Final Report

AE Senior Thesis
Lighting Electrical

Xiaoyin Wu
Thesis Advisors: Shawn Good, Leslie Beahm, Dr. Kevin Houser
Apr 9th 2014

acknowledgments

I would like to thank all the individuals who have offered much help and have been very supportive of me throughout the years in AE at Penn State.

Special thanks to:

Dr. Kevin Houser	Student advisor, AE lighting professor, Penn State
Dr. Richard Mistrick	AE lighting professor, Penn State
Mr. Shawn Good	Thesis lighting advisor
Ms. Leslie Beahm	Thesis Electrical advisor
Professor Kevin Parfitt	Thesis advisor
Professor Charles Cox	Architecture advisor
Ms. Dorene Mannicia	Philips
Ms. Carol Jones	Philips
Ms. Meg Smith	Philips
Dr. Kurt Roth	Fraunhofer
Mr. J Cruz	DiMella Shaffer

And the most special thanks to my parents and all my friends that I love so much!

executive summary

The thesis is to find solution of lighting design for four spaces in the building of Fruanhofer Center of Sustainable Energy as well as the electrical system redesign to keep up with the changed lighting load. The Fraunhofer CSE building is located in Fort Point Channel in Boston. It's a historical building within in a historic neighborhood where more and more commercial and professional companies are merging in and using the old buildings as their new homes.

The thesis report discusses the existing condition of each space and the approach of the design solution, then the calculation and rendering for the solution to test the design and compare with the requirement and criteria. The existing designs were studied in the previous technical reports from last semester. And the report only includes the results of the lighting design, electrical system redesign as well as architectural and structural breadths.

In the lighting design portion, the lighting depth successfully achieved the design goals both in the qualitatively and aesthetically. Most of the criteria and requirements are met for each space and the final renderings also address the concept of the design that is proposed in the schematic design phase. For the electrical depth, new branch circuits are redesigned as well as the feeders are resized as needed.

The two breadths are focusing on the changing of interior architecture and the structure system resizing. The architectural breadth is proposed not only to change the looking of the space in the building to create a better working environment, but also to accommodate the new lighting design and provide it a more opportunities for more creative design. And the structure is automatically needed to be studied for the big change of the architecture.

table of contents

building statistic

Building Name: Fraunhofer CSE Project **http://cse.fraunhofer.org/**

Location: 5 Channel Center Street, Boston, MA

Occupancy Type:

Offices and research laboratories (Group B) and conference room (Group A-3)

Size: 42150SF

Number of Stories above Grade: 6

Project Teams

Owner: Fraunhofer USA

General Contractor/Construction Manager: Gilbane Building Co. www.gilbaneco.com

Architects: DiMella Shaffer www.dimellashaffer.com

Structural Engineer: McNamara/Salvia, Inc. www.mcsal.com

MEP/FP/Tel Data Engineer: BR+A Consulting Engineers www.brplusa.com

Lighting Consultant: Lam Partners www.lampartners.com

Plumbing/HVAC Services: Northeastern Mechanical www.northeasternmech.com

Civil Engineer: VHB, Inc. www.vhb.com

Geotechnical Engineer: Haley & Aldrich, Inc. www.haleyaldrich.com

Dates of Construction: Jan 2012— Apr 2013

Architecture Design and Functional Component:

The project is a renovation for a 100-year old historical building of six-story, three-bay loft brick structure with classical revival-style detailing. The Fort Point Channel district is marked by an exceptional degree of visual uniformity. Fraunhofer Building, one of the buildings in the Fort Point Channel area, is not an exception of a loft structure built in 1913 by the Boston Wharf Company, and represent an unusually coherent and well-preserved collection of late 19th and early 20th century lofts that reflect a critical period of social, economic, and physical development in the City

and the region. The loft buildings are generally masonry, with simple volumes and flat roofs. Buildings are elegantly proportioned, with classically inspired details concentrated at entrances and cornices. And the structure is left unchanged in this project to conserve the significant continuity throughout the District in terms of massing, scale, and style.

The majority of the structure has been left almost unchanged since its construction 100 years ago. In planning the renovations, CSE worked closely with the Fort Point Channel Landmark District Commission and National Park Service's Historic Preservation Planning Program, developing a retrofit plan that could deliver energy savings and still respect the building's historic character.

Applicable Codes

CODE TYPE	APPLICALE CODE (Model Code Basis)
Buliding 780 CMR	Massachusetts Building code (8th Ed.) (International Building Code 2009, amended)
Fire Prevention	527 CMR: Massachusetts Fire Prevention Regulations
ADA	Americans with Disabilities Act (2010 ADAAG), & Title II
FHA	Fair housing Act (Safe Harbor: FHA Design Manual)
Electrical	527 CMR 12.00: Massachusetts Electrical Code (2011 National Electrical Code, amended)
Elevators	524 CMR: Massachusetts Elevator Code
Mechanical	2009 International Mechanical Code
Plumbing	248 CMR: Massachusetts Plumbing Code (2005)

Zoning

Industrial District—Restricted Manufacturing: Planned Development Area Designation
http://www.bostonredevelopmentauthority.org/zoning/downloadZone.asp

Historical Requirement

The Fort Point Channel Landmark District Standards and Criteria (Design Guidelines, 2008)
http://www.cityofboston.gov/landmarks/historic/fpc.asp

Construction

This project is a historical building renovation and tenant fit-out. Gilbane Building Co. is the general contractor of this building and is responsible for the construction process of the Fraunhofer CSE building. The whole construction process lasts for over a year from January, 2012 to April, 2013.

Due to the special situation of the particular project, there is hardly an official estimate for the renovation. The almost all the building electrical, lighting and mechanical system as well as building material are donated from different manufacturers for the building technology showcase purpose

of the building. The owner cannot provide an estimation number of this construction project. The delivery is not a regular method. It's a base building--tenant fitup process.

Electrical

There is a single electrical entry into the building providing power to the main distribution switchboard and the main fire pump. The electrical system of the building has a utilization voltage of 480/227V, 3 phase. Different utilization voltage is used throughout the building due to the variety of equipment needs in the building. The building emergency power system is powered by a 350kW, diesel filled, 480/277V, 3 phase, 4 wire standby emergency generator located on the rooftop. It provides the building with 120V emergency power for lighting and receptacles. There are 3 photovoltaic arrays on the rooftop inverting solar power to electric power for the building. There are pv panels mounted on the roof and west and east façades.

Lighting

The lighting design for Fraunhofer CSE building is energy efficient and sophisticated. The building is the project of the Fraunhofer building technology showcase. The lighting system donator provided the project the very up front. Most of the lighting fixture sources are LED and some are fluorescent source. A large amount of color changing LED is used in the building as well for the aesthetic purposes. The lighting systems work on both 277V and 120V system. Dimmable lighting fixtures are widely applied throughout the entire building. The lighting control system is connected to BAS system. Shading system is installed in the building as part of a daylightign control system.

Mechanical

There are 2 boilers to reheat/preheat the hot water, 4 pumps for roof hot water service and basement fuel oil supply. There are two air handling units locate on the roof serve for building ventilation and exhaust. They work on 460V, 3 phase motors. The AHU supply air quantity to be 20,000 CFM. And its cooling coil load is based on 100% CFM and the preheat coil load sized for 75% CFM preheat coil sized for 100% outside air at 0^{o}F. High efficient active chilled beams are used in the building to supply heating and cooling air. The building also utilizes in-floor radiant heating cooling system on 1st and 3rd floor for additional heating and cooling. 11 water pumps are located on different levels in the building supply for chilled water, condenser water and chilled beam water.

Structure

The building is a three-bay loft steel frame structure. All columns are the existing steel columns with existing concrete column bases. The typical bay spans as long as 20ft. The main wall structure is masonry, brick wall with metal studs. The floors are existing typical wood decking with glass fiber reinforced concrete on top and the roof is existing wood deck and concrete slab. The building is a 100-year-old historical building so the typical beams sizes are hard to be obtained at the point.

lighting design depth

In the lighting depth, there are four spaces being redesigned are

Lobby | circulation space

Conference room | special purpose space

Open office | large work space

Façade | exterior space

The design concept for this a-hundred-year old historical building is developed through the company profession which is clean, intelligent and corporative.

INTRODUCTION

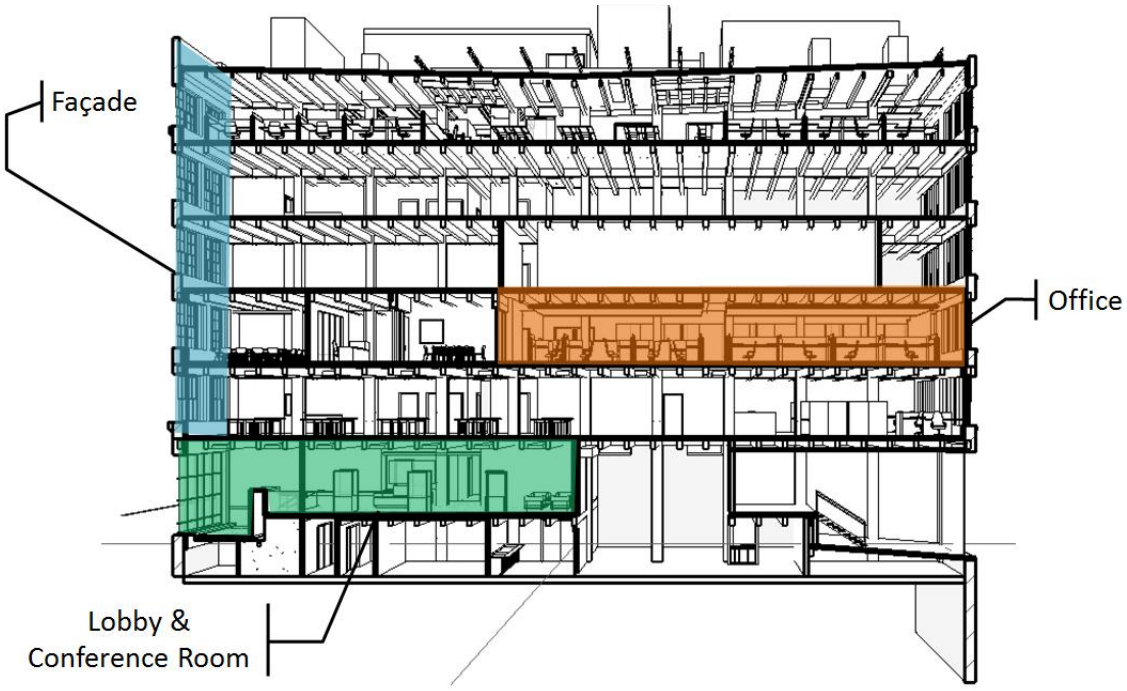


Figure 1

The design concept is extracted from the company profession that they want to advertise to the public and the related industry about clean energy, intelligent building system and collaborative research on sustainable material. From there I concentrate the main design ideas to be clean, intelligent and collaborative. From those ideas, the design of four spaces will mainly contains linear or simple line lighting patterns that will create a modern and technological look in the spaces like those typical appearances in the sci-fi movies. The lighting will create layers in the space to help emphasize the architectural features in this classical style building so to collaborate the modern and classic style together.

DESIGN CONCEPT

The general idea of the concept is to create the modern look of the building also with the idea of presenting the company image of high-end and environmental-friendly. And the design could also really help the people who stay in the space to enjoy the time and work with good mood. To incorporate this idea, some images I found could be a great way to show the concept and the driven idea when comes to the fixture selection and layout planning.

Figure 3

Figure 2

These images represent the look I'm trying to go for in the lighting design. Straight continuous lighting pattern will be the dominant look in all the spaces. The design is trying to make people working in the space could enjoy the refreshing look of the company during the daytime.

LOBBY

Space Description

The lobby is located on the ground floor/first floor on the north side of building. The lobby consists of two parts with two different floor heights. The lower part of the lobby with a small floor area serves as a transition area from vestibule to the reception area. The upper level of the lobby is the main reception area which is the designated design area for the depth. The two parts are connected by a short length of stair and a short wall with the company name on. The north side of the lower portion is the north wall of the building with large window area. A convertible partition glass wall is on the longitude side of the upper portion lobby separating the lobby and the large conference room. The south side of the lobby is the overlook window to the PV lab in the basement. A specially designed reception desk is on the upper level facing the large conference room. For plan see *Figure 4*.

The primary tasks of the lobby are reception, circulation and showcase. The company is currently under the discussion of putting some touch screen table and display closets for future showcase purposes. By removing the movable wall between the large conference room and reception area, the large area can serve as a gallery for new products exhibition.

Room Dimension

Width: 19'-10"

Length: 47'-8"

Height: 8'-10 ¼

Room Finishing/Glazing

Table 1

	SURFACE	MATERIALS	FINISH	DESCRIPTION	REFLECTANCE
Upper Lobby (Reception) F113	Floor	Rubber	RBT-1,2,3	Three color rubber finishing on 2 layers of ¾" ply wood subfloor	0.4, 0.7
	Wall	GWB/Glass	PT-1,ACC	5/8" GWB, 3 5/8" Mtl. framing furring wall/ Dorma Moveo moveable wall	0.94
	Ceiling	Timber, act panel	PT-1,3,4	Exposed beams, acoustical panel	0.8

