatively cool air temperatures.

- In contrast, during warmer months, the ample ventilation of the space along with design techniques, will create a cool breeze to make the space seem cooler than it really is, even though it is still bright and sunny outside.

- The potential for views out in the midst of a frosty winter will increase the apparent operative temperature, making the space seem especially delightful.

- Stone slabs as features and thermal masses in the space will contribute their cool, heavy ambiance to the space, making it delightful when the space may be a little on the warm side.

design intent

goals for heat delivery:

- This design plans to have heat delivery that responds to the needs of its occupants, the surrounding environmental conditions, and personal preference. There are enough switches within the unit to easily change the operative function for personal preference throughout a day, keeping occupants comfortable.

- We plan for the unit to collect most of its heat during the day, especially morning, and if there is too much heat gain, the venting and shading elements will be deployed to prevent overheating.

- Thermal masses will store this collected heat to be radiated both back into the sunspace, as well as into the dwelling unit during the cooler hours of the night. This lag in solar radiation to stored heat radiation makes for a space that can keep a relatively consistent temperature, with a few minor swings.

- The amount of heat needed, how much can be collected without overheating the space, and what the insulative value of the unit itself is, all contribute to the effective sizing of glazing, thermal masses, and the shading schedule. We will first use intuition and aesthetic preferences to schedule and size elements, them massage the product into a highly functional sunspace.

design intent

precedents:


Tamedia Building


Canopea

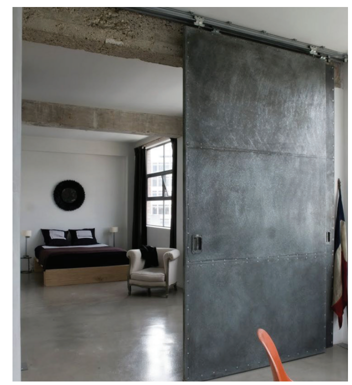
These images show our ideas for implementing louvers within our glazing area, for better control of the shading systems and glare mediation.


South Korea skyscraper


Knight Campus

These images are examples of our idea to create a modular element that can be replicated and placed on a number of facades, each as successful as the last. The modularity allows for each piece to not interfere with others it borders.


Trombe wall example


Heavy sliding door example

These photos show our ideas of using a thermal mass wall to store and radiate heat energy into the space behind. Included is the plan to incorporate thermal mass into a solid, sliding door, improving functionality of the wall.

design intent

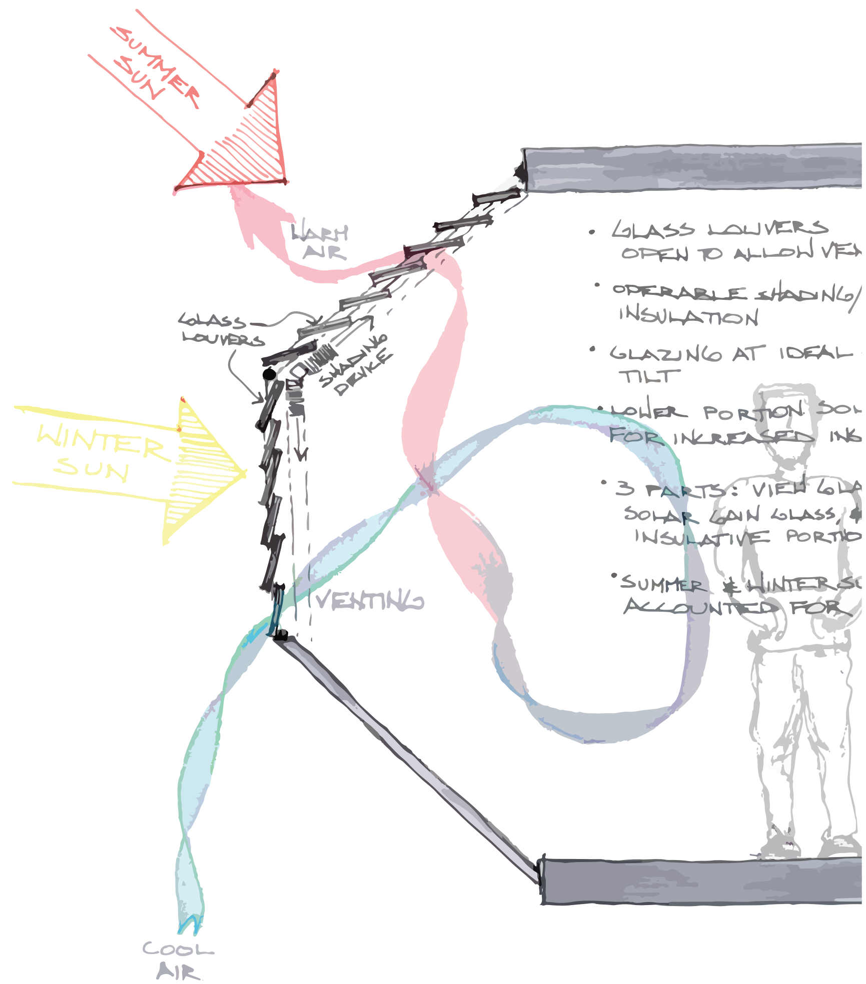
systems:

Angled glass facades allow for the control of sunlight angles and placement of glass louvers at the optimum 40 degree angle for sun transmittance.

Both winter and summer sun are accounted for, with opportunities to shade the top portion from summer heat while keeping the lower glazing area open for views and venting.

Venting opportunities happen naturally when glass louvers are rotated 'open' to prevent overheating.

The design also features shading/ insulation device that extends both ways from the center, working to both shade and insulate the space when desired. These louvers will rotate in place as well for improved features.



design intent

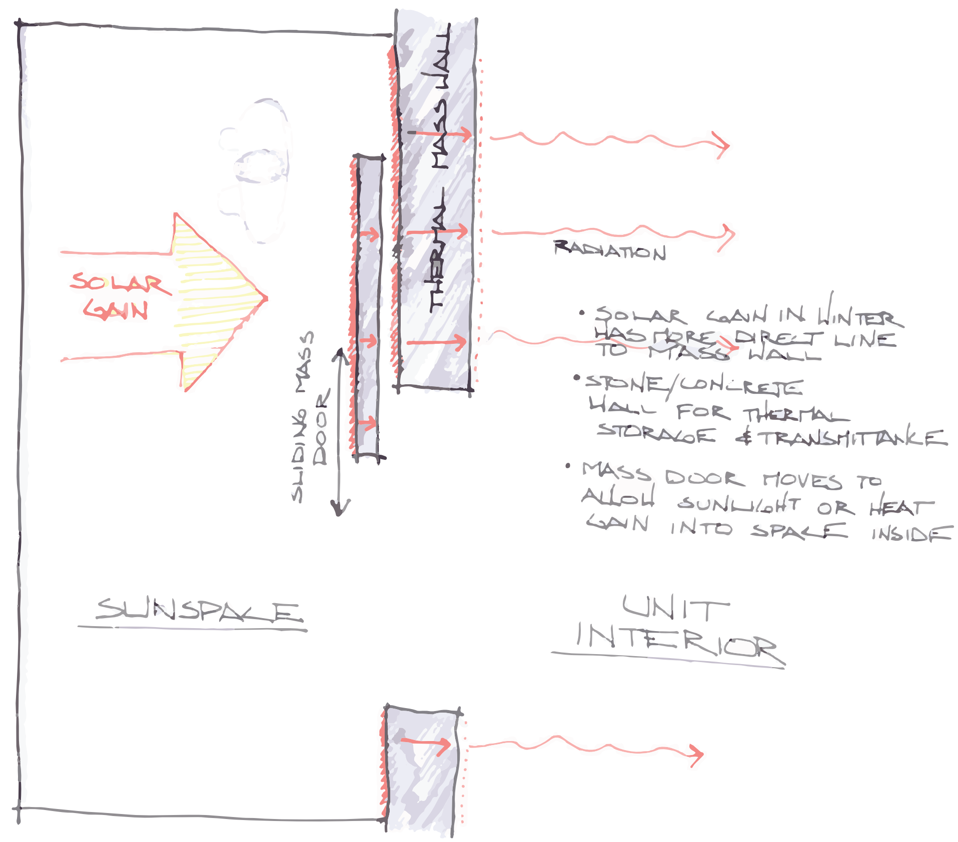
thermal mass:

We plan to use a thermal mass in the back wall of the sunspace, that can collect solar energy and transmit it through and into the dwelling in later, cooler times.

The thermal mass is increased with a concrete sliding door, allowing more control of the sunspace as well. This door can open to let light into the dwelling, or close to shelter it from direct light/heat, and later use the radiated thermal energy, along with the wall.

The wall is back from the face of the glazing enough to shelter from high, summer sun angles, and yet allow the lower, winter sun angles to have an almost direct line of impact.

These features have been removed from the final design as they create too much mass in the space, lowering the temperature.



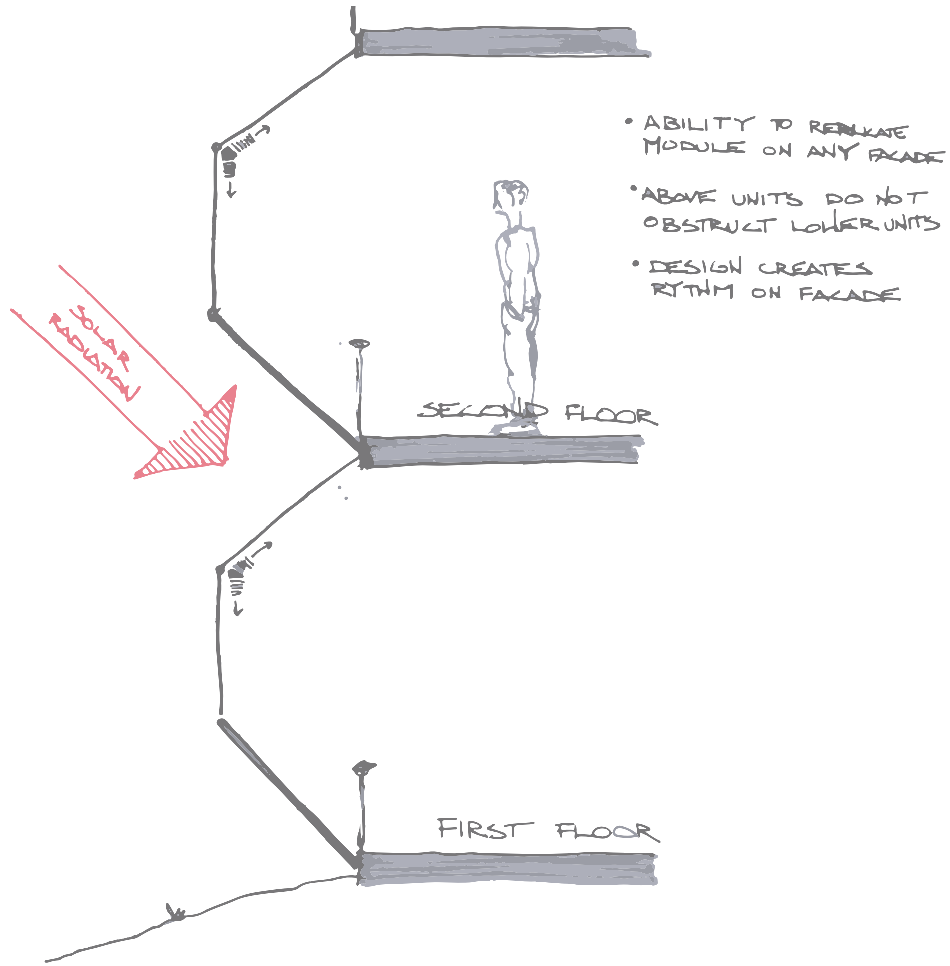
design intent

form:

This will be a dynamic, undulating facade composition created through the angled design, as the module can be repeated any number of times on man different buildign forms.

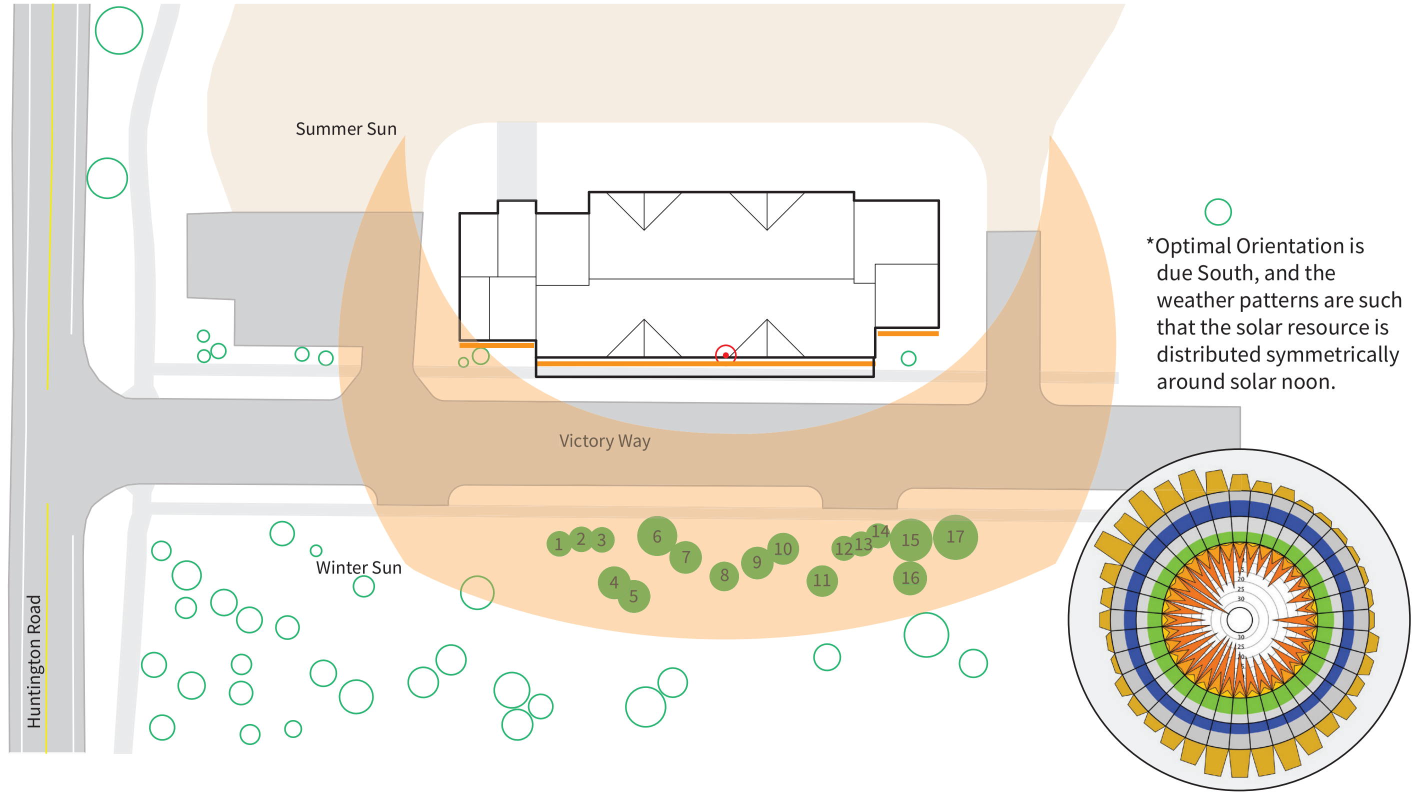
The alterations to the existing building should be minimal, with most of the structure able to fasten to the balcony ceiling and floor slabs.

This design is meant ot add a modern, expressive flare to any building to which it is attached, not simply opting for a functional, drab, standard construction.



design intent

site plan



Site Plan
50' 100'

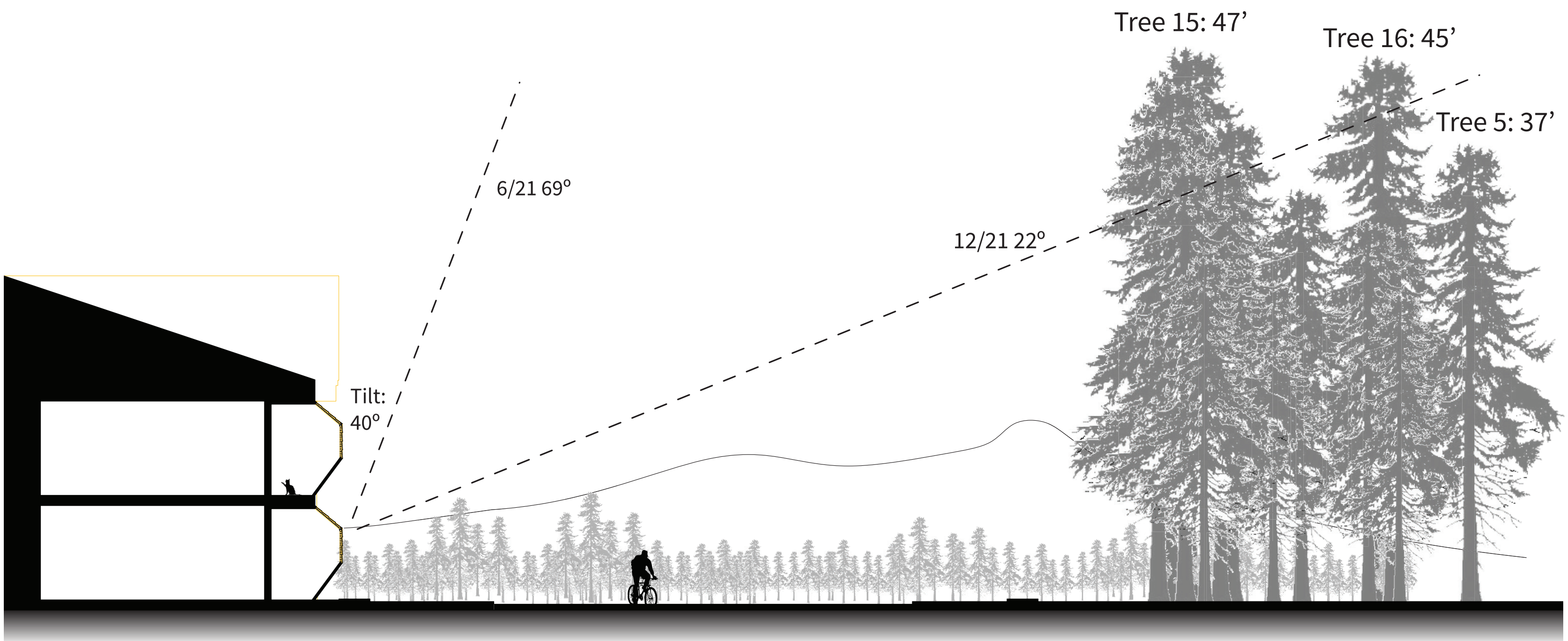
*Temperature from 1/15/18
Air Temp 12:30: 47°
*Wind Speed: 3.4 mph WSW

Pathfinder | Critical Trees | Non-Critical Trees
Dirt: 39° | Asphalt: 50.5° | Concrete: 41.3°

N

solar site survey

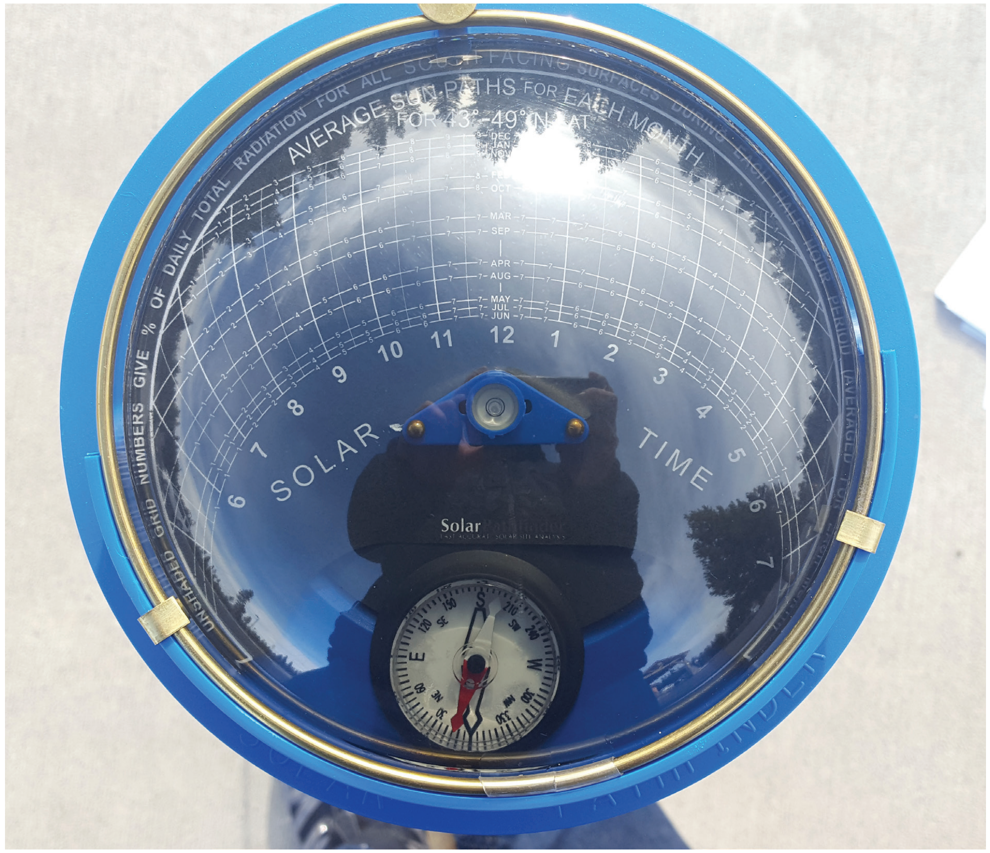
site section



Site Section Looking East:

solar site survey

pathfinder

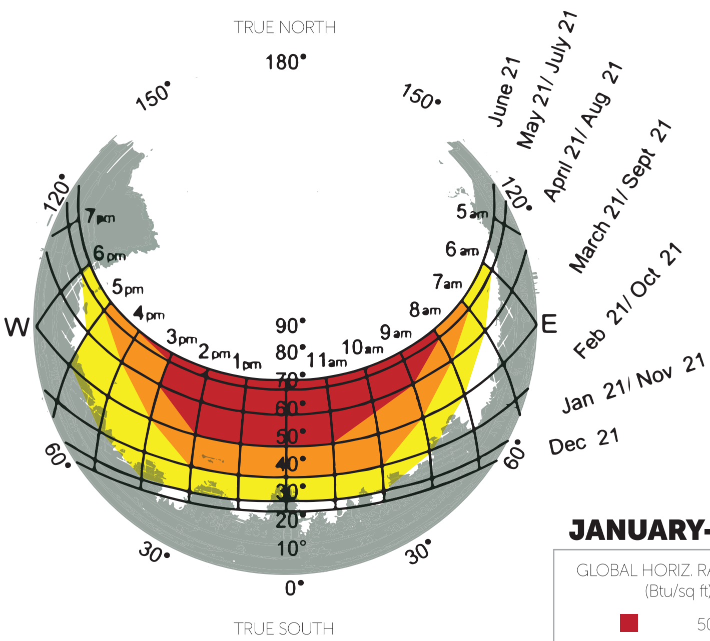


solar site survey

tree IDs

solar site survey

solar resources

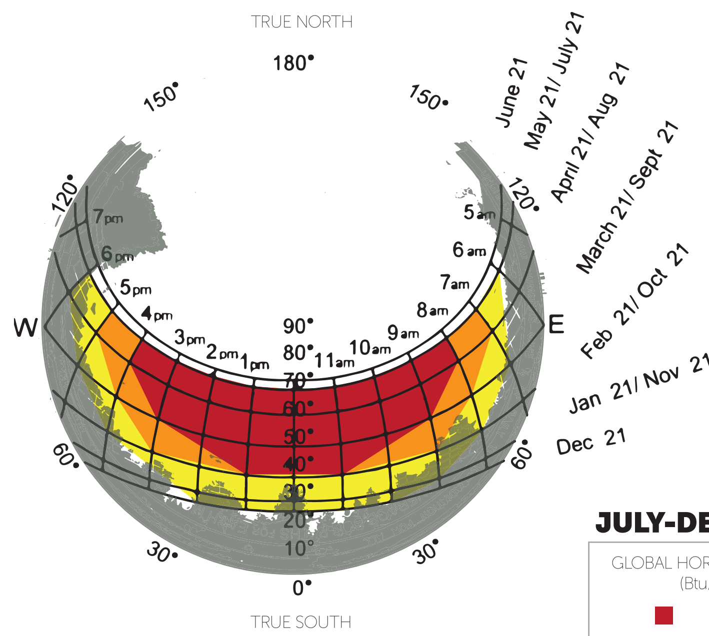


SUNPATH DIAGRAM, 44° N LATITUDE

JANUARY-JUNE

GLOBAL HORIZ. RADIATION (Btu/sq ft)

- 50-100
- 100-150
- >150



SUNPATH DIAGRAM, 44° N LATITUDE

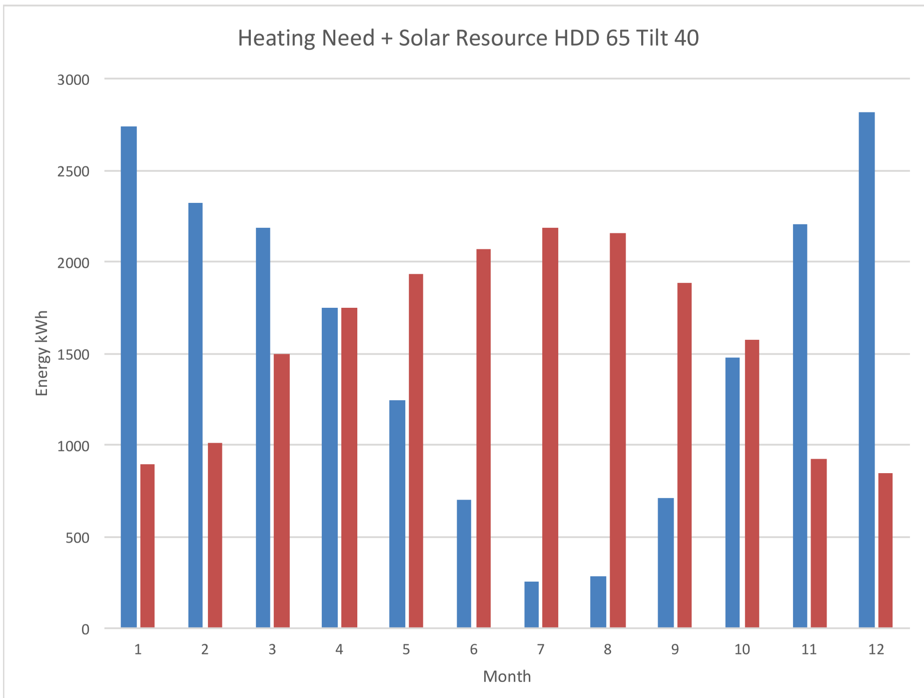
JULY-DECEMBER

GLOBAL HORIZ. RADIATION (Btu/sq ft)

- 50-100
- 100-150
- >150

solar site survey

heating need/ solar resources



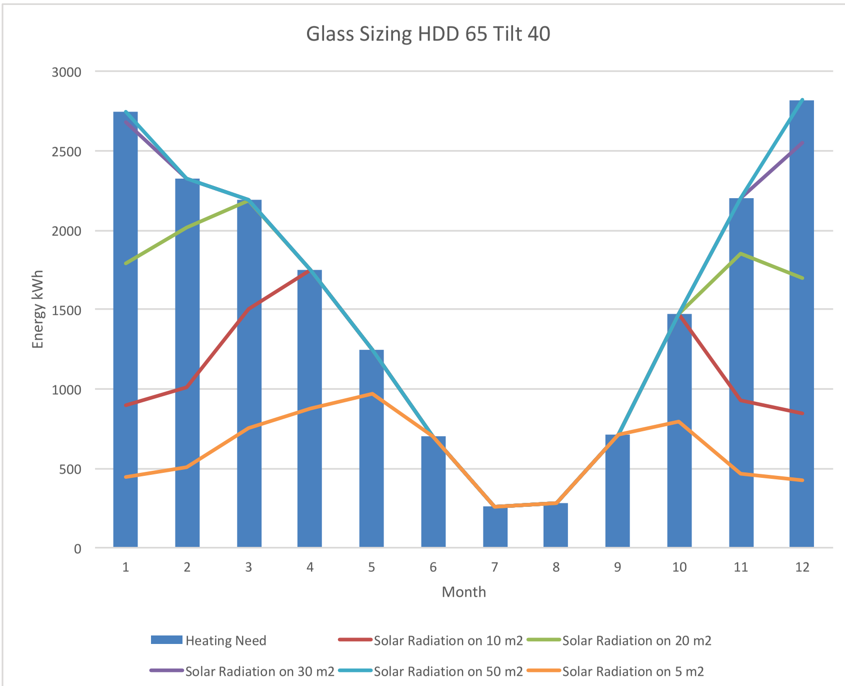
- Heating need is shown in blue, and solar resources are shown in red. It is apparent that there is much more heating need in the winter, with much less solar resources.

- The shorter days and lower sun angles account for this lessening of the solar resources in winter.

- For our design, we need to counteract this by providing both shading in summer to prevent overheating, and allow for low angle solar collection in winter, maximizing the heat we can collect then.

graphs

glass sizing



- This graph shows the amount of solar radiation we could collect based upon the area amount of glass we have at 40 degrees.

- With the heating need shown behind, it is apparent that we need a large amount; about 20 or 30 square meters of glass to get close to accommodating the heating need.

-For this size space, it is difficult to get upwards of 10 square meters of glazing, but with other strategies employed, our 22 square meters of glass, 11 tilted, will collect enough solar radiation to sufficiently heat the sunspace, and partially the dwelling behind.

graphs

glazing assembly

ID #: 1 Name: Single Clear

Layers: 2 Tilt: 90 ° IG Height: 1000.00 mm

Environmental Conditions: NFRC 100-2010 IG Width: 1000.00 mm

Comment:

erall thickness: 26.096 mm Mode: # Model Deflection

	ID	Name	Mode	Thick	Flip	Tsol	Rsol1	Rsol2	Tvis	Rvis1	Rvis2	Tir	E1	E2	Cond	Comment
Glass 1	102	CLEAR_3.DAT	#	3.0	☐	0.834	0.075	0.075	0.899	0.083	0.083	0.000	0.840	0.840	1.000	
Gap 1	9	Air (10%) / Argon (90%) Mix		20.0												
Glass 2	102	CLEAR_3.DAT	#	3.0	☐	0.834	0.075	0.075	0.899	0.083	0.083	0.000	0.840	0.840	1.000	

Ufactor	SC	SHGC	Rel. Ht. Gain	Tvis	Keff	Layer 1 Keff	Gap 1 Keff	Layer 2 Keff
W/m2-K			W/m2		W/m-K	W/m-K	W/m-K	W/m-K
2.628	0.879	0.764	575	0.814	0.1244	1.0000	0.0982	1.0000

- The glass we chose has a high U value (2.624), meaning lots of heat will enter, but also means it is not very insulated, factoring toward the need for movable insulation to supplement.

- With a high SHGC (.764) and high visible transmittance (.814), this glazing chosen will allow for optimum viewing out, as well as a high potential for solar energy to enter and heat the space.

graphs

thermal mass sizing

Target Month: March
Solar Radiation: 17.5 kWh = 6300kJ

6300 kJ solar radiation x 0.6 solar absorptance = 3780 kJ ptl. uptake

Temperatures:
-Coolest expected: -2 degrees celsius
-Warmest expected: 10.5 degrees celsius

Difference: 10.5 - -2 = 12.5 degrees celsius = 12.5 K desired temperature difference

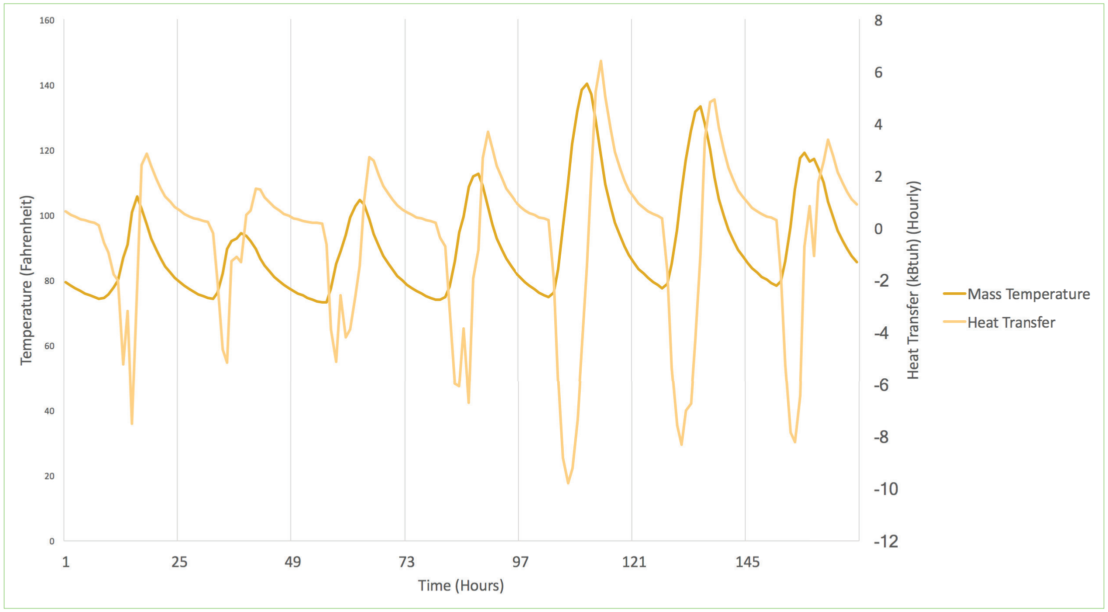
Brick Mass:
-Solar Absorptance = .6
-Heat Capacity = .85 kJ/kgK
-Density = 2000 kg/m3

(1/.85) kg K/kJ x 3780 kJ / 12.5 K = 355 kg mass

Thickness:
355 kg mass x 1m3/2000kg = .17 m3 volume / 14 m3 area = .0128 m = .5"

graphs

mass surface temp/hourly mass conduction



- This graph is showing the absorption of solar heat energy into the thermal mass, as well as showing the heat transfer from it later, into the space.

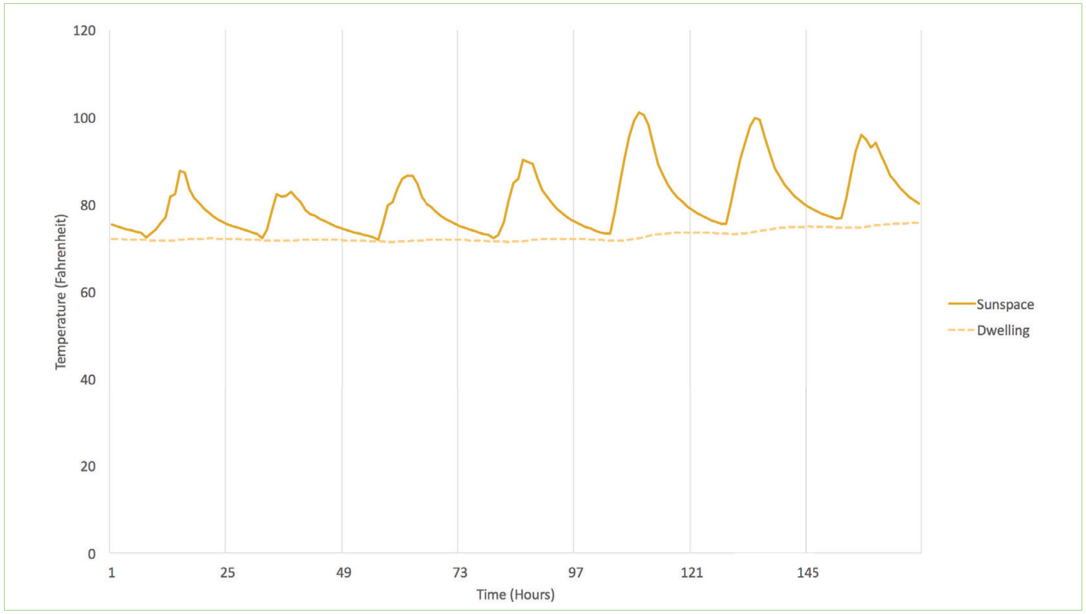
- From this data we can deduce that there is a successful lag time between the heat being absorbed, and the heat leaving the mass into the space, which is how we planned.

- This allows for the space to be passively heated, even when solar resources have diminished.

- Over the time plotted, it is clear that the heat transfer is lowest during peak solar energy harvesting, reaching -10 kBtu/h, and peaks a bit after the solar energy does, reaching up to 7 kBtu/h.

graphs

operative temp. in sunspace/ dwelling



- This graph is showing the operative temperatures in both the sunspace as well as the dwelling, comparing the two, to see how they interact.

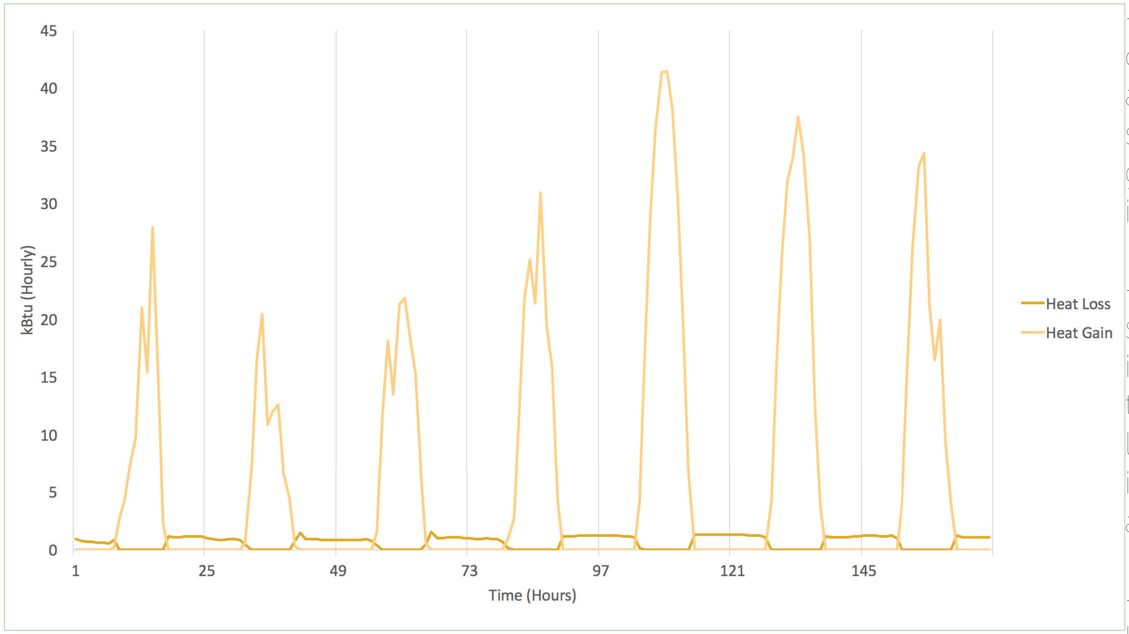
- It is clear through the data plotted that while the sunspace fluctuates in its temperature swings, the dwelling stays consistently the same.

- Through our design we have enabled the sunspace to successfully heat the dwelling when needed, and protect the space form getting too hot as well.

