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**BIOCLIMATIC DESIGN GUIDELINES:
A VALUABLE TOOL FOR LANDSCAPE ARCHITECTS**

by

Laura Patricia Reyes Romero

**Thesis submitted in partial fulfillment
of the requirements for the degree**

of

DEPARTMENTAL HONORS

in

**Landscape Architecture
in the Department of Landscape Architecture & Environmental Planning**

Approved:

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UTAH STATE UNIVERSITY
Logan, UT

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Abstract

This research project aims to create awareness, among landscape architects, on the importance of ecological design. Bioclimatic knowledge contributes to enhance the coexistence between natural and built environments, resulting in healthy places with high quality of life. The study examines ways of graphically representing climate information, to facilitate the understanding and application of bioclimatic design strategies for human comfort. Cache Valley, Utah is used as an example to demonstrate how extensive data can be represented graphically in a more readable and useful manner for practicing professionals. Temperature, humidity, wind and solar information were analyzed and converted into graphics through methods of bioclimatic analysis. The outcome is a recollection of graphic design guidelines to specific climate conditions, in this case Cache Valley, Utah. The resulting design guidelines will aid professionals to design sensitive spaces that minimize energy consumption while maximizing human comfort.

Dedication

I lovingly dedicate this thesis to my parents, who taught me value of hard work and perseverance. To my brothers and sister, who inspire me to be better everyday. To my family, for supporting me each step of the way. To my friends, for making every day brighter. Thank you for being genuinely happy for my success. I will eternally be grateful for all of you.

Laura P. Reyes Romero

Acknowledgements

I would like to express my appreciation and respect to my advisor, Dr. Carlos V. Licon, for his guidance and encouragement throughout this process. His sage advice and patience helped me see the light at the end of the tunnel. Thanks to the Utah Climate Center for making available the data for this study.

Special thanks to Dr. Bo Yang, for his support and enthusiasm towards my work, and to the faculty of the Department of Landscape Architecture and Environmental Planning, for inspiring me to better everyday.

Laura P. Reyes Romero

Table of Contents

Abstract	2
Dedication	3
Acknowledgements	4
Table of Contents	5
List of Figures	6
List of Tables	8
Introduction	9
Objectives.....	11
Methods	12
Results	30
Findings	32
Conclusions	35
Future Work	36
Appendix	37
References	38
Author’s Biography	40

List of Figures

Figure 1 - Climate Diagram	13
Figure 2 - Comfort Ranges	14
Figure 3 - Annual Comfort Ranges, Logan, UT	15
Figure 4 - Spring Comfort Ranges, Logan, UT	16
Figure 5 - Summer Comfort Ranges, Logan, UT	16
Figure 6 - Fall Comfort Ranges, Logan, UT	16
Figure 7 - Winter Comfort Ranges, Logan, UT	16
Figure 8 - Annual Comfort Ranges, Logan, UT	16
Figure 9 - Annual Bioclimatic Chart, Logan, UT	18
Figure 10 - Spring Bioclimatic Chart, Logan, UT	19
Figure 11 - Summer Bioclimatic Chart, Logan, UT	19
Figure 12 - Fall Bioclimatic Chart, Logan, UT	19
Figure 13 - Winter Bioclimatic Chart, Logan, UT	19
Figure 14 - Bioclimatic Needs Table	20
Figure 15 - Sun Path Diagram - Summer and Fall	21
Figure 16 - Sun Path Diagram - Spring and Winter	22
Figure 17 - Annual Wind Rose	25
Figure 18 - Spring Wind Rose	26
Figure 19 - Summer Wind Rose	27
Figure 20 - Fall Wind Rose	28
Figure 21 - Winter Wind Rose	29
Figure 22 - Prototype Home for Cache Valley, Utah - Plan View	33

Figure 23 - Summer Southeast View - June 21st 2:00 pm33
Figure 24 - Winter Southeast View - December 21st 10:00 am34
Figure 25 - Summer Southwest View - June 21st 2:00 pm34
Figure 26 - Winter Southwest View - December 21st 10:00 am34

List of Tables

Table A - Comfort Range Distribution	14
Table B - Annual Wind Ranges	24
Table C - Spring Wind Ranges	24
Table D - Summer Wind Ranges	24
Table E - Fall Wind Ranges	24
Table F - Winter Wind Ranges	24
Table G - Top 5 Design Guidelines for Cache Valley	32

Introduction

Ancient civilizations' understanding of the importance of regional adaptation of shelter offers valuable lessons for contemporary designers. It seems our societies can quickly forget some of the basic premises of sustainable practices and the importance of adapting shelter to climate as our earlier settlements did. We forget that the environmental qualities of a site are the main tools we can use to design healthy places, and that "The desirable procedure would be to work with, not against the forces of nature and to make use of their potentialities to create better living conditions" (Olgyay, 1963).

The resources for designers of the built environment to create healthy places have existed for decades. Victor Olgyay in his book *Design with Climate* (1963) specifically examines the impact of climate, on building principles, by taking three main steps. The first step to define the requirements for comfort of a specific location. Then, review the existing climatic conditions and finally synthesize the results and turn them into architectural expression that can be used for designing. In his book, he divides climate conditions for the United States into 4 main zones and creates design typologies appropriate for each condition.

Olgyay's creative and analytical approach to design has been the base to many studies on bioclimatic and passive architecture. Edward Mazria in *The Passive Solar Energy Book* (1979) analyzes how site, climate, local building materials and sun can enhance design strategies to create passive solar buildings. Pursuing this further, G.Z. Brown in his book *Sun, Wind and Light* (1985) uses Olgyay's approach to discuss the energy consequences of basic design decisions. Brown analyzes the relationship between architectural form and energy use by using bioclimatic charts, sun path diagrams and wind roses. Since decades ago, Olgyay's work has been greatly influential in the field of bioclimatic design.

The study of bioclimatic design is still promoted nowadays. The Passive Low Energy Architecture (PLEA) is a worldwide organization that focuses on sustainable architecture and urban design. PLEA organizes an annual conference where professionals meet to find ways of better addressing ecological and environmental responsibility in architecture and planning. Other organizations, such as Solar Architecture in Europe (Steemers, 1991), organize similar events. This one specifically focused on finding ways to benefit European economy by reducing imported oil, reducing products' cost and environmental pollution. There is no doubt that a lot has been done in the past regarding the study of bioclimatic and passive architecture, but by looking at contemporary methods of designing we can quickly see that most of these valuable studies are not being used to enhance the quality of life of the spaces we create.

In recent years, an increasing interest in sustainable design has adopted LEED (Leadership in Energy and Environmental Design) guidelines and regulations. Even though these "green buildings" follow environmentally friendly building practices according to the Sustainable Site Initiative (SSI) they do not fully address landscape sustainability. Therefore, the Sustainable Sites Initiative (SSI) emerges as an effort "to develop standards and guidelines for site development that will reduce the environmental impact of landscapes"(The Sustainable Sites, 2007). It is clear that the rapid depletion of resources and the demand for energy have made important and necessary the adoption of specific strategies of sustainable design. As sustainability measures get adopted by counties and states all over the country, the importance of preserving and conserving our resources for future generations becomes more evident.

Objectives

The poor clarity of the information available is one of the reasons as to why climate information is not currently used as a primary factor to design. Even though there is a lot of information available on sustainable practices, there is not enough connection between the information and the current methods of designing. The interest in sustainable practices, and the necessity of recovering this vision of design drove this research project to make this information available and useful for professionals in the field of landscape architecture.

Making bioclimatic information readable and applicable will allow landscape architects to design functional passive systems that will reduce environmental and economic impacts. Taking an ecological approach to design will positively affect the environmental, economic, and social dimensions of the community, by increasing stewardship of the land. This project uses Cache Valley, Utah to show how climate information can be transformed into useful resources for landscape architects and planners. The graphic outcome of this project can be analyzed and used to create design guidelines that will help professionals create healthy places with high quality life.

Methods

This study sets forth to process climate information that will be instrumental in the generation of graphic representations of climate conditions for Cache Valley, Utah. Weather information is aggregated by using the following charts and tools:

- Thermal Comfort Condition Charts

- Bioclimatic Chart

- Bioclimatic Needs Table

- Sun Path Diagram

- Wind Rose

Design considerations are extracted from each analysis and the information is later transformed into a design typology that is responsive to the bioclimatic needs identified for Cache Valley, Utah.

Weather Information

In order to create an accurate representation of the bioclimatic conditions of the area, it was necessary to make an analysis of climate data from three weather stations in Cache Valley. Hourly climate data, for the past 5 years, was obtained from Greenville Farm, Birch Creek Golf Course and Utah State University weather stations. The databases provided us with appropriate information to represent the climatic conditions of the valley. Temperature, relative humidity, wind speed and direction were the main fields analyzed in this study. Data was grouped in order to generate different graphs that could be used to create design guidelines.

Climate Comfort Parameters

Thermal comfort is determined by the body's ability to dissipate heat and moisture at the same rate it generates them. It can be achieved by providing an adequate combination of heat transfer. Heat transfers in our environment by convection, conduction and radiation. Even though thermal comfort can vary between individuals, it is possible to define the major contributing factors to achieve human satisfaction. This study aims to specify design strategies that will contribute to create comfort by the use of bioclimatic design parameters. Figure 1, derived from Victor Olgyay's "Relation of human body to the climatic elements" (Olgyay, 1963) displays heat transfer occurring around the human body.

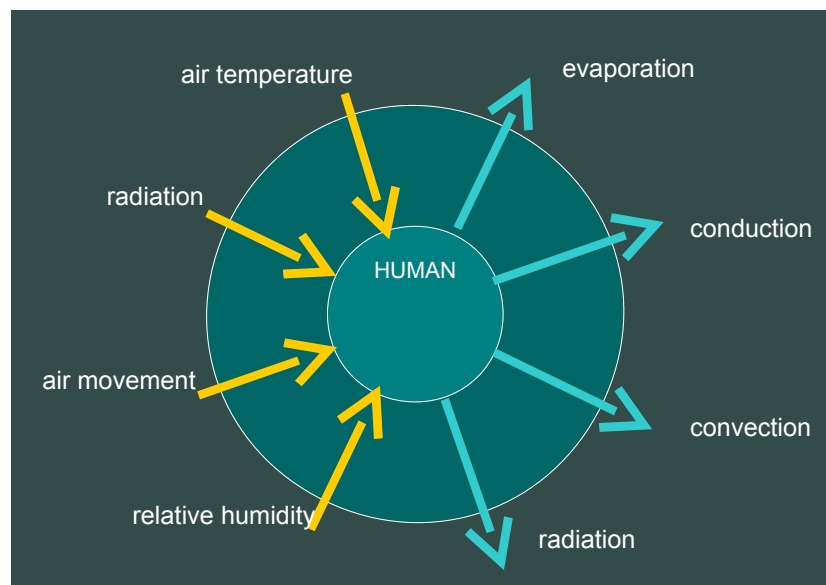


Figure 1 - Climate Diagram (Olgyay, 1963)

Thermal Comfort Condition Charts

Based on temperature and relative humidity, two different type of charts (Figures 3 and 8) were created to represent the thermal comfort distribution of Cache Valley. Both figures classify

monthly comfort ranges into: hot & dry, hot, hot & humid, dry, comfortable, humid, cold & dry, cold, and cold & humid. Table A shows the amount of hours per day that follow in each range. The ranges derived from Victor Olgyay’s bioclimatic chart level of comfort, as shown in Figure 2.

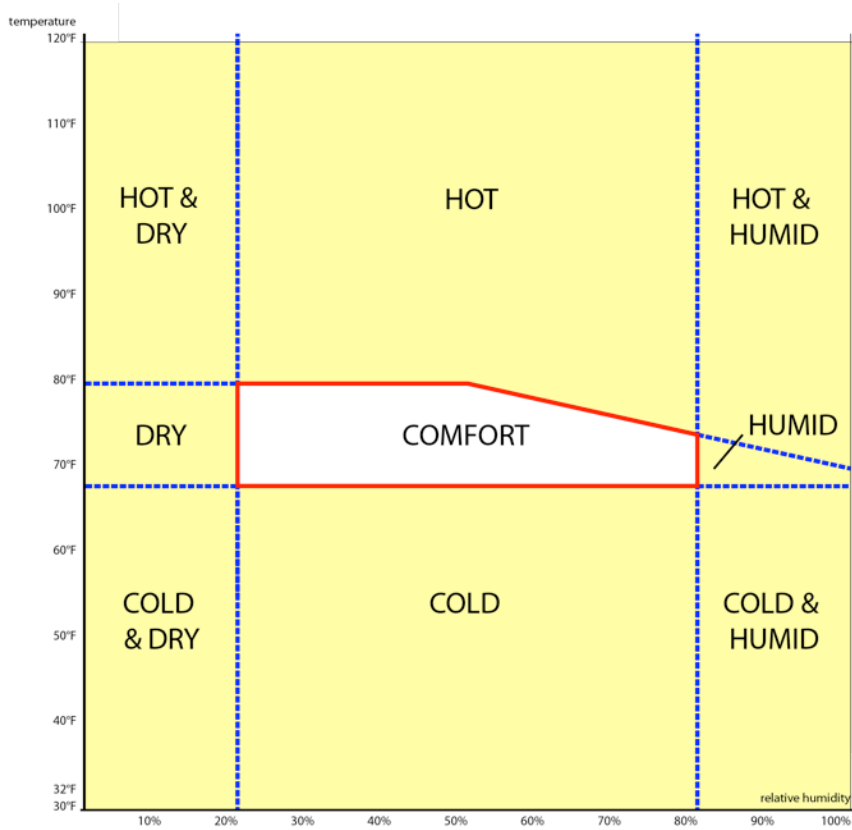


Figure 2 - Comfort Ranges

	hot & dry	hot	hot & humid	dry	comfort	humid	cold & dry	cold	cold & humid
January	0	0	0	0	0	0	0	657	87
February	0	0	0	0	0	0	0	680	16
March	0	0	0	0	0	0	0	731	13
April	0	0	0	0	0	0	0	720	0
May	0	0	0	4	66	0	0	674	0
June	35	25	0	0	184	0	0	476	0
July	103	171	0	0	272	0	0	198	0
August	77	104	0	0	266	0	0	297	0
September	10	4	0	13	171	0	0	522	0
October	0	0	0	0	5	0	0	739	0
November	0	0	0	0	0	0	0	719	1
December	0	0	0	0	0	0	0	520	224

Table A- Comfort Range Distribution

Figures 3 through 7 are two dimensional representations of the distribution of seasonal and annual thermal comfort. Figure 8 is a three dimensional representation of Figure 3 which allows us to see more clearly the distribution of temperature ranges throughout the year.