Architectural Drawings of Existing Design

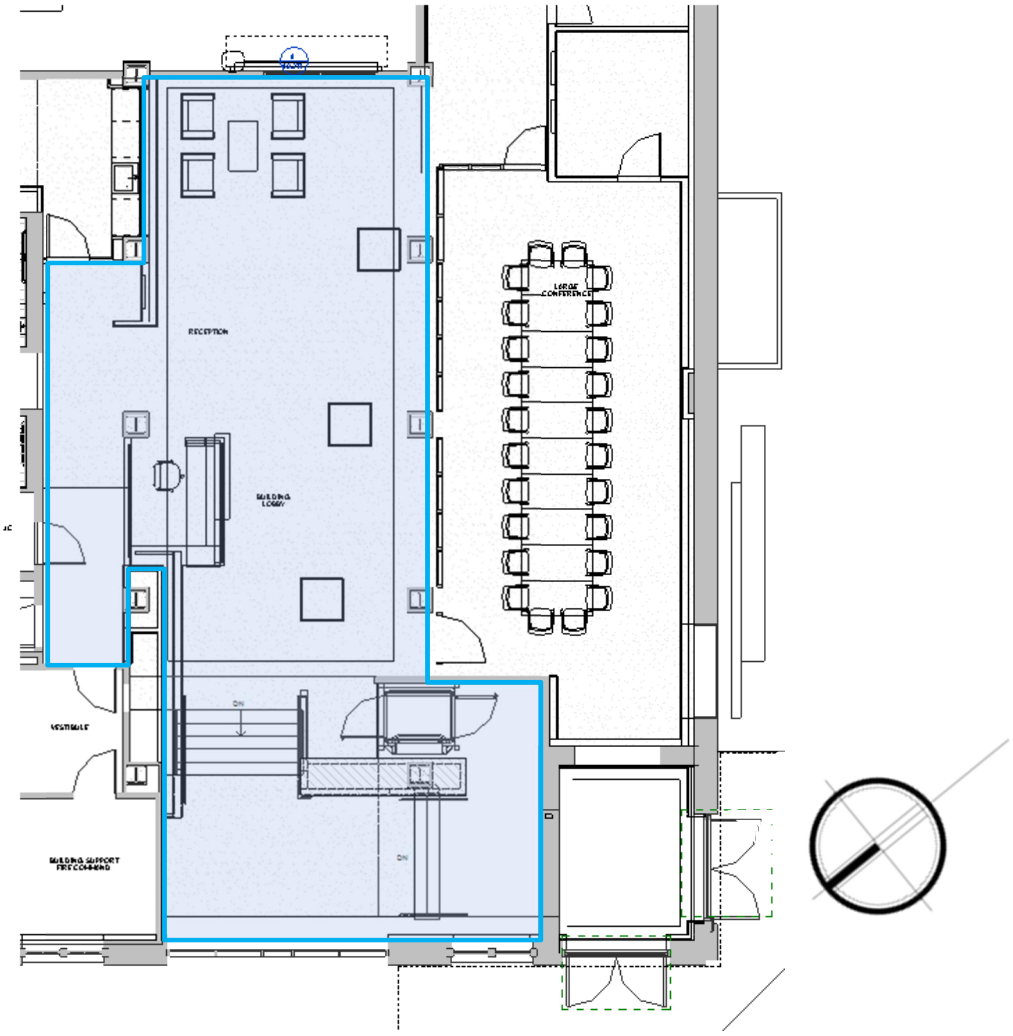


Figure 4

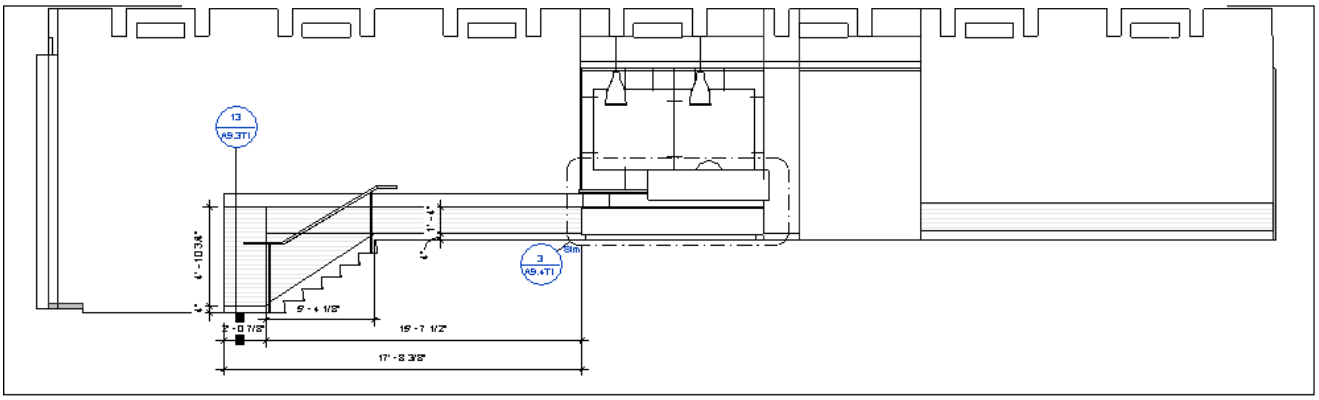


Figure 5

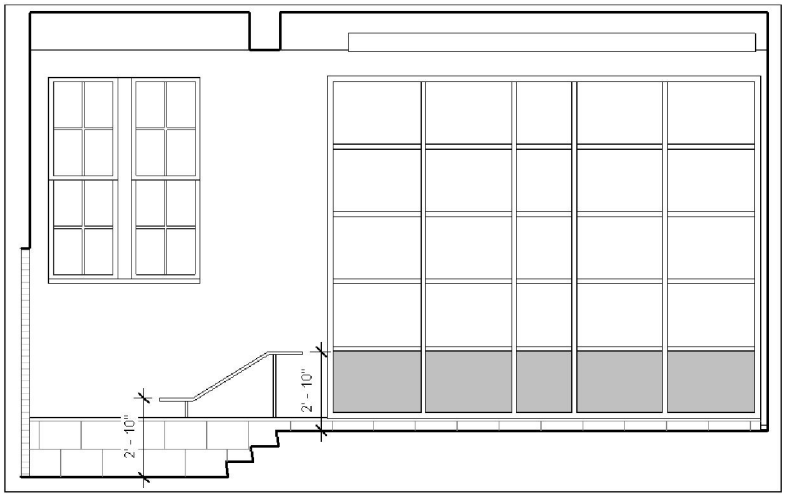


Figure 6

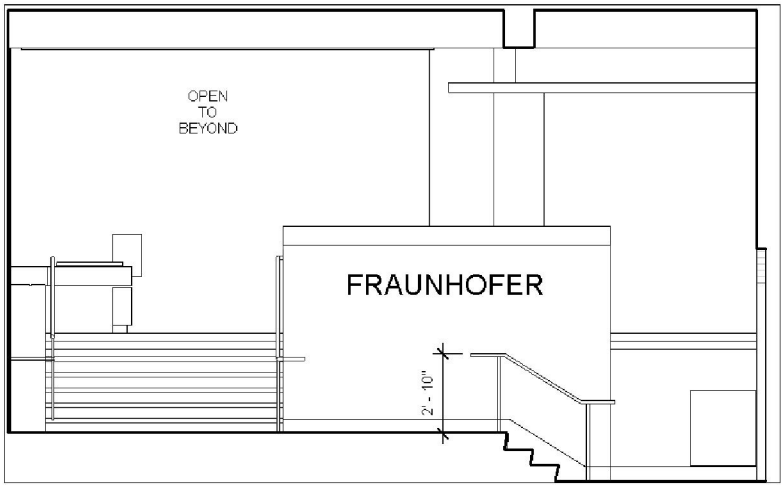


Figure 7

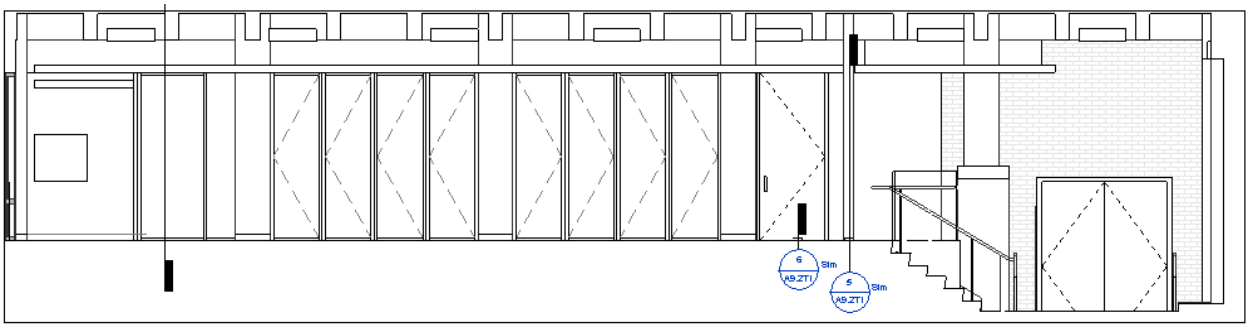


Figure 8

Lighting Design Criteria & Consideration

Lobby is the space where people gather. This lobby is a part of the entry passage of the building. It directly connects the vestibule. Therefore the lobby area presents the company image in a very crucial way. The color rendering and uniformity are two priority issues that needed to be considered. Also, since this space will also be used as a showcase/gallery area, aesthetic appearance plays a very important part in this space. More kinetic and high-tech lighting design should be considered of use to help improving the visual representation of the space. The reception desk area should be specially considered due to the fact that writing and reading tasks will be conducted in the reception area. The space should be designed with the consideration of the conference room design, because the two spaces are designed to have the possibility of joint use as an open exhibiting space. The location of the lobby decides that there isn't much daylight available in the space, so most lights will be on during large portion of time during the day, so energy efficient fixtures are the better choice when dealing the fixture selection.

IES Illuminance Recommendation

Table 2

Space		Eh	Ev	Avg:Min
Upper Lobby (F113)	Reception Desk	150 lux	50 lux	4:1
	General Area	100 lux	30 lux	4:1

ASHRAE 90.1 (2010) Requirements

Power Density Allowance: 0.90 W/sf

Control requirements: The space shall have automatic shutoff control. The control shall be schedule basis or controlled by other signal from building automatic system. The automatic control device shall be manual on or automatically turn lights on to 50%.

Accenting

The main goal for the lobby is for congregation and orientation. And accenting is used for visual attraction and way finding.

Appearance and Aesthetic Consideration

Use the lighting effects and layouts to reinforce the form and neutrality of the architecture. The illuminance and uniformity decide the people's satisfactory of the space. Those are some critical issues for an entrance space like lobby.

Color Quality of Light

Color rendering affects people's sense of perception of clarity and visual comfort. Good color appearance is important for the entrance space like lobby. Lamps with CRI of about 80 will be considered a better option of fixture selection.

Glare

Controlling glare from luminaires is essential to maintain occupant visual comfort. By selection luminaire with sufficient optics and install with the right aiming angles will reduce the glare to the minimum.

Installation and Maintenance

The installation in the lobby requires some minor finish changing of the original space. Ceiling panels and column finish needs to be changed with the new design solution in order to realize the recessed luminaire along the ceiling and the columns.

Controls and Flexibility

The lighting can be controlled in different zone groups for dimming purposes. Unless the space is joined with the conference room, no multi-scene is needed for the general purpose.

Design Goals

As the gateway of the company, lobby plays an important part of representing a company's image. With this thought in mind, of all the designs for the four spaces, lobby has the most sophisticated design and it contains the most features to showcase the design concepts. The lobby is on the first and connecting the lower level vestibule with two sections of short length staircases with a landing in between. The upper level lobby is the reception area. There are multiple layers created in the lobby and the layers helps defining the shape of the space. Linear lighting fixtures

that highlight the columns to the beams are the main feature of the space. Those linear white lights make the space has a feeling like in the sci-fi movies. Warm colored indirect light from in between the beams are used to add up the layers above the exposed ceiling structures. The light hide beneath the stairs helps define the transition areas and leading people into the space. The logo wall by the landing next to the stairs is combines with light fixtures and helps emphasizing that the company's profession is about technology.

Luminaires and Equipment

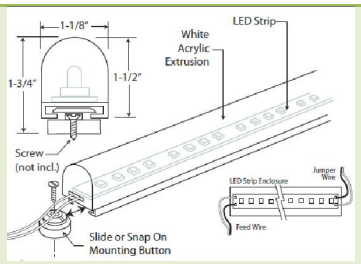
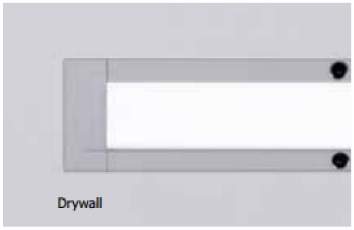
In order to reach the goal of energy efficient design, when selecting the fixtures, the goal is to minimize the wattage consumption and reach the desire illuminance level.

Luminaire Schedule

Table 3

TYPE	#	DESCRIPTION	MANUFACTURER	MODEL	LAMP	WATTS	VOLTS
L1	31	Recessed 6" wide seamless linear dimmable LED light with acylic lens	PRULITE	BIO-SM-06-SAL-YGW	LED	19.2	277
D2	16	Wall surface mounted 3" squre downlight	Edison Price	LED-SQ-XSM-DL4-1000	LED	18.66	120
L4	34	Recessed 2.5" wide continuous linear white-LED light with 1.6" diffuser lens	Pure Edge	TL1.6-5WDC-3FT-24K-WH	LED	18.55	120
P1	1	Pendant mounted 4' diameter round white LED circular light with constant voltage driver	DELRAY	6704-S-W41	LED	48.6	120
L5	144'	Continuous LED dimmable light strip mounted inside a squre clear or frosted acrylic channel	Dreamscape	DLED-5400	LED	2.5/ft	24
L7	5	Surface mounted white LED strip light with 3000K color temperature	Bartco	ECO5-JP-3-35F	LED	5.7	120

Table 4

	L1		P1
	D2		L5
	L4		L7

Light Loss Factors

All LED lamped luminaire are assumed to have a LLF of 0.7.

Computer Rendering and Calculation

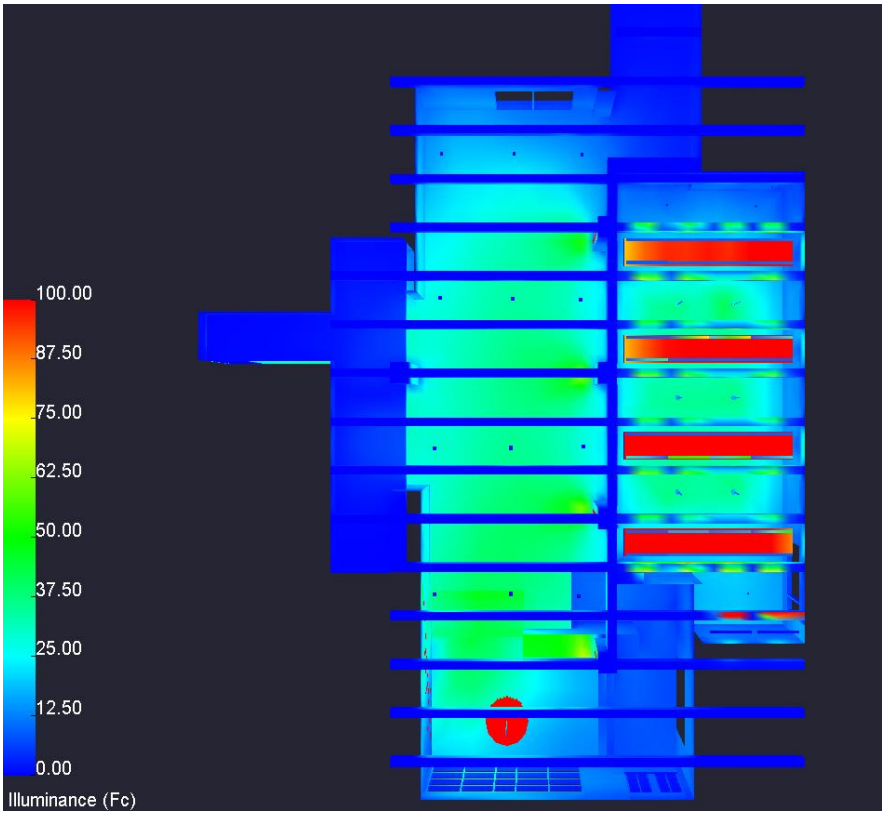


Figure 9

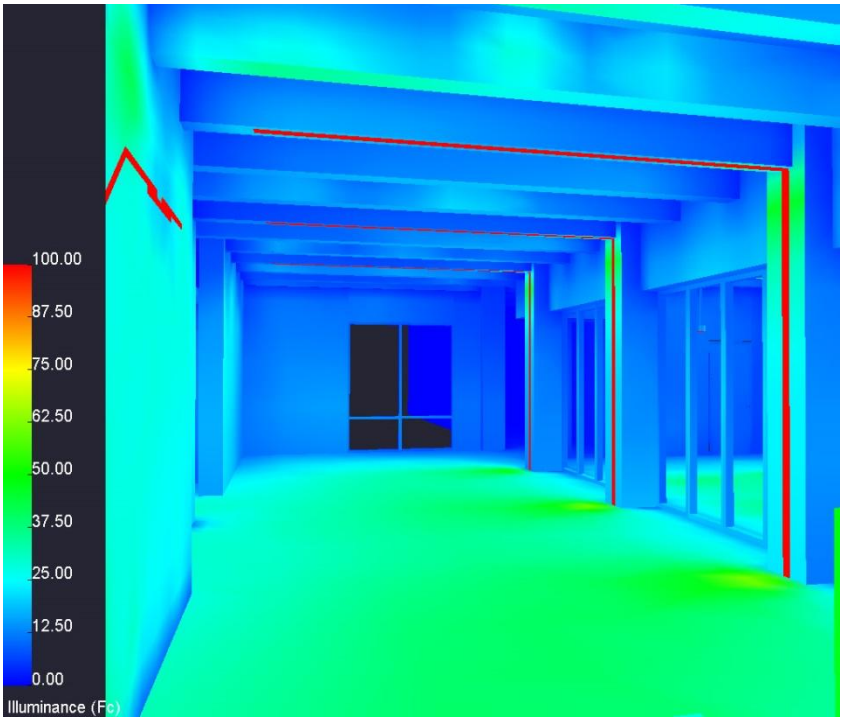


Figure 10

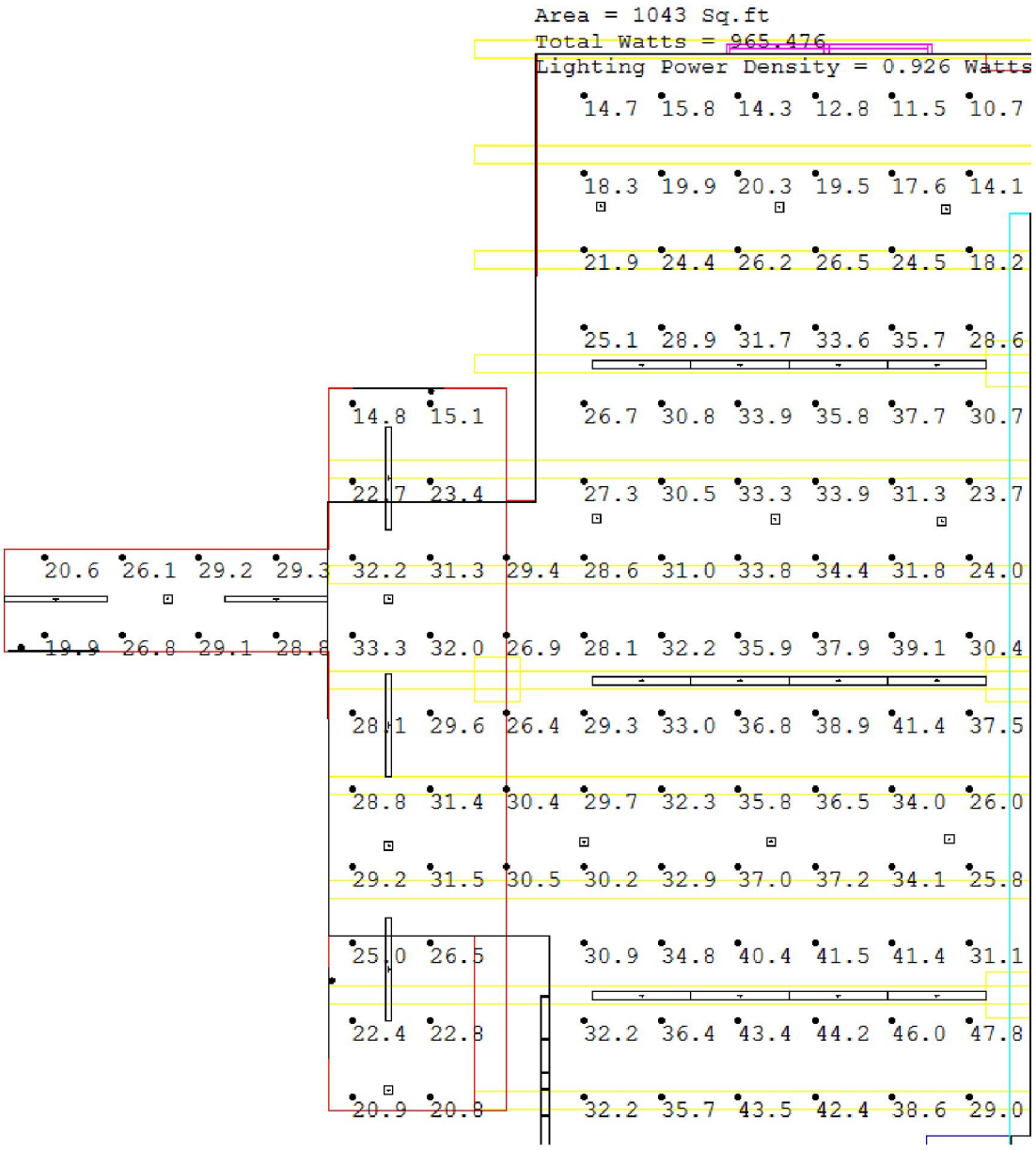


Figure 11

Project_1
Calc Pts

Whole
Illuminance (Fc)
Average=29.57 Maximum=47.8 Minimum=10.7
Avg/Min=2.76 Max/Min=4.47

