SUNROOM AS PASSIVE CONDITIONING STRATEGY IN PHILADELPHIA, PENNSYLVANIA

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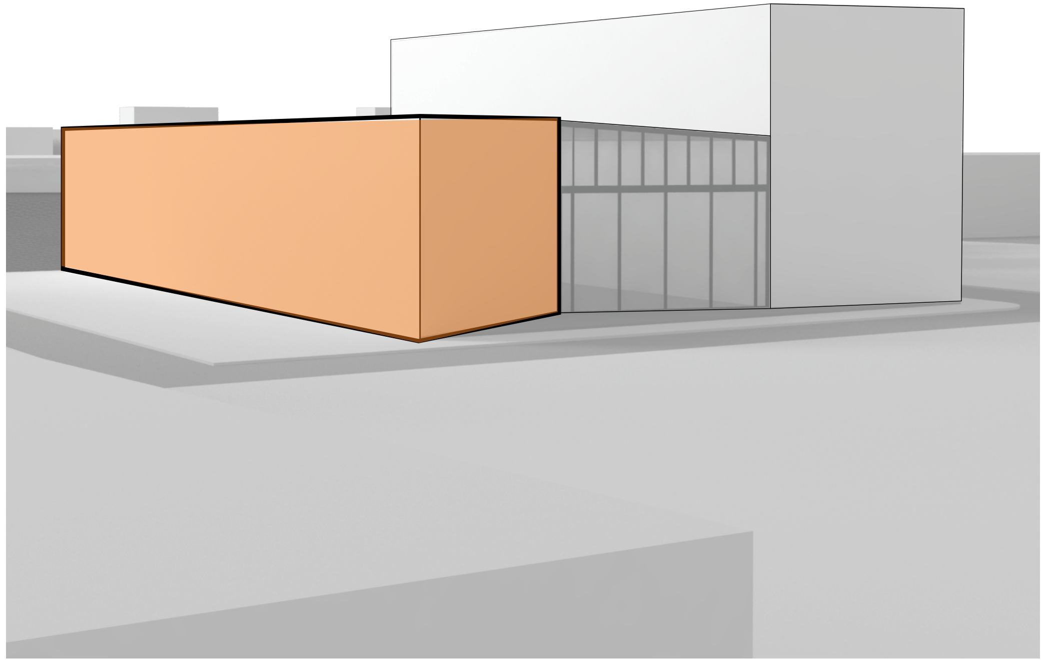
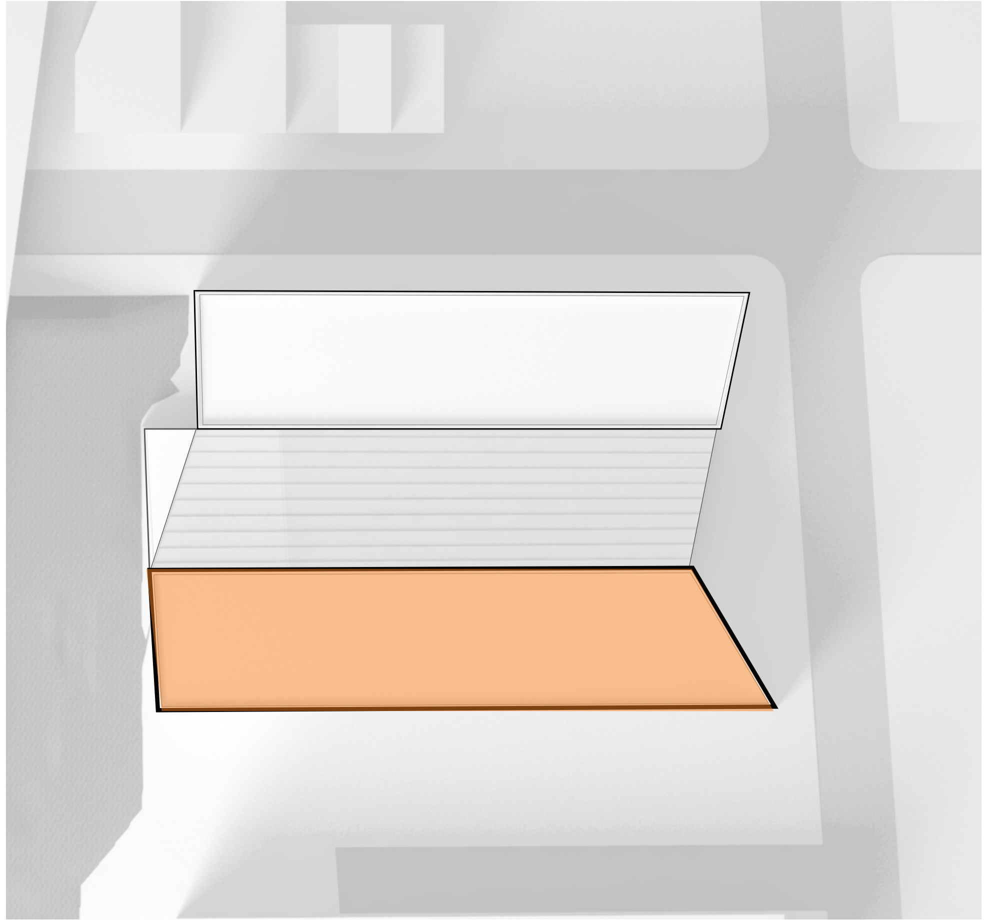
DESIGN OBJECTIVE

To figure out how we can use passive solar strategies to condition and achieve maximum thermal comfort in a 20,000 square foot office building in Philadelphia.

We want to prove sunrooms are an effective strategy for passive conditioning in Philadelphia while amalgamating into the design narrative of the building seamlessly.





WORKFLOW

PHASE 1

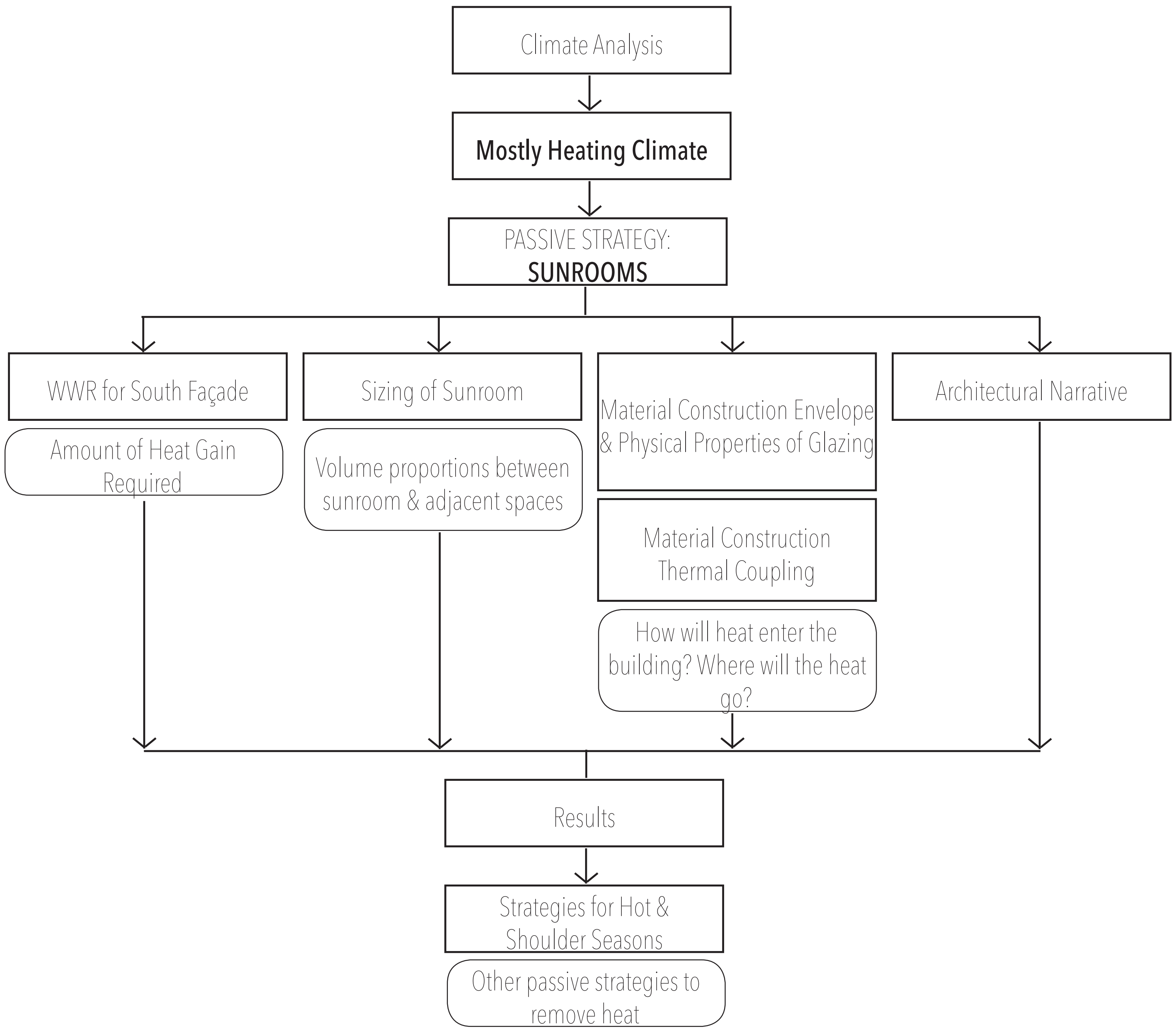
Our climate analysis of Philadelphia revealed that we have significantly more cold stress than heat stress and is comfortable the majority of the time. From our research on passive strategies we discovered sunrooms work well in this climate.

PHASE 2

In the second phase of our workflow we will test multiple variables in relationship to sunroom and thermal mass coupling to determine the most comfortable conditions for occupancy. We plan to take that information to make design decisions about the type of activity within the sunrooms that can maximize the utility of the space in accordance with the programming for the building.

PHASE 3

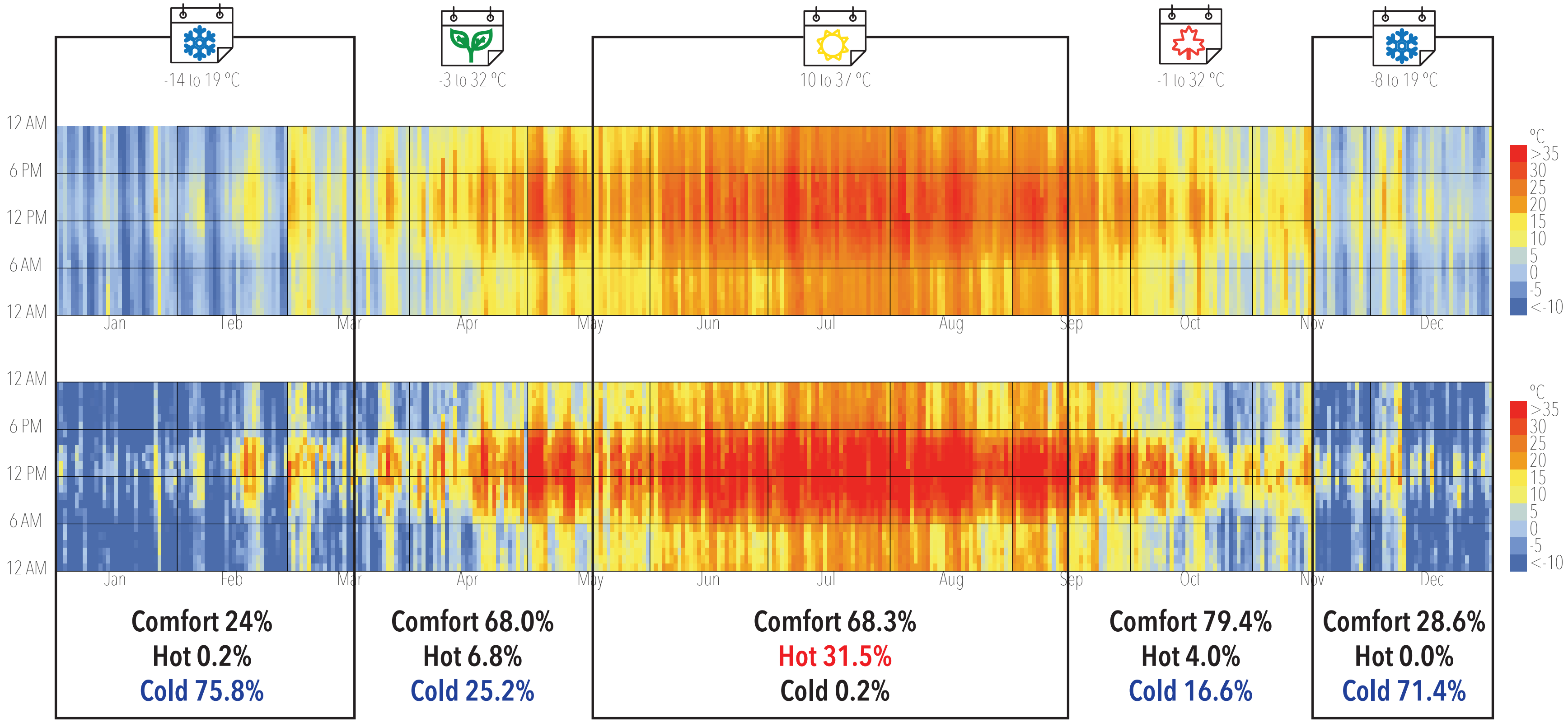
Once we determined our best possible conditions for cold stress we will take the sunroom design and apply passive strategies such as shading and ventilation to achieve maximum comfort for hot and shoulder seasons.



