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Analyzing the Efficiency of 101 Seaport's Glass Facade

Environmental Consultants Specialized in Building Envelopes

Introduction

The Seaport District in South Boston, is one of the fastest developing areas of Boston, Massachusetts. The Seaport's rapid transformation from industrial warehouses and parking lots to premier innovation district has certainly drawn new residents and businesses to the area in impressive numbers. Hence why the company Skanska, along with other development firms, was interested in joining the development boom. Since 2011, Skanska, a multinational construction and development company based in Sweden, has been an integral part in the planning and build-out of the Seaport District. Currently, Skanska has three large developments all along Seaport Boulevard, the main road that traverses the district. Their first primarily office development was 101 Seaport Boulevard, completed in 2015. 101 Seaport Boulevard, which received LEED Platinum certification, sits next to LEED Gold and LEED Platinum Skanska built and developed buildings, defining these three structures as making up the "most sustainable row of office and residential buildings in Boston" (SKANSKA USA, 2016).

For our term project, our team has decided to play the role of environmental design consultants to Skanska, with a special focus on the building envelope, as they construct 101 Seaport Boulevard. Our overall goal is to optimize the energy and financial losses during construction and operation due to the completely glass facade design. Through energy and daylighting studies we also hope to optimize the indoor environmental quality, enhancing tenant productivity and overall wellbeing.

101 Seaport Boulevard Overview

101 Seaport will be a Class A, 460,000 square foot office building with ground floor retail that is LEED Platinum certified. Standing at 17 stories, 101 Seaport is planned to have 440,000SF dedicated to office space and 20,000SF of retail and restaurant space. The majority of the building will be dedicated to the New England headquarters of the multinational accounting firm PricewaterhouseCoopers, PwC. (101 Seaport Facts)The building itself sits approximately 740 feet from Boston Harbor's edge with expansive views of the water and Downtown. The rectangular building will be sitting on an angle along Seaport Boulevard, the main thoroughfare in the district. The entrance and front face of the building points NorthEast, while the backside of the building will face SouthWest. This is important to note considering almost 100% of the building envelope is planned to be floor to floor high-efficiency triple glazing curtain wall. Skanska's overall goal is to have the building substantially complete by October 2015, where the construction schedule does not exceed 26 months, and to sell the development after the building's first fully operational year. (site bpda)

a) 101 Seaport 3D View

a) 101 Seaport 2D Map

101 Seaport Geopraphic Location

Skanska Overview

Skanska is a multinational construction and development firm based in Stockholm, Sweden. Skanska operates several different business streams that also work within many different industries. In both Europe and North America, their largest business stream is their construction branch. However, they also have a commercial property development and residential development arm. Their construction branch includes both civil and building construction management. Within construction, they also offer other building services such as their own safety, virtual design and construction, building equipment services, sustainability, and owner's project manager groups. In New England specifically, Skanska operates their building construction, civil construction and commercial development business streams. There are over 40,000 employees world wide and 300+ employees just in the Boston area. The company has been operating in New England for over 70 years and has invested over one billion dollars in commercial development properties. 100% of their projects in New England have received LEED Gold certification or higher (SKANSKA USA, 2016).

However, Skanska Commercial Development is unique in how they function. They operate under a few rules that are specific to Skanska. First, all projects must be built by the Skanska Construction business stream. Second, Skanska does not maintain or keep any of their properties. They are to be sold almost immediately after a year of full operation. Third ,and most importantly, Skanska self-finances the majority of their projects. (SKANSKA USA, 2016). By immediately selling their buildings after construction they hope to reduce their financial burden by making back the money they initially put into the investment more quickly.

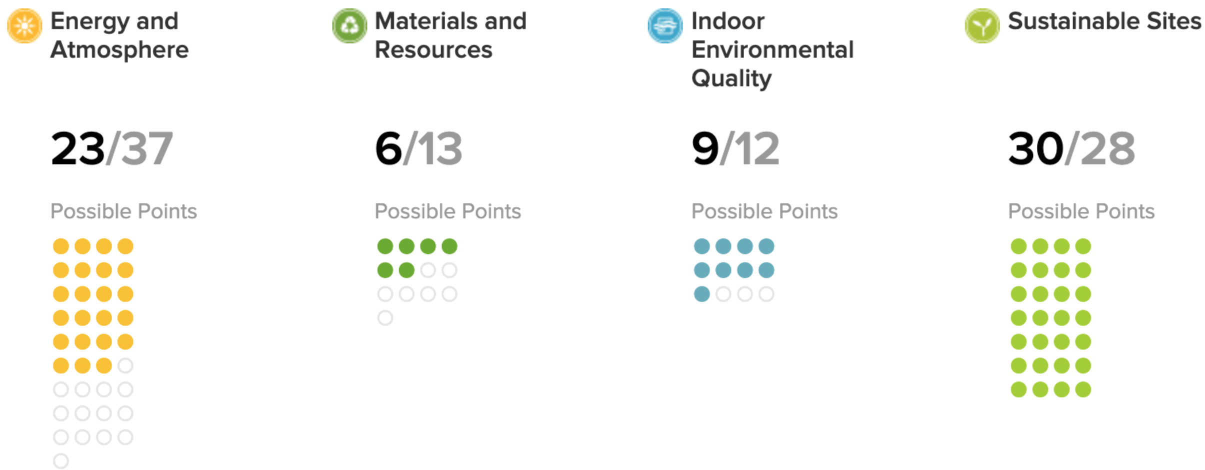
101 Seaport Green Building Report 37

As green consultants, we will be reviewing the Final Article 37 Green Building Report that supplements the LEED checklist for 101 Seaport.

