Tobin Center for the Performing Arts

San Antonio, TX

Final Thesis Report

Laura Ashley A. Alferes
Lighting | Electrical
Faculty Advisor | Dr. Kevin Houser

04.09.2014

Tobin Center for the Performing Arts

100 Auditorium Circle, San Antonio, TX

Architecture

New multipurpose auditorium positioned at a 75 degree angle to the existing south facade.
Back of the orchestra level will be at the same level as the existing lobby.
Studio Theater to be located within the historic west facade & a new Event Plaza alongside the river walk.

Lighting + Electrical

Utility Network: CPS Energy
(4) four submersible, dry-type main service transformers, each rated at 13.8 kV, 480/277V.
Two main switchboards are located in the basement.
MB-1: 4000A, 480/277V, 3-Phase, 4W+Gnd., 150kAIC, 20% growth capacity for future expansion
MB-2: 3000A, 480/277V, 3-Phase, 4W+Gnd., 150kAIC, 10.2% growth capacity for future expansion

Mechanical

Air distribution system is comprised of multiple (12) variable volume air handling units.
Displacement ventilation utilized beneath auditorium seating.
Central plant provides chilled water, condenser water, heating hot water and coil reheat/dehumidification.
HVAC runs on a Building Automation System

Structural

Steel braced frames. Concrete slab cast on composite metal deck diaphragm attached to steel floor members.
Metal deck diaphragm attached to roof members.

Statistics

Size: 172,970 gsf
Number of Stories: 6+1 basement
Estimated Cost: $135 million
Occupancy: Assembly Group A-1
Delivery: Design-Bid-Build
Construction Dates: Jan 8, 2010 - July 29, 2014

Overview

Owner: Bexar County Performing Arts Center Foundation
Construction Manager: Linbeck
Architect: LMN Architects
Civil Engineer: Pape-Dawson Engineers, Inc.
Structural Engineer: Walter P. Moore
Mechanical Engineer: Timmons Designer Engineers
Electrical Engineer: TTG Goetting

South facade view from Auditorium Circle

Executive Summary

This thesis focused on the Tobin Center for the Performing Arts in San Antonio, TX. Historically known as the Municipal Auditorium, the Tobin Center will be transformed into a striking architectural landmark, both locally and nationally. The primary elements consist of a 1,750 seat H-E-B Performance Hall; a 200 seat flat floor Alvarez Family Studio; the Leroy Denman Founders Lounge; McCombs Grand Lobby; and a River Walk Plaza.

Within this thesis, several systems, methods, and their results were thoroughly studied during a yearlong capstone project on the Tobin Center for the Performing Arts. The fall 2013 semester included an investigation of existing systems and to further study spaces for analysis and potential redesign. The spring 2014 semester concentrated on developing design concepts and integrating alternative engineering systems.

This thesis contains lighting and electrical depths, as well as construction management and mechanical breadths. The lighting depth explores design alternatives for a circulation space, a special purpose space, a large work space, and an outdoor space. The electrical depth analyzes a branch circuit redesign based on new lighting loads, a short circuit analysis, and finally the implementation of a Building-Integrated Photovoltaic (BIPV) system.

The construction management is interrelated with the BIPV system, in which a cost and schedule analysis was performed. The mechanical breadth studies the potential use of biogas as a renewable energy source, especially for cogeneration purposes.

All sections of this thesis project are based on a thorough examination of the building, as well as a coherent design solution to address the potential for system alternatives.

Table of Contents

SECTION ONE | project background

The existing south façade, known as the Municipal Auditorium, is located in Bexar County of San Antonio, TX. It's considered one of the finest examples of the Spanish Revival style found in a public building in Texas. At the time of its construction, this style was very popular. The new addition, which is the bulk of this thesis report, will exemplify today's popular style of modern aesthetics and extensive interior and exterior design integration.

San Antonio looks forward to the completion of the TCPA because the old and new style of design will become one. The building shall continue to be a valuable cultural landmark of the city, interlocking the life of the building with the life of the city.

Section Two | building statistics

The following subsections describe the site location, building type and project team, as well as the various systems used throughout the Tobin Center.

Site Information

The site for the Tobin Center for the Performing Arts is located on the current site of the San Antonio Municipal Auditorium. The north-side is bordered by the San Antonio River, where patrons will have access to an Event Plaza and the San Antonio Riverwalk. On the east is Fourth Street and Richmond Street on the west. Auditorium Circle is located on both the east and west sides of the site.

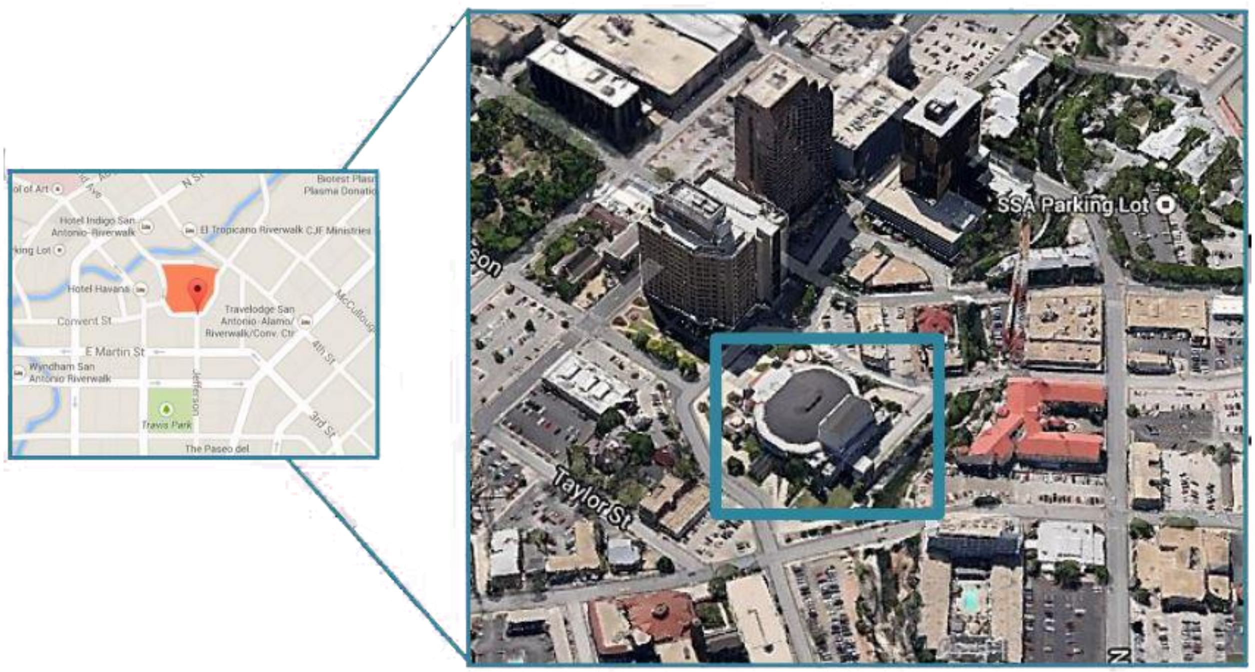


Figure 1: Tobin Center Aerial View [Photo Credit: Google Maps]
Note: The above image shows the old performing arts building. After completion, it is assumed the building will be updated to its new 3D form.

Across the street from the south entrance is the Memorial Plaza. Additionally, two (2) large bronze sculptures, a Korean War Memorial and a Vietnam Veteran Memorial, shall remain.

General Building Data

Building Name: Tobin Center for the Performing Arts
Location and Site: 100 Auditorium Circle, San Antonio, TX 78205
Building Occupant Name: Tobin Center for the Performing Arts
Occupancy Types: Assembly Group A-1 (Primary Occupancy)
Size: 172,970 GSF
Number of Stories Above Grade: 6 + 1 Basement
Primary Project Team:
Owner: Bexar County Performing Arts Center Foundation
Owner's Rep: The Projects Group, Zacry Construction Corp., Marmon Mok
Construction Manager: Linbeck
Architect of Record/FOH (Prime): LMN Architects
Civil Engineer: Pape-Dawson Engineers, Inc.
Structural Engineer: Walter P. Moore (Prime/FOH)
Mechanical & Plumbing Engineer: Timmons Designer Engineers (Prime)
Electrical Engineer: TTG Goetting
Architectural Lighting: Horton Lees Brogden, Inc.
Dates of Construction: January 8, 2010 – July 29, 2014
Projected Cost of Project: $135 million
Project Delivery Method: Design-Bid-Build

Architectural Information

The Tobin Center for the Performing Arts is an inspiring expression for the performing arts in San Antonio. Its design integrates functionality, theatricality, and community in both its historic elements and new addition. The design is driven by four distinctive objectives

- To maintain the primary historic and iconic facades, as well as enhance the south entry
- To create a dynamic interplay of form, geometry and material between historic elements and the new addition
- To orient the Studio Theater and lobby toward the San Antonio River
- To integrate a new Event Plaza along the San Antonio River Walk, encouraging more city events and outdoor performance space

The key to these objectives is the geometric relationship of the new multipurpose auditorium to the historic south façade and arcade wings, known as the Municipal Auditorium. Therefore, the new multipurpose auditorium will be positioned at a 75° angle to the existing south façade, and the back of the orchestra level will be at the same level as the existing lobby. This configuration allows for the Studio Theater to be located within the historic west façade and a new Event Plaza alongside the river walk.

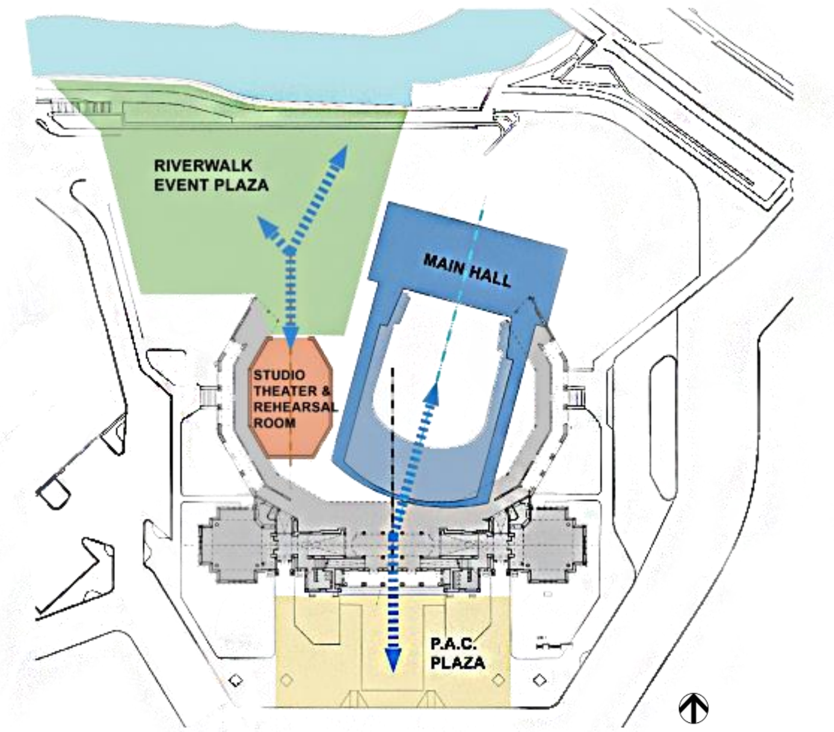


Figure 2: Geometric Relationship & Configuration
[Photo Courtesy of LMN Architects]

It will function as a state of the art performance center for various performing arts organizations in San Antonio. The Main Auditorium will include 1750 seats, an appropriate setting for symphonic, operatic, theatrical and amplified presentations. Additionally, a flat floor Studio Theater, with 200 seats, will feature theatrical configurations, music rehearsals and community events.

Sustainability Features

The Bexar County Performing Arts Center [BCPAC] strives for sustainability in this venue. Through preservation, restoration, and rehabilitation, especially with an existing structure such as the Municipal Auditorium, a sustainable act is in practice. To evaluate sustainable features, two versions of the LEED for new construction [LEED-NC] Rating System have been adopted: version 2.2 & 2009. Using either version makes it possible to achieve LEED certification

LEED-NC 2.2	LEED-NC 2009	Registered as LEED NCv2.2

As a guide to sustainability, the target is to understand the location of the city. This promotes public transportation, use of exterior plazas for public space, outdoor air delivery monitoring, and water conserving plumbing fixtures and water reuse.

Construction Method

Linbeck Group, LLC is the construction management firm for the Tobin Center. The delivery method is design-bid-build, with a projected budget of $135 million. Additionally, the project has a second budget that address upgrades to the site, specifically for improved access to the San Antonio Riverwalk, an Event Plaza, and a memorial to veteran Medal of Honor winners from San Antonio.

Lighting System

Fluorescent, incandescent, HID, and LED fixtures are used throughout. The stage and house lighting control system will include a number of twenty ampere and fifty ampere high-density, solid-state dimmers, as well as single-pole and two-pole relays that feed receptacles in outlet boxes above the stage and in the auditorium in a dimmer-per-circuit configuration. This system will be controlled by an electronic memory to establish, store, and recall preset intensity levels and fade times that can be accessed from both the main control console and remote pushbutton or touchscreen preset stations.

Electrical System

The utility service, CPS Energy, provides power for each of the four submersible, dry-type main service transformers, each rated at 13.8 kV on the primary and 480/277V on the secondary. They are sized, controlled and engineered by the local utility company. The main service from these transformers is provided through two indoor, surface-mounted, single-ended main switchboards, MSB-1 and MSB-2, located in the main electrical room of the basement. Both switchboards are 480/277V, 3-phase, 4 wires + ground, 150 kAIC, with NEMA 1 enclosure. MSB-1 and MSB-2 steps down the voltage of either 208Y/120V or 218Y/126V to switchboards and distribution panels. Emergency power is provided by a diesel generator rated at 250 kW/312.5 kVA. No optional back-up power exists in the system.

Mechanical System

The mechanical system, which is run by a BAS, is designed to optimize performance, and minimize maintenance and energy use. A newer technique of displacement ventilation is utilized beneath auditorium seating. It offers thermal comfort for patrons, the quietest possible air distribution, and energy efficiency advantages. Conditioned air is distributed near the patrons, and as it warms, it rises to the top of the auditorium volume. Optimum indoor air quality is provided by supplying air at low levels and driving contaminants out of the occupied air zone. In addition to comfort, the noise reduction associated with displacement helps to meet acoustical requirements, especially since auditoriums and theaters, in general, are sound-sensitive.

Structural System

The ability of the structural frame to resist lateral loads and provide stability under gravity loads derives from the complete installation of a lateral-force resisting system and diaphragm. Included in the structure are steel braced frames. A concrete slab cast on composite metal deck diaphragm is completely attached to all steel floor members. A metal deck diaphragm is completely attached to all roof members. The entire diaphragm creates a continuous element linking the lateral-force resisting system to all other columns.

SECTION THREE | lighting depth

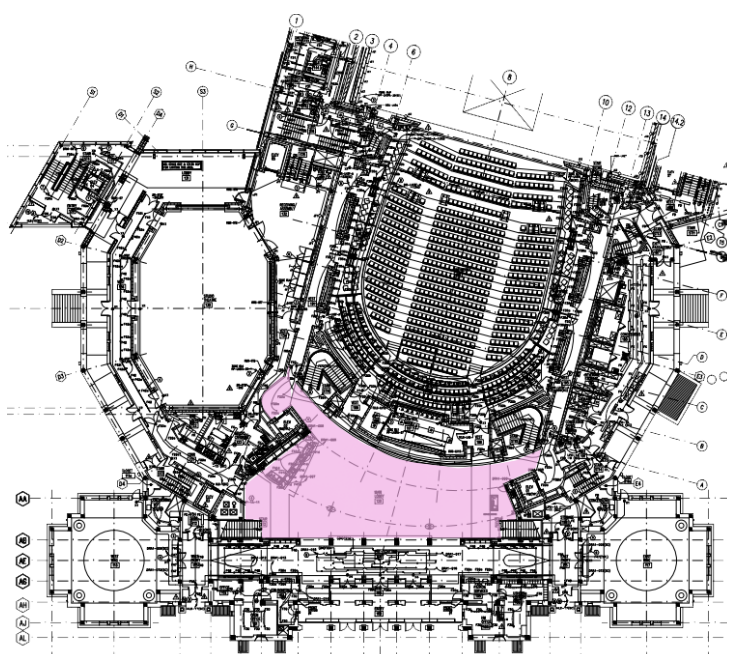
The purpose of the performing arts center is to bring people together to witness several forms of creative activity, in which artists use their body and/or voice to convey artistic expression. With this as a driving force, lighting for the Tobin Center will aim to create engaging environments that are welcoming to patrons and visitors. It will enhance the idea of having the opportunity and responsibility of supporting the goals of the Tobin Center in inspirational and pragmatic ways. To inspire and welcome, the lighting must resonate with the community and celebrate connections between the Tobin Center, the greater fabric of San Antonio, and the Riverwalk.

Equally, to realize its greatest potential, the functional and technical aspects of security, visibility and maintenance will be integrated into the design of the architectural and landscape lighting components.

MAIN LOBBY | CIRCULATION SPACE

DESCRIPTION

The main lobby is a large circulation space, in which attendees can congregate and socialize. It is located on two levels, an upper and lower lobby. For the purpose of the redesign, the lower lobby will be the focus. This space shall provide a strong visual and experiential connection between the historic/pre-ticketing foyer and the new auditorium. A curve wall, concessions area, view of the Patron's Lounge, and a donor wall are architectural elements that make the space unique.



Dimensions

Area	3626 SF
Ceiling Height	67'-5"

Figure 3: Main Lobby Floor Plan [Photo Courtesy of LMN Architects]

SURFACE MATERIAL

Surface	**Type**	**Description**	**Reflectance** (Upper Lobby/Lower Lobby)
Floor	TER-1/2/3	Thinset Epoxy Terrazzo	50%/20%
North Wall	GFRG-1	Glass Fiber Reinforced Gypsum Panels, paint with ArmourColor, Perlata sprayed textured, with clearseal gloss Color: PLS	80%/50%
	PNT-12	Paint Color No. DEA109 Bonfire Flame Manufacturer: Dunn Edwards	80%/50%
E & W Wall	PNT-5	Paint Color. No. OC-138 White Drifts Manufacturer: Benjamin Moore	80%/50%
	PNT-12	Paint Color No. DEA109 Bonfire Flame Manufacturer: Dunn Edwards	80%/50%
South West	PNT-5	Paint Color. No. OC-138 White Drifts Manufacturer: Benjamin Moore	80%/50%
Ceiling	PNT-6	Paint Color No. OC-64 Pure White Manufacturer: Benjamin Moore	80%/80%
	SPCLG-1	Support Ceiling	80%/80%

DESIGN CRITERIA

Qualitative Criteria:

The main lobby serves as the primary transition space between the historic entry/pre-ticketing foyer and the new main auditorium. The lighting in this space should be engaging and inviting, allowing patrons to gain a strong sense of layers of architecture. Therefore, various layers of lighting shall be zoned separately, allowing for a flexible lighting system to respond to the various uses of the main lobby.

Additional criteria that was considered included: (1) general lighting to meet illuminance recommendations for safety regulations, (2) having a dramatic difference in lighting approach from the pre-ticketing foyer, which has a lower ceiling, into the main lobby, and (3) special lighting treatment should be incorporated to distinguish destination points, especially the main auditorium's entry.

IES suggested very important criteria:
Appearance of space and luminaires
Point(s) of interest
IES suggested important criteria:
Modeling of faces and objects
Surface characteristics

Quantitative Criteria:

Illuminance recommendations [IES Lighting Handbook 10th Edition (Table 28.2)]

Space	E_h	E_v
Lobbies – distant from entries	100 lux @ floor	30 lux @ 5ft AFF

Energy Allowance [ASHRAE 90.1]

Space	**Power Density (W/sf)**
Lobby for Performing Arts Theater	2.00 W/ft^2

DESIGN APPROACH

The main lobby's layers of architecture were interpreted as a musical composition. Typically, compositions involve several complimenting layers to make a masterpiece. Therefore, the lighting design shall provide layers of light to highlight points of interest and intuitive way finding.

1. The lobby will be illuminated to highlight various layers of architecture throughout the space.
2. The focal point of the lighting design will be custom chandeliers, resembling the structure of a musical note's stem and body.
3. Downlights, located in the light cove, will graze the curve wall. Doing so provides visual interest of its curvature and elongation. Its repeated pattern reflects a steady rhythmic pattern, commonly found in musical compositions.
4. The donor wall continuously changes, due to the ongoing donor contributions. Thus, the wall shall be backlit to highlight the individual and group names, giving it importance.

