

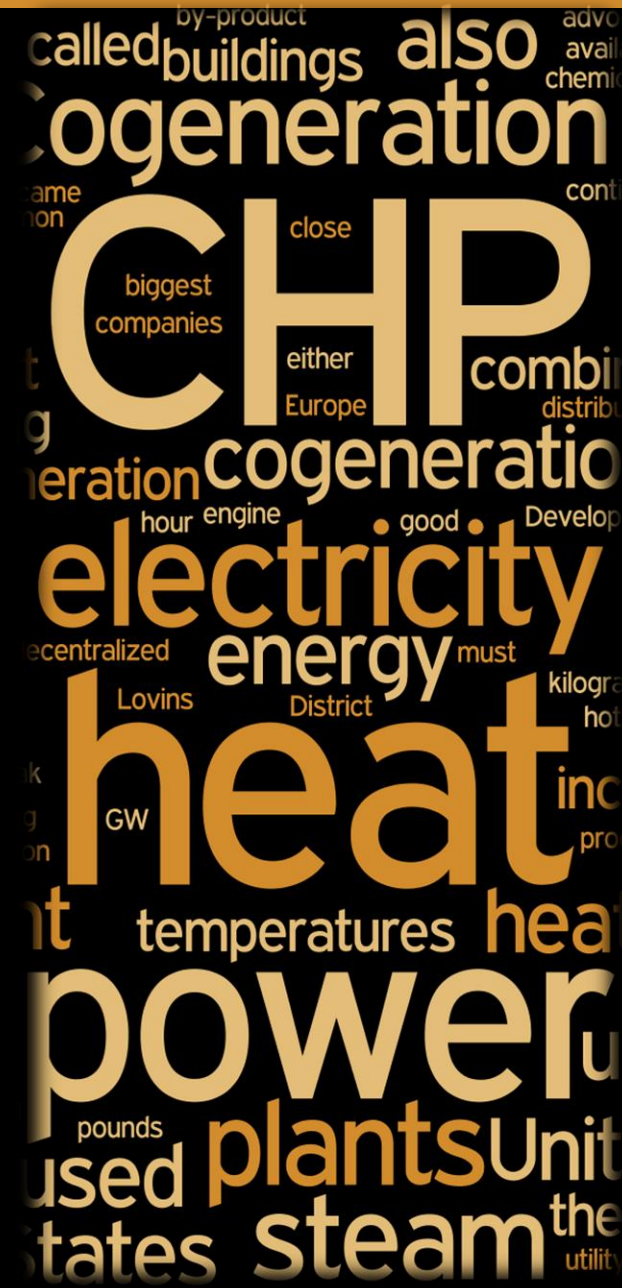
**Northfield Mental
Healthcare Center
Northfield, Ohio**



Senior Thesis 2013

**Ji Won Park
Mechanical Option**

Advisor: Dr. Stephen Treado



- Introduction
 - Northfield Mental Healthcare
 - Mechanical System
 - Design Goals
- Alternative 1: Cogeneration
- Alternative 2: Tri-generation
- Comparison
- Breadth: Electrical Breadth
- Summary
- Acknowledgements
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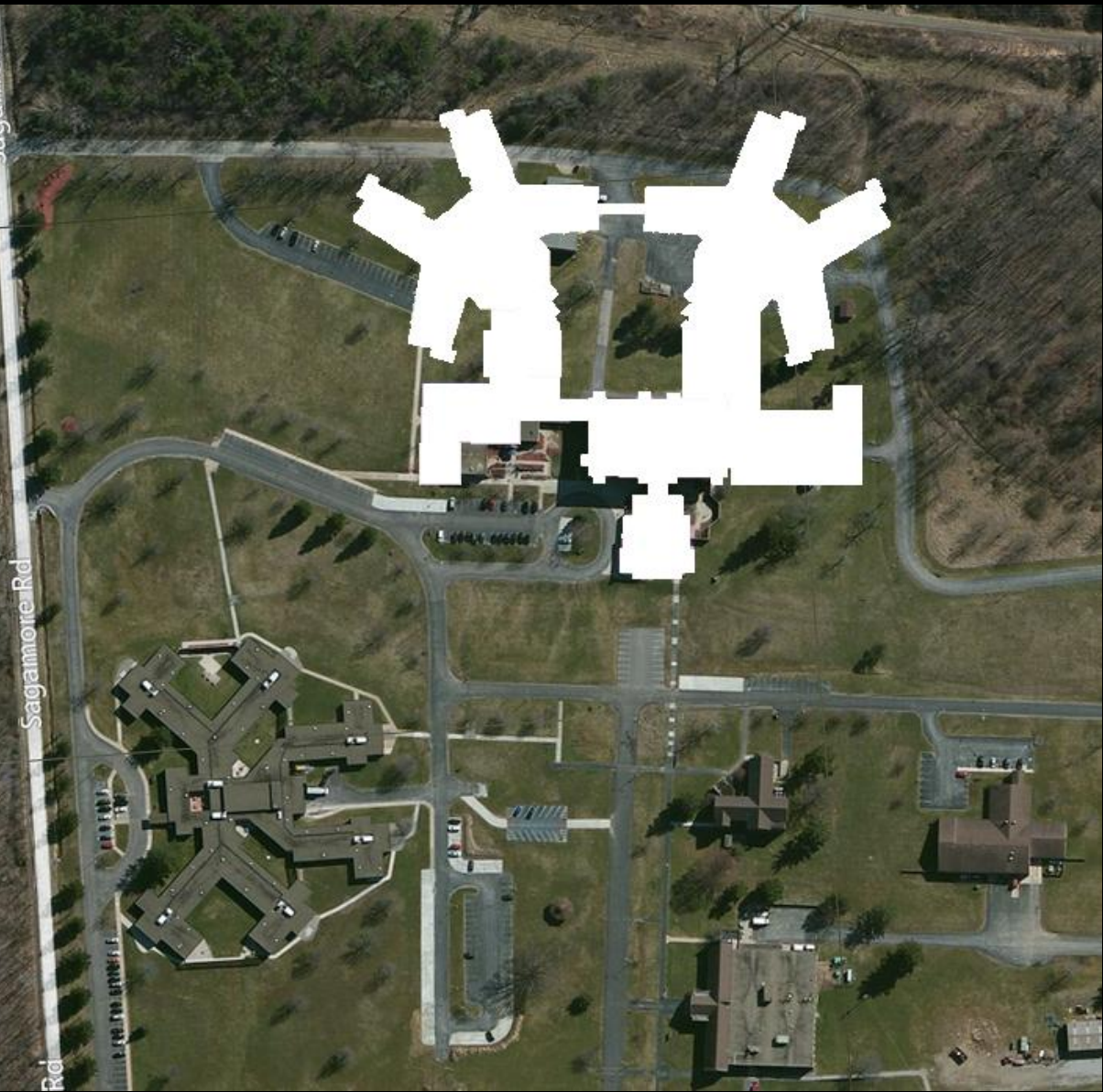
Function: mental clinic

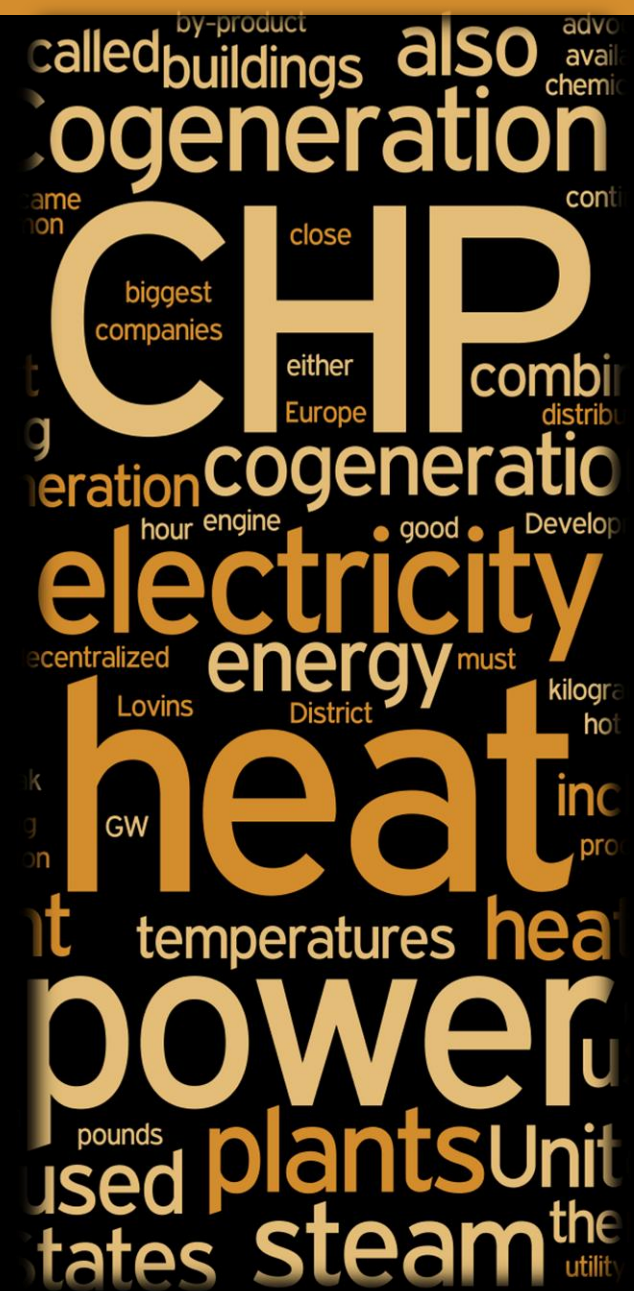
SIZE: ~260,000 SF
 (Additional 200,000 SF to existing 60,000 SF)

Overall Cost: ~62.5 million

Delivery Method: design-bid-build (multiple prime)

Construction Date: approx. April, 2013 – January, 2014





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- Owner: Ohio Department of Mental Health

- Architects: Hasenstab Architects, Inc.

- Landscape: Bedell-Tucci, LLC (N/A)

- MEP and Fire Protection: Scheeser Buckley Mayfield, LLC

- Structural Engineers: Thorson Baker & Associates

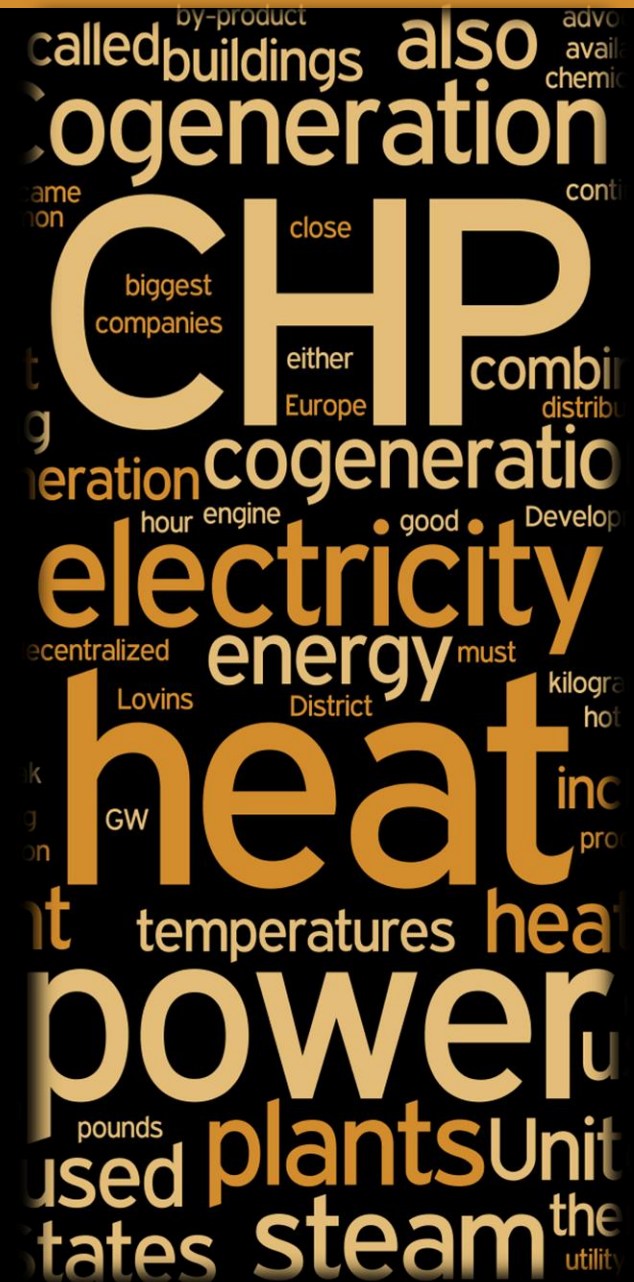
- Provided high quality for care and safety

