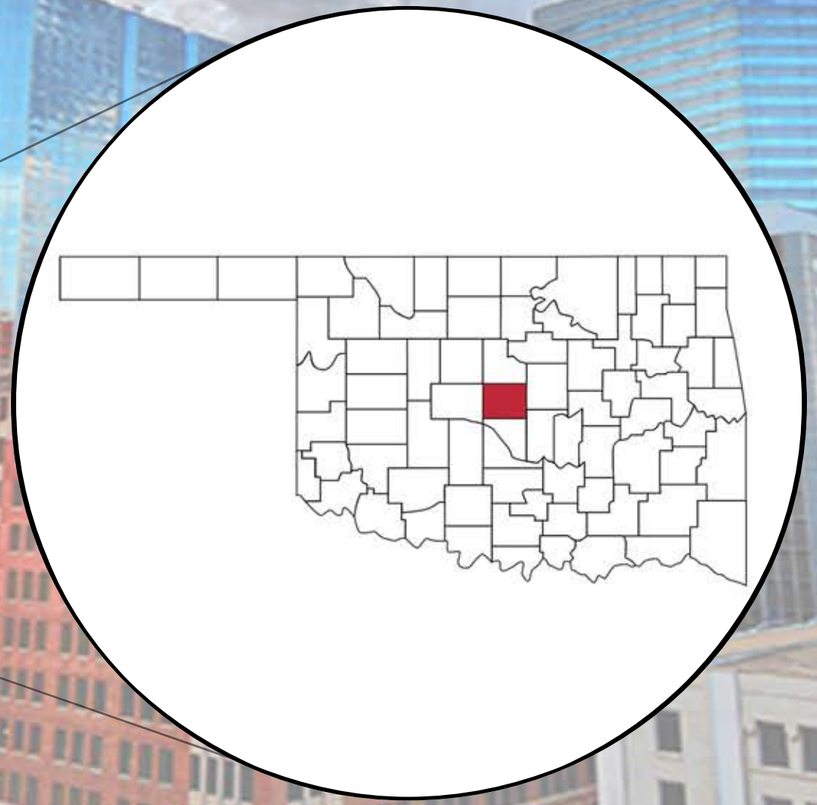
BUILDING PERFORMANCE SIMULATION FINAL PROJECT

MAKING MY DREAM ROOM A REALITY

JUAN D. GUARIN

CLIMATE ANALYSIS

OKLAHOMA CITY, OKLAHOMA



OKLAHOMA CITY

POPULATION:
638,317

MINIMUM ANNUAL TEMPERATURE:
-19.3°C

MAXIMUM ANNUAL TEMPERATURE:
36.7°C

COORDINATES:
35° N 97°W

WEATHER STATION:
WILL ROGERS AIRPORT

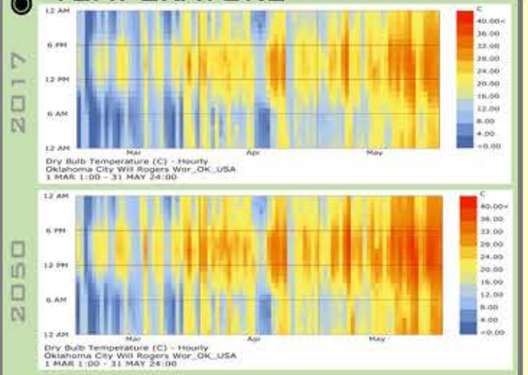
FILE TYPE:
TMY3

ROOM ORIENTATION:
WEST

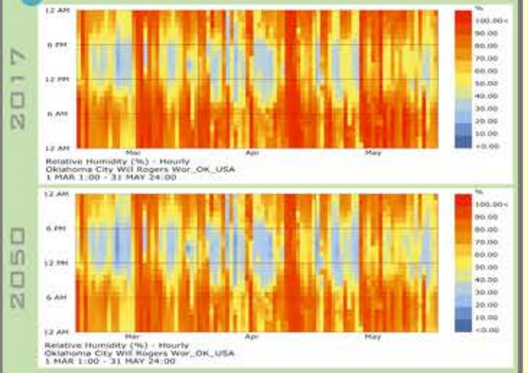
HOURS OF USE:
8:00 PM - 8:00 AM

SPRING (MAR 1 - MAY 31)

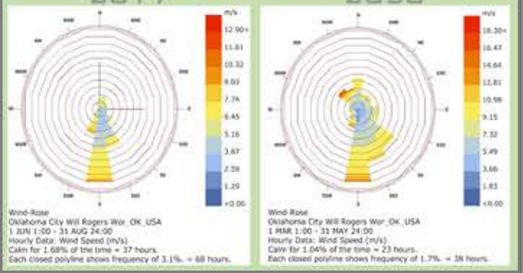
TEMPERATURE



RELATIVE HUMIDITY

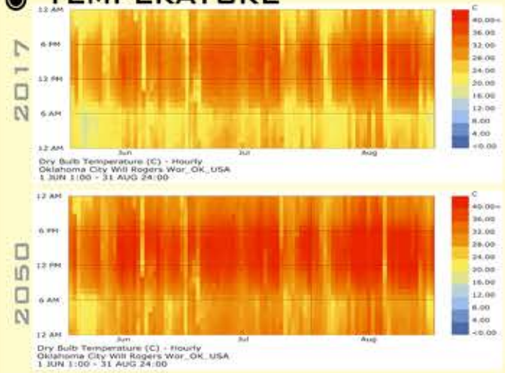


WIND SPEEDS

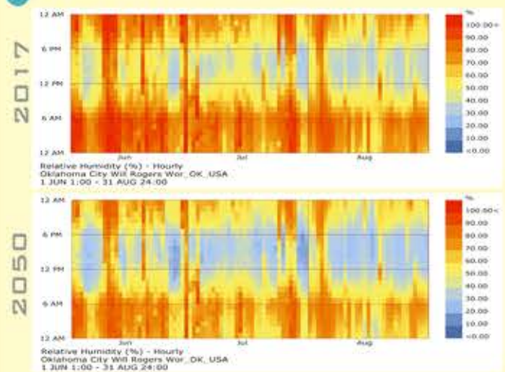


SUMMER (JUN 1 - AUG 31)

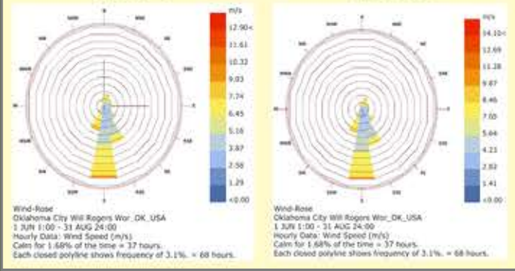
TEMPERATURE



RELATIVE HUMIDITY

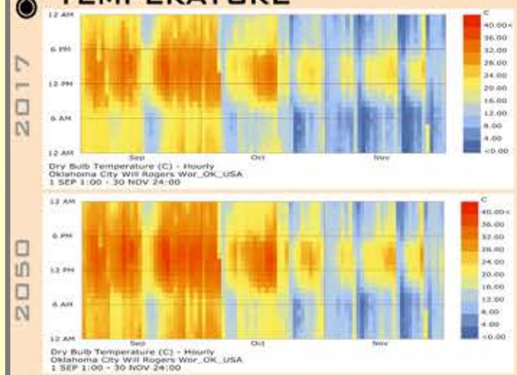


WIND SPEEDS

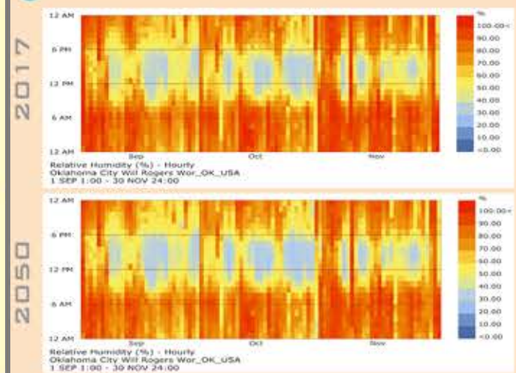


FALL (SEPT 1 - NOV 31)

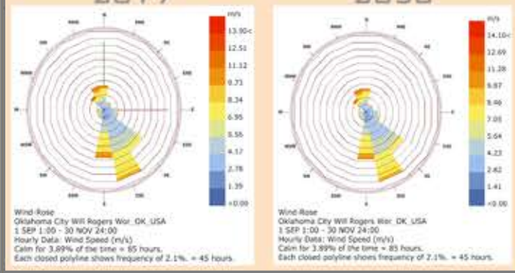
TEMPERATURE



RELATIVE HUMIDITY

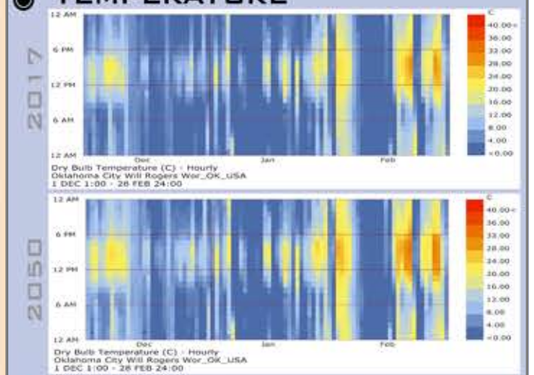


WIND SPEEDS

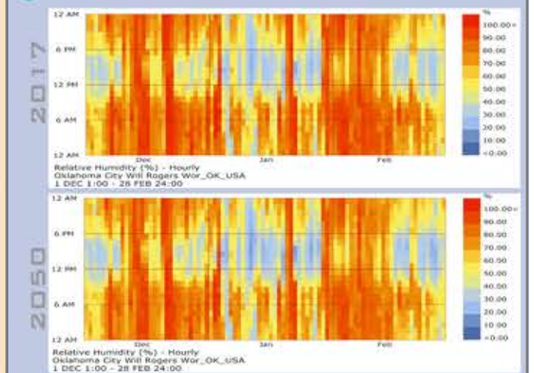


WINTER (DEC 1 - FEB 28)

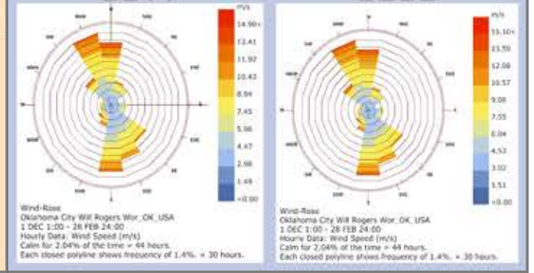
TEMPERATURE



RELATIVE HUMIDITY



WIND SPEEDS



CLIMATE CONCLUSIONS

- TEMPERATURES IN OKLAHOMA CITY ARE PREDOMINANTLY HIGH THROUGHOUT THE YEAR, REACHING PEAKS OF ALMOST 35°C DURING THE SUMMER. EVENTHOUGH WINTERS ARE NOT VERY LONG, THERE MIGHT BE SOME DAYS IN JANUARY WITH TEMPERATURES OF UP TO -18°C.

- THE OKLAHOMA CITY REGION IS A PLACE WITH A CONSIDERABLY HIGH RELATIVE HUMIDITY, SPECIALLY. DURING MORNING AND NIGHT HOURS. THIS CAN AFFECT THE TEMPERATURE PERCEPTION, MAKING THE COLD DAYS SEEM COLDER AND THE HOT DAYS SEEM HOTTER.

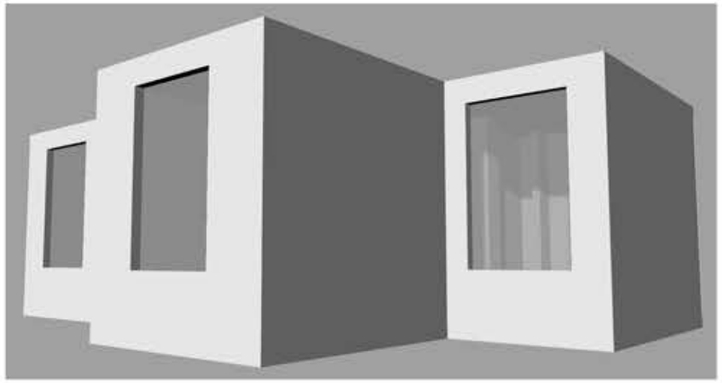
- EVENTHOUGH WINDS ARE MAINLY PREDOMINANT FROM THE NORTHERN AND SOUTHERN DIRECTION, THEY CAN REACH EXTREMELY HIGH SPEEDS OF UP TO 18 M/S. THIS CAN ALSO AFFECT THE TEMPERATURE PERCEPTION ESPECIALLY DURING WINTER AND SPRING, WHERE WINDS ARE THE FASTEST.

- "TORNADO SEASON" IN OKLAHOMA IS CONSIDERED TO GO FROM MARCH 15 TO JUNE 15, WHICH IS THE PERIOD OF TIME WITH THE HIGHEST WIND SPEEDS AND THE HIGHEST RELATIVE HUMIDITY IN THE YEAR.

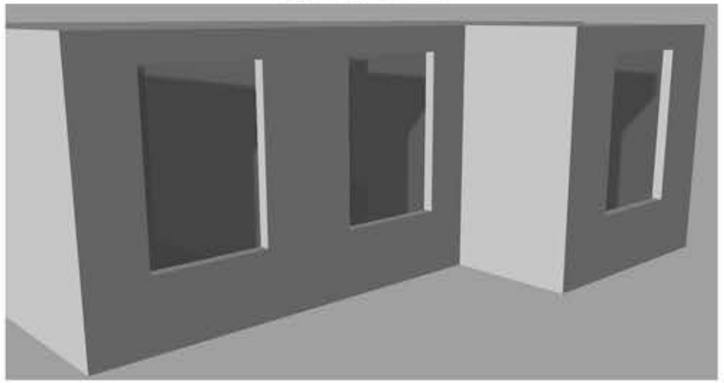
- THERE ARE SEVERAL INDICATORS THAT SHOW GLOBAL WARMING WILL BE WORSE BY 2050. HIGHER TEMPERATURES, WITH PEAKS OF UP TO 45°C IN THE SUMMER, PROVE THE EARTH WILL BE WARMER BY 2050. HIGHER WIND SPEEDS DURING TORNADO SEASONS SHOW THAT NATURAL CATASTROPHES WILL BE MORE POWERFUL AND EXTREME.

BASELINE: ACTUAL CONDITIONS

3D VIEW 1



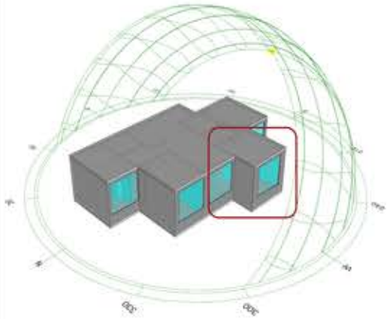
3D VIEW 2



YEARLY COMFORT RESULTS

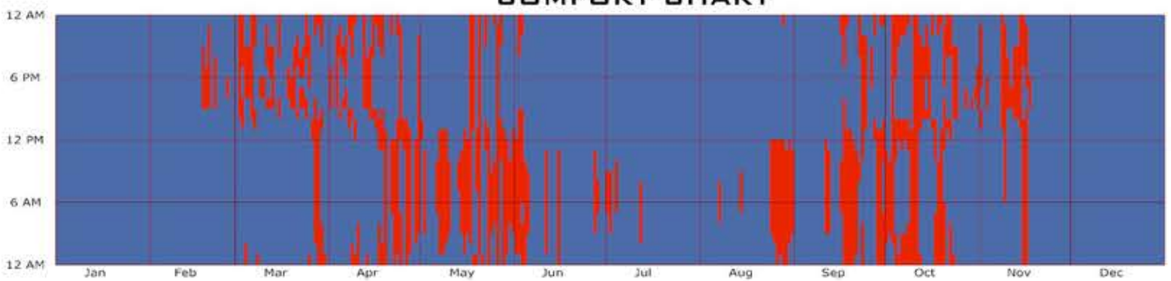
PERCENTAGE OF TIME COMFORTABLE	15.87%
PERCENTAGE OF TIME TOO HOT	48.68%
PERCENTAGE OF TIME TOO COLD	35.45%

3D SUN PATH DIAGRAM



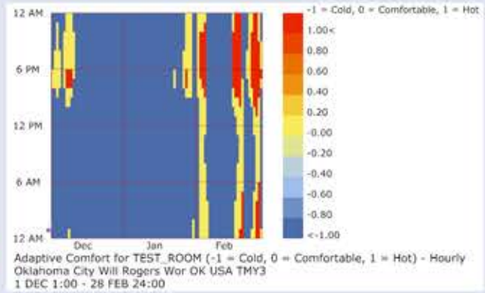
FLOOR PLAN SUN PATH DIAGRAM

COMFORT CHART



Comfortable
Not Comfortable

WINTER

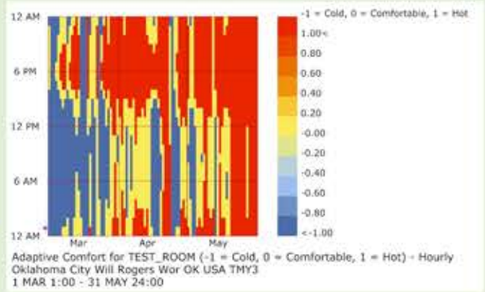


PERCENTAGE OF TIME COMFORTABLE: 11.44%

PERCENTAGE OF TIME TOO HOT: 5.14%

PERCENTAGE OF TIME TOO COLD: 83.43%

SPRING

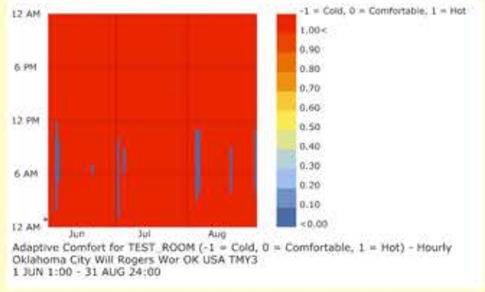


PERCENTAGE OF TIME COMFORTABLE: 28.85%

PERCENTAGE OF TIME TOO HOT: 43.75%

PERCENTAGE OF TIME TOO COLD: 27.40%

SUMMER

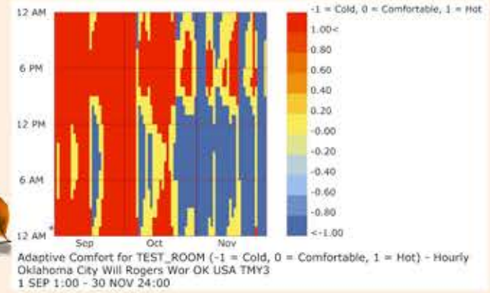


PERCENTAGE OF TIME COMFORTABLE: 2.49%

PERCENTAGE OF TIME TOO HOT: 97.51%

PERCENTAGE OF TIME TOO COLD: 0.00%

FALL



PERCENTAGE OF TIME COMFORTABLE: 20.65%

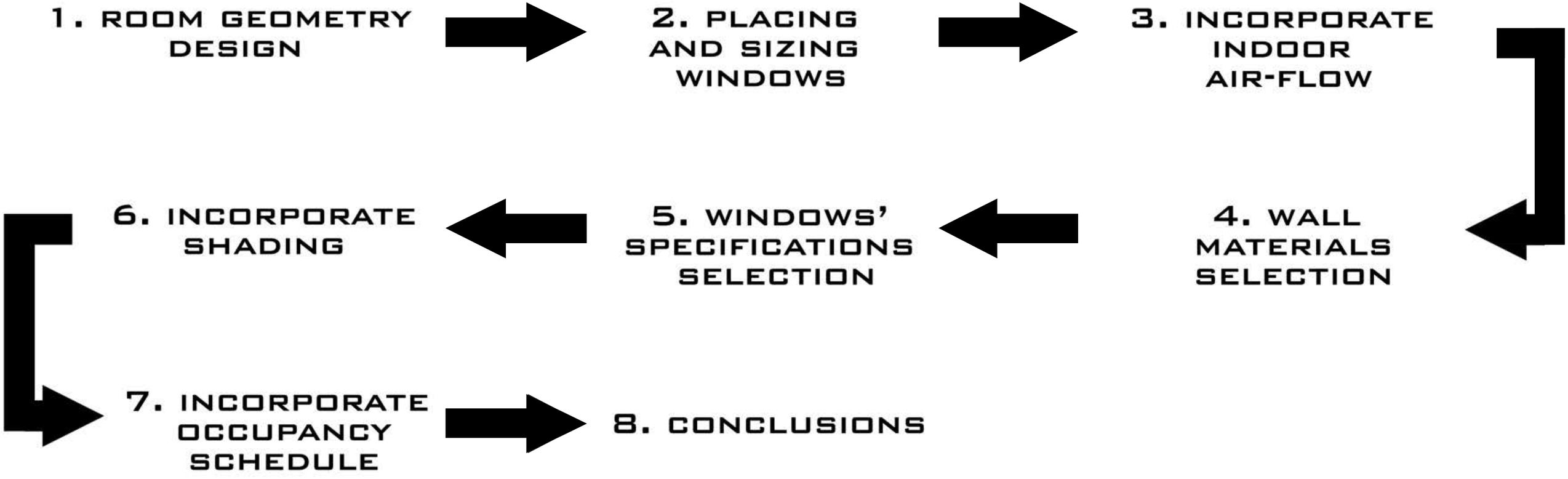
PERCENTAGE OF TIME TOO HOT: 47.34%

PERCENTAGE OF TIME TOO COLD: 32.01%

DESIGN CHALLENGES AND OPPORTUNITIES

CHALLENGES	OPPORTUNITIES	WEATHER LESSONS
SINCE THE REGION HAS SEVERE COLD AND HOT CONDITIONS, ONE DECISION THAT CAN BE BENEFICIAL FOR THE SUMMER, COULD ALSO BE HARMFUL FOR THE WINTER.	PREDOMINANT WIND AND SOLAR RADIATION COME FROM THE SOUTH. OPENING THIS FACE OF THE ROOM CAN BE BENEFICIAL.	DEFINING A COMMON LOW BOUND AND A HIGH BOUND IS EXTREMELY IMPORTANT WHEN COMPARING GRAPHS.
GETTING RID OF MOISTURE AND ACHEIVING THERMAL COMFORT ARE GOING TO BE BIG CHALLENGES BECAUSE OF THE HIGH HUMIDITY IN THE REGION.	WIND SPEEDS ARE CONSIDERABLY HIGH, MEANING THAT INDOOR AIR-FLOW COULD BE AN INTERESTING POSSIBILITY.	ANALIZING WHAT HAPPENS DURING EACH SEASON CAN GIVE YOU A BETTER UNDERSTANDING OF THE ROOM'S THERMAL CONDITIONS.
HAVING THREE WALLS FACING THE EXTERIOR REPRESENTS A CHALLENGE IN TERMS OF THERMAL BRIDGING. THE AREA EXPOSED TO OUTDOOR WEATHER IS CONSIDERABLY HIGH.	ADJACENT ROOMS CAN BE USED AS SHADING ELEMENTS.	IT IS EXTREMELY IMPORTANT TO CATEGORIZE AND LABEL EACH SET OF COMPONENTS IN GRASSHOPPER BASED ON THE EFFECT THEY HAVE ON THE SIMULATION. YOU SHOULD ALWAYS UNDERESTIMATE YOUR MEMORY
THE SIZE OF THE ROOM IS A CHALLENGE. GIVEN THAT THE ROOM HAS SMALL DIMENSIONS, IT MIGHT HEAT UP OR COOL DOWN VERY FAST.	THE FACT THAT THE ROOM IS AN EXTRUDED VOLUME FROM THE FAÇADE ALLOWS THE POSSIBILITY OF HAVING OPENINGS IN THE SOUTHERN, WESTERN AND NORTHERN FACES.	IN THE WIND ROSE, WIND SPEED IS DIFFERENT FROM PREDOMINANT WIND DIRECTION, AND WIND TEMPERATURE.

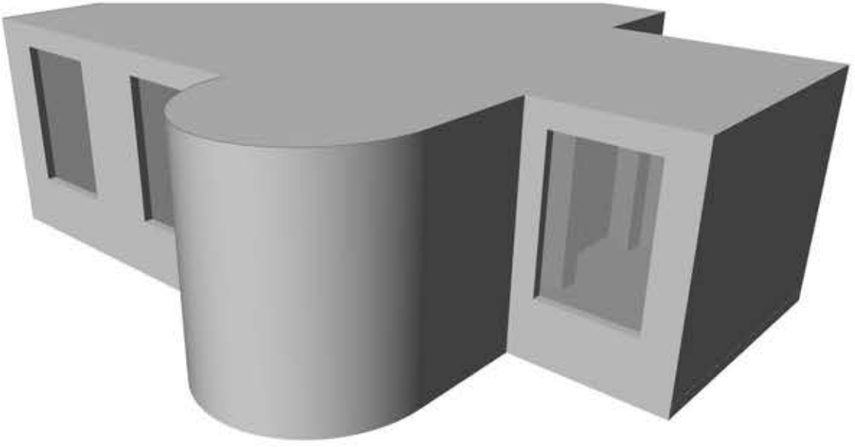
DESIGN WORKFLOW



SELECTING THE GEOMETRY

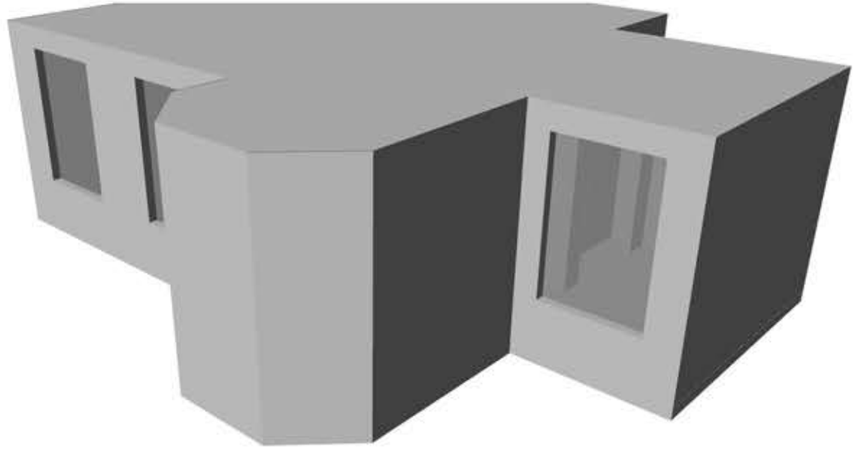
OPTION 1:

ROUNDED ROOM



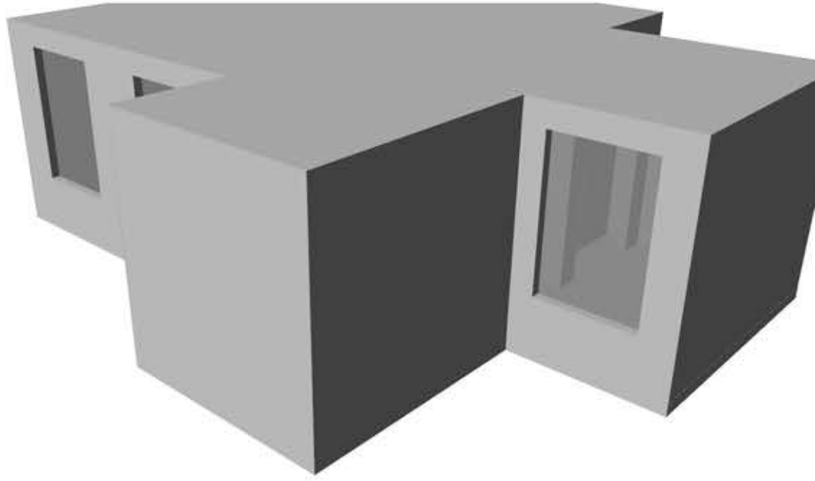
OPTION 2:

HEXAGONAL ROOM



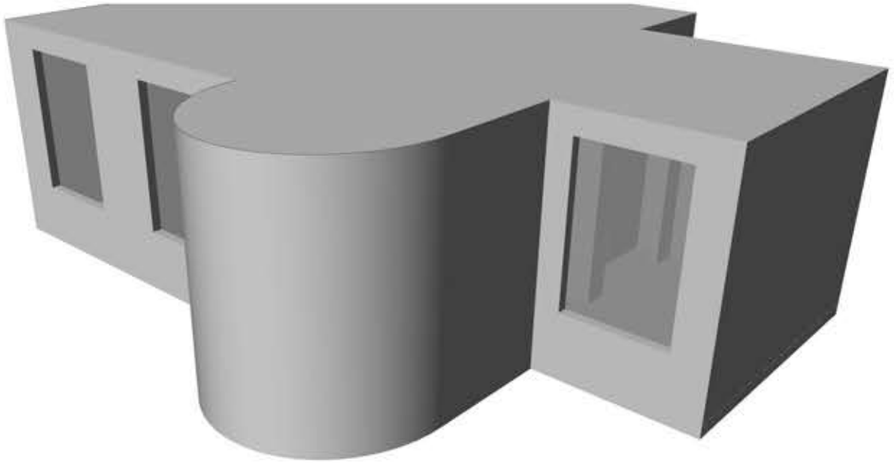
OPTION 3:

SQUARED ROOM

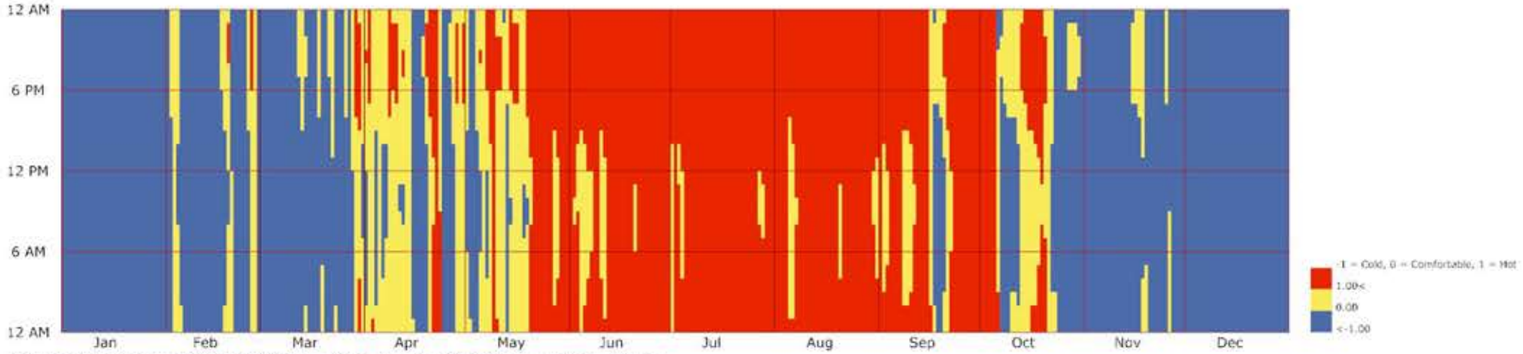


OPTION 1: ROUNDED ROOM

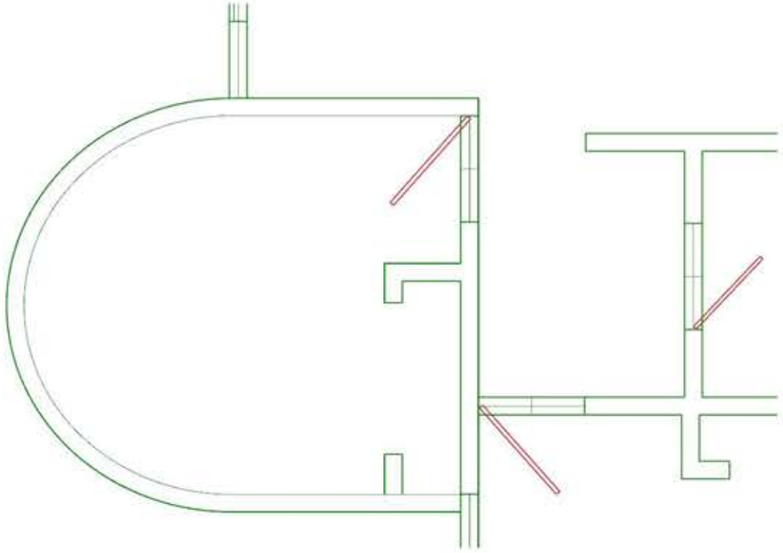
3D VIEW



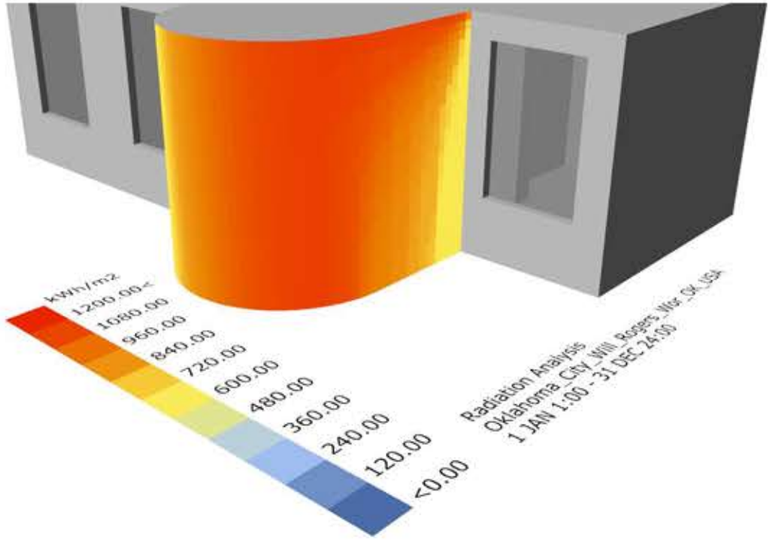
COMFORT CHART



FLOOR PLAN



RADIATION ANALYSIS

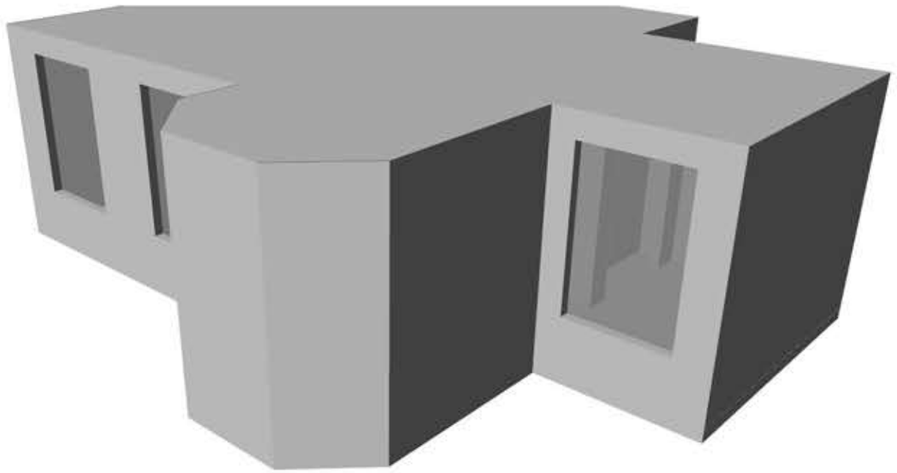


ROOM'S DATA

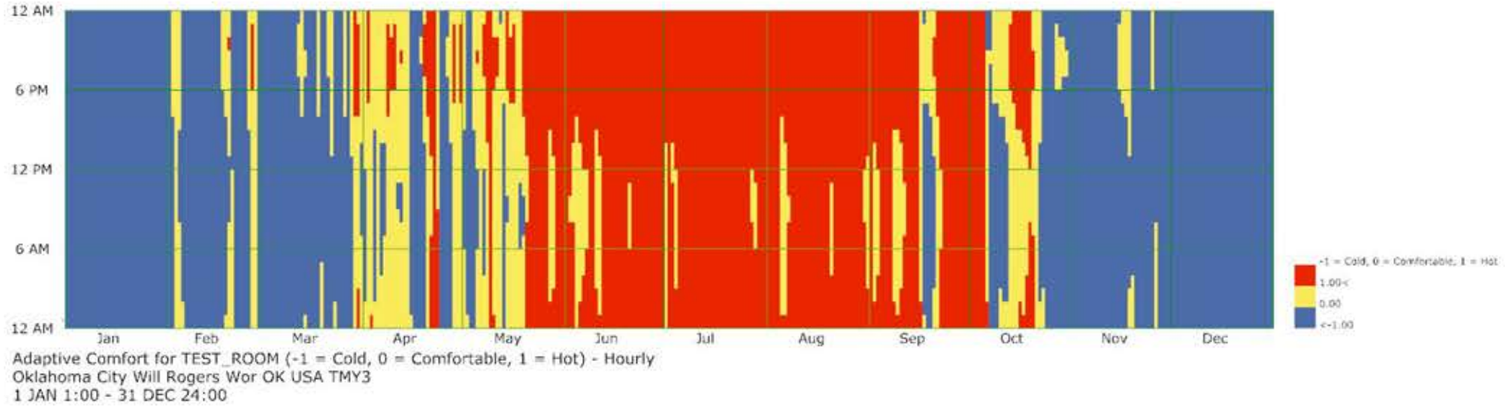
YEARLY RADIATION	15,042 KWH/M2
% OF TIME COMFORTABLE	17.32 %
% OF TIME TOO HOT	37.26 %
% OF TIME TOO COLD	45.41 %
AREA	7.1 M2

OPTION 2: HEXAGONAL ROOM

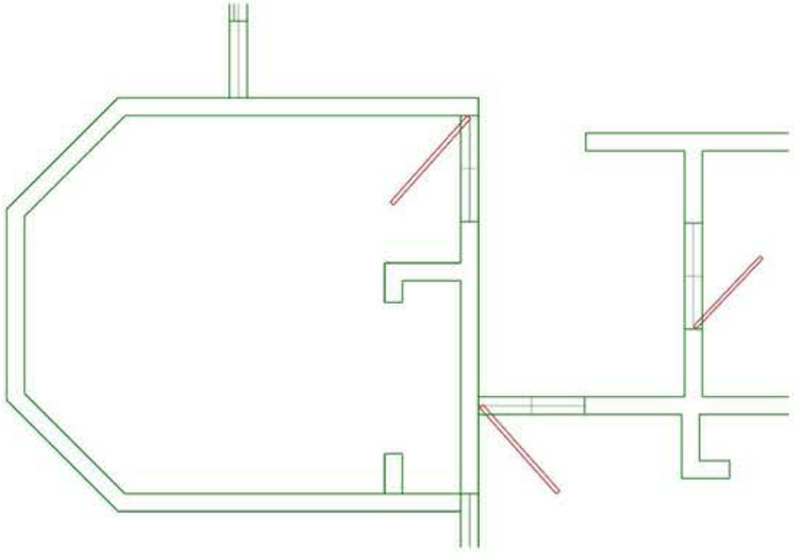
3D VIEW



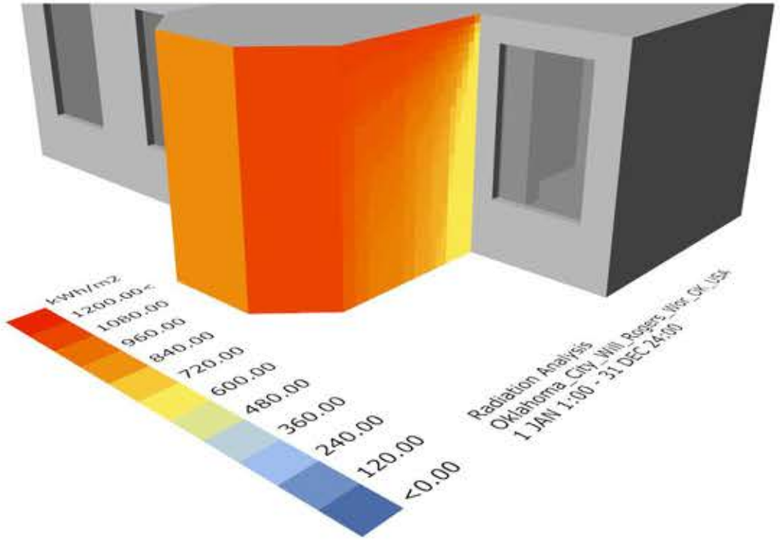
COMFORT CHART



FLOOR PLAN



RADIATION ANALYSIS

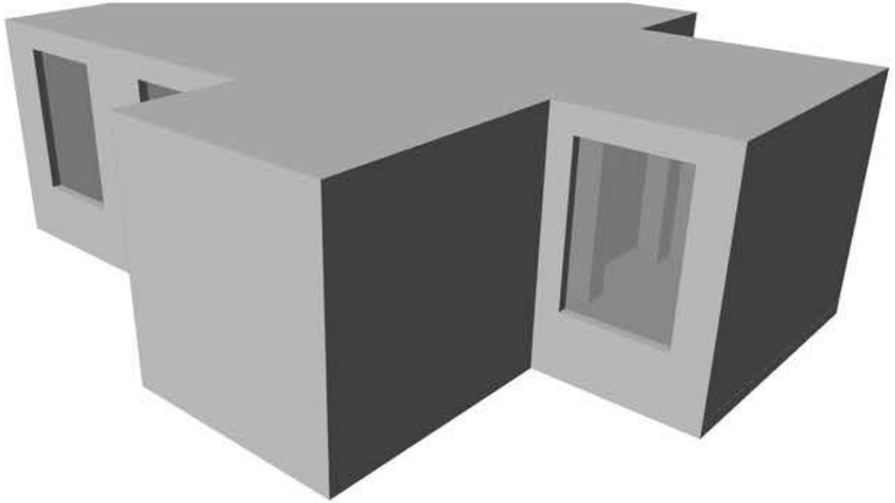


ROOM'S DATA

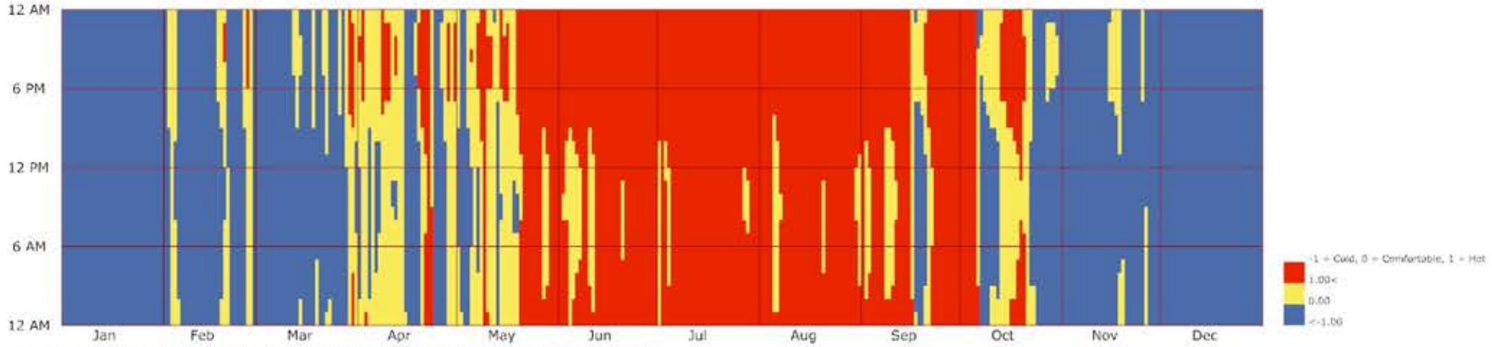
YEARLY RADIATION	15,774 KWH/M2
% OF TIME COMFORTABLE	17.39 %
% OF TIME TOO HOT	36.87 %
% OF TIME TOO COLD	45.73 %
AREA	7.35 M2

OPTION 3: SQUARED ROOM

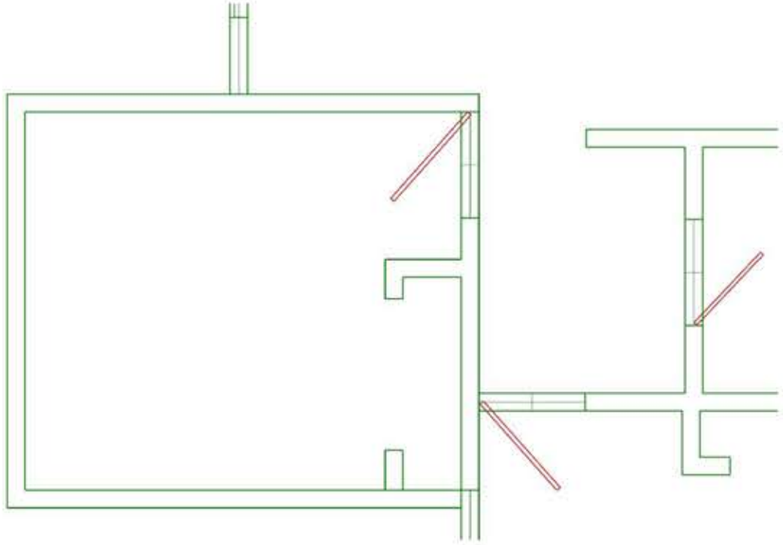
3D VIEW



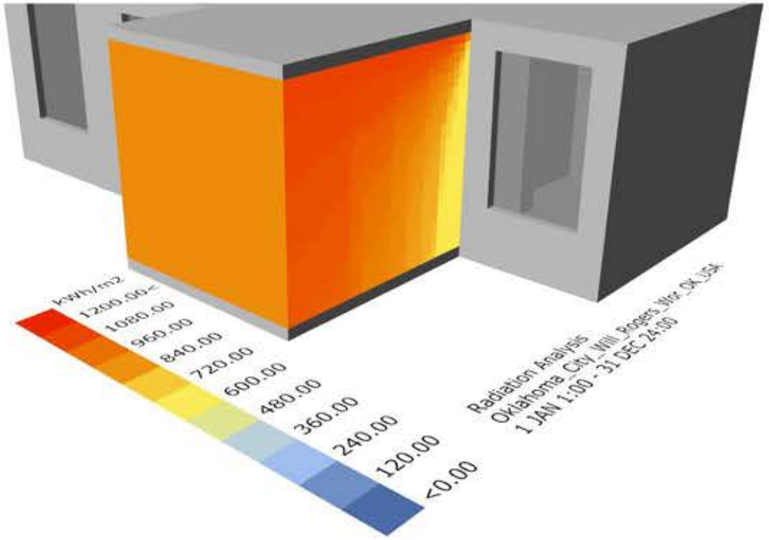
COMFORT CHART



FLOOR PLAN



RADIATION ANALYSIS

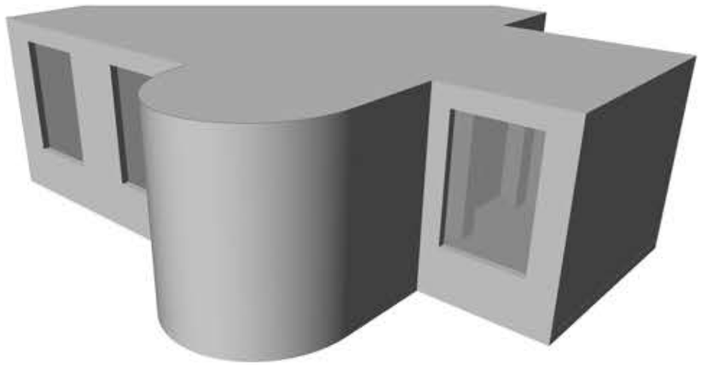
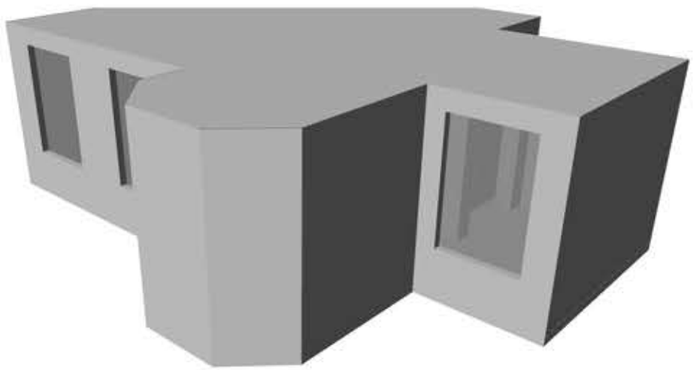
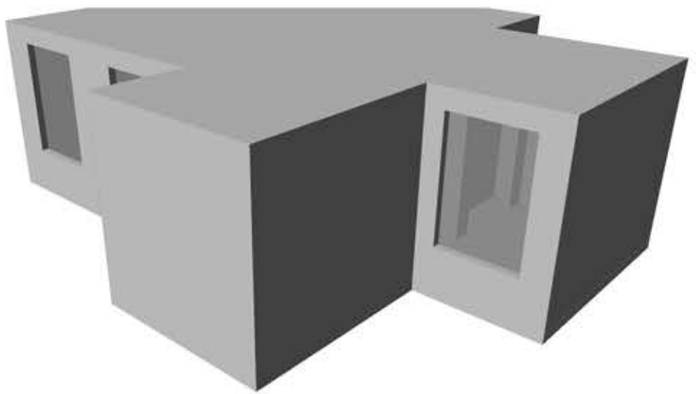


ROOM'S DATA

YEARLY RADIATION	15,989 KWH/M2
% OF TIME COMFORTABLE	17.48 %
% OF TIME TOO HOT	37.18 %
% OF TIME TOO COLD	45.33 %
AREA	7.82 M2

ROOM GEOMETRY CONCLUSIONS

LEGEND: BEST → WORST

			
RADIATION	✓	+ −	✗
COMFORT	✗	+ −	✓
TOO HOT	✗	✓	+ −
TOO COLD	+ −	✗	✓
AREA	✗	+ −	✓

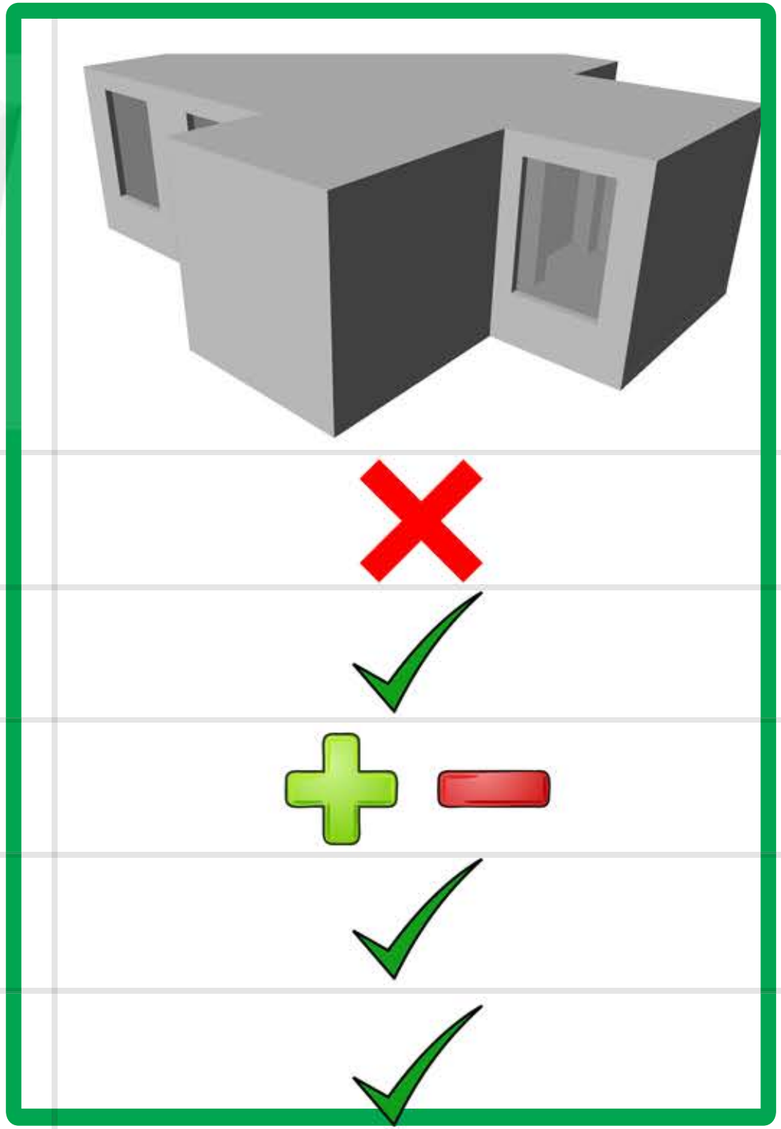
ROOM GEOMETRY CONCLUSIONS

RADIATION CAN BE CONTROLLED IN THE FUTURE WITH SHADING SYSTEMS OR GLAZING CONFIGURATION.

