THE PENNSYLVANIA STATE UNIVERSITY
SCHREYER HONORS COLLEGE

DEPARTMENT OF ARCHITECTURAL ENGINEERING

ENERGY EFFICIENT LIGHTING AND ELECTRICAL SYSTEMS DESIGN FOR A HIGHRISE BUILDING WITH AN EXPLORATION OF THE URBAN IMPACT ON DAYLIGHTING

LARA NOELLE KAISERIAN
SPRING 2014

A thesis
submitted in partial fulfillment
of the requirements
for a baccalaureate degree
in Architectural Engineering
with honors in Architectural Engineering

Reviewed and approved* by the following:

Richard Mistrick
Associate Professor of Architectural Engineering
Thesis Supervisor
Honors Adviser

Kevin Houser
Professor of Architectural Engineering
Thesis Reader

* Signatures on file in the Schreyer Honors College.

ABSTRACT

This report details the lighting and electrical design for a net-zero office highrise in San Francisco, CA. This is just one part of a team design that included the mechanical, structural, electrical, and lighting systems, as well as a construction engineering plan. The group worked together to create a cohesive design that prioritized energy efficiency, environmental considerations, and occupant comfort. Also, as San Francisco is in a seismic region, occupant safety in an earthquake situation was of paramount importance.

The project focuses on the lobby and a typical office floor, as well as whole-building systems design. The lighting and electrical design strove to increase efficiency and decrease total energy consumption, and this was achieved through the use of a number of different strategies. For lighting, these include daylighting, lighting controls, and task lighting. The electrical system uses a combination AC/DC distribution system, dual emergency electrical risers, natural gas-powered fuel cells, and a server room supporting virtual computing.

To offset the building's energy use, energy is generated via onsite and offsite solar arrays, as well as an onsite human waste-to-power converter. Through the combination of energy efficient design and energy generation techniques, the building achieves a net-zero annual energy consumption.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGEMENTS

I would like to thank the following individuals for their support throughout the year, as this thesis would not have been possible without them.

The members of my thesis team, **AEVITAS**, for their hard work and cooperation in overcoming the challenges of designing in an interdisciplinary group, as well as for their much appreciated company on a number of late nights:

Robert Livorio
Drew Canfield
Kieran Carlisle
Abigail Kreider
Jonathan Sharp
Kristin Sliwinski
Alexander van Eeden

The Penn State faculty members who offered guidance throughout the design process:

Dr. Richard Mistrick
Professor Moses Ling
Professor Kevin Parfitt
Dr. Ryan Solnosky
Dr. Charles Cox
Dr. Kevin Houser

The industry members who contributed their expertise and technical support:

Angela Matchica – EwingCole
Mary Alcaraz – AKF Group
Kathy Jooss – Pratt School of Engineering, Duke University
Scott Wheaton – HGA Architects and Engineers
Ryan Kannass – HGA Architects and Engineers

The companies that went above and beyond to provide product details and answer questions:

ClearEdge Power
Nextek Power Systems
Sun Light & Power

And finally, my family and friends who contributed more to my success than I could ever describe. They were a constant source of encouragement and support, and I cannot possibly thank them enough.

Very special thank yous go to my mother and father, Carol and Ed Kaiserian, for fielding countless phone calls throughout the year and for always knowing exactly what to say to get me back on track.

Chapter 1

Introduction

This project was completed as part of a joint effort between members of the lighting/electrical, construction, mechanical, and structural Architectural Engineering disciplines. The team, **AEVITAS**, was responsible for the design of all building systems, as well as the construction engineering for 350 Mission, a 30-story office highrise located in San Francisco, CA. The following report details the lighting and electrical systems design of the building, completed in collaboration with Robert Livorio.

Executive Summary

AEVITAS is an integrated design team, composed of representatives from the construction, structural, electrical, and mechanical disciplines. With the end goal of designing a net-zero high-rise building in the heart of San Francisco, **AEVITAS** developed the overarching attitude of [ZEROimpact], encompassing four focus areas of [ZEROinterruption], [ZEROenergy], [ZEROwaste], and [ZEROemissions]. Through a unified effort, **AEVITAS** achieved the net-zero design goals set forth at the beginning of the process. The design of 350 Mission is summarized in Table 1, and the lighting and electrical systems design is detailed in depth in this report.

Table 1. System Overview Breakdown

ARCHITECTURAL	Floor Plan Changes, Vestibule Addition, Integrated Public Art Piece
FAÇADE	Natural Ventilation Louvers, Seismic Connections, Electrochromic Glazing
MECHANICAL	Radiant Floor System, Natural Ventilation Louvers, Dedicated Outdoor Air System
LIGHTING	LED Lighting, DALI Controls Responsive to Daylighting and Occupancy, Task Lighting
ENERGY GENERATION	Onsite Solar Array, Offsite Solar Array, Human Waste to Power Converter
ELECTRICAL	AC and DC Distribution, Natural Gas-Powered Fuel Cells, Dual Electrical Risers

STRUCTURAL	Steel Superstructure, Braced Frame Core, Composite Beams and Deck, Outrigger System, Concrete Substructure
CONSTRUCTION	Production Planning, Matrix Scheduling, Waste Management, BIM Execution Planning, Site Planning

The lighting and electrical design strove to increase efficiency and decrease total energy consumption, and this was achieved through the use of a number of different strategies. The design focused on the lobby and a typical office floor, as well as whole-building systems design.

The desire to optimize daylighting and thermal properties of the glazing led to a façade design that benefitted both the mechanical systems and lighting design. Electrochromic glass is used on the façade of all office floors in place of shades to preserve views to the exterior and offer maximum flexibility to the occupants. Daylight photosensor dimming results in savings for the entire building, exceeding 100,000 kWh annually.

Efficient lighting design decisions, such as task lighting, resulted in a building lighting power density (LPD) of 0.434 W/sf, well below the 0.728 W/sf allowed by California Title 24 and CALGreen space-by-space method.

The building's electrical system features natural gas-powered fuel cells and both AC and DC distribution, designed to minimize conversion losses. The DC system feeds a server room that supports virtual computing on the office floors, saving almost 600,000 kWh of computer loads annually.

Taking the building's location in a seismic region into account, both the lighting and electrical design make special accommodations to ensure the safety of its occupants. The lighting follows guidelines for seismic design laid out by the California Department of General Services. The electrical system features dual emergency risers to give the building an added level of redundancy in a seismic event.

Energy is generated via onsite and offsite solar arrays, as well as an onsite human waste-to-power converter. These systems combined generate 5,544,000 kWh of energy annually, which is more than enough to cover the building's total expected annual consumption of 5,264,570 kWh.

350 Mission adheres to the traditional definition of net-zero by returning as much energy to the grid as it consumes in a year, and it also meets the broader goals defined by **AEVITAS** by minimizing emissions and waste and by creating a design that responds to the earthquake-prone environment to ensure continuity of operation even after a seismic event. Lifecycle cost analyses determined a payback period of 10.8 years for the mechanical systems and energy generation equipment.

The final building design successfully responds to the project requirements and achieves the project goals through the use of innovative and efficient design techniques.

Team Direction: Goals and Attitude

350 Mission is above all else, a collaboration. Through a joint effort, the concept of 'net-zero building' has grown to fully encompass the idea of green living and **AEVITAS** is on the forefront of this movement. In order to reach the infinite goals that are stemming from such sustainable building ideas, **AEVITAS** set out to define the way the team would approach 350 Mission. Provided with an established architectural design but a different set of owner goals, the team has been dedicated to making design decisions that reflect the new goals of the owner, as well as the community and future tenants. **AEVITAS** is a talented team comprised of eight individuals with varying educations and diverse experience including backgrounds in structural design, MEP systems design, and construction engineering and management.

When coming together as a unified design force, the team as a whole was adamant early on about developing something more than a set of goals, something that would enable our interconnected thought process throughout design – our over-arching attitude. This attitude would encompass all team-driven specifications, with the owner profile and competition goals providing direction. From these motives, [ZEROimpact] was born. [ZEROimpact] is the way the project team defines the sustainable practices that are driving design decisions and owner goal integration. Within this all-encompassing team attitude and a strong mission statement, there are four focus areas that the goals are derived from, as shown below in Figure 1.

Taking an **integrated approach**, **AEVITAS** strives to **minimize environmental influences** by **engaging our community** with **sustainable** practices in energy conservation and emission reduction.

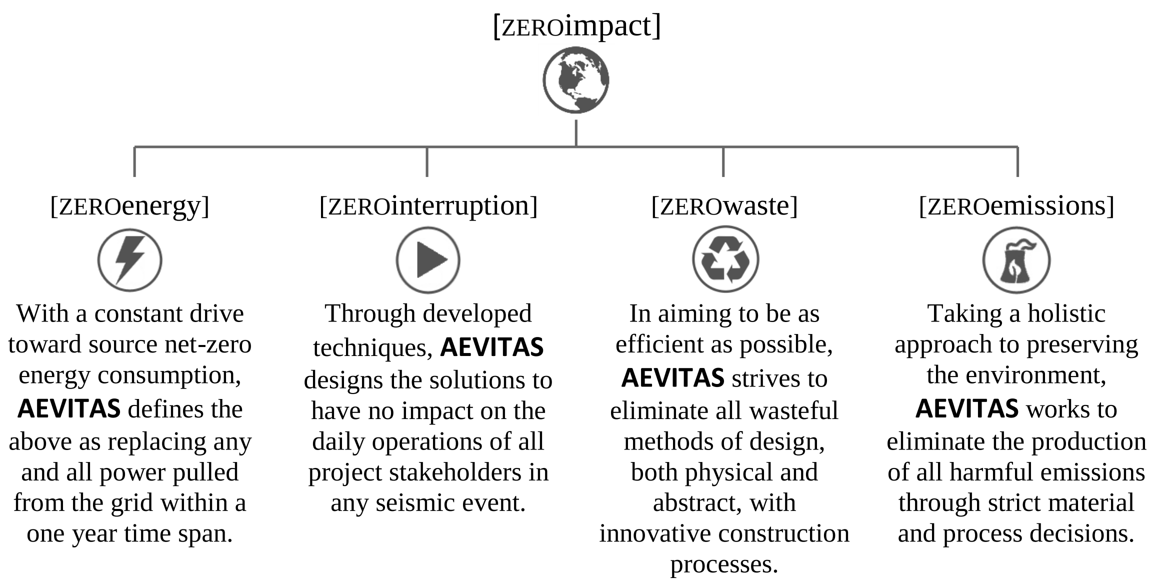


Figure 1. AEVITAS Attitude with Goal Breakout

Design Process

All decisions were made using an integrated design process. Each option was weighed based on its impact on the project goals, potential impact on the other disciplines, and its pros and cons related to the lighting and electrical design. Compromises were made in order to make the decisions that were best for the building design as a whole, with no discipline consistently taking priority. Many lighting and electrical decisions were made by working to identify the most efficient option, as the [ZEROenergy] focus area was a main concern; however, this also had to be balanced with the task of creating an appealing and functional work environment.

Code Analysis

350 Mission was designed to the following codes and standards found within the California Building Standards Code (California Title 24):

- 2010 California Electrical Code and San Francisco Amendments
- 2010 California Energy Code and San Francisco Amendments
- 2010 California Fire Code and San Francisco Amendments
- California Green Building Standards Code (CALGreen)

California Title 24/California Energy Code is used in place of AHSRAE 90.1 for energy standards. The California Green Building Standards Code (CALGreen) requires an additional 15% energy savings beyond the mandatory California Title 24 savings for green buildings.

Chapter 2

Energy

As with any 'net-zero' building, achieving net-zero energy consumption is one of the most important and challenging aspects. This is done in part by making educated design decisions to select the most efficient equipment and systems and reduce the overall energy consumption of the building, but it also requires the generation of energy to offset what the building must use in order to function properly.

Extensive research was conducted to determine the most viable energy generation tactics, both onsite and offsite. The selected technologies will be presented here. Information about the other systems that were investigated, as well as reasons for their dismissal, can be found in Appendix A.

Onsite Energy

Due to the location of the site, the relationship with the surrounding buildings, and the limited space, onsite energy generation alone was deemed inadequate to fulfill the needs of the building in a cost-effective manner. Wind, biomass, and geothermal generation, among other systems, were rejected due to findings related to the site. Two systems are being employed onsite, in combination with the offsite source outlined in the next section.

Onsite Solar Energy

Even though the building is not in an ideal location for onsite solar generation, analysis of the roof area showed that there is potential for some collection. Figures 2 and 3 show the potential kWh/m^2 values throughout the year, assuming 100% efficient panels and using typical meteorological year (TMY) weather data. An efficiency multiplier of 0.15 and derate factor of 0.77 were applied to these initial values to determine that a roof solar array can produce 194,145 kWh of energy during an average year. Based on the available roof area, a 200kW array was selected.

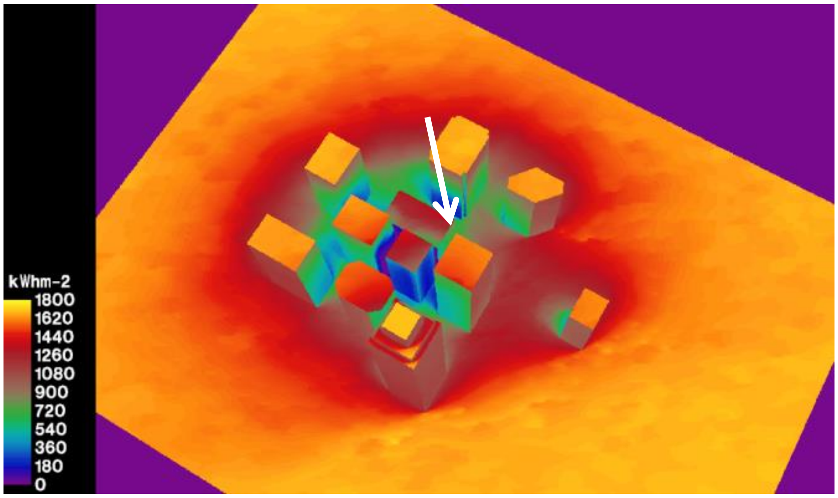


Figure 2. Solar Radiation Map with Context

Through coordination with the mechanical and structural engineers, the mechanical cooling tower was placed below the roof surface in order to minimize possible shading of the panels due to the equipment. There is a hole in the roof above and space around the tower to allow for air flow. The addition of photovoltaic panels required a 4' parapet wall to be added around the cooling tower hole and building perimeter for safety. The calculations also take into account the amount of space required for maintenance walkways, as the potential kWh value was adjusted to exclude a percentage of the total roof area. Payback will occur in 12.4 years with 30% incentive coverage or 8.8 years with 50% incentive coverage. More information on the calculations and incentives can be found in Appendix B.

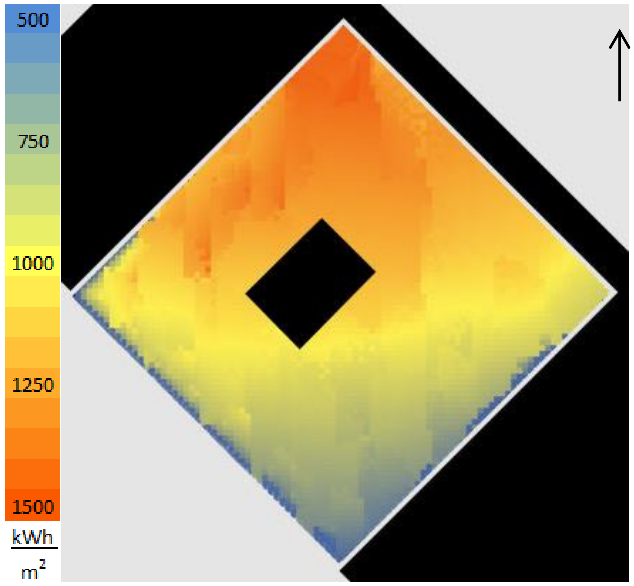


Figure 3. Roof Solar Radiation Map

Human Waste-to-Power

Normally, human waste is sent from buildings to a sewage treatment plant, where it can be refined to create fertilizer and water that is sometimes released into rivers and streams. Methane is released into the air, along with other undesirable gases. This is harmful to the environment, as well as being a waste of a potential energy source. 350 Mission will be equipped with a unit that utilizes supercritical water oxidation and gasification (SCWO/SCWG) to convert this waste into usable energy.

As summarized in Figure 4, waste moves from a holding tank into the cargo container-sized unit. Its pressure and temperature are increased via high pressure pump and economizer. It is then sent to a reactor where it is combined with oxygen to produce a sterile combination of water, carbon dioxide, and inert salts.

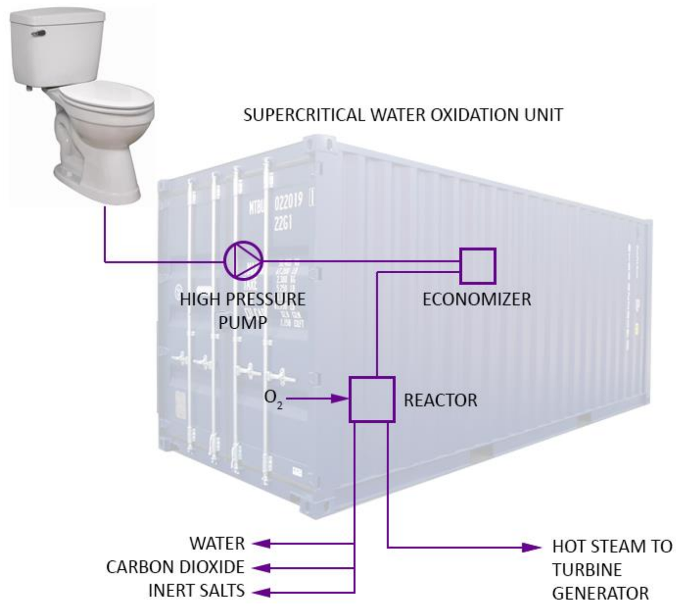


Figure 4. Supercritical Water Oxidation Schematic

The resulting steam is used to both sustain the supercritical combustion and operate a steam generator. This process and system are well-suited for use in a building because all of the waste-processing can take place onsite and requires no separation of wastes. SCWO can also process any other materials that find their way into the sewage.

It is estimated that this unit will generate 290,625 kWh per year and will pay back in 26 years on its own; however this period is shorter when combined with the rest of the building systems, and the benefit to the environment cannot be quantified. Calculations can be found in Appendix B.

Offsite Energy

After researching a number of offsite generation options, solar power was determined to be the most viable, based on system cost, site procurement, and permit requirements. It was selected over geothermal generation, tidal energy, and wind, as discussed in Appendix A. Rather than feeding 350 Mission directly, this solar installation will contribute to Pacific Gas and Electric’s (PG&E) utility grid and offset 350 Mission’s usage.

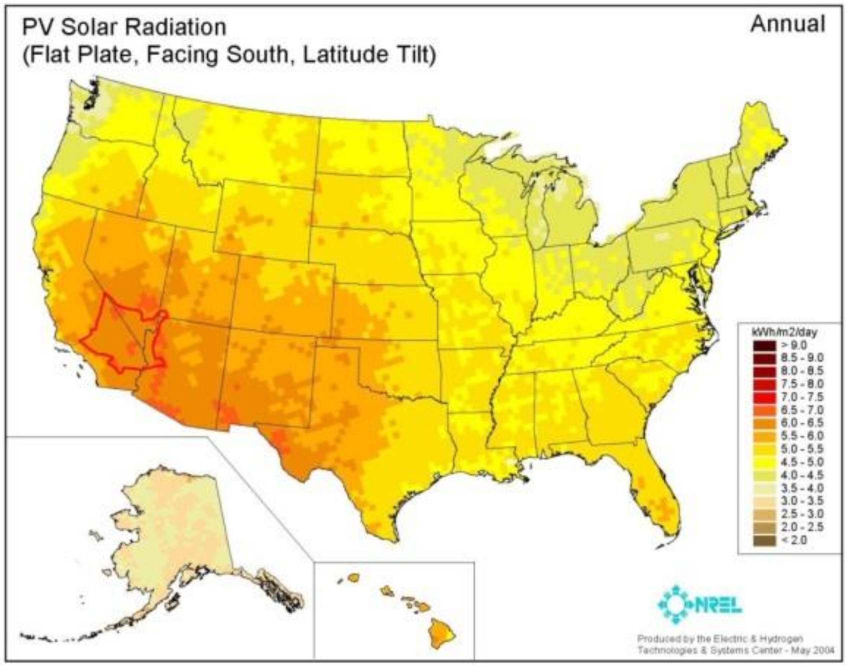


Figure 5. Annual Solar Radiation Map of the United States

The installation will be located in a secured compound in the Mojave Desert. This location is optimal for sunlight exposure and cost. Solar radiation maps of the United States, such as the one in Figure 5, show that it is one of the best locations in the country for harnessing solar power (outlined in red). In order to offset the remainder of the building's energy use, a 3.5 acre tract of land is required. With the addition of some space for maintenance paths and a security enclosure, as well as allowing the possibility of growth, a 10 acre tract of land was chosen. The cost of the selected plot, shown in Appendix B, is listed at $13,000. A number of other lots of this size can be found at prices, on average, ranging between $10,000 and $20,000.

In order to offset the remainder of the building's energy usage that is not accounted for by onsite generation techniques, a 3000 kW PV array is required. An array of this size will cost about $5,115,000.[1] While the price is steep, generous incentives are available for new installations. Local, state, and federal incentives may cover between 30-50% of the installation.

The fixed-tilt system is expected to generate 5,059,186 kWh of energy annually during an average weather year. This number takes into account site location, array tilt, and derating factors that decrease the efficiency of the system. Fortunately, the size of the array will allow for a large inverter and transformer, which are much more efficient than smaller systems, and reduce the losses of converting direct current (DC) to alternating current (AC) for the grid. While fixed-tilt arrays generate about 20% less energy than axis-tracking systems, the added tracking feature comes with an increased price, maintenance, and potential for malfunction.

Energy can be sold to the utility company for $0.10509/kWh assuming a 20-year contract starting in 2016 (the expected building completion year), and the payback period for the entire 3.5 acre array is 6.7 years with 30% covered by incentives, or 4.8 years with 50% covered by incentives. More information on the site, cost, and calculations can be found in Appendix B.

Chapter 3

Daylighting

Lobby Spatial Daylight Autonomy

The lobby is a four-story, 100% glass, open-air atrium located at the base of the building. Due to the relatively low light levels required in most of the space, daylighting alone can fill the circulation area requirements during the majority of daytime hours.

The lobby curtain wall uses double pane, low-e glass with a 55% visible light transmittance and 0.34 solar heat gain coefficient.

Integrating daylighting and electric light through the use of the building control system saves approximately 8,661 kWh annually.

Daylighting calculations were conducted using a spatial daylight autonomy (sDA) analysis. Spatial daylight autonomy shows the percent of occupied hours that the illuminance due to daylight at a certain point in a space exceeds the target illuminance. This can also be summarized for a space in a single number as the percent of points that have an illuminance exceeding the target for at least 50% of occupied hours. sDA numbers were used to estimate the energy savings due to daylighting in the 1st floor and 2nd floor lobby circulation spaces. The results are shown in Figures 6 and 7 along with a useful daylight illuminance (UDI) analysis.

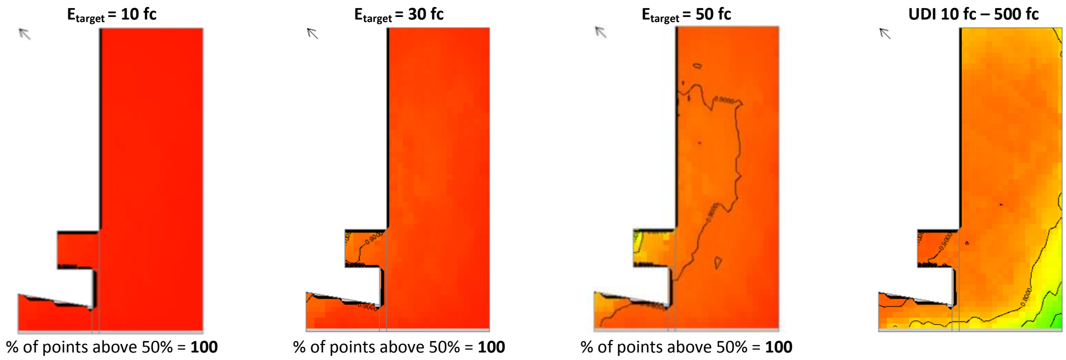


Figure 6. First Floor Lobby Circulation Spatial Daylight Autonomy

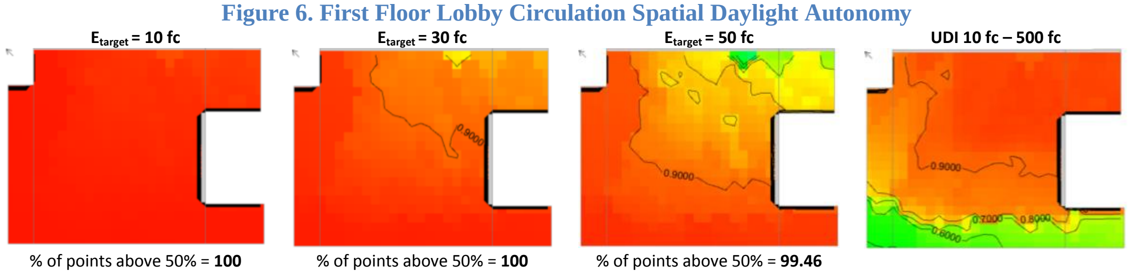


Figure 7. Second Floor Lobby Circulation Spatial Daylight Autonomy

The minimum was placed at 10 fc as that is the required illuminance in many of the transition spaces and the maximum at 500 fc as that is the upper limit set by the U.S. Green Building Council (USGBC) in the Leadership in Energy and Environmental Design (LEED) 2009 guidelines.

The spreadsheet showing the energy savings calculations is shown in Table 2 in the "Spatial Daylight Autonomy Calculations" section.

Office Façade Design

The façade design of 350 Mission required an integrated effort in order to engineer a system that would mutually benefit all disciplines. The design focused on making choices that would contribute to the [ZEROimpact] goal while also maintaining the woven aesthetic of the façade and the vision of the architect.

In collaboration with the mechanical engineers, the decision was made to alter the façade to optimize daylighting and mechanical savings. A daylighting study was conducted in order to determine the glass percentage that would allow a sufficient amount of daylighting without placing an unnecessary thermal burden on the mechanical systems. Figure 8 shows a view of the resulting façade design.

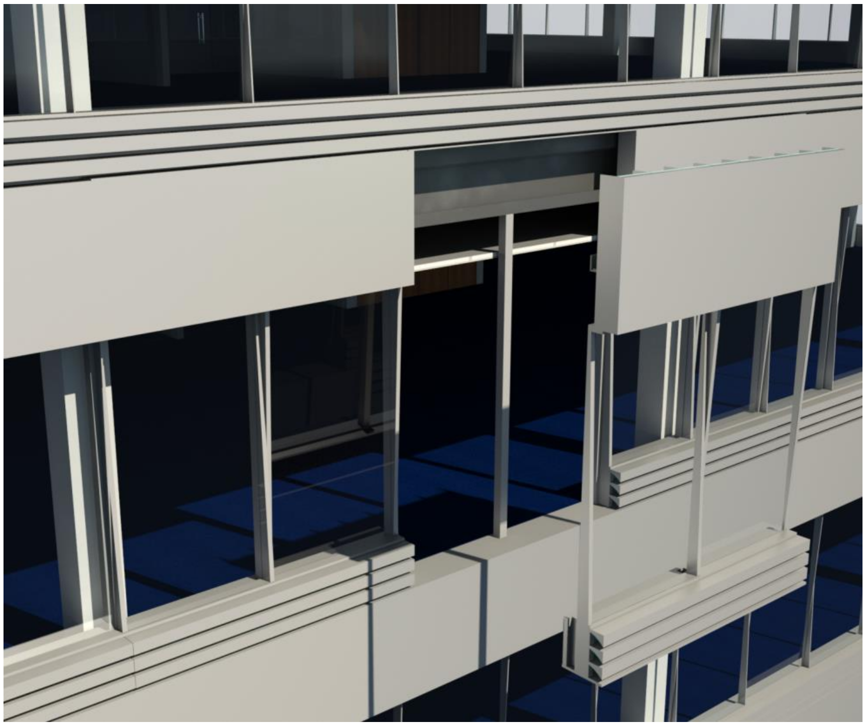


Figure 8. Façade Design with Panel Removed

The design includes an 8'-6" window with alternating tilted glass panes. Below this window is a natural ventilation box that contains operable louvers used to control the amount of outdoor air entering the space, based on environmental conditions and the demands of the mechanical system. A detailed façade section can be found in Appendix C.

Shading

The solar radiation maps shown in Figure 9 were used to determine that an automated shading system is required to maintain occupant comfort throughout the office floors.

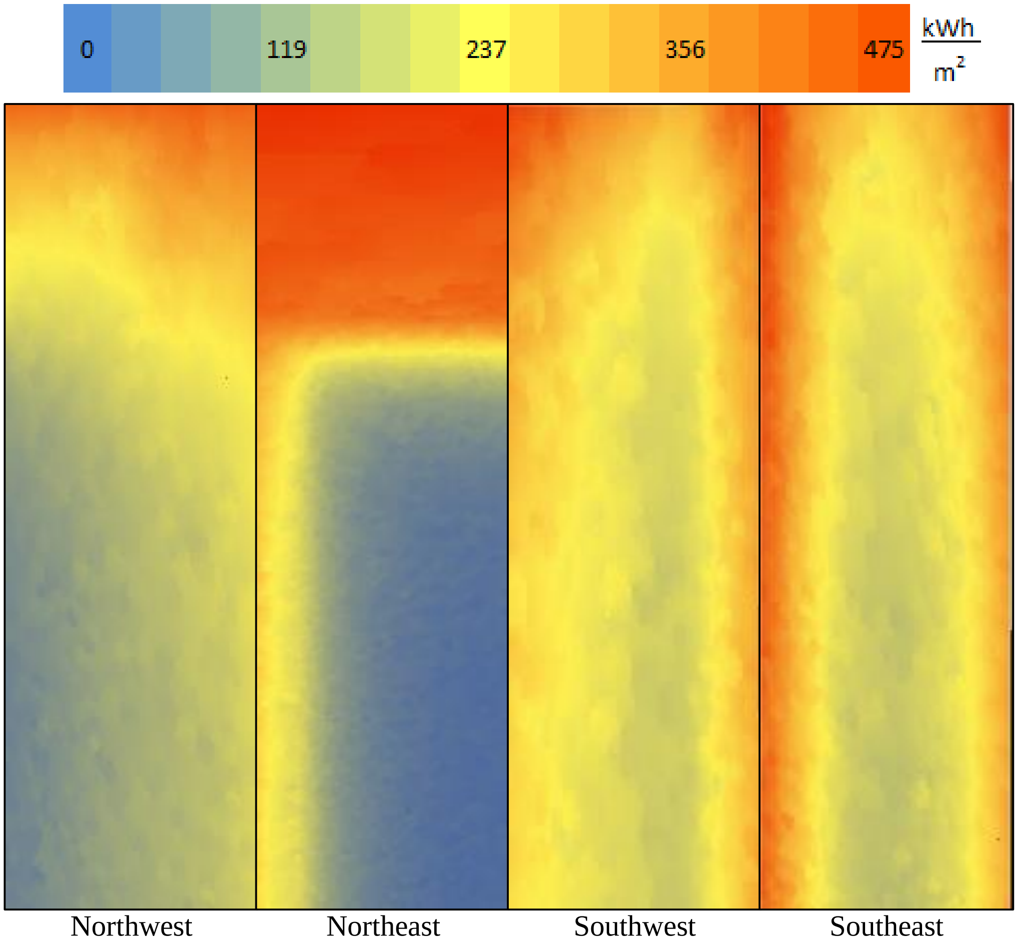


Figure 9. Façade Solar Radiation Maps

As anticipated, the entire southwestern and southeastern facades receive a significant amount of solar radiation throughout the year. However, these radiation maps show that the northwestern and northeastern facades also receive considerable solar radiation and cannot be ignored when planning the shading system.

Rather than using traditional glass and fabric shades, 350 Mission will be equipped with electrochromic glass. This special glass receives an electrical signal that tells it to tint or untint based on commands sent by the control system. As the glass tints, it also adjusts its solar heat gain properties, with the solar heat gain coefficient ranging between 0.42 when clear and 0.09 when fully tinted. The visible light transmission can range from 60% in its clear state to 2% when fully tinted. Depending on the size of the glass panels, desired tint level, and temperature, the tinting process takes between three and ten minutes.

Aside from controlling daylight, it can be used in conference rooms and other spaces where A/V presentations may take place. It can be integrated into the building control system and programmed to react to different environmental conditions or lighting scenes in a space.

Figure 10. Renderings of Untinted and Tinted Electrochromic Glass

Traditional shades, when lowered, obscure views to the outside far more than the tinted glass, and preserving these views was a priority for maximizing occupant comfort. When viewing the building from the outside, shades can negatively impact the building aesthetic by drastically taking away from the uniformity of the façade. Electrochromic glass will also lead to some variation on the façade, depending on the level of shading; however it will not be as noticeable from street level as traditional shades. Furthermore, it creates a façade that reacts to the building's surroundings to maximize energy savings. The mechanical implications of using electrochromic glazing are expected to be minimal, but the mechanical and electrical equipment have been sized to accommodate fluctuations in the cooling and heating load.

Electrochromic glass is used on the office floors in every façade section that borders an occupied space. Cost analysis revealed that it is equivalent cost-wise, if not less expensive, than using traditional glass and shades. Details of the cost analysis can be found in Appendix C. Approximately 73,000 ft^2 of the building's glass will be electrochromic.

Application of the glass to all occupied spaces ensures that regardless of how the functions of the spaces and the floor layouts may change, all interior spaces will remain functional and comfortable for the occupants. It also eliminates the risk of surrounding buildings causing glare inside the building, as glass panes can be tinted as needed to maximize comfort.

Office Spatial Daylight Autonomy

In order to assess the office floors, sDA calculations were taken at the 5^{th}, 18^{th}, and 30^{th} floors, and data was interpolated for the other office floors based on these results. For energy savings purposes, calculations assumed no shading system, as the glass can be adjusted to the exact level of transparency required to maximize the positive effects of the available daylight.

Figure 11 summarizes the spatial daylight autonomy calculations for these key floors.

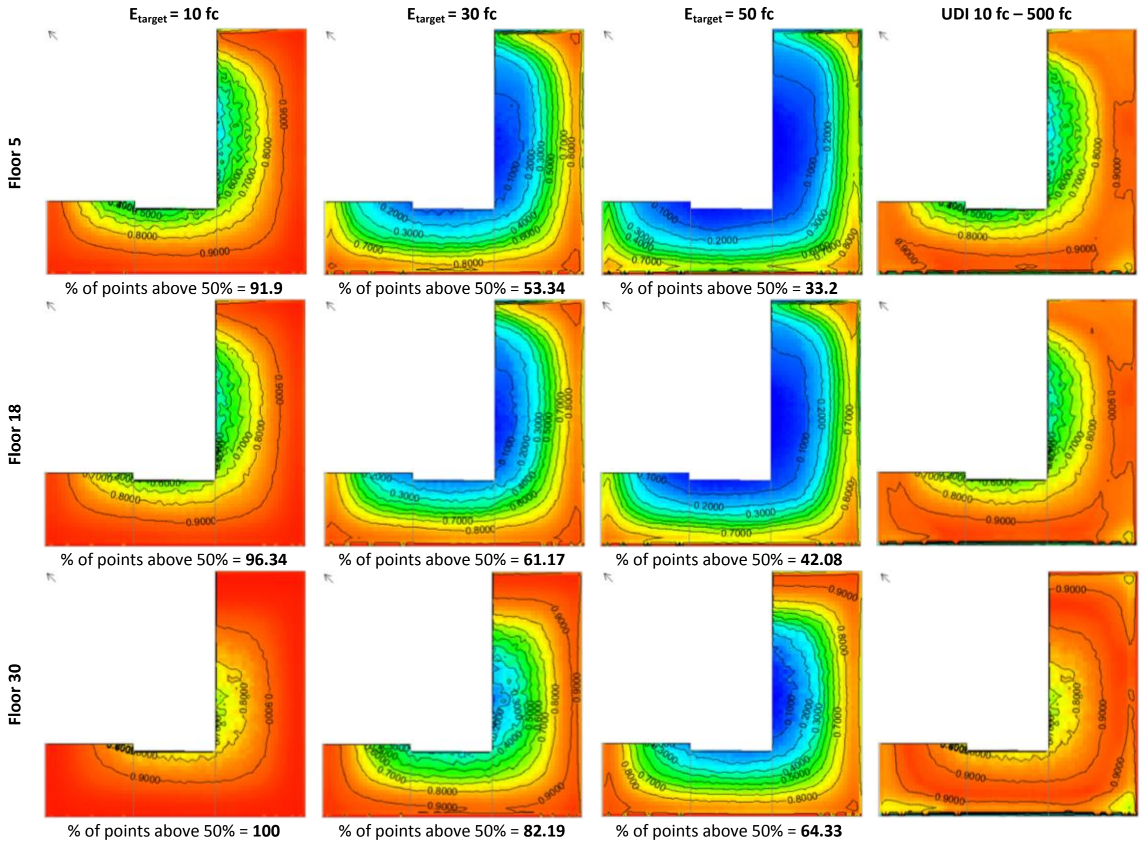


Figure 11. Open Office Daylight Autonomy

Spatial Daylight Autonomy Calculations

Using the information gathered from the sDA studies in the lobby and office floors, as well as the electric lighting layouts described in Chapter 5, calculations were conducted to estimate the potential annual daylight savings.

Lobby studies included the first and second floor circulation spaces, and office studies included open office and break/dining areas on various floors. Values were interpolated for intermediate floors.

Table 2 shows a summary of the spatial daylight autonomy values assumed for each space.