COMPUTER RENDERINGS

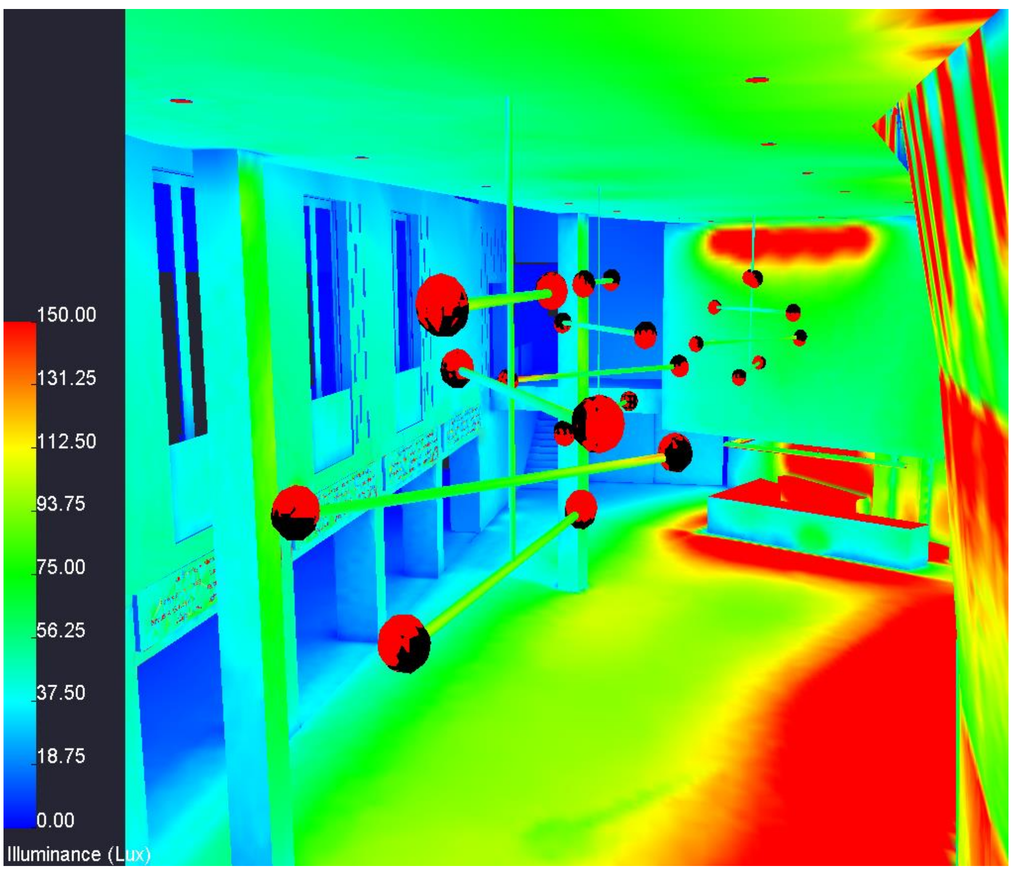


Figure 4: Main Lobby Render, looking NE

Figure 5: Main Lobby Render, looking SW

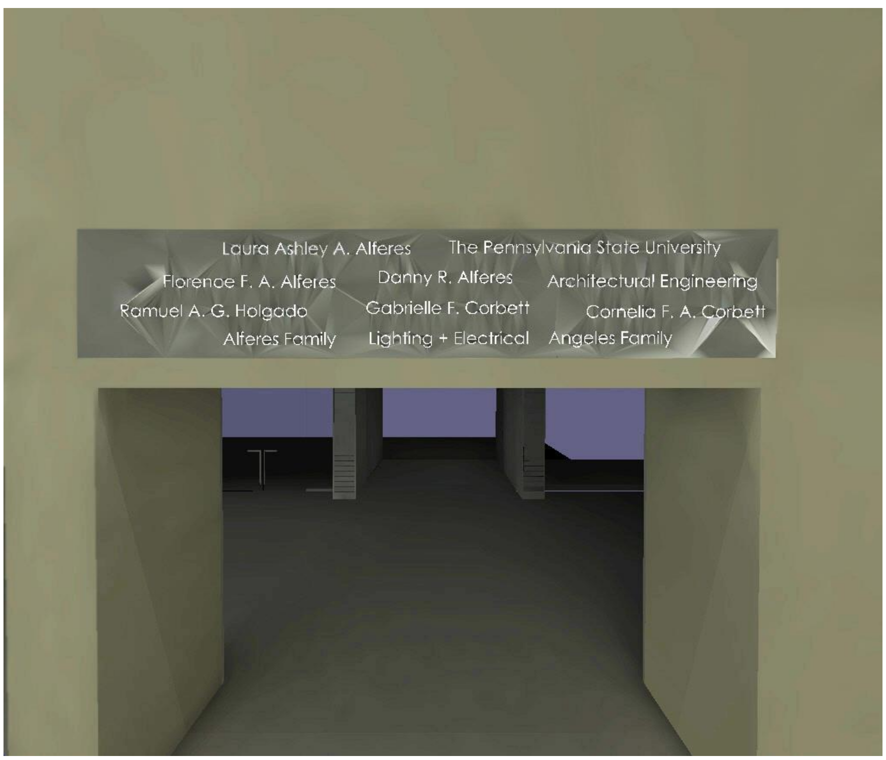


Figure 6: Main Lobby Render, Donor Wall

LUMINAIRE SCHEDULE

Type	Description	Mounting	Manufacturer	Catalog Number	Lamps	Input Watts
E	Custom chandelier, glove with white glass diffuser, electronic ballast	Chandelier	Lithonia Lighting	e67cf937-e3ff-46bb-8aa7-38b22f4359f1 (lamp catalog no.)	CFL	12.5
F1	Recessed LED downlight, round fixed, brushed stainless steel, 3500K	Ceiling Recessed	Lucifer Lighting	DL1YP-IC-SS-4-801335-1	LED	32.509
G	Track LED, silver texture, narrow flood, 3500K	Cove	Amerlux Global Lighting	C2TV-G2-34-LED-E-ST-TN2-120-NF-35OO	LED	33.15
H	Wet location flexible LED linear ribbon, 5500K	Surface	Gm Lighting Solutions	LTR60WP-SO-PW	LED	4.7
J	Recessed ceiling wall wash, silver finish	Ceiling Recessed	Bega	6791	T4 G9 Halogen	60
K	Theory 4' long decorative luminous LED pendant, molded patterned acrylic exterior mounted to aluminum body, matte white interior reflector, die cast endcaps in polished chrome finish, 3000k	Pendant	Focal Point Lighting	FTHPL-LLP-LL1-L30-2C-277-L3D-T-HS-CLV60	LED	34
L	Recessed ceiling luminaire with perforated diffuse interior and clear flat glass lens	Downlight	Bega	6940	Incandescent	50
M	Recessed ceiling downlight, symmetrical light distribution, cast aluminum housing, spun specular patterned aluminum reflector, clear glass enclosure with cast aluminum trim	Ceiling Recessed	Bega	6800LED	LED	8.7

LIGHTING PLAN

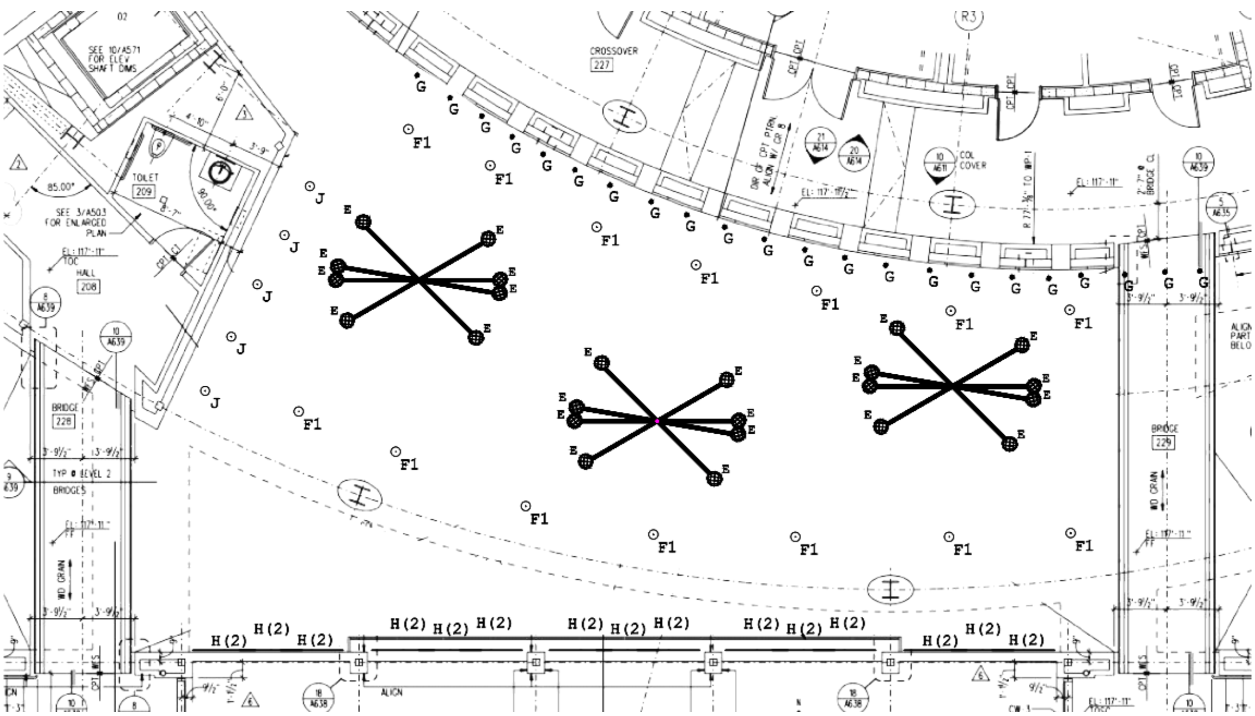


Figure 7: Main Lobby RCP

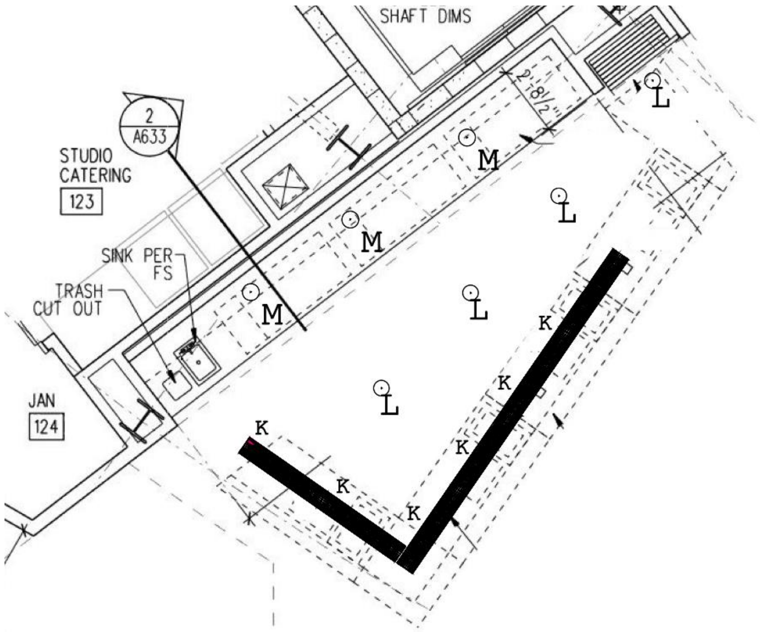


Figure 8: Main Lobby Concessions RCP

PERFORMANCE DATA

Illuminance level – target | provided	100 lux | 127.20 lux
Power Density – target | provided	2.00 W/ft² | 0.767 W/ft²

PERFORMANCE SUMMARY

Spotlights located in the light cove will need to be aimed accordingly to give a clean rhythmic pattern of light and graze along the curve wall's surface. Custom "musical note" chandeliers are focal points that offer visual interest. Patrons in the lobby can enjoy its geometric orientation from below, whereas those in the Patron's Lounge can view it from the side.

With this being a large transition space, the design complements the materials and geometric features, while creating an engaging and welcoming environment. Mindful of the random circulation, the design still enables intuitive way finding. Points of interest are highlighted to exaggerate structural and meaningful purpose, such as the elongated curve wall and donor wall. A flexible dimming system will be integrated into the design to subtly inform patrons that a performance is about to begin.

Overall, the light redesign for the space took a different approach from the existing lighting design. Inspired by musical composition and the structure of a musical note, the lighting design intertwined with the architecture came together as one masterpiece. Design criteria were met.

Patron's Lounge | special purpose space

DESCRIPTION

Located on the second level, the Patron's Lounge functions as a space for socialization, in which patrons and performers can congregate, as well as support donor accommodations and special events. Its architecture is unique but simple, for a structural glass wall support framing allows patrons to see below into the main lobby, and there exists two ceiling heights.

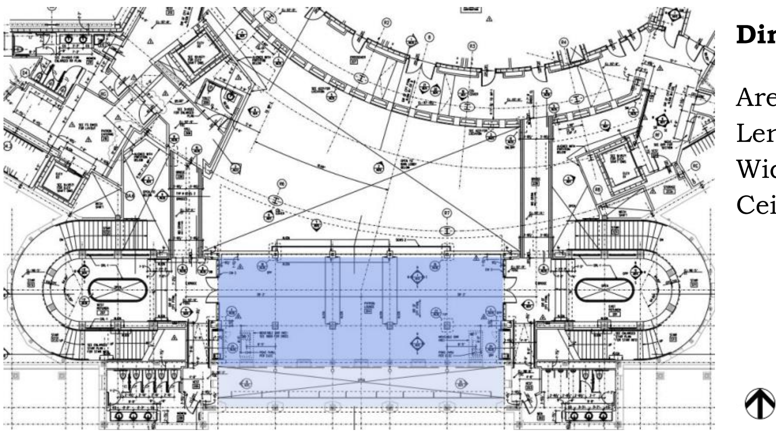


Figure 9: Patron's Lounge Floor Plan [Photo Courtesy of LMN Architects]

Dimensions

Area	1558 SF
Length	64'-2"
Width	24'-3"
Ceiling Height	13'-6" (South), 16'-6" (North)

SURFACE MATERIAL

Surface	Type	Description	Reflectance
Floor	CPT-1	Broadloom Carpet	5%
N,S, E,W Walls	PNT-22	Paint Color No. G7634882 (smooth pearl w/ satin clearcoat) Manufacturer: Scuffmaster	50%
Ceiling	SPCLG-1,PNT-24,PNT-25	Paint Color No. DE790 Ice Gray, Paint Color No. G7170210 (smooth pearl w/ satin clearcoat) Manufacturers: Dunn Edwards, Scuffmaster	80%
Cove	PNT-4	Paint Color No. HC-166 Kendall Charcoal Manufacturer: Benjamin Moore	10%
Columns	PNT-22	Paint Color No. G7634882 (smooth pearl w/ satin clearcoat) Manufacturer: Scuffmaster	64%

DESIGN CRITERIA

Qualitative Criteria:

The appropriate lighting for the Patron's Lounge shall respond to its unique architectural expression, and support the programmatic needs of the space to serve as a special retreat for patrons. A control system is suitable for this space to permit various layers of lighting to be zoned separately, allowing flexibility of the lighting system.

To reinforce the psychological impression of relaxation, the room should project a feeling of comfort, conversation, and gathering. In accordance to John Flynn's lighting mode and subjective impression of relaxation, such factors are fitting for this type of space:

- Non-uniform peripheral lighting,
- Lower light levels
- Warmer-toned light sources

IES suggested very important criteria:
Modeling of faces and objects
IES suggested important criteria:
System control and flexibility

Quantitative Criteria:

Illuminance recommendations [IES Lighting Handbook 10th Edition (Table 28.2)]

Space	**E_h**	**E_v**	**Avg:Min**
Lounges Social/Waiting Area	40 lux @ floor	15 lux @ 4ft AFF	2:1

Energy Allowance [ASHRAE 90.1]

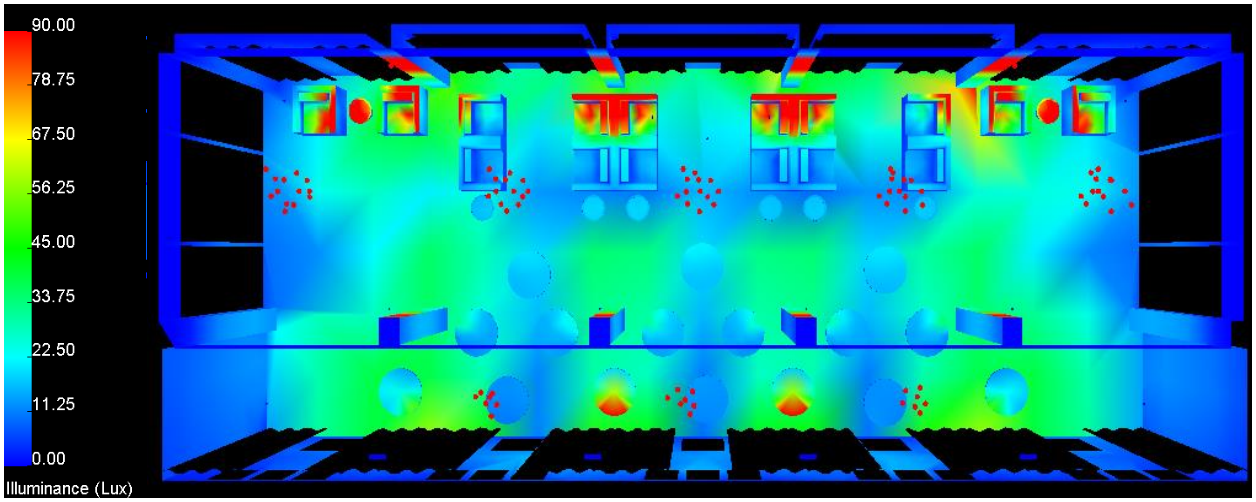
Space	**Power Density (W/sf)**
Lounge	0.73 W/ft^2

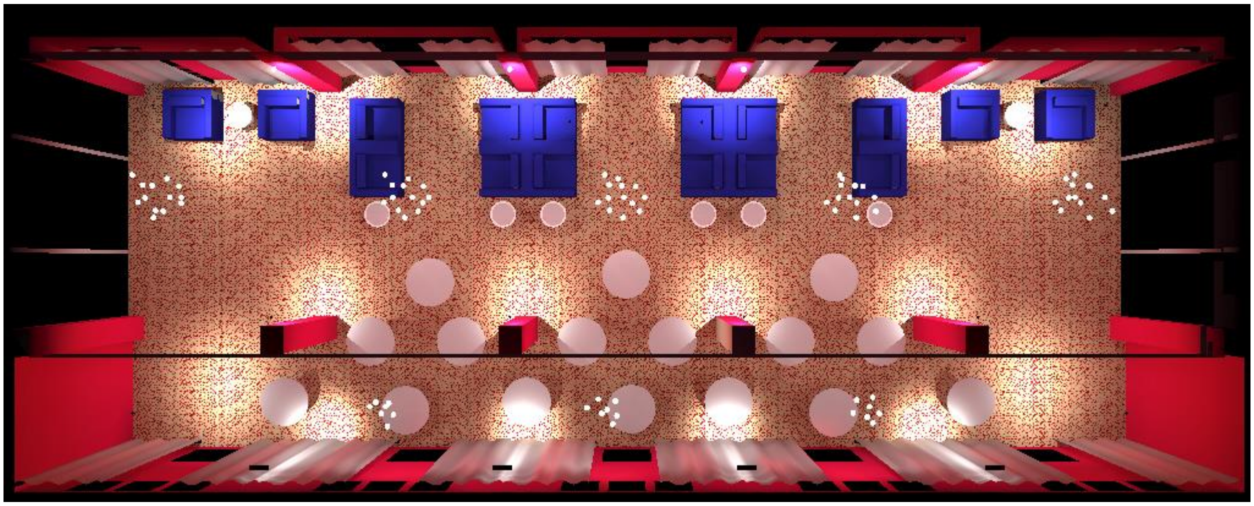
DESIGN APPROACH

In relation to the concept of embracing the arts, it was important for the space to invoke an engaging and close conversation atmosphere, just the same as when performers engage their viewers while on stage. The lighting solution explores Flynn's idea of "relaxation." Non-uniform, low color temperature sources are implemented for focal glow and ambient luminescence. A dap of sparkle from custom bubble chandeliers stimulate the spirit of the arts.

As part of the design, the system should be flexible. The lounge serves several functions, including cocktail hours, banquets, and lectures. Depending on the owner's preference, floor and small table lamps can be placed throughout the space.

COMPUTER RENDERINGS





Figures 10-14: Patron's Lounge Renders

LUMINAIRE SCHEDULE

Type	Description	Mounting	Manufacturer	Catalog Number	Lamps	Input Watts
A	Versa Star LED, satin aluminum finish, narrow spot (red indicator), 3000K, integral dimming driver	Ceiling semi-recessed	B-K Lighting	VS-LED-e22-NSP-A3-SAP-12	LED	8.2
B	Downlight regressed 1-3/4" pinhole flush mounted, black trim, black Alzak reflector, 3500K, universal voltage driver	Ceiling recessed	Juno Lighting Group	IC943L-835-N-U-4307N-BL-FM	LED	20
C1	14-7 series (7 spheres per canopy), seamed cast glass sphere, frosted cylindrical void, height varies, transformer	Pendant	Bocci	Refer to Bocci Lamp Spec Sheet	LED	1.5
C2	14-4 series (14 spheres per canopy), seamed cast glass sphere, frosted cylindrical void, height varies, transformer	Pendant	Bocci	Refer to Bocci Lamp Spec Sheet	LED	1.5
D	EcoSpec Linear HP INT Wall Wash Mono-Color, 1'-0" length, red color, 6x6 optic	Surface	EcoSense	10LC-12-RD-120-6	LED	12.5

LIGHTING PLAN

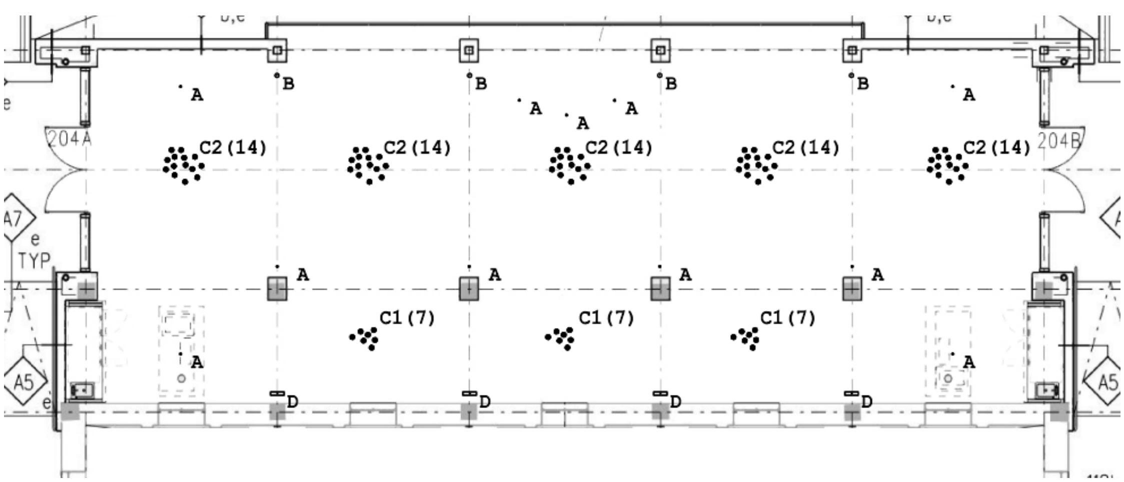


Figure 15: Patron's Lounge RCP

PERFORMANCE DATA

Illuminance level – target | provided	40 lux | 41.4 lux
Power Density – target | provided	0.73 W/ft^2 | 0.22 W/ft^2

PERFORMANCE SUMMARY

The lighting redesign was successful in an attempt to explore the Flynn mode of "relaxation" and Richard Kelly's three elements of light: (1) focal glow, (2) ambient luminescence and (3) play of brilliance.

