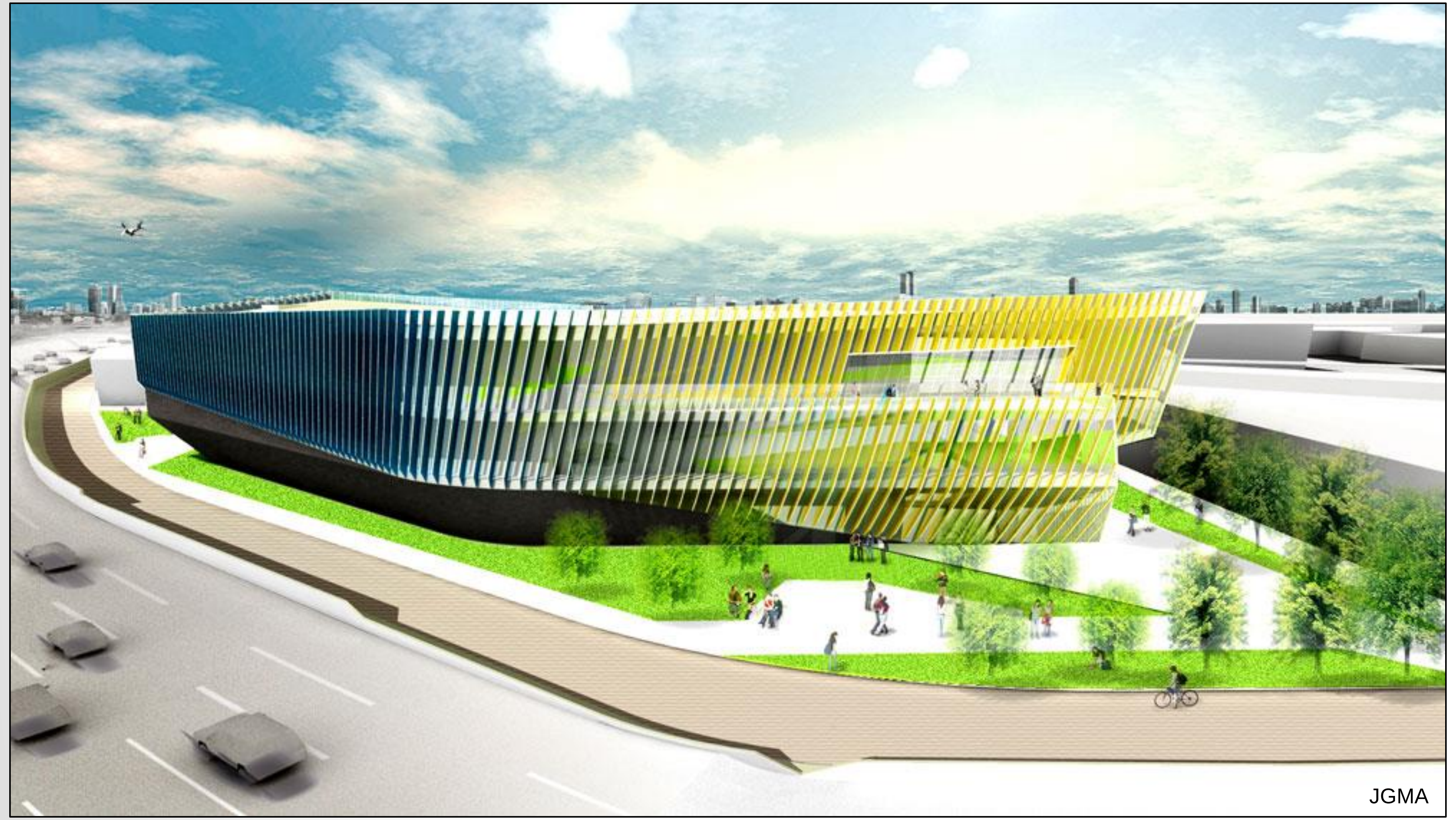
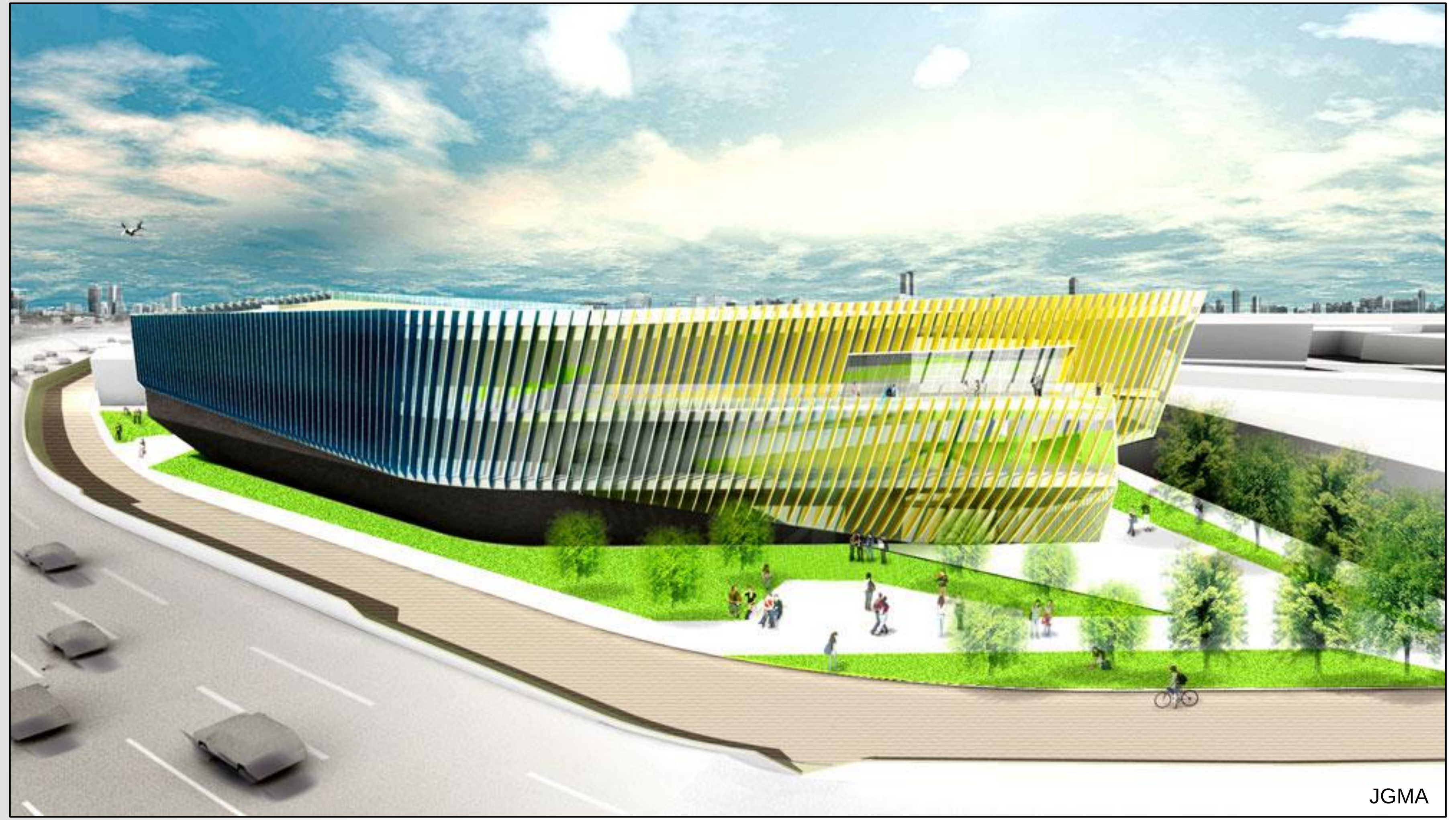


Northeastern Illinois University's El Centro Building

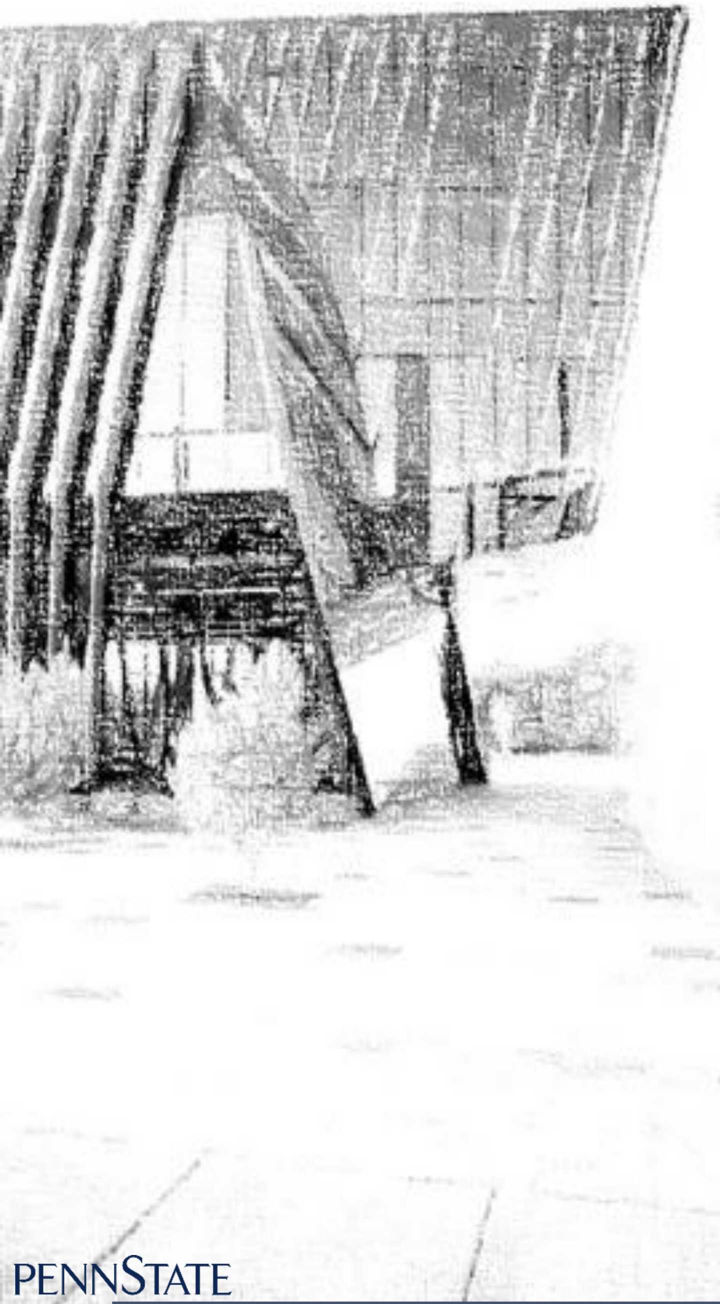
Chicago, Illinois

Michael Gramarossa, BAE/MAE
Mechanical Option

Advisor: Dr. James Freihaut



- Building Summary
- Thesis Objective
- Mechanical Depth
- Structural Breadth
- Electrical Breadth
- Evaluation and Conclusion



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    - Cooling and Ventilation
    - Heating
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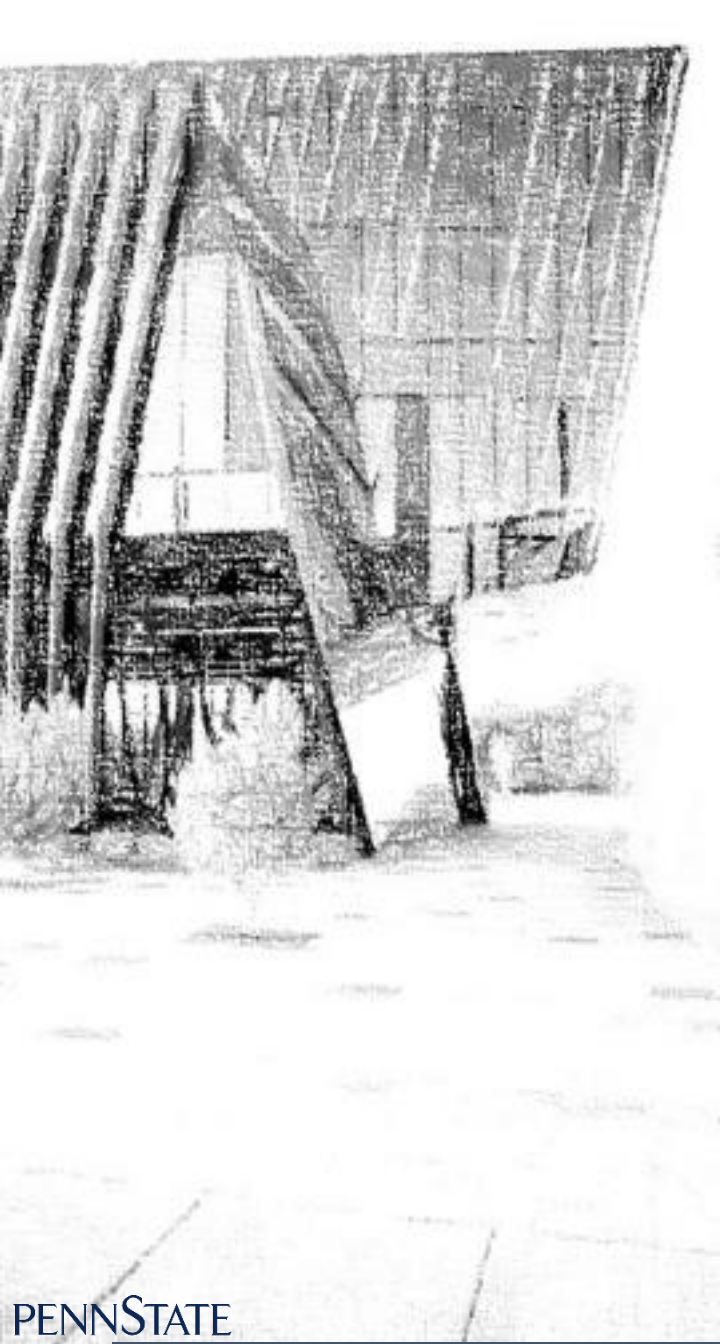
- Electrical Breadth
- Evaluation & Conclusion

Site and Location

- Chicago Illinois
  - Summer: 91.9°F (0.4%)
  - Winter -4.0°F (99.6%)



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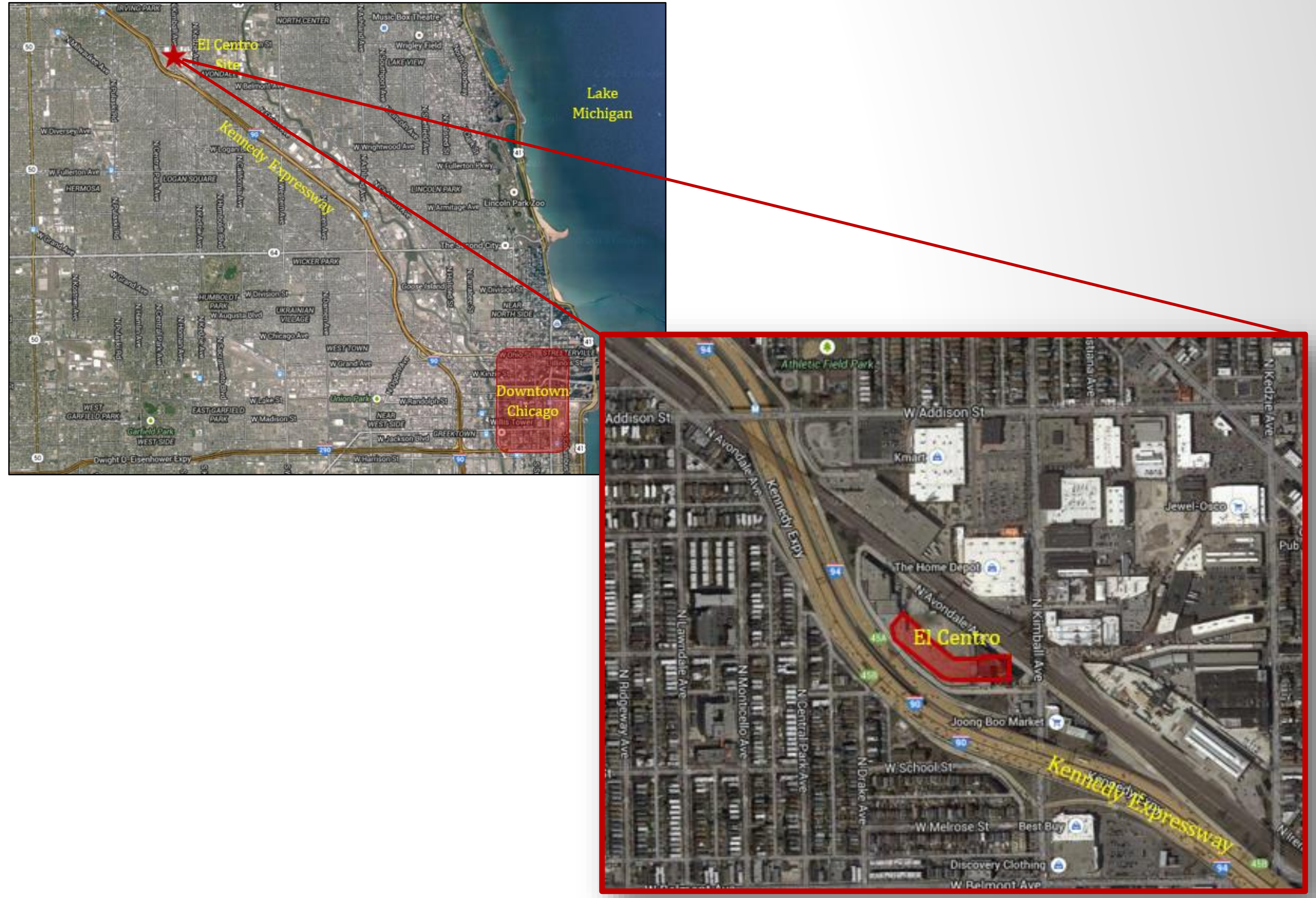

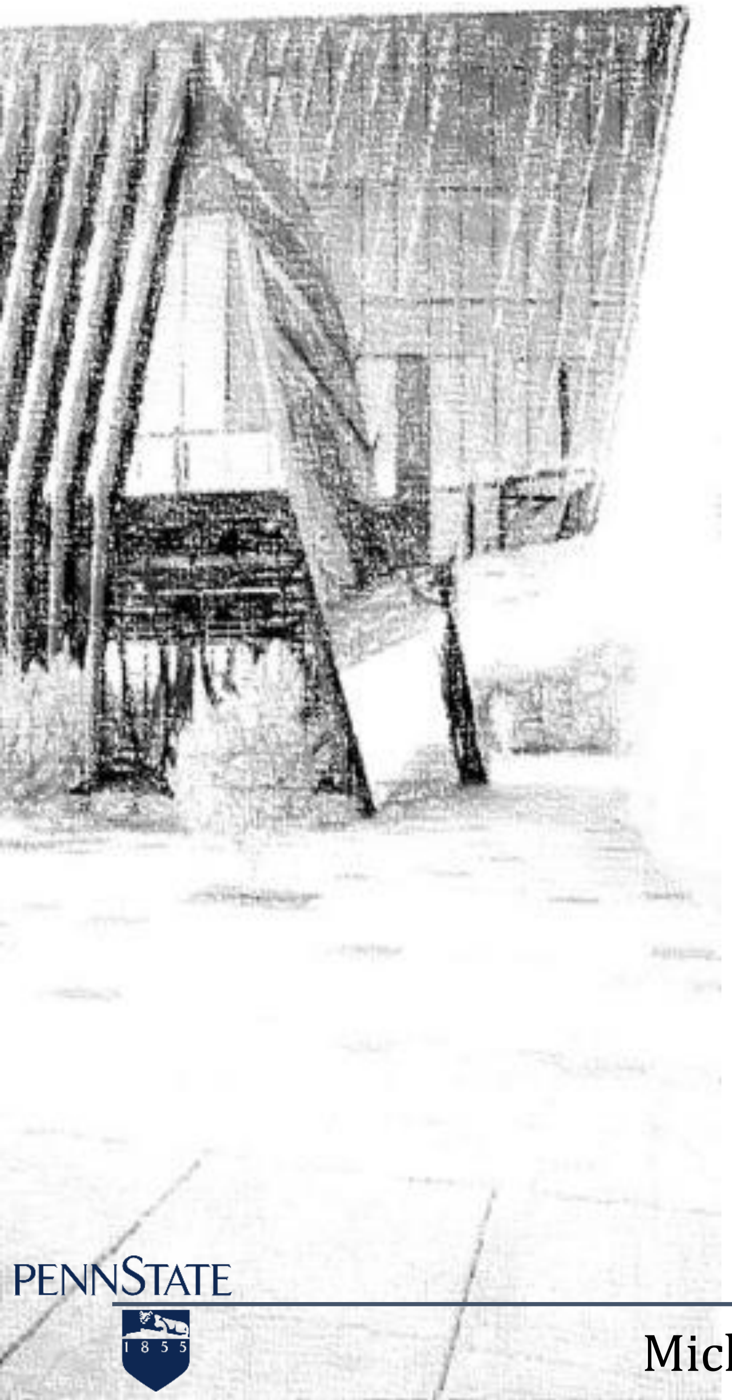

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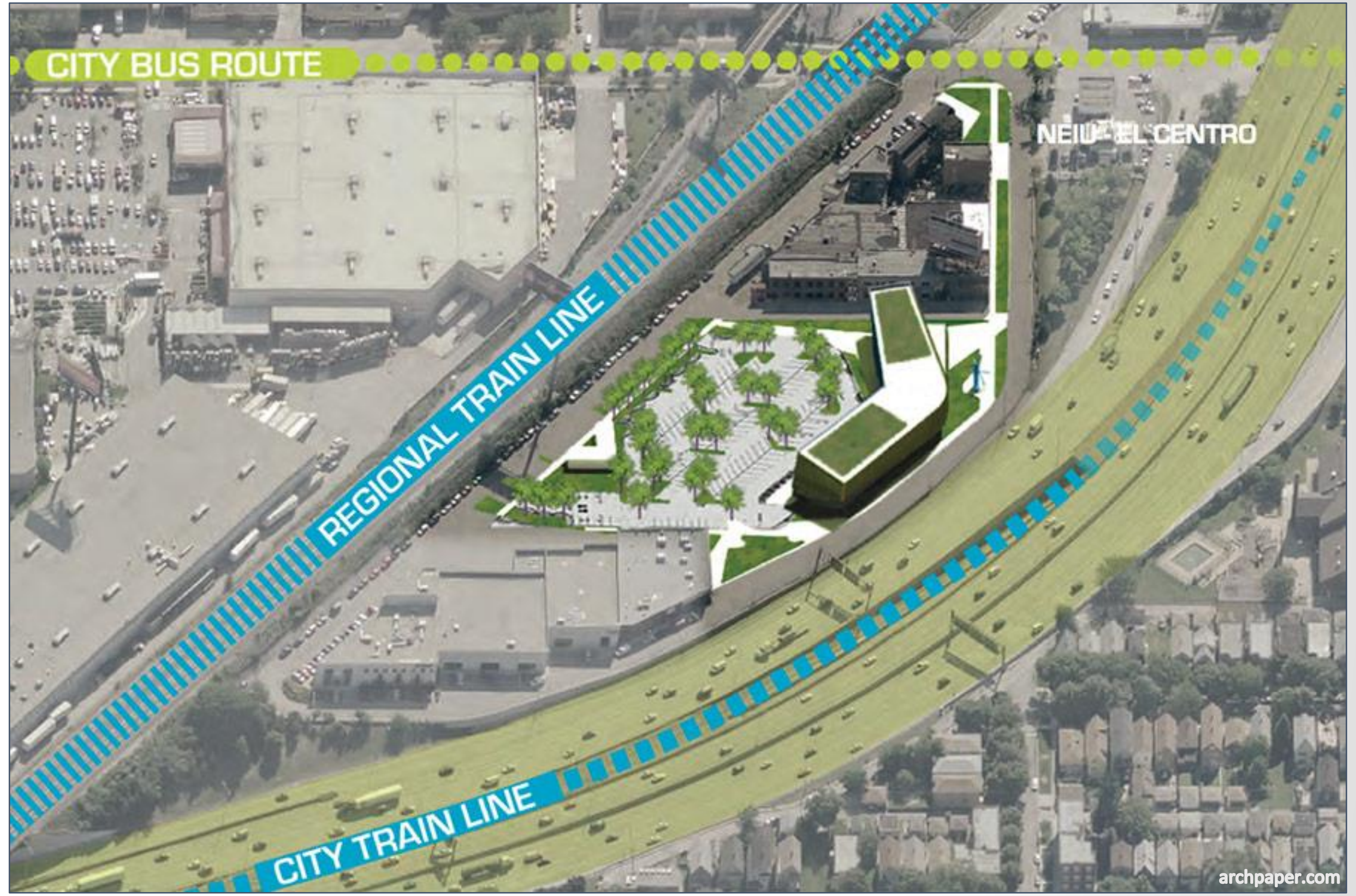
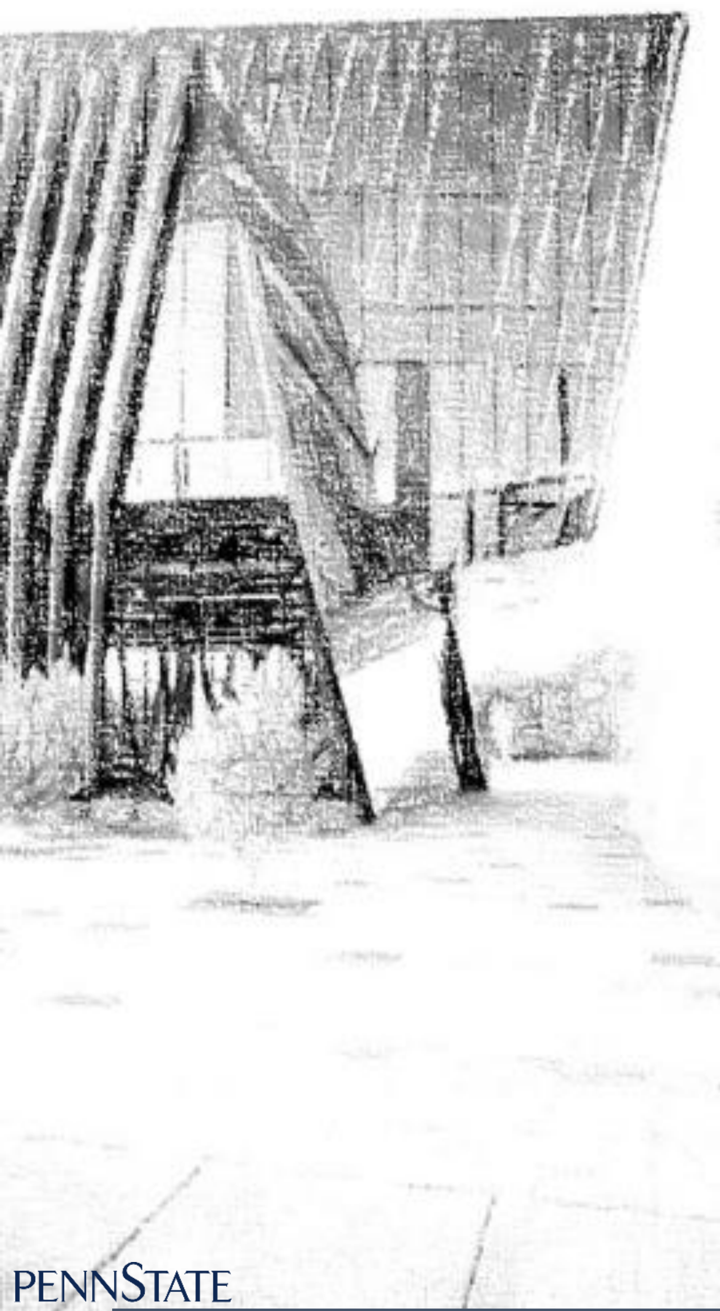
Site and Location

- Chicago Illinois
  - Summer: 91.9°F (0.4%)
  - Winter -4.0°F (99.6%)
- Located along Kennedy Expressway
- Passed by 400,000 vehicles each day





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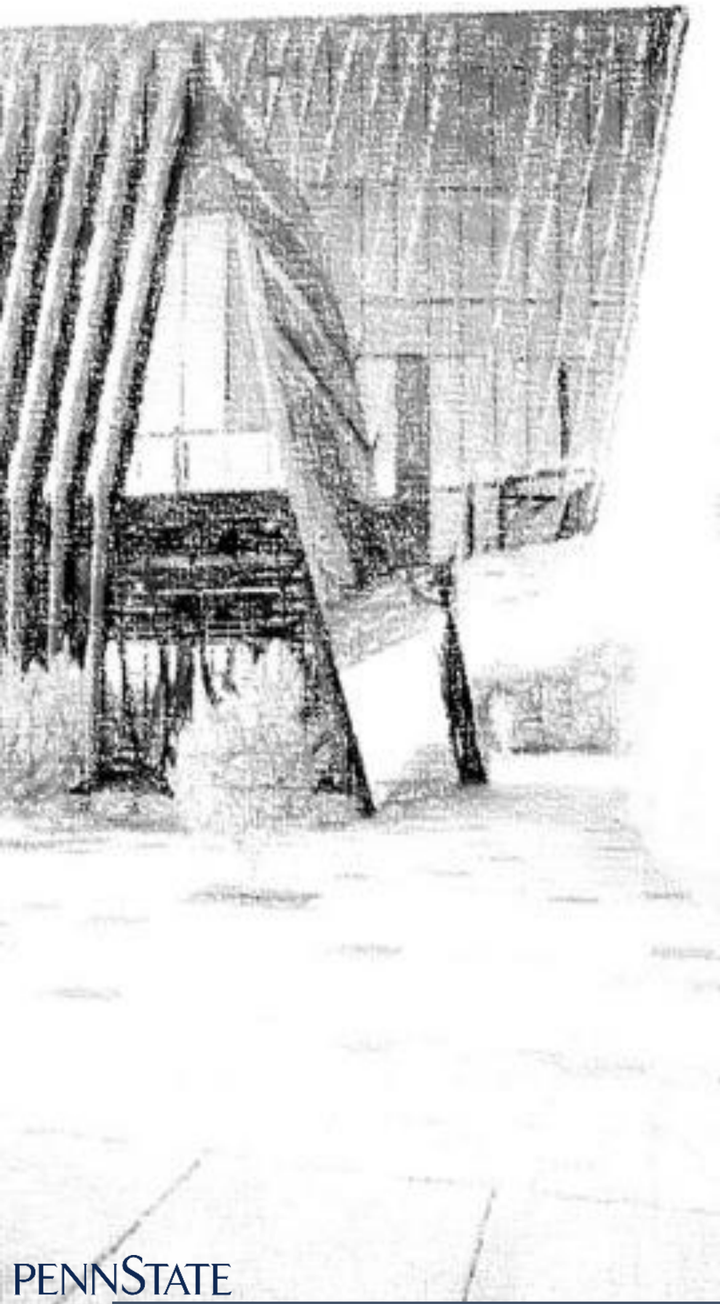
Architecture and Façade

- Recently completed in September 2014
- 3 stories (no basement)
- 55,000 ft^2
- Classrooms, offices, labs, lounges, etc.