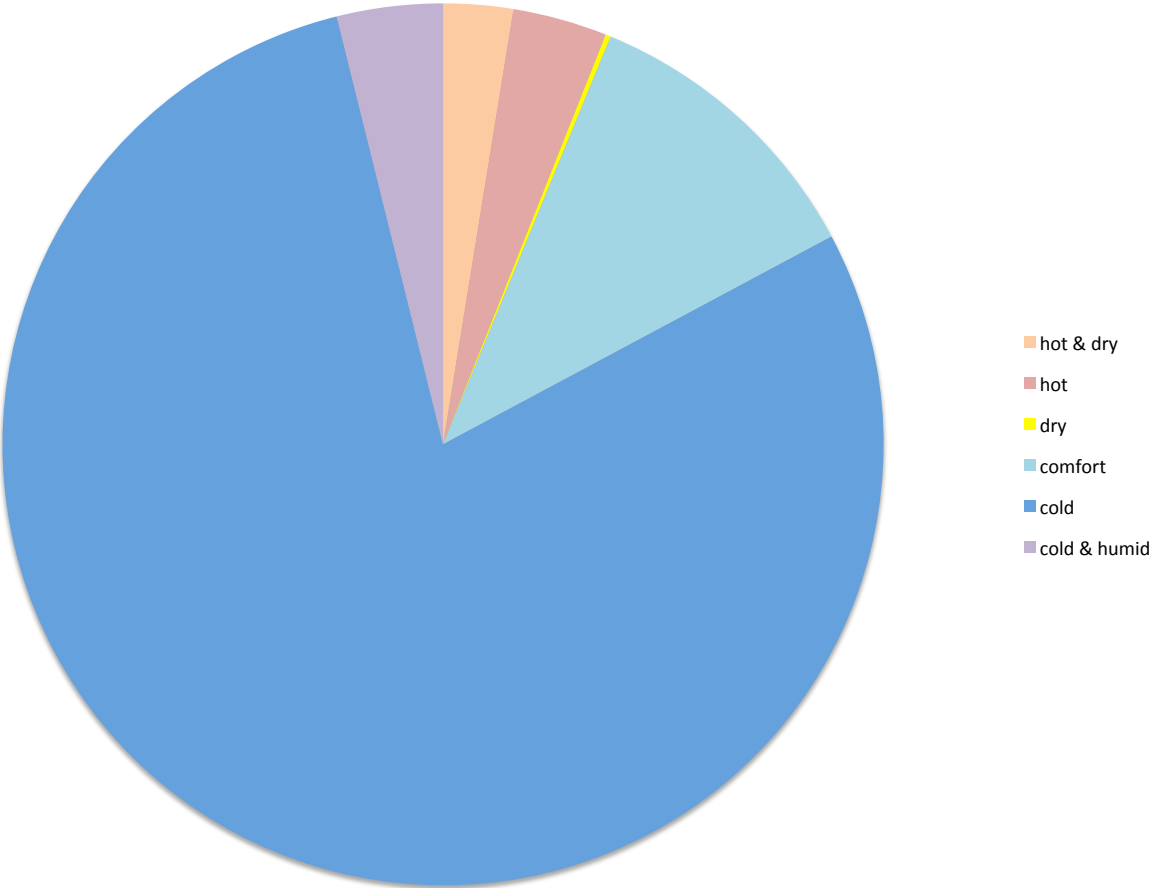


Figure 3 - Annual Comfort Ranges, Logan, UT
Ave. Temperature 2005-2011

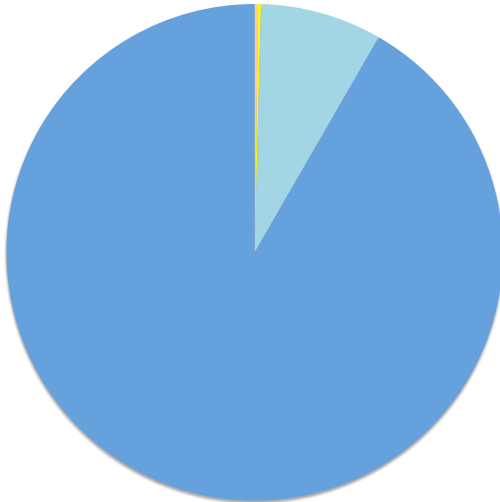


Figure 4 - Spring Comfort Ranges, Logan, UT

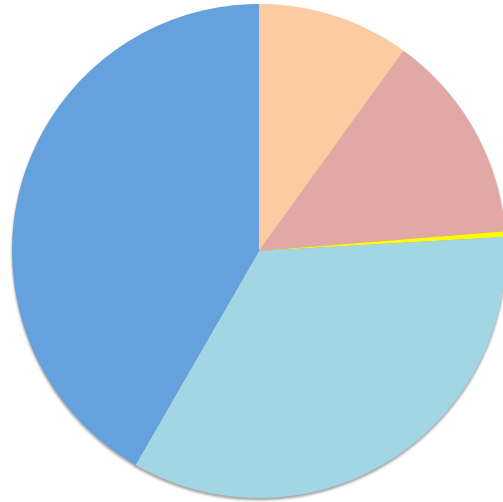


Figure 5 - Summer Comfort Ranges, Logan, UT

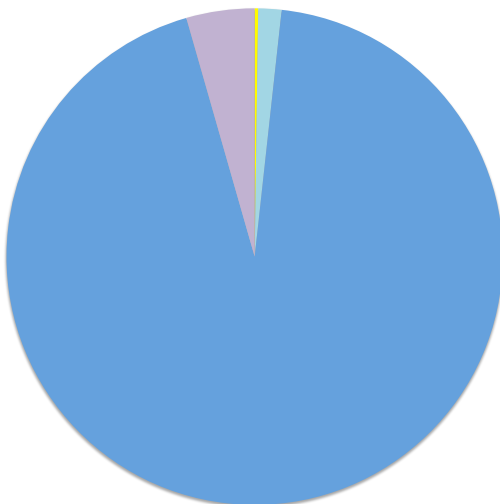


Figure 6 - Fall Comfort Ranges, Logan, UT

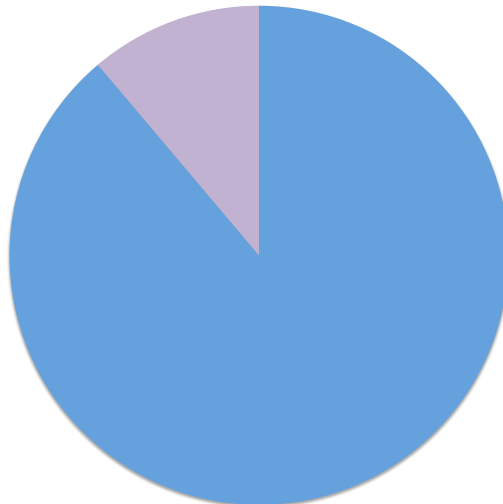


Figure 7 - Winter Comfort Ranges, Logan, UT

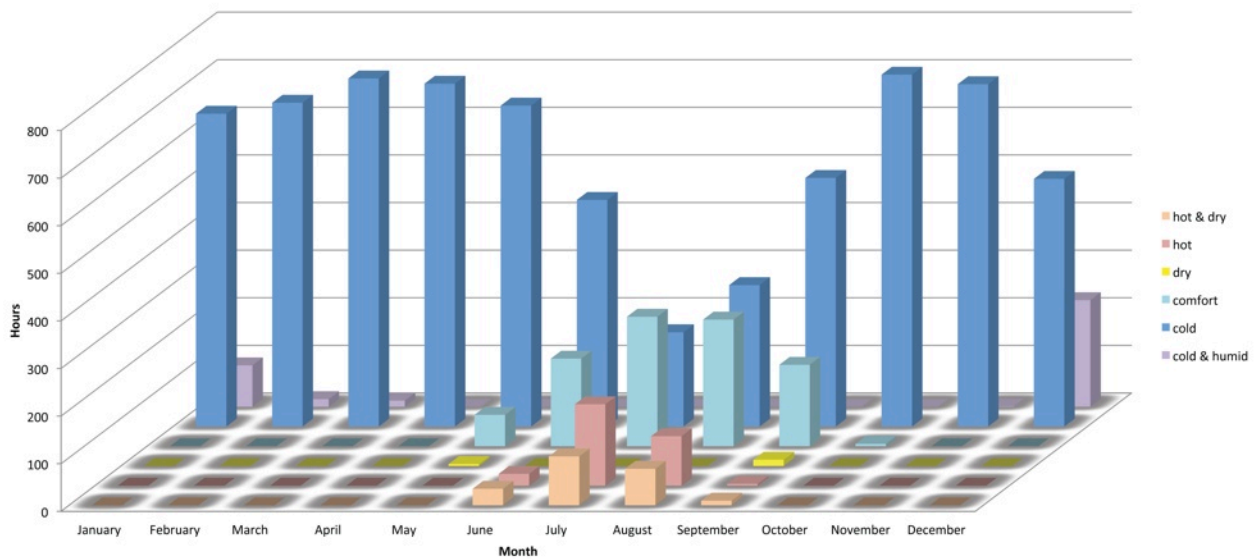


Figure 8 - Annual Comfort Ranges, Logan, UT

Bioclimatic Chart

The Bioclimatic Chart (Figure 9), a preliminary analysis tool originally developed by Victor Olgyay, was used for this project with slight modifications to make it more related to Cache Valley's conditions. The Bioclimatic Chart (Figure 9) analyzes the combination of temperature and relative humidity, to determine the bioclimatic strategies needed to provide comfort throughout the year. It indicates the comfort zone where no design strategies are necessary to maintain thermal comfort, and allows us to visualize how much comfort can be achieved through different design strategies that are mentioned below.

- Thermal mass and ventilation

- Evaporative coolers

- Thermal mass

- Natural ventilation

- Passive solar heating

To create this graph points were plotted on a Excel chart. Each one of these points represents the average temperature and relative humidity per hour for the past five years. The Excel file allows us to visualize the plotted points daily, monthly, seasonally and/or annually, in order to accommodate for the needs of any project. In order to create a general analysis of Cache Valley we created seasonal and annual Bioclimatic Charts.

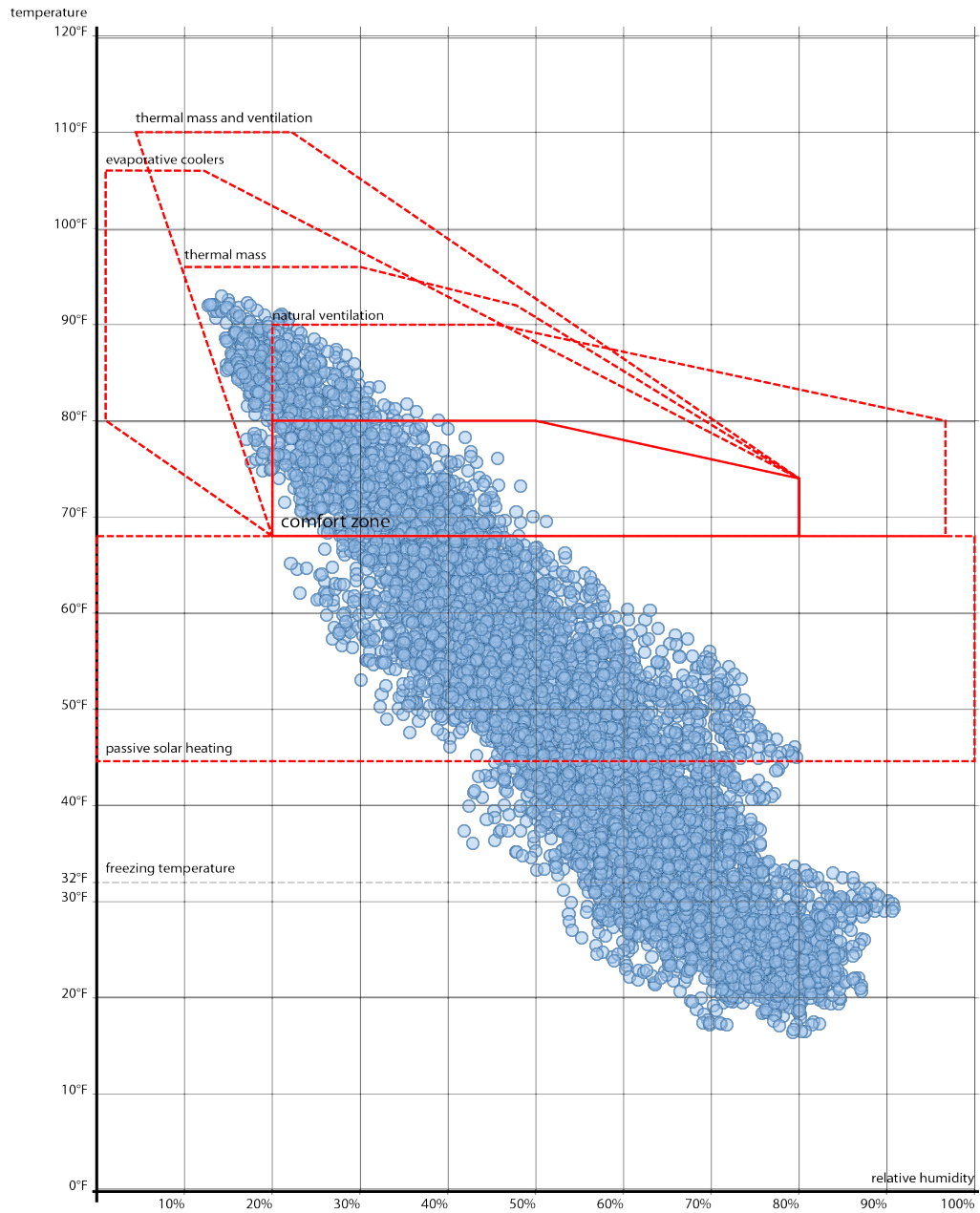


Figure 9 - Annual Bioclimatic Chart, Logan, UT
Ave. Temperature 2005-2011

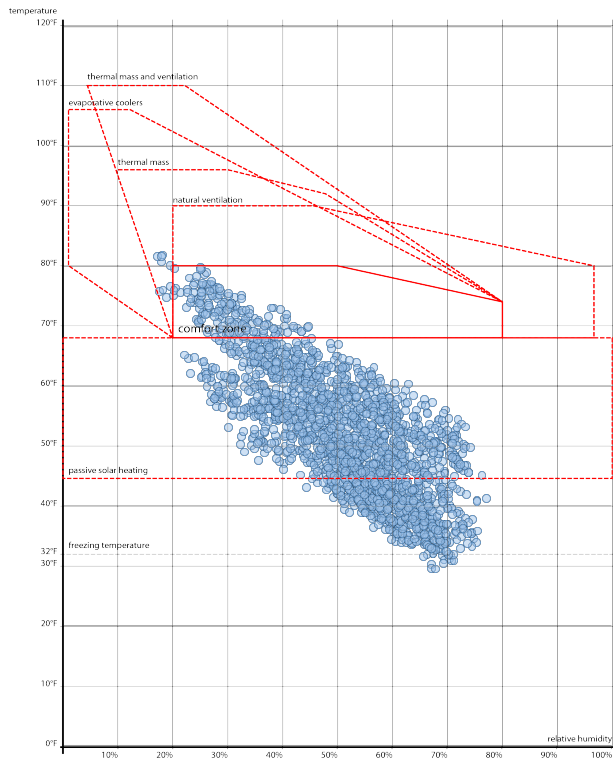


Figure 10 - Spring Bioclimatic Chart, Logan, UT

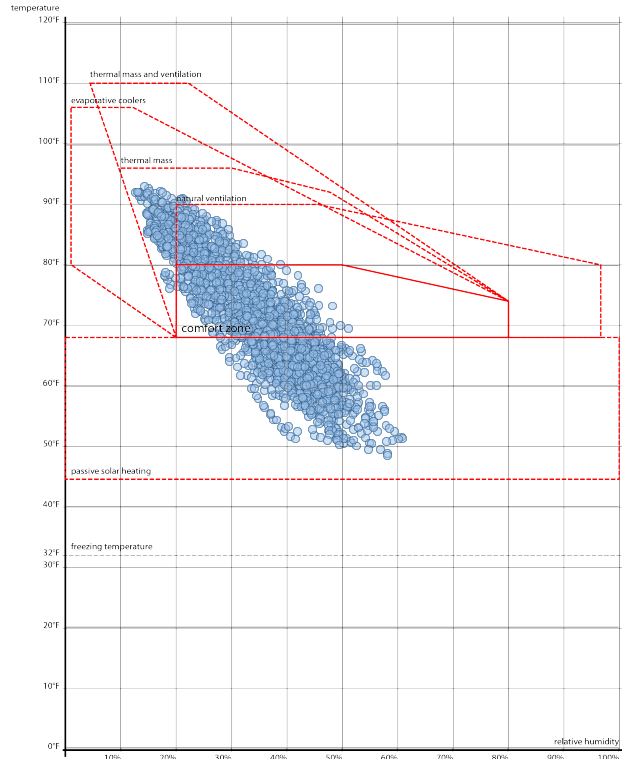


Figure 11 - Summer Bioclimatic Chart, Logan, UT

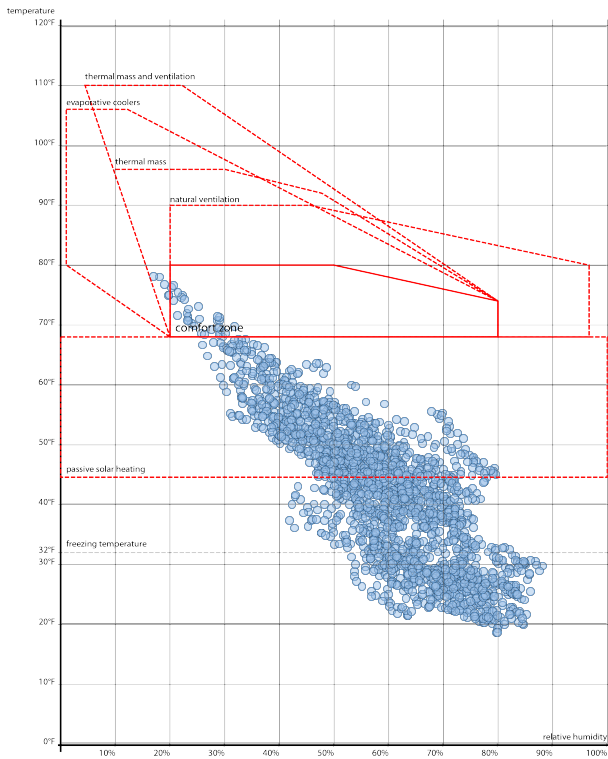


Figure 12 - Fall Bioclimatic Chart, Logan, UT

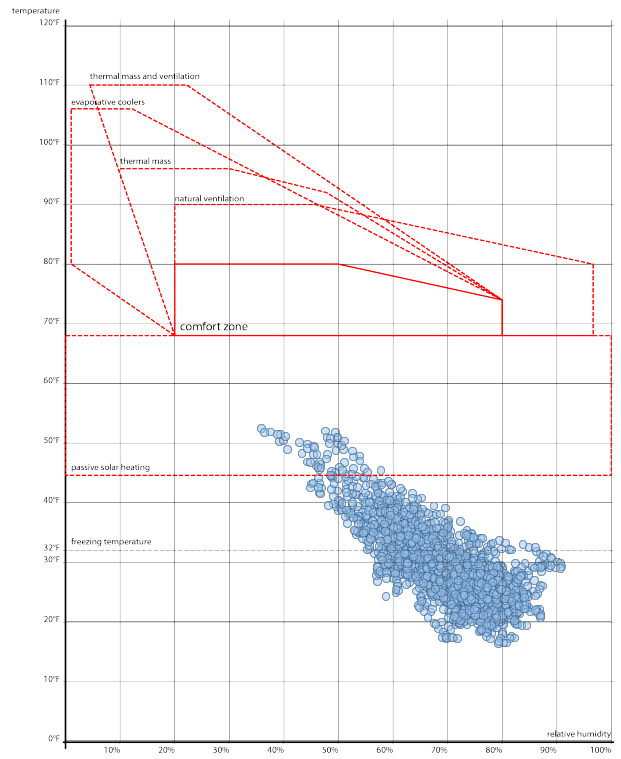


Figure 13 - Winter Bioclimatic Chart, Logan, UT

Bioclimatic Needs Table

The Bioclimatic Needs Table (Figure 14) displays the typical temperature range by hour throughout the day in order to identify times and seasons of the year below or above comfortable ranges. The blue dashed lines represent sunrise and sunset hours. The graph plots temperatures occurring through the year in 5°F increments. Considering a comfortable environment between 65°F and 80°F, this graph helps us identify when shade or sun exposure is needed, for establishing design guidelines.

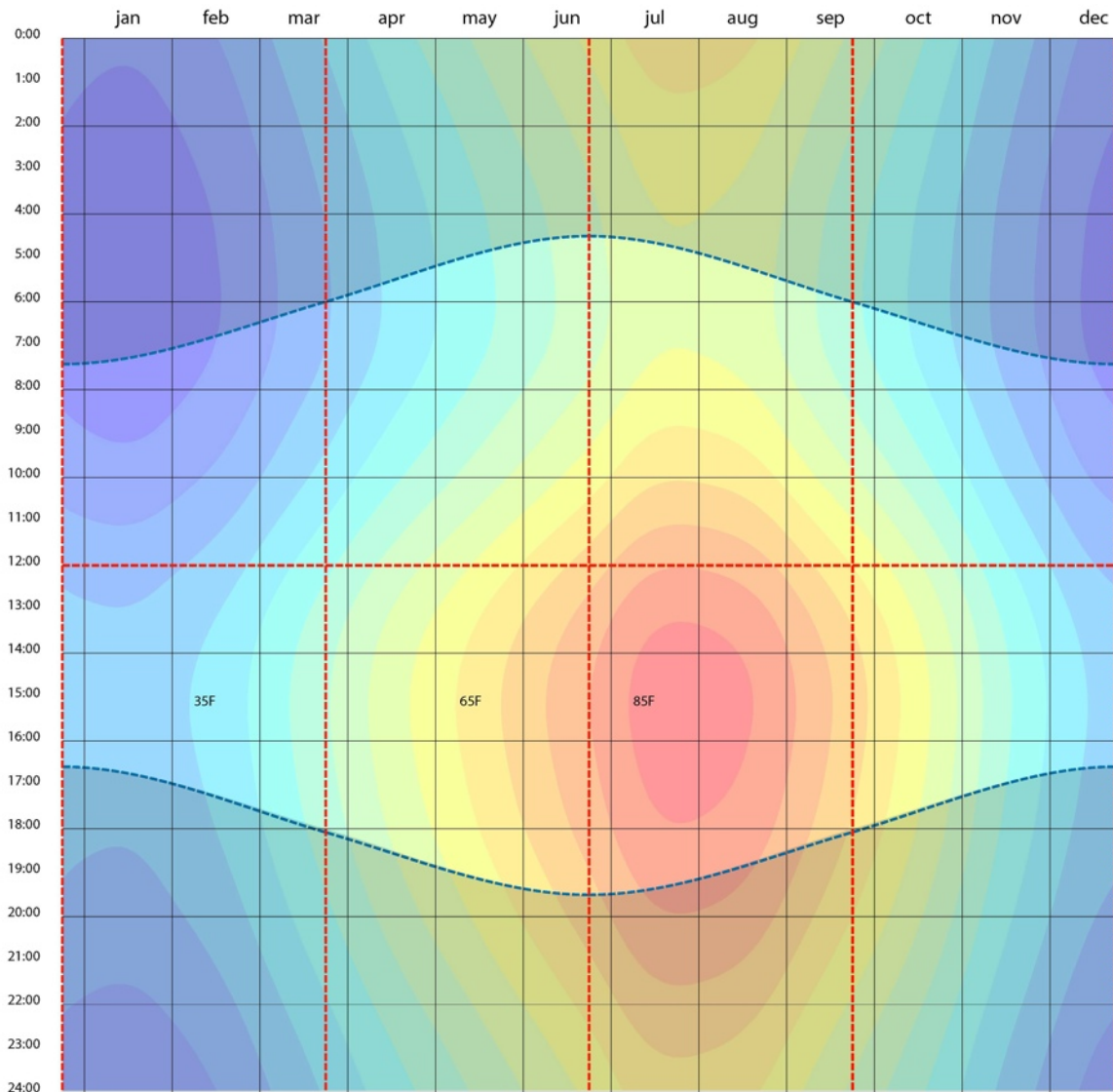


Figure 14 - Bioclimatic Needs Table

Sun Path Diagram

The sun's position throughout the year is critical to complement the results of temperature and humidity conditions assessment. Sun Path Diagrams specifically made for Cache Valley's latitude (42 degrees North) were created for this analysis. The Sun Path Diagram (Figures 15 and 16) is a graphic representation of the sun's trajectory across the sky. This diagram can help us calculate solar position in altitude and azimuth (orientation), which is useful when determining the solar availability for a site.

