SUPPORTING DOCUMENTS

REFERENCES

CODES AND HANDBOOKS

Wisconsin Commercial Building Code

International Building Code 2009

IECC 2009

2010 Florida Building Code

National Electrical Code 2011

NFPA 72

Illuminating Engineering Society Handbook 10th Edition

COMPUTER PROGRAMS

Autodesk Revit 2014

ElumTools 2014

DAYSIM

Ecotect Analysis 2011

Microsoft Excel 2013

REPORT IMAGES

Figure 2: Generator image in cycle figure courtesy of Viessmann

Figure 4: Aquaponics image courtesy of Nelson Pade

Figure 7: United Stated Latitude map courtest of Tutapoint

Figure 12: Visible spectrum response image courtesy of Sunmaster Grow Lamps

Figure 13: Chlorophyll absorption peak graph courtesy of Wikipedia

Figure 17: Grow Light image courtesy of Illumitex

Figure 19: Greenhouse shading image courtesy of Svensson

Figure 23: Lighting control system images courtesy of Lutron

Figure 25: Systems power image courtesy of SmartDesks

Figure 26: Machine-Room-Less Elevator image courtesy of Otis

Figure 27: Device images courtesy of Advantech, Silicon Labs, Schneider Electric, Mantra, Home Auto, Excel Networking, Microm, & EC&M

SD1: PV solar radiation map courtesy of NREL

SD2: Wind resource map courtesy of NREL

PHOTOVOLTAIC ARRAY AND WIND TURBINE RESOURCES

1. Brooks, William P.E.; Dunlop, James P.E. Photovoltaic (PV) Installer Resource Guide. NABCEP. Dec. 2014.Web. March 2012.
2. Wilson, Alex. “The Folly of Building Mounted Wind Turbines.” BuildingGreen.com. Web. 29 April 2009.

GREENHOUSE DESIGN RESOURCES

3. Ciolkosz, Daniel. "Design Daylight Availability for Greenhouses Using Supplementary Lighting." Science Direct (2007): 571-80. Web. 10 Feb. 2015.
4. Ciolkosz, Daniel E. On the Selection of Percentile Criteria for Greenhouse Lighting System Design. Proc. of 2008 ASABE Annual International Meeting, Rhode Island Convention Center, Providence. Print.
5. “Conversion - PPF to Lux." Apogee Instruments. Web. 10 Feb. 2015.
6. "Current Environment." Living Shade Greenhouse RSS. Web. 10 Feb. 2015.
7. "Eclipse ES2 | Illumitex." Illumitex. Web. 10 Feb. 2015
8. "Illumitex LED Grow Lights." Illumitex. Web. 10 Feb. 2015.
9. "PPFD Calculator." Illumitex. Web. 10 Feb. 2015.
10. "Understanding Watts Lumens Lux PAR." OrganicSoilTechnology RSSWeb. 10 Feb. 2015.

LIGHTING DESIGN RESOURCES

11. "Lutron Energi Savr Node™ Solutions Overview." Lutron. Web. 10 Feb. 2015.
12. "MechoSystems - Shadecloth - Thermoveil." Mechoshade. Web. 10 Feb. 2015.
13. "SOLARBAN® Solar Control Low-e Glass." PPG Ideascapes. Web. 10 Feb. 2015.

SUB-SYSTEMS DESIGN RESOURCES

14. Cisco and Johnson Controls. Building Automation System over IP (BAS/IP) - Design and Implementation Guide. Aug. 2008. Web. Nov. 2014
15. Haworth. Power Base™ Brochure. Feb. 2015. Web. 2015.
16. OTIS Elevator Company. GEN2®. Jan. 2015. Web. 2014.
17. A Practical Guide to Fire Alarm Systems (2011): n. pag. CSAAIntl. 2011. Web. 10 Feb. 2015.

ADDITIONAL RESOURCES

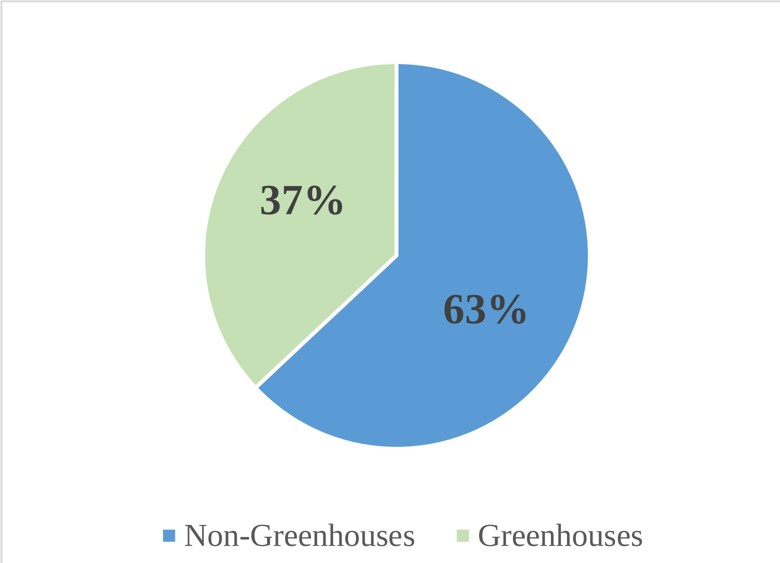
Dr. Richard Mistrick, PE. Lighting and daylighting advising.

Gary Golaszewski, PE, LEED AP. Interviews on power distribution.

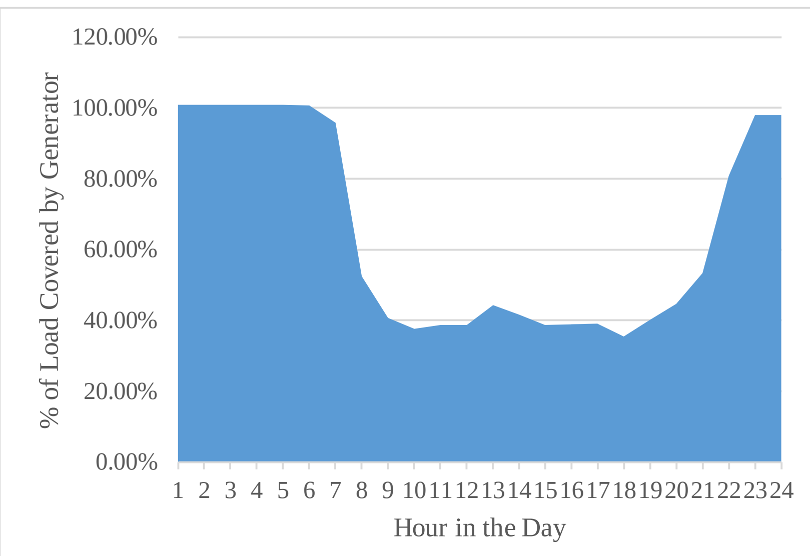
Sara Lappano, PE, LC, LEED AP BD+C. Interviews on net-zero strategies and power distribution.

Dr. Robert Berghage. Campus greenhouse & aquaponics tour

BUILDING ELECTRICAL LOAD ANALYSIS

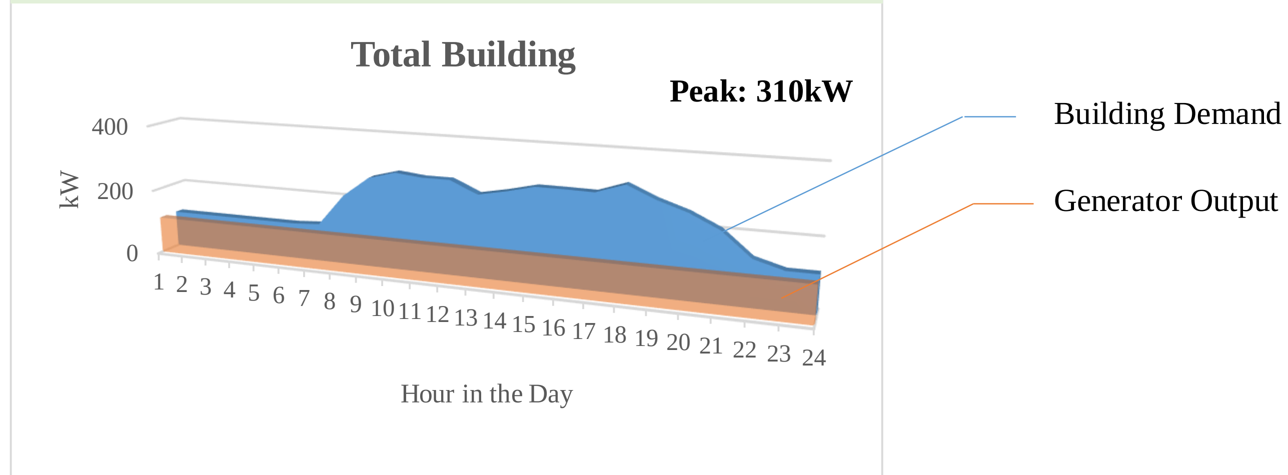


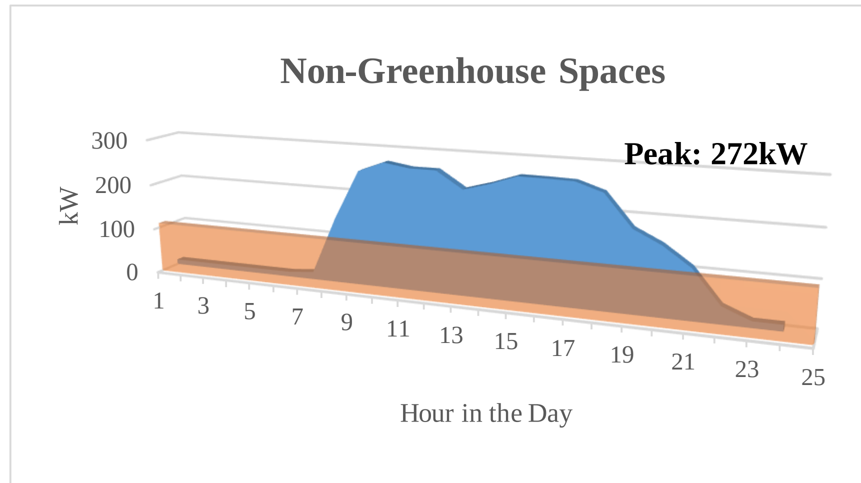
The total building load is **536kW,** and the power density is **10 W/SF.** Shown above is the load breakdown per section of the building.

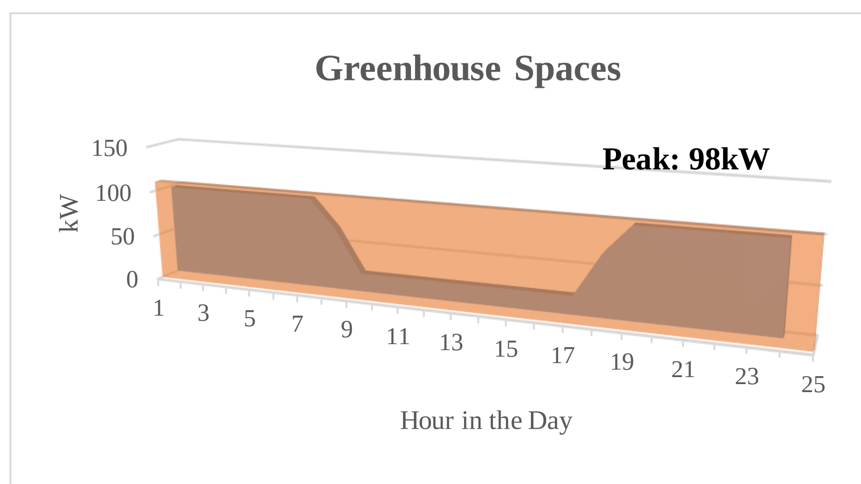


At maximum output, the two generators can completely offset the building load at night, and during the day the system can offset about **40%** of the building load due to scheduling.

TYPICAL DAILY ELECTRICAL LOAD PROFILES





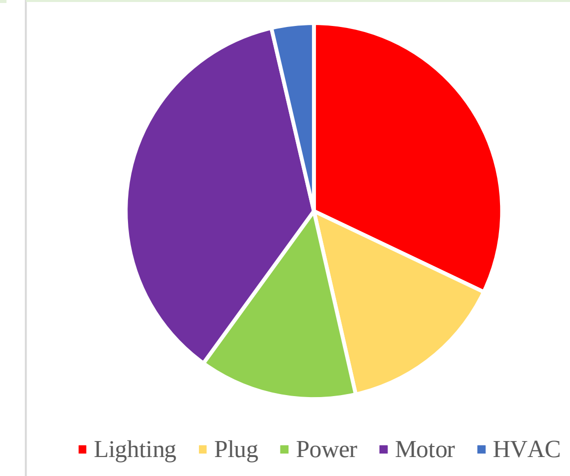


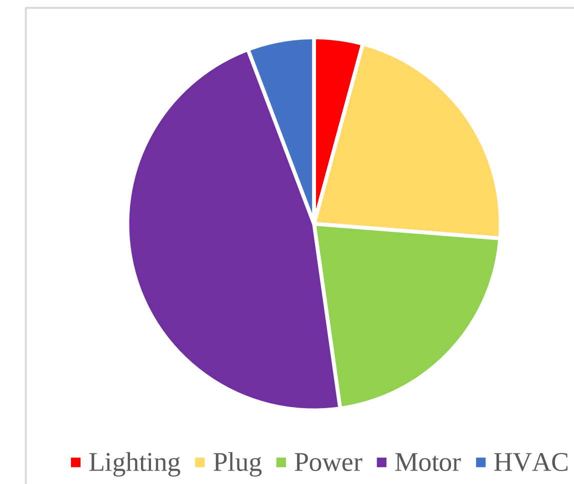
ANALYSIS

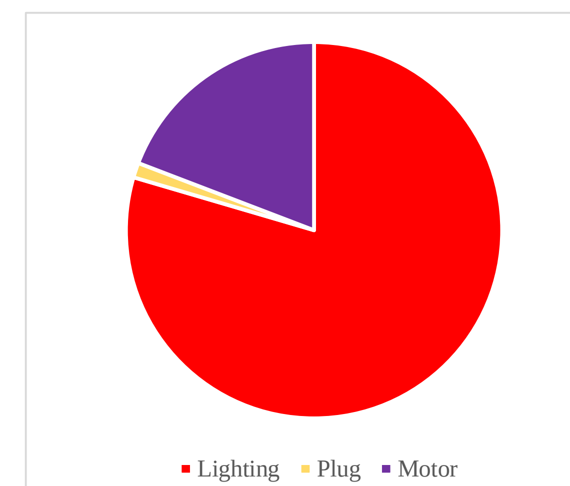
In the **non-greenhouse spaces**, the load profile follows a typical shape for educational/office shape, having a peak in the middle of the day and leveling off at night. Motors dominate the load types, as the building contains many water source heat pumps, anaerobic digester motors, and rain water pumps.