- The dwelling stays within a comfortable range of around 75 degrees Fahrenheit, while the sunspace swings from around 73 up to 96 degrees.

graphs

sunspace heat gain AND heat loss



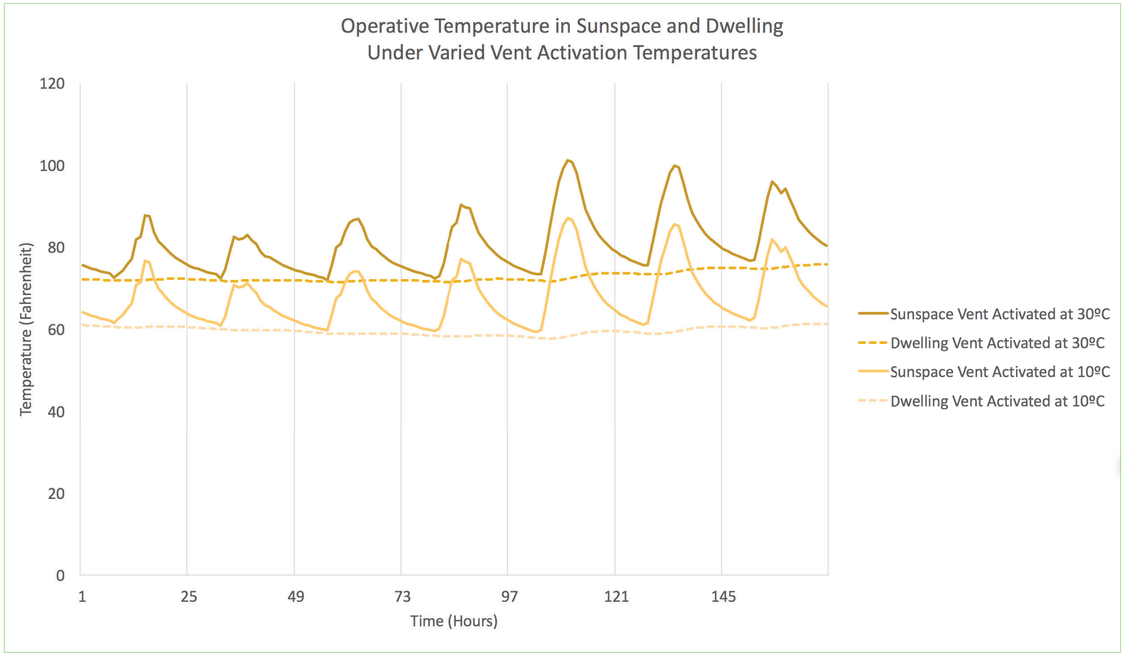
- This graph shows the correlation between heat gain and loss in the sunspace, showing how effective both our glazing area as well as movable insulation is.

- While the heat gain in the space swings up to 42 kBtu/h in peak solar harvesting times, the heat loss keeps a relatively level profile, indicating that the insulation we have set to deploy at night is effective.

- Heat loss tops out at about 1 kBtu/h, which is very efficient, and shows that our insulation is working well.

graphs

varied conditions



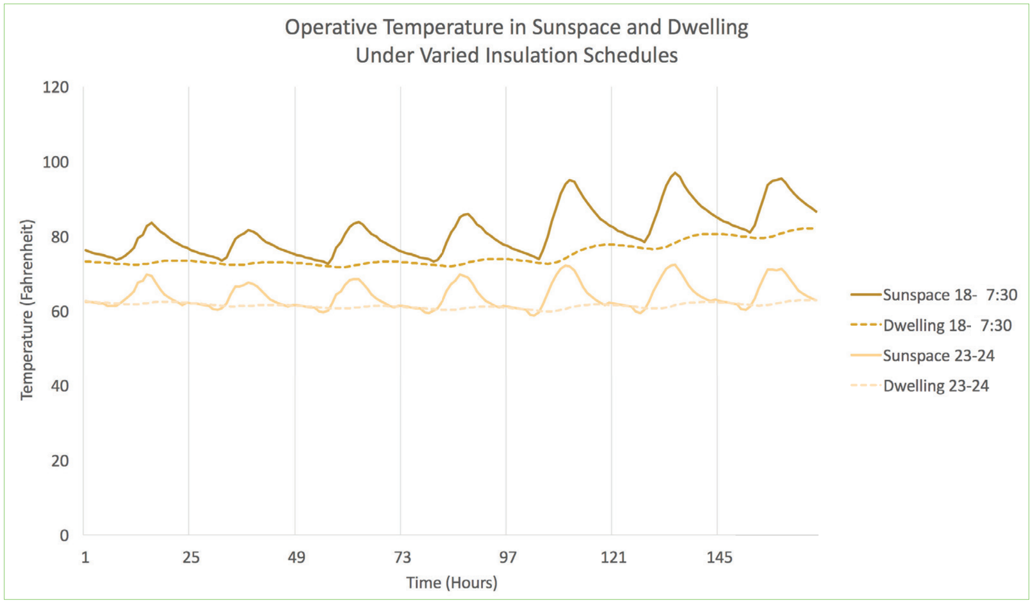
- By comparing the activation temperatures for our natural ventilation system, it is clear that the ideal temperature to activate is at 30 degrees Celsius, not at 10 degrees.

- When activated too soon, it is quite difficult to keep both spaces at a comfortable temperature range. In this case, it is staying more around 60 for the dwelling, and ranging from 60-80 for the sunspace.

- With a higher activation time, it is easier to keep the dwelling at a comfortable 70-73 degrees at all times, while the sunspace ranges from 70 to 96 degrees, which could be considered uncomfortable.

graphs

varied conditions



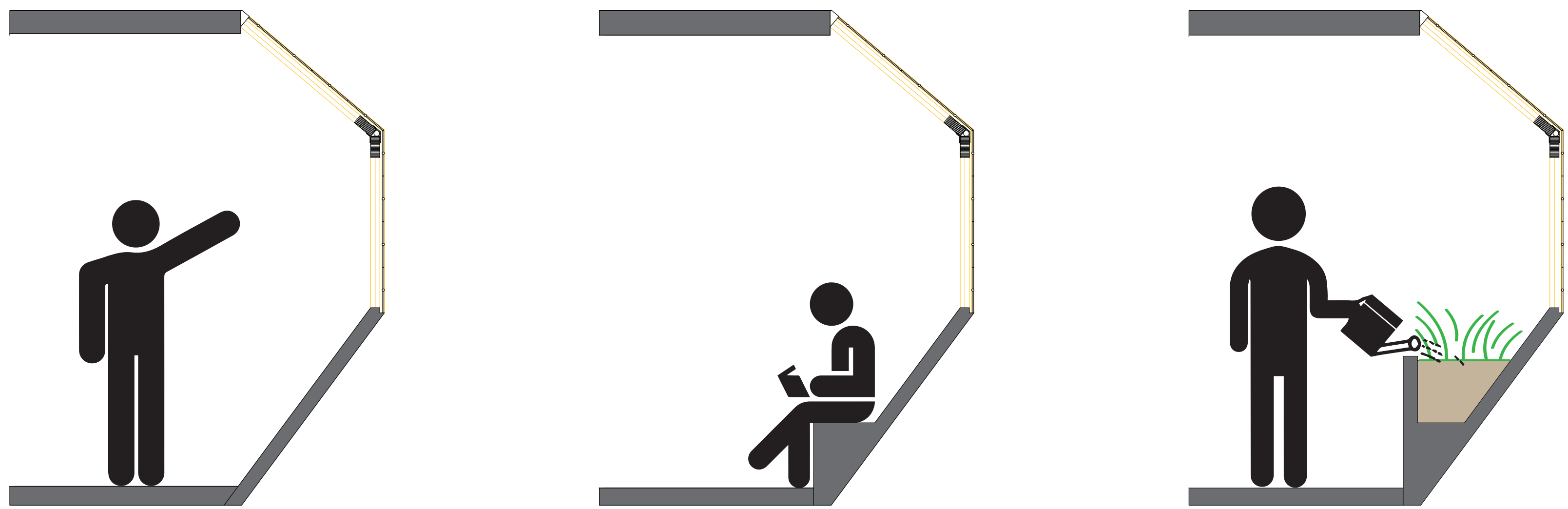
- By comparing the deployment times for movable insulation in two models, we have found the more effective time in which to deploy it, based on the amount of heat kept inside the space.

- If the insulation is only deployed for one hour, from 11-12 at night, there is not enough time to keep the heat in, therefore the average temperature stays at a lower than comfortable operative temperature.

- If the insulation is deployed from 6pm to 7:30am, there is much more time for the insulation to do its job in retaining heat, so the space stays at a much more comfortable, around 70 degree range.

graphs

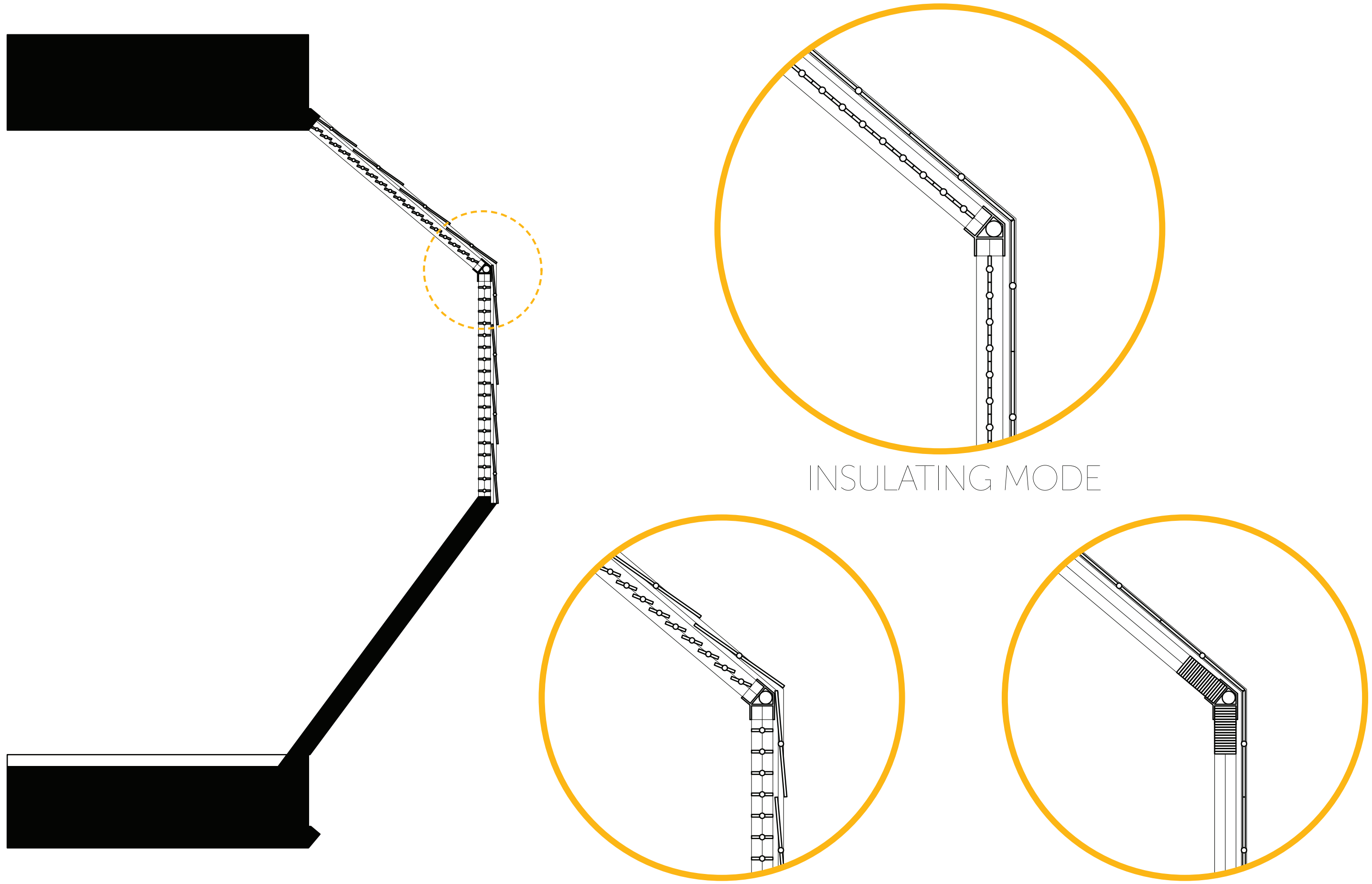
section diagrams



Section diagrams showing the variations of configurations of our module. The lower portion of the sunspace exterior, without glazing, may be used for either a seat, or for a built-in planter box. Otherwise, it can remain open, as shown in our base design module. This angle allows for light to reach the module below.

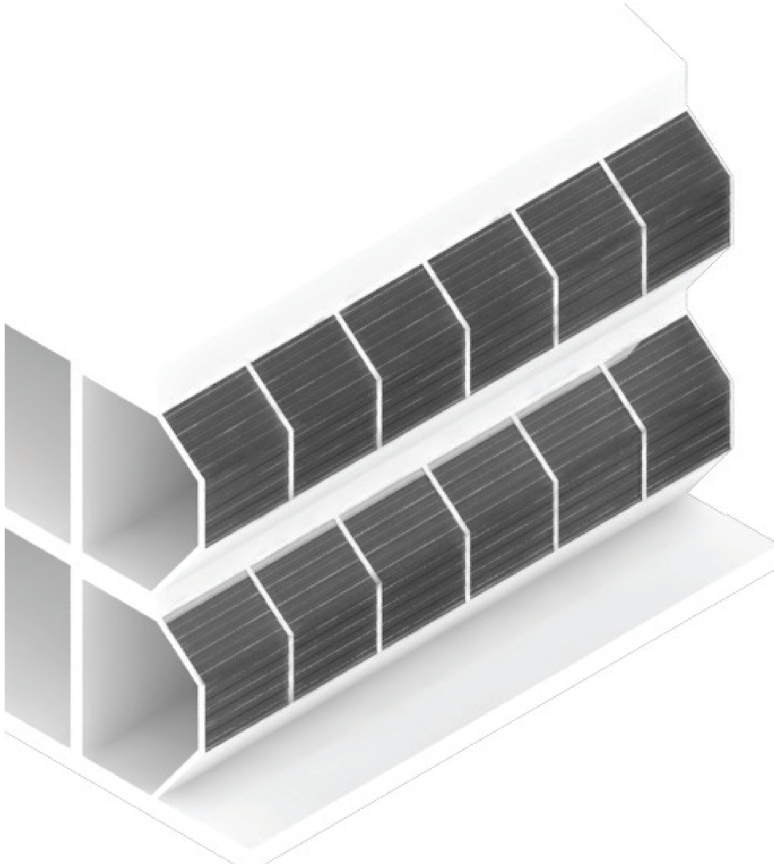
design

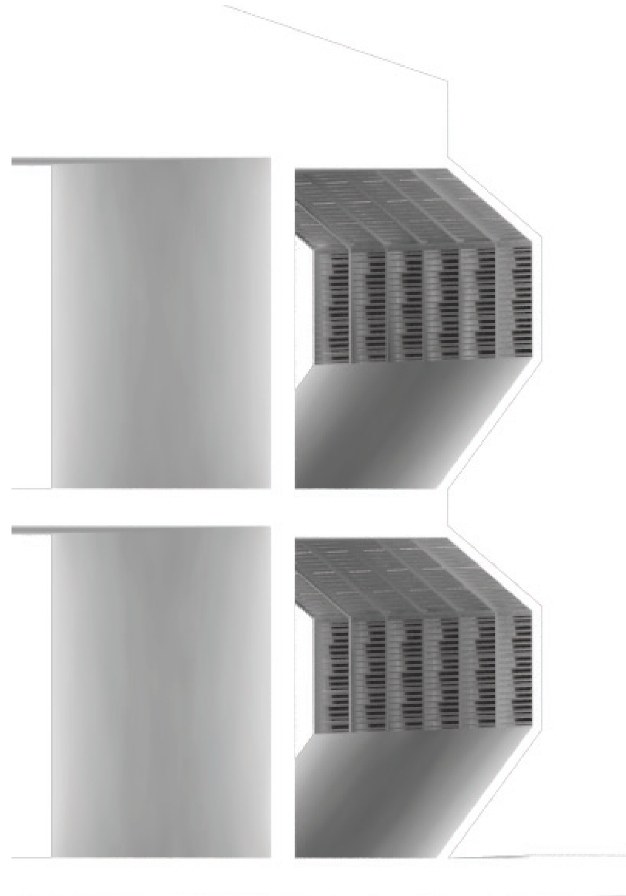
movable insulation detail



design

design rendering



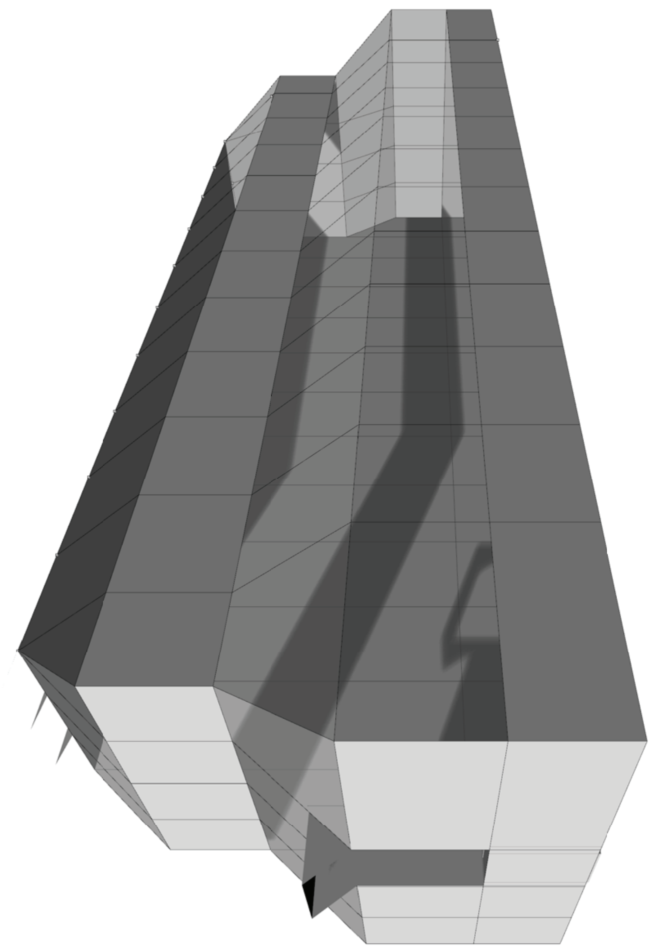


design

Appendix B: Community Greenhouses Presentations

GREENHAUS DESIGN

RENEE DOBRE | CHAMPE HOLBECK | RYAN MARK



PRECEDENT STUDIES

TARTU NATURE HOUSE

-Using angled glazing in order to gain optimal daylighting in the space for plant life.

-Wood frame construction to reduce thermal bridging.

-Using heat lamps to heat the space in the winter.

GEODOME GREENHOUSE WATER TANK

-Using a water tank to serve as thermal mass during the hot summer months of the season

-The warm water in the tank is used to water plants. Plants thrive better when watered with stagnant water.

-The water in the tank becomes stagnant because of the lack of flow. The chlorine from the water source is also evaporated when the water is warmed up.

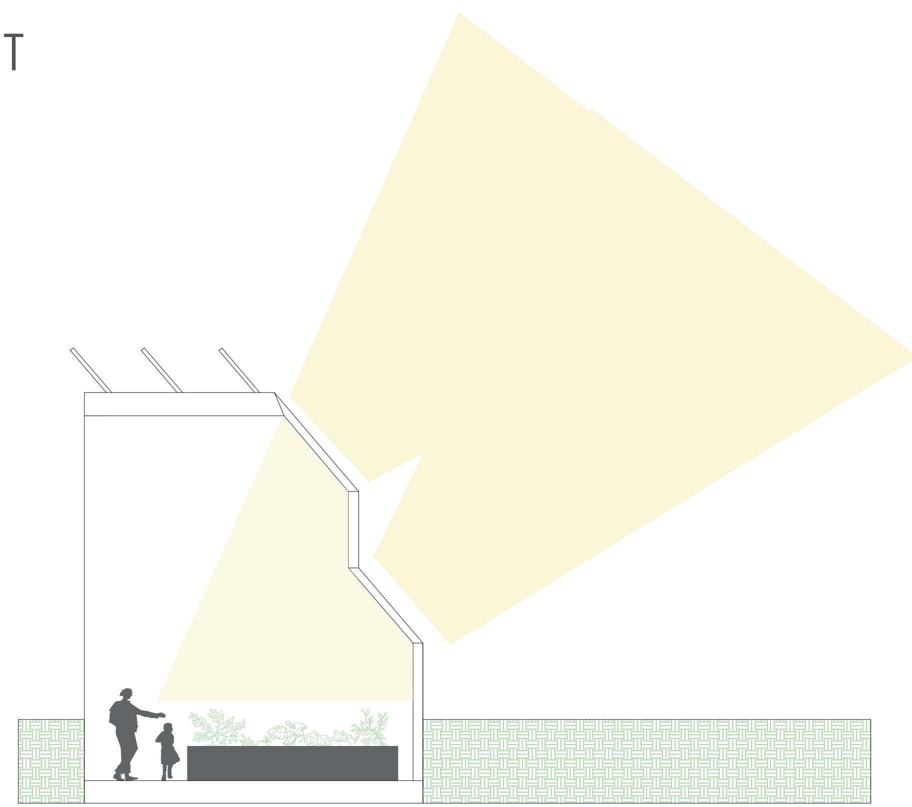
FKI TOWER

-Using variations of angled glazing in order to alter the amount of daylighting in the space.

-Using solar panels at optimal angles to receive maximum sunlight.

-Staggering angled glass in order to decrease probability of height issues.

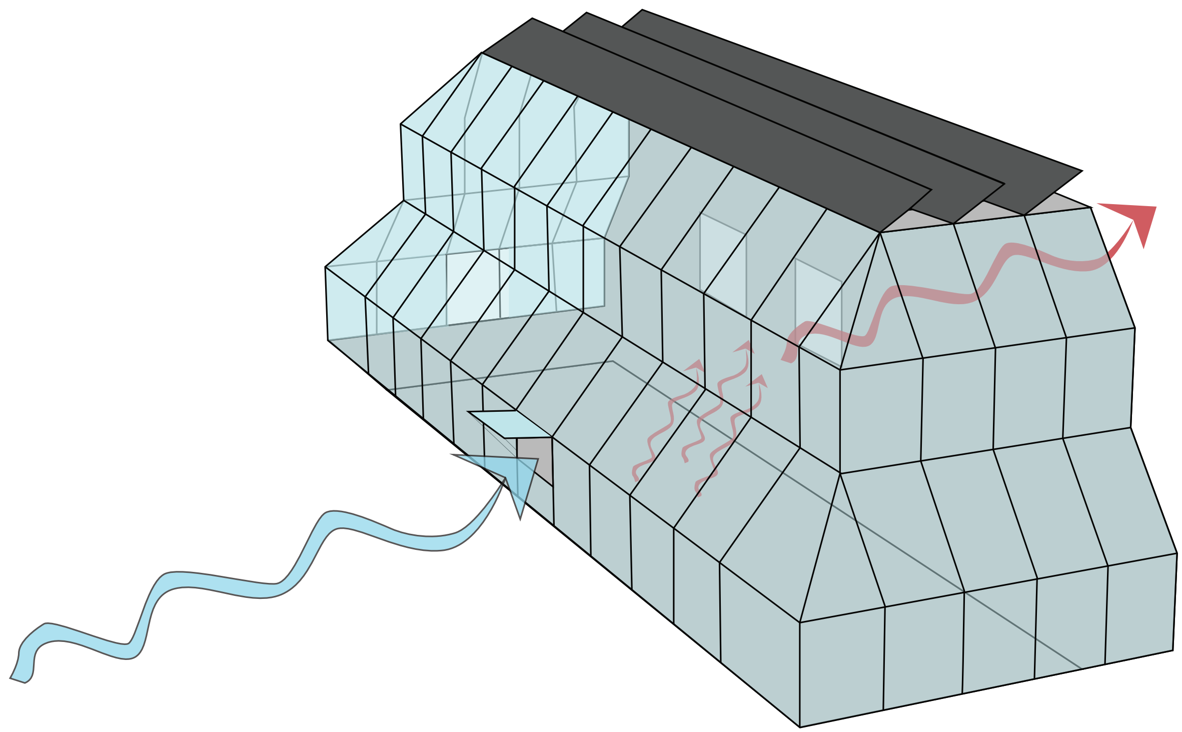
DESIGN INTENT



OPTIMAL SOLAR GAIN FOR PLANT LIFE

PROVIDING OPTIMAL SOLAR GAIN FOR PLANT LIFE TO THRIVE IN THE WINTER OREGON CLIMATE. PRIORITY IS GIVEN TO PLANTS OVER HUMAN OCCUPANTS BECAUSE THE SPACE IS MOSTLY OCCUPIED BY PLANT LIFE.

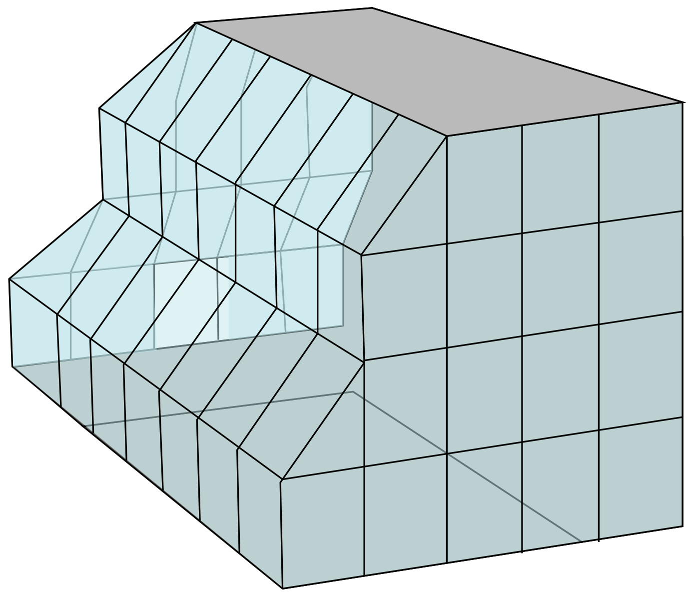
DESIGN INTENT

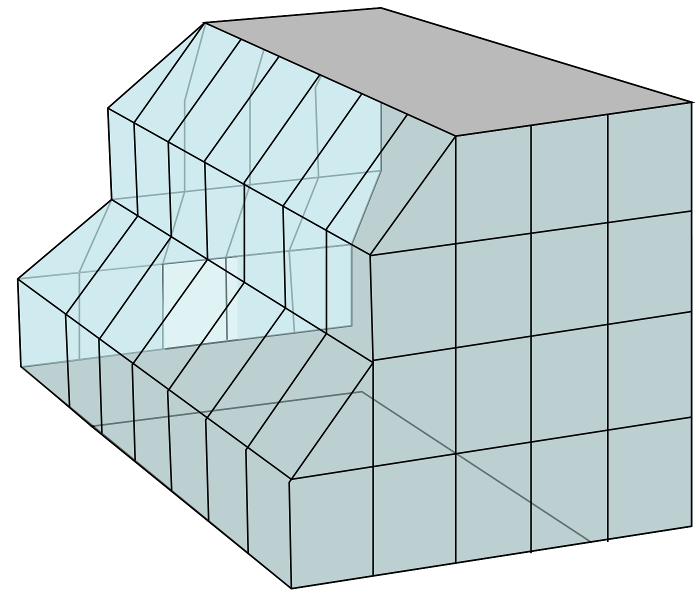


User Operable Glazing

ALLOWS WINDS FROM THE SOUTH TO BE USED TO COOL THE SPACE IN THE SUMMER TIME WHEN HEAT CAN BE MORE OF A PROBLEM AND ALSO KEEP THE AIR MORE FRESH TO ENHANCE THE USER EXPERIENCE.

DESIGN INTENT

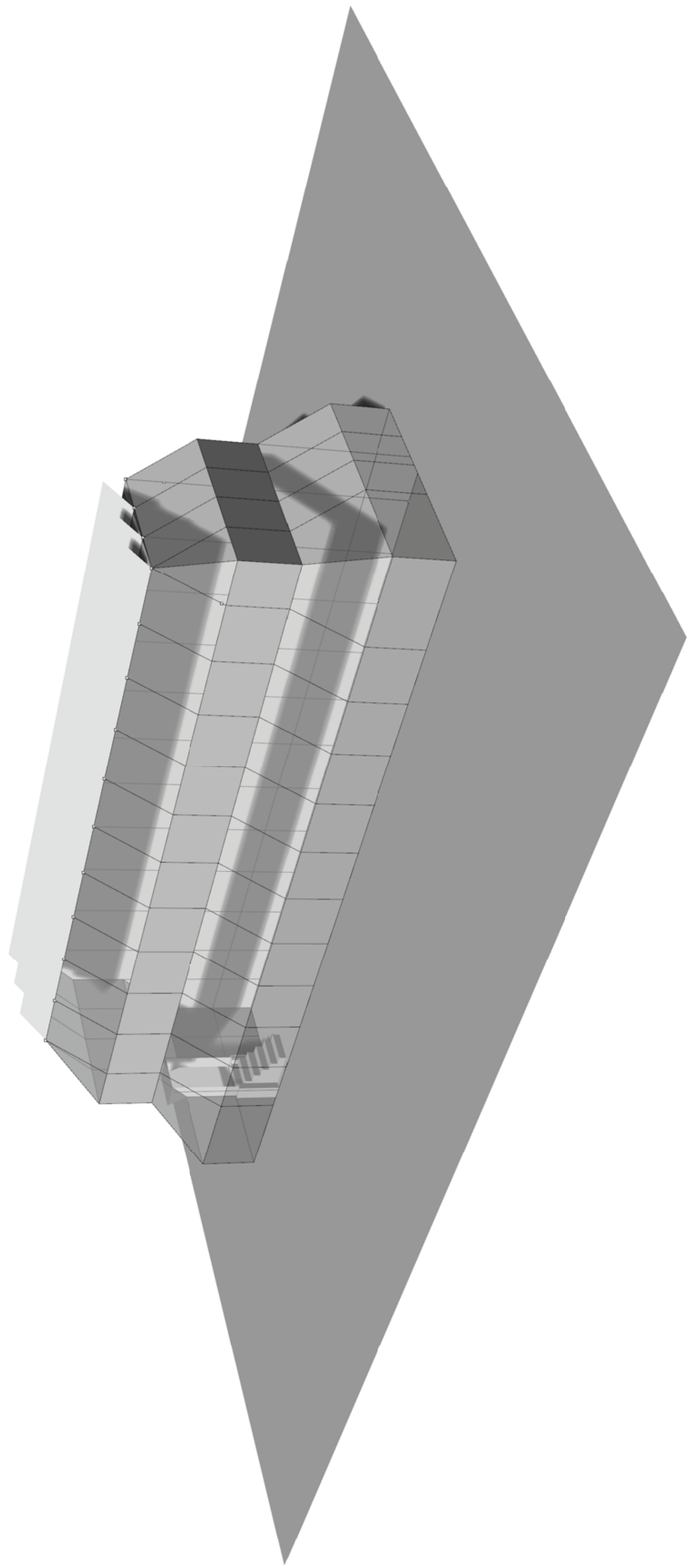




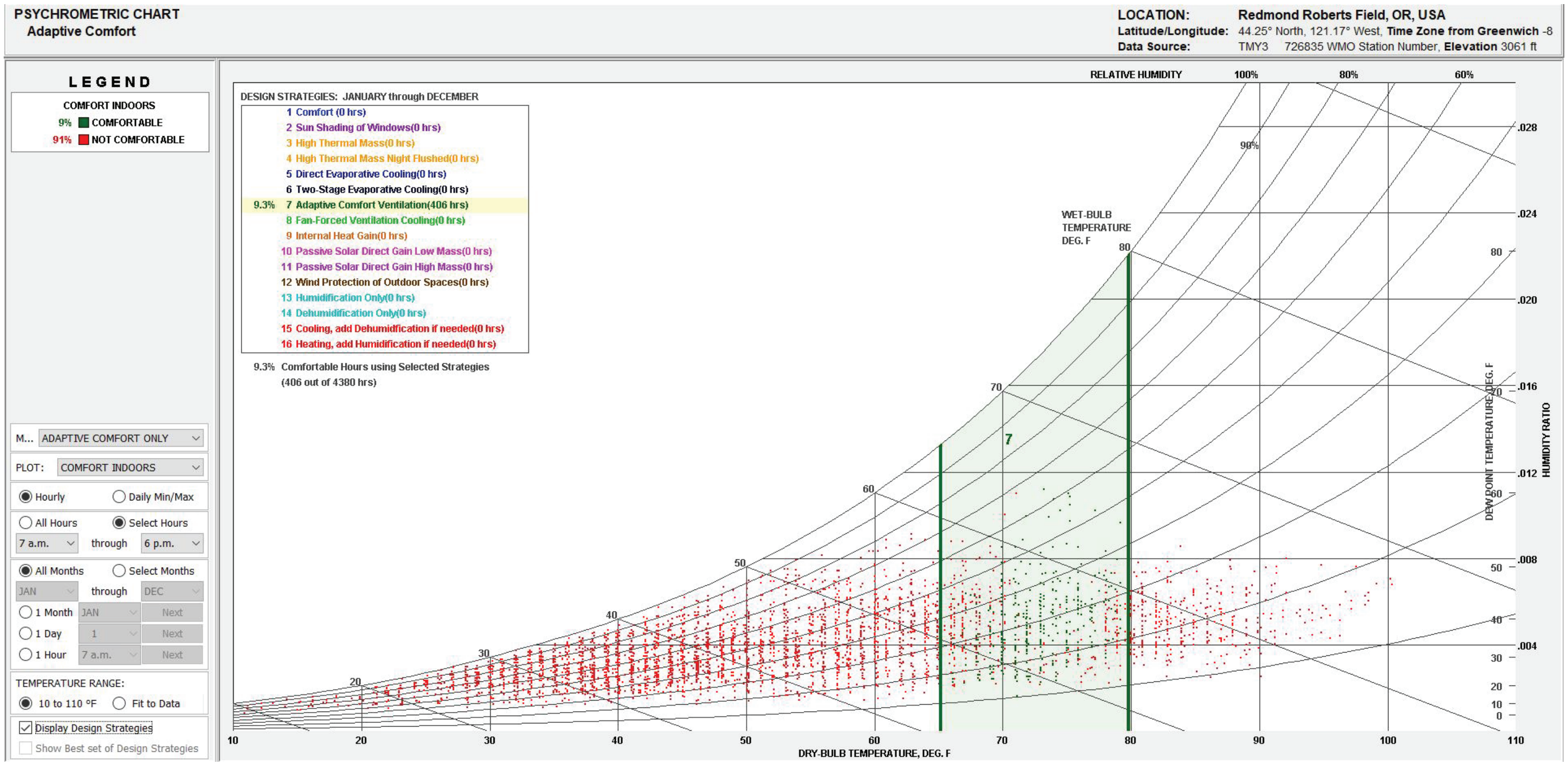
Simple Modular Design

ALLOWS FOR EASY CONSTRUCTION AND ALLOWS FOR FUTURE EXPANSION BY EITHER ADDING ON TO ONE GREENHOUSE OR BUILDING MORE, SMALLER UNITS IN THE AREA. THIS ALLOWS MORE DIVERSITY FOR SOME PLANTS THAT MAY NEED TO BE KEPT AT A CERTAIN TEMPERATURE OR FOR TENANTS THAT DON'T WANT TO SHARE.

3D VIEW



GOALS: THERMAL COMFORT FOR PLANTS

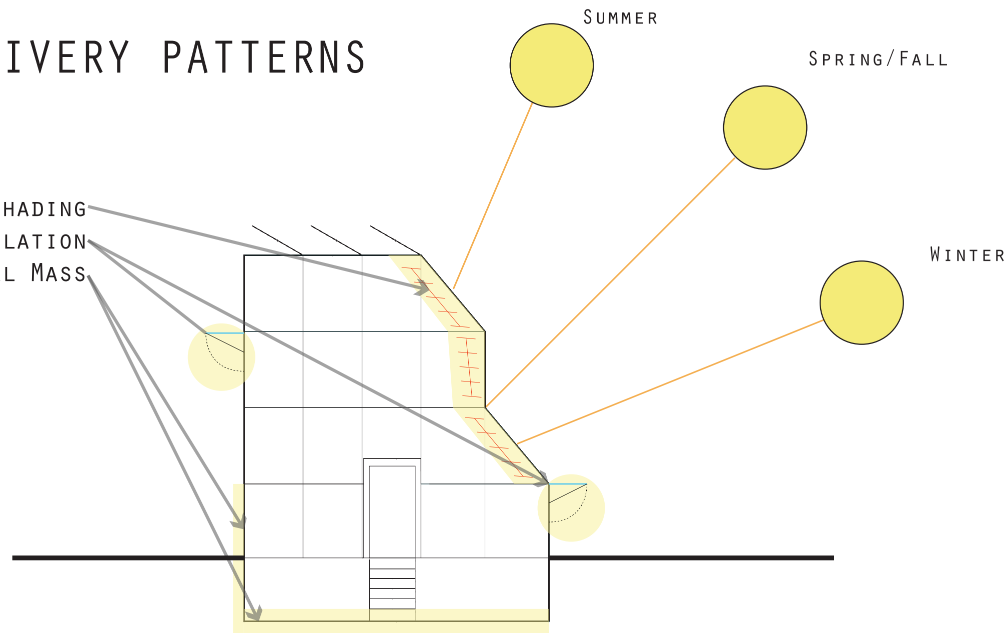


The space is not always inhibited by humans. Therefore, thermal comfort is not a large priority. An intended design temperature of 60°F was decided to provide a comfortable atmosphere for plants as well as a bareable one for individuals. The plants we chose all thrive within the range of 60°F for the air temperature. A minimum soil temperature of 45°F will be maintained to assure that the plants can still grow in their environment. This will be made possible with optimal solar gain throughout the year. Solar powered heat lamps will be provided in the the winter if the soil and air temperature become too low. Since the greenhouse is mostly glazing, it will get very hot in the summer. Therefore, flexible ventilation will be put into place in order to allow individuals to cool the space when needed. Movable insulation will also be placed on a schedule to reduce heat losses at night during the colder months. Thermal masses will be put into the space in order to allow for them to collect heat in the hotter months.

GOALS: THERMAL DELIGHT FOR OCCUPANTS

THE GREENHOUSE WILL PROVIDE AN OASIS TYPE SPACE DURING BOTH THE WINTER AND SUMMER MONTHS. THE SPACE WILL GENERATE THERMAL COMFORT TO SEVERE TEMPERATURES. THIS INVOLVES THE SPACE BECOMING A PLACE OF WARMTH DURING THE WINTER. THIS WILL BE MADE POSSIBLE THROUGH SOLAR POWERED HEATING LAMPS, OPTIMAL TILT FOR THE HIGHEST SOLAR GAIN, AND THERMAL MASS THAT WILL REDISTRIBUTE HEAT THROUGHOUT THE SPACE AS THE DAY GETS COLDER. IN THE SUMMER, HOWEVER, MOVABLE INSULATION WILL BE PROVIDED TO REDUCE HEAT GAINS. THERMAL MASS WILL COLLECT HEAT AND REDISTRIBUTE IT DURING THE NIGHT WHEN THE TEMPERATURES ARE COOLER. MOVABLE GLAZING WILL ALSO PROVIDE FLEXIBLE VENTILLATION FOR THE OCCUPANTS THAT CAN ALLOW A WIND BREEZE TO COME IN. AROMATIC PLANTS WILL BE STRATEGICALLY PLACED THROUGHOUT THE SPACE IN ORDER TO PROVIDE COMFORT THROUGH THE SENSES.

GOALS: HEAT DELIVERY PATTERNS



The greenhouse aims to maintain steady soil and air temperatures for the plants inside the space to thrive. Having an average design temperature at 60°F will assure this. In order to maintain this temperature, different methods are necessary for the hot summer months and the cold winter.

During the summer, movable insulation will be used earlier in the day to reduce heat gains. Thermal mass will play a large part in collecting the heat gain during the hot days and redistributing it at night. Operable ventilation will be provided to allow adaptable conditions were occupants can open up windows if the space reaches a temperature that is too high according to a monitored thermostat.

The winter months will require the maintenance of maximum solar gain throughout the day. This will be made possible with the 50° tilt of the glazing. The ground floor of the greenhouse is also pushed underground in order to collect heat from the earth. Thermal mass will collect heat during the day and redistribute it at night while the space is at its coldest. The water tanks that serve as thermal mass will have warm water that will heat up the soil. Movable insulation will be used in the space in the afternoon to early morning to reduce heat losses. Lastly, solar powered heat lamps will be provided to warm the space when needed. These will be powered by solar panels tilted on the roof.