Custom bubble chandeliers have pinpoints of light placed in glass spheres at varying heights. With a glass material, the light contributes to the subtle general illumination of the space in all directions. Columns were lit to reassure safe movement around them, especially since this space is meant for continuous socializing.

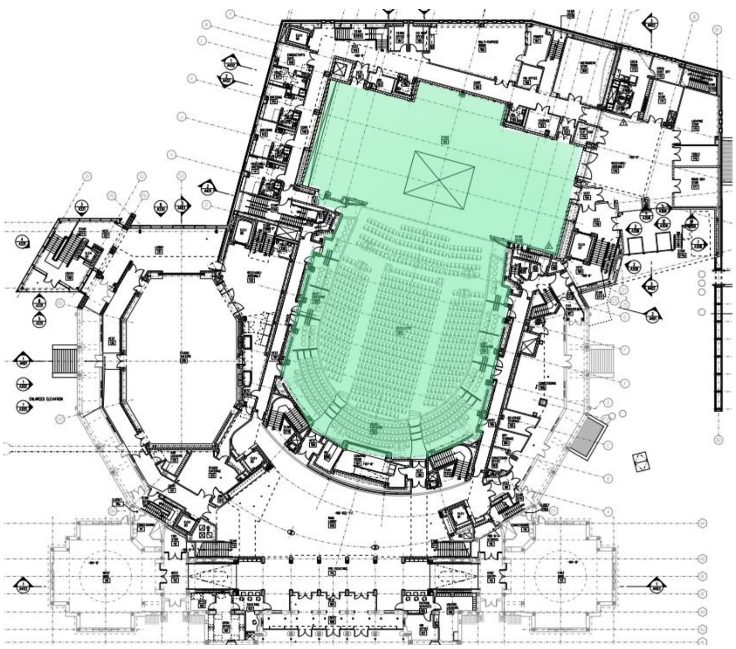
The system is flexible due to various uses, including cocktail hours, banquets and lectures. For the purpose of cocktail and banquet functions, seating and standing areas are not illuminated directly. This was intended for the possible placement of floor or table lamps and to encourage close conversation amongst individuals. The lecture layout, however, has the podium illuminated by adjustable downlights directed towards the speaker.

Overall, the lighting redesign achieved both performance purpose and design criteria. The space serves as a retreat for patrons. Inspired by the concept of embracing the arts, patrons become engaged with one another, similar to performers engaging their audience.

MAIN AUDITORIUM | LARGE WORK SPACE

DESCRIPTION

The main auditorium is located in the center of the building program, and can house 1,750 audience members. It is a suitable venue space for multiple productions, such as theatrical productions, orchestral concerts, dance performances, films, amplified events, and lectures.



Dimensions

Area	11,648 SF
Length	176.17’-0”
Width	92.01’-0”
Ceiling Height	88’-0”

Figure 16: Main Auditorium Floor Plan [Photo Courtesy of LMN Architects]

SURFACE MATERIAL

Surface	**Type**	**Description**	**Reflectance**
Floor	CPT-2	Modular Tile Carpet	20%
N, S, E, W Walls	PNT-17	Paint Color No. DEA 146 Scarlet Apple Manufacturer: Dunn Edwards	20%
Ceiling	PNT-21	Paint Color No. DEA 195 Primitive Plum Manufacturer: Dunn Edwards	20%

DESIGN CRITERIA

Qualitative Criteria:

It is necessary for the architectural lighting to be flexible, in order to respond to various lighting and rigging requirements. The control system should have performance-quality dimming, allowing for a smooth and continuous dimming from full output to extreme low output and vice versa. Without quality dimming ability, abrupt lighting changes and unsettling color shifts will occur.

It is critical for aisle, step, and seat lighting to meet safety requirements. Audience members should be able to safely and conveniently access into and out of the auditorium at all times.

IES suggested very important criteria:
Modeling of faces and objects
Color appearance and contrast
IES suggested important criteria:
System control and flexibility

Quantitative Criteria:
Illuminance recommendations [IES Lighting Handbook 10th Edition (Table 28.2)]

Space	**E_h**	**E_v**	**Avg:Min**
Audience – during production	2 lux @ floor	1 lux @ 5ft AFF	2:1
Audience – pre/post show, intermission	100 lux @ floor	30 lux @ 5ft AFF	2:1
Circulation – during production	2 lux @ floor	4 lux @ 5ft AFF	5:1
Circulation – pre/post show, intermission	100 lux @ floor	30 lux @ 5ft AFF	2:1

Energy Allowance [ASHRAE 90.1]

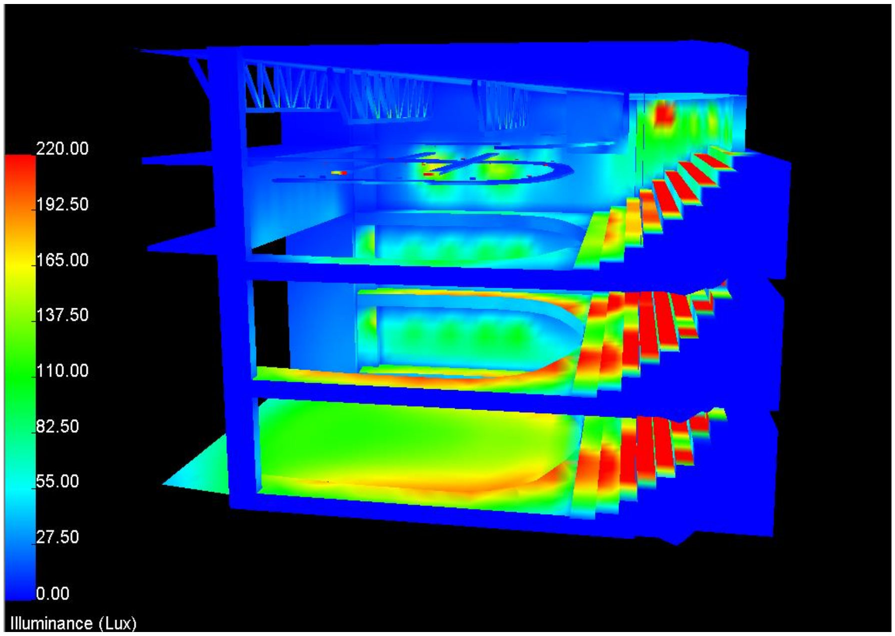
Space	**Power Density (W/sf)**
Auditorium/Seating Area – Permanent (for Performing Arts Theater)	2.43 W/ft^2
Decorative Allowance	1.00 W/ft^2

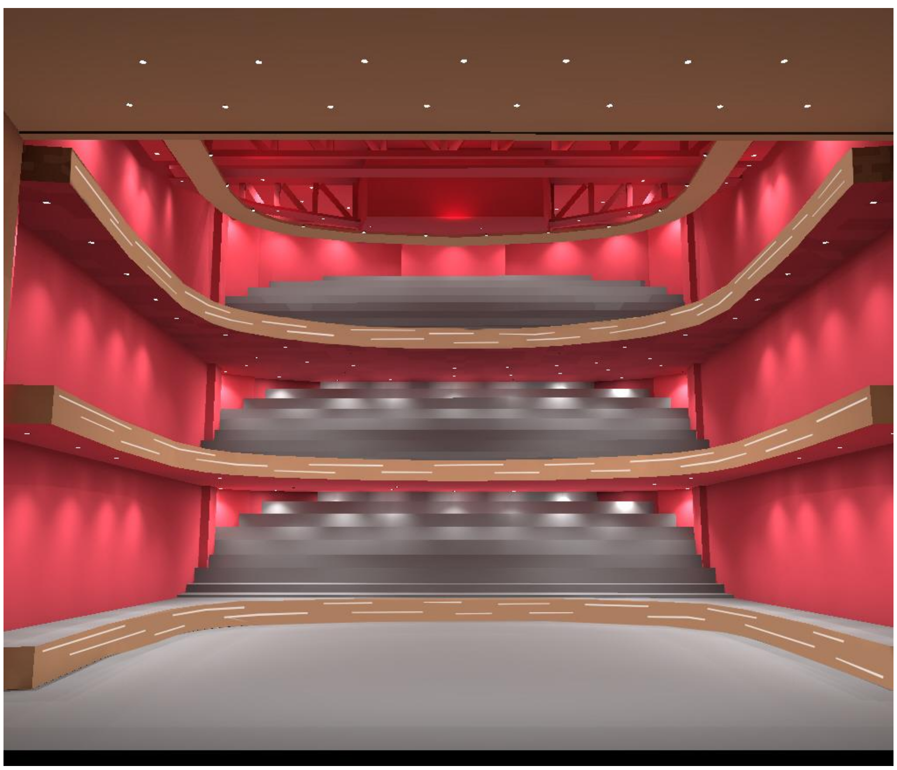
DESIGN APPROACH

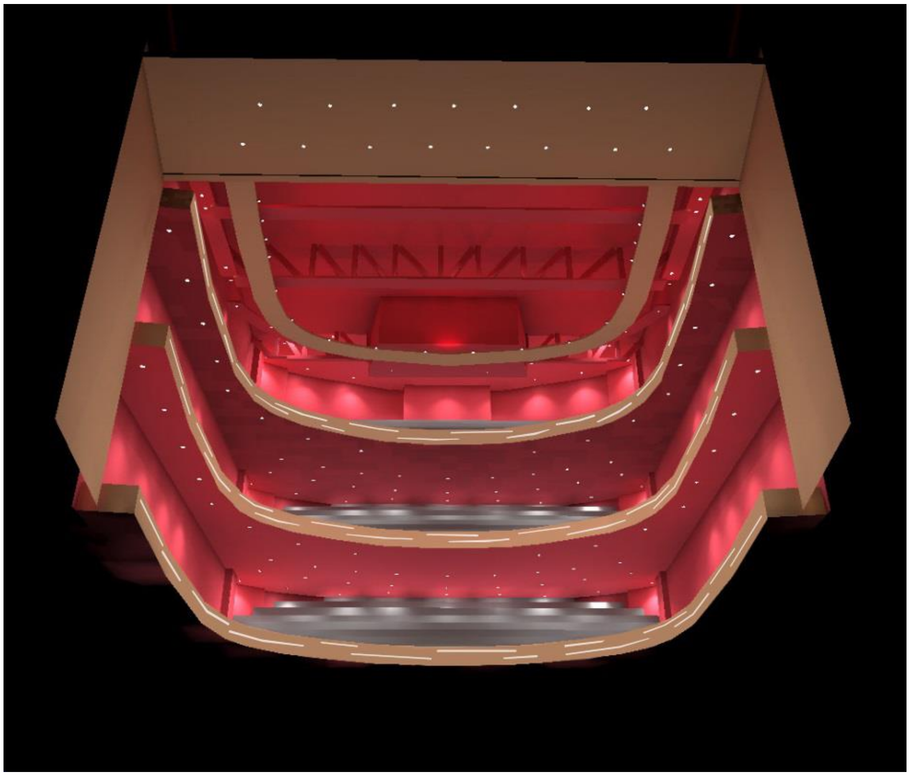
In order to incorporate the concept of embracing the arts, it was ideal to connect the concept of musical composition from the lobby into the main auditorium. To recall, the main lobby has points of interest that resemble musical notes and motifs, which contributes to a composition. The main auditorium shall complete the masterpiece by including linear luminaires recessed into the balcony fascia. These represent the grand bar staff, which are bar lines that musical notes are placed. This encourages audience members to observe the simplicity of horseshoe architecture. More importantly, the balcony lighting draws the eye towards the stage.

Due to the space having a multipurpose nature, the lighting solution shall be visually pleasing and comfortable for occupants. It is essential to have a flexible, performance-quality dimming and preset scene control system. Not only does this address the variable purposes, but it also will meet way finding requirements before, during and after a performance.

COMPUTER RENDERINGS







Figures 17-19: Patron's Lounge Renders

LUMINAIRE SCHEDULE

Type	Description	Mounting	Manufacturer	Catalog Number	Lamps	Input Watts
N	8" HID metal halide downlight, white open reflector, magnetic ballast	Ceiling Recessed	Lithonia	LP8HN-100M-8W1-270	MH	128
P	6" Incito open downlight, clear trim color, semi-specular finish, 2700K	Surface	Gotham Architectural Lighting	ICO 27/60 6AR 70 277	LED	101.4
Q	ColorBlast Powercore 86 degree (no optic) LED, cast metal housing with diffuse interior, cast white painted metal lens frame	Surface	Philips Color Kinetics	87001234	LED	50.7
T1	Pathway, aisle lighting LEDs, 0'-2" O.C. spacing, smoke lens, 3000K	Floor	CALI Lighting	AIL1700-2"-LED-3.0K-SLC	LED	0.25
T2	Step lighting, 0'-2" O.C. spacing, smoke lens, 3000K	Floor	CALI Lighting	STL6200-2"-LED-3.0K-LED-3.0K-SL	LED	0.45
T3	Sentinel Seat Light I LED, die cast aluminum housing, black anodized metal finish, 2700K, graphics panel with Arial font, black anodized metal finish graphics panel, black graphics plate color	Seat	Tempo Industries	3400-BK-C-27K (Seat light LED) 34GP-BK-BK-100 (Graphics panel)	LED	0.44
U	Covelum Designer Series LED modules, 2.5" O.C., opal lens, dark warm white	Balcony	Tivoli	CLL-SM-2.5-DW-26+PSU	LED	5.38 per ft

LIGHTING PLAN

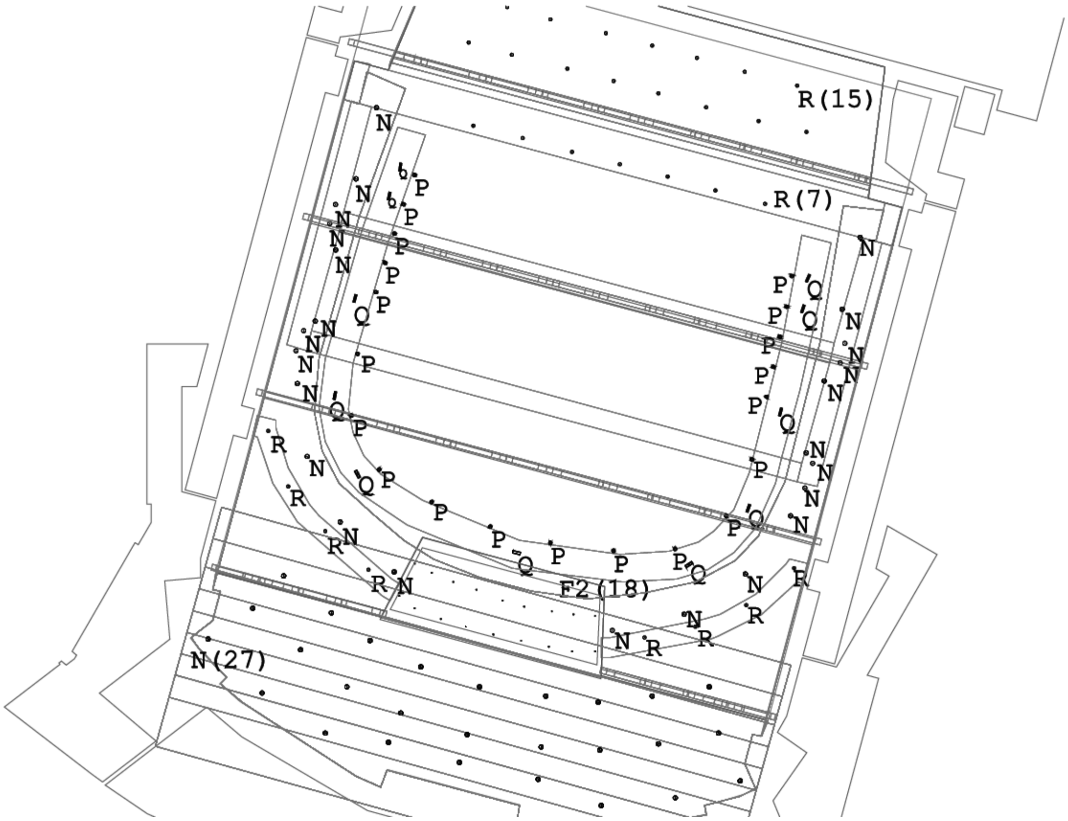


Figure 20: Main Auditorium RCP

PERFORMANCE DATA

	target	provided
Illuminance level – target | provided	100 lux	138.48 lux
Power Density – target | provided	2.43 W/ft²	2.05 W/ft²
Decorative Allowance – target | provided	1.00 W/ft²	0.28 W/ft²

(Decorative Allowance only includes balcony lighting)

PERFORMANCE SUMMARY

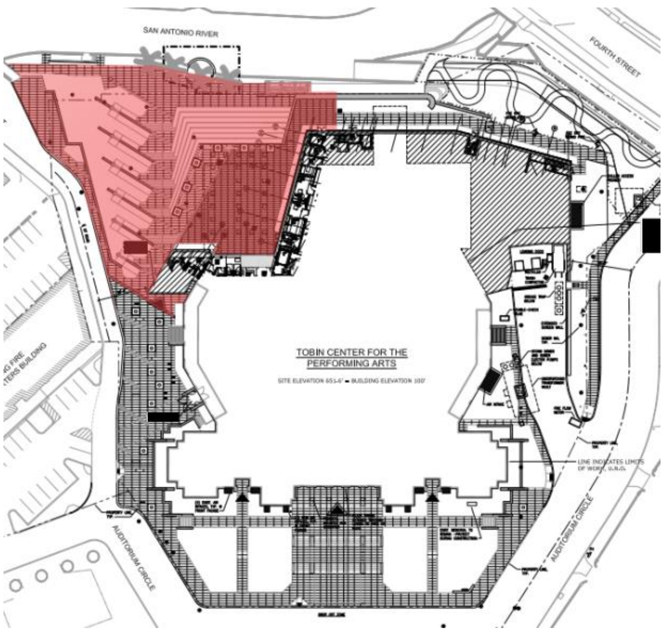
The lighting redesign for the main auditorium successfully creates various options for multiple presets for different activities. The system is flexible with performance-quality dimming and preset scene controls. Based on the performance data, IES recommendations were achieved to meet criteria for audience and circulation purposes.

Specific auditorium aisle, step, and seat lighting were thoroughly researched to ensure safe wayfinding for pre-, during, and post-performance. For circulation pathways on all levels, an LED system was integrated, instead of HID lighting. Seating areas, however, was illuminated by HID sources. The new system primarily demands LEDs, even though HIDs are used. This helped to reduce the power density and electrical loads, as compared to an all traditional HID system.

Event Plaza | outdoor space

DESCRIPTION

The Event Plaza, known as "The Second Front Door," is a unique transition to the outdoors, in which the public is exposed to a strong sense of exterior happenings. It is located primarily on the northwest side of the site, linking the San Antonio Riverwalk to the Tobin Center. Patrons enjoy a view of the San Antonio River, as well as outdoor performances that enhance the experience of events being held inside the Tobin Center.



Dimensions

Area 1558 SF

Figure 21: Event Plaza Site Plan [Photo Courtesy of LMN Architects]

SURFACE MATERIAL

Surface	Type	Description
Site	-	Ground/Grass
Walkways	-	Brick
Planters	-	Concrete
Bench	-	Concrete
Monument	-	Concrete

DESIGN CRITERIA

Qualitative Criteria:
The appropriate lighting for the Event Plaza should address illuminance recommendations for the following: (1) pedestrian pathways, (2) performance space, (3) accent lighting and (4) tree lighting.

Lighting for pedestrian pathways and performance space depends on nighttime outdoor lighting zone and activity level. Zone LZ3 (moderately high ambient lighting outdoor lighting situation) would be ideal for this situation. According to the IES Handbook 10th edition, LZ3 addresses areas of human activity where vision is adapted to moderately high light levels. It is desired for lighting to accommodate safety, security, and convenience needs, but also be uniform and/or continuous. As activity level declines, lighting may be extinguished or reduced.

Accent lighting can highlight monuments throughout the plaza. Tree lighting could be considered moderate focal points. They establish a visual outdoor perimeter and avoid a black hole effect.