In the **greenhouse spaces**, grow lighting dictates the load profile, as some plants require supplementary lighting throughout the night. During the day, small fans and pumps will run to operate the greenhouses, but grow lighting does not have to be at full output.

LOAD BREAKDOWNS

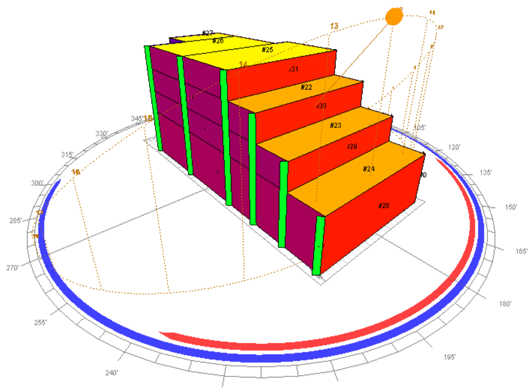




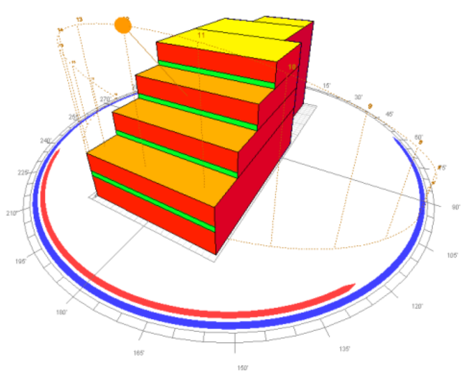


SOLAR POWER STUDY

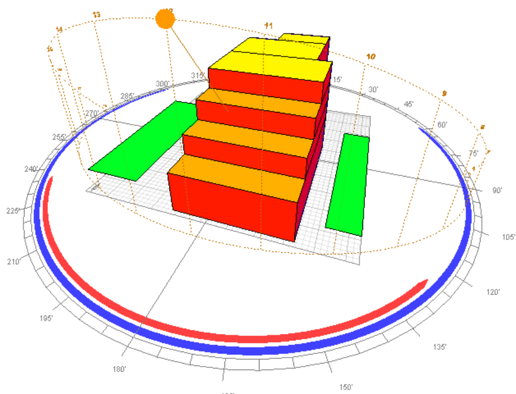
PV ARRAY DESIGN ITERATIONS



EAST & WEST FINS

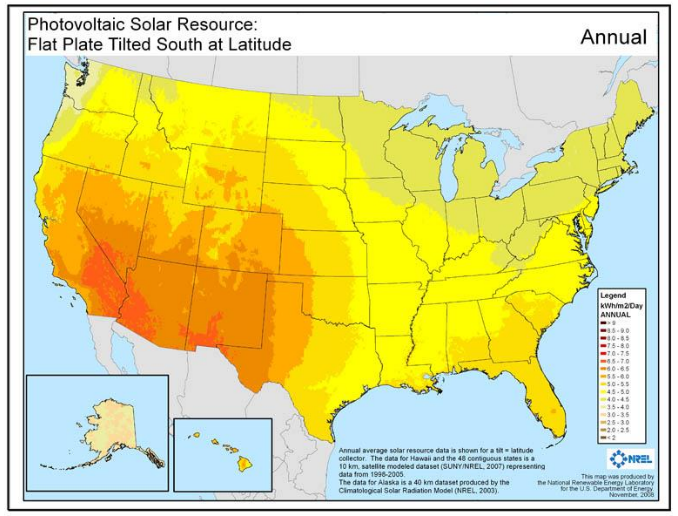


SOUTHERN-FACING



PARKING LOT

Yearly Analysis			
	SF (m^2)	Annual Production (kWh)	% Building Energy Offset
Milwaukee Fins	83	9,576	0.54%
Milwaukee South	41	5,283	0.30%
Milwaukee Parking	173	20,023	1.13%
Miami Parking	173	38,442	2.16%



SD1: Photovoltaic Solar Resource map

PROCESS

Prototyping was the main challenge in analyzing the feasibility of solar power for Growing Power's building. Keeping the building footprint tight was a major design goal so that the photovoltaic arrays could be implemented for any future Growing Power location. As a result, all array designs analyzed were implemented into the building fabric. Arrays are shown in green on the left.

One array included fin-type panels on the east and west side of the building.; another included panels implemented into the south façade, from the floor to the workplane (3 feet high) so as to not disturb the plant bed daylight availability; and the last option was to place panels overtop parking stalls.

Using the computer software Ecotect with a Typical Meteorological Year (TMY) weather file for Milwaukee, the amount of solar radiation reaching the array surface over a year was calculated, which was then converted to an actual energy production (kWh), taking into account typical conversion and efficiency losses of 15%.

ANALYSIS

The table on the left shows that the arrays in both Milwaukee and Miami were unsuccessful in generating a sizeable amount of energy to offset the building load due to the limited area of panels. The fins and parking stall arrays would be shaded for half the day, and the south facing arrays eventually would have been blocked by the new roof design. As a result, solar power was not implemented into the design.

However, there are many areas within the United States that would be much more successful in harvesting solar power. The map to the left portrays the average potential energy per year that could be harvested from solar power across the United States. These maps should be consulted to see if solar power is viable in future Growing Power Locations, as solar power can easily be incorporated into the electrical distribution. Refer to the Construction Management report for an example payback analysis (CM|4).

WIND POWER STUDY

PROCESS

Keeping the building footprint tight for matters of prototyping, building-mounted wind turbines were investigated first. However, case studies show that building-mounted wind turbines cause vibration, noise, and load issues. Furthermore, although there are no height restrictions by Milwaukee code, tower heights of wind turbines should be at least 30 feet above surrounding areas in order to avoid turbulent wind flow(2). However, since the Milwaukee site is in a residential area, the electrical team decided this would not be ideal aesthetically.

Small, commercial horizontal wind turbines, which are more efficient than vertical wind turbines, were analyzed next. Using yearly Milwaukee weather data, the numbers of hours at different speeds were analyzed. Then, the power that could be potentially generated at each speed by a 3 meter long blade was calculated using the equation shown. Multiplying that number by the number of hours at that speed in a year, the yearly energy generation was calculated, taking into account a 30% efficiency factor.

Wind Generation Equation

$P = 0.5 \times \pi \times r^2 \times 1.23 \times v^3$

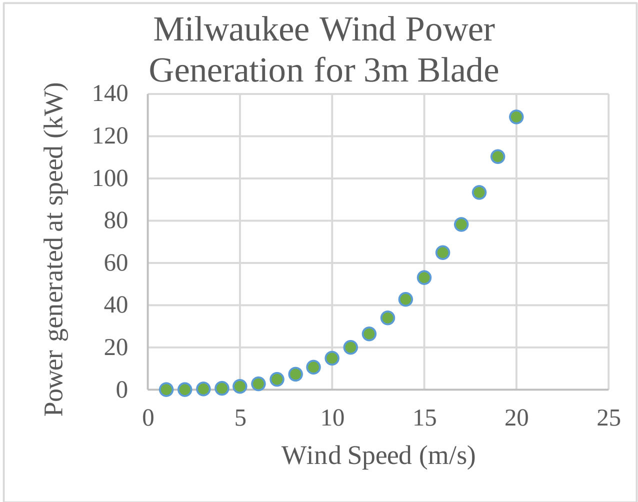
P = Power in Watts

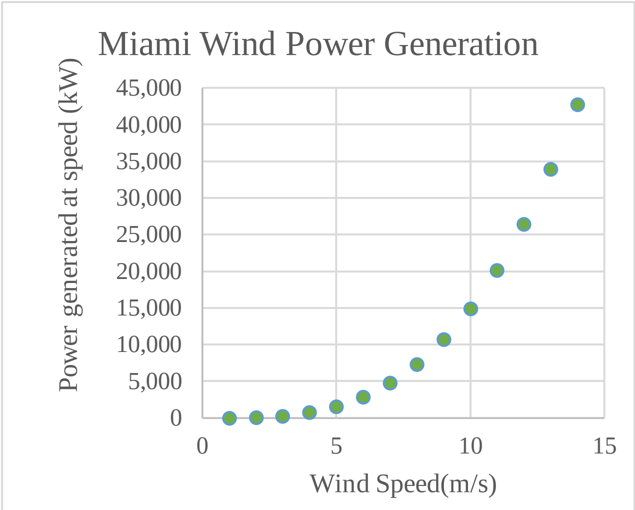
r= radius of wind turbine blade

v = wind velocity

RESULTS

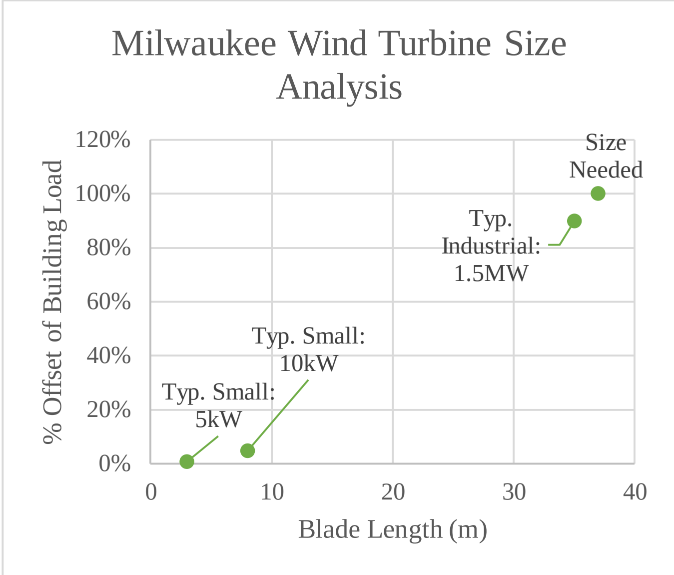
Yearly Analysis		
	Milwaukee	Miami
Annual Production (kWh)	11,731	6,833
% Building Energy Offset	0.66%	0.38%



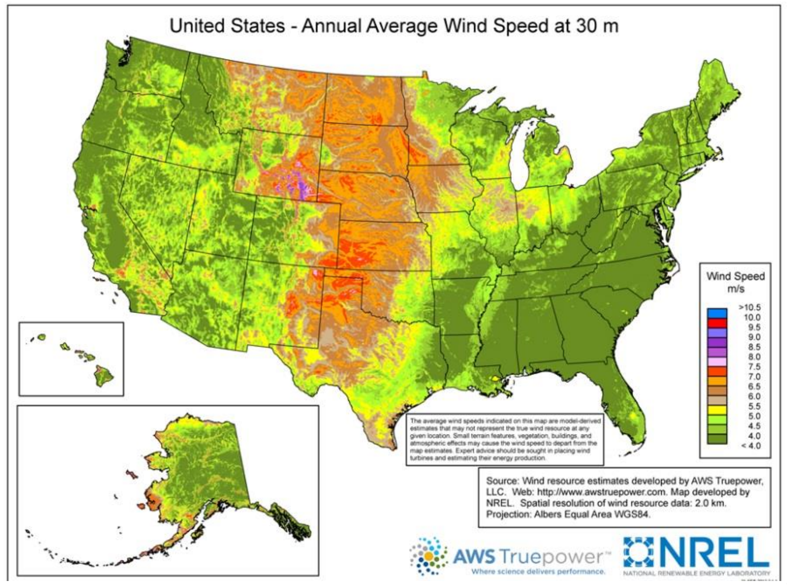


ANALYSIS

The 3 meter long wind turbine blade that was analyzed for Milwaukee is a typical size for a small commercial wind turbine. Other size blades were also analyzed for comparison, including another small commercial wind turbine with an 8 meter blade and an industrial size wind turbine with a 35 meter blade. The results can be seen above. For a wind turbine to completely offset the building load in Milwaukee, a 37 meter blade is needed. Space for this large of a turbine was not available on site.



Due to this extremely low offset and poor space allocation for the turbine, it was decided that wind power system would not be viable for the Milwaukee site. However, the electrical distribution system can still incorporate wind power if a future site decides it would be viable. The map below portrays the average potential energy per year that could be harvested from solar across the United States. These maps should be consulted to see if these strategies are viable in future Growing Power locations.



SD2: Annual average wind speed map

GREENHOUSE DESIGN

GREENHOUSE GLAZING AREA COMPARISONS

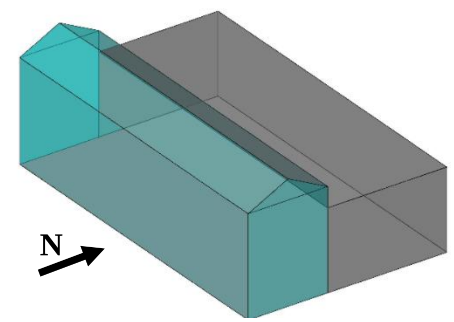
DESIGN ITERATIONS

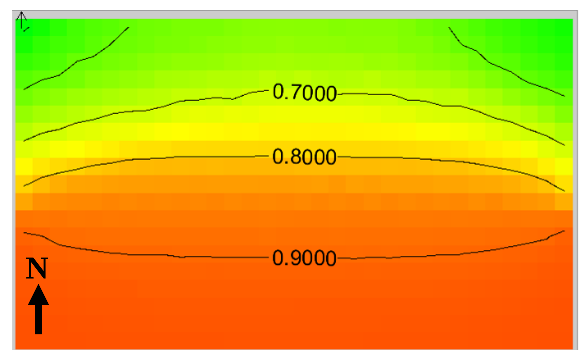
1. By eliminating the eastern and western greenhouse glazing, the glazing area was decreased by 22% and the sDA was barely affected.
2. Further analysis showed that eliminating the eastern, western, and northern glazing reduced the original glazing area by 41%. However, the sDA decreased by only 8%.
3. Therefore, the new design balances daylighting and glazing area. The new glazing area is equitable to the original design without the eastern, western, and northern glazing, and the sDA was restored to close the original amount.

