Scope

The scope of this design exercise is limited to carrying out modifications to my studio apartment within the envelope of the building so that they can be carried out in **a conventional building renovation project.**

The **bathroom, closet and kitchen will not be considered** in the present analysis.

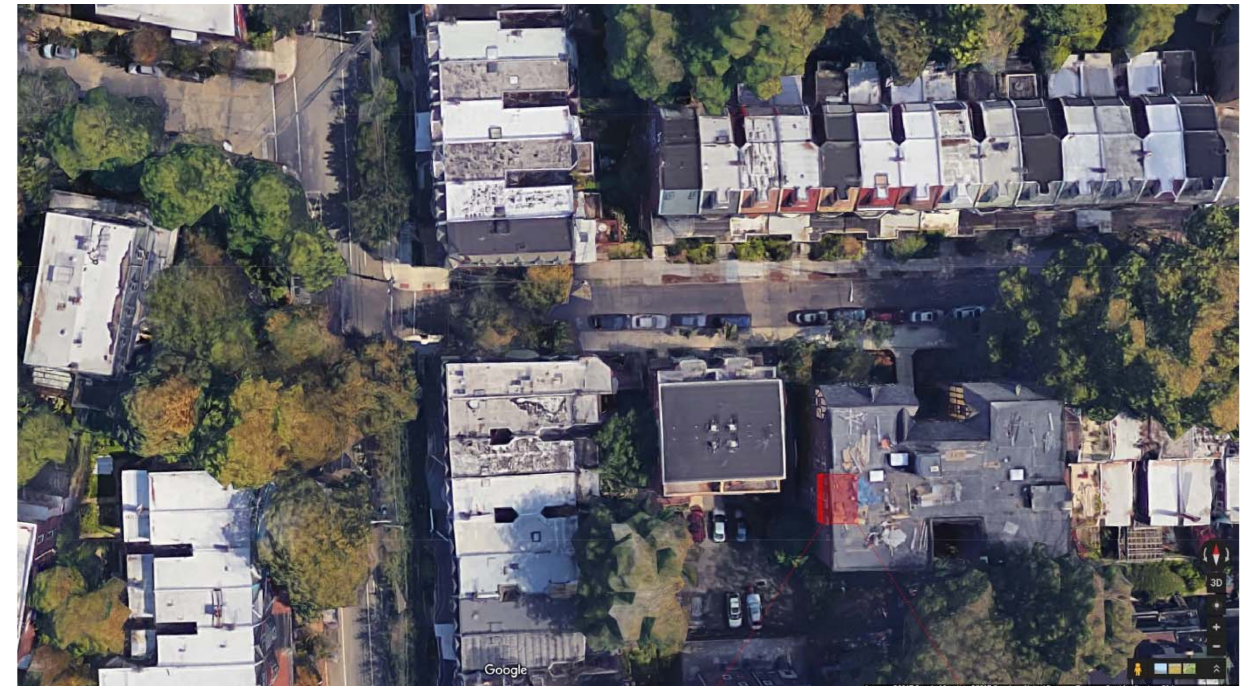
It is assumed that **adjacent spaces** such as the bathroom, closet, kitchen and hallway **are at the same temperature** as the apartment space to be analyzed.

Context

The apartment is sandwiched between apartments above and below.

The West-facing windows of the apartment are shaded by the neighboring building to the North-West of the building.

There is often a draught near the windows indicating a high rate of infiltration.



LOCATION
- Philadelphia, PA, USA

APARTMENT FEATURES
- Four storey building
- 3rd floor studio apartment
- West facing windows
- Four storey adjacent building to the North West
- Steam radiator for heating
- No air-conditioner

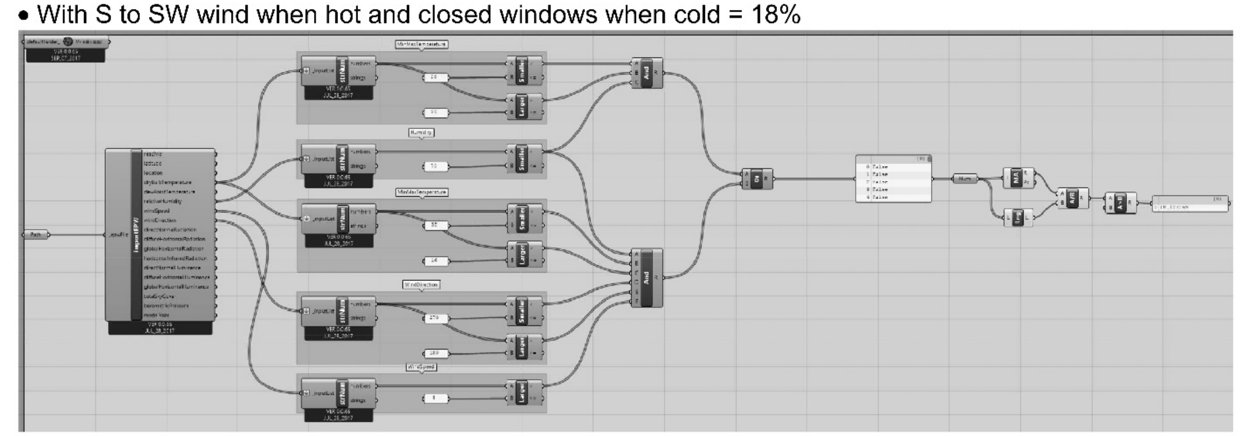
Occupancy-Based Climate Analysis

I have lived in this apartment for one year and have developed certain behavioral adaptations to the space which include:

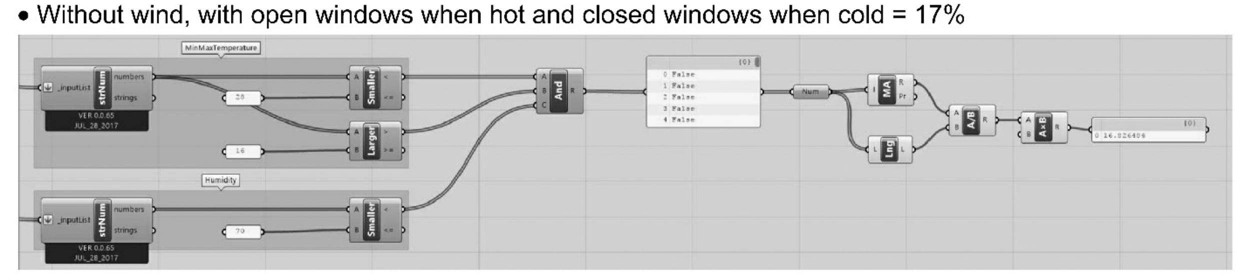
- Opening the windows when I feel hot and/or sticky inside
- Closing the windows when I feel cold inside
- Wearing warm clothing when I feel cold
- Looking out of the windows to enjoy the view

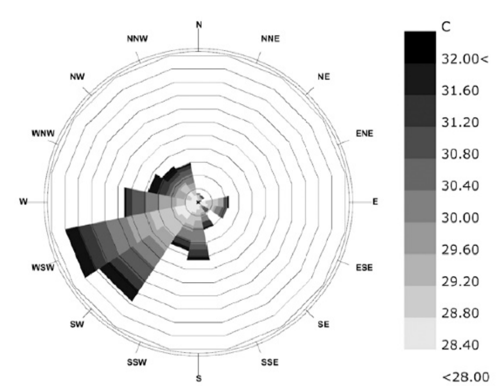
PERSONAL COMFORT PARAMETERS (based on one year in the apartment)
- Max. temperature with open window and wind @ 4m/s = 32°C
- Max. temperature with open window = 28°C
- Max. temperature with closed window = 24°C
- Min. temperature with closed windows = 19°C
- Min. temperature with closed windows and sweater = 16°C
- Max. humidity = 70%
- Wind direction = 180° - 270° (due to orientation and adjacent building)