AREA IS THE MOST IMPORTANT COMPONENT IN THE LIST: THERMAL CONDITIONS CAN BE IMPROVED, AREA NOT!

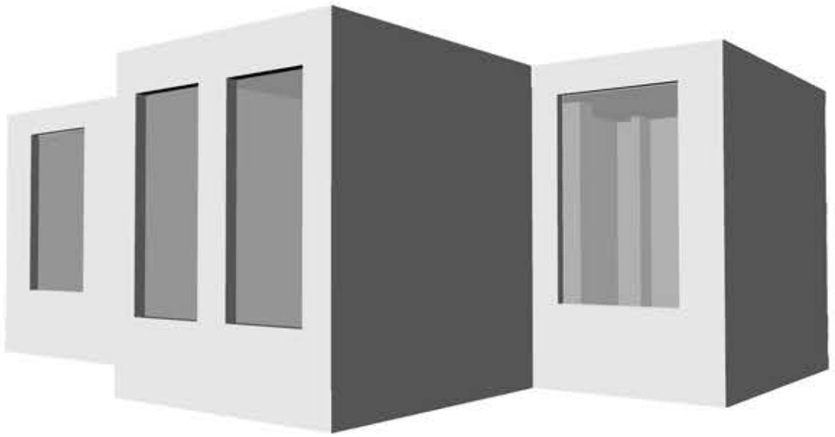
SINCE THE SQUARED ROOM HAS MORE AREA, IT ALSO HAS THE MOST AMOUNT OF WALLS SURFACES EXPOSED TO SUNLIGHT.

RADIATION CAN BE AN OPPORTUNITY IN THE FUTURE FOR HEATING THE ROOM DURING COLD SEASONS.

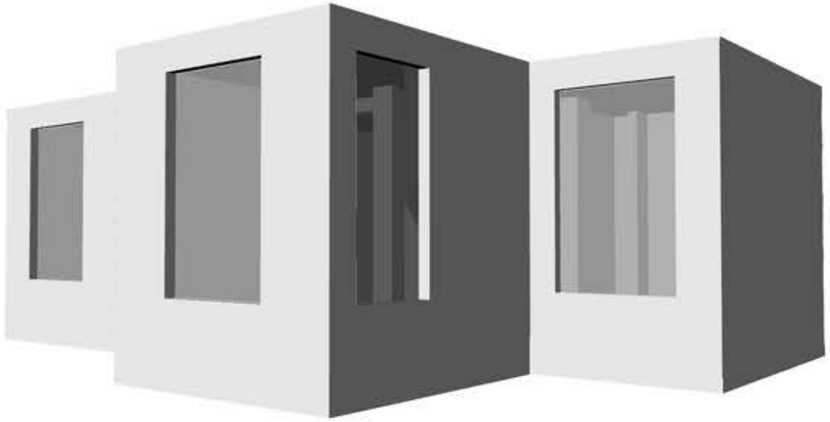


PLACING AND SIZING WINDOWS

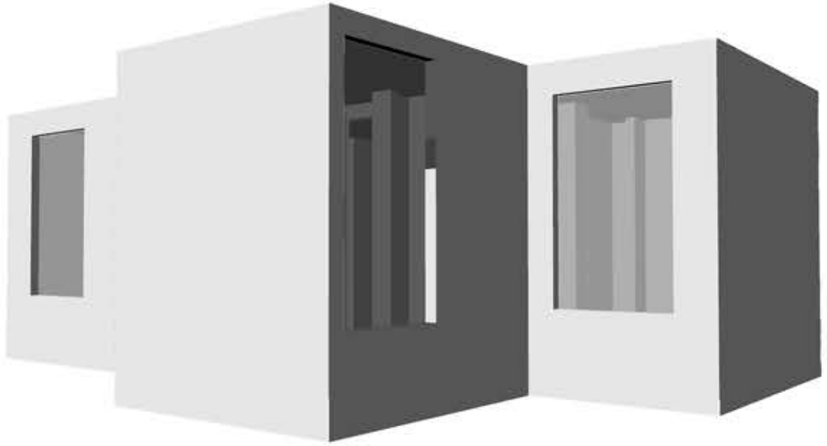
OPTION 1:
TWO BIG WESTERN WINDOWS



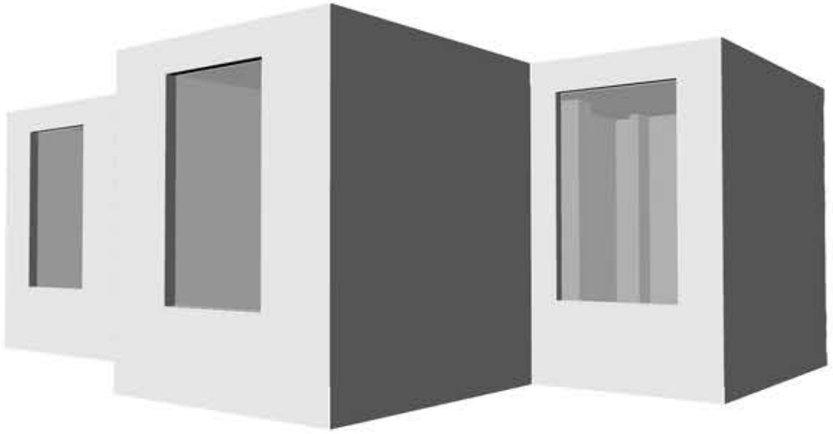
OPTION 2:
BIG SOUTHERN WINDOW+
BIG WESTERN WINDOW



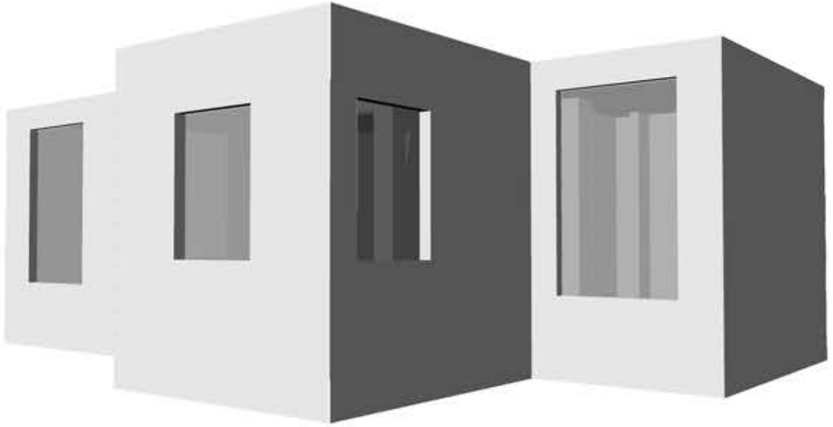
OPTION 3:
BIG SOUTHERN WINDOW+
SMALL NORTHERN WINDOW



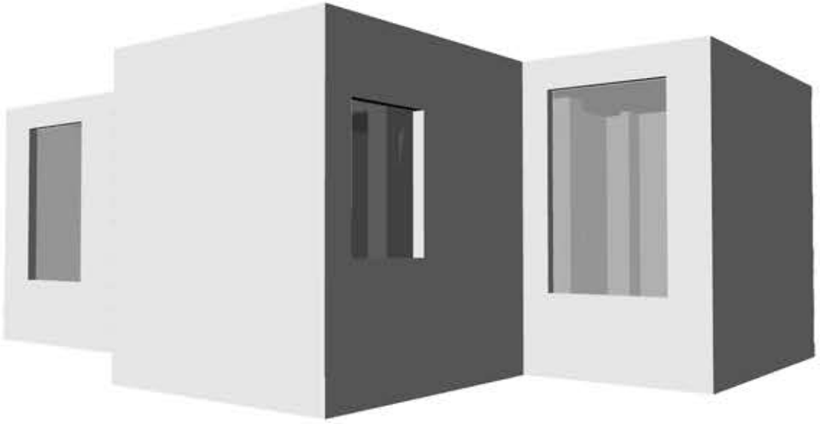
OPTION 4:
BIG WESTERN WINDOW



OPTION 5:
SMALL SOUTHERN WINDOW+
SMALL WESTERN WINDOW+
SMALL NORTHERN WINDOW

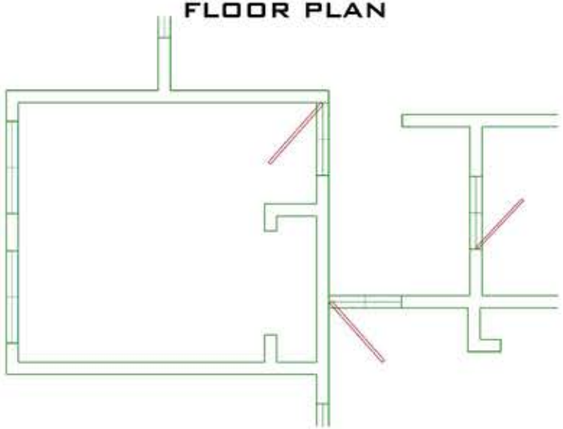


OPTION 6:
SMALL SOURTHERN WINDOW+
SMALL NORTHERN WINDOW



OPTION 1: TWO WESTERN WINDOWS

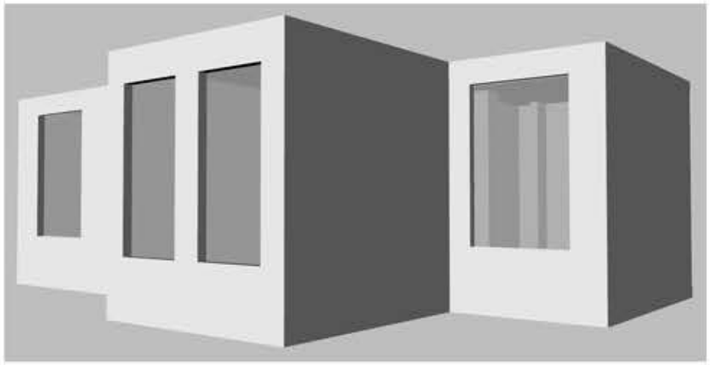
FLOOR PLAN



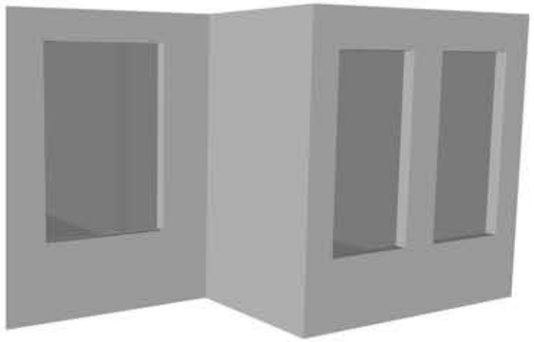
YEARLY RESULTS

PERCENTAGE OF TIME COMFORTABLE	16.35%
PERCENTAGE OF TIME TOO HOT	51.25%
PERCENTAGE OF TIME TOO COLD	32.38%
USEFUL DAYLIGHT ILLUMINANCE	64.78%

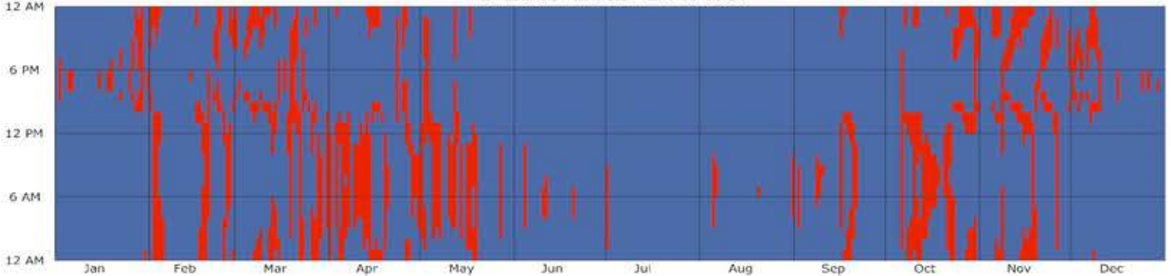
3D VIEW 1



3D VIEW 2

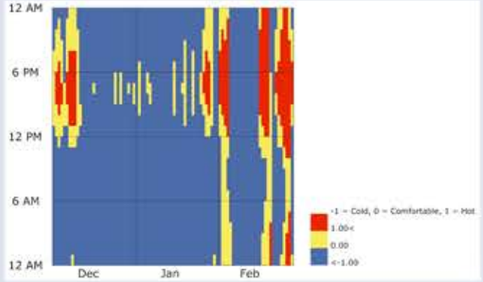


COMFORT CHART



Not Comfortable
Comfortable

WINTER

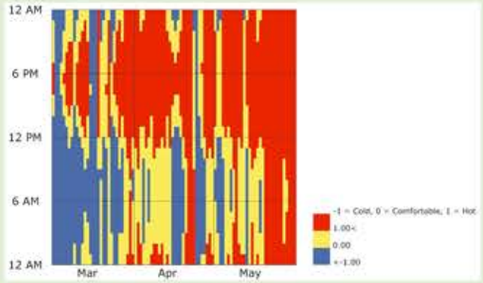


PERCENTAGE OF TIME COMFORTABLE:
13.33%

PERCENTAGE OF TIME TOO HOT:
8.84%

PERCENTAGE OF TIME TOO COLD:
77.82%

SPRING

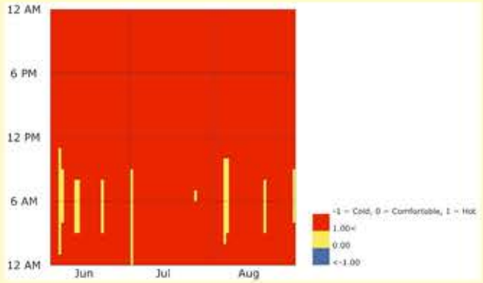


PERCENTAGE OF TIME COMFORTABLE:
28.94%

PERCENTAGE OF TIME TOO HOT:
45.96%

PERCENTAGE OF TIME TOO COLD:
52.09%

SUMMER

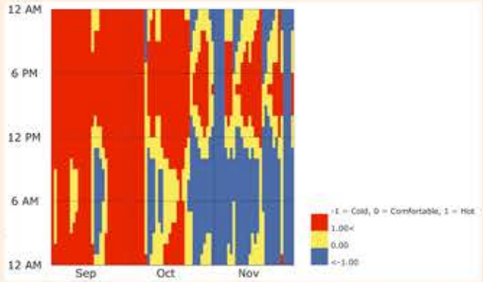


PERCENTAGE OF TIME COMFORTABLE:
2.94%

PERCENTAGE OF TIME TOO HOT:
97.05%

PERCENTAGE OF TIME TOO COLD:
0.00%

FALL



PERCENTAGE OF TIME COMFORTABLE:
20.19%

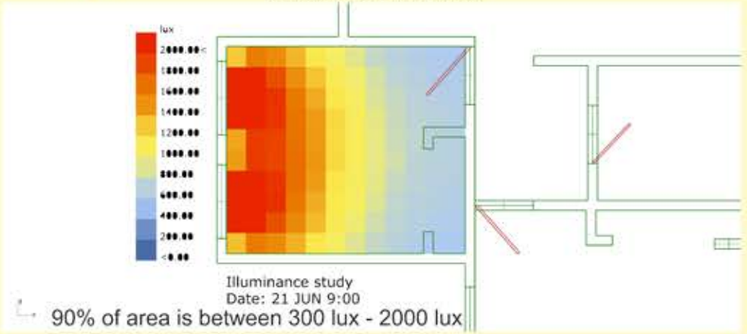
PERCENTAGE OF TIME TOO HOT:
52.24%

PERCENTAGE OF TIME TOO COLD:
27.56%

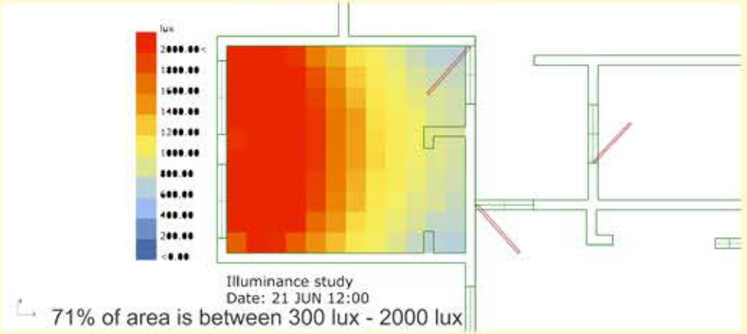
OPTION 1: TWO WESTERN WINDOWS - POINTS IN TIME ANALYSIS

SUMMER SOLSTICE

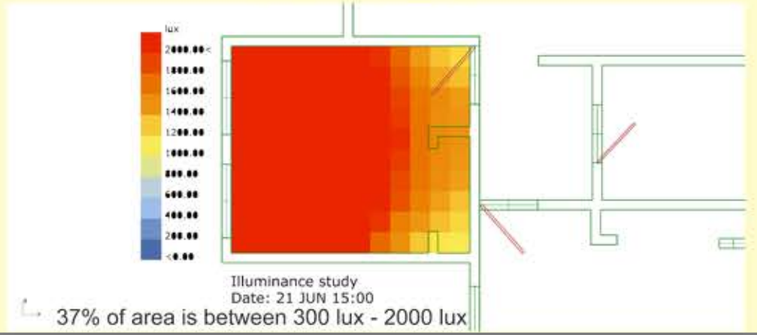
SUMMER 9:00 AM



SUMMER 12:00 PM

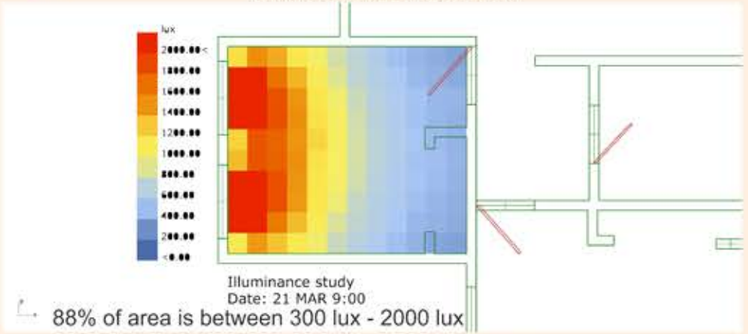


SUMMER 3:00 PM

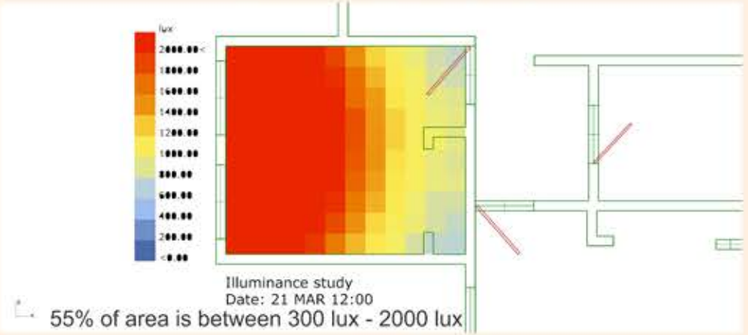


FALL/SPRING EQUINOX

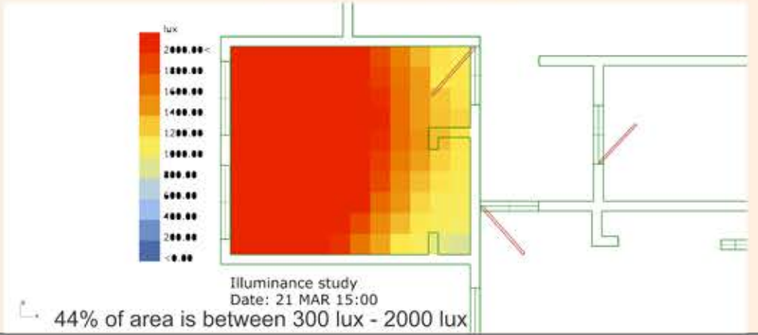
SPRING/FALL 9:00 AM



SPRING/FALL 12:00 PM

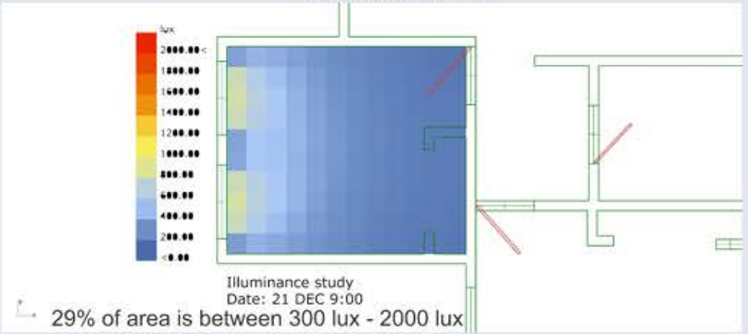


SPRING/FALL 3:00 PM

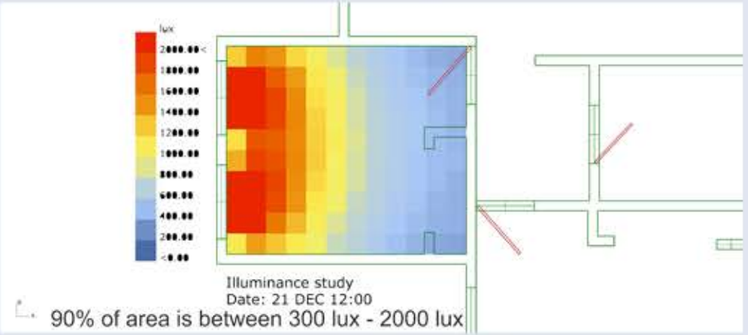


WINTER SOLSTICE

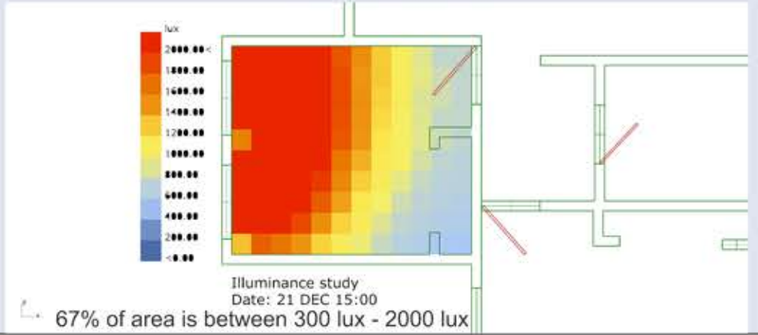
WINTER 9:00 AM



WINTER 12:00 PM

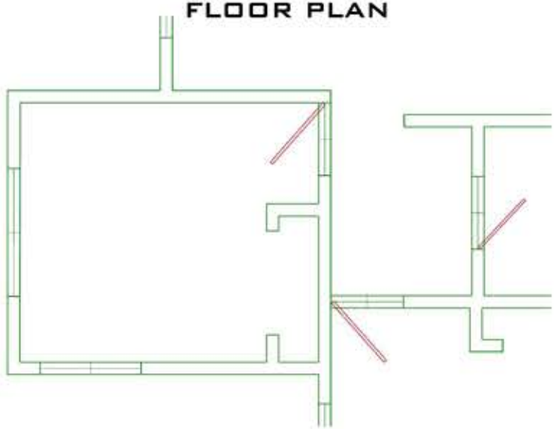


WINTER 3:00 PM



OPTION 2: BIG SOUTHERN WINDOW+BIG WESTERN WINDOW

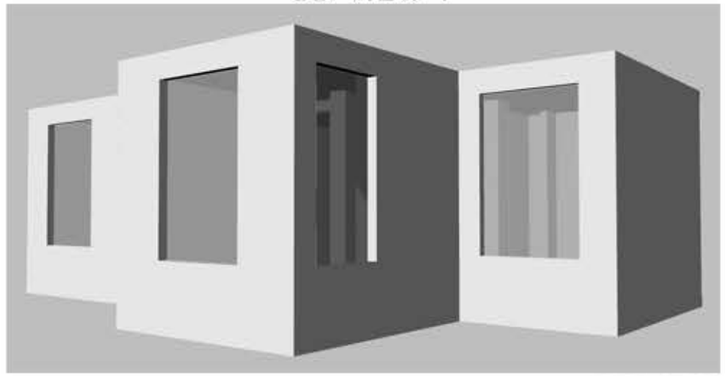
FLOOR PLAN



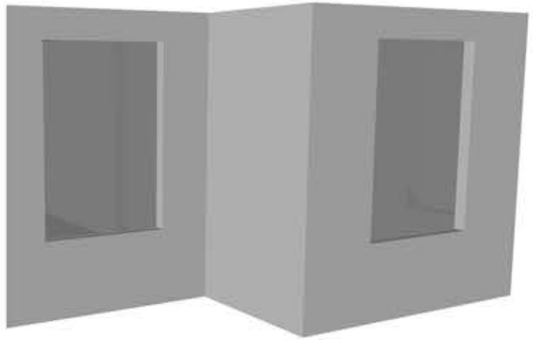
YEARLY RESULTS

PERCENTAGE OF TIME COMFORTABLE	15.57%
PERCENTAGE OF TIME TOO HOT	56.90%
PERCENTAGE OF TIME TOO COLD	27.52%
USEFUL DAYLIGHT ILLUMINANCE	57.05%

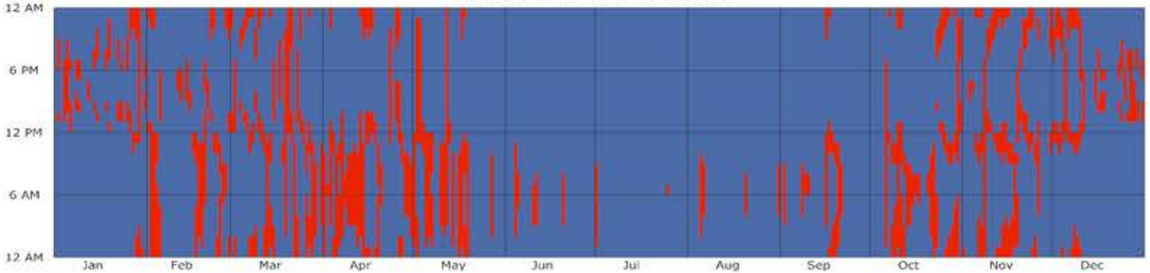
3D VIEW 1



3D VIEW 2

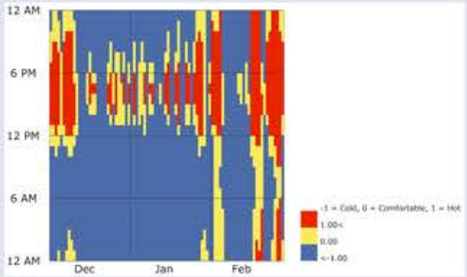


COMFORT CHART



Not Comfortable
Comfortable

WINTER

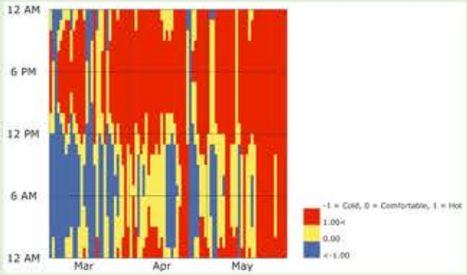


PERCENTAGE OF TIME COMFORTABLE: 16.01%

PERCENTAGE OF TIME TOO HOT: 15.97%

PERCENTAGE OF TIME TOO COLD: 68.01%

SPRING

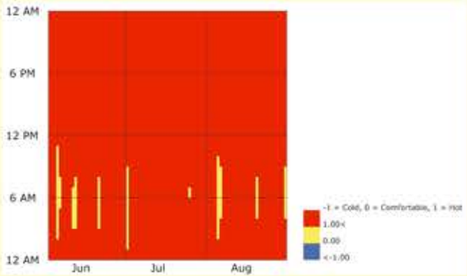


PERCENTAGE OF TIME COMFORTABLE: 26.04%

PERCENTAGE OF TIME TOO HOT: 53.63%

PERCENTAGE OF TIME TOO COLD: 20.33%

SUMMER

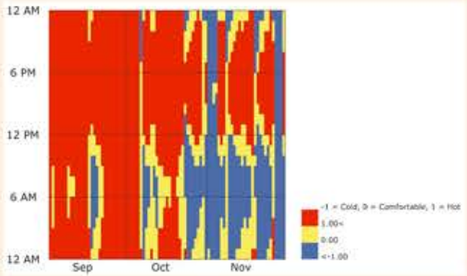


PERCENTAGE OF TIME COMFORTABLE: 2.58%

PERCENTAGE OF TIME TOO HOT: 97.41%

PERCENTAGE OF TIME TOO COLD: 0.00%

FALL



PERCENTAGE OF TIME COMFORTABLE: 17.67%

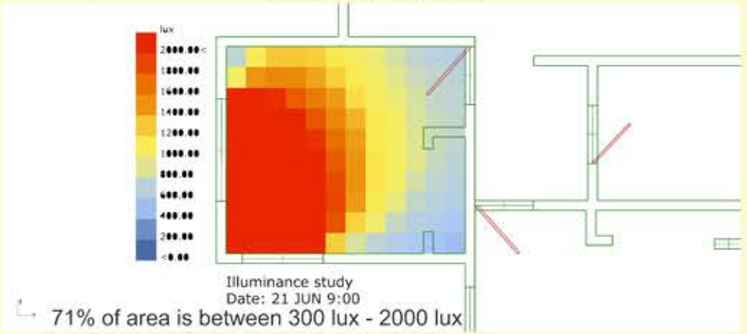
PERCENTAGE OF TIME TOO HOT: 59.75%

PERCENTAGE OF TIME TOO COLD: 22.57%

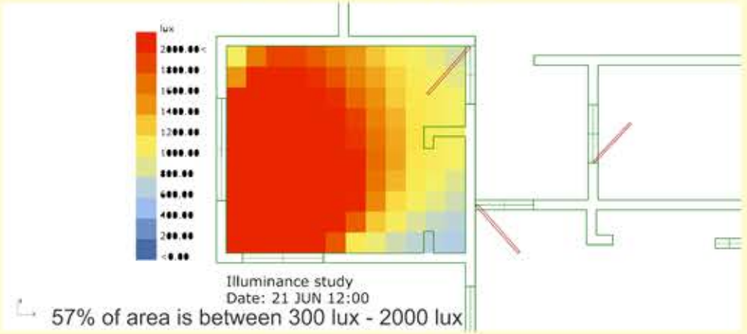
OPTION 2: BIG SOUTHERN WINDOW+BIG WESTERN WINDOW - POINTS IN TIME ANALYSIS

SUMMER SOLSTICE

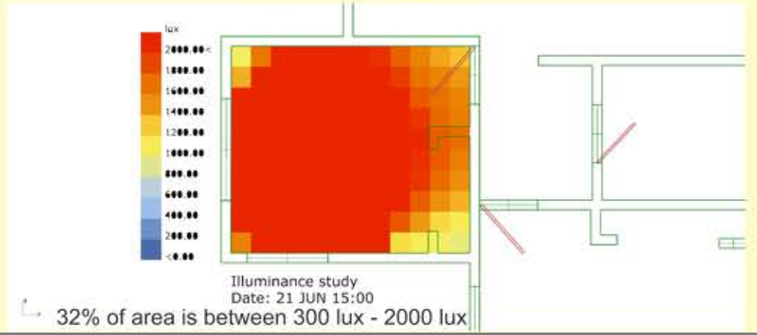
SUMMER 9:00 AM



SUMMER 12:00 PM

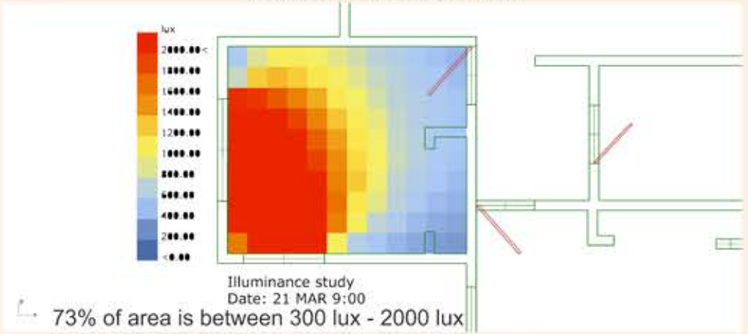


SUMMER 3:00 PM

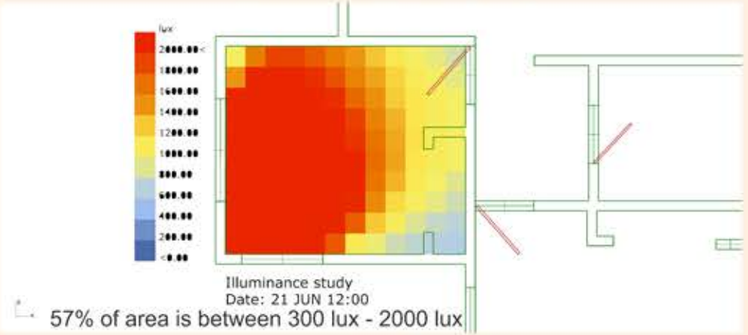


FALL/SPRING EQUINOX

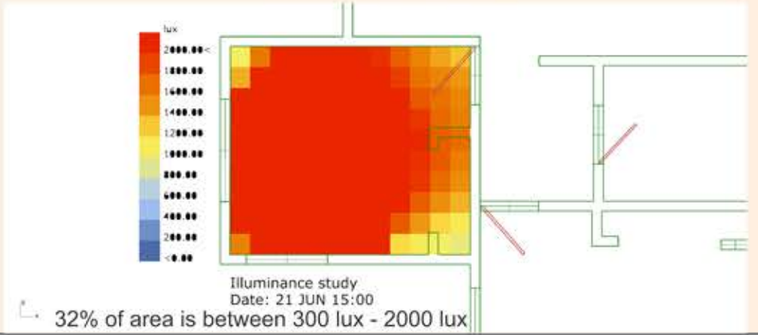
SPRING/FALL 9:00 AM



SPRING/FALL 12:00 PM

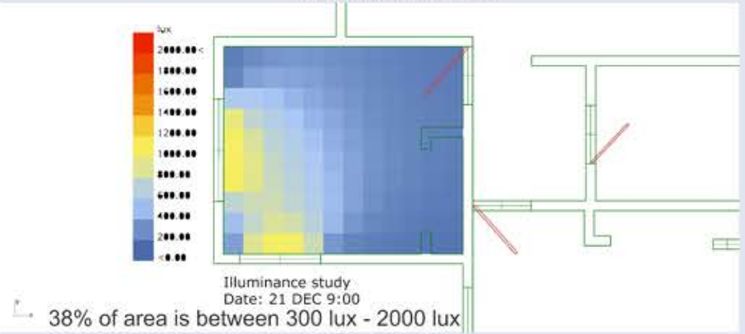


SPRING/FALL 3:00 PM

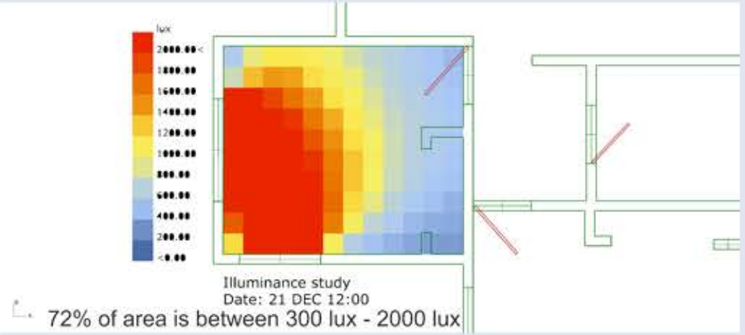


WINTER SOLSTICE

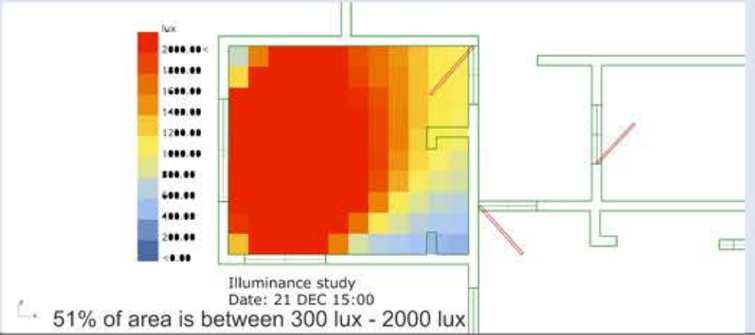
WINTER 9:00 AM



WINTER 12:00 PM

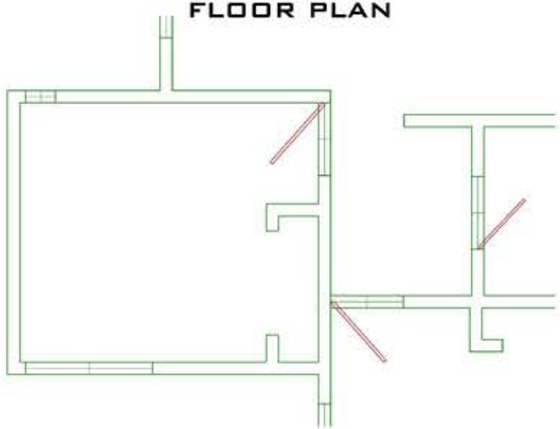


WINTER 3:00 PM



OPTION 3: BIG SOUTHERN WINDOW+ SMALL NORTHERN WINDOW

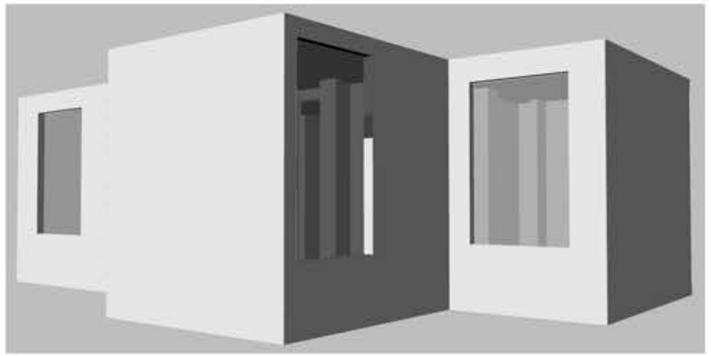
FLOOR PLAN



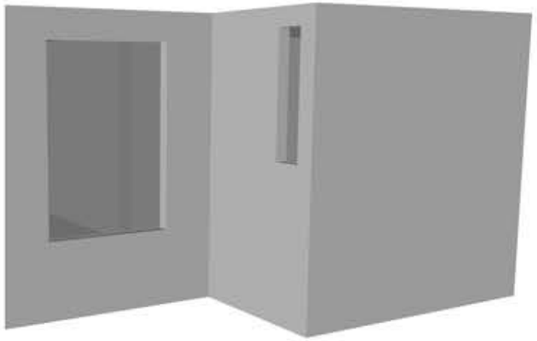
YEARLY RESULTS

PERCENTAGE OF TIME COMFORTABLE	18.75%
PERCENTAGE OF TIME TOO HOT	57.04%
PERCENTAGE OF TIME TOO COLD	26.19%
USEFUL DAYLIGHT ILLUMINANCE	67.67%

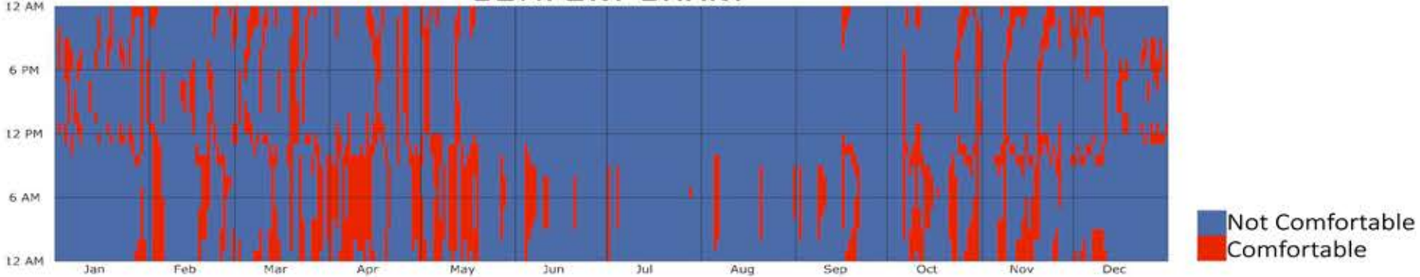
3D VIEW 1



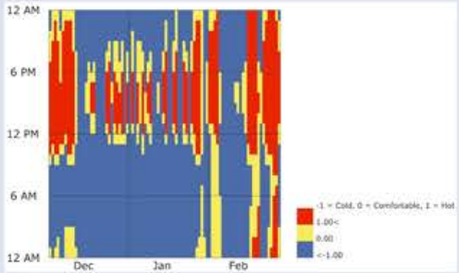
3D VIEW 2



COMFORT CHART



WINTER

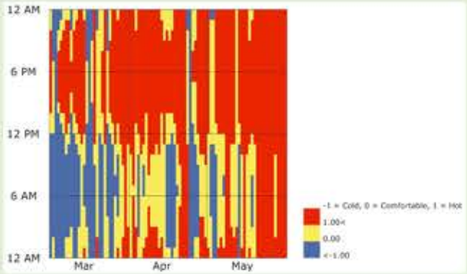


PERCENTAGE OF TIME COMFORTABLE: 16.52%

PERCENTAGE OF TIME TOO HOT: 21.06%

PERCENTAGE OF TIME TOO COLD: 62.40%

SPRING

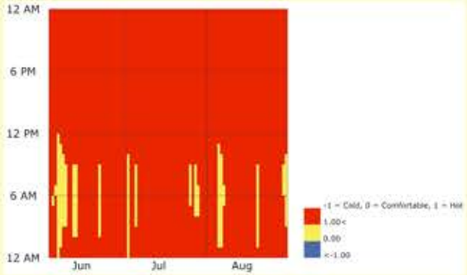


PERCENTAGE OF TIME COMFORTABLE: 28.84%

PERCENTAGE OF TIME TOO HOT: 48.73%

PERCENTAGE OF TIME TOO COLD: 22.41%

SUMMER

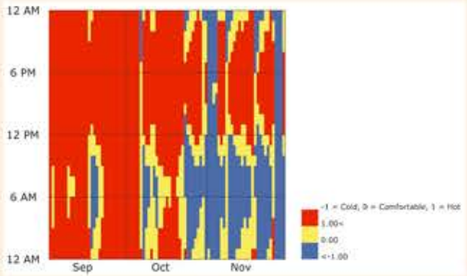


PERCENTAGE OF TIME COMFORTABLE: 6.07%

PERCENTAGE OF TIME TOO HOT: 93.92%

PERCENTAGE OF TIME TOO COLD: 0.00%

FALL



PERCENTAGE OF TIME COMFORTABLE: 17.58%

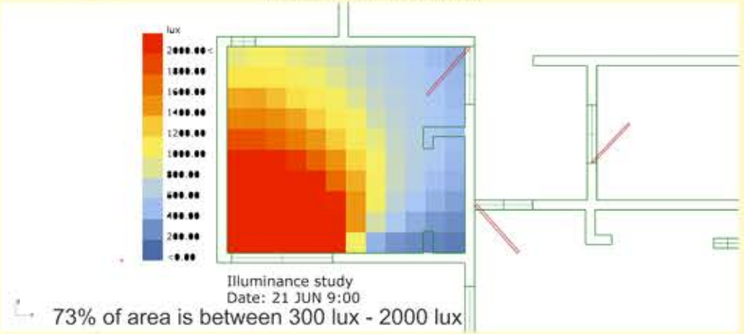
PERCENTAGE OF TIME TOO HOT: 61.72%

PERCENTAGE OF TIME TOO COLD: 20.69%

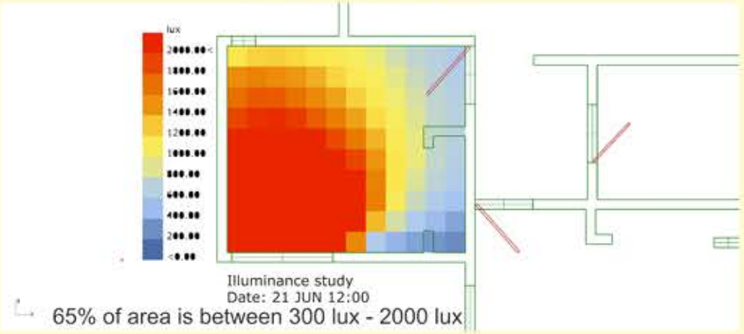
OPTION 3: BIG SOUTHERN WINDOW+SMALL NORTHERN WINDOW - POINTS IN TIME ANALYSIS

SUMMER SOLSTICE

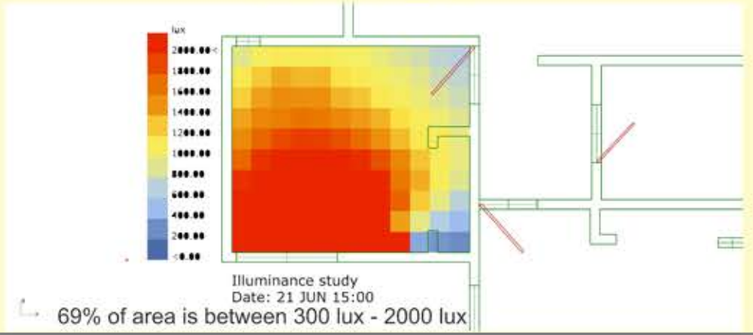
SUMMER 9:00 AM



SUMMER 12:00 PM

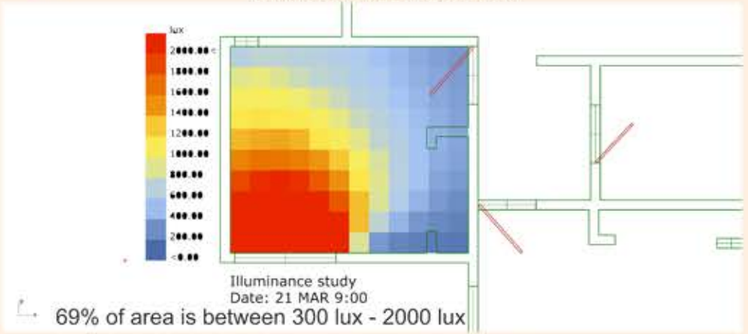


SUMMER 3:00 PM

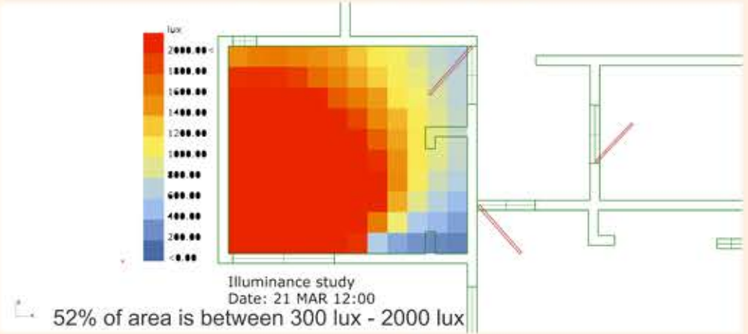


FALL/SPRING EQUINOX

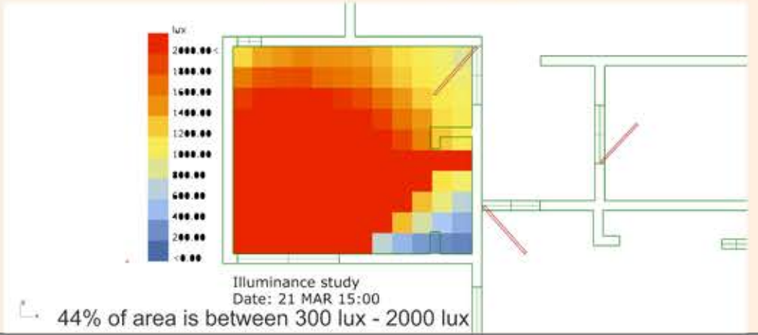
SPRING/FALL 9:00 AM



SPRING/FALL 12:00 PM

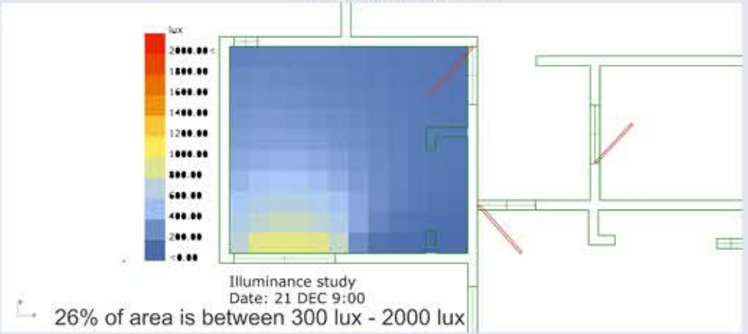


SPRING/FALL 3:00 PM

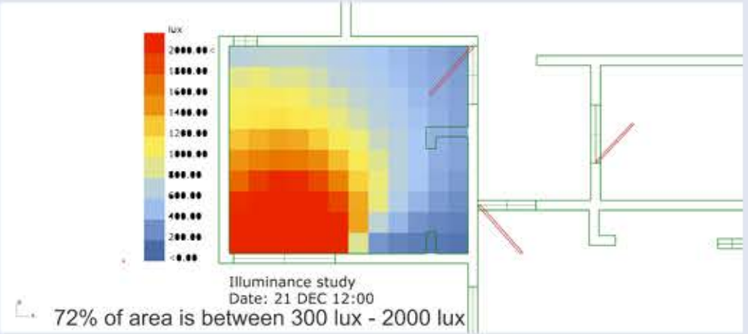


WINTER SOLSTICE

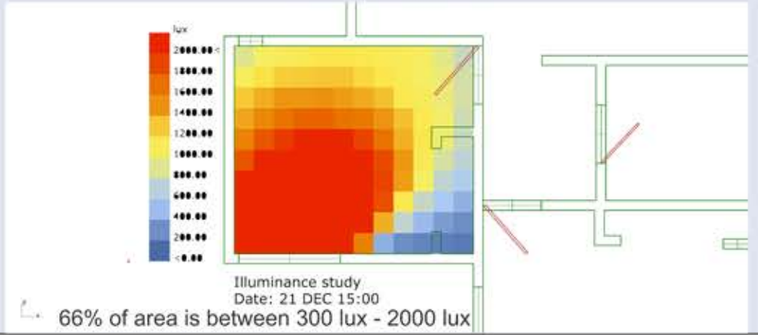
WINTER 9:00 AM



WINTER 12:00 PM

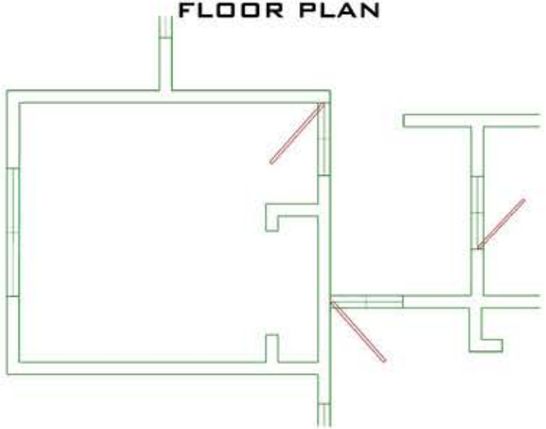


WINTER 3:00 PM



OPTION 4: BIG WESTERN WINDOW

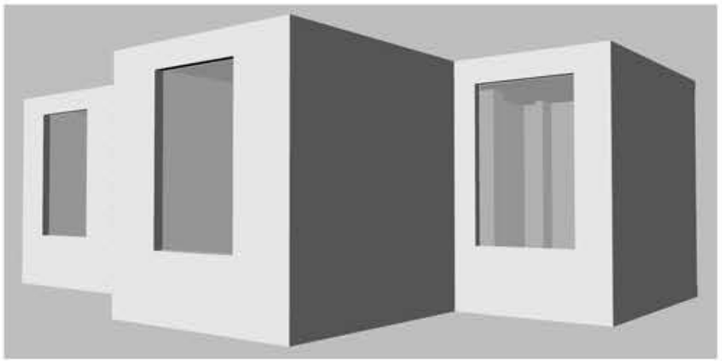
FLOOR PLAN



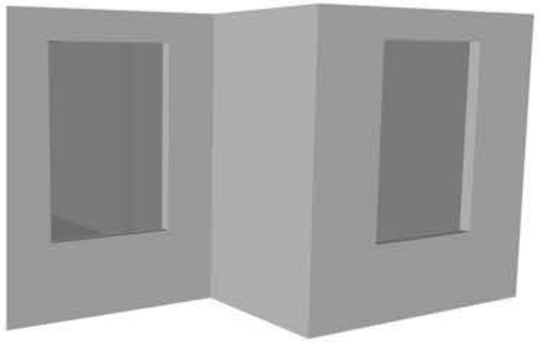
YEARLY RESULTS

PERCENTAGE OF TIME COMFORTABLE	15.28%
PERCENTAGE OF TIME TOO HOT	49.53%
PERCENTAGE OF TIME TOO COLD	35.18%
USEFUL DAYLIGHT ILLUMINANCE	80.10%