SPATIAL DAYLIGHT AUTONOMY $sDA_{4000,\ 50\%}$ = %

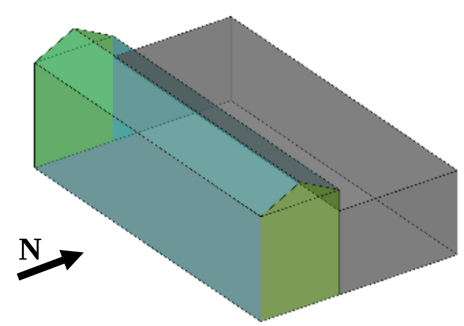
Percentage of time in the year that 50% of the points in the space reach 4000 lux (typical daylight illuminance) utilizing strictly daylight.

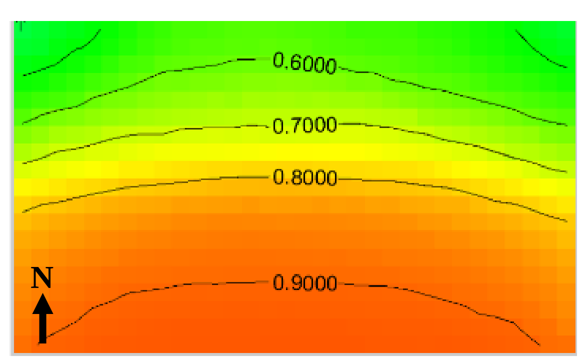
ORIGINAL GABLE



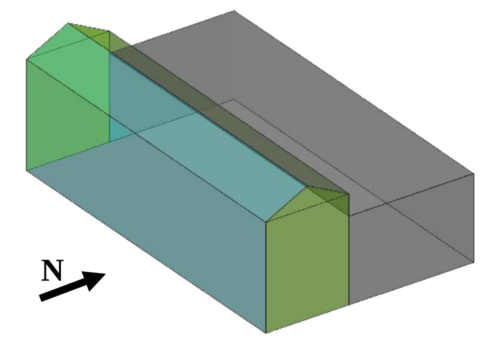


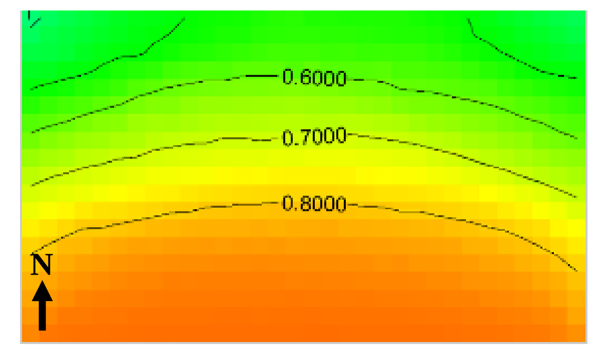
1. ORIGINAL GABLE WITHOUT EAST AND WEST GLAZING



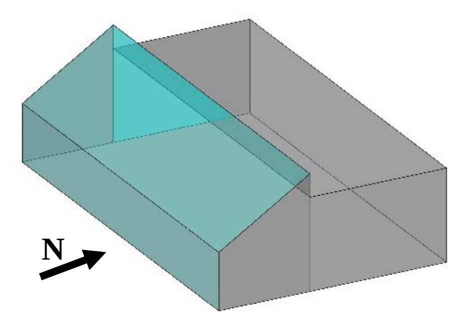


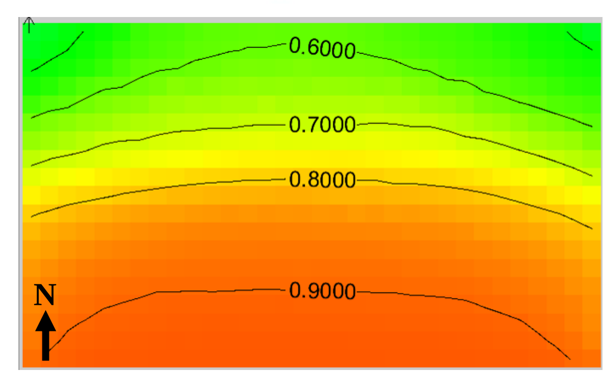
2. ORIGINAL GABLE WITHOUT EAST, WEST, AND NORTH GLAZING

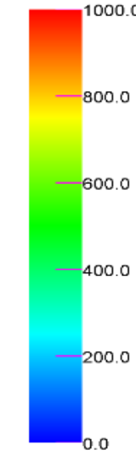




3. TBD DESIGN

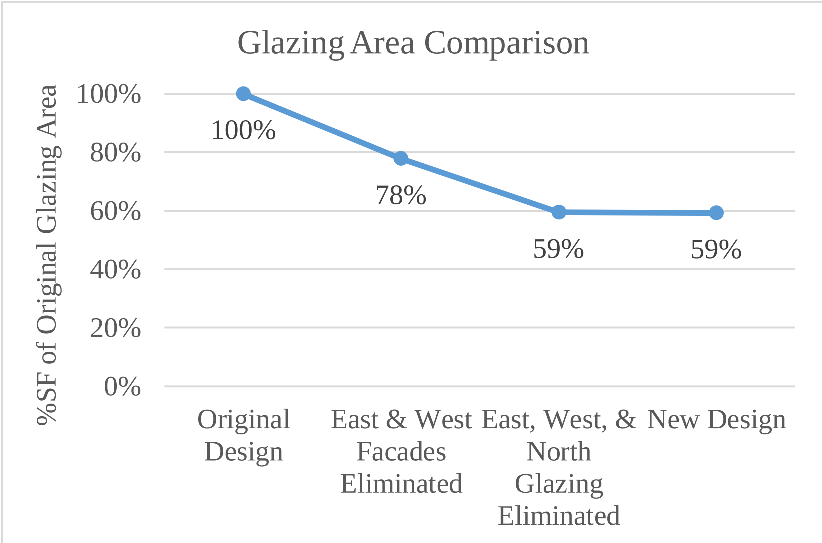


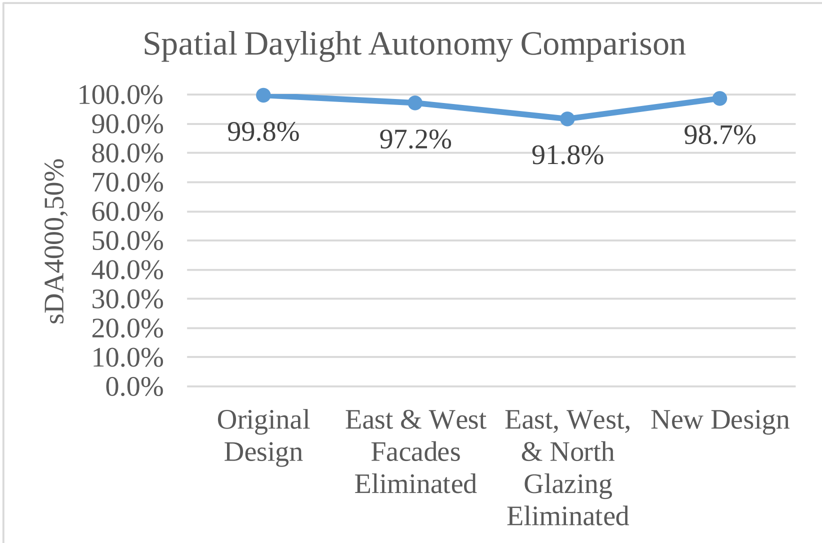




This scale shows the illuminance values in lux that the pseudo-colors represent.

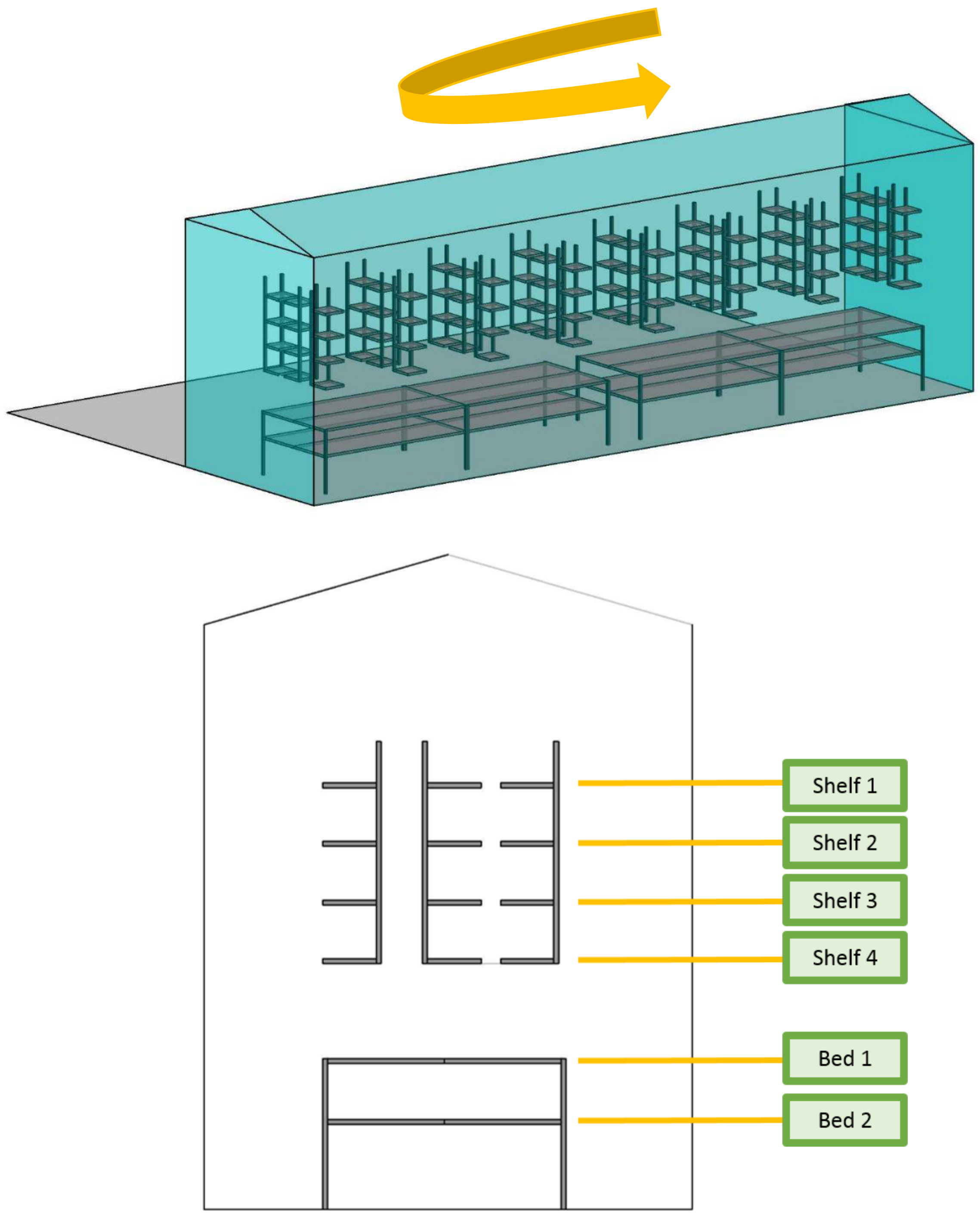
The points within each contour reach $DA_{4000,50\%}$ for the associated percentage of the year.





ORIGINAL PLANT BED DAYLIGHT AVAILABILITY ANALYSIS

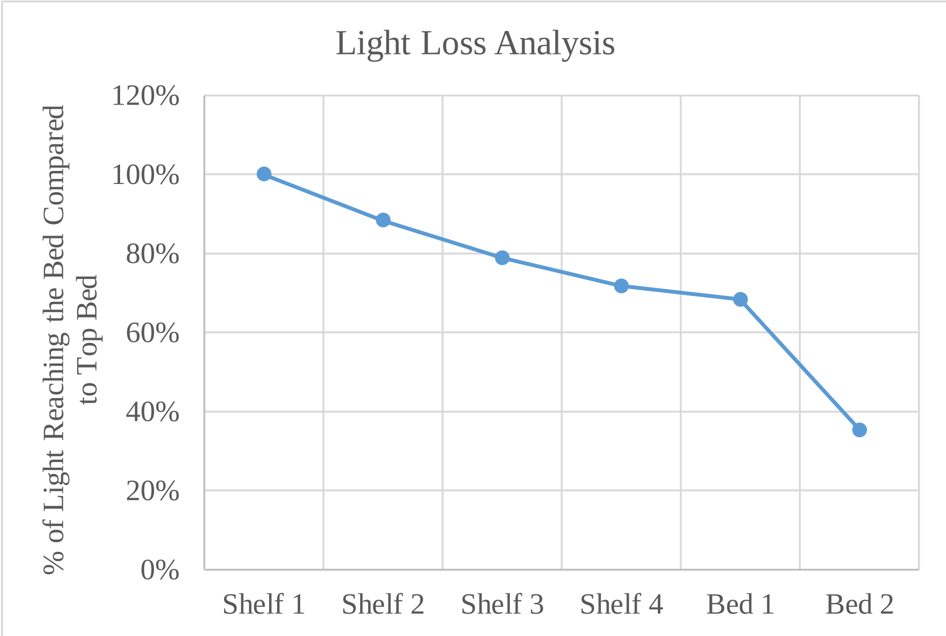
ORIGINAL DESIGN



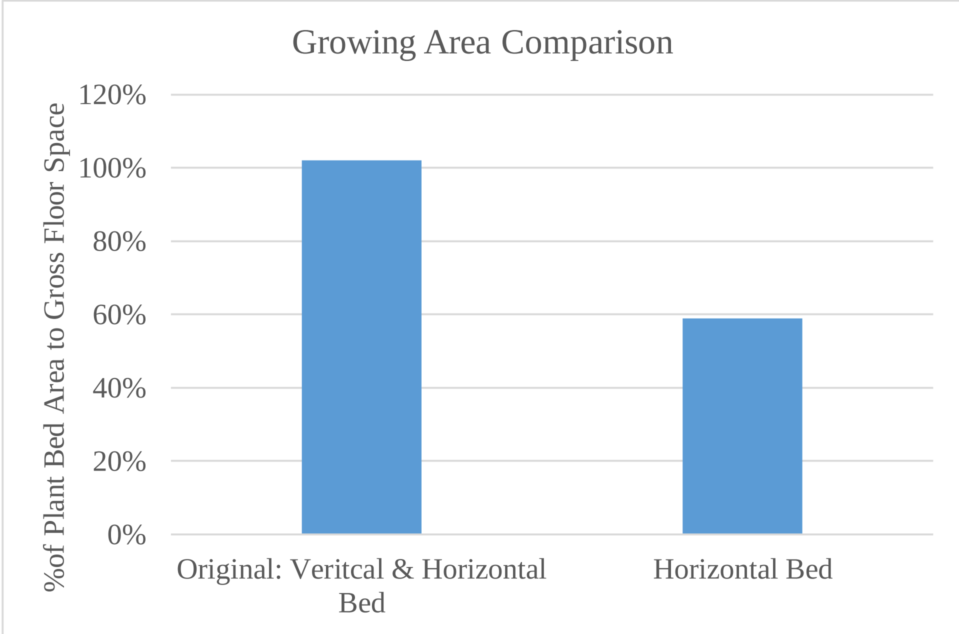
The original plant bed design combined vertical plant beds rotating in a horizontal plane over stationary horizontal plant beds.

