



FINAL THESIS
PRESENTATION

THE BARNES FOUNDATION

2025 BENJAMIN FRANKLIN PARKWAY
PHILADELPHIA, PA 19130

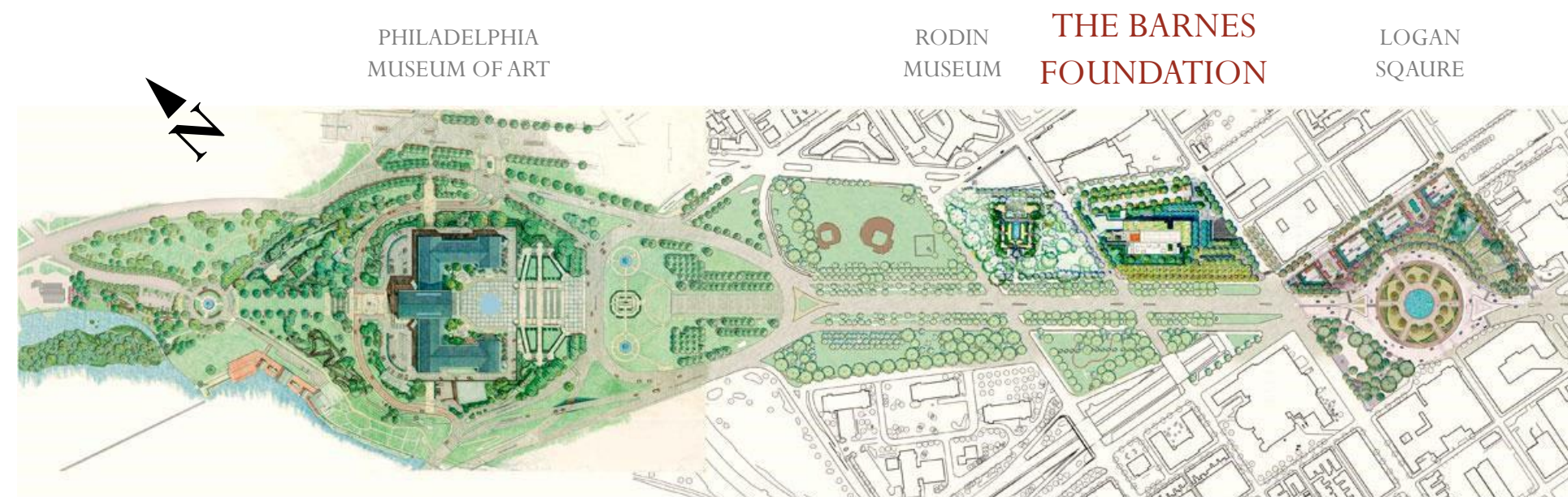
JOSEPH BRENNER
LIGHTING | ELECTRICAL
4 | 15 | 2015

BUILDING
PROJECT
LIGHTING
STRUCTURAL
DAYLIGHTING
ELECTRICAL
CONCLUSION
CREDITS

THE BARNES FOUNDATION



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LOCATION
SIZE
OCCUPANCY
COST
DELIVERY

ARCHITECT

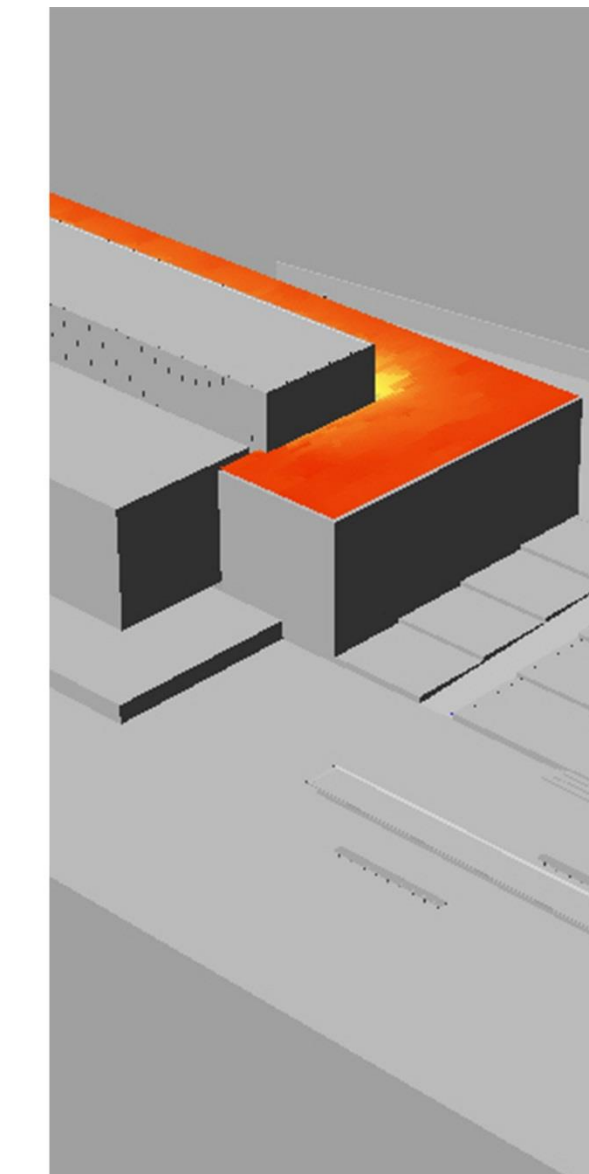
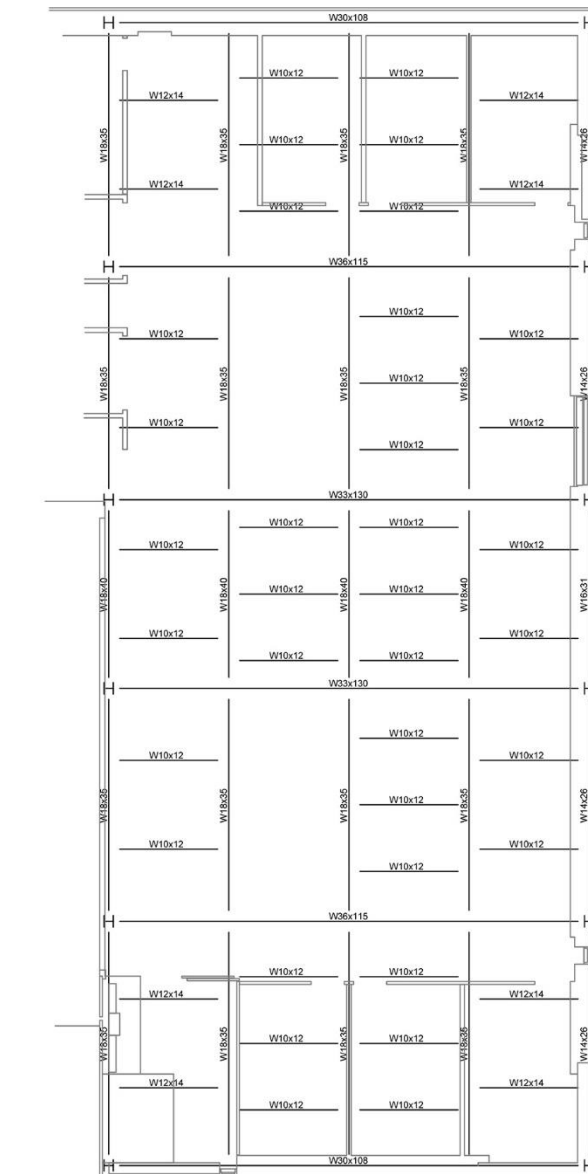
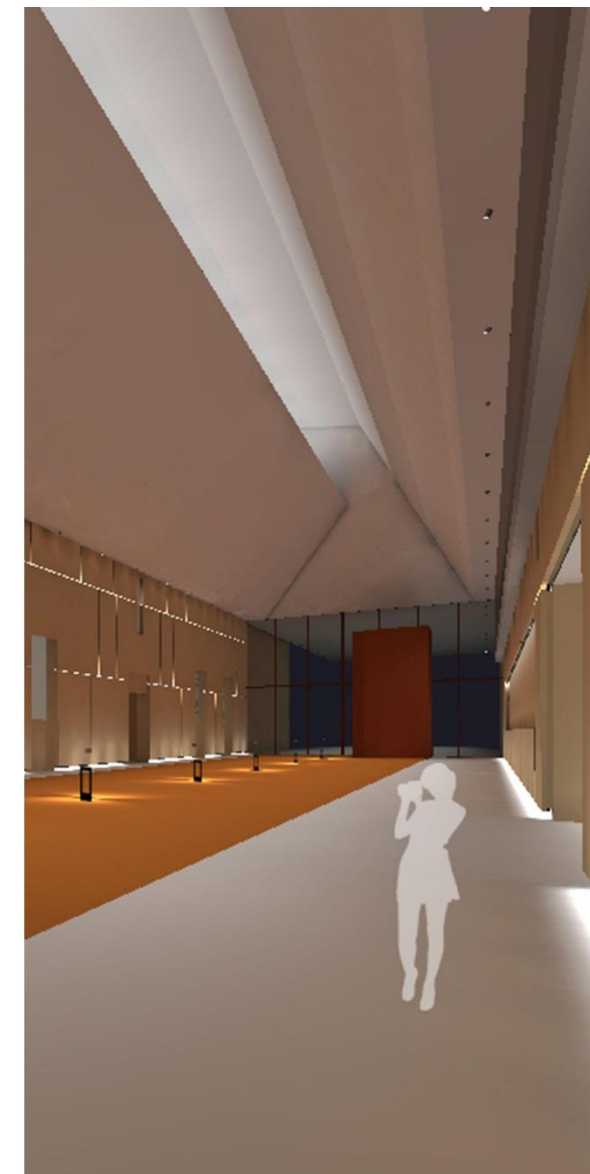
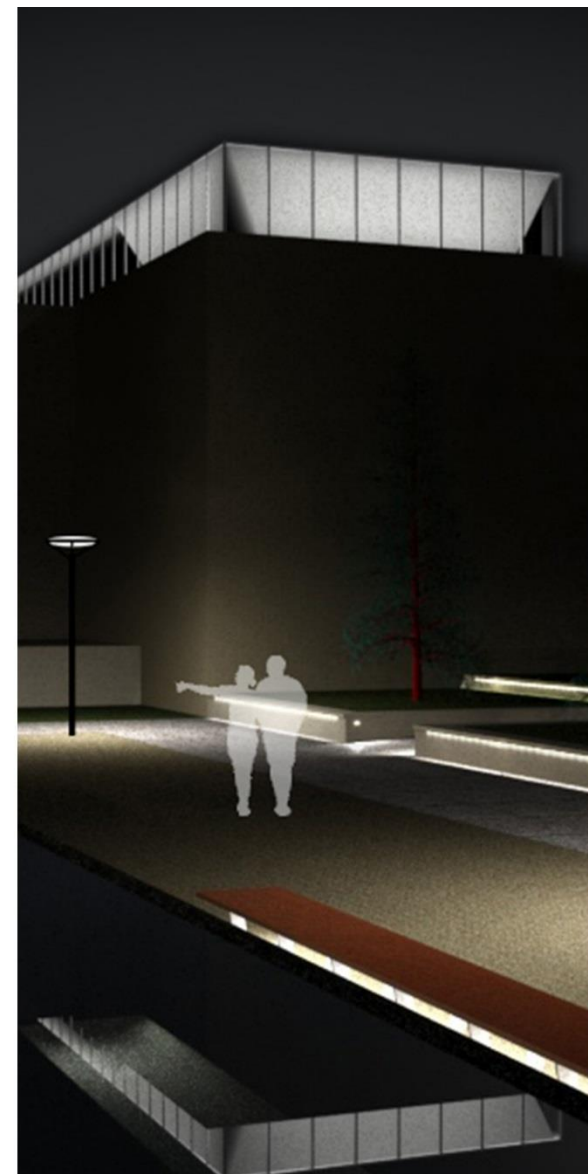
| PHILADELPHIA, PA
| 91,748 FT²
| ASSEMBLY, BUSINESS
| \$75,890,374
| GUARANTEED MAXIMUM PRICE

| TOD WILLIAMS AND BILLIE TSUEN ARCHITECTS

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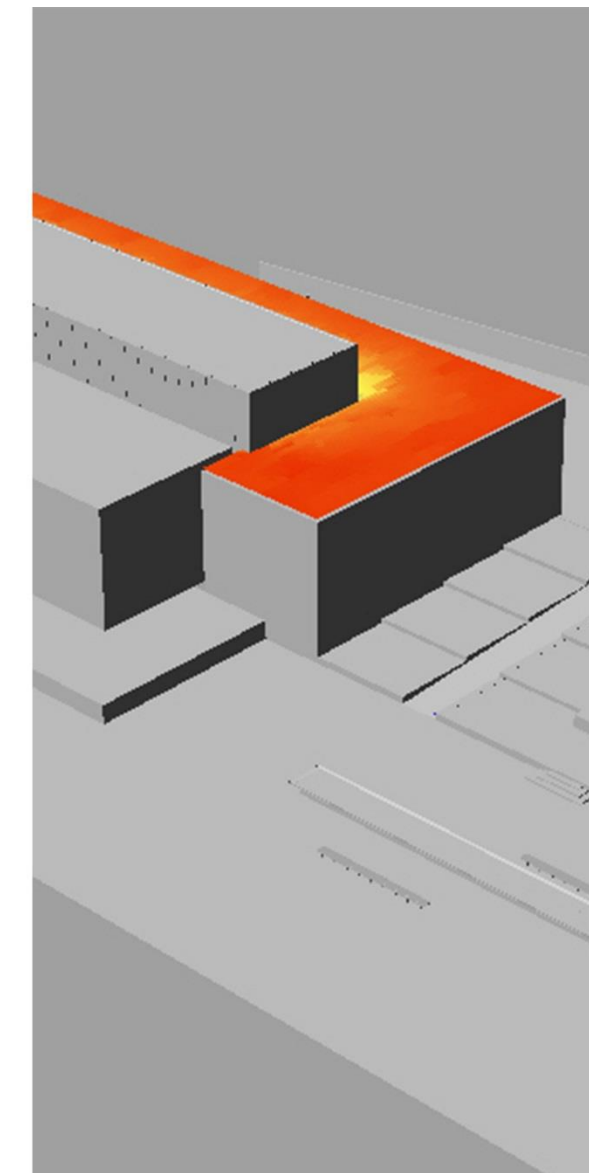
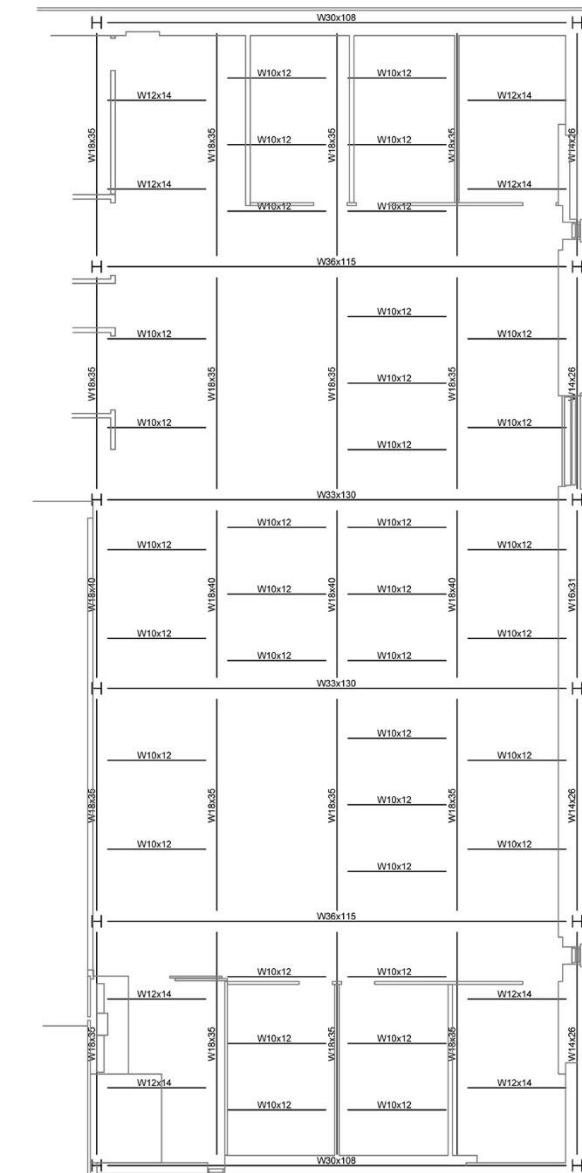
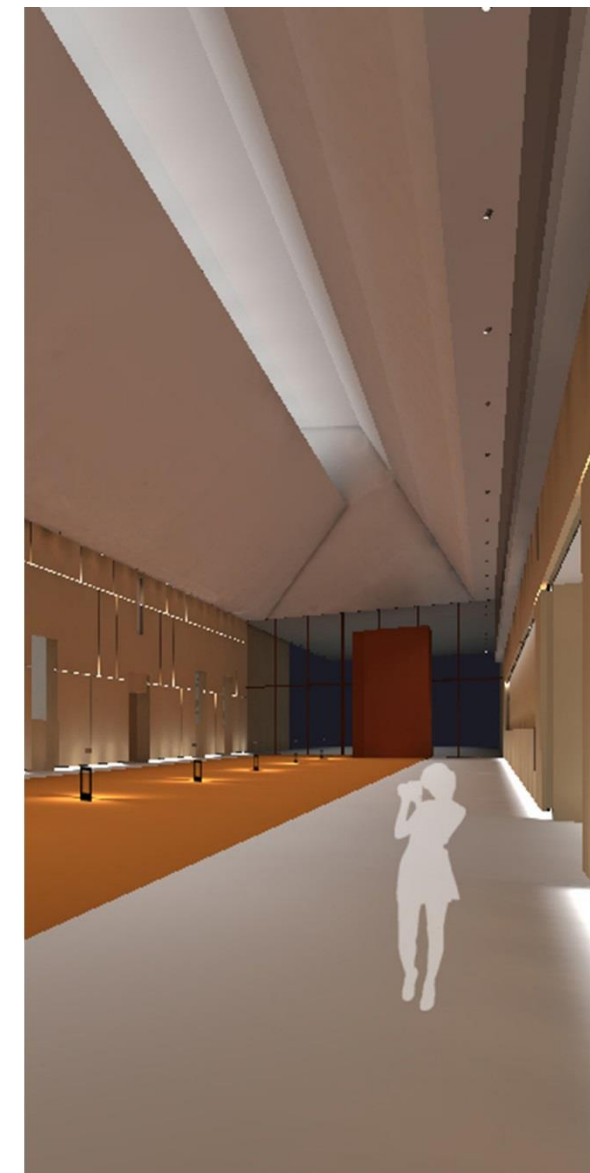
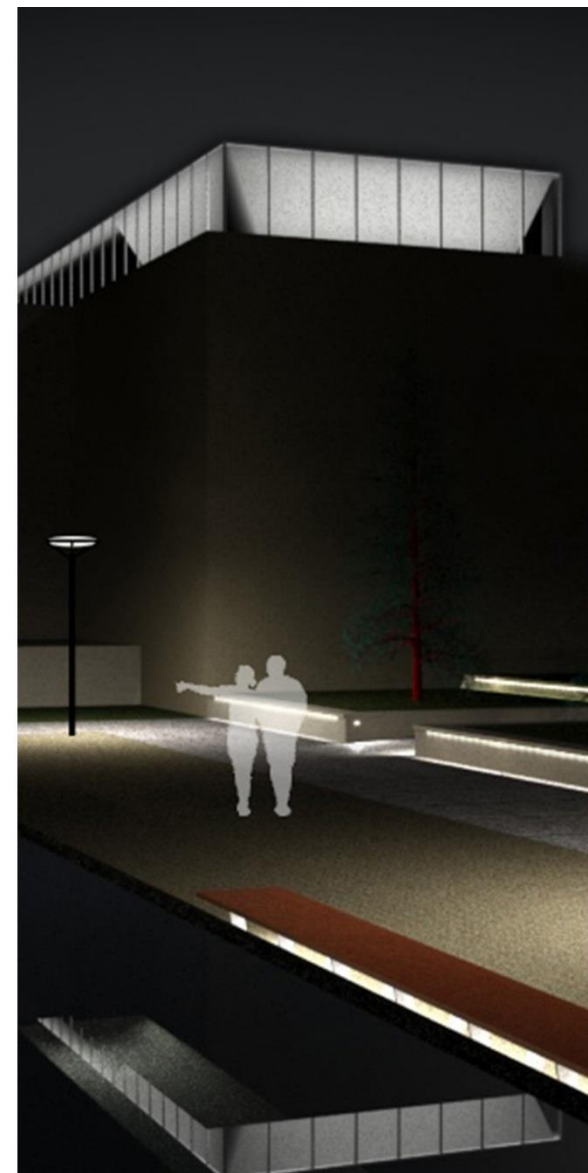
- LIGHTING
 - SITE
 - LIGHT BOX
 - LIGHT COURT
 - LOWER LOBBY
 - OFFICE
- STRUCTURAL
 - OFFICE ROOF REDESIGN
- DAYLIGHTING
 - SKYLIGHT WELL ANALYSIS
- ELECTRICAL
 - BRANCH CIRCUIT REDESIGN
 - SHORT CIRCUIT ANALYSIS
 - PHOTOVOLTAIC ARRAY STUDY
- MECHANICAL
 - MECHANICAL SYSTEM ANALYSIS

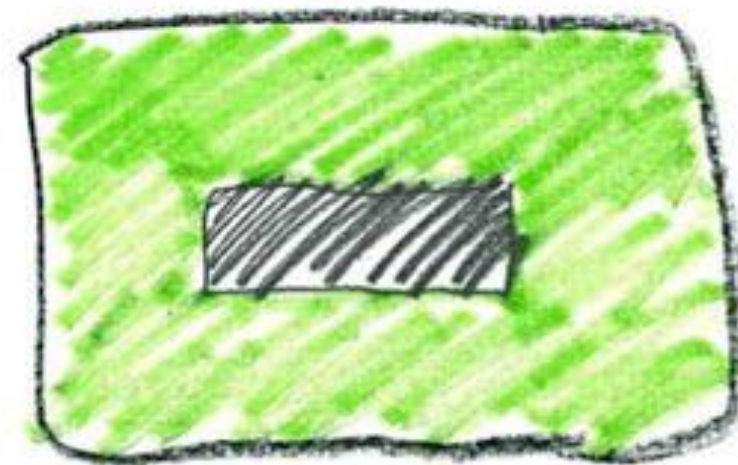


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- MECHANICAL
 - MECHANICAL SYSTEM ANALYSIS





*gallery in a
garden*

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A GALLERY IN A GARDEN
AND A GARDEN IN A GALLERY



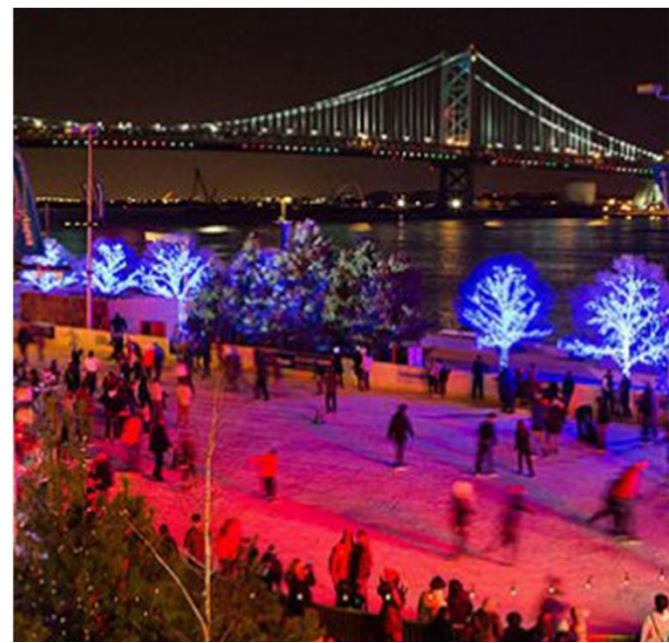
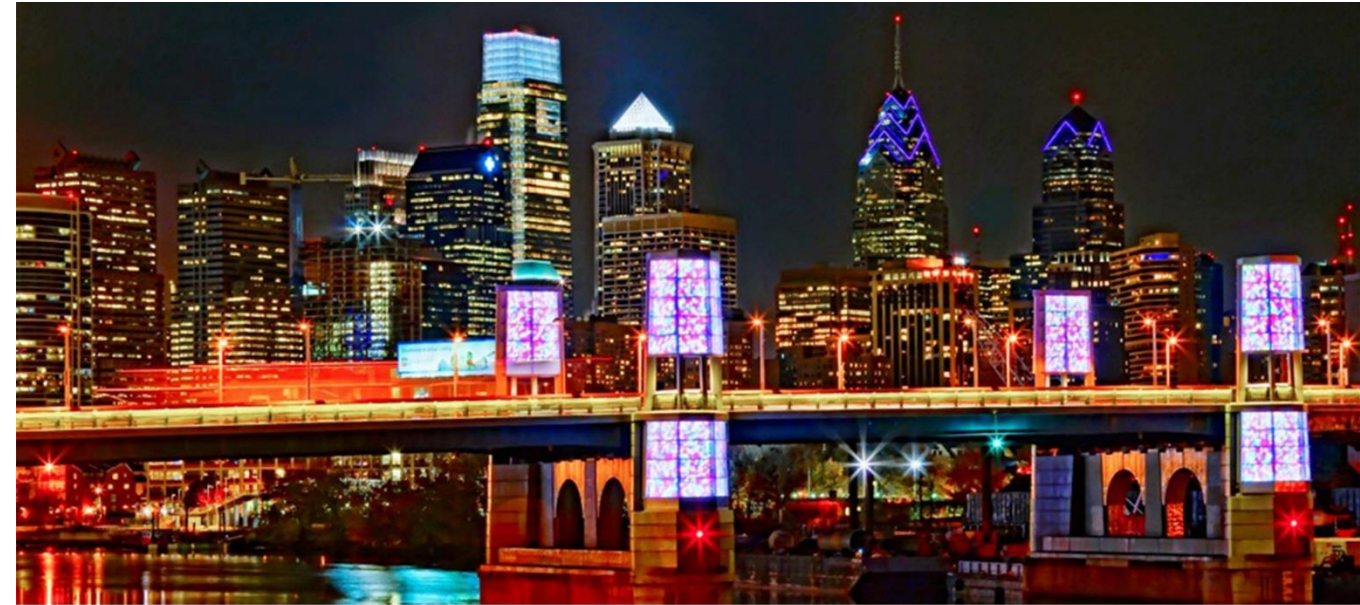
*garden in a
gallery*

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THE BARNES IN PHILLY AND PHILLY IN THE BARNES



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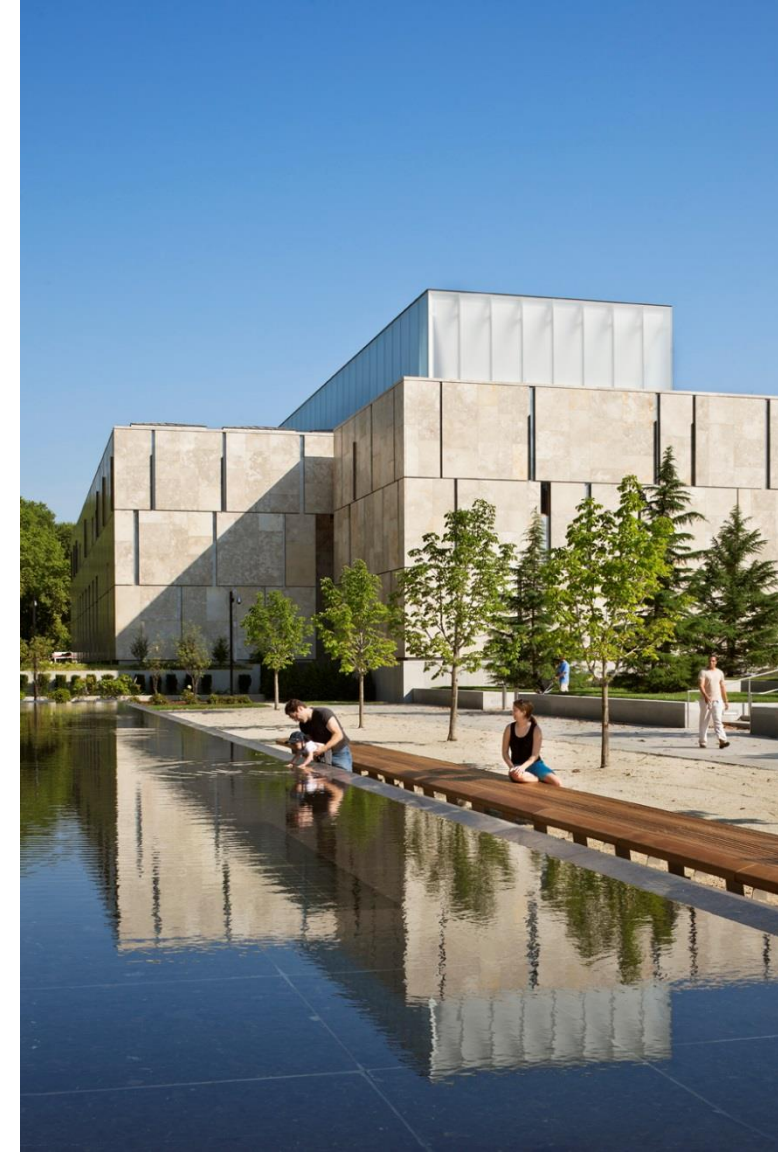
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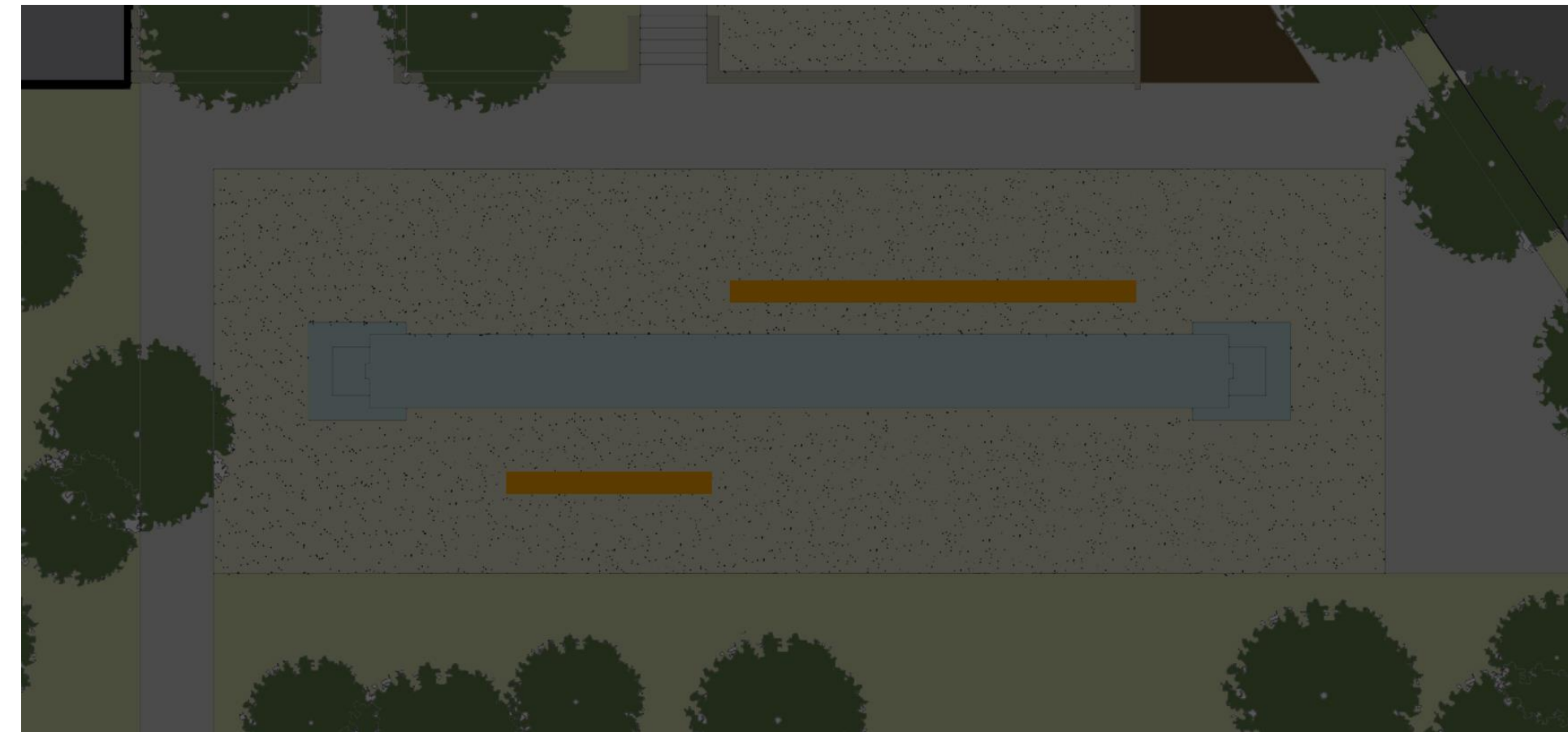


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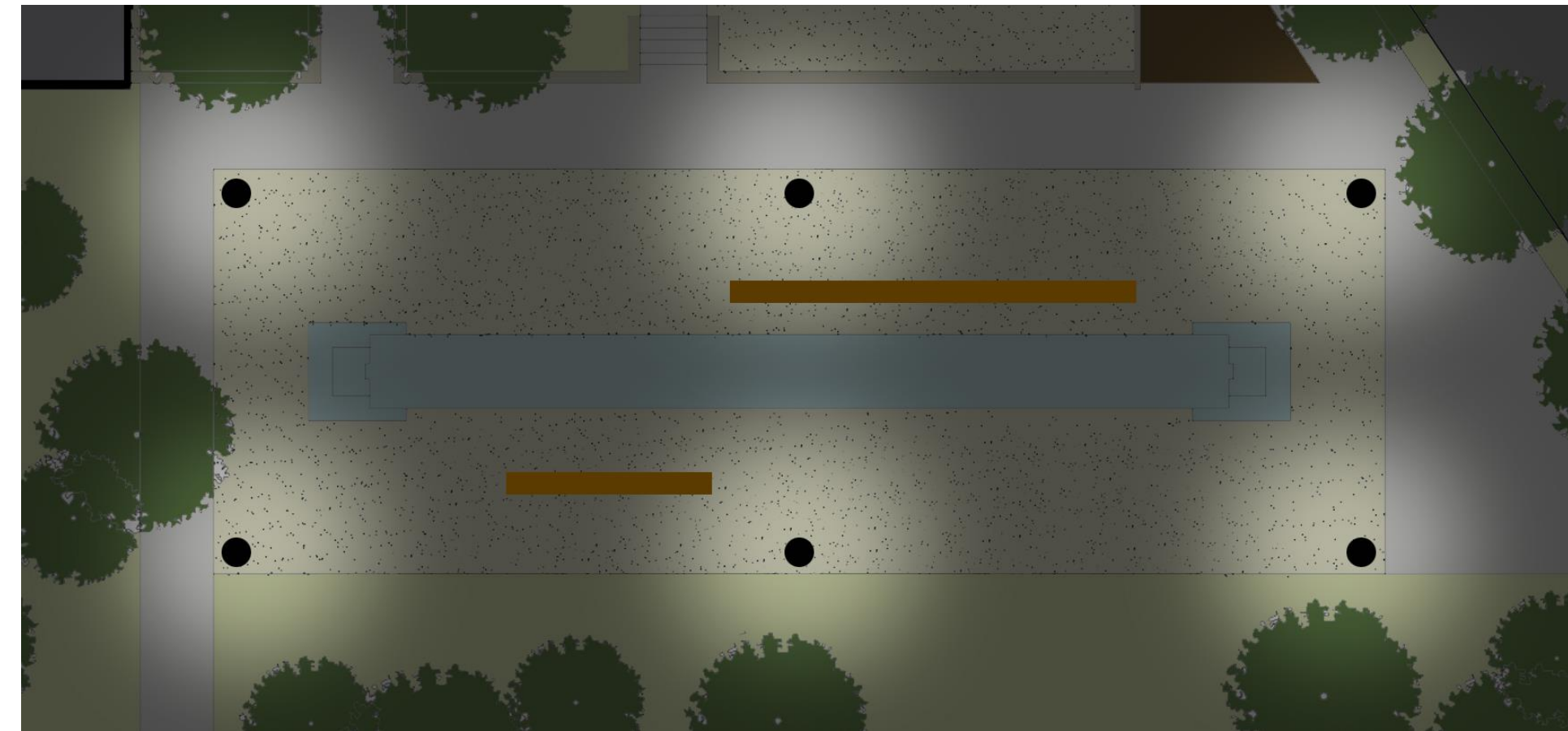
Space	Eh (fc)
	Criteria
Entry Park	0.4

Space	ASHRAE 90.1 LPD (W/ft ²)
	Criteria
Site	0.16

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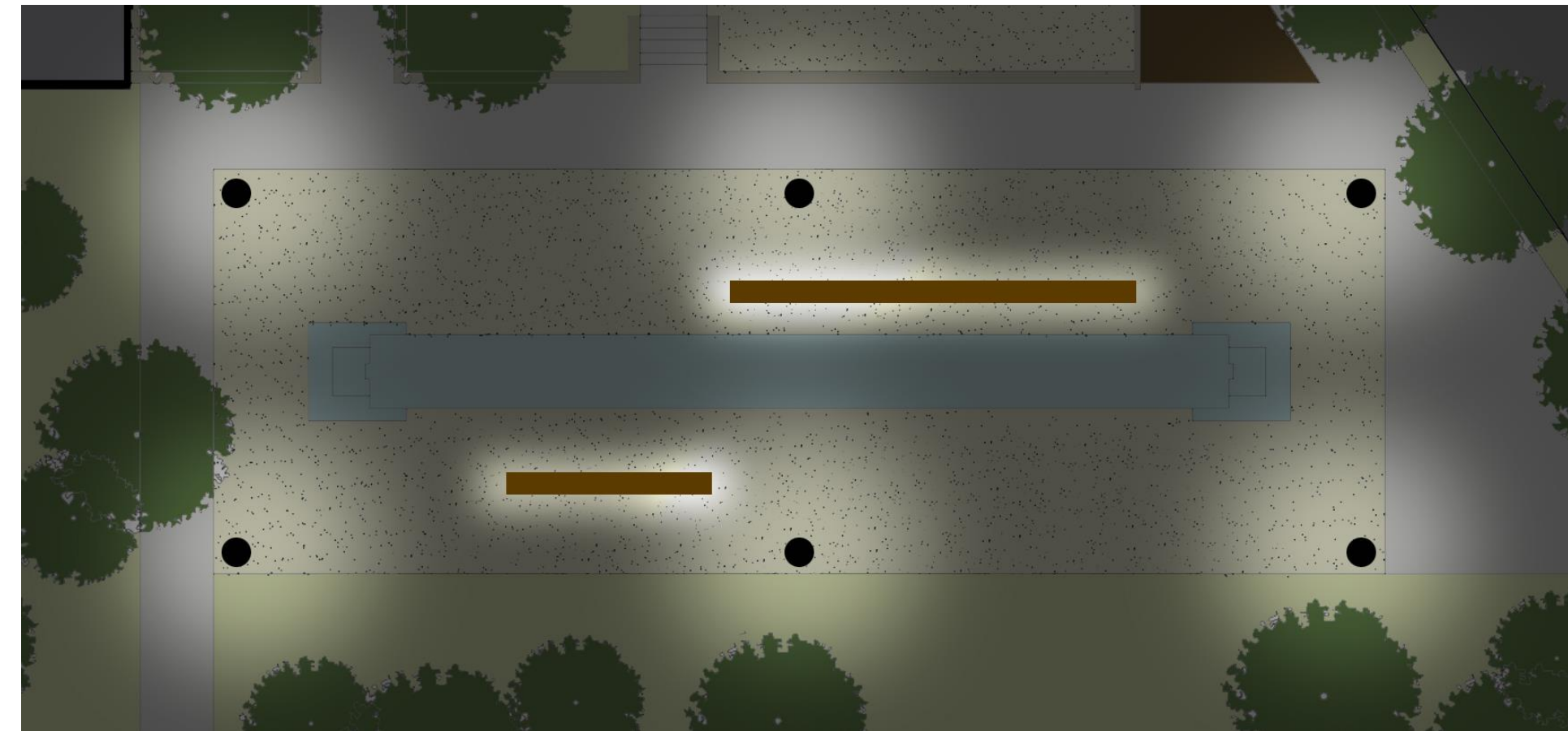
Space	Eh (fc)
	Criteria
Entry Park	0.4