LPD-UWLR Areas

Lobby LPD
Area(Sq.ft)=1043 Total Watts=965.476 LPD (Watts/Sq.ft)=0.926

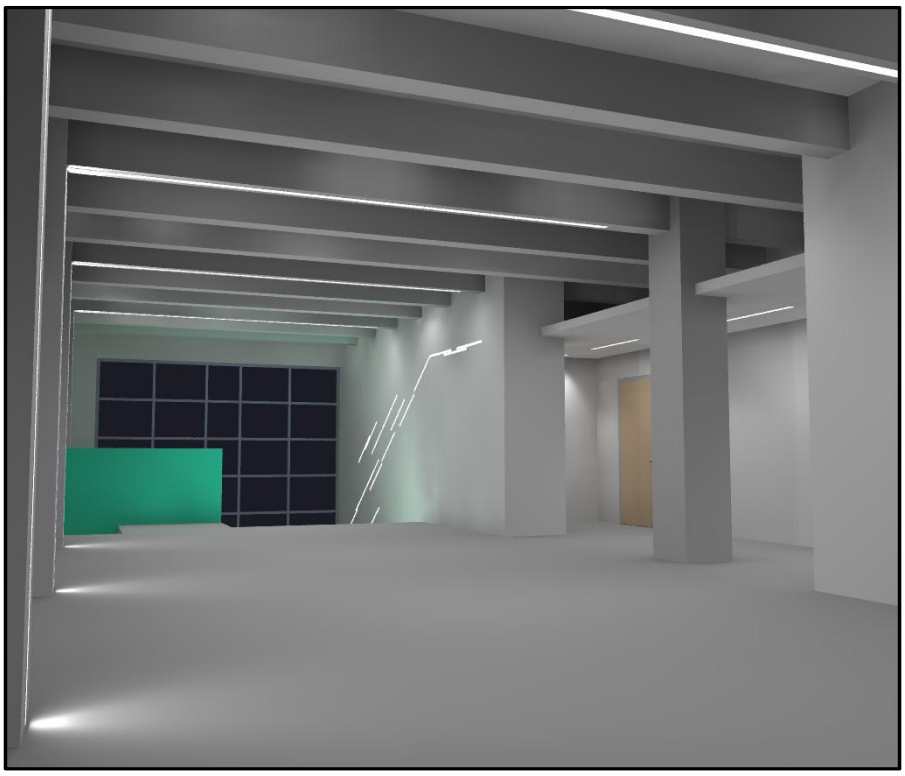


Figure 12

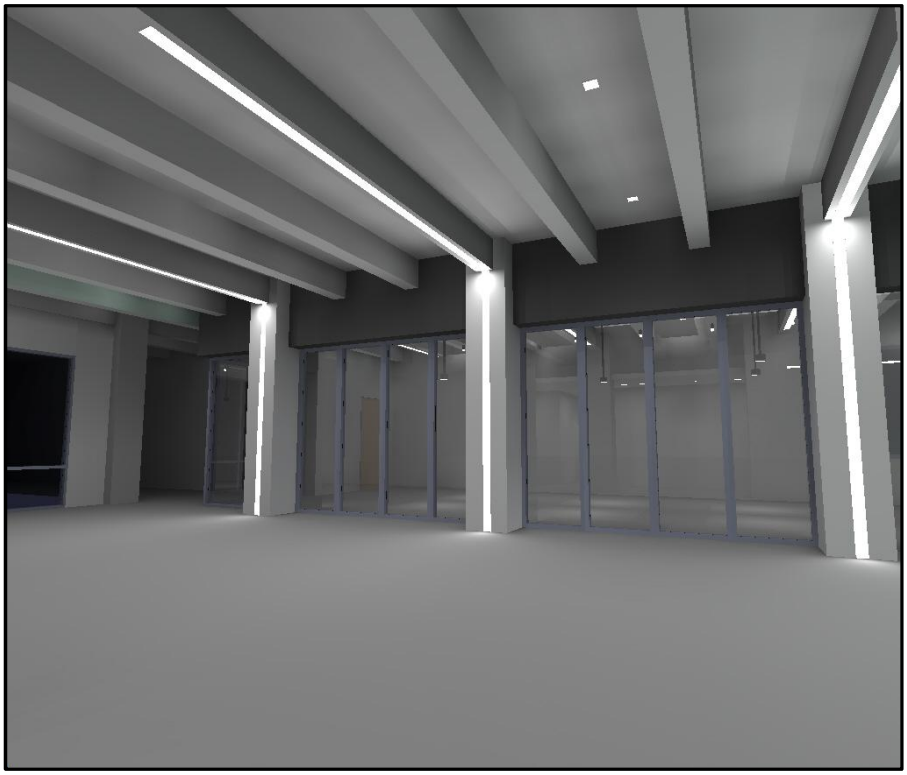


Figure 13

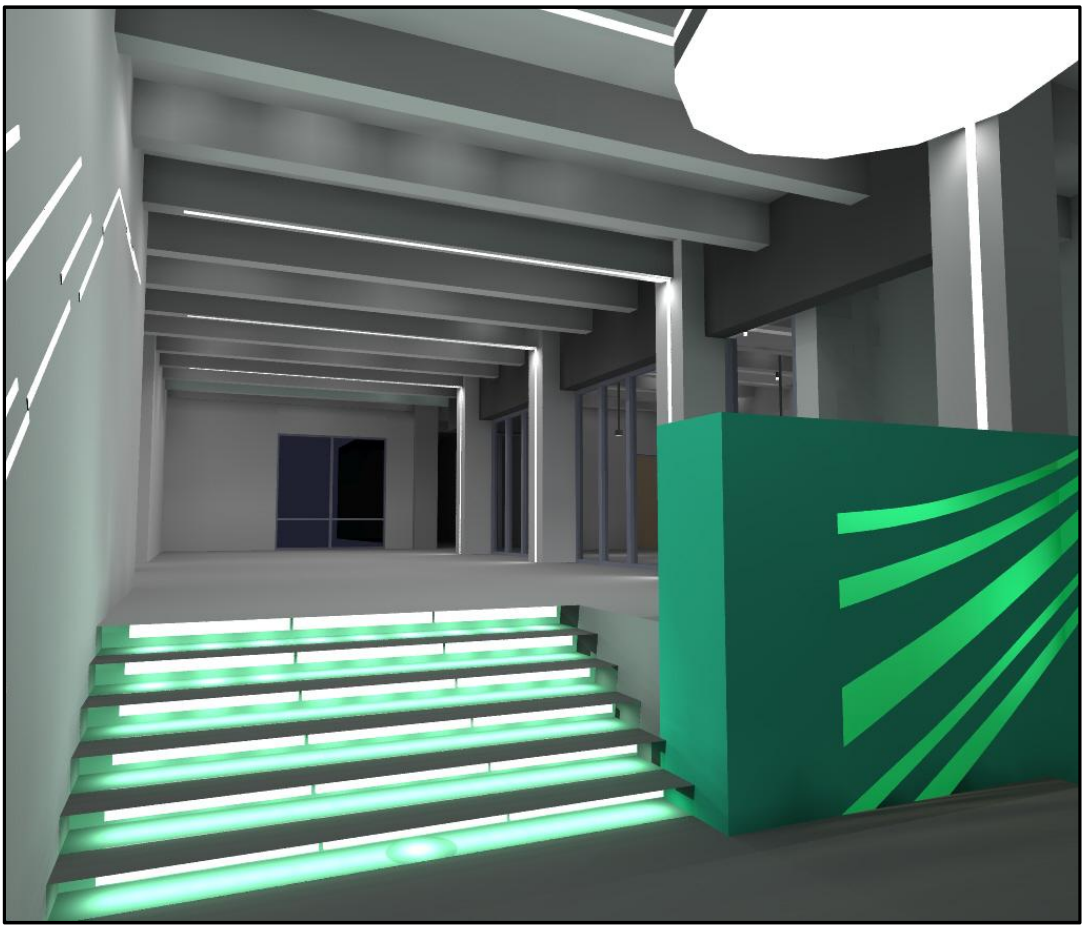
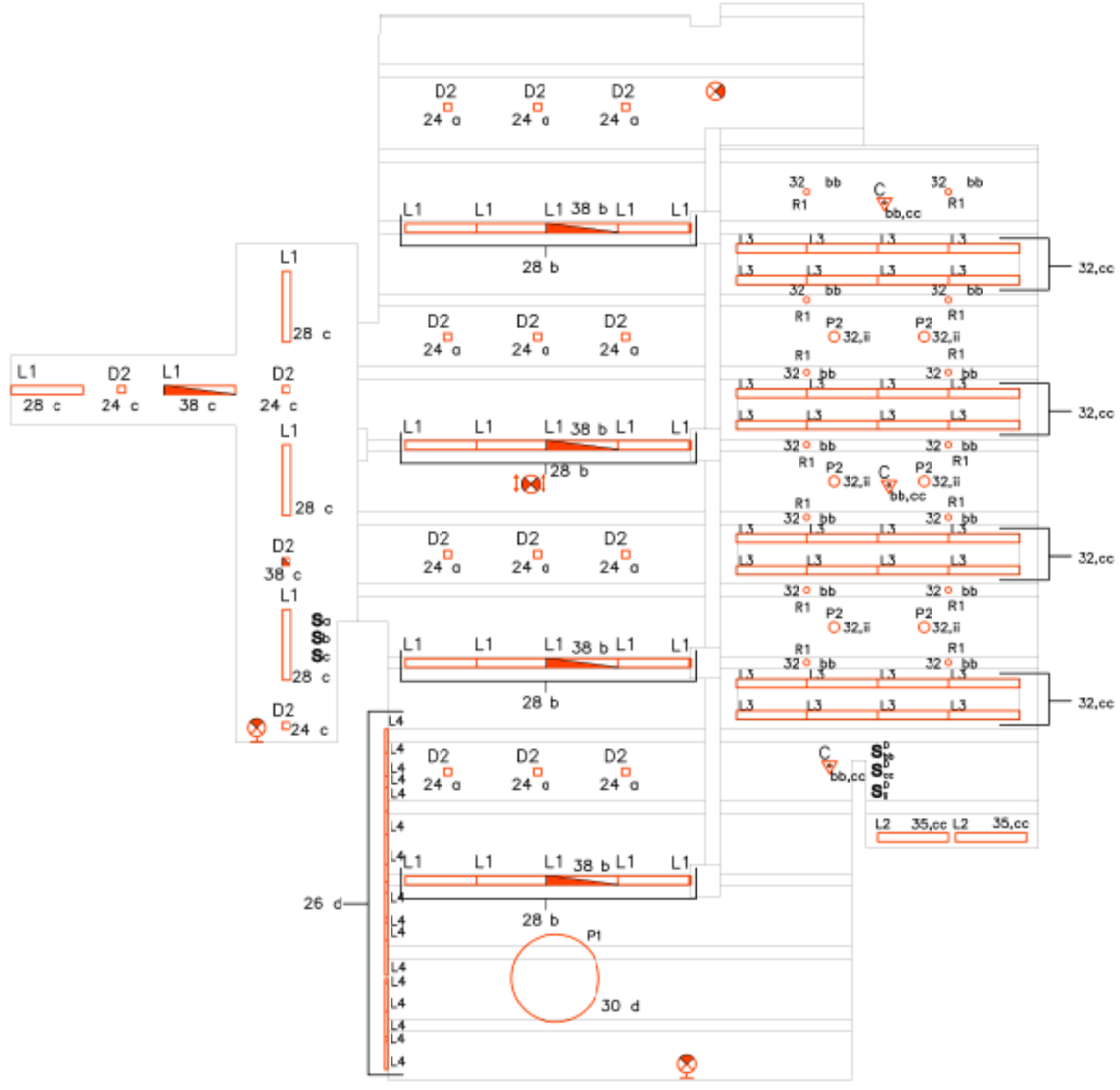


Figure 14

Lighting Plan



5/32"=1'-0"

PROJECT:
FRAUNHOFER CSE

CONTENT:
LIGHTING PLAN
LOBBY
CONFERENCE RM

DRAWN BY
XIAOYIN WU

DATE:
APR 2014

Evaluation

The lobby lighting design main goal is to provide general illumination for the psychological impression of modern and techno feeling. The new lighting design style brings more scientific fictional impression into the space. It achieves the goal of making a good first impression to the people entering the building for the first time.

The continuous linear fixtures that are installed along the columns and beams helps define the space volume. The downlights that are placed in between the beam grooves help make the entire space uniformly lit up.

Lobby has an average illuminance of 29fc and max:min ration = 4:1. The average value exceeds the IES criteria. But this is a space dedicate for a more decorative and image display function of the building. So the illuminance criterion becomes a less important factor in the design consideration.

CONFERENCE ROOM

Space Description

The large conference room is a rectangular shaped room on the first floor locates right next to the lobby. The conference room is separated from the reception area by a movable petition glass wall which can be removed and converts the first floor into a large open space. The conference room is also served as a multi-function work space if needed. There is one small window of the west façade.

Room Dimension

36’ x 16’ 8” x 8’-10 ¼” (L/W/H)

Room Finishing/Glazing

Table 5

SURFACE	MATERIALS	FINISH	DESCRIPTION	REFLECTANCE
Floor	Carpet/Rubber	RBT-3/CPT-1	Dark color carpeting on 2-color rubber finish	0.3, 0.7
Wall	GWB/Glass	PT-1,2,4	5/8” GWB, 6” Mtl. framing furring wall/ Dorma Moveo moveable wall	0.94, 0.6
Ceiling	Timber, Acoustical Panel	PT-1	Exposed beams, acoustic panel	0.8

Architectural Drawings of Existing Design

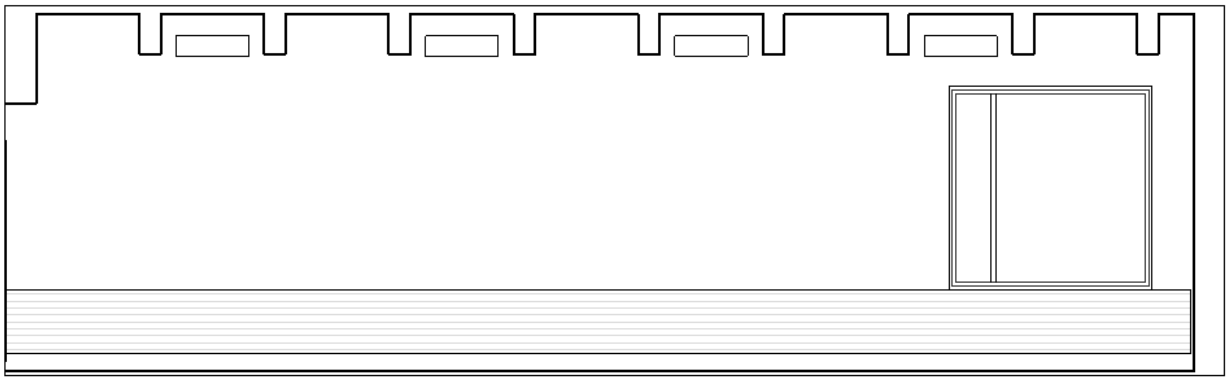


Figure 15

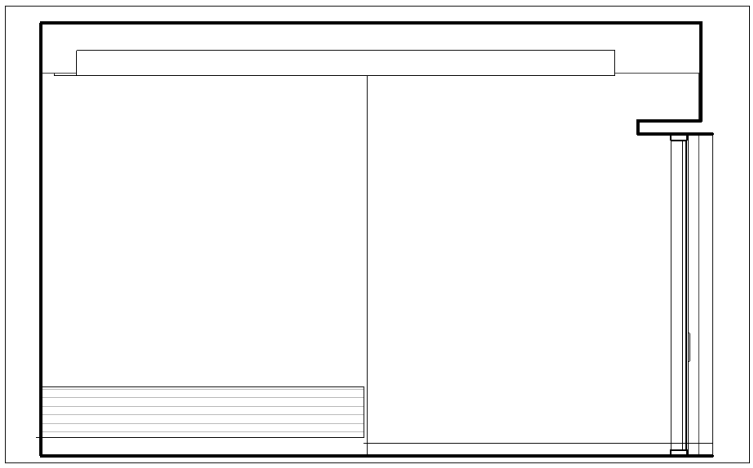


Figure 16

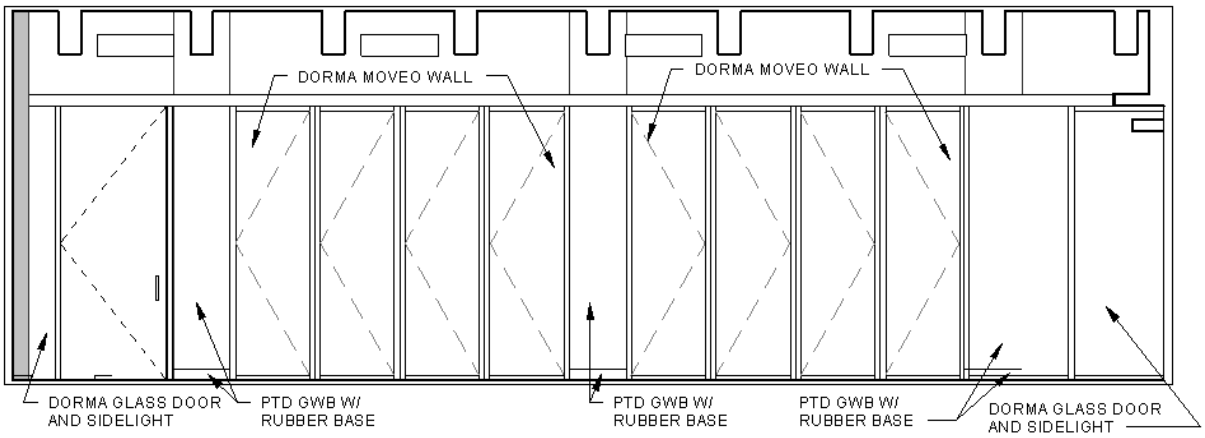


Figure 17

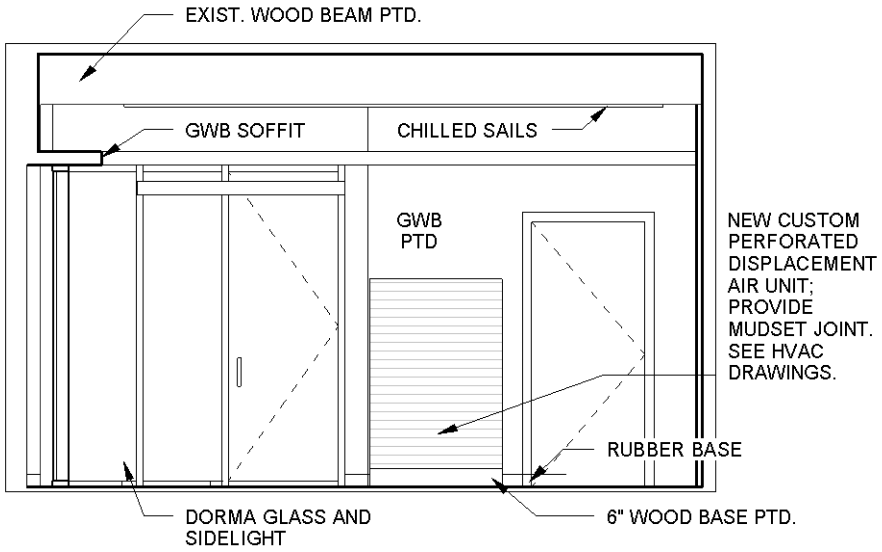


Figure 18

Existing Furnishing

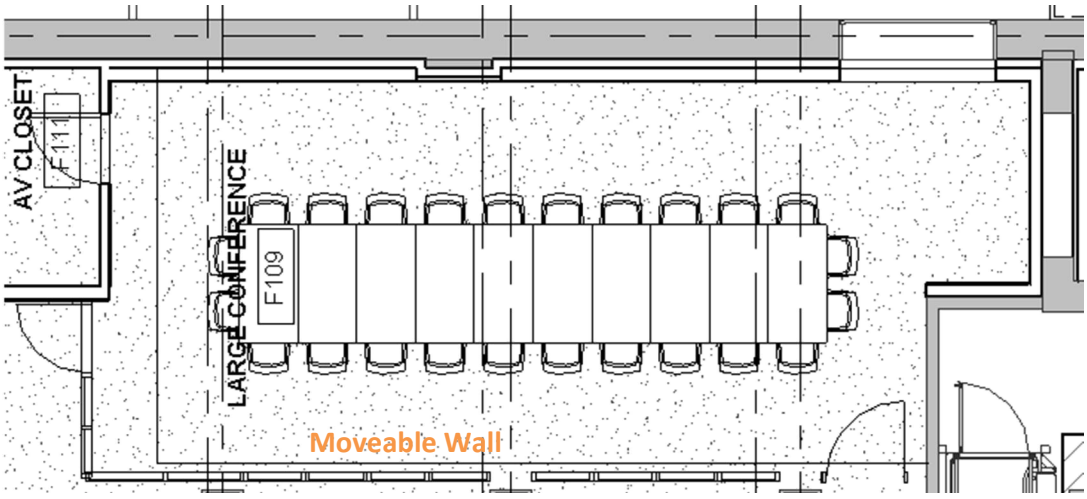


Figure 19

Lighting Design Criteria & Consideration

IES Handbook 10th Ed. Recommendation

Table 6

Surface/Purpose	Eh	Ev	Avg:Min
Meeting	150	75	1.5:1
AV	30	30	
Front-screen projection		50	
Faces	300	400	1.5:1

ASHRAE 90.1 (2010) Requirements

Lighting Power Density = 1.23 W/sf

Control requirement will be discussed in detail in the electrical depth section of this report.

Appearance and Aesthetic Consideration

Lighting layout that highlighted the architectural features will make the space look spacious and brings view pleasure to the people in the space.

Flicker

Flicker can distract and bother the users in the space. It is very essential that the work space is flicker free to provide a comfortable working environment.

Light Distribution

Lighting should be functional and can addresses qualitative factors affecting users' work performance. For the task driven oriented space, sufficient light level across all the work planes is critical in the office space.

Reflected Glare

Veiling reflecting is important issue due to the reading and writing will be the major tasks in the space. And lighting design shall minimize the reflection and glare in the space.

Shadows

Shadows shall be eliminated to provide an evenly lit-up space in order to create a spacious feeling in the office.

Controls and Flexibility

Conference room shall be controlled with multi-scene lighting configuration. Because the conference room may serve different types of meeting with varies purposes, such as presentation, meeting, AV, etc. So the control system will be designed in accordance with this goal.

Design Goals

The conference room is a special purpose space. It is essential that the lighting design reach both task oriented purposes as well as aesthetic visual comfort. Different approaches, like both direct and indirect lights lighting shall be used to provide varies lighting condition along with different light levels and aiming angles.