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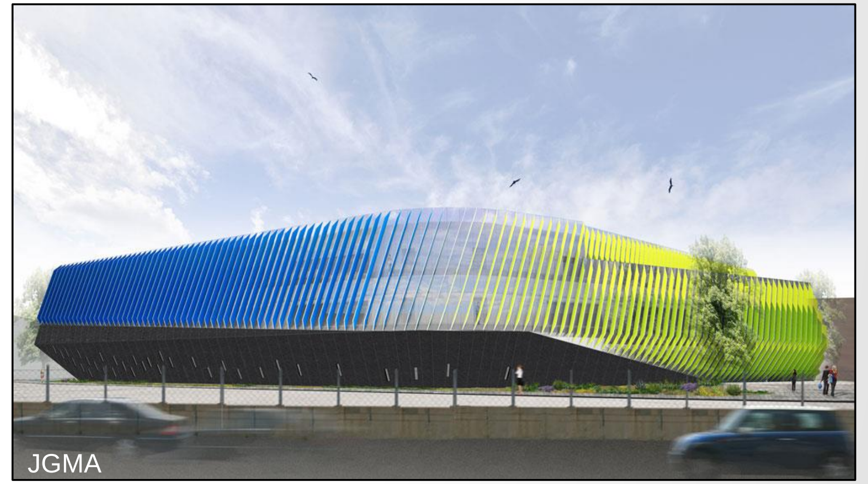
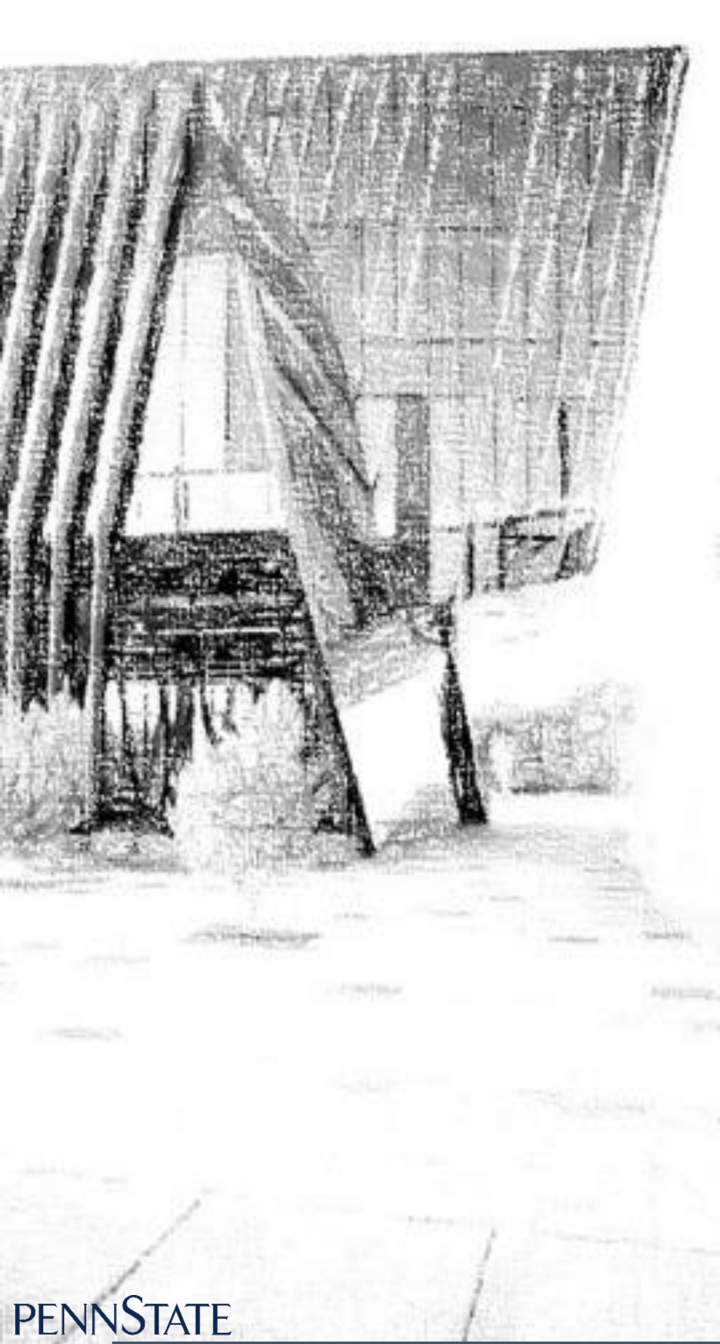
Architecture and Façade

- Recently completed in September 2014
- 3 stories (no basement)
- 55,000 ft^2
- Classrooms, offices, labs, lounges, etc.
- Curtain Wall Façade with solar fins
- Blue and Gold Fins



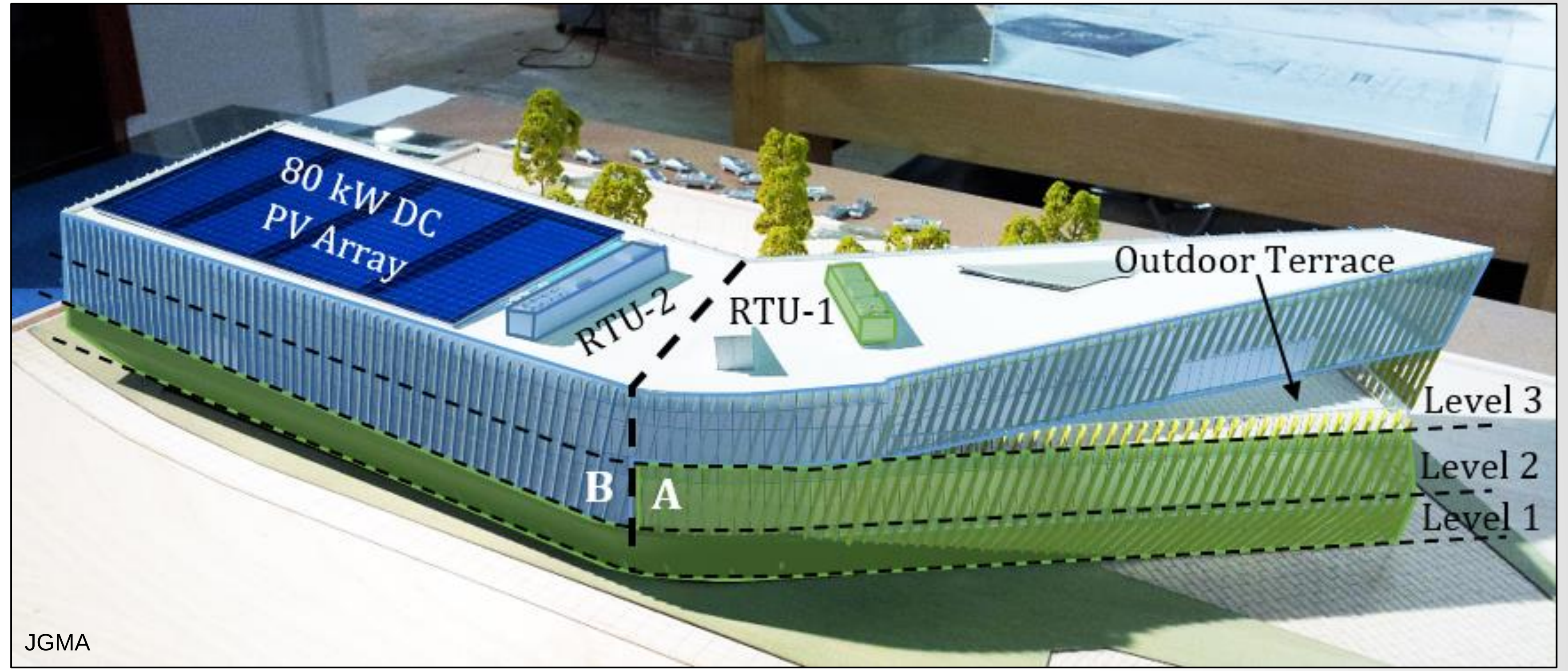
Existing Mechanical System
Cooling and Ventilation

- [2] 100 ton air handling roof top units (RTUs)
- The RTUs supply 55°F air year round

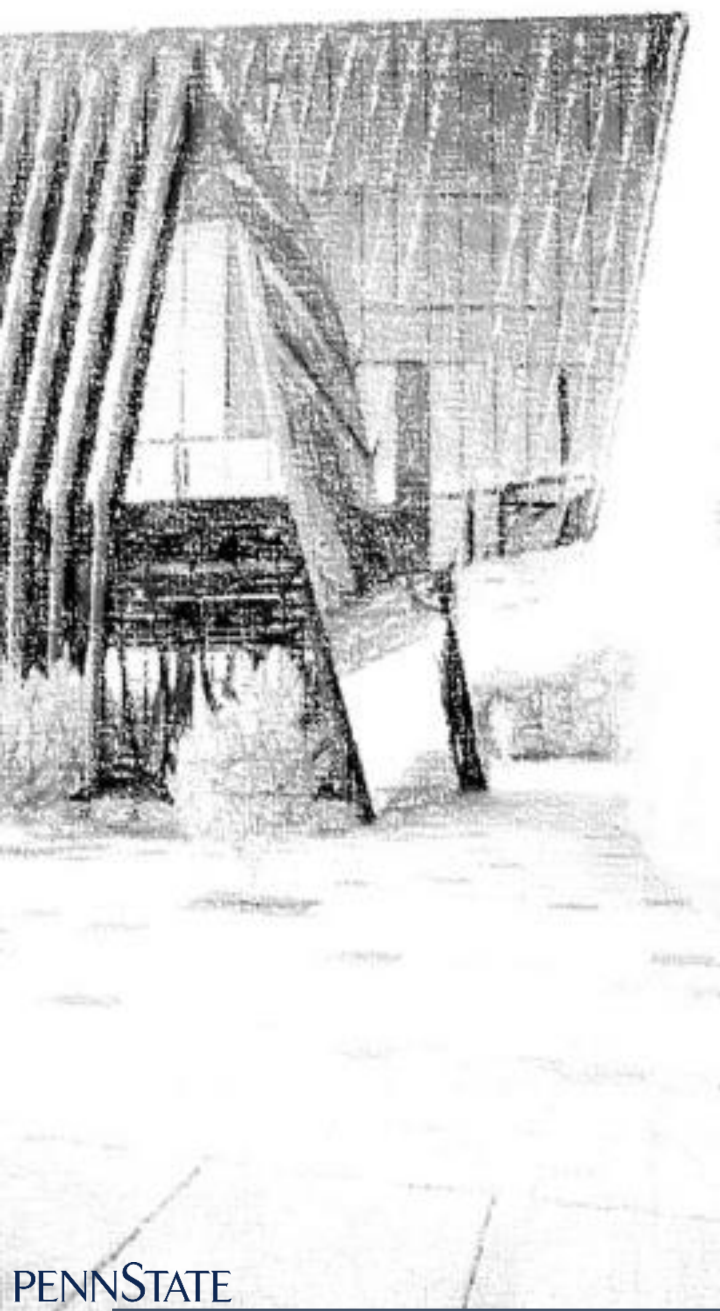


Existing Mechanical System
Cooling and Ventilation

- [2] 100 ton air handling roof top units (RTUs)
- The RTUs supply 55°F air year round
- RTU-1 & RTU-2
- Separate Air Cooled Condensing Units (CU-1 & CU-2)



Unit	Area Served (ft^2)	Supply Capacity (CFM)	Ventilation (CFM)	Cooling (Ton)	Heating (MBh)
RTU-1	24,000	38,000	12,000	100	1250
RTU-2	27,800	38,000	12,000	100	1250



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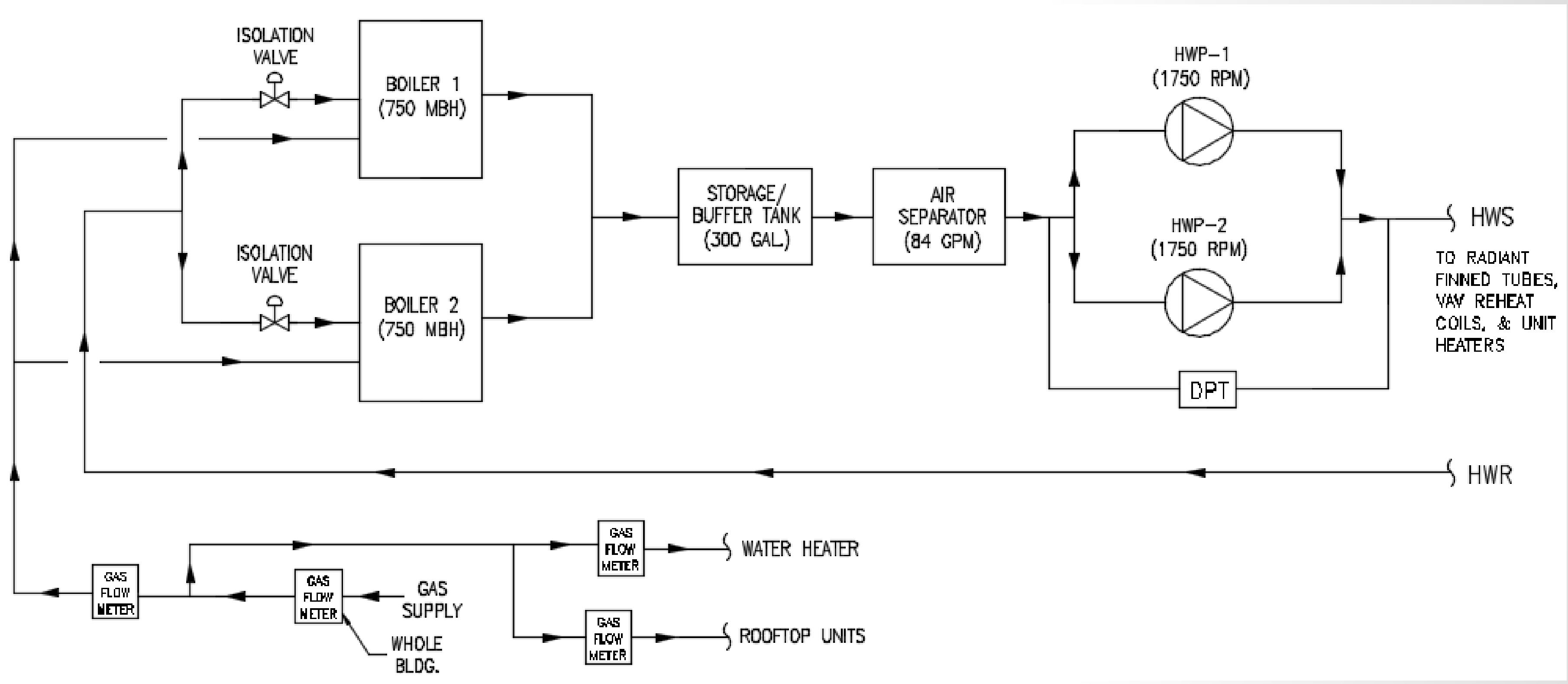
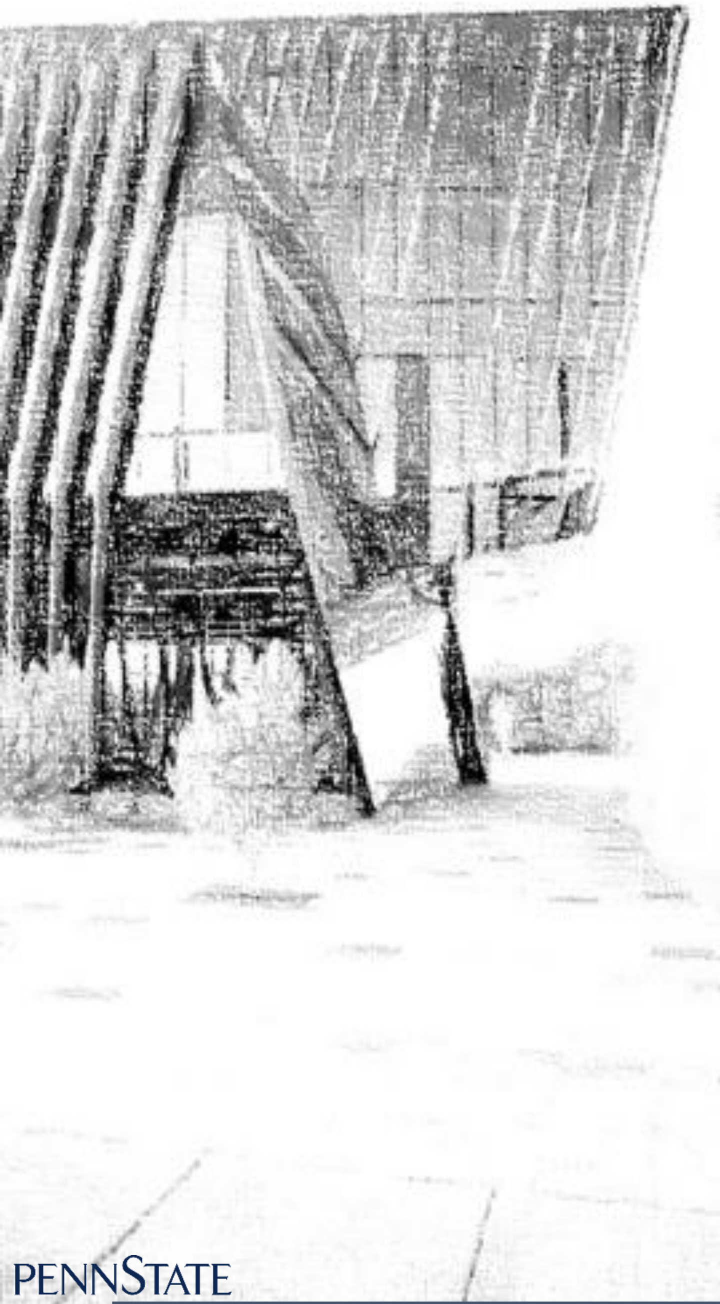
Existing Mechanical System
Heating

- [2] 750 MBh Boilers
- Boilers serve 71 VAV reheat coils and hot water radiant finned tubes



Tag	Fuel Type	Rating (MBH)		Water Temperature (°F)		Flow Rate (GPM)	Min. Thermal Efficiency (%)
		Input	Output	Entering	Leaving		
B-1	NG	750	657	130	150	66	90
B-2	NG	750	657	130	150	66	90



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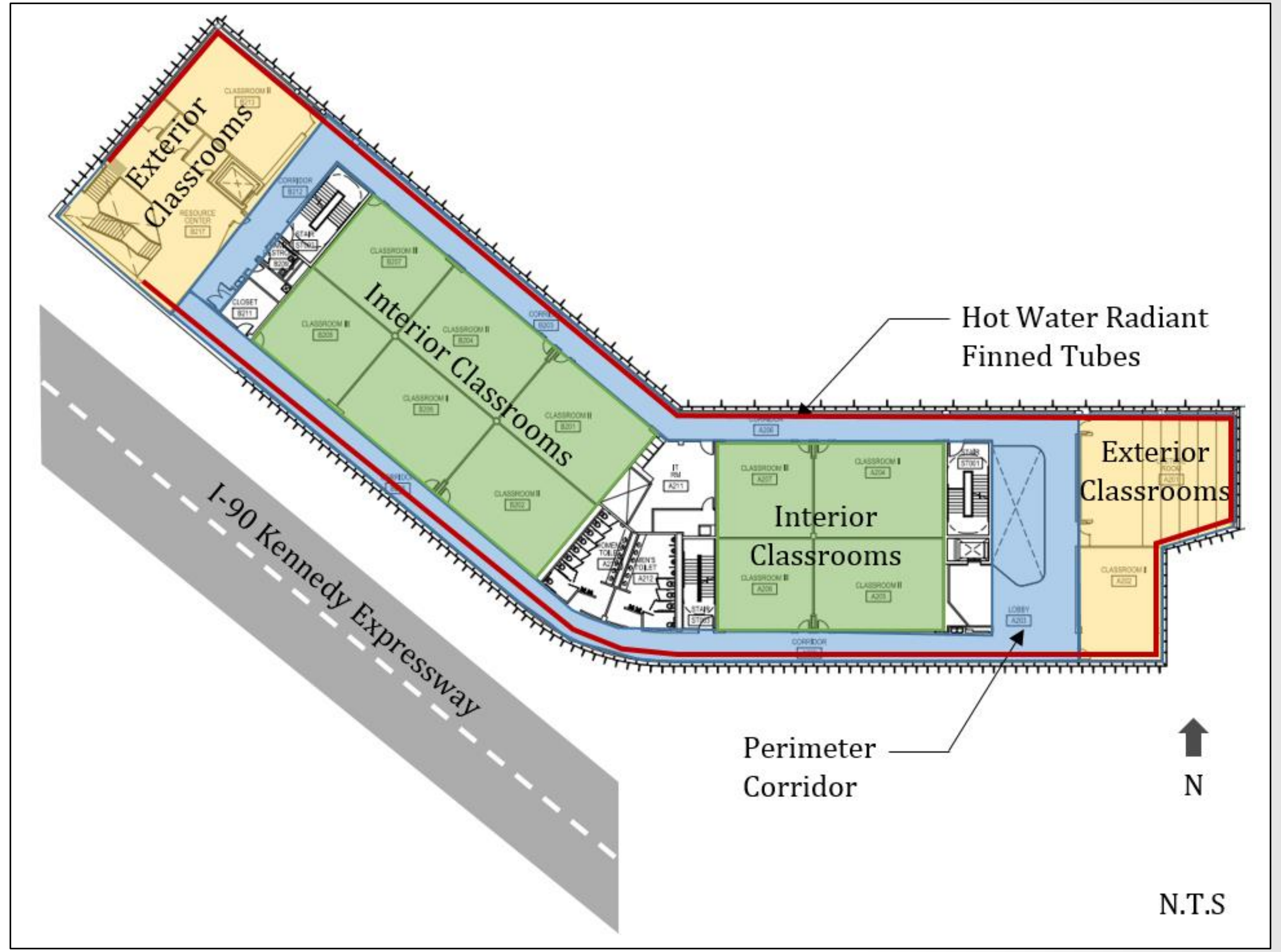
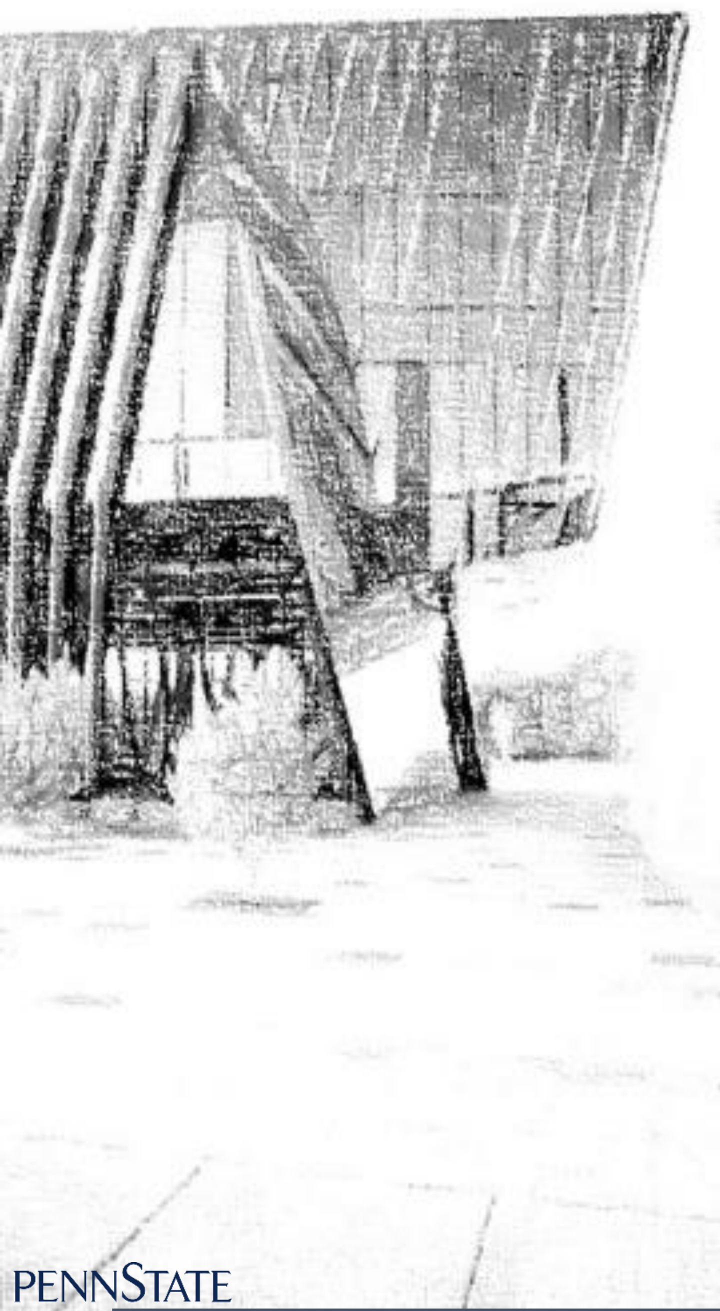


Second Floor Plan Hot Water Schematic



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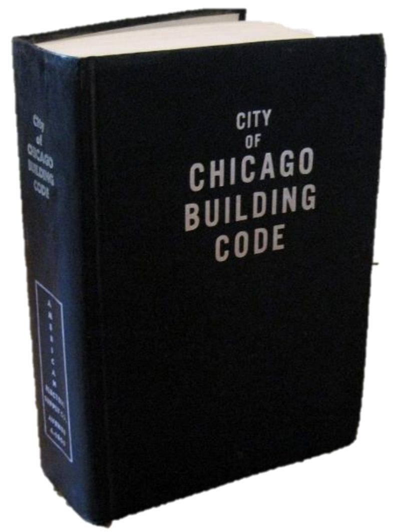
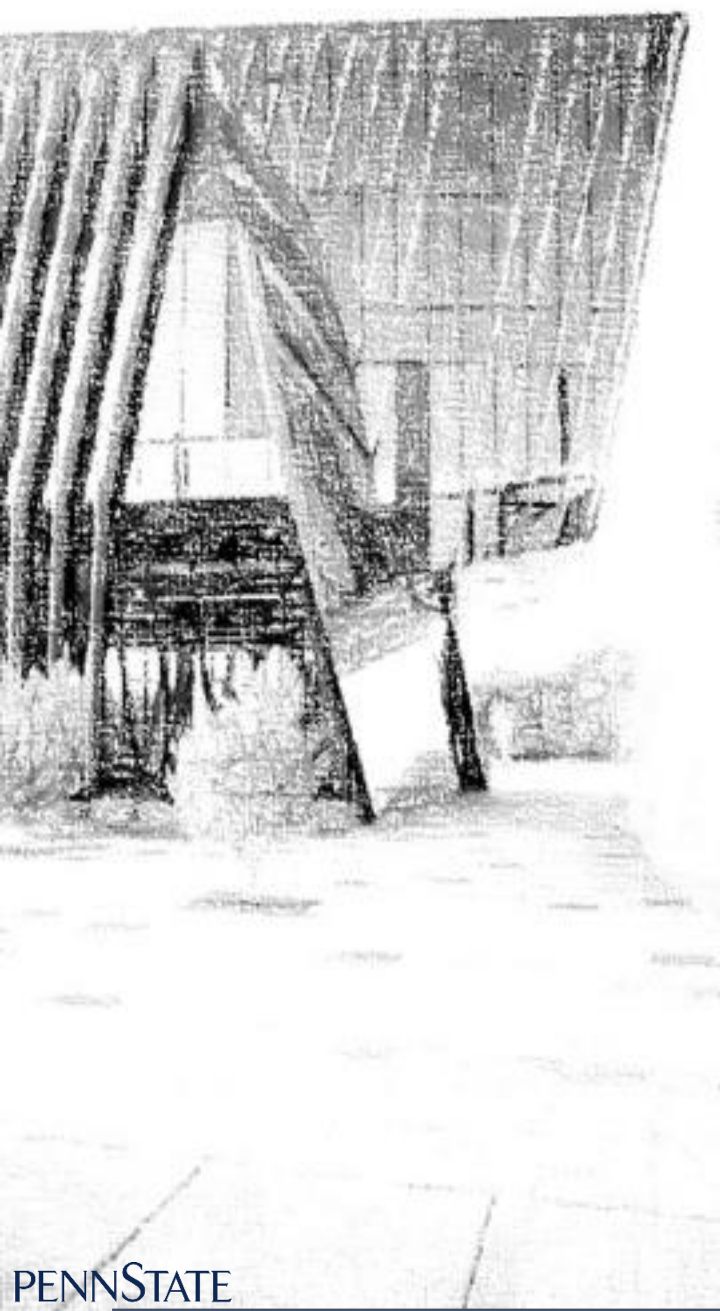
Thesis Objective

- The Chicago Building Code (CBC) requires a certain amount of airflow be supplied to a space regardless of the load