Space	ASHRAE 90.1 LPD (W/ft ²)
	Criteria
Site	0.16

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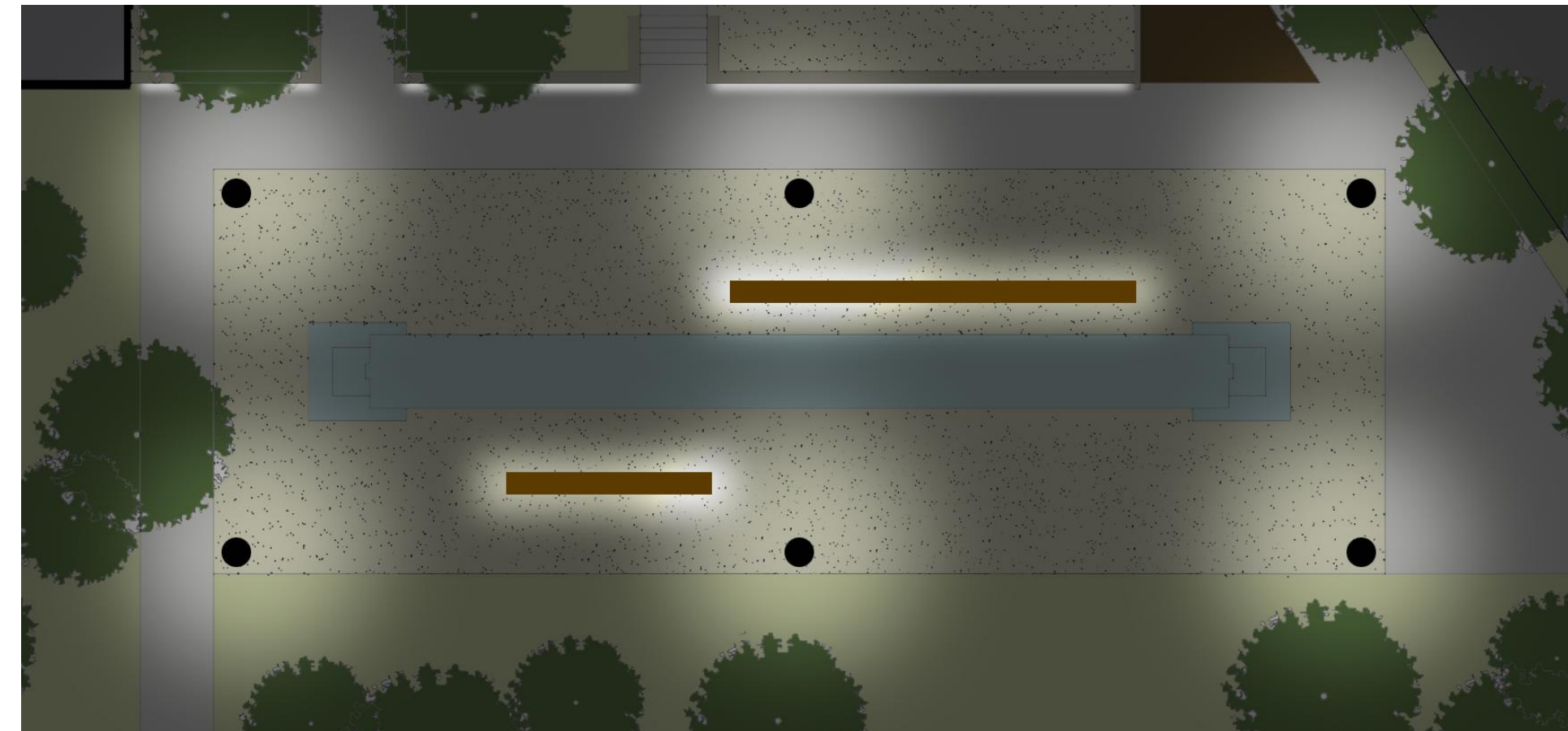
Space	Eh (fc)
	Criteria
Entry Park	0.4

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Site	0.16

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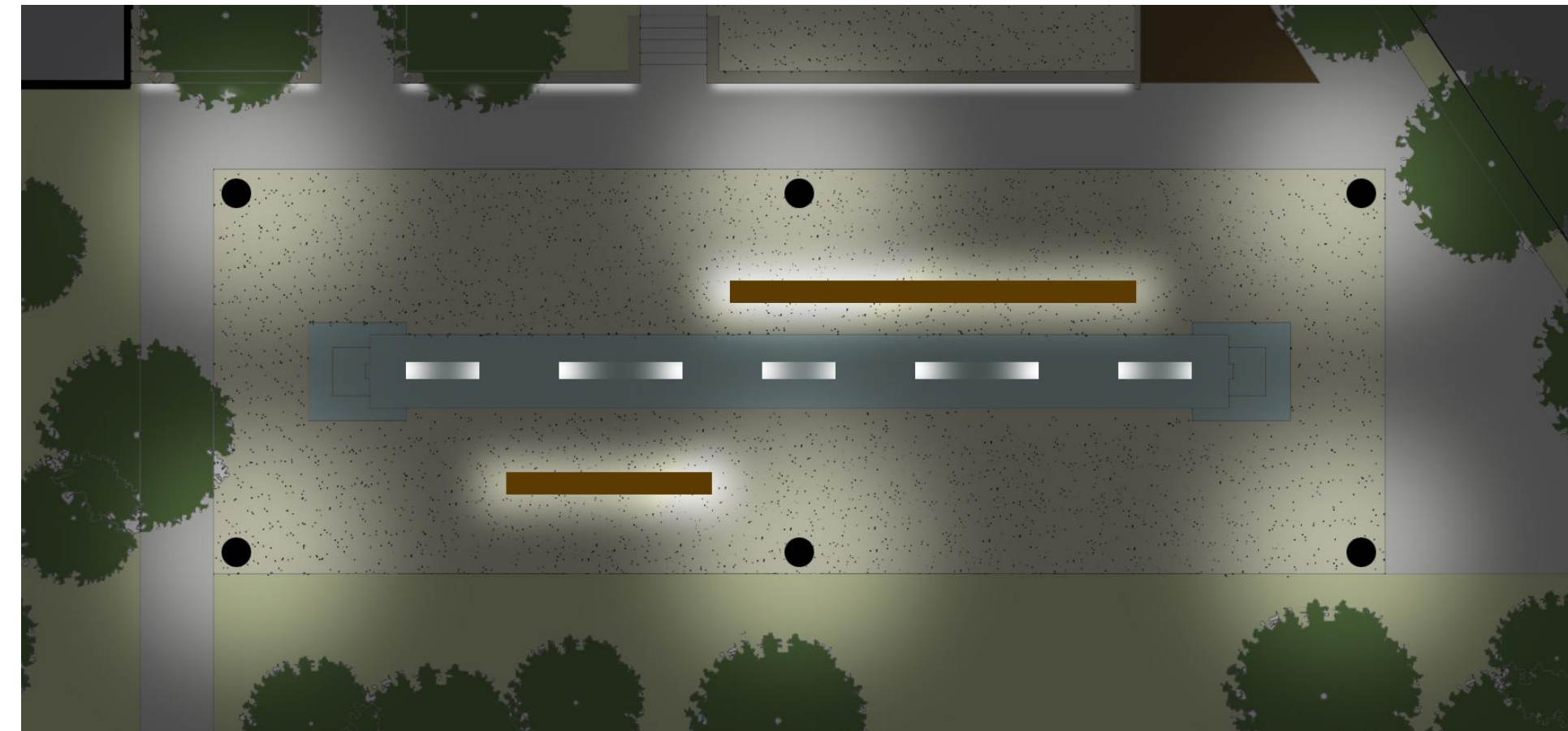
Space	Eh (fc)
	Criteria
Entry Park	0.4

Space	ASHRAE 90.1 LPD (W/ft ²)
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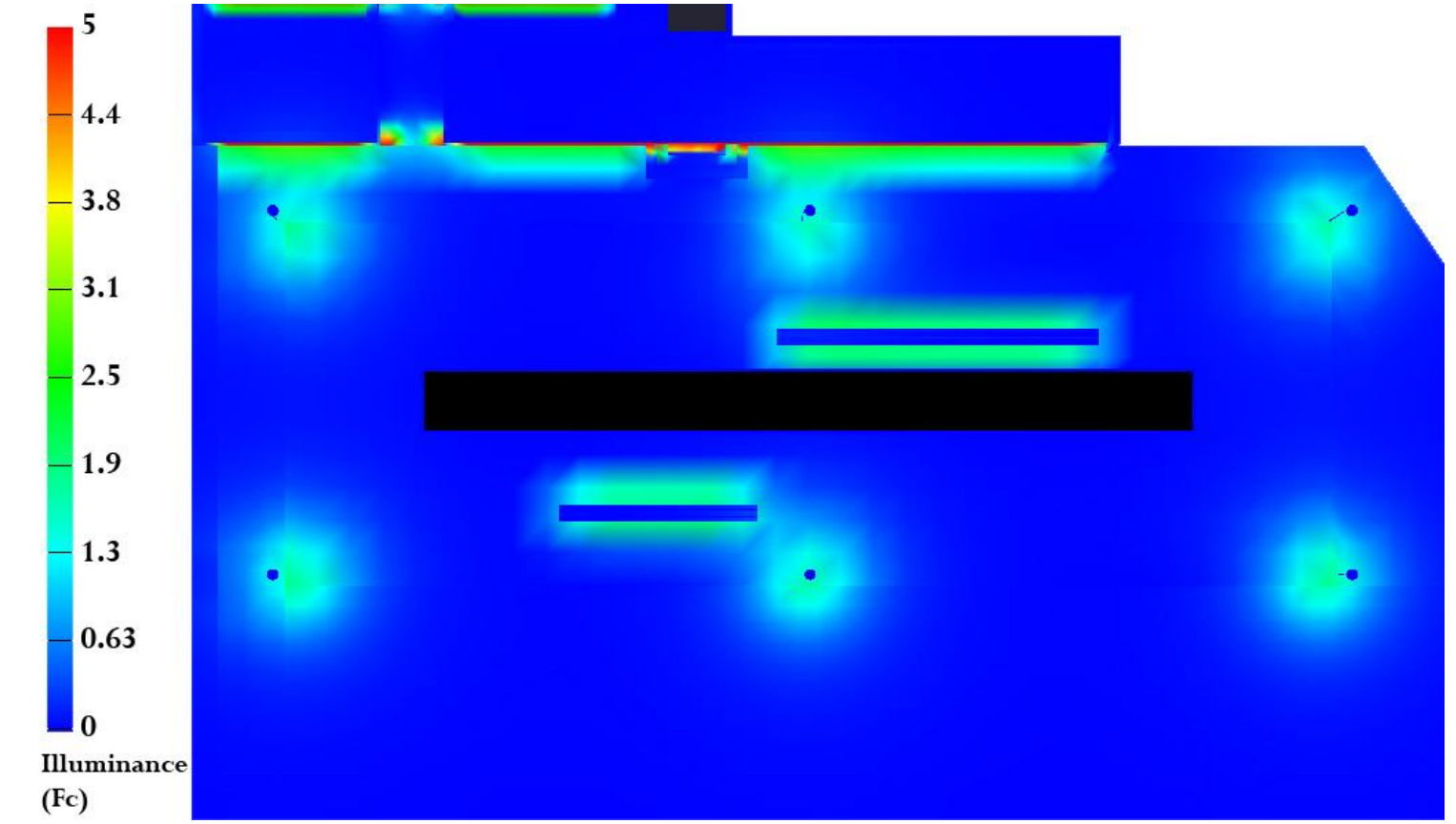
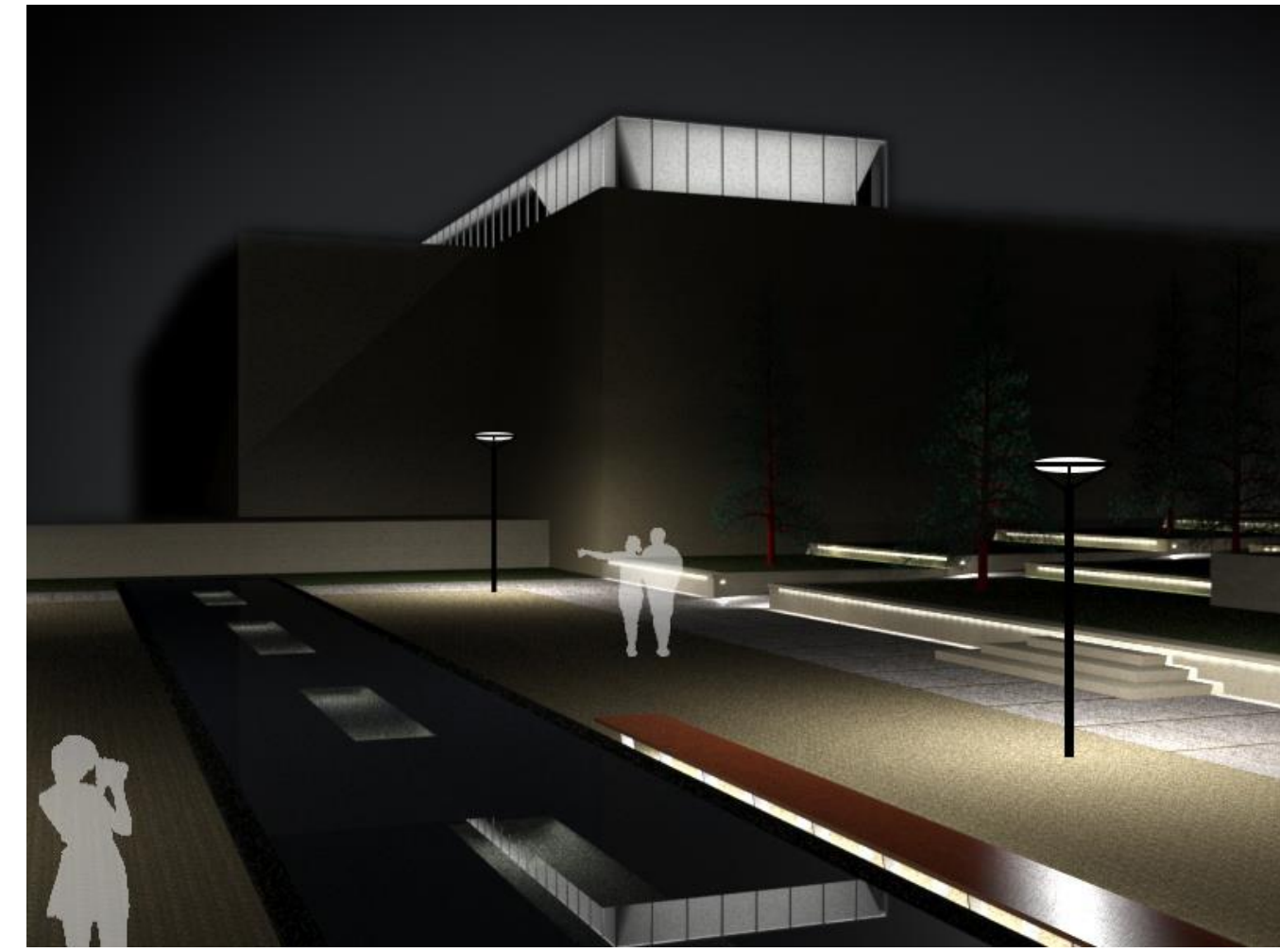
Space	Eh (fc)
	Criteria
Entry Park	0.4

Space	ASHRAE 90.1 LPD (W/ft ²)
	Criteria
Site	0.16

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Space	Eh (fc)	
	Criteria	Calculated
Entry Park	0.4	0.38

Space	ASHRAE 90.1 LPD (W/ft ²)
	Criteria
Site	0.16

BUILDING
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LIGHTING

SITE

LIGHT COURT

STRUCTURAL

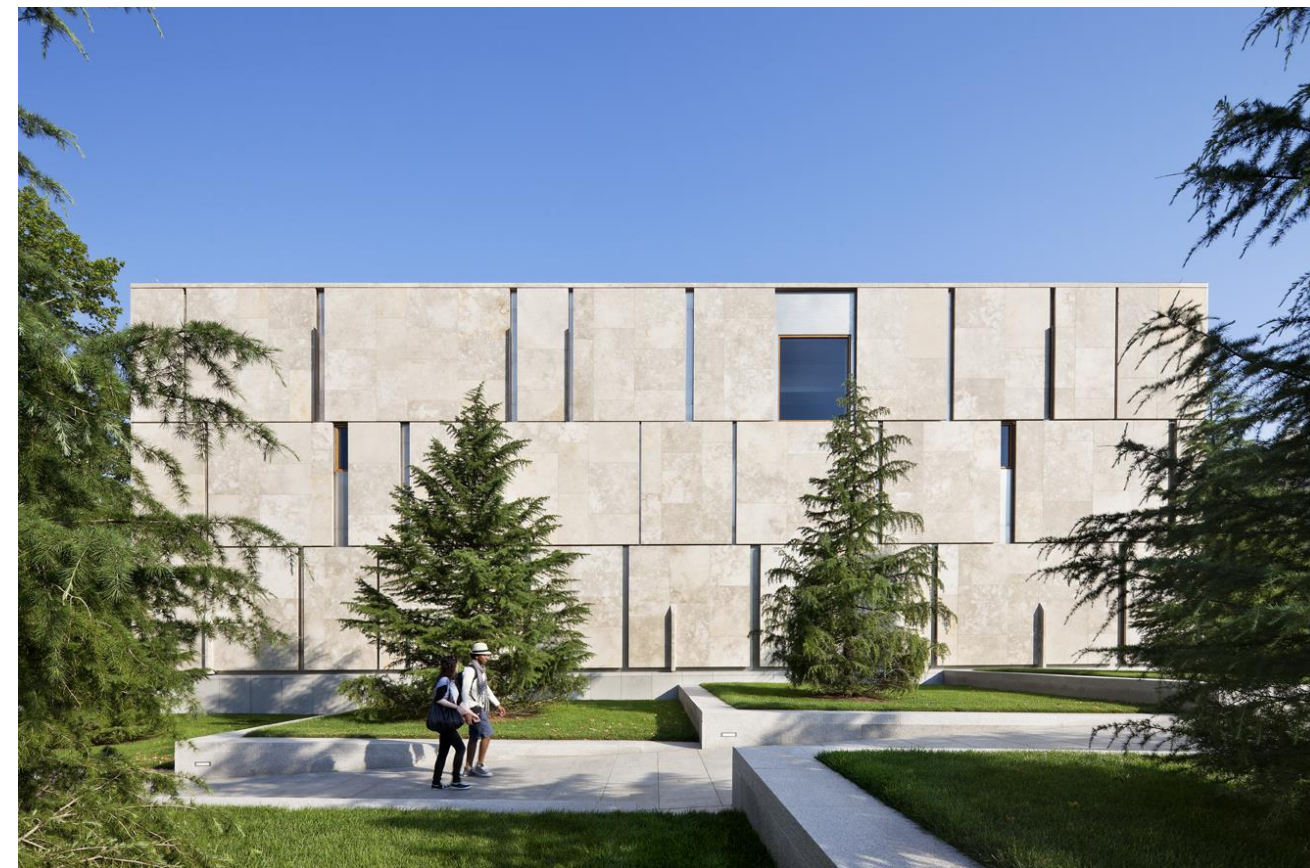
DAYLIGHTING

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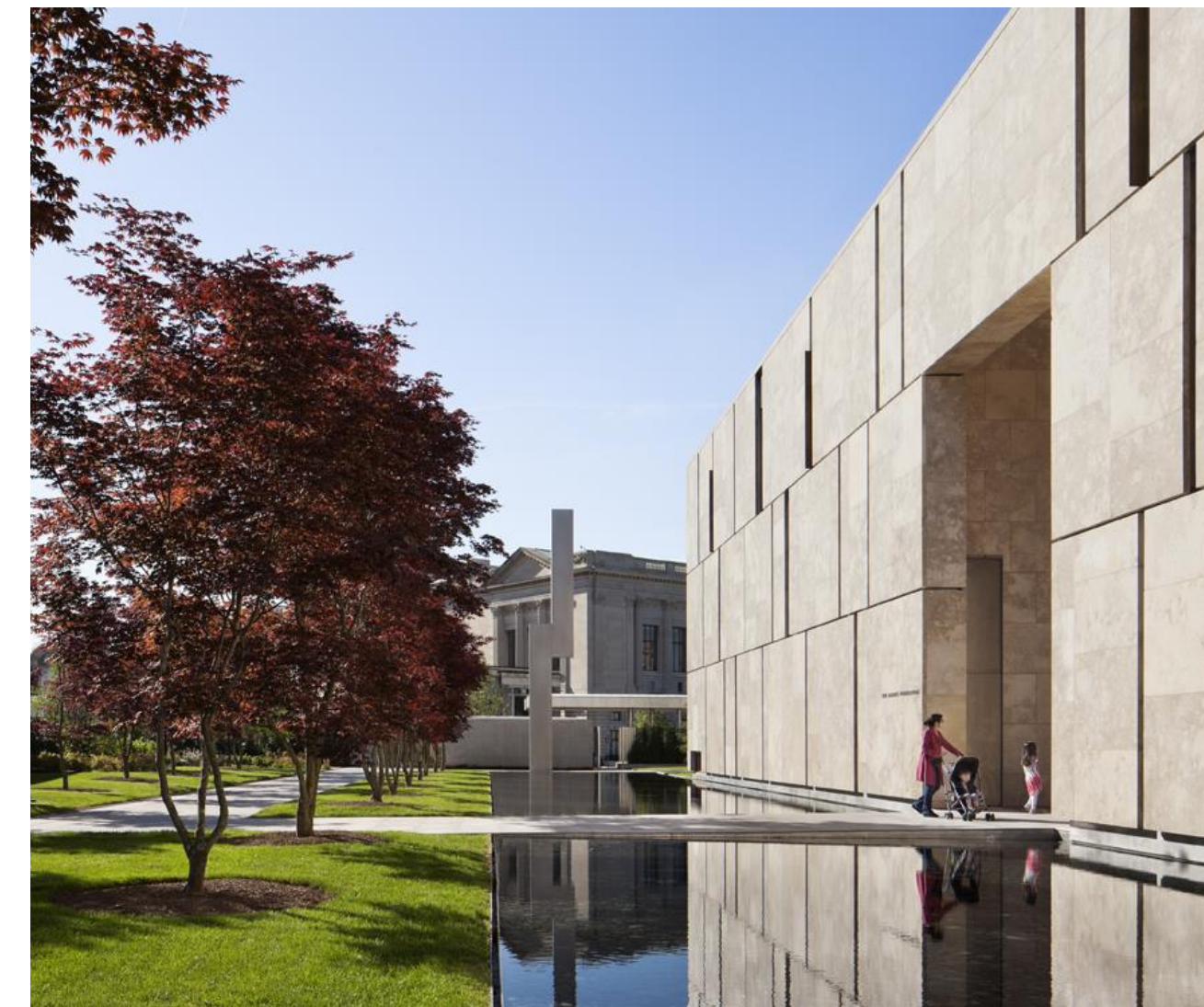
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Space	Eh (fc)
	Criteria
Entry Court	0.4
Ramps	0.6

Space	ASHRAE 90.1 LPD (W/ft ²)
	Criteria
Site	0.16

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Space	Eh (fc)
	Criteria
Entry Court	0.4
Ramps	0.6

Space	ASHRAE 90.1 LPD (W/ft ²)
	Criteria
Site	0.16

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Space	Eh (fc)
	Criteria
Entry Court	0.4
Ramps	0.6

Space	ASHRAE 90.1 LPD (W/ft ²)
	Criteria
Site	0.16

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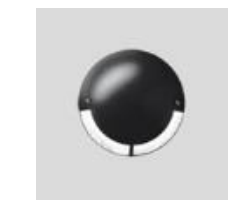
Space	Eh (fc)
	Criteria
Entry Court	0.4
Ramps	0.6

Space	ASHRAE 90.1 LPD (W/ft ²)
	Criteria
Site	0.16

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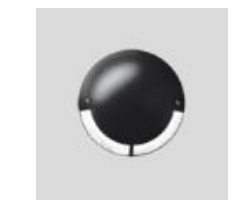
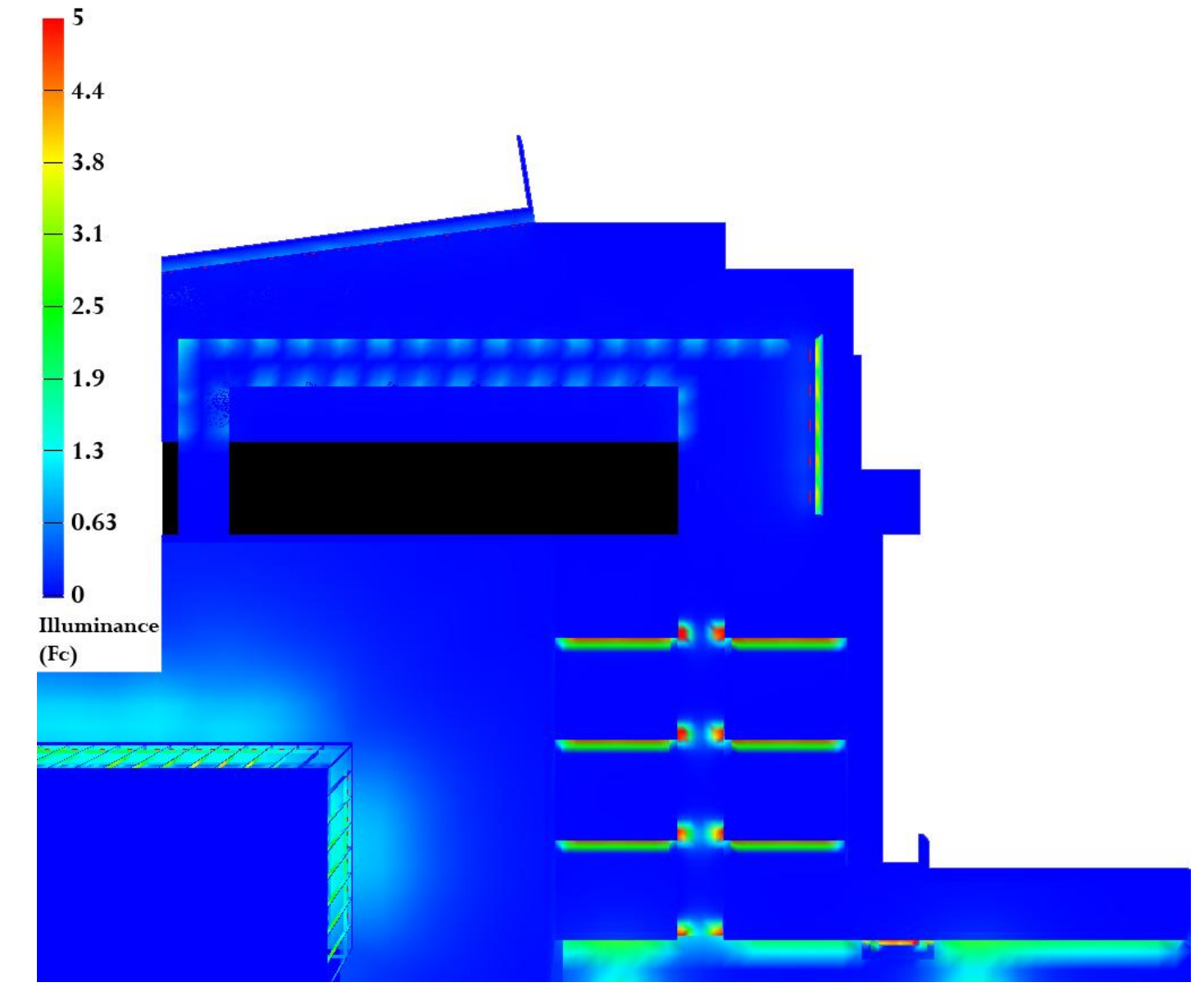
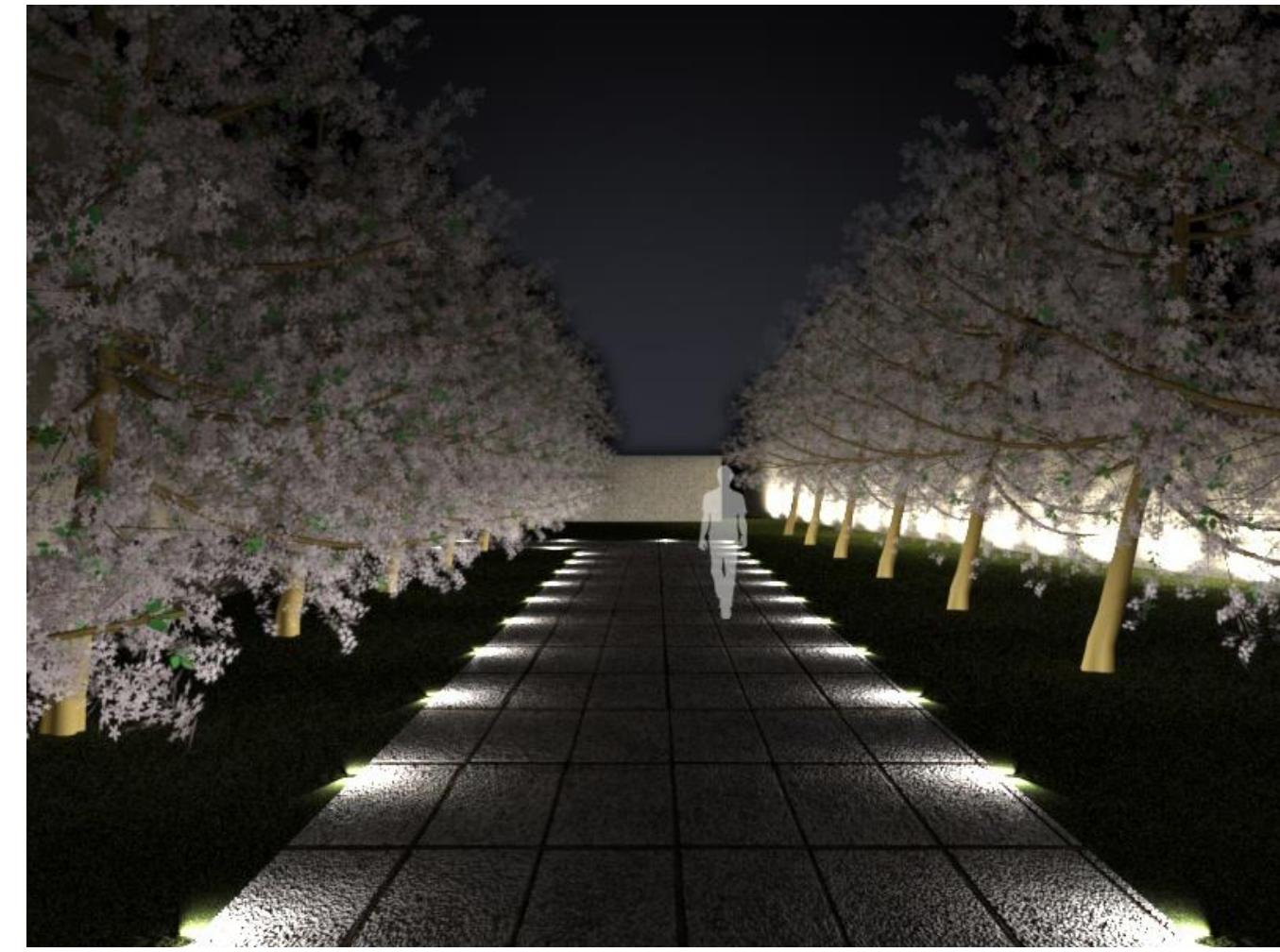
Space	Eh (fc)
	Criteria
Entry Court	0.4
Ramps	0.6

Space	ASHRAE 90.1 LPD (W/ft ²)
	Criteria
Site	0.16

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Space	Eh (fc)	
	Criteria	Calculated
Entry Court	0.4	0.3
Ramps	0.6	0.74

Space	ASHRAE 90.1 LPD (W/ft ²)	
	Criteria	Calculated
Site	0.16	0.03

BUILDING
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- SITE**
- LIGHT COURT
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STRUCTURAL