Luminaire and Equipment

April 9th, 2014

Luminaire Schedule

Table 7

TYPE	#	DESCRIPTION	MANUFACTURER	MODEL	LAMP	WATTS	VOLTS
L3	32	Ceiling surface mounted linear strip LED lighting with3000K color temperature	WINONA	WSL-106-4-30-30K	LED	25.1	120
R1	14	Surpace mounted 3000K warm white LED wash light with cylindrical light head	ERCO	71015.023	LED	6	120
P2	6	Pendant mounted task downlight with bronze sconce decorative shade	LITHONIA	MWS C BZ WITH DMCN BZ SHADE	LED	9.9	120
L2	2	Recessed white LED wall washer with frosted lens for glare free lighting	FINELITE	HPW-FR-LED-3500K	LED	37	120

Table 8

L3

P2

R1

L2

Control Schedule

Table 9

	LEBEL	#	MANUFACTURER	MODEL	TYPE	WATTS
	C	3	WATTSTOPPER	UT-305	Ultrasonic	120

Computer Rendering & Calculation

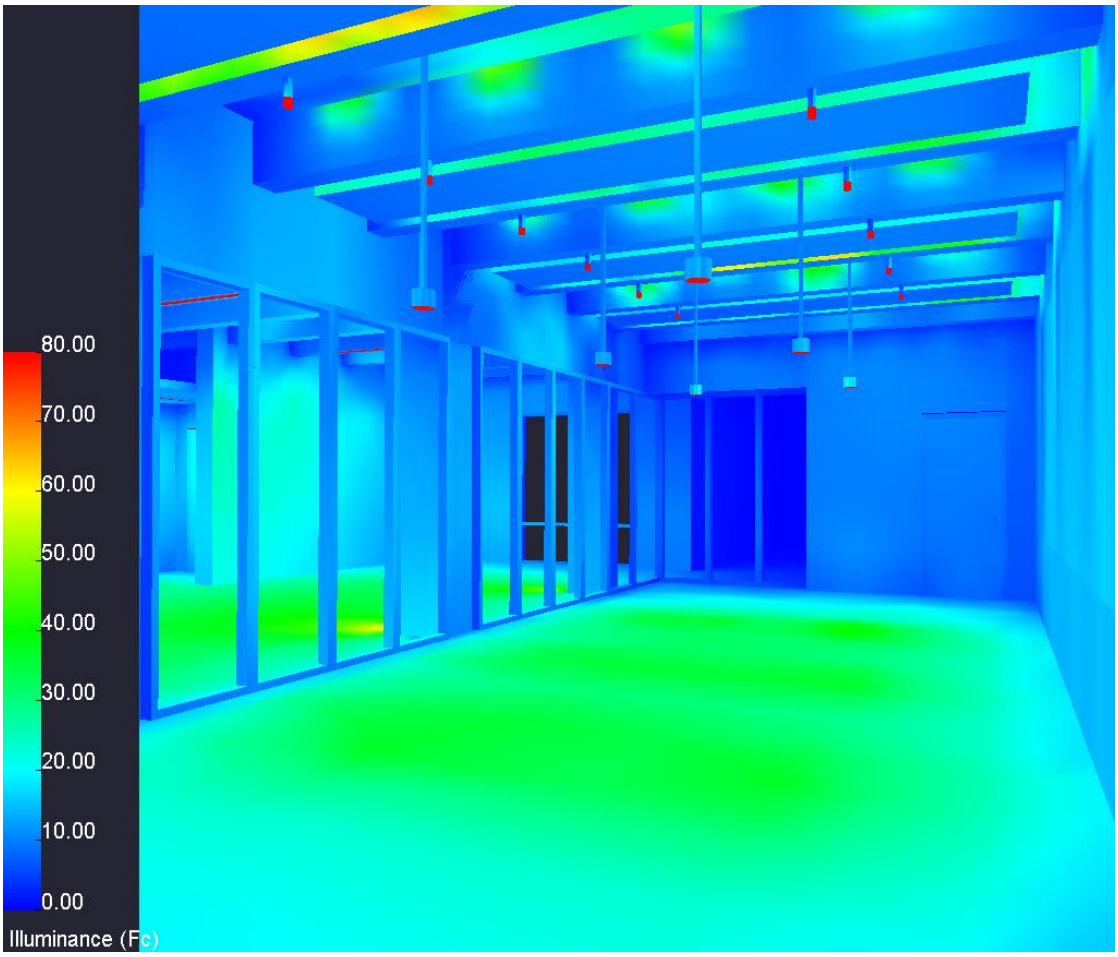


Figure 20

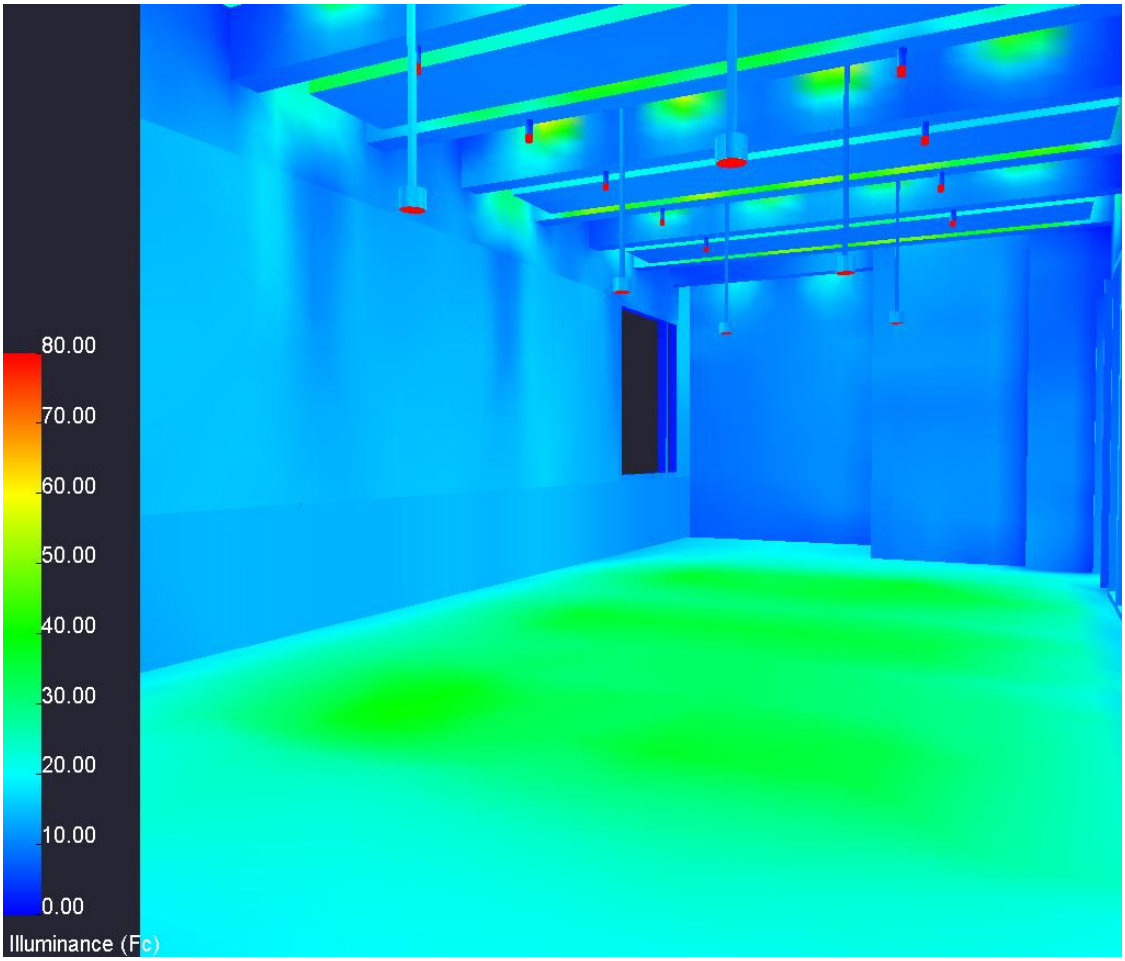


Figure 21


Area = 682.68 Sq.ft
Total Watts = 1032.74
Lighting Power Density = 1.513 Watts/Sq.ft
9.1 10.2 9.9 10.9 12.3 10.0
10.2 14.6 12.4 12.9 10.2 12.2
12.7 16.1 14.2 14.7 11.4 13.9
14.6 24.8 23.2 23.8 26.0 15.4
13.6 22.6 17.3 17.7 23.5 15.5
12.6 23.7 22.5 21.8 25.2 15.4
15.6 14.8 13.6 17.1 15.8 15.7
16.1 22.6 17.9 18.2 23.6 16.0
14.3 27.7 27.0 27.3 28.3 15.4
13.2 19.8 16.3 16.6 20.5 13.6
11.9 14.9 12.5 12.9 15.2 9.5
12.5 12.8 8.0
Project 1
Calc Pts
Conference
Illuminance (Fc)
Average=16.44 Maximum=28.3 Minimum=8.0
Avg/Min=2.06 Max/Min=3.54
LPD-UWLR Areas
Conf LPD
Area(Sq.ft)=682.68 Total Watts=1032.74 LPD (Watts/Sq.ft)=1.513

Figure 22

Figure 23

Lighting Plan

See the same lighting plan in the Lobby section on Page-22.

Evaluation

In order to incorporate the ceiling acoustic panels laid between the beams in the conference room. The indirect lighting serves as the accenting lighting. But the high output result in high wattage consumption. And the Lighting Power Density is 1.5W/sf which exceeds the ASHRAE 90.2 requirement of 1.23W/sf. Although the rest of the building low LPD will make up to this. The pendant luminaires are designed to be the task lighting mainly for the writing and reading purposes on the work plane, while the spotlights are places in two rows for washing the vertical surfaces and the people's faces. By washing the vertical surfaces instead of directly lighting up the space gives the space an evenly distributed lighting effect and also helps reduce the direct glare to the minimum. Besides that, when the removable walls are removed between the lobby and the conference room for the showcasing and exhibition purpose, the aiming angles of the spot lights can be adjusted to serve that task very efficiently.

OFFICE

Space Description

The open office on the third floor takes up most of the floor area. It's a narrow rectangular shaped area locates in the center of the floor space. This open office space is surrounded by private offices and labs, except on the building east side. The east side of the open office area is directly against the exterior wall which has three big windows with shading system. A small conference room with complete glass partition is on the west side of the office area right in front of the 3rd floor reception area. The private offices and labs are located along the outer side of the floor, most with glass front facing the open office area. And the cafeteria is by the reception area on the west side corner.

Room Dimension

102' x 33' 8" x 10' 7"

Room Finishing/Glazing

Table 10

SURFACE	MATERIALS	FINISH	REFLECTANCE
Floor	Rubber	RBT-1,2,3	0.3, 0.7
Wall	GWB Glass	PT-1,2,3,4	0.94, 0.5
Ceiling	Exposed timber beam, Acoustical panel	PT-1/AC T-1	0.8

Figure 3.1-Existing furnishing plan

Architectural Drawing of Existing Condition

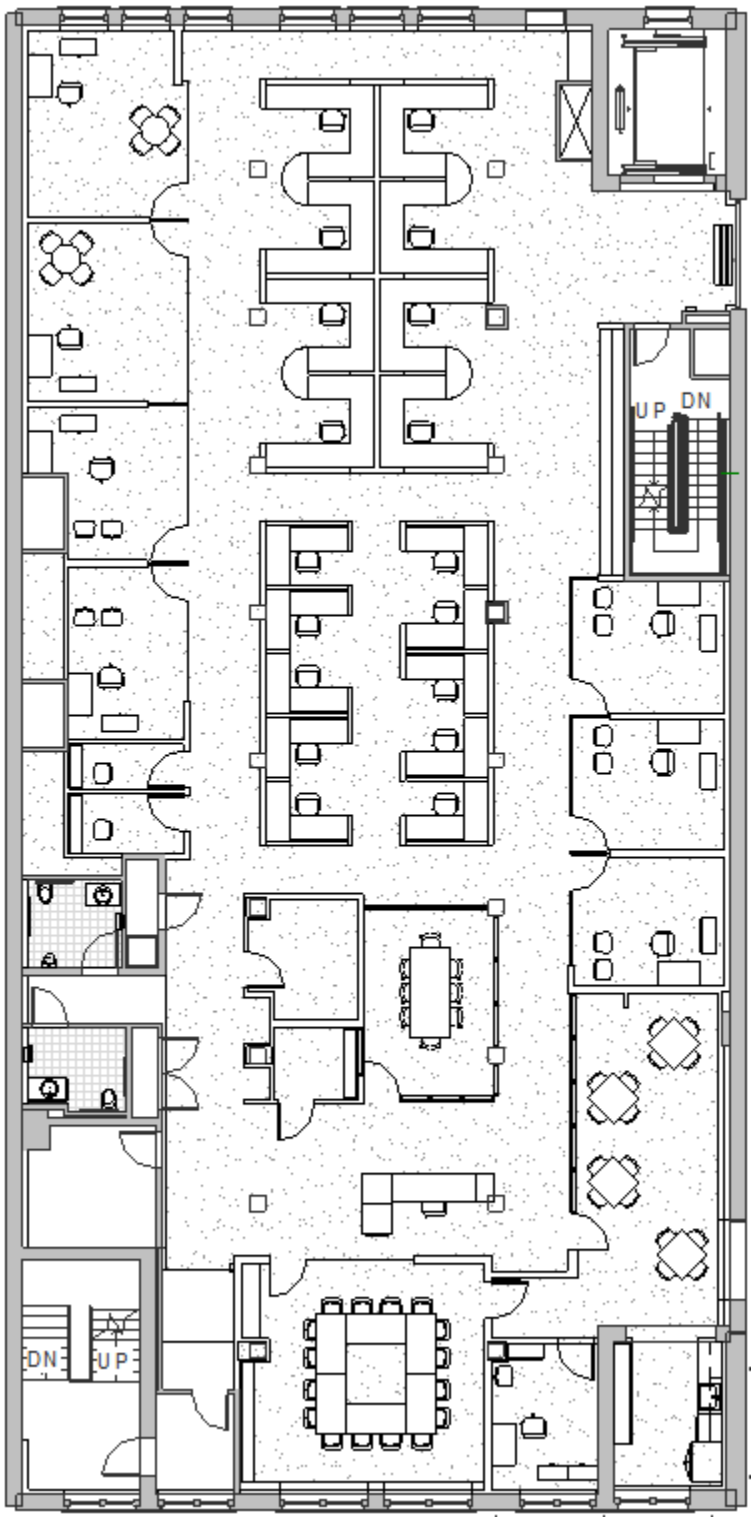


Figure 24

Lighting Design Criteria & Consideration

The open office is a work space. So uniformity is one of the most important issues that will affect the lighting performance. Also, energy is a very important factor of a good lighting design. As for a company like Fruanhofer that dedicates into energy saving building technology, it is especially crucial to present a very environmentally friendly lighting/control system. Smart lighting system with dimmable luminaires and automatic control system need to be used. The control system should be able to automatically adjust light level according to vacancy status and daylighting condition as well as automatically shut lights off when necessary according to codes.

IES Illuminance Recommendation

Table 11

Surface/Purpose	Eh	Ev	Avg:Min
Work plane (computer)	150	50	1.5:1

ASHRAE 90.1 (2010) Requirements

Lighting Power Density Allowance = 0.98 W/sf

Control Requirement:

- Automatic shutoff control device is required to shut off building lighting in all spaces
- Automatic control device is required to manually turns light on or automatically turns light on to 50%
- Multi-level control is required to have at least one control step between 30% and 70% of full lighting power in addition to all off
- Potential auto daylighting control for primary sidelighted areas is required if the combined primary sidelighted area in the space is equal or exceeds 250sf
- Additional lighting control for special purposes and multi-scene control will be needed if applicable

Accenting

In work space, accent lighting minimizes the fatiguing effects of long-term close-up viewing of tasks and provides visual relief by addressing luminance aspects. Additionally, accent

lighting addresses some special and psychological factors. In the office space, ambient lighting is the most crucial way of lighting, however, accent lighting for certain surfaces can make the interior space more defined and visually attracting.

Appearance and Aesthetic Consideration

Lighting layout that highlighted the architectural features will make the space look spacious and brings view pleasure to the people in the space.

Flicker

Flicker can distract and bother the users in the space. It is very essential that the work space is flicker free to provide a comfortable working environment.

Light Distribution

Lighting should be functional and can addresses qualitative factors affecting users' work performance. For the task driven oriented space, sufficient light level across all the work planes is critical in the office space.

Maintenance and Installation

In the newly design office space, it will be harder to maintain the lighting scene as the ceiling height raised compare to the previous design. The layout is slightly trickier than the original design as well.

Reflected Glare

Veiling reflecting is important issue due to the reading and writing will be the major tasks in the space. And lighting design shall minimize the reflection and glare in the space.

Shadows

Shadows shall be eliminated to provide an evenly lit-up space in order to create a spacious feeling in the office.

Controls and Flexibility

Different areas in the office are controlled separately with occupancy sensors and control systems. It is critical for the purpose of energy saving.

Design Goals

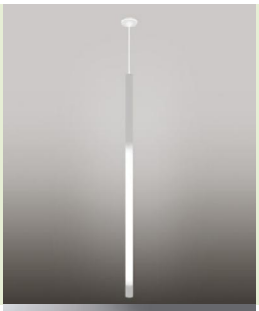
The goal for the office lighting design is to improve the working environment and truly promote the technology supported lighting design. Different types of lighting features and clean-line lighting elements coordinates smoothly together helps redefine the space. The original open office is a small narrow space with very low ceiling level and exposed HVAC system. The lighting design for this condition is aimed to help creating a spacious feeling and make people who work in there will be able to enjoy the working experience for the company. The proposed design for this space is to open up the ceiling in the center bay to the upper floor (which is current vacant and under design process for future use). With this change, it expends to a much larger volume and provides the space much larger room for creative lighting design. The lighting will help celebrate the architectural features while create a high-end modern office look. Refreshing and spacious feeling will be the main concept of the design in the office with simple line lighting fixtures. Indirect lighting together with washing or grazing method will help define the space, as well as create layers so that all features collaborate together for the whole image of the look. . At the same time, more decorative lighting is used to provide a more dynamic looking and the changing views from different perspectives in the same space. Washing fixtures are largely used to redefine the shape of the space. The high illuminated surfaces create an even more spacious impression. With the help of increasing the ceiling height, more day-lighting will be coordinated within the lighting design.

