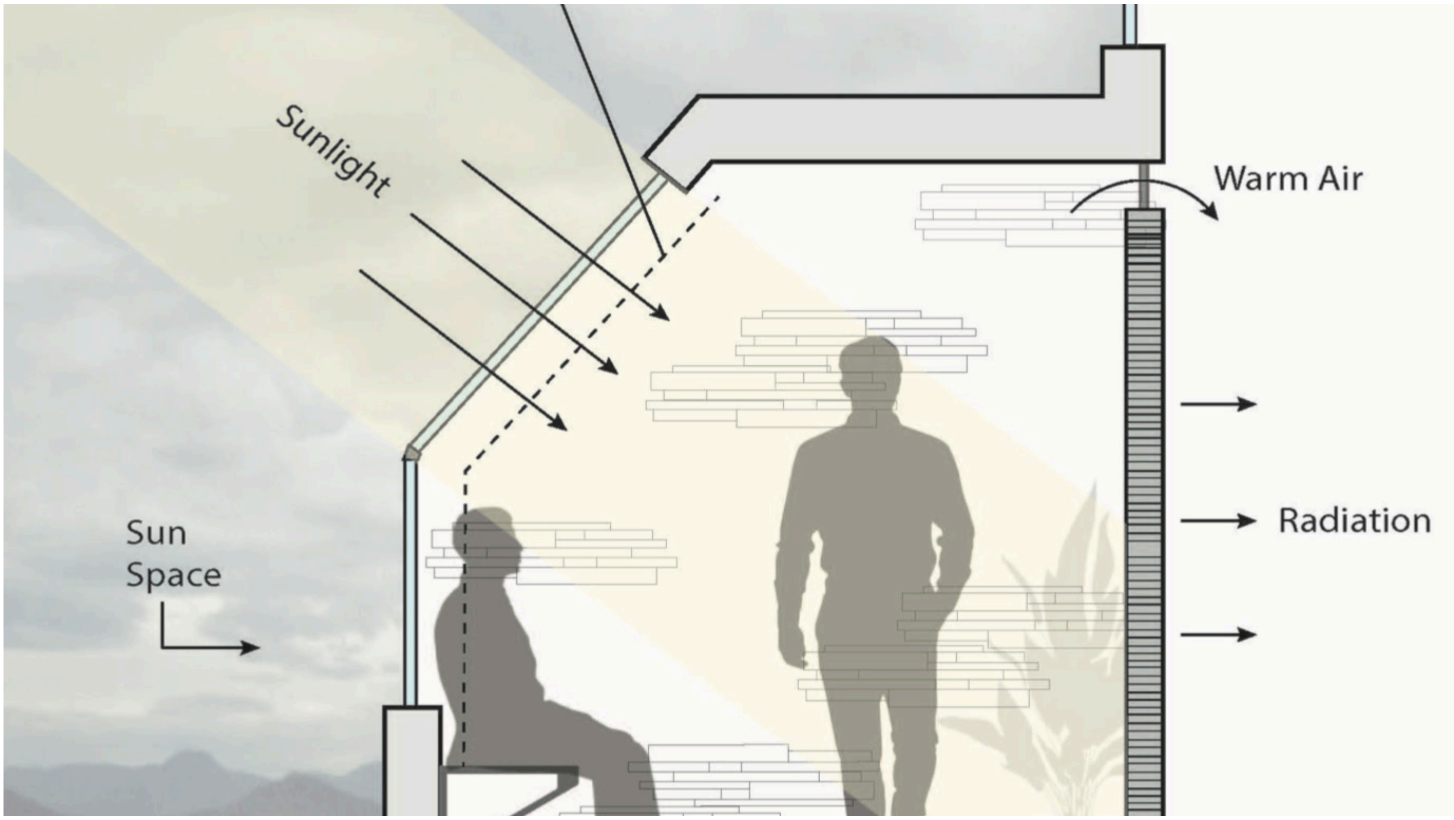


# Passive Heating Strategies for Silverton, Oregon

Winter 2020
Silverton

Sydney Palmer • Alexandra Rempel, Ph.D., M.Arch

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UNIVERSITY OF OREGON
SCI Sustainable Cities Institute
SCYP Sustainable City Year Program

# Passive Heating Strategies for Silverton, Oregon

**Sydney Palmer**
Report Author • Architecture

**Alexandra Rempel, Ph.D., M.Arch.**
Assistant Professor • Environmental Studies Program

ENVIRONMENTAL STUDIES

UNIVERSITY OF OREGON

Sustainable Cities Institute

Sustainable City Year Program

## Acknowledgments

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**Jason Gottgetreu,** Community Development Director, City of Silverton
**Elizabeth Gray,** Assistant to the City Manager / Human Resources Coordinator, City of Silverton

# Contents

# About SCI

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

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

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

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

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

# About SCYP

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

# About Silverton, Oregon

The first settlers came to the banks of Silver Creek, following timber and water power, in the 1800s. Silverton was incorporated in 1885. The young town was a trading and banking center of prominence and ranked among the most progressive towns of western Oregon.

By 1921, Silverton industries were producing exports for other areas and even some foreign countries. The Fischer Flour Mills on South Water Street was among the exporters. Power for the mill was obtained by damming Silver Creek at a point near the present pool, diverting water into a millrace that ran along the creek to the mill and then dumped back into the creek.

The development and opening of the Oregon Garden in the 1990s signify the success of a partnership between the Garden, a private enterprise attracting tourists to botanical displays, and the city of Silverton. The Oregon Garden's expansive wetlands area has benefited from the City's excess reclaimed water since 2000, while the community benefits from trade the Garden draws to the area. Silverton was recognized for these reuse efforts as a "Community Water Champion" by the National Water Reuse Association in 2018.

Today, approximately 10,380 residents call the city of Silverton home. In addition to the Oregon Garden, the City features a historic downtown, hospital, community pool, and access to nature activities including nearby Silver Falls State Park.

## Course Participants

**ALEXANDRIA CLARK,** Architecture Undergraduate
**BENJAMIN CLARK,** Architecture Undergraduate
**KYLA CLARY,** Architecture Graduate
**EJ DEL ROSARIO**, Environmental Science Undergraduate
**NICK DWORSHAK,** Architecture Undergraduate
**BROOKE EVERARD,** Architecture Undergraduate
**EMILY FOX,** Architecture Undergraduate
**JACOB FRIAR,** Architecture Undergraduate
**KYLE HIKIDO,** Architecture Undergraduate
**YUMNA IMTIAZ,** Architecture Graduate
**BEN MARTINEZ,** Architecture Undergraduate
**SAEIDEH NEKOUEE,** Architecture Graduate
**SYDNEY PALMER,** Architecture Undergraduate
**BRYAN PETERS,** Architecture Undergraduate
**SUMMER PUTMAN,** Architecture Undergraduate
**GABRIELLE RAVIOLO,** Environmental Science Undergraduate
**KYLE TASIK,** Architecture Undergraduate
**OLIVIA WEBSTER,** Architecture Undergraduate

# Executive Summary

The city of Silverton partnered with the University of Oregon's Sustainable City Year Program to analyze the proposed site for a new police station and city hall and propose passive heating strategies.

Eight student teams analyzed the site, calculated optimal tilts for solar energy-collecting glass, determined thermal mass goals and sizes, proposed building masses and orientations, and investigated movable insulation solutions. This report explains the specific passive heating strategies that can be applied to the Silverton project and gives background on how students arrived at their recommendations. Each student group provided unique recommendations and designs for the building's passive heating system. Recommendations include optimal siting locations, optimal glazing tilts, thermal mass considerations, and ideal moveable insulation options, among others. Incorporating passive heating into Silverton's new police station and city hall can help the City move towards more sustainable and efficient construction modes while remaining economically feasible and people friendly.

# Introduction

The city of Silverton plans to anchor the historic downtown with a new community-oriented city hall and police station. The historic Eugene Field School site that has been chosen for this project sits at the north entrance of the downtown, where visitors get their first glimpse of the city core. One element of the community vision guiding the project is a focus on sustainability. As the City approaches the design stages of their project, they have expressed interest in exploring energy efficient architecture and site planning that complement the rich natural context of the City. Passive heating is one element of an array of "green" strategies including shading, natural ventilation, water reclamation, LED lighting, rain gardens, and low/no VOC finishes that the City may consider for the new buildings.

The goal of a passive building is to minimize reliance on energy-intensive mechanical systems for heating and cooling to keep people in the building comfortable. Mechanical systems can be complex, expensive, and redundant when the sun and wind can provide free heating and cooling. In reality, some mechanical systems will be necessary for the coldest days of winter and the warmest days of summer, but the goal of passive design is to reduce dependence on these artificial systems. The Passive Heating class focused on passive design strategies that can help heat a space such as overall building orientation, thermal mass, tilted glazing, and movable insulation. These strategies will help reduce the reliance on mechanical heating and thus lower the carbon footprint of the building.

Students in the Passive Heating course formed teams to analyze the site, Silverton's climate, and project-specific goals to propose ways that passive heating could be integrated into the building design. Students used scientific analysis of the climate and solar resources to ground their physical design recommendations. As the various design ideas in the student reports indicate, passive strategies do not necessarily dictate the aesthetic or form of the building.

This report synthesizes student work and presents a range of scientifically-based passive heating strategies. Students investigated strategies that are tailored to Silverton's climate, and these results are intended to inform the City and their architects of the potential for passive heating in this and future developments.

# Background

### PASSIVE HEATING IN SILVERTON AND THE PACIFIC NORTHWEST

Passive Design is deeply rooted in the climate of the specific place, and therefore it is important to begin with an understanding of Silverton's climate. Silverton's location in the Willamette Valley results in typical Pacific Northwest weather, including frequent rain and clouds. These overcast conditions might seem to limit the effectiveness of passive heating. However, just as a person can still get sunburned on an overcast day, the sun's energy can still heat a building even when direct sun is not shining.

Passive strategies in the Pacific Northwest cannot be expected to fully support the heating load of a building in the winter. Instead, passive strategies in this climate aim to reduce the period of time that mechanical heating is needed, reducing the load on mechanical systems during the coldest months and eliminating it altogether during "shoulder seasons" in which outdoor temperatures are milder.

# Areas of Study

### SITING THE BUILDING

The most important choice to be made with regard to passive heating is where to site the building. Maximizing sun exposure and minimizing shade are key for any passive solar heating strategy to work. In the Northern Hemisphere, a due south orientation is a good starting point, with adjustments made based on data collected on the site. Students started with a visual survey of the site, noting tree locations, species, and branch densities, as well as topography, ground cover, and surrounding buildings. They then used a specialized piece of equipment called a pathfinder to record the shading at different points throughout the site. These observations and pathfinder results allowed each group to determine the best location for solar exposure on the site.

The solar pathfinder also helped students understand how the sun moves through the sky throughout the year, as it traces the sun's altitude (angle above the horizon) as well as its azimuth (i.e. orientation).

### HEATING NEED

The heating need of a building is determined by the difference between a building's heat losses through its opaque envelope, windows, and infiltration and its heat gains from people, lights, and equipment, at the desired indoor temperature. Here, students estimated envelope and infiltration heat losses according to envelope area estimates and ASHRAE 90.1-2016: Energy Standard for Buildings Except Low-Rise Residential Buildings. Office lighting heat gains were also estimated from this standard, while office heat gains from equipment and people were estimated from National Renewable Energy Laboratory reports. These calculations revealed that the future buildings are likely to need heat primarily when the outdoor air temperature drops below 60°F, assuming a desired indoor air temperature averaging 68°F during the winter. As a result, the heating season is expected to extend from October through May. The sun angles of interest were therefore those that occur during this 8-month period.

## SOLAR COLLECTION STRATEGY

Passive solar heating can be accomplished by several different strategies, and the best strategy for a specific project depends on the winter climate type, the clients' desire for outdoor room character, and the hours during which heat is needed. Because Silverton's winter climate is cloudy and mild, with limited solar resources during the coolest months, and because daytime warmth would be widely useful in both program types, "indirect gain" or Trombe wall systems were eliminated from consideration. These system types rely on the transmission of solar energy through vertical glass, which is not optimal in cloudy climates (see below), followed by interception by substantial thermal mass, which delays its delivery to the interior. Trombe walls are therefore best suited to sunny winter climates with large day-night temperature swings, because of their effectiveness in countering those temperature swings, and to spaces that benefit from nighttime heat.

Instead, students found that "direct gain" systems were more promising, in which solar energy could be admitted directly to atria, corridors, lobbies, and other spaces in which temporary bright sun might be welcome. In this way, warm air would be created for immediate use; massive materials on floors, such as ceramic tile, would also receive some of the radiation and carry that energy through the following night hours. If an air-only system were desired, "flat panel" collectors would be another promising option, in which solar energy warms air in a clean, dry roof plenum that is then circulated to occupied space.

## OPTIMAL TILT FOR GLAZING

Vertical glass is not optimal for passive heating strategies in the cloudy Pacific Northwest climate. While intuitively it might seem that the brightest spot in the sky should be at the sun's position, this is not the case. On overcast days when the sun is obscured behind the clouds, the brightest part of the sky is directly above the observer; in other words, the most energetic part of the sky is the top of the sky dome. Harnessing this energy is critical, especially in a climate where direct sun can be rare in winter and early spring. Vertical glass simply cannot capture much cloud-diffused solar energy because it encounters the glass at such shallow angles (i.e. nearly parallel to the glass itself) that much of it is reflected away.

The natural question then becomes what angle to tilt the glass. Completely horizontal glass will capture maximum energy on cloudy days, but on sunny days, especially in the winter when the sun is low, very little energy will be captured. To maximize the energy captured during the heating season, students needed to find the optimal surface tilt. To accomplish this, students consulted solar resource charts generated from contemporary solar radiation models that mapped out the raw energy incident upon a surface tilted in increments of 10 degrees in a specified city. The solar resource charts pointed all the groups to an optimal tilt between 40 degrees and 50 degrees from the horizontal. This is a good target for all passive solar glass on the south side of the Silverton project.

## GLASS AREA

Once the glazing tilt has been decided, the next step is to estimate the glazing area that would balance the solar heat gain benefit against the cost of night insulation. Here, students determined that a reasonable goal was to meet the full heating needs of March, April, May, and October, but only part of the heating needs of the cooler months, since each additional unit of glass after that delivered progressively less benefit  per area but required just as much moveable insulation. The result is that most projects recommended solar glazing areas equal to about 10% of the total floor area, or 1000sf for the 10,000sf city hall offices. Lesser areas could also be used effectively; they would simply offset smaller proportions of the heating need.

### GLAZING FOR PASSIVE SOLAR WINDOWS

Passive solar windows should be treated as a completely different architectural element from the windows on the west, north and east facades. Passive solar design requires putting more thought into what each window aperture needs. For windows that are primarily for views and will not contribute to the passive heating strategy, windows that minimize heat loss are appropriate. However, the technology that keeps heat in also keeps heat out, which does not allow for very effective passive heating.

Instead, when specifying windows for south-facing windows included in a solar heating scheme, it is important to pay attention to two main window performance metrics: the SHGC and U-value. The solar heat gain coefficient (SHGC) measures the portion of the heat energy incident upon the glass that will be transmitted through the window and into the space. The SHGC varies from 0 and 1, with 0 being a mirror (no energy passing through) and 1 being an impossibly thin piece of glass that allows all the energy to pass through. The super-insulating glass that often gets installed in ”efficient” buildings has a low SHGC, so these windows only permit a fraction of the solar energy they intercept into the building. These are not the windows one wants to be using for passive heating, as very little of the available solar energy will be transmitted. Instead, for passive solar windows, a high SHGC is best; above 0.7 is ideal. This window will let in 70% of the solar energy that reaches its surface. The second performance factor to become familiar with is the U-value (sometimes referred to as the U-factor). This unit measures the insulating property of a material: low U-values indicate a more insulating material, and vice-versa. The ideal passive heating window has a high SHGC, to collect as much heat as possible, and a low U-value to retain this heat. In practice, a high SHGC takes priority if the solar-collecting glazing is insulated at night, as it should be.

### MOVEABLE INSULATION

Passive solar windows must be insulated at night for best performance, since solar-collecting windows tend to radiate some of the energy collected during the day back out into colder nighttime surroundings. To combat this, passive solar designers have come up with a wide array of strategies to insulate these windows at night. As indicated in the group suggestions, moveable insulation can be as complicated or as simple as desired; some projects propose automated shutters while others propose hand cranked systems or simple sliding panels. The best designs showcase how moveable insulation can become a beautiful expression of the building’s passive solar system as the building changes in harmony with the natural environment.

### THERMAL MASS

Generally, thermal mass needs are low in cloudy climates as compared with sunnier climates in the Southwest U.S., but thick thermal mass has been a large part of passive heating strategies since the 1970s. The basic idea is that dense materials provide thermal storage, counteracting outdoor temperature changes. In climates with large daily temperature swings like deserts, a properly sized thermal mass absorbs sun energy during the hot days and releases heat into the cold nights. The following day, the mass stays cool much longer than the air and will help cool the space, drawing heat out of the space for later release. In cloudy climates, the thermal mass does not receive as much solar energy, and thus it needs to be thinner to reach warm enough temperatures that it can re-radiate heat into the space during the night. If mass is oversized in a cloudy climate, the result will be that the building requires more heat to become warm than it would have, otherwise.

For best results in the Silverton project, thermal mass should be sized carefully, using an appropriate building energy performance simulator, and applied in relatively thin layers (up to 2”) to surfaces or added in the form of “internal mass” elements such as potted plants, furniture, or sculpture, that are exposed to the sky through solar-collecting glass.

## PASSIVE COOLING

All passive solar heating strategies and spaces have the potential to overheat in the summer if passive cooling strategies are not employed. Although detailed investigation of cooling measures was beyond the scope of the course, students did consider cooling measures in the configurations of their heating systems. In all climates, the easiest way to deactivate passive solar heating is simply by shading the solar-collecting glass, either internally or externally, to minimize solar collection. In many cases, the same elements that serve as moveable insulation for winter operation can serve as shading for summer operation.

In the Pacific Northwest, with reliably cool summer night air, another highly effective strategy is night ventilation of mass, in which the same mass that absorbed solar energy for heating is pre-cooled overnight to absorb some of the following day’s internal and solar heat gains. Removal of shading from glass at night is also recommended to facilitate radiative cooling to night skies, which can be tens of degrees Fahrenheit cooler than outdoor air temperatures on clear nights.

## THERMAL DELIGHT

An essential feature of passive heating (and cooling) strategies is that they shape the experience of the occupied space itself. A space collecting solar energy will be bright, even on cloudy days, and will have a sense of airiness from the full-spectrum light; it may also be colored and textured by stone, brick, concrete, tile, or plants used as thermal mass. These elements provide a thermal sense separate from the air temperature itself. A space adjacent to one collecting solar energy will acquire part of that experience, as well, and a person passing from one to the other will sense the change in light color, distribution, and intensity, as well as the change in surface temperatures that make up the radiant environment. In the summer, a shaded space has bluer light and lower illumination, causing it likewise to feel cooler than its air temperature might suggest. In this way, passive systems support the creation of “thermal delight”, or sensations of thermal variety and interest independent of actual air temperatures.

# Analysis and Recommendations

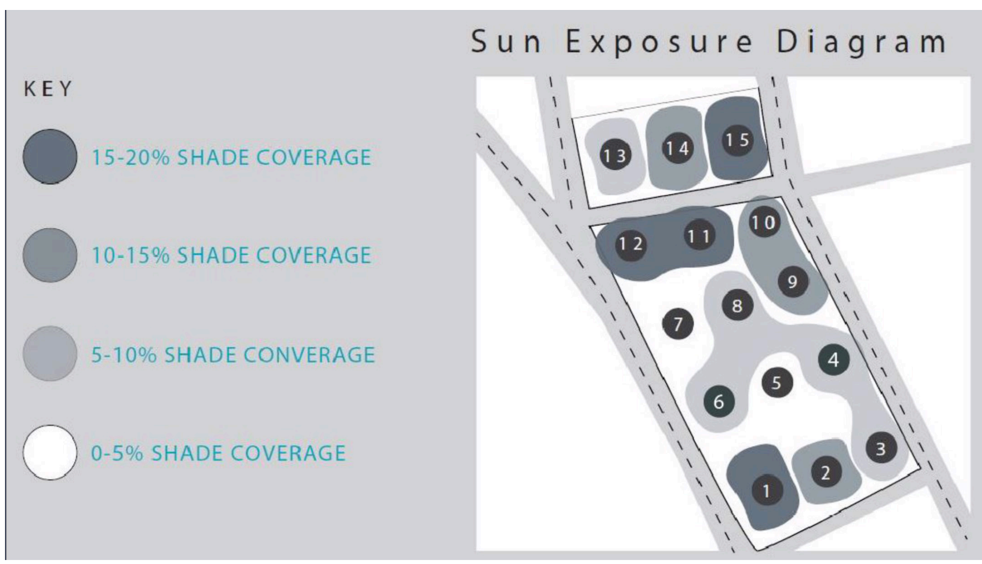
## METHODOLOGY

Each group began the term with a field trip to the Silverton building site. Students analyzed site shading, tree canopy, and sun angles using a solar pathfinder. They researched Silverton's climate and calculated the heating season for the buildings based on an estimated level of internal heat gains. Using this information, they identified an optimal tilt for glazing and ideal building orientation. The combination of heating needs and a strategically-chosen glazing assembly helped establish a ballpark glazing area recommended to meet about half of the annual heating need. Based on the need for nighttime insulation for solar collection glazing, students proposed different moveable insulation systems. They also diagrammed potential solar collection strategies on building masses. Finally, students calculated the amount of thermal mass needed to help store heat energy during the day and release it into the evening. The project summaries below highlight a few key takeaways from each student team's project, and full projects can be found in the Appendix.

## PROJECT 1 HIGHLIGHTS: ALEX AND NICK

Alex and Nick mapped out the shade across the full site to identify the areas with the most potential for passive heating. They identified the middle of the site as the best place for sun exposure, marked as spot 7 and spot 5 on their diagram below. These areas had the least shade coverage and will make for the best place to take advantage of passive heating strategies.

FIG. 1
Site solar exposure



Based on their research, Alex and Nick recommended a set of south-facade corridor sunspaces to capture heat during the day. They positioned a thin layer of thermal mass on the back of each sunspace to absorb the energy from the sun and radiate heat into the adjacent space. This separation yields three main benefits, the most important being occupant comfort. Sunspace solar collection would also heat air for delivery to adjacent spaces. They proposed the sunspaces to work as circulation for the building, thus these would not be spaces where people would spend a large portion of their time. Some mild temperature swings would be more tolerable in corridors than in office spaces. Another benefit of the thermal separation would be the thermal lag between energy collection by the thermal mass and its eventual radiation into the space. The mass would absorb heat during the day and then radiate heat into the adjacent space in the early evening and night, offsetting night heating needs. Finally, the physical separation would eliminate glare, or high visual contrast, which is very uncomfortable in work environments. Alex and Nick also included vents at the topsand bottom of the thermal mass to allow warm air to flow into adjacent office spaces. These vents could be closed on days when warm air is not desired.

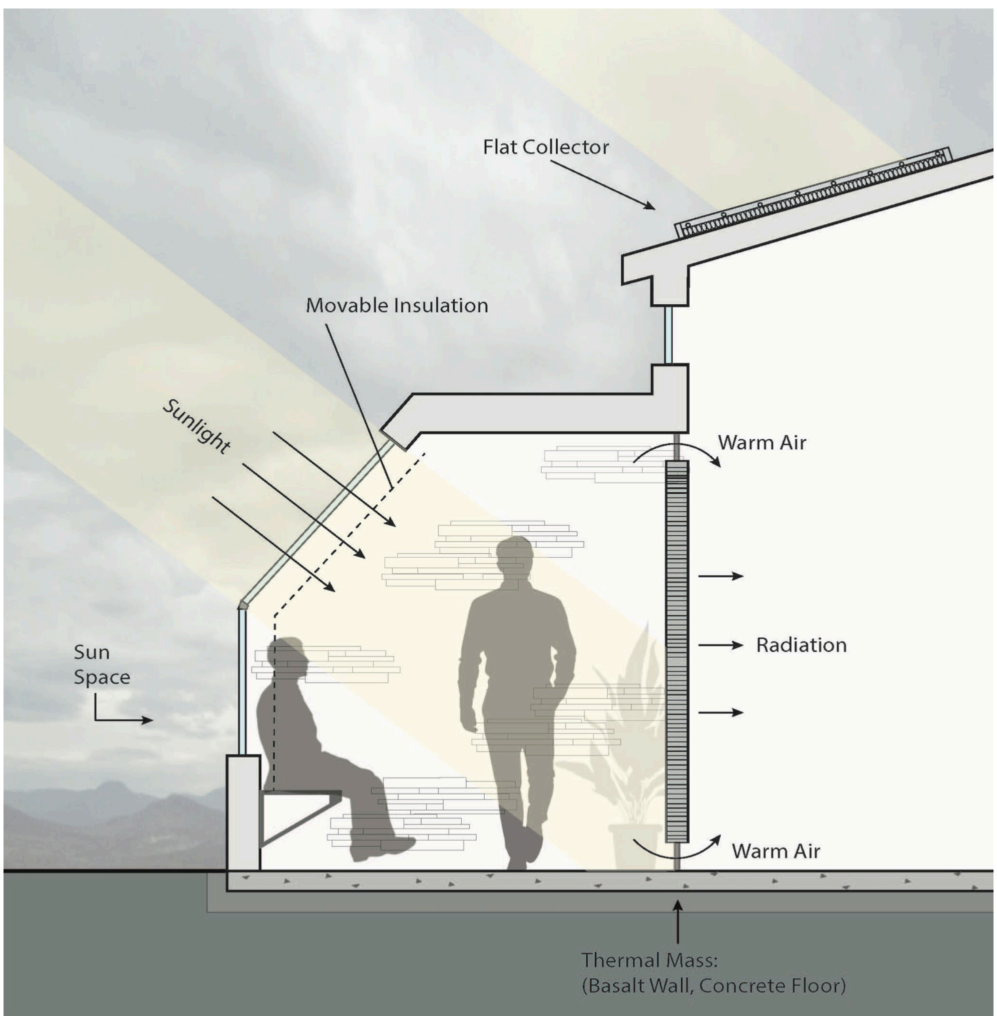
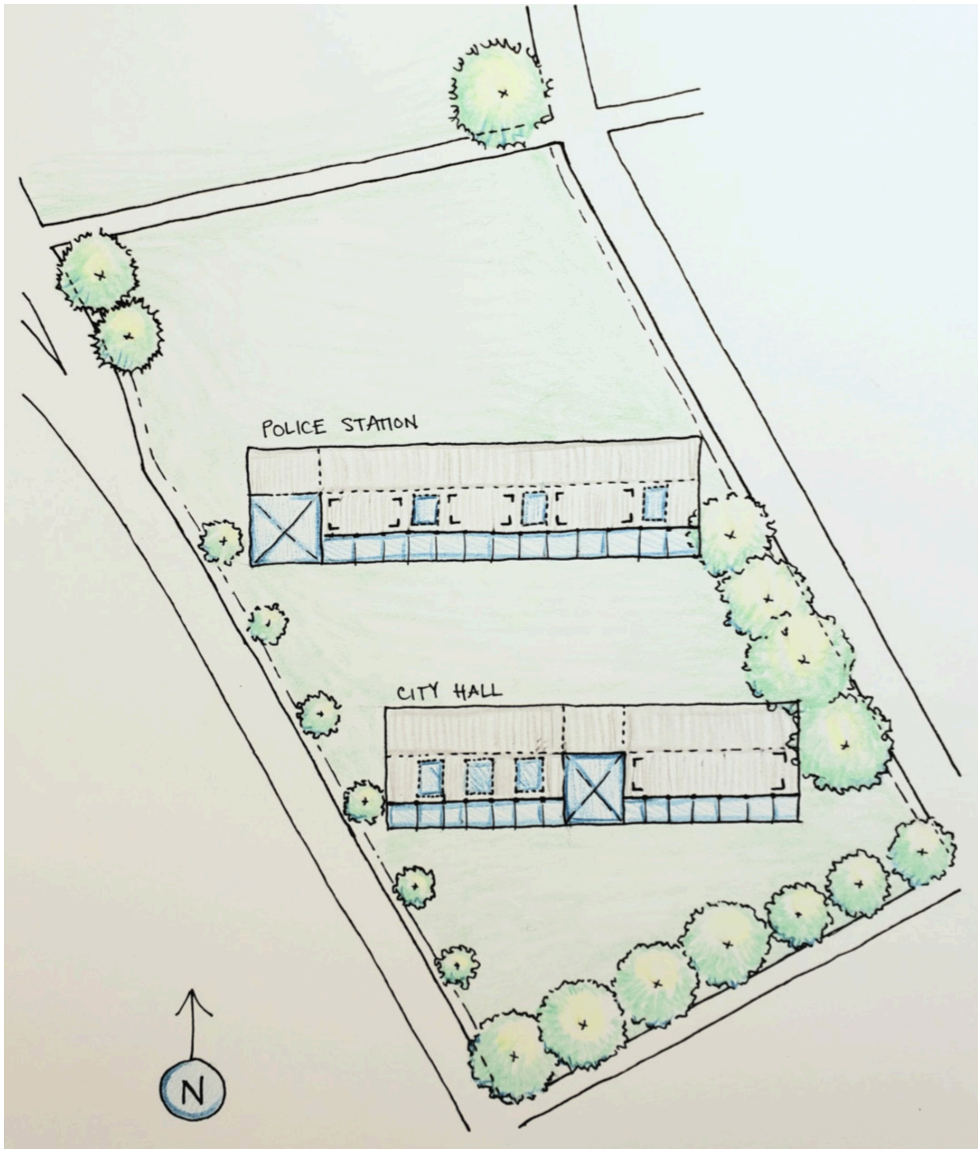



FIG. 2
**Corridor Sunspace**

One possible arrangement of buildings on the site is portrayed below in Figure 3. Most importantly, note the south exposure and the location of buildings in the middle zone of the site. Both of these factors help to maximize the solar energy available to heat the building.

FIG. 3
Building position and orientation




**Recommendations:**

- Site buildings near the middle of the property or farther north
- Orient the long edge of the buildings to face South
- Collect solar energy with thermally separate sunspaces adjacent to offices

## PROJECT 2 HIGHLIGHTS: YUMNA AND SAEIDEH

Yumna and Saeideh calculated the heating need met for three different areas of solar collecting glazing. The table below helps illustrate that greater glazing area meets a greater proportion of the heating need. The orange line represents a 500 square foot (sf) area of glass. This would make only a small contribution to the heating need, while the remaining portion of the heating need would have to be met with active heating systems. In contrast, the yellow line represents a 2000sf area of solar collecting glazing, amounting to 14% of the 14,000sf city hall floor area. With this much solar glazing, the entire heating need could be met from March through October, with active systems required primarily from November through February. Glazing beyond this area would not be recommended, however, because of the diminishing additional solar gain per area combined with the need for additional moveable insulation.

Yumna and Saeideh proposed sawtooth glazing over two internal direct-gain atria as shown below, creating potential gathering and vertical circulation spaces. The sawtooth roof pitch remains within the recommended 40-50 degree tilt, but it gives the architectural design more flexibility, consistent with a contemporary city hall aesthetic.

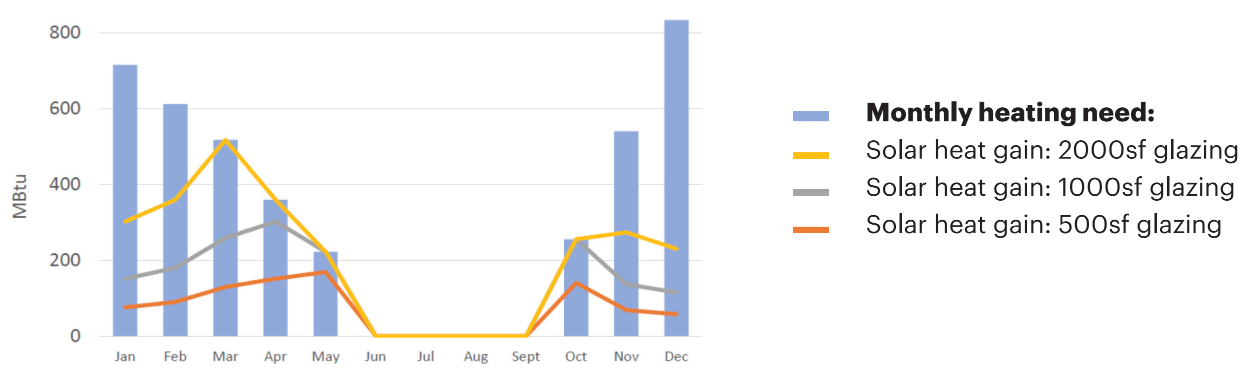



FIG. 5

Heating need met as a function of solar-collecting glazing area

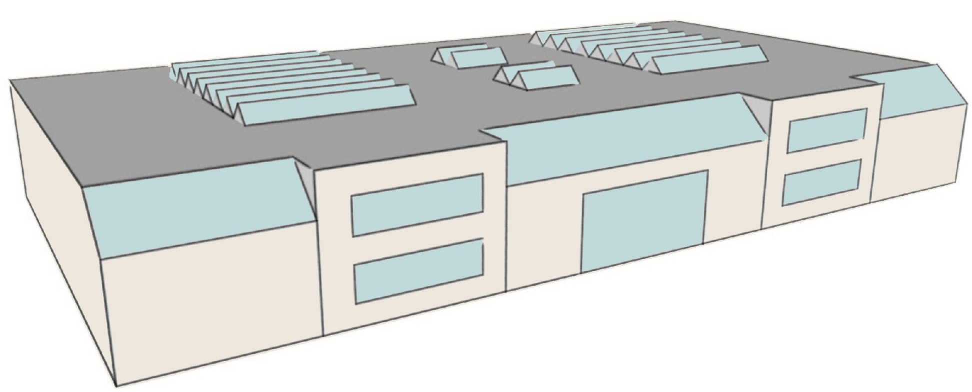
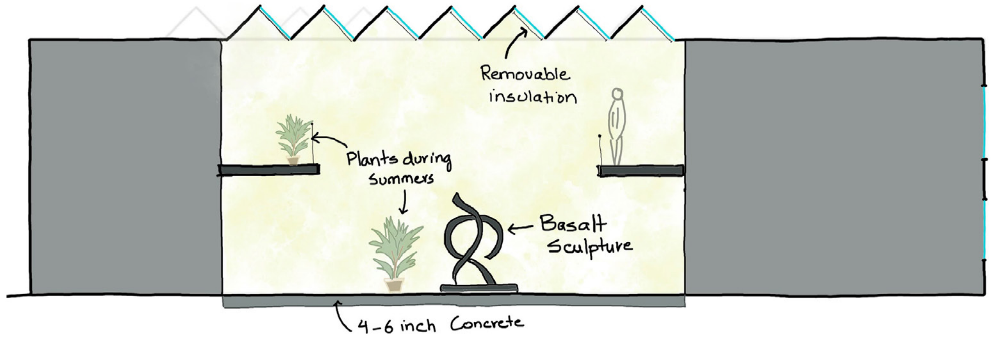


FIG. 4

Perspective showing sawtooth roofs of internal atria

FIG. 6

Atrium with sawtooth roof and internal mass




**Recommendations:**

- Consider a large glazing area, up to 30% of roof area for maximum passive heating in shoulder seasons.
- Passive heating has evolved since the 1970's. There are functional, modern alternatives like the sawtooth roof.

## PROJECT 3 HIGHLIGHTS: BROOKE, EJ, AND KYLE

Brooke, EJ, and Kyle began with a thorough analysis of the existing trees on the site, taking careful note of species, branch density, height, and position. This information helped them understand seasonal changes in the tree canopy as well as identify shady zones. Using information from their tree analysis as well as their solar pathfinder analysis, they were able to map the levels of sun to identify where the site would provide the greatest solar resources. They identified the two points marked with red circles (next page) as those with the greatest solar exposure.

FIG. 7

Tree identities and heights

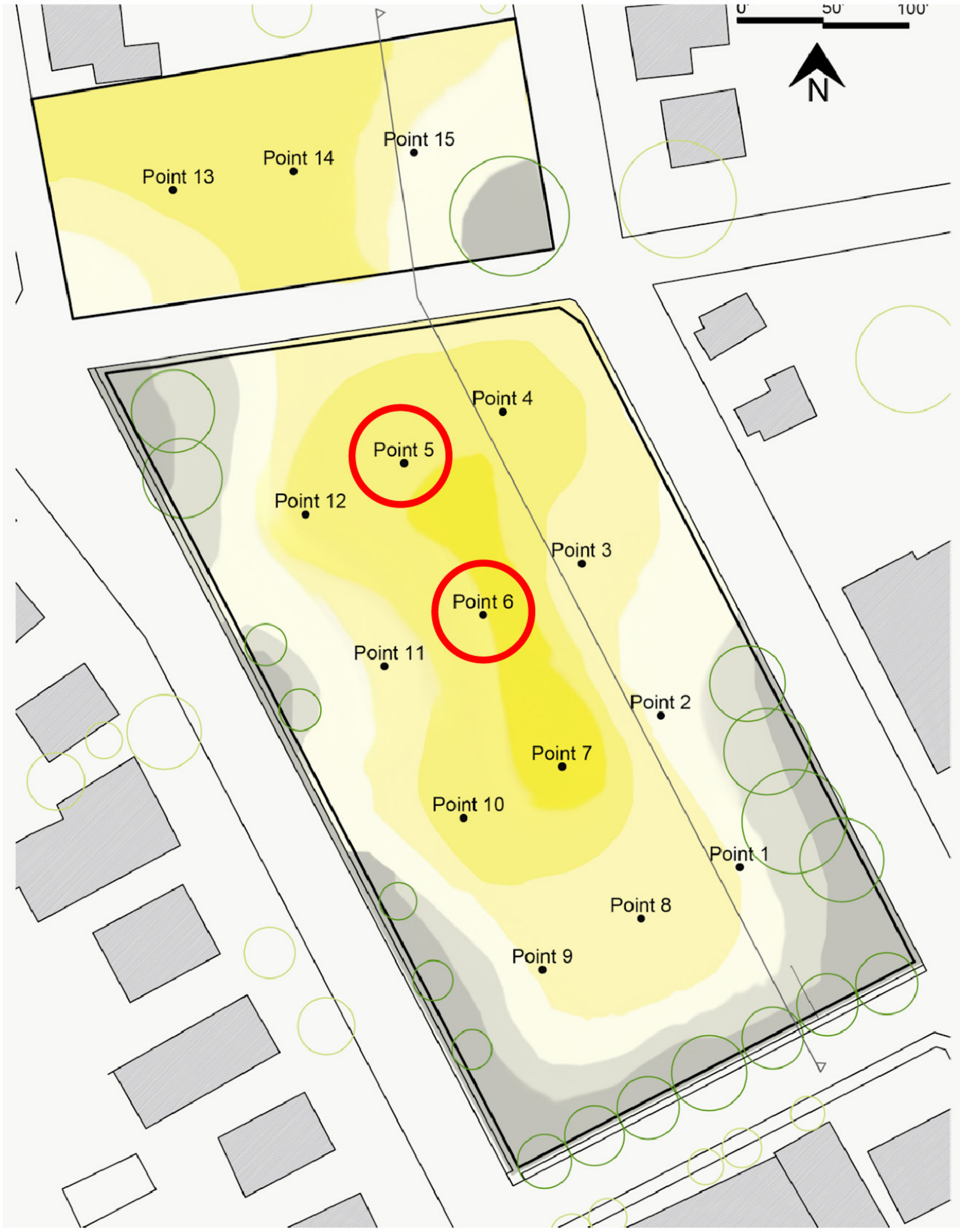



FIG. 8

Positions of greatest solar exposure

Figure 8 (next page) illustrates the integration of tilted glazing, thermal mass, and moveable insulation. Sunlight streams through the tilted glazing to warm the thermal mass below. The thermal mass absorbs the heat through the day and at night, the moveable insulation is deployed to retain the heat that is released from the thermal mass. Without any one of these elements, the system would not function properly.

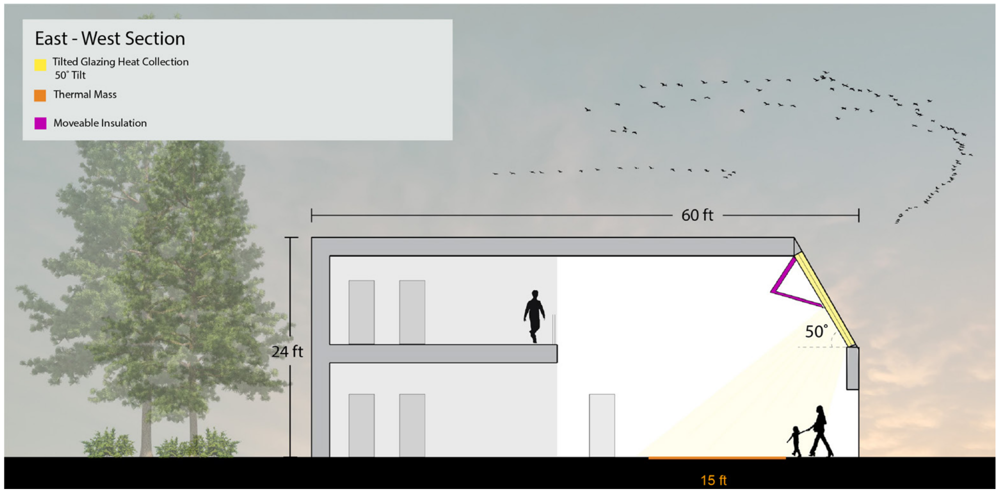



FIG. 9

Direct-gain atrium space on the south facade with moveable insulation

**Recommendations:**

- Site the building in the middle or northern part of the property for optimal sun exposure.
- Include the three major elements of passive heating: tilted glazing, thermal mass, and moveable insulation

## PROJECT 4 HIGHLIGHTS: BEN AND OLIVIA

Like Alex and Nick, Ben and Olivia found that sunspaces would be among the most effective passive heating strategies in this climate. Their sunspace configuration would allow energy to flow through the tilted glazing into the thermal mass in the back wall and the floor. An operable vent on top of the thermal mass would also allow warm air to move from the sunspace into the space on the other side of the mass. Operable windows allow the sunspace to be vented in the summertime to prevent overheating.

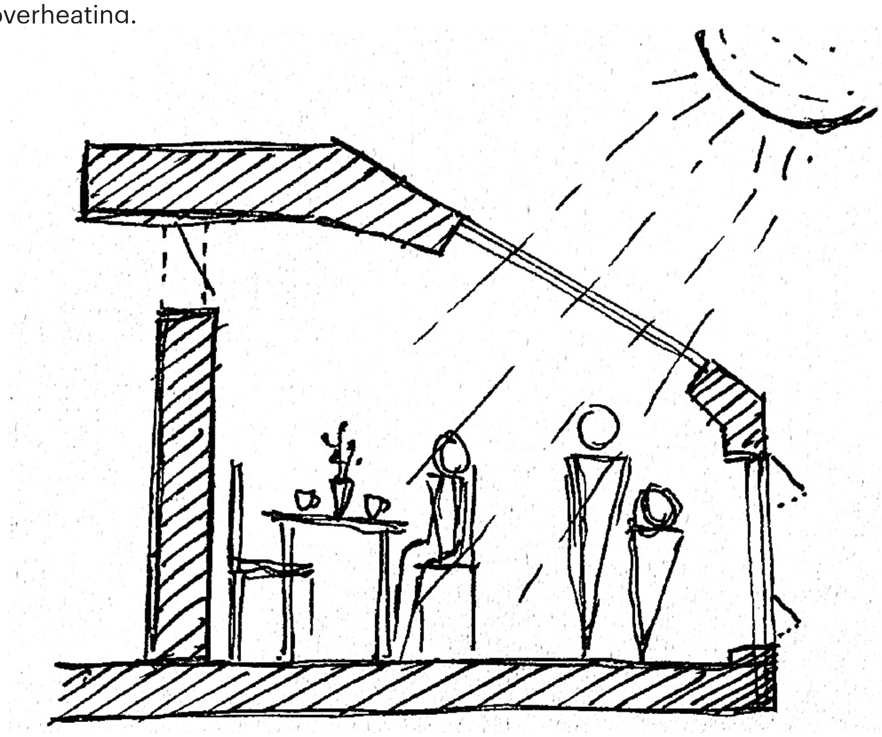


FIG. 10

Cafe sunspace with vent to release warm air to adjacent space

A set of different solar heating strategies is shown working side-by-side to address different spaces in the same building, below; this is often a very effective approach, as it limits the distance collected heat must travel. The roof holds a flat collector. This system is fan-assisted, in which cool air is drawn from the outside, warmed as it travels through the collector plenum backed by black roofing material, and then delivered to the receiving space. Flat collectors do not require major design interventions, but the roof tilt is very important, and as this is the solar absorbing surface, it needs to be angled at the optimal tilt angle of 45 degrees. Flat collectors are particularly flexible as they can be turned off in the summer simply by switching off the fan and venting the plenum to the exterior.

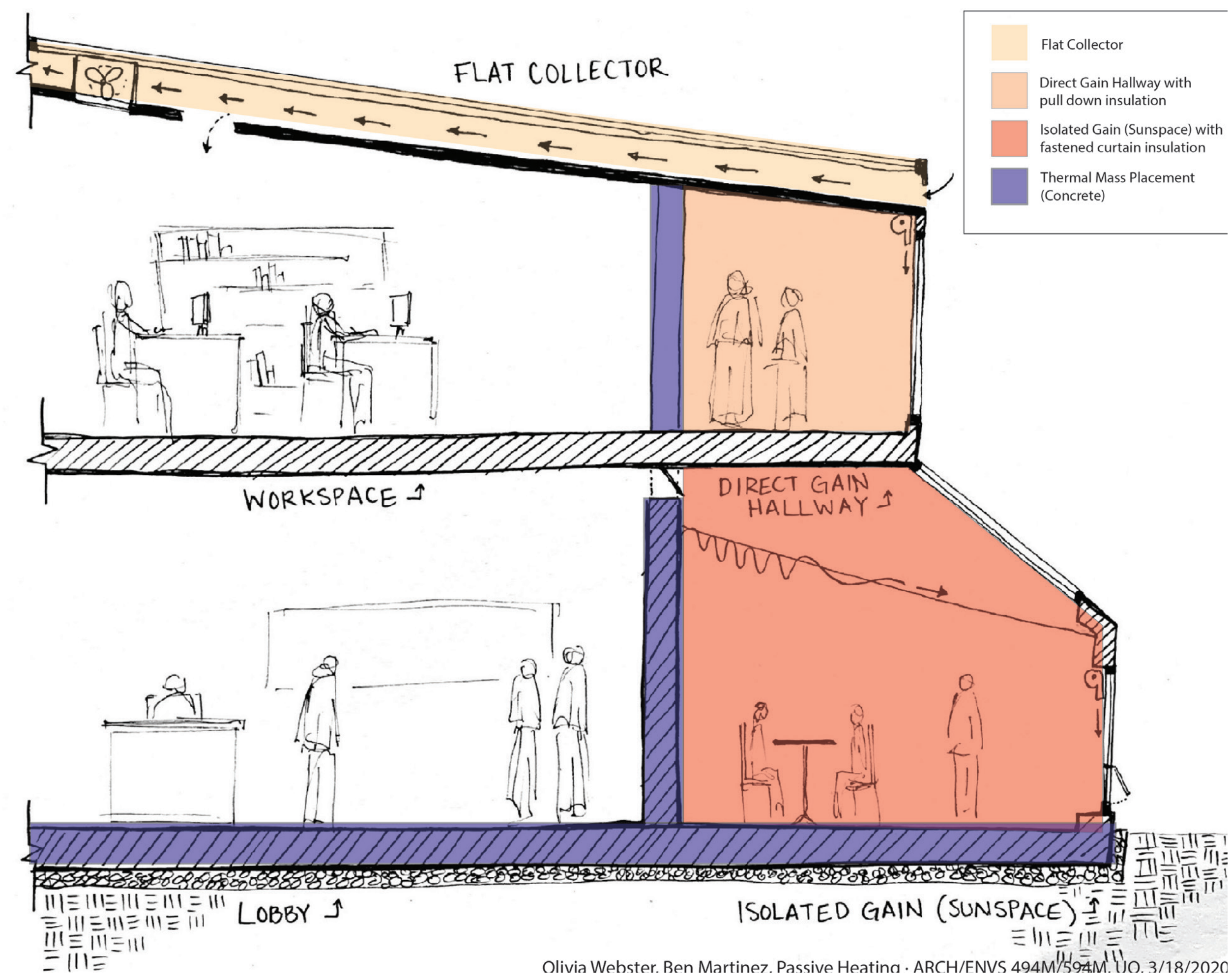


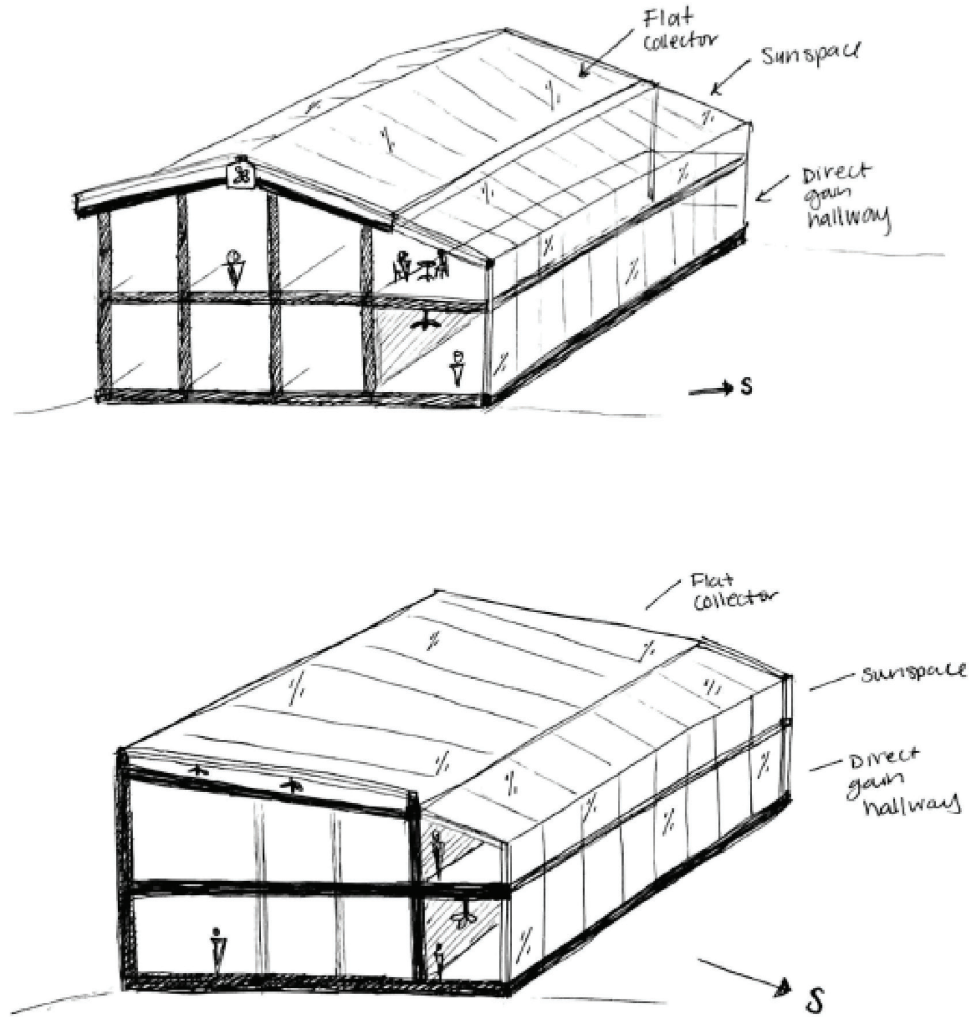

FIG. 11

**Flat collector, corridor sunspace, and cafe sunspace working in concert to heat individual spaces**

Each of the solar heating systems shown above are shown to the left on a building-wide scale: a flat collector system on the top, with isolates and direct gain spaces on the sides.