PHASE 1 » CLIMATE ANALYSIS » PHILADELPHIA » MOSTLY HEATING CLIMATE

Dry Bulb Temperature

Universal Thermal Climate Index

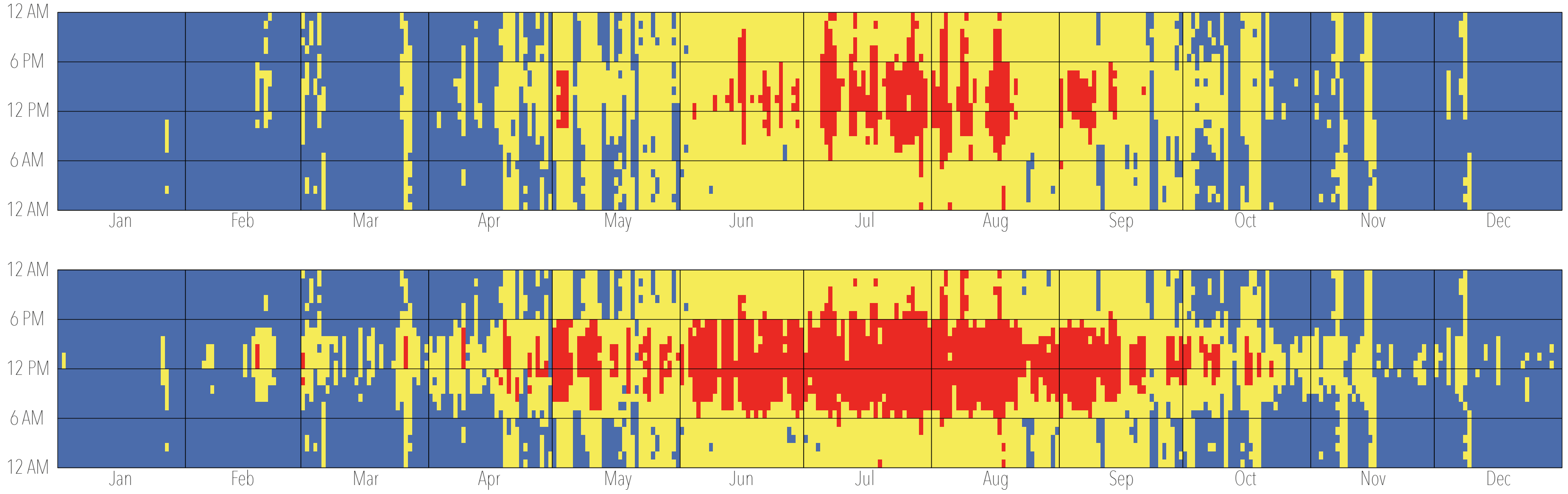


From the climate analysis we see that Philadelphia is comfortable for most of the year. We also have more cold stress than heat stress throughout the year.

Below we see that during hotter temperatures, adding shading reduces heat stress significantly.

Adaptive Comfort Shaded

Adaptive Comfort Outdoor



SHADED - % COMFORTABLE

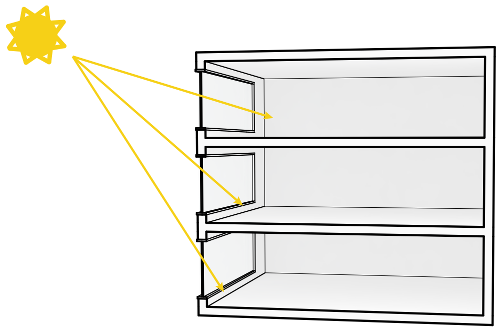
Heat Stress	3.1 %
Comfortable	**41.3 %**
Cold Stress	34.3 %

OUTDOOR - % COMFORTABLE

Heat Stress	12.5 %
Comfortable	**37.3 %**
Cold Stress	31.6 %

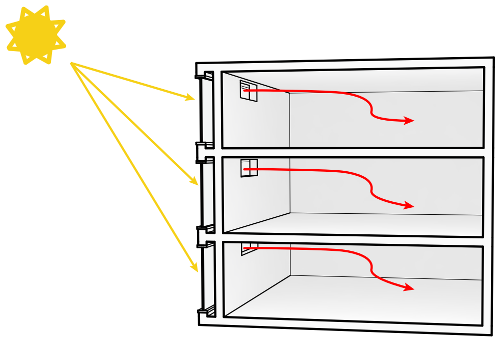
PHASE 1 » PASSIVE STRATEGY » SUNROOMS

DIRECT GAIN



Typical glazing strategy allows for light and heat into a space but does not effectively capture heat in the way we would want to.

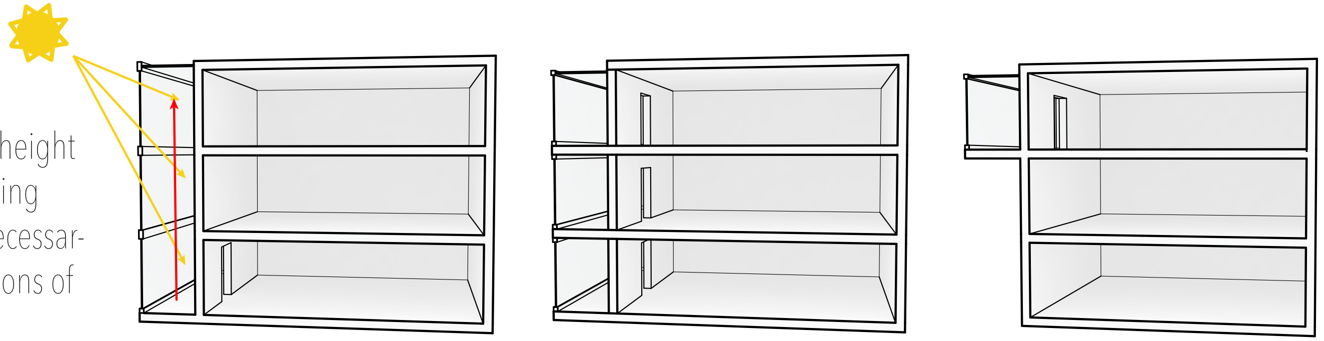
INDIRECT GAIN (TROMBE WALL)



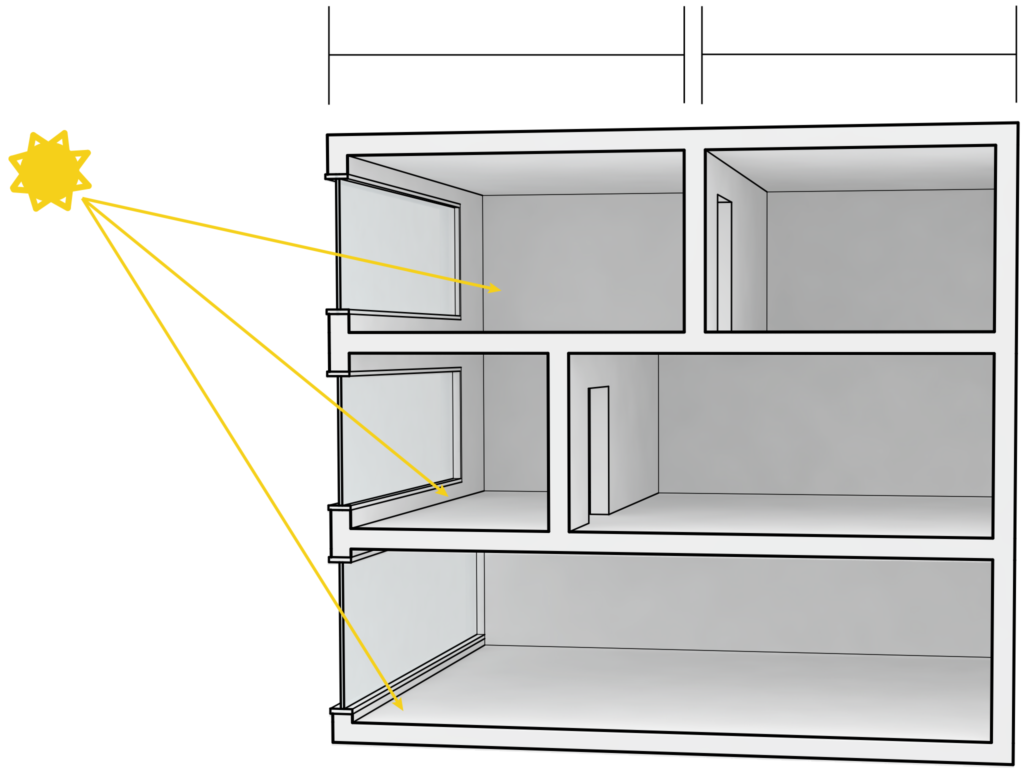
Use of thermal mass to heat adjacent, occupiable space. Our studies showed this created excessive heat. Also, creates a void but not a functional space.

ISOLATED GAIN (SUNROOM)

We were concerned that a multi-story height would create stratification. The protruding spaces could be occupiable but not necessarily integrated well into the other functions of the space behind them.