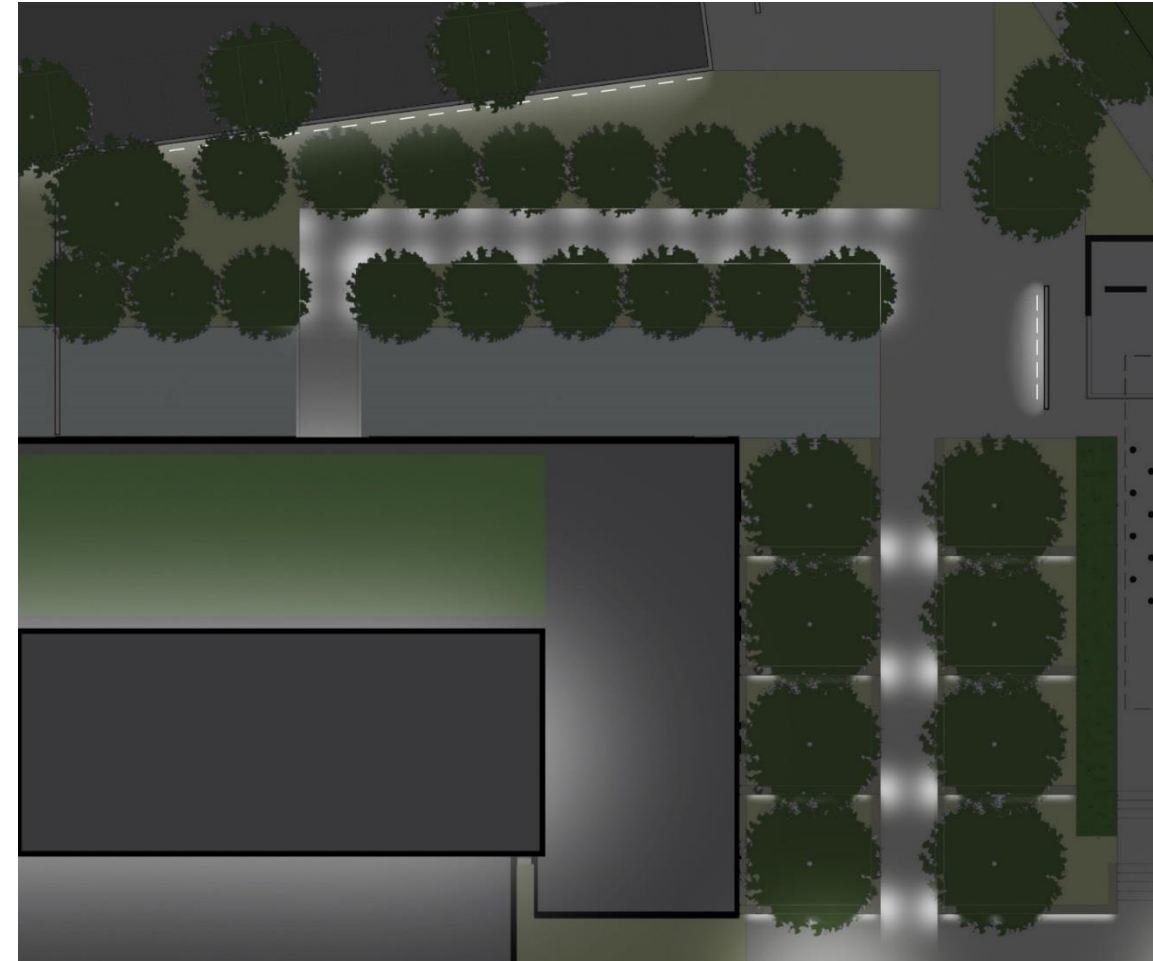
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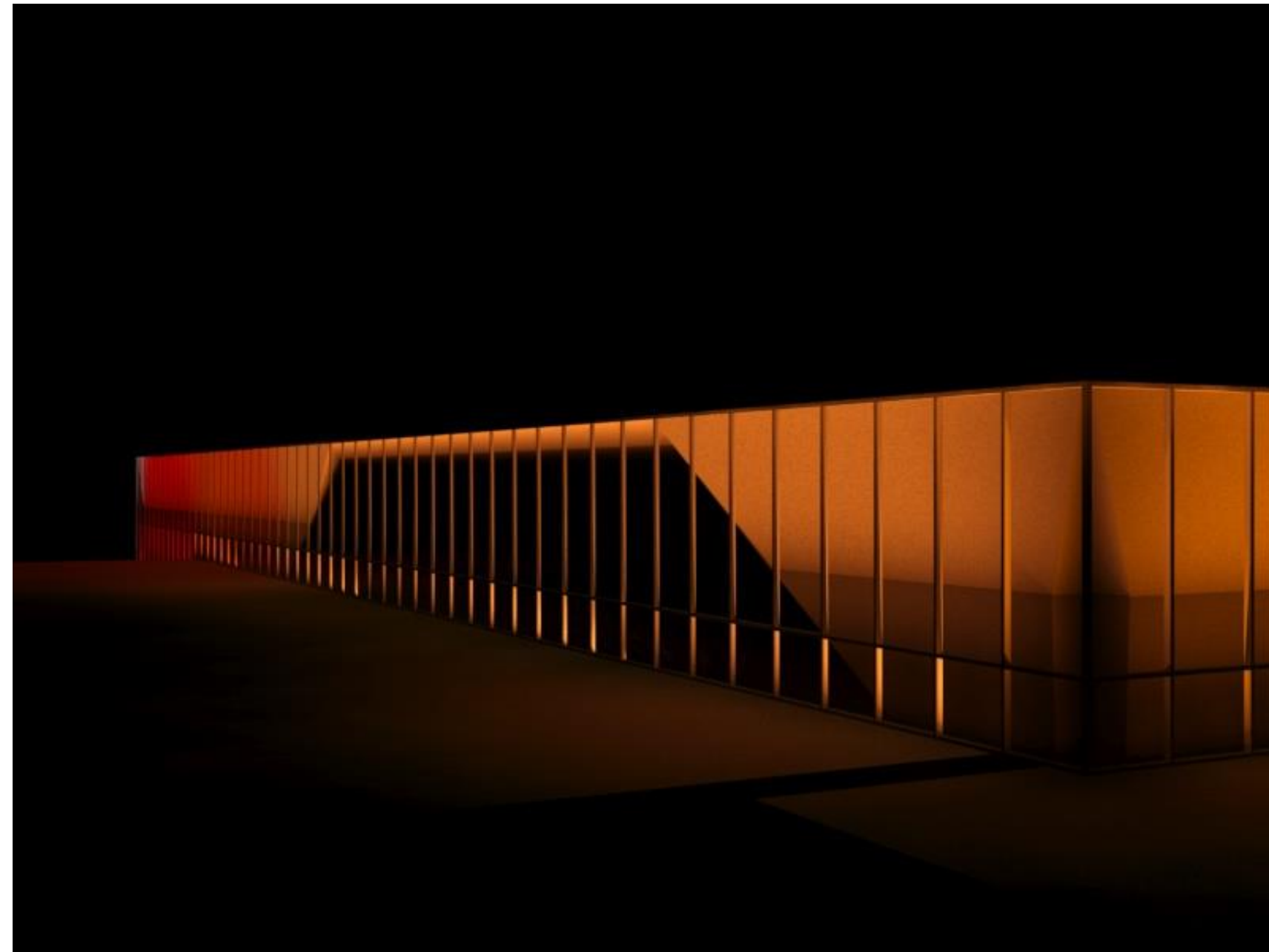
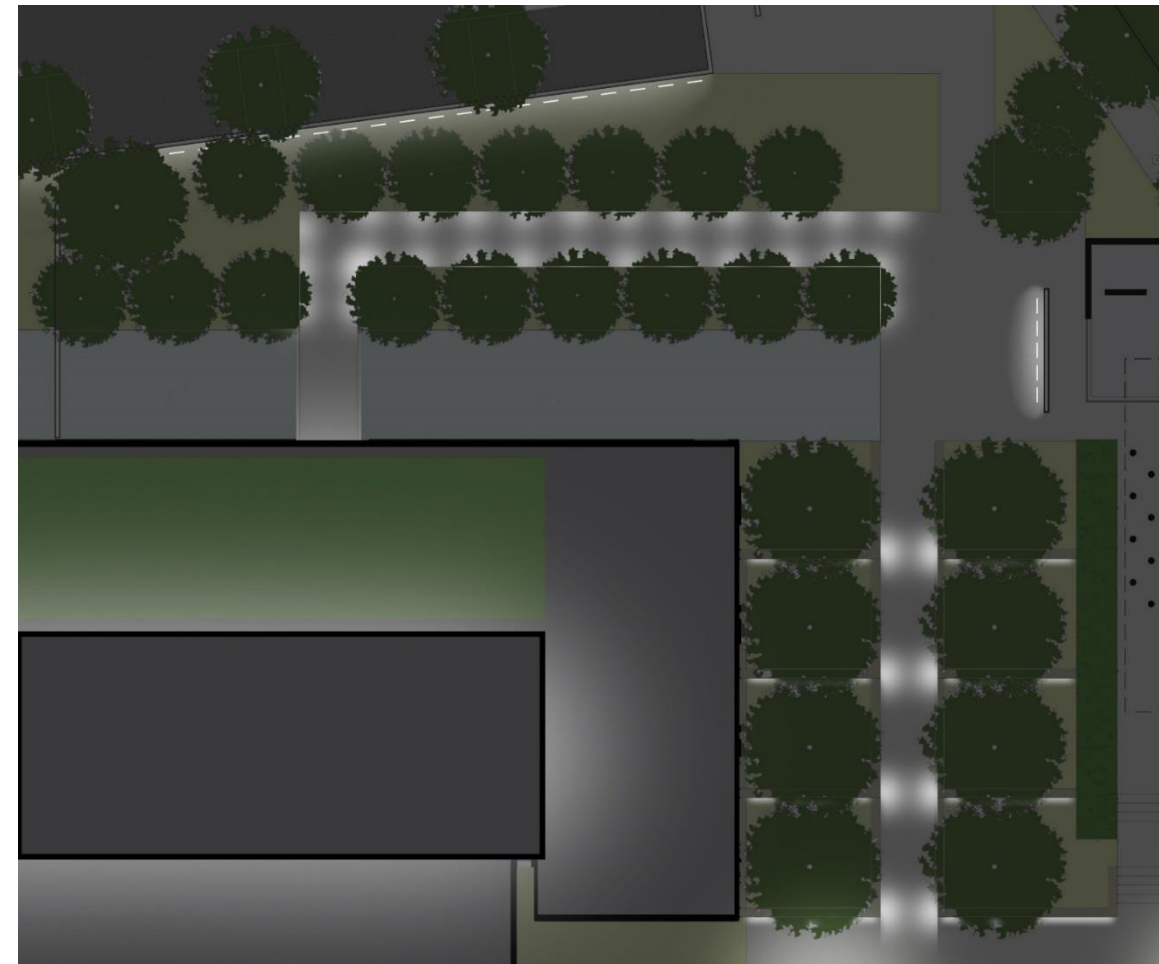
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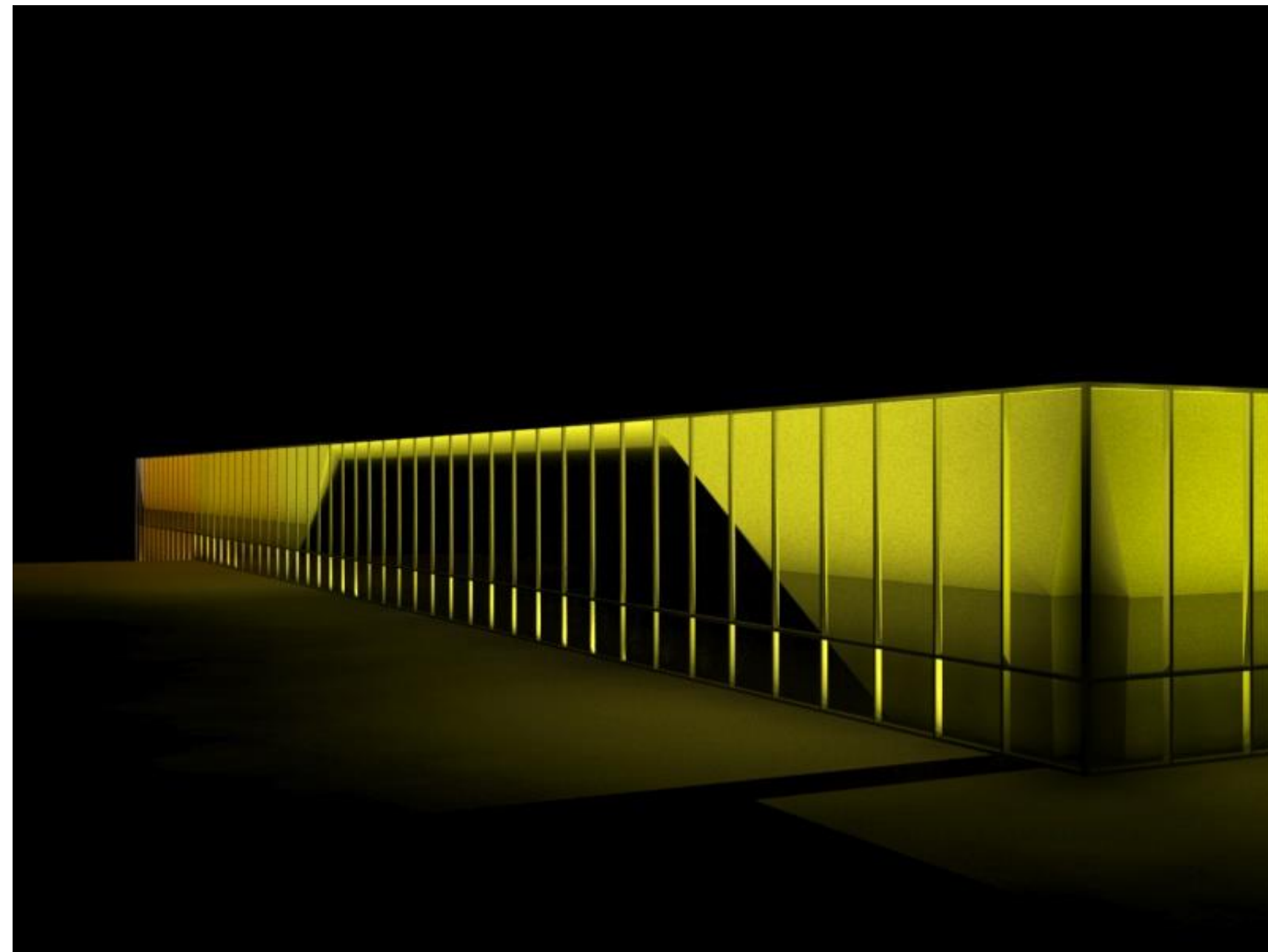
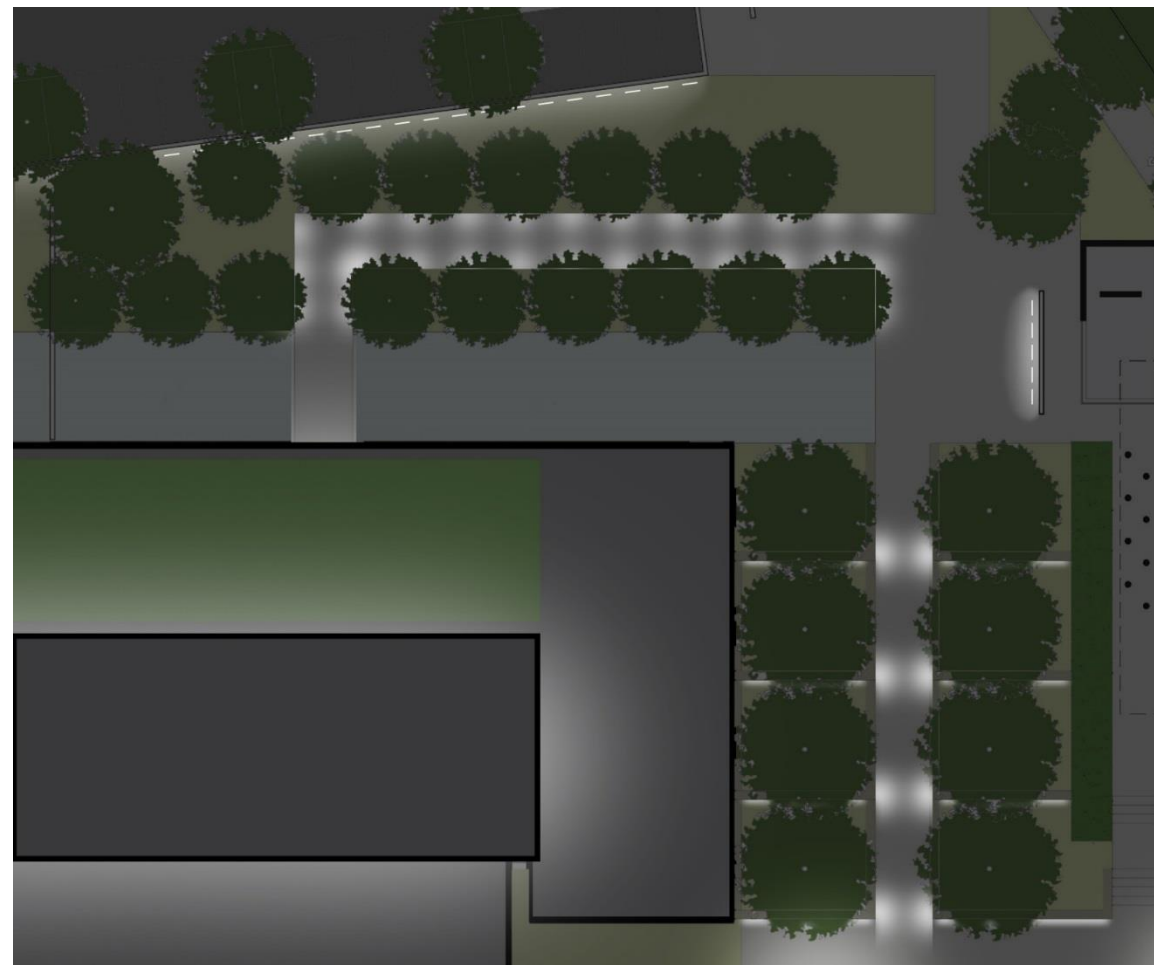
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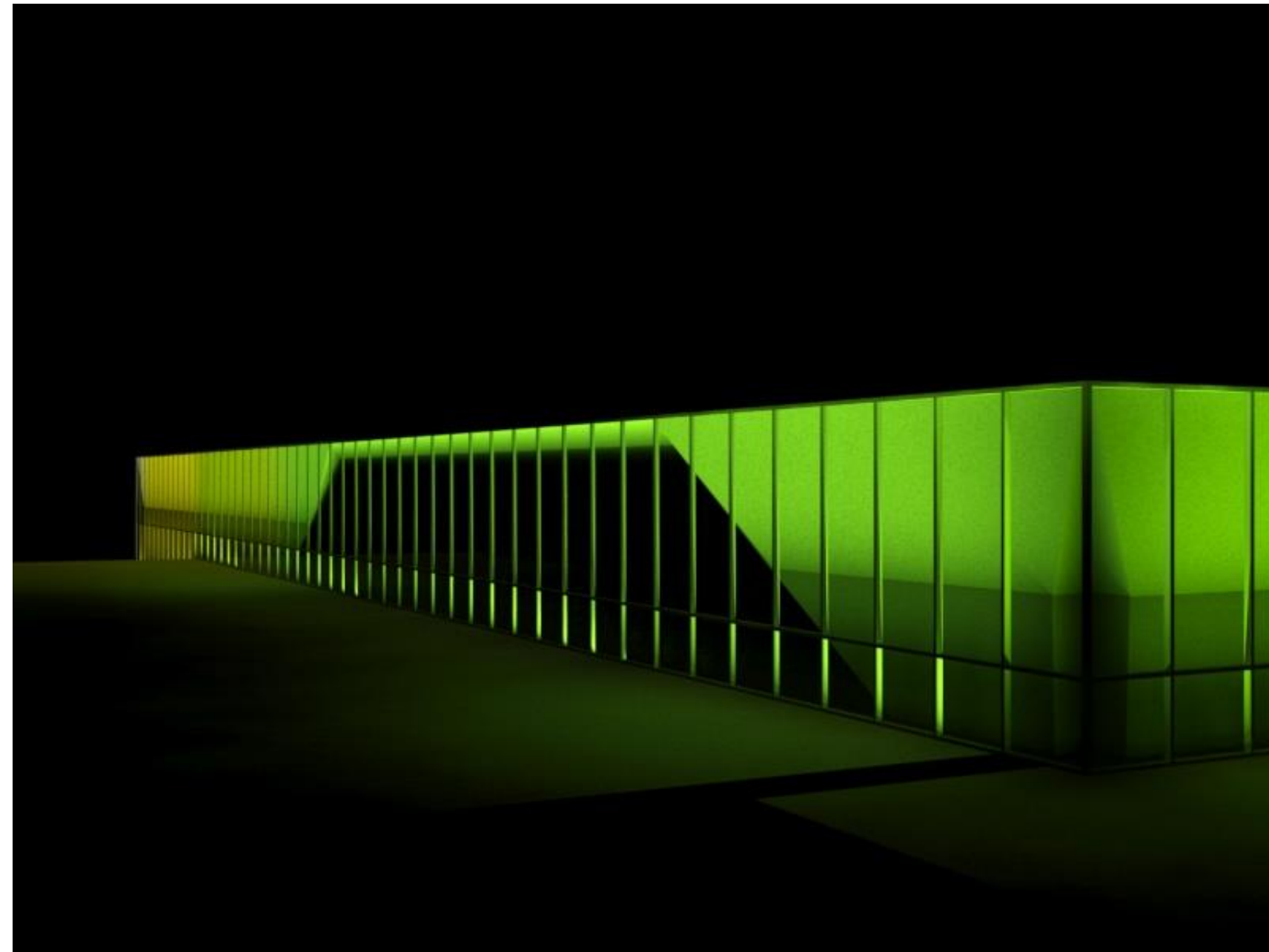
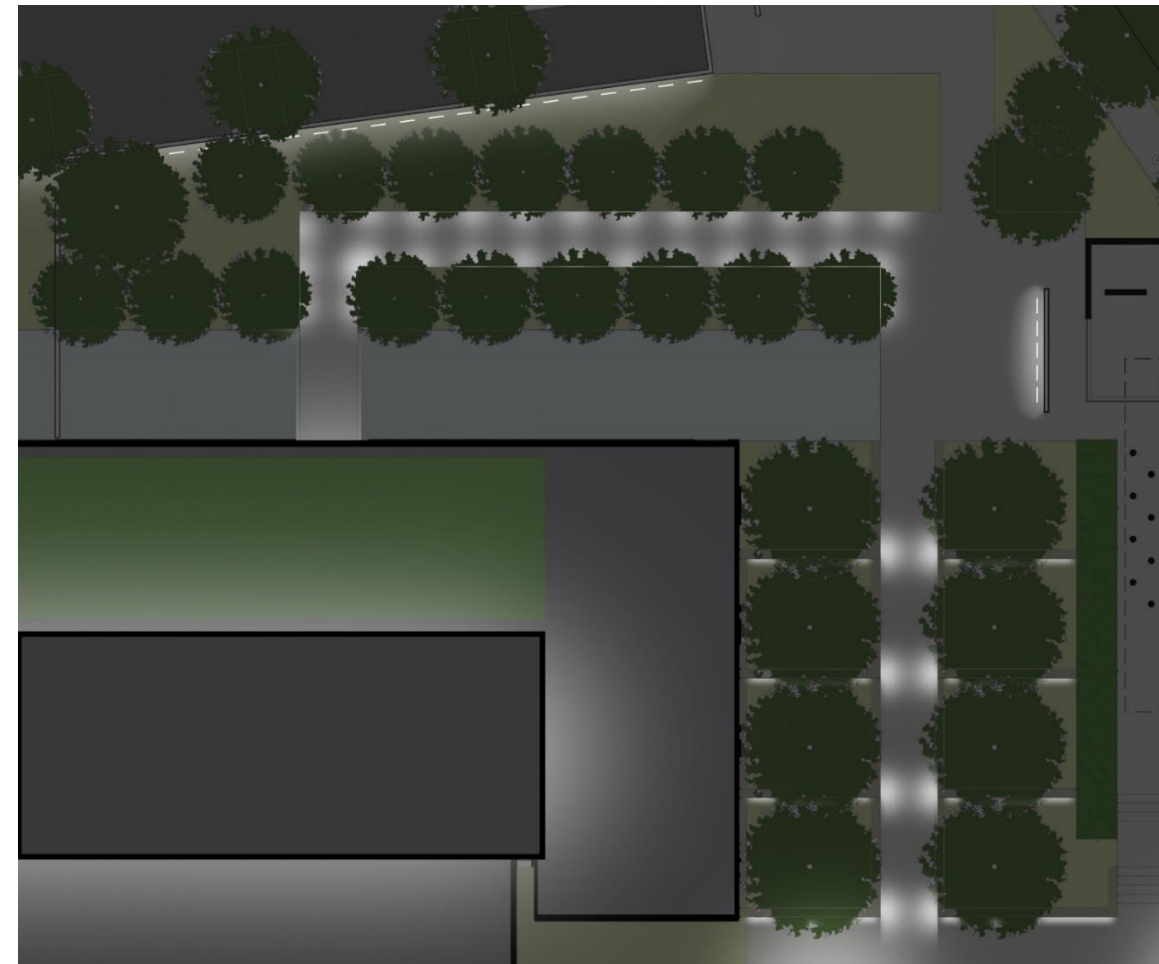
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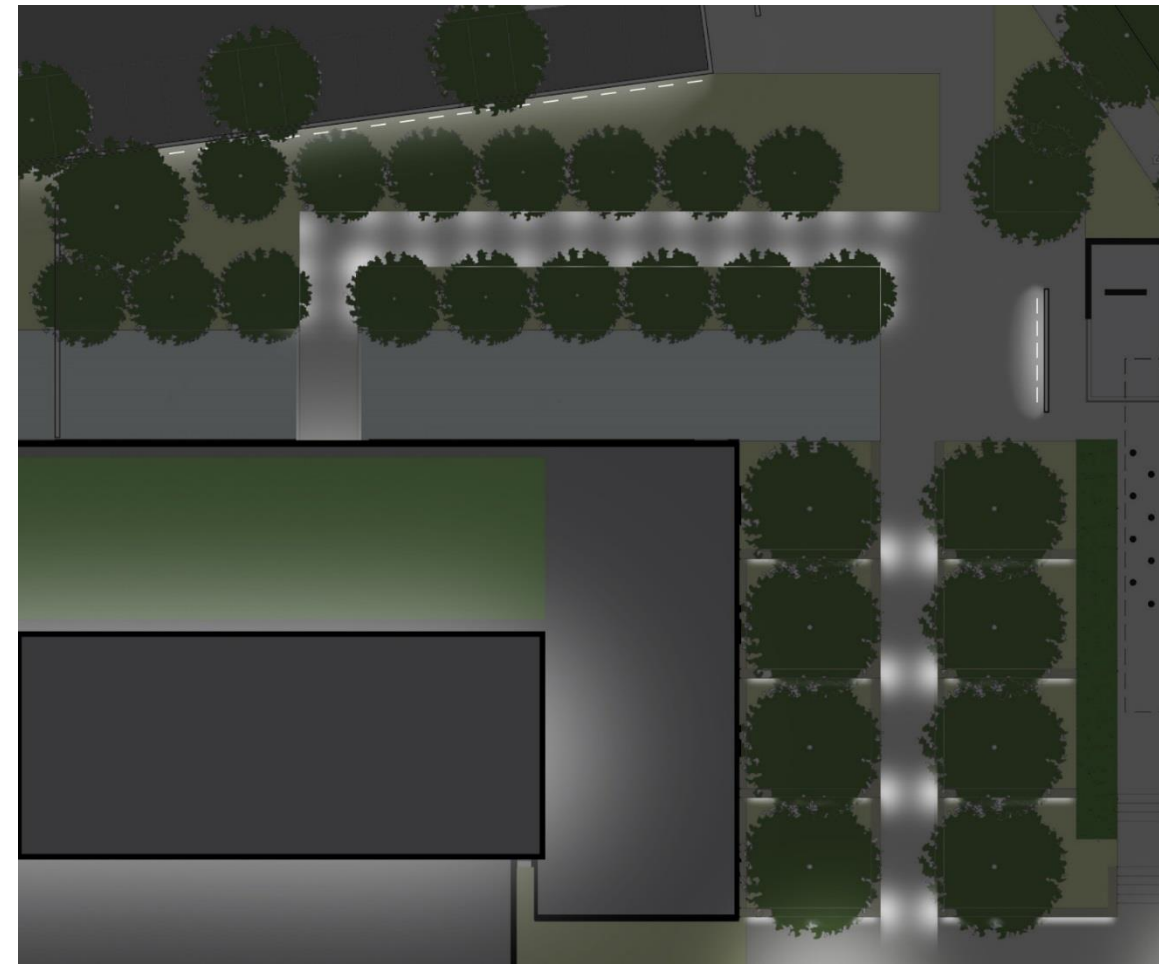
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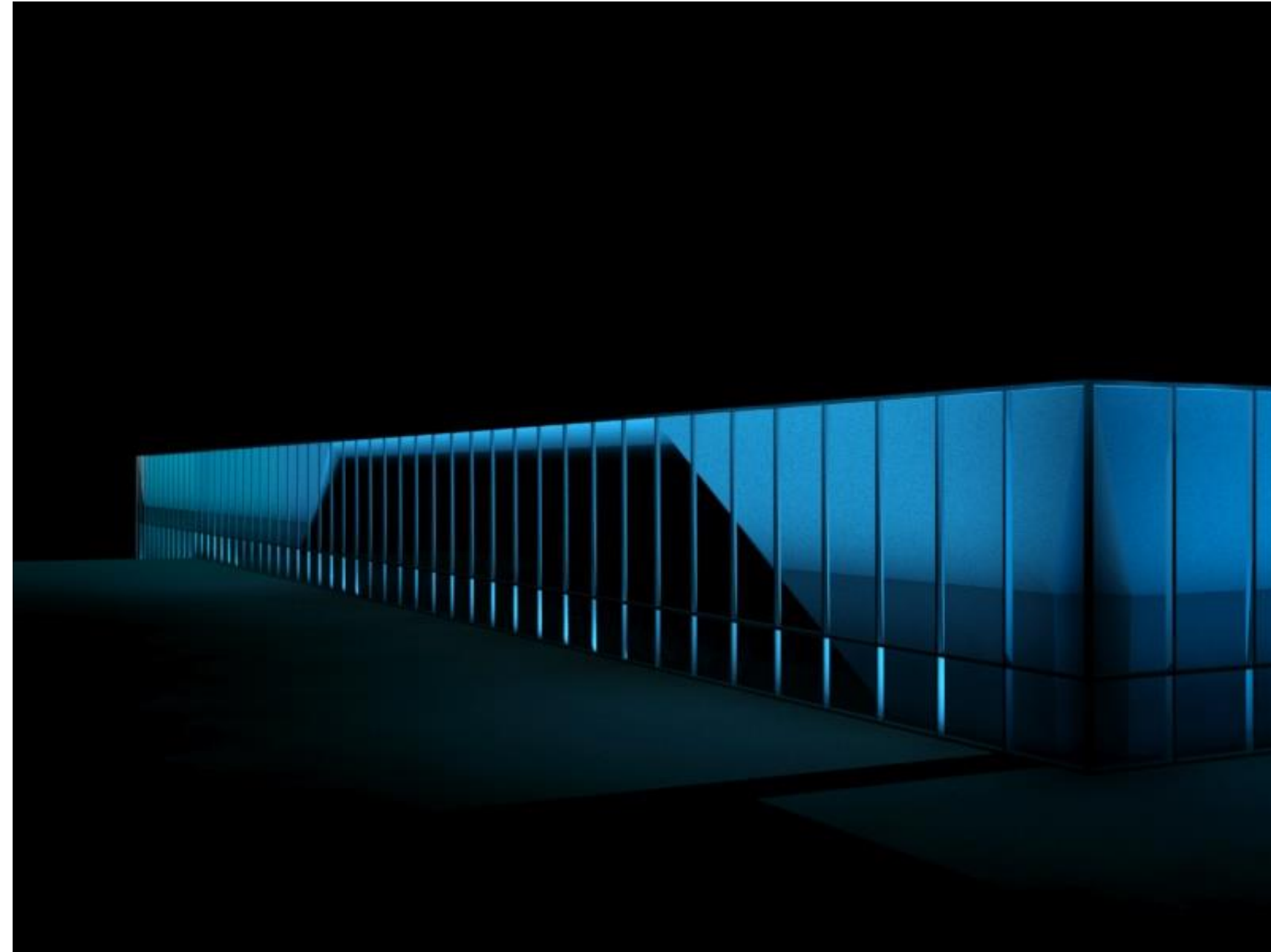
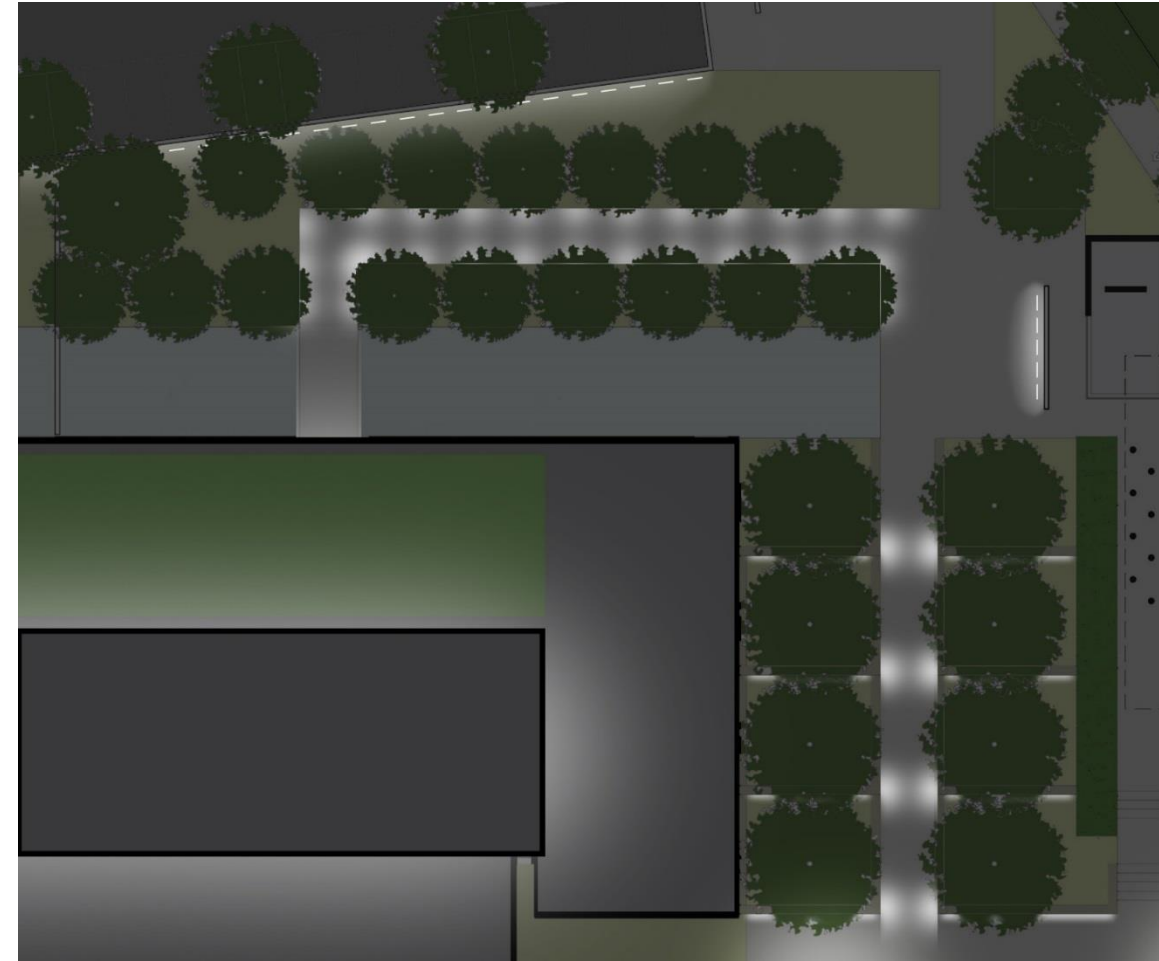
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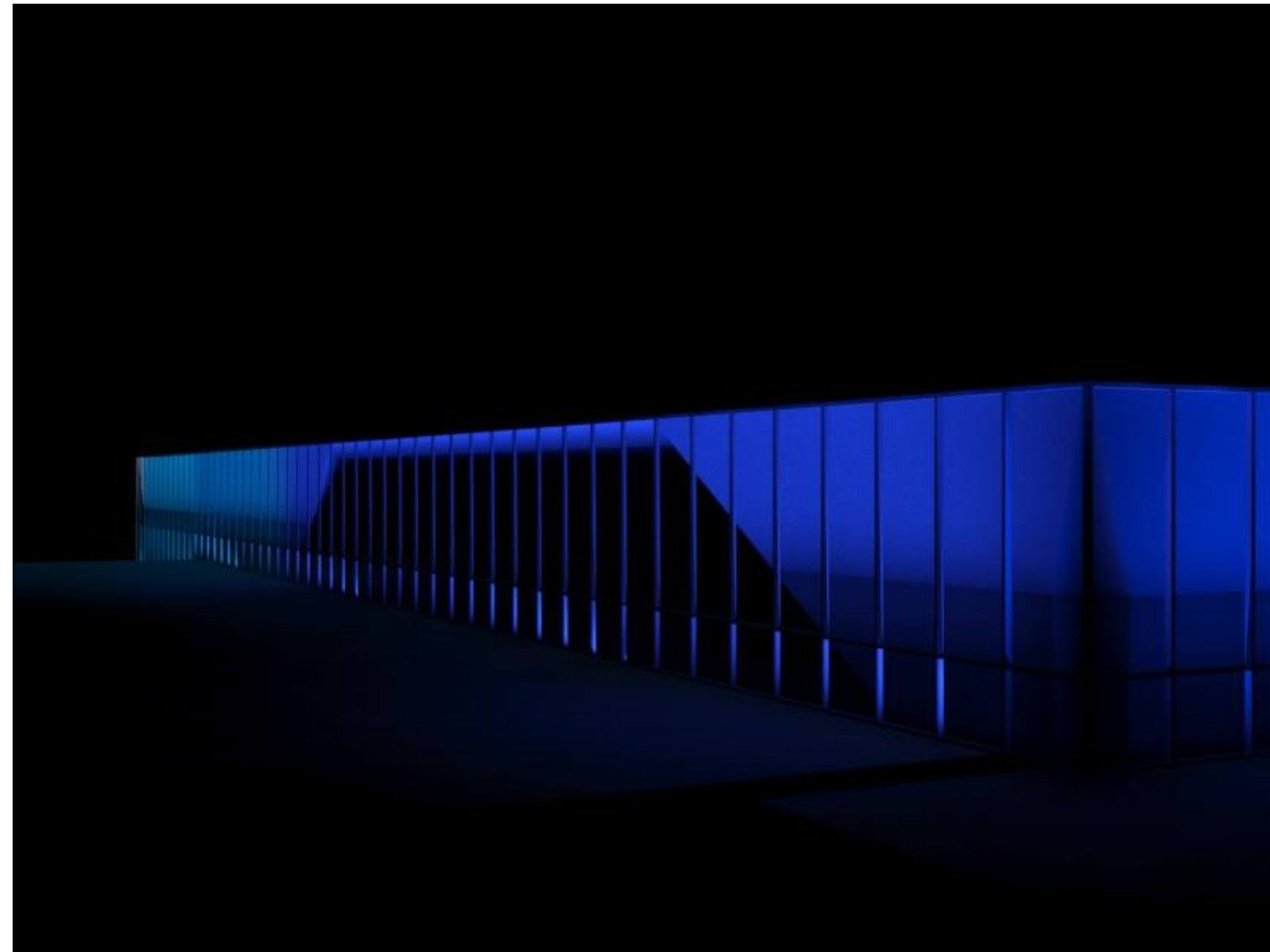
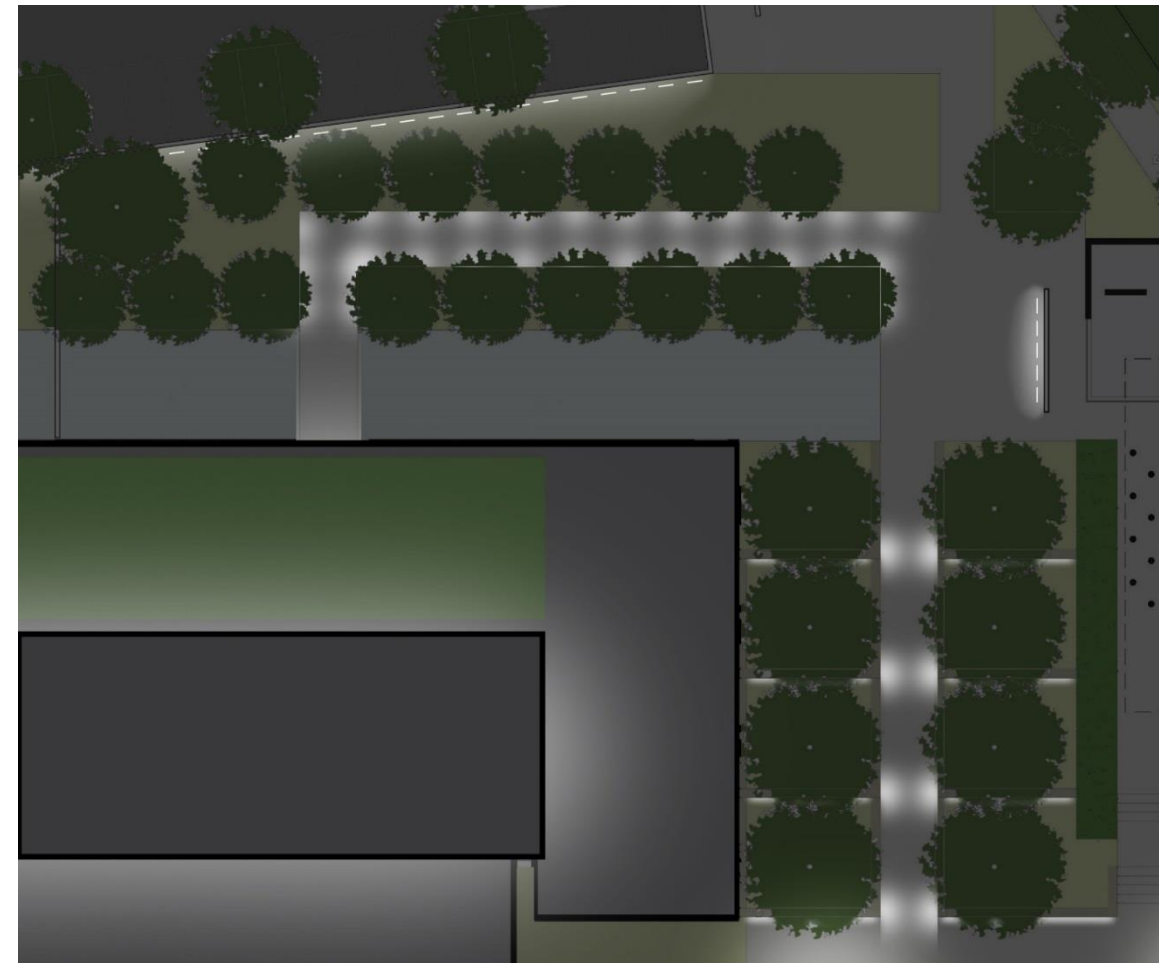
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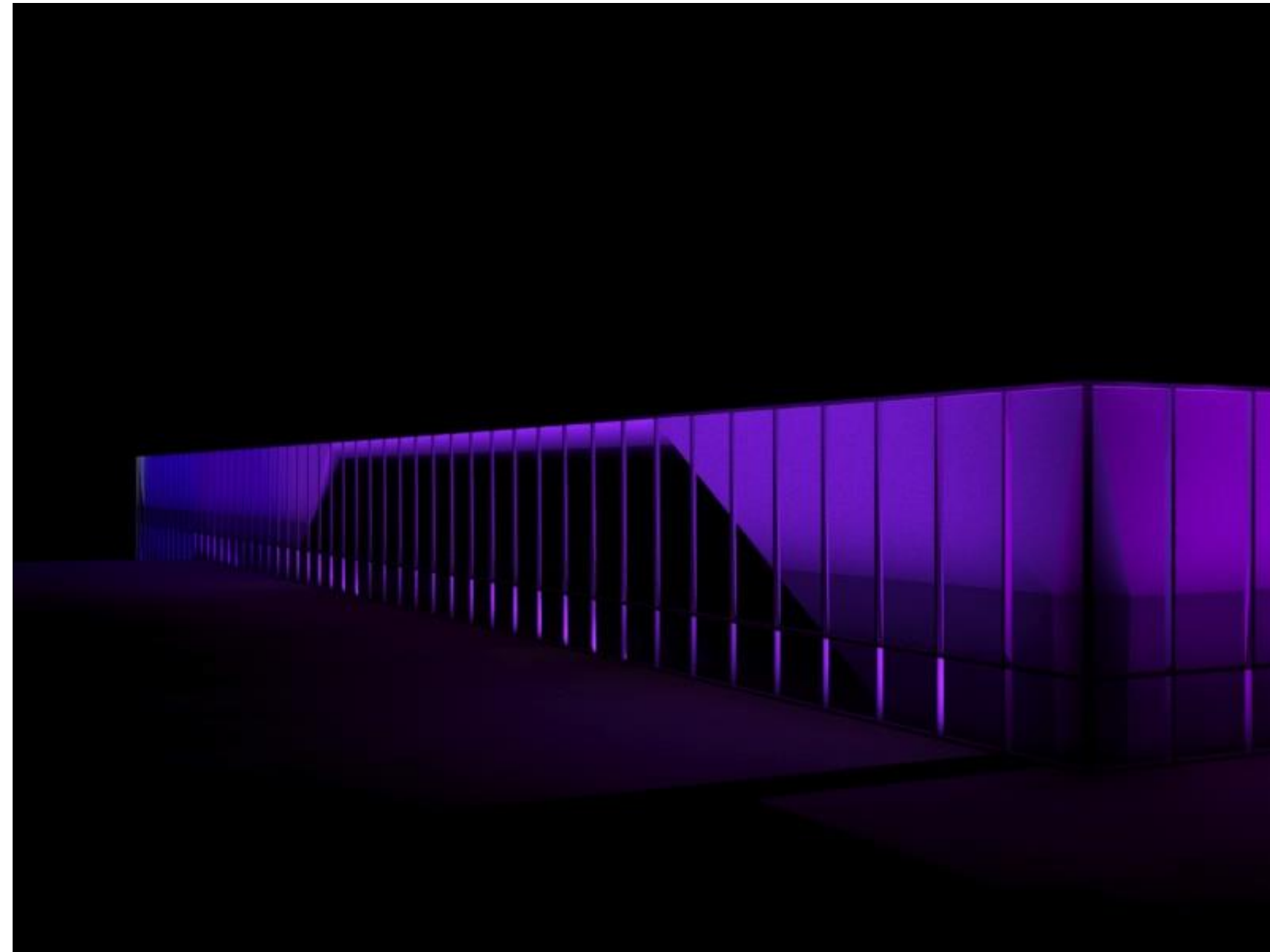
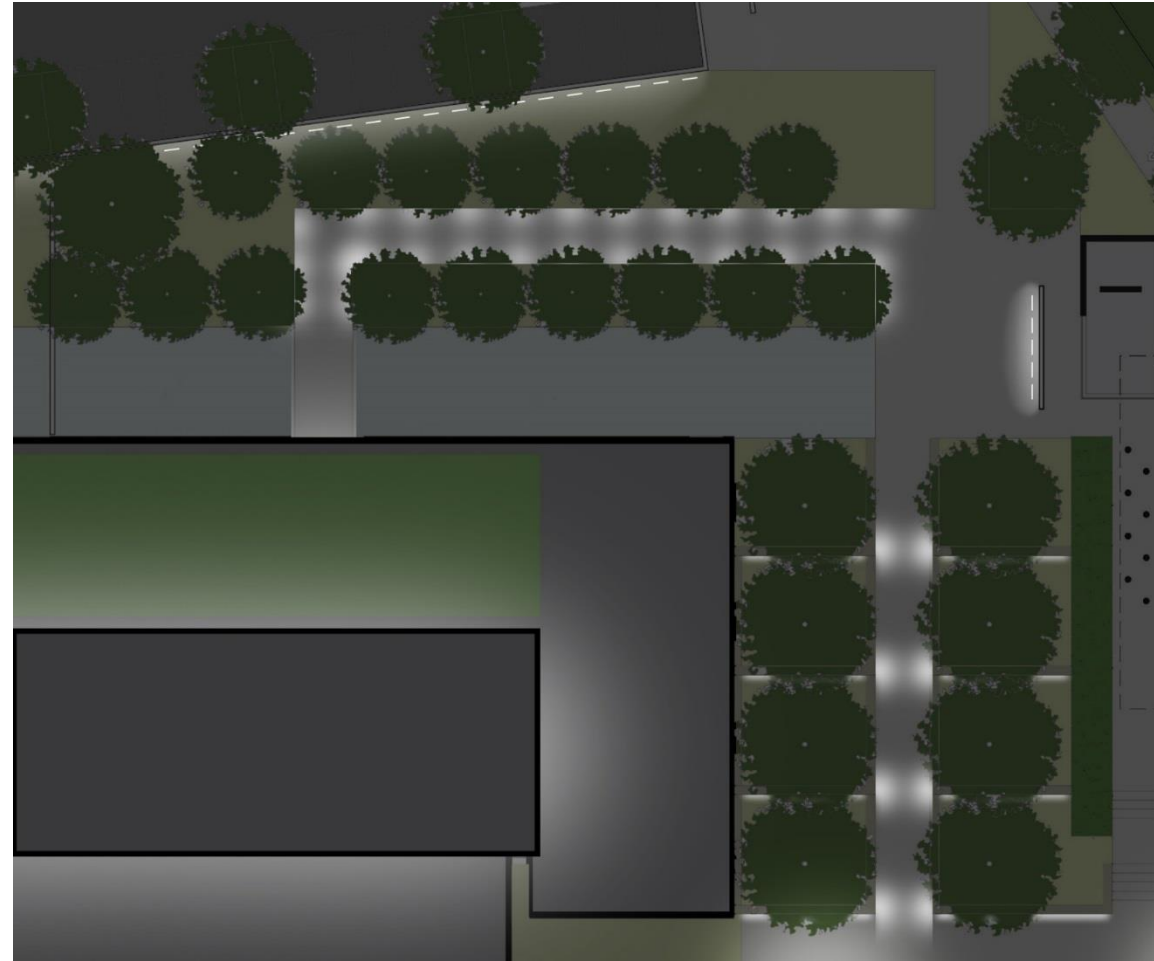
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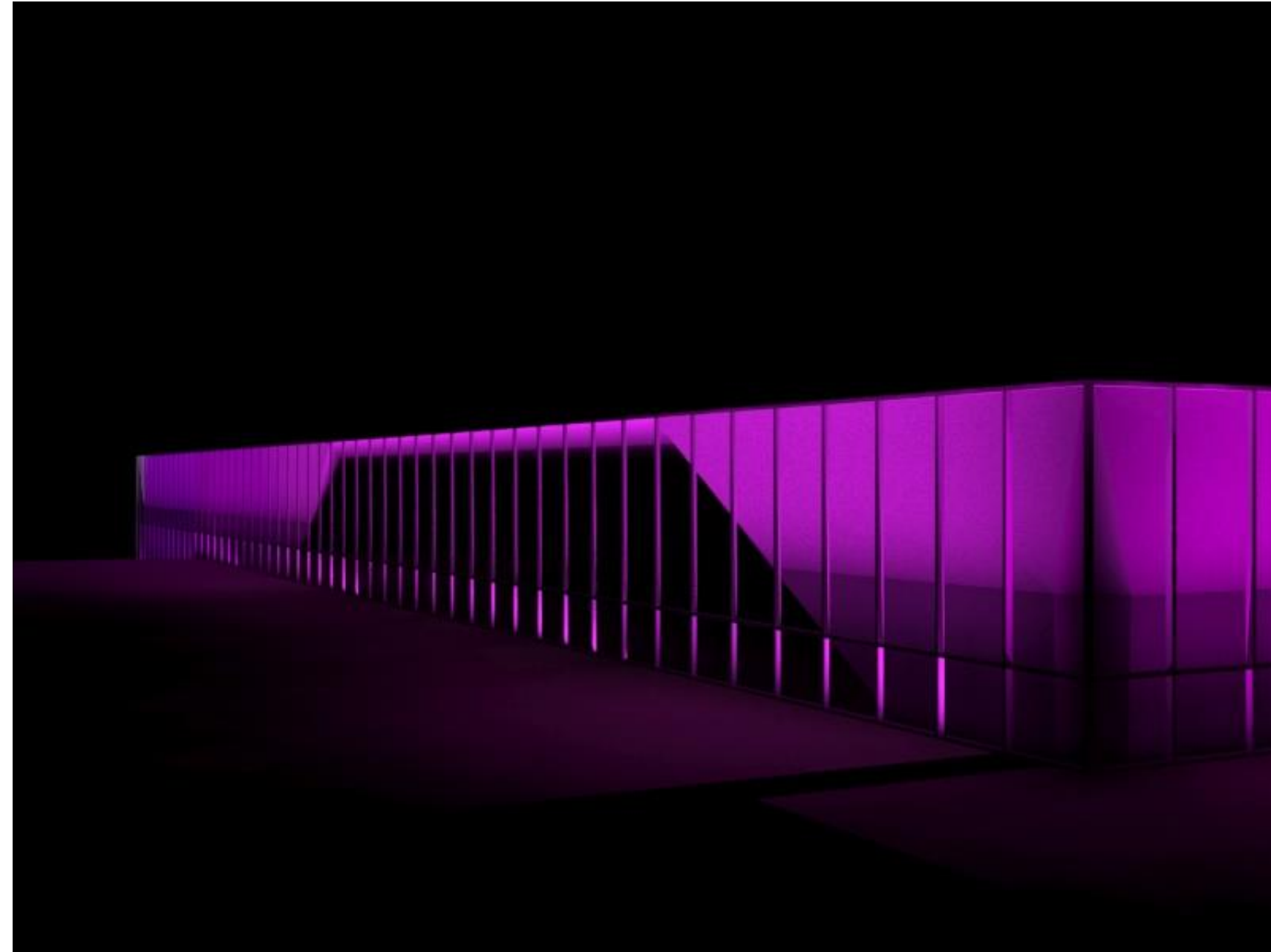
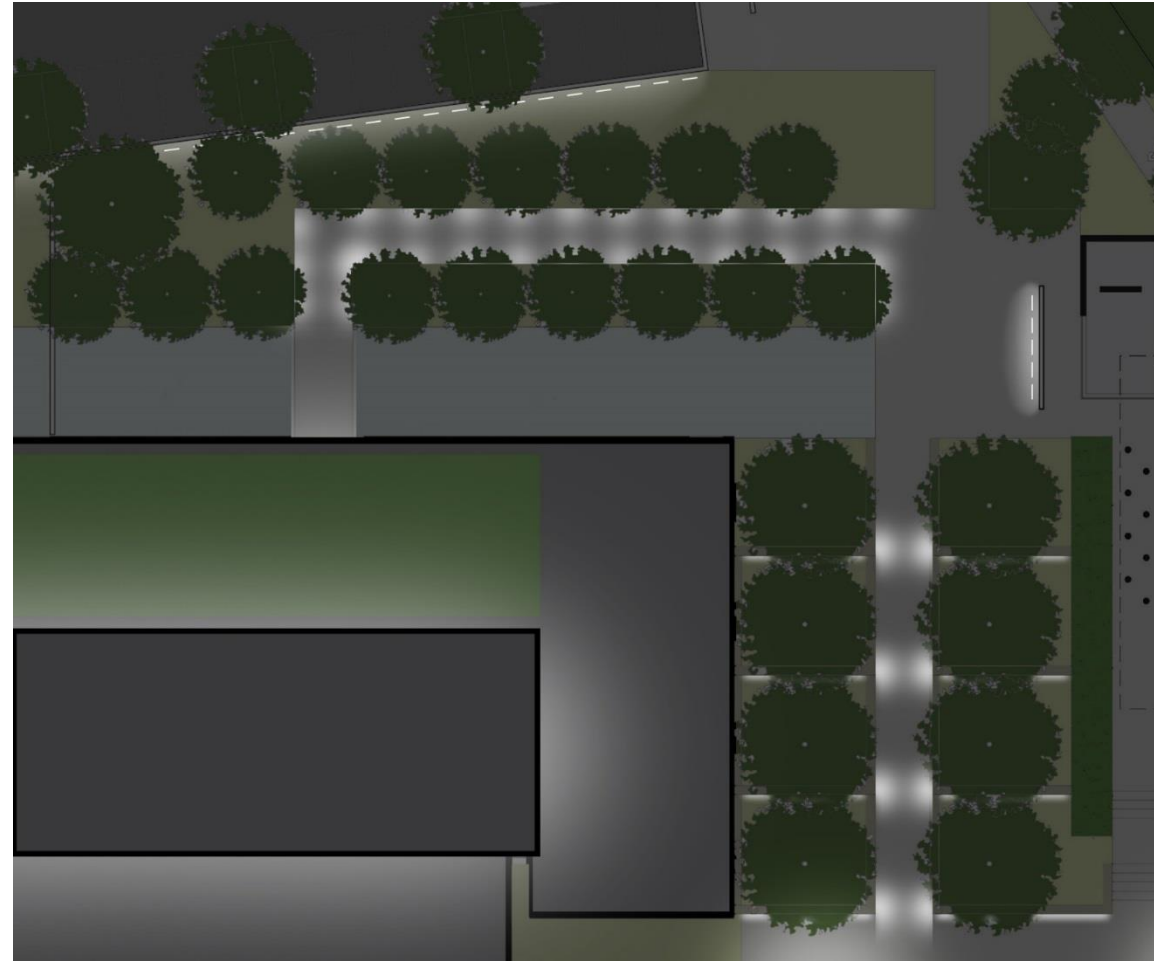
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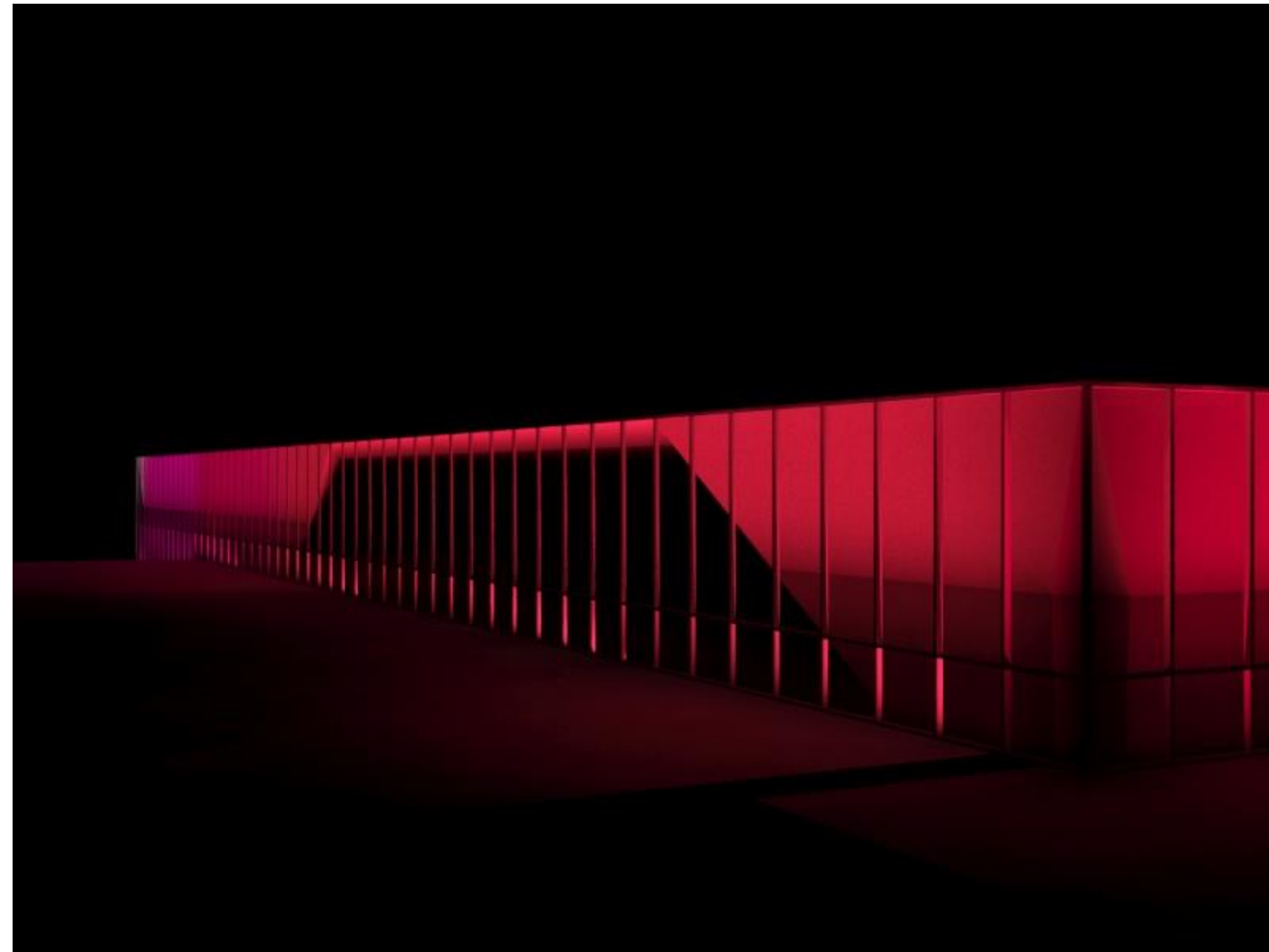
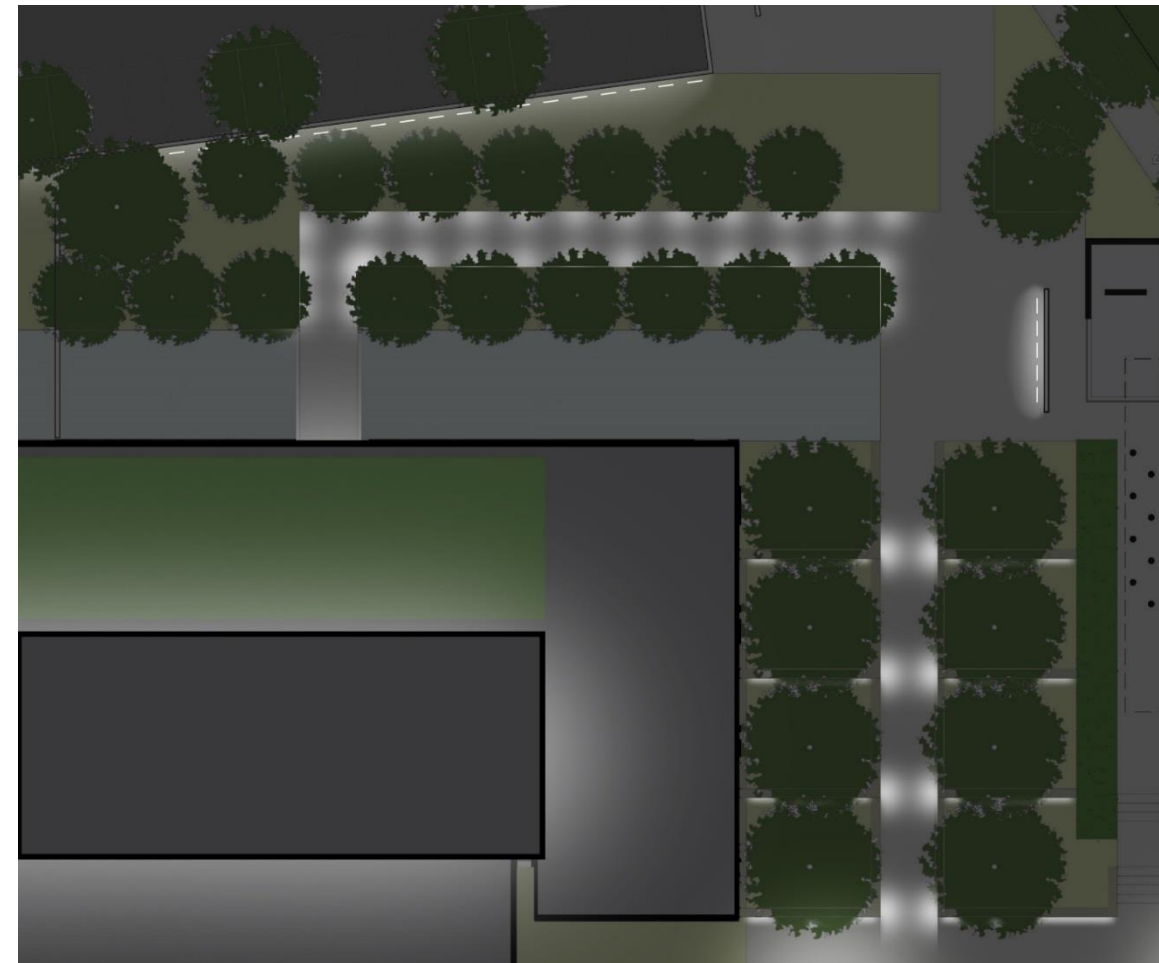
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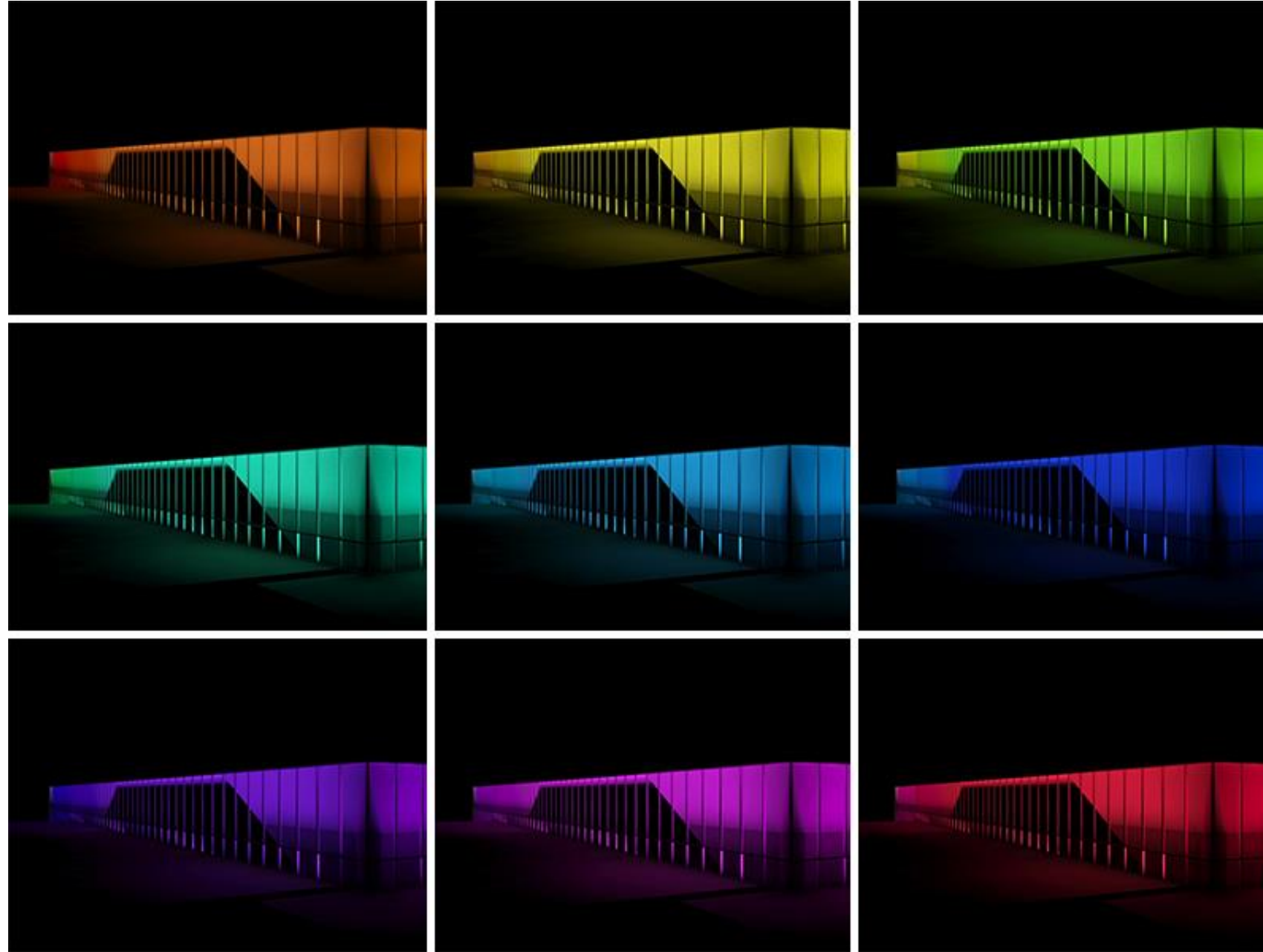
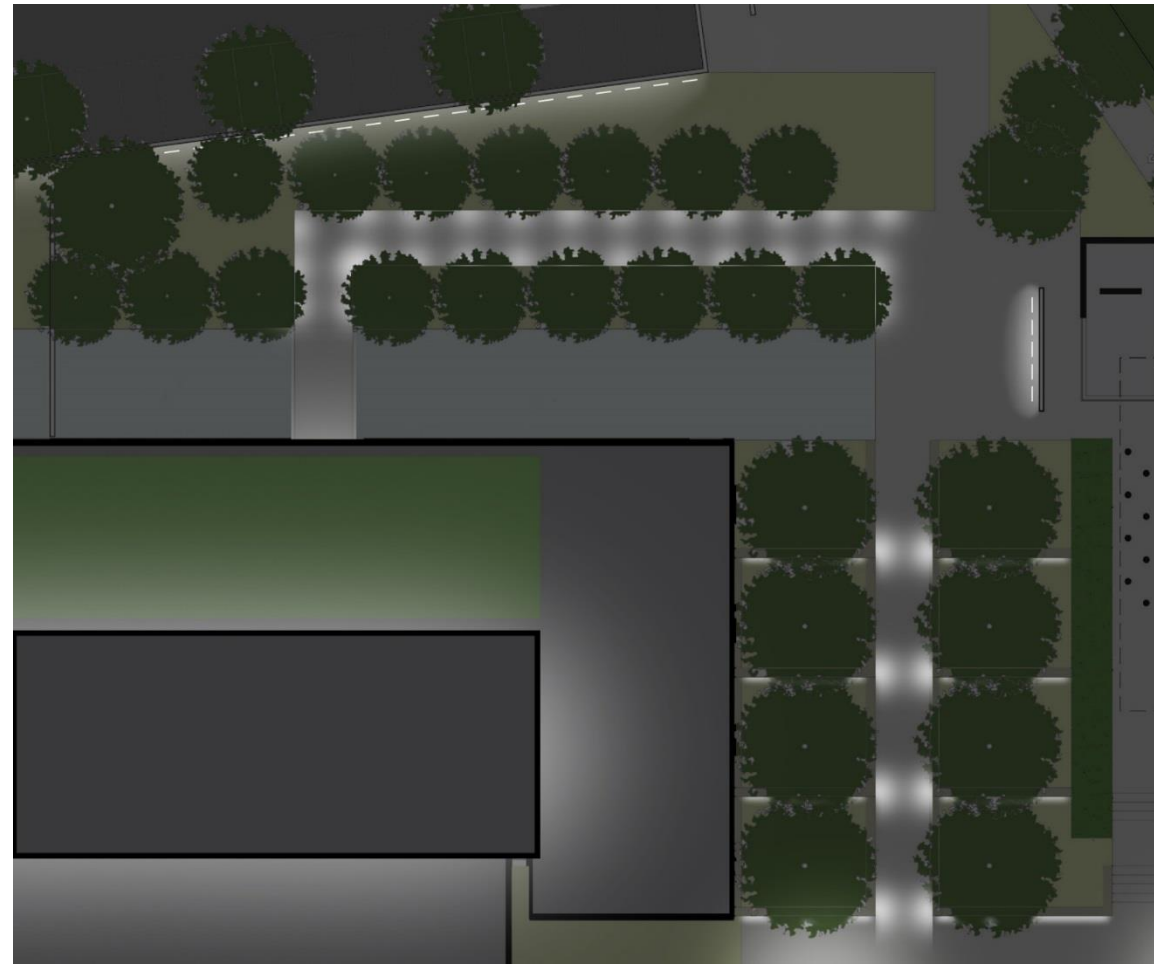
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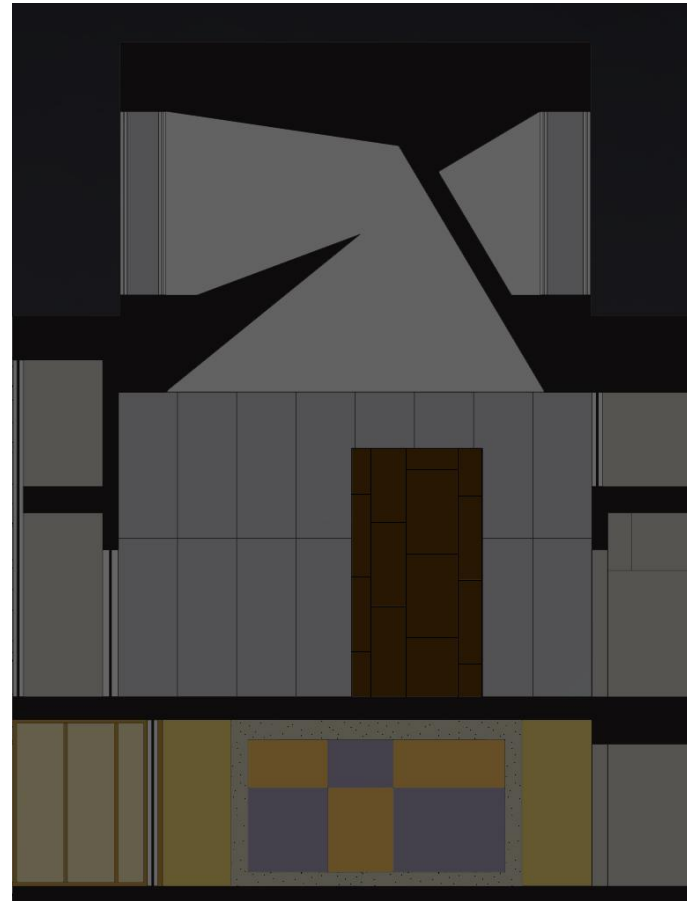