- Designed to respect surrounding facilities

- Provided additional recreation areas and therapeutic spaces

- Used face brick exterior walls to match the existing building

- Used smooth CMU, textured CMU, and curtain walls to highlight the new design



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Existing:

- Existing Constant Volume AHU (70,000 CFM)
- Existing Constant Volume AHU (14,000 CFM)

Patient Wing Left / Right:

2 Custom AHUs (65,000 CFM Each) w/ DDC-VAV terminals

Clinic / Admin:

Variable Air Volume AHU (7,950 CFM) w/ DDC-VAV terminals

Dietary:

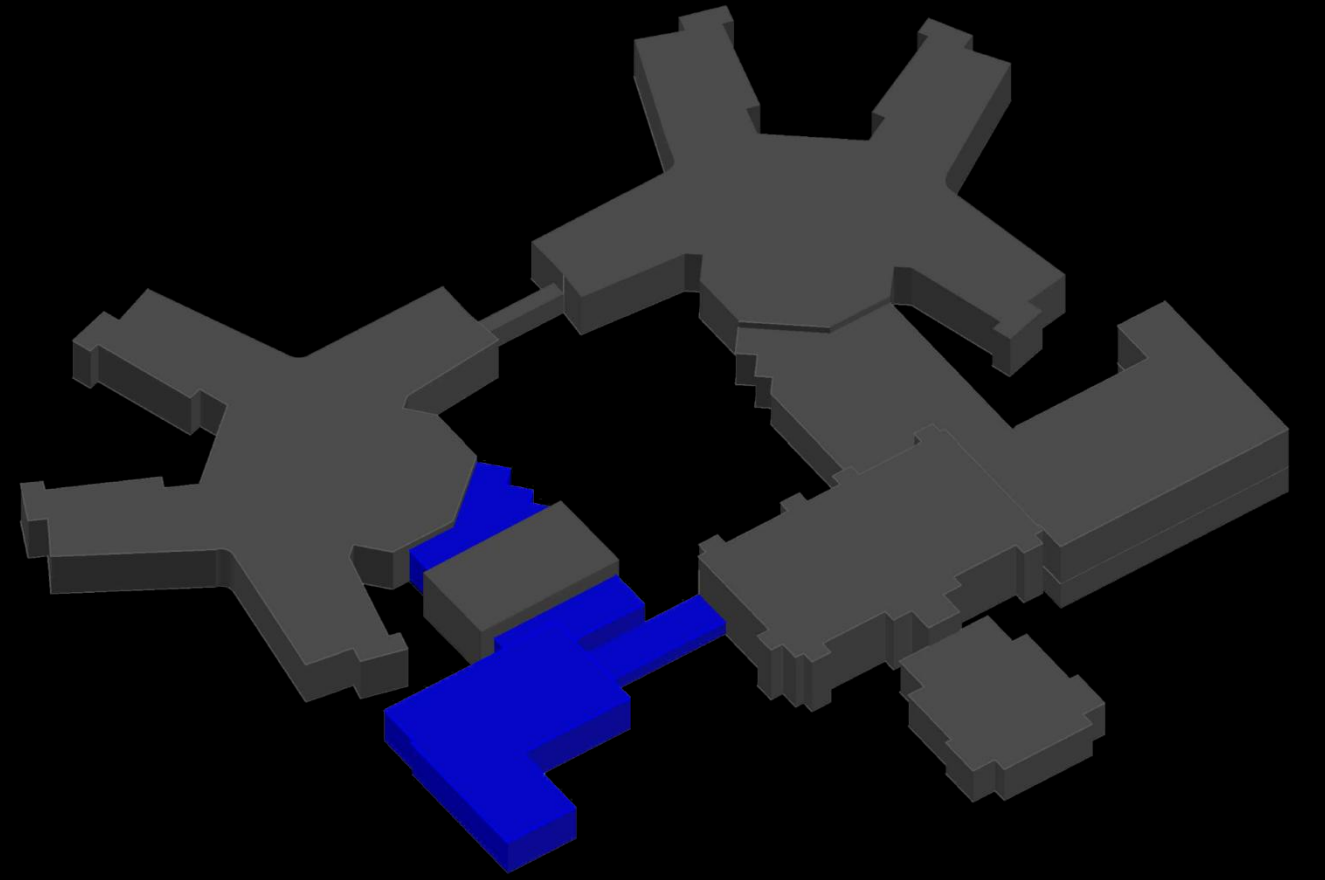
Variable Air Volume AHU (8,400 CFM) w/ DDC-VAV terminals

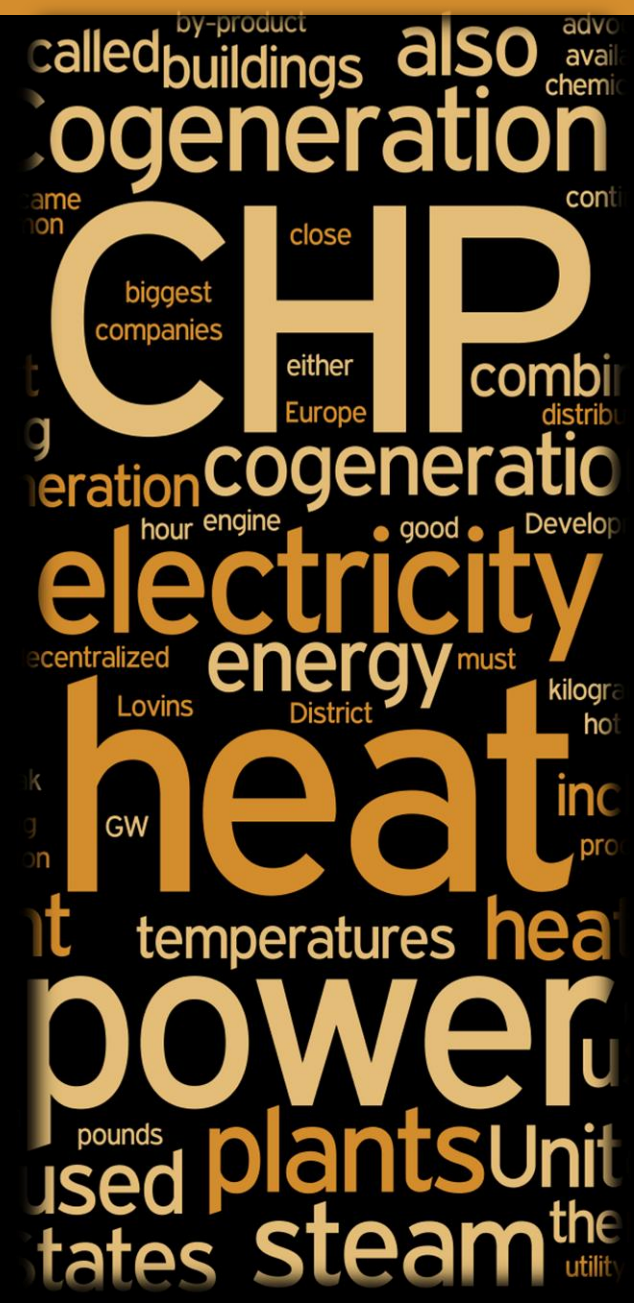
Gym:

Constant Volume AHU (3,700 CFM) w/ Sensible Wheel

Boiler Plant & Chiller Plant & Electrical Room

- 2 Constant Volume AHUs (5,000 CFM Each)
- Variable Air Volume AHU (6,000 CFM)