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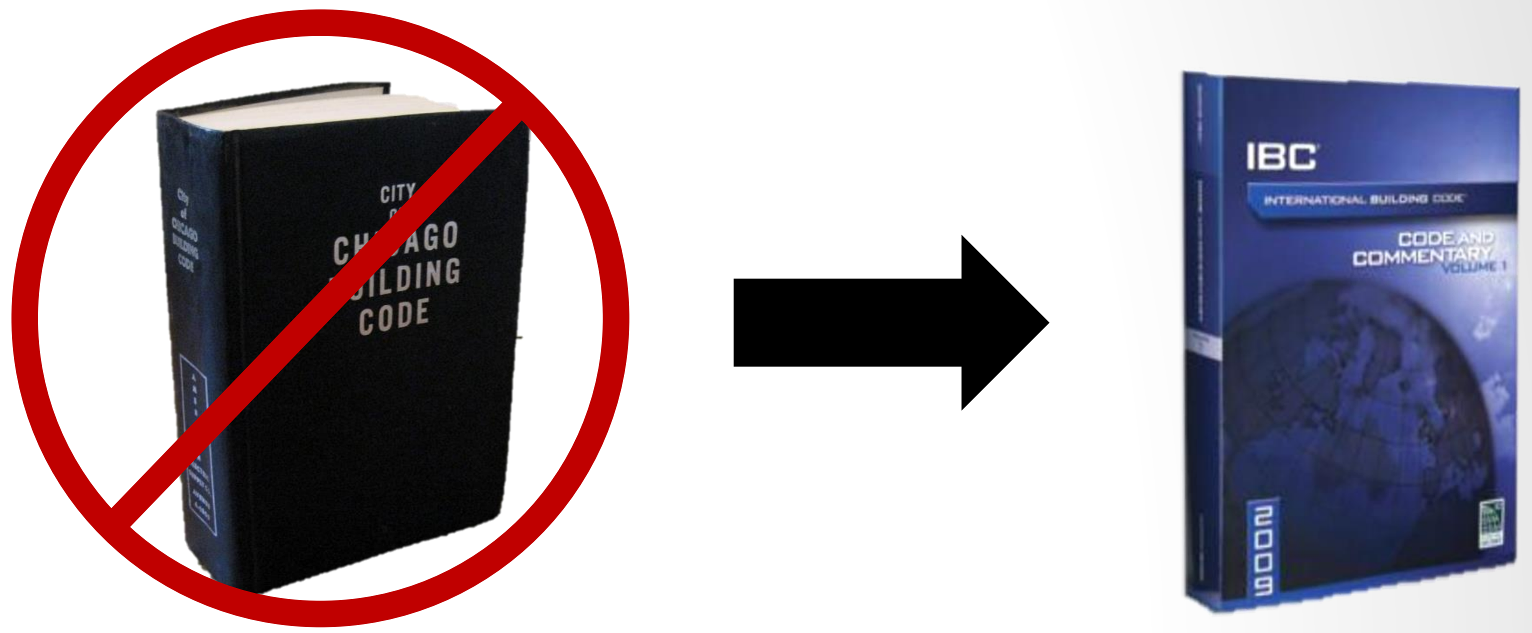
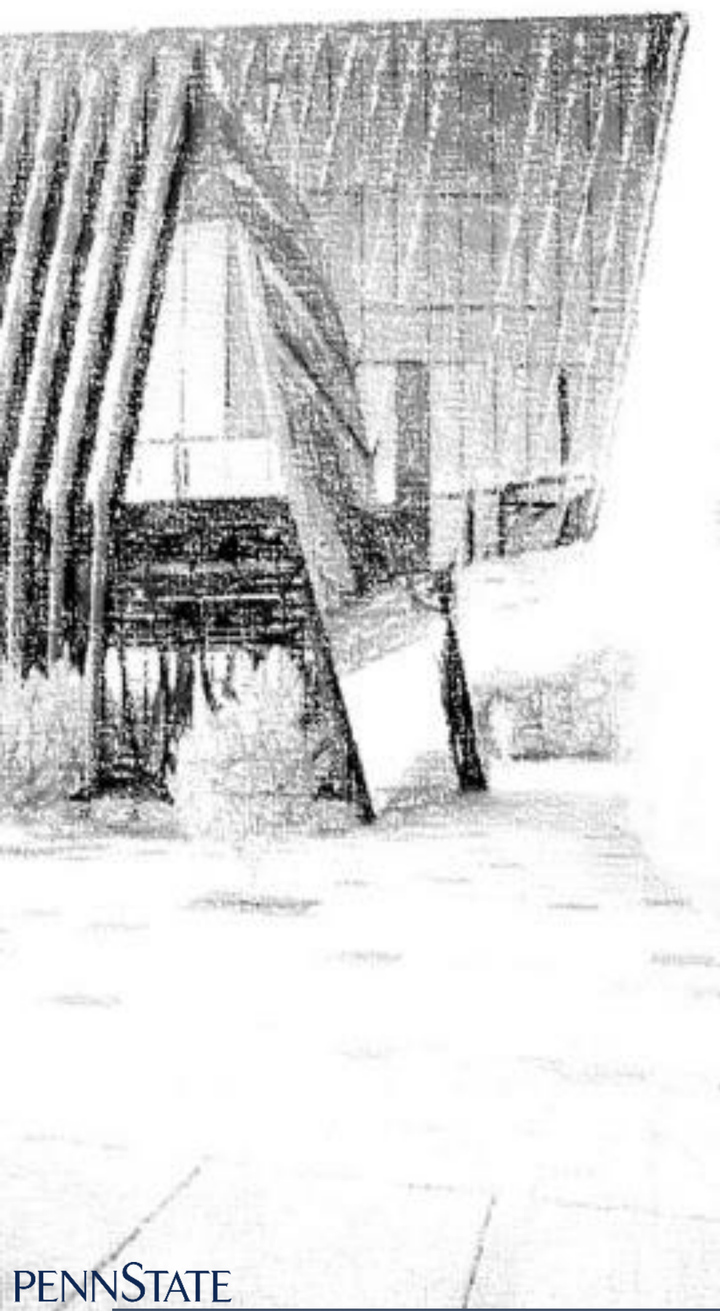
Thesis Objective

- The Chicago Building Code (CBC) requires a certain amount of airflow be supplied to a space regardless of the load
- Redesign the current mechanical system according to the International Building Code (IBC)





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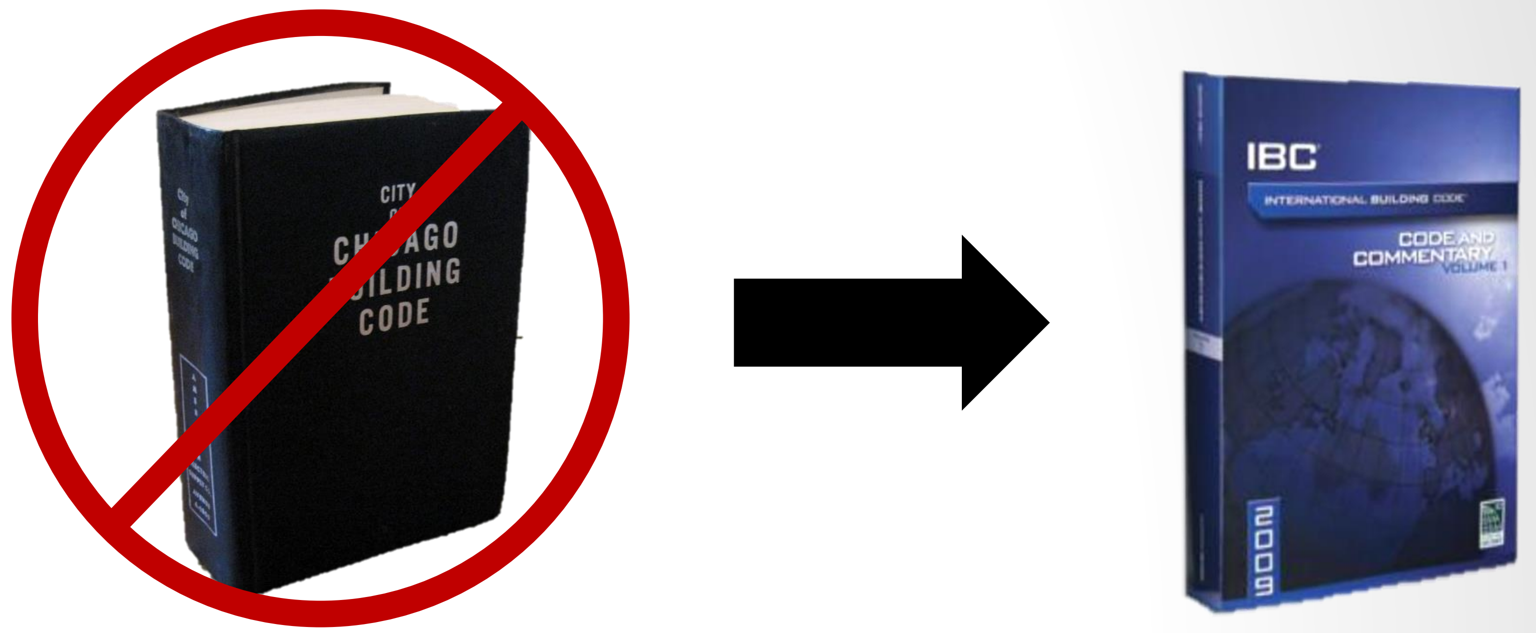
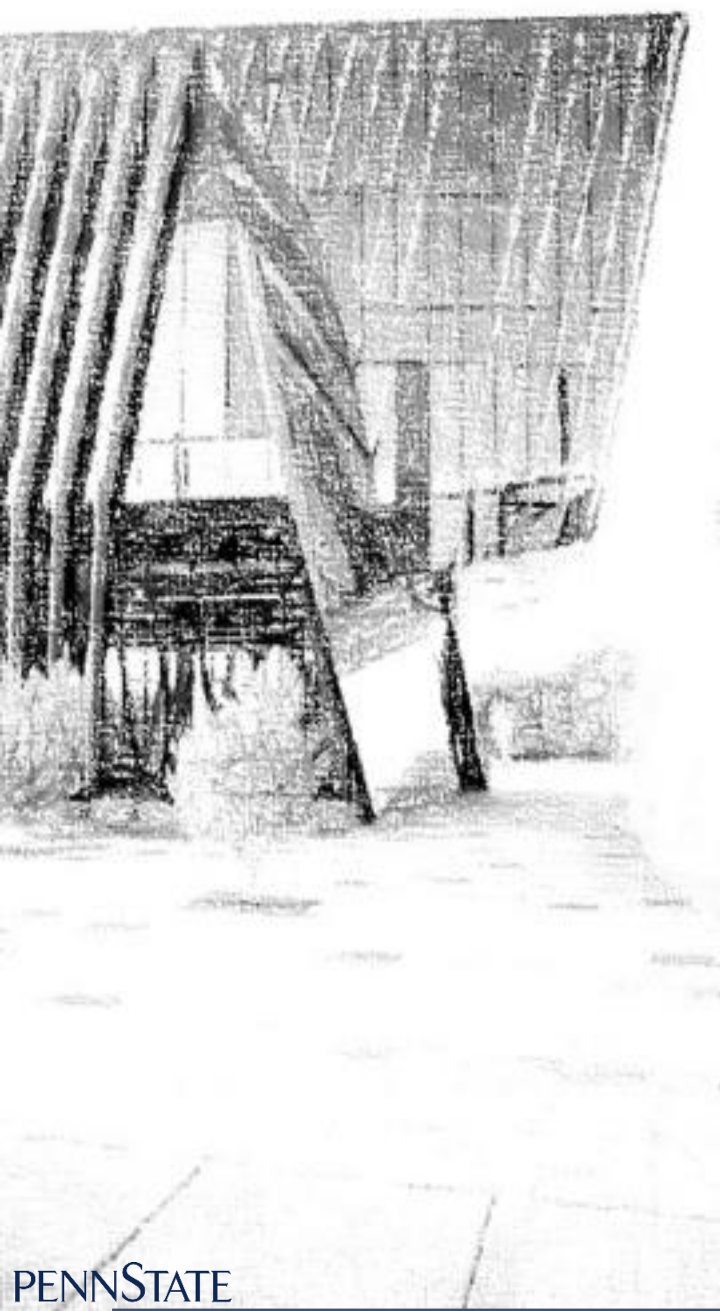
Thesis Objective

- The Chicago Building Code (CBC) requires a certain amount of airflow be supplied to a space regardless of the load
- Redesign the current mechanical system according to the International Building Code (IBC)
- What are the greater implications if all mechanical systems for commercial buildings in Chicago were designed to the IBC rather than CBC.





- Building Summary
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  - Energy Savings
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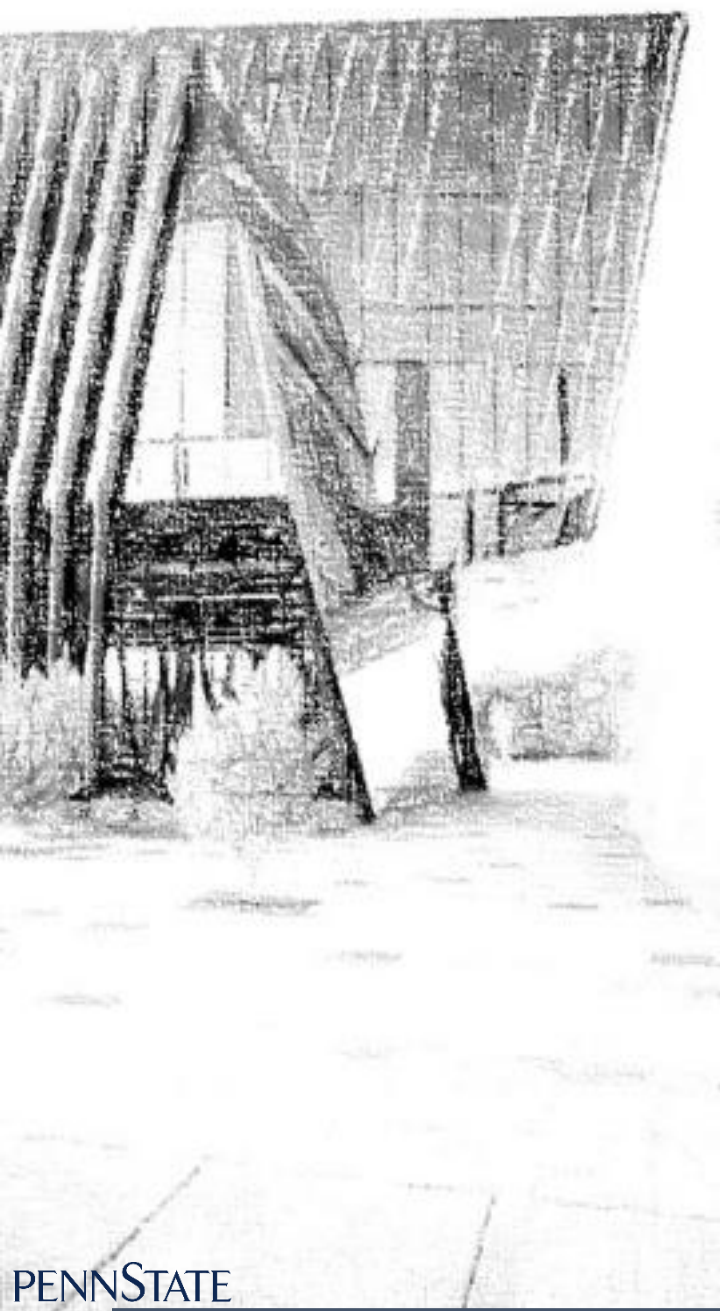
RTU Resize

Ventilation Requirements

System	CBC	IBC/IMC	% Saved
	Req'd OA (CFM)	Req'd OA (CFM)	
RTU-1 Total	9260	5761	37.79%
RTU-2 Total	10890	8292	23.86%
System Total	20150	14053	30.26%

Load Requirements

System	CBC		IBC/IMC	
	Cooling (Tons)	Supply Air (CFM)	Cooling (Tons)	Supply Air (CFM)
RTU-1	93	20,700	84	20,700
RTU-2	97	22,100	89	22,100
Total	190	42,800	173	42,800
		% Saved	*-9.10%*	*0%*



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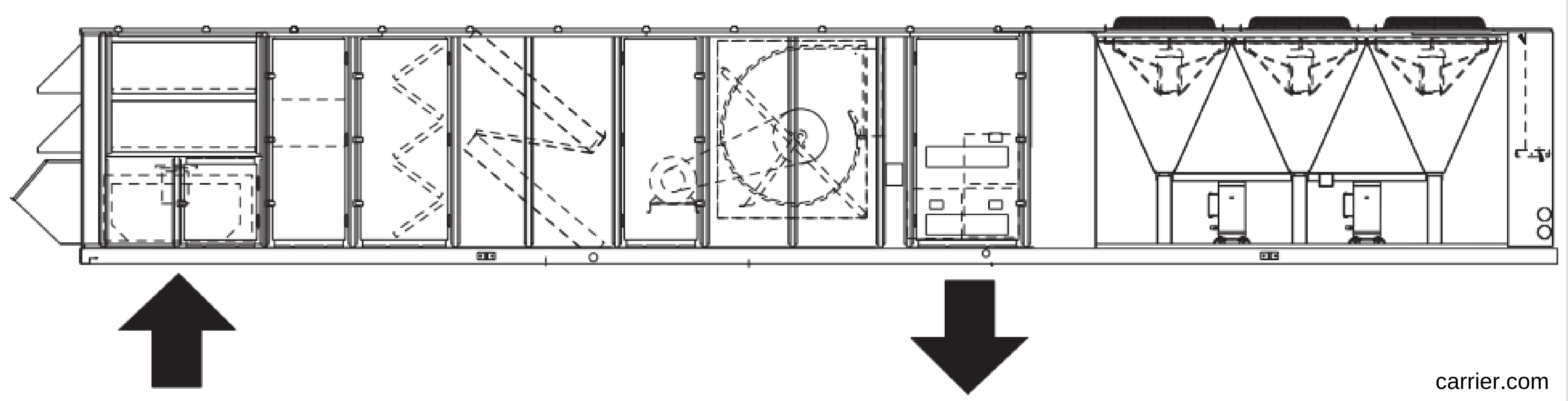
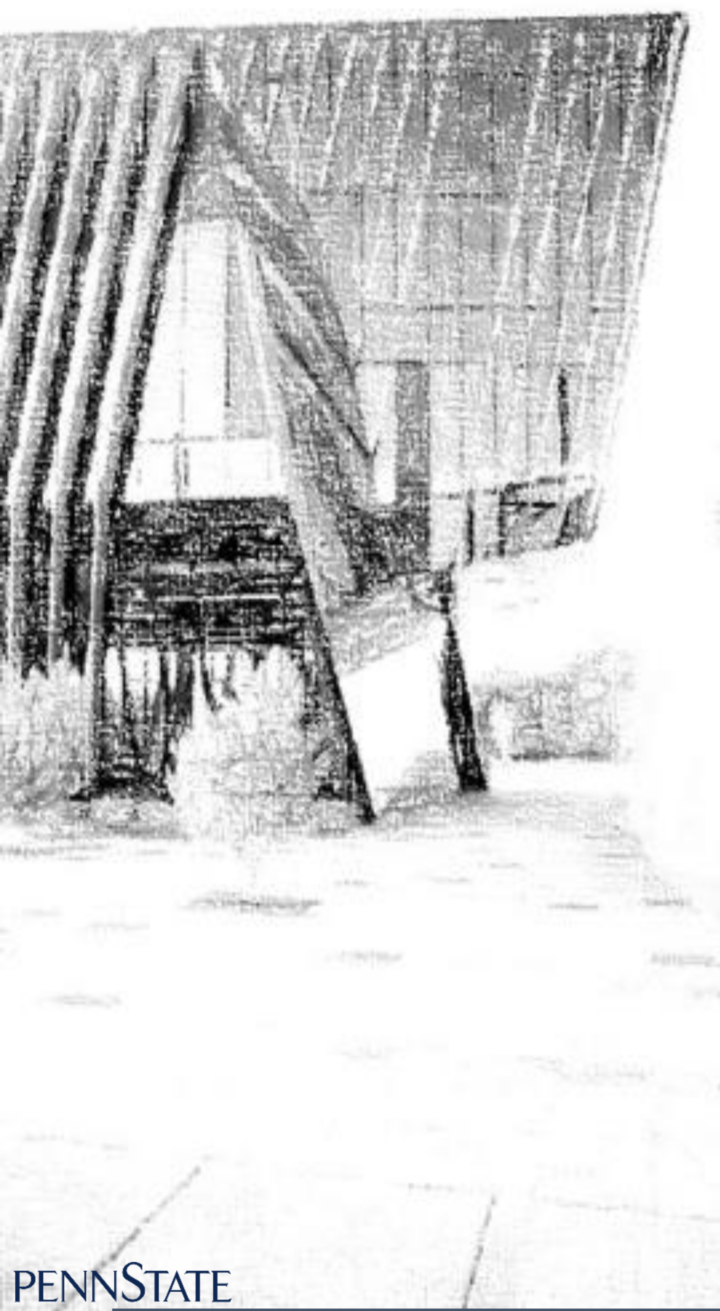
Carrier model number chosen

48 P3 D 090 6 1

- 48 – Cooling Unit with Gas Heat
- P3 – Vertical Supply/Return with VAV Control
- D – Low Gas Heat
- 090 – Unit Size (90 Nominal Tons)
- 6 – 460V/3 PH/60 HZ
- 1 – First Design Revision





RTU Resize

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Carrier

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48 — Cooling Unit with Gas Heat
P3 — Vertical Supply/Return with VAV Control
D — Low Gas Heat
090 — Unit Size (90 Nominal Tons)
6 — 460V/3 PH/60 HZ
1 — First Design Revision

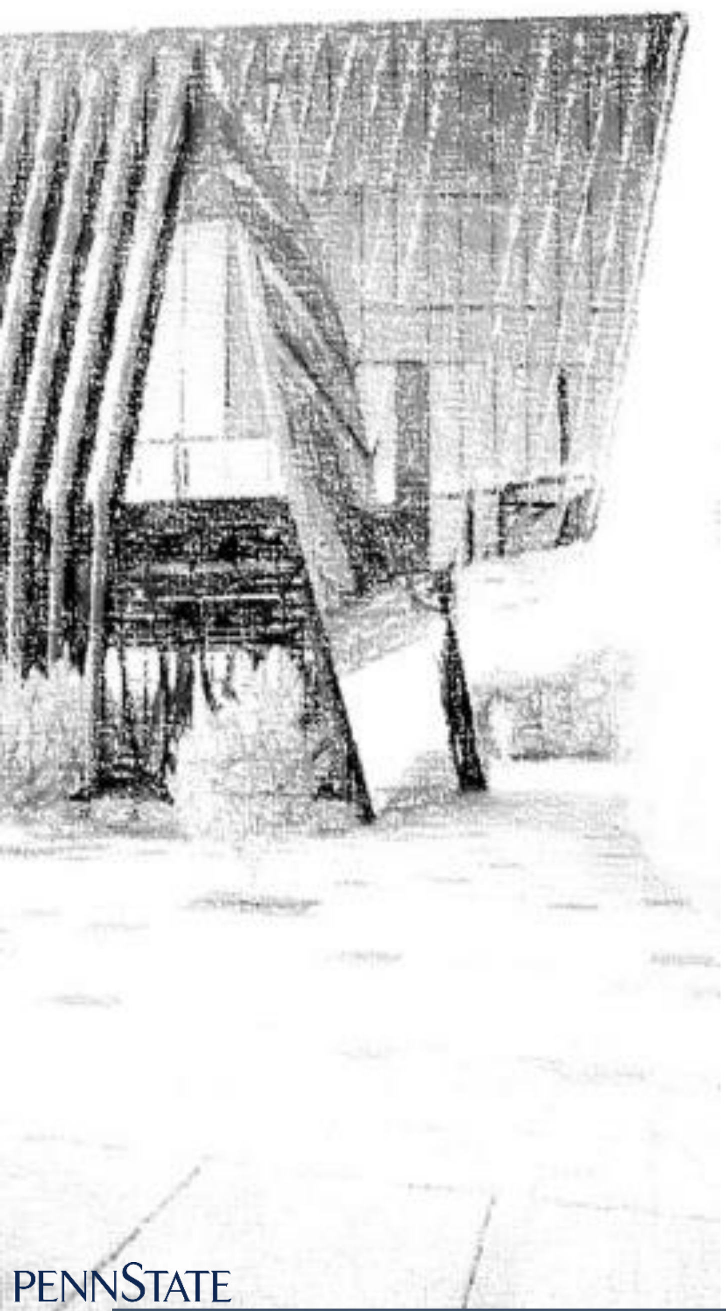
Low Gas Heat Capacity: 527 MBH
High Gas Heat Capacity: 790 MBH

$$q\left(\frac{BTU}{hr}\right) = 1.10 * Q(CFM) * \Delta T(°F)$$

$$where\ \Delta T = T_s - T_{ma} = 0.3(-10°F) + 0.7(70°F) = 9°F$$

$$q = 1.10 * (34{,}000\ CFM) * (9°F) = 336{,}600\ \frac{BTU}{hr}$$

$$q = 337\ MBH \ \leq 527\ MBH\ ✓$$



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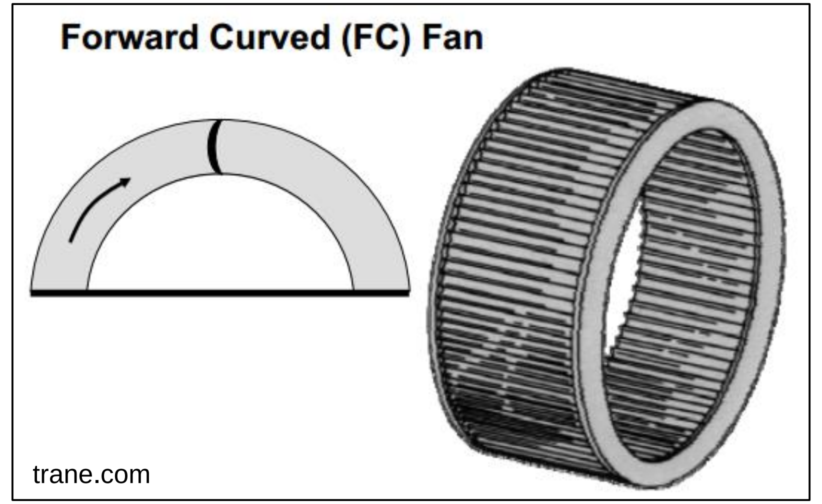
RTU Resize

Fan Selection



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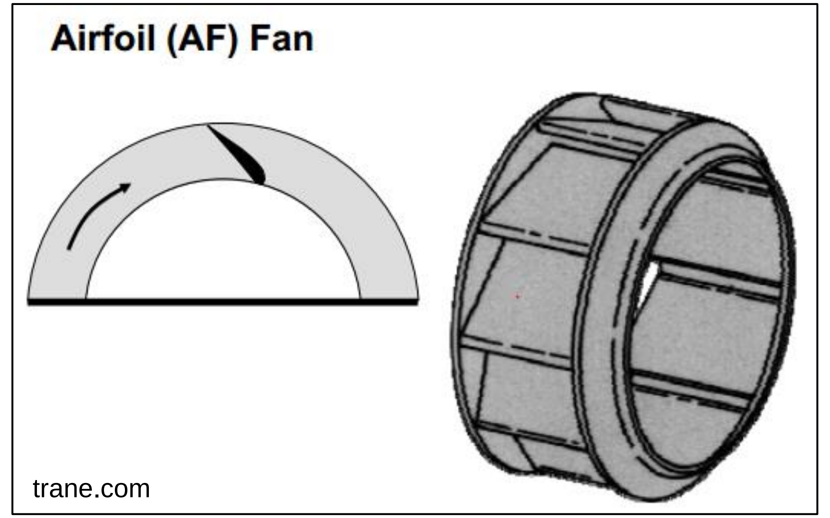

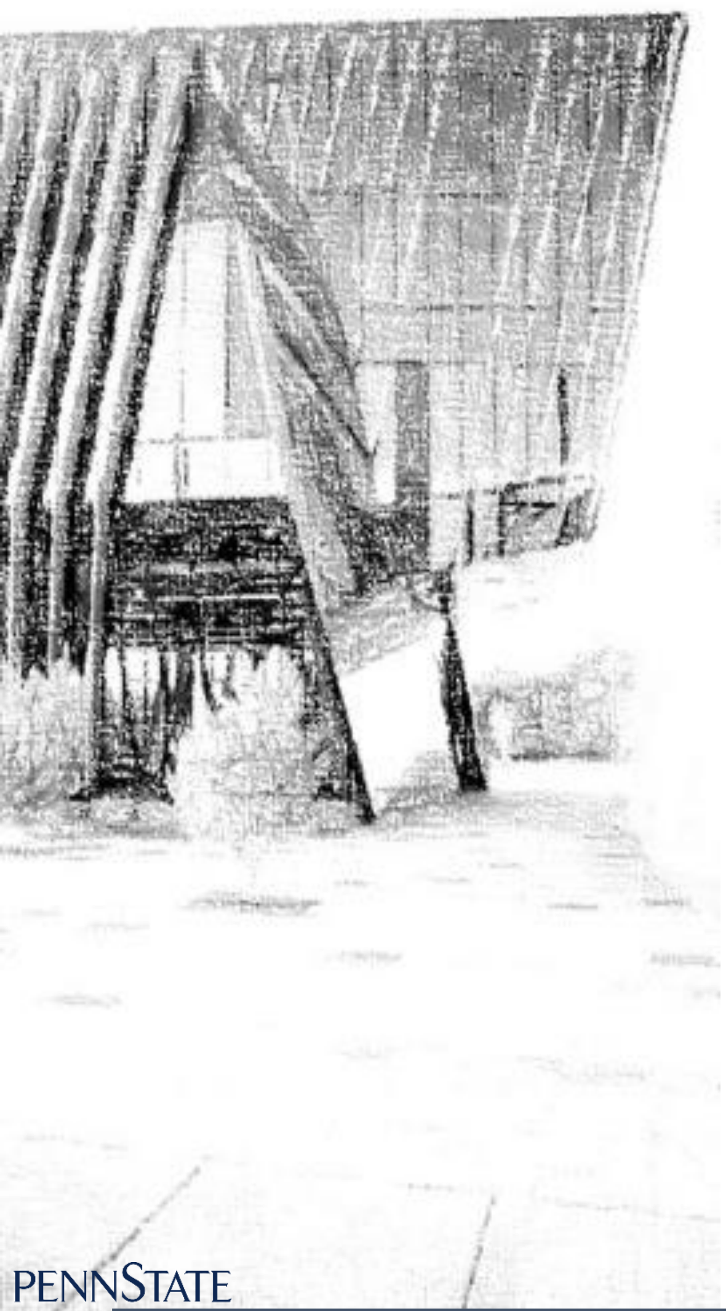

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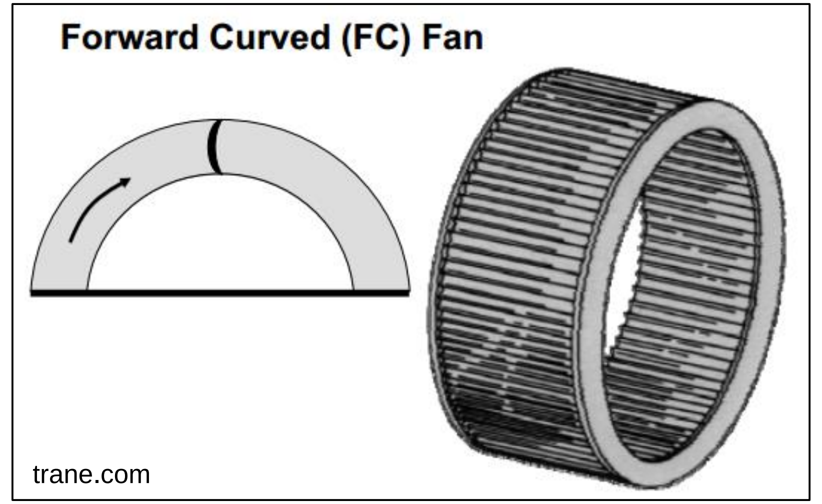
RTU Resize