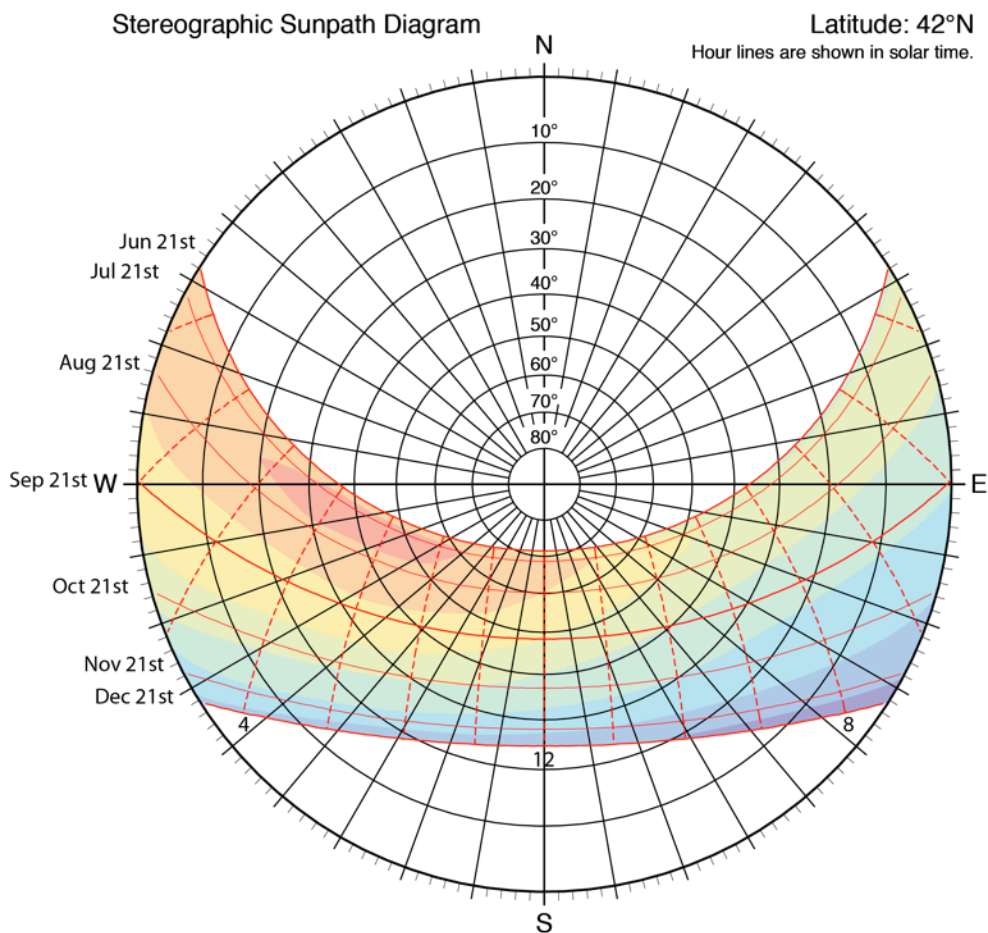


Figure 15 - Sun Path Diagram - Summer and Fall

Two diagrams were created by plotting average temperature data in 10°F increments throughout the year. Figure 15 represents summer and fall conditions, while Figure 16 represents winter and spring conditions.

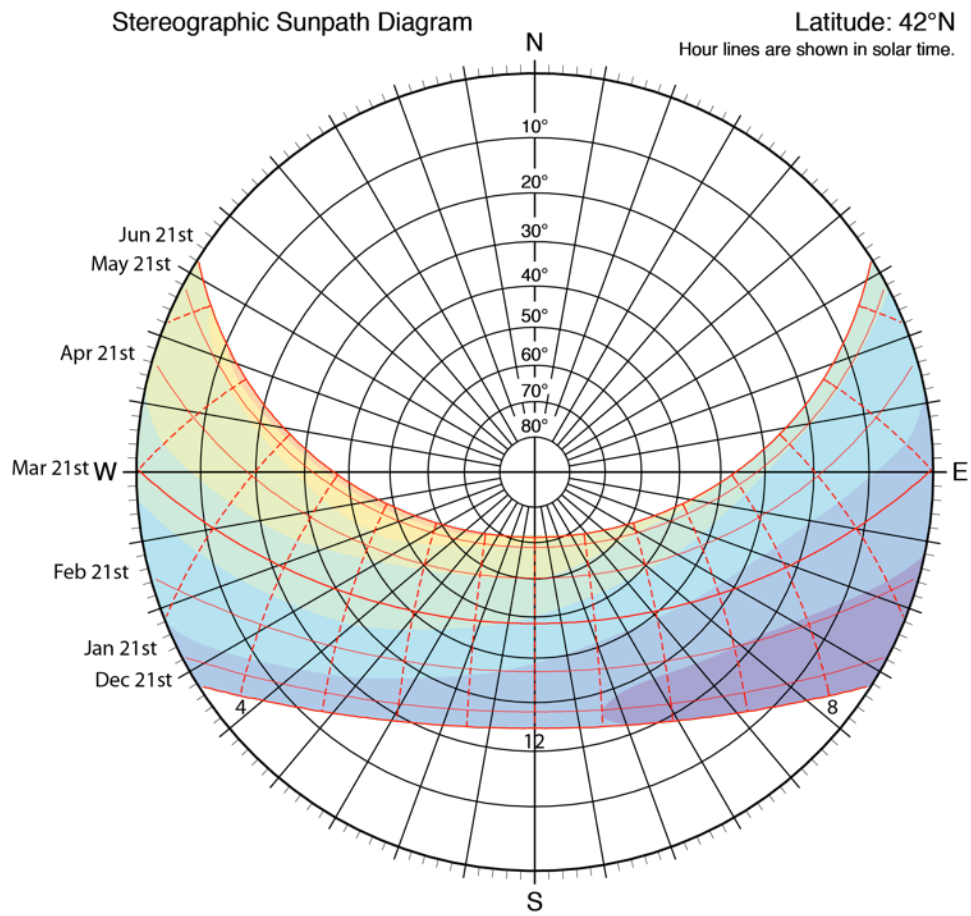






Figure 16 - Sun Path Diagram - Spring and Winter

Wind Rose

Annual and seasonal wind roses were created in order to visualize wind frequency, speed and direction in specific areas of Cache Valley. The wind roses were created by using wind speed and direction data from the Greenville weather station, as this weather station provided us with the most accurate wind information. The wind roses organize wind information in 16 cardinal directions composed by color-coded bands that represent different wind speed ranges that are associated to levels of human comfort.

Wind Speed and Human Perception of Comfort

-  1.2 mph or less - pleasant
-  1.2 - 2.4 mph - pleasant + aware of wind
-  2.4 - 4.8 mph - enjoyable during summer but unpleasant during winter
-  4.8 or more mph - generally unpleasant

The first step on creating the wind roses was to classify wind direction, originally in azimuth degrees, into 16 cardinal directions. Then, to calculate and classify wind frequency for each one of the ranges listed above by counting the percent of total hours that wind blows in each direction. Tables B-F display wind frequency percentages per speed ranges. This values were graphed using Adobe Illustrator to display frequency in color coded bands associated to wind ranges.

ANNUAL																
%	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
< 1.2	4.53%	0.43%	0.50%	0.83%	1.39%	1.08%	0.51%	0.29%	0.23%	0.20%	0.15%	0.21%	0.23%	0.37%	0.58%	0.46%
1.3-2.4	1.22%	1.16%	1.60%	3.45%	7.34%	3.88%	1.65%	0.87%	0.52%	0.38%	0.32%	0.35%	0.55%	1.28%	1.55%	1.43%
2.5-4.8	2.57%	1.64%	1.50%	2.74%	5.93%	3.88%	3.12%	2.07%	1.69%	1.14%	0.83%	0.79%	1.26%	3.68%	5.23%	4.65%
4.8 >	4.23%	0.68%	0.34%	0.28%	0.44%	0.56%	0.76%	0.47%	1.6%	1.52%	1.22%	0.64%	0.61%	0.9%	1.34%	2.14%

Table B - Annual Wind Ranges

SPRING																
%	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
< 1.2	4.15%	0.31%	0.35%	0.58%	0.89%	0.76%	0.51%	0.24%	0.18%	0.14%	0.10%	0.09%	0.12%	0.17%	0.20%	0.28%
1.3-2.4	0.84%	0.76%	1.10%	2.30%	4.94%	3.27%	1.78%	0.99%	0.56%	0.38%	0.31%	0.25%	0.33%	0.58%	0.78%	0.95%
2.5-4.8	2.24%	1.59%	1.48%	2.42%	4.36%	3.92%	4.24%	2.64%	1.95%	1.25%	0.81%	1.18%	1.47%	2.70%	4.77%	4.74%
4.8 >	9.77%	0.70%	0.23%	0.30%	0.41%	0.68%	0.90%	0.61%	2.07%	2.12%	1.75%	1.30%	1.12%	1.60%	2.21%	3.28%

Table C - Spring Wind Ranges

SUMMER																
%	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
< 1.2	1.23%	0.25%	0.27%	0.45%	0.80%	0.62%	0.21%	0.13%	0.11%	0.06%	0.01%	0.04%	0.06%	0.08%	0.23%	0.25%
1.3-2.4	0.89%	0.80%	1.04%	3.21%	6.36%	3.56%	1.54%	0.85%	0.38%	0.19%	0.18%	0.13%	0.20%	0.50%	0.82%	1.16%
2.5-4.8	3.55%	1.61%	1.51%	3.26%	8.17%	6.13%	4.39%	3.22%	2.23%	1.61%	1.13%	0.99%	1.21%	2.33%	5.19%	6.74%
4.8 >	5.35%	0.27%	0.13%	0.28%	0.59%	0.88%	1.50%	0.60%	1.30%	1.85%	2.19%	0.80%	0.57%	0.62%	1.11%	2.08%

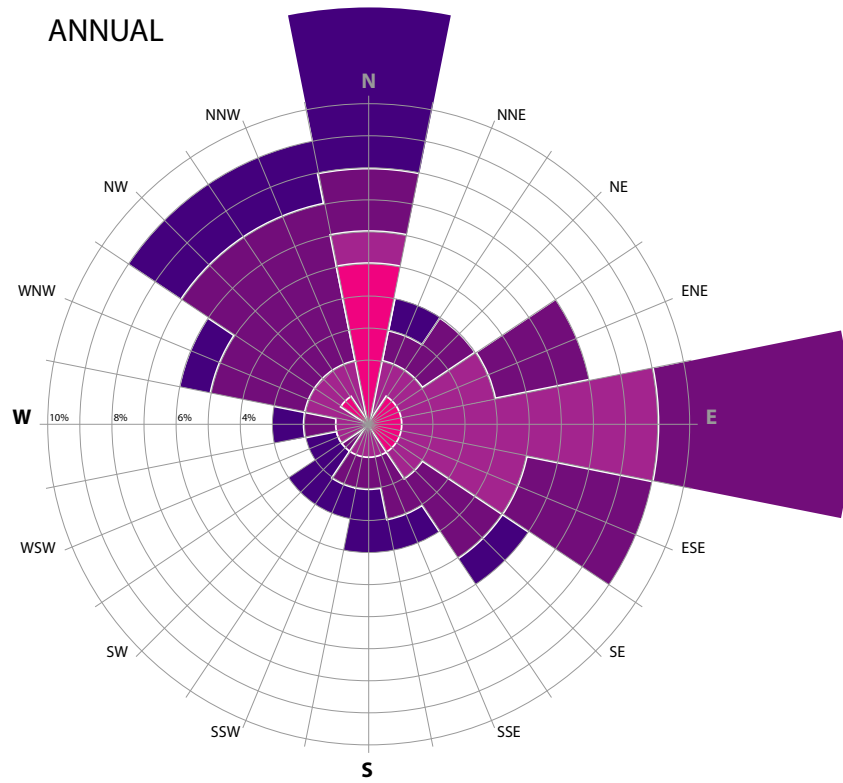
Table D - Summer Wind Ranges

FALL																
%	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
< 1.2	3.68%	0.48%	0.63%	1.07%	1.90%	1.25%	0.54%	0.38%	0.33%	0.23%	0.20%	0.28%	0.26%	0.53%	0.77%	0.47%
1.3-2.4	1.39%	1.32%	1.87%	4.20%	10.43%	4.94%	1.90%	0.90%	0.63%	0.47%	0.34%	0.54%	0.88%	1.86%	2.08%	1.61%
2.5-4.8	2.18%	1.57%	1.34%	3.13%	7.67%	3.58%	2.27%	1.52%	1.47%	0.98%	0.81%	0.62%	1.49%	4.16%	5.19%	3.99%
4.8 >	1.00%	0.17%	0.11%	0.08%	0.40%	0.42%	0.31%	0.36%	1.34%	1.12%	0.62%	0.26%	0.30%	0.52%	0.91%	1.77%

Table E - Fall Wind Ranges

WINTER																
%	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
< 1.2	9.15%	0.65%	0.74%	1.17%	1.89%	1.64%	0.79%	0.42%	0.31%	0.34%	0.29%	0.40%	0.48%	0.67%	1.08%	0.84%
1.3-2.4	1.73%	1.71%	2.31%	3.93%	7.18%	3.61%	1.38%	0.73%	0.50%	0.48%	0.46%	0.46%	0.76%	2.06%	2.40%	1.96%
2.5-4.8	2.32%	1.79%	1.67%	2.09%	3.22%	1.88%	1.73%	1.00%	1.17%	0.75%	0.58%	0.42%	0.86%	5.40%	5.72%	3.17%
4.8 >	1.54%	1.61%	0.95%	0.47%	0.37%	0.28%	0.41%	0.29%	1.73%	1.09%	0.39%	0.27%	0.55%	0.97%	1.24%	1.54%

Table F - Winter Wind Ranges

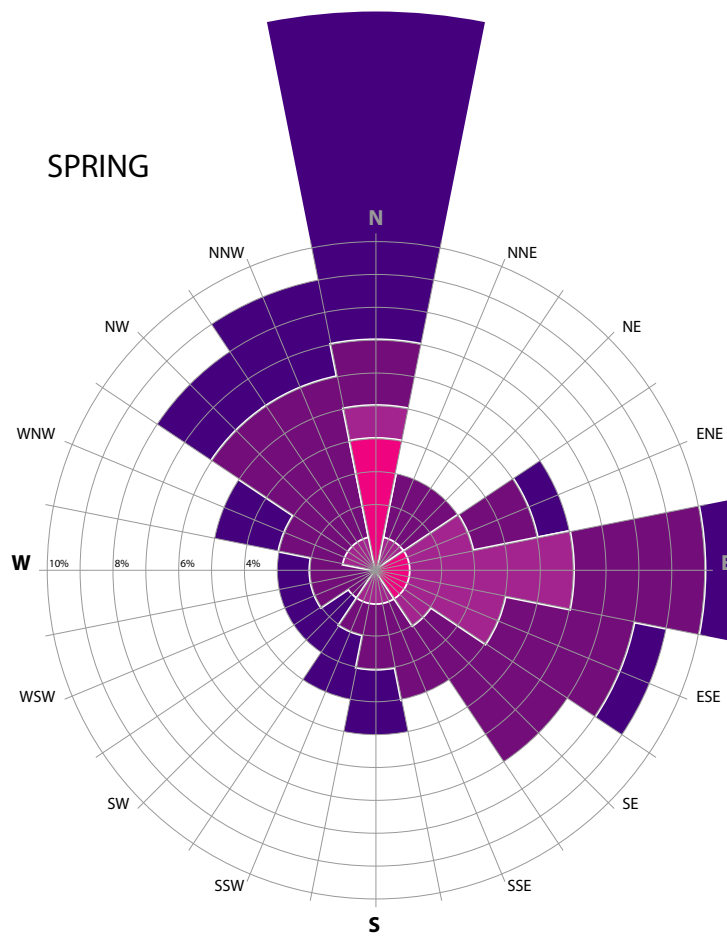


Wind Rose for Greenville

Data Source: Greenville Farm Weather Station, Utah Division of Water Resources

- 1.2 mph wind or less
- 1.2 - 2.4 mph wind
- 2.4 - 4.8 mph wind
- 4.8 or more mph wind

Figure 17- Annual Wind Rose

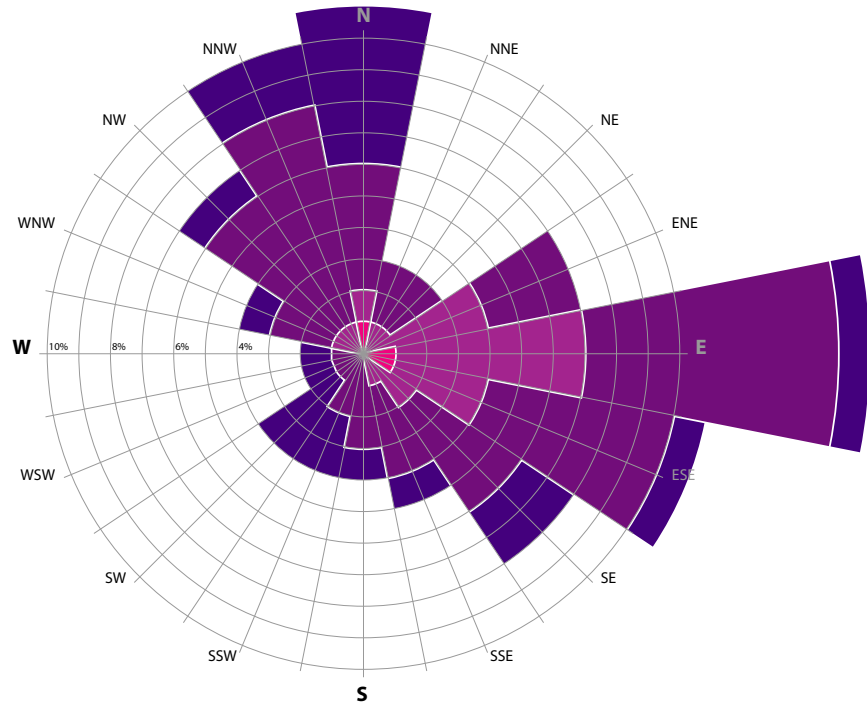


Wind Rose for Greenville
 Data Source: Greenville Farm Weather Station, Utah Division of Water Resources