ANALYSIS

To analyze the original bed design, a custom calculation grid was created for the model that included only points on the beds, and a yearly daylighting study was performed.



Results showed a **downside** to the original design. Each successive bed below the top bed loses a significant amount of light. By the time the light reached the lower bed, there is a 65% loss of light, as in the bottom beds receive 35% of the light that the top beds receive. Even though the beds will rotate in a horizontal plane, lower beds will still never get the chance to receive the same amount of light as the top beds.



One **benefit** of implementing the original plant bed design, though, is that it provides a large amount of growing space per gross floor area of greenhouse when compared to a traditional plant bed layout, which implements one layer of horizontal bed.

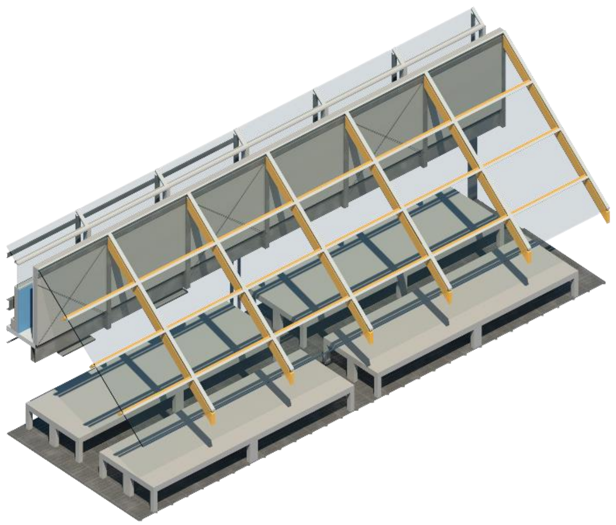
However, overall these results were not acceptable. Consequently, the original plant bed design was analyzed separately. The new designs include long layers of vertical beds rotating in a vertical plane from one layer to another to even out the performance across all the planters, as well as one layer of a stationary horizontal bed.

DAYLIGHT AVAILABILITY FOR TBD'S HORIZONTAL BEDS

$$\textit{available daylight integral} + \textit{supplementary light integral} = \textit{daily light integral}$$

YEARLY DAYSIM ILLUMINANCE OUTPUT

To acquire the most accurate results, a complicated custom sensor points file was created that contained points only on each of the beds. A simulation was then performed that produced daylight illuminance values for each point, for every hour year, producing over 24 million data points to analyze for all the configurations described.



PAR CONVERSION & DATA PROCESSING

Daylight illuminance values for each point, for every hour of the year, were then converted to PAR values using the equations below[5]:

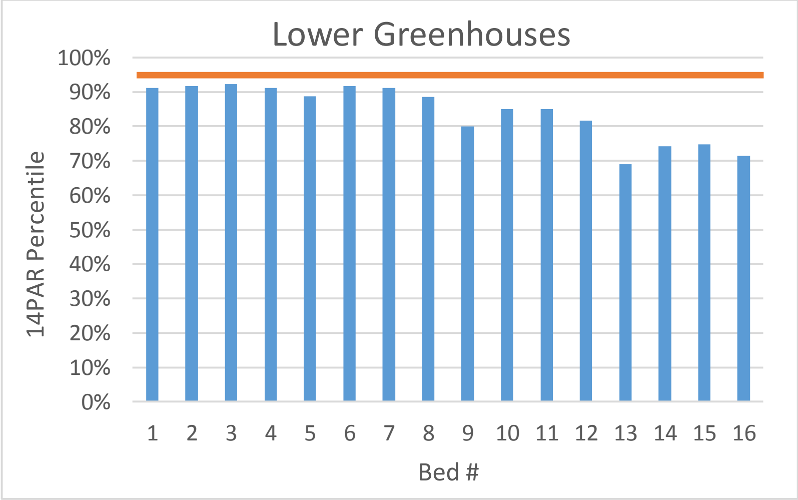
$$Illuminace\ (lux) \times \frac{1\ PPF\ Sunlight}{54\ Lux} = \frac{\mu mol}{m^2 \cdot sec} PPFD$$

$$\frac{\mu mol}{m^2 \cdot sec} \times \frac{84600 sec}{1 day} \times \frac{1 mol}{10^6 \mu mol} = \frac{mol}{m^2 \cdot day} PAR\ (or\ DLI)$$

An average PAR value per day was calculated for each point, and then points were grouped into their associated beds to create a daily PAR average for that bed.

14 PAR PERCENTILE

Using the daily PAR average values per bed, 14 PAR Percentile values were calculated for each bed, which portrays the percentage of days in the year that a bed receives 14 PAR or more. The results below show that the single layer of horizontal bed configurations perform very well in terms of available daylight for plants, as the target percentile is 95%. However, for days when beds do not receive an average of 14 PAR, supplementary grow lighting will need to supply an average of 2.7 to 4 PAR.

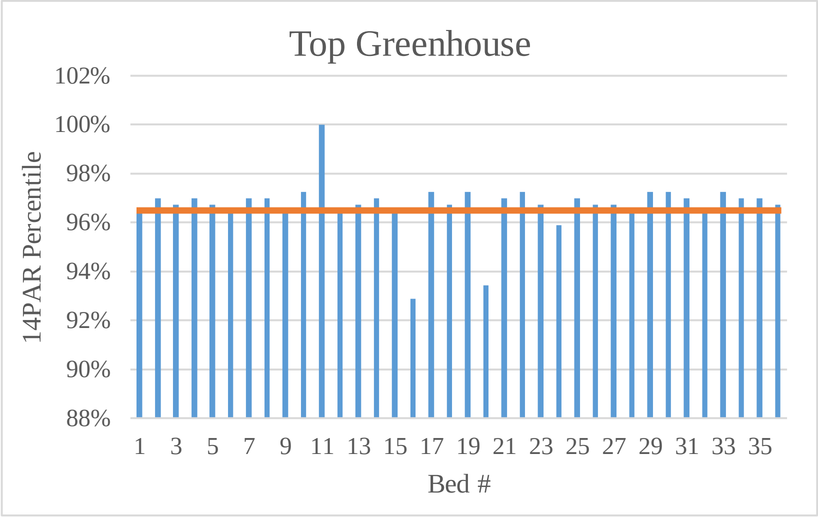


14 PAR PERCENTILE IN THE SPACE:

89.9%

AVERAGE PAR DEFICIENCY IN THE SPACE:

4.0



14 PAR PERCENTILE IN THE SPACE:

97%

AVERAGE PAR DEFICIENCY IN THE SPACE:

2.7

Daylight Availability for TBD's Vertical Beds

Analysis

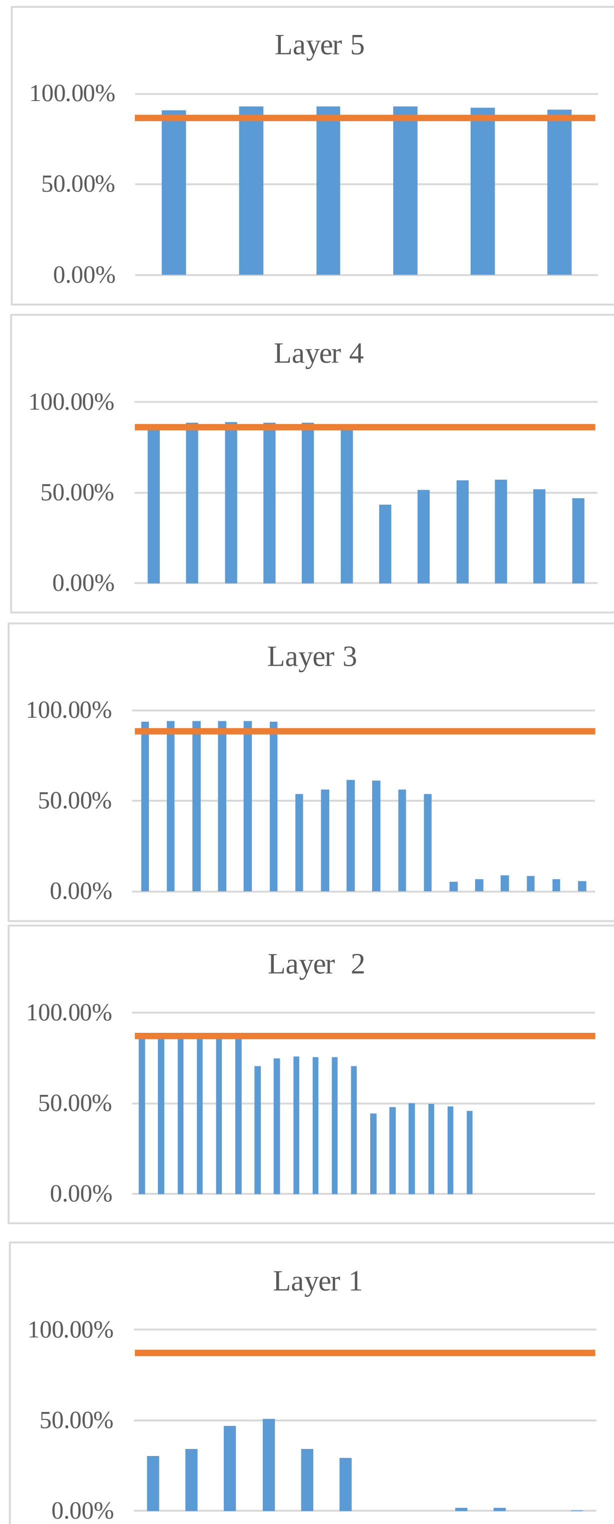
The same process described for the horizontal beds was then performed for the vertical beds.

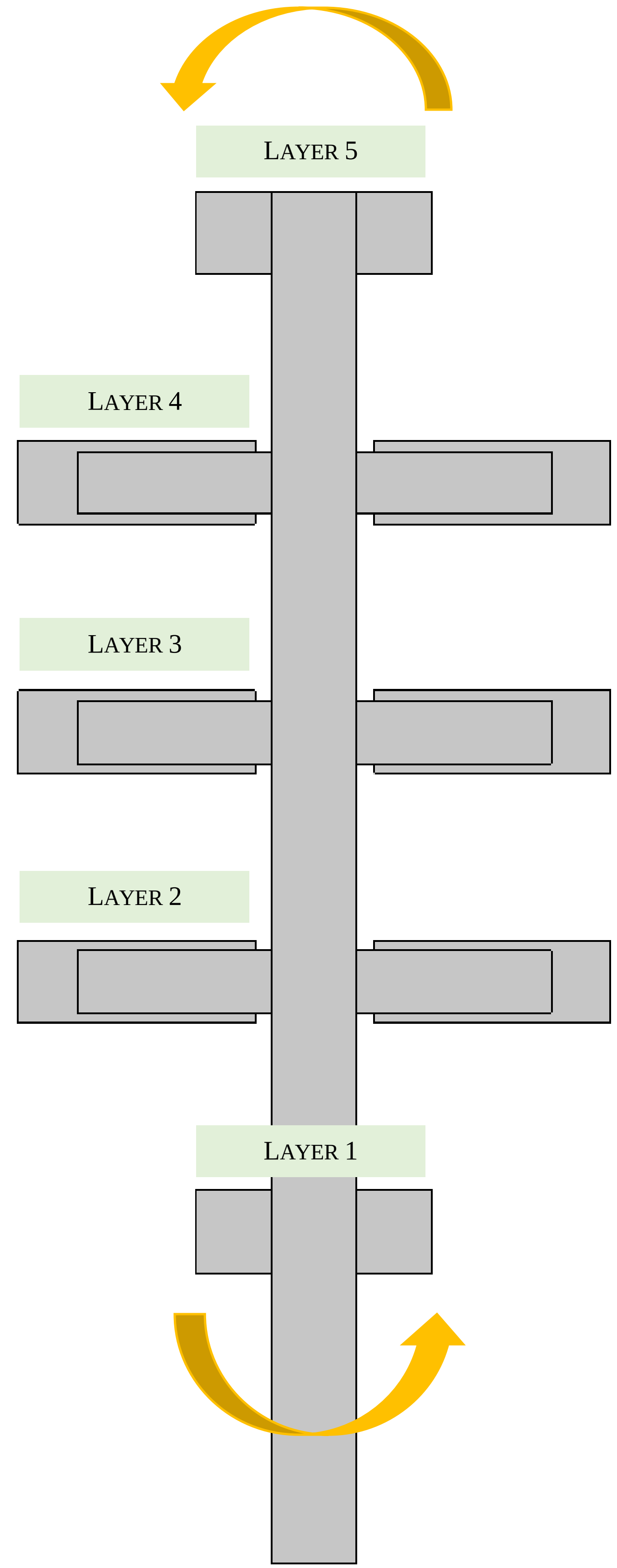
Each graph shows the 14 PAR Percentile values for each bed at a specific level in the vertical bed configuration.