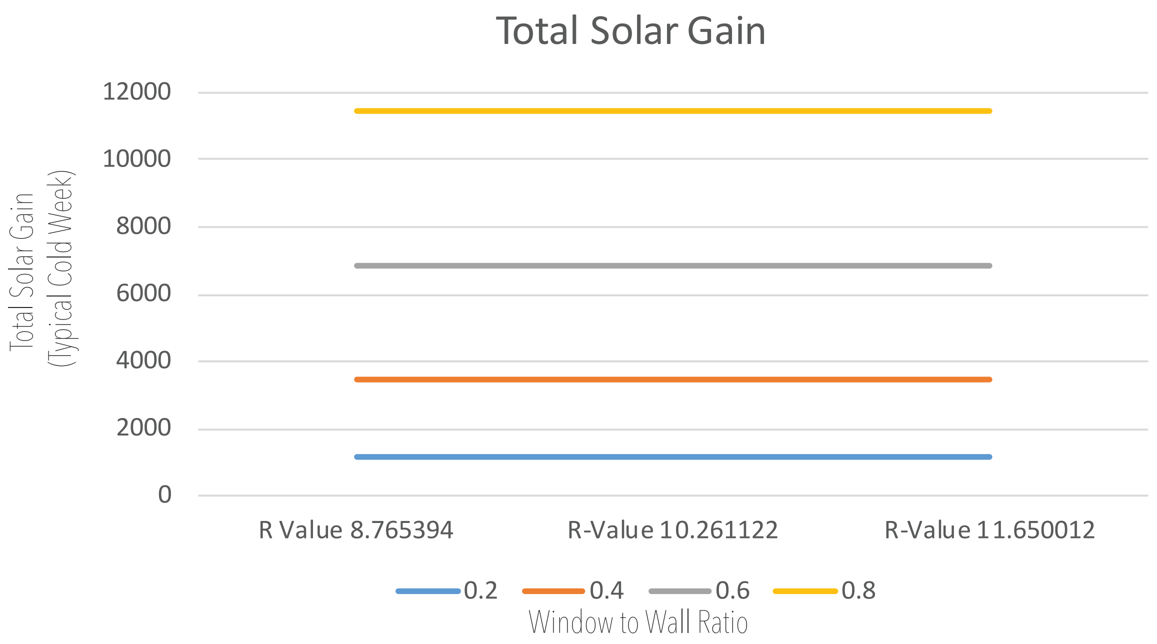
OUR STRATEGY: DIRECT + INDIRECT GAIN

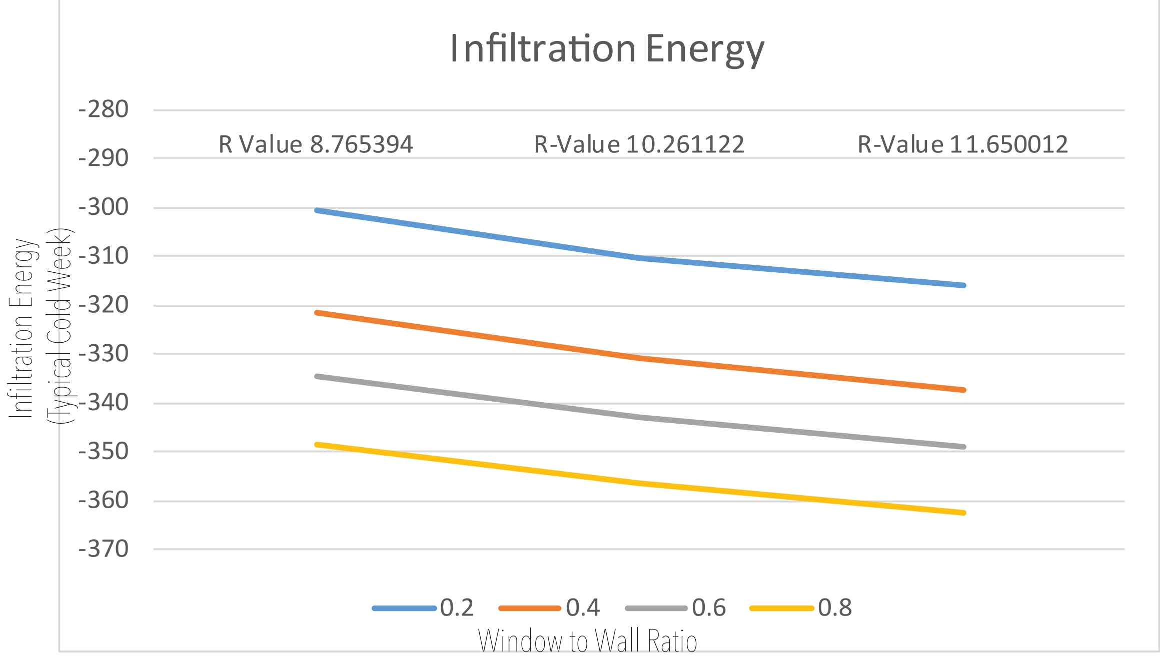


We envision a sunroom design that is a combination of the direct solar gain and trombe wall strategies. The intention is for the sunrooms to be occupiable and whose activity depends on its size and the function of the surrounding program areas. The rooms adjacent to the sunrooms will be passively conditioned by way of heat transfer through thermal mass connecting the two spaces.

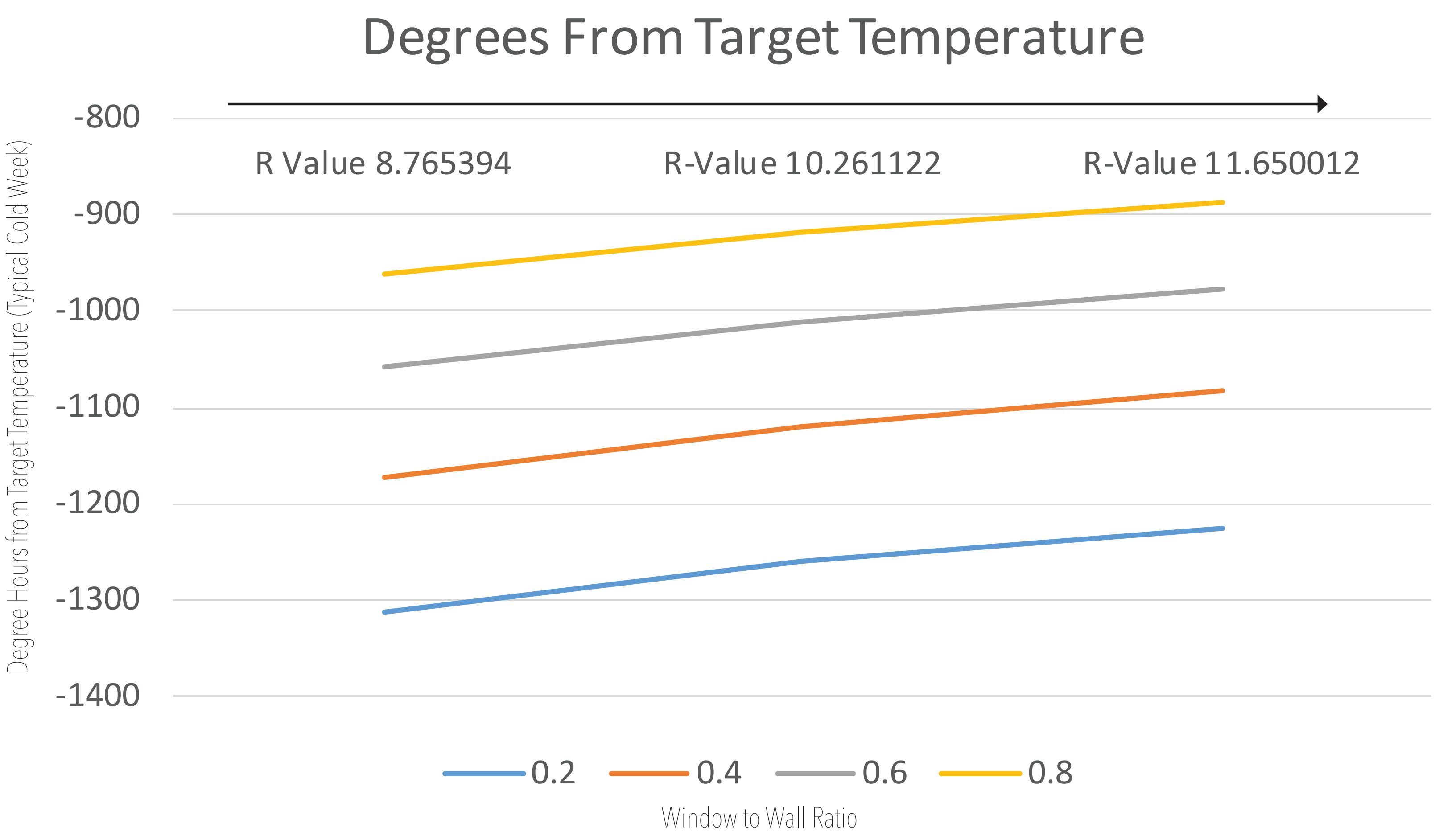
These sunroom spaces are intended to be comfortable for the majority of time, but allow for flexible programming that encourages behaviorial change instead of mechanical conditioning when the temperatures are outside of an individual's comfort parameters.

PHASE 2 » PASSIVE STRATEGY » EFFECT OF CONSTRUCTION & HEAT GAIN

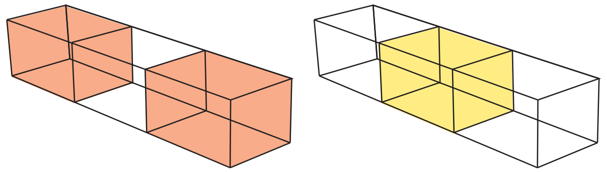
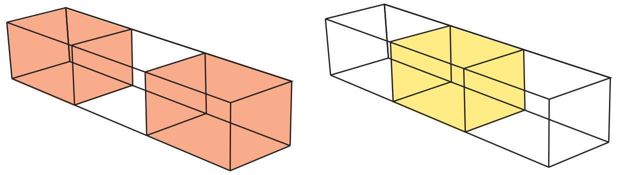
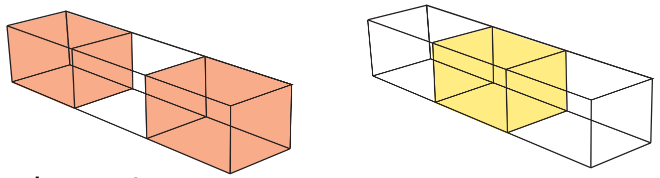




Increasing the R-value of the construction increases comfort



PHASE 2 » PASSIVE STRATEGY » CENTRALIZED SUNROOM

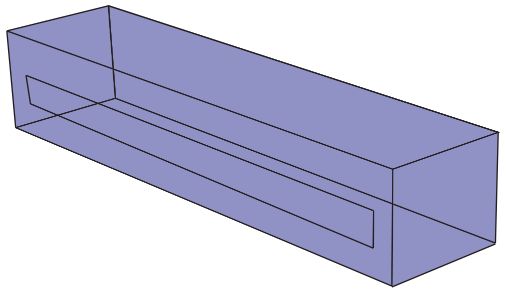
	TYPICAL COLD WEEK FEB 12 - FEB 18			TYPICAL WEEK OCT 29 - NOV 4			TYPICAL HOT WEEK AUG 19 - AUG 25		
									
		Adjacent Space	Sun Room		Adjacent Space	Sun Room		Adjacent Space	Sun Room
Step 1	Baseline Case (ASHRAE Zone 4A Construction)	2% 17% 81%		Baseline Case (ASHRAE Zone 4A Construction)	18 % 51 % 31 %		Baseline Case (ASHRAE Zone 4A Construction)	98 % 2 % 0 %	
Step 2	Baseline Case (ASHRAE Zone 4A Construction) + SunRoom (ASHRAE Zone 4A Construction)	6 % 17 % 77 %	11 % 17 % 72 %	Baseline Case (ASHRAE Zone 4A Construction) + SunRoom (ASHRAE Zone 4A Construction) + High Thermal Mass (Interior Walls)	29 % 48 % 23 %	39 % 38 % 23 %	Baseline Case (ASHRAE Zone 4A Construction) + SunRoom (ASHRAE Zone 4A Construction) + Shading Louvers	83 % 17 % 0 %	64 % 36 % 0 %
Step 3	Baseline Case (ASHRAE Zone 4A Construction) + SunRoom (ASHRAE Zone 4A Construction) + High Thermal Mass (Interior Walls)	3 % 18 % 79 %	12 % 17 % 71 %	Baseline Case (ASHRAE Zone 4A Construction) + SunRoom (ASHRAE Zone 4A Construction) + High Thermal Mass (Interior Walls) + Natural Ventilation (@ minimum indoor temp. 24 C)	5 % 67 % 28 %	7 % 60 % 30 %	Baseline Case (ASHRAE Zone 4A Construction) + SunRoom (ASHRAE Zone 4A Construction) + Shading Louvers + High Thermal Mass (Interior Walls) + Night Purging	14 % 86 % 0 %	13 % 79 % 8 %