- 1.2 mph wind or less
- 1.2 - 2.4 mph wind
- 2.4 - 4.8 mph wind
- 4.8 or more mph wind

Figure 18 - Spring Wind Rose

SUMMER



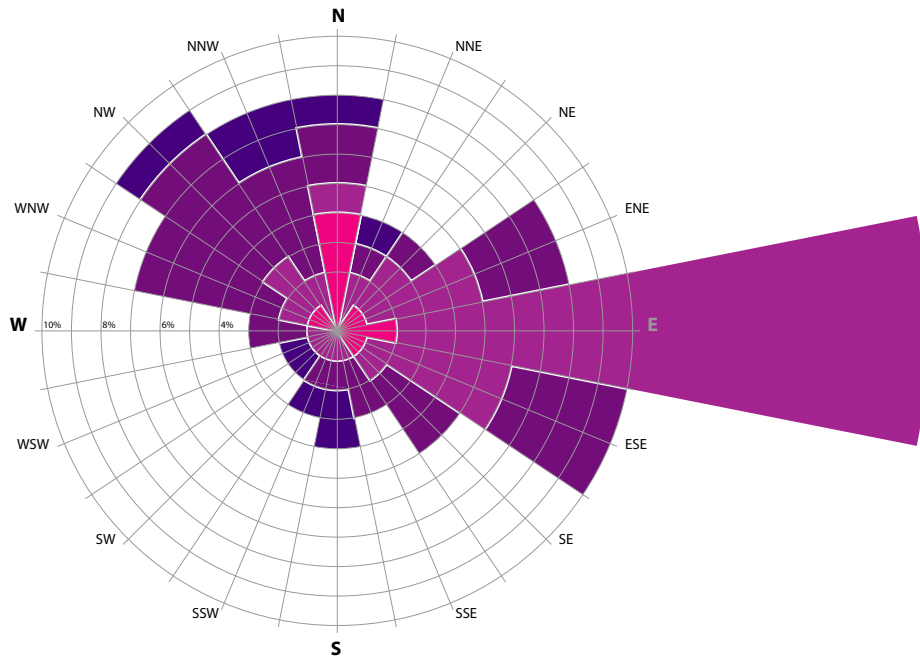
Wind Rose for Greenville

Data Source: Greenville Farm Weather Station, Utah Division of Water Resources

- 1.2 mph wind or less
- 1.2 - 2.4 mph wind
- 2.4 - 4.8 mph wind
- 4.8 or more mph wind

Figure 19 - Summer Wind Rose

FALL

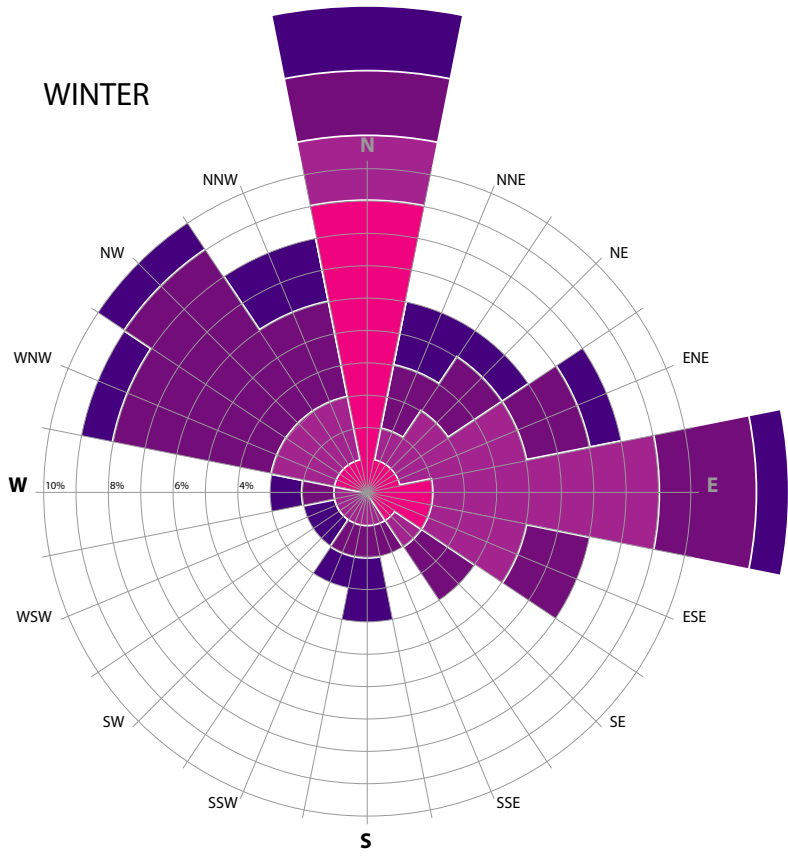


Wind Rose for Greenville

Data Source: Greenville Farm Weather Station, Utah Division of Water Resources

- 1.2 mph wind or less
- 1.2 - 2.4 mph wind
- 2.4 - 4.8 mph wind
- 4.8 or more mph wind

Figure 20 - Fall Wind Rose



Wind Rose for Greenville
Data Source: Greenville Farm Weather Station, Utah Division of Water Resources

- 1.2 mph wind or less
- 1.2 - 2.4 mph wind
- 2.4 - 4.8 mph wind
- 4.8 or more mph wind

Figure 21 - Winter Wind Rose

Results

Several design considerations can be extracted from the analysis of the previous graphs in order to establish appropriate bioclimatic design strategies for Cache Valley, Utah.

Thermal Comfort Condition Charts

Even though the climate in Cache Valley is predominantly cold, as shown in Figure 3, it has two contrasting temperature patterns being dominantly hot and dry during the summer (Figure 5) and mainly cold during the winter (Figure 7). Therefore, it is ideal to maximize radiation absorption, increase heat gain and retention, and allow for light to enter the buildings during the winter, while providing shaded areas during the summer.

Bioclimatic Chart

In the Bioclimatic Charts (Figures 9 through 13), we can see drastic changes in seasonal temperature and relative humidity. By looking at Figure 11 and Figure 13 we can see that climate conditions during summer and winter are completely opposite in Cache Valley, which confirms previous findings from the Thermal Comfort Condition Charts. For this reason, it is necessary to take into consideration design strategies that will be functional in contrasting climate conditions. Figure 10, Figure 11 and Figure 12, shows us that many of the climate issues during spring, summer and fall, can be addressed through passive solar heating, natural ventilation and thermal mass.

Bioclimatic Needs Table

The bioclimatic needs table allows us to visualize times and season below or above comfortable ranges. From this table, specific shading and solar access recommendations were created for different times and seasons of the year.

Sun Path Diagram

The following design considerations can be extracted from the information provided on the Sun Path Diagrams (Figures 15 and 16):

- No sun exposure from June 21st to August 21st. between noon to sunset.
- Full sun exposure all year before 10:00am.
- Full sun exposure all day from September 21st to March 21st.

The Sun Path Diagram contributes to define the orientation angle in which the building must be place in order to maximize radiation absorption, and provide needed shaded areas during the summer. According to the findings the appropriate orientation angle for Cache Valley, lies at 30° North of East.

Wind Rose

The Wind Roses (Figures 17 through 21) indicate that eastern wind has the adequate speed and frequency to allow for ventilation during summer and fall, while northern wind should be minimized to maintain heat during the winter and avoid high speed winds during spring.

Findings

Several design guidelines outlined by Victor Olgyay were tested against the results of this study. The main guidelines considered in the study are discussed in Table G.

TOP 5 DESIGN GUIDELINES FOR CACHE VALLEY	
Suggested guidelines are indicated in the three dimensional prototype (Figure 6).	
1. ORIENTATION	For optimizing early solar gain throughout the year and preventing afternoon sun access during the summer, the ideal orientation for spaces lies at about 30° North of East
2. FORM, VOLUME	Cold weather requires compact structures with reduced exterior surface to maintain heat. Recommended footprint proportion is 2:3 along the EW axis
3. ROOF	Sloping roofs to allow for snow removal.
4. SHADING DEVICES	Shading during the summer is desirable, but it should not interfere with solar access gain during under-heated seasons. Covered terraces, pergolas and sunrooms are ideal in order to optimize solar access.
5. LANDSCAPE	Evergreen trees need to be carefully sited to block strong winds during the winter and allow for comfortable winds to provide ventilation during the summer. Deciduous trees should be placed in the Southeast in order to mitigate heat and create usable outdoor spaces during the summer.

Table G - Top 5 Design Guidelines for Cache Valley

As shown in Figure 22, the relationship between indoor and outdoor spaces offer ideal locations for certain activities to occur. It is important to consider the placing of openings in order for the building to be effective. Southeast openings should be maximized to allow for ventilation during the summer, and solar access gain during the winter. Reducing Northwest openings can help retain heat during the winter while blocking high speed wind throughout the year.

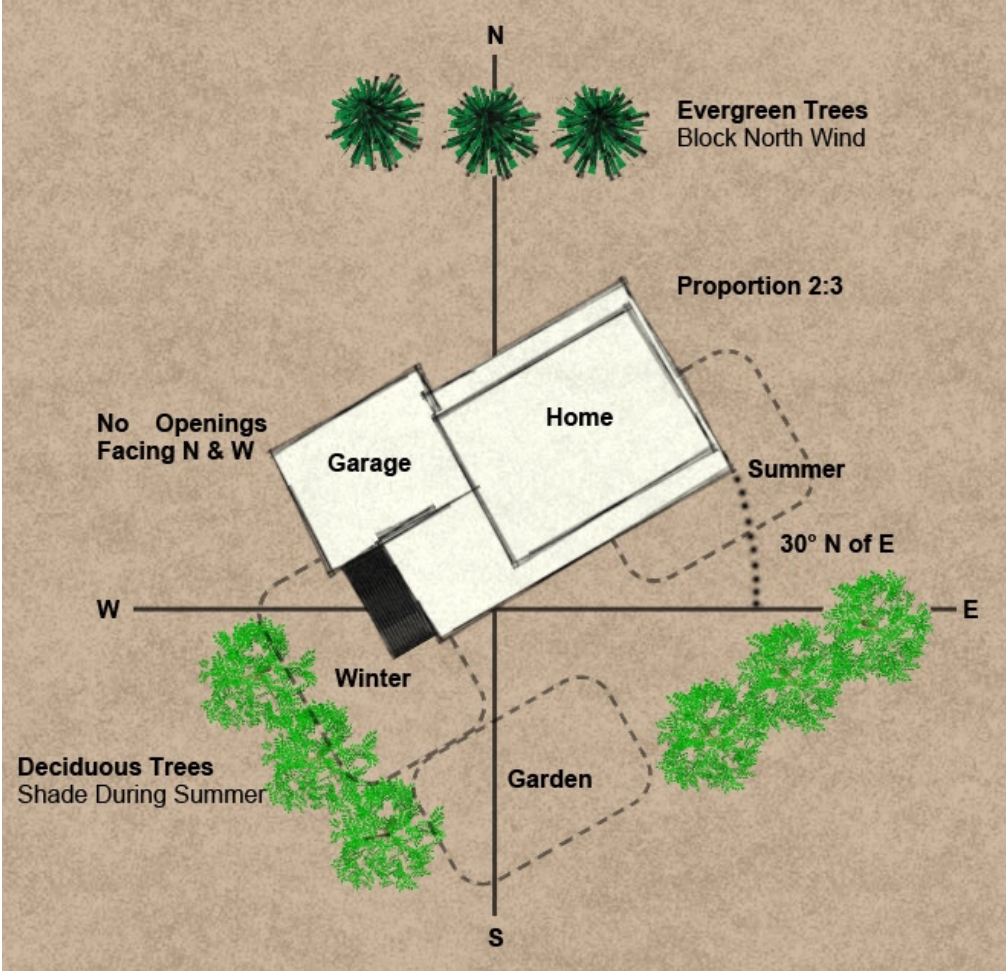


Figure 22 - Prototype Home for Cache Valley, Utah - Plan View

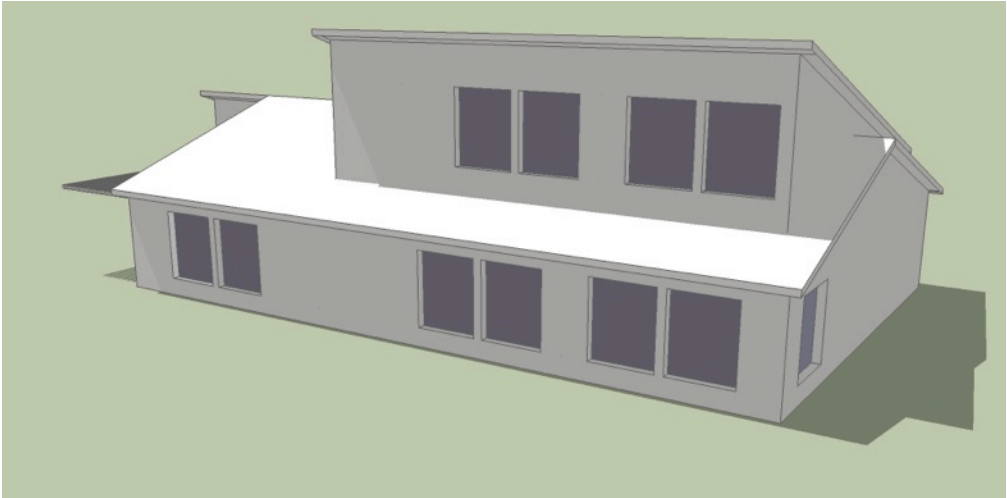
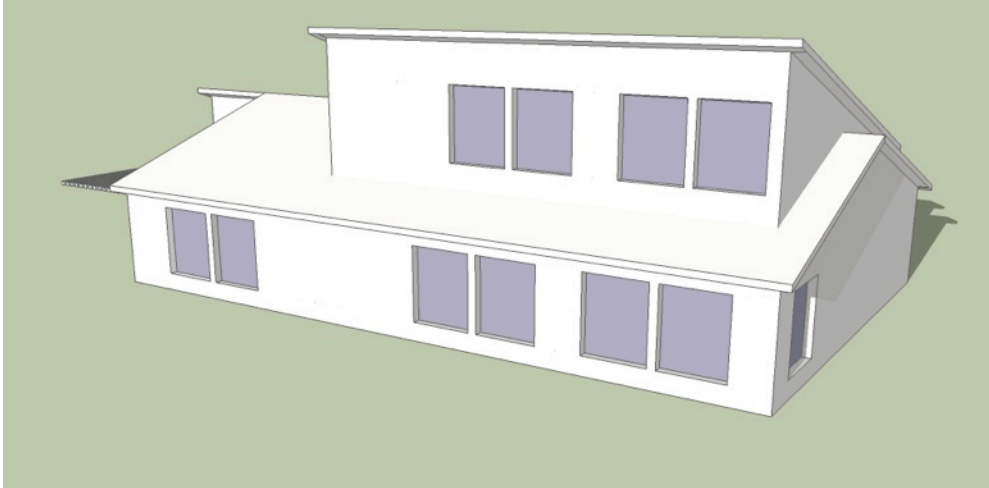
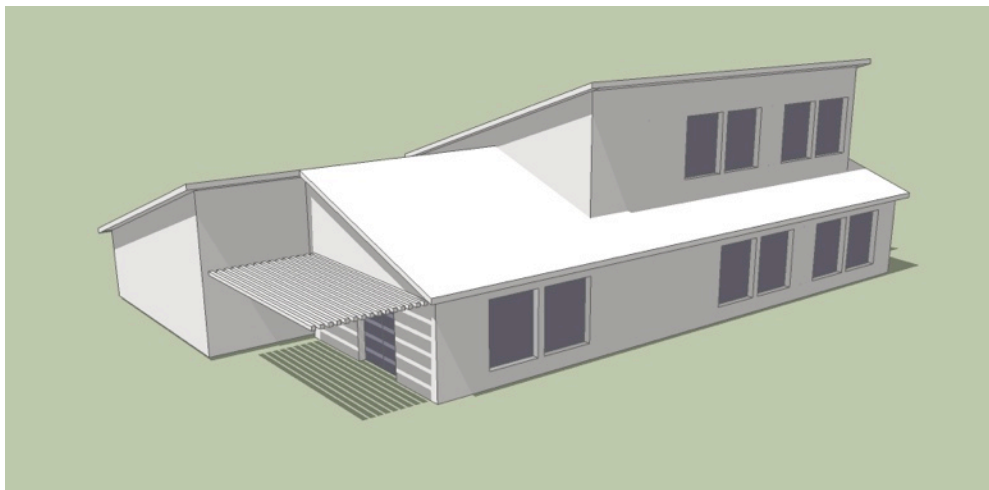


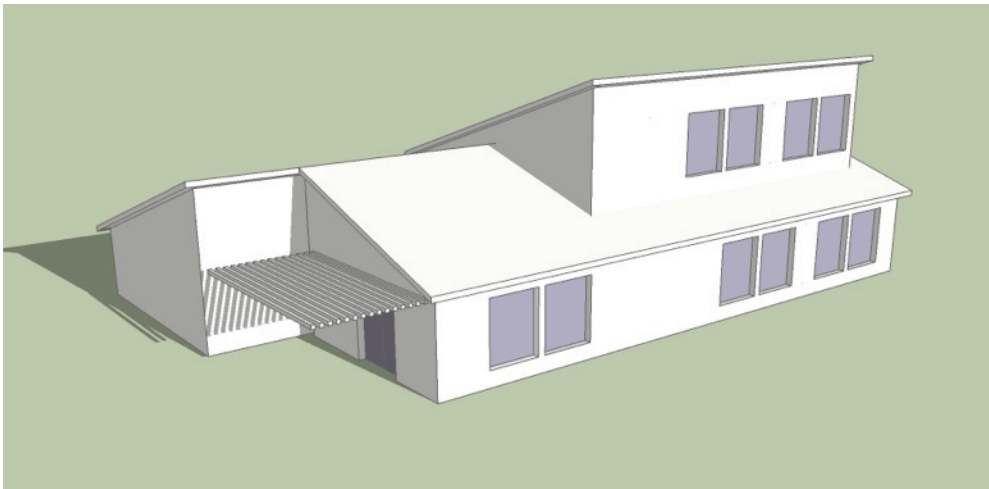
Figure 23 - Prototype Home for Cache Valley, Utah
 Summer Southeast View - June 21st 2:00 pm



*Figure 24 - Prototype Home for Cache Valley, Utah
Winter Southeast View - December 21st 10:00 am*



*Figure 25 - Prototype Home for Cache Valley, Utah
Summer Southwest View - June 21st 2:00 pm*



*Figure 26 - Prototype Home for Cache Valley, Utah
Winter Southwest View - December 21st 10:00 am*

Conclusions

Bioclimatic strategies can greatly enhance the design process, while creating a working relationship between architecture and environment. By looking at design in ancient times, we can clearly see how the principles of bioclimatic architecture were used by our ancestors hundreds of years ago. Designing with plant material requires landscape architects to develop sensitivity for climate and site conditions. Nowadays, technology can help us address design issues in a much more effective and simple manner, and as landscape architects it is important that we use those resources to benefit the spaces we create.