3D VIEW 1

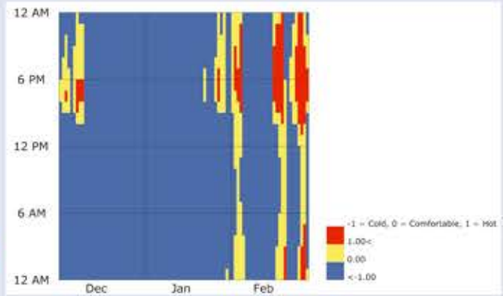


3D VIEW 2



COMFORT CHART

WINTER

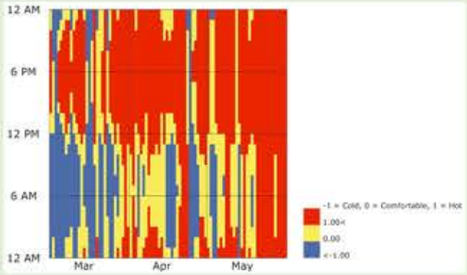


PERCENTAGE OF TIME COMFORTABLE: 10.83%

PERCENTAGE OF TIME TOO HOT: 4.81%

PERCENTAGE OF TIME TOO COLD: 84.35%

SPRING

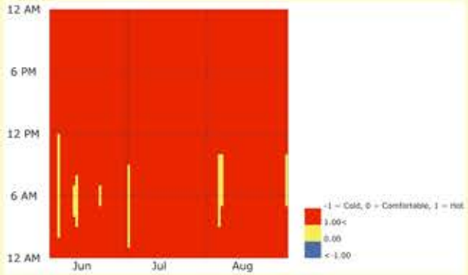


PERCENTAGE OF TIME COMFORTABLE: 28.17%

PERCENTAGE OF TIME TOO HOT: 46.19%

PERCENTAGE OF TIME TOO COLD: 25.63%

SUMMER

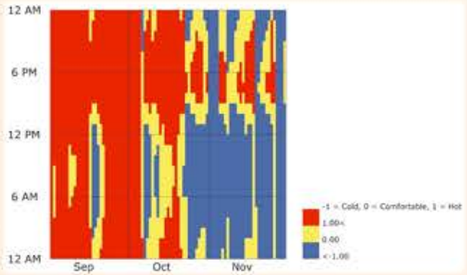


PERCENTAGE OF TIME COMFORTABLE: 2.03%

PERCENTAGE OF TIME TOO HOT: 97.96%

PERCENTAGE OF TIME TOO COLD: 0.00%

FALL



PERCENTAGE OF TIME COMFORTABLE: 20.05%

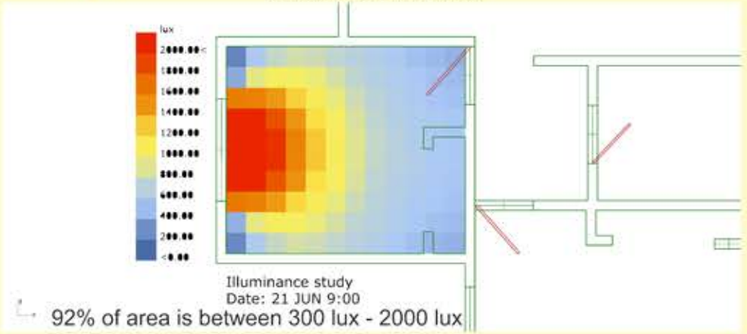
PERCENTAGE OF TIME TOO HOT: 48.16%

PERCENTAGE OF TIME TOO COLD: 31.77%

OPTION 4: BIG WESTERN WINDOW - POINTS IN TIME ANALYSIS

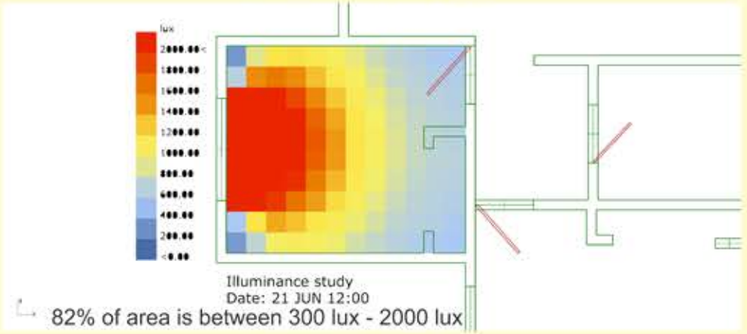
SUMMER SOLSTICE

SUMMER 9:00 AM



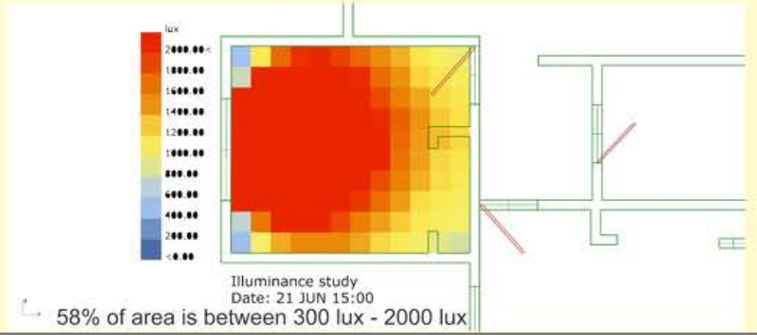
92% of area is between 300 lux - 2000 lux

SUMMER 12:00 PM



82% of area is between 300 lux - 2000 lux

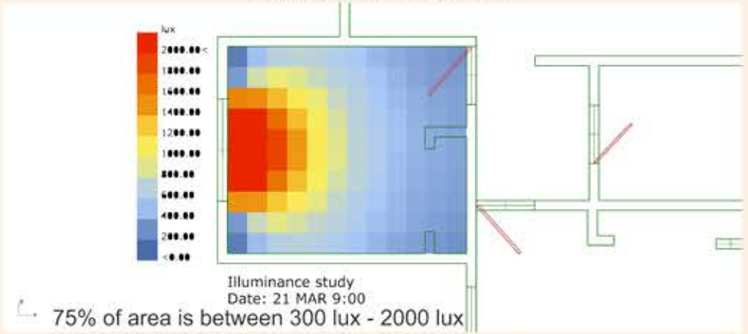
SUMMER 3:00 PM



58% of area is between 300 lux - 2000 lux

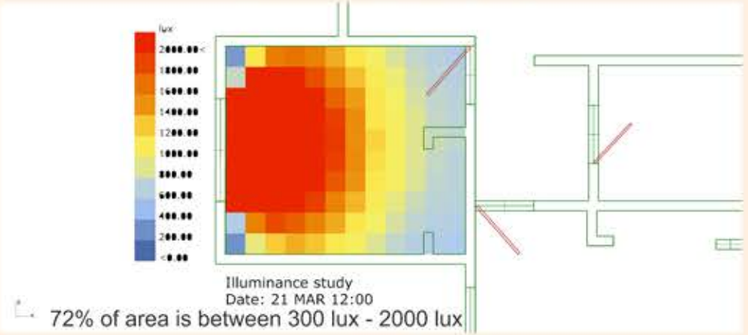
FALL/SPRING EQUINOX

SPRING/FALL 9:00 AM



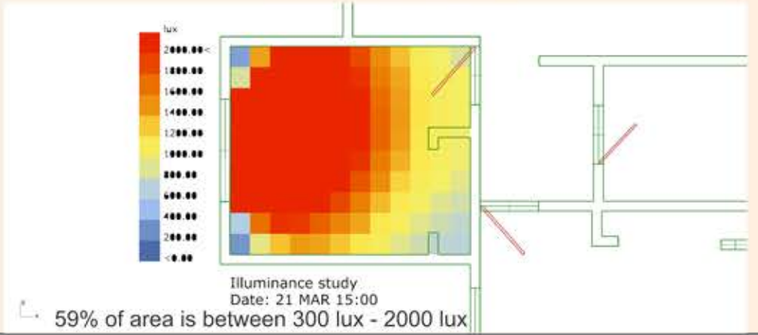
75% of area is between 300 lux - 2000 lux

SPRING/FALL 12:00 PM



72% of area is between 300 lux - 2000 lux

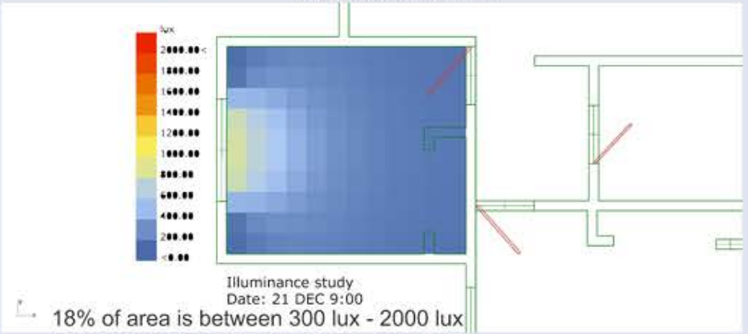
SPRING/FALL 3:00 PM



59% of area is between 300 lux - 2000 lux

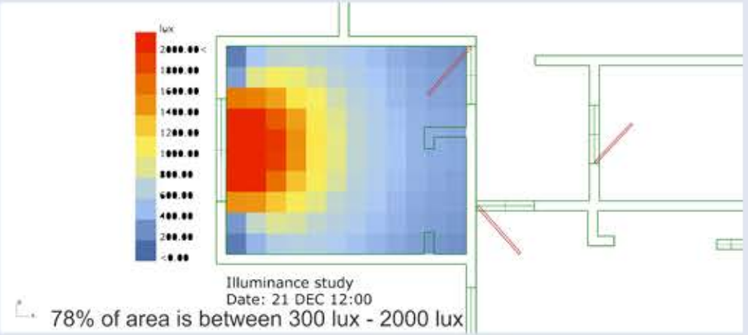
WINTER SOLSTICE

WINTER 9:00 AM



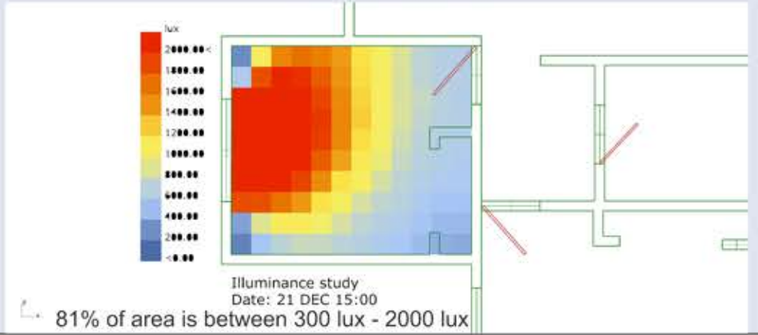
18% of area is between 300 lux - 2000 lux

WINTER 12:00 PM



78% of area is between 300 lux - 2000 lux

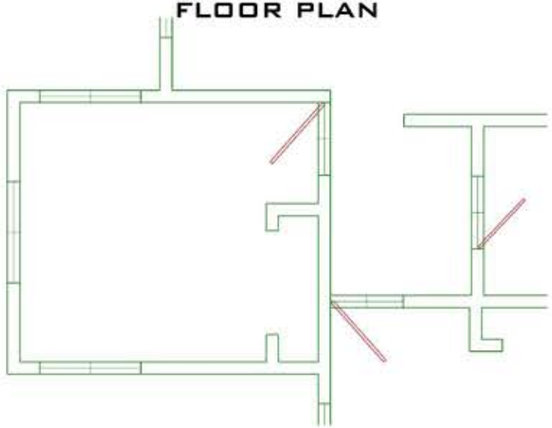
WINTER 3:00 PM



81% of area is between 300 lux - 2000 lux

OPTION 5: SMALL SOUTHERN WINDOW+ SMALL WESTERN WINDOW+ SMALL NORTHERN WINDOW

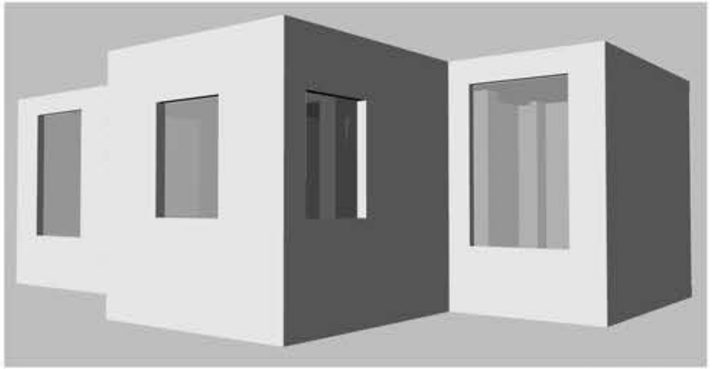
FLOOR PLAN



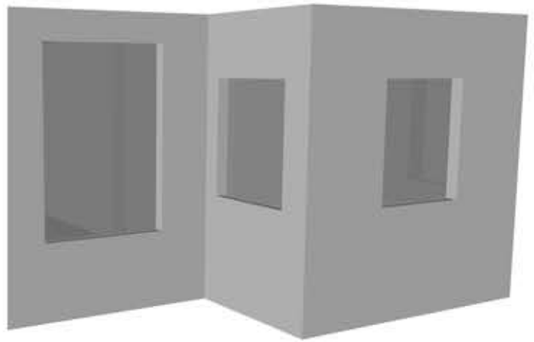
YEARLY RESULTS

PERCENTAGE OF TIME COMFORTABLE	18.48%
PERCENTAGE OF TIME TOO HOT	47.14%
PERCENTAGE OF TIME TOO COLD	34.37%
USEFUL DAYLIGHT ILLUMINANCE	65.93%

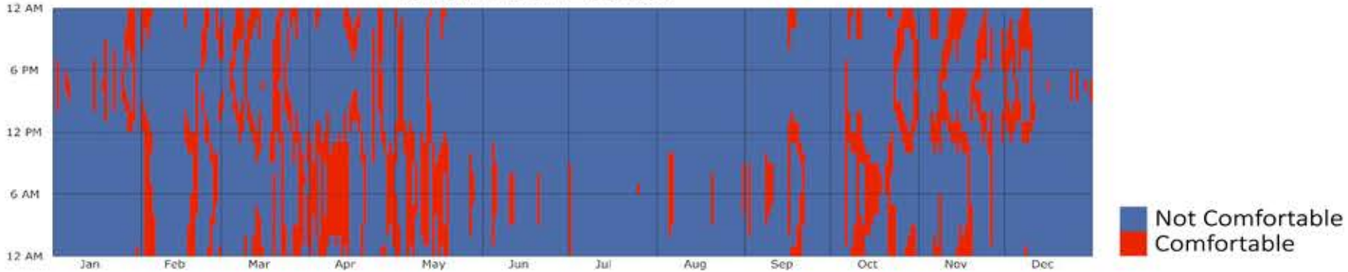
3D VIEW 1



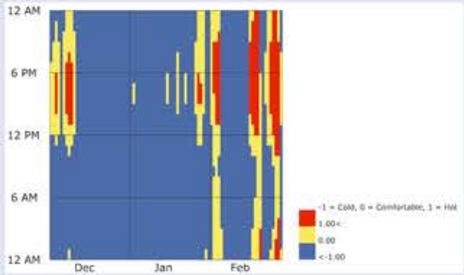
3D VIEW 2



COMFORT CHART



WINTER

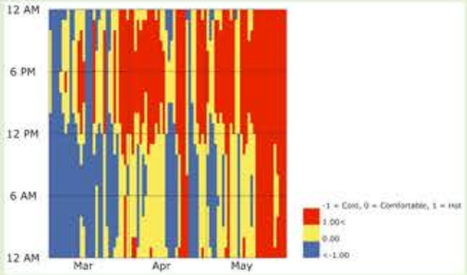


PERCENTAGE OF TIME COMFORTABLE: 13.61%

PERCENTAGE OF TIME TOO HOT: 6.62%

PERCENTAGE OF TIME TOO COLD: 79.76%

SPRING

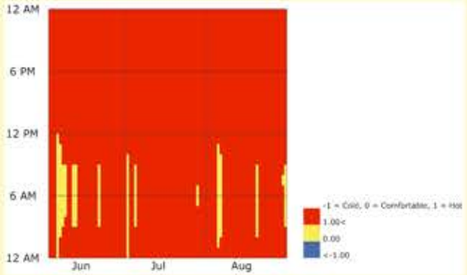


PERCENTAGE OF TIME COMFORTABLE: 32.83%

PERCENTAGE OF TIME TOO HOT: 37.95%

PERCENTAGE OF TIME TOO COLD: 29.21%

SUMMER

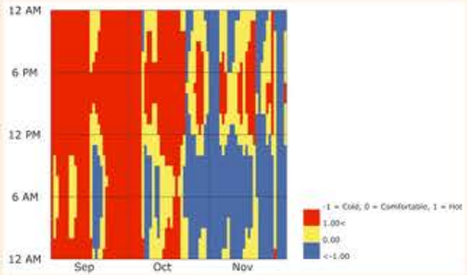


PERCENTAGE OF TIME COMFORTABLE: 4.52%

PERCENTAGE OF TIME TOO HOT: 95.47%

PERCENTAGE OF TIME TOO COLD: 0.00%

FALL



PERCENTAGE OF TIME COMFORTABLE: 22.89%

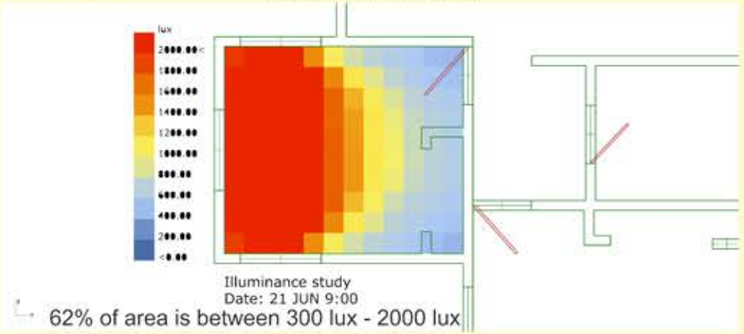
PERCENTAGE OF TIME TOO HOT: 47.66%

PERCENTAGE OF TIME TOO COLD: 29.44%

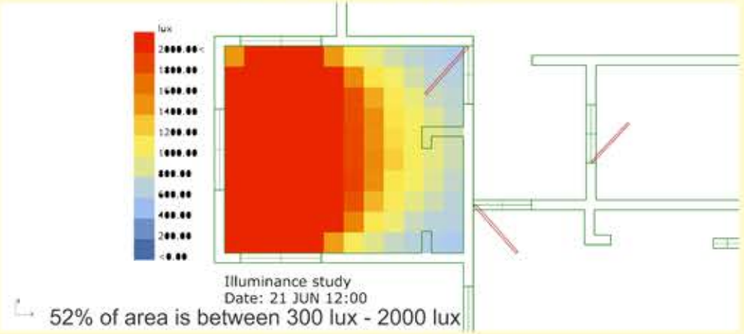
OPTION 5: SMALL SOUTHERN WINDOW+SMALL WESTERN WINDOW+SMALL NORTHERN WINDOW - POINTS IN TIME ANALYSIS

SUMMER SOLSTICE

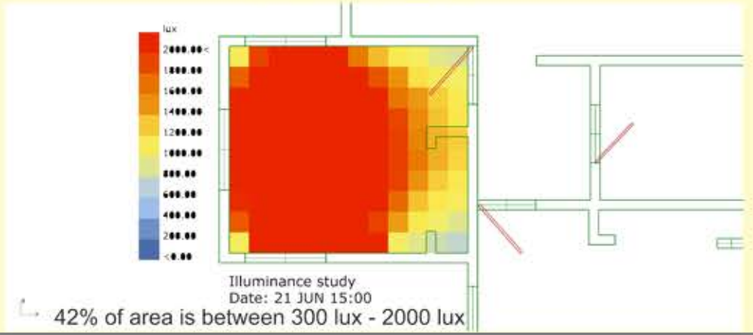
SUMMER 9:00 AM



SUMMER 12:00 PM

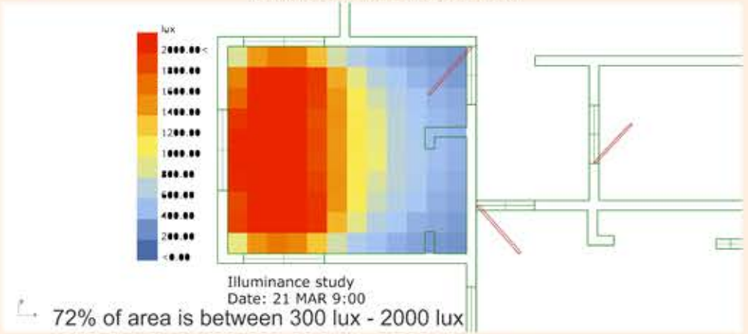


SUMMER 3:00 PM

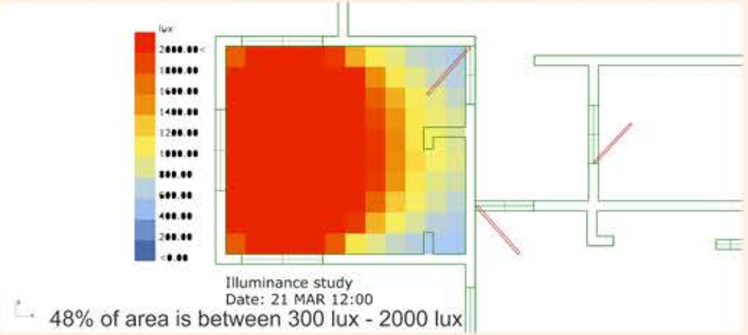


FALL/SPRING EQUINOX

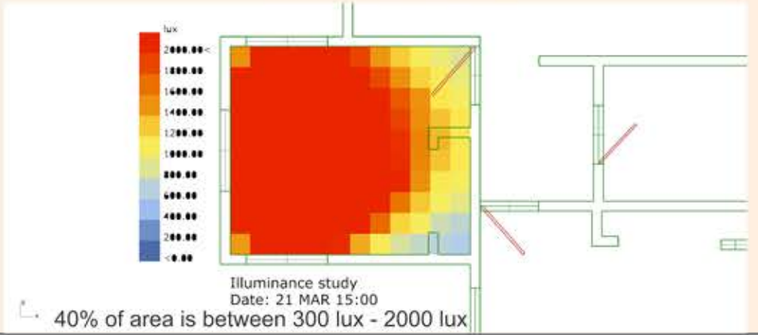
SPRING/FALL 9:00 AM



SPRING/FALL 12:00 PM

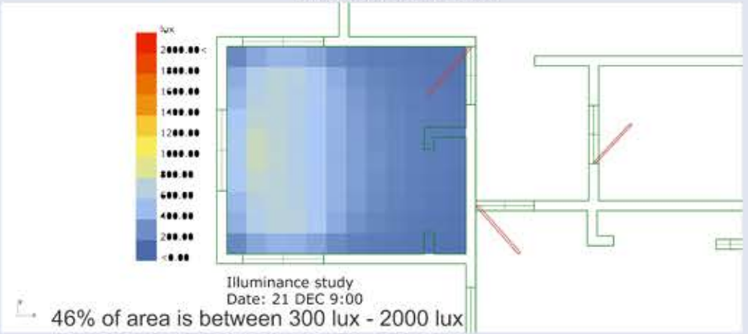


SPRING/FALL 3:00 PM

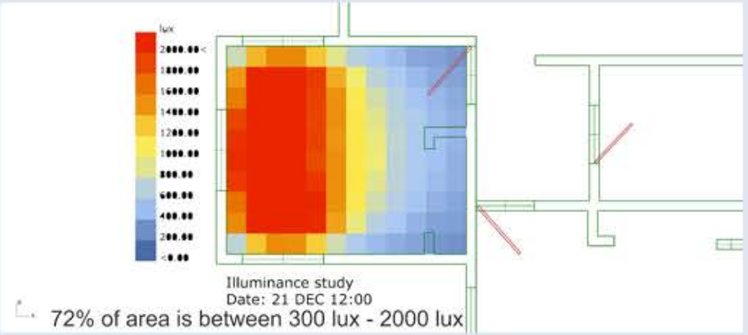


WINTER SOLSTICE

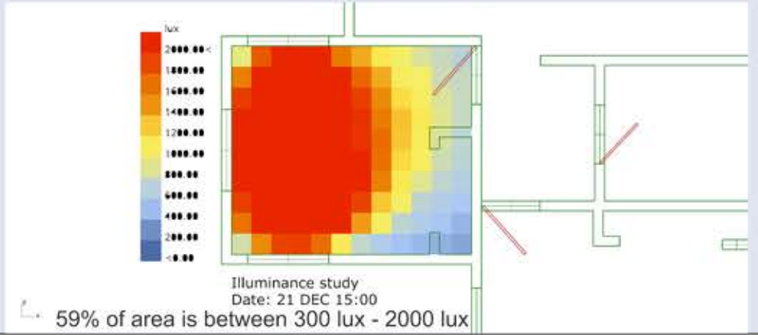
WINTER 9:00 AM



WINTER 12:00 PM

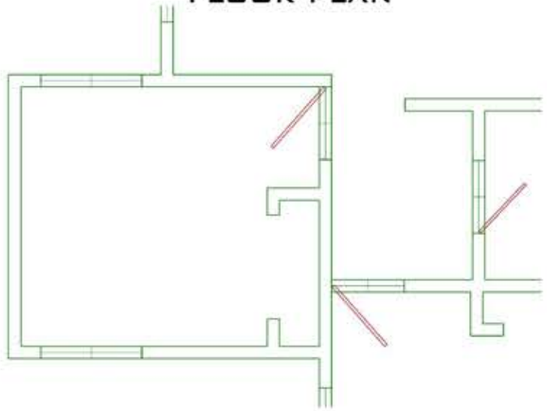


WINTER 3:00 PM



OPTION 6: SMALL SOUTHERN WINDOW + SMALL NORTHERN WINDOW

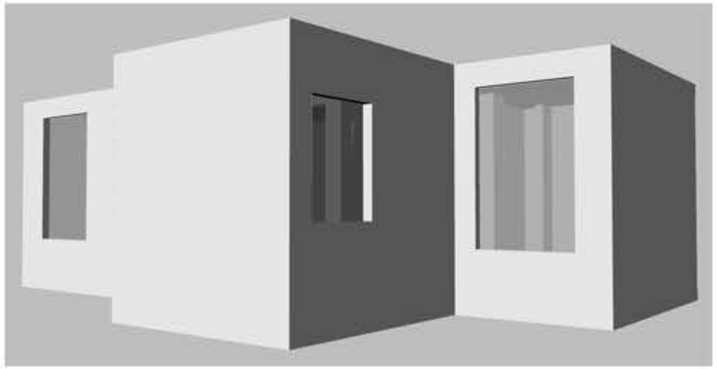
FLOOR PLAN



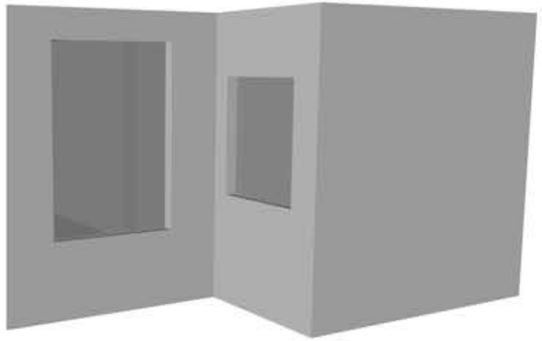
YEARLY RESULTS

PERCENTAGE OF TIME COMFORTABLE	18.21%
PERCENTAGE OF TIME TOO HOT	47.50%
PERCENTAGE OF TIME TOO COLD	34.28%
USEFUL DAYLIGHT ILLUMINANCE	79.50%

3D VIEW 1

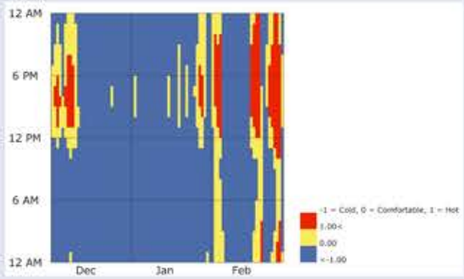


3D VIEW 2



COMFORT CHART

WINTER

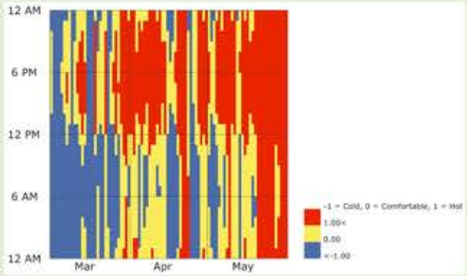


PERCENTAGE OF TIME COMFORTABLE: 13.60%

PERCENTAGE OF TIME TOO HOT: 7.63%

PERCENTAGE OF TIME TOO COLD: 78.84%

SPRING

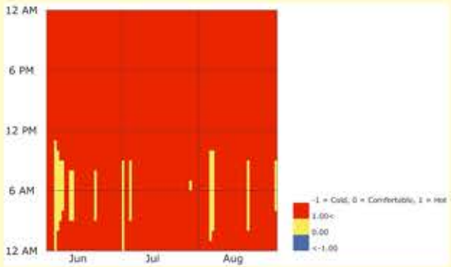


PERCENTAGE OF TIME COMFORTABLE: 31.56%

PERCENTAGE OF TIME TOO HOT: 38.85%

PERCENTAGE OF TIME TOO COLD: 29.57%

SUMMER

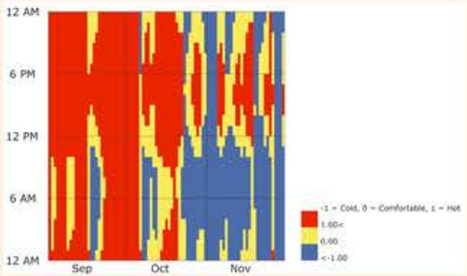


PERCENTAGE OF TIME COMFORTABLE: 5.66%

PERCENTAGE OF TIME TOO HOT: 94.33%

PERCENTAGE OF TIME TOO COLD: 0.00%

FALL



PERCENTAGE OF TIME COMFORTABLE: 22.06%

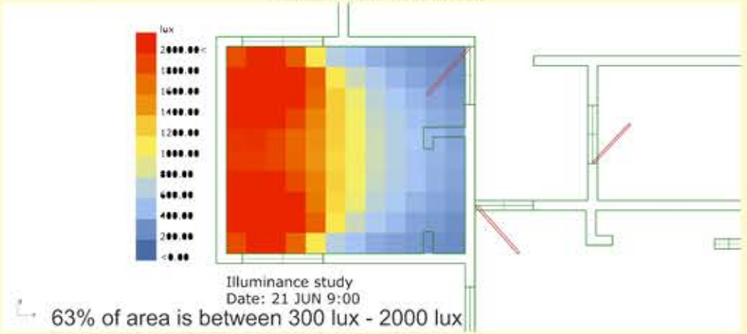
PERCENTAGE OF TIME TOO HOT: 48.30%

PERCENTAGE OF TIME TOO COLD: 29.62%

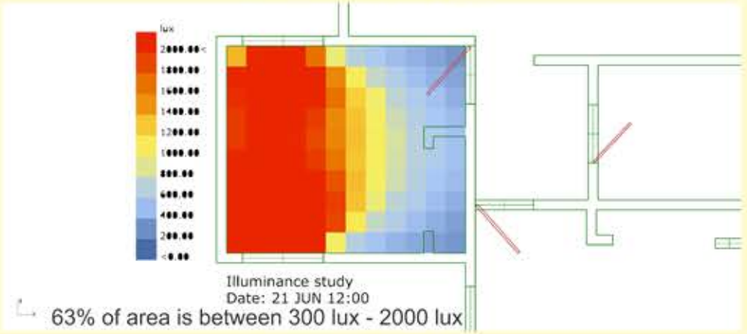
OPTION 6: SMALL SOUTHERN WINDOW+SMALL NORTHERN WINDOW - POINTS IN TIME ANALYSIS

SUMMER SOLSTICE

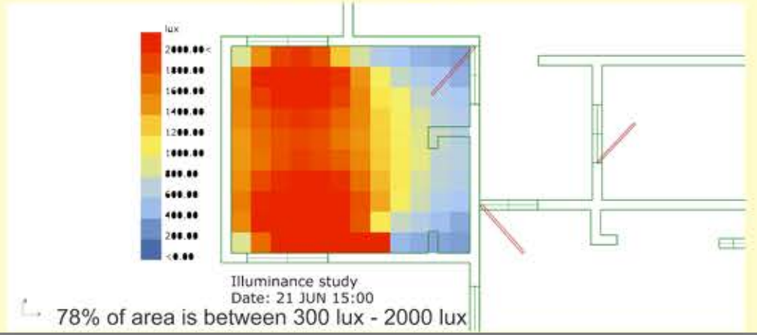
SUMMER 9:00 AM



SUMMER 12:00 PM

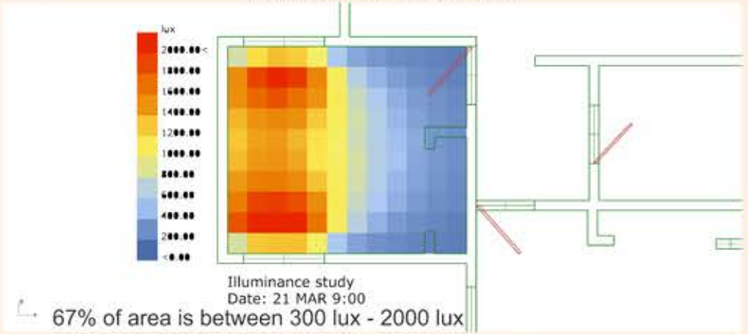


SUMMER 3:00 PM

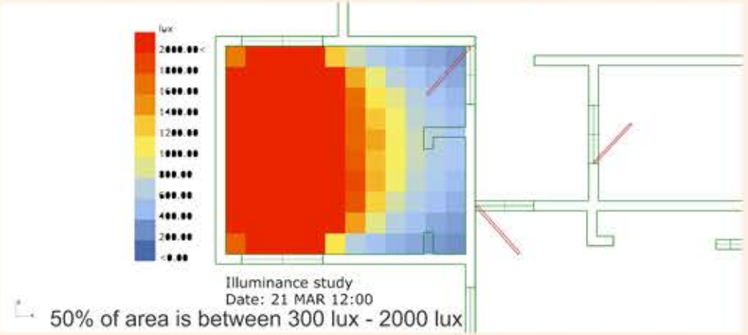


FALL/SPRING EQUINOX

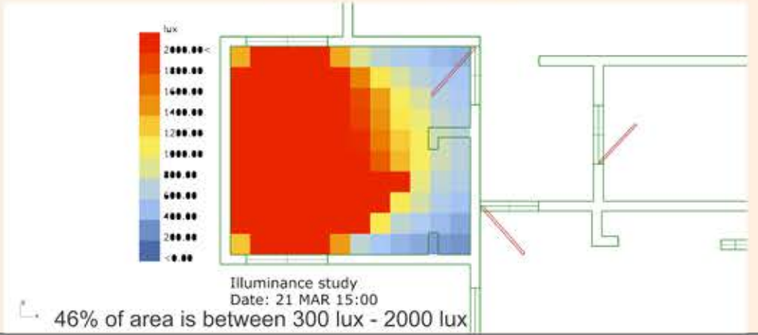
SPRING/FALL 9:00 AM



SPRING/FALL 12:00 PM

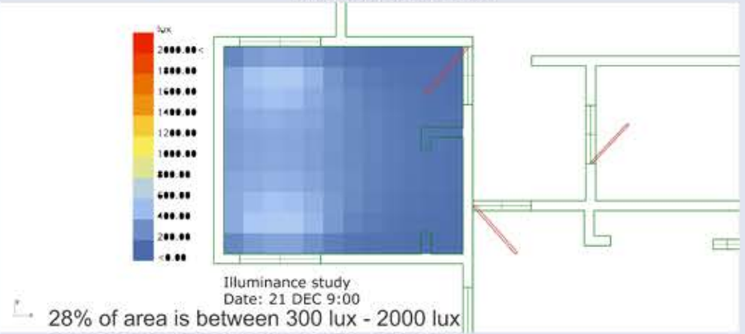


SPRING/FALL 3:00 PM

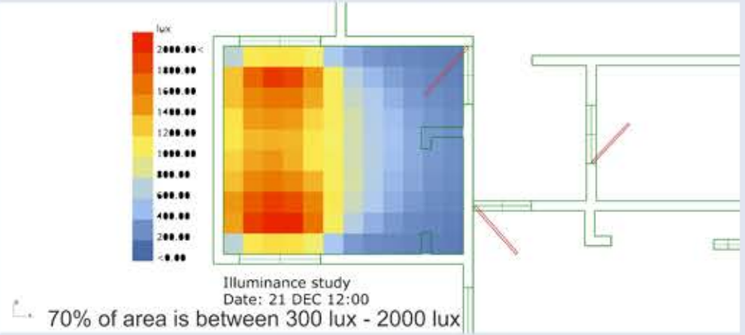


WINTER SOLSTICE

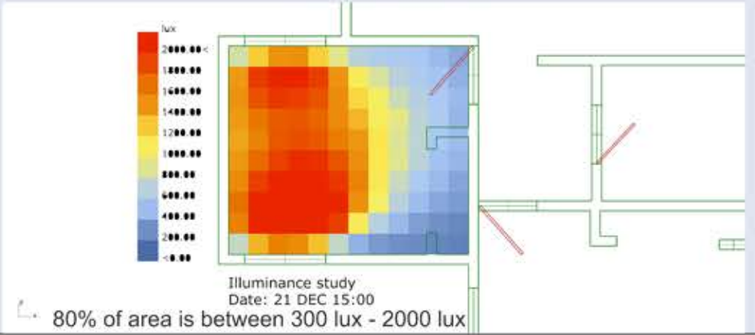
WINTER 9:00 AM



WINTER 12:00 PM

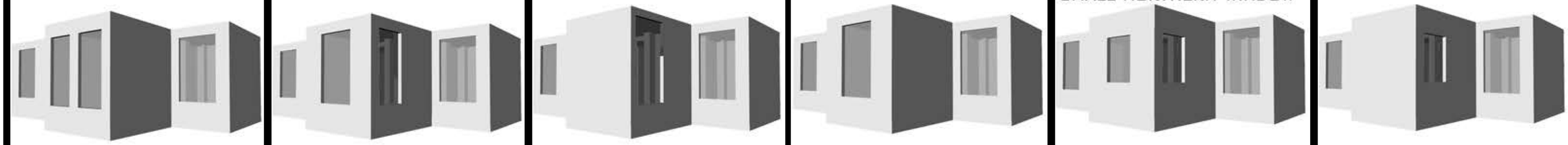


WINTER 3:00 PM



PLACING AND SIZING WINDOWS CONCLUSIONS

LEGEND: BEST 1ST → 6TH WORST



		TWO BIG WESTERN WINDOWS	BIG SOUTHERN WINDOW+ BIG WESTERN WINDOW	BIG SOUTHERN WINDOW+ SMALL NORTHERN WINDOW	BIG WESTERN WINDOW	SMALL SOUTHERN WINDOW+ SMALL WESTERN WINDOW+ SMALL NORTHERN WINDOW	SMALL SOURTHERN WINDOW+ SMALL NORTHERN WINDOW
WINTER	UDI	1ST	6TH	5TH	2ND	4TH	3RD
	COMFORT	5TH	2ND	1ST	6TH	3RD	4TH
SPRING	UDI	2ND	4TH	3RD	1ST	6TH	5TH
	COMFORT	3RD	6TH	4TH	5TH	1ST	2ND
SUMMER	UDI	4TH	5TH	2ND	1ST	6TH	3RD
	COMFORT	4TH	5TH	1ST	6TH	3RD	2ND
FALL	UDI	2ND	4TH	3RD	1ST	6TH	5TH
	COMFORT	3RD	5TH	6TH	4TH	1ST	2ND

BIG SOUTHERN WINDOW+
SMALL NORTHERN WINDOW

5TH
1ST
3RD
4TH
2ND
1ST
3RD
6TH

HAVING A SOUTHERN AND A NORTHERN OPENING EASES THE IMPLEMENTATION OF CROSS VENTILATION IN THE FUTURE.

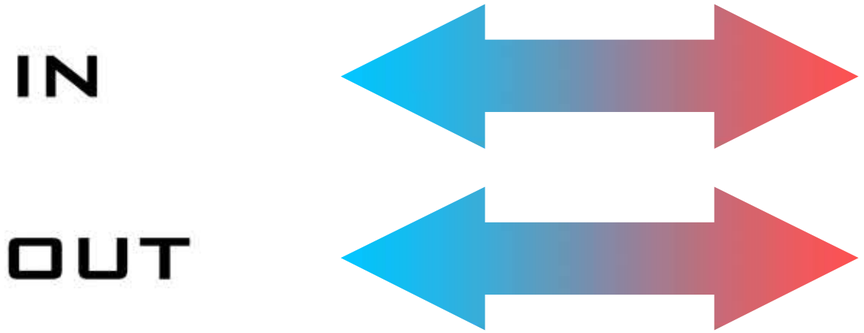
THE BIG OPENING IN THE SOUTH MEANS THERE WILL BE HIGH AMOUNTS OF HEAT GAINS DURING THE WINTER, MAKING THE ROOM MORE COMFORTABLE DURING THIS TIME OF THE YEAR.

SHADING DEVICES MIGHT BE CONSIDERED IN THE FUTURE TO IMPROVE THE CONDITIONS IN THE SUMMER.

EVENTHOUGH USING PARAMENTRIC GEOMETRIES CAN HELP YOU FIND MULTIPLE WINDOW TO WALL RATIOS, USING BREPS WILL GIVE YOU MORE FLEXIBILITY.