FIG. 12

**Multiple passive solar heating strategies working together**

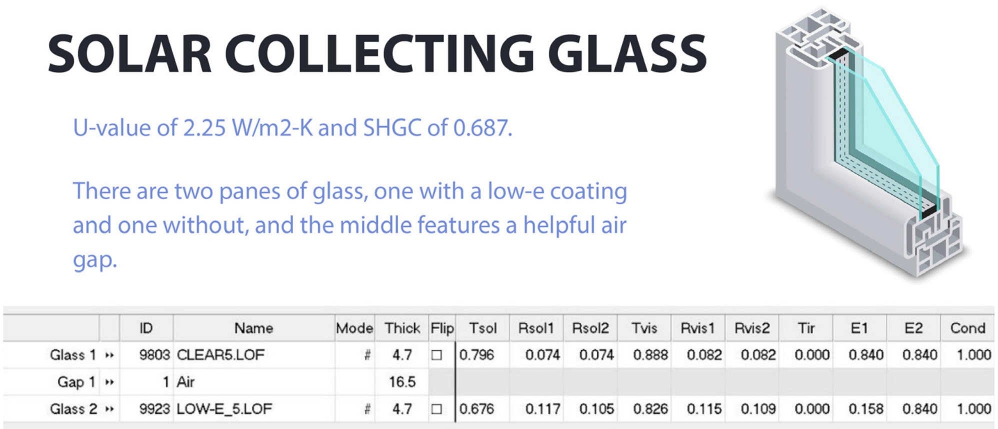



**Recommendations:**

- Consider operable exterior windows throughout the building to help mitigate overheating in direct gain and isolated gain spaces.
- Identify the passive solar strategies that will work best for the project goals and budget.

**PROJECT 5 HIGHLIGHTS: SUMMER AND EMILY**

Summer and Emily investigated glazing assemblies closely, ultimately finding one with particular promise for solar heating. In searching for assemblies with the highest possible solar heat gain coefficient (SHGC) and lowest possible thermal transmittance (U-value), they found an unusually high-performing passive solar window. This assembly has an SHGC of 0.687, meaning that about 70% of the energy incident upon the outer window surface should be transmitted to the space, and a U-value of 0.39 Btu/h-sf-°F (2.25 W/m$^2$-K), which quite low for a window of such high SHGC. It is challenging to find a window that has both a high SHGC as well as a low U-value because the elements of a window like extra panes and special coatings that slow heat loss, including additional panes of glass and applied coatings, tend to reduce the SHGC. This assembly is a Pilkington Glass product, consisting of an outer pane of Clear Optifloat glass, a 16.5mm air gap, and an inner pane of EnergyAdvantage LowE, with the coating placed on surface #3.




| | ID | Name | Mode | Thick | Flip | Tsol | Rsol1 | Rsol2 | Tvis | Rvis1 | Rvis2 | Tir | E1 | E2 | Cond |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Glass 1 | 9803 | CLEAR5.LOF | # | 4.7 | ☐ | 0.796 | 0.074 | 0.074 | 0.888 | 0.082 | 0.082 | 0.000 | 0.840 | 0.840 | 1.000 |
| Gap 1 | 1 | Air | | 16.5 | | | | | | | | | | | |
| Glass 2 | 9923 | LOW-E_5.LOF | # | 4.7 | ☐ | 0.676 | 0.117 | 0.105 | 0.826 | 0.115 | 0.109 | 0.000 | 0.158 | 0.840 | 1.000 |

FIG. 13

**High solar gain Low-E glazing assembly**

Summer and Emily also explored custom moveable insulation in which automated shutters pivot with the push of a button. These could be on a timer, and mechanically actuated, or they could rely on manual operation. They could also be useful in a gathering hall where it would be helpful to limit the glare while watching a presentation or performance. An occupant could adjust the shutters based on the needs of the room, but the shutters would need to be re-opened for passive heating to continue after the event.

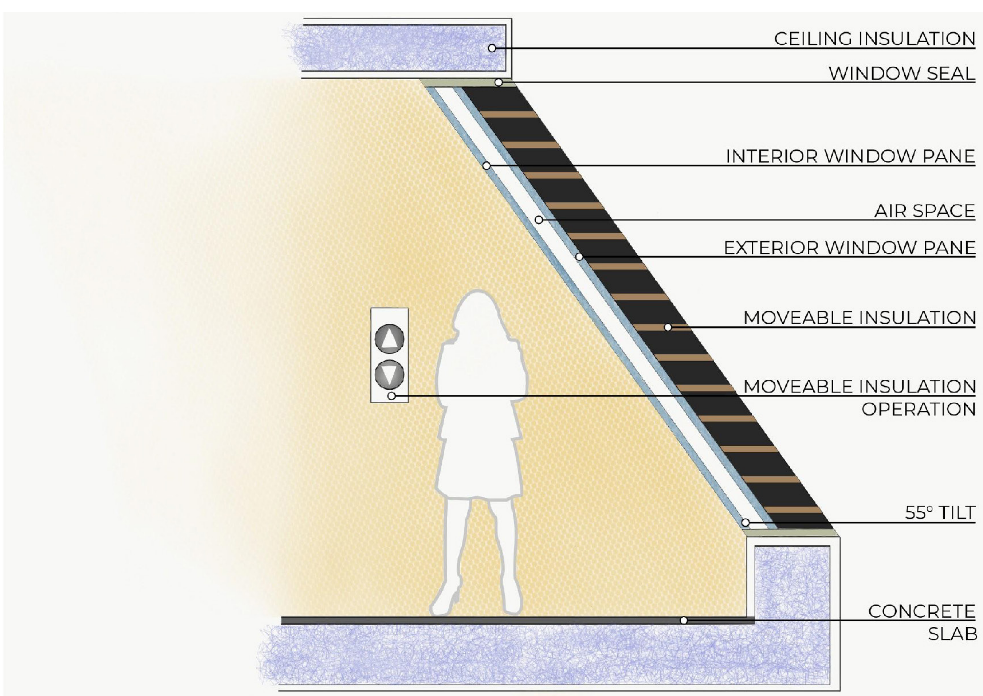



FIG. 14

**Optimally-tilted direct gain glazing with louvered night insulation**

**Recommendations:**

- For solar-collecting glass, consider one of the new "high solar gain Low-E" assemblies that has an unusual combination of high solar heat gain and high resistance to heat loss (moderately low U-value)
- Make the movable insulation as easy to operate as possible, perhaps through manually operated remote-control systems that allow convenient regular opening and closing without the expense of full automatic control.

## PROJECT 6 HIGHLIGHTS: SYDNEY AND BEN

Below, Sydney and Ben diagrammed their process for finding the optimum glazing tilt for the solar-collecting windows. They began by analyzing the solar resource chart for a nearby city: Salem, Oregon (no data were available for the city of Silverton specifically). First, they marked which angles of tilt received the highest radiation during each individual month of the heating season in orange. This gives a visual representation of the optimal angle for sun exposure in each month of the heating season. To try to balance the angle at something that would work year round, they went for the middle set of angles. To further refine the comparison, they added up the energy quantity for each angle. Even though the 30 degree tilt yielded the highest yearly energy gain, it contributed most of this energy in summer months when heat is not needed as much and could even increase the summer cooling need. The 50 degree tilt provides almost as much energy as the 30 degree tilt but limits summer heating as well as increases energy collected in the coldest months. Consequently, students recommend the 50 degree tilted above the horizon.

FIG. 15

Schematic-design level estimation of optimal solar glazing tilt

| **EUGENE, OR** | | **Solar radiation (kBtu/ft$^2$ mo) on a surface of tilt:** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Mo** | **D65** | **90°** | **80°** | **70°** | **60°** | **50°** | **40°** | **30°** | **20°** | **10°** | **0°** |
| Jan | 753 | 19 | 20 | 21 | 21 | 21 | 20 | 19 | 17 | 15 | 12 |
| Feb | 617 | 22 | 23 | 25 | 25 | 25 | 25 | 24 | 22 | 20 | 17 |
| Mar | 569 | 28 | 31 | 33 | 35 | 36 | 36 | 36 | 34 | 32 | 29 |
| Apr | 446 | 27 | 32 | 36 | 39 | 42 | 43 | 44 | 44 | 42 | 40 |
| May | 307 | 27 | 33 | 38 | 43 | 47 | 50 | 52 | 53 | 53 | 52 |
| Jun | 157 | 27 | 34 | 41 | 47 | 53 | 57 | 61 | 63 | 63 | 62 |
| Jul | 36 | 31 | 39 | 47 | 54 | 60 | 65 | 68 | 69 | 69 | 67 |
| Aug | 31 | 36 | 43 | 50 | 56 | 60 | 63 | 65 | 64 | 63 | 59 |
| Sep | 121 | 36 | 41 | 45 | 48 | 49 | 50 | 49 | 47 | 43 | 39 |
| Oct | 382 | 32 | 35 | 37 | 38 | 39 | 38 | 37 | 34 | 31 | 27 |
| Nov | 603 | 17 | 18 | 19 | 19 | 19 | 18 | 17 | 16 | 14 | 12 |
| Dec | 784 | 15 | 16 | 16 | 16 | 16 | 15 | 14 | 13 | 11 | 9 |

Highest solar gain per month

Optimum Tilt Angle

Stereographic sunpath diagrams helped inform each group about a number of important elements of the site. The base layer is a gray shading mask generated from the solar pathfinder imagery obtained at the site. The shading mask with the radiation overlay determines how much of the radiation will get shaded out, making it unavailable for solar heating. Based on the radiation plotted below, not very much is shaded out, so a normal southern exposure will yield the most solar gain throughout the year.

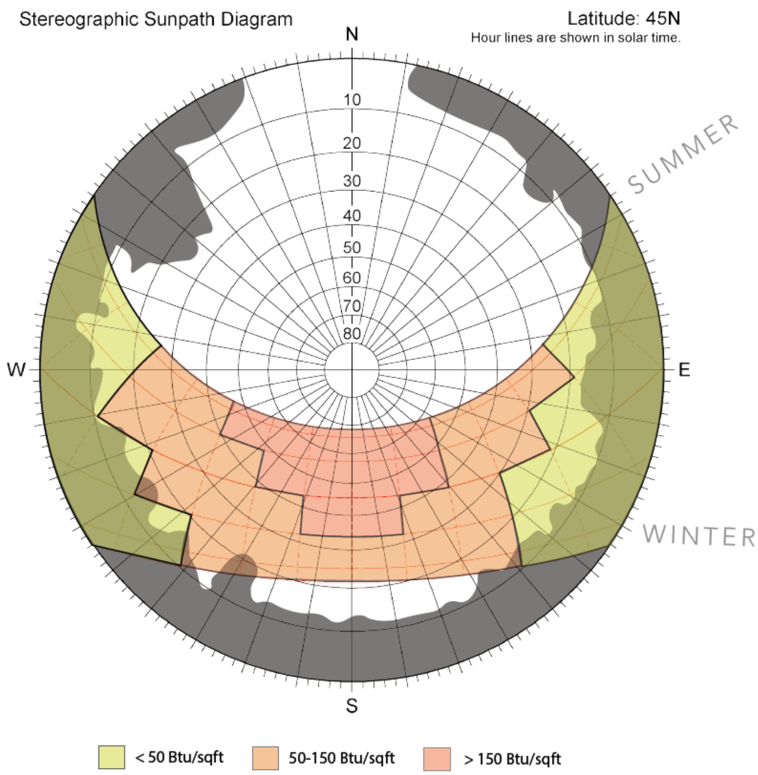



FIG. 16

Sunpath diagram showing hourly solar radiation intensities as well as site shading, Dec-June

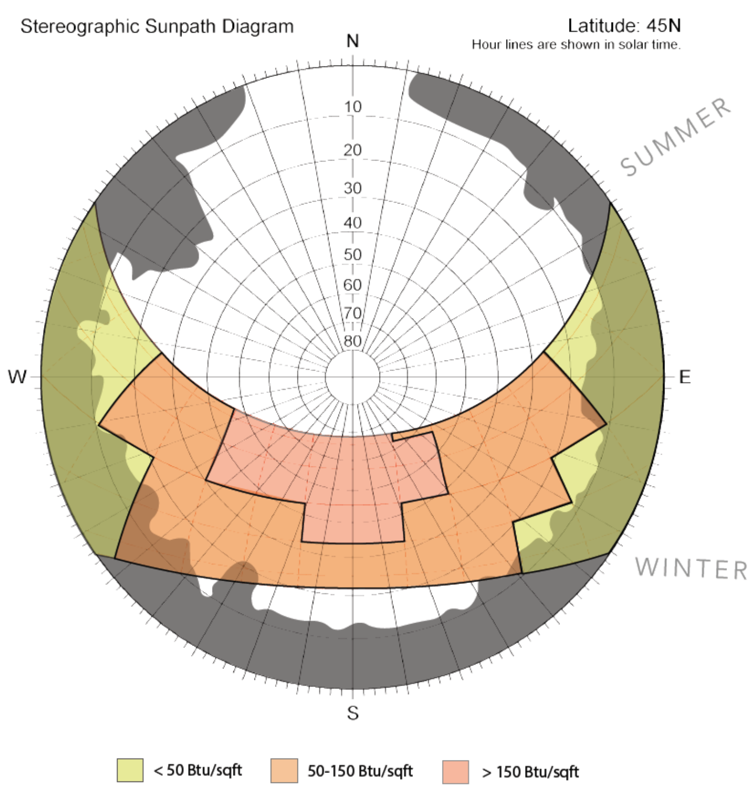



FIG. 17

Sunpath diagram showing hourly solar radiation intensities as well as site shading, June-Dec

**Recommendations:**

- Tilt solar collecting glass 50 degrees above the horizon.
- Orient building to the south or south-southwest to maximize glazing effectiveness

# Conclusion

As environmentally-friendly design grows more mainstream, it is increasingly important that sustainable strategies are employed on a well-grounded, scientific basis. Close attention to the building's site and climate is critical to the proper design of these green buildings.

The University of Oregon Passive Heating class thoroughly researched and analyzed the proposed site for the new Silverton police station and city hall. Five key findings were present in each group's analysis. **First**, the project is expected to have an approximate 8-month heating season in the Silverton climate, causing the months of interest for clear-sky sun angles as well as extent of cloud cover to be October through May. **Second**, the best-suited passive solar heating strategies are expected to include direct-gain spaces such as atria, lobbies, and cafes where intermittent bright sunlight is acceptable; thermally separate spaces such as sunspace corridors that can deliver warm air to adjacent spaces and/or buffer those spaces from the cooler exterior; and flat collectors that deliver warm air rapidly to occupied spaces. **Third,** a due south or slightly southwest building orientation would be ideal to minimize shading by site trees. **Fourth**, solar-collecting glazing should be tilted between 40 and 50 degrees. **Fifth**, the glazing chosen for the solar collecting glass should have a high solar heat gain coefficient (SHGC), with a U-value as low as the high SHGC will permit; new "high solar gain Low-E" assemblies are worth consideration. **Sixth**, moveable insulation should be employed to prevent heat loss at night, with excellent edge sealing to avoid the circulation of warm air behind the insulation to reach cold glass. This should be as convenient to operate as possible, to ensure that it is operated daily. **Seventh**, thermal mass should be sized carefully for Silverton's climate using appropriate performance simulators. And **finally,** the opportunity for thermal delight should be celebrated in the design.

We are delighted that the city of Silverton is exploring passive heating strategies in their new buildings, and we look forward to supporting these efforts as they proceed. This project has exceptional potential to embody climate-responsive design in contemporary Oregon architecture.

# Appendix A

## Brooke, EJ, and Kyle

# Final Presentation

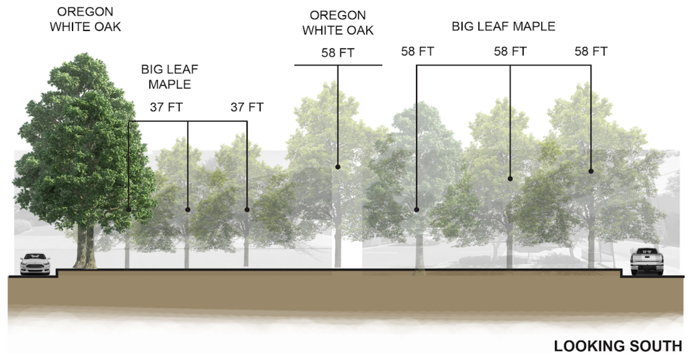
Passive Heating Seminar · ARCH/ENVS 494M/594M

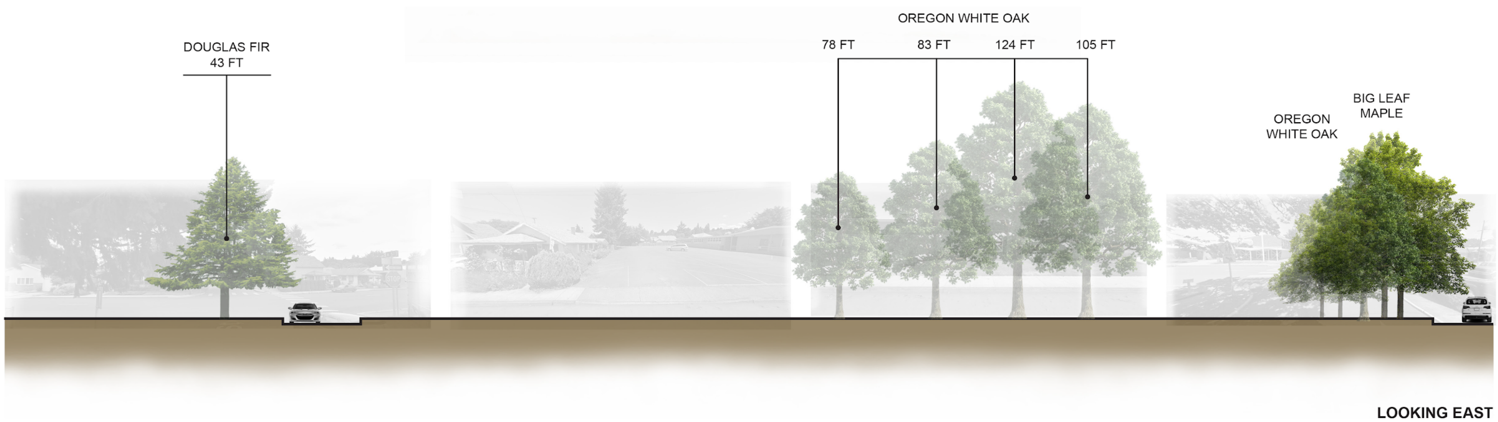
Brooke Everard, EJ Del Rosario, Kyle Tasik

# Site Plan

Silverton, Oregon.

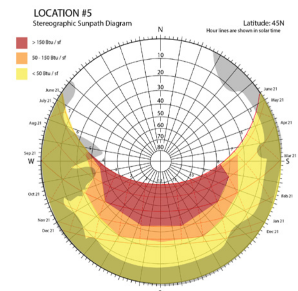
# Site Sections

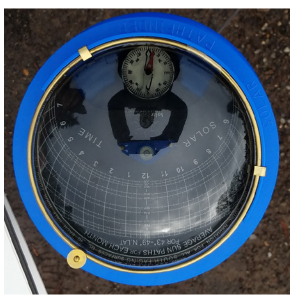


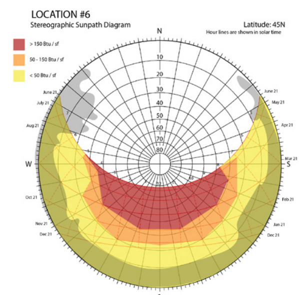



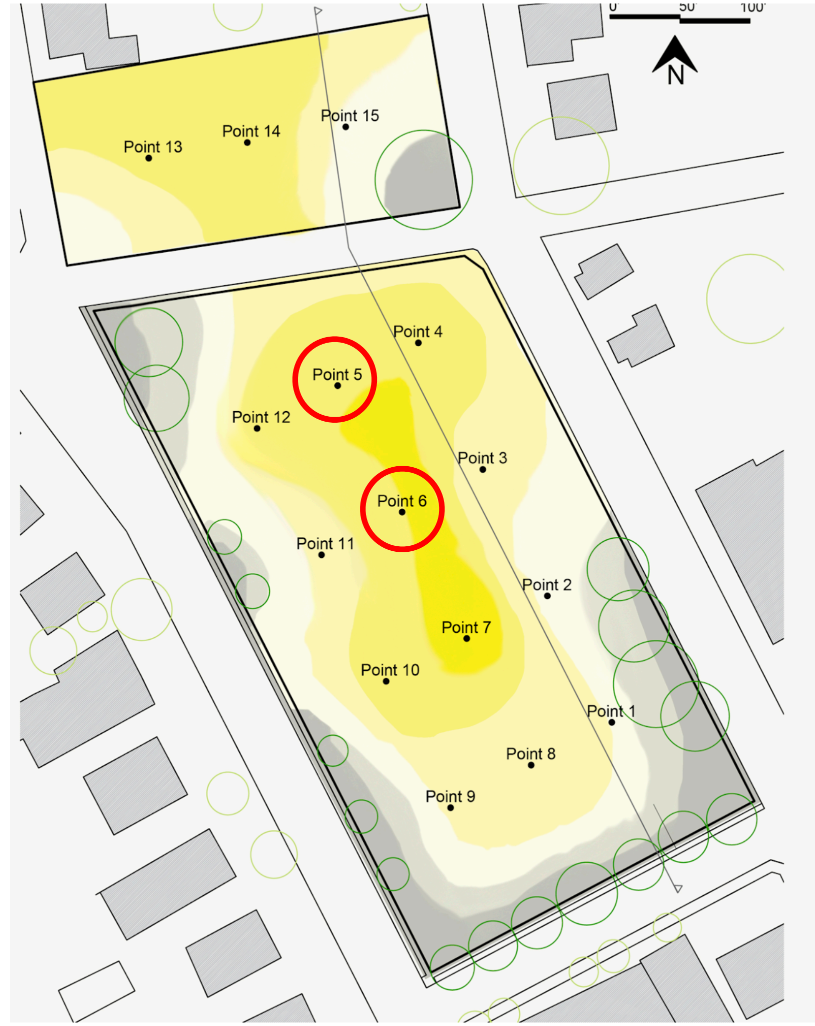
# Solar Site Survey

Point 5 and 6 were the most optimal location for the proposed buildings due to their increase in solar exposure and lack of shainding influences (e.g. trees)



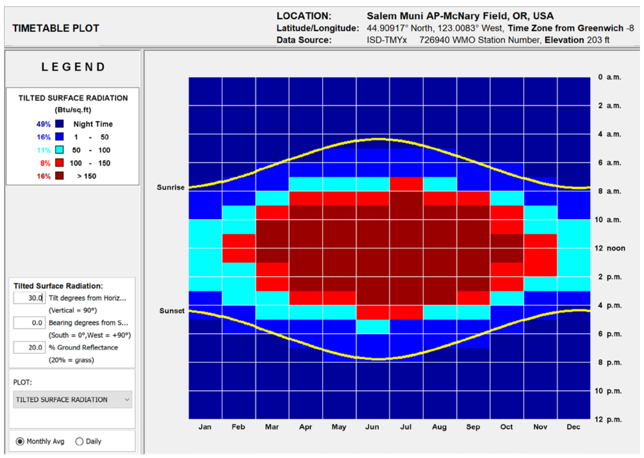



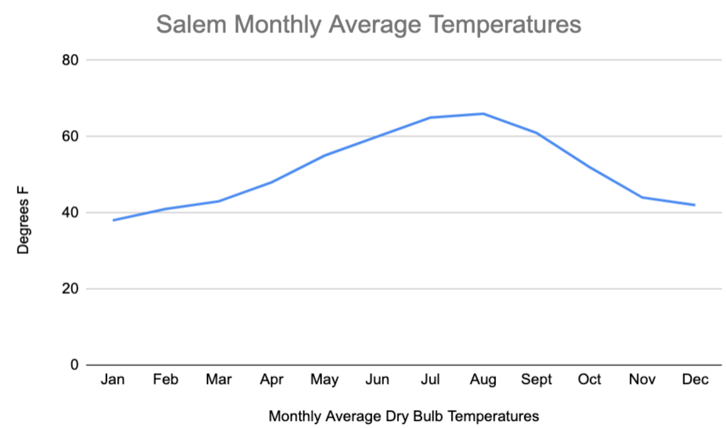


# Silverton, OR Climate Data

- Weather file for Salem, OR was used due to lack of weather file for Silverton, OR
- Highs: 65 F; Lows: 38 F
- Cloudy winters and sunny summers




Source: Climate.onebuilding.org, “TMYx 2004-2018 weather file”.

# Design Intent

- Accomplish positive thermal gains with lasting impact throughout the day and night both socially and experimentally
- Capture heat throughout the day from solar gains and redistribute it back into the space
- Avoid integrating work/private environments with high thermal fluctuations due to passive technologies
- Maintain a consistent temperature in the space, helping mitigate mechanical system usage

# Envelope Assembly Areas and U-Values

## Police Building (2 story)

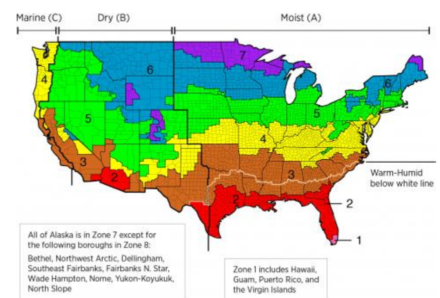
Total Floor Area: 27,000 SF
Floor 1: 18,000 SF
Floor 2: 9,000 SF
Height: 24 ft
Width: 60ft
Length: 300 ft
Total Glazing Area: 30% window to wall ratio

## City Hall (2 story)

Total Floor Area: 15,750 SF
Floor 1: 10,500 SF
Floor 2: 5,250 SF
Height: 24 ft
Width: 60ft
Length: 175 ft
Total Glazing Area: 30% window to wall ratio

**Table 5.5-4** ***Building Envelope*** **Requirements for Climate Zone 4 (A,B,C)***

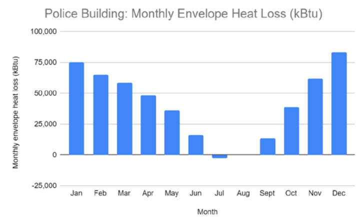
| *Opaque* Elements | Nonresidential | | Residential | | Semiheated | |
|---|---|---|---|---|---|---|
| | Assembly Maximum | Insulation Min. *R-Value* | Assembly Maximum | Insulation Min. *R-Value* | Assembly Maximum | Insulation Min. *R-Value* |
| *Roofs* | | | | | | |
| *Insulation entirely above deck* | U-0.032 | R-30 c.i. | U-0.032 | R-30 c.i. | U-0.093 | R-10 c.i. |
| *Metal building*[a] | U-0.037 | R-19 + R-11 *Ls* or R-25 + R-8 *Ls* | U-0.037 | R-19 + R-11 *Ls* or R-25 + R-8 *Ls* | U-0.082 | R-19 |
| *Attic and other* | U-0.021 | R-49 | U-0.021 | R-49 | U-0.034 | R-30 |
| *Walls, above Grade* | | | | | | |
| *Mass* | U-0.104 | R-9.5 c.i. | U-0.090 | R-11.4 c.i. | U-0.580 | NR |
| *Metal building* | U-0.060 | R-0 + R-15.8 c.i. | U-0.050 | R-0 + R-19 c.i. | U-0.162 | R-13 |
| *Steel-framed* | U-0.064 | R-13 + R-7.5 c.i. | U-0.064 | R-13 + R-7.5 c.i | U-0.124 | R-13 |
| *Wood-framed and other* | U-0.064 | R-13 + R-3.8 c.i. or R-20 | U-0.064 | R-13 + R-3.8 c.i. or R-20 | U-0.089 | R-13 |
| *Wall, below Grade* | | | | | | |
| *Below-grade wall* | C-0.119 | R-7.5 c.i. | C-0.092 | R-10 c.i. | C-1.140 | NR |
| *Floors* | | | | | | |
| *Mass* | U-0.057 | R-14.6 c.i. | U-0.051 | R-16.7 c.i. | U-0.107 | R-6.3 c.i. |
| *Steel joist* | U-0.038 | R-30 | U-0.038 | R-30 | U-0.052 | R-19 |
| *Wood-framed and other* | U-0.033 | R-30 | U-0.033 | R-30 | U-0.051 | R-19 |
| *Slab-on-Grade Floors* | | | | | | |
| *Unheated* | F-0.520 | R-15 for 24 in. | F-0.520 | R-15 for 24 in. | F-0.730 | NR |
| *Heated* | F-0.843 | R-20 for 24 in. | F-0.688 | R-20 for 48 in. | F-0.900 | R-10 for 24 in. |
| *Opaque Doors* | | | | | | |
| *Swinging* | U-0.370 | | U-0.370 | | U-0.370 | |
| *Nonswinging* | U-0.310 | | U-0.310 | | U-0.360 | |

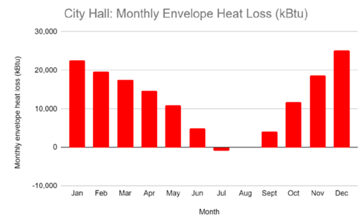


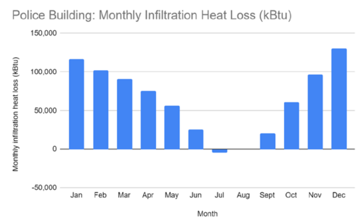

Source: *American Society of Heating Refrigeration, and Air Conditioning Engineers*. 2016., Table 5.5-4.

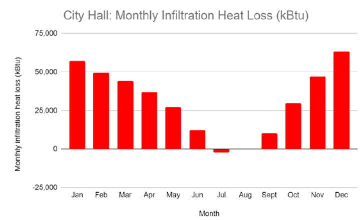
# Building Heat Loss / Gain

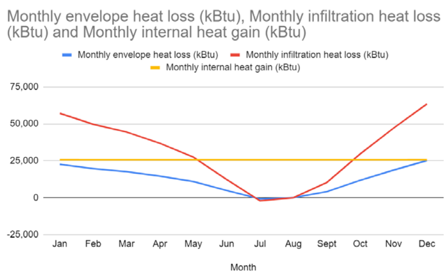
- All monthly heat loss through envelope and infiltration were based on approximate size of each building
- All internal loads were calculated using 24 hour occupancy

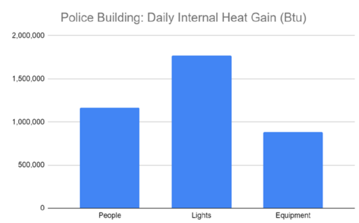


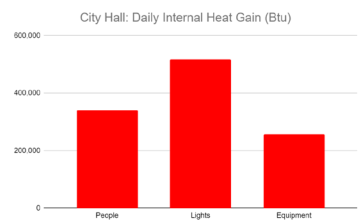




Source: Grondzik, Walter T., and Kwok, Alison G. *Mechanical and Electrical Equipment for Buildings*. Thirteenth ed., John Wiley & Sons, Inc., 2019.

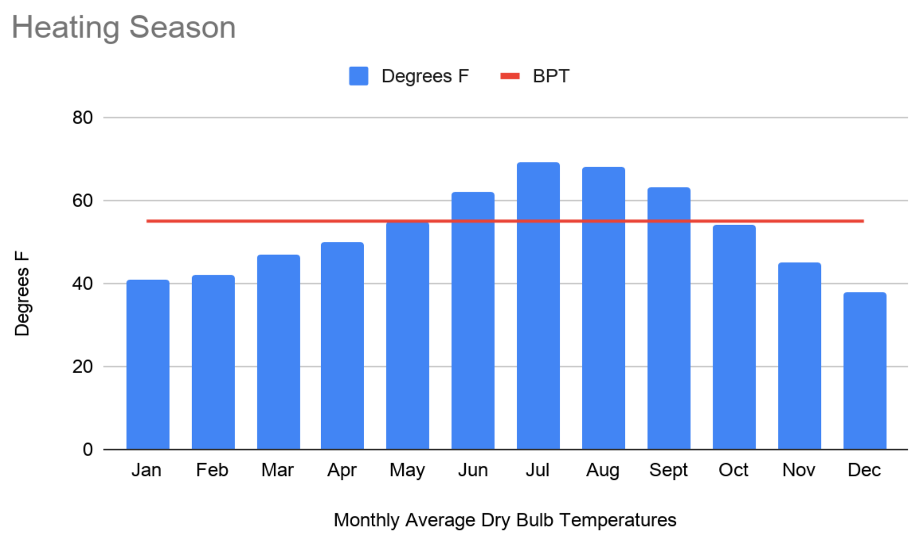
# Balance Point Temperature / Heating Season



The outdoor temperature at which internal + solar heat gains "balance" envelope heat losses, to maintain a desired indoor temperature, over the course of a 24 hour day.

<u>Our BPT is:</u> 55°F

<u>Our Heating Season is:</u>
Oct - May




Source: Grondzik, Walter T., and Kwok, Alison G. *Mechanical and Electrical Equipment for Buildings*. Thirteenth ed., John Wiley & Sons, Inc., 2019.

Envelope Assembly Areas and U-Values
Envelope Heat loss
Envelope Infiltration
Building Internal Heat Gains
Balance Point Temperature
Heating Season
**Optimal Solar Collector Tilt**
Solar Collector System
Moveable Insulation System
Thermal Mass

# Optimal Solar Collector Tilt

- 30 degrees tilt is the optimal angle for our solar collector given the climate of Silverton, OR
- Decision based on calculating average solar radiation exposure for each angle per month

| | | Solar Radiation (kbtu/ft2 month) on a surface of tilt | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **D65** | **90˚** | **80˚** | **70˚** | **60˚** | **50˚** | **40˚** | **30˚** | **20˚** | **10˚** | **0˚** |
| January | 731 | 19 | 20 | 21 | 21 | 20 | 20 | 18 | 16 | 14 | 12 |
| February | 594 | 22 | 24 | 25 | 26 | 26 | 25 | 24 | 22 | 20 | 17 |
| March | 522 | 29 | 33 | 35 | 37 | 38 | 38 | 37 | 36 | 33 | 30 |
| April | 383 | 27 | 31 | 35 | 38 | 40 | 41 | 42 | 41 | 40 | 37 |
| May | 224 | 28 | 34 | 40 | 45 | 49 | 52 | 54 | 54 | 54 | 52 |
| June | 91 | 27 | 33 | 40 | 45 | 50 | 53 | 56 | 58 | 58 | 57 |
| July | 17 | 31 | 38 | 45 | 51 | 56 | 59 | 62 | 63 | 63 | 61 |
| August | 10 | 34 | 41 | 47 | 52 | 56 | 58 | 59 | 59 | 57 | 54 |
| September | 76 | 34 | 39 | 42 | 45 | 47 | 47 | 47 | 45 | 42 | 38 |
| October | 315 | 28 | 31 | 32 | 34 | 34 | 33 | 32 | 30 | 27 | 24 |
| November | 551 | 17 | 18 | 19 | 19 | 19 | 19 | 18 | 16 | 15 | 13 |
| December | 763 | 17 | 18 | 19 | 19 | 18 | 17 | 16 | 15 | 13 | 10 |
| Avg. solar radiation | | 26.1 | 30.0 | 33.3 | 36.0 | 37.8 | 38.5 | 38.8 | 37.9 | 36.3 | 33.8 |

Source: Grondzik, Walter T., and Kwok, Alison G. *Mechanical and Electrical Equipment for Buildings*. Thirteenth ed., John Wiley & Sons, Inc., 2019.

**Solar Collector System**

Design Intent for Heat Return:

- Direct solar gains for heat return
- Thermal delight

Climate Characteristics:

- Overcast/low sun exposure

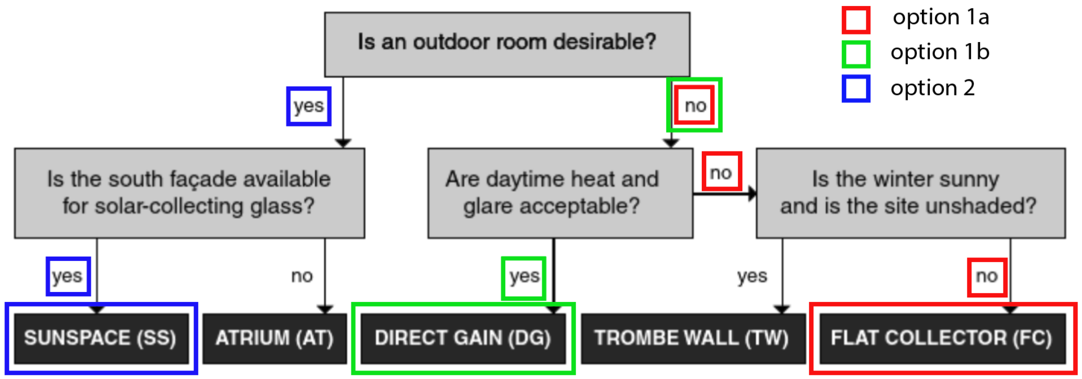
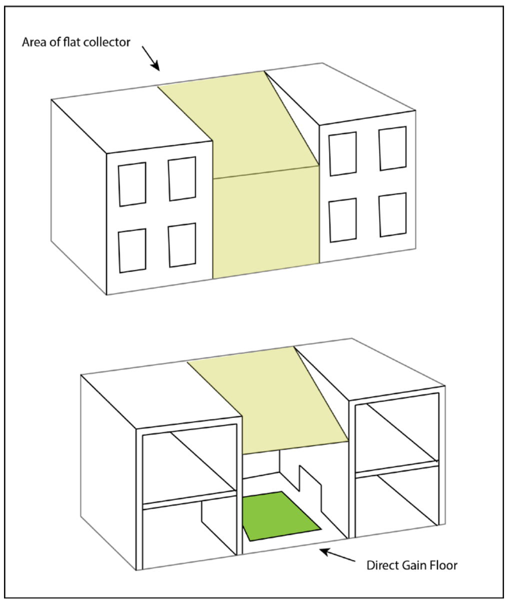


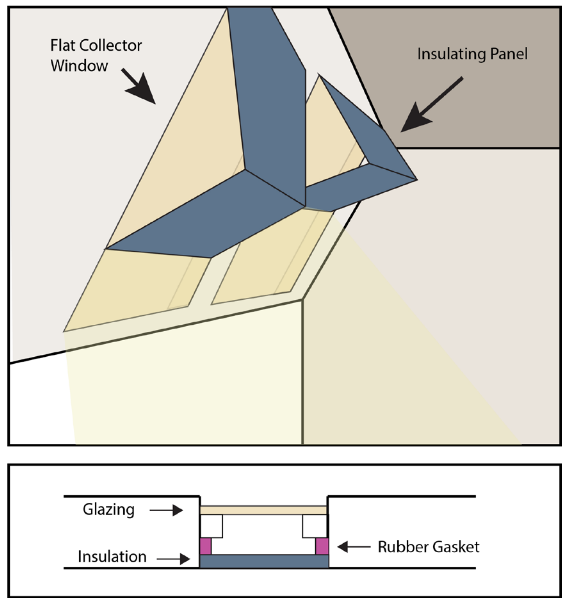

***Fig. 11.25*** *Decision tree for passive solar heating system selection.*

Source: Grondzik, Walter T., and Kwok, Alison G. *Mechanical and Electrical Equipment for Buildings*. Thirteenth ed., John Wiley & Sons, Inc., 2019.

# Movable Insulation System

Intent: To reduce envelope, infiltration and interior heat loss, the flat collector glazing is covered with movable nighttime insulation that features a rubber gasket seal.




Source: Source: Grondzik, Walter T., and Kwok, Alison G. *Mechanical and Electrical Equipment for Buildings*. Thirteenth ed., John Wiley & Sons, Inc., 2019.

# Thermal Mass Proposal - Direct Gain Floor

Concrete Mass

- Logic: Concrete can store thermal energy deep within itself and emmit that heat consistently over a long period of time
- Position: Below flat collector
- Thickness: **3.6 (in)**
- Volume: **449 sf**

Slate Mass

- Logic: Slate is very similar to concrete, however it excels in solar absorptance, thermal conductivity and emissivity
- Position: Below flat collector
- Thickness: **9.5 (in)**
- Volume: **1,183 sf**

Concrete Properties

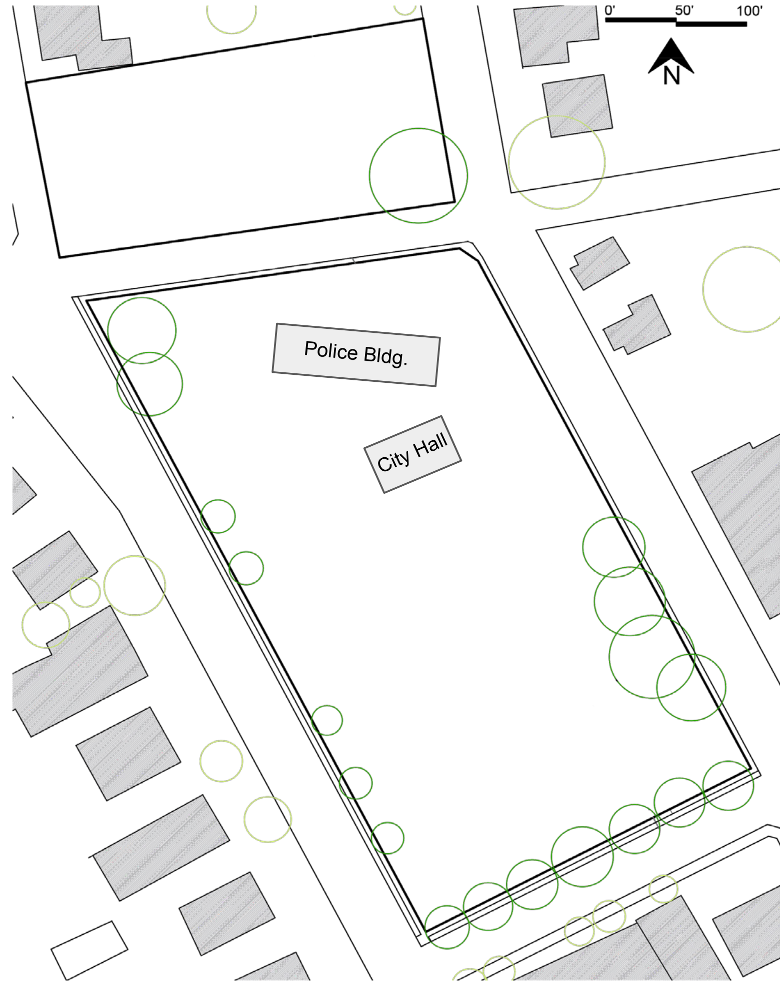
- Density: 140(Ib/sf)
- Specific Heat Capacity: 0.189 (Btu/Ib F)
- Volumetric Heat Capacity: 29 (Btu/sf F),
- Absorb Factor: 0.60
- Thermal Conductivity: 0.231-0.405 (Btu/ft F)

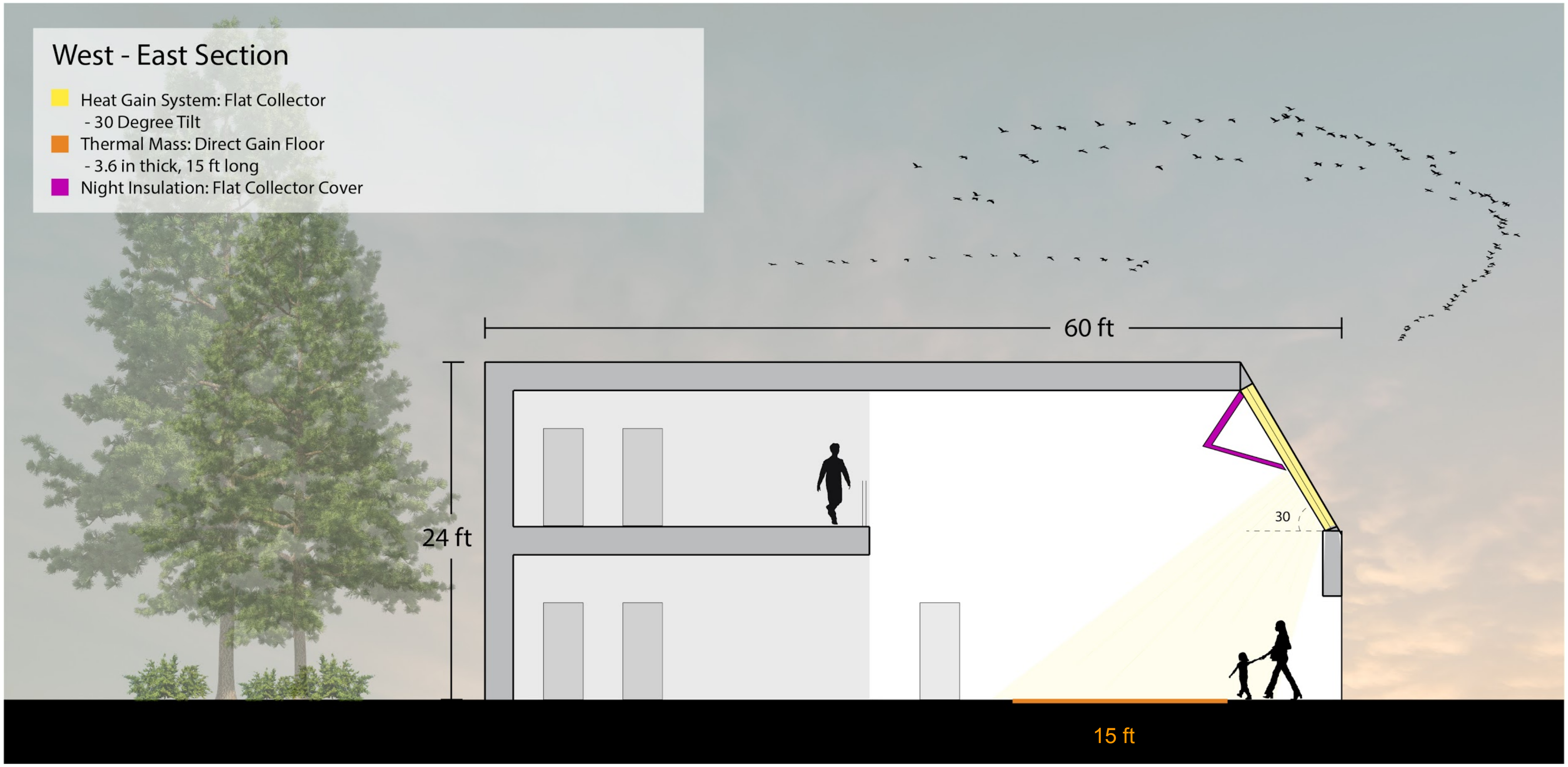
Slate Properties

- Density: 80 (Ib/sf)
- Specific Heat Capacity: 0.182 (Btu/Ib F)
- Volumetric Heat Capacity: 15 (Btu/sf F),
- Absorb Factor: 0.87
- Thermal Conductivity: 1.16 (Btu/ft F)

Source: “Emissivity Coefficients for Some Common Materials.” *Engineering ToolBox*, www.engineeringtoolbox.com/radiation-heat-emissivity-d_432.html.

# Building Placement in Plan





West - East Section
Heat Gain System: Flat Collector
- 30 Degree Tilt
Thermal Mass: Direct Gain Floor
- 3.6 in thick, 15 ft long
Night Insulation: Flat Collector Cover
60 ft
24 ft
30
15 ft

# Conclusions

Central Recommendations:

- Intent: To design a passive a building with passive heating strategies.
- Optimal Orientation: Based on our calculations and climate data the optimal tilt for our solar collector should be 30 degrees.
- Glazing Choice: Glazing for our solar collector should have a high SHGC and a low U-value such that it will allow the most solar radiation to transmit through the glass.
- System Type: Flat solar collector
- Thermal Mass: A Concrete or slate floor mass in the City Hall gathering room.
- Movable Insulation: Movable panel with rubber gasket seal.