Luminaire Schedule

Table 12

Type	#	Description	Manufacturer	Model	Lamp	Watts	Volts
P3	16	Suspended linear 2.5" diameter tube with fluorescent lamping and acrylic lens enclose	SPI-STILE	SIP11575-2F28	2FT5	57.5	277
L6	16	Surface mounted white LED tube cove light with iron phosphate pretreatment casing	COOPER	SNLED-LD1-32-UNV-L840-CD1-U	LED	28.4	120

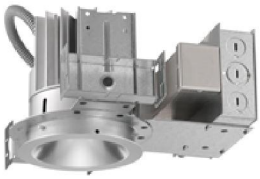
L2	32	Recessed white LED wall washer with frosted lens for glare free lighting	FINELITE	HPW-FR-LED-3500K	LED	37	120
L1	69	Recessed 6" wide seamless linear dimmable LED light with acrylic lens	PRULITE	BIO-SM-06-SAL-YGW	LED	19.2	277
D1	9	4" recessed LED downlight with anodized aluminum reflector	JUNO-INDY	L4-1530+L400HW-CL	LED	8.7	120
R2	12	Pendant 6" diameter white LED downlight with extruded aluminum cylinder body	PRESCOLITE	LD6LED4P	LED	28	277



P3

L1

L6



D1

L2

R2

Control Devices Schedule

Table 13

	LEBEL	#	MANUFACTURER	MODEL	TYPE	WATTS
	C	10	WATTSTOPPER	UT-305	Ultrasonic	120

Computer Rendering + Calculation

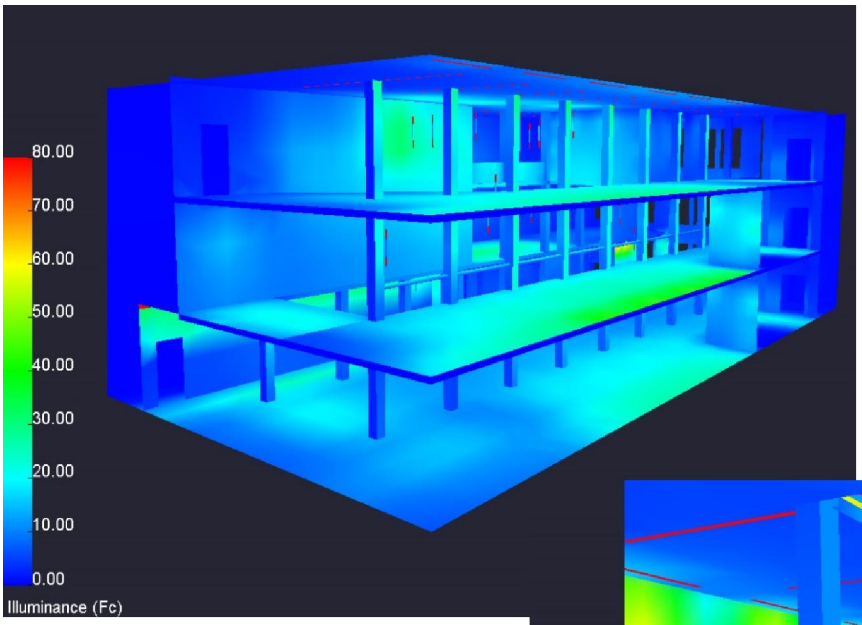


Figure 25

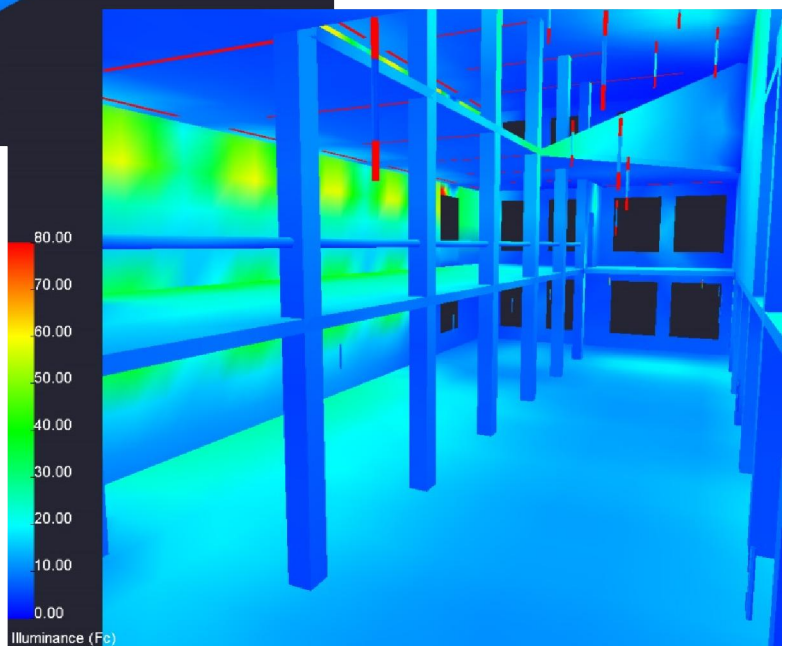


Figure 26

Figure 27

Figure 28

Figure 29

Calculation result from AGi32

Project_1
Calc Pts

1st side
Illuminance (Fc)
Average=17.74 Maximum=30.8 Minimum=5.8 Avg/Min=3.06
Max/Min=5.31

2nd flr big
Illuminance (Fc)
Average=6.84 Maximum=9.3 Minimum=3.6 Avg/Min=1.90
Max/Min=2.58

2nd side_1
Illuminance (Fc)
Average=22.89 Maximum=33.8 Minimum=6.1 Avg/Min=3.75
Max/Min=5.54

3rd side
Illuminance (Fc)
Average=22.55 Maximum=35.0 Minimum=6.2 Avg/Min=3.64
Max/Min=5.65

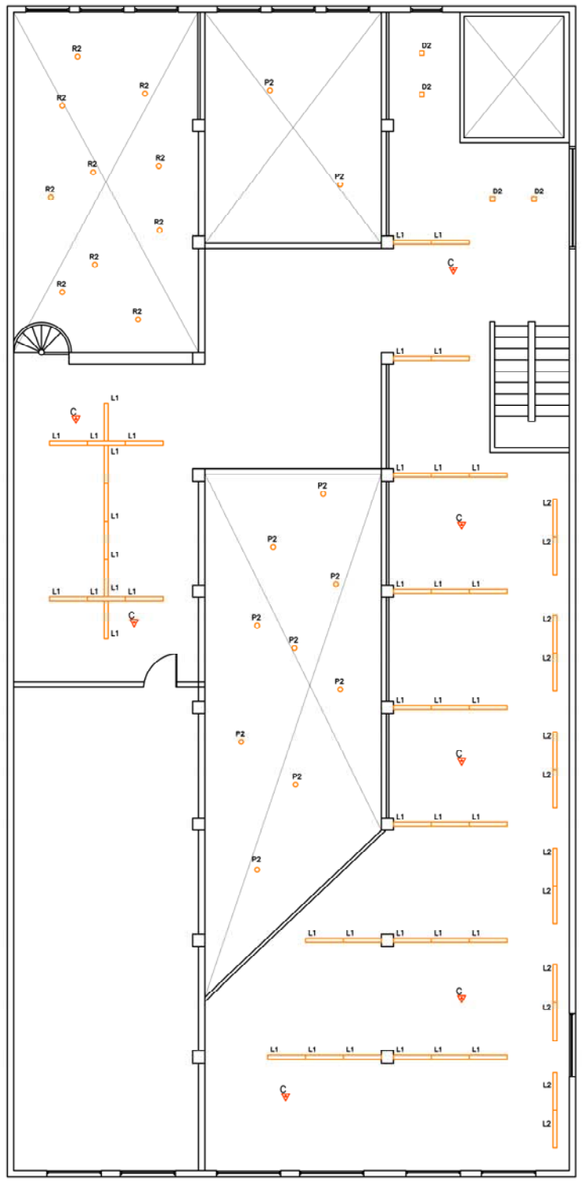
Atrium
Illuminance (Fc)
Average=12.88 Maximum=24.0 Minimum=5.7 Avg/Min=2.26
Max/Min=4.21

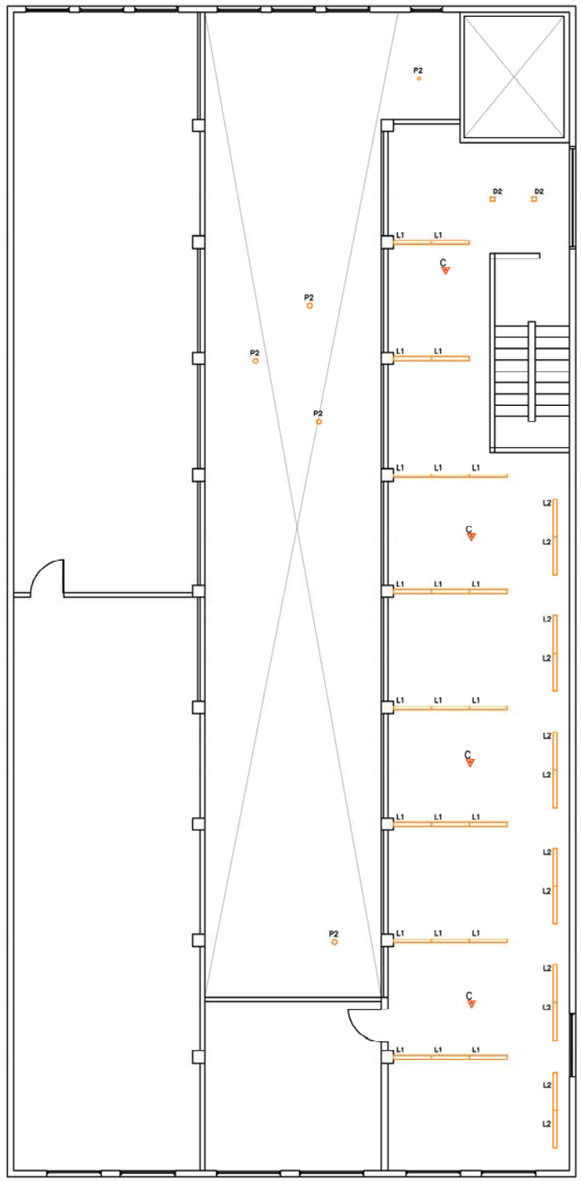
circulation
Illuminance (Fc)
Average=16.70 Maximum=29.8 Minimum=3.1 Avg/Min=5.39
Max/Min=9.61

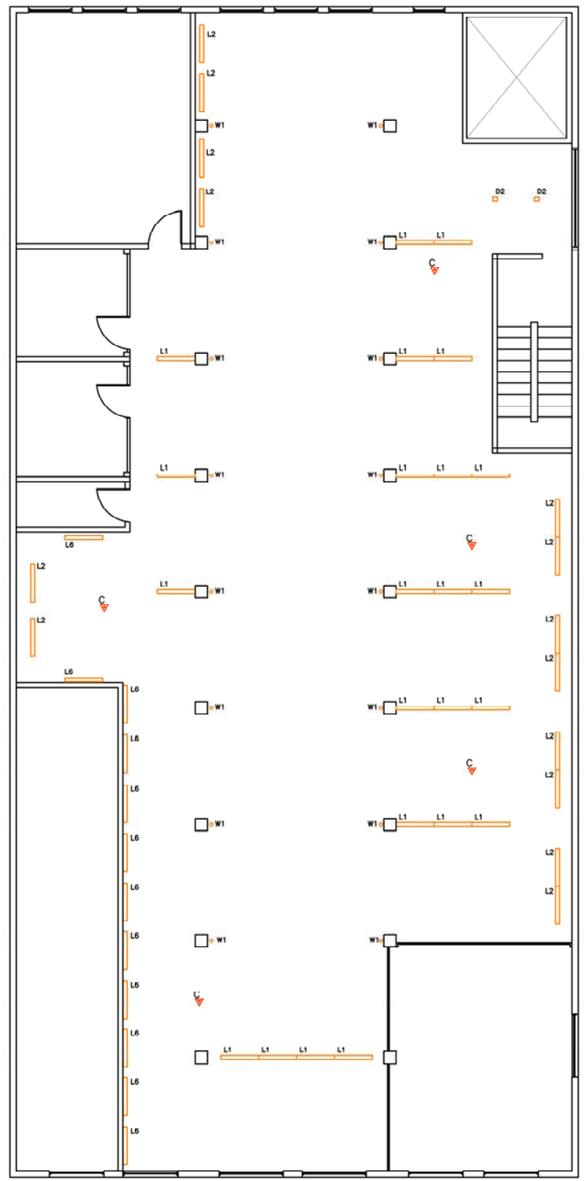
LPD-UWLR Areas

LPD Open Area
Area(Sq.ft)=4782 Total Watts=4186.578 LPD(Watts/Sq.ft)=0.875

Lighting Plan







PROJECT:
FRAUNHOFER CSE

CONTENT:
LIGHTING PLAN
LOBBY
CONFERENCE RM

DRAWN BY
XIAOYIN WU

DATE:
APR 2014

SCALE:

1/16"=1'-0"

Evaluation

The new architectural interior design provides the office a much open-up space to allow more diversity of lighting design possibilities. The changing of ceiling height in the central bay atrium area generates a lot more vertical space for the options of pendant fixture that original design would not allowed. The vertical tube pendant fixtures are all with different pendant length, also suspended from different levels. This design adds some flavors to the aesthetic aspect of the space and makes the entire space look more dynamic. As it can be seen from the renderings, the side bay areas are mostly either open up to the atrium or can see the atrium through the glazing. Look from different locations in the space, the views with the pendant lights in the opened center space are different. The vertical fixture choice makes sure that the fixtures do no look too dominant in whole the look of the open space. The slim design of the luminaire is like the light beams that go through the tree branches and provide sufficient illuminance for the tasks taking place in the office work space. The recessed continuous linear fixtures are of the same type of the ones in the lobby to remain the consistency of the entire design concept as a whole. The layout is placed along the columns location one is to create a uniform distribution, and also eliminate the glare people may perceive from other area in the open office. The wall washers are installed in all the side bay open working area. The side bay working areas are visually connected to the central atrium and the lit up wall helps define the depth of the space and create the feeling of spaciousness. In general, the opened-up space brings difficulties of reaching uniformity and lighting trespass between the different areas of the space. But the design solution is successfully meet most if not all the goals and the criteria by selecting the right luminaires and layouts adjustment.

FAÇADE

Figure 30

Space Description

The project is a renovation project of a 100-year old historical building of six-story, three-bay loft brick structure with classical revival-style detailing. The Fort Point Channel district is marked by an exceptional degree of visual uniformity. Fraunhofer Building, one of the buildings in the Fort Point Channel area, is not an exception of a loft structure built in 1913 by the Boston Wharf Company, and represent an unusually coherent and well-preserved collection of late 19th and early 20th century lofts that reflect a critical period of social, economic, and physical development in the City and the region. The loft buildings are generally masonry, with simple volumes and flat roofs. Buildings are elegantly proportioned, with classically inspired details concentrated at entrances and cornices. And the structure is left unchanged in this project to conserve the significant continuity throughout the District in terms of massing, scale, and style. In this project, the majority of the structure has been left almost unchanged, especially the façade. Besides the new entrance is more modernized after the renovation, almost the entire of the building façade remain exactly the same as it is about 100 years ago. The façade is mainly made of red bricks with mainly two window types taking up the façade wall.

Dimension

75’ x 61’ 8” (Height x Width), 6 story, two front entrances

Finishing & Glazing

Table 14

SURFACE	MATERIALS	DESCRIPTION	REFLECTANCE
Ext. Wall	Bricks, masonry window	Salvaged existing red color bricks	0.26

Architectural Drawing

Figure 31

Lighting Design Criteria & Consideration

Façade being an important part of architectural lighting design is usually for the reason that it plays a big role in advertising the architectural features of the building by highlighting the beauty of the structure and/or façade, and also improving the company image. In this project, the hundred-year old building façade was preserved almost entirely. The lighting design should help emphasizing the massing and proportion of the building structure. At the same time, the lighting design shall bear the idea in mind that the company is dedicates in researching energy saving building technology products. So eco-friendly fixtures and design concept should also be a primary consideration.

IES Illuminance Recommendation

Façade with reflection<0.5 and low activity: Ev = 40 lux

ASRAE 90.1 Standard (2010) Requirement

- Building entrances and exits: main entries = 20W/linear-ft of door width
- Façade: 0.1W/sf for each illuminated wall or surface or 2.5 W/linear ft for each illuminated wall or surface length

Lighting Trespass

Light trespass is a critical issue for exterior lighting, because light pollution is now a big problem in the urban area. So the lighting design needs to make sure the aiming and reflection of the light does not trespass to the neighborhood that exceeds the allowance.

Accenting

Accenting is a major way to decorate the exterior of the building that will emphasize the elements of architecture.

Design Goal

The building is a company that does not have activity after around 5pm. Then there is not much need of lighting up the exterior be cause is not a commercial building and advertising the

building is not so necessary. So in my design, very subtle lighting that highlights the cornices on the façade would be efficient for a minor decorative purpose of the exterior design goal.

Luminaire Schedule

Table 15

TYPE	#	DESCRIPTION	MANUFACTURER	MODEL	LAMP	WATTS	VOLTS
F1	44	Surface mounted high performance flood lights	RAB	FXLED150SF/PCS	LED	150	120
W1	2	Double sconce direct-indirect wall sconce with white tube diffuser	LIGHTOLIER	PPL5DSW	LED	2.4	120
W2	4	Direct-indirect wall sconce flood light	B-K	OL-LED	LED	75	120

Lighting Plan

Figure 32

Rendering

Figure 33

Evaluation

The design goal is to use the minimum light and reach a low profile façade lighting design. And the design reaches the goal of celebrating the architectural elements, say, the cornices. At the same time it uses the least output to create the visual affect without making any discomfort to the surroundings.

architectural breadth

The point of altering the interior space of the office area is to generating a pleasant working environment for the users and promote a modern looking of the interior space that contrasting the exterior impression the building. With the help of the lighting design concept, the goal of the new architectural design is to create a spacious working space and coordinate perfectly with the new lighting design.

DESIGN CONCEPT

Before digging into the new design concept, the original look of the office can explain the motivation of my desire of redesign the space.

Figure 34

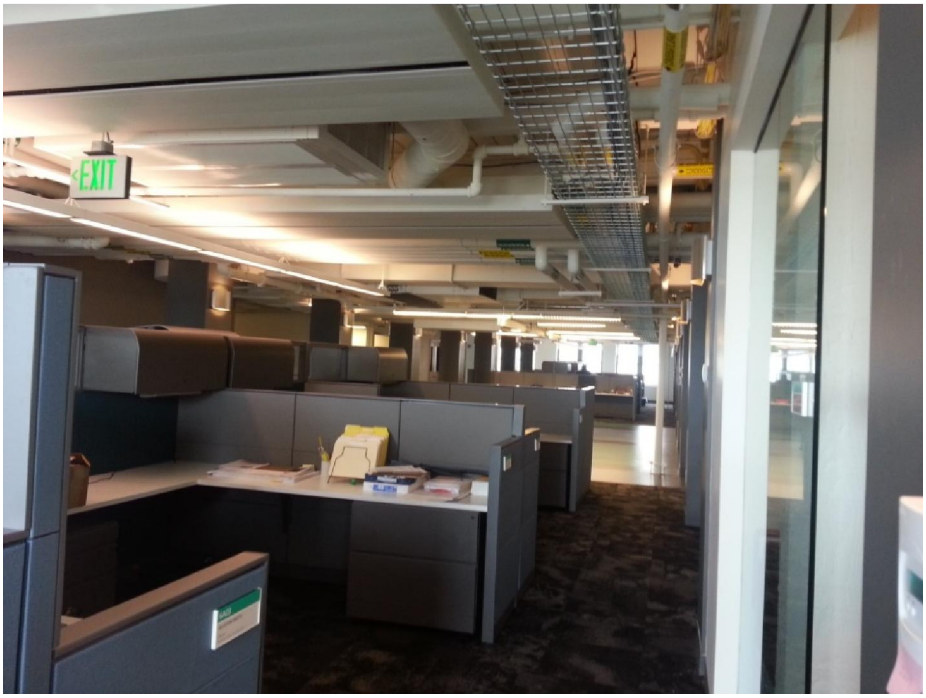


Figure 35

As it can be easily seen from the real pictures, both the space condition before renovation and the current design after the tenant moved in the building. The owner settle with the idea of exposed ceiling structures and mechanical systems and largely use of pendant mounting lighting fixtures with direct and indirect distribution for the ambient light in the work space. Wall sconces are installed for the accenting purpose of the space. Dark color floor carpeting takes a large portion of the floor surface. And the partitions of work station cubicles are blocking the open view of the office area that make the office space even lower and dim. Without the portable table lamps, I doubt the work planes will receive much illuminance as it needed. The building has large windows in a row on every floor on the east and west facades, but the room height and sharp angles are going to prevent enough sunlight getting into the space. The primary daylighting area is so small for the long and narrow office space.

In order to avoid all the downside about the office I'm not completely satisfied with, design concept is decided easily to make the office spacious and bright.

BRIGHTEN YOUR EVERYDAY

Office is the space that people who work there spend most of the daytime in. It is strange in a way, that places that people only stop by for temporarily are well designed, while the place we spend everyday life are designed with the least consideration of appearance. I think office is just as important as the fancy hospitality and retail spaces, and as important as the home design. For example, Google spends large amount of money and effort of build the high end and most considerate campus for its employees and clients. It is a huge investment for building a campus like Google does, but a relatively better quality work environment will sure has some payback from the employees who enjoy working there and have high efficient performance. So I want the office to be able to brighten everyday life of the users and users in return brighten the company the same way.

DESIGN APPROACH

"OPEN" & "TRANSPARENT" are the two key words of my design ideas. To get rid of the gloomy and suppressed feeling of the office space and to provide the users pleasant feeling, a new lighting design for the space solely is not enough for this goal. So I want to bring in more opportunity to the space for a better working environment. Considering the 4th and 5th floors are still vacant and to be designed for more office spaces, it is not hard to come up with the idea that the 3rd floor office can be opened up to the upper levels and redo the layout to make the space more dimensional.