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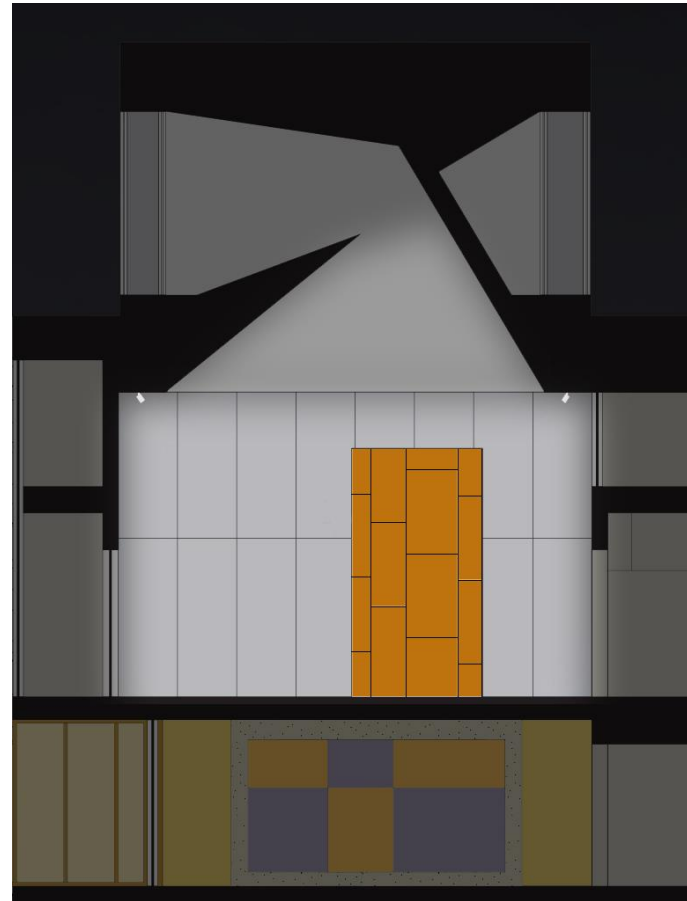
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	Criteria		
Lobby	5	2	4

Space	ASHRAE 90.1 LPD (W/ft ²)
	Criteria
Lobby	1.65

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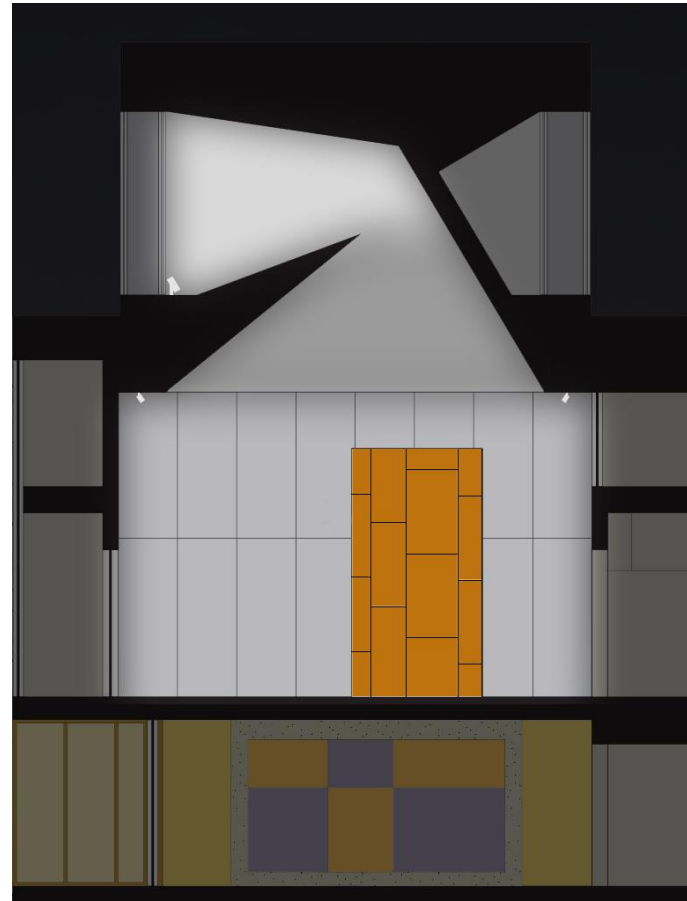
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	Criteria		
Lobby	5	2	4

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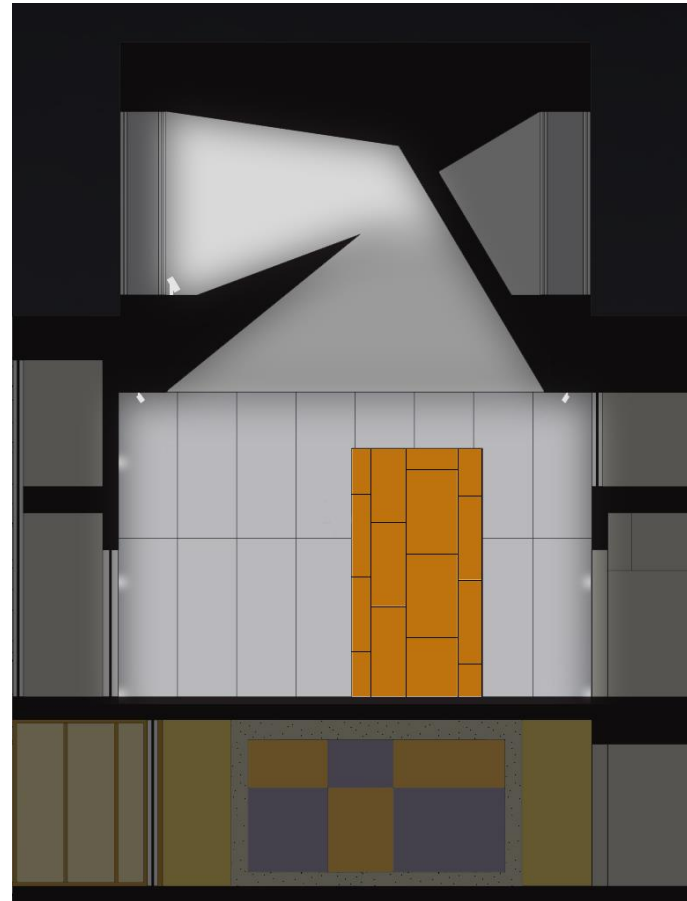
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	Criteria		
Lobby	5	2	4

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	Criteria
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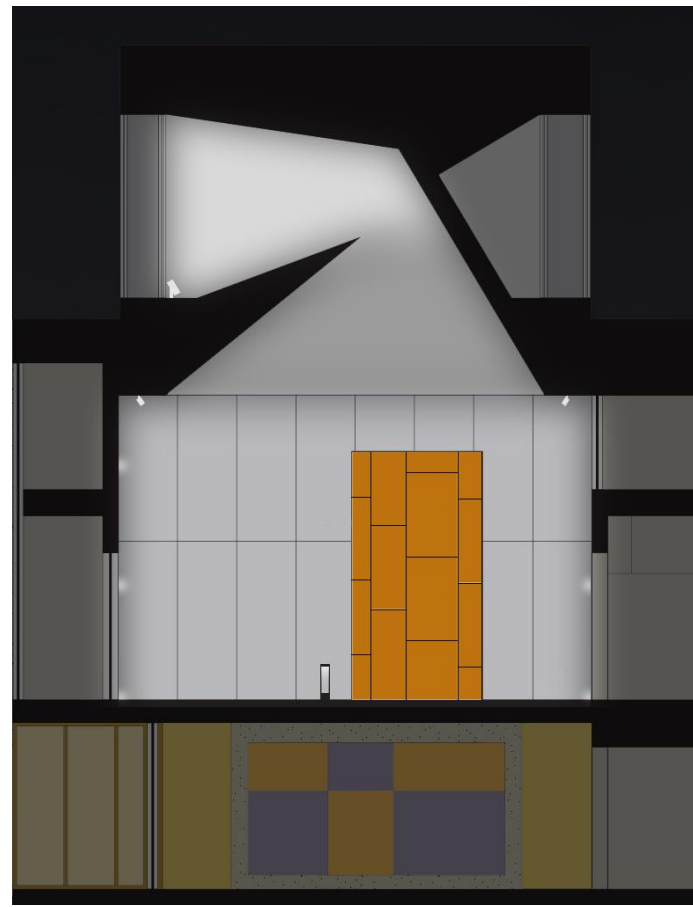
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	Criteria		
Lobby	5	2	4

Space	ASHRAE 90.1 LPD (W/ft ²)
	Criteria
Lobby	1.65

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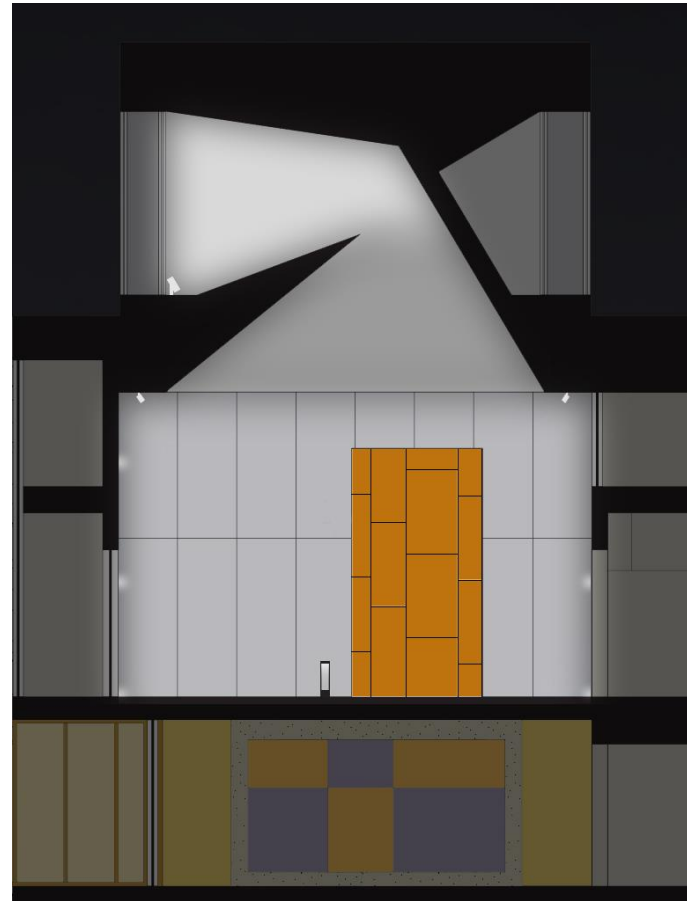
Space	Eh (fc)	Ev (fc)	Avg/Min
	Criteria		
Lobby	5	2	4