IES suggested very important criteria:
Modeling of faces and objects
Color appearance and contrast
Points of interest
Reflected and direct glare
Surface characteristics
IES suggested important criteria:
Light pollution
Light trespass
Distribution of light onto surfaces

Quantitative Criteria:
Illuminance recommendations [IES Lighting Handbook 10th Edition (Table 15.2)]

Space	Attraction	Role	Focal-Point Reflectance	Illuminance Ratio	E_h	E_v
Accenting - Performance Area	Moderate	Feature	<50%	10:1 focal-point-to-task	10:1 average illuminance of horizontal orientation	-

Illuminance recommendations [IES Lighting Handbook10th Edition (Table 34.2)]

Space	E_h	E_v	Max:Avg	Avg:Min
Plazas - Medium Activity LZ3	4 lux @ pavement	2 lux @5ft AFG in at least the two primary directions of circulation	4:1	5:1
Plazas - Ramps, Stairs, and Steps - Medium Activity LZ3	6 lux @ treads/landings	2 lux @ 5ft AFG in at least the two primary directions of circulation	4:1	5:1

Medium Activity – IES Lighting Handbook 10th Edition (Table 22.4)
Lighting Zone LZ3 – IES Lighting Handbook 10th (Table 26.4)

Energy Allowance [ASHRAE Standard 90.1]

Space	**Power Density (W/sf)**
Plaza Areas - Walkways 10ft wide or greater	0.16 W/ft^2
Stairways	1.0 W/ft^2
Landscaping	0.05 W/ft^2

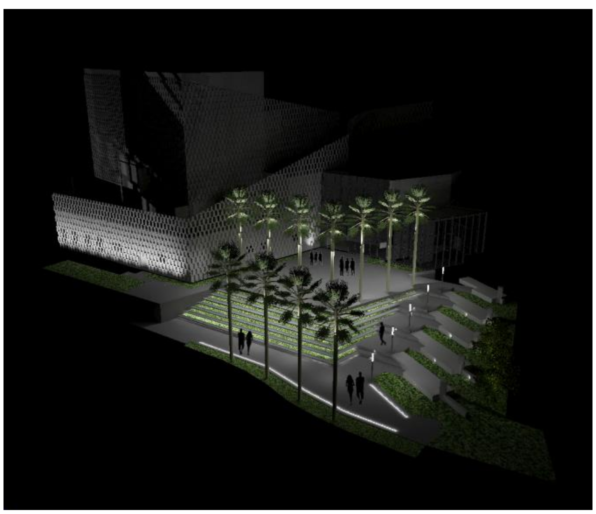
DESIGN APPROACH

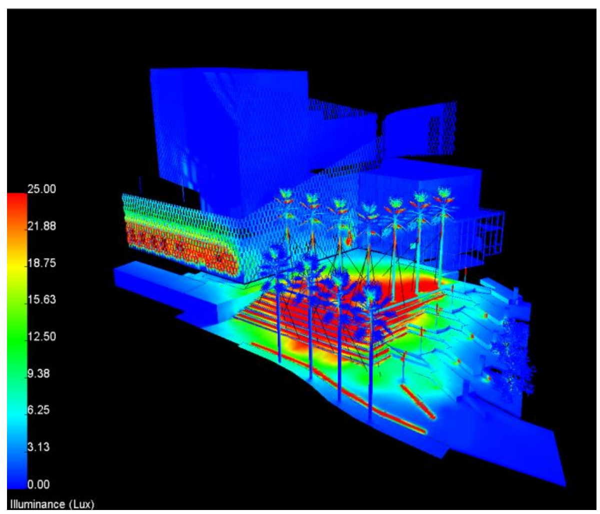
The Event Plaza is known as “The Second Front Door.” Inspired by the concept of embracing the arts, the new lighting system should appear eventful, showing off the exterior as a landmark in San Antonio. Whether riding the water taxi or strolling along the Riverwalk, patrons are welcomed by an engaging environment.

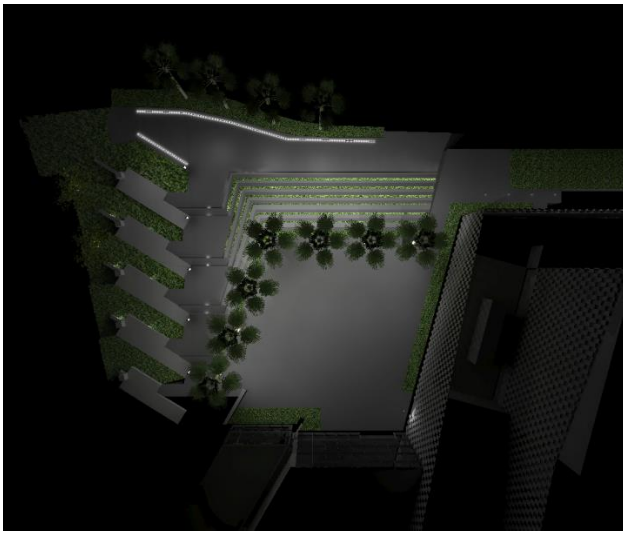
Subtle layers of light step upwards towards the main event space, where banquets, performances, etc. occur. The redesign shall not only create a safe environment for various activities and pedestrian circulation, but also have minimal skyglow contribution.

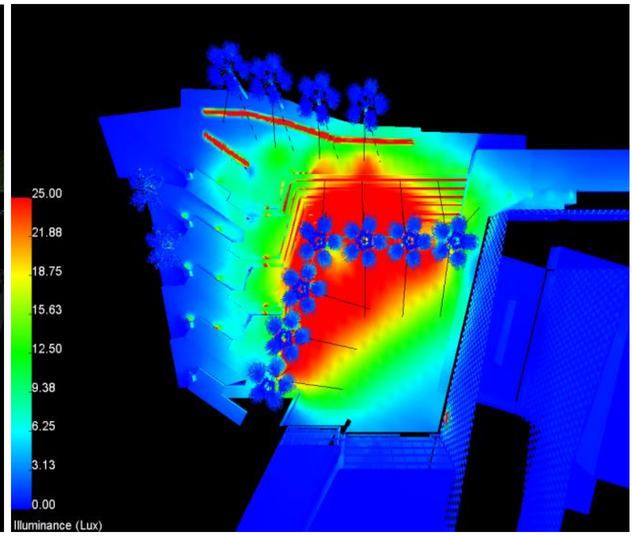
Aesthetically placing daps of light in this space is important. However, it is also critical to consider exterior lighting zone and safety requirements. Vertical illumination is an essential criterion to achieve, especially to properly render faces.

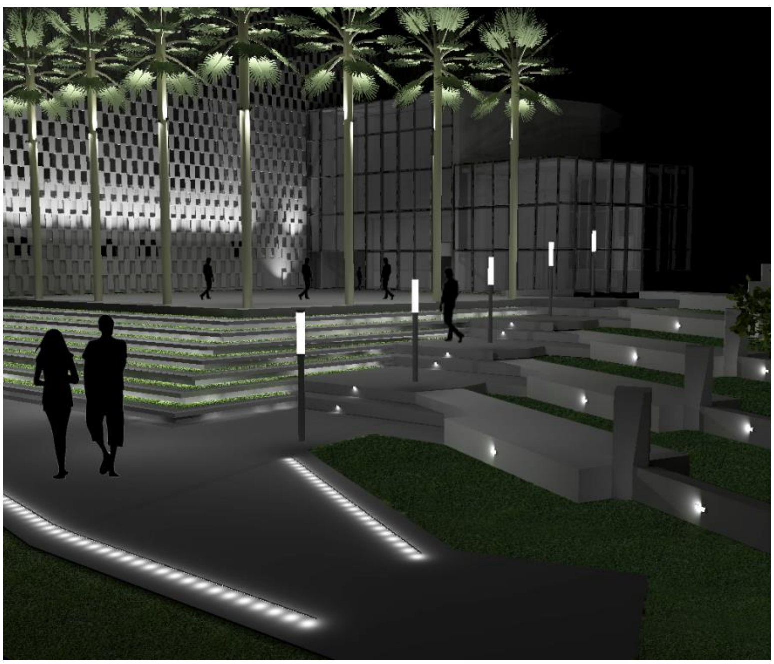
COMPUTER RENDERINGS











Figures 22-26: Event Plaza Renders

EVENT PLAZA

Type	Description	Mounting	Manufacturer	Catalog Number	Lamps	Input Watts
X1	Denali Floodlight, bronze finish, clear lens, flush cap stype, 25WLED/3000K, LED driver	Tree	B-K Lighting	DE-LED-x25-FL-BZP-9-C	LED	28.7
X2	Super Nova aged brass finish, flood, 2700K, MR16 LED	Tree	SPJ Lighting	Super Nova-AG-Flood-4000K-8-24V	LED	6
X3	Monochrome Tube CW, aluminum housing, 5700K (cold white), white translucent PC diffuser, LED engine, monochrome tube interconnection cable and mounting bracket	Cove	Traxon	TU.DM.0160001	LED	9.13
X4	Ground linear white LED, aluminum body	In-ground	DesignPlan	7101101-C11 BLANCO	LED	10
X5	Smith light column LED, metalic silver finish, 6x36 LED, 2700K	Column	Ligman	SM-21121-W27	LED	64.9
X6	LED step light, opal marker trim, bronze textured paint	Surface	Juno	LMSW-3K-M-BZ	LED	2.7
X7	Exterior die-cast LED step light, black finish, etched glass face plate, 3000K, LED light engine	Surface	Intense Lighting	ILEDS70-NW-B-ED	LED	2.85
X8	Round in-ground LED, narrow spot, brushed stainless steel finish, sand blasted lens, 2700K, magnetic transformer	In-ground	Vortech Lighting	IVG30L27-30ST	LED	3.6
X9	Small scale in-grade LED, stainless steel, aluminum reflector	In-ground	Bega	7027 LED	LED	1.77

LIGHTING PLAN

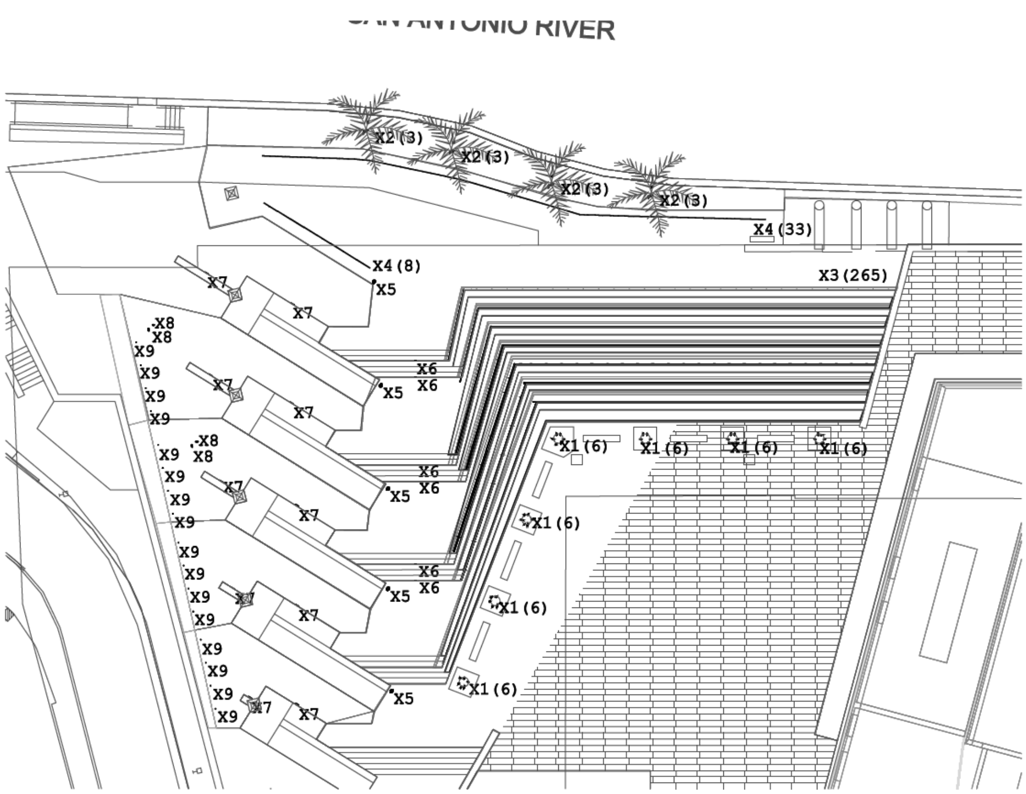


Figure 27: Event Plaza Lighting Plan

PERFORMANCE DATA

Performance Area Illuminance level – target | provided	10:1 lux | 15.67 lux
Performance Area Power Density – target | provided	0.16 W/ft^2 | 0.15 W/ft^2
Riverwalk Illuminance level – target | provided	6 lux | 8.90 lux
Riverwalk Power Density – target | provided	0.16 W/ft^2 | 0.158 W/ft^2
Planter Illuminance level – target | provided	6 lux | 16.77 lux
Planter Power Density – target | provided	1.00 W/ft^2 | 0.78 W/ft^2
Step & Landing Illuminance level – target | provided	6 lux | 8.84 lux
Step & Landing Power Density – target | provided	1.00 W/ft2 | 0.16 W/ft2

PERFORMANCE SUMMARY

The Event Plaza is a unique outdoor space, where several banquets, performances and other functions are held. The new lighting enhances the exterior plaza and heightens the exciting new veil façade. The performance area is primarily lit by tree mounted luminaires, with additional light from the veil façade and the new studio lobby glass curtain wall.

Based on the performance data, the Event Plaza was divided into four exterior areas. According to ASHRAE 90.1 Table 9.4.3B, which specifies individual lighting power allowances for building exteriors, each area is considered a tradable surface. Thus, there can be wattage tradeoffs between areas/surfaces. A supplemental allowance equal to 5% of total allowed wattage may be applied toward compliance of tradable surfaces. A detailed surface power calculation can be seen on the COMcheck document, located in Appendix II.

SECTION FOUR | electrical depth

The network consists of (4) four submersible, dry-type main service transformers, each rated at 13.8kV, 480/277V, 3-phase, 4 wires + ground. They are sized, controlled and engineered by the local utility company, CPS Energy. The main service from these transformers is provided through (2) two indoor, surface-mounted, single-ended main switchboards, MSB-1 & MSB-2, located in the electrical room of the basement. From each main switchboard, power is distributed to their designated panelboards. A 250kW/312.5kVA, 480/277V emergency diesel generator is used, along with (2) two automatic transfer switches to provide power for a house emergency lighting transfer system, (2) two large hall emergency lighting transfer system, and studio theater emergency lighting transfer system.

The electrical depth involves the redesign of the branch circuits for the four spaces, a short circuit analysis, and a Building-Integrated Photovoltaic system depth topic.

EXISTING ELECTRICAL SYSTEM

The following is an overview of the original electrical system. Two main switchboards, MSB-1 and MSB-2, exist. The actual connected building load analysis is as follows:

Electrical Load Analysis: MSB-1 System Voltage – 480/277V, 3-Phase, 4 Wire + Ground 4000A, 480/277V, 3-Phase, 4 Wire + Ground, 150 kAIC				
Load Description	Connected Load – KVA	Demand Factor	Demand Load	
			KVA	Amperes
Company Switches	1260.0	0.55	688.0	827
Dimmer Racks	3500.0	0.30	1061.0	1276
Relay Panels	576.0	0.31	181.0	218
HVAC Loads	275.0	1.00	275.0	331
Audio/Visual Loads	237.0	0.52	123.2	148
Elevators (4 Total)	391.0	0.85	332.4	400
N.E.C. Demand Load - Total			2660.5	3200
Service Entrance Design			3325.5	4000
Spare Capacity (20.0%)			665.0	800

Electrical Load Analysis: MSB-2 System Voltage – 480/277V, 3-Phase, 4 Wire + Ground 3000A, 480/277V, 3-Phase, 4 Wire + Ground, 150 kAIC				
Load Description	Connected Load – KVA	Demand Factor	Demand Load	
			KVA	Amperes
Theatrical Panelboards	360.0	0.40	145.4	175
Theatrical Rigging Motors	445.0	1.00	445.0	535
HVAC Loads	600.0	1.00	600.0	722
Receptacles	325.0	0.52	167.5	201
Lighting	520.0	1.25	650.0	782
Elevators (3 Total)	95.0	0.90	85.5	103
Kitchen	225.0	0.65	146.3	176
N.E.C. Demand Load - Total			2239.7	2694
Service Entrance Design			2494.2	3000
Spare Capacity (10.2%)			254.5	306

The utility service voltage is 13.8 kV for (4) four transformers. The building utilization voltage at 480/277V is fed into (2) main switchboards, MSB-1 and MSB-2. The following is a breakdown of service.

MSB-1: serves transformers T1, T3, T4, T5, and T6

Transformer	*Serves*	*Electrical Characteristics*
T1	Switchboard DPl-1	2000-Amp MCB, 200% Neutral, 208/120V, 3-Phase, 4W+Gnd.
T3	Distribution Panel DPl-3	800-Amp MCB, 200% Neutral, 208/120V, 3-Phase, 4W Iso. Gnd. + Gnd
T4	Switchboard DPL-4	1600 Amp MCB, 200% Neutral, 208/120V, 3-Phase, 4W+Gnd.
T5	Switchboard DPL-5	1600 Amp MCB, 200% Neutral, 218/126V, 3-Phase, 4W+Gnd.
T6	Switchboard DPL-6	1600 Amp MCB, 200% Neutral, 218/126V, 3-Phase, 4W+Gnd.

MSB-1 distribution steps down to transformers T1, T3, T4, T5, and T6.

- T1: 780 kVA, steps down to 208Y/120V, 3-phase, 4 wires + ground, type K-13
- T3: 225 kVA, steps down to 208Y/120V, 3-phase, 4 wires + ground, type K-13
- T4: 500 kVA, steps down to 208Y/120V, 3-phase, 4 wires + ground, type K-13
- T5: 500 kVA, steps down to 218Y/126V, 3-phase, 4 wires + ground, type K-13
- T6: 500 kVA, steps down to 218Y/126V, 3-phase, 4 wires + ground, type K-13

MSB-2: serves transformers T2 and T7

Transformer	*Serves*	*Electrical Characteristics*
T2	Switchboard DPL-2	1600 Amp MCB, 200% Neutral, 208/120V, 3-Phase, 4W+Gnd.
T7	Distribution Panel DPL-DS	400 Amp, 208/120V, 3-Phase, 4W+Gnd. *Note: This is a step-down voltage from distribution panelboard DPH-DS at 480/277V.*

MSB-2 distribution steps down to transformers T2 and T7.

- T2: 500 kVA, steps down to 208Y/120V, 3-phase, 4 wires + ground, type K-13
- T7: 112.5 kVA, steps down to 208Y/120V, 3-phase, 4 wires + ground

BRANCH CIRCUIT DESIGN

Branch circuits were redesigned for the Patron's Lounge, Main Lobby, Main Auditorium, and Event Plaza. To accommodate the new lighting system and controls, lighting and equipment loads were altered; therefore, feeders and panelboards were resized respectively for branch circuit modifications.

Based on the lighting redesign for the four spaces, COMcheck-Web software was used to verify energy code compliance. COMcheck determines whether or not new commercial buildings, additions, and alterations meet IECC and ASHRAE 90.1-2010 requirements, as well as state-specific codes. Please refer to the Compliance Certificates for interior and exterior lighting in Appendix II.

Interior Lighting			
Total Allowed Watts	Total Proposed Watts	Pass (Y/N)	If yes, % better than code
36694W	22956W	Y	37%
Compliance Statement per COMcheck: The proposed lighting design represented in this document is consistent with the building plans, specifications and other calculation submitted with this permit application. The proposed lighting system has been designed to meet the 90.1 (2010) Standard requirements in COMcheck-Web and to comply with the mandatory requirements in the Requirements Checklist.			

Exterior Lighting				
Total Tradable Watts	Total Allowed Watts	Total Allowed Supplemental Watts	Total Proposed Watts	Pass (Y/N)
4602W	4602W	1300W	4291W	Y
Compliance Statement per COMcheck: The proposed exterior lighting design represented in this document is consistent with the building plans, specifications and other calculation submitted with this permit application. The proposed lighting system has been designed to meet the 90.1 (2010) Standard requirements in COMcheck-Web and to comply with the mandatory requirements in the Requirements Checklist.				

All existing panels that were affected by the new lighting have significant change in load. Therefore, new lighting panels and their corresponding feeders and overcurrent protection devices (OCPD) were resized. All feeders will be type THHN-THWN and copper material.

The new panel schedules, based on changes made by the new lighting, can be seen below. Lighting for the Patron's Lounge and Main Lobby are found on Panel LP-2BB; Event Plaza on Panel LP-4AA; and the Main Auditorium is distributed amongst Panels LP-3AA and LP-3DD.

The new lighting fixtures on emergency panel LLS serves the Main Auditorium. This lighting is required during a power failure to adhere to safety and egress purposes. There was a minimal significant change in load; therefore, the feeder and OCPD remain the same.

Proper tables, in the National Electric Code 2011, associated with determining branch circuits, OCPD, and feeder sizes were used thoroughly. *[Table 220.12, Article 240.6(A), Table 250.122, Table 310.15(B)(3)(a), Table 310.15(B)(16), and Table C.1]*

Calculations per space, based on NEC requirements, can be seen in Appendix II.