# Appendix B

## Nick and Alex

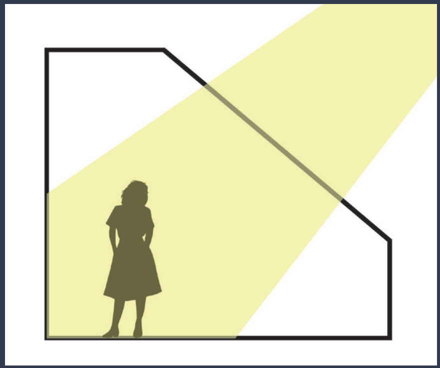
# Silverton Proposal:

## Passive Heating StrategIES

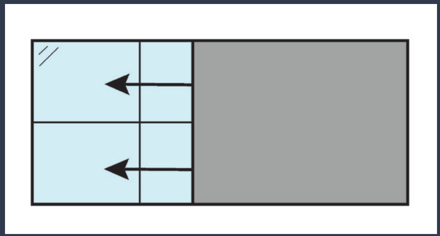
Alexandria Clark & Nick Dworshak
ARCH 494M/594M
University of Oregon
3/17/2020

## Design Intent

- Variety of Thermal Spaces for Thermal Delight
- South Facing Glazing for best sun exposure
- Vernacular Design & Materials
- Opportunity for Natural Light
- Designed for the heating needs of February.
- Non-Invasive Moveable Insulation



Natural Light



Movable Insulation

Vernacular Architecture

# Tree Densities

1.

Giant Sequoia (73.3%)

2.

Spruce (76.3%)

3.

Maple (36%)

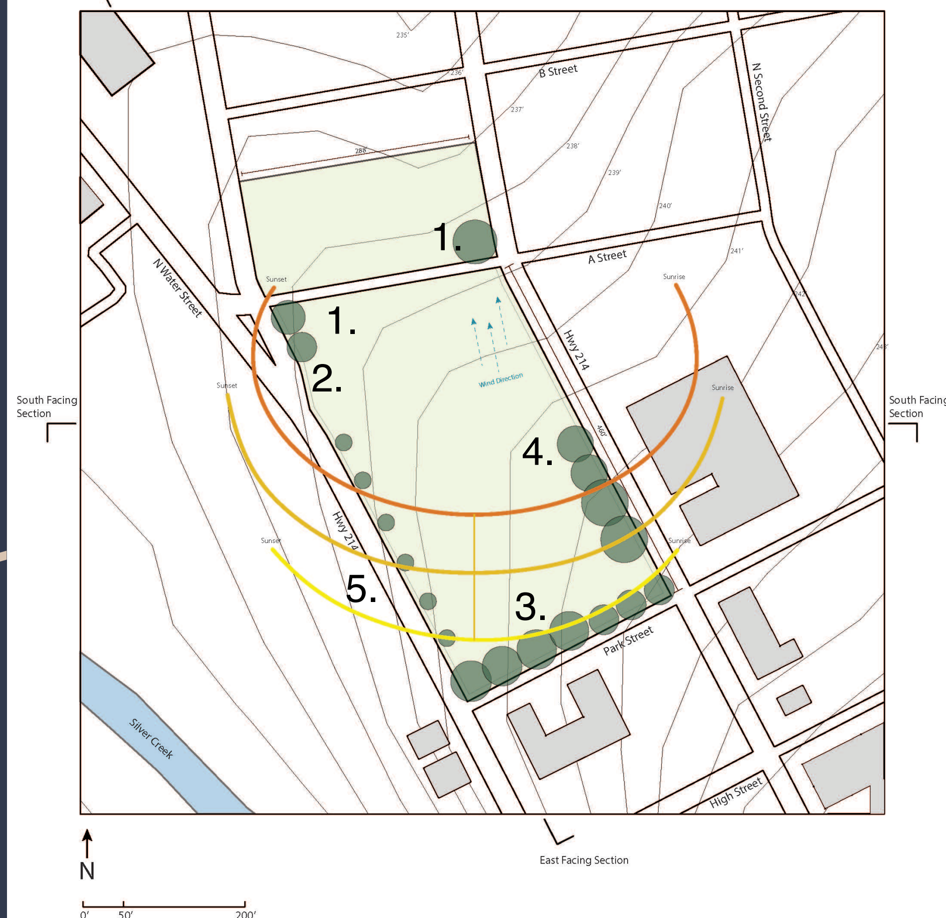
4.

Oak (33%)

5.

Callery Pear (24%)

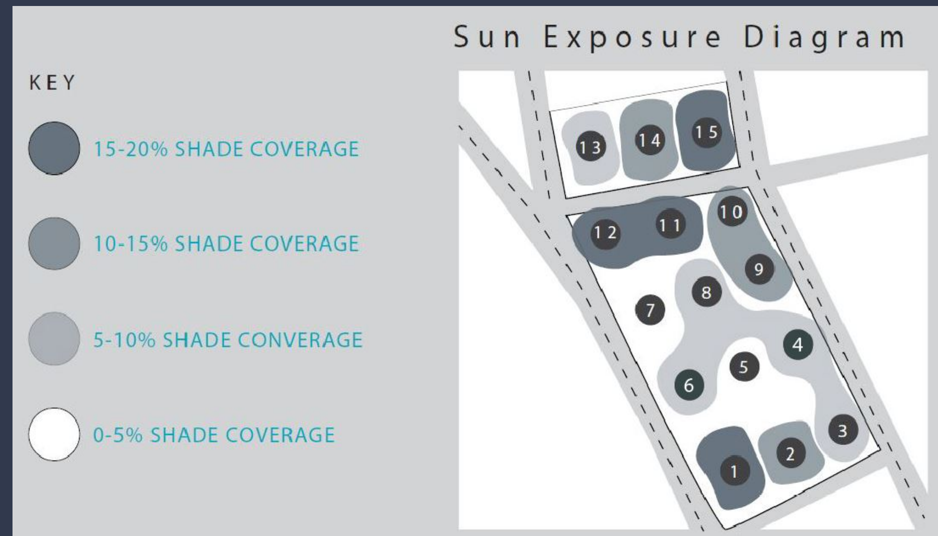
# Site PLAN

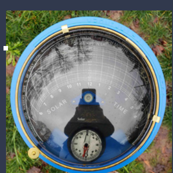
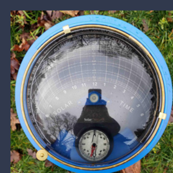


## Sun Exposure-

PathFinder Data

We combined the area and density of the shade during daylight hours to find % Coverage at each location. We chose photo 4 to represent the average shade conditions for the building at it's ideal location for further solar analysis.




1. 
2. 
3. 
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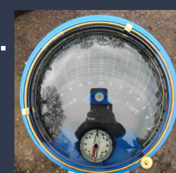
5. 
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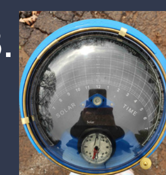
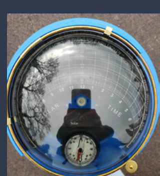
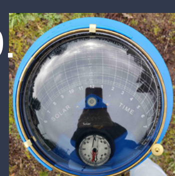
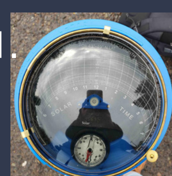
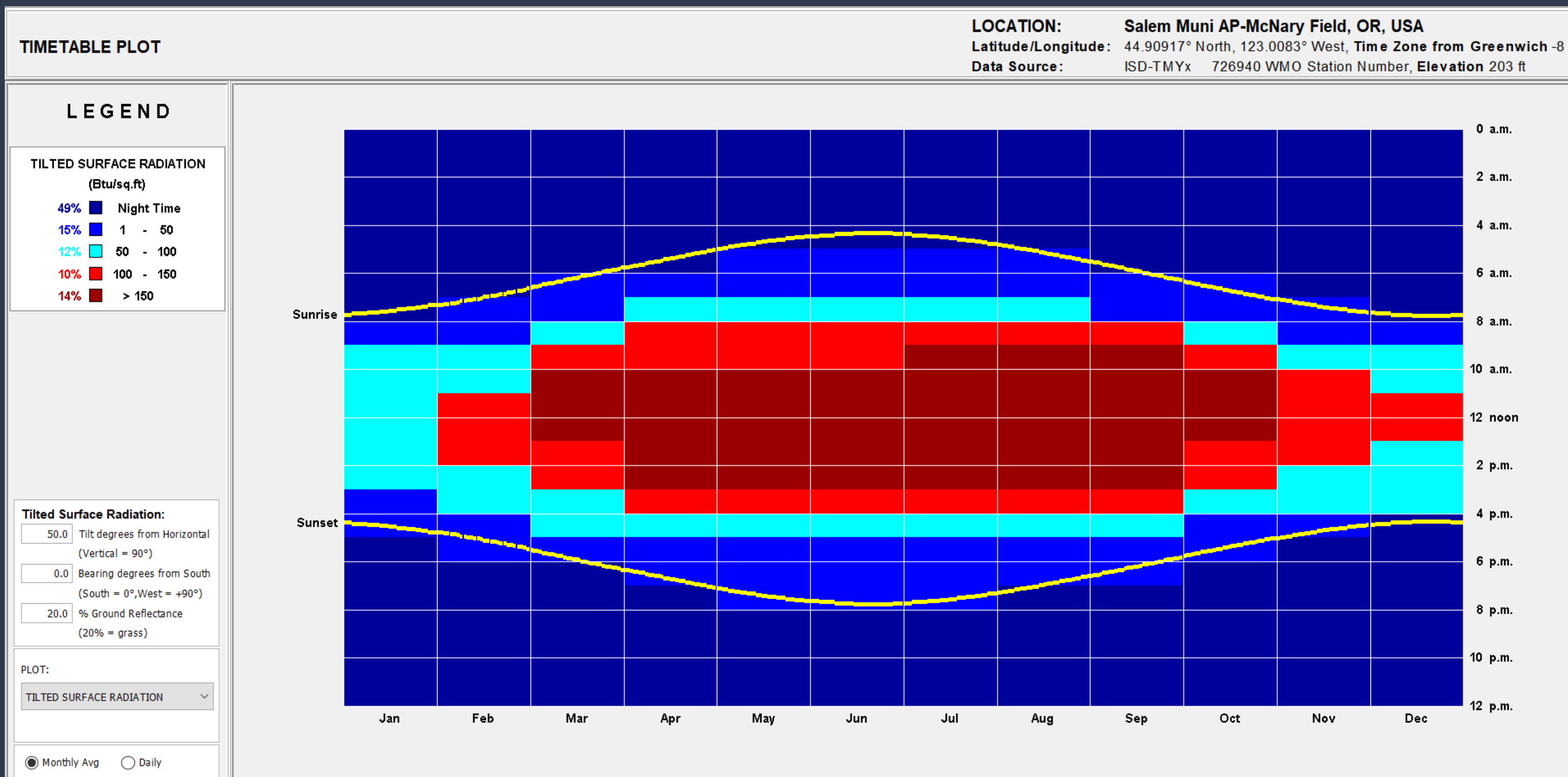
8. 
9. 
10. 
11. 
12. 
13. 
14. 
15. 

# Optimal Orientation

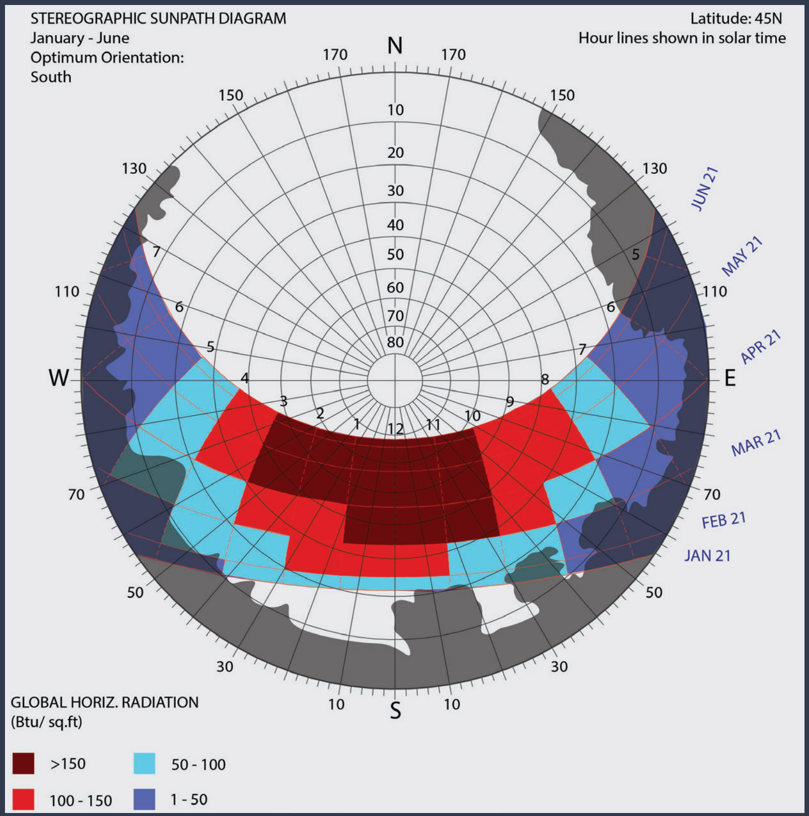
Which direction the glazing should be facing, based off of the Solar Radiation Data for a 50 °F tilt, as well as the shadows casted on the site by nearby trees and buildings.

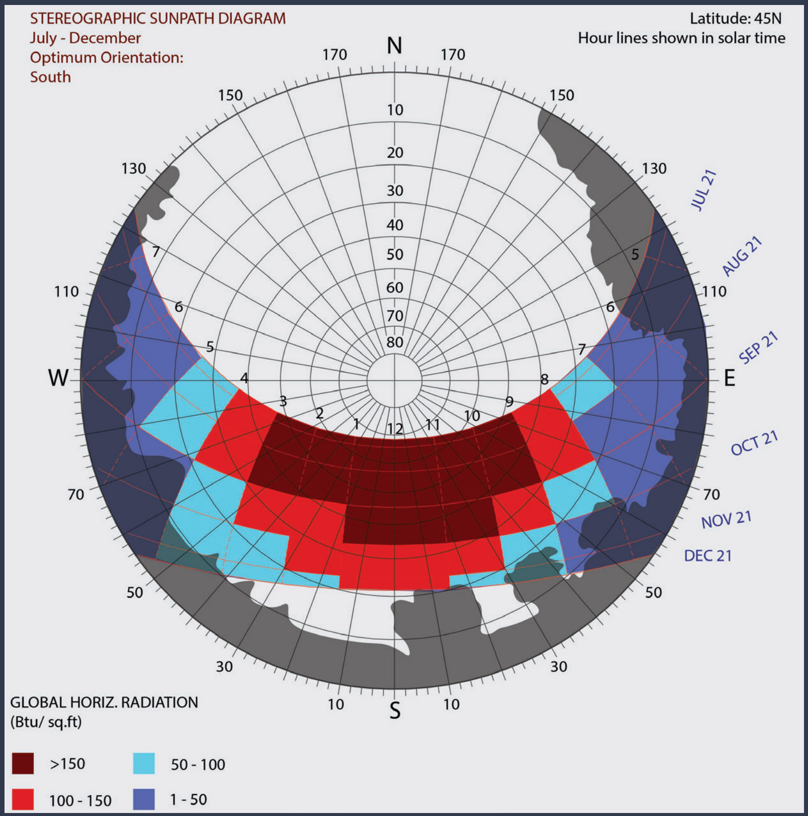
**CHOSEN ORIENTATION**: South

# Tilted SOLAR RADIATION



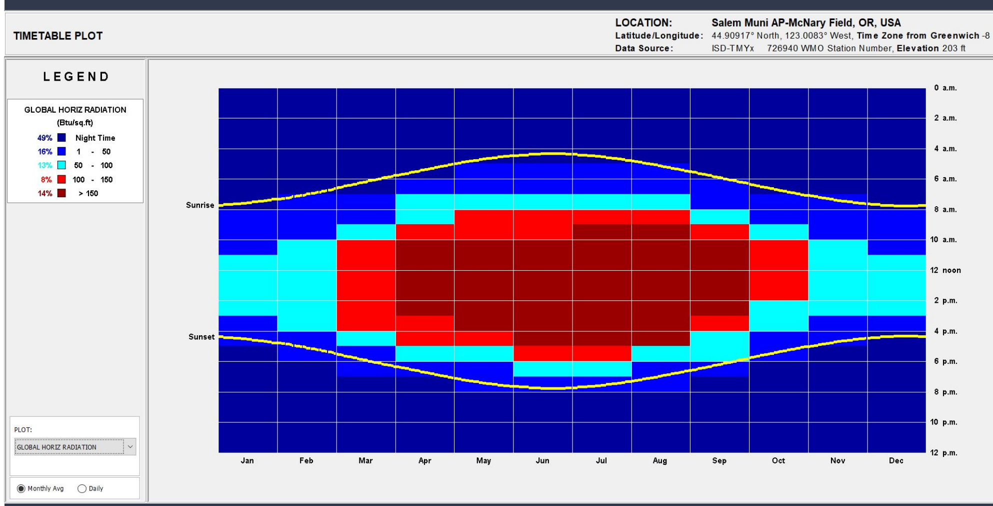
# StereoGraphic Sun-Path Diagrams

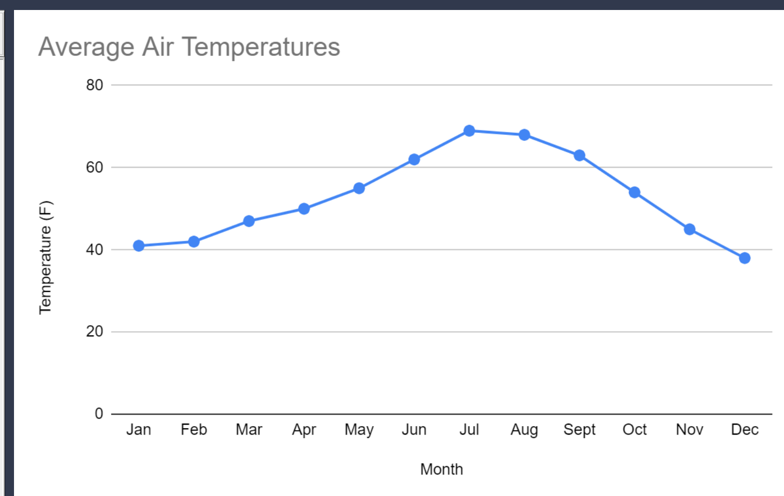


# GLOBAL HORZ. SOLAR RADIATION

The Global Horizontal Solar Radiation Chart is evidence that flat surfaces are not ideal for collecting solar gains during the heating season. While there is an abundance of Solar Radiation during the middle of the year, it does not expand into months that actually need it for our climate (as compared to the 50 deg. Tilt Solar Radiation graph above).



# Building Placement

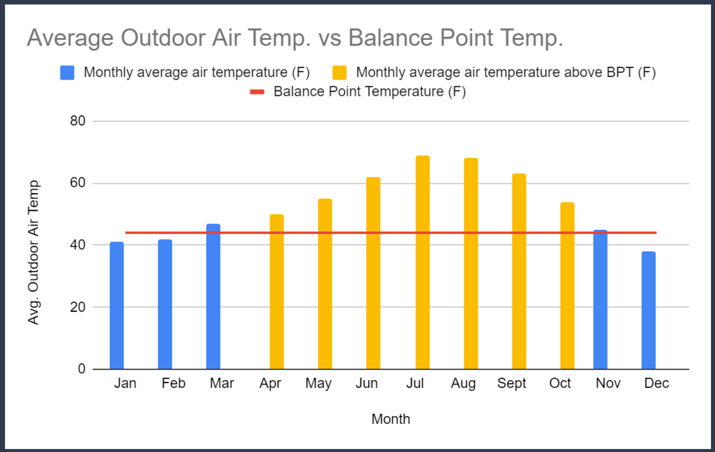
- South Orientation
- Placed in a spot which has the least shade and interruption.
- Set far enough apart to avoid one building from shading the other.
- East to West length to allow for the most Southern Exposure and opportunity for natural light.

# Balance Point Temperature

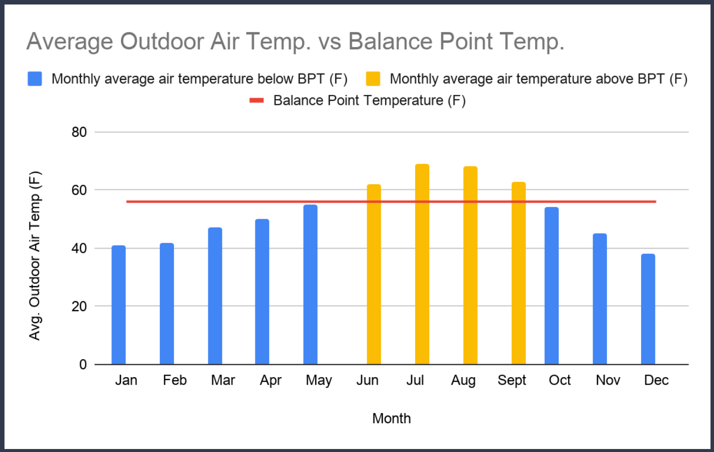
Definition: The building balance point temperature is the outdoor air temperature when the heat gains of the building are equal to the heat losses.

Internal Gains = Envelope Losses + Infiltration Losses

POLICE STATION - BPT 44 (F)




CITY HALL - BPT 56 (F)



## Envelope Losses:

$q_{env} = \Sigma QA * \Delta T$

CITY HALL -

- ΣUA = 1,546 (Btu/hF)
  - Surface Area
  - U-Value
- Desired Indoor Temperature (F) : 68
- Hours in a month: (h) : 720

Example Problem: March (Avg. Outdoor: 47 F)

q env = (1,546 Btu/hF) * (68 F - 47 F) * (720 h)

= 23,374,310 Btu OR = 23,374 kBtu

POLICE STATION -

- ΣUA = 1,720 (Btu/hF)
  - Surface Area
  - U-Value
- Desired Indoor Temperature (F) : 68
- Hours in a month: (h) : 720

Example Problem: March (Avg. Outdoor: 47 F)

q env = (1,720 Btu/hF) * (68 F - 47 F) * (720 h)

= 26,003,376 Btu OR = 26,003 kBtu

## Infiltration Losses:

q inf = (cp) * (**ρ**) *(n) *(V) * (**Δ**T)

CITY HALL -

- Volume (V) = 114,750 (ft^3)
- Air Density (**ρ**) = 0.075 (lb/ft^3)
- Air Heat Capacity (cp) = 0.24 (Btu/lb F)
- Desired Indoor Temperature (F) : 68 F
- Hours in a month: (h) : 720 h

Example Problem: March (Avg. Outdoor: 47 F)

q inf = (114,750 ft^3) * (0.24 Btu/lb F) * (0.075 lb/ft^3) *(68 F - 47 F) * (720 h)

= 39,395,160 Btu OR = 39,395 kBtu

POLICE STATION -

- Volume (q**v**) = 165,000 (ft^3)
- Air Density (**ρ**) = 0.075 (lb/ft^3)
- Air Heat Capacity (cp) = 0.24 (Btu/lb F)
- Desired Indoor Temperature (F) : 68 F
- Hours in a month: (h) : 720 h

Example Problem: March (Avg. Outdoor: 47 F)

q inf = (165,000 ft^3) * (0.24 Btu/lb F) * (0.075 lb/ft^3) *(68 F - 47 F) * (720 h)

= 44,906,400 Btu OR = 44,906 kBtu

## Internal Gains:

q int = (Intensity Btu/hsf)*(hrs)*(Building Area)

### CITY HALL -

- People: 2.3 (Btu/hsf)
- Lights: 2.73 (Btu/hsf)
- Equipment: 1.67 (Btu/hsf)
- Occupied hours per day (h): 12 h
- Building Area(sf) : 14,475 sf

Example Problem: Gains from People

q int = (2.3 Btu/hsf) * (12 h) * (14,475 sf)

= 399510 Btu OR = 399.5 kBtu

### POLICE STATION -

- People: 2.3 (Btu/hsf)
- Lights: 2.73 (Btu/hsf)
- Equipment: 1.67 (Btu/hsf)
- Occupied hours per day (h): 24 h
- Building Area(sf) : 16,500 sf

Example Problem: Gains from People

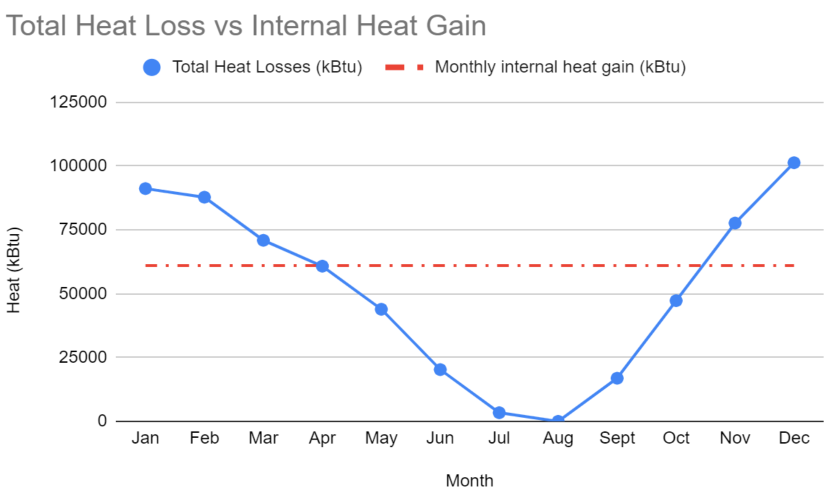
q int = (2.3 Btu/hsf) * (24 h) * (16,500 sf)

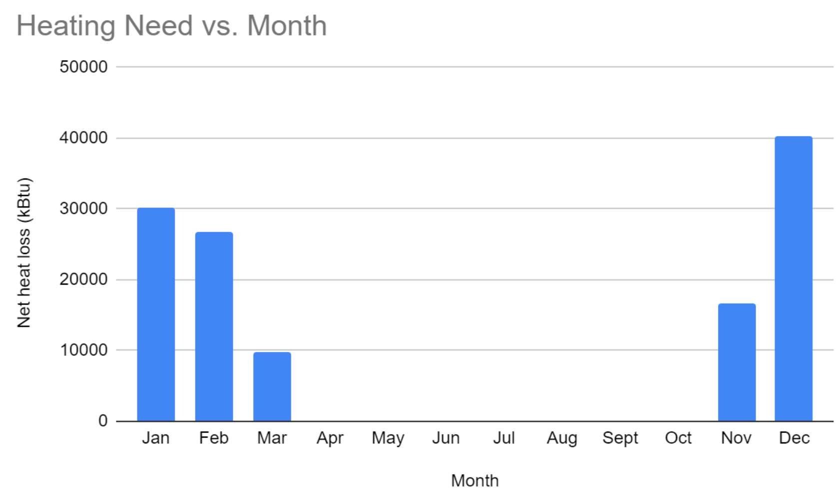
= 910,800 Btu OR = 910.8kBtu

# Net Heat Loss - Police Station

| Month | Monthly average air temperature (F) | Monthly envelope heat loss (kBtu) | Monthly infiltration heat loss (kBtu) | Monthly internal heat gain (kBtu) | Net heat loss (kBtu) |
|---|---|---|---|---|---|
| Jan | 41 | 33,433 | 57,737 | 61,024 | 30,146 |
| Feb | 42 | 32,195 | 55,598 | 61,024 | 26,769 |
| Mar | 47 | 26,003 | 44,906 | 61,024 | 9,886 |
| Apr | 50 | 22,289 | 38,491 | 61,024 | -244 |
| May | 55 | 16,097 | 27,799 | 61,024 | -17,127 |
| Jun | 62 | 7,430 | 12,830 | 61,024 | -40,764 |
| Jul | 69 | 1,238 | 2,138 | 61,024 | -57,647 |
| Aug | 68 | 0 | 0 | 61,024 | -61,024 |
| Sept | 63 | 6,191 | 10,692 | 61,024 | -44,140 |
| Oct | 54 | 17,336 | 29,938 | 61,024 | -13,750 |
| Nov | 45 | 28,480 | 49,183 | 61,024 | 16,639 |
| Dec | 38 | 37,148 | 64,152 | 61,024 | 40,276 |
| Total | -- | -- | -- | -- | 123,717 |

# Loss vs Gains - Police Station

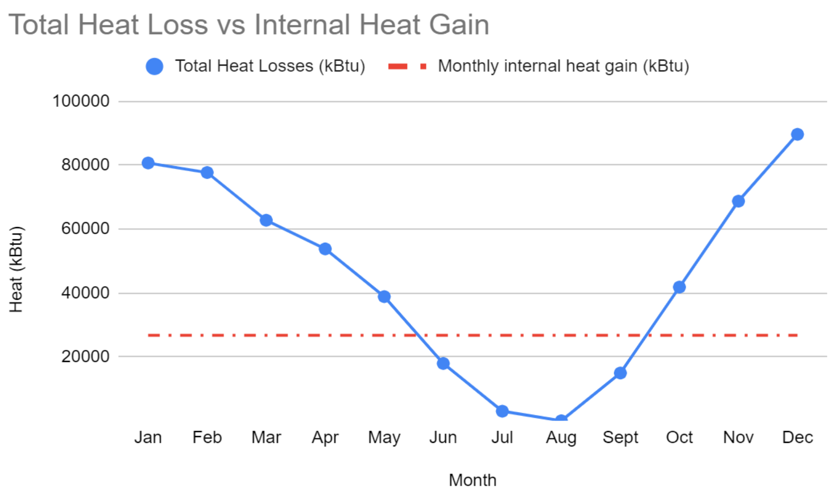


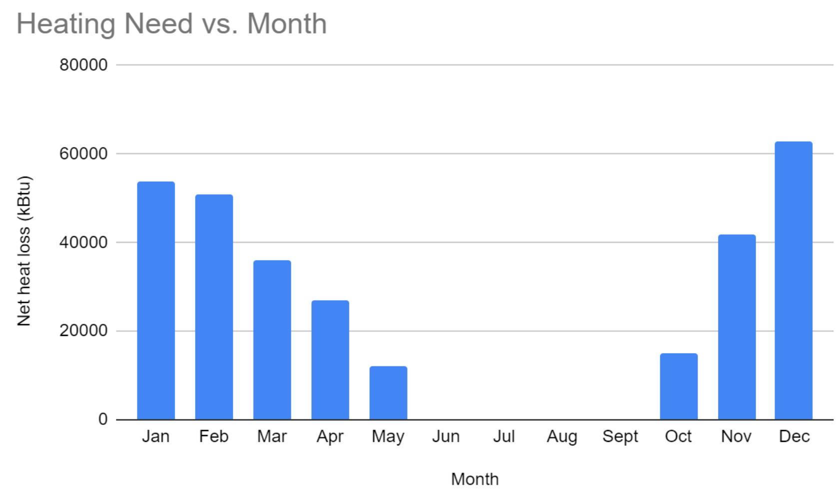



# Net Heat Loss - City Hall

| Month | Monthly average air temperature (F) | Monthly envelope heat loss (kBtu) | Monthly infiltration heat loss (kBtu) | Monthly internal heat gain (kBtu) | Net heat loss (kBtu) |
|---|---|---|---|---|---|
| Jan | 41 | 30052.6848 | 50650.92 | 26767.17 | 53936.4348 |
| Feb | 42 | 28939.6224 | 48774.96 | 26767.17 | 50947.4124 |
| Mar | 47 | 23374.3104 | 39395.16 | 26767.17 | 36002.3004 |
| Apr | 50 | 20035.1232 | 33767.28 | 26767.17 | 27035.2332 |
| May | 55 | 14469.8112 | 127565.28 | 26767.17 | 115267.9212 |
| Jun | 62 | 6678.3744 | 11255.76 | 26767.17 | -8833.0356 |
| Jul | 69 | 1113.0624 | 1875.96 | 26767.17 | -23778.1476 |
| Aug | 68 | 0 | 0 | 26767.17 | -26767.17 |
| Sept | 63 | 5565.312 | 9379.8 | 26767.17 | -11822.058 |
| Oct | 54 | 15582.8736 | 26263.44 | 26767.17 | 15079.1436 |
| Nov | 45 | 25600.4352 | 43147.08 | 26767.17 | 41980.3452 |
| Dec | 38 | 33391.872 | 56278.8 | 26767.17 | 62903.502 |
| Total | -- | -- | -- | -- | 403152.2928 |

# Loss vs Gains - City Hall



# Tilted Windows

What angle is best at allowing Solar Radiation penetrate through the glazing. This will depend on the decided heating season and the site location. With the proper angle of incidence, we will have optimal light transmission.

**OPTIMAL TILT**: 50 Degrees

# Solar Radiation Table -
## 50 degree tilt

| Month | Optimal Tilt (Degrees) | Solar Radiation (kBtu/ft^2) |
|---|---|---|
| **Jan** | **50**, 60, 70 | 21 |
| **Feb** | 40, **50**, 60, 70 | 25 |
| **Mar** | 30, 40, **50** | 36 |
| **Apr** | 20, 30 | 44 |
| **May** | 10, 20 | 53 |
| **Oct** | **50** | 39 |
| **Nov** | **50**, 60, 70 | 19 |
| **Dec** | **50**, 60, 70, 80 | 16 |

- Highest Solar Radiation during the Heating Season.
  - January
  - February
  - March
  - October
  - November
  - December

- Used for both buildings for uniformity.

## Glazing Type

Choosing a type of glass which will allow the most Solar Gains.

Goals:

- High Solar Heat Gains (SHGC)
- Double Glazing
- Low-E Coating on Surface

Chosen Glazing: Double Low-E

- SHGC: 0.754
- Low-E Coating on Surface #3
- U-Value: 0.273 BTU/h sf F
- Air gap: Xenon

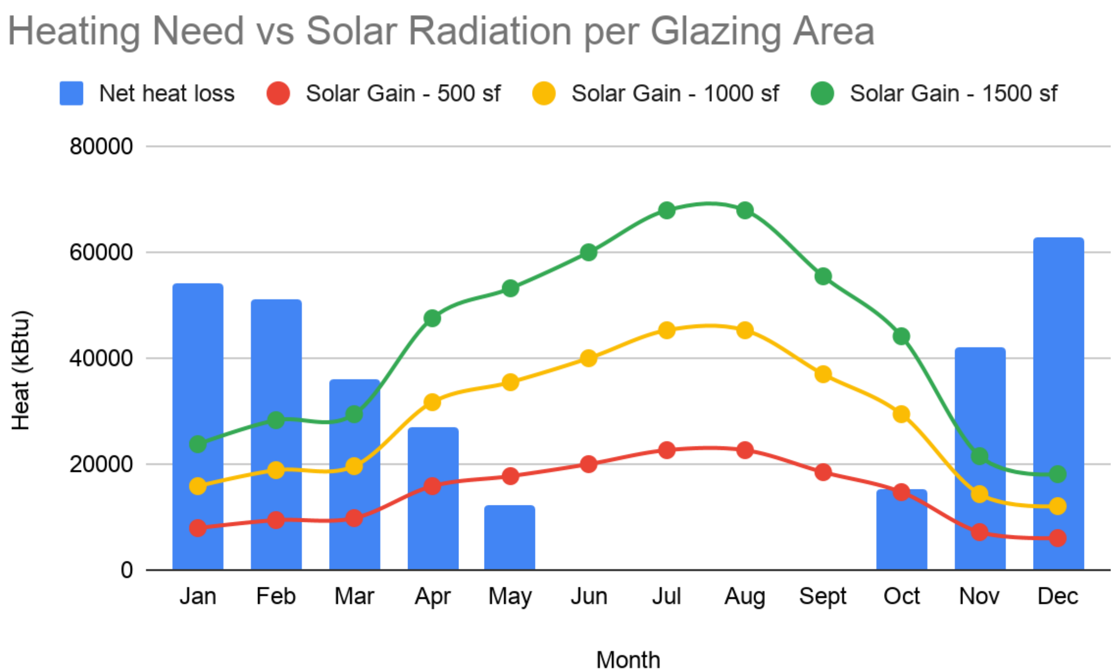
## Glazing Area

The square footage of glazing needed to fulfill a large portion of the monthly heating need during the heating Season.

### Chosen Area(s)

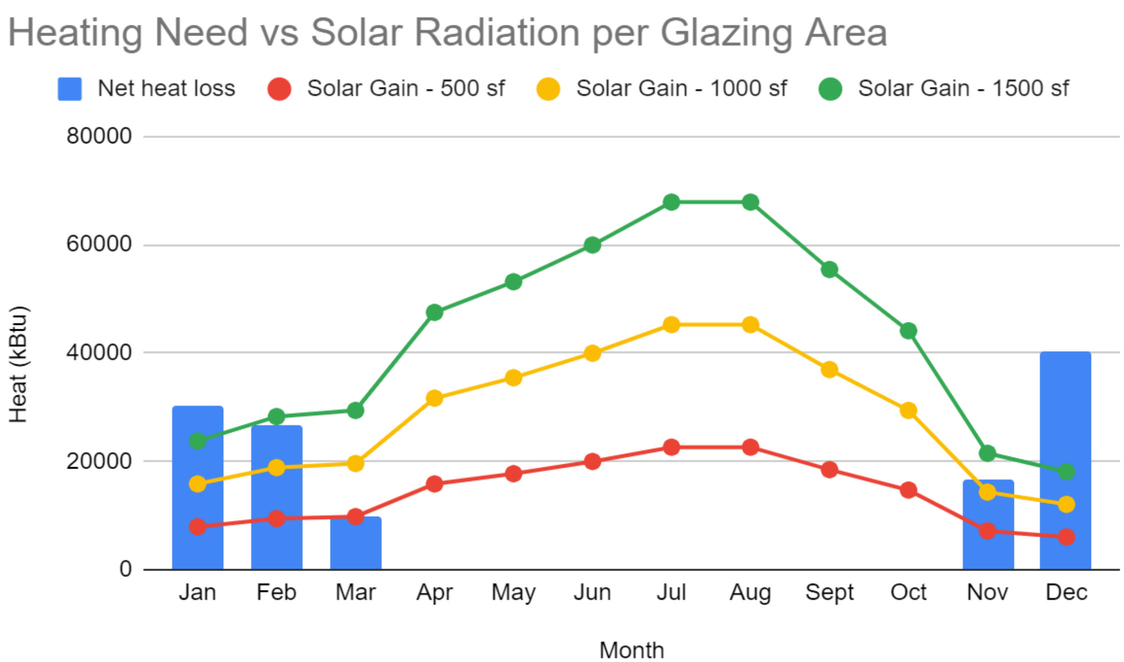
- City Hall: 1500 sq ft
- Police Station: 1000 sq ft

# Glazing Area -
## City Hall




We chose **1,500 sf** because when designing for February, is was capable of fulfilling about half of the heating need without being over designed for later months of the heating need.

# Glazing Area -
## Police Station




We chose **1,000 sf** because when designing for February, is was capable of fulfilling about two thirds of the heating need without overheating (as shown with the 1,500 sf).

# SYSTEM TYPES

Choose Passive Systems that are most appropriate for a commercial building in the appropriate Climate.

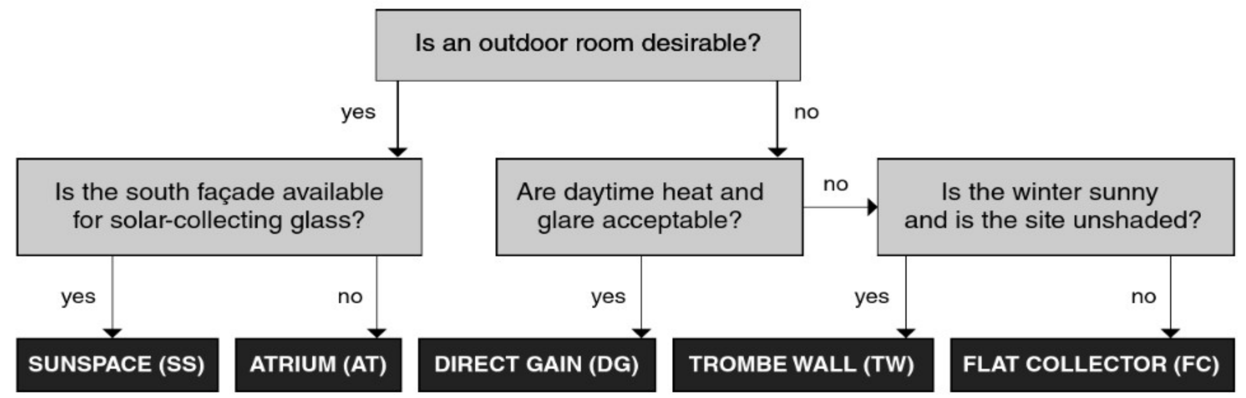



*Fig. 11.25* Decision tree for passive solar heating system selection.

# WHAT PASSIVE SYSTEM DO YOU CHOOSE?

- Sun Space  (SS) - Great method for Thermal Delight in break rooms, cafe spaces, and corridors. Thermal Delight.
- Direct Gain (DG) - In areas that have a lot of light, and are allowed glare (non-working spaces).
- Flat Collector (FC) -Versatile Design. Works well in colder climates for morning heating.
- Atrium (AT) - Good for large public areas, internal natural lighting opportunity from South..

# Thermal Mass

Basalt (wall) and Concrete (floor)

- Moderate Thermal Conductivities
- Vernacular material/Aesthetic quality
- Basalt Heat Capacity: 0.2 BTU/lb F
- Concrete Heat Capacity: 0.19 BTU/lb F

Sunspaces

- 2"-4" Thick
- City Hall Wall Mass: 57,490 lbs
- City Hall Floor Mass: 28,942 lbs
- Police Station Wall Mass: 90,341 lbs
- Police Station Floor Mass: 28,942 lbs

## Why Sunspaces?

- Thermal Delight Spaces (temporarily occupied) to create spaces that have variety but will not overwhelm others who may perceive it as too hot.
- South facing rooms
- Heat is absorbed and radiated into adjacent rooms
- 2"-4" thick
- Thicker in Police Station and thinner in City Hall

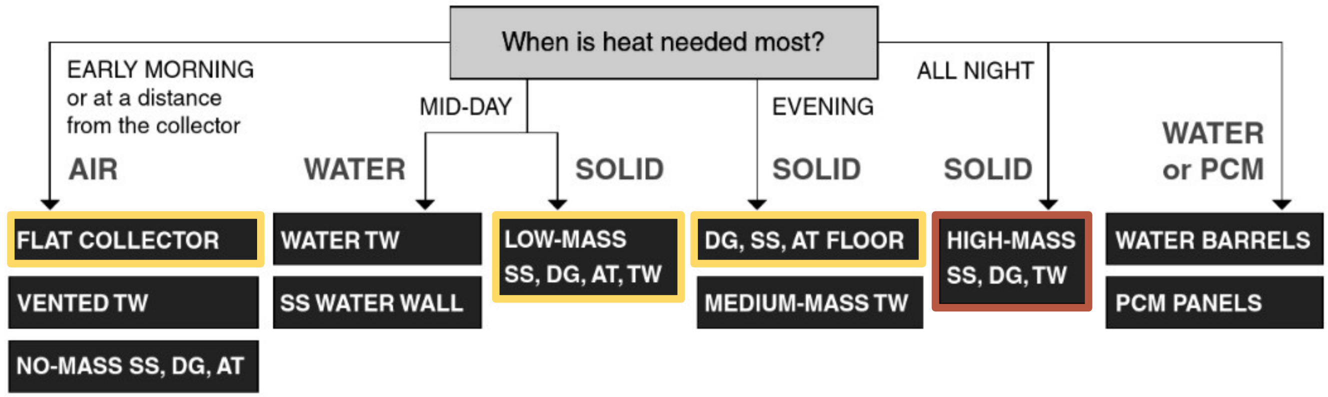



***Fig. 11.37*** *Decision tree for thermal mass configuration in conceptual design. TW = Trombe wall; SS = sunspace; DG = direct gain; AT = atrium; PCM = phase-change material. Low, medium, and high mass levels are defined in Table 11.2.*

## City Hall

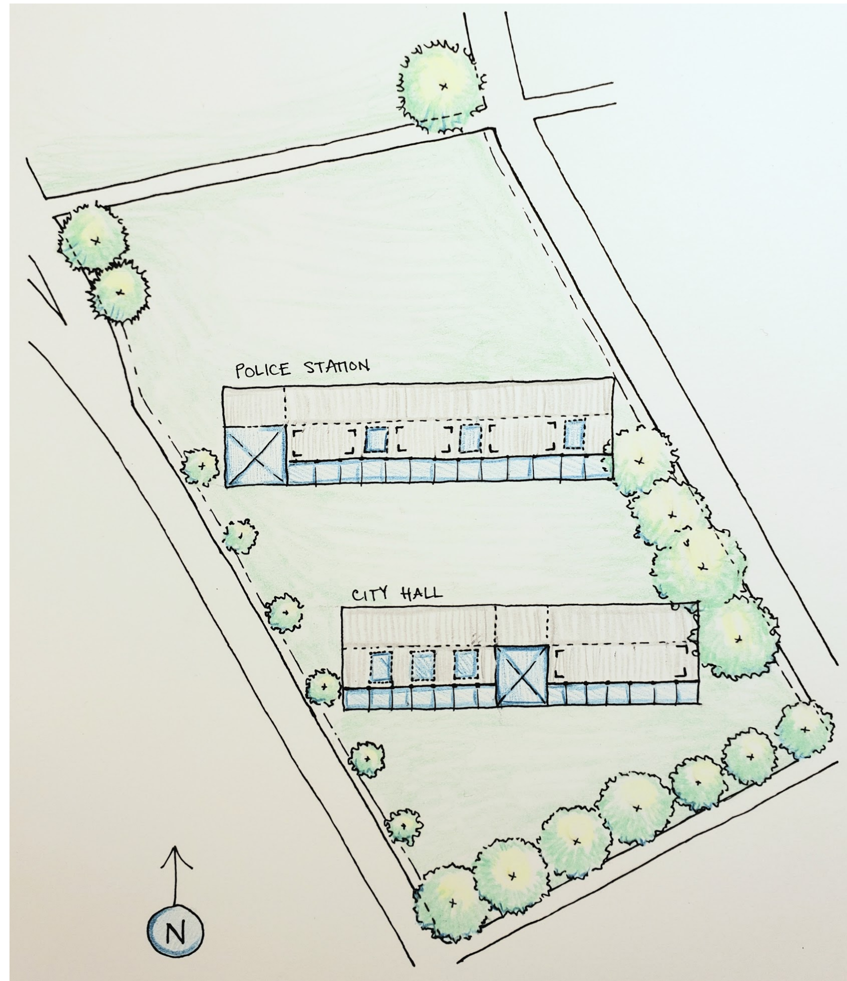
- Early Morning - Flat Collectors
- Mid-Day - Low-Mass SS and TW.
- Evening - DG at Floor

## POLICE STATION

- Early Morning - Flat Collectors
- Evening - DG at Floor
- All Night - High Mass TW, DG, and SS.

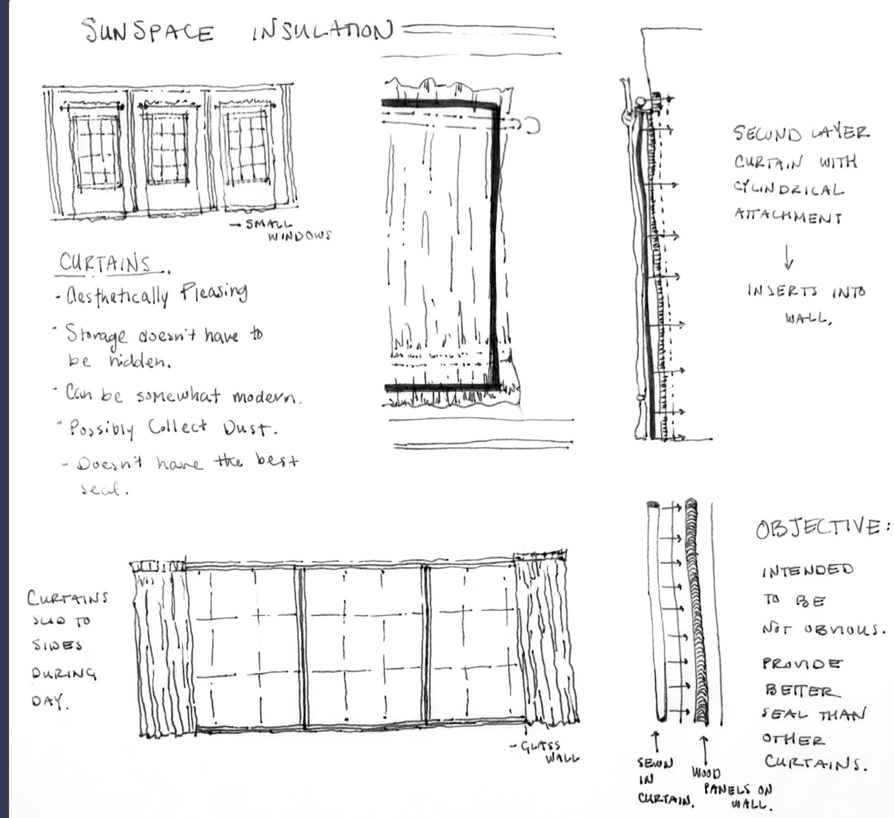
## Building Plan

- Bright Lobby Spaces: Includes a large open atrium
- Neutral Work Spaces: Non specific temperatures to accommodate the masses.
- Sun Space Corridors: Temporary use circulation space.
- Flat Collectors: In rooms that are not good with glare.