Taking into consideration simple bioclimatic strategies can greatly reduce environmental costs and add to the quality of the place created. Transforming climate information into graphic representation can help landscape architects and designers to have access to readable information that can be implemented during the design process. Design guidelines can be easily deducted from the graphs to create design typologies that can be applied in small or large scale design projects.

Future Work

Bioclimatic design possibilities need to be explored in a more profound manner, by future generations, in order to better understand the quality of the places we live in. A lot of aspects such as the influence of different plant and animal communities, hydrological and geological processes, can become an excellent source of information for sustainable practices in the design fields.

It would also be beneficial to measure energy needs of a regular building versus a building(of relatively the same size) designed following the bioclimatic strategies discussed in this paper. The energy consumption rates could then be transformed into amount of money spent on energy per year. This would give individuals an idea on how much they can profit by following simple guidelines of bioclimatic architecture.

Appendix

Bioclimatic Design for Cache Valley, UT

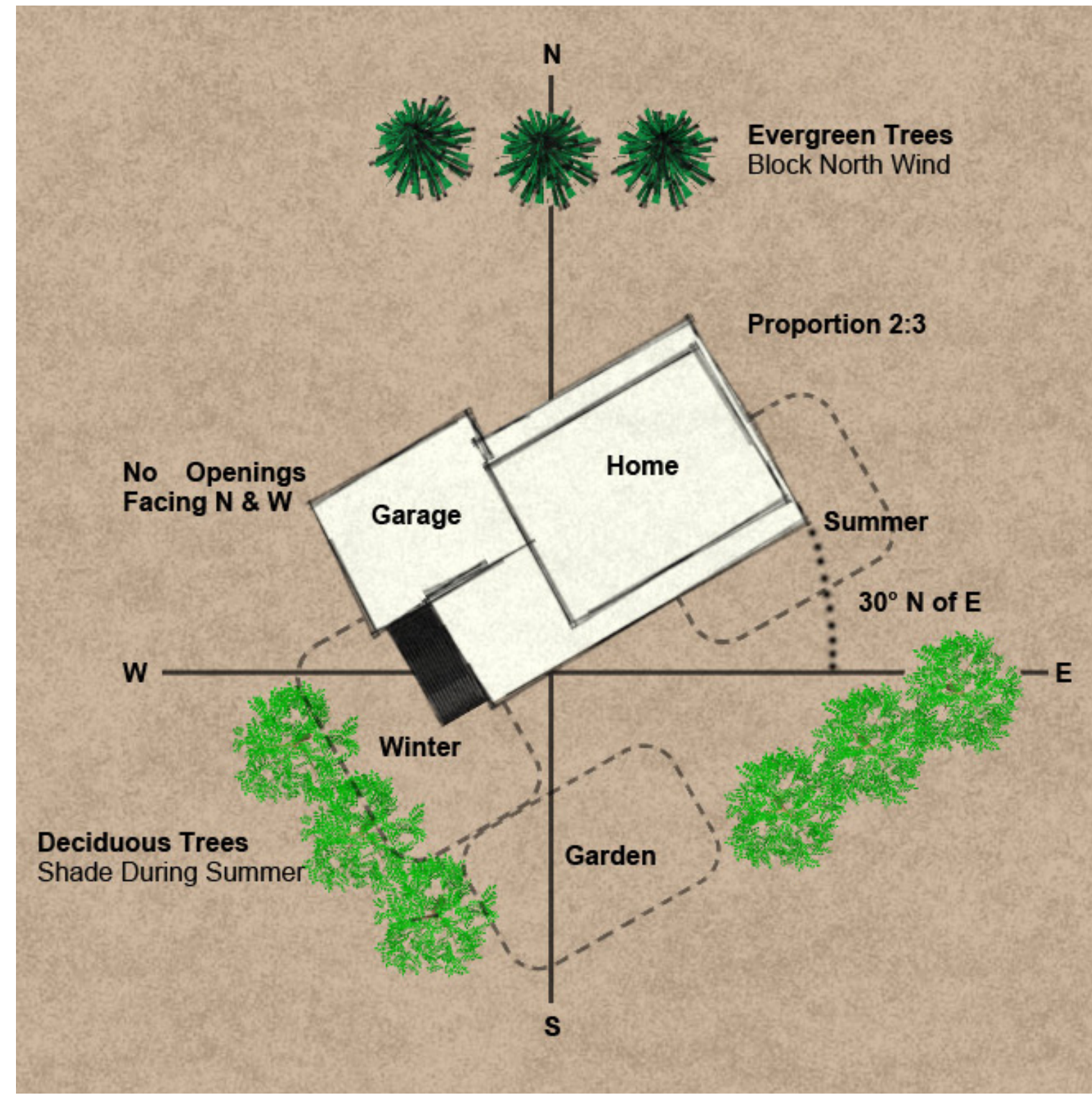


Figure 1 - Prototype Home for Cache Valley, Utah - Plan View

Several design considerations can be extracted from the analysis of these graphs in order to establish appropriate bioclimatic design strategies for Cache Valley, Utah.

Bioclimatic Chart

In the Bioclimatic Charts (Figures 2 through 6), we can see drastic changes in seasonal temperature and relative humidity. By looking at Figure 4 and Figure 6 we can see that climate conditions during summer and winter are completely opposite in Cache Valley. For this reason, it is necessary to take into consideration design strategies that will be functional in contrasting climate conditions. Figure 3, Figure 4 and Figure 5, shows us that many of the climate issues during spring, summer and fall, can be addressed through passive solar heating, natural ventilation and thermal mass.

Bioclimatic Needs Table

The bioclimatic needs (Figure 7) table allows us to visualize times and season below or above comfortable ranges. From this table, specific shading and solar access recommendations were created for different times and seasons of the year.

Sun Path Diagram

The following design considerations can be extracted from the information provided on the Sun Path Diagrams (Figures 8 and 11):

- No sun exposure from June 21st to August 21st, between noon to sunset.
- Full sun exposure all year before 10:00am.
- Full sun exposure all day from September 21st to March 21st.

The Sun Path Diagram contributes to define the orientation angle in which the building must be placed in order to maximize radiation absorption, and provide needed shaded areas during the summer. According to the findings the appropriate orientation angle for Cache Valley, lies at 30° North of East.

Wind Rose

The Wind Roses (Figures 14 through 18) indicate that eastern wind has the adequate speed and frequency to allow for ventilation during summer and fall, while northern wind should be minimized to maintain heat during the winter and avoid high speed winds during spring.

Design Guidelines

Several design guidelines outlined by Victor Olgyay were tested against the results of this study and are discussed below.

Suggested guidelines are indicated in plan view (Figure 1) and three dimensional prototype (Figures 9, 10, 12 and 13).

TOP 5 DESIGN GUIDELINES FOR CACHE VALLEY, UT

1. ORIENTATION	For optimizing early solar gain throughout the year and preventing afternoon sun access during the summer, the ideal orientation for spaces lies at about 30° North of East
2. FORM, VOLUME	Cold weather requires compact structures with reduced exterior surface to maintain heat. Recommended footprint proportion is 2:3 along the EW axis
3. ROOF	Sloping roofs to allow for snow removal.
4. SHADING DEVICES	Shading during the summer is desirable, but it should not interfere with solar access gain during under-heated seasons. Covered terraces, pergolas and sunrooms are ideal in order to optimize solar access.
5. LANDSCAPE	Evergreen trees need to be carefully sited to block strong winds during the winter and allow for comfortable winds to provide ventilation during the summer. Deciduous trees should be placed in the Southeast in order to mitigate heat and create usable outdoor spaces during the summer.

As shown in Figure 1, the relationship between indoor and outdoor spaces offer ideal locations for certain activities to occur. It is important to consider the placing of openings in order for the building to be effective. Southeast openings (Figures 9, 10, 12 and 13) should be maximized to allow for ventilation during the summer, and solar access gain during the winter. Reducing Northwest openings can help retain heat during the winter while blocking high speed wind throughout the year.