Space	ASHRAE 90.1 LPD (W/ft ²)
	Criteria
Lobby	1.65

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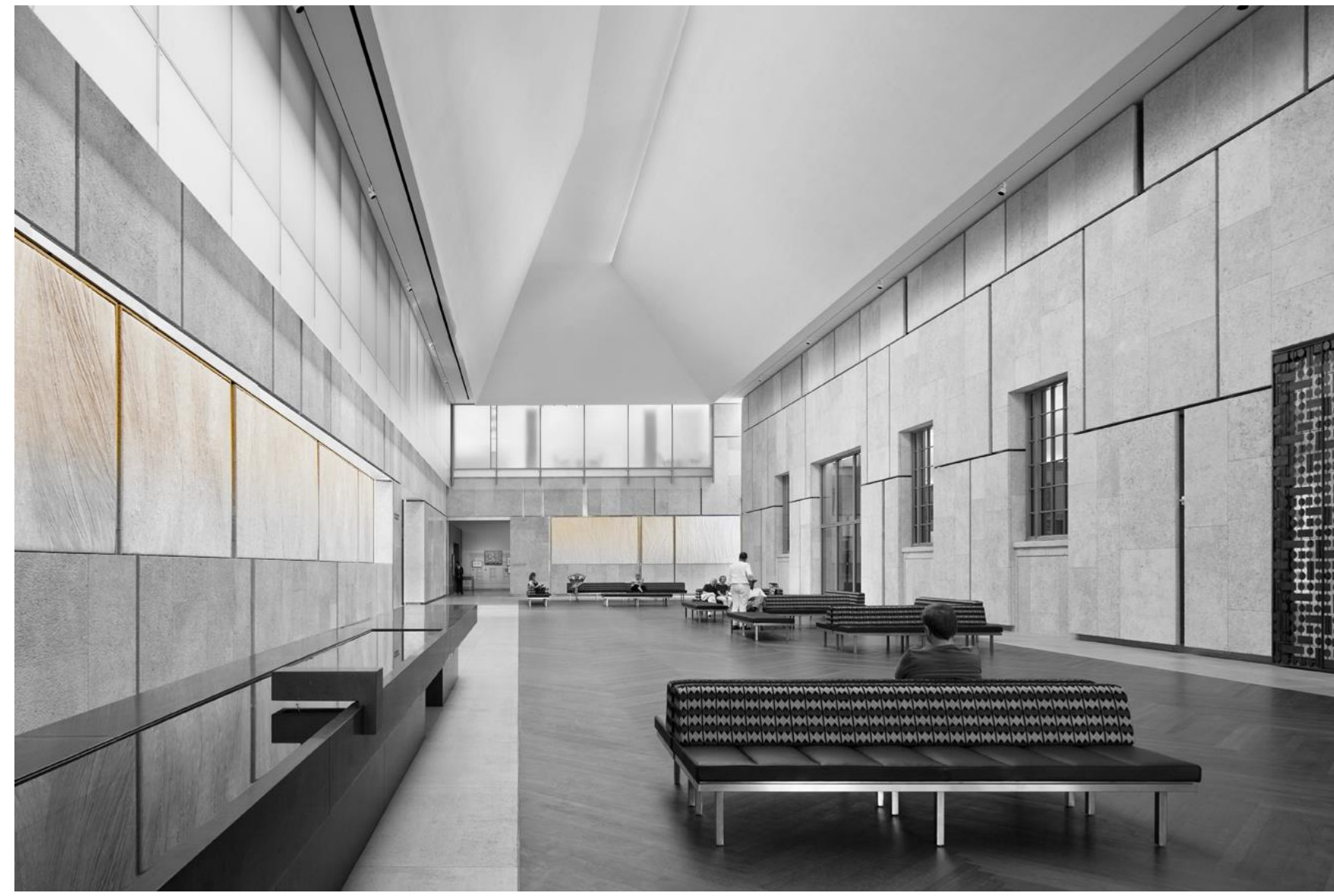
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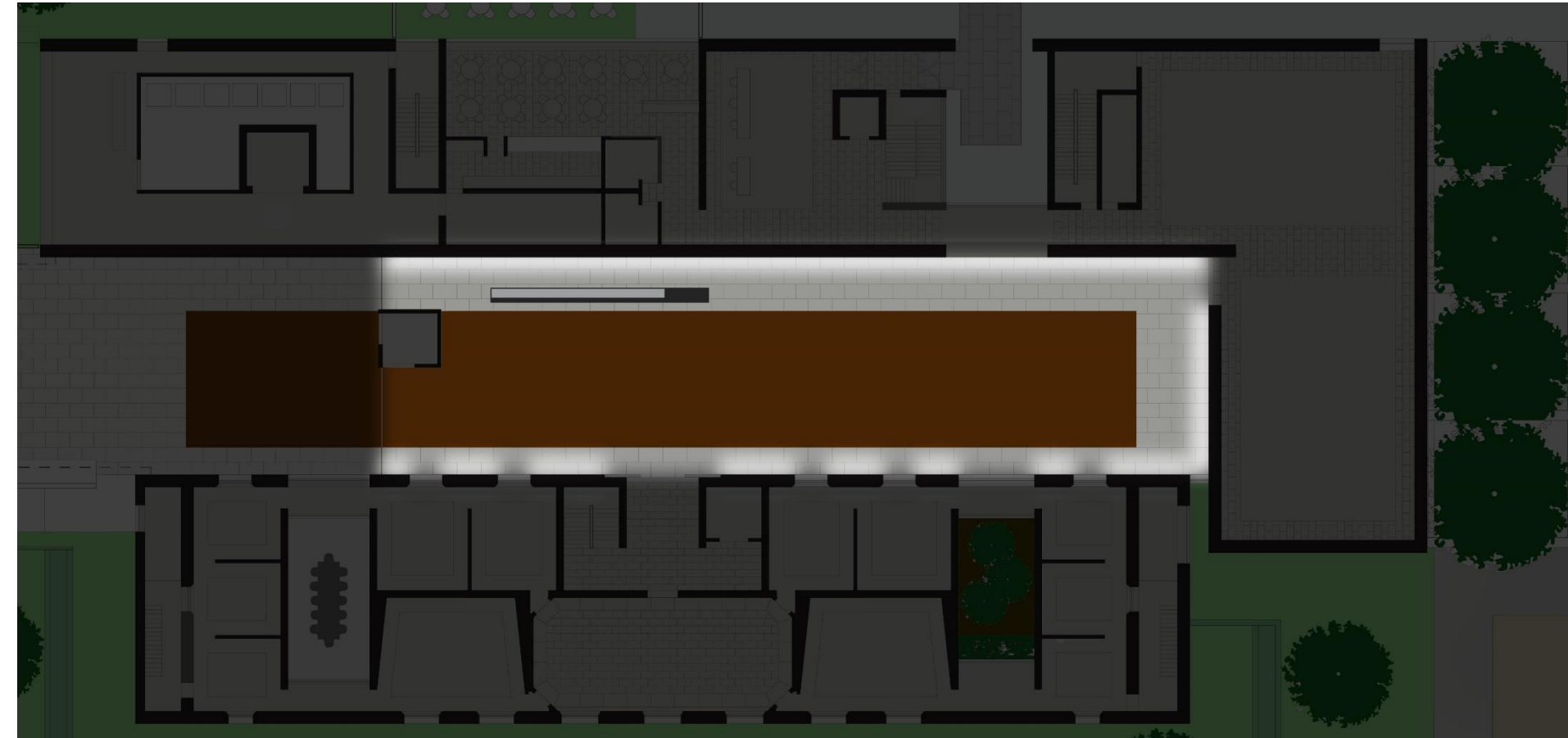
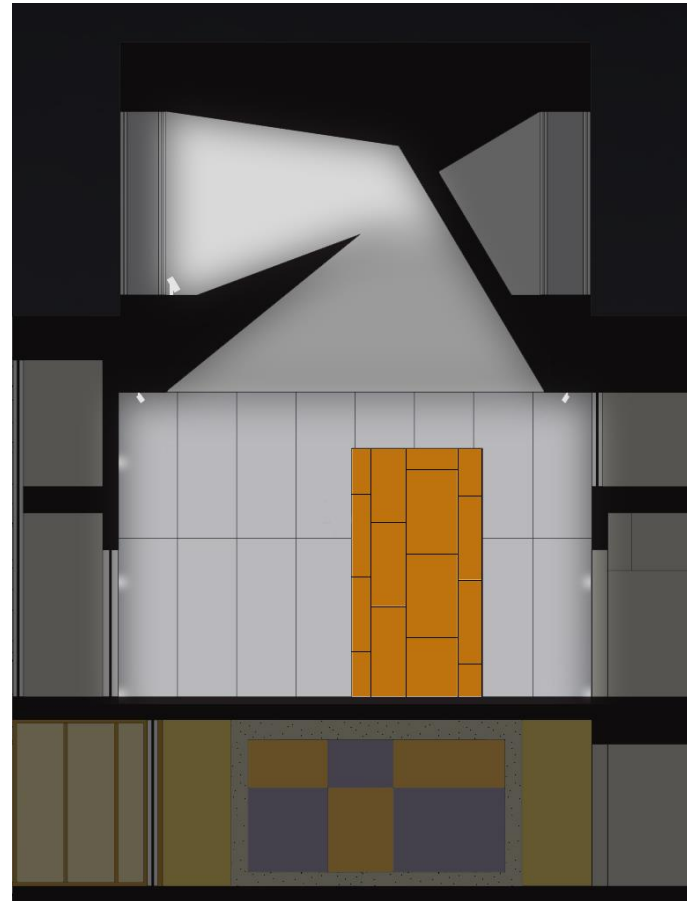
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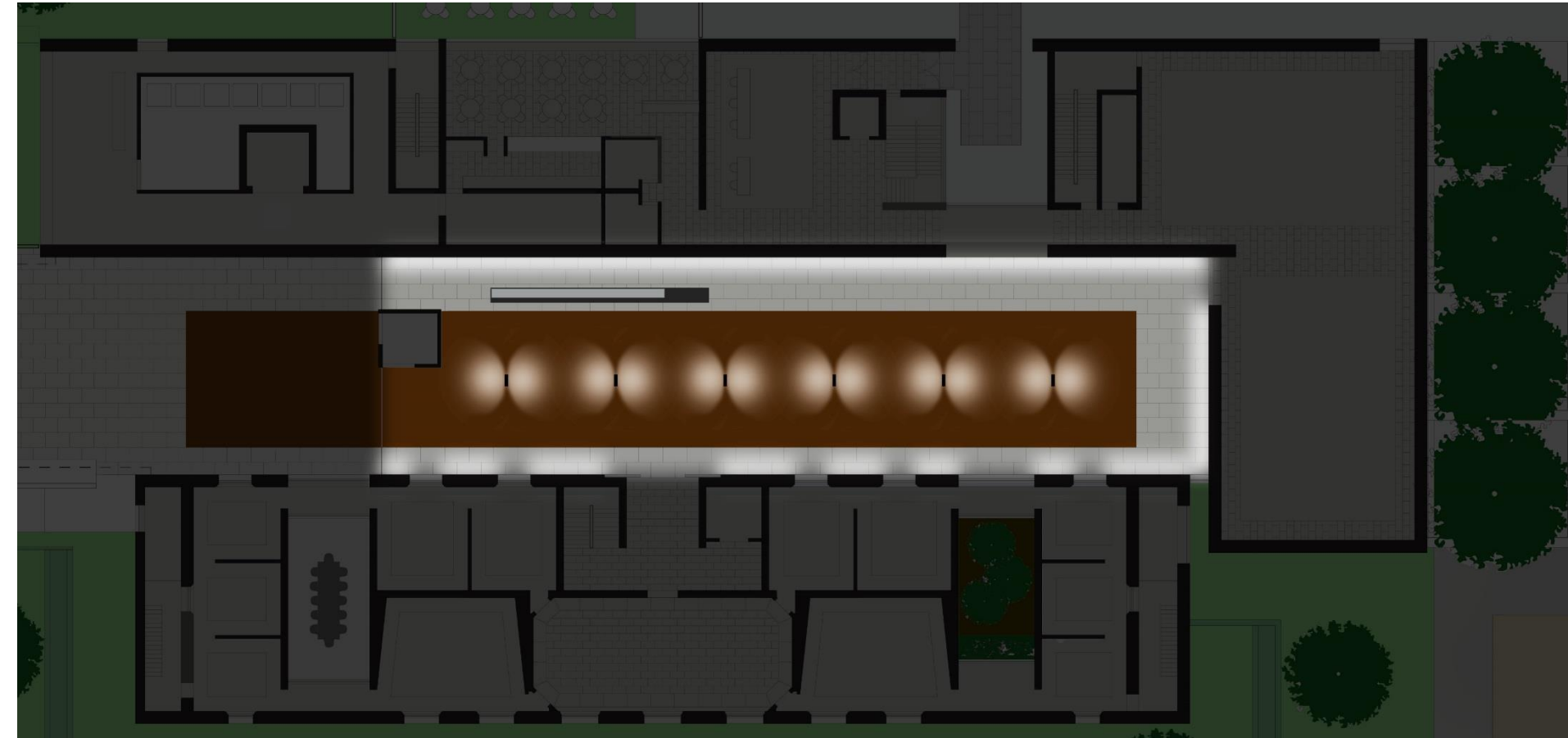
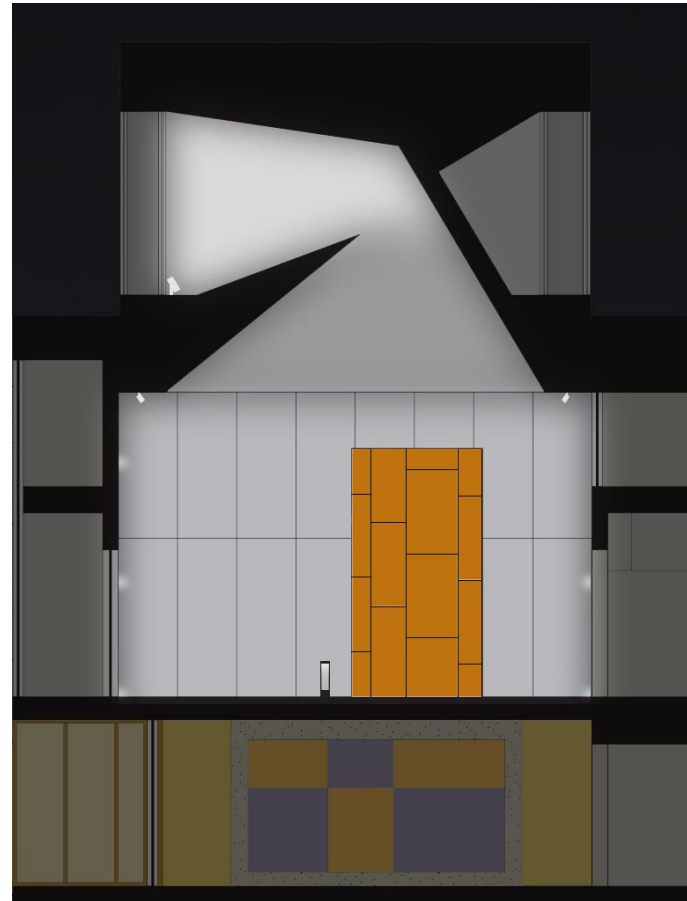
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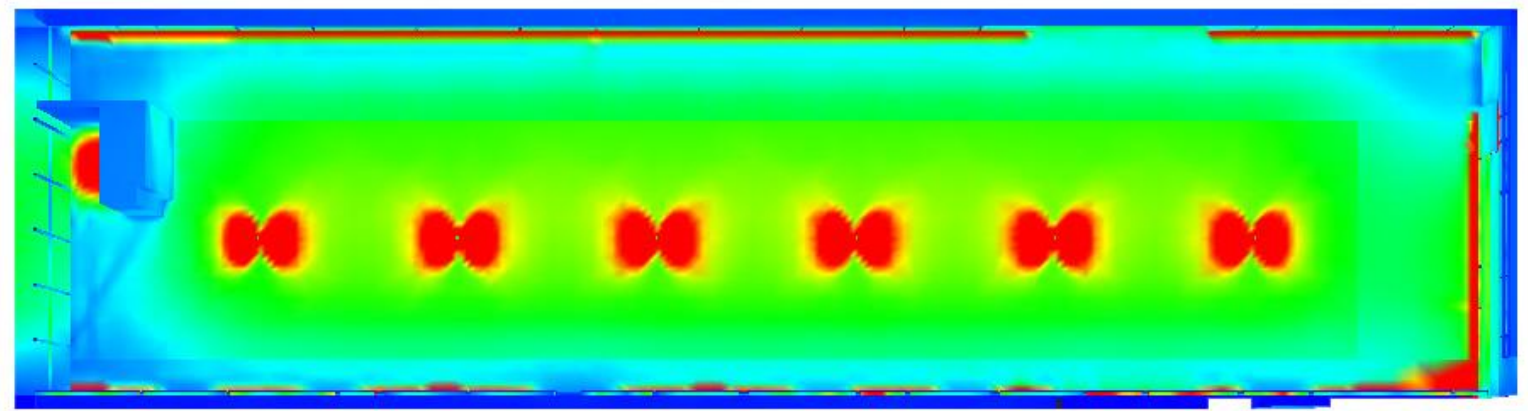
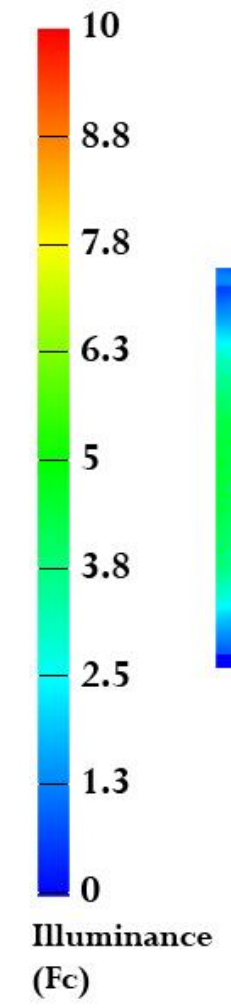
Space	Eh (fc)	Ev (fc)	Avg/Min
	Criteria		
Lobby	5	2	4

Space	ASHRAE 90.1 LPD (W/ft ²)
	Criteria
Lobby	1.65

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Space	Eh (fc)		Ev (fc)		Avg/Min	
	Criteria	Calculated	Criteria	Calculated	Criteria	Calculated
Lobby	5	4.84	2	2.2	4	5.36

Space	ASHRAE 90.1 LPD (W/ft ²)	
	Criteria	Calculated
Lobby	1.65	1.00

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Courtesy of FMS

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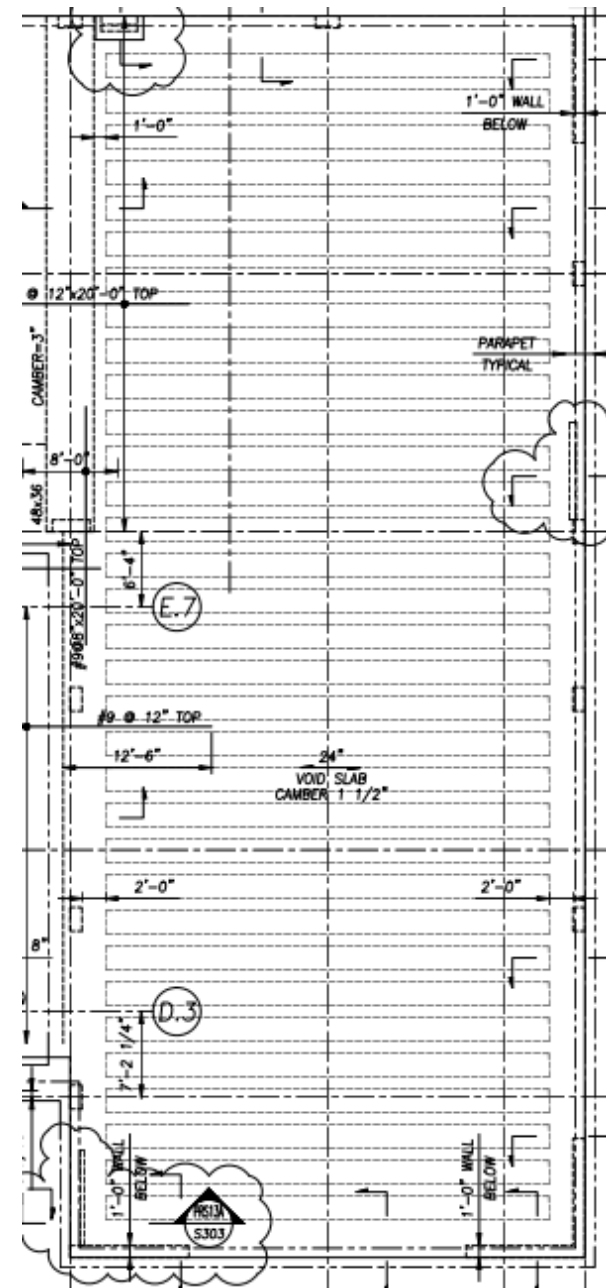
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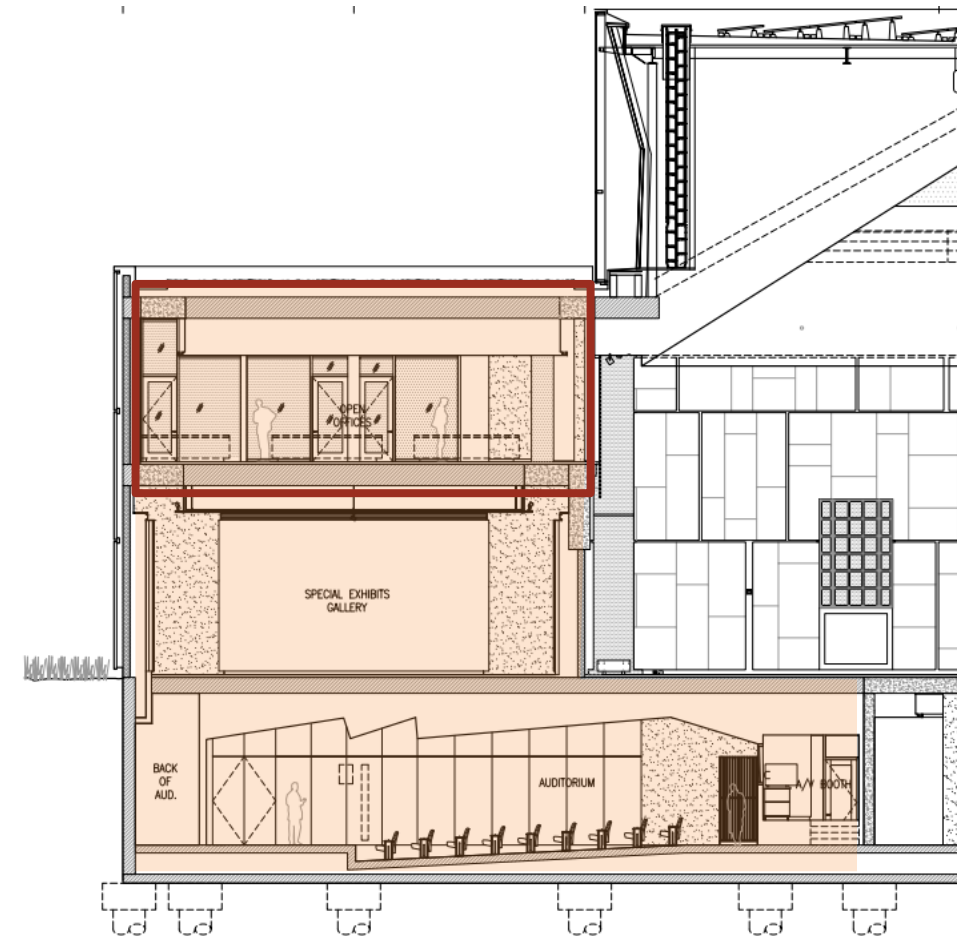
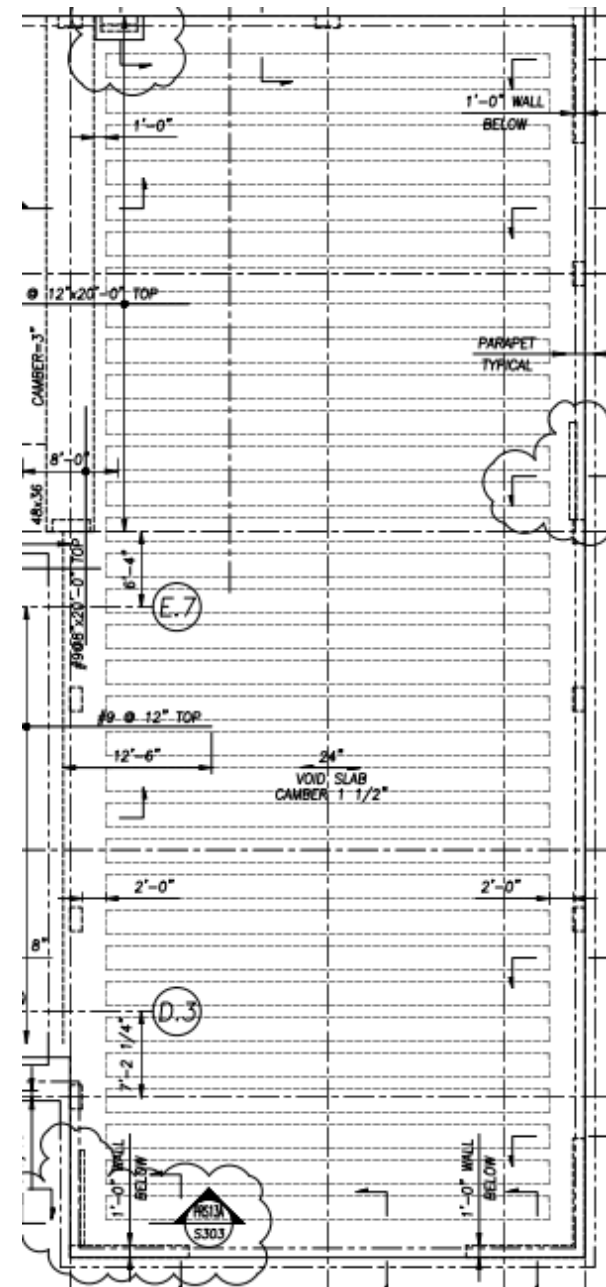
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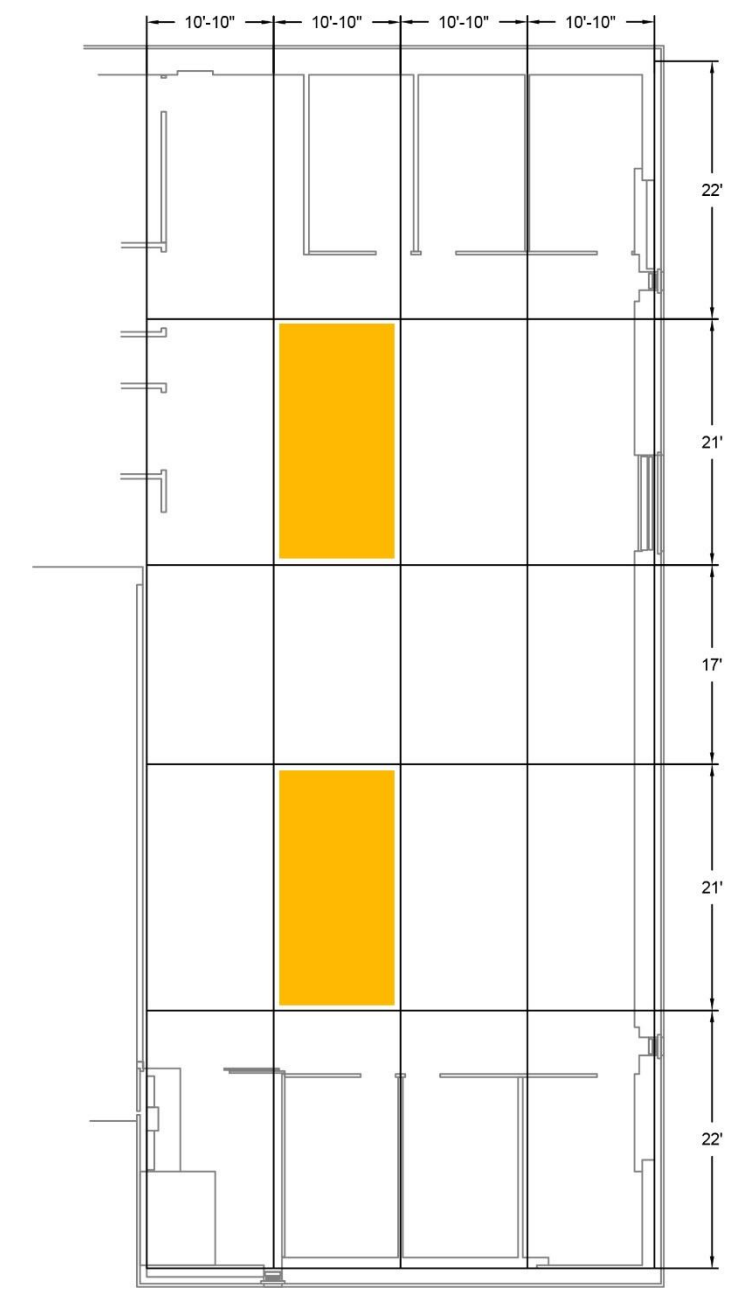
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Material	PSF
Lightweight Concrete, 4"	38.33
PVC Membrane	1
Rigid Roof Insulation	3
Protective Sheathing	1.7
Vapor Retarder	1
Deck - 1.5B16, 3 Span	3.54
Skylights	15
PV Array	2
Total	65.57

$$w_u = 1.2(w_{DL}) + 1.6(w_{LL})$$

$$M_u = \frac{w_u \times L^2}{8}$$

$$I = \frac{5 \times w_u / 12 \times (L \times 12)^4}{L / 360 \times 384 \times 29000}$$

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INFILL BEAMS | W10x12

GIRDERS | W14x26

| W18x31

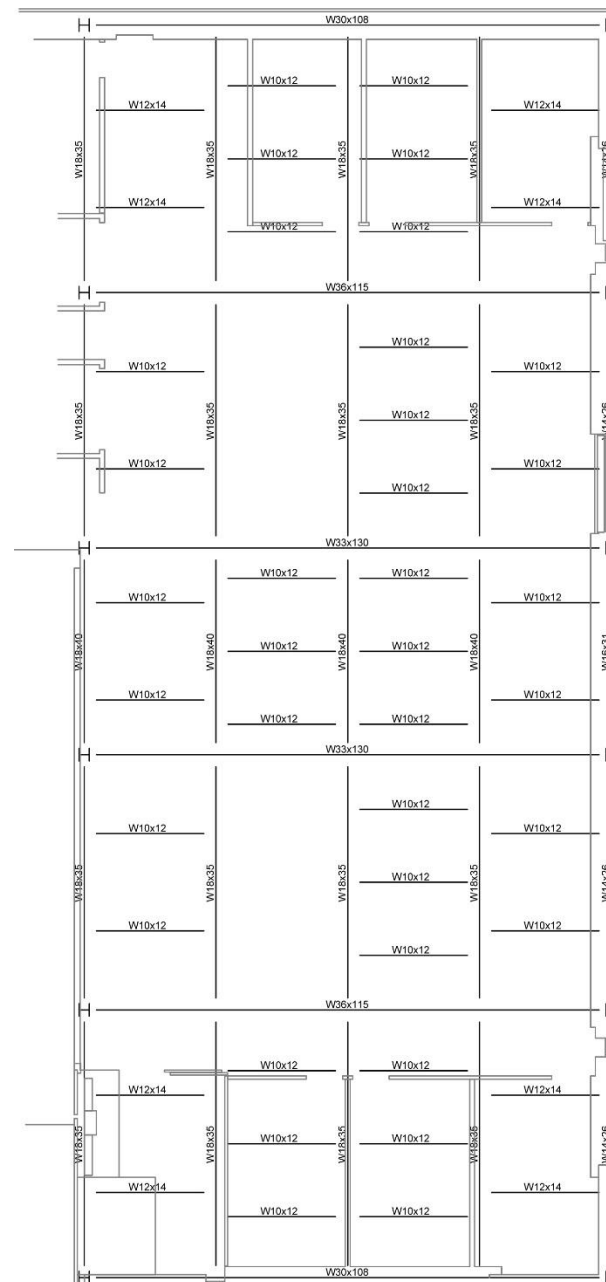
| W18x35

| W18x40

TRANSFER-GIRDERS | W30x108

| W33x130

| W36x115



Material	PSF
Lightweight Concrete, 4"	38.33
PVC Membrane	1
Rigid Roof Insulation	3
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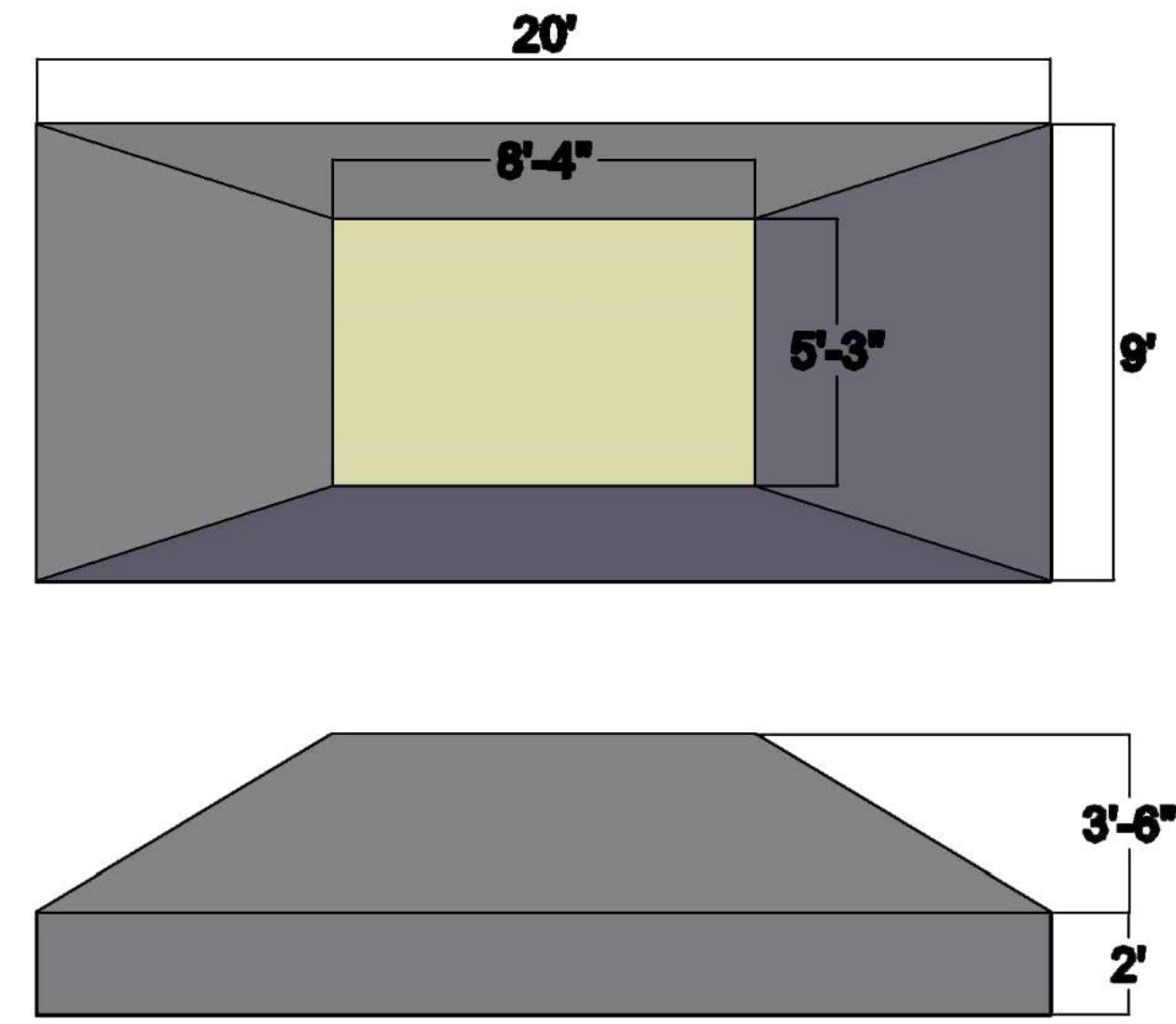
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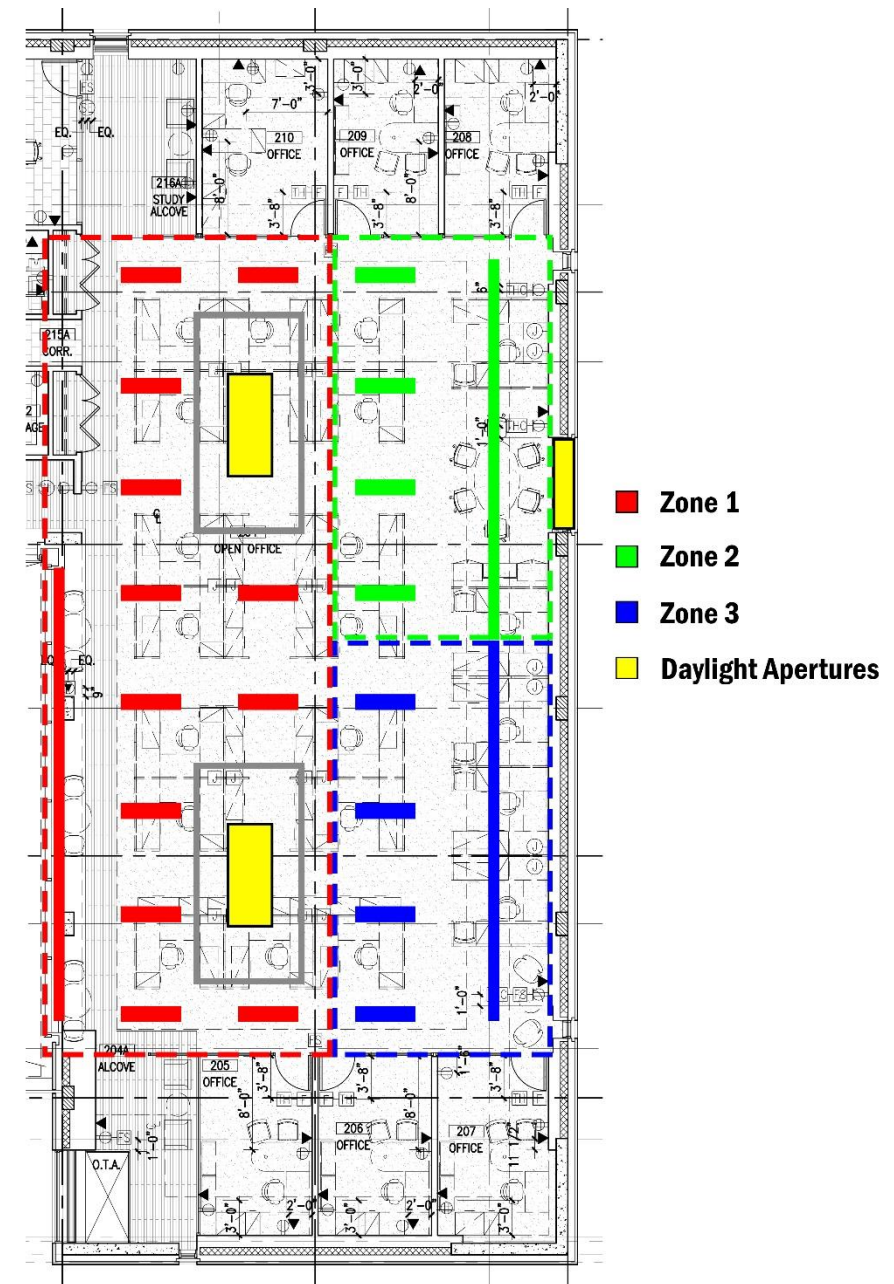
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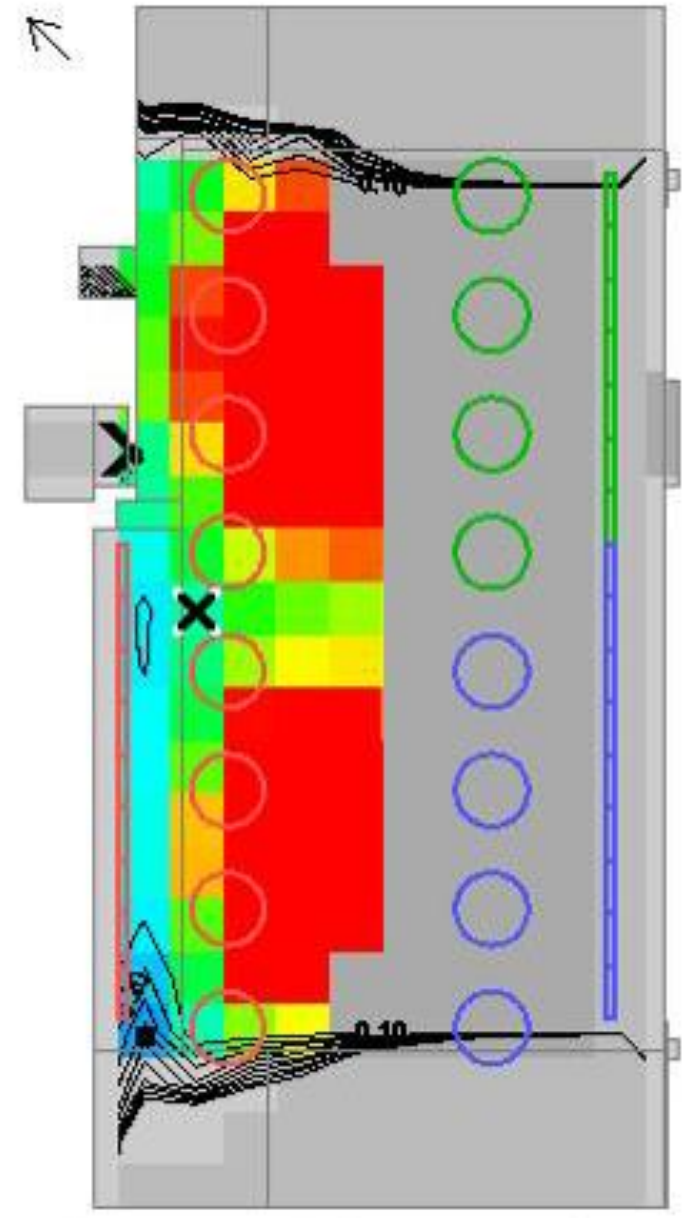
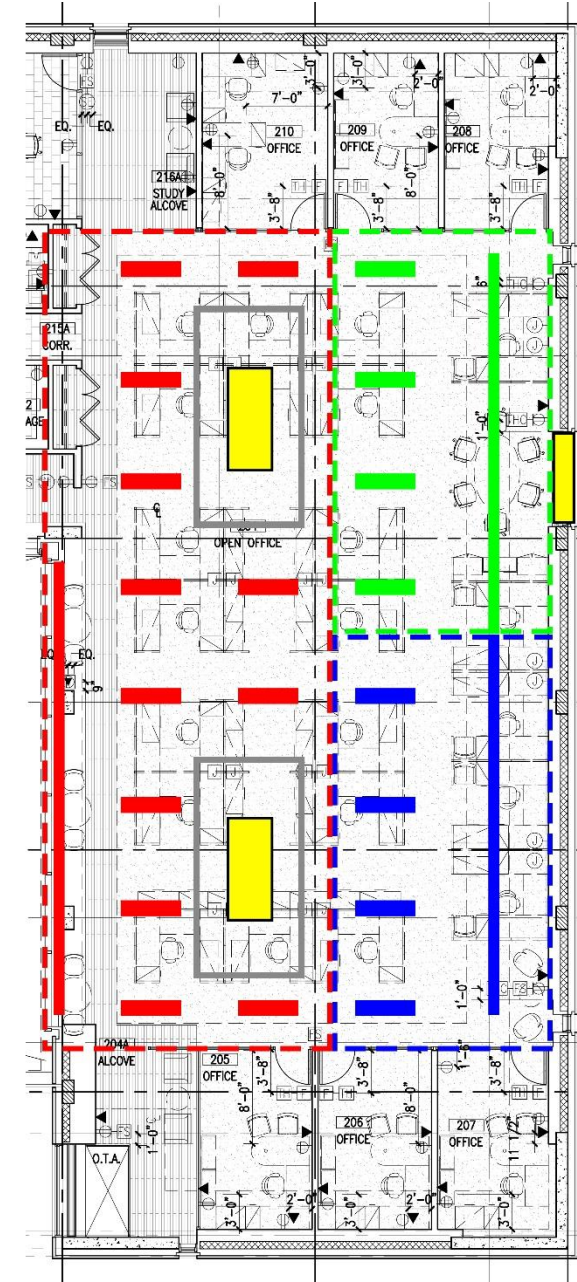
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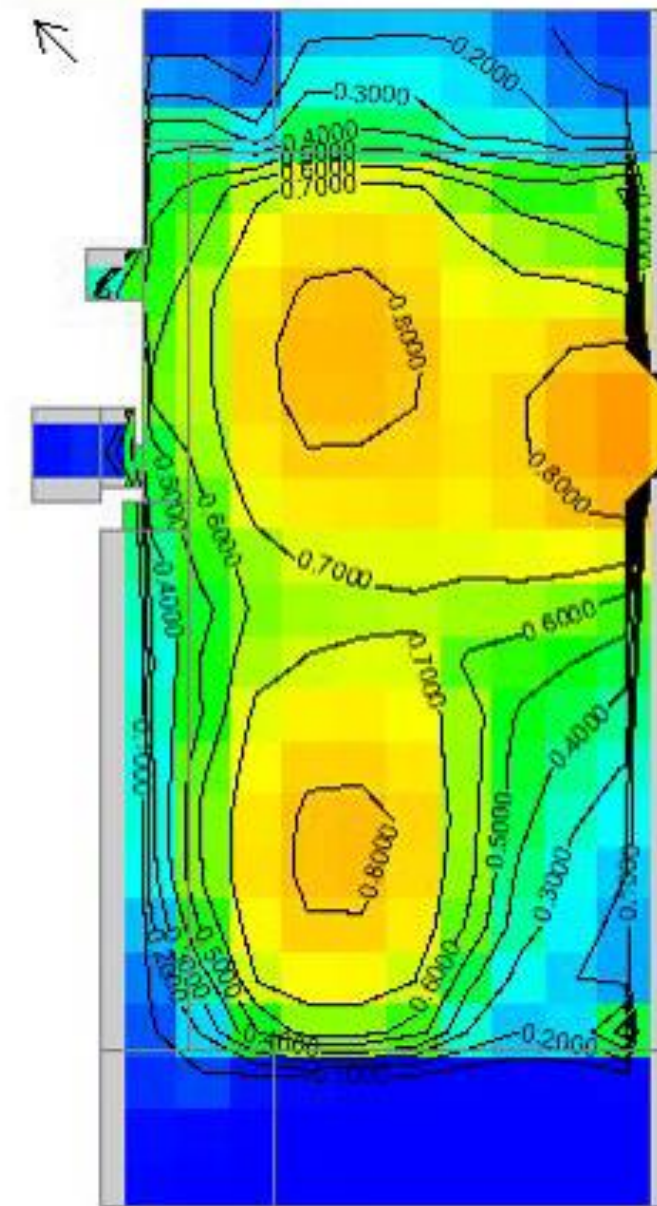
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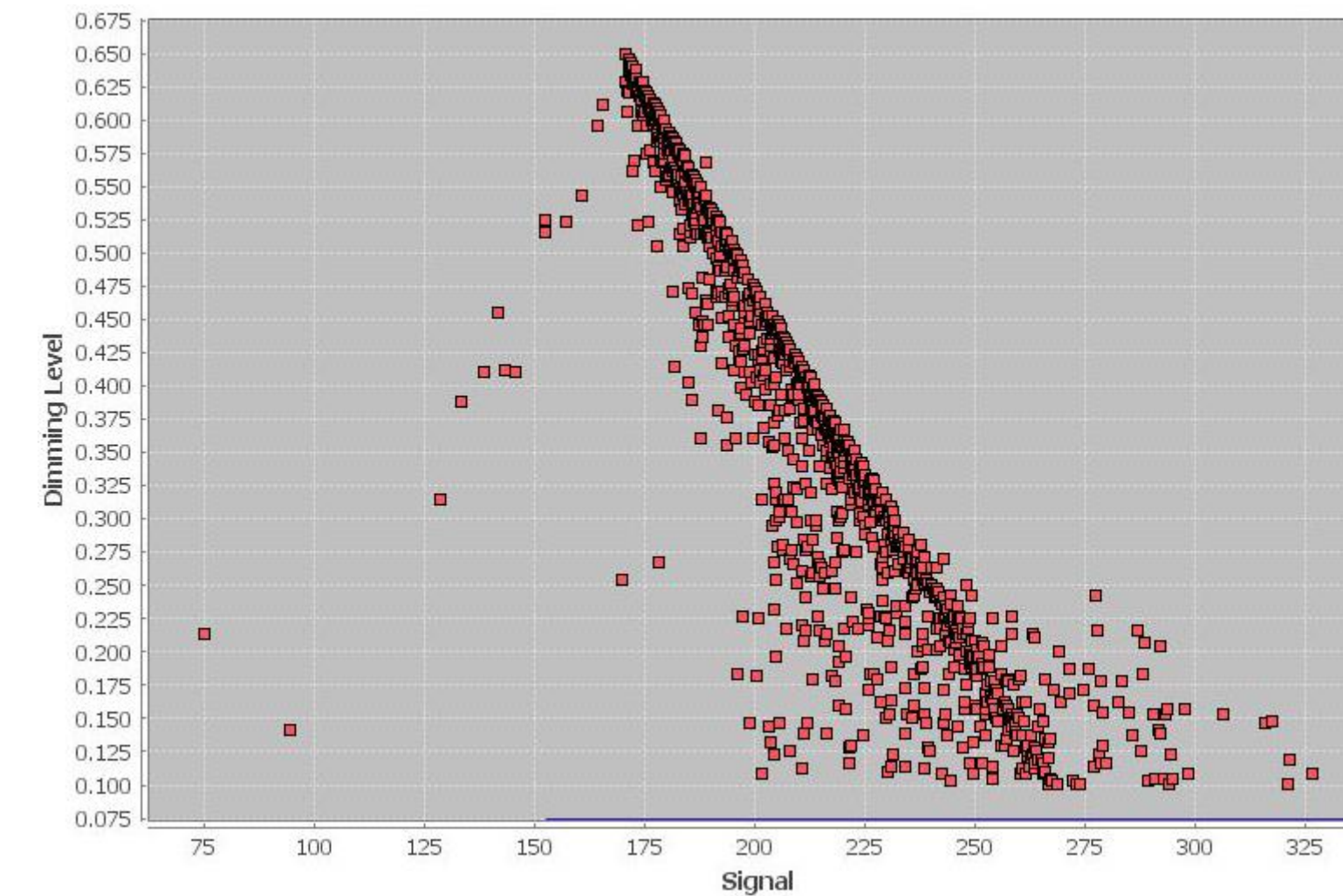
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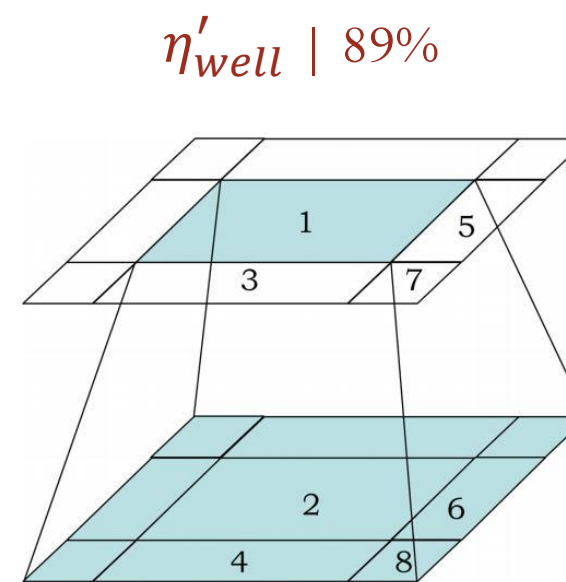
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Percent of points above 50%: **55.74**