Results show that lower beds receive sufficiently less PAR than upper beds. Beds towards the back of the room also are much more PAR deficient, as beds towards the front of the room block sunlight. In the lower greenhouses, the vertical beds only receive 14 PAR 52% of the year, and the top greenhouse vertical beds only receive 14 PAR 79% of the year.

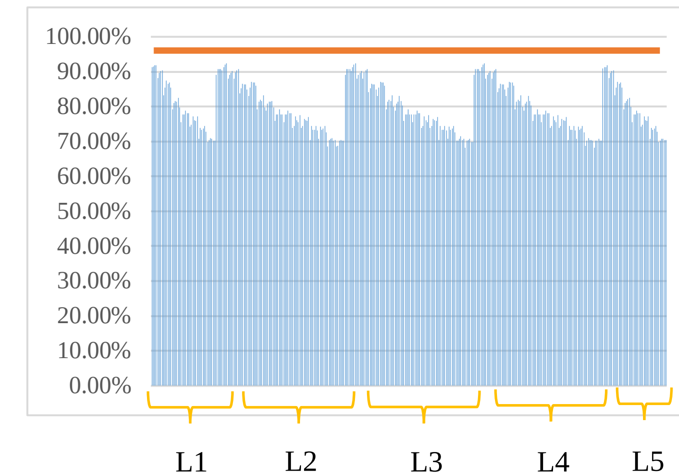
As a result, the vertical bed configuration would need to utilize more supplementary lighting that horizontal beds to make up for an average of 2.3 PAR to 5 PAR. However, if these beds were rotated throughout the day, these results could be improved.

Lower Greenhouses





Top Greenhouse



Summary

Lower Greenhouses

14 Par Percentile in the Space:

52.9%

Average PAR Deficiency in the Space:

5.0

Top Greenhouse

14 Par Percentile in the Space:

79.63%

Average PAR Deficiency in the Space:

2.32

SUPPLEMENTARY LIGHTING DESIGN

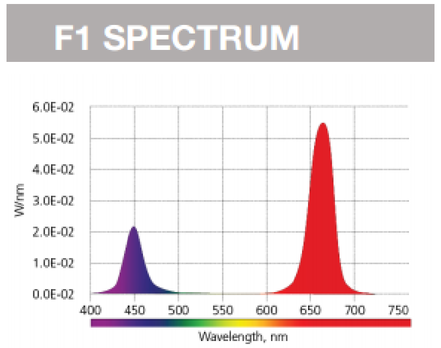
$$\underline{\text{available daylight integral} + \text{supplementary light integral}} = \text{daily light integral}$$

PROCESS

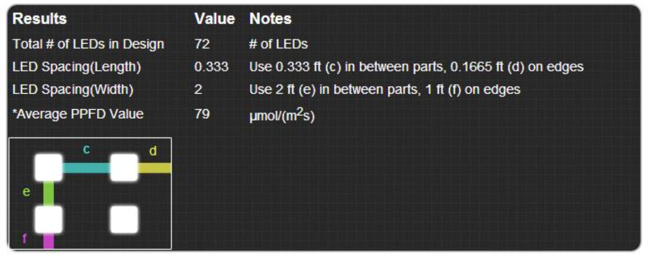
In order to specify the amount of supplementary grow light fixtures needed to make up for the PAR deficiency, a target of 4 PAR emitted from the grow lights was used for design.

4 PAR = 46 PPFD

An output of around 46 PPFD is needed by a fixture per bed. The manufacturer *Illumitex* offers a calculator[9] estimation of the amount of LED chips needed to achieve that amount of PPFD. After defining the ideal spectrum, the area to be illuminated, and the arrangement of LEDs in the fixture chosen (type ES2), results show that the beds require 2 rows of LEDs in order to create a uniform illuminance. Unfortunately, this amount emits for almost double the PPFD needed (79 PPFD) for the horizontal beds and almost four times the amount needed for the vertical beds (176 PPFD). However, these fixtures can be dimmed to reach the optimal amount of PPFD needed.



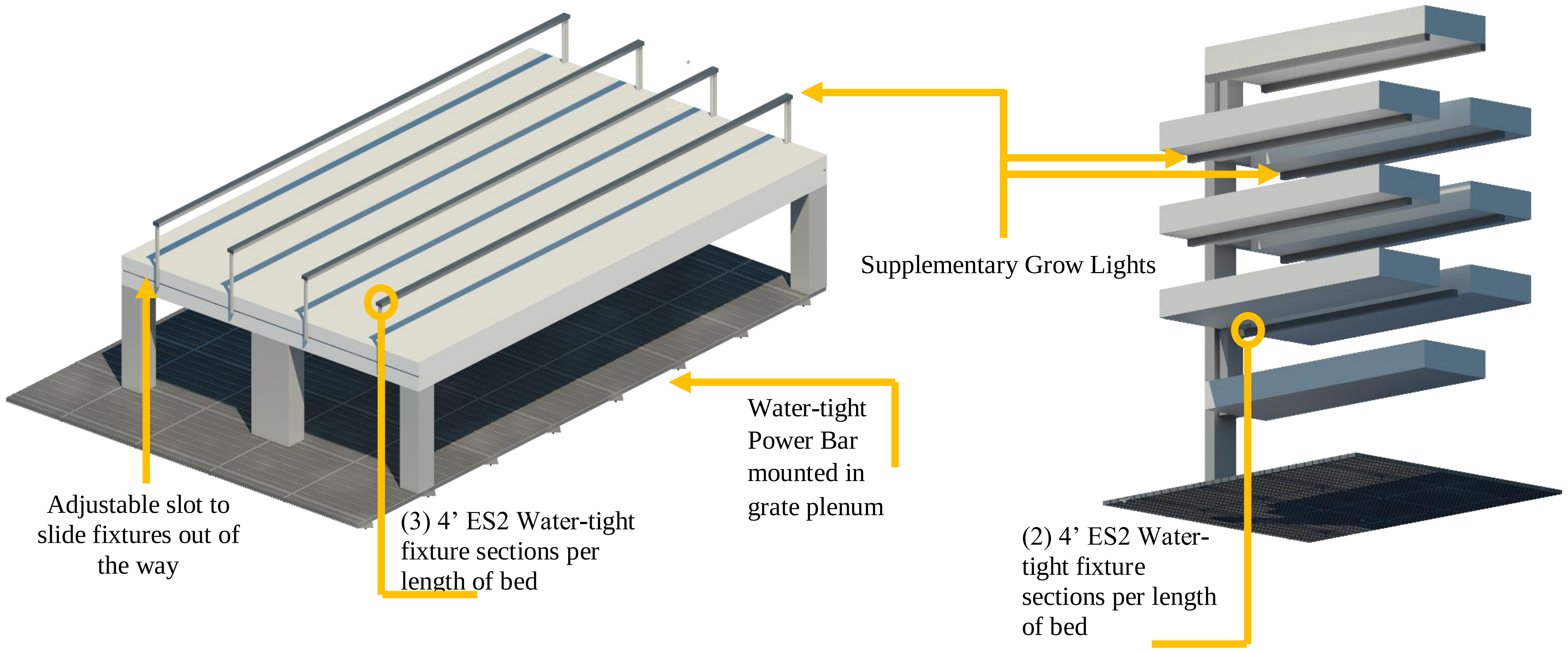
Spectrum emitted by ES2 Fixtures

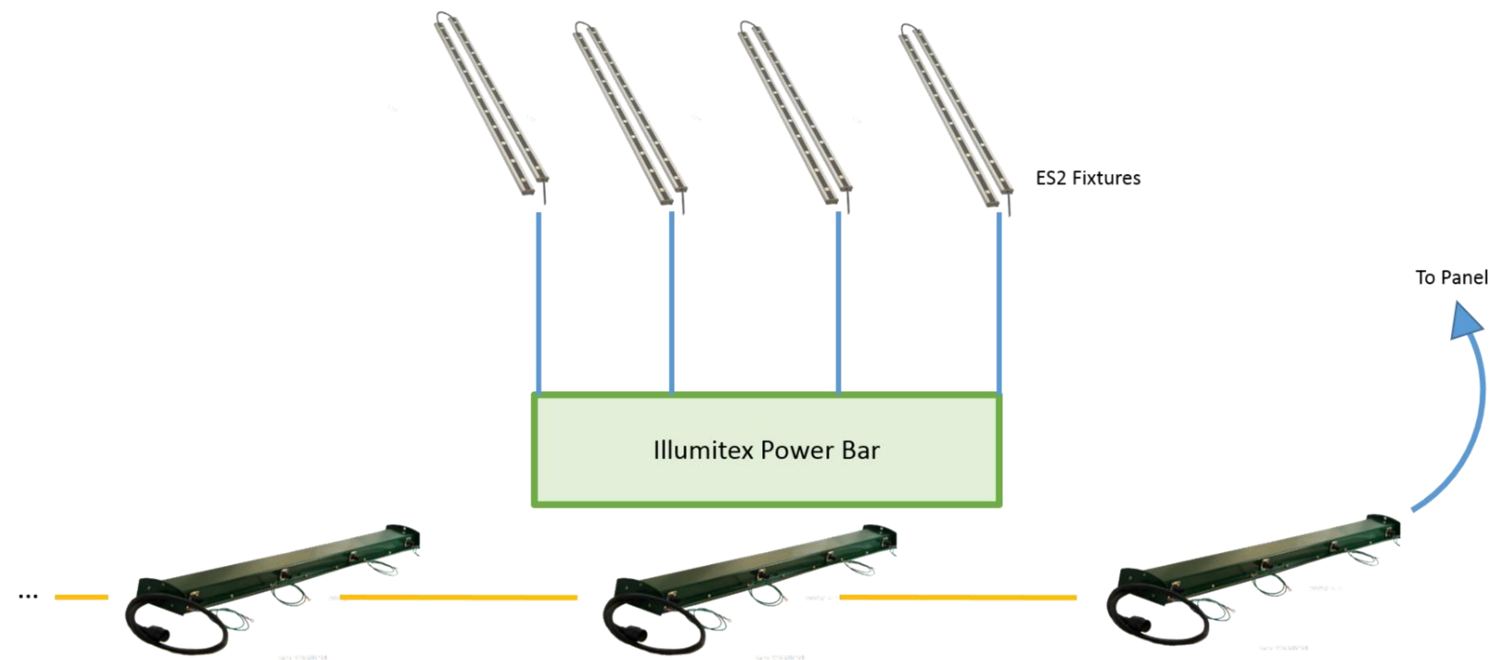


Results	Value	Notes
Total # of LEDs in Design	72	# of LEDs
LED Spacing(Length)	0.333	Use 0.333 ft (c) in between parts, 0.1665 ft (d) on edges
LED Spacing(Width)	2	Use 2 ft (e) in between parts, 1 ft (f) on edges
*Average PPFD Value	79	μmol/(m²s)

Example calculator output

SUPPLEMENTARY GROW LIGHTS DESIGN



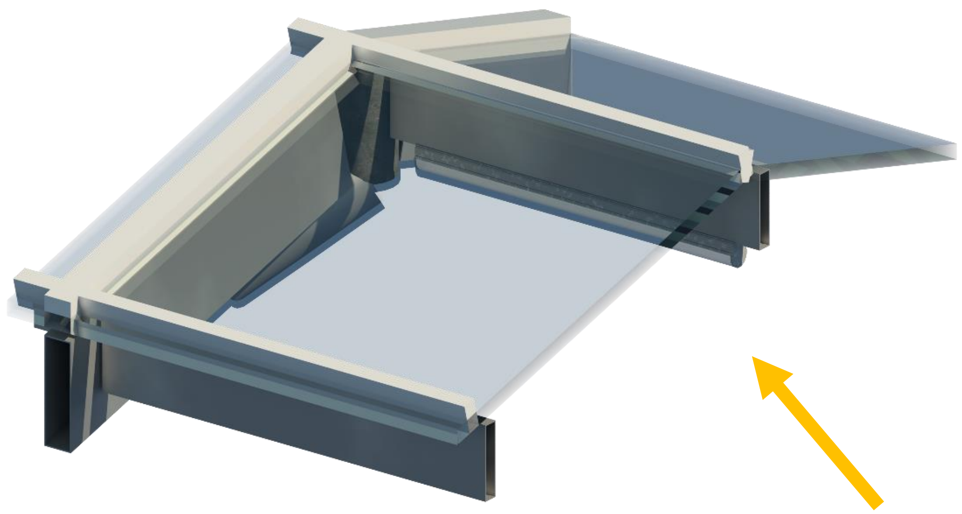


(4) ES2 Fixtures, each having (2) 4' sections, can be connected to one Power Bar. With 4 ES2's connected, each power bar contains 520W, so a maximum of 8 power bars can be circuited together to a 277V panel.

GENERAL OCCUPANT LIGHTING FOR GREENHOUSES

Linear LED strip fixtures (D8) were mounted to the overhead structure in the greenhouses for general ambient lighting for the occupants. The specified fixture is wet-location rated to protect the fixture from inevitable moisture forming in the greenhouses.

TOP GREENHOUSE	LOWER GREENHOUSES



Fixture mounted to structure above

Fixture mounted to structure above

LIGHTING & DAYLIGHTING DESIGN FOR COMMUNITY SPACES

FAÇADE DESIGN

DESIGN ITERATIONS

1. Solarban 70XL
2. Solarban 67 + Vertical Fins

The first iteration required that the shades be pulled most of the day in order to maintain the target illuminance. This prevented occupants from views to the outside.

As a result, a glazing with a lower visible transmittance value but a similar U-value and solar heat gain coefficient was used. Vertical fins were also added on the east and west facades in order to block direct sunlight. This solution allowed for less shade deployment and more views to the outside.

Moreover, energy savings through automated controls (dimming electric light through photosensors) were greater in the new solution.