PLANT TYPES

AROMATIC:

LAVENDAR:
MINIMUM SOIL TEMP 40°F
PRACTICAL SOIL TEMP 50°F - 60°F
AVERAGE AIR TEMP 65°F - 70°F

ONION:
MINIMUM SOIL TEMP 35°F
PRACTICAL SOIL TEMP 50°F - 95°F
AVERAGE AIR TEMP 55°F - 74°F

CARROTS:
MINIMUM SOIL TEMP 40°F
PRACTICAL SOIL TEMP 40°F - 80°F
AVERAGE AIR TEMP 60°F - 65°F

BEET:
MINIMUM SOIL TEMP 40°F
PRACTICAL SOIL TEMP 50°F - 85°F
AVERAGE AIR TEMP 50°F - 85°F

LETTUCE:
MINIMUM SOIL TEMP 35°F
PRACTICAL SOIL TEMP 40°F - 80°F
AVERAGE AIR TEMP 60°F - 65°F

PARSLEY:
MINIMUM SOIL TEMP 40°F
PRACTICAL SOIL TEMP 50°F - 85°F
AVERAGE AIR TEMP 60°F - 65°F

PATHFINDER PHOTOS

PATHFINDER 1

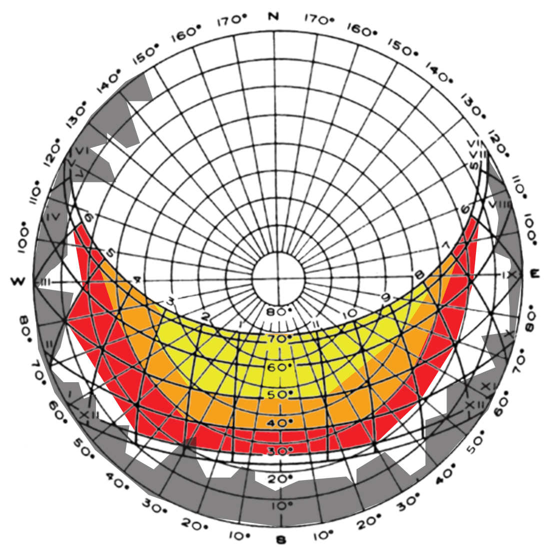
PATHFINDER 2

PATHFINDER 3

SITE SHADING MASKS

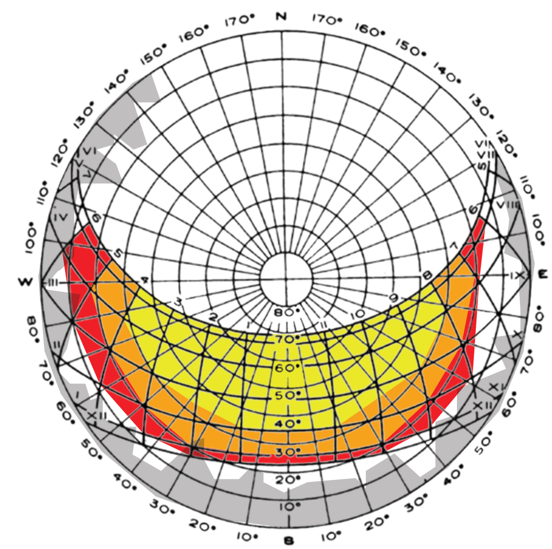
JANUARY - JUNE

- 50-100 Btu/sq. ft.
- 100-150 Btu/sq. ft.
- 150+ Btu/sq. ft.



JULY - DECEMBER

- 50-100 Btu/sq. ft.
- 100-150 Btu/sq. ft.
- 150+ Btu/sq. ft.



TREE IDENTIFICATION

Species - Western White Pine

Density - 94%

Height - 59ft

Species - Lodgepole Pine

Density - 56%

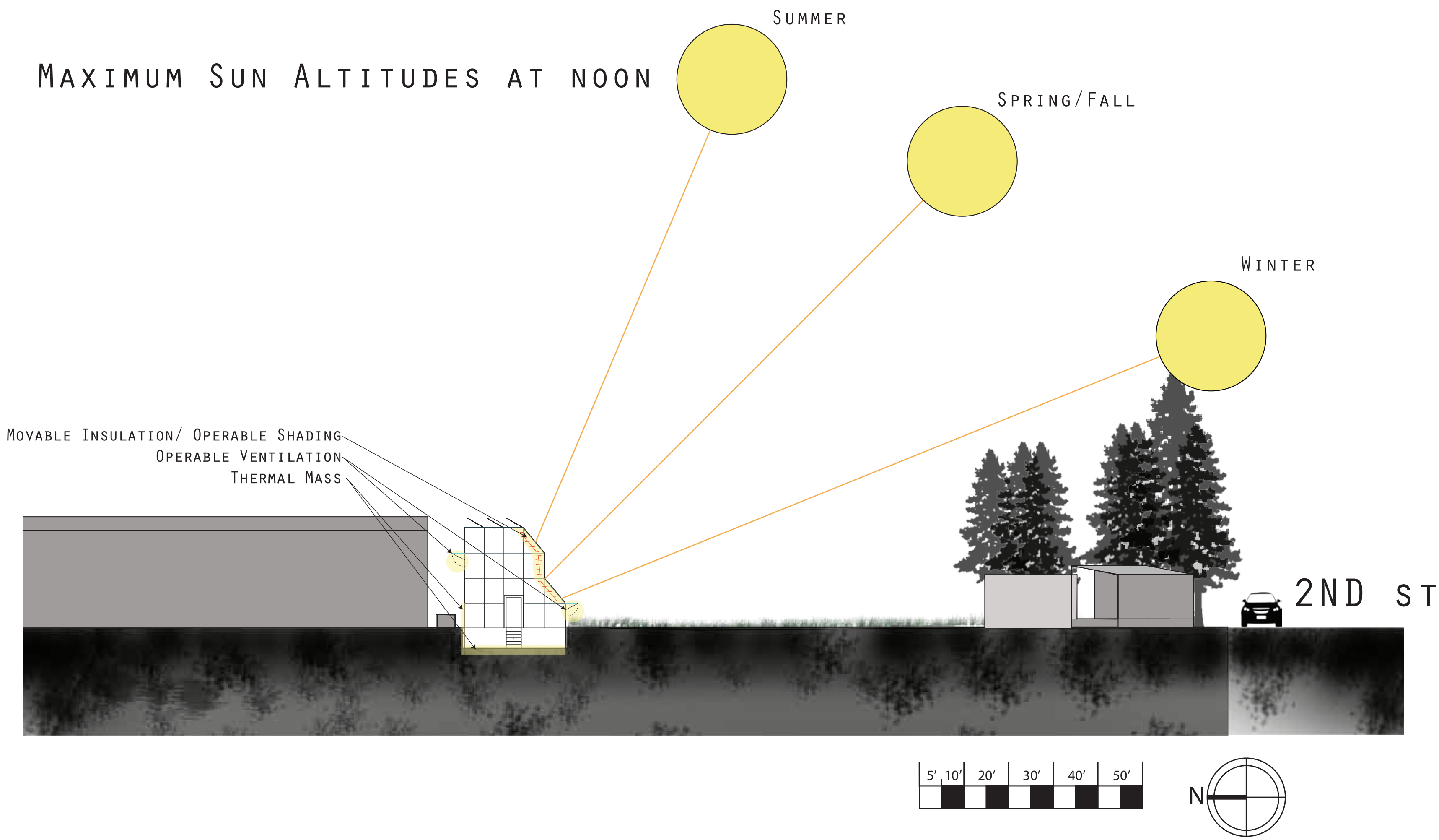
Height - 54ft

SITE PLAN

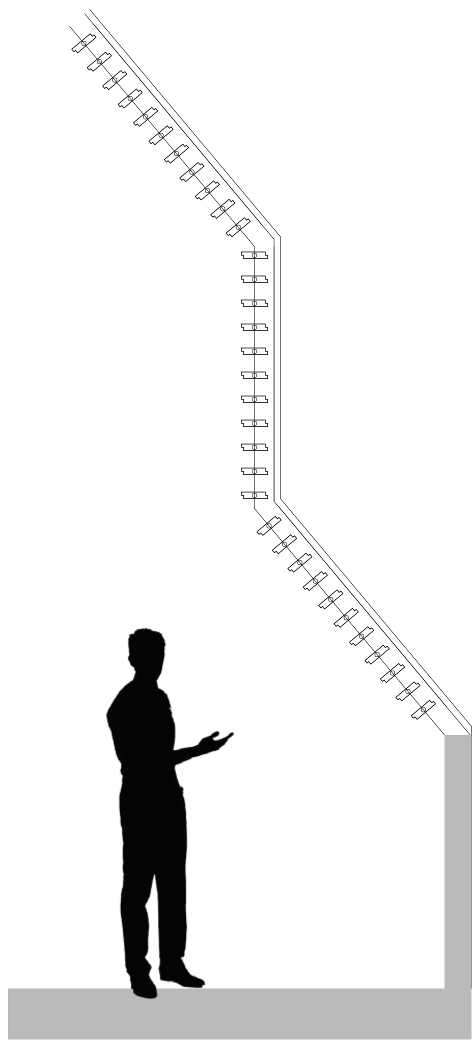
HUNTINGTON RD
MAIN ST
MORSON ST
2ND ST
N
5' 10' 20' 30' 40' 50'
1
2
3
Pathfinders
Summer Wind
Winter Wind

SITE SECTION

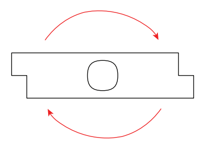
Maximum Sun Altitudes at Noon



Operable Shading/Insulation Device

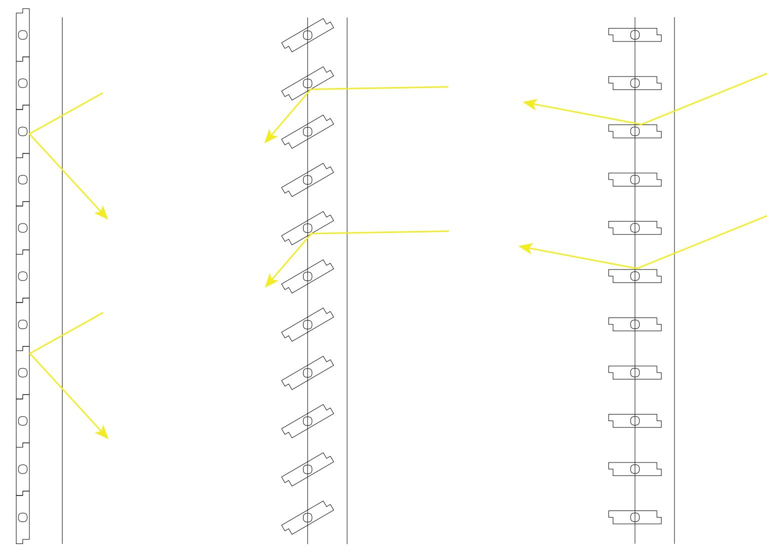


Scale: 1/2" = 1'

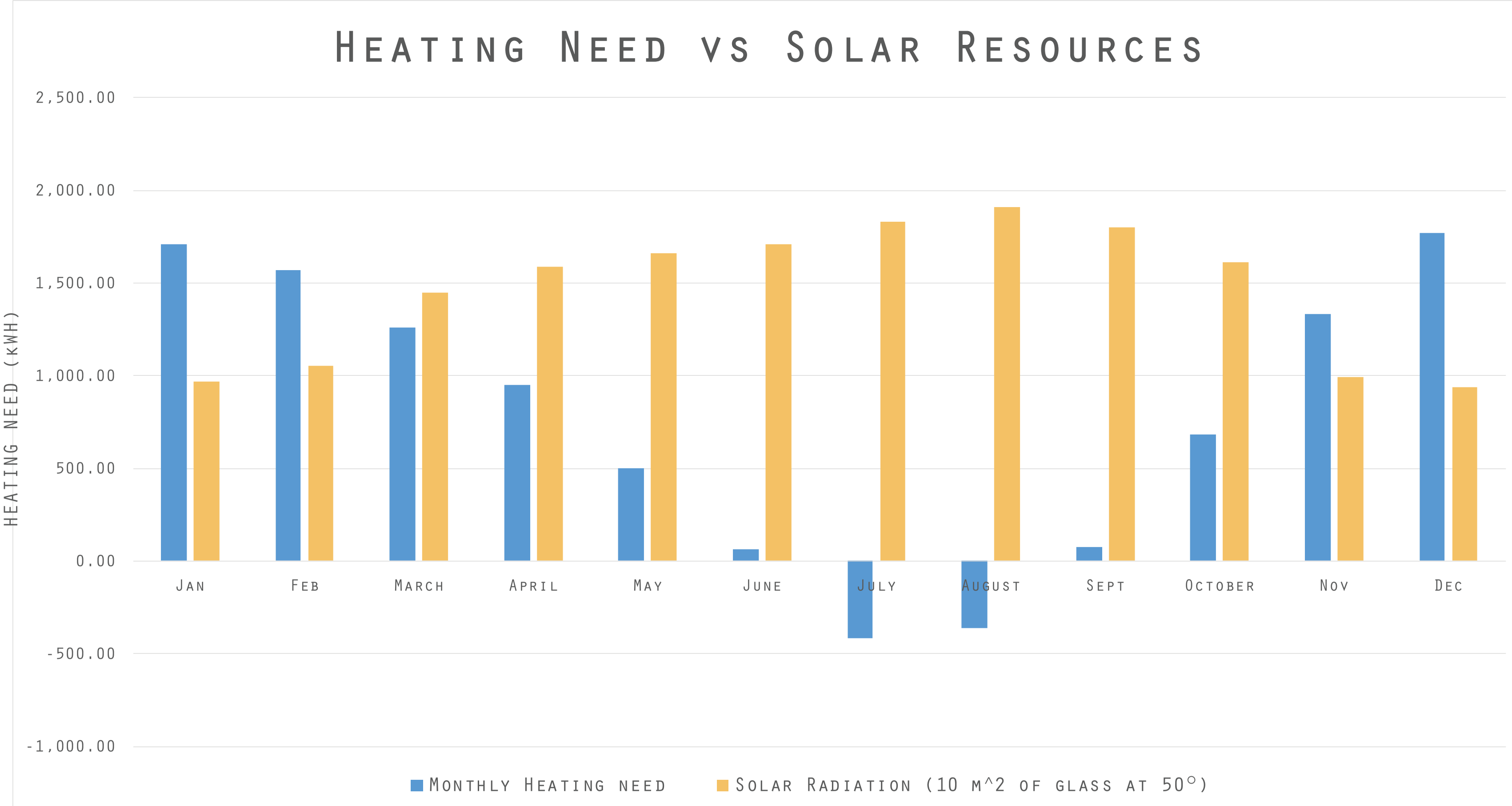


The Unit

A single rotating louvre is repeated to form the operable shading and insulation device. Each louvre is composed of a layer of insulation covered with a reflective surface that faces either upward to reflect light when the shade is open or form an insulating membrane when in the closed position. The device would be operated mechanically and adjusted by a user controlled switch.



Scale: 1" = 1'

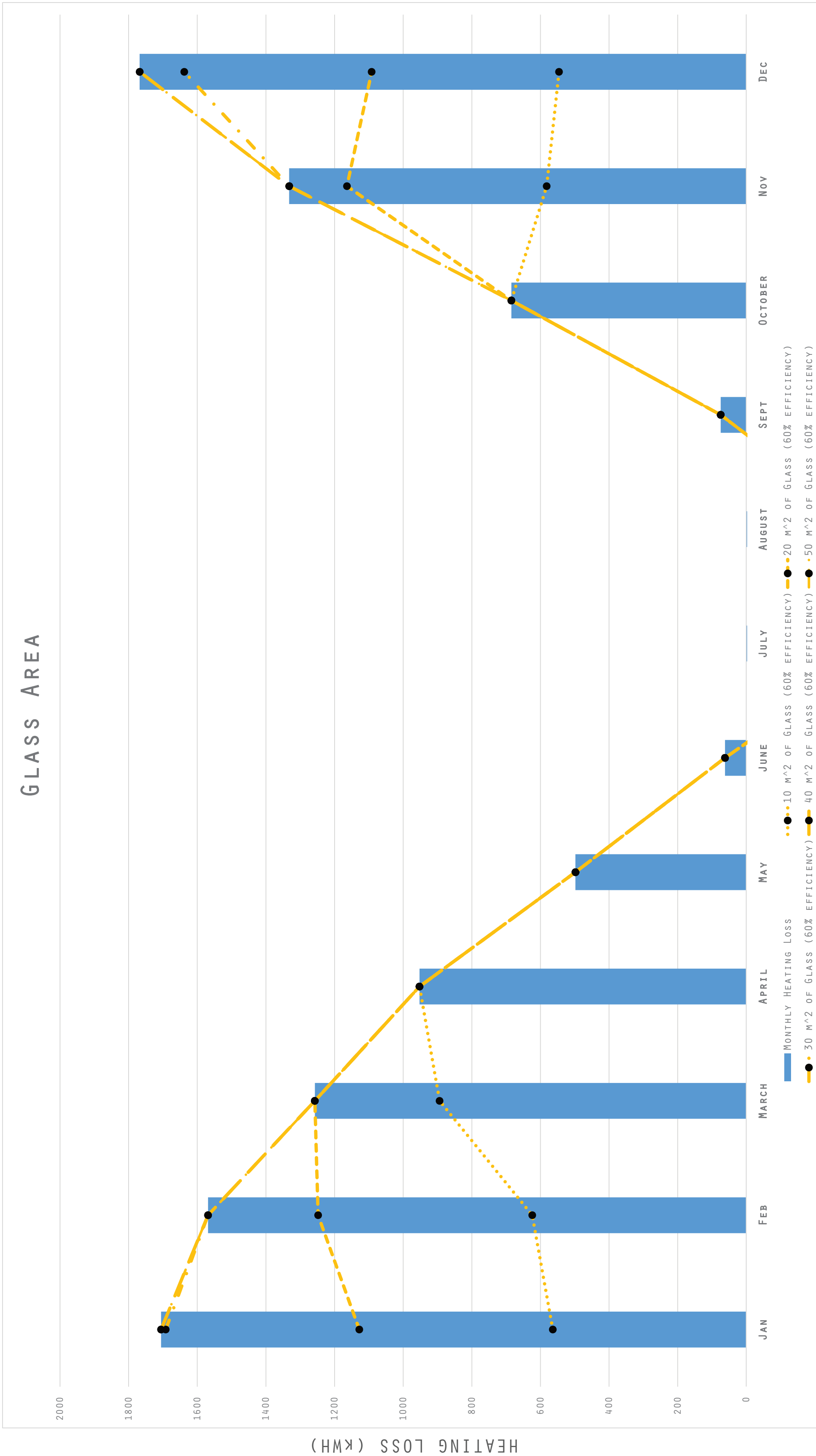


Total heat loss:
monthly heat loss + infiltration
U*(AREA)*ΔT + Cp * p * q * (Tin * Tout)

-The building losses approximately 8,474 kWh per month according to the U factor and temperature difference. it loses about 706 kWh per month due to infiltration,

Solar radiation:
Assuming optimal tilt of 50° in Eugene, Oregon
assuming 100% of energy is consumed
using 10 m^2 of glass

-The building gains from 1000 - 1900 kWh of energy with every 10 m^2 of glass. this assumes 60% was absorbed.



GLASS AREA
HEATING LOSS (KWH)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
JAN
FEB
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPT
OCTOBER
NOV
DEC
MONTHLY HEATING LOSS
10 M^2 OF GLASS (60% EFFICIENCY)
20 M^2 OF GLASS (60% EFFICIENCY)
30 M^2 OF GLASS (60% EFFICIENCY)
40 M^2 OF GLASS (60% EFFICIENCY)
50 M^2 OF GLASS (60% EFFICIENCY)

GLASS AREA SIZING

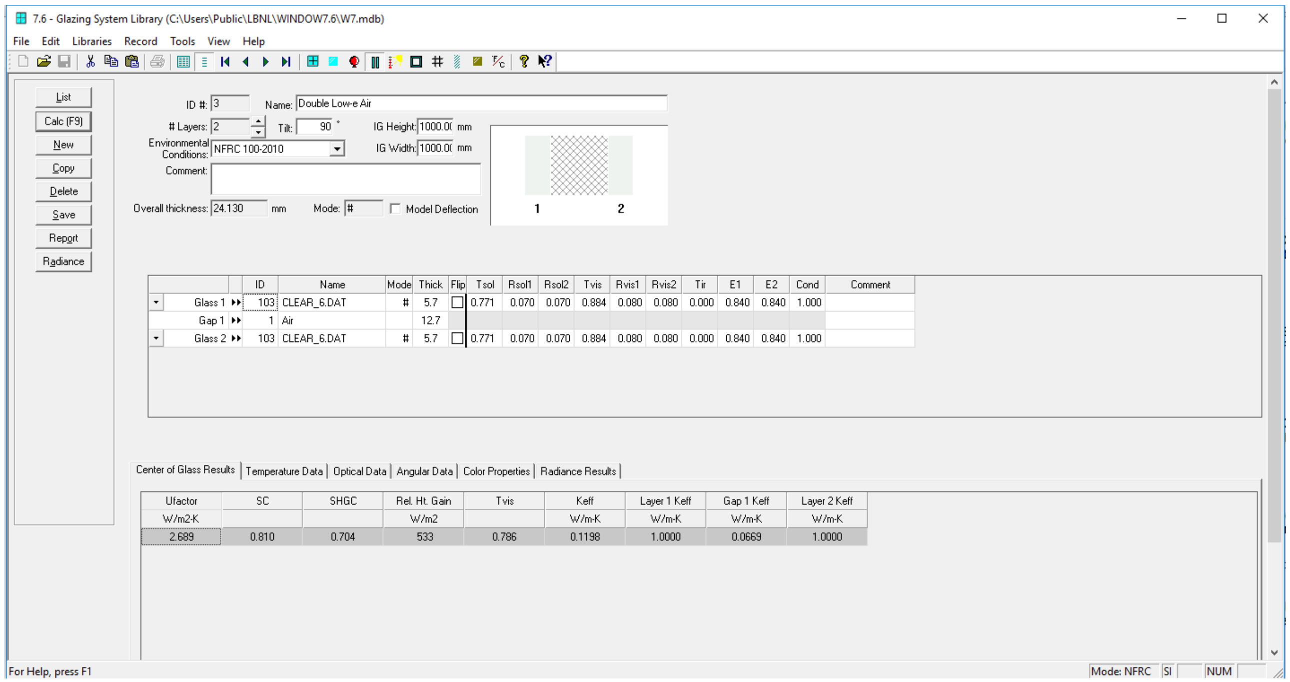
Tilt (Degrees above the horizontal): 50	(kWh/m^2)	60% Heat transmitted	10 m^2 of Glass	20 m^2 of Glass	30 m^2 of Glass	40 m^2 of Glass	50 m^2 of Glass
Jan	94	56.4	564	1128	1692	2256	2820
Feb	104	62.4	624	1248	1872	2496	3120
March	149	89.4	894	1788	2682	3576	4470
April	169	101.4	1014	2028	3042	4056	5070
May	182	109.2	1092	2184	3276	4368	5460
June	191	114.6	1146	2292	3438	4584	5730
July	203	121.8	1218	2436	3654	4872	6090
August	206	123.6	1236	2472	3708	4944	6180
Sept	187	112.2	1122	2244	3366	4488	5610
October	162	97.2	972	1944	2916	3888	4860
Nov	97	58.2	582	1164	1746	2328	2910
Dec	91	54.6	546	1092	1638	2184	2730

GLASS AREA SIZING:

ASSUMING USE OF 50° TILT IN LA PINE, OREGON
ASSUMING 60% OF HEAT IS TRANSMITTED
TESTING 10, 20, 30, 40, 50 M^2 OF GLASS

-THE BUILDING GAINS LARGE AMOUNTS OF ENERGY WITH THE 50° TILT. 50° WAS DECIDED TO MAKE THE SPACE EFFICIENT ENOUGH TO WARM PLANTS AND KEEP THE ROOM AT A DESIGN TEMPERATURE OF 60° WITHOUT ACCOUNTING FOR HEAT TRANSMITTED FROM THE PLANTS, THERMAL MASS, HEAT LAMPS, AND BODIES. ACCORDING TO THE CHART, BOTH 20 AND 30 M^2 EVEN OUT THE MONTHLY HEATING LOSS. 40 M^2 AND 50 M^2 COLLECT TOO MUCH ENERGY AND WOULD MAKE THE SPACE OVERHEAT IN THE SUMMER MONTHS. 10 M^2 DOES NOT FIT THE REQUIREMENT OF THE MONTHLY HEATING LOSS BUT DOES WELL IN THE SUMMER MONTHS BY NOT OVERHEATING THE SPACE TOO MUCH. THEREFORE, GLASS WILL BE REDUCED ON THE HORIZONTAL PLANES OF THE SOUTH FACADE TO PREVENT OVERHEATING IN THE SUMMER. THIS PROVIDES US WITH THE FREEDOM OF USING 40 M^2 - 50 M^2 OF GLASS AREA WITH REDUCTIONS.

Glazing Choice



Glazing: Generic Clear Glass

Manufacturer: Generic Glass

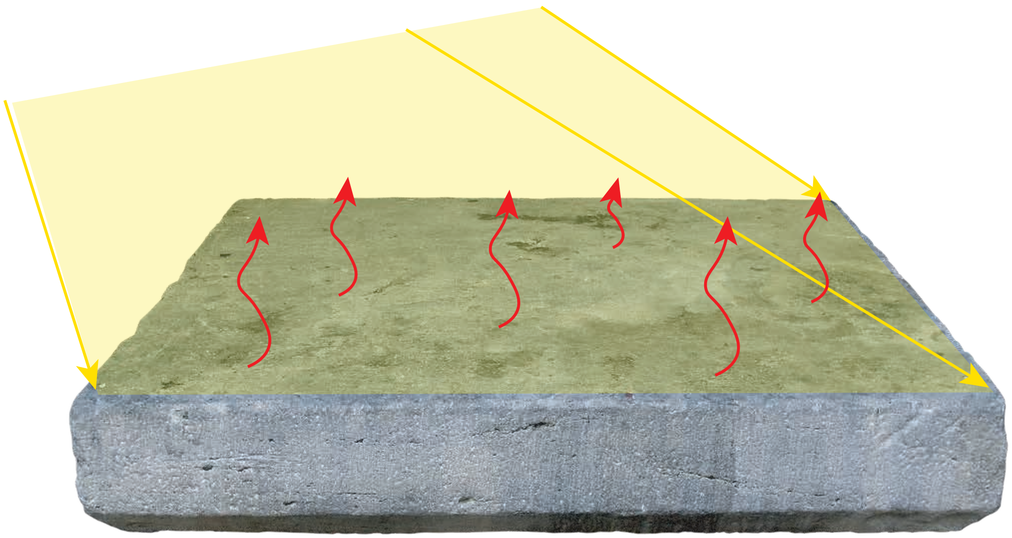
U-Value: 2.7 W/m^2 * K

SHGC: 0.704

Double pane system

The glazing chosen for the greenhouse is clear glass with a solar heat gain coefficient of 0.704 and a U- Value of 2/7 W/m^2 * K. We are using this glass type as a double pane system with no low E coatings to allow as much of the full spectrum of solar radiation into the greenhouse to benefit plant growth. A very low solar heat gain coefficient isn't prioritized due to the need for heat gain in colder months and the ability to cool the greenhouse using operable shading and ventilation in the months when additional heat isn't required.

Thermal Mass



Thermal Mass Choice - Concrete slab floor

Concrete floor slab

Density: 2242.3 kg/m
Heat Capacity: 850 J/kg
Solar Absorptance: 0.6

Temperature difference

Highest desired temperature: 80°F / 299.8 K
Lowest daily temperature: 34.6 °F / 274.6 K

Solar radiation available

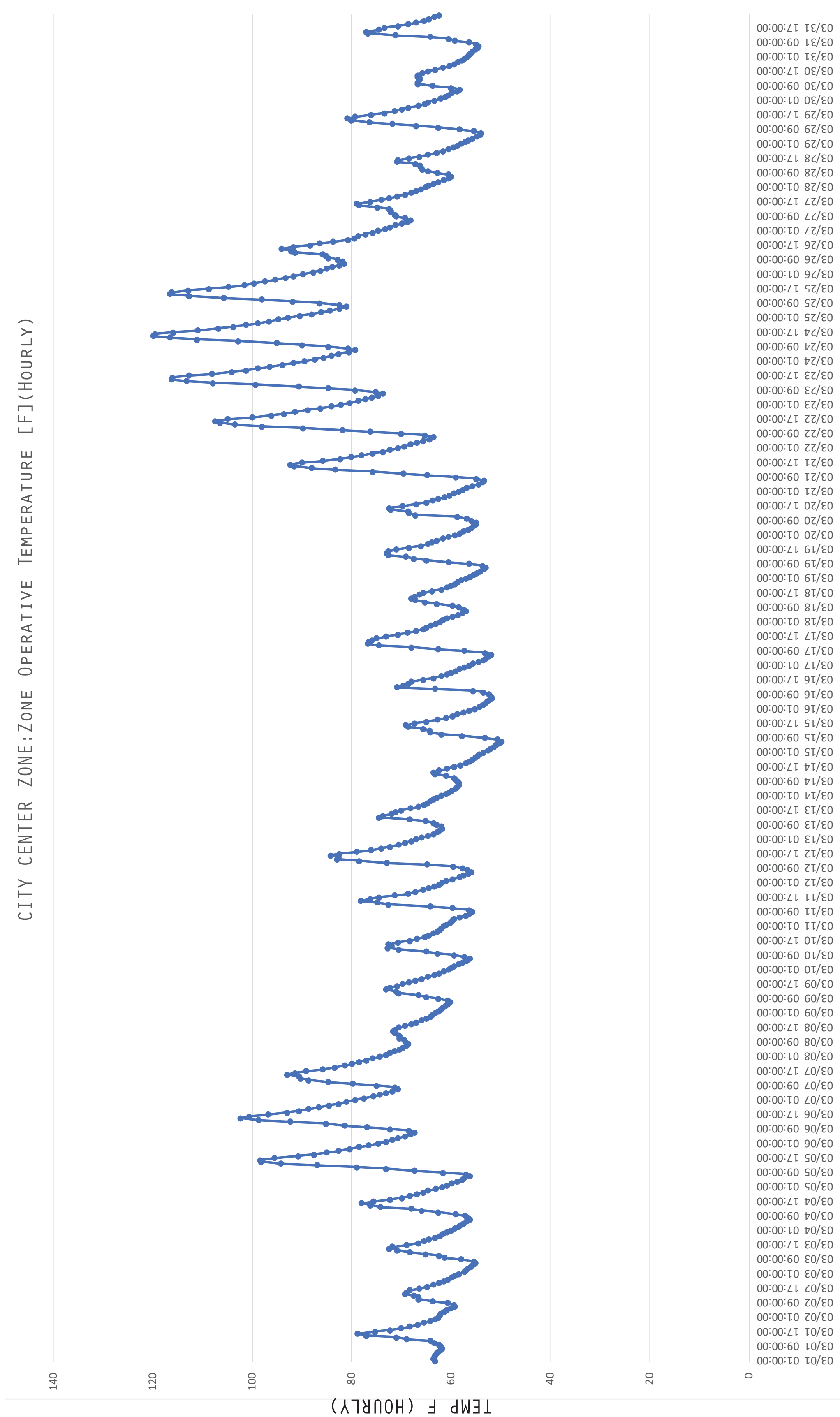
Solar radiation transmitted through glass:
9.6×10^7 J/

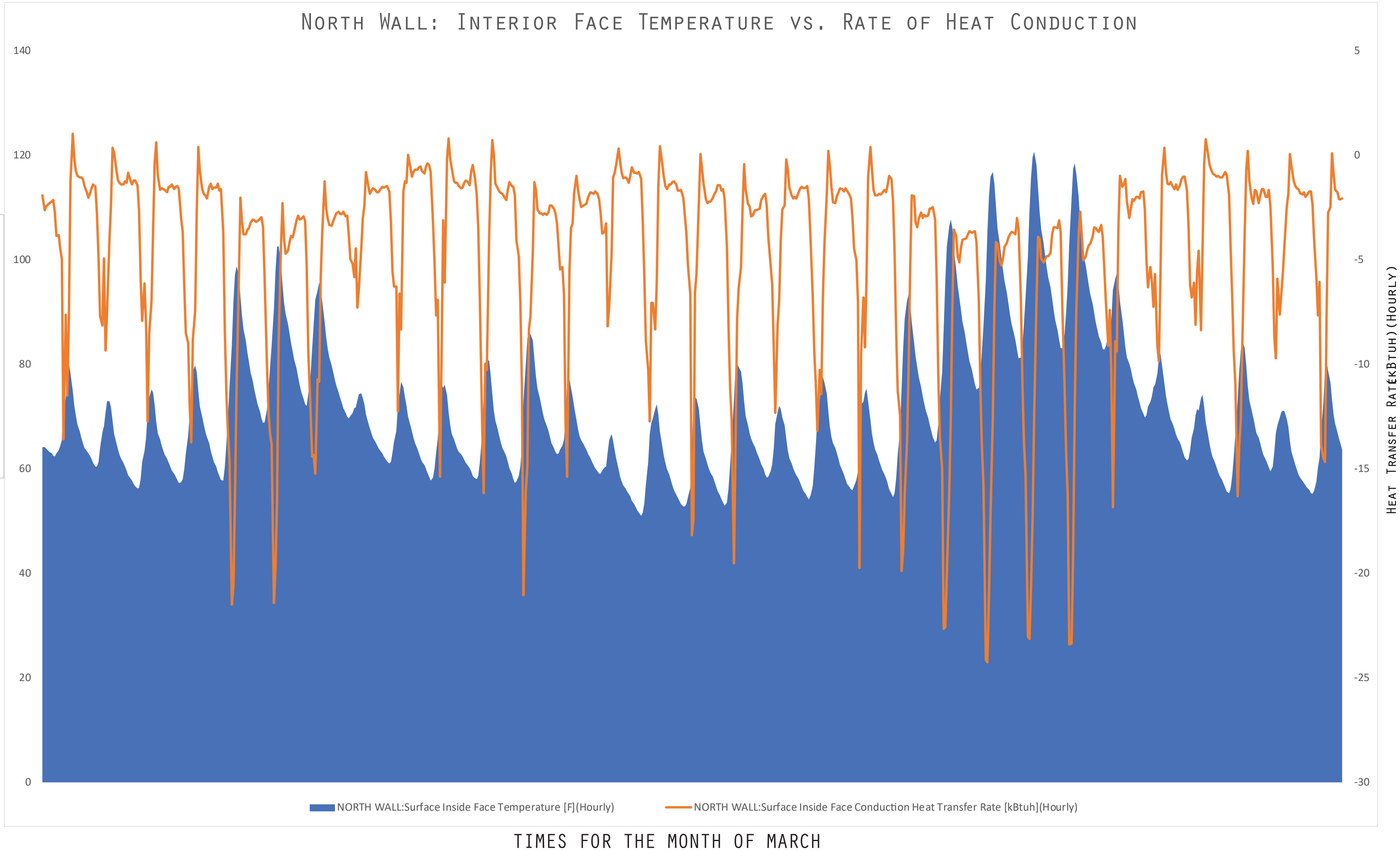
Necessary mass

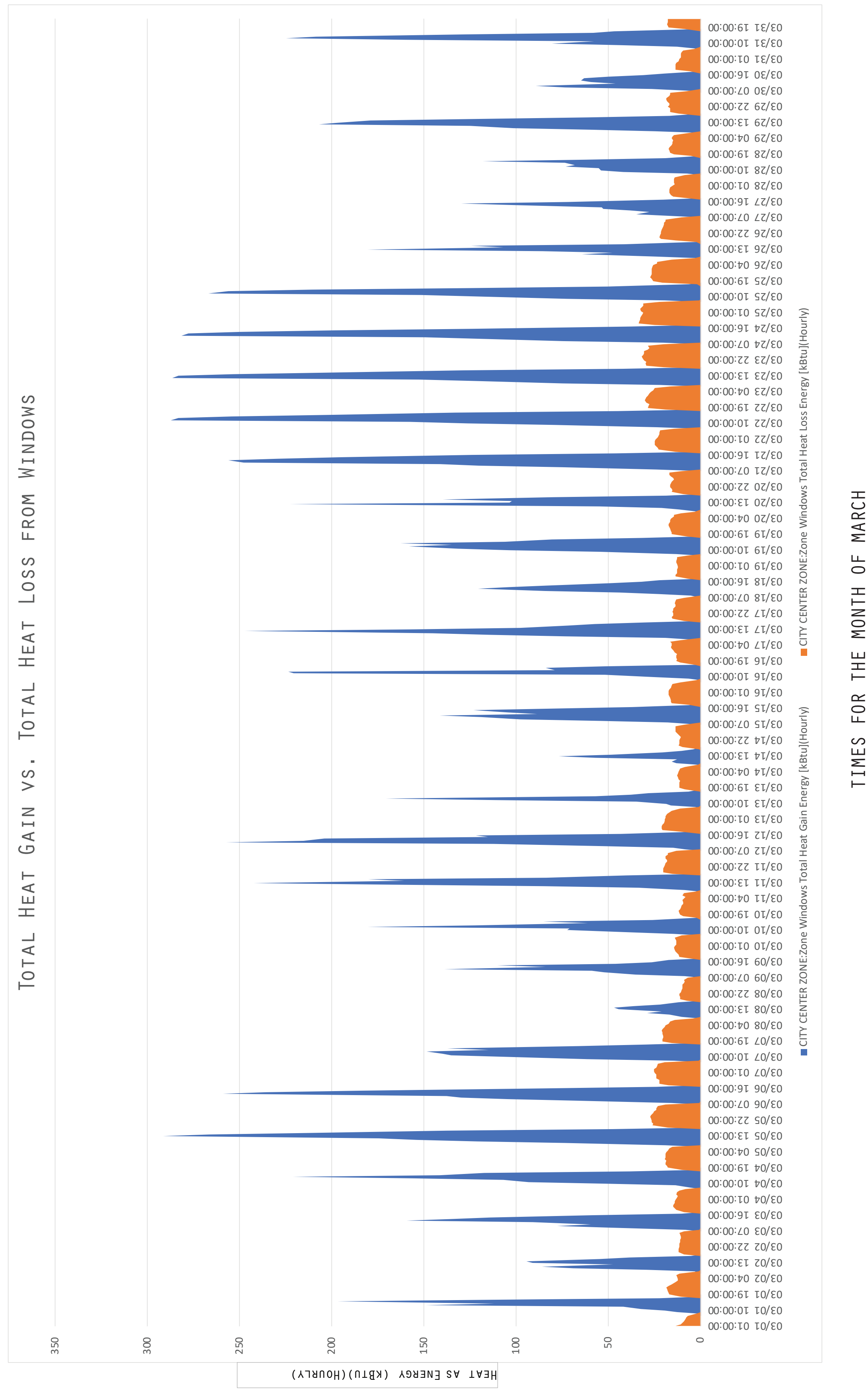
$1/(850\ J/kgK) \times [(9.6 \times 10^7\ J) \times (0.6)] / 25.2\ K = 2689$ kgs

Necessary thickness

$2689\ kgs \times (1m^3 / 2242.3\ kg/m) / 40m^2 = 3cm$ thick


CITY CENTER ZONE:ZONE OPERATIVE TEMPERATURE [F](HOURLY)
TEMP F (HOURLY)
TIMES FOR THE MONTH OF MARCH
0
20
40
60
80
100
120
140


North Wall: Interior Face Temperature vs. Rate of Heat Conduction
Face Temperature (F)(Hourly)
Heat Transfer Rat€kBtuh)(Hourly)
140
120
100
80
60
40
20
0
5
0
-5
-10
-15
-20
-25
-30
NORTH WALL:Surface Inside Face Temperature [F](Hourly)
NORTH WALL:Surface Inside Face Conduction Heat Transfer Rate [kBtuh](Hourly)
TIMES FOR THE MONTH OF MARCH


Total Heat Gain vs. Total Heat Loss from Windows
Heat as Energy (kBtu)(Hourly)
Times for the Month of March
CITY CENTER ZONE:Zone Windows Total Heat Gain Energy [kBtu](Hourly)
CITY CENTER ZONE:Zone Windows Total Heat Loss Energy [kBtu](Hourly)
0
50
100
150
200
250
300
350

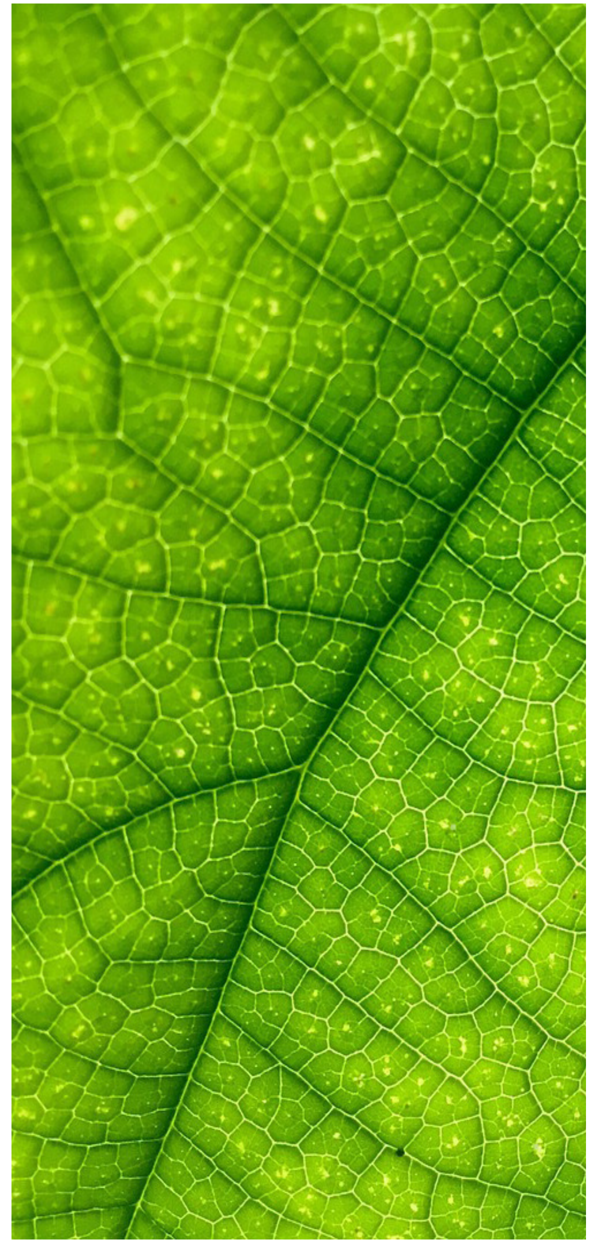
Greenhouse

Gabe Haug | Kyomi Tamura | Kai Miyajima | Zach Bradby

Thermal Comfort & Delight

The greenhouse will be a place where the community of La Pine can gather year round to participate in the cultivation of plants and learn about gardening. Our goal is to have the greenhouse maintain a minimum indoor nighttime temperature of 40 degrees. To make this possible we plan to utilize a rammed earth mass wall to absorb the sun's heat and radiate back to ensure protection and continuous growth of plants, and to have a comfortable working environment for the occupants of the greenhouse.