COMFORTABLE HOURS IN A TYPICAL YEAR
- With S to SW wind when hot and closed windows when cold = 18%

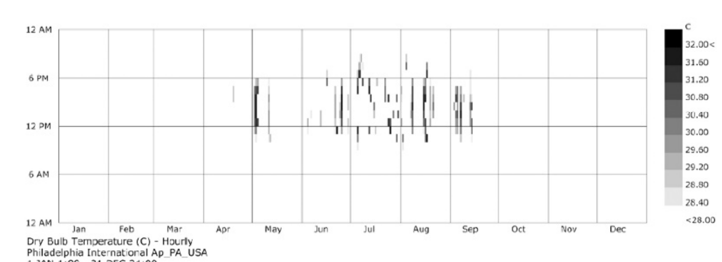


- Without wind, with open windows when hot and closed windows when cold = 17%





Wind-Rose
Philadelphia International Ap_PA_USA
1 JAN 1:00 - 31 DEC 24:00
Hourly Data: Dry Bulb Temperature (C)
Calm for 0.00% of the time = 0 hours.
Each closed polyline shows frequency of 0.1%. = 7 hours.
... ...
Conditional Selection Applied:
28 < Dry Bulb Temperature < 32
383.0 hours of total 8760.0 hours (4.37%).



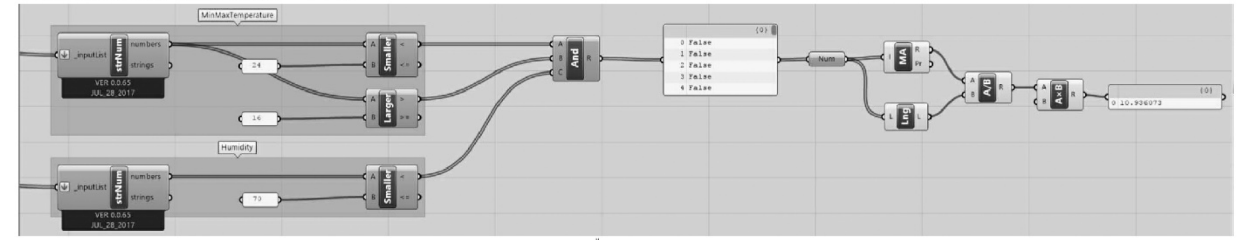
CONCLUSION: The hours of the year where wind can be utilized for cooling (between 24-32°C & RH < 70) is negligible, though wind direction is favorable under these conditions

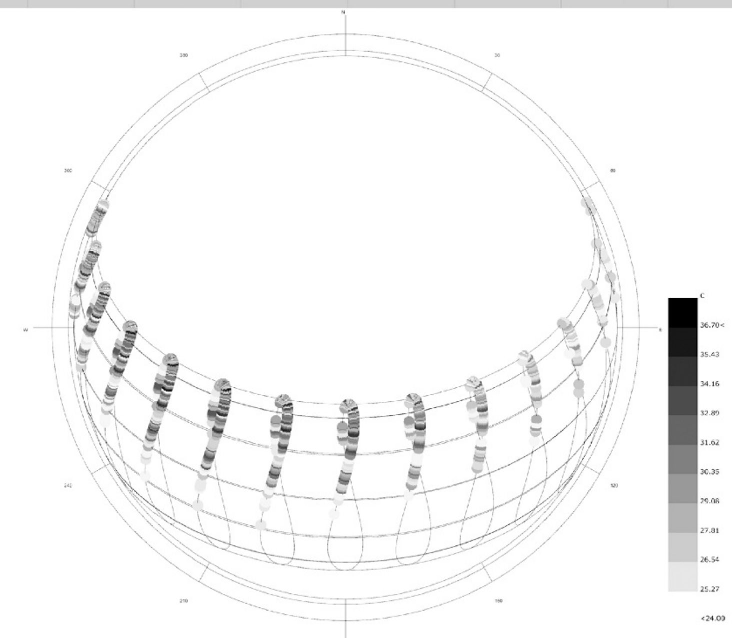
Using these behavioral adaptations as a basis for the climate analysis, I reached the following conclusions:

- Radiation (in this case, from the West) needs to be reduced in summers without affecting the view
- Radiation (in this case, from the West) needs to be increased in winters without causing glare
- Natural ventilation is a viable strategy in summer
- Increasing clothing is a viable strategy in winter

On this basis, the **Adaptive Comfort Model was selected** for use in this analysis.

• With closed windows = 11%

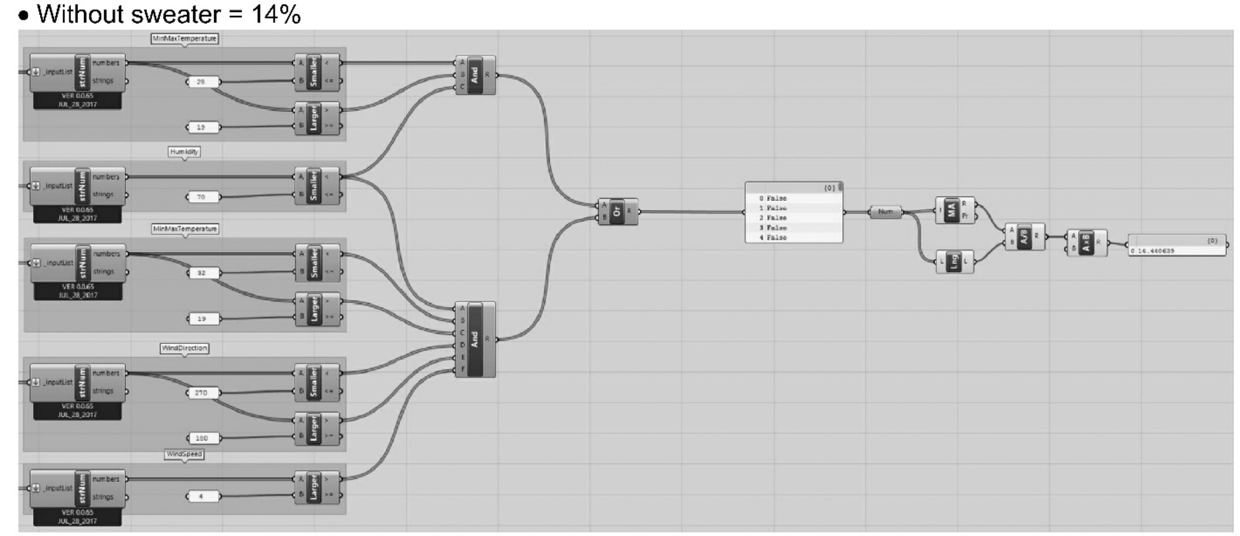




Sun-Path Diagram - Latitude: 39.87
Hourly Data: Dry Bulb Temperature (C)
Philadelphia International Ap_PA_USA
...
Conditional Selection Applied:
Dry Bulb Temperature > 24
1059.0 hours of total 4398.0 sun up hours(24.08%).

CONCLUSION: Opening windows above 24°C significantly increases the number of comfortable hours (as it allows the internal and external temperatures to equalize, somewhat mitigating the effect of radiation from the West).