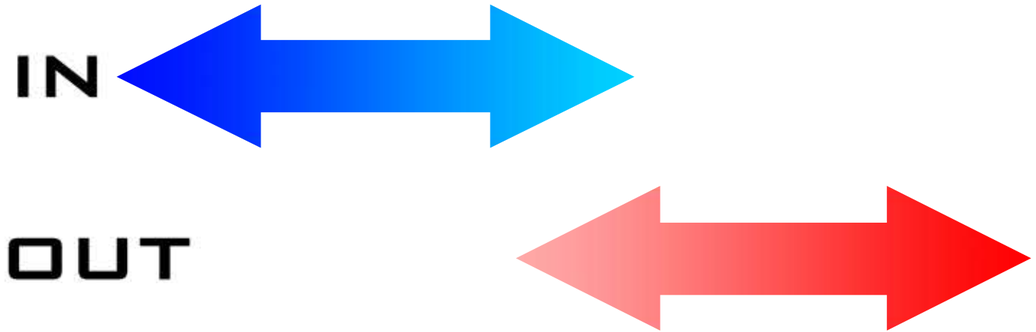
INCORPORATING INDOOR AIR-FLOW

OPTION 1:
SMALL DELTAS: TEMPERATE CONDITIONS

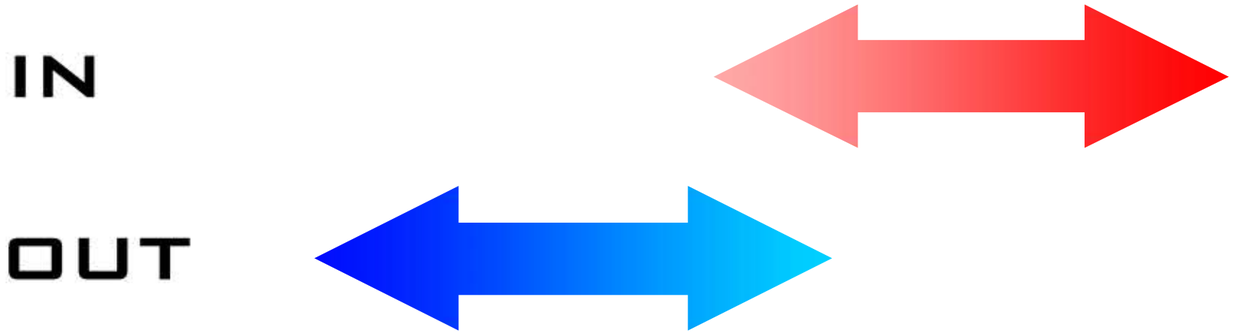


OPTION 2
BIG DELTAS: EXTREME CONDITIONS

OPTION 3:
SMALL DELTAS: COLD INSIDE/HOT OUTSIDE



OPTION 4:
SMALL DELTAS: HOT INSIDE/COLD OUTSIDE



OPTION 1: SMALL DELTAS: TEMPERATE CONDITIONS WITHOUT WIND DRIVEN CROSS VENTILATION

INDOOR TEMPERATURE FOR AIR-FLOW:

MIN: 24°C — MAX: 27°C

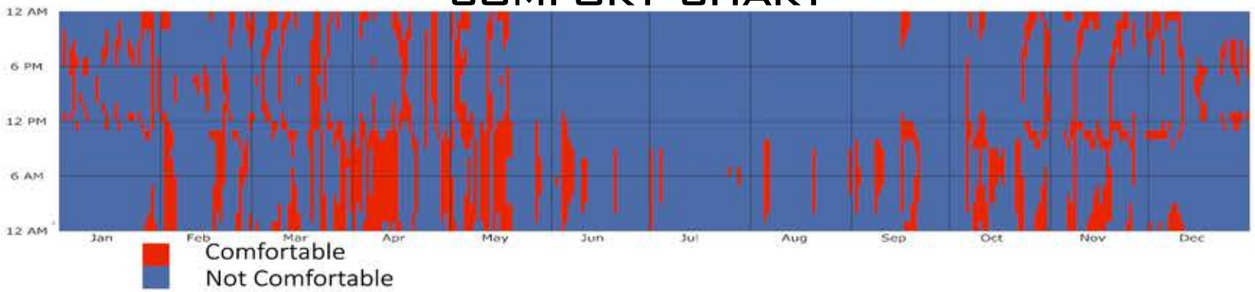
OUTDOOR TEMPERATURE FOR AIR-FLOW:

MIN: 22°C — MAX: 30°C

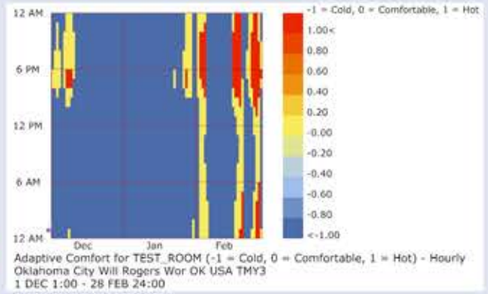
YEARLY COMFORT RESULTS: WITHOUT WIND-DRIVEN CROSS VENTILATION

PERCENTAGE OF TIME COMFORTABLE	17.12%
PERCENTAGE OF TIME TOO HOT	55.15%
PERCENTAGE OF TIME TOO COLD	27.71%
INFILTRATION RATE (AIR TIGHT)	0.0001 M3/S PER M2

COMFORT CHART



WINTER

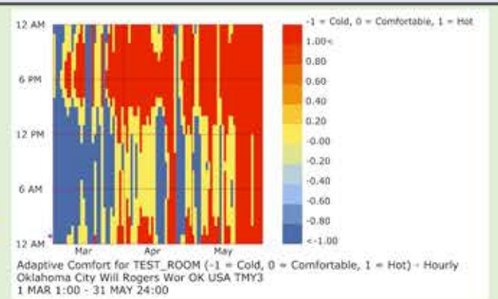


PERCENTAGE OF TIME COMFORTABLE: 11.44%

PERCENTAGE OF TIME TOO HOT: 5.14%

PERCENTAGE OF TIME TOO COLD: 83.43%

SPRING

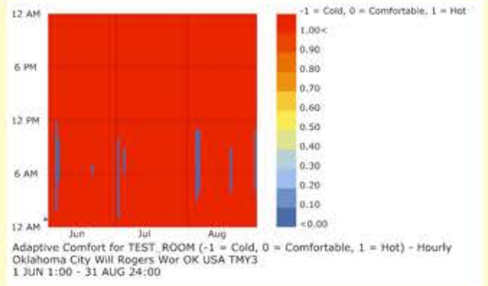


PERCENTAGE OF TIME COMFORTABLE: 28.85%

PERCENTAGE OF TIME TOO HOT: 43.75%

PERCENTAGE OF TIME TOO COLD: 27.40%

SUMMER

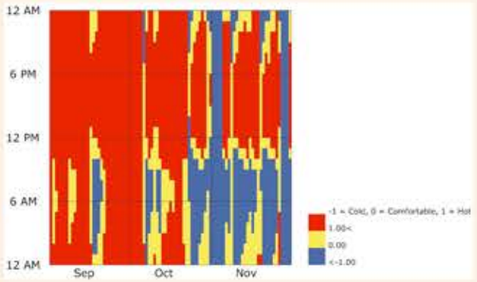


PERCENTAGE OF TIME COMFORTABLE: 2.49%

PERCENTAGE OF TIME TOO HOT: 97.51%

PERCENTAGE OF TIME TOO COLD: 0.00%

FALL



PERCENTAGE OF TIME COMFORTABLE: 17.81%

PERCENTAGE OF TIME TOO HOT: 59.79%

PERCENTAGE OF TIME TOO COLD: 22.39%

OPTION 1: SMALL DELTAS: TEMPERATE CONDITIONS WITH WIND-DRIVEN CROSS VENTILATION

INDOOR TEMPERATURE CONDITIONS FOR AIR-FLOW TO HAPPEN:

MIN: 24°C ⟷ MAX: 27°C

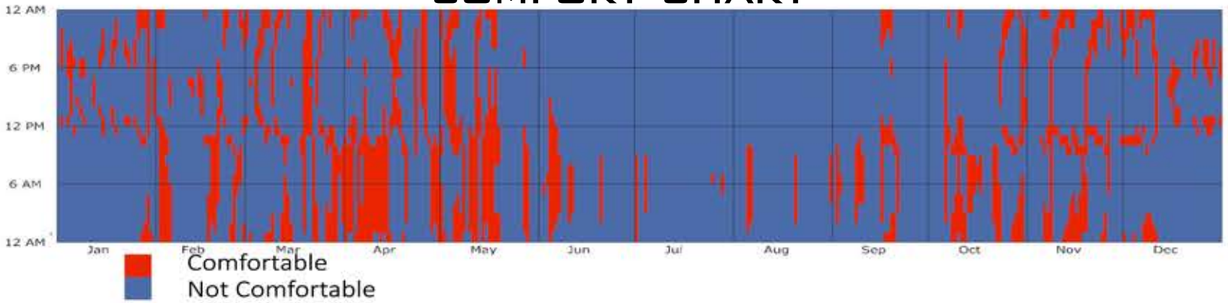
OUTDOOR TEMPERATURE CONDITIONS FOR AIR-FLOW TO HAPPEN:

MIN: 22°C ⟷ MAX: 30°C

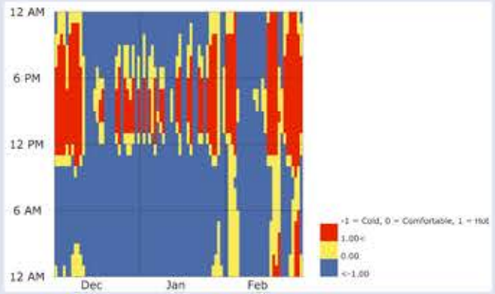
YEARLY COMFORT RESULTS: WITH WIND-DRIVEN CROSS VENTILATION

PERCENTAGE OF TIME COMFORTABLE	17.64%
PERCENTAGE OF TIME TOO HOT	54.55%
PERCENTAGE OF TIME TOO COLD	27.79%
INFILTRATION RATE (AIR TIGHT)	0.0001 M3/S PER M2

COMFORT CHART



WINTER

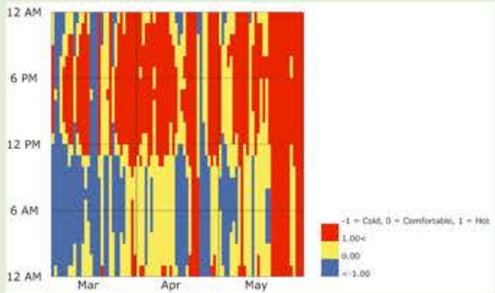


PERCENTAGE OF TIME COMFORTABLE: 15.55%

PERCENTAGE OF TIME TOO HOT: 19.35%

PERCENTAGE OF TIME TOO COLD: 65.09%

SPRING

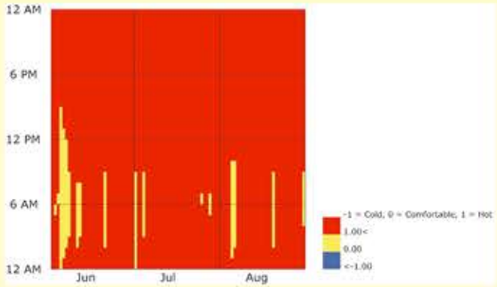


PERCENTAGE OF TIME COMFORTABLE: 31.97%

PERCENTAGE OF TIME TOO HOT: 43.70%

PERCENTAGE OF TIME TOO COLD: 24.32%

SUMMER

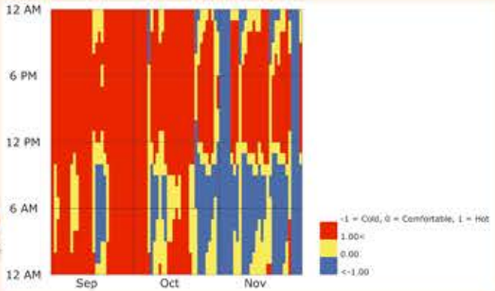


PERCENTAGE OF TIME COMFORTABLE: 4.98%

PERCENTAGE OF TIME TOO HOT: 95.01%

PERCENTAGE OF TIME TOO COLD: 0.00%

FALL



PERCENTAGE OF TIME COMFORTABLE: 18.04%

PERCENTAGE OF TIME TOO HOT: 59.43%

PERCENTAGE OF TIME TOO COLD: 22.52%

OPTION 2: BIG DELTAS: EXTREME CONDITIONS WITHOUT WIND-DRIVEN CROSS VENTILATION

INDOOR TEMPERATURE CONDITIONS FOR AIR-FLOW TO HAPPEN:

MIN: 20°C ⟷ MAX: 35°C

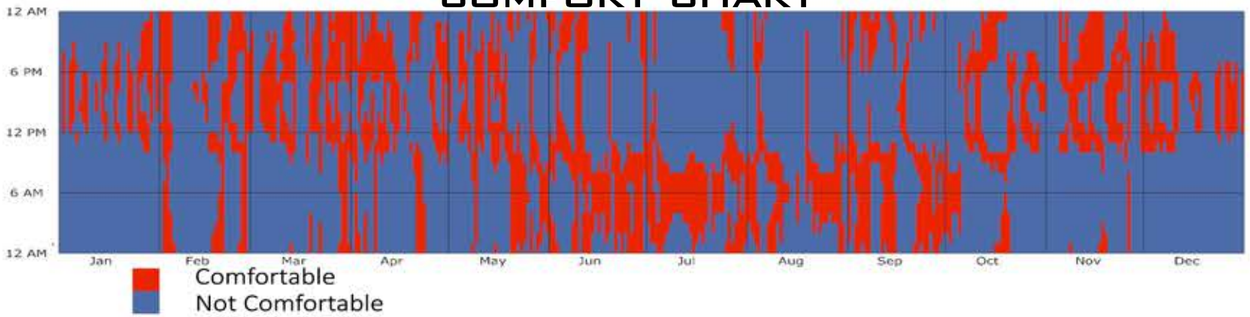
OUTDOOR TEMPERATURE CONDITIONS FOR AIR-FLOW TO HAPPEN:

MIN: 0°C ⟷ MAX: 30°C

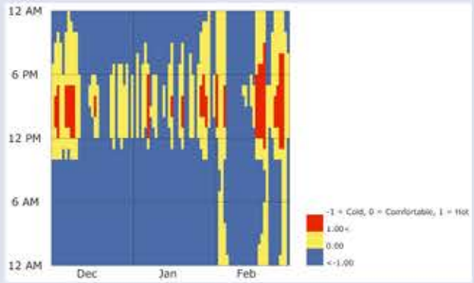
YEARLY COMFORT RESULTS: WITHOUT WIND-DRIVEN CROSS VENTILATION

PERCENTAGE OF TIME COMFORTABLE	30.36%
PERCENTAGE OF TIME TOO HOT	26.42%
PERCENTAGE OF TIME TOO COLD	43.20%
INFILTRATION RATE (AIR TIGHT)	0.0001 M3/S PER M2

COMFORT CHART



WINTER

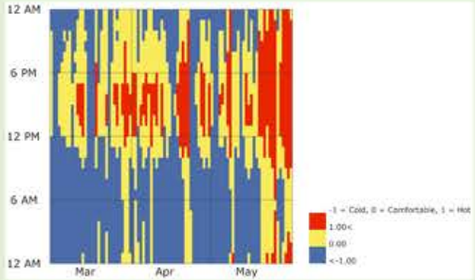


PERCENTAGE OF TIME COMFORTABLE: 23.33%

PERCENTAGE OF TIME TOO HOT: 5.23%

PERCENTAGE OF TIME TOO COLD: 71.43%

SPRING

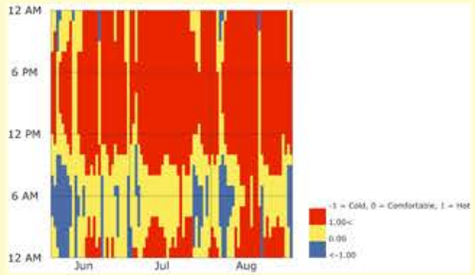


PERCENTAGE OF TIME COMFORTABLE: 34.55%

PERCENTAGE OF TIME TOO HOT: 15.94%

PERCENTAGE OF TIME TOO COLD: 49.50%

SUMMER

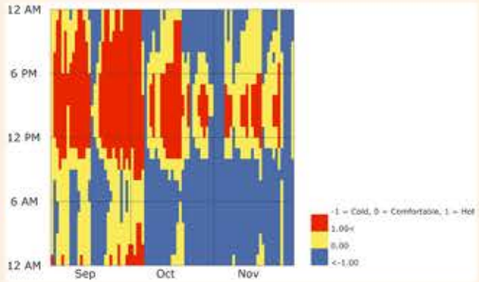


PERCENTAGE OF TIME COMFORTABLE: 32.06%

PERCENTAGE OF TIME TOO HOT: 58.83%

PERCENTAGE OF TIME TOO COLD: 9.10%

FALL



PERCENTAGE OF TIME COMFORTABLE: 30.36%

PERCENTAGE OF TIME TOO HOT: 26.42%

PERCENTAGE OF TIME TOO COLD: 43.20%

OPTION 2: BIG DELTAS: EXTREME CONDITIONS WITH WIND-DRIVEN CROSS VENTILATION

INDOOR TEMPERATURE CONDITIONS FOR AIR-FLOW TO HAPPEN:

MIN: 20°C ⟷ MAX: 35°C

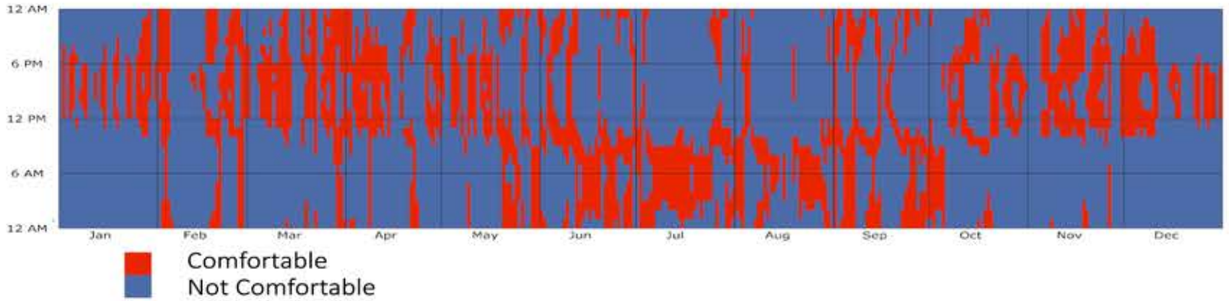
OUTDOOR TEMPERATURE CONDITIONS FOR AIR-FLOW TO HAPPEN:

MIN: 0°C ⟷ MAX: 30°C

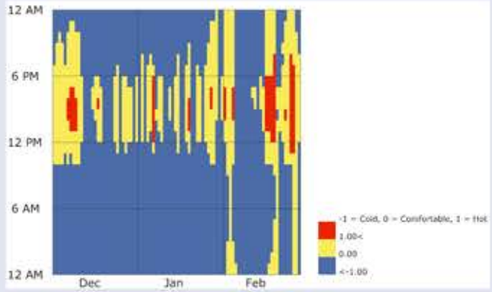
YEARLY COMFORT RESULTS: WITH WIND-DRIVEN CROSS VENTILATION

PERCENTAGE OF TIME COMFORTABLE	30.13%
PERCENTAGE OF TIME TOO HOT	22.29%
PERCENTAGE OF TIME TOO COLD	47.56%
INFILTRATION RATE (AIR TIGHT)	0.0001 M3/S PER M2

COMFORT CHART



WINTER

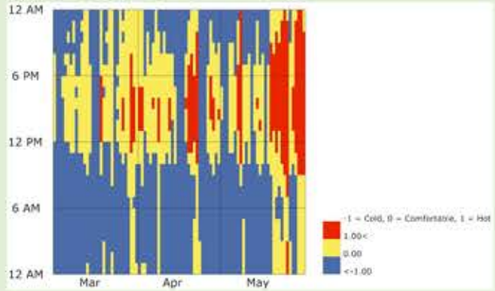


PERCENTAGE OF TIME COMFORTABLE: 24.12%

PERCENTAGE OF TIME TOO HOT: 3.37%

PERCENTAGE OF TIME TOO COLD: 72.5%

SPRING

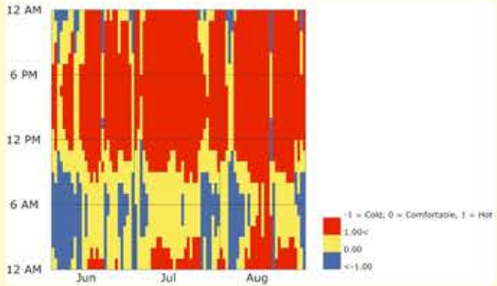


PERCENTAGE OF TIME COMFORTABLE: 33.28%

PERCENTAGE OF TIME TOO HOT: 11.14%

PERCENTAGE OF TIME TOO COLD: 55.57%

SUMMER

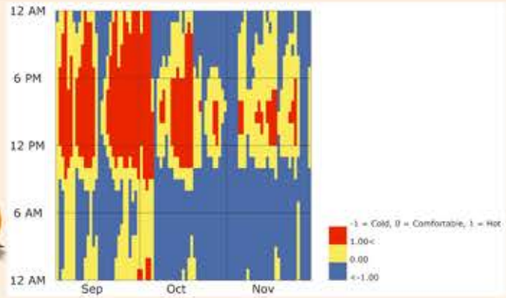


PERCENTAGE OF TIME COMFORTABLE: 31.74%

PERCENTAGE OF TIME TOO HOT: 53.66%

PERCENTAGE OF TIME TOO COLD: 14.58%

FALL



PERCENTAGE OF TIME COMFORTABLE: 31.27%

PERCENTAGE OF TIME TOO HOT: 20.55%

PERCENTAGE OF TIME TOO COLD: 48.16%

OPTION 3: SMALL DELTAS: COLD INSIDE/HOT OUTSIDE WITHOUT WIND-DRIVEN CROSS VENTILATION

INDOOR TEMPERATURE CONDITIONS FOR AIR-FLOW TO HAPPEN:

MIN: 20°C ⟷ MAX: 35°C

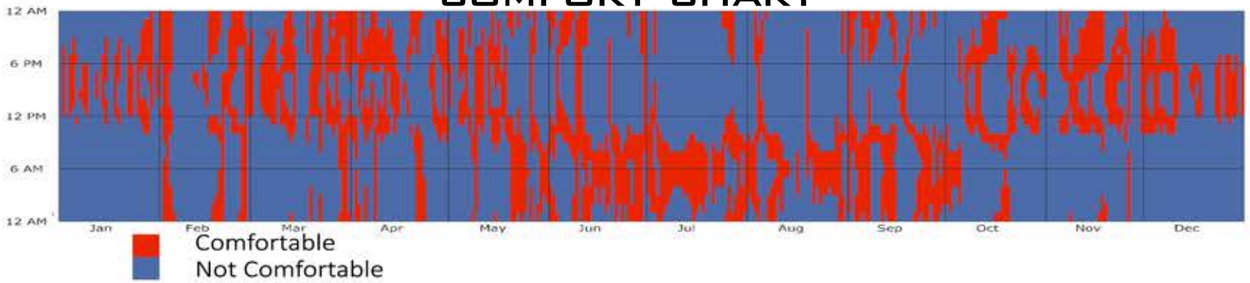
OUTDOOR TEMPERATURE CONDITIONS FOR AIR-FLOW TO HAPPEN:

MIN: 0°C ⟷ MAX: 30°C

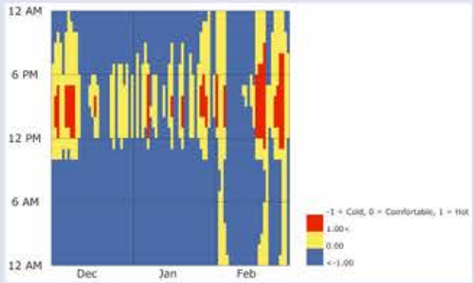
YEARLY COMFORT RESULTS: WITHOUT WIND-DRIVEN CROSS VENTILATION

PERCENTAGE OF TIME COMFORTABLE	30.36%
PERCENTAGE OF TIME TOO HOT	26.42%
PERCENTAGE OF TIME TOO COLD	43.20%
INFILTRATION RATE (AIR TIGHT)	0.0001 M3/S PER M2

COMFORT CHART



WINTER

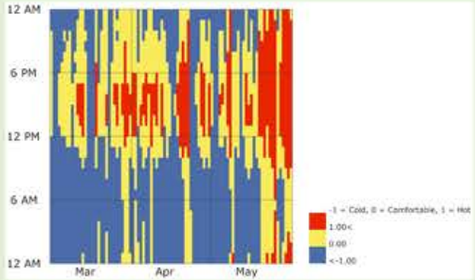


PERCENTAGE OF TIME COMFORTABLE: 23.33%

PERCENTAGE OF TIME TOO HOT: 5.23%

PERCENTAGE OF TIME TOO COLD: 71.43%

SPRING

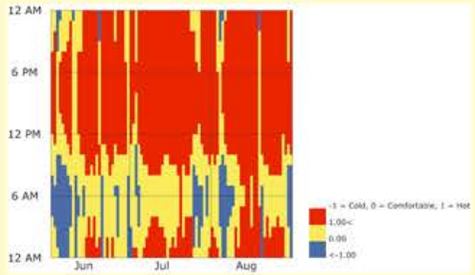


PERCENTAGE OF TIME COMFORTABLE: 34.55%

PERCENTAGE OF TIME TOO HOT: 15.94%

PERCENTAGE OF TIME TOO COLD: 49.50%

SUMMER

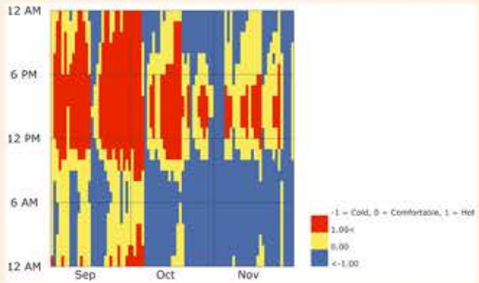


PERCENTAGE OF TIME COMFORTABLE: 32.06%

PERCENTAGE OF TIME TOO HOT: 58.83%

PERCENTAGE OF TIME TOO COLD: 9.10%

FALL



PERCENTAGE OF TIME COMFORTABLE: 30.36%

PERCENTAGE OF TIME TOO HOT: 26.42%

PERCENTAGE OF TIME TOO COLD: 43.20%

OPTION 3: SMALL DELTAS: COLD INSIDE/HOT OUTSIDE WITH WIND-DRIVEN CROSS VENTILATION

INDOOR TEMPERATURE CONDITIONS FOR AIR-FLOW TO HAPPEN:

MIN: 20°C ⟷ MAX: 35°C

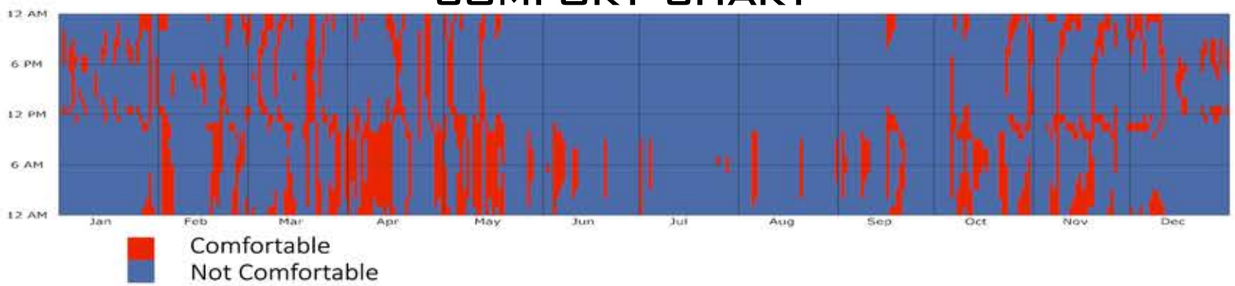
OUTDOOR TEMPERATURE CONDITIONS FOR AIR-FLOW TO HAPPEN:

MIN: 0°C ⟷ MAX: 30°C

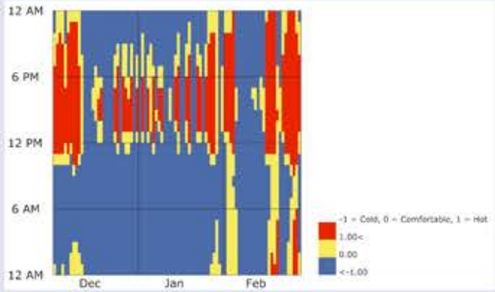
YEARLY COMFORT RESULTS: WITH WIND-DRIVEN CROSS VENTILATION

PERCENTAGE OF TIME COMFORTABLE	16.60%
PERCENTAGE OF TIME TOO HOT	55.78%
PERCENTAGE OF TIME TOO COLD	27.60%
INFILTRATION RATE (AIR TIGHT)	0.0001 M3/S PER M2

COMFORT CHART



WINTER

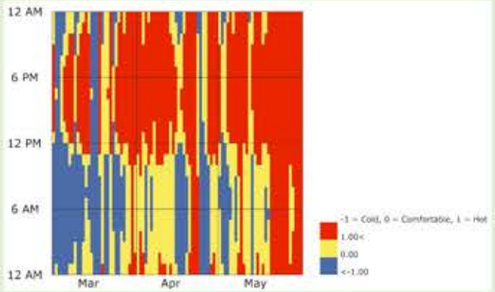


PERCENTAGE OF TIME COMFORTABLE: 15.55%

PERCENTAGE OF TIME TOO HOT: 19.39%

PERCENTAGE OF TIME TOO COLD: 65.04%

SPRING

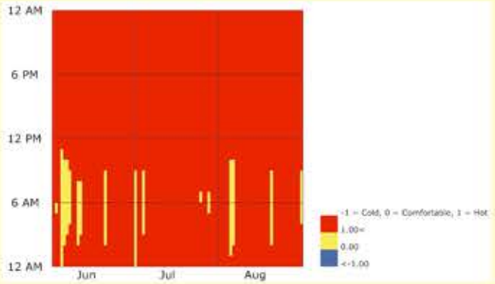


PERCENTAGE OF TIME COMFORTABLE: 28.84%

PERCENTAGE OF TIME TOO HOT: 47.37%

PERCENTAGE OF TIME TOO COLD: 23.77%

SUMMER

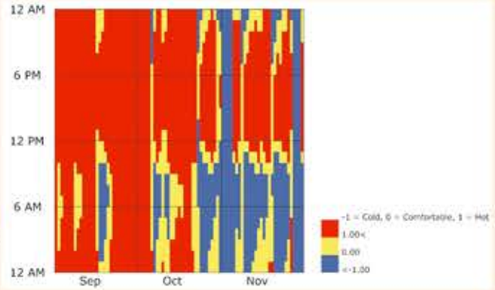


PERCENTAGE OF TIME COMFORTABLE: 4.39%

PERCENTAGE OF TIME TOO HOT: 95.60%

PERCENTAGE OF TIME TOO COLD: 0.00%

FALL



PERCENTAGE OF TIME COMFORTABLE: 17.62%

PERCENTAGE OF TIME TOO HOT: 60.02%

PERCENTAGE OF TIME TOO COLD: 22.34%

OPTION 4: SMALL DELTAS: HOT INSIDE/COLD OUTSIDE WITHOUT WIND-DRIVEN CROSS VENTILATION

INDOOR TEMPERATURE CONDITIONS FOR AIR-FLOW TO HAPPEN:

MIN: 30°C ⟷ MAX: 35°C

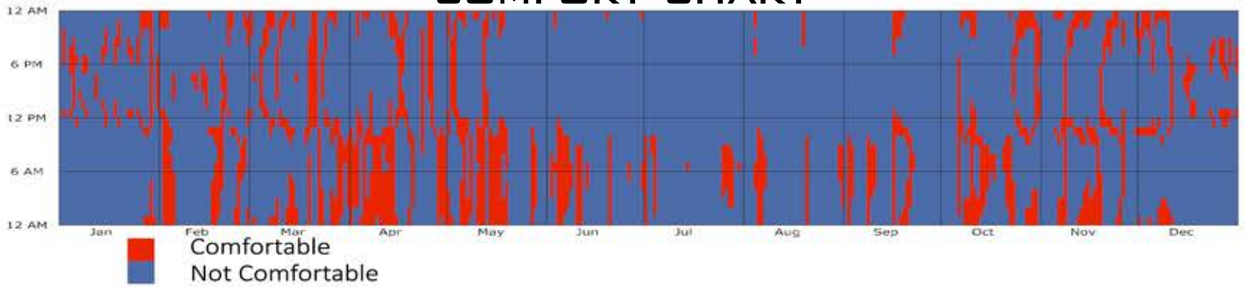
OUTDOOR TEMPERATURE CONDITIONS FOR AIR-FLOW TO HAPPEN:

MIN: 20°C ⟷ MAX: 25°C

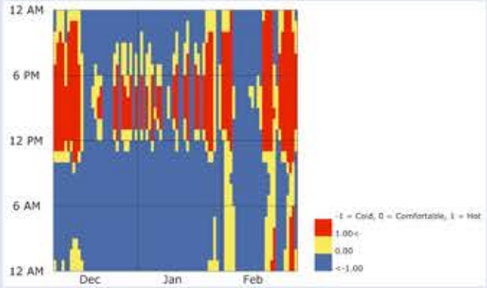
YEARLY COMFORT RESULTS: WITHOUT WIND-DRIVEN CROSS VENTILATION

PERCENTAGE OF TIME COMFORTABLE	18.18%
PERCENTAGE OF TIME TOO HOT	53.71%
PERCENTAGE OF TIME TOO COLD	28.10%
INFILTRATION RATE (AIR TIGHT)	0.0001 M3/S PER M2

COMFORT CHART



WINTER

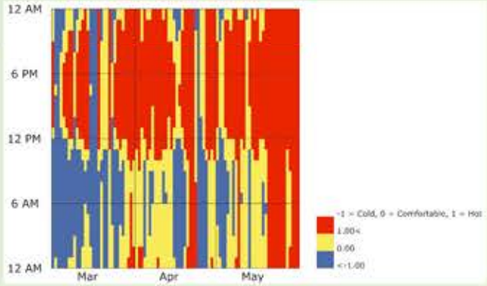


PERCENTAGE OF TIME COMFORTABLE: 15.50%

PERCENTAGE OF TIME TOO HOT: 19.25%

PERCENTAGE OF TIME TOO COLD: 65.23%

SPRING

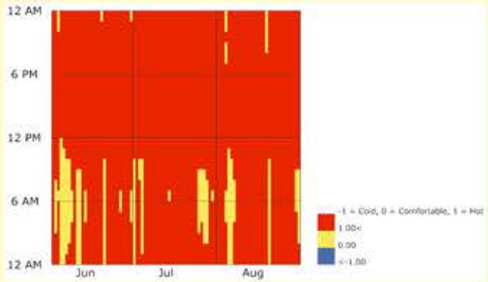


PERCENTAGE OF TIME COMFORTABLE: 29.57%

PERCENTAGE OF TIME TOO HOT: 45.78%

PERCENTAGE OF TIME TOO COLD: 24.63%

SUMMER

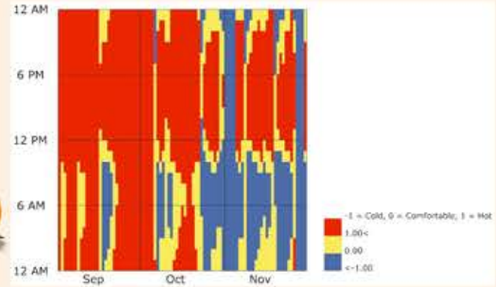


PERCENTAGE OF TIME COMFORTABLE: 4.39%

PERCENTAGE OF TIME TOO HOT: 95.60%

PERCENTAGE OF TIME TOO COLD: 0.00%

FALL



PERCENTAGE OF TIME COMFORTABLE: 18.86%

PERCENTAGE OF TIME TOO HOT: 57.82%

PERCENTAGE OF TIME TOO COLD: 23.30%

OPTION 4: SMALL DELTAS: HOT INSIDE/COLD OUTSIDE WITH WIND-DRIVEN CROSS VENTILATION

INDOOR TEMPERATURE CONDITIONS FOR AIR-FLOW TO HAPPEN:

MIN: 30°C ⟷ MAX: 35°C

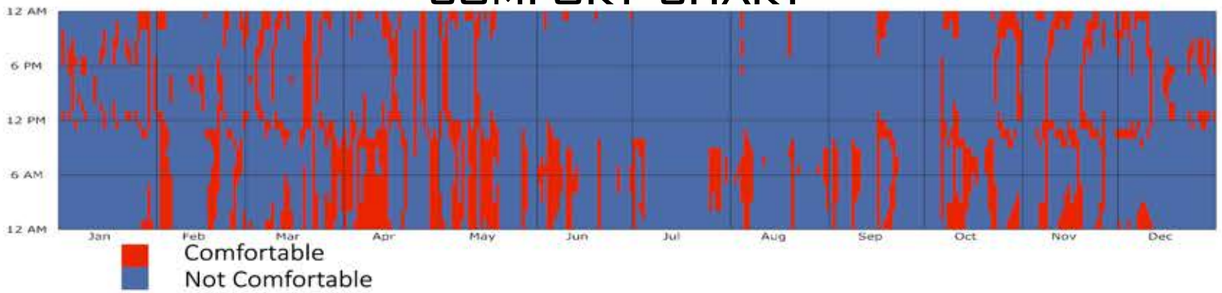
OUTDOOR TEMPERATURE CONDITIONS FOR AIR-FLOW TO HAPPEN:

MIN: 20°C ⟷ MAX: 25°C

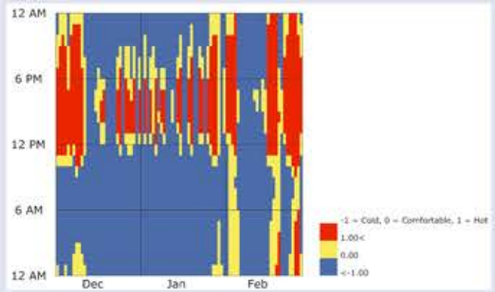
YEARLY COMFORT RESULTS: WITH WIND-DRIVEN CROSS VENTILATION

PERCENTAGE OF TIME COMFORTABLE	18.48%
PERCENTAGE OF TIME TOO HOT	53.34%
PERCENTAGE OF TIME TOO COLD	28.17%
INFILTRATION RATE (AIR TIGHT)	0.0001 M3/S PER M2

COMFORT CHART



WINTER

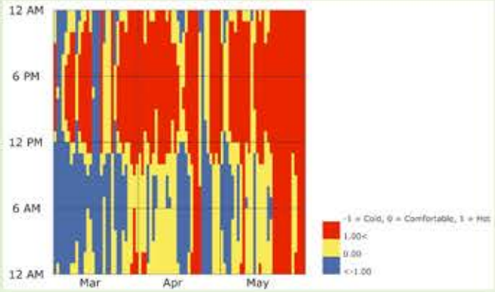


PERCENTAGE OF TIME COMFORTABLE: 15.50%

PERCENTAGE OF TIME TOO HOT: 19.25%

PERCENTAGE OF TIME TOO COLD: 65.23%

SPRING

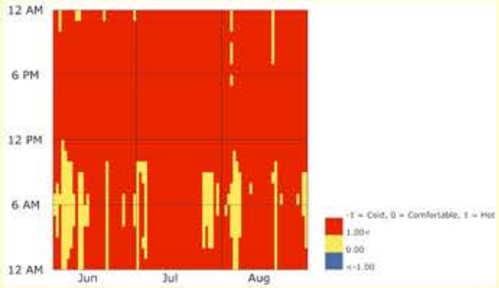


PERCENTAGE OF TIME COMFORTABLE: 29.66%

PERCENTAGE OF TIME TOO HOT: 45.60%

PERCENTAGE OF TIME TOO COLD: 24.72%

SUMMER

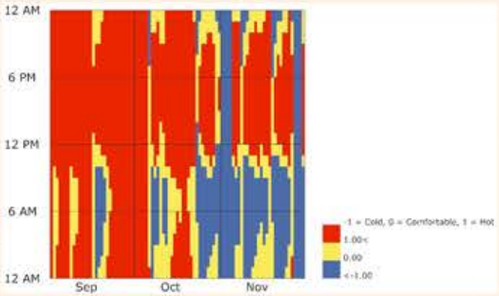


PERCENTAGE OF TIME COMFORTABLE: 9.82%

PERCENTAGE OF TIME TOO HOT: 90.17%

PERCENTAGE OF TIME TOO COLD: 0.00%

FALL



PERCENTAGE OF TIME COMFORTABLE: 18.86%

PERCENTAGE OF TIME TOO HOT: 57.64%

PERCENTAGE OF TIME TOO COLD: 23.48%

INTERIOR AIR-FLOW CONCLUSIONS

LEGEND

BEST 1ST

7TH WORST

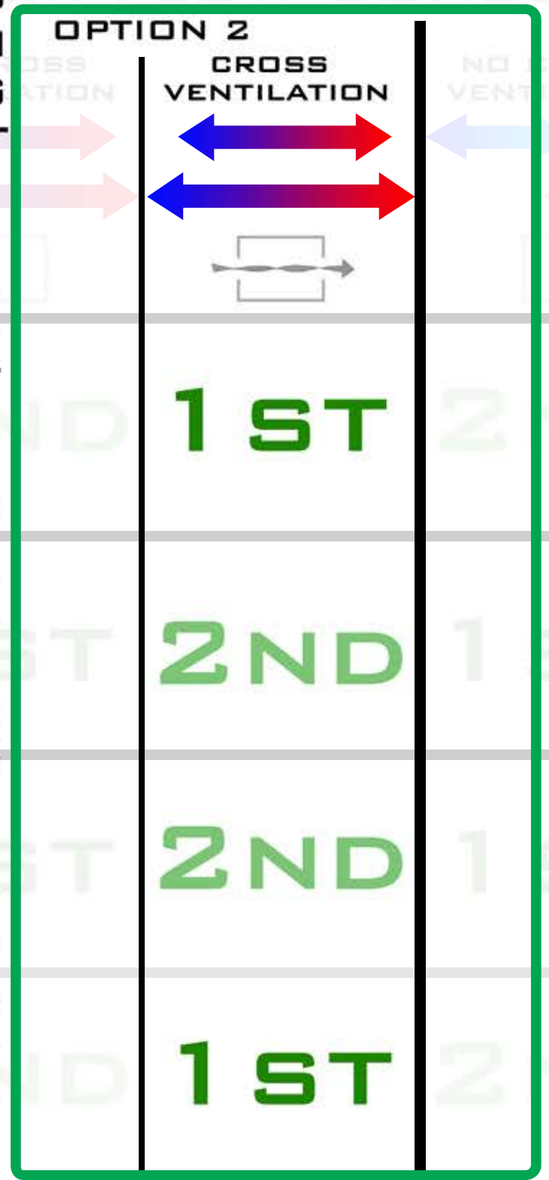
	OPTION 1		OPTION 2		OPTION 3		OPTION 4	
	NO CROSS VENTILATION	CROSS VENTILATION	NO CROSS VENTILATION	CROSS VENTILATION	NO CROSS VENTILATION	CROSS VENTILATION	NO CROSS VENTILATION	CROSS VENTILATION
WINTER COMFORT %	5TH	3RD	2ND	1ST	2ND	3RD	4TH	4TH
SPRING COMFORT %	6TH	3RD	1ST	2ND	1ST	7TH	5TH	4TH
SUMMER COMFORT %	5TH	4TH	1ST	2ND	1ST	6TH	6TH	3RD
FALL COMFORT %	5TH	4TH	2ND	1ST	2ND	6TH	3RD	3RD

HAVING A BIG DELTA ALLOWS YOU TO USE THE WINDOW WITH MORE FLEXIBILITY DURING MORE MOMENTS THROUGHOUT THE YEAR.

CHANGING THE MINIMUM AND MAXIMUM INDOOR/OUTDOOR VALUES HAS A MASSIVE EFFECT ON THE COMFORT LEVELS.

ACTIVATING CROSS VENTILATION ALSO HAD A HUGE IMPACT IN THE THERMAL COMFORT, PROVING THAT HAVING A SOUTHERN AND NORTHERN WINDOW WAS USEFUL.

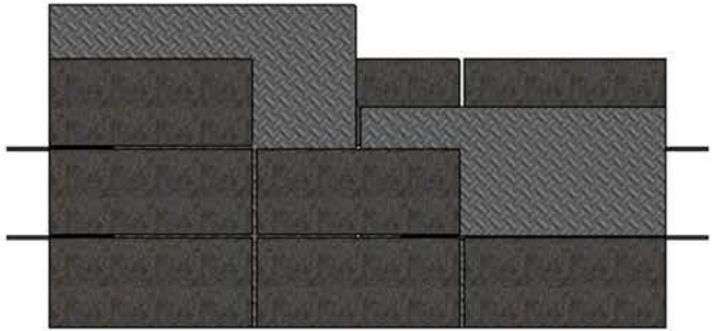
HAVING VERY DIFFERENT RANGES FOR INDOOR AND OUTDOOR TEMPERATURE WILL PRODUCE HIGH DISCOMFORT, BECAUSE OF THE THERMAL BRIDGING GENERATED.