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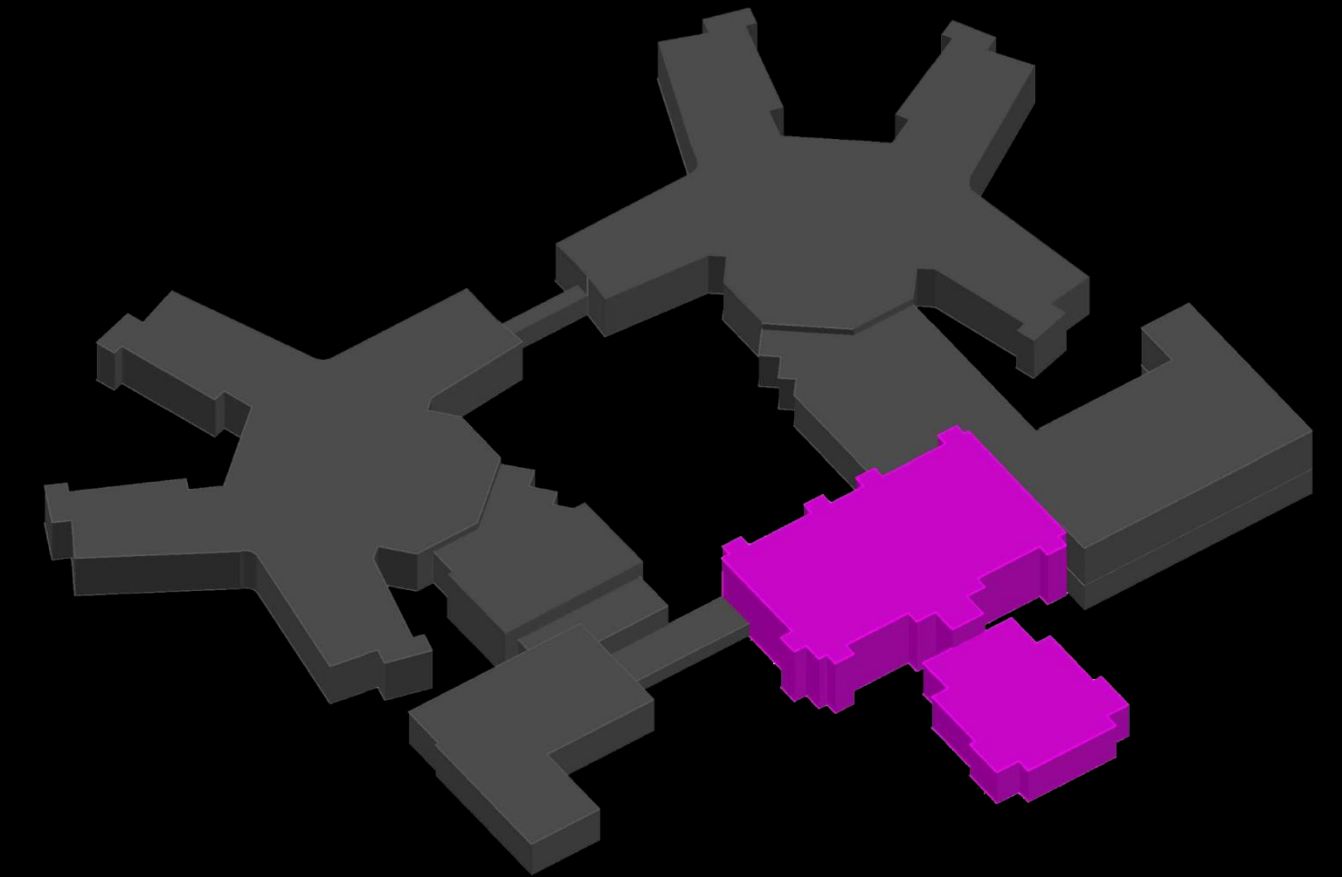
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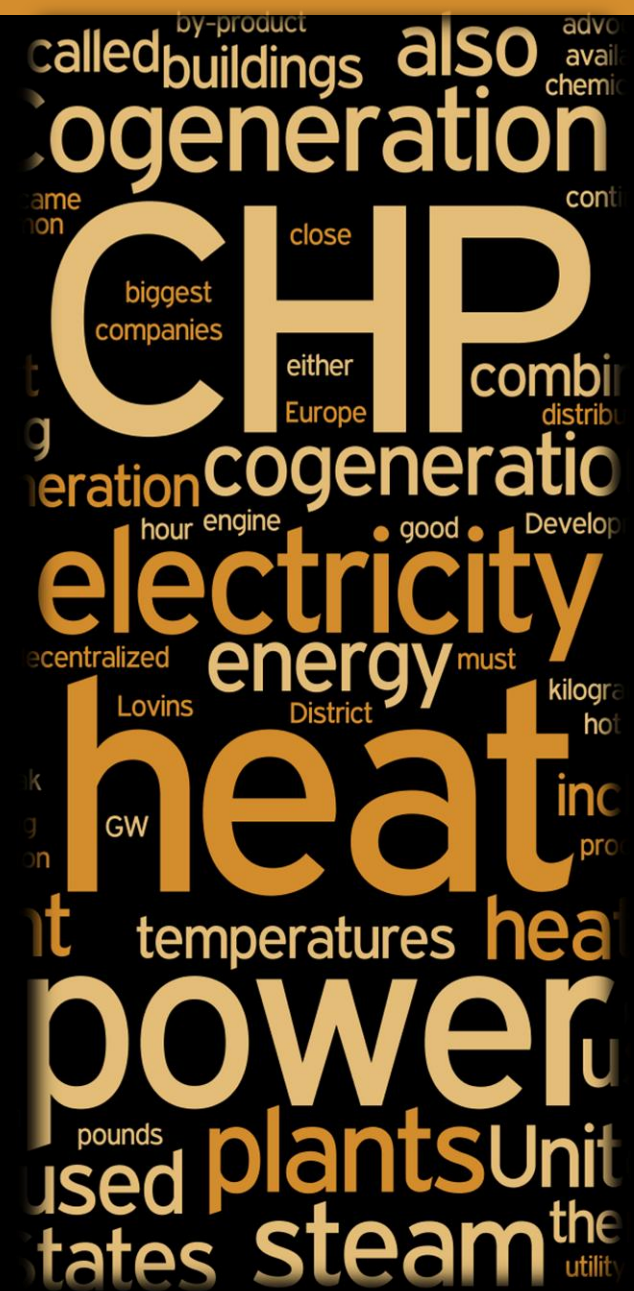
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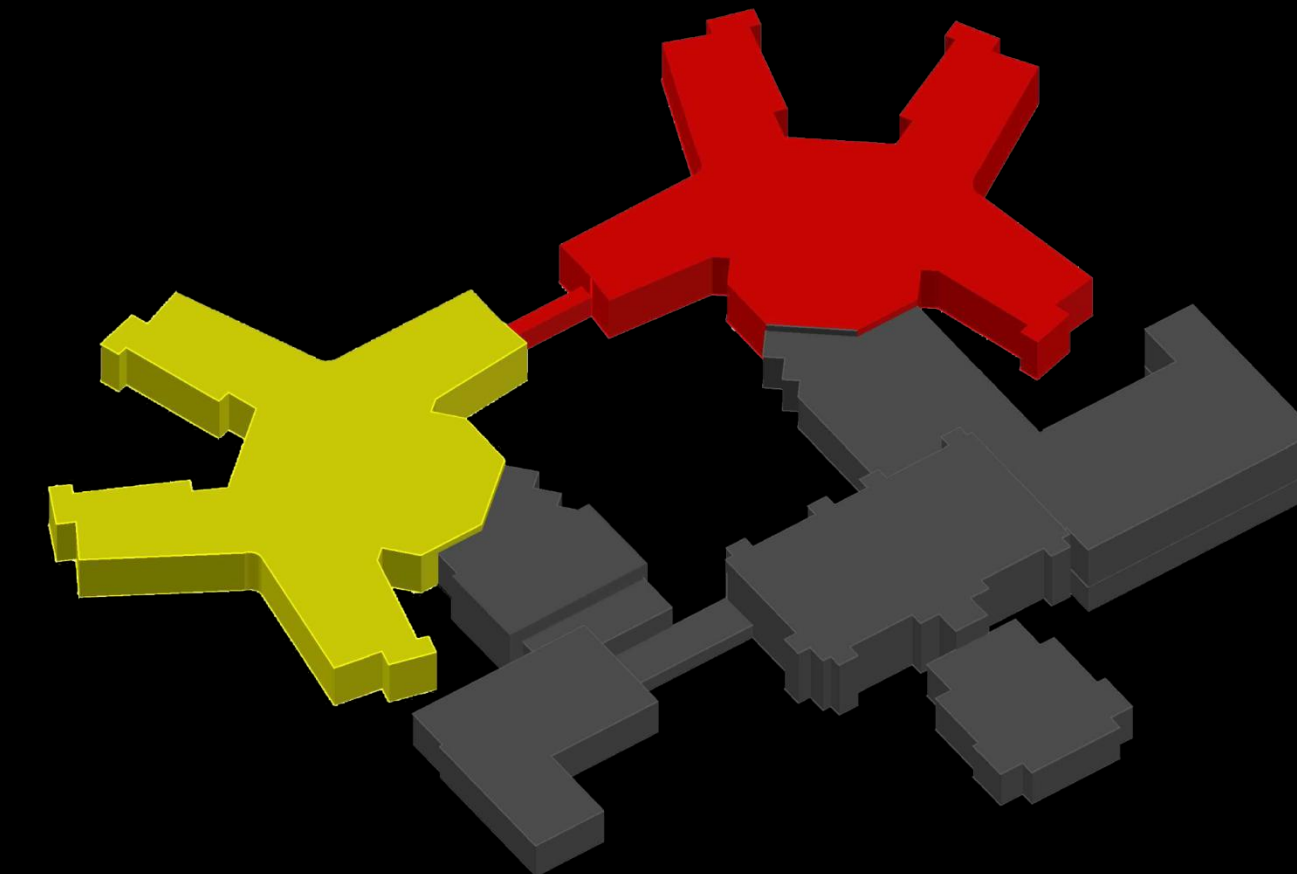
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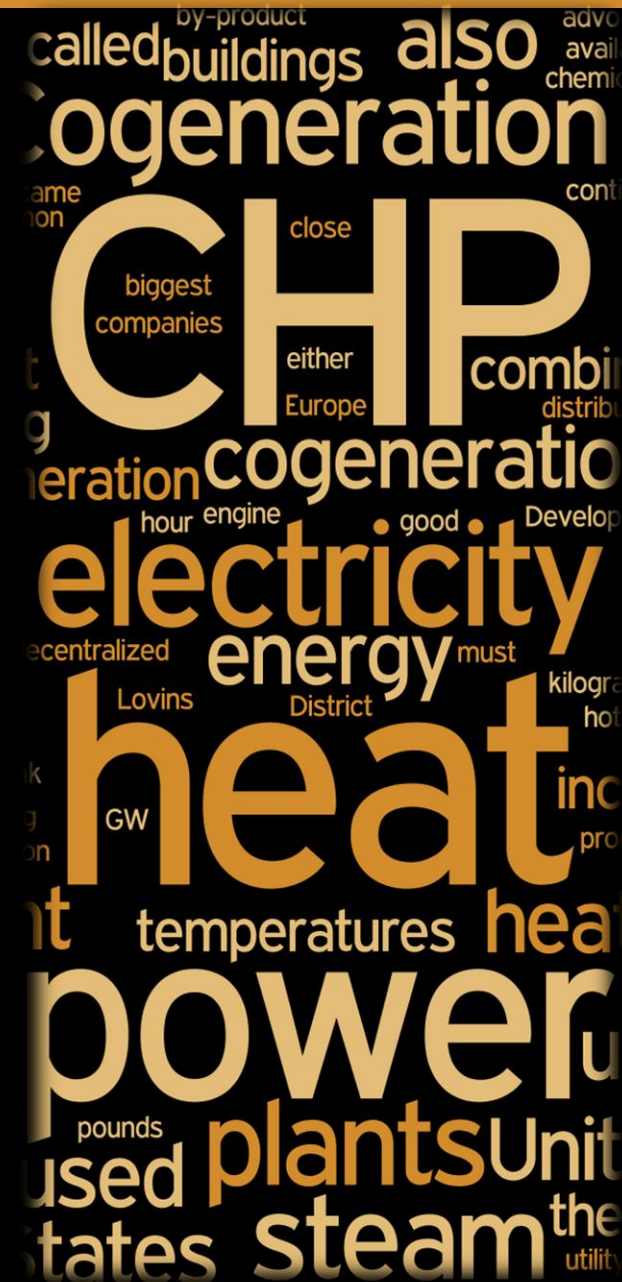
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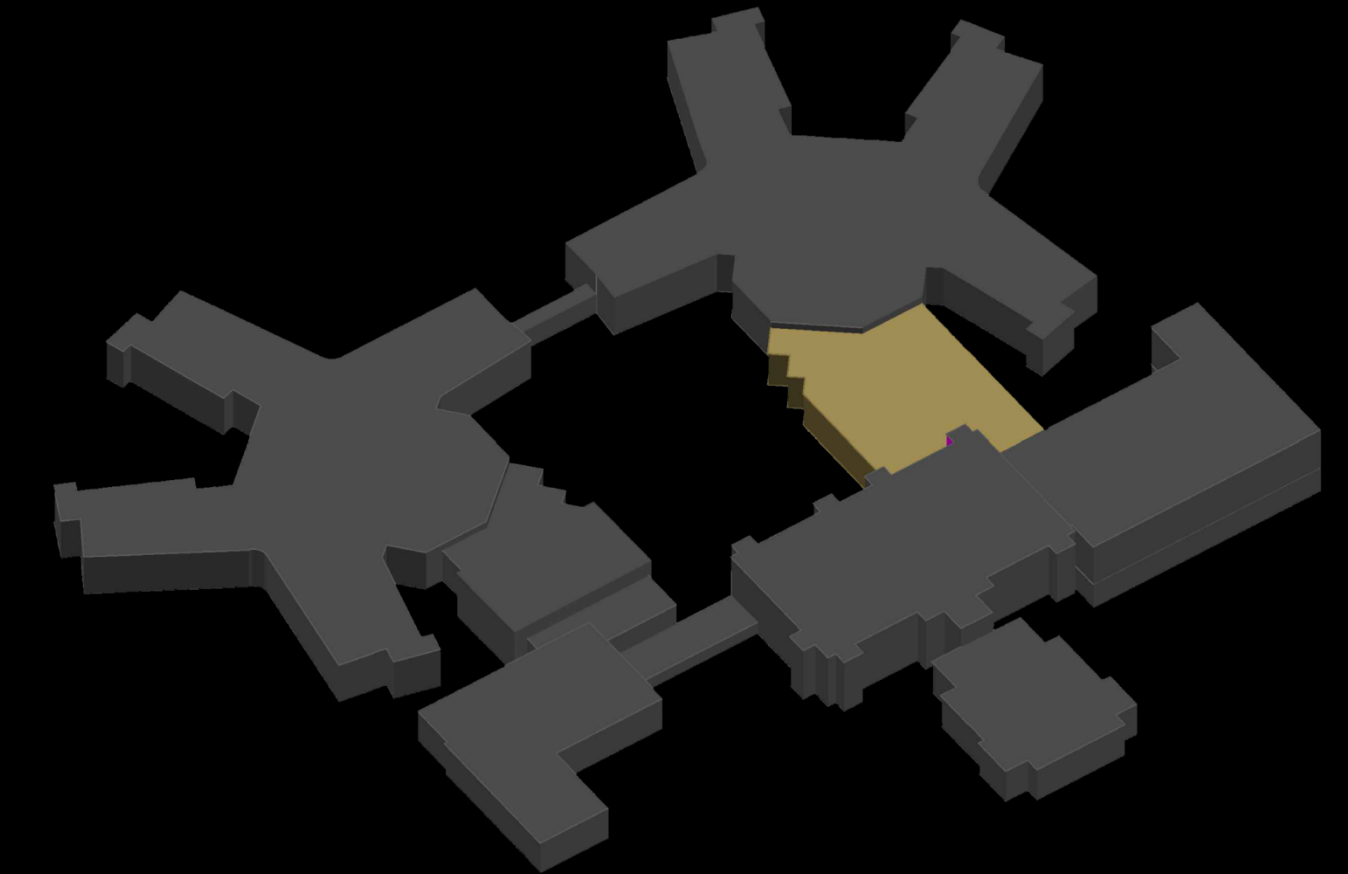