This report includes the intent of the designers to maximize tenant efficiency and flexibility of use by providing a combination of large and small floor plates and nearly column-free space on the tower floors. The report states that the building will provide tenants with unique brand visibility and accessibility. In addition, tenants will have several common spaces to meet and recharge like the third floor rooftop terrace and the second floor fitness facility. The report also states that sustainability is an important design priority for 101 Seaport. The exterior façade will feature a floor to floor high-performance glass curtain wall, coupled with a 10-foot floor to ceiling interior to provide tenants with unique opportunities for daylight harvesting and views to the exterior. The building will also feature a variety of sustainable materials, including locally sourced stone and reclaimed wood piles from Boston Harbor. (Boston Plans, 1)

Overall, the report generally reflects that the project from conception through construction has incorporated many aspects of sustainability to “ensure the longevity of the project while reducing the overall ecological footprint of the building”.(Boston Plans, 1) Some aspects that this project has focused on are: overall energy and water conservation, reduction of virgin material use, and occupant wellbeing. At first glance, when reviewing the LEED certification checklist and the overall goals of the projects; the project seems environmentally conscious. However, our job as consultants is to make this project benefit it’s occupants more, instead of it satisfying a mere list. The research below analyzes the Energy and Atmosphere and Indoor Environmental Quality sections, to see if they can be improved for the future occupants of the building.

Based on the current LEED report from 101 Seaport, the building’s credit achievements will be as follows:

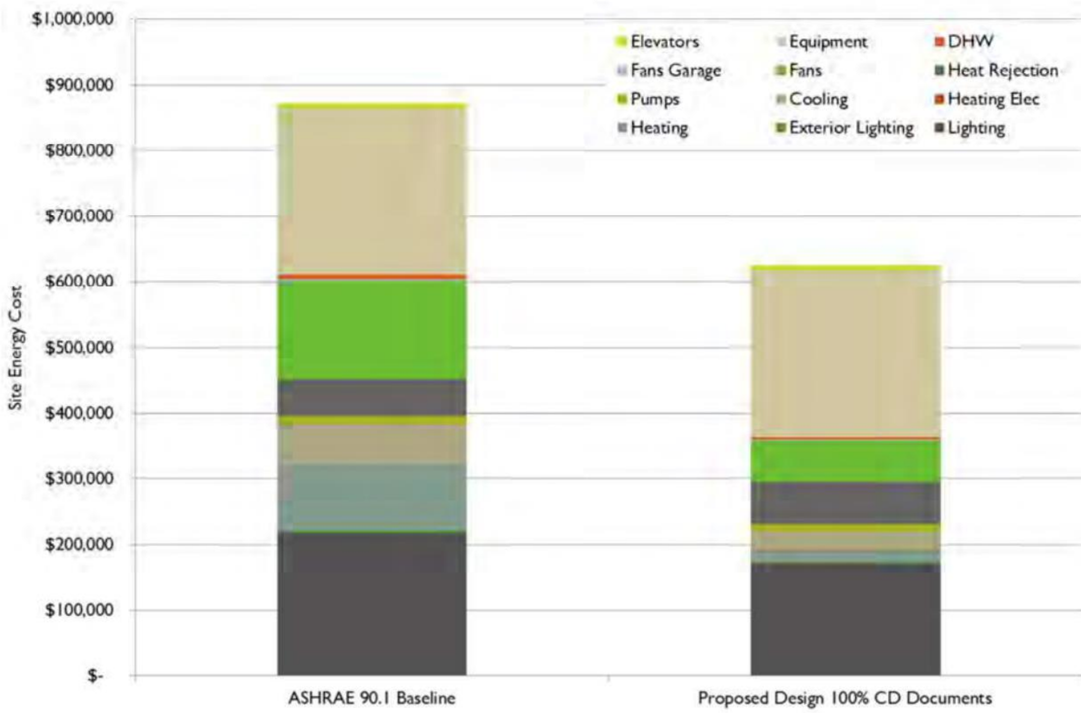


(USGBC, 101 Seaport at Seaport Square)

Energy and Atmosphere

Through a commissioning process, the following energy systems will be implemented in 101 Seaport:

Heating, Ventilating, Air Conditioning and Refrigeration (HVAC&R) systems (mechanical and passive) with associated controls, lighting and daylighting controls, domestic hot water systems, renewable energy systems (wind, solar, etc.).



(Boston Plans, 14)

Major energy savings contributions include: lighting power reductions, the use of high efficiency chillers and boilers, a fanwall and heat recovery at the air handling units, the use of chilled beams as the primary conditioning source, and an optimized triple glazed envelope (Boston Plans, 1).

The report mentions that a whole building energy simulation was carried out using IES VE software to optimize energy performance for the project. Using the performance rating method in ASHRAE 90.1 2007 appendix G, overall site energy cost savings was compared to the baseline model. **The resultant cost savings equates to 28.5%.**

Credit Achievement

EAc1: Optimize Energy Performance	EAc2: On-Site Renewable Energy	EAc3: Enhanced Commissioning	EAc4: Enhanced Refrigerant Management
13/21	0/4	2/2	2/2
Possible Points	Possible Points	Possible Points	Possible Points

(USGBC, 101 Seaport at Seaport Square)

However, as shown above, the optimizing of Energy Performance is quite low based on LEED anticipated results. In addition to that, the project mentioned a renewable energy system, but that meant retrieving 30% the electricity bought from renewable energy plants rather than building on-site ones. Hence, the project did not deliver on these two aspects of the certification. As consultants, we are writing this report, partly, to address the above deficits in the design, but we also want to guarantee the health and safety of occupants of the building in the long run.

