MILLENNIUM SCIENCE COMPLEX

AE SENIOR THESIS: IPD/BIM (2010-2011)

Building STIMULUS

Paul Kuehnel:
Structural

Mike Lucas:
Electrical & Lighting

The Pennsylvania State University
Millennium Science Complex

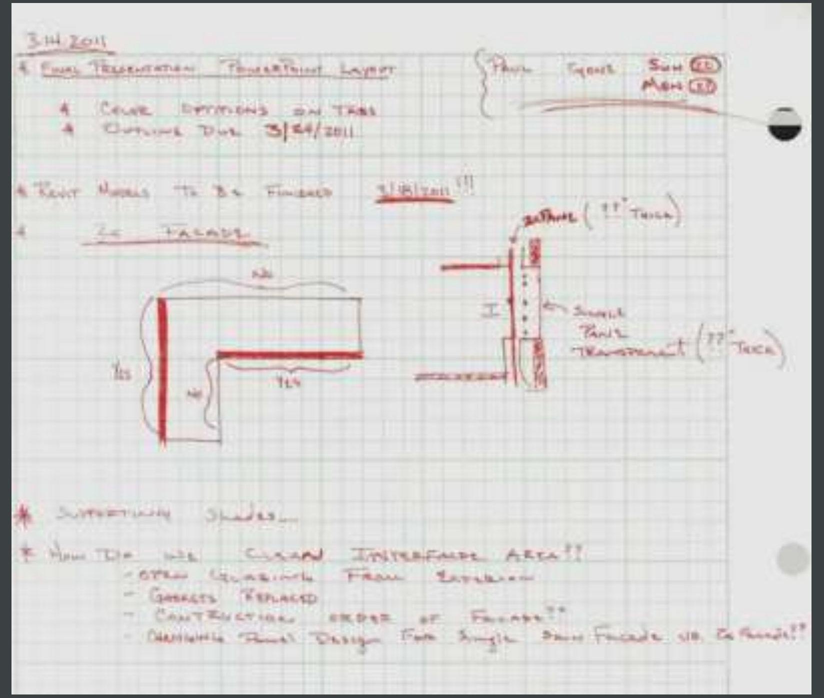
WHITING-TURNER
RAFAEL VIÑOLY ARCHITECTS
Thornton Tomasetti
WSP • FLACK+KURTZ
PENNSTATE

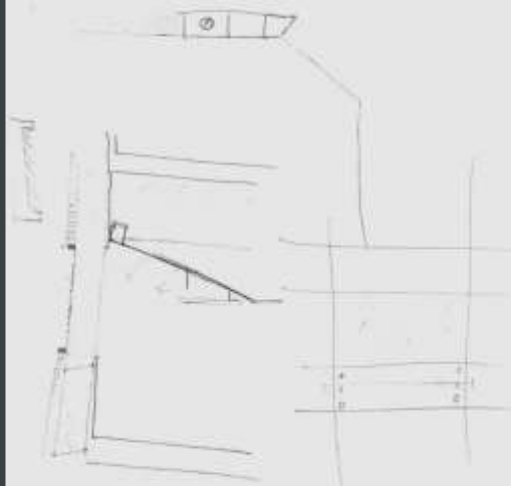
Jon Brangan:
Construction Management

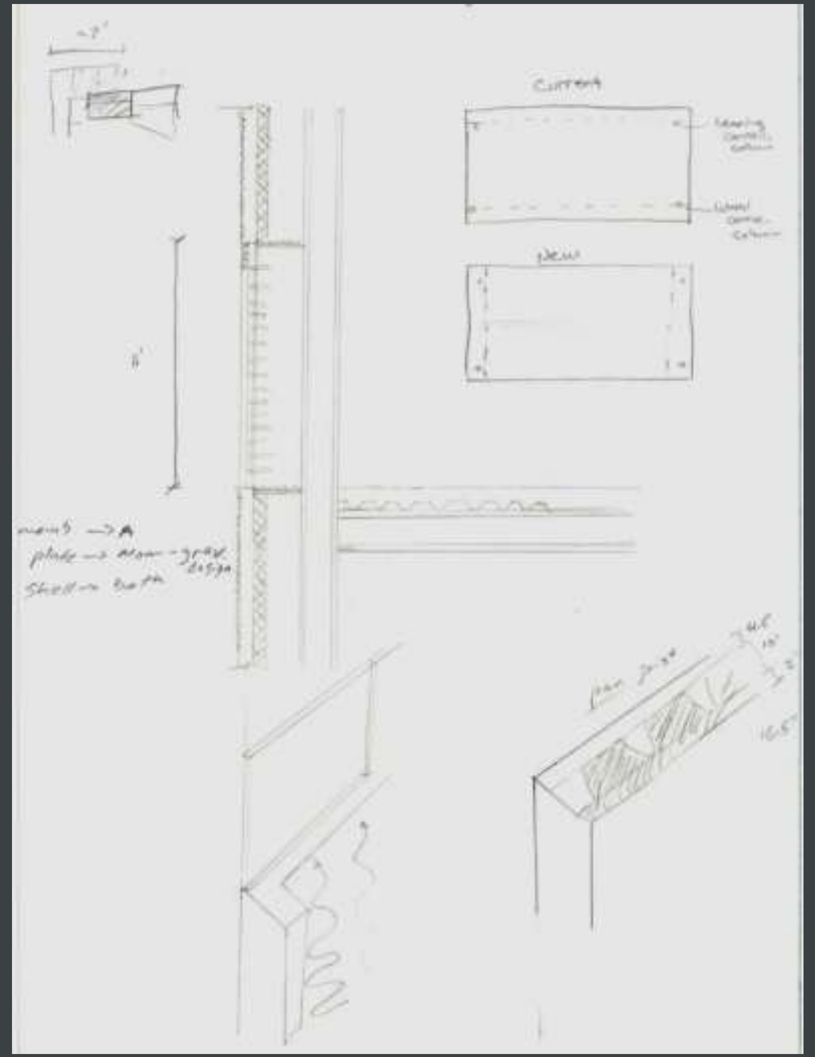
Sara Pace:
Mechanical

Building Overview

- Location: University Park, PA
- Construction Dates: June 2008 – June 2011
- Estimated Cost: $230 Million budgeted
- Project Delivery Method: Design-Bid-Build
- Size: 275,600 Square Feet
- Type of Use: Science Complex

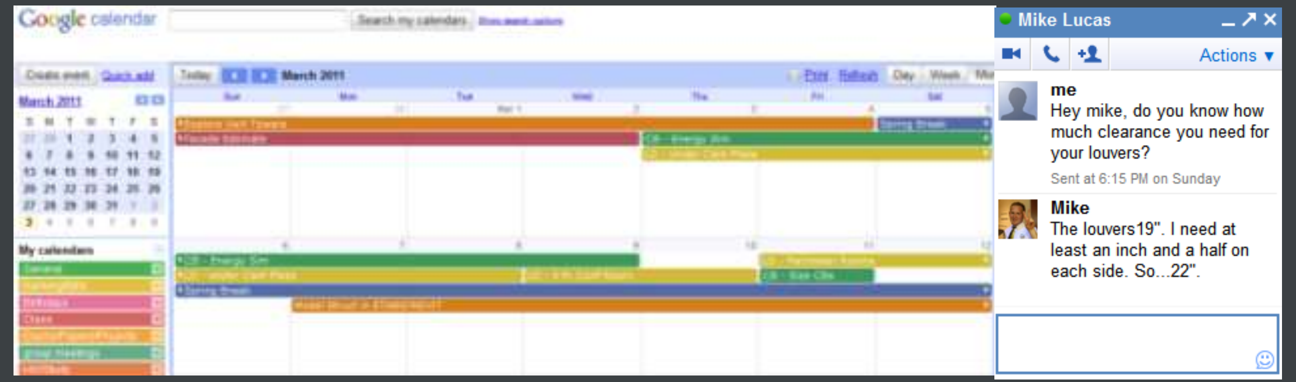




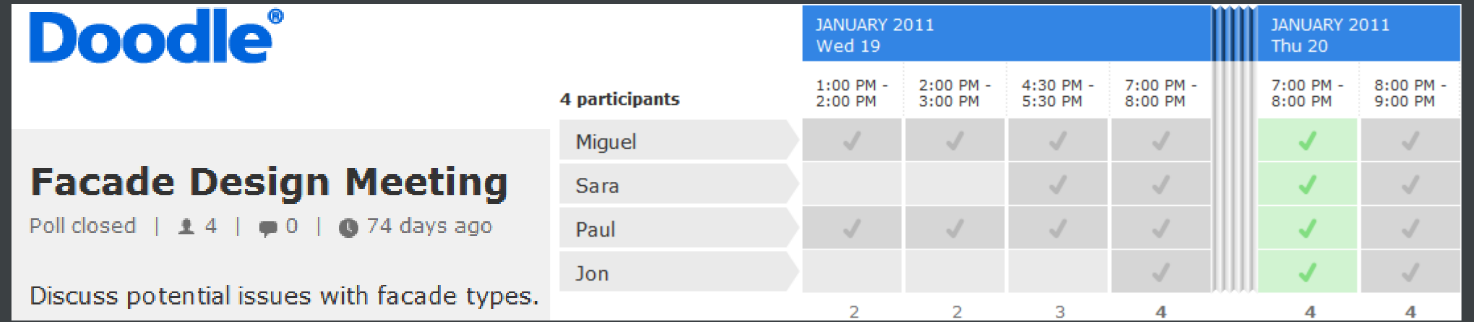


Integrated Project Delivery

- Weekly Meetings
- Project Work Spaces
- Essential Communication Tools



Microsoft Office Project



Building Overview | **IPD/BIM Thesis** | Design Goals | Cantilever Design | Façade Design | Energy Modeling | Reflection

Building STIMULUS

What is BIM?

"Building Information Modeling is the process of generating and managing building data during it's life cycle."

- Lee, Sacks and Eastman (2006)

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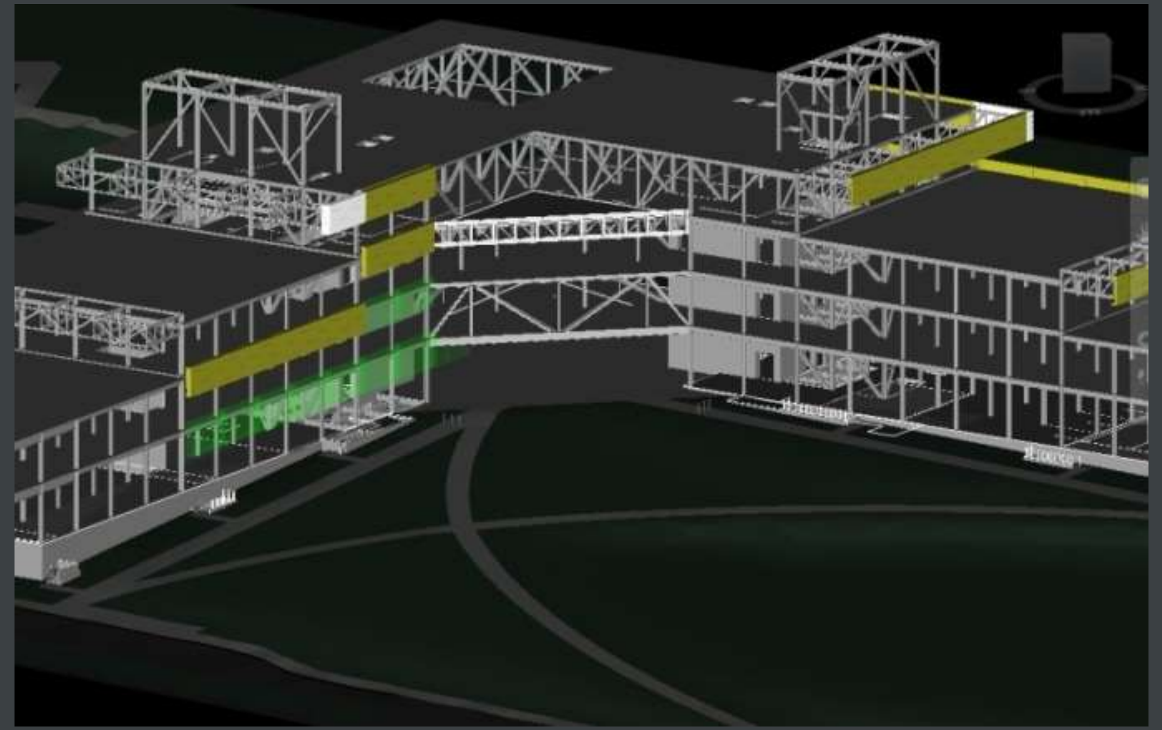
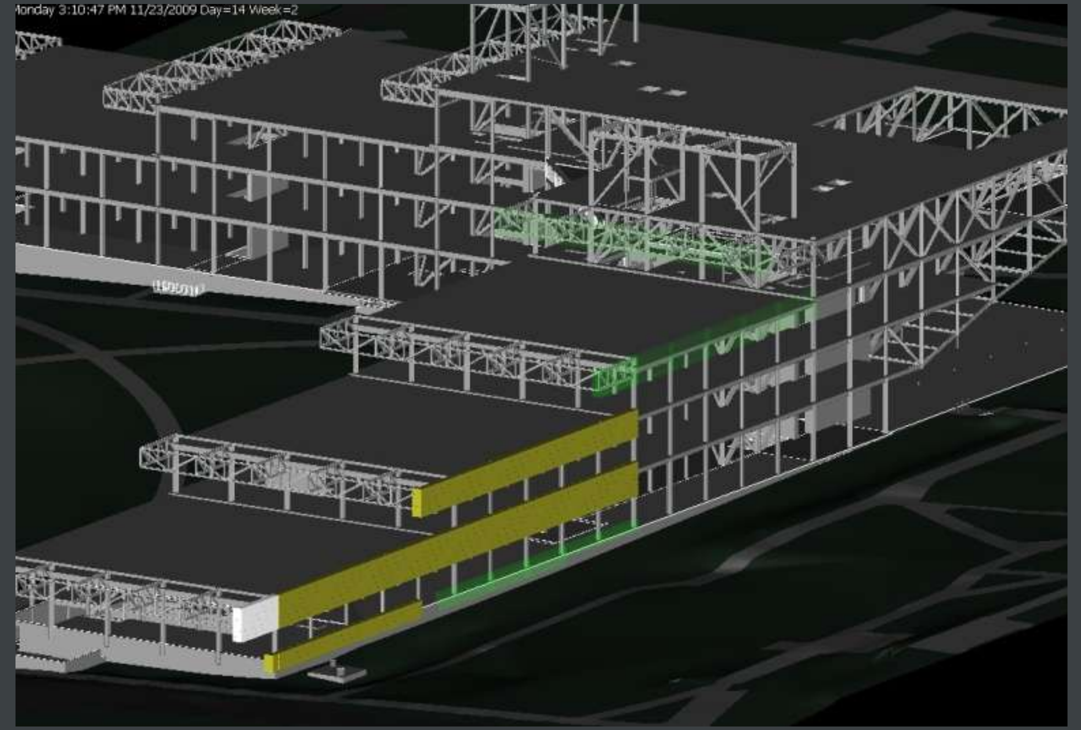
Planning with BIM

- 4D Modeling
- Sequencing
- Site Utilization





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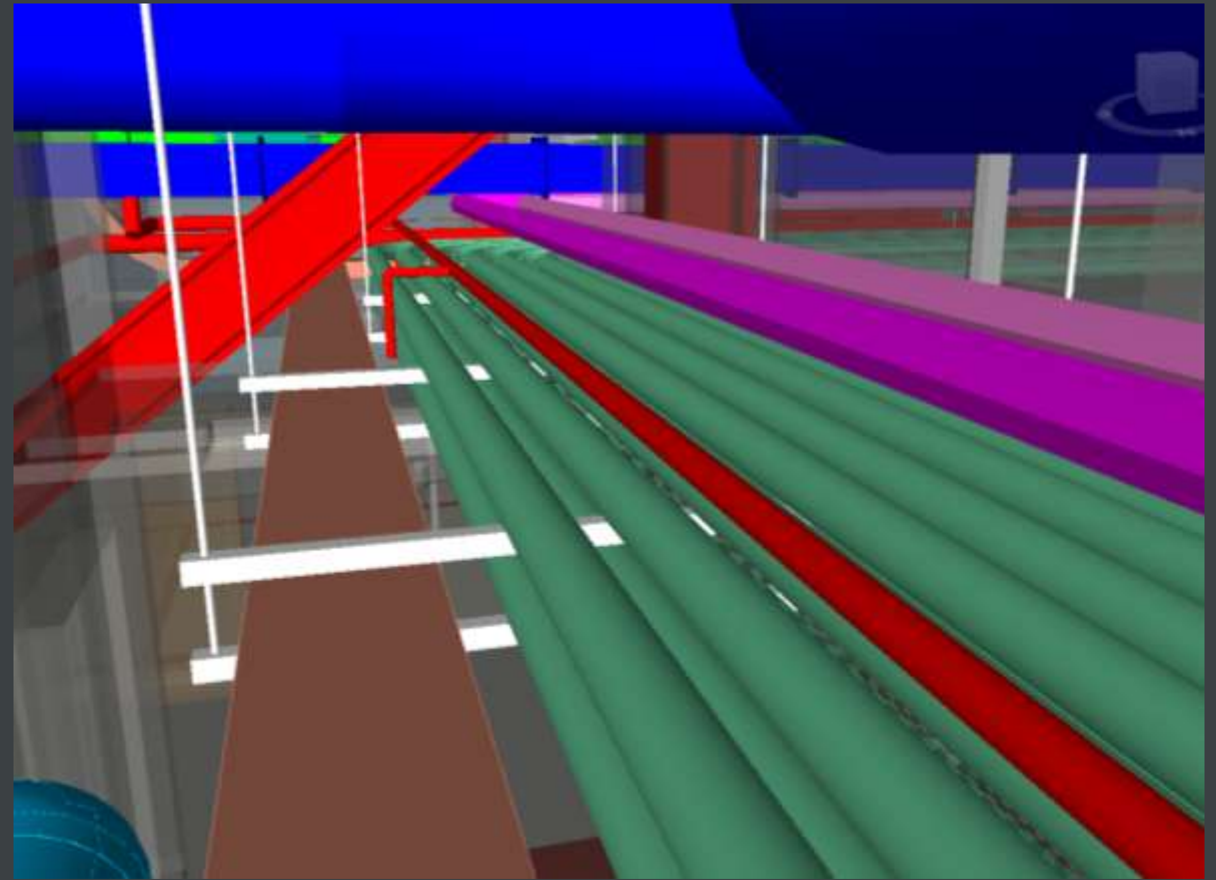
Construction & Coordination

- 3D Trade Coordination



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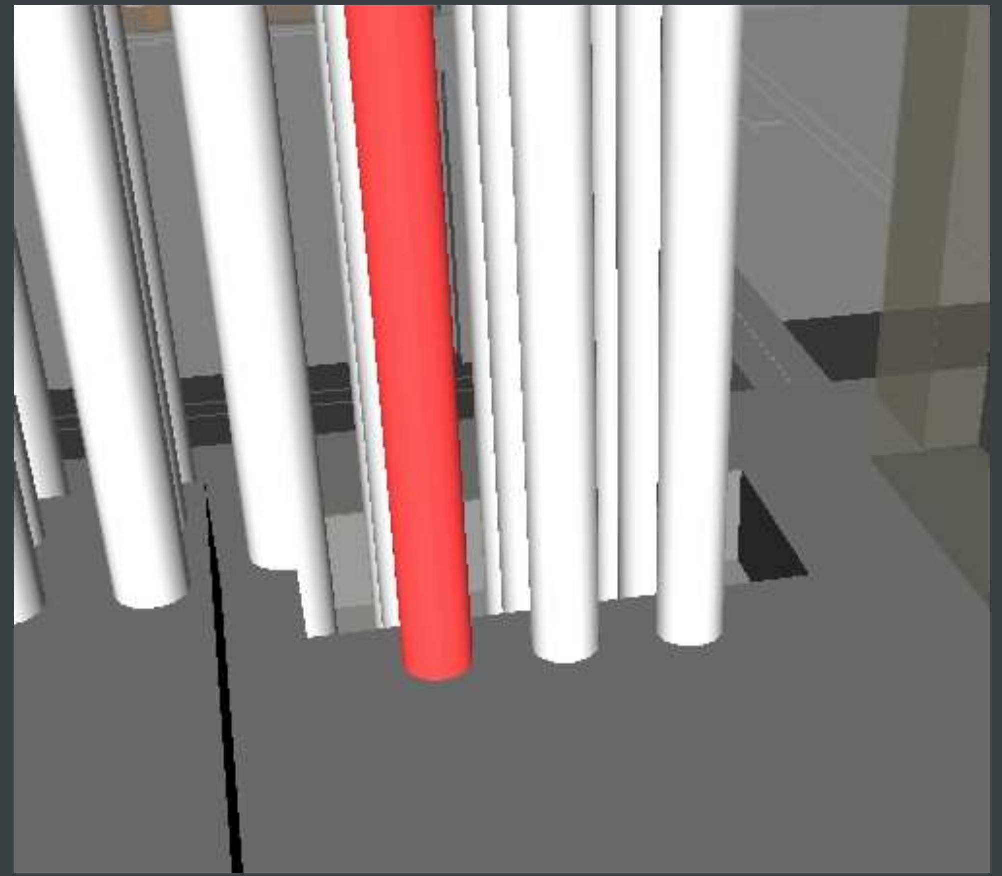
Construction & Coordination

- 3D Trade Coordination
- Clash Detection



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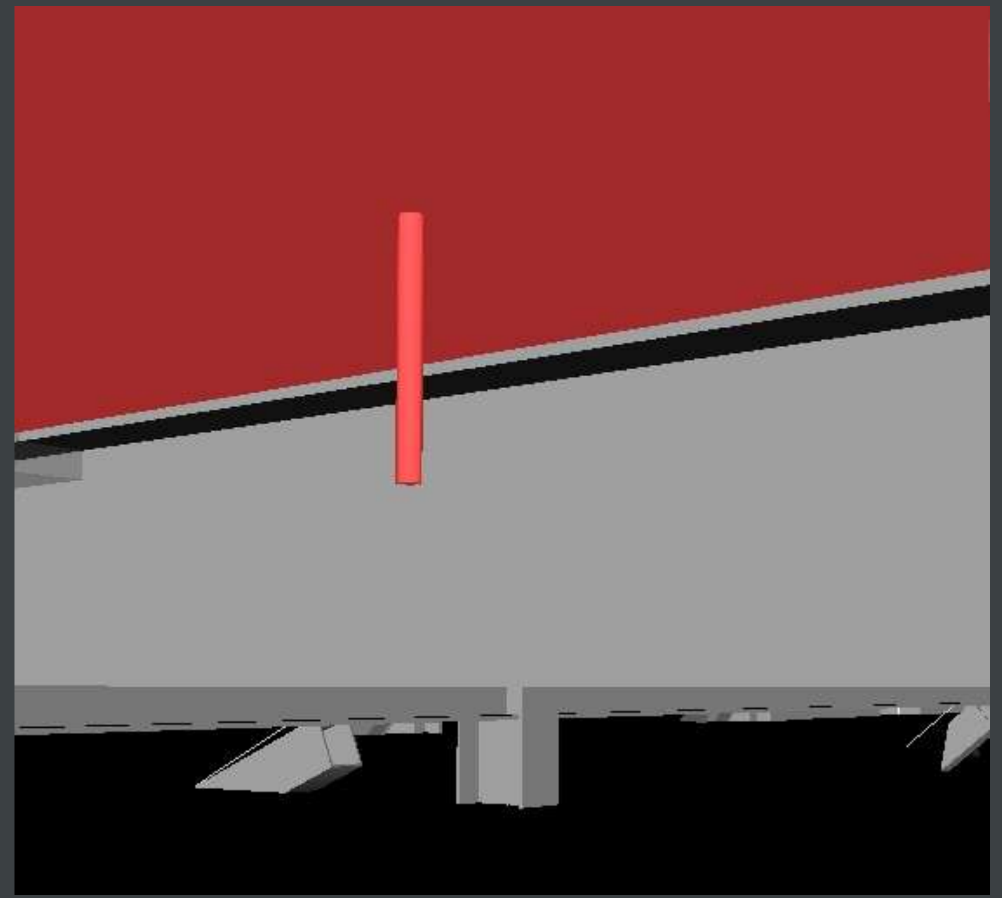
Construction & Coordination

- 3D Trade Coordination
- Clash Detection
- Verifying Model Accuracy



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Facilities Management

- Primary use of BIM Post-Construction

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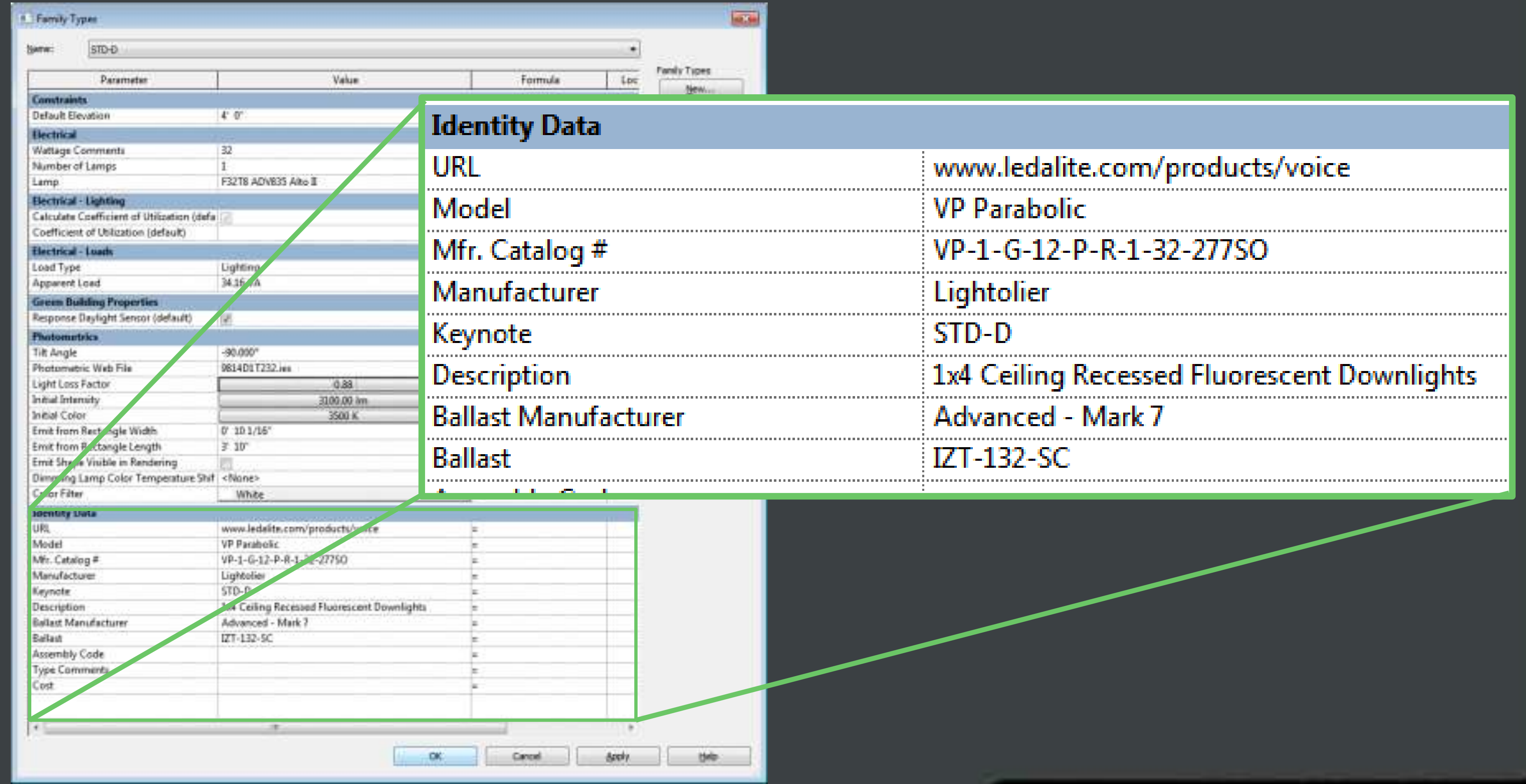
Facilities Management

- Primary use of BIM Post-Construction
- F.M. Model Contains:
  - Manufacturer Information
  - Model Numbers
  - Website Link

Family Product Information



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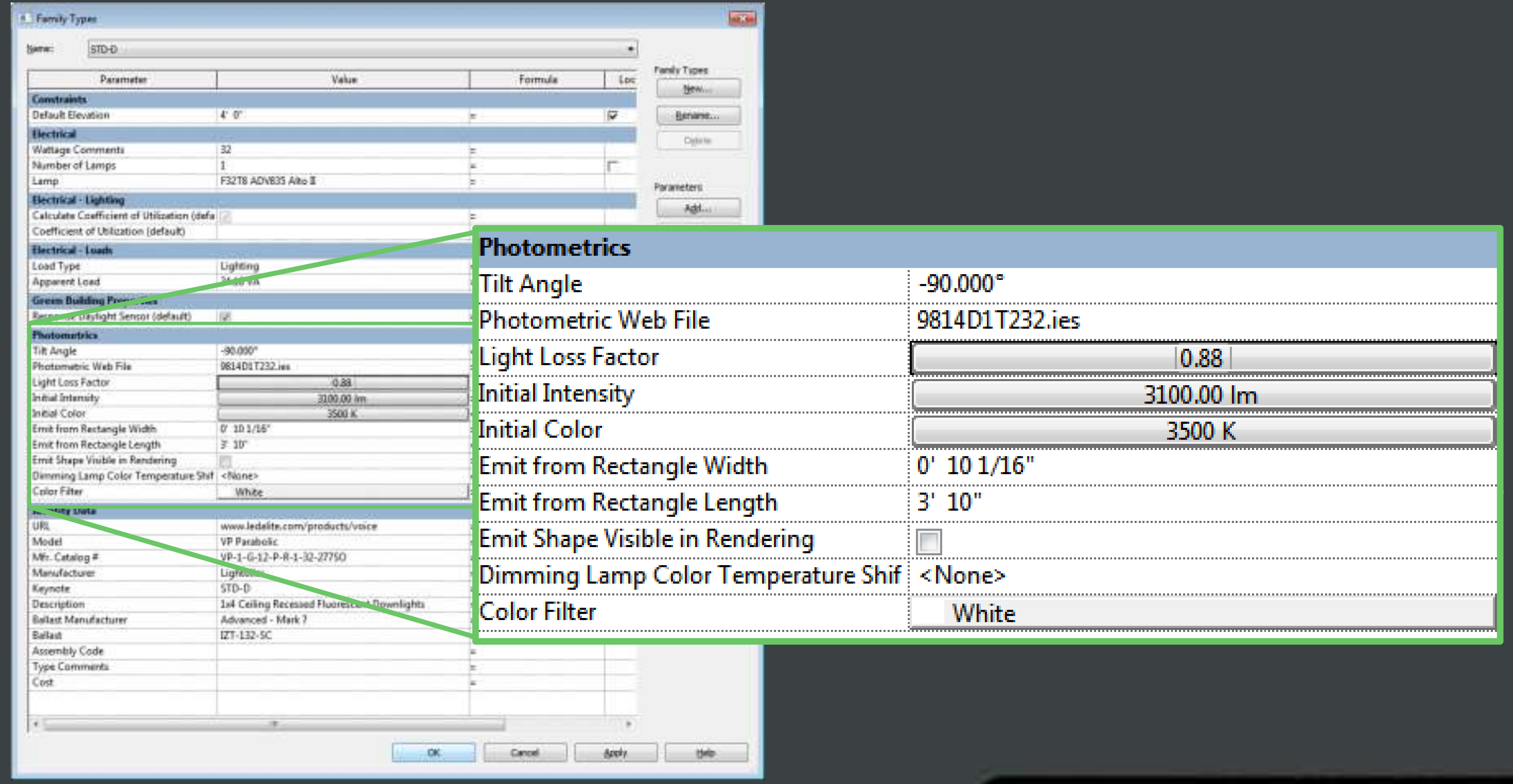

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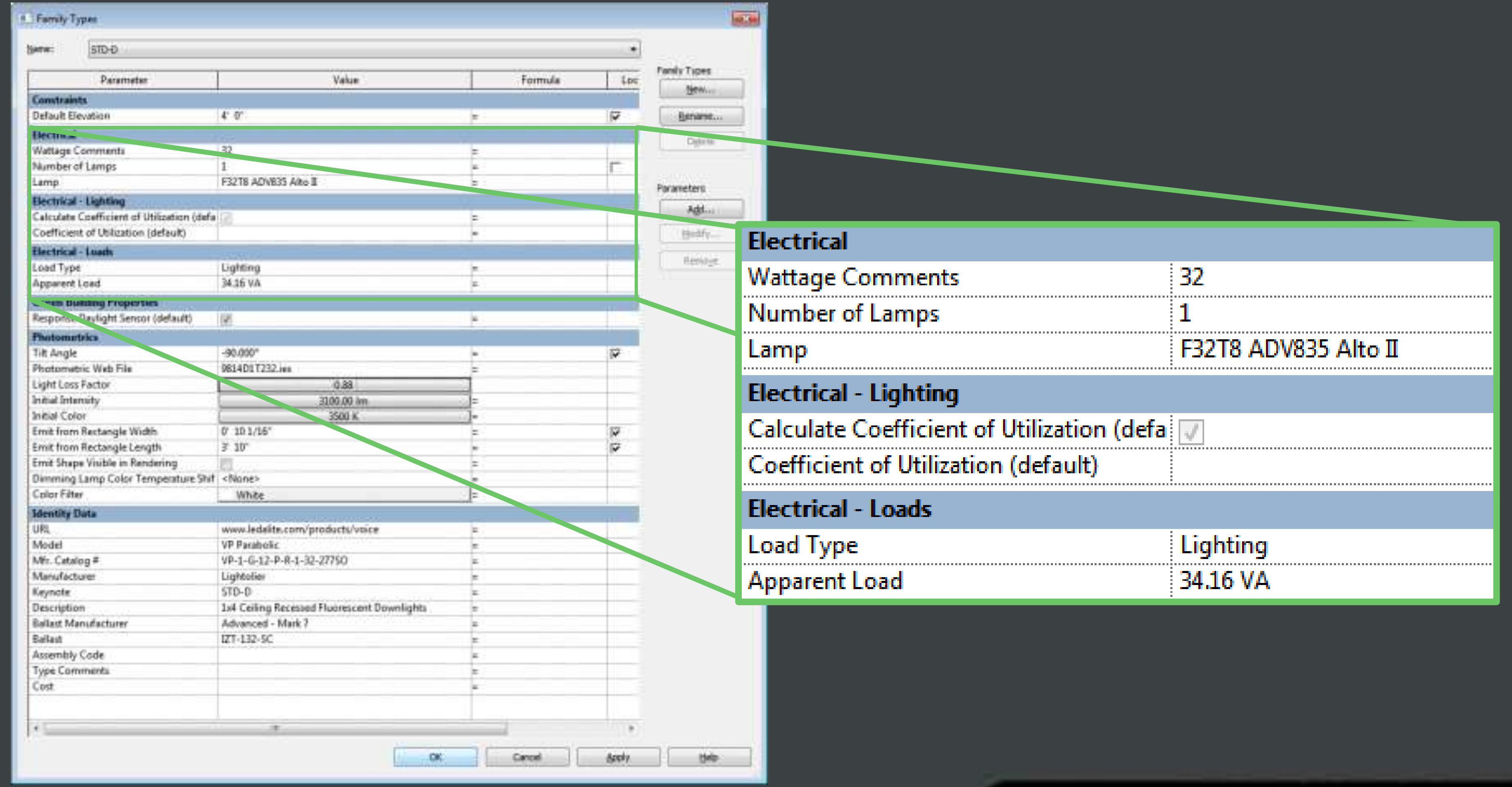
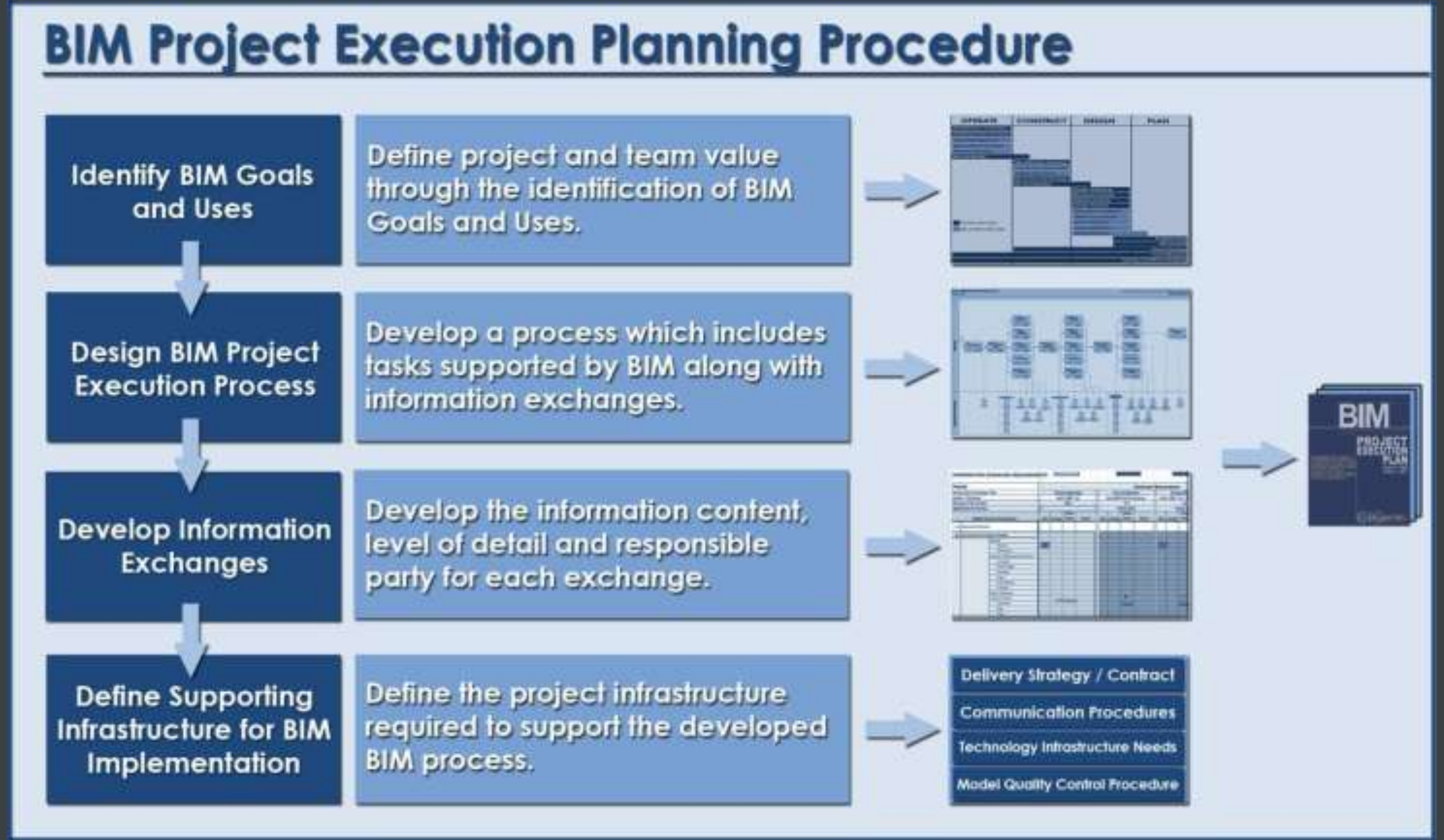
Facilities Management

- Primary use of BIM Post-Construction
- F.M. Model Contains:
  - Design Information
  - Quantities
  - Engineering Information

Family Product Information



Building Stimulus Design Goals



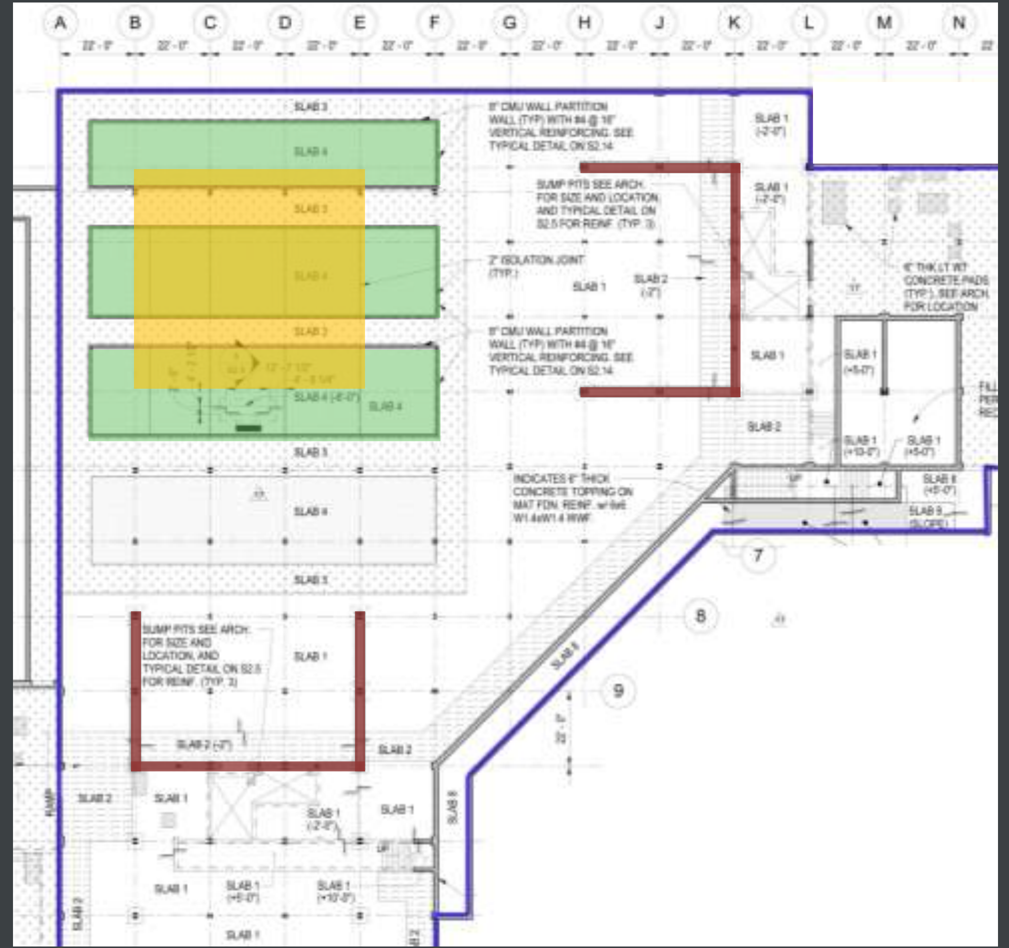
- Areas of Focus
- BIM Project Execution Plan
  – BIM/Project Goals
  – BIM Uses
- Identify Metrics of Success

PRIORITY (HIGH/ MED/ LOW)	GOAL DESCRIPTION	POTENTIAL BIM USES
H	Assess Cost Associated with Design Changes	Cost Estimation, Existing Conditions Modeling
H	Increase Effectiveness of Design	Design Authoring, Design Reviews, 3D Coordination, Engineering Analysis, Existing Conditions Modeling
H	Interdisciplinary Design Coordination	Design Reviews, 3D Coordination

Building Stimulus Cantilever Overview

- Main architectural feature of the building
- Intersection of Materials Sciences and Life Sciences
- Occupiable and Non-Occupiable space on 3rd and 4th floors (Mech. Penthouse)
- Features a 3 bay x 3 bay opening
- 3 isolated quiet labs below plaza