I want the tenant in the building perceive a much broadened view without much clatter as well. The completely opened space has an issue of the sound transmit throughout the entire space that doesn't have partition separate the different areas. So glazing is largely used in the space. The finishing of the interior surfaces is mainly white colored theme. It will help the space look modern and spacious visually and will help the light bounces around. The ceiling will have panel finish so to get rid of the expose beam structure and the HVAC system hanging above the work area. The space will look much cleaner and contemporary.

The following pictures are some major inspiration and the look that I was going for for the office space in the beginning. It is a way for me to be sure about the design concept I have is not just an idea on the drawing, but also some real life projects are done the similar way as well.

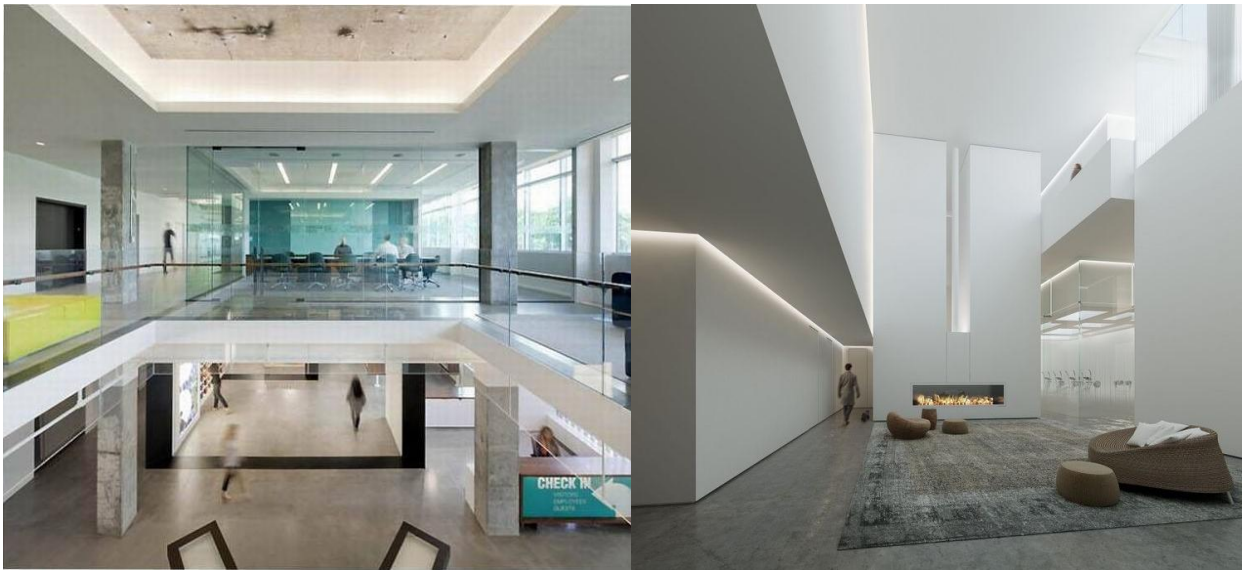


Figure 36

The section below shows the part I will modify in the building. Most of the floor and ceiling between the 3rd and 4th, 4th and 5th levels are removed to have the open atrium. Part of the center bay will remain as for the diversity of floor plan layout as well as make it easier to circulate around the building.

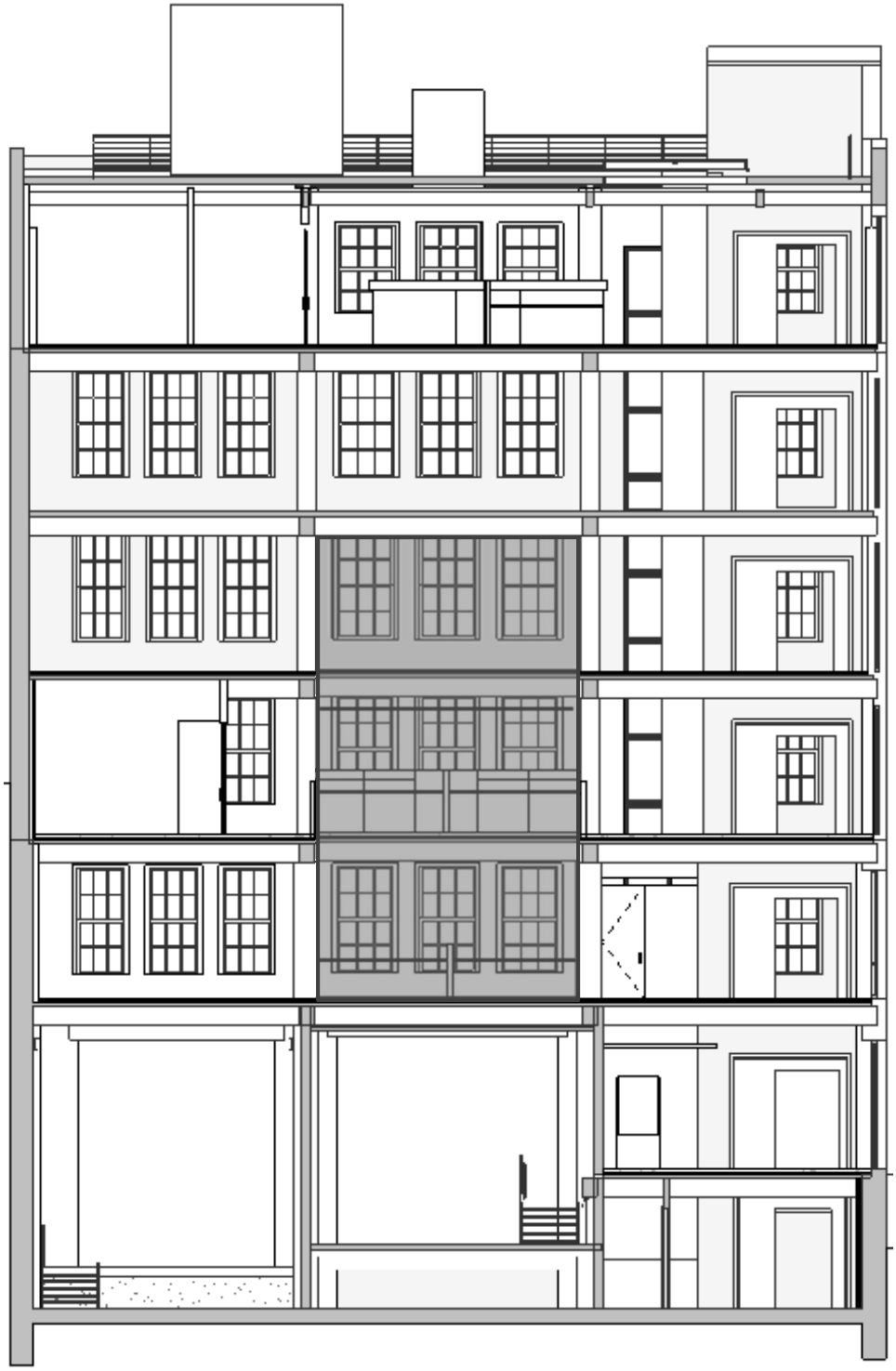


Figure 37

EXISTING FLOOR PLAN

Please Refer to the Appendix C for Floor Plan.

FLOOR PLAN

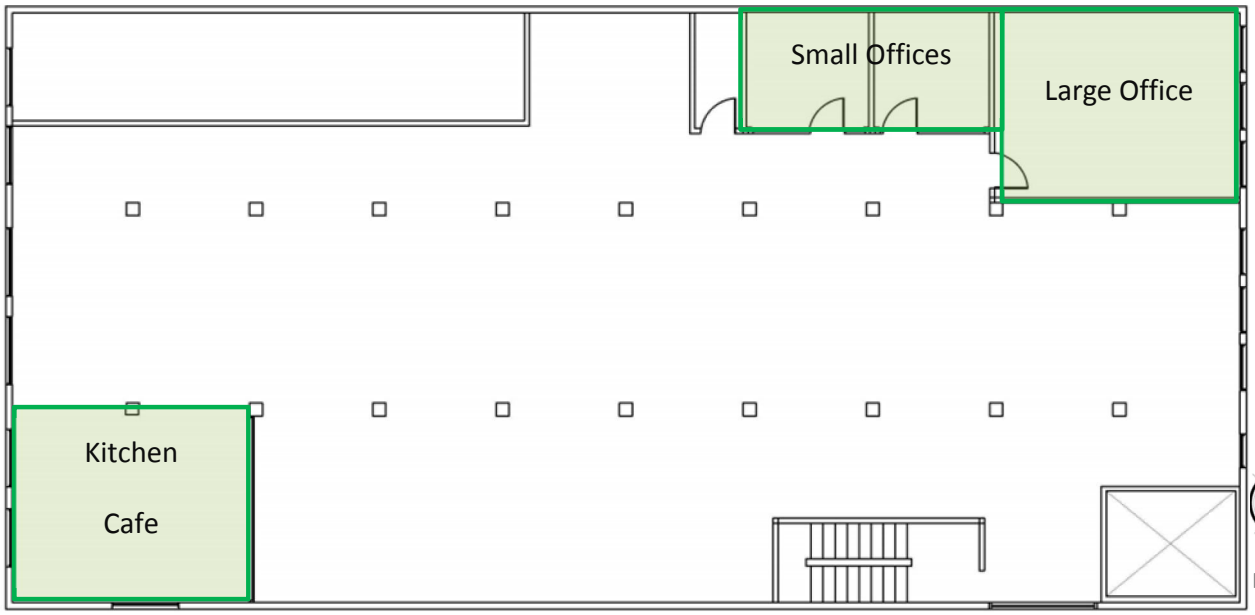


Figure 38

The north corner of the building remains almost unchanged because that's the main stair case and some electrical shaft and mechanical room and bathroom. So I leave that space as it is all the way through the three levels. And the stairs and the elevator shaft at the south corner also stay the same. There are different sizes of private offices on the 3rd floor just as in the previous design where enclosed offices are located on the side bays of the building. In the north corner on the two upper levels, more private offices will be place in there too. But that will be out of my design scope, and I will not have the detailed design solution for that space.

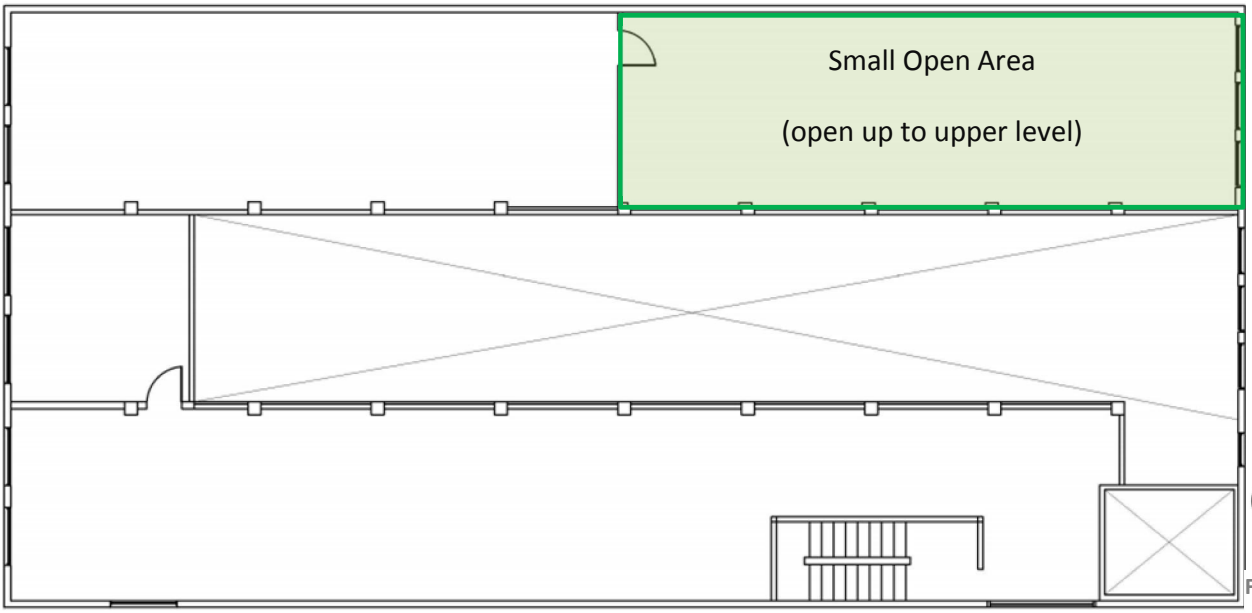


Figure 39

The big space on the east corner of the plan is another high ceiling space within the new open office area. That area is a small open office in size and has two story-tall ceiling. It is connect to the upper level platform on the 5th floor level. That enclosed space solely is another form of the loft structure that also represents the idea of diverse geometry of the open office design.

On the most upper level (5th floor level), the west corner bridge connect the north and south bay of the building and not shaped regularly along the beam direction. However it creates more floor area and a more convenience circulation purposes.

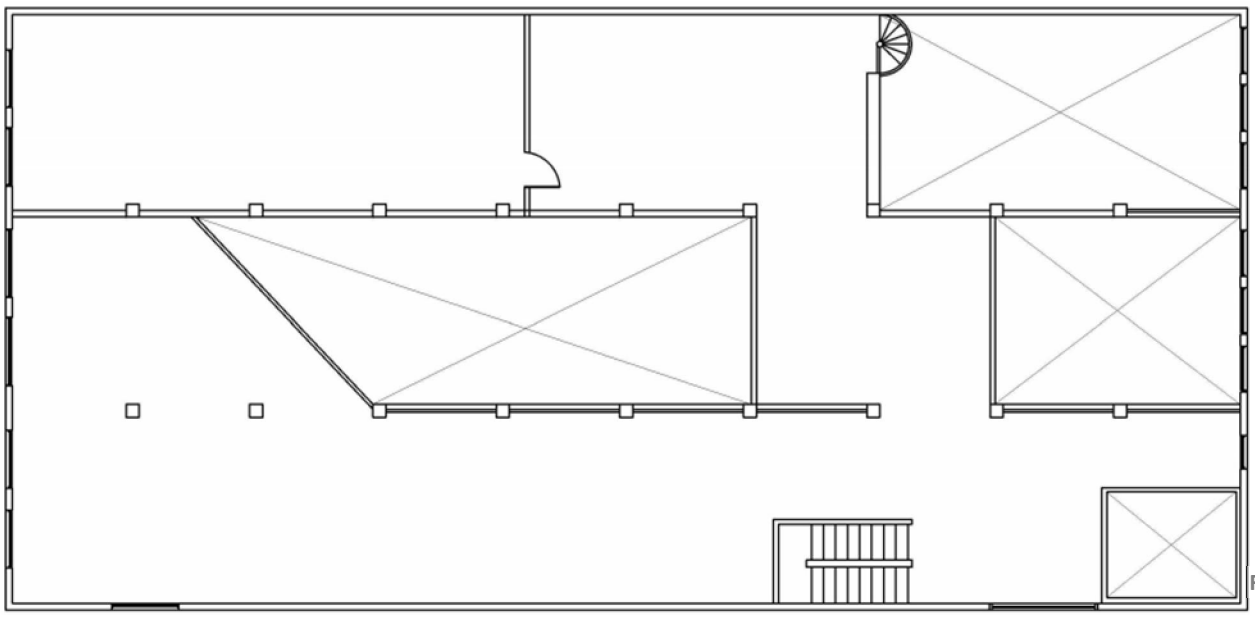


Figure 40

RENDERING

Figure 41

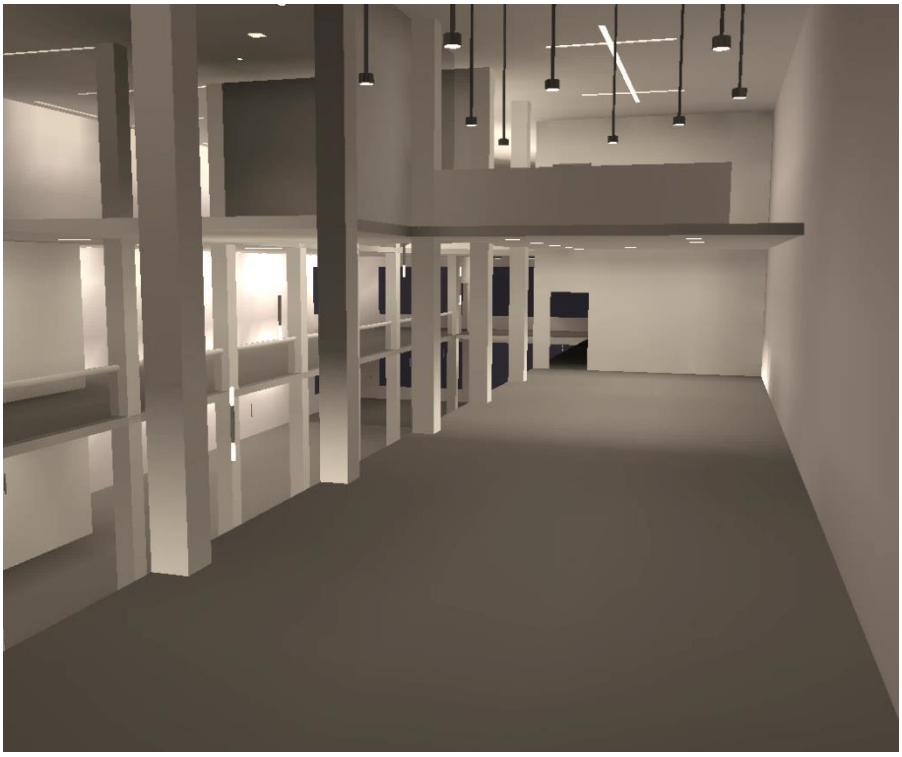


Figure 42

structural breadth

Structural breadth is conducted to support the significant architectural change in the office space. This breadth includes the analysis of the feasibility of the changing being made in the interior building structure and calculations to make sure if resizing the structure element is necessary.

OVERVIEW

By removing the floor in part of the center bay of the structure, the deadload decreases on the column. In the depth,

EXISTING STRUCTURE

Figure 43

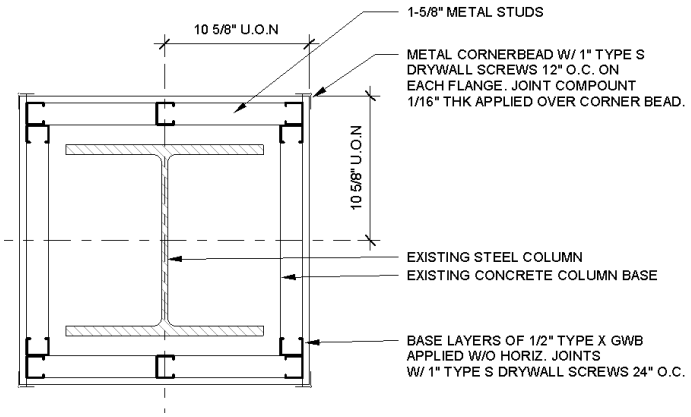


Figure 44

Table 16

	Type	Load
Level 4 floor	dead load	80 PSF
Level 5 floor	dead load	80 PSF
People	liveload	60 PSF

CALCULATION

The reduced deadload of floor from the 4th floor is:

Total removed floor area = 1786SF

Total deadload = 142,990 LB = 143 kip

Tributary are for columns in the center: 122.5SF

Tributary area for columns on the end: 183.7SF

Existing Beams:

Timber beams 8.5 x 16

In this case, there will be less beam-bearing load. And the center bay beams that span over 20' will be removed. So the columns will be bearing the load on the side bays.

The only place that will need new beams is the 5th floor level triangle shape. Longer beam will need to be place to bridge from one end diagonally to the other side.