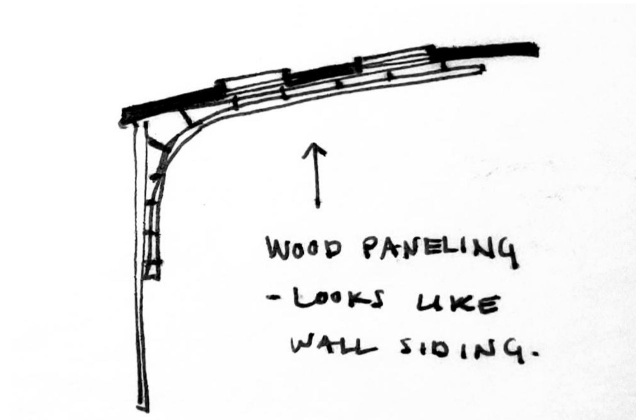
# MOVABLE INSULATION

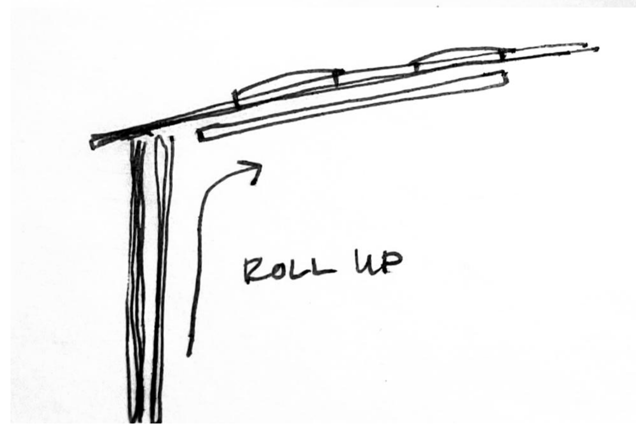
- Discrete: Remains relatively unnoticeable or abrasive.
- Can be Modern: Sleek curtain materials
- Prevents Leakage: Sewn in rods which snap into the wall to prevent leakage.
- Easy Storage: Pushed to the sides without taking up needed space.
- Low R-Value: Could have trouble actually insulating the space unless a certain fabric were chosen.
- Vertical Glass: Would not operate well on the preferred tilted glass.



# MOVABLE INSULATION

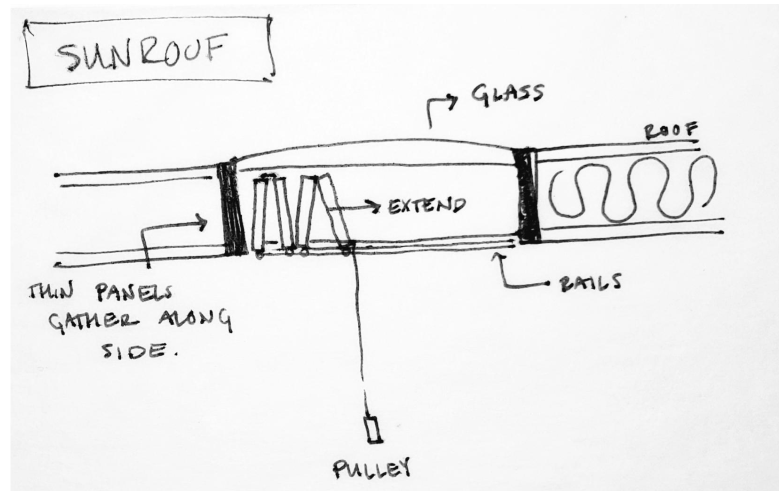
- Easy to operate: This system slides up on a track and retracts easily.
- Covering Potential: Could cover one or multiple skylights at once.
- Wood Paneling to match wall siding:This paneling matches the interior and is not noticable when being used.
- Wear and Tear: This has the potential to fall apart or malfunction over time.
- Questionable Seal: May not be able to be close enough to the window to properly seal.

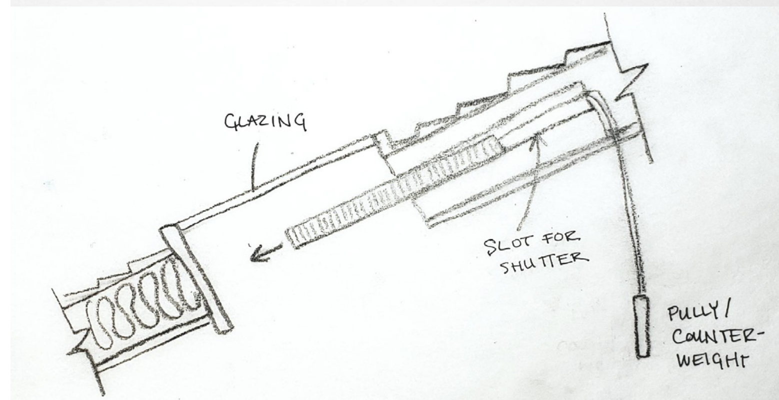


## MOVABLE INSULATION

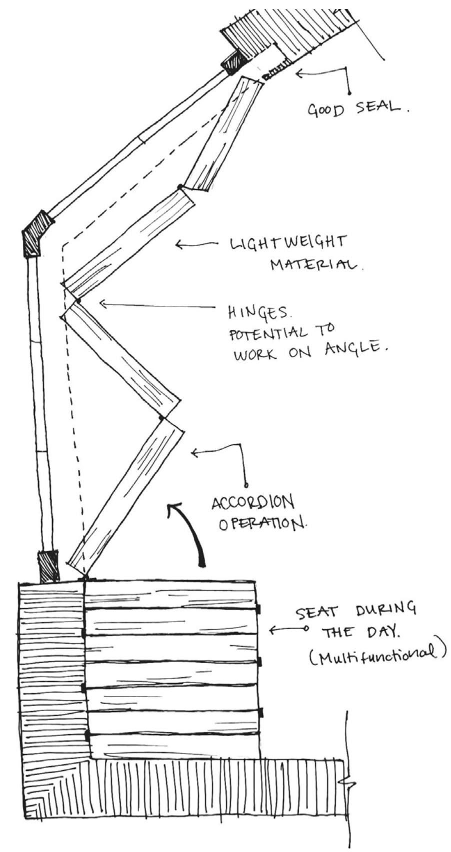
- Easy to operate: These operate by a manual pulley system which should be light and smooth.
- Hidden panelling: Not a separate piece that requires storage.
- Wear and Tear: This has the potential to fall apart or malfunction over time.
- Convection: A leak in the seal could create significant currents and dew along the glazing.
- Complex to Build: Might not be easy to install into new or preexisting structures.



## MOVABLE INSULATION

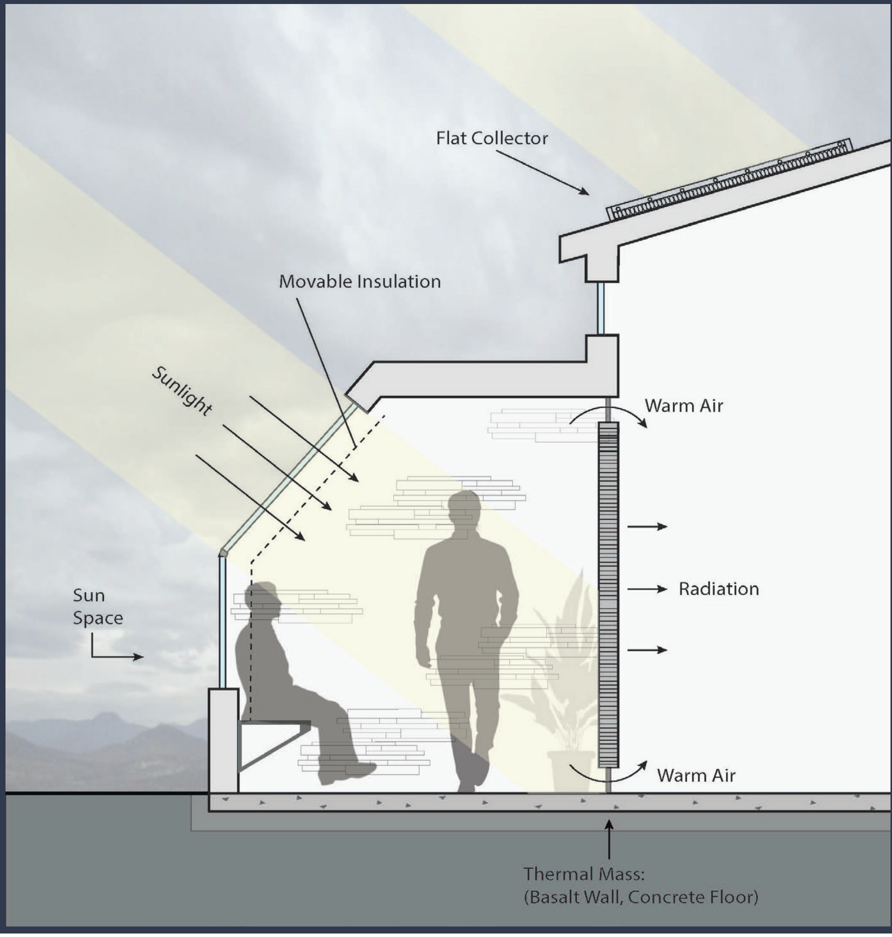
- Multifunctional: Is a good use of space during the day when it needs to be stored.
- Wear and Tear: This has the potential to fall apart over time, especially if people sit on it frequently.
- Convection: A leak in the seal could create significant currents and dew along the glazing.
- Labor Intensive: Could prevent people from going through effort to put up.
- Difficult to Operate: May be hard to put up without help.



## Conclusion

- South Orientation
- 50 Degree Glazing Tilt
- High SHGC Glazing
- City Hall - 1,500 sf Glass
- Police Station - 1,000 sf Glass
- None-Medium Thermal Mass Thickness
- Use Moveable Insulation (Good Seal, high R-Value)
- Provide a variety of room experiences for variety and "Thermal Delight".

### Section Drawing



# Appendix C

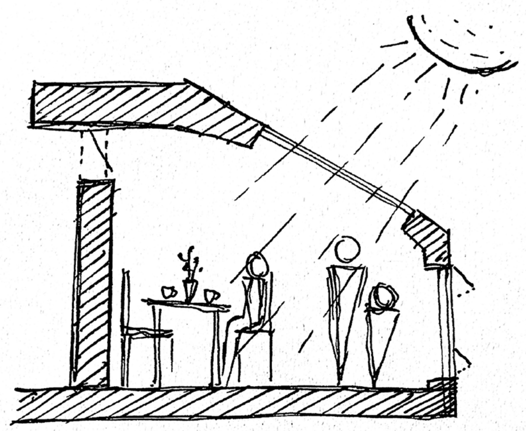
## Olivia and Ben

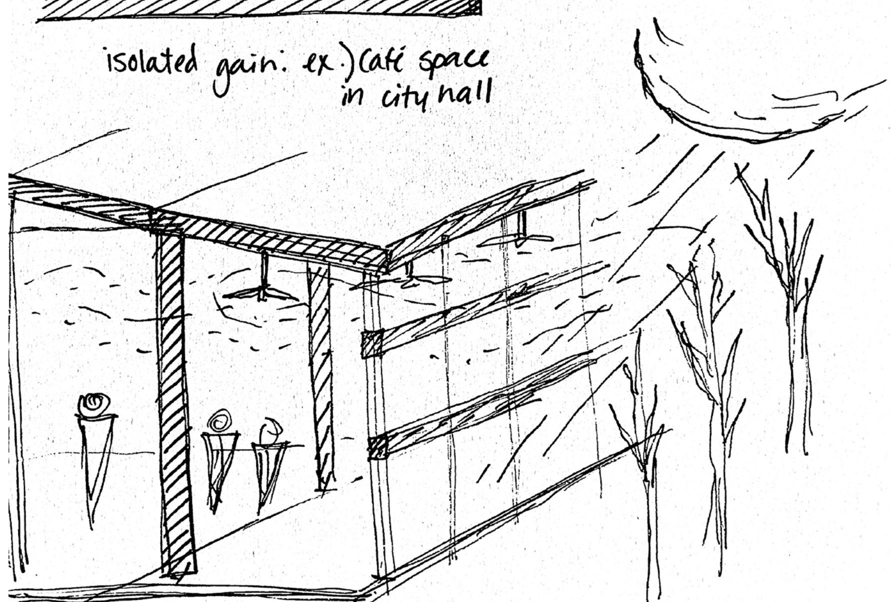
# FINAL PROJECT

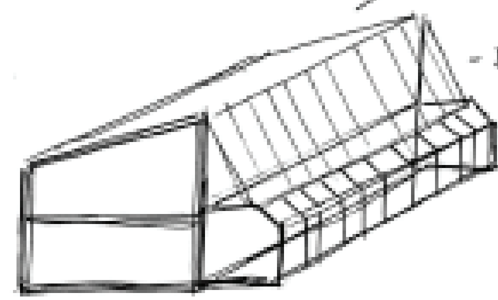
OLIVIA WEBSTER
BEN MARTINEZ

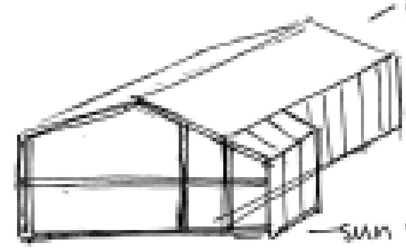
## Design Intent

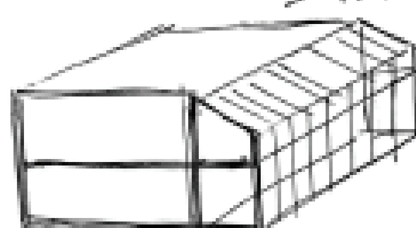
- Maintain a level of thermal comfort throughout the heating season.
- Create spaces with unique thermal and light conditions.
- Use different passive heating design types as ways to organize space in the building.
- Create night insulation that is easy to use and intuitive.
- Select the correct window type, sizing, placement, and tilt.
- Create areas of thermal delight, for users to experience contrast between hot and cold.
- Use different passive heating techniques in different areas of the buildings to address user types and needs, such as no glare in the workspaces.

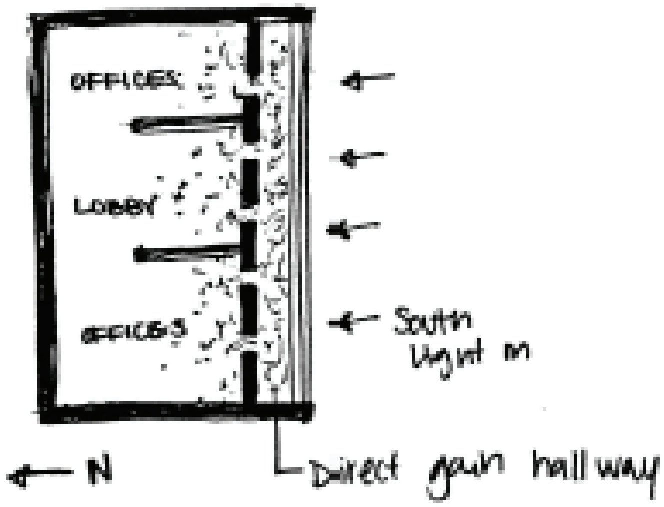

isolated gain: ex.) café space
in city hall

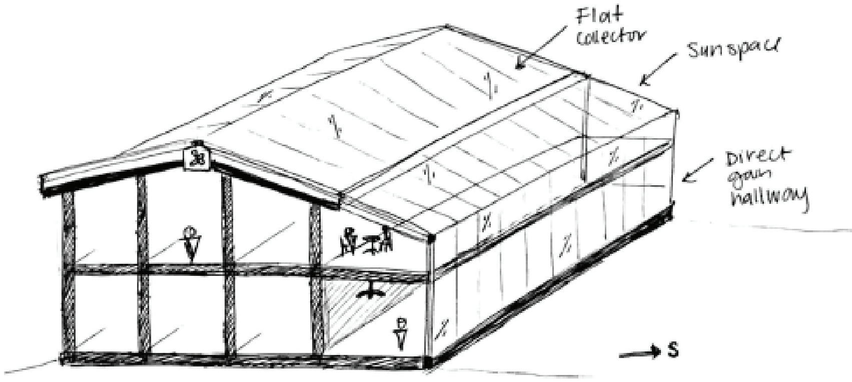

Direct gain:
ex.) circulation space with
fans to circulate warm air

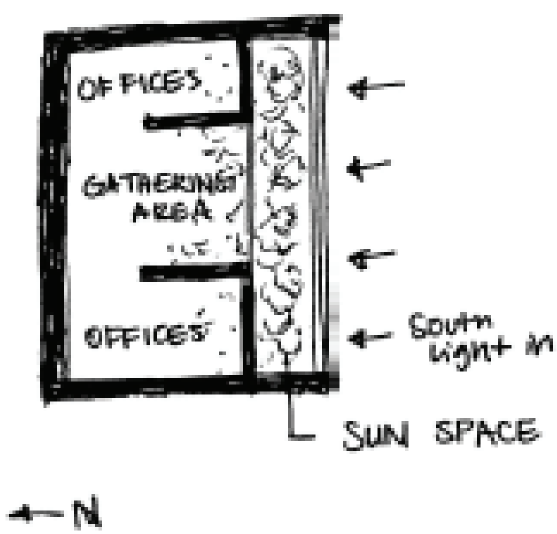

Flat collector
Direct gain
Sun space

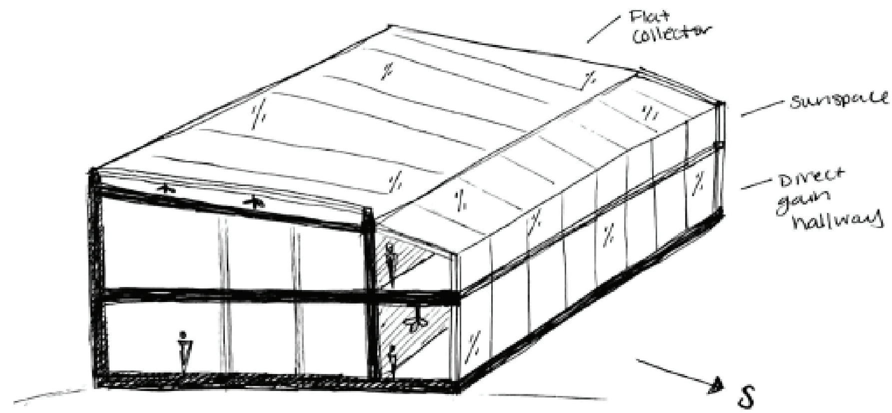

Flat collector
Direct gain
Sun space

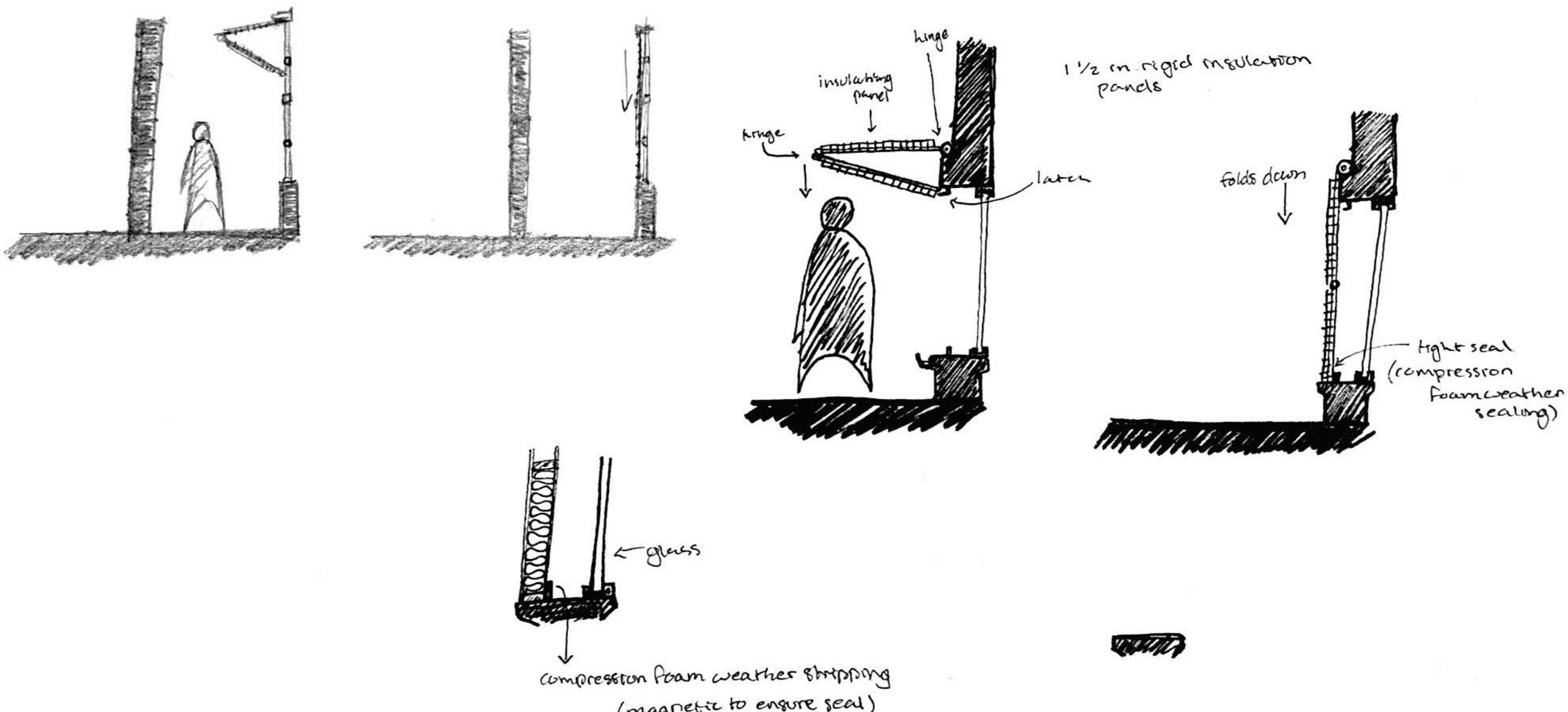

flat collector
sun space
Direct gain


OFFICES
LOBBY
OFFICES
South light in
Direct gain hallway
N


Flat collector
Sunspace
Direct gain hallway
S

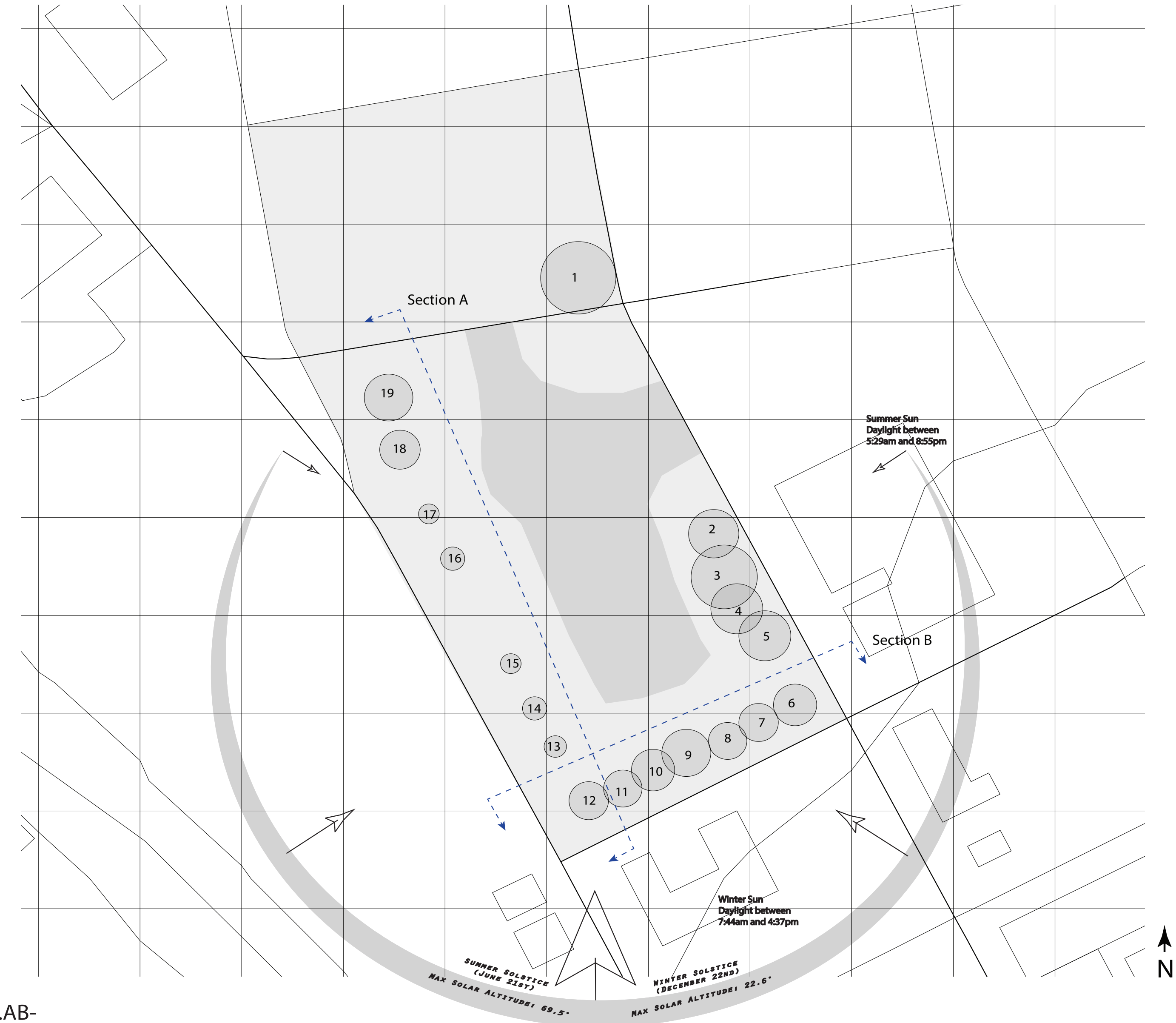

OFFICES
GATHERING AREA
OFFICES
South light in
SUN SPACE
N


Flat collector
Sunspace
Direct gain hallway
S


hinge
insulating panel
hinge
latch
1 1/2 in. rigid insulation panels
folds down
tight seal (compression foam weather sealing)
glass
compression foam weather stripping (magnetic to ensure seal)

Solar Site Survey

## SITE PLAN:




USA_OR_Salem.Muni.AB-McNary.Field.726940_TMYx.2004-2018,climate.onebuilding.org

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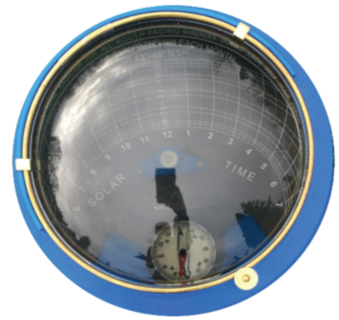
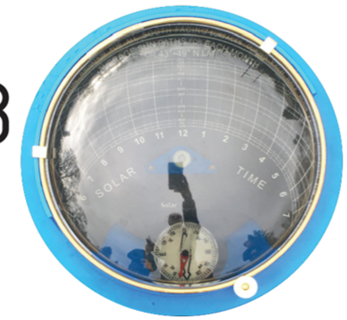
1.) Position on the site

Our Pathfinder photos point to the middle of the site, slightly to the west and south of the actual center, as having the greatest solar exposure. Large trees occupy the northwest, east, and southeast edges of the site. These trees limit solar exposure on the east and south portions of the site, while only small trees exist to the west side of the site. These are newer trees however, so it would be best to push the site slightly to the center to account for future growth. The final chosen position on the site is #13.

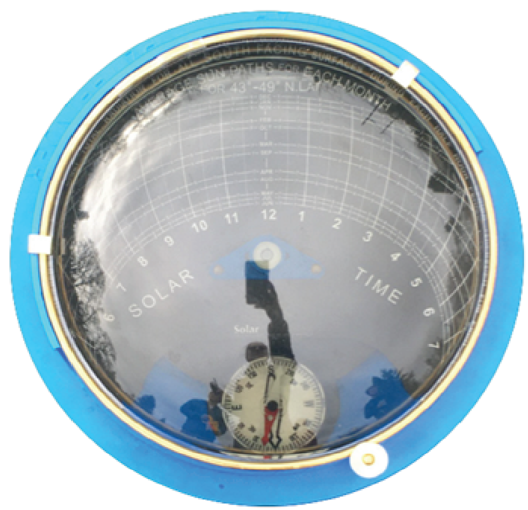
1 2

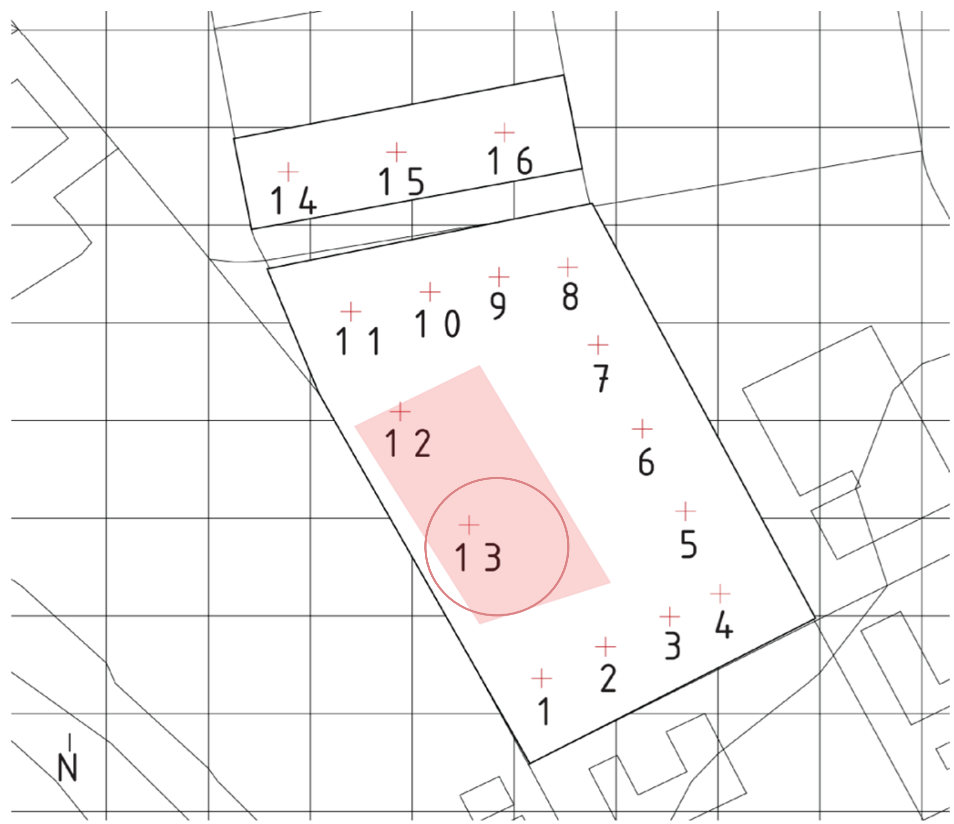


1 3

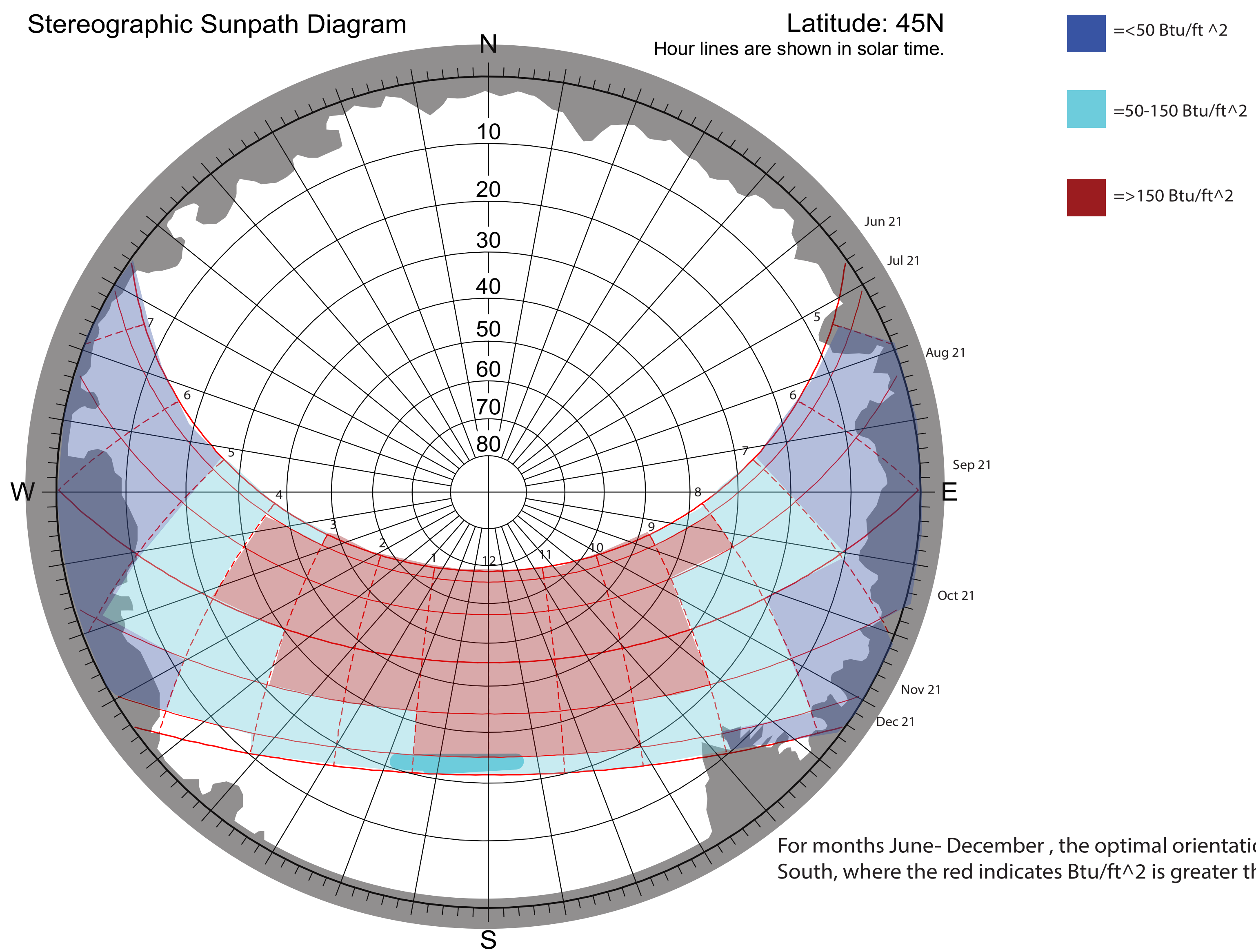


1 3





# Optimal Collector orientation




For months June- December , the optimal orientation is South, where the red indicates Btu/ft^2 is greater than 150.

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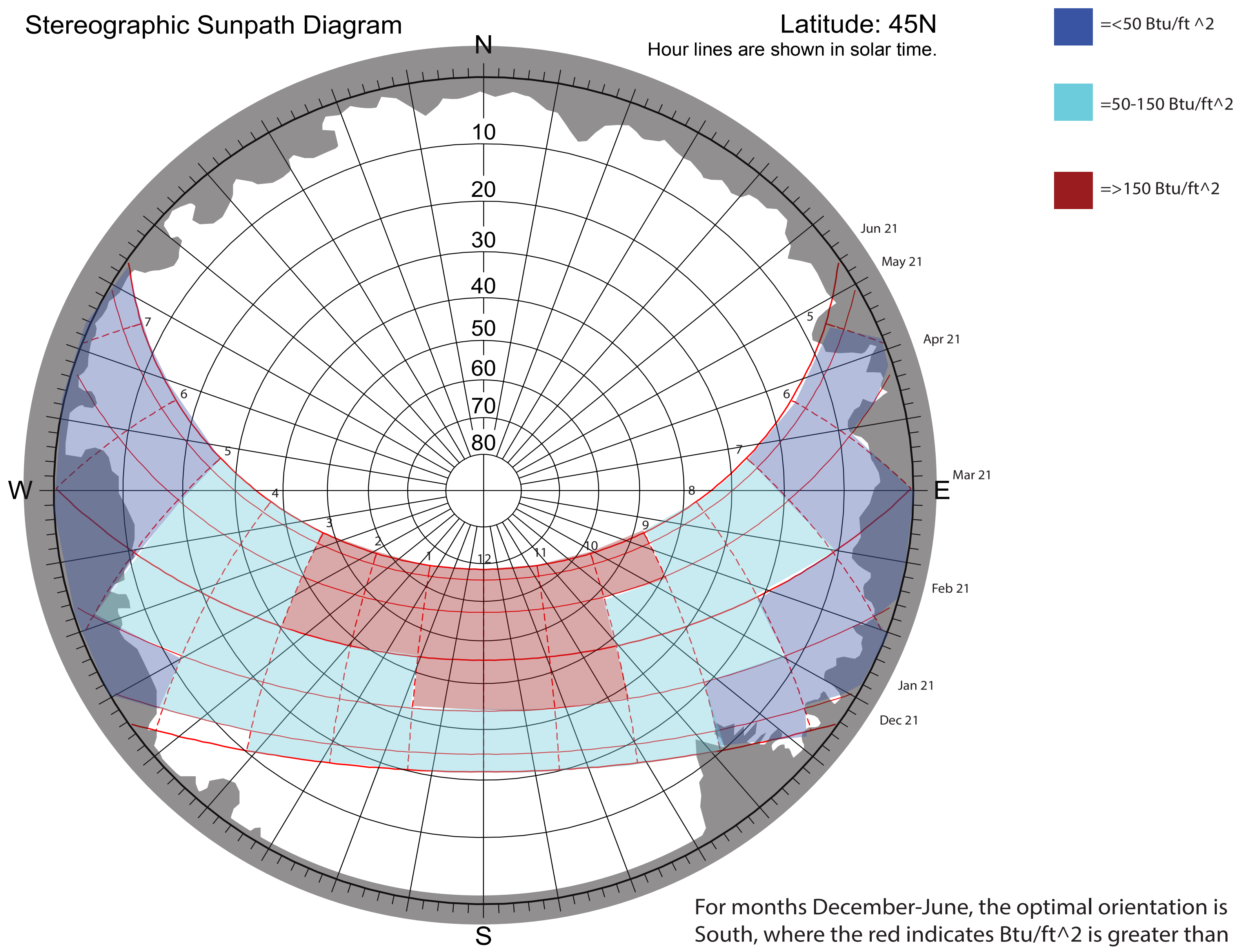


For months December-June, the optimal orientation is South, where the red indicates Btu/ft^2 is greater than 150.

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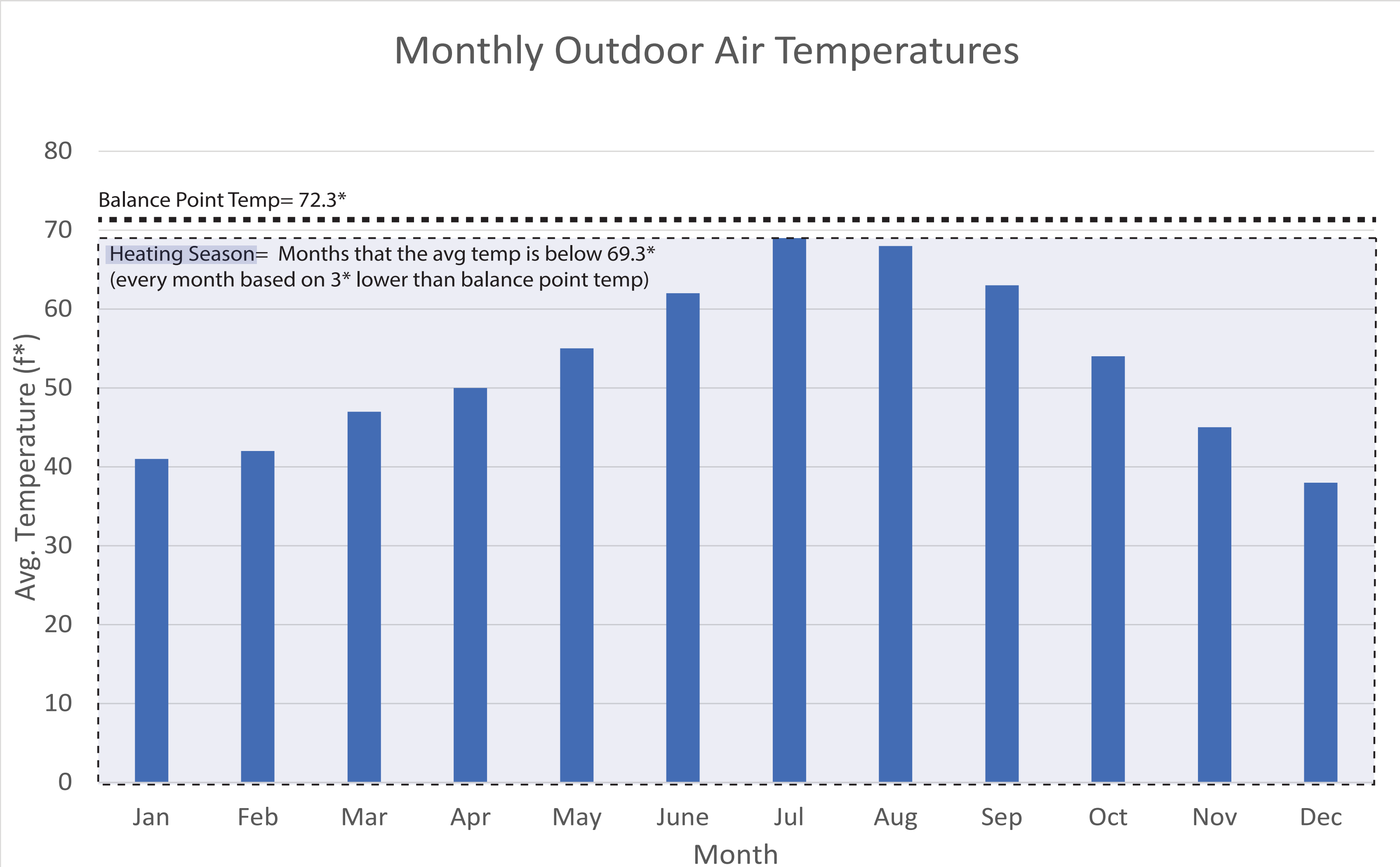
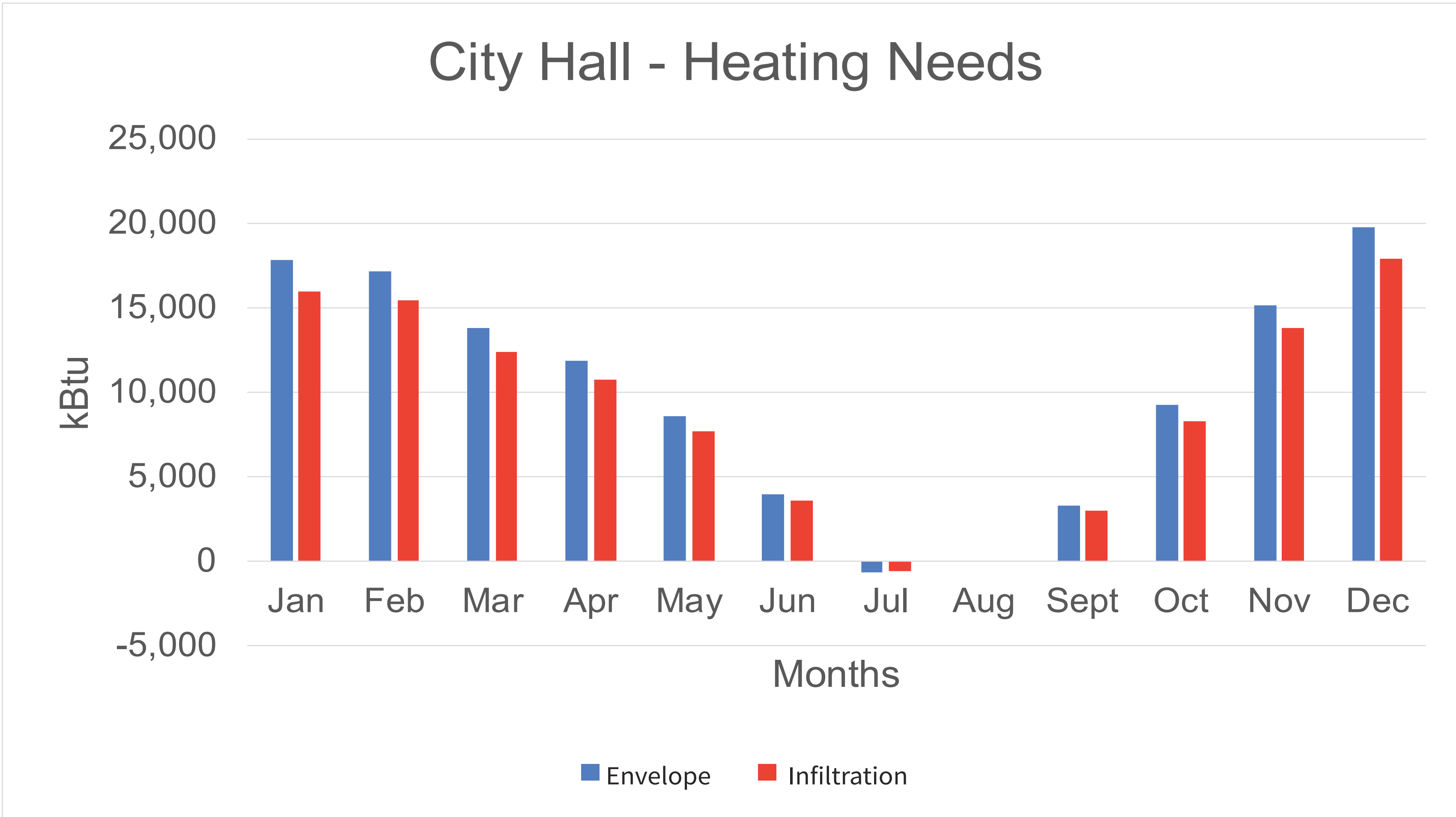
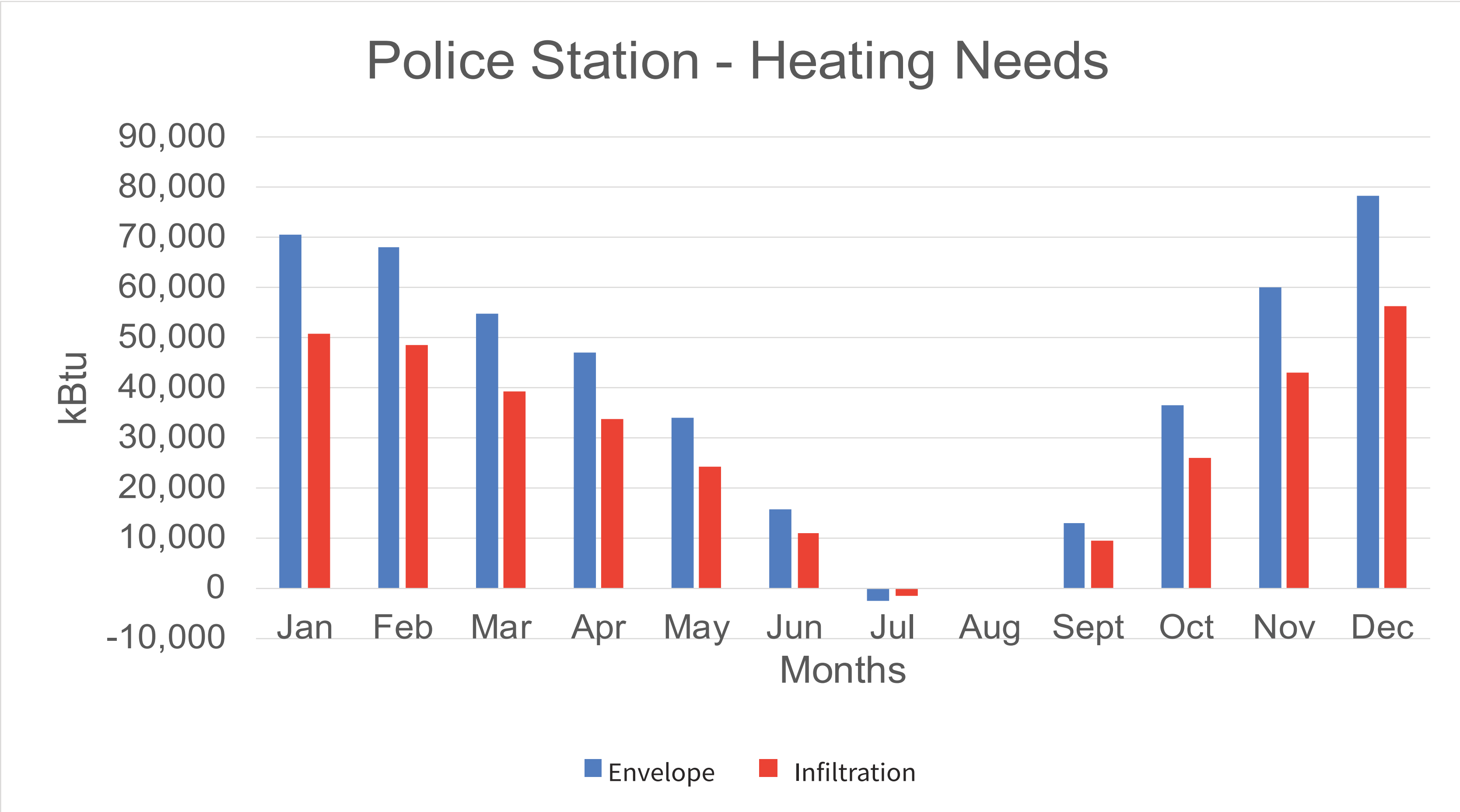
## Balance Point Temperature:

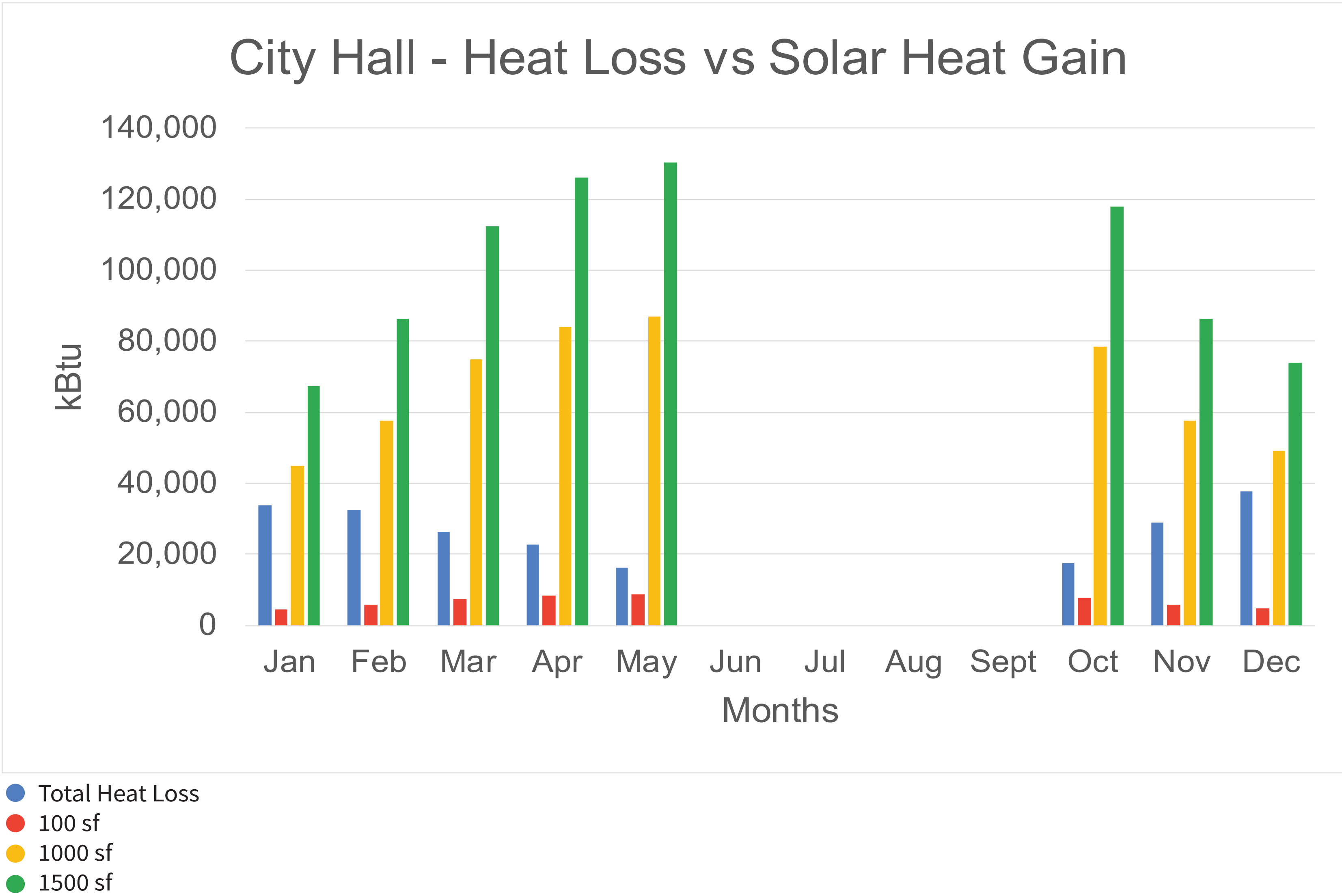
The outdoor air temperature at which total heat gains equal total heat losses. Allows one to estimate the heating season as months that are 2 to 3 degrees cooler than the balance point temperature.