150 feet

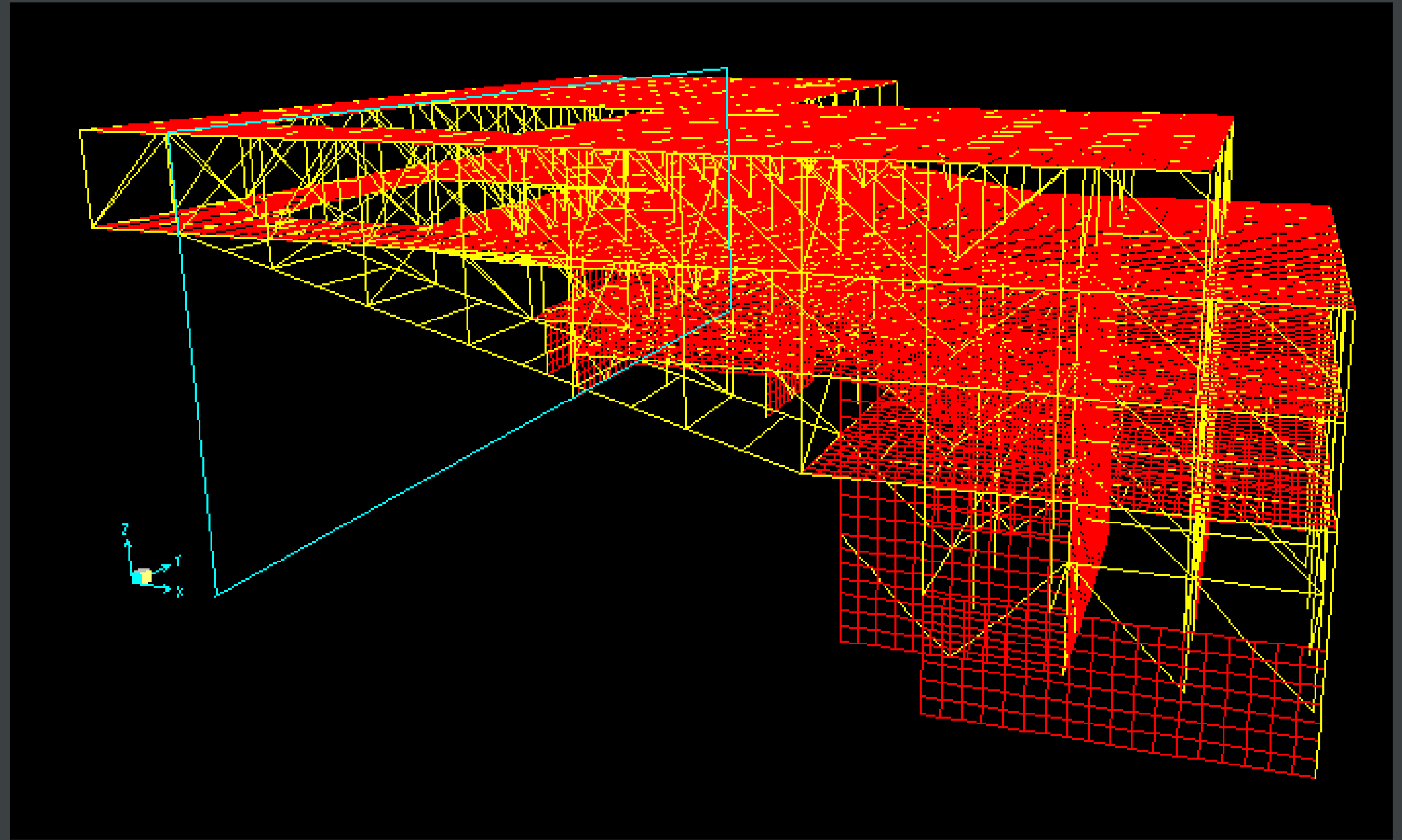


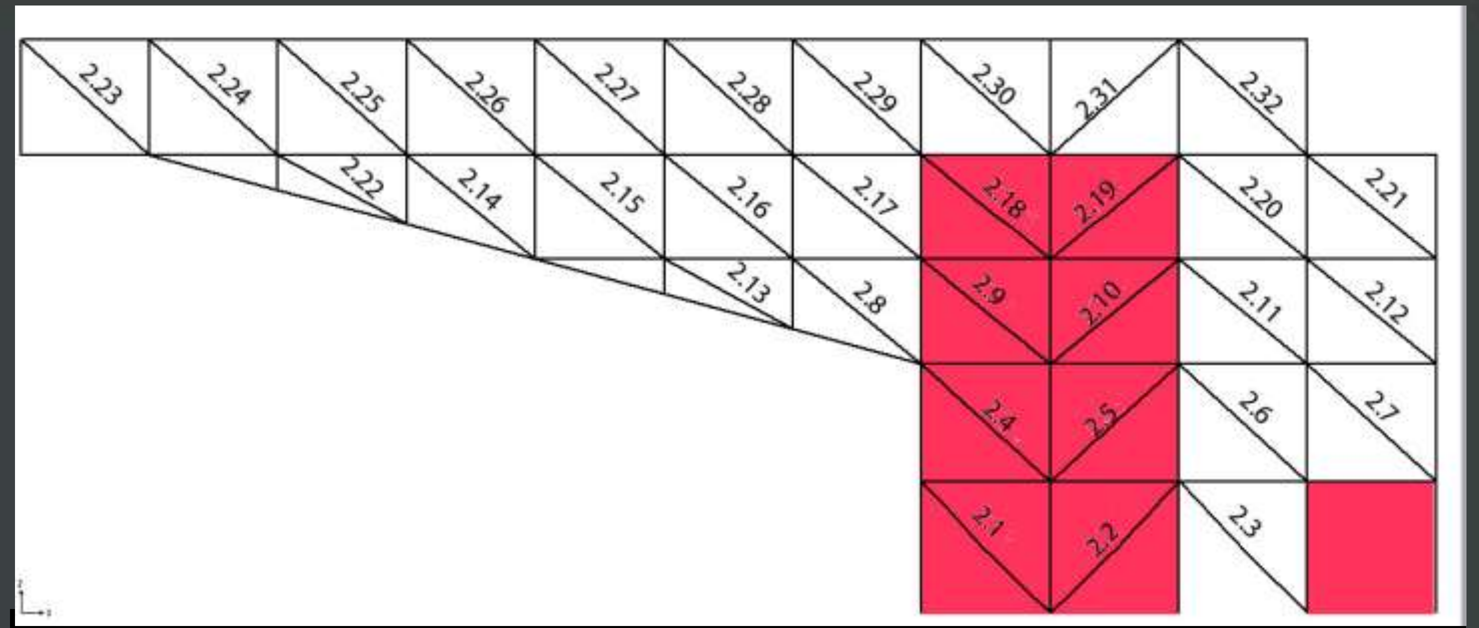
Building Stimulus Cantilever Design Goals

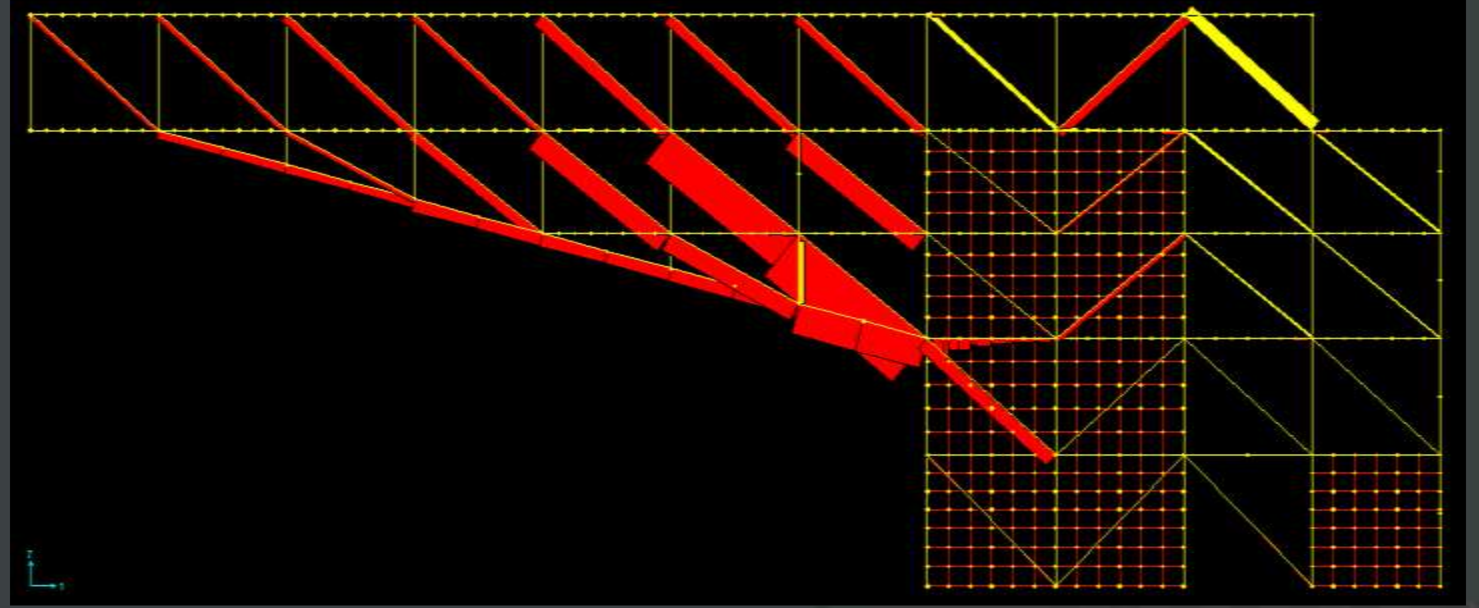
- Structure: Reduce steel and increase load path efficiency
- Lighting: Create an Inviting Entrance
- Construction: Increase Productivity
- Alternative Energy

Building Stimulus Cantilever Structural Redesign

- SAP 2000 used to model the structural system of the cantilever
- Existing Conditions modeled and checked for:
  - Member strength
  - Overall Deflection
  - Stiffness







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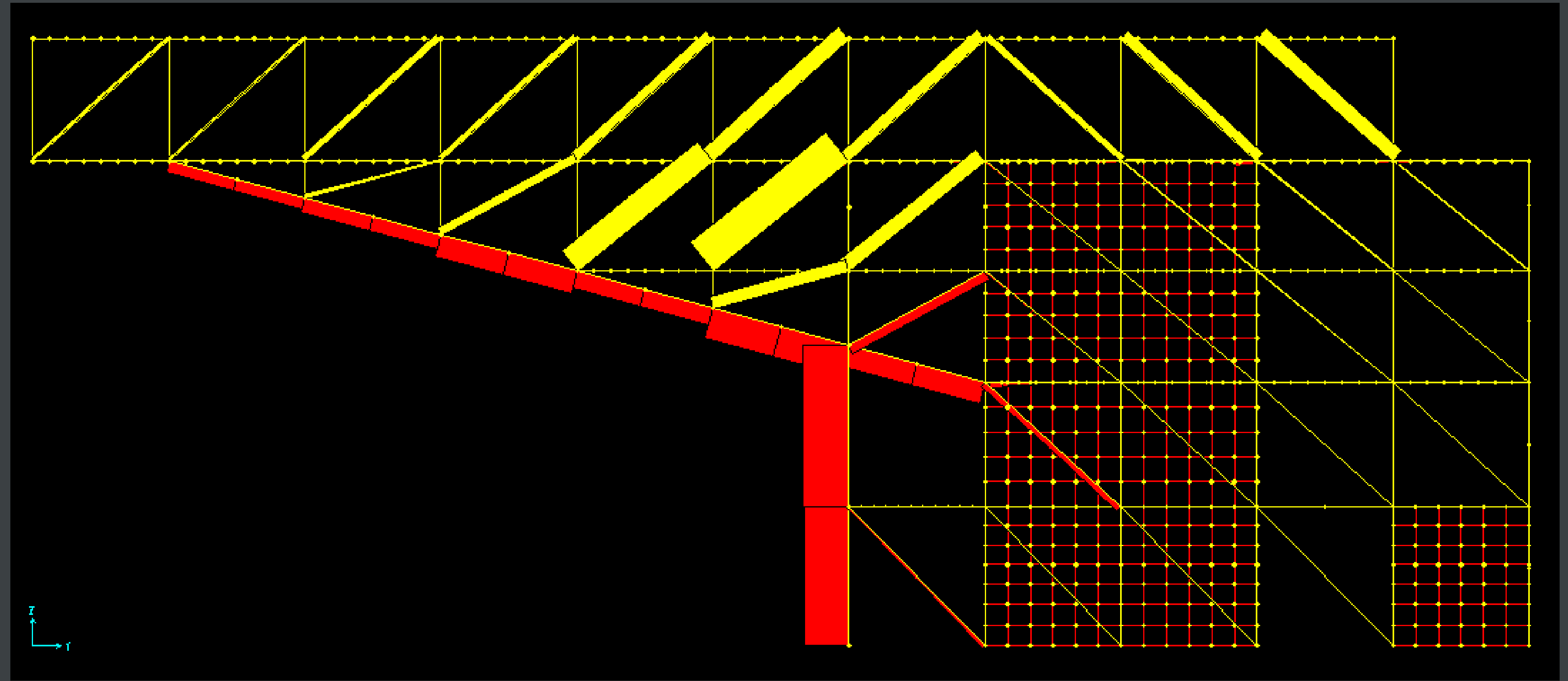

Switch Braces to Tension

Increase in Deflection and Inefficiency of Load Path

Do not continue with Tension iteration, continue with Compression

Building Stimulus Cantilever Structural Redesign

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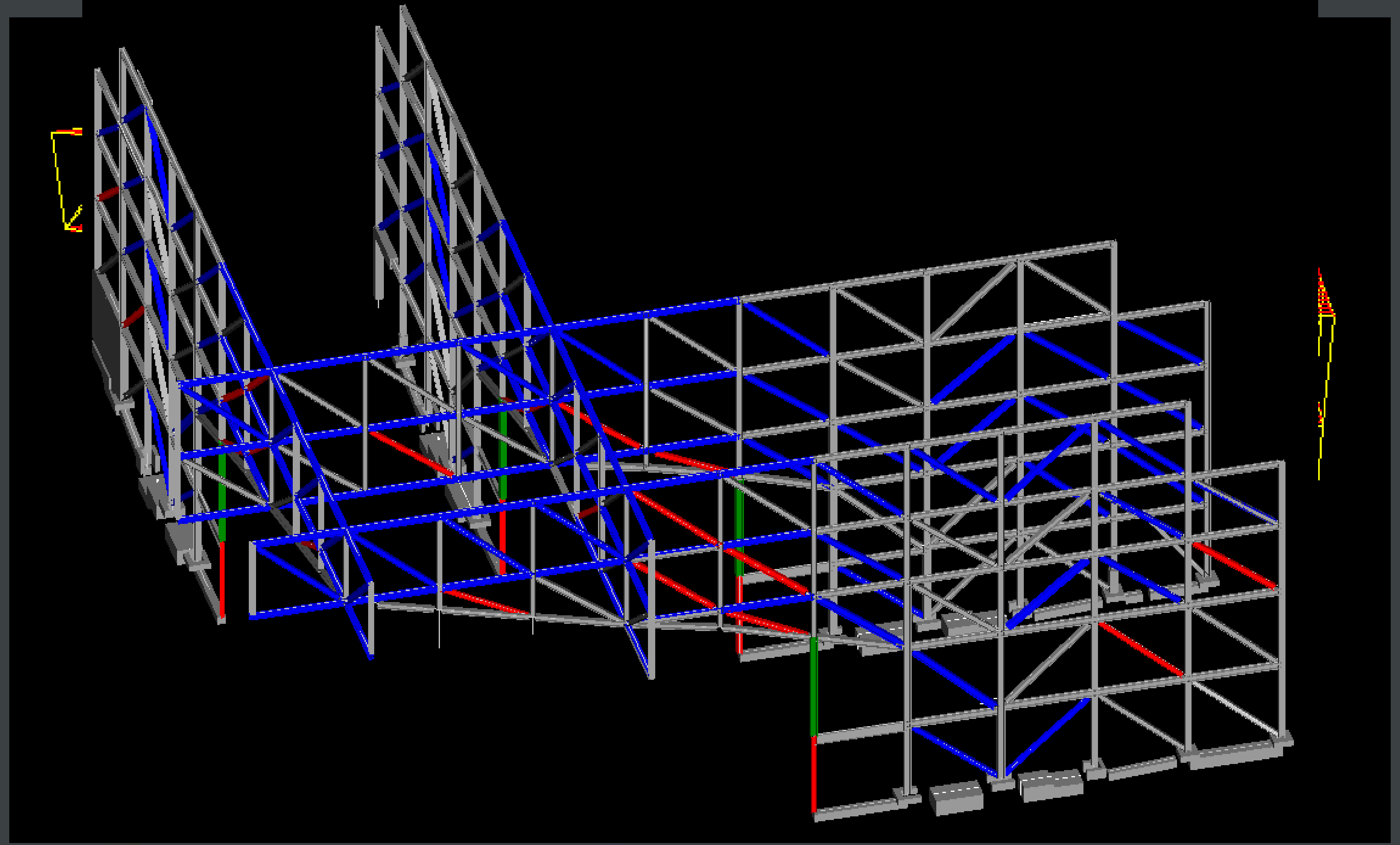

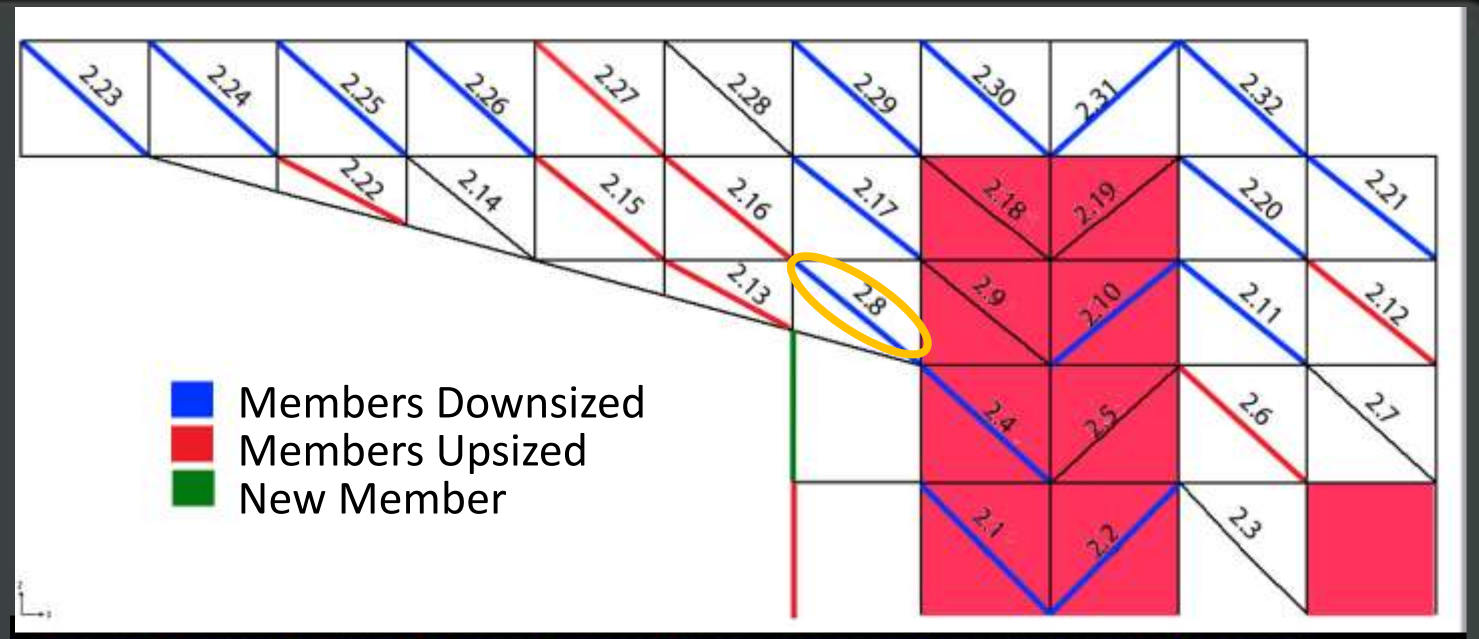

Frame	Section	Station	P	V2	V3	M2	M3	L	K	KL
		in	Kip	Kip	Kip	Kip-in	Kip-in	in		
Frame 2.8	W14X257	341.104	-1882.07	8.275	4.529	-999.241	-832.527	341.104	0.8	22.74
Frame 2.8		0	-1898.65	-11.997	4.529	545.488	-1467.19			
P_r	P_c	P_r/P_c		M_r2	M_r3	$px10^3$	$b_x x10^3$	$b_y x10^3$	Interaction Eqn.	
				Kip-ft	Kip-ft					
-1898.652	2472.32	0.768	H1-1a	-83.27	-122.27	0.404	0.508	0.964	0.9103	<1.0 OK

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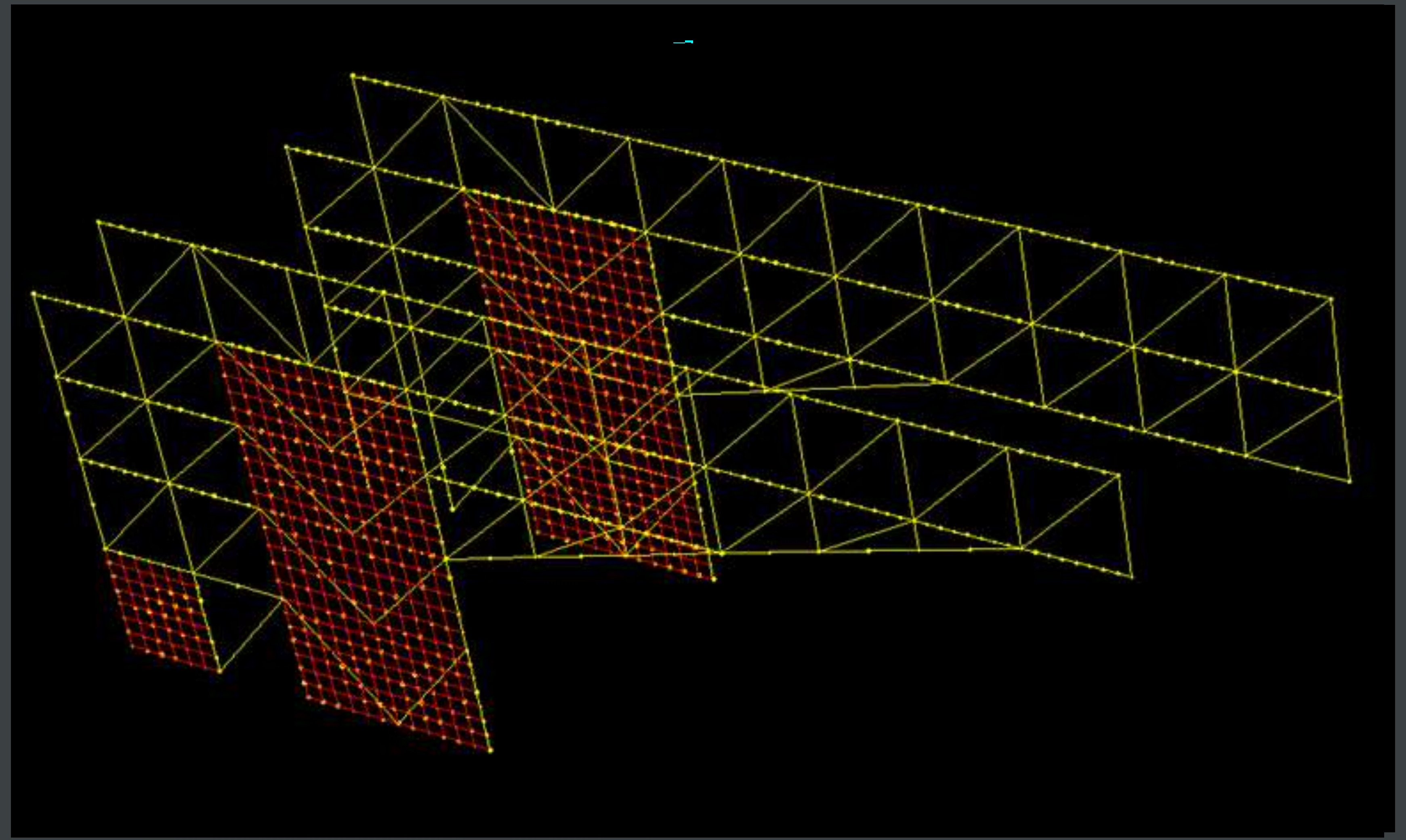


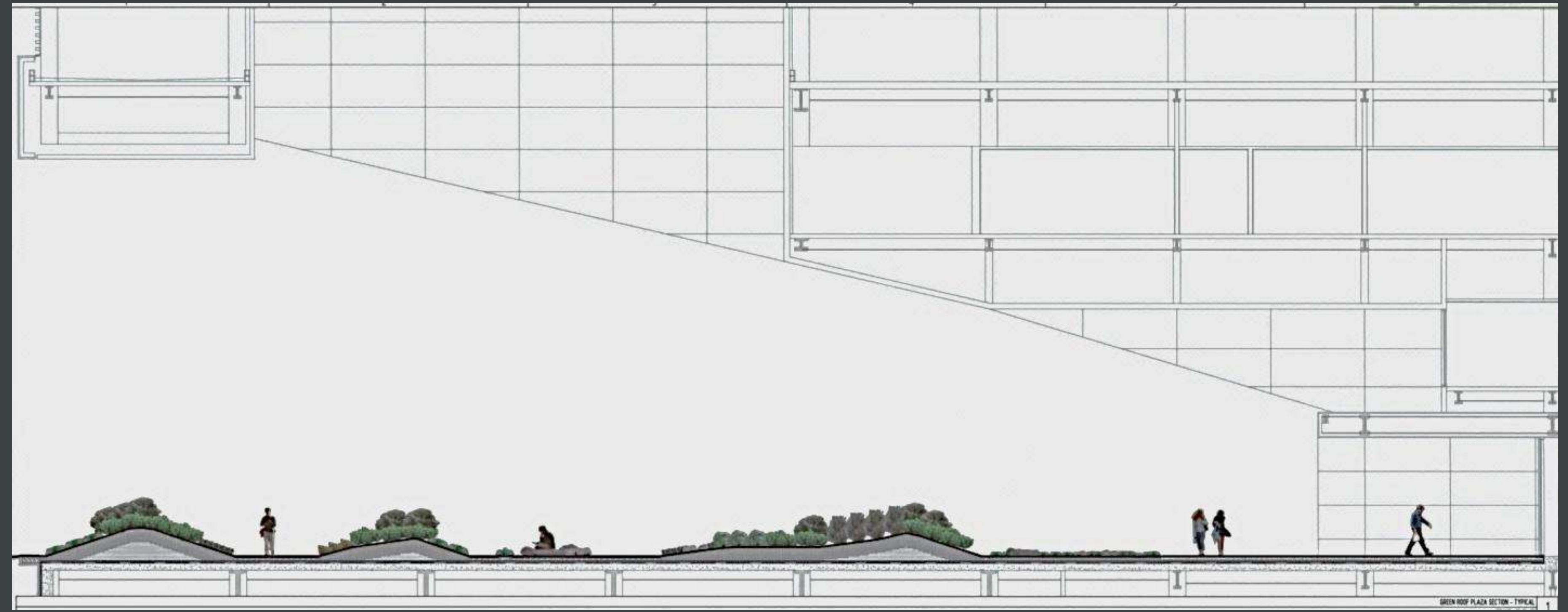
	Existing		Redesign	
Frame	2	5	2	5
P	1000	1000	1000	1000
U	11.5141	12.8985	12.9544	11.7441
K	0.011514	0.012899	0.012954	0.011744
% diff		11.34		9.80

- Redesigned trusses to have similar stiffness for load sharing
- Result: percent difference in stiffness less than 10%

Exterior Plaza Lighting Design

Plan View

Section View



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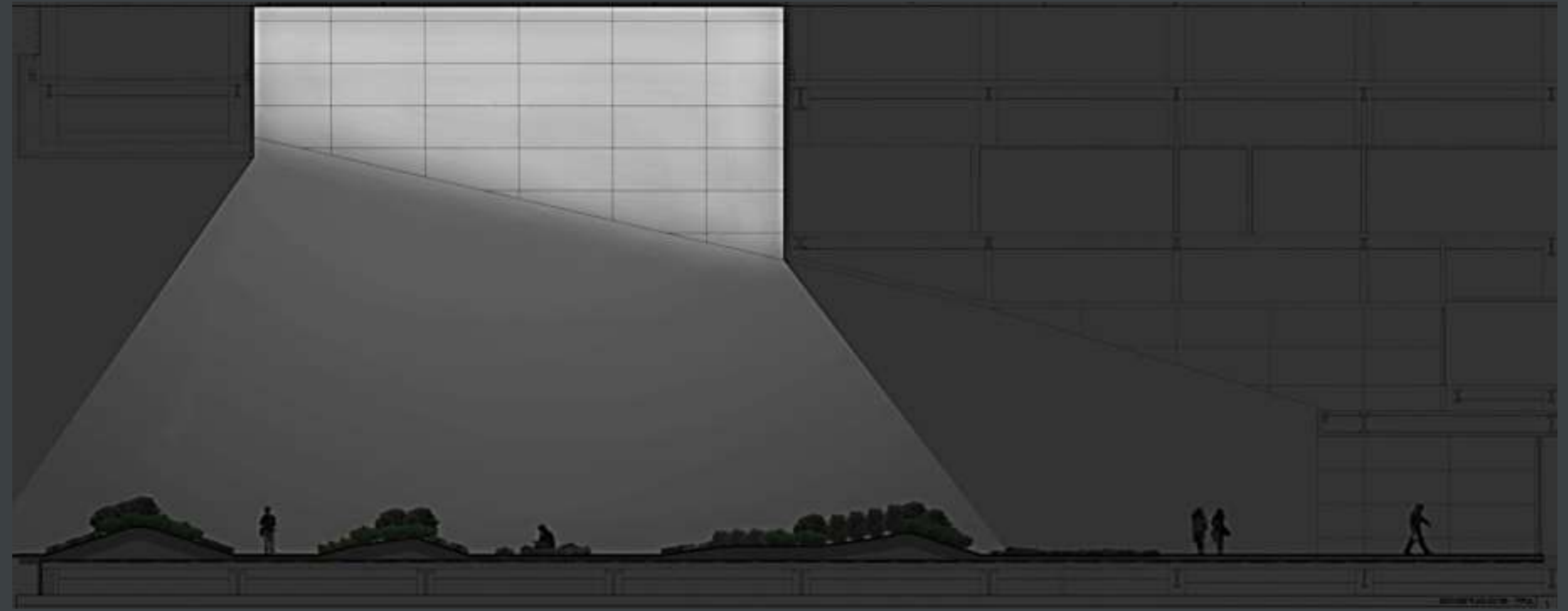

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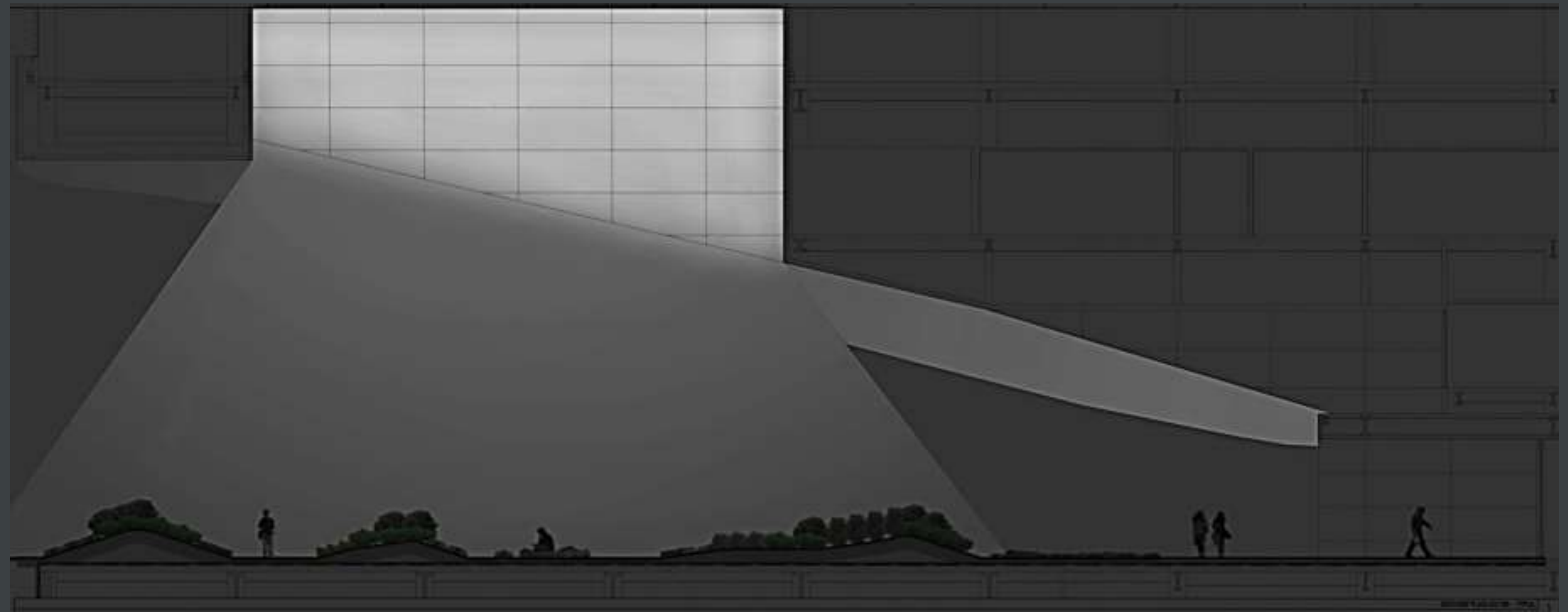

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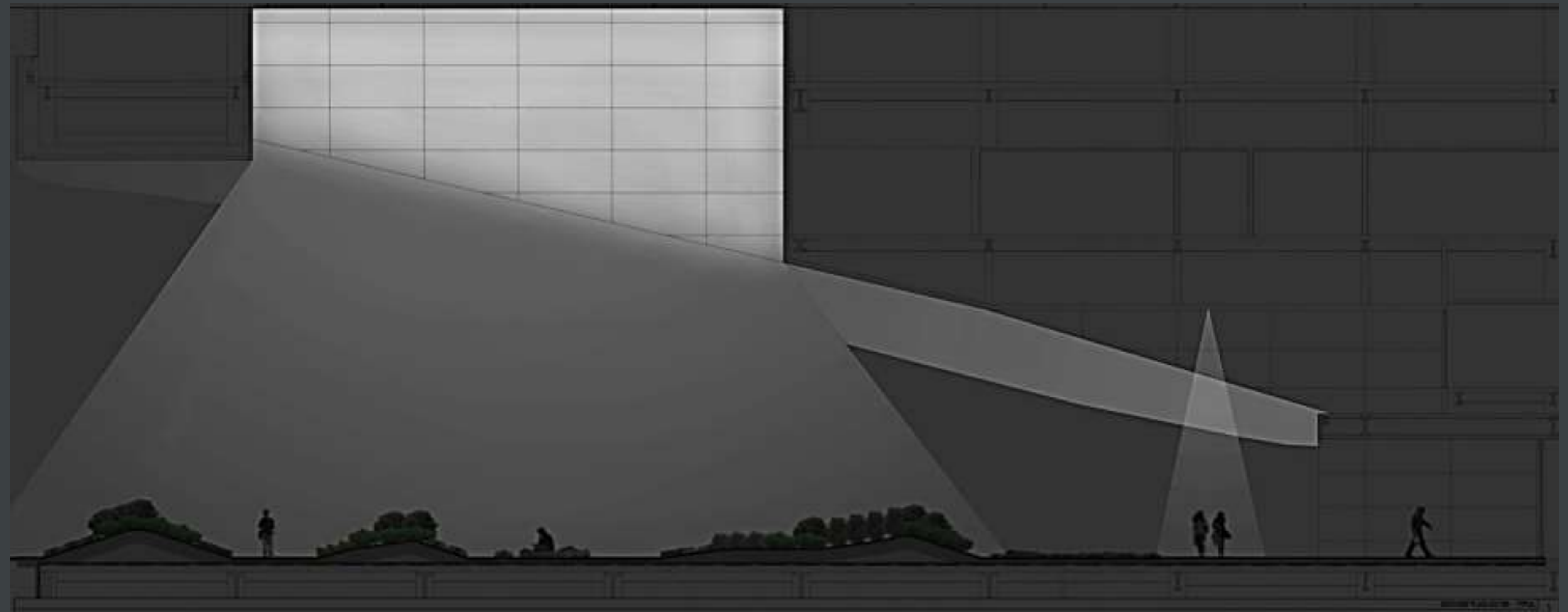

Building STIMULUS

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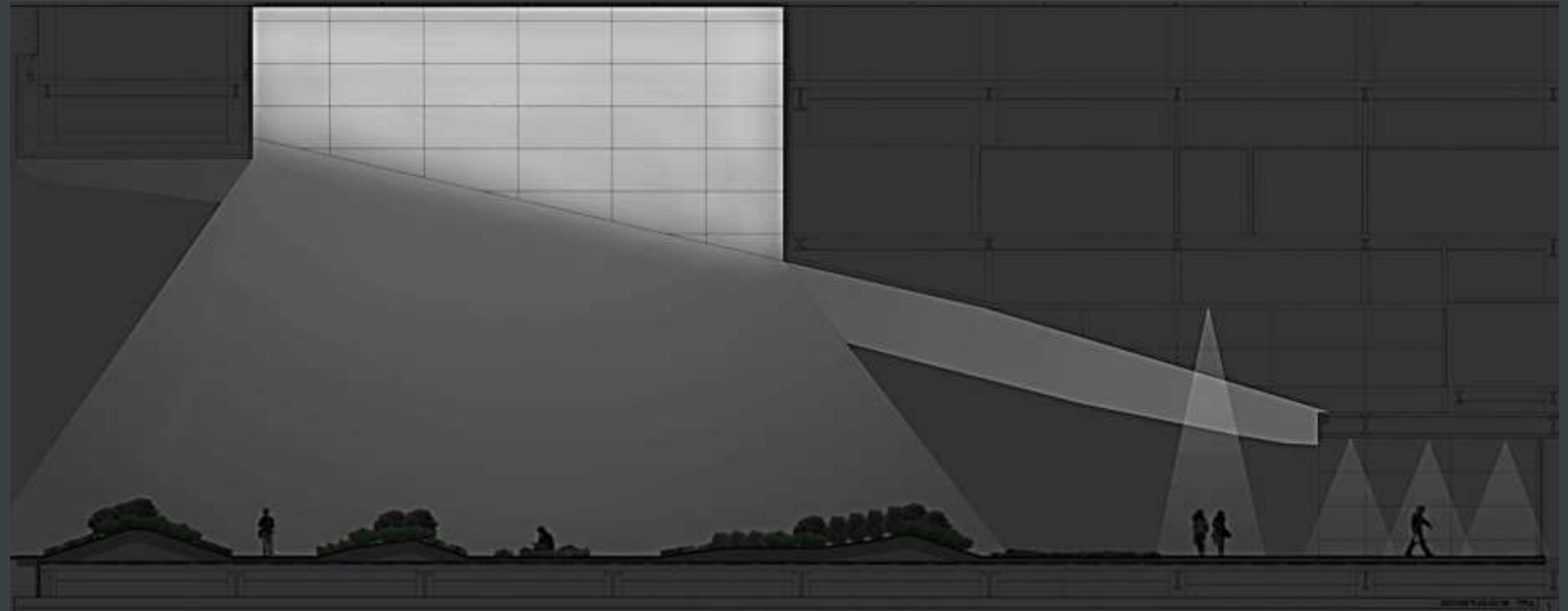

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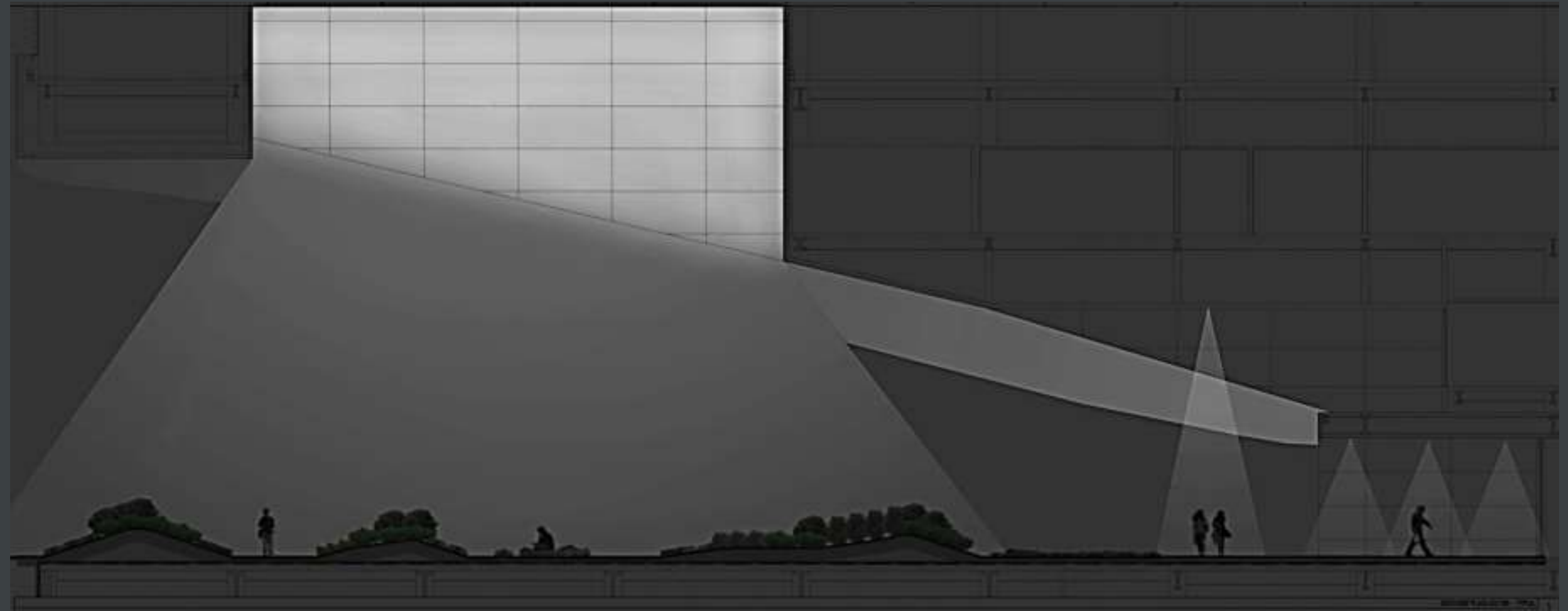
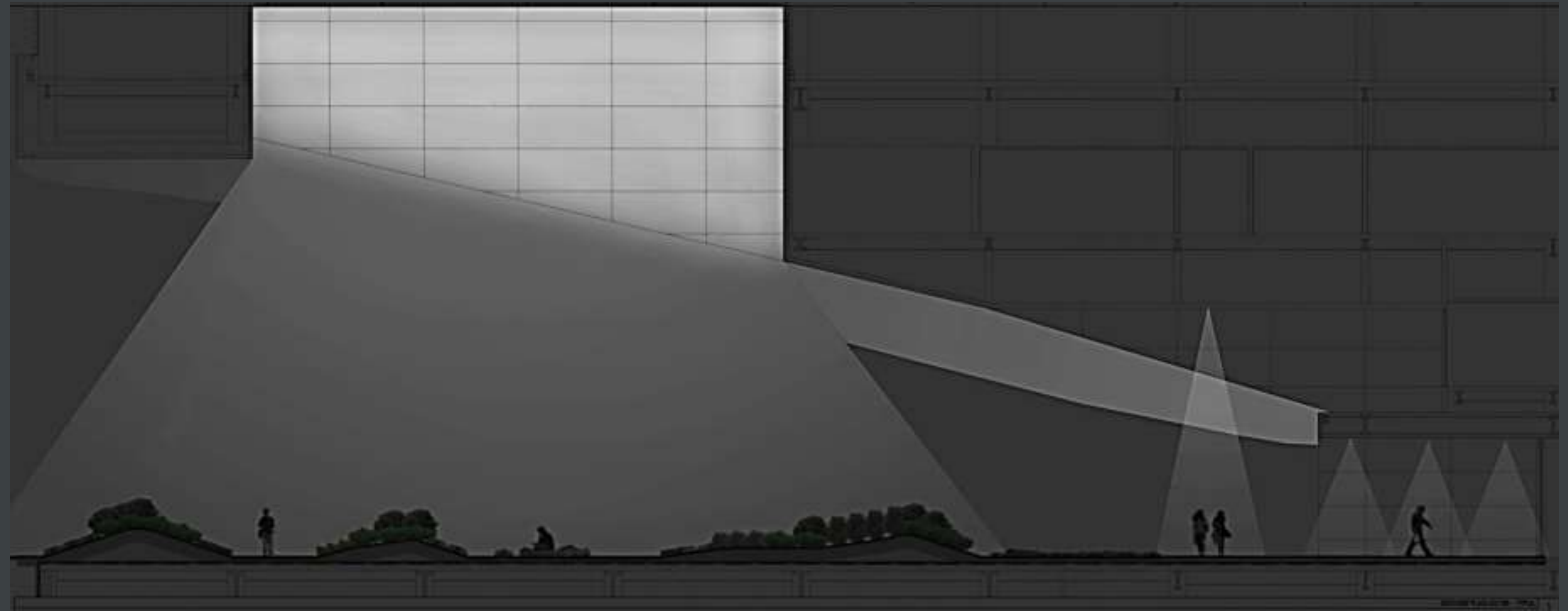