PANEL 'LP-2B'

PROJECT: TOBIN CENTR PA
PROJECT #: 840396
LOCATION:
NOTES:
SCHEDULE DATE: #######

MAIN CIRCUIT BREAKER:
MAIN LUGS ONLY: 225A
BUSSING: 225A
VOLTAGE: 208/120V, 3PH, 4W
INTERRUPTING: 10 kAIC RMS SYM

ENCLOSURE: NEMA 1
MOUNTING: SURFACE
CB TYPE: BOLT-ON
PROVIDE: NEUTRAL BUS
GROUND BUS
ELECTRICAL #153

0 RECPT, 1 LTG, 2 EQUIP, 3 MTR, 4 COMP, 5 HEAT, 6 A/C, 7 KITCH, 8 ELEVE, 9 125%

CCT	AMP	P	CIRCUIT DESCRIPTION	LOAD	TYPE	PH	TYPE	LOAD	LOAD DESCRIPTION	AMP	P	CCT
1	20	1	RECEPTACLES - VEST 215	900	0	A	2	1500	HAND DRYER - WOMEN 211	20	1	2
3	20	1	RECEPTACLES - FURN STORAGE 214	540	0	B	2	1500	HAND DRYER - WOMEN 209	20	1	4
5	20	1	VIDEO DISPLAY - VEST 213	500	2	C	2	1500	HAND DRYER - WOMEN 206	20	1	6
7	20	1	RECEPTACLES - VEST 215	900	0	A	2	500	VIDEO DISPLAY - PATRONS LOUNGE 204	20	1	8
9	20	1	RECEPTACLES - WOMEN 206	540	0	B	0	360	RECEPTACLES - PATRONS LOUNGE 204	20	1	10
11	20	1	RECEPTACLES - PATRONS LOUNGE 204	540	0	C	0	720	RECEPTACLES - LEVEL 02 VESTIBLES	20	1	12
13	20	1	REFRIGERATED CAB. - PATRON LOUNGE 204	780	7	A	7	360	BACK BAR- CONCESSION LVL 2	20	1	14
15	20	1	CART FRONT - CONCESSION LVL 2	360	7	B	1	80	SIGNAGE - PATRON LOUNGE 204	20	1	16
17	20	1	SIGNAGE - CROSSOVER 227	200	1	C	2	500	AUTOMATIC WINDOW SHADE SYSTEM	20	1	18
19	20	1	SIGNAGE - VEST 215	240	1	A	0	540	RECEPTACLES - LEVEL 6 WP GFCI'S	20	1	20
21	20	1	SPARE			B			SPARE	60	1	22
23	20	1	SPARE			C			SPARE	20	1	24
25			TO PANEL LP-2BB	1039	1	A			SPARE	20	1	26
27	60	3	"	1039	1	B			SPARE	20	1	28
29			"	1039	1	C			SPARE	20	1	30
31			TO PANEL LP-2BB	1209	1	A			SPARE	20	1	32
33	60	3	"	1209	1	B			SPARE	20	1	34
35			"	1209	1	C			SPARE	20	1	36
37	20	1	SPARE			A			SPARE	20	1	38
39	20	1	SPARE			B			SPARE	20	1	40
41	20	1	SPARE			C		360	VAV 2-1, 2-2 & CAV 2-1	20	1	42

	PANEL VA	SUB FEED	FEED THRU	TOTAL CONN	TOTAL DEMAND VA	TOTAL DEMAND AMPS	NOTES:
PHASE A	7968	0	0	7968	8590	72	
PHASE B	5628	0	0	5628	6210	52	
PHASE C	6568	0	0	6568	7180	60	
TOTAL	20163	0	0	20163	21980	61	GOETTING & ASSOCIATES R1.0

PANEL 'LP-2BB'

PROJECT: TOBIN CENTR PA
PROJECT #: 840396
LOCATION:
NOTES:
SCHEDULE DATE: #######

MAIN CIRCUIT BREAKER:
MAIN LUGS ONLY: 225A
BUSSING: 225A
VOLTAGE: 208/120V, 3PH, 4W
INTERRUPTING: 10 kAIC RMS SYM

ENCLOSURE: NEMA 1
MOUNTING: SURFACE
CB TYPE: BOLT-ON
PROVIDE: NEUTRAL BUS
GROUND BUS

0 RECPT, 1 LTG, 2 EQUIP, 3 MTR, 4 COMP, 5 HEAT, 6 A/C, 7 KITCH, 8 ELEVE, 9 125%

CCT	AMP	P	CIRCUIT DESCRIPTION	LOAD	TYPE	PH	TYPE	LOAD	LOAD DESCRIPTION	AMP	P	CCT
1	20	1	PATRON'S LOUNGE LTG TYPE C1&C2	240	1	A	1	1374	LOBBY LTG TYPE E&H	20	1	2
3	20	1	PATRON'S LOUNGE LTG TYPE A&D	140	1	B	1	455	LOBBY LTG TYPE F1	20	1	4
5	20	1	PATRON'S LOUNGE LTG TYPE B	89	1	C	1	792	LOBBY LTG TYPE G	20	1	6
7	20	1	SPARE			A	1	300	LOBBY LTG TYPE J	20	1	8
9	20	1	SPARE			B	1	449	LOBBY LTG TYPE K,L,M	20	1	10
11	20	1	SPARE			C			SPARE	20	1	12
13	20	1	SPARE			A			SPARE	20	1	14
15	20	1	SPARE			B			SPARE	20	1	16
17	20	1	SPARE			C			SPARE	20	1	18
19	20	1	SPARE			A			SPARE	20	1	20
21	20	1	SPARE			B			SPARE	60	1	22
23	20	1	SPARE			C			SPARE	20	1	24
25	20	1	SPARE			A			SPARE	20	1	26
27	20	1	SPARE			B			SPARE	20	1	28
29	20	1	SPARE			C			SPARE	20	1	30
31	20	1	SPARE			A			SPARE	20	1	32
33	20	1	SPARE			B			SPARE	20	1	34
35	20	1	SPARE			C			SPARE	20	1	36
37	20	1	SPARE			A			SPARE	20	1	38
39	20	1	SPARE			B			SPARE	20	1	40
41	20	1	SPARE			C			SPARE	20	1	42

	PANEL VA	SUB FEED	FEED THRU	TOTAL CONN	TOTAL DEMAND VA	TOTAL DEMAND AMPS	NOTES:
PHASE A	1914	0	0	1914	2393	20	
PHASE B	1044	0	0	1044	1306	11	
PHASE C	881	0	0	881	1101	9	
TOTAL	3840	0	0	3840	4800	13	GOETTING & ASSOCIATES R1.0

LP-2BB
Serves: Patron's Lounge & Main Lobby
Minimum Required Branch Circuits: 5 ckts
OCPD: 20A
Feeders: 1#4, 1#3 Gnd. in ¾" Conduit
LP-2BB is served by LP-2B. Based on redesign, the new circuit breaker size is 200A and the feeder size is 1-#3/0, 1-#6 Gnd. in 1-1/2" Conduit

PANEL 'LP-4A'

PROJECT: TOBIN CENTR PA
PROJECT #: 840396
LOCATION:
NOTES:
SCHEDULE DATE: #######

MAIN CIRCUIT BREAKER:
MAIN LUGS ONLY: 225A
BUSSING: 225A
VOLTAGE: 208/120V, 3PH, 4W
INTERRUPTING: 10 kAIC RMS SYM

ENCLOSURE: NEMA 1
MOUNTING: SURFACE
CB TYPE: BOLT-ON
PROVIDE: NEUTRAL BUS
GROUND BUS

0 RECPT
1 LTG
2 EQUIP
3 MTR
4 COMP
5 HEAT
6 A/C
7 KITCH
8 ELEVE
9 125%

CCT	AMP	P	CIRCUIT DESCRIPTION	LOAD	TYPE	PH	TYPE	LOAD	LOAD DESCRIPTION	AMP	P	CCT
1	20	1	SIGNAGE-VEST 401	40	1	A	0	360	RECEPTACLE - SE EXTERIOR WALL	20	1	2
3	20	1	SIGNAGE-VEST 407	40	1	B	2	500	ELEVATOR #3 ROOF VENT	20	1	4
5	20	1	RECEPTACLE - SW EXTRIOR WALL	540	0	C	2	500	ELEVATOR #5 ROOF VENT	20	1	6
7	20	1	SPARE			A			SPARE	20	1	8
9			TO PANEL 'LP-4AA'	1503	1	B	1	1503	TO PANEL 'LP-4AA'			10
11	60	3	"	1503	1	C	1	1503	"	60	3	12
13			"	1503	1	A	1	1503	"			14
15			TO PANEL 'LP-4AA'	1503	1	B	1	1503	TO PANEL 'LP-4AA'			16
17	60	3	"	1503	1	C	1	1503	"	60	3	18
19			"	1503	1	A	1	1503	"			20
21			TO PANEL 'LP-4AA'	1503	1	B	1	1503	TO PANEL 'LP-4AA'			22
23	60	3	"	1503	1	C	1	1503	"	60	3	24
25			"	1503	1	A	1	1503	"			26
27	20	1	SPARE			B	1	1503	TO PANEL 'LP-4AA'	20	1	28
29	20	1	SPARE			C			SPARE	20	1	30
31	20	1	SPARE			A			SPARE	20	1	32
33	20	1	RECEPTACLE - STAIR ST29, 26	1080	0	B			SPARE	20	1	34
35	20	1	RECEPTACLE - STAIR ST25, 30	1080	0	C			SPARE	20	1	36
37	20	1	RECEPTACLE - S ROOF TOP	180	0	A	0	360	RECEPTACLE - NW ROOF TOP	20	1	38
39	20	1	SPARE			B	0	900	RECEPTACLE - VEST 402	20	1	40
41	20	1	SPARE			C	0	900	RECEPTACLE - VEST 406	20	1	42

	PANEL VA	SUB FEED	FEED THRU	TOTAL CONN	TOTAL DEMAND VA	TOTAL DEMAND AMPS	NOTES:
PHASE A	9958	0	0	9958	13348	111	
PHASE B	13041	0	0	13041	15681	131	
PHASE C	12038	0	0	12038	14293	119	
TOTAL	35037	0	0	35037	43321	120	GOETTING & ASSOCIATES R1.0

PANEL 'LP-4AA'

PROJECT: TOBIN CENTR PA
PROJECT #: 840396
LOCATION:
NOTES:
SCHEDULE DATE: #######

MAIN CIRCUIT BREAKER:
MAIN LUGS ONLY: 225A
BUSSING: 225A
VOLTAGE: 208/120V, 3PH, 4W
INTERRUPTING: 10 kAIC RMS SYM

ENCLOSURE: NEMA 1
MOUNTING: SURFACE
CB TYPE: BOLT-ON
PROVIDE: NEUTRAL BUS
GROUND BUS

0 RECPT
1 LTG
2 EQUIP
3 MTR
4 COMP
5 HEAT
6 A/C
7 KITCH
8 ELEVE
9 125%

CCT	AMP	P	CIRCUIT DESCRIPTION	LOAD	TYPE	PH	TYPE	LOAD	LOAD DESCRIPTION	AMP	P	CCT
1	20	1	EVENT PLAZA LTG TYPE X1	1033	1	A	1	382	EVENT PLAZA LTG TYPE X5, X6, X7	20	1	2
3	20	1	EVENT PLAZA LTG TYPE X2 & X4	702	1	B	1		SPARE	20	1	4
5	20	1	EVENT PLAZA LTG TYPE X3	8833	1	C	1		SPARE	20	1	6
7	20	1	"	8833	1	A	1		SPARE	20	1	8
9	20	1	"	8833	1	B	1		SPARE	20	1	10
11	20	1	SPARE			C			SPARE	20	1	12
13	20	1	SPARE			A			SPARE	20	1	14
15	20	1	SPARE			B			SPARE	20	1	16
17	20	1	SPARE			C			SPARE	20	1	18
19	20	1	SPARE			A			SPARE	20	1	20
21	60	1	SPARE			B			SPARE	60	1	22
23	20	1	SPARE			C			SPARE	20	1	24
25	20	1	SPARE			A			SPARE	20	1	26
27	20	1	SPARE			B			SPARE	20	1	28
29	20	1	SPARE			C			SPARE	20	1	30
31	20	1	SPARE			A			SPARE	20	1	32
33	20	1	SPARE			B			SPARE	20	1	34
35	20	1	SPARE			C			SPARE	20	1	36
37	20	1	SPARE			A			SPARE	20	1	38
39	20	1	SPARE			B			SPARE	20	1	40
41	20	1	SPARE			C			SPARE	20	1	42

	PANEL VA	SUB FEED	FEED THRU	TOTAL CONN	TOTAL DEMAND VA	TOTAL DEMAND AMPS	NOTES:
PHASE A	10249	0	0	10249	12811	107	
PHASE B	9535	0	0	9535	11919	99	
PHASE C	8833	0	0	8833	11042	92	
TOTAL	28617	0	0	28617	35771	99	GOETTING & ASSOCIATES R1.0

LP-4AA
Serves: Event Plaza
Minimum Required Branch Circuits: 19 ckts
OCPD: 20A
Feeders: 2#1/0, 1#4 Gnd. in 1-1/4” Conduit
LP-4AA is served by LP-4A. Based on redesign, the new circuit breaker size is 400A and the feeder size is 4-#3/0, 1-#3 Gnd. in 1-1/4” Conduit

PANEL 'LP-3A'

PROJECT: TOBIN CENTR PA
PROJECT #: 840396
LOCATION:
NOTES:
SCHEDULE DATE: #######

MAIN CIRCUIT BREAKER:
MAIN LUGS ONLY: 225A
BUSSING: 225A
VOLTAGE: 208/120V, 3PH, 4W
INTERRUPTING: 10 kAIC RMS SYM

ENCLOSURE: NEMA 1
MOUNTING: SURFACE
CB TYPE: BOLT-ON
PROVIDE: NEUTRAL BUS
GROUND BUS
ELECTRICAL #153

0 RECPT 5 HEAT
1 LTG 6 A/C
2 EQUIP 7 KITCH
3 MTR 8 ELEVE
4 COMP 9 125%

CCT	AMP	P	CIRCUIT DESCRIPTION	LOAD	TYPE	PH	TYPE	LOAD	LOAD DESCRIPTION	AMP	P	CCT
1	20	1	VANITY LIGHTING RM. 326	1560	1	A	2	1667	EQUIPMENT RACK, ER-LH1F	20	1	2
3	20	1	VANITY LIGHTING RM. 326	1560	1	B	2	1667	-	20	1	4
5	20	1	VANITY LIGHTING RM. 323	1560	1	C	2	1667	-	20	1	6
7	20	1	VANITY LIGHTING RM. 323	1560	1	A	0	360	G.P. RECEPTACLE	20	1	8
9	20	1	UPPER LOBBY LTG. RM. 370	466	1	B	1	416	TO PANEL LP-3AA			10
11	20	1	WEST/EAST TOWER (3RD FL.) LIGHTING	400	1	C	1	416	-	60	3	12
13	20	1	FUTURE HAND DRYER - WOMEN RM. 365			A	1	416	-			14
15			TO PANEL LP-3AA	416	1	B	1	1150	LIGHTING FIXTURE TYPE F27	20	1	16
17	60	3	-	416	1	C	1	416	TO PANEL LP-3AA			18
19			-	416	1	A	1	416	-	60	3	20
21			TO PANEL LP-3AA	416	1	B	1	416	-			22
23	60	3	-	416	1	C	1	416	TO PANEL LP-3AA			24
25			-	416	1	A	1	416	-	60	3	26
27	20	1	CURTAIN MOTOR - CATWALK 3RD LVL	400	3	B	1	416	-			28
29	20	1	CURTAIN MOTOR - CATWALK 3RD LVL	600	3	C	3	45	ACI-25	20	1	30
31	20	1	SHADE CURTAIN - VEST RM. 328	200	3	A	3	45	-	20	1	32
33	20	1	DRYER - WOMEN LOWER 365	1500	2	B	3	66	ACI-3, ACI-19, & ACI-4	20	1	34
35	20	1	FUTURE HAND DRYER - TOILET 367			C	3	66	-	20	1	36
37	20	1	DRYER - TOILET 313	1500	2	A	3	720	VAV 3-1, 3-2, 3-3, 3-4, 3-5 & CAV 3-1	20	1	38
39	20	1	DRYER - TOILET 325	1500	2	B	3	290	FC-1	20	1	40
41	20	1	DRYER - TOILET 324	1500	2	C	3	290	FC-3	20	1	42

	PANEL VA	SUB FEED	FEED THRU	TOTAL CONN	TOTAL DEMAND VA	TOTAL DEMAND AMPS	NOTES:
PHASE A	9692	0	0	9692	10992	92	
PHASE B	10679	0	0	10679	11993	100	
PHASE C	8208	0	0	8208	9218	77	
TOTAL	28579	0	0	28579	32203	89	GOETTING & ASSOCIATES R1.0

PANEL 'LP-3AA'

PROJECT: TOBIN CENTR PA
PROJECT #: 840396
LOCATION:
NOTES:
SCHEDULE DATE: #######

MAIN CIRCUIT BREAKER:
MAIN LUGS ONLY: 225A
BUSSING: 225A
VOLTAGE: 208/120V, 3PH, 4W
INTERRUPTING: 10 kAIC RMS SYM

ENCLOSURE: NEMA 1
MOUNTING: SURFACE
CB TYPE: BOLT-ON
PROVIDE: NEUTRAL BUS
GROUND BUS
ELECTRICAL #153

0 RECPT 5 HEAT
1 LTG 6 A/C
2 EQUIP 7 KITCH
3 MTR 8 ELEVE
4 COMP 9 125%

CCT	AMP	P	CIRCUIT DESCRIPTION	LOAD	TYPE	PH	TYPE	LOAD	LOAD DESCRIPTION	AMP	P	CCT
1			MAIN AUDITORIUM LTG TYPE N	2662	1	A	1	113	MAIN AUDITORIUM LTG TYPE T3	20	1	2
3	60	3	"	2662	1	B			SPARE	20	1	4
5			"	2662	1	C			SPARE	20	1	6
7			MAIN AUDITORIUM LTG TYPE N	2662	1	A			SPARE	20	1	8
9	60	3	"	2662	1	B			SPARE	20	1	10
11			"	2662	1	C			SPARE	20	1	12
13	20	1	SPARE			A			SPARE	20	1	14
15			MAIN AUDITORIUM LTG TYPE P	676	1	B			SPARE	20	1	16
17	60	3	"	676	1	C			SPARE	20	1	18
19			"	676	1	A			SPARE	20	1	20
21	20	1	SPARE			B			SPARE	60	1	22
23	20	1	SPARE			C			SPARE	20	1	24
25	20	1	SPARE			A			SPARE	20	1	26
27	20	1	SPARE			B			SPARE	20	1	28
29	20	1	SPARE			C			SPARE	20	1	30
31	20	1	SPARE			A			SPARE	20	1	32
33	20	1	SPARE			B			SPARE	20	1	34
35	20	1	SPARE			C			SPARE	20	1	36
37	20	1	SPARE			A			SPARE	20	1	38
39	20	1	SPARE			B			SPARE	20	1	40
41	20	1	SPARE			C			SPARE	20	1	42

	PANEL VA	SUB FEED	FEED THRU	TOTAL CONN	TOTAL DEMAND VA	TOTAL DEMAND AMPS	NOTES:
PHASE A	6113	0	0	6113	7641	64	
PHASE B	6000	0	0	6000	7500	63	
PHASE C	6000	0	0	6000	7500	63	
TOTAL	18113	0	0	18113	22641	63	GOETTING & ASSOCIATES R1.0

LP-3AA
Serves: Main Auditorium
Minimum Required Branch Circuits: 12 ckts
OCPD: 20A
Feeders: 1-#3/0, 1-#6 Gnd. in 1-1/2" Conduit
LP-3AA is served by LP-3A. Based on redesign, the new circuit breaker size is 300A and the feeder size is 1-300kcmil, 1#4 Gnd. in 2" Conduit

PANEL 'LP-3D'

PROJECT: TOBIN CENTR PA
PROJECT #: 840396
LOCATION:
NOTES:
SCHEDULE DATE: #######

MAIN CIRCUIT BREAKER:
MAIN LUGS ONLY: 225A
BUSSING: 225A
VOLTAGE: 208/120V, 3PH, 4W
INTERRUPTING: 10 kAIC RMS SYM

ENCLOSURE: NEMA 1
MOUNTING: SURFACE
CB TYPE: BOLT-ON
PROVIDE: NEUTRAL BUS
GROUND BUS
ELECTRICAL #153

0 RECPT, 1 LTG, 2 EQUIP, 3 MTR, 4 COMP, 5 HEAT, 6 A/C, 7 KITCH, 8 ELEVE, 9 125%

CCT	AMP	P	CIRCUIT DESCRIPTION	LOAD	TYPE	PH	TYPE	LOAD	LOAD DESCRIPTION	AMP	P	CCT
1	20	1	G.P. RECEPTACLE	180	0	A	2	1667	EQUIPMENT RACK, ER-LH1F	20	1	2
3	20	1	G.P. RECEPTACLE	180	0	B	2	1667	-	20	1	4
5	20	1	REMOTE CONDENSING UNIT #130	1800	2	C	2	1667	-	20	1	6
7	20	1	VEIL LIGHTING - SOUTH ELEVATION	450	1	A	3	65	ACI-9	20	1	8
9	20	1	VEIL LIGHTING - SOUTH ELEVATION	450	1	B	3	65	-	20	1	10
11	20	1	VEIL LIGHTING - SOUTH ELEVATION	450	1	C	3	45	ACI-26	20	1	12
13	20	1	VEIL LIGHTING - SOUTH ELEVATION	450	1	A	3	45	-	20	1	14
15	20	1	VEIL LIGHTING - EAST ELEVATION	450	1	B	1	416	TO PANEL LP-3DD			16
17	20	1	VEIL LIGHTING - EAST ELEVATION	600	1	C	1	416	-	60	3	18
19	20	1	VEIL LIGHTING - EAST ELEVATION	600	1	A	1	416	-			20
21	20	1	VEIL LIGHTING - EAST ELEVATION	600	1	B	1	416	TO PANEL LP-3DD			22
23	20	1	VEIL LIGHTING - EAST ELEVATION	450	1	C	1	416	-	60	3	24
25	20	1	VEIL LIGHTING - EAST ELEVATION	450	1	A	1	416	-			26
27	20	1	VEIL LIGHTING - EAST ELEVATION	600	1	B	1	416	TO PANEL LP-3DD			28
29	20	1	VEIL LIGHTING - EAST ELEVATION	600	1	C	1	416	-	60	3	30
31	20	1	VEIL LIGHTING - EAST ELEVATION	600	1	A	1	416	-			32
33	20	1	VEIL EQUIPMENT RACK #2	1500	1	B	3	45	EF-11	20	1	34
35			TO PANEL LP-3DD	416	1	C	3	290	FC-2	20	1	36
37	60	3	-	416	1	A	3	290	FC-4	20	1	38
39			-	416	1	B	3	290	FC-5	20	1	40
41	20	1	TO PANEL LP-3DD	416	1	C	3	290	FC-6	20	1	42

	PANEL VA	SUB FEED	FEED THRU	TOTAL CONN	TOTAL DEMAND VA	TOTAL DEMAND AMPS	NOTES:
PHASE A	6461	0	0	6461	7515	63	
PHASE B	7511	0	0	7511	8452	70	
PHASE C	8272	0	0	8272	9317	78	
TOTAL	22244	0	0	22244	25284	70	GOETTING & ASSOCIATES R1.0

PANEL 'LP-3DD'