WALL MATERIALS SELECTION

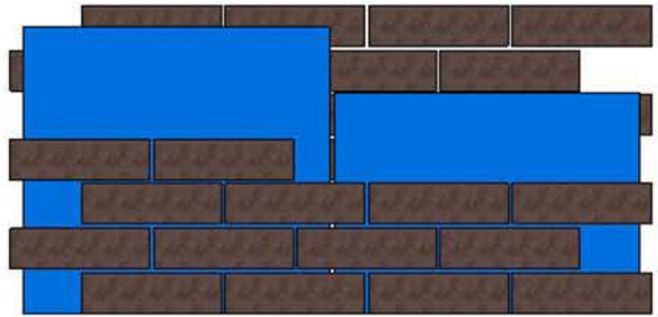
OPTION 1:

(CMU) CONCRETE EXTERIOR MASONRY WALL+
VACUUM INSULATED PANEL+
(CMU) CONCRETE INTERIOR MASONRY WALL



OPTION 2:

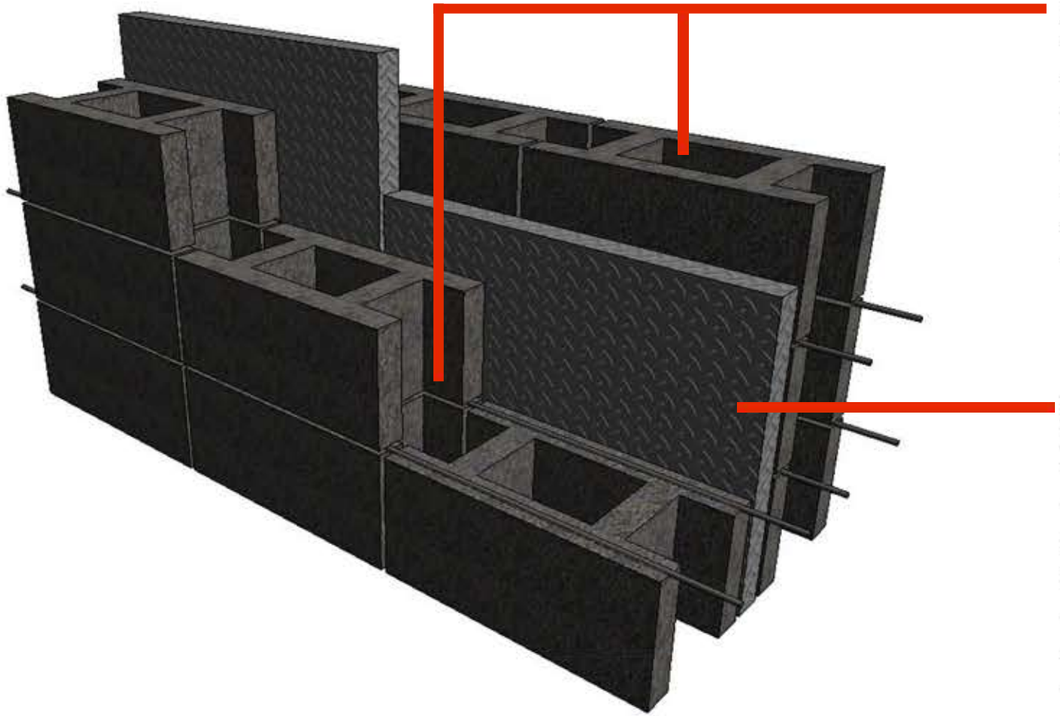
CLAY EXTERIOR BRICK+
FOAM INSULATION PANEL+
CLAY INTERIOR BRICK



OPTION 3:

SOLID ADOBE WALL

OPTION 1: CMU (CONCRETE MASONRY UNIT) WALL



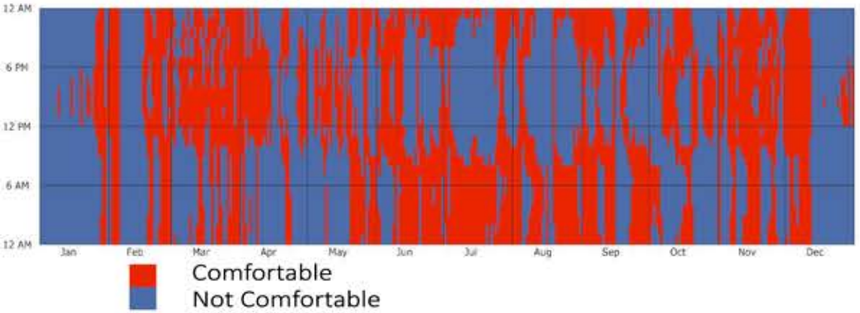
CONCRETE MASONRY UNIT:

- -ROUGHNESS: MEDIUM
- -THICKNESS: 0.20 METERS
- -CONDUCTIVITY: 1.95 W/M-K
- -DENSITY: 2240 KG/M3
- -SPECIFIC HEAT: 900 J/KG-K
- -THERMAL ABSORTANCE: 0.9
- -SOLAR ABSORTANCE: 0.7

THERMAL VISIONS VACUUM INSULATED PANELS:

- -ROUGHNESS: MEDIUM
- -THICKNESS: 0.05 METERS
- -CONDUCTIVITY: 0.005 W/M-K
- -DENSITY: 190 KG/M3
- -SPECIFIC HEAT: 837 J/KG-K
- -THERMAL ABSORTANCE: 0.9
- -SOLAR ABSORTANCE: 0.5

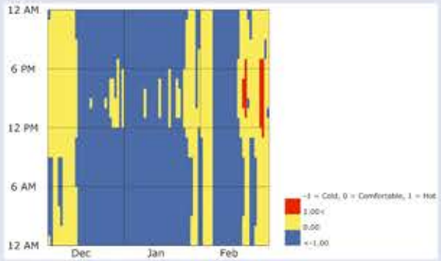
COMFORT CHART



YEARLY COMFORT RESULTS

PERCENTAGE OF TIME COMFORTABLE	45.86%
PERCENTAGE OF TIME TOO HOT	15.91%
PERCENTAGE OF TIME TOO COLD	38.21%

WINTER

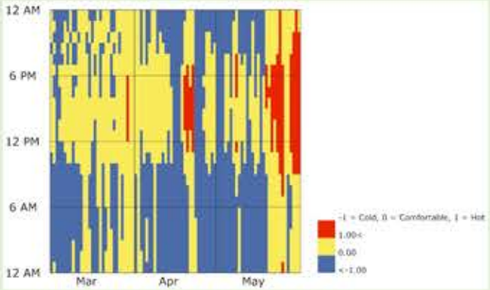


PERCENTAGE OF TIME COMFORTABLE: 33.28%

PERCENTAGE OF TIME TOO HOT: 1.11%

PERCENTAGE OF TIME TOO COLD: 65.60%

SPRING

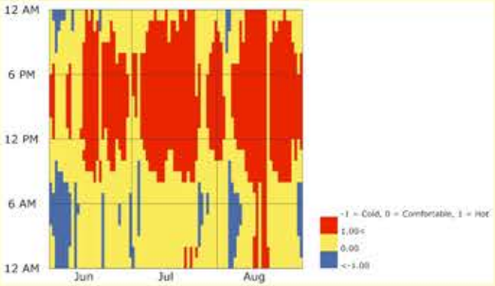


PERCENTAGE OF TIME COMFORTABLE: 47.10%

PERCENTAGE OF TIME TOO HOT: 6.38%

PERCENTAGE OF TIME TOO COLD: 46.51%

SUMMER

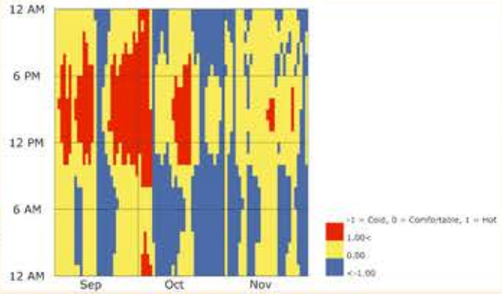


PERCENTAGE OF TIME COMFORTABLE: 51.31%

PERCENTAGE OF TIME TOO HOT: 41.34%

PERCENTAGE OF TIME TOO COLD: 7.33%

FALL

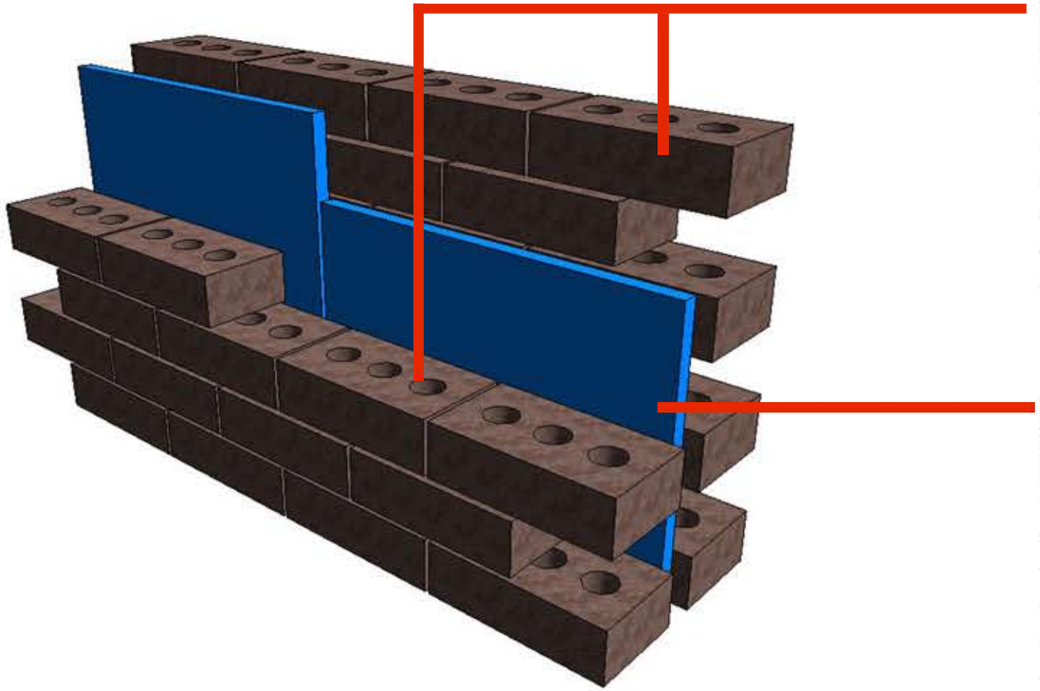


PERCENTAGE OF TIME COMFORTABLE: 51.55%

PERCENTAGE OF TIME TOO HOT: 14.46%

PERCENTAGE OF TIME TOO COLD: 33.97%

OPTION 2: CLAY BRICK WALL



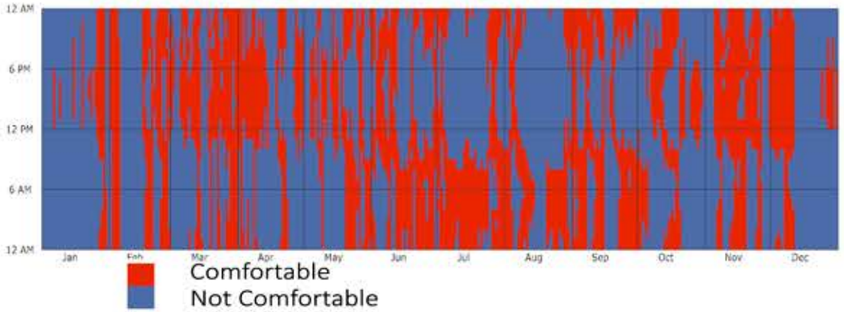
PACIFIC CLAY COMMON FULL RED CLAY STANDARD BRICK:

- -ROUGHNESS: MEDIUM
- -THICKNESS: 0.10 METERS
- -CONDUCTIVITY: 0.89 W/M-K
- -DENSITY: 1920 KG/M3
- -SPECIFIC HEAT: 790 J/KG-K
- -THERMAL ABSORTANCE: 0.9
- -SOLAR ABSORTANCE: 0.7

KINGSPAN INSULATION POLYSTYRENE FOAM BOARD INSULATION:

- -ROUGHNESS: MEDIUM
- -THICKNESS: 0.16 METERS
- -CONDUCTIVITY: 0.0432 W/M-K
- -DENSITY: 91 KG/M3
- -SPECIFIC HEAT: 837 J/KG-K
- -THERMAL ABSORTANCE: 0.9
- -SOLAR ABSORTANCE: 0.5

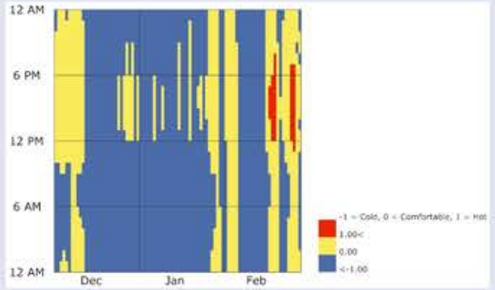
COMFORT CHART



YEARLY COMFORT RESULTS

PERCENTAGE OF TIME COMFORTABLE	41.03%
PERCENTAGE OF TIME TOO HOT	17.80%
PERCENTAGE OF TIME TOO COLD	41.15%

WINTER

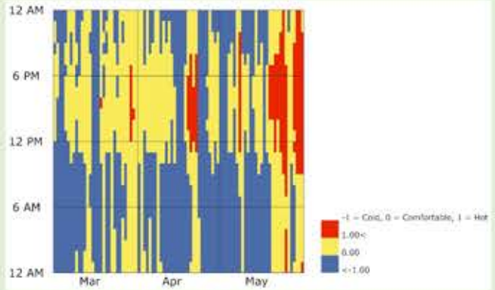


PERCENTAGE OF TIME COMFORTABLE: 30.41%

PERCENTAGE OF TIME TOO HOT: 1.48%

PERCENTAGE OF TIME TOO COLD: 68.10%

SPRING

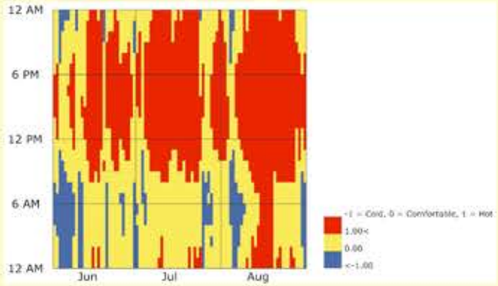


PERCENTAGE OF TIME COMFORTABLE: 43.16%

PERCENTAGE OF TIME TOO HOT: 7.60%

PERCENTAGE OF TIME TOO COLD: 49.23%

SUMMER

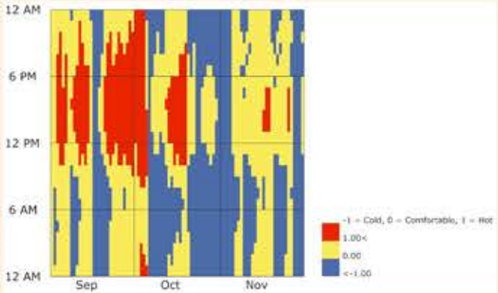


PERCENTAGE OF TIME COMFORTABLE: 44.65%

PERCENTAGE OF TIME TOO HOT: 46.10%

PERCENTAGE OF TIME TOO COLD: 9.23%

FALL

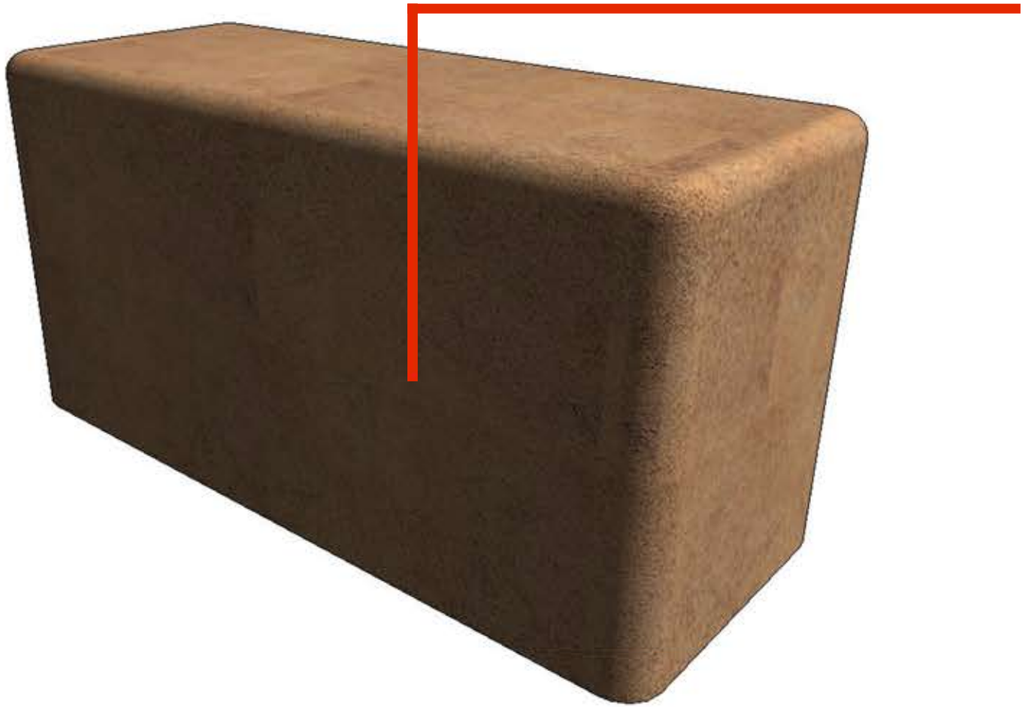


PERCENTAGE OF TIME COMFORTABLE: 45.74%

PERCENTAGE OF TIME TOO HOT: 15.65%

PERCENTAGE OF TIME TOO COLD: 38.59%

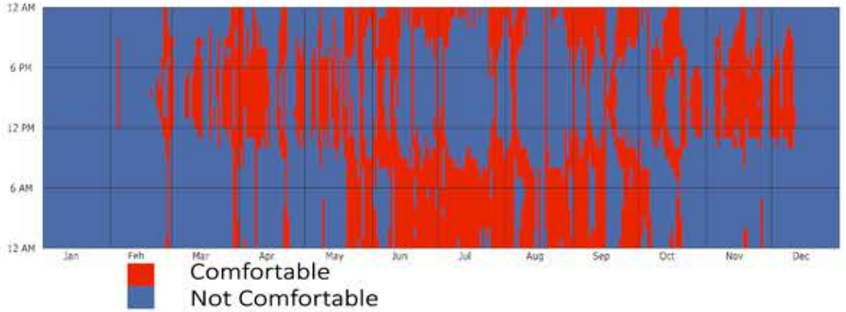
OPTION 3: SOLID ADOBE WALL



ADOBE WALL:

- -ROUGHNESS: MEDIUM
- -THICKNESS: 1.00 METERS
- -CONDUCTIVITY: 1.7 W/M-K
- -DENSITY: 2200 KG/M3
- -SPECIFIC HEAT: 840 J/KG-K
- -THERMAL ABSORTANCE: 0.6
- -SOLAR ABSORTANCE: 0.6

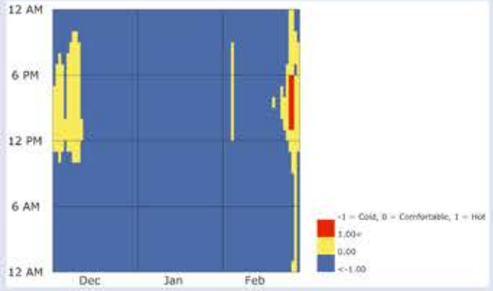
COMFORT CHART



YEARLY COMFORT RESULTS

PERCENTAGE OF TIME COMFORTABLE	32.87%
PERCENTAGE OF TIME TOO HOT	16.52%
PERCENTAGE OF TIME TOO COLD	50.59%

WINTER

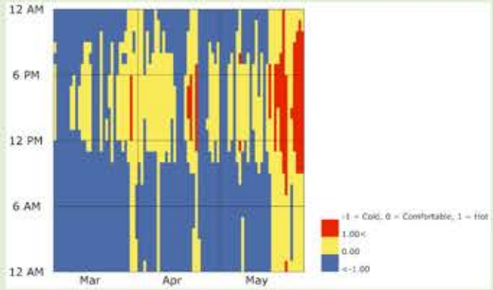


PERCENTAGE OF TIME COMFORTABLE: 7.54%

PERCENTAGE OF TIME TOO HOT: 0.46%

PERCENTAGE OF TIME TOO COLD: 91.99%

SPRING

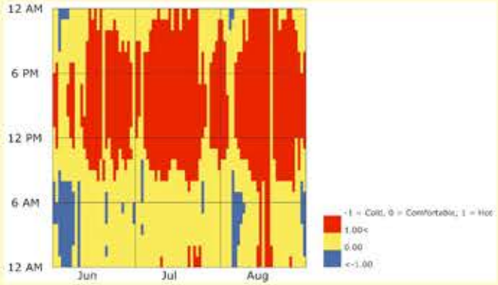


PERCENTAGE OF TIME COMFORTABLE: 34.01%

PERCENTAGE OF TIME TOO HOT: 5.84%

PERCENTAGE OF TIME TOO COLD: 60.14%

SUMMER

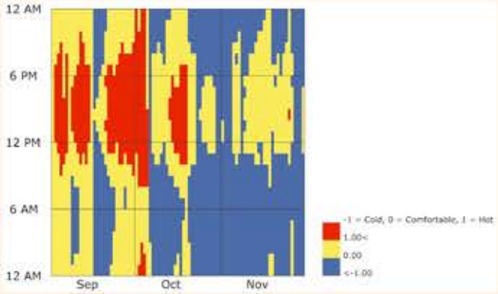


PERCENTAGE OF TIME COMFORTABLE: 49.50%

PERCENTAGE OF TIME TOO HOT: 45.10%

PERCENTAGE OF TIME TOO COLD: 5.38%

FALL



PERCENTAGE OF TIME COMFORTABLE: 39.97%

PERCENTAGE OF TIME TOO HOT: 14.33%

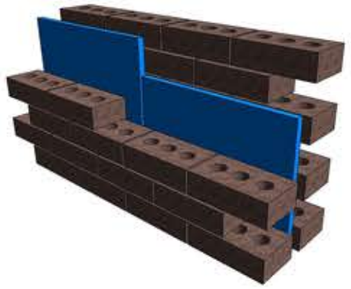
PERCENTAGE OF TIME TOO COLD: 45.69%

WALL MATERIALS CONCLUSIONS

LEGEND

WORST ✗ ← → BEST ✓

LOW ← → HIGH

			
COMFORT %	✓	+ −	✗
COMFORT %	✓	+ −	✗
COMFORT %	✓	✗	+ −
COMFORT %	✓	+ −	✗
THICKNESS	■■□□	■□□□	■■■■
CONDUCTIVITY	■□□□	■■□□	■■■□
DENSITY	■■■■	■■■□	■□□□

WALL MATERIALS CONCLUSIONS

LEGEND

WORST ⟷ BEST

LOW ⟷ HIGH

COMFORT %	
COMFORT %	✓
COMFORT %	✓
COMFORT %	✓
THICKNESS	✓
CONDUCTIVITY	■■□□
DENSITY	■□□□
	■■■■

HAVING HIGH THICKNESS MATERIALS DOESN'T NECESSARILY MEAN THAT THE ROOM WILL BE WELL INSULATED. THICK, BULKY MATERIALS WILL PERFORM WELL UNDER HOT CONDITIONS BUT NOT SO WELL UNDER COLD CONDITIONS.

CREATING YOUR OWN CUSTOM MATERIAL BY LOOKING AT THE PRODUCER'S SPECIFICATIONS IS THE BEST WAY TO ACHIEVE ACCURATE WALL CONFIGURATION.

SPECIFICATIONS CAN BE SOMEHOW CHALLENGING TO READ. DIFFERENT COUNTRIES AND EVEN DIFFERENT COMPANIES HAVE MULTIPLE STANDARDS AND UNITS FOR CLASSIFIYNG THEIR PRODUCTS.

WINDOWS' SPECIFICATIONS SELECTION

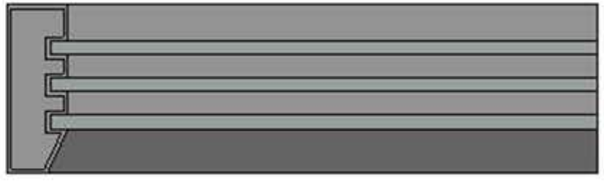
OPTION 1:
CLEAR DOUBLE PANE WINDOW

OPTION 3:
CLEAR TRIPLE PANE WINDOW

OPTION 5:
CLEAR QUAD PANE WINDOWS

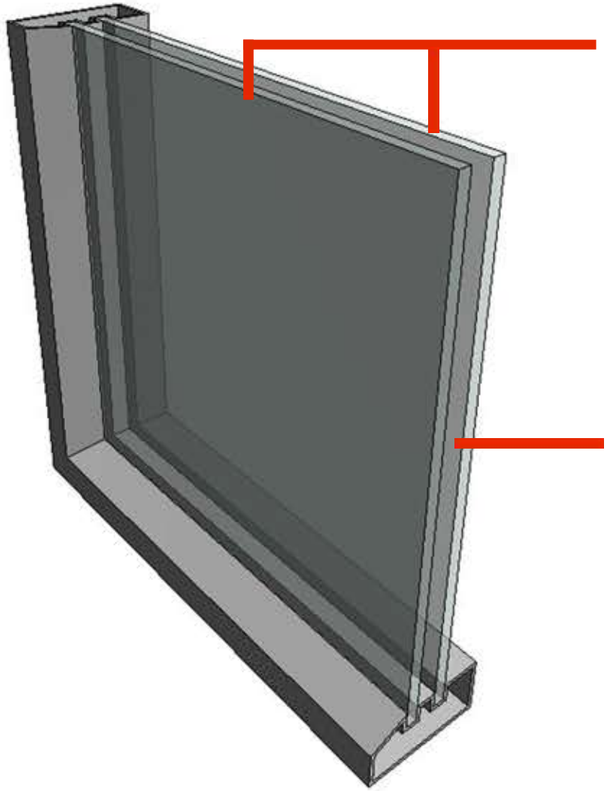
OPTION 2:
LOW-E COATED DOUBLE PANE WINDOWS

OPTION 4:
LOW-E COATED TRIPLE PANE WINDOWS



OPTION 6:
LOW-E COATED QUAD PANE WINDOWS

OPTION 1: CLEAR DOUBLE PANE WINDOWS



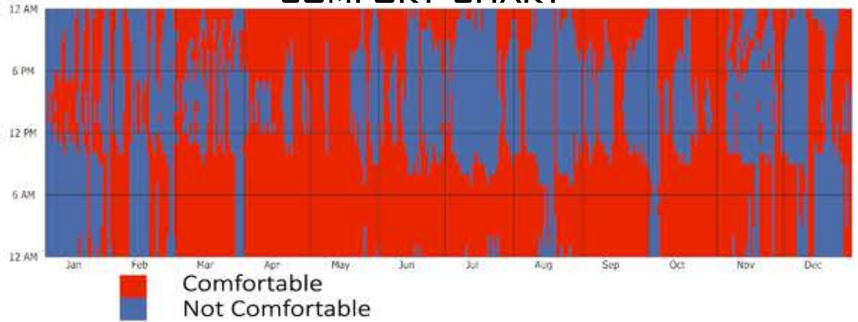
CLEAR WINDOW GLAZING:

-THICKNESS: 0.003 METERS
-SOLAR TRANSMITTANCE AT NORMAL INCIDENCE : 0.837
-SOLAR REFLECTANCE: 0.075
-VISIBLE TRANSMITTANCE: 0.898
-VISIBLE REFLECTANCE: 0.081
-FRONT EMISSIVITY: 0.84
-BACK EMISSIVITY: 0.84

AIR GAP

-THICKNESS: 0.0127 METERS

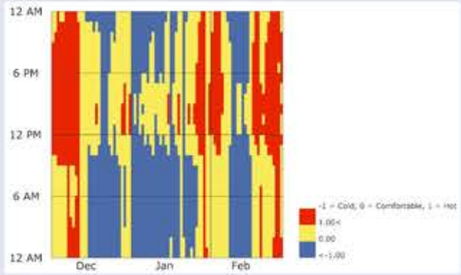
COMFORT CHART



YEARLY COMFORT RESULTS WITHOUT LOW-E

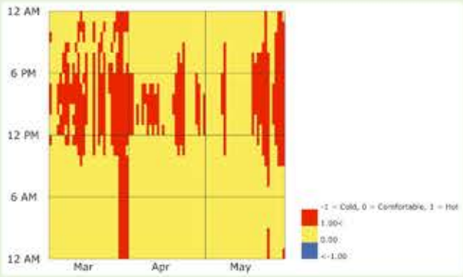
PERCENTAGE OF TIME COMFORTABLE	59.41%
PERCENTAGE OF TIME TOO HOT	31.70%
PERCENTAGE OF TIME TOO COLD	8.88%

WINTER



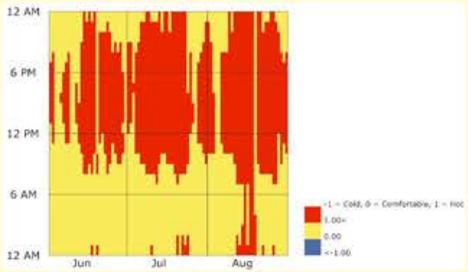
PERCENTAGE OF TIME COMFORTABLE: 41.20%
PERCENTAGE OF TIME TOO HOT: 22.77%
PERCENTAGE OF TIME TOO COLD: 36.01%

SPRING



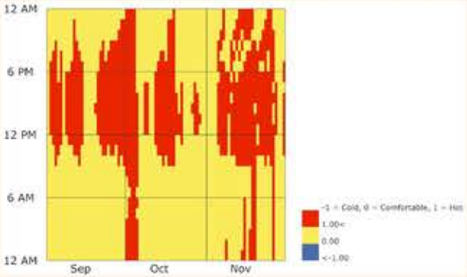
PERCENTAGE OF TIME COMFORTABLE: 77.53%
PERCENTAGE OF TIME TOO HOT: 22.46%
PERCENTAGE OF TIME TOO COLD: 0.00%

SUMMER



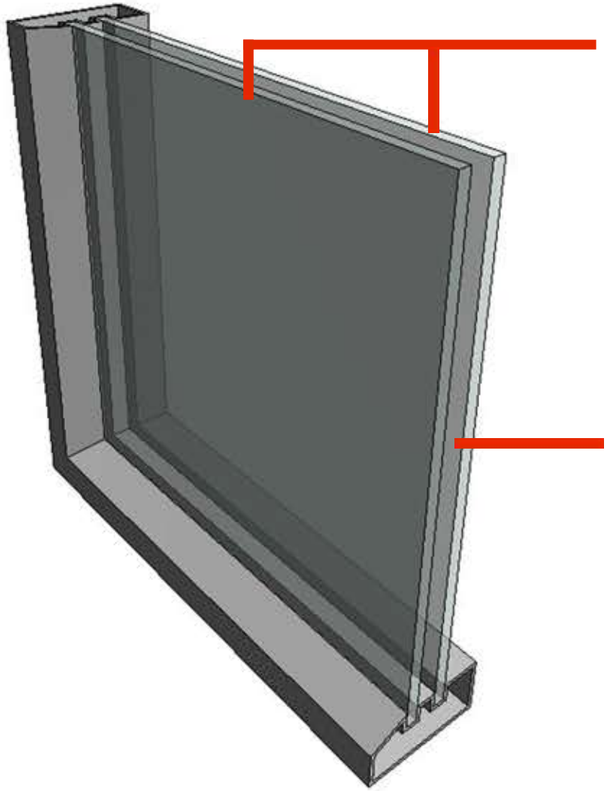
PERCENTAGE OF TIME COMFORTABLE: 52.89%
PERCENTAGE OF TIME TOO HOT: 47.10%
PERCENTAGE OF TIME TOO COLD: 0.00%

FALL



PERCENTAGE OF TIME COMFORTABLE: 65.70%
PERCENTAGE OF TIME TOO HOT: 34.29%
PERCENTAGE OF TIME TOO COLD: 0.00%

OPTION 2: LOW-E COATED DOUBLE PANE WINDOWS



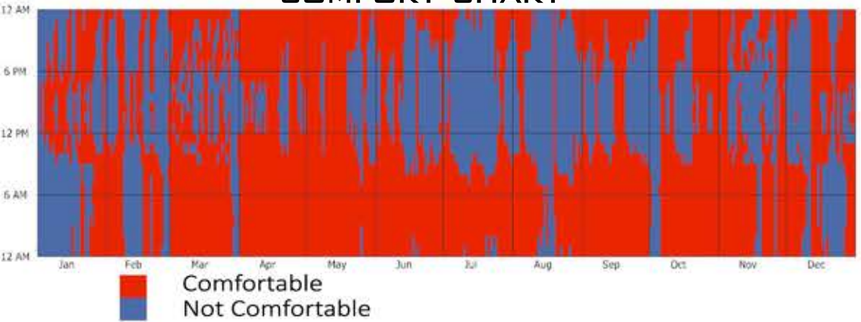
LOW E COATED WINDOW GLAZING:

- THICKNESS: 0.003 METERS
- SOLAR TRANSMITTANCE AT NORMAL INCIDENCE : 0.69
- SOLAR REFLECTANCE: 0.01
- VISIBLE TRANSMITTANCE: 0.50
- VISIBLE REFLECTANCE: 0.45
- FRONT EMISSIVITY: 0.40
- BACK EMISSIVITY: 0.40

AIR GAP

- THICKNESS: 0.0127 METERS

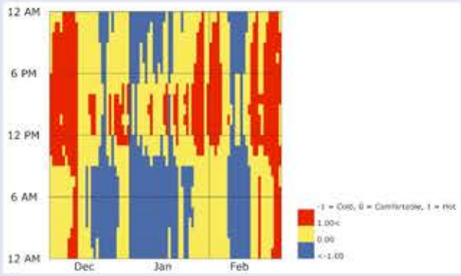
COMFORT CHART



YEARLY COMFORT RESULTS WITH LOW-E

PERCENTAGE OF TIME COMFORTABLE	62.08%
PERCENTAGE OF TIME TOO HOT	30.82%
PERCENTAGE OF TIME TOO COLD	7.08%

WINTER

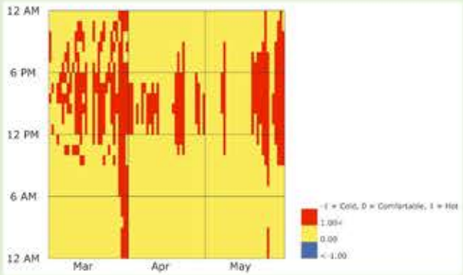


PERCENTAGE OF TIME COMFORTABLE: 47.08%

PERCENTAGE OF TIME TOO HOT: 24.16%

PERCENTAGE OF TIME TOO COLD: 28.75%

SPRING

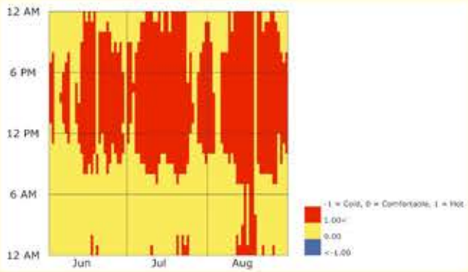


PERCENTAGE OF TIME COMFORTABLE: 79.66%

PERCENTAGE OF TIME TOO HOT: 20.33%

PERCENTAGE OF TIME TOO COLD: 0.00%

SUMMER

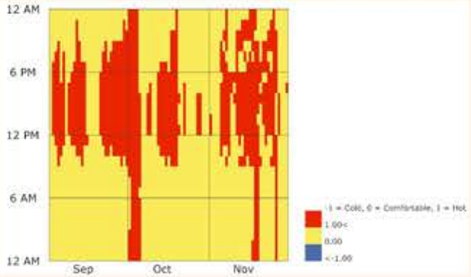


PERCENTAGE OF TIME COMFORTABLE: 52.76%

PERCENTAGE OF TIME TOO HOT: 47.23%

PERCENTAGE OF TIME TOO COLD: 0.00%

FALL

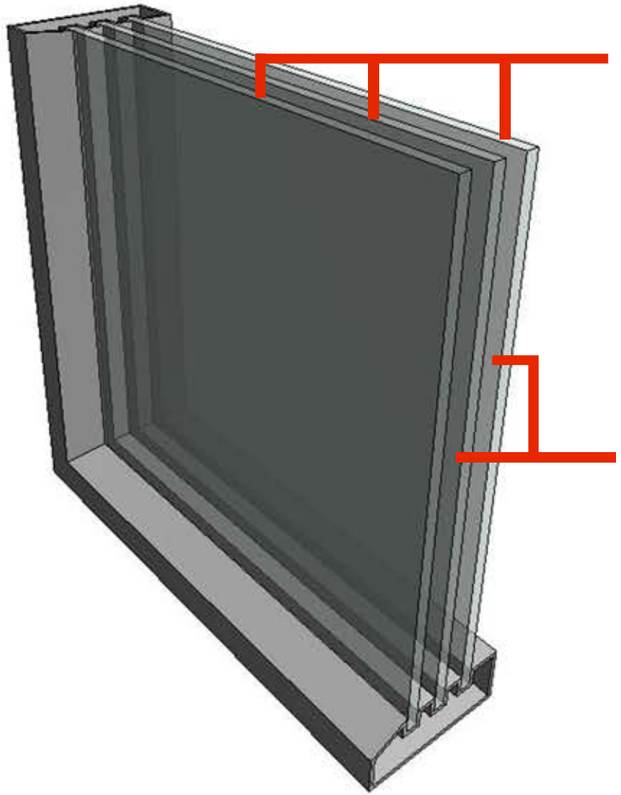


PERCENTAGE OF TIME COMFORTABLE: 68.58%

PERCENTAGE OF TIME TOO HOT: 31.41%

PERCENTAGE OF TIME TOO COLD: 0.00%

OPTION 3: CLEAR TRIPLE PANE WINDOWS



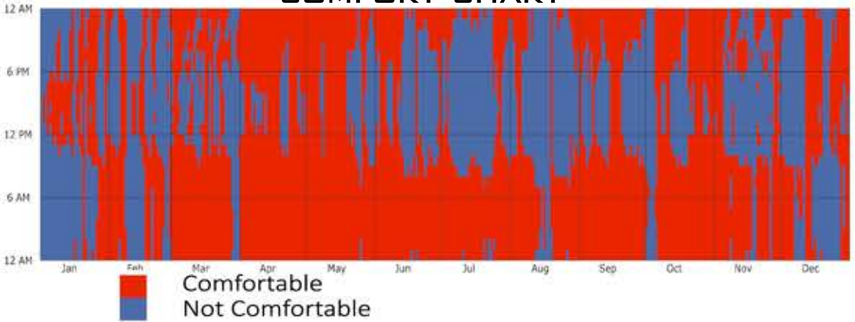
CLEAR WINDOW GLAZING:

-THICKNESS: 0.003 METERS
-SOLAR TRANSMITTANCE AT NORMAL INCIDENCE : 0.837
-SOLAR REFLECTANCE: 0.075
-VISIBLE TRANSMITTANCE: 0.898
-VISIBLE REFLECTANCE: 0.081
-FRONT EMISSIVITY: 0.84
-BACK EMISSIVITY: 0.84

AIR GAP

-THICKNESS: 0.0127 METERS

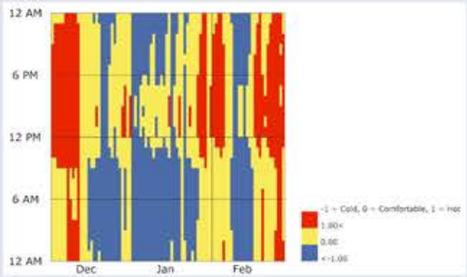
COMFORT CHART



YEARLY COMFORT RESULTS WITHOUT LOW-E

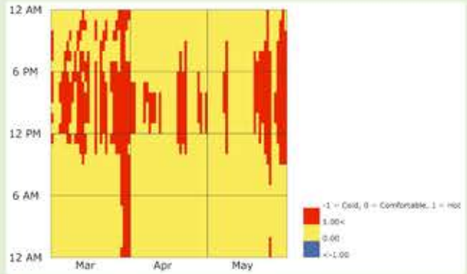
PERCENTAGE OF TIME COMFORTABLE	60.62%
PERCENTAGE OF TIME TOO HOT	30.89%
PERCENTAGE OF TIME TOO COLD	8.48%

WINTER



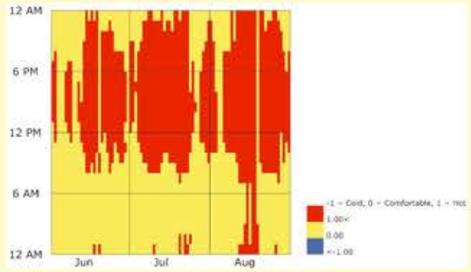
PERCENTAGE OF TIME COMFORTABLE: 43.05%
PERCENTAGE OF TIME TOO HOT: 22.54%
PERCENTAGE OF TIME TOO COLD: 34.39%

SPRING



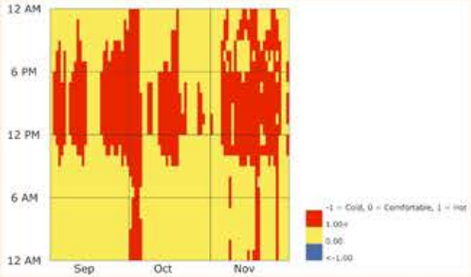
PERCENTAGE OF TIME COMFORTABLE: 78.71%
PERCENTAGE OF TIME TOO HOT: 21.28%
PERCENTAGE OF TIME TOO COLD: 0.00%

SUMMER



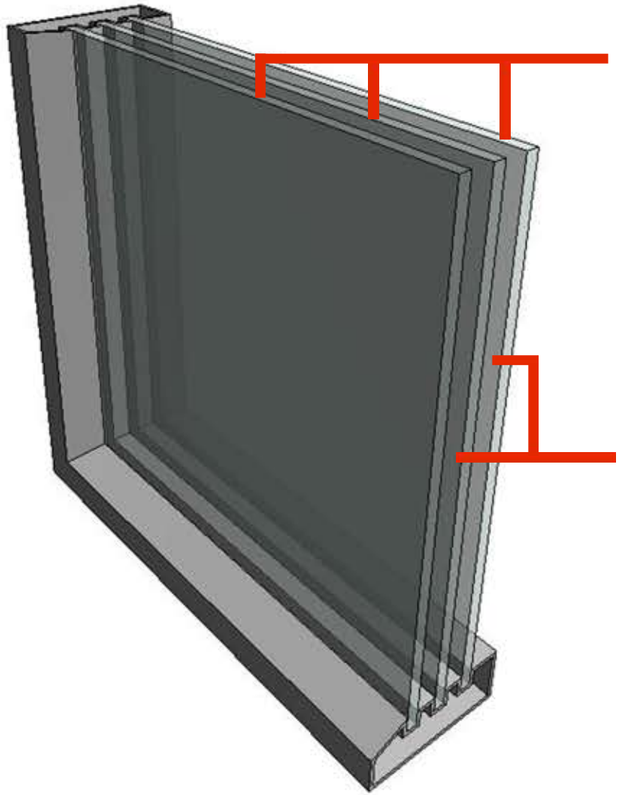
PERCENTAGE OF TIME COMFORTABLE: 53.89%
PERCENTAGE OF TIME TOO HOT: 46.10%
PERCENTAGE OF TIME TOO COLD: 0.00%

FALL



PERCENTAGE OF TIME COMFORTABLE: 66.52%
PERCENTAGE OF TIME TOO HOT: 33.47%
PERCENTAGE OF TIME TOO COLD: 0.00%

OPTION 4: LOW-E COATED TRIPLE PANE WINDOWS



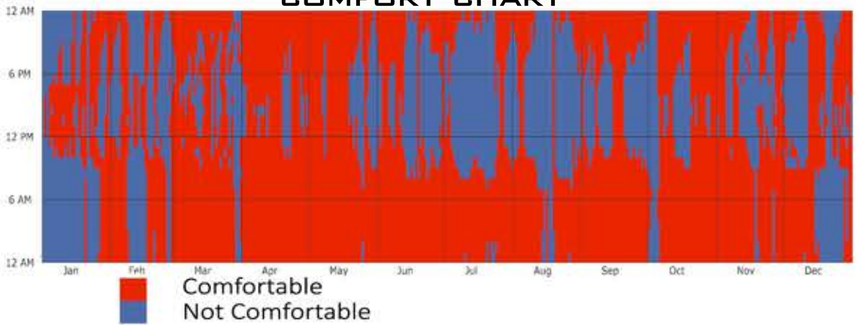
LOW E COATED WINDOW GLAZING:

-THICKNESS: 0.003 METERS
-SOLAR TRANSMITTANCE AT NORMAL INCIDENCE : 0.69
-SOLAR REFLECTANCE: 0.01
-VISIBLE TRANSMITTANCE: 0.50
-VISIBLE REFLECTANCE: 0.45
-FRONT EMISSIVITY: 0.40
-BACK EMISSIVITY: 0.40

AIR GAP

-THICKNESS: 0.0127 METERS

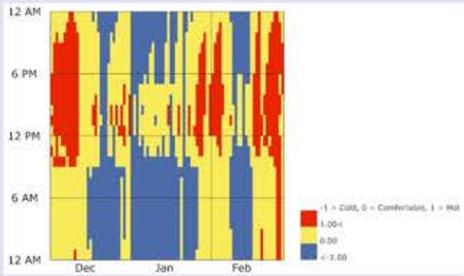
COMFORT CHART



YEARLY COMFORT RESULTS WITH LOW-E

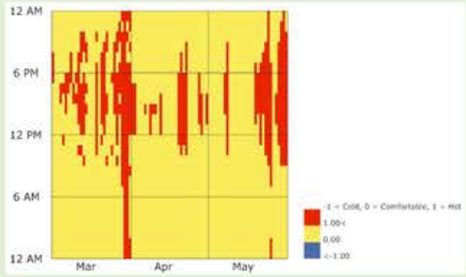
PERCENTAGE OF TIME COMFORTABLE	64.45%
PERCENTAGE OF TIME TOO HOT	27.07%
PERCENTAGE OF TIME TOO COLD	8.47%

WINTER



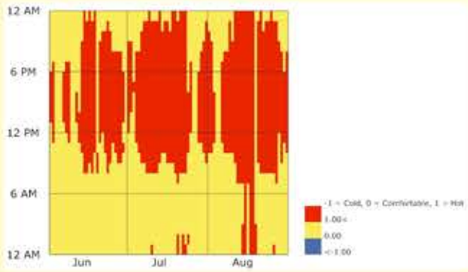
PERCENTAGE OF TIME COMFORTABLE: 48.00%
PERCENTAGE OF TIME TOO HOT: 17.63%
PERCENTAGE OF TIME TOO COLD: 34.35%

SPRING



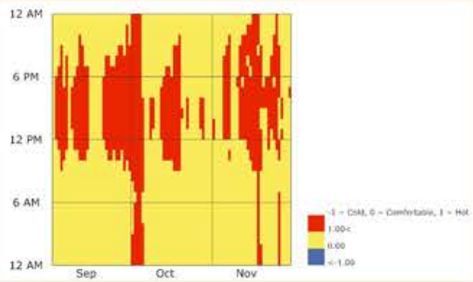
PERCENTAGE OF TIME COMFORTABLE: 82.69%
PERCENTAGE OF TIME TOO HOT: 17.30%
PERCENTAGE OF TIME TOO COLD: 0.00%

SUMMER



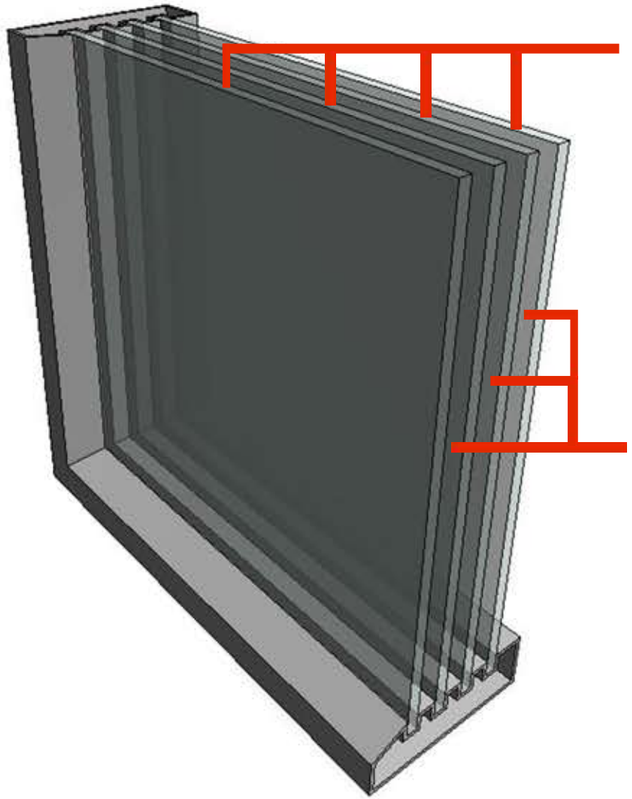
PERCENTAGE OF TIME COMFORTABLE: 54.89%
PERCENTAGE OF TIME TOO HOT: 45.10%
PERCENTAGE OF TIME TOO COLD: 0.00%

FALL



PERCENTAGE OF TIME COMFORTABLE: 71.93%
PERCENTAGE OF TIME TOO HOT: 28.06%
PERCENTAGE OF TIME TOO COLD: 0.00%

OPTION 5: CLEAR QUAD PANE WINDOWS



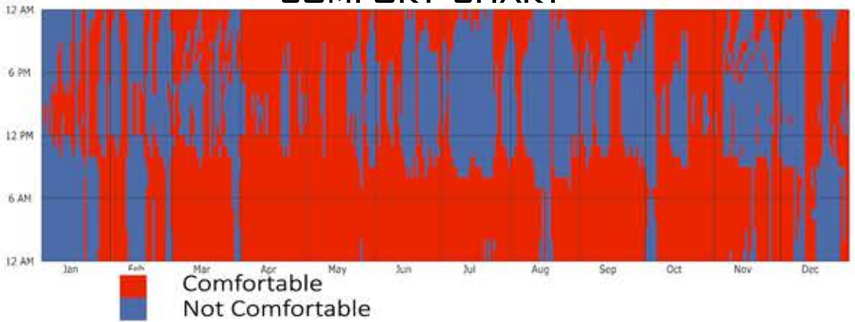
CLEAR WINDOW GLAZING:

-THICKNESS: 0.003 METERS
-SOLAR TRANSMITTANCE AT NORMAL INCIDENCE : 0.837
-SOLAR REFLECTANCE: 0.075
-VISIBLE TRANSMITTANCE: 0.898
-VISIBLE REFLECTANCE: 0.081
-FRONT EMISSIVITY: 0.84
-BACK EMISSIVITY: 0.84

AIR GAP

-THICKNESS: 0.0127 METERS

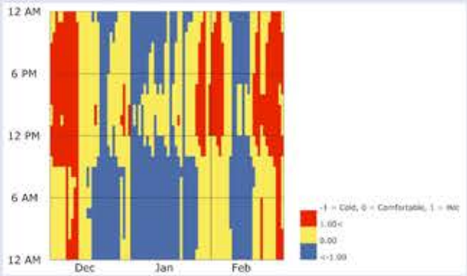
COMFORT CHART



YEARLY COMFORT RESULTS WITHOUT LOW-E

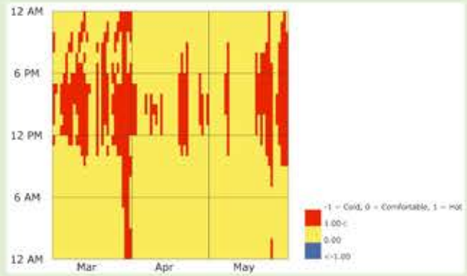
PERCENTAGE OF TIME COMFORTABLE	61.43%
PERCENTAGE OF TIME TOO HOT	29.69%
PERCENTAGE OF TIME TOO COLD	8.86%

WINTER



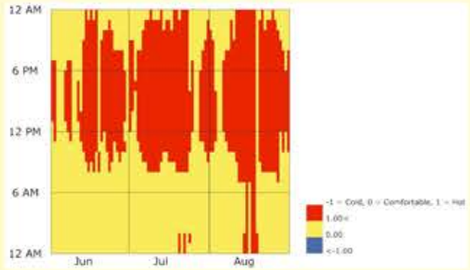
PERCENTAGE OF TIME COMFORTABLE: 42.96%
PERCENTAGE OF TIME TOO HOT: 21.06%
PERCENTAGE OF TIME TOO COLD: 35.97%

SPRING



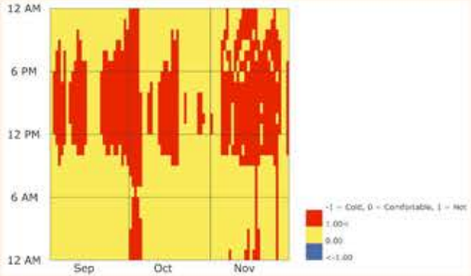
PERCENTAGE OF TIME COMFORTABLE: 79.61%
PERCENTAGE OF TIME TOO HOT: 20.38%
PERCENTAGE OF TIME TOO COLD: 0.00%

SUMMER



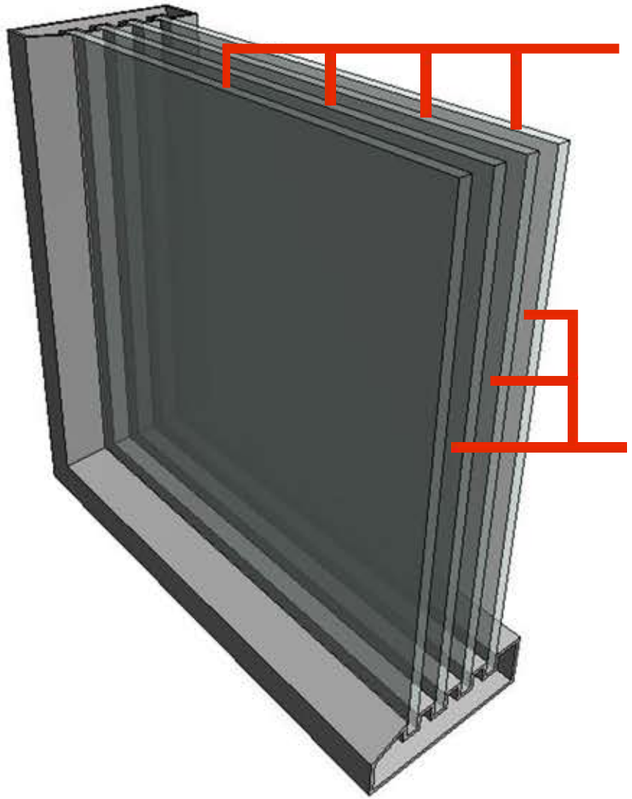
PERCENTAGE OF TIME COMFORTABLE: 55.38%
PERCENTAGE OF TIME TOO HOT: 44.61%
PERCENTAGE OF TIME TOO COLD: 0.00%

FALL



PERCENTAGE OF TIME COMFORTABLE: 67.44%
PERCENTAGE OF TIME TOO HOT: 32.55%
PERCENTAGE OF TIME TOO COLD: 0.00%

OPTION 6: LOW-E QUAD PANE WINDOWS



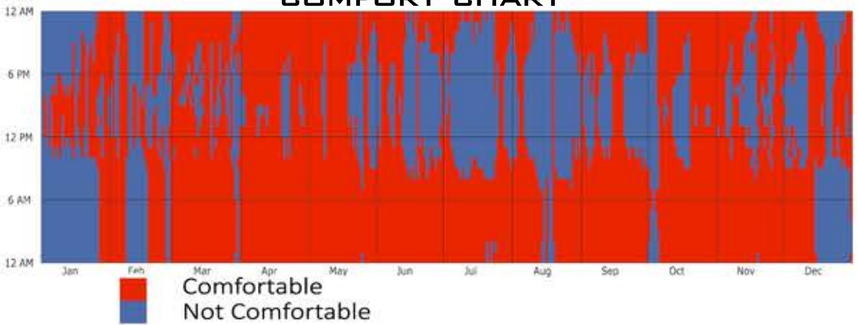
LOW E COATED WINDOW GLAZING:

- THICKNESS: 0.003 METERS
- SOLAR TRANSMITTANCE AT NORMAL INCIDENCE : 0.69
- SOLAR REFLECTANCE: 0.01
- VISIBLE TRANSMITTANCE: 0.50
- VISIBLE REFLECTANCE: 0.45
- FRONT EMISSIVITY: 0.40
- BACK EMISSIVITY: 0.40

AIR GAP

- THICKNESS: 0.0127 METERS

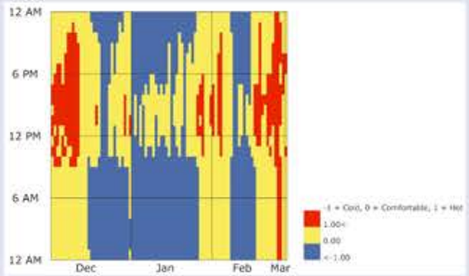
COMFORT CHART



YEARLY COMFORT RESULTS WITHOUT LOW-E

PERCENTAGE OF TIME COMFORTABLE	66.48%
PERCENTAGE OF TIME TOO HOT	23.49%
PERCENTAGE OF TIME TOO COLD	10.02%

WINTER

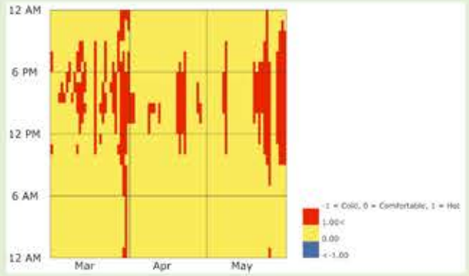


PERCENTAGE OF TIME COMFORTABLE: 47.48%

PERCENTAGE OF TIME TOO HOT: 12.31%

PERCENTAGE OF TIME TOO COLD: 40.20%

SPRING

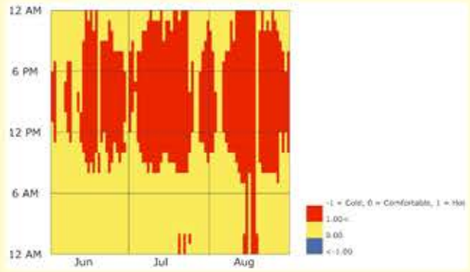


PERCENTAGE OF TIME COMFORTABLE: 85.86%

PERCENTAGE OF TIME TOO HOT: 14.13%

PERCENTAGE OF TIME TOO COLD: 0.00%

SUMMER

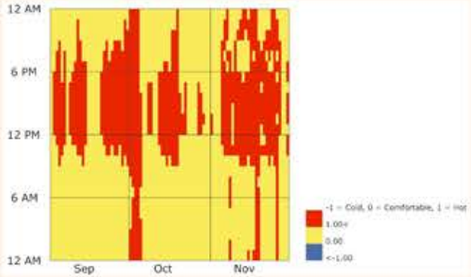


PERCENTAGE OF TIME COMFORTABLE: 56.20%

PERCENTAGE OF TIME TOO HOT: 43.79%

PERCENTAGE OF TIME TOO COLD: 0.00%

FALL



PERCENTAGE OF TIME COMFORTABLE: 76.51%

PERCENTAGE OF TIME TOO HOT: 23.48%

PERCENTAGE OF TIME TOO COLD: 0.00%

WINDOWS' SPECIFICATIONS CONCLUSIONS

LEGEND

6TH WORST — 1ST BEST

LOW — HIGH

	DOUBLE PANE		TRIPLE PANE		QUAD PANE	
	CLEAR	LOW-E COATED	CLEAR	LOW-E COATED	CLEAR	LOW-E COATED
WINTER COMFORT %	6TH	3RD	4TH	1ST	5TH	2ND
SPRING COMFORT %	6TH	3RD	5TH	2ND	4TH	1ST
SUMMER COMFORT %	5TH	6TH	4TH	3RD	2ND	1ST
FALL COMFORT %	6TH	4TH	4TH	2ND	3RD	1ST
THICKNESS	■□□□□□	■□□□□□	■■■□□□	■■■□□□	■■■■■■	■■■■■■
LIGHT TRANSMITTED	■■■■■■	■■■■■□	■■■■□□	■■■□□□	■■□□□□	■□□□□□
HEAT TRANSMITTED	■■■■■■	■■■■■□	■■■■□□	■■■□□□	■■□□□□	■□□□□□

WINDOWS' SPECIFICATIONS CONCLUSIONS

THE DIFFERENCE BETWEEN WINDOWS WITH LOW-E COATING AND WITHOUT LOW-E COATING IS NOT SIGNIFICANT...