Color Rendering

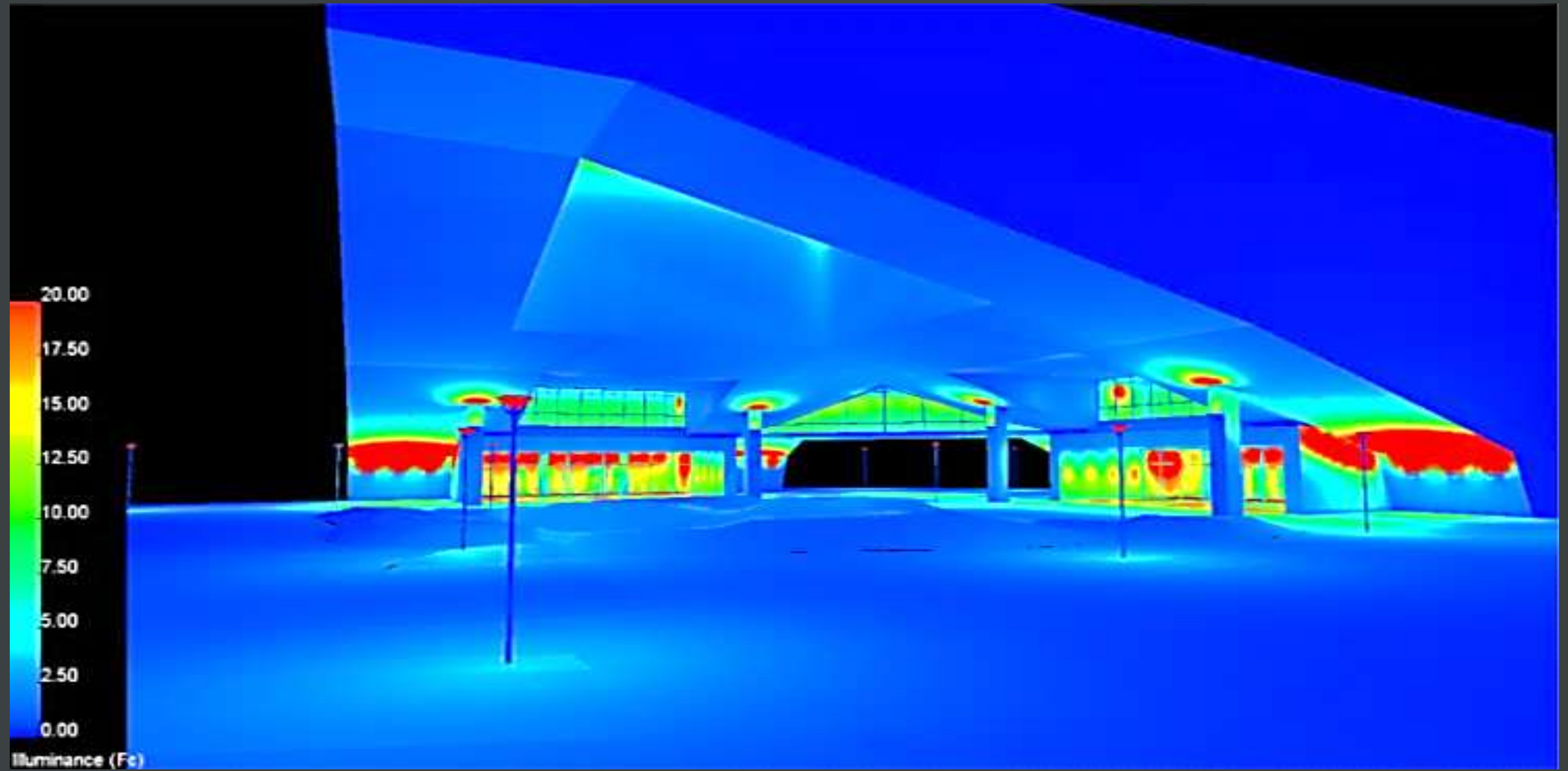
Exterior Plaza Lighting Design

Plan View

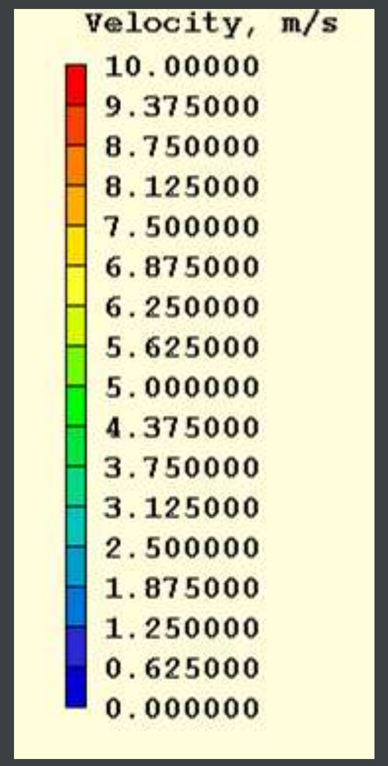
Section View



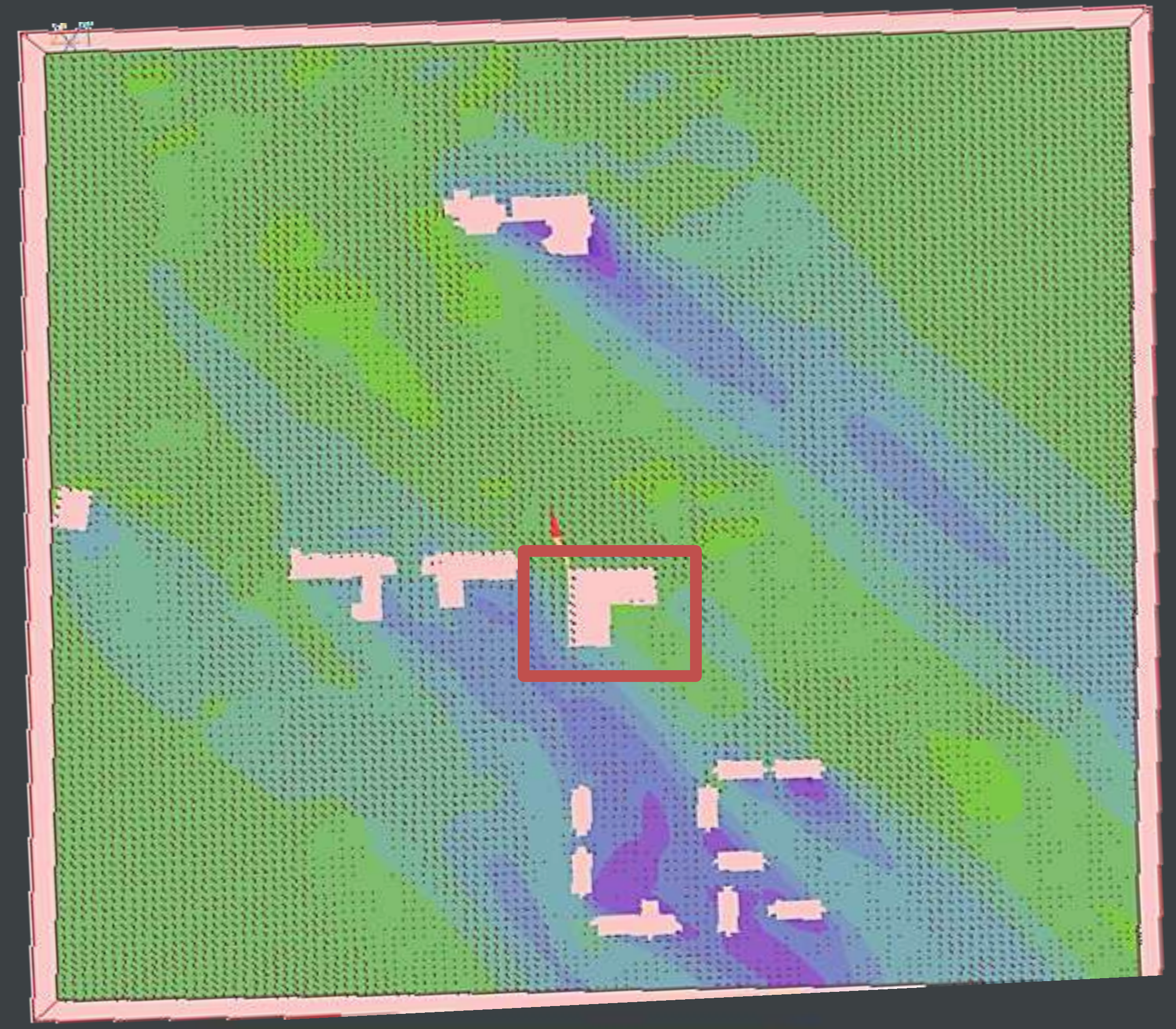
Pseudo Color Rendering



Wind Turbine Analysis



Z-Plane : 0.5 m



Z-Plane : 24 m

Model

- Domain Size: 900 x 900 x 100 m
- Standard K-ε Chen Model
- Hybrid Scheme

Simulation Results

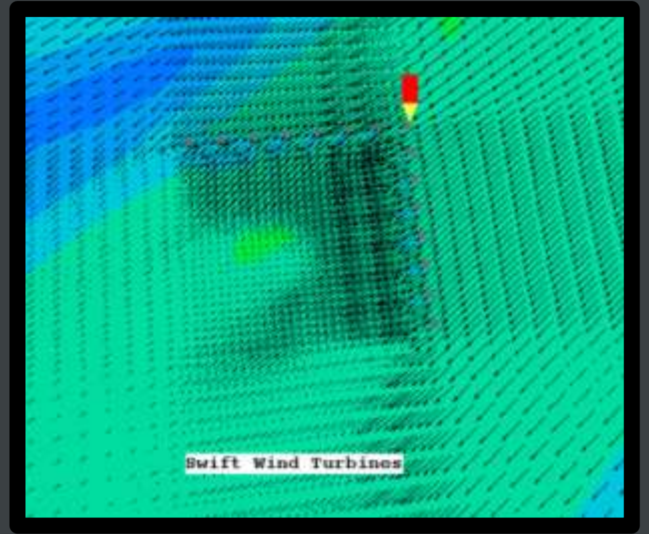
- Grid Size: 107 x 108 x 20
- Iterations: 5000
- Duration: 4 hrs. 22 min
- % Mass Residual: 0.0906%

Wind Turbine Analysis

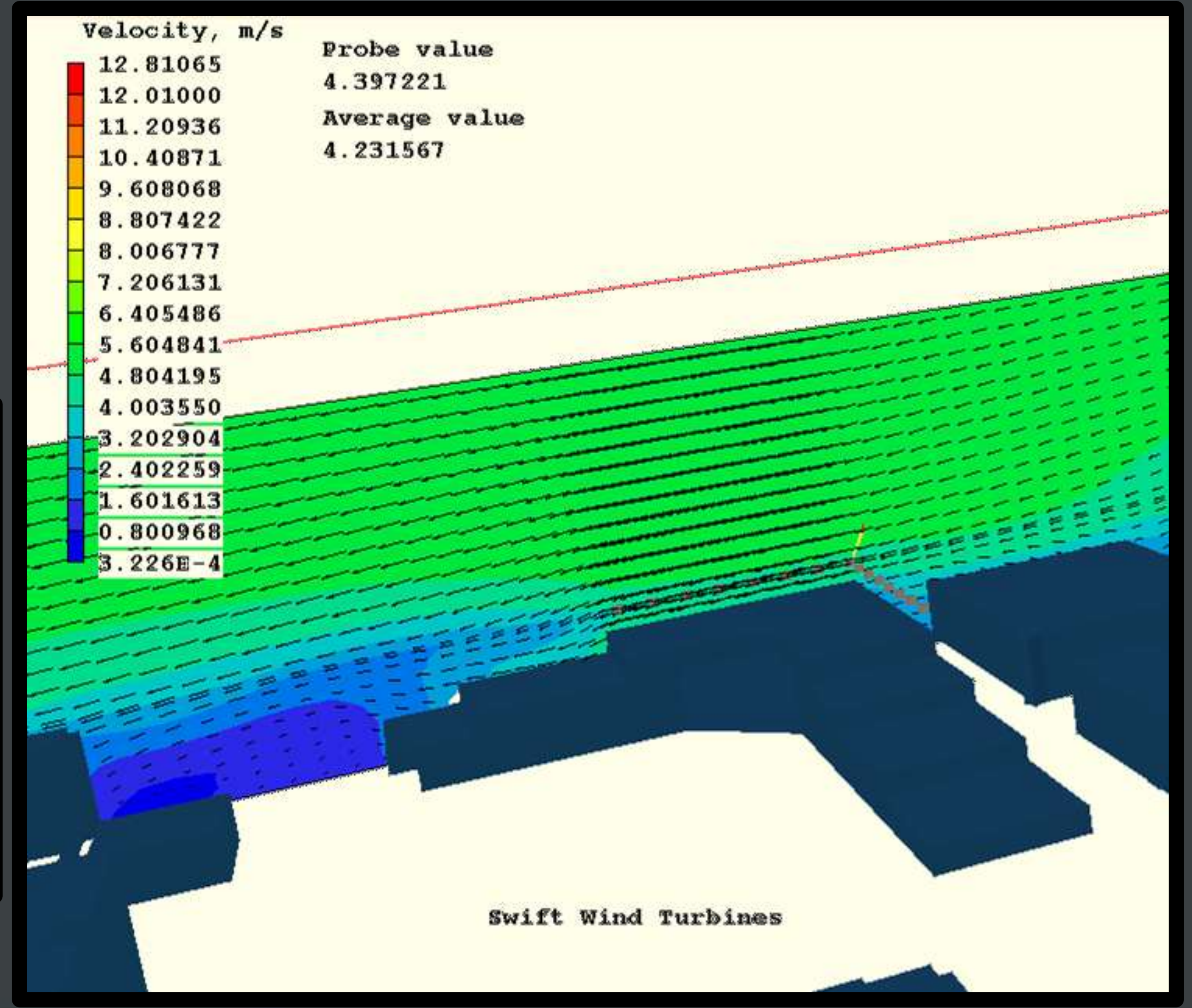
Cascade Swift Wind Turbine

- Start-up Speed: 3.58 m/s
- 1200 kWh/year at 5 m/s
- Spacing Requirements: 22 ft

- Grid Size: 123 x 134 x 22
- Iterations: 3000
- Duration: 4 hrs. 48 min
- Mass Residual: 0.166%



Z-Plane : 30 m



Final Results

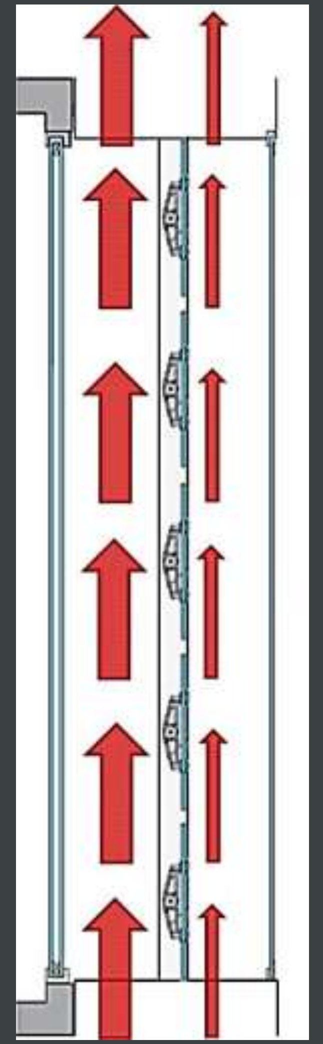
- 18 turbines
- Total Array: 21,600 kWh/year
- Cost: $8,500/unit
- Total savings: $1,624

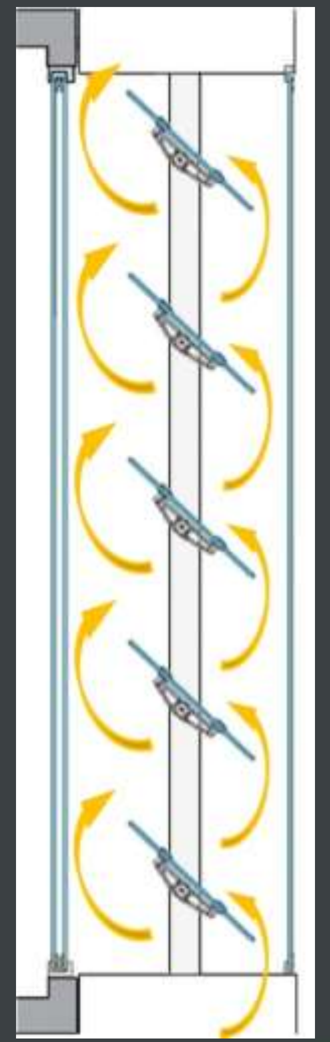
Building Stimulus Façade Design Goals

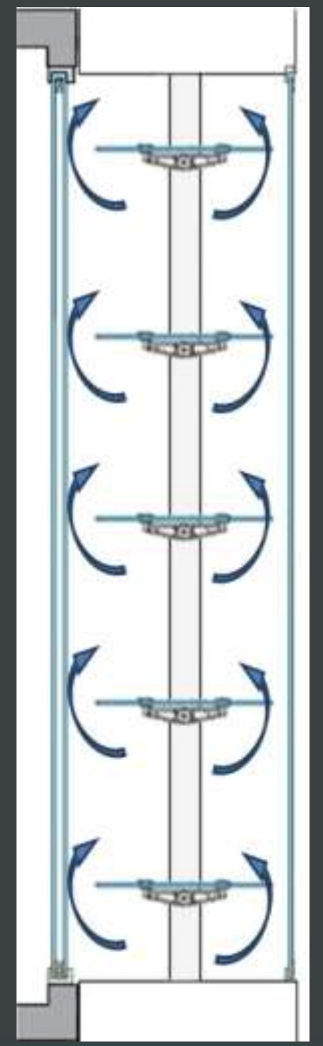
- Increase Thermal Efficiency
- Reduce Precast Panel Weight
- Create Efficient Construction Process
- Daylighting Integration& User Comfort

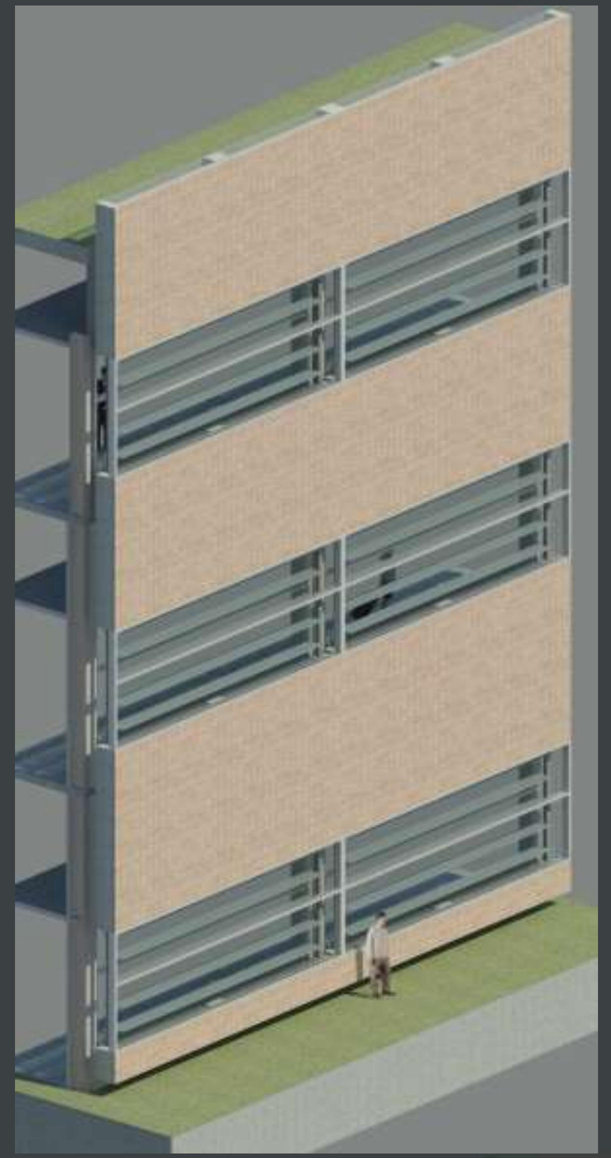
Double Skin Facade

- Two Glazing Configurations
- Large Cavity Space
  - Thermal Barrier
  - Daylighting Integration



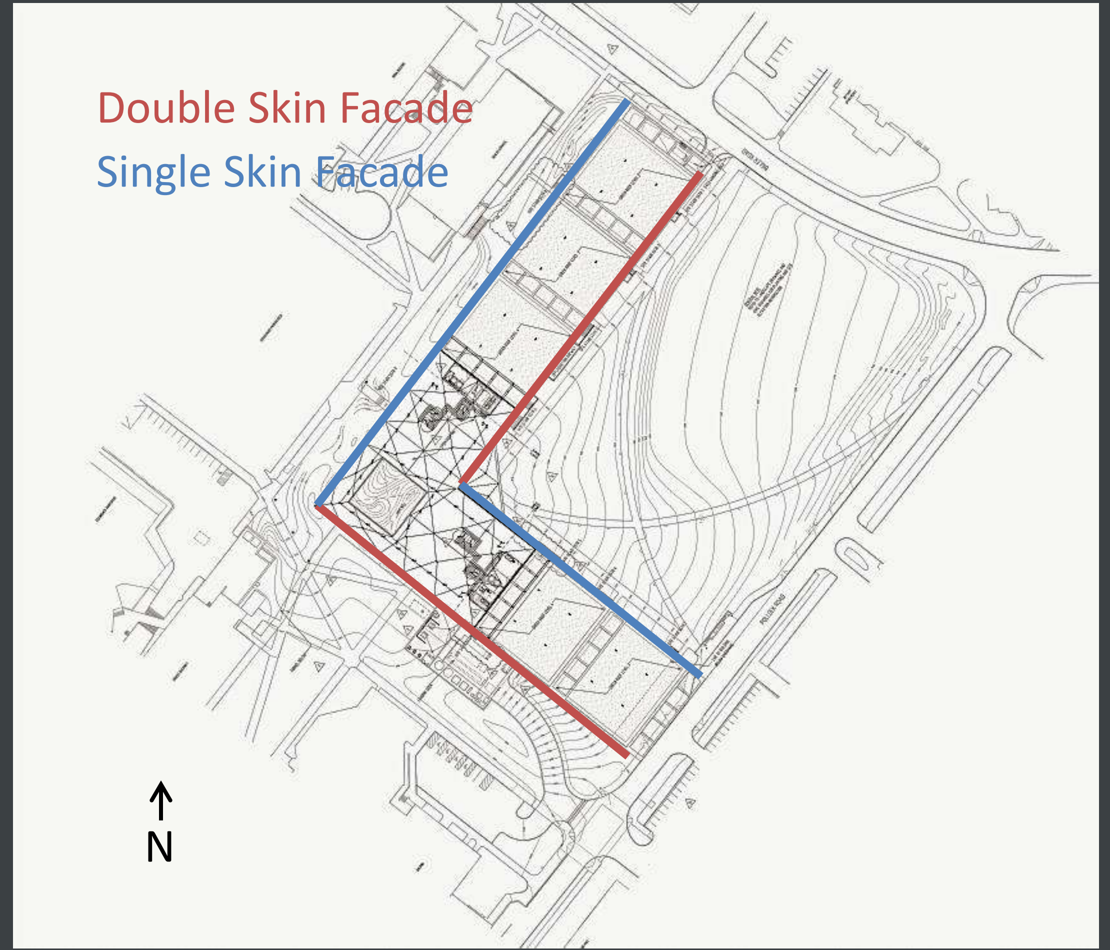




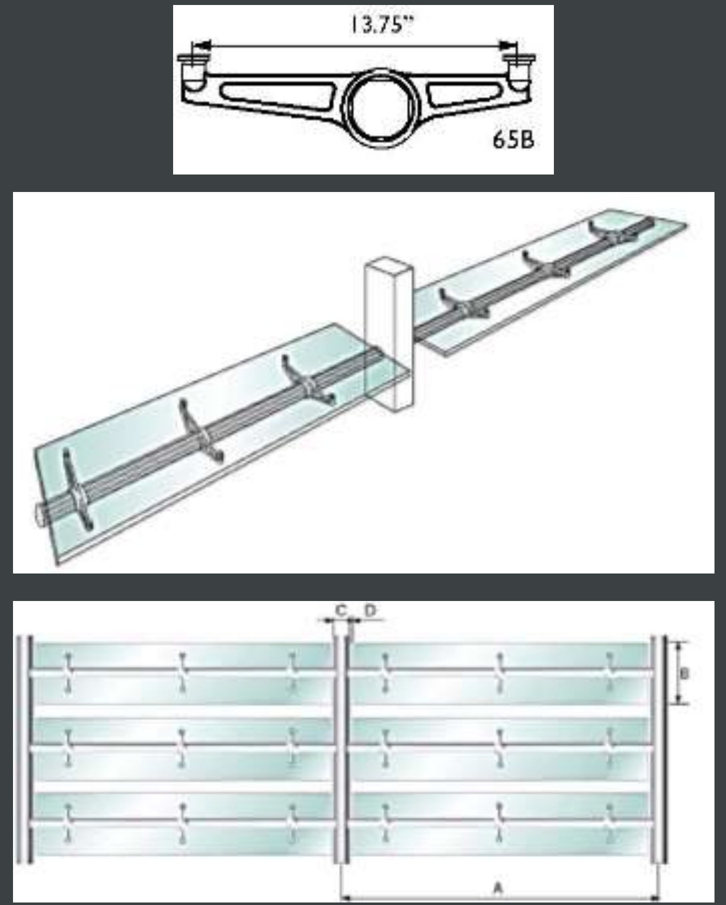


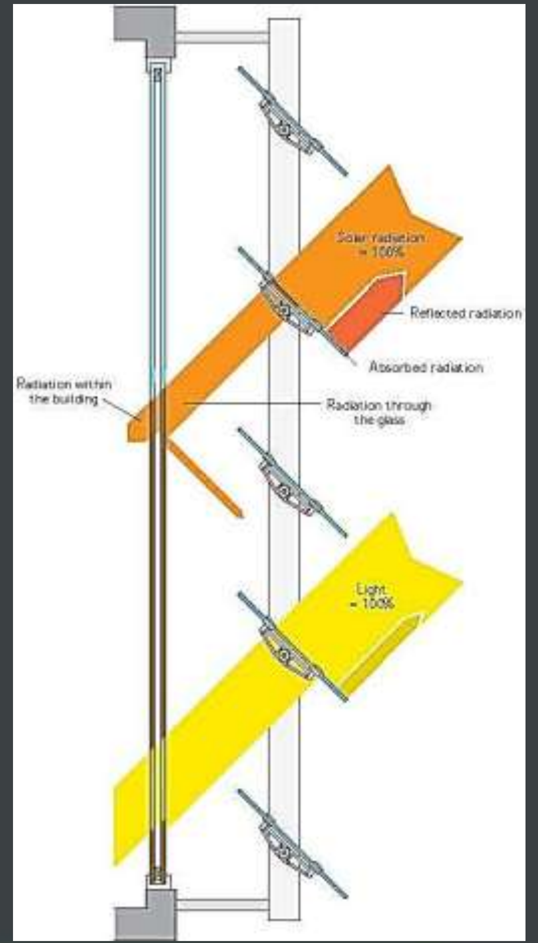
Daylighting Integration

Building Orientation

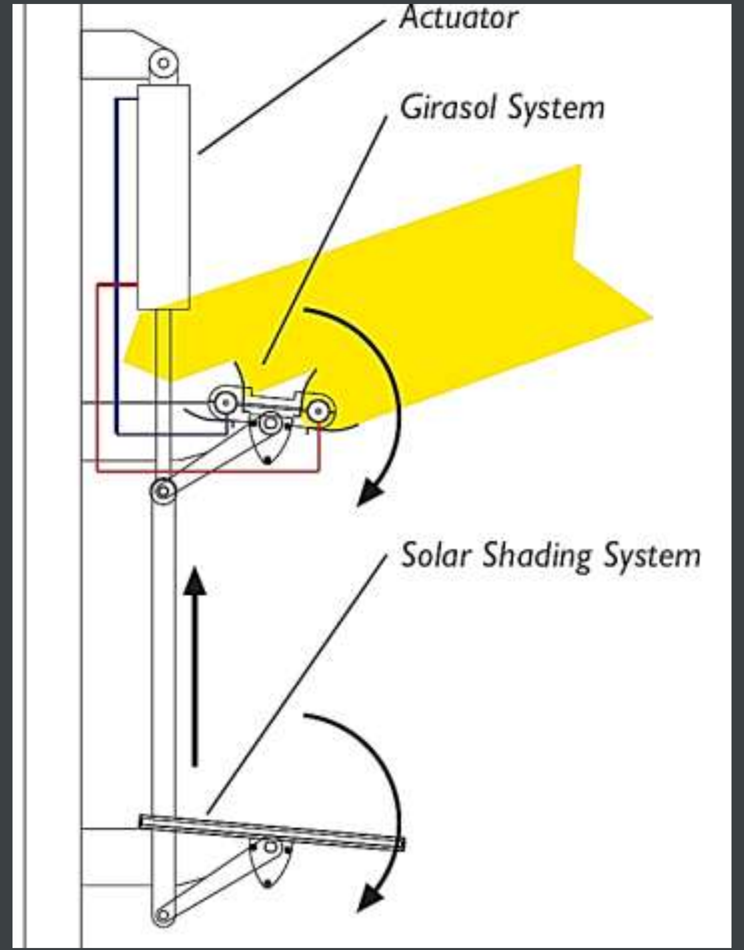


Double Skin Shading System





Shading Control



- Girasol System
- Requires No Electricity

Daylighting Integration

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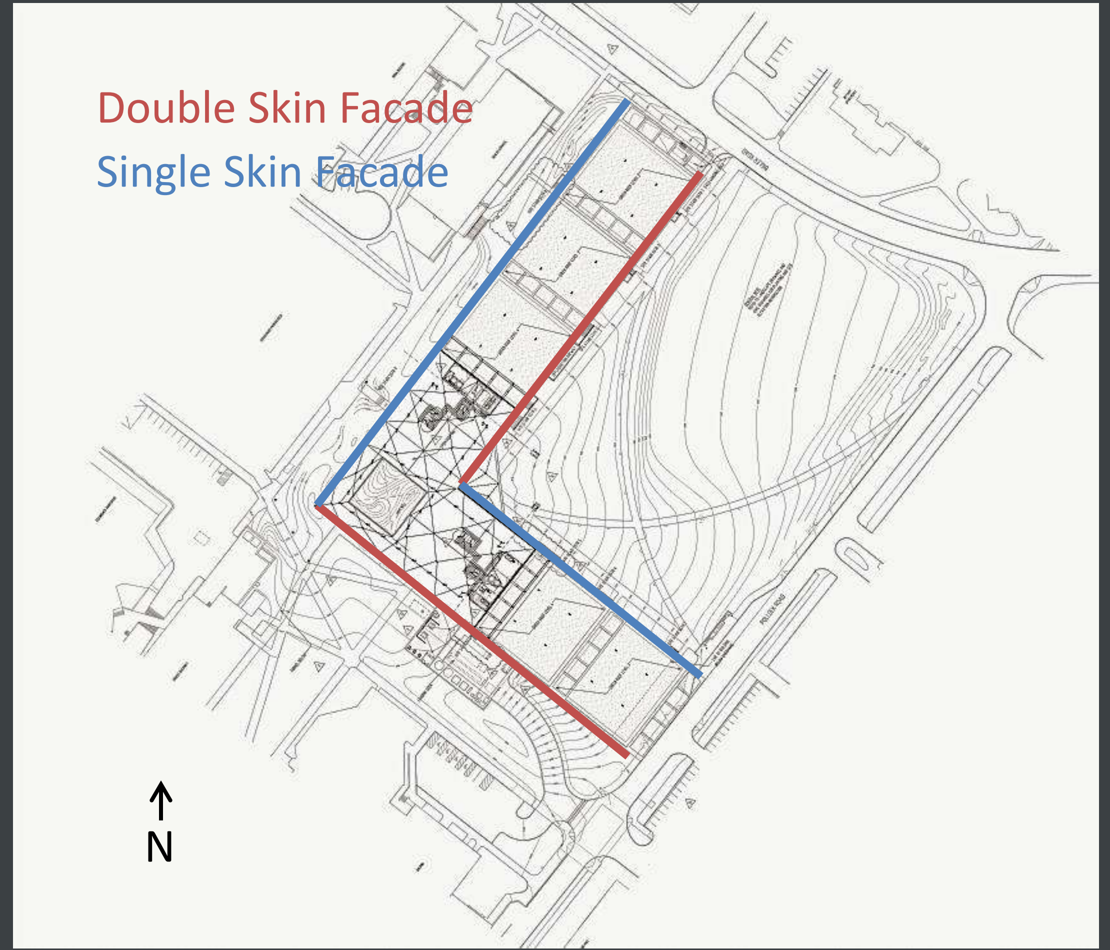

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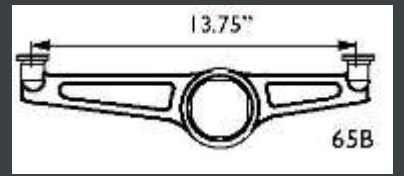

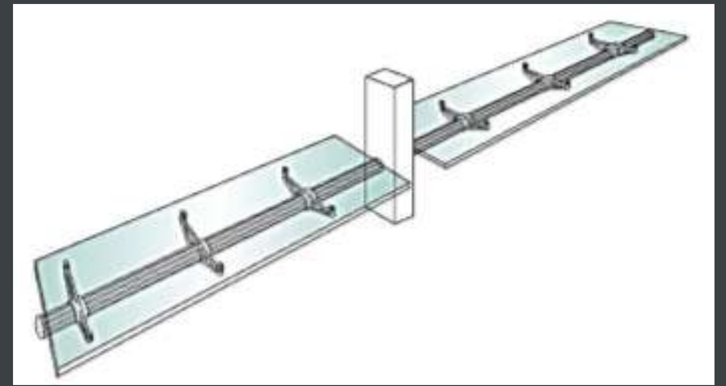

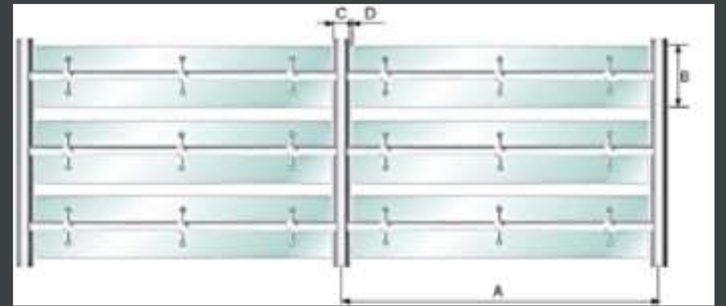

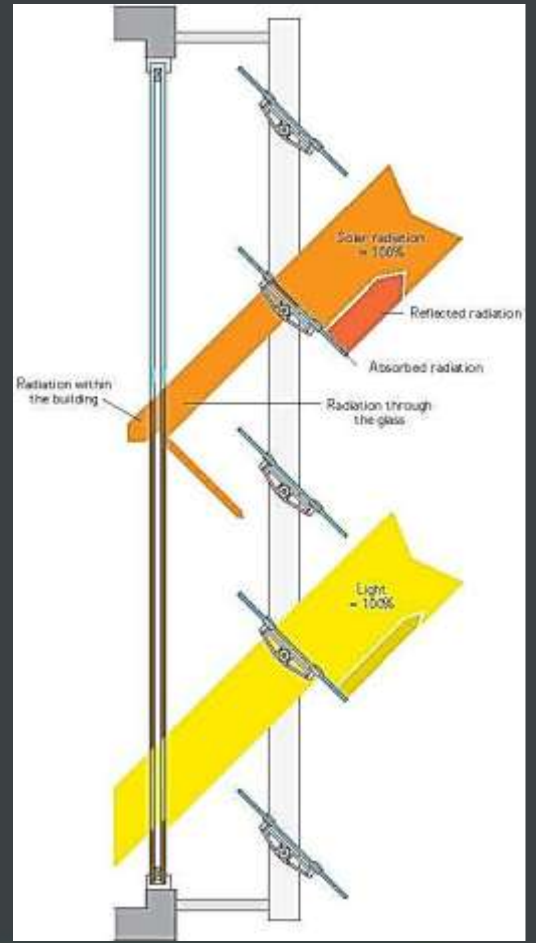

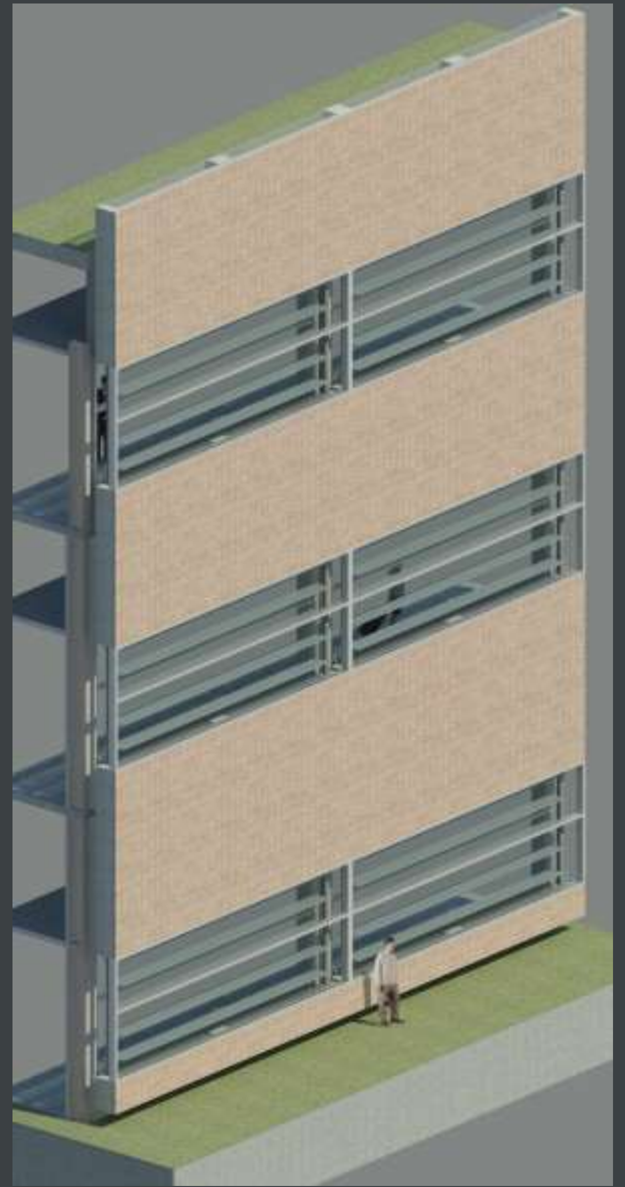

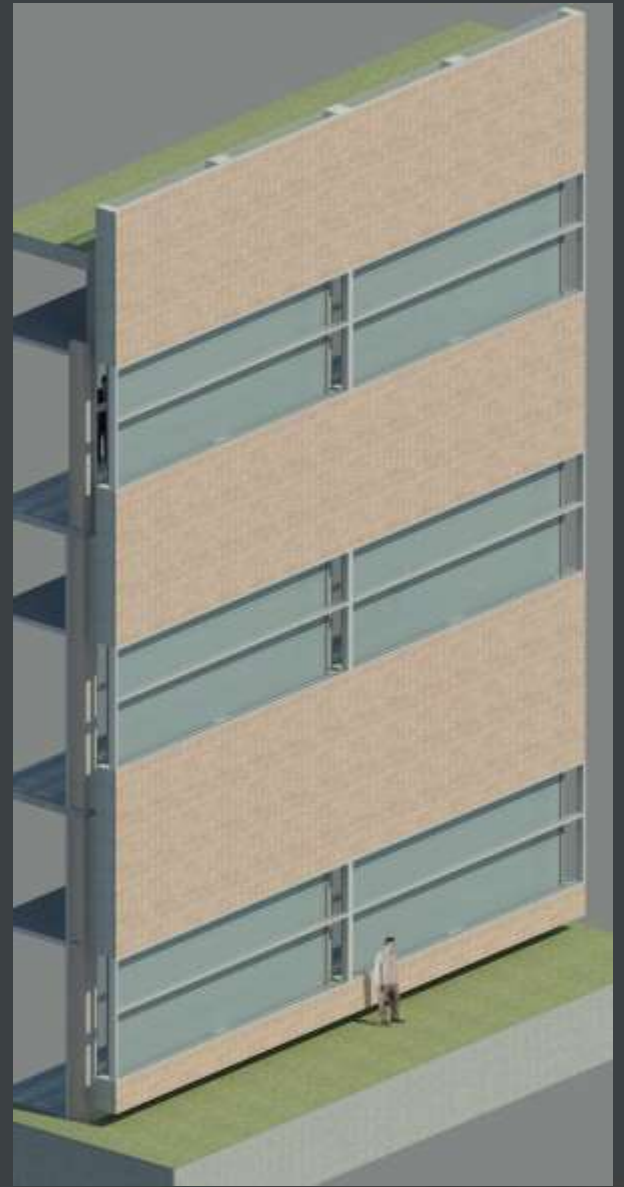

Daylighting Integration

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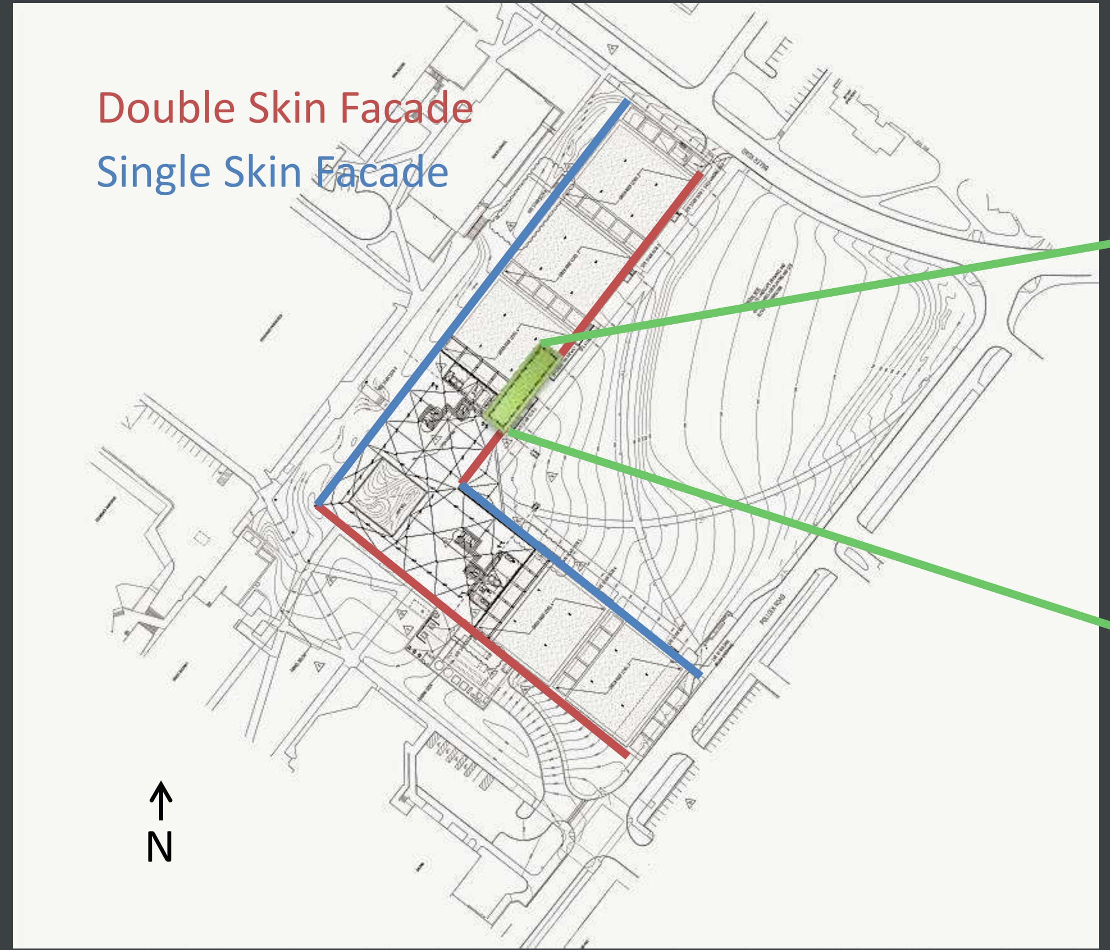
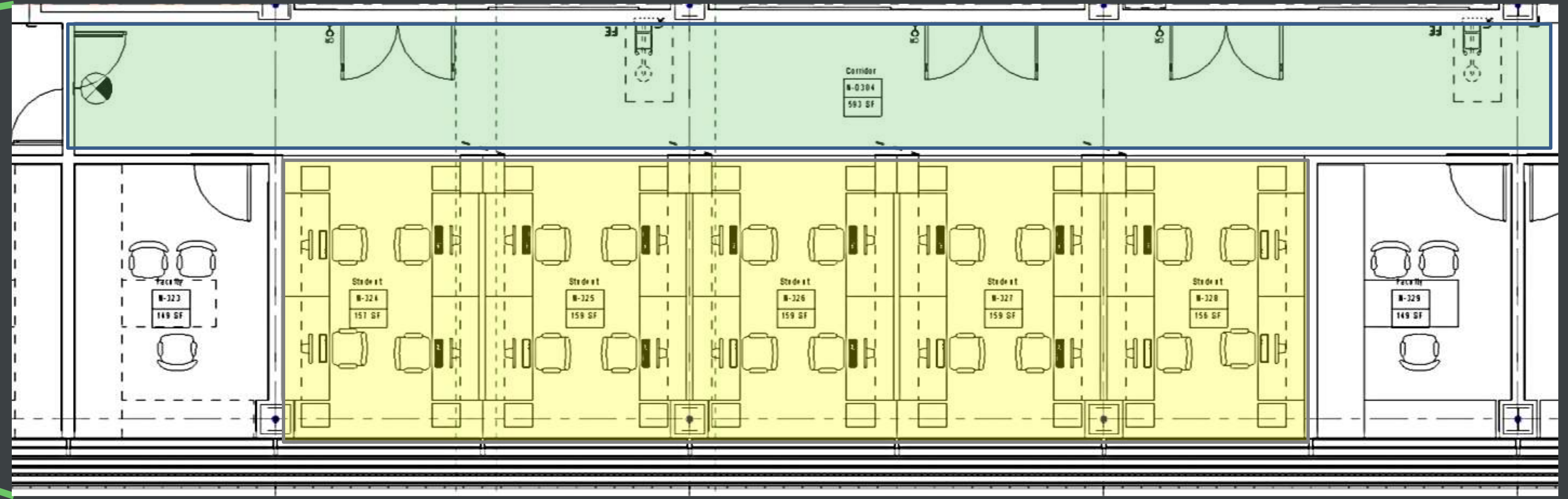
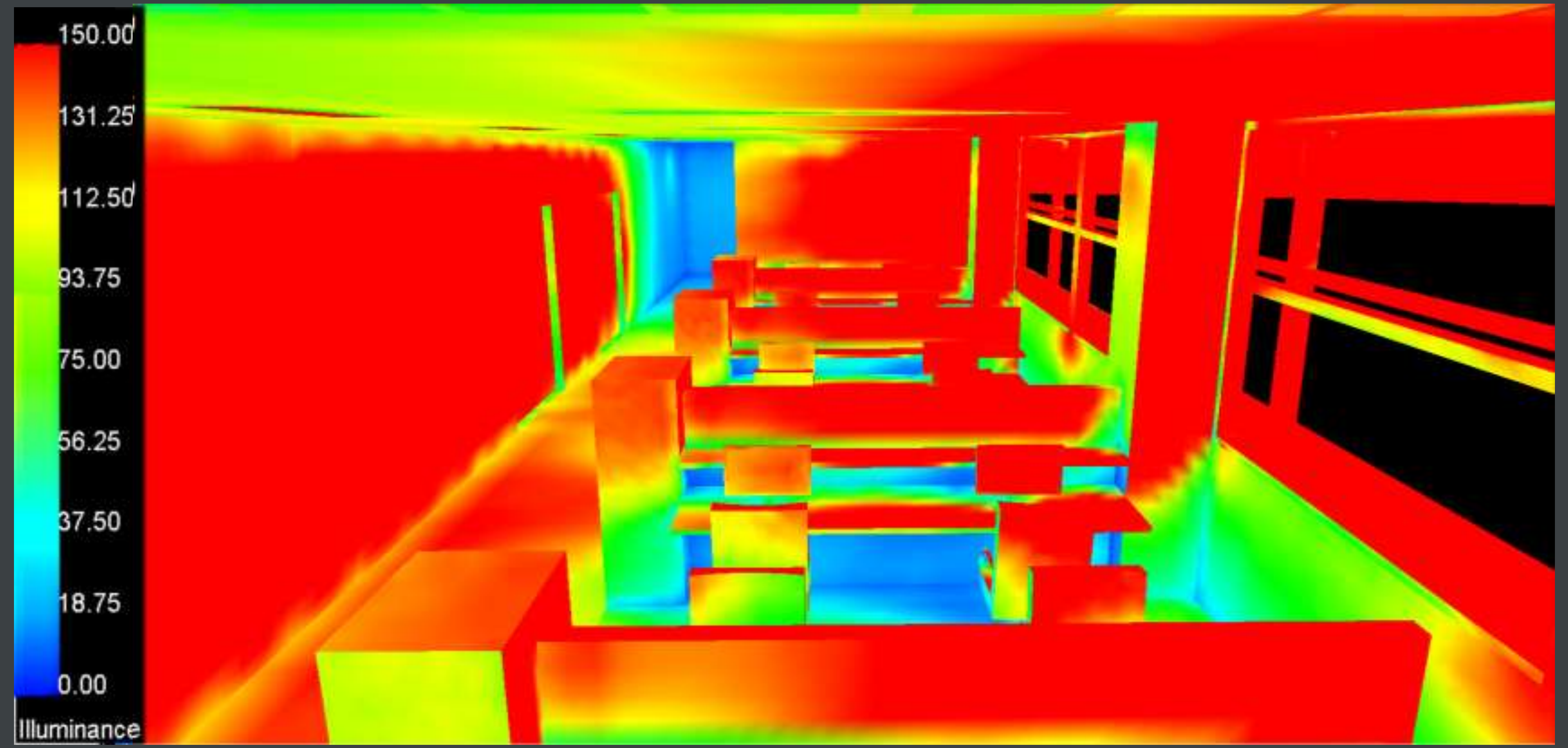