Table 2. Spatial Daylight Autonomy Summary

Daylight Autonomy Summary			
Space	Floor	Threshold	DA Value
Lobby	1st Floor	50 lux	100.0
		100 lux	100.0
		200 lux	100.0
		300 lux	100.0
	2nd Floor	50 lux	100.0
		100 lux	100.0
		200 lux	100.0
		300 lux	100.0
Open Office	Low	50 lux	100.0
		100 lux	91.9
		200 lux	68.1
		300 lux	53.3
	Middle	50 lux	100.0
		100 lux	96.3
		200 lux	75.5
		300 lux	61.2
	High	50 lux	100.0
		100 lux	100.0
		200 lux	95.2
		300 lux	82.2
Dining/ Break	Low	50 lux	100.0
		100 lux	97.4
	Middle	50 lux	100.0
		100 lux	100.0
	High	50 lux	100.0
		100 lux	100.0

Daylight Autonomy Definition

Percentage of the floor area that exceeds E_{target} for at least 50% of the time

Daylight Autonomy Energy Savings Equation

$$kwh\ saved = (\%\ floor\ area\ met\ 50\%\ of\ time)x(LPD\ of\ space)x(total\ hours\ of\ lighting\ use)x\frac{0.5}{1000}$$

Energy Savings Calculation General Information		
Lobby 1st Floor Area	4700	$ft.^2$
Lobby 2nd Floor Area	2167	$ft.^2$
Open Office Area	8350	$ft.^2$/floor
Dining/Break Area	1347	$ft.^2$/floor
Lobby Design LPD	0.290	$W/ft.^2$
Open Office Design LPD	0.387	$W/ft.^2$
Dining/Break Design LPD	0.145	$W/ft.^2$
Lobby Annual Lighting	4015	hrs
Open Office Annual Lighting	2800	hrs
Dining Break Annual Lighting	2800	hrs

Daylight Hour Assumptions
7:00 am - 6:00 pm, 365 days
7:00 am - 6:00 pm 250 days, 5 hours on another 10 days

Annual Lighting Hours of Use Assumptions
Assume that all lighting is at full output (no dimming)
11 hours per day (daylight hours), 365 days per year
11 hours of use per workday, 250 workdays, 5 hours of use on 10 additional days
11 hours of use per workday, 250 workdays, 5 hours of use on 10 additional days

Daylight Autonomy Approximated by Floor					Daylight Autonomy Difference				Daylight Autonomy Approximated by Floor			Daylight Autonomy Difference	
Open Office					Open Office				Dining/Break			Dining/Break	
Floor	50 lux	100 lux	200 lux	300 lux	Floor	50 - 100	100 - 200	200 - 300	Floor	50 lux	100 lux	Floor	50 - 100
5	100.0	91.9	68.1	53.3	5	8.1	23.8	14.7	5	100.0	97.4	5	2.6
6	100.0	92.3	68.7	54.0	6	7.7	23.6	14.7	6	100.0	97.7	6	2.3
7	100.0	92.6	69.3	54.6	7	7.4	23.3	14.7	7	100.0	97.9	7	2.1
8	100.0	93.0	69.9	55.3	8	7.0	23.1	14.6	8	100.0	98.1	8	1.9
9	100.0	93.4	70.6	56.0	9	6.6	22.8	14.6	9	100.0	98.3	9	1.7
10	100.0	93.8	71.2	56.6	10	6.2	22.6	14.6	10	100.0	98.5	10	1.5
11	100.0	94.1	71.8	57.3	11	5.9	22.3	14.5	11	100.0	98.7	11	1.3
12	100.0	94.5	72.4	57.9	12	5.5	22.1	14.5	12	100.0	98.9	12	1.1
14	100.0	94.9	73.0	58.6	14	5.1	21.8	14.5	14	100.0	99.1	14	0.9
15	100.0	95.2	73.6	59.2	15	4.8	21.6	14.4	15	100.0	99.4	15	0.6
16	100.0	95.6	74.3	59.9	16	4.4	21.3	14.4	16	100.0	99.6	16	0.4
17	100.0	96.0	74.9	60.5	17	4.0	21.1	14.4	17	100.0	99.8	17	0.2
18	100.0	96.3	75.5	61.2	18	3.7	20.8	14.3	18	100.0	100.0	18	0.0
19	100.0	96.6	77.1	62.9	19	3.4	19.5	14.2	19	100.0	100.0	19	0.0
20	100.0	97.0	78.8	64.7	20	3.0	18.2	14.1	20	100.0	100.0	20	0.0
21	100.0	97.3	80.4	66.4	21	2.7	16.8	14.0	21	100.0	100.0	21	0.0
22	100.0	97.6	82.1	68.2	22	2.4	15.5	13.9	22	100.0	100.0	22	0.0
23	100.0	97.9	83.7	69.9	23	2.1	14.1	13.8	23	100.0	100.0	23	0.0
24	100.0	98.2	85.4	71.7	24	1.8	12.8	13.7	24	100.0	100.0	24	0.0
25	100.0	98.5	87.0	73.4	25	1.5	11.5	13.6	25	100.0	100.0	25	0.0
26	100.0	98.8	88.7	75.2	26	1.2	10.1	13.5	26	100.0	100.0	26	0.0
27	100.0	99.1	90.3	76.9	27	0.9	8.8	13.4	27	100.0	100.0	27	0.0
28	100.0	99.4	92.0	78.7	28	0.6	7.4	13.3	28	100.0	100.0	28	0.0
29	100.0	99.7	93.6	80.4	29	0.3	6.1	13.2	29	100.0	100.0	29	0.0
30	100.0	100.0	95.2	82.2	30	0.0	4.8	13.1	30	100.0	100.0	30	0.0

Table 3. Spatial Daylight Autonomy Energy Savings

Daylight Autonomy Energy Savings [kwh]			Daylight Autonomy Energy Savings [kwh]		Daylight Autonomy Savings Summary			
Floor	Open Office	Dining/Break	1st Floor	2nd Floor				
5	3278	270	5928	2733	Lobby 1st Floor	5928	kwh	annually
6	3300	270			Lobby 2nd Floor	2733	kwh	annually
7	3322	271			Open Office	90998	kwh	annually
8	3344	271			Dining/Break	6813	kwh	annually
9	3366	271			Total	106473	kwh	annually
10	3388	271						
11	3410	272						
12	3432	272						
14	3454	272						
15	3476	273						
16	3498	273						
17	3519	273						
18	3541	273						
19	3595	273						
20	3648	273						
21	3702	273						
22	3755	273						
23	3809	273						
24	3863	273						
25	3916	273						
26	3970	273						
27	4023	273						
28	4077	273						
29	4130	273						
30	4184	273						
Totals	90998	6813						

The potential energy savings shown in Table 3 combine the sDA values with the lighting power densities achieved through the electric lighting design.

The spatial daylight autonomy study concluded that the use of a daylighting control system in the lobby circulation, open office, and dining/break areas has the potential to save 106,473 kWh annually.

Chapter 4

Urban Daylighting Study

The initial daylighting analyses described in Chapter 3 yielded interesting results when comparing the interior illuminance values between different floors and façade orientations. The led to the desire to conduct a separate study to further explore the impact of an urban environment on the daylighting potential of a building. A new, simplified building model was constructed in an attempt to make the results applicable to a wider range of buildings; however, the results for two buildings will never be the same when taking into account all factors including surrounding buildings' locations and heights, façade orientation, and floor plan, among others. This chapter details the process used to conduct the study, as well as summarizes the findings.

Scope of Study

Results do not reflect the conditions inside the building as they would appear during actual occupancy, as shades were not included in the study. The purpose of this study is simply to make comparisons between the amount of daylight entering each space and draw conclusions based on the façade orientations and surrounding buildings. This is not necessarily all usable daylight, as shades would be applied in cases of direct sun and high illuminance levels.

A direct sun study was conducted to estimate the annual number of occupied hours when the shading system will likely be employed due to direct sun.

All factors, excluding floor height and façade orientation, were held constant to make the comparison as accurate as possible. While results do not necessarily reflect actual office conditions, as there is no furniture, the intent of the study was to make comparisons between the various trials. Since all trials make the same assumptions, they can be compared to one another, even though they cannot necessarily be compared to outside results.

A direct sun study was also conducted to help make assumptions about the number of hours each year when shade application would be absolutely necessary. This only provides an estimate of hours when shades will be down due to direct sun, not those when the illuminance levels in the space are too high; however these can be approximated using the daylight autonomy at 500 fc, the maximum set by LEED for usable daylight.

The Model

The building footprint is 130’-4” x 122’-10”, and the 40’-8” x 51’-6” core is centered in the floor plan. Six columns are evenly spaced along each façade. The floor is divided into separate areas for the four façade orientations, as shown by the green, yellow, red, and blue areas in Figure 12.

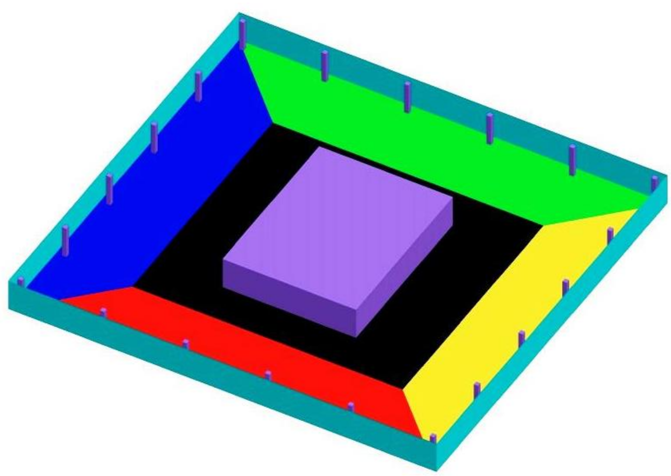


Figure 12. AutoCAD Office Floor Model

The analysis areas extend 24’ into the space, and 10’ tall floor-to-ceiling windows wrap around the entire floor.

The individual floor model was inserted into a city model that included 350 Mission in its entirety, as well as the surrounding buildings that were expected to have an impact on the amount of daylight in the space.

Three floors were evaluated – the 5th, 18th, and 30th. These are the bottom, middle, and top office floors and are 54’, 236’, and 418’ from street level, respectively.

The reflectance and transmittance values used for the office floor are summarized in Table 4.

Table 4. Office Floor Surface Reflectance/Transmittance

Surface	Reflectance/ Transmittance
Ceiling	0.80
Floor	0.20
Core/Columns	0.50
Windows	0.55

The glass transmittance value assumed the use of PPG Sungate 400 Passive Low-e glass, as seen in Table 5.

Table 5. PPG Sungate 400 Glass Performance

Glass Type	Transmittance			Reflectance		U-Value (Imperial)		European U-Value	Shading Coefficient	Solar Heat Gain Coefficient	Light to Solar Gain (LSG)
	Ultra-violet %	Visible %	Total Solar Energy %	Visible Light %	Total Solar Energy %	Winter Night-time	Summer Day-time				
Insulating Vision Unit Performance Comparisons 1-inch (25mm) units with 1/2-inch (13mm) airspace and two 1/4-inch (6mm) lites; interior lite clear											
SUNGATE® 400 Low-E											
SUNGATE 400 (2) Clear + Clear	28	76	51	14	16	0.32	0.31	1.8	0.69	0.60	1.27
SUNGATE 400 (2) *STARPHIRE* + *STARPHIRE*	39	80	65	14	20	0.32	0.31	1.8	0.78	0.68	1.18
Clear + *SUNGATE* 400 (3) Clear	28	76	51	14	17	0.32	0.31	1.8	0.73	0.63	1.21
STARPHIRE + *SUNGATE* 400 (3) *STARPHIRE*	39	80	65	14	22	0.32	0.31	1.8	0.83	0.73	1.10
SOLEXIA + *SUNGATE* 400 (3) Clear	15	66	33	11	9	0.32	0.31	1.8	0.50	0.44	1.50
ATLANTICA + *SUNGATE* 400 (3) Clear	8	58	25	10	7	0.32	0.31	1.8	0.40	0.35	1.66
AZURIA + *SUNGATE* 400 (3) Clear	20	59	25	10	7	0.32	0.31	1.8	0.39	0.34	1.74
PACIFICA + *SUNGATE* 400 (3) Clear	7	37	19	7	6	0.32	0.31	1.8	0.34	0.30	1.23
SOLARBLUE + *SUNGATE* 400 (3) Clear	15	48	31	8	9	0.32	0.31	1.8	0.49	0.42	1.14
SOLARBRONZE + *SUNGATE* 400 (3) Clear	12	46	32	8	10	0.32	0.31	1.8	0.50	0.44	1.05
SOLARGRAY + *SUNGATE* 400 (3) Clear	12	38	27	7	9	0.32	0.31	1.8	0.44	0.39	0.97
GRAYLITE II + *SUNGATE* 400 (3) Clear	1	8	5	4	5	0.32	0.31	1.8	0.17	0.15	0.53
OPTIBLUE + *SUNGATE* 400 (3) Clear	21	55	41	9	13	0.32	0.31	1.8	0.62	0.54	1.02

It also assumes five foot windows supported by four inch mullions, causing a mullion factor of 0.93. The combination of this mullion factor with the 59% visible light transmittance of the glass resulted in the 0.55 window transmittance value.

Surrounding Buildings

The daylight in a space is greatly impacted by the building's surroundings. In an urban context, where buildings are close together and are often very tall, the impact is even more significant. Figure 13 shows the buildings surrounding 350 Mission, as well as their heights.

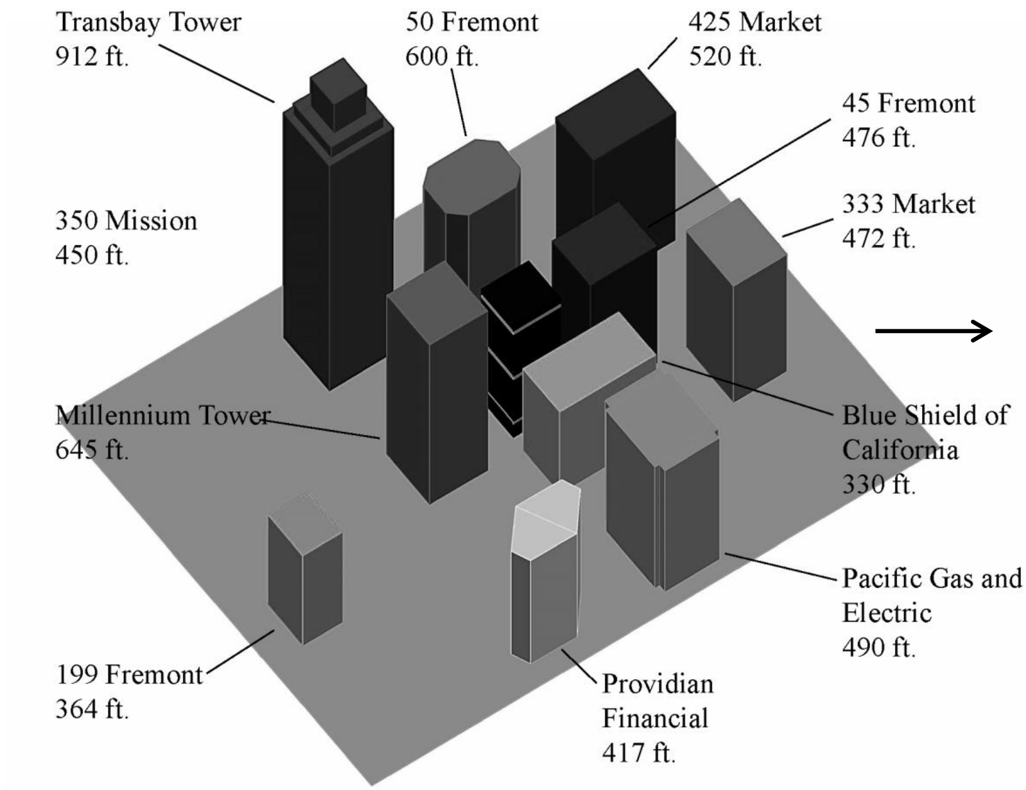


Figure 13. 350 Mission Urban Context

350 Mission is situated in a valley of much taller buildings. 50 Fremont, Transbay Tower, and Millennium Tower, located south of the building, are all 150' taller at minimum. The Blue Shield of California Building is not taller; however its façade is only 40' away from the northeast façade of 350 Mission.

The surrounding building reflectances were estimated and are summarized in Table 6.

Table 6. Surrounding Surface Reflectances

Building	Reflectance
Transbay Tower	0.10
50 Fremont	0.41
425 Market	0.26
45 Fremont	0.36
333 Market	0.25
Blue Shield of California	0.07
Pacific Gas and Electric	0.30
Providian Financial	0.36
199 Fremont	0.28
Millennium Tower	0.25
Ground	0.15

The Trials

Using Daysim, trials were run for each of the twelve analysis areas (three floors, four facades/analysis areas per floor). Daylight autonomy values were gathered for each area at various footcandle values: 10, 20, 30, 50, 100, 250, 500, and 1000. Useful daylight illuminance images were also generated, setting the boundaries at 25 fc for the minimum and 500 fc for the maximum, as these are the values set by LEED 2009 as the acceptable range for useful daylight [12].

Calculation grids were 4' x 3', with the 4' dimension running parallel to the windows and the 3' dimension running perpendicular. Points were raised 2.5' off of the ground to simulate typical workplane height.

For the direct sunlight study, a line of points was applied to the windows on the twelve façade/floor combinations. These points were placed 5' from the bottom of the windows and spaced 4' apart. One trial was conducted with surrounding buildings, and the other was conducted with the building completely isolated in order to analyze the impact of the surrounding buildings on the amount of direct sunlight that reaches the façade.

Occupancy was assumed from 6AM – 7PM, Monday – Friday throughout the entire year.

The Results

Spatial Daylight Autonomy

A selection of the resulting spatial daylight autonomy images can be seen in Appendix D, and the results are summarized in Figures 14-20. Figures 14-16 compare the sDA values for the different facades at each floor.

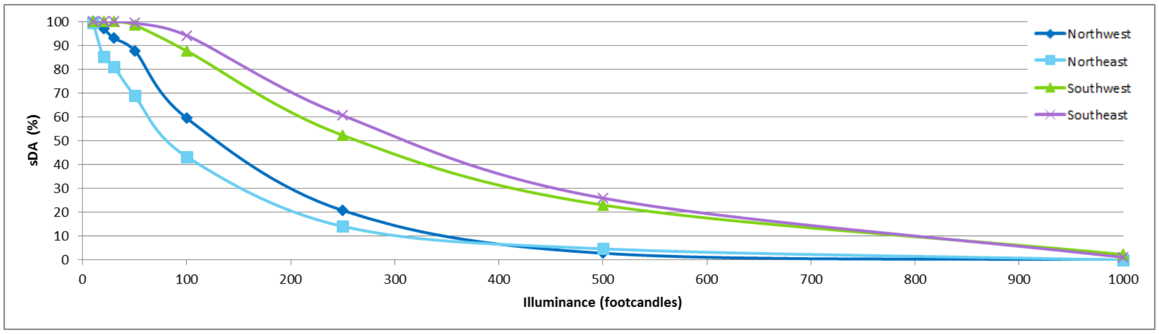


Figure 14. Spatial Daylight Autonomy Comparison – Floor 5

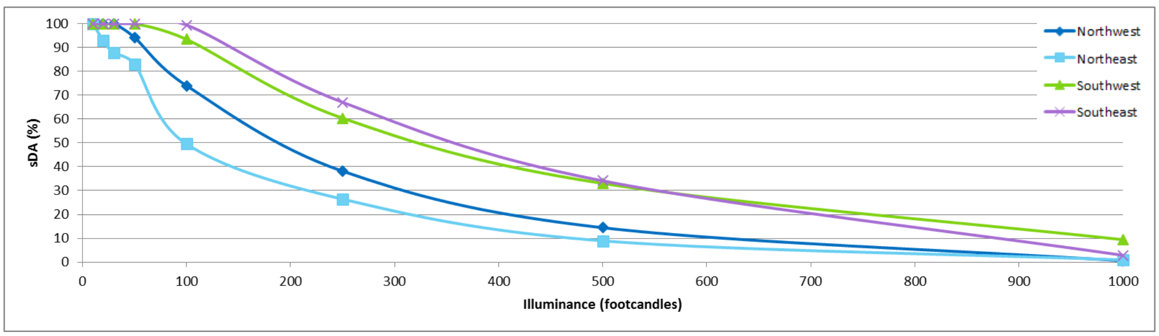


Figure 15. Spatial Daylight Autonomy Comparison – Floor 18

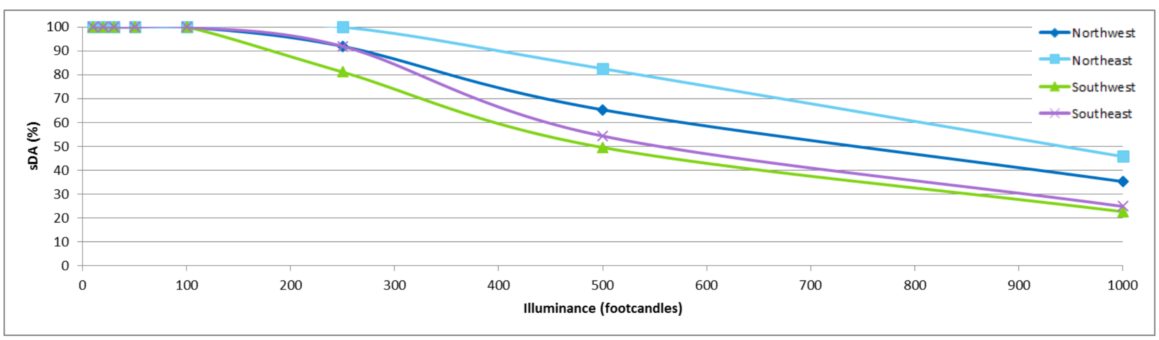


Figure 16. Spatial Daylight Autonomy Comparison – Floor 30

The floor comparison presents some interesting results. On the lower floors, the southeast and southwest façades yield higher spatial daylight autonomy values. The difference between the north façades and south façades is the most obvious on Floor 5, shown in Figure 14. Here, the north façades are dramatically affected by the neighboring buildings, and this is compounded by the fact that the façades are north facing. By Floor 18, the difference is not quite as large; however, Figure 15 still clearly shows two pairs of lines – the two north façades and the two south façades. These results were expected, as the south facing façades are generally the focus when designing to avoid intrusive daylight.

An interesting switch occurs on Floor 30. The northeast façade, formerly the bottom curve, became the façade with the highest daylight autonomy values. Just as surprising, the second highest curve is the northwest façade. After looking at the building model, the reason for this difference becomes clearer. At Floor 30, the northeast façade no longer has a neighboring building blocking it, making it very easy for daylight to enter the space. The northwest façade still has a taller building at this level, but it is only about 25' taller. This clearly does not have as much of an impact.

The southeast and southwest façades face taller buildings, and these are the tallest in the area. Even at Floor 30, their presence has a considerable impact on the daylighting potential in the space.

Figures 17-20 compare the spatial daylight autonomy values on different floors for each façade.

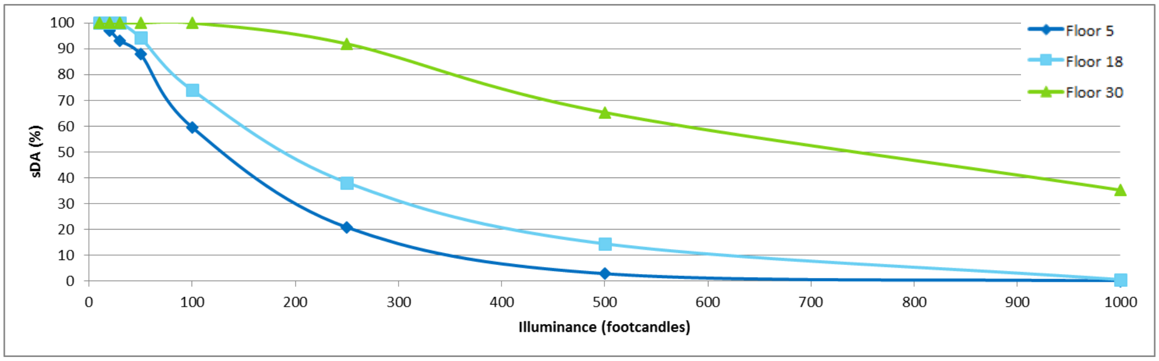


Figure 17. Spatial Daylight Autonomy Comparison – Northwest Façade

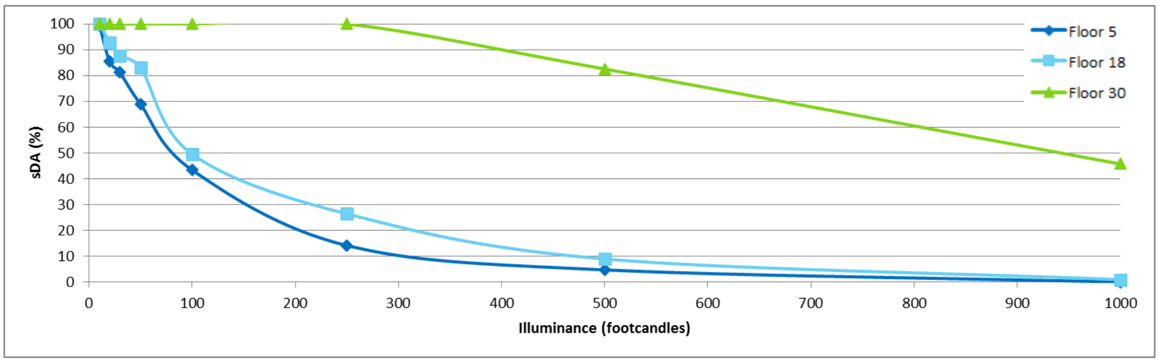


Figure 18. Spatial Daylight Autonomy Comparison – Northeast Façade

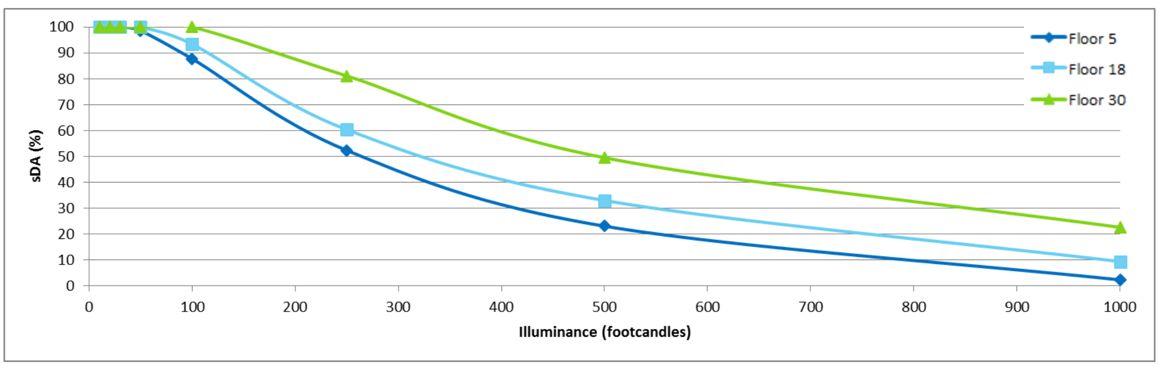


Figure 19. Spatial Daylight Autonomy Comparison – Southwest Façade

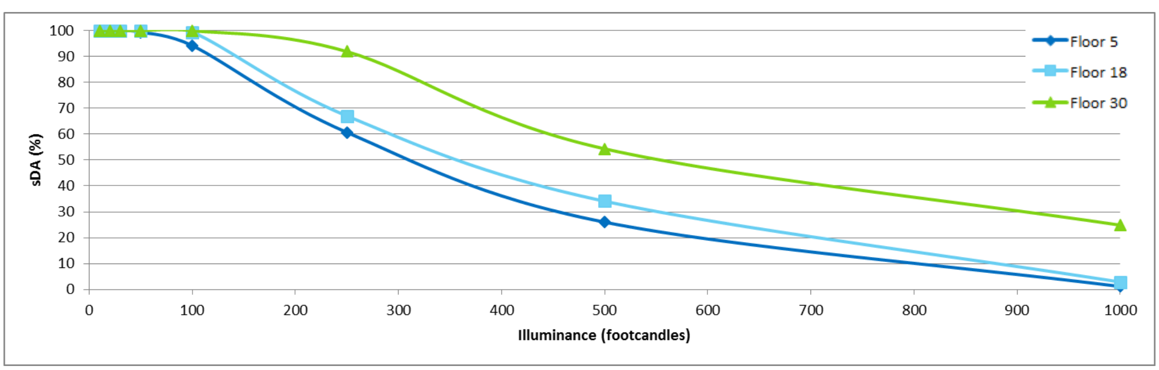


Figure 20. Spatial Daylight Autonomy Comparison – Southeast Façade

The façade comparison graphs reinforce the conclusions drawn from the floor comparison graphs. In the northwest and northeast graphs, the curves representing Floor 30 are dramatically difference from those for Floor 5 and Floor 18. Even without looking at the city model, it is obvious that there is an external factor that changes at Floor 30, creating the substantial difference reflected in the graphs. In the southwest and southeast graphs, on the other hand, the curves for each floor follow a similar shape, and the higher floors receive more sunlight, as expected. These consistent curve shapes show that the relative impact of the surrounding buildings remains the same at all floors, and this conclusion is supported by the geometry and the fact that the southwest and southeast buildings are much taller than 350 Mission.

Annual Direct Sun

Figures 21-24 summarize the results of the direct sun study. Numerical values for the annual hours of direct sun for each façade and floor can be found in Appendix D.

The graphs show the annual hours of direct sun at each calculation point, moving across the façade from left to right as viewed from the building exterior.

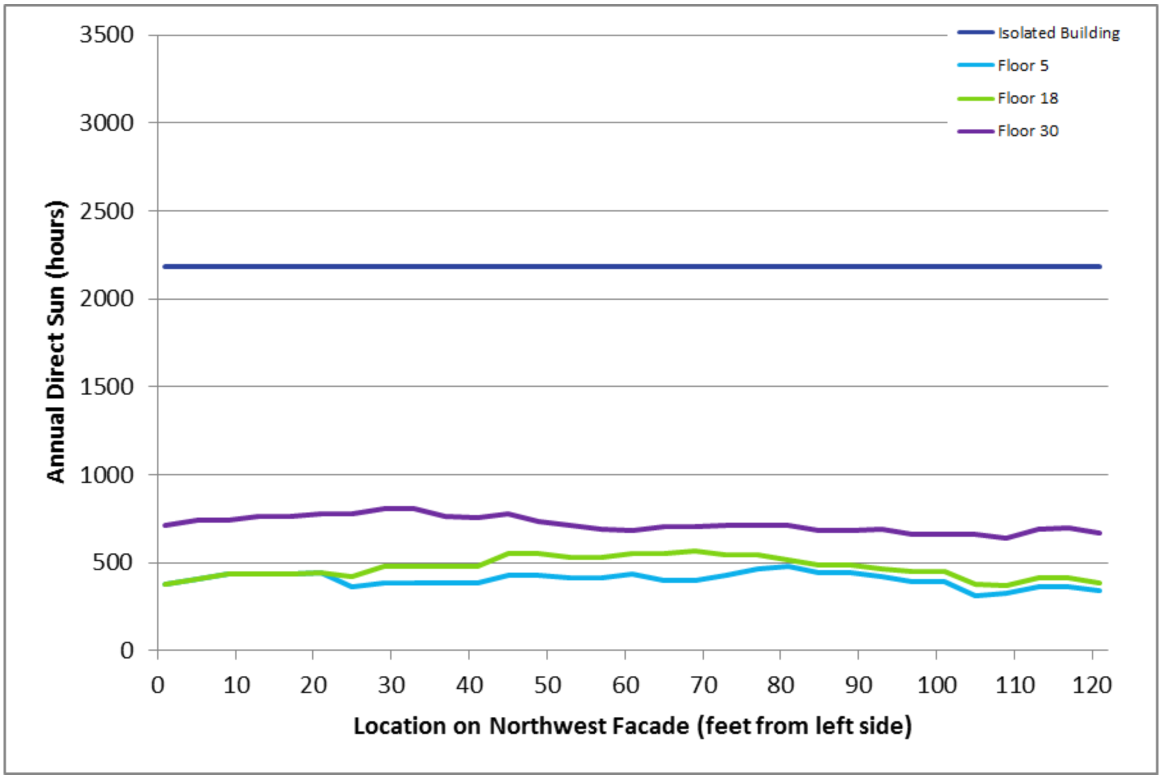


Figure 21. Annual Direct Sun Summary – Northwest Façade

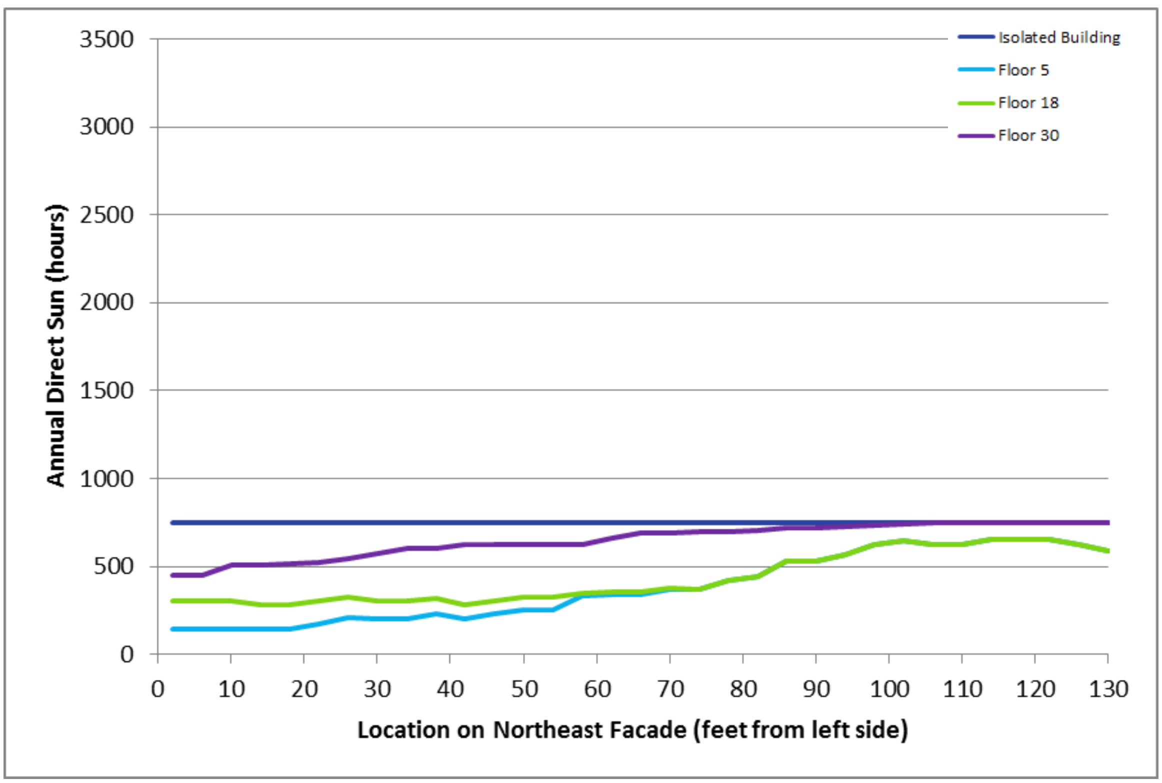


Figure 22. Annual Direct Sun Summary – Northeast Façade

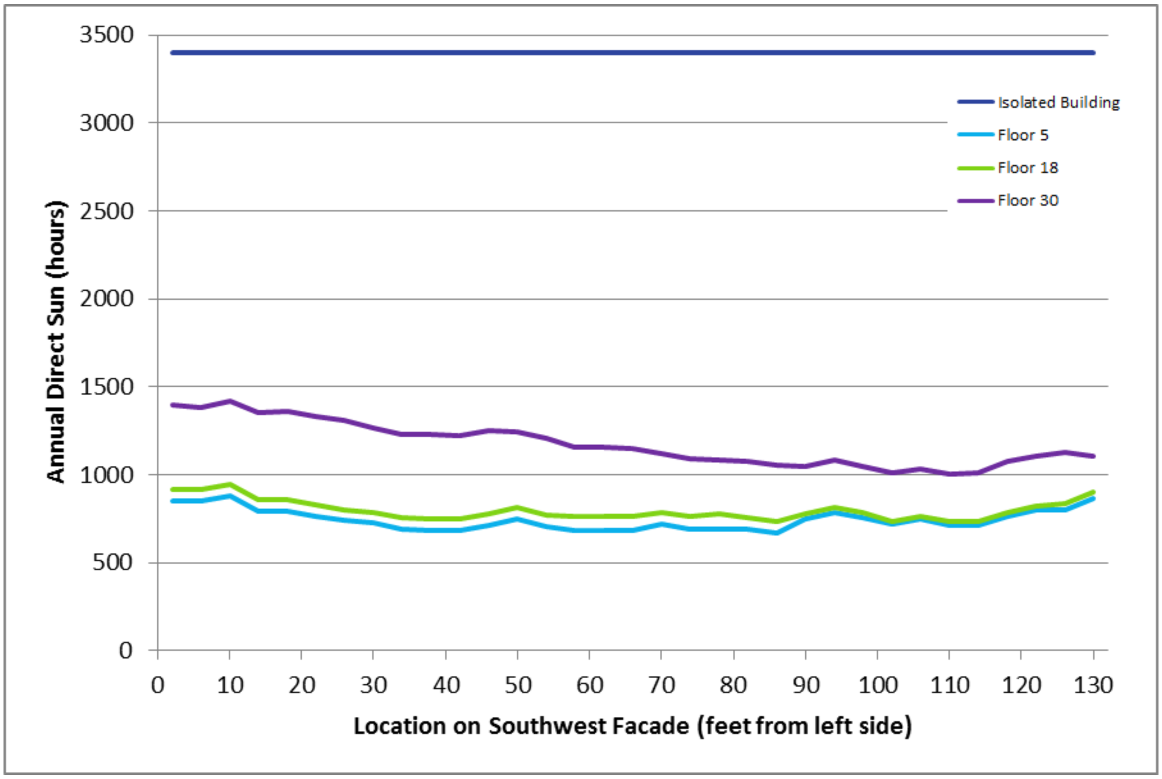


Figure 23. Annual Direct Sun Summary – Southwest Façade

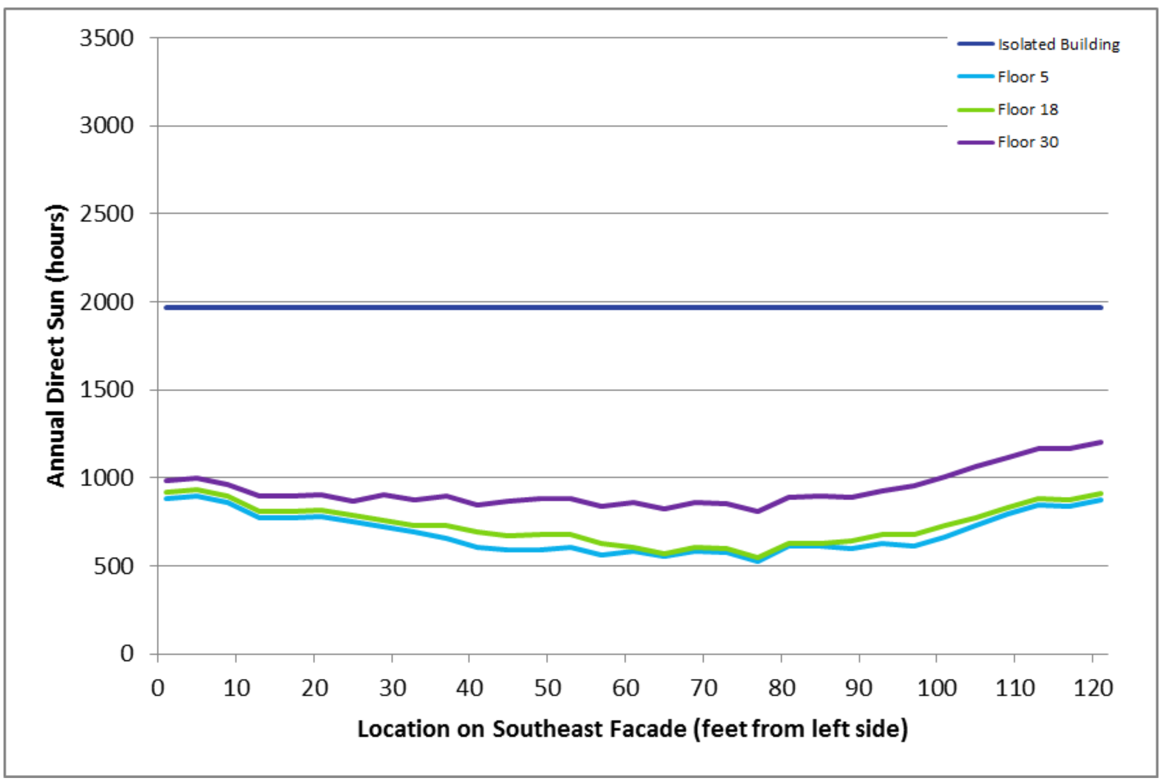


Figure 24. Annual Direct Sun Summary – Southeast Façade

The southwest façade receives the most direct sun, even after the surrounding buildings are factored in. For all façades, with the exception of the northeast, the addition of the surroundings reduces the hours of direct sun exposure by more than 50% over the course of the year. In the case of 350 Mission specifically, the northeast is not affected as dramatically due to the height of the neighboring building. Floor 30, as expected, is affected the least, as the neighboring building's roof is below this level.