Building Envelope

Building envelopes can play a key role in achieving targets for climate change mitigation and energy sustainability whilst enhancing the wellbeing of building tenants. Based on article 37, WSP USA's MEP and Built Ecology teams and the designers are hoping that 101 Seaport will achieve LEED Platinum. This is said to be particularly challenging with all-glass facade buildings, which begs the questions: *why is all glass?*

101 Seaport's facade design consists of a triple glazing glass that is believed to improve thermal comfort for the occupants of the buildings (by reducing cold spots and eliminating cold downdrafts) as well as allowing for better acoustic performance, increased security, reduced solar gain in the summer and a reduction in surface condensation. In combination with other energy saving design features, it can result in noticeable reduction in utility costs. It may also increase the value of a building. However, triple glazing is likely to cost around 20% more than double glazing, which in itself is unlikely to be paid back in terms of energy savings in the US within 10-15 years (Lee et.al.). This means it is not necessarily an economically justifiable choice as a

stand alone design decision. In addition it takes more materials to manufacture, and so has a higher embodied energy. High efficiency triple glazing is also heavier than double glazing and so may require a more substantial supporting structure that is more costly and more complex to fit. Finally, triple glazing also reduces solar gain in the winter which can increase the amount of heating required (Lee et. al) Below is a breakdown of important features of triple glazed and double glazed windows that need to be taken into consideration:

COST of Triple Glazed Windows: In average, 1 installation is $700 per triple paned window + the cost of steel reinforcement in the building to support them.

COST of Double Glazed Windows: In average, 1 installation is $375 per double paned window.

Lifespan of Triple Glazed Windows: a triple glazed window will have a lifetime of roughly 10-20 years.

Lifespan of Double Glazed Windows: a double glazed window will have a lifetime of 25-30 in a sheltered location. Under extreme weather, it roughly lasts 20 years.

U value: Single pane traditional windows will typically have a U value of 5. A double glazed window will typically have a U value between 1.6 and 1.4.

Research suggests that triple pane windows have a better U-factor than double pane and 20-30% better on energy efficiency — that’s a substantial margin. But are these increases in efficiency worth the trade off of increased cost for the triple windows? Or would adding sun shading, or louvers compensate for this?

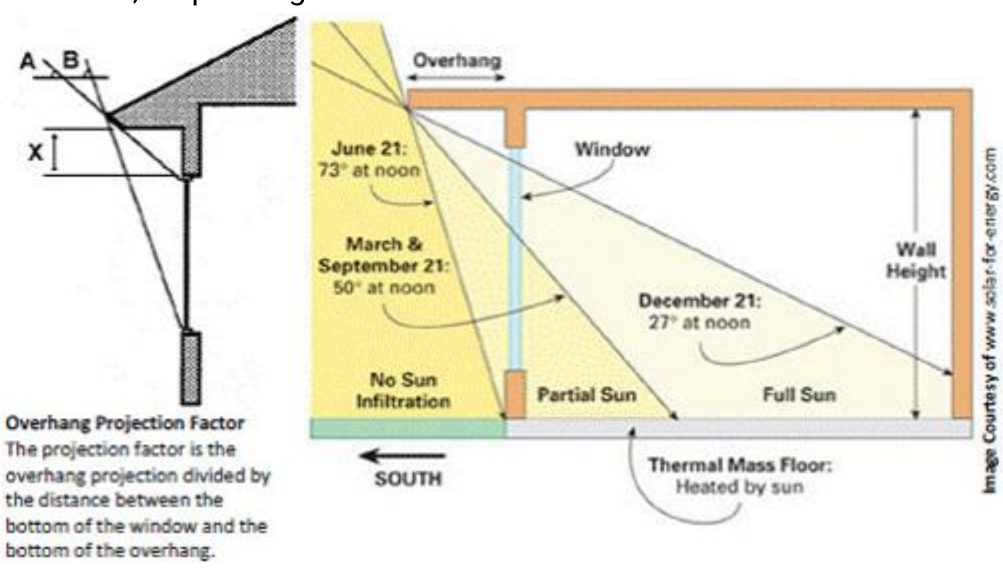
Shading Systems and Louvers

In the summer, 101 Seaport will admit sun into the building, and excess solar gain may result in high cooling energy consumption. On the other hand, the winter sun in Boston entering from the south facade can positively contribute to passive solar heating. Hence, a well-designed sun control and shading device can dramatically reduce building peak heat gain and cooling requirements and improve the natural lighting quality of 101 Seaport. The average reduction in annual cooling energy consumption can reach up to 15%.

For 101 Seaport, we researched whether an interior or exterior shading system would be beneficial. Our findings show that exterior shading systems have a big advantage over interior systems: they significantly reduce unwanted solar heat gain by eliminating one of the sources of that gain. Solar radiation is absorbed by shading material, whether installed inside or outside a building. The short-wave solar energy that is absorbed by the shading system is converted into long wave energy (i.e., heat). With an exterior system, this heat is radiated outside the building and never reaches the glazing. However, solar energy that is absorbed by an interior shading system and is then radiated as heat is trapped inside the building (Prowler, “Sun Control and Shading”). Hence, we’re recommending exterior shading for 101 Seaport (appendix 1, appendix 2).

Examples of shading systems are Louvers and blinds, which are composed of multiple horizontal or vertical slats that cover the facades of buildings. Exterior blinds are more durable and usually made of galvanized steel, anodized or painted aluminum or PVC for low maintenance. For 101 Seaport, painted aluminum is the material chosen, with a depth of 2ft.

Another aspect of shading is its ability to redirect daylight. While fixed systems are designed mainly for solar shading, operable systems can be used to control thermal gain, reduce glare, and redirect sunlight. Operable systems (whether manual or automatically controlled) provide more flexibility because the blinds can be retracted and tilted, responding to the outdoor conditions.