Student Study Area & Corridor Layout



Pseudo Color Rendering – 6.21 10AM



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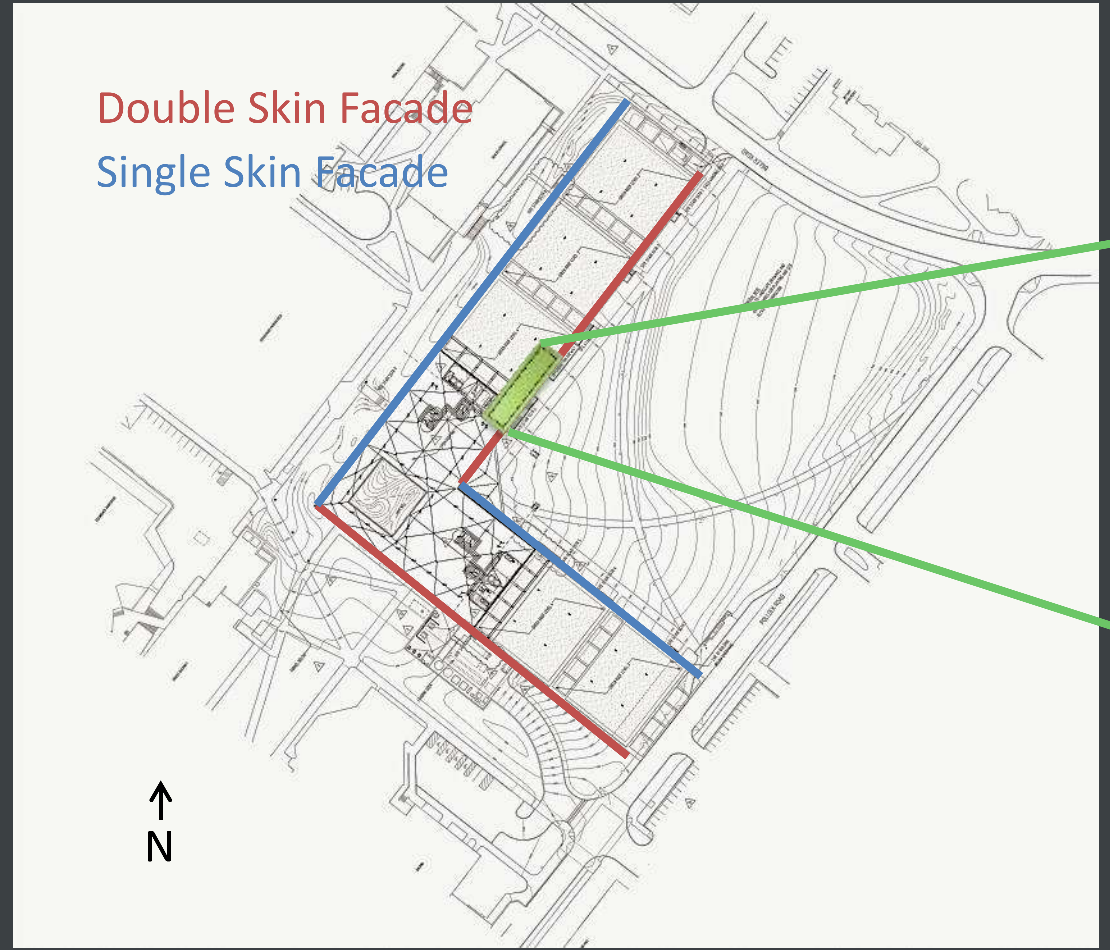

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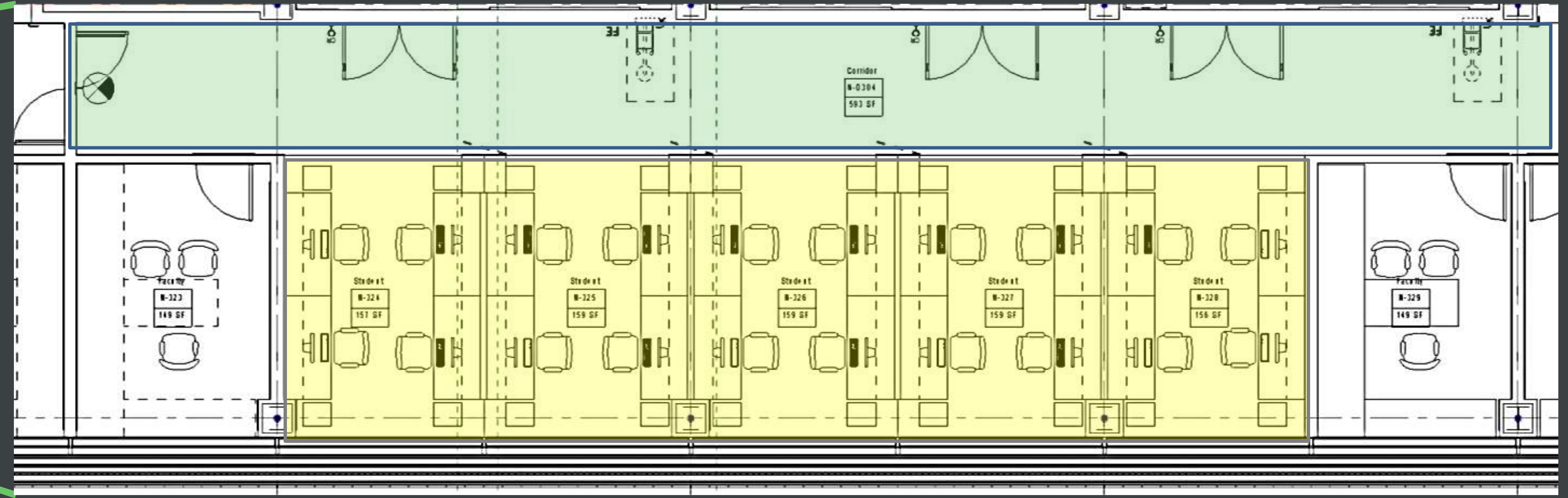
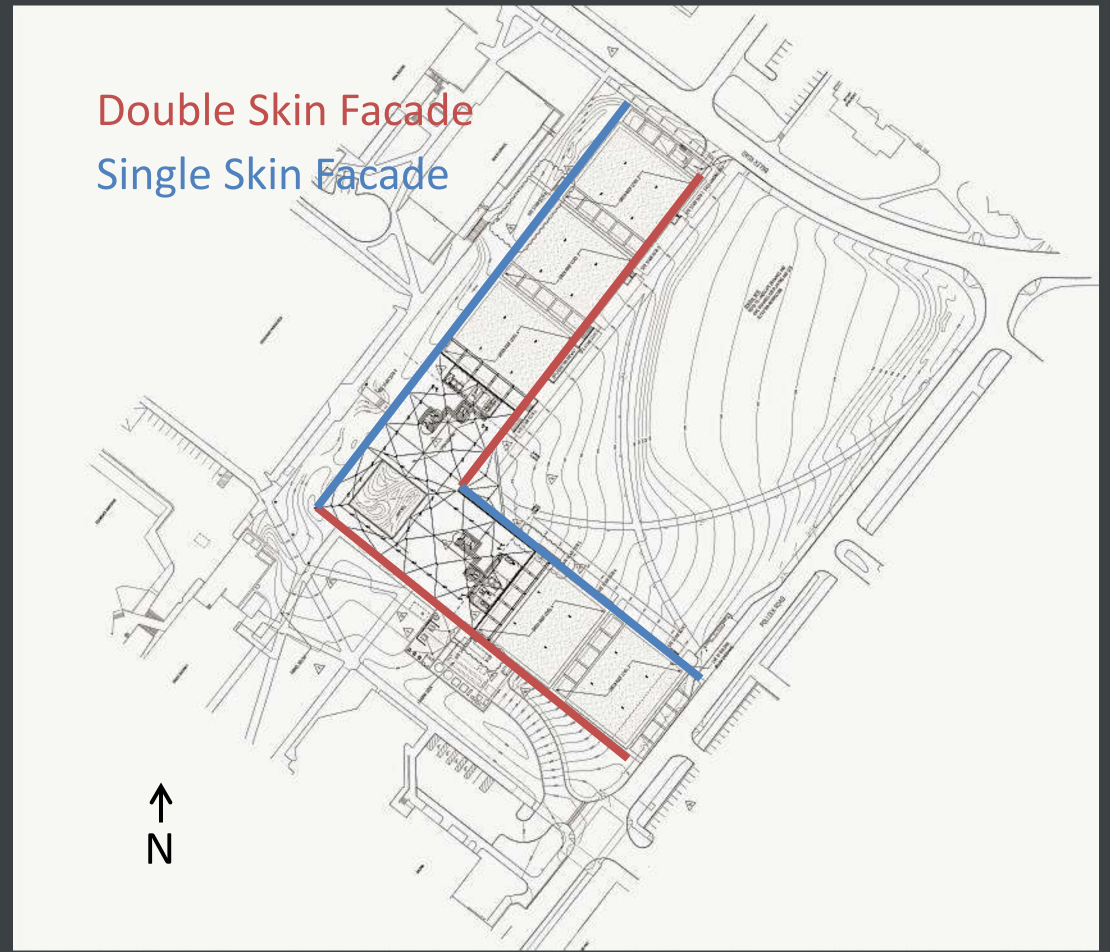
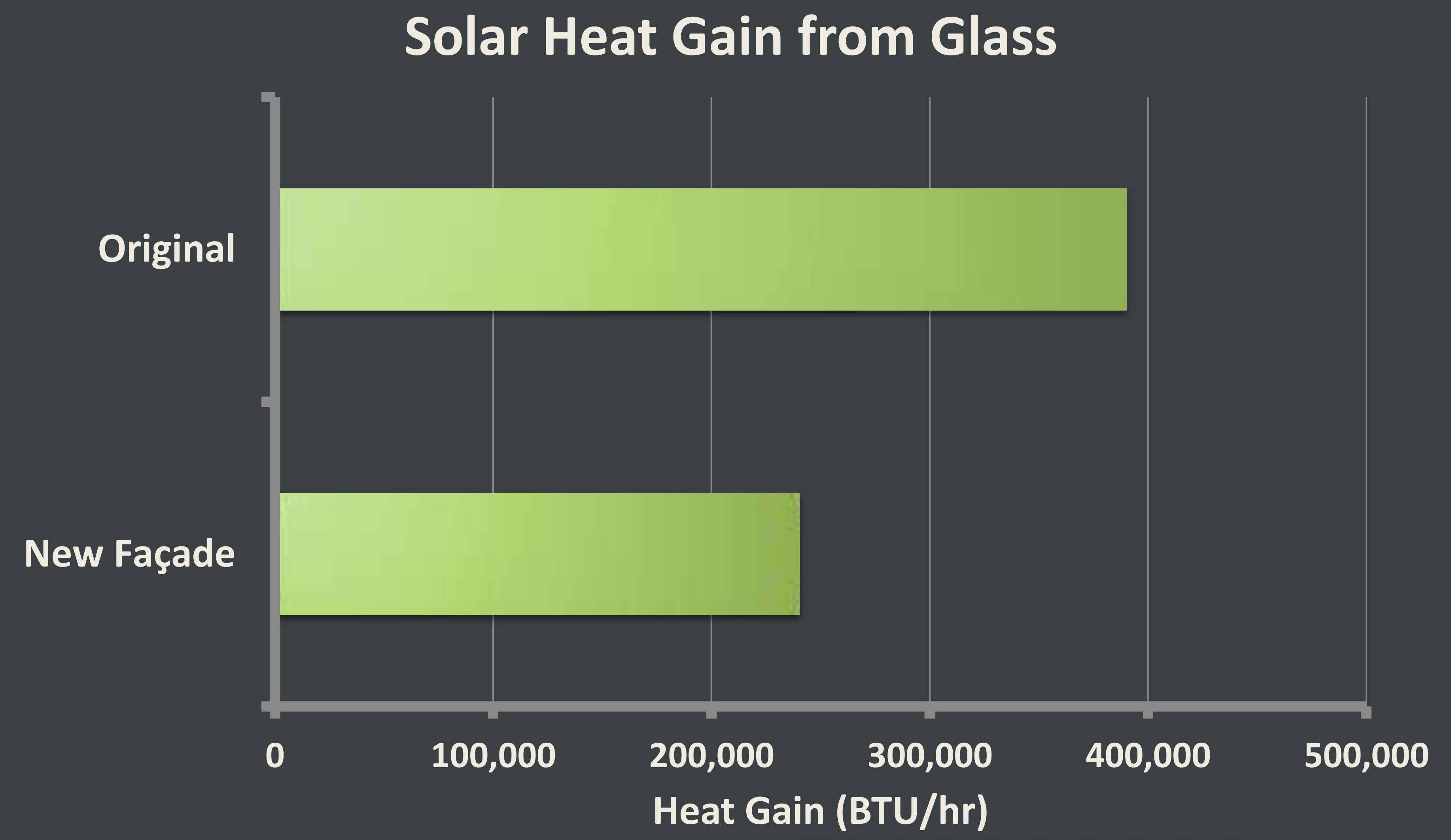