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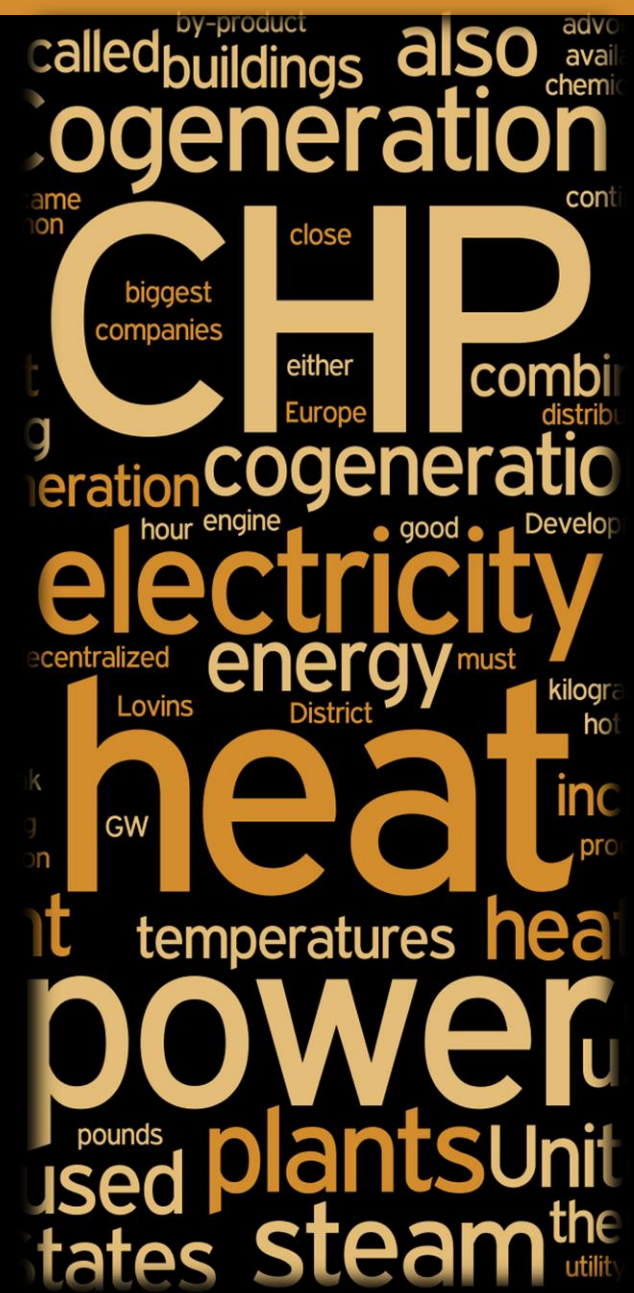
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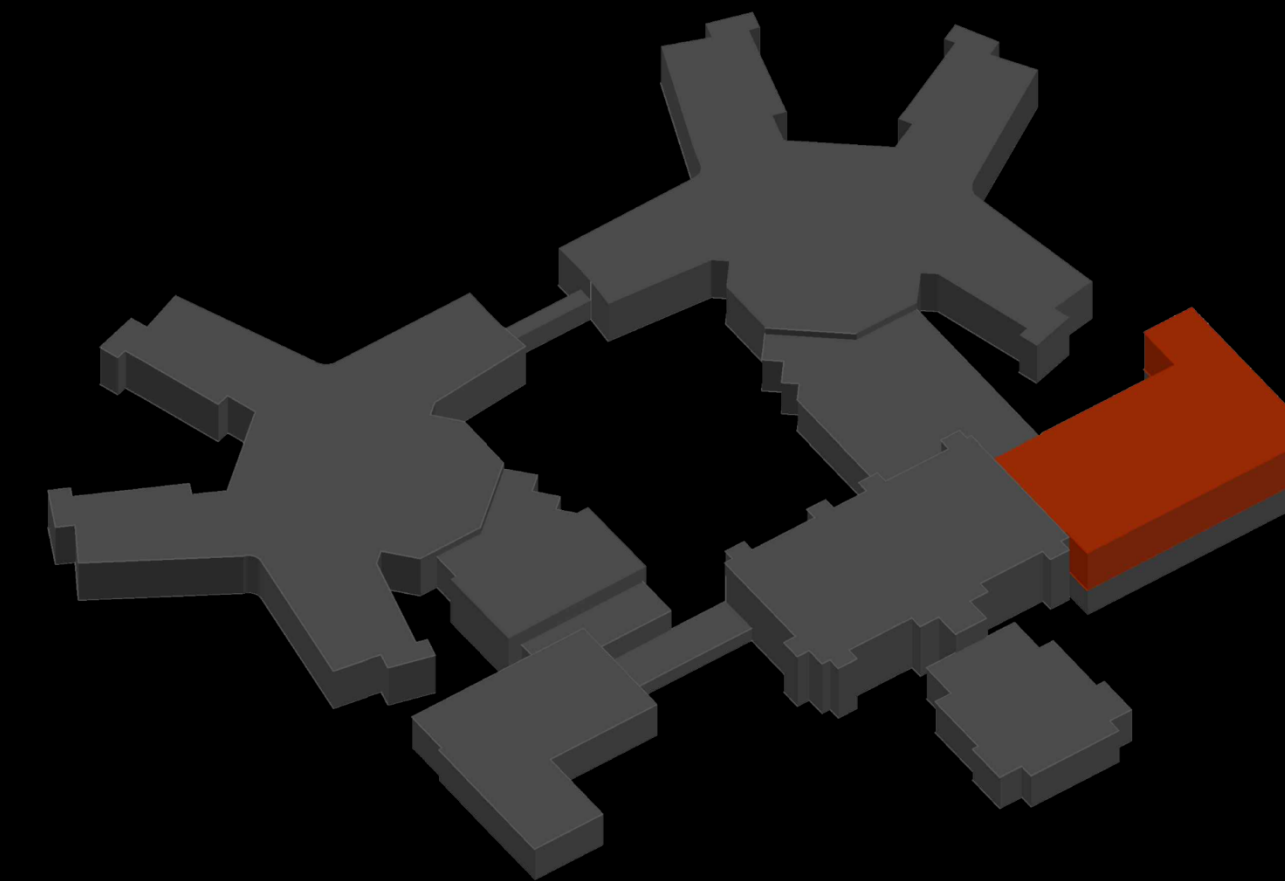
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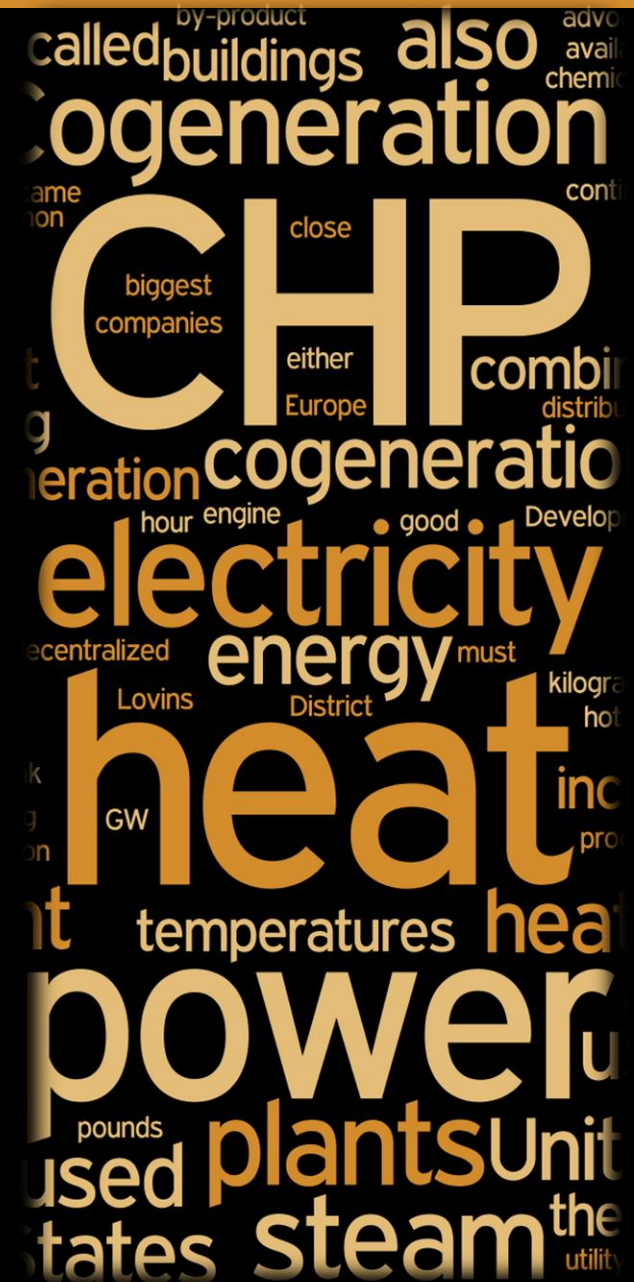
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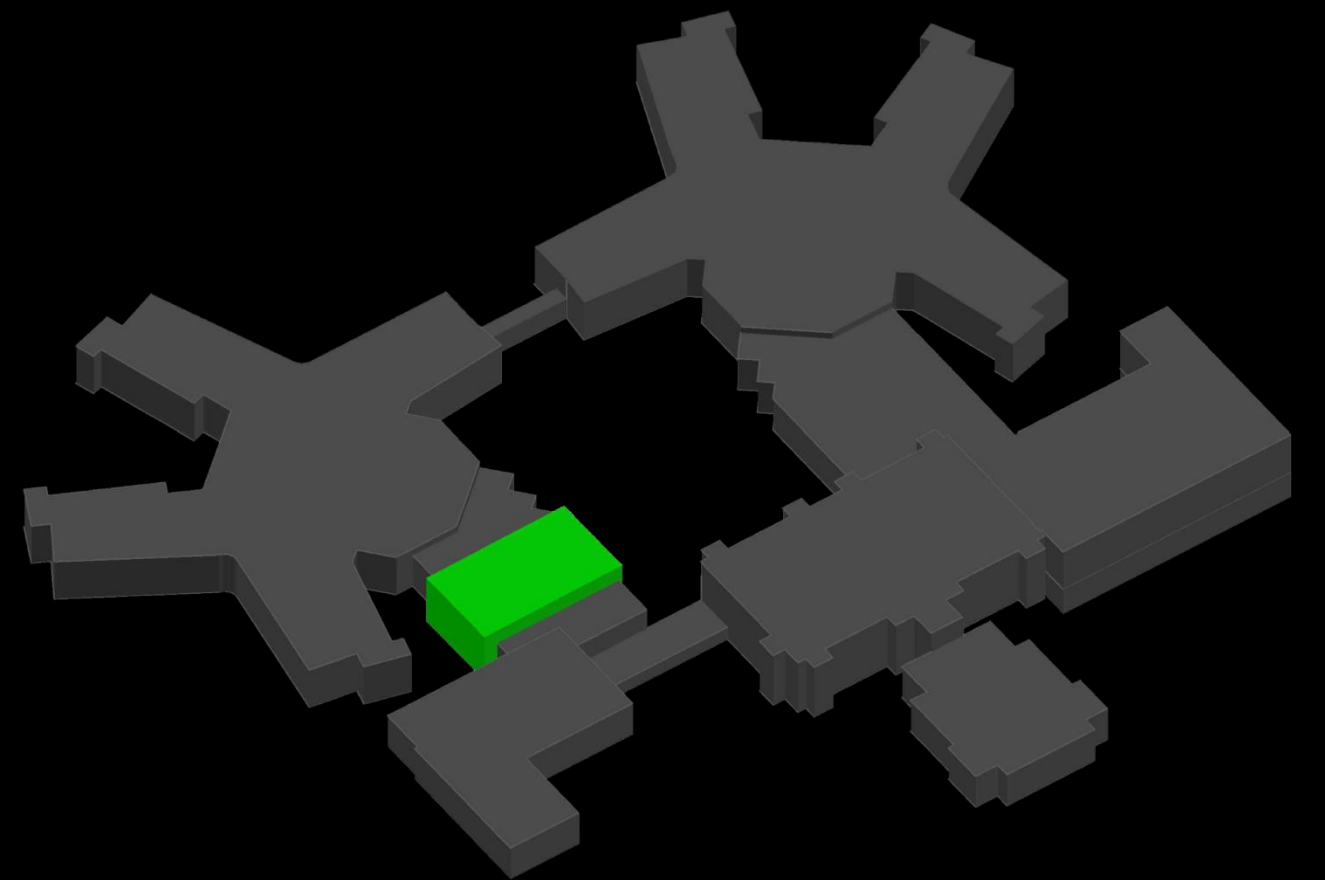
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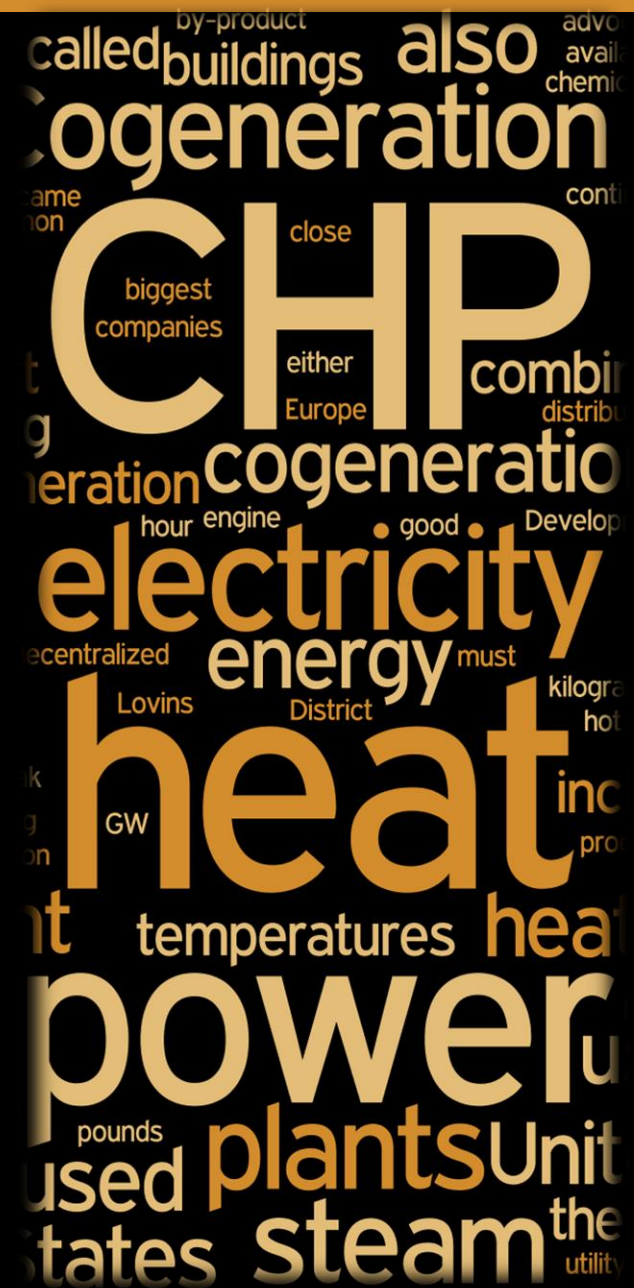