HEAT STRESS
COMFORTABLE
COLD STRESS

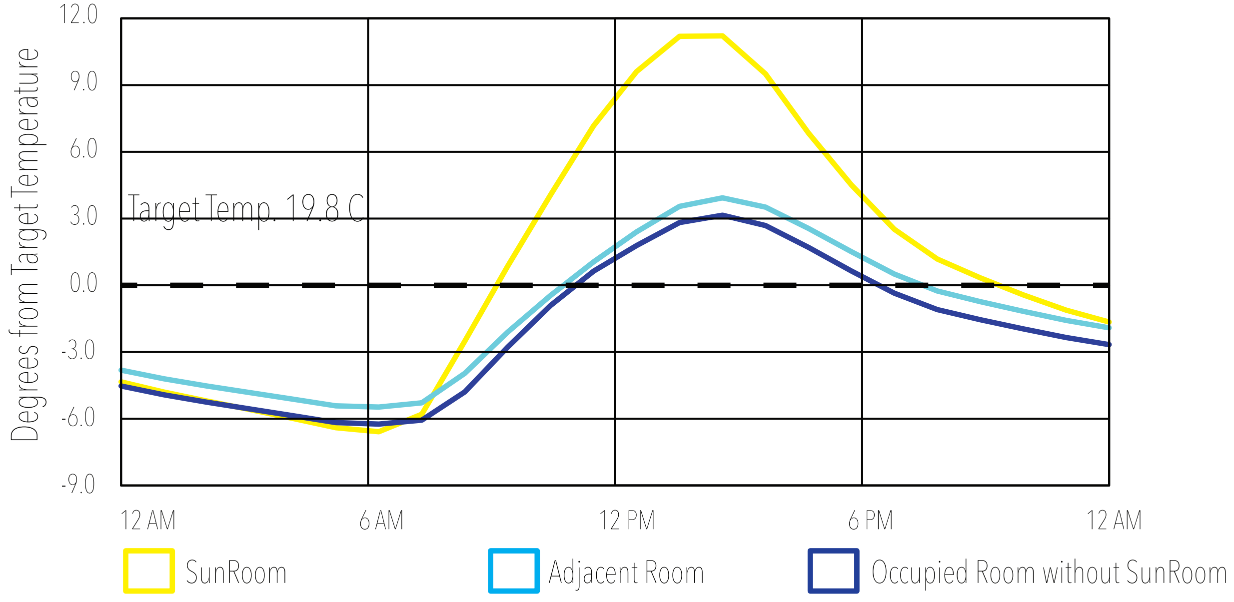
PHASE 2 » PASSIVE STRATEGY » CENTRALIZED SUNROOM

TEMPERATURE STUDY FOR A TYPICAL COLD DAY with CENTRAL SUNROOM » 18TH FEBRUARY

Wall	1IN Stucco 8IN CONCRETE HW RefBldg Mass Wall Insulation R-7.23 IP 1/2IN Gypsum
Window	Fixed Window 3.12/0.40/0.31
Roof	Roof Membrane IEAD Roof Insulation R-19.72 IP Metal Decking

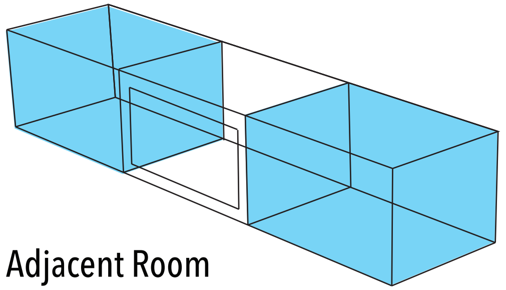


Occupied Room without SunRoom

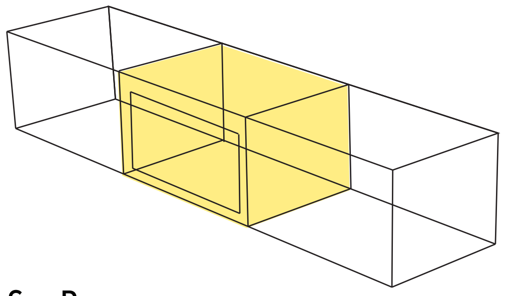


Wall	1IN Stucco 8IN CONCRETE HW RefBldg Mass Wall Insulation R-7.23 IP 1/2IN Gypsum
Window	Fixed Window 3.12/0.40/0.31
Roof	Roof Membrane IEAD Roof Insulation R-19.72 IP Metal Decking

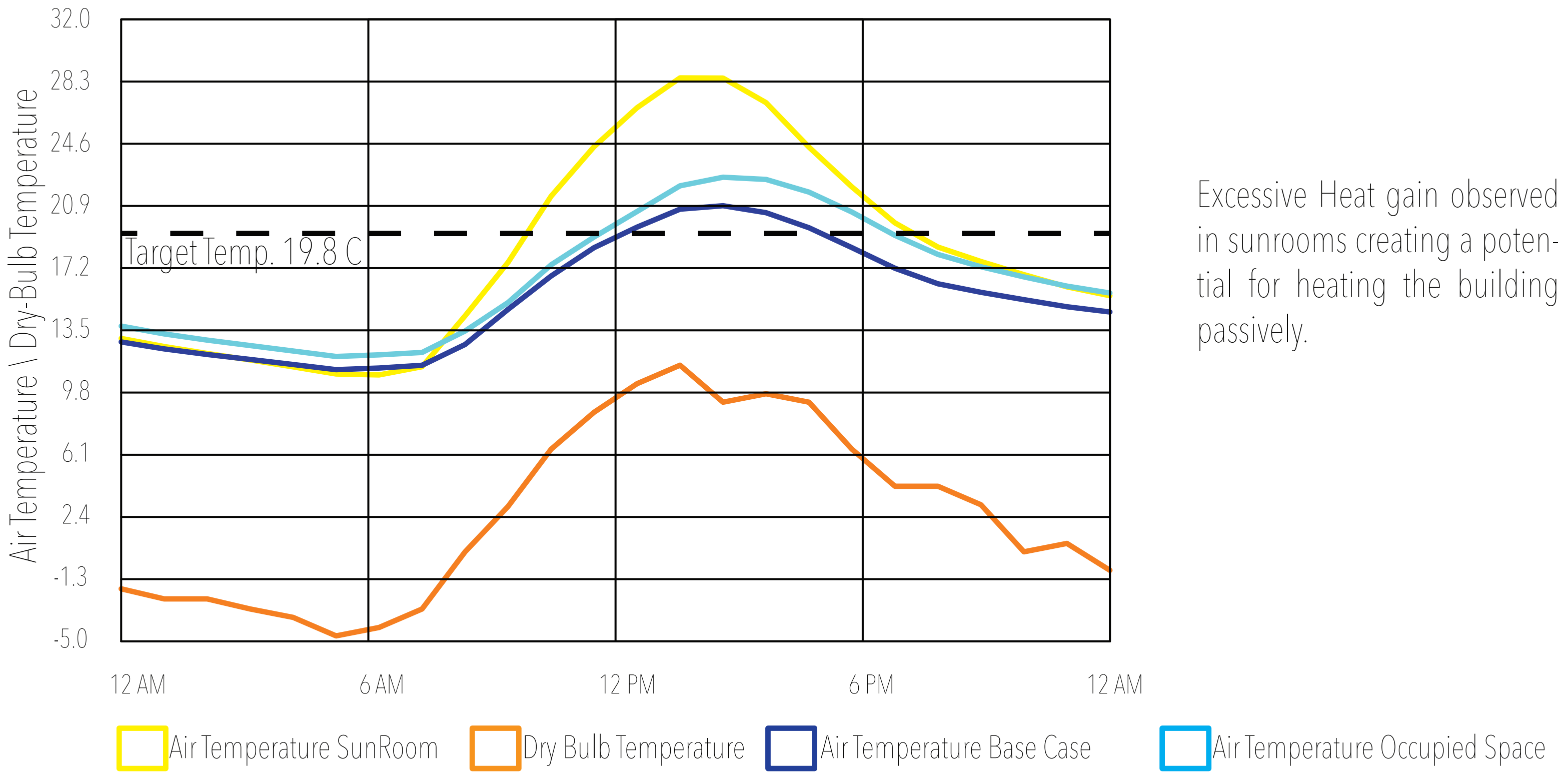
Thermal Mass Adjacent Wall
16inch Concrete Wall



Adjacent Room



SunRoom



Excessive Heat gain observed in sunrooms creating a potential for heating the building passively.