When entering the greenhouse we hope that the warm moist air, that smells of fertile soil and plants, will be a pleasant contrast to cold of the winter months and the dry air of the summer months.



Precedents

Tartu Nature House | Karisma Architects | Tartu, Estonia

-Tiered greenhouse spaces

-Light and natural

Paul's Greenhouse | Northern Arizona

-Stepped down design that allows for part of the greenhouse to be earth sheltered

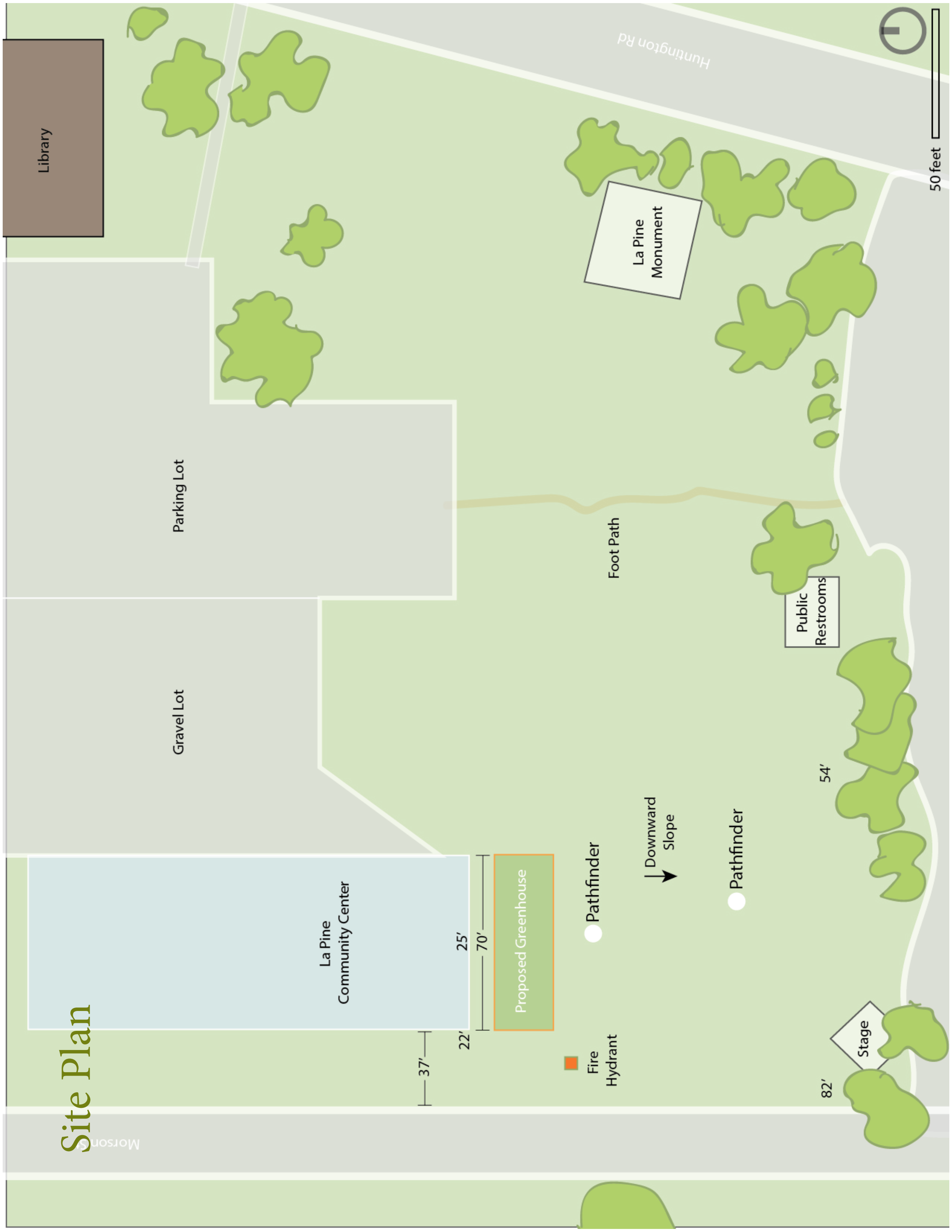
-Simple shape, materials and construction

EVE | Earthship Biotecture | Taos, New Mexico

-Use of upcycled materials

-Simple construction process of bottle and can walls would allow for people in the community to take part in the building process

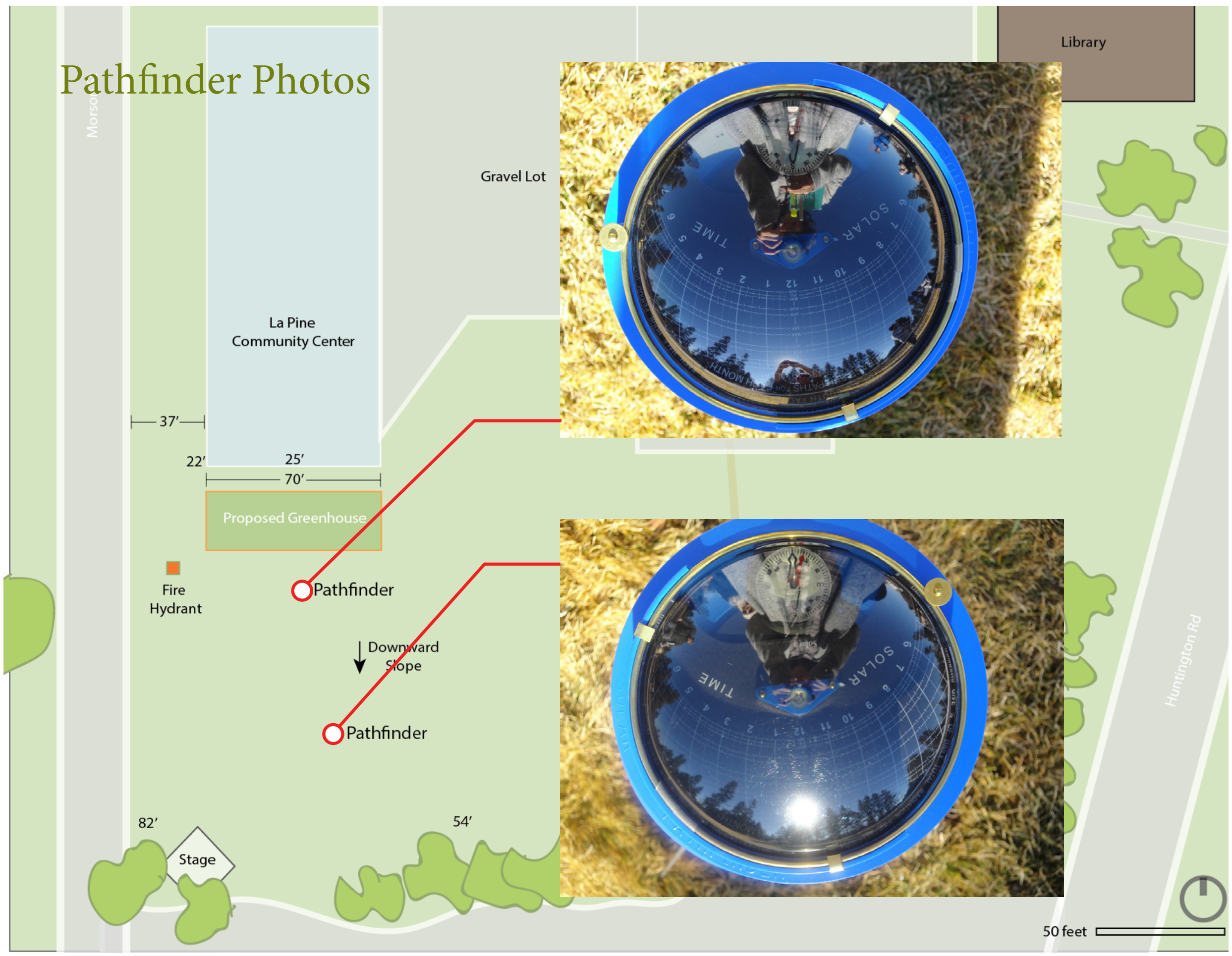
-Preserves La Pine's rustic aesthetic


Site Plan
Library
Huntington Rd
50 feet
La Pine Monument
Parking Lot
Foot Path
Public Restrooms
Gravel Lot
54'
Downward Slope
Pathfinder
Pathfinder
La Pine Community Center
25'
70'
Proposed Greenhouse
22'
37'
Fire Hydrant
Stage
82'

Site Section

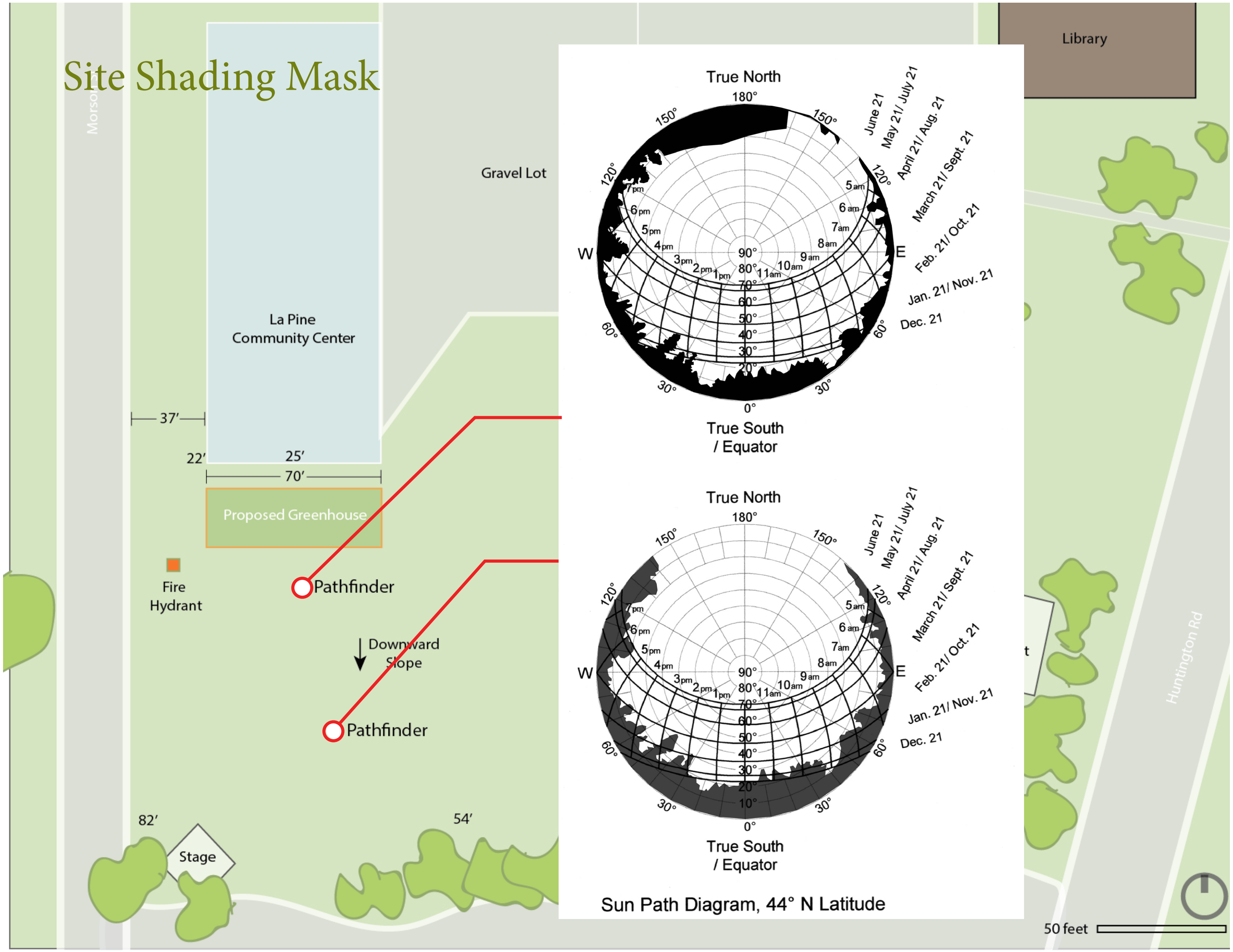

Pinus Contorta


75% Average Density
CAR WASH



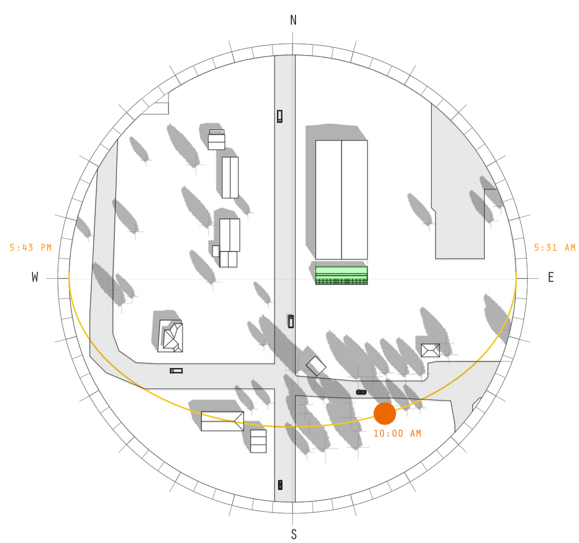
Pathfinder Photos
Library
Gravel Lot
La Pine
Community Center
37′
22′
25′
70′
Proposed Greenhouse
Fire
Hydrant
Pathfinder
Downward
Slope
Pathfinder
82′
54′
Stage
Huntington Rd
50 feet

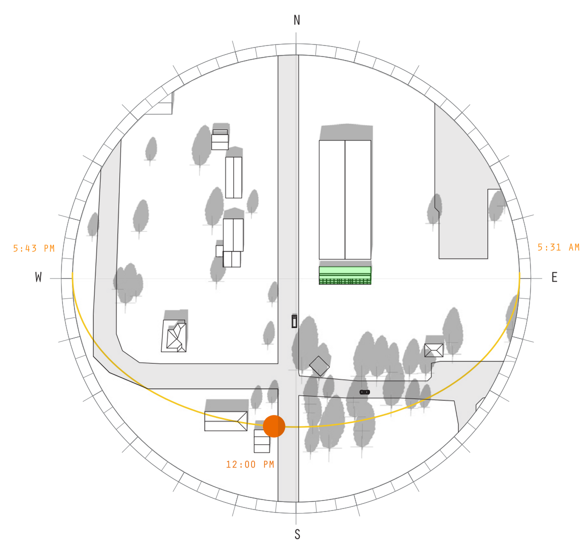
Site Shading Mask

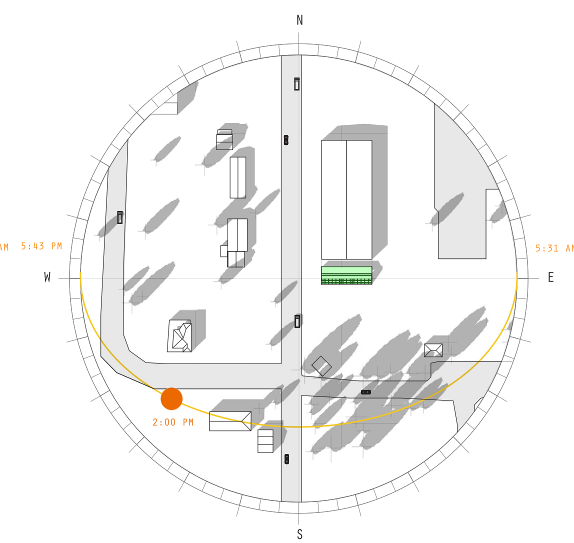


Sun Path Diagrams

Spring + Fall Equinox | 10am, 12pm, 2pm

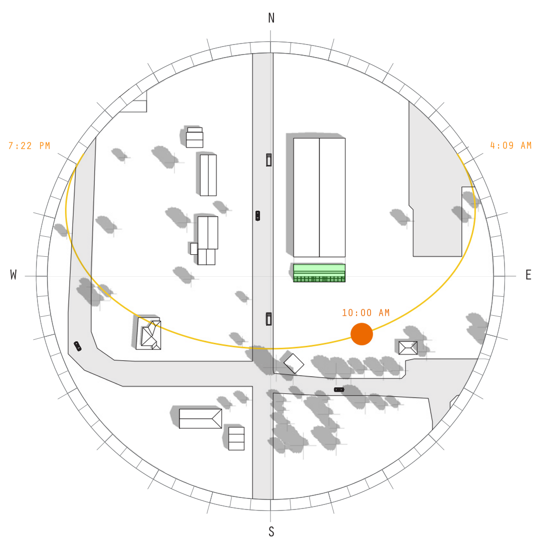


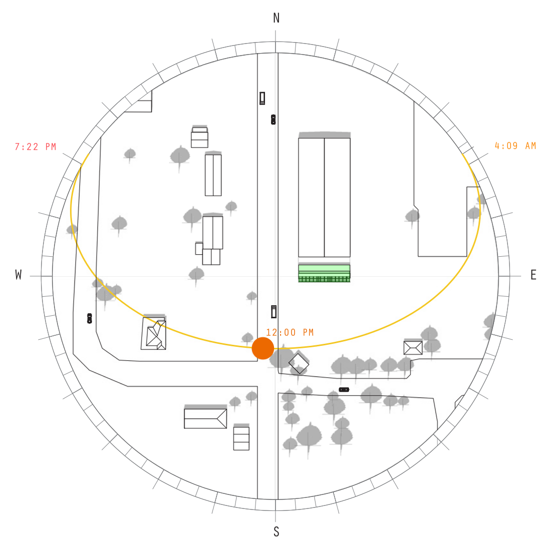


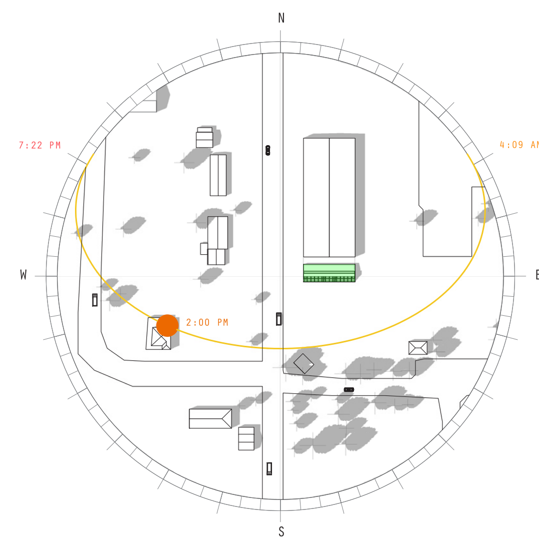


Sun Path Diagrams

Summer Solstice | 10am, 12pm, 2pm

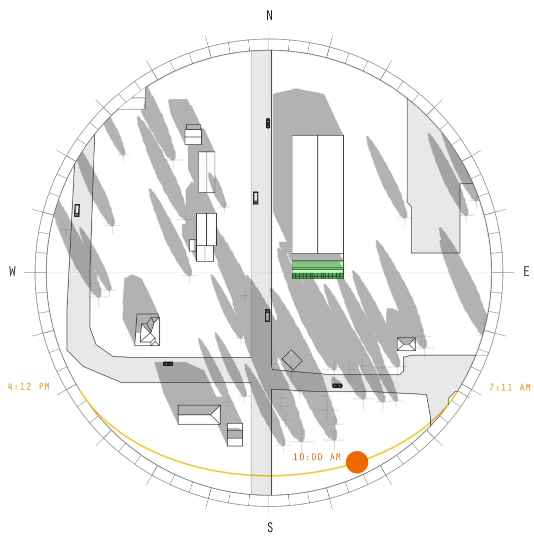


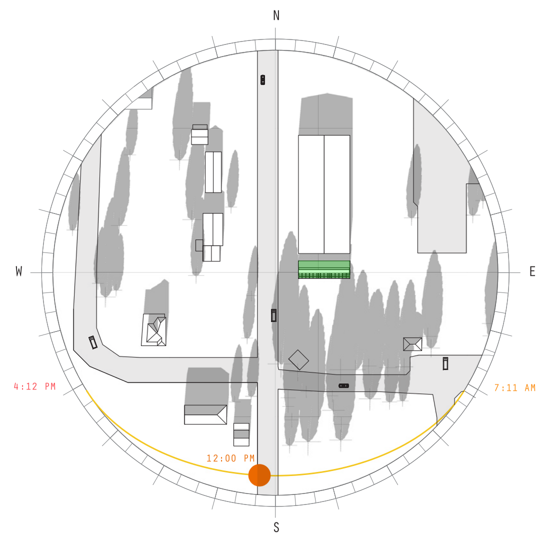


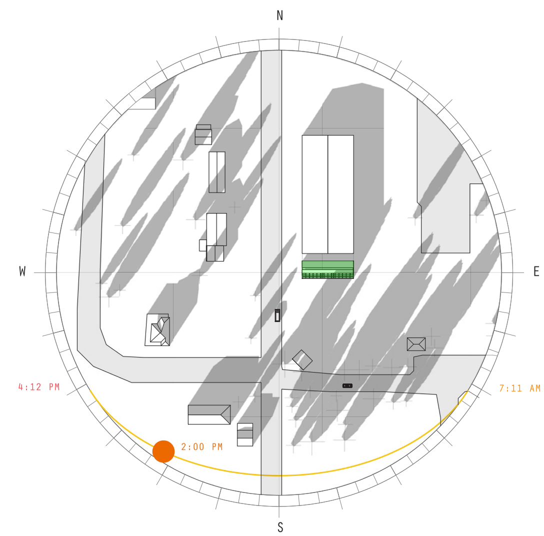


Sun Path Diagrams

Winter Solstice | 10am, 12pm, 2pm



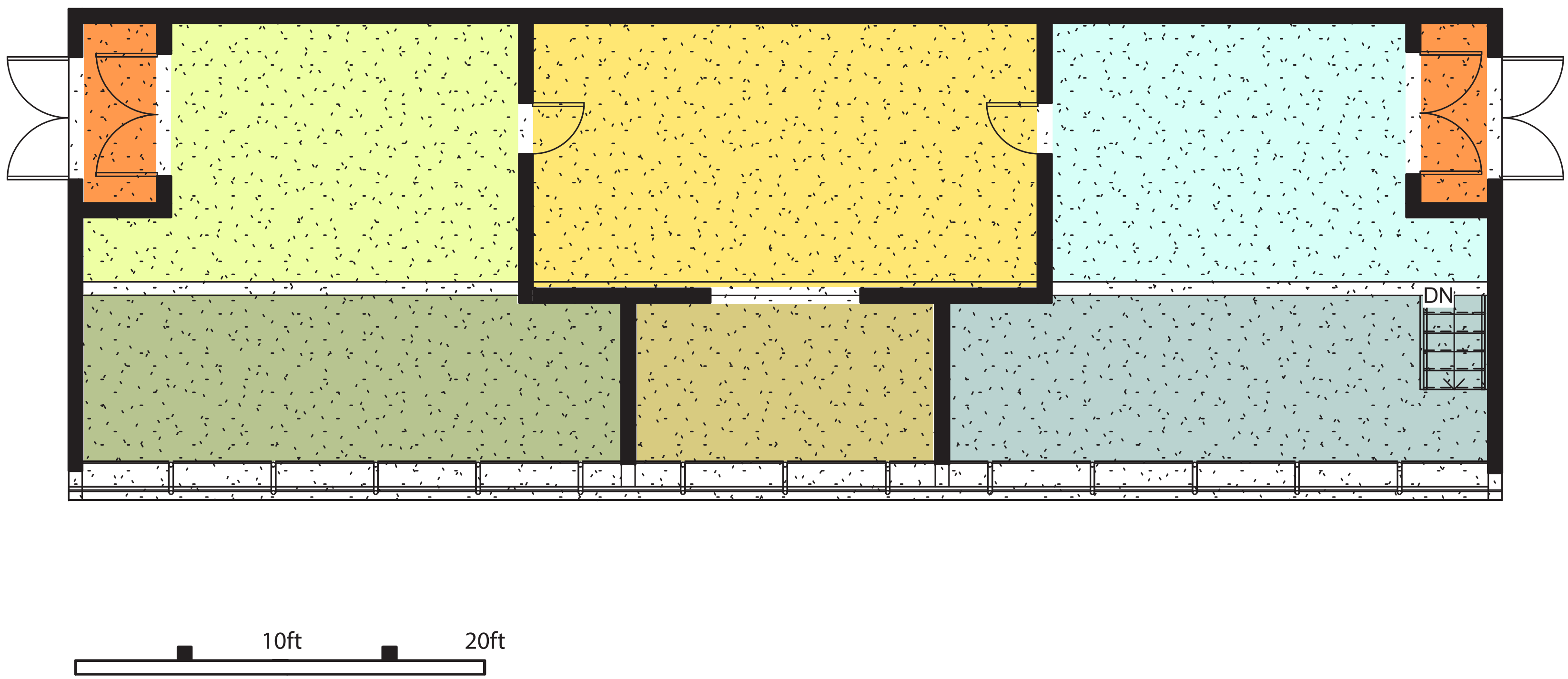




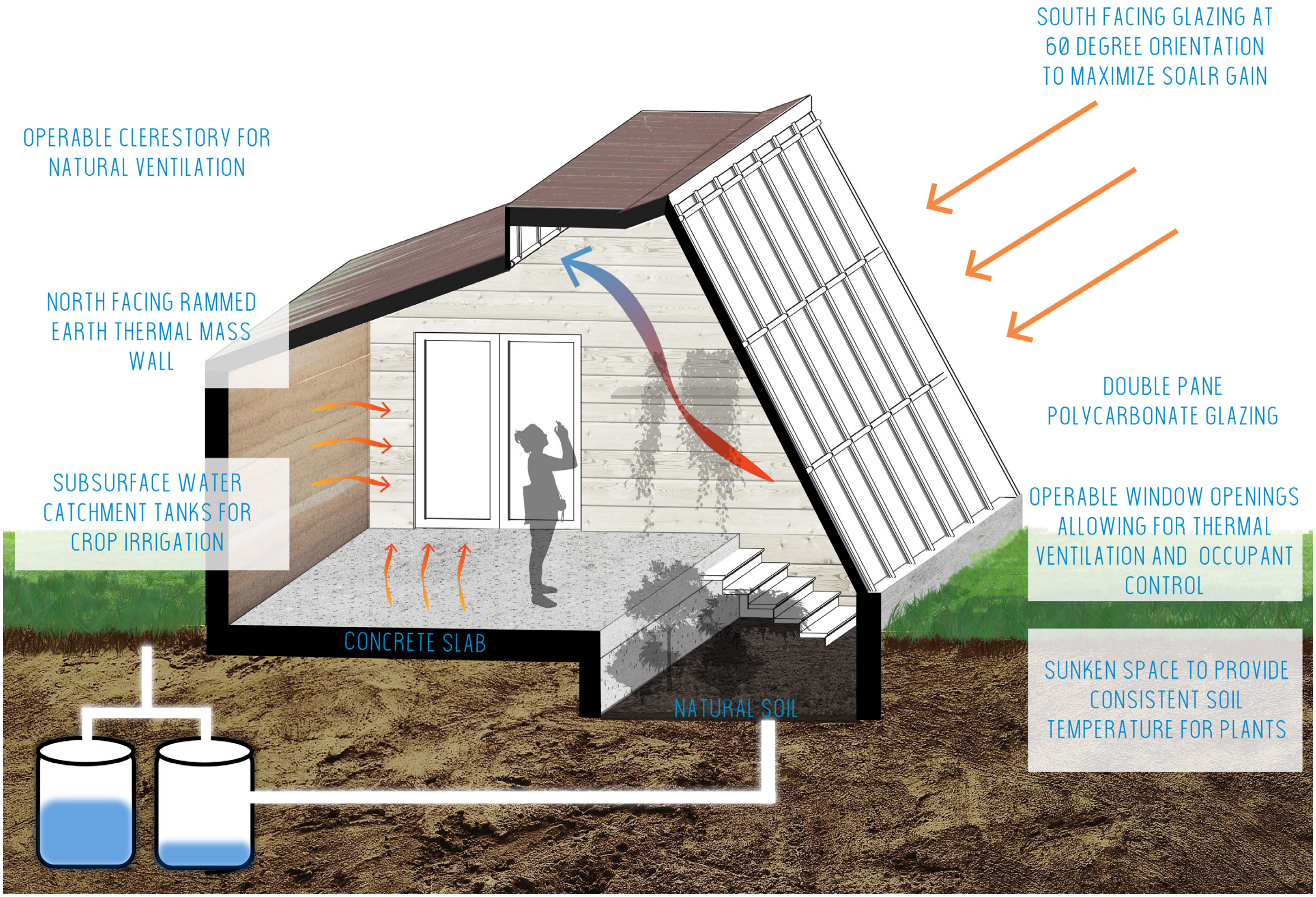
Programatic Ideas

Double doors act as an airlock and serve as a storage space

Greenhouse can be partitioned to accommodate different needs



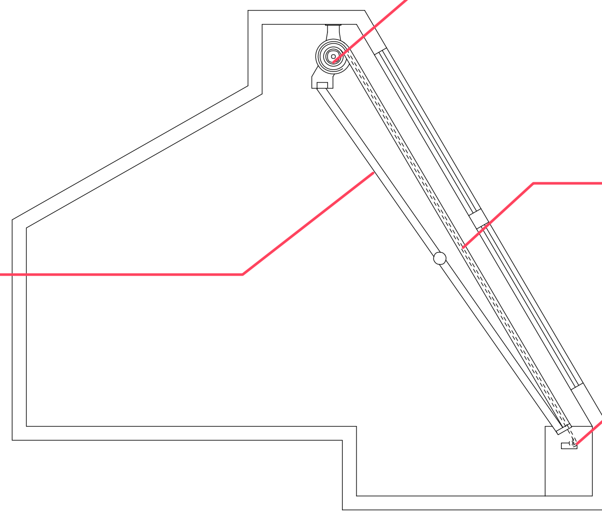
Materials and Intentions



Movable Insulation

Spring Arm:

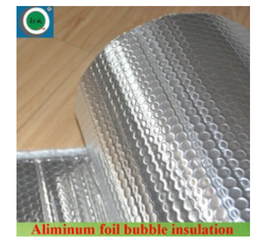
The arm which contains spring has large tension that wanted to stretch to certain direction.



Roller Motor

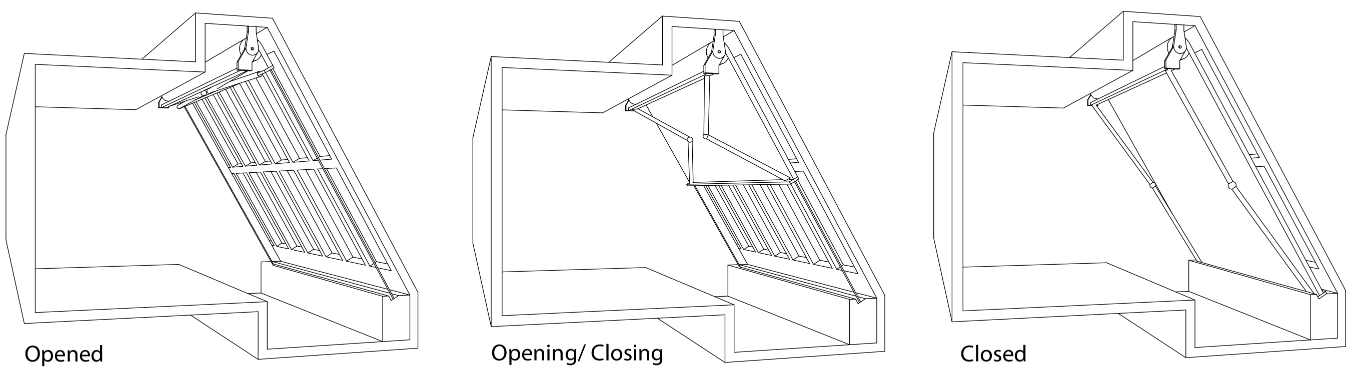
Layers of Metallized Film:

4inch- thick multiple layers of metallized film used as movable insulation.



Tension Wire roller:

Inserting the wire inside of insulation stables and controles the insulation.



Opened

Opening/ Closing

Closed

Thermal Mass Thickness Calculations

Information about thermal mass		
Loamy moist soil		
Density	1600	kg.m^3
Heat Capacity	0.89	KJ/kgk
Solar absorbtance	0.7	
Total Surface area	118.916	m^2

February solar radiance		
Monthly (60)	105	Kwh/m^2
Daily	3.5	Kwh/m^2
Glazing cut	2.0755	Kwh/m^2
Total	80.98186	KWh
Convert	291534.7	KJ

February Temperature		
Warmist	12.7	C
Coolist	-8.9	C
Change	21.6	C

Glazing Information		
Area	600	ft^2
	55.74	m^2
Transmittance	0.407	

1. Total Solar radiance:

60degree tilt Daily solar energy x Total glazing area x Transmittance

= 80.9

Conversion:

80.9 x 3600KJ

=291,534.7KJ

2. Desired temperature

Warmist - Coolist

= 21.6C

3. Thermal Mass thickness

{(1/Heat Capacity) x Solar Radiation}
Desired Temperature increase

= 15165.14 kg

15165.14 / Density / Total surface area

=0.08m

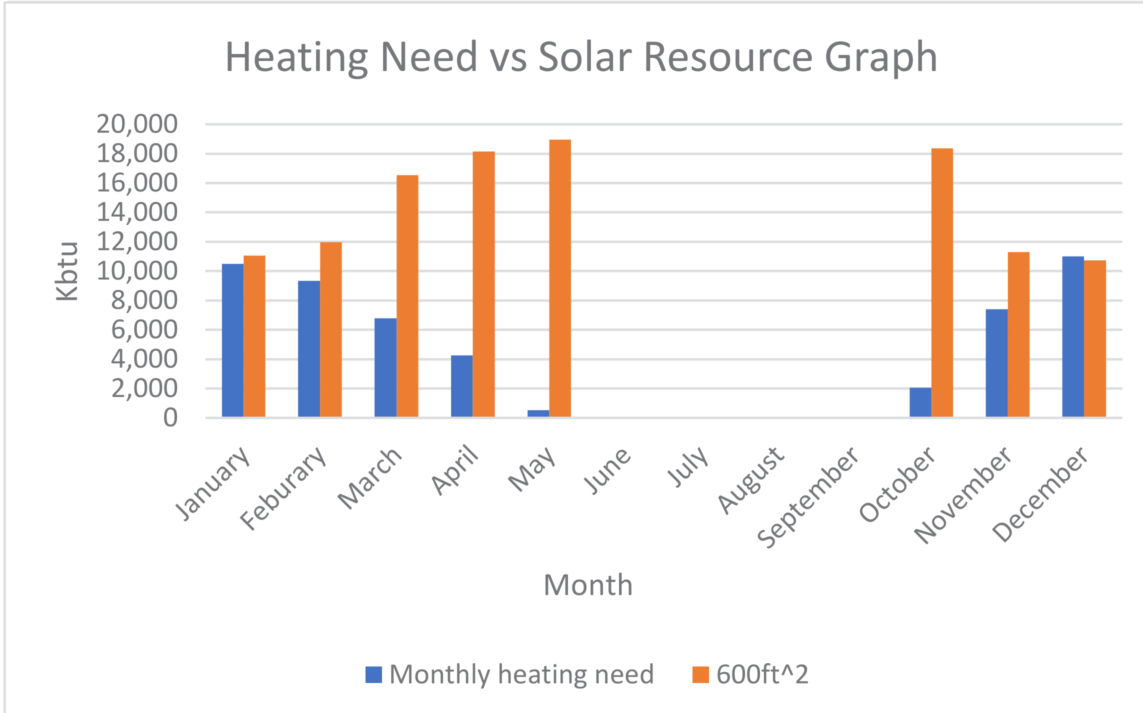
= 3.14 inch thickness

Heating Needs Calculations

Building Information		
Main glazing Area	600	ft^2
Clerestory window Area	212	ft^2
Volume	20419	ft^3
Total Glazing Area	812	ft^2
U-value(U)	2.388	W/m^2k
U-value(U)	0.42	Btu/sf h F
Design temperature	50	F

Infiltration Information(Btu/hr)		
Equation for ACH	1*Volume	
Equation for Infiltration	Cp*p*q*ΔT	Btu/hr
ACH(q)	20419	ft^3/hr
Heat capacity (Cp)	0.24	Btu/lbF
Density(p)	0.076	lb/ft^3

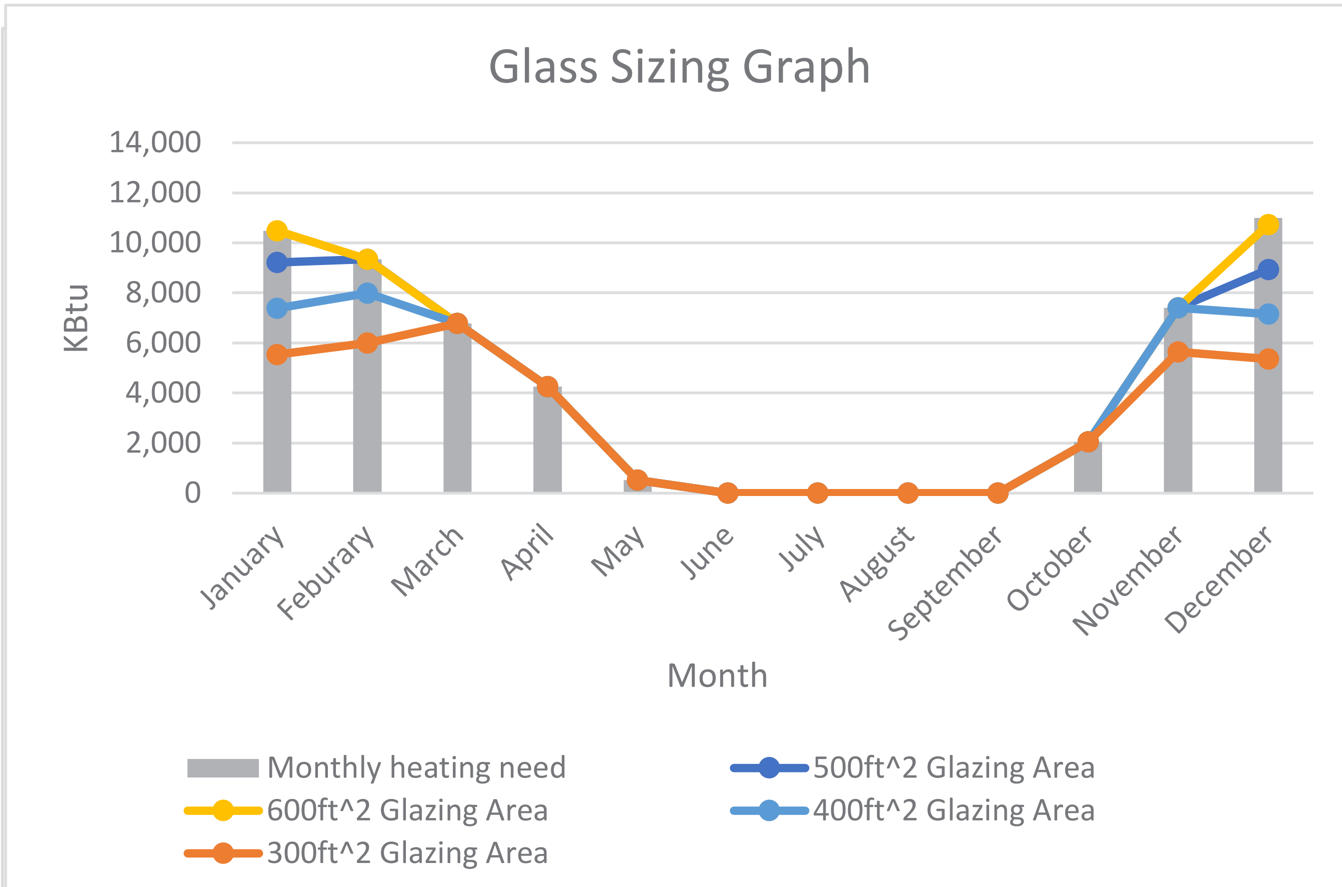
Month	Average Temperature (F)	Temperature Differenc
January	29.6	20.4
Feburary	31.8	18.2
March	36.8	13.2
April	41.7	8.3
May	49	1
June	56	0
July	63.7	0
August	62.8	0
September	55.8	0
October	46	4
November	35.6	14.4
December	28.6	21.4



	Tilt (degrees above horizontal)(Kwh/m^2)									
	90	80	70	60	50	40	30	20	10	0
January	90	94	97	97	94	89	82	73	62	50
February	91	98	103	105	104	101	95	87	77	65
March	113	127	138	145	149	150	147	140	130	117
April	110	129	146	159	169	175	177	174	168	157
May	102	125	147	166	182	194	201	204	202	196
June	96	123	148	171	191	207	218	224	225	222
July	105	133	159	183	203	219	229	235	234	229
August	123	149	172	191	206	215	220	219	213	201
September	136	155	170	180	187	188	185	177	164	147
October	136	148	157	161	162	158	150	138	122	104
November	90	96	99	99	97	92	85	76	65	53
December	90	94	95	94	91	85	77	67	55	42
Total	474	509	531	540	535	517	486	443	390	327

Reason:
After we calculate total solar energy from October to May (Those are month that the green house need heating), we figured out that 60 degrees will have the highest energy gain through-out the year

- Choosing 50F as the Design temperature. Since green house is difficult to maintain thermal comfort, we made it lower.
- U-value: 0.42 (For 10mm double pane Poly carbonate window)
- Basesd on Temperature difference on the data table, the heating season will be from October to May.
- Use 60 degrees for tilt



Glass Sizing Consideration:

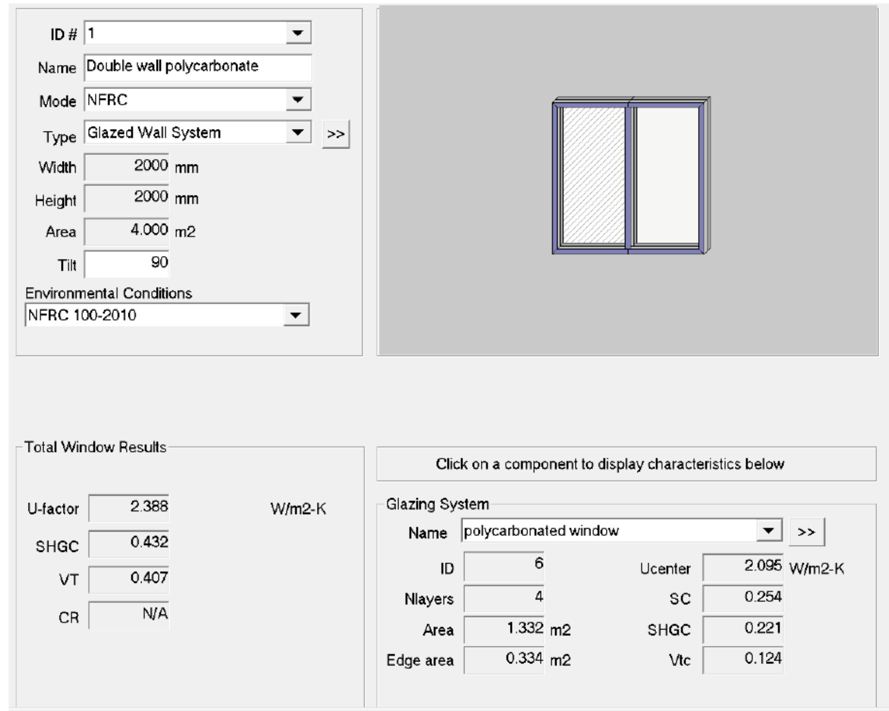
- Figuring out minimum glazing area for covering most monthly heating needs
- Possibility on inserting extra thermal mass
- We need massive area of window in order to provide enough daylight for plants.
- 600ft^2 was the most efficient glazing area that covers most of heating needs with minimal area.