Fan Selection



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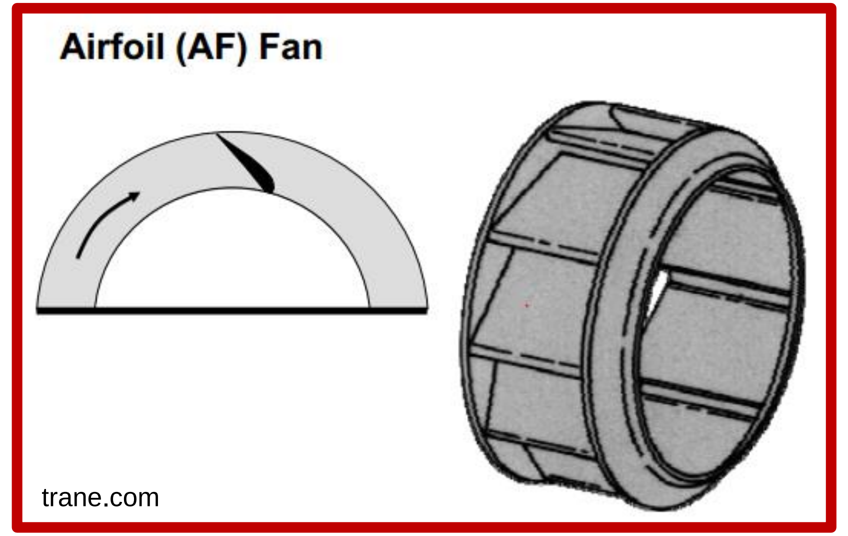

Fan Type	Total Supply (CFM)	Input Power (BHP)	Speed (rpm)
Housed FC	34,000	42.9	592
Housed AF	34,000	36.7	1432

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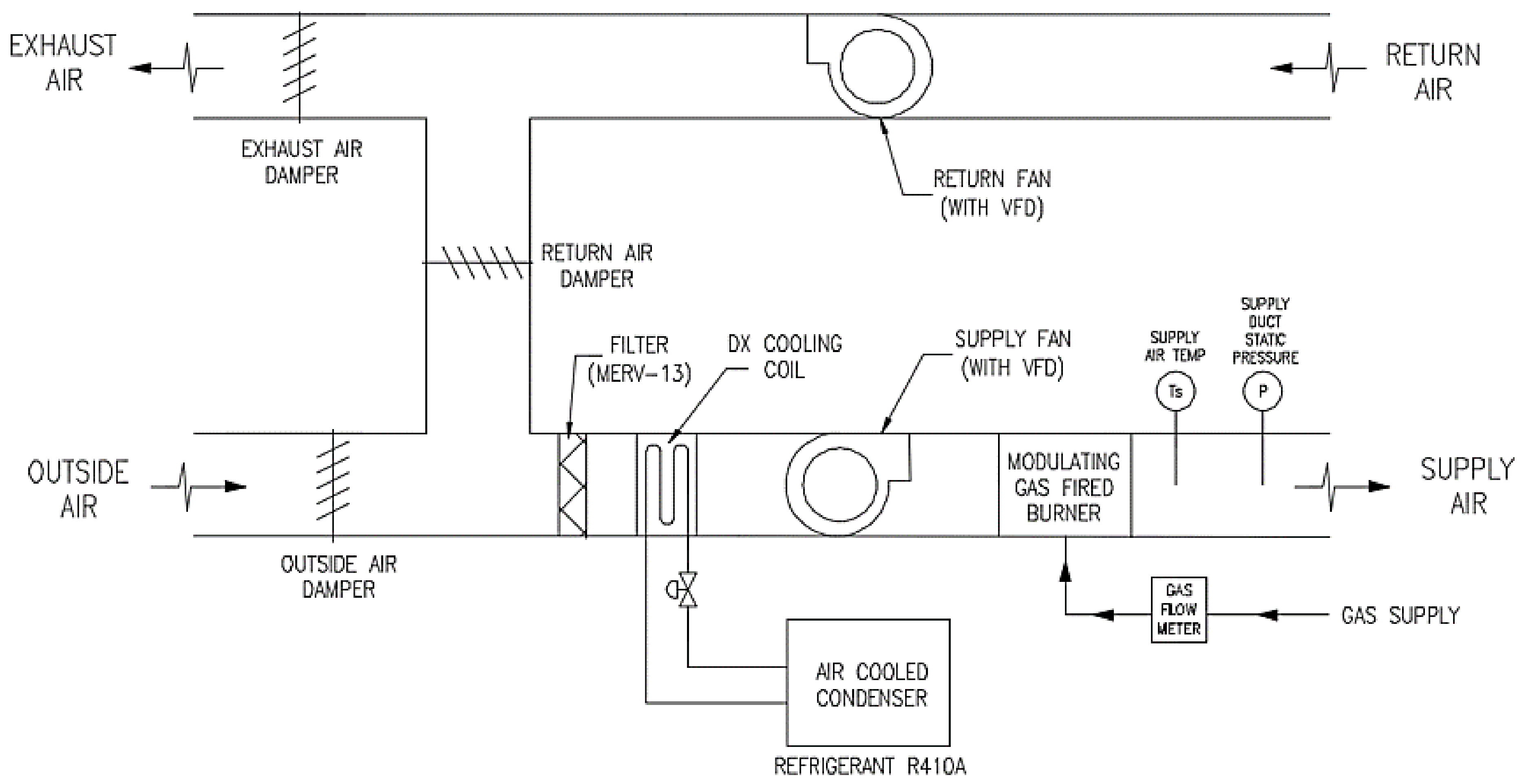
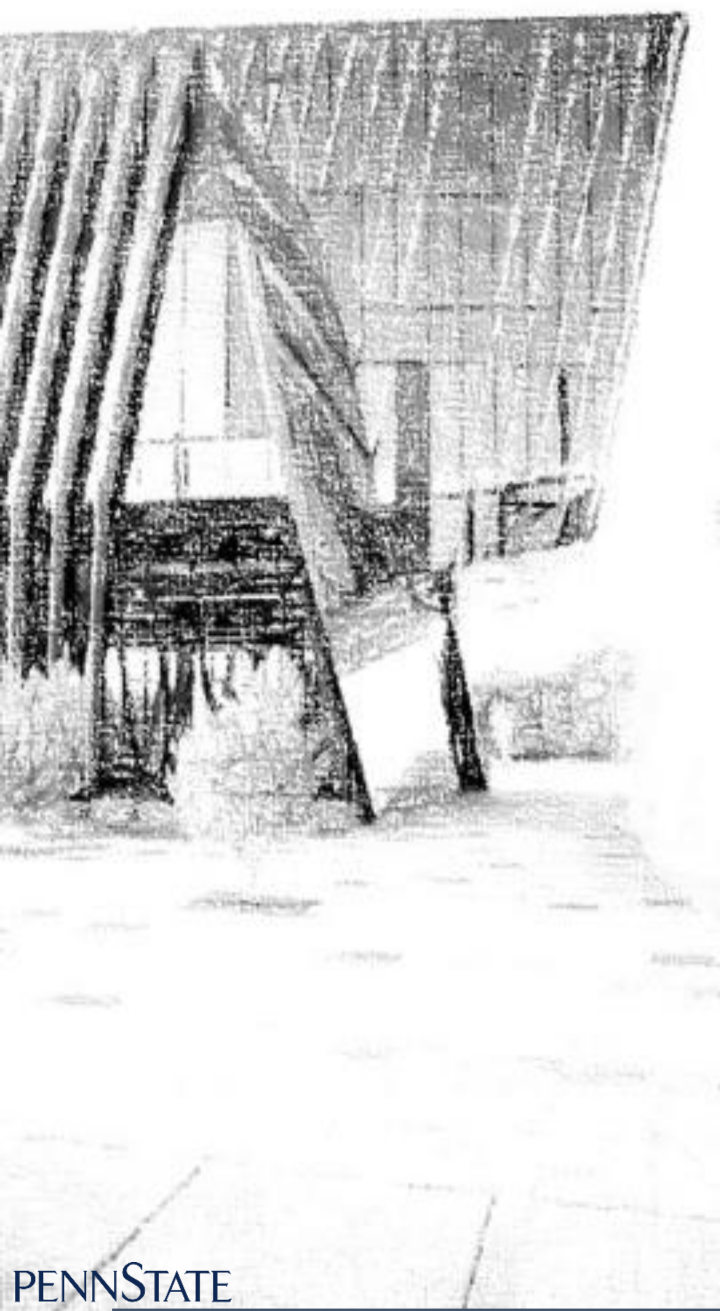
RTU Resize

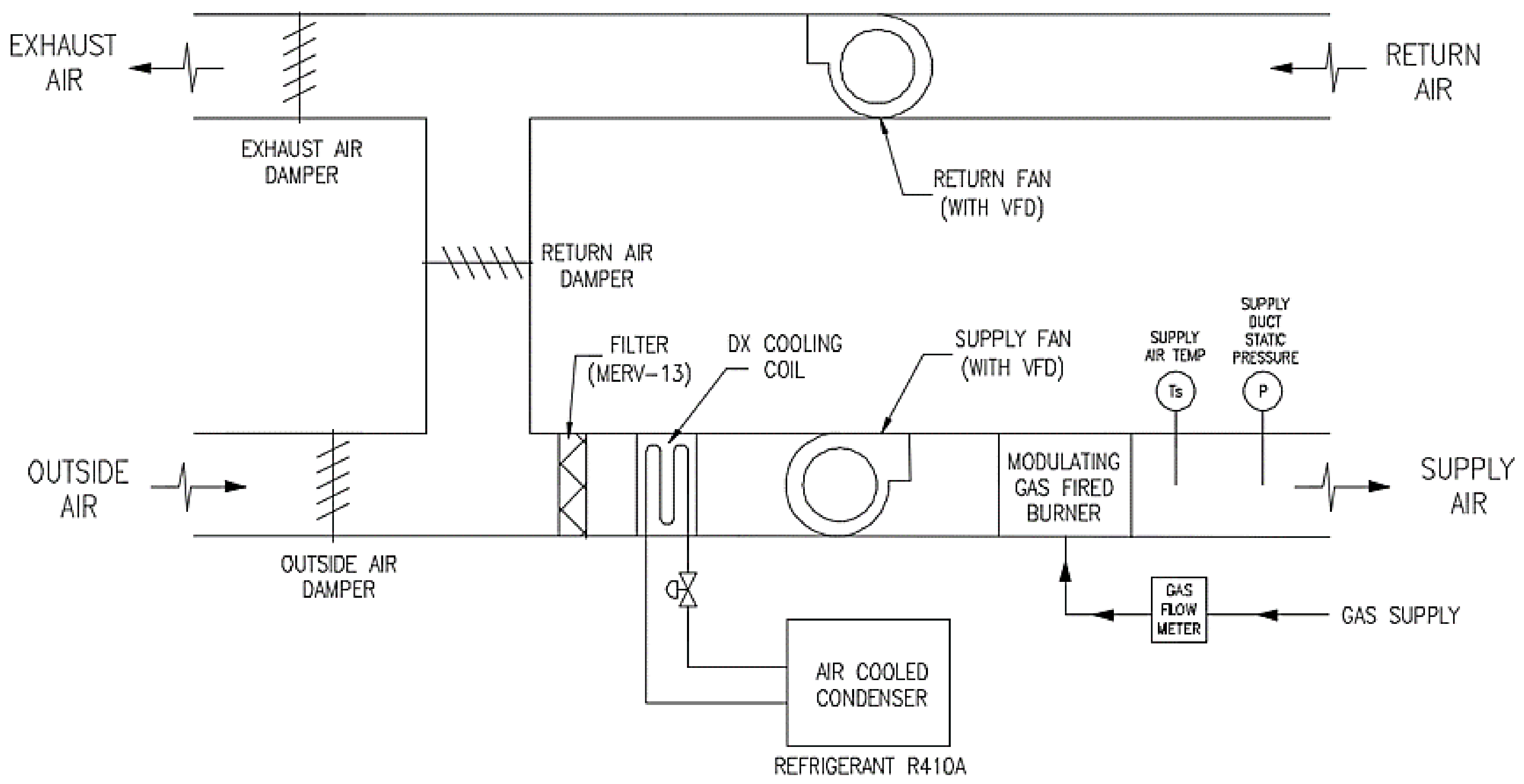
RTU Schematic





RTU Resize

RTU Schematic



Code	RTU Size	Cost (incl. O&P)	Location Factor	Adjusted Cost	Qty. of RTUs	Total Cost
CBC	105 tons	$252,000	113.6%	$286,272	2	$572,544
IBC/IMC	90 tons	$225,500	113.6%	$256,168	2	$512,336

Potential Savings
10.5%
$60,000

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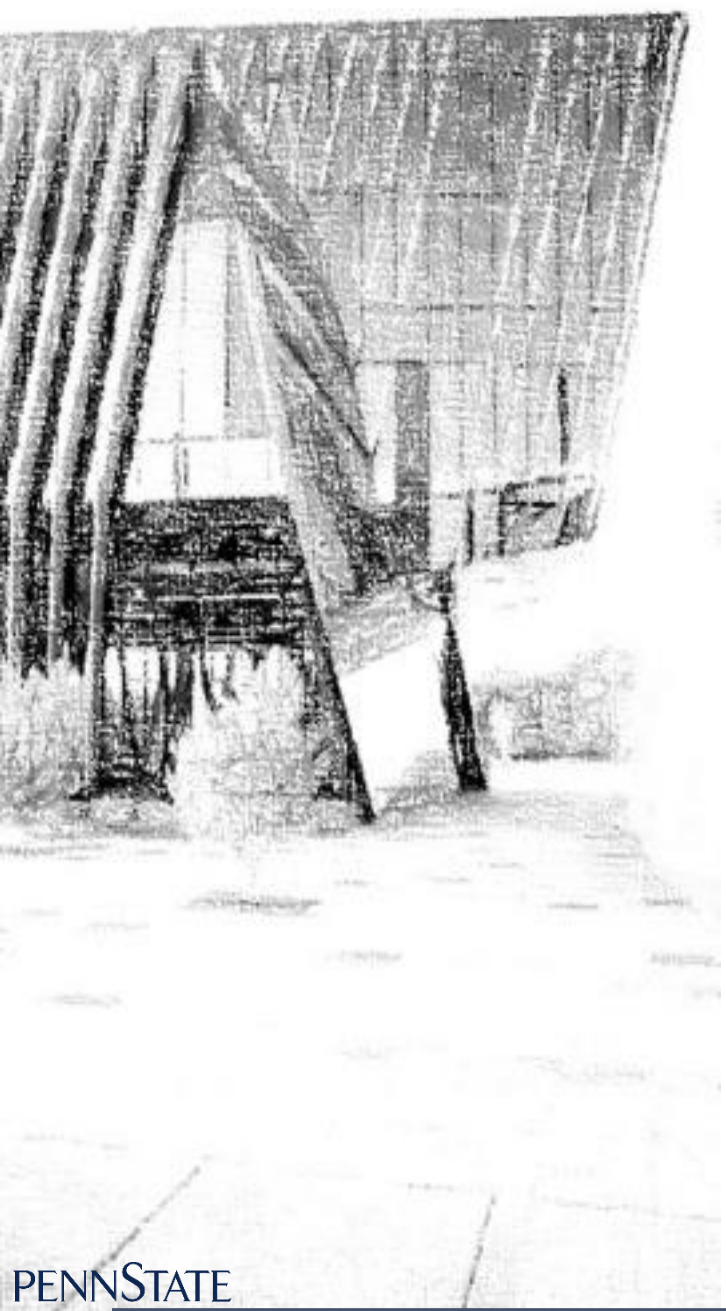
Annual Utility Usage

CBC			IBC/IMC		
Elec Used (kWh)	**NG Used (therms)**	**Total Utility Cost**	**Elec Used (kWh)**	**NG Used (therms)**	**Total Utility Cost**
727,000	9,600	$65,500	723,000	7,400	$63,700
		Savings	*0.5%*	*29.5%*	*2.9%*

- Electricity Cost Savings: 0.5%
- Natural Gas Cost Savings: 29.5%
- Total Utility Cost Savings: 2.9%
- Electric & NG Cost Savings: $1800



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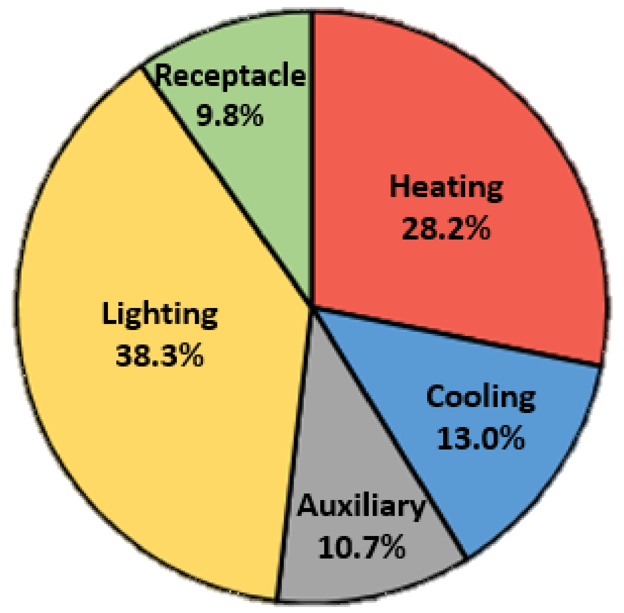
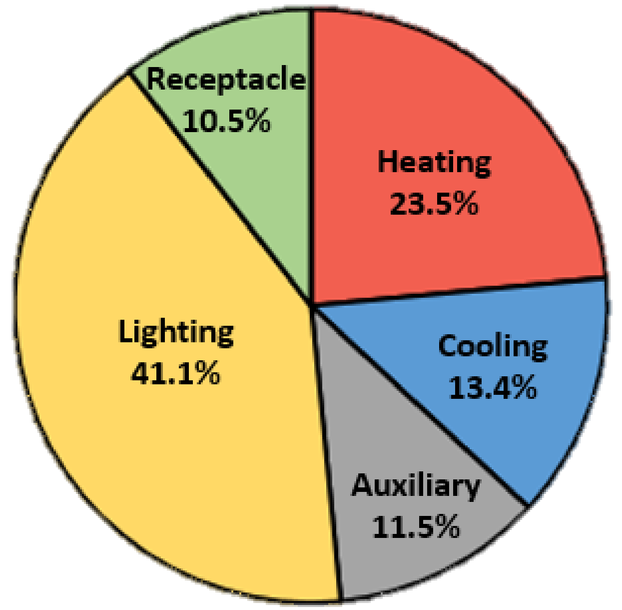
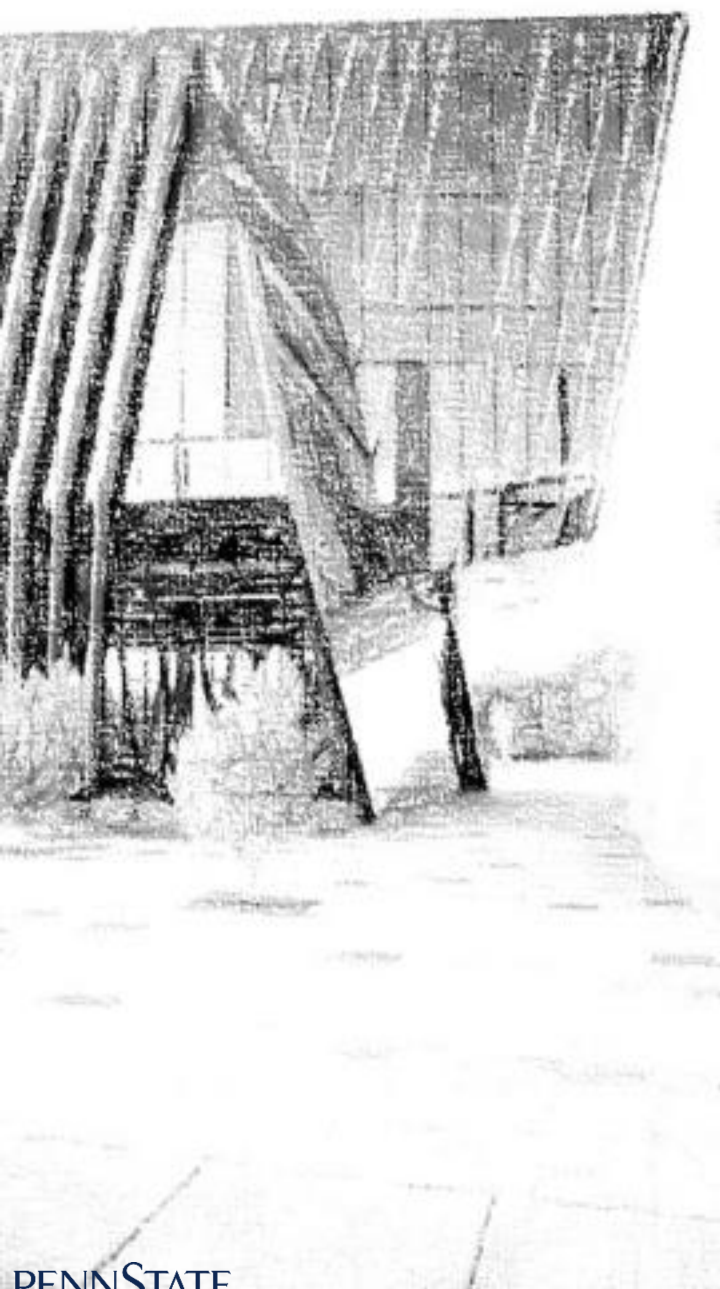
CBC



IBC/IMC



Why are there more energy savings in the heating system than the cooling system?



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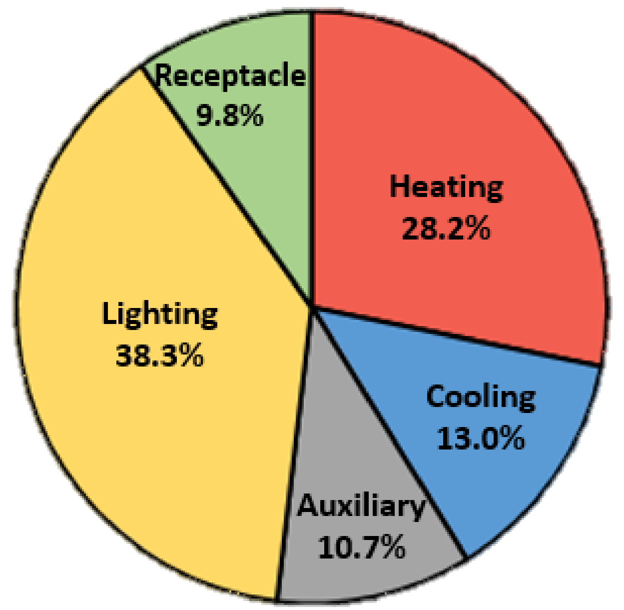
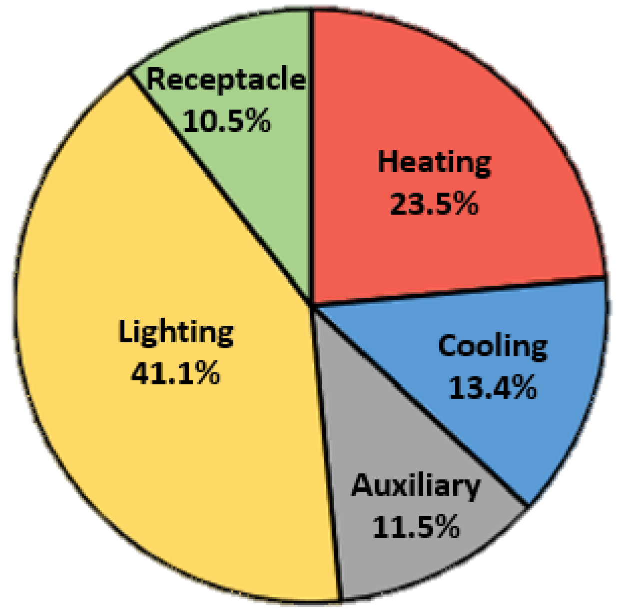


IBC/IMC



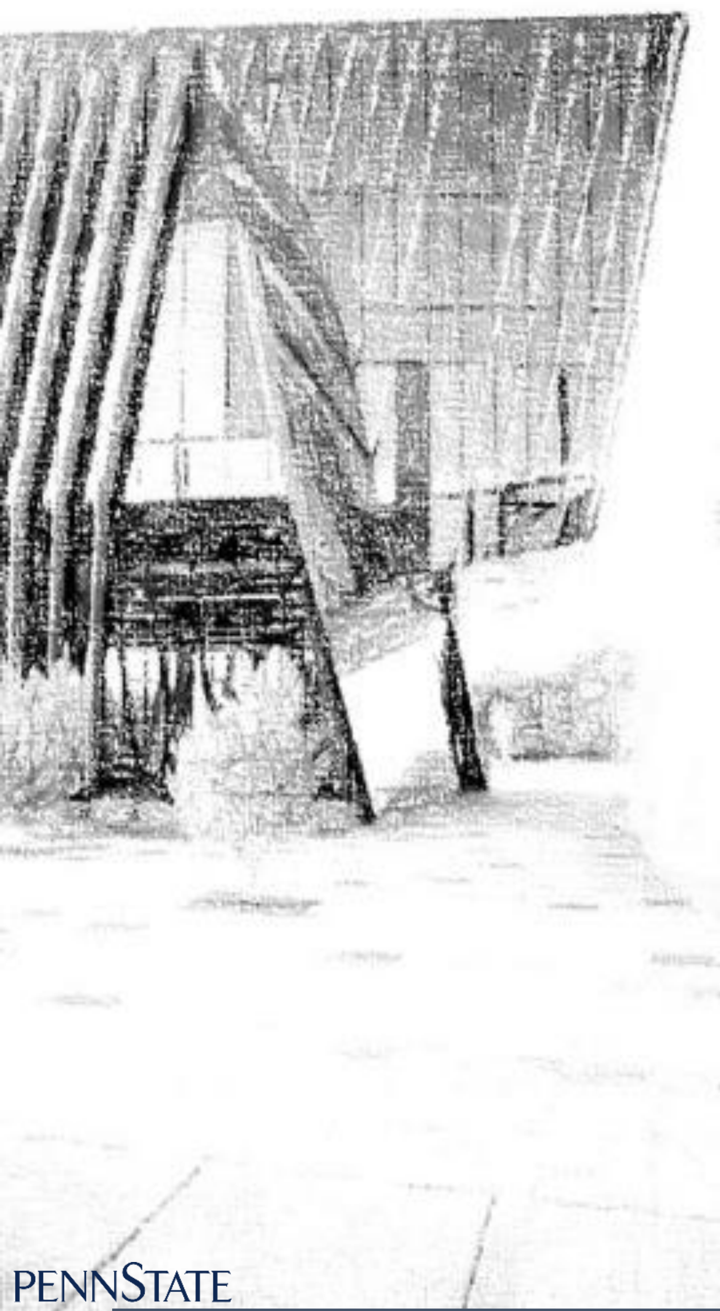
Why are there more energy savings in the heating system than the cooling system?