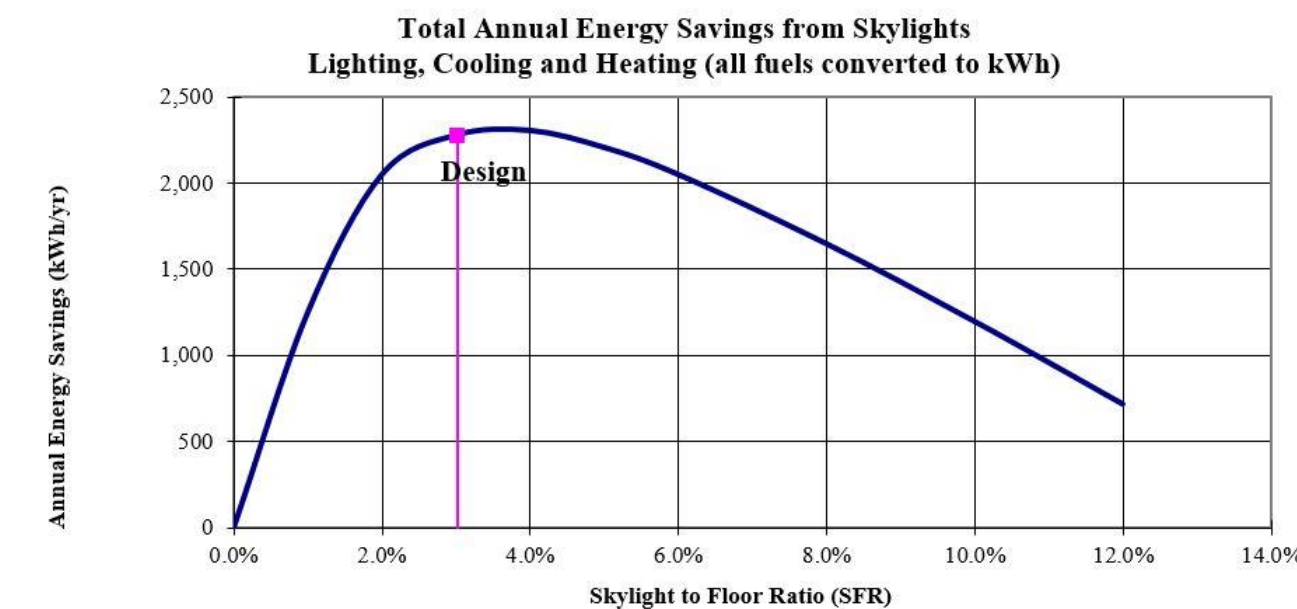
TOTAL SAVINGS | 3473.82 kWh





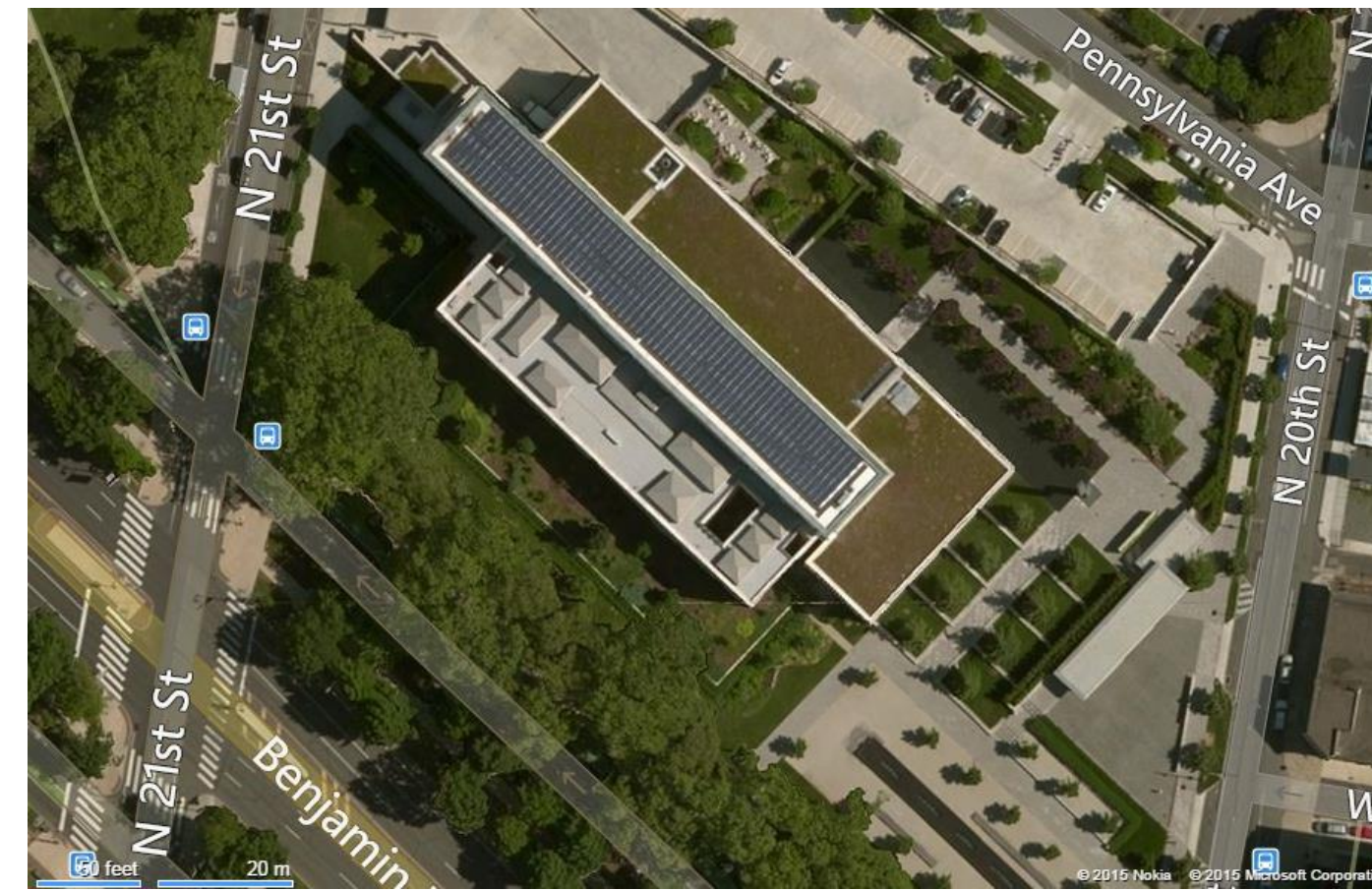
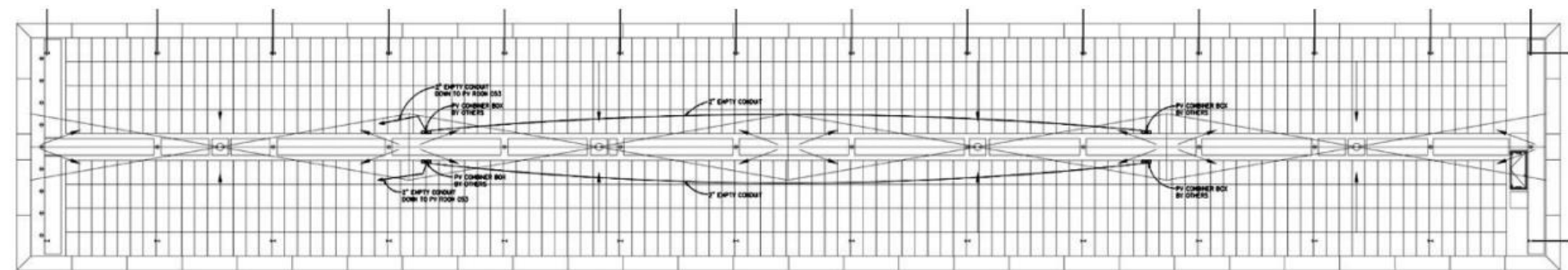
$$F_{t-b} = \frac{A_{(1+3+5+7)}F_{(1+3+5+7)-(2+4+6+8)} + A_7F_{7-8} - A_{(3+7)}F_{(3+7)-(4+8)} - A_{(5+7)}F_{(5+7)-(6+8)}}{A_1}$$

Savings from Functioning Photocontrol System		
Savings	Annual Energy Savings (kWh/yr)	Annual Cost Savings (\$/yr)
Lighting	3473.82	\$521.073
Cooling	382.64	\$57.40
Heating	-60.92	\$-2.11
Total	3795.53	\$576.36



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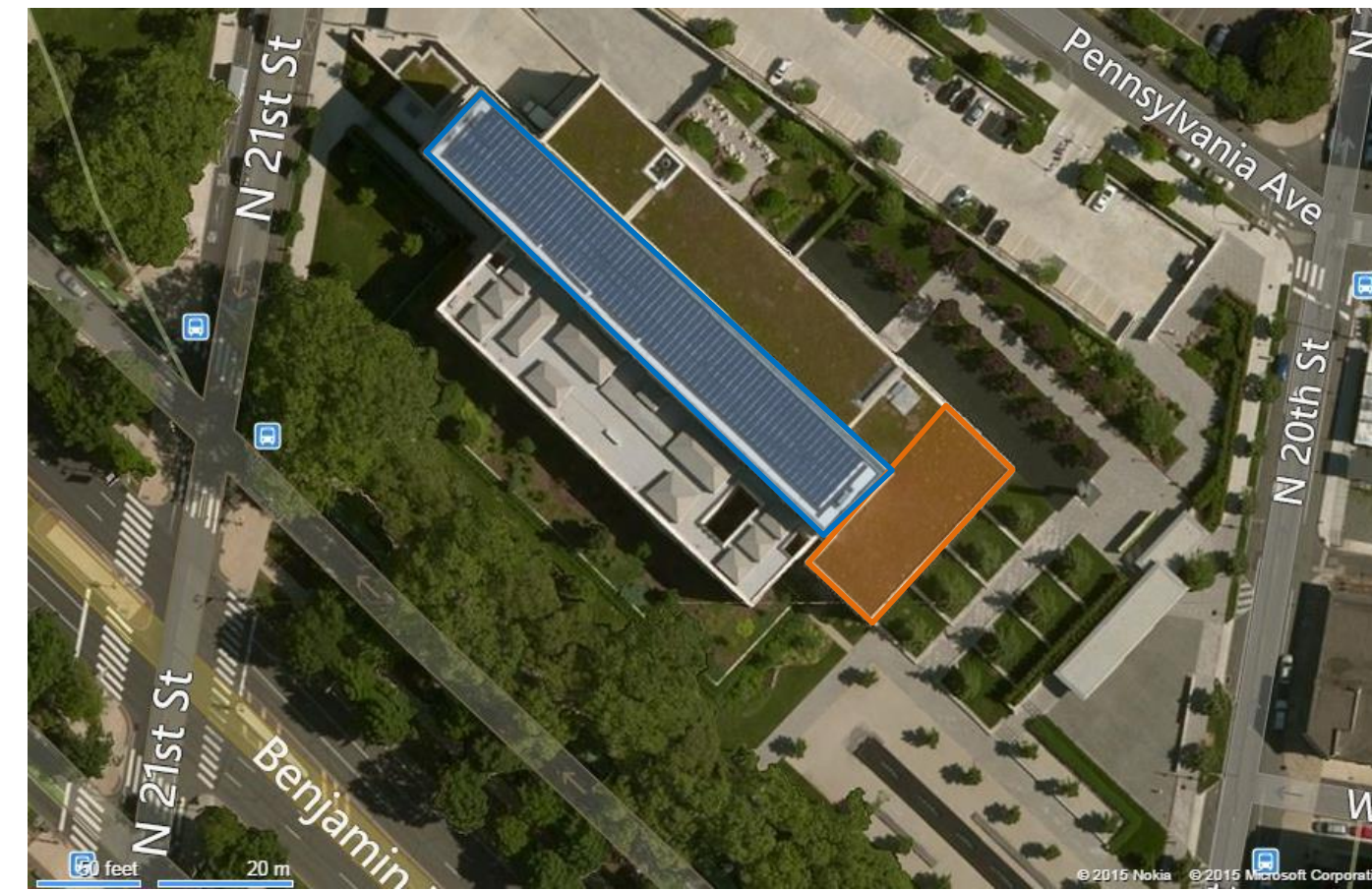
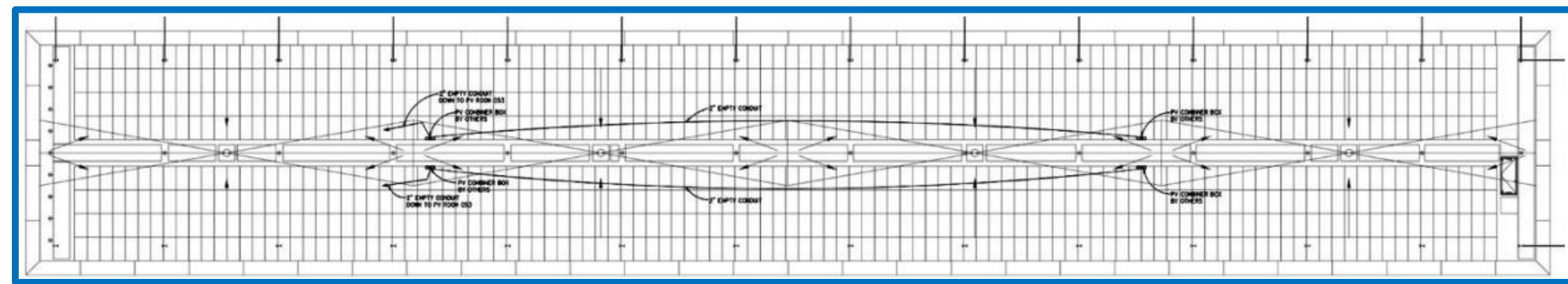
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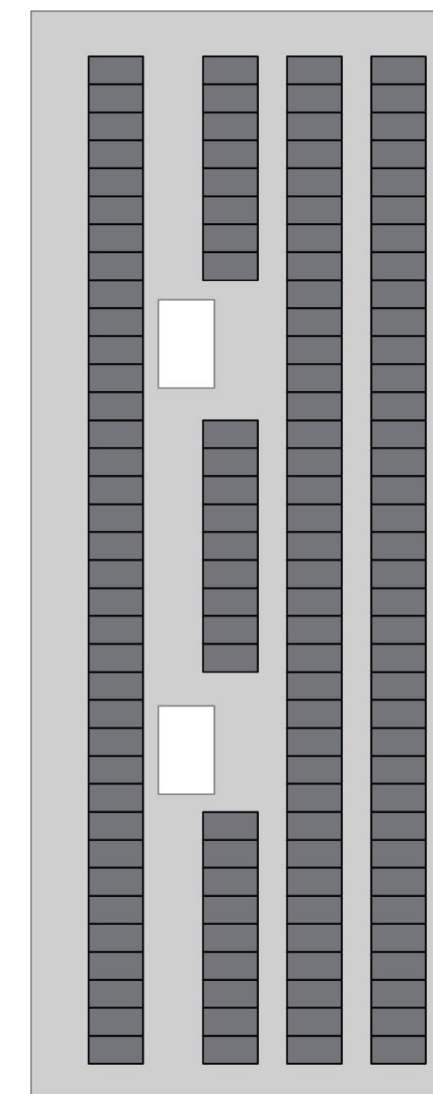
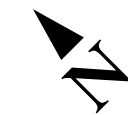
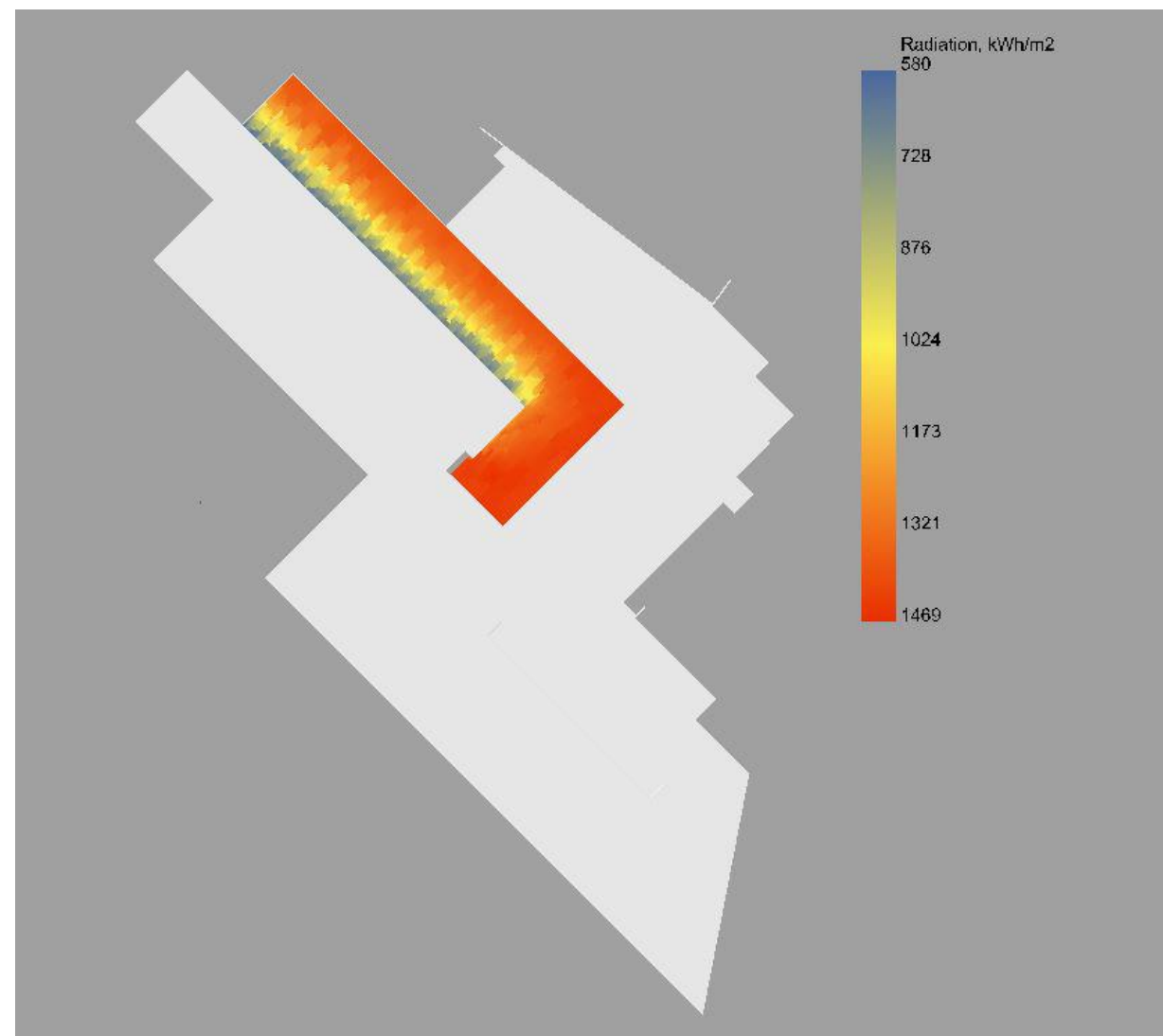
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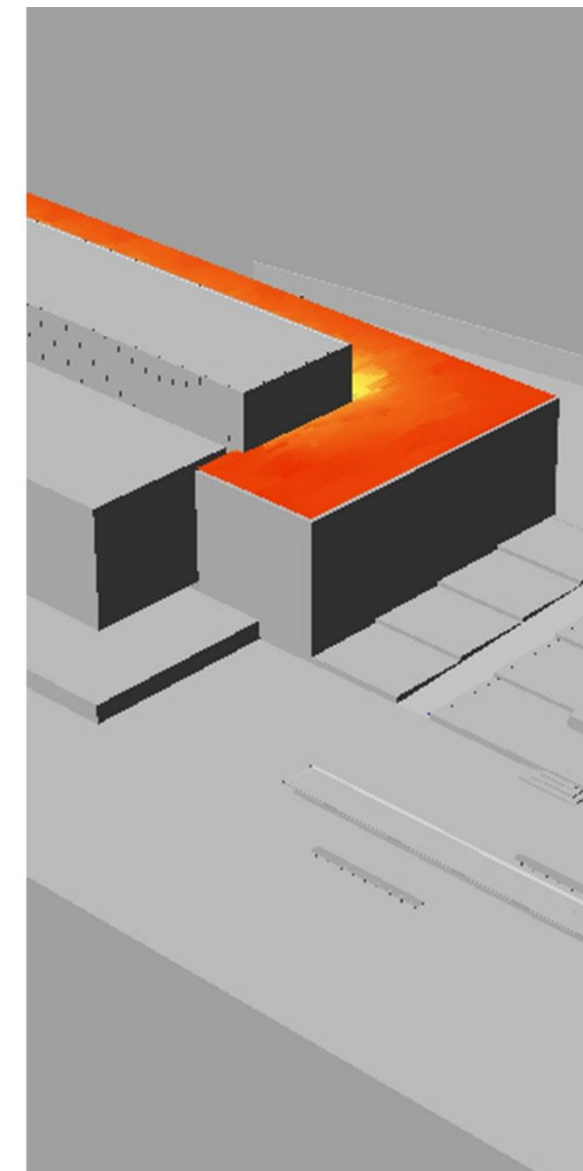
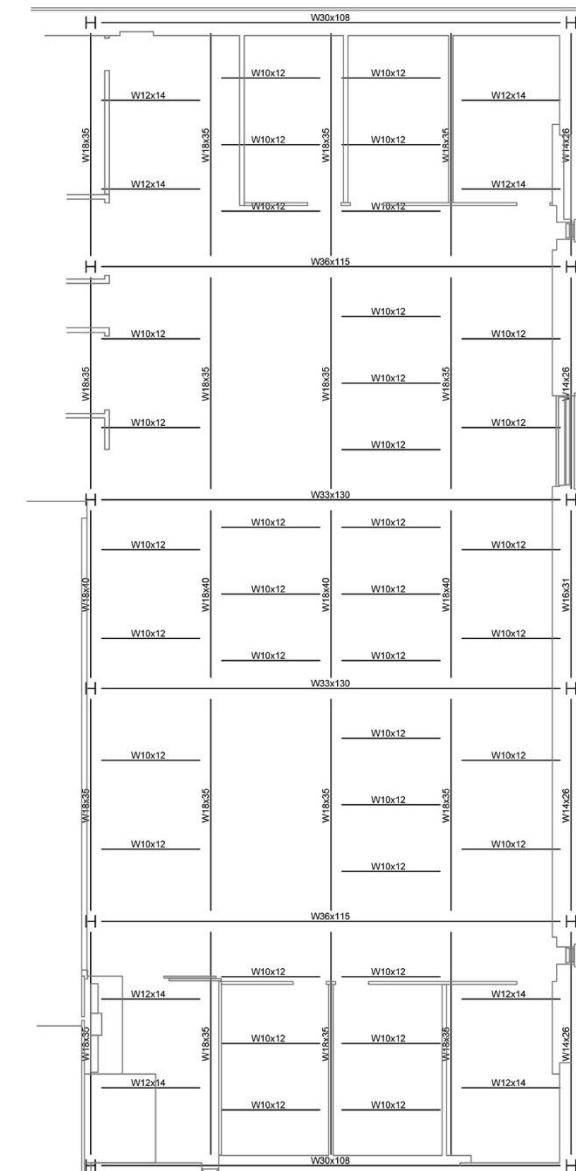
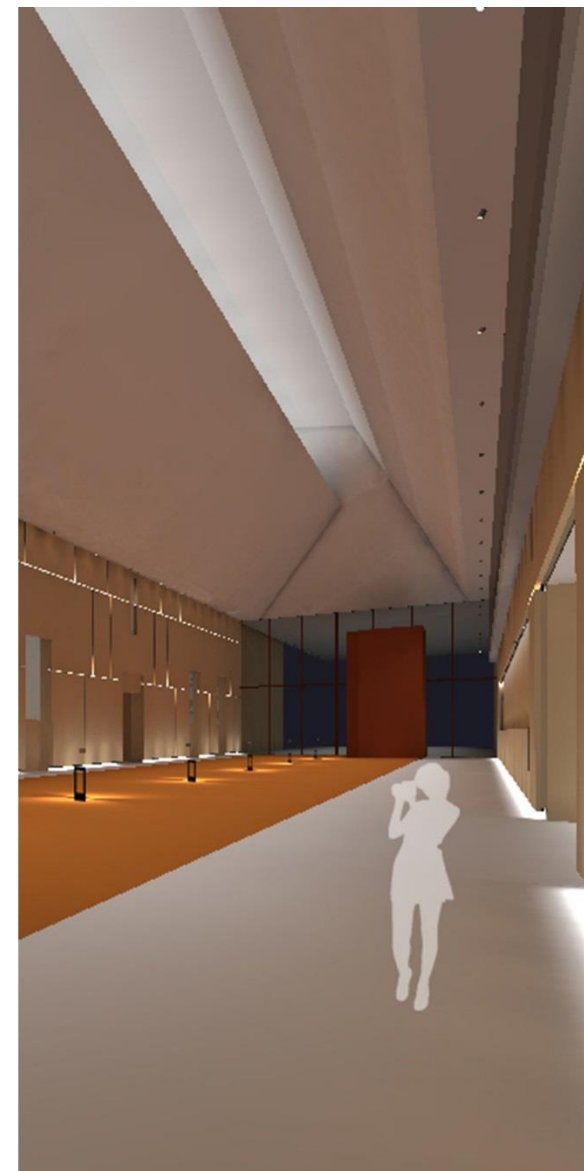
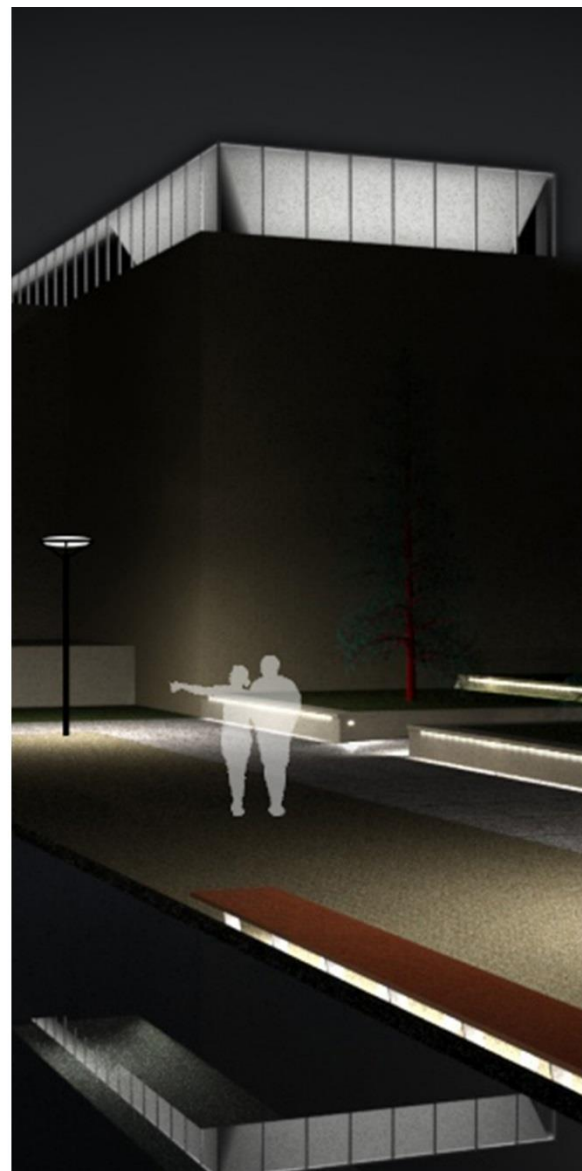
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THANKYOU