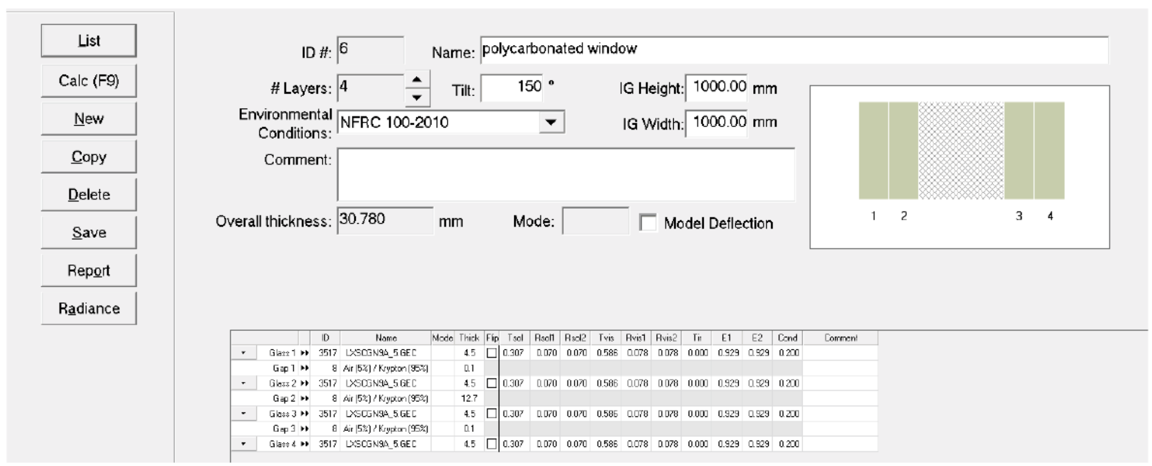
Glass Selection

Glass we chose: double 10mm pane
Poly-carbonated panel

Description:
U-Value= 0.42
SHGC= 0.432
VT= 0.407
The reason we chose:

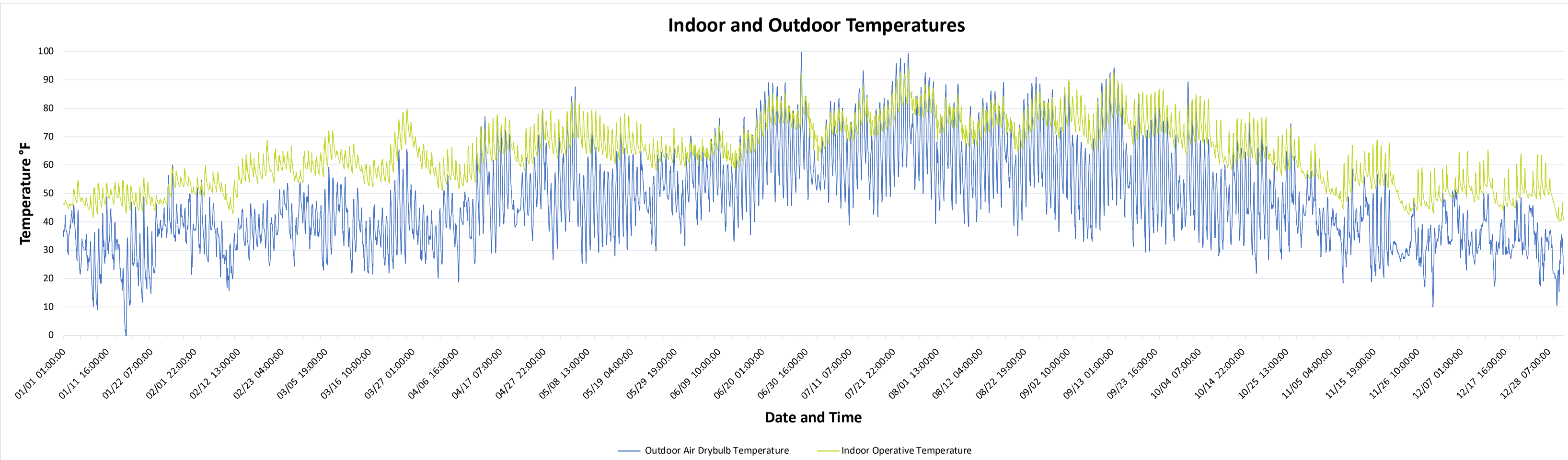
- Popular material for green house
- Double pane glass provide higher insulation than other windows
- Tried to reduce as much SHGC as possible inorder to decrease extra heat gain.
- Placing lower U-value makes the daylight easier to penetrate the window and hits to the thermal mass. Since we have exceeded amount of solar energy most of the time, lower U-value window creates the nice balance.





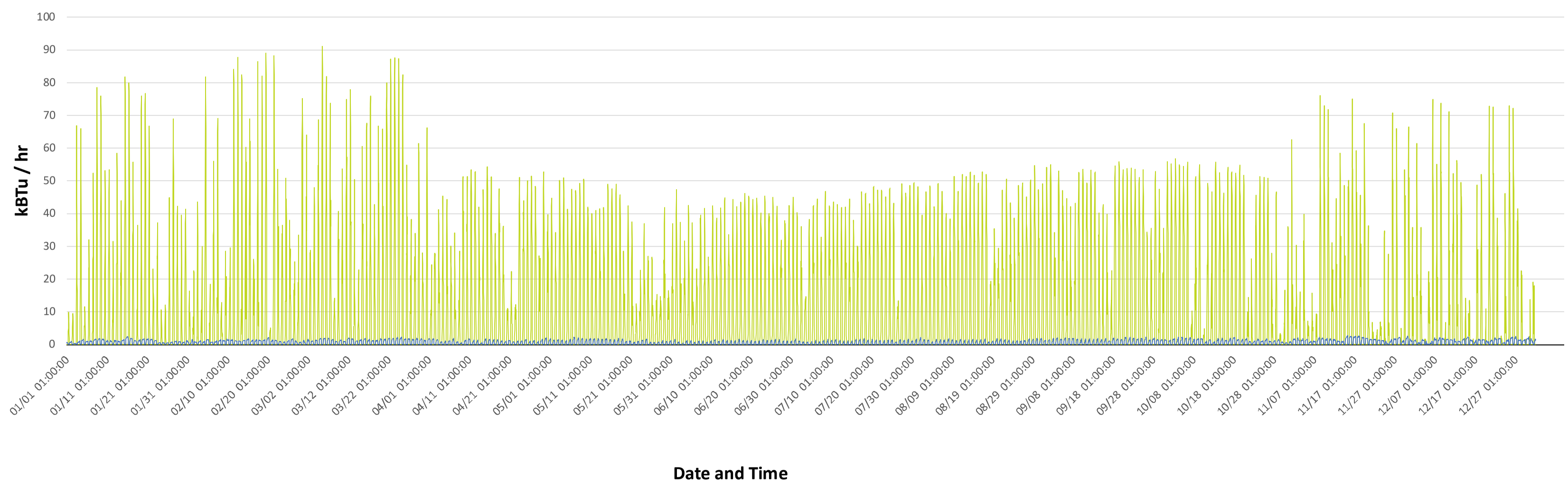
Performance- Whole year

Indoor and Outdoor temperatures

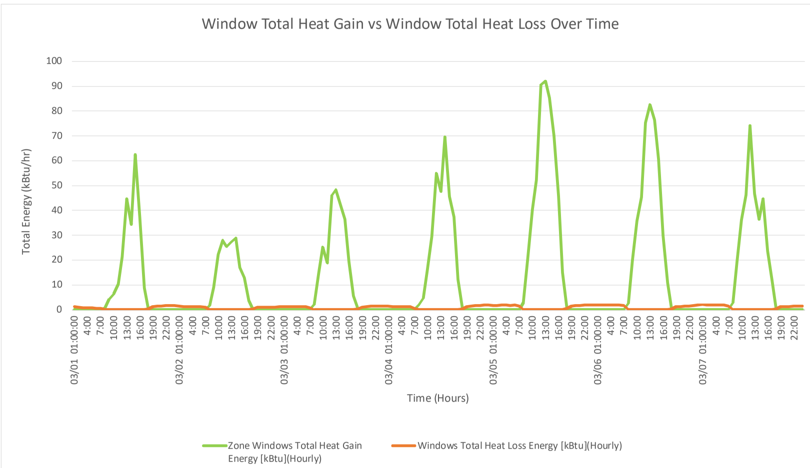


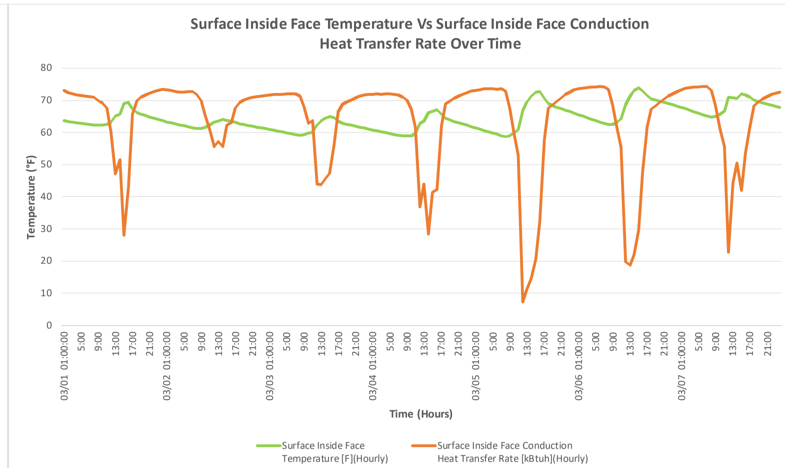
Performance- Whole year

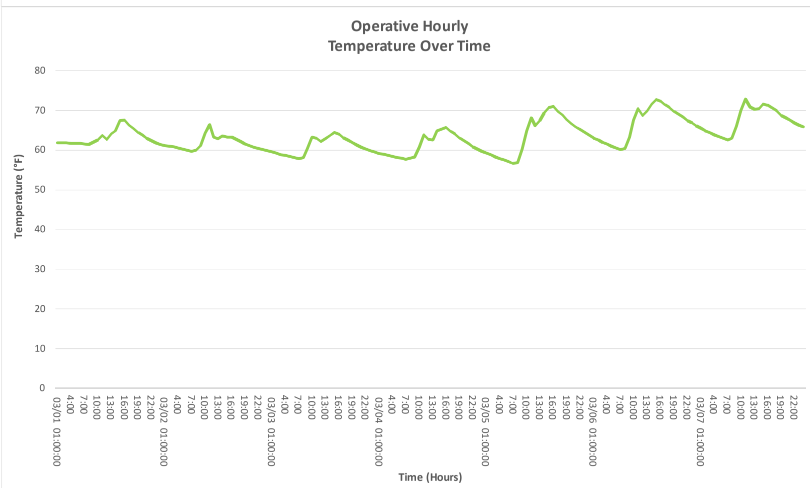
Heat Gain (Green) vs Heat Loss (Blue)



Performance- Base design





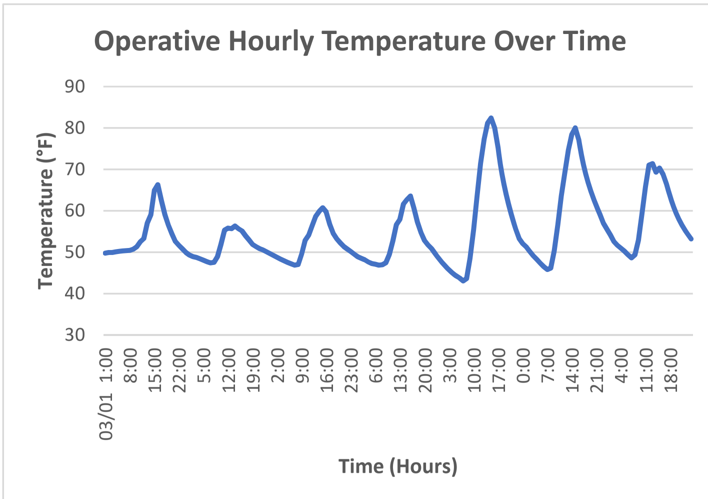


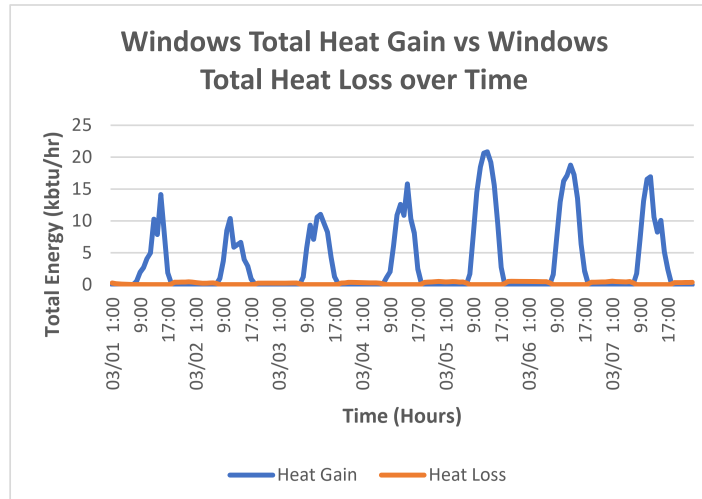
Analysis:
The results from the window heat gains and losses graph correlates to the moveable insulation schedule applied in Energy Plus. For each day in March, Insulation is removed from 11:00am to 5:00pm each day. This time range for each day has a dramatic spike in heat gain which corresponds to a positive spike in operative temperature during the same time interval. However, the Thermal mass wall has a spike of heat loss due to there being more exposed glazing that heat can flow through.

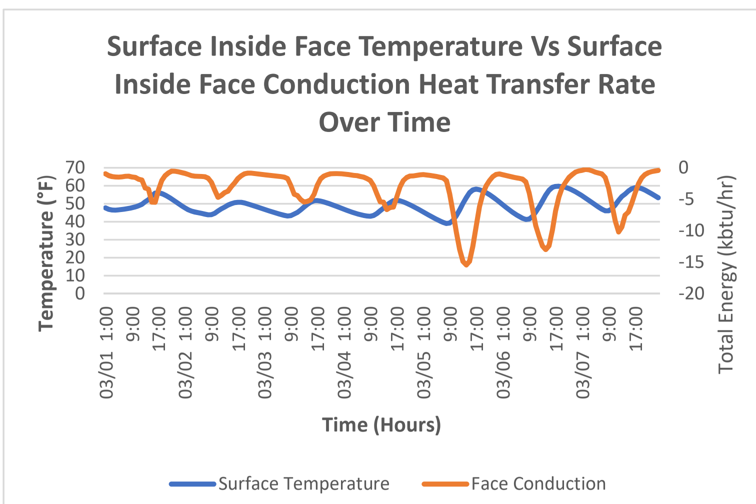
The operative temperature low is 58°F and the high is 72°F . Given the comfortable temperature range of 70°F to 83°F according to ASHRE 5.2.1.1, the space is uncomfortable. However, because the space is a greenhouse, people will most likely wear thick work clothes for gardening that have a higher range of clo value instead of the assumed 0.5 to 1.0 range. People will therefore be comfortable based on adding more layers of clothing. Depending on plant specie, this temperature range is also sufficient for plant vitality.

Performance- Version 1

Gabe Haug | Passive Heating | Winter 2018



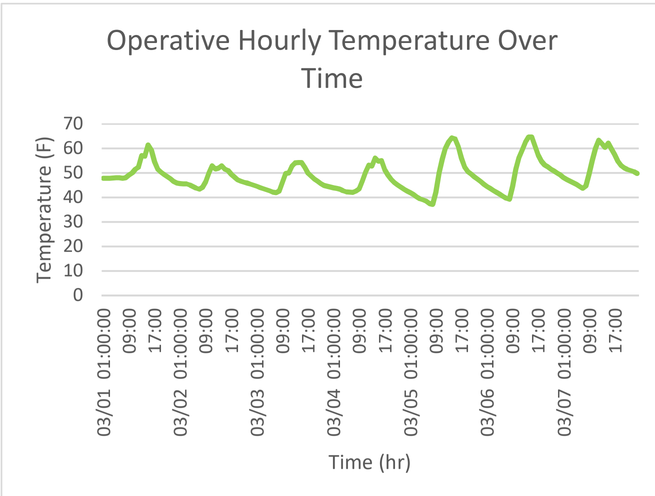


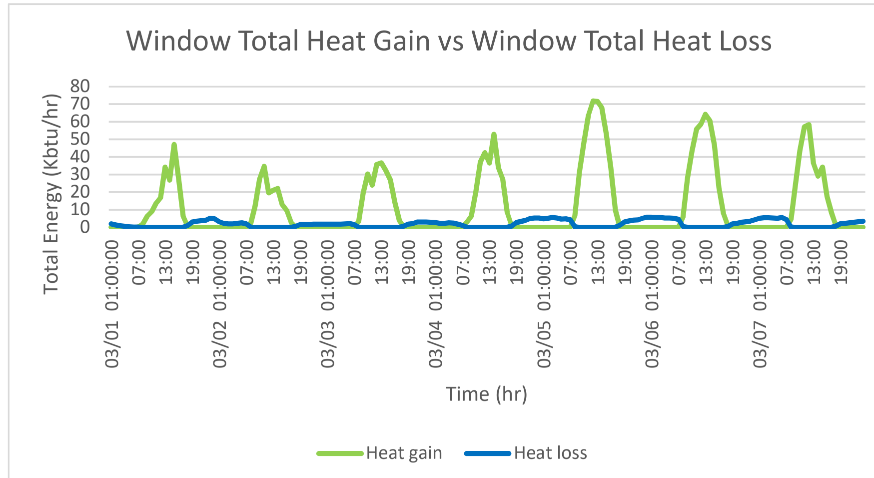


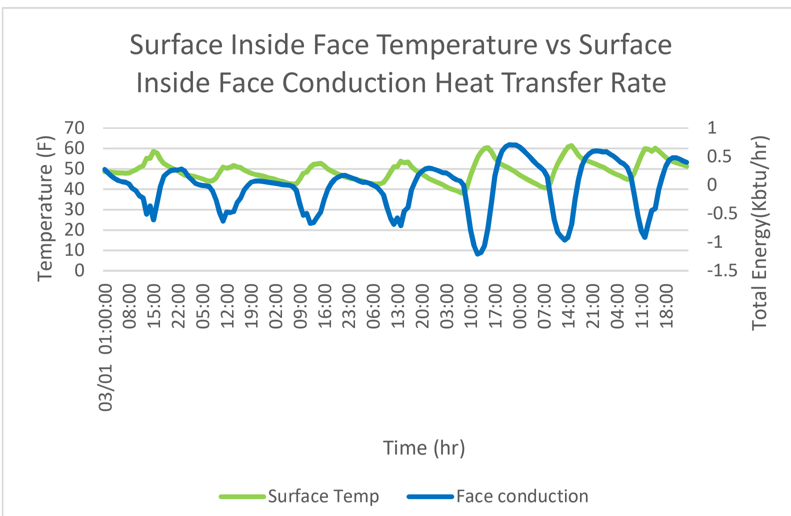
Concrete Thermal Storage Wall

Operative hourly temperature appears to range from 42° F to 83° F, which is seemingly sufficient for a greenhouse environment. The heat gain and heat loss calculations for the concrete north-facing wall seemed to be sufficient for the greenhouse, however, the concrete seemed to have a much lower heat gain than the rammed earth which may have been impacted by the sizing and thermal properties of my individually modeled south facing glazing. The concrete has a much higher face conduction heat transfer rate than the water or rammed earth, and therefore, conducts more heat from the wall surface to the interior of the greenhouse in the same length of time.

Performance- Version 2







●Addition: Inserting water roof and scheduling the movable insulation by temperature. (Activate when the outside temperature went over 28C, 80F).

●Analysis: Total heat gain was lower than the original graph. Thus, the operative temperature was also lower than Original ones. However, through operative temperature, the temperature is very consistant. Perhaps the effective of water pond. Same for surface temperature. Another reason for this is that the face conduction heat rate range was narrower than other versions.

Appendix C: City Centers Presentations

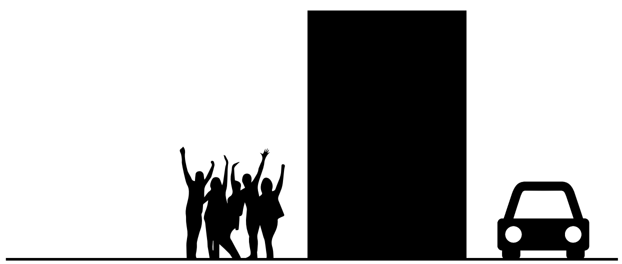
LA PINE CITY CENTER

Khiseth Abramvicka, Courtney Cisler, James Li

Passive Heating

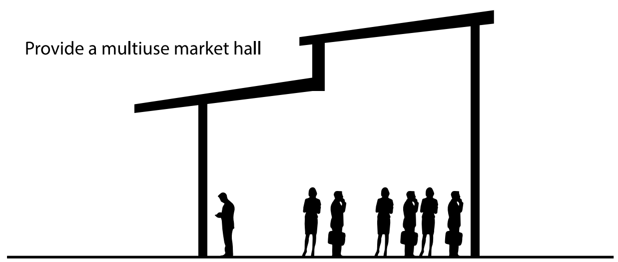
Programmatic Ideas

Building As Buffer to Highway



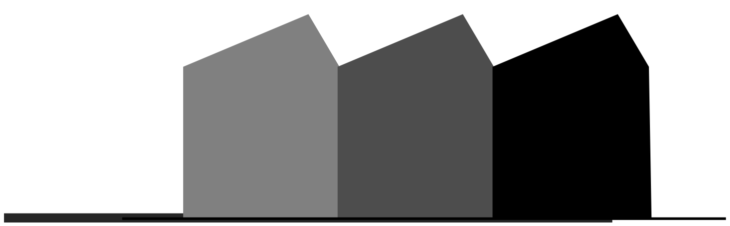
Using the building to provide enclosure to what is now a primarily open site. Building can act a a buffer to existing nearby high. The buildings use as a buffer helps to protect the site from noise and pollution.

Provide a multiuse market hall



The incorporation of a large multiuse market hall on the site provides a sheltered indoor space to house community activities.

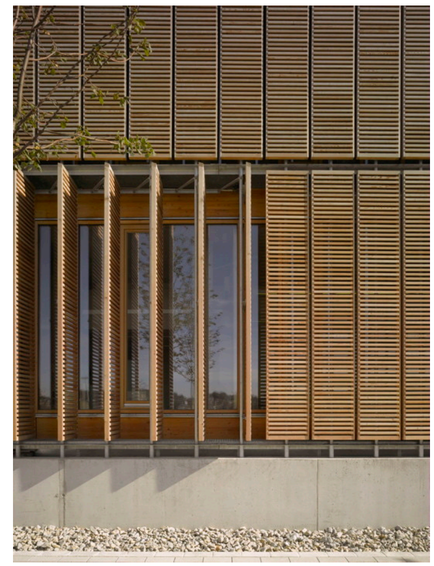
Using Saw Tooth Roof to subdivide space and capture sunlight



The saw tooth roof design helps to programmatically subdivide the space based upon the roof form. With the use of operable shading devices the spaces can be heated separately to varying degrees based upon their programmatic needs. Spaces with varying temperatures creates the opportunity for thermal delight.

Precedent: Aalen University Extension

Germany



Movable shading: the wooden shutters create a deep, changing surface; create between visual transparency and closeness.

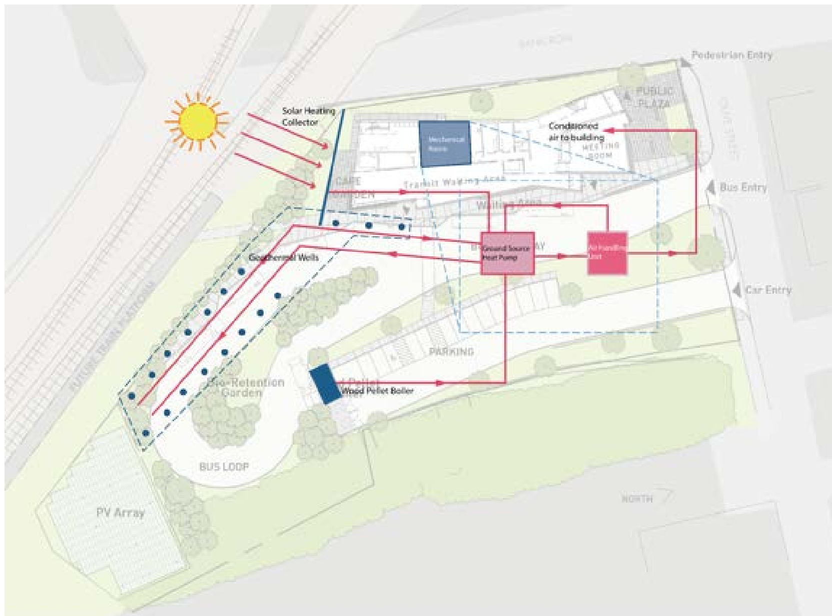
Precedent: Mill Office

Zwartsluis, Netherlands

- Building effectively brings natural light into the building while subdividing the space into different programmatic zones

Precedent: John W Olver Transit Center

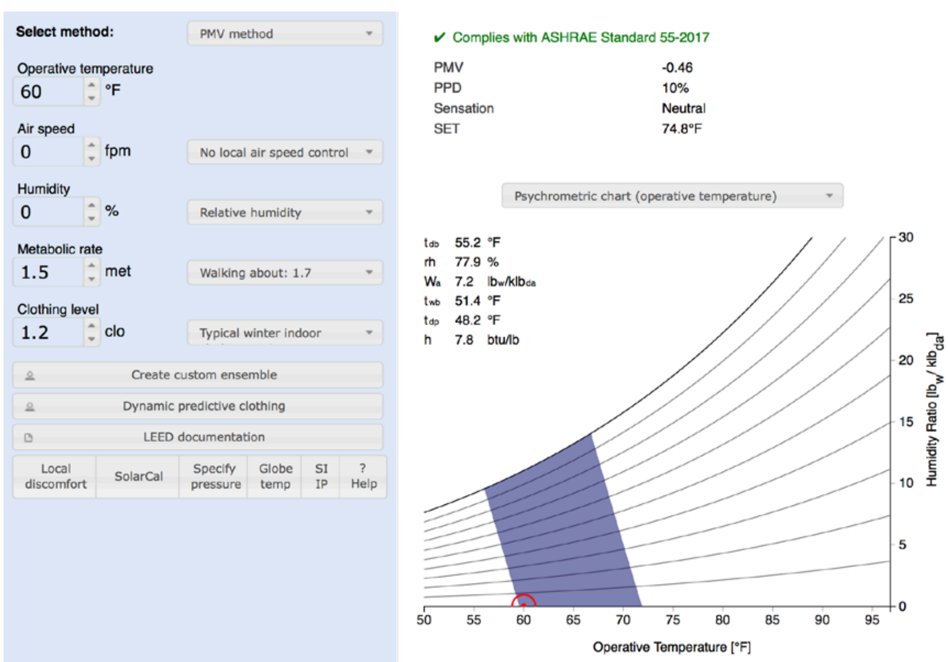
Springfield, MA



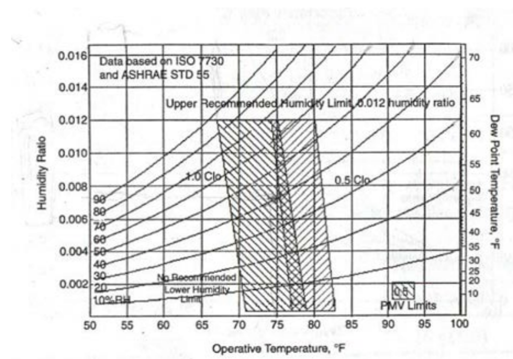
- Net zero energy building designed for passive heating in cold climate
- Owners agreed on wider temperature and humidity range for comfort
- Contains offices, community space, and storage
- Program elements used to buffer temperature extremes and block low sun angles from reaching office spaces

Goals for Thermal Comfort

To provide a market hall space that is passively solar heated to an operative temperature of 60 Degrees during typical winter months.

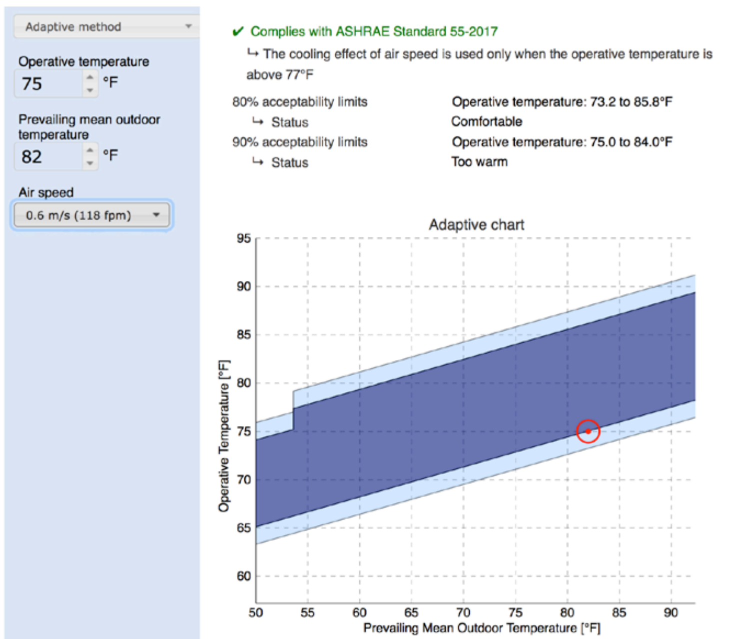


Thermal comfort range for this zone was created using the PMV method and was designed to allow for cooler indoor air temperatures. Our space factors in a higher level of clo and a high metabolic heart rate in order to create a thermal comfort zone that our operative temperature can fall under. These parameters were able to be changed based upon how we viewed user to inhabit the market hall space.



Goals for Thermal Comfort

To provide a space that during warmer month can remain thermally comfortable with an operative temperature of 75 degrees.



Our Thermal comfort zone for warmer summer months uses adaptive zones and makes use of air speed to help cool the building. With effective use of venting the building can make use of the sites natural wind tunnel and cross ventilate the space from east to west.

Goals for Thermal Delight

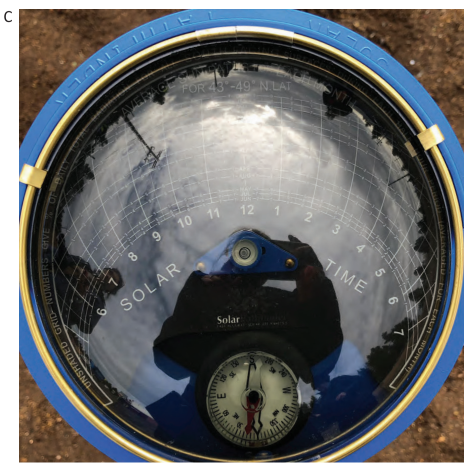
Provide multiuse adaptive zones that can be used to provide refuge from temperature extremes.

- Shaded areas for the warmer summer months
- Warm heated areas for cooler winter months.