• Without sweater = 14%

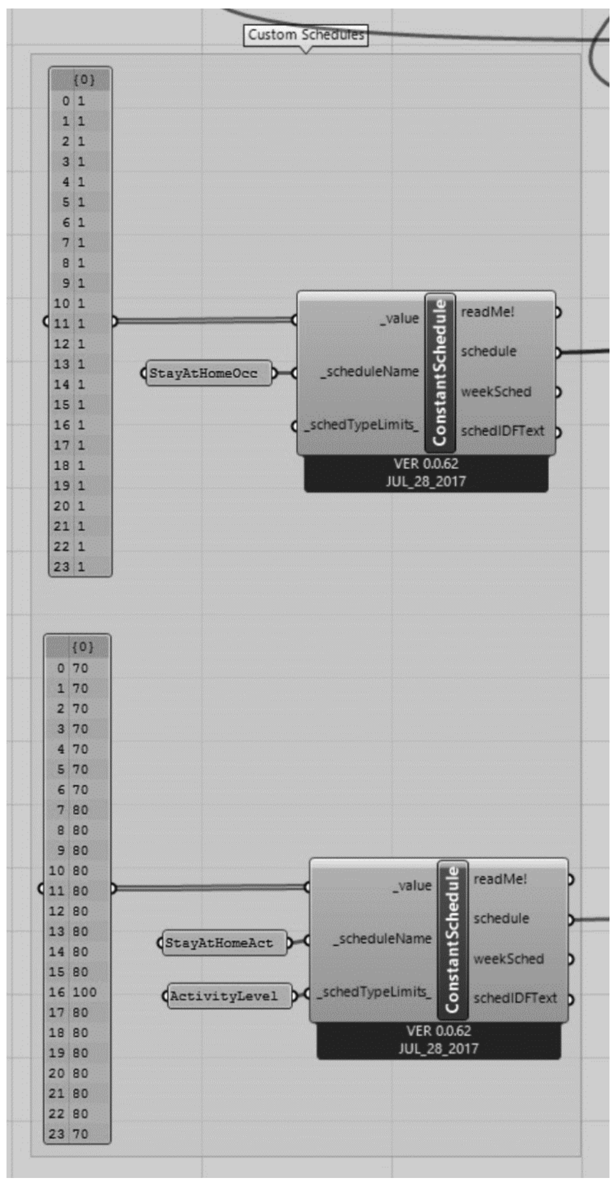


CONCLUSION: Wearing a sweater increases the number of comfortable hours by 4%.

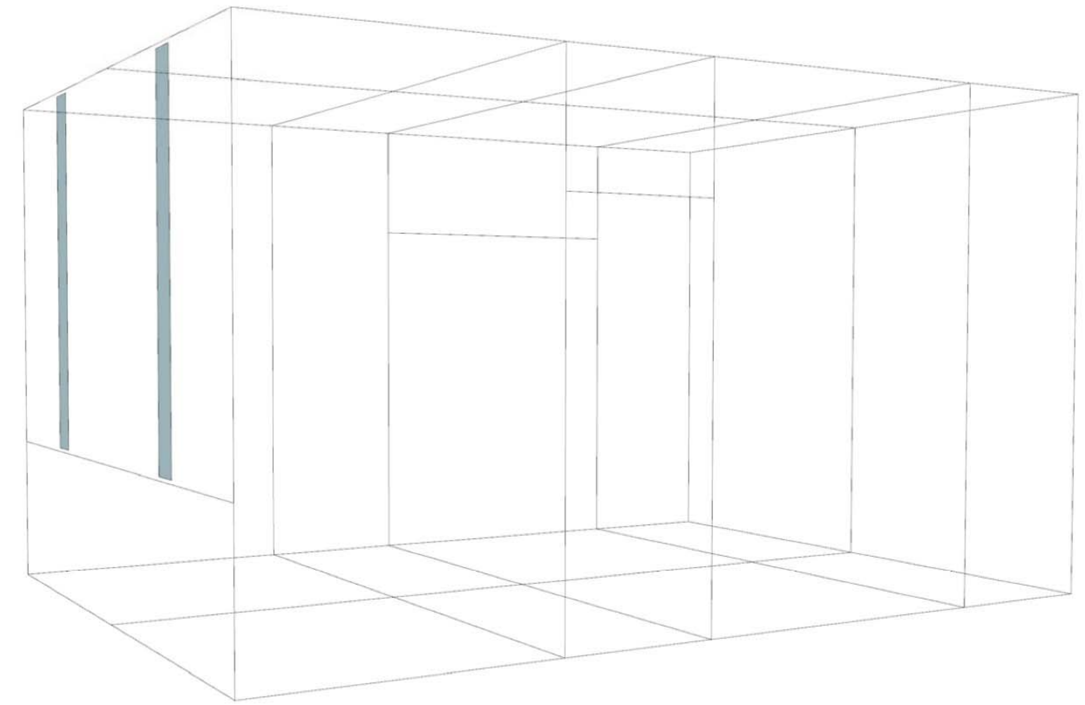
Simulation Set-Up

Based on the scope, context and climate analysis the simulation model contained the following features:

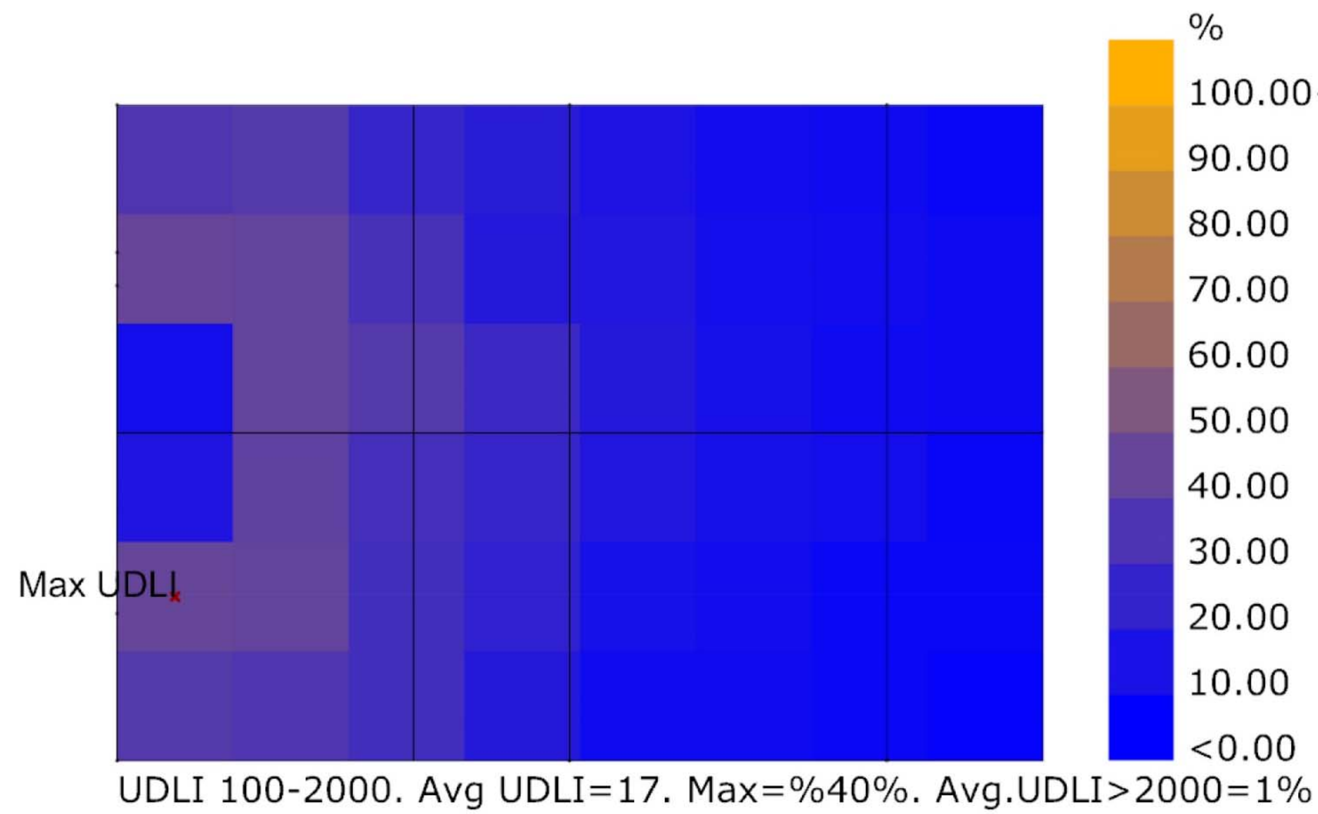
- A custom occupancy schedule to calculate energy for lighting
- A custom activity schedule including sleeping, working and yoga to calculate energy gain from activities
- Interior walls, floor and ceiling surfaces divided for microclimate analysis
- Internal openings to adjacent spaces modelled as air walls
- A lighting sensor placed at the location with maximum UDLI
- Internal walls are assumed to be adiabatic