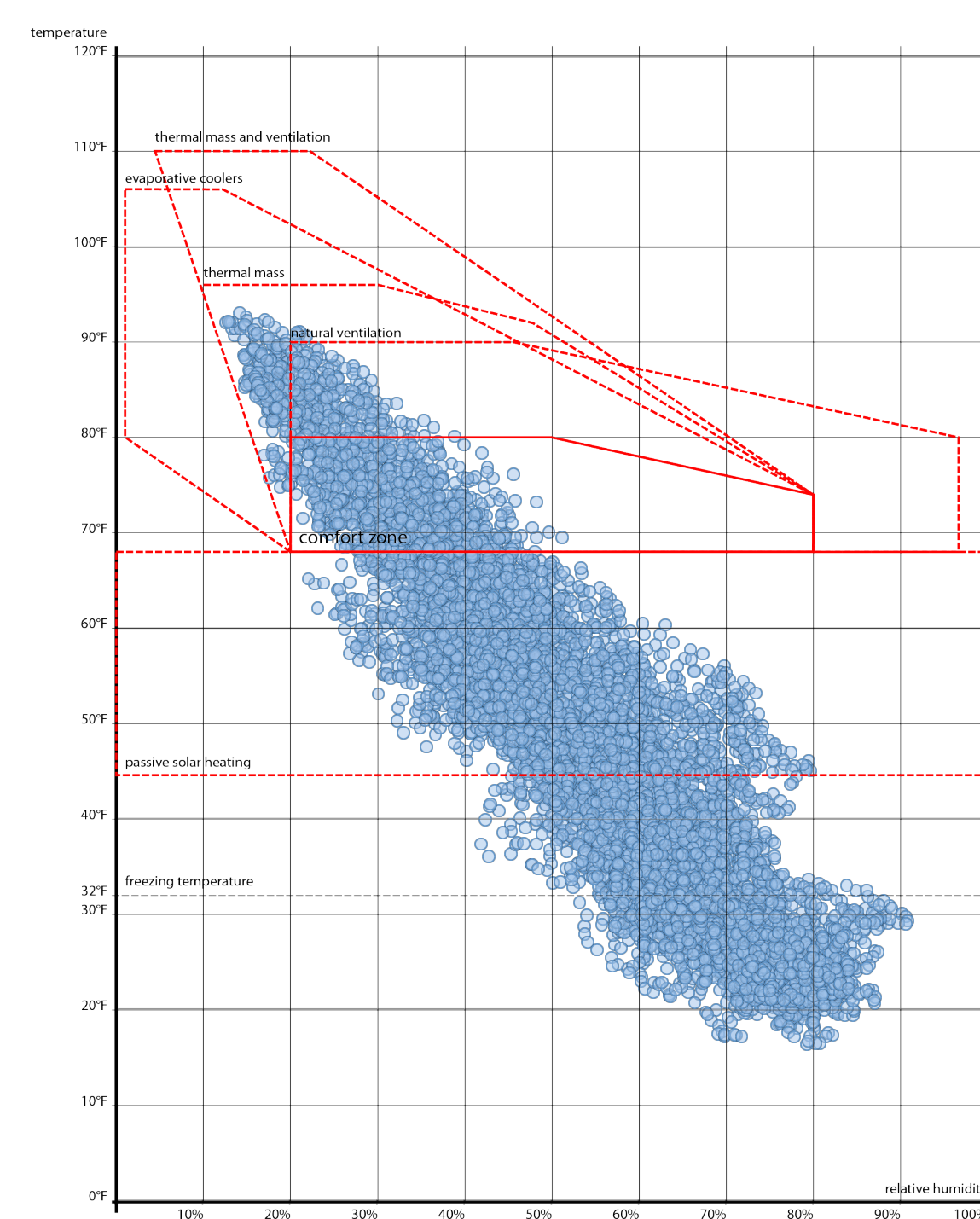


Figure 2 - Annual Bioclimatic Chart, Logan, UT Ave. Temperature 2005-2011

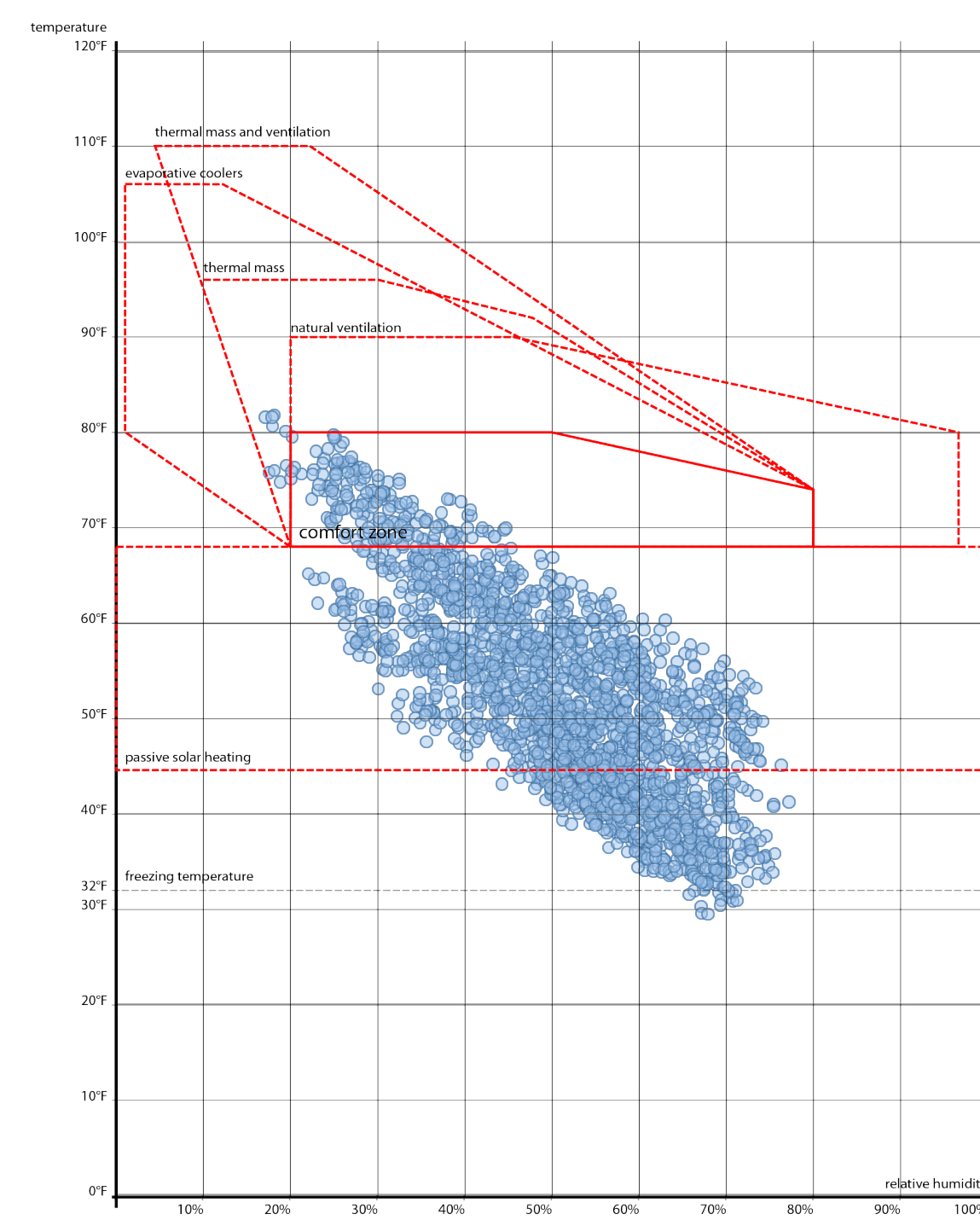


Figure 3 - Spring Bioclimatic Chart, Logan, UT Ave. Temperature 2005-2011

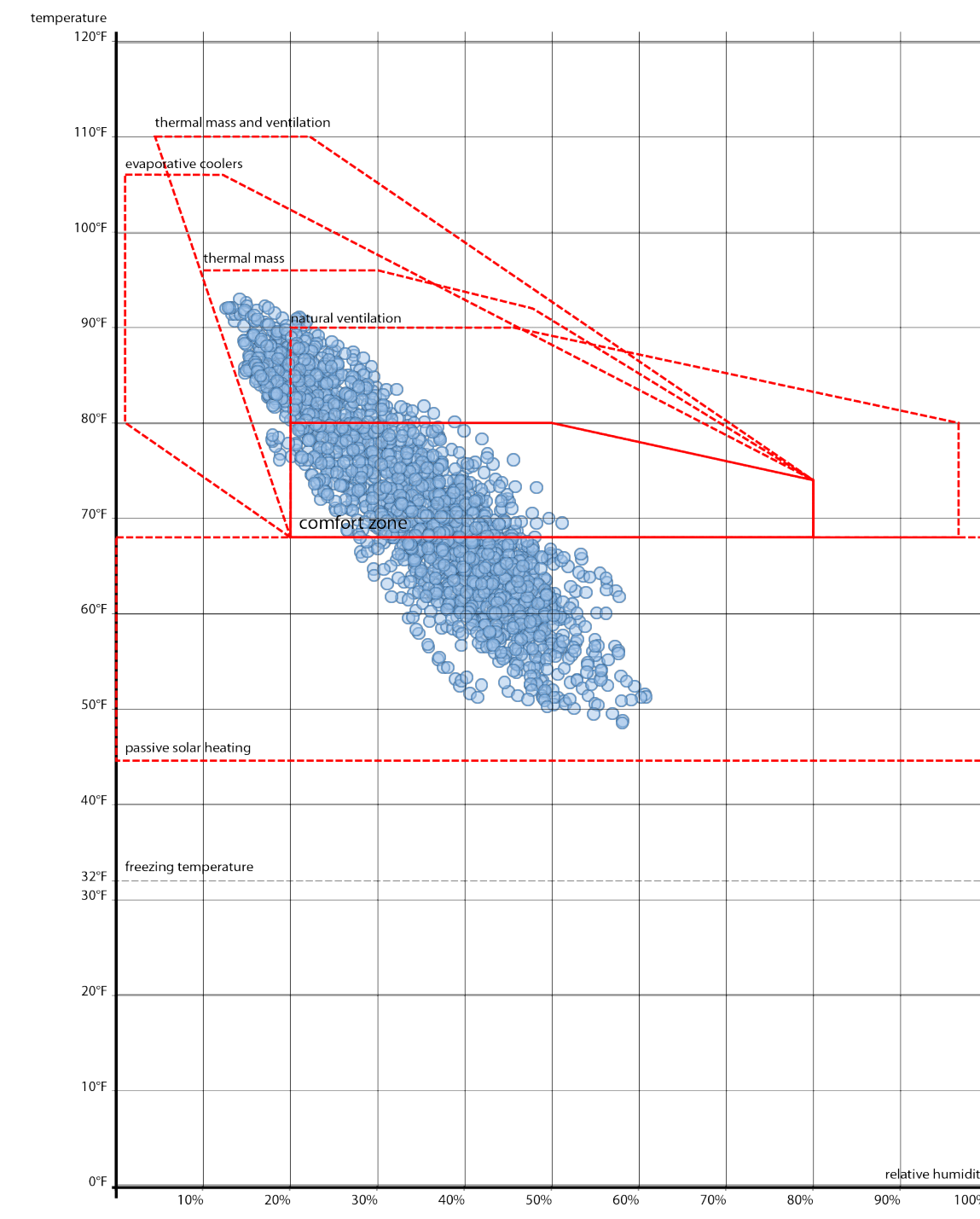


Figure 4 - Summer Bioclimatic Chart, Logan, UT Ave. Temperature 2005-2011

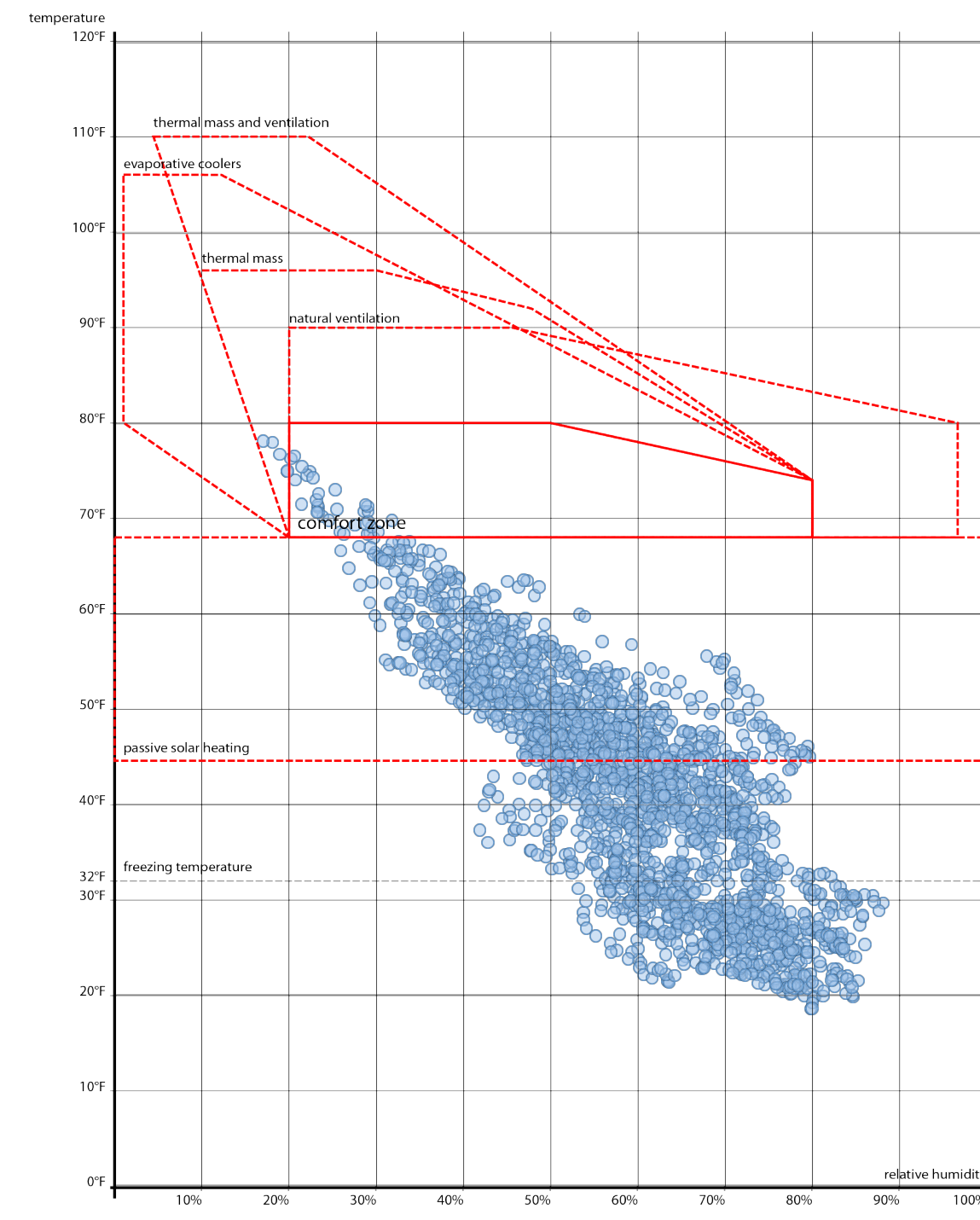


Figure 5 - Fall Bioclimatic Chart, Logan, UT Ave. Temperature 2005-2011

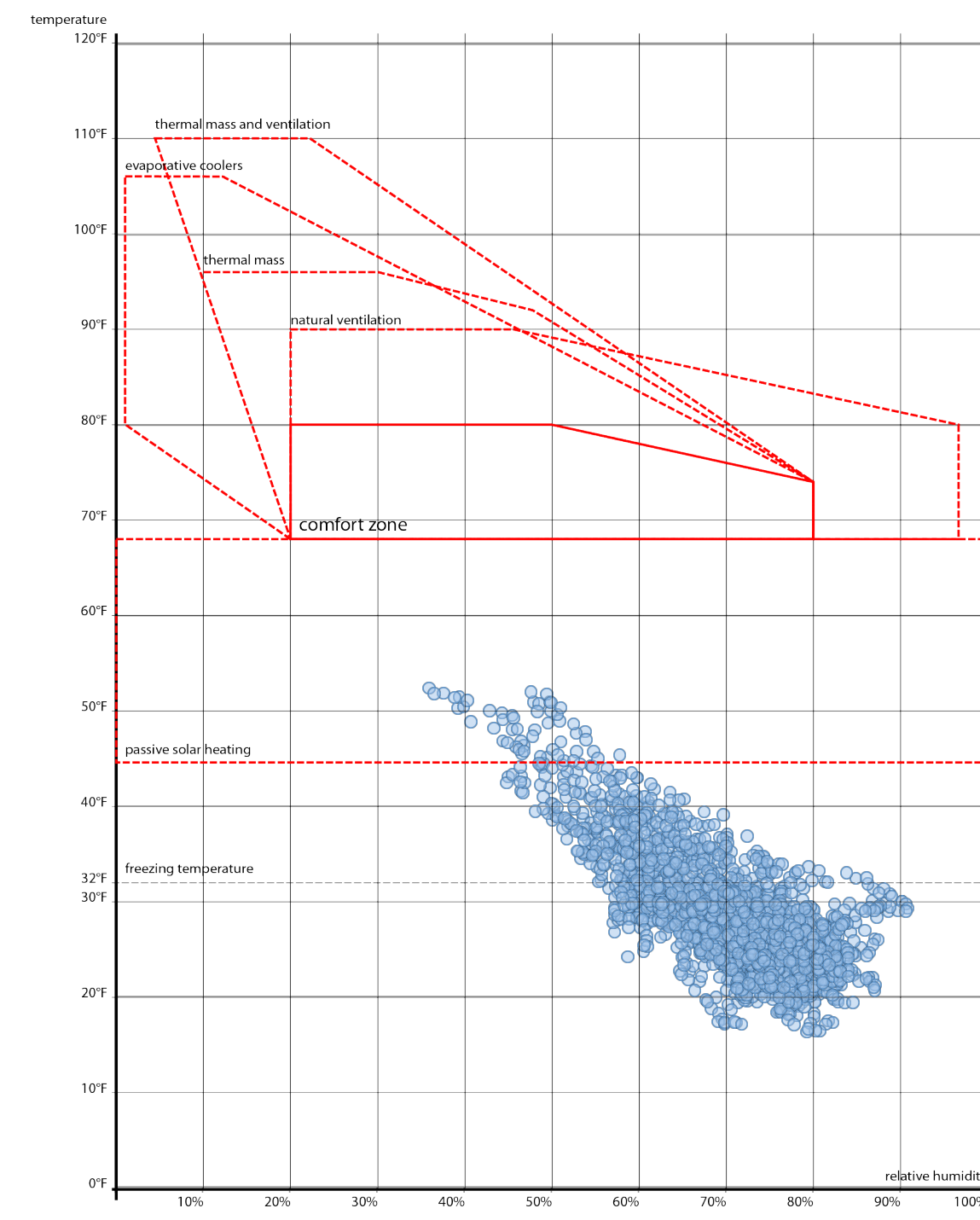


Figure 6 - Winter Bioclimatic Chart, Logan, UT Ave. Temperature 2005-2011

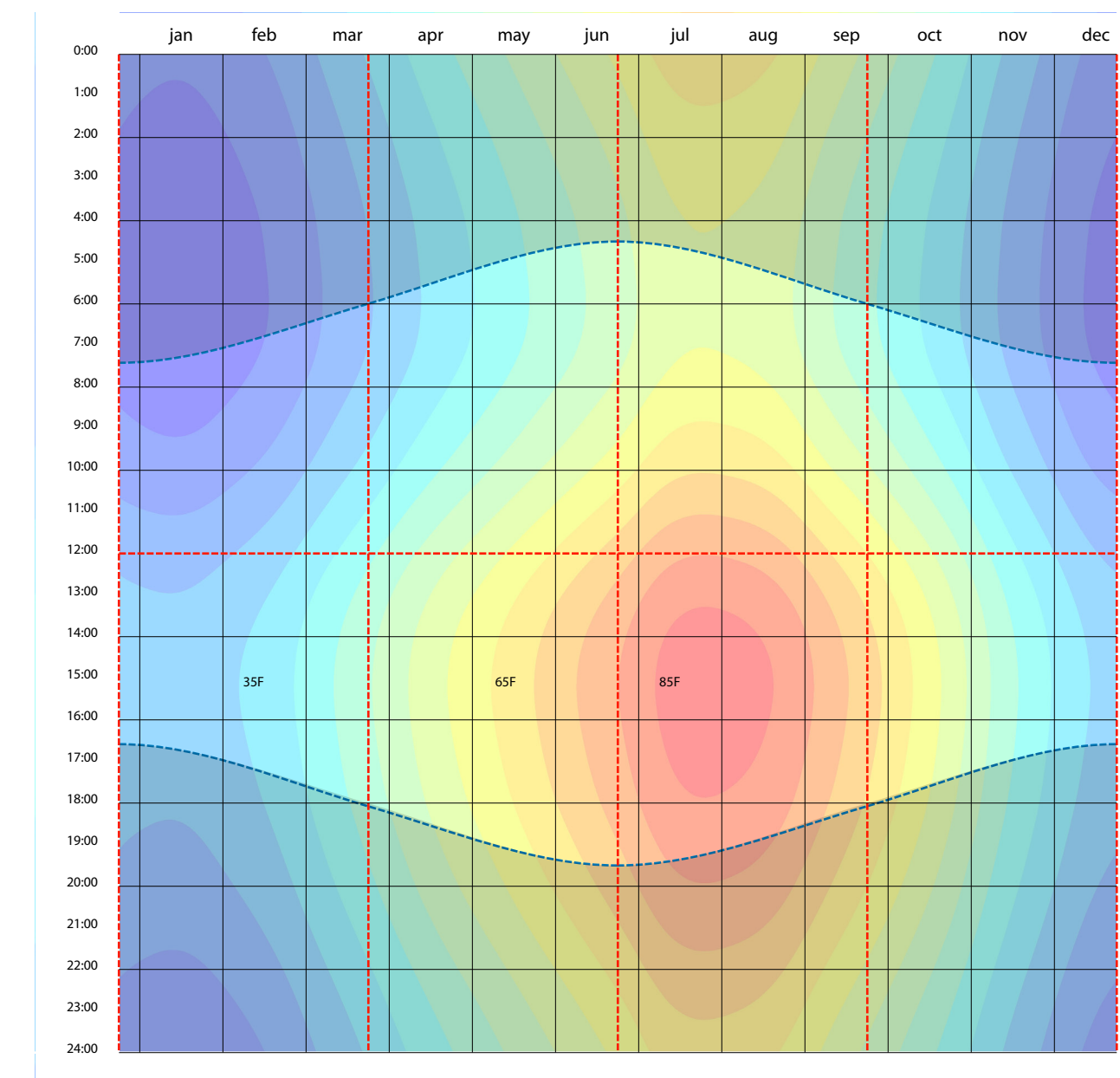


Figure 7 - Bioclimatic Needs Table

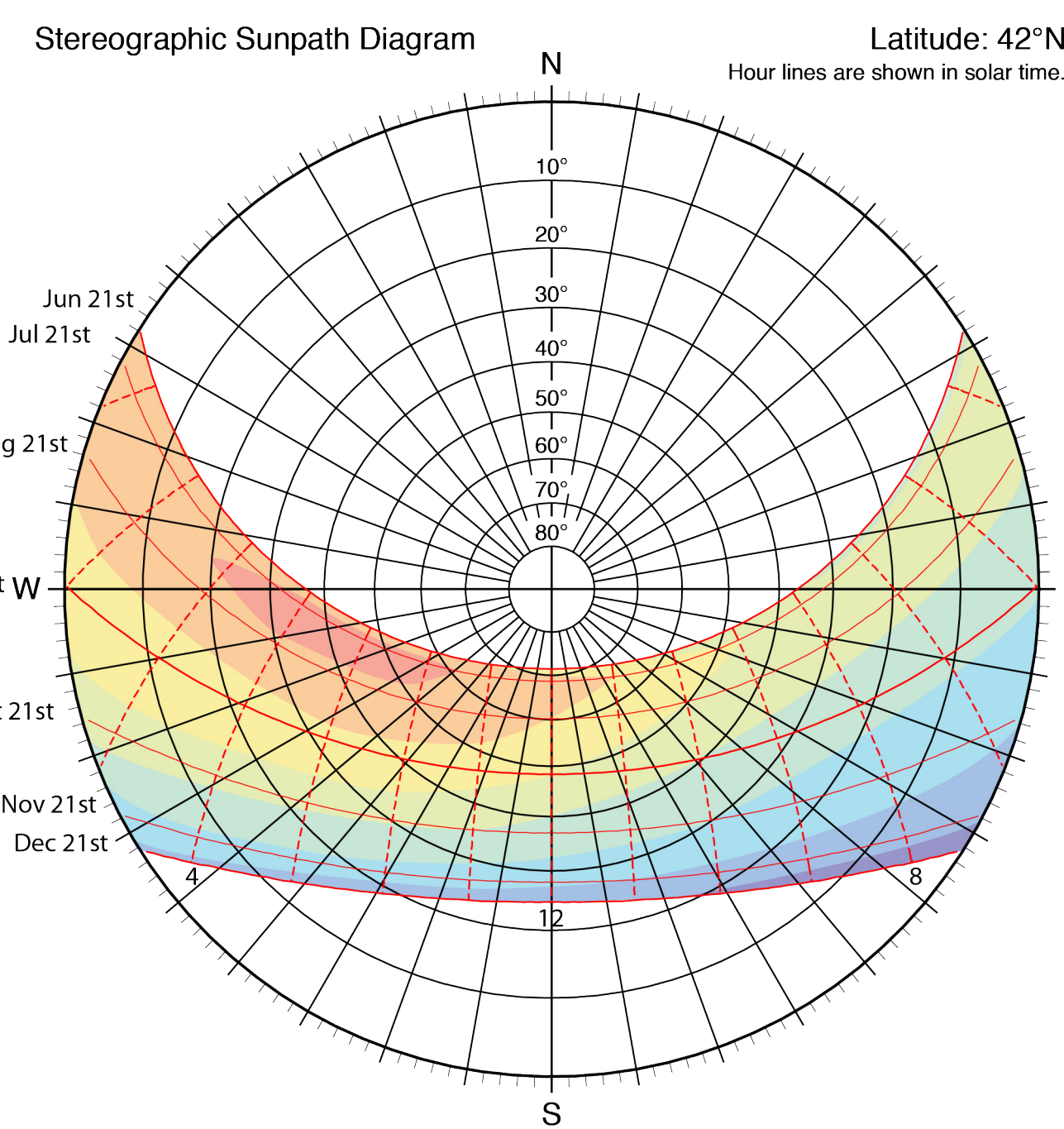


Figure 8 - Sun Path Diagram - Summer and Fall

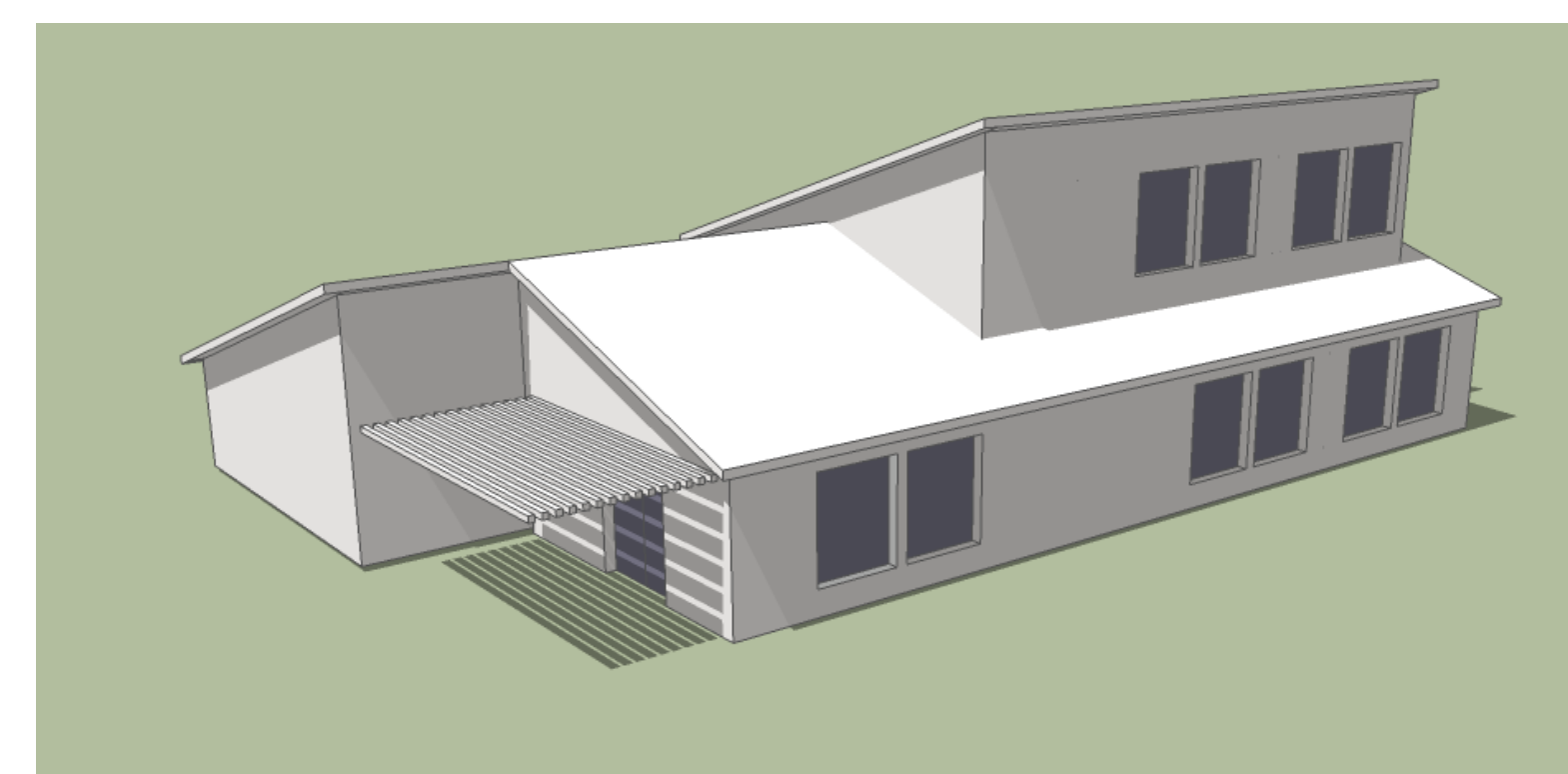


Figure 9 - Prototype Home for Cache Valley, Utah Summer Southwest View - June 21st 2:00 pm