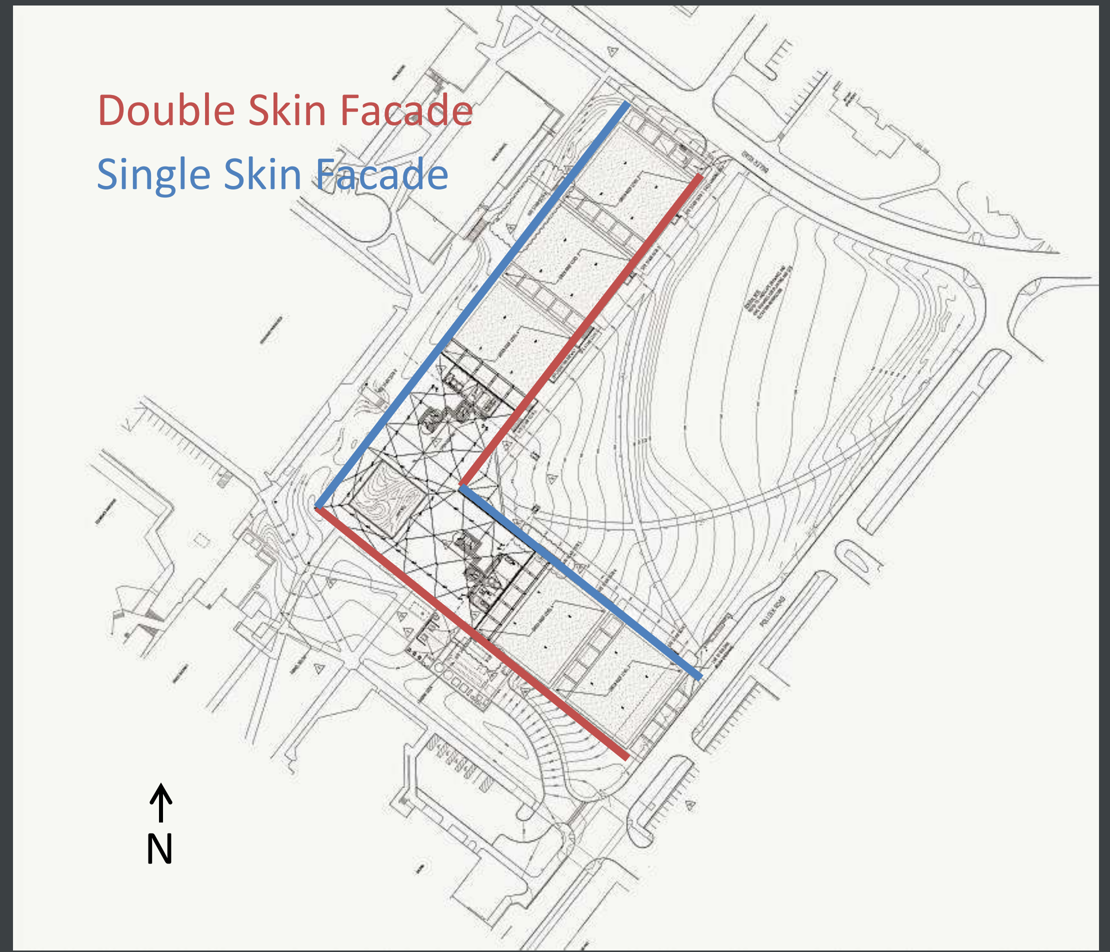
Color Rendering – 6.21 10AM

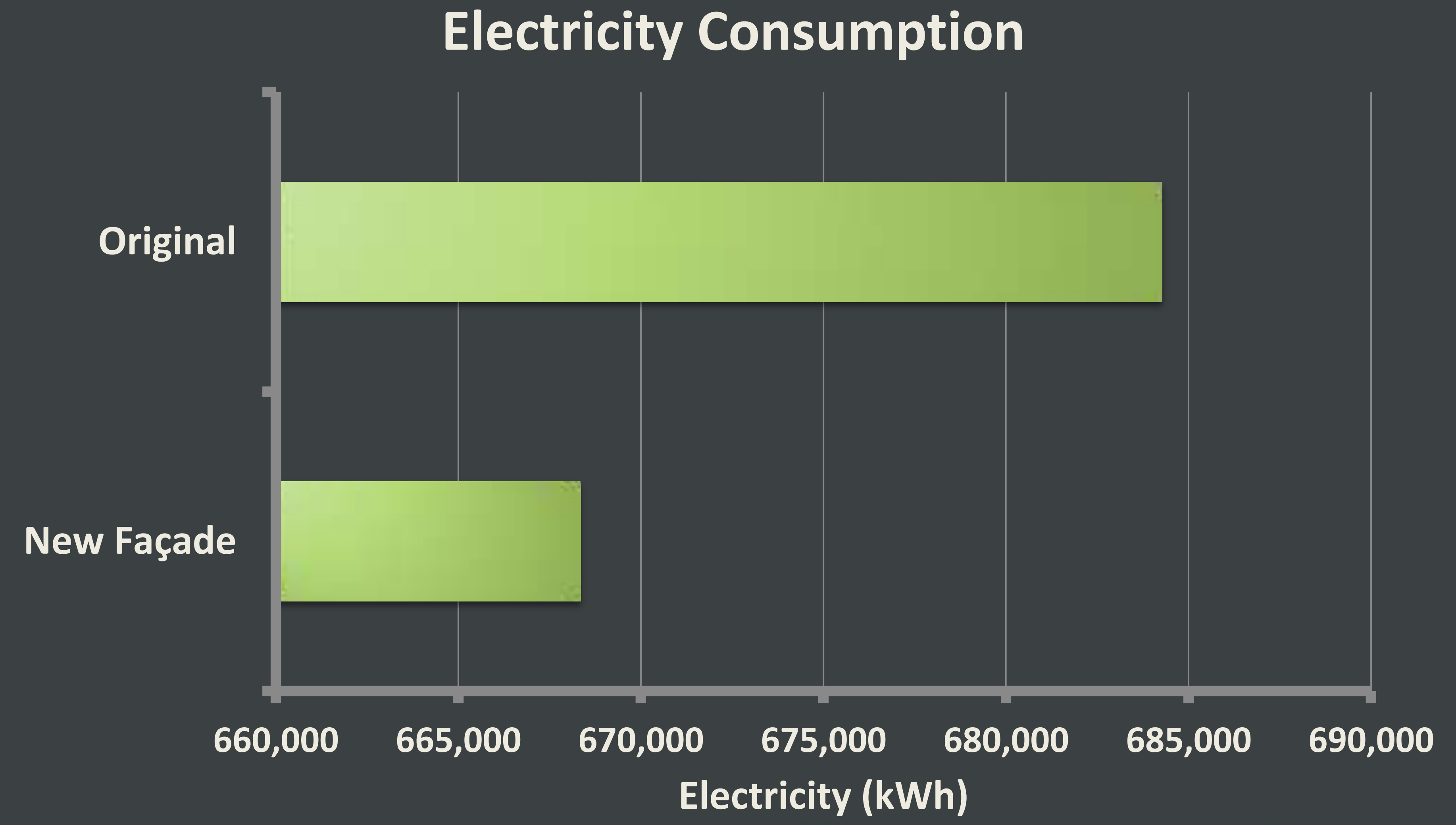
Energy Performance

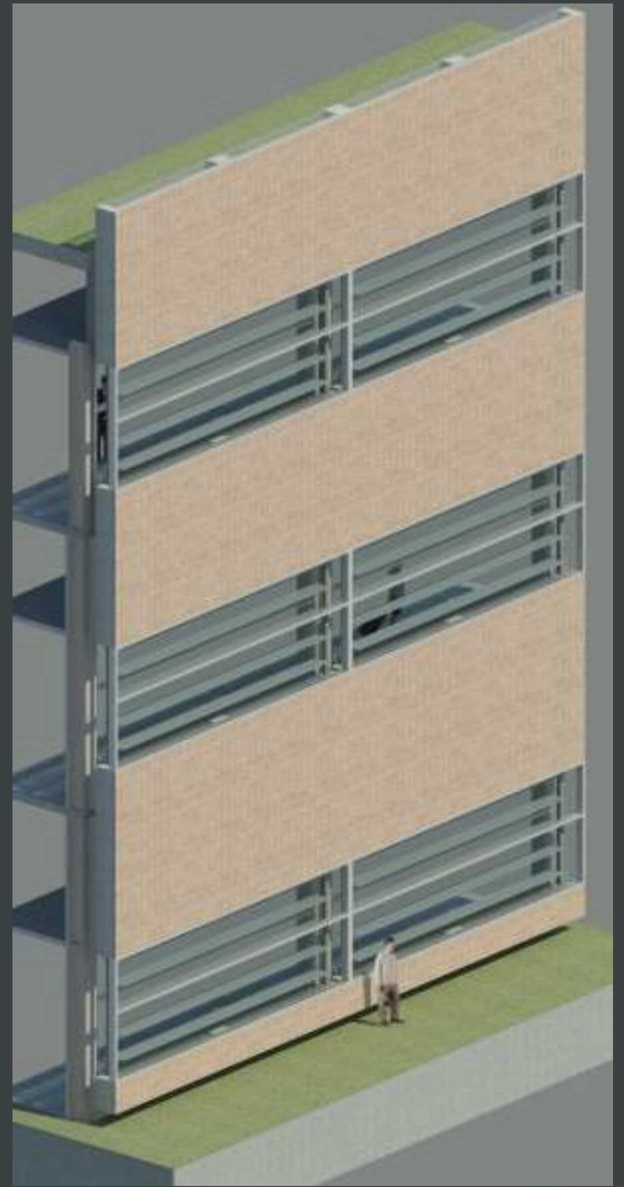




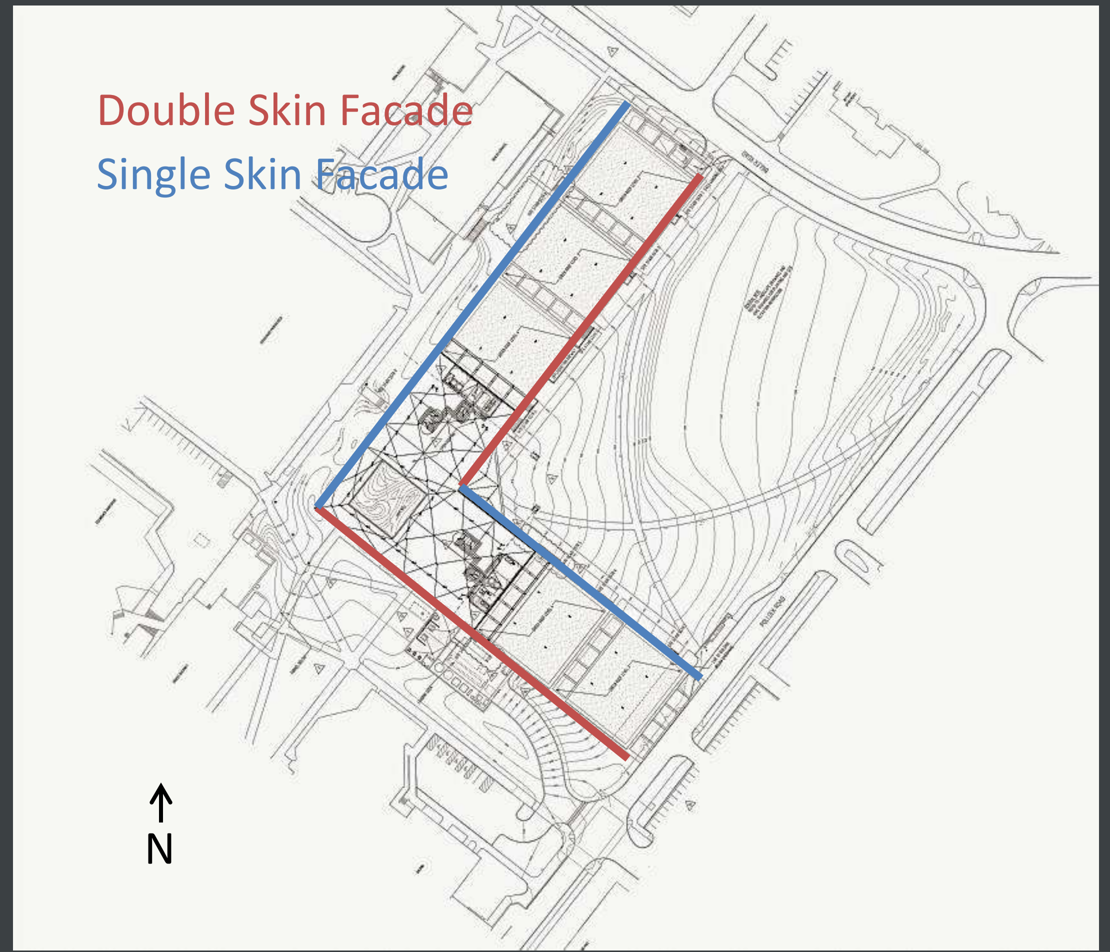
Energy Performance

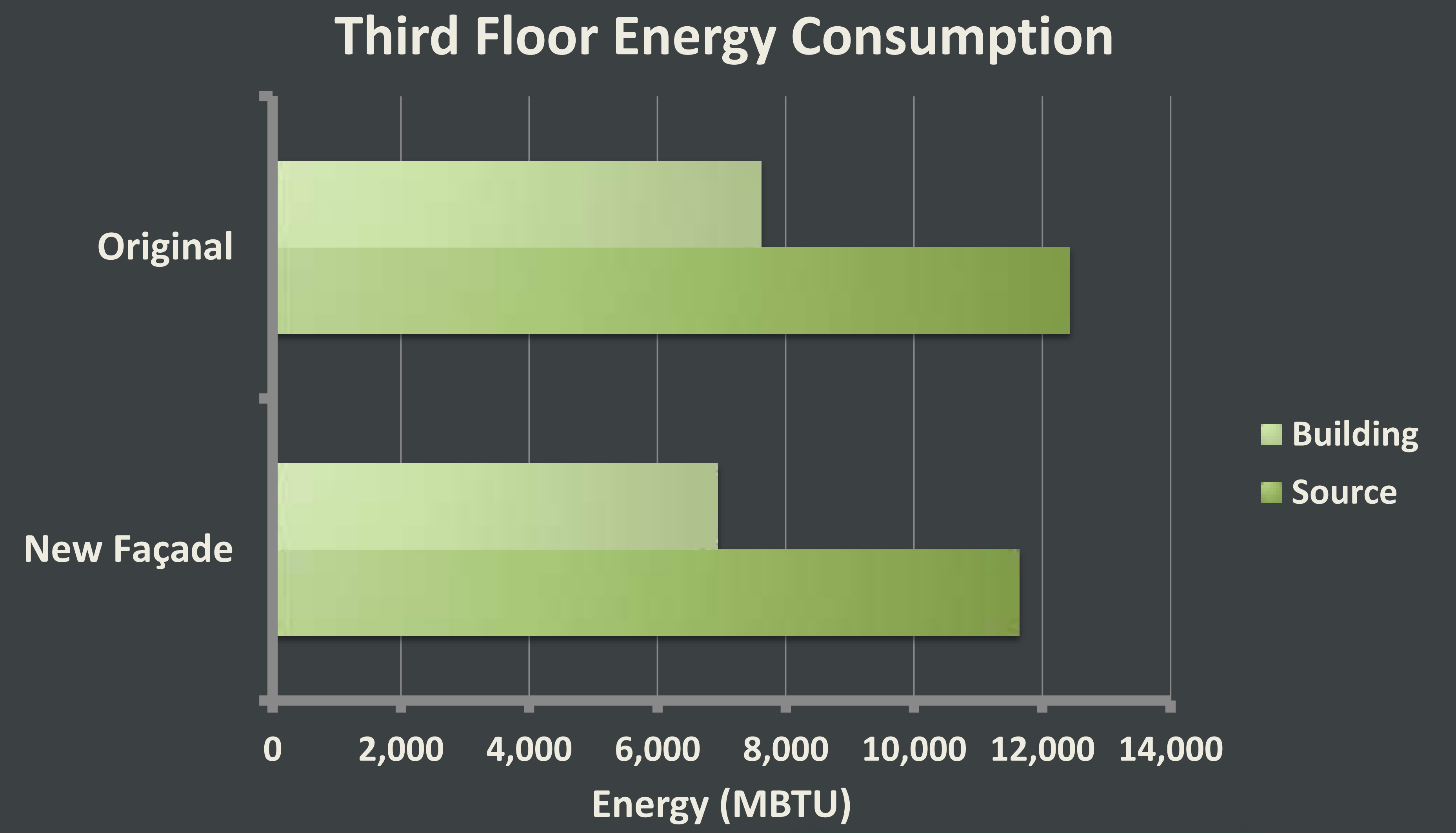




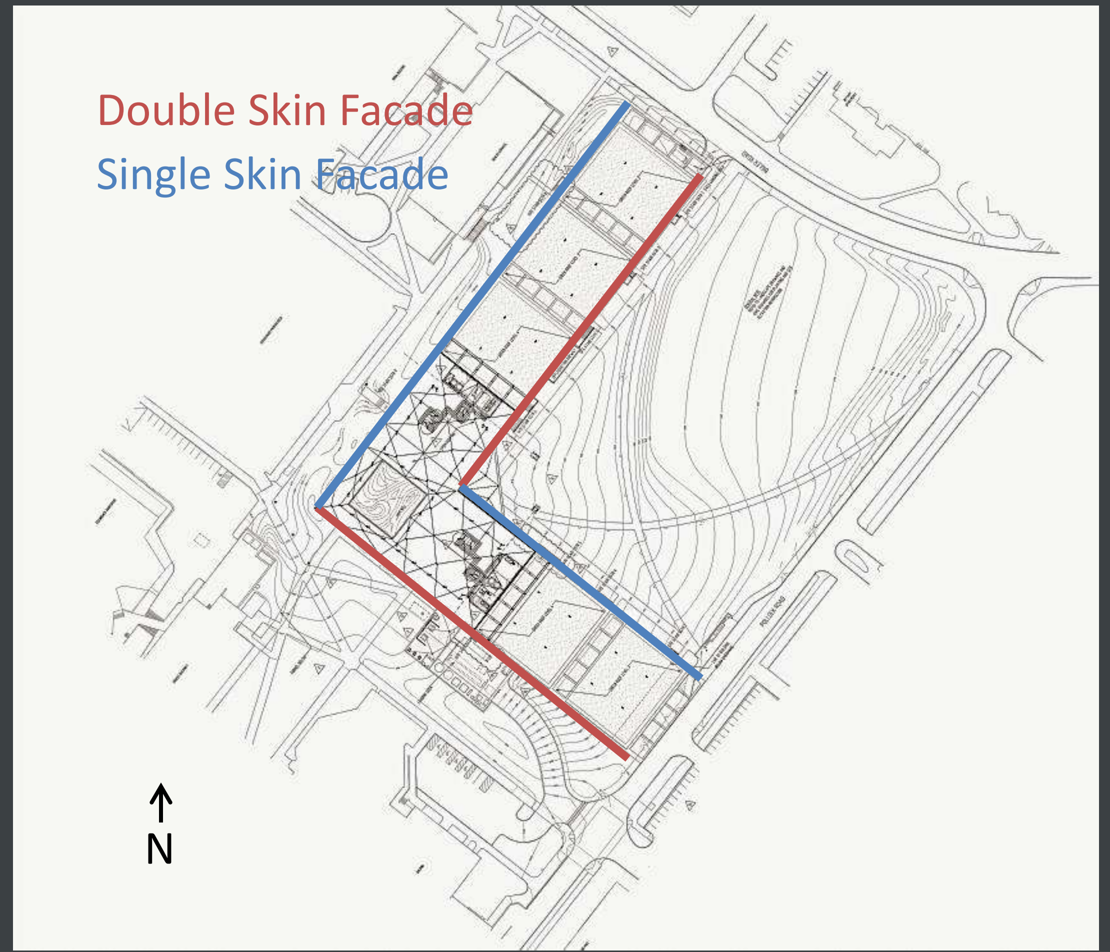


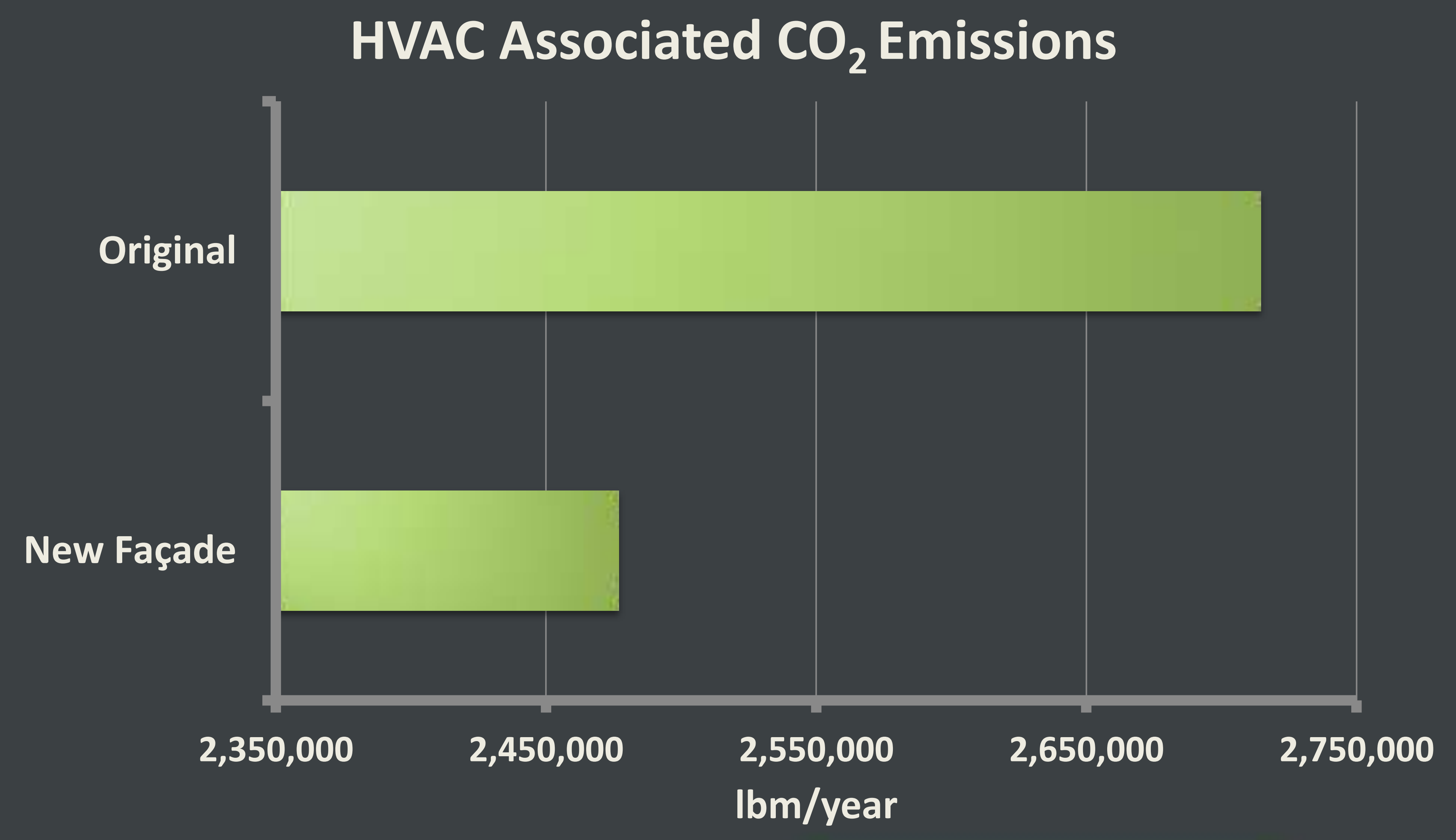
Energy Performance



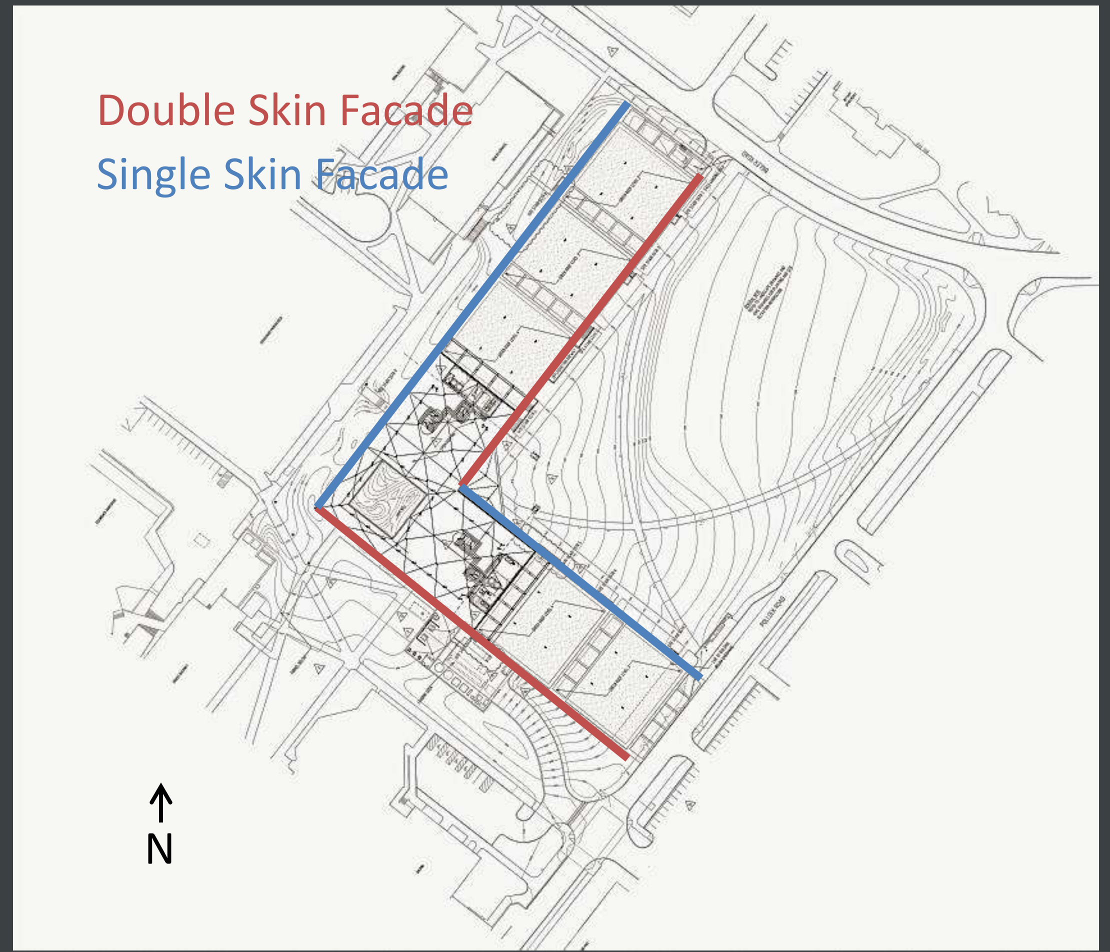


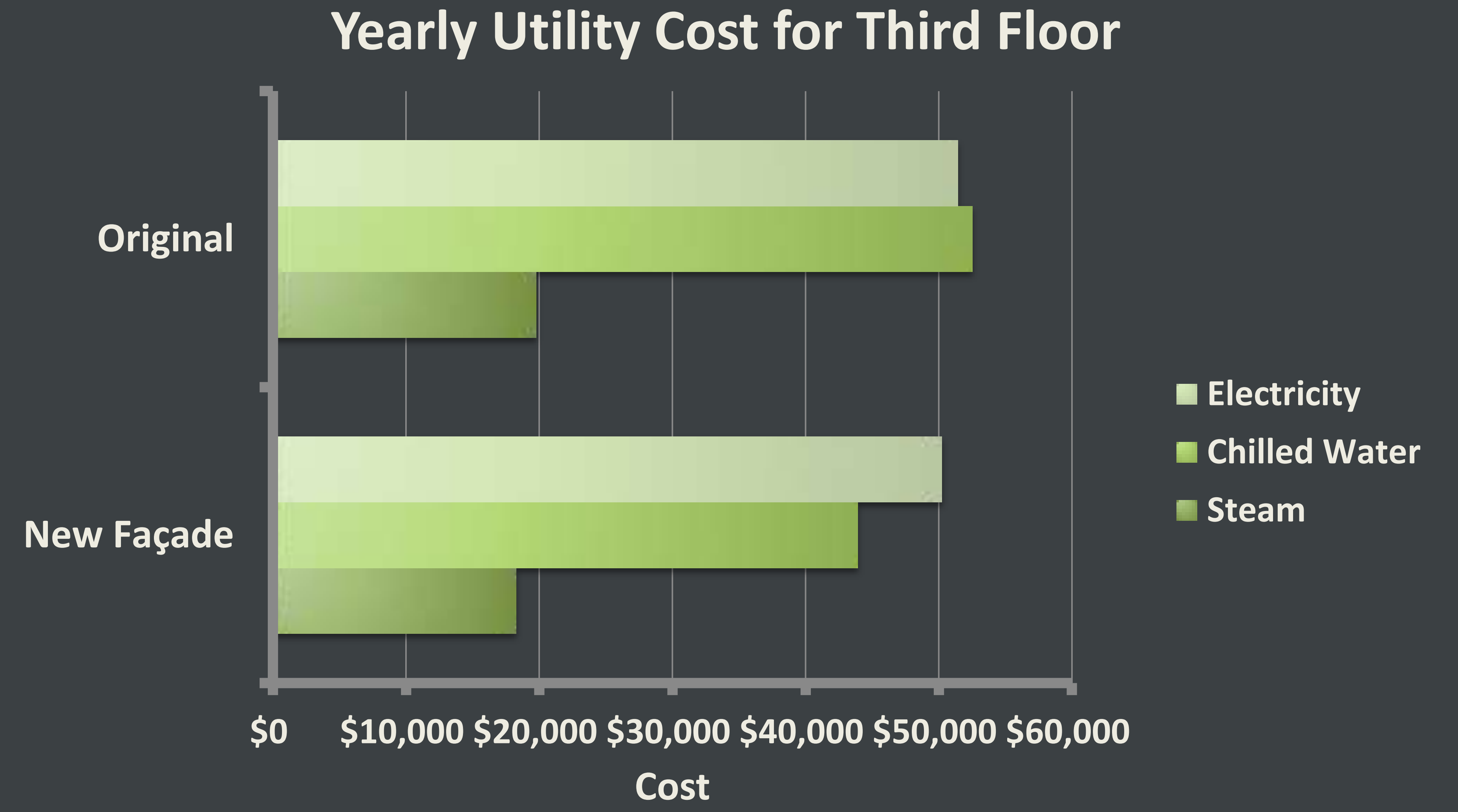
Energy Performance

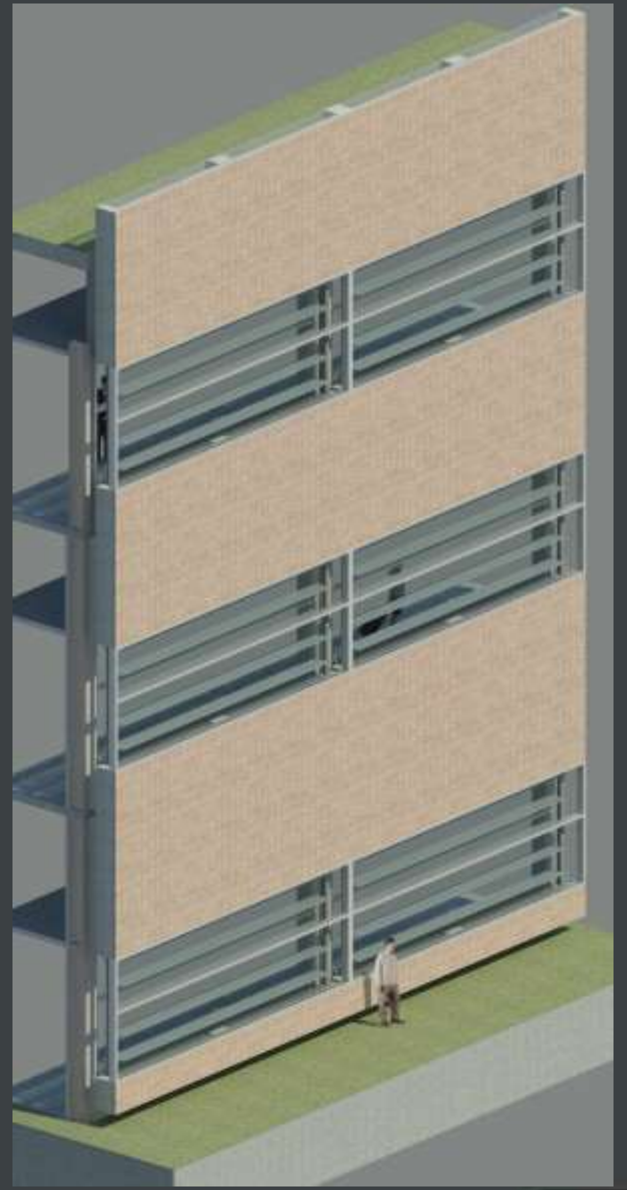




Energy Performance





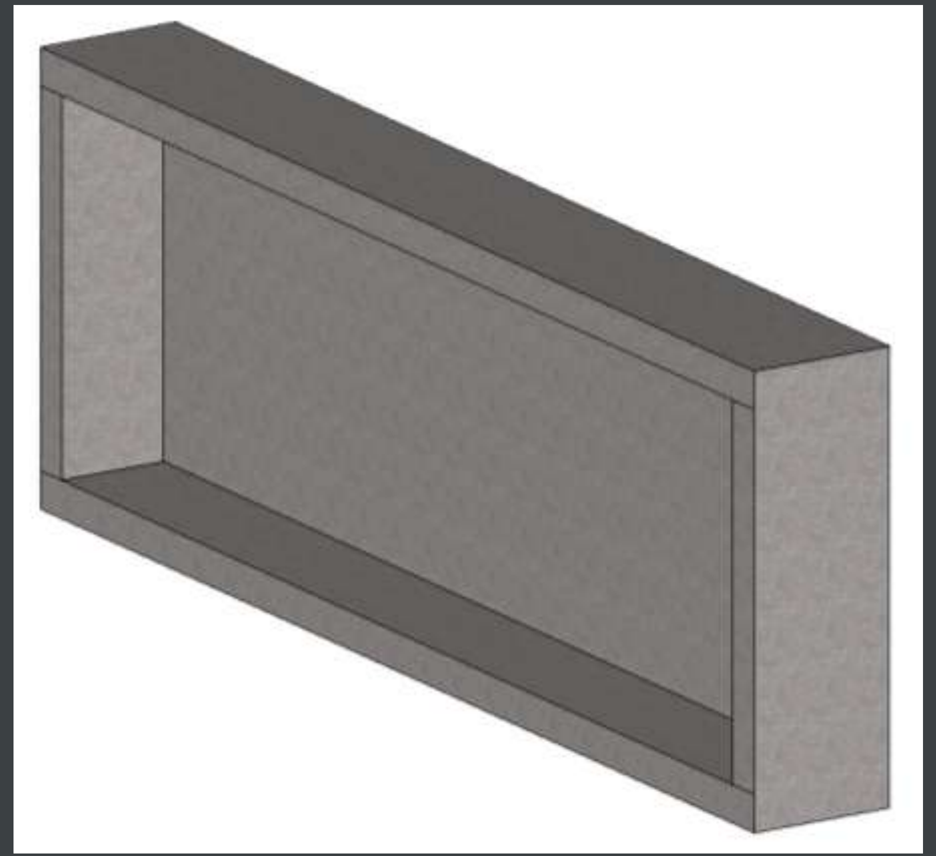


Precast Panel Design

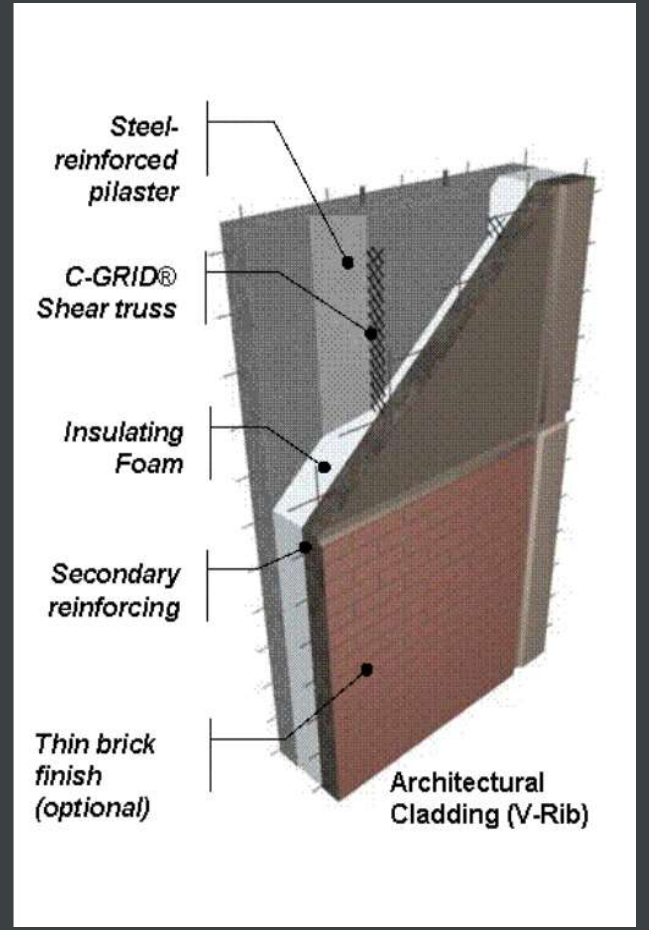
Design Goals/Tolerances

- Reduce weight of panel
- 24 in. air gap between inner face of precast panel and outer face of interior wall.
- Maintain continuous vertical air gap
- No cracking under transportation, construction, or service loads

Existing Precast Panel



Panel Material Research

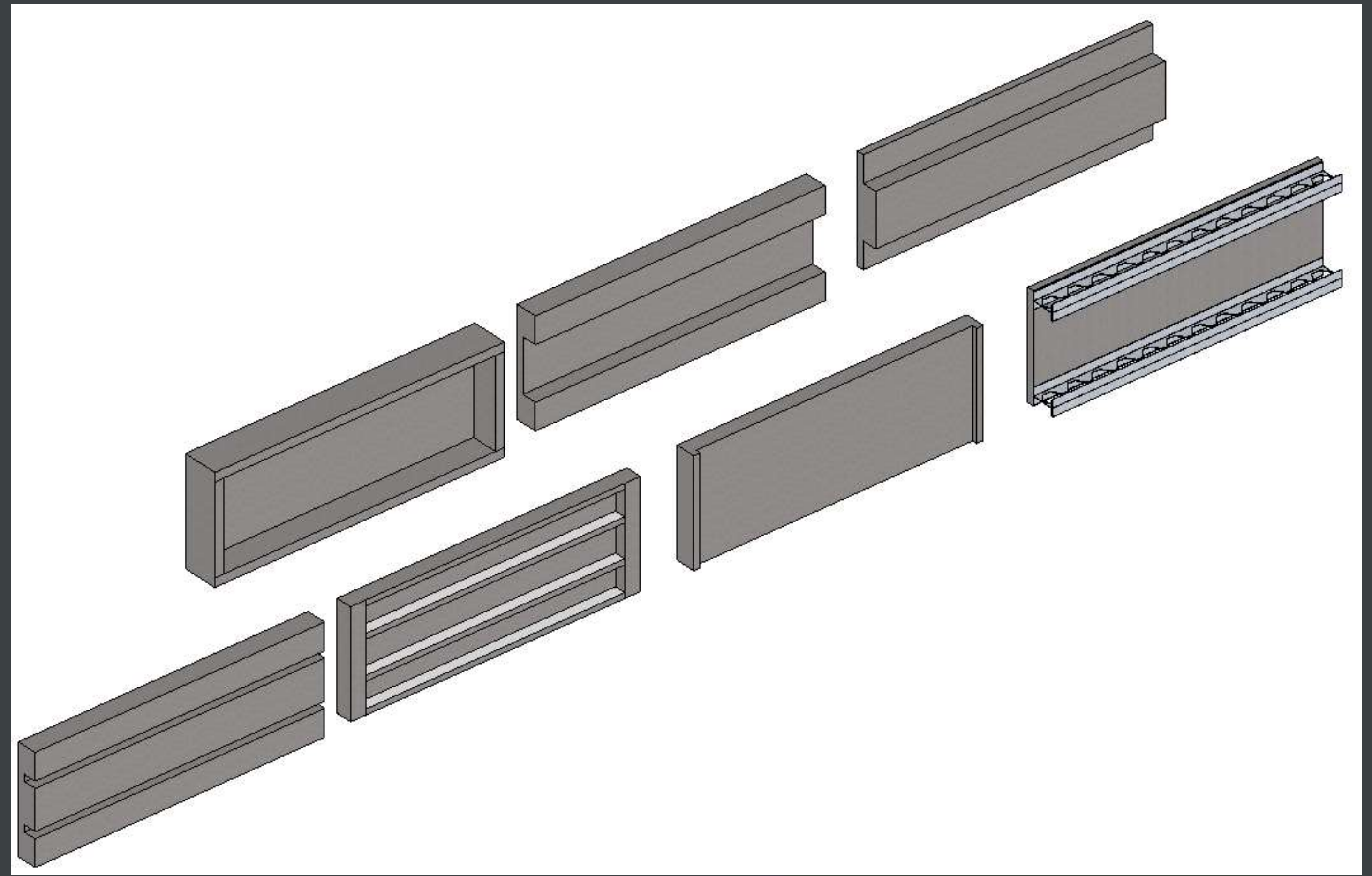


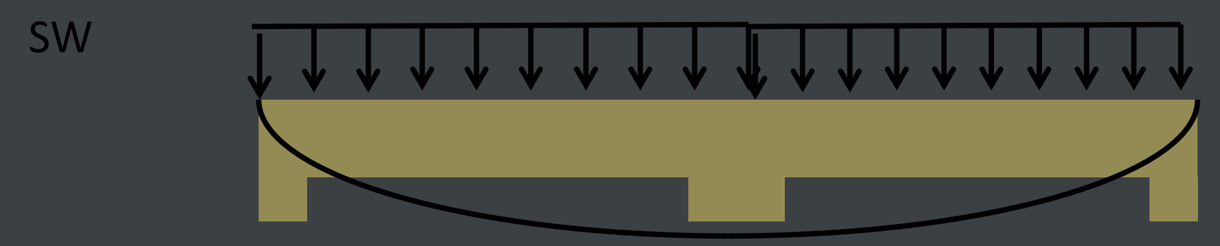
Precast Panel Design

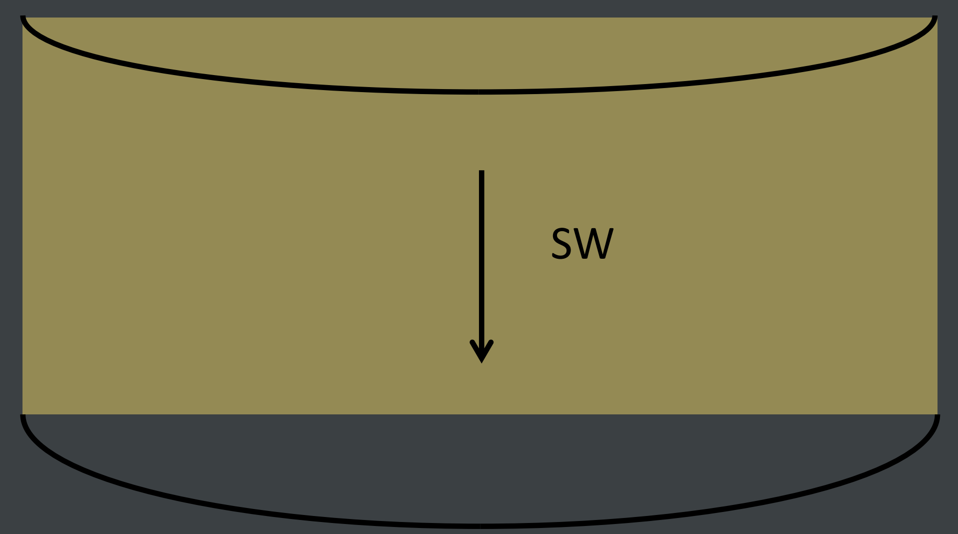
Design Goals/Tolerances

- Reduce weight of panel
- 24 in. air gap between inner face of precast panel and outer face of interior wall.
- Maintain continuous vertical air gap
- No cracking under transportation, construction, or service loads

Precast Panel Iterations





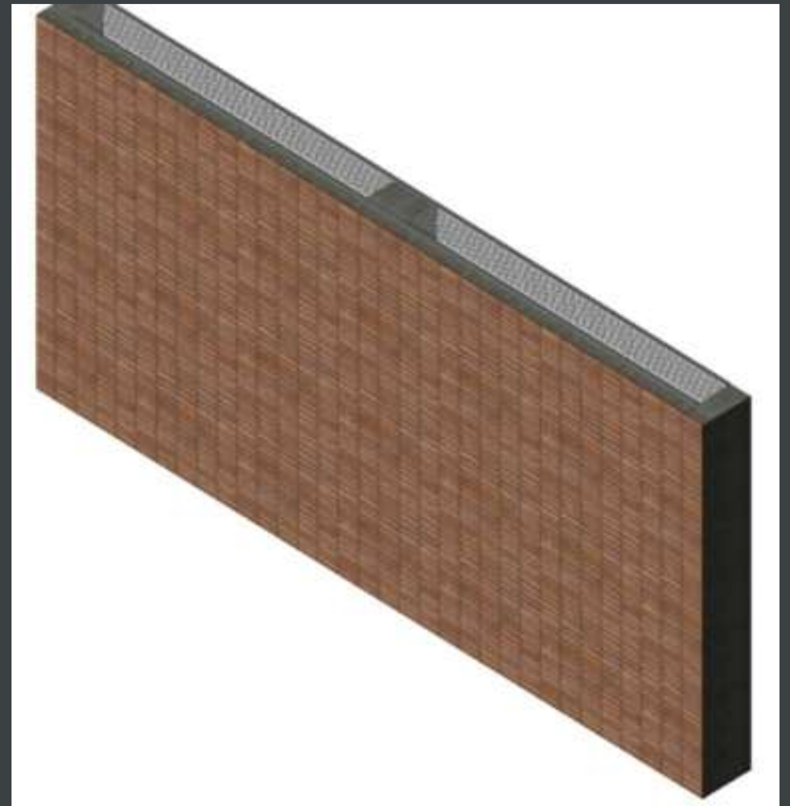


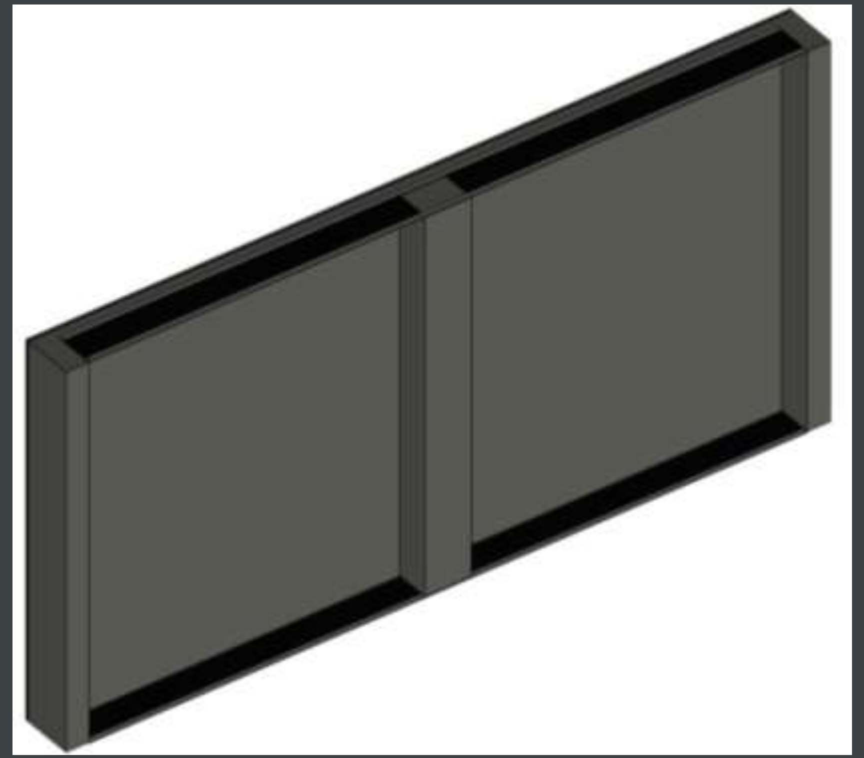
Precast Panel Design

Design Goals/Tolerances

- Reduce weight of panel
- 24 in. air gap between inner face of precast panel and outer face of interior wall.
- Maintain continuous vertical air gap
- No cracking under transportation, construction, or service loads

Precast Panel Final Design





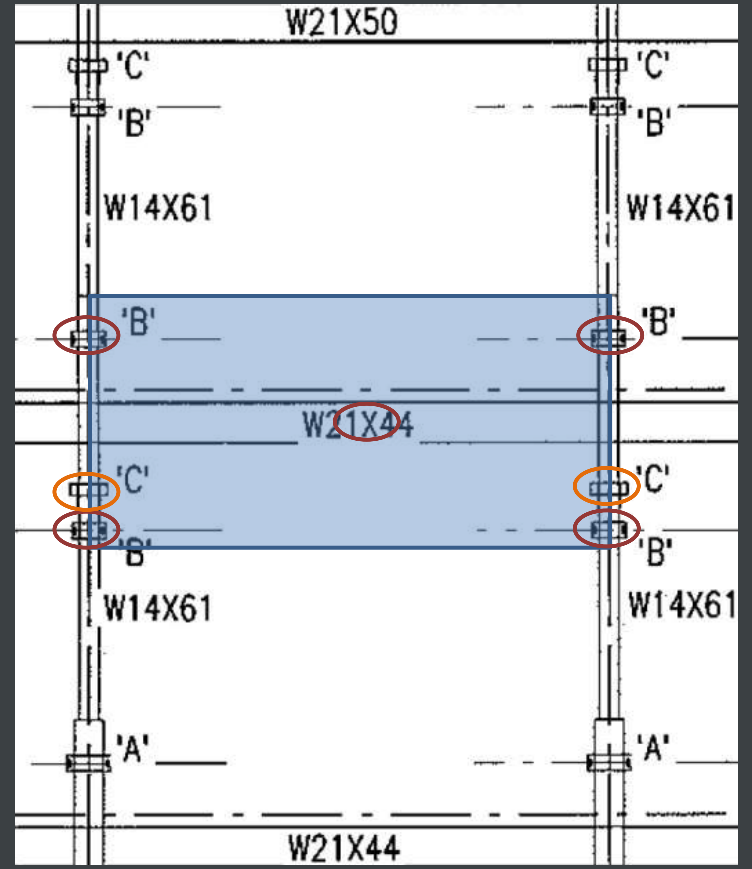
- f'_c = 5000 psi
- f_r = 353.55 psi with FOS = 1.5 (PCI p363)
- Slab Thickness = 6 in
- End Rib Dimensions = 6 in x 12 in
- Mid Rib Dimensions = 8 in x 12 in

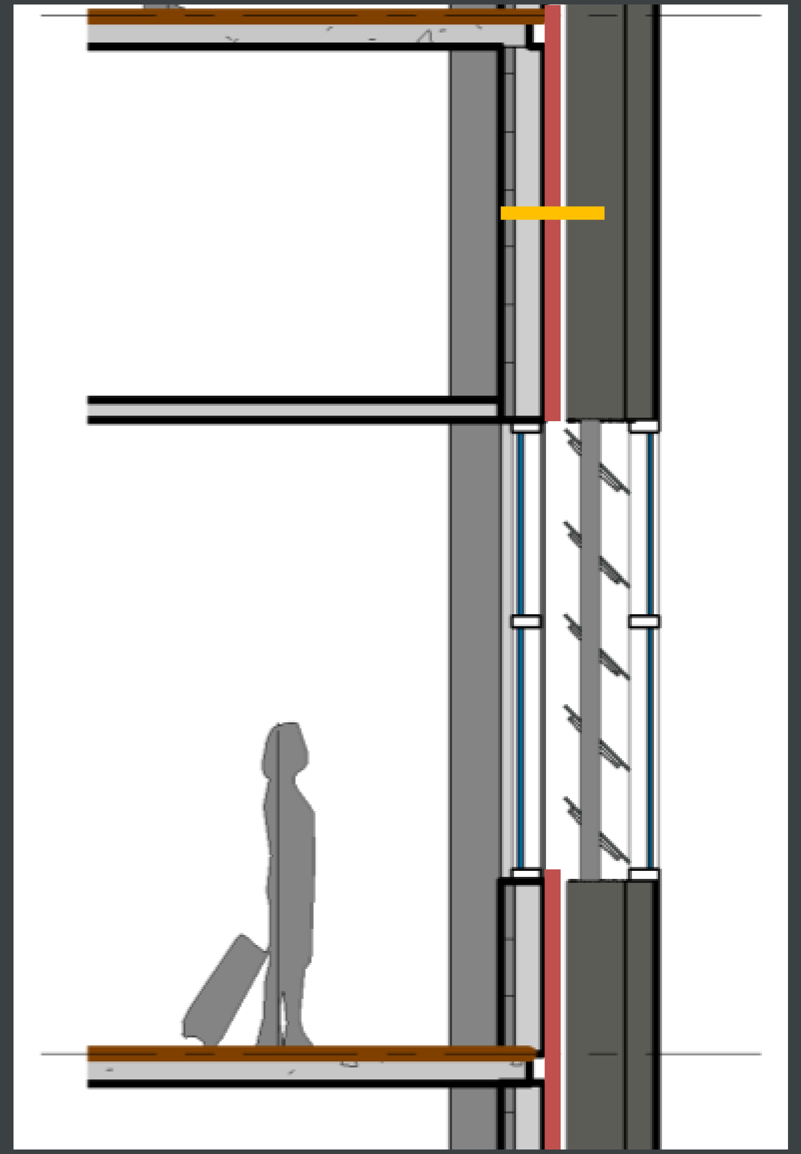
Precast Panel Design

Design Goals/Tolerances

- Reduce weight of panel
- 24 in. air gap between inner face of precast panel and outer face of interior wall.
- Maintain continuous vertical air gap
- No cracking under transportation, construction, or service loads

Precast Panel Final Design





Precast Panel Design

Design Goals/Tolerances

- Reduce weight of panel
- 24 in. air gap between inner face of precast panel and outer face of interior wall.
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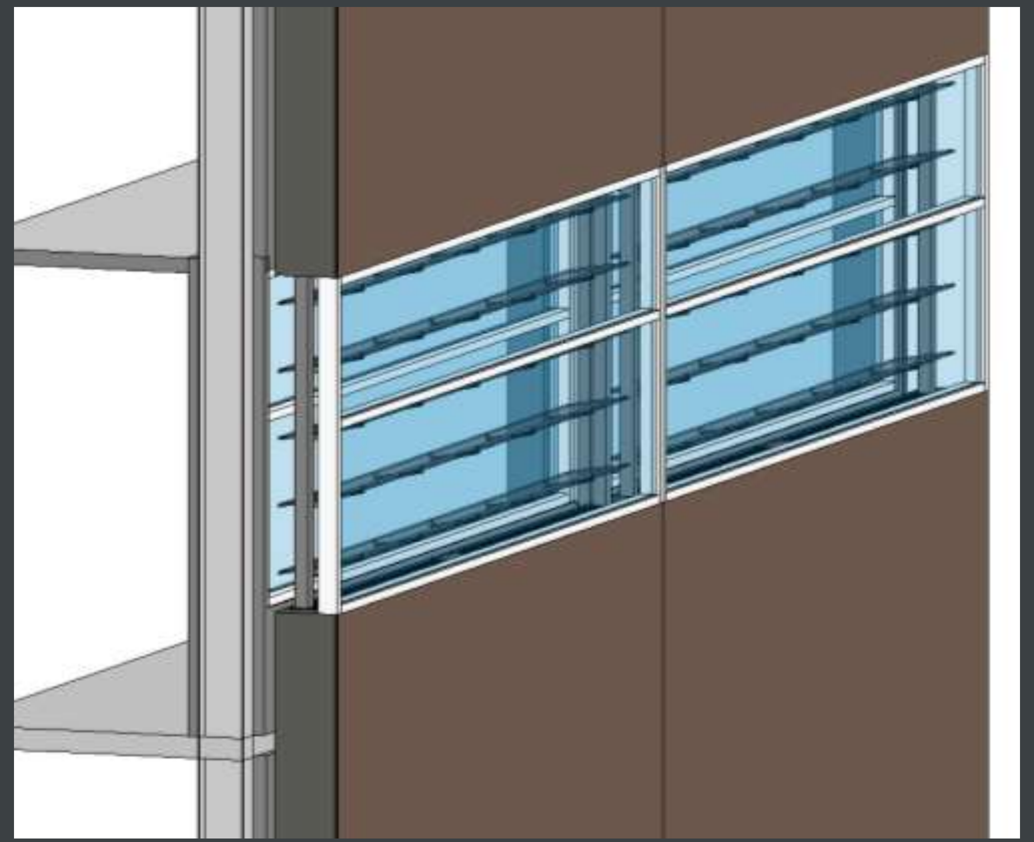
- No cracking under transportation, construction, or service loads

Precast Panel Final Design – Constructability



- Steel stud perimeter wall
- Interior Wall
- Insulation
- Vapor Barrier
- Interior Glazing
- Precast Panel
- Exterior Glazing

Precast Panel Design

Design Goals/Tolerances

- Reduce weight of panel
- 24 in. air gap between inner face of precast panel and outer face of interior wall.
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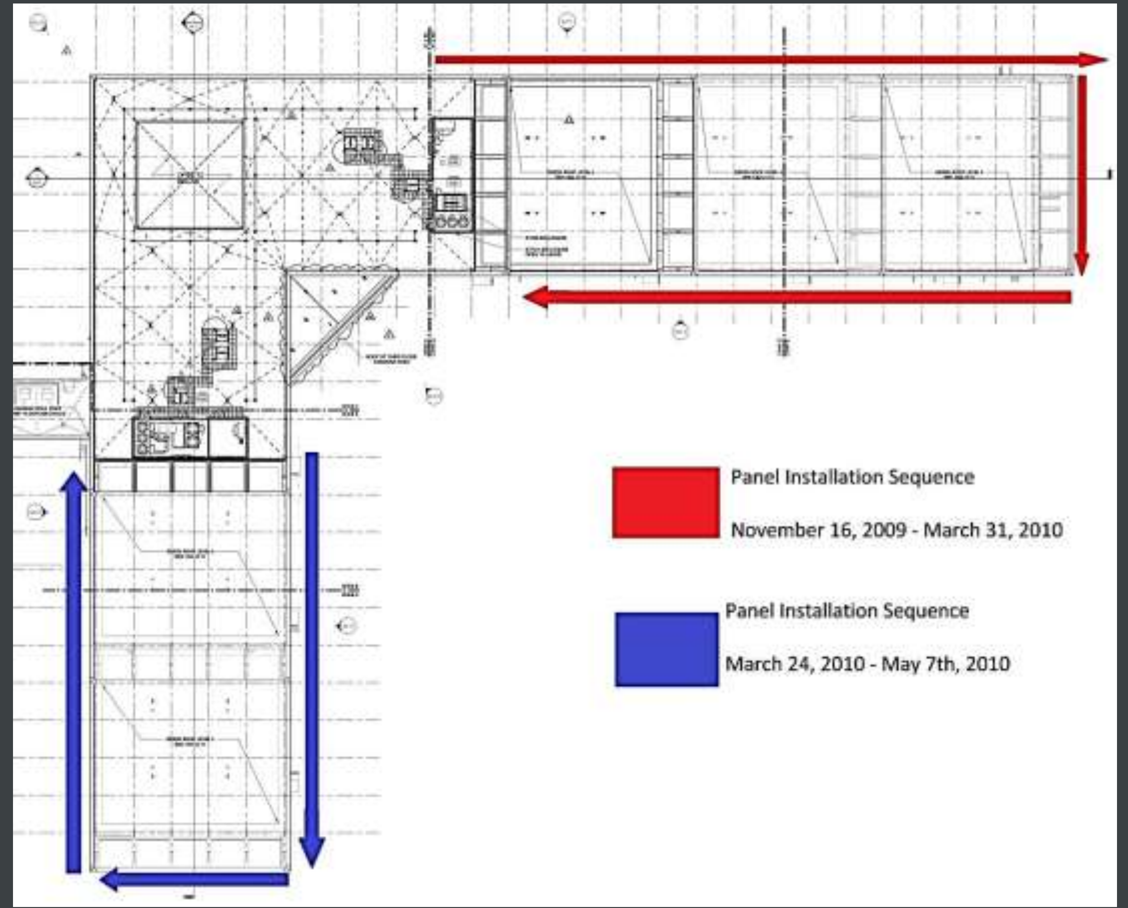
- No cracking under transportation, construction, or service loads

Original Panel Installation Sequence



Precast Panel Design

Design Goals/Tolerances

- Reduce weight of panel
- 24 in. air gap between inner face of precast panel and outer face of interior wall.
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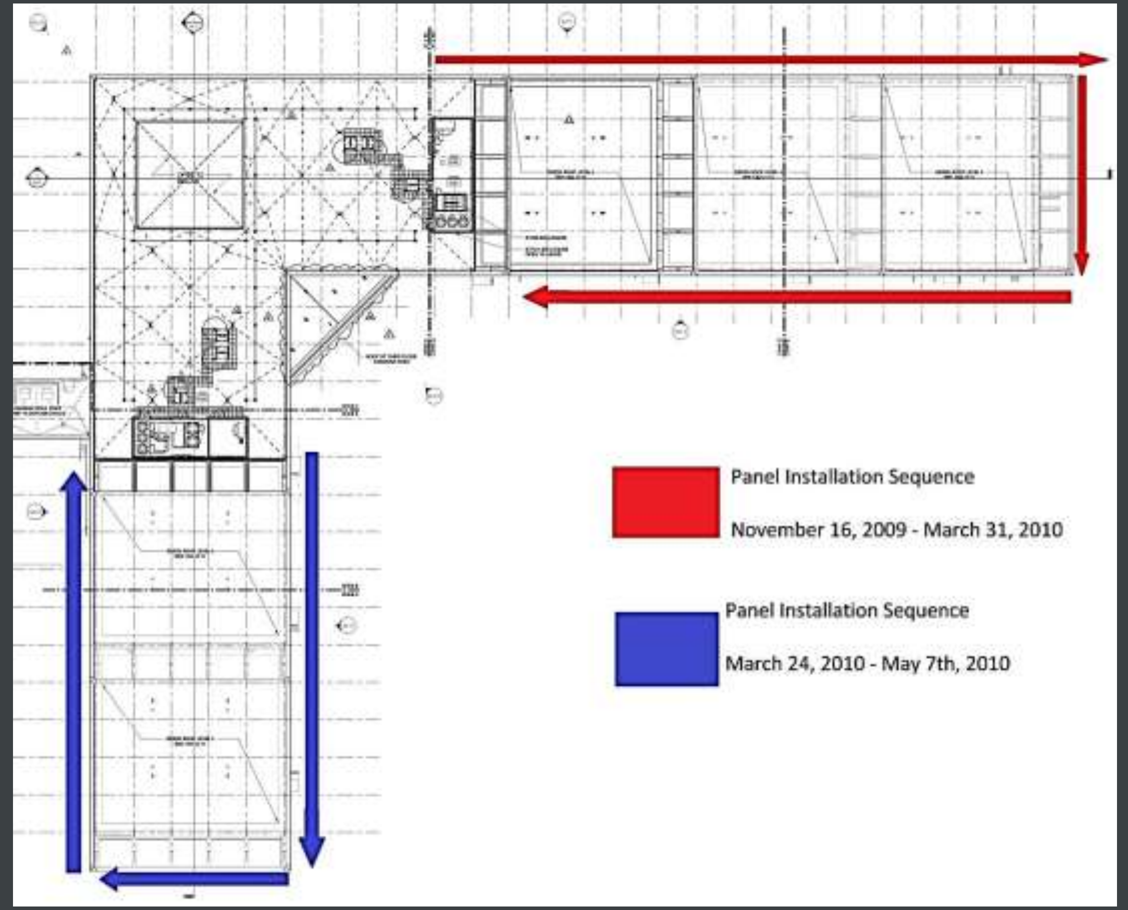
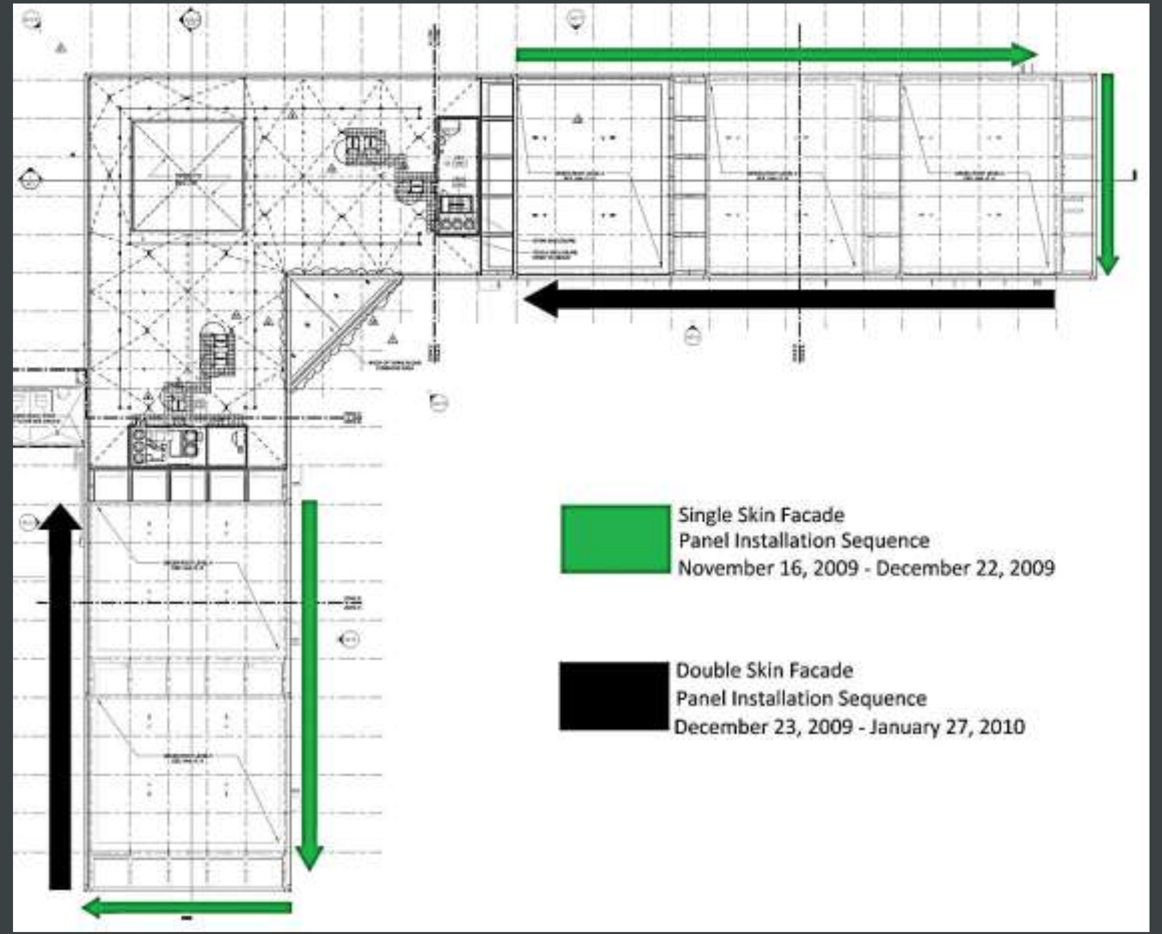
- No cracking under transportation, construction, or service loads

Original Panel Installation Sequence



Double Skin Panel Installation Sequence

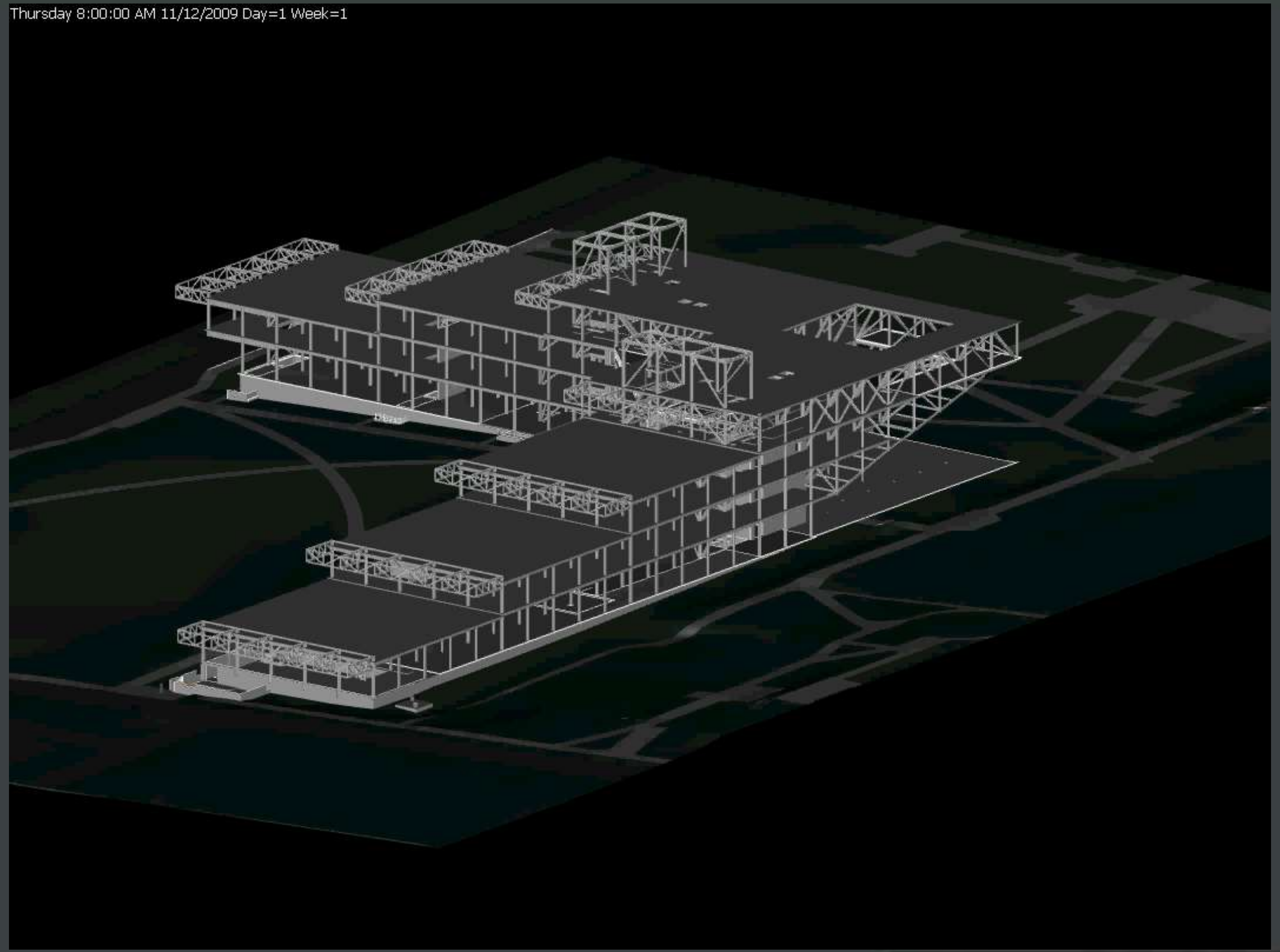


Precast Panel Design

Design Goals/Tolerances

- Reduce weight of panel
- 24 in. air gap between inner face of precast panel and outer face of interior wall.
- Maintain continuous vertical air gap
- No cracking under transportation, construction, or service loads

4D Model



Precast Panel Design

Design Goals/Tolerances

- Reduce weight of panel
- 24 in. air gap between inner face of precast panel and outer face of interior wall.
- Maintain continuous vertical air gap
- No cracking under transportation, construction, or service loads