PROJECT: TOBIN CENTR PA
PROJECT #: 840396
LOCATION:
NOTES:
SCHEDULE DATE: #######

MAIN CIRCUIT BREAKER:
MAIN LUGS ONLY: 225A
BUSSING: 225A
VOLTAGE: 208/120V, 3PH, 4W
INTERRUPTING: 10 kAIC RMS SYM

ENCLOSURE: NEMA 1
MOUNTING: SURFACE
CB TYPE: BOLT-ON
PROVIDE: NEUTRAL BUS
GROUND BUS
ELECTRICAL #153

0 RECPT, 1 LTG, 2 EQUIP, 3 MTR, 4 COMP, 5 HEAT, 6 A/C, 7 KITCH, 8 ELEVE, 9 125%

CCT	AMP	P	CIRCUIT DESCRIPTION	LOAD	TYPE	PH	TYPE	LOAD	LOAD DESCRIPTION	AMP	P	CCT
1	20	1	MAIN AUDITORIUM LTG TYPE Q	558	1	A	1	158	MAIN AUDITORIUM LTG TYPE T1 & T2	20	1	2
3			MAIN AUDITORIUM LTG TYPE U	2680	1	B			SPARE	20	1	4
5	60	3	"	2680	1	C			SPARE	20	1	6
7			"	2680	1	A			SPARE	20	1	8
9			MAIN AUDITORUM LTG TYPE U	2680	1	B			SPARE	20	1	10
11	60	3	"	2680	1	C			SPARE	20	1	12
13			"	2680	1	A			SPARE	20	1	14
15			MAIN AUDITORUM LTG TYPE U	2680	1	B			SPARE	20	1	16
17	60	3	"	2680	1	C			SPARE	20	1	18
19			"	2680	1	A			SPARE	20	1	20
21	20	1	SPARE			B			SPARE	60	1	22
23	20	1	SPARE			C			SPARE	20	1	24
25	20	1	SPARE			A			SPARE	20	1	26
27	20	1	SPARE			B			SPARE	20	1	28
29	20	1	SPARE			C			SPARE	20	1	30
31	20	1	SPARE			A			SPARE	20	1	32
33	20	1	SPARE			B			SPARE	20	1	34
35	20	1	SPARE			C			SPARE	20	1	36
37	20	1	SPARE			A			SPARE	20	1	38
39	20	1	SPARE			B			SPARE	20	1	40
41	20	1	SPARE			C			SPARE	20	1	42

	PANEL VA	SUB FEED	FEED THRU	TOTAL CONN	TOTAL DEMAND VA	TOTAL DEMAND AMPS	NOTES:
PHASE A	8755	0	0	8755	10944	91	
PHASE B	8040	0	0	8040	10050	84	
PHASE C	8040	0	0	8040	10050	84	
TOTAL	24835	0	0	24835	31044	86	GOETTING & ASSOCIATES R1.0

LP-3DD

Serves: Main Auditorium
Minimum Required Branch Circuits: 16 ckts
OCPD: 20A
Feeders: 1-300kcmil 1-#4 Gnd. in 2” Conduit
LP-3DD is served by LP-3D. Based on redesign, the new circuit breaker size is 225A and the feeder size is 1-#4/0, 1-#4 Gnd. in 1-1/2” Conduit

PANEL 'LLS'

PROJECT:	TOBIN CENTR PA	MAIN CIRCUIT BREAKER:		ENCLOSURE:	NEMA 1	0 RECPT	5 HEAT
PROJECT #:	840396	MAIN LUGS ONLY:	225A	MOUNTING:	SURFACE	1 LTG	6 A/C
LOCATION:		BUSSING:	225A	CB TYPE:	BOLT-ON	2 EQUIP	7 KITCH
NOTES:		VOLTAGE:	208/120V, 3PH, 4W	PROVIDE:	NEUTRAL BUS	3 MTR	8 ELEVE
SCHEDULE DATE:	#######	INTERRUPTING:	10 kAIC RMS SYM		GROUND BUS	4 COMP	9 125%
					ELECTRICAL #153		

CCT	AMP	P	CIRCUIT DESCRIPTION	LOAD	TYPE	PH	TYPE	LOAD	LOAD DESCRIPTION	AMP	P	CCT
1	20	1	ELEVATOR #1 CAB LIGHTS	128	1	A	1	128	ELEVATOR #5 CAB LIGHTS	20	1	2
3	20	1	ELEVATOR #2 CAB LIGHTS	128	1	B	1	128	ELEVATOR #6 CAB LIGHTS	20	1	4
5	20	1	ELEVATOR #3 CAB LIGHTS	128	1	C	1	128	ELEVATOR #7 CAB LIGHTS	20	1	6
7	20	1	ELEVATOR #4 CAB LIGHTS	128	1	A	2	1500	FIRE ALARM CONTROL PANEL	20	1	8
9	20	1	DIMMING RACK 'DPA1' CONTROLLER	500	2	B	0	720	RECEPTACLES - SECURITY OFFICE 006	20	1	10
11	20	1	EXTERIOR DECORATIVE LIGHTING	750	1	C	0	360	RECEPTACLES - SECURITY OFFICE 006	20	1	12
13	20	1	EXTERIOR LIGHTING	375	1	A	2	500	ELEVATOR #1 ROOF VENT	20	1	14
15	20	1	SPARE			B	2	500	ELEVATOR #2 ROOF VENT	20	1	16
17	20	1	SPARE			C			SPARE	20	1	18
19	20	1	SPARE			A			SPARE	20	1	20
21	20	1	SPARE			B			SPARE	60	1	22
23	20	1	SPARE			C			SPARE	20	1	24
25	20	1	MAIN AUDITORIUM LTG TYPE T1 & T2	158	1	A			BUSSED SPACE			26
27						B			BUSSED SPACE			28
29						C			BUSSED SPACE			30
31						A			BUSSED SPACE			32
33						B			BUSSED SPACE			34
35						C			BUSSED SPACE			36
37						A			BUSSED SPACE			38
39						B			BUSSED SPACE			40
41						C			BUSSED SPACE			42

	PANEL VA	SUB FEED	FEED THRU	TOTAL CONN	TOTAL DEMAND VA	TOTAL DEMAND AMPS	NOTES:
PHASE A	2917	0	0	2917	3146	26	
PHASE B	1976	0	0	1976	2040	17	
PHASE C	1366	0	0	1366	1618	13	
TOTAL	6259	0	0	6259	6804	19	GOETTING & ASSOCIATES R1.0

Added lighting panels can be seen in a revised single line diagram in Appendix II.

SHORT CIRCUIT ANALYSIS

A protective device coordination study was conducted to address a single path through the distribution system. This path extends from the CPS Energy utility to panel LP-4AA, a new lighting panel added to the electrical distribution system. The following is a visual representation of the short circuit path analyzed.

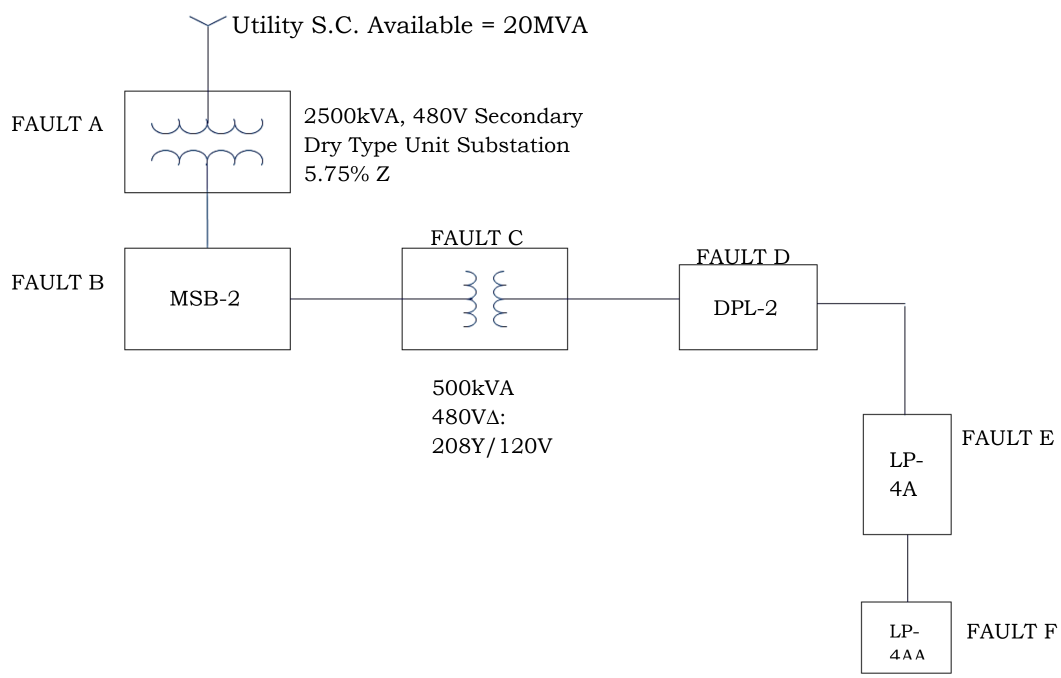


Figure 28: Fault Current Single-Line Diagram

Short Circuit Calculations:

Fault A

$$Utility\ per\ Unit\ X\ (10{,}000kVA\ base) = \frac{10{,}000kVA}{20{,}000kVA} = 0.5$$

Xfmr per Unit X: 5.75% = Z, 7.5 = X/R, X = 7.5R, X = 5.69956, R = 0.759941

$$X_u = \frac{0.0569956 \times 10{,}000}{2500kVA} = 0.227982$$

$$R_u = \frac{0.007599 \times 10{,}000}{2500kVA} = 0.030398$$

Fault A		
	X	R
Utility	0.5	-
Xfmr	0.2279	0.030398
Sum	0.727982	0.030398

$Z^2 = X^2 + R^2 \rightarrow Z = 0.728617$

$$I_{sc} = \frac{10{,}000}{\sqrt{3} \times 0.48\ \times 0.728617} = 16{,}508.2A\ @\ Fault\ A$$

Fault B

Cable: 8 sets, 4-600kcmil in each of (8) 4" C. & (2) 4" C. Spares
X & R values found in Table 17 of GET-3550F in Appendix II.

$$R = \frac{0.0249}{1000ft} \times 150ft \equiv 0.003735 \div 8\ sets\ per\ phase\ \equiv 0.000467$$

$$X = \frac{0.0299}{1000ft} \times 150ft \equiv 0.004485 \div 8\ sets\ per\ phase\ \equiv 0.000561$$

$$X_u = \frac{0.000561 \times 10{,}000}{1000 \times .48^2} = 0.024333$$

$$R_u = \frac{0.000467 \times 10{,}000}{1000 \times .48^2} = 0.020264$$

Fault B		
	X	R
Previous	0.727982	0.030398
Xfmr	0.024333	0.020264
Sum	0.752315	0.050662

$Z^2 = X^2 + R^2 \rightarrow Z = 0.754019$

$$I_{sc} = \frac{10{,}000}{\sqrt{3} \times 0.48 \ \times 0.754019} = 15{,}952A \ @ \ Fault\ B$$

Fault C

Cable: 2 sets, 3-600kcmil, 1#1/0 Gnd. in each of (2) 4”C.

$$R = \frac{0.0249}{1000ft} \times 40ft \equiv 0.000996 \div 2 \ sets\ per\ phase \ \equiv 0.000498$$

$$X = \frac{0.0299}{1000ft} \times 40ft \equiv 0.001196 \div 2 \ sets\ per\ phase \ \equiv 0.000598$$

$$X_u = \frac{0.000598 \times 10{,}000}{1000 \times .48^2} = 0.025955$$

$$R_u = \frac{0.000498 \times 10{,}000}{1000 \times .48^2} = 0.021615$$

Xfmr:

TABLE 14—Dry-type transformers—Type QHT, % Impedance, Reactance and Resistance ‡

kVA	Single-phase			Three-phase			
	%IX	%IR	%IZ	kVA	%IX	%IR	%IZ
5	1.68	2.94	3.4	6	1.72	2.72	3.2
7.5	1.84	2.42	3.0	9	1.16	2.31	2.6
10	1.92	2.04	2.75	15	1.82	2.1	2.8
15	2.02	1.60	2.6	30	1.37	3.8	4.0
25	2.3	1.4	2.7	45	1.73	2.52	3.1
37.5	2.7	3.6	4.5	75	1.91	2.27	3.0
50	2.8	3.1	4.2	112½	3.87	2.43	4.6
75	3.7	2.48	4.45	150	5.0	2.35	5.5
100	3.55	2.12	4.14	225	5.5	1.15	5.9
167	3.25	1.60	3.63	300	4.5	1.8	4.9
				500	5.9	1.6	6.1

‡Typical values based on data from several manufacturers.

$$R = \frac{0.0249}{1000ft} \times 40ft \equiv 0.000996 \div 2 \ sets\ per\ phase \ \equiv 0.000498$$

$$X = \frac{0.0299}{1000ft} \times 40ft \equiv 0.001196 \div 2 \ sets\ per\ phase \ \equiv 0.000598$$

$$X = \frac{0.059 \times 10{,}000}{500kVA} = 1.18$$

$$R = \frac{0.016 \times 10{,}000}{500kVA} = 0.32$$

Fault C		
	X	R
Previous	0.752315	0.050662
Cable	0.025955	0.021615
Xfmr	1.18	0.32
Sum	1.95827	0.392277

$Z^2 = X^2 + R^2 \rightarrow Z = 1.99717$

$$I_{sc} = \frac{10{,}000}{\sqrt{3} \times 0.208 \ \times 1.99717} = 13{,}898.3A\ @\ Fault\ C$$

Fault D

Cable: 5 sets, 3-600kcmil, 2-600kcmil Neutrals 1#4/0 Gnd. in each of (5) 4"C.

$$R = \frac{0.0249}{1000ft} \times 30ft \equiv 0.000747 \div 5\ sets\ per\ phase\ \equiv 0.000149$$

$$X = \frac{0.0299}{1000ft} \times 30ft \equiv 0.000897 \div 5\ sets\ per\ phase\ \equiv 0.000179$$

$$X_u = \frac{0.000179 \times 10{,}000}{1000 \times .208^2} = 0.041466$$

$$R_u = \frac{0.000149 \times 10{,}000}{1000 \times .208^2} = 0.034532$$

Fault D		
	X	R
Previous	1.95827	0.392277
Cable	0.041466	0.034532
Sum	1.99974	0.426809

$Z^2 = X^2 + R^2 \rightarrow Z = 2.04478$

$$I_{sc} = \frac{10{,}000}{\sqrt{3} \times 0.208 \ \times 2.04478} = 13{,}574.7A\ @\ Fault\ D$$

Fault E

Cable: 4#4/0, 1#4 Gnd. in each of 2-1/2"C.

$$R = \frac{0.0614}{1000ft} \times 20ft \equiv 0.001228$$

$$X = \frac{0.0326}{1000ft} \times 20ft \equiv 0.000652$$

$$X_u = \frac{0.000652 \times 10{,}000}{1000 \times .208^2} = 0.150703$$

$$R_u = \frac{0.001228 \times 10{,}000}{1000 \times .208^2} = 0.283839$$

Fault D		
	X	R
Previous	1.99974	0.426809
Cable	0.150703	0.283839
Sum	2.15044	0.710648

$$Z^2 = X^2 + R^2 \rightarrow Z = 2.26482$$

$$I_{sc} = \frac{10{,}000}{\sqrt{3} \times 0.208 \times 2.26482} = 12{,}255.8A \text{ @ } Fault\ E$$

Fault F

Cable: 2#1/0, 1#4 Gnd. in each of 1-1/4"C.

$$R = \frac{0.1231}{1000ft} \times 15ft \equiv 0.001847$$

$$X = \frac{0.035}{1000ft} \times 15ft \equiv 0.000525$$

$$X_u = \frac{0.000525 \times 10{,}000}{1000 \times .208^2} = 0.121348$$

$$R_u = \frac{0.001847 \times 10{,}000}{1000 \times .208^2} = 0.426798$$

Fault D		
	X	R
Previous	2.15044	0.710648
Cable	0.121348	0.426798
Sum	2.27179	1.13745

$$Z^2 = X^2 + R^2 \rightarrow Z = 6.4548$$

$$I_{sc} = \frac{10{,}000}{\sqrt{3} \times 0.208 \times 6.4548} = 10{,}925.3A \text{ @ } Fault\ F$$

Tables used to calculate the S.C. analysis are found in Appendix II. They include Z, X, and R-values, as well as

Fault	Equipment	Current
Fault A	2500kVA Transformer	16,508.24A
Fault B	MSB-2	15,952A
Fault C	500kVA Transformer	13,898.3A
Fault D	DPL-2	13,574.7A
Fault E	LP-4A	12,255.8A
Fault F	LP-4AA	10,925.3A

BUILDING-INTEGRATED PHOTOVOLTAIC (BIPV)

In the construction management breadth, a cost and schedule analysis was performed for the implementation of a BIPV system. In this electrical depth, the specific characteristics of the BIPV system will be analyzed with the use of a System Advisor Model (SAM).

SAM models performance and financial data for those involved in the renewable energy industry. It provides performance predictions and cost estimates based on installation and operating costs, as well as specific parameter input to the model. SAM is a useful tool, for it provides data for both sides of the industry, either the customer side or the utility side. The customer side involves buying and selling electricity at retail rates. On the other hand, the utility side involves selling electricity at a cost negotiated through a power purchase agreement.

Photovoltaics are a promising renewable technology, in which it produces electricity on site, directly from the sun, without being worried about energy supply or environmental harm. The next generation of solar panels, however, will not only bear little resemblance to their predecessors, but they will consist of integrating photovoltaic modules into the building envelope.

The implementation of a Building Integrated Photovoltaic (BIPV) system has been studied. It can become an integral part of the Tobin Center, in which solar modules are integrated into the façade of the new addition, known as the 'veil.' Instead of placing a photovoltaic array near the building site, a BIPV system will add architectural interest to the building.

CPS Energy is a utility company that supplies electricity to the Tobin Center. The following website provides detailed information about solar power and solar savings, specifically for San Antonio: http://www.cpsenergysavers.com/commercial/start-saving/solar-rebates

Preliminary Understanding & Research

Central goal of solar energy design:
maximize solar utility for a client or stakeholders in a given locale.

How does sunlight become solar power?

- PV solar panels convert sunlight into electricity.
- Typically installed where there is a maximum exposure to the sun.
- Effective any time when the sun is shining.
- When sunlight is intense and it strikes a PV module directly, more electricity is produced.
- Solar heat and light is absorbed by PV modules and is converted into direct current (DC) electricity.
- An inverter converts DC power into alternating current (AC) electricity. This current may be stored or used immediately.

SAM Step-by-Step Process

System Advisor Model (SAM)	
Location and Resource	
Location:	San Antonio, TX
Latitude:	29.5°
Longitude:	-98.5°
Elevation:	242 meters
Time Zone:	GMT-6
Weather Data Information	
Direct Normal:	1655.2 kWh/m²
Global Horizontal:	1815.1 kWh/m²
Dry-Bulb Temperature:	20°C
Wind Speed:	4.2 m/s

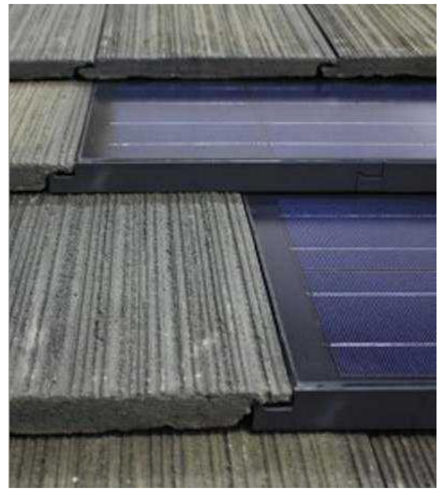


Figure 29: 54W BIPV, BIPV-54-T86
[Photo credit: http://www.freecleansolar.com]

Based on the location and weather data of San Antonio, weather data graphs can be simulated by SAM. To see these graphs, refer to Appendix II.