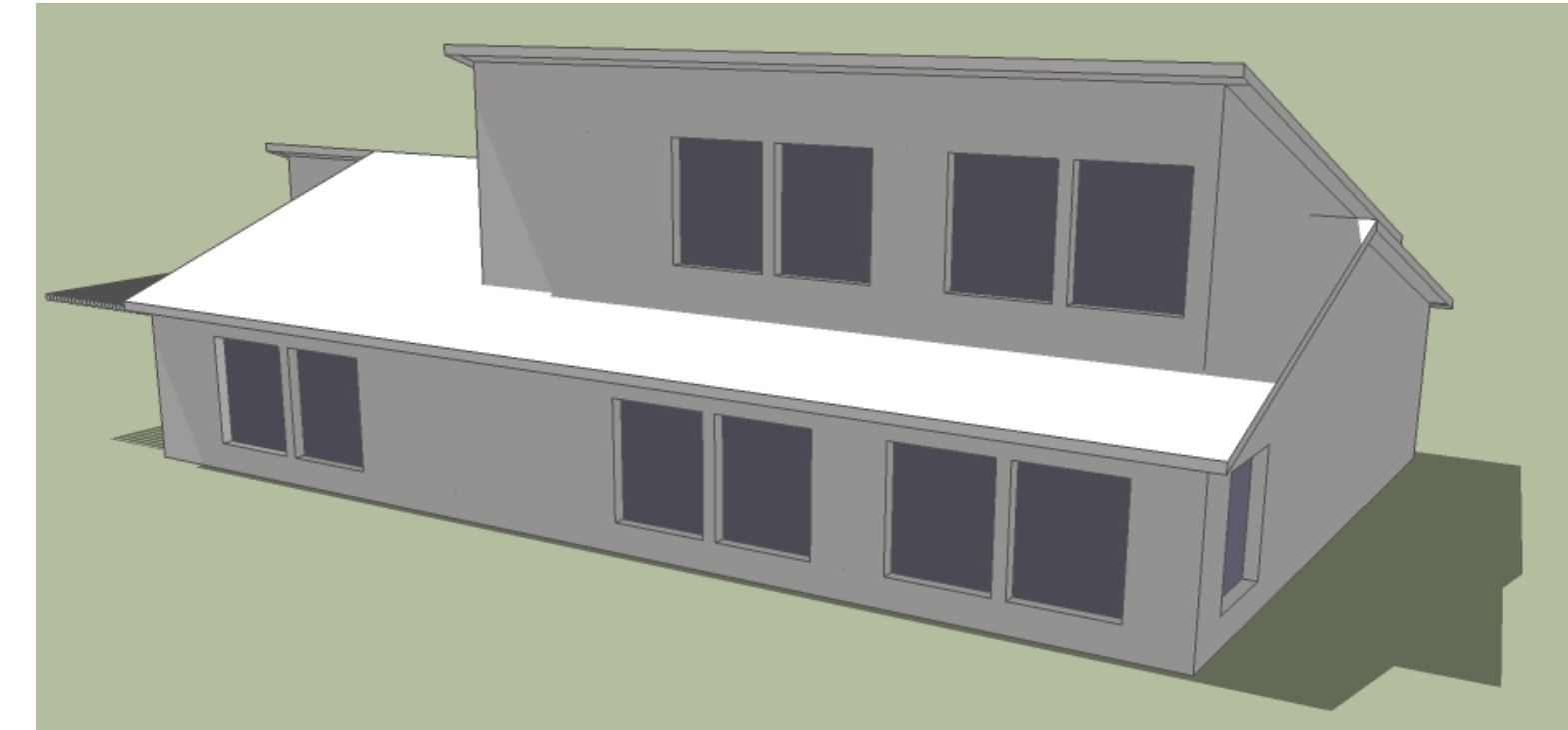


Figure 10 - Prototype Home for Cache Valley, Utah Summer Southeast View - June 21st 2:00 pm

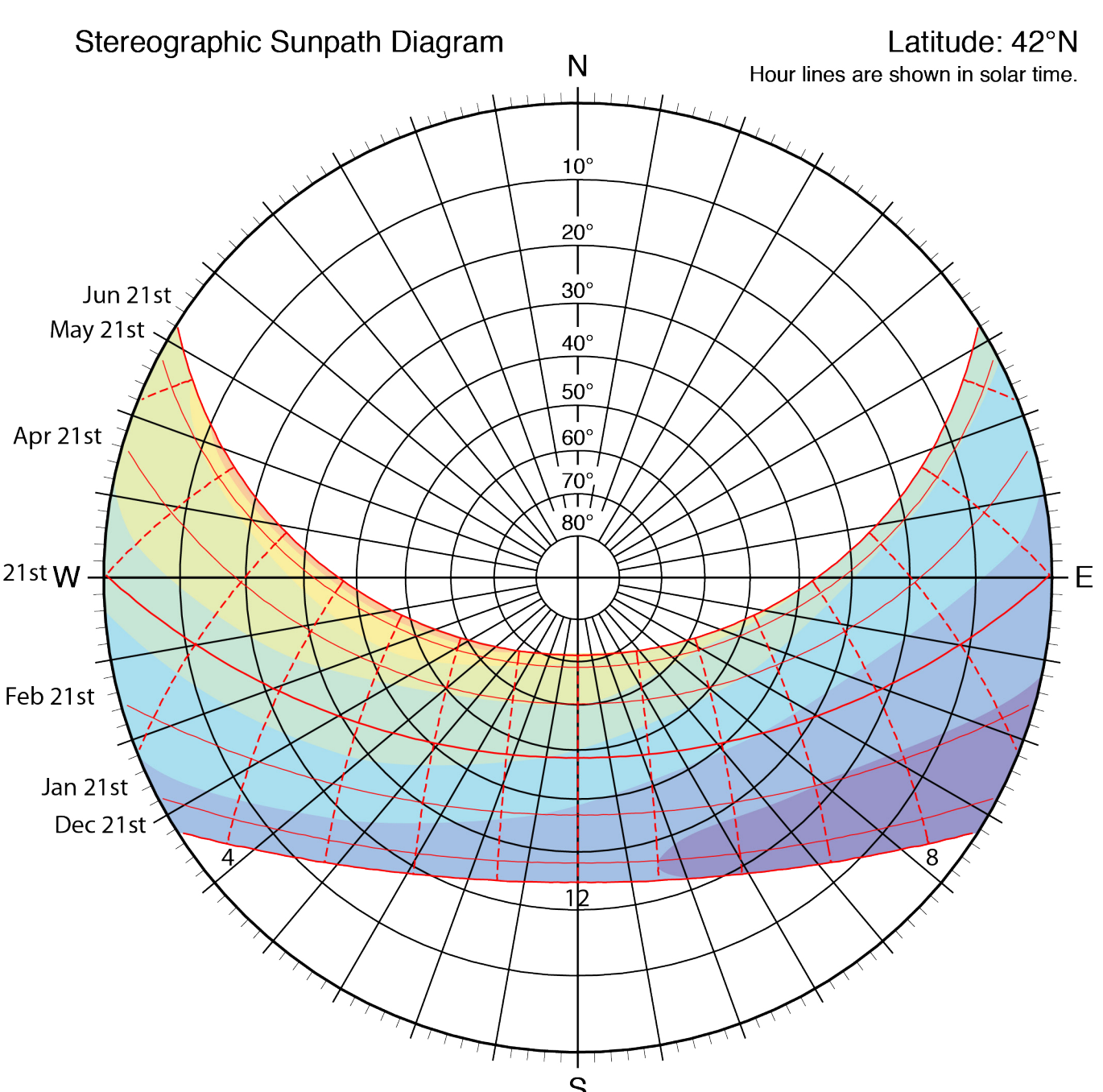


Figure 11 - Sun Path Diagram - Spring and Winter

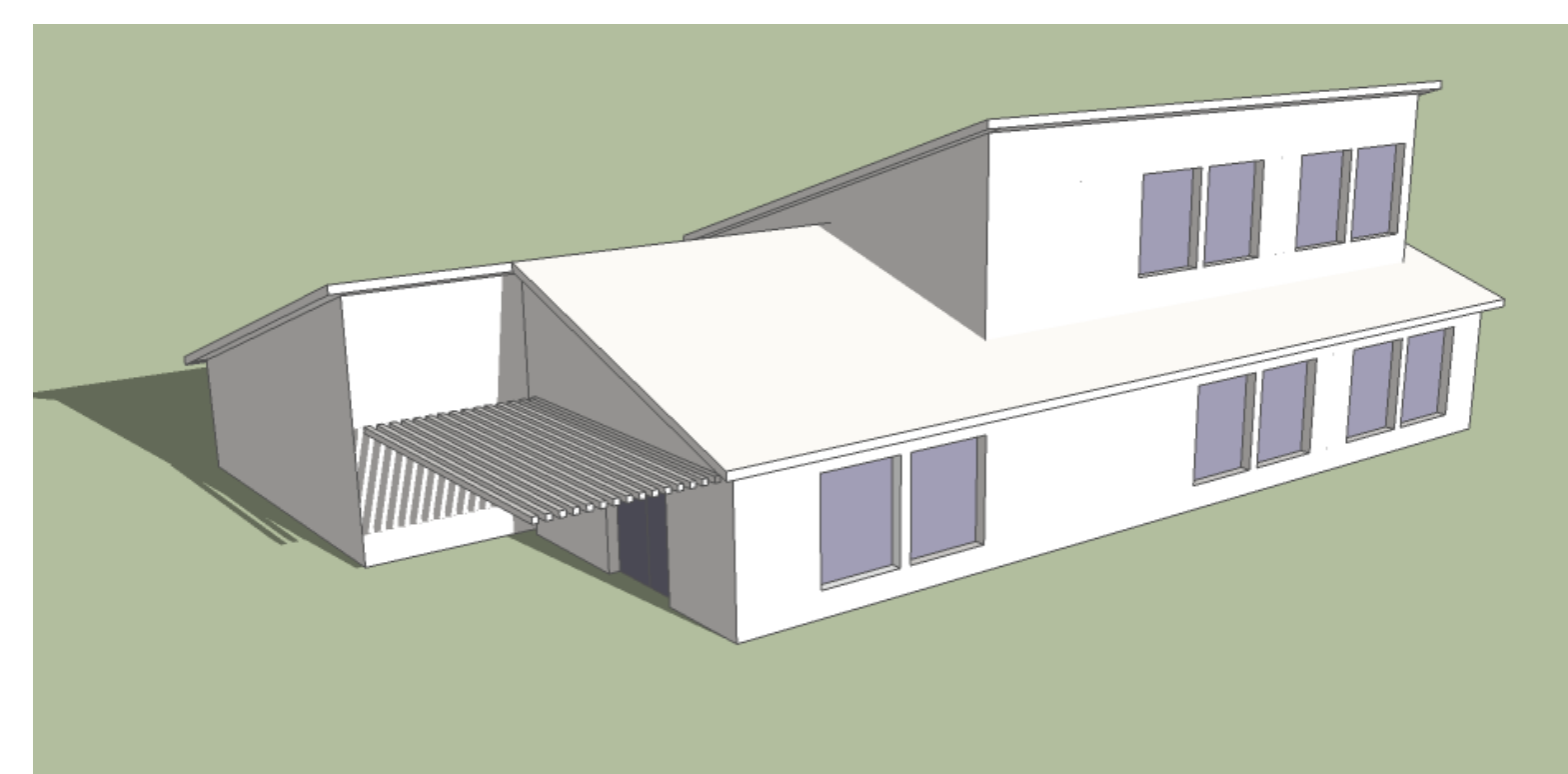


Figure 12 - Prototype Home for Cache Valley, Utah Winter Southwest View - December 21st 10:00 am

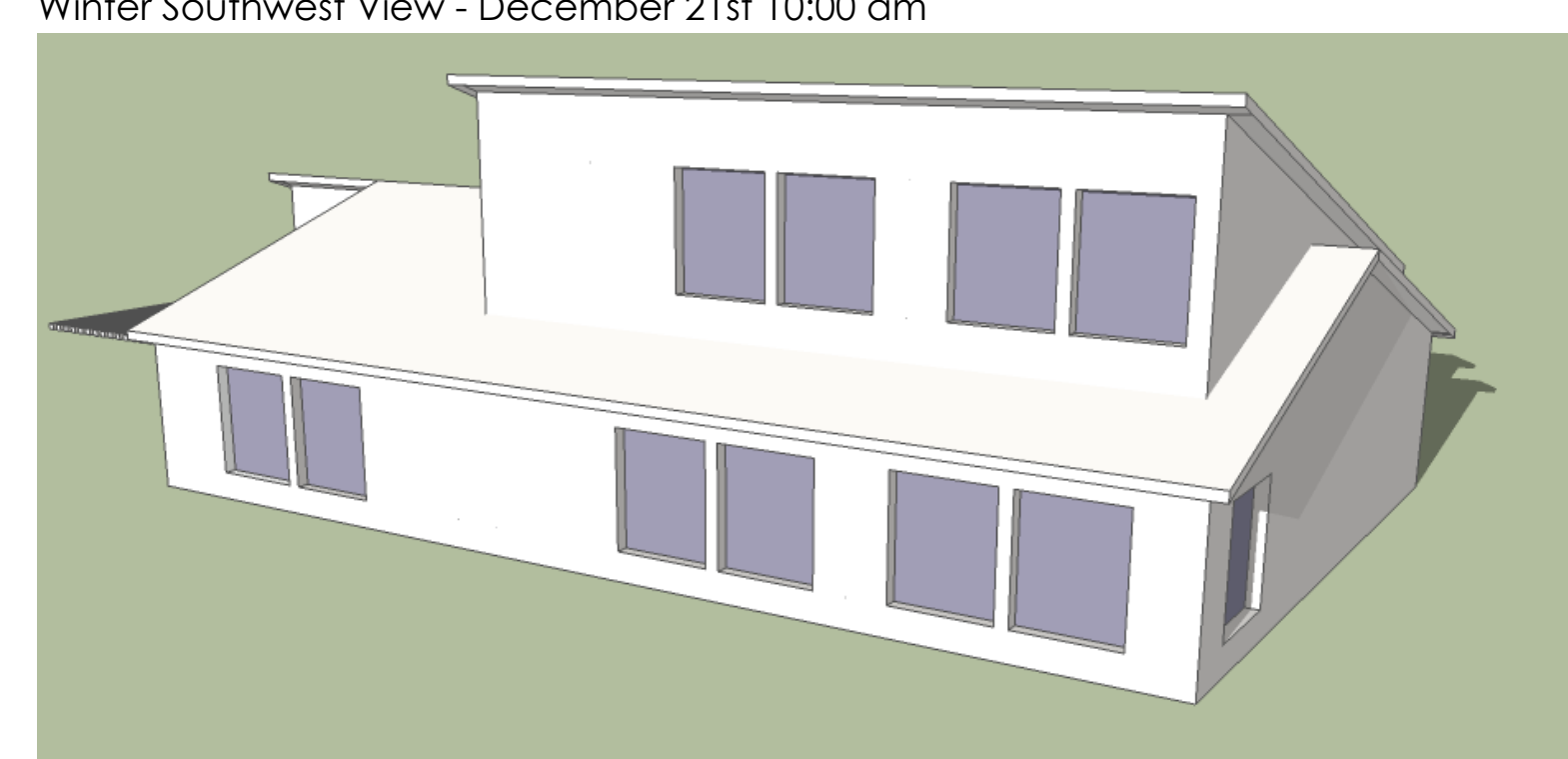


Figure 13 - Prototype Home for Cache Valley, Utah Winter Southeast View - December 21st 10:00 am