Custom Schedules



Surface Divisions for Microclimate Analysis



Illumination Sensor Placed at Max UDLI Point

Iteration 1: Reflective Curtains

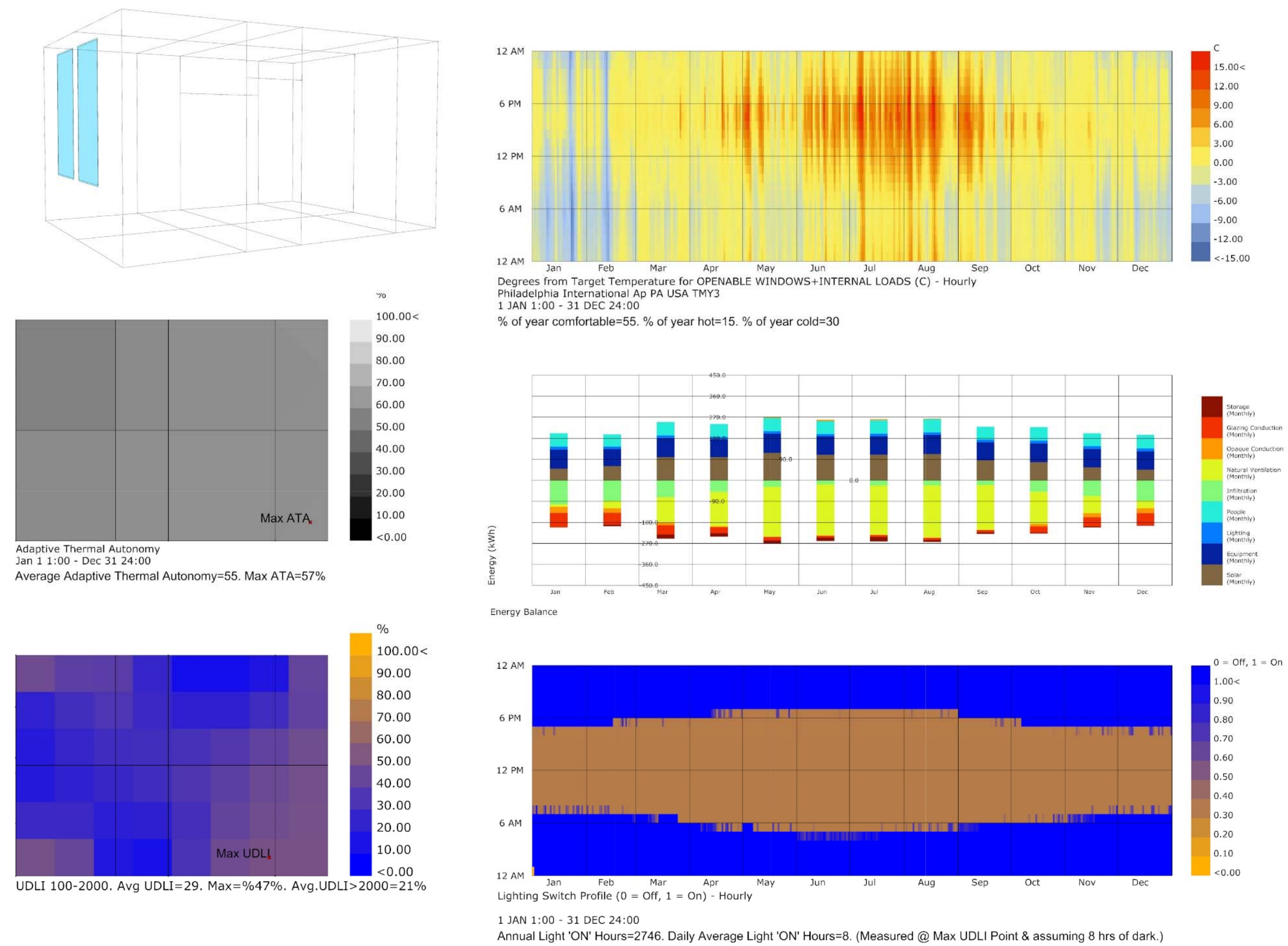
A simulation of the existing apartment shows the following:

1. The openings to the closet space and kitchen reduce the diffuse light in the space:

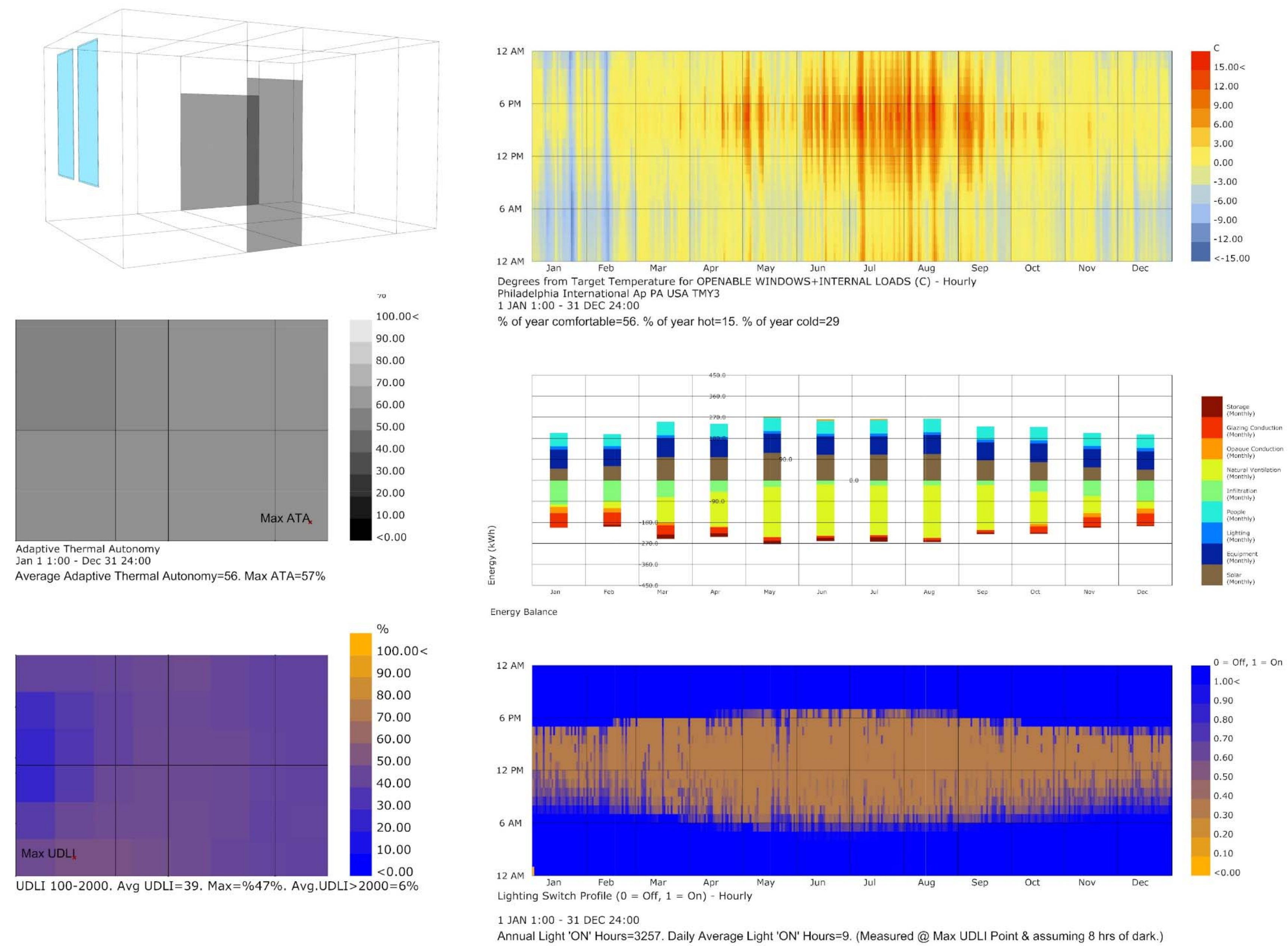
- therefore it is proposed to fit reflective curtains on these openings to improve the average UDLI (the ‘number of bounces’ in the Radiance parameters had to be increased to 3 in order to make this simulation more accurate)

2. The opaque conduction in the energy balance is minimal:

- therefore there is no need to insulate external walls further



The Existing Apartment



The Addition of Curtains

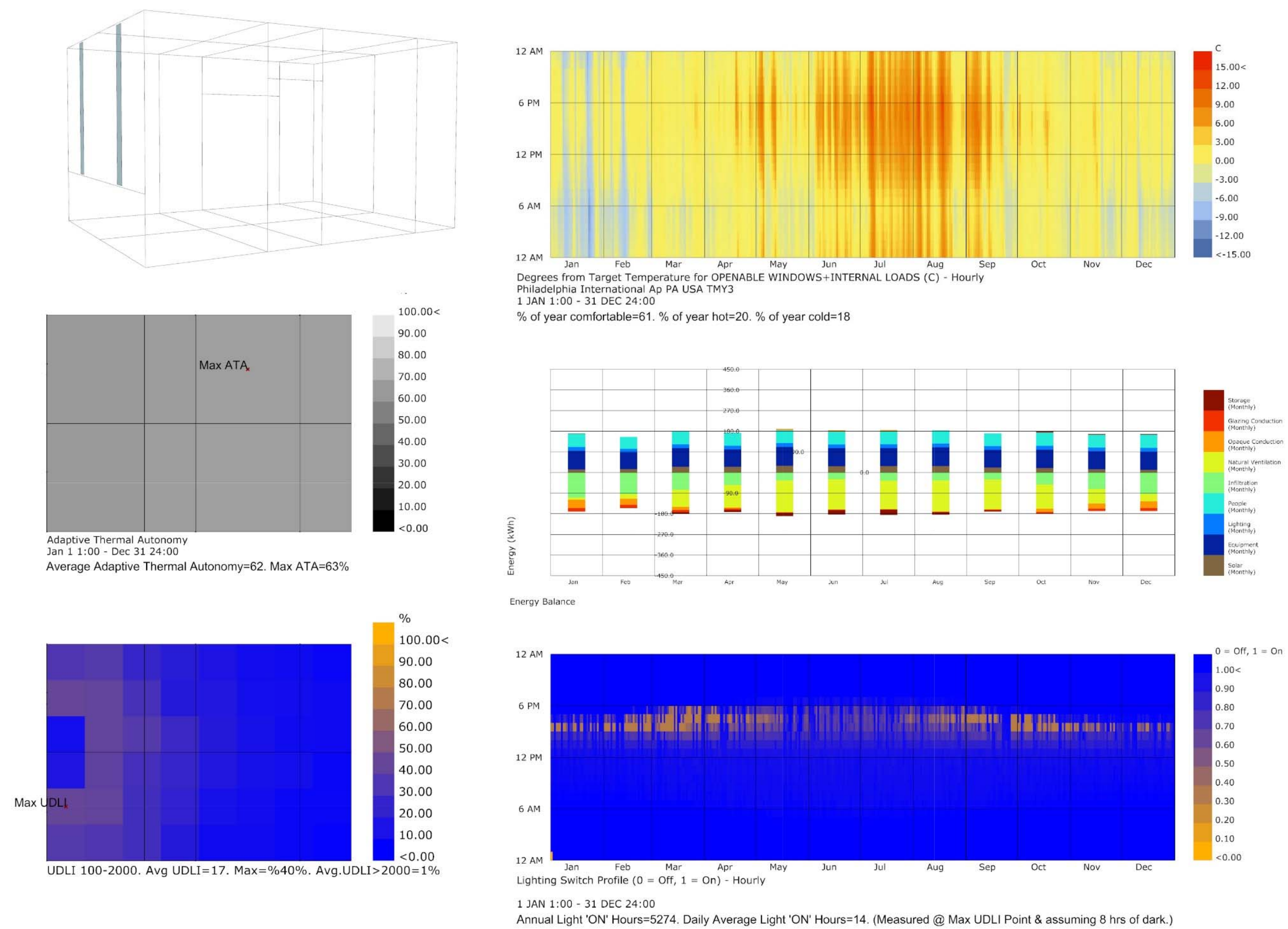
Iteration 2: Glazing Ratio

Adjustments to the Glazing Ratio show the following:

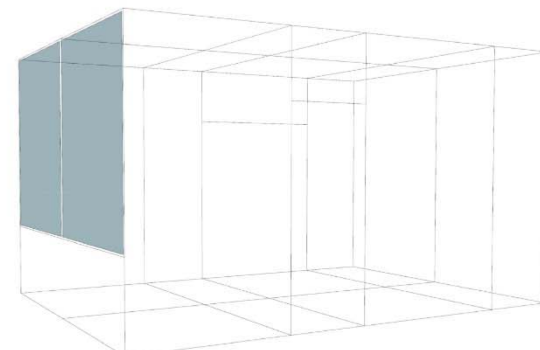
- Increasing the Glazing Ratio decreases Adaptive Thermal Autonomy (ATA)
- Increasing the Glazing Ratio increases UDLI up to a point and then causes glare (UDLI>2000lux)
- Increasing the Glazing Ratio increases interior air temperature in summer and decreases it in winter
- There is no objective function to balance UDLI and ATA – it is a subjective and contextual choice
- Increased glare can be countered with shading