The table below shows the eligible photovoltaic modules specifically for BIPV. Additionally, they were found in SAM; therefore, they are approved by CPS Energy to be used for BIPV. The BIPV used for this exercise will be ***BIPV054-T86***:

Updated as of March 5, 2014

Manufacturer Name	Module Model Number	Description	BIPV*	PTC**	Notes
BIPV	BIPV050-S11	50W Sun Energy Shingle Brown	Y	40.0	
BIPV	BIPV050-T11	50W Sun Energy Tile Brown	Y	40.3	
BIPV	BIPV050-T16	50W Sun Energy Tile	Y	40.3	
BIPV	BIPV050-T86	50W Sun Energy Tile	Y	40.3	
BIPV	BIPV052-S11	52W Sun Energy Shingle Brown	Y	41.6	
BIPV	BIPV052-S16	52W Sun Energy Shingle	Y	41.6	
BIPV	BIPV052-S86	52W Sun Energy Shingle	Y	41.6	
BIPV	BIPV052-T11	52W Sun Energy Tile Brown	Y	42.1	
BIPV	BIPV052-T16	52W Sun Energy Tile	Y	42.1	
BIPV	BIPV052-T86	52W Sun Energy Tile	Y	42.1	
BIPV	BIPV054-S11	54W Sun Energy Shingle Brown	Y	43.2	
BIPV	BIPV054-S16	54W Sun Energy Shingle	Y	43.2	
BIPV	BIPV054-S86	54W Sun Energy Shingle	Y	43.2	
BIPV	BIPV054-T16	54W Sun Energy Tile	Y	44.3	
BIPV	BIPV054-T86	54W Sun Energy Tile	Y	44.3	

Note: A complete list of Photovoltaic manufacturers can be found at the following website. The PVs shown in the table above are specifically for BIPV http://www.gosolarcalifornia.ca.gov/equipment/pv_modules.php

System Advisor Model (SAM) - Module

Manufacturer	Module Number	Output (Wdc)	Reference Conditions	Efficiency (%)	Max Power (Wdc)	Power Voltage (Vdc)	Power Current (Adc)	Circuit Voltage (Vdc)	Short Circuit Current (Adc)	Temperature Correction			Physical Characteristics		
										Mounting Configuration	Module Width (m)	Module Length (m)	Material	Module Area (m2)	Number of Cells
BIPV	BIPV050-S11	49.7	Total Irradiance = 1000 W/m2, Cell temp = 25 degrees Celcius	12.74	49.6836	6.66	7.46	8.66	8.01	Integrated	1	0.39	Multi-c-Si	0.39	14
BIPV	BIPV050-T11	9.47		49.982	49.982	6.7	7.46	8.7	8.01	Integrated	1	0.528	Multi-c-Si	0.528	14
BIPV	BIPV050-T16	50		9.47	49.982	6.7	7.46	8.7	8.01	Integrated	1	0.528	Multi-c-Si	0.528	14
BIPV	BIPV050-T86	50		9.47	49.982	6.7	7.46	8.7	8.01	Integrated	1	0.528	Multi-c-Si	0.528	14
BIPV	BIPV052-S11	51.9		9.84	51.9435	6.79	7.65	8.7	8.07	Integrated	1	0.528	Multi-c-Si	0.528	14
BIPV	BIPV052-S16	51.9		9.84	51.9435	6.79	7.65	8.7	8.07	Integrated	1	0.528	Multi-c-Si	0.528	14
BIPV	BIPV052-S86	51.9		9.84	51.9435	6.79	7.65	8.7	8.07	Integrated	1	0.528	Multi-c-Si	0.528	14
BIPV	BIPV052-T11	51.9		9.84	51.9435	6.79	7.65	8.7	8.07	Integrated	1	0.528	Multi-c-Si	0.528	14
BIPV	BIPV052-T16	51.9		9.84	51.9435	6.79	7.65	8.7	8.07	Integrated	1	0.528	Multi-c-Si	0.528	14
BIPV	BIPV052-T86	51.9		9.84	51.9435	6.79	7.65	8.7	8.07	Integrated	1	0.528	Multi-c-Si	0.528	14
BIPV	BIPV054-S11	54		13.84	53.976	6.92	7.8	8.87	8.22	Integrated	1	0.39	Multi-c-Si	0.39	14
BIPV	BIPV054-S16	54		13.84	53.976	6.92	7.8	8.87	8.22	Integrated	1	0.39	Multi-c-Si	0.39	14
BIPV	BIPV054-S86	54		13.84	53.976	6.92	7.8	8.87	8.22	Integrated	1	0.39	Multi-c-Si	0.39	14
BIPV	BIPV054-T16	54		13.84	53.976	6.92	7.8	8.87	8.22	Integrated	1	0.39	Multi-c-Si	0.39	14
BIPV	BIPV054-T86	54		13.84	53.976	6.92	7.8	8.87	8.22	Integrated	1	0.39	Multi-c-Si	0.39	14

System Advisor Model (SAM) - Inverter

Manufacturer	Module Number	CEC Weighted Efficiency (%)	European Weighted Efficiency (%)	Max AC Power (Wac)	Max DC Power (Wdc)	Power consumption during operation (Wdc)
SMA America	ST42	95.9774	95.5877	42000	44012.6	287.416

System Advisor Model (SAM) - Inverter

Power consumption at night (Wac)	Nominal AC voltage (Vac)	Maximum DC voltage (Vdc)	Maximum DC current (Adc)	Minimum MPPT DC voltage (Vdc)	Nominal DC voltage (Vdc)	Maximum MPPT voltage (Vdc)
1.41	277	600	180	250	309.357	480

Note: A complete list of Photovoltaic inverters can be found at the following website
http://www.gosolarcalifornia.ca.gov/equipment/inverters.php

System Size (assumption)

Modules per String:	45
Strings in Parallel:	130
Number of Inverters:	8

Actual Layout (assumption)

Modules:		Inverters	
Nameplate Capacity:	315.76kWdc	Total Capacity:	336 kWac
Number of Modules:	5850	Total Capacity:	352.1 kWdc
Modules per String:	45	Number of Inverters:	8
Strings in Parallel:	130	Maximum DC Voltage:	600 Vdc
Total Module Area:	2281.5 m^2	Minimum MPPT Voltage:	250 Vdc
String Voc:	399.15 V	Maximum MPPT Voltage:	480 Vdc
String Vmp:	311.4 V		

Sizing

Actual DC to AC Ratio is 0.94.

Subarray

A design assumption for direction and orientation is to have the BIPV on the south 'veil' façade. Therefore, the subarray is fixed.

Nameplate capacity and string Vmp are at module reference conditions. String Voc is at 1000 W/m^2 incident irradiance and at 25^{o}C cell temperature.

Performance Adjustment & Assumptions

Percent of annual output: 100%

Year-to-year decline in output: 0.5% (compounded annually)

The system is scheduled for maintenance between 8am and noon for one week in July. The Hourly Factors table, shown below, specified a value of 0.20 for the July hours of 8am, 9am, 10am, 11am, and 12pm to approximate the reduction in output during that time frame.

Additional adjustments can be made, such as if the grid operator curtails the system for a certain amount of time. The Hourly Factors table would be adjusted.

Hourly Factors (24-hour profile for each month) 0=No Output, 1=Full Output 1 Apply to selected cells

	12am	1am	2am	3am	4am	5am	6am	7am	8am	9am	10am	11am	12pm	1pm	2pm	3pm	4pm	5pm	6pm	7pm	8pm	9pm	10pm	11pm
Jan	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Feb	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Mar	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Apr	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
May	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Jun	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Jul	1	1	1	1	1	1	1	1	0.2	0.2	0.2	0.2	0.2	1	1	1	1	1	1	1	1	1	1	1
Aug	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Sep	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Oct	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Nov	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Dec	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

System Cost Data

Direct Capital Costs

Equipment & Installation Labor

This cost represents an expense for a specific piece of equipment or installation service that applies in year zero of the cash flow.

Indirect Capital Costs

Permitting, Engineering, Land-Related Costs

This cost is typically one that cannot be identified with a specific piece of equipment or installation service.

Operation and Maintenance Costs

Labor, Equipment, Other costs associated with operating the project

These costs represent annual expenditures on equipment and services that occur after the system is installed.

Total Installed Cost

This cost is the project's investment cost that applies in year zero of the project cash flow.

Cost data is shown below. Boxes in blue are calculated by SAM, however, boxes in white were adjusted based on research values and assumptions.

PV System Costs

Direct Capital Costs

Module	5850	units	0.1	kWdc/unit	315.76	kWdc	$ 1.05	$/Wdc	$ 331,547.58
Inverter	8	units	42.0	kWac/unit	336	kWac	$ 0.26	$/Wac	$ 87,360.00

Balance of system, equipment	0	$	0	$/Wdc	0	$/m2	$ 0.00
Installation labor	0	$	0	$/Wdc	1.6	$/m2	$ 3,650.40
Installer margin and overhead	0	$	0	$/Wdc	1.3	$/m2	$ 2,965.95

Contingency 10 % — $ 42,552.39

Total Direct Cost — $ 468,076.32

Indirect Capital Costs

	% of Direct Cost	Cost $/Wdc	Fixed Cost	Total
Permitting, Environmental Studies	10 %	0.17	$ 0.00	$ 100,486.76
Engineering	15 %	0.18	$ 0.00	$ 127,048.18
Grid interconnection	5 %	0.15	$ 0.00	$ 70,767.76

Land Costs

Total Land Area 1.4094 acres

	Cost $/acre	% of Direct Cost	Cost $/Wdc	Fixed Cost	Total
Land	0.00	0 %	0.00	$ 0.00	$ 0.00
Land preparation	0.00	0 %	0.00	$ 0.00	$ 0.00

Sales Tax of 5 % applies to 100 % of Direct Cost — $ 23,403.82

Total Indirect Cost — $ 321,706.51

Total Installed Costs

Total Installed Cost — $ 789,782.84

Total Installed Cost per Capacity ($/Wdc) — $ 2.50

Financing Data

Commercial Loan Parameters

Debt Fraction	100	%
Loan Term	25	years
Loan Rate	7.5	%/year
Principal Amount	$ 789,782.84	
WACC	5.02	%

Analysis Parameters

Analysis Period	25	years
Inflation Rate	2.50	%/year
Real Discount Rate	5.20	%/year
Nominal Discount Rate	7.83	%/year

Tax and Insurance Rates

Federal Income Tax Rate	28.00	%/year
State Income Tax Rate	7.00	%/year
Sales Tax	5.00	% of installed cost
Insurance Rate (Annual)	0.50	% of installed cost

Property Tax

Assessed Percent	100.00	% of installed cost
Assessed Value	$ 789,782.84	
Annual Decline	0.00	%/year
Property Tax	2.00	%/year

Note: The following rates were found in the following website *http://www.sanantonioedf.com/business-profile/taxes-a-incentives*

Incentives

CPS Energy – Solar PV Rebate Program	
State:	Texas
Incentive Type:	Utility Rebate Program
Eligible Renewable/Other Technologies:	Photovoltaics
Applicable Sectors:	Commercial
Amount:	Commercial using local installer: $1.60/W for first 25kW; $1.30/W for any additional capacity
Maximum Incentive:	$80,000 for Commercial using local installer
Eligible System Size:	1kW AC minimum, special considerations apply to systems larger than 100kW
Equipment Requirements:	PV modules and inverters must be listed on the California Energy Commission (CEC) website. Warranties: Installer 5 year, PV module 20 years, Inverter 5 years
Installation Requirements:	Systems must be grid connected and installed by a CPS Energy registered installer must have NABCEP certification within 2 years); Systems should be South oriented with at least 250 square feet of unobstructed space.
Ownership of Renewable Energy Credits:	CPS Energy; unless RECs required for LEED certification
Funding Source:	Save for Tomorrow Energy Plan (STEP)
Program Budget:	Expected to be ~$2.5M per year (PV and SWH); may be adjusted according to demand
Expiration Date:	STEP extends through 2020, annual program year expiration dates may apply
Website:	http://www.cpsenergysavers.com/start-saving/rebates/solar/solar-photovoltaic-rebates

Note: Incentives for this particular building type and location was found under the Database of State Incentives for Renewables and Efficiency (DSIRE) http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=TX60F

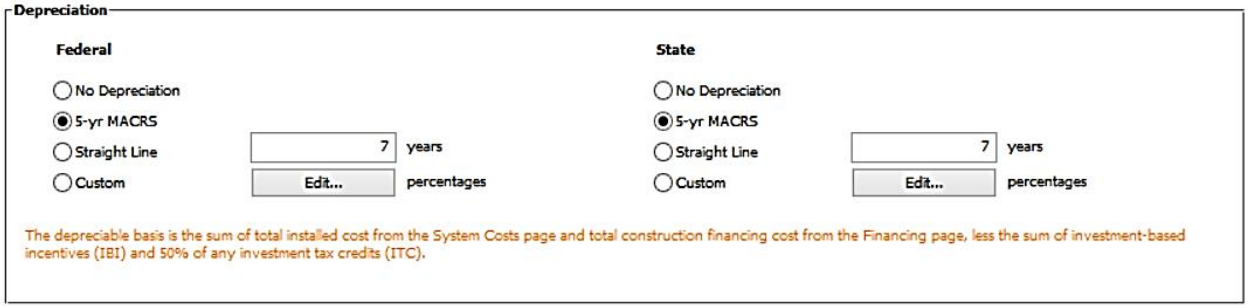
Investment Tax Credit (ITC)

	Amount		Reduces Depreciation Basis: Federal	Reduces Depreciation Basis: State
Federal	$ 0		☑	☑
State	$ 0		☐	☐
	Percentage	**Maximum**		
Federal	30 %	$ 1e+099	☑	☑
State	0 %	$ 1e+099	☐	☐

Capacity Based Incentive (CBI)

	Amount	Maximum	Taxable Incentive: Federal	Taxable Incentive: State	Reduces Depreciation and ITC Bases: Federal	Reduces Depreciation and ITC Bases: State
Federal	0 $/W	$ 1e+099	☑	☑	☐	☐
State	0 $/W	$ 1e+099	☑	☑	☐	☐
Utility	5.43231e-315 $/W	$ 200000	☑	☑	☐	☐
Other	0 $/W	$ 1e+099	☑	☑	☐	☐

Depreciation


Depreciation

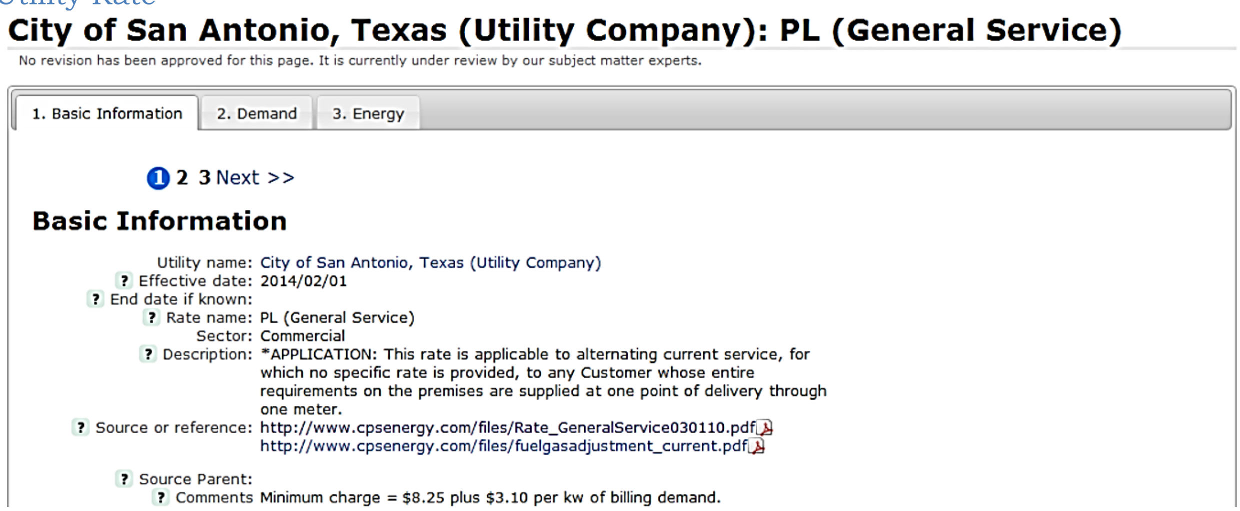
Federal
- No Depreciation
- (selected) 5-yr MACRS
- Straight Line — 7 years
- Custom — Edit... percentages

State
- No Depreciation
- (selected) 5-yr MACRS
- Straight Line — 7 years
- Custom — Edit... percentages

The depreciable basis is the sum of total installed cost from the System Costs page and total construction financing cost from the Financing page, less the sum of investment-based incentives (IBI) and 50% of any investment tax credits (ITC).

5-yr MACRS: Modified Accelerated Cost Recovery System depreciation schedule that the Federal government offers and some states using a five-year life and half-year convention. This tax deduction, expressed as a percentage of the depreciable basis, applies to the first five years of the project life as follows: 20%, 32%, 19.2%, 11.52%, 11.52%, and 5.76%.

Utility Rate


City of San Antonio, Texas (Utility Company): PL (General Service)

No revision has been approved for this page. It is currently under review by our subject matter experts.

1. Basic Information | 2. Demand | 3. Energy

1 2 3 Next >>

Basic Information

Utility name: City of San Antonio, Texas (Utility Company)
Effective date: 2014/02/01
End date if known:
Rate name: PL (General Service)
Sector: Commercial
Description: *APPLICATION: This rate is applicable to alternating current service, for which no specific rate is provided, to any Customer whose entire requirements on the premises are supplied at one point of delivery through one meter.
Source or reference: http://www.cpsenergy.com/files/Rate_GeneralService030110.pdf
http://www.cpsenergy.com/files/fuelgasadjustment_current.pdf
Source Parent:
Comments: Minimum charge = $8.25 plus $3.10 per kw of billing demand.

Weekday Schedule

	12 am	1 am	2 am	3 am	4 am	5 am	6 am	7 am	8 am	9 am	10 am	11 am	12 pm	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm	7 pm	8 pm	9 pm	10 pm	11 pm
Jan	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Feb	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Mar	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Apr	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
May	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Jun	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Jul	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Aug	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Sep	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Oct	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Nov	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Dec	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2

Weekend Schedule

	12 am	1 am	2 am	3 am	4 am	5 am	6 am	7 am	8 am	9 am	10 am	11 am	12 pm	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm	7 pm	8 pm	9 pm	10 pm	11 pm
Jan	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Feb	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Mar	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Apr	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
May	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Jun	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Jul	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Aug	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Sep	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Oct	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Nov	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Dec	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2

	Period 1			Period 2		
	Max Usage kWh	Buy Rate $/kWh	Sell Rate $/kWh	Max Usage kWh	Buy Rate $/kWh	Sell Rate $/kWh
Tier 1	600	0.0695	0	600	0.0695	0
Tier 2	1600	0.087	0	1600	0.0795	0
Tier 3	1e+099	0.05	0	1e+099	0.0425	0
Tier 4	1e+099	0	0	1e+099	0	0
Tier 5	1e+099	0	0	1e+099	0	0
Tier 6	1e+099	0	0	1e+099	0	0

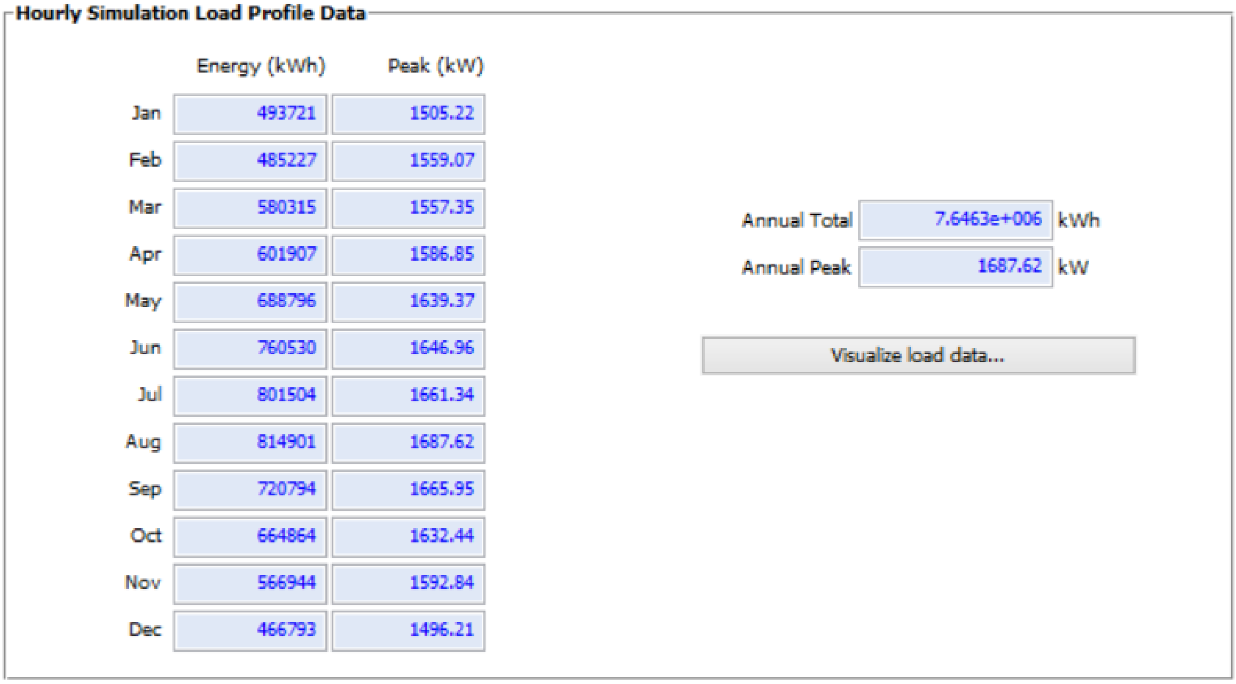
Annual Escalation

Out-year Escalation Value 5 %/yr

Applies to all rates and charges. Inflation applies to single value, but not to annual schedule. Use nominal values in annual schedule. See Help for details.

Note: The following data was found under the OpenEI Online Utility Rate Database: http://en.openei.org/wiki/Data:3fdba0a4-3ea2-4056-a036-a428daccc19a#tab=1__Basic_Information

Electric Load



Hourly Simulation Load Profile Data

	Energy (kWh)	Peak (kW)
Jan	493721	1505.22
Feb	485227	1559.07
Mar	580315	1557.35
Apr	601907	1586.85
May	688796	1639.37
Jun	760530	1646.96
Jul	801504	1661.34
Aug	814901	1687.62
Sep	720794	1665.95
Oct	664864	1632.44
Nov	566944	1592.84
Dec	466793	1496.21

Annual Total 7.6463e+006 kWh

Annual Peak 1687.62 kW

Visualize load data...

Results

Based on the input information into SAM for module BIPV054-T86, the following data was simulated:

Metric	Value
Annual Energy:	464,762 kWh
LCOE Nominal:	8.41 ¢/kWh
LCOE Real:	6.63 ¢/kWh
Electricity cost without system:	$672,063.88
Electricity cost with system:	$626,699.13
Net savings with system:	$45,366.08
Net present value ($)	$114,635.56
Payback (years)	14.4334 years
Capacity Factor	16.8%
First year kWhac/kWdc	1,472
System performance factor (%)	0.82
Total Land Area	1.41 acres

With a positive net present value, implementing this particular BIPV system is economically feasible. The payback period is the time in years that it will take for the project savings in years two and beyond of the cash flow to equal the investment cost in year zero.

To view additional performance and cost data, see Appendix II.

The image below would be a possible implementation of BIPV onto the south facing veil façade.

Figure 30: Proposed BIPV on South-Facing 'Veil' Façade
[Photo credit: HLB Lighting, Inc., 'veil' mock-up]

CENTRAL vs. DISTRIBUTED TRANSFORMER

This exercise was an original concept that was intended to be pursued as an additional electrical depth topic. The Tobin Center currently steps down the voltage from Main Switchboard-1, MSB-1, to five transformers with 480/277V primary to 208Y/120V and 218Y/126V secondary. Additionally, MSB-1 feeds power to two chillers and four elevators. A study would have been conducted to compare costs, efficiency and other implications of replacing the distributed transformers with that of a central transformer system.

Main Switchboard-1 Electrical Breakdown		
Main Switchboard	MSB-1	4000-AMP MCB, 480/277V, 3P, 4W + Gnd., 150 kAIC
Transformer	T1	750kVA, 480V Δ: 208Y/120V, Type K-13
Transformer	T3	225 kVA, 480V Δ: 208Y/120V, Type K-13
Transformer	T4	500 kVA, 480V Δ: 208Y/120V, Type K-13
Transformer	T5	500 kVA, 480V Δ: 218Y/126V, Type K-13
Transformer	T6	500 kVA, 480V Δ: 218Y/126V, Type K-13

The total kVA for the transformers is 2475kVA; therefore, a central transformer rated at 2500kVA would have been used. MSB-1 would then only include two chillers and elevators, and the distribution panels would have been stepped down from the transformer. Below is a visual representation of an altered single line diagram for MSB-1.