DESIGN PROPERTIES

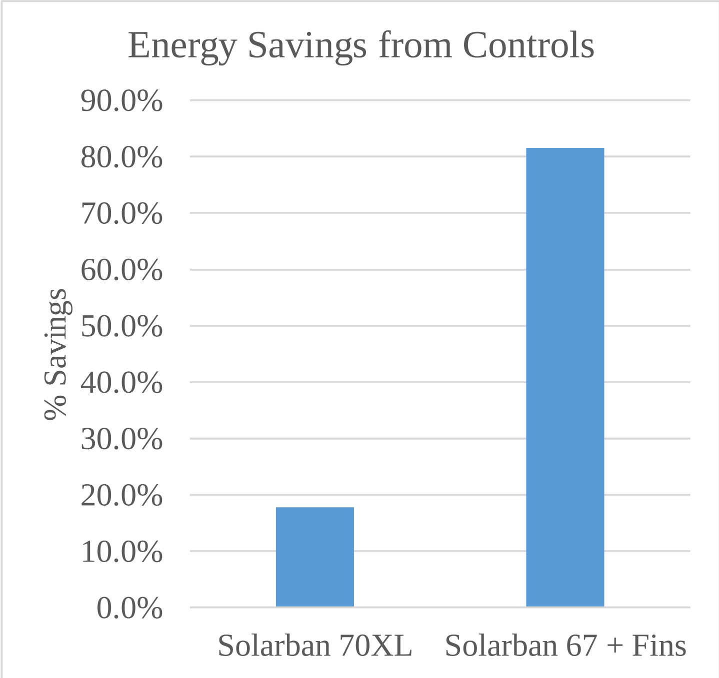
Dimensions of the window were chosen in order for the window to fit modularly into the rain screen façade.

Glazing Properties Comparison [13]		
	Iteration 1	**Iteration 2**
	SOLARBAN 70XL Solar Control Low-E Glass	**SOLARBAN 67 Solar Control Low-E Glass**
Visible Light Transmittance	0.64	0.54
Winter U-Value	0.28	0.29
Solar Heat Gain Coefficient	0.27	0.29
Light to Solar Gain Ratio	2.37	1.86

Shade Properties [12]			
	Solar Reflectance	**Visible Transmittance**	**Openness Factor**
Mechoshade Thermoveil 0901	0.72	0.04	0.0

RESULTS

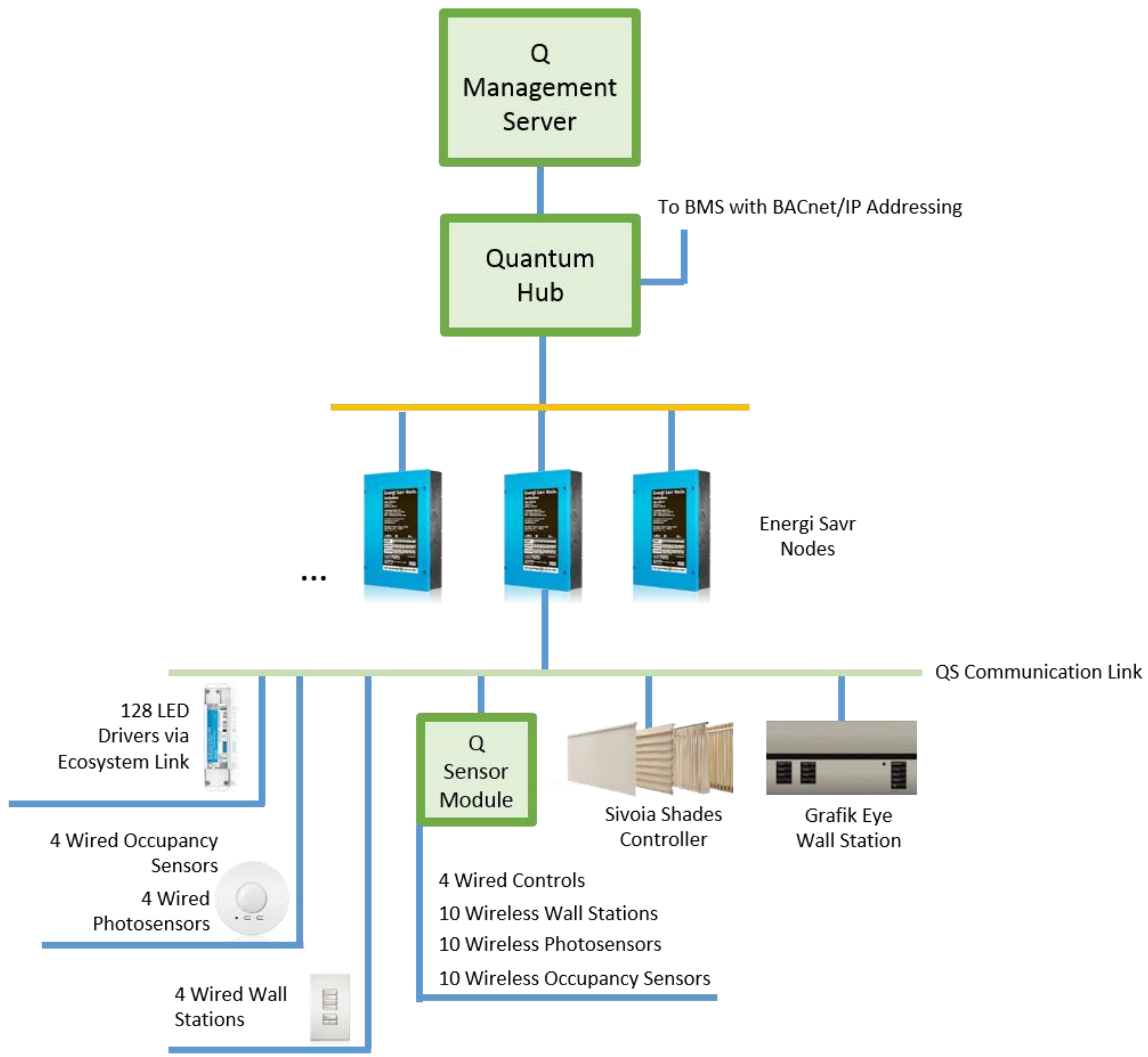
Shade Deployment Comparison		
	Iteration 1	**Iteration 2**
% of Year Shades Deployed	40.31%	12.65%



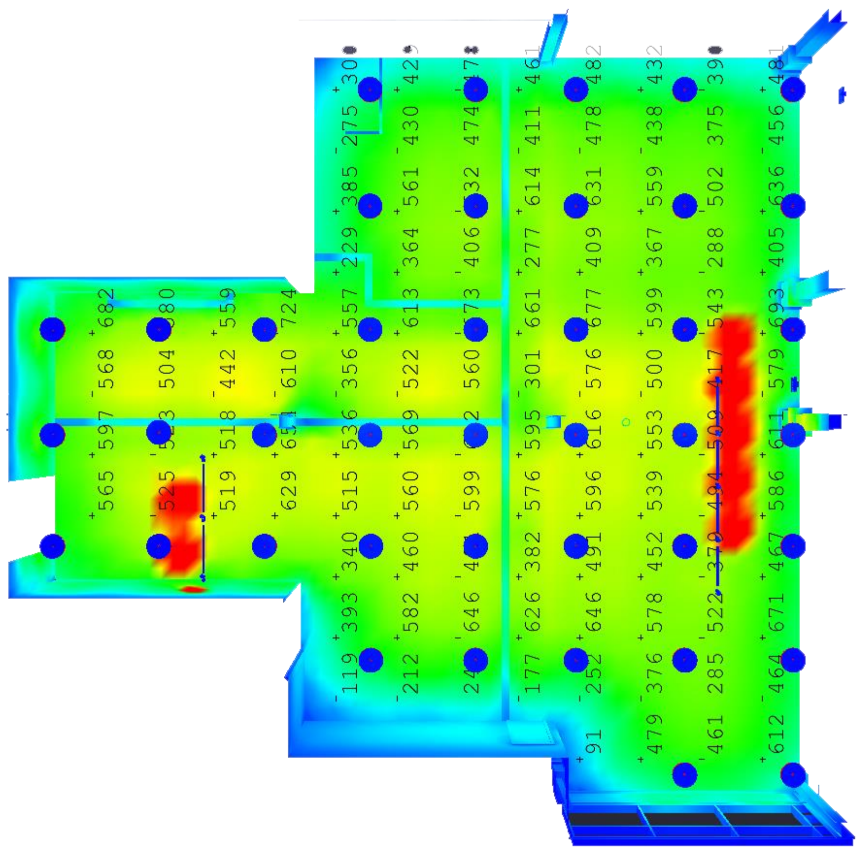
LIGHTING CONTROLS

LUTRON ENERGI SAVR NODE WITH ECOSYSTEM

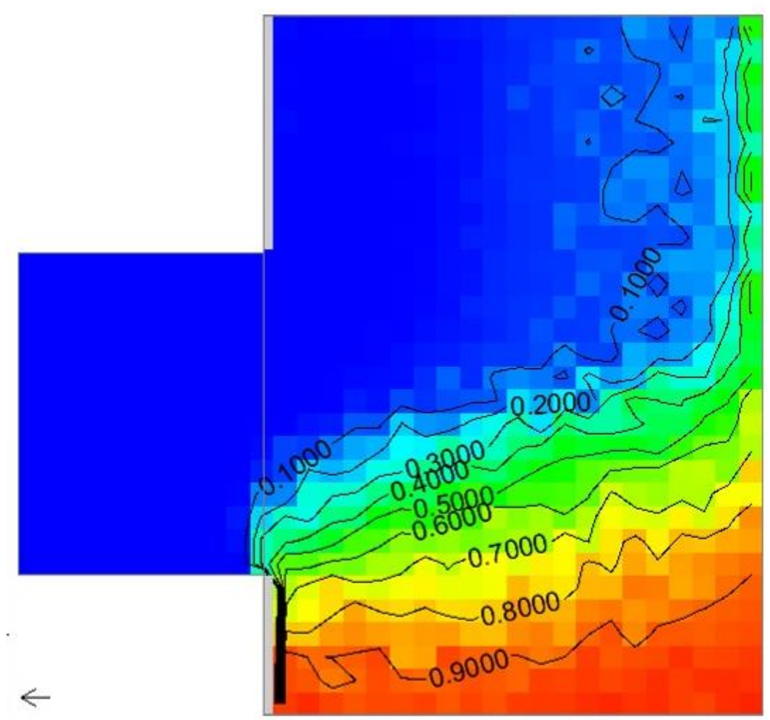
TBD has implemented into the design a digitally addressable lighting control system. *Lutron's Energi Savr Node System* provides an integrated solution to many different types of lighting controls via the *QS Communication Link* (11). Each *Energi Savr Node* can control (2) loops of 64 LED Drivers on the *Ecosystem* link, as well as some wallstations, photosensors, and occupancy sensors. All fixtures to be digitally addressed are specified as compatible partners with *Ecosystem* drivers. For more controls, a *Q Sensor Module* can be added to the communication link which provides access for wireless controls. Other systems can be connected to the communication link, such as the *Grafik Eye* wall station, which provides preset scene control, and the *Sivoia shades* controller. Nodes refer back to the *Quantum hub*, which can interact with the overall building network, and all systems on the communication link can be viewed at the *Q management server*, which is a user-interface program. This system is beneficial because it allows Growing Power to easily monitor and control its entire lighting system, and zones of fixtures can be easily reconfigured. More so, it interacts with the overall building network, which provides for a seamlessly integrated building.



INTERIOR SPACES
MARKET



N



LIGHTING & DAYLIGHTING DESIGN RESULTS

E_{target} / E_{design} = 500 lux / 508 lux (avg)

$W_{designed}$/$W_{allowed}$: 5048 W / 3302 W

$sDA_{400lux,\ 50\%}$ = 27.68%

Photosensor Energy Savings per control zone: 46%

Left: *Illuminance psuedocoloring*

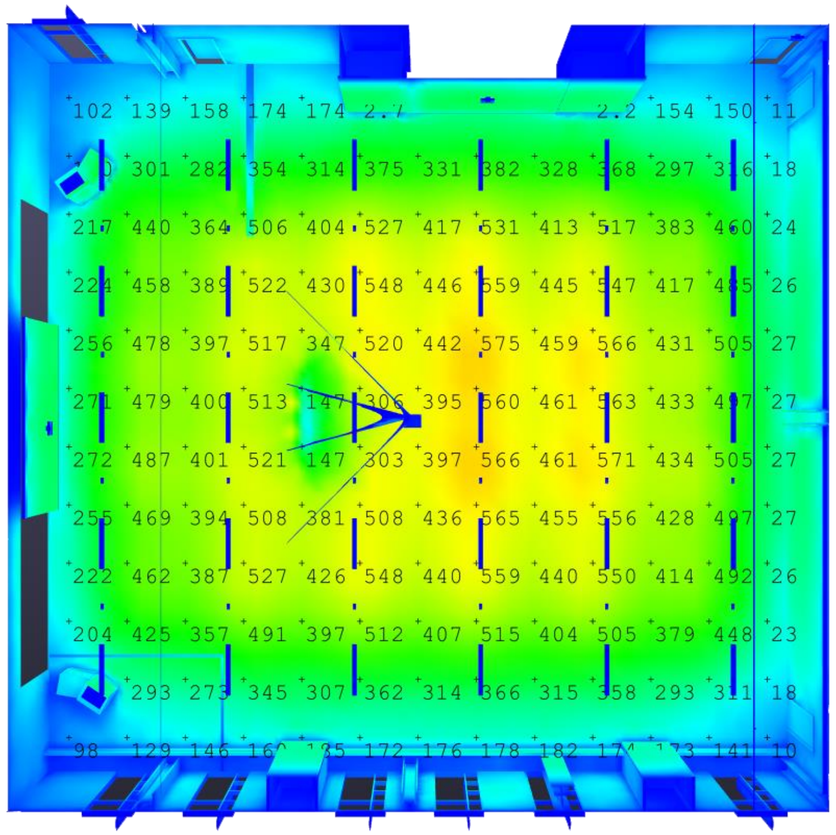
Bottom Left: *Contours for the Spatial Daylight Autonomy*

CONTROLS SCHEMATIC

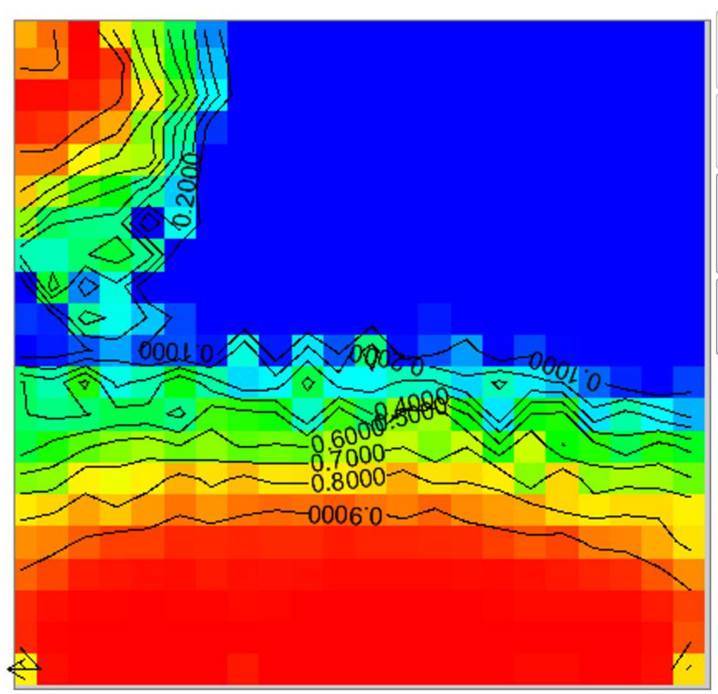
During the day, fixtures will be on and dimmed accordingly by photosensors, and the lighting management system's time clock will turn the fixtures off at night. However, the timeclock can be overridden by vacancy sensors (D8).