Panel Design Cost

	Redesign	Original	Difference
Panel Design	$ 5,034,645	$ 5,492,340	$ (457,695)
Connections	$ 181,250	$ 150,000	$ 31,250
Total	$ 5,629,240	$ 6,007,802	$ (378,562)

Enclosure System Cost

System	Total Proposed	Original	Difference
Panels	$ 5,629,240	$ 6,007,802	$ (378,562)
Insulation	$ 842,792	$ 741,948	$ 100,844
Caulking	$ 204,081	$ 168,917	$ 35,164
Louvers	$ 123,200	$ 366,600	$ (243,400)
Windows	$ 3,277,210	$ 2,719,570	$ 557,640
Total	$ 15,429,539	$ 15,357,852	$ 71,687

Building Stimulus Energy Modeling Design Goals

- Reduce Energy Consumption
- Lighting and Mechanical Integration
- Simulate a More Realistic Energy Profile

MEP Information Exchange

Base Model

- ASHRAE LPD's
- ASHRAE MPD's
- Existing Systems

Progress Model 1

- Preliminary Façade
- Preliminary Daylighting

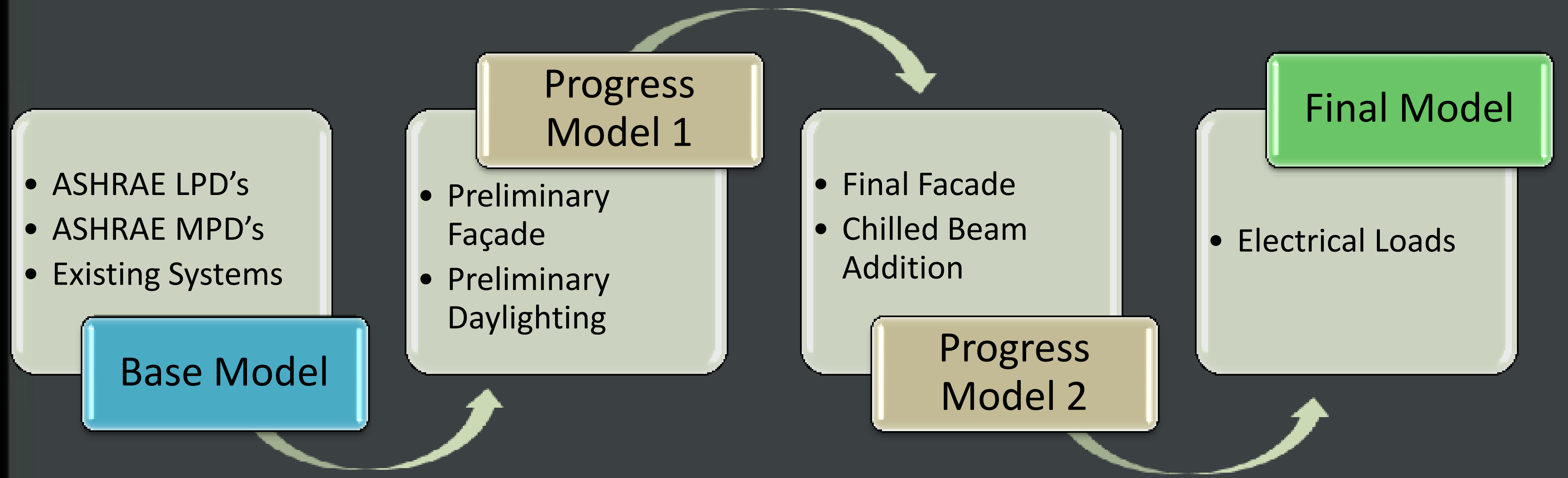
Progress Model 2

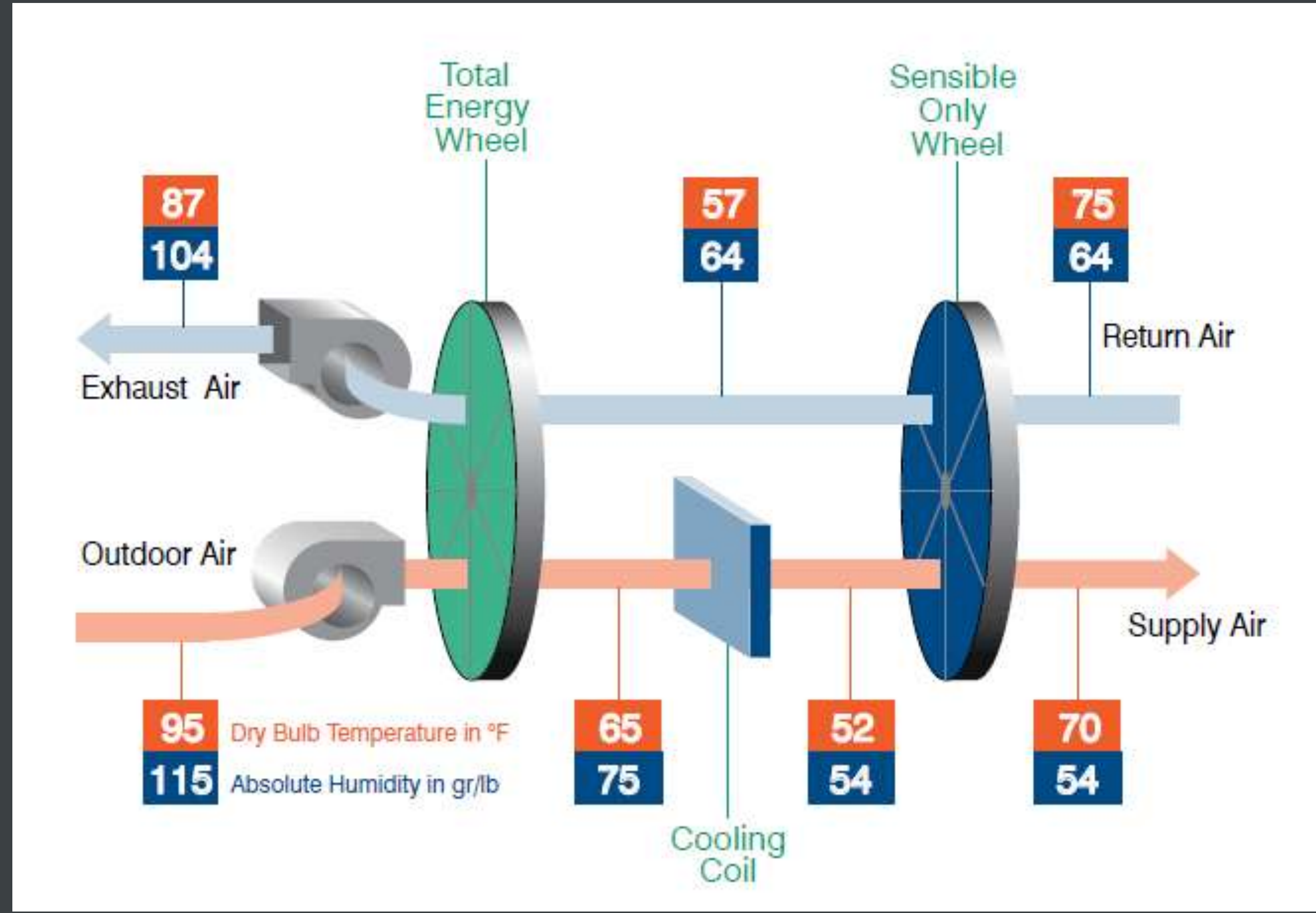
- Final Facade
- Chilled Beam Addition

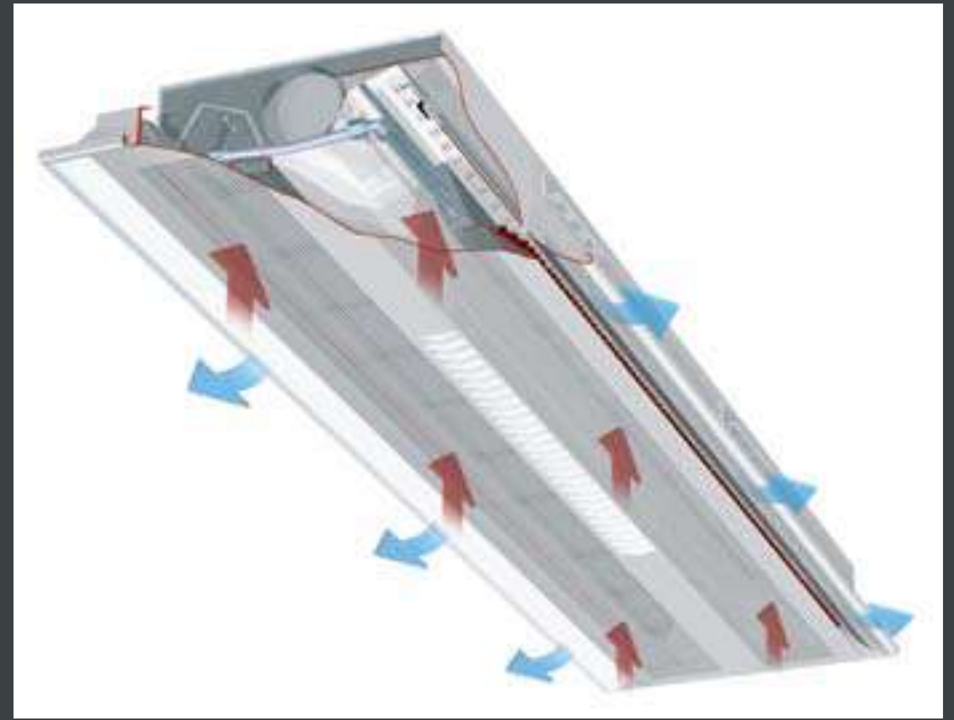
Final Model

- Electrical Loads

Chilled Beams







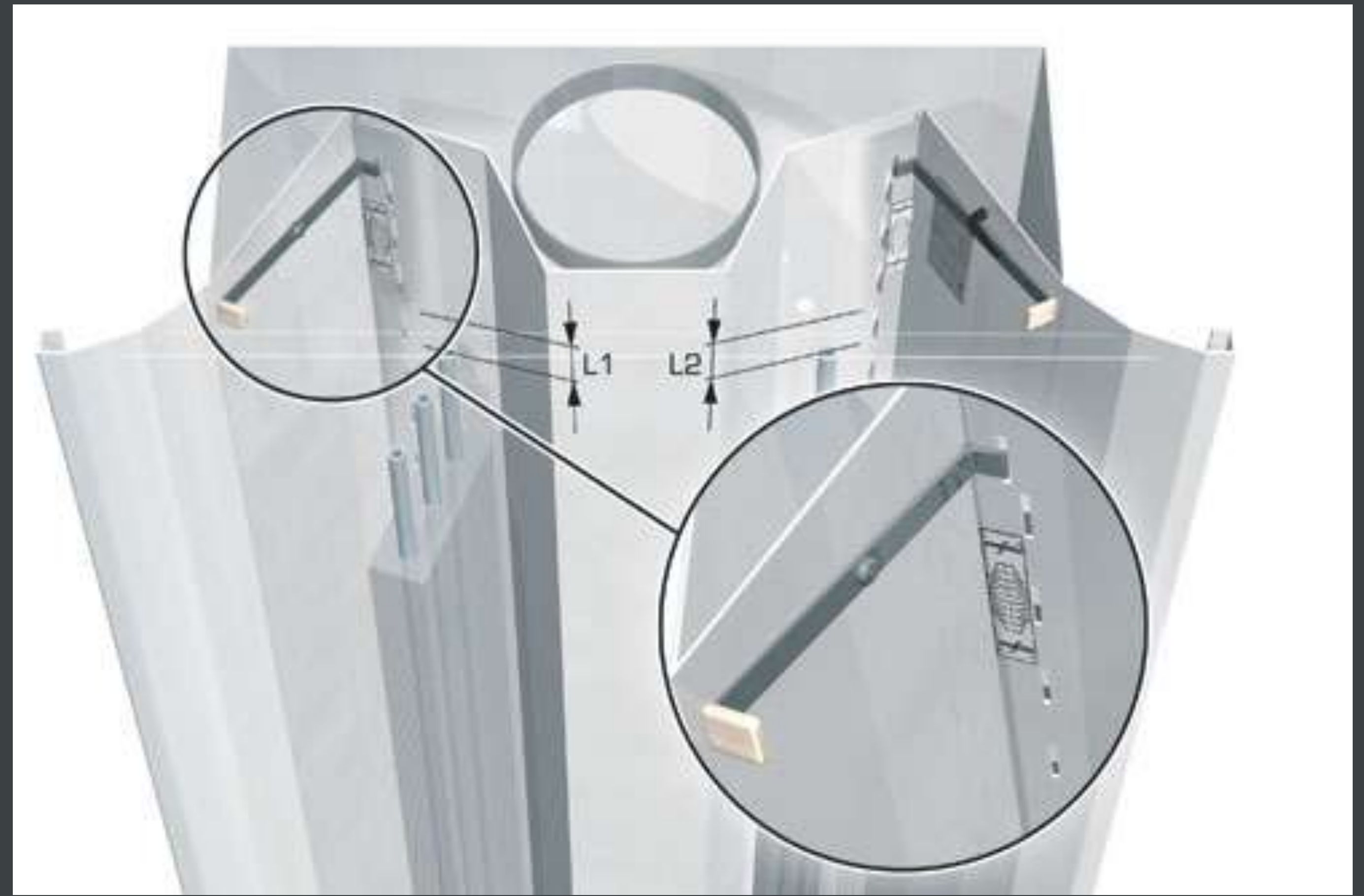
Chilled Beams

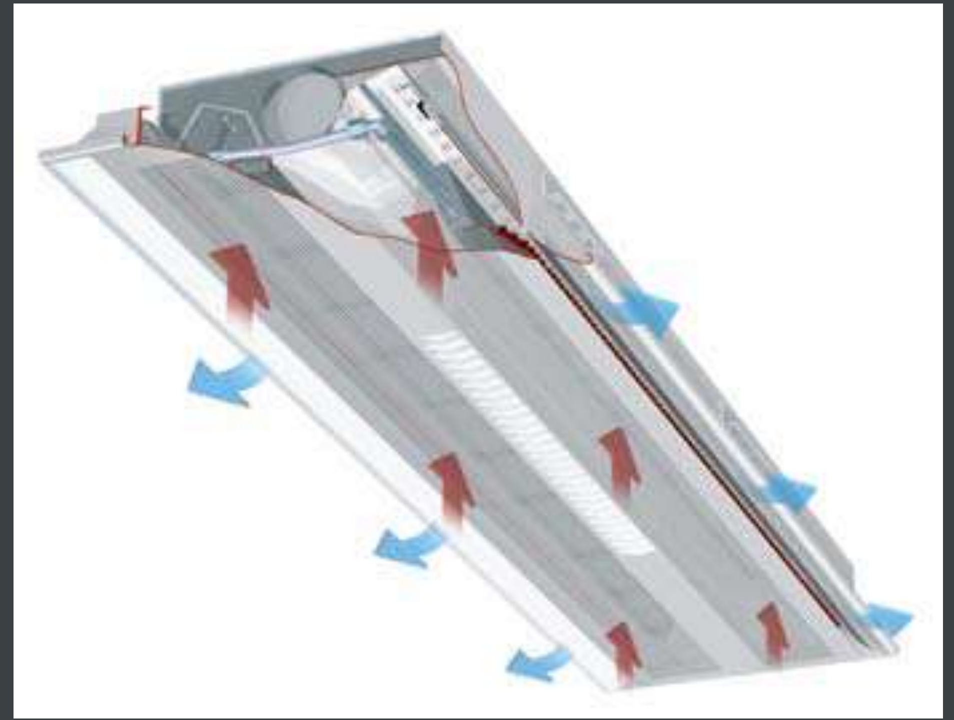
Base Model
- ASHRAE LPD's
- ASHRAE MPD's
- Existing Systems

Progress Model 1
- Preliminary Façade
- Preliminary Daylighting

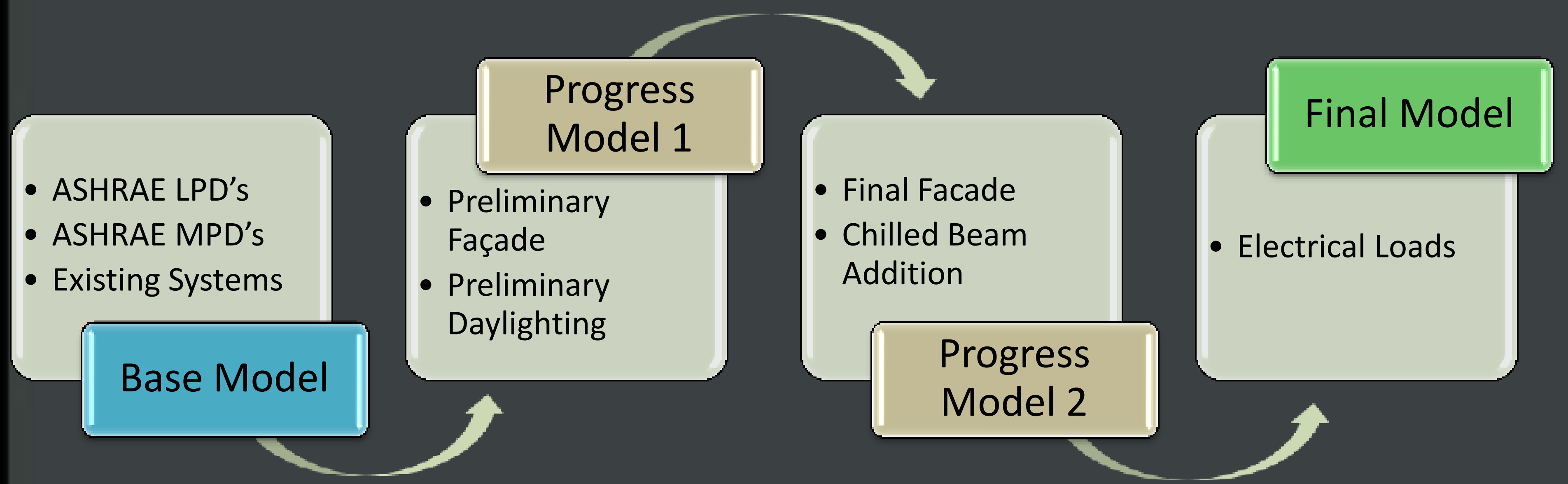
Progress Model 2
- Final Facade
- Chilled Beam Addition

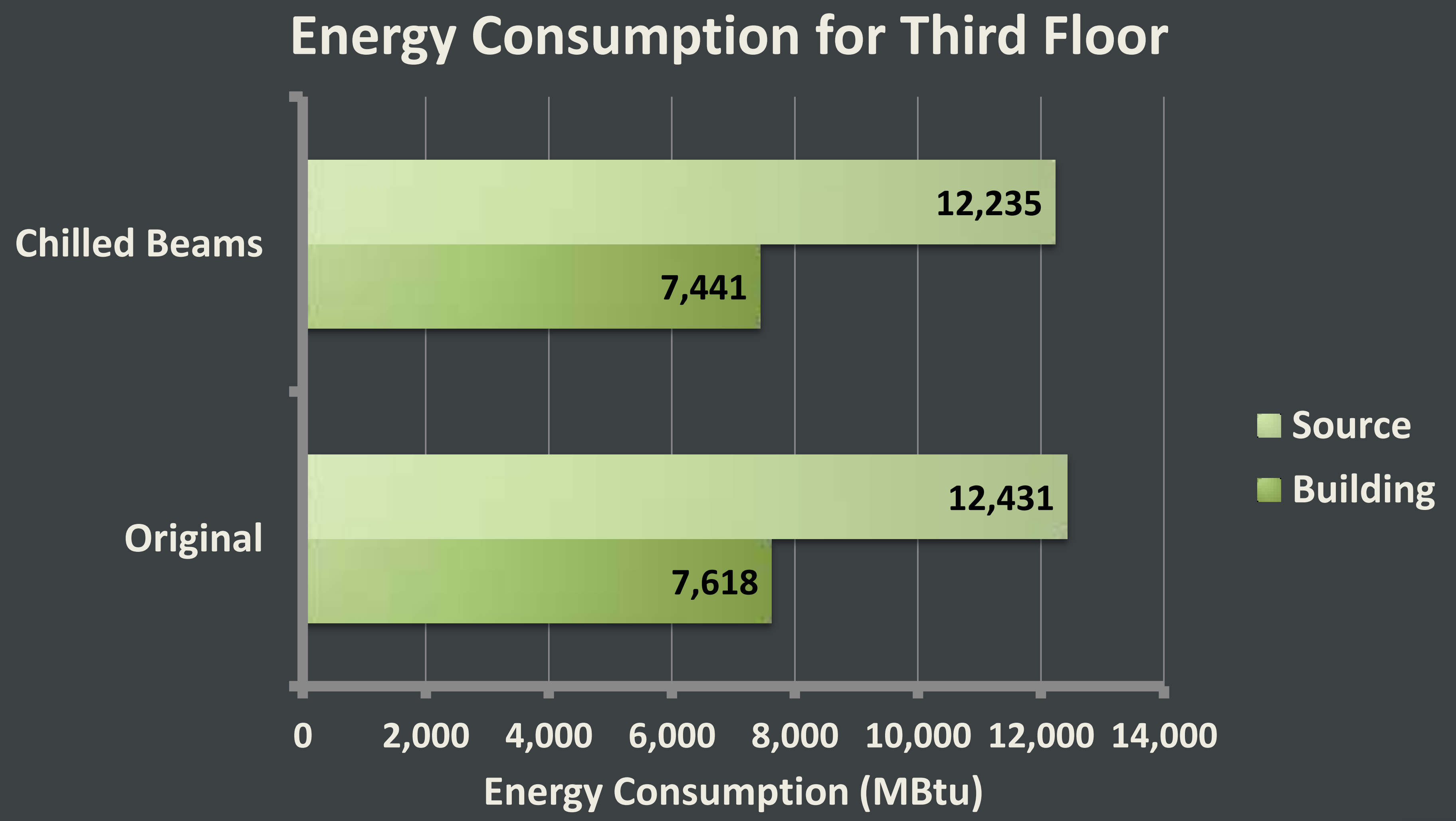
Final Model
- Electrical Loads





Chilled Beams





Chilled Beams

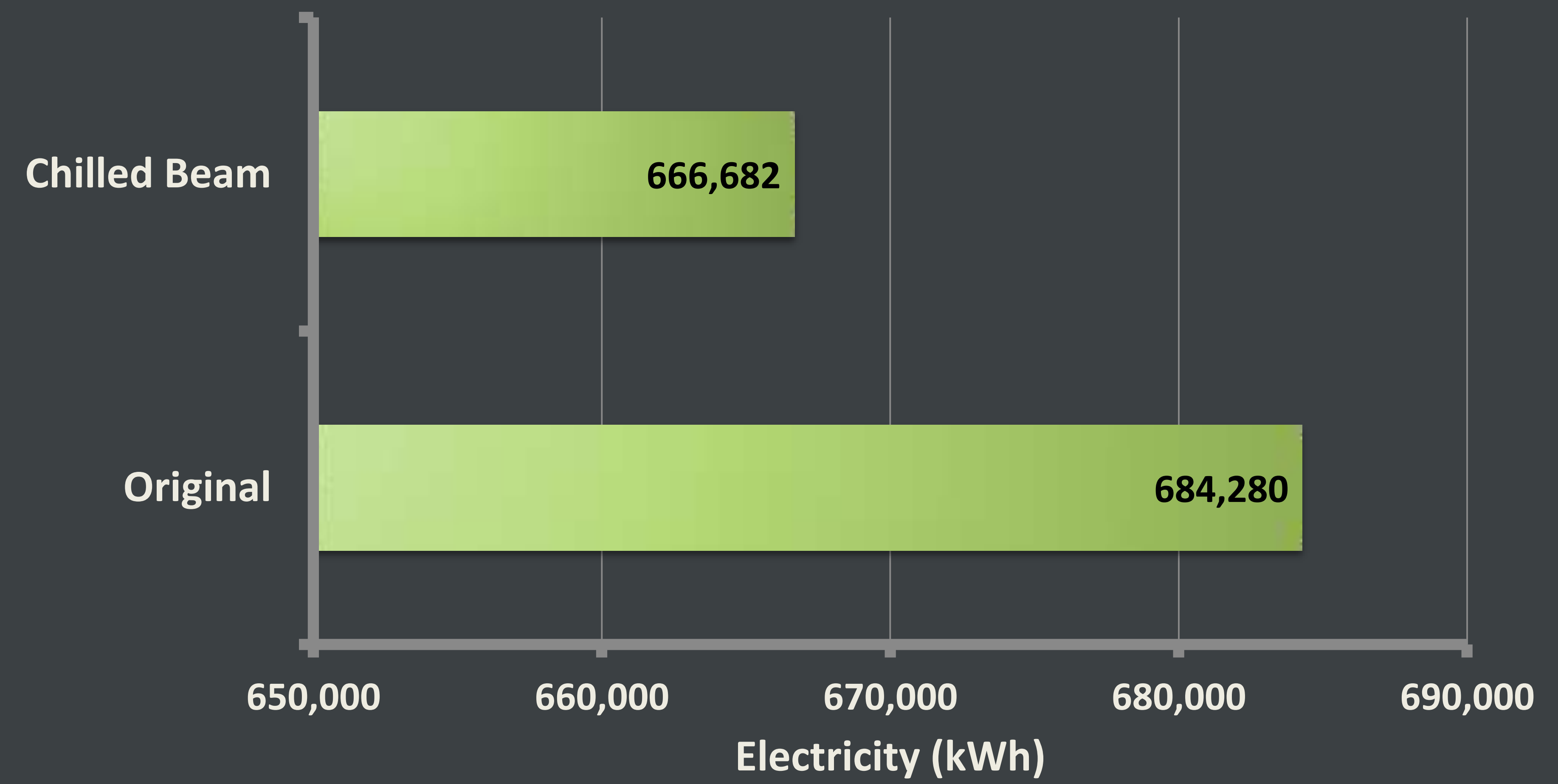
Base Model
- ASHRAE LPD's
- ASHRAE MPD's
- Existing Systems

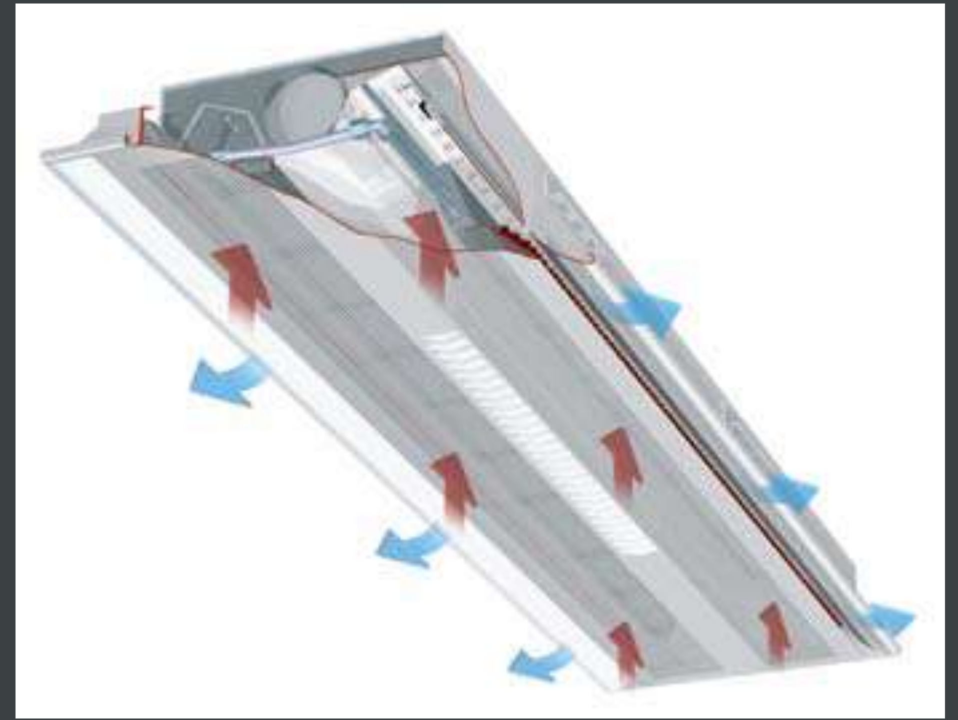
Progress Model 1
- Preliminary Façade
- Preliminary Daylighting

Progress Model 2
- Final Facade
- Chilled Beam Addition

Final Model
- Electrical Loads

Electricity Consumption for Third Floor





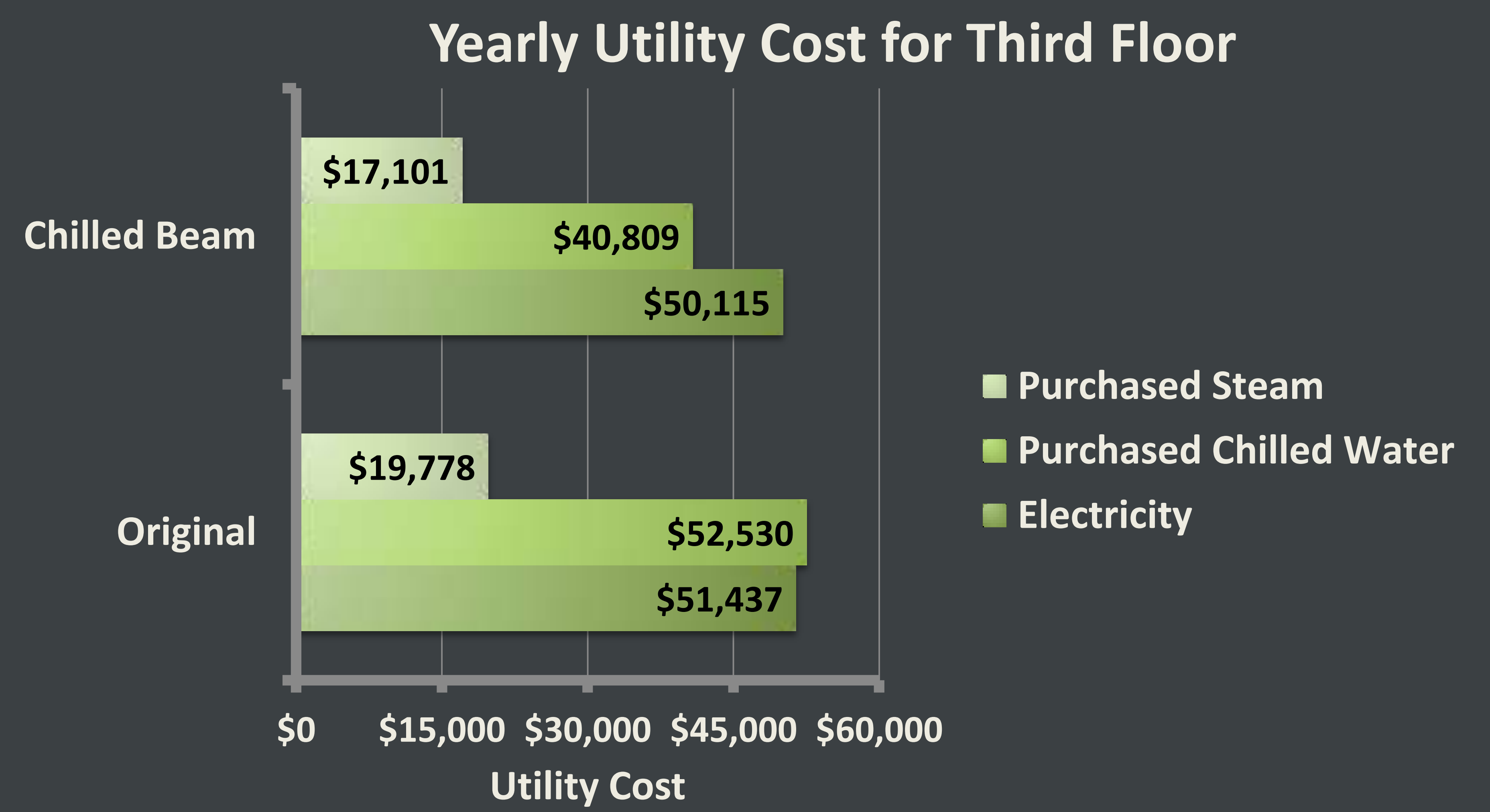
Chilled Beams

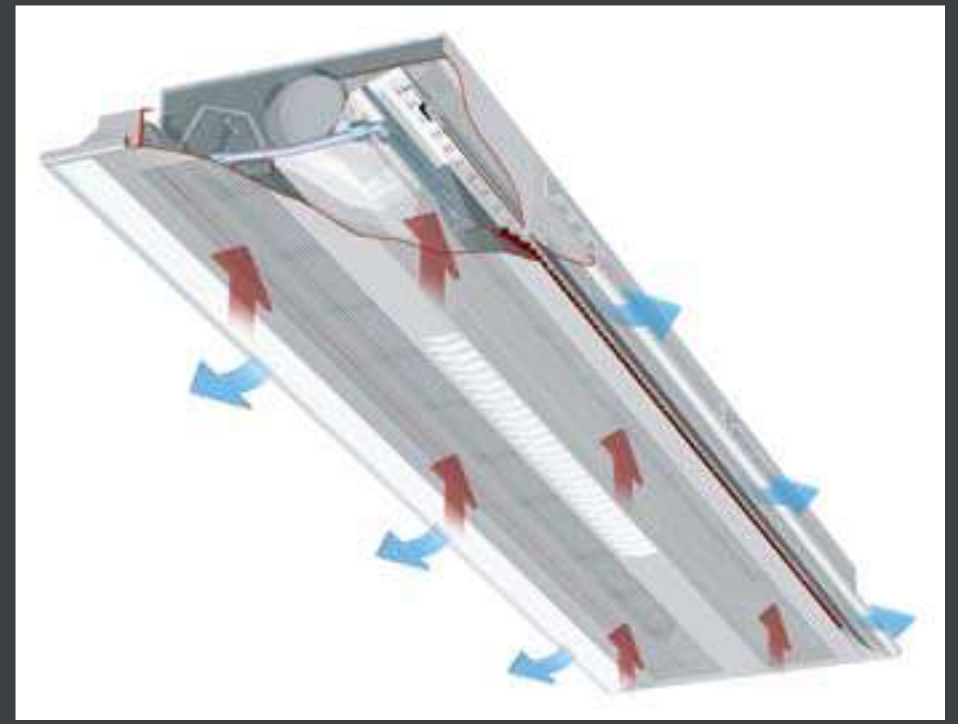
Base Model
- ASHRAE LPD's
- ASHRAE MPD's
- Existing Systems