Cooling Degree Days	842
Heating Degree Days	6311

$$\Delta T = |T_{RA} - T_{OA}|$$

$$\Delta T_{cooling} = |75°F - 85°F| = 10°F$$

$$\Delta T_{heating} = |70°F - 25°F| = 45°F$$



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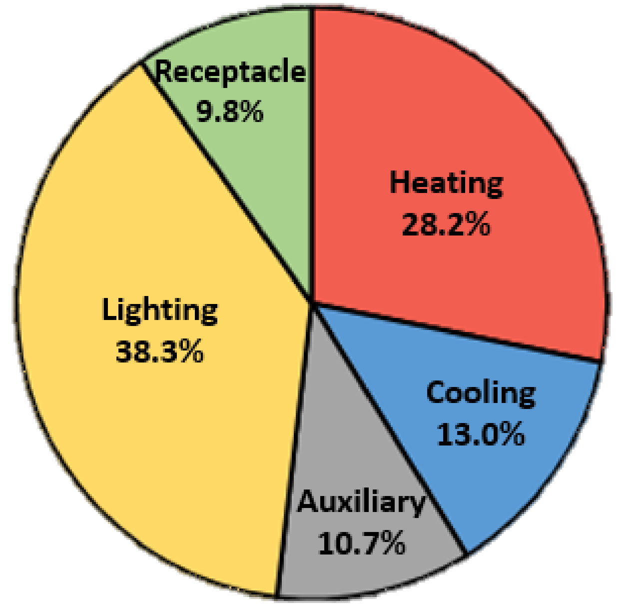
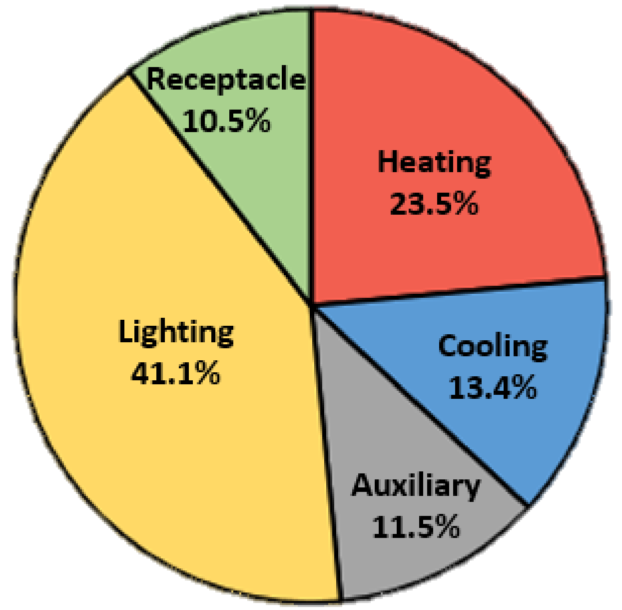
Annual Utility Usage

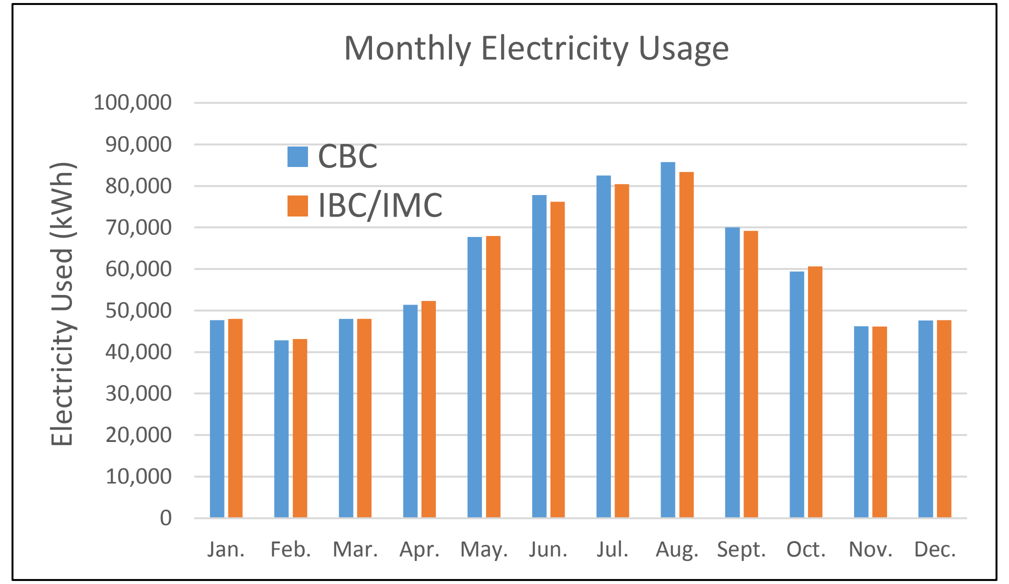
CBC			IBC/IMC		
Elec Used (kWh)	NG Used (therms)	Total Utility Cost	Elec Used (kWh)	NG Used (therms)	Total Utility Cost
727,000	9,600	$65,500	723,000	7,400	$63,700
		Savings	*0.5%*	*29.5%*	*2.9%*

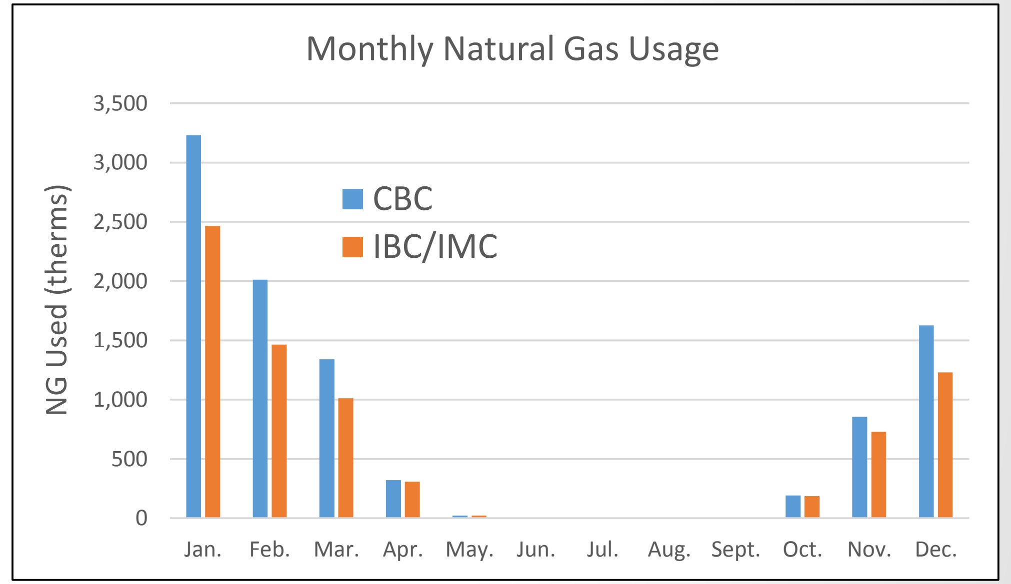
CBC

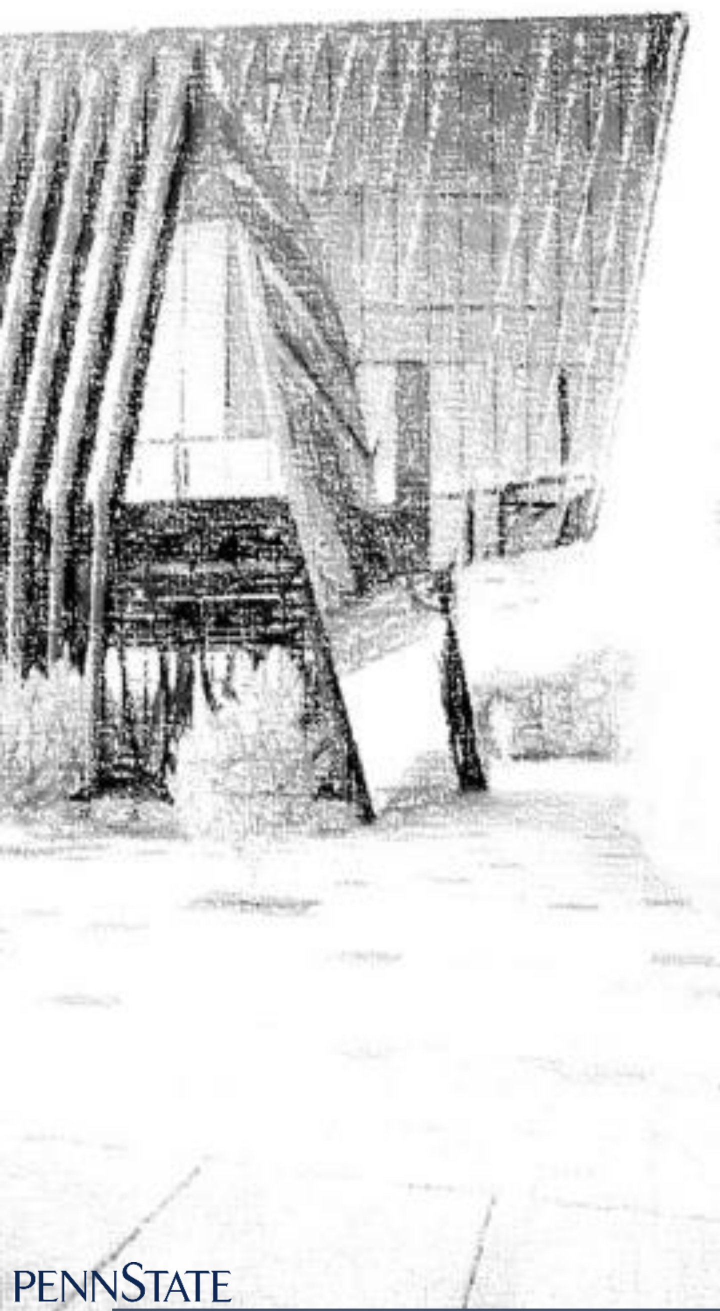


IBC/IMC









- Building Summary
- Thesis Objective
- **Mechanical Depth**
  - RTU Resize
  - **Energy Savings**
  - Emission Savings
- Structural Breadth
- Electrical Breadth
- Evaluation and Conclusion

Annual Utility Usage

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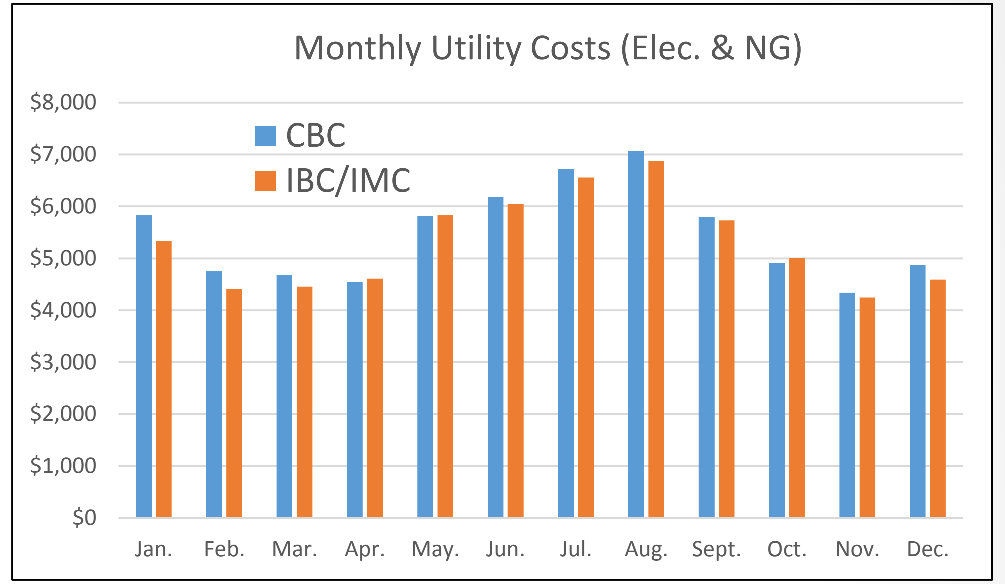
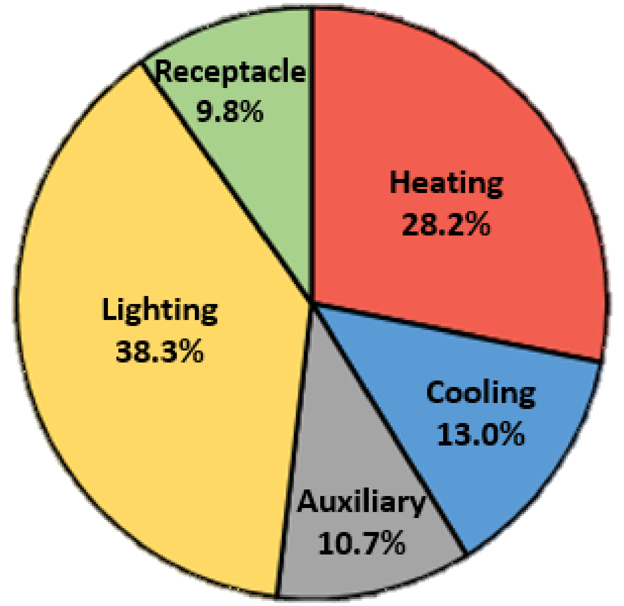


CBC



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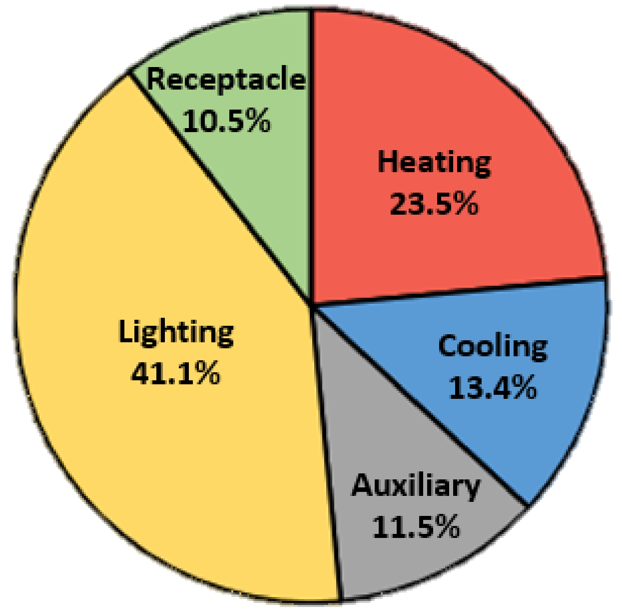
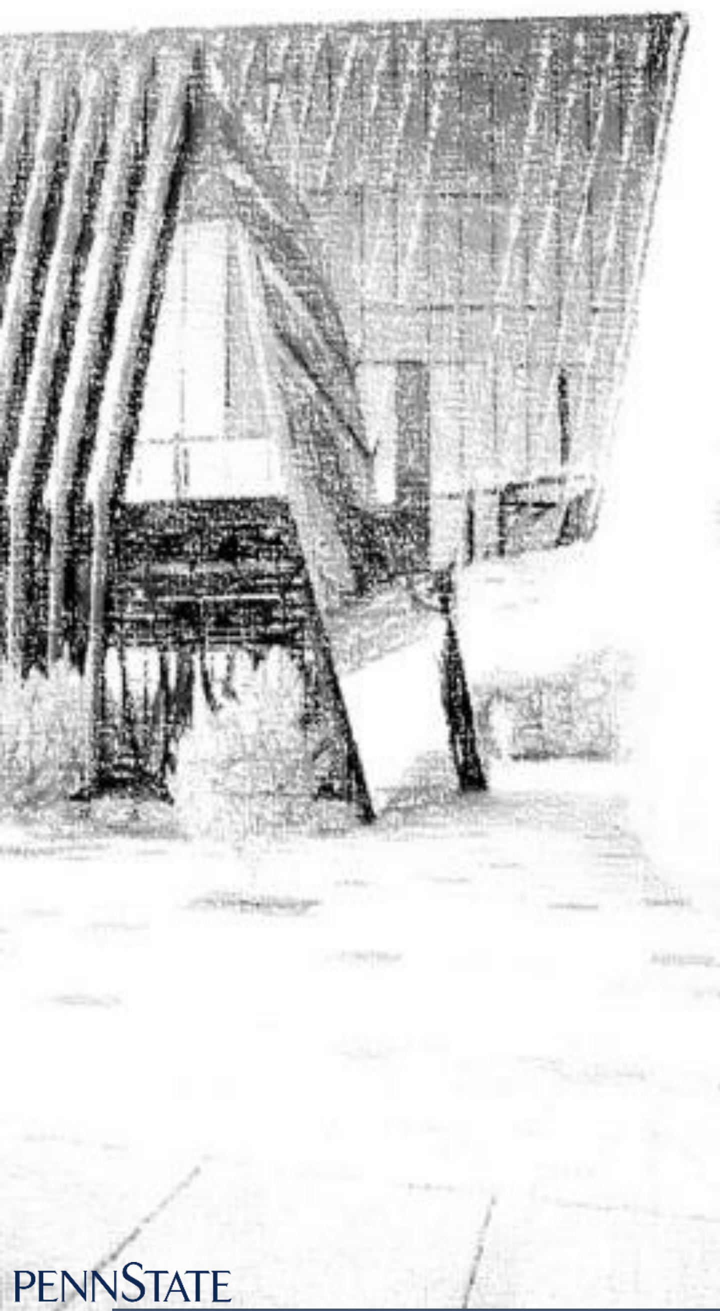


PENNSTATE



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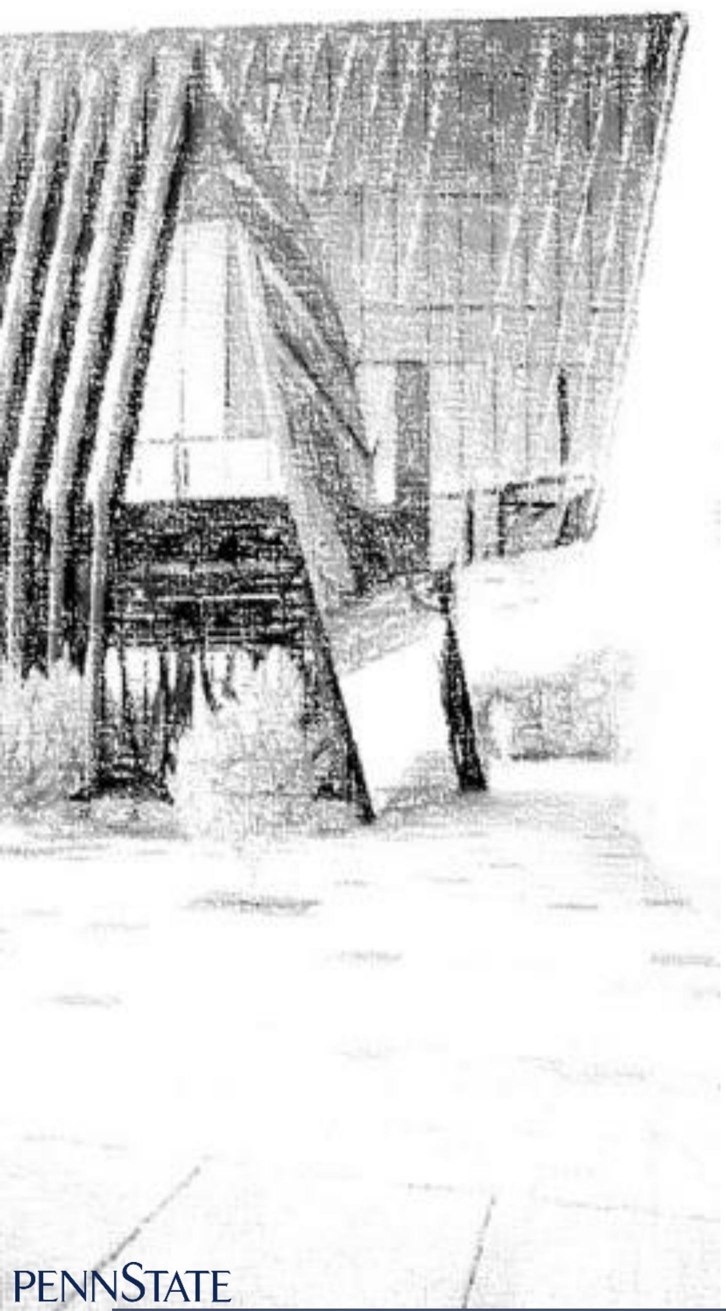
Emission Savings

Code	Pollutant	Electricity		Natural Gas		Total
		lb/kWh	lbs.	lb/MCF	lbs.	(lbs pollutant/year)
CBC	CO_{2e}	1.74	1,273,668	123	118,080	1,391,748
	CO_2	1.64	1,200,469	122	117,120	1,317,589
	NO_x	0.003	2,196	0.111	107	2,303
IBC	CO_{2e}	1.74	1,266,904	123	91,229	1,358,134
	CO_2	1.64	1,194,094	122	90,487	1,284,581
	NO_x	0.003	2,184	0.111	82	2,267
		% Saved (CO_{2e})	0.53%		22.74%	2.42%

Emission Savings ~37,000 lbs. CO_{2e} per year



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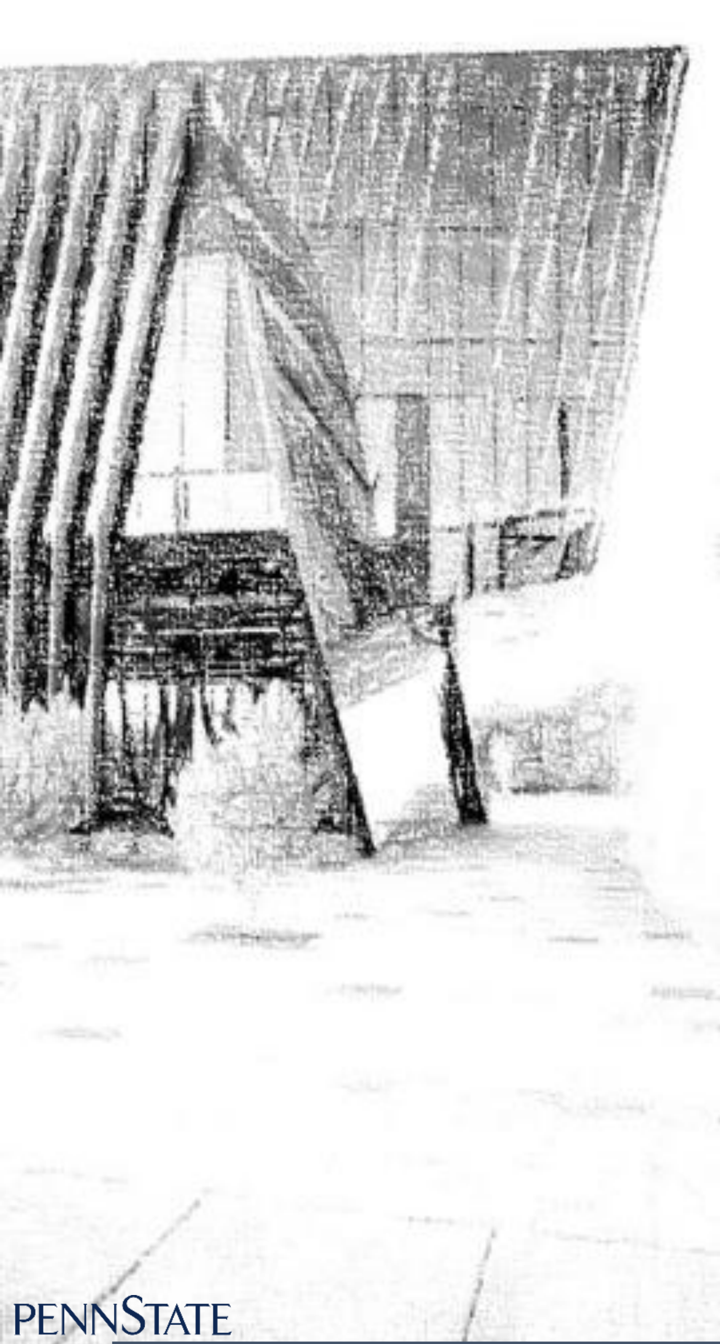
  - RTU-2
  - RTU-1
  - Conclusion
- Electrical Breadth
- Evaluation & Conclusion

Structural Breadth

Will smaller RTU’s designed according to the IBC lead to a reduction in structural steel?



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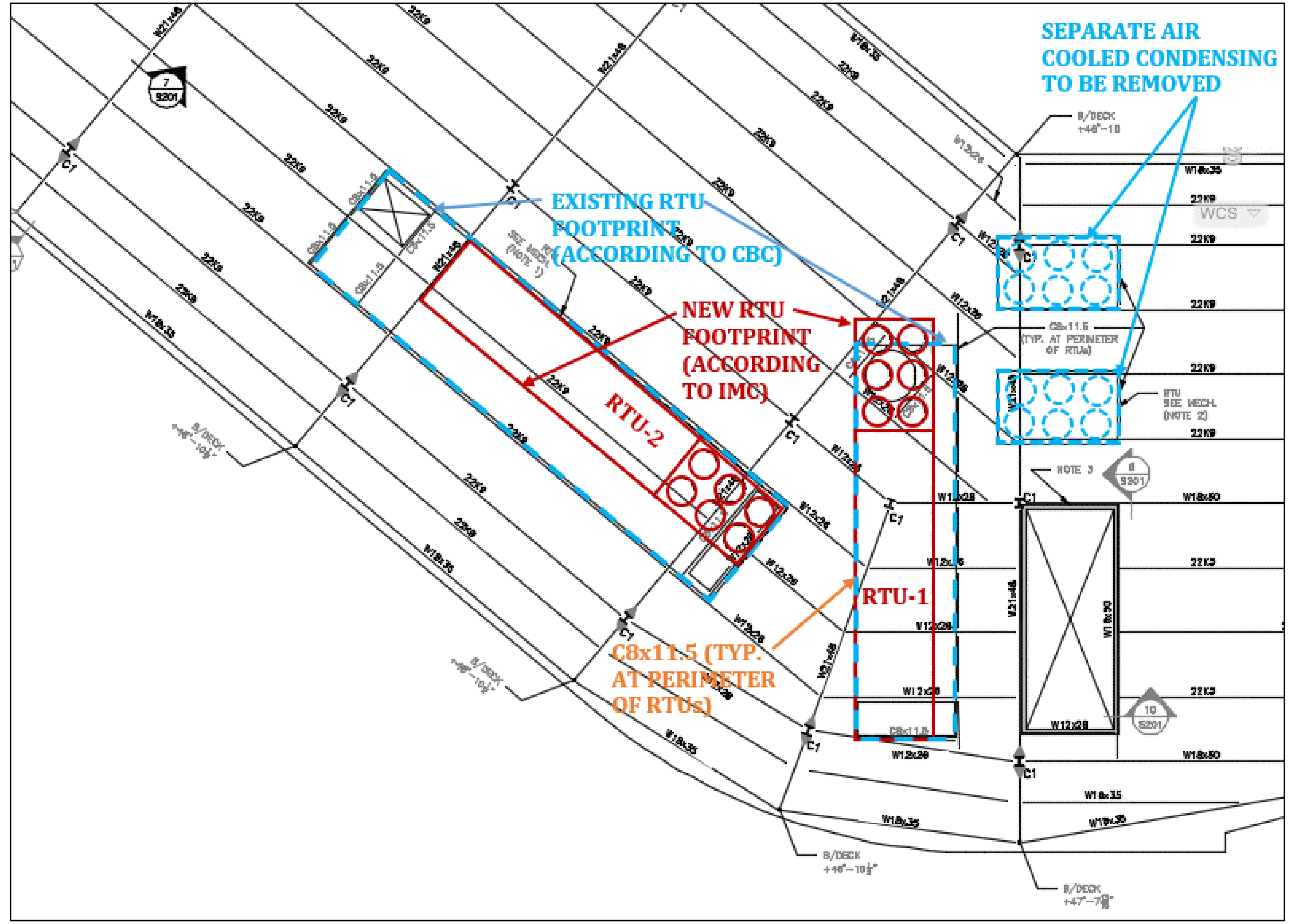
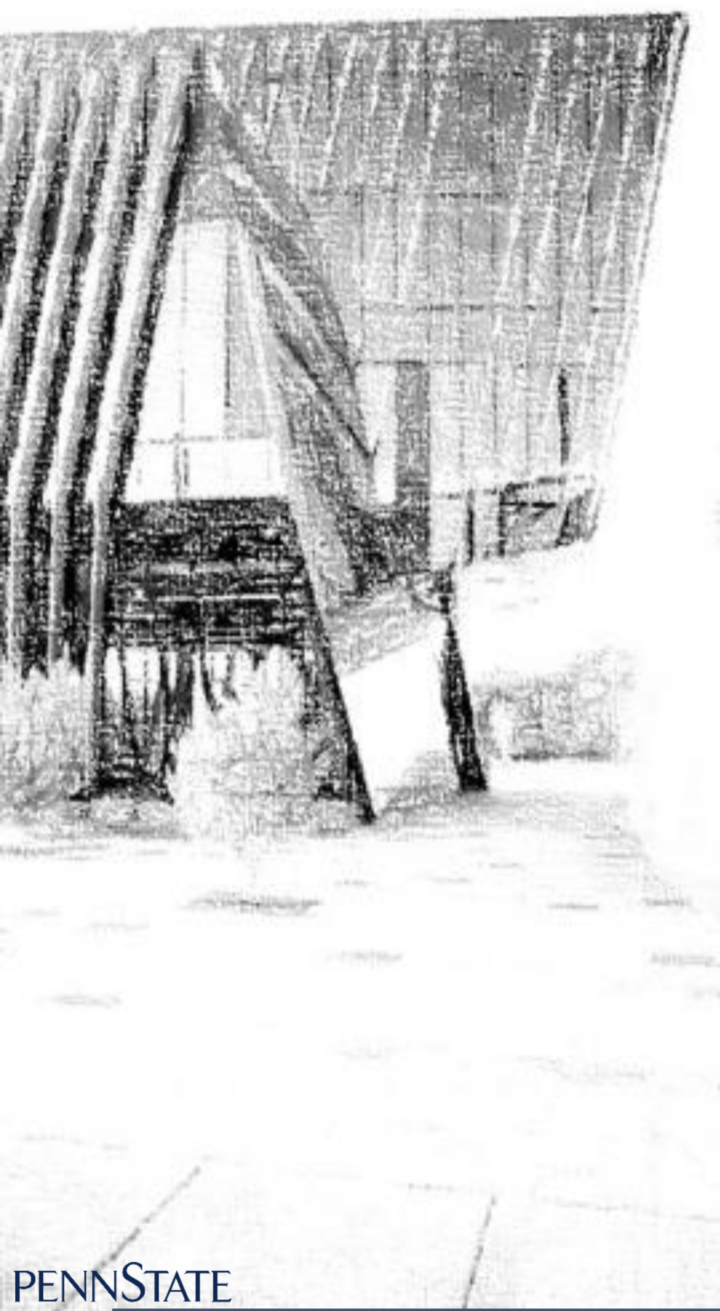
Structural Breadth