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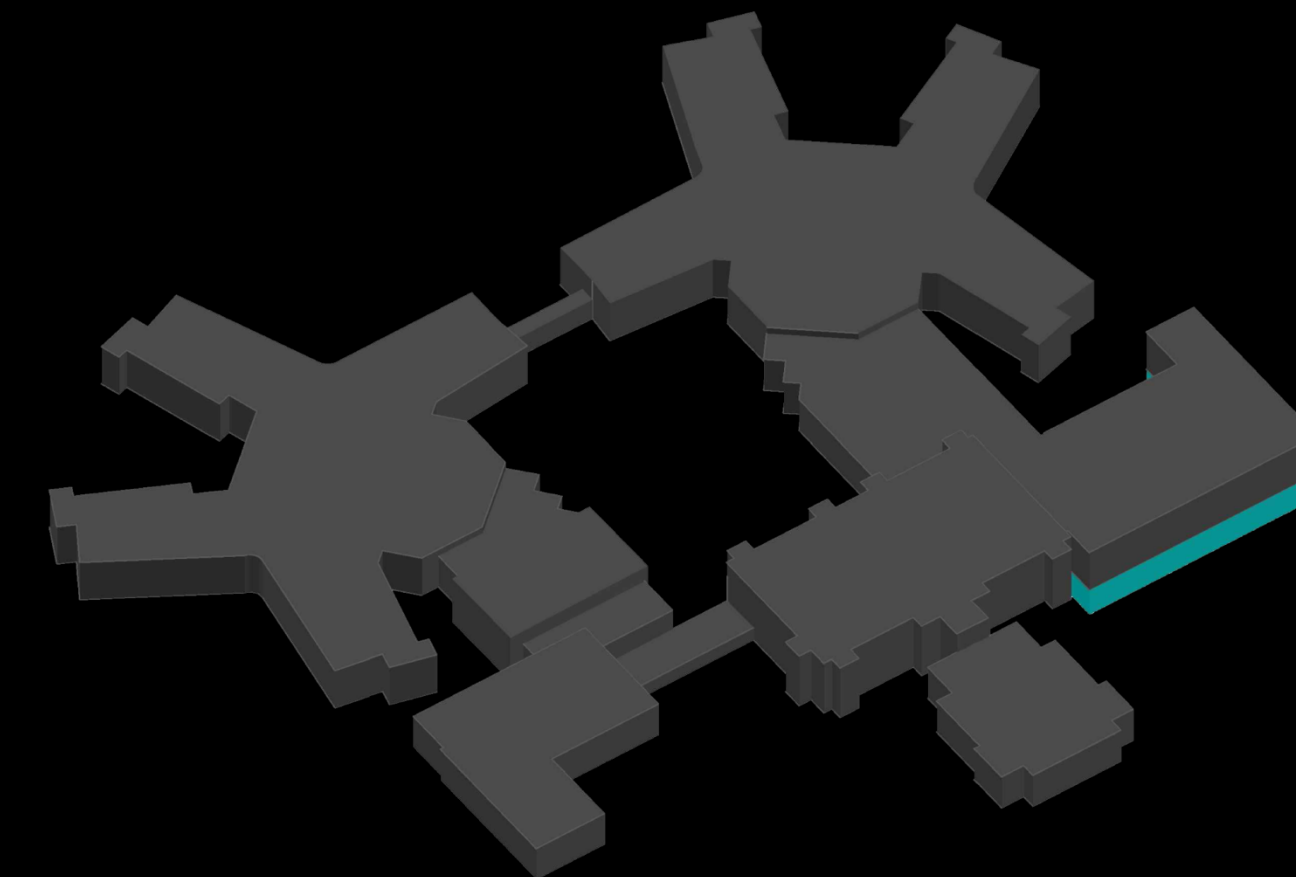
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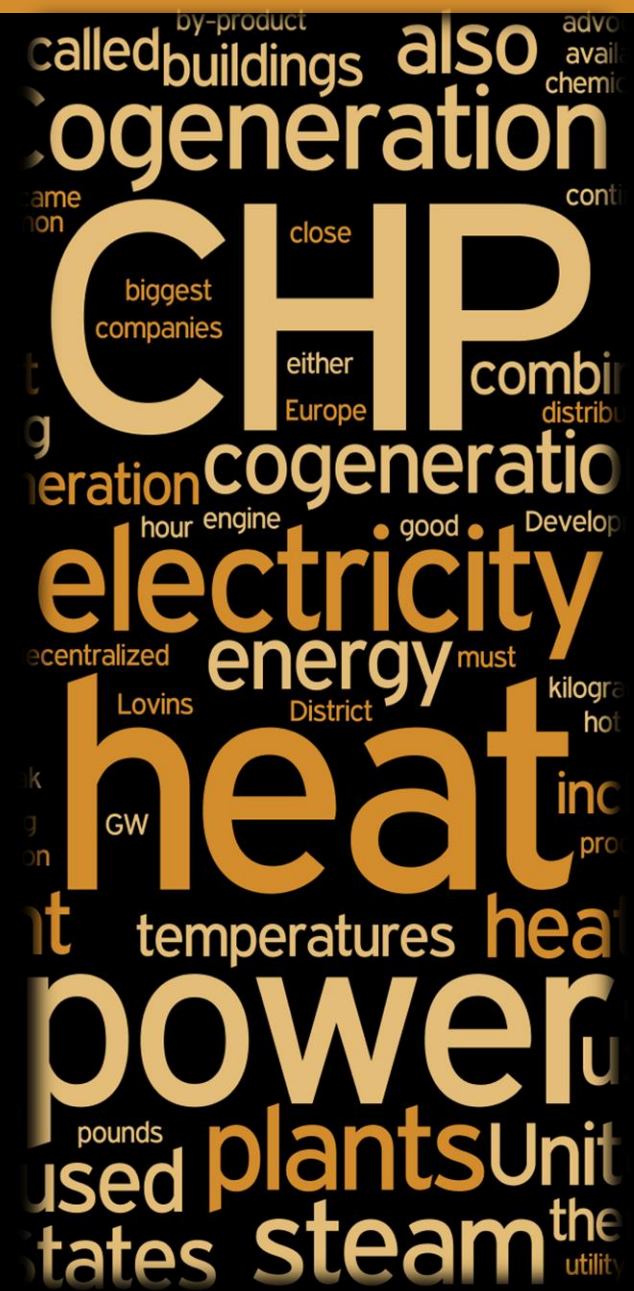
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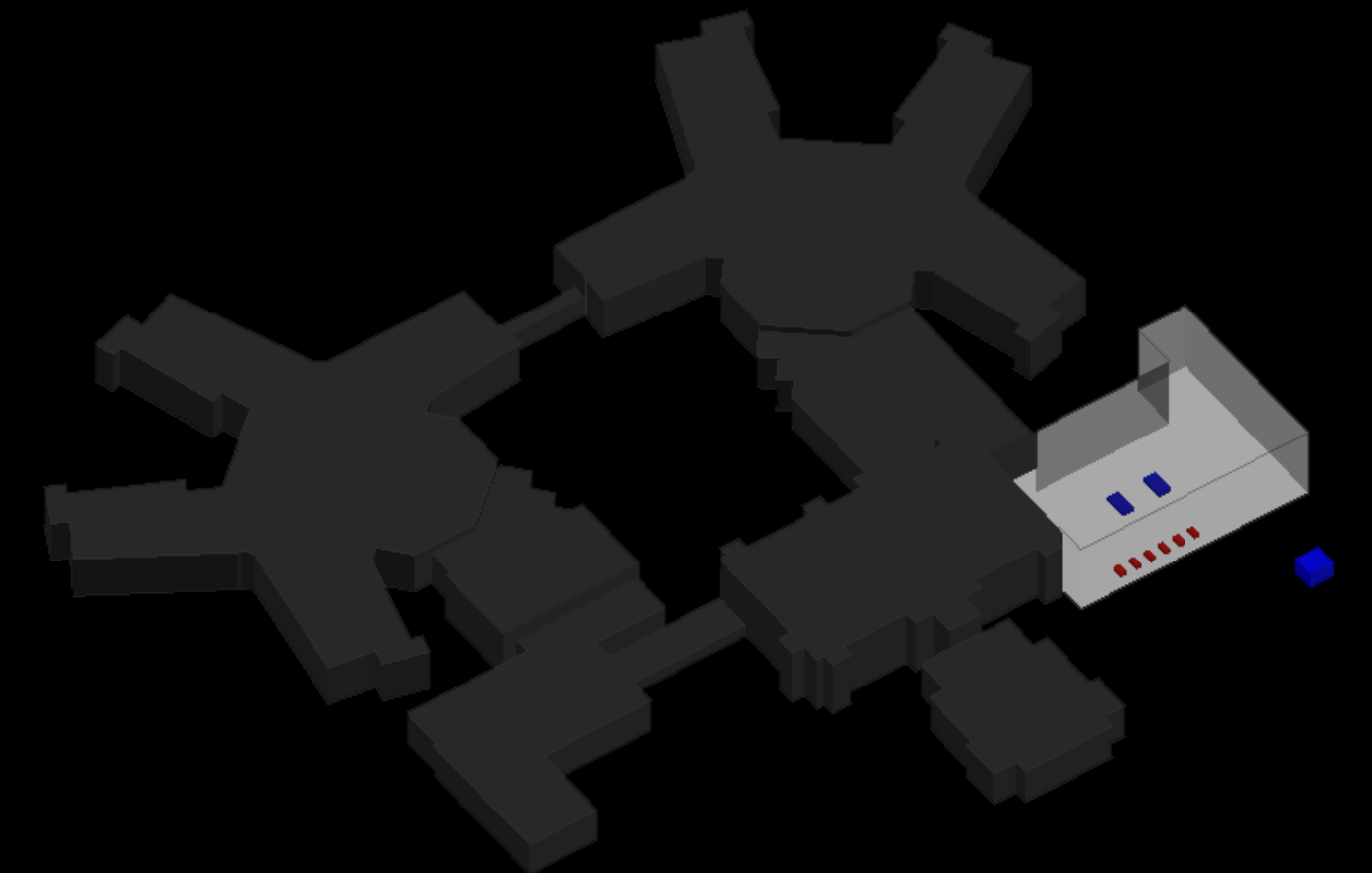
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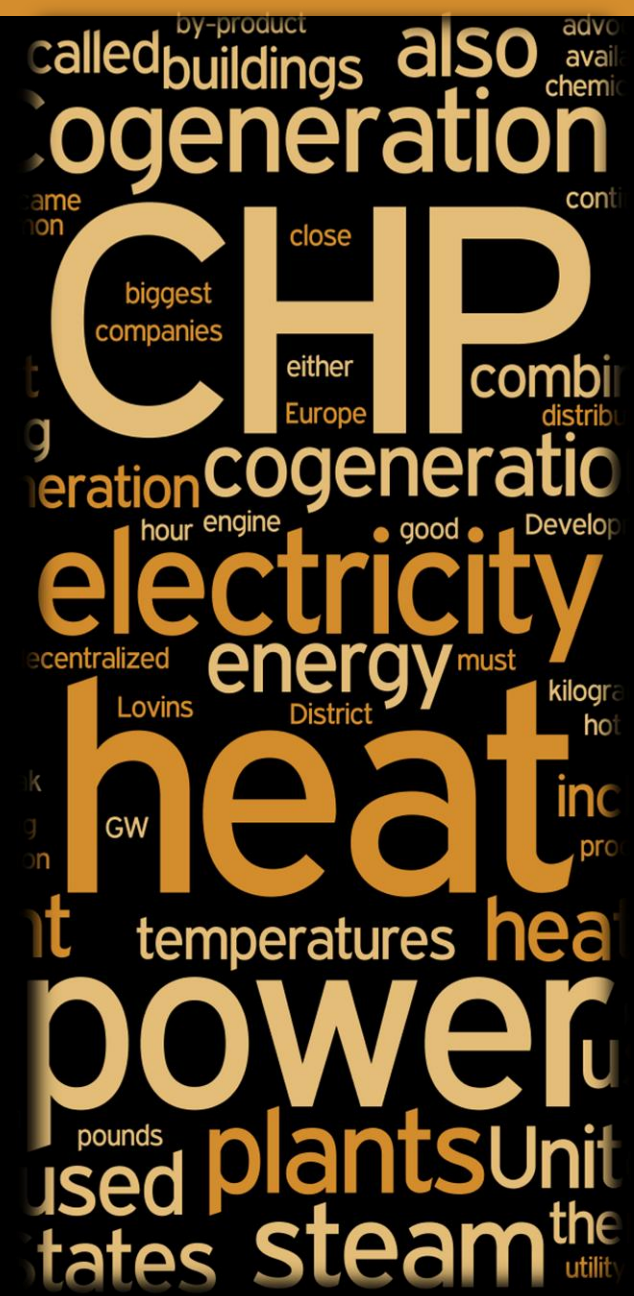
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6 Natural Gas Fired Boilers (4,000 MBH each)