During the hours when there is direct sun incident on the building façade, it is likely that the use of a shading system would be required to maintain a comfortable working space.

Conclusions

This urban daylighting study reinforces the idea that context is important when designing a building system. Without taking measurements and doing studies such as this one, a designer may assume that the south facing façades are the only ones of concern, whereas this study clearly showed that is not the case. The daylight conditions on different floors of a highrise building are greatly affected by the floor height, the height of surrounding buildings, façade orientation, and the distance of the surrounding buildings from the building façades. The large number of factors that affect the daylighting in a space make it critical to use simulations to aid in design, and most importantly, to create models that accurately and completely include the building's surroundings.

Chapter 5

Electric Lighting

Lighting Design Concept

Prior to designing the electric lighting for 350 Mission, design criteria and a concept were developed in order to guide design decisions and ensure that each one was made with the project goals in mind.

350 Mission is located in the SoMa (South of Market) neighborhood of San Francisco. This area used to be called “South of Slots”, referring to the cable cars that once dominated the streets. Paying tribute to the history of the area, the concept for the lighting design is cable cars. These represent the innovation of the city, as San Francisco was the first to implement a cable car system. Even now, San Francisco is a leader in energy efficiency and recycling programs. The lighting design for 350 Mission builds on these traditions of innovation and efficiency. Linear forms can be found throughout the design, reminiscent of the cable car tracks and wires that still line the streets of San Francisco.

After developing the concept and design criteria outlined in the following sections and evaluating the various available light source options, LED lighting was chosen as the primary source for 350 Mission due to its low energy consumption and competitive color rendering and glare control properties. Dimming is an important part of the lighting control system to ensure that energy is not wasted, and is also inherently favorable to LED luminaires by decreasing the amount of heat that needs to be exhausted and contributing positively to luminaire life and resistance to color shift.

In storage rooms and other back-of-house spaces, fluorescent lighting will be used as it is more cost-effective and will not be in use as frequently as the lighting in the public and office spaces.

Lobby

Although the lobby is a big, open space, it has a variety of separate functions. These include circulation, reception, retail, and gathering areas, as shown in Figure 25.

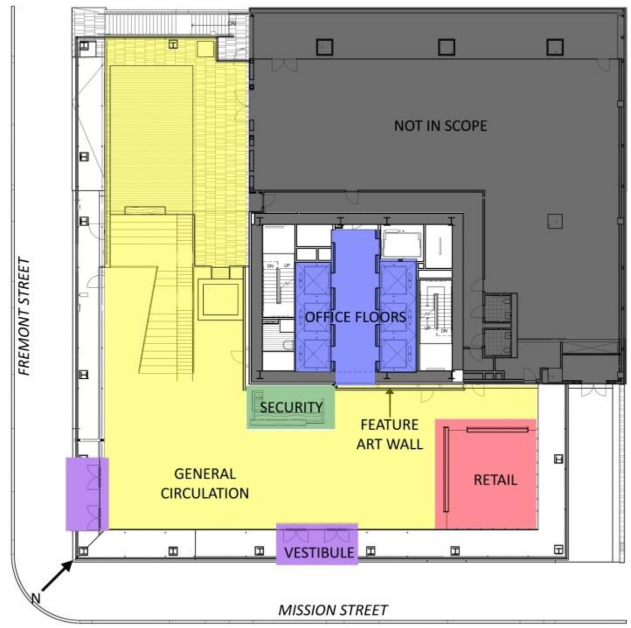


Figure 25. Lobby Space Allocation

The lighting design strives to clearly distinguish the separation of these areas, as well as address the other design criteria listed in Table 7. Quantitative criteria were defined by the Illuminating Engineering Society (IES) illuminance requirements for the various building space functions.

Table 7. Lobby Design Criteria

Qualitative		
• Guide visitors to key points • Maximize use of daylight • Integrated with/enhance architecture • Create visual interest • Visually reduce scale of the lobby • Earthquake-conscious design • Separate various functions of the open space • CRI above 80 • CCT – 4000K		
Quantitative (values are in fc)		
Space Type	**Criteria**	**Actual**
Circulation	10	10.5
Elevator Lobby	10	10.4
Stairs	10	10.9
Security Desk	30	34
Vestibule	15	14.1

Linear luminaires configured into squares are suspended from the drop ceiling, as shown in Figure 26, providing enough light for general ambiance. The design is decorative to make the lobby visually interesting, even when electric lighting is not needed, and the hollow centers of the luminaires avoid detracting from the architecture. The restaurant and east corner retail area have been left to allow flexibility to the future tenants. Some adjustable ambient lighting is supplied in the east corner retail area, mounted via monorails extending from the partition walls. The rest will be integrated into the displays brought in by the tenants. Receptacles are provided in the floor for this purpose.

Figure 26. Lobby General Circulation Lighting Rendering

More information about the special considerations for general circulation area lighting can be found in the “Seismic Design” section in Chapter 6. The lighting plan can be found in Appendix E.

The lobby lighting design resulted in an LPD of 0.41 W/sf, as compared to the 0.97 W/sf allowed by code.

Public Art

The San Francisco Planning Department requires that new construction projects allocate 1% of the total construction cost of the building to publicly displayable art. Originally, architect’s vision for the space included a three-story LED media canvas. While this is a novel way to interact with the public and attract people to the lobby, its operation would require a substantial amount of energy, which is not ideal for a building aiming to be highly energy efficient. The new design transforms the space into a similar public attraction, but one using less energy.

A design competition will be held for local artists to create a mural that incorporates dynamic lighting effects to be installed on the feature wall, as shown in Figure 27, and people in the lobby will have the opportunity to interact with the art and the building by using the power of their footsteps.

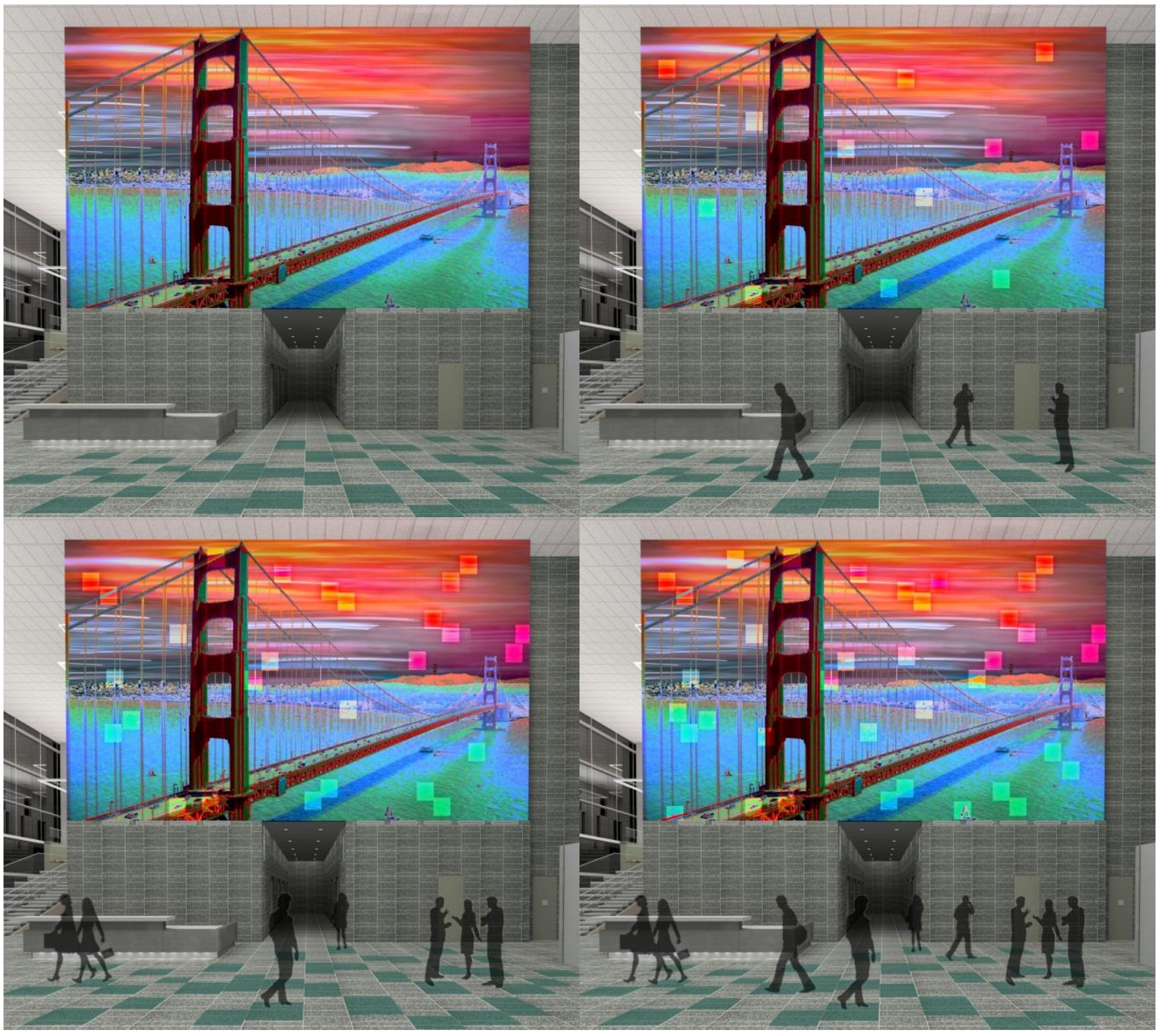


Figure 27. Public Art Example

PaveGen tiles are energy-generating floor tiles that use piezoelectric polymer material to convert kinetic energy produced by human foot traffic to electricity. The technology is a new kind of renewable energy, one that directly interacts with humans, but it is not yet a realistic source of building-scale energy generation as the electrical output is too low and the cost too high.

As an integrated part of the work of art, however, the PaveGen tiles can be purchased under the public art allowance. The tiles will be installed throughout the lobby floor in a pattern determined by the artist, with each tile activating some portion of the lighting in the mural. In this way, people walking across the lobby will interact with the public art using the kinetic energy of their footsteps. The higher the level of interaction with the floor tiles, the more the dynamic lighting on the wall reacts.

As important as energy efficient building systems are to creating a near net-zero highrise, occupant participation is also critical to minimizing energy use. The interactive art display is intended to make the building occupants more conscious of their role in conserving, and even in this case, creating energy. Since the luminaires used in the wall are only on when triggered by a floor tile, the energy requirements are quite low, and the tiles are sufficient to supply the display.

The electric lighting in the lobby was coordinated with the public art wall to ensure that the view of the wall is not obstructed by suspended luminaires from any location in the lobby from which the wall is visible. Views showing this coordination and other renderings can be found in Appendix E.

Office

The office area consists of an open office area, smaller conference and meeting rooms, a break room, and circulation space. These spaces are defined in Figure 28.

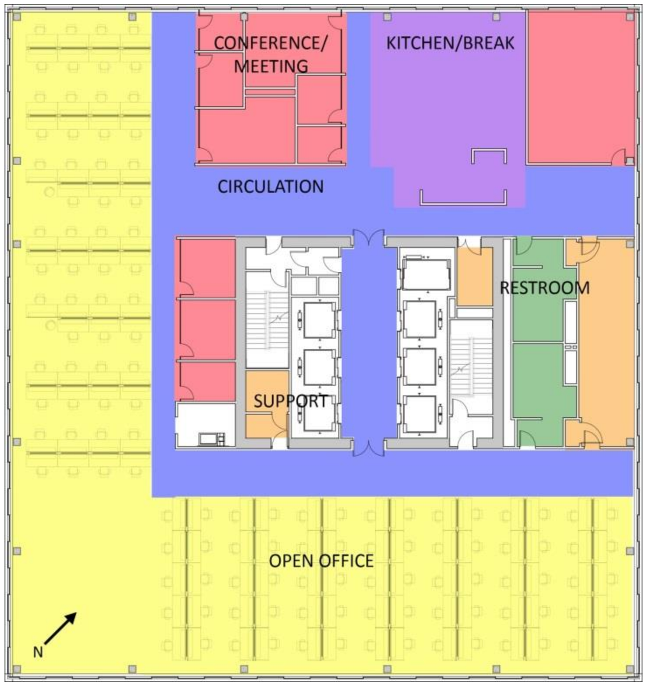


Figure 28. Office Floor Space Allocation

The driving forces behind the lighting design of the office floors were simplicity, energy efficiency, and user flexibility. Energy efficiency on the office floors is especially important because the energy savings resulting from this lighting design are multiplied by 25 (the number of office floors). A summary of the office design criteria can be found in Table 8.

Table 8. Office Design Criteria

Qualitative		
• Create a welcoming, work-friendly environment • Provide as much controlled daylight as possible • Prevent glare on computer screens, desks, etc. • Avoid visual clutter • CRI above 80 • CCT – 4000K		
Quantitative (values are in fc)		
Space Type	**Criteria**	**Actual**
Open Office-Desk	30	30.6
Open Office-Circ.	10	15.2
Circulation	10	11.8
Small Conference	30	29.7
Large Conference	30	30.1
Kitchen	30	29.9
Dining/Break Area	10	10.7
Restroom	5	5.5
Copy Room	10	12.0

The primary ambient lighting comes from continuous runs of linear LED fixtures. The fixtures use diffuse lenses and a low lumen package to reduce the risk of glare. They are placed above the partitions between rows of desks to avoid shadowing on the work area and glare on computer screens. Overhead lighting only provides 2/3 of the required maintained illuminance levels, with the other 10 fc provided by dimmable LED task luminaires. These luminaires have adjustable arms for maximum flexibility and are mounted to the front partition on each desk, as shown in Figure 29.

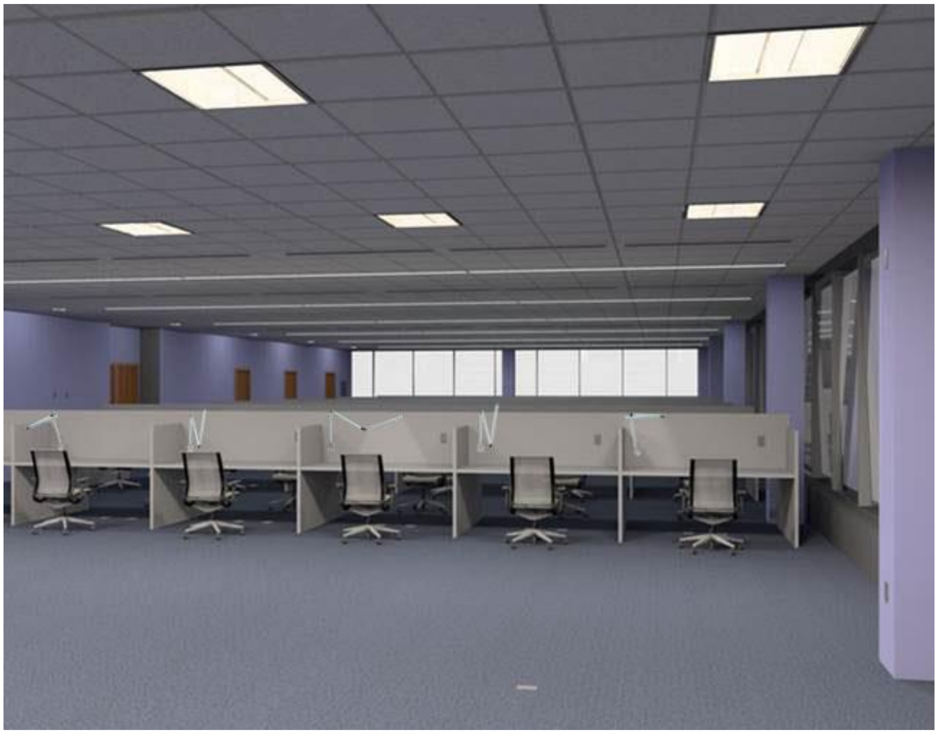


Figure 29. Office Task Lighting

Employees can choose whether or not they need the task lights after evaluating light levels from daylighting and the overhead lighting. Task lighting is the most efficient means of delivering light to the workplane, and combining this with the overhead lighting reduces the lighting load on the office floors.

The office lighting design resulted in an LPD of 0.42 W/sf, as compared to the code allowable 0.76 W/sf. The lighting plan, as well as a summary of all building lighting power densities, can be found in Appendix E.

The lighting design was also coordinated with the mechanical and electrical systems. All recessed luminaires extend into the plenum less than six inches to create more space for mechanical ductwork and dampers. The DC electrical distribution, detailed further in Chapter 5, also runs through the plenum and feeds all of the ceiling recessed lighting, low voltage controls, and telecom devices. Linear mechanical diffusers are installed to match the linear luminaires over the open office workstations. This ceiling coordination is shown in Figure 30, with luminaires shown in red, ductwork and diffusers shown in blue, and electrical power server modules shown in green.

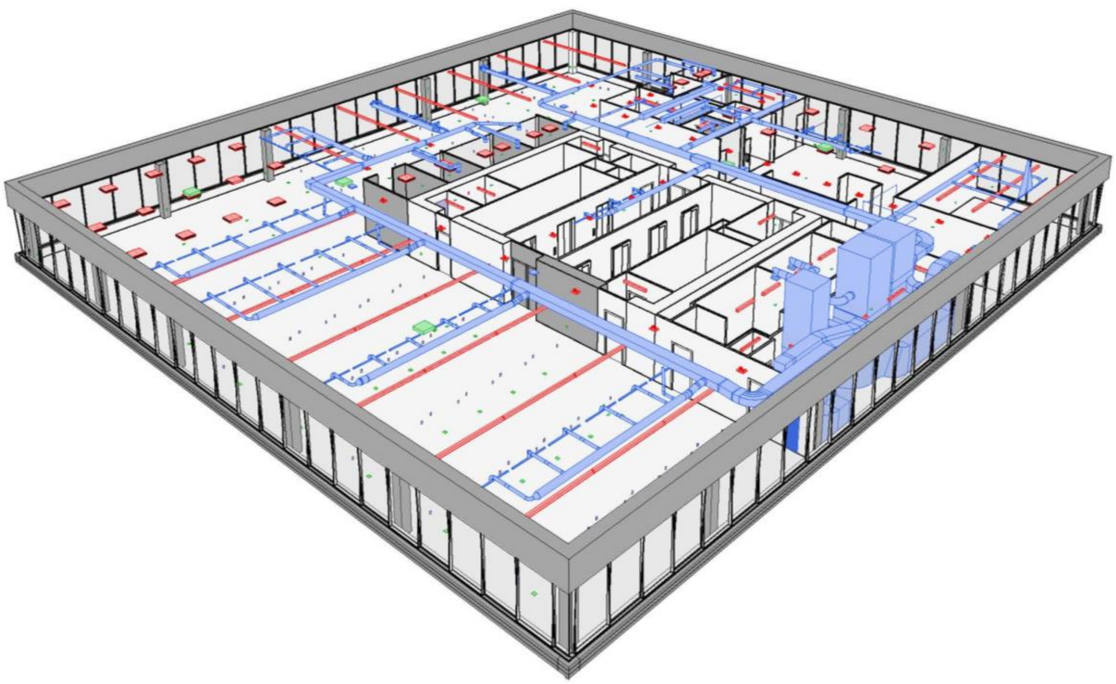


Figure 30. Office Floor Ceiling Coordination

Emergency Lighting

The emergency lighting provides one foot-candle of horizontal illuminance at the floor along the path of egress, as required by the California Building Code. This includes all stairwells, corridors, and travel routes that building occupants must take to reach these egress paths, including large partitioned rooms and utility spaces. In both the lobby and office floors, emergency lighting is integrated into the normal lighting design. To accommodate this, the emergency panel is supplied by normal and emergency power supplies and controlled by an automatic transfer switch (ATS). The power server modules (discussed further in the "AC/DC Distribution" section in Chapter 6) that receive the 380VDC and convert it to 24VDC have multiple inputs, one from the normal panel and one from the emergency panel, and are programmed so that only the output channels supporting emergency loads draw power from the emergency panel when the normal feed stops.

Controls

A Digitally Addressable Lighting Interface (DALI) system is used to control the glass tinting and electric lighting in the building.

Table 9. Control System Design Criteria

Qualitative
• Monitor energy use • Minimize energy use • Comply with code • Maximize safety • Seamless integration of daylight and electric lighting • Flexible • Control electric lighting and shading systems • Dimming in daylit spaces • Maximize occupant comfort • Integrate with Building Automation System (BAS)

This lighting control system was selected after developing the design criteria listed in Table 9, and is tied into a Building Automation and Control Network (BACnet) that also manages the mechanical systems in the building, as shown in Figure 31.

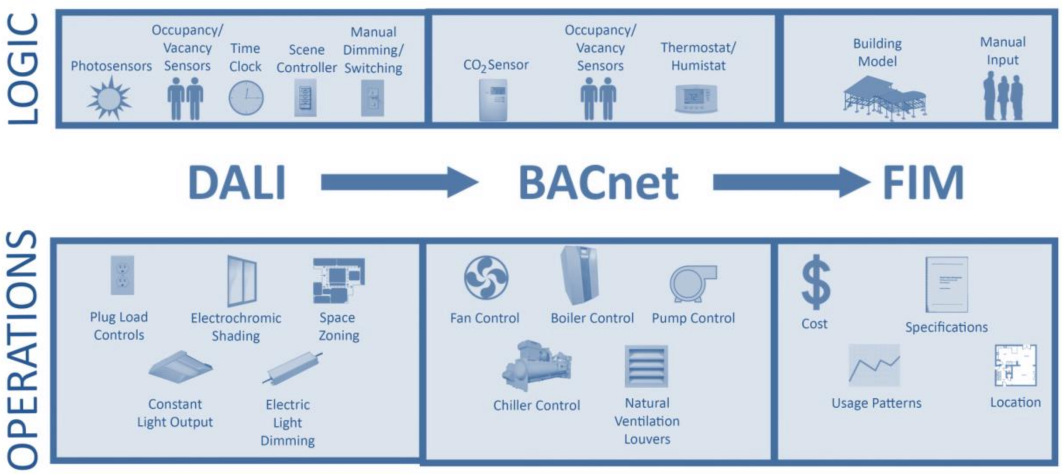


Figure 31. DALI Integration with BACnet and FIM Systems

These systems function within the definition of the Facilities Integration Model (FIM). This model is created by the general contractor and specialty contractors during construction and is handed over to the building owner and facilities manager after the building is completed. Aside from controlling the lighting, electrical, and mechanical systems, the FIM also contains product data, making replacement of parts more efficient and ensuring that product information is available to the facilities manager throughout the lifetime of the building.

The integration of these systems allows the building operations team to view a summary of the building's energy use, aiding in the identification of systems that are not performing as anticipated and permitting analysis of how the building is performing in regards to the net-zero goal. The offsite solar array is also monitored, sending information back to the main building control system for inclusion in the overall building energy use reports.

The DALI system for lighting control allows for two-way communication between the central control station and each associated device. The control system can both send signals to the devices, telling the lights to dim or the glass to tint, and receive signals from the devices, informing the operator of failed drivers or motors or of LEDs that have reached the end of useful life. DALI is also an open standard, so a wide variety of manufacturers offer devices and luminaires that are compatible, removing any interoperability limitations.

In all locations where LEDs are used, the control system is programmed to adjust power input throughout the LED life to maintain a constant lumen output. Calculations were performed with a 0.7 lumen depreciation factor, and without an adjustment by the control system, areas will be considerably over lit. There is a linear relationship between power input and lumen output, so the initial input for each LED fixture will be 70% of the maximum. Light levels will be monitored via photosensors that tell the control system when the LEDs have depreciated to the point where electric light levels are too low and the power input needs to be increased. Doing this saves energy while also maintaining appropriate light levels, making the spaces more comfortable for the occupants.

Lobby

The lobby is divided into separate control areas based on function. A summary of the lobby controls can be found in Table 10.

Table 10. Lobby Lighting Controls Summary

SPACE TYPE	MANUAL ON	MANUAL OFF	DIMMING	OVERRIDE SWITCH	MULTI SCENE CONTROLLER	KEY SWITCH	TIME CLOCK ON	TIME CLOCK OFF	OCCUPANCY SENSOR ON	OCCUPANCY SENSOR OFF	PHOTOCONTROL DIMMING
General Circulation Area											X
Reception Desk – task	X	X								X	
Reception Desk – decorative							X	X			
Retail – ambient			X	X			X	X			X
Retail – merchandise			X				X	X			
Elevator Lobby							X	X	X	X	

The complete controls narrative is below. The lobby control zones reference the areas outlined in Figure 32 and include all luminaires located within the boundary.

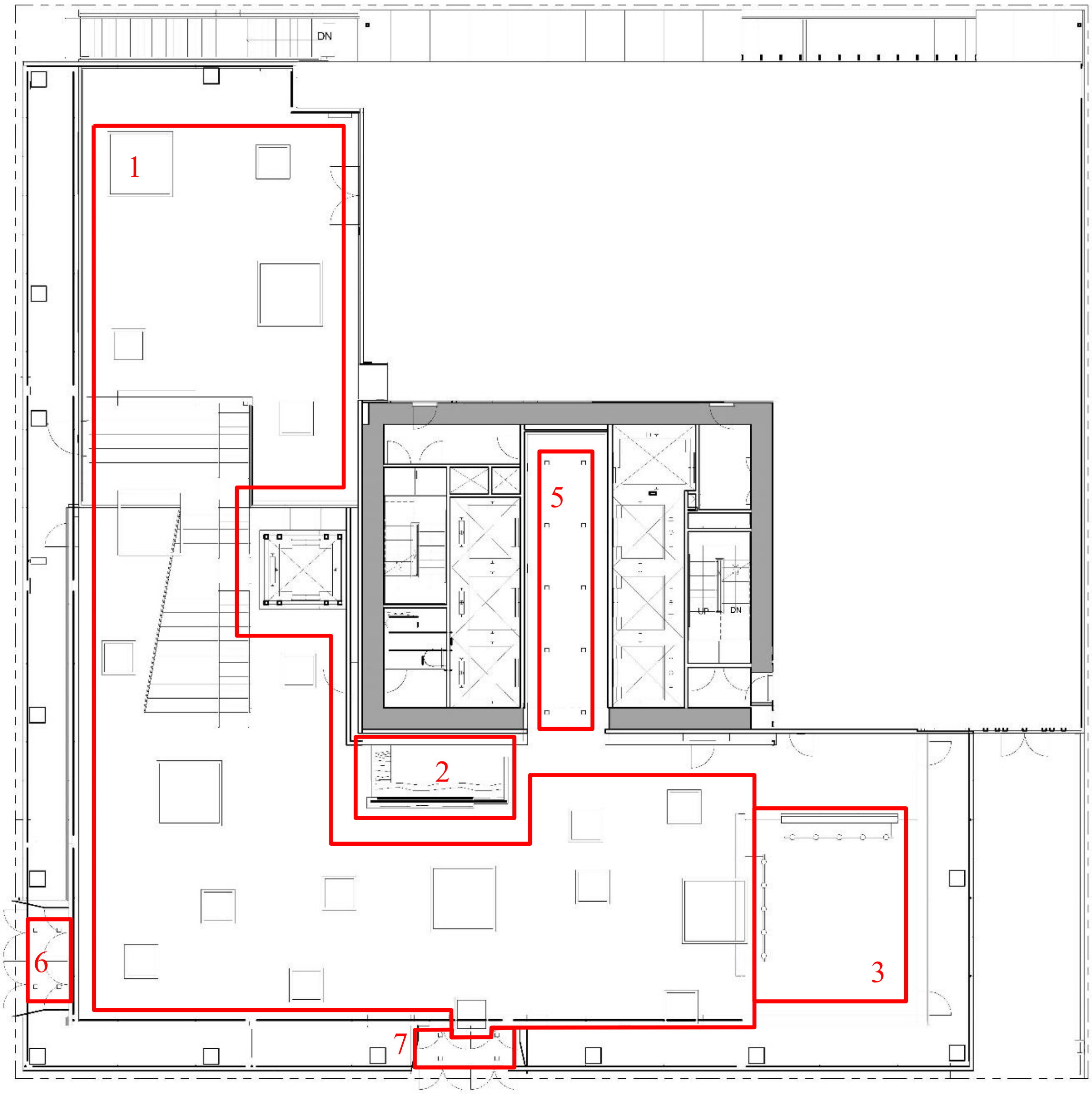


Figure 32. Lobby Control Zones

General Circulation Area CZ1

The suspended luminaires in the general circulation area are on from dusk to dawn for security purposes and throughout the day as needed. They are controlled by multiple photosensors attached to the fixtures and calibrated to approximate the ground illuminance levels. The lights dim as daylight levels allow, and when the amount of daylight in the lobby is adequate for general circulation, the lights are turned completely off. Each luminaire is controlled individually due to the size and layout of the lobby, ensuring that the entire space will have adequate light levels regardless of the time of day or exterior conditions.

Reception Desk CZ2

The reception desk lighting is divided into two groups – task lighting on the desktop area and decorative lighting underneath the desk. The task lighting is controlled by a manual on/off and occupancy sensor off. Throughout much of the day, this lighting will likely not be necessary as the daylight values in the space are more than adequate. However, it is available if needed. The decorative lighting is time clock controlled, turning on at 6AM and off at 7PM each day.

Retail CZ3-CZ4

There are two retail areas, one underneath the stairs to the second floor and the other at the east corner of the building. The stair retail area has ceiling recessed fixtures that are switched together and have manual on/time clock off controls, with the time clock set based on store operating hours.

The east corner retail area has two levels of lighting – ambient and merchandise lighting. The ambient lighting has time clock on/off controls, set to remain on during operating hours. These lights can be dimmed based on the tenant requirements, and there is an override switch in case of housekeeping or other after-hours usage. Due to the store’s location, ambient luminaires are also controlled by a photosensor and are dimmed/switched off when daylight levels allow.

The merchandise lighting in this area is also controlled by a time clock on and off; however this can be set separately from the ambient lighting to allow the tenant to light merchandise during closed hours for advertising and security purposes. This lighting is flexible and can be dimmed as desired by the tenant.

Elevator Lobby CZ5

The elevator lobby is controlled by a time clock for the majority of the work day, turning all lights on at 6AM and off at 7PM. Outside of these hours, occupancy sensors are responsible for the on/off controls.

Vestibule CZ6-CZ7

Vestibule lighting is controlled primarily via a time clock that switches the lights on when the building opens in the morning and off when it closes at night. During the day, it is also controlled by a photosensor that dims and switches the lights when there is enough daylight to do so. All of the lights in each vestibule are controlled together.

Office

As the office layout is flexible, the lighting controls are described as they would be designed for the typical floor layout that is being used as the standard. Due to the flexibility offered by DALI control systems, any changes made to the floor plan after the initial programming can be reflected in an adjustment of the control system settings to fit the new specifications.

Table 11. Office Floor Lighting Controls Summary

SPACE TYPE	**MANUAL ON**	**MANUAL OFF**	**DIMMING**	**OVERRIDE SWITCH**	**MULTI SCENE CONTROLLER**	**KEY SWITCH**	**TIME CLOCK ON**	**TIME CLOCK OFF**	**OCCUPANCY SENSOR ON**	**OCCUPANCY SENSOR OFF**	**PHOTOCONTROL DIMMING**
Open Office – overhead	X			X				X			X
Open Office – task lighting	X	X								X	
Flex Space	X			X				X			X
Electrical/Mechanical Rooms	X	X								X	
Restrooms									X	X	
Elevator Lobby							X	X	X	X	
Corridors							X	X	X	X	
Copy Room									X	X	
Interview Rooms	X	X								X	
Teleconference Rooms	X	X	X							X	
Conference Rooms	X	X	X		X					X	
Dining/Break Area									X	X	X
Kitchen									X	X	

A summary of the office floor controls can be found in Table 11. The complete office controls narrative is below and references the control zones shown in Figure 33.

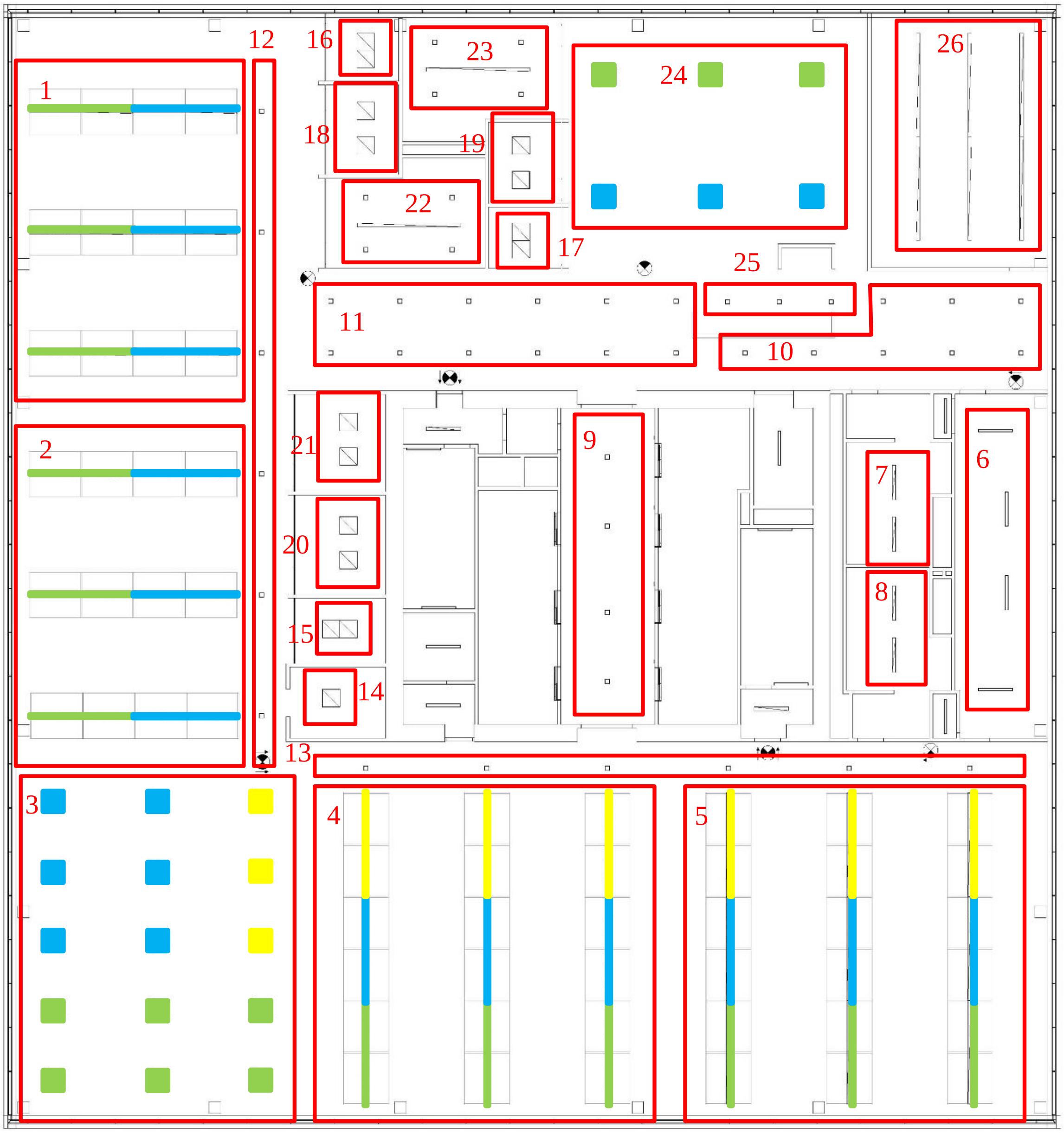


Figure 33. Office Floor Control Zones

<u>Open Office/Flex Space CZ1-CZ5</u>

The open office lighting consists of the overhead lights and the task lighting on each workstation. Task lighting is locally controlled, only turning on when switched on by an occupant. These lights can either be switched off manually or a vacancy sensor located under each desk does so automatically after a preset period of time.

The overhead lighting is controlled by a manual “on” at the beginning of each day, with each fixture being assigned to a control zone as designated by the red outlines. At 6:00PM each day, lights blink several times as a five minute shutoff warning. If the override switch is not activated during that time, the lights turn off at 6:05PM. Use of the override causes lights in the specified control area to remain on for an additional 90 minutes, and at the end of this additional time, the same shutoff warning occurs. The override option is available to all employees through the use of the Voice over Internet Protocol (VoIP) phones located at each desk or the physical override switches located in the vicinity of each control zone.