PHASE 2 » COMFORT ANALYSIS » EFFECT OF BUILDING MASSING » EXTREME COLD WEEK

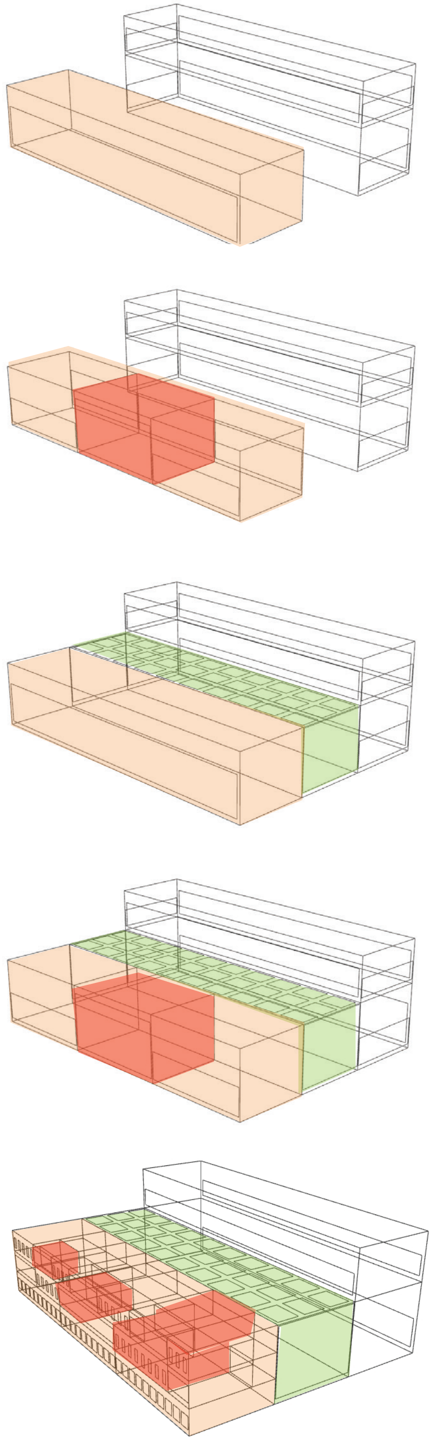
South Block

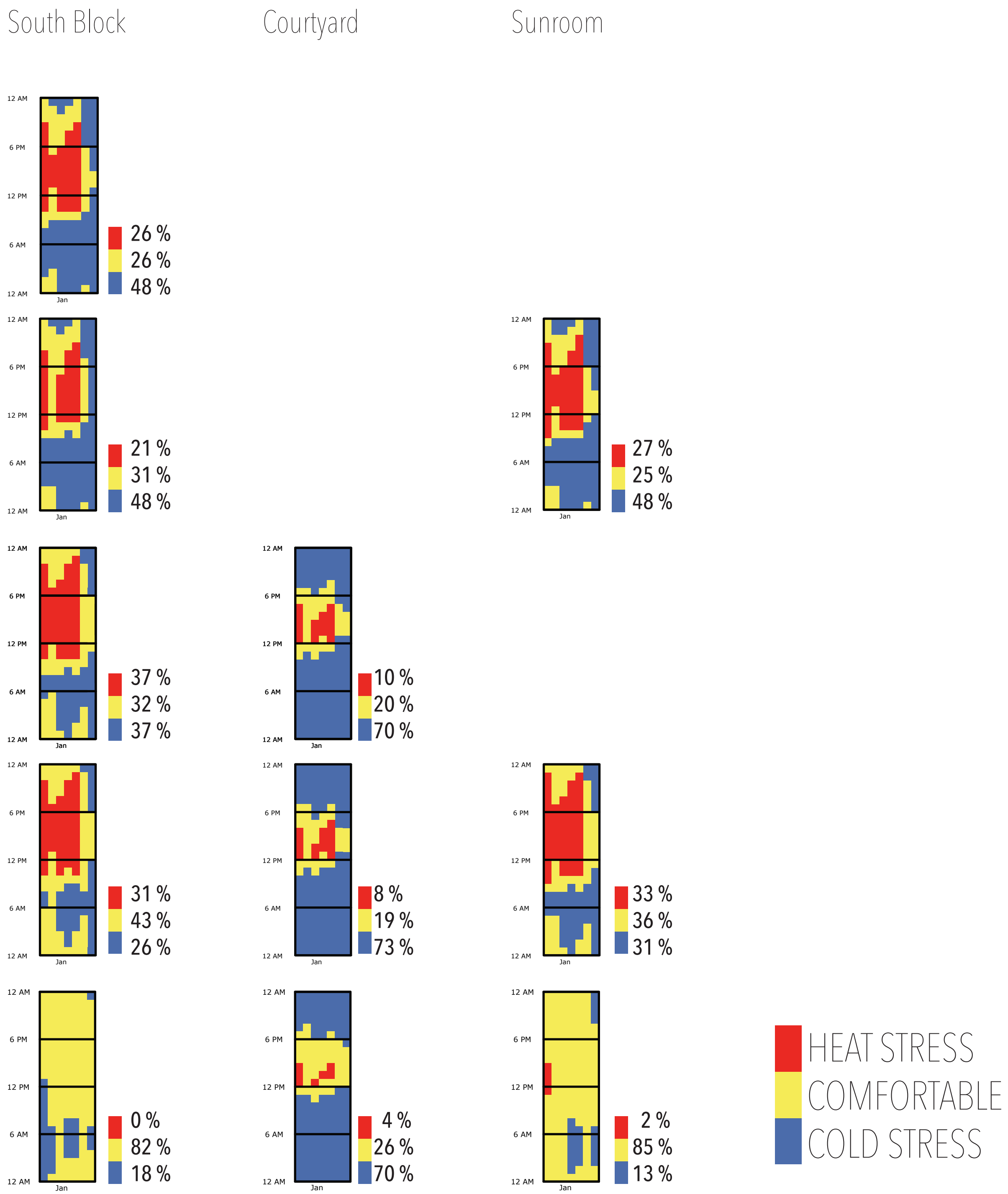
South Block
Cenral Sunroom

South Block
Courtyard

South Block
Courtyard
Central Sunroom

South Block
Courtyard
Scattered Sunroom





Adaptive Comfort Charts
ExtremeCold Week
15 JANUARY to 21 JANUARY

Wall (R-Value 36.39 h·ft2·°F/Btu)
1IN STUCCO
8IN CONCRETE HW
INSULATION R-35.07 IP
1/2IN GYPSUM

Roof (R-Value 45.98 h·ft2·°F/Btu)
ROOF MEMBRANE
ATTICFLOOR INSULATION R-45.65 IP
METAL DECKING

Window (R-Value 4.83 h·ft2·°F/Btu)
LOW E CLEAR 6MM
AIR 6MM
LOW E CLEAR 6MM
AIR 6MM
LOW E CLEAR 6MM

WWR
NORTH .6
SOUTH .6
EAST .4
WEST .4

PHASE 2 » TESTING VARIABLES » TYPICAL COLD WEEK » 800 ITERATIONS

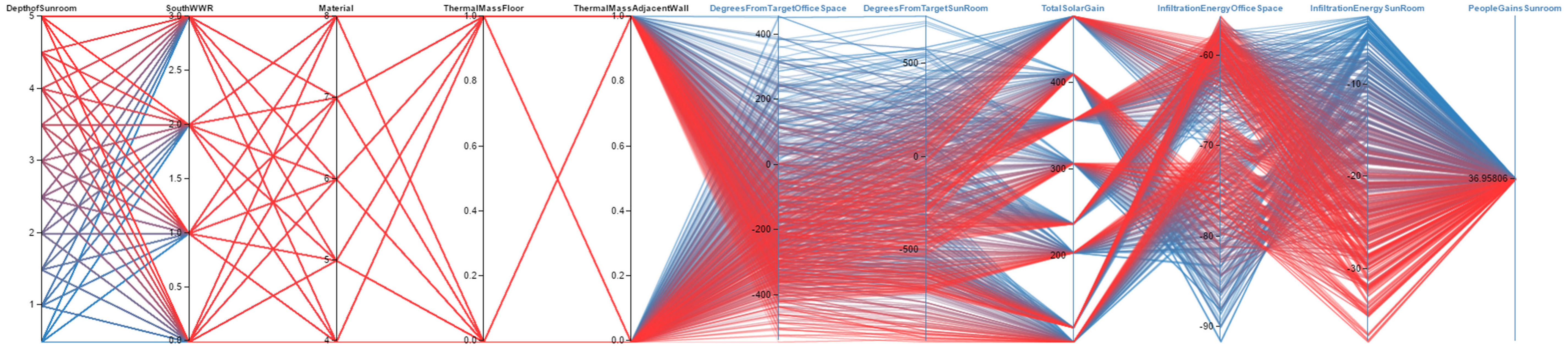
Depth of Sunroom
5 meter
4 meter
3 meter
2 meter
1 meter

Material Constructions
ASHRAE Zone 8
ASHRAE Zone 7
ASHRAE Zone 6
ASHRAE Zone 5
ASHRAE Zone 4

Thermal Mass: Adjacent Walls
16 in. thick concrete
8 in. thick concrete

Degrees from Target: Sunroom
Cummulative degree hourse during Typical Cold Week
(Approx. 20°C)

Infiltration Energy: Office Space



Window-to-Wall Ration on South Elevation
.8
.6
.4
.2

Thermal Mass: Sunroom Floor
16 in. thick concrete
8 in. thick concrete

Degrees from Target: Office Space
Cummulative degree hours during Typical Cold Week
(Approx. 20°C)

Total Solar Gain

Infiltration Energy: Sunroom

PHASE 2 » TESTING VARIABLES » TYPICAL COLD WEEK

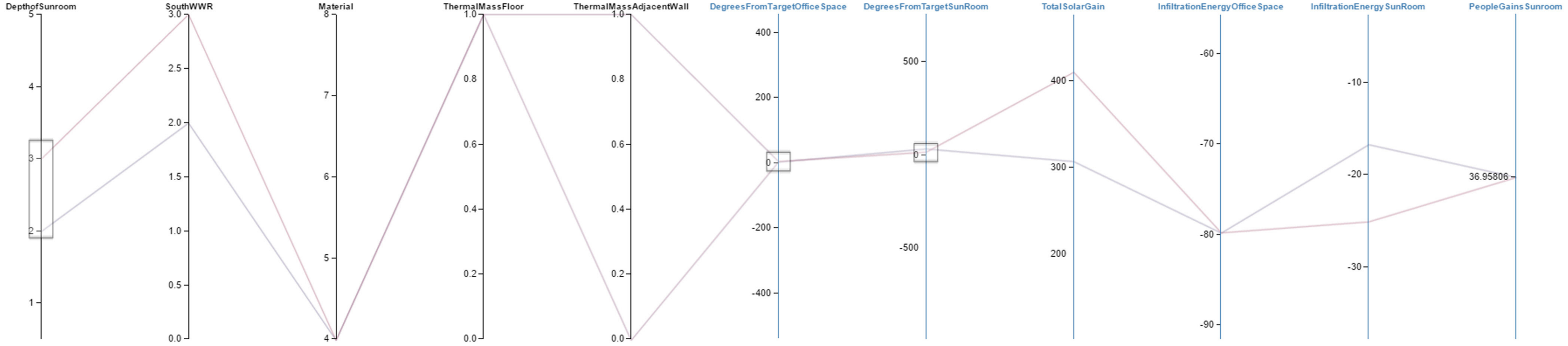
2 Options between depths of
2 to 3 meters (6.5′ to 9.8′)

Material Options
ASHRAE Zone 4

Thermal Mass: Adjacent Wall
16 in. thick concrete
8 in. thick concrete

Total Solar Gain

Infiltration Energy: Sunroom



Window-to-Wall Ration on South Elevation
.8
.6

Thermal Mass: Sunroom Floor
16 in. thick concrete

Range Approx 20°C

Infiltration Energy: Office Space

PHASE 2 » COMFORT ANALYSIS » RELATIONSHIP BETWEEN VARIABLES » 160 ITERATIONS

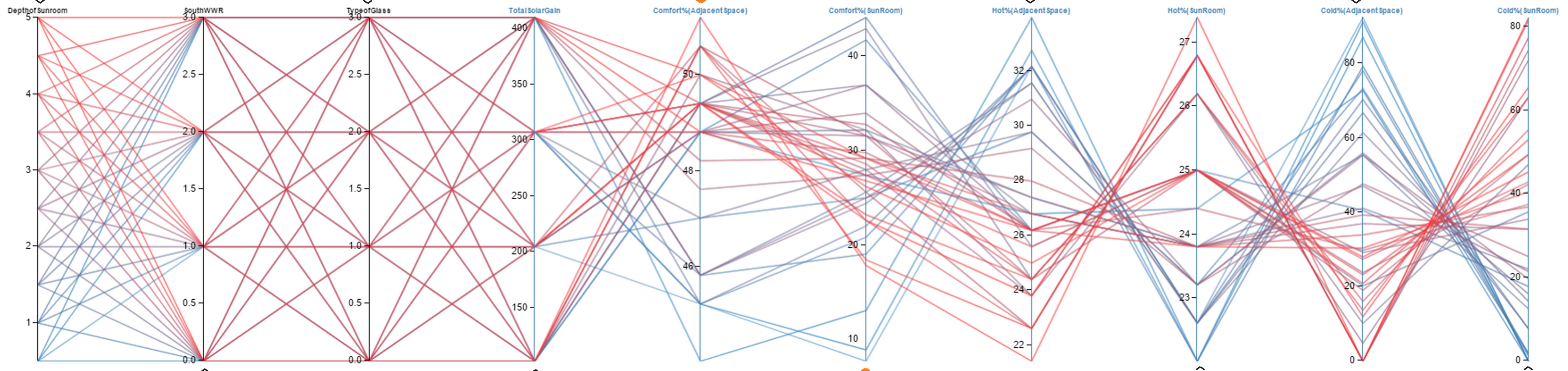
Depth of Sunroom
5 meter
4 meter
3 meter
2 meter
1 meter

Type of Glazing:
Triple Glaze with Argon
Triple Glaze
Double Glaze
Single Glaze

% Comfort: Adjacent Space
Extreme Cold Week
January 15-21

% Heat Stress: Adjacent Room

% Cold Stress: Adjacent Space



Window-to-Wall Ration on South Elevation
.8
.6
.4
.2

Total Solar Gain

% Comfort: Sunroom
Extreme Cold Week
January 15-21

% Heat Stress: Sunroom

% Cold Stress: Sunroom

PHASE 2 » COMFORT ANALYSIS » RELATIONSHIP BETWEEN VARIABLES

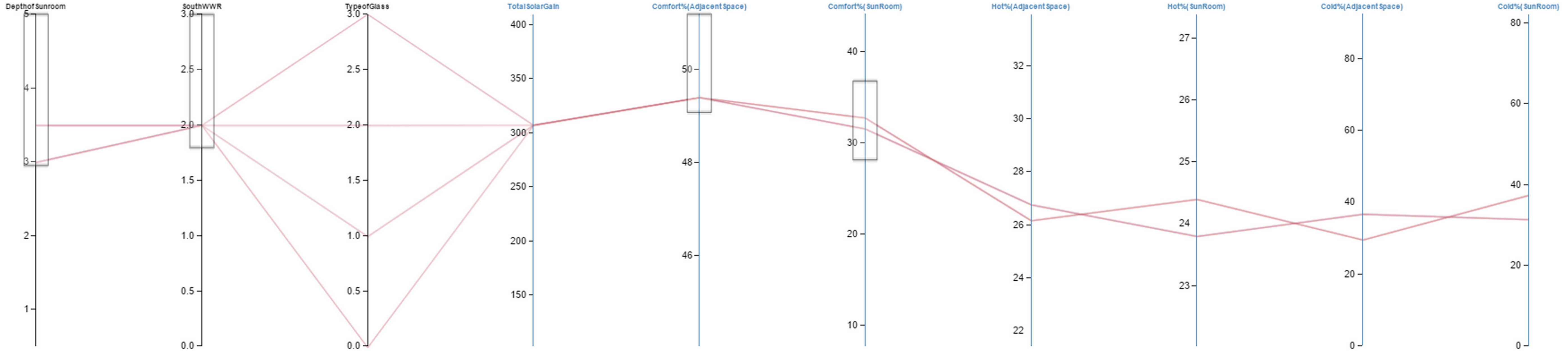
2 m < Sunroom Depth < 5 m

Type of Glazing:
Triple Glaze with Argon
Triple Glaze
Double Glaze
Single Glaze

% Comfort: Adjacent Space

% Heat Stress: Adjacent Room

% Cold Stress: Adjacent Space



Window-to-Wall Ration on South Elevation
.6 - .8

Total Solar Gain

% Comfort: Sunroom

% Heat Stress: Sunroom

% Cold Stress: Sunroom

PHASE 2 » DE-CENTRALIZED SUNROOMS » TEMPERATURE EFFECT » TYPICAL COLD DAY

TEMPERATURE STUDY FOR A TYPICAL COLD DAY with SUNROOM » 18TH FEBRUARY

CONSTRUCTION

Baseline

Office Room 10m by 10m
No Windows
Climate Zone 4 Construction
1IN Stucco
8IN CONCRETE HW RefBldg
Mass Wall Insulation R-7.23 IP
1/2IN Gypsum