2 Electric Centrifugal Chillers (450 Tons each)

A 2-cell-cooling tower (Max. 900 Tons)





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Energy Efficient Devices

DDC-VAV terminals for AHU 1, 2, 4 & 5

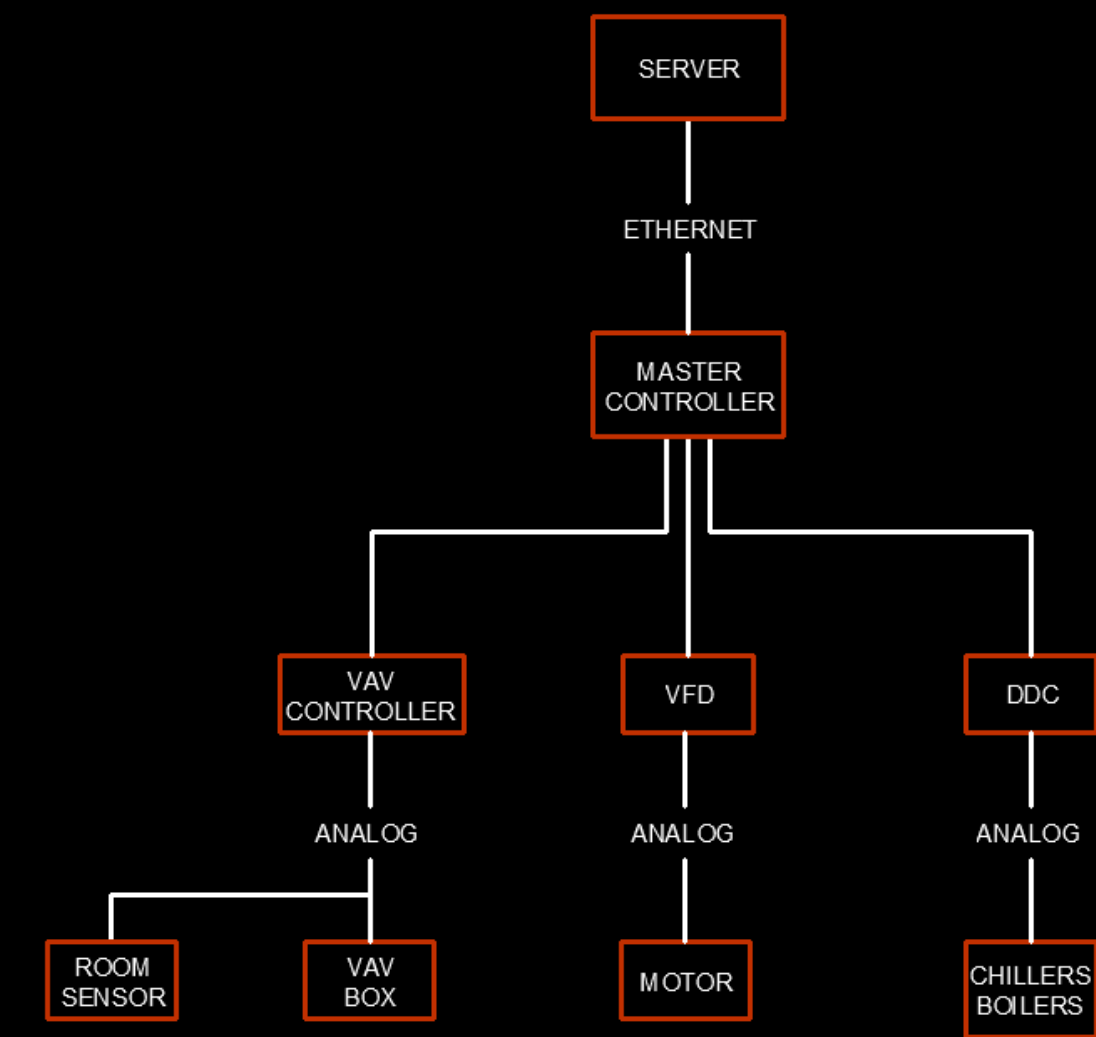
VFD for supply and return fans for AHU 1, 2, 3, 4, 5 & 8