By using a W10x39 beam

Mu (Demand)	74.08 kip-ft
Φ Mn (Capacity)	126.36 kip-ft
Controlling Equation	F2.1: Yielding
Location	10' 5"
Load Combo	1.4D
Bending=0.59	

Vu (Demand)	-12.29 kip
ΦVn (Capacity)	67.50 kip
Controlling Equation	G2.1: Nominal Shear Strength
Location	18' 3"
Load Combo	1.4D

Shear = 0.18

Based On	Service Cases
Max Service Case	Wind Limit
Max Dy	-0.678 in = L/370
Live Load Limit	L/360
Dead + Live Limit	L/360
Snow or Wind Limit	L/360
Total Load Limit	L/240

Deflection=0.97

electrical design

With the lighting design largely altered in several spaces in the building, the panelboards that feed the lighting circuits will need to be updated. And with the changing lighting load, a short circuit study also need to be studied to make sure whether the protection system is sufficient enough to support the new electrical system according to the new lighting design. Then a depth on integrating the photovoltaic arrays in the power system will be discussed to see how the PV arrays can be utilized in the electrical system to provide sustainable energy supply.

INTRODUCTION

After the changing of design in the four spaces in the building, the panelboards needs to be redesigned to keep up with the current design. The levels that have the lighting systems remain unchanged can be left as it is on the related panelboards. Otherwise, the affected panelboards will be updated and some spare circuits on the panelboard that currently not serving any load will be used as well to accommodate the new lighting system. Automatic control systems are installed according to the ASHRAE 90.1 standard. In the open office space, not only occupancy sensors, but also photosensors will be applied. Because the architecture is largely altered in the office space in order to provide more daylight entrance in the space, so the lighting should be controlled based on the changing of daylighting during the day, in order to minimize the energy usage in the electrical system.

CONTROL SYSTEM

In the new design, more automatic control system and dimming equipment are designed be used in the building.

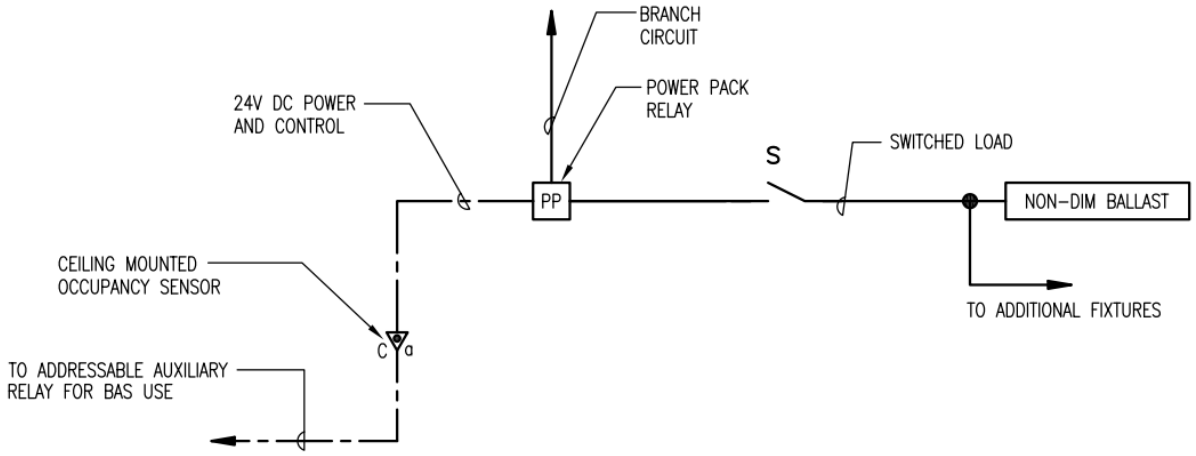
The goal of the control system is to turn off/or dim the lights when there are no occupant in the area or when the daylight is available so to save energy. In general, the automatic shut off system will be used in the entire building according to the requirement in the ASHRAE 90.1 standard that interior lighting in building shall be controlled with an automatic control device to shut off building lighting in all spaces. For conference room especially, occupant sensor is required that turns off lights within 30min of occupants leaving the space. At the same time, the automatic control devices in all the interior spaces shall be manual on or auto on to 50%. The conference room and lobby do not need automatic daylighting control devices because the combined primary sidelighted area in spaces do not exceed 250 SF not there are any skylights. The open office atrium needs the automatic daylighting control.

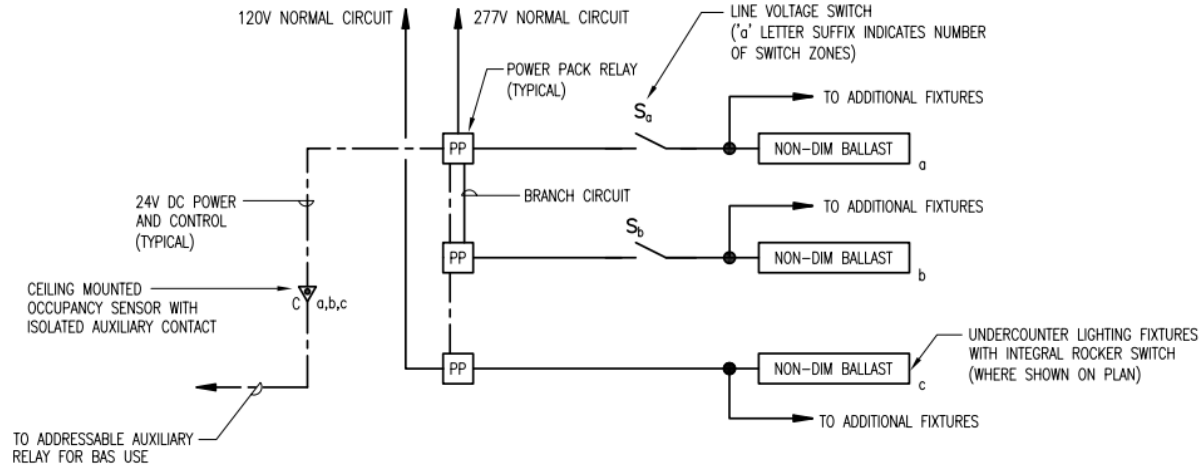
Control Devices

The conference room control system are using the *WattStopper®*'s occupancy sensors and control panel to meet to requirement of having automatic shut-off control system. No other automatic control system is needed because it's a multi-scene space.

The open office uses area vacancy sensor on the two side bays and photo sensors for the central bay atrium area.

The drawings below show the operation diagram. The first one shows the ceiling occupancy sensor controlling single light source. And the second one is for ceiling occupancy sensor controlling multiple lighting sources. The occupancy sensor enables automatic control of room lighting upon occupant detection. Sensors do not turn on lighting solely upon occupant detection. Sensors shall turn off all room lighting upon room vacancy after adjustable time as long as it's within 30 minutes.





The control devices cutsheets can be found in the appendix A.

PANELBOARDS and BRANCH CIRCUIT REDESIGN

The lobby and conference room are located on the first floor. So the panelboads will be updated with the new loads that I calculate with the new lighting fixture information. The take-up of the new load is a simple process by summing up the existing lighting load and replaced by the new total load in the space. So on the panel board, the relating circuit will be replaced by new circuits that serving the new load.

The third floor office space is altered significantly and the whole lighting system on the affected space, fourth and fifth floors, will be considered as a whole and current panelboards on not only the 3rd floor but also 4th and 5th floors. And spare circuit will most likely to be used for adding in finished lighting design on the 4th and the 5th floor because there are no current finished lighting system on the two floor.

After removing the existing lighting load and assign the new loads to the circuit evenly, adding more new circuits as needed and then resize the feeders, wires and conduits by following the requirements on NEC.

The panelborads that will be affected by the new design in the four areas I designed in the building is listed in the table below. And the distribution panels that feeds the panels are DP21A and DP21B that located in the basement and the on the 4th floor.

Table 17

Panel Tag	Voltage	Lobby	Conference	Office	Façade
P21B	120/208V	X	X		
P23	120/208V			X(LVL3)	
L42	277/480V			X(LVL3)	
L44	277/480V			X(LVL5)	X(LVL6)
EP4B	277/480V	X		X	X
EP2B	120/208V	X		X	

First, I want to explain how the electrical load take-out. The panelboard schedule shown below is the original panel board schedule. The circuits that highlighted in red are the circuits that will be changed after the new design. The circuits to be replaced with the new loads basically follow the same idea of how the loads are distributed in the original design. Circuit that wires a certain

area is still designated to the same area also with the consideration of how to change the total load in each line. This way, it will avoid resizing the wire, conduit and bus. But over current protection will be discussed later to make sure the current protection system is up to date and are efficient to support the new load, since the new load will be larger than before on Level 1.

P21B	120/208V		3 PHASE		4 WIRE		TOTAL WATTS L1: 9650				TOTAL WATTS: 31998	
	MAIN BREAKER: MLO						TOTAL WATTS L2: 8666				LOCATION	
	MAIN BUS: 225A						TOTAL WATTS L3: 13682				LEVEL 1 ELEC. RM	
LOAD	DIRECTORY	L1	L2	L3	CKT	AMPS	AMPS	CKT	L1	L2	L3	DIRECTORY	LOAD
R	RECEPTION REC	800			1	20	20	2	864			DISPOSER 1/2HP	E
R	FIRE COMMAND REC		600		3	20	20	4		360		RECEP. ST-11	R
R	LOBBY RECEP			720	5	20	20	6			540	GFCI	R
R	LOBBY REC	1000			7	20	20	8	720			RECEP. F113	R
R	LARGE CONF.		800		9	20	20	10		800		SP1 PANEL RM F103	E
R	LARGE CONF. PART			1000	11	20	20	12			1176	FCU-3	E
R	LARGE CONF.	800			13	20	20	14	864			FCU-4	E
R	TV REC		600		15	20	20	16		2400		FCU-4	E
R	OFFICE			1000	17	20	20	18			2400	FPB-2	E
R	CORRIDOR	800			19	20	20	20	200			SP1 PANEL RM F103	R
R	LOAD CHECK		400		21	20	20	22		800		VP AND MS	E
R	ELEV EM			400	23	20	20	24			1524	LEVEL1 VIA LVRP-1-3,5	L
E	DOOR POWER SUPPLY	800			25	20	20	26	1684			LEVEL 1 LVRP-1-6	L
E	FCU-10				27	20	20	28		1226		LEVEL 1 LVRP-1-7	L
E	FDCG-70			2400	29	20	20	30			1250	LOBBY LTG	L
E	QUAD F11	360			31	20	20	32	758			LEVEL 1 LVRP-1-11	L
E	RECEP F104		180		33	20	20	34		500		RECEP F114&FCU-34	R
L	LEVEL1 VIA LVRP-1-2			912	35	20	20	36			360	RECEP. F114	R
S	SPARE				37	20	20	38				SPARE	S
S	SPARE				39	20	20	40				SPARE	S
S	SPARE				41	20	20	42				SPARE	S
	SUBTOTAL	4560	2580	6432					5090	6086	7250		

The affected lighting loads are summarized in table-#. The lights are being taken out of the current design are summed up by circuit. The new assignment of the new lighting system onto the panel board P21B is shown in table-#. When assigning new load to the circuit, I tried not to exceed the original load in order to avoid the possibility of resizing of wire or feeder.

Table 18

CKT #	Type	#	Watt	Total watt	Total on circuit
7	L17	7	12.5	87.5	**87.5**
24	W10	10	4.8	48	
	R11	3	39	117	
	L20	6	13	78	
	L20A	4	6	24	
	L15B	1	32	32	**386.5**
26	R10	1	39	39	
	R11	7	39	273	
	L20A	4	6	24	
	L20	2	13	26	
	L21	1	38	38	**400**
28	L20	4	13	52	
	P1	3	10	30	
	L21	2	38	76	**158**
30	L20A	6	6	36	
	L19	4	10	40	
	T3	3	16	48	**124**
32	R13	18	11	198	**198**
35	L21	3	38	114	**114**

Table 19

Type	Description	#	Watt	Total Watts	Location	Asssgn. Ckt
L1	Linear	27	19.2	518.4	lobby	28
L2	Wallwasher	2	35	70	conf	35
D2	Downlight	16	18.6	297.6	lobby	24
L3	Cove	32	25.1	803.2	conf	38
L4	Wall recessed	16	18.55	296.8	lobby	26
P2	Pendant	6	9.9	59.4	conf	32
R1	Downlight	14	8	112	conf	32
P1	Pendant above desk	1	48.6	48.6	lobby	30
L5	Logo wall	4	5.9	23.6	lobby	30

The following table is the new panelboard schedule for panelboard P12B. The cells that are highlighted in yellow are the altered circuit with new load based on the table above. The total load is slightly higher than the original design. Although I think it is not a problem because more lighting

fixtures with decorative purposed are installed in the lobby area. But as discussed in the lighting depth, most of the lighting loads are contributed by the fixtures in the large conference room, and

P21B	120/208V		3 PHASE		4 WIRE		TOTAL WATTS L1: 10275				TOTAL WATTS: 32878	
	MAIN BREAKER: MLO						TOTAL WATTS L2: 9026				LOCATION	
	MAIN BUS: 225A						TOTAL WATTS L3: 13577				LEVEL 1 ELEC. RM	
LOAD	DIRECTORY	L1	L2	L3	CKT	AMPS	AMPS	CKT	L1	L2	L3	DIRECTORY	LOAD
R	RECEPTION REC	800			1	20	20	2	864			DISPOSER 1/2HP	E
R	FIRE COMMAND REC		600		3	20	20	4		360		RECEP. ST-11	R
R	LOBBY RECEP			720	5	20	20	6			540	GFCI	R
R	LOBBY REC	913			7	20	20	8	720			RECEP. F113	R
R	LARGE CONF.		800		9	20	20	10		800		SP1 PANEL RM F103	E
R	LARGE CONF. PART			1000	11	20	20	12			1176	FCU-3	E
R	LARGE CONF.	800			13	20	20	14	864			FCU-4	E
R	TV REC		600		15	20	20	16		2400		FCU-4	E
R	OFFICE			1000	17	20	20	18			2400	FPB-2	E
R	CORRIDOR	800			19	20	20	20	200			SP1 PANEL RM F103	R
R	LOAD CHECK		400		21	20	20	22		800		VP AND MS	E
R	ELEV EM			400	23	20	20	24			1515	LEVEL1 VIA LVRP-1-3,5	L
E	DOOR POWER SUPPLY	800			25	20	20	26	1619			LEVEL 1 LVRP-1-6	L
E	FCU-10				27	20	20	28		1586		LEVEL 1 LVRP-1-7	L
E	FDCG-70			2400	29	20	20	30			1198	LOBBY LTG	L
E	QUAD F11	360			31	20	20	32	732			LEVEL 1 LVRP-1-11	L
E	RECEP F104		180		33	20	20	34		500		RECEP F114&FCU-34	R
L	LEVEL1 VIA LVRP-1-2			868	35	20	20	36			360	RECEP. F114	R
S	SPARE				37	20	20	38	803			LEVEL 1 LOBBY	L
S	SPARE				39	20	20	40				SPARE	S
S	SPARE				41	20	20	42				SPARE	S
	SUBTOTAL	4473	2580	6388					5802	6446	7189		

the power density in the lobby area is actually much lower than the current design.

With the same method, other panel boards are updated in the similar fashion. Here are the new panel board schedules. The original schedules can be found in the appendix pages. Also, the affected circuits are in red for convenience of comparing with the new schedules.

L42	277/480V		3 PHASE		4 WIRE		TOTAL WATTS L1:		6060		TOTAL WATTS: 20920	
	MAIN BREAKER: MLO						TOTAL WATTS L2:		6008		LOCATION	
	MAIN BUS: 100A						TOTAL WATTS L3:		8852		LEVEL 2 ELEC. RM	
LOAD	DIRECTORY	L1	L2	L3	CKT	AMPS	AMPS	CKT	L1	L2	L3	DIRECTORY	LOAD
L	BASEMENT	1100			1	20	20	2				STAIR 2	L
L	STAIR 1				3	20	20	4		800		LVL 2, CORE	L
L	LVL.1 CORE			1200	5	20	20	6			2301	LVL 3, CORE	L
L	LVL.1 ELEX&LD DOCK	1480			7	20	20	8	1091			BASEMENT	L
L	LEVEL 1		900		9	20	20	10		700		BASEMENT	L
L	LEVEL 2			512	11	20	20	12			1380	PV HIGH BAY	L
L	SPARE				13	20	20	14				SPARE	L
L	SPARE				15	20	20	16		768		LEVEL 1 LTG	L
L	SPARE				17	20	20	18			1408	LEVEL 2	L
L	LEVEL 2 LVRP-1-15	203			19	20	20	20	1104			LVL2 LVRP-1-13,14,15	L
S	SPARE				21	20	20	22		2300		LEVEL 3	L
L	LEVEL 3			882	23	20	20	24			969	LEVEL 3 LVRP-1-20,21	L
L	LIGHTING	882			25	20	20	26					
L	LIGHTING CONTROL		200		27	20	20	28					
L	LIGHTING CONTROL			200	29	20	20	30					
L	LIGHTING CONTROL	200			31	20	20	32					
L	LIGHTING		340		33	20	20	34					
					35	20	20	36					
					37	20	20	38					
					39	20	20	40					
					41	20	20	42					
	SBUTOTAL	3865	1440	2794					2195	4568	6058		

EP2B	120/208V		3 PHASE		4 WIRE		TOTAL WATTS L1:		3664		TOTAL WATTS: 20920	
	MAIN BREAKER: MLO						TOTAL WATTS L2:		3778		LOCATION	
	MAIN BUS: 100A						TOTAL WATTS L3:		1702		LEVEL 2 ELEC. RM	
LOAD	DIRECTORY	L1	L2	L3	CKT	AMPS	AMPS	CKT	L1	L2	L3	DIRECTORY	LOAD
E	FOP-1, LEVL1 (1/4HP)	1400			1	20	20	2	500			ELEV CAB LTG	E
E	FOP-2, LEVL1 (1/4HP)		1400		3	20	20	4		500		ELEV CAB PWR	E
E	LVL 1 FACP				5	20	20	6			500	ELEV REM. MONTR	E
E	LVL 1 FACP				7	20	20	8	500			GEN. PWR	E
E	LVL 4 FACP				9	20	20	10		500		GEN. LTG	E
E	LVL 4 FACP				11	20	20	12			200	EMRG ELEC RM REC	R
E	LVL 6 BDA				13	20	20	14	200			FIRE PUMP REC	R
E	LVL 6 BDA				15	20	20	16		550		ELEV PIT & CNTRL RM	R
E	SBSMNT. SMOKE DAMP				17	20	20	18			550	TOP ELEV SHAFT	R
E	LVL 1 SMOKE DAMP				19	20	20	20	200			BSMNT HEAT TRACE	E
E	LVL 2 SMOKE DAMP				21	20	20	22		78		LIGHTING VESTIBULE	L
E	LVL 3 SMOKE DAMP				23	20	20	24			75	LVL 1 LIGHTING	L
E	LVL 4 SMOKE DAMP				25	20	20	26	864			FIRE SHUTTER	E
E	LVL 5 SMOKE DAMP				27	20	20	28		200		FIRE SHUTTER CTRL	E
E	LVL 6 SMOKE DAMP				29	20	20	30			377	LVL 2 LIGHTING	L
E	SPARE				31	20	20	32				SPARE	S
L	LVL 6 LIGHTING		390		33	20	20	34		160		LVL 3 LIGHTING	L
S	SPARE				35	20	20	36				SPARE	S
S	SPARE				37	20	20	38				SPARE	S
S	SPARE				39	20	20	40				SPARE	S
S	SPARE				41	20	20	42				SPARE	S
	SUBTOTAL	1400	1790	0					2264	1988	1702		