(Prowler, “Sun Control and Shading”)

Illuminance and Glare

Two elements that contribute to tenant wellbeing are illuminance and glare. The intent of USGBC's daylight and views category is to "provide building occupants with a connection between indoor spaces and the outdoors through the introduction of daylight and views into the regularly occupied areas of the building". Illuminance is defined as the level of light on a surface. According to USGBC's LEED certification rules, in order to achieve 1-2 points the building must demonstrate illuminance levels between "300 lux and 3,000 lux for 9 a.m. and 3 p.m., both on a clear-sky day at the equinox" while preserving views. After our simulation (appendix 3) we discovered that the average illuminance without shading is well beyond the maximum lux, at 4128 lux. Glare must also be accounted for. According to our simulation the glare without shading is extreme at 79% of the building affected by near intolerable glare (appendix 4). The inclusion of vertical shading will reduce both the illuminance and glare substantially. While illuminance levels do go down by 32%, the lux still remains at the upper end of the scale at 2794 lux for the building. This maintains the positive effects of the daylight for the tenants. Glare is also reduced by 25%, which will greatly impact the tenant's ability to see their screens and do work. Vertical shading louvers will maintain views while reducing illuminance and glare by the appropriate amount to hopefully attain the 2 extra points in the daylight and views category, while increasing the overall wellbeing of the tenant's wellbeing .

Renewable Energy

On-site renewable energy generation can produce significant environmental, economic, and sovereignty benefits. On-site renewable energy reduces energy costs by decreasing a building's susceptibility to fossil fuel price volatility. It also reduces air pollution and greenhouse gas emissions. Based on the current plans, 101 Seaport does not have any on-site renewable energy planned. Hence, in our report, we will calculate if it's economically viable to have on-site solar panels which can be used for solar electric (photovoltaic), solar hot water, and passive solar design systems. Below are a few incentives to encourage on-site solar installation.

Code Incentive Examples

General	Targeted – Energy
• Expedited permitting process • Expedited easement approval process • Permit fee waivers or reductions • Reduced inspections	• Incentives to build smaller • Incentives to use less energy per square foot • Incentives to construct buildings that are more energy efficient than the minimum requirements of the jurisdiction • Incentives for renewable energy: solar, wind, geothermal, low-impact hydro or bio-gas projects

[1]

However, installing solar panels is in reality incredibly pricey. Given a solar panel system size of 5 kilowatts (kW), an average solar installation in Boston, MA ranges in cost from $13,685 to $18,515, with the average gross price for solar in Boston, MA coming in at $16,100. To make up a 5kW solar system, the building needs 17 solar panels, assuming we use 300W panels – that will actually give you 5.1kW. Each panel will be about 1.6m x 1m, so they will need at least 17.2m² of roof space (appendix 7).

Our Calculations

To think of ways to enhance both the Energy and Atmosphere of 101 Seaport, and to understand what has been mentioned above, our team pursued the below approach for analysis:

	Project	Installation Cost	Energy Cost($/sq2/y)	Annual Energy Cost	Annual Energy Cost saving	EUI (Kwh/sq2/y)	CO2 Emission (Kg/sq/y)
1	Triple Glazing without shading	$24,198,906	$1.41	$641,973.00		30.0445	8.169
1A	Triple Glazing with shading	$24,688,246	$1.07	$486,260.40	$155,712.60	21.988	6.18
2	Double Glazing without shading	$20,026,680	$1.46	$664,282.70		31.4	8.4
2A	Double Glazing with shading	$20,516,020	$1.09	$494,911.10	$169,371.60	22.657	6.29

[1] Tribal Green Building Toolkit (June 2020 Link Updates)

As shown in the table above, the difference between triple glazing with shading is quite close to that of double glazing with shading. For starters, the energy cost ($/sq2/y) is roughly $1.07 for triple, to $1.09 for double. As for the energy lost, that is also evidently quite similar between the two options, from 21.988 to 22.57 annually (Kwh/sq2) (appendix 5, appendix 6).

Triple Glazing Cost, Shading, and Other Projects

	Project	Cost
1	Triple Glazing	$ 24,198,905.58
2	lighting controls	$ 400,000.00
3	chillers and boilers	$ 4,200,000.00
4	Fanwall and heat recovery together with typical air handlers/installation	$ 1,635,000.00
5	chilled beams + installation	$ 7,310,000.00
6	Vertical and Horizontal Shading	$ 489,340.00
7	Total cost with Triple Glazing	$ 38,233,245.58

Double Glazing Cost, Shading, and Other Projects

	Project	Cost
1	Double Glazing	$ 20,026,680.48
2	lighting controls	$ 400,000.00

3	chillers and boilers	$ 4,200,000.00
4	Fanwall and heat recovery together with typical air handlers/installation	$ 1,635,000.00
5	chilled beams +installation	$ 7,310,000.00
6	Vertical and Horizontal Shading	$ 489,340.00
7	**Total cost with Double Glazing**	**$ 34,061,020.48**

With double glazing and shading, 101 Seaport will save **$3,682,885.10.**

15 Year Full Cost Analysis

Project	Payback Yrs	MOI 15 yr	ROI yr1, yr2	IRR 15 yrs	NPV 15 yrs
Triple Glazing w/ shades	50.77	0.30	2%	-12%	$19,641,028.91
Double Glazing w/ shades	41.45	0.36	2%	-11%	$15,379,012.50

Final Recommendations

After analyzing the financial and energy savings data, as green consultants for the construction of the envelope of 101 Seaport Boulevard we recommend that Skanska invest in double glazing panels with the addition of a shading system. It is clear that the energy savings, as well as, the annual cost savings is much greater when a shading system is added to the building. There will be approximately a 28% savings in energy with a shading system added to a glazing system. While the energy savings may be less for double glazed panels both alone and with a shading system, the overall annual energy cost savings due to the facade is well over $10,000 greater than that of a triple glazing envelope with a shading system. The difference in EUI between a triple glazing system and shades compared with the double glazed panels with shading (21.988 versus 22.657kwh/sq/y) is so small that the overall financial savings carries greater weight. Not only does the double glazing option financially make more sense, but also, as stated previously, the double glazing panels have a longer lifespan, reducing the need for new materials within a shorter amount of time.

We also conducted a 15 year full cost cash flow analysis of both types of glazing with shading. Overall, the double glazing with shading yet again seems like the better option. However, it is important to note that while the IRR for both options are negative, these two percentages are more arbitrary because each project only contributes to a portion of the total IRR for the building. Thus, when assessing the IRR, the project with the higher IRR will contribute more positively to the building's total IRR in the end.