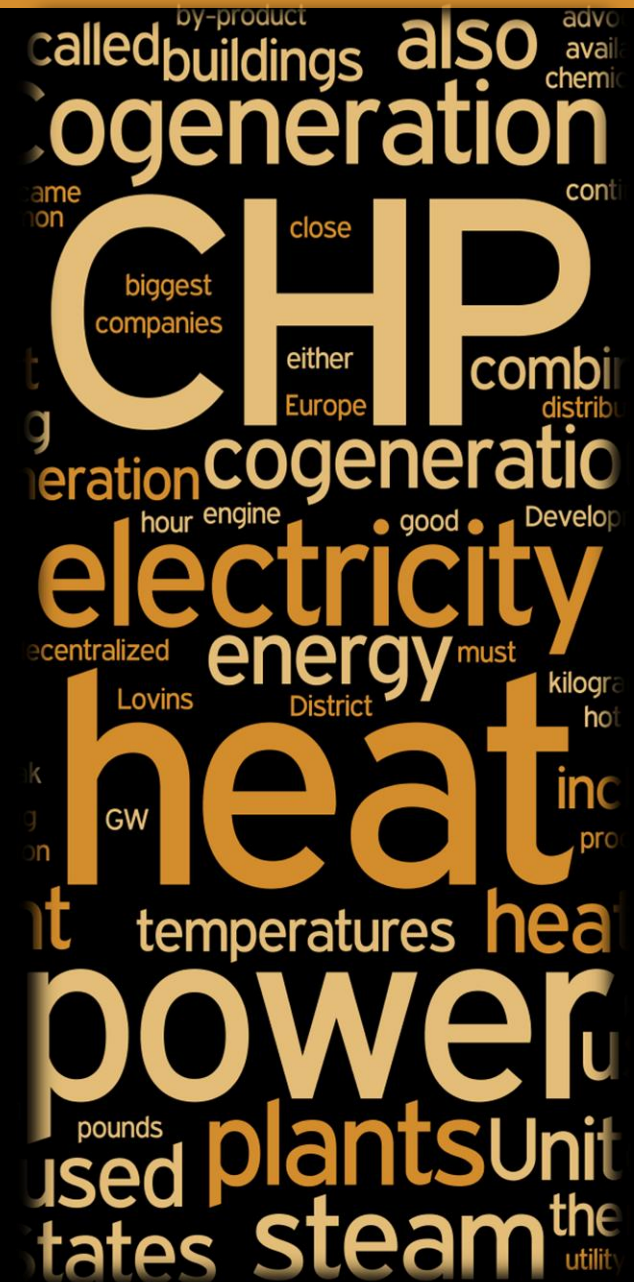
VFD for Secondary Heating Water Pumps

VFD for Secondary Chilled Water Pumps

VFD for Cooling Tower

VFD for Cooling Tower Pumps





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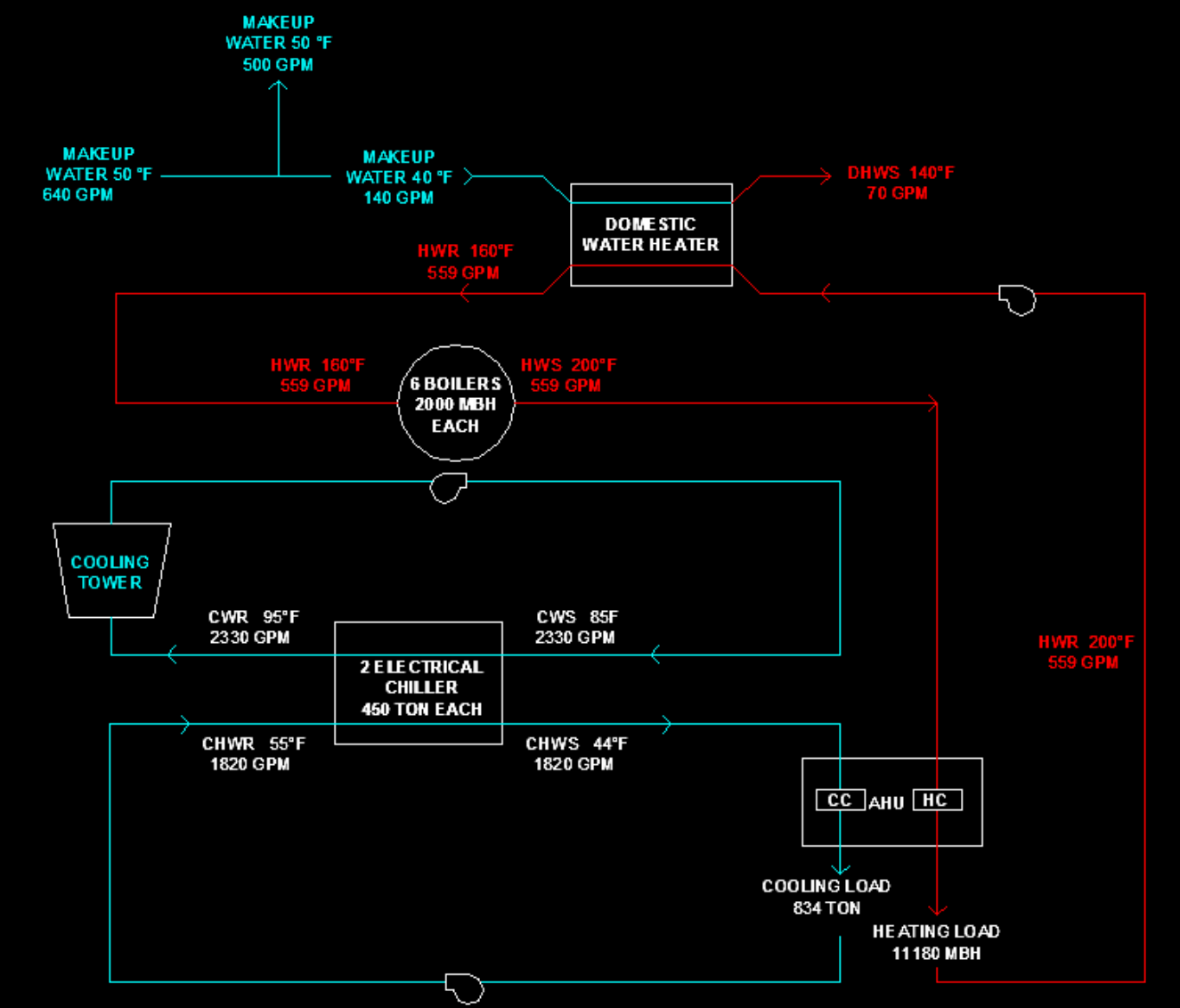
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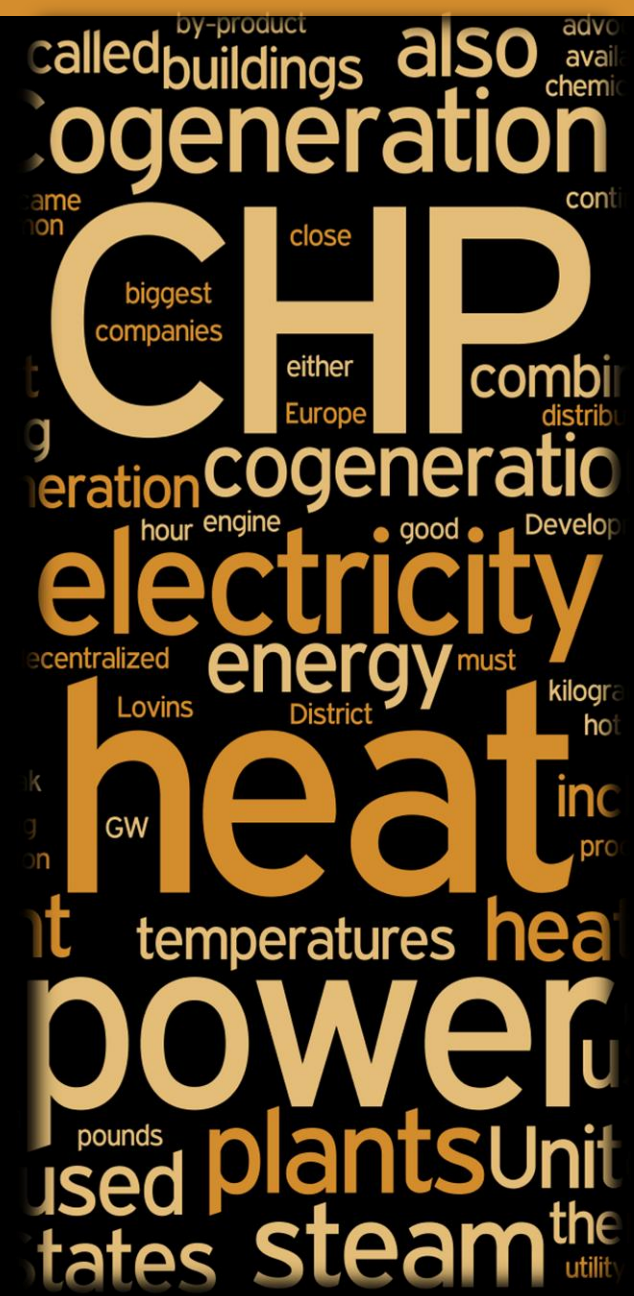
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Summary of Load	
Cooling (TONS)	834 TONS
Space Heating (MBH)	11,180 MBH

Summary of Water Supply Needs	
Chilled Water @11F Difference	1,820 GPM
Hot Water @ 40F Difference	560 GPM
Domestic Hot Water	140 GPM



EXISTING SCHEMATIC- CONVENTIONAL SYSTEM



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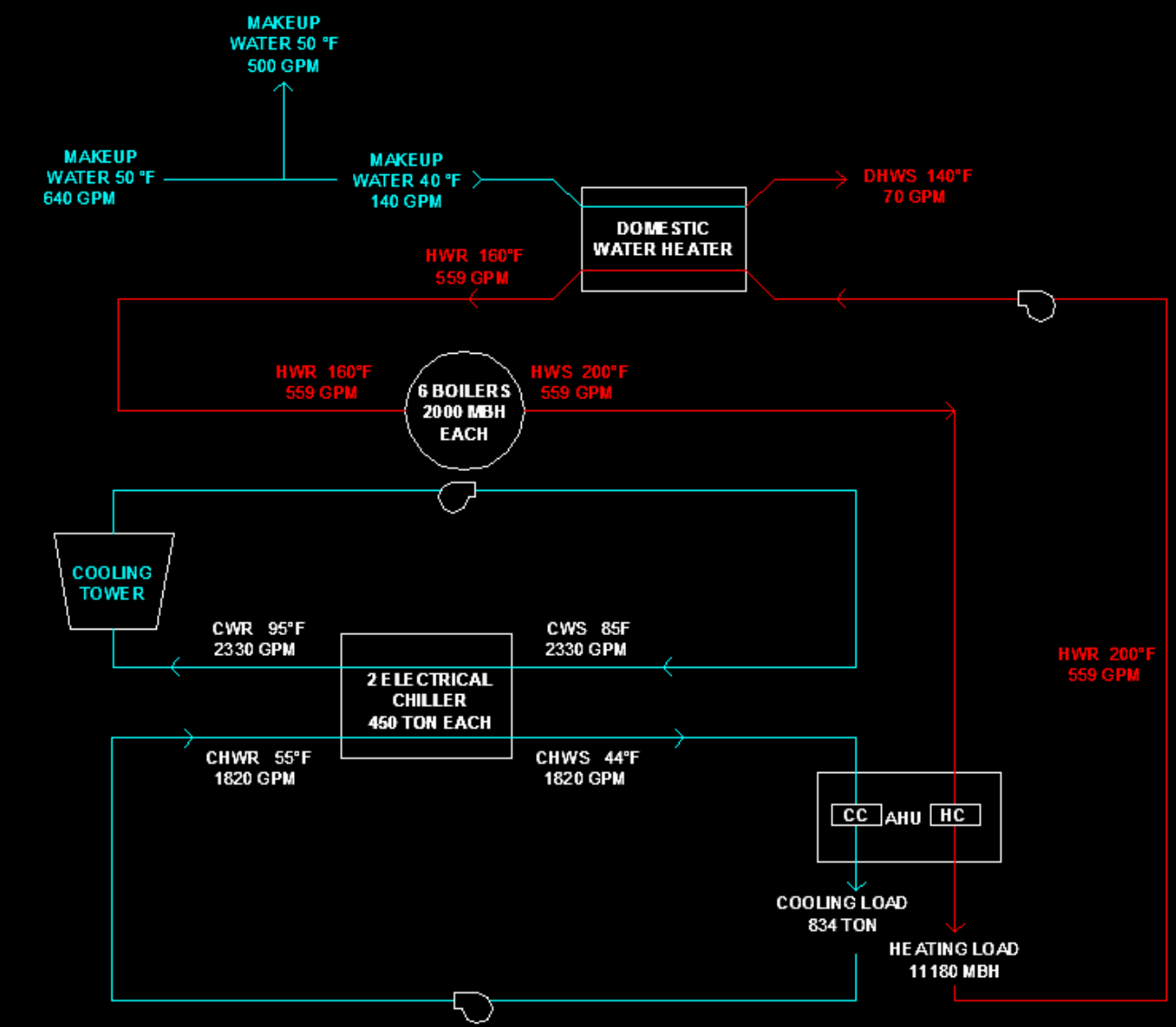
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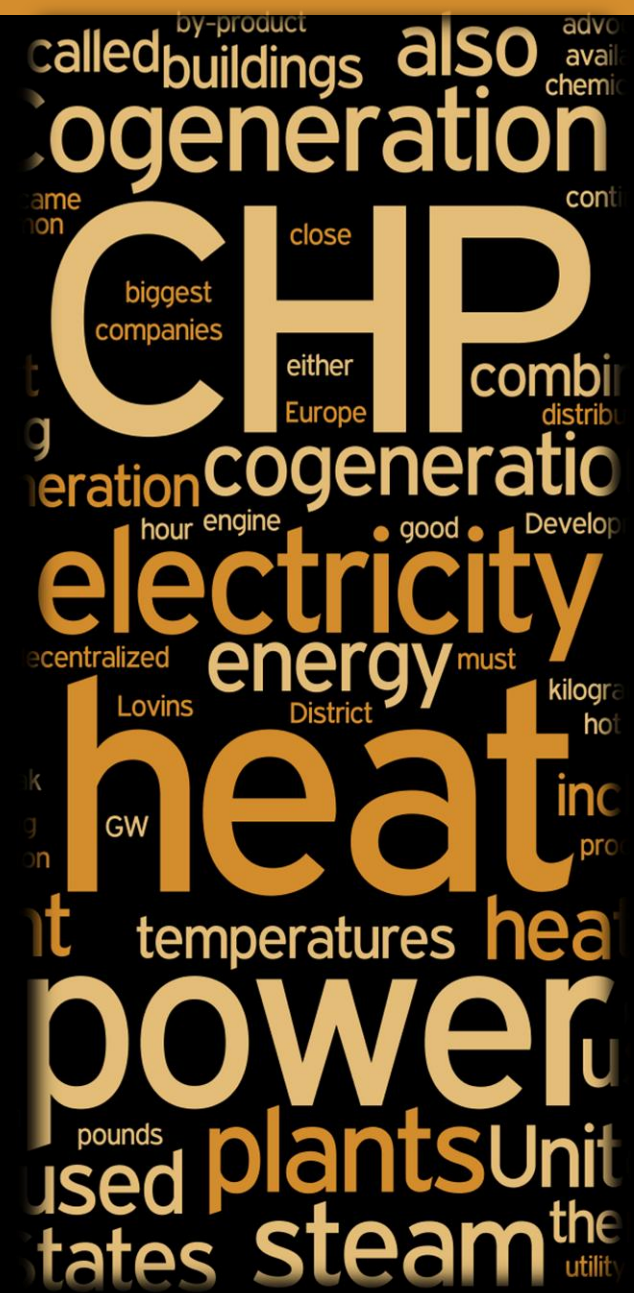
Summary of Annual Energy Consumption	
Total Electricity Consumption	14,127,906 KWh
Total Natural Gas Consumption	636,589 Therms
Total Energy Consumption	32,779,801 KWh