During hours where daylight harvesting is possible, lights dim according to the signals received by closed-loop daylight sensors located in the ceiling. Each control zone is also divided into dimming zones. Luminaires of the same color in the same control zone are controlled by one photocell to prevent each fixture from dimming to a different level, as occupants generally prefer dimming to occur in groups rather than each fixture dimming individually.

An override switch is also provided for housekeeping. CZ1 and CZ2 are controlled by the same housekeeping switch, and CZ3-CZ5 are controlled together. When the housekeeping override is activated, lights in the designated zones will turn on for 30 minutes. These are the only spaces in which a housekeeping override is required, as most other areas on the office floor are occupancy sensor controlled.

Mechanical Room CZ6

These fluorescent luminaires are controlled with a manual on/off as well as occupancy sensor off. The controls for the rest of the electrical/telecom/etc. spaces (unmarked on the plan) are the same as this room. Switches are located at the entrances to each room and control all of the lights in the area.

Restrooms CZ7-CZ8

The restrooms are controlled solely by occupancy sensors. There is a wall switch sensor at the entrance to the room, as well as ceiling mounted occupancy sensors in the stall area to ensure that the lights do not turn off while occupants are in the restroom.

Elevator Lobby CZ9

The elevator lobby is controlled by a time clock for the majority of the work day, turning all lights on at 7AM and off at 6PM. Outside of these hours, occupancy sensors are responsible for the on/off controls.

Corridors CZ10-CZ13

Similar to the elevator lobby, the corridors are controlled by time clock to constantly remain on from 7AM-6PM. At other times, occupancy sensors assume control, and lights only turn on when a sensor is triggered. The luminaires located in each control zone are controlled as a group, and occupancy sensors are located as required to ensure that lights turn on when the corridor area is occupied.

Copy Room CZ14

The copy room uses an occupancy sensor for on/off control at all hours.

Interview Rooms CZ15-CZ17

Interview rooms utilize a manual on/off switch located at the door, as well as a vacancy sensor to prevent lights from staying on and wasting energy while the room is unoccupied.

Teleconference Rooms CZ18-CZ21

Similar to the interview rooms, the teleconference rooms have a manual on/off controller at the door and a vacancy sensor. In addition, the wall controller allows for dimming to accommodate the various light level needs depending on the current function of the room.

Conference Rooms CZ22-CZ23

Conference rooms are equipped with scene controllers to accommodate the variety of activities that may occur in these spaces. They can be used for formal and informal meetings, brainstorming sessions, audio/visual presentations, etc. The lighting requirements for each of these scenarios are different, and scenes are programmed for each. A/V presentation mode turns off the majority of lights, excluding the two rear downlights, and the electrochromic glass on the façade will tint to allow for better screen visibility. Meeting mode consists of all lights turned on. Other scenes can be programmed into the controller as the needs of the tenants require. There is also a vacancy sensor to ensure that lights are off when the room is not being used.

Dining/Break Area CZ24

Occupancy sensors located in the break area control on/off switching of the luminaires. The control zone also contains two photosensor dimming zones, shown by the luminaire colors in the control diagram.

Kitchen CZ25

The kitchen is controlled by occupancy sensors that switch the lights on and off.

Large Conference Room CZ26

This conference room also has a scene controller to accommodate the variety of activities that may take place, including meetings, presentations, training sessions, etc. A/V presentation mode turns off the front lights, dims the middle, and leaves the front lights on. It also shades the glass. Normal presentation mode has the same luminaire controls, but the glass does not tint. Other scenes can be programmed into the controller as the needs of the tenants require. There is also a vacancy sensor to ensure that lights are off when the room is not being used.

Chapter 6

Electrical Design

AC/DC Distribution

The electrical system in 350 Mission was designed to maximize efficiency, utilizing dual alternating current and direct current (AC/DC) electrical distribution to support building loads. While AC infrastructure is the industry standard, the popularity of DC power distribution is on the rise. Semiconductor-based loads, including LED lighting, computer servers, and low voltage controls inherently require DC voltage, making the standard practice of converting AC distribution to low voltage DC at each device inefficient. Renewable onsite energy generation can also directly interface with DC distribution systems, eliminating the need for an inverter.

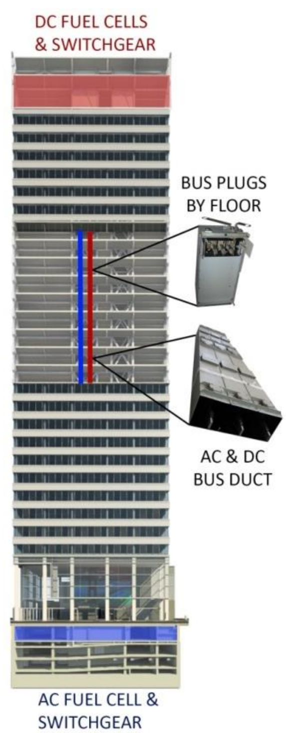


Figure 34. Bus Duct Schematic

As shown in Figure 34, the utility-paralleling AC switchgear is located adjacent to the PG&E vault in the primary electrical space on level B1 and distributes normal and emergency power via a 480VAC bus duct running vertically through the electrical rooms in the core. The DC switchgear, also in parallel with the utility and receiving input from both onsite energy sources, is located in the penthouse. Its distribution runs through a separate 380VDC bus duct also running through the electrical rooms in the core. An additional emergency riser runs vertically through the electrical closet and will be discussed in the “Seismic Design” section. The bus ducts act as large feeders, allowing power taps using bus plugs to “plug” into the copper runs where power is needed. This offers greater end-use flexibility by eliminating individual feeders and consolidating vertical runs into a large bus accessible at plug locations.

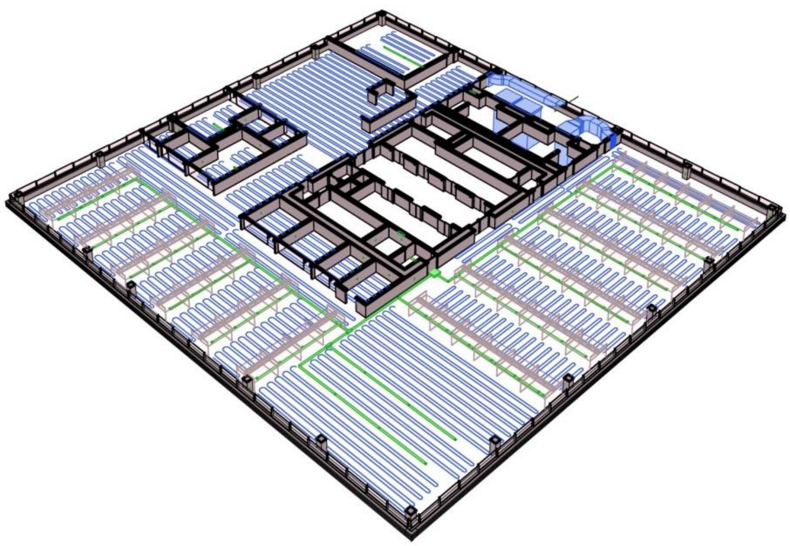


Figure 35. Office Level Floor Coordination

The AC and DC bus ducts are contacted at each office floor and in the lobby spaces to provide power to main circuit breaker (MCB) panels, the AC panel via a small step-down transformer. Panelboards feeding the restaurant and retail areas are separately metered to monitor the energy use of those vendors. AC distribution runs primarily under the floor slab of the floor below and pokes through the slab at receptacle junctions, and DC distribution runs in the ceiling plenum. The AC distribution locations were coordinated with the mechanical radiant floor system, as shown in Figure 35.

Maintaining AC distribution throughout the building was necessary for receptacles feeding electronics and appliances that have not yet penetrated the DC market. For example, the desktop computer loads at each office floor run on AC distribution because the market is dominated by AC computer power supply units (PSUs). The building’s computers are discussed in more detail in the “Server Room” section. A detailed schematic showing the AC/DC breakdown of building loads and the electrical riser diagram can be found in Appendix F.

Concerning capital cost, the dual AC/DC system presents a tradeoff between quantity and size. It requires more equipment to accommodate the two voltage distributions, but components can be smaller as the building load is divided. Realistically, the dual system presents at least some increase in equipment and installation costs, but this should pay for itself as the DC distribution is expected to result in a 5% increase in efficiency at a very minimum.[2]

Mechanical

350 Mission’s approximately 350 kW of connected mechanical equipment requiring power runs on 380VDC. While AC and DC motors have similar efficiencies depending on the size and manufacturer, DC variable frequency drives (VFDs) offer a significant advantage over AC.

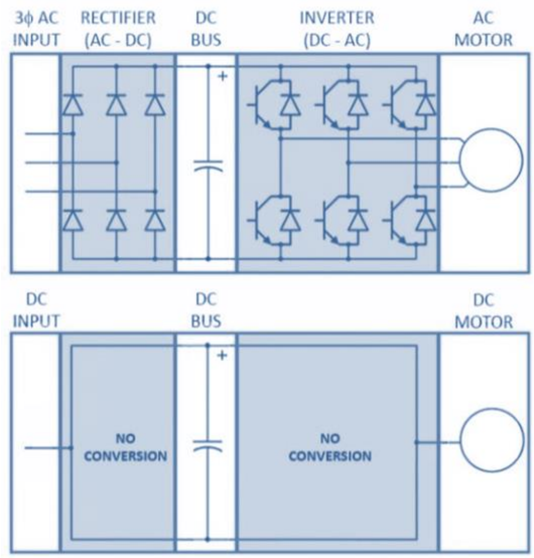


Figure 36. AC vs. DC VFD

As shown in Figure 36, a VFD supporting an AC motor and receiving AC input experiences two conversions, AC-DC and then DC-AC, whereas a VFD feeding a DC motor with DC input experiences no conversions. Every device has heat and mechanical losses, but eliminating conversions is the key to improving system efficiency. The DC motor and VFD combination allows pumps and fans to maintain near-peak efficiency even when running at partial load, which is critical considering that all mechanical equipment is oversized to some degree. Mechanical loads also generally have lower power factors than other equipment, but with DC distribution there are no phases, so this is not an issue.

Lighting

Before considering energy savings for daylight harvesting and controls, electric lighting is expected to consume 30% of the building's energy use. Therefore, making the electrical system feeding the lighting as efficient as possible was critical. The branch panelboard in the lobby, restaurant and office floor electrical rooms is fed by the 380VDC bus duct and distributes 380VDC to the 2 kW and 123 kW of connected lighting in the lobby and the 25 office floors, respectively. With almost 16,000 ft2 of office space, the 380VDC is distributed as close to the loads as possible using strategically located power server modules (PSMs). The modules then convert 380VDC to 24VDC at an efficiency of over 96%, with the 24VDC distribution reaching the lighting, controls, and other low voltage loads through one of the 16 95W output channels.

Each output channel operates independently, so the power to several luminaires can be turned off without disrupting the others. Control wires for the DALI system run separately from the power wiring. The modules can also receive more than one input, allowing emergency circuits to also be connected to a module serving normal loads. Under normal operating conditions, all loads in the module are served by normal power, and only the emergency channels are served by the emergency feed if necessary.

Six PSMs supply all of the 24VDC loads on each office floor, aside from the actuators in the façade, which have their own DC-DC converters. In order to verify that the voltage drop on each branch circuit does not exceed 3%, as recommended by the National Electrical Code (NEC), the placement of the power server modules and wiring to the lighting fixtures was anticipated for the typical office layout. Figure 37 shows the layout and wiring of the circuits to guarantee that the voltage drop on all branch circuits, from DC panel to PSM to load, remains under 3%. The spreadsheet used to conduct these calculations can be found in Appendix F. 12 AWG conductors were used, as this is the same size that is typically found on AC lighting circuits.

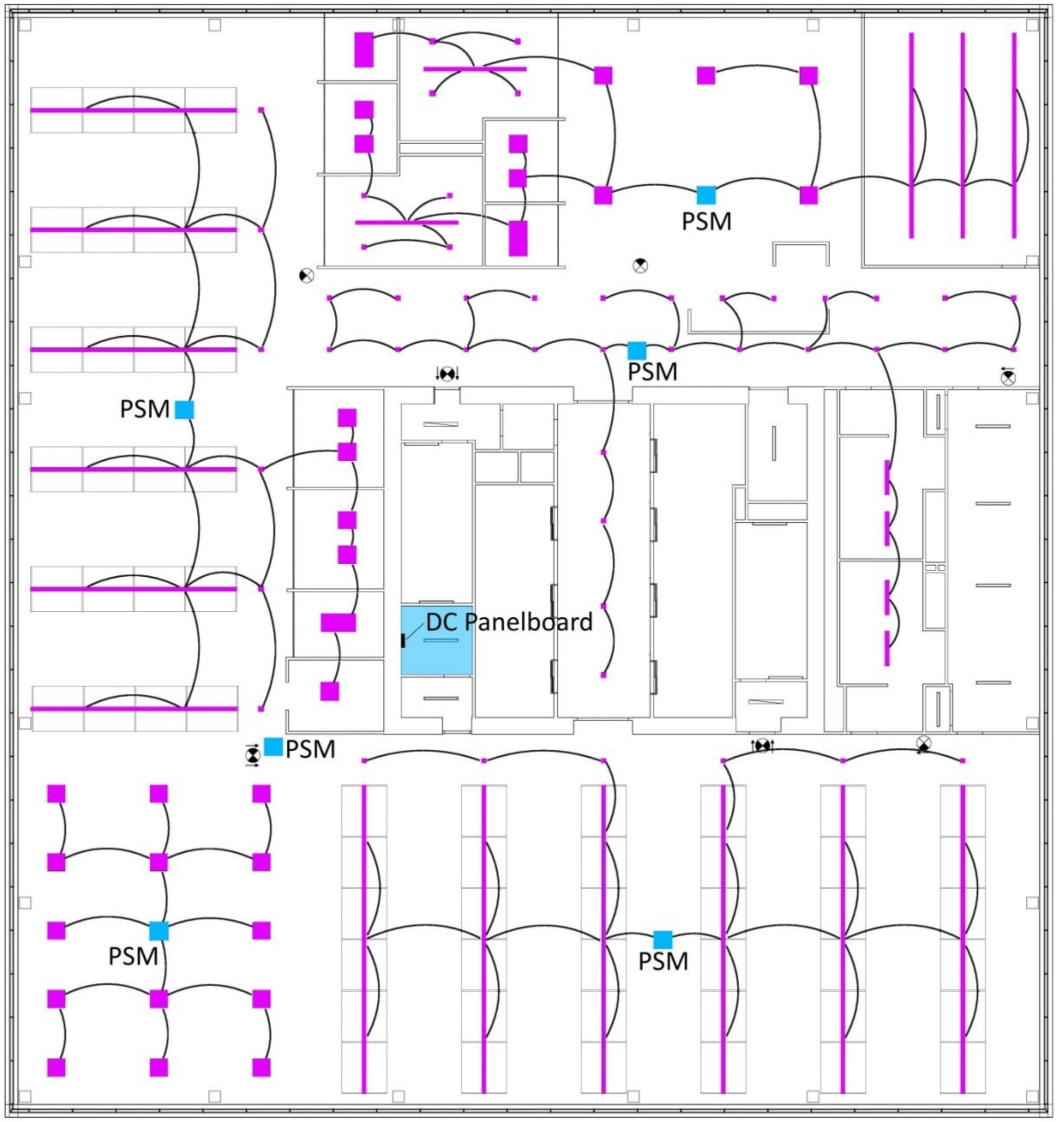


Figure 37. Power Server Module Locations and DC Wiring

With these modules, distribution happens at a higher voltage, preventing voltage drop and allowing the use of the same wire sizes found in a typical AC system. Each module receives the 380VDC distribution voltage and converts it to 24VDC through various output channels for use by the LED DC-DC drivers and DC fluorescent ballasts. From the DC switchgear to each luminaire, the voltage experiences only one 96% efficient conversion at the power server module and minor losses within the DC-DC drivers that regulate the 24VDC current for dimming.

Façade

The actuators that adjust and hold the natural ventilation louvers are located every ten feet within the system. They run on 24VDC and are supplied via the 380VDC panelboard on each office floor, with one 90% efficient 380VDC to 24VDC conversion occurring in a small DC-DC converter located at the first actuator on each façade. Only 1 W of power is required for the actuator to hold the louvers in place, and 2.5 W are required to move them, equating to about 25,000 kWh annually for the entire building.

The electrochromic glass also contributes to the total building load very minimally. At most, it will draw 3 kW of power if all of the installed glass is tinted to the maximum level at the same time, a scenario that will never occur. The current required to tint the glass will also be supplied via a DC-DC converter at approximately 4VDC.

Due to the wide range of efficiencies available for both AC and DC power sources, it is impossible to quantify an exact value for anticipated savings resulting from using DC over AC. However, 350 Mission's electrical design minimizes conversions between the two waveforms. It expands upon the idea of configuring localized DC grids within a building and creates a building-scale DC microgrid to complement the traditional AC distribution, from site generation through end use. This brings 350 Mission one step closer to the goal of [ZEROimpact].

Source Fuel vs. Site Fuel

When considering the impact of a building, it should not be viewed as an isolated system. It leaves an energy, waste, and emissions footprint beyond the building site itself. Reliance on the electric grid expands 350 Mission's boundary of influence to include the power plants and transmission lines of PG&E, as shown in Figure 38.

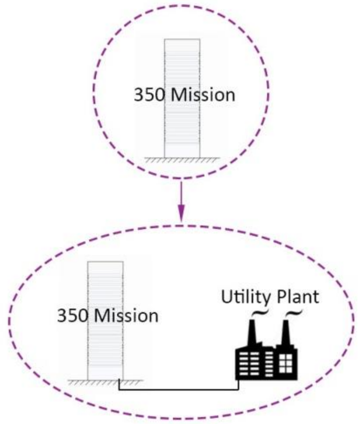


Figure 38. 350 Mission Boundary of Influence

On average, the process of utility generation and distribution is only 31% efficient in the United States. In other words, for every unit of energy reaching the building site, three units of primary fuel are consumed. This awareness of the environmental impact of source fuel was the catalyst behind the decision to use fuel cells for onsite energy generation to reduce dependence on the grid and minimize the overall building footprint.

Fuel Cell

Natural gas comprises approximately 25% of the primary fuel that feeds PG&E's electric utility grid, but there is also an extensive existing network of natural gas lines in downtown San Francisco available for use directly at the building site. Onsite natural gas mitigates the inefficiencies associated with the electric grid, as conservative estimates anticipate approximately 10% transmission losses. Like the boilers and service water heating in 350 Mission, the fuel cells use natural gas as their primary fuel. The fuel cell cycle is outlined in Figure 39.

Three 400 kW units, two DC and one AC, support the expected DC and AC building loads of 535 kW and 393 kW respectively. Two smaller DC fuel cells were chosen, first to allow for flexibility of future use with additional onsite DC energy generation and second to maximize efficiency. The additional capacity would be especially useful for an expansion of the server-based virtual computing or added mechanical equipment. The maximum efficiency for these units occurs when operating around 220 kW output, so using two fuel cells to meet the expected DC power demand comes at no efficiency cost.

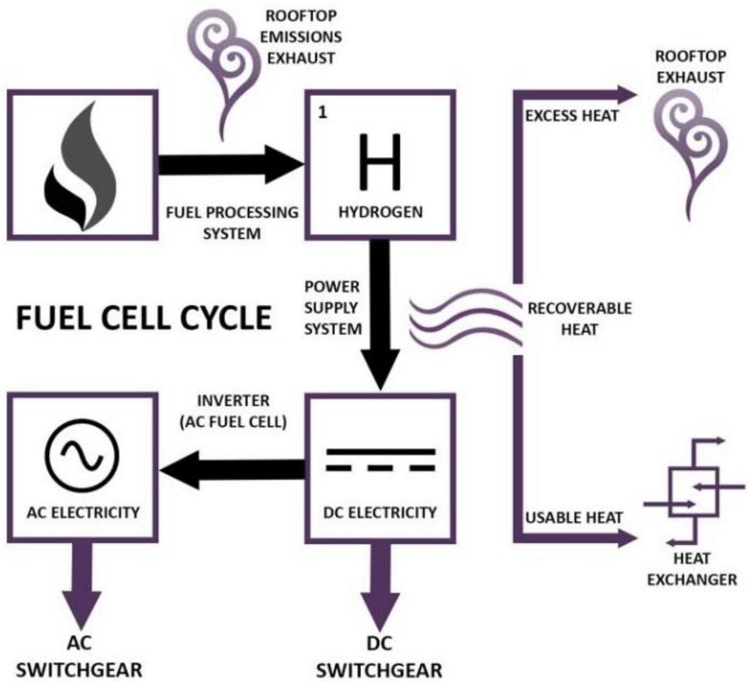


Figure 39. Fuel Cell Cycle Summary

The standard output of the fuel cell is 480VAC power which directly feeds the AC switchgear. The other two fuel cells require a custom order to remove the inverter within the assembly, resulting in 380VDC output that feeds the DC switchgear and producing an efficiency increase by removing a conversion.

Under normal conditions, 350 Mission can operate free of the electric utility grid. In the event of an unexpected peak in demand power, the fuel cell output can be supplemented by the grid through paralleling switchgear. Also, problems with natural gas infrastructure are uncommon but not unprecedented, making this grid connection a necessary source of redundancy. Paralleling also allows electricity to be supplied back onto the grid if the fuel cells and onsite renewable sources are producing more energy than the building requires, and two-way metering ensures that 350 Mission is credited for this energy.

Using fuel cells rather than the utility grid saves about 1,326,000 kWh of primary energy each year, and they also produce heat that is recovered for use in the building's mechanical system. Approximately 343,563 kWh of recovered heat can be used to heat 350 Mission annually, directly reducing the fuel consumption of the natural gas boilers. When considering the electrical generation and recovered heat together, the fuel cells are 48% efficient as compared to the utility's 31%. Though the building's carbon footprint is not eliminated, as CO_2 is still a byproduct, its quantity is greatly reduced. The CO_2 and unused heat will be exhausted via a duct running through the core to the roof of 350 Mission.

The cost of the installation will be approximately $7,000,000, but the capital cost is only $1,000,000 as the system's size qualifies it for over $6,000,000 in self-generation incentives from the federal government and PG&E. Using utility natural gas over electric will also save the building owner $230,000 annually. More information on the fuel cell and calculations can be found in Appendix G.

Server Room

The building computing loads are supported primarily by a virtual desktop infrastructure. Excess space on the lobby mechanical platform was partitioned into a server room, housing the rack servers that provide the majority of the building's processing power. The servers are accessed by thin client desktops, which require less than 20% of the power of full-capacity desktops.

There are approximately 120 thin client desktops and 12 full-capacity desktops per office floor, included to accommodate employees with very heavy program and application uses. The servers were sized to accommodate medium to heavy computing needs on the thin clients.

Servers save substantial energy for two main reasons. First, they can run directly on 380VDC power, eliminating AC-DC conversion losses that occur in computer power supply units and increasing efficiency by more than 15%. Second, they maximize processor utilization. Energy consumption and processing output in computers and servers are not linearly related, so underutilized or idle devices are consuming wasted energy that does not contribute to any real computing application. The servers in 350 Mission were sized adequately but not oversized, ensuring high processor utilization and energy savings.

Onsite server installation was chosen over cloud-based virtual computing because it offers the tenants of 350 Mission more security and flexibility in creating their own computing infrastructure, and again, considering an energy boundary beyond the building site, cloud-based virtualization simply moves the energy consumption to an offsite data center. Cloud-based computing can be implemented by future tenants if desired, simply by removing the servers.

This virtual server-based infrastructure is expected to save 56% in computing energy use annually. A detailed analysis of server sizing and specification and computing power and energy calculations and a graphic outlining data distribution can be found in Appendix H.

Emergency Power System

The building's emergency power is supplied by standby batteries to maximize the advantages of using DC distribution. The emergency loads consist of egress lighting and life safety mechanical equipment, such as smoke exhaust fans and fire pumps, and all are fed with 380VDC. The fire alarm system will run on the battery packs within the control panels in the event of an emergency.

The battery units consist of battery packs wired in series to achieve the high voltage distribution necessary to feed the emergency loads. Many of the emergency loads also operate on normal power during standard building operation. Therefore, the emergency panels are served by normal output from the DC switchgear, and the battery packs are placed in parallel. The output from the DC switchgear is always at a slightly higher voltage, so the batteries are never in use until this normal voltage either stops or decreases substantially in the event of a utility outage or emergency. The building control system periodically verifies that the voltage of the batteries is adequate, and the battery packs replace the need for purchasing a generator and supplying and storing its fuel. This increases the reliability of the emergency system because there is no risk of interruption of the generator fuel supply.

Seismic Design

Lobby Lighting

One of the challenges with the design in the lobby was the conflict between the criteria of visually reducing the scale of the lobby and creating an earthquake-conscious design. The scale reduction was achieved through the use of suspended luminaires; however, these can be dangerous in earthquake scenarios. Neither criterion could be discarded as each was developed for a reason, one for occupant comfort and the other for occupant safety. In order to address both of these concerns, the initial conceptual design using suspended luminaires was maintained, and the design for the lobby follows the guidelines set forth by the Federal Emergency Management Agency (FEMA) and the California Department of General Services (DGS) for the support of pendant mounted light fixtures in earthquake-prone areas. As required by DGS, the design ensures that all luminaires can swing to 45 degrees without the risk of collision with another fixture, support cables, columns, or walls. The model shown in Figure 40 was used to define the swing area of each luminaire and aid in the design of the space. More information about how the design follows these guidelines can be found in Appendix I.

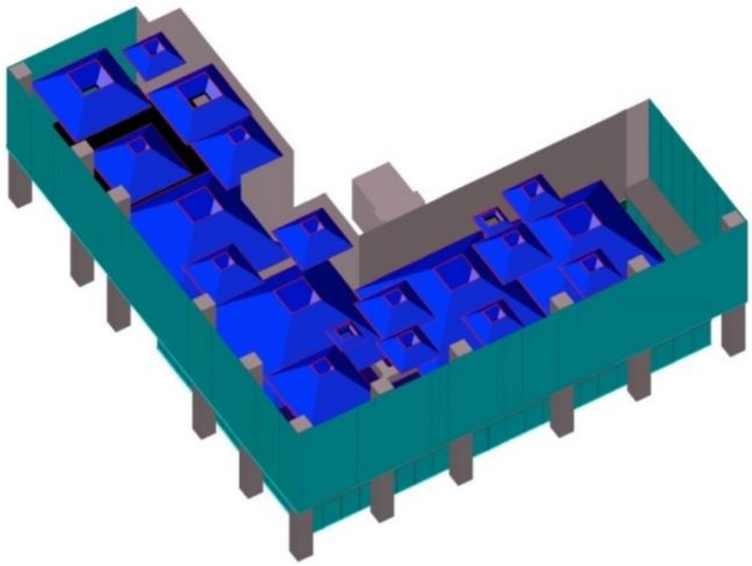


Figure 40. Isometric View of Lobby with Luminaire Swing Areas Defined

Dual Electrical Risers

As San Francisco is located in a seismic region, the electrical system was designed with an extra emphasis on safety and redundancy. In the event of an earthquake or other emergency, it is important for the emergency lighting and other important electrical loads to be maintained. While most buildings have a single set of electrical risers carrying power to the entire building, the electrical design for 350 Mission contains two sets of electrical risers, one being the bus duct located in the main electrical room and the other located in the electrical closet, as shown in Figure 41.

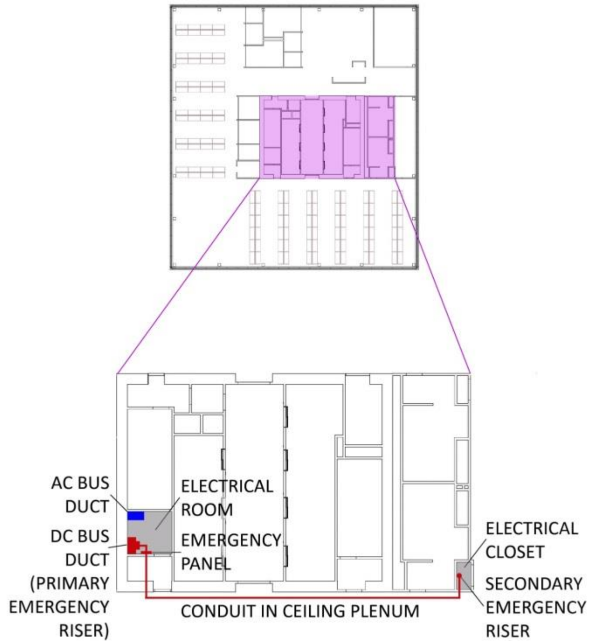


Figure 41. Electrical Riser Locations

Multiple electrical risers have been utilized in other buildings in earthquake-prone areas, such as Taipei 101 in Taiwan.[6] The rooms are located on opposite sides of the core, decreasing the likelihood that risers located in both locations would be damaged in the event of an earthquake.

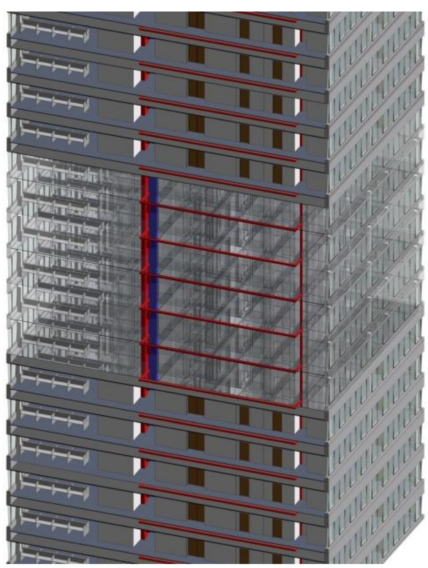


Figure 42. Isometric View of Dual Riser System

As shown in Figure 42, the electrical room contains the normal power electrical risers, both AC (blue) and DC (red), and a DC emergency riser. During normal building operation, the entire electrical load is served by the electrical room. If the utility fails during an emergency, the building will switch to battery power and feed the emergency loads, which are all on DC power, through the electrical room emergency riser.

If the electrical risers in the main electrical room are damaged, the building clearly will have undergone serious structural damage, and occupant safety during egress will be of paramount importance. In this situation, getting power to the emergency loads would be impossible with a traditional single riser. 350 Mission has a secondary emergency riser that serves the life safety loads. If the primary riser is damaged, an ATS switches the emergency battery feed to this secondary emergency riser, supplying power to the most vital building loads. All of the emergency loads are on DC power, and as a result, the electrical closet will only contain a DC riser.

Plug Load Controls

Like most modern office buildings, plug loads comprise more of the overall electrical energy use than any other component or system. Computers, electronics, and appliances that remain plugged in continue to draw small amounts of power, despite the fact that they might be in standby mode or even turned off. Since unplugging everything at the end of the day is impractical, plug load controls help remedy this wasted energy, which is sometimes called a “phantom load.” Quantifying the savings from plug load controls is complex and involves many assumptions about future use.

In order to quantify these savings, the results of an extensive plug load control study conducted by the California Utilities Statewide Codes and Standards Team in conjunction with

PG&E using prototype office spaces was used [13]. The study's recommended plug load control strategies are employed in 350 Mission, with similar energy savings expected.

As summarized in Table 12, time switch controls are used to open circuits during non-working hours in order to achieve maximum energy savings. Occupancy sensors also supplement the time clock in some spaces to save energy during working hours when electronics are not in use. Despite potential energy savings, some electronics should always remain in at least a standby power mode, such as continuous-use devices, like refrigerators. Desktops are also considered non-controllable loads, since they might receive updates or be remotely accessed at any time, and VoIP phones must always be capable of receiving messages.

Table 12. 350 Mission Plug Load Controls Summary

Plug Load	Control Strategy
Computer monitors	These devices operate on both time clock controls and occupancy sensors. There is no threat of losing data if the device shuts off due to inactivity in the space. With 120 open office work stations per floor, under-desk occupancy sensors have the potential to save task lighting and computer monitor energy. AV equipment in conference rooms may go unused for long periods of time when the rooms are empty.
Open office task lighting	
Audio/visual equipment	
General use receptacles	
Printing, copying, and scanning equipment	Receptacles serving these loads operate solely on a time clock. Most kitchen appliances require operation throughout the work day, even when the kitchen is not occupied, and copy room devices often receive signals when the room is empty.
Kitchen Appliances	

The intelligence behind the plug load system will rely on the DALI system and the established infrastructure of controls that are using for the office lighting. Controlling plug loads comes at a higher capital cost with more complex installation, as circuiting must be done such that loads with similar controls are included on the same circuits, but this quickly pays for itself through energy savings. As with any energy saving system, the occupants must be educated on how the system operates to maximize participation. This control strategy is expected to save 183,000 kWh annually, as summarized in Table 13.

Table 13. Expected Plug Load Energy Savings

Plug Load Savings			
Large Offices	0.61	kwh / year / ft.^{2}	Based on "large" (175,000 ft.^{2} office)
350 Mission Area	300,000	ft.^{2}	Usable office space on 25 office floors
Estimated Energy Savings	183,000	kwh / year	See plug load control section for description of control strategy

The power plan is shown in Figure 43. Quadruplex receptacles are provided at workstations to provide power to the thin client computers. Other receptacles are located throughout the space to accommodate less consistent loads. Junction boxes in the ceiling show the locations of the DC power supply modules.

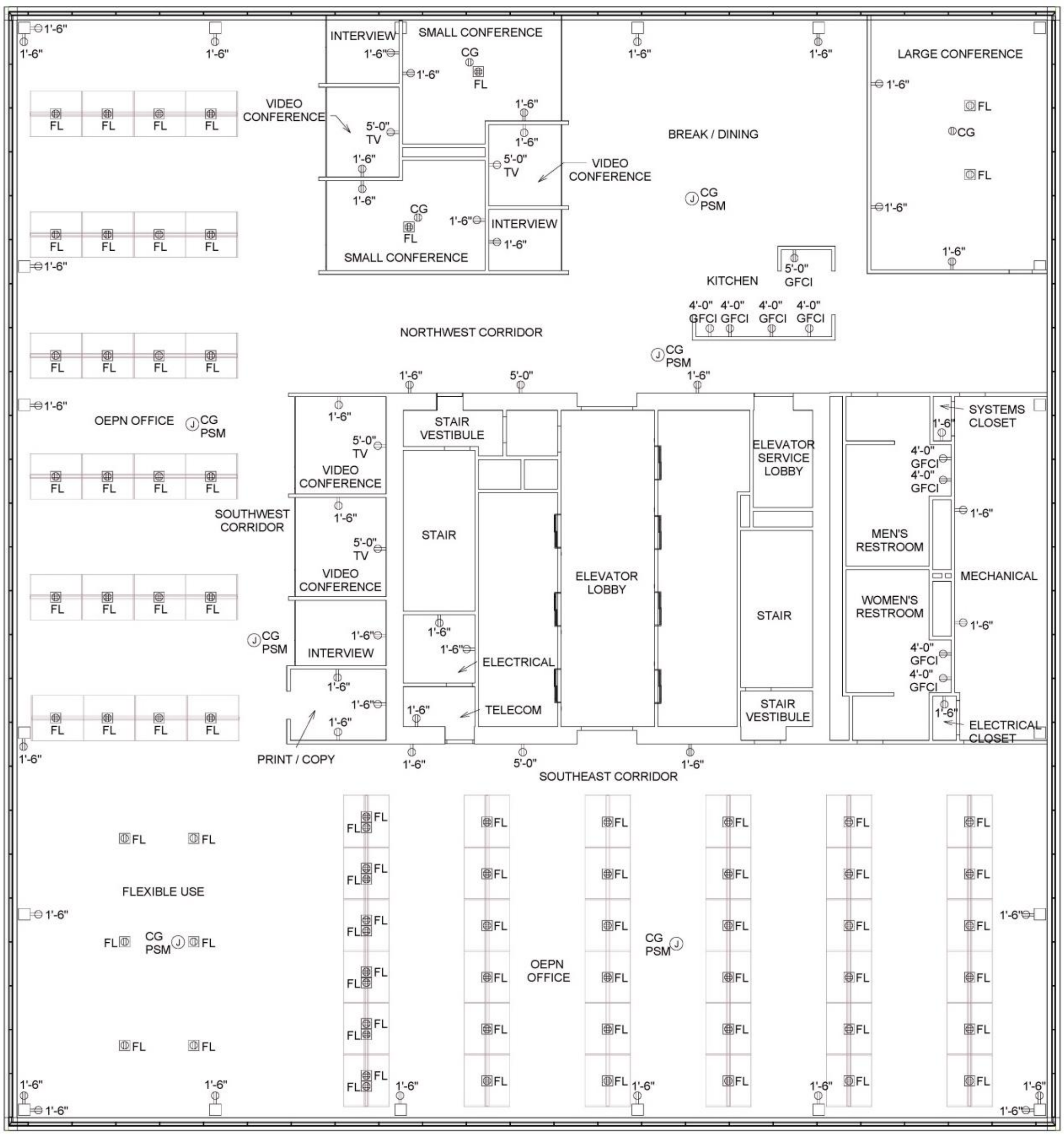


Figure 43. Office Floor Power Plan

The spreadsheet shown in Table 14 summarizes the connected, demand, and expected office receptacle loads.