Load Type	Material	Weight (psf)
Dead Load	PVC Roof	10
	1/2" Cover Board	2
	R-30 Insulation Board	2
	Galvanized Metal Deck	2
	Misc. (lights, duct, PV array, etc.)	10
Live Load or Snow Load	Live Load	20
	Snow Load	25
Total	***Dead Load***	***26***
	Snow Load	***25***

$$1.2(26\ psf) + 1.6(25\ psf) = 71\ psf\ factored\ load$$



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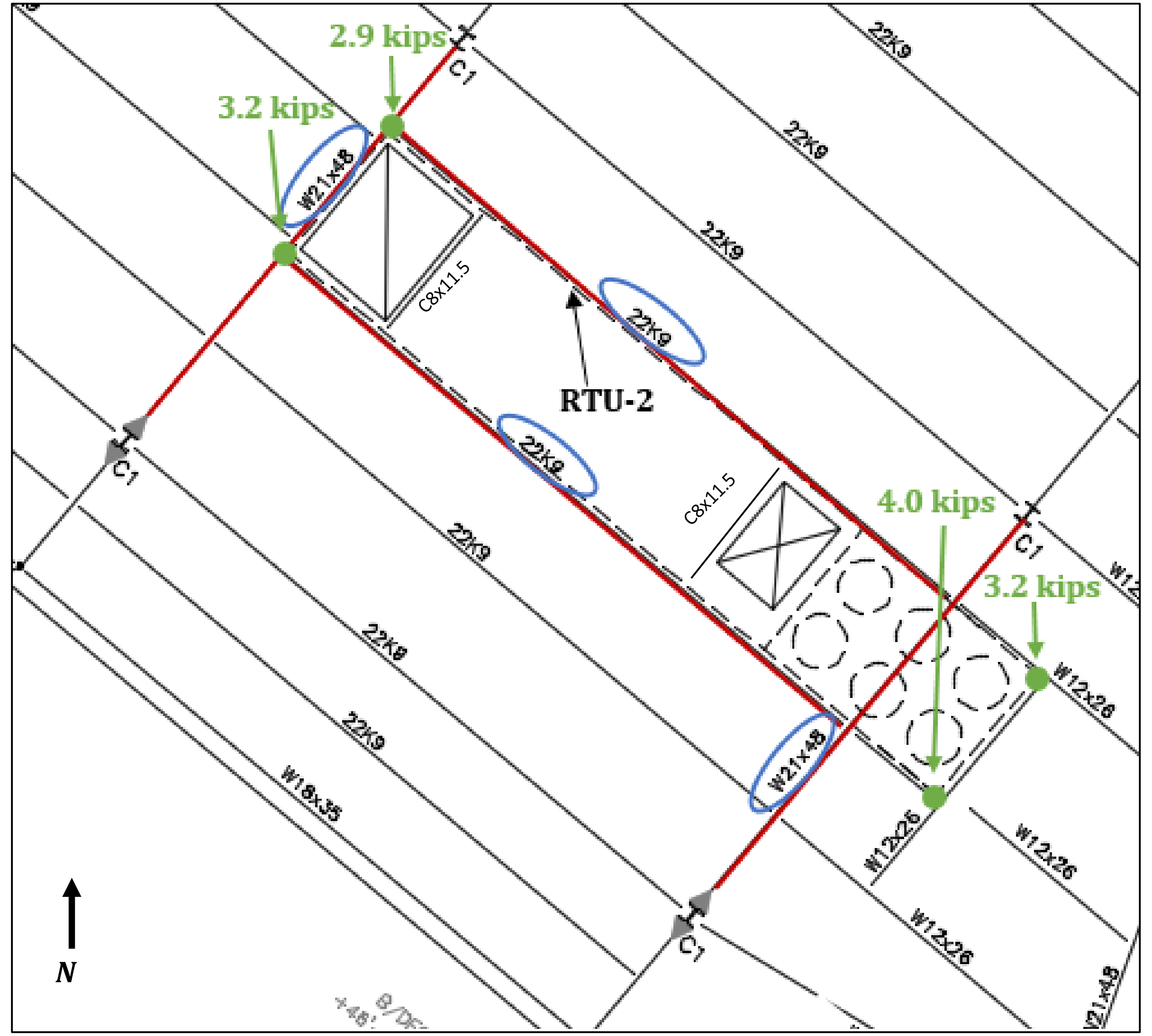
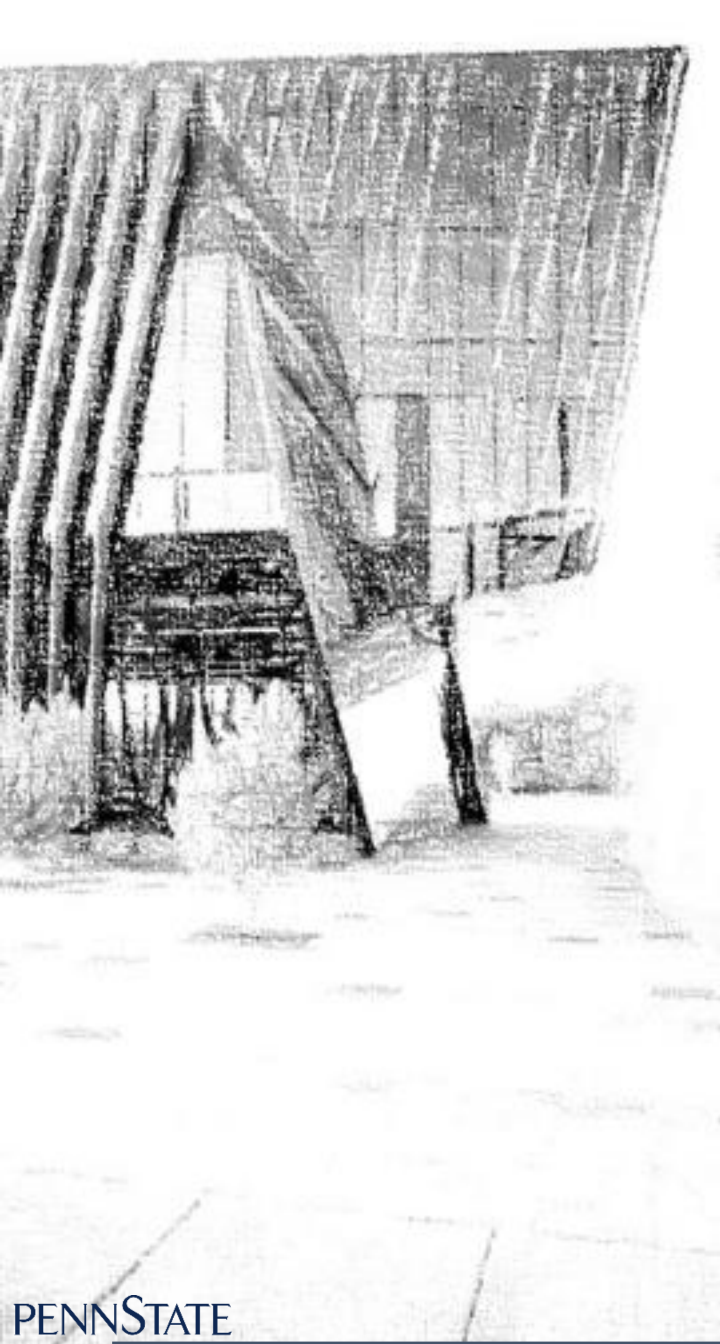
RTU-2 Analysis





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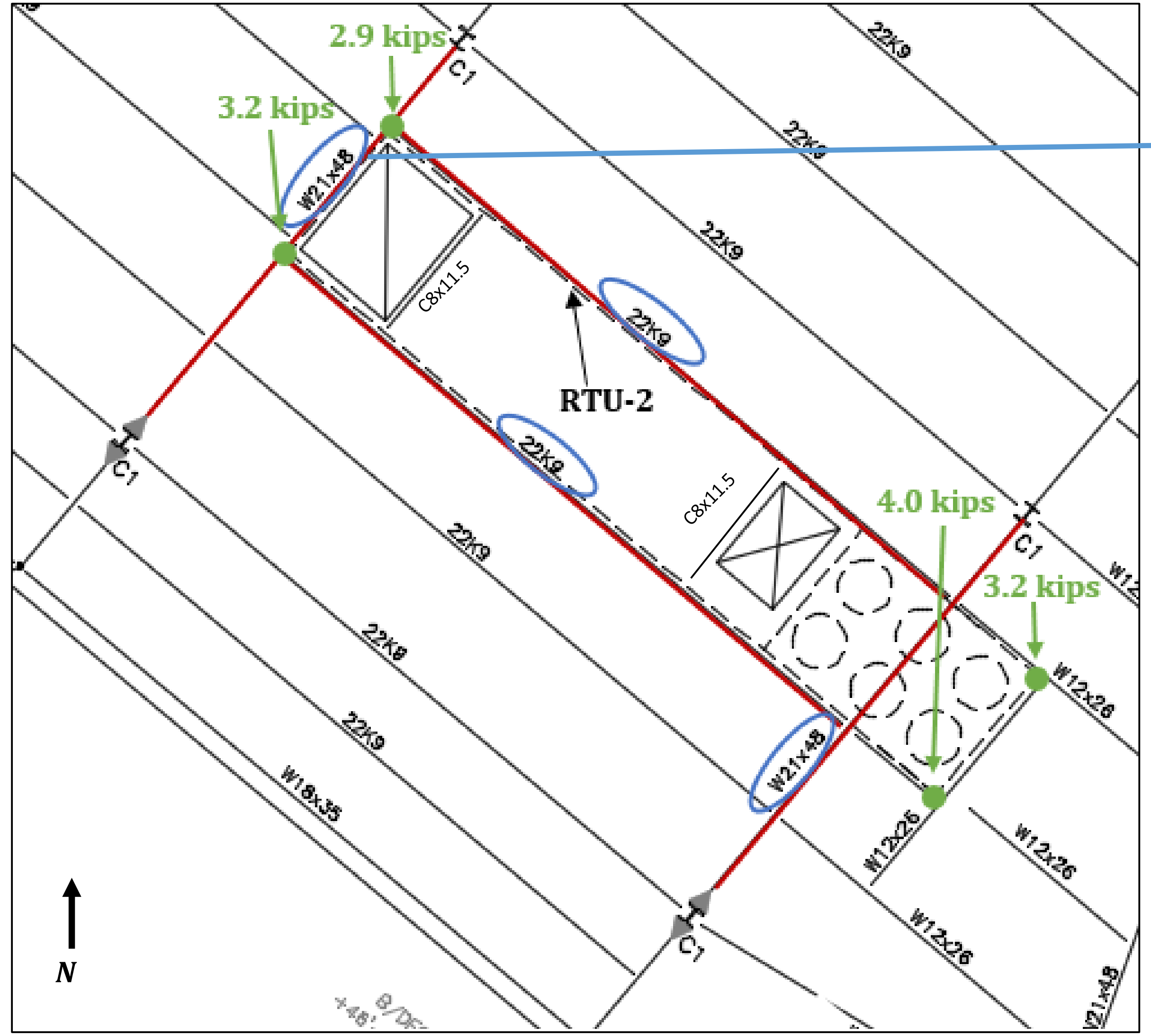
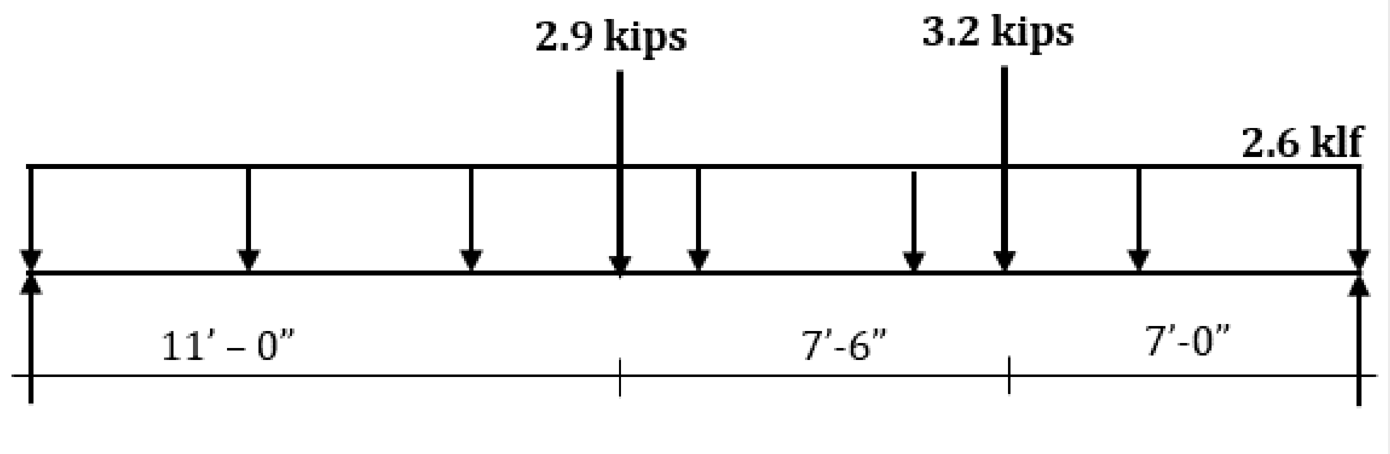
RTU-2 Analysis





➢ Building Summary

➢ Thesis Objective

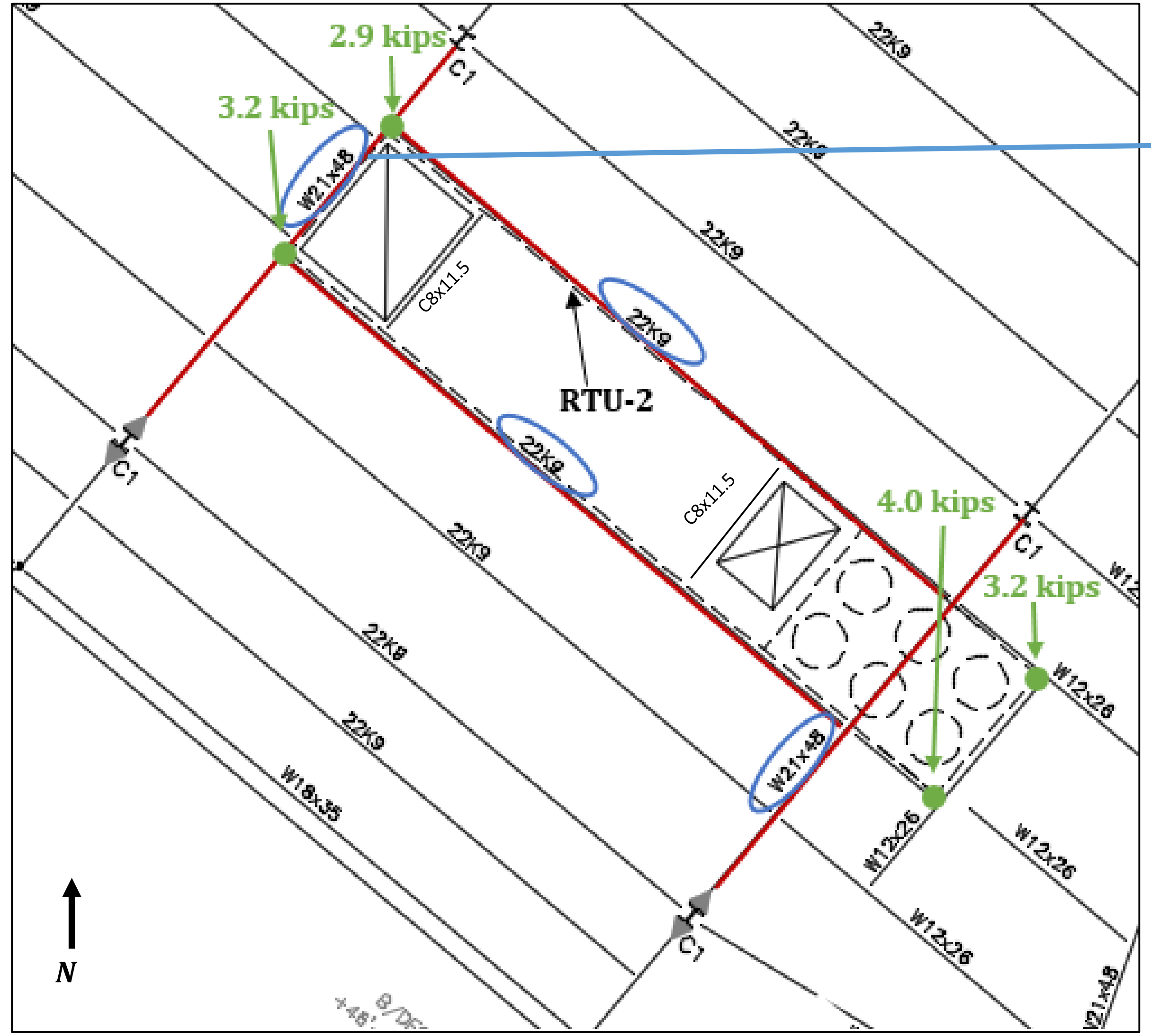
➢ Mechanical Depth

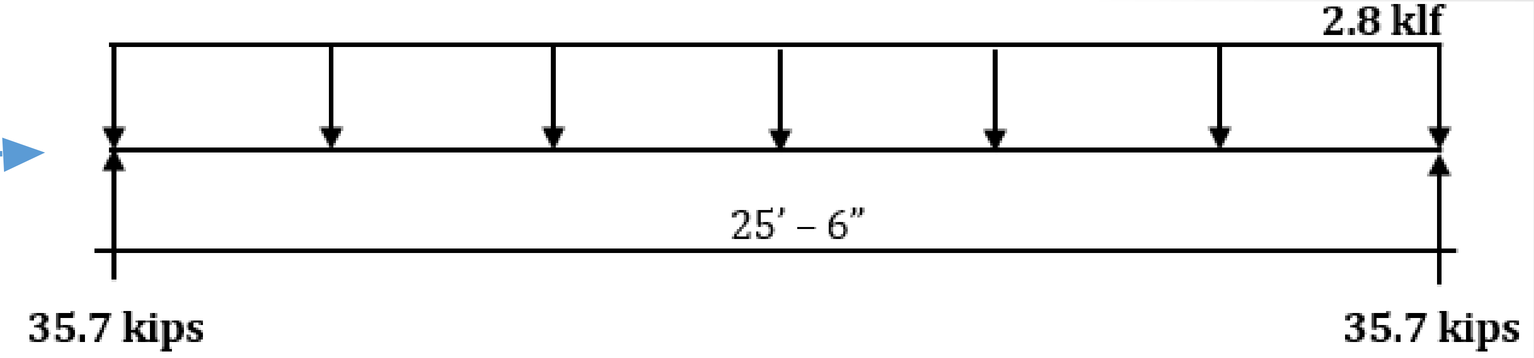
➢ **Structural Breadth**
   ➢ **RTU-2**
   ➢ RTU-1
   ➢ Conclusion

➢ Electrical Breadth

➢ Evaluation & Conclusion

RTU-2 Analysis





Mid Span Moment $M = \frac{wl^2}{8} = \frac{(2.8\,klf)(25.5\,ft)^2}{8} = 228\ kip - ft$

Max Deflection $\Delta \leq \frac{L}{240} = \frac{25.5\,ft * 12\frac{in}{ft}}{240} = 1.275\ in.$

- Building Summary
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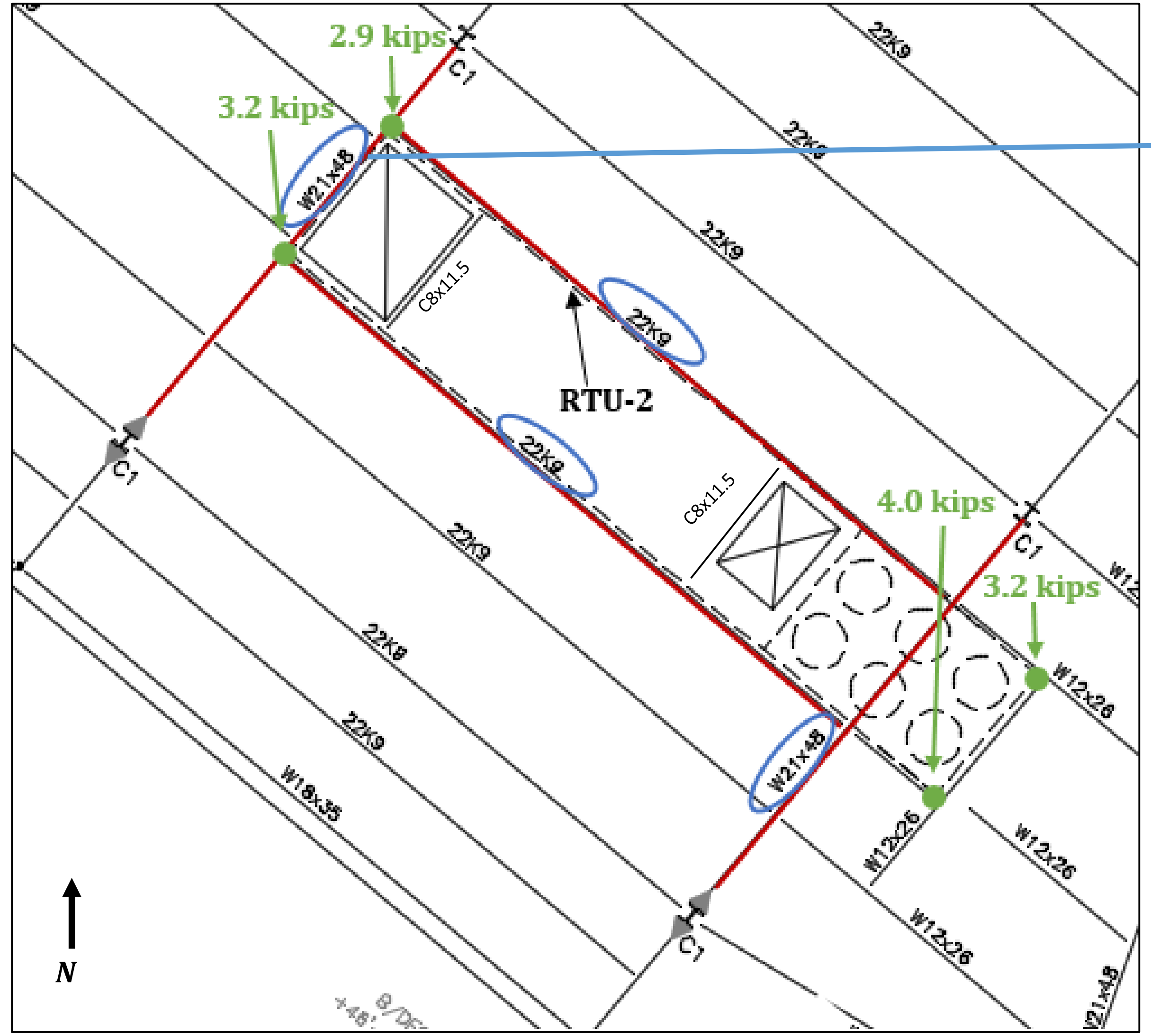
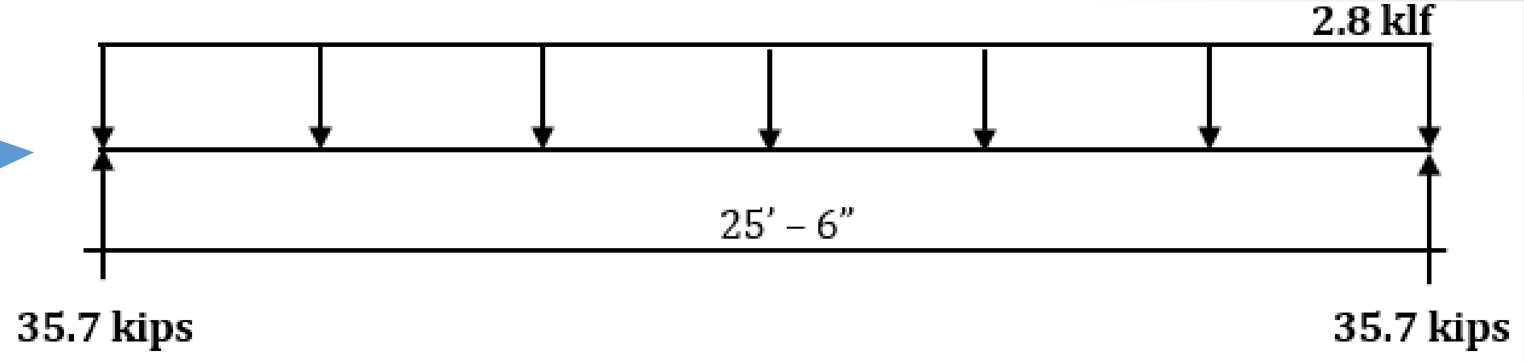
RTU-2 Analysis



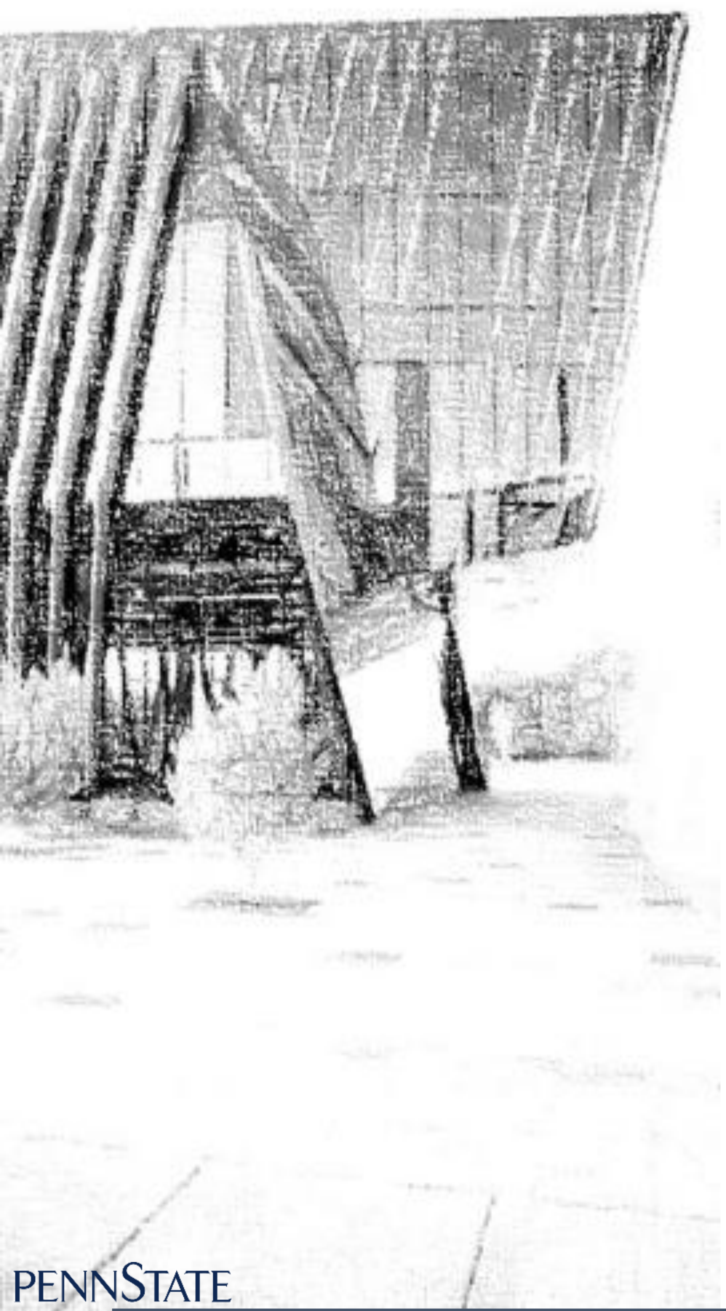


Mid Span Moment $M = \frac{wl^2}{8} = \frac{(2.8\ klf)(25.5\ ft)^2}{8} = \boxed{228\ kip-ft}$

Max Deflection $\Delta \leq \frac{L}{240} = \frac{25.5\ ft * 12\frac{in}{ft}}{240} = \boxed{1.275\ in.}$

W21x44 $(I_x = 843)$
(Max M = $\boxed{358\ kip\text{-}ft) ✓}$

$$\Delta = \frac{5wl^4}{EI} = \frac{5\left(233.3\frac{lb}{in}\right)(306\ in)^4}{384(30 * 10^6\frac{lb}{in^2})(843\ in^4)} = \boxed{1.053\ in.\ ✓}$$



- Building Summary
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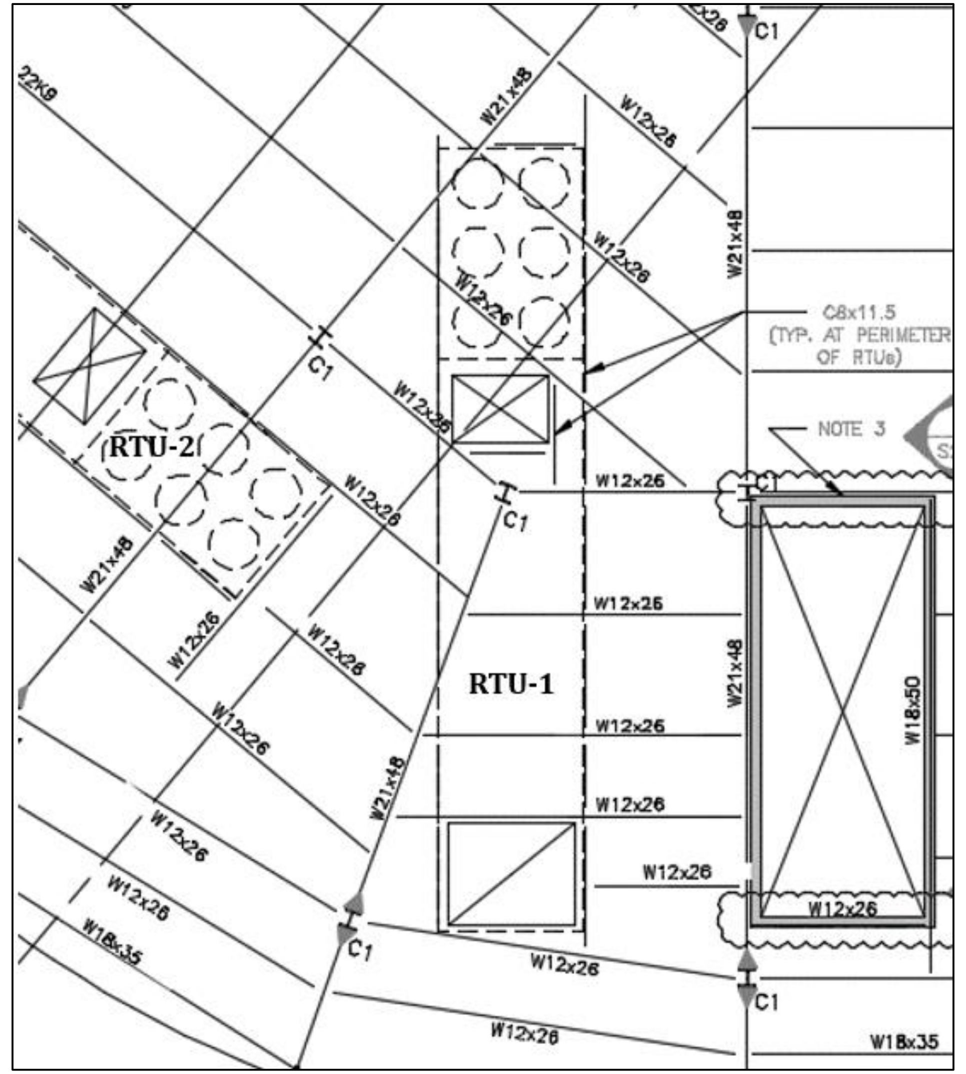
  - Conclusion
- Electrical Breadth
- Evaluation & Conclusion

RTU-1 Analysis

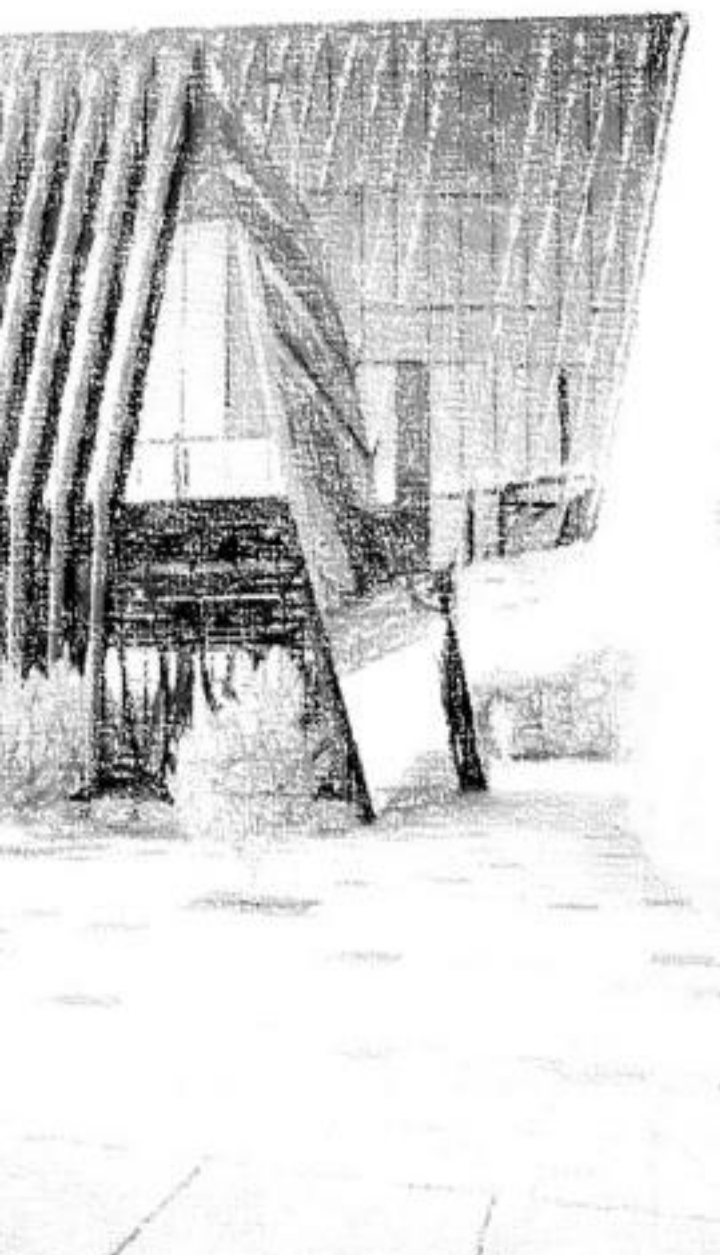


These beams are not reduced in size because the structural engineer did not use a smaller beam than W12x26.