ASHRAE Standards 90.1-2016: Energy Standard for Buildings Except Low-Rise Residential Buildings, Table 5.5-4 pg. 55


Police Station - Heating Needs
kBtu
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
-10,000
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sept
Oct
Nov
Dec
Months
Envelope
Infiltration

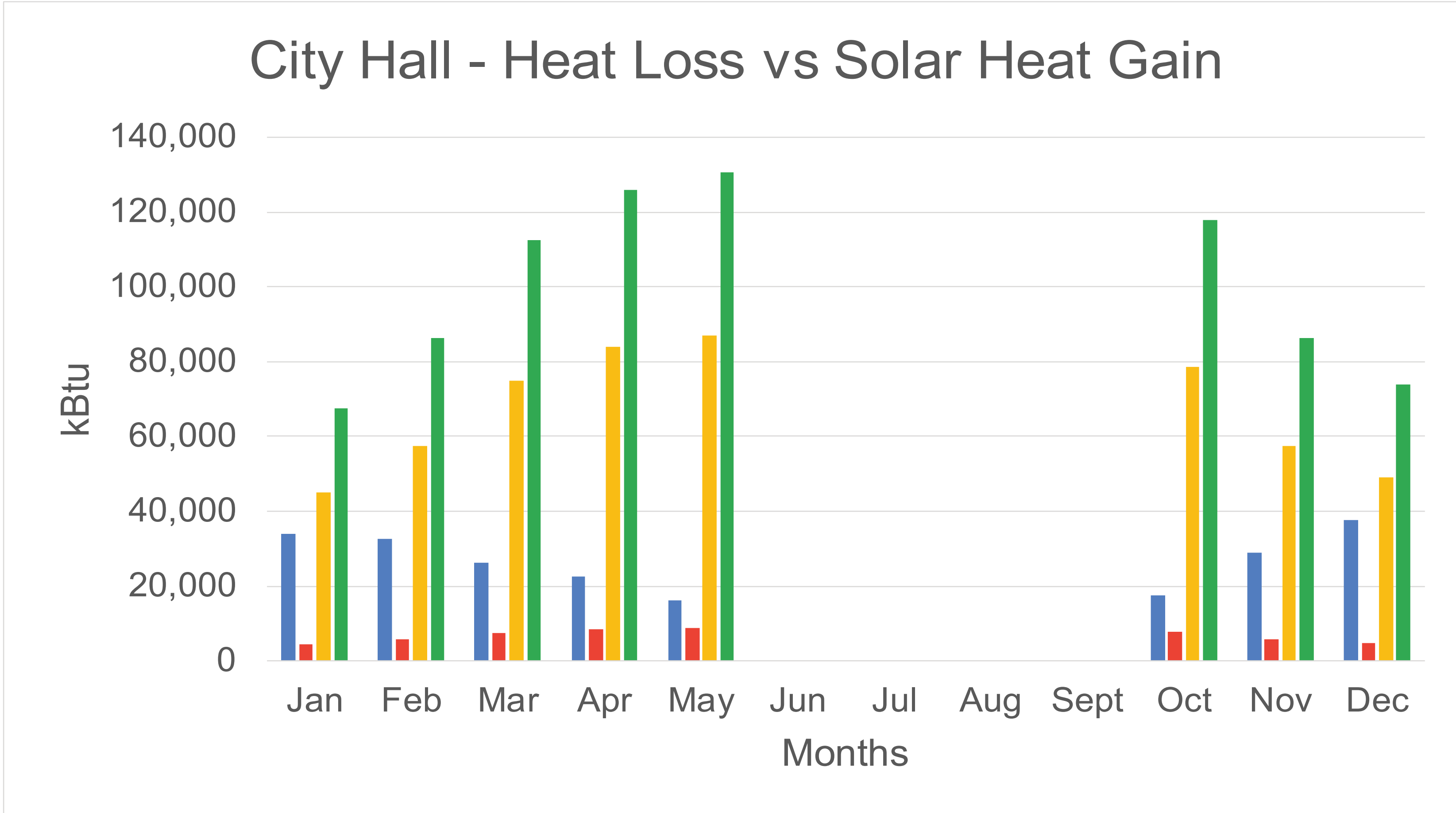

City Hall - Heat Loss vs Solar Heat Gain
kBtu
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sept
Oct
Nov
Dec
Months
Total Heat Loss
100 sf
1000 sf
1500 sf

| Months | Avg Monthly Temperature | Envelope Heat Los | Infiltration Heat Loss | Internal Heat Ga |
|---|---|---|---|---|
| Jan | 41 | 17,802 | 16,008 | 18,584 |
| Feb | 42 | 17,143 | 15,456 | 18,584 |
| Mar | 47 | 13,846 | 12,420 | 18,584 |
| Apr | 50 | 11,868 | 10,764 | 18,584 |
| May | 55 | 8,571 | 7,728 | 18,584 |
| Jun | 62 | 3,956 | 3,588 | 18,584 |
| Jul | 69 | -659 | -552 | 18,584 |
| Aug | 68 | 0 | 0 | 18,584 |
| Sept | 63 | 3,296 | 3,036 | 18,584 |
| Oct | 54 | 9,231 | 8,280 | 18,584 |
| Nov | 45 | 15,165 | 13,800 | 18,584 |
| Dec | 38 | 19,780 | 17,940 | 18,584 |



ASHRAE Standards 90.1-2016: Energy Standard for Buildings Except Low-Rise Residential Buildings, Table 5.5-4 pg. 55

Grondzik, Walter T., and Alison G. Kwok. Mechanical and Electrical Equipment for Buildings. 13th ed., John Wiley & Sons, Incorporated, 2019.




- Total Heat Loss
- 100 sf
- 1000 sf
- 1500 sf

Since solar heat gain only needs to cover approximately one-third of total heat loss due to this space being a workplace, around 1000 square feet meets the building's heating needs on most months. Therefore, approximately 500 square feet of skylighting meets half of the need, and around 100 meets 10% of the total need.

| Months | Average Temperatu | Envelope Heat Los | Infiltration Heat Loss | Internal Heat Ga |
|---|---|---|---|---|
| Jan | 41 | 70,554 | 50,784 | 36,984 |
| Feb | 42 | 67,942 | 48,576 | 36,984 |
| Mar | 47 | 54,876 | 39,192 | 36,984 |
| Apr | 50 | 47,036 | 33,672 | 36,984 |
| May | 55 | 33,970 | 24,288 | 36,984 |
| Jun | 62 | 15,678 | 11,040 | 36,984 |
| Jul | 69 | -2,652 | -1,656 | 36,984 |
| Aug | 68 | 0 | 0 | 36,984 |
| Sept | 63 | 13,064 | 9,384 | 36,984 |
| Oct | 54 | 36,584 | 25,944 | 36,984 |
| Nov | 45 | 60,102 | 43,056 | 36,984 |
| Dec | 38 | 78,394 | 56,304 | 36,984 |

## Citations:

Grondzik, Walter T., and Alison G. Kwok. Mechanical and Electrical Equipment for Buildings. 13th ed., John Wiley & Sons, Incorporated, 2019.

ASHRAE 90.1- 2016, Table 9.5.1

2016 NREL Plug Loads document, Table 3-2

# Solar Collecting Glass

## Collector Tilt

| Solar Radiation (kBtu/sqft) on a surface of a tilt: | 70° | 60° | 50° | 40° | 30° |
|---|---|---|---|---|---|
| Month: | | | | | |
| Oct | 32 | 34 | 34 | 33 | 32 |
| Nov | 19 | 19 | 19 | 19 | 18 |
| Dec | 19 | 19 | 18 | 17 | 16 |
| Jan | 21 | 21 | 20 | 20 | 18 |
| Feb | 25 | 26 | 26 | 25 | 24 |
| Mar | 35 | 37 | 37 | 38 | 37 |
| Apr | 35 | 38 | 40 | 41 | 42 |
| May | 40 | 45 | 49 | 52 | 54 |
| Total: | 226 | 239 | 243 | 245 | 241 |

From Previous lab:
Balance Point Temperature: 58.7 °F
Heating Season: October - May

According to Meeb Apendix I;
the Solar degree tilt of 40* had the highest solar gain
over the totality of the heating season.

<u>Optimal Tilt: 40° above the horizontal</u>

:
Grondzik, Walter T., and Alison G. Kwok. Mechanical and Electrical Equipment for Buildings. 13th ed., John Wiley & Sons, Incorporated, 2019.
Apendix I, Table I.1, Eugene Or.

## Glass choice

Fibertec Window

Triple glazed glass

Argon/Krypton

U-factor: <0.22

SHGC: 0.41 - 0.60

VT = 0.41-0.50

Window found from : Efficient Windows Collaborative
Manufactures of Window 18

This window was selected because it had the highest SHGC Value, while having a relatively low U-Value in comparrison to the high SHGC. This combination allows for more solar heat gain through the window due to the transmittance from the high SHGC, while the low U-factor
reduces the amount of heat loss through the window.

Additionally, the argon and Krypton gas in between the three panes of glass helps with
insulation.

## Sizing

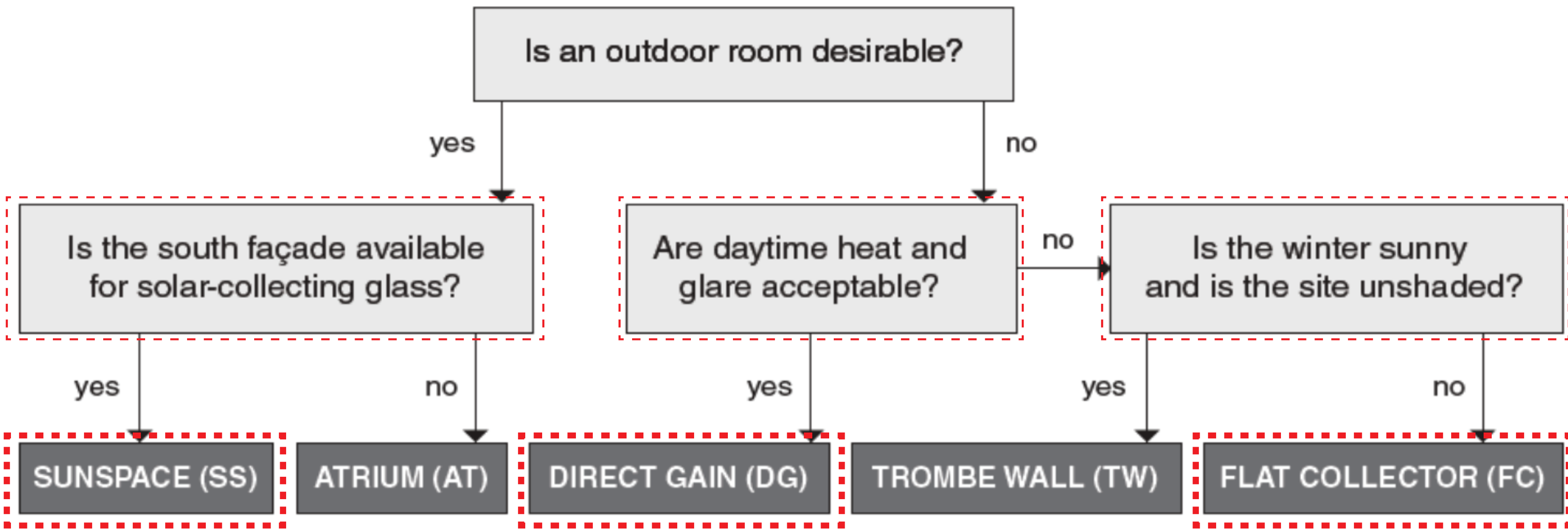
| Month: | Envelope Heat Loss: (Btu/h) | Monthly Solar Heat Gain (Btu/h*sf) | 100 sf | 1000 sf | 1500 sf |
|---|---|---|---|---|---|
| Oct | 128,590 | 78.6 | 7,860 | 78,600 | 117,900 |
| Nov | 211,255 | 57.6 | 5,760 | 57,600 | 86,400 |
| Dec | 275,550 | 49.2 | 4,920 | 49,200 | 73,800 |
| Jan | 247,995 | 45 | 4,500 | 45,000 | 67,500 |
| Feb | 238,810 | 57.6 | 5,760 | 57,600 | 86,400 |
| Mar | 192,885 | 75 | 7,500 | 75,000 | 112,500 |
| Apr | 165,330 | 84 | 8,400 | 84,000 | 126,000 |
| May | 119,405 | 87 | 8,700 | 87,000 | 130,500 |

## System Types

While an atrium works well in a situation where the south facade may be un-available to glazing, south glazing is available for this project so we're focusing more on other system types. We believe indirect gain by using a trombe wall is the least effective system type for this project. While a trombe wall system is less prone to overheating, it also provides less opacity, less heat delivery, and less control over heating. Alternatively, a direct gain heating system provides rapid heating to the living space.

Unfortunately, a direct gain system can result in glare and overheating in the main occupied space, which is undesirable for a work-space. This can be mitigated by making the direct gain space primarily circula-tion and lobby space. The next heating system, using a sunspace, provides a de-sirable outdoor room and allows for easy heat delivery. The main disadvantage, rapid heat loss at night, matters very little to a workspace. Flat collector systems have a similar disadvantage, while also providing rapid, easily distributed, low-glare heating. We believe primarily focusing on flat collectors and sunspac-es, with direct gain circulation spaces, will be the most effective combination of systems for this site.

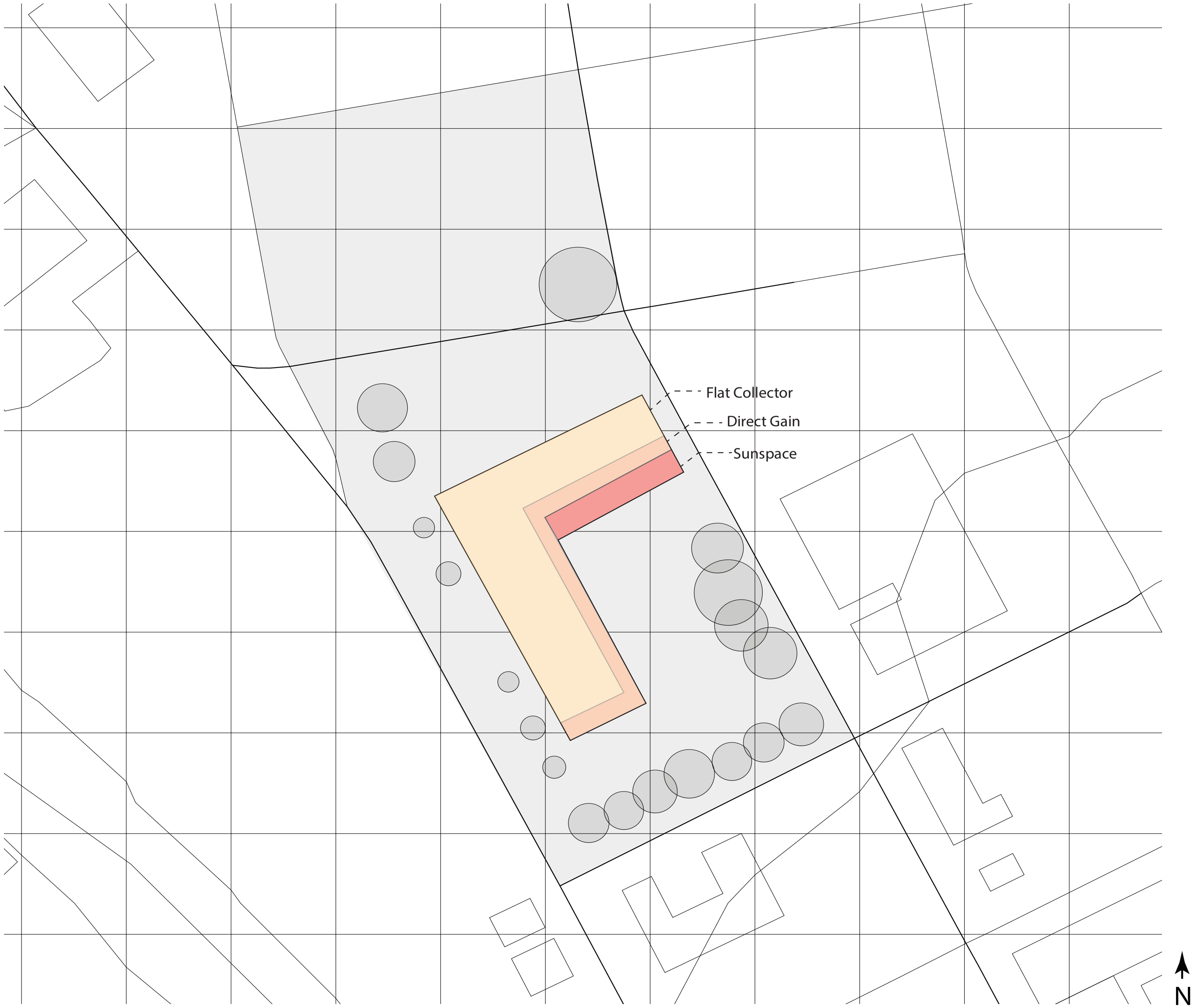
# How to choose passive heating system type:






Grondzik, Walter T., and Alison G. Kwok. Mechanical and Electrical Equipment for Buildings. 13th ed., John Wiley & Sons, Incorporated, 2019.

# Configuration vision

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# Thermal Mass Proposal

- Passive heating system that releases heat during the work day hours, especially in the afternoon.

- No glare created for the workers.

- Good acoustic qualities for the workspace.

- The different space types include the lobby, offices, café spaces, circulation areas and hallways, and community gathering spaces.

- Use thermal mass to differentiate between program spaces in the building.

- The wall separating our direct gain circulation spaces from the offices would make a good thermal mass, to distribute heat to the offices.

- Combination of floor thermal massing with vertical walls placed directly next to solar collecting sun spaces.

- Make the floor a thin thermal mass material that is completely insulated.

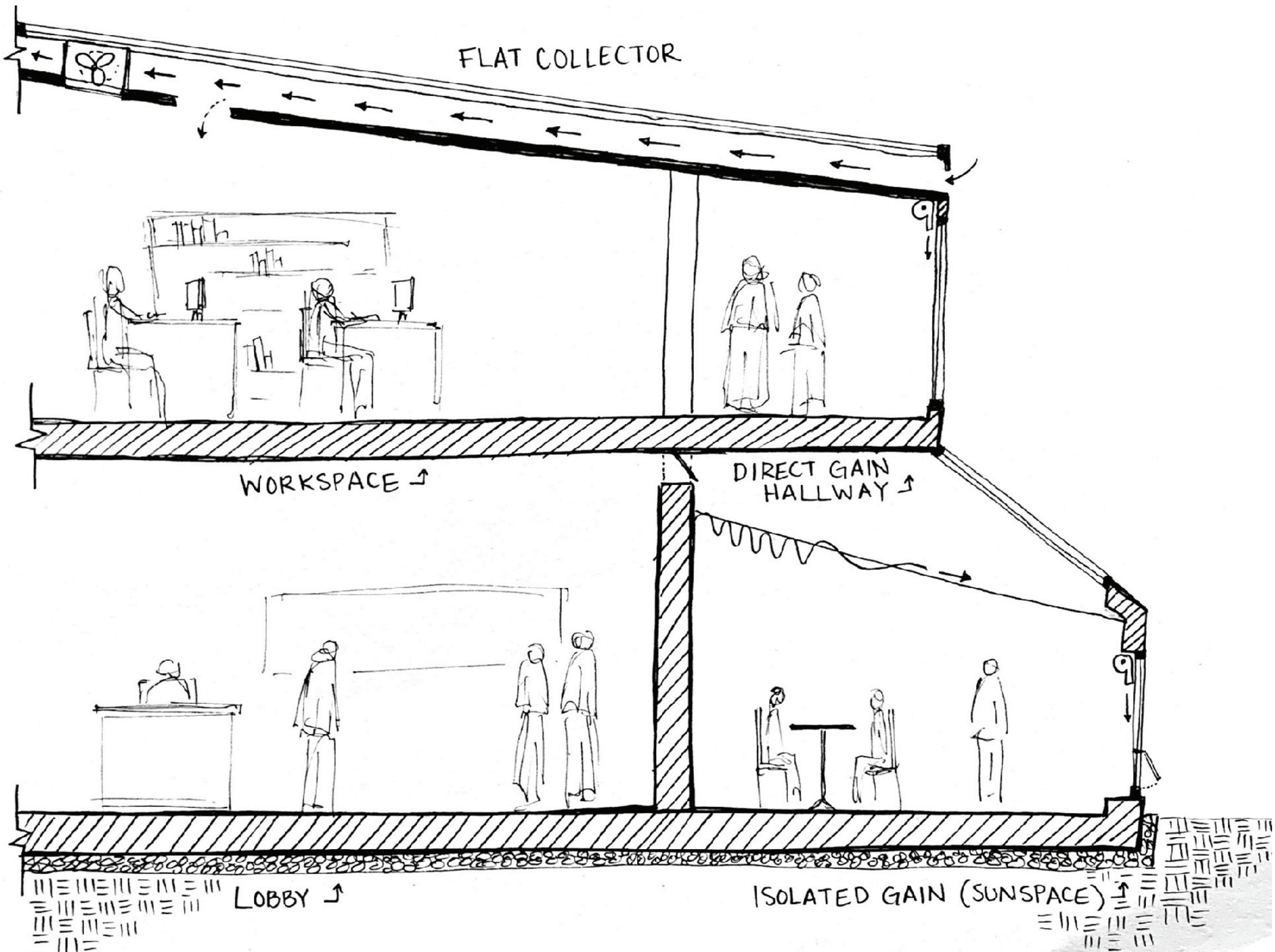
- We want the heat to stored and released quickly back to the building spaces, since it is a work environment and the offices are primarily occupied during the mid-day and afternoon.

A thermal mass which is much higher than surrounding space is more desirable for a workplace, as it will release heat rapidly and warm during the busiest times of the day.

| Mass Material | Density (lb/ft3) | Specific heat capacity: cp (Btu/lb*F)) | Volumetric heat capacity (Btu/cu.ft-*F) | Absorb Factor | Thermal Conductivity (Btu/(fthF)) |
|---|---|---|---|---|---|
| Granite | 140 | 0.189 | 38 | 0.55 | 0.982-2.31 |
| Concrete | 140 | 0.21 | 28 | 0.60 | 0.231-0.405 |

1,036,800 Btu (0.55)= 570,240 Btu
115*F-64*F=51*F
((1/0.189 Btu/lb*F) (570,240 Btu))/ 51*F= 59,160 lb
59,160 lb (1/140 lb/ft^3)=422 ft^3/1500 ft^2= 0.281 ft = 3.5 in

1,036,800 Btu (0.6)= 622,080 Btu
115*F-64*F=51*F
((1/0.21 Btu/lb*F) (622,080 Btu))/ 51*F= 58,084 lb
58,084 lb (1/140 lb/ft^3)=415 ft^3/1500 ft^2= 0.277 ft = 3.5 in

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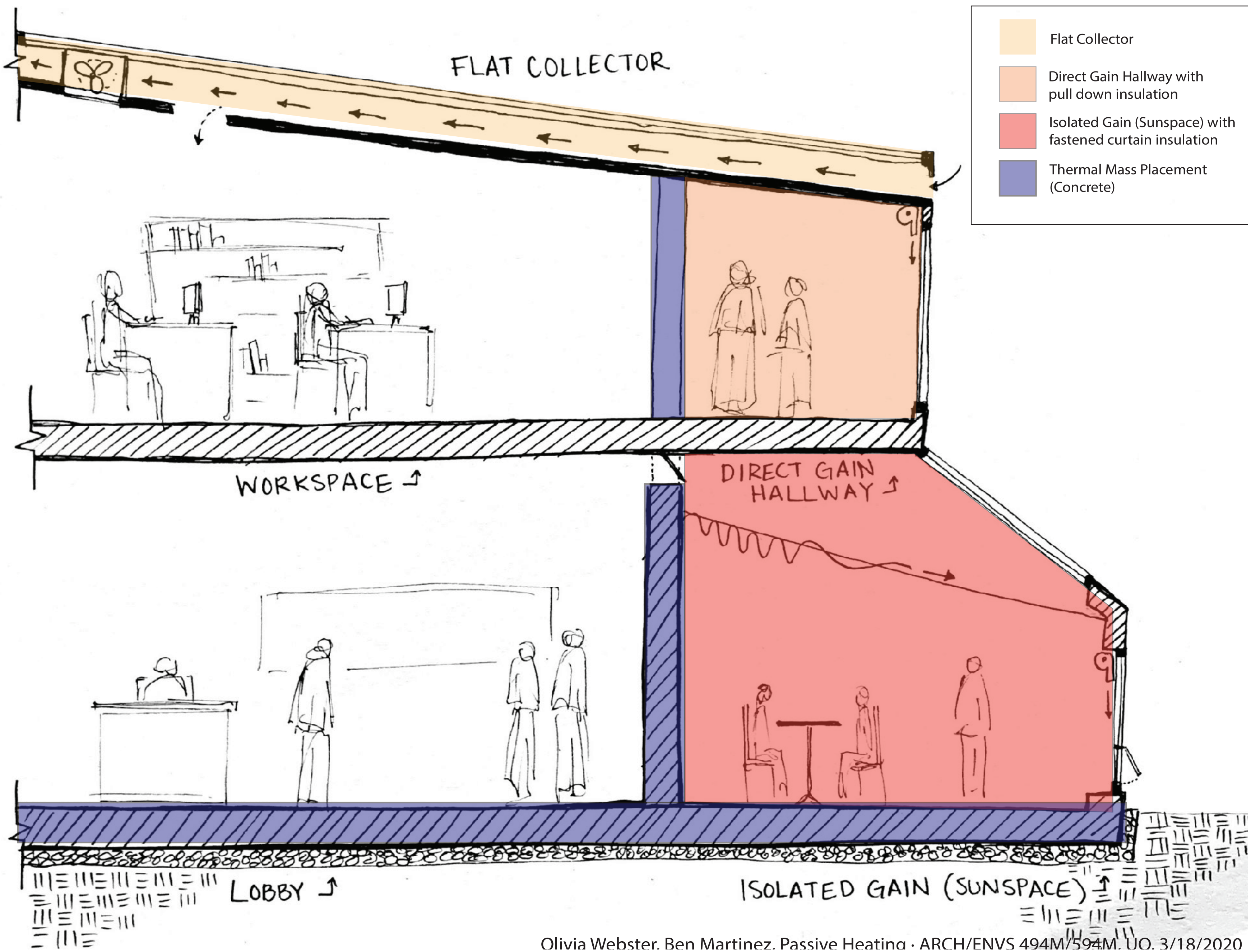



Olivia Webster, Ben Martinez, Passive Heating · ARCH/ENVS 494M/594M, UO, 3/18/2020

## Conclusions

-Position the building on the site in a way that optimizes potential solar heat gain, by placing it in a central location free from obstructions and with plenty of southern exposure.

-Use plenty of tilted glazing, approximately 1500 to 1700 square feet, to offset heat losses during colder months.

-Utilize several passive heating system types, to best optimize the advantages of each system.

-Apply moveable insulation during the midafternoon, and remove in the morning, to reduce heat losses during the evening.

-Fully insulate thermal mass in the floor, to prevent heat loss.

Sources:

Grondzik, Walter T., and Alison G. Kwok. Mechanical and Electrical Equipment for Buildings. 13th ed., John Wiley & Sons, Incorporated, 2019.

ASHRAE 90.1- 2016, Table 9.5.1

2016 NREL Plug Loads document, Table 3-2

https://windows.lbl.gov/software/window

Efficient Windows Collaborative: https://www.efficientwindows.org/manu_products.php?mfgID=2722&id=68&windID=18&city=Des%20Moines&state=Iowa&houseType=2story&prodType=WN&new=N

# Appendix D

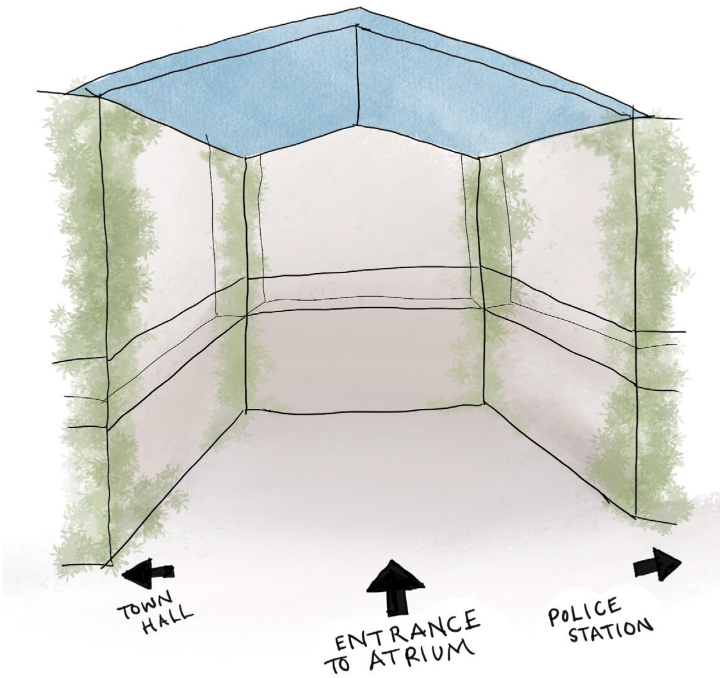
## Summer and Emily

# PASSIVE DESIGN STRATEGIES
# SILVERTON, OR

Summer Putman and Emily Fox / ARCH 494 / Winter 2020

# 1.

# DESIGN INTENT



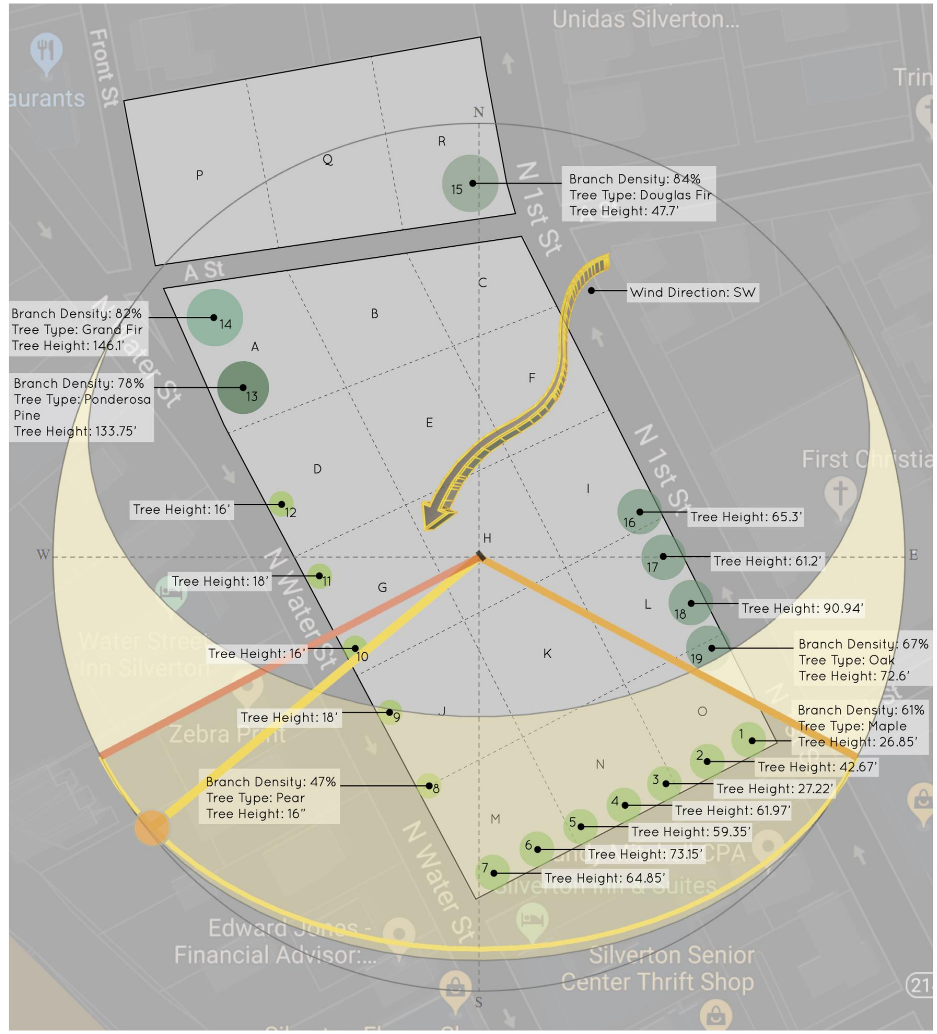

- The town hall and police department spaces will be one single building with a large central point (atrium) for entrance, meetings, and events

- The central sunny atrium space filled with light and plants as a community space will create a wonderful entrance and function as solar collection for the whole building.

- For occupied work spaces, a flat collector will function to provide heat

# 2.

# SOLAR SITE SURVEY



# 2.

# SOLAR SITE SURVEY


Position A


Position B


Position C


Position J


Position K


Position L


Position S


Oak Trees #16-19
Branch Density: 67%


Position D


Position E


Position F


Position M


Position N


Position O


Pear Trees #8-12
Branch Density: 47%

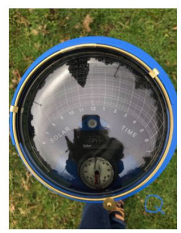

Oak Trees #16-19
Branch Density: 67%


Position G


Position H


Position I

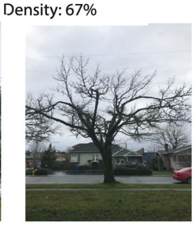

Position P


Position Q


Position R

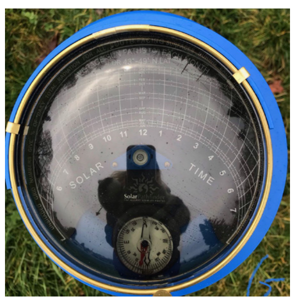

Oak Trees #16-19
Branch Density: 66%

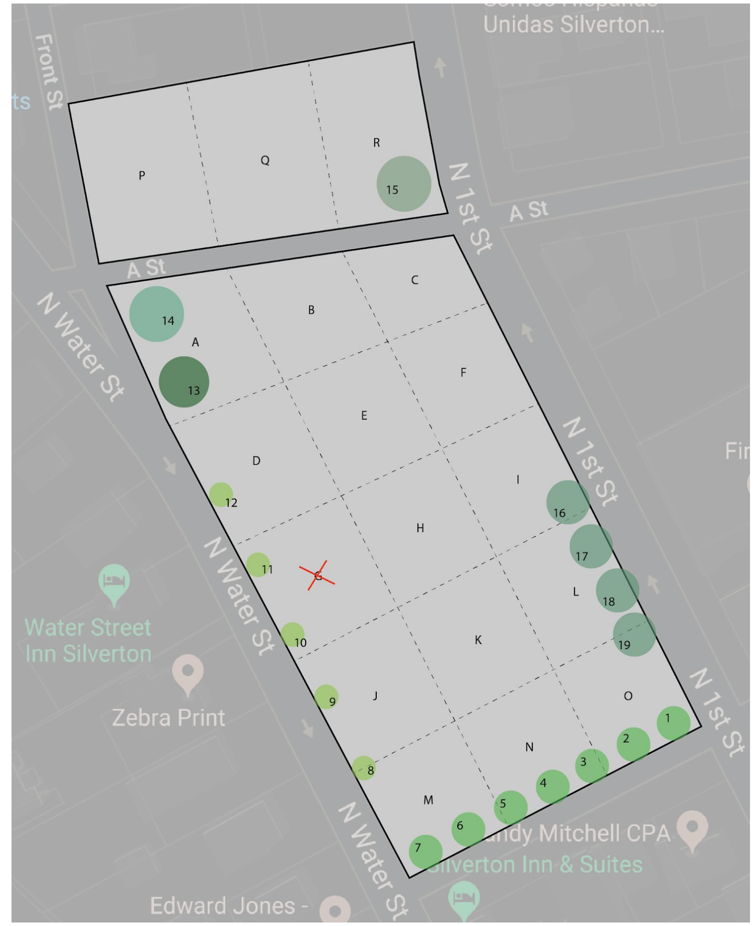

Douglas Fir Tree #15
Branch Density: 84%


Maple Trees #1-7
Branch Density: 61%

# 2.
# SOLAR SITE SURVEY

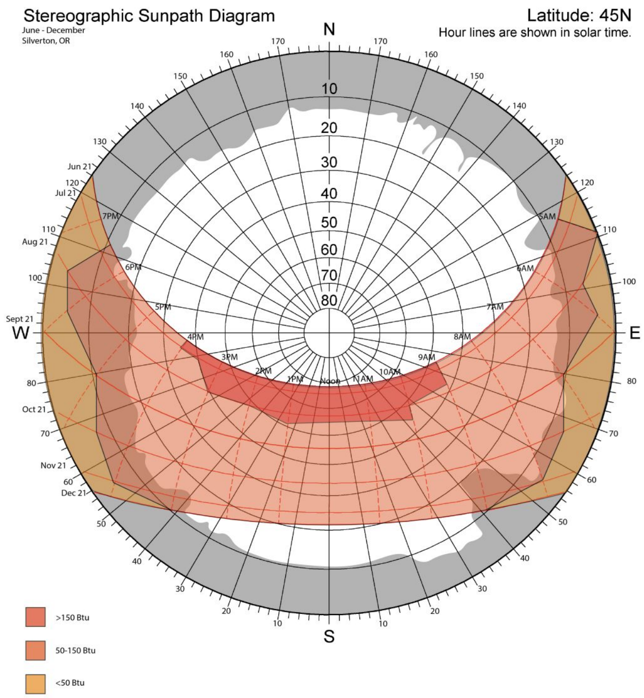
- According to the solar pathfinder images, polision G has the greatest amount of solar exposure. There is also good sun exposure in the D, E, H, K and J sections so any building placed in that area will have good opportunities for solar exposure.



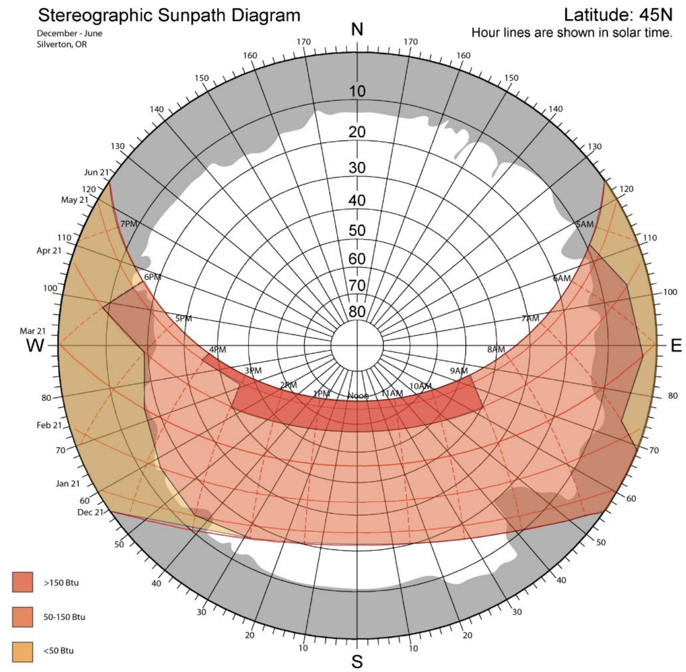



# 2.

# SOLAR SITE SURVEY



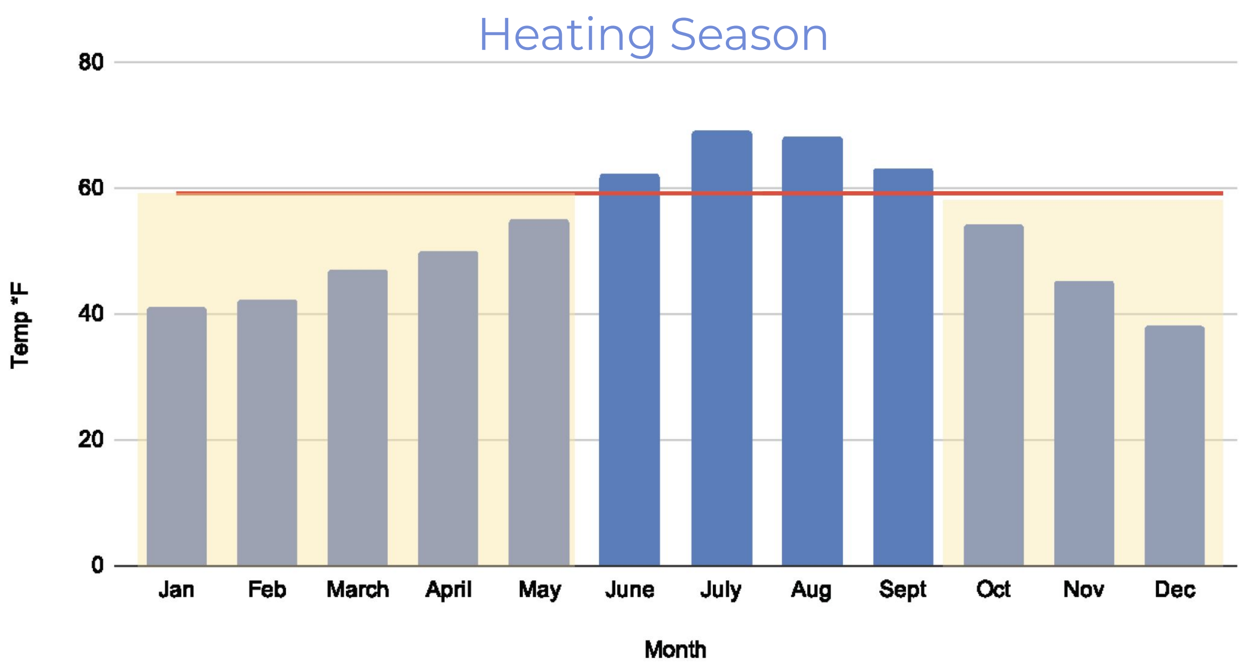

Optimal orientation: South




Optimal orientation: South

# 3.

# BUILDING HEAT LOSS




File: USA_OR_Salem-McNary.Field.726940_TMY

# 3.

# BUILDING HEAT LOSS

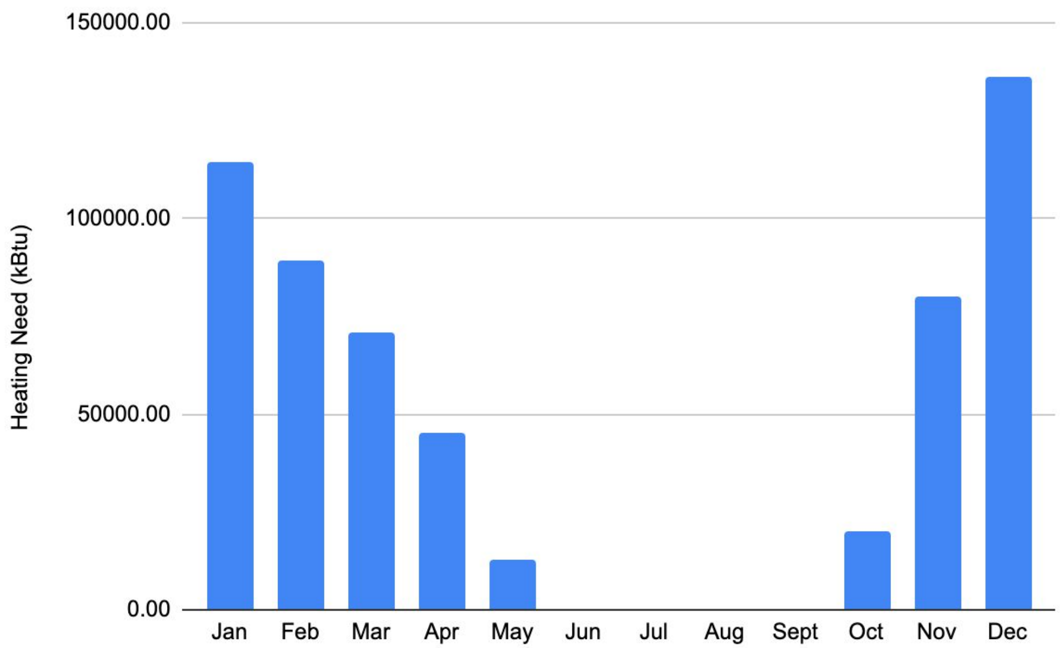
Comparison for sizing: CITY HALL

| Month | Monthly average air temperature (F) | Monthly envelope heat loss (kBtu) | Monthly infiltration heat loss (kBtu) | Monthly internal heat gain (kBtu) | Net heat loss (kBtu) |
|---|---|---|---|---|---|
| Jan | 41 | 71945.57 | 124043.70 | 81325.00 | 114664.27 |
| Feb | 42 | 62576.32 | 107889.86 | 81325.00 | 89141.18 |
| Mar | 47 | 55957.67 | 96478.43 | 81325.00 | 71111.10 |
| Apr | 50 | 46416.50 | 80028.19 | 81325.00 | 45119.69 |
| May | 55 | 34640.46 | 59724.74 | 81325.00 | 13040.20 |
| Jun | 62 | 15472.17 | 26676.06 | 81325.00 | 0.00 |
| Jul | 69 | -2664.65 | -4594.21 | 81325.00 | 0.00 |
| Aug | 68 | 0.00 | 0.00 | 81325.00 | 0.00 |
| Sept | 63 | 12893.47 | 22230.05 | 81325.00 | 0.00 |
| Oct | 54 | 37305.11 | 64318.96 | 81325.00 | 20299.07 |
| Nov | 45 | 59309.97 | 102258.25 | 81325.00 | 80243.22 |
| Dec | 38 | 79939.53 | 137826.33 | 81325.00 | 136440.86 |
| Total | -- | -- | -- | -- | 570059.59 |

*Grondzik, Walter T., and Kwok, Alison G. Mechanical and Electrical Equipment for Buildings. Thirteenth ed. Hoboken, New Jersey: John Wiley & Sons, 2019*