Table 14. Office Receptacle Load Summary

Type	Location	Purpose	Quantity	Maximum Power per		Connected Power per floor		Connected Power for Building		Demand Power for Building		Expected Demand Power for		Notes and Assumptions about Expected Demand Power
General Use Receptacles														
Duplex	Column covers	General use	18	180	VA	3.24	kVA	81	kVA	45.5	kVA	4.55	kV	Assume 10% are in use at any given time
Open Office														
Quadruplex	Open office floor, under desk partitions	Thin client desktops, computer monitors	66	360	VA	23.8	kVA	594	kVA	594	kVA	222	kVA	Thin client desktop = 30W, LED backlit monitor = 30W, full desktop = 175W (Max power) Assume 10% full desktop
Hard-wired	At each open office desk	Task light	120	6.5	VA	0.78	kVA	19.5	kVA	19.5	kVA	12.19	kVA	Assume that 50% of task lights will be at full output and 25% at half output simultaneously
Flexible Space														
Duplex	Floor	Thin client desktops, computer monitors	6	180	VA	1.1	kVA	27	kVA	27	kVA	10.5	kVA	Thin client desktop = 40W, LED backlit monitor = 30W (Max power)
Large Conference Room														
Duplex	Walls	General use of additional electronics	3	180	VA	0.5	kVA	13.5	kVA	11.8	kVA	5.88	kVA	Assume that 50% of conference rooms are simultaneously in use
Duplex	Ceiling	Video projector	1	180	VA	0.2	kVA	4.5	kVA	7.25	kVA	3.63	kVA	Assume that 50% of conference rooms are simultaneously in use
Duplex	Floor	For use at central conference table	2	180	VA	0.4	kVA	9	kVA	9	kVA	4.50	kVA	Assume that 50% of conference rooms are simultaneously in use
Small Conference Rooms														
Duplex	Walls	General use of additional electronics	4	180	VA	0.7	kVA	18	kVA	14	kVA	7	kVA	Assume that 50% of conference rooms are simultaneously in use
Duplex	Ceiling	Video projector	2	180	VA	0.4	kVA	9	kVA	9.5	kVA	4.75	kVA	Assume that 50% of conference rooms are simultaneously in use
Quadruplex	Floor	For use at central conference table	2	360	VA	0.7	kVA	18	kVA	18	kVA	9	kVA	Assume that 50% of conference rooms are simultaneously in use
Video Conference Rooms														
Duplex	Near TV screen	Operation of TV and video conference equipment	4	180	VA	0.7	kVA	18	kVA	18	kVA	2.23	kVA	TV, LCD = 60W, speakers = 30W Assume that 33% of video conference rooms are simultaneously in use
Duplex	Adjoining wall	General use of additional electronics	4	180	VA	0.7	kVA	18	kVA	14	kVA	4.62	kVA	Assume that 33% of video conference rooms are simultaneously in use
Interview Rooms														
Duplex	Wall	General use of electronics	3	180	VA	0.5	kVA	13.5	kVA	11.8	kVA	2.35	kVA	Assume that 20% of interview rooms are simultaneously in use
Printer/Copier Room														
Duplex	At equipment locations	(1) laser printer, (1) inkjet multifunction printer	1	180	VA	0.2	kVA	4.5	kVA	4.5	kVA	2.34	kVA	Laser printer = 130W, Inkjet MFD = 26W Assume 60% of units are in use simultaneously
Duplex	Opposite walls of current equipment	General purpose recetacles for growth	2	180	VA	0.4	kVA	9	kVA	9	kVA	0.9	kVA	Assume 10% are simultaneously in use
Northwest and Southeast Corridors														
Duplex	around building core	General use	4	180	VA	0.7	kVA	18	kVA	14	kVA	1.4	kVA	Assume 10% are simultaneously in use
Duplex	Entrance to elevator corridor	TV's showing energy use on office floor	2	180	VA	0.4	kVA	9	kVA	9.5	kVA	3	kVA	TV, LCD = 60W
Kitchen														
Duplex (special purpose) GFI	At equipment locations	Coffee maker	1	464	VA	0.5	kVA	11.6	kVA	11.6	kVA	5.59	kVA	Equipment on standby = 2W Assume 50% of coffee makers are on standby, 50% active
Duplex (special purpose) GFI	At equipment locations	Microwave oven	1	1620	VA	1.6	kVA	40.5	kVA	40.5	kVA	11.39	kVA	Equipment on standby = 3W Assume 75% of microwaves are on standby, 25% active
Duplex GFI	At equipment locations	Water dispenser	1	180	VA	0.2	kVA	4.5	kVA	4.5	kVA	0.65	kVA	Water dispenser = 90W, standby = 1W Assume 75% of dispenser are on standby, 25% active
Duplex (special purpose) GFI	At equipment locations	Hot beverage dispenser	1	1650	VA	1.7	kVA	41.3	kVA	41.3	kVA	12.90	kVA	Equipment on standby = 75W Assume 75% of dispensers are on standby, 25% active
Duplex (special purpose) GFI	At equipment locations	Refrigerator	1	650	VA	0.7	kVA	16.3	kVA	16.3	kVA	16.25	kVA	Always in use
Restrooms														
Duplex GFI	Above sinks	Miscellaneous use	4	180	VA	0.7	kVA	18	kVA	14	kVA	0.70	A	Assume 5% are simultaneously in use
Utility Spaces (Electrical, Mechanical, Telecom)														
Duplex	Walls	Miscellaneous use	7	180	VA	1.3	kVA	31.5	kVA	20.8	kVA	1.04	kV	Assume 5% are simultaneously in use
OFFICE FLOORS TOTAL								**Connected**		**Demand**		**Expected**		
								1034	kVA	968	kVA	341	kV	

Building Space Use Summary

The diagram shown in Figure 44 details the locations of the various equipment and system components and gives a clearer picture of how all of the various parts work together to create the final overall lighting and electrical system.

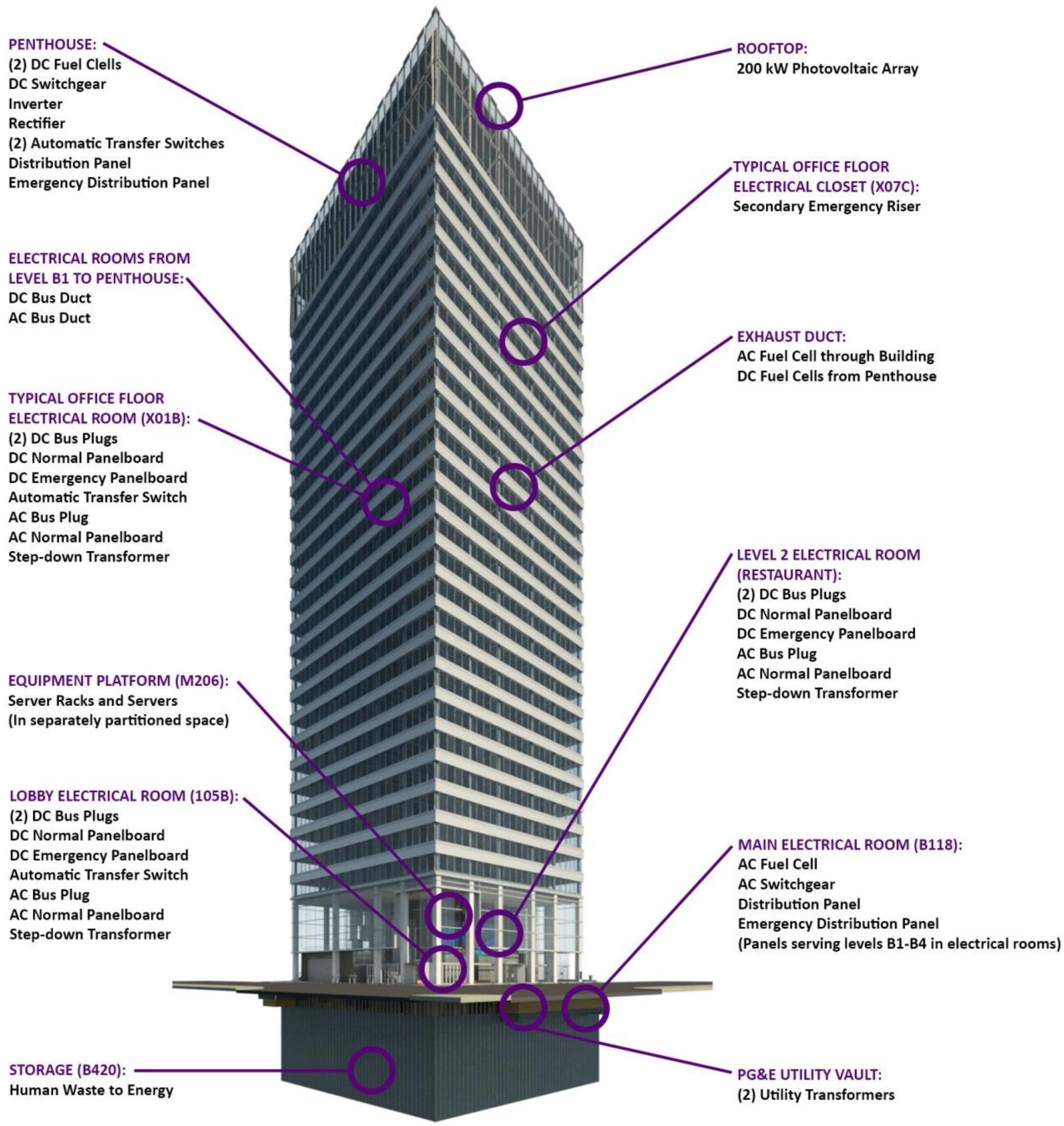


Figure 44. Building Equipment Summary

Chapter 7

Fire Alarm Design

The primary fire alarm control panel is located in the fire command room on the first floor of the lobby. This panel contains the logic of the fire alarm system by interfacing with the BACnet system's duct smoke detectors and receives input from smaller panels located on each level of the building. The fire alarm circuits run on 24VDC.

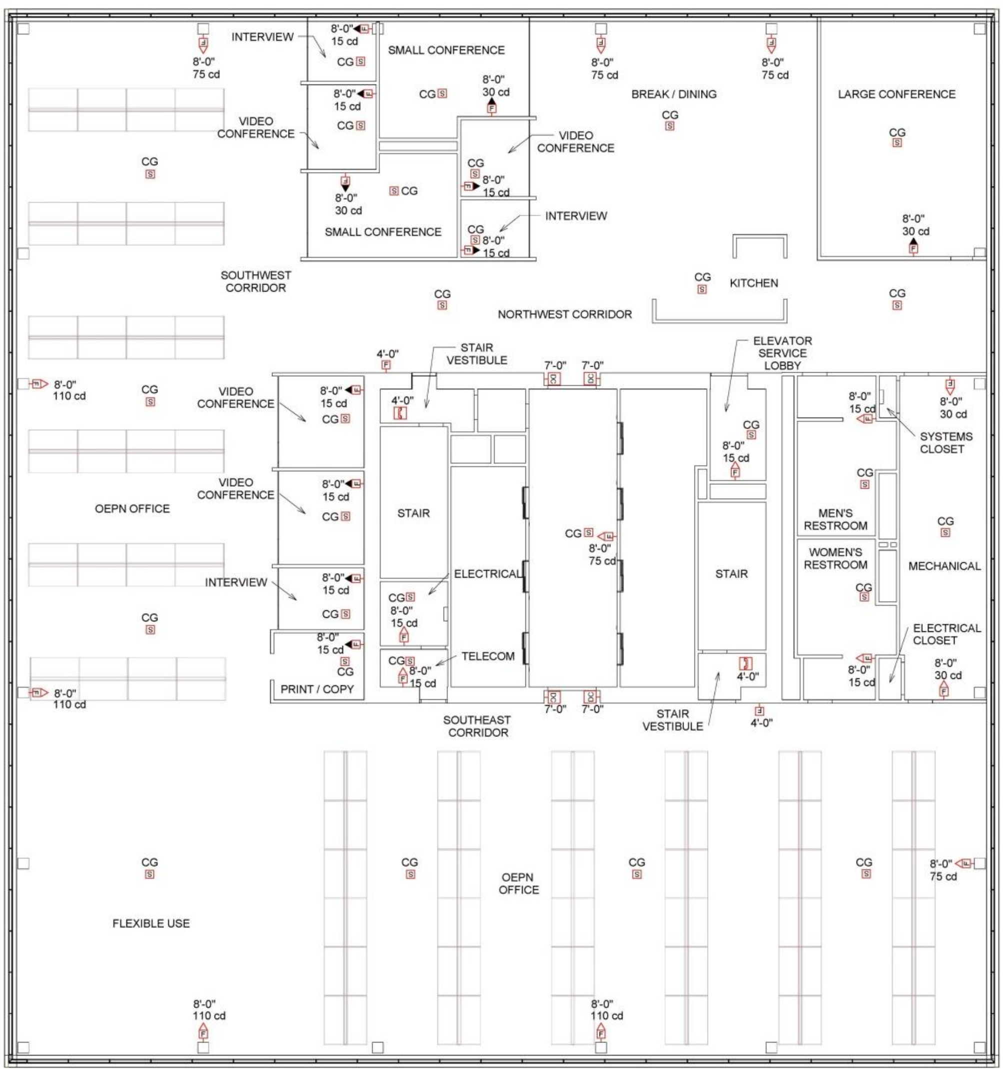


Figure 45. Office Floor – Fire Alarm Plan

As shown in the floor plan in Figure 45, two small control panels are located in the electrical room and systems closets on each floor. These are fed by 208Y/120VAC with integral rechargeable battery backup in accordance with National Fire Protection Association mandates.

Figure 46. Open Office and Circulation Speaker-Strobe Coverage

After receiving a signal from the alarm initiation devices, notification appliances shown in Figure 46 alert occupants to the potential emergency. Speaker-strobe devices are located in open spaces, corridors, and utility spaces, and their coverage is shown. Visual strobes are located in all of the conference rooms. Automatic door operators automatically close (but do not lock) the doors to the elevator lobby in the event of an emergency to discourage elevator use and prevent the spread of fire through the core.

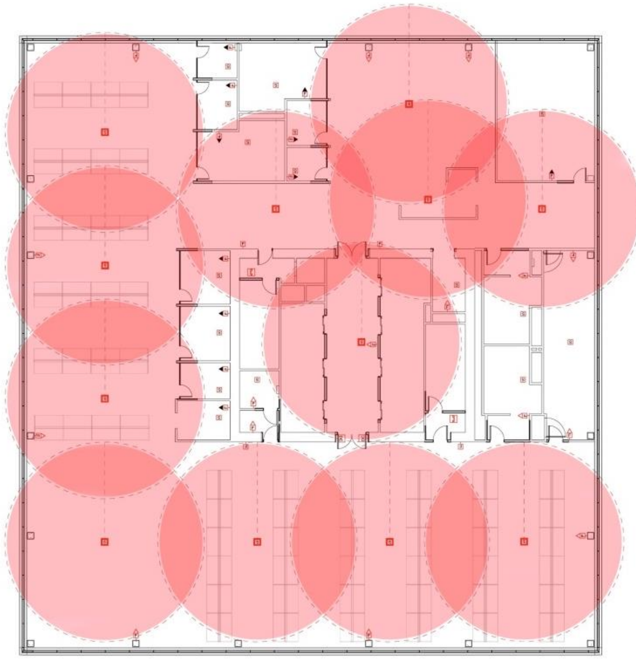


Figure 47. Open Office and Circulation Smoke Detector Coverage

Each panel has two 24VDC initiating device circuits that supply the smoke detectors and manual pull stations. The 20’ radius smoke detector coverage of the open spaces and corridors is shown in Figure 47, and each separately partitioned space has its own dedicated smoke detector. Manual pull stations are located in the primary egress path at the entrances to the stairways. Stair vestibules contain rescue intercom stations for two-way communication with a central station to dispatch the fire department.

Chapter 8

Data/Telecommunications Design

The data and telecom infrastructure provides the flexibility for future building occupants to create a building area network (BAN) or multiple local area networks (LANs) to allow data sharing between network users. The servers providing computing power and the telecom equipment loads are served by the 380VDC distribution and converted using a highly efficient 380VDC-48VDC power supply designed for data and telecom applications.

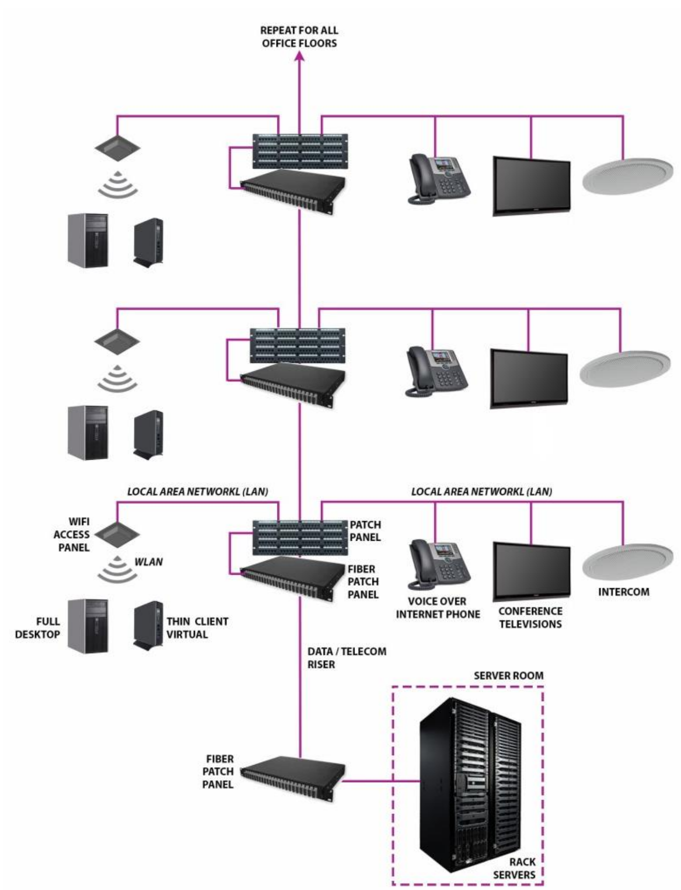


Figure 48. Building Data Riser Schematic

Figure 48 shows a schematic of the building data system. At each floor, the data and telecom services are supplied through a fiber patch panel and patch panel. Six hardwired access panels provide WiFi, and open office workstations are equipped with a voice/data outlet for VoIP phones, as shown in the floor plan in Figure 49. Conference rooms have a TV outlet and voice/data outlet. TV outlets/TVs are also provided near the elevator lobby to make occupants aware of their monthly energy usage.

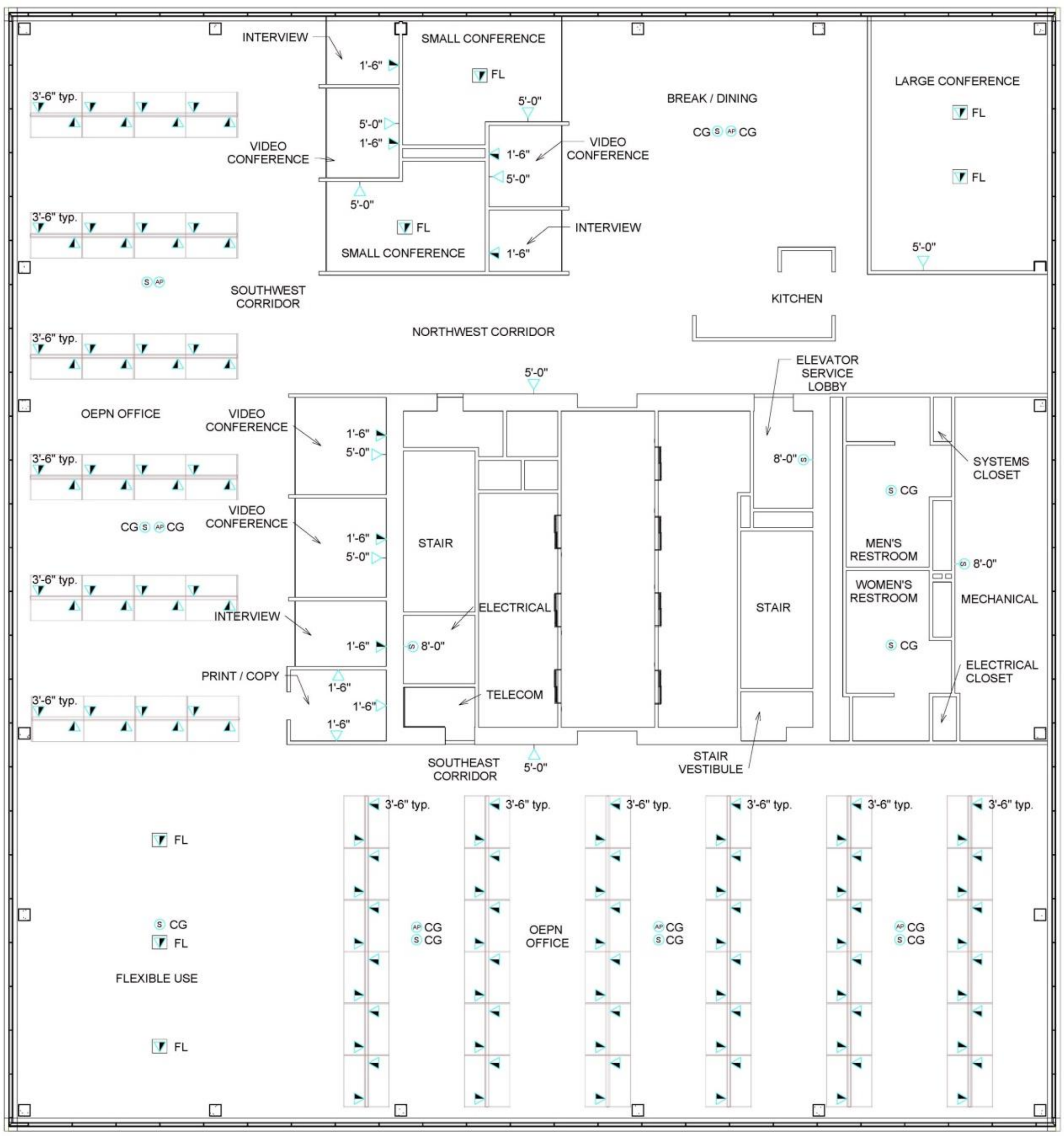


Figure 49. Office Floor – Data and Telecommunications Floor Plan

Chapter 9

LEED

Under the LEED 2009 for New Construction and Major Renovations Checklist, 350 Mission can achieve LEED Platinum Accreditation, accumulating 93 points out of a possible 110 points. Receiving Daylight & Views credits, along with other points associated with lighting and electrical design, contributed to achieving this level of certification. [12]

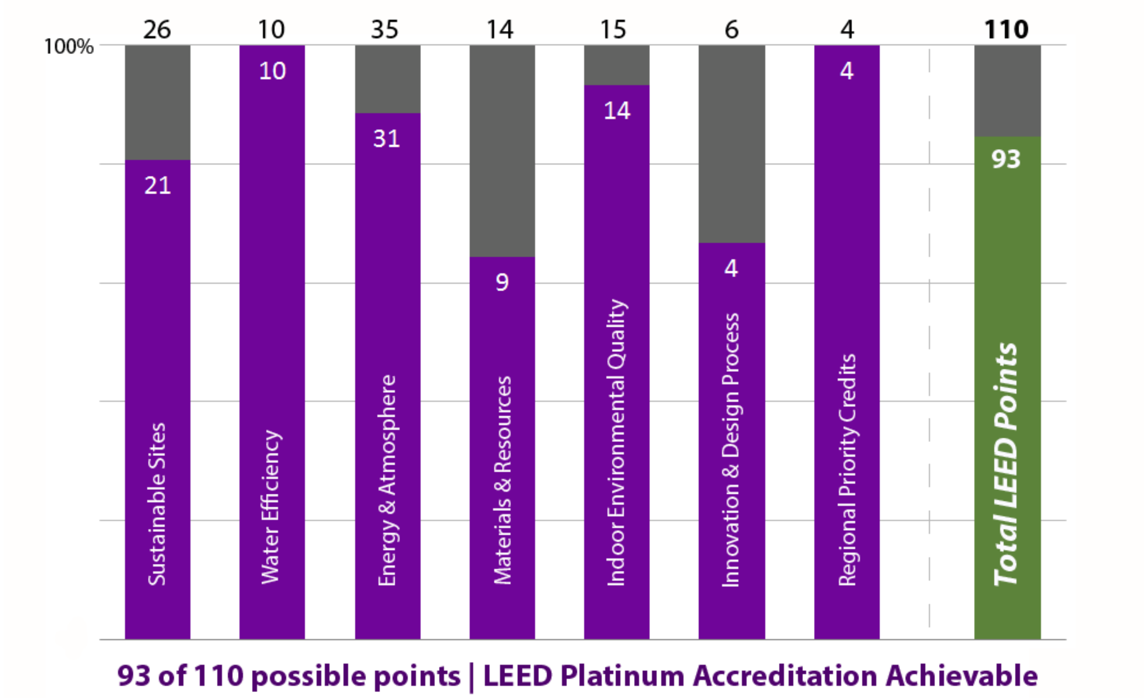


Figure 50. LEED Point Summary

Figure 50 summarizes the LEED points achieved in each of the seven categories. The complete list of categories and points received is listed below:

Sustainable Sites (21/26 Points)

Prereq 1	Construction Activity Pollution Prevention	
Credit 1	Site Selection	1 Point
Credit 2	Development Density and Community Connectivity	5 Points
Credit 4.1	Alternative Transportation – Public Transportation Access	6 Points
Credit 4.2	Alternative Transportation – Bicycle Storage and Changing Rooms	1 Point

Credit 4.3	Alternative Transportation – Low-Emitting and Fuel-Efficient Vehicles	3 Points
Credit 4.4	Alternative Transportation – Parking Capacity	2 Points
Credit 6.1	Stormwater Design – Quantity Control	1 Point
Credit 7.1	Heat Island Effect – Non-roof	1 Point
Credit 8	Light Pollution Reduction	1 Point

Water Efficiency (10/10 Points)

Prereq 1	Water Use Reduction – 20% Reduction	
Credit 1	Water Efficient Landscaping | No Potable Water Use or Irrigation	4 Points
Credit 2	Innovative Wastewater Technologies	2 Points
Credit 3	Water Use Reduction | Reduce by 40%	4 Points

Energy and Atmosphere (31/35 Points)

Prereq 1	Fundamental Commissioning of Building Energy Systems	
Prereq 2	Minimum Energy Performance	
Prereq 3	Fundamental Refrigerant Management	
Credit 1	Optimize Energy Performance| Improve by 48%+ for New Buildings	19 Points
Credit 2	On-Site Renewable Energy | 72% Renewable Energy	7 Points
Credit 3	Enhanced Commissioning	2 Points
Credit 5	Measurement and Verification	3 Points

Materials and Resources (9/14 Points)

Prereq 1	Storage and Collection of Recyclables	
Credit 2	Construction Waste Management | 75% Recycled or Salvaged	2 Points
Credit 3	Materials Reuse | Reuse 10%	2 Points
Credit 4	Recycled Content | 20% of Materials	2 Points
Credit 5	Regional Materials	2 Points
Credit 7	Certified Wood	1 Point

Indoor Environmental Quality (14/15 Points)

Prereq 1	Minimum Indoor Air Quality Performance	1 Point
Prereq 2	Environmental Tobacco Smoke (ETS) Control	1 Point
Credit 1	Outdoor Air Delivery Monitoring	1 Point
Credit 2	Increased Ventilation	1 Point
Credit 3.1	Construction IAQ Management Plan – During Construction	1 Point
Credit 3.2	Construction IAQ Management Plan – Before Occupancy	1 Point
Credit 4.1	Low-Emitting Materials – Adhesives and Sealants	1 Point
Credit 4.2	Low-Emitting Materials – Paints and Coatings	1 Point
Credit 4.3	Low-Emitting Materials – Flooring Systems	1 Point
Credit 4.4	Low-Emitting Materials – Composite Wood and Agrifiber Products	1 Point
Credit 5	Indoor Chemical and Pollutant Source Control	1 Point
Credit 6.1	Controllability of Systems – Lighting	1 Point
Credit 6.2	Controllability of Systems – Thermal Comfort	1 Point
Credit 7.1	Thermal Comfort – Design	1 Point
Credit 7.2	Thermal Comfort – Verification	1 Point

Credit 8.2	Daylight and Views - Views	1 Point

Innovation and Design Process (4/6 Points)

Credit 1.1	Innovation in Design: Acoustics Pilot Credit	1 Point
Credit 1.2	Innovation in Design: Interior Lighting – Quality Pilot Credit	1 Point
Credit 1.3	Innovation in Design: Sustainable Wastewater Management Pilot Credit	1 Point
Credit 2	LEED Accredited Professional	1 Point

Regional Priority Credits (4/4 Points)

Credit 1.1	Regional Priority: On-site Renewable Energy	1 Point
Credit 1.2	Regional Priority: Daylight & Views - Daylight	1 Point
Credit 1.3	Regional Priority: Innovative wastewater technologies	1 Point
Credit 1.4	Regional Priority: Water use reduction	1 Point

Total LEED Points 93/110

Chapter 10

Conclusion

The underlying attitude of [ZEROimpact] guided the approach of the project through the four design emphases of [ZEROenergy], [ZEROinterruption], [ZEROwaste], and [ZEROemissions]. In conjunction with other building systems, the lighting and electrical system design effectively contributes to all four areas while remaining economically feasible. The approach has culminated in a design that is beneficial to the environment, building occupants, and owner.

Fuel savings due to the mechanical and electrical systems are summarized in Figure 51.

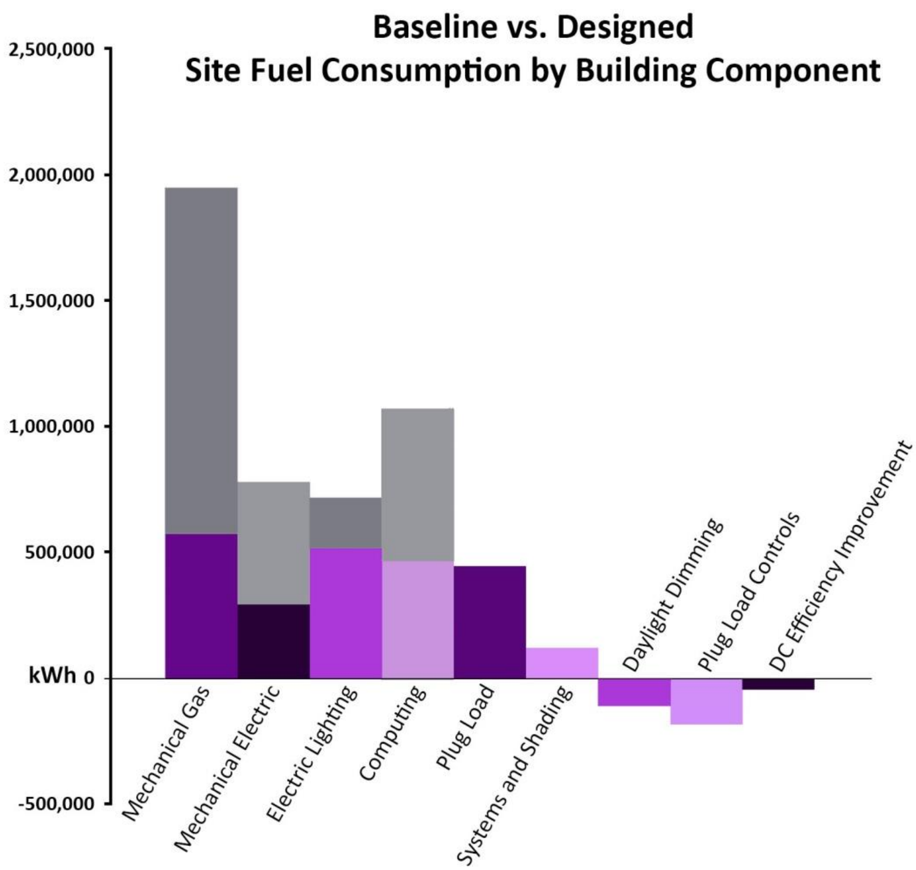


Figure 51. Baseline vs. Designed Site Fuel Consumption by Building Component

The lighting design features a daylighting and control system and energy efficient lighting that result in over 100,000 kWh of savings annually and a building LPD of 0.434 W/sf, as compared to the code-allowed value of 0.728 W/sf.

The innovative electrical system fully embraces DC distribution, using it to power computer servers, LED lighting, VFDs, motors, low voltage controls, and other devices. Virtual computing eliminates the need for full-sized desktop computers at every workstation, saving almost 600,000 kWh each year.

Fuel cells supply energy to the building and save over $230,000 in energy costs annually by allowing the owner to purchase natural gas rather than electricity from the utility grid, and their exhaust heat is sufficient to cover the heating needs of the building 87% of the time.

Energy is generated via onsite and offsite solar arrays, as well as an onsite human waste-to-power converter. These systems combined generate 5,544,000 kWh annually, which is more than enough to cover the building's overall annual consumption of 5,264,570 kWh.

With its advanced mechanical and electrical systems, 350 Mission has a higher upfront cost than the baseline building meeting the code-minimum requirements, as shown in Figure 52.

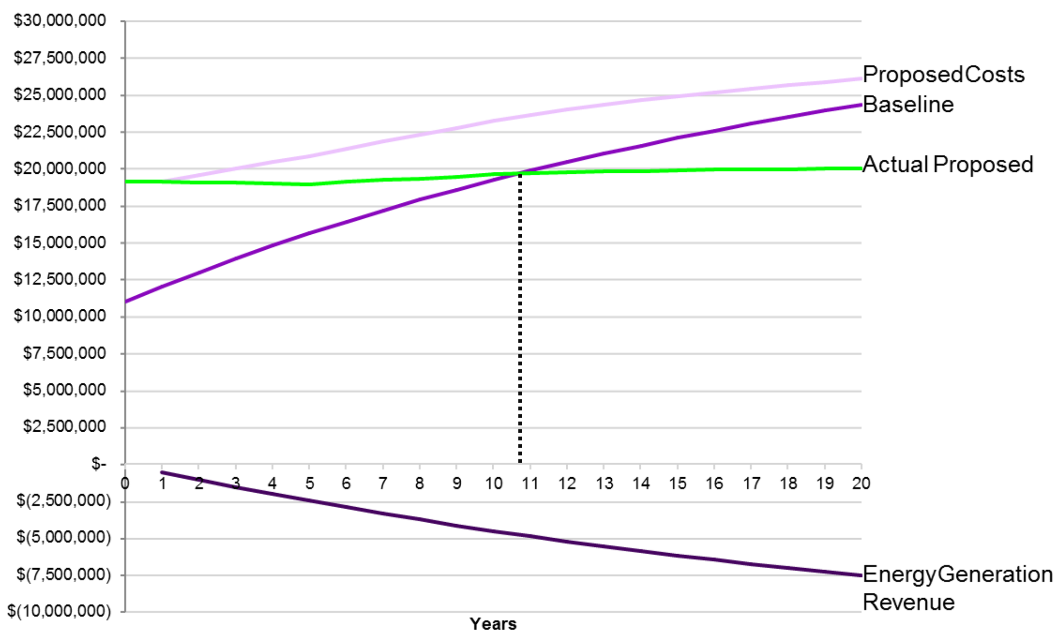


Figure 52. Net Present Value of Mechanical and Electrical Proposed Design Compared to Baseline

However, through the profit accrued by selling the energy generated by onsite and offsite solutions back to the utility company, these advanced systems will pay back in 10.8 years, making them well worth the initial investment.

350 Mission adheres to the traditional definition of net-zero by returning as much energy to the grid as it consumes in a year, and it also meets the broader goals defined by **AEVITAS** by minimizing emissions and waste and by creating a design that responds to the earthquake-prone environment to ensure continuity of operation even after a seismic event.

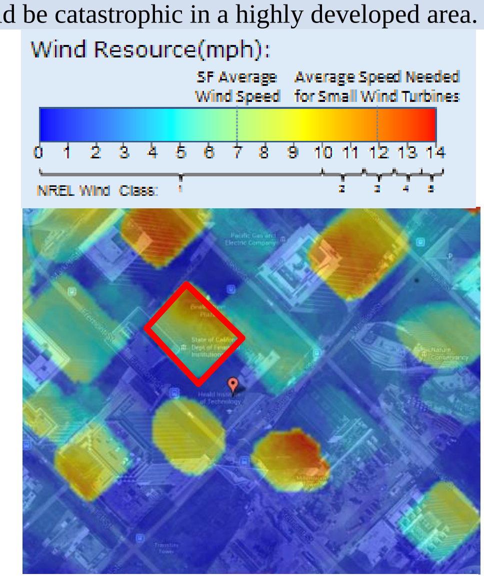
The final building design successfully responds to the project requirements and achieves the project goals through the use of innovative and efficient design techniques.

Appendix A

Rejected Energy Generation Methods

Onsite Energy

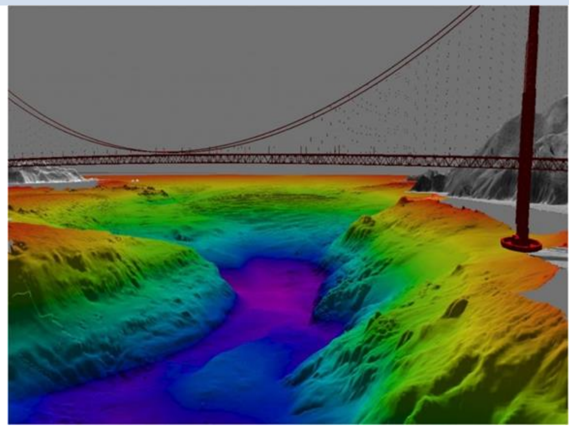
Table 15. Rejected Onsite Energy Generation Methods

Alternative Energy Technology	Reason(s) for Rejection	Details
Geothermal electrical generation	Feasibility, threat of induced seismicity	While geothermal heating is possible, ground water temperatures hot enough to power steam turbines for electricity generation require drilling more than 1 mile into the earth. This scale of drilling would not reasonably occur under a highrise in downtown San Francisco. Drilling at that scale for geothermal wells in a highly seismic region also runs the risk of induced seismic events, events that could be catastrophic in a highly developed area.
Wind	Building site	The average wind speed required for building-scale wind turbines is about 12 mph, and San Francisco's average wind speed is 7 mph. However, the effect of wind funneling through the downtown buildings also had to be considered. In general, tall buildings to the northwest of Market Street tend to obstruct and redirect the flow of wind, decreasing the downwind resource southeast of Market. In Figure 53, the building outlined in red is 35' taller than 350 Mission and only has potential on a portion of its roof. Even this potential is not present on the roof of 350 Mission, as it is blocked by the red building.[7]  Figure 53. Wind Velocity Map
PaveGen	Cost, lack of useful production	PaveGen floor tiles use piezoelectric polymers to convert kinetic energy in the form of footsteps to mechanical energy. This technology was explored due to the anticipated high foot traffic in the building lobby and circulation spaces and because it is highly renewable by harnessing the movement of occupants. While PaveGen is a unique feature, the energy generated is difficult to quantify based on its existing installations (several have been installed in past testing phases) and the initial cost is unreasonable for a large installation. Instead, PaveGen will be used as a teaching tool in the public art installation and not relied upon as a substantial source of energy.

Algae and Plant Biomass	Issue of scale, location	While algae and plant biomass has been successfully implemented in buildings, the scale of onsite biomass that could be achieved in an urban setting for a highrise would not provide enough electrical power to justify the additional costs and maintenance associated with it. Successful building installations of algae have taken place on sites with a great deal of sun exposure, which is necessary to cultivate the biomass. Instead of creating biomass fuels onsite, the goal is to utilize byproducts of occupancy, namely human waste, to create energy.
Municipal Waste to Power Converter	Inadequate volume of input materials	The city of San Francisco is on a mission to become the greenest city in America, with the ultimate goal of diverting 100% of its waste from landfills by the year 2020. The city is currently diverting about 80% of its waste due to composting and recycling programs. The conversion process takes non-recyclable and non-compostable waste and turns it into usable power through a gasification process. While this technology was found to be very useful, with the small amount of applicable waste produced by the 350 Mission, it is not worth the investment and will not produce a useful amount of power.