Fixed Window 3.12/0.40/0.31

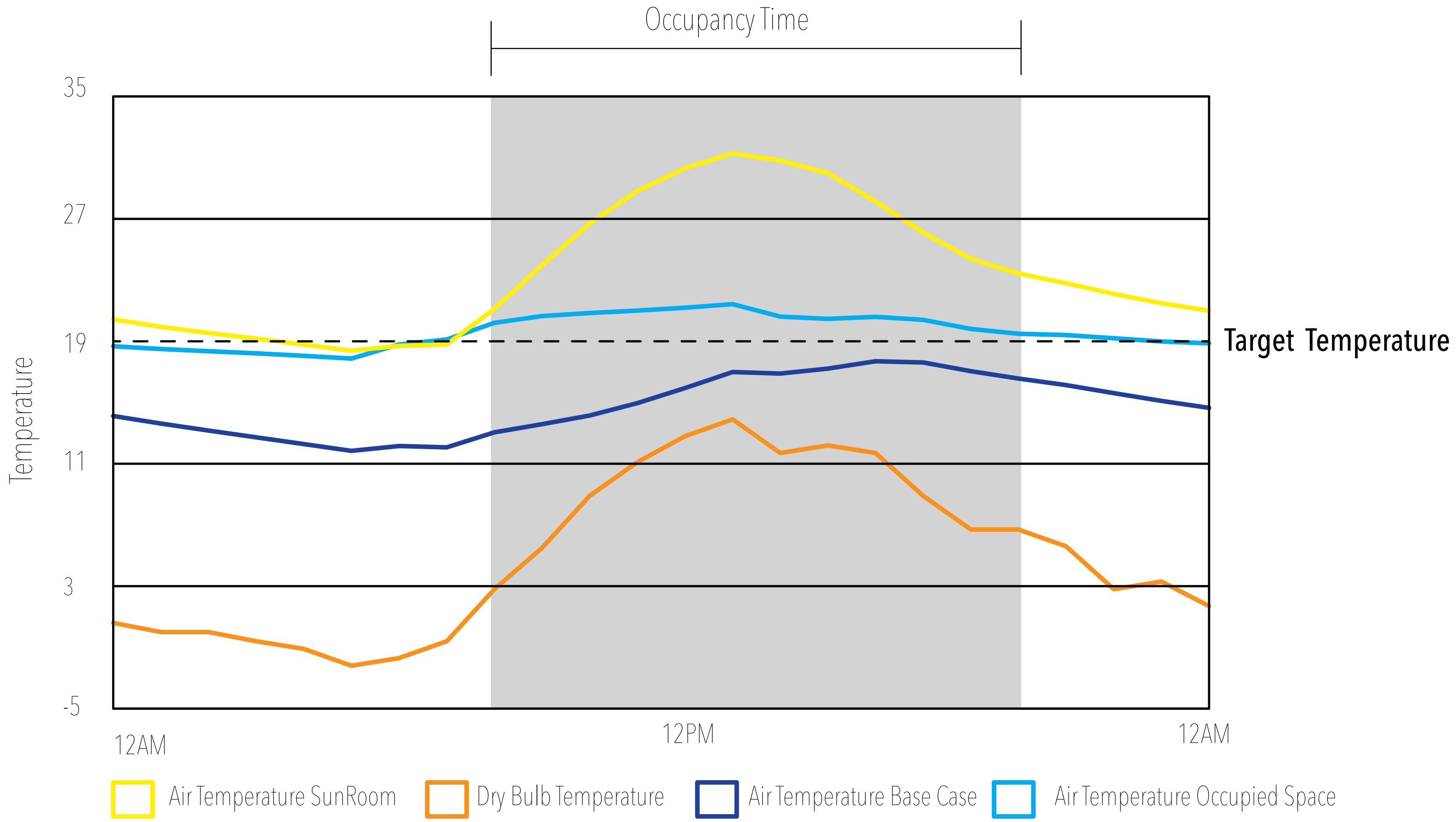
Roof Membrane
IEAD Roof Insulation R-19.72 IP
Metal Decking

Improved Case

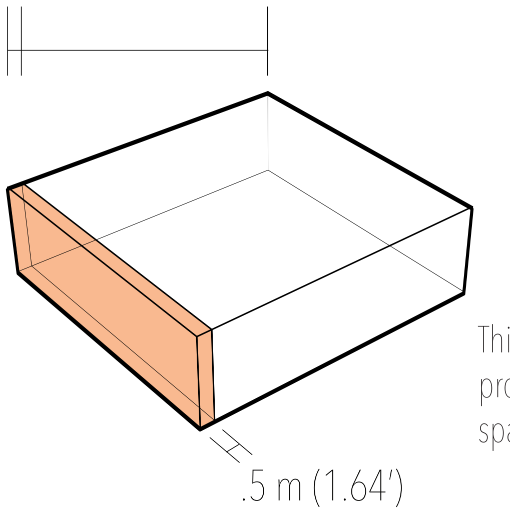
Office Room 10m by 10m Adjacent to 3m Depth Sunroom
.6 WWR on South Facade of Sunroom
Climate Zone 6 Construction
1IN Stucco
8IN CONCRETE HW RefBldg
Mass Wall Insulation R-10.11 IP
1/2IN Gypsum
Fixed Window 3.12/0.40/0.31

Roof Membrane
IEAD Roof Insulation R-19.72 IP
Metal Decking

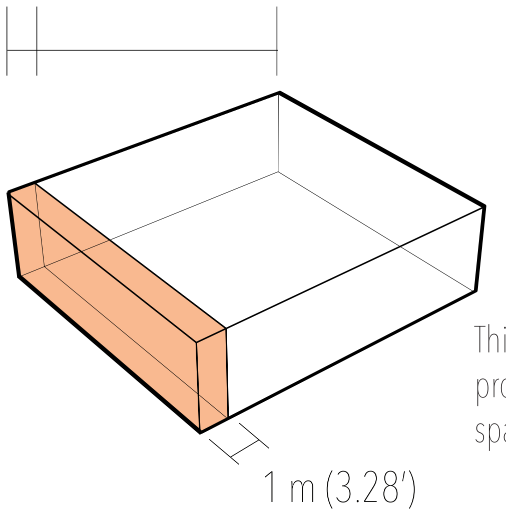
Thermal Mass Adjacent Wall
16inch Concrete Wall



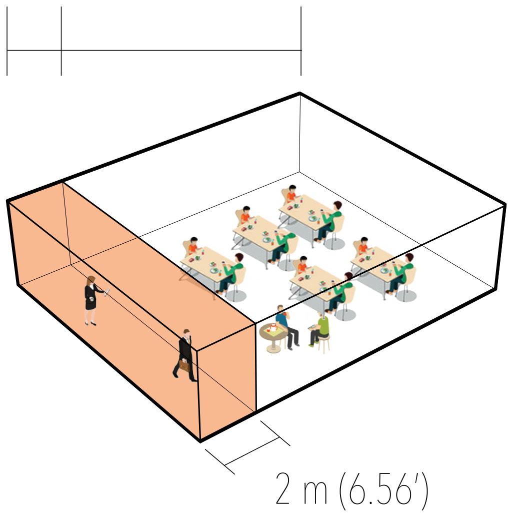
PHASE 2 » ARCHITECTURAL NARRATIVE » PROGRAM



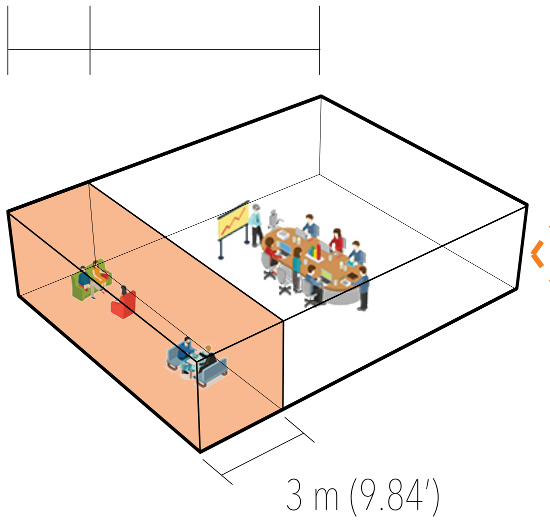
This size sunroom does not provide distinctive, occupiable space



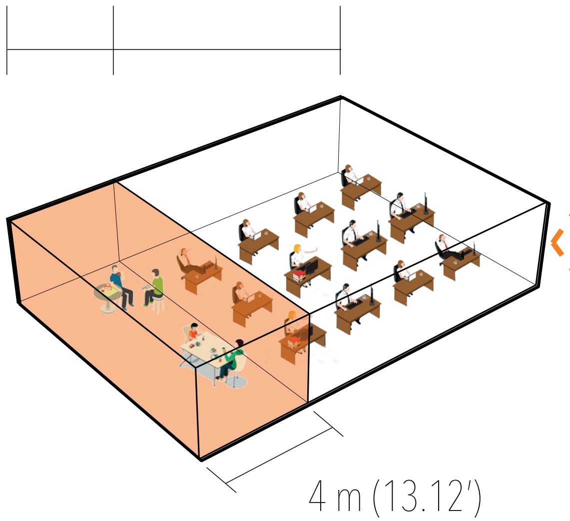
This size sunroom does not provide distinctive, occupiable space