# 3.

# BUILDING HEAT NEED



# 3.

# BUILDING HEAT LOSS

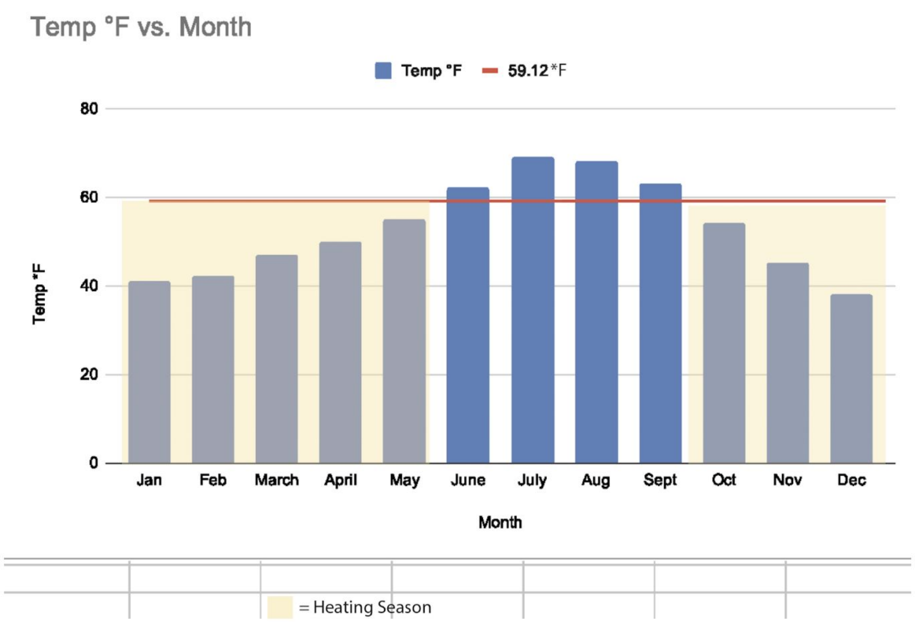
- BALANCE POINT TEMPERATURE

| | | | | | | |
|---|---|---|---|---|---|---|
| Part 4: Balance point temp and heating season | | | | | | |
| | | | | | | |
| q internal = q external | in BTU/h | | | | | |
| internal q (BTU/h) | | Envelope q | | | infiltation q | |
| 386799.22 | = | 32173.83444 | x change in T | + | 11369.74033 | x change in T |
| 386799.22 | = | 43543.57477 | x change in T | | | |
| Change in T | = | 8.883037786 | | | | |
| | | | | | | |
| Balance Point Temp= | 68-(change in T) = | 59.12 | | | | |
| | | | | | | |
| Heating degree days | | | | | | |
| Month | Temp °F | BPT °F | difference | days in month | HDD per month | |
| Jan | 41 | 59.12 | 18.12 | 31 | 561.63 | |
| Feb | 42 | 59.12 | 17.12 | 29 | 496.39 | |
| March | 47 | 59.12 | 12.12 | 31 | 375.63 | |
| April | 50 | 59.12 | 9.12 | 30 | 273.51 | |
| May | 55 | 59.12 | 4.12 | 31 | 127.63 | |
| June | 62 | 59.12 | -2.88 | 30 | | |
| July | 69 | 59.12 | -9.88 | 31 | | |
| Aug | 68 | 59.12 | -8.88 | 31 | | |
| Sept | 63 | 59.12 | -3.88 | 30 | | |
| Oct | 54 | 59.12 | 5.12 | 31 | 158.63 | |
| Nov | 45 | 59.12 | 14.12 | 30 | 423.51 | |
| Dec | 38 | 59.12 | 21.12 | 31 | 654.63 | |
| | | | Heating Season | | | |
| Heating season- October through May (8 months) | | | | | | |

# 4.

# SOLAR COLLECTING GLASS

- OPTIMAL GLAZING TILT - 55 degrees above the horizon




Incident Solar Radiation on Tilted Surface
MEEB ed. 131 Appendix I - location Portland, OR

| Month | D65 | 60° | 50° |
|---|---|---|---|
| Oct | 315 | 34 | 34 |
| Nov | 551 | 19 | 19 |
| Dec | 763 | 19 | 18 |
| Jan | 732 | 21 | 20 |
| Feb | 594 | 26 | 26 |
| Mar | 522 | 37 | 38 |
| Apr | 383 | 38 | 40 |
| May | 224 | 45 | 49 |

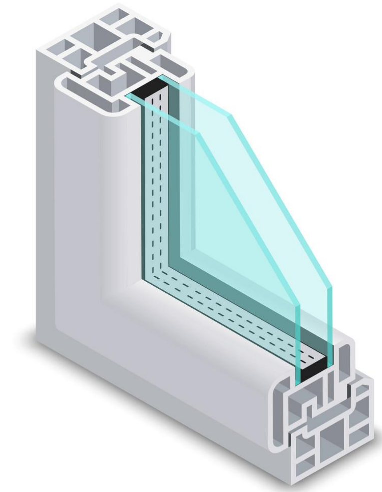
In the middle = most optimal

<u>Most optimal tilt:</u> 55° above the horizon

# 4.

# SOLAR COLLECTING GLASS

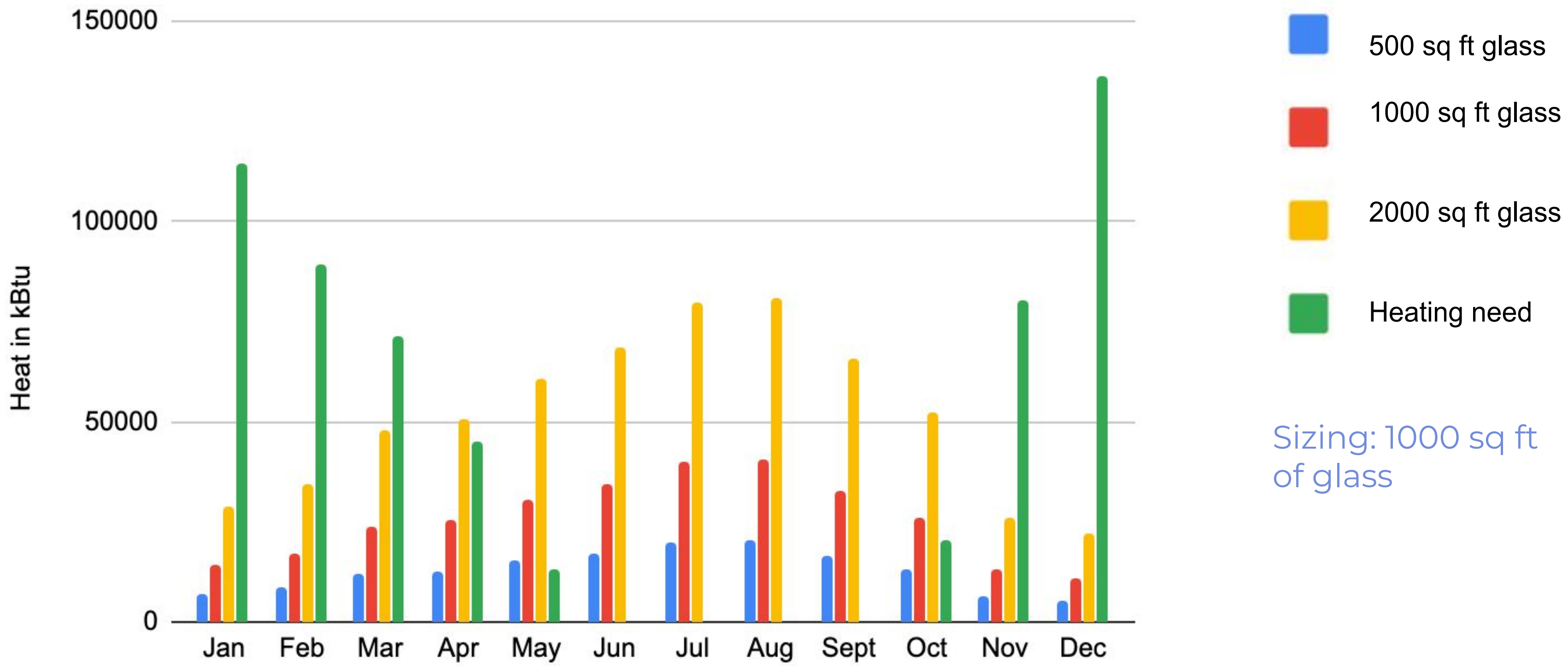
- U-value of 2.25 W/m2-K and SHGC of 0.687.
- There are two panes of glass, one with a low-e coating and one without, and the middle features a helpful air gap.



| | | ID | Name | Mode | Thick | Flip | Tsol | Rsol1 | Rsol2 | Tvis | Rvis1 | Rvis2 | Tir | E1 | E2 | Cond |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Glass 1 | ▸▸ | 9803 | CLEAR5.LOF | # | 4.7 | ☐ | 0.796 | 0.074 | 0.074 | 0.888 | 0.082 | 0.082 | 0.000 | 0.840 | 0.840 | 1.000 |
| Gap 1 | ▸▸ | 1 | Air | | 16.5 | | | | | | | | | | | |
| Glass 2 | ▸▸ | 9923 | LOW-E_5.LOF | # | 4.7 | ☐ | 0.676 | 0.117 | 0.105 | 0.826 | 0.115 | 0.109 | 0.000 | 0.158 | 0.840 | 1.000 |

# 4.

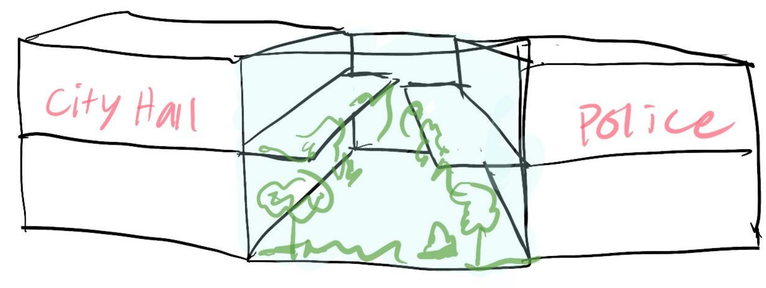
# SOLAR COLLECTING GLASS




Sizing: 1000 sq ft of glass

# 5.
# SYSTEM TYPES

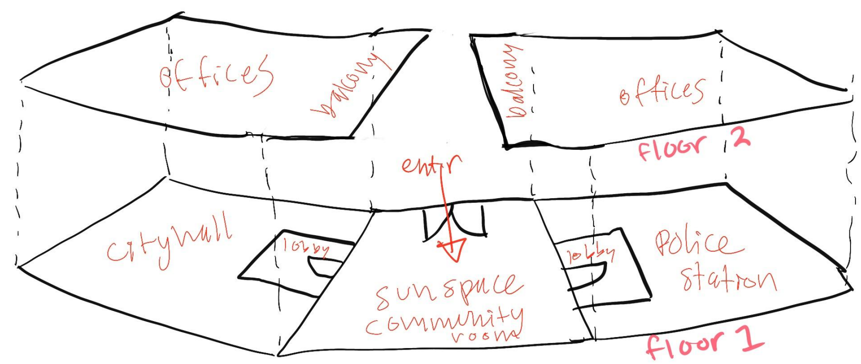
- A sunny atrium space will be a great addition to the city hall
- In the community space, it would be great to have a bright room with plants
- This is a workplace that will be occupied throughout the day
- Tolerance is low for the city hall, making it best to have a flat collector or trombe wall



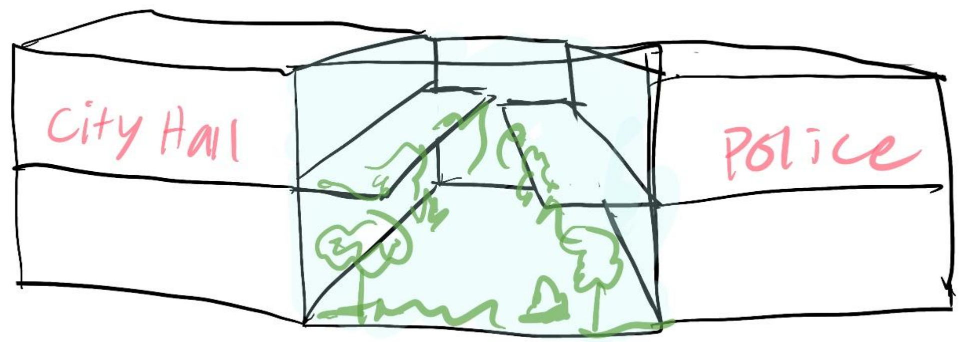
# 5.
# SYSTEM TYPES

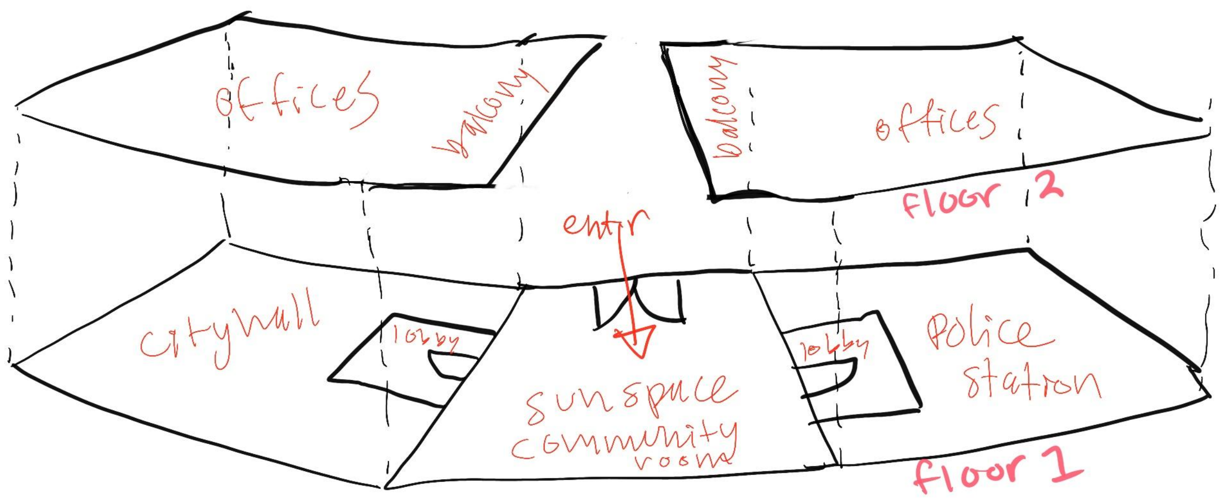
- Silverton's winters are fairly sunny and the site is not very shaded, making a trombe wall possible and effective
- However, the flat collector is still the best system for the city hall over the trombe wall, which would still be helpful for passive heating

Primary system: Atrium space
Secondary system: Sunspace
Tertiary system: Flat collector

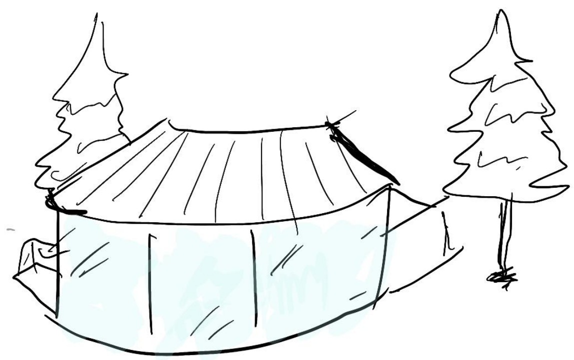


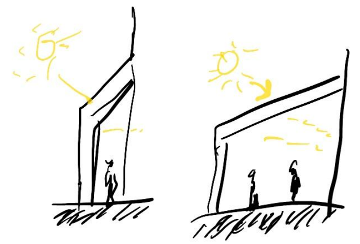
# 5.
# SYSTEM TYPES

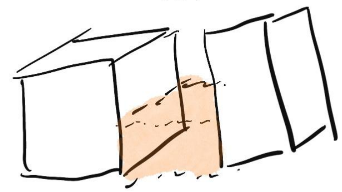


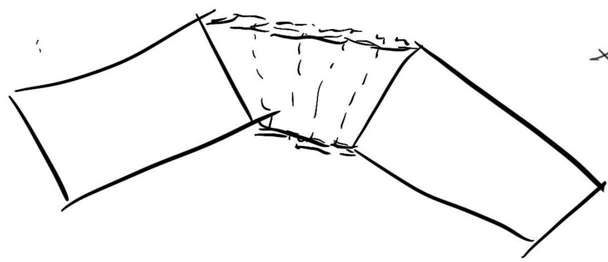



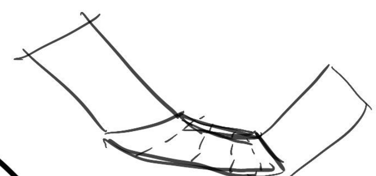
# 5.
# SYSTEM TYPES

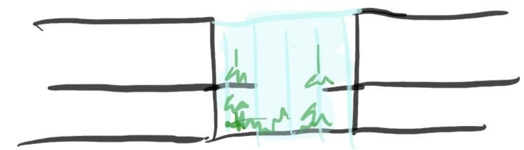


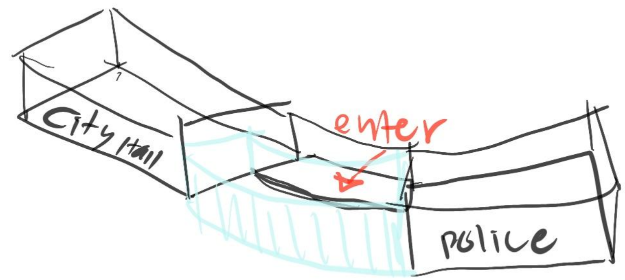




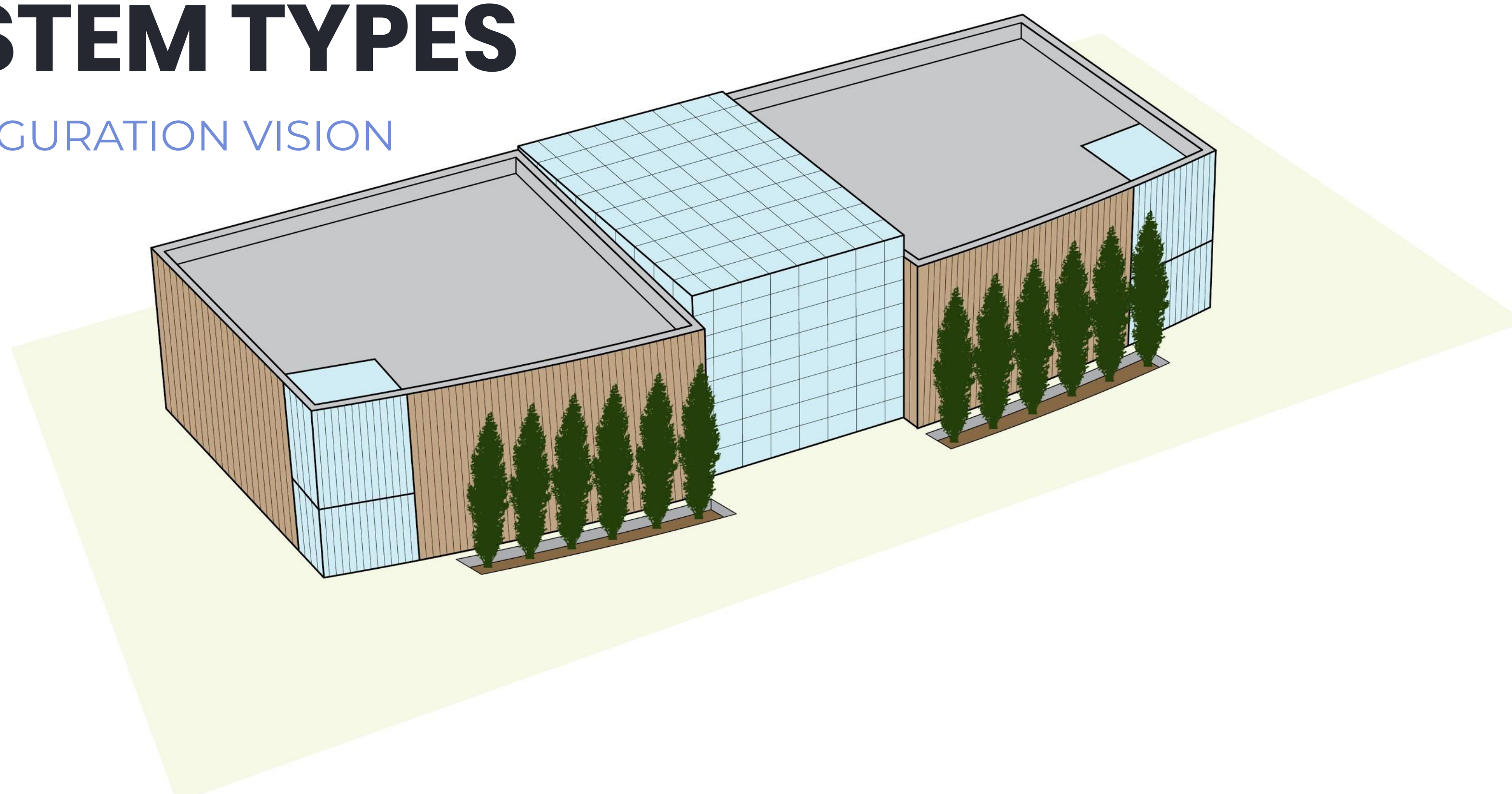









# 5.
# SYSTEM TYPES
## CONFIGURATION VISION



# 6.
# THERMAL MASS PROPOSAL

Located in the community atrium, the main thermal mass within the atrium is the large volume of air. This allows the space to be warm when most needed (mid-day). The second effective thermal mass will be a thin, solid, concrete floor, which is effective for climates with cloudy winters and buildings that need heat released from thermal mass during the mid-day (MEEB Table 11.2). This floor will be good in the community space because it will be a pleasant area for people of Silverton to sit and relax in. The warm floor will be thermally enjoyable on the cold toes of passerbyers. The thermal mass floor slab will be located in the atrium community space to maximize its solar heat collection and will be a 34.2 sq.in. (0.237 sq ft) slab at 1.5 inches thick.

# 7.

# MOVABLE INSULATION–

## AND OPERATION

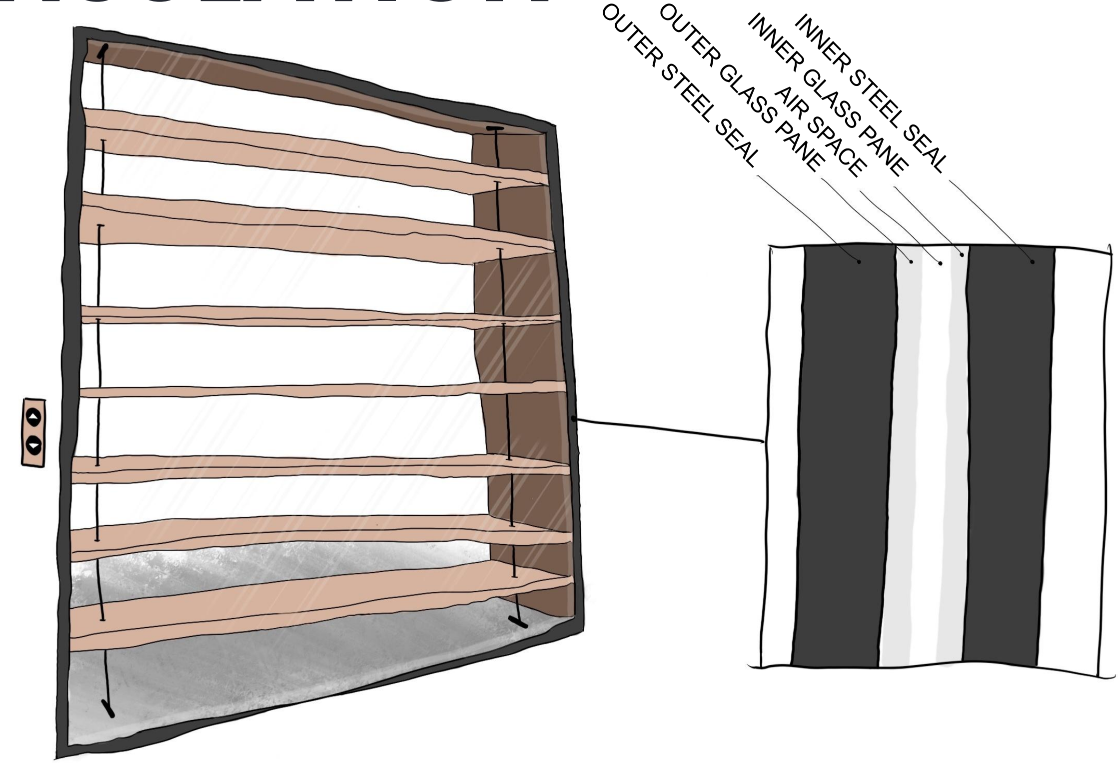
STATEMENT OF INTENT:

- Make the space as uninterrupted as possible
- The movable insulation will be located on the exterior of the building and operated electronically by a switch inside
- The insulation will consist of wood slats that can be opened during the day to let in sunlight and views outside, and closed during the night to insulate and create a cozy, woodclad feeling.
- The user will easily be able to decide the environment of the space with the use of a single switch

# 7.

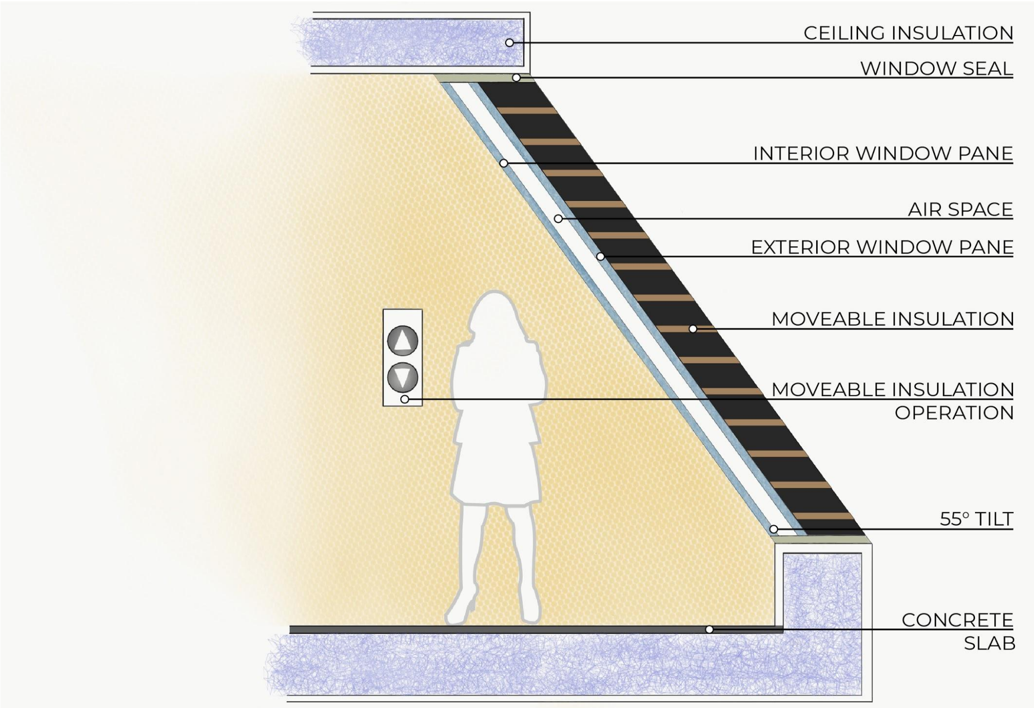
# MOVABLE INSULATION–

## AND OPERATION



# 8.

# SECTION DRAWING



# 9. CONCLUSIONS

- The site in Silverton, Oregon would benefit from a large atrium space, smaller sun spaces, and concrete slabs for thermal mass as passive heating design strategies
- The optimal glazing tilt for this site is 55 degrees above the horizon to most efficiently collect solar radiation with a high SHGC and low u-value glass
- Moveable insulation will insulate glazing during cold nights
- The most effective site location for solar collection is position G (center of Eastern side of site), as well as the surrounding positions

# Appendix E

## Sydney and Ben

# SILVERTON CITY HALL AND POLICE STATION

## PASSIVE HEATING BUILDING RECOMMENDATIONS

BEN CLARK AND SYDNEY PALMER
UNIVERSITY OF OREGON
PASSIVE HEATING ARCH 494M

# DESIGN INTENT

- Sustainable, science-based
- Comfortable for occupants
- Straightforward climate control
- Thermally delightful


IMAGE SOURCES:
HASTINGS R. (2013) PASSIVE SOLAR HEATING IN BUILT ENVIRONMENT. IN: LOFTNESS V., HAASE D. (EDS) SUSTAINABLE BUILT ENVIRONMENTS. SPRINGER, NEW YORK, NY

HTTPS://WWW.BOSTONGLOBE.COM/OPINION/2015/07/25/GIVE-BOSTON-CITY-HALL-MUCH-NEEDED-MAKEOVER/N9FAECKRPETJNG3JO6ZGTL/STORY.HTML

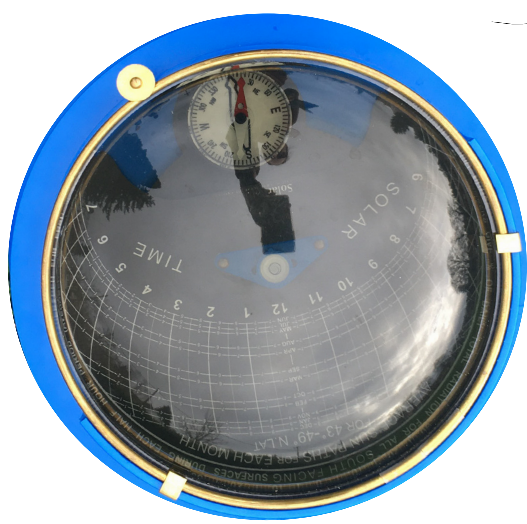
HTTP://ALBUQUERQUEMODERNISM.UNM.EDU/WP/SOLAR-BUILDING/

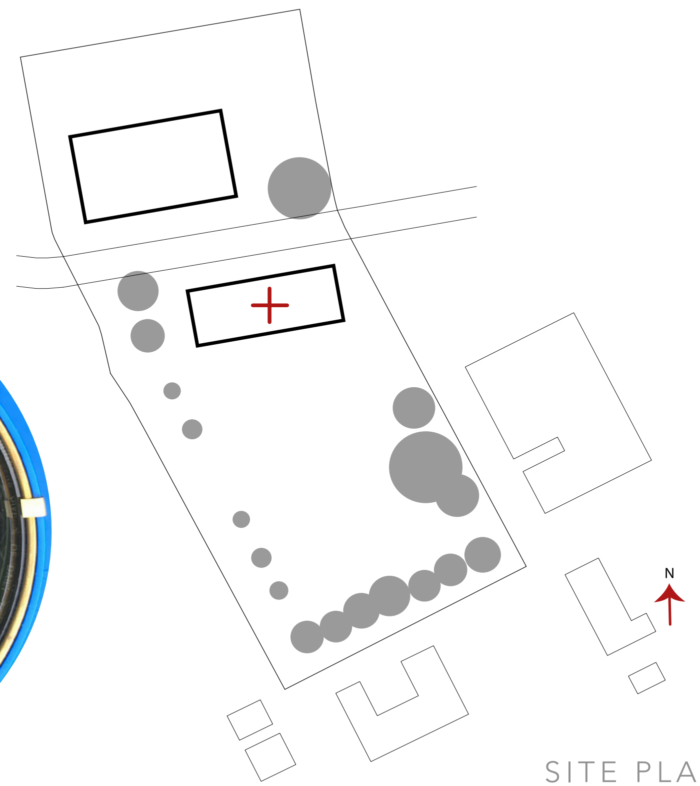
HTTPS://WWW.THENATURALHOME.COM/PLANTERBED2/

# THE SITE - SOLAR SURVEY

## BASED ON THE 3A SCHEME AS VOTED UPON BY SILVERTON RESIDENTS

SOLAR PATHFINDER IMAGE

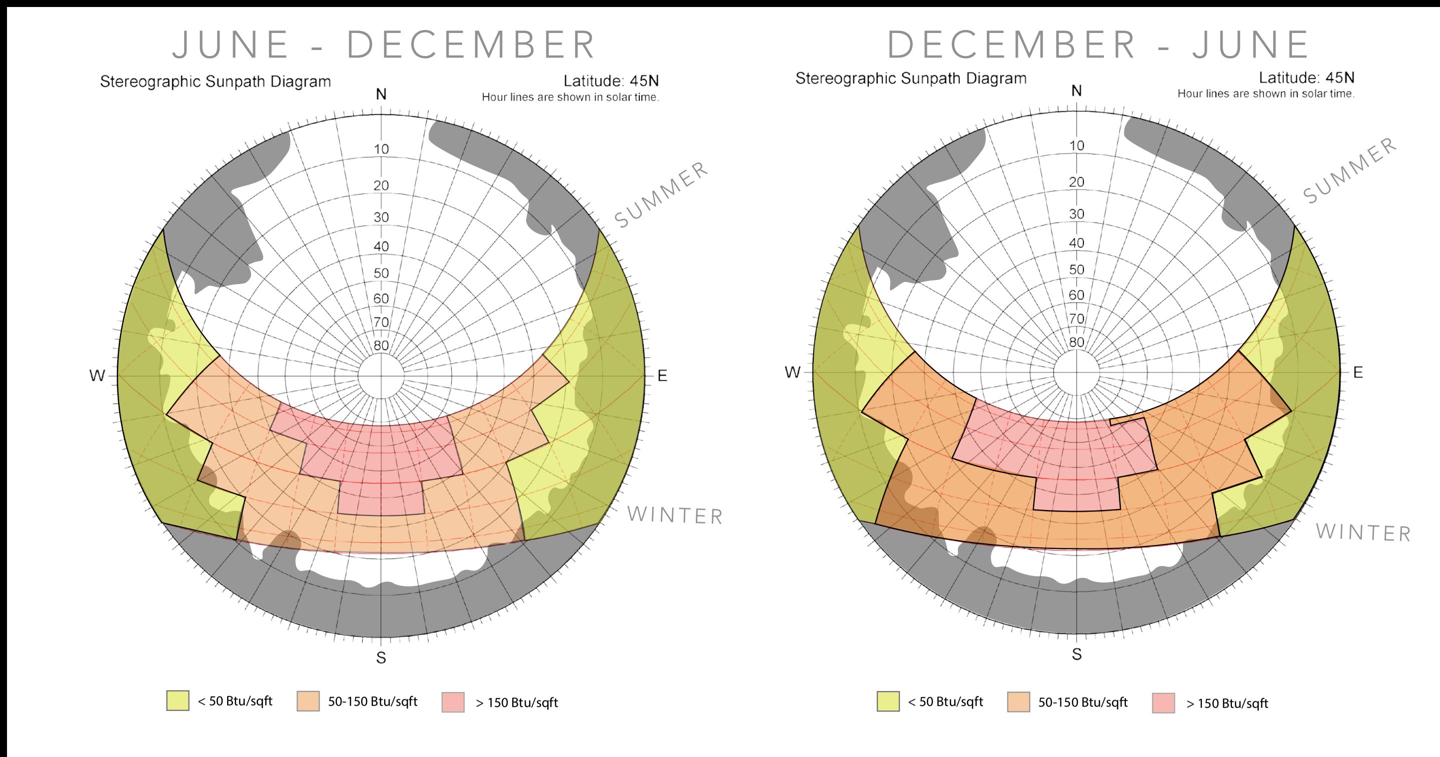



SITE PLAN

# THE SITE - SOLAR RESOURCE CHARTS

SOURCE: CLIMATE.ONEBUILDING.ORG: "USA_OR_SALEM.MUNI.AP-MCNARY.FIELD.726940_TMYX.2004-2018.EPW"

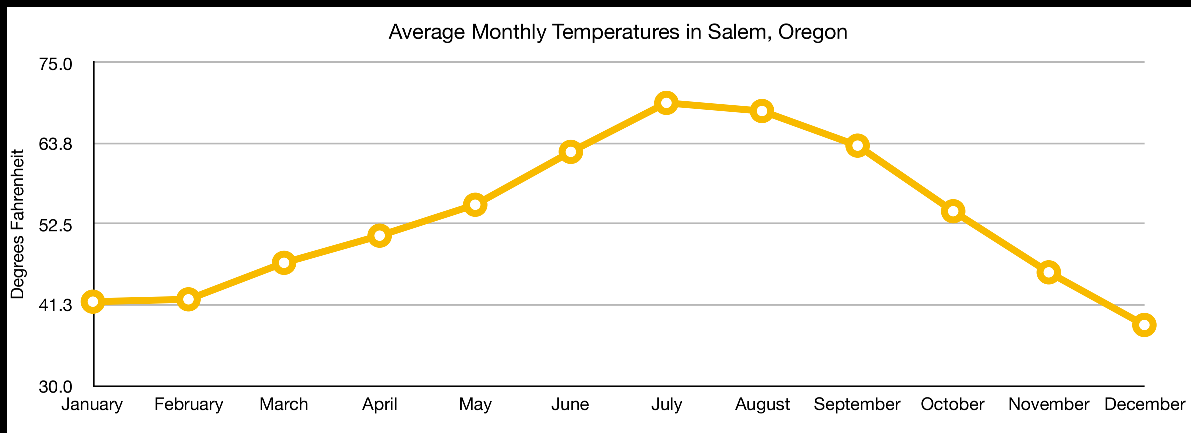



## OPTIMAL ORIENTATION IS DUE SOUTH

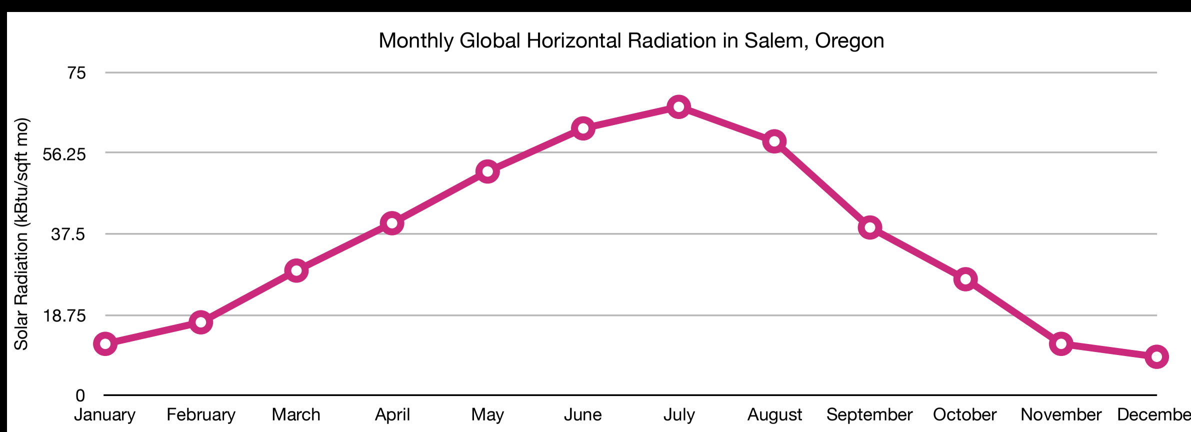
MAJORITY OF THE MOST INTENSE SOLAR RESOURCE (THE RED) IS POINTED SOUTH

# CLIMATE ANALYSIS

## MONTHLY AVERAGE TEMPERATURES AND GLOBAL HORIZONTAL RADIATION




SOURCE: CLIMATE.ONEBUILDING.ORG: "USA_OR_SALEM.MUNI.AP-MCNARY.FIELD.726940_TMYX.2004-2018.EPW"




SOURCE: MEEB 13TH ED, P. 1783, APPENDIX I TABLE I.1

# BUILDING HEAT LOSS

## BUILDING HEAT LOSS SIMPLIFIED SPREADSHEET

Comparison for sizing: CITY HALL

| Month | Monthly average air temperature (F) | Monthly envelope heat loss (kBtu) | Monthly infiltration heat loss (kBtu) | Monthly internal heat gain (kBtu) | Net heat loss (kBtu) |
|---|---|---|---|---|---|
| Jan | 41 | 43732.224 | 111974.4 | 59174.4 | 96532.224 |
| Feb | 42 | 42112.512 | 107827.2 | 59174.4 | 90765.312 |
| Mar | 47 | 34013.952 | 87091.2 | 59174.4 | 61930.752 |
| Apr | 50 | 29154.816 | 74649.6 | 59174.4 | 44630.016 |
| May | 55 | 21056.256 | 53913.6 | 59174.4 | 15795.456 |
| Jun | 62 | 9718.272 | 24883.2 | 59174.4 | -24572.928 |
| Jul | 69 | 1619.712 | 4147.2 | 59174.4 | -53407.488 |
| Aug | 68 | 0 | 0 | 59174.4 | -59174.4 |
| Sept | 63 | 8098.56 | 20736 | 59174.4 | -30339.84 |
| Oct | 54 | 22675.968 | 58060.8 | 59174.4 | 21562.368 |
| Nov | 45 | 37253.376 | 95385.6 | 59174.4 | 73464.576 |
| Dec | 38 | 30689.28 | 124416 | 59174.4 | 95930.88 |

SOURCES:

EUGENE FIELD SITE: CONCEPT PLAN: BUILDING FOOTPRINT AREAS
CLIMATE.ONEBUILDING.ORG: "USA_OR_SALEM.MUNI.AP-MCNARY.FIELD.726940_TMYX.2004-2018.EPW"
ASHRAE 90.1-2016, TABLE 9.5.1: POLICE STATION LPD 0.80 W/FT^2; TOWN HALL LPD 0.80 W/FT^2
MEEB APPENDIX G, TABLE G.1: HEAT FROM PEOPLE 1.3 W/FT^2
2016 NREL PLUG LOADS TABLE 3-2: MULITENANT PLUG LOADS 0.49 W/FT^2
ASHRAE 90.1-2016, ONLINE, TABLE 5.5: U-VALUES OF MATERIALS

# BALANCE POINT TEMPERATURE

THE OUTDOOR AIR TEMPERATURE AT WHICH INTERNAL HEAT PRODUCTION AND ABSORBED SOLAR ENERGY BALANCES WITH HEAT ESCAPING THROUGH THE ENVELOPE AND AIR

Balance Point Temp: internal + ~~solar heat gains~~ = envelope + infiltration heat loss

Infiltration Heat Loss = Cp * p * q * ΔT
Envelope Heat Loss = UAΔT
Internal heat gains = 1,286,400 Btu/day

internal = envelope + infiltration heat loss

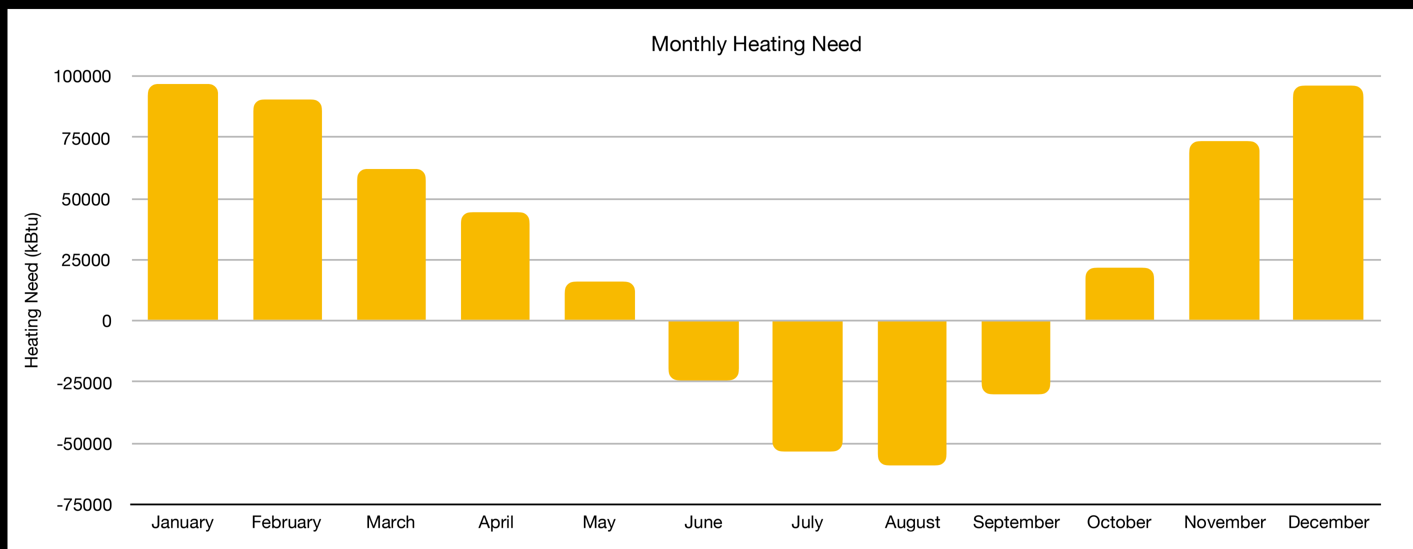
2,572,800 Btu/day = (UAΔT) + (Cp * p * q * ΔT)
2,572,800 Btu/day = ΔT (UA + Cp * p * q)
2,572,800 Btu/day = (68˚F - BPT) (54,000 Btu/day ˚F + 138,240 Btu/day ˚F)

13.38 = 68˚F - BPT

**BPT = 54.62˚F**

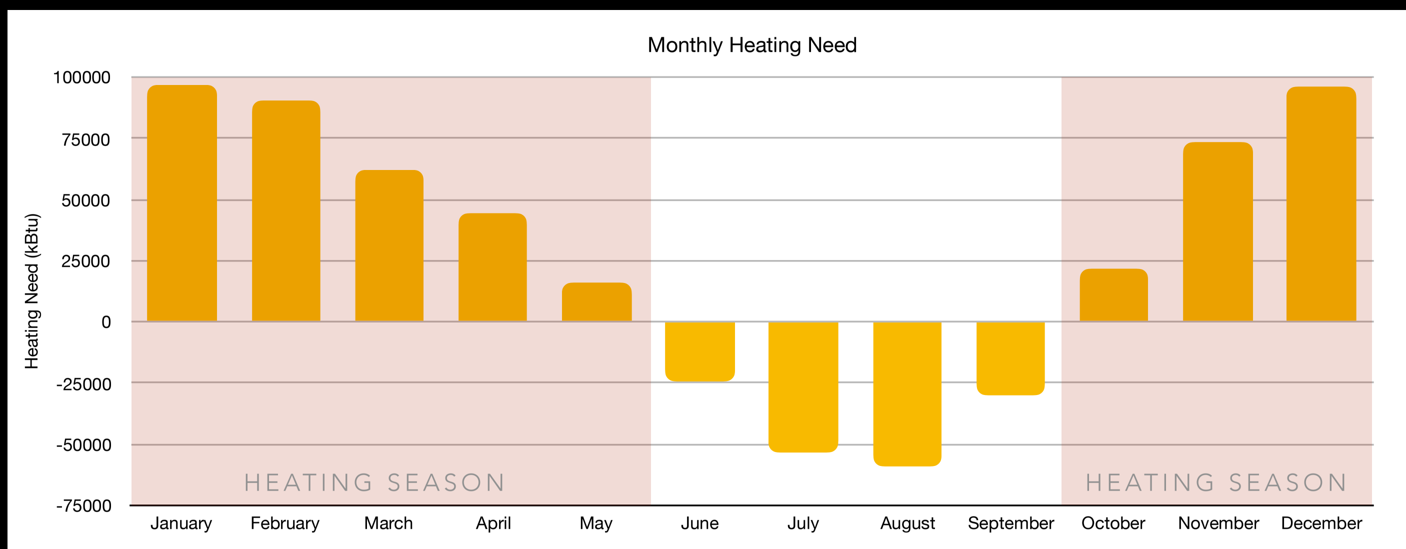
# MONTHLY HEATING NEED

(ENVELOPE HEAT LOSS + INFILTRATION HEAT LOSS)- INTERNAL HEAT GAIN = THE HEAT THAT NEEDS TO BE MADE UP BY SOLAR RADIATION



# MONTHLY HEATING NEED

(ENVELOPE HEAT LOSS + INFILTRATION HEAT LOSS)- INTERNAL HEAT GAIN = THE HEAT THAT NEEDS TO BE MADE UP BY SOLAR RADIATION




BUILDING NEEDS ADDED HEAT FROM OCTOBER TO MAY TO MAINTAIN 68° F THUS WE SAY THE "HEATING SEASON" IS FROM OCTOBER TO MAY.

BEN CLARK AND SYDNEY PALMER, PASSIVE HEATING, ARCH 494, UNIVERSITY OF OREGON, WINTER 2020

# OPTIMAL GLAZING TILT

## MAXIMIZE SOLAR RADIATION IN THE HEATING SEASON (RED HIGHLIGHT)

| EUGENE, OR | | Solar radiation (kBtu/ft² mo) on a surface of tilt: | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Mo** | **D65** | **90°** | **80°** | **70°** | **60°** | **50°** | **40°** | **30°** | **20°** | **10°** | **0°** |
| Jan | 753 | 19 | 20 | 21 | 21 | 21 | 20 | 19 | 17 | 15 | 12 |
| Feb | 617 | 22 | 23 | 25 | 25 | 25 | 25 | 24 | 22 | 20 | 17 |
| Mar | 569 | 28 | 31 | 33 | 35 | 36 | 36 | 36 | 34 | 32 | 29 |
| Apr | 446 | 27 | 32 | 36 | 39 | 42 | 43 | 44 | 44 | 42 | 40 |
| May | 307 | 27 | 33 | 38 | 43 | 47 | 50 | 52 | 53 | 53 | 52 |
| Jun | 157 | 27 | 34 | 41 | 47 | 53 | 57 | 61 | 63 | 63 | 62 |
| Jul | 36 | 31 | 39 | 47 | 54 | 60 | 65 | 68 | 69 | 69 | 67 |
| Aug | 31 | 36 | 43 | 50 | 56 | 60 | 63 | 65 | 64 | 63 | 59 |
| Sep | 121 | 36 | 41 | 45 | 48 | 49 | 50 | 49 | 47 | 43 | 39 |
| Oct | 382 | 32 | 35 | 37 | 38 | 39 | 38 | 37 | 34 | 31 | 27 |
| Nov | 603 | 17 | 18 | 19 | 19 | 19 | 18 | 17 | 16 | 14 | 12 |
| Dec | 784 | 15 | 16 | 16 | 16 | 16 | 15 | 14 | 13 | 11 | 9 |

HEATING SEASON (Jan–May)

HEATING SEASON (Oct–Dec)

Highest solar gain per month

Optimum Tilt Angle

SOURCE: MEEB 13TH ED, P. 1783, APPENDIX I TABLE I.1

THE IDEAL TILT TO MAXIMIZE RADIATION IN THE HEATING SEASON IS BETWEEN 40 AND 50°. CHOOSE THE STEEPER TILT TO MINIMIZE SUMMERTIME HEAT GAINS.

# GLASS FOR PASSIVE SOLAR

WHAT ARE WE LOOKING FOR?