Pathfinder

A


B


C


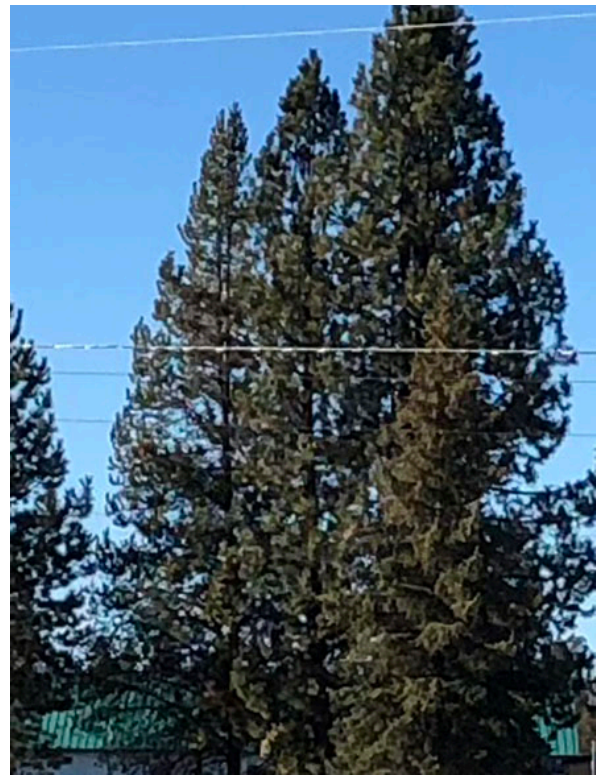
Tree Photo, ID, Density

- Tree 1:

  Ponderosa Pine, Density: 32%

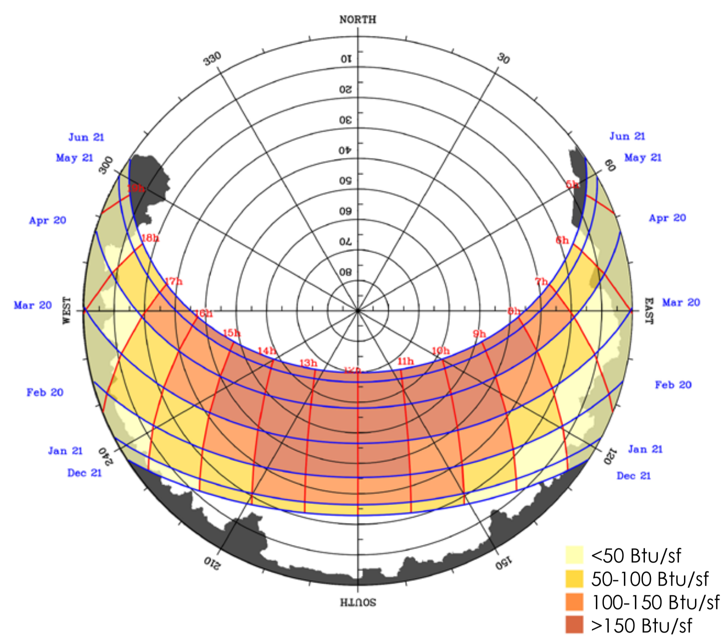
- Tree 2:

  Ponderosa Pine, Density: 53%

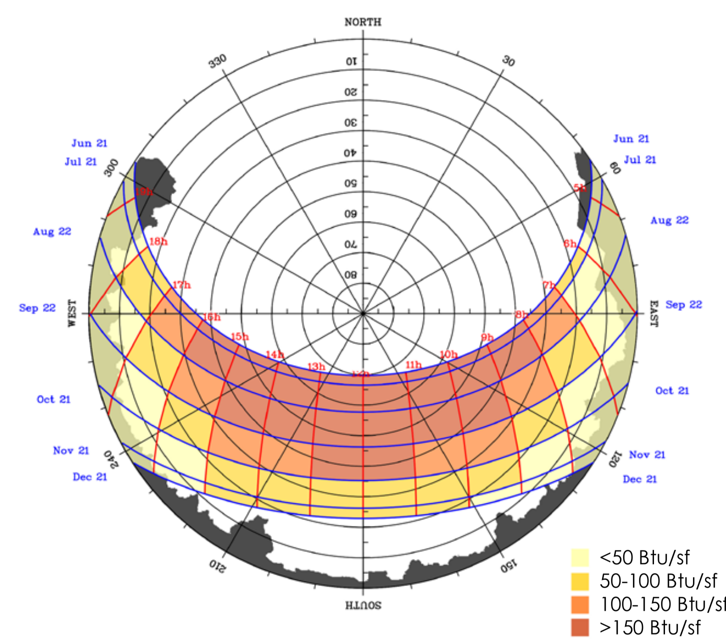


Sun Path Charts

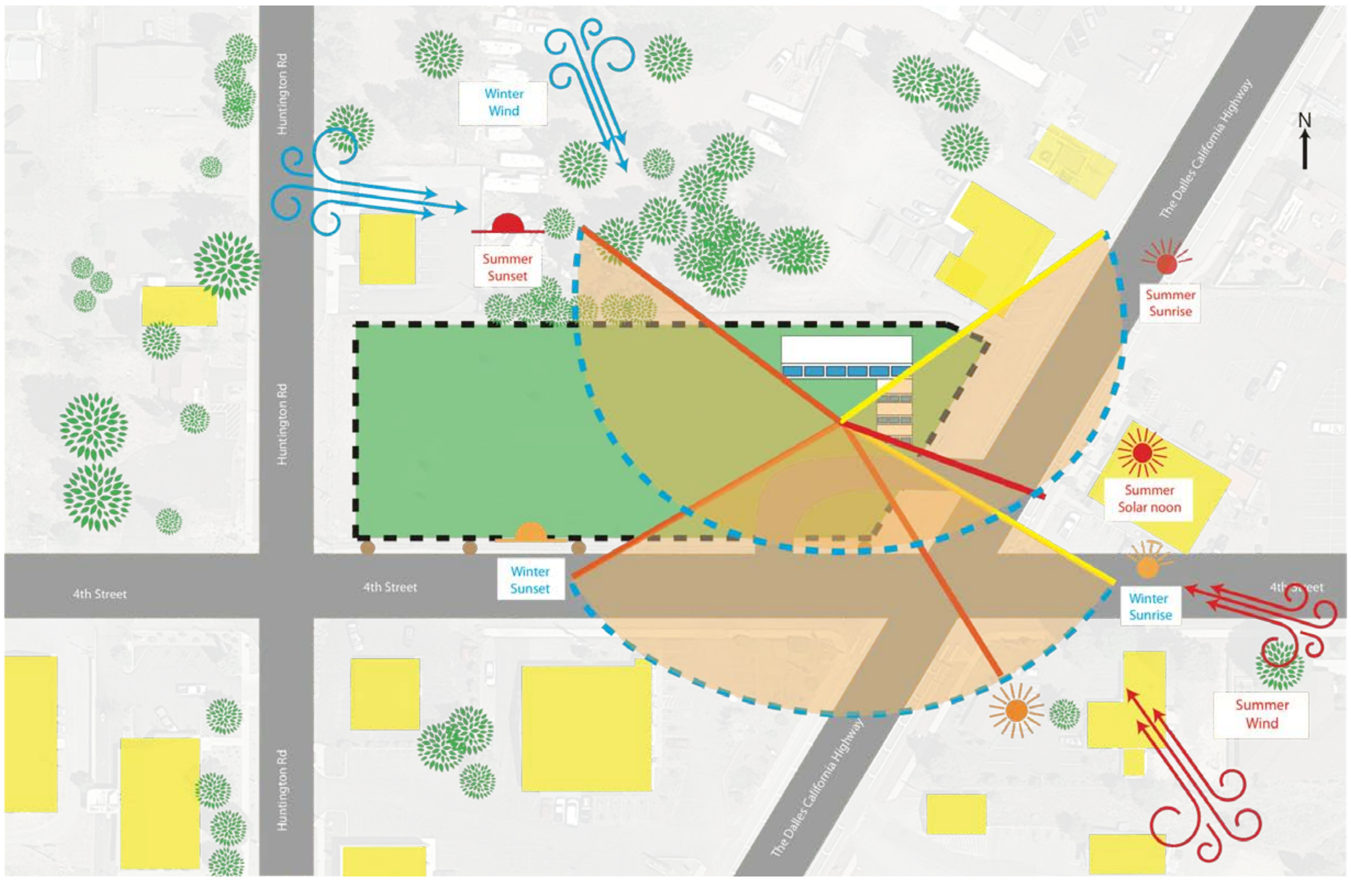
Spring



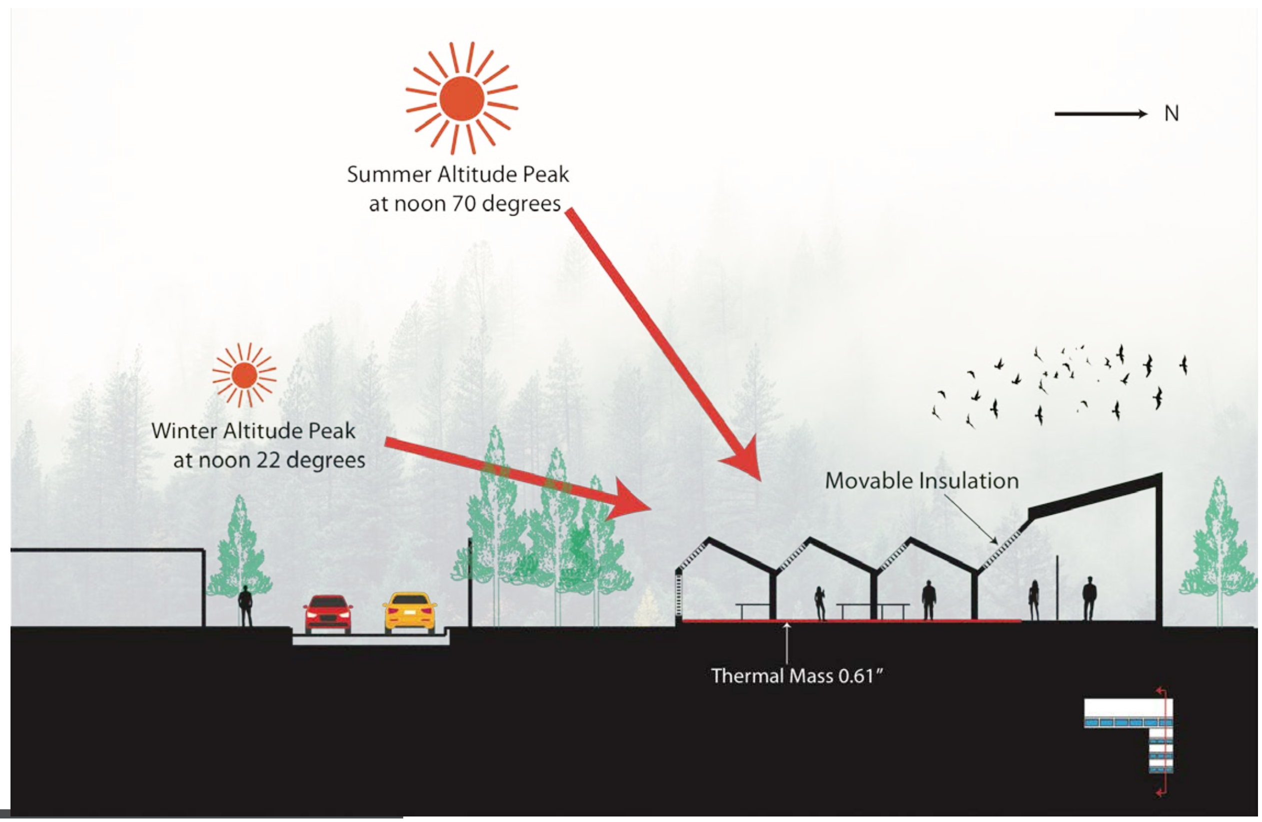
Fall



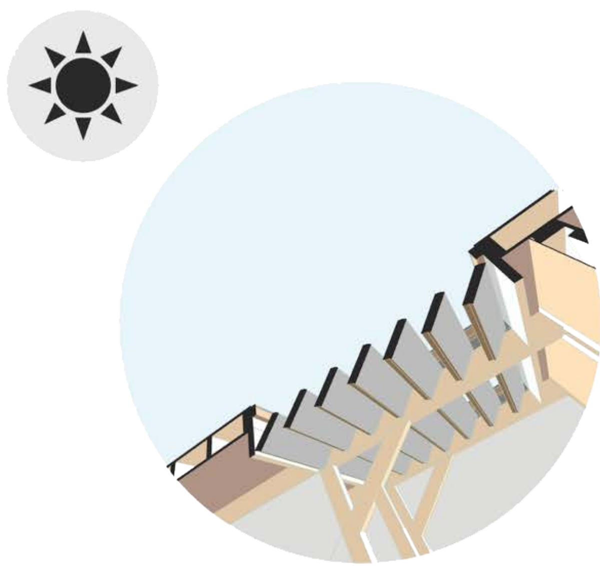
Site Plan

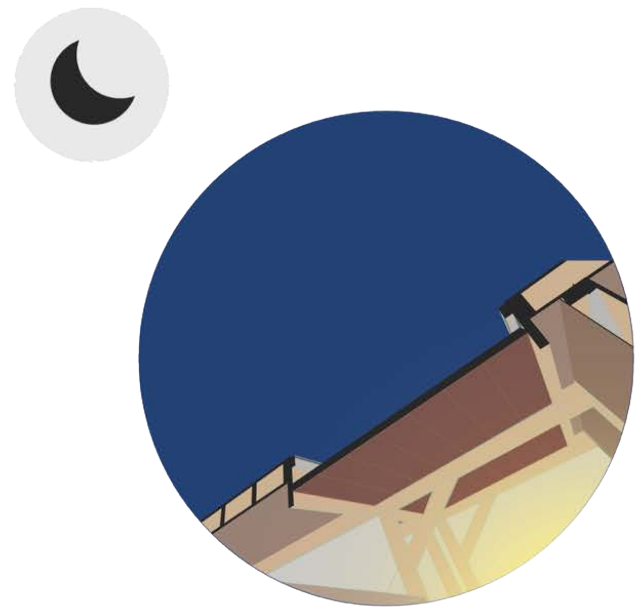

N
Huntington Rd
Huntington Rd
Huntington Rd
4th Street
4th Street
4th Street
The Dalles California Highway
The Dalles California Highway
Winter
Wind
Summer
Sunset
Winter
Sunset
Summer
Sunrise
Summer
Solar noon
Winter
Sunrise
Summer
Wind

Building Section



Moveable Insulation Detail





Thermal Mass Calculations

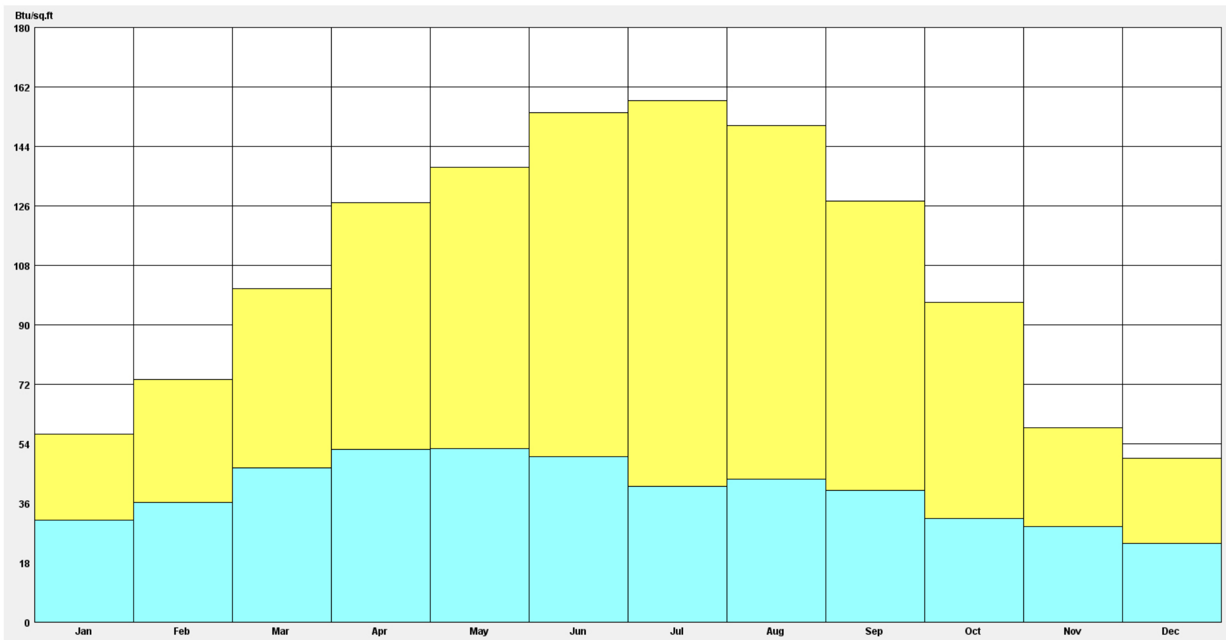
- Solar Radiation for February Day:
  150 W/m2 x 24hrs =3600 KJ x .6 solar absorptance =
  2160 kJ uptake

  Temperatures:
  15.5 C- -6.6 C=
  22.1K Desired Temperature Difference

  Concrete mass:
  Solar absorptance= .06
  Heat Capacity= .9 kJ/kgk
  Density= 2000 kg/m^3
  (1/.09) kg xK/kJ x 2160 kJ / 22.1K =
  108.5 kg

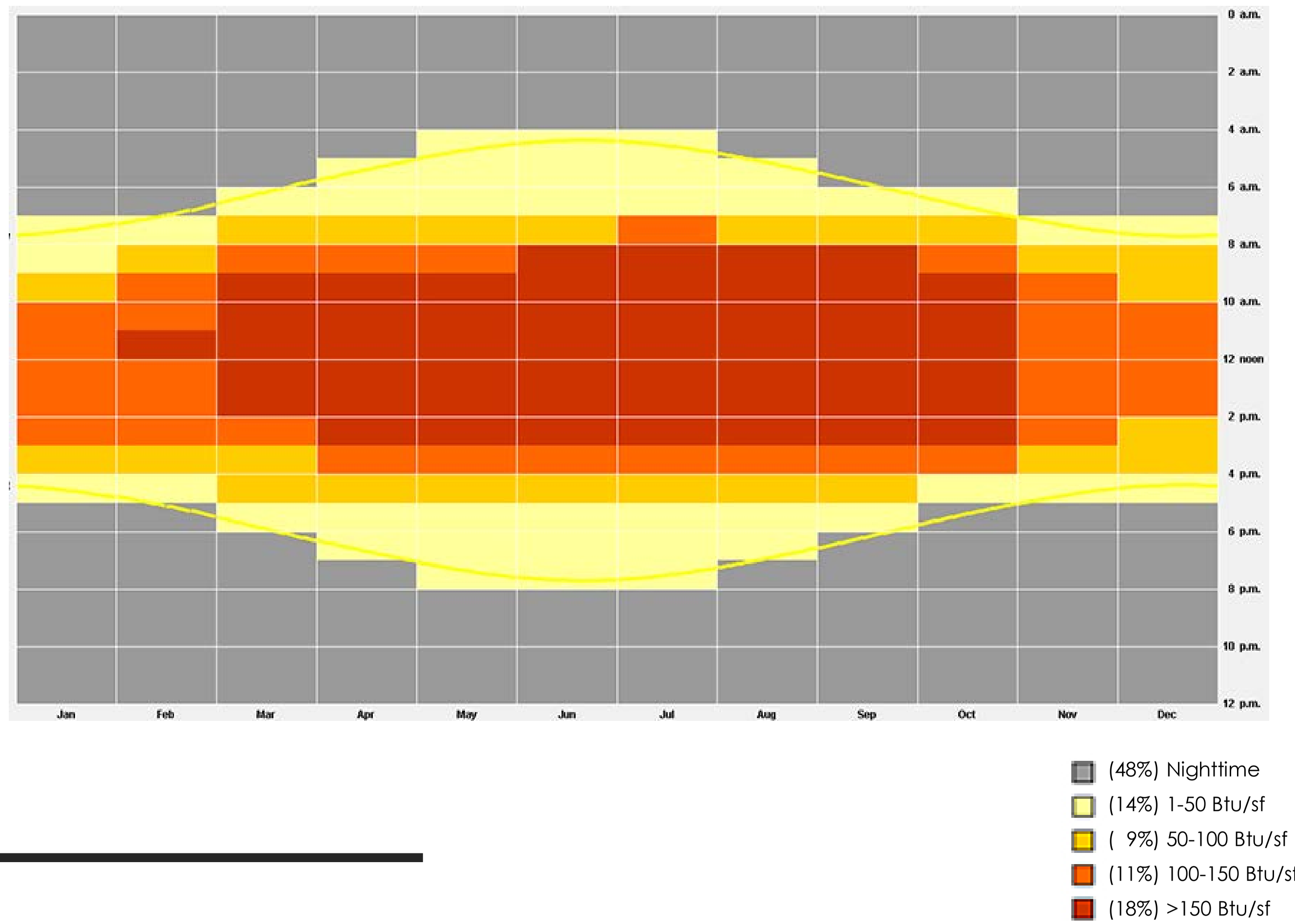
  Thickness:
  108.5 kg x 1m^3/2000kg= 0.05425m^3 /35m^2 =1.55cm or .61inches

Average Daily Radiation

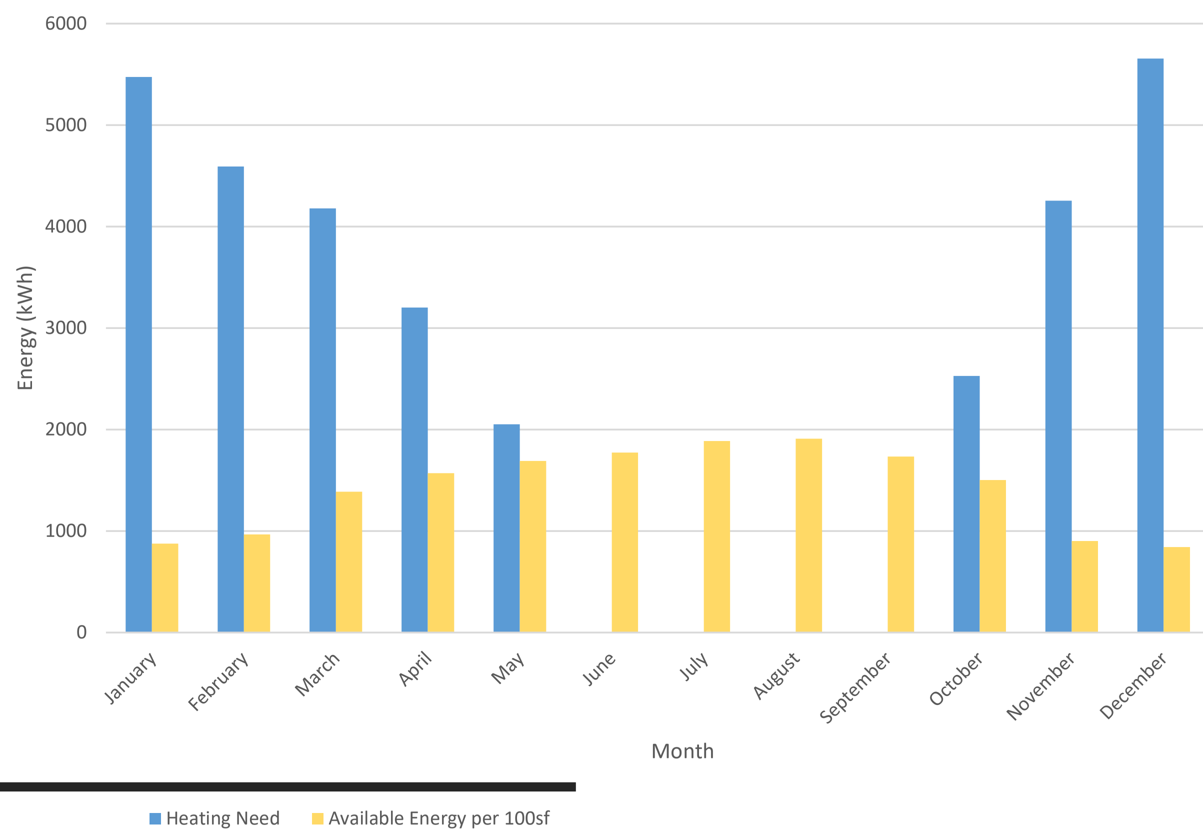


Total Horizontal Radiation (Btu/sf)
Diffuse Radiation (Btu/sf)

Daily Radiation on 50° Tilted Surface



Heating Need vs. Solar Energy on Tilted Window

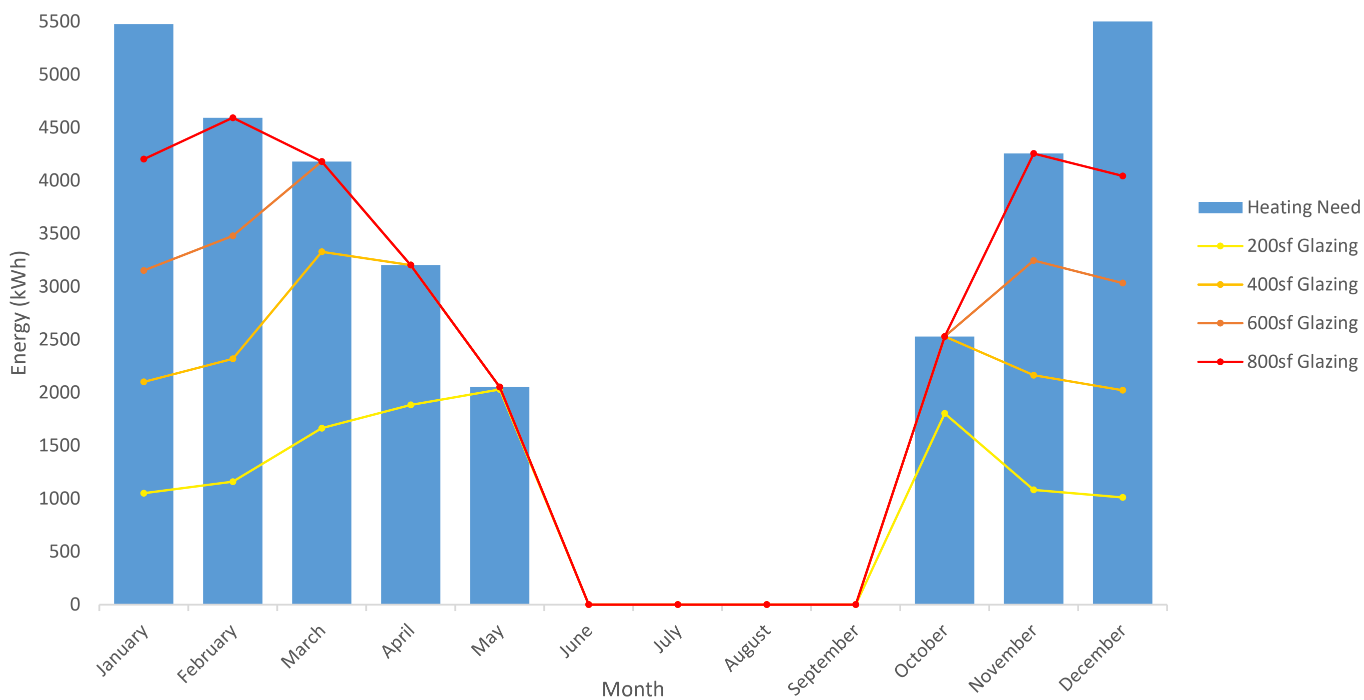


Design balance-point temperature: 60F

- relies on adaptive comfort zone
- large amount of infiltration due to high traffic
- varying lengths of time spent inside
- occupants' clothing levels adapted to weather

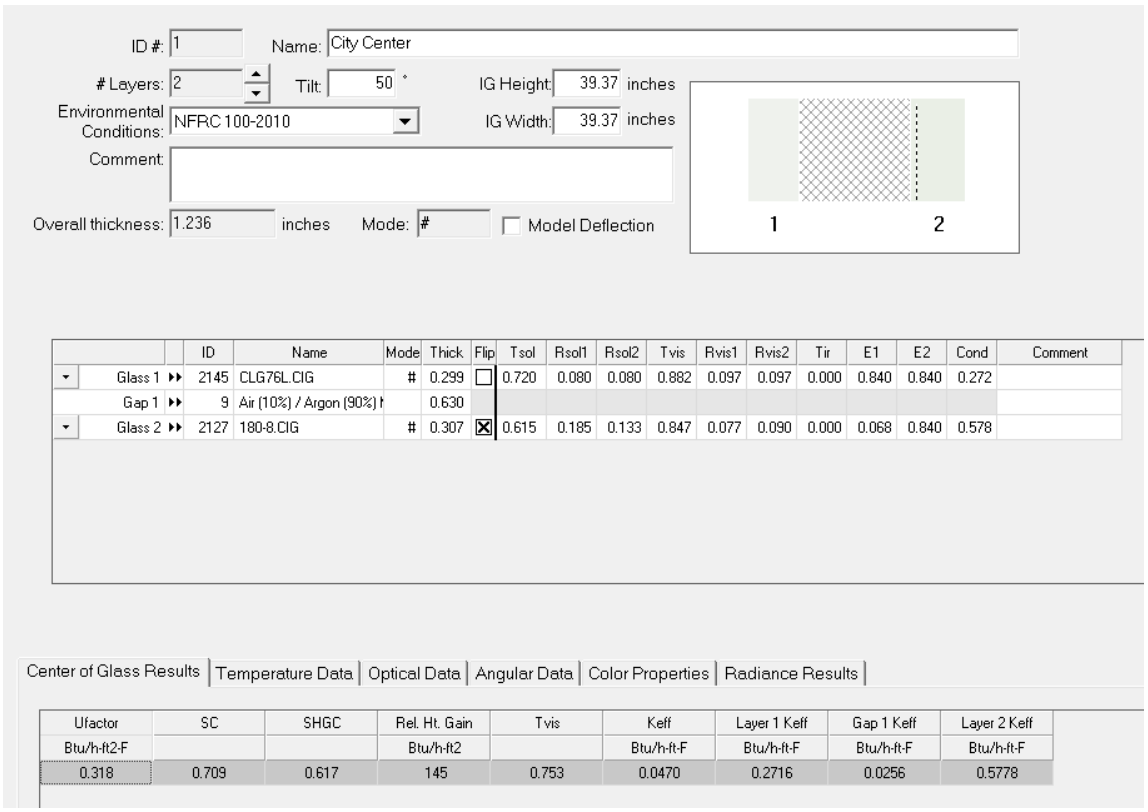
June – September cooling months

Heating Need vs. Available Energy per Area of Glazing



- 50 degrees ideal glazing tilt
- 800sf fully accommodates 6 of 8 heating months
- high energy gain in summer requires cooling, though higher indoor temperature in summer is acceptable

Glazing Selection



ID #: 1 Name: City Center

Layers: 2 Tilt: 50 ° IG Height: 39.37 inches

Environmental Conditions: NFRC 100-2010 IG Width: 39.37 inches

Comment:

Overall thickness: 1.236 inches Mode: # Model Deflection

1 2

	ID	Name	Mode	Thick	Flip	Tsol	Rsol1	Rsol2	Tvis	Rvis1	Rvis2	Tir	E1	E2	Cond	Comment
Glass 1	2145	CLG76L.CIG	#	0.299	☐	0.720	0.080	0.080	0.882	0.097	0.097	0.000	0.840	0.840	0.272	
Gap 1	9	Air (10%) / Argon (90%)		0.630												
Glass 2	2127	180-8.CIG	#	0.307	☒	0.615	0.185	0.133	0.847	0.077	0.090	0.000	0.068	0.840	0.578	

Center of Glass Results | Temperature Data | Optical Data | Angular Data | Color Properties | Radiance Results

Ufactor	SC	SHGC	Rel. Ht. Gain	Tvis	Keff	Layer 1 Keff	Gap 1 Keff	Layer 2 Keff
Btu/h-ft2-F			Btu/h-ft2		Btu/h-ft-F	Btu/h-ft-F	Btu/h-ft-F	Btu/h-ft-F
0.318	0.709	0.617	145	0.753	0.0470	0.2716	0.0256	0.5778

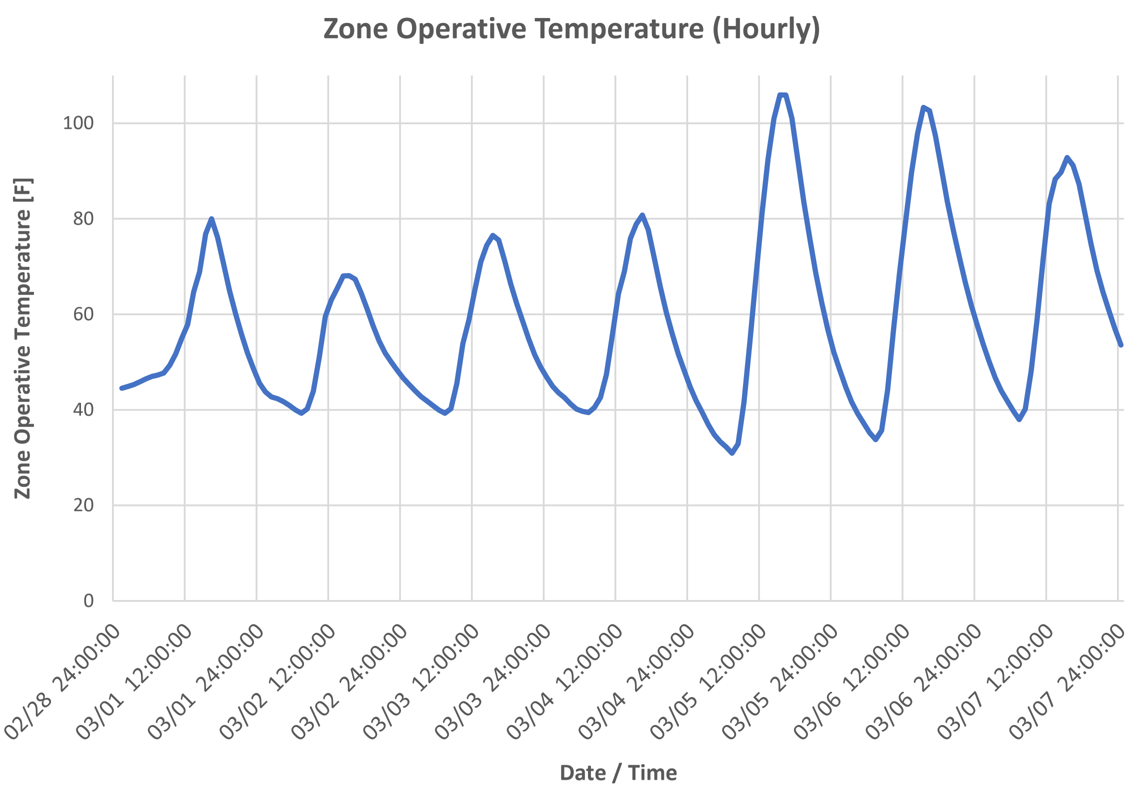
Goals

- low U-value of 0.318 traps winter heat
- high SHGC of 0.617 allows more solar energy to reach thermal mass in the winter
- low-E coating on face 3 traps heat inside
- moveable insulation in place sunset to sunrise

414.482 Btu/h average gain on heating day

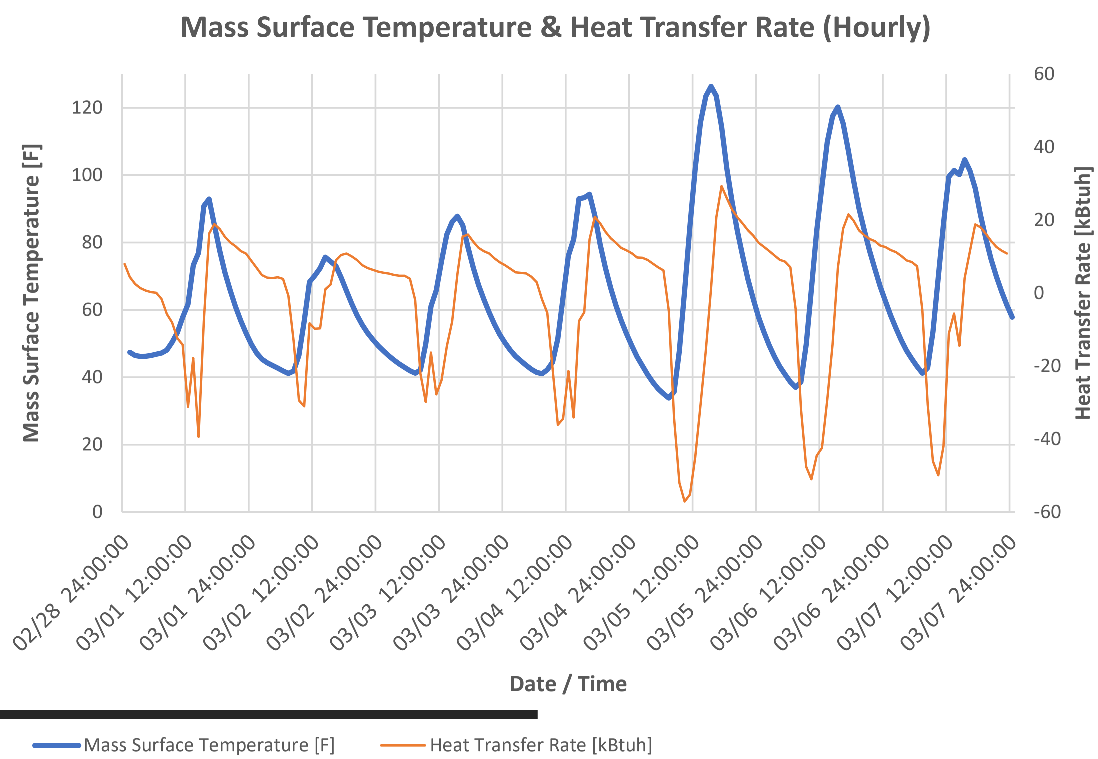
369.15 Btu/h average gain on cooling day

Zone Operative Temperature



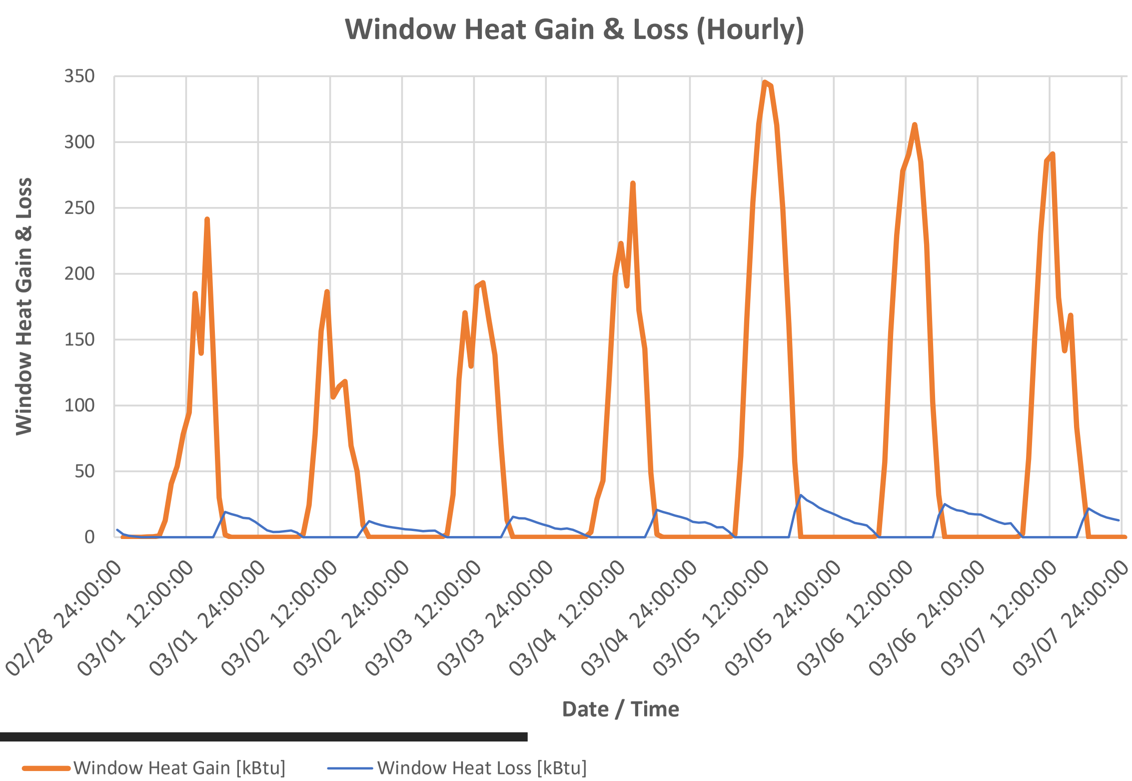
Based upon the modeled data, the building over-performs during the hottest parts of the day. At night the building falls below the operative temperature of 60 degrees, but because the building will not be occupied at that time it doesn't serve as a problem. Effective passive cooling strategies will be necessary to keep the building thermally comfortable during the warmest parts of the day. The building design makes use of air flow and adaptive zones to do this.

Mass Surface Temperature & Heat Transfer Rate



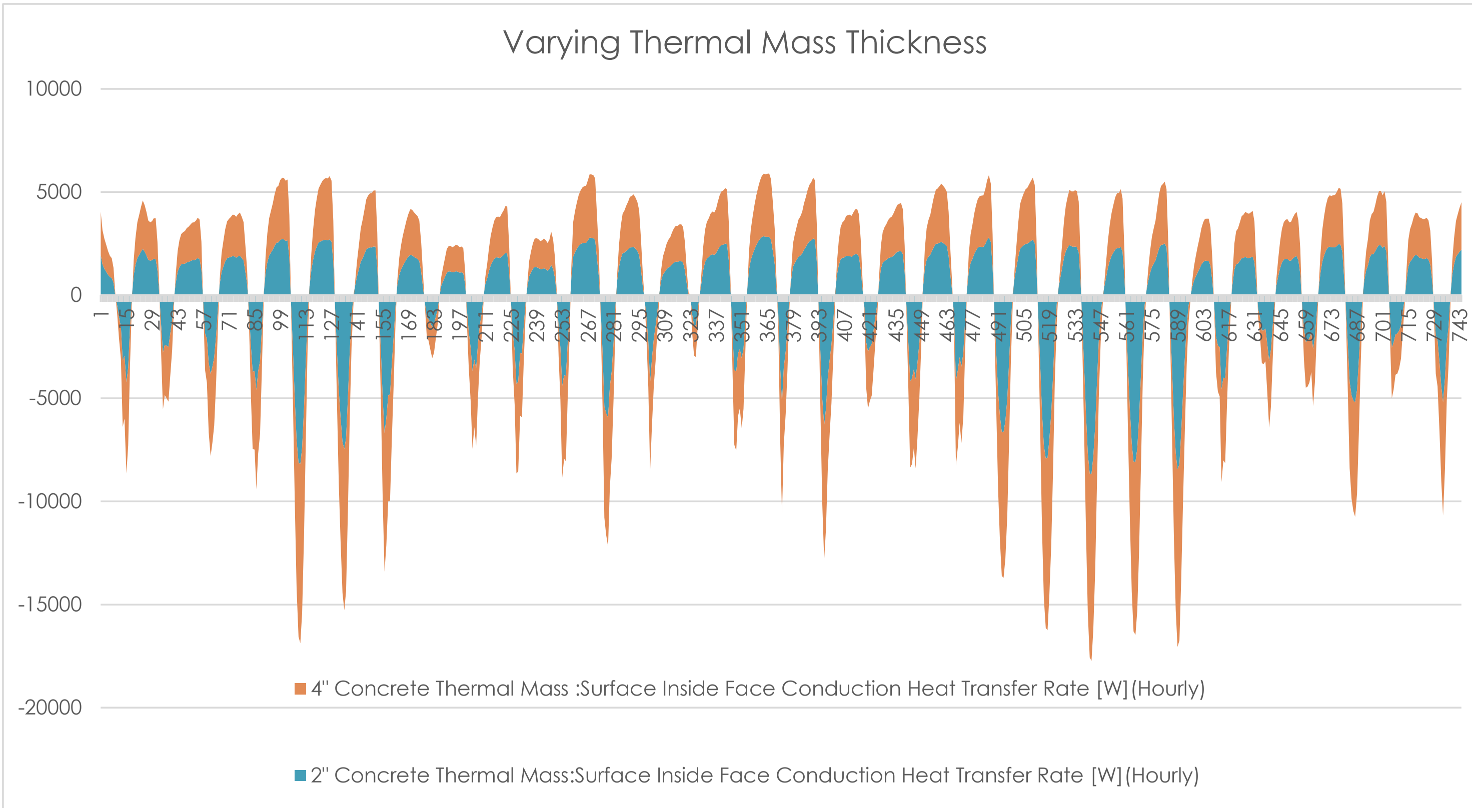
Based upon our design intent we wanted a source of thermal mass that would store and release heat relatively quickly. This was because the area would primarily only be occupied during the day, meaning long term storage wasn't necessary. Based upon the data collected our thermal mass appears to be doing exactly what we hoped for in terms of storage and release time.