...ON THE OTHER SIDE, DIFFERENT NUMBERS OF LAYERS OF GLASS CHANGE CONSIDERABLY THE IMPACT ON THE COMFORT LEVELS.

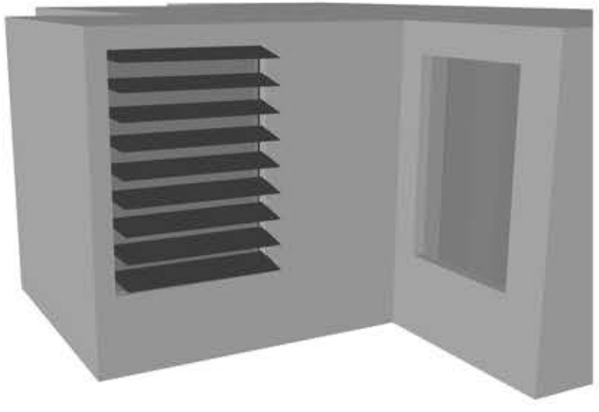
THE MORE LAYERS THE WINDOW HAS, THE MORE RADIATION IT WILL REPEL, MEANING THAT THE ROOM WON'T BE SIGNIFICANTLY HOT IN THE SUMMER, BUT IT WILL BE QUITE COLD IN THE WINTER.

THERE IS A VERY CLEAR RELATION BETWEEN THE NUMBER OF LAYERS AND THE COMFORT LEVELS: THE MORE LAYERS OF GLASS, THE MORE COMFORTABLE THE SPACE WILL BE.

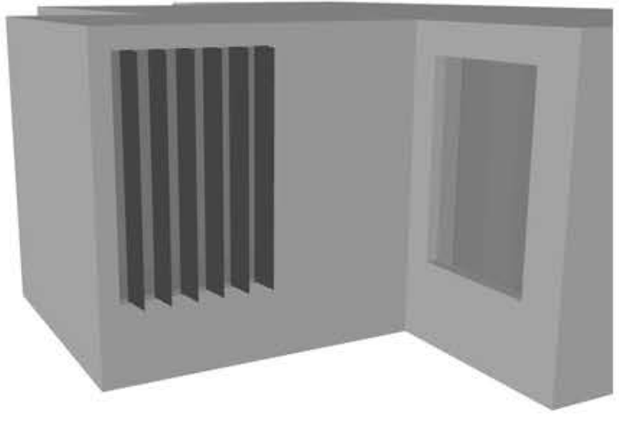
QUAD PANE
LOW-E COATED
2ND
1ST
1ST
1ST

INCORPORATING SHADING

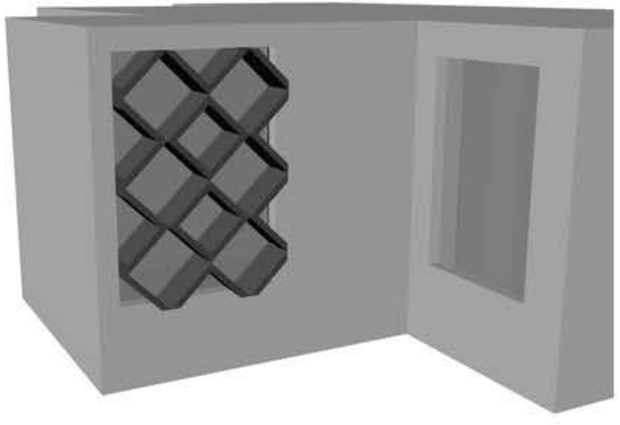
OPTION 1:
HORIZONTAL SHADING



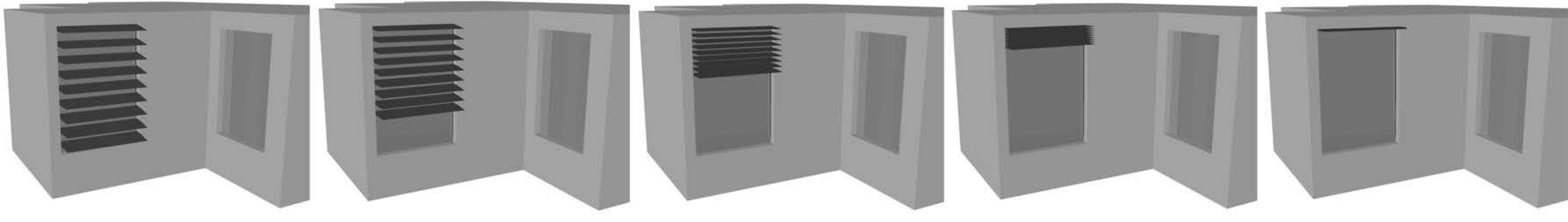
OPTION 2:
VERTICAL SHADING



OPTION 3:
DIAGONAL SHADING

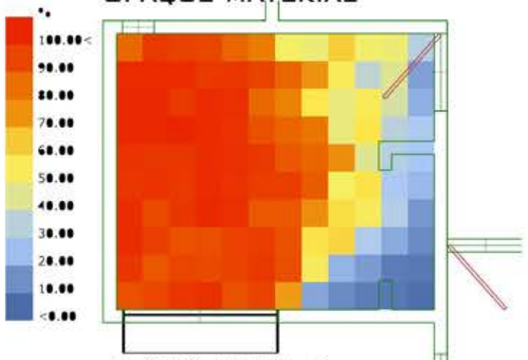


OPTION 4:
DEPLOYABLE SHADING



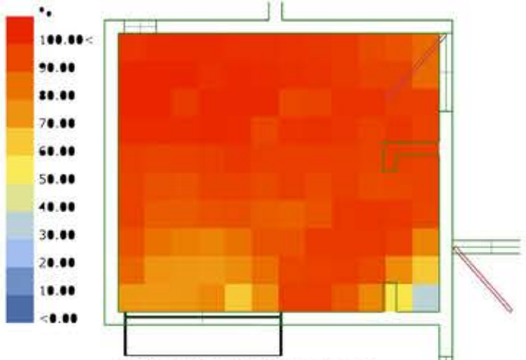
HORIZONTAL SHADING

USEFUL DAYLIGHT ILLUMINANCE: OPAQUE MATERIAL



Useful Daylight Illuminance
% between 100 lux-2000 lux

USEFUL DAYLIGHT ILLUMINANCE: REFLECTIVE MATERIAL

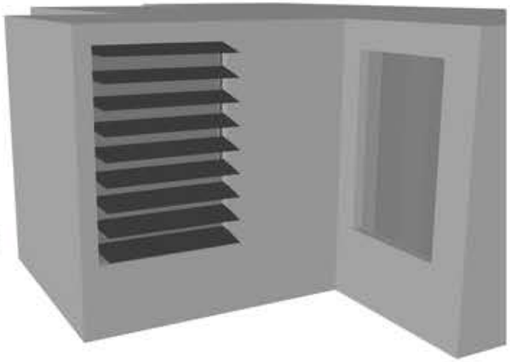


Useful Daylight Illuminance
% between 100 lux-2000 lux

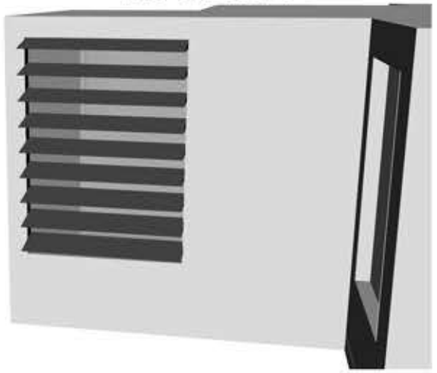
YEARLY RESULTS

PERCENTAGE OF TIME COMFORTABLE	16.35%
PERCENTAGE OF TIME TOO HOT	51.25%
PERCENTAGE OF TIME TOO COLD	32.38%
USEFUL DAYLIGHT ILLUMINANCE MATERIAL: 10% REFLECTIVE	68.49%
USEFUL DAYLIGHT ILLUMINANCE MATERIAL: 90% REFLECTIVE	88.64%

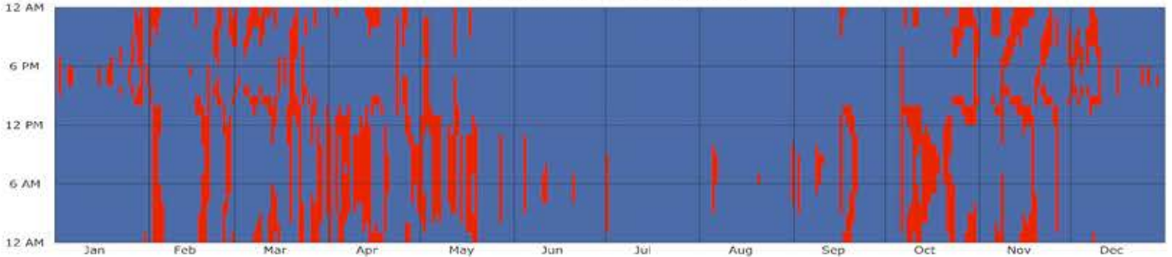
3D VIEW 1



3D VIEW 2

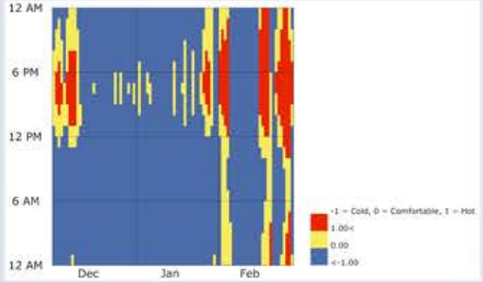


COMFORT CHART



Not Comfortable
Comfortable

WINTER

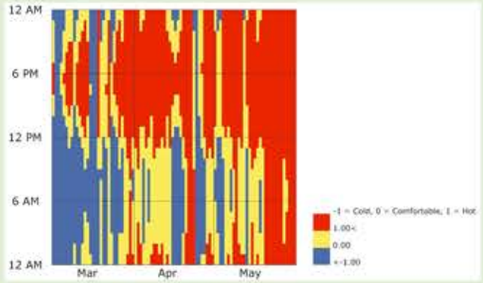


PERCENTAGE OF TIME COMFORTABLE: 13.33%

PERCENTAGE OF TIME TOO HOT: 8.84%

PERCENTAGE OF TIME TOO COLD: 77.82%

SPRING

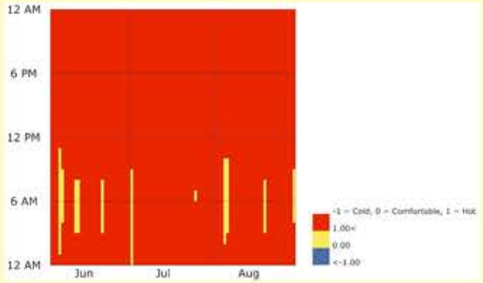


PERCENTAGE OF TIME COMFORTABLE: 28.94%

PERCENTAGE OF TIME TOO HOT: 45.96%

PERCENTAGE OF TIME TOO COLD: 52.09%

SUMMER

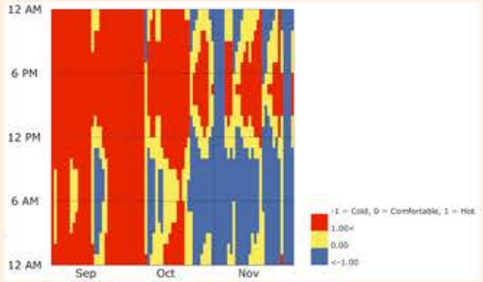


PERCENTAGE OF TIME COMFORTABLE: 2.94%

PERCENTAGE OF TIME TOO HOT: 97.05%

PERCENTAGE OF TIME TOO COLD: 0.00%

FALL



PERCENTAGE OF TIME COMFORTABLE: 20.19%

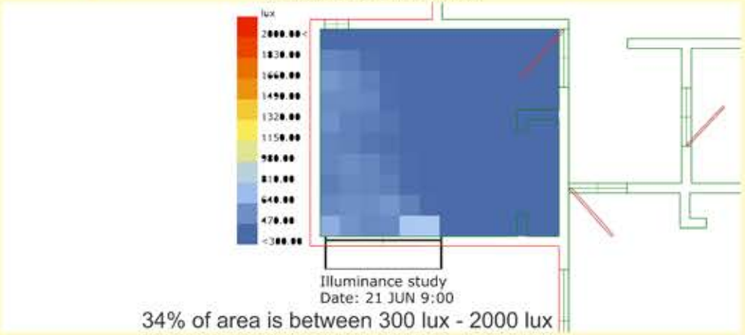
PERCENTAGE OF TIME TOO HOT: 52.24%

PERCENTAGE OF TIME TOO COLD: 27.56%

POINTS IN TIME ANALYSIS: 10% REFLECTIVE HORIZONTAL SHADING

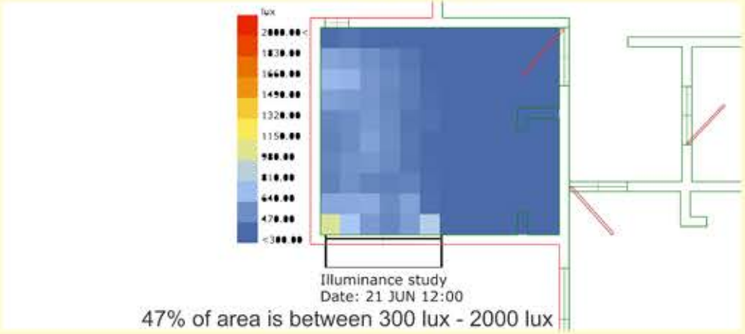
SUMMER SOLSTICE

SUMMER 9:00 AM



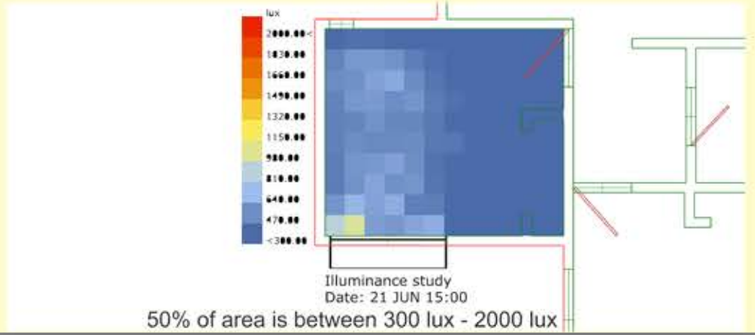
34% of area is between 300 lux - 2000 lux

SUMMER 12:00 PM



47% of area is between 300 lux - 2000 lux

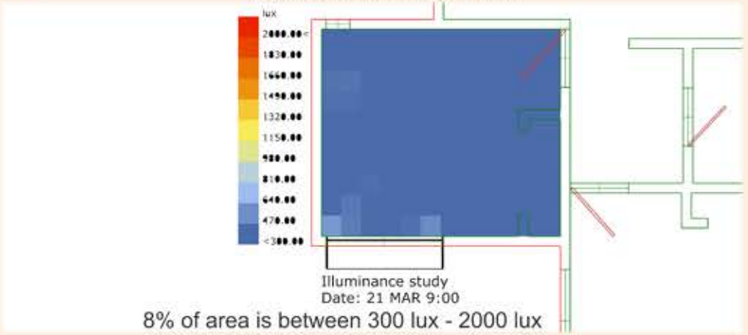
SUMMER 3:00 PM



50% of area is between 300 lux - 2000 lux

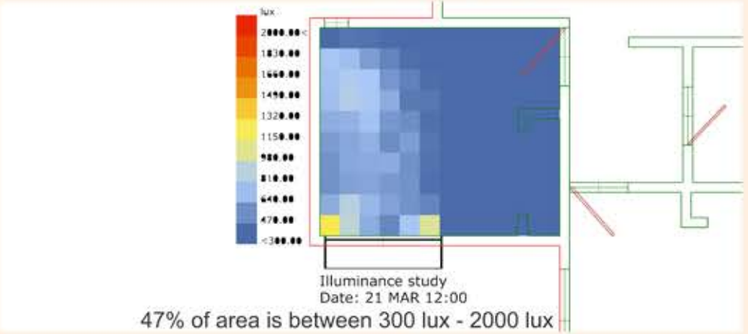
FALL/SPRING EQUINOX

SPRING/FALL 9:00 AM



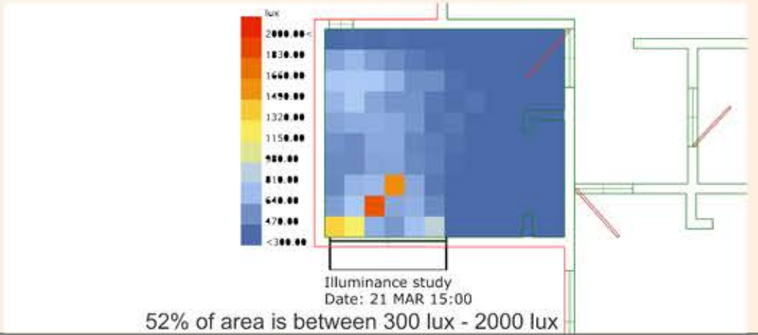
8% of area is between 300 lux - 2000 lux

SPRING/FALL 12:00 PM



47% of area is between 300 lux - 2000 lux

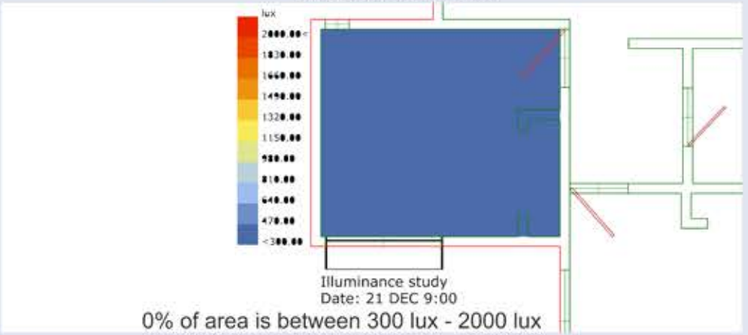
SPRING/FALL 3:00 PM



52% of area is between 300 lux - 2000 lux

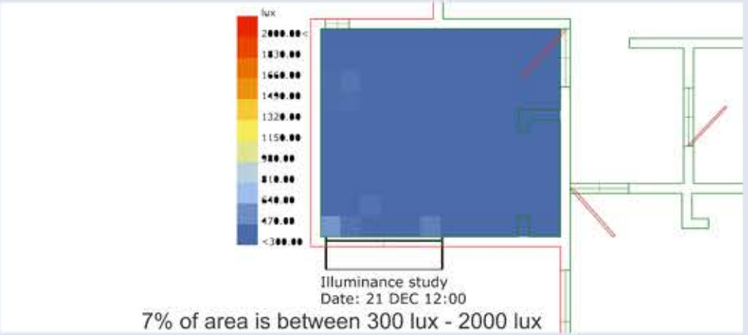
WINTER SOLSTICE

WINTER 9:00 AM



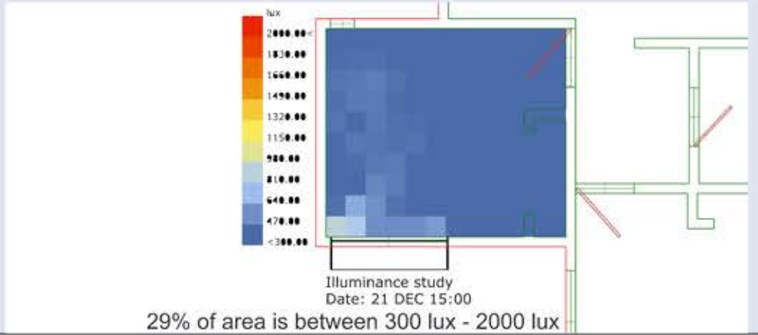
0% of area is between 300 lux - 2000 lux

WINTER 12:00 PM



7% of area is between 300 lux - 2000 lux

WINTER 3:00 PM

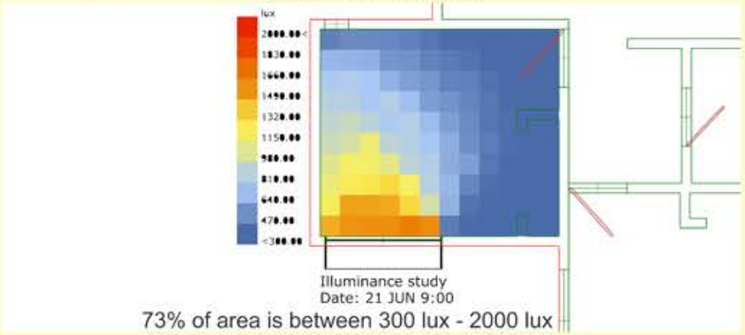


29% of area is between 300 lux - 2000 lux

POINTS IN TIME ANALYSIS: 90% REFLECTIVE HORIZONTAL SHADING

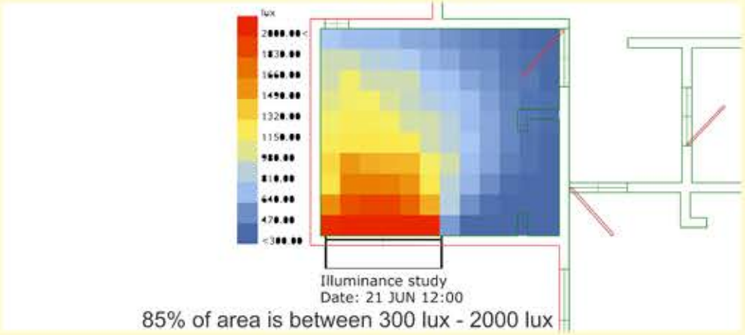
SUMMER SOLSTICE

SUMMER 9:00 AM



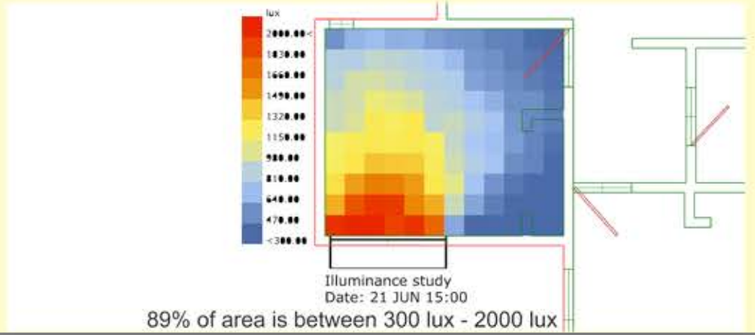
73% of area is between 300 lux - 2000 lux

SUMMER 12:00 PM



85% of area is between 300 lux - 2000 lux

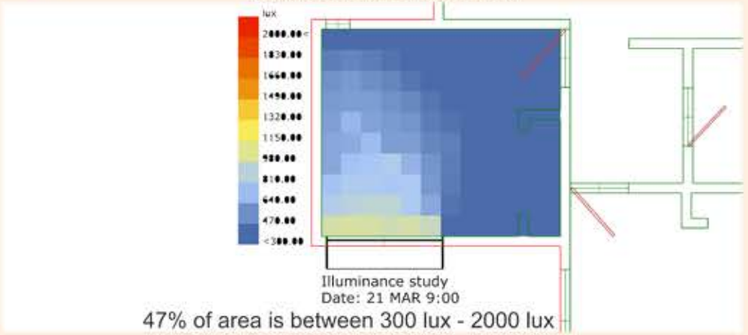
SUMMER 3:00 PM



89% of area is between 300 lux - 2000 lux

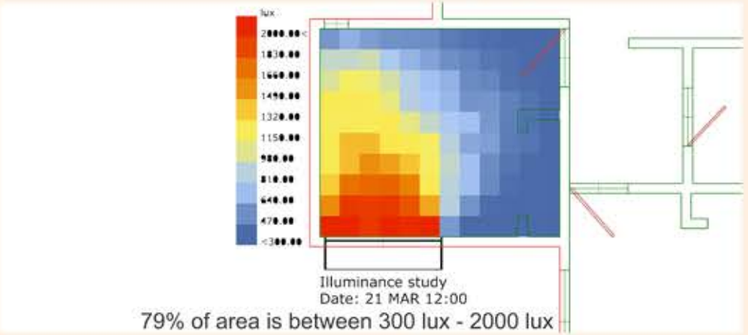
FALL/SPRING EQUINOX

SPRING/FALL 9:00 AM



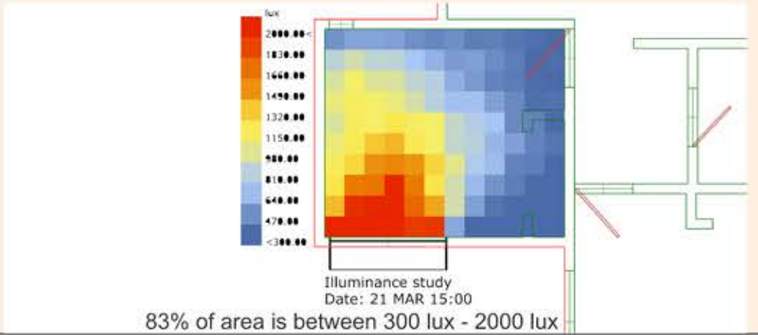
47% of area is between 300 lux - 2000 lux

SPRING/FALL 12:00 PM



79% of area is between 300 lux - 2000 lux

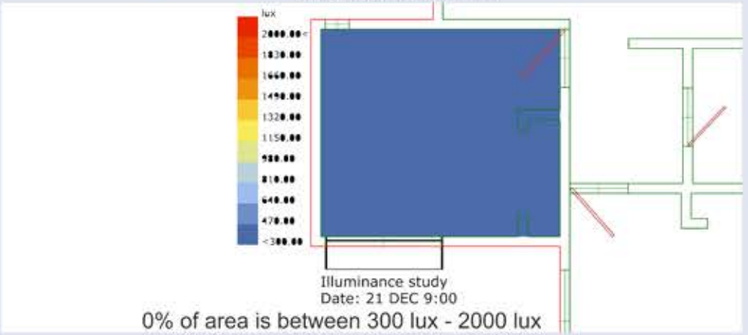
SPRING/FALL 3:00 PM



83% of area is between 300 lux - 2000 lux

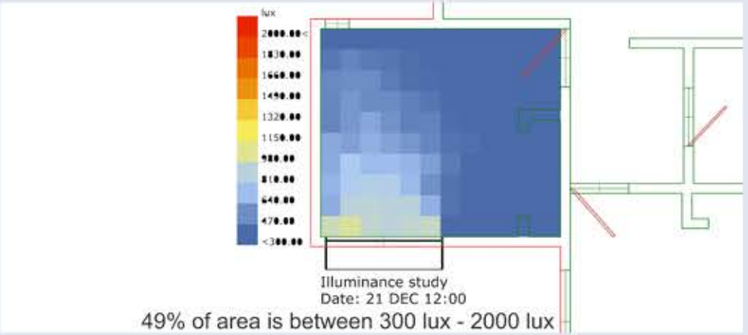
WINTER SOLSTICE

WINTER 9:00 AM



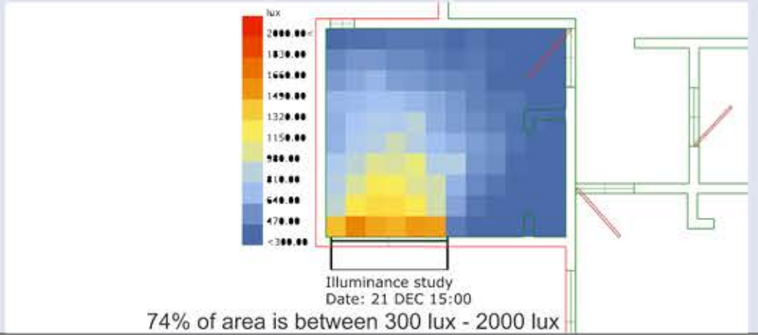
0% of area is between 300 lux - 2000 lux

WINTER 12:00 PM



49% of area is between 300 lux - 2000 lux

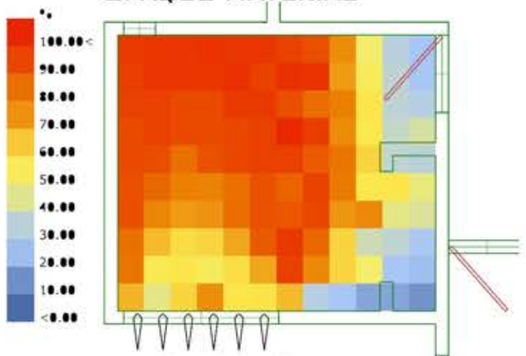
WINTER 3:00 PM



74% of area is between 300 lux - 2000 lux

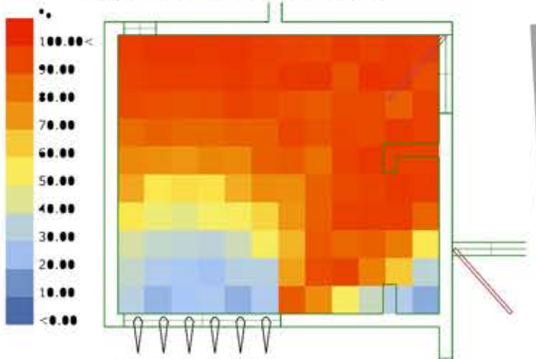
VERTICAL SHADING

USEFUL DAYLIGHT ILLUMINANCE: OPAQUE MATERIAL



Useful Daylight Illuminance
% between 100 lux-2000 lux

USEFUL DAYLIGHT ILLUMINANCE: REFLECTIVE MATERIAL

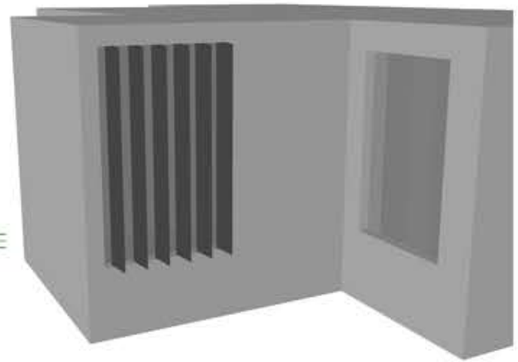


Useful Daylight Illuminance
% between 100 lux-2000 lux

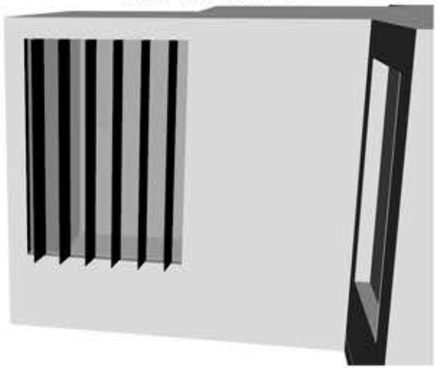
YEARLY RESULTS

PERCENTAGE OF TIME COMFORTABLE	67.76%
PERCENTAGE OF TIME TOO HOT	15.01%
PERCENTAGE OF TIME TOO COLD	21.22%
USEFUL DAYLIGHT ILLUMINANCE MATERIAL: 10% REFLECTIVE	68.68%
USEFUL DAYLIGHT ILLUMINANCE MATERIAL: 90% REFLECTIVE	72.11%

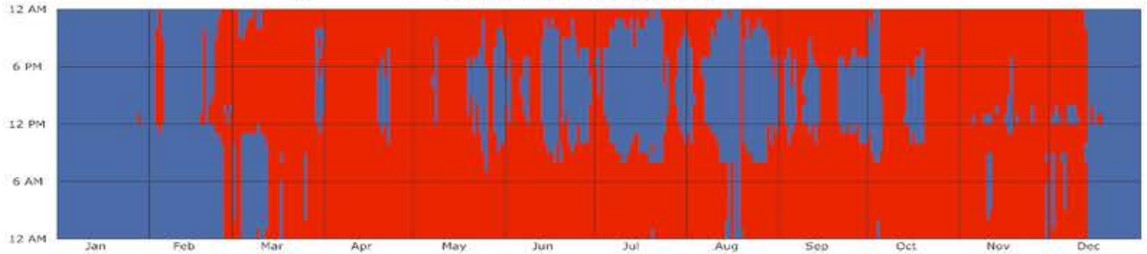
3D VIEW 1



3D VIEW 2

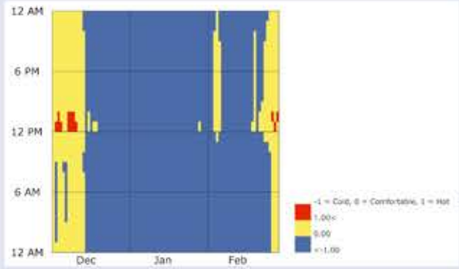


COMFORT CHART



Comfortable
Not Comfortable

WINTER



PERCENTAGE OF TIME COMFORTABLE: 20.37%

PERCENTAGE OF TIME TOO HOT: 0.64%

PERCENTAGE OF TIME TOO COLD: 78.98%

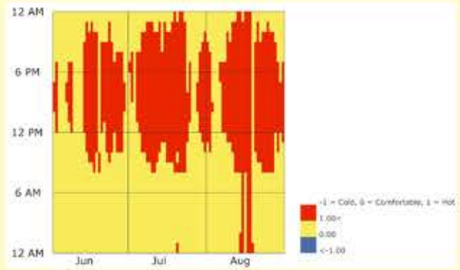
SPRING

PERCENTAGE OF TIME COMFORTABLE: 86.50%

PERCENTAGE OF TIME TOO HOT: 7.47%

PERCENTAGE OF TIME TOO COLD: 6.02%

SUMMER

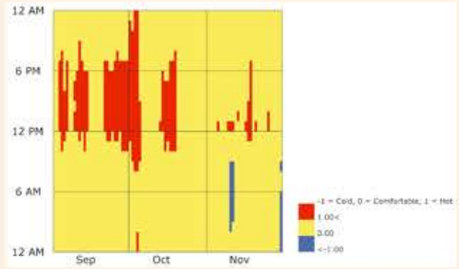


PERCENTAGE OF TIME COMFORTABLE: 61.36%

PERCENTAGE OF TIME TOO HOT: 38.63%

PERCENTAGE OF TIME TOO COLD: 0.00%

FALL



PERCENTAGE OF TIME COMFORTABLE: 86.12%

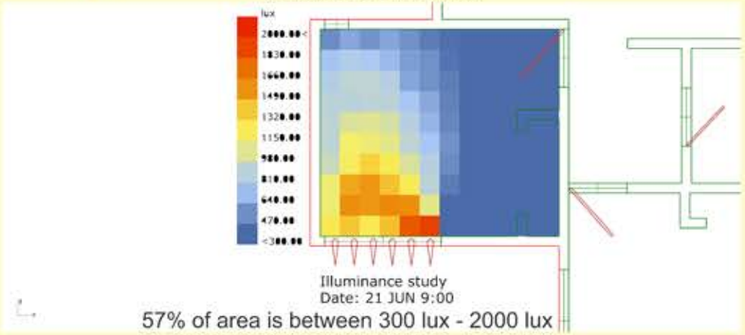
PERCENTAGE OF TIME TOO HOT: 12.95%

PERCENTAGE OF TIME TOO COLD: 0.91%

POINTS IN TIME ANALYSIS: 10% REFLECTIVE VERTICAL SHADING

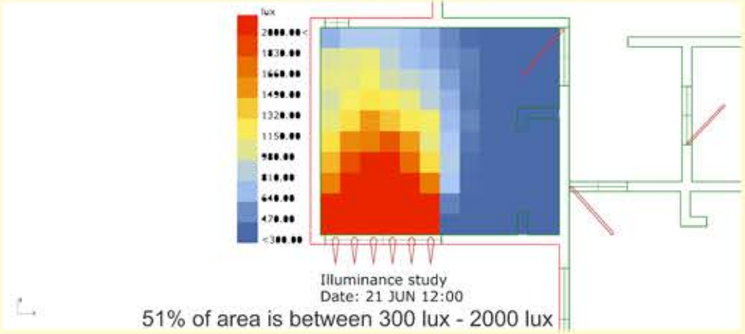
SUMMER SOLSTICE

SUMMER 9:00 AM



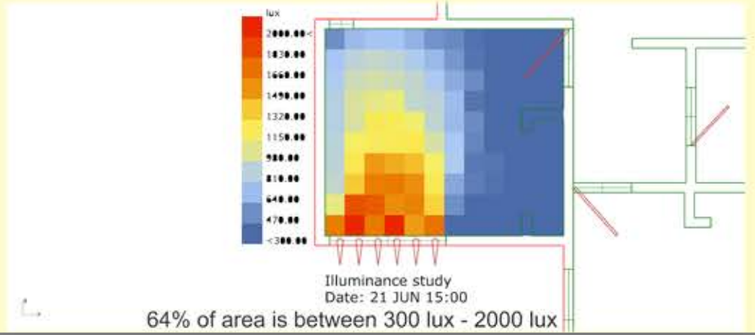
57% of area is between 300 lux - 2000 lux

SUMMER 12:00 PM



51% of area is between 300 lux - 2000 lux

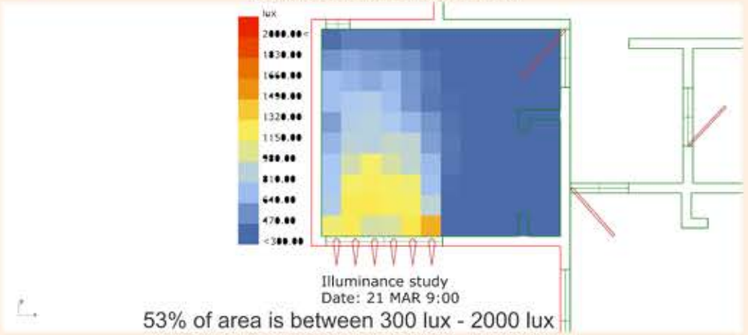
SUMMER 3:00 PM



64% of area is between 300 lux - 2000 lux

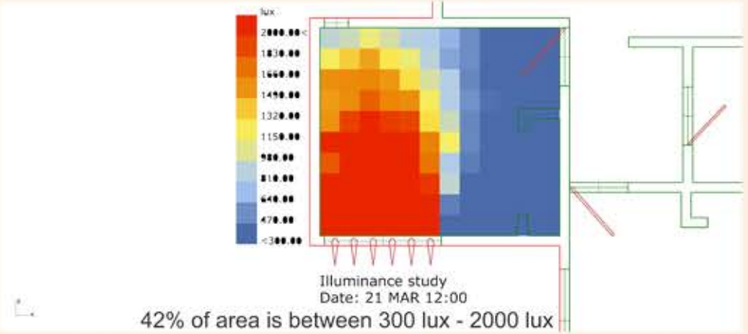
FALL/SPRING EQUINOX

SPRING/FALL 9:00 AM



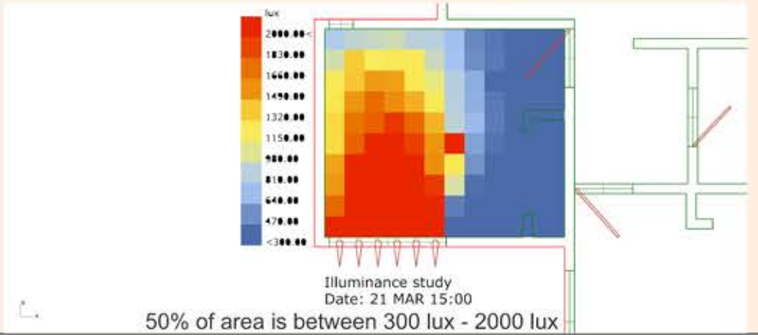
53% of area is between 300 lux - 2000 lux

SPRING/FALL 12:00 PM



42% of area is between 300 lux - 2000 lux

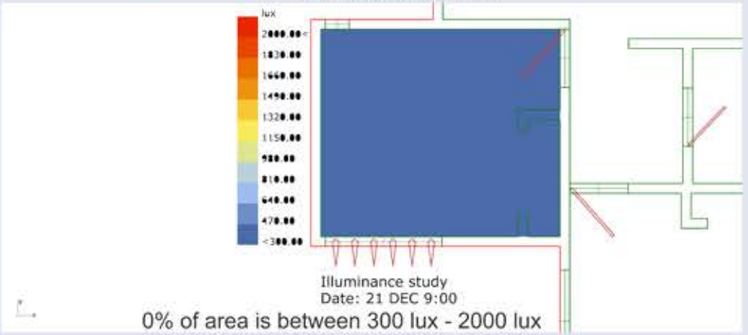
SPRING/FALL 3:00 PM



50% of area is between 300 lux - 2000 lux

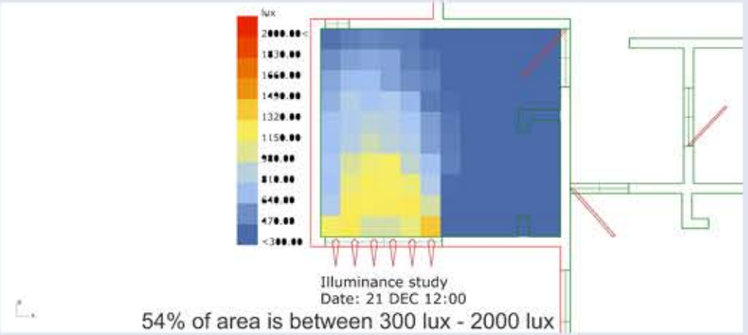
WINTER SOLSTICE

WINTER 9:00 AM



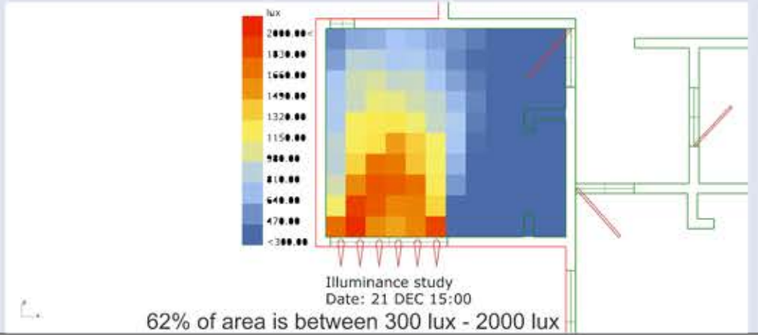
0% of area is between 300 lux - 2000 lux

WINTER 12:00 PM



54% of area is between 300 lux - 2000 lux

WINTER 3:00 PM

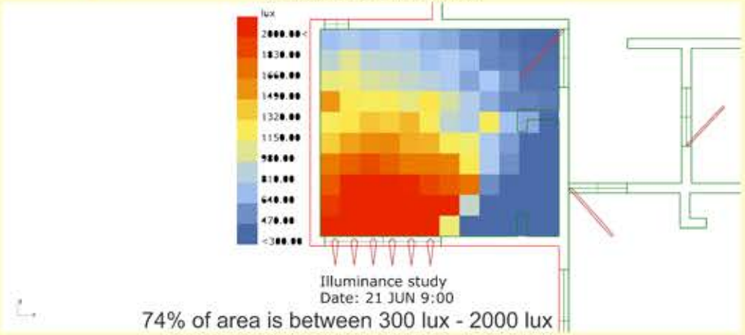


62% of area is between 300 lux - 2000 lux

POINTS IN TIME ANALYSIS: 90% REFLECTIVE VERTICAL SHADING

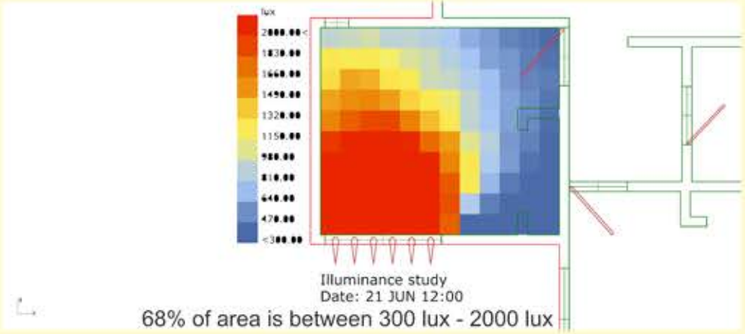
SUMMER SOLSTICE

SUMMER 9:00 AM



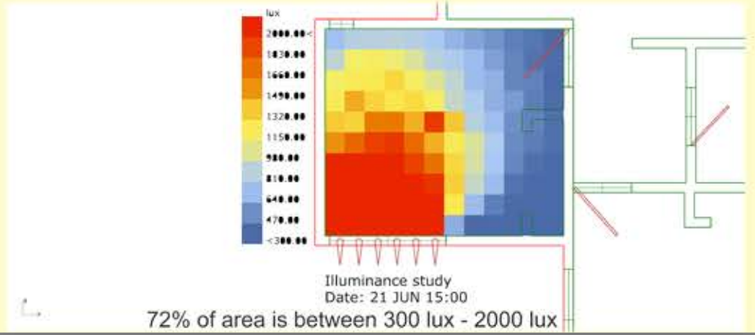
74% of area is between 300 lux - 2000 lux