Offsite Energy

Table 16. Rejected Offsite Energy Generation Methods

Alternative Energy Technology	Reason(s) for Rejection	Details
Geothermal electrical generation	Cost, issue of scale, procurement of land	San Francisco lies within California's "Pacific Ring of Fire," which makes it a prime location for geothermal energy generation. PG&E receives some of its utility capacity from The Geysers, a large complex of geothermal plants located 72 miles north of San Francisco. Creating a geothermal electrical generation site to offset the energy usage of one building becomes impractical due to the cost and issues of scale associated with it.
Tidal energy	Infancy of technology, lack of suitable locations, permits	 **Figure 54. San Francisco Bay Bathymetry** San Francisco Bay was identified as a potential site for tidal energy because it has strong currents, minimal turbulent flow, and areas with appropriate depths. An extensive study was conducted jointly by PG&E, the City of San Francisco, and Golden Gate Energy Company on the potential use of tidal power as a renewable energy source in San Francisco Bay. The study found that the only locations in the generally shallow bay that were deep enough for tidal turbines and had high enough water velocity to move them were located in shipping lanes. The bathymetry can be seen in Figure 54. As of May 2011, after pumping millions of dollars into the study, PG&E abandoned its efforts, saying that tidal power is still too new for practical use in the Bay.[5]
Wind	Issue of scale, procurement of land	Most wind energy in California is concentrated at three utility-scale wind farms. The closest one is located at Altamont Pass, lying 40 miles east of San Francisco. The use of wind energy has seen large increases in California over the past decade, and offshore wind has even been explored by the city of San Francisco. However, much like geothermal electrical generation, creating a large-scale wind farm to offset the electrical use of one building is an ambitious pursuit. Not to mention, PG&E already uses the wind energy at Altamont Pass as one of its renewable sources.

Appendix B

Onsite and Offsite Energy

Onsite Solar

Table 17. Onsite Solar Costs

	Cost
Solar Panels	$360,000

Table 18. Onsite Solar Income/Incentives

	Amount
Incentives	$108,000
Annual energy generation	194,144 kWh
Annual Income	$20,400

With the minimum 30% incentives, the array will cost $3,580,500 and will pay back in 12.4 years. With 50% covered by incentives, this payback period is reduced to 8.8 years.

Table 19. Portion of Onsite Solar Array Analysis Spreadsheet

Onsite Solar Potential Analysis									
Area represented by each point			3.861225	ft^2	=	0.358719	m^2		
Sensor Point			Sensor Orientation			Annual	Daily	Annual	Daily
x	y	z	x	y	z	kwh/m2	kwh/m2	kwh	kwh
-92.9875	-0.27729	440.1	0	0	1	663.74	1.82	238.10	0.65
-92.9875	1.687739	440.1	0	0	1	789.08	2.16	283.06	0.78
-91.0225	-2.24232	440.1	0	0	1	713.62	1.96	255.99	0.70
-91.0225	-0.27729	440.1	0	0	1	946.03	2.59	339.36	0.93
87.79528	3.652769	440.1	0	0	1	1078.48	2.95	386.87	1.06
89.76031	-0.27729	440.1	0	0	1	1058.49	2.90	379.70	1.04
89.76031	1.687739	440.1	0	0	1	1065.26	2.92	382.13	1.05
#	#	nodegroup00					Sum	1769374	
#	0	0	1				Efficiency	265406.03	
#	-0.7071	0.7071	0				Derate	204362.65	
#	-0.7071	-0.7071	0				Walkways	194144.51	
#	1.965								
#	1.965								
#	-1								
#									
#	4278								

The spreadsheet shown in Table 19 was used to calculate the potential for onsite solar harvesting. A simulation was conducted using Diva for Rhino, and the output was imported into Excel for analysis. The data has been cropped, but 4278 calculation points were used with each representing a 1.965’ x 1.965’ area of the roof. Solar radiation numbers were converted to kWh values and summed, and efficiency values were applied to get the final number outlined in red.

Human Waste – to – Power

10 dry tons generates 18,868 kWh → 1 pound generates 0.93 kWh

The average person will generate about 0.25 dry pounds per day.

$$0.25\,\frac{dry\ pounds}{person} * 5000\,people = 1250\,dry\ pounds$$

$$1250\,dry\ lbs * 0.93\,kWh = 1163\,\frac{kWh}{day}$$

$$1163\,\frac{kWh}{day} * 250\,\frac{working\ days}{year} = 290{,}625\,\frac{kWh}{year}$$

Simple Payback

$$\$0.13\,per\ kWh * 290{,}625\,\frac{kWh}{year} = \$37{,}781\,annually$$

$$\frac{\$1{,}000{,}000\,approximate\ initial\ cost}{\$37{,}781\,per\ year} = 26\,years$$

Offsite Solar Array

After the site was selected, the National Renewable Energy Laboratory’s (NREL) PVWatts calculator to determine the required array size and its generation potential, seen in Figure 55. The PG&E power purchase agreement shown in Figure 56 lists the sell-back amount as $0.10509/kWh, assuming a 20-year contract and building completion in 2016.

Station Identification	
Cell ID:	0176359
State:	California
Latitude:	34.9 ° N
Longitude:	118.1 ° W
PV System Specifications	
DC Rating:	3000.0 kW
DC to AC Derate Factor:	0.750
AC Rating:	2250.0 kW
Array Type:	Fixed Tilt
Array Tilt:	34.9 °
Array Azimuth:	180.0 °
Energy Specifications	
Cost of Electricity:	14.4 ¢/kWh

Results			
Month	Solar Radiation ($kWh/m^2/day$)	AC Energy (kWh)	Energy Value ($)
1	5.27	348266	50031.89
2	5.98	358230	51463.32
3	6.78	440047	63217.15
4	7.24	450080	64658.49
5	7.52	468484	67302.41
6	7.71	452164	64957.88
7	7.62	454446	65285.71
8	7.88	471687	67762.56
9	7.56	447211	64246.33
10	7.09	448603	64446.31
11	6.12	386421	55513.24
12	5.13	333546	47917.22
Year	6.83	5059186	726802.67

Figure 55. Offsite Solar Panel Analysis

PG&E **Pacific Gas and Electric Company**
San Francisco, California
U 39

Revised Cal. P.U.C. Sheet No. 28701-E
Cancelling Original Cal. P.U.C. Sheet No. 28031-E

ELECTRIC SCHEDULE E-SRG Sheet 3
SMALL RENEWABLE GENERATOR PPA

SPECIAL CONDTIONS: (cont'd)

6. The Market Price Referent (MPR) is stated in the table below, which the Commission approved in Resolution E-4442, effective December 6, 2011. (T) (T)

Adopted 2011 Market Price Referents (N)
(Nominal - dollars/kWh)

Resource Type	10-Year	15-Year	20-Year
2012 Baseload MPR	0.07688	0.08352	0.08956
2013 Baseload MPR	0.08103	0.08775	0.09375
2014 Baseload MPR	0.08454	0.09151	0.09756
2015 Baseload MPR	0.08804	0.09520	0.10132
2016 Baseload MPR	0.09156	0.09883	0.10509
2017 Baseload MPR	0.09488	0.10223	0.10859

Advice Letter No: 3965-E-A
Decision No.
3C0

Issued by
Brian K. Cherry
Vice President
Regulatory Relations

Date Filed February 10, 2012
Effective January 3, 2012
Resolution No. E-4442

Figure 56. PG&E Renewable Energy Credit Purchase Price

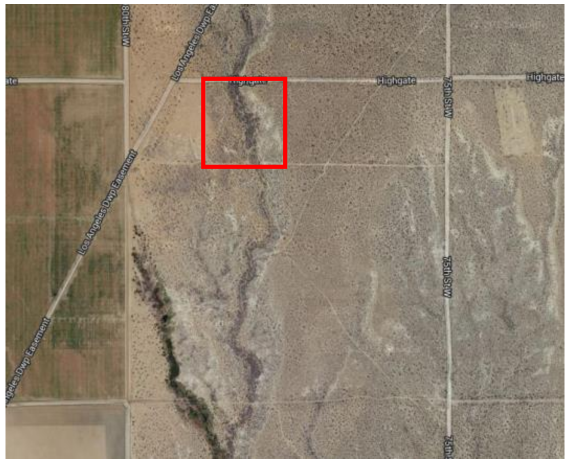


Figure 57. Offsite Solar Array Location

The array is 3000kW and covers 3.5 acres of the 10 acre site shown in Figure 57. It costs approximately $5,115,000, but at least 30% of this is covered by federal incentives, as shown in Figure 58. Additional incentives from PG&E are possible, but they require an application and waiting list and are not definite. 30% was assumed as a minimum.

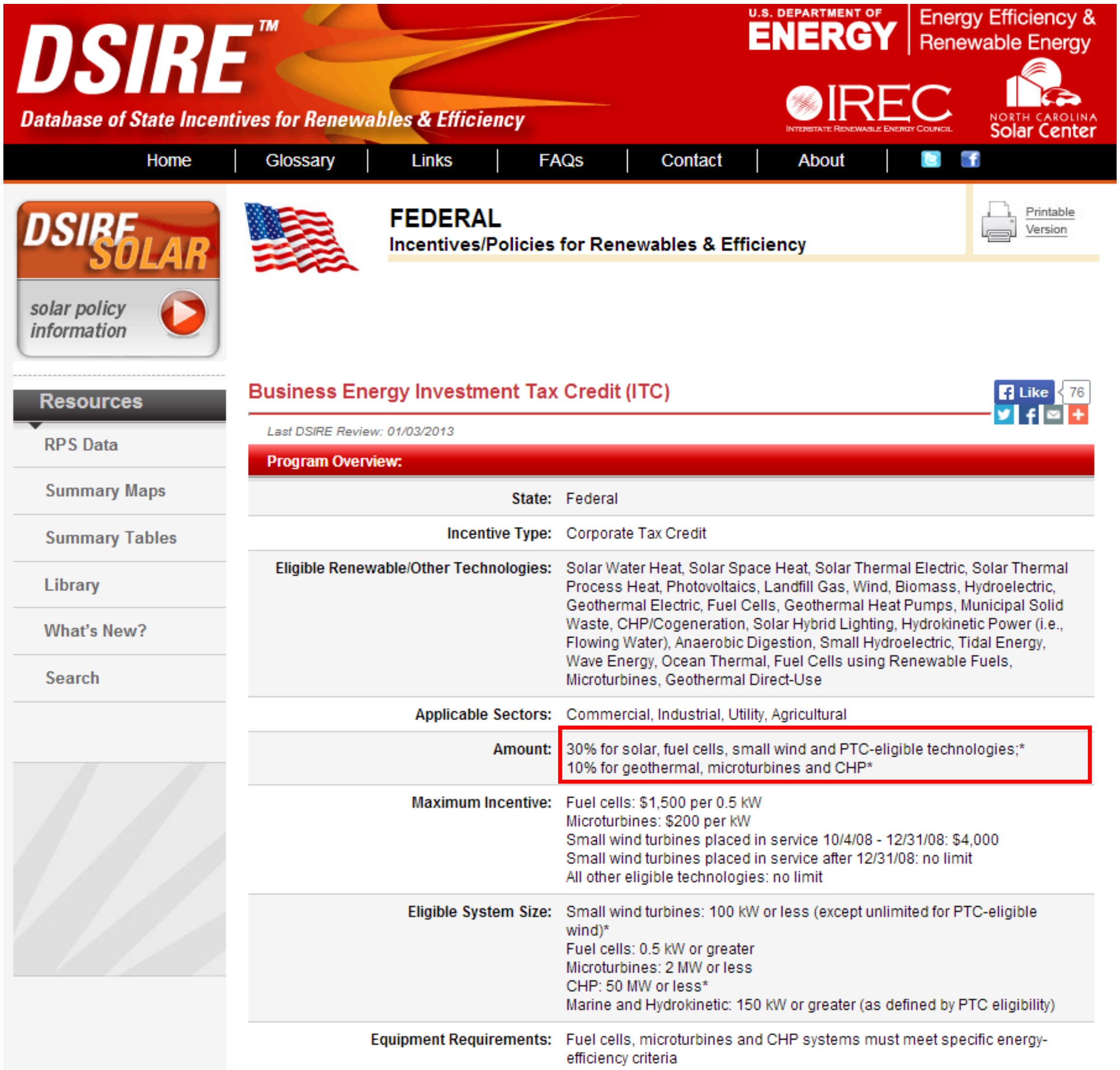
Table 20. Offsite Solar Costs

	Cost
Land	$13,000
Solar Panels	$5,115,000

Table 21. Offsite Solar Income/Incentives

	Amount
Incentives	$1,534,500
Annual energy generation	5,059,186 kWh
Annual Income	$531,670

With the minimum 30% incentives, the array will cost $3,580,500 and will pay back in 6.7 years. With 50% covered by incentives, this payback period is reduced to 4.8 years.



DSIRE™
Database of State Incentives for Renewables & Efficiency

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

IREC Interstate Renewable Energy Council

North Carolina Solar Center

Home | Glossary | Links | FAQs | Contact | About

DSIRE SOLAR solar policy information

Resources

- RPS Data
- Summary Maps
- Summary Tables
- Library
- What's New?
- Search

FEDERAL
Incentives/Policies for Renewables & Efficiency

Printable Version

Business Energy Investment Tax Credit (ITC)

Like 76

Last DSIRE Review: 01/03/2013

Program Overview:

State:	Federal
Incentive Type:	Corporate Tax Credit
Eligible Renewable/Other Technologies:	Solar Water Heat, Solar Space Heat, Solar Thermal Electric, Solar Thermal Process Heat, Photovoltaics, Landfill Gas, Wind, Biomass, Hydroelectric, Geothermal Electric, Fuel Cells, Geothermal Heat Pumps, Municipal Solid Waste, CHP/Cogeneration, Solar Hybrid Lighting, Hydrokinetic Power (i.e., Flowing Water), Anaerobic Digestion, Small Hydroelectric, Tidal Energy, Wave Energy, Ocean Thermal, Fuel Cells using Renewable Fuels, Microturbines, Geothermal Direct-Use
Applicable Sectors:	Commercial, Industrial, Utility, Agricultural
Amount:	30% for solar, fuel cells, small wind and PTC-eligible technologies;* 10% for geothermal, microturbines and CHP*
Maximum Incentive:	Fuel cells: $1,500 per 0.5 kW Microturbines: $200 per kW Small wind turbines placed in service 10/4/08 - 12/31/08: $4,000 Small wind turbines placed in service after 12/31/08: no limit All other eligible technologies: no limit
Eligible System Size:	Small wind turbines: 100 kW or less (except unlimited for PTC-eligible wind)* Fuel cells: 0.5 kW or greater Microturbines: 2 MW or less CHP: 50 MW or less* Marine and Hydrokinetic: 150 kW or greater (as defined by PTC eligibility)
Equipment Requirements:	Fuel cells, microturbines and CHP systems must meet specific energy-efficiency criteria

Figure 58. Federal Incentives for Renewable Energy

Appendix C

Facade

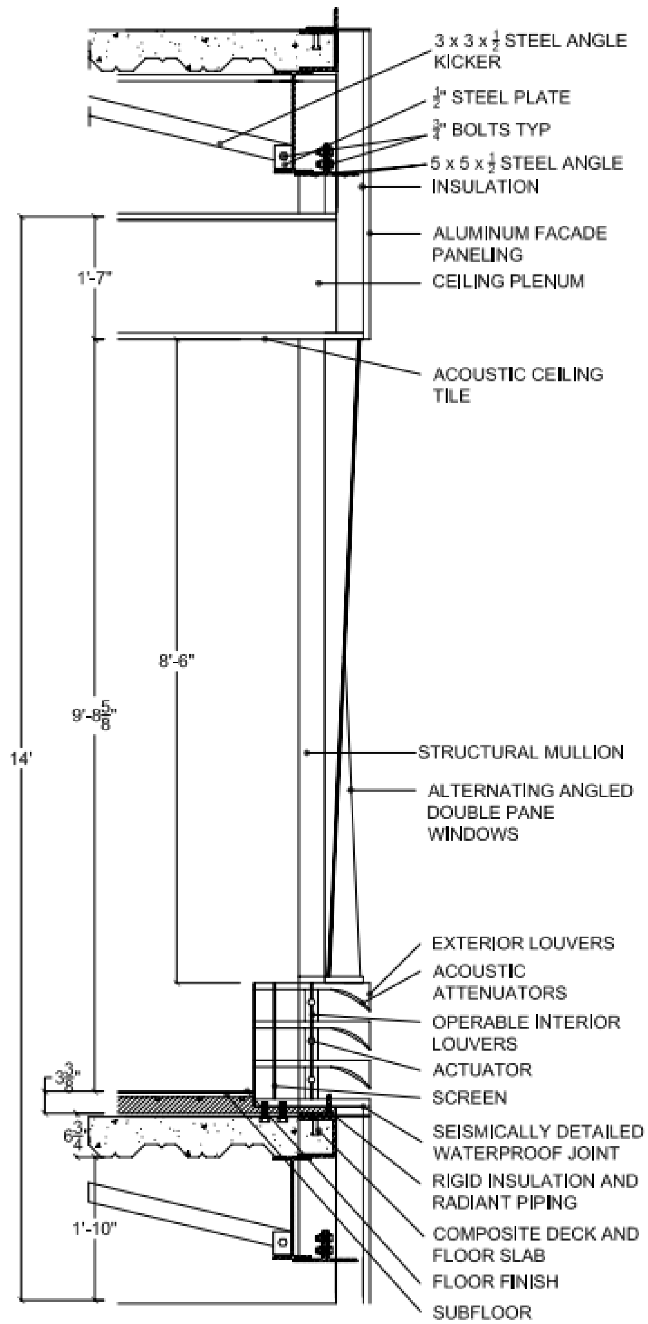


Figure 59. Detailed Façade Section

Electrochromic Glass Cost Analysis

Table 22. Electrochromic Glass Cost Analysis

Traditional Windows/Shades	Price	SF value (5'x8' windows)
Low e, double pane glass	$40-55/sf	$40
Shade fabric	$28/sf	$28
Automatic shade motor	$370 per unit	$2.50
Total		**$70.50**
Electrochromic Glass		
Glass	$50-65/sf	$65
Total		**$65**

Cost data for this analysis was drawn from two sources: numbers for the traditional solution are from a Lutron cost comparison study [16] (summary shown in Table 23) and the electrochromic glass numbers are from the Sage Glass cost data sheet shown in Figure 60. If a price range was given, the lower numbers were used for the traditional solution and the higher numbers were used for the electrochromic glass.

These numbers are for materials alone; they do not include any labor costs. However, with traditional shades, there are labor costs for both the window installation and shade installation. With electrochromic glass, installations are hardly more complex than installing normal glass, and there is no additional shade installation.

Table 23. Lutron Cost Comparison Study – Price Summary

			Qty	Total Price (USD)
Labor	Window Treatment Contractor	Administrative Charges	-	$1,950.00
		Keypad Cable Labor	-	$400.00
		Shades Installation and Programming	-	$11,518.00
	Electricical Contractor	Line voltage wiring and circuit installation	-	$10,172.19
	Total Labor			$24,040.19
Wiring	Breakers & Electrical Materials	20 A Breakers	6	$157.15
		Miscellaneous Materials	-	$2,099.59
	Cable (Qty. in feet)	#12/3 MC Cable (Shades Wiring)	2300	$3,878.69
		#12/2 MC Cable (Breaker Wiring)	300	$301.34
		Low Voltage 4 Conductor Keypad Cable	400	$193.60
	Total Wiring			$6,630.37
Components	Shades, Brackets and Lineals	Open Office Sheer Shade Pairs	17	$18,464.15
		Conference Rooms & Executive Office Dual Shade Pairs	6	$6,950.94
	Keypads	Group A, B, A+B Keypads	4	$369.81
	Power and Control	Group Controllers	6	$2,207.55
	Total Components			$27,992.45
Total Installed Cost				**$58,663.01**

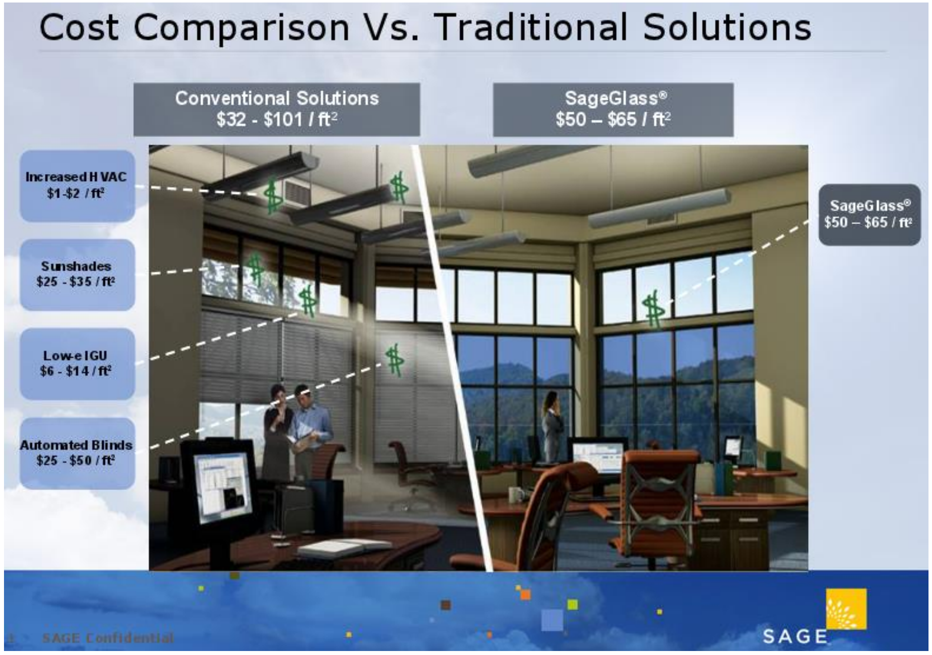


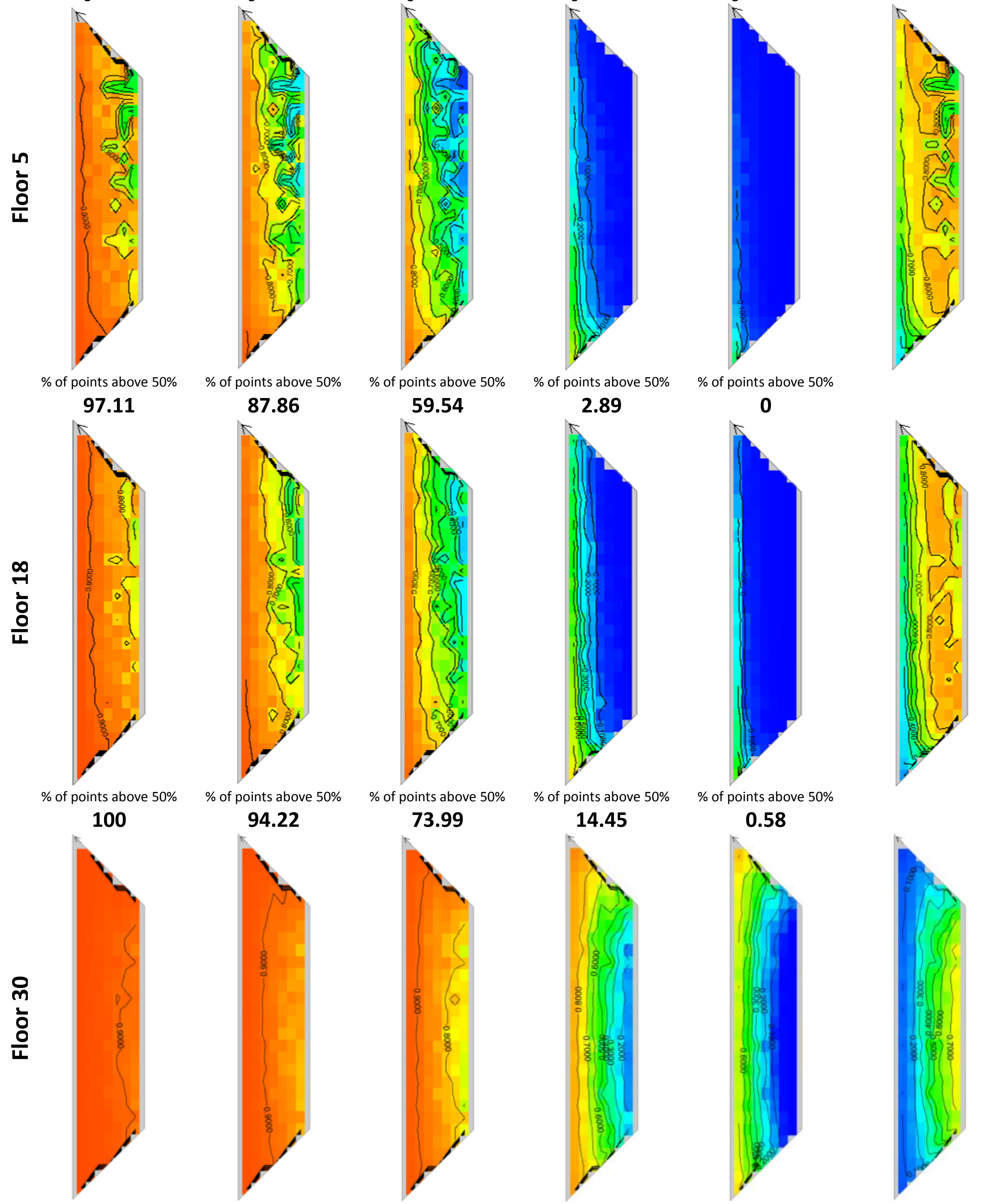
Figure 60. Electrochromic Glass Cost Comparison – Sage Electronics

The cost comparison prices shown in Table 23 are for a line voltage AC shading system. The windows are the same size as those found in 350 Mission. The "per square foot" numbers were found by dividing the total price by the quantity shown in the table. This was then divided by the area of each shade represented by that number. For shade material, this was the area of one shade (5' x 8'). For motors, this was the area of four shades, as the Lutron study assumed four shades per controller. Only the glass, shade fabric, and motors were included in the study as the controls, wiring, etc. were assumed to be comparable for the two scenarios.

Appendix D

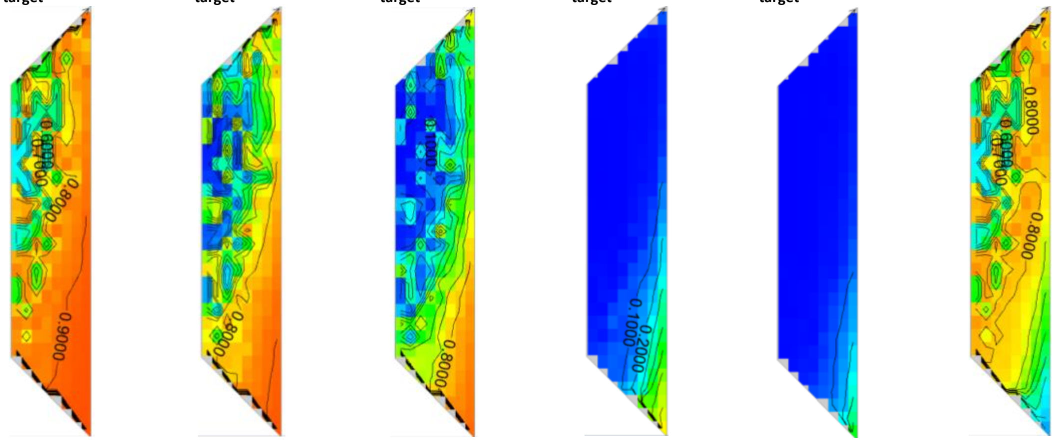
Urban Daylighting Study

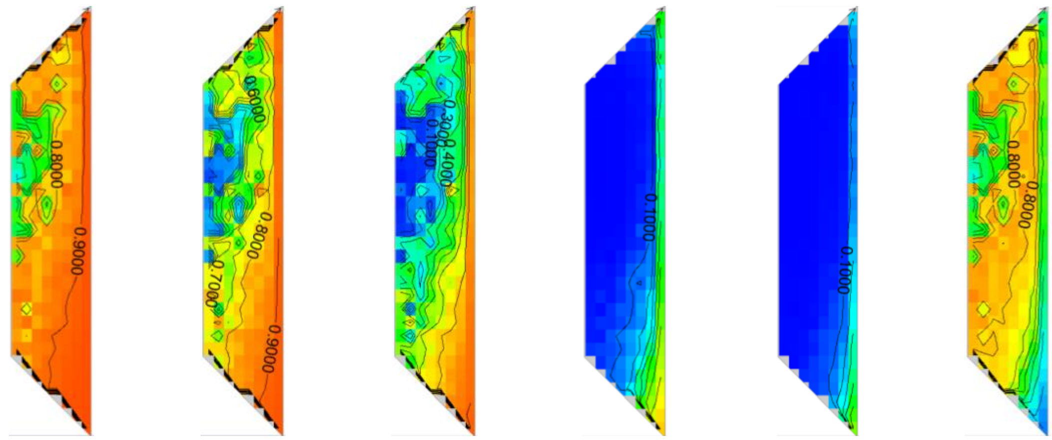
Table 24. Spatial Daylight Autonomy and Useful Daylight Illuminance Results – Northwest Façade

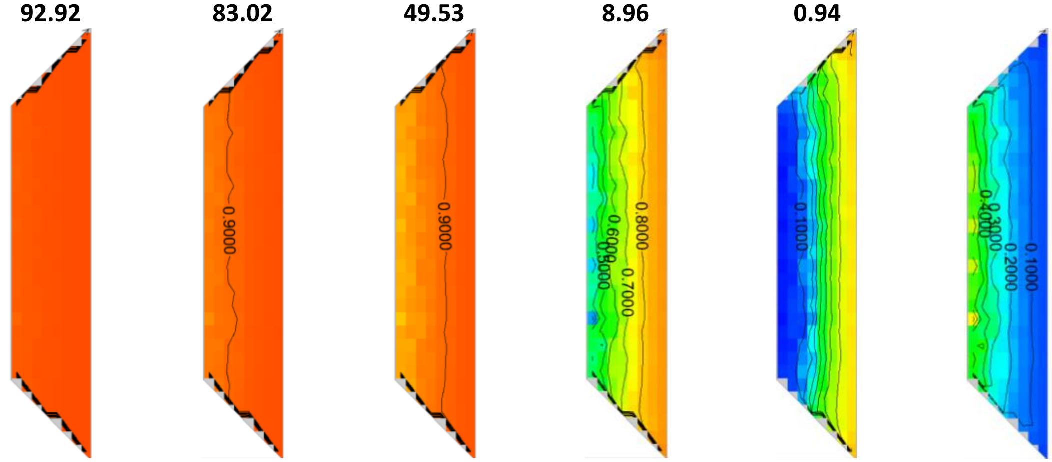


	E_{target} = 20 fc	E_{target} = 50 fc	E_{target} = 100 fc	E_{target} = 500 fc	E_{target}= 1000 fc	UDI 25fc-500fc
Floor 5	% of points above 50% **97.11**	% of points above 50% **87.86**	% of points above 50% **59.54**	% of points above 50% **2.89**	% of points above 50% **0**	
Floor 18	% of points above 50% **100**	% of points above 50% **94.22**	% of points above 50% **73.99**	% of points above 50% **14.45**	% of points above 50% **0.58**	
Floor 30	% of points above 50% **100**	% of points above 50% **100**	% of points above 50% **100**	% of points above 50% **65.32**	% of points above 50% **35.26**	

Table 25. Spatial Daylight Autonomy and Useful Daylight Illuminance Results – Northeast Façade



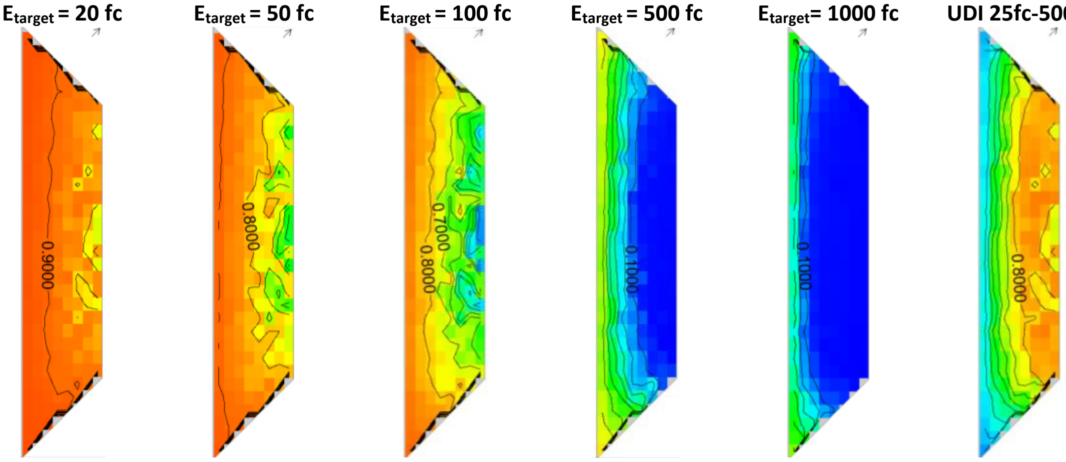




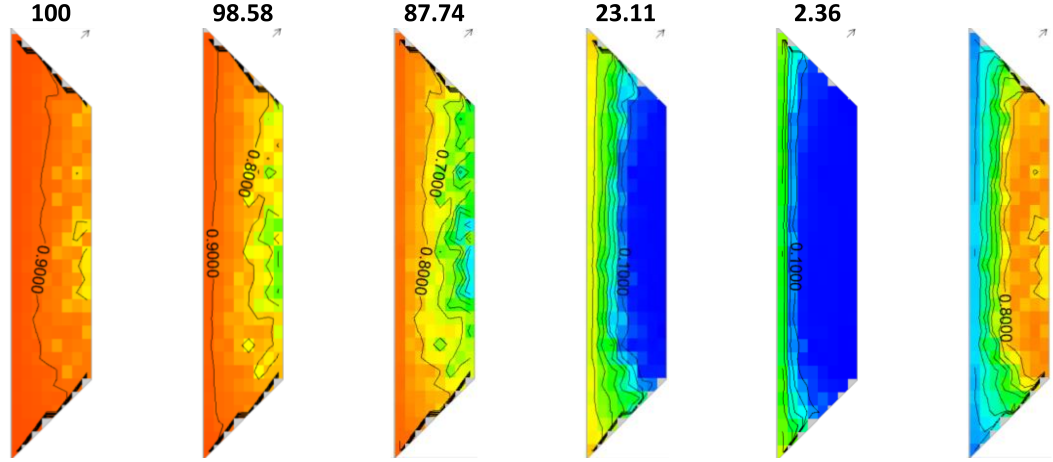
	E_{target} = 20 fc	E_{target} = 50 fc	E_{target} = 100 fc	E_{target} = 500 fc	E_{target}= 1000 fc	UDI 25fc-500fc
Floor 5	% of points above 50% **85.38**	% of points above 50% **68.87**	% of points above 50% **43.40**	% of points above 50% **4.72**	% of points above 50% **0**	
Floor 18	% of points above 50% **92.92**	% of points above 50% **83.02**	% of points above 50% **49.53**	% of points above 50% **8.96**	% of points above 50% **0.94**	
Floor 30	% of points above 50% **100**	% of points above 50% **100**	% of points above 50% **100**	% of points above 50% **82.55**	% of points above 50% **45.75**	

Table 26. Spatial Daylight Autonomy and Useful Daylight Illuminance Results – Southwest Façade

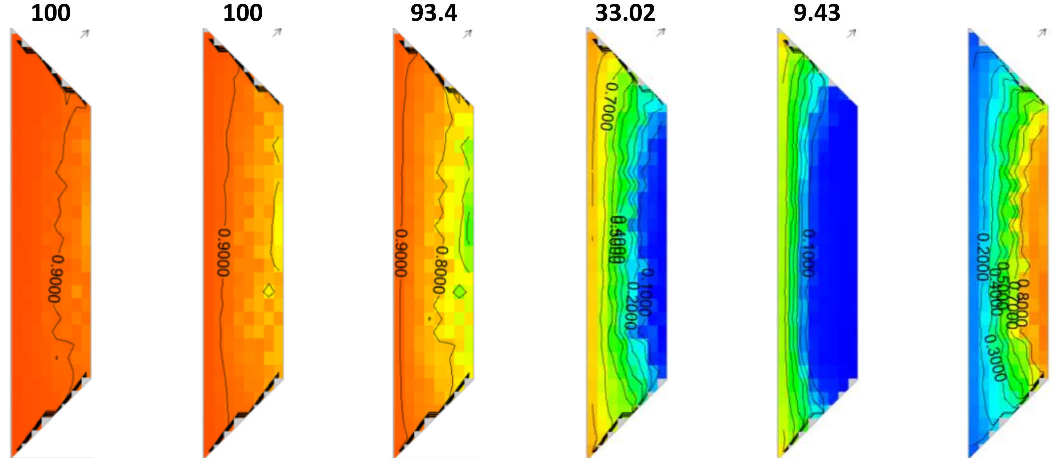
Floor 5



Floor 18



Floor 30



	E_{target} = 20 fc	E_{target} = 50 fc	E_{target} = 100 fc	E_{target} = 500 fc	E_{target}= 1000 fc	UDI 25fc-500fc
Floor 5 – % of points above 50%	**100**	**98.58**	**87.74**	**23.11**	**2.36**	
Floor 18 – % of points above 50%	**100**	**100**	**93.4**	**33.02**	**9.43**	
Floor 30 – % of points above 50%	**100**	**100**	**100**	**49.53**	**22.64**	

Table 27. Spatial Daylight Autonomy and Useful Daylight Illuminance Results – Southeast Façade