Left: *Switching zones are shown through colored fixture symbols, photosensor zones are shown in cyan boxes, render view is indicated by the purple arrow.*

GATHERING SPACE



N



LIGHTING & DAYLIGHTING DESIGN RESULTS

E_{target} / E_{design} = 50 lux / 361 lux (avg)

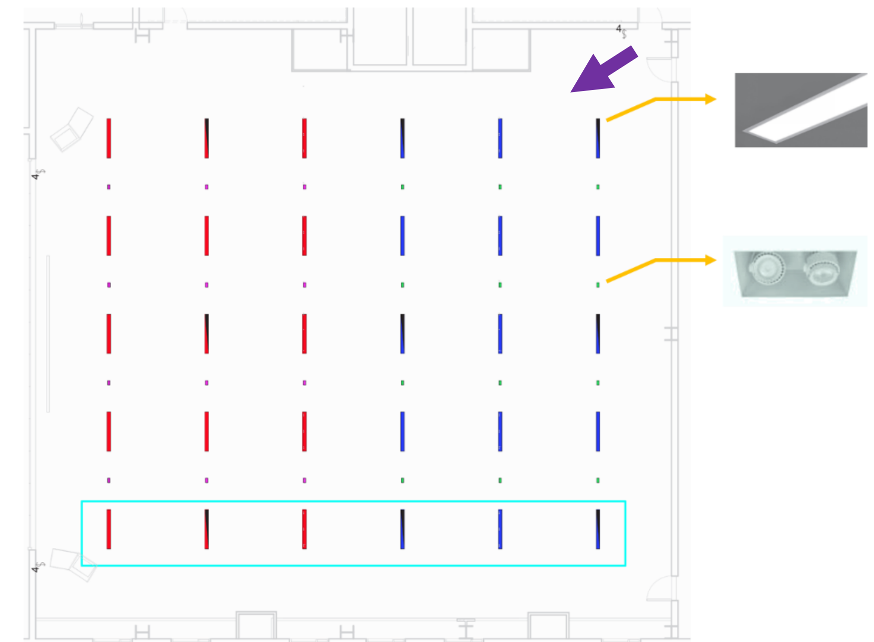
$W_{allowed}$ / $W_{designed}$: 3600 W / 942 W

$sDA_{100lux, 50\%}$ = 45.67%

Left: *Illuminance psuedocoloring*

Bottom Left: *Contours for the Spatial Daylight Autonomy*

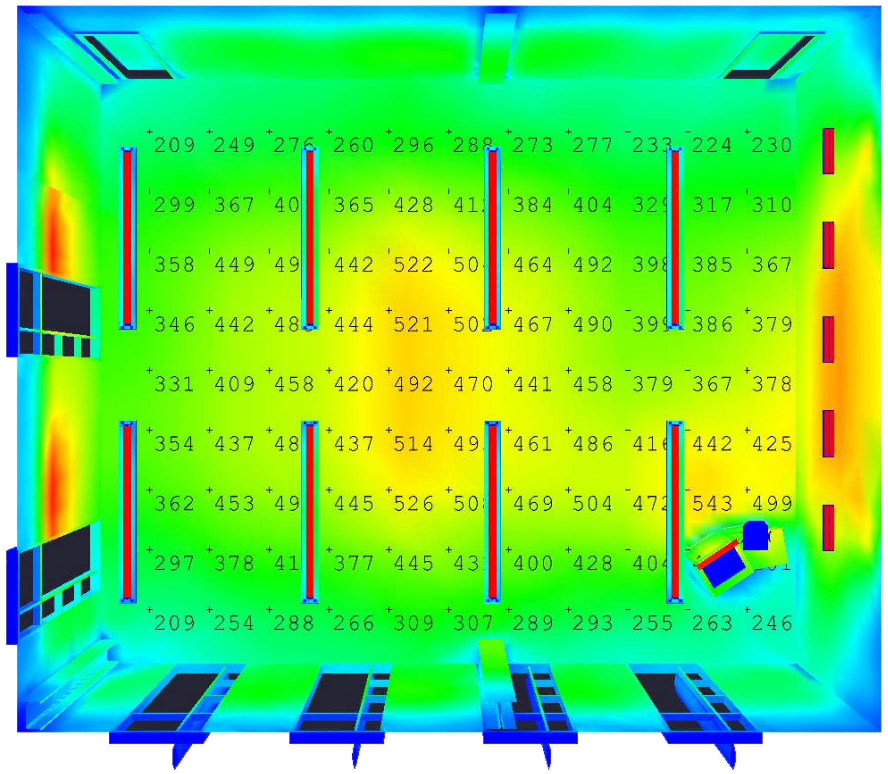
CONTROLS SCHEMATIC



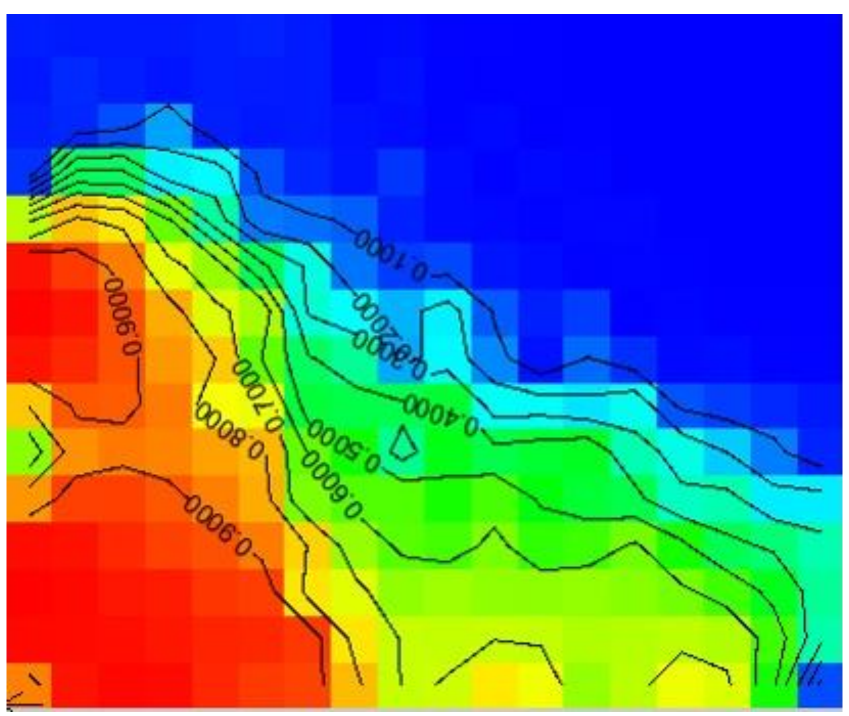
Fixtures will be turned on by users and turned off via a vacancy sensor. However, if the space is being used for a specific event, the lighting management system will override the vacancy sensors and keep the fixtures on as needed (D8).

Left: *Switching zones are shown through colored fixture symbols, photosensor zones are shown in cyan boxes, and render view is indicated by the purple arrow.*

WESTERN CLASSROOM



N



LIGHTING & DAYLIGHTING DESIGN RESULTS

E$_{target}$ / E$_{design}$ = 400 lux / 389 lux (avg)

W$_{allowed}$ / W$_{designed}$: 1470 W / 722 W

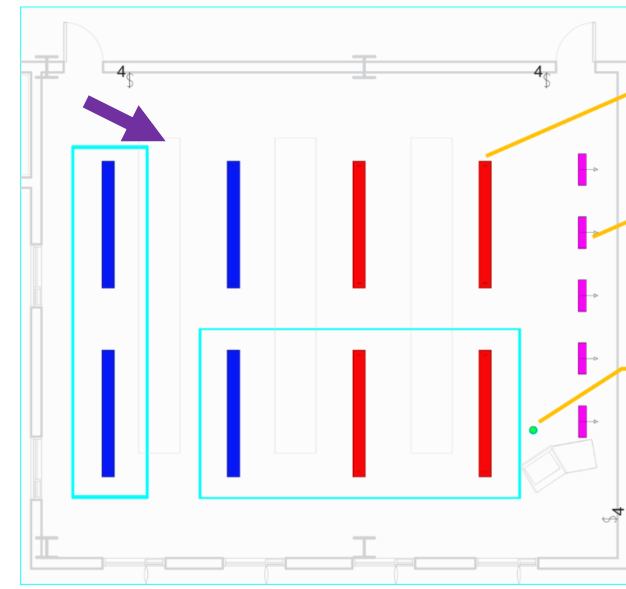
sDA$_{400lux, 50\%}$ = 41.11%

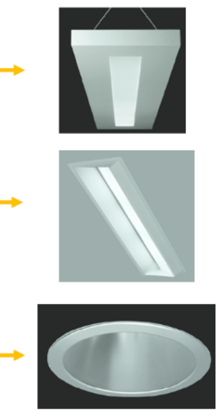
Photosensor Energy Savings per control zone: 86.4%

Left: *Illuminance psuedocoloring*

Bottom Left: *Contours for the Spatial Daylight Autonomy*

CONTROLS SCHEMATIC

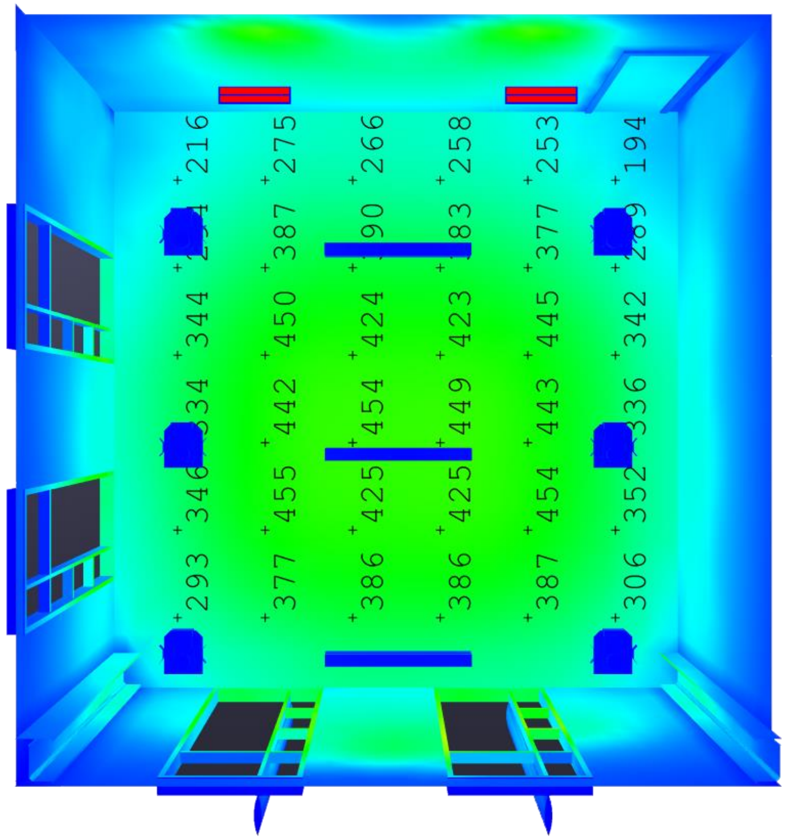




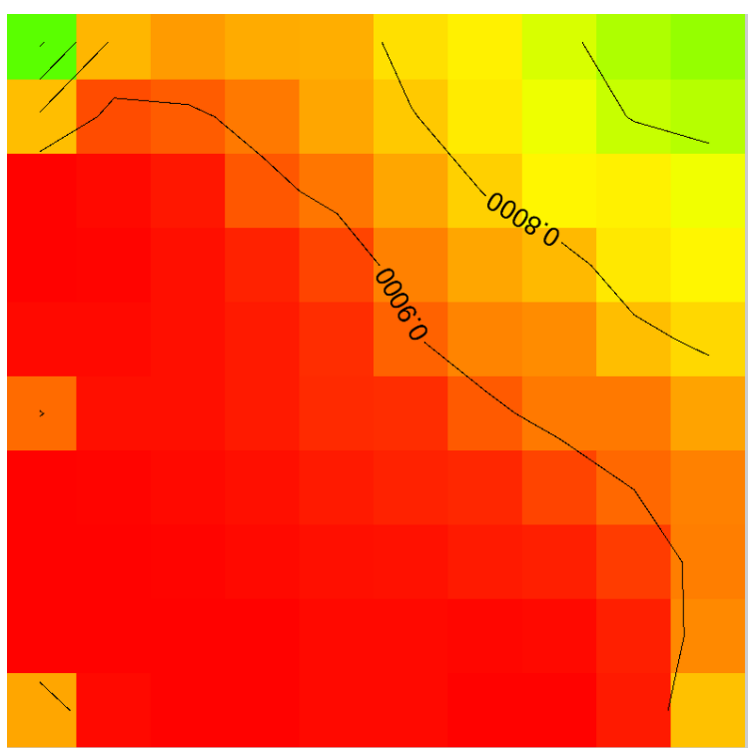
Fixtures will be turned on by users and turned off via a vacancy sensor (D8).