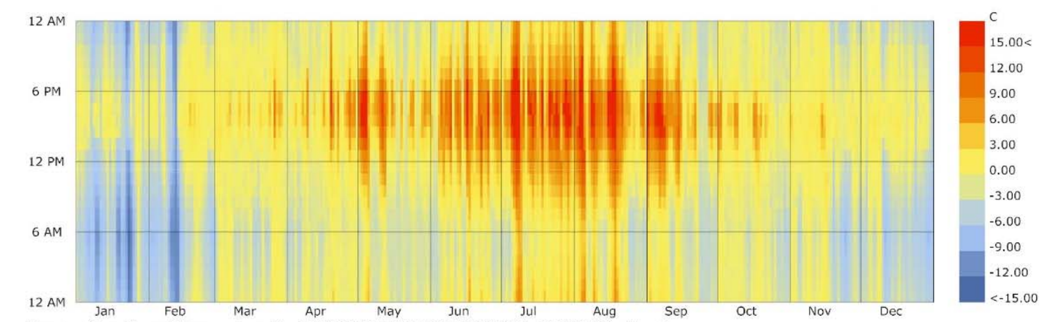
Therefore, the following choices were made in the analysis:

- The existing Glazing Ratio will be maintained for the remainder of this analysis
- An internal shading device will be designed
- The relationship between Glazing Ratios and shading design may be explored through Design Explorer

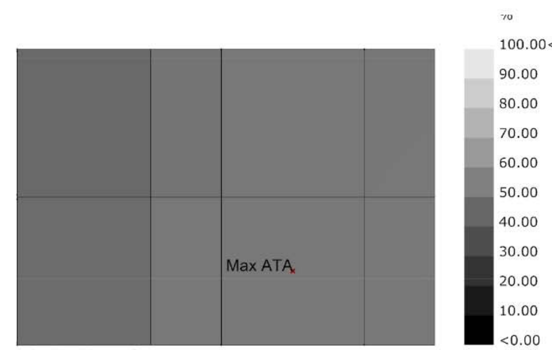


Glazing Ratio = 0.1

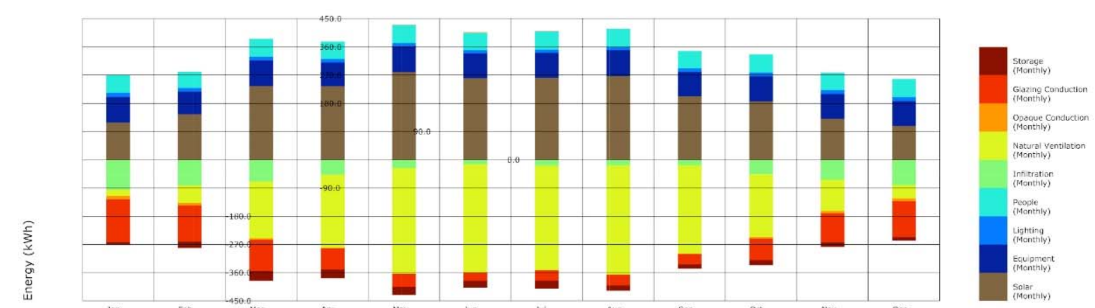




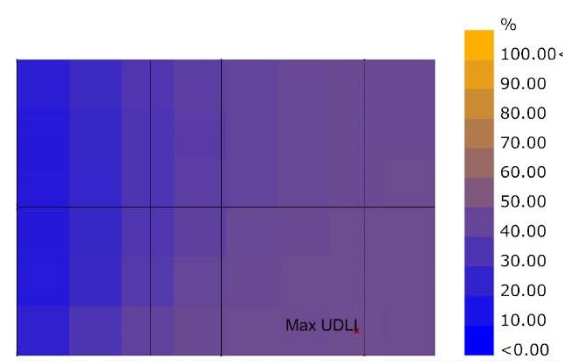
Degrees from Target Temperature for OPENABLE WINDOWS+INTERNAL LOADS (C) - Hourly
Philadelphia International Ap PA USA TMY3
1 JAN 1:00 - 31 DEC 24:00
% of year comfortable=46. % of year hot=16. % of year cold=38



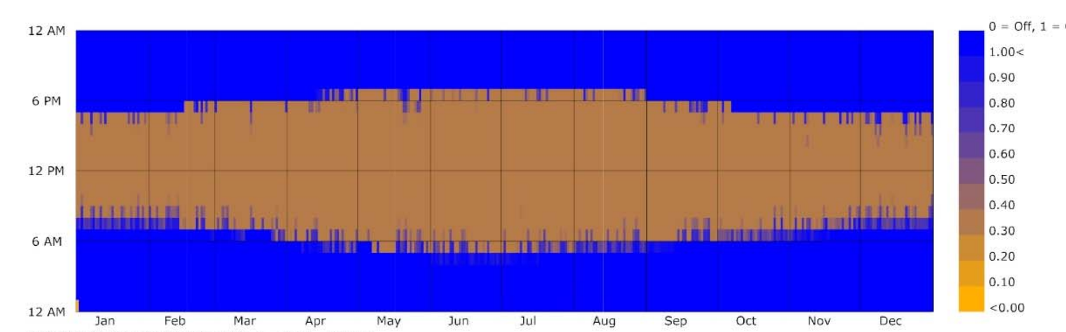
Adaptive Thermal Autonomy
Jan 1 1:00 - Dec 31 24:00
Average Adaptive Thermal Autonomy=46. Max ATA=48%



Energy Balance



UDLI 100-2000. Avg UDLI=35. Max=%44%. Avg.UDLI>2000=14%



Lighting Switch Profile (0 = Off, 1 = On) - Hourly

1 JAN 1:00 - 31 DEC 24:00
Annual Light 'ON' Hours=2892. Daily Average Light 'ON' Hours=8. (Measured @ Max UDLI Point & assuming 8 hrs of dark.)

Glazing Ratio = 0.95

Iteration 3: Internal Shading Device

Parametric modelling was used to design an internal shading device for the windows.

The shading device was designed with the following characteristics:

- The shading device is tapered towards the top to increase the light reaching the ceiling
- The shading device is wider at the base to reduce the direct illumination of the work-plane
- The shading device is rotated to adjust to further increase the light reaching the ceiling and reduce the direct illumination of the work-plane

The shading device has the following positive impacts on UDLI depending on the input parameters of the design:

- The shading device reduces glare (UDLI >2000lux)
- The shading device reduces variation in illumination across the apartment space (Average UDLI)

However, the shading device has the following negative impacts:

- The shading device reduces the total illumination in the space
- The shading device has no significant impact on comfort (ATA)

The shading device was modelled as a thermal mass to reduce temperature variations in summer and winter. Two alternative simulations were run with the following materials:

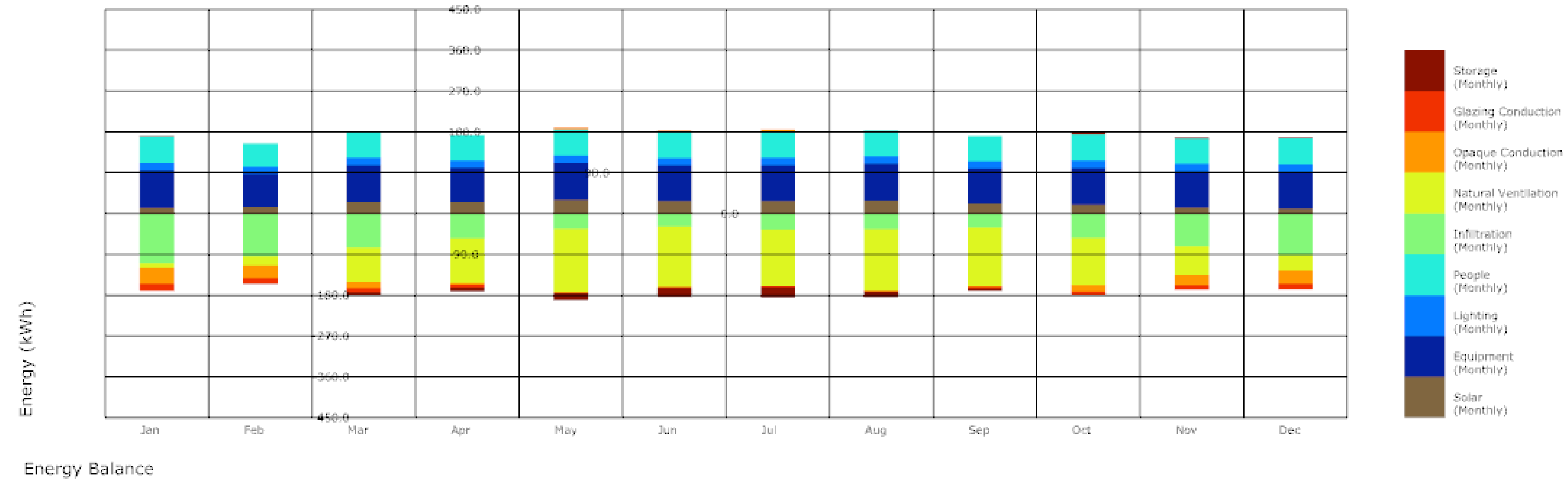
- Wood
- Gypsum to check its potential as a thermal mass

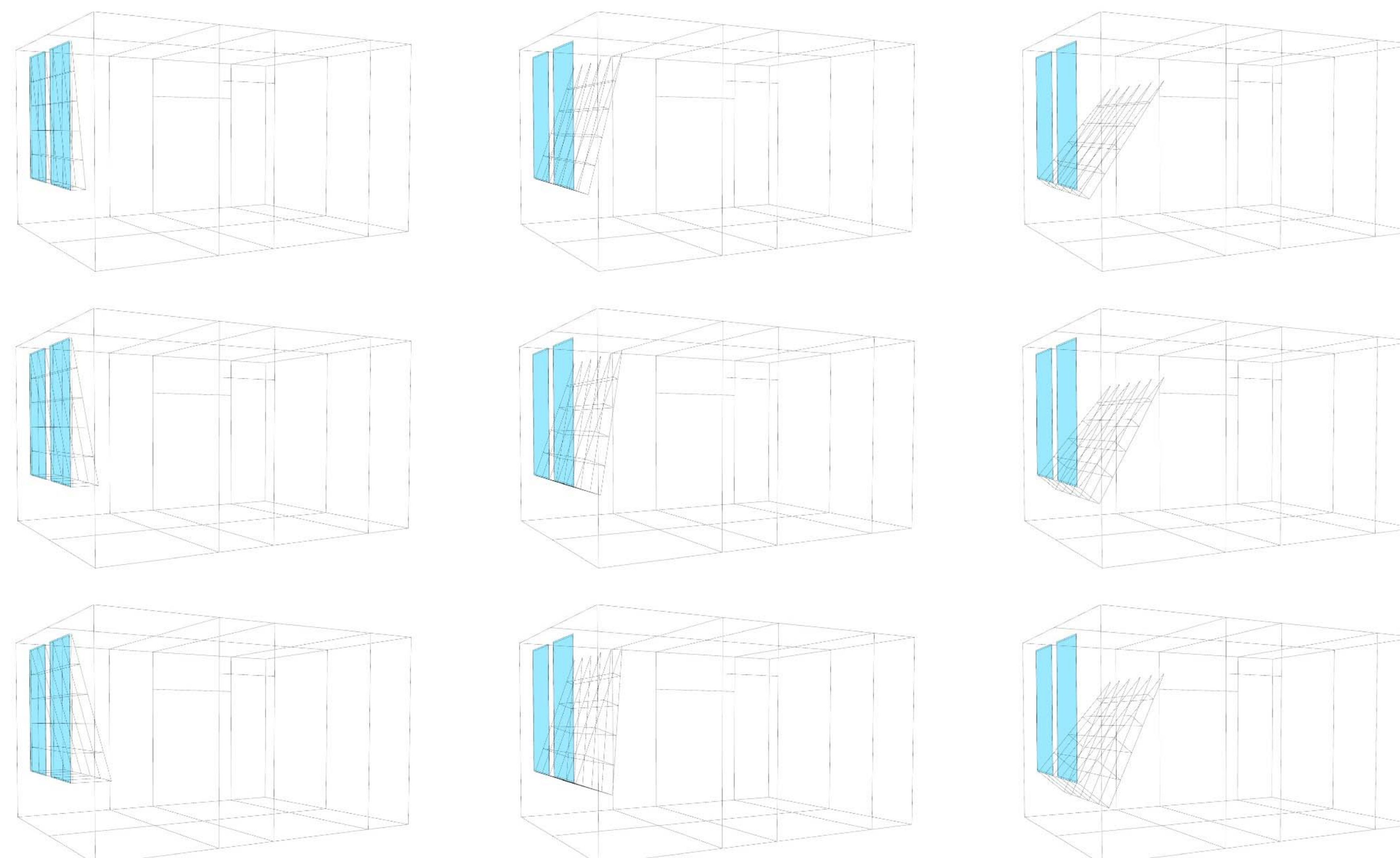
The performance of the shading device as a thermal mass has the following results:

- The Storage quantity in the Energy Balance is positive in winter
- The Storage quantity in the Energy Balance is negative in summer

This demonstrates the benefit of a thermal mass in reducing temperature variation in summer and winter. However:

- The thermal mass of the shading device is too low to make any significance difference to the Adaptive Thermal Autonomy (ATA).





Above: Shading Device as a Thermal Mass. Below: Parametric Variations in the Depth and Angle of the Shading Device