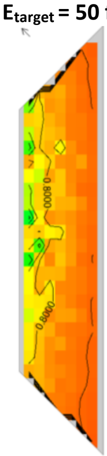
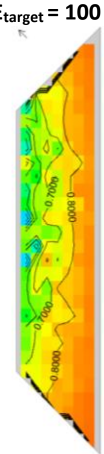
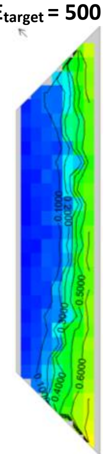
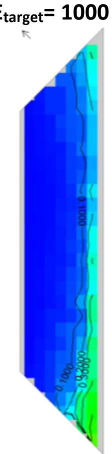
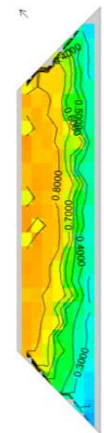
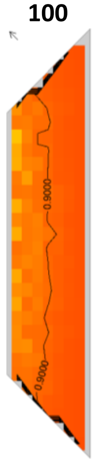
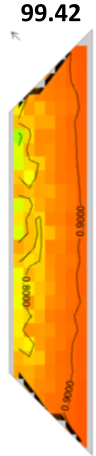
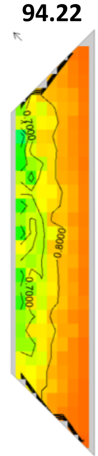
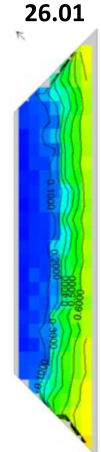
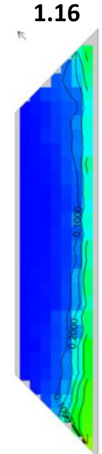
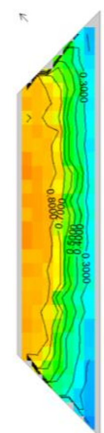
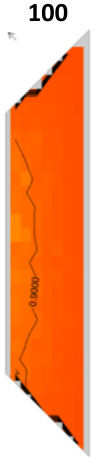
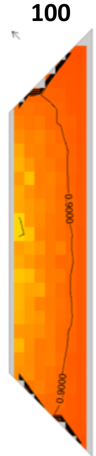
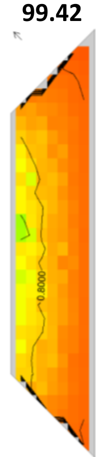
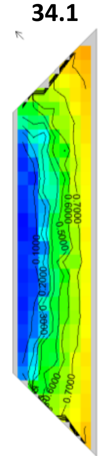
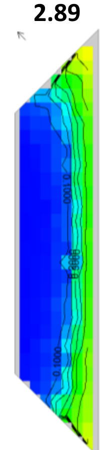
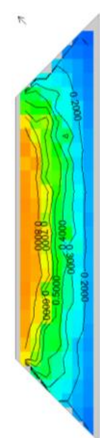
	E_{target} = 20 fc	E_{target} = 50 fc	E_{target} = 100 fc	E_{target} = 500 fc	E_{target}= 1000 fc	UDI 25fc-500fc
Floor 5	 % of points above 50% **100**	 % of points above 50% **99.42**	 % of points above 50% **94.22**	 % of points above 50% **26.01**	 % of points above 50% **1.16**	
Floor 18	 % of points above 50% **100**	 % of points above 50% **100**	 % of points above 50% **99.42**	 % of points above 50% **34.1**	 % of points above 50% **2.89**	
Floor 30	 % of points above 50% **100**	 % of points above 50% **100**	 % of points above 50% **100**	 % of points above 50% **54.34**	 % of points above 50% **24.86**	

Table 28. Summary of Annual Direct Sun Hours

Northwest Façade (hours of direct sun)																																	
Isolated	2181	2181	2181	2181	2181	2181	2181	2181	2181	2181	2181	2181	2181	2181	2181	2181	2181	2181	2181	2181	2181	2181	2181	2181	2181	2181	2181	2181	2181	2181	2181		
Floor 5	379	403	434	434	434	445	361	383	383	383	383	431	431	412	412	436	402	402	430	466	475	443	443	420	390	390	310	323	363	363	337		
Floor 18	379	403	434	434	434	445	421	479	479	479	479	550	550	531	531	555	549	569	544	544	516	484	484	461	453	453	373	372	412	412	386		
Floor 30	714	740	740	763	763	774	774	804	804	761	756	775	734	709	691	686	703	703	715	711	712	680	680	692	661	661	661	639	687	697	671		
Northeast Façade (hours of direct sun)																																	
Isolated	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750
Floor 5	145	145	145	145	145	171	210	201	201	235	201	232	255	255	337	345	345	367	367	421	446	531	531	568	628	651	622	622	655	655	655	629	590
Floor 18	305	305	305	280	280	306	326	305	305	323	282	303	326	326	349	357	357	379	367	421	446	531	531	568	628	651	622	626	655	655	655	629	590
Floor 30	450	453	507	510	515	524	549	578	606	606	625	625	625	625	627	665	693	693	695	700	708	720	722	725	734	745	750	750	750	750	750	750	750
Southwest Façade (hours of direct sun)																																	
Isolated	3400	3400	3400	3400	3400	3400	3400	3400	3400	3400	3400	3400	3400	3400	3400	3400	3400	3400	3400	3400	3400	3400	3400	3400	3400	3400	3400	3400	3400	3400	3400	3400	3400
Floor 5	854	854	879	793	793	762	739	725	693	685	685	713	751	705	687	687	687	720	694	694	694	668	748	787	757	718	750	715	715	767	800	802	865
Floor 18	918	918	943	857	857	826	803	789	757	749	749	777	815	769	765	765	765	788	762	777	757	731	775	814	784	732	764	737	737	789	822	839	902
Floor 30	1395	1381	1421	1352	1362	1331	1308	1264	1232	1233	1224	1252	1243	1211	1159	1159	1151	1119	1093	1086	1078	1052	1047	1086	1047	1008	1031	1004	1011	1076	1109	1126	1106
Southeast Façade (hours of direct sun)																																	
Isolated	1966	1966	1966	1966	1966	1966	1966	1966	1966	1966	1966	1966	1966	1966	1966	1966	1966	1966	1966	1966	1966	1966	1966	1966	1966	1966	1966	1966	1966	1966	1966		
Floor 5	880	895	862	775	775	782	749	725	692	658	607	589	592	606	561	584	551	587	578	525	610	610	600	627	616	666	726	793	846	840	874		
Floor 18	917	932	899	812	812	819	786	762	729	728	690	672	675	675	630	605	572	608	599	546	631	631	641	675	678	728	774	828	881	875	909		
Floor 30	981	996	963	896	896	903	870	905	872	894	843	871	883	883	838	858	825	861	852	808	893	899	891	926	953	1003	1063	1117	1170	1170	1204		

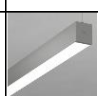
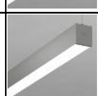
Appendix E

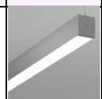
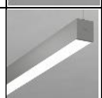
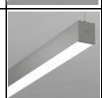
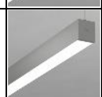
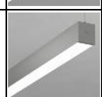
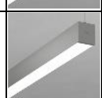
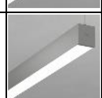
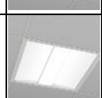
Lighting Design

Luminaire Schedule

The luminaire selection process was detailed and thorough. All options were assessed with efficacy as one of the most important criteria. The luminaire schedule in its entirety is shown on the following two pages.

Table 29. Luminaire Schedule

LUMINAIRE SCHEDULE														
Luminaire Symbol	Image	Luminaire Type	Manufacturer and Series	Light Source	Correlated Color Temperature (K)	Color Rendering Index (CRI)	Wattage [W] at Full Output	Initial Lumens [lm] (lumen package)	Luminaire Efficacy [lm/W]	Luminaire Efficiency	Voltage	Mounting	Height into Plenum [inches]	Notes	Lumen Maintenance
C		1" x 7.6" LED undercabinet strip	Feelux Diva 2	LED	4000	> 80	2.4	146	60.8	-	24VDC	Surface-mounted	-	Square diffuser	L_{70} at 40,000
DA		6" x 6" downlight	Gotham EVO	LED	4100	83	20.0	1125	56.3	-	24VDC	Recessed	6 3/4	Open	L_{70} at 50,000
DB		6" x 6" downlight	Gotham EVO	LED	4100	83	26.3	1590	60.5	-	24VDC	Recessed	6 3/4	Open	L_{70} at 50,000
DC		6" x 6" downlight	Gotham EVO	LED	4100	83	33.6	2150	64.0	-	24VDC	Recessed	6 3/4	Open	L_{70} at 50,000
DD		4" x 4" downlight	Gotham EVO	LED	4100	83	20.0	1016	50.8	-	24VDC	Recessed	6 3/4	Open	L_{70} at 50,000
I1		1-lamp industrial strip	Philips Day-Brite	F32T8	4100	90	34.0	2900	72.5	85.0%	24VDC	Surface-mounted	-	Open	-
I2		2-lamp industrial strip	Philips Day-Brite	F32T8	4100	90	67.0	5800	71.0	82.0%	24VDC	Surface-mounted	-	Open	-
L12		12' x 4" linear	Axis Beam 4	LED	4000	> 80	46.2	4800	104.0	-	24VDC	Recessed	4 3/4	Lensed	L_{70} at 50,000
L4		4' x 4" linear	Axis Beam 4	LED	4000	> 80	15.4	1600	104.0	-	24VDC	Recessed	4 3/4	Lensed	L_{70} at 50,000
M		Monorail mounted, aimable LED MR16 head	LBL Lighting Orbit Swivel	LED	4000	80	6.0	360	60.0	-	120VAC	Monorail	-	MR16 LED lamp	L_{70} at 30,000
O		Adjustable task light	Koncept Z-Bar Mini	LED	4500	85	6.5	230	53.0	-	120VAC	Desk-braced	-	Lensed	L_{70} at 50,000

Luminaire Symbol	Image	Luminaire Type	Manufacturer and Series	Light Source	Correlated Color Temperature (K)	Color Rendering Index (CRI)	Wattage [W] at Full Output	Initial Lumens [lm] (lumen package)	Luminaire Efficacy [lm/W]	Luminaire Efficiency	Voltage	Mounting	Height into Plenum [inches]	Notes	Lumen Maintenance
PDA		4' x 4" linear direct pendant	Axis Beam 4	LED	4000	> 80	11.0	1200	104.0	-	24VDC	Pendant	-	Lensed, configured into squares of 4 fixtures	L_{70} at 50,000
PDB		4' x 4" linear direct pendant	Axis Beam 4	LED	4000	> 80	14.7	1600	104.0	-	24VDC	Pendant	-	Lensed, configured into squares of 4 fixtures	L_{70} at 50,000
PDC		4' x 4" linear direct pendant	Axis Beam 4	LED	4000	> 80	19.0	2000	100.6	-	24VDC	Pendant	-	Lensed, configured into squares of 4 fixtures	L_{70} at 50,000
PDD		4' x 4" linear direct pendant	Axis Beam 4	LED	4000	> 80	30.7	3000	93.4	-	24VDC	Pendant	-	Lensed, configured into squares of 4 fixtures	L_{70} at 50,000
PUA		8' x 4" linear direct/indirect pendant	Axis Beam 4	LED	4000	> 80	22.0	2400 up/ 2400 down	104.0	-	24VDC	Pendant	-	Lensed, configured into squares of 4 fixtures	L_{70} at 50,000
PUB		8' x 4" linear direct/indirect pendant	Axis Beam 4	LED	4000	> 80	25.7	2400 up/ 3200 down	104.0	-	24VDC	Pendant	-	Lensed, configured into squares of 4 fixtures	L_{70} at 50,000
PUC		8' x 4" linear direct/indirect pendant	Axis Beam 4	LED	4000	> 80	30.0	2400 up/ 4000 down	102.0	-	24VDC	Pendant	-	Lensed, configured into squares of 4 fixtures	L_{70} at 50,000
ST		2-lamp stairwell	Philips Day-Brite	F32T8	4100	90	67.0	5800	65.5	75.7%	24VDC	Surface-mounted	-	Lensed	-
TA		2' x 2' troffer	Axis Day 2x2	LED	4000	> 80	25.2	2500	99.3	-	24VDC	Recessed	3 7/8	Lensed	L_{70} at 50,000
TB		2' x 2' troffer	Axis Day 2x2	LED	4000	> 80	47.3	4400	93.1	-	24VDC	Recessed	3 7/8	Lensed	L_{70} at 50,000
X1		Edge-lit green LED exit sign	Philips Chloride	LED	-	-	3.5	-	-	-	24VDC	Ceiling mounted	-	Double or single faced with chevrons as indicated on plan	-

Lobby Lighting Design

The lobby lighting layout in Figure 61 shows the suspension lengths of the decorative pendant squares, as well as the locations of the recessed, monorail mounted, and undercounter luminaires. Creative solutions were required due to the scale and layout of the space.

Figure 61. Lobby Lighting Plan

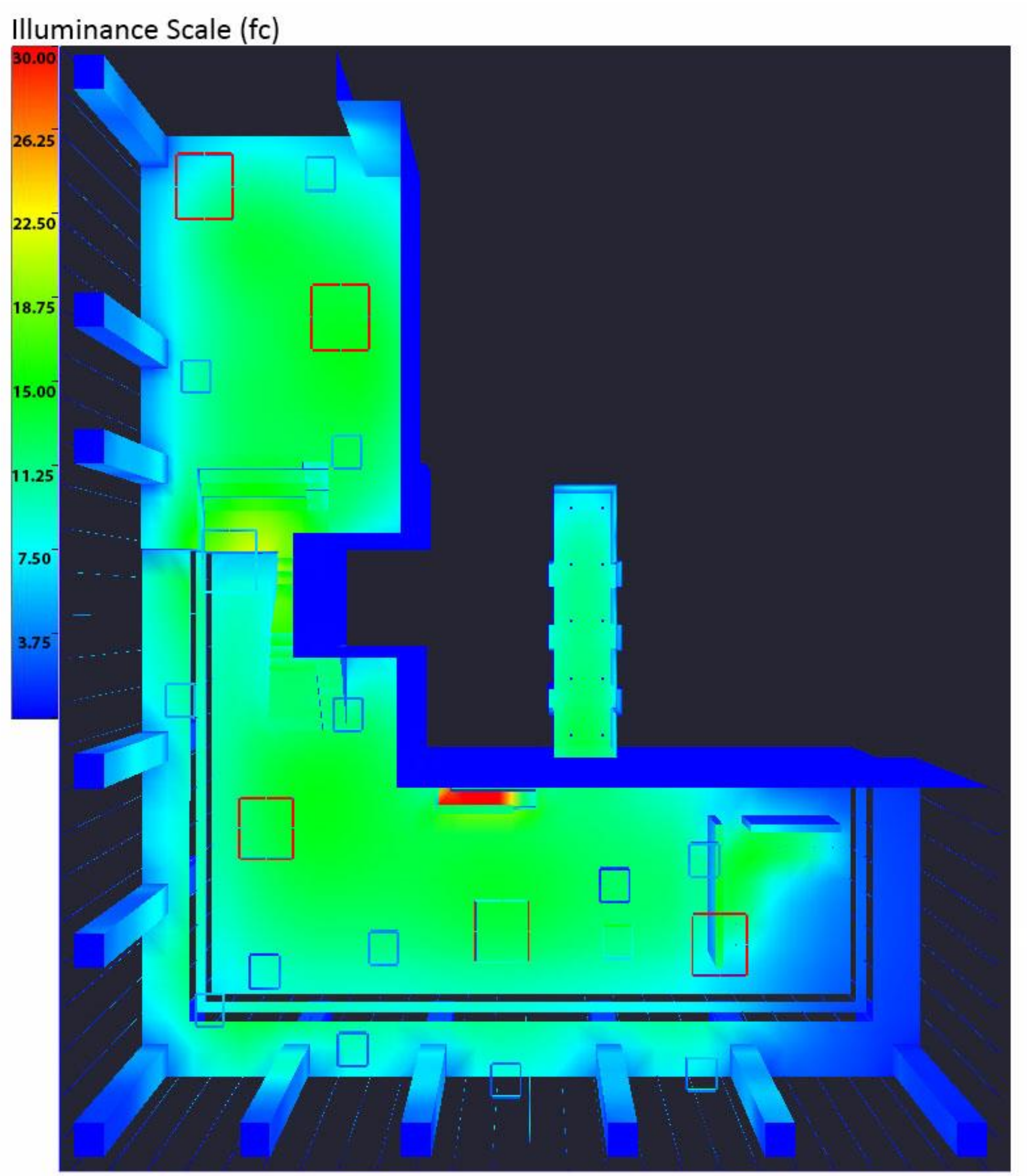


Figure 62. Lobby Pseudocolor Rendering

The pseudocolor rendering in Figure 62 shows the illuminance levels in the lobby, designed to meet the criteria defined by IES requirements.

Most of the circulation areas are at 10 fc, shown by the green. The reception desk has higher illuminance levels to accommodate reading and writing.

Additional renderings of the lobby space are shown in Figures 63 and 64.

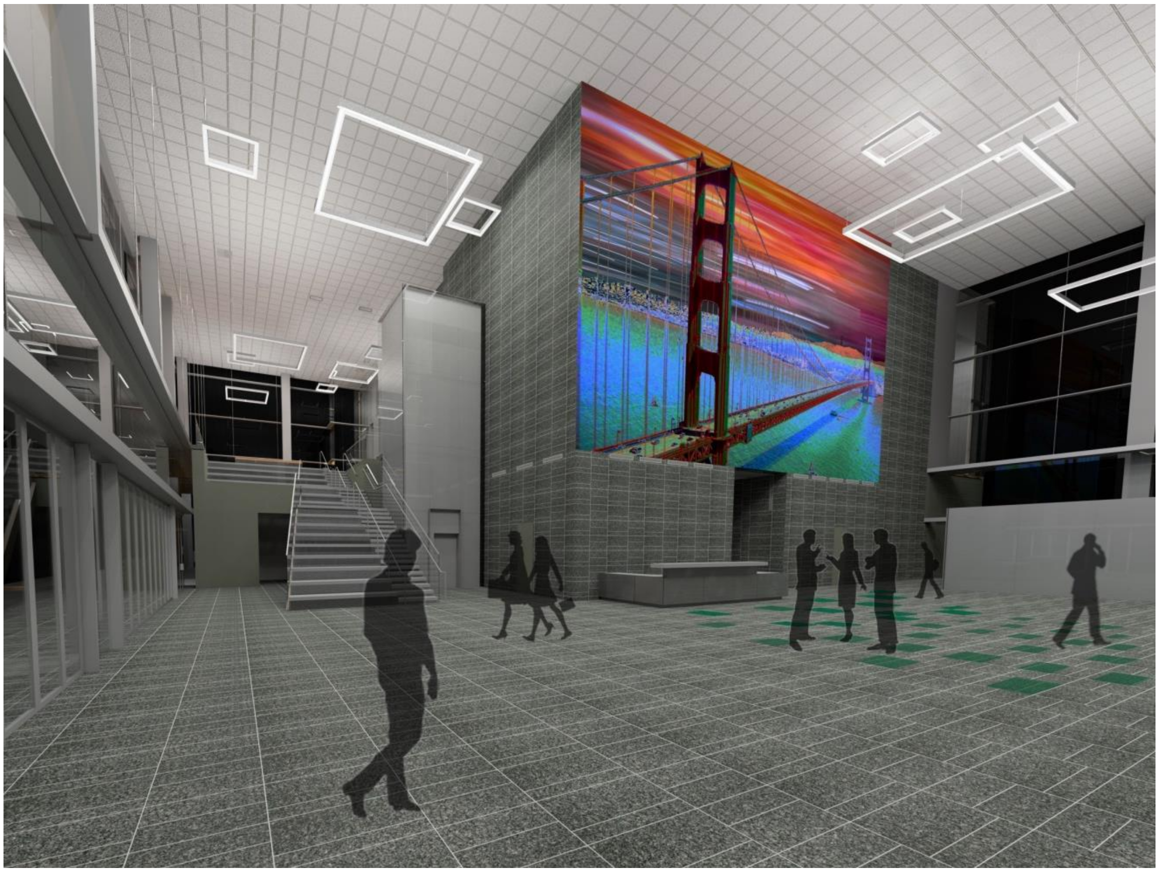


Figure 63. Lobby Rendering with View of Public Art Wall

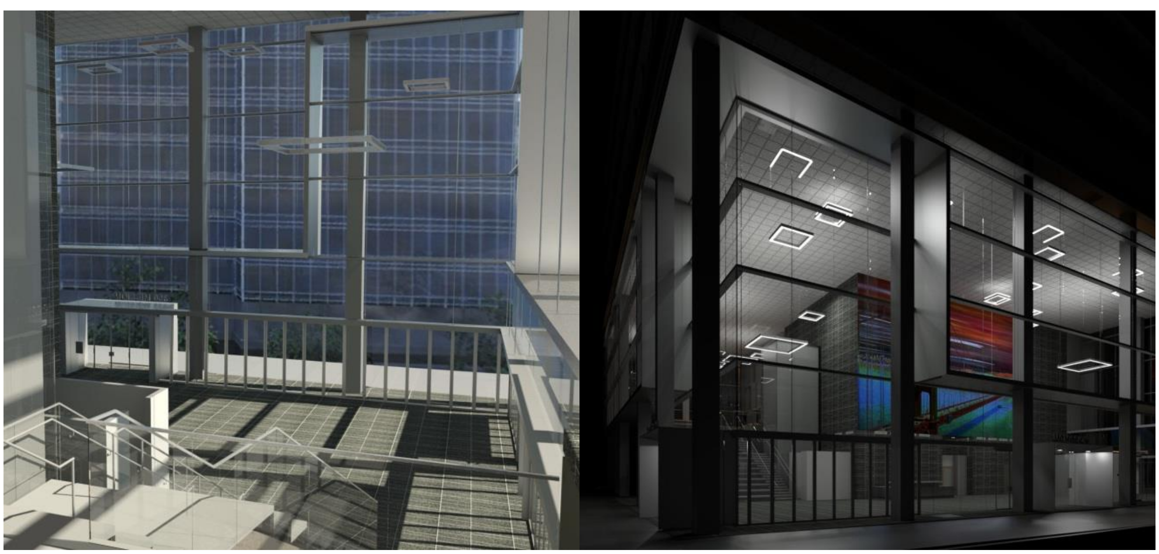


Figure 64. Day and Nighttime Views of Lobby Lighting

Office Lighting Design

The office lighting is shown in Figure 65, with the exception of the task lighting located at each workstation. Exit signs are provided to mark the paths of egress, and emergency lighting provides 1 fc for egress circulation in the event of a power outage.

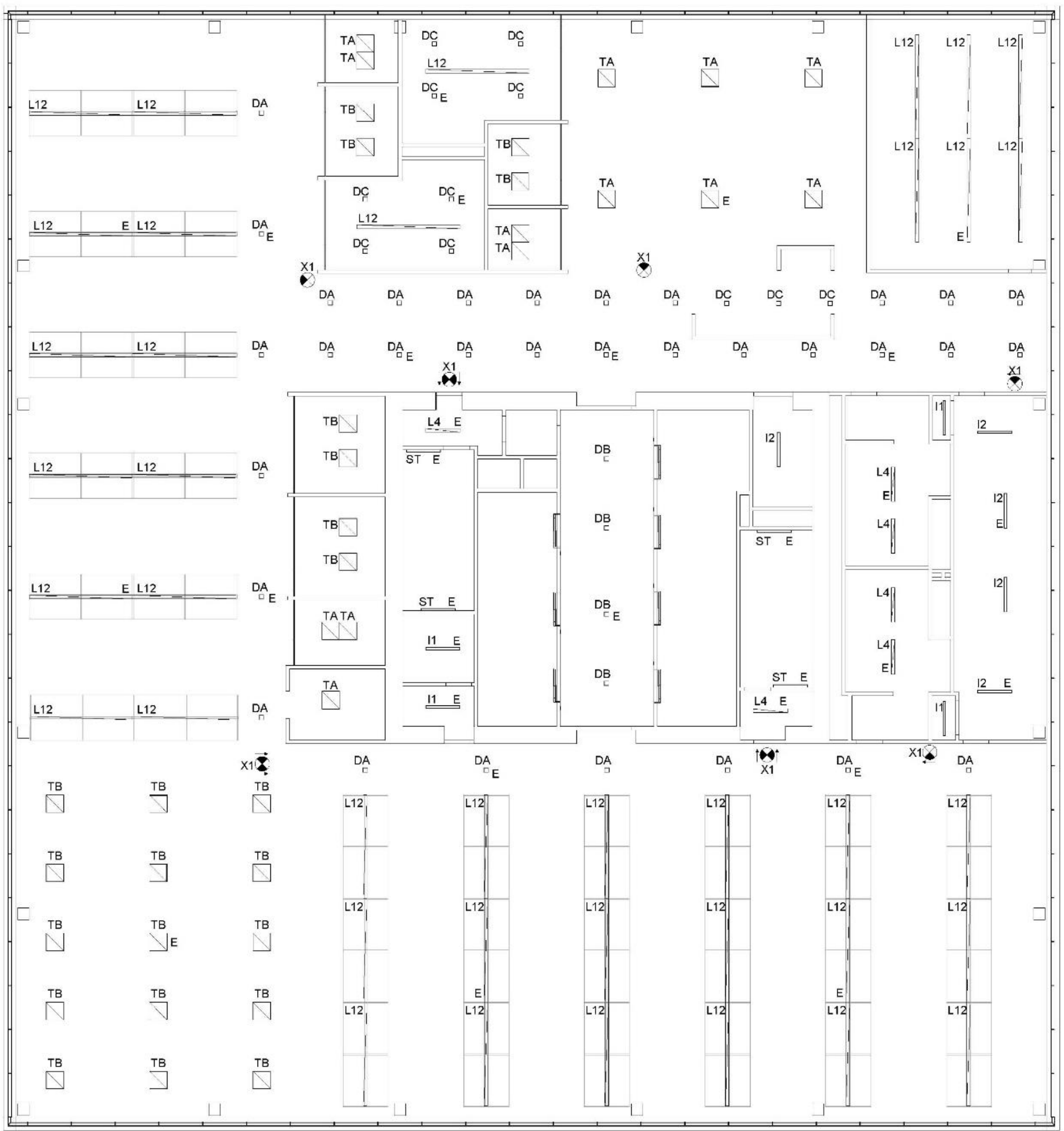


Figure 65. Office Floor Lighting Plan

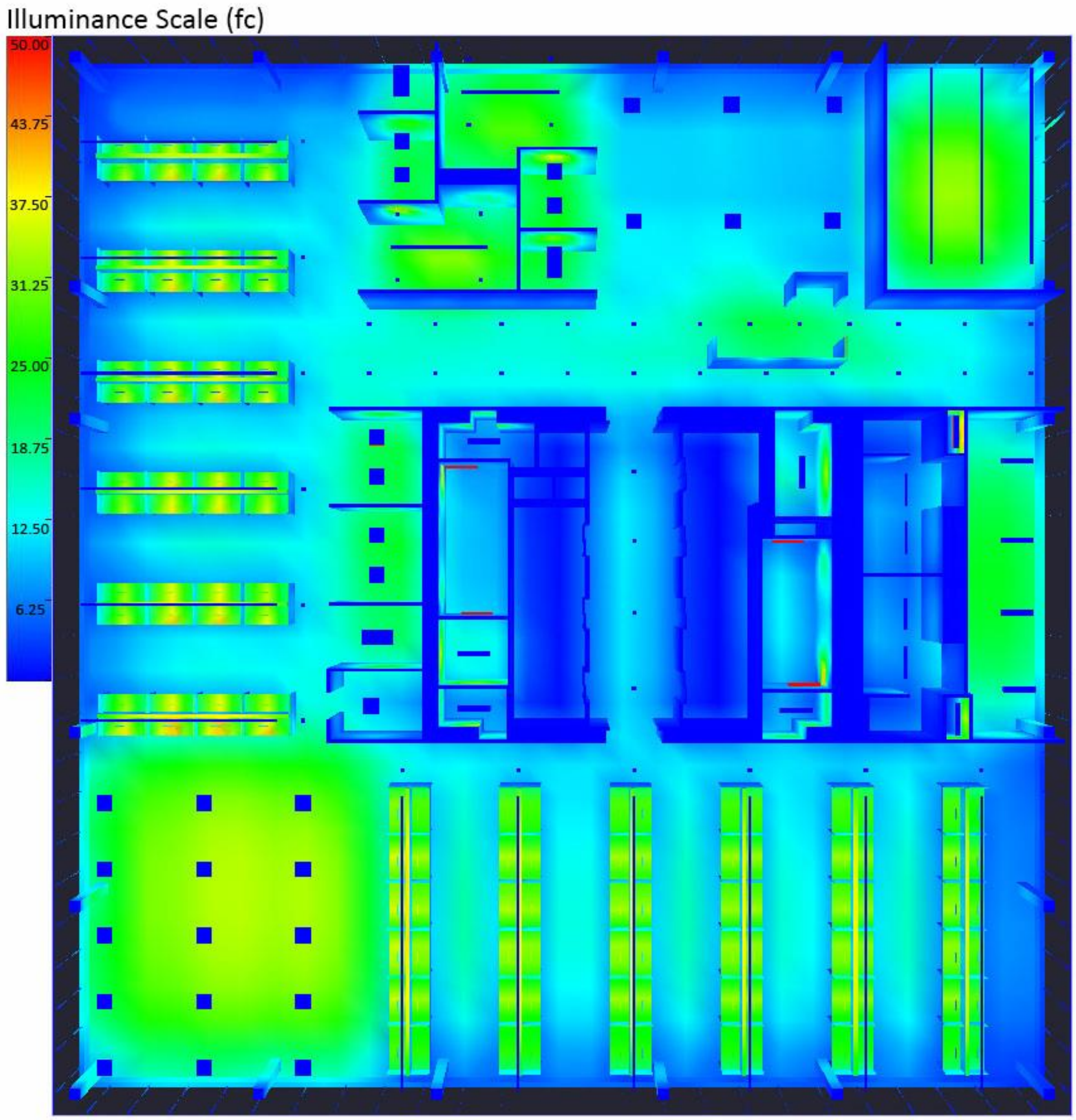


Figure 66. Office Pseudocolor Rendering

Figure 66 shows a visual representation of the office illuminance levels due to electric lighting, designed to meet IES requirements.

Most of the circulation areas are at 10 fc, shown by the light blue.

The circulation areas around the desks are only at about 15 fc, with the additional illuminance on the workplane being supplied by task lighting.

The flex area, in the absence of task lighting, has an even distribution of 30 fc across the space.

Building Lighting Power Densities

Table 30. Space by Space Lighting Power Density Analysis

Space	Total Area [ft.^{2}]	Code Category	Code LPD [W/ft.^{2}]	Code LPD with CalGreen Reduction (15%)	Allowable Watts [W]	Watts as Designed [W]	LPD as Designed [W/ft.^{2}]
Typical Office Floor							
Open Office DC	5600	Office (>250 ft.^{2})	0.9	0.77	4284.0	2166	0.39
Flexible Space	1100	Office (>250 ft.^{2})	0.9	0.77	841.5	709.5	0.65
Break/Dining	1040	Dining	1.1	0.94	972.4	151.2	0.15
Kitchen	100	Kitchen/Food preparation	1.6	1.36	136.0	100.8	1.01
Large Conference	600	Conference	1.4	1.19	714.0	277.2	0.46
(2) Small Conference	455	Conference	1.4	1.19	541.5	361.2	0.79
(4) Video Conference	405	Office (<250 ft.2)	1.1	0.94	378.7	378.4	0.93
(3) Interview Room	205	Office (<250 ft.2)	1.1	0.94	191.7	151.2	0.74
Printer/Copy	92	Support	0.6	0.51	46.9	25.2	0.27
Southwest Corridor	620	Corridor	0.6	0.51	316.2	120	0.19
Southeast Corridor	500	Corridor	0.6	0.51	255.0	120	0.24
Northwest Corridor	1025	Corridor	0.6	0.51	522.8	400	0.39
Elevator Lobby	400	Lobby/Waiting Area	1.1	0.94	374.0	105.2	0.26
Men's Restroom	200	Restroom	0.6	0.51	102.0	30.8	0.15
Women's Restroom	205	Restroom	0.6	0.51	104.6	30.8	0.15
(2) Stair and Vestibule	300	Stair	0.6	0.51	153.0	134	0.45
Service Lobby	75	Support	0.6	0.51	38.3	67	0.89
Electrical and Electrical Closet	80	Electrical room	0.7	0.60	47.6	68	0.85
Telecom and Telecom Closet	50	Telephone room	0.7	0.60	29.8	34	0.68
Mechanical	425	Mechanical room	0.7	0.60	252.9	268	0.63
Lobby							
General Illumination	5359	Lobby	1.1	0.94	5010.7	1545.6	0.29
Retail Area	922	Retail	1.6	1.36	1253.9	979.8	1.06
Feature Stairs	558	Stair	0.6	0.51	284.6	10.5	0.02
Elevator Lobby	383	Lobby/Waiting Area	1.1	0.94	358.1	200	0.52
Vestibule	196	Lobby/Waiting Area	1.1	0.94	183.3	160	0.82
Reception Desk	212	Office	0.9	0.77	162.2	72	0.34
Feature Art Wall	55 ft long	Wall Display	3.5	2.975	163.6	163.6	2.97
Undesigned Spaces (Assume design utilizes maximum LPD)							
Restaurant Dining	3800	Dining	1.1	0.94	3553.0	-	-
Restaurant Kitchen	500	Kitchen	1.6	1.36	680.0	-	-
Restaurant Restrooms	120	Restroom	0.6	0.51	61.2	-	-
Restaurant Corridor	460	Corridor	0.6	0.51	234.6		
Lobby Support Space	1700	Support	0.6	0.51	867.0		
Locker rooms below grade	1200	Locker room	0.6	0.51	612.0	-	-
Stairs below grade	1050	Stair	0.6	0.51	535.5		
Elevator Lobby below grade	800	Lobby/Waiting Area	1.1	0.94	748.0		
Parking Garage Parking	10920	Parking area	0.2	0.17	1856.4	-	-
Parking Garage Ramps	26800	Parking ramps	0.6	0.51	13668.0		
Mechanical penthouse and below grade spaces	5730	Mechanical room	0.7	0.60	3409.4	-	-
Electrical below grade spaces	2300	Electrical room	0.7	0.60	1368.5	-	-
Telcom Room below grade	600	Telephone room	0.7	0.60	357.0		
Below grade support spaces (water storage, pump room)	2875	Support	0.6	0.51	1466.3	-	-
Below grade storage	3650	Storage	0.6	0.51	1861.5		

Table 31.Lighting Power Density Load Summary

Lighting Power Summary				Note about Expected Load
Total Connected DC Load [kW]	Total Connected AC Load [kW]	Total Expected DC Load [kW]	Total Expected AC Load [kW]	Apply a diversity factor of 0.10 to all support, storage, electrical, mechanical, and telecom space. This assumes that no more than 10% will ever be in use simultaneously. The lighting in these spaces is controlled by occupancy sensors.
156.2	20.5	138.0	20.5	
Total Lighting LPD		0.434	W/ft²	
Lighting Energy Summary				**Note about Energy Calculations**
Connected DC Energy Use [kwh]	Connected AC Energy Use [kwh]	Expected DC Energy Use [kwh]	Expected AC Energy Use [kwh]	Energy calculation use assumes maximum light output (no dimming), 12 hours of use per workday, 250 workdays per year, and 5 hours of use on 10 additional days on office floors. The lobby general illumination is on 24 hours, 365 days a year, the restuarant and retail is considered to be in use 14 hours a day, 360 days of the year. Parking areas are in use 16 hours a day.
505,314	62,282	454,273	62,282	

Lighting Comparison to Maximum LPD (Baseline)				
	Connected Load [kW]	Expected Load [kW]	Connected Energy [kwh]	Expected Energy [kwh]
As Designed	176.7	158.5	567,596	516,554
Allowable by Code	296.3	278.6	763,259	718,342
Baseline Reduction	119.6	120.2	195,663	201,788

Appendix F

AC/DC Distribution

Table 32 summarizes the required conversions for each equipment type.

Table 32. AC/DC Required Conversion Summary

DC DISTRIBUTION			
INPUT			
380VDC	DC FUEL CELL	NO CONVERSIONS	
	ONSITE PHOTOVOLTAICS		
	HUMAN WASTE TO POWER		
	BACKUP UTILITY ELECTRIC	*VIA*	*UTILITY XFMR AND RECTIFIER*
OUTPUT			
380VDC BUILDING RISER			
380VDC	MECHANICAL VFDS, MOTORS	NO CONVERSIONS	
48VDC	RACK SERVERS	VIA	380VDC TO 48VDC POWER SUPPLY
	DATA/TELECOM POWER SUPPLIES		
24VDC	LIGHTING	VIA	380VDC TO 24VDC POWER SERVER MODULE
	DALI CONTROL POWER SUPPLY		
	LOW VOLTAGE DEVICES		
	FAÇADE ACTUATORS	VIA	380VDC TO 24VDC CONVERTER
< 4 VDC	ELECTROCHROMIC GLASS	VIA	380VDC TO <4VDC CONVERTER
AC DISTRIBUTION			
INPUT			
480VAC	AC FUEL CELL	VIA	FUEL CELL INVERTER
	BACKUP UTILITY ELECTRIC	*VIA*	*UTILITY TRANSFORMER*
OUTPUT			
480 VAC BUILDING RISER			
208Y/120 VAC	RECEPTACLES	VIA	480Δ TO 208Y/120V STEP-DOWN TRANSFORMER & DEVICE POWER SUPPLY AND DRIVER AC-DC RECTIFIERS
	DESKTOPS, MONITORS		
	TASK AND RETAIL LIGHTING		
	FIRE ALARM CONTROL PANELS		

The schematic in Figure 67 details the building's AC and DC distribution systems and their associated loads. All DC equipment and components are shown in blue, AC in green, and natural gas-powered equipment is shown in red. The distribution systems work together to provide a balance between efficient and cost effective electrical design.