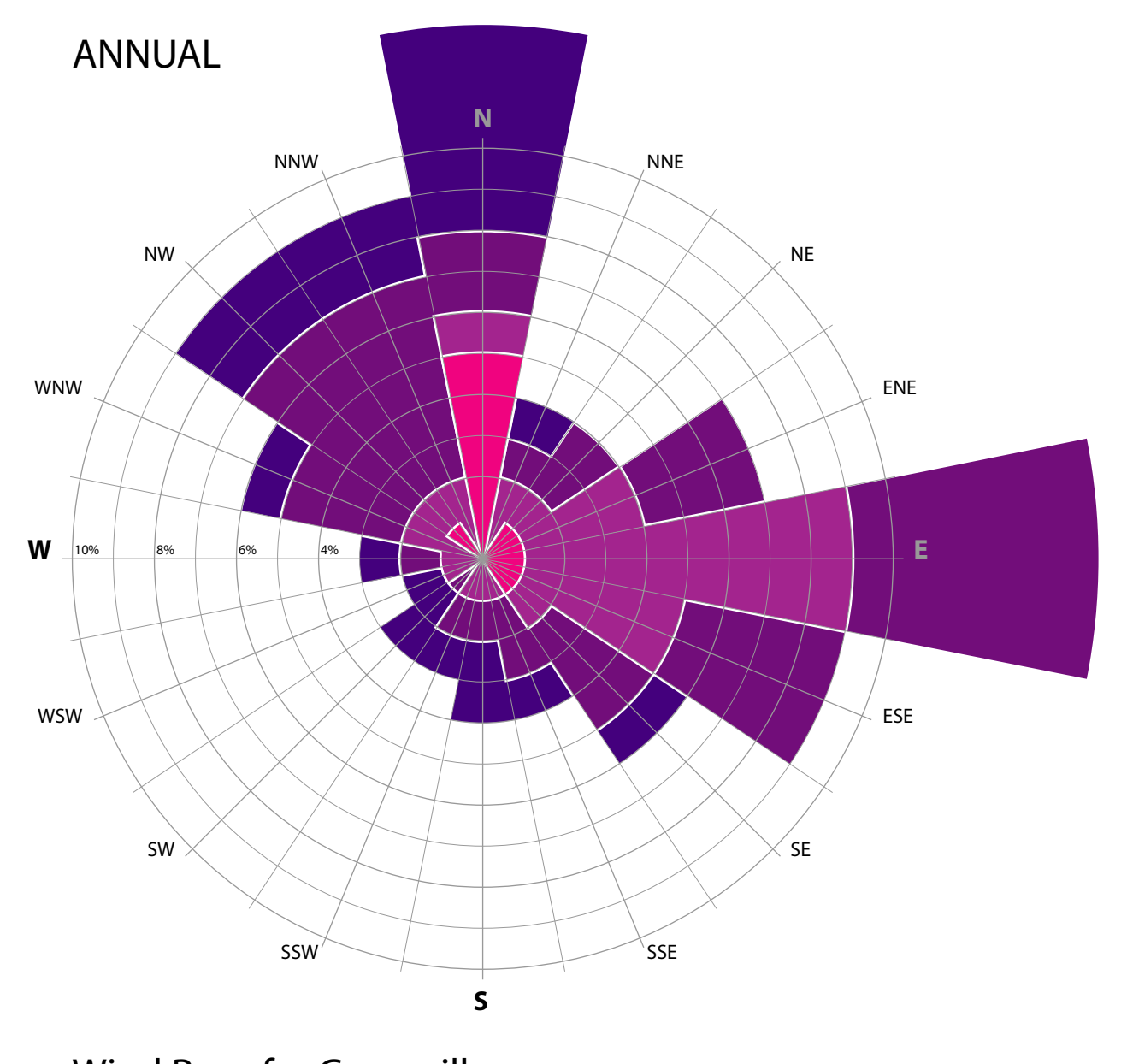


Figure 14 - Annual Wind Rose

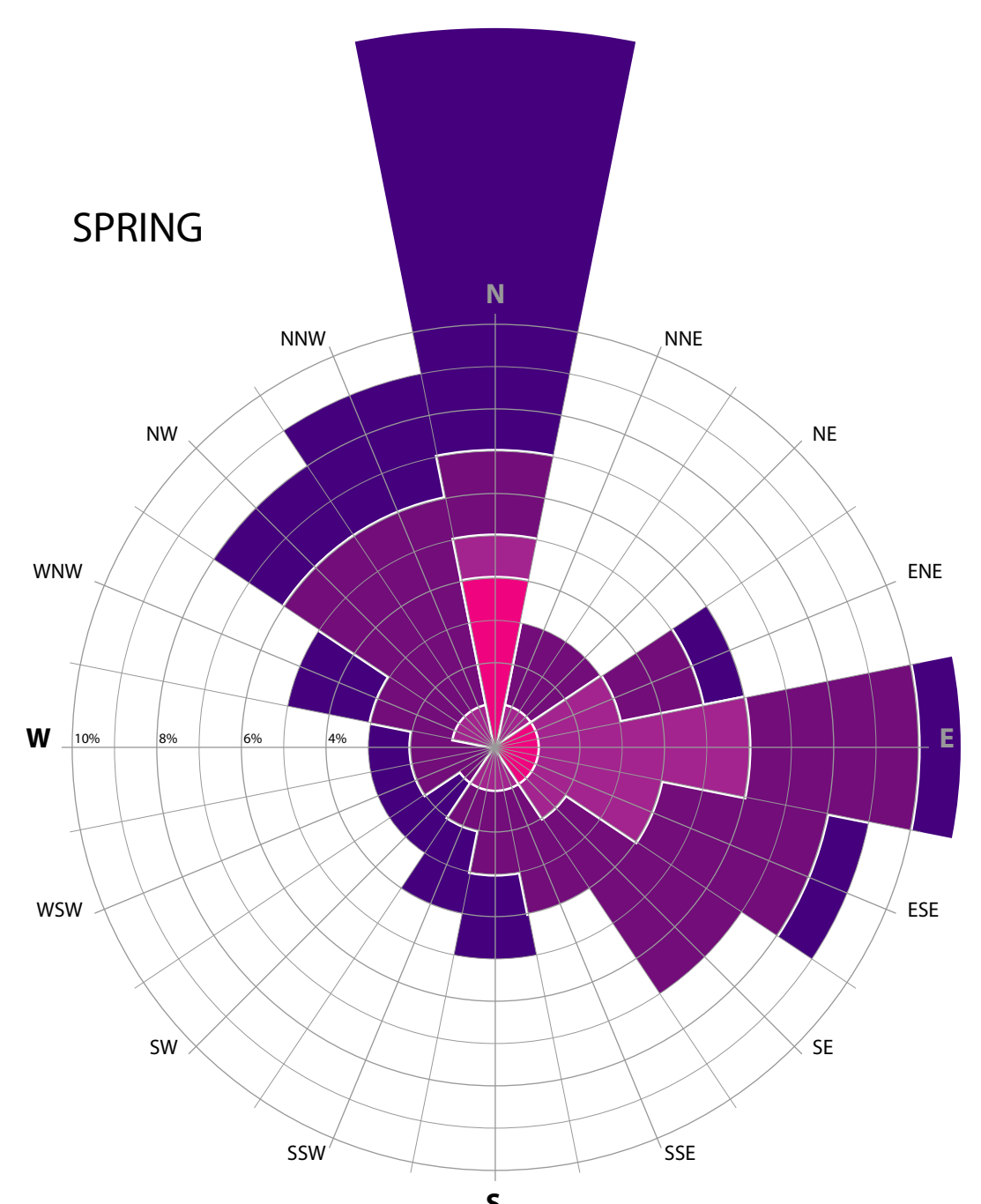


Figure 15 - Spring Wind Rose

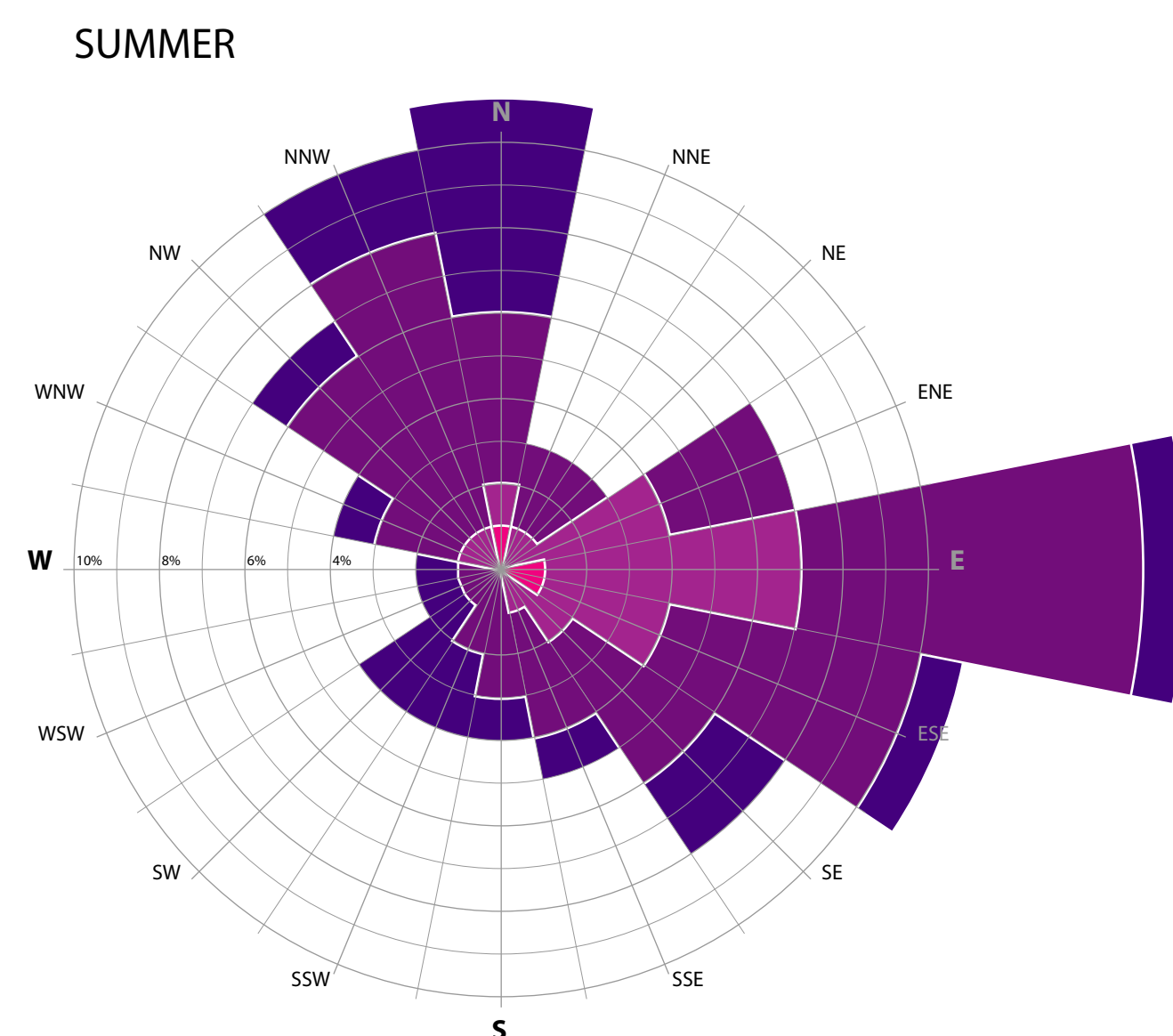


Figure 16 - Summer Wind Rose

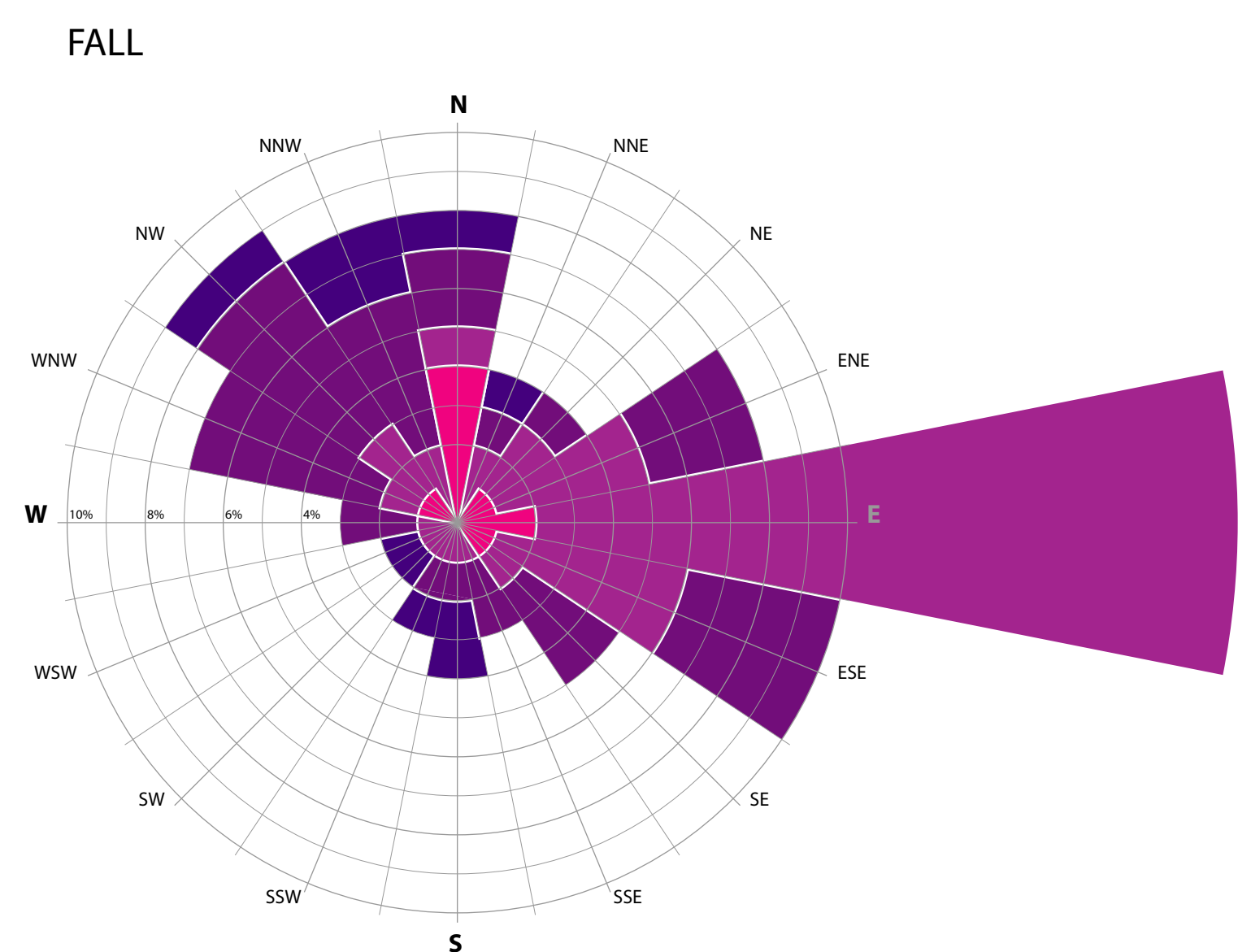


Figure 17 - Fall Wind Rose

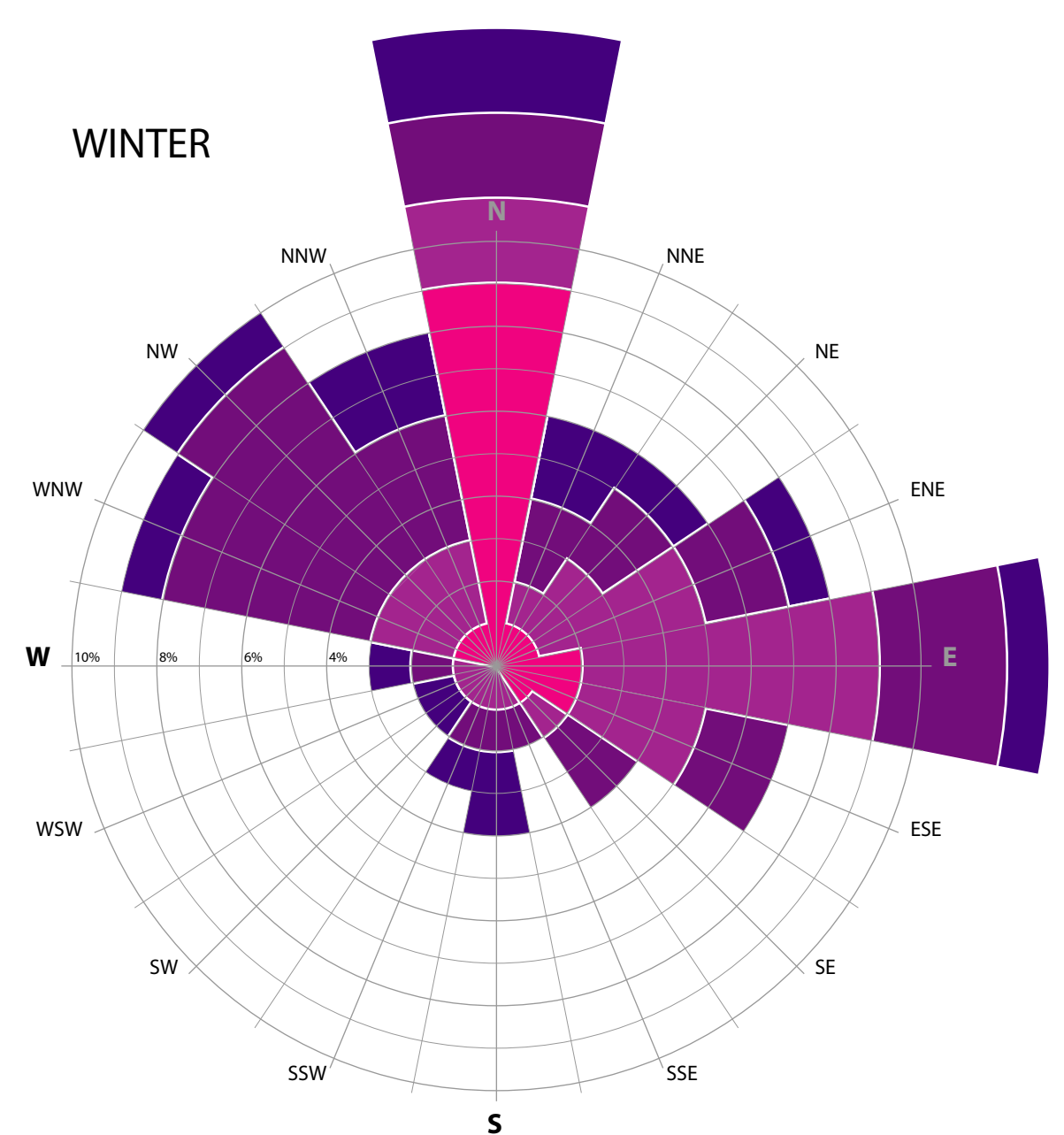


Figure 18 - Winter Wind Rose

References

- Brown, G. Z. (1985). *Sun, wind, and light: Architectural design strategies*. New York: John Wiley & Sons, Inc.
- Cofaigh, E. O., Olley, J. A., & Lewis, J. O. (1996). *The Climatic Dwelling: An Introduction to Climate-Responsive Residential Architecture*. Earthscan.
- Evans, J. M. (2003). Evaluating comfort with varying temperatures: a graphic design tool. *Energy and Buildings*, 35(1), 87–93.
- Lynch, K., & Hack, G. (1984). *Site Planning*. Cambridge: MIT Press.
- Mazria, E. (1979). *Passive Solar Energy Book*. Emmaus: Rodale Press.
- Olgyay, V. (1963). *Design with climate--bioclimatic approach to architectural regionalism*. New York: Van Nostrand Reinhold.
- Passive And Low Energy Architecture (14o: 1998; Lisboa, P., Maldonado, E. (ed.), & Yannas, S. (ed.). (1998). *Environmentally Friendly Cities*.
- Ryn, S. V. D., & Cowan, S. (2007). *Ecological Design*. Island Press.
- Stemers, T. (1991). *Solar architecture in europe: Design, performance and evaluation*. Dorset: Commission of the European Communities.
- Stein, R. G. (1977). *Architecture and energy*.
- Swaid, H., Bar-El, M., & Hoffman, M. E. (1993). A bioclimatic design methodology for urban outdoor spaces. *Theoretical and Applied Climatology*, 48(1), 49–61.
- The sustainable sites initiative*. (2007). Retrieved from www.sustainablesites.org
- Utah Division of Water Resources [www.conservewater.utah.gov] *USU, Greenville Farm and Birch Creek Golf Course Weather Stations*.

Yeang, K. (2006). *Ecodesign: A manual for ecological design*. Great Britain: John Wiley & Sons, Inc.

Author's Biography

Laura Patricia Reyes Romero was born in Santo Domingo, Dominican Republic and spent great part of her childhood in San Juan, Puerto Rico. Ms. Reyes attended Arroyo Hondo Catholic School until her graduation in June 2007. In the summer of 2007, she obtained a DR-USU Full Presidential Scholarship that allowed her to relocate in Utah to pursue her interests in landscape architecture. She is also pursuing a minor in Parks and Recreation and is an active member of the Honor's Program at Utah State University. Laura has been involved in several research projects along with faculty from the Department of Landscape Architecture and Environmental Planning. She has developed a broad range of interests within the fields of landscape architecture, planning and recreation. She is passionate about historic preservation, ecological and bioclimatic design, and play environments for children with Autism Spectrum Disorders.

Following graduation Ms. Reyes wishes to obtain work experience on a multidisciplinary firm where she can further explore her interests, and eventually pursue graduate studies in Urban Design. Ms. Reyes is determined to become a spokesperson in the development of landscape architecture as a profession in the Dominican Republic.