Overall, using double glazing panels with a shading louvre system will reduce the EUI by 25% as compared to the initial plan of using only a triple glazing curtain wall. This change will also reduce the carbon emissions due to the facade by 23%. The shading system will also positively impact the tenant's day-to-day experience in the building. As stated previously, the dhading will reduce glare substantially, but will continue to maintain views and an appropriate illuminance level.

We also assessed the feasibility of onsite renewable energy via PV panels. Unfortunately, in Massachusetts the amount and total cost of panels necessary to productively contribute to the building's overall energy usage is too much to provide any financial or energy gain. Thus, as consultants, we do not recommend the use of PV panels in the project.

PV Panels	
size of panels	1 x 1.65m
number of panels	600
watts per panel	265
Total watts	159000
cost of panels pwatt	$ 3.12
Total cost	$ 496,080.00

Finally, our recommendation will not only save Skanska over 3 million dollars in construction but also will also positively impact the future sale of the building. Skanska as the current owner plans to immediately flip the building after construction. Our double glazing and shading system projects a greater annual financial savings on utilities for the future owners and tenants. Due to their business model, this is something that Skanska may not have taken much consideration in, as they will not be maintaining the building in the future.

References

Boroyan, Nate. “Seaport Square's 1st Office Tower Is Now Structurally Complete.” *Americaninno.com*, 23 Sept. 2014, www.americaninno.com/boston/101-seaport-boston-topping-off-skanska-usa/.

Boston Plans, 2014, *Final Article 37 Green Building Report*, www.bostonplans.org/getattachment/a5c4190c-f3ec-49da-a4e4-5afea867cf1b.

“Business Model: Skanska - Global Corporate Website.” *Skanska*, SKANSKA, 22 Apr. 2021, group.skanska.com/about-us/strategy/business-model/.

Lee, Eleanor, Selkowitz, Stephen, Bazjanac, Vladimir, Inkarojrit, Vorapat, and Kohler, Christian. *High-performance commercial building facades*. United States: N. p., 2002. Web. doi:10.2172/834266.

LEED v4 for BUILDING DESIGN AND CONSTRUCTION, USGBC, 25 July 2019, www.usgbc.org/sites/default/files/LEED%20v4%20BDC_07.25.19_current.pdf.

Prowler, Don. “Sun Control and Shading Devices .” *WBDG*, 8 Sept. 2016, www.wbdg.org/resources/sun-control-and-shading-devices.

“Skanska USA Sells 101 Seaport to Union Investment .” SKANSKA USA, 2016.

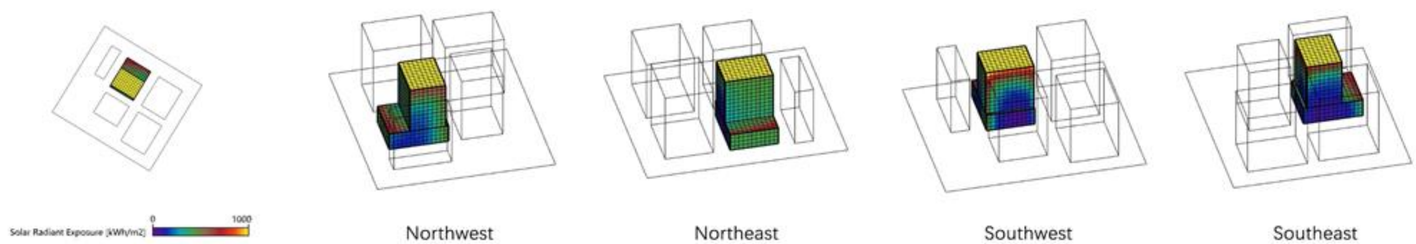
“101 Seaport at Seaport Square.” *U.S. Green Building Council*, 2016, www.usgbc.org/projects/101-seaport-seaport-square.

101 Seaport - Union Investment, www.101seaport.com/#facts.

Appendix

Appendix 1

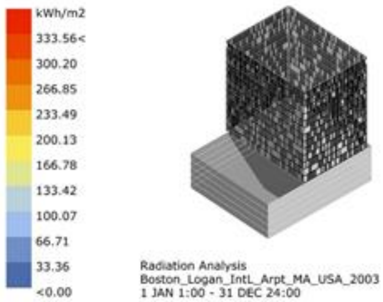
a) Solar Radiation Map: 3pm, June 21th *Energy Density 428.35 kwh/m2*



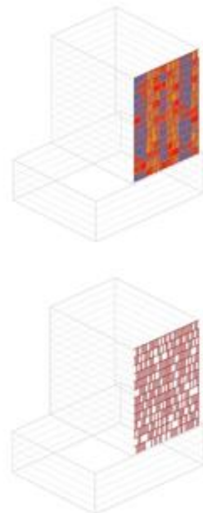
b) Solar Radiance Effect: 3pm, June 21th *Intolerable Glare 84%DGP (clear sky with sun)*

Radiation and Radiance Analysis on Solstice

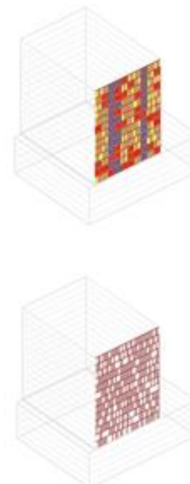
Appendix 2



West Shading
Annual Radiation:
528662 kwh



East Shading
Annual Radiation:
957764 kwh



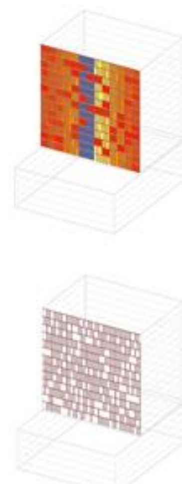
Vertical:

Size: 3.8 x 0.6 m
Amount: 1532
Material: Aluminum

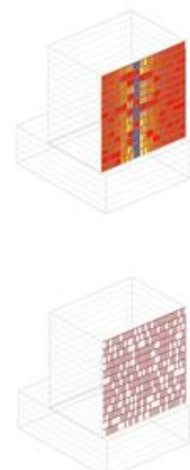
Horizontal:

Size: 2 x 0.6 m
Amount: 1222
Material: Aluminum

North Shading
Annual Radiation:
718285 kwh



South Shading
Annual Radiation:
2.342e+6 kwh

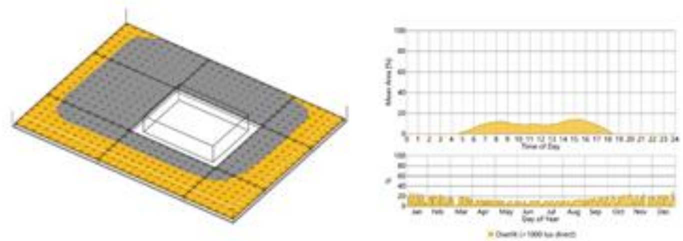


Iterative Radiation Analysis Based on Each Facade

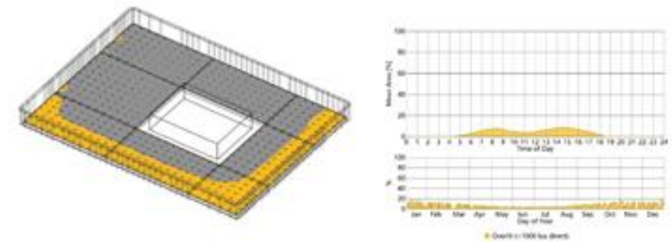
Appendix 3

Daylight Simulation

a) ASE (Annual Sunlight Exposure)

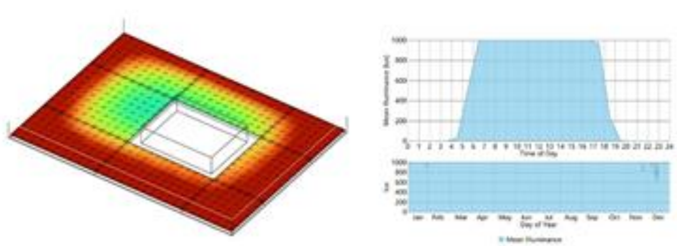


Without Shading
ASE = 40.6%

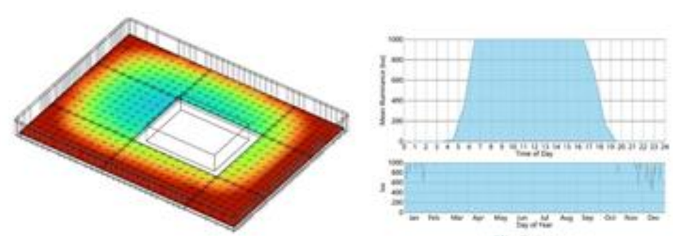


With Shading
ASE = 28.6%

b) Illuminance (Average lux)



Without Shading
avg lux = 4128



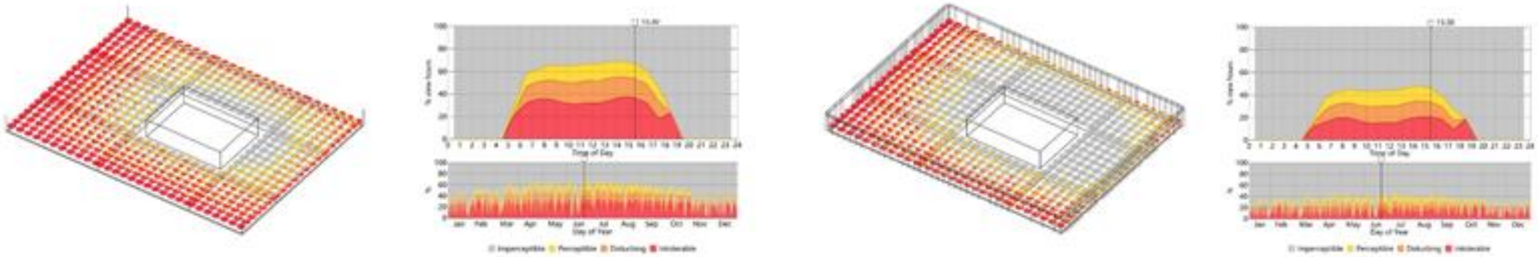
With Shading
avg lux = 2794

Daylight Simulation in Climate Studio

Appendix 4

Glare Simulation

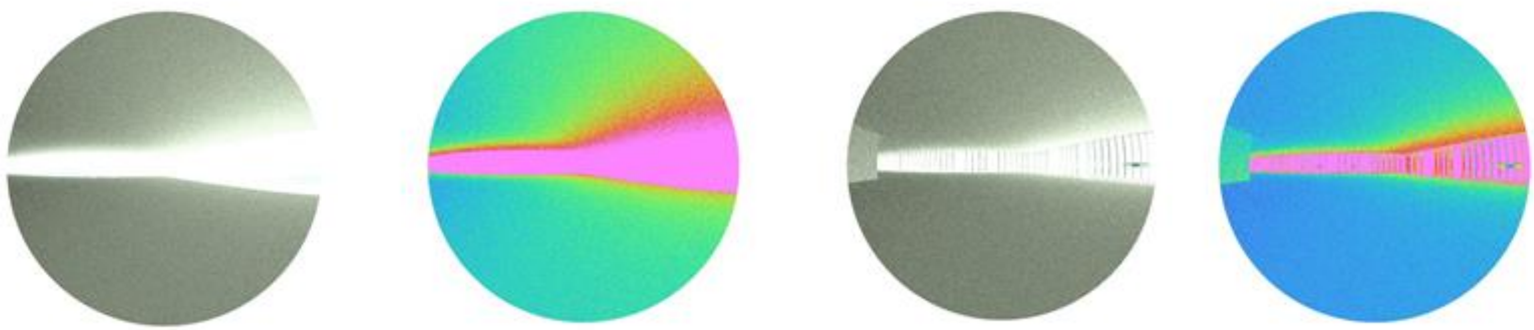
a) sDG (Solar Disturbing Glare), 3:30 pm, June 21