IN ORDER OF IMPORTANCE

1. **Large Solar Heat Gain Coefficient** (SHGC) to allow energy in
2. **Low U-Value** to retain heat during the night
3. **Low-E coating** to minimize heat loss through radiation
4. **Large Visible Light Transmittance** to maximize natural light

# GLASS FOR PASSIVE SOLAR

WHAT WE FOUND

## Cardinal Glass Industries, LoE-179 Window

GLASS PERFORMANCE

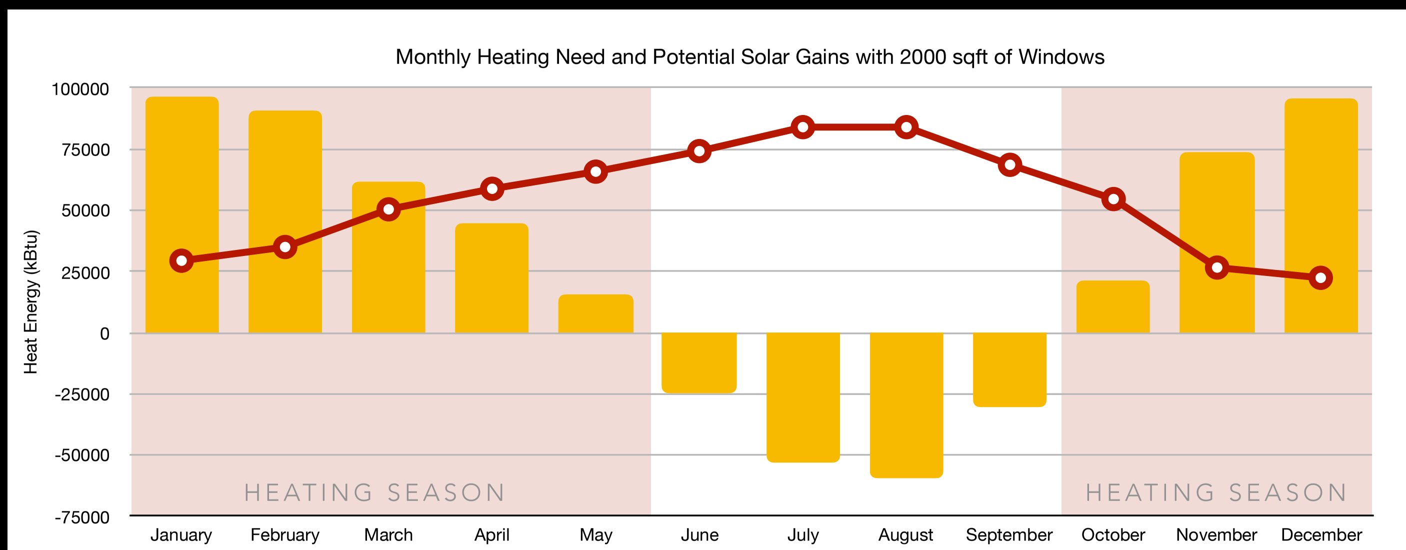
| PRODUCT | VISIBLE LIGHT TRANSMITTANCE % | SOLAR HEAT GAIN COEFFICIENT | WINTER U-FACTOR (ARGON) | UV | FADING TRANSMISSION |
|---|---|---|---|---|---|
| Single-pane, clear | 90% | .86 | -- | .71 | .84 |
| Double-pane, clear | 81% | .76 | -- | .56 | .74 |
| Ordinary low-e | 75% | .72 | .31 | .44 | .63 |
| **LoĒ-179** | **79%** | **.70** | **.28** | **.24** | **.61** |

SOURCE: WWW.LORMA.CA/MEDIA/179BROCHURE.PDF

1. SHGC: 0.7
2. U-Value: 0.28
3. Low E Coating
4. Visible Light Transmittance: 79%

# GLAZING SIZING

## THE HEAT THAT NEEDS TO BE MADE UP BY SOLAR RADIATION




2000 SQFT OF GLAZING MEETS THE HEATING NEED IN MARCH AND ABOUT HALF THE NEED IN FEBRUARY

# PASSIVE SOLAR SYSTEMS

## BIGGER PICTURE PASSIVE HEATING WHEN/WHERE DO WE NEED HEAT?

- Heat return in the afternoons and evenings
- Systems that work with a cloudy climate
- Minimal upkeep
- Adjustable by the occupants for optimal comfort
- Insulated at night to reduce heat loss

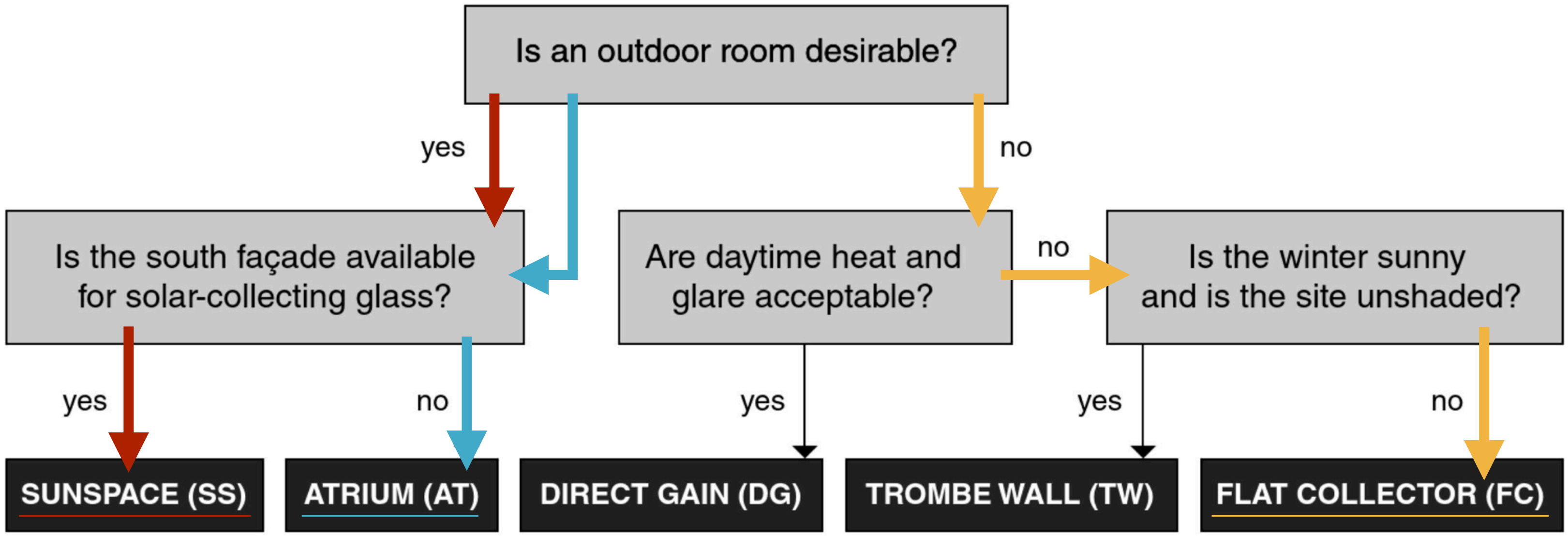



***Fig. 11.25*** *Decision tree for passive solar heating system selection.*

SOURCE: MEEB 13TH ED, P. 400, PASSIVE HEATING STRATAGIES FIG. 11.25

## Sunspace

- ✓ POTENTIAL SOUTH EXPOSURE
- ✓ BRINGS IN NATURAL LIGHT
- ✓ INCORPORATE INTO HALLWAY
- – POTENTIAL OVERHEATING
- – GLARE RESTRICTS LOCATION

## Atrium

- ✓ NATURAL ENTRANCE
- ✓ CONNECTION TO OUTDOORS
- – DIFFICULT TO INSULATE AT NIGHT
- – "GLASS BOX" MAY NOT BE SUITED TO SMALL TOWN
- – HARD TO CLEAN

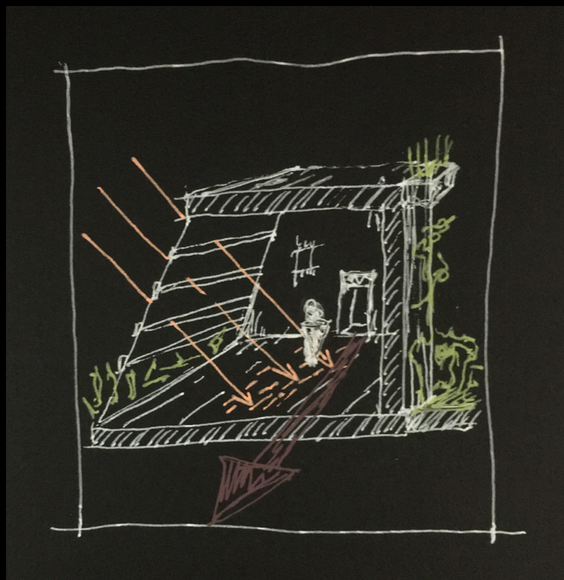
## Flat Collector

- ✓ HIDDEN SYSTEM
- ✓ WARM AIR EARLY IN THE WORKDAY
- ✓ WORKS IN CLOUDY CLIMATES
- – ACTIVE ELEMENT PROBABLY NEEDED
- – MAINTENANCE OF FAN SYSTEM

BEN CLARK AND SYDNEY PALMER, PASSIVE HEATING, ARCH 494, UNIVERSITY OF OREGON, WINTER 2020

# Hallway Sunspace

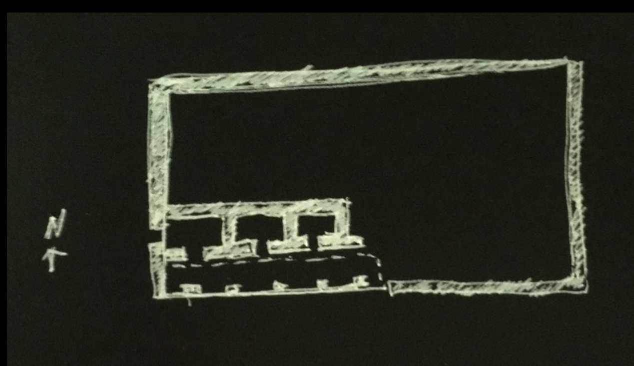
- PROVIDE THERMAL DELIGHT IN HALLWAYS, WARMTH AND DIRECT LIGHT
- OCCUPANTS CAN ADJUST FOR THERMAL COMFORT BY OPENING/CLOSING DOOR



ANGLED WALL SUNSPACE

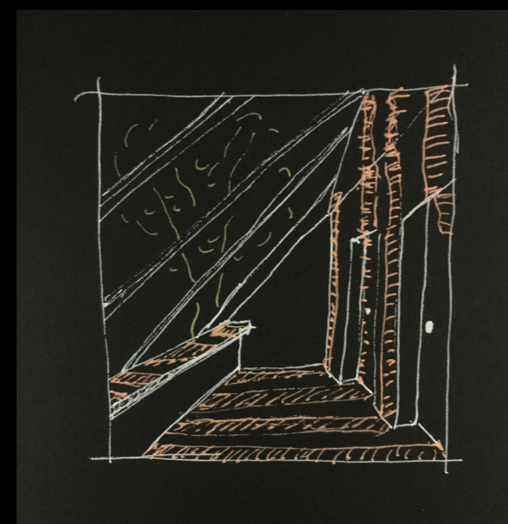
SUMMER SHADED SUNSPACE

DIRECT SUN




PLAN OF SUN HALLWAY

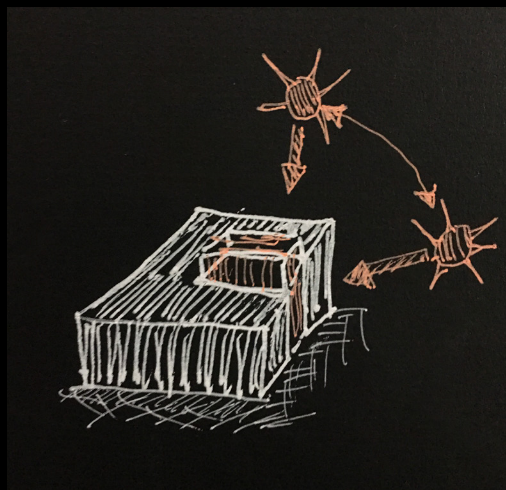
- RISK OF OVERHEATING
- REQUIRES NIGHT INSULATION



PERSPECTIVE OF HALLWAY

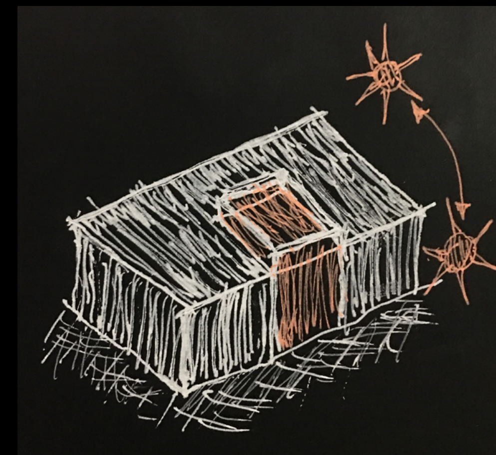
BEN CLARK AND SYDNEY PALMER, PASSIVE HEATING, ARCH 494, UNIVERSITY OF OREGON, WINTER 2020

# Central Atrium

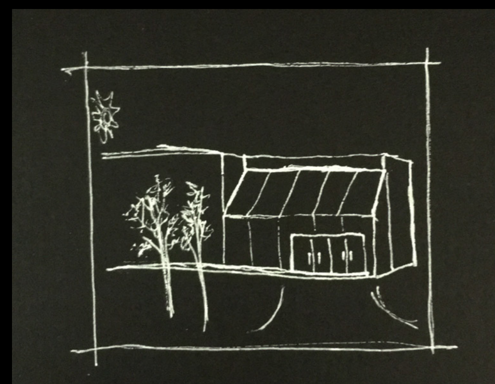


CENTRAL ATRIUM FACING SOUTH

- WELCOMING LIGHT MAKES INVITING ENTRANCE
- CENTRAL HEART OF THE BUILDING
- WARMS SURROUNDING SPACES

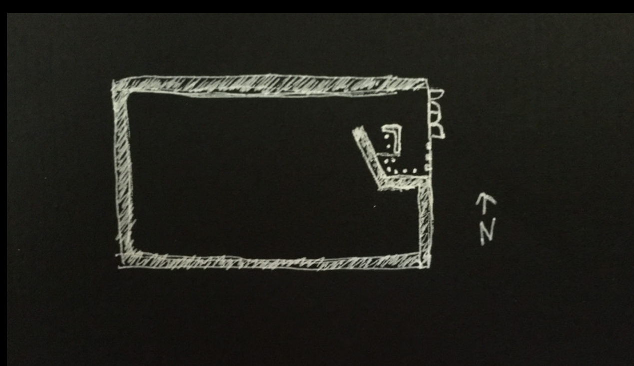


CENTRAL ATRIUM FACING WEST

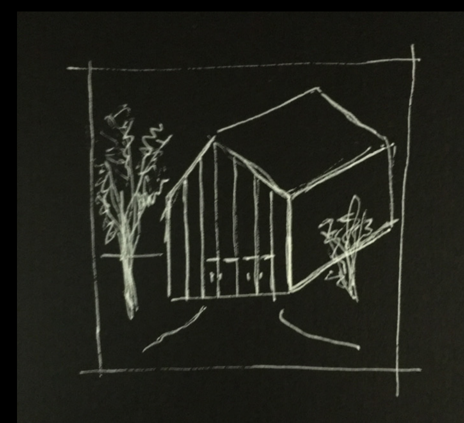


SLOPED ROOF ATRIUM

PLAN OF ATRIUM LOBBY

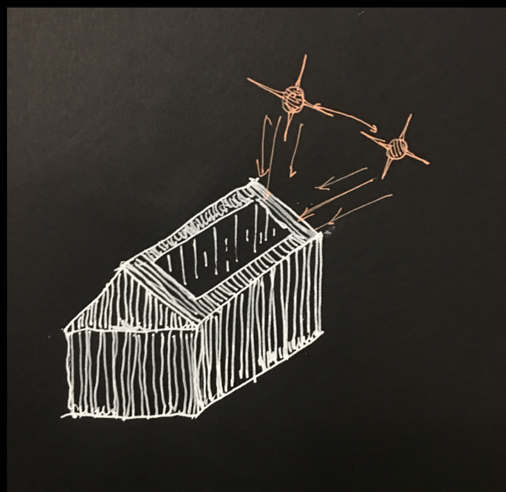



- HARD TO CLEAN AND MAINTAIN
- DIFFICULT TO INSULATE SUCH LARGE SPACES AT NIGHT



FRONT VERTICALLY GLAZED ATRIUM

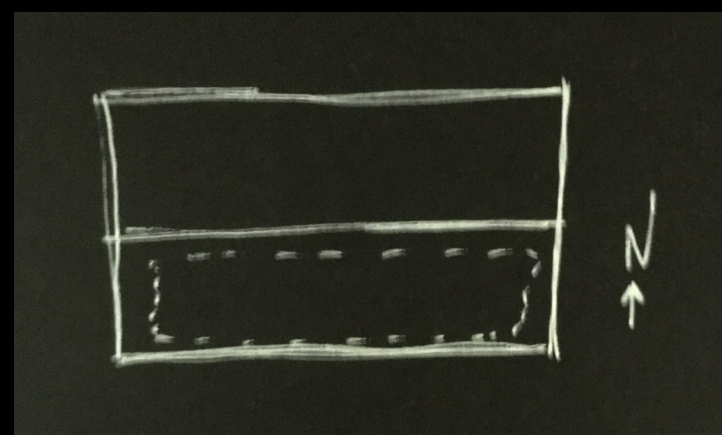
# Flat Collector



FLAT COLLECTOR FACING SOUTH

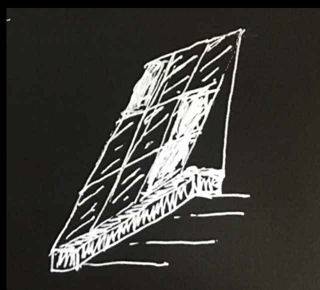
- QUIET AND UNOBTRUSIVE HEATING
- WORKS IN CLOUDY CLIMATES
- NO RISK OF OVER HEATING OR UNHAPPY OCCUPANTS

ROOF PLAN OF FLAT COLLECTOR

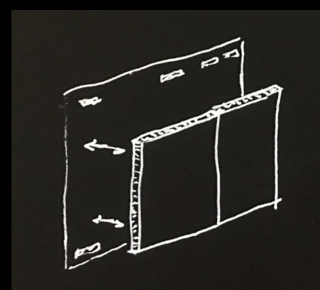



- LESS OPPORTUNITY FOR THERMAL DELIGHT
- SOME UPKEEP NECESSARY

# MOVABLE INSULATION

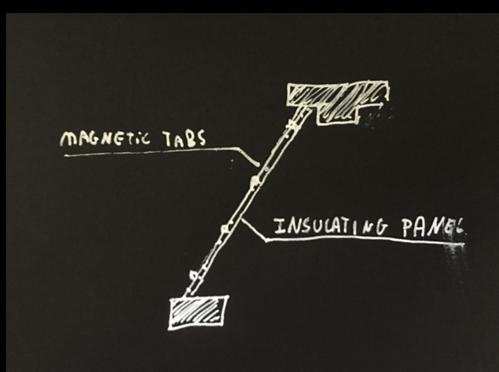


MAGNETIC INSULATION PANELS: MODULAR, CLEAN, EFFECTIVE



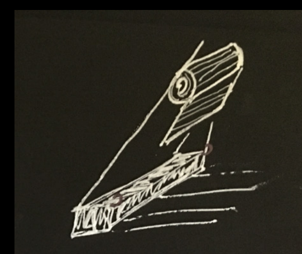
- HIGH INSULATION VALUE
- CLEAN LOOK WHEN DEPLOYED
- REPLACEABLE, MODULAR PARTS

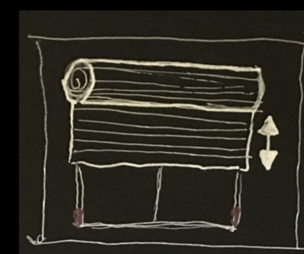
- DIFFICULT TO STORE
- TEDIOUS TO APPLY AND REMOVE



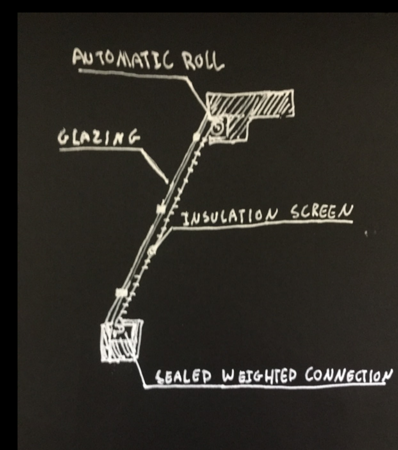

ROLL DOWN INSULATION: FAST, SELF-STORING, AUTOMATED

- QUICK, EASY OPERATION
- SELF-CONTAINED STORAGE
- MAY BE AUTOMATED





- COMPLICATED TO HIDE ROLLED UP INSULATION
- LOOKS INDUSTRIAL WHEN DEPLOYED



# THERMAL MASS

WHAT ARE WE LOOKING FOR IN A THERMAL MASS MATERIAL?

- **Moderate Heat Capacity** to hold heat but release it within hours
- **High Solar Absorbance** to capture most of the radiation
- **Moderate Thermal Conductivity** to move heat through the mass

# THERMAL MASS

## WHAT SHOULD THE THERMAL MASS BE?

We propose concrete or granite floors.

Both materials have **moderate heat capacity** at 850 and 840 c/J kg^-1 K^-1 respectively. Meaning they can hold significant heat before radiating into the space. This will allow heat storage throughout the day.

Their **thermal conductivity** is in an ideal range to provide heat after direct gains cease.

Both materials can be treated to **increase solar absorbance**, for example, low gloss finishes and concrete dye.

# THERMAL MASS

## WHERE SHOULD THE THERMAL MASS BE?

Thermal mass should be concentrated in areas with high solar gains, so the mass can absorb the energy to store. This will primarily be by windows or under skylights.

## HOW MUCH THERMAL MASS DO WE NEED?

1/HEAT CAPACITY X SOLAR RADIATION / DESIRED TEMP INCREASE = MASS NEEDED

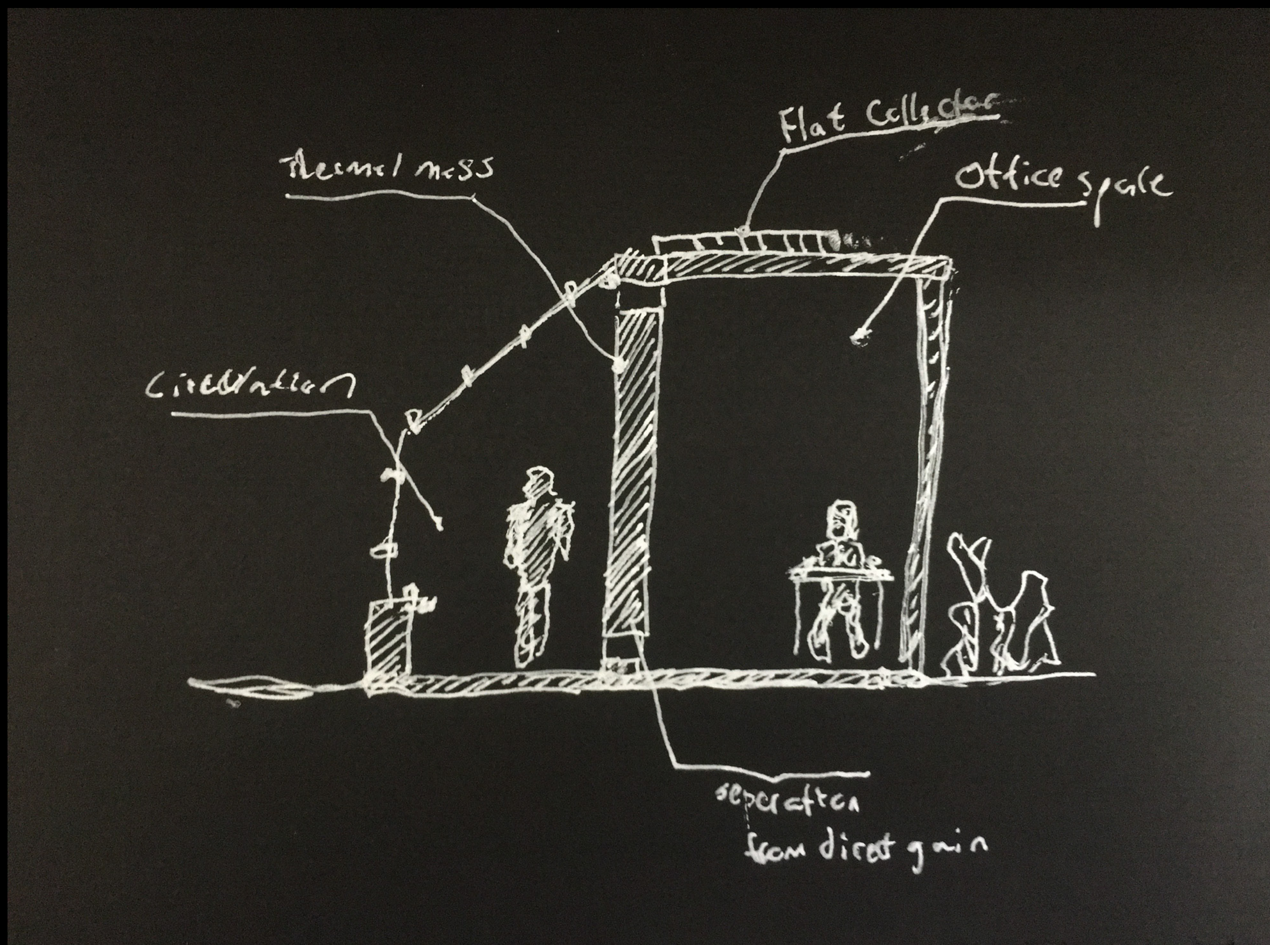
For a concrete Atrium space floor with 2000 sf of glazing we would need about 164,000 lbs of concrete spread in a 3" layer

or

For a granite Atrium space floor with 2000 sf of glazing we would need about 160,000 lbs of granite in a 3" layer.

# CONCLUSIONS

## WHAT COULD ALL THESE STRATEGIES LOOK LIKE TOGETHER?



# CONCLUSIONS

WHAT ARE THE KEY TAKEAWAYS?

- Orient the building with maximum southern exposure
- Tilt glazing to 50° for maximum solar heat gains
- Pick solar systems that work for cloudy climates
- Insulate high SHGC glazing at night
- Use thermal mass efficiently to store heat and release later

# Appendix F

## Yumna and Saeideh

# Silverton City Hall and Police Station

**ARCH/ENVS 595 M: Passive Heating**

**Winters 2020**

*Yumna Imtiaz, Saeideh Nekouee*



UNIVERSITY OF OREGON

# Process of Study

This is a passive solar heating project. The aim is to design two passive solar heated buildings in Silverton, Oregon.

**The project process:**

**Solar radiation + Site survey** (Design alternative selection, site survey)

**Climates and heating needs** (Estimating heating needs and heating season for our buildings)

**Glass and design strategy** (finding an optimal tilt and orientation, choosing a glazing assembly, specifying and sizing the system)

**Movable insulation** (where to put the glass in a massing model, proposing a moveable insulation)

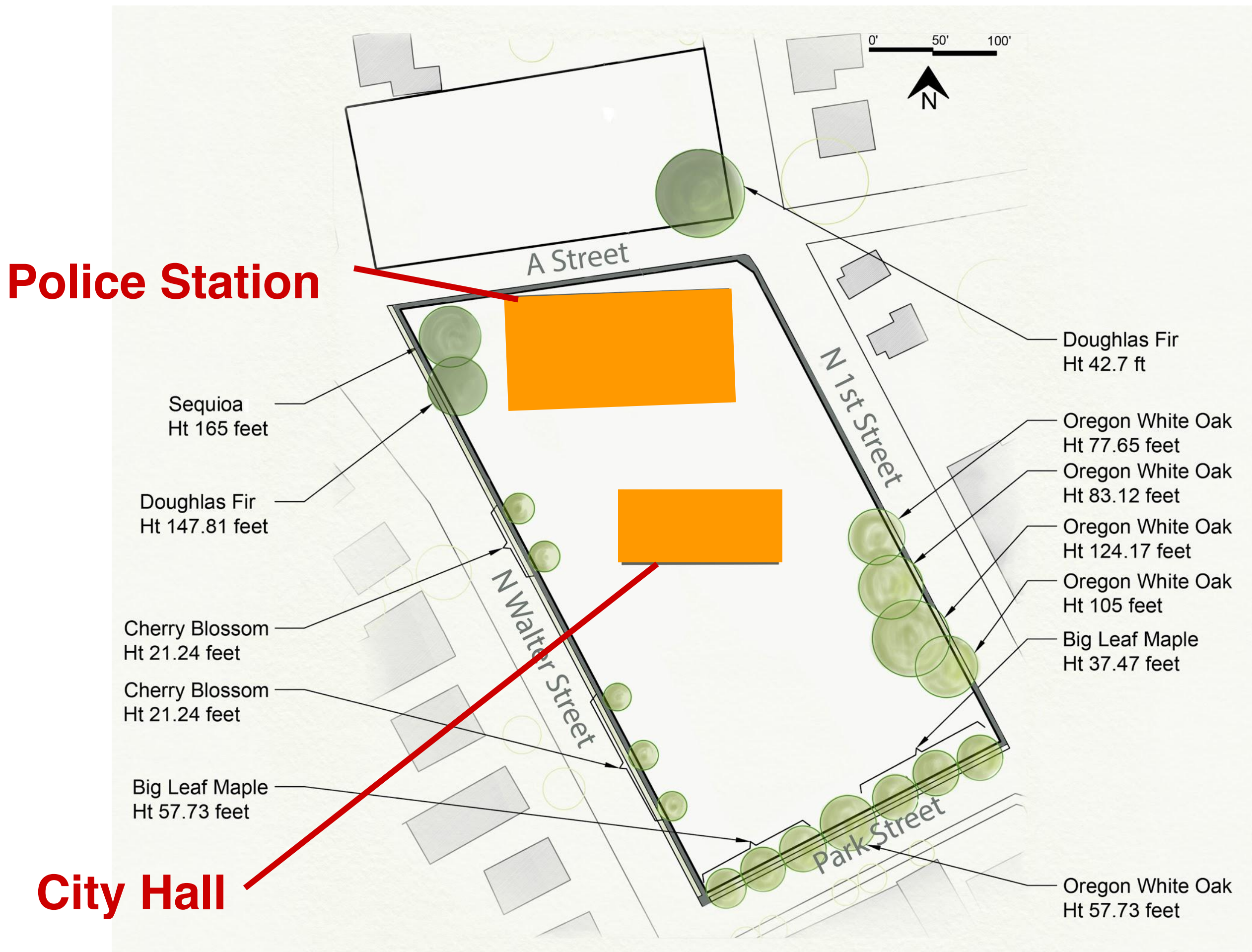
**Thermal mass** (Temperature range estimation for the mass to warm and cool, area and thickness of material calculation)

# Design Intent

- We envision the solar-collection spaces to be integrated into active areas that are used commonly by the users.
- These spaces can be entrance, lobbies, casual sitting areas, cafe etc.
- These spaces will be brighter and warmer than the rest of the building providing a pleasant contrast.
- The intensity of activities in such spaces can add to the perception of warmth.
- Integrating eating spaces into such spaces will add the aromas, adding to the coziness of spaces.
- The spaces can be differentiated into public, semi-public and semi private spaces, for varying levels of privacy.
- The solar collection spaces will be the hallmark of building. The will be put on the front for publicizing the use of sustainable practices of using solar heating.

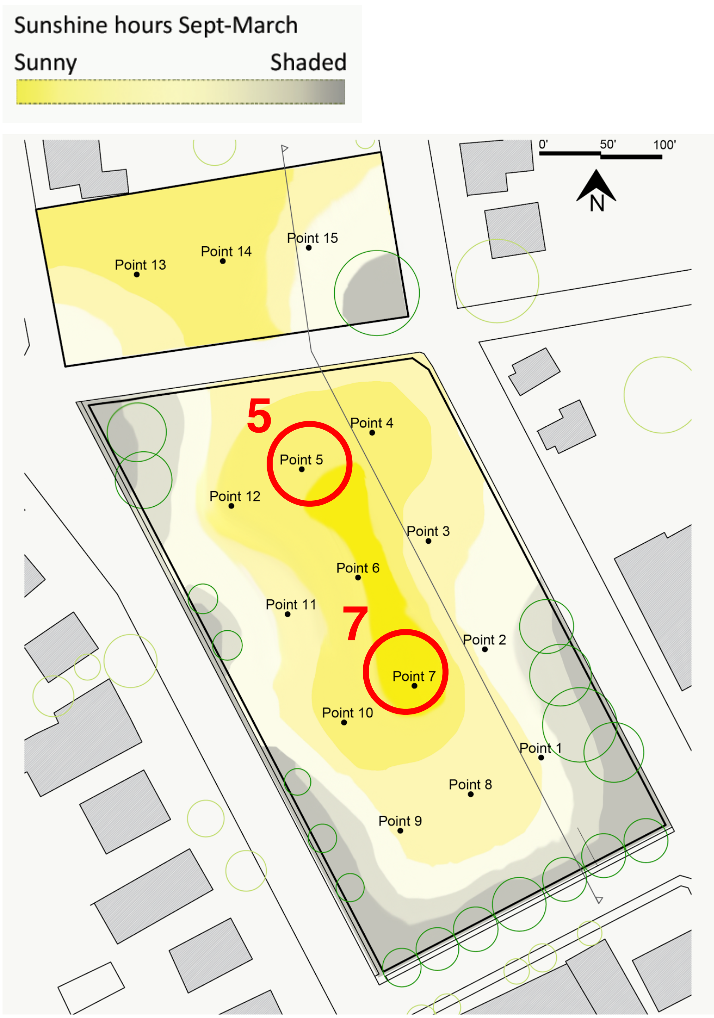
# Solar Site Survey

- **Site Plan**

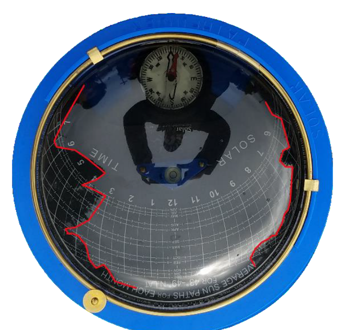



USA_OR_Salem.Muni.AB-McNary.Field.726940_TMYx.2004-2018,climate.onebuilding.org
Project conceptual design documents

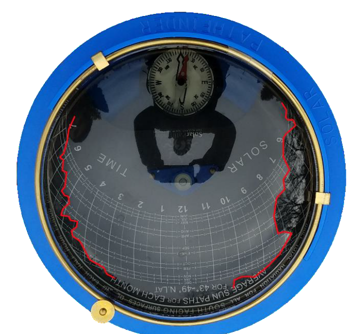
# Solar Site Survey




- **Sun-path Finder**
  - During our site visit we recorded data about sunshine hours on each point.
  - Based on findings we identified points with maximum sunshine hours during heating season
  - We placed our building on the site in these spaces, to maximize the possibilities of solar gains.
  - We identified point 5 and point 7 as best positions for the buildings.



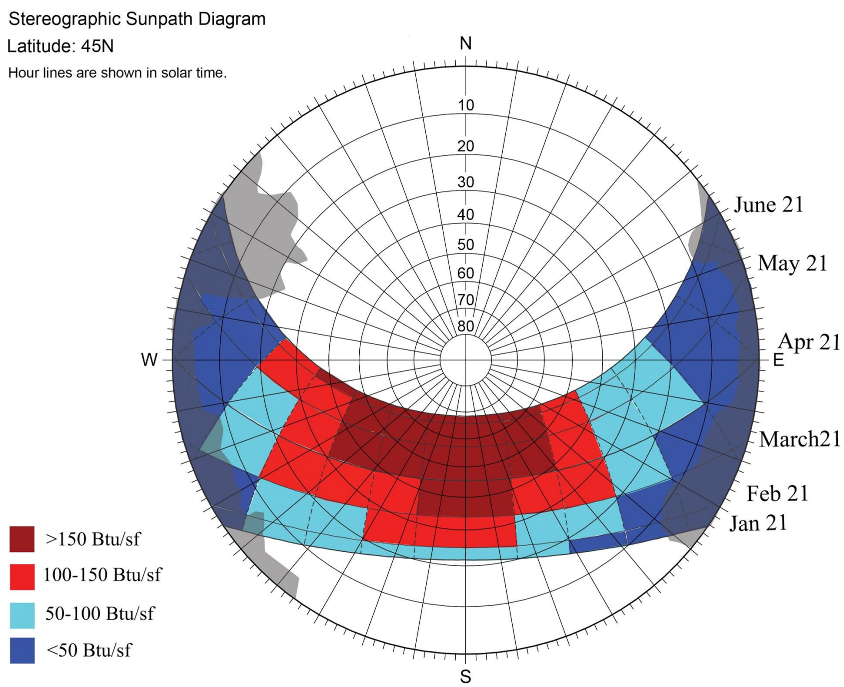
Point 5

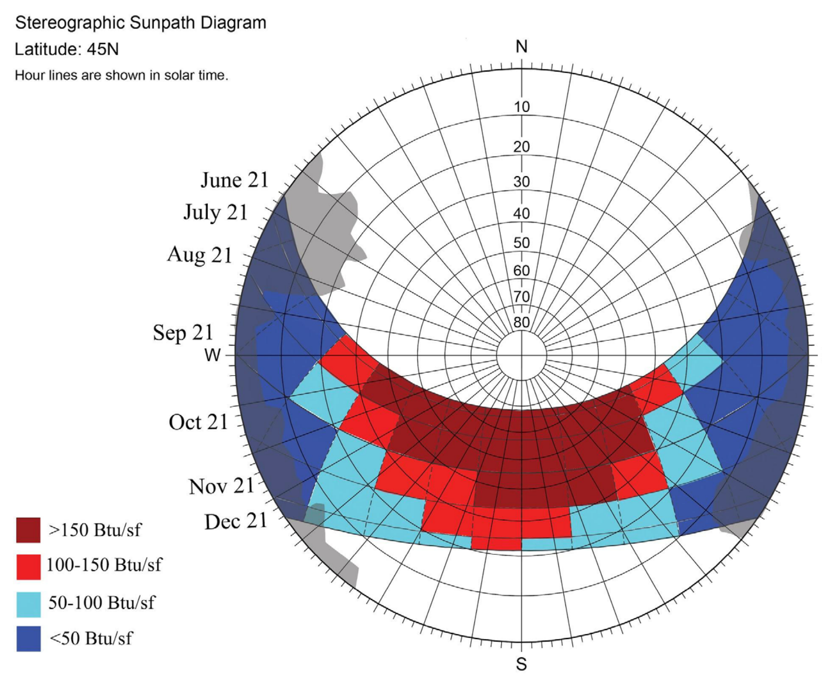


Point 7

# Solar Site Survey

- **Solar resource chart and optimal orientation**
  - According to the solar resource chart the optimal orientation will be due south.

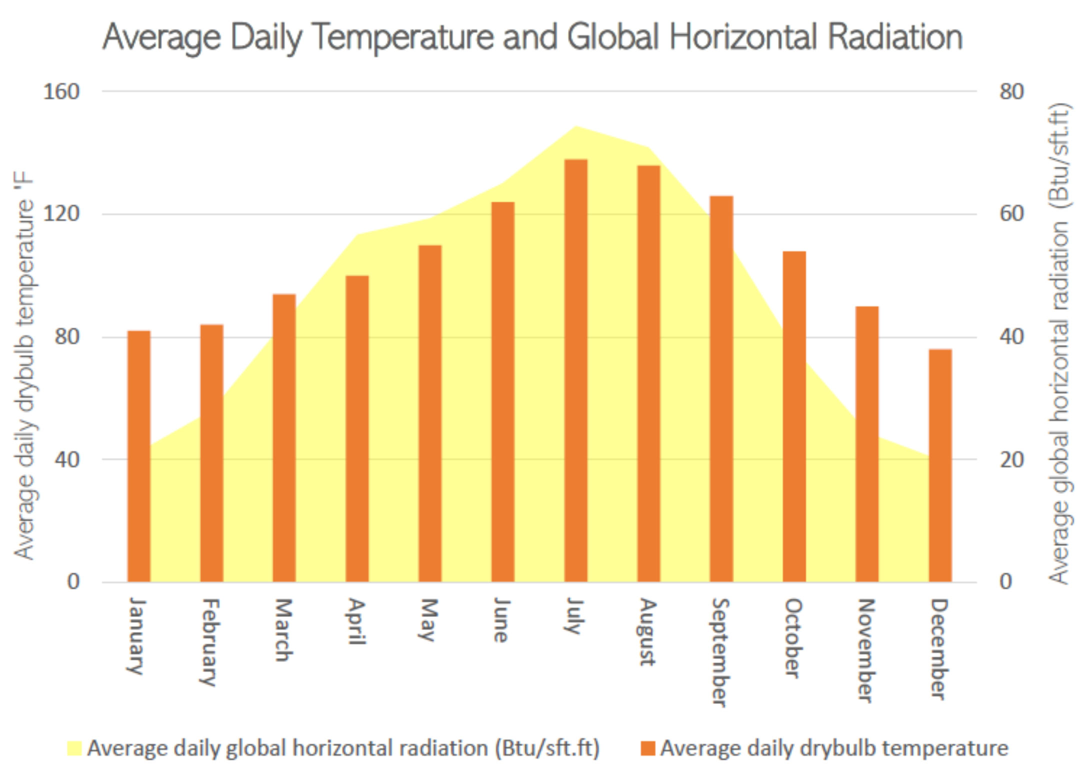



USA_OR_Salem.Muni.AB-McNary.Field.726940_TMYx.2004-2018,climate.onebuilding.org via Climate Consultant Software
NOAA Magnetic Field Calculator (www.ngdc.noaa.gov/geomag/calculators/magcalc.shtml#declination)

# Building Heating Needs

- **Silverton Climate**
  - The temperature remains moderately cold, however the low temperatures last longer
  - The solar radiation amount decreases during winters due to cloudy skies.




USA_OR_Salem.Muni.AB-McNary.Field.726940_TMYx.2004-2018,climate.onebuilding.org

# Building Heating Needs

- Balance Point Temperature
  - The outdoor temperature at which Buildings energy gains are equal to building energy losses at a desired internal temperature.
  - Internal gains + Solar gains=Envelop Losses+Infiltration Losses or $\mathbf{q_e + q_{inf} = q_s + q_i}$ (Where $q_e + q_{inf}$ are dependant on temperature difference between indoor and outdoor)
  - To isolate balance point temperature

$t_b$=$t_i$-[($q_s$ + $q_i$)÷($q_e$ as a function of Δt+$q_{inf}$ as a function of Δt)]

# Building Heating Needs

- **Envelop losses as a function of temp. difference-City Hall**
  - Envelop Losses = U X A X ΔT

| Component | Length (ft) | Width or Height (ft) | Area (sf) | U-value (Btu/sf h F)* | UA (Btu/h F) |
|---|---|---|---|---|---|
| Roof | 140 | 50 | 7000 | 0.032 | 224 |
| Wall 1 | 140 | 24 | 2352 | 0.064 | 151 |
| Wall 2 | 50 | 24 | 840 | 0.064 | 54 |
| Wall 3 | 140 | 24 | 2352 | 0.064 | 151 |
| Wall 4 | 50 | 24 | 840 | 0.064 | 54 |
| Windows | -- | -- | 2736 | 0.46 | 1259 |
| Exterior Floor | 140 | 50 | 7000 | -- | -- |
| **Total** | **--** | **--** | **--** | **--** | **1,891** |

*ASHRAE Standards 90.1-2016: Energy Standard for Buildings Except Low-Rise Residential Buildings, Table 5.5-4 pg 55.

# Building Heating Needs

- **Envelop losses as a function of temp. difference-Police Station**
  - Envelop Losses = U X A X $\Delta T$

| Component | Length (ft) | Width or Height (ft) | Area (sf) | U-value (Btu/sf h F)* | UA (Btu/h F) |
|---|---|---|---|---|---|
| Roof | 175 | 90 | 15750 | 0.32 | 5040 |
| Wall 1 | 175 | 24 | 2940 | 0.064 | 188 |
| Wall 2 | 90 | 24 | 1512 | 0.064 | 97 |
| Wall 3 | 175 | 24 | 2940 | 0.064 | 188 |
| Wall 4 | 90 | 24 | 1512 | 0.064 | 97 |
| Windows | -- | -- | 15744 | 0.46 | 7242 |
| Exterior Floor | 175 | 90 | 15750 | -- | -- |
| **Total** | **--** | **--** | **--** | **--** | **12,852** |

*ASHRAE Standards 90.1-2016: Energy Standard for Buildings Except Low-Rise Residential Buildings, Table 5.5-4 pg 55.