SUMMER 12:00 PM



68% of area is between 300 lux - 2000 lux

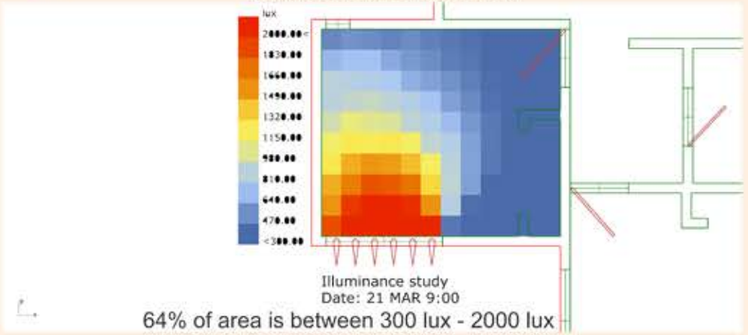
SUMMER 3:00 PM



72% of area is between 300 lux - 2000 lux

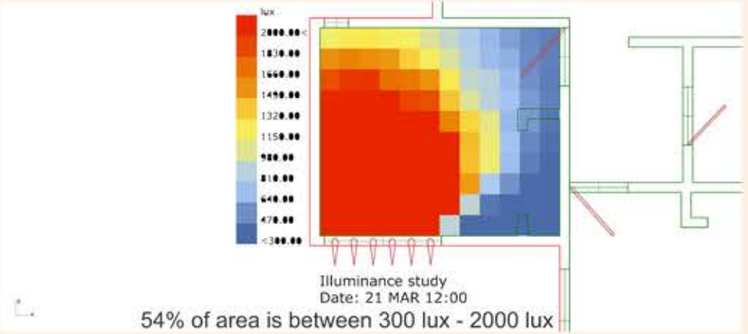
FALL/SPRING EQUINOX

SPRING/FALL 9:00 AM



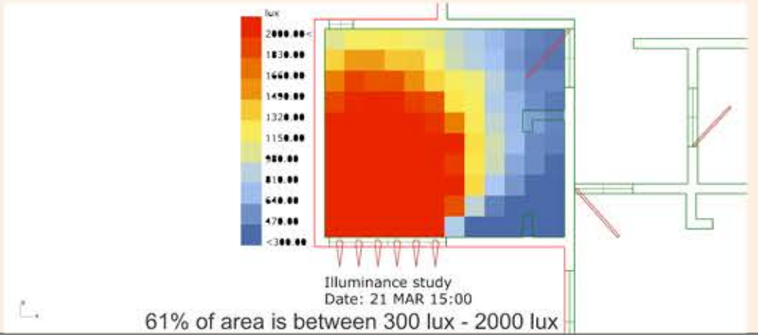
64% of area is between 300 lux - 2000 lux

SPRING/FALL 12:00 PM



54% of area is between 300 lux - 2000 lux

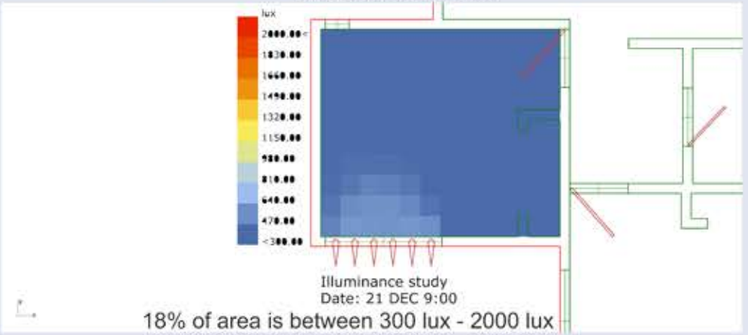
SPRING/FALL 3:00 PM



61% of area is between 300 lux - 2000 lux

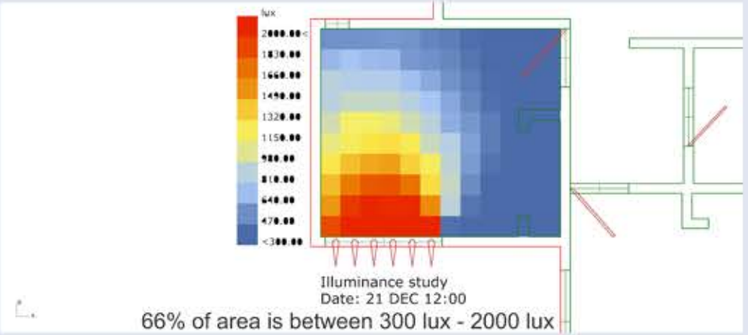
WINTER SOLSTICE

WINTER 9:00 AM



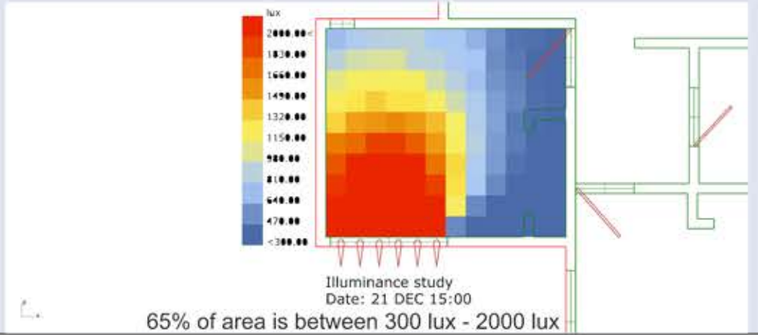
18% of area is between 300 lux - 2000 lux

WINTER 12:00 PM



66% of area is between 300 lux - 2000 lux

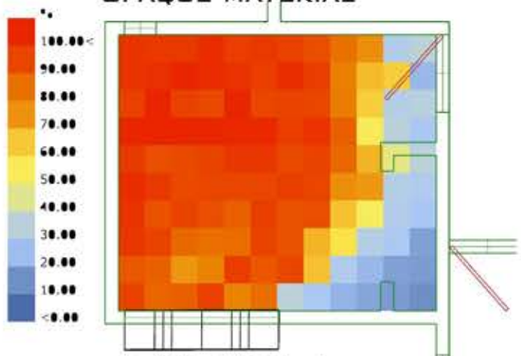
WINTER 3:00 PM



65% of area is between 300 lux - 2000 lux

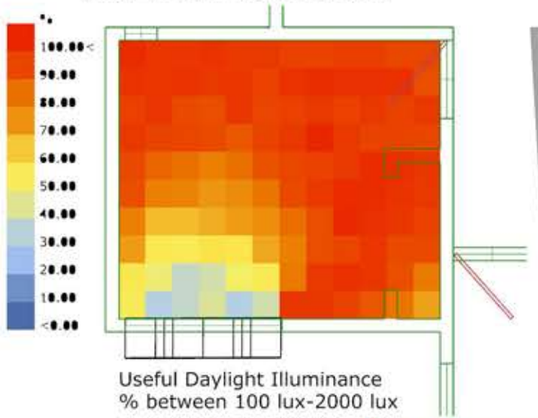
DIAGONAL SHADING

USEFUL DAYLIGHT ILLUMINANCE: OPAQUE MATERIAL



Useful Daylight Illuminance
% between 100 lux-2000 lux

USEFUL DAYLIGHT ILLUMINANCE: REFLECTIVE MATERIAL

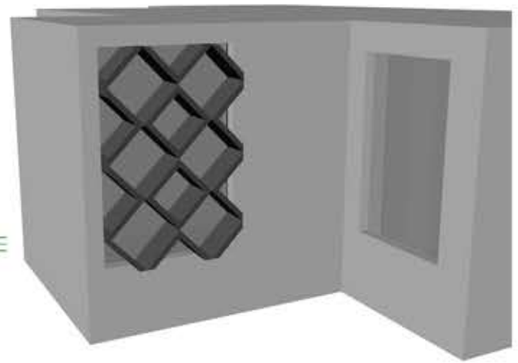


Useful Daylight Illuminance
% between 100 lux-2000 lux

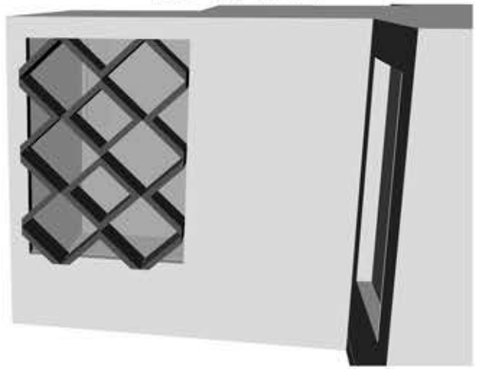
YEARLY RESULTS

PERCENTAGE OF TIME COMFORTABLE	60.28%
PERCENTAGE OF TIME TOO HOT	12.91%
PERCENTAGE OF TIME TOO COLD	26.80%
USEFUL DAYLIGHT ILLUMINANCE MATERIAL: 10% REFLECTIVE	72.67%
USEFUL DAYLIGHT ILLUMINANCE MATERIAL: 90% REFLECTIVE	82.55%

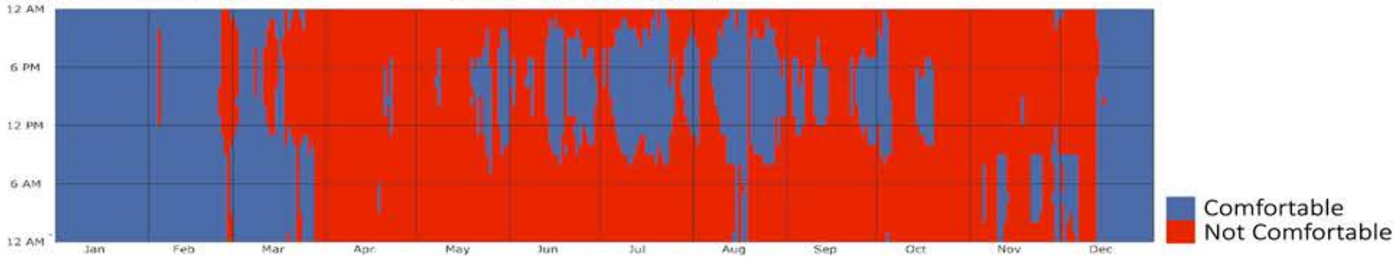
3D VIEW 1



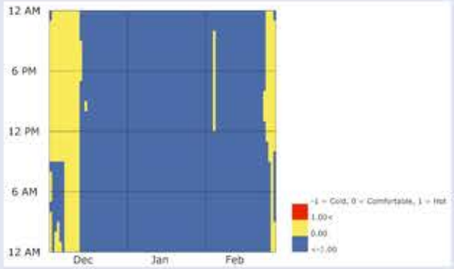
3D VIEW 2



COMFORT CHART



WINTER

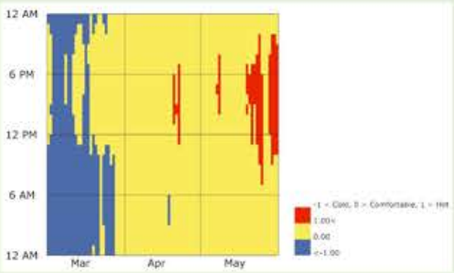


PERCENTAGE OF TIME COMFORTABLE: 15.37%

PERCENTAGE OF TIME TOO HOT: 0.00%

PERCENTAGE OF TIME TOO COLD: 84.62%

SPRING

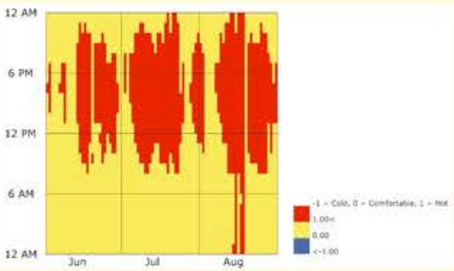


PERCENTAGE OF TIME COMFORTABLE: 75.04%

PERCENTAGE OF TIME TOO HOT: 5.29%

PERCENTAGE OF TIME TOO COLD: 19.65%

SUMMER

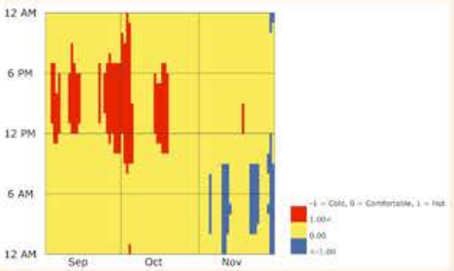


PERCENTAGE OF TIME COMFORTABLE: 64.17%

PERCENTAGE OF TIME TOO HOT: 35.82%

PERCENTAGE OF TIME TOO COLD: 0.00%

FALL



PERCENTAGE OF TIME COMFORTABLE: 85.85%

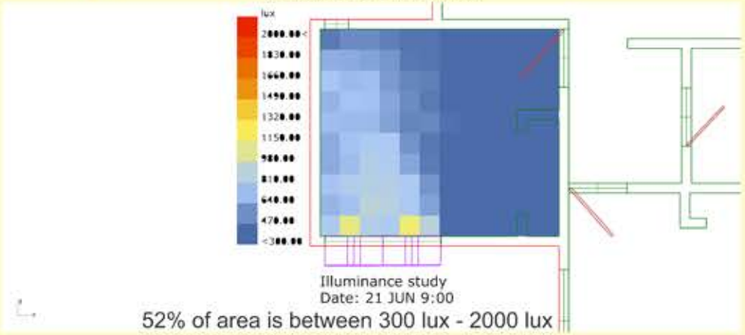
PERCENTAGE OF TIME TOO HOT: 10.21%

PERCENTAGE OF TIME TOO COLD: 3.93%

POINTS IN TIME ANALYSIS: 10% REFLECTIVE DIAGONAL SHADING

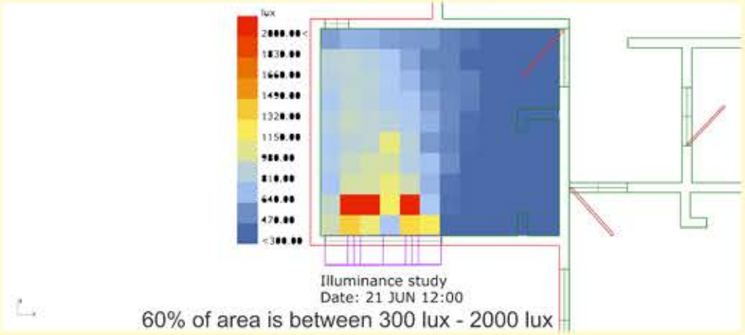
SUMMER SOLSTICE

SUMMER 9:00 AM



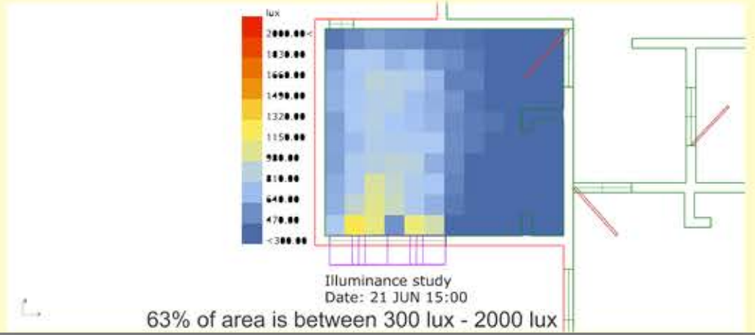
52% of area is between 300 lux - 2000 lux

SUMMER 12:00 PM



60% of area is between 300 lux - 2000 lux

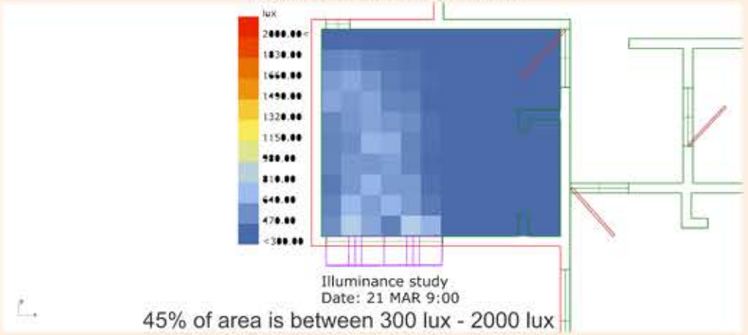
SUMMER 3:00 PM



63% of area is between 300 lux - 2000 lux

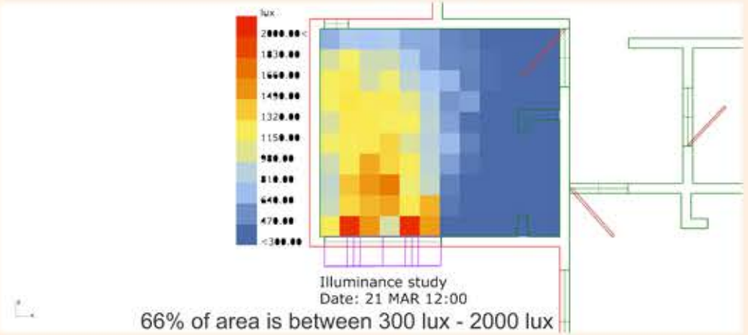
FALL/SPRING EQUINOX

SPRING/FALL 9:00 AM



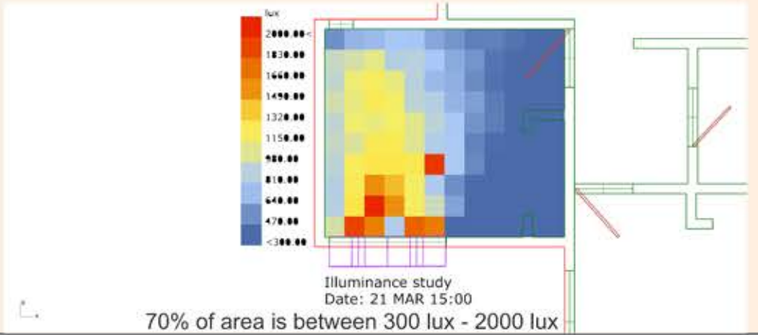
45% of area is between 300 lux - 2000 lux

SPRING/FALL 12:00 PM



66% of area is between 300 lux - 2000 lux

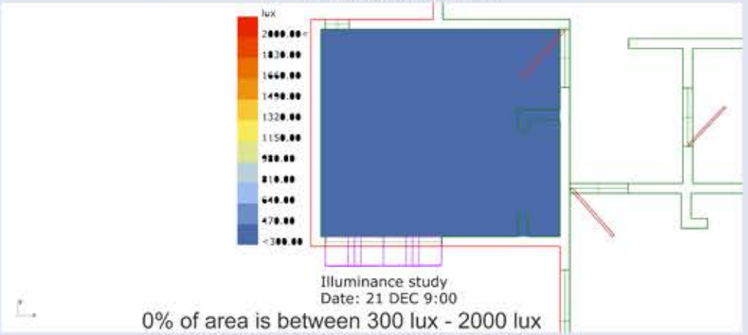
SPRING/FALL 3:00 PM



70% of area is between 300 lux - 2000 lux

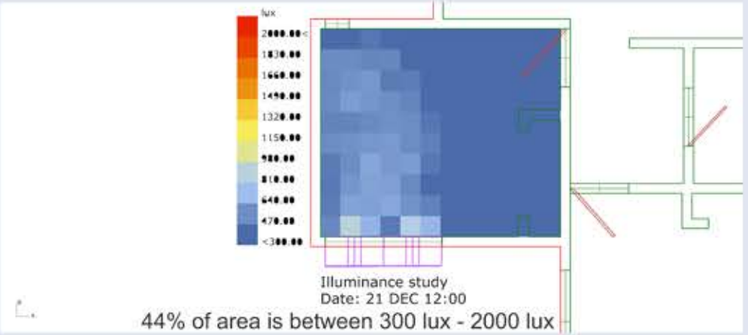
WINTER SOLSTICE

WINTER 9:00 AM



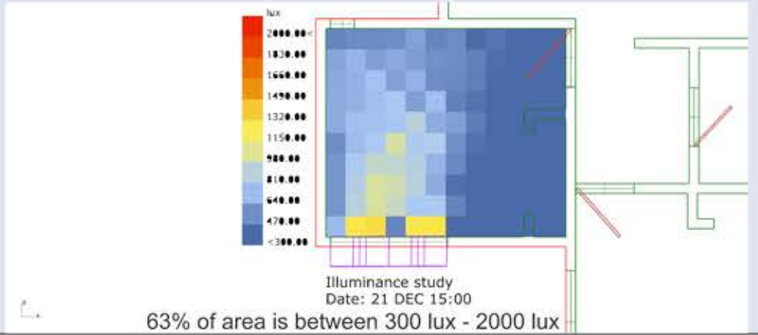
0% of area is between 300 lux - 2000 lux

WINTER 12:00 PM



44% of area is between 300 lux - 2000 lux

WINTER 3:00 PM

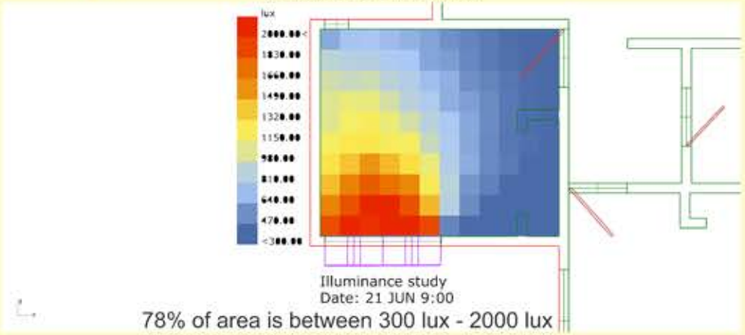


63% of area is between 300 lux - 2000 lux

POINTS IN TIME ANALYSIS: 90% REFLECTIVE DIAGONAL SHADING

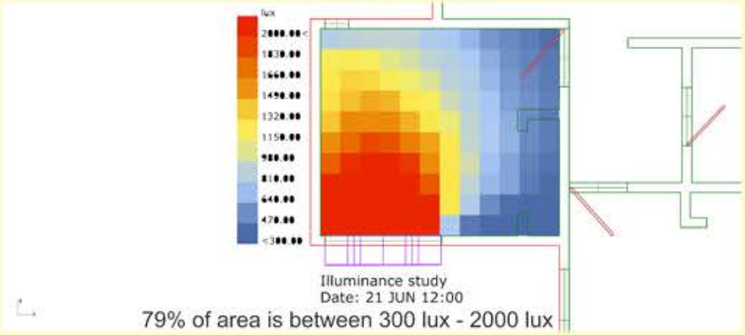
SUMMER SOLSTICE

SUMMER 9:00 AM



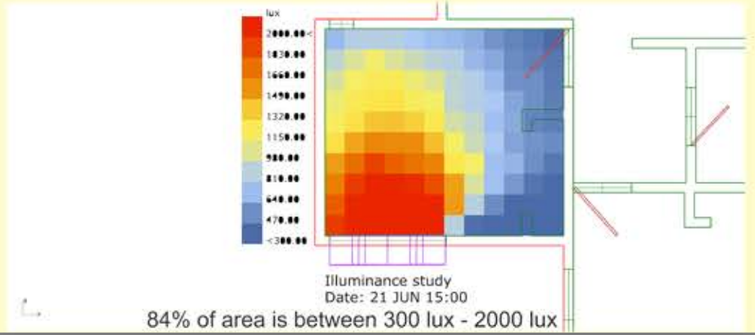
78% of area is between 300 lux - 2000 lux

SUMMER 12:00 PM



79% of area is between 300 lux - 2000 lux

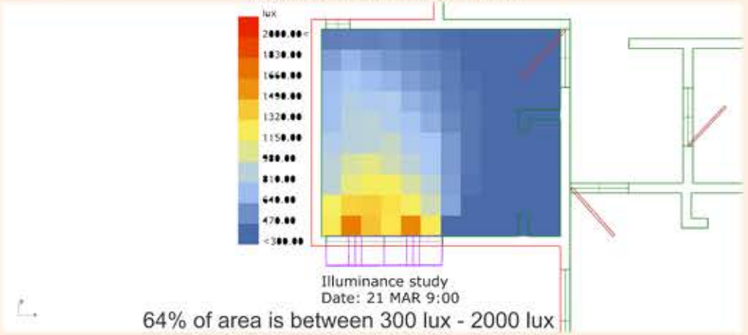
SUMMER 3:00 PM



84% of area is between 300 lux - 2000 lux

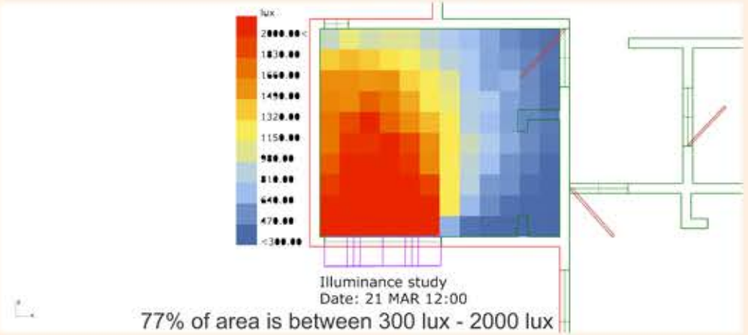
FALL/SPRING EQUINOX

SPRING/FALL 9:00 AM



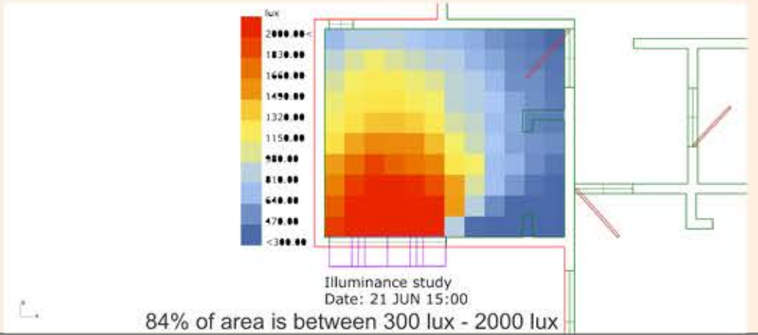
64% of area is between 300 lux - 2000 lux

SPRING/FALL 12:00 PM



77% of area is between 300 lux - 2000 lux

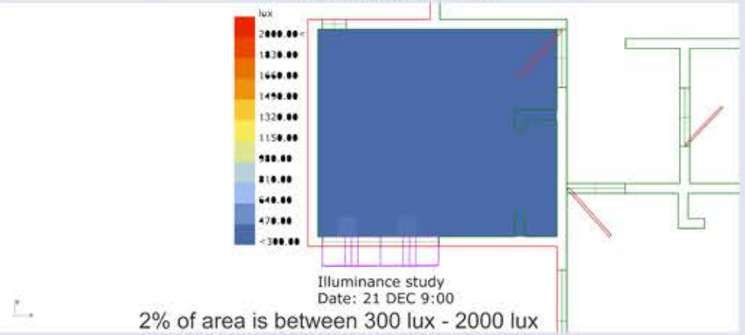
SPRING/FALL 3:00 PM



84% of area is between 300 lux - 2000 lux

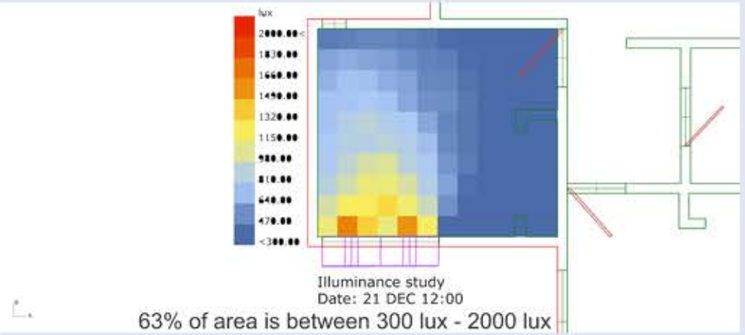
WINTER SOLSTICE

WINTER 9:00 AM



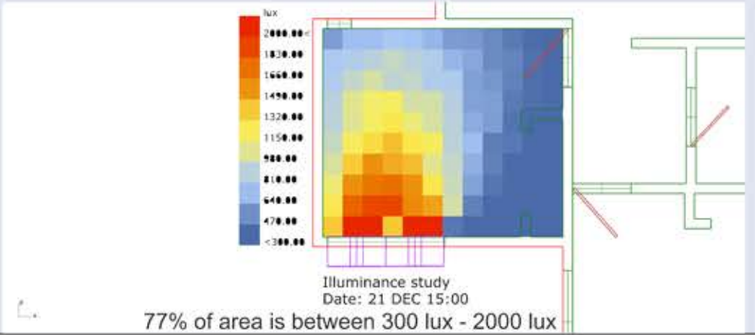
2% of area is between 300 lux - 2000 lux

WINTER 12:00 PM



63% of area is between 300 lux - 2000 lux

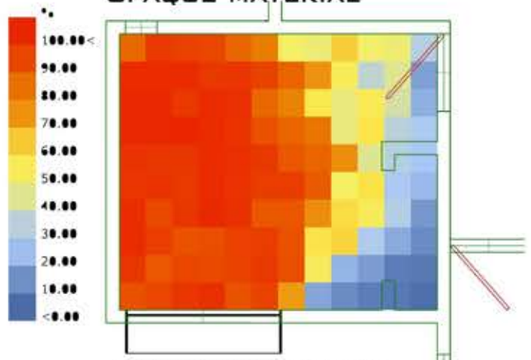
WINTER 3:00 PM



77% of area is between 300 lux - 2000 lux

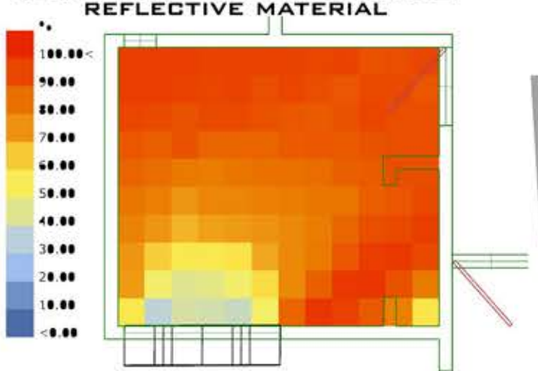
DEPLOYABLE SHADING: DEPLOYS WHEN TEMPERATURE IS ABOVE 22°C

USEFUL DAYLIGHT ILLUMINANCE: OPAQUE MATERIAL



Useful Daylight Illuminance
% between 100 lux-2000 lux

USEFUL DAYLIGHT ILLUMINANCE: REFLECTIVE MATERIAL

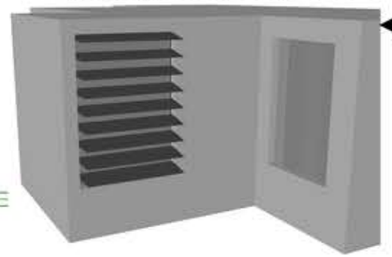


Useful Daylight Illuminance
% between 100 lux-2000 lux

YEARLY RESULTS

PERCENTAGE OF TIME COMFORTABLE	71.80%
PERCENTAGE OF TIME TOO HOT	17.75%
PERCENTAGE OF TIME TOO COLD	10.44%
USEFUL DAYLIGHT ILLUMINANCE MATERIAL: 10% REFLECTIVE	72.79%
USEFUL DAYLIGHT ILLUMINANCE MATERIAL: 90% REFLECTIVE	79.02%

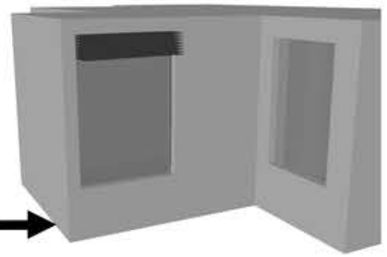
SHADING BELOW 22°C



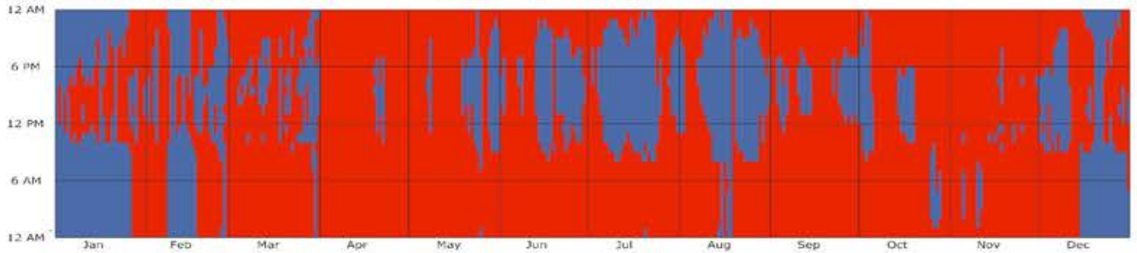
<22°C

>22°C

SHADING ABOVE 22°C

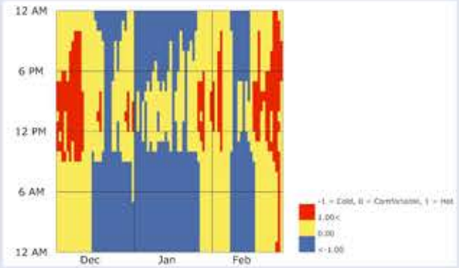


COMFORT CHART



Comfortable
Not Comfortable

WINTER

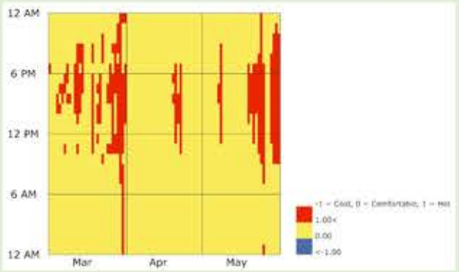


PERCENTAGE OF TIME COMFORTABLE: 47.45%

PERCENTAGE OF TIME TOO HOT: 12.08%

PERCENTAGE OF TIME TOO COLD: 40.46%

SPRING

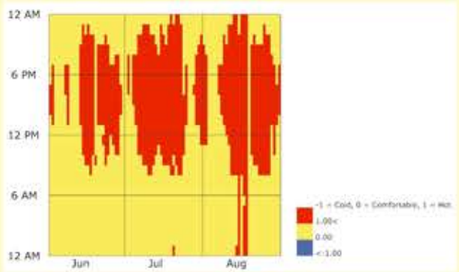


PERCENTAGE OF TIME COMFORTABLE: 87.13%

PERCENTAGE OF TIME TOO HOT: 12.86%

PERCENTAGE OF TIME TOO COLD: 0.00%

SUMMER

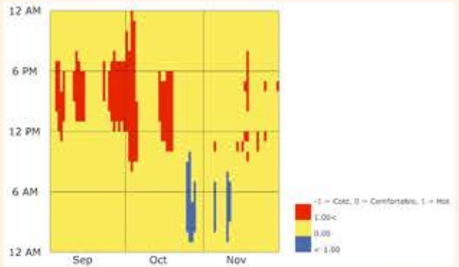


PERCENTAGE OF TIME COMFORTABLE: 63.85%

PERCENTAGE OF TIME TOO HOT: 36.14%

PERCENTAGE OF TIME TOO COLD: 0.00%

FALL



PERCENTAGE OF TIME COMFORTABLE: 88.41%

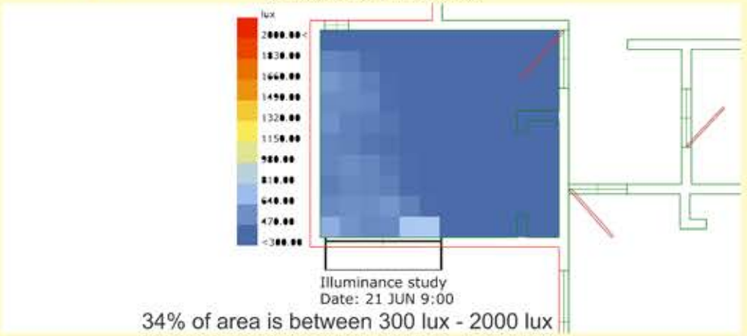
PERCENTAGE OF TIME TOO HOT: 9.70%

PERCENTAGE OF TIME TOO COLD: 1.87%

POINTS IN TIME ANALYSIS: 10% REFLECTIVE DEPLOYABLE SHADING

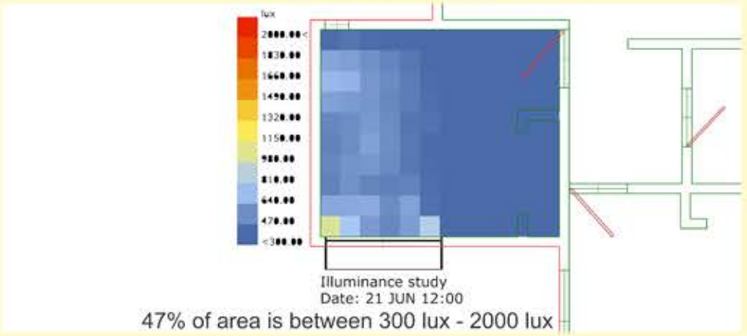
SUMMER SOLSTICE

SUMMER 9:00 AM



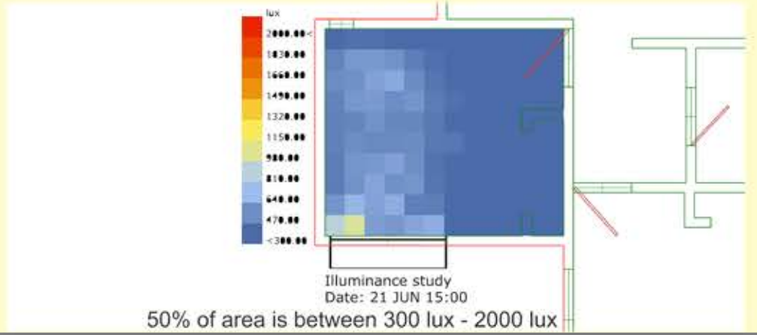
34% of area is between 300 lux - 2000 lux

SUMMER 12:00 PM



47% of area is between 300 lux - 2000 lux

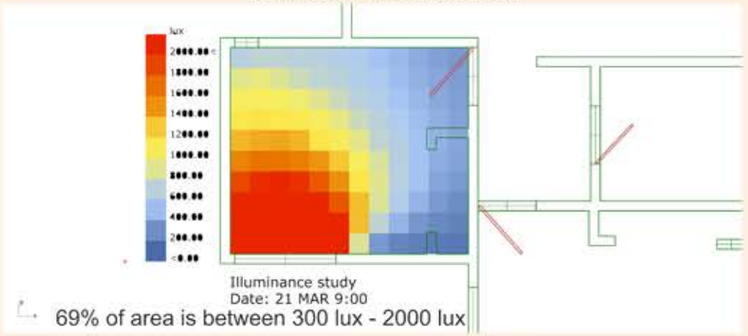
SUMMER 3:00 PM



50% of area is between 300 lux - 2000 lux

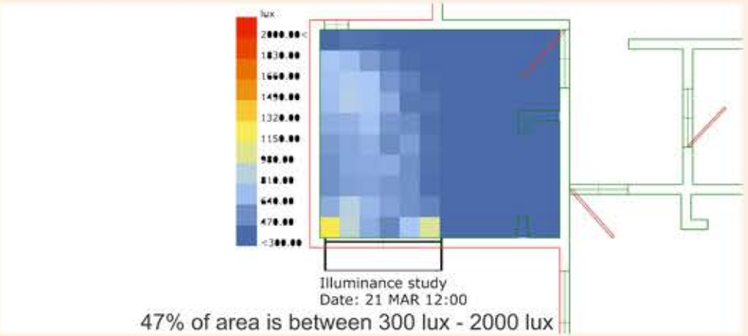
FALL/SPRING EQUINOX

SPRING/FALL 9:00 AM



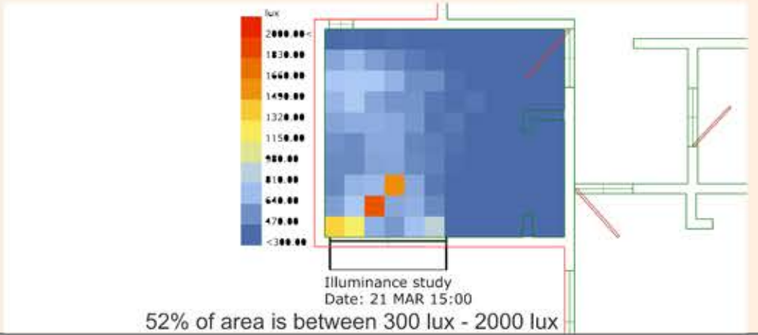
69% of area is between 300 lux - 2000 lux

SPRING/FALL 12:00 PM



47% of area is between 300 lux - 2000 lux

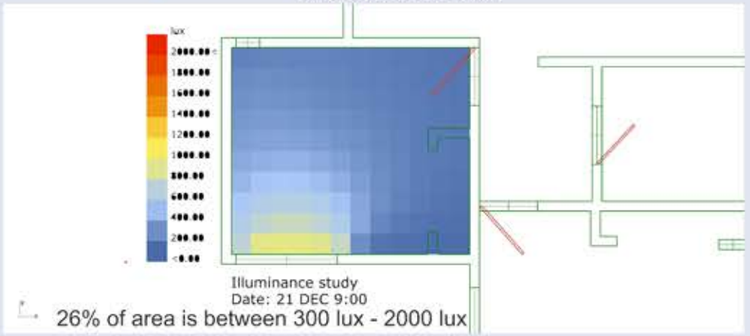
SPRING/FALL 3:00 PM



52% of area is between 300 lux - 2000 lux

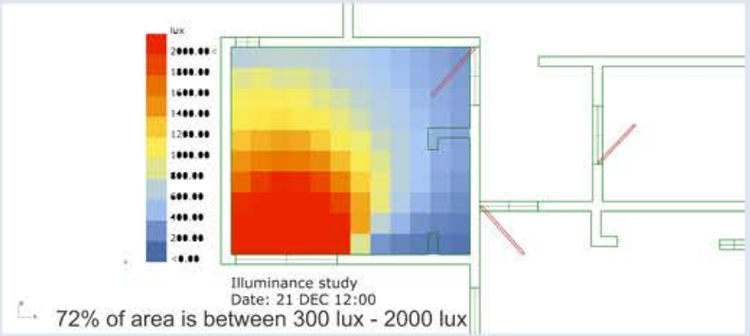
WINTER SOLSTICE

WINTER 9:00 AM



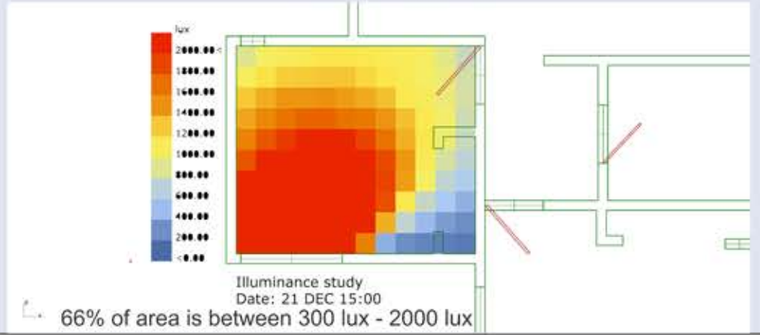
26% of area is between 300 lux - 2000 lux

WINTER 12:00 PM



72% of area is between 300 lux - 2000 lux

WINTER 3:00 PM

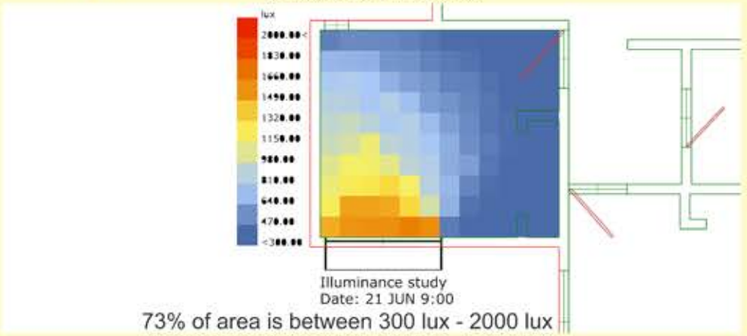


66% of area is between 300 lux - 2000 lux

POINTS IN TIME ANALYSIS: 90% REFLECTIVE DEPLOYABLE SHADING

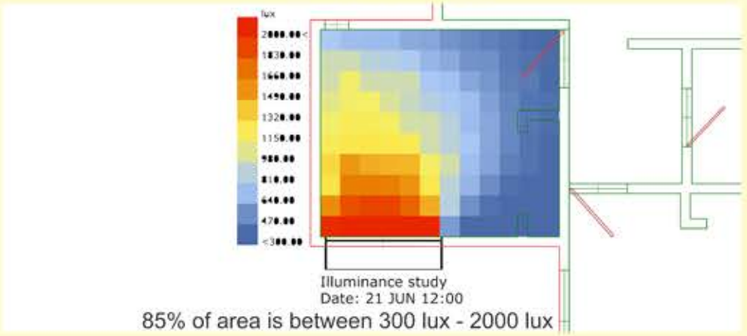
SUMMER SOLSTICE

SUMMER 9:00 AM



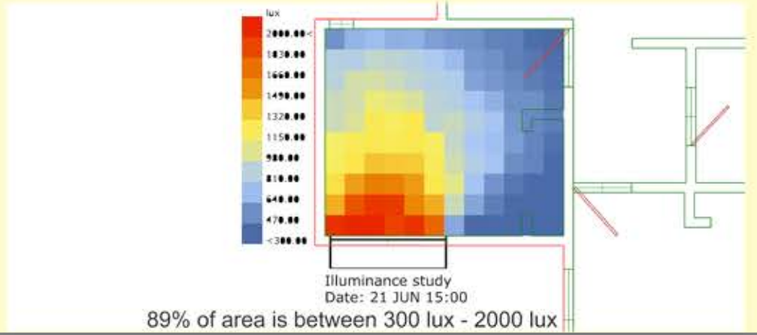
73% of area is between 300 lux - 2000 lux

SUMMER 12:00 PM



85% of area is between 300 lux - 2000 lux

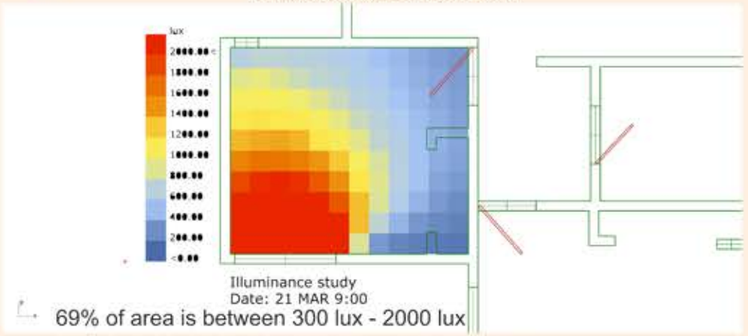
SUMMER 3:00 PM



89% of area is between 300 lux - 2000 lux

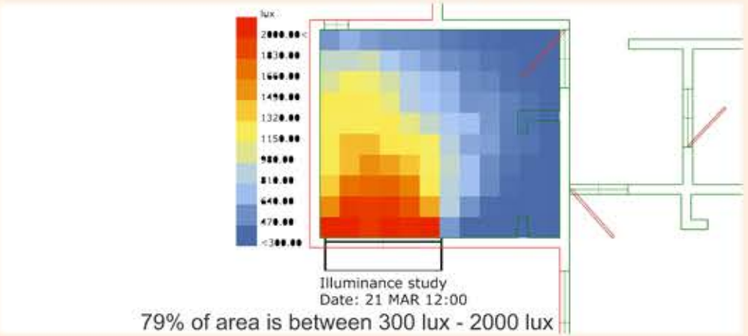
FALL/SPRING EQUINOX

SPRING/FALL 9:00 AM



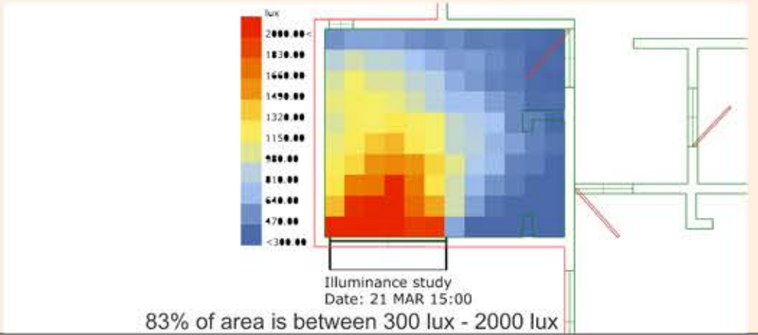
69% of area is between 300 lux - 2000 lux

SPRING/FALL 12:00 PM



79% of area is between 300 lux - 2000 lux

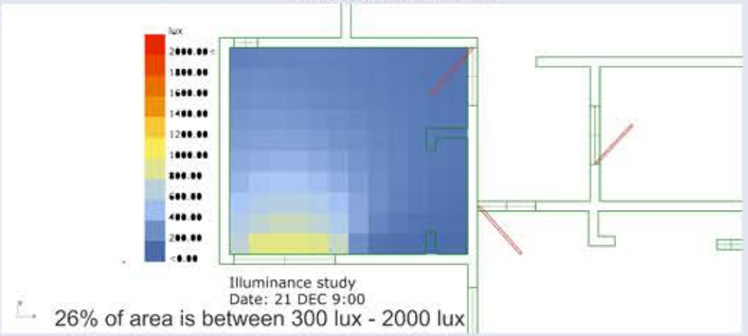
SPRING/FALL 3:00 PM



83% of area is between 300 lux - 2000 lux

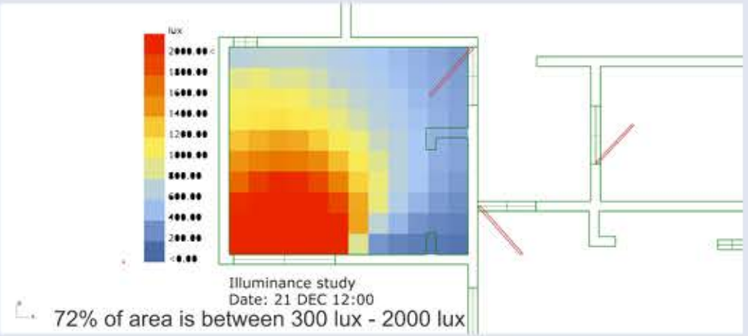
WINTER SOLSTICE

WINTER 9:00 AM



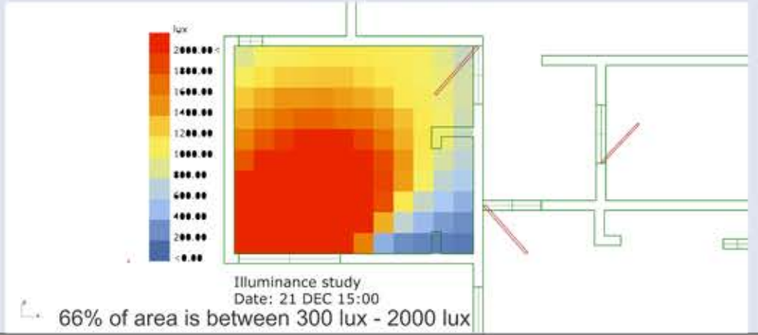
26% of area is between 300 lux - 2000 lux

WINTER 12:00 PM



72% of area is between 300 lux - 2000 lux

WINTER 3:00 PM



66% of area is between 300 lux - 2000 lux

SHADING CONCLUSIONS

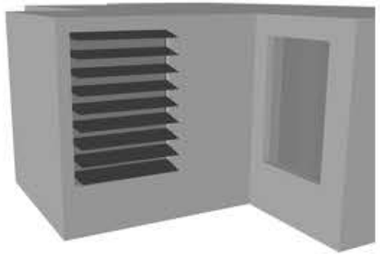
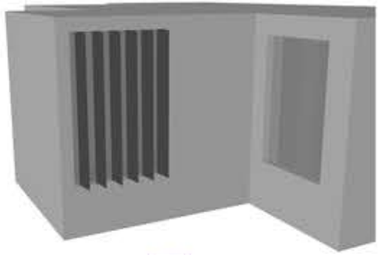
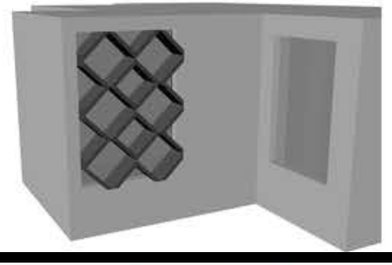
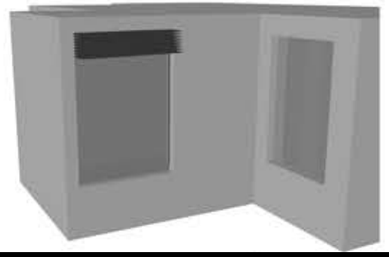
LEGEND

✓ BEST

\+

−

✗ WORST

	HORIZONTAL SHADING	VERTICAL SHADING	DIAGONAL SHADING	DEPLOYABLE SHADING
				
WINTER COMFORT %	✗	+	−	✓
SPRING COMFORT %	✗	+	−	✓
SUMMER COMFORT %	✗	−	✓	+
FALL COMFORT %	✗	+	−	✓
UDI WITH OPAQUE SHADING	✗	−	+	✓
UDI WITH REFLECTIVE SHADING	✓	✗	+	−

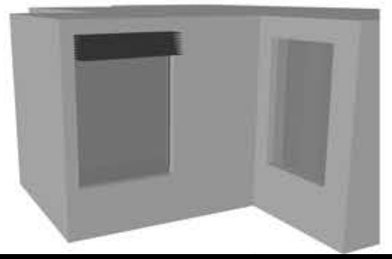
DEPLOYABLE SHADING CAN GIVE THE USER FLEXIBILITY FOR SELECTING WHEN TO PROTECT FROM THE SUN AND WHEN TO RECEIVE DAYLIGHTING.