Without Shading
sDG = 79.1%

With Shading
sDG = 62.0%

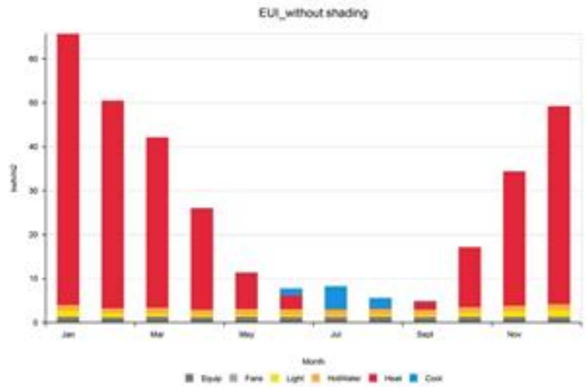
b) Radiance Rendering, 3:30 pm, June 21

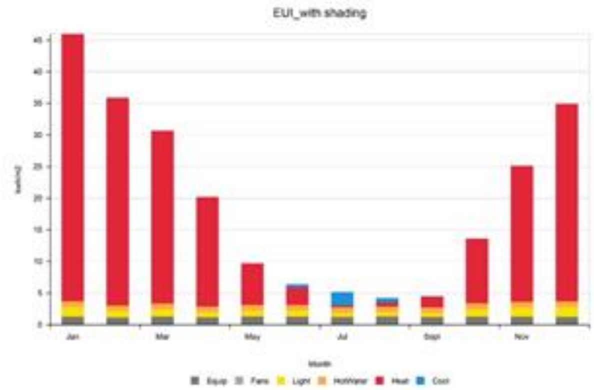


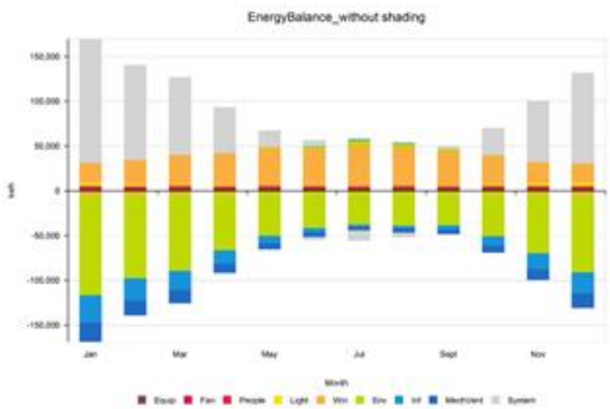
Without Shading
Intolerable Glare, 0.48

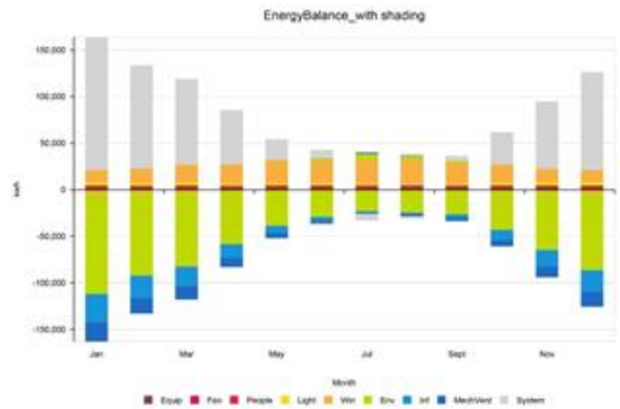
With Shading
Perceptible Glare, 0.36

Glare Simulation in Climate Studio





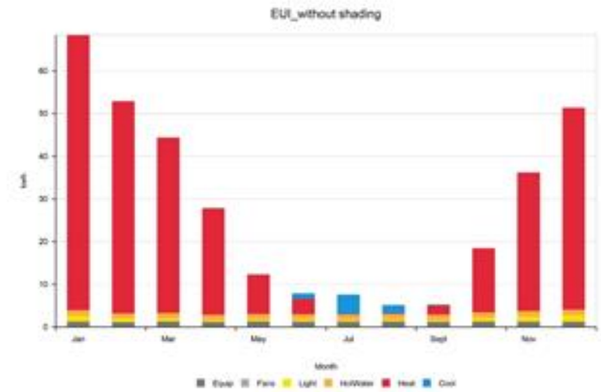


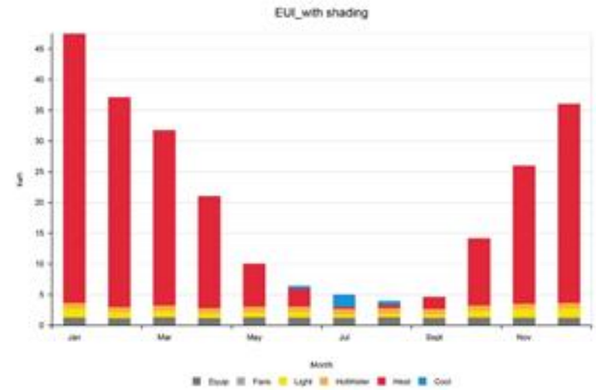


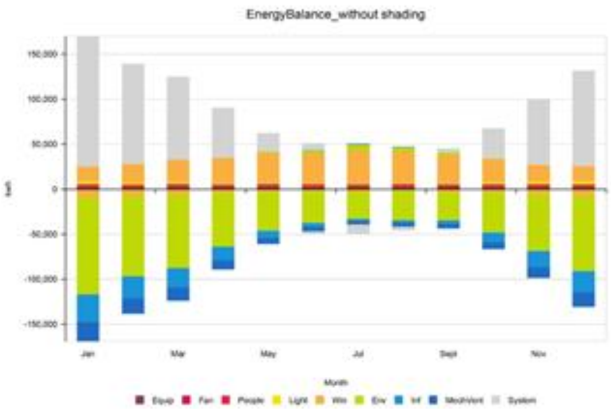
Energy Calculation	EUI (kwh/m2/y)	AIA EUI Baseline	Energy Cost ($/m2/y)	CO2 Emission (kg/m2/y)
Without Shading	323.4	328.1	15.2	87.9
With Shading	236.6	328.1	11.5	66.5