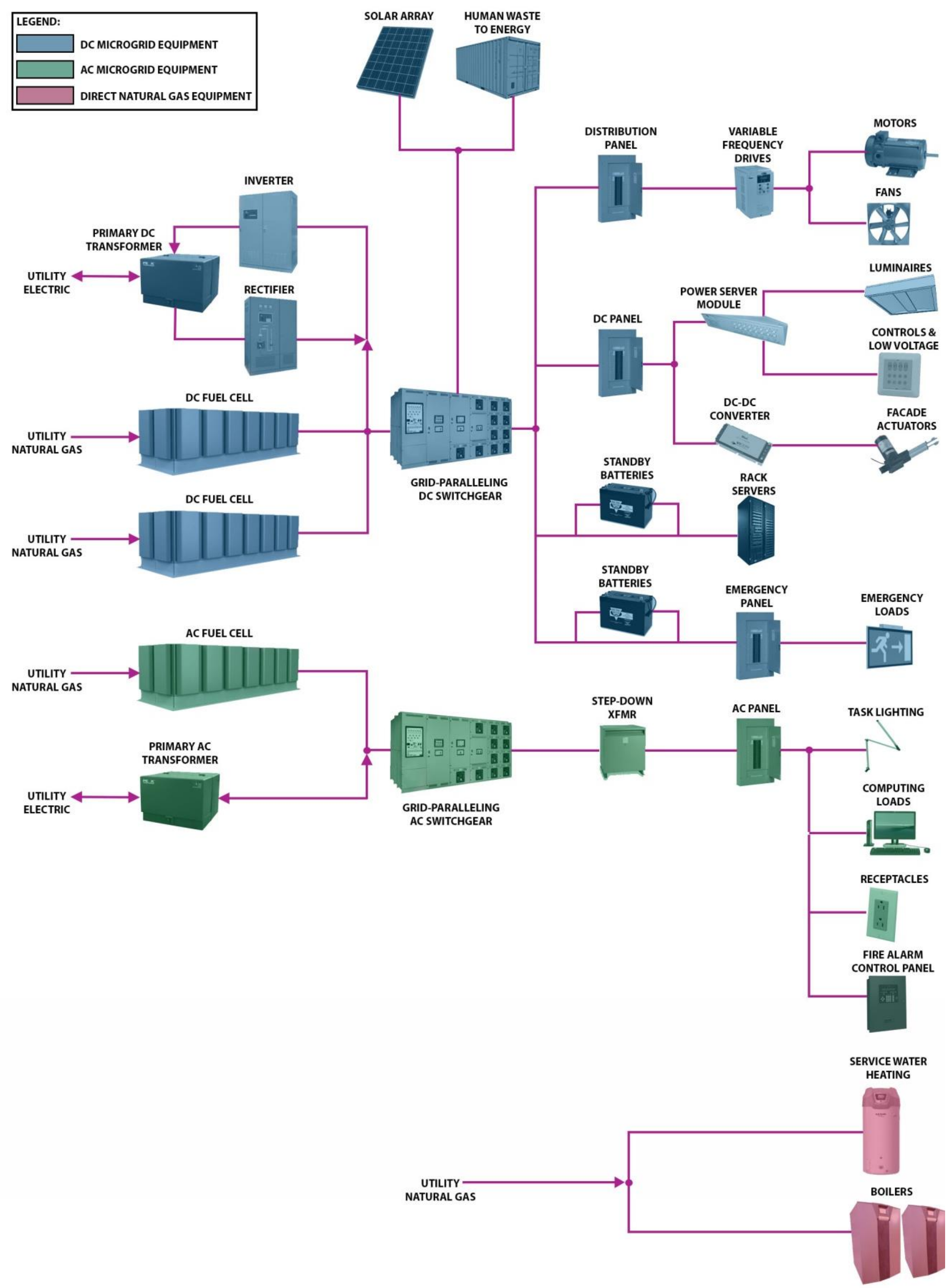


Figure 67. Load Classification Schematic

Table 33. Office DC Voltage Drop Calculation Spreadsheet

380VDC Distribution							24VDC Distribution								
Circuit	Load Type	Max Load [A]	Actual Load [A]	Breaker on Panel [A]	Max Distance	V_{drop} Panel - PSM	PSM	Load [VA]	Load [A]	Channel	Load [VA]	Load [A]	Max Dist.	V_{drop} PSM - Luminaire	Max Total Branch Circuit V_{drop}
1	Lighting, controls	4.00	1.87	15	64	0.2%	1 (Flex)	662.2	27.6	1	94.6	3.9	24	1.4%	1.6%
										2	94.6	3.9	24	1.4%	
										3	94.6	3.9	16	0.7%	
										4	47.3	2.0	12	0.3%	
										5	47.3	2.0	12	0.3%	
										6	94.6	3.9	16	0.7%	
										7	94.6	3.9	24	1.4%	
										8	94.6	3.9	24	1.4%	
								47.3	2.0	9 E	47.3	2.0	<1	0.0%	
2	Lighting, controls	4.00	2.50	15	60	0.2%	2 (Open Office)	819.2	34.1	1	40	1.7	56	1.3%	2.8%
										2	40	1.7	56	1.3%	
										3	92.4	3.9	47	2.6%	
										4	92.4	3.9	47	2.6%	
										5	92.4	3.9	47	2.6%	
										6	92.4	3.9	47	2.6%	
										7	92.4	3.9	33	1.8%	
										8	92.4	3.9	33	1.8%	
										9	92.4	3.9	18	1.0%	
										10	92.4	3.9	18	1.0%	
								132.4	5.5	11 E	66.2	2.8	40	1.6%	
										12 E	66.2	2.8	40	1.6%	
3	Lighting, controls	4.00	2.47	15	54	0.2%	3 (Open Office)	806.8	33.6	1	40	1.7	41	1.0%	2.8%
										2	40	1.7	41	1.0%	
										3	92.4	3.9	47	2.6%	
										4	92.4	3.9	47	2.6%	
										5	92.4	3.9	18	1.0%	
										6	92.4	3.9	18	1.0%	
										7	46.2	1.9	18	0.5%	
										8	46.2	1.9	18	0.5%	
										9	94.6	3.9	31	1.7%	
										10	94.6	3.9	39	2.1%	
										11	75.6	3.2	57	2.6%	
								132.4	5.5	12 E	66.2	2.8	50	2.0%	
										13 E	66.2	2.8	50	2.0%	
4	Lighting, controls	4.00	2.84	15	114	0.4%	4 (Dining/ Break)	941	39.2	1	50.4	2.1	57	1.7%	2.8%
										2	94.6	3.9	43	2.3%	
										3	79.8	3.3	46	2.1%	
										4	67.2	2.8	56	2.2%	
										5	50.4	2.1	30	0.9%	
										6	94.6	3.9	32	1.8%	
										7	79.8	3.3	46	2.1%	
										8	67.2	2.8	56	2.2%	
										9	50.4	2.1	26	0.8%	
										10	75.6	3.2	38	1.7%	
										11	92.4	3.9	36	2.0%	
										12	46.2	1.9	42	1.1%	
										13	92.4	3.9	45	2.4%	
								138.6	5.8	14 E	71.4	3.0	30	1.3%	
										15 E	67.2	2.8	58	2.3%	
5	Lighting, controls, systems	4.00	1.79	15	98	0.3%	5 (Corridor)	576.8	24.0	1	60	2.5	49	1.7%	3.0%
										2	80	3.3	34	1.6%	
										3	60	2.5	18	0.6%	
										4	87.2	3.6	26	1.3%	
										5	73.6	3.1	35	1.5%	
										6	80	3.3	58	2.7%	
										7	52.6	2.2	24	0.7%	
										8	52.6	2.2	42	1.3%	
										9	30.8	1.3	56	1.0%	
								101.7	4.2	10 E	66.3	2.8	62	2.4%	
										11 E	35.4	1.5	78	1.5%	
6	Telecom devices, controls	4.00	-	15	-	-	6	Location and loads based on low voltage device placement and wiring.							

The spreadsheet shown in Table 33 shows the calculations conducted to ensure that the voltage drop on the office floor DC circuits does not exceed 3%. The equation

$$V_{drop} = \frac{K(I)(L)(2)}{cmils}$$

K = resistance (ohms/cmil-ft)
    11 for copper loaded to less than 50% ampacity
    12 for copper loaded to greater than 50% ampacity
I = load in amps
L = one-way distance

was used to calculate the voltage drop.

Building Loads

The spreadsheet shown in Table 34 shows a numerical breakdown of the various building loads, with AC and DC loads calculated separately. Energy savings, when quantifiable, are shown as well.

Table 34. Building Load Summary

BUILDING ELECTRIC POWER DEMAND AND ENERGY SUMMARY						
Location	**DC Loads**			**AC Loads**		
	Connected Load	**Demand Load**	**Expected Load**	**Connected Load**	**Demand Load**	**Expected Load**
Interior Lighting						
Office	123.0 kW	123.0 kW	112.6 kW	19.5 kW	19.5 kW	19.5 kW
Lobby	2.0 kW	2.0 kW	2.0 kW	1.0 kW	1.0 kW	1.0 kW
Undesigned Spaces	31.3 kW	31.3 kW	22.4 kW	- kW	- kW	- kW
Total	156.2 kW	156.2 kW	137.0 kW	20.5 kW	20.5 kW	20.5 kW
		DC Energy Use	**AC Energy Use**	**Savings Source**	**Reference or Assumptions**	
	Total Energy	454,273 kwh	62,282 kwh		See LPD analysis	
	Energy Savings	95,825 kwh	10,647 kwh	Daylight harvesting	See DA analysis	
	Energy Savings	17,922 kwh	- kwh	5% efficiency increase for DC		
	Expected Energy	340,525 kwh	51,634 kwh			
Receptacles (Plug load - not including desktops and monitors or lighting)						
Office	- kW	- kW	- kW	393 kW	328 kW	105 kW
Lobby	- kW	- kW	- kW	20 kW	17 kW	6 kW
Undesigned Spaces	- kW	- kW	- kW	19 kW	14 kW	11 kW
Total	- kW	- kW	- kW	432 kW	359 kW	121 kW
		DC Energy Use	**AC Energy Use**	**Savings Source**	**Reference or Assumptions**	
	Total Energy	- kwh	447,275 kwh		See office power plan	
	Energy Savings	- kwh	183,000 kwh	Plug load controls	See plug load in support	
	Expected Energy	- kwh	264,275 kwh			

(continued on following page)

(from previous page)

Computing Loads (Desktops and monitors on receptacles)												
Rack Servers	35	kW	35	kW	35	kW	-	kW	-	kW	-	kW
Desktops & Monitors	-	kW	-	kW	-	kW	621	kW	621	kW	242	kW
Total	35	kW	35	kW	35	kW	621	kW	621	kW	242	kW

	DC Energy Use		AC Energy Use		Savings Source	Reference or Assumptions
Total Energy	64,983	kwh	403,764	kwh		See computing power
Energy Savings	3,249	kwh	-	kwh	5% efficiency increase for DC	
Expected Energy	61,734	kwh	403,764	kwh		

Mechanical Equipment												
Office	15	kW	15	kW	15	kW	-	kW	-	kW	-	kW
Below Grade	36.5	kW	36.5	kW	36.5	kW	-	kW	-	kW	-	kW
Mechanical Platform	37.4	kW	37.4	kW	37.4	kW	-	kW	-	kW	-	kW
Penthouse	68.3	kW	45.3	kW	45.3	kW	-	kW	-	kW	-	kW
Rooftop	95	kW	95	kW	95	kW	-	kW	-	kW	-	kW
Total	252.2	kW	229.2	kW	229.2	kW		kW		kW		kW

	DC Energy Use		AC Energy Use		Savings Source	Reference or Assumptions
Total Energy	295,769	kwh	-	kwh		See mechanical loads
Energy Savings	14,788	kwh	-	kwh	5% efficiency increase	
Expected Energy	280,980	kwh	-	kwh		

Systems												
Fire Alarm	-	kW	-	kW	-	kW	37	kW	37	kW	9	kW
Telecom/Data	130	kW	130	kW	130	kW	-	kW	-	kW	-	kW
Total	130	kW	130	kW	130	kW	37	kW	37	kW	9	kW

	DC Energy Use		AC Energy Use		Savings Source	Reference or Assumptions
Total Energy	39,000	kwh	78,840	kwh		
Energy Savings	1,950	kwh	-	kwh	5% efficiency increase	
Expected Energy	37,050	kwh	78,840	kwh		

Miscellaneous												
Electrochromic glass	3	kW	3	kW	3	kW	-	kW	-	kW	-	kW
Total	3	kW	3	kW	3	kW		kW		kW		kW

	DC Energy Use		AC Energy Use		Savings Source	Reference or Assumptions
Total Energy	3,000	kwh	-	kwh		
Energy Savings	150	kwh	-	kwh	5% efficiency increase	
Expected Energy	2,850	kwh	-	kwh		

Electric Power Demand Summary											
DC Loads						AC Loads					
Connected Load		Demand Load		Expected Load		Connected Load		Demand Load		Expected Load	
576.4	kW	553.4	kW	534.2	kW	1,110.1	kW	1,037.5	kW	392.4	kW

Expected Energy Use					
DC Energy			AC Energy		
Before Savings	857,024	kwh	Before Savings	992,161	kwh
After Savings	723,139	kwh	After Savings	798,514	kwh

Conservative Energy Estimate					
DC Energy			AC Energy		
1,000,000	annual	kwh	800,000	annual	kwh

Fuel cell analysis conducted assuming additional DC load as a conservative estimate in the event that projected DC energy savings are lower than expected. Server or mechanical expansion may result in larger DC energy use.

Appendix G

Fuel Cell

After considering several fuel cell options, three 400 kW units were selected to support the expected 1,000 kW building load without under or over sizing.

Table 35. Fuel Cell Analysis Summary

FUEL CELL ANALYSIS

Fuel Cell	Max Output		Output Voltage		Electrical Efficiency	Natural Gas Consumption		Heat for Recovery			CO_2 Emissions			Space Required (Dimen. & Area)
ClearEdge Model 400 PureCell	400	kW	480	VAC	42%	3,630,000	Btu/h	1,550,000	Btu/h	at 140°F	1059	lb/MWh	no recovery	27'4" x 8'4" x 10'
			380	VDC	47%						497	lb/MWh	w/ recovery	

Expected AC Energy	800,000	kwh	Annually
Expected DC Energy	1,000,000	kwh	Annually

Natural Gas Fuel Usage

Fuel Cell	Electrical Energy Use		Hours of Use		Total Energy Consumption [using electrical efficiency]		Cas Consumption in kBtu		Gas Consumption in Therms		Monthly Therms	
ClearEdge AC	800000	kwh	2000	hr	1904762	kwh	6499048	kBtu	64990	therms	5416	therms
ClearEdge DC1	500000	kwh	1250	hr	1063830	kwh	3629787	kBtu	36298	therms	3025	therms
ClearEdge DC2	500000	kwh	1250	hr	1063830	kwh	3629787	kBtu	36298	therms	3025	therms
Total	1800000	kwh	4500	hr	4032421	kwh	13,758,622	kBtu	137586	therms	11466	therms

Heat for Recovery

	Heat Recovery from Fuel Cell		Actual Heat to Mechanical Equ.		Annual Energy Used in Recovery Heat	
ClearEdge Model 400	6975000	kBtu	4185000	kBtu	1226553	kwh

Carbon Footprint (CO_2)

ClearEdge Model 400	1906200	lb	864637	kg	Annually, no recovery
	894600	lb	405783	kg	Annually, with recovery

Cost Analysis

Summer $/Month	Winter $/Month	Flat $	Total $	
Cost using natural gas				
$9,239.83	$9,815.10	$1,808.64	$116,138.22	Annually
Cost using grid electricity				
$35,259.50	$22,458.50	-	$346,308.00	Annually
Monetary Savings from using Fuel Cells			$230,169.78	Annually

Primary Fuel Comparison

Energy Source	Annual Primary Fuel Energy Consumption		Assumptions
Grid Natural Gas with Fuel Cells	4,480,468	kwh	Natural gas tranmission results in 10% losses from source to site
Grid Electric	5,806,452	kwh	Electric grid is 33% efficient from source to site after generation and tranmission
Savings	1,325,983	kwh	

Primary Fuel Utilization Comparison

Energy Source	Energy Use	Energy Consumption	
Fuel Cell	Total Required	4,480,468	kwh
	Electricity	1,800,000	kwh
	Recovery Heat	343,563	kwh
	Percent of total	48%	kwh
Electric Grid	Total Required	5,806,452	kwh
	Electricity	1,800,000	kwh
	Percent of Total	31%	kwh

Table 35 analyzes the impact of using fuel cells to produce enough energy to meet the entirety of the building's electrical loads. Each fuel cell has an electrical output of 400 kW, making them capable of supplying 800 kW of DC power and 400 kW of AC power simultaneously to cover the expected 540 kW DC load and 393 kW AC load. The connected AC load (1,110 kW) exceeds the capacity of the AC fuel cell, but the fuel cell was sized to the expected load. The connected load includes the maximum receptacle loads, even though this capacity will not be reached.

The expected energy is calculated from this value using assumptions about when equipment will be used throughout the year. It also accounts for potential energy savings. The expected natural gas consumption was calculated using the expected AC and DC energy usage and the electrical efficiency of the fuel cells. It is important to note that the increase in efficiency of the DC fuel cells comes as a result of the inverter being eliminated from the system. On average, industrial inverters operating at partial load will have efficiency at or below 95%.[4] Heat can also be recovered from the process, and mechanical simulations anticipate that it will meet the heating load 87% of the time. Extra heat is exhausted through a duct to the rooftop along with the carbon dioxide that is produced as a byproduct. From a maintenance standpoint, the fuel cell stacks will require replacement after 10 years of use.

Due to the low price of PG&E's natural gas compared to its electric grid, which continues to increase rates, using the fuel cells to supply the building's electrical loads will save approximately $230,000 annually. The capital cost of the fuel cells is also low, as the self-generation incentives shown in Figure 58 from the federal government and Figure 68 (below) from PG&E provide over 80% of the initial cost.

Self-Generation Incentive Program (SGIP)

The 2014 incentive levels are as follows:

$33.4 million per year in available incentives	75 percent renewable and emerging/25 percent nonrenewable	
Incentive levels	**Technology**	**Incentive ($/watt)**
Renewable, waste heat capture technologies	Wind turbines	$1.13/W
	Waste heat to power	$1.13/W
	Pressure reduction turbine	$1.13/W
	Renewable microturbine (on-site or directed biogas)	$2.08/W*
	Renewable internal combustion engine (on-site or directed biogas)	$2.08/W*
	Renewable gas turbine (on-site or directed biogas)	$2.08/W*
	Renewable fuel cells (on-site or directed biogas)	$3.45/W*
Emerging technologies	Advanced Energy Storage (AES)	$1.62/W
	Fuel cells: combined heat and power (CHP) or electric	$1.83/W

Figure 68. Fuel Cell PG&E Incentives

Most importantly, as 350 Mission aims to be net-zero, the comparison of primary fuel usage between onsite generation with the fuel cells and the electric grid is shown in the red box in Table 35. The natural gas fuel cells save over 100,000 kWh annually and lead to a 15% efficiency increase.

Appendix H

Server Room Sizing

VMware is an industry leader in cloud and virtualization software. The following method for sizing 350 Mission's server room is derived from a VMware publication entitled "Server and Storage Sizing Guide for Windows 7 Desktops in a Virtual Desktop Infrastructure." The results were then verified with actual rack server technical specification sheets and server sizing guides from Dell, HP, and IBM. The comparison found the results of this method to be an accurate estimate of server sizing.

$$(Virtual\ Machines\ per\ Server) = \frac{Cores\ Available\ on\ Server}{vCPUs\ Needed\ per\ Virtual\ Machine}\ x\ (Overcommit\ Ratio\ of\ vCPUs\ per\ pCPU)$$

pCPU = physical central processing unit
vCPU = virtual central processing unit

Table 36. Required Processing Power for Various Applications [14]

USER/WORKER TYPE	APPLICATIONS (OPEN SIMULTANEOUSLY)	VIRTUAL MACHINE CONFIGURATION
Task-based worker (light)	Limited (1-5 applications, light use)	1 virtual CPU 1GB memory
Knowledge worker (medium)	Standard office (1-5 applications, regular use)	2 virtual CPUs 2GB memory
Power user (heavy)	Compute-intensive (5+ applications, regular use)	2 virtual CPUs 4GB memory
Power user plus (heavy)	Compute-intensive (5+ applications, intense use)	2+ virtual CPUs 4GB memory

It is assumed that most employees would not require more intensive power requirements than the category highlighted in the table above. This is likely a conservative estimate that will result in more processing power than will be required, but it is not excessive to the point that processing power is being wasted. To accommodate users with heavy processing demands, 12 non-virtual desktops are planned for each office floor.

Conservative overcommit ratio = 6:1 (vCPUs:pCPU)

Rack servers are available in countless configurations with various packages of processing cores, internal memory, storage, and other options. For these calculations, a server with 24 available cores was chosen, as it offered an adequate balance between performance, power consumption, and cost (based on Dell, HP, and IBM servers). The Eltek Flatpack2 DC/DC converter for data center applications operates at an industry-leading 98% efficiency and is specified for the 350 Mission server room. IBM and HP manufacture 380VDC server power supplies as well.

$$Virtual\ Machines\ per\ Server = \frac{24}{2} x\ 6 = 72\ Virtual\ Machines\ per\ Server$$

Based on this calculation, a server with 24 cores can serve approximately 70 thin client virtual desktops. Therefore, it would require two servers per office floor to accommodate the necessary computing capacity. Again, this value is on the conservative side, as these servers will accommodate about 140 virtual desktops, which exceeds the demand of each office floor.

On average, with the technology available, a server of this capacity consumes a maximum of 700 Watts. The resulting reduction in demand power using the server room arrangement compared to full-capacity, non-virtual desktops is summarized in Table 37.

Table 37. Computing Power Demand Comparison – Virtual vs. Traditional Computing

COMPUTING POWER DEMAND

Average rack server	Max Power [W]	700	Avg. Power [W]	600	Idle Power [W]	420	Sleep Power [W]	200	Off Power [W]	5
Average thin client	Max Power [W]	30	Avg. Power [W]	15	Idle Power [W]	10	Sleep Power [W]	4	Off Power [W]	2
Average full-capacity desktop	Max Power [W]	175	Avg. Power [W]	120	Idle Power [W]	85	Sleep Power [W]	5	Off Power [W]	3
Average LED or LCD monitor	Max Power [W]	30	Avg. Power [W]	30	Idle Power [W]	20	Sleep Power [W]	2	Off Power [W]	1

Maximum Power Per Office Floor

Computing Method	Rack Servers	DC Power [kW]	Thin Client Desktops	AC Power [kW]	Full-Capacity Desktops	AC Power [kW]	Monitors (Backlit LED)	AC Power [kW]	Total Maximum Power	
Virtual Computing	2	1.4	120	3.6	12	2.1	132	4.0	11.1	kW
Traditional Computing	-	-	-	-	132	23.1	132	4.0	27.1	kW
Maximum Power for the Entire Building										
Virtual Computing	50	35	3000	90	300	52.5	3300	99	276.5	kW
Traditional Computing	-	-	-	-	3300	577.5	3300	99	676.5	kW

Computing Maximum Power Demand Summary

Virtual Computing Connected Power	276.5	kW
Traditional Computing Connected Power	676.5	kW
Connected Power Reduction	400	kW
Connected Power Reduction	59%	-

Note about Computing Power Demand Analysis

The AC computer loads (every load except the servers) is supplied by receptacles and are included in the receptacle table and load summaries. This analysis was completed for two reasons, the first being a method of quantifying estimated energy savings over traditional computing methods. The second was to evaluate whether the computing loads could be met by the fuel cells when using actual loads, and not receptacles loads that conservatively overestimate power demand.

Estimated Energy Usage					Energy Assumptions
Virtual Computing Connected Power	1865.4	kwh per workday	476,872	kwh annually	Assume an average of 7 hours of active use, 1.5 hours of idle use, 1 hours of sleep use, and 14.5 hours of off use per workday. 'Off' status on weekends and holidays. Assume 255 annual workdays.
Traditional Computing Connected Power	4199.3	kwh per workday	1,072,327	kwh annually	Assume an average of 7 hours of active use, 1.5 hours of idle use, 1 hours of sleep use, and 14.5 hours of off use per workday. 'Off' status on weekends and holidays. Assume 255 annual workdays.
Connected Power Reduction	2333.9	kwh per workday	595,454	kwh annually	-
Connected Power Reduction	56%	kwh per workday	56%	kwh annually	-

As shown in Figure 69, at each floor, the data and telecom services are supplied through a fiber patch panel and patch panel. Six hardwired access panels provide WiFi, and open office workstations are equipped with a voice/data outlet for voice over internet protocol (VoIP) phones. Conference rooms have a TV outlet and voice/data outlet. TV outlets/TVs are also provided near the elevator lobby to make occupants aware of their monthly energy usage.

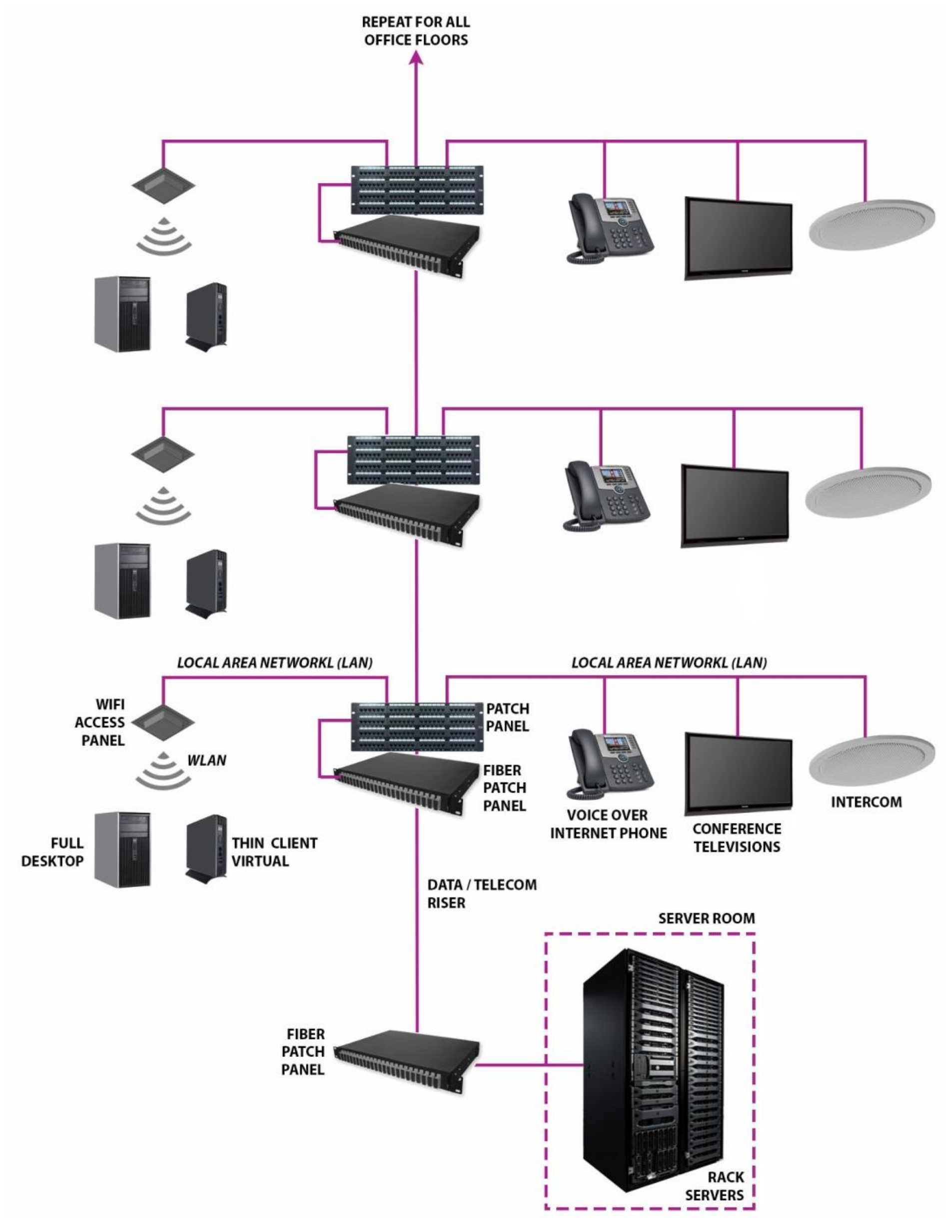


Figure 69. Data System Schematic

Appendix I

Seismic Design

Lobby Earthquake Analysis

California Department of General Services · Division of the State Architect · Interpretation of Regulations Document

PENDANT MOUNTED LIGHT FIXTURES **IR 16-9**

References:
California Code of Regulations (CCR), Title 24 Part 2, California Building Code (CBC)
2001 CBC, Section 2501A.5.2
2007 CBC, Section 1614A1.12.
2010 CBC, Section 1615A1.16, 1615.10.13*
ASCE 7 Sections 13.6.1 and 13.2.3

Revised 11-03-10
Issued 06-22-09

Discipline: Structural

This Interpretation of Regulations (IR) is intended for use by the Division of the State Architect (DSA) staff, and as a resource for design professionals, to promote more uniform statewide criteria for plan review and construction inspection of projects within the jurisdiction of DSA which includes State of California public elementary and secondary schools (grades K-12), community colleges and state-owned or state-leased essential services buildings. This IR indicates an acceptable method for achieving compliance with applicable codes and regulations, although other methods proposed by design professionals may be considered by DSA.

This IR is reviewed on a regular basis and is subject to revision at any time. Please check the DSA web site for currently effective IRs. Only IRs listed in the document at http://www.dgs.ca.gov/dsa/Resources/IRManual.aspx at the time of plan submittal to DSA are considered applicable.

*Indicates alternative 2010 CBC sections that may be used by community colleges, per 2010 CBC Section 1.9.2.2.

Purpose: The purpose of this Interpretation of Regulations (IR) is to set forth an acceptable method for support of pendant mounted light fixtures.

General: Pendant mounted light fixtures that are free to swing in the lateral direction shall be detailed and installed so that they can swing at least 45 degrees from the vertical in any direction without contacting an obstruction. Adjacent fixtures shall be separated by a distance equal to at least one and one half times the length of the pendant.

Exception: When it can be demonstrated by rational analysis that fixtures will swing less than 45 degrees in the maximum credible earthquake, fixture location and spacing may be based on such analysis.

1. SAFETY CABLES: Fixtures that are supported by cables shall have cables (including cable connections and supports) designed to support a load of at least 1.4 times the weight of the fixture acting simultaneously in the vertical and horizontal direction and applied at the point of lateral support. Fixtures supported by hollow rods, or other support mechanisms shall be provided with a "safety cable" attached directly to the fixture and directly to competent supporting structure above. The safety cable, its connections, and supports shall be designed to support a load of at least 1.4 times the weight of the fixture acting simultaneously in the vertical and horizontal direction and applied at the point of lateral support.

Figure 70. DGS Regulations for Pendant Mounted Luminaires in Earthquake Areas

The document shown in Figure 70, created by the California Department of General Services (DGS), outlines the requirements for the use of pendant mounted light fixtures in earthquake-prone areas. The sections outlined in red are those that specifically relate to 350 Mission.

The fixture support cables and connections to the ceiling are designed to carry 1.4 times the weight of the fixtures they are supporting. Connections allow movement in all directions, as required by both the California DGS and the Federal Emergency Management Agency (FEMA).

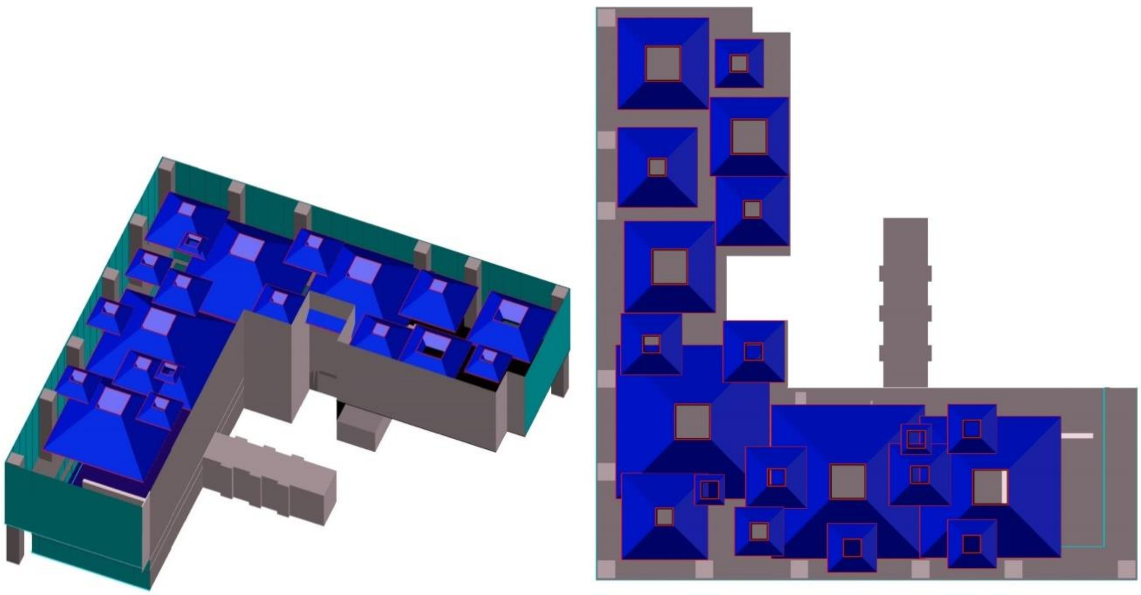


Figure 71. Isometric and Plan Views of Lobby with Luminaire Swing Areas Defined

Figure 71 shows various views of the model that aided in the lobby design. The blue planes define the interference space for each. Fixtures can swing 45^0 in any direction without the risk of colliding with another luminaire or its support cables. The edges of the swing areas are lined in red to improve visibility.

These figures prove that the lobby lighting design follows the requirements set by the California DGS. FEMA has less explicit instructions for design, simply stating that “care must be taken to avoid seismic interactions with adjacent objects when the suspended component swings.” This lighting layout satisfies all of the required earthquake safety measures.

BIBLIOGRAPHY

Websites

[1] "Commercial Flat Roof Grid-Tie Solar Panel Systems." Solar Electric Supply, Inc.. http://www.solarelectricsupply.com/commercial-solar-systems/flat-roof

[2] "EMerge Alliance." EMerge Alliance. http://www.emergealliance.org/

[3] "Federal Business Energy Investment Tax Credit (ITC)." DSIRE USA. http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US02F

[4] "List of Eligible Inverters per SB1 Guidelines." Go Solar California. http://www.gosolarcalifornia.ca.gov/equipment/inverters.php

[5] "Mapping California's Seafloor." California Ocean Protection Council. http://www.opc.ca.gov/

[6] "Power Supply System." Taipei 101. http://www2.taipei-101.com.tw/en/Tower/buildind_07-1.html

[7] San Francisco Department of the Environment and CH2M HILL. "San Francisco Urban Wind Map." San Francisco Energy Map. http://www.sfenergymap.org/

[8] "Self-Generation Incentive Program (SGIP)." PG&E. http://www.pge.com/en/mybusiness/save/solar/sgip.page

[9] "Supercritical Sanitation Systems: Neighborhood-Scale Sewage Treatment." Duke University, Pratt School of Engineering. http://sanitation.pratt.duke.edu/home

Documents/Books

[10] "A Practical Guide to Fire Alarm Systems." Central Station Alarm Association. http://www.csaaintl.org/2011FireAlarmBookONLINE.pdf

[11] DiLaura, David, Kevin Houser, Richard Mistrick, and Gary Steffy. The Lighting Handbook: Reference and Application. 10th ed. New York, NY: Illuminating Engineering Society, 2011.

[12] "LEED 2009 for New Construction and Major Renovations Rating System." U.S. Green Building Council. http://www.usgbc.org/Docs/Archive/General/Docs5546.pdf

[13] "Plug Load Circuit Controls: 2013 California Building Energy Efficiency Standards ." California Utilities Statewide Codes and Standards Team. http://www.energy.ca.gov/title24/2013standards/prerulemaking/documents/current/Reports/Nonresidential/Lighting_Controls_Bldg_Power/2013_CASE_NR_Plug_Load_Circuit_Control_Oct_2011.pdf

[14] "Server and Storage Sizing Guide for Windows 7 Desktops in a Virtual Desktop Infrastructure." VMware. https://www.vmware.com/files/pdf/view/Server-Storage-Sizing-Guide-Windows-7-TN.pdf

[15] Shalva, Anthony. "The ABC's of Fire Alarm Systems." IMSA Journal, May/June (2009): 42-45.

[16] "Total installed cost comparison study of motorized shading systems." Lutron Electronics, Inc.. http://www.lutron.com/TechnicalDocumentLibrary/367-1548.pdf

Programs

PROGRAM	USES	FILE TYPE	INPUT FROM	OUTPUT TO
AGI32	Lighting Calculations	.agi	AutoCAD	N/A
AUTOCAD	3D Modeling 2D Sections and Details	.dwg & .dxf	Revit	AGI32, Rhino
DAYSIM	Daylight Calculations	.hea	AutoCAD	Excel
DIVA FOR RHINO	Daylight Calculations Radiation Maps	.3dm	AutoCAD	Excel
EXCEL	Data Analysis Load Calculations	.xls	Daysim, DIVA	
PHOTOSHOP	Graphic Development	.psd	Revit, AGI	
PV WATTS	Solar Panel Analysis			
REVIT	Floor Plans, Model Development	.rvt		AutoCAD

ACADEMIC VITA

Lara Kaiserian
larakaiserian@gmail.com

Education

The Pennsylvania State University
Schreyer Honors College, University Park, PA
Master and Bachelor of Architectural Engineering, Lighting/Electrical Option
Minor: Architectural Studies
EIT upon graduation (Pennsylvania FE Exam, April 2013)

Professional Experience

EwingCole (Philadelphia, PA)
Lighting/Electrical Engineering Intern
Project team member for this fully-integrated architecture, engineering, interior design, and planning firm in the design of a net-zero building; used AutoCAD 2010 MEP, Revit 2012

- Completed daylighting (Daysim) and lighting (AGI 32) calculations
- Selected luminaires and developed layouts, circuited fixtures, created schedule
- Prepared lighting and electrical drawings including floor plans, installation and layout details, and equipment and panel schedules (AutoCAD 2010 MEP, Revit 2012)
- Designed spreadsheets for automated lighting calculations (Microsoft Excel)

Study Abroad

Completed two seven-week Architectural Engineering study abroad sessions
China – Shanghai, Beijing, Hong Kong

- Studied the rapid development of modern Chinese cities, toured Chinese historical sites
- Attended 10 day International Construction seminar at Tsinghua University, Beijing
- Design and Urban Planning Museum for Hong Kong; created physical and Revit models

Italy – based in Rome, organized travel to Florence, Venice, Naples, Verona, Como, Milan

- Used historic maps and architectural drawings combined with physical evidence to trace the evolution of Rome and Roman architecture from ancient times to modern day
- Designed an art museum for Rome, combining cultural traditions and contemporary ideas

Activities/Honors

Penn State Club Water Polo
    Captain 2012-14, , Webmaster 2010-14, Vice President 2013, Treasurer 2010-12
    Collegiate Water Polo Association
        All-American 2013, All-Conference 2011, 2012, 2013
        Academic All-American 2010, 2011, 2012, 2013
Penn State Homecoming
    Merchandise Director 2012, Merchandise Captain 2010, 2011
Engineering Ambassadors 2012-13
IFC/Panhellenic Dance Marathon (THON)
    Captain 2014, Committee Member 2010-13