Structural Breadth Conclusion

Beam Size	Existing Design Length (ft)	New Design Length (ft)	Cost ($/LF)
C8x11.5	151	124	$83.68
W21x44	0	51	$84.21
W21x48	51	0	$94.34
Total Cost	*$17,447*	*$14,671*	

New design leads to $2,800 in savings



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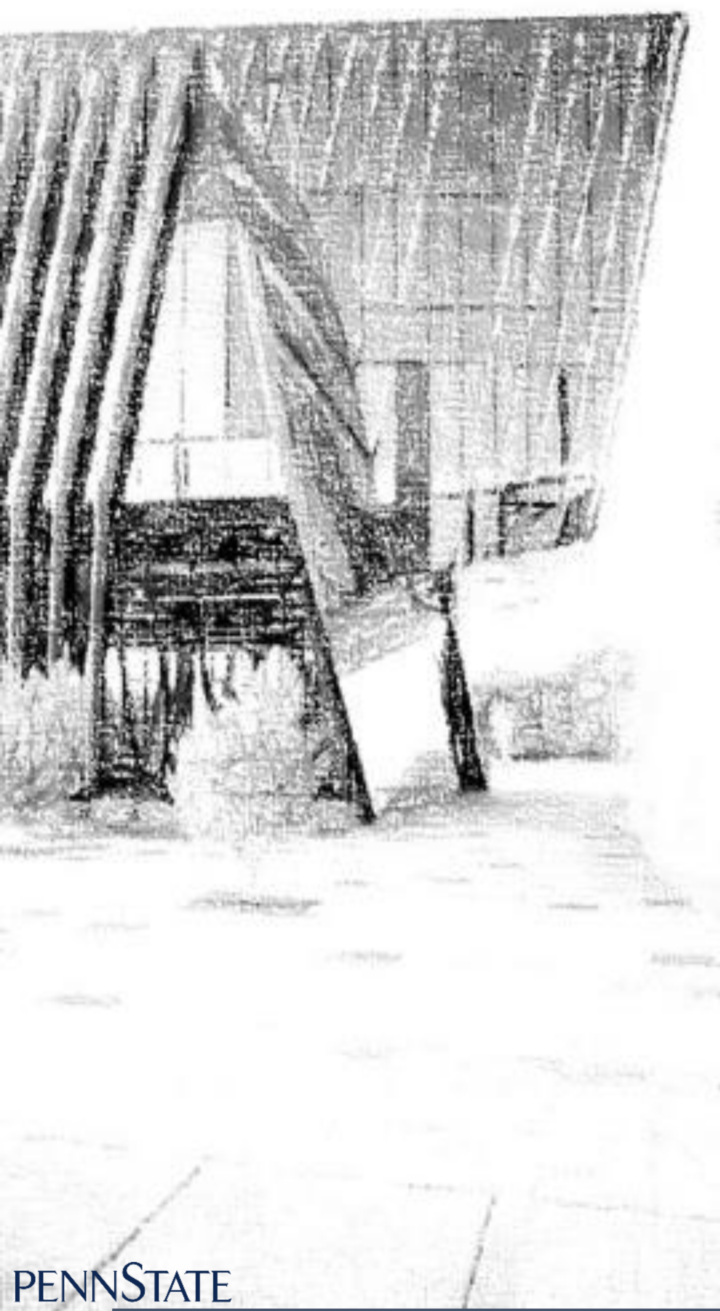
Structural Breadth Conclusion

Beam Size	Existing Design Length (ft)	New Design Length (ft)	Cost ($/LF)
C8x11.5	151	124	$83.68
W21x44	0	51	$84.21
W21x48	51	0	$94.34
Total Cost	*$17,447*	*$14,671*	

New design leads to $2,800 in savings

- Structural steel savings are a result of a different design approach.
- There would be negligible structural steel savings associated with designing to the IBC rather than the CBC with regards to the mechanical system.



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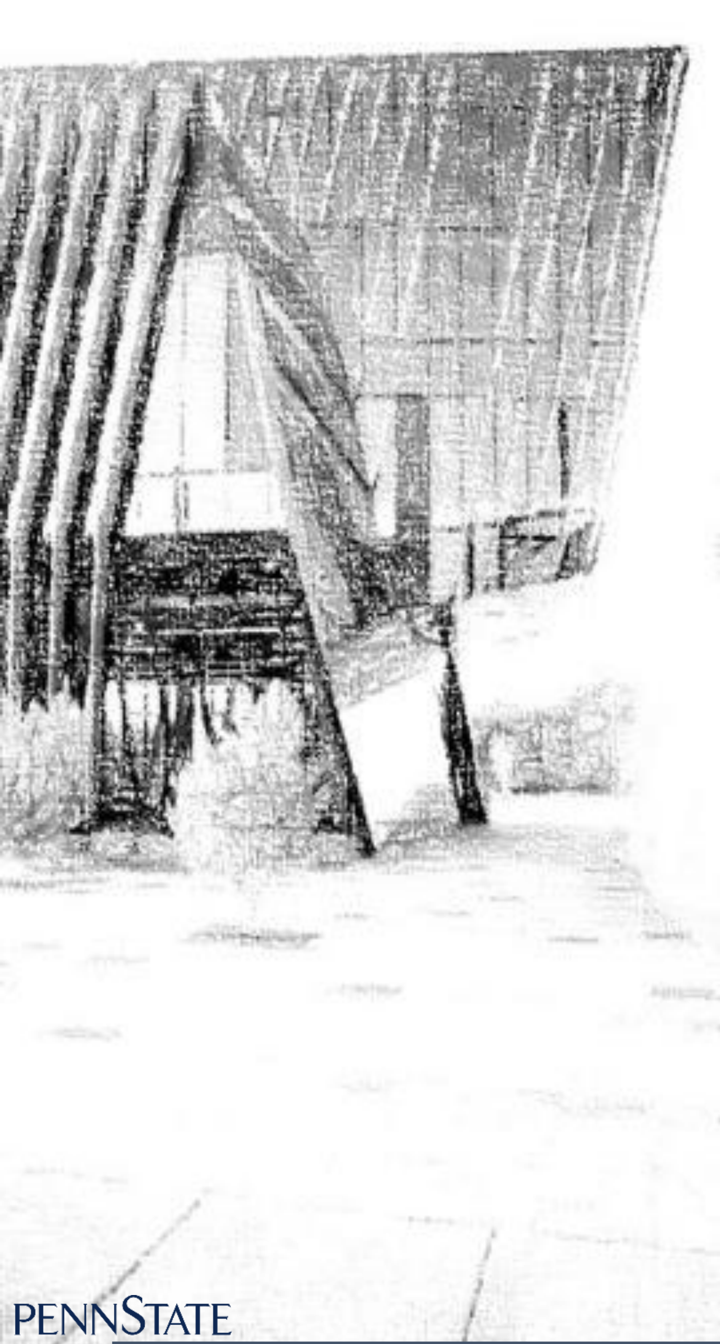
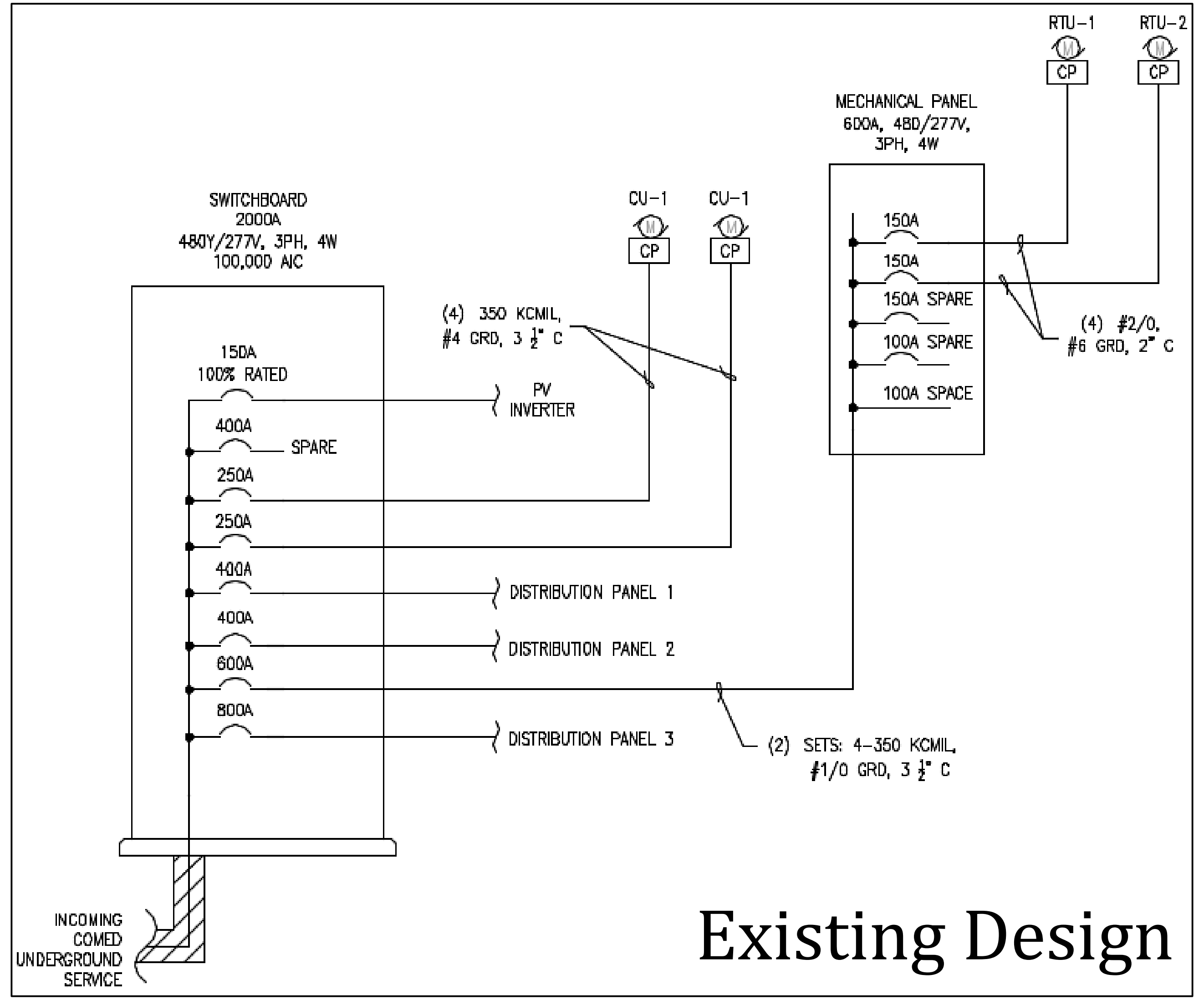
- **Electrical Breadth**
- Evaluation & Conclusion

Electrical Breadth

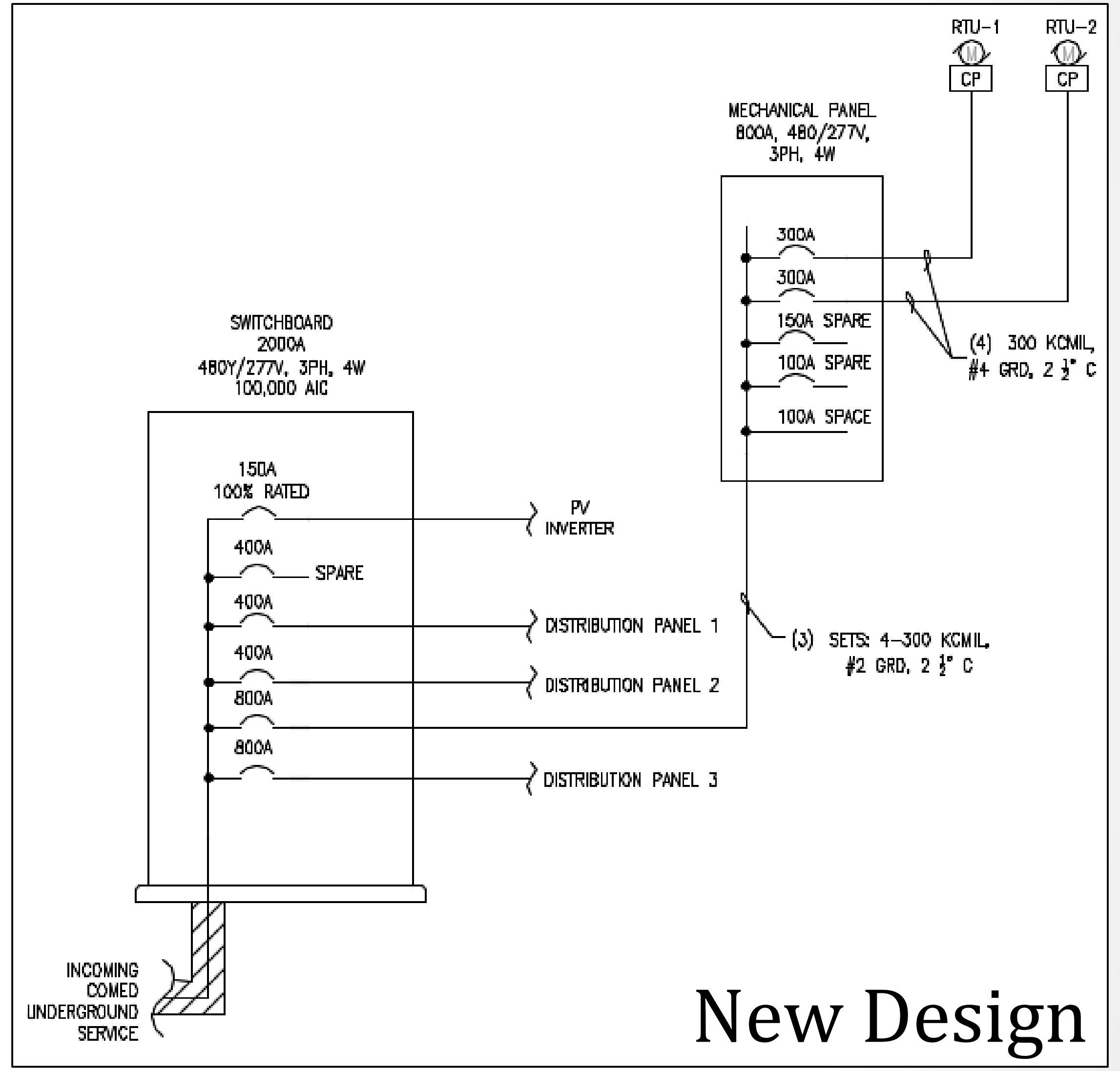
Will smaller RTU's designed according to the IBC lead to a reduction in electrical wiring?



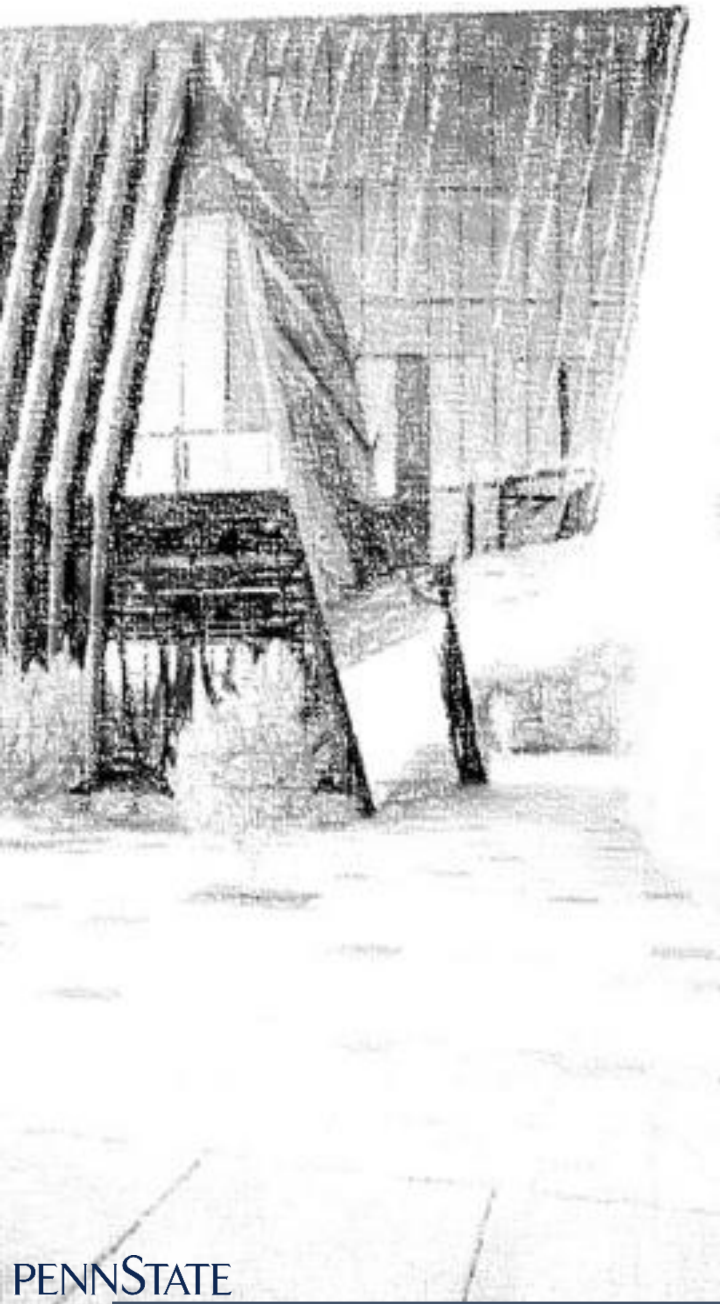
Electrical Breadth



Existing Design

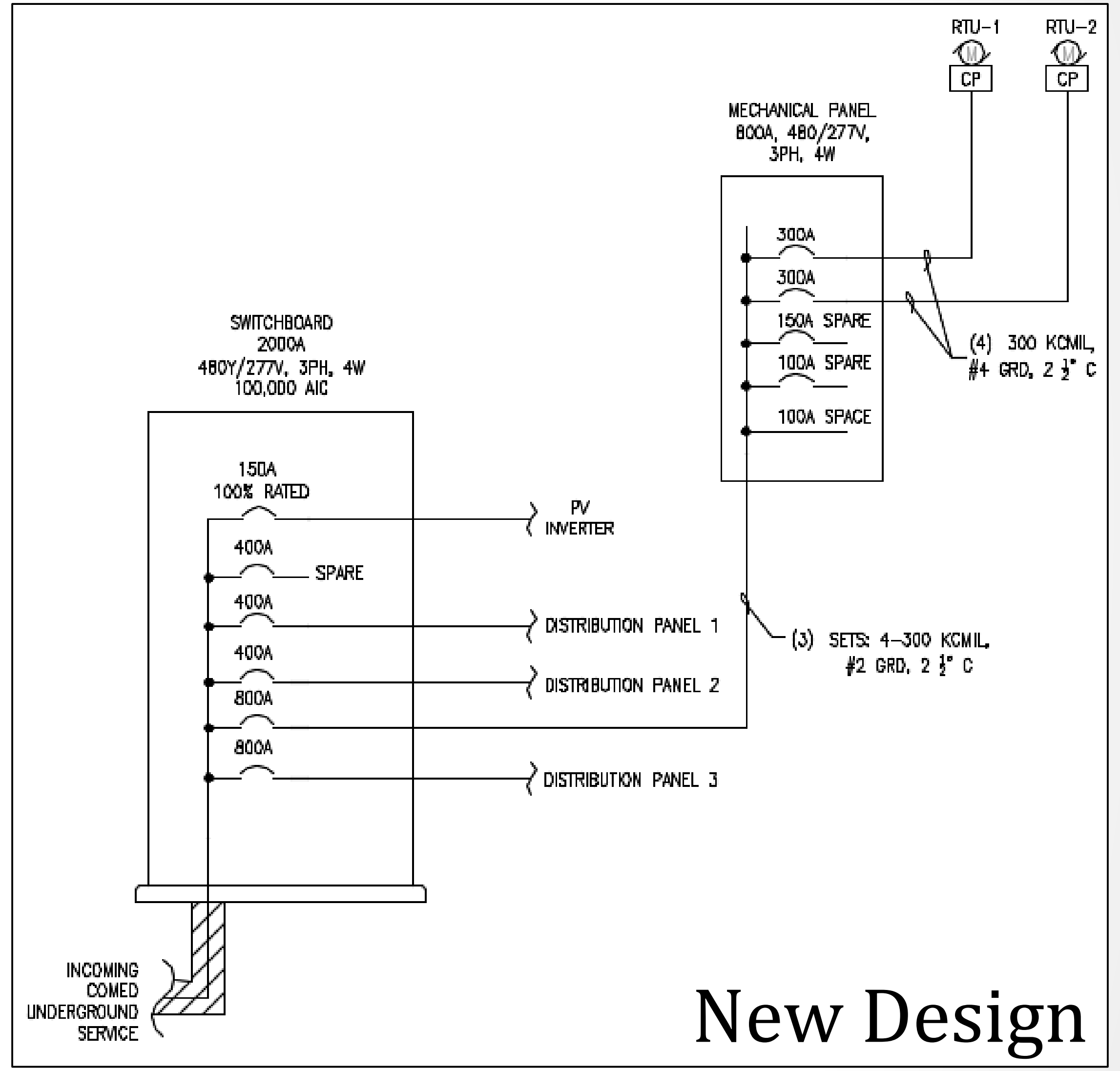


New Design

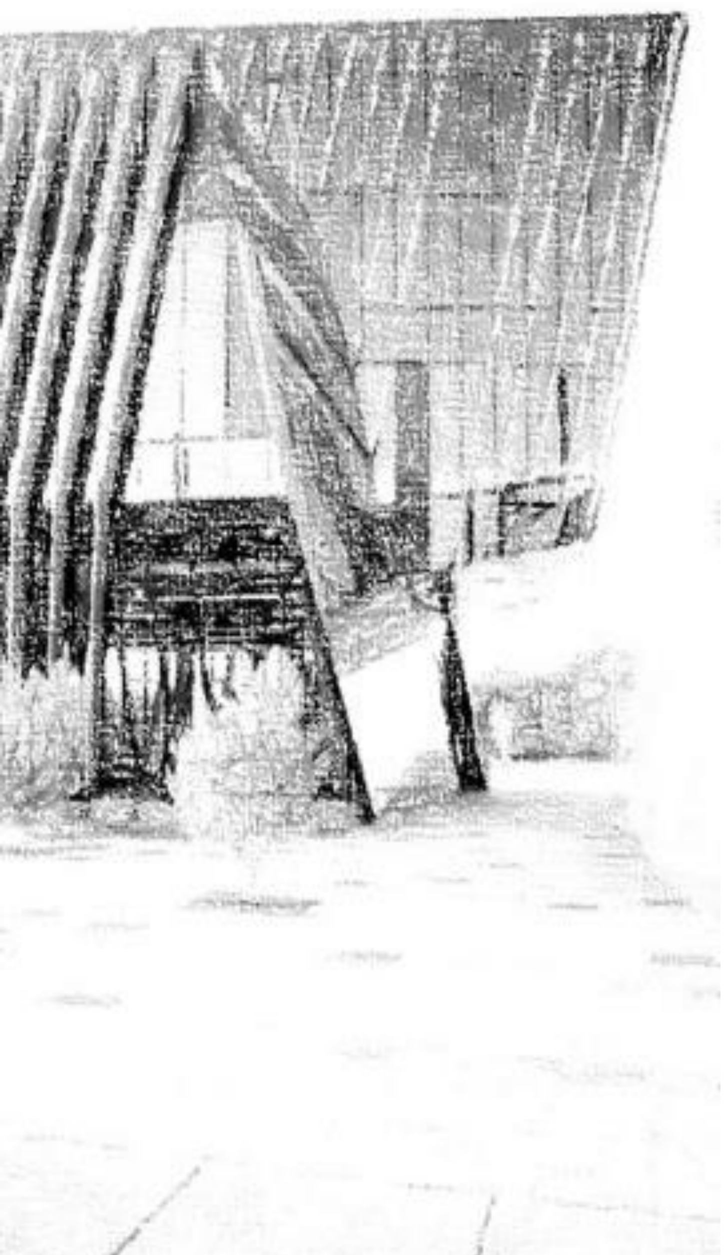


Electrical Breadth

- The same as structural, using the IBC in lieu of the CBC will lead to minimal to no electrical cost savings
- The savings associated were a result of a different design strategy



New Design



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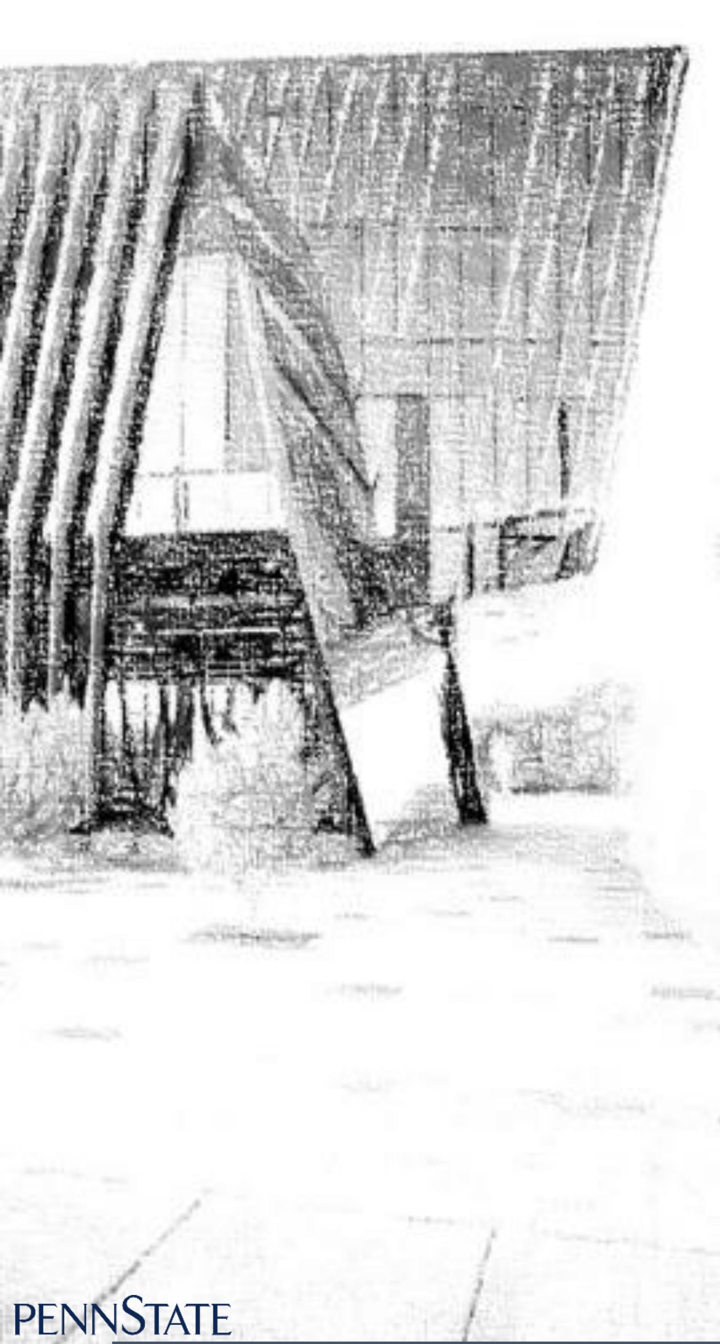
  - **City of Chicago Study**
  - Overall Evaluation
  - Acknowledgements

City of Chicago Study



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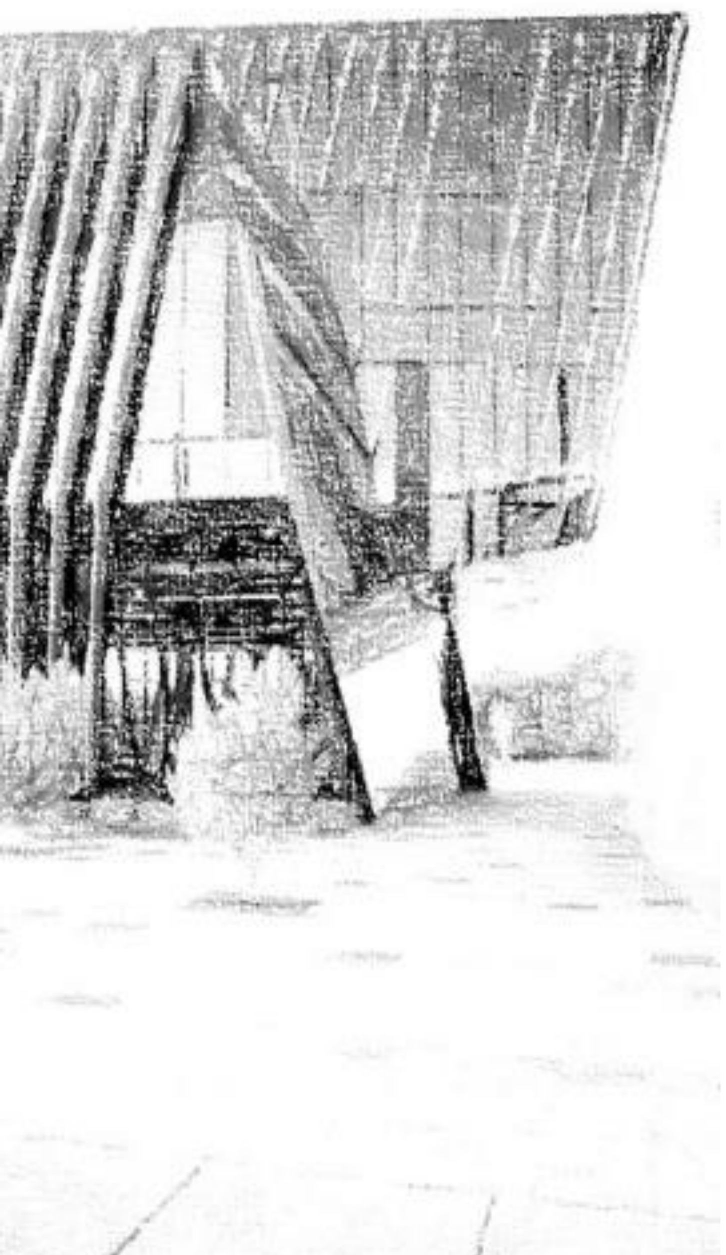
City of Chicago Study