IN TERMS OF COMFORT LEVELS, HAVING A DEPLOYABLE SYSTEM BASED ON TEMPERATURE WAS MORE EFFICIENT THAN HAVING IT BY RADIATION OR BY MONTHS OF THE YEAR.

CHANGING THE SHADING'S MATERIALS HAS A HUGE IMPACT ON THE AMOUNT OF DAYLIGHT THAT ENTERS THE SPACE: HAVING A REFLECTIVE MATERIAL REFLECTS A CONSIDERABLE AMOUNT OF LIGHT INTO THE ROOM.

IT IS CURIOUS HOW THE HORIZONTAL SHADING, WHICH WAS THE WORST PERFORMING SYSTEM THROUGHOUT THE ANALYSIS, BECOMES THE THE BEST AT THE MOMENT OF APPLYING A REFLECTIVE MATERIAL. THIS PROVES THAT PROTECTING FROM THE SUN'S RADIATION DOESN'T NECESSARILLY MEAN THAT YOUR ROOM WILL BE DARK.

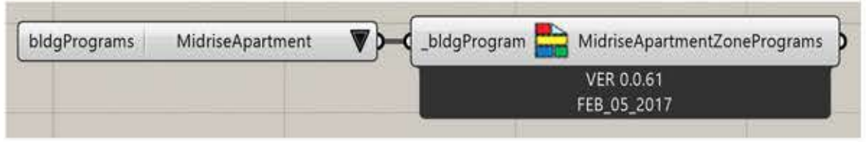
DEPLOYABLE SHADING



INCORPORATING OCCUPANCY+LIGHTING SCHEDULE

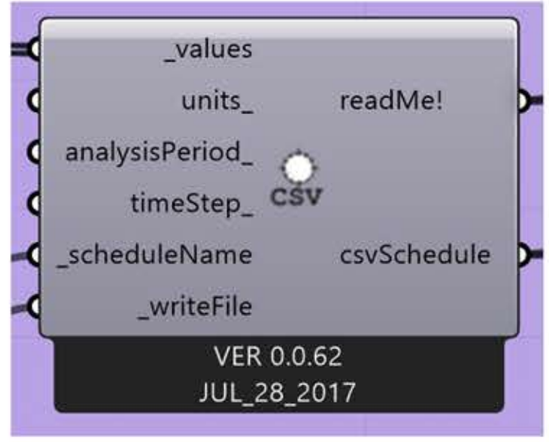
OPTION 1:

USING ENERGY PLUS MID-RISE
DEFAULT OCCUPANCY SCHEDULE
+
USING ENERGY PLUS MID-RISE
LIGHTING SCHEDULE



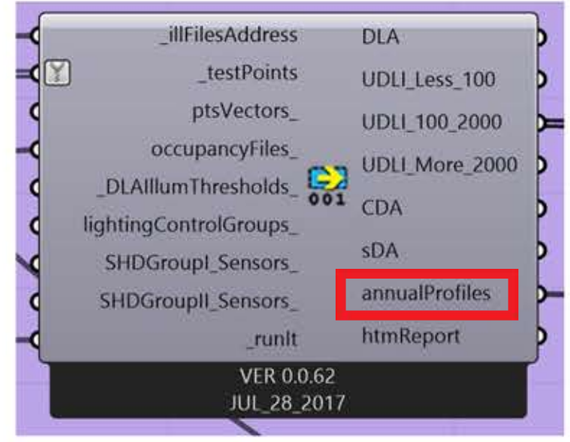
OPTION 2:

USING CUSTOM
OCCUPANCY SCHEDULE
+
USING ENERGY PLUS MID-RISE
LIGHTING SCHEDULE



OPTION 3:

USING CUSTOM
OCCUPANCY SCHEDULE
+
USING DAYLIGHTING ANNUAL
PROFILE LIGHTING SCHEDULE

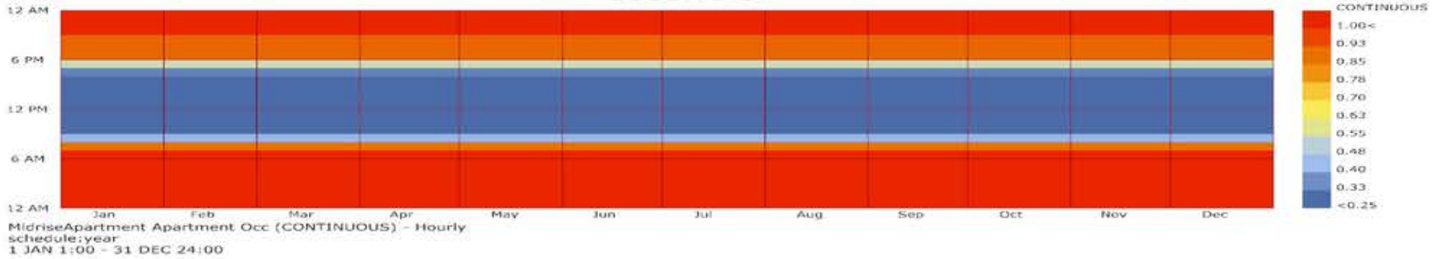


OPTION 1: USING ENERGY PLUS MID-RISE DEFAULT OCCUPANCY SCHEDULE+ USING ENERGY PLUS MID-RISE LIGHTING SCHEDULE

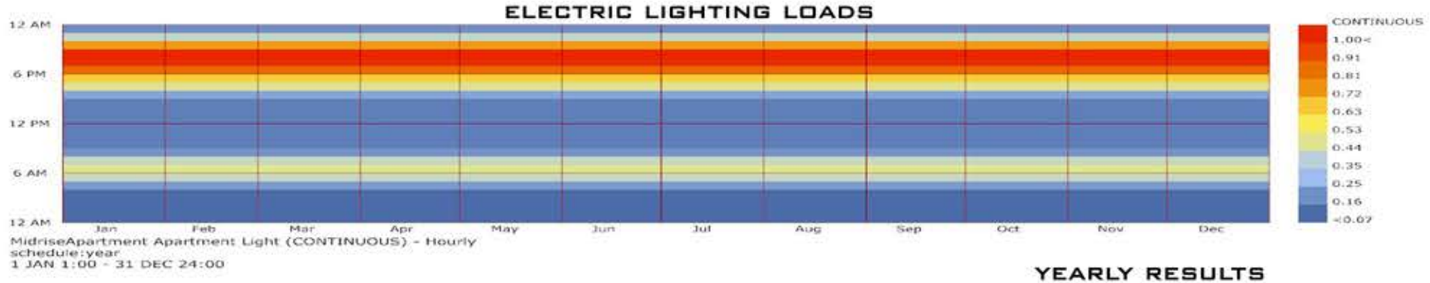
ENERGY PLUS DEFAULT OCCUPANCY SCHEDULE FOR MID-RISE APARTMENT: WEEKDAYS+WEEKENDS

HOUR:	12:00 am	1.00 am	2:00 am	3:00 am	4:00 am	5:00 am	6:00 am	7:00 am	8:00 am	9:00 am	10:00 am	11:00 am	12:00 pm	1:00 pm	2:00pm	3:00 pm	4:00 pm	5:00 pm	6:00 pm	7:00 pm	8:00 pm	9:00 pm	10:00 pm	11:00 pm
OCCUPANCY:	100%	100%	100%	100%	100%	100%	100%	85%	39%	25%	25%	25%	25%	25%	25%	25%	30%	52%	87%	87%	87%	100%	100%	100%

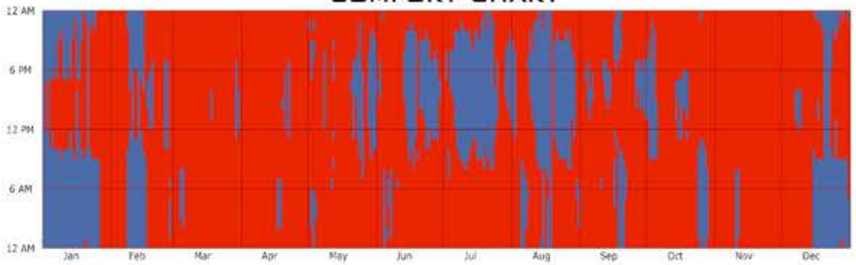
OCCUPANCY



ELECTRIC LIGHTING LOADS



COMFORT CHART

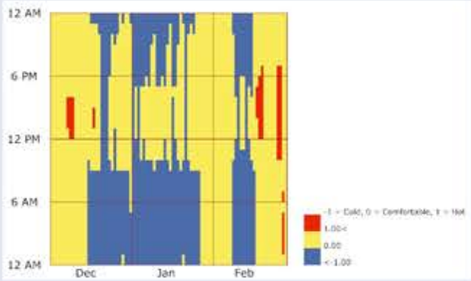


Not Comfortable
Comfortable

YEARLY RESULTS

PERCENTAGE OF TIME COMFORTABLE	76.86%
PERCENTAGE OF TIME TOO HOT	11.70%
PERCENTAGE OF TIME TOO COLD	11.43%
ELECTRIC LOADS	266.41 KWH
HEATING LOADS (IS CONDITIONED SET TO TRUE)	2,424.89 KWH
COOLING LOADS (IS CONDITIONED SET TO TRUE)	4,944.77 KWH

WINTER

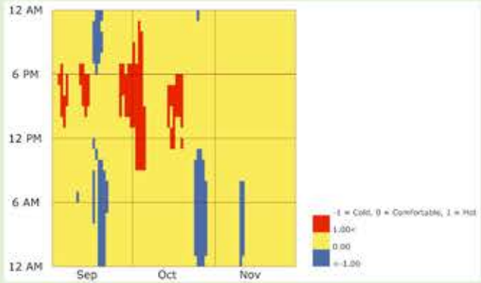


PERCENTAGE OF TIME COMFORTABLE: 61.48%

PERCENTAGE OF TIME TOO HOT: 2.40%

PERCENTAGE OF TIME TOO COLD: 36.11%

SPRING

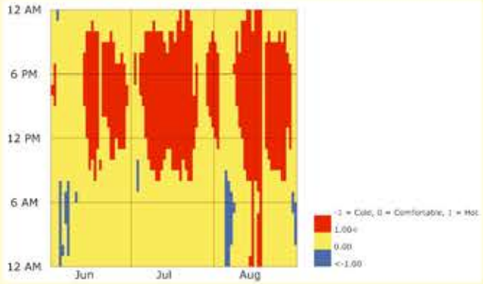


PERCENTAGE OF TIME COMFORTABLE: 92.01%

PERCENTAGE OF TIME TOO HOT: 5.84%

PERCENTAGE OF TIME TOO COLD: 2.12%

SUMMER

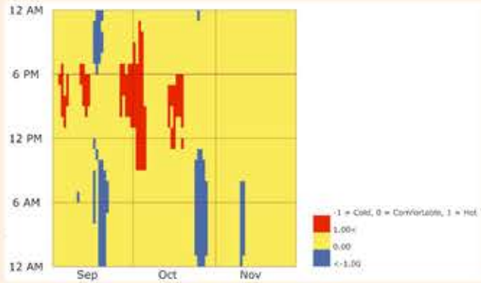


PERCENTAGE OF TIME COMFORTABLE: 65.12%

PERCENTAGE OF TIME TOO HOT: 32.47%

PERCENTAGE OF TIME TOO COLD: 2.40%

FALL



PERCENTAGE OF TIME COMFORTABLE: 88.59%

PERCENTAGE OF TIME TOO HOT: 5.81%

PERCENTAGE OF TIME TOO COLD: 5.58%

OPTION 2: USING CUSTOM OCCUPANCY SCHEDULE+ USING ENERGY PLUS MID-RISE LIGHTING SCHEDULE

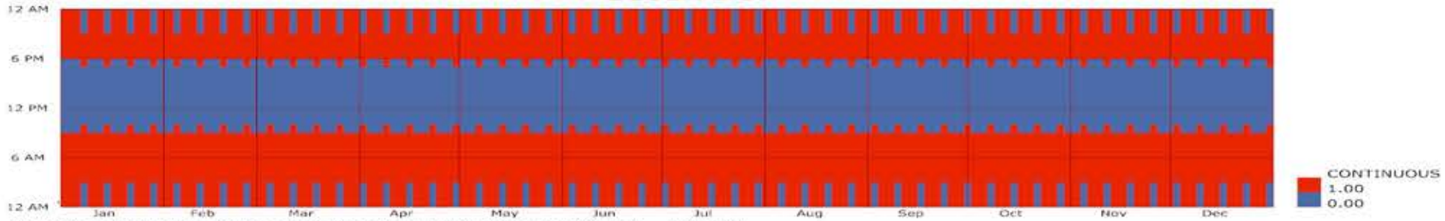
CUSTOM OCCUPANCY SCHEDULE FOR MID-RISE APARTMENT: WEEKDAYS

HOUR:	12:00 am	1:00 am	2:00 am	3:00 am	4:00 am	5:00 am	6:00 am	7:00 am	8:00 am	9:00 am	10:00 am	11:00 am	12:00 pm	1:00 pm	2:00pm	3:00 pm	4:00 pm	5:00 pm	6:00 pm	7:00 pm	8:00 pm	9:00 pm	10:00 pm	11:00 pm
OCCUPANCY:	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	100%	100%	100%	100%	100%

CUSTOM OCCUPANCY SCHEDULE FOR MID-RISE APARTMENT: WEEKENDS

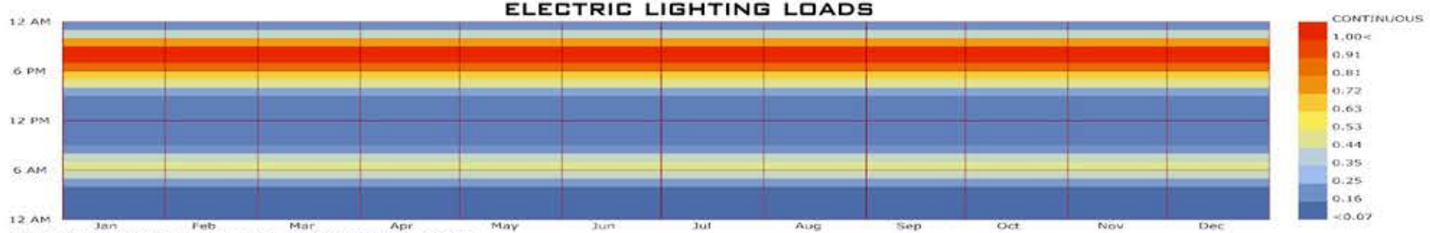
HOUR:	12:00 am	1:00 am	2:00 am	3:00 am	4:00 am	5:00 am	6:00 am	7:00 am	8:00 am	9:00 am	10:00 am	11:00 am	12:00 pm	1:00 pm	2:00pm	3:00 pm	4:00 pm	5:00 pm	6:00 pm	7:00 pm	8:00 pm	9:00 pm	10:00 pm	11:00 pm
OCCUPANCY:	0%	0%	0%	100%	100%	100%	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%	0%	100%	100%	100%	100%	0%	0%	0%

OCCUPANCY



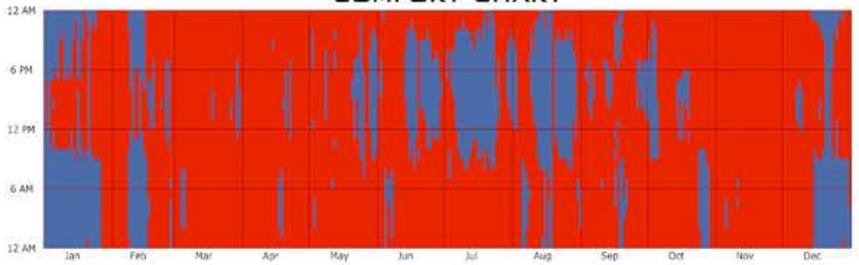
SCHOccupancy_Room_Oklahoma.csv (CONTINUOUS) - Hourly
schedule:year
1 JAN 1:00 - 31 DEC 24:00

ELECTRIC LIGHTING LOADS



MidriseApartment Apartment Light (CONTINUOUS) - Hourly
schedule:year
1 JAN 1:00 - 31 DEC 24:00

COMFORT CHART

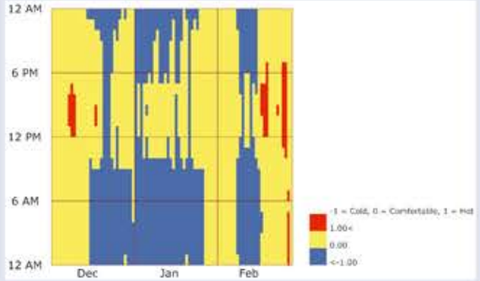


Not Comfortable
Comfortable

YEARLY RESULTS

PERCENTAGE OF TIME COMFORTABLE	77.18%
PERCENTAGE OF TIME TOO HOT	11.68%
PERCENTAGE OF TIME TOO COLD	11.13%
ELECTRIC LOADS	266.41 KWH
HEATING LOADS (IS CONDITIONED SET TO TRUE)	2,400.89 KWH
COOLING LOADS (IS CONDITIONED SET TO TRUE)	4,937.73 KWH

WINTER

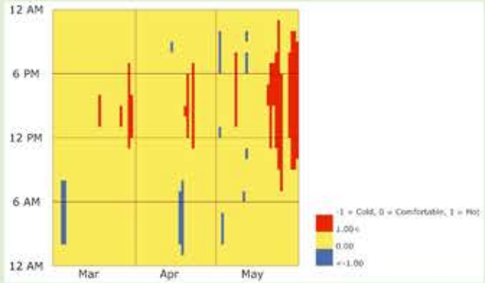


PERCENTAGE OF TIME COMFORTABLE: 61.15%

PERCENTAGE OF TIME TOO HOT: 2.43%

PERCENTAGE OF TIME TOO COLD: 36.38%

SPRING

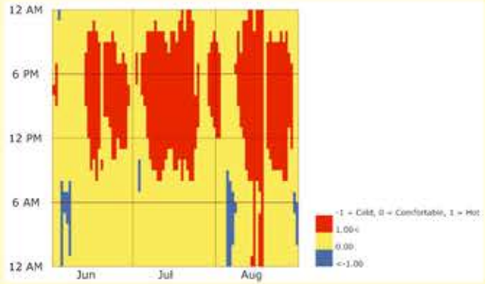


PERCENTAGE OF TIME COMFORTABLE: 92.30%

PERCENTAGE OF TIME TOO HOT: 5.97%

PERCENTAGE OF TIME TOO COLD: 1.72%

SUMMER

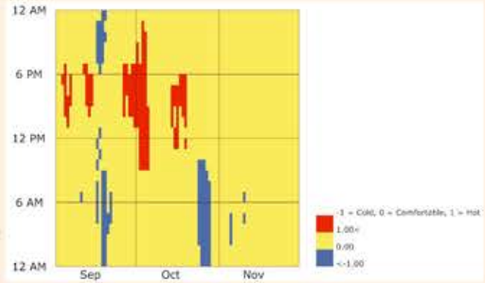


PERCENTAGE OF TIME COMFORTABLE: 65.26%

PERCENTAGE OF TIME TOO HOT: 32.33%

PERCENTAGE OF TIME TOO COLD: 2.40%

FALL



PERCENTAGE OF TIME COMFORTABLE: 89.78%

PERCENTAGE OF TIME TOO HOT: 5.72%

PERCENTAGE OF TIME TOO COLD: 4.48%

OPTION 3: USING CUSTOM OCCUPANCY SCHEDULE+ USING DAYLIGHTING ANNUAL PROFILE LIGHTING SCHEDULE

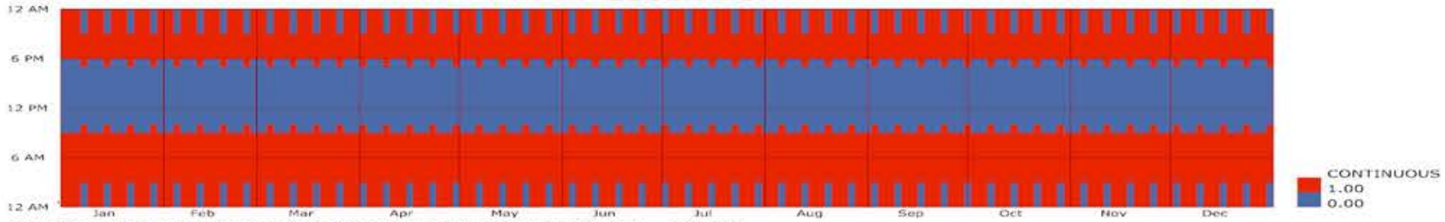
CUSTOM OCCUPANCY SCHEDULE FOR MID-RISE APARTMENT: WEEKDAYS

HOUR:	12:00 am	1:00 am	2:00 am	3:00 am	4:00 am	5:00 am	6:00 am	7:00 am	8:00 am	9:00 am	10:00 am	11:00 am	12:00 pm	1:00 pm	2:00pm	3:00 pm	4:00 pm	5:00 pm	6:00 pm	7:00 pm	8:00 pm	9:00 pm	10:00 pm	11:00 pm
OCCUPANCY:	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	100%	100%	100%	100%	100%

CUSTOM OCCUPANCY SCHEDULE FOR MID-RISE APARTMENT: WEEKENDS

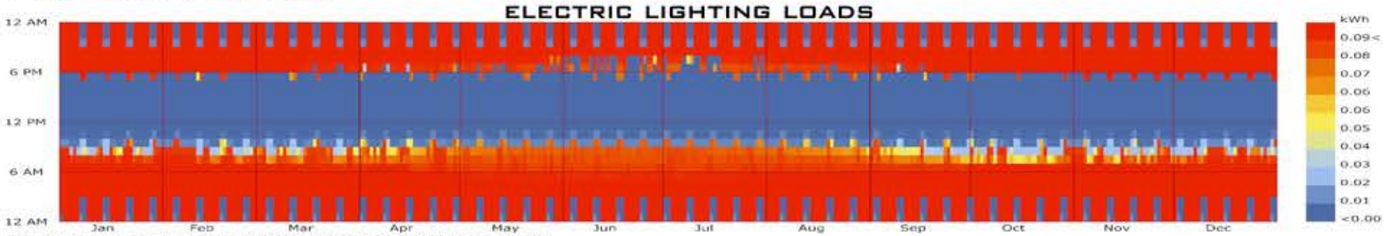
HOUR:	12:00 am	1:00 am	2:00 am	3:00 am	4:00 am	5:00 am	6:00 am	7:00 am	8:00 am	9:00 am	10:00 am	11:00 am	12:00 pm	1:00 pm	2:00pm	3:00 pm	4:00 pm	5:00 pm	6:00 pm	7:00 pm	8:00 pm	9:00 pm	10:00 pm	11:00 pm
OCCUPANCY:	0%	0%	0%	100%	100%	100%	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%	0%	100%	100%	100%	100%	0%	0%	0%

OCCUPANCY



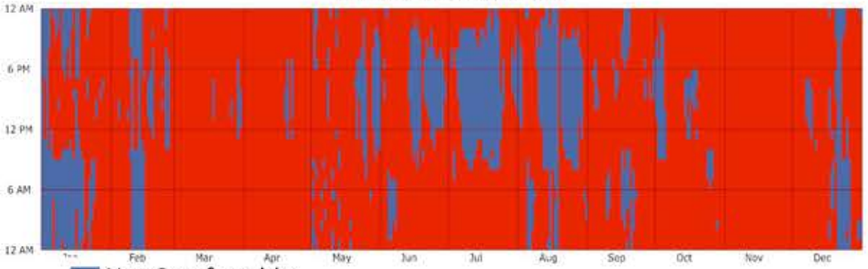
SCHOccupancy_Room_Oklahoma.csv (CONTINUOUS) - Hourly
schedule:year
1 JAN 1:00 - 31 DEC 24:00

ELECTRIC LIGHTING LOADS



Electric Lighting Energy for OKLAHOMA_CITY_ROOM (kWh) - Hourly
Oklahoma City Will Rogers Wor OK USA TMY3
1 JAN 1:00 - 31 DEC 24:00

COMFORT CHART

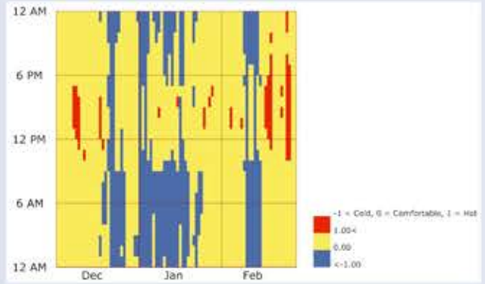


Not Comfortable
Comfortable

YEARLY RESULTS

PERCENTAGE OF TIME COMFORTABLE	80.73%
PERCENTAGE OF TIME TOO HOT	11.33%
PERCENTAGE OF TIME TOO COLD	7.93%
ELECTRIC LOADS	437.73 KWH
HEATING LOADS (IS CONDITIONED SET TO TRUE)	2,866.72 KWH
COOLING LOADS (IS CONDITIONED SET TO TRUE)	4,968.99 KWH

WINTER

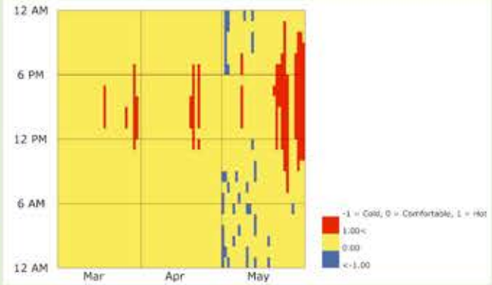


PERCENTAGE OF TIME COMFORTABLE:
72.40%

PERCENTAGE OF TIME TOO HOT:
3.33%

PERCENTAGE OF TIME TOO COLD:
24.25%

SPRING

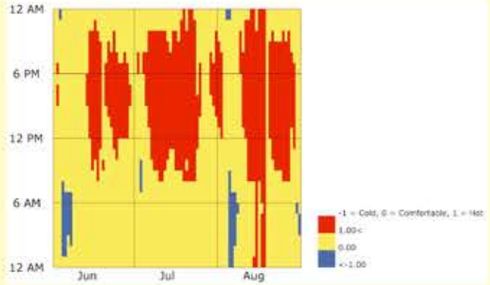


PERCENTAGE OF TIME COMFORTABLE:
92.03%

PERCENTAGE OF TIME TOO HOT:
6.02%

PERCENTAGE OF TIME TOO COLD:
1.94%

SUMMER

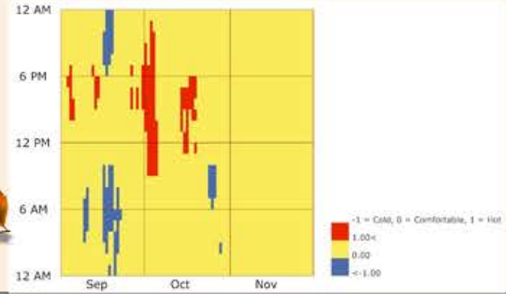


PERCENTAGE OF TIME COMFORTABLE:
66.34%

PERCENTAGE OF TIME TOO HOT:
31.25%

PERCENTAGE OF TIME TOO COLD:
2.40%

FALL



PERCENTAGE OF TIME COMFORTABLE:
92.07%

PERCENTAGE OF TIME TOO HOT:
4.48%

PERCENTAGE OF TIME TOO COLD:
3.43%

WALL MATERIALS CONCLUSIONS

LEGEND

WORST ✗ ← → BEST ✓

	OPTION 1: DEFAULT ENERGY PLUS OCCUPANCY SCHEDULE + ENERGY PLUS MID-RISE LIGHTING SCHEDULE	OPTION 2: CUSTOM OCCUPANCY SCHEDULE + ENERGY PLUS MID-RISE LIGHTING SCHEDULE	OPTION 3: CUSTOM OCCUPANCY SCHEDULE + DAYLIGHTING PROFILE LIGHTING SCHEDULE
COMFORT %	+ −	✗	✓
COMFORT %	✗	✓	+ −
COMFORT %	✗	+ −	✓
COMFORT %	✗	+ −	✓
ELECTRIC LIGHTING LOADS	✓	+ −	+ −
HEATING LOADS	+ −	✓	✗
COOLING LOADS	+ −	✓	✗

ENERGY PLUS SCHEDULES ARE SOMEHOW LIMITED AND LACK INFORMATION.

HAVING A CUSTOM OCCUPANCY SCHEDULE REFLECTS MORE TRUTHFULLY THE ACTIVITIES THAT HAPPEN IN THE ROOM. UNIVERSITY CLASSES, LATE NIGHT WORKING, AND GOING OUT UNTIL LATE DURING THE WEEKENDS, IS SOMETHING YOU CAN ACKNOWLEDGE IN YOUR CUSTOM SCHEDULE.

IN THE SIMULATIONS' RESULTS, HEATING, COOLING, AND ELECTRIC LIGHTING LOADS WERE INVERSELY PROPORTIONAL TO THE COMFORT LEVELS, MEANING THAT A COMFORTABLE SPACE UNDER NATURAL CONDITIONS, WILL HAVE A SIGNIFICANT SYSTEMS CONSUMPTION WHEN A/C OR COOLING ARE NEEDED.

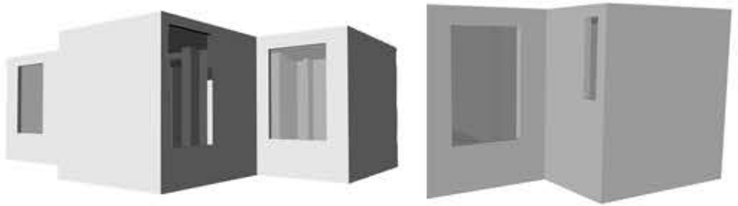
LOADS DISTRIBUTION BAR CHARTS ARE QUITE HARD TO GENERATE. IT IS A VERY INTERESTING TOOL THAT MIGHT BE REDESIGNED IN FUTURE HONEYBEE VERSIONS, FOR EASIER USE.

OPTION 3:

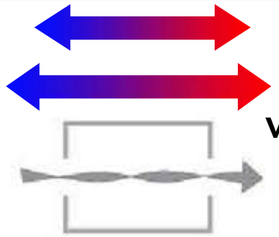
CUSTOM OCCUPANCY SCHEDULE
+
DAYLIGHTING PROFILE LIGHTING SCHEDULE

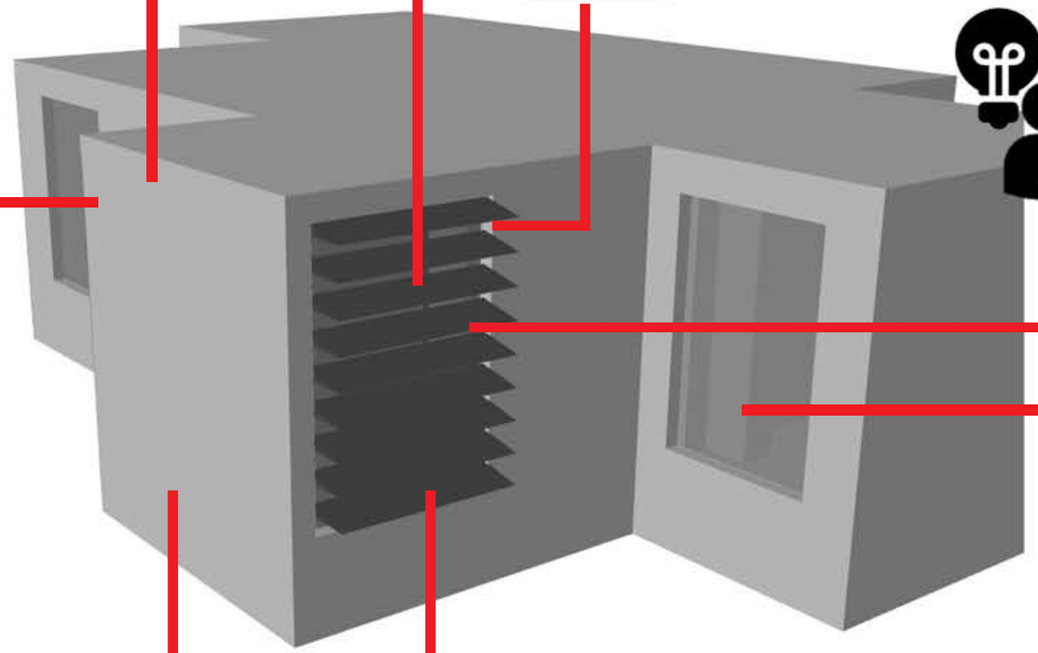
FINAL CONCLUSIONS: STRATEGIES APPLIED

BIG SOUTHERN WINDOW+
SMALL NORTHERN WINDOW



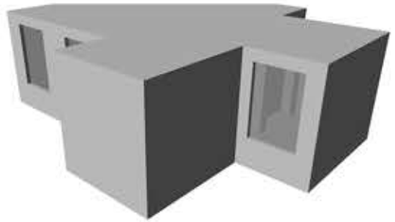
WIDE RANGE INDOOR/OUTDOOR
NATURAL AIR FLOW CONDITIONS
+
WIND-DRIVEN CROSS VENTILATION



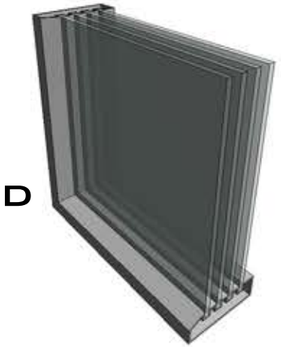


CUSTOM
OCCUPANCY SCHEDULE
+
DAYLIGHTING ANNUAL
LIGHTING SCHEDULE

SQUARED ROOM GEOMETRY

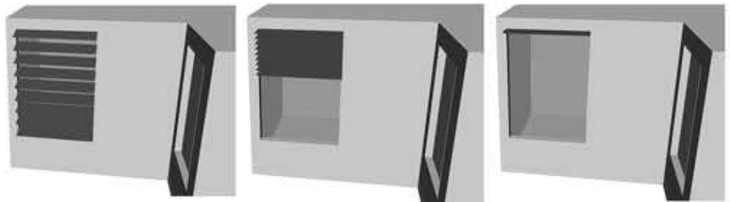


WINDOWS:
QUAD PANE
LOW-E COATED
GAS FILLED

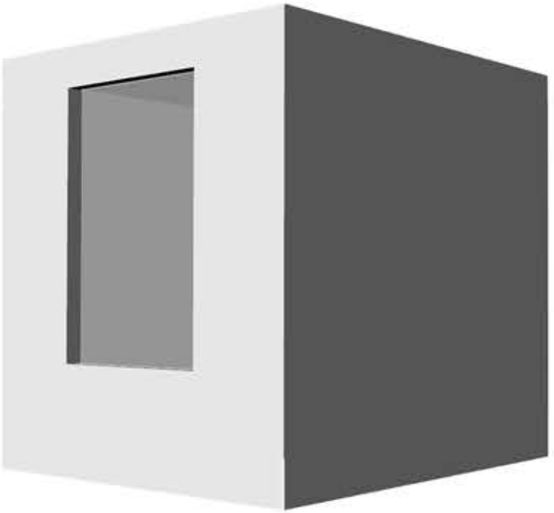


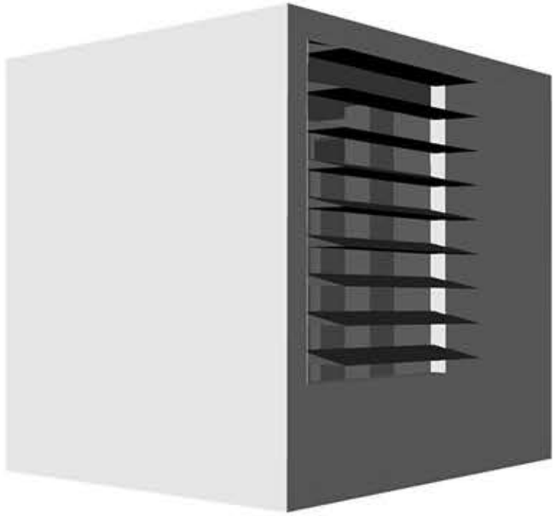
WALLS:
EXTERIOR CMU LAYER
VACUUM INSULATED INSULATION
INTERIOR CMU LAYER

REFLECTIVE DEPLOYABLE SHADING



FINAL CONCLUSIONS: BASELINE VS IMPROVED VERSION

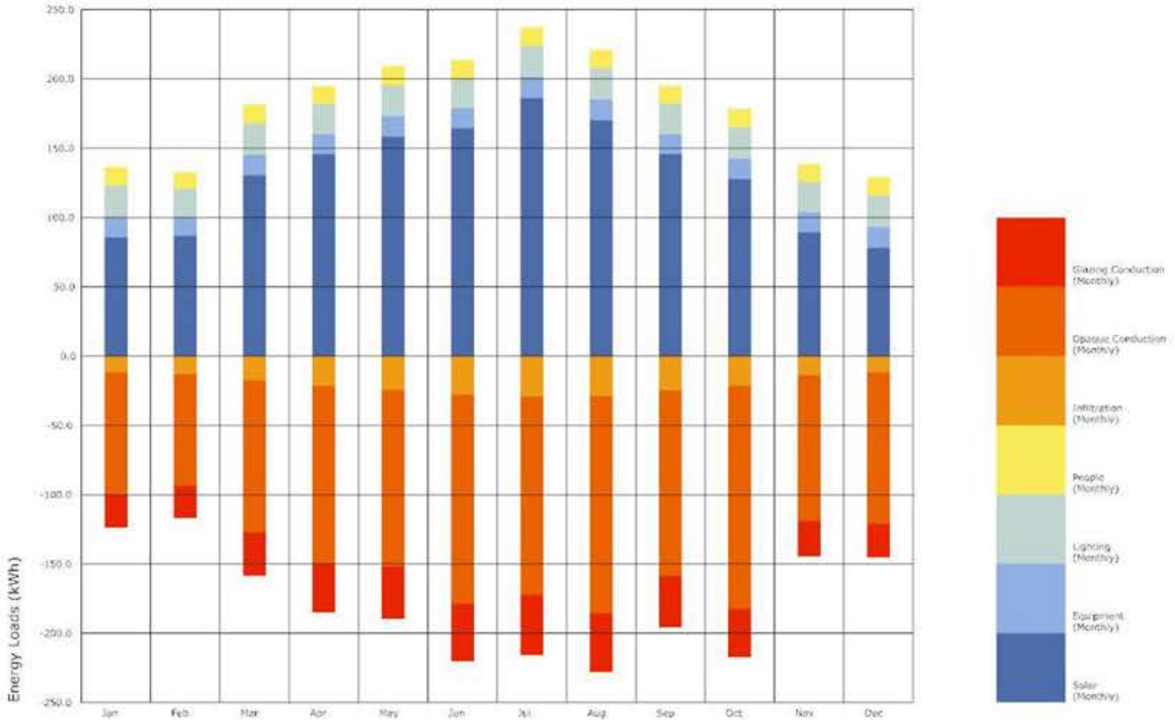




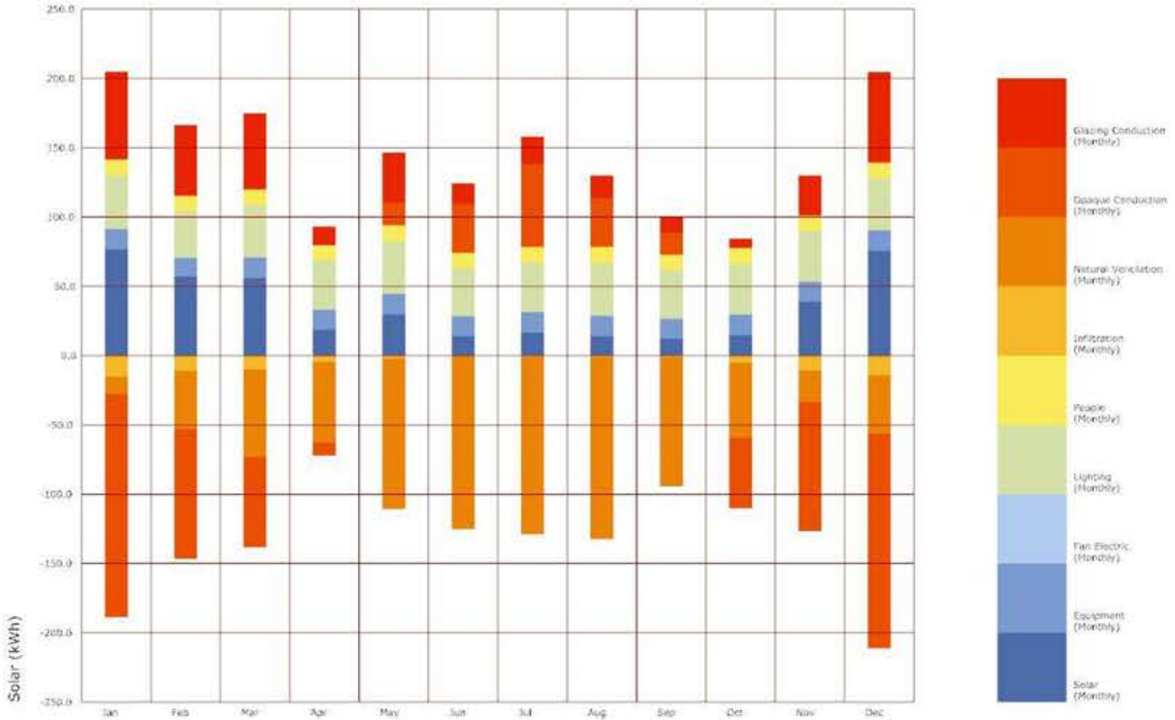
BASELINE		IMPROVED
18.75%	YEARLY COMFORT	80.73%
16.52%	WINTER COMFORT	72.40%
28.84%	SPRING COMFORT	92.03%
6.07%	SUMMER COMFORT	66.34%
17.58%	FALL COMFORT	92.07%
57.04%	% TOO HOT	11.33%
26.19%	% TOO COLD	7.93%
67.67%	USEFUL DAYLIGHT ILLUMINANCE	79.02%

FINAL CONCLUSIONS: BASELINE VS IMPROVED VERSION
ENERGY LOADS COMPARISON

BASELINE



IMPROVED VERSION



FINAL CONCLUSIONS: LESSONS

- BREAKING DOWN THE ANALYSIS INTO SEASONS, AND UNDERSTANDING WHAT IS HAPPENING ON EVERY SINGLE ONE OF THEM CAN GIVE YOU CLUES OF WHERE THE PROBLEM IS LOCATED IN THE CALENDAR AND HOW TO APPROACH IT.
- EVEN THOUGH OPTIMIZATION STRATEGIES MIGHT GIVE YOU THE BEST PERFORMING SOLUTIONS, IN REAL LIFE THIS IS NOT A VERY PRACTICAL APPROACH, BECAUSE YOU ARE KILLING THE DESIGN COMPONENT OF THE PROJECT: YOUR TYPICAL CLIENT WILL ASK YOU FIND THE BEST OPTION TO MULTIPLE DESIGN ALTERNATIVES.
- ENERGY AND DAYLIGHTING SIMULATIONS OFFER A WHOLE NEW VARIABLE IN TERMS OF DESIGNING ARCHITECTURE. DEPLOYABLE SHADINGS, WALL GEOMETRIES, AND MATERIALS CONFIGURATIONS, ARE SOME EXAMPLES OF HOW ENERGY MODELS CAN ENRICH THE DESIGN PROCESS.
- CUSTOMIZATION IS A VERY IMPORTANT AND PRACTICAL TOOL OFFERED BY HONEYBEE AND LADYBUG. THE FACT THAT YOU ARE ABLE TO CUSTOMIZE EVERYTHING, FROM THE LEGENDS AND COLORS OF YOUR CHARTS, TO YOUR OWN MATERIAL ASSEMBLIES, GIVES YOU LIMITLESS POSSIBILITIES AT THE MOMENT OF IMPLEMENTING A SOLUTION.
- IT IS IMPOSSIBLE NOT TO ENCOUNTER CHALLENGES AT THE MOMENT OF PERFORMING AN ENERGY MODEL. ERRORS WILL OCCUR, YOUR COMPUTER WILL CRASH, AND YOU MIGHT EVEN NEED TO RECONSIDER YOUR POSITIONS. AS LONG AS YOU UNDERSTAND WHAT YOU ARE DOING, AND HAVE A CLEAR DESIGN WORKFLOW, THESE PROBLEMS WILL TURN INTO OPPORTUNITIES

- USUALLY, ONE DECISION THAT IMPROVES COMFORT FOR HOT THERMAL CONDITIONS WILL WORSEN COMFORT FOR COLD THERMAL CONDITIONS, AND VICE VERSA. FINDING A SOLUTION THAT CAN HELP YOU REDUCE SIGNIFICANTLY HOT AND COLD CONDITIONS AT THE SAME TIME IS EXTREMELY DIFFICULT.
- ORDER IS FUNDAMENTAL AT THE MOMENT OF SCRIPTING YOUR GRASSHOPPER CODE. COMPLEX ENERGY AND DAYLIGHT SIMULATIONS MIGHT REQUIRE MULTIPLE COMPONENTS THAT HAVE DIFFERENT PROPERTIES, AND NOT ORGANIZING THEM IN A DISCIPLINED WAY MIGHT DIFFICULT THE READING OF THE FILE.
- NEVER TRUST YOUR MEMORY! NAMING AND LABELING EACH SET OF COMPONENTS CAN HELP YOU REMEMBERING AND UNDERSTANDING THEIR FUNCTION IN THE SCRIPT. SOMETIMES IT IS BETTER TO SPEND A COUPLE OF SECONDS GROUPING AND NAMING YOUR COMPONENTS, THAN A CUOPLE OF MINUTES TRYING TO FIGURE OUT DISORGANIZED SCRIPTS.
- THERE IS NO PERFECT SOLUTION TO ANY PROBLEM IN THE ENERGY SIMULATION WORLD: ANY APPROACH YOU DECIDE TO IMPLEMENT WILL HAVE ITS BENEFITS AND ITS TRADEOFFS. IT'S JUST A MATTER OF SELECTING THE MOST SUITABLE OPTION TO YOUR OBJECTIVES.
- ENERGY MODELING IS A VERY USEFUL AND PRACTICAL TOOL, THAT HELPS INCORPORATE ENVIRONMENTAL DESIGN INTO ARCHITECTURE, BUT THERE ARE STILL MULTIPLE LIMITATIONS AND PROBLEMS THAT MAKE THIS TOOL FAR FROM PERFECT. UNDERSTANDING THE SOFTWARE'S AND THE INTERFACE'S LIMITATIONS AND POSSIBILITIES CAN HELP YOU IMPLEMENT ENERGY MODELING IN A BROADER WAY.