Left: *Switching zones are shown through colored fixture symbols, photosensor zones are shown in cyan boxes, and render view is indicated by the purple arrow.*

CONFERENCE ROOM



N



LIGHTING & DAYLIGHTING DESIGN RESULTS

E$_{target}$ **/ E**$_{design}$ = 300 lux / 363 lux (avg)

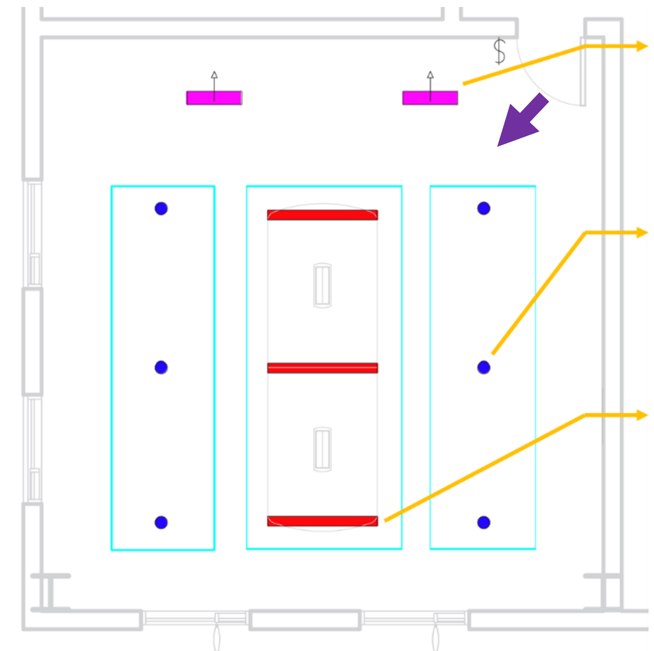
W$_{allowed}$ **/ W**$_{designed}$**:** 517 W / 227 W

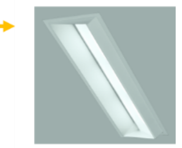
sDA$_{300lux,\ 50\%}$ = 100%

Left: *Illuminance psuedocoloring*

Bottom Left: *Contours for the Spatial Daylight Autonomy*

CONTROLS SCHEMATIC

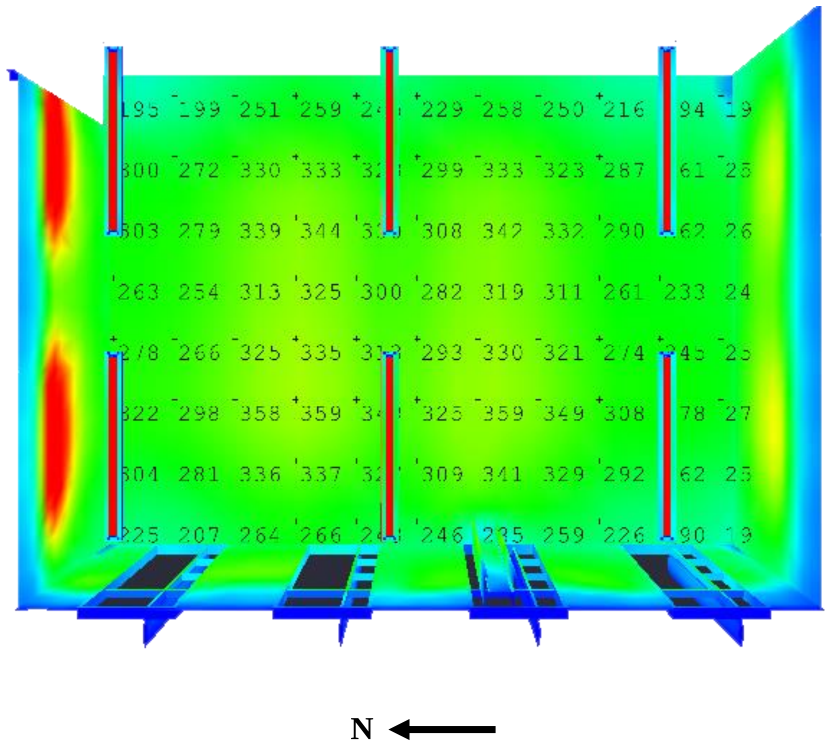


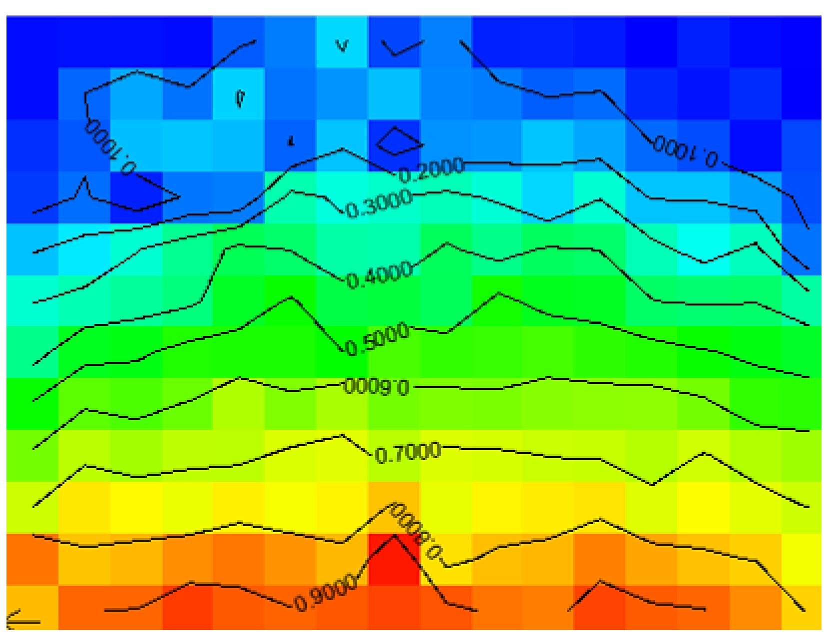


Fixtures will be turned on by users and turned off via a vacancy sensor (D8).

Left: *Switching zones are shown through colored fixture symbols, photosensor zones are shown in cyan boxes, and render view is indicated by the purple arrow.*

OPEN OFFICE





LIGHTING & DAYLIGHTING DESIGN RESULTS

E_{target} / E_{design} = 300 lux / 285 lux (avg)

$W_{allowed}$ / $W_{designed}$: 718 W / 432 W

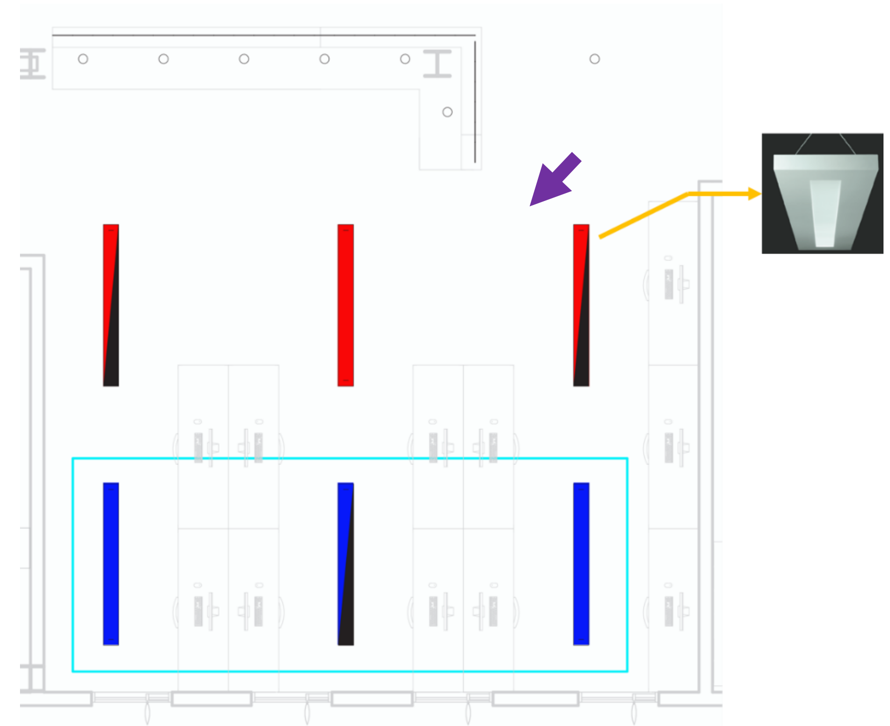
$sDA_{300lux, 50\%}$ = 48.44%

Photosensor Energy Savings per control zone: 80%

Left: *Illuminance psuedocoloring*

Bottom Left: *Contours for the Spatial Daylight Autonomy*

CONTROLS SCHEMATIC



During the day, occupancy sensors will control the fixtures, and they will be dimmed accordingly via photosensors. The lighting management system's time clock will turn the fixtures off at night. However, the timeclock can be overridden by the occupancy sensors. Task lighting will also be utilized to meet the illuminance target (D8).

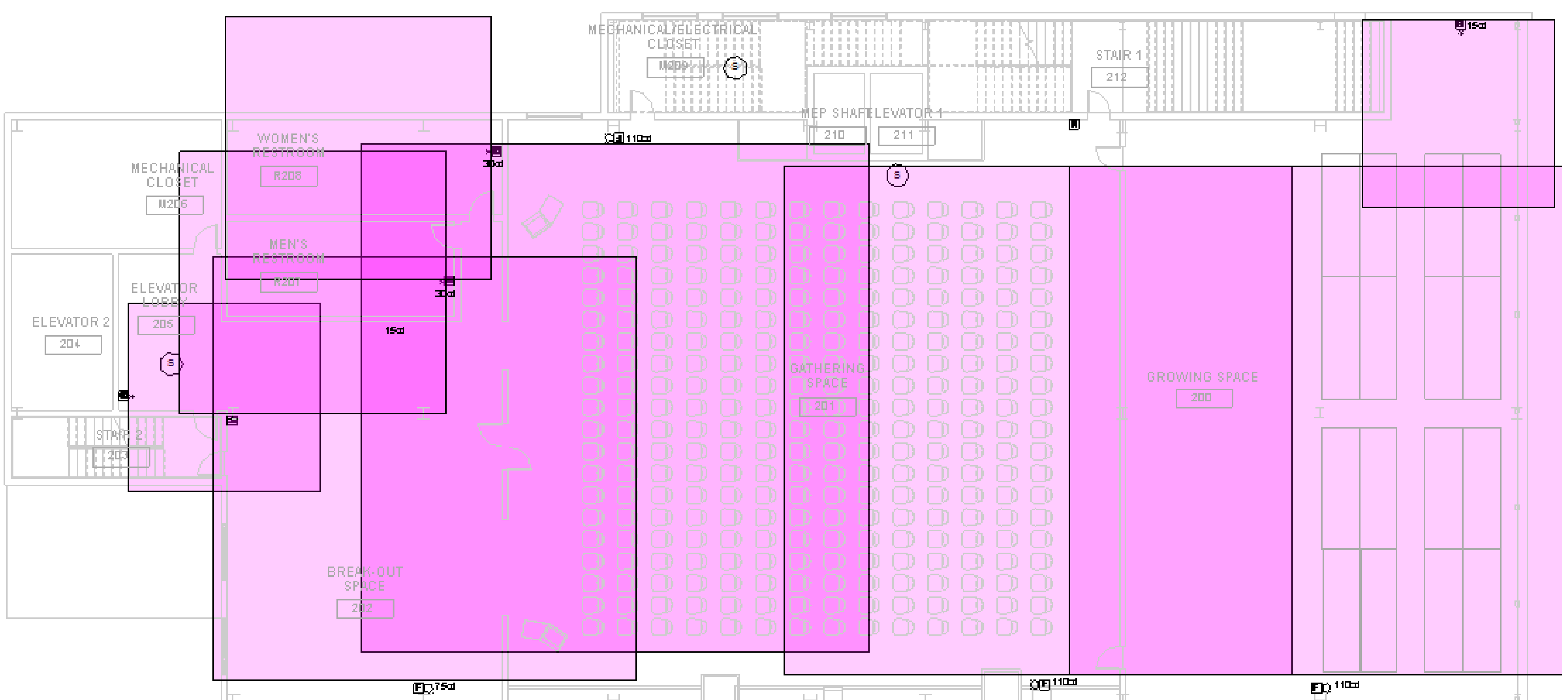
Left: *Switching zones are shown through colored fixture symbols, photosensor zones are shown in cyan boxes, and render view is indicated by the purple arrow.*

FIRE ALARM DESIGN CRITERIA

The main fire alarm equipment is placed in the main mechanical/electrical room in the basement. These include a Digital Alarm Communicator transmitter (DACT), a Fire Alarm Terminal Cabinet (FATC), and a Fire Alarm Control Panel (FACP). The Fire Alarm Annunciator Panel (FAAP) is located at the fire department's entrance, which is at the northeast loading dock. A list of the equipment and their purpose is outlined below:

DACT	Sends alarm signal to fire department
FATC	Houses wiring
FACP	Controls fire alarm devices within the building
FAAP	Shows fire department the location of the fire within the building

DESIGN LAYOUT



Manual pull stations were placed at appropriate exit locations. Additionally, strobes and horn/strobes were located throughout the building based on their visual area of coverage according to their candela rating, seen in the table below by NFPA72. The diagram on the left shows a successful layout of the strobes on the second floor, as the whole area is accounted for.

Candela Rating (cd)	Area of Coverage
15	20' x 20'
30	28' x 28'
75	45' x 45'
110	54' x 54'

TOTAL BUILDING NETWORK DESIGN

BUILDING SYSTEMS INTEGRATION

Below is a more detailed diagram of the building control and monitoring network. Through BACnet/IP wiring, a shared network is created to integrate building systems. The systems listed below will be controlled and monitored via a remote server [14].

Key components to the building electrical operations take part in this network.

- Electrical demand data collected from meters can be monitored.
- To prioritize loads on the generator, contactors upstream of a panel can be controlled to shut off all the loads on an entire panel.
- The Quantum Hub lighting control can communicate with other systems such as HVAC devices.
- Greenhouse devices such as pumps, fans, and other systems integral to its operation can be monitored and controlled along with the building controls.