Progress Model 1
- Preliminary Façade
- Preliminary Daylighting

Progress Model 2
- Final Facade
- Chilled Beam Addition

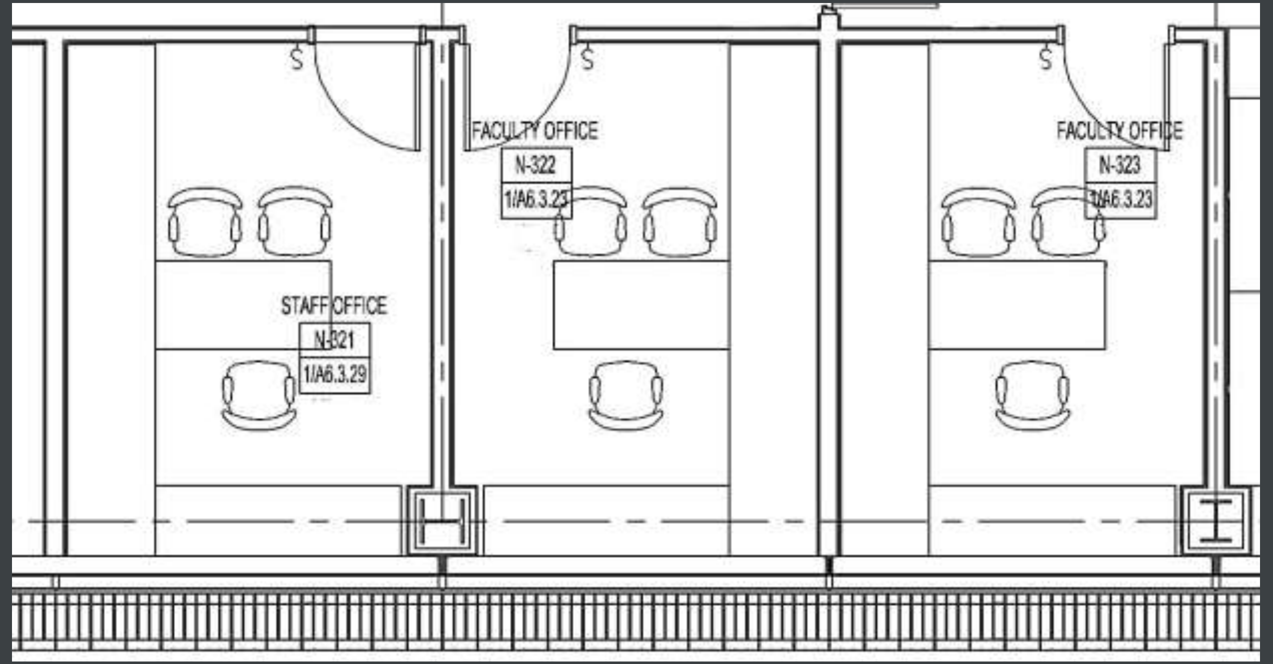
Final Model
- Electrical Loads





Chilled Beam Luminaire Integration

Private Office Floorplan

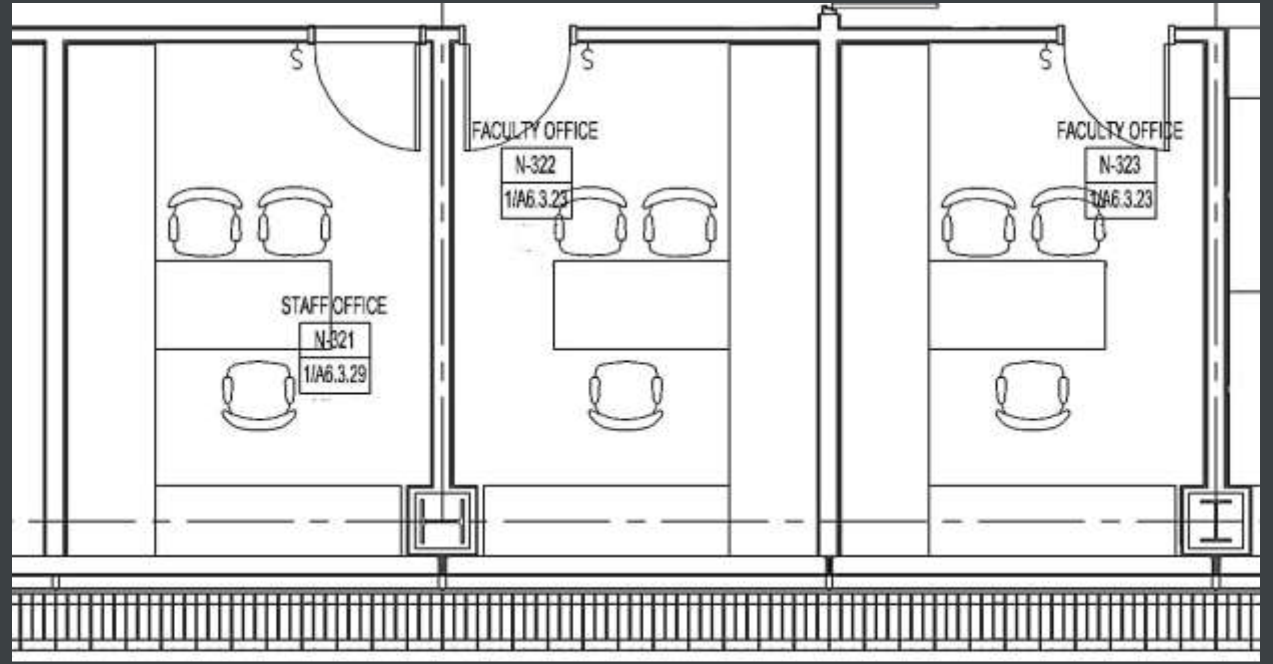


Color Render

Chilled Beam Luminaire

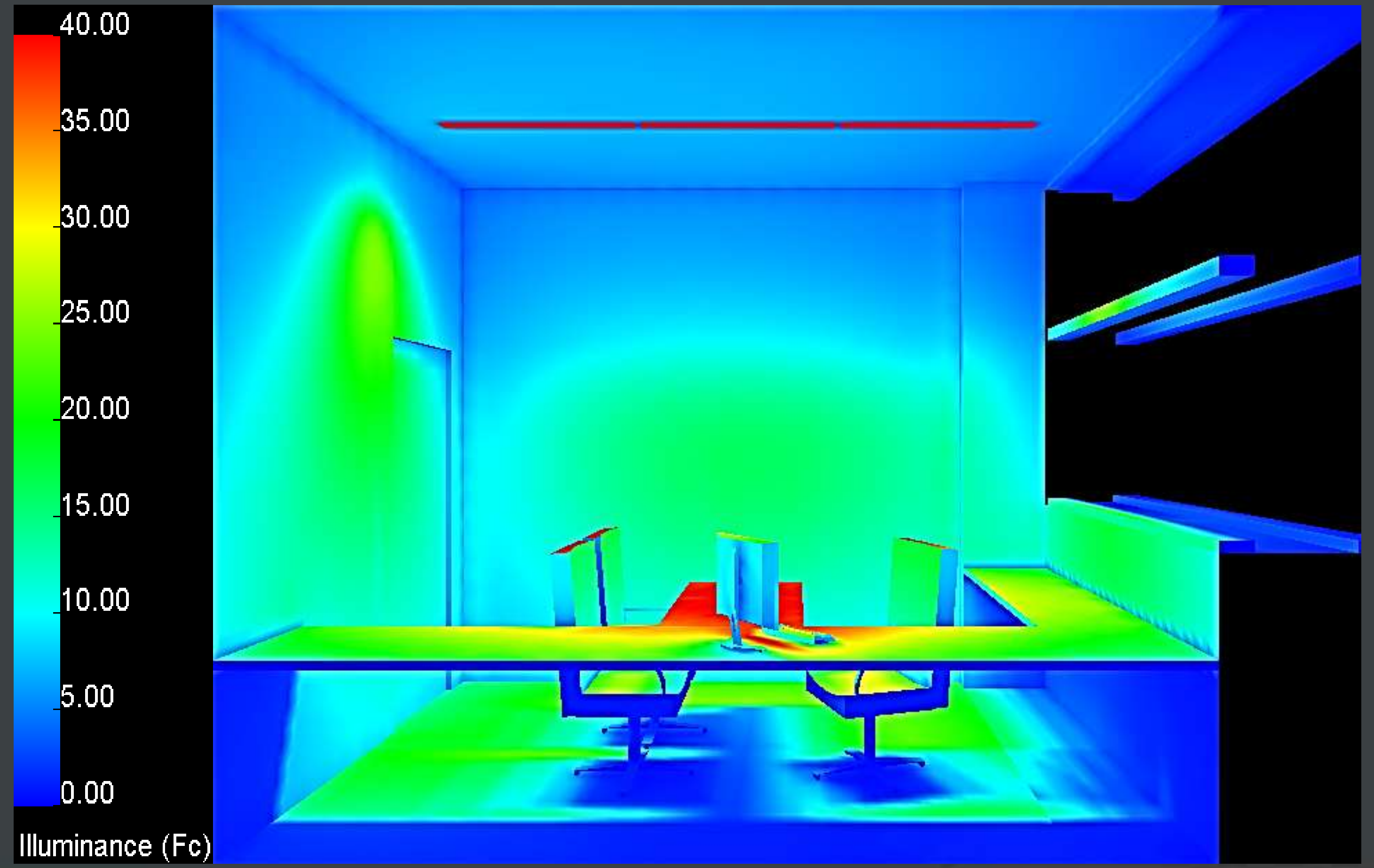
Chilled Beam Luminaire Integration

Private Office Floorplan



Color Render

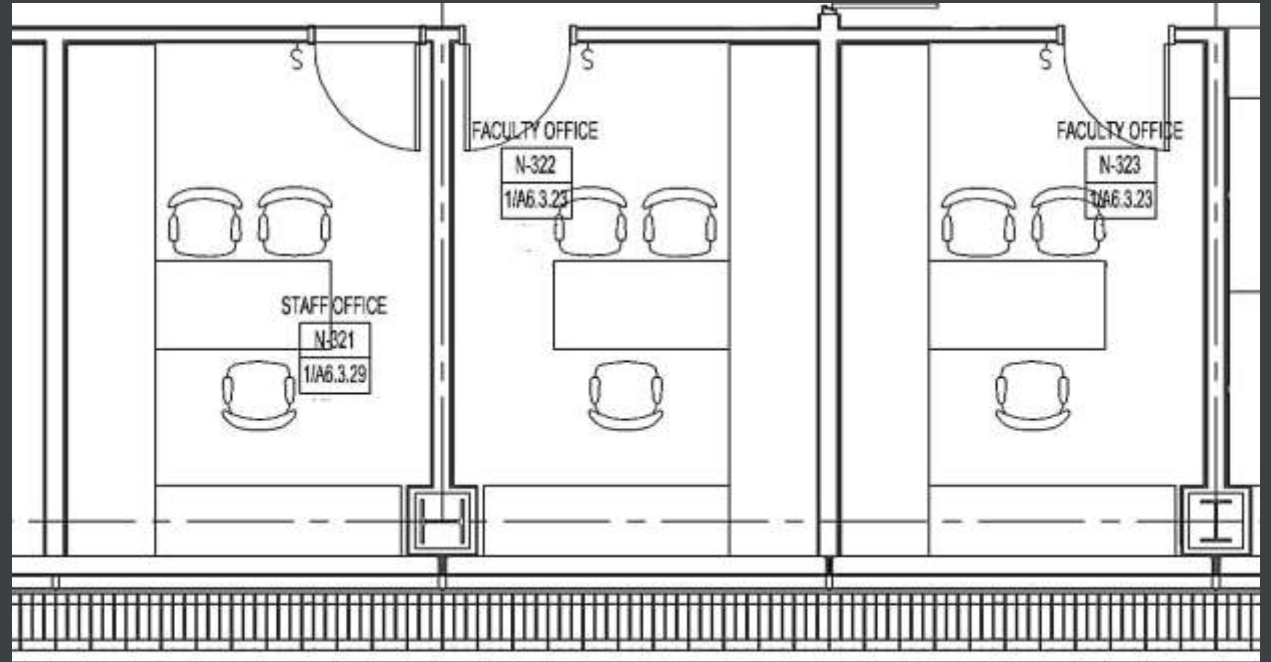
Illuminance Pseudo Color



Building STIMULUS

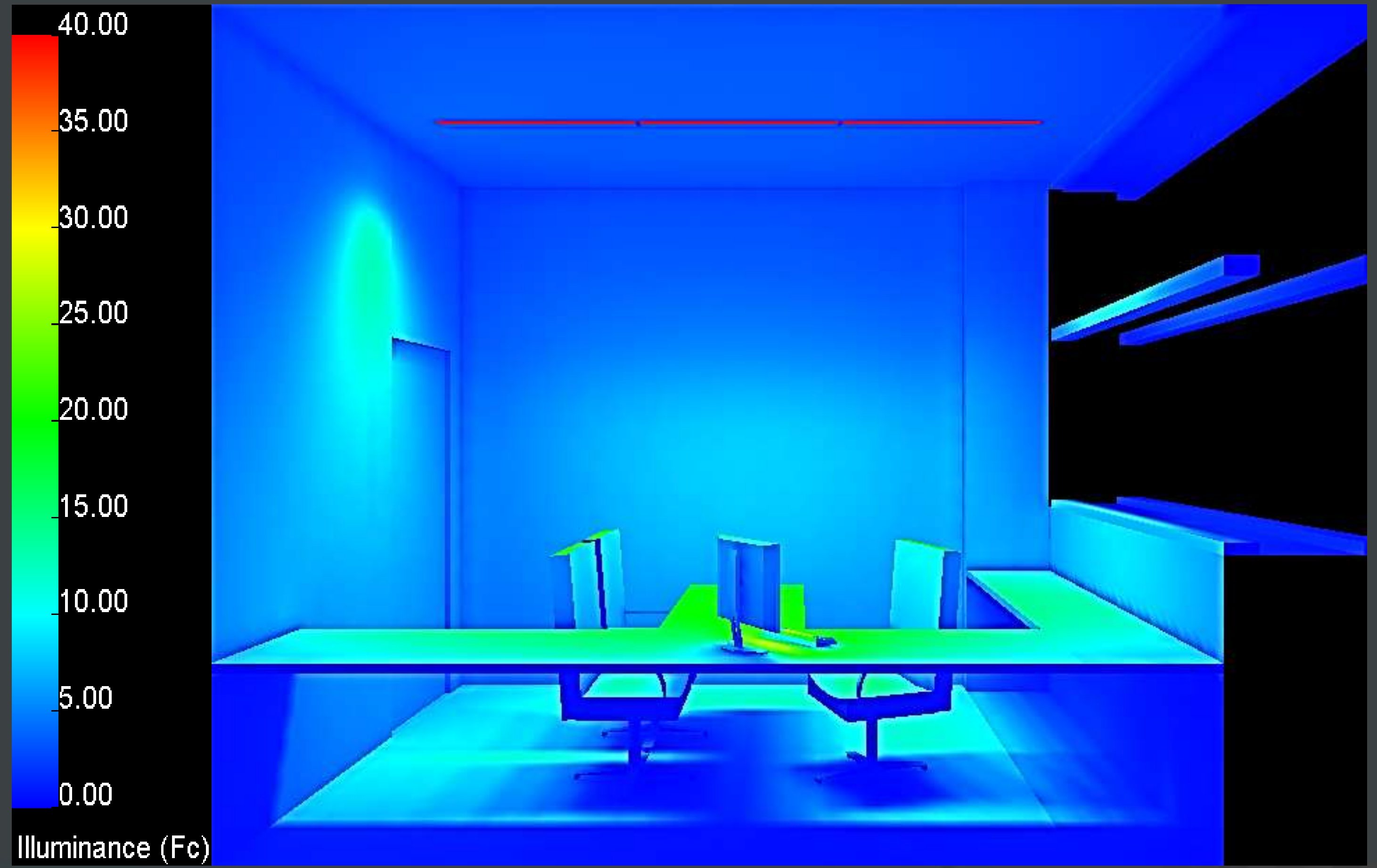
Chilled Beam Luminaire Integration

Private Office Floorplan



Color Render

Illuminance Pseudo Color

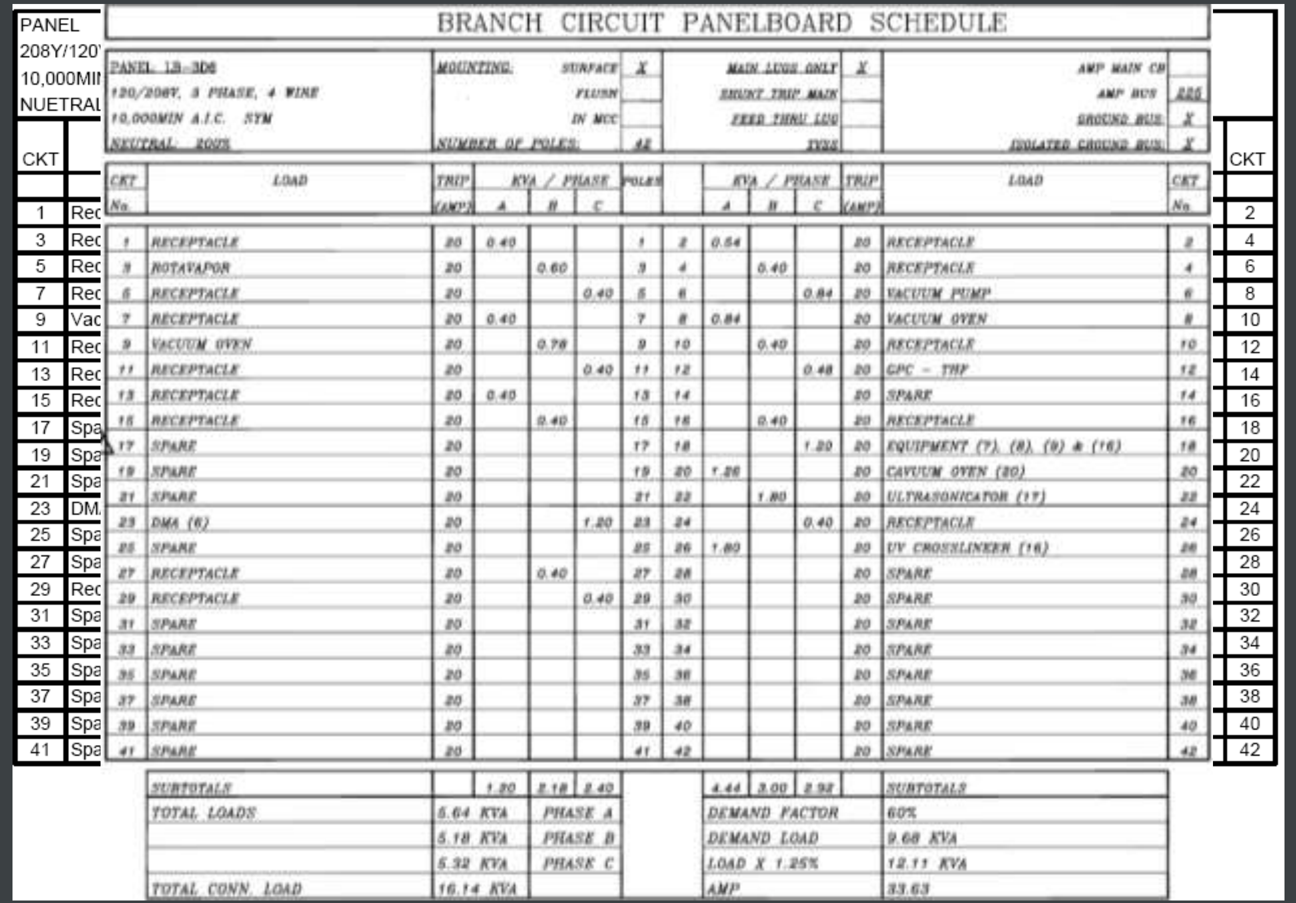


Building STIMULUS

Determining Existing Plug Loads

Determining Existing Plug Loads

Existing Panel Schedule



BRANCH CIRCUIT PANELBOARD SCHEDULE

PANEL: LB-306 | 120/208V, 3 PHASE, 4 WIRE | 10,000MIN A.I.C. SYM | NEUTRAL: 200%

MOUNTING: SURFACE X | FLUSH | IN MCC | NUMBER OF POLES: 42

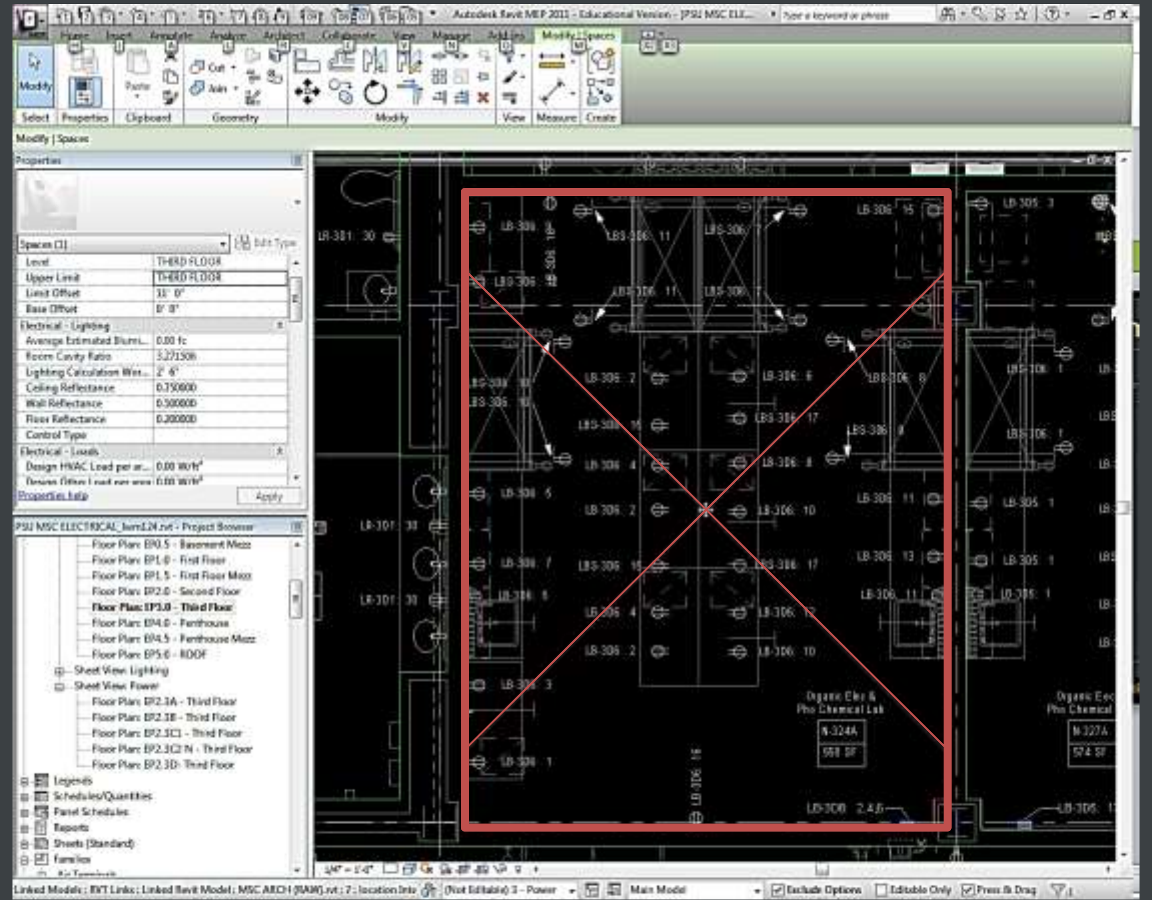
MAIN LUGS ONLY X | SHUNT TRIP MAIN | FEED THRU LUG | TVSS

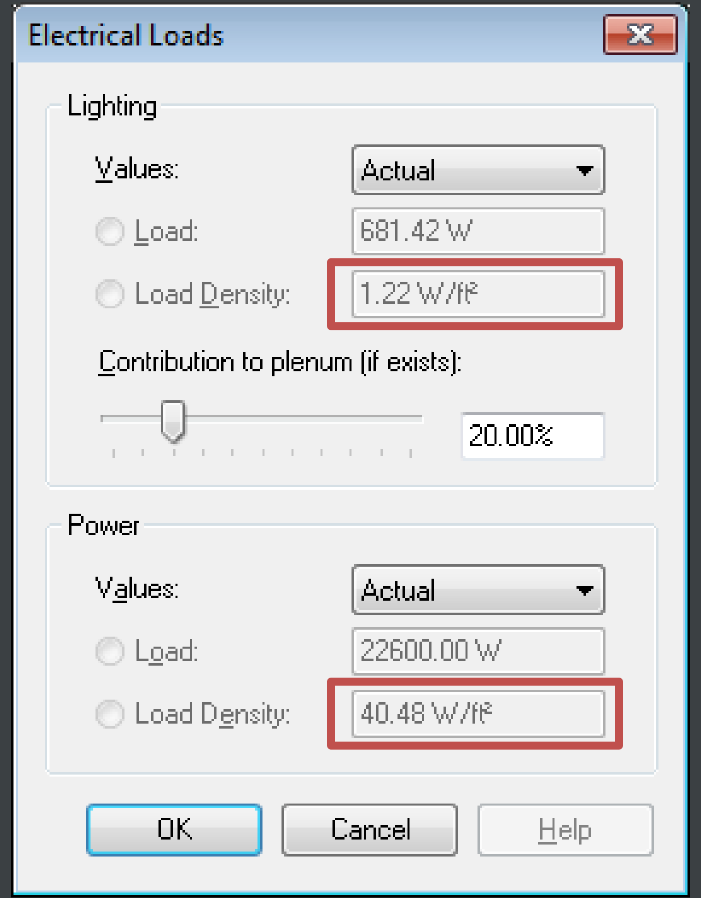
AMP MAIN CB | AMP BUS 225 | GROUND BUS X | ISOLATED GROUND BUS X

CKT No.	LOAD	TRIP (AMP)	KVA / PHASE A	B	C	POLES		KVA / PHASE A	B	C	TRIP (AMP)	LOAD	CKT No.
1	RECEPTACLE	20	0.40			1	2	0.54			20	RECEPTACLE	2
3	ROTAVAPOR	20		0.60		3	4		0.40		20	RECEPTACLE	4
5	RECEPTACLE	20			0.40	5	6			0.84	20	VACUUM PUMP	6
7	RECEPTACLE	20	0.40			7	8	0.84			20	VACUUM OVEN	8
9	VACUUM OVEN	20		0.78		9	10		0.40		20	RECEPTACLE	10
11	RECEPTACLE	20			0.40	11	12			0.48	20	GPC – THF	12
13	RECEPTACLE	20	0.40			13	14				20	SPARE	14
15	RECEPTACLE	20		0.40		15	16		0.40		20	RECEPTACLE	16
17	SPARE	20				17	18			1.20	20	EQUIPMENT (7), (8), (9) & (16)	18
19	SPARE	20				19	20	1.26			20	CAVUUM OVEN (20)	20
21	SPARE	20				21	22		1.80		20	ULTRASONICATOR (17)	22
23	DMA (6)	20			1.20	23	24			0.40	20	RECEPTACLE	24
25	SPARE	20				25	26	1.80			20	UV CROSSLINKER (16)	26
27	RECEPTACLE	20		0.40		27	28				20	SPARE	28
29	RECEPTACLE	20			0.40	29	30				20	SPARE	30
31	SPARE	20				31	32				20	SPARE	32
33	SPARE	20				33	34				20	SPARE	34
35	SPARE	20				35	36				20	SPARE	36
37	SPARE	20				37	38				20	SPARE	38
39	SPARE	20				39	40				20	SPARE	40
41	SPARE	20				41	42				20	SPARE	42
	SUBTOTALS		1.20	2.18	2.40			4.44	3.00	2.92		SUBTOTALS	

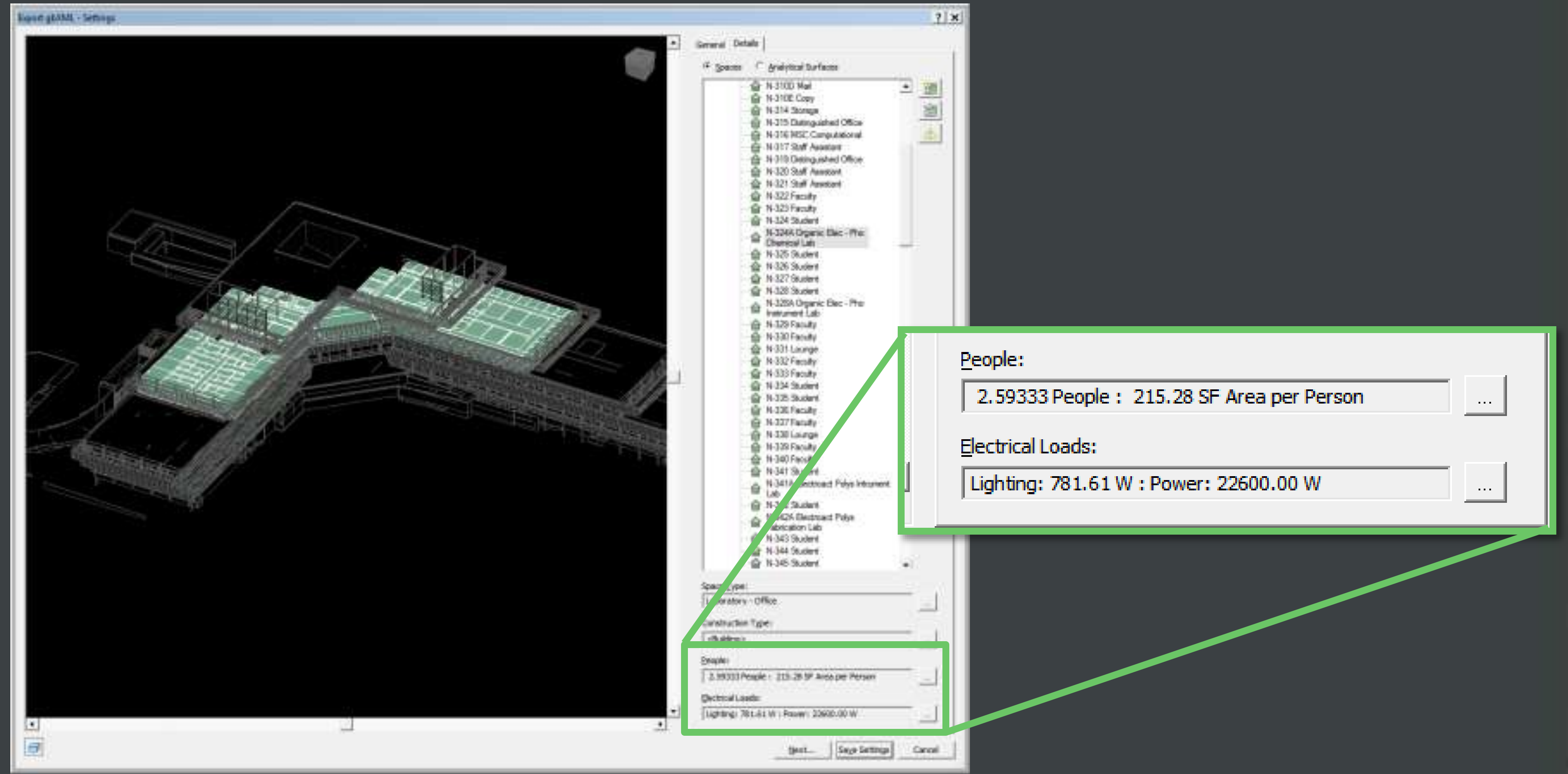
TOTAL LOADS	5.64 KVA	PHASE A	DEMAND FACTOR	60%
	5.18 KVA	PHASE B	DEMAND LOAD	9.68 KVA
	5.32 KVA	PHASE C	LOAD X 1.25%	12.11 KVA
TOTAL CONN. LOAD	16.14 KVA		AMP	33.63

Modeling Electrical Information In Revit





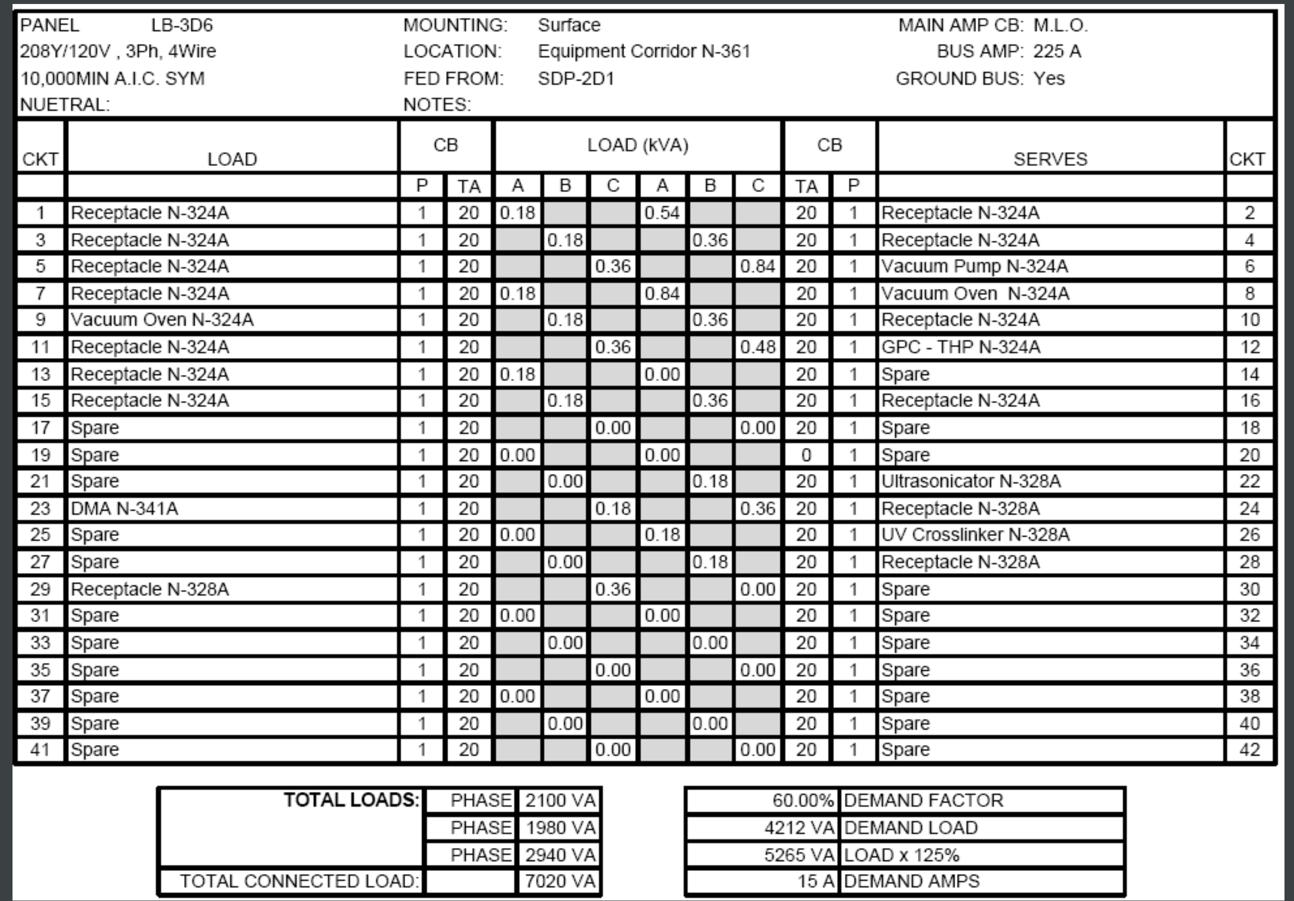
Exporting to Trace



Building STIMULUS

Determining Existing Plug Loads

Existing Panel Schedule



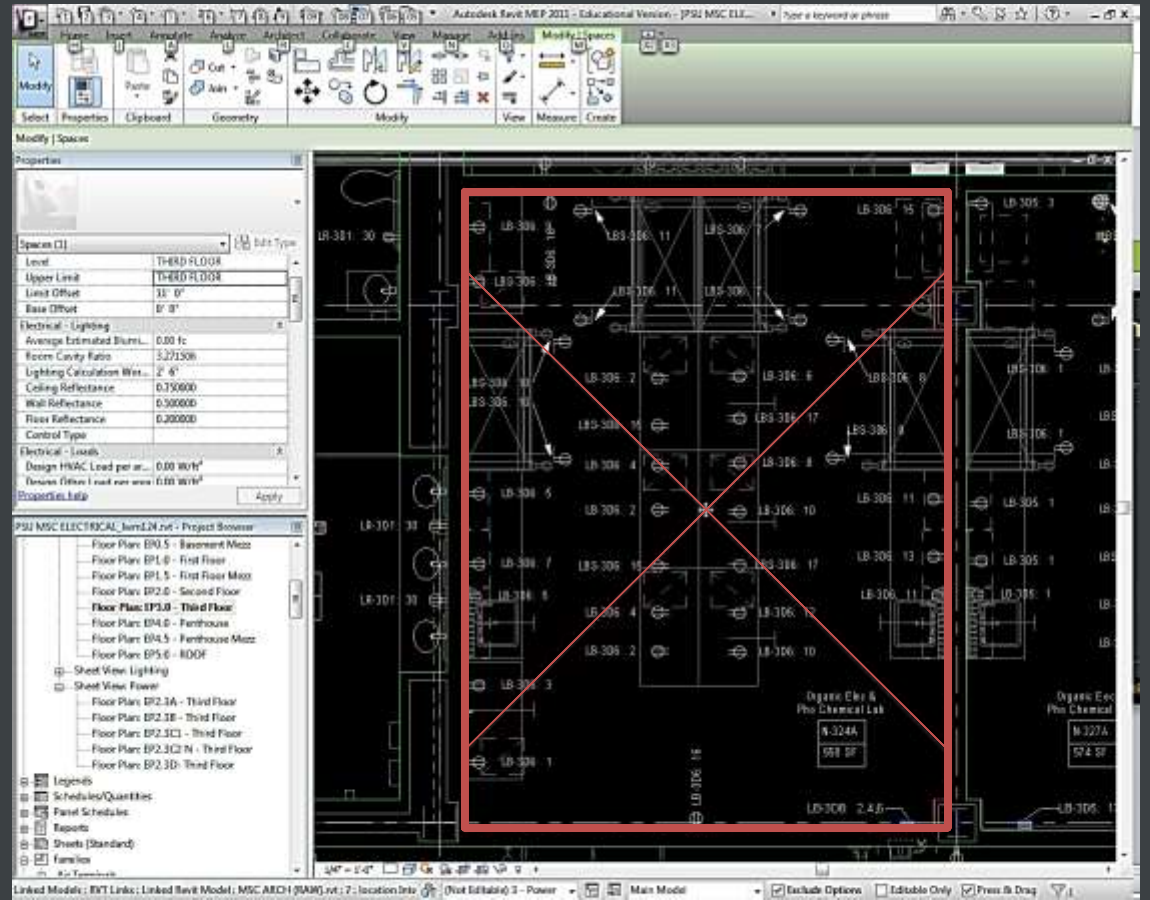
PANEL LB-3D6	MOUNTING: Surface	MAIN AMP CB: M.L.O.	
208Y/120V , 3Ph, 4Wire	LOCATION: Equipment Corridor N-361	BUS AMP: 225 A	
10,000MIN A.I.C. SYM	FED FROM: SDP-2D1	GROUND BUS: Yes	
NUETRAL:	NOTES:		

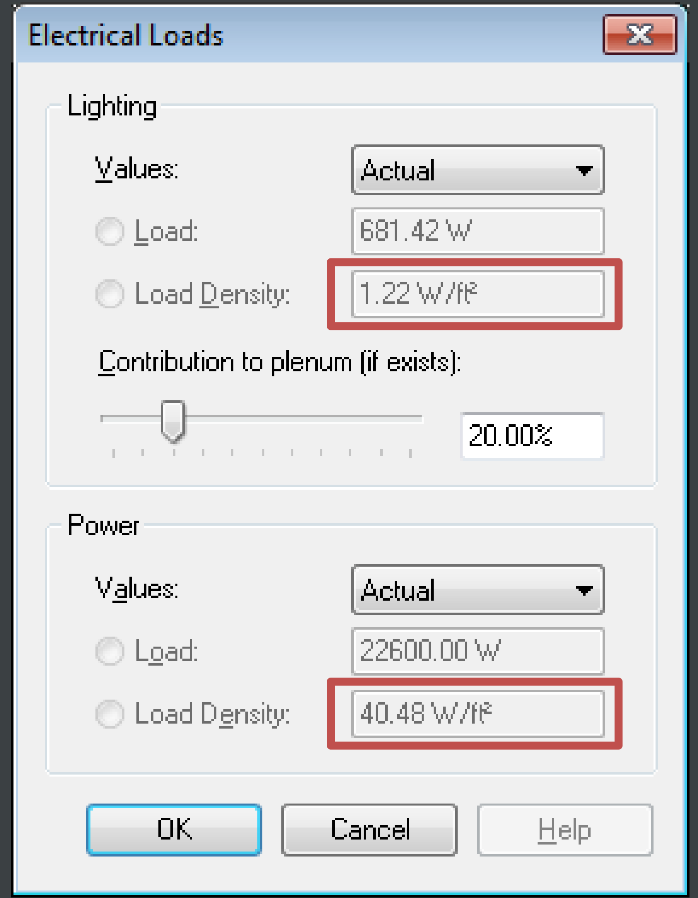
CKT	LOAD	CB		LOAD (kVA)						CB		SERVES	CKT
		P	TA	A	B	C	A	B	C	TA	P		
1	Receptacle N-324A	1	20	0.18			0.54			20	1	Receptacle N-324A	2
3	Receptacle N-324A	1	20		0.18			0.36		20	1	Receptacle N-324A	4
5	Receptacle N-324A	1	20			0.36			0.84	20	1	Vacuum Pump N-324A	6
7	Receptacle N-324A	1	20	0.18			0.84			20	1	Vacuum Oven N-324A	8
9	Vacuum Oven N-324A	1	20		0.18			0.36		20	1	Receptacle N-324A	10
11	Receptacle N-324A	1	20			0.36			0.48	20	1	GPC - THP N-324A	12
13	Receptacle N-324A	1	20	0.18			0.00			20	1	Spare	14
15	Receptacle N-324A	1	20		0.18			0.36		20	1	Receptacle N-324A	16
17	Spare	1	20			0.00			0.00	20	1	Spare	18
19	Spare	1	20	0.00			0.00			0	1	Spare	20
21	Spare	1	20		0.00			0.18		20	1	Ultrasonicator N-328A	22
23	DMA N-341A	1	20			0.18			0.36	20	1	Receptacle N-328A	24
25	Spare	1	20	0.00			0.18			20	1	UV Crosslinker N-328A	26
27	Spare	1	20		0.00			0.18		20	1	Receptacle N-328A	28
29	Receptacle N-328A	1	20			0.36			0.00	20	1	Spare	30
31	Spare	1	20	0.00			0.00			20	1	Spare	32
33	Spare	1	20		0.00			0.00		20	1	Spare	34
35	Spare	1	20			0.00			0.00	20	1	Spare	36
37	Spare	1	20	0.00			0.00			20	1	Spare	38
39	Spare	1	20		0.00			0.00		20	1	Spare	40
41	Spare	1	20			0.00			0.00	20	1	Spare	42

TOTAL LOADS:	PHASE	2100 VA
	PHASE	1980 VA
	PHASE	2940 VA
TOTAL CONNECTED LOAD:		7020 VA

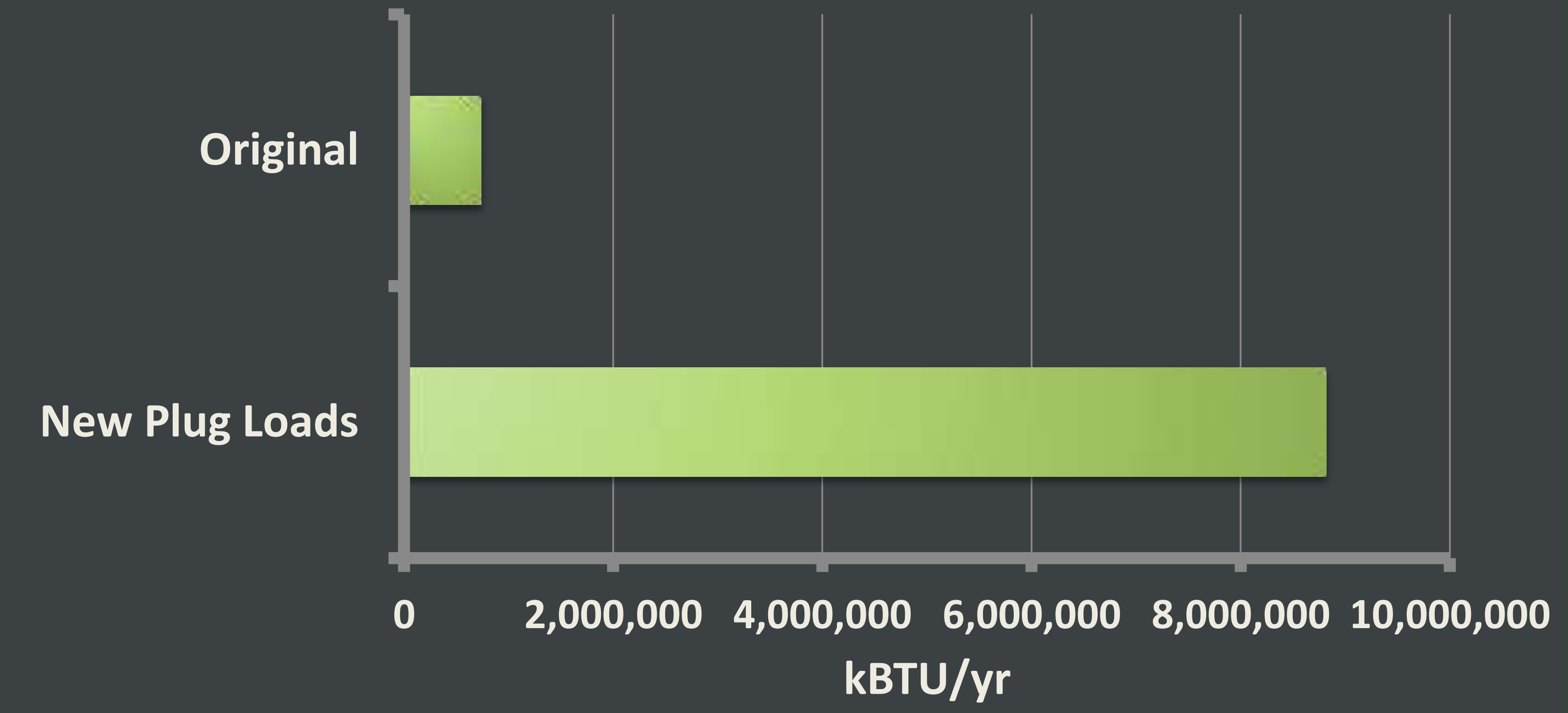
60.00%	DEMAND FACTOR
4212 VA	DEMAND LOAD
5265 VA	LOAD x 125%
15 A	DEMAND AMPS

Modeling Electrical Information In Revit



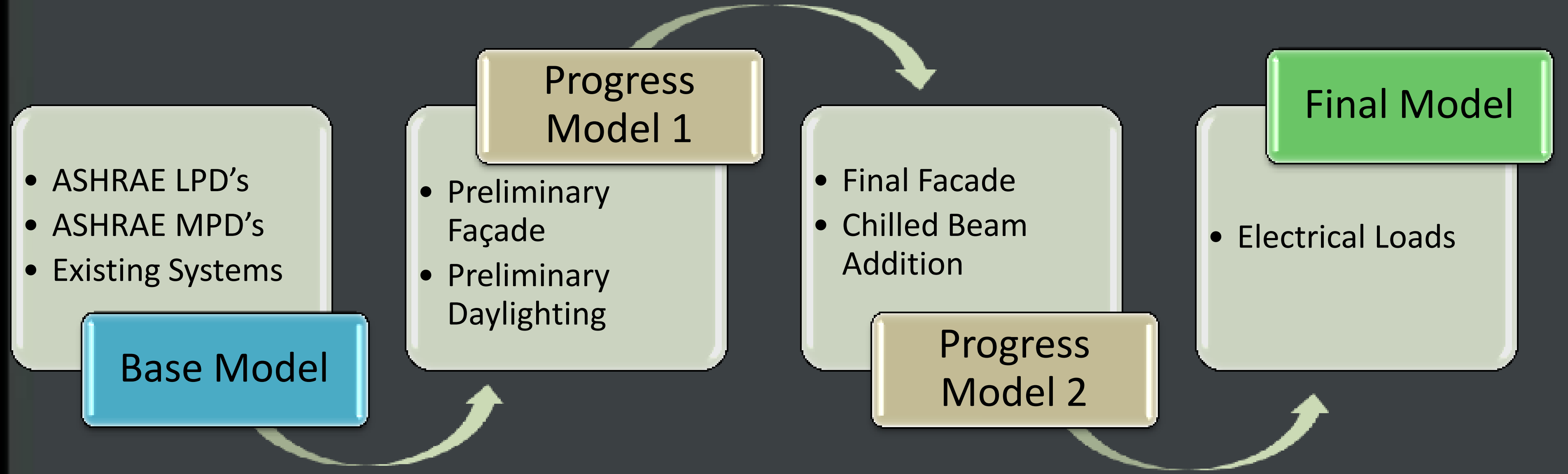


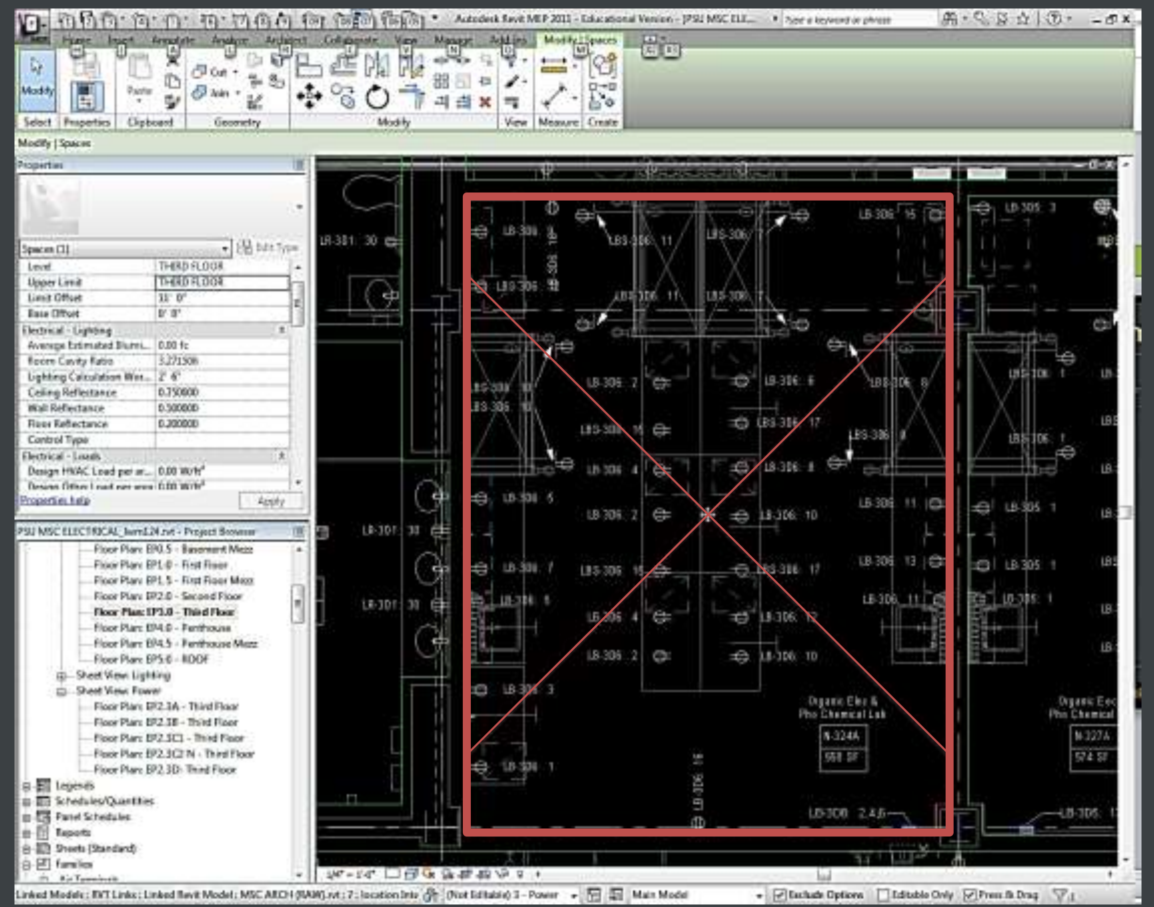
Receptacle Energy Consumption (3rd Floor)