Window Heat Gain & Loss

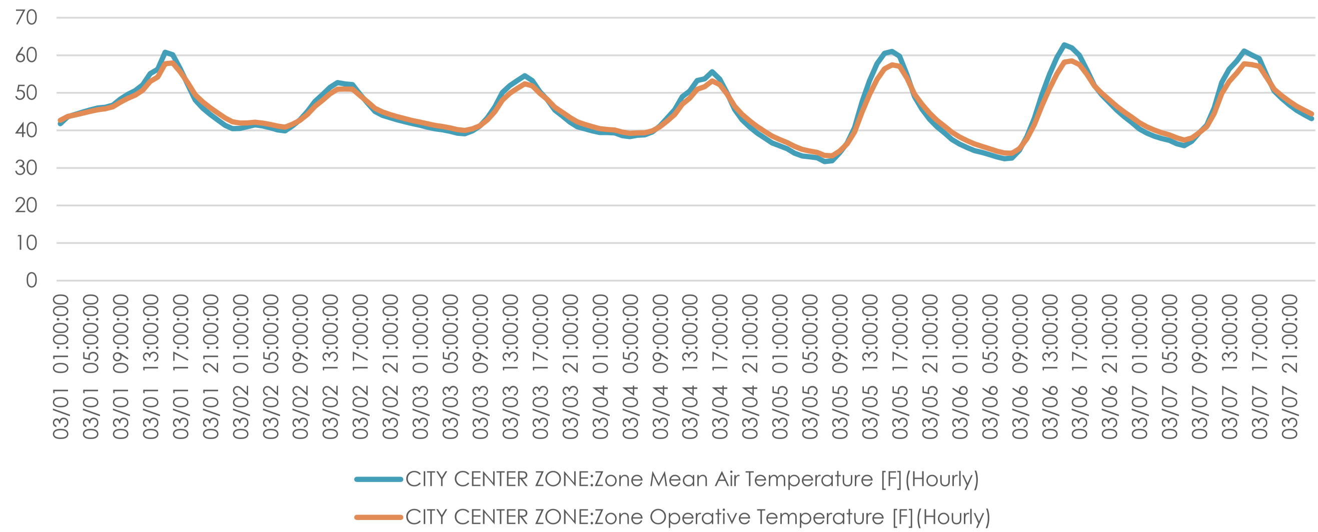


The data show there is a lot of heat gain in the afternoon and not much heat loss. Heat gain begins at 7am and peaks at 1pm, and heat loss begins at 6pm when the insulation is added. The movable insulation reduces heat loss at night and opens up during the day to allow for heat gain. Removal of nighttime insulation could be delayed an hour to retain additional heat because heat gain does not begin until an hour after the insulation is removed at 6am.

Individual Graphs



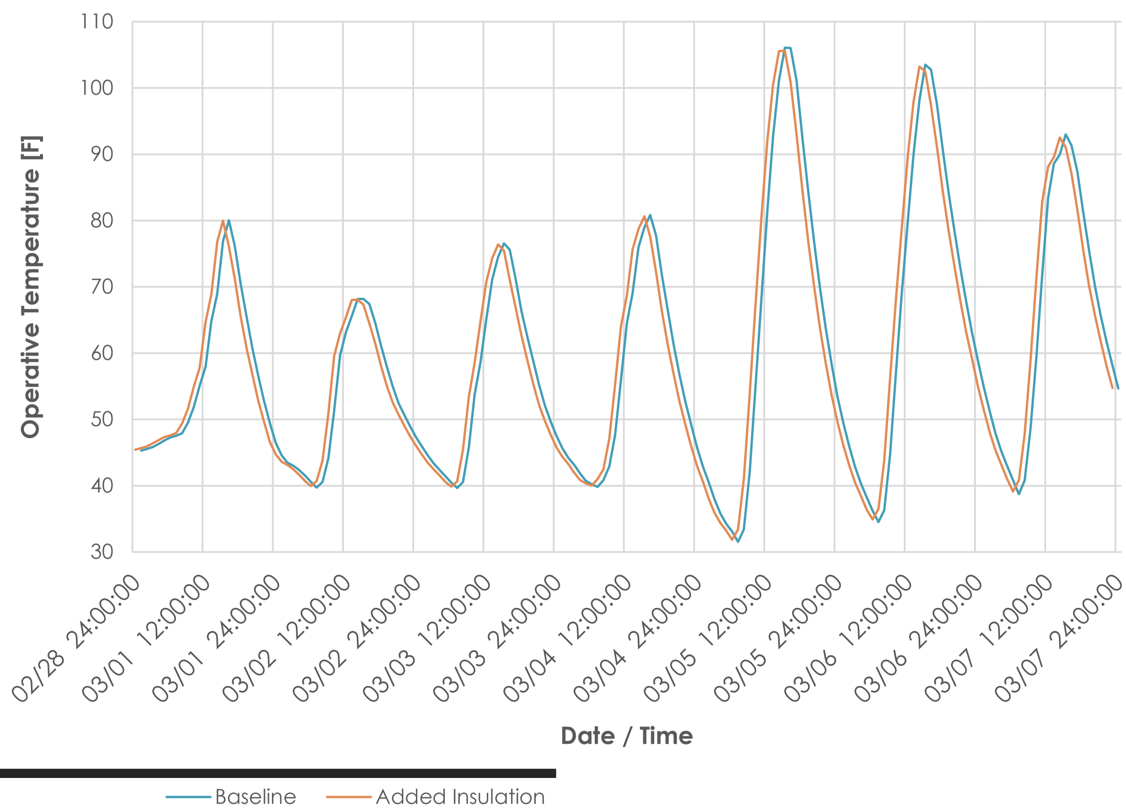
Individual Graphs



Based on the graphic showing the operative temperature has more stable indoor door temperature, which tells us when we compare the mean air temperature to operative area, operative are has better control in temperature.

Individual Graphs

Operative Temperature with Modified Insulation Thickness and Schedule



Change

- operable insulation thickness quadrupled
- insulation remains in place two hours past sunrise
- insulation replaced an hour before sunset
- summer insulation used as shading

Result

- 8am to 5pm is cooler (up to 1F)
- 5pm to 8am is warmer (up to 0.5F)
- larger mediating effect on extremes

La Pine Steepwind City Center

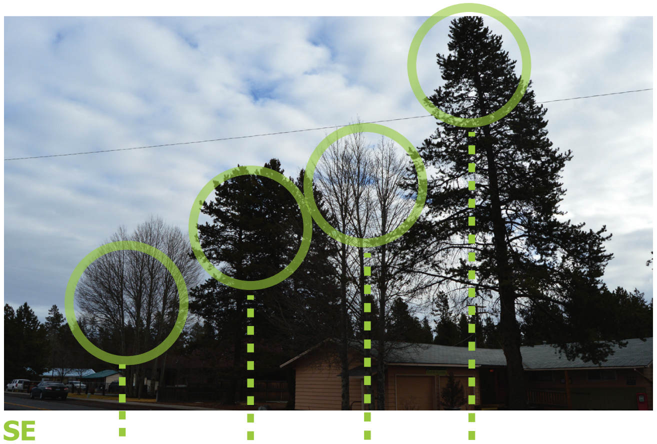
LA4/500 Winter 2018 | Passive Heating | Alexandra Rempel

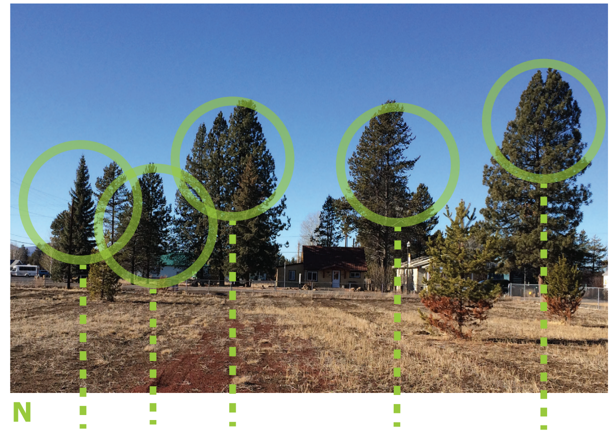
Austin Daich
Jared Dukes
Zoé Walker Aparicio

OPTIMAL ORIENTATION IS TO THE SOUTH

wind orientation was to south to southeast ranging from 1-6 miles per hour with the strongest coming from the south

site survey



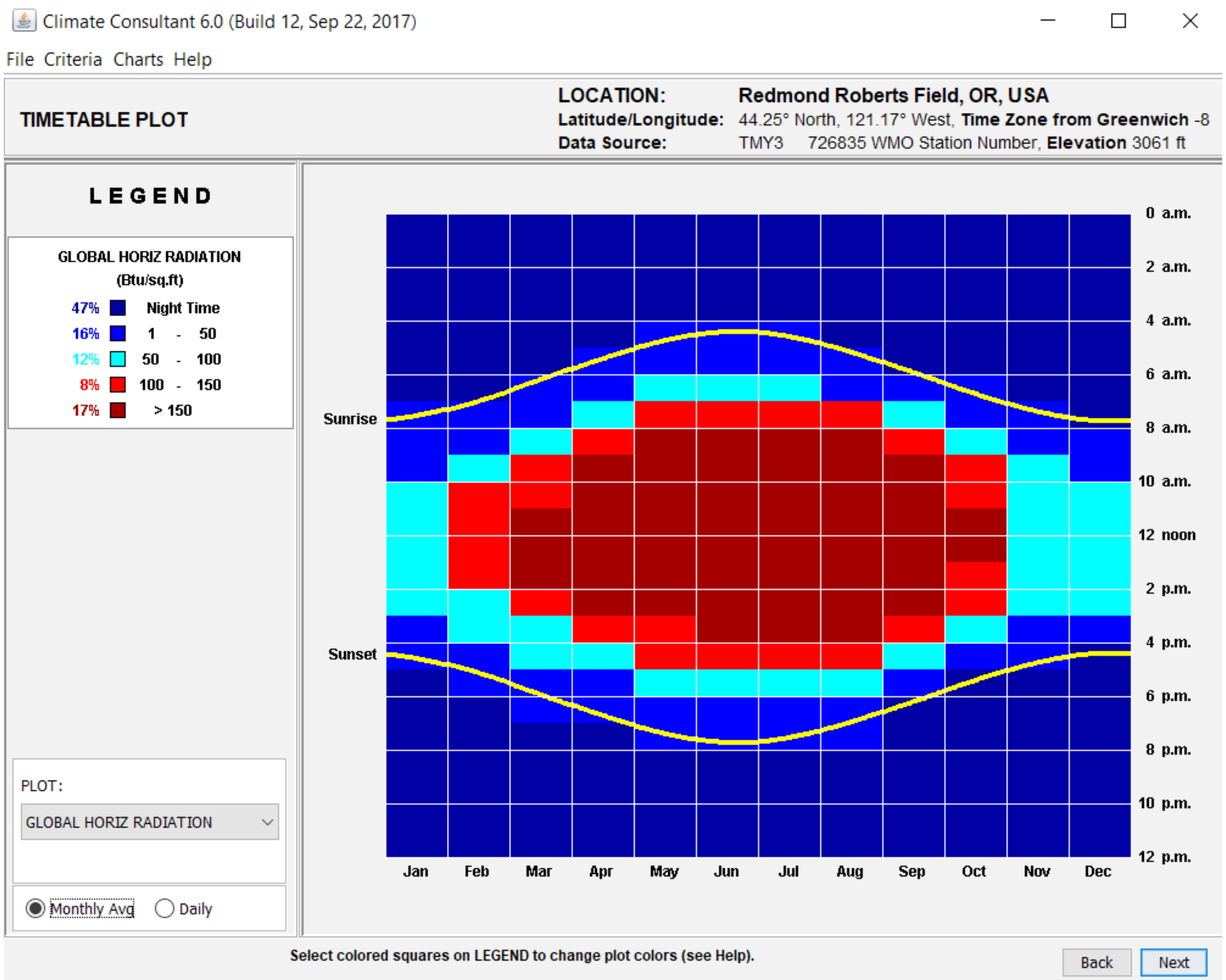


tree densities

43’ From front fence & 32’ w from electrical pole

45’ 9” From front fence & 5’ w of existing trees

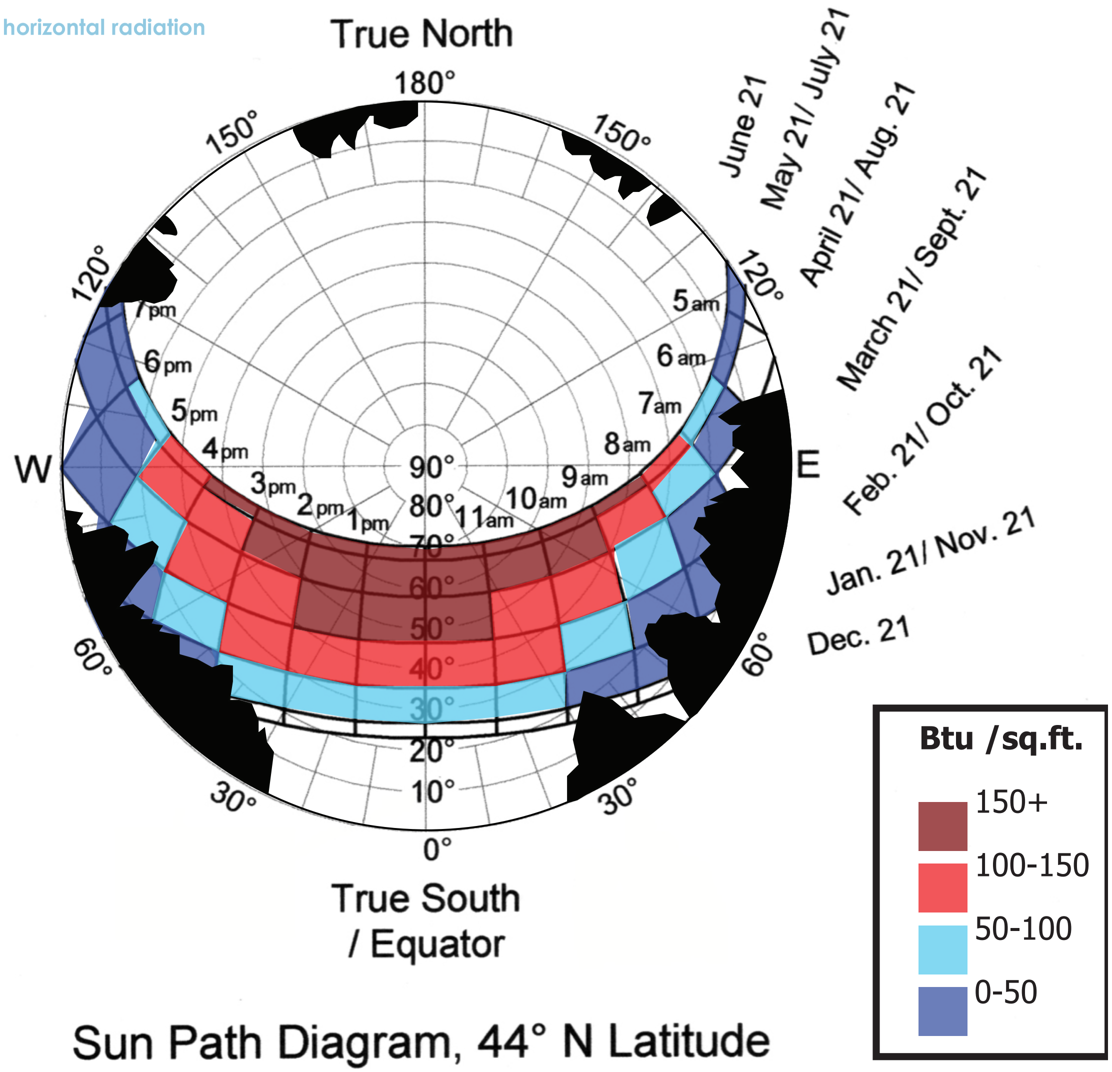
pathfinder photos



climate consultant data

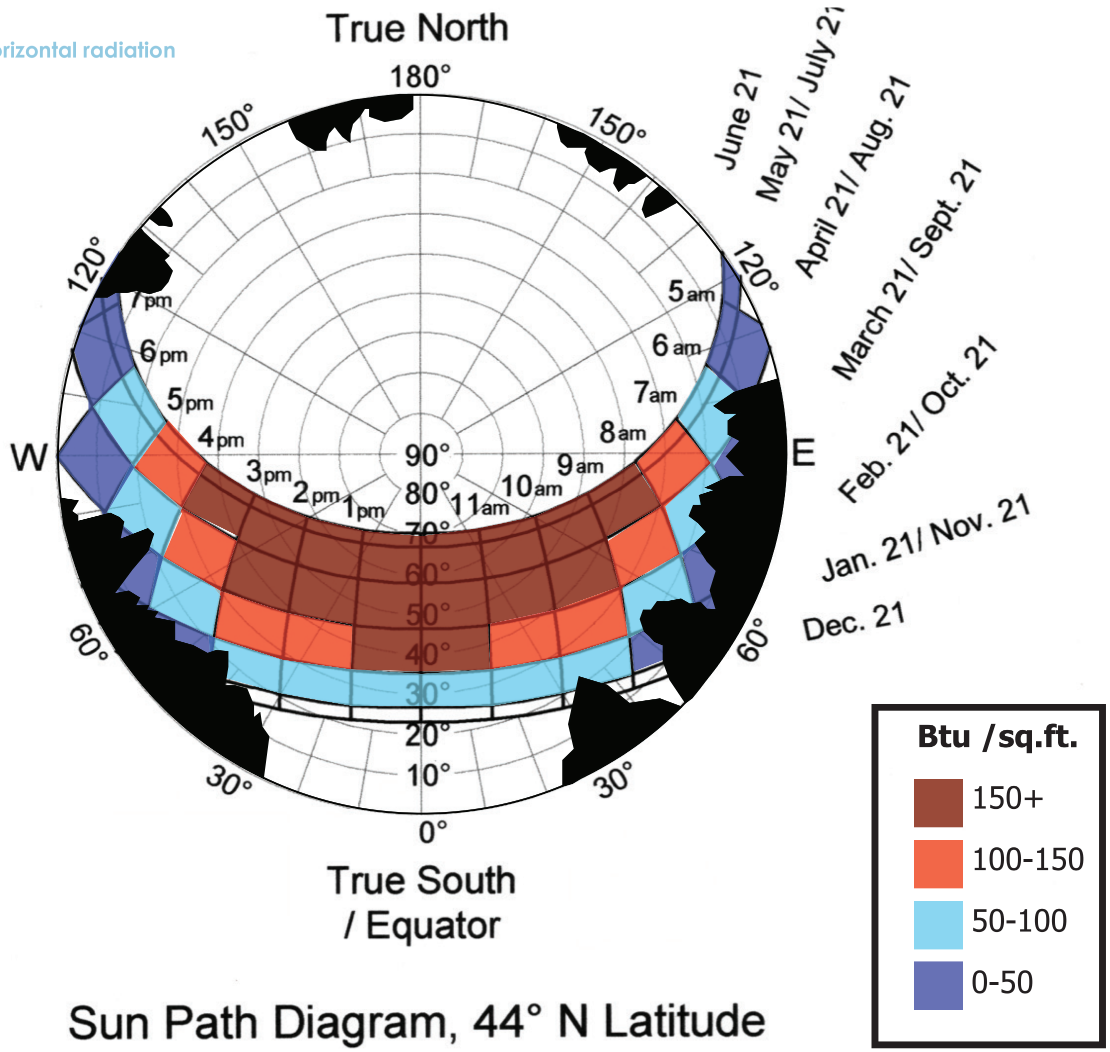
solar resource & shading masks | spring

global horizontal radiation



Sun Path Diagram, 44° N Latitude

global horizontal radiation



Sun Path Diagram, 44° N Latitude

solar resource & shading masks | fall

top: WinterCreek Resoration & Nursery Bend, OR | native central Oregon lowshrub landscape to minimize solar obstruction
bottom right: Zion Visitor Center, Utah | skylights on the pitched roof for solar gain and increased light
bottom left: Roland Reisley House, NY | tilted roof pitch to maximize solar gain

precedents

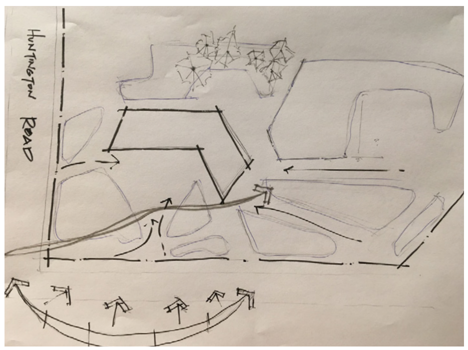
goals for thermal comfort

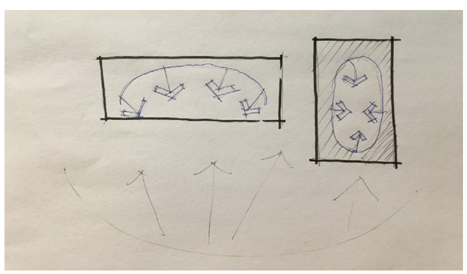
+ an indoor space that meets our base temperature of at least 60°F during the cold season

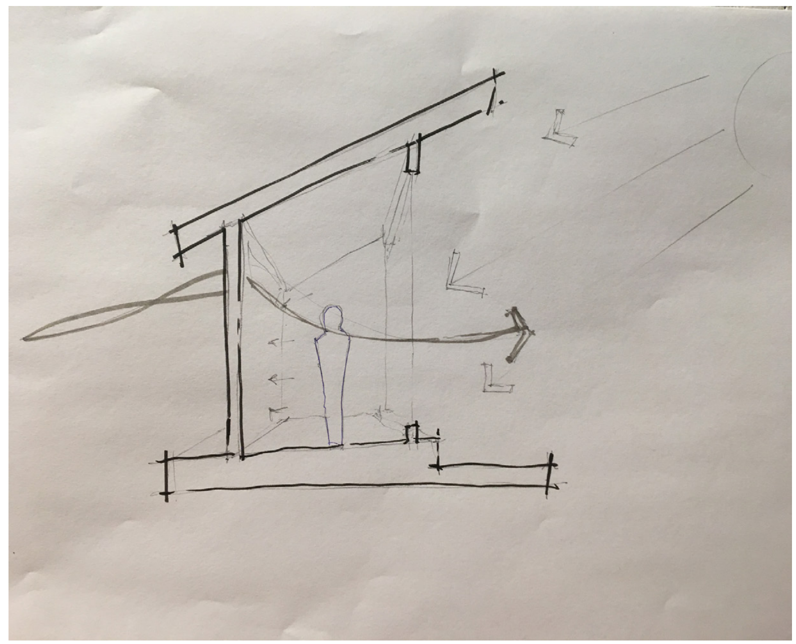
+ reaching our HDD for a minimum of 8 hrs a day

+ reach temperatures that do not rely on additional and are comfortable during sedentary activity

diagrams:







+ the indoor fireplace functions as a gathering place during the cold season

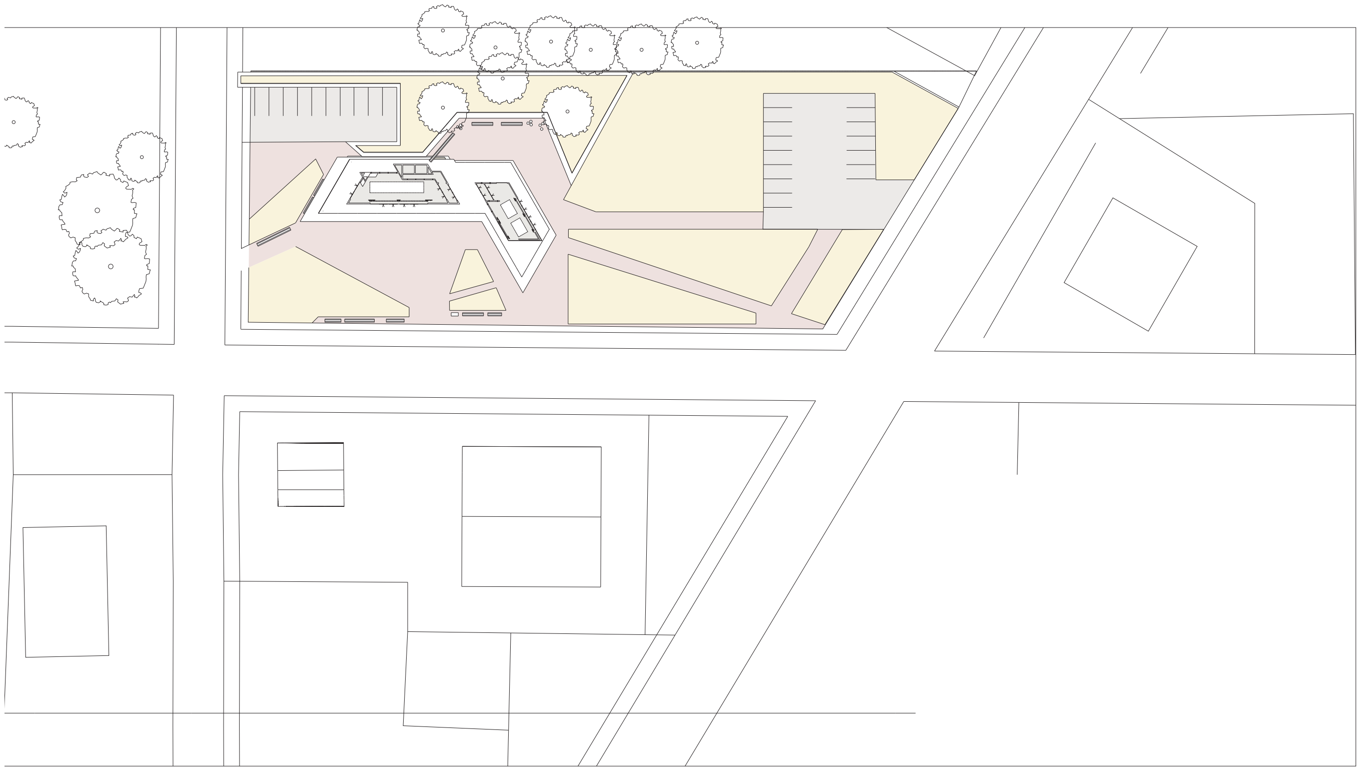
+ a cool zone on the north side allows for year-round use

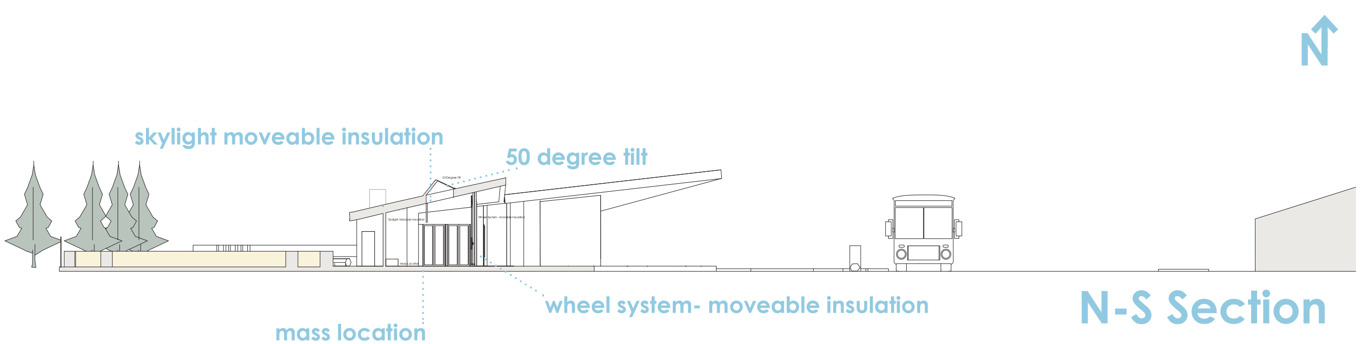
+ basalt seating in the front plaza provides warm outdoor seating

+ basalt seating in the cool zone provides cool and shaded seating

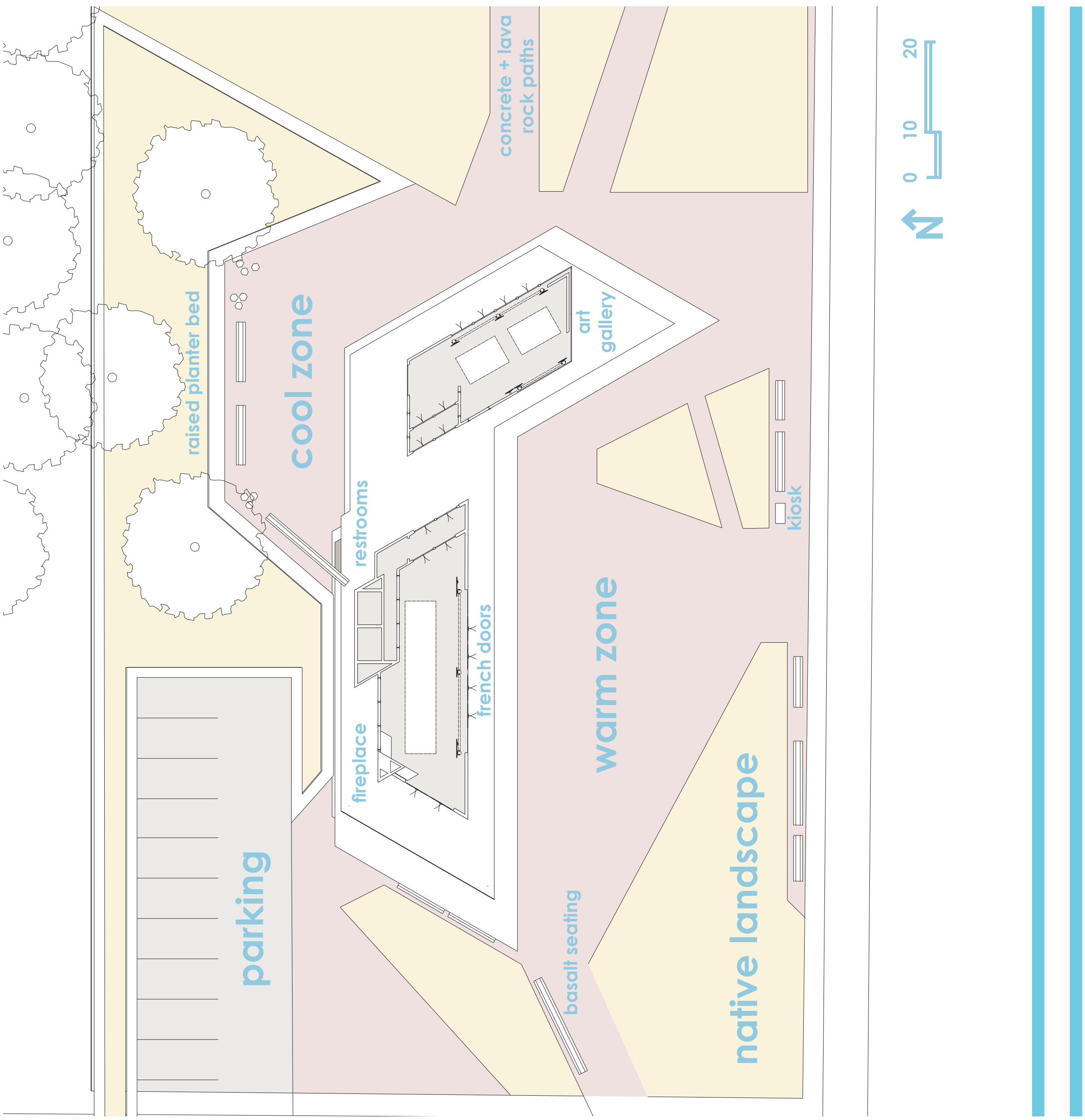
+ french doors allow for a breeze during hot summer months

goals for thermal delight

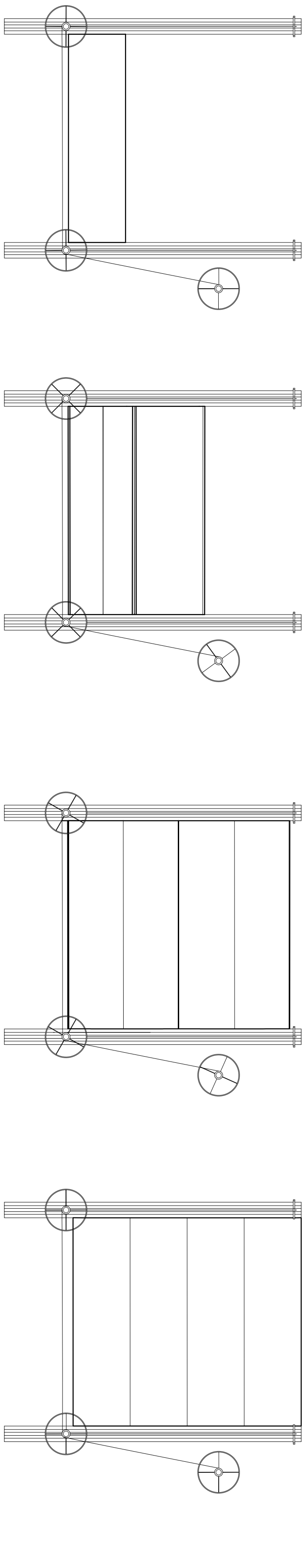



N
skylight moveable insulation
50 degree tilt
wheel system- moveable insulation
mass location

N-S Section


concrete + lava
rock paths
raised planter bed
cool zone
art
gallery
restrooms
kiosk
french doors
fireplace
warm zone
parking
basalt seating
native landscape
0
10
20
N

moveable insulation details



U.S. Department of Commerce
National Oceanic & Atmospheric Administration
National Environmental Satellite, Data, and Information Service

Summary of Monthly Normals
1981-2010
Generated on 01/29/2018

National Centers for Environmental Information
151 Patton Avenue
Asheville, North Carolina 28801

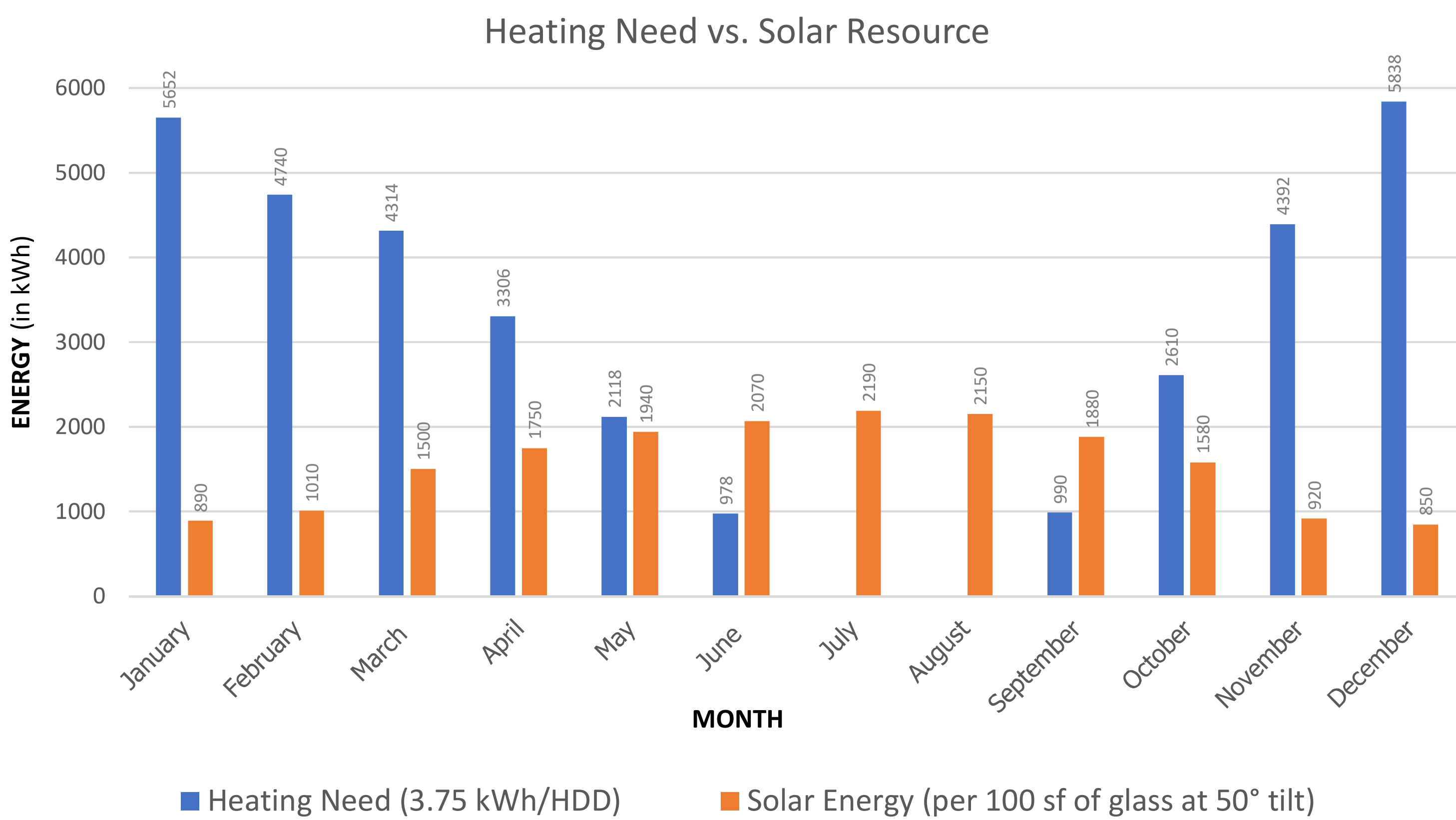
Current Location: Elev: 4358 ft. Lat: 43.6825° N Lon: -121.6874° W
Station: **WICKIUP DAM, OR US USC00359316**