EP2B	120/208V		3 PHASE		4 WIRE		TOTAL WATTS L1:		892			TOTAL WATTS: 6179	
	MAIN BREAKER: MLO						TOTAL WATTS L2:		2800			LOCATION	
	MAIN BUS: 100A						TOTAL WATTS L3:		2487			BSMNT EMRG. ELEC RM	
LOAD	DIRECTORY	L1	L2	L3	CKT	AMPS	AMPS	CKT	L1	L2	L3	DIRECTORY	LOAD
S	SPARE				1	20	20	2	400			ELEC. ROM. CORR.	R
E	FCU-20		2400		3	20	20	4		400		VESTIBULE REC	R
L	LVL 4,5 LIGHTING			1647	5	20	20	6			840	LVL 4,5 LIGHTING	L
L	LVL 4,5 LIGHTING	184			7	20	20	8	308			LVL 4,5 LIGHTING	L
S	SPARE				9	20	20	10				SPARE	S
S	SPARE				11	20	20	12				SPARE	S
S	SPARE				13	20	20	14				SPARE	S
S	SPARE				15	20	20	16				SPARE	S
S	SPARE				17	20	20	18				SPARE	S
S	SPARE				19	20	20	20				SPARE	S
S	SPARE				21	20	20	22				SPARE	S
S	SPARE				23	20	20	24				SPARE	S
S	SPARE				25	20	20	26				SPARE	S
S	SPARE				27	20	20	28				SPARE	S
S	SPARE				29	20	20	30				SPARE	S
S	SPARE				31	20	20	32				SPARE	S
S	SPARE				33	20	20	34				SPARE	S
S	SPARE				35	20	20	36				SPARE	S
S	SPARE				37	20	20	38				SPARE	S
S	SPARE				39	20	20	40				SPARE	S
S	SPARE				41	20	20	42				SPARE	S
	SUBTOTAL	184	2400	1647					708	400	840		

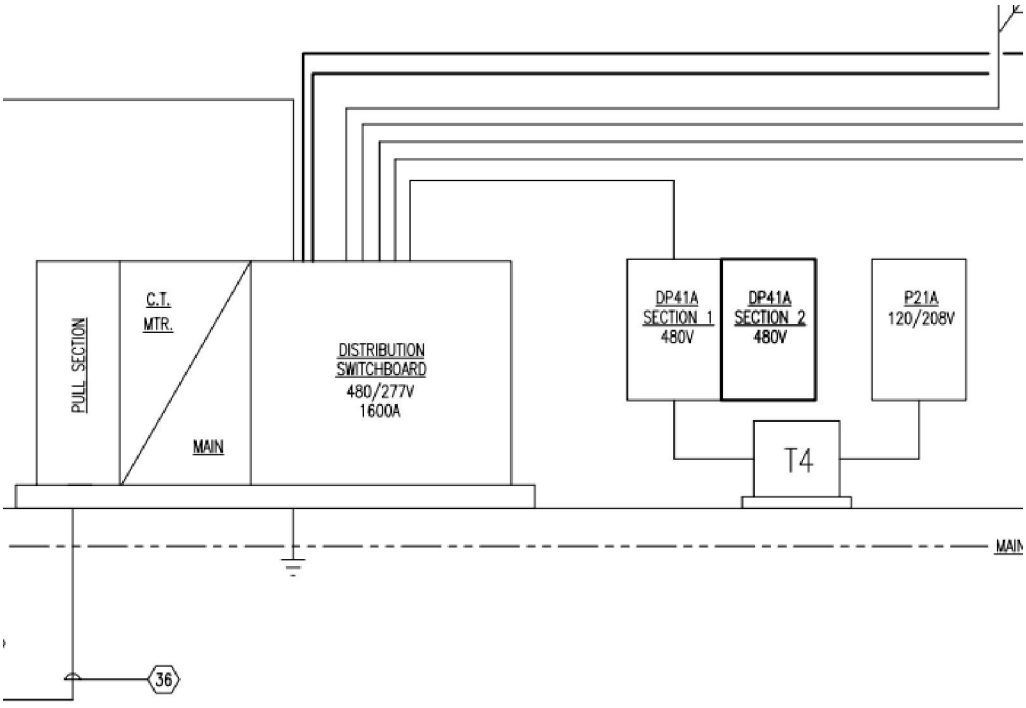
As can be seen from all the panel boards that have been changed, the total wattage exceeds the original design. However, the fourth and fifth floor does not have designed so there aren't lighting systems installed. In this condition, the exceeding part of the wattage is actually a very small portion and it will be more energy efficient compares to the two the floors if there is fully installed lighting system.

SHORT CIRCUIT ANALYSIS

Short circuit analysis is conducted for the Fruanhofer CSE building electrical system to ensure the equipment can support the new load or needs to be replaced.

SWITCHBOARD "SWBD-1" SCHEDULE													
HORZ. BUS: 1600A		VERT. BUS: 1600A				S.C.R.: *					NEUT. BUS: 1600A		
GROUND BUS: FULL		NEMA CLASS: *				VOLTAGE: 480/277V, 3ø, 4W					ENCL. NEMA TYPE: *		
COMPT. NO.	EQUIPMENT DESIGNATION	DISCONNECT DEVICE				FEEDER						REMARKS
						WIRE		GROUND		CONDUIT		
		POLES	FRAME	TRIP	TYPE	NO.	SIZE	NO.	SIZE	NO.	SIZE	
1	INCOMING LINE					(36)						
2	UTILITY METERING											
3	MAIN CIRCUIT BREAKER	3	1600	1600	–							–
4	CH-1 (200 TONS)	3	400	350	–	3	#250	1	#4	1	2-1/2"	1
5	DISTRIBUTION PANEL 'DP41A'	3	400	400	–	(24)						–
6	DISTRIBUTION PANEL 'DP41B'	3	400	400	–	(24)						–
7	'DP21A' VIA XFMR	3	400	300	–	REFER TO TRANSFORMER SCHEDULE						–
8	'DP21B' VIA XFMR	3	400	300	–	REFER TO TRANSFORMER SCHEDULE						–
9	DISTRIBUTION PANEL 'DP4P'	3	400	400	–	(24)						–
10	ATS-700	3	400	400	–	(24)						–
11	PENTHOUSE PANEL "DP2P"	3	400	300	–	REFER TO TRANSFORMER SCHEDULE						
12	SPARE	3	400	350	–	(21)						
13	SPARE											
14	SPARE											

The calculation starts from the main circuit breaker and a series of following distribution system to the panelboards on different locations in the building. If the current does not exceed the existing feeder capacity, there is no need to replace the equipment, however if the current is over the capacity, that means the over current may occur and the equipment needs to be updated to support the new load.



FLA=1600A

Multiplier = $\frac{100}{3.5} = 28.57$

Isc = 1600x28.57=42,855A

Isc,moter = 4 x 1600 = 6400A

I_total = 42,855 + 6400 = 49,255A

f=$\frac{1.732 \times 30.8 \times 42855}{16483 \times 3 \times 480} = 0.0963$

M = $\frac{1}{1+0.0963} = 0.912$

Isc sysrms = 42,855 x 0.912 = 39,091A

Isc moter = 4 x 1600 = 6400A

I_total = 39091 + 6400 = 37,491A

With the same method and the distribution riser diagram and the according conductor size in the legend below.

f= $\frac{1.732 \times 112.4 \times 39091}{22965 \times 4 \times 480} = 0.1726$

M= $\frac{1}{1+0.1726} = 0.8528$

Isc sysrms = 39091 x 0.8528 = 33,337A

Isc moter = 4 x 1600 = 6400A

I_total = 33,337+6400 = 39737A

LEGEND OF FEEDER SIZES

COPPER CONDUCTORS – XHHW/XHHW-2

FEEDER SYMBOL	CONDUCTORS (3 PHASE, 3 WIRE WITH GROUND)	RACEWAY SIZE CONDUIT	CONDUCTORS (3 PHASE, 4 WIRE WITH GROUND)	RACEWAY SIZE CONDUIT	NOMINAL AMPERE RATING
1	3#4 & 1#10G.	1"			60
2			4#4 & 1#10G.	1 1/4"	
3	3#4 & 1#8G.	1"			70
4			4#4 & 1#8G.	1 1/4"	
5	3#1 & 1#8G.	1 1/2"			100
6			4#1 & 1#8G.	1 1/2"	
7	3#1/0 & 1#6G.	1 1/2"			125
8			4#1/0 & 1#6G.	2"	
9	3#1/0 & 1#6G.	2"			150
10			4#1/0 & 1#6G.	2"	
11	3#2/0 & 1#6G.	2"			175
12			4#2/0 & 1#6G.	2"	
13	3#3/0 & 1#6G.	2"			200
14			4#3/0 & 1#6G.	2 1/2"	
15	3#4/0 & 1#4G.	2 1/2"			225
16			4#4/0 & 1#4G.	2 1/2"	
17	3#250 KCMIL & 1#4G.	2 1/2"			250
18			4#250 KCMIL & 1#4G.	2 1/2"	
19	3#350 KCMIL & 1#4G.	3"			300
20			4#350 KCMIL & 1#4G.	3"	
21	3#500 KCMIL & 1#3G.	3"			350
22			4#500 KCMIL & 1#3G.	3 1/2"	
23	3#600 KCMIL & 1#3G.	3 1/2"			400
24			4#600 KCMIL & 1#3G.	4"	
25	6#250 KCMIL & 2#2G.	2-2 1/2"			500
26			8#250 KCMIL & 2#2G.	2-3"	
27	6#350 KCMIL & 2#1G.	2-3"			600
28			8#350 KCMIL & 2#1G.	2-3"	
29	6#600 KCMIL & 2#1/0G.	2-3 1/2"			800
30			8#600 KCMIL & 2#1/0G.	2-4"	
31	9#400 KCMIL & 3#2/0G.	3-3"			1000
32			12#400 KCMIL & 3#2/0G.	3-3 1/2"	
33	9#600 KCMIL & 3#3/0G.	3-3 1/2"			1200
34			12#600 KCMIL & 3#3/0G.	3-4"	
35	12#600 KCMIL & 4#4/0G.	4-3 1/2"			1600
36			16#600 KCMIL & 4#4/0G.	4-4"	
37	15#600 KCMIL & 5#250 KCMIL G.	5-4"			2000
38			20#600 KCMIL & 5#250 KCMIL G.	5-4"	

DISTRIBUTION PANEL "DP4P" SECTION 1 SCHEDULE							PENTHOUSE
277/480 VOLTS		3 PHASE		4 WIRE			* AIC
MAIN BUS SIZE: 400 AMPS		NEUTRAL: 100%			GROUND BUS: FULL		
MAIN DEVICE: MLO		MOUNTING: SURFACE					
CIRCUIT NUMBER	LOAD ITEM		OVERCURRENT DEVICE			FEEDER SIZE	REMARKS
			FRAME	TRIP	POLE		
1	PANEL 'P2P' VIA XFMR (EXISTING)		100	80	3	REFER TO TRANSFORMER SCHEDULE	(1)
2	HWP-1 (EXISTING)	(5HP)	100	20	3	REFER TO MOTOR WIRING SCHEDULE	VIA VFD (1)
3	HWP-2, STANDBY (EXISTING)	(5HP)	100	20	3	REFER TO MOTOR WIRING SCHEDULE	VIA VFD (1)
DISTRIBUTION PANEL "DP4P" SECTION 2 SCHEDULE							PENTHOUSE
277/480 VOLTS		3 PHASE		4 WIRE			* AIC
MAIN BUS SIZE: 400 AMPS		NEUTRAL: 100%			GROUND BUS: FULL		
MAIN DEVICE: MLO		MOUNTING: SURFACE			NOTE: FED THRU LUGS FROM DP4P SECTION 1 INSTALLED UNDER SHELL AND CORE PHASE		
CIRCUIT NUMBER	LOAD ITEM		OVERCURRENT DEVICE			FEEDER SIZE	REMARKS
			FRAME	TRIP	POLE		
9	AHU-1	(64FLA)	100	100	3	3#4 & 1#6G - 1 1/4"C	VIA VFD
10	EAHU-1	(50FLA)	100	100	3	3#4 & 1#6G - 1 1/4"C	VIA VFD
11	CT-1	(20HP)	100	60	3	REFER TO MOTOR WIRING SCHEDULE	VIA VFD
12	HEAT TRACE		100	20	3		-
13	AC-1	(1.5HP)	100	20	3	REFER TO MOTOR WIRING SCHEDULE	-
14	SPARE		100	30	3		
15	SPARE		100	30	3		
16	HRW	(1/2HP)	100	20	3	REFER TO MOTOR WIRING SCHEDULE	VIA VFD
17	CBWP-7	(1.5HP)	100	15	3	REFER TO MOTOR WIRING SCHEDULE	-
18	CBWP-5	(1HP)	100	15	3	3#10 & 1#10G - 3/4"C	-
19	CBWP-6	(1HP)	100	15	3	3#10 & 1#10G - 3/4"C	-
20	SPACE		100	-	3		

From the distribution panelboard schedule, the current equipment can support the new lighting load.

Depth: PHOTOVOLTAIC ARRAY

With the higher and high demand of electrical and fossil energy worldwide, clean and renewable energy takes a bigger part in the building industry. By having photovoltaic system in the building are encouraged by the USGBC. As a national leader in sustainability and innovation, the City of Boston created the Renew Boston Solar map to assist in tracking our community's clean energy progress and meeting Mayor Thomas M. Menino's goal of reducing greenhouse gas emissions by 25% in 2020.

In order to maximize the energy efficient goal of that the company is dedicated in, solar photovoltaic arrays are designed for the building. The study is to determine whether the photovoltaic system will be a good idea for the building with the consideration of the geographic reason and the surrounding conditions. The original design has photovoltaic arrays installed on the roof as well as the building exterior walls with two purposes. One is for energy saving, the other is for research and data collecting. When the building was under design phase, there are no tall buildings close to the site. However when the tenant moved in the building, there is a new construction happened right next to it and are taller than the Fraunhofer building. And the photovoltaic arrays that are located on the west exterior walls may not serve the power supply as well as design.

For building with more than 10 kilowatts in size, the installed price for photovoltaic systems is usually $4.60/W for commercial buildings. In this case, a single multijunction photovoltaic panel can reach the efficiency of as high as 40%.

Also there is another PV system is installed in the building. The PV panels on the east façade are from the provider called Pythagoras. Pythagoras Solar PVGU are solar glass panels that can be installed within the building envelope that will provide high transparency glazing as well as transferring solar energy into electrical power. It can contribute to achieving LEED points in the areas such as optimizing energy performance, on-site renewable energy, daylight and views.

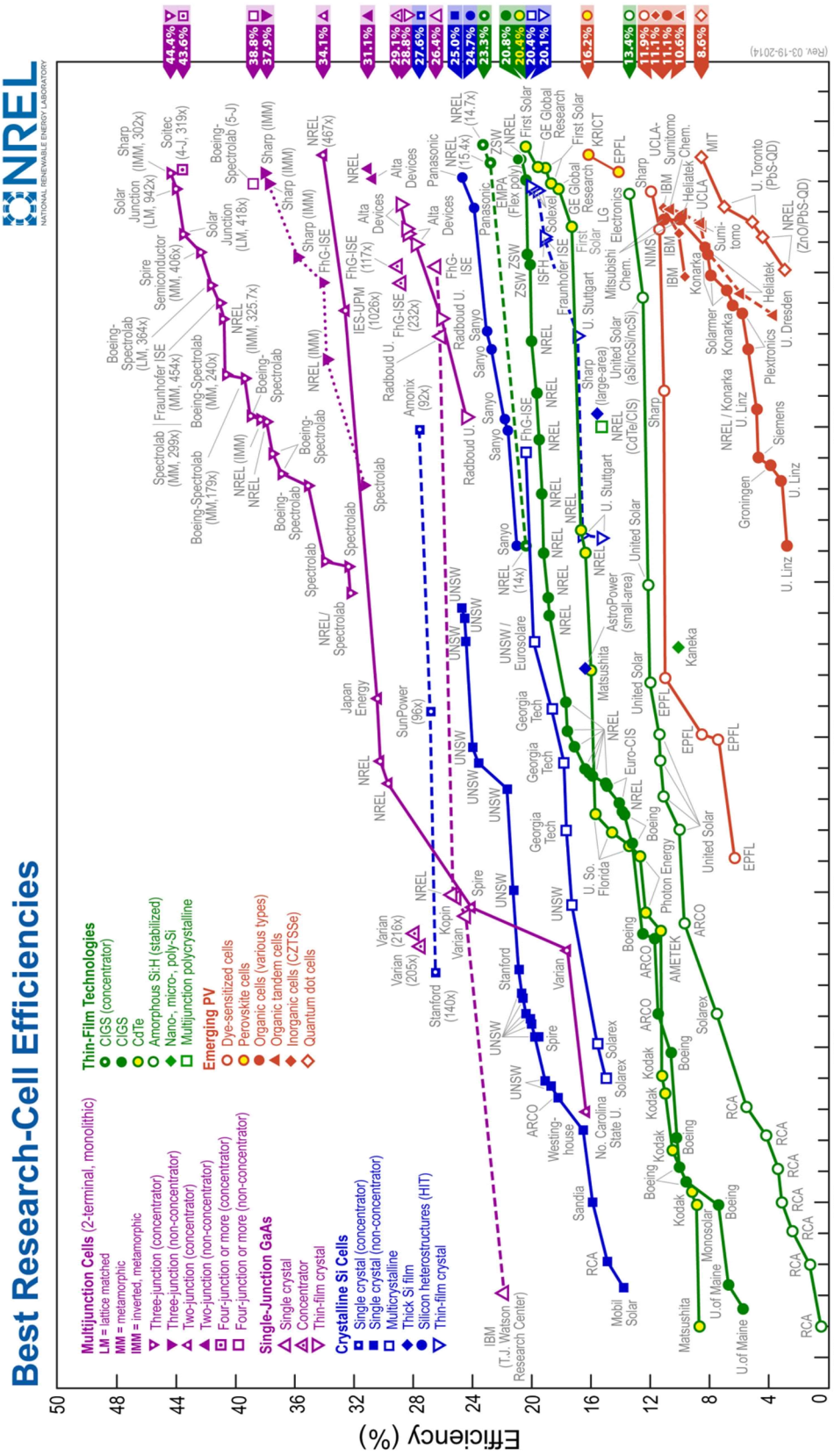

Best Research-Cell Efficiencies
NREL
NATIONAL RENEWABLE ENERGY LABORATORY
Efficiency (%)
Multijunction Cells (2-terminal, monolithic)
LM = lattice matched
MM = metamorphic
IMM = inverted, metamorphic
Three-junction (concentrator)
Three-junction (non-concentrator)
Two-junction (concentrator)
Two-junction (non-concentrator)
Four-junction or more (concentrator)
Four-junction or more (non-concentrator)
Single-Junction GaAs
Single crystal
Concentrator
Thin-film crystal
Crystalline Si Cells
Single crystal (concentrator)
Single crystal (non-concentrator)
Multicrystalline
Thick Si film
Silicon heterostructures (HIT)
Thin-film crystal
Thin-Film Technologies
CIGS (concentrator)
CIGS
CdTe
Amorphous Si:H (stabilized)
Nano- micro- poly-Si
Multijunction polycrystalline
Emerging PV
Dye-sensitized cells
Perovskite cells
Organic cells (various types)
Organic tandem cells
Inorganic cells (CZTSSe)
Quantum dot cells
(Rev. 03-19-2014)
44.4%
43.6%
38.8%
37.9%
34.1%
31.1%
29.1%
28.8%
27.6%
26.4%
25.0%
24.7%
23.9%
20.8%
20.4%
20.4%
20.1%
16.2%
13.4%
11.9%
11.1%
11.1%
10.6%
8.6%
1975
1980
1985
1990
1995
2000
2005
2010
2015
0
4
8
12
16
20
24
28
32
36
40
44
48
50

Figure 45

references

1. Lighting Criteria:
2. Illumination Engineering Society Handbook, 10th Edition
3. ASHRAE 90.1 Standard (2010)
4. Picture from www.archdaily.com, photo courtesy of ODA
5. http://gis.cityofboston.gov/solarboston/
6. http://www.nrel.gov/ncpv/

Computer Programs

- AGi32 2014
- AutoCAD 2014
- Autodesk 3ds Max 2014
- Revit