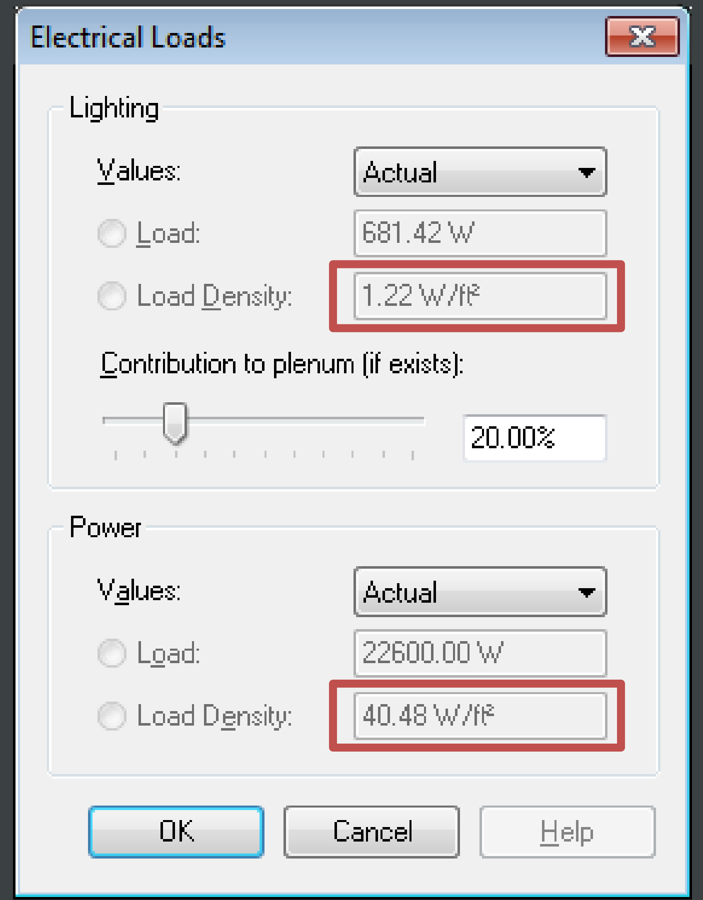


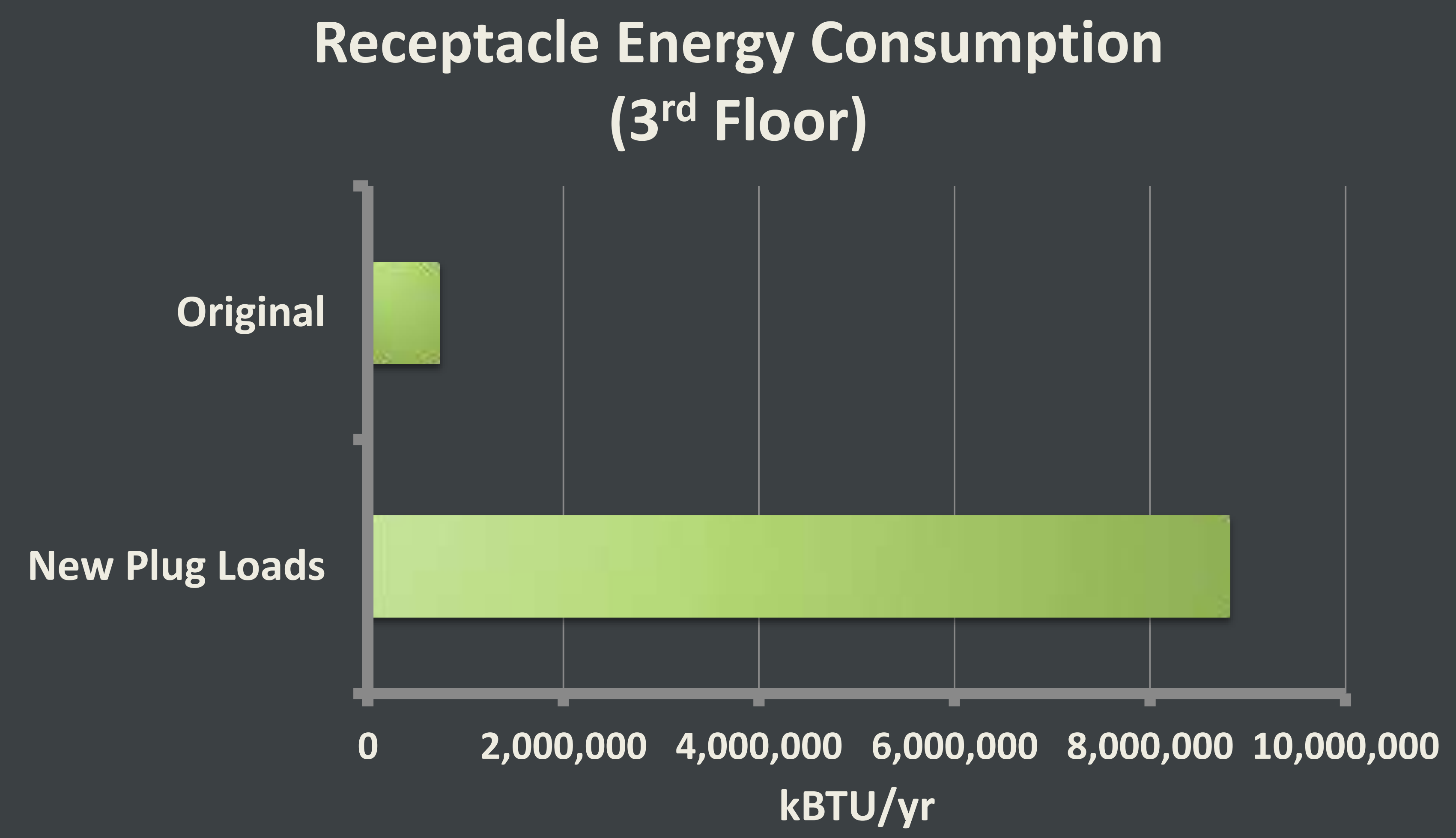
Determining Existing Plug Loads

Modeling Electrical Information In Revit

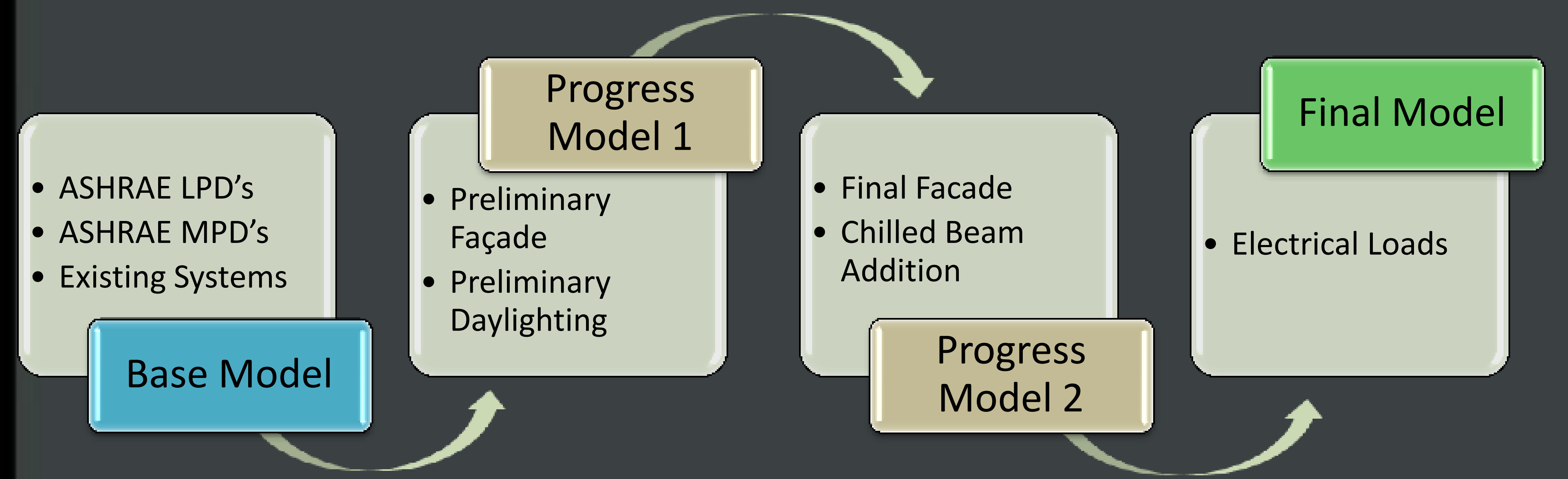


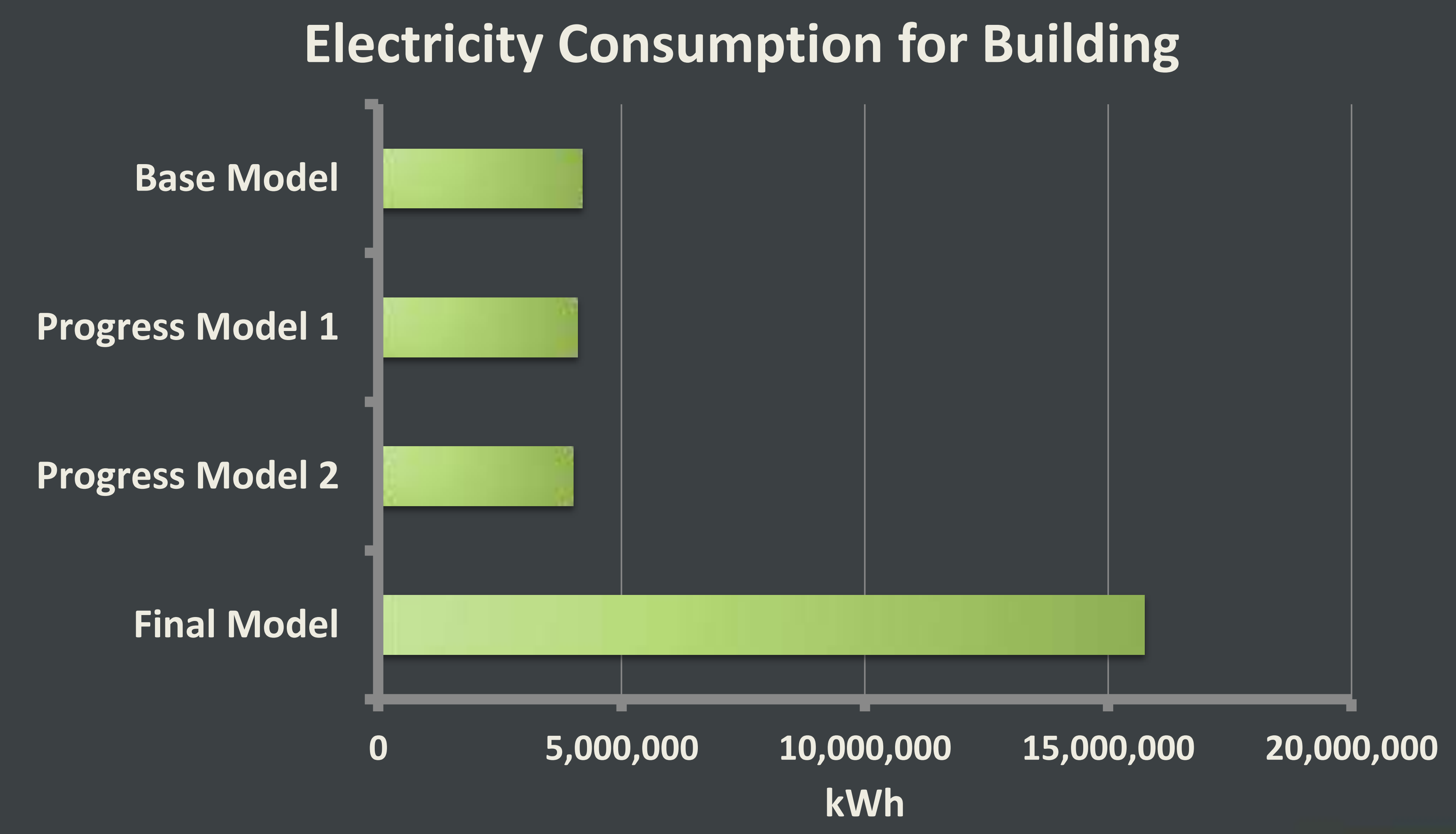


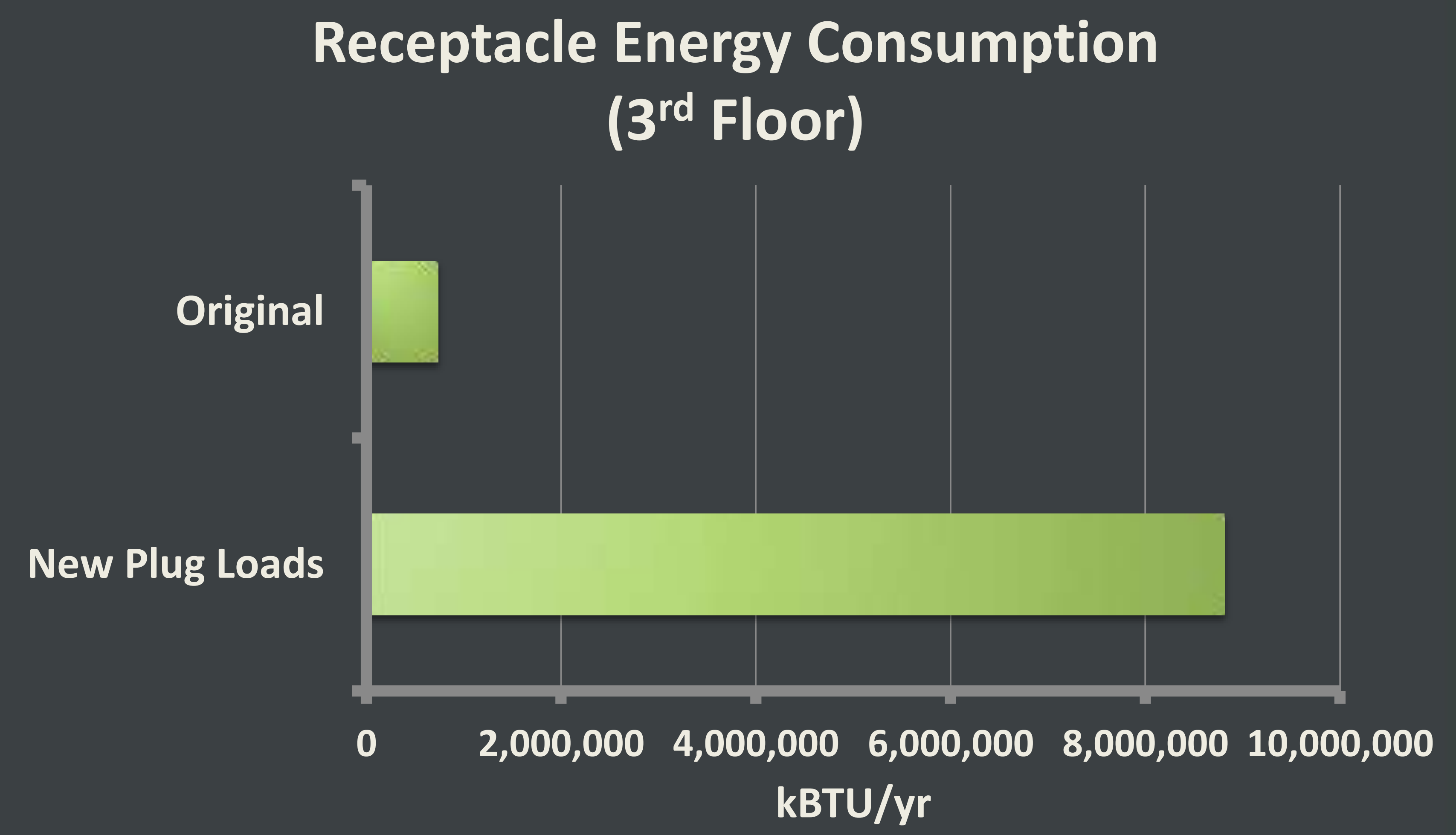




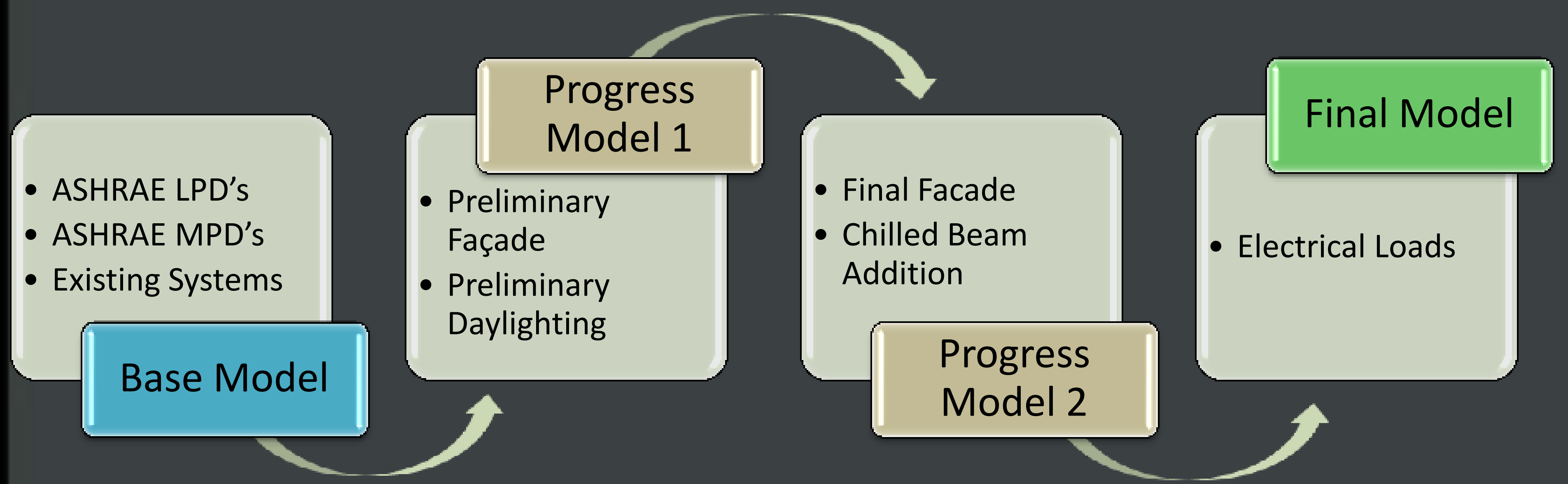
Determining Existing Plug Loads

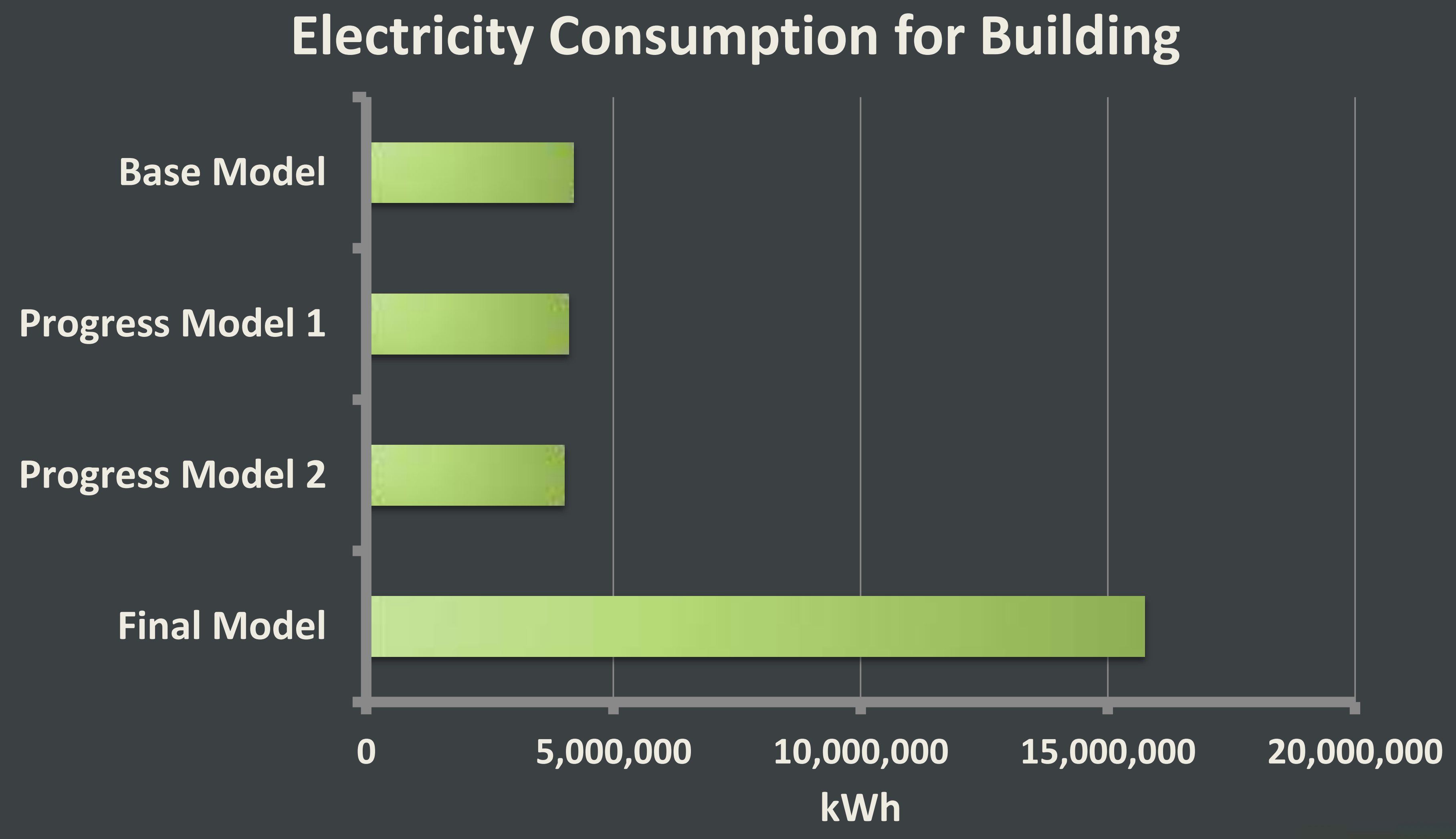


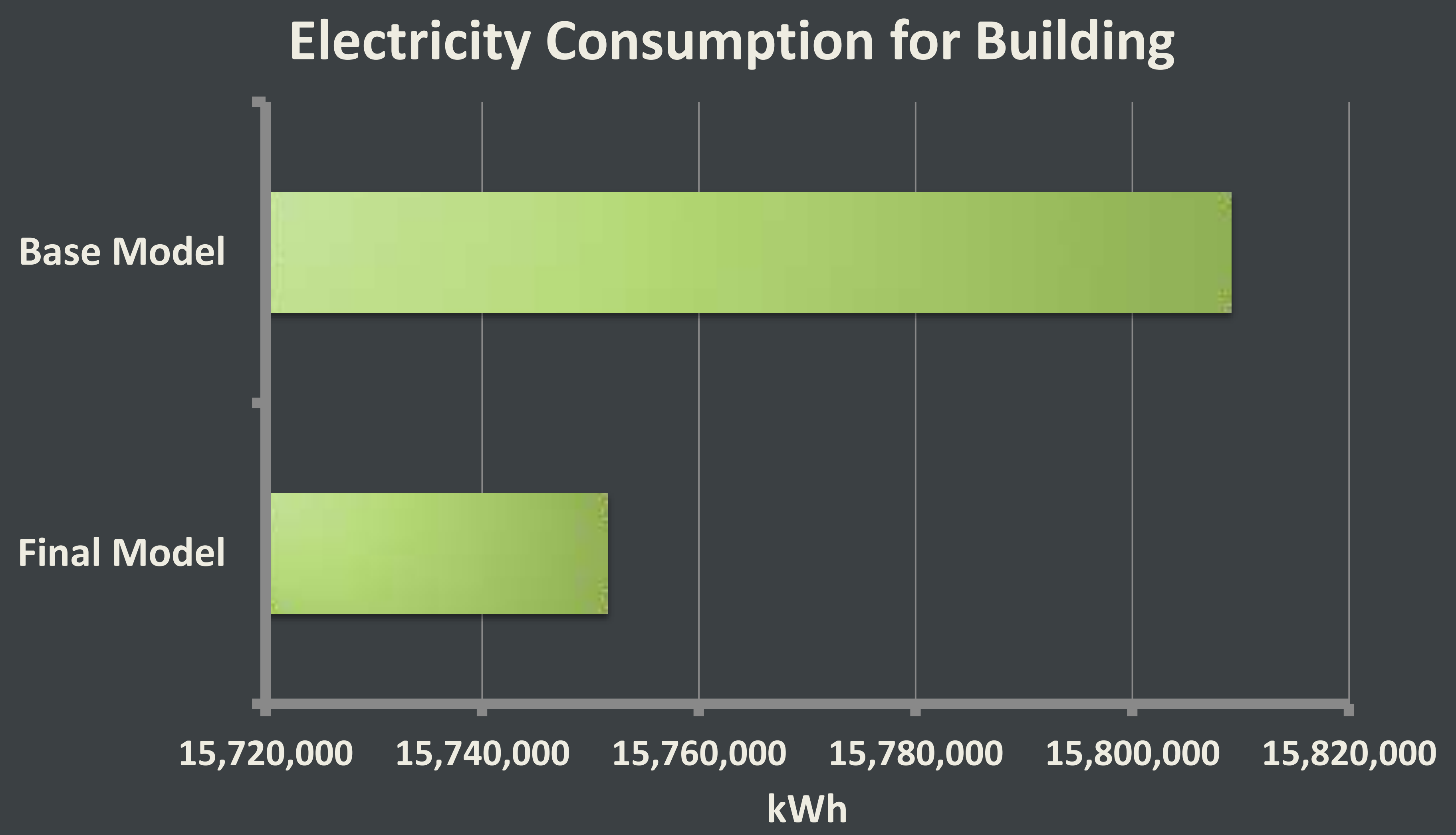




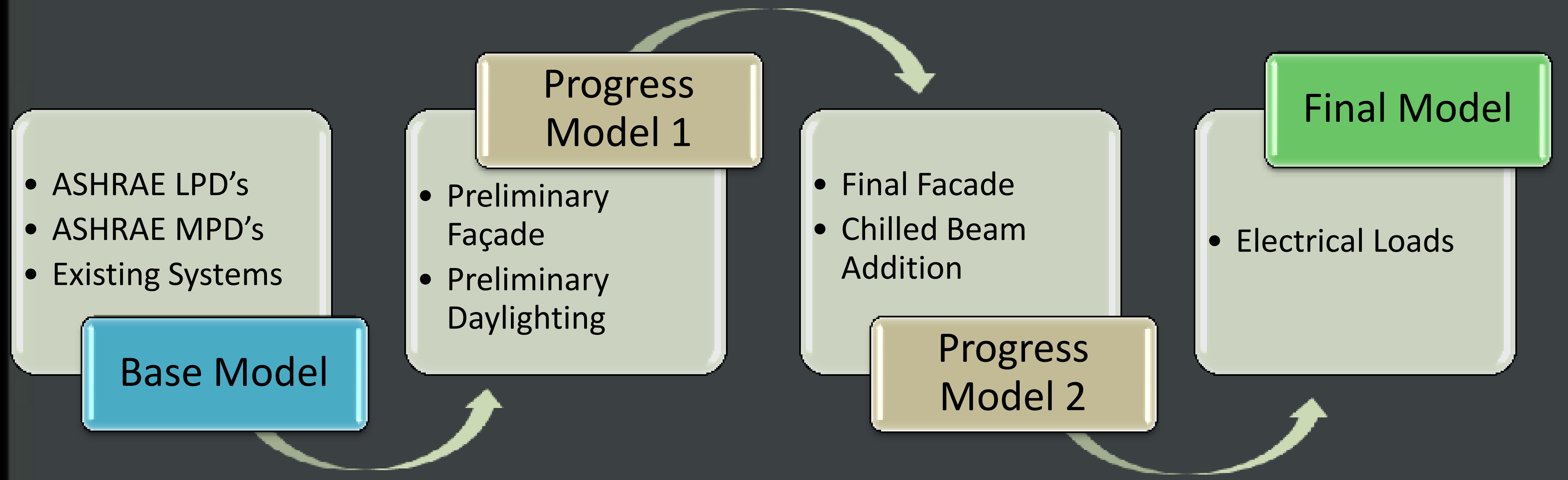
Determining Existing Plug Loads

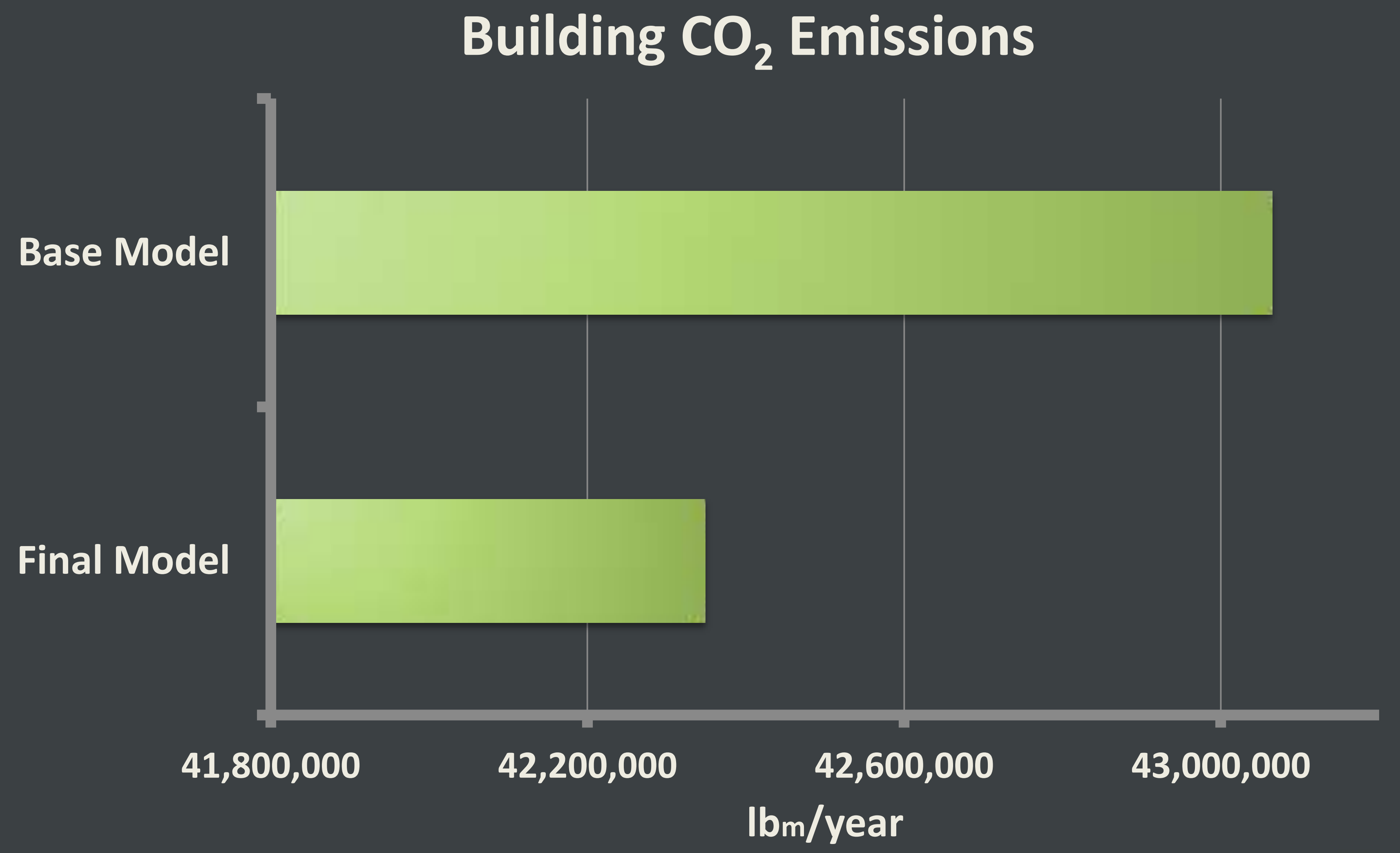


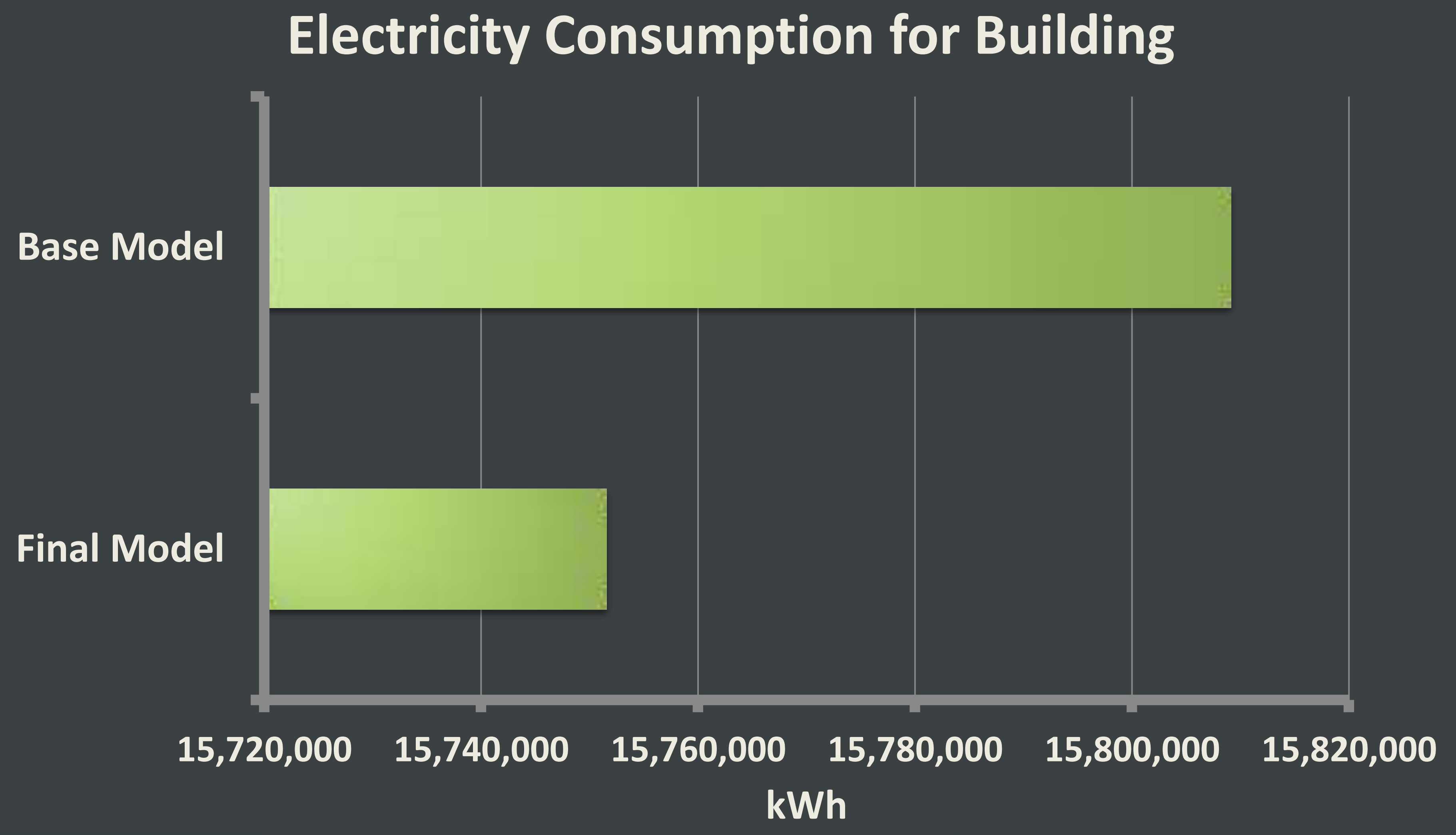




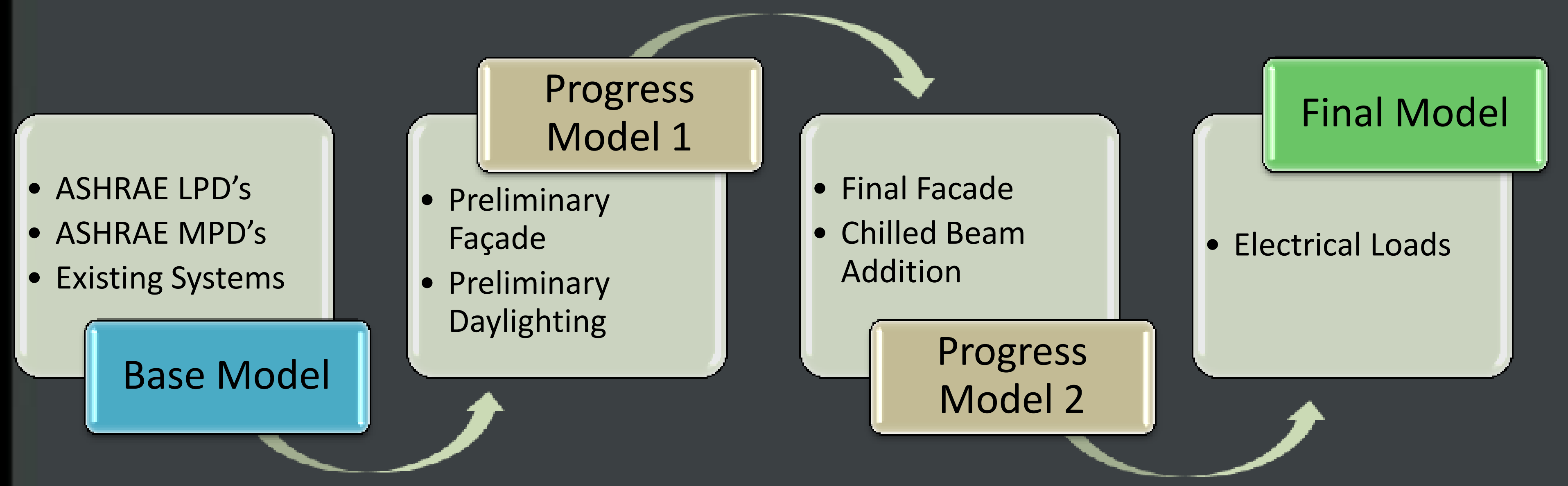
Determining Existing Plug Loads

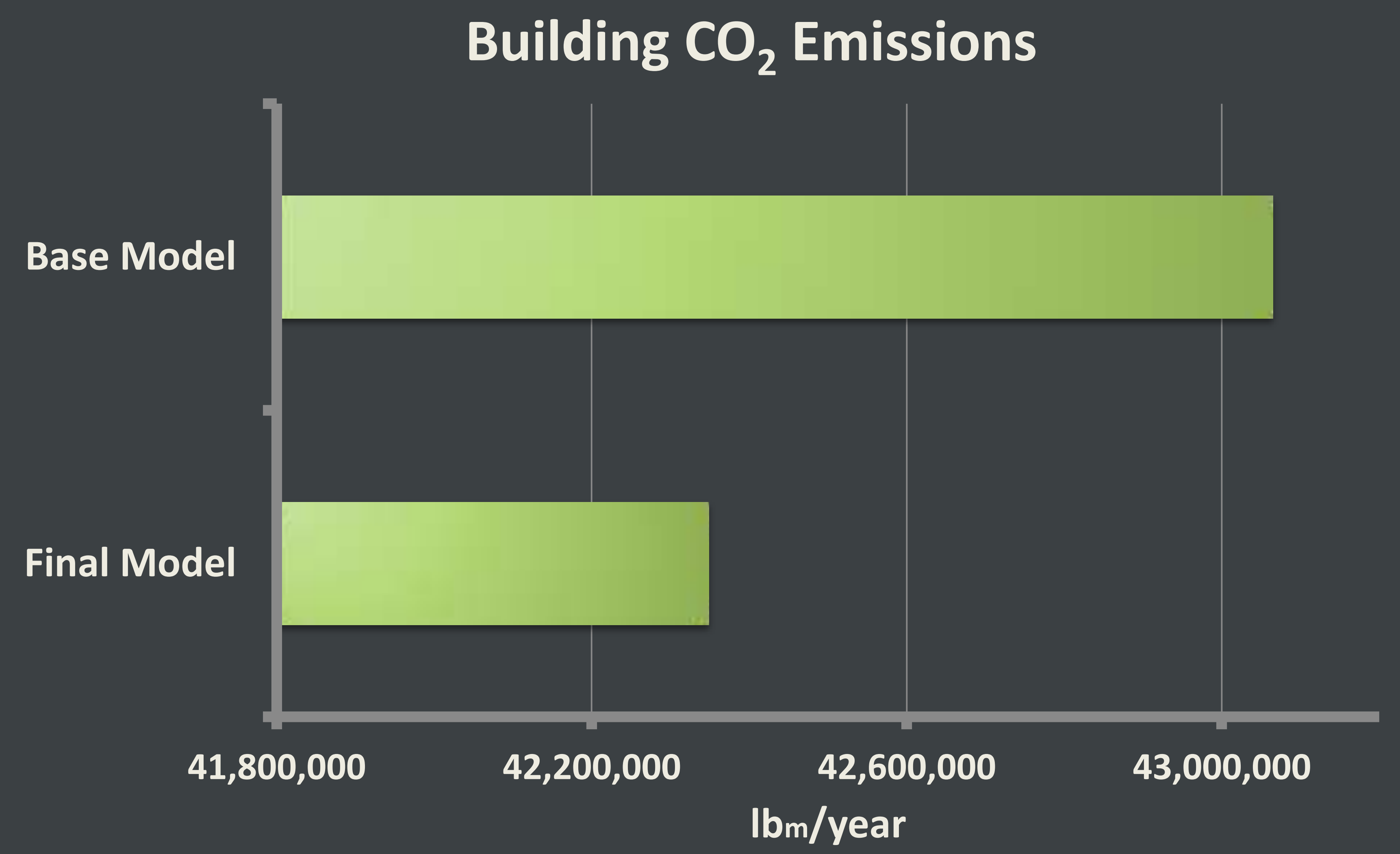


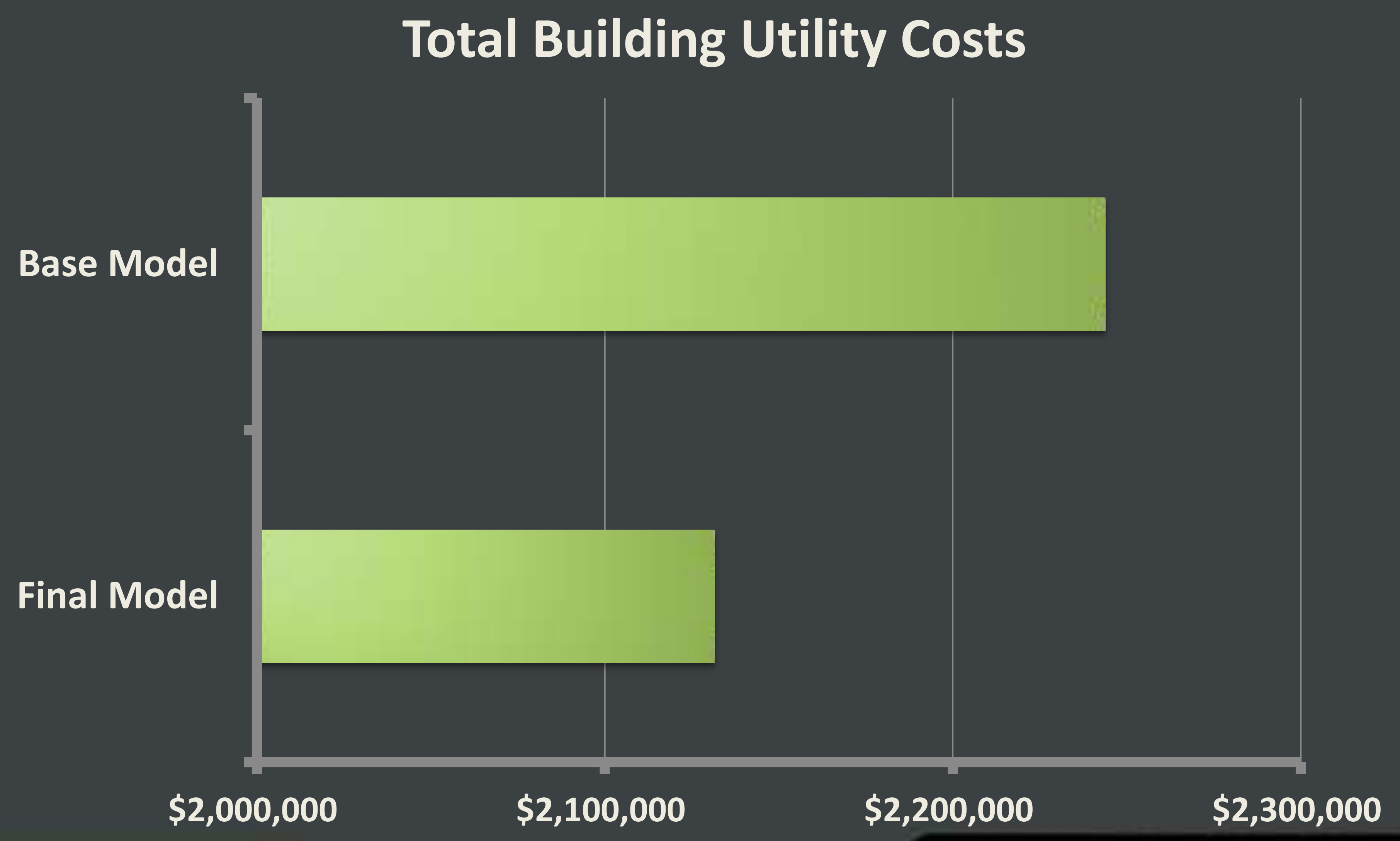




Determining Existing Plug Loads







Metrics of Success and Reflection

Façade Redesign

- Peak Envelope Loads Reduction
  - Cooling Load
  - Heating Load
- Reduce Panel Weight
- Daylight Integration
  - Improve Visual Comfort
  - Improve Overall Appearance
  - Reduce Solar Heat Gain
- Minimize Constructability Issues

Cantilever Redesign

- Alternative Energy Implemented
- Steel Tonnage Reduced
- Truss Design Efficiency Increased
- Lighting Design
  - Emphasize Architectural Features and Entrance

Energy Usage

- Primary Energy Use Reduction (MBtu/yr)
- Reduced Life Cycle Cost
- Meet ASHRAE Lighting Power Densities

- Thorton Tomasetti Engineers
- Rafael Viñoly Architects
- Flak & Kurtz
- Bob Biter Electric
- Whiting Turner
- Eric Mitchel (Mechanical P.M. - Flak & Kurtz)
- Josh Miller (B.I.M. Coordinator at Gilbane)
- Chris Dolan (Whiting Turner)
- Adam Fry (Electrical P.M. at Mueller Associates)
- Stephanie Hill (M.E.at Mueller Associates)
- Matthew Danowski (M.E.at Mueller Associates)

The Pennsylvania State University
Millennium Science Complex

WHITING-TURNER

RAFAEL VIÑOLY ARCHITECTS
Thornton Tomasetti
WSP ▪ FLACK+KURTZ

PENNSTATE

Building STIMULUS

- Randy Phillips Central Regional Manager,
  Semco Flaktwoods
- John Jackson (HOK)
- Corey Wilkinson for quick and successful responses to
  countless computer issues.
- Members of BIMCeption
- Members of K.G.B. Maser
- Last but not least, all friends and family

QUESTIONS & COMMENTS

AE SENIOR THESIS: IPD/BIM (2010-2011)