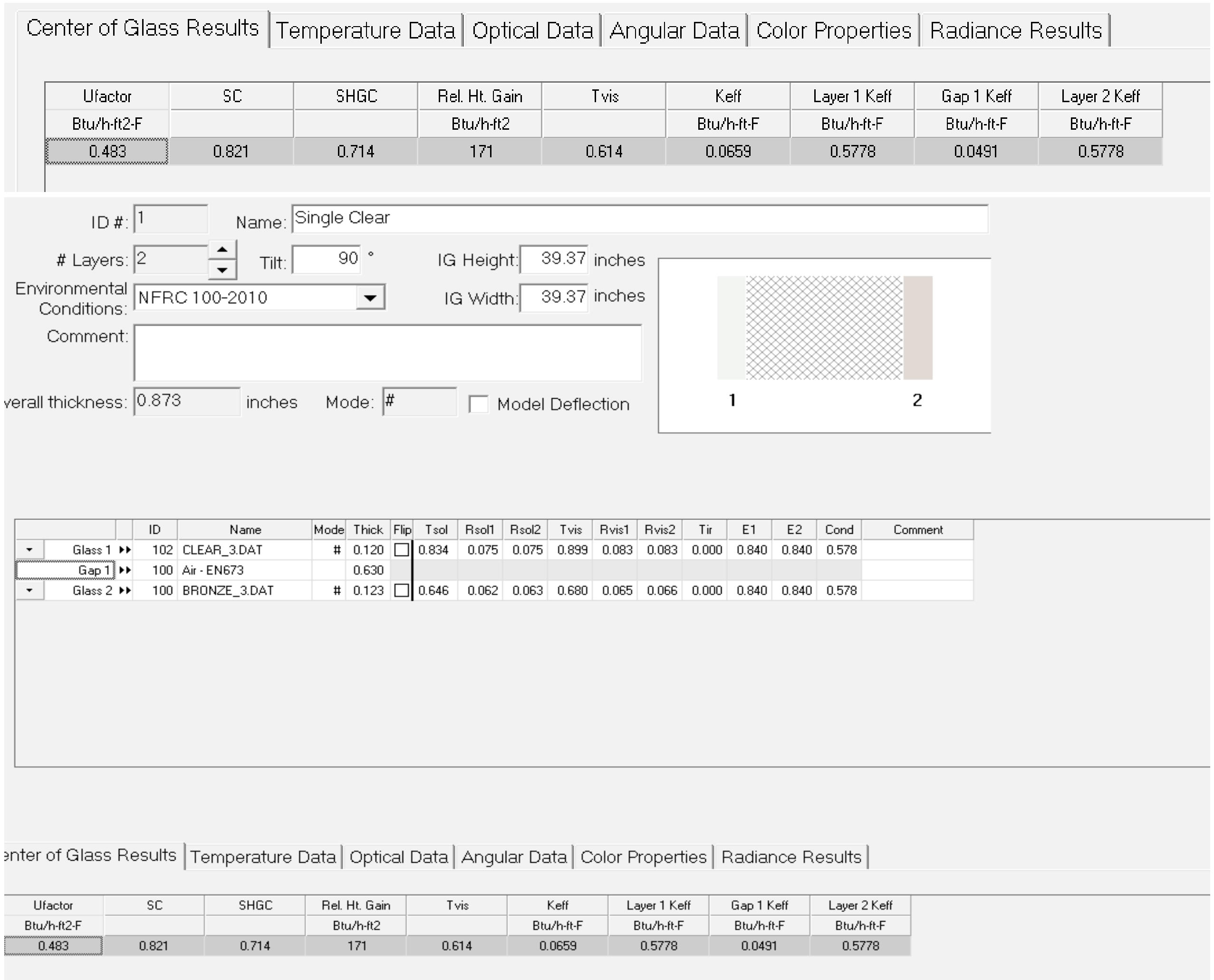
Temperature (°F)																						
Mean							Cooling Degree Days Base (above)						Heating Degree Days Base (above)				Mean Number of Days					
Month	Daily Max	Daily Min	Mean	Long Term Max Std Dev	Long Term Min Std Dev	Long Term Avg Std Dev	55	57	60	65	70	72	55	57	60	65	Max >= 100	Max >= 90	Max >= 50	Max <= 32	Min <= 32	Min <= 0
01	39.3	19.9	29.6	2.6	5.0	3.6	0	0	0	0	0	0	787	849	942	1097	0.0	0.0	1.8	4.1	29.0	1.0
02	42.8	20.8	31.8	3.8	4.8	3.9	0	0	0	0	0	0	649	705	790	930	0.0	0.0	5.0	2.1	26.0	1.0
03	48.3	25.3	36.8	3.7	2.7	2.9	-7777	-7777	0	0	0	0	564	626	719	874	0.0	0.0	12.0	0.4	28.1	-7777
04	54.4	28.9	41.7	4.1	2.5	3.1	3	1	-7777	-7777	0	0	403	462	551	700	0.0	0.0	17.5	0.0	21.9	0.0
05	63.1	34.9	49.0	4.3	2.1	2.9	39	25	12	2	-7777	-7777	225	273	353	498	0.0	0.1	26.8	0.0	10.4	0.0
06	71.4	40.6	56.0	3.5	1.9	2.6	108	77	43	11	2	1	78	107	163	281	0.0	0.6	29.7	0.0	2.1	0.0
07	81.7	45.7	63.7	4.0	2.6	3.1	281	228	155	62	14	6	12	20	41	103	0.1	5.5	31.0	0.0	0.2	0.0
08	81.6	43.9	62.8	2.8	1.9	1.8	251	198	127	44	8	3	11	20	42	114	0.1	4.7	31.0	0.0	0.3	0.0
09	74.4	37.2	55.8	4.7	2.0	2.9	105	74	39	7	-7777	-7777	81	110	165	283	0.0	1.7	29.5	0.0	5.3	0.0
10	61.6	30.4	46.0	4.6	1.9	2.7	11	5	1	-7777	0	0	290	346	435	589	0.0	0.0	25.6	0.0	19.2	0.0
11	45.3	25.9	35.6	3.8	4.0	3.4	-7777	-7777	0	0	0	0	582	642	732	882	0.0	0.0	8.1	1.0	24.9	0.3
12	37.6	19.6	28.6	2.9	4.3	3.2	0	0	0	0	0	0	818	880	973	1128	0.0	0.0	0.9	5.8	29.2	1.4
Summary	58.5	31.1	44.8	3.7	3.0	3.0	798	608	377	126	24	10	4500	5040	5906	7479	0.2	12.6	218.9	13.4	196.6	3.7

-7777: a non-zero value that would round to zero
Empty or blank cells indicate data is missing or insufficient occurrences to compute value

heating degree days

heating need vs. solar resource





Center of Glass Results | Temperature Data | Optical Data | Angular Data | Color Properties | Radiance Results

Ufactor	SC	SHGC	Rel. Ht. Gain	Tvis	Keff	Layer 1 Keff	Gap 1 Keff	Layer 2 Keff
Btu/h-ft2-F			Btu/h-ft2		Btu/h-ft-F	Btu/h-ft-F	Btu/h-ft-F	Btu/h-ft-F
0.483	0.821	0.714	171	0.614	0.0659	0.5778	0.0491	0.5778

ID #: 1 Name: Single Clear

Layers: 2 Tilt: 90 ° IG Height: 39.37 inches

Environmental Conditions: NFRC 100-2010 IG Width: 39.37 inches

Comment:

verall thickness: 0.873 inches Mode: # Model Deflection

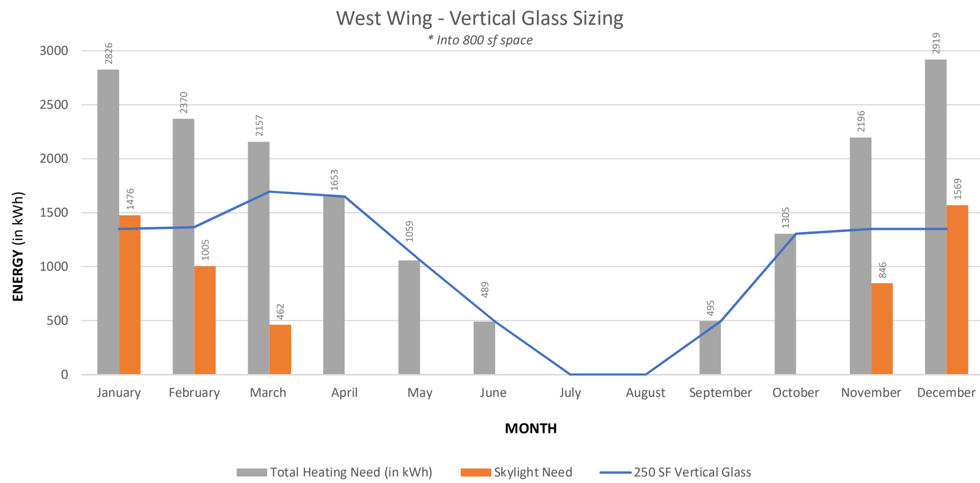
1 2

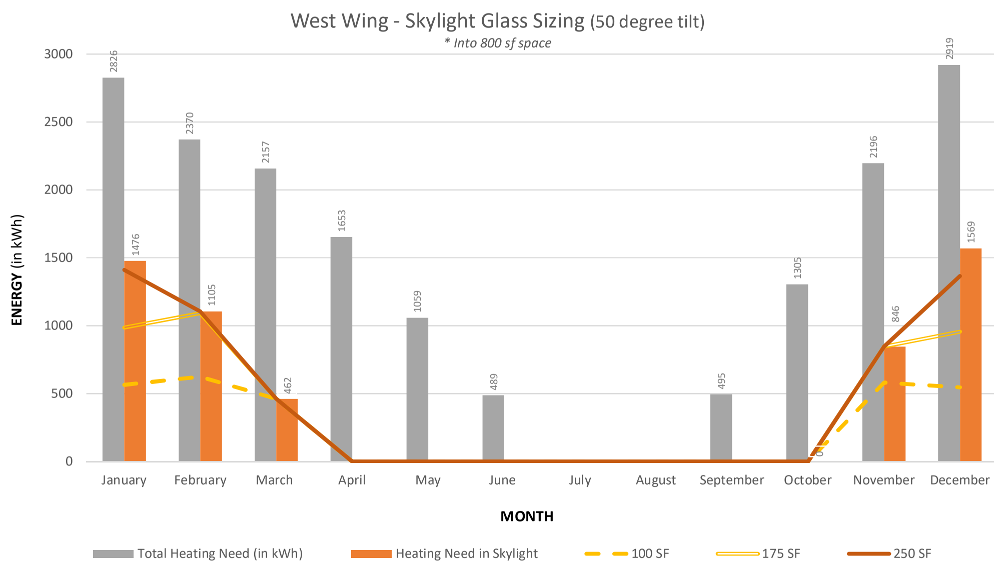
	ID	Name	Mode	Thick	Flip	Tsol	Rsol1	Rsol2	Tvis	Rvis1	Rvis2	Tir	E1	E2	Cond	Comment
Glass 1	102	CLEAR_3.DAT	#	0.120		0.834	0.075	0.075	0.899	0.083	0.083	0.000	0.840	0.840	0.578	
Gap 1	100	Air - EN673		0.630												
Glass 2	100	BRONZE_3.DAT	#	0.123		0.646	0.062	0.063	0.680	0.065	0.066	0.000	0.840	0.840	0.578	

enter of Glass Results | Temperature Data | Optical Data | Angular Data | Color Properties | Radiance Results

Ufactor	SC	SHGC	Rel. Ht. Gain	Tvis	Keff	Layer 1 Keff	Gap 1 Keff	Layer 2 Keff
Btu/h-ft2-F			Btu/h-ft2		Btu/h-ft-F	Btu/h-ft-F	Btu/h-ft-F	Btu/h-ft-F
0.483	0.821	0.714	171	0.614	0.0659	0.5778	0.0491	0.5778

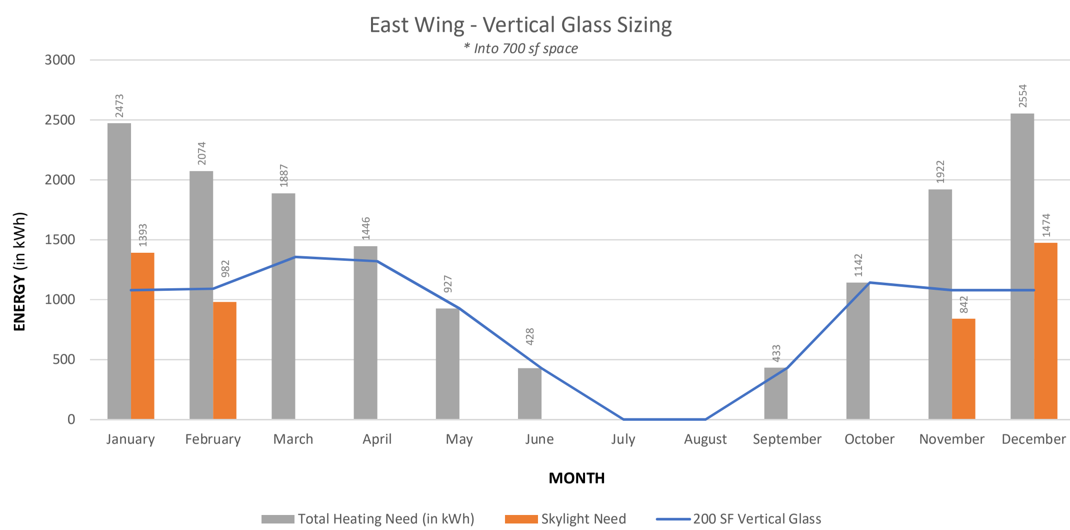
french door glazing selection

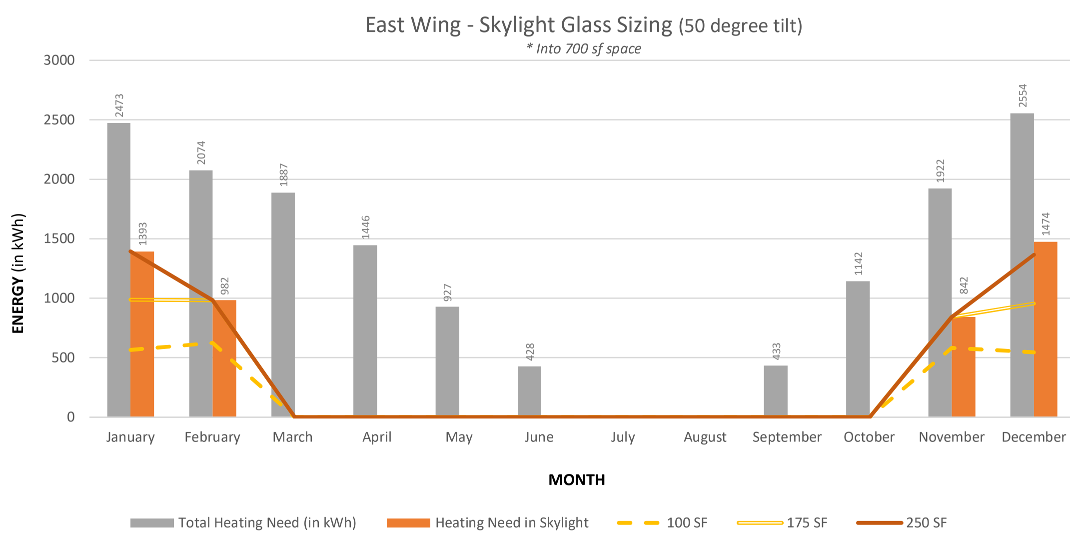




+ vertical glass was set at 250sq.ft. for our design
+ the verical glass collected solar radiation which was subtracted from the total heating need to determine the amount of solar radiation required through skylights
+ this amount was used to determine the skylight sizing at 250sq.ft.

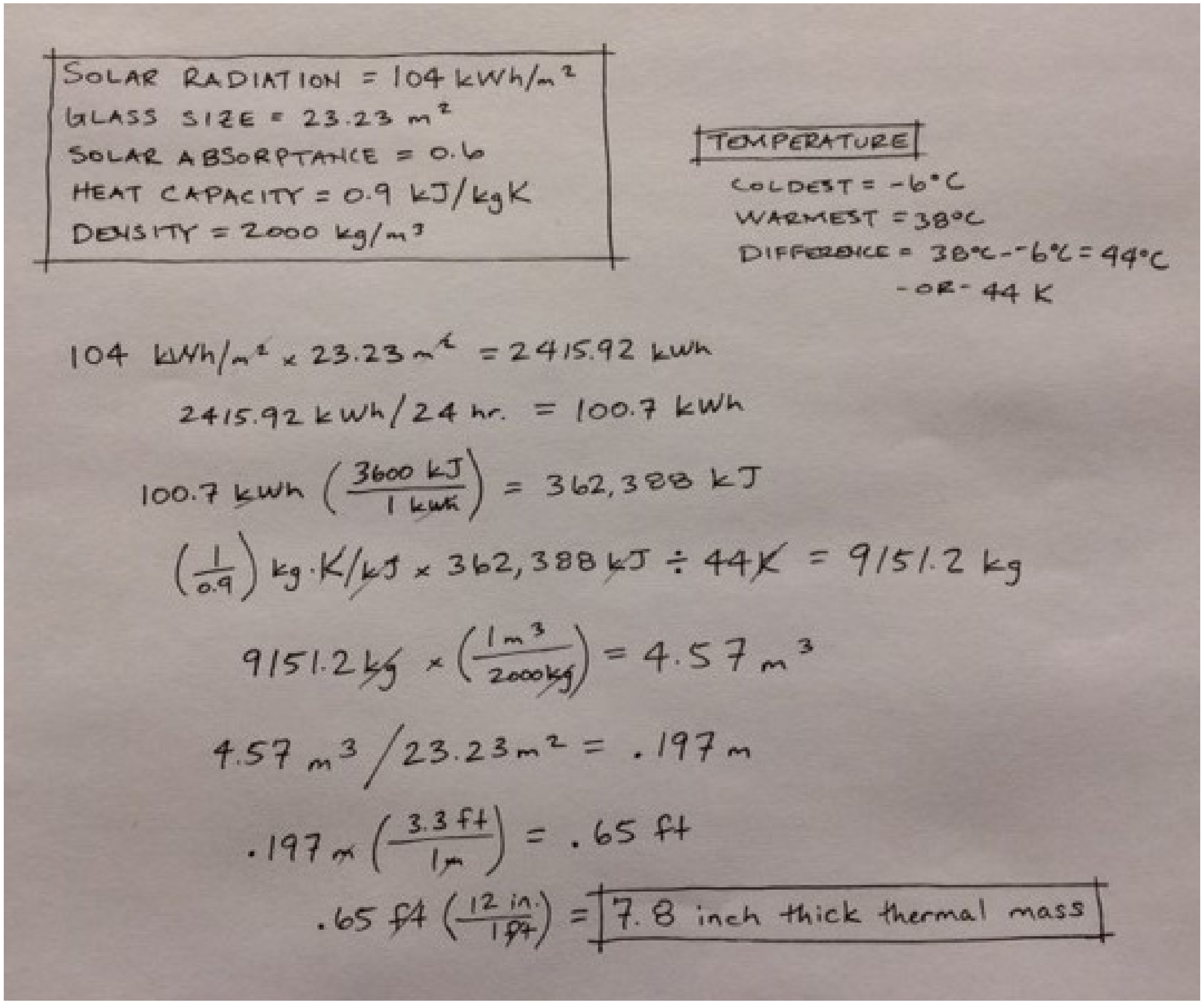
west wing glass sizing





+ vertical glass was set at 200sq.ft. for our design
+ the verical glass collected solar radiation which was subtracted from the total heating need to determine the amount of solar radiation required through skylights
+ this amount was used to determine the skylight sizing at 250sq.ft.

east wing glass sizing



SOLAR RADIATION = 104 kWh/m²
GLASS SIZE = 23.23 m²
SOLAR ABSORPTANCE = 0.6
HEAT CAPACITY = 0.9 kJ/kgK
DENSITY = 2000 kg/m³

TEMPERATURE
COLDEST = -6°C
WARMEST = 38°C
DIFFERENCE = 38°C - -6°C = 44°C
-OR- 44 K

$104 \ kWh/m^2 \times 23.23 \ m^2 = 2415.92 \ kWh$

$2415.92 \ kWh / 24 \ hr. = 100.7 \ kWh$

$100.7 \ kWh \left(\frac{3600 \ kJ}{1 \ kWh}\right) = 362{,}388 \ kJ$

$\left(\frac{1}{0.9}\right) kg \cdot K/kJ \times 362{,}388 \ kJ \div 44 K = 9151.2 \ kg$

$9151.2 \ kg \times \left(\frac{1 \ m^3}{2000 \ kg}\right) = 4.57 \ m^3$

$4.57 \ m^3 / 23.23 \ m^2 = .197 \ m$

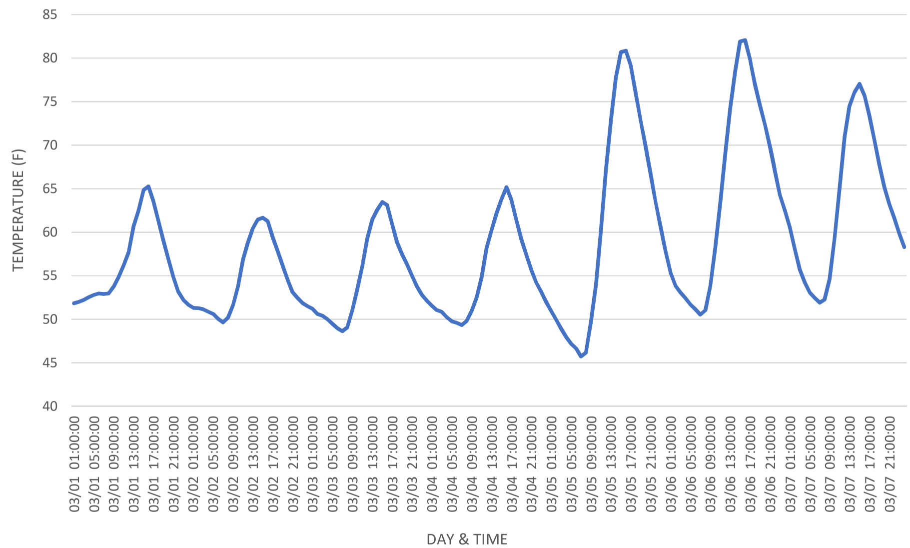
$.197 \ m \left(\frac{3.3 \ ft}{1 \ m}\right) = .65 \ ft$

$.65 \ ft \left(\frac{12 \ in.}{1 \ ft}\right) =$ 7.8 inch thick thermal mass

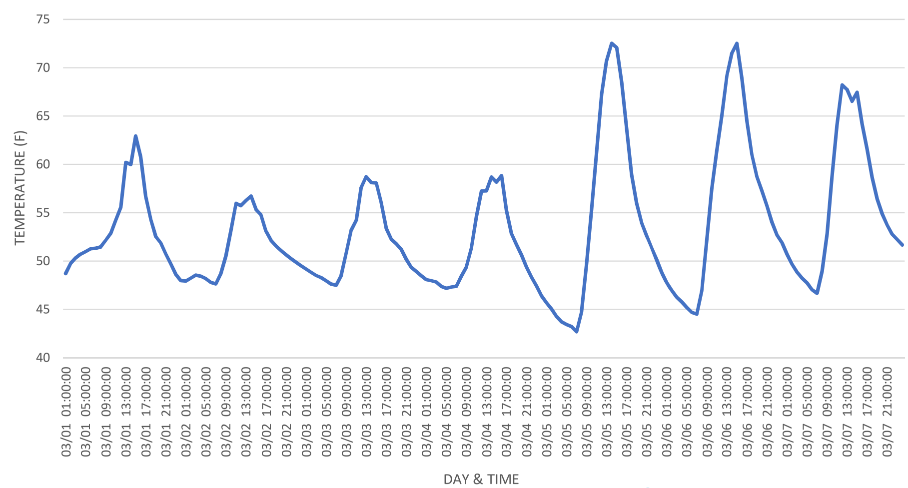
thermal mass sizing calculations

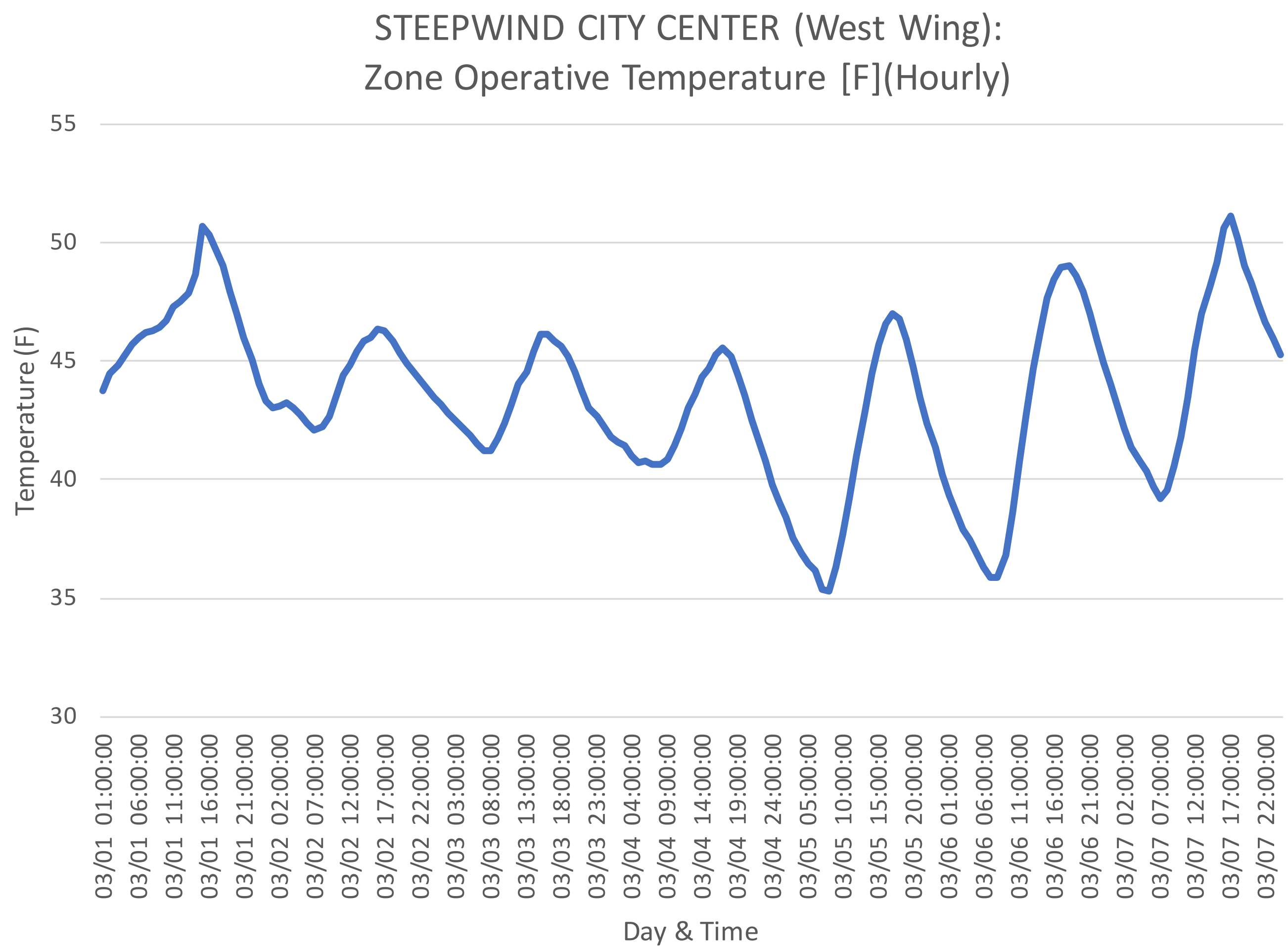
hourly operative temperatures

EAST WING: Zone Operative Temperature [F](Hourly)

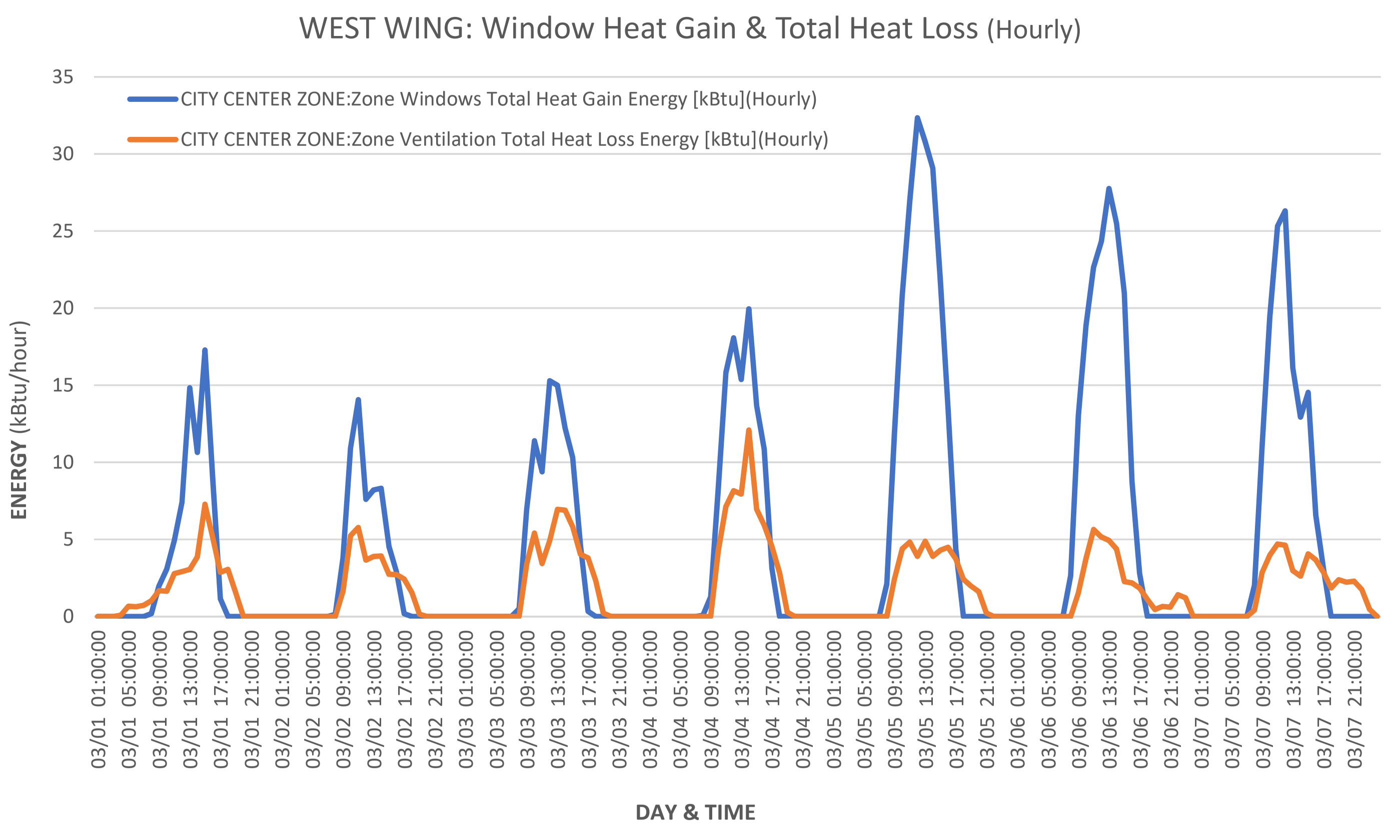


WEST WING: Zone Operative Temperature [F](Hourly)



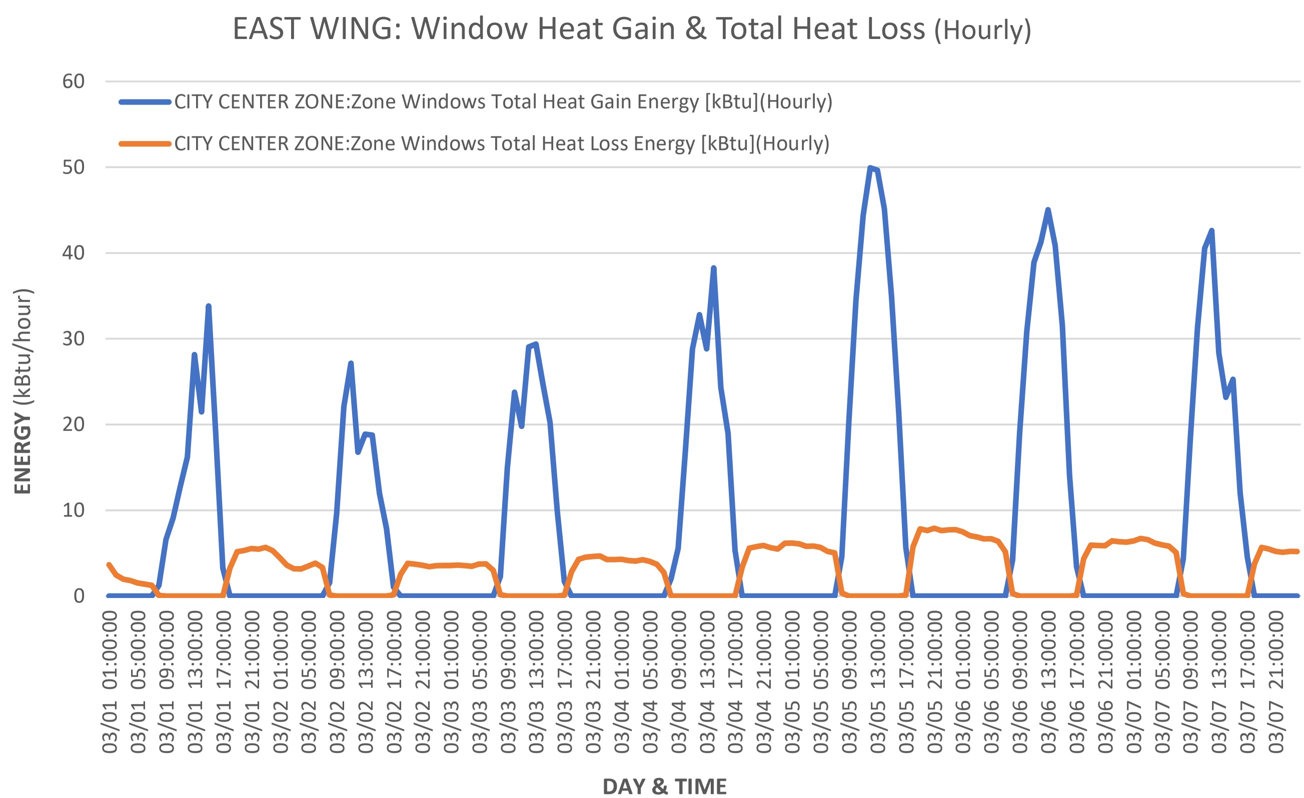


hourly operative temperatures version 2



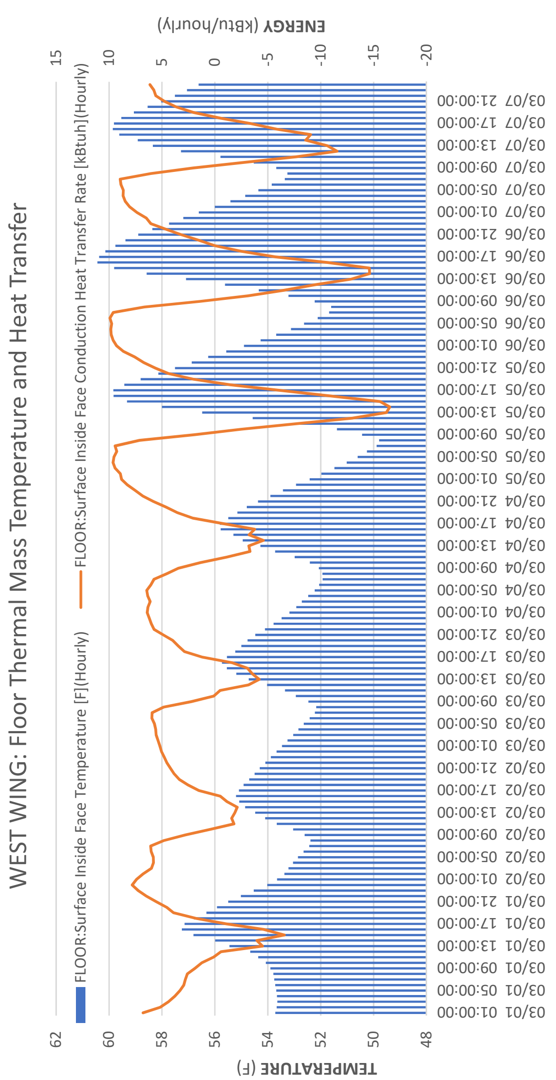
+ moveable insulation was effective in west wing with some loss in the evenings when insulation is in use

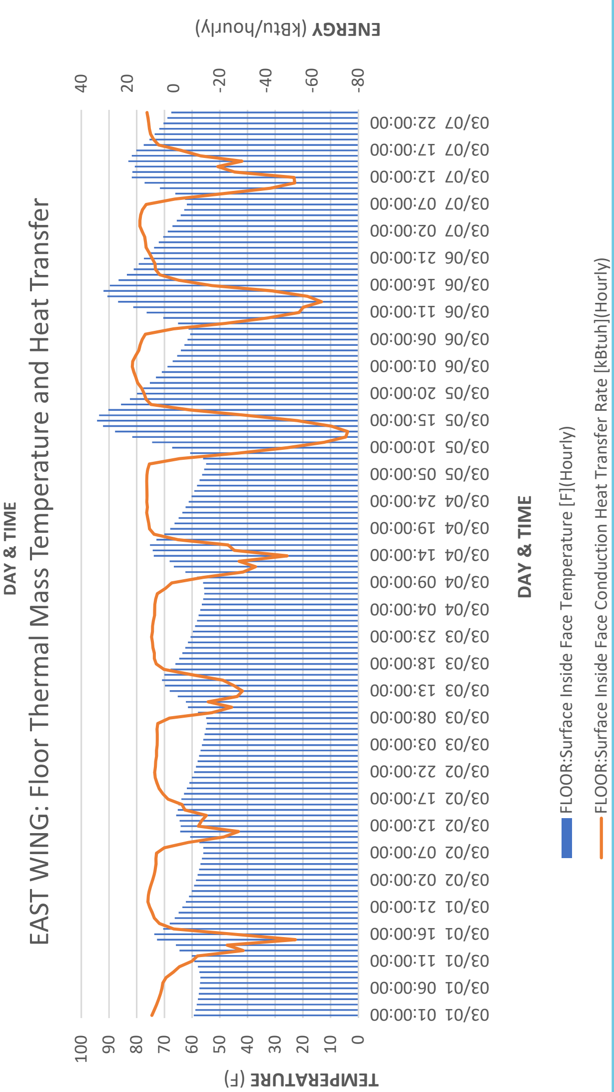
window heat gain&loss hourly | west wing



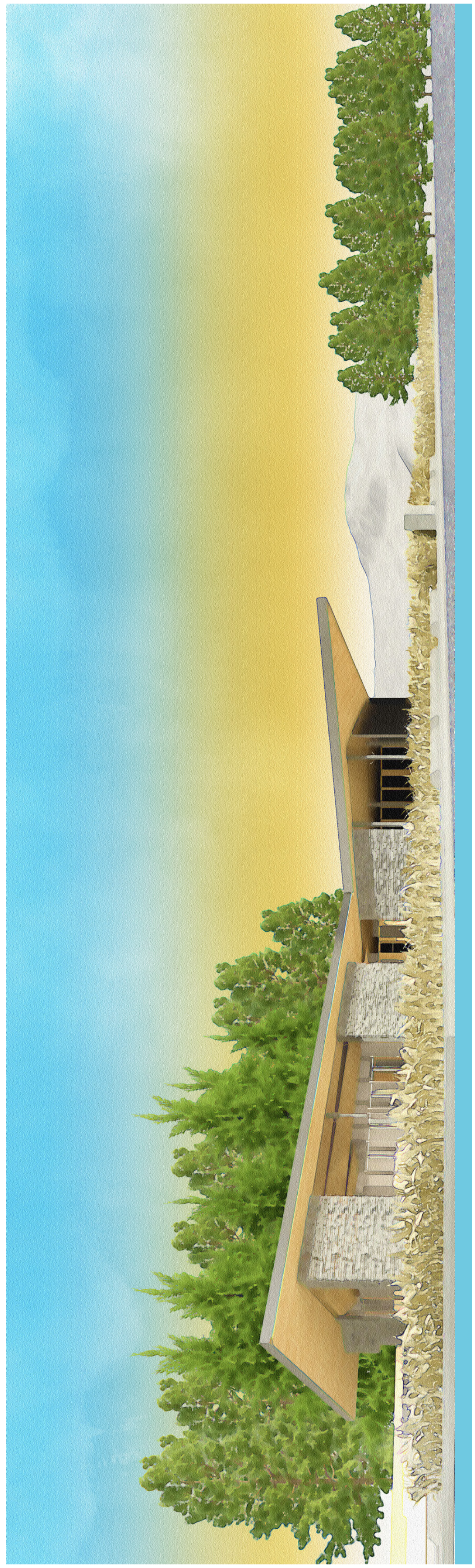
+ moveable insulation could be more effective in east wing, currently it is losing approximately 5-8 kBtu/hr while th emoveable insulation is in use at night

window heat gain&loss hourly | east wing


WEST WING: Floor Thermal Mass Temperature and Heat Transfer
FLOOR:Surface Inside Face Temperature [F](Hourly)
FLOOR:Surface Inside Face Conduction Heat Transfer Rate [kBtuh](Hourly)
TEMPERATURE (F)
ENERGY (kBtu/hourly)
DAY & TIME


EAST WING: Floor Thermal Mass Temperature and Heat Transfer
TEMPERATURE (F)
ENERGY (kBtu/hourly)
DAY & TIME
FLOOR:Surface Inside Face Temperature [F](Hourly)
FLOOR:Surface Inside Face Conduction Heat Transfer Rate [kBtuh](Hourly)

thank you.



References

Grondzik, Walter T., and Alison G. Kwok. Mechanical and Electrical Equipment for Buildings. 12th ed., Wiley, 2015.