AE DEPARTMENT

DR. RICHARD MISTRICK

SHAWN GOOD

GARY GOLASZIEWSKI

DR. THOMAS BOOTHBY

PROFESSOR M. KEVIN PARFITT

FISHER MARANTZ STONE

PAULA MARTINEZ-NOBLES

TWBTA

VINCENT D'ANTONIO

MICHAEL MORAN

TOM CRANE

FRIENDS

MOM | DAD



FINAL THESIS
PRESENTATION

THE BARNES FOUNDATION

2025 BENJAMIN FRANKLIN PARKWAY
PHILADELPHIA, PA 19130

JOSEPH BRENNER
LIGHTING | ELECTRICAL
4 | 15 | 2015

APPENDIX

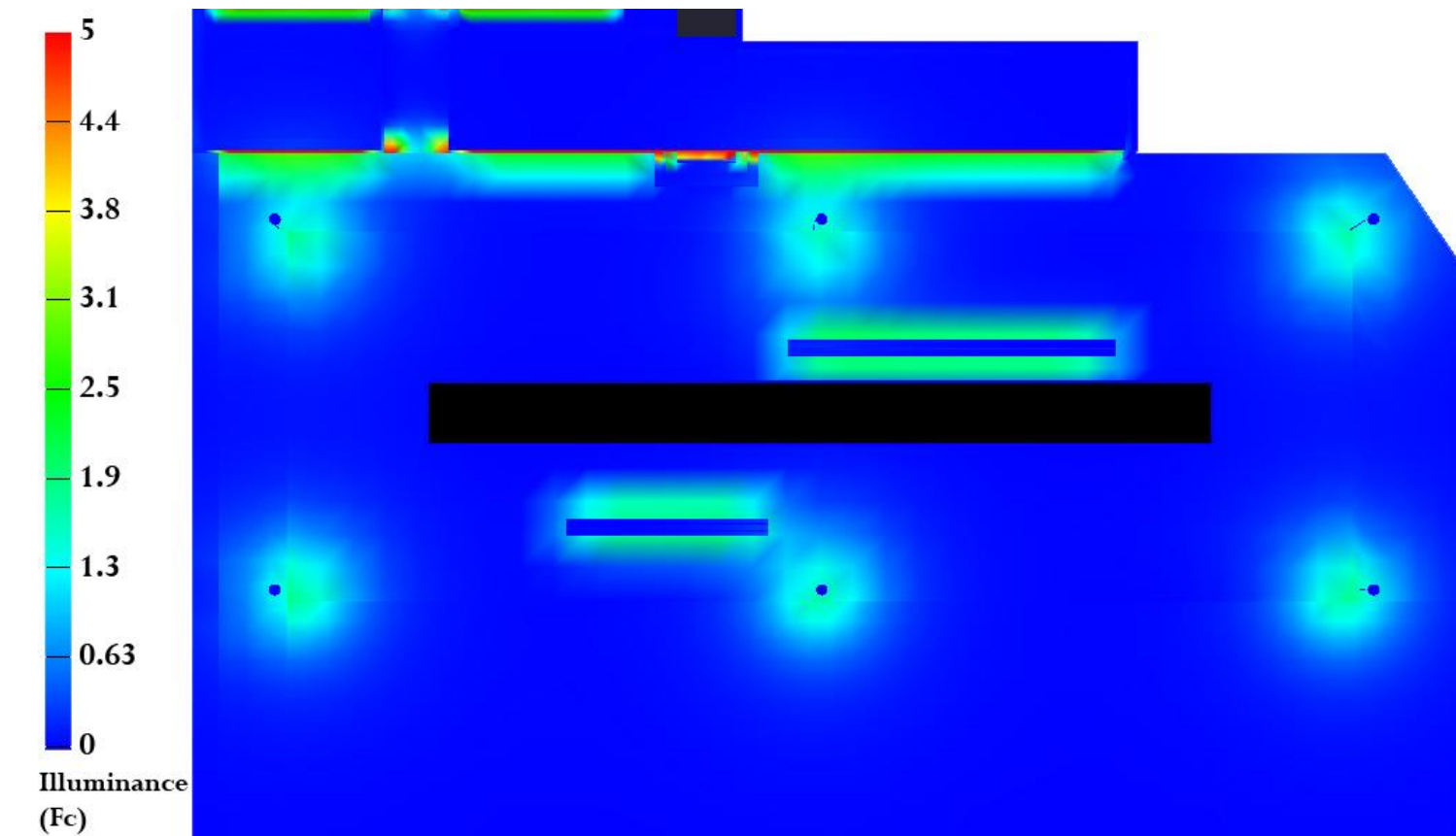
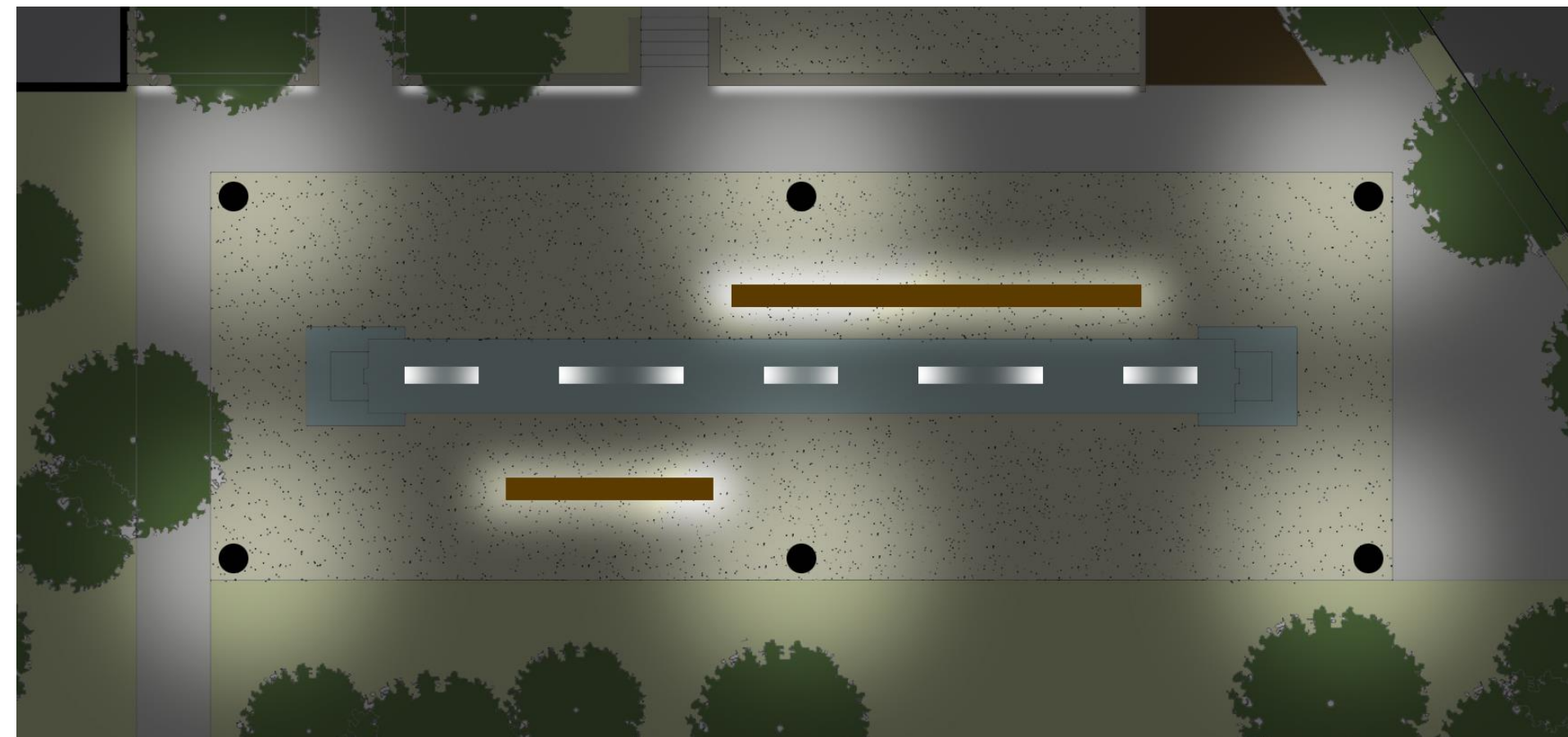
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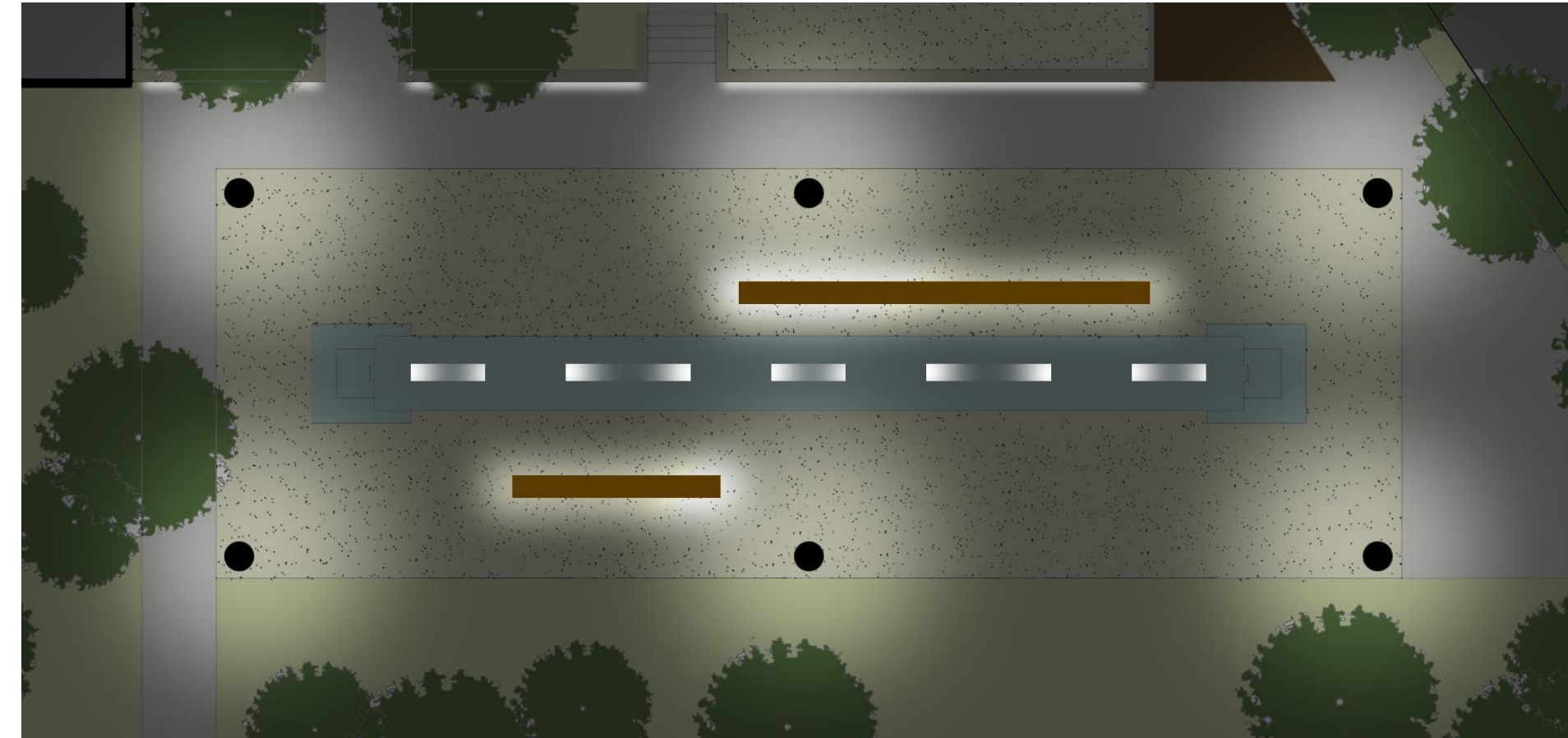
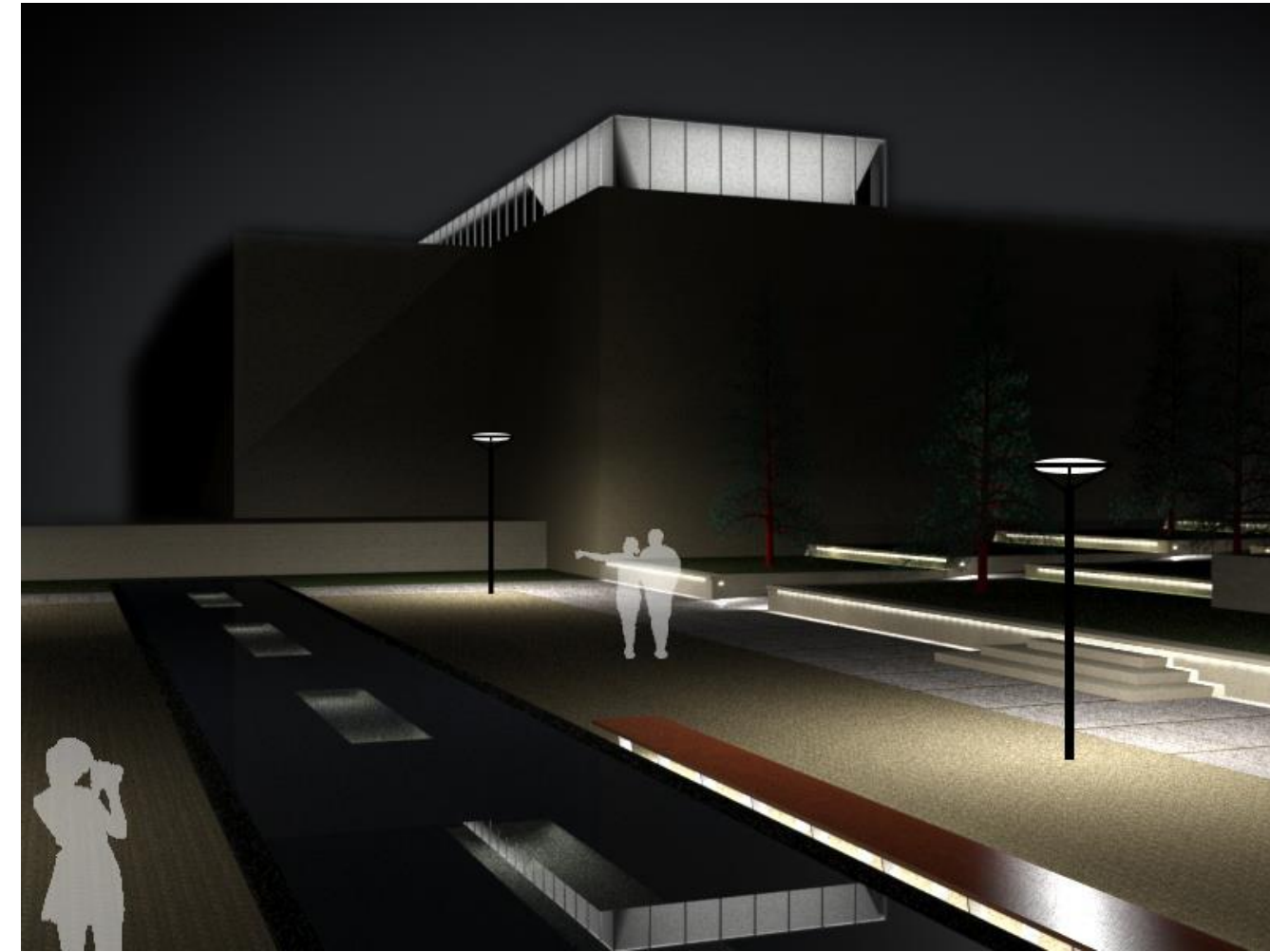
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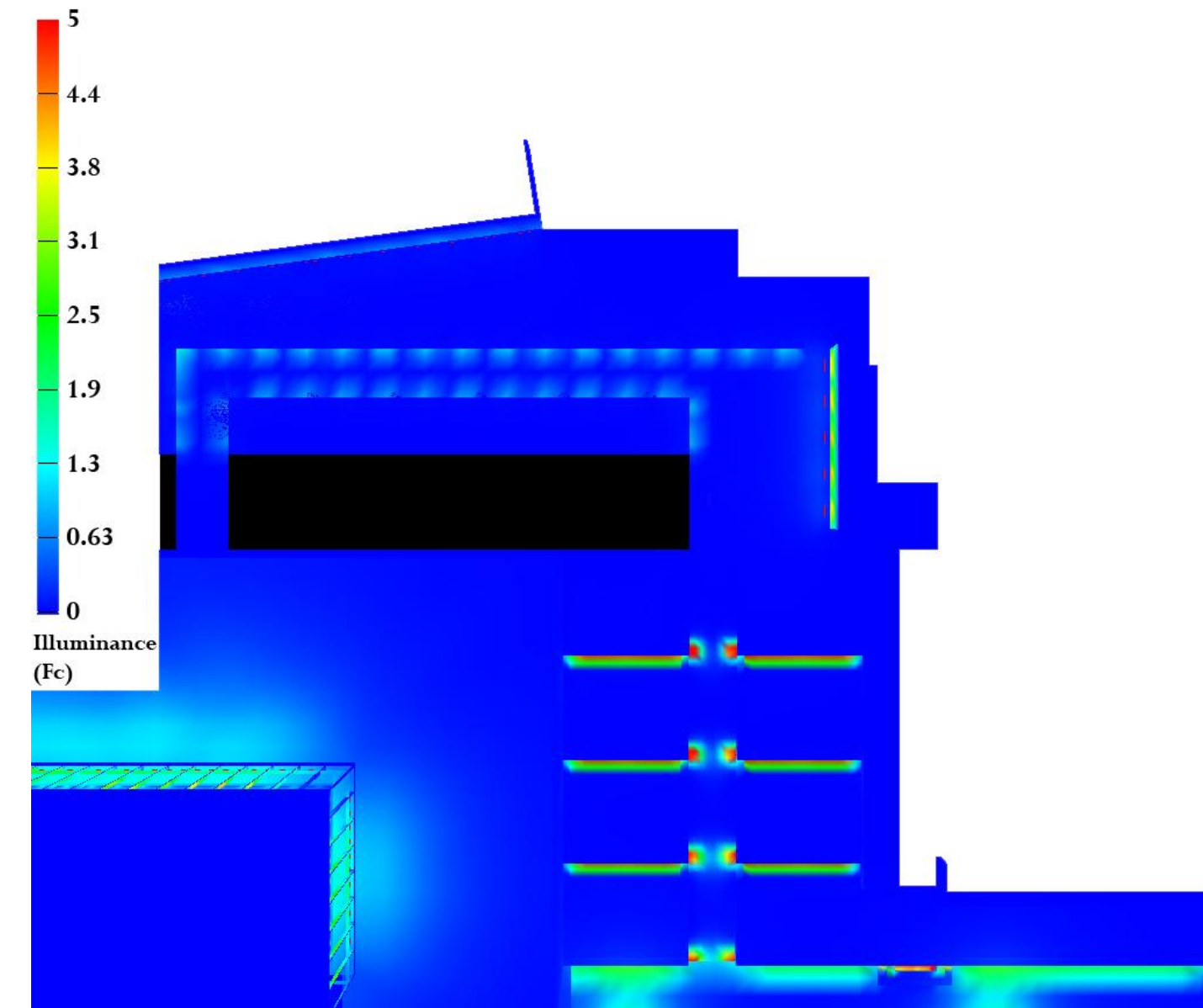
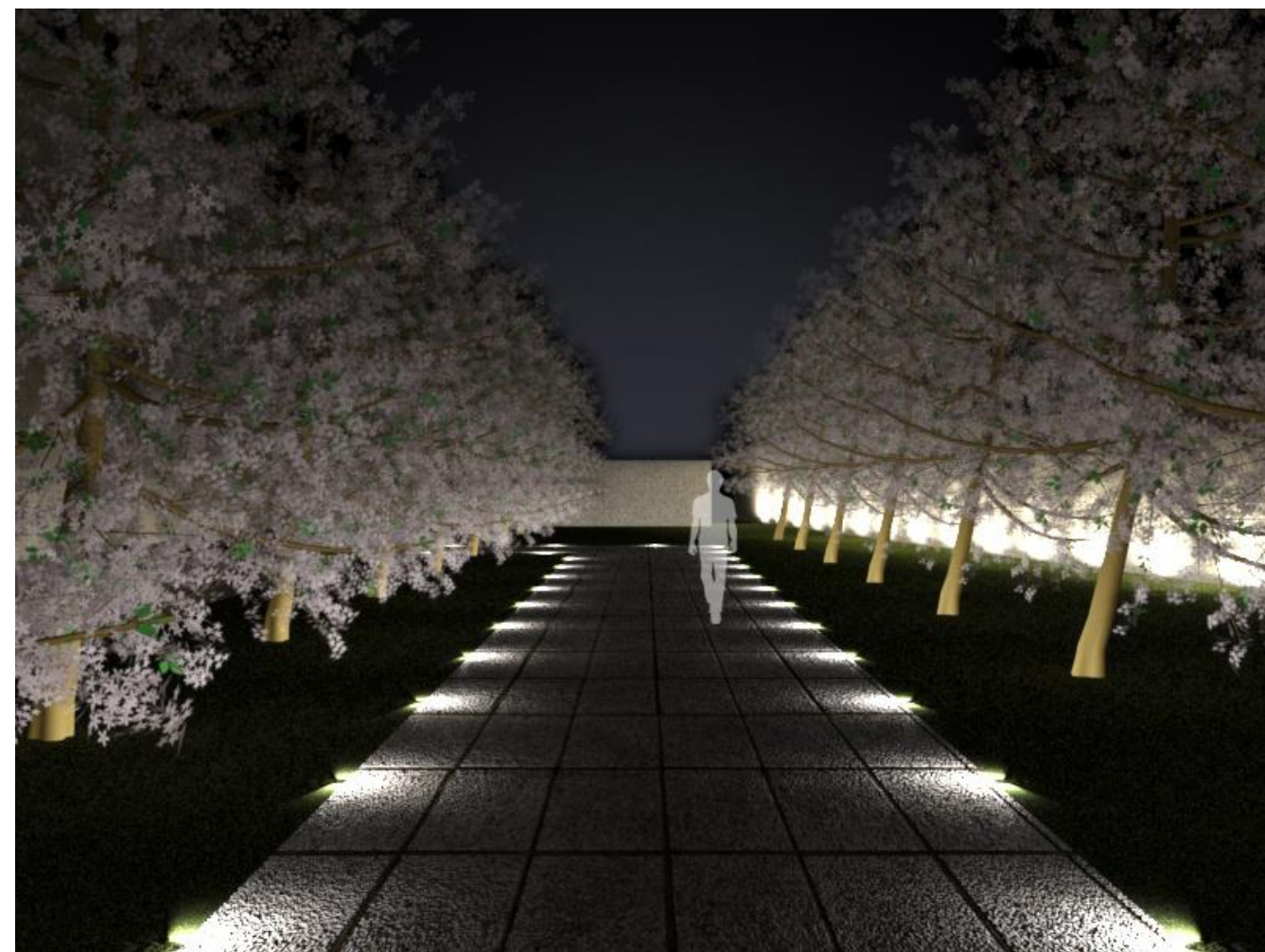
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Type	Description	MFR.
XFC	 Exterior LED pole light with integral electronic driver and 13' pole height.	Bega
XFD	 Surface mounted LED light with half-sided light sector at 3000K.	Bega
XFE	 Recessed LED wall light at 3000K with clear safety glass.	Bega
XFF	 In-grade LED flood light with assymetrical distribution at 3000K. Clear safety glass included.	Bega
XFG	 Recessed LED underwater wall light at 3000K with aluminum reflector.	Bega
XFH	 Linear LED strip light at 3500K.	LED Linear

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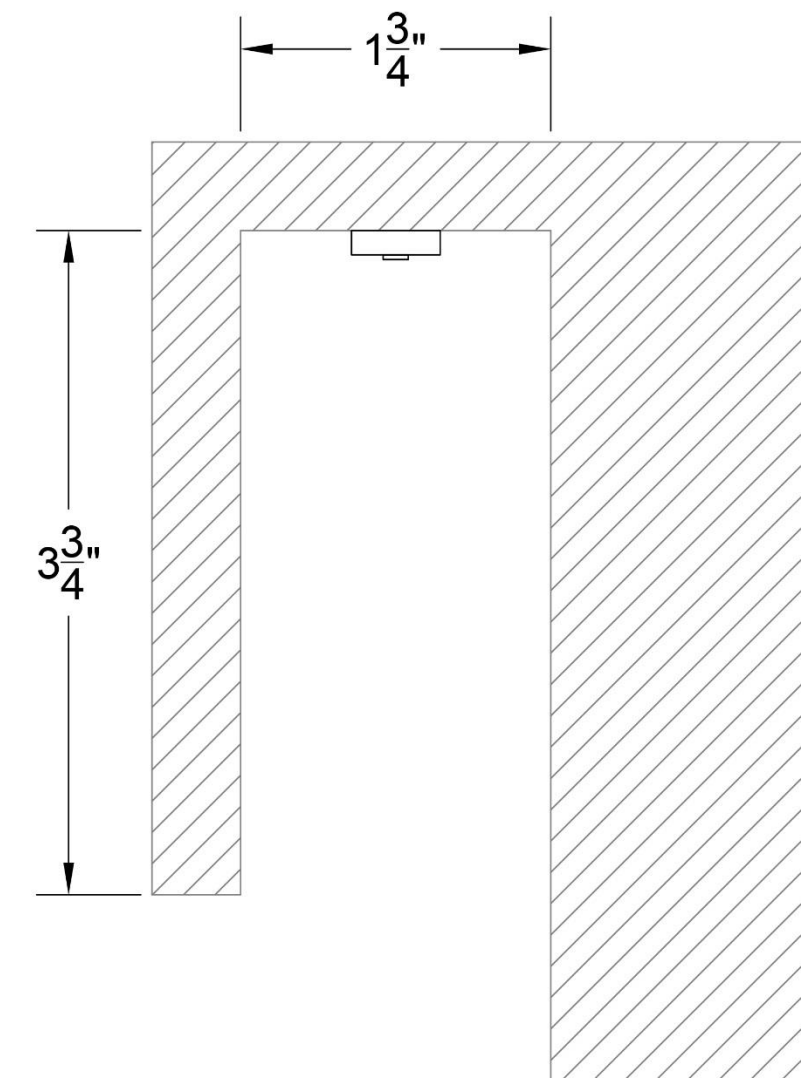


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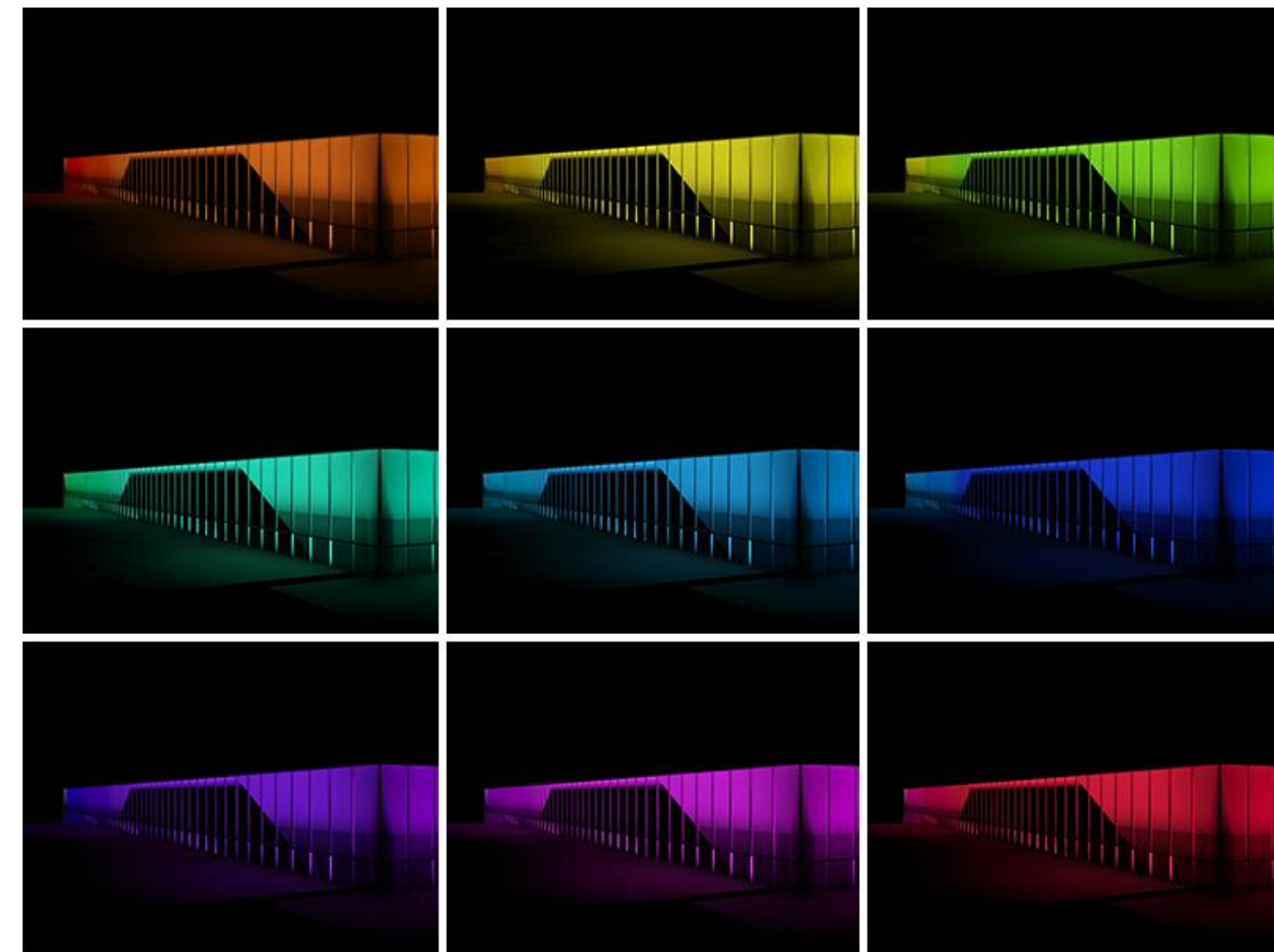
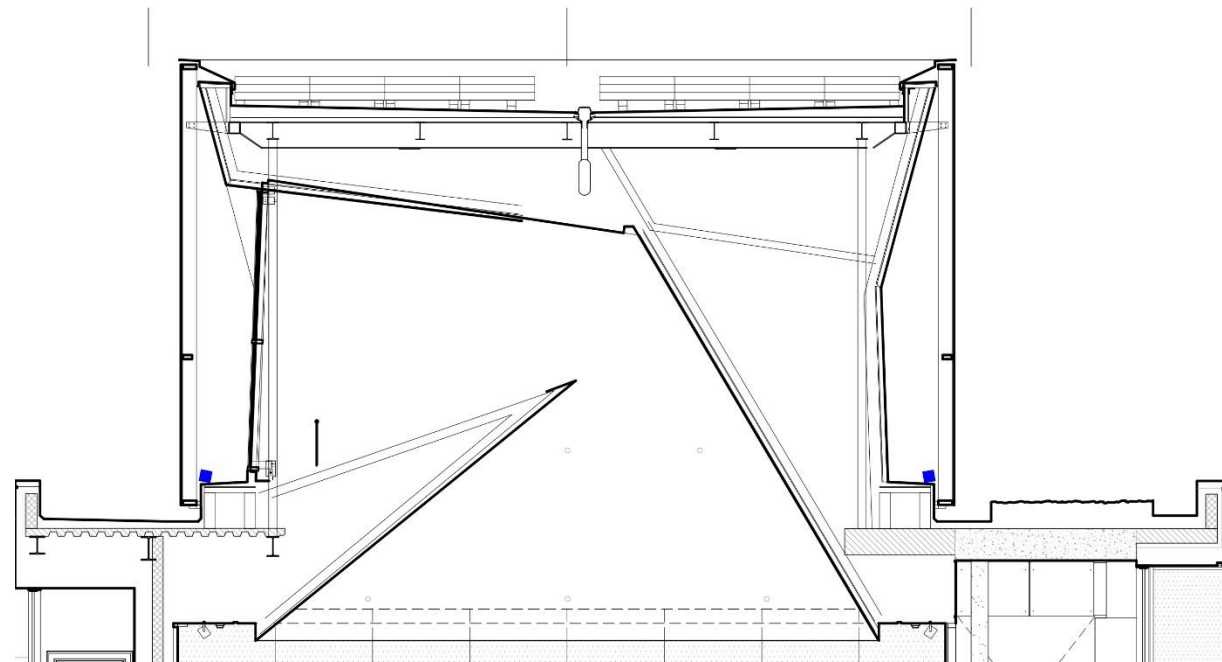
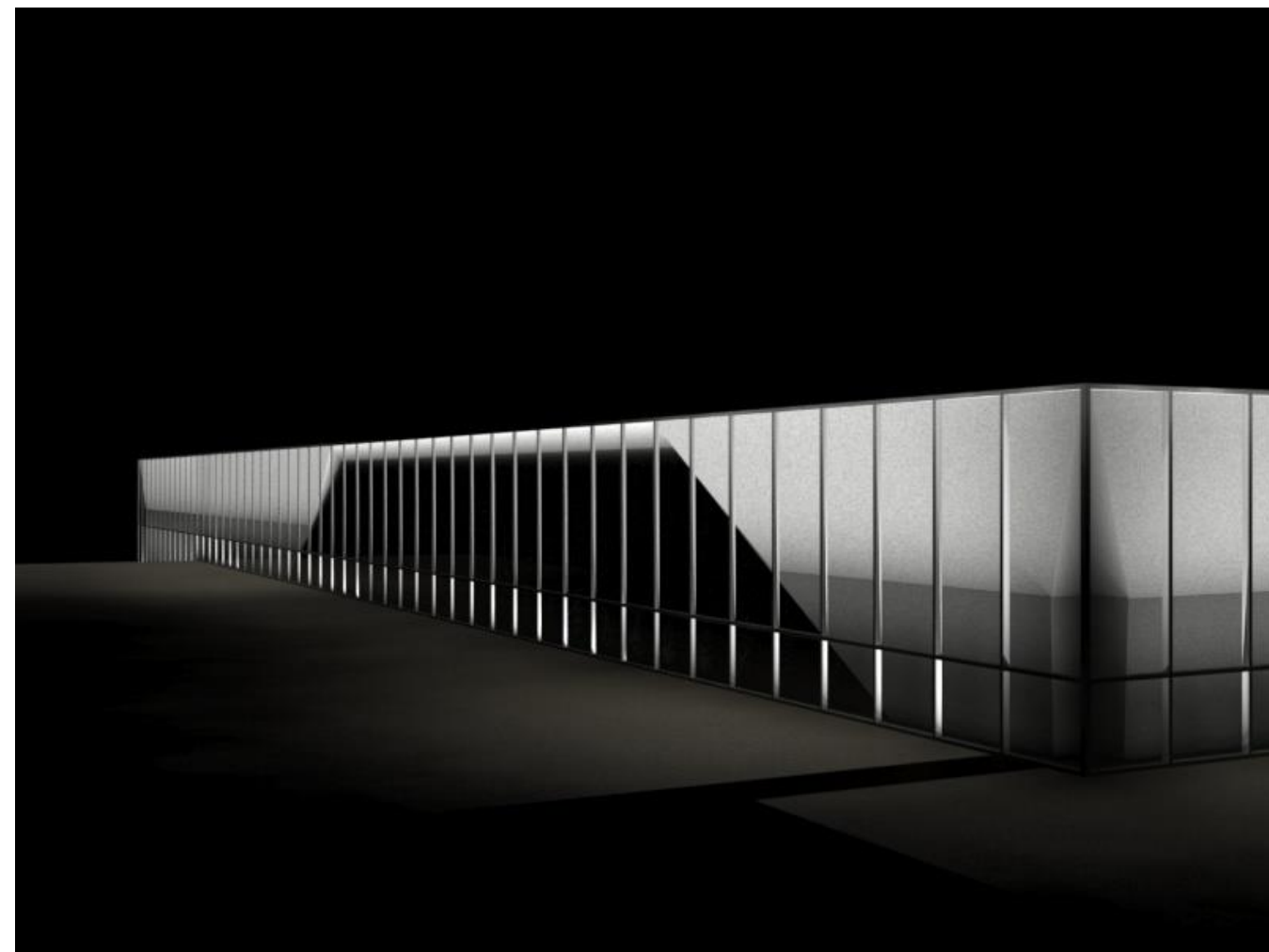


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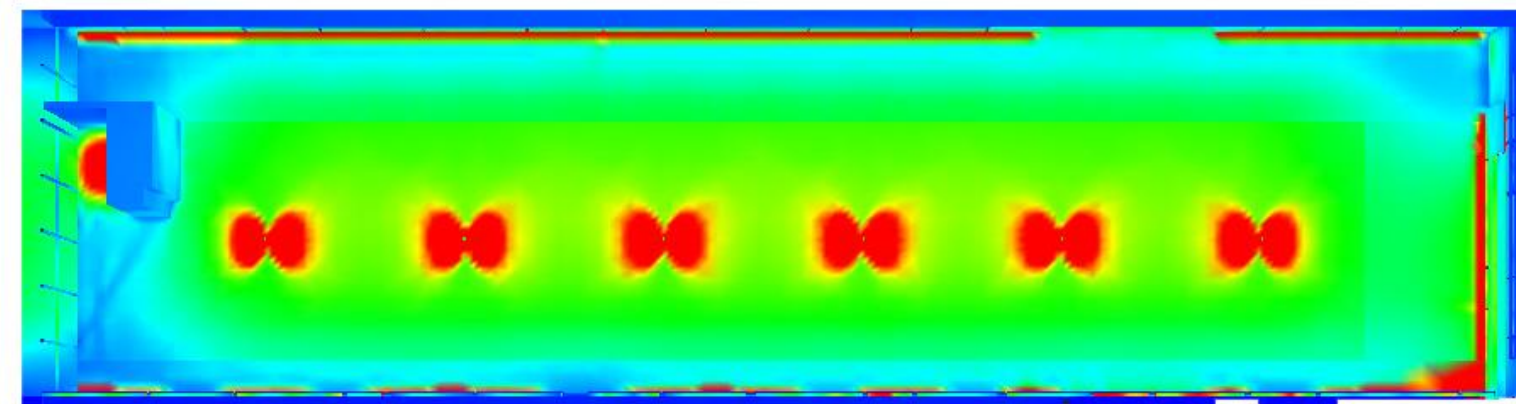
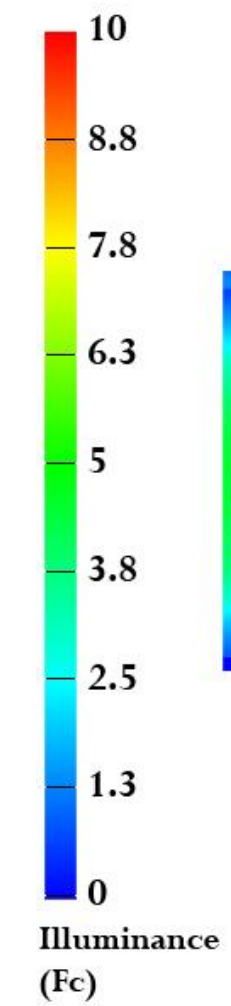
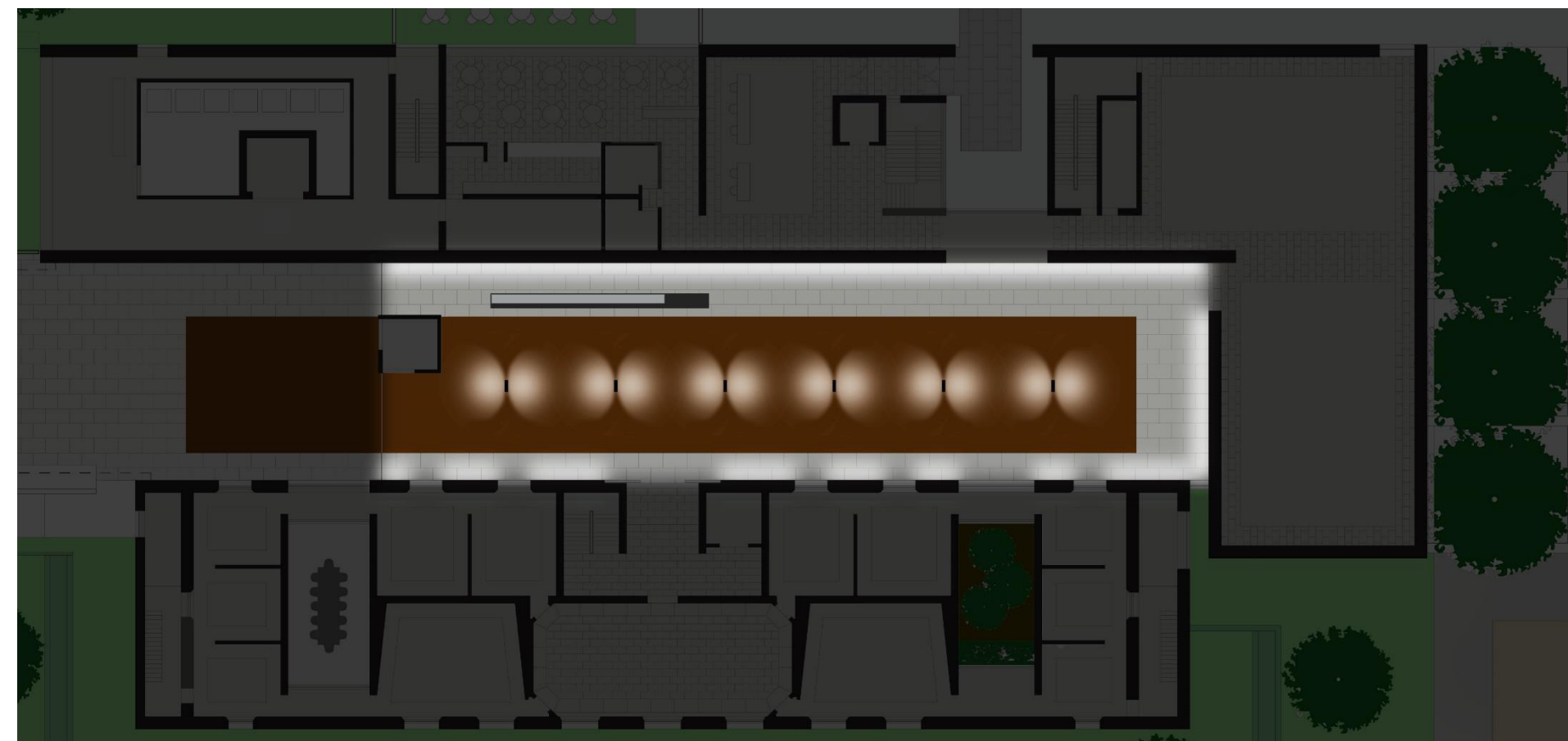
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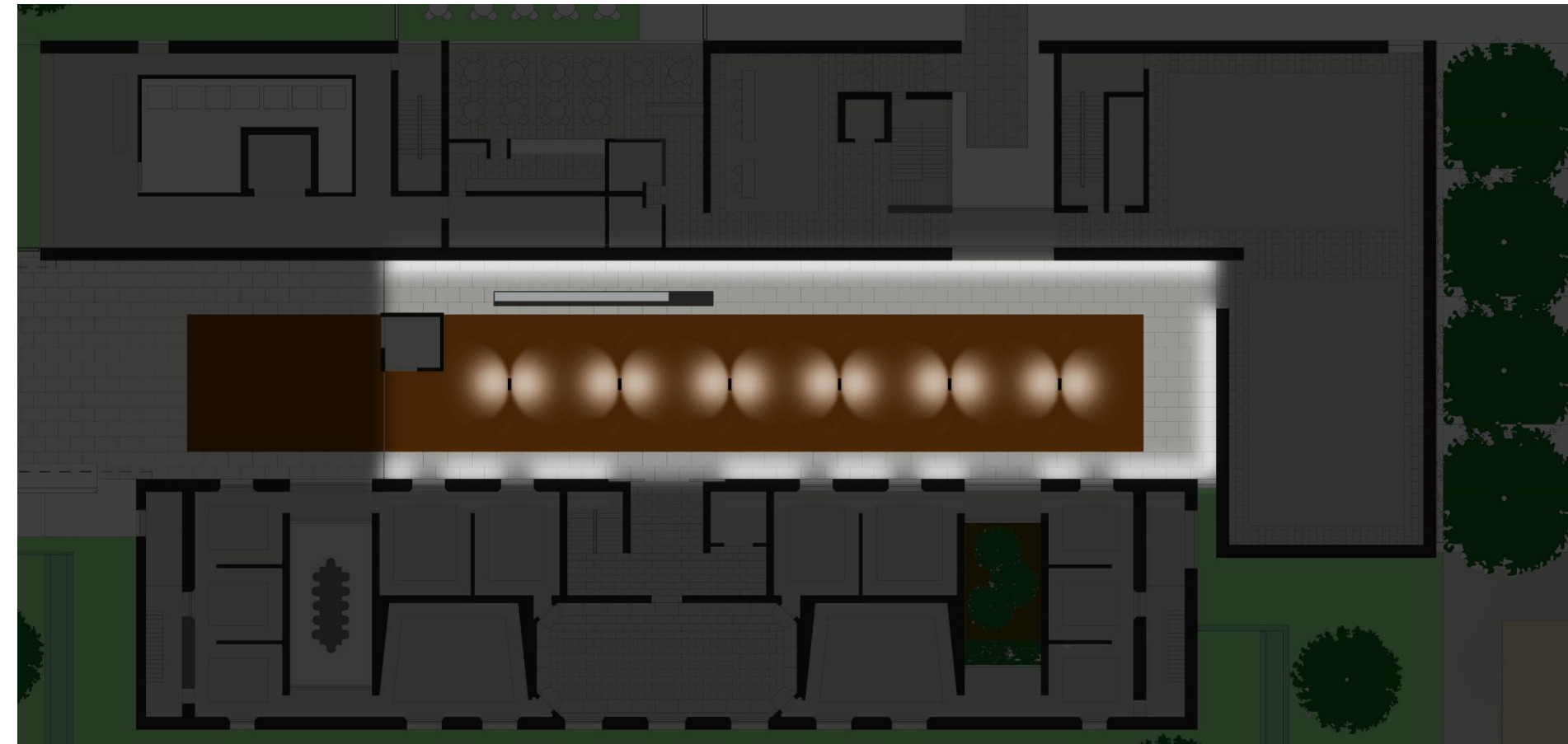
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Type	Description	MFR.
FA	 Base mounted LED flood light with 36° frosted lens at 4000K. Angled at 45° from vertical.	Phillips
FB	 Shielded LED bollard at 3000K.	Bega
FC	 Fully recessed two-circuit lighting track with flush trim.	Edison Price
FD	 Track mounted adjustable LED accent light at 3500K. Nominally 5.75" diameter with matte black cross-baffle.	Edison Price
FE	 Linear LED strip light at 3500K.	LED Linear
FF	 Linear LED wallwasher at 3500K. Aimed at a 45° angle with clear cover.	LED Linear
FJ	 Recessed LED downlight with nominally 4" aperture at 3500K, 20° spread reflector.	Edison Price