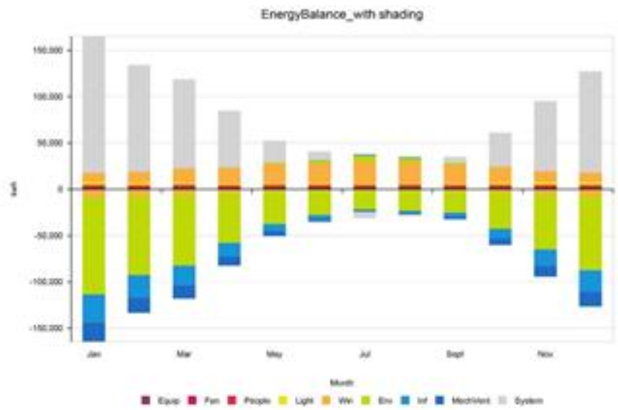
Shoebox Model Energy Calculation

Appendix 6 - *Double Glazing Energy Model*







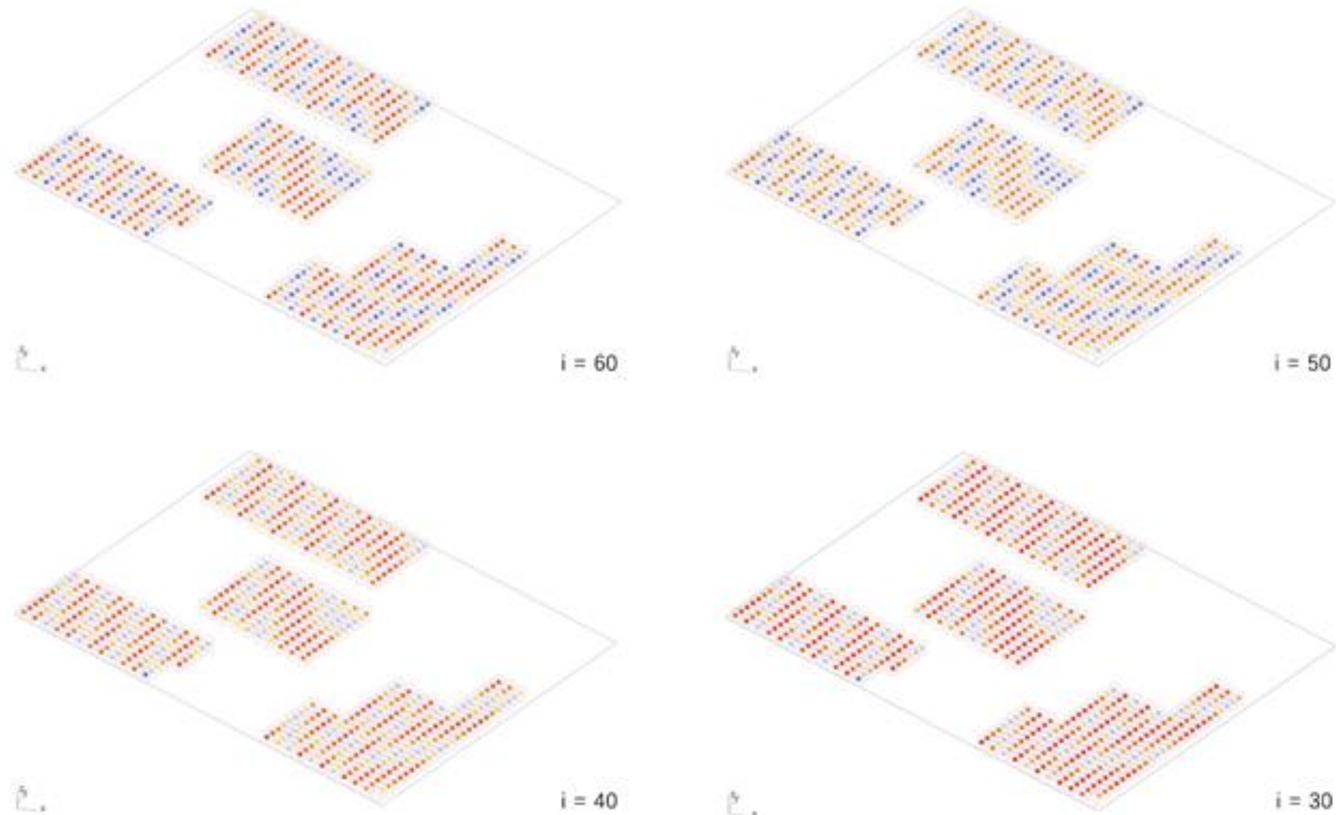


Energy Calculation	EUI (kwh/m2/y)	AIA EUI Baseline	Energy Cost ($/m2/y)	CO2 Emission (kg/m2/y)
Without Shading	337.9	328.1	15.7	90.4
With Shading	243.8	328.1	11.7	67.7

Shoebox Model Energy Calculation (Double Low-E)

Appendix 7

Inclination Variation of PV Panel



PV Calculation	Size	Amount	Power	Efficiency	Effective Area	PV Energy (kwh/y)
60 deg	1 x 1.65 m	600	265 W	20%	80%	75281
50 deg						75224
40 deg						75306
30 deg						75364

PV Optimization and Annual Energy Calculation