# Building Heating Needs

- **Infiltration losses as a function of temp. difference-City Hall**
  - Infiltration losses= Cp X Air Density X ACH X Volume X Δt

    Infiltration losses= 0.24 Btu/lb-F X 0.075lb/cft X 1/h X 16,800 cft X Δt

    **Infiltration losses= 3024 X Δt Btu/h-F**

- **Infiltration losses as a function of temp. difference-Police Station**
  - Infiltration losses= Cp X Air Density X ACH X Volume X Δt

    Infiltration losses= 0.24 Btu/lb-F X 0.075lb/cft X 1/h X 378,000 cft X Δt

    **Infiltration losses= 6804 X Δt Btu/h-F**



Grondzik, Walter T., and Alison G. Kwok. (2019) Mechanical and Electrical Equipment for Buildings, Chapter 11 page 414

# Building Heating Needs

- **Calculating Internal Gains**
  - Internal gains= Gains from (People+Equipment+Lights)

**City Hall** (avg. internal gains per hour= 44,505 Btu/hr)

| Component | Intensity (Btu/sf h) | Occupied hours per day (h) | Building area (sf) | Daily internal heat gain (Btu) |
|---|---|---|---|---|
| People* | 2.3 | 12 | 14,000 | 386,400 |
| Lights** | 2.69 | 12 | 14,000 | 451,920 |
| Equipment*** | 1.36 | 12 | 14,000 | 228,480 |
| **Total** | -- | -- | -- | **1,066,800** |

*Grondzik, Walter T., and Alison G. Kwok. (2019) Mechanical and Electrical Equipment for Buildings, Appendix G, Table G.1 pg. 1744
***ASHRAE Standards 90.1-2016: Energy Standard for Buildings Except Low-Rise Residential Buildings, Table 9.5.1 pg 151.
****Sheppy, Michael and Gentile-Polese, Luigi. (2014) Plug and Process Loads Capacity and Power Requirements Analysis, NREL Plug Loads Guidelines, 2014, Table 3-2, pg. 11

# Building Heating Needs

- **Calculating Internal Gains**
  - Internal gains= Gains from (People+Equipment+Lights)

**Police Station** (avg.  internal gains per hours = 211,050 Btu/h)

| Component | Intensity (Btu/sf h) | Occupied hours per day (h) | Building area (sf) | Daily internal heat gain (Btu) |
|---|---|---|---|---|
| People* | 2.3 | 24 | 31,500 | 1,738,800 |
| Lights** | 2.7 | 24 | 31,500 | 2,041,200 |
| Equipment*** | 1.7 | 24 | 31,500 | 1,285,200 |
| **Total** | -- | -- | -- | **5,065,200** |



*Grondzik, Walter T., and Alison G. Kwok. (2019) Mechanical and Electrical Equipment for Buildings, Appendix G, Table G.1 pg. 1744
**ASHRAE Standards 90.1-2016: Energy Standard for Buildings Except Low-Rise Residential Buildings, Table 9.5.1 pg 151.
***Sheppy, Michael and Gentile-Polese, Luigi. (2014) Plug and Process Loads Capacity and Power Requirements Analysis, NREL Plug Loads Guidelines, 2014, Table 3-2, pg. 11

# Building Heating Needs

- **Balance Point Temperature For City Hall at setpoint of 68 F**

$t_b = t_i - [(q_s + q_i) \div (q_e \text{ as a factor of } \Delta t + q_{inf} \text{ as a factor of } \Delta t)]$

$t_b = 68\text{ F} - [(0 + 44{,}450\text{ Btu}) \div (1891\text{ Btu/h-F} + 3024\text{ Btu/h-F})]$

**$t_b$ = 59 F**

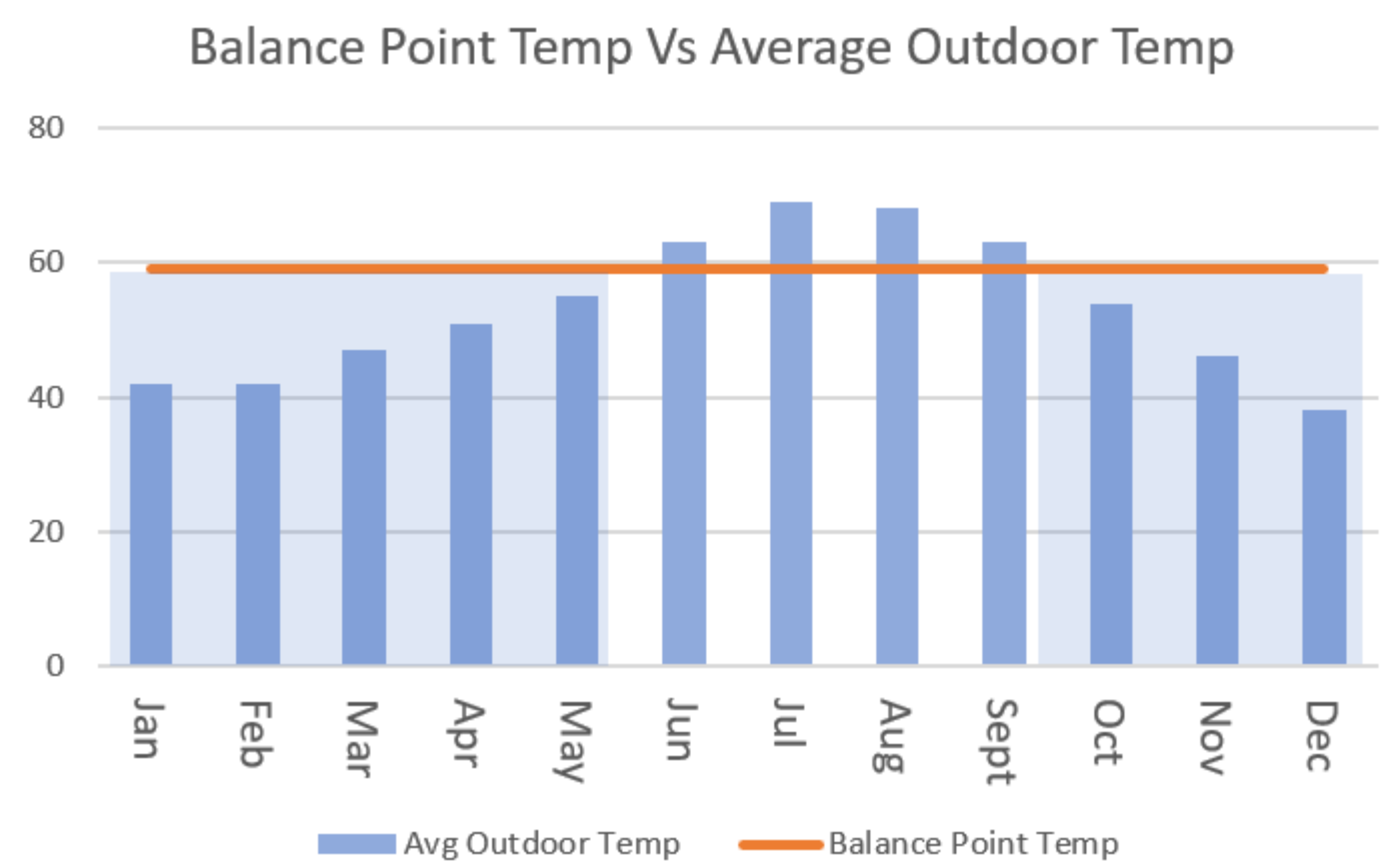
- **Balance Point Temperature For Police Station at setpoint of 68 F**

$t_b = t_i - [(q_s + q_i) \div (q_e \text{ as a factor of } \Delta t + q_{inf} \text{ as a factor of } \Delta t)]$

$t_b = 68\text{ F} - [(0 + 211{,}050\text{ KBtu}) \div (12{,}852\text{ Btu/h-F} + 6804\text{ Btu/h-F})]$

**$t_b$ = 57 F**

# Building Heating Needs




USA_OR_Salem.Muni.AB-McNary.Field.726940_TMYx.2004-2018,climate.onebuilding.org

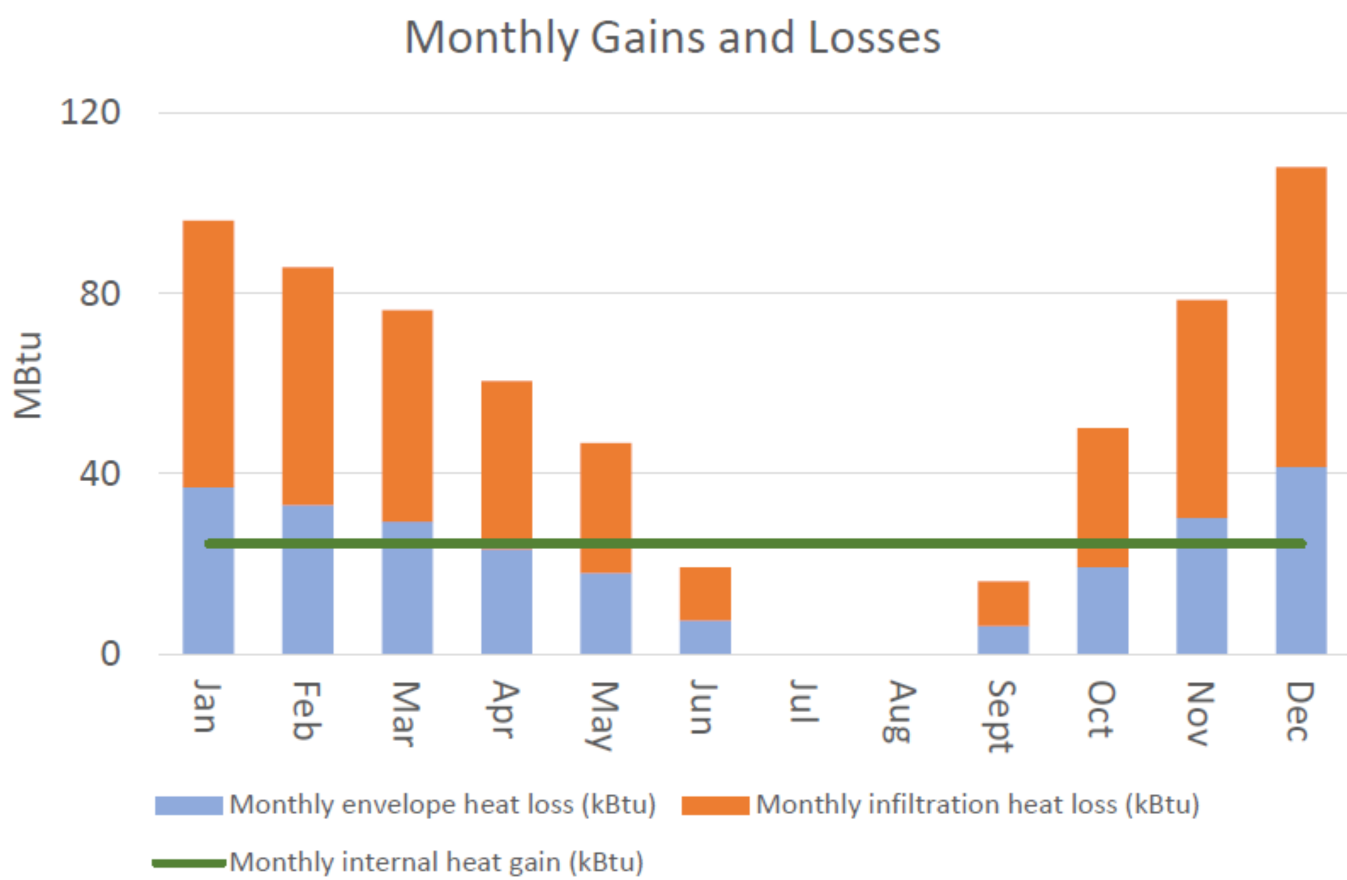
# Building Heat Loss

- **Net heat losses City Hall**

| Month | Monthly envelope heat loss (kBtu) (68 - avg. outdoor temp) X ∑UA | Monthly infiltration heat loss (kBtu) (68 - avg. outdoor temp) X Cp X air density X V X ACH | Monthly internal heat gain (kBtu) | Net heat loss (kBtu) ∑heat losses - heat gains |
|---|---|---|---|---|
| Jan | 36,989 | 59,146 | 24,536 | 71,599 |
| Feb | 32,994 | 52,759 | 24,536 | 61,217 |
| Mar | 29,374 | 46,970 | 24,536 | 51,808 |
| Apr | 23,281 | 37,227 | 24,536 | 35,971 |
| May | 17,997 | 28,778 | 24,536 | 22,239 |
| Oct | 19,270 | 30,813 | 24,536 | 25,546 |
| Nov | 30,236 | 48,348 | 24,536 | 54,047 |
| Dec | 41,555 | 66,448 | 24,536 | 83,467 |
| **Total** | **--** | **--** | **--** | **405,895** |

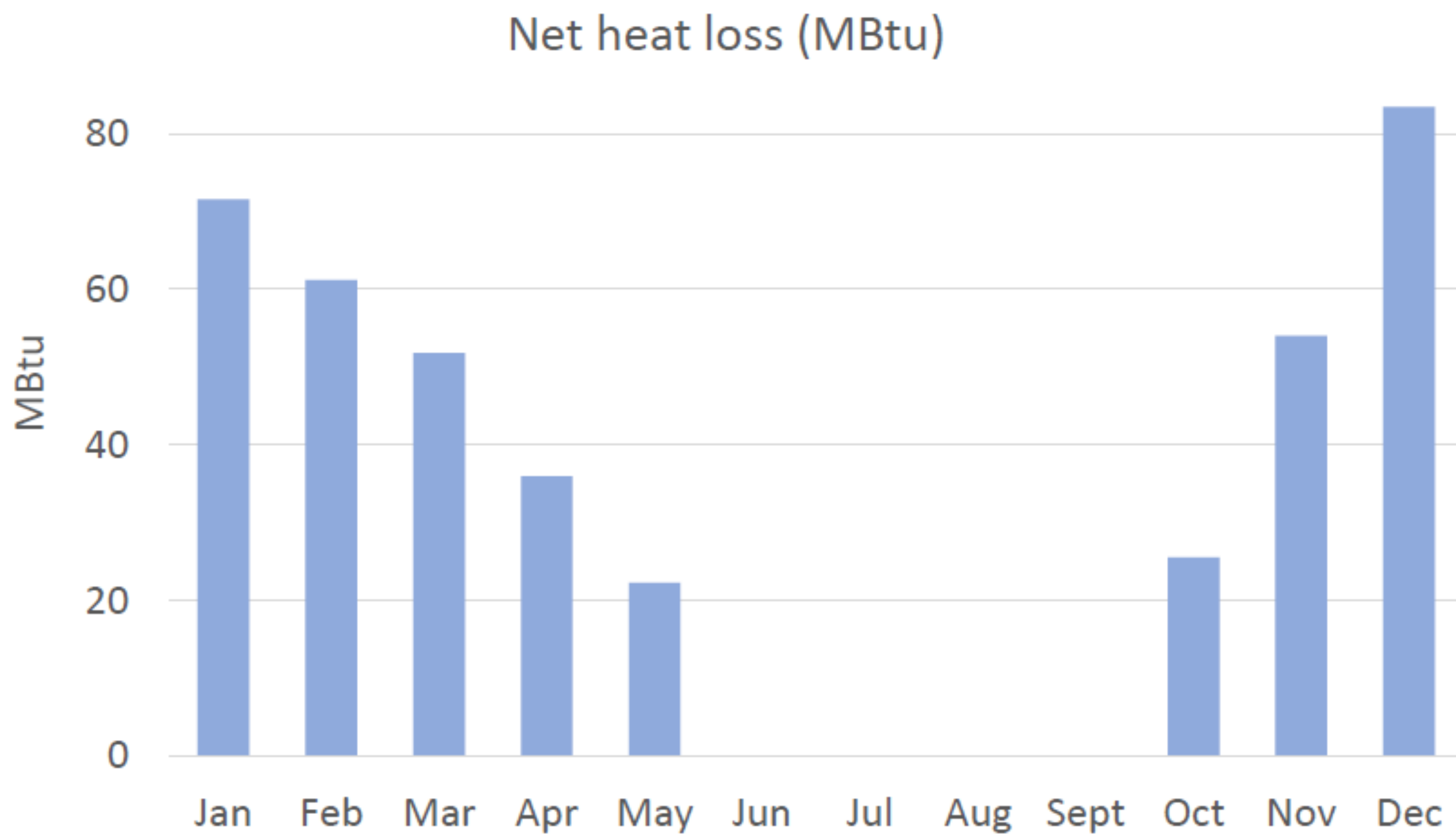
# Building Heat Loss

- **Net heat losses City Hall**



# Building Heat Losses

- Heating Needs-City Hall (406 MBtu)



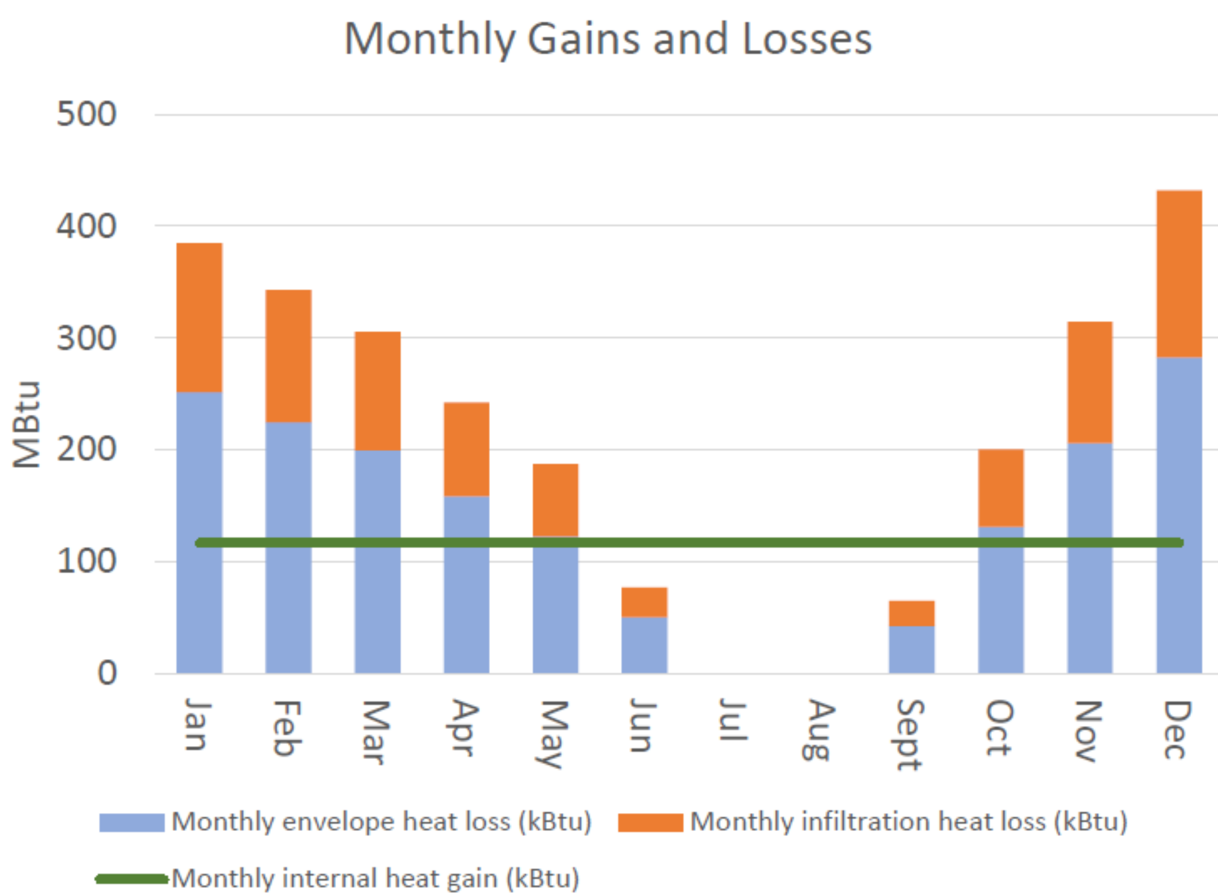
# Building Heat Loss

- **Net heat losses Police Station**

| Month | Monthly envelope heat loss (kBtu) (68 - avg. outdoor temp) X ∑UA | Monthly infiltration heat loss (kBtu) (68 - avg. outdoor temp) X Cp X air density X V X ACH | Monthly internal heat gain (kBtu) | Net heat loss (kBtu) ∑heat losses - heat gains |
|---|---|---|---|---|
| Jan | 251,374 | 133,079 | 116,500 | 267,954 |
| Feb | 224,229 | 118,708 | 116,500 | 226,438 |
| Mar | 199,626 | 105,684 | 116,500 | 188,810 |
| Apr | 158,214 | 83,760 | 116,500 | 125,474 |
| May | 122,308 | 64,751 | 116,500 | 70,560 |
| Oct | 130,956 | 69,329 | 116,500 | 83,785 |
| Nov | 205,481 | 108,783 | 116,500 | 197,765 |
| Dec | 282,408 | 149,509 | 116,500 | 315,417 |
| **Total** | **--** | **--** | **--** | **1,476,202** |

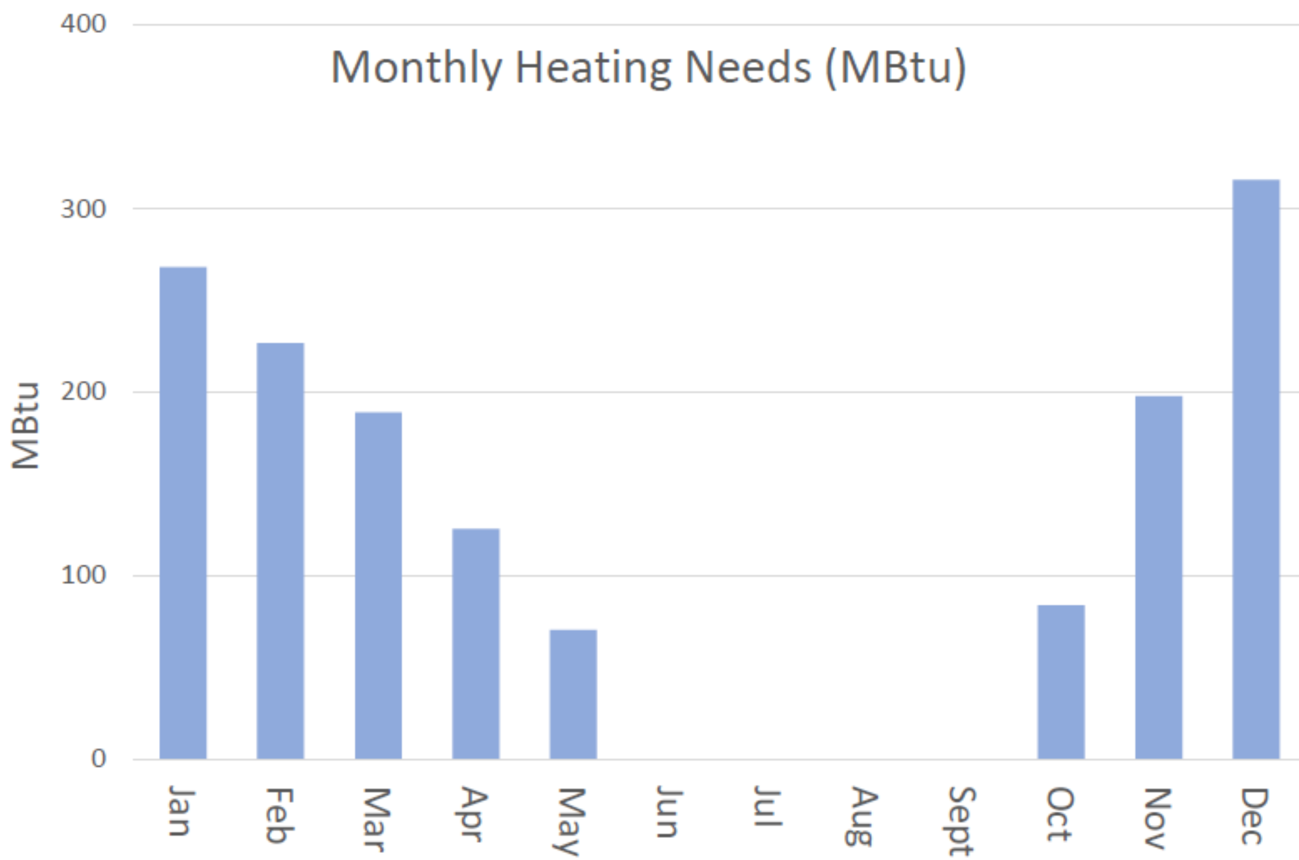
# Building Heat Loss

- **Net heat losses Police Station**



# Building Heat Losses

- Heating Needs-Police Station (1,476 MBtu)



# Solar-Collecting Glass

- Optimum tilt

| Month | Glazing Tilted at 90 Degree Vertical | Glazing Tilted at 80 Degree | Glazing Tilted at 70 Degree | Glazing Tilted at 60 Degree | Glazing Tilted at 50 Degree | Glazing Tilted at 40 Degree | Glazing Tilted at 30 Degree | Glazing Tilted at 20 Degree | Glazing Tilted at 10 Degree | Glazing Tilted at 0 Degree Horizontal |
|---|---|---|---|---|---|---|---|---|---|---|
| **Jan** | **19** | **20** | **21** | **21** | **21** | **20** | **18** | **16** | **14** | **12** |
| **Feb** | **22** | **23** | **25** | **25** | **25** | **25** | **24** | **22** | **20** | **17** |
| **Ma** | **28** | **31** | **33** | **35** | **36** | **36** | **37** | **36** | **33** | **30** |
| **Apr** | **27** | **32** | **36** | **39** | **42** | **43** | **42** | **41** | **40** | **37** |
| **May** | **27** | **33** | **38** | **43** | **47** | **50** | **54** | **54** | **54** | **52** |
| Jun | 27 | 34 | 41 | 47 | 53 | 57 | 56 | 58 | 58 | 57 |
| Jul | 31 | 39 | 47 | 54 | 60 | 65 | 62 | 63 | 63 | 61 |
| Aug | 36 | 43 | 50 | 56 | 60 | 63 | 59 | 59 | 57 | 54 |
| Sept | 36 | 41 | 45 | 48 | 49 | 50 | 47 | 45 | 42 | 38 |
| **Oct** | **32** | **35** | **37** | **38** | **39** | **38** | **32** | **30** | **27** | **24** |
| **Nov** | **17** | **18** | **19** | **19** | **19** | **18** | **18** | **16** | **15** | **13** |
| **Dec** | **15** | **16** | **16** | **16** | **16** | **15** | **16** | **15** | **13** | **10** |
| Total gains oct-may | 187 | 208 | 225 | 236 | **245** | **245** | 241 | 230 | 216 | 195 |

- We need a tilt that gathers most sunlight during heating season i.e. Oct-May
- A tilt of 40 and 50 degrees receives maximum radiation during Heating season.
- We chose to use 45 degree as the intermediate value.

Grondzik, Walter T., and Alison G. Kwok. (2019) Mechanical and Electrical Equipment for Buildings, Appendix I, Table I.1, Eugene OR

# Solar-Collecting Glass

- Glazing specification

The specifications of the glazing assembly we generated through Window 7 are as follows:

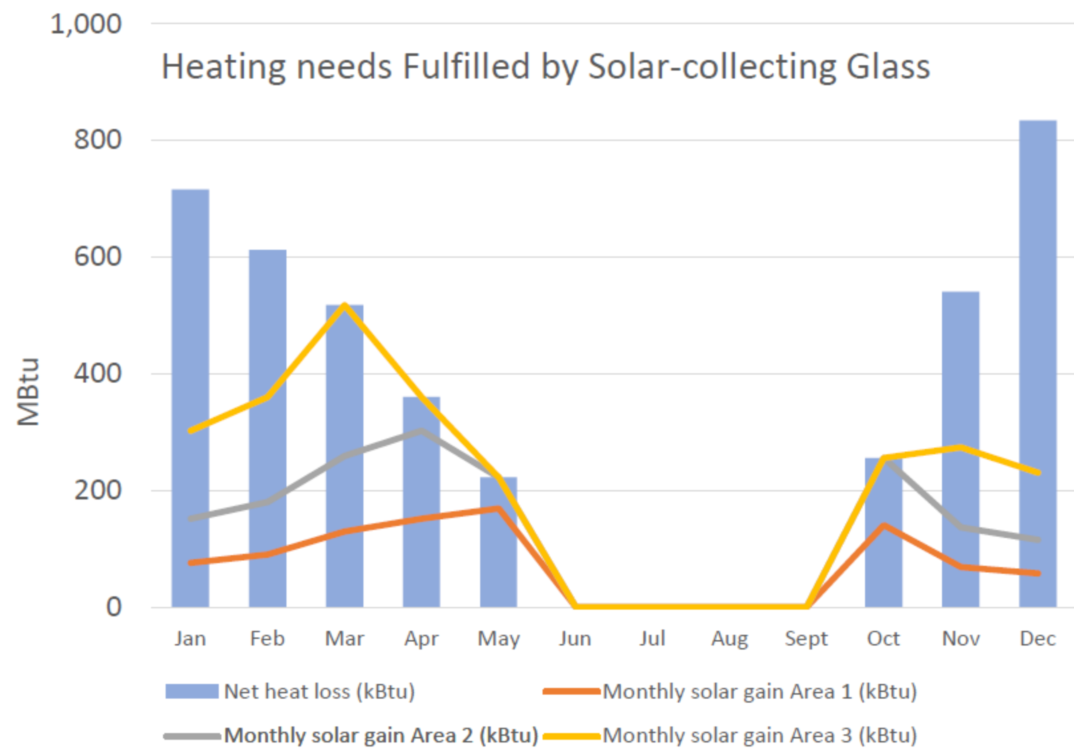
- Window Name: Double Clear Glass
- Glass Name: Extra Clear 4.gvb
- Air Gap: Air 10%, Argon 90%
- U Factor: 0.550
- SHGC: 0.72
- VT: 0.691

- window 7 software (software)

# Solar-Collecting Glass

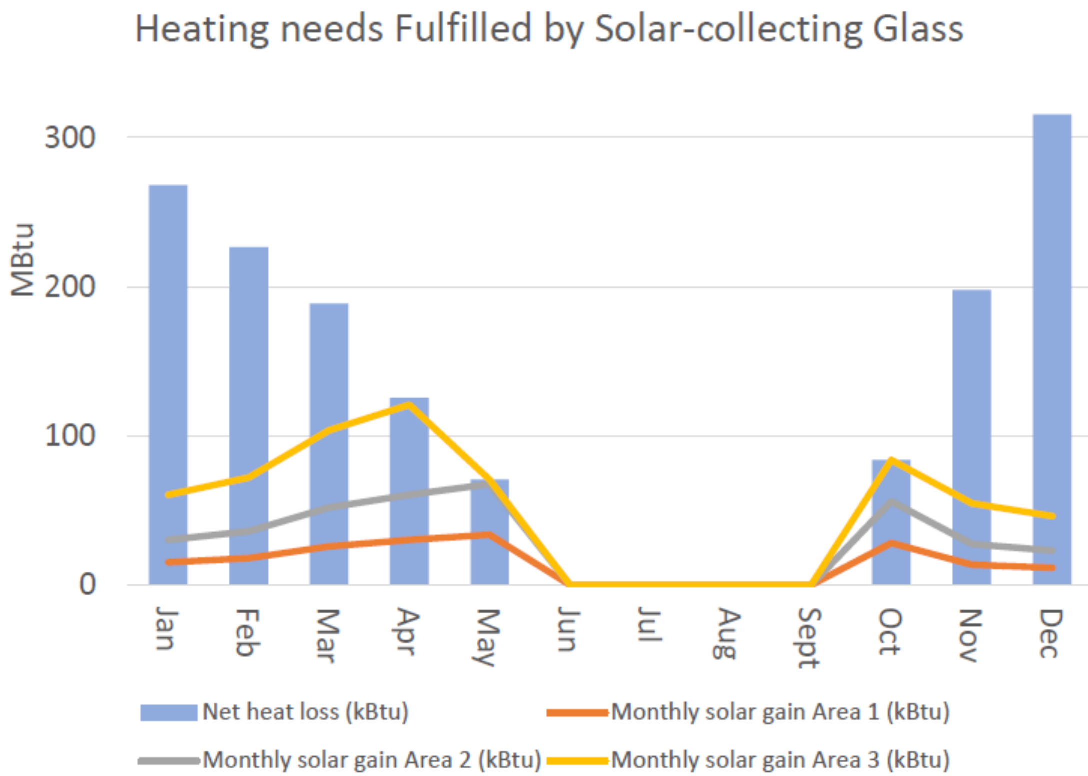
- **Glazing size-City Hall**

- 2000 sft fulfills 75% of building heating needs and covers 30% of the roof area.
- 1000 sft fulfills 50% of buildings heating needs and covers  and covers 15%of the roof area.
- We will use 2000 sft of solar-collecting glass.



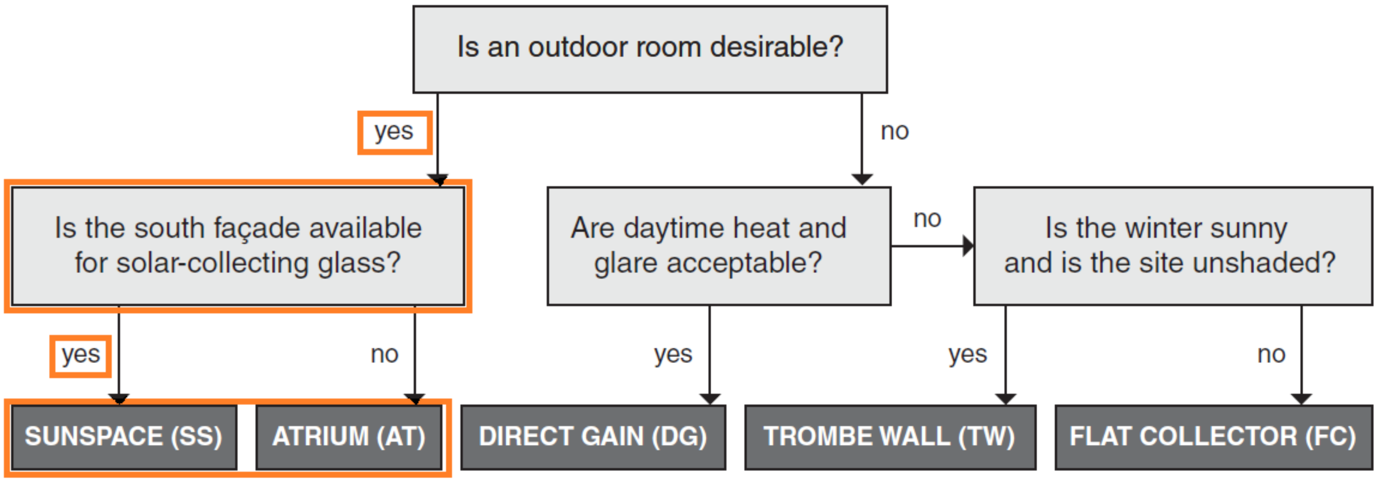
# Solar-Collecting Glass

- **Glazing size-Police station**




- 4000 sft fulfills 50% of building heating needs and covers 25% of the roof area.
- 2000 sft fulfills 25% of buildings heating needs and covers  and covers 13%of the roof area
- We will use 4000 sft of solar-collecting glass.

# Heat Collection System



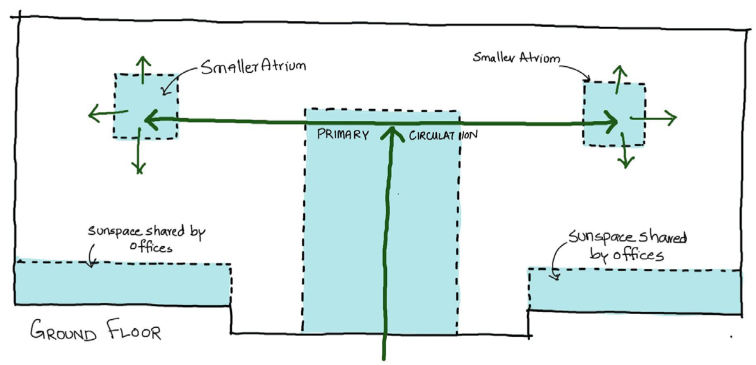

Grondzik, Walter T., and Alison G. Kwok. (2019) Mechanical and Electrical Equipment for Buildings, Chapter 11, Fig 11.25 Pg 400

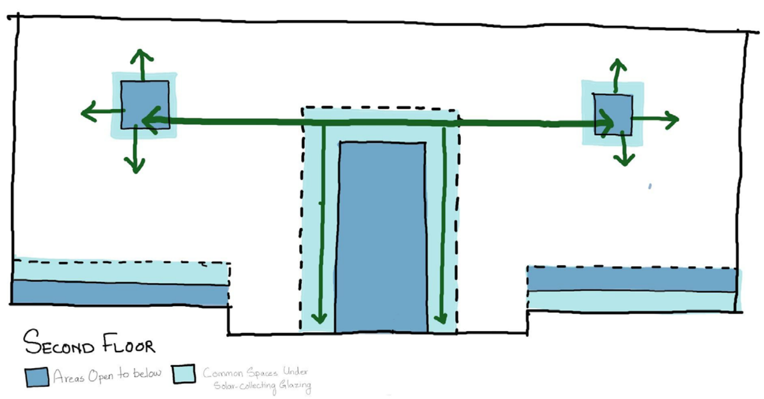
- Based on the size and functions of our buildings outdoor rooms are desirable. They can be integrated with the casual areas such as lobby, cafe or waiting space.
- The south face is available for solar collection, however keeping in view the cloudy winters, and the scale of our buildings, sunrooms alone cannot fulfill the heating needs. An atrium can work better in this case.
- Atrium will be the main outdoor room and will have the reception lobby, waiting spaces and cafe.
- Sun spaces will be adjacent to groups of offices. They function well in smaller size, thus they will serve lower number of occupants. Sunrooms will reduce the glare into office spaces, compared to office spaces with direct gain.

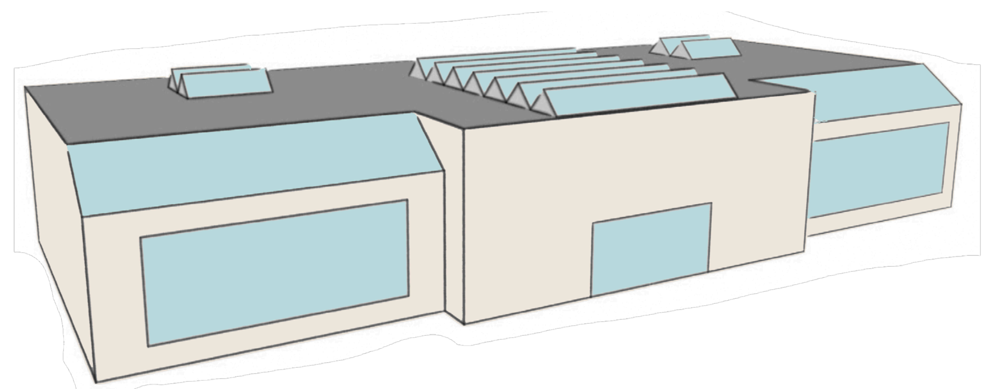
# Heat Collection System

## City Hall

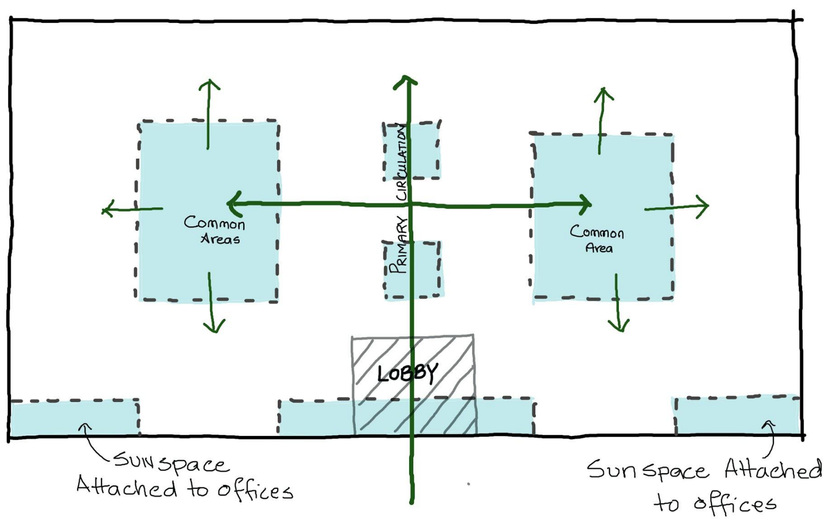
- Atrium as the grand entrance
- Sunspaces will be shared by offices
- Smaller atriums for penetration of sunlight into dark areas
- Air from the atrium will be circulated throughout the building for heating other spaces



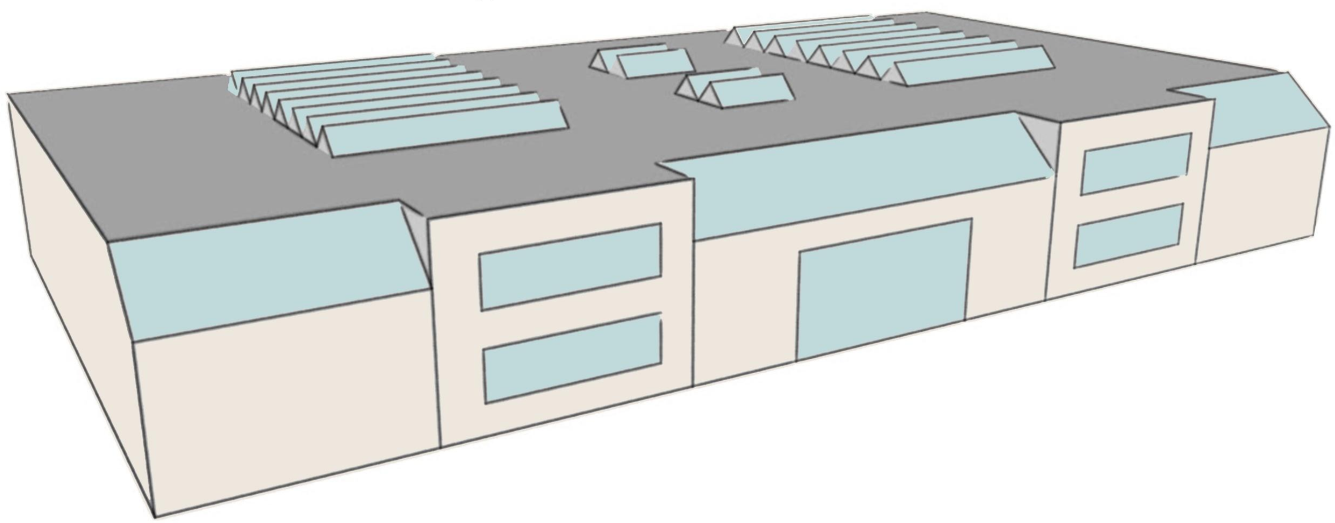



# Heat Collection System




## Police Station

- Two Atriums as common spaces
- Sun spaces over entrance lobby
- Sun spaces shared between offices
- Air from the atrium will be circulated throughout the building for heating other spaces

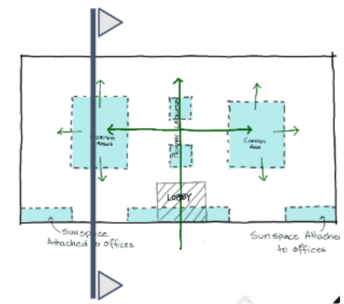


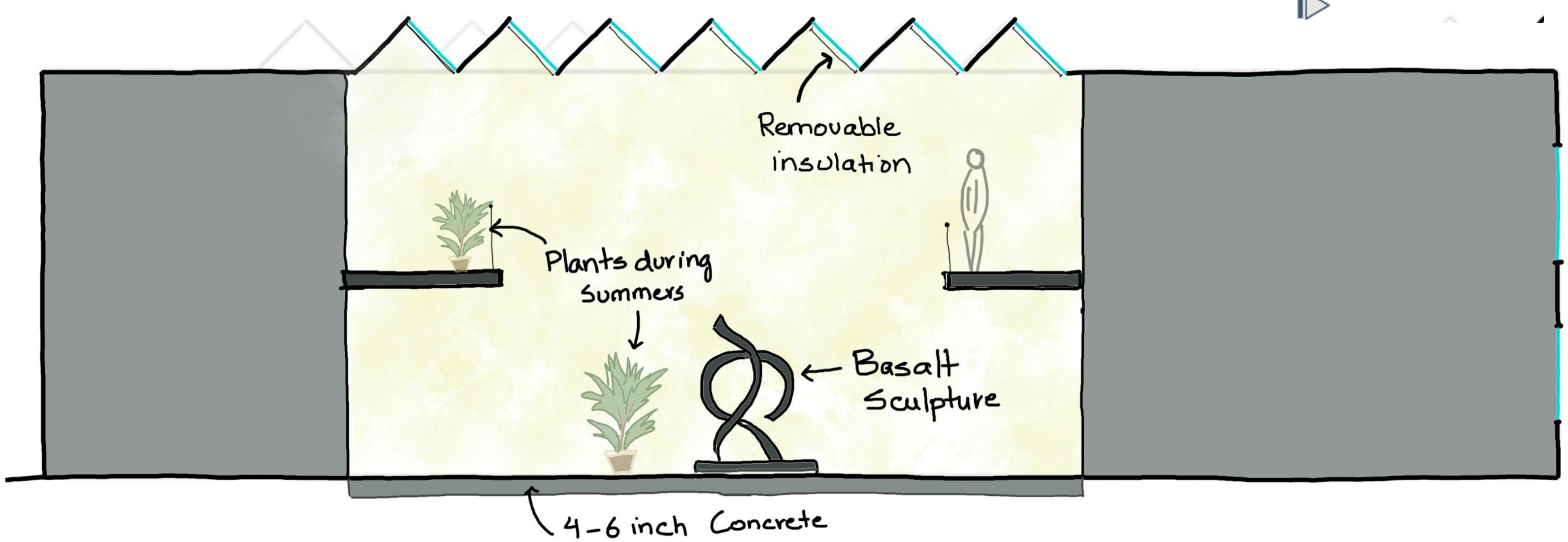
# Heat Storage

- **Thermal Mass - City Hall**
  - We want the heat in the city hall to be delivered day time, as soon as it starts collecting.
  - The floor of atrium will act as small amounts of thermal mass (0”-2”)
  - In winters the floors can be covered with carpets to further reduce the absorption of heat by the floors. They help in creating perception of thermal comfort visually as well.
  - During summers plants can be brought into the atrium to increase thermal mass and for cooling
  - Therefore we will use an air based heat collection system
  - The atrium space and sunspaces will acts as zones where air will be heated up.
  - The heat will be delivered to other areas inside building through air circulation.
  - Air circulation can be done through natural or mechanical means

# Heat Storage

- **Thermal Mass - Police Station**
- The occupancy of police station is 24 hours, so we want heat to be delivered throughout the day.
- We are using 4”-6” of thermal mass in the form of concrete floor in the atriums and sunspaces.
- The atriums will have a basalt centerpiece sculpture, which will also act as thermal mass.
- In summers plants will be added to atriums for cooling.



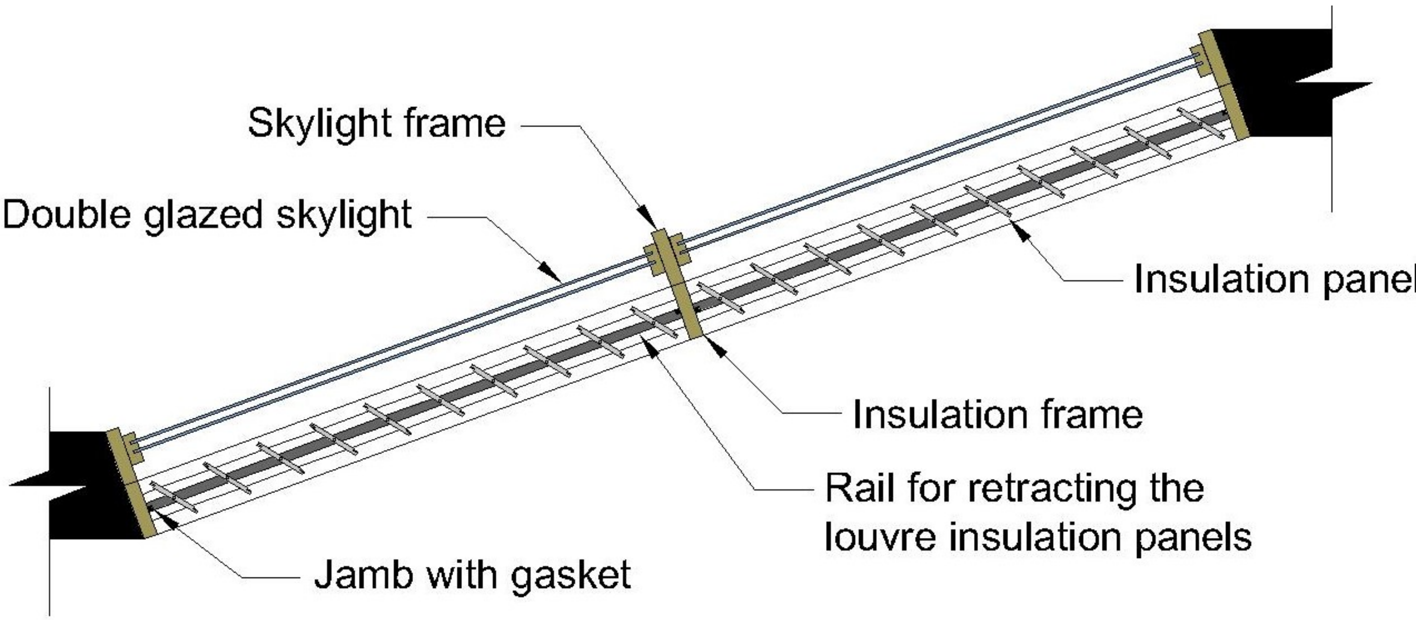


# Heat Storage

- **Thermal mass-Police Station**
  - Density of concrete= 137-150 $lb/ft^3$ (using 143 as the intermediate value)
  - Solar Absorptance of concrete= 0.4-0.5
  - Heat capacity of concrete= 0.22-0.24 (using 0.23 as intermediate value)
    - Solar radiation transmitted through 4000 sft of glass=103680 KBtu/month or 3344 Kbtu/day
    - Daily Uptake by Concrete=3344 KBtu/day X 0.5 = 1,672 KBtu/day
  - Desired Temperature Difference for round clock heat return = 85-60 = 25 ‘F
    - Required weight of concrete = $1/C_p$ X Solar radiation ÷ temp. difference
      1/.23(lb F/Btu) X 1,337,000 (Btu) ÷ 25 F =**232,500 lb**
    - Volume of concrete = Weight ÷ density
      232,500 lbs ÷ 143 (lbs/cft ) = **1,626 cft**
    - For 5 inch thick concrete 1626 cft = **3,965 sft** (approximately equal to glazing area)

Grondzik, Walter T., and Alison G. Kwok. (2019) Mechanical and Electrical Equipment for Buildings, Appendix I, Table I.2, Pg 1818

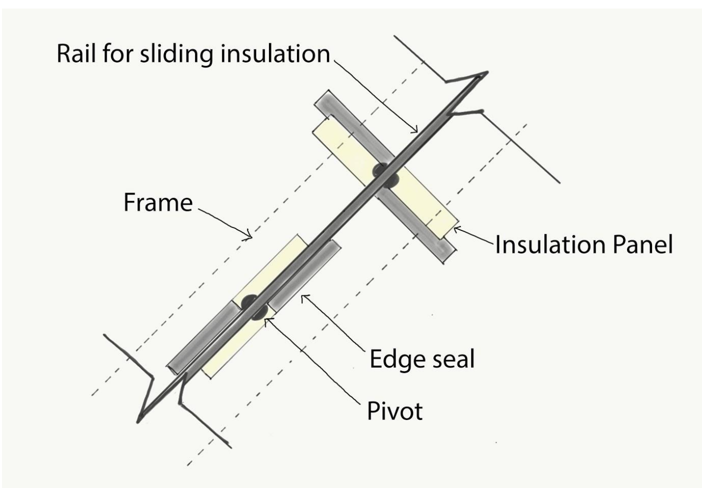
# Night Insulation

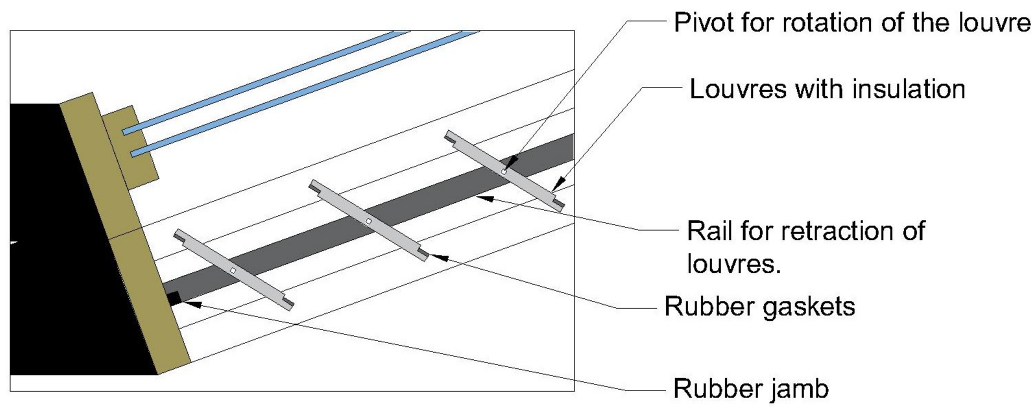



- Insulation will be modular, transformable and fully retractable
- The insulation panels will be upto 1 feet wide.
- In summers it can serve as a screen letting in patterns of light and shade for a dynamic experience
- It can be used to deliver diffused light in summers

# Night Insulation

- Louvered panels can swing open and close, this providing better seals with the help of rubber gaskets
- The pivots will allow the panels to rotate around and change the angle of louvres
- Louvres will be installed on rails and can be fully retracted to allow maximum sunlight during winters.



# Results at a Glance

Location on the site: points with maximum sunshine hours
Optimal orientation: towards south
Heating season: **Jan to May** and from **October to December** (8 months)
Glazing specification: U-factor: **0.550**- SHGC: **0.72**
Night insulation: modular, transformable and fully retractable

**City Hall:**

- Heating needs:  405 MBtu
- Optimum tilt: 45 degrees
- Glazing size: 2000 sft of solar collecting glass fulfills 75% of building heating needs and covers 30% of the roof area.
- Heat collection system: Atrium + Sunspace
- Thermal mass:  Air based heat collection system

# Results at a Glance

**Police station:**

- Heating needs:  1,476 MBtu
- Optimum tilt: 45 degrees
- Glazing size: 4000 sft of solar collecting glass fulfills 50% of building heating needs and covers 30% of the roof area.
- Heat collection system: Atrium + Sunspace
- Thermal mass: 5” of thermal mass in the form of concrete floor in the atriums and sunspaces =3,965 sft (approximately equal to glazing area)
- Basalt centerpiece sculpture in atrium

## SCI Directors and Staff

| | |
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