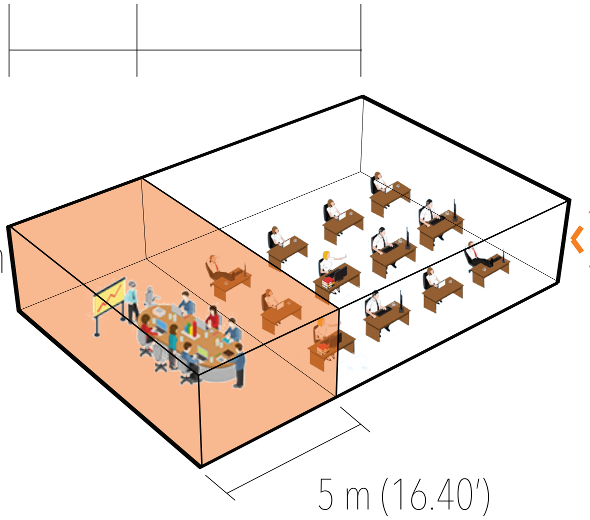
· Corridor



· Study Lounge
· Office Library
· Waiting Room

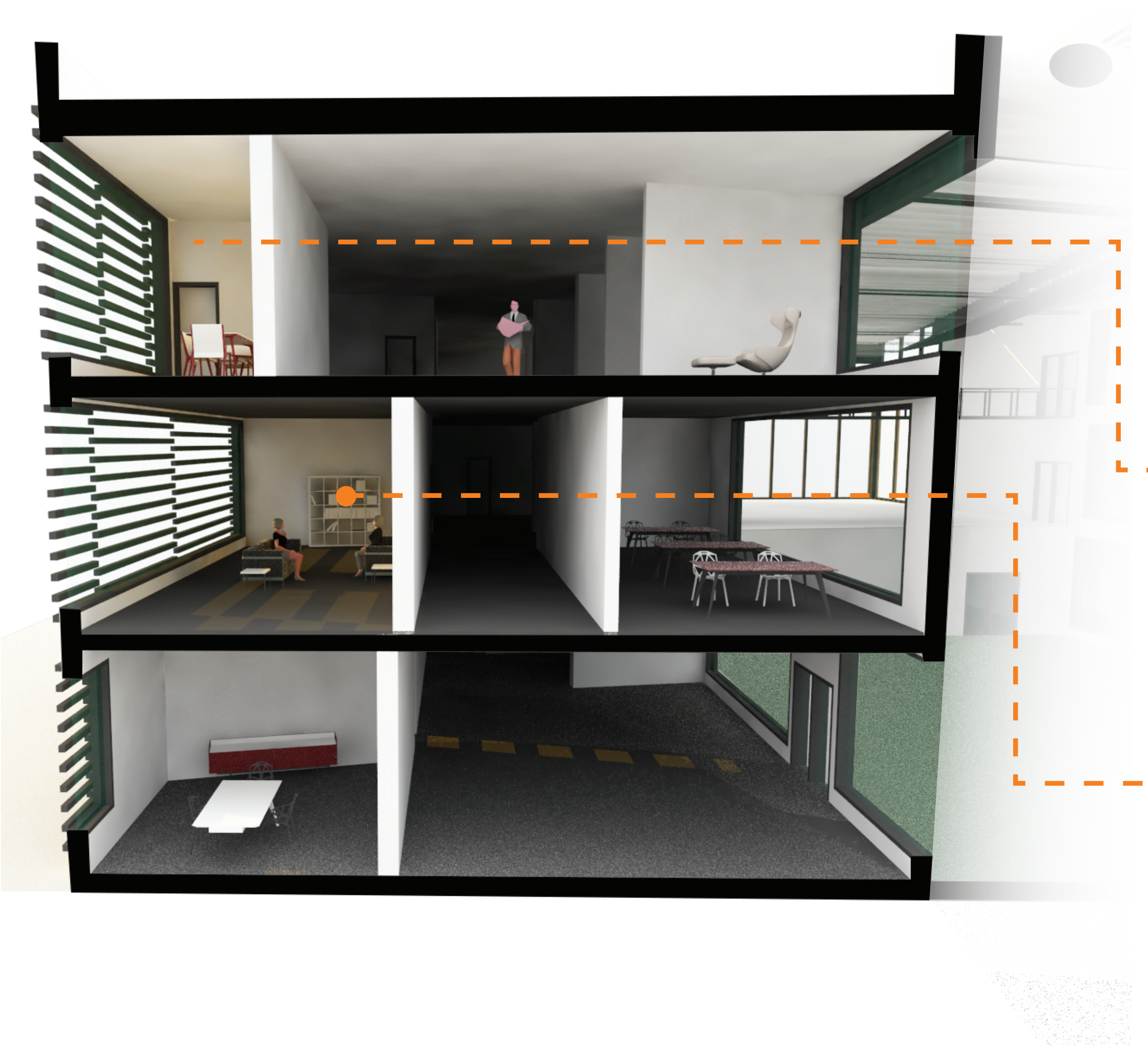


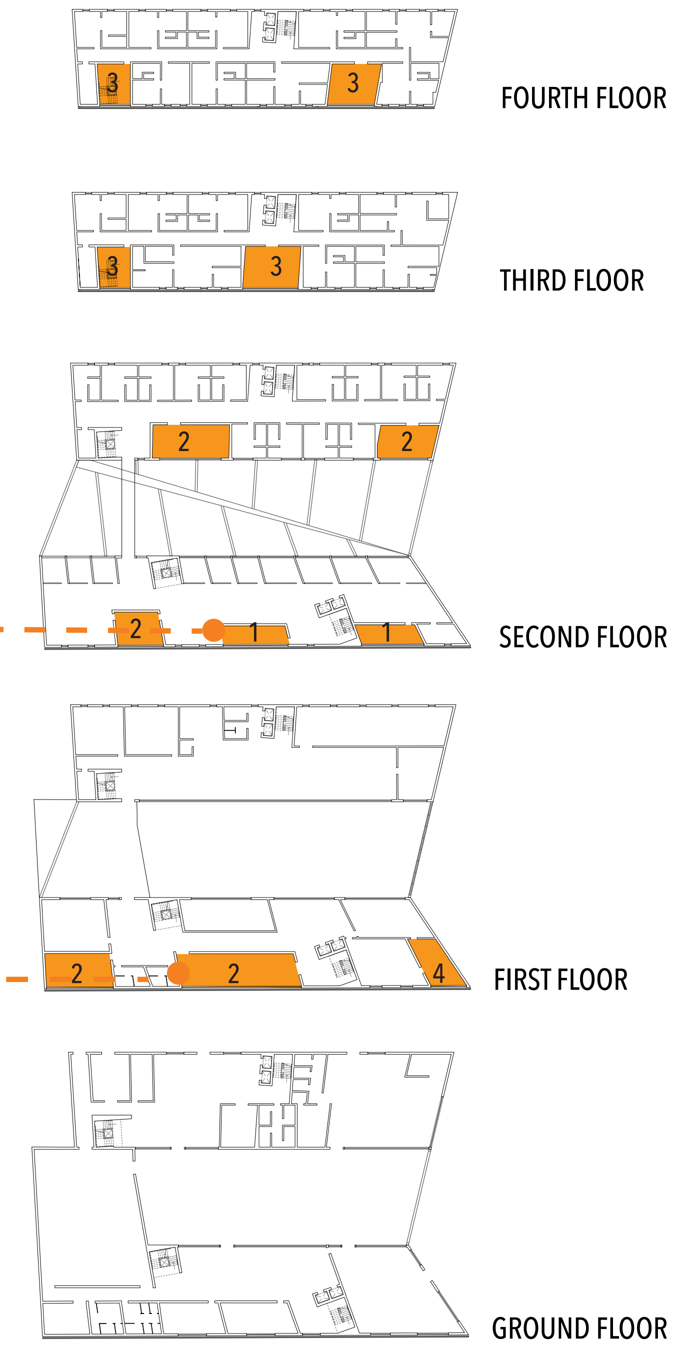
· Office Lounge
· Small Conference Room
· Office Dining Area