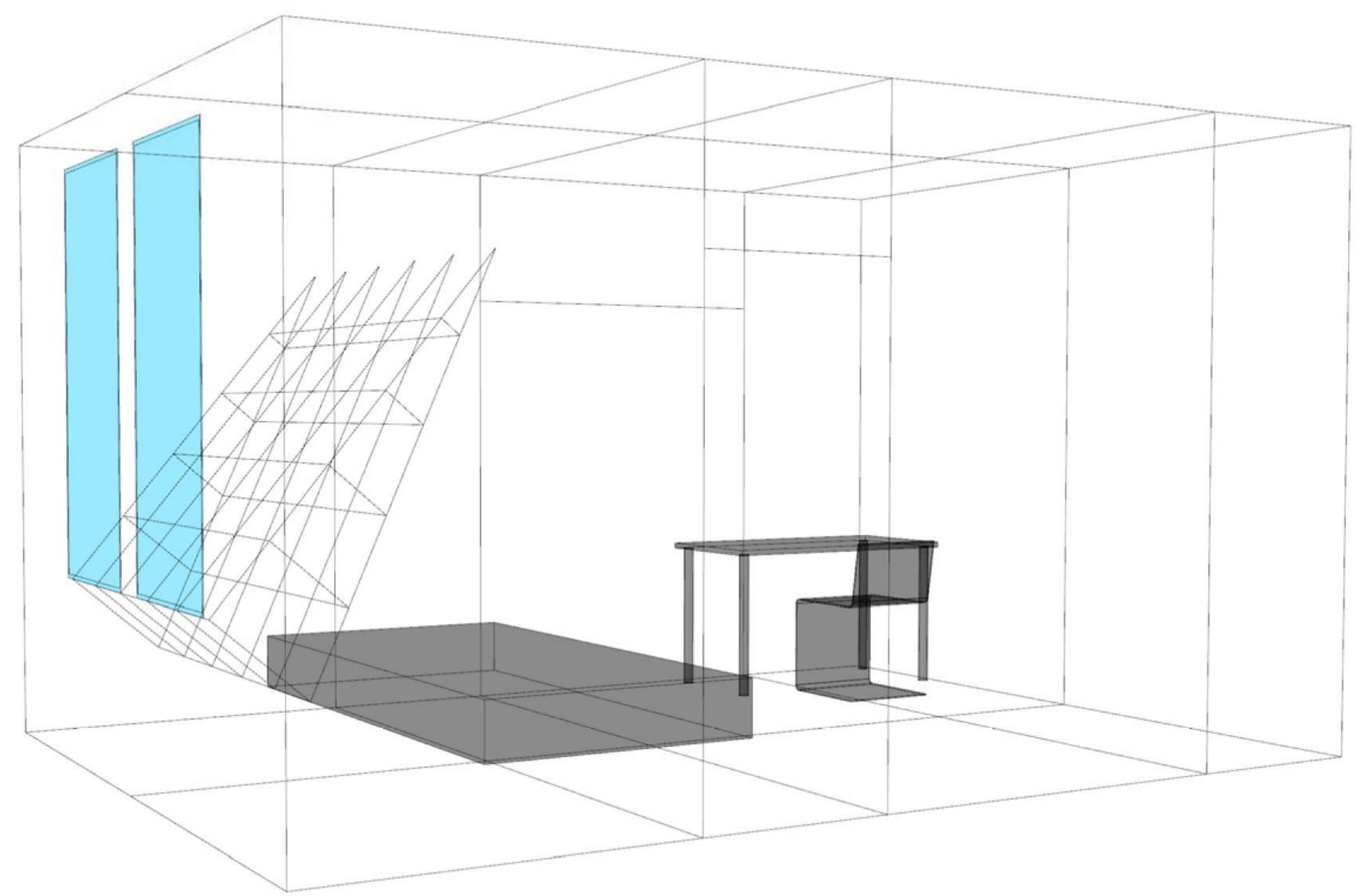
Iteration 4: Furniture Placement

The following factors may be considered in the placement of the bed and study table based on the microclimate analysis:

- The UDLI is irrelevant to sleeping, so there is no benefit in placing the bed at the Maximum UDLI Point
- The variation in ATA across the apartment space is never greater than 10%
- The Maximum ATA Point and the Maximum UDLI Point are in different parts of the apartment space

Based on these factors the following suggestions are made for furniture placement:

- The study table may be placed at the Maximum UDLI Point
- The bed may be places at the Maximum ATA Point for maximum comfort



Furniture Placement

Iteration 5: Design Exploration

The simulation results can be used to inform the selection of design options through Design Explorer.

Genome:

- Glazing Ratio
- Shading Angle
- Shading Depth

Phenome:

- Average UDLI
- Maximum UDLI
- Average Adaptive Thermal Autonomy
- Maximum Adaptive Thermal Autonomy
- Average Lights 'ON' Hours/Day
- Lights 'ON' Hours/Year

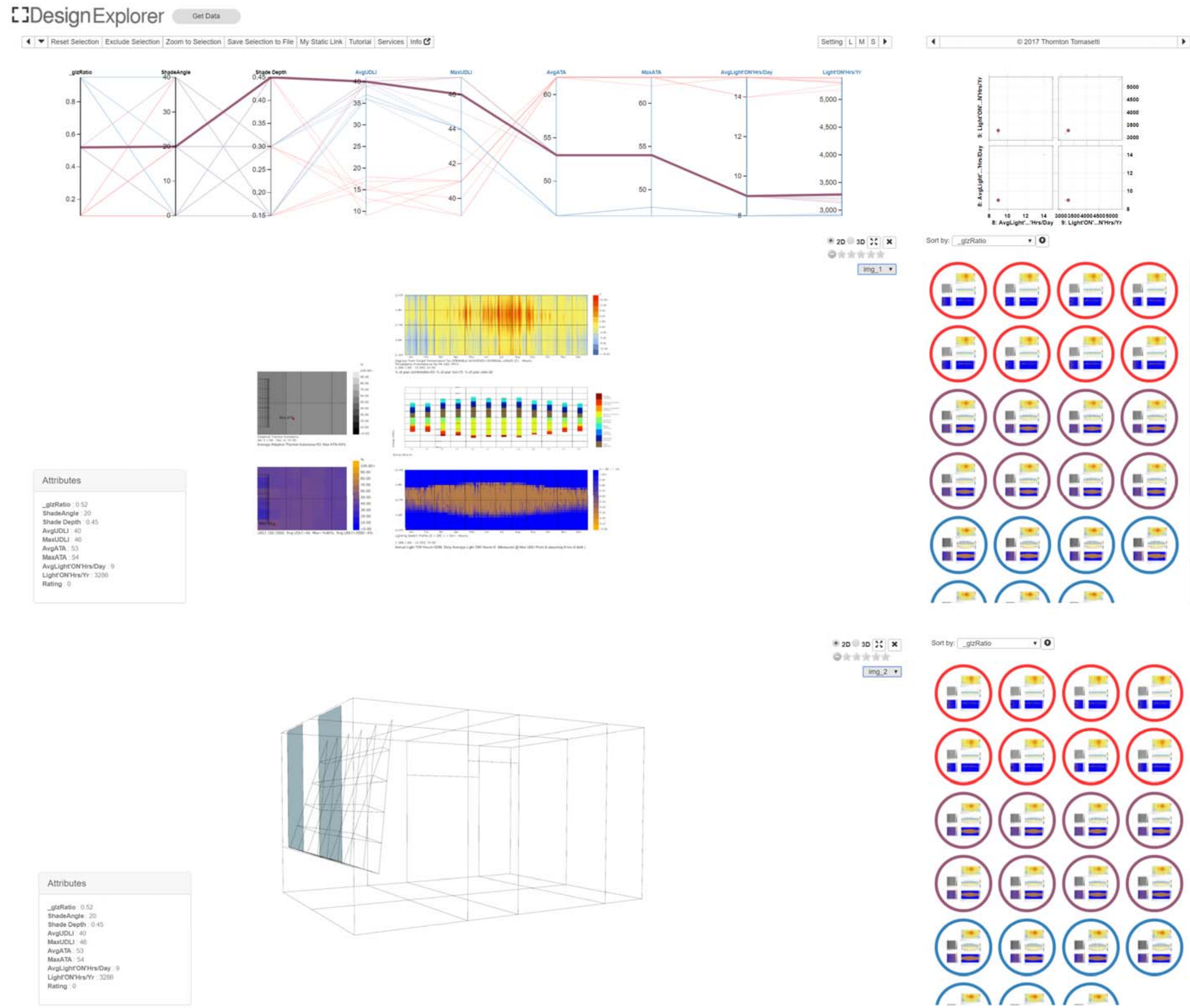
The data folder is located at the following URL:

- https://drive.google.com/drive/folders/1zPbr-kDpp2kx4DoGYirK7xe_XNWq0lXh?usp=sharing

The Design Explorer link is:

- https://goo.gl/Kk5CQ7

Of the 100,000+ possible design iterations this link contains 27 representative examples.



Design Explorer Interface

The design shown to the right was selected as a compromise between UDLI, ATA and Lighting Hours >>