CHICAGO CLIMATE ACTION PLAN

Reduce Chicago's greenhouse gas emissions by 80% below 1990 levels by 2050

- **Energy Efficient Buildings (30%)**
- Clean & Renewable Energy Sources (34%)
- Improved Transportation Options (23%)
- Reduction Waste & Industrial Pollution (13%)
- Adaptation



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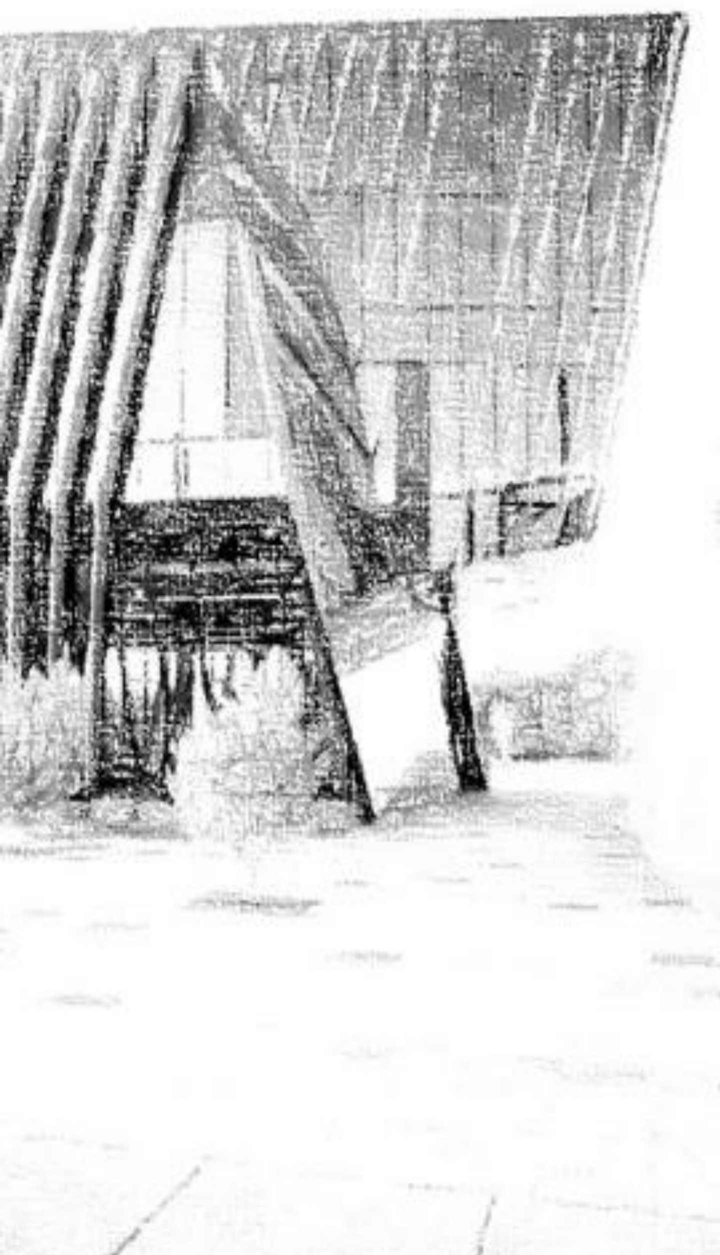
City of Chicago Study

Chicago Building Energy
$3 billion per year

Potential Savings 2.9%
$87 million per year



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City of Chicago Study

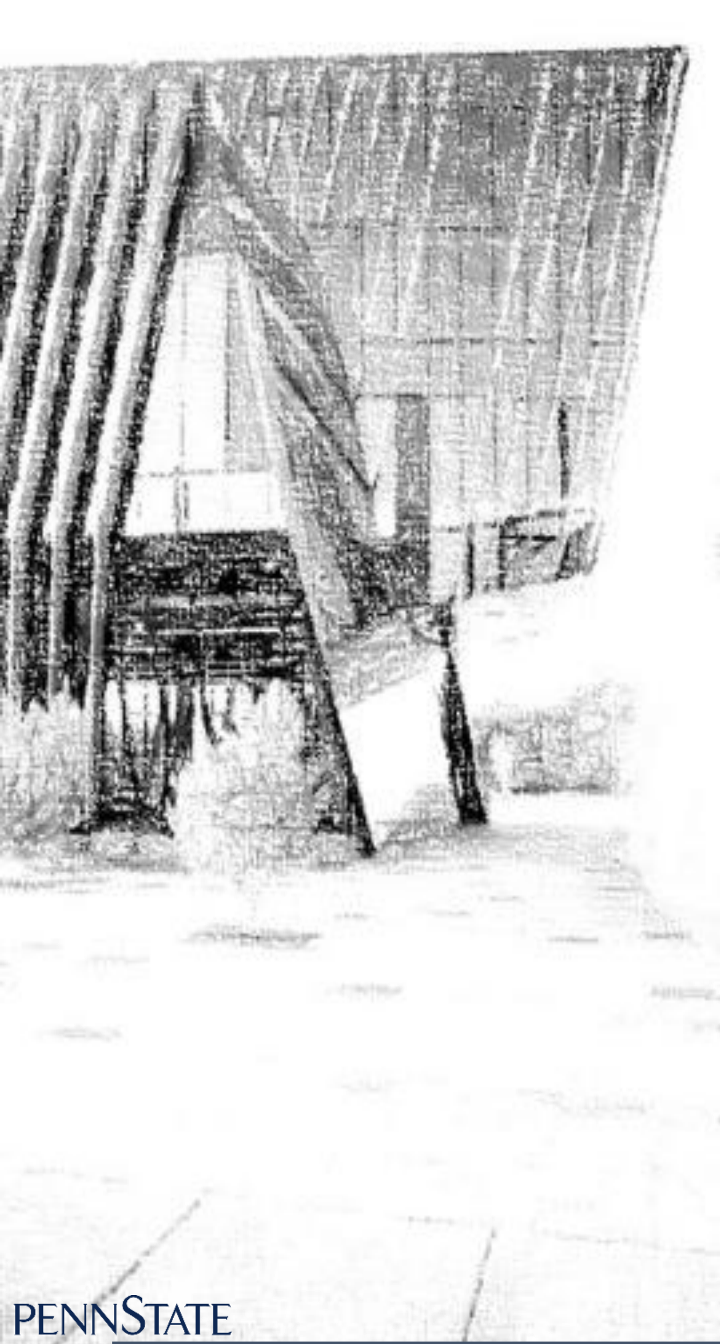
Chicago Building Energy
$3 billion per year

Potential Savings 2.9%
$87 million per year

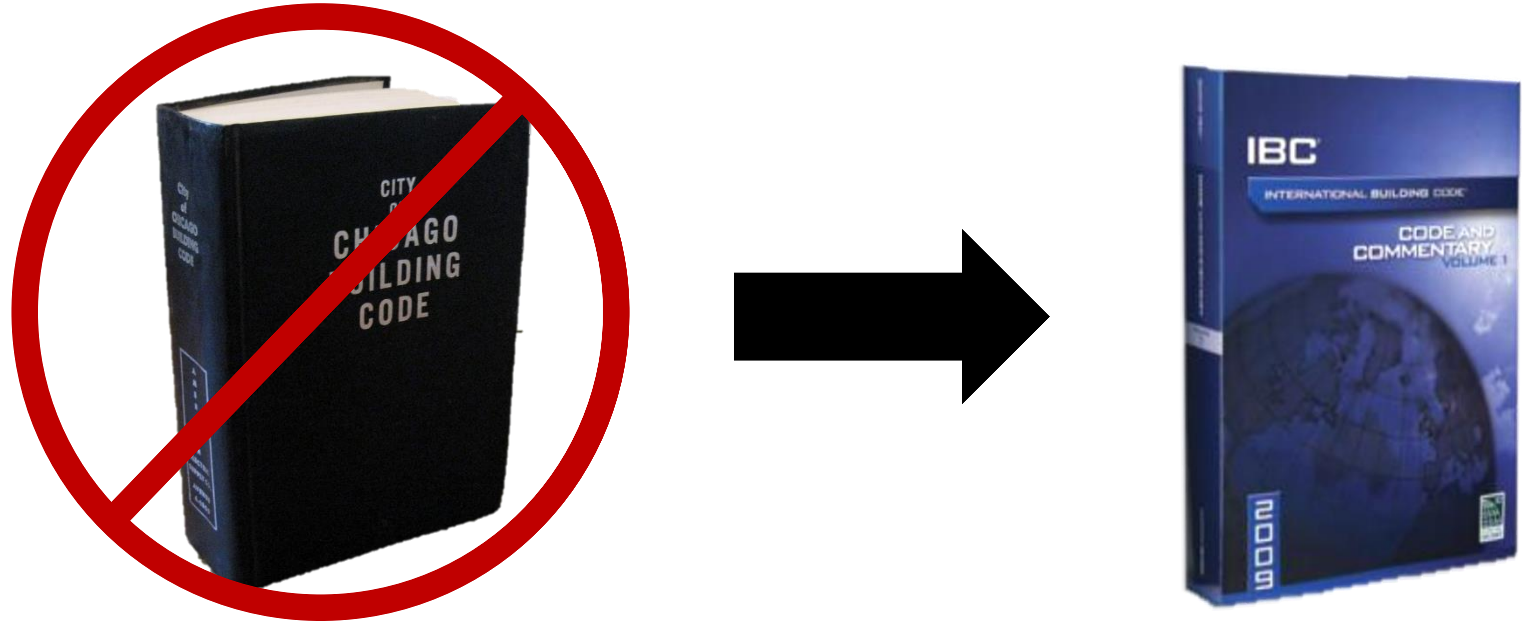
Chicago Building Emissions
63 billion lbs. CO_{2e} per year

Potential Savings 2.42%
1.5 billion lbs. CO_{2e} per year

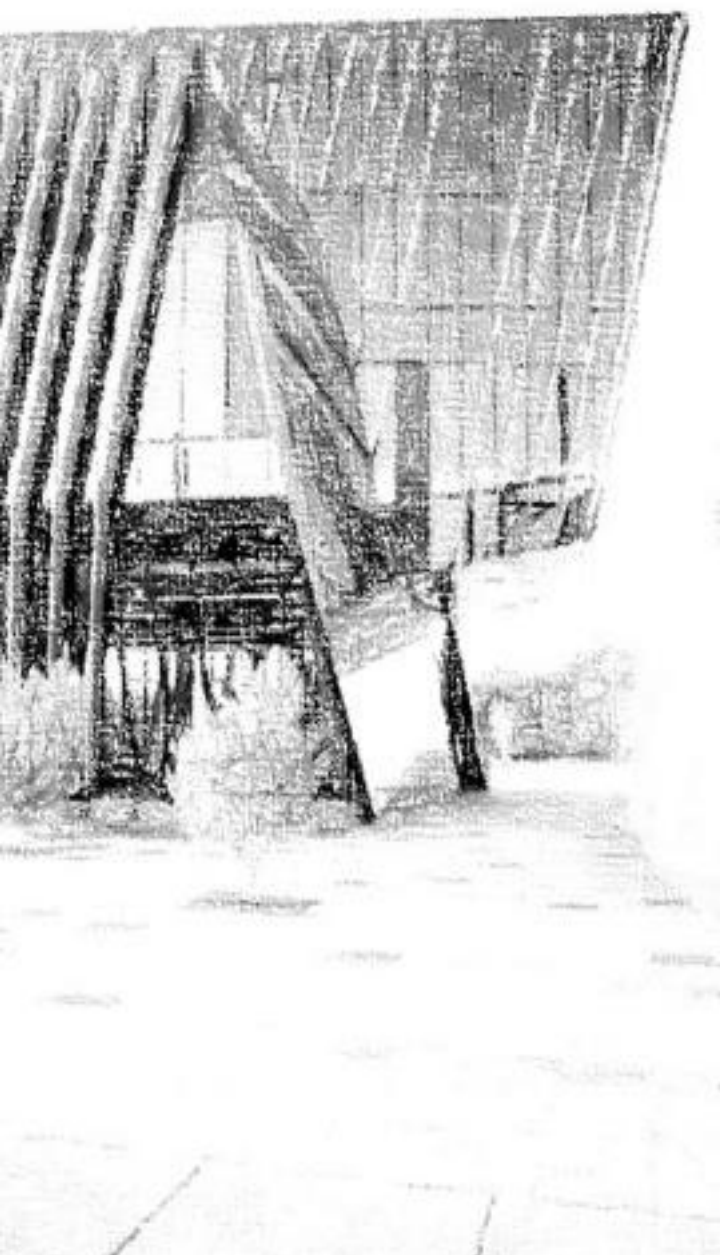
Equivalent to taking 184,000 cars off of the road



Overall Evaluation



- Possible Mechanical First Cost Savings
- No Structural or Electrical Cost Savings
- Energy Cost Savings 2.9%
- Emission Savings 2.42%



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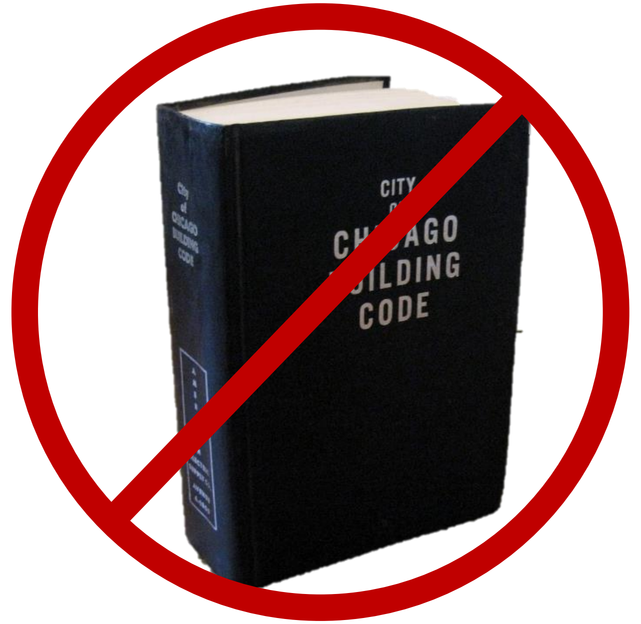
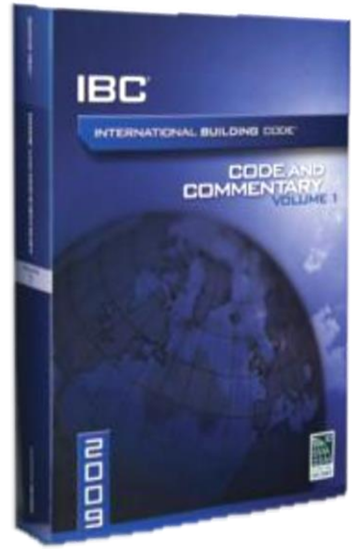
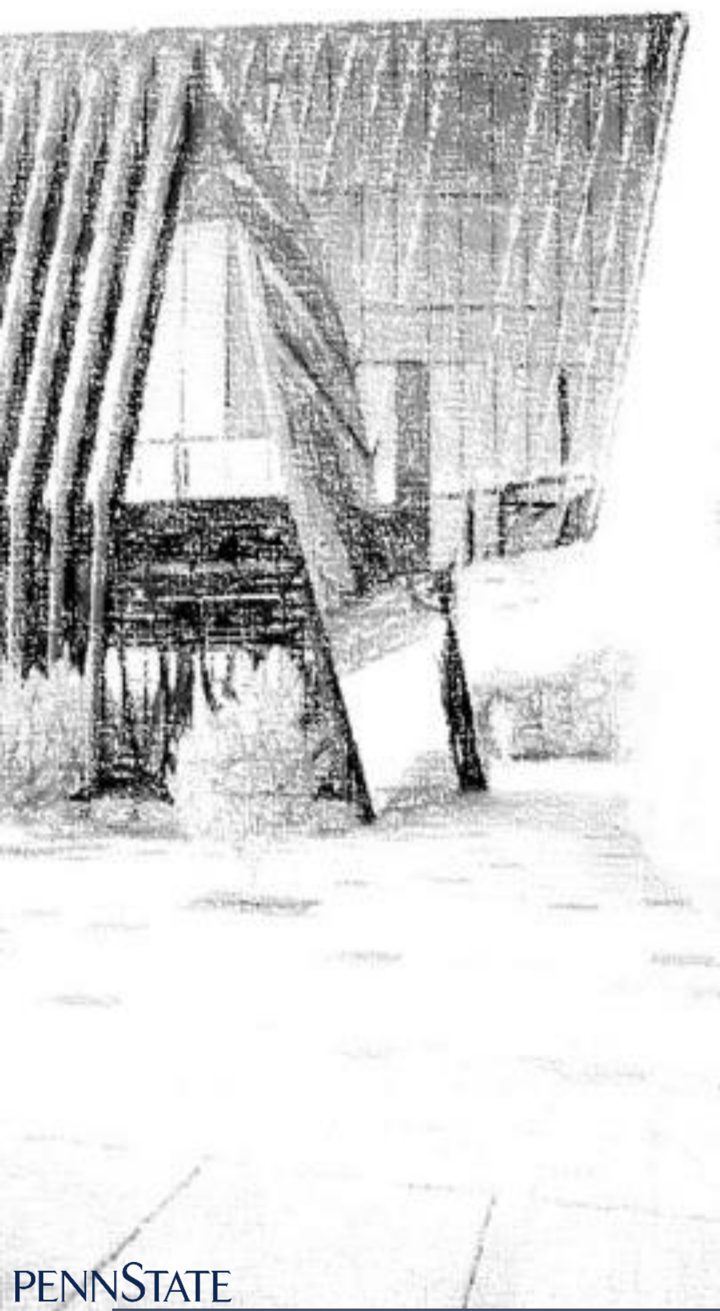
Overall Evaluation



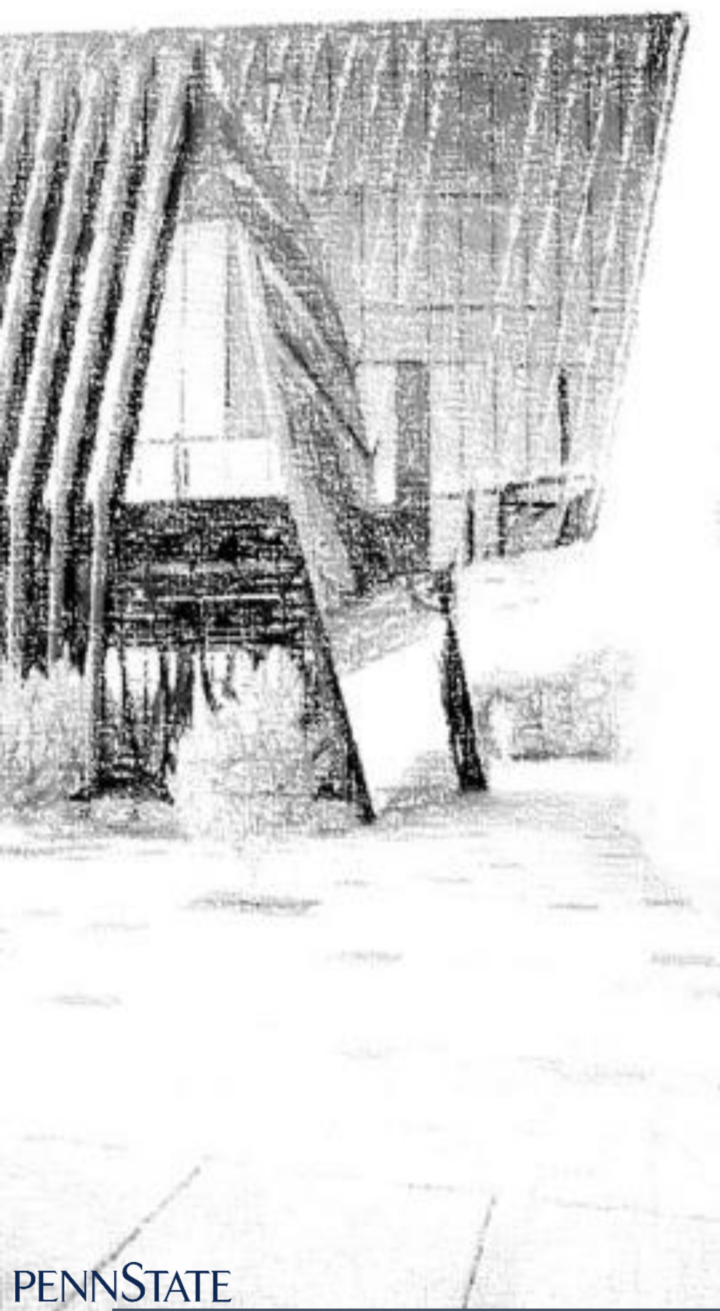


- Possible Mechanical First Cost Savings
- No Structural or Electrical Cost Savings
- Energy Cost Savings 2.9%
- Emission Savings 2.42%
- Minimal Impact on a small scale
- Big impact on a large scale



Acknowledgements

- Primera Engineers
- Professor Freihaut
- Penn State AE Faculty and Staff
- Friends and Family
- And of course,



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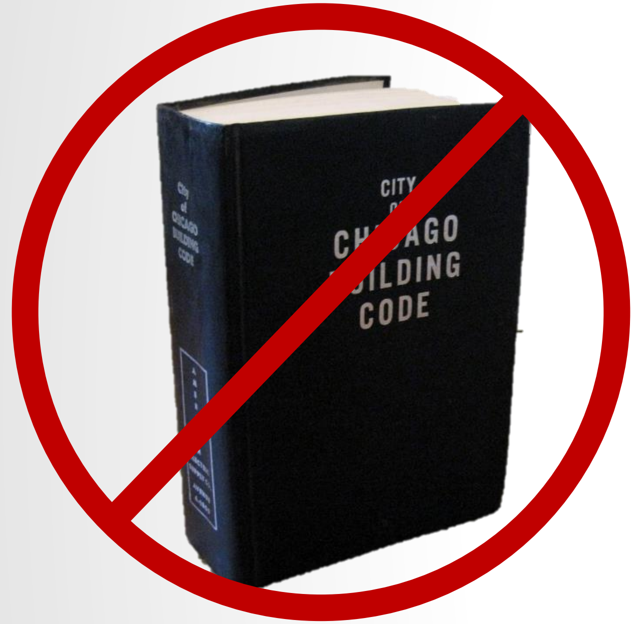
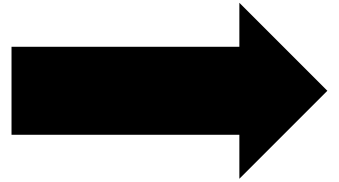
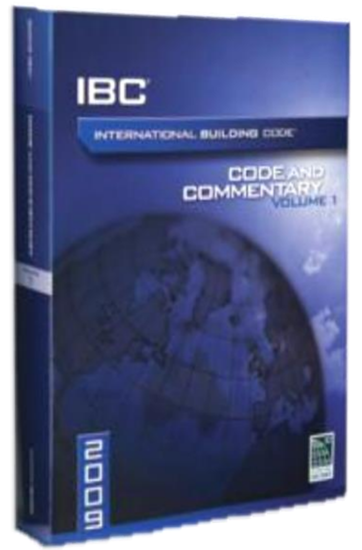
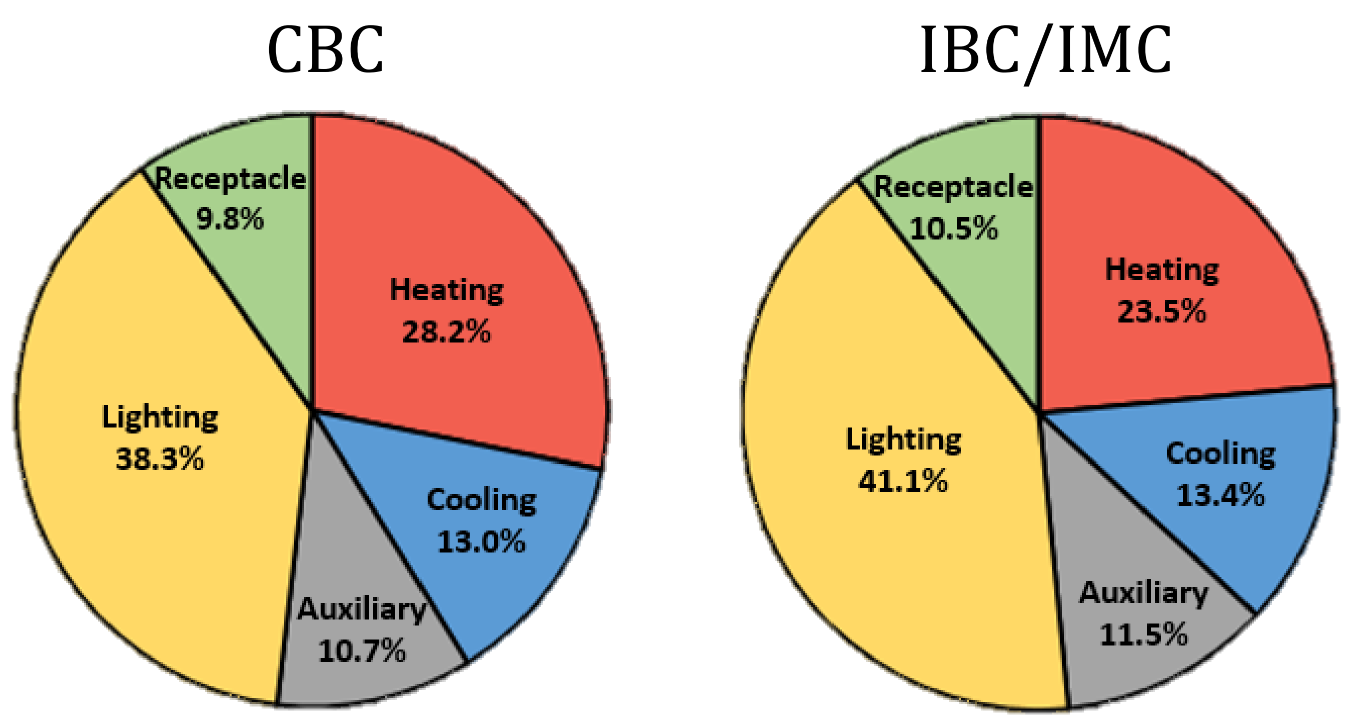
- And of course, President Obama

Questions?









Summary of Savings	Energy Savings		Annual Cost Savings		Emission Savings	
	%	kBtu/year	%	$/year	%	lbs. CO_{2e}/yr
NEIU El Centro	6.70%	232,000	2.90%	$1,850	2.42%	33,600
City of Chicago	6.70%	10.4 billion	2.90%	$87 million	2.42%	1.5 billion

Electrical Appendix

System	Equipment	V/PH/Hz	FLA	MOCP	kVA	Wire (Copper) (THWN)	Ground (Copper)	Conduit (EMT)
Existing	RTU-1	460/3/60	149	150 A	124	(4) #2/0	#6	2"
	RTU-2	460/3/60	149	150 A	124	(4) #2/0	#6	2"
	CU-1	460/3/60	227	250 A	189	(4) 350 kcmil	#4	3 1/2"
	CU-2	460/3/60	227	250 A	189	(4) 350 kcmil	#4	3 1/2"
New	RTU-1	460/3/60	257	300 A	214	(4) 300 kcmil	#4	**2 1/2"**
	RTU-2	460/3/60	257	300 A	214	(4) 300 kcmil	#4	**2 1/2"**

Table 26 – Existing and New Branch Wire Sizing for RTUs

$$[300\ kcmil] \quad 0.4608\ in^2 * 4 = 1.8432\ in^2$$
$$[\#4] \quad 0.0824\ in^2 * 1 = 0.0824\ in^2$$

$1.9256\ \text{in}^2$ ∴ use **2 ½" Conduit**

System	Panel Label	Equipment Served	Voltage	FLA	kVA	MOCP	Feeder Size (Copper, THWN, EMT)
Existing	DPM3-1	RTU-1 & RTU-2	480/277	298	248	600 A	(2) sets: 4-350 kcmil, #1/0 Grd, 3 1/2" C
New	DPM3-1	RTU-1 & RTU-2	480/277	514	428	800 A	(3) sets: 4-300 kcmil, #2 Grd, **2 1/2" C**

Table 27 – Existing and New Feeder Sizing for RTUs

$$[300\ kcmil] \quad 0.4608\ in^2 * 4 = 1.8432\ in^2$$
$$[\#2] \quad 0.1158\ in^2 * 1 = 0.1158\ in^2$$

$1.959\ \text{in}^2$ ∴ use **2 ½" Conduit**

City of Chicago Appendix

Total Amount Chicago Spends on Building Energy ($)	Potential Savings (%)	Potential Savings ($)
$3 billion	2.90%	**$87 million**

Total Amount of Energy Used by Chicago Buildings (kBtu/year)	Potential Savings (%)	Potential Savings ($/year)
155 billion kBtu	6.70%	**10.4 billion kBtu**

Unit	Total Pollutants Produced by Chicago Buildings (CO_{2e}/year)	Potential Savings (%)	Potential Savings (CO_{2e}/year)
lbs. CO_{2e}/year	63 billion lbs.	2.42%	**1.5 billion lbs.**
tons CO_{2e}/year	31.6 million tons	2.42%	**765,000 tons**
Equivalent of Cars on the Road per year	7.6 million cars	2.42%	**184,000 cars**

Rank	City	Country	No. of Skyscrapers
1	Hong Kong	China	302
2	New York City	United States	235
3	Dubai	United Arab Emirates	148
4	Shanghai	China	126
5	**Chicago**	**United States**	**115**
6	Tokyo	Japan	112
7	Chongqing	China	94
8	Guangzhou	China	93
9	Shenzhen	China	83
10	Singapore	Singapore	79

Building Type	kBTU/ft^2/yr
Large Office	43
Medium Office	48
Small Office	51
Warehouse	24
Stand-alone Retail	81
Strip Mall	85
Primary School	65
Secondary School	76
Supermarket	195
Quick Service Restaurant	657
Hospital	148
Outpatient Facility	271
Small Hotel	80
Large Hotel	138
Mid-Rise Apartment	47
NEIU El Centro*	**62**