EUI Value Calculated	
Electricity EUI	185 kBtu / SF
Natural Gas EUI	250 kBtu / SF
EUI	435 kBtu / SF

EUI Value of Typical Hospital (Baseline Model)	
EUI	388 kBtu / SF



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Combined Heat and Power (CHP) system

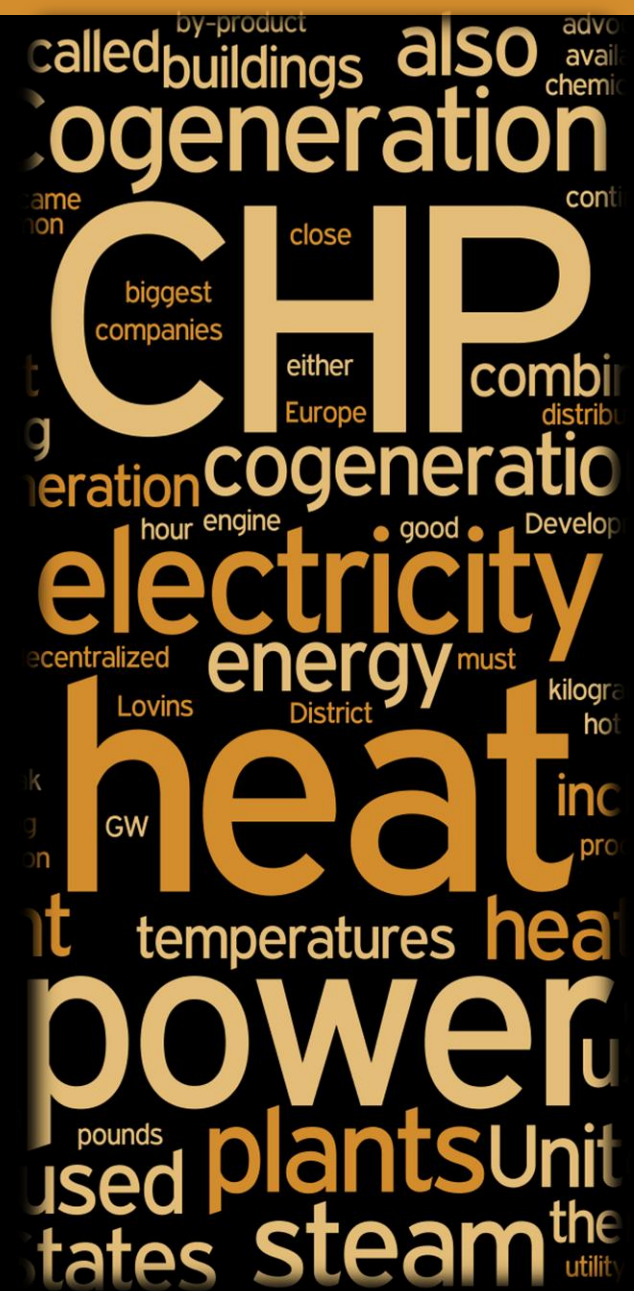
CHP supplies energy in two forms:

- Electricity
- Heat

• Spark Spread

- Difference between electricity and gas rate in \$/MMBtu
- Spark Spread >\$12/MMBtu → CHP has the potential for favorable payback

Spark Spread	
Determine the Average Annual Electric Cost (\$/MMBtu)	29.30
Determine the Average Gas Cost (\$/MMBtu)	7.550
Spark Spread	22

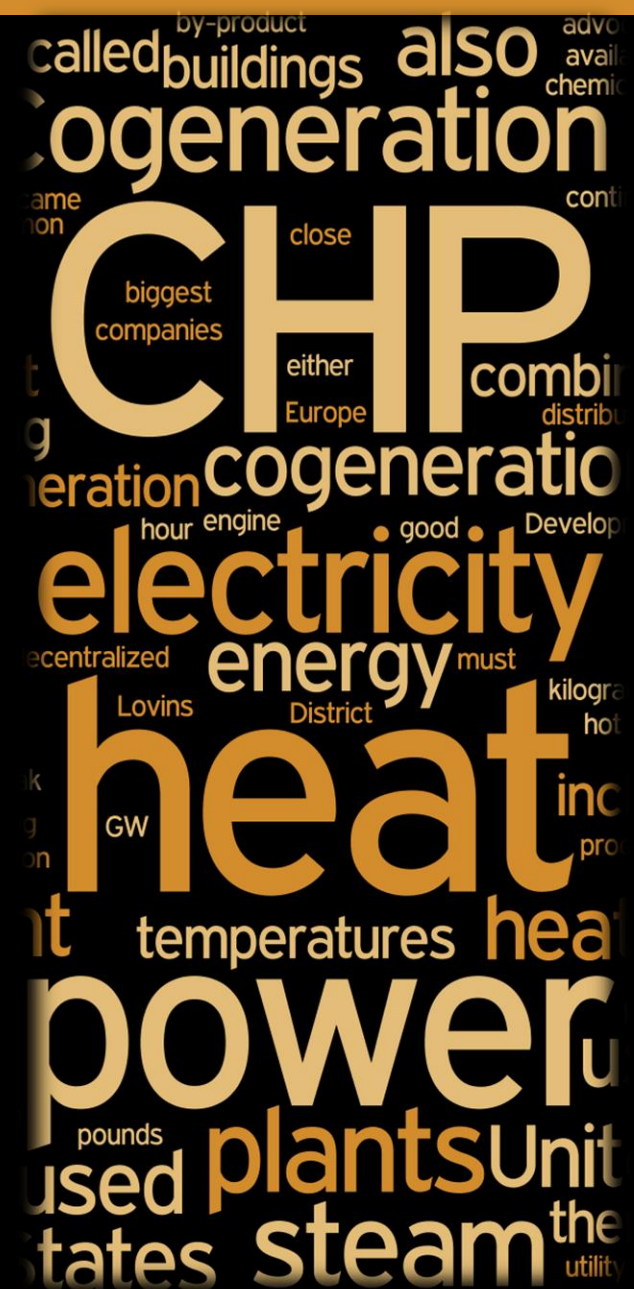


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T/P Ratio	
1. Determine Thermal Use	
Total Thermal Energy Delivered/Used	63,658,920,000 Btu
2. Determine Electrical Use	
Total Electric	48,218,544,000 Btu
3. Determine T/P Ratio	
T/P Ratio - Divide Total Thermal (Btu) by Total Electric (Btu):	1.32

Recommended Prime Mover Technology Based on T/P Ratio	
If T/P =	
0.5 to 1.5	Consider engines
1 to 10	Consider gas turbines
3 to 20	Consider steam turbines

	Capacity	Installation Costs	O&M Costs
Reciprocating Engines	5 kWe - 20 MWe	\$1,000 to \$1,800 per kW	\$0.010 to \$0.015 per kWh
Gas Turbines	25 kWe – 500 kWe	\$800 to \$1,500 per kW	\$0.005 to \$0.008 per kWh
Microturbines	500 kWe – 100 kWe	\$1,000 to \$2,000 per kW	\$0.010 to \$0.015 per kWh

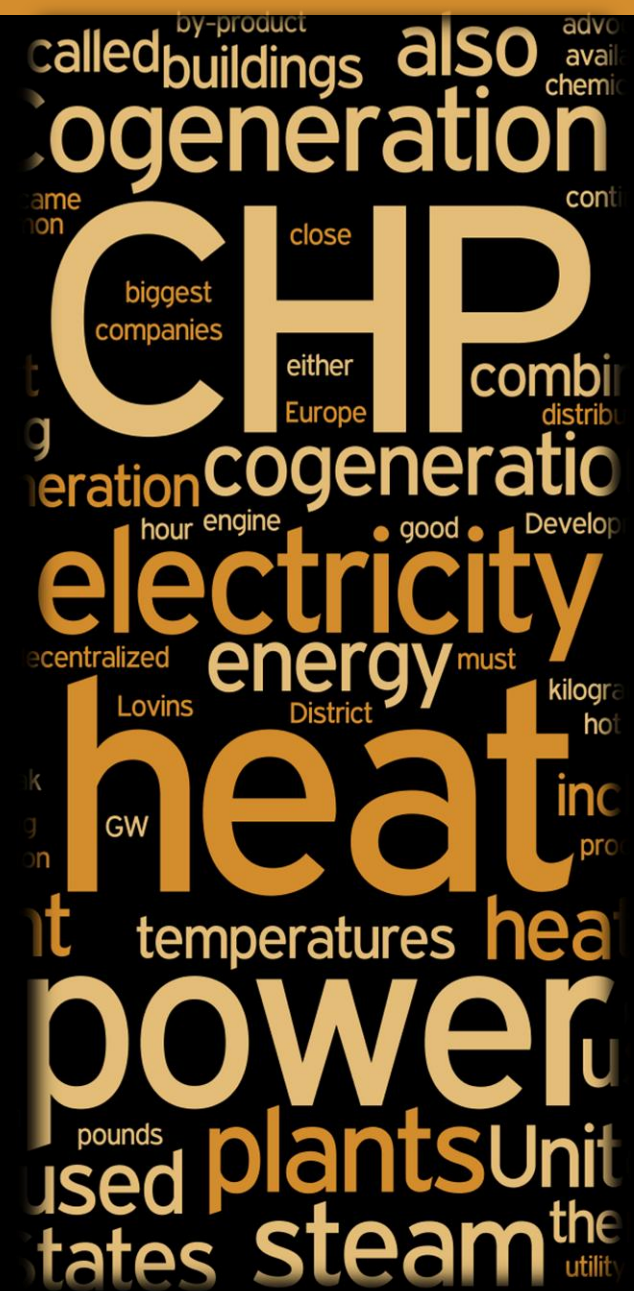


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Primary Design		
Building Size (SF)	Heating Baseline (MBH)	Heating Load (MBH)
260,000	5,640	11,180
Heating Baseline = Total Heating Load X 50%		

$$5,640 \text{ MBH} \times \frac{1,000 \text{ Btu/h}}{1 \text{ MBH}} \times \frac{1 \text{ kW}}{3,413 \text{ Btu/h}} = 1,653 \text{ kW}$$

CHP COGENERATION MODULE - 2G 1540 NG	
Reciprocating engine MWM® TCG2020	
Configuration	Natural Gas
Electrical Output	1540 KW
Thermal Output	1778 KW
Electrical Efficiency	42.00%
Thermal Efficiency	44.06%
Total efficiency	80.06%
Thermal Heat	6,066,787 Btu/h (Usable)
Water Flow rate High Temp	17,100 Gph
Water Temp	194F
Fuel Consumption	12508 MBtu/h
Energy Consumption	8,122 Btu / kW



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