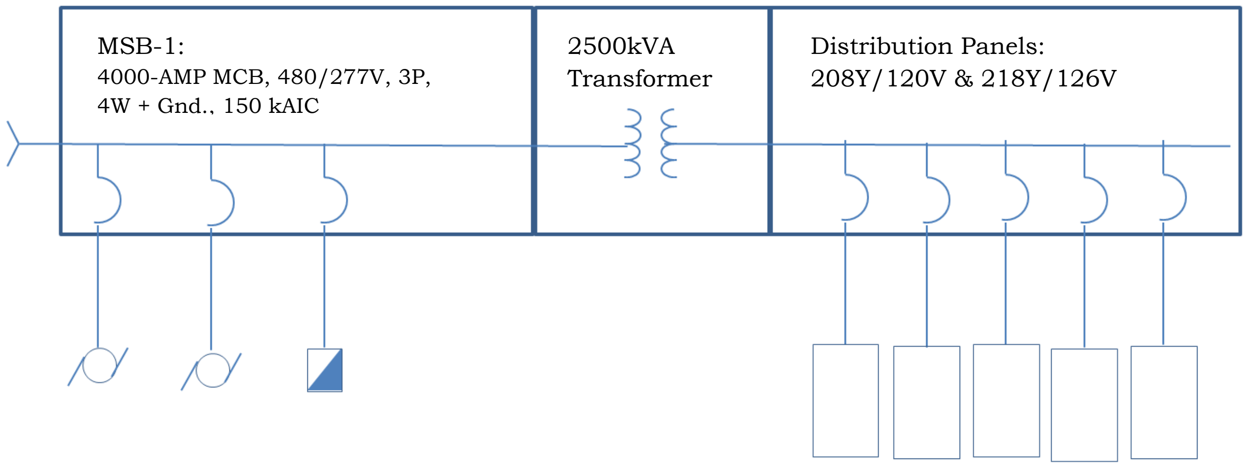


Figure 31: Proposed Electrical Redesign

Based on the research conducted, as well as speaking with vendors, this cannot be done because the largest in-line transformer available is 300kVA. Therefore, the original single line diagram is best for the electrical system serving the specified panels from MSB-1.

SECTION FIVE | construction management breadth

Contributing to a possible implementation of a Building-Integrated Photovoltaic system, an in-depth cost and schedule study was performed. Assembly estimates and supplier/vendor quotes was provided for insight on projected initial costs and offsets, as well as the amount of building materials and labor necessary. Additionally, comparative studies of how this system can impact construction time and cost was researched.

The construction management breadth was completed in conjunction with the electrical depth under the Building-Integrated Photovoltaic system. Please refer to that section for further system detail and information.

CASE STUDIES

The Philadelphia Eagles Stadium, known as the Lincoln Financial Field, has the largest solar array in the Philadelphia area and in any professional football stadium. Its peak power reaches to approximately 3MW, from more than 11,000 solar panels located on the south facade. NRG is the utility company who provided an energy solution for the stadium, as well as on-site power generation.

Certain challenges presented itself in the design process. The panels have to be able to withstand exposure to the elements. However, rooftop panels need protection from fireworks shock waves launched from above during games. If this was not addressed properly, potential malfunction could occur, causing the panels to short.

Not only do the solar panels function as an energy resource, but also celebrate the spirit of the Philadelphia Eagles. Integrated behind certain panels, green LED lights resemble the Eagles' helmets wings. The configuration of the solar panels can be seen during the day. However, at night, the Eagles' wings can be seen when driving by.

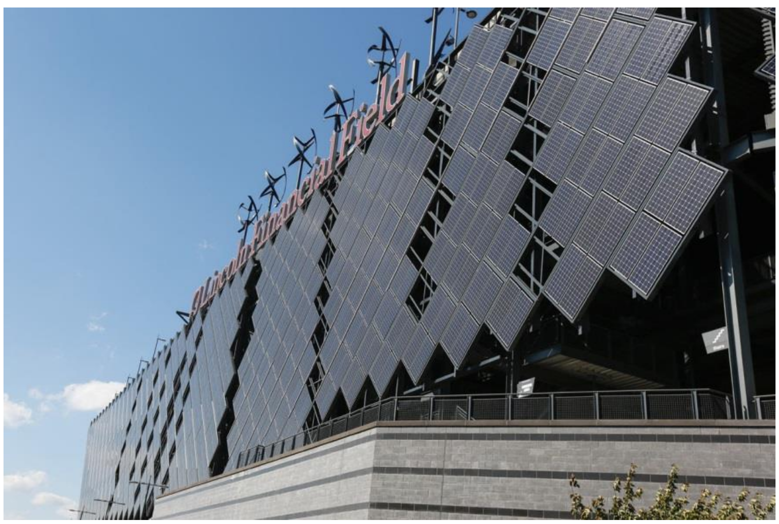


Figure 32: Lincoln Financial Field in Philadelphia, PA
[Photo Credit: Photographer Brian Garfinkel/AP Photo]

COST ANALYSIS

Get-A-Quote.net is an online source that was used to obtain costs for the BIPV system. Contractors can use this site to help with construction estimating. The 2013 Cost Estimating Guide cost book was used to obtain assembly estimates and supplier/vendor quotes.

An Integrated Photovoltaic System was the input material. The following data was provided. For analysis purposes, polycrystalline or crystalline ribbon solar cells was chosen.

Integrated Photovoltaic System	Craft@Hrs	Unit	Material	Labor	Total
Thin film single crystal solar cells	G1@.045	SF	78.00	2.04	80.04
Polycrystalline or crystalline ribbon solar cells	G1@.035	SF	71.00	1.59	72.59
Amorphous solar cells	G1@.035	SF	28.00	1.59	29.59

Provided is a breakdown of what each column indicates as estimates:

- Craft@Hrs column: (1) Who will do the work [the craft code], (2) An @ symbol which means @, and (3) How long the work will take [manhours].
- Unit column: square feet
- Material column: This doesn't entail retail nor wholesale prices. These are estimates of what majority of the contractors who buy in moderate volume will pay suppliers. Discounts maybe available for larger volumes of purchases.
- Labor Costs: This is for installing the material or doing the work described. The labor cost per unit is the labor cost per hour multiplied by the manhours per unit shown after the @ sign in the Craft@Hrs column. The labor costs include basic wage, employer's contribution to welfare, pension, vacation and apprentice and all tax and insurance charges based on wages.

Based on the breakdown of information, the following is a breakdown of costs for the system specified. The Craft@Hrs column for Polycrystalline or crystalline ribbon solar cells shows:

G1@.035

That means one should estimate the installation rate for crew G1 at .035 manhours per square. It's the same as 35 manhours per 1,000 square feet. Crew G1 is composed of two craftsmen: 1 glazier, 1 laborer. To install 1,000 square feet of solar cells at .035 manhours per square foot, that crew would need 35 manhours (approximately two 8-hour days for a crew of two). The average cost per manhour for crew G1 is $38.11. Costs in the Labor column are the cost per manhour multiplied by the installation time, in manhours. Therefore, the labor cost for installing the solar cells is $1.59 per square foot. That's the installation time (.035 manhours per square foot) multiplied by $38.11, the average cost per manhour for crew G1. It Is assumed that crew G1 will install the entire system, which includes the BIPV and inverters.

Commercial Labor Costs				
Craft	**Hourly wage and benefits ($)**	**Typical employer burden (%)**	**Employer's burden per hour ($)**	**Hourly cost ($)**
Building Laborer	28.17	29.20%	8.22	36.39
Glazier	35.83	27.20%	9.75	45.58

SCHEDULE ANALYSIS

A construction schedule, dated February 1, 2012, was provided for the purpose and use of this thesis. Recent and updated schedules, however, were not provided. The original schedule concluded with major construction equipment, including tower crane(s), erect crane(s), and operates crane(s). Refer to Appendix III for the original construction schedule.

The following assumptions have been made:

- 'Veil' façade erection (~7 wks)
- BIPV installation on the 'veil' (~3 wks)

Based on this assumption and from the original schedule provided, the critical path will not be affected in a negative way. With the proper crew and their allotted manhours, construction time, including the BIPV installation, should still be on schedule for completion in July 2014.

CONCLUSION

Based on this assumption and from the original schedule provided, the critical path will not be affected in a negative way. With the proper crew and their allotted manhours, construction time, including the BIPV installation, should still be on schedule for completion in July 2014.

SECTION SIX | mechanical breadth

The mechanical breadth includes utilizing biogas as a renewable energy source for onsite use. Thorough research was done to understand how such greenhouse gases can be transformed into a power source and used as energy for electricity and heat generation. Further studies focus on system implementation and interaction with the HVAC and power distribution systems.

ENVIRONMENTAL TRIFECTA

Texas is typically associated with oil, but with its ongoing armloads of green jobs, solar energy is highly embraced. Located in Bexar County, TX, the San Antonio Water System (SAWS) partnered with a national energy company, Ameresco, Inc., to process and treat wastewater for positive environmental outcomes. This partnership established the first sustainable project of its kind in the nation at a biogas facility at the Dos Rios Water Recycling Center.

Wastewater is commonly disposed of quickly. However, SAWS Dos Rios turns wastewater into valuable resources, which they like to call the "environmental trifecta."

SAWS Dos Rios "Environmental Trifecta":

- **Recycled water**: irrigation an industrial processes
- **Compost**: biosolids to compost production and soil conditioning
- **Biogas**: captured gas to be used for heat and power production

BIOGAS

Biogas is a byproduct of several agricultural, food processing and industrial processes. It is used today as a fuel source for engine generators. Biogas is produced through anaerobic decomposition or organic waste, which consists primarily of methane and carbon dioxide. Biodegradable materials, such as manure, sewage, municipal waste, plant material, etc., are fermented through this process. However, several other gases from organic waste-industries to animal or domestic origin waste, etc., contribute to its chemical composition and physical characteristics.

The chemical composition of a gas from a digester depends on the substrate's organic matter load and the digester's feeding rate. Hydrogen Sulfide (H2S), Carbon Dioxide (CO2) and water cause biogas to be very corrosive; therefore, requiring the use of adapted materials.

Typical Chemical Composition		
Compound	Molecular Formula	%
Methane	CH_4	50-75
Carbon dioxide	CO_2	25-50
Nitrogen	N_2	0-10
Hydrogen	H_2	0-1
Hydrogen sulphide	H_2S	0-3
Oxygen	O_2	0-0

Note: The following data was found under on Wikipedia
http://en.wikipedia.org/wiki/Biogas#Composition

METHOD

Two primary methods of recovering biogas for use as energy:

1. Create an anaerobic digestion system to process waste, typically manure or other wet biomass.
2. Recover natural biogas production that is formed in existing landfills. This can then be converted into energy is several methods.

Anaerobic digestion is made up of several components:

- Manure collection system
- Anaerobic digester
- Biogas handling system
- Gas use device

A manure collection system is needed to collect and transport manure to the anaerobic digester, which typically is in the form of a covered lagoon or tank. Anaerobic digesters stabilize manure and optimize methane production. The biogas handling system collects, treats, and pipes biogas to a gas use device. From there, biogas can be used to generate electricity, as a boiler fuel for water or space heating, upgraded to natural gas pipeline quality, or other uses.

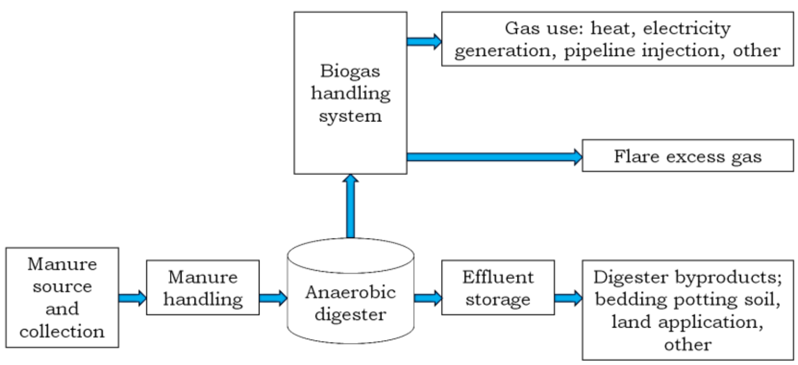


Figure 33: Biogas Process

Anaerobic digesters are typically made out of plastic, steel, brick or concrete. However, they all consist of the same basic components

- Pre-mixing area or tank
- Digester vessel
- System for using biogas
- System for distributing or spreading effluent

The two types of anaerobic digesters are batch and continuous. Batch digesters are simply built, in which their operation includes loading the digester with organic materials and allowing it to digest. Temperature and other factors influence retention time. After digester is finished, effluent is removed and the process repeats.

Continuous digesters operation, on the other hand, consists of organic material constantly being fed into the digester. They produce biogas without interruption of loading material and unloading effluent. Continuous digesters come in the form of vertical tank systems, horizontal tank or plug-flow systems, and multiple tank systems. With proper design, operation, and maintenance of continuous digesters, a steady supply of useable biogas is produced, which is better for large-scale operations.

Landfill gas collection system is made up of several components:

- Landfill gas well
- Landfill gas wellhead
- Landfill gas processing and treatment
- Landfill gas flare

The same anaerobic digestion process occurs naturally underground in landfills. Waste is covered and compressed by deposited material from above. Doing so prevents oxygen exposure; therefore, chemical reactions act upon the waste. Production time depends on waste composition and landfill geometry.

A series of wells and a blower/flame system extracts landfill gas from landfills. Collected gas is directed to a central point to be processed and treated depending on the use of the gas.

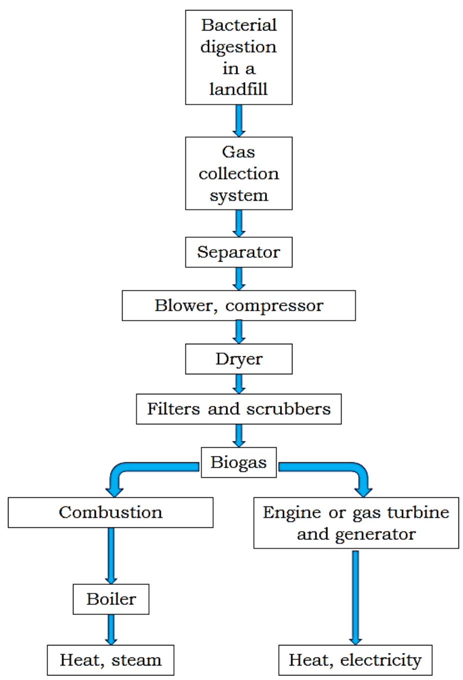


Figure 34: Blower/Flame System

PROCESS

1. Dos Rios Water Recycling Center treats wastewater that is collected in the central sewer shed of San Antonio.

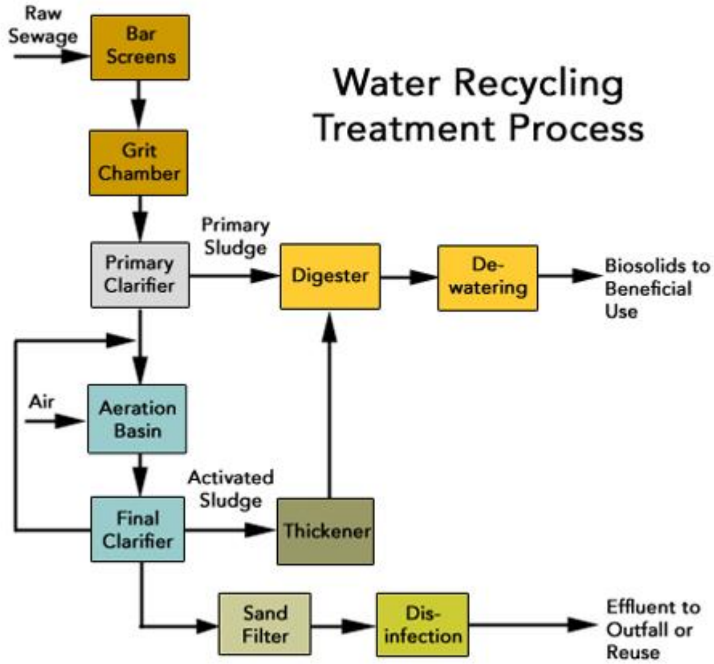


Figure 35: Water Recycling Treatment Process
Photo credit: San Antonio Water System
http://earthtechling.com/2010/10/san-antonio-opens-poo-to-fuel-plant/

2. From biosolids during the sewage treatment process, approximately 1-1.5 million cubic feet of methane gas is generated.
3. Methane gas is transferred to the Ameresco processing facility.
4. Rather than using flares to burn off the gas, Ameresco treats and transfers approximately 900,000 cubic feet (25,485,162 liters) of gas to a commercial pipeline, where it is sold on an open market for retail sale.
5. Biogas transferred to a combined heat and power (CHP) unit in a cogeneration plant to produce electricity and thermal energy.

INSPIRATIONS FOR BIOGAS

Energy – replacement of fossils to local resources
Recovery – from wastes to production of new products
Agricultural – fertilizers, waste treatment
Social – regional development and labor market

ENVIRONMENTAL BENEFITS

1. Methane is the largest contributor of greenhouse gases. Rather than burning the gas off using flames, harnessing biogas allows for a mitigation of methane concentrations and a reduction of global climate changes.
2. Displacement of fossil fuels reduces CO_2 emissions.
3. Treatment of wastes reduces air and water pollution and destroys pathogens.
4. Environmentally responsible

PROPOSED SYSTEM REDESIGN

Currently, the mechanical and electrical systems are highly complex. There are two main switchboards that distribute power to all systems. Eleven air-handling units (AHU) supply and circulate air throughout the building.

Since CPS Energy is the utility provider, they support and encourage cogeneration, where combined heat and power (CHP) devices produce thermal and electrical energy. A proposed system redesign would involve eliminating AHUs that serve the Tobin Center and replace with fewer CHP units or the amount needed to carry mechanical and electrical loads.

A proposed system redesign would involve:

- Completely replace or eliminate the appropriate amount of AHU
- Reduce and resize main switchboards and distribution panels

Probable outcome:

- Increase energy efficiency
- Resize mechanical and electrical equipment
- Reduce square footage of mechanical and electrical rooms

Summary & Conclusion

Overall, great endeavor was put forth to provide designs for engineering systems in the Tobin Center for the Performing Arts. With embracing the arts as a core concept, the lighting creates an engaging and welcoming environment in all spaces redesigned. Interior and exterior lighting complements the unique architecture that makes up each space, giving rise for it to resonate in San Antonio.

In addition, the electrical depths and breadth topics explored potential solar and energy system integrations. Implementing a Building-Integrated Photovoltaic system cannot only help gain solar energy and converting it to electricity, but also reduce total energy loads. Biogas can be a form of energy for on-site use.

Although many aspects of the existing system designs were already impressive and efficient, this thesis was successful in accomplishing the goal to consider alternative and new designs, while meeting or possibly exceeding the same criteria.

Many aspects of the existing system designs were already impressive and efficient. However, for the purpose of this thesis, it was successful in accomplishing the goal to consider alternative and new designs, while meeting or possibly exceeding the same criteria, but with a different concept.

References

DiLaura, David L., Kevin W. Houser, Richard G. Mistrick, and Gary R. Steffy, eds. *Illumination Engineering Society Lighting Handbook 10th Edition Reference and Application*.

"Light in Architecture and Psychology of Light, RS Lighting Design." Lecture. *Http://www.rsltg.com/images/ArchID_-_Light_in_Architecture_and_Psychology_of_Light.pdf*. Web.

Product, #. 86269. *Ashrae 90.1-2010 Energy Standard for Buildings except Low-rise Residential Buildings*. [S.l.]: Ashrae, n.d. Print.

"COMcheck." *Building Energy Codes Program*. N.p., n.d. Web. 14 Mar. 2014. <https://www.energycodes.gov/comcheck>.

Earley, Mark W., and Jeffrey S. Sargent. *National Electrical Code*. 2011 ed. Quincy, MA: National Fire Protection Association, 2010. Print.

GE. "Short-Circuit Current Calculations for Industrial and Commercial Power Systems." *GE Industrial*. GE, n.d. Web. 10 Feb. 2014. <http://apps.geindustrial.com/publibrary/checkout/GET-3550F?TNR=White%20Papers|GET-3550F|generic>.

"Get A Quote On Nearly Any Construction Material." *Get A Quote On Nearly Any Construction Material*. N.p., n.d. Web. 10 Mar. 2014. <http://www.get-a-quote.net/>.

NRG Energy, Inc., ed. *Solar Power Installation at Lincoln Financial Field*. Publication. NRG Energy, Inc., n.d. Web. 10 Mar. 2014. <http://www.nrgsolar.com/wp-content/uploads/2013/07/lincolnNRG-1671-Lincoln-Football-Stadium-Fact-Sheets-v8-EMAIL.pdf>.

"San Antonio Opens Poo-To-Fuel Plant." *EarthTechling*. N.p., n.d. Web. 16 Mar. 2014. <http://earthtechling.com/2010/10/san-antonio-opens-poo-to-fuel-plant/>.

"San Antonio Water System." *San Antonio Water System*. N.p., n.d. Web. 15 Mar. 2014. <http://www.saws.org/>.

"Solar PV." *Commercial Solar Rebates*. N.p., n.d. Web. 15 Mar. 2014. <http://www.cpsenergysavers.com/commercial/start-saving/solar-rebates>.

"Taxes & Incentives." *Taxes & Incentives*. N.p., n.d. Web. 17 Mar. 2014. <http://www.sanantonioedf.com/business-profile/taxes-a-incentives>.

Acknowledgements

Thank you to the many individuals who made this thesis possible.

Matthew Snellgrove	Project Director, The Projects Group
Clifton Manahan	Lighting Designer, HLB Lighting Design, Inc.
Dr. Kevin Houser	Thesis Advisor, AE Lighting Professor, Penn State
Leslie Beahm	Electrical Advisor, Reese Engineering
Dr. Richard Mistrick	AE Lighting Associate Professor, Penn State
Dr. Jeffrey Brownson	Assistant Professor, Department of Energy % Mineral Engineering, Penn State

Family and friends for their continuous support.