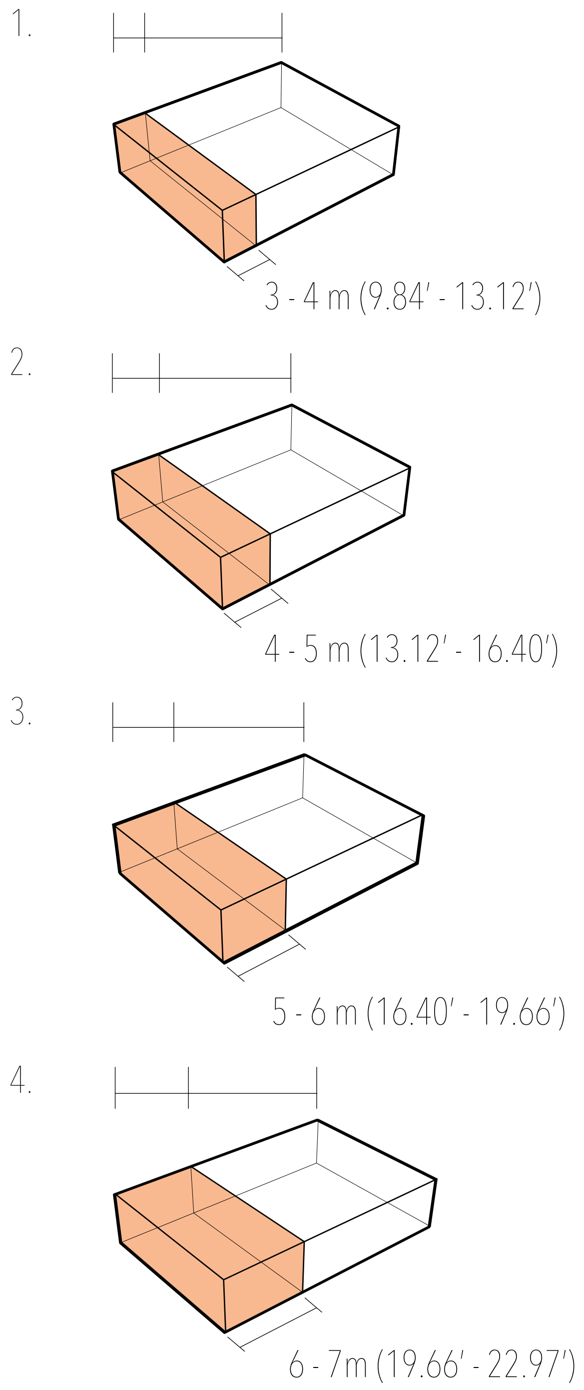


· Conference Room
· Casual Workstations

PHASE 2 » DE-CENTRALIZED SUNROOMS » DISTRIBUTION STRATEGY

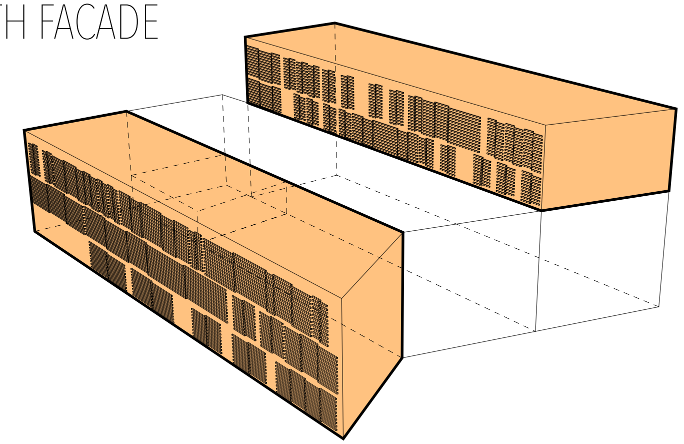




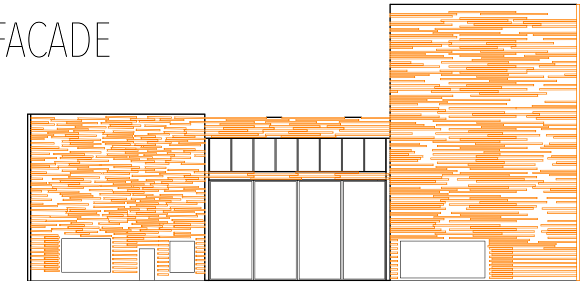


PHASE 3 » HEAT REMEDIATION

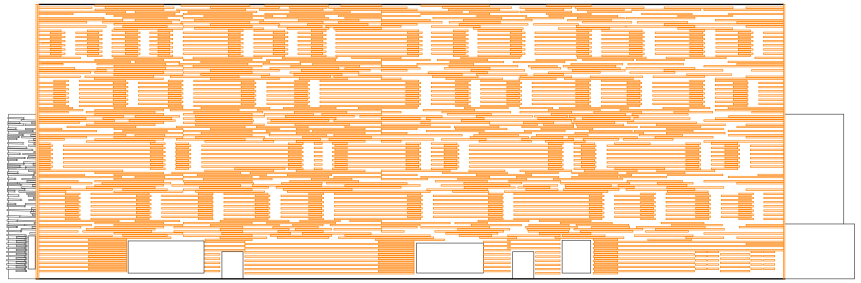
DYNAMIC SHADING: SOUTH FACADE



STATIC SHADING: EAST FACADE

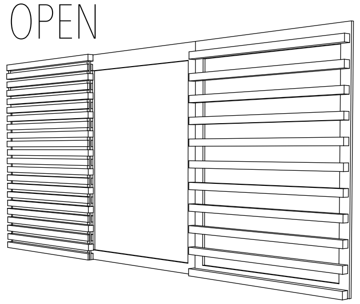


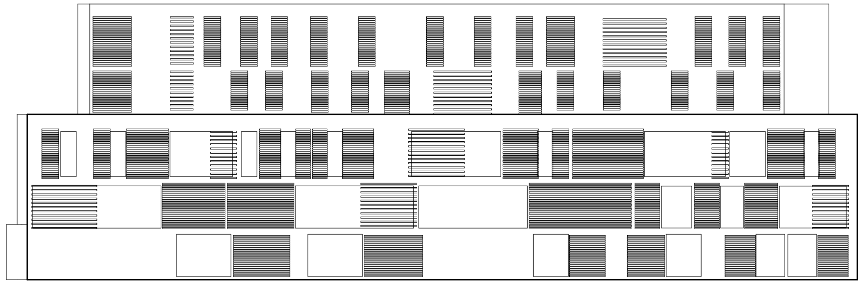
STATIC SHADING: NORTH FACADE



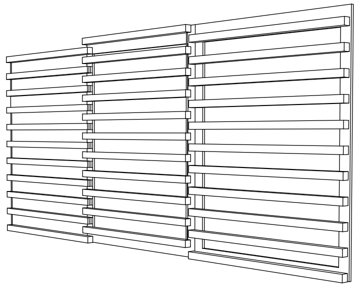
DYNAMIC SHADING STATES

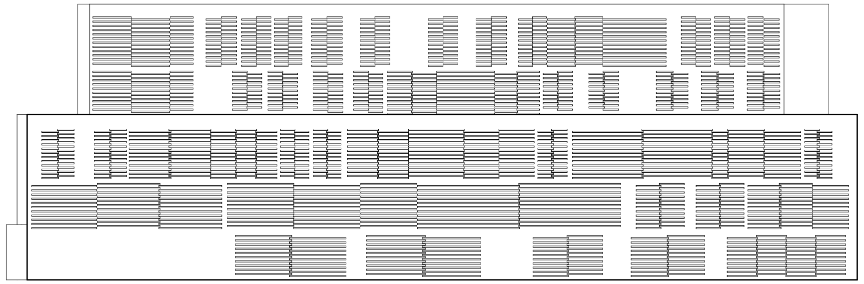
OPEN



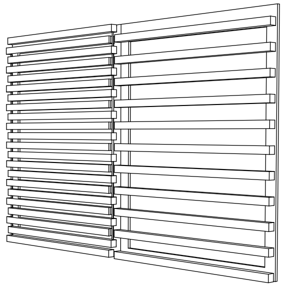


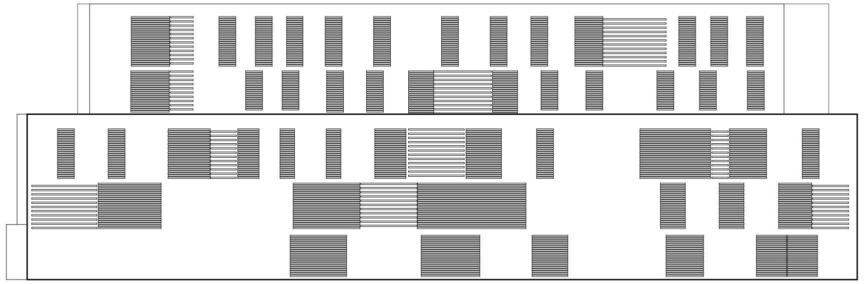
HALF-OPEN



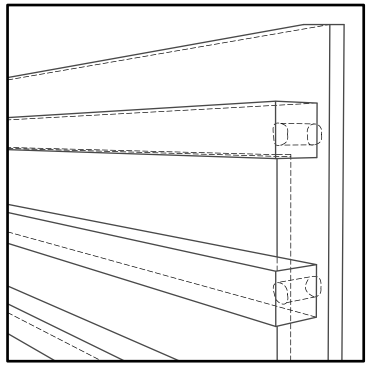


CLOSED

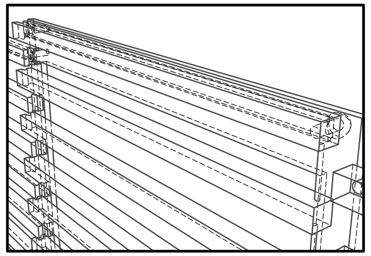




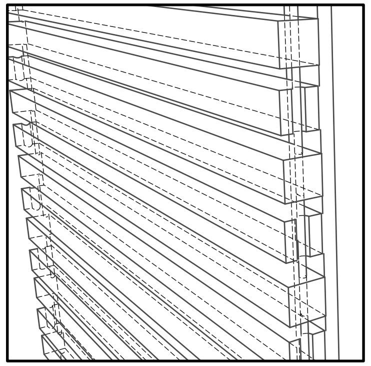
MECHANISMS



Pins: Static Shades



Rails: Sliding Movement

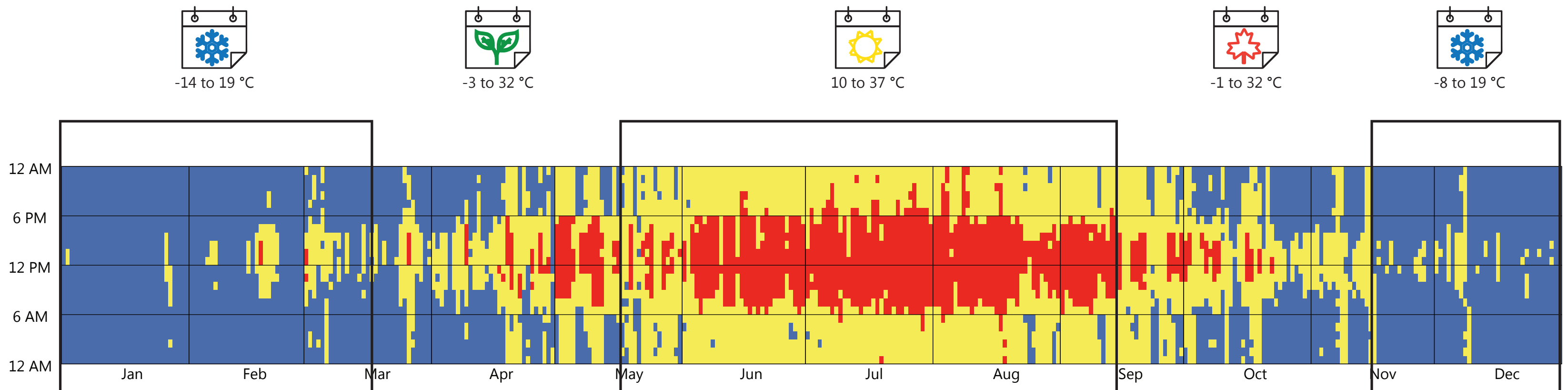


Dowels: Brace Individual Shades

FINAL » SUNROOM COMFORT » OFFICES

HEAT STRESS
COMFORTABLE
COLD STRESS

Outdoor



Comfort 24%
Hot 0.2%
Cold 75.8%

Comfort 68.0%
Hot 6.8%
Cold 25.2%

Comfort 68.3%
Hot 31.5%
Cold 0.2%

Comfort 79.4%
Hot 4.0%
Cold 16.6%

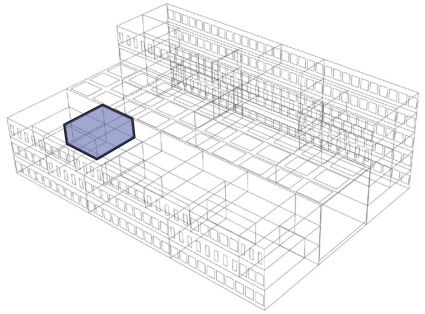
Comfort 28.6%
Hot 0.0%
Cold 71.4%

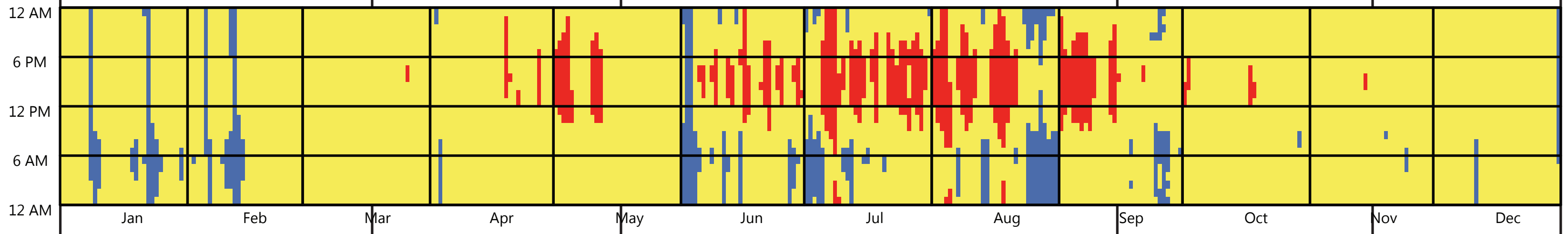
13 %
37 %
32 %

Comfortable
Slight Cold/Heat

18.6 %

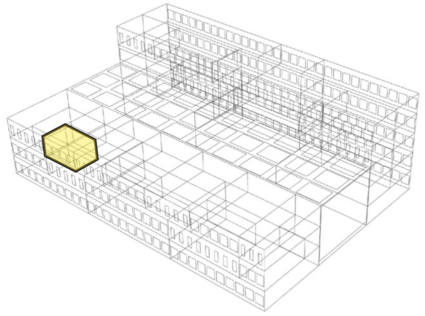
Office adjacent to Sunroom

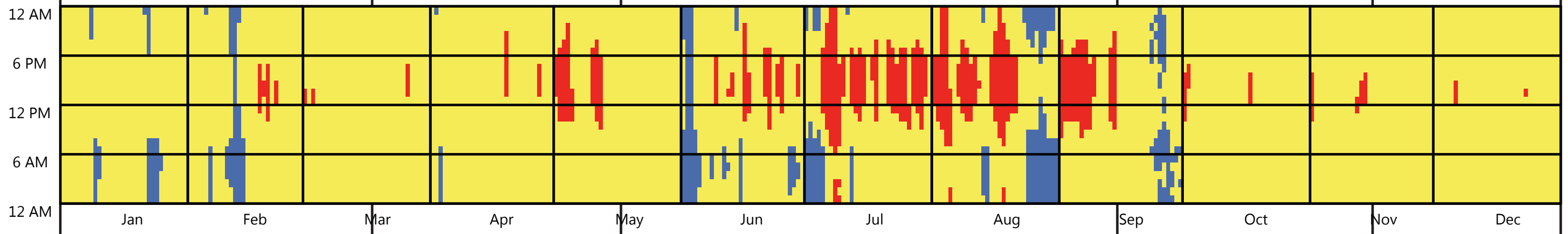




8 %
86 %
6 %

Sunroom





8 %
87 %
5 %

FINAL » SUNROOM COMFORT » CLASSROOM

HEAT STRESS
COMFORTABLE
COLD STRESS

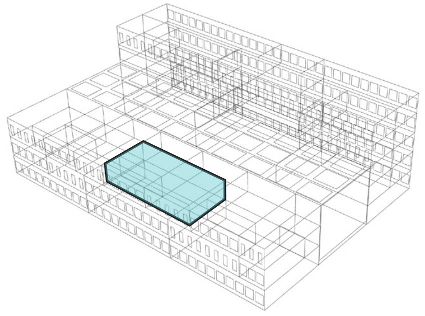
Outdoor

13 %
37 %
32 %

Comfortable
Slight Cold/Heat

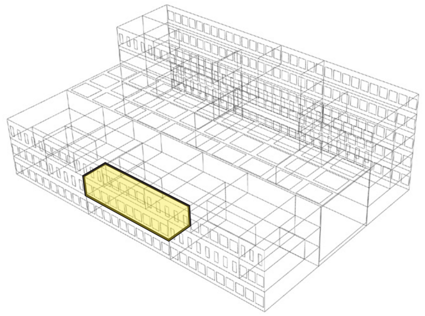
18.6 %

Classroom adjacent to Sunroom



8 %
86 %
6 %

Sunroom



12 %
83 %
5 %

In conclusion, de-centralized sunrooms worked to increase comfort in a 20,000 square foot building with the following conditions:

- use of thermal mass to collect heat in sunroom and transfer to adjacent rooms
- use of thermal mass to store heat for diurnal swings
- passive house standard construction
- use of shading in the summer to keep sunrooms from over-heating

These strategies allowed us to achieve around 85% annual comfort for the sunrooms and adjacent rooms.