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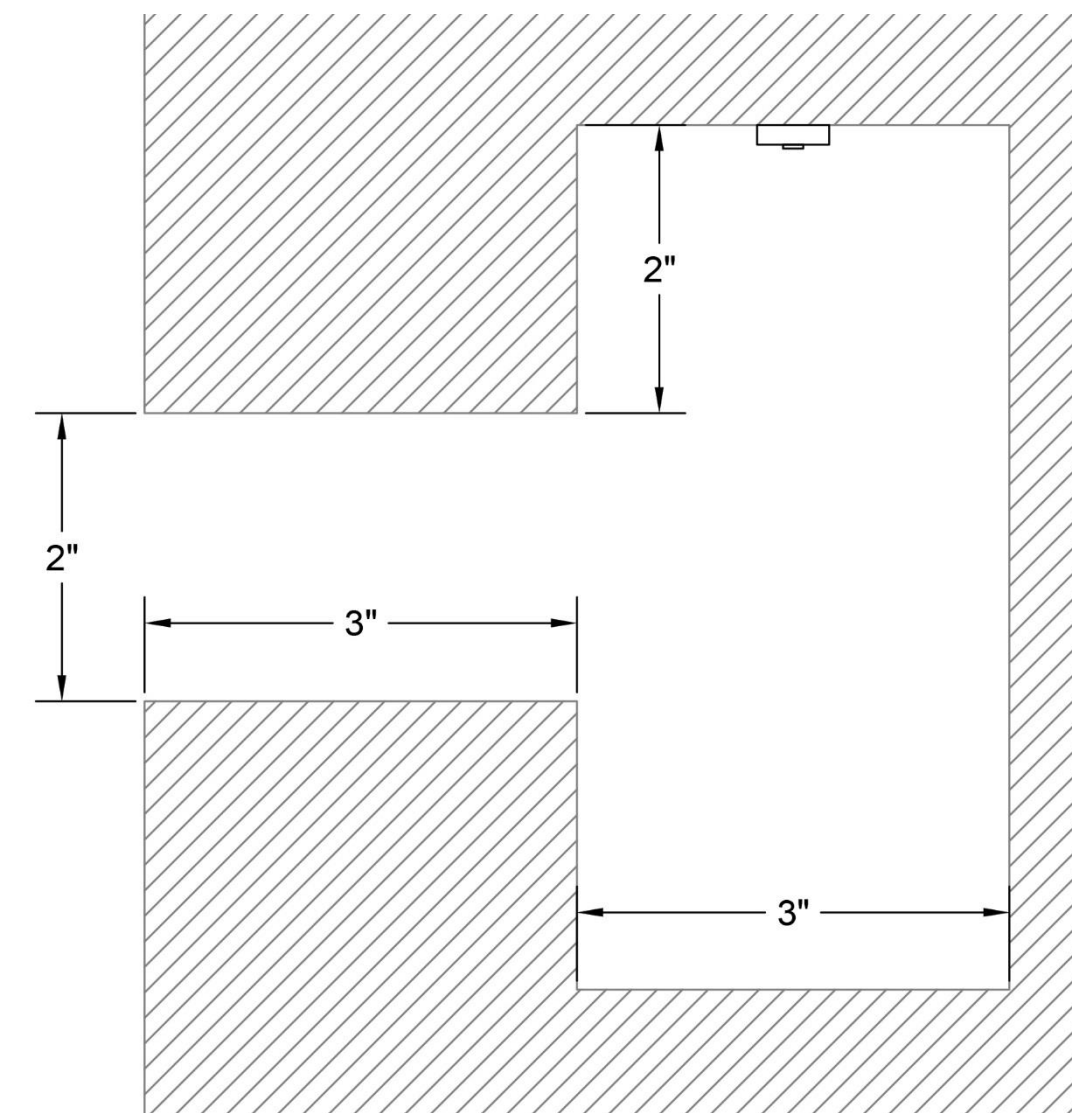
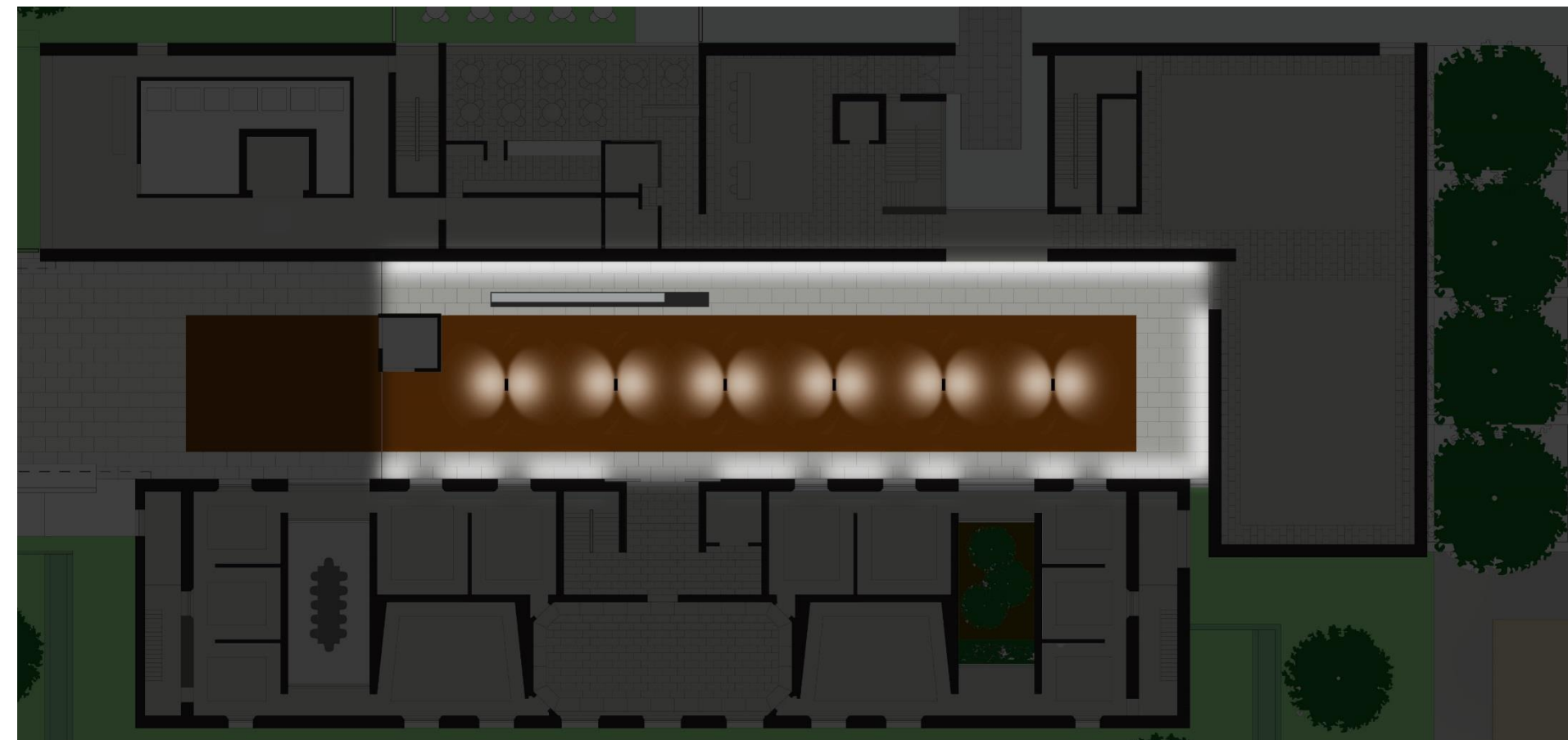
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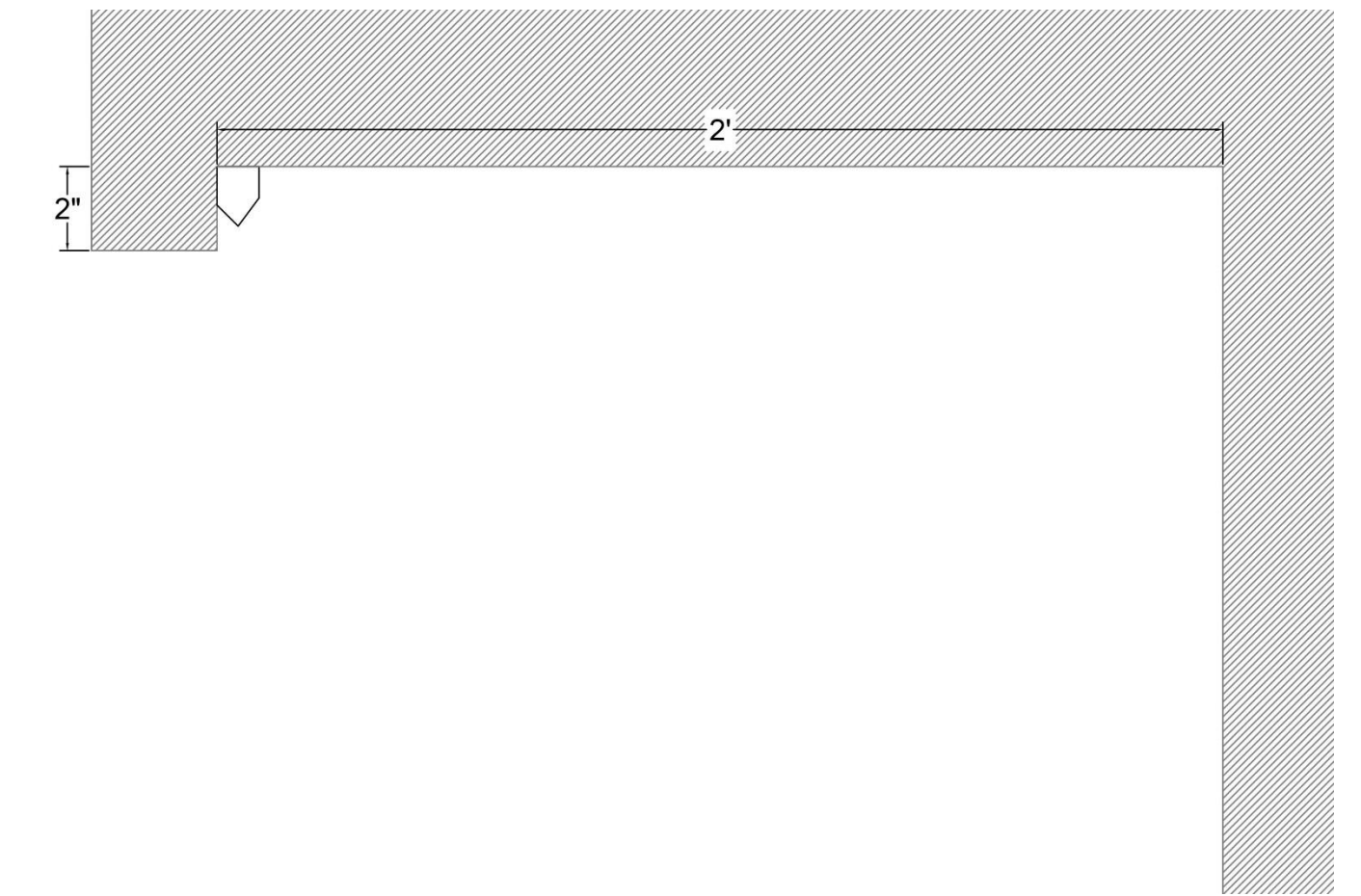


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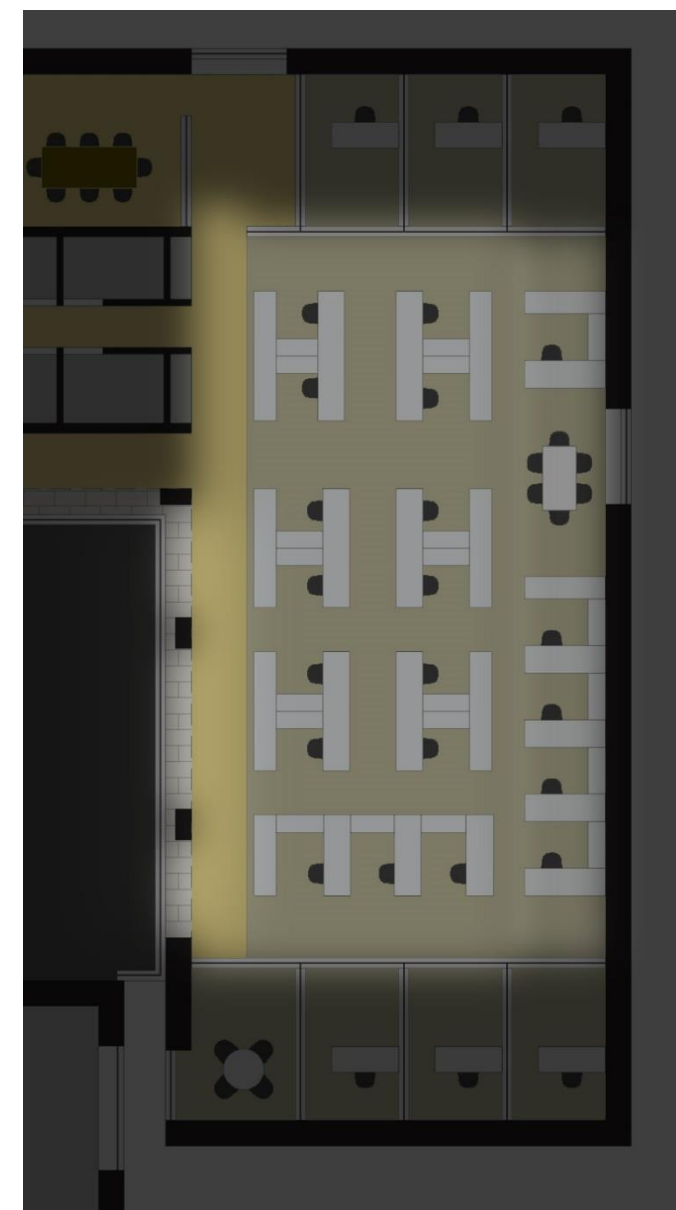
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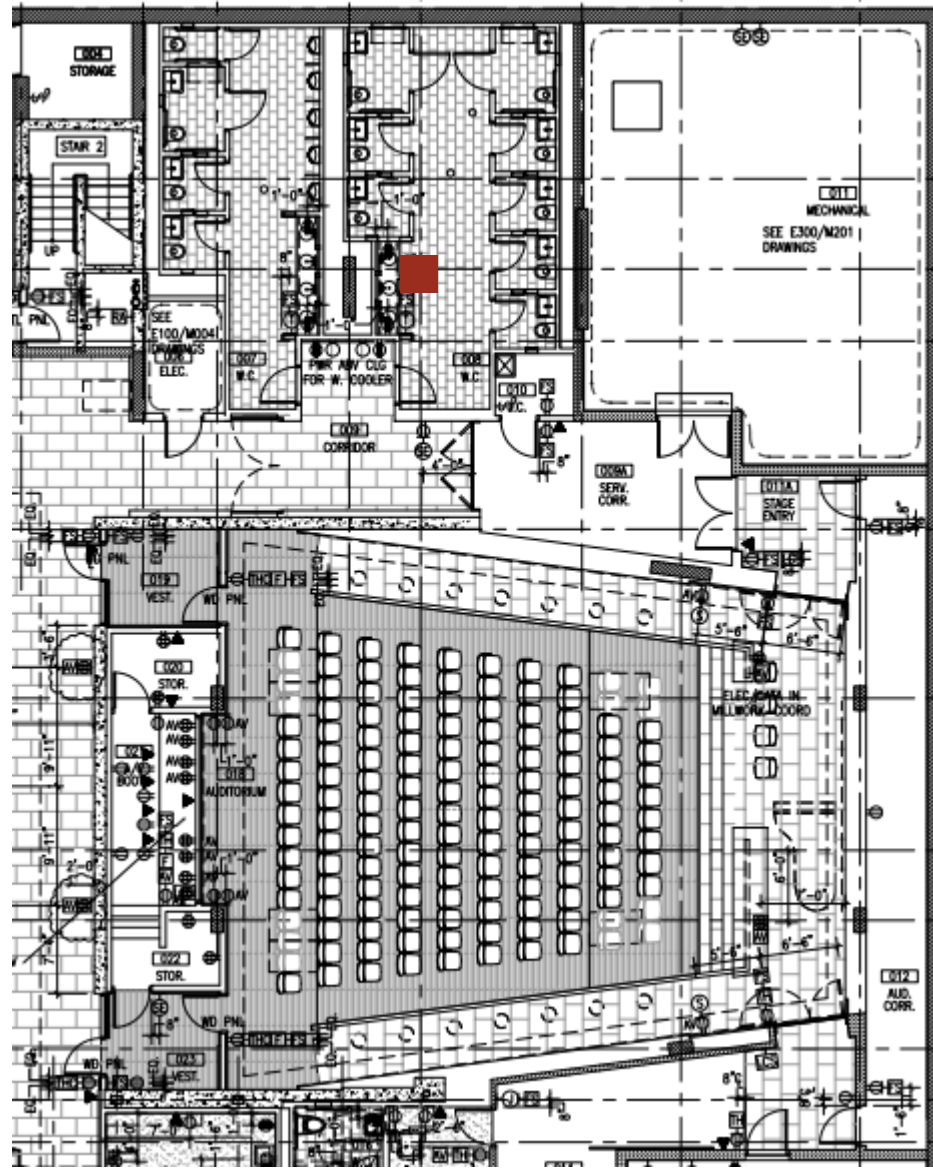
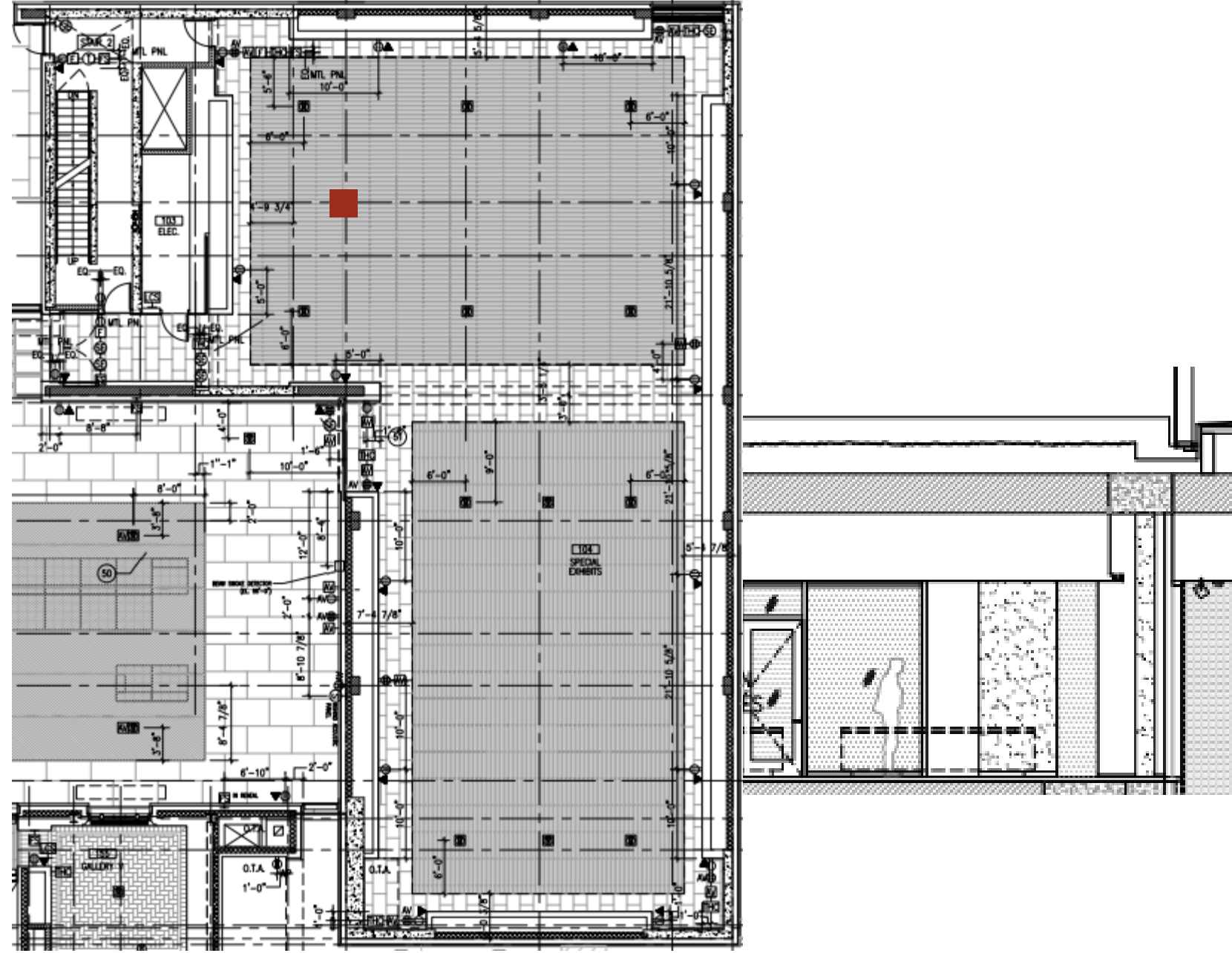
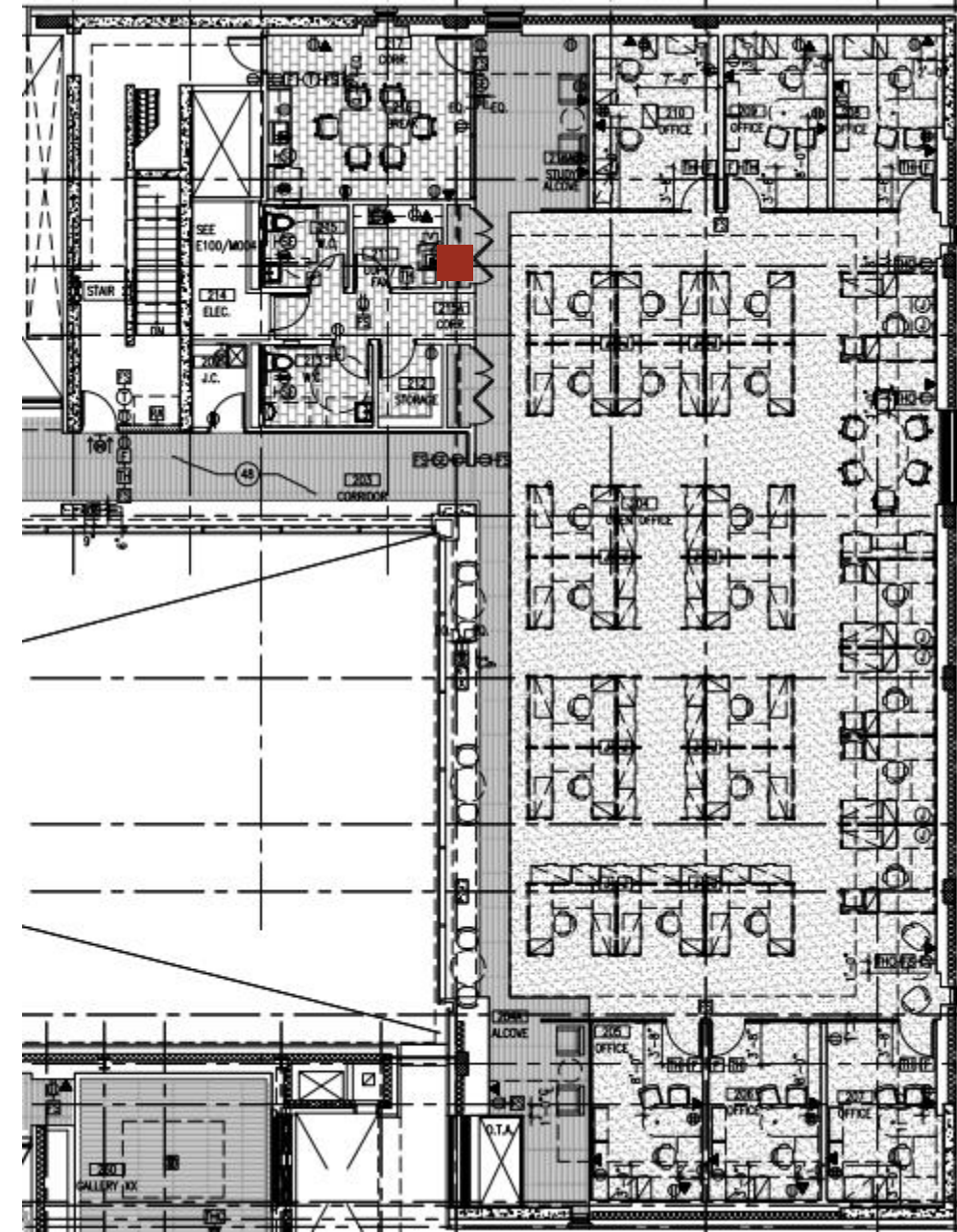
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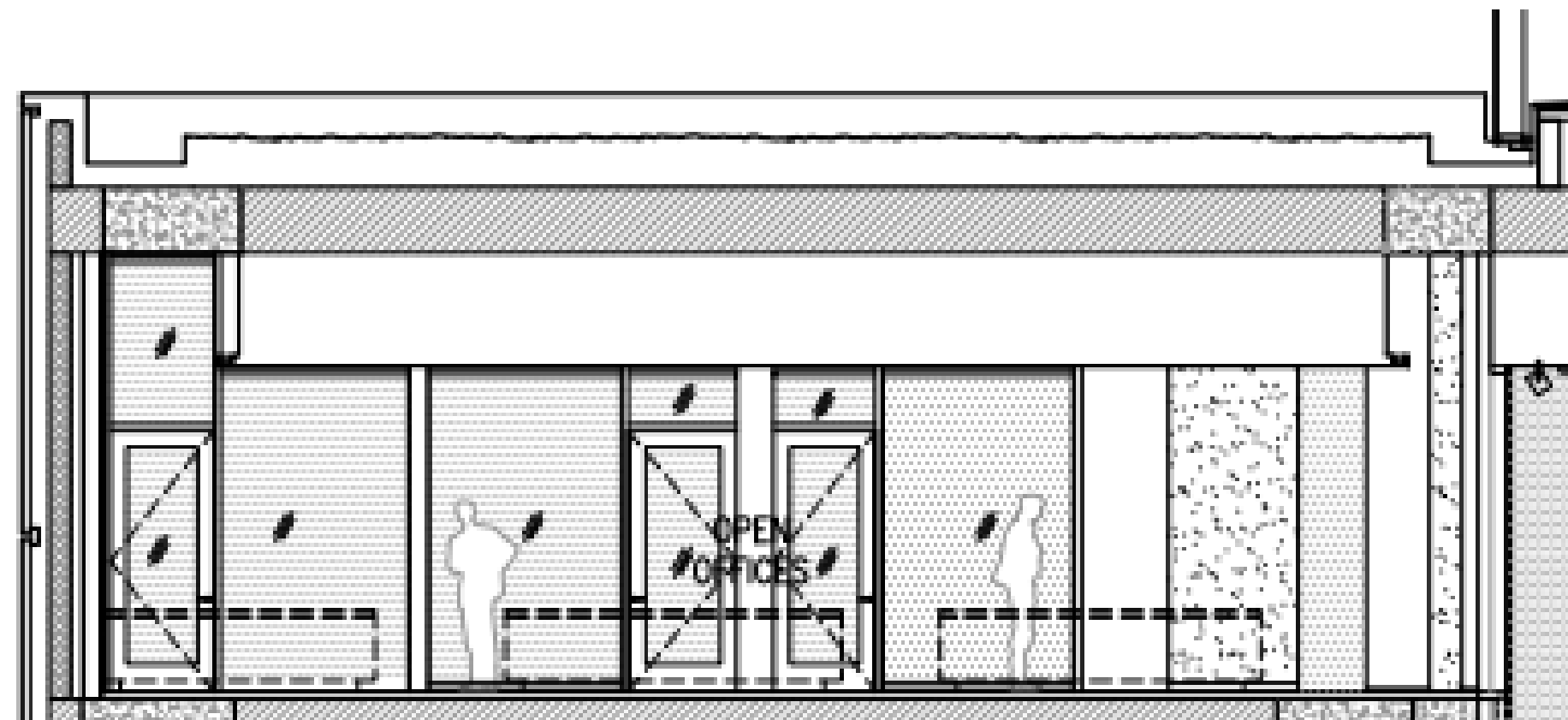
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Control Algorithm Settings (Values are for Critical Point)

Calibrate Sensor - Closed Loop Proportional (Values are for Critical Point)

Condition	Parameter	Value
Night Condition	Illuminance (Elec)	594.6
	Target	300.0
	Signal @ Target	200.5
Daylight Condition	Daylight Illum.	347.0
	Daylight Signal	337.0
	Non-Dimmed	19.0
	Target	300.0
	Dimming Level	-0.114
	Signal	316.6

Off Condition

Month/Day/Time: 6/25 11:00AM

Sky: Weather Tape

Reset Daylight Condition

Dimming Level (-0.114) below minimum or above maximum.

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Module Characteristics at Reference Conditions
Reference conditions: Total Irradiance = 1000 W/m², Cell temp = 25 C

SunPower SPR-225E-BLK-D

Nominal efficiency	18.0941 %	Temperature Coefficients	
Maximum power (Pmp)	225.090 Wdc		-0.367 %/°C -0.826 W/°C
Max power voltage (Vmp)	41.0 Vdc		
Max power current (Imp)	5.5 Adc		
Open circuit voltage (Voc)	48.5 Vdc	-0.280 %/°C	-0.136 V/°C
Short circuit current (Isc)	5.9 Adc	0.043 %/°C	0.003 A/°C

Temperature Correction

Nominal operating cell temperature (NOCT) method
 Heat transfer method

Refer to Help for more information about CEC cell temperature models.

NOCT method parameters:
Mounting standoff: Ground or rack mounted
Array height: One story building height or lower

Heat transfer method parameters:
Mounting configuration: Rack
Heat transfer dimensions: Module Dimensions
Mounting structure orientation: Structures do not impede flow underneath module
Module width: 1 m
Module length: 1.24 m
Rows of modules in array: 1
Columns of modules in array: 10
Temperature behind the module: 20 °C
Space between module back and roof surface: 0.05 m

Physical Characteristics

Material	Mono-c-Si	Module area	1.244 m ²	Number of cells	72
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Additional Parameters

T _{noct}	49.2 °C	I _{L_ref}	5.875 A	R _s	0.307 Ohm
A _{ref}	1.8705 V	I _{o_ref}	3.14e-011 A	R _{sh_ref}	328.34 Ohm

AC-DC RATIO | 1.0

Efficiency Curve and Characteristics
Satcon Technology Corporation: PVS-100 (480V) 480V [CEC 2008]

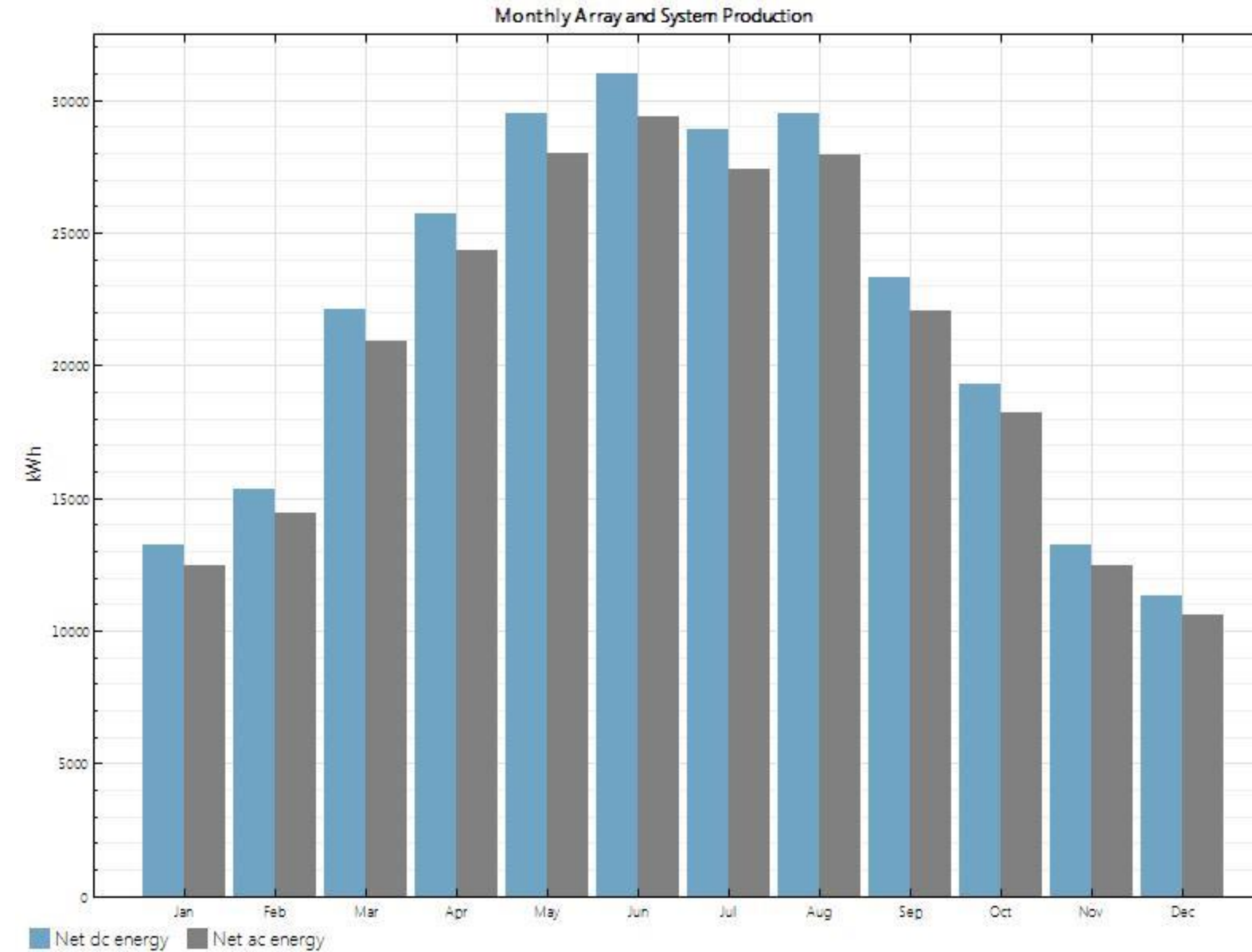
CEC weighted efficiency	96.244 %		
European weighted efficiency	95.931 %		
Maximum AC power	100,000.000 Wac	C0	-0.000 1/Wac
Maximum DC power	104,208.070 Wdc	C1	0.000 1/Vdc
Power consumption during operation	499.470 Wdc	C2	0.000 1/Vdc
Power consumption at night	66.130 Wac	C3	0.000 1/Vdc
Nominal AC voltage	480 Vac		
Maximum DC voltage	600.0 Vdc		
Maximum DC current	331.0 Adc		
Minimum MPPT DC voltage	315.0 Vdc		
Nominal DC voltage	362.8 Vdc		
Maximum MPPT DC voltage	600.0 Vdc		

APPENDIX

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THE BARNES FOUNDATION

Metric	Value
Annual energy	217,095 kWh
Capacity factor	14.10%
First year kWhAC/kWDC	1,235 kWh/kW
Performance ratio	0.84
Levelized cost (nominal)	7.56 ¢/kWh
Levelized cost (real)	5.46 ¢/kWh
Electricity cost without system	\$639,220
Electricity cost with system	\$622,874
Net savings with system	\$16,345
Net present value	\$-18,227
Payback period	35.6 years
Initial cost	\$447,925
Initial cost less cash incentives	\$447,925
Equity	\$0
Debt	\$447,925



Metric	Value
Annual energy	248,065 kWh
Capacity factor	14.10%
First year kWhAC/kWDC	1,237 kWh/kW
Performance ratio	0.84
Levelized cost (nominal)	7.55 ¢/kWh
Levelized cost (real)	5.45 ¢/kWh
Electricity cost without system	\$639,220
Electricity cost with system	\$620,597
Net savings with system	\$18,623
Net present value	\$-21,098
Payback period	35.7 years
Initial cost	\$511,013
Initial cost less cash incentives	\$511,013
Equity	\$0
Debt	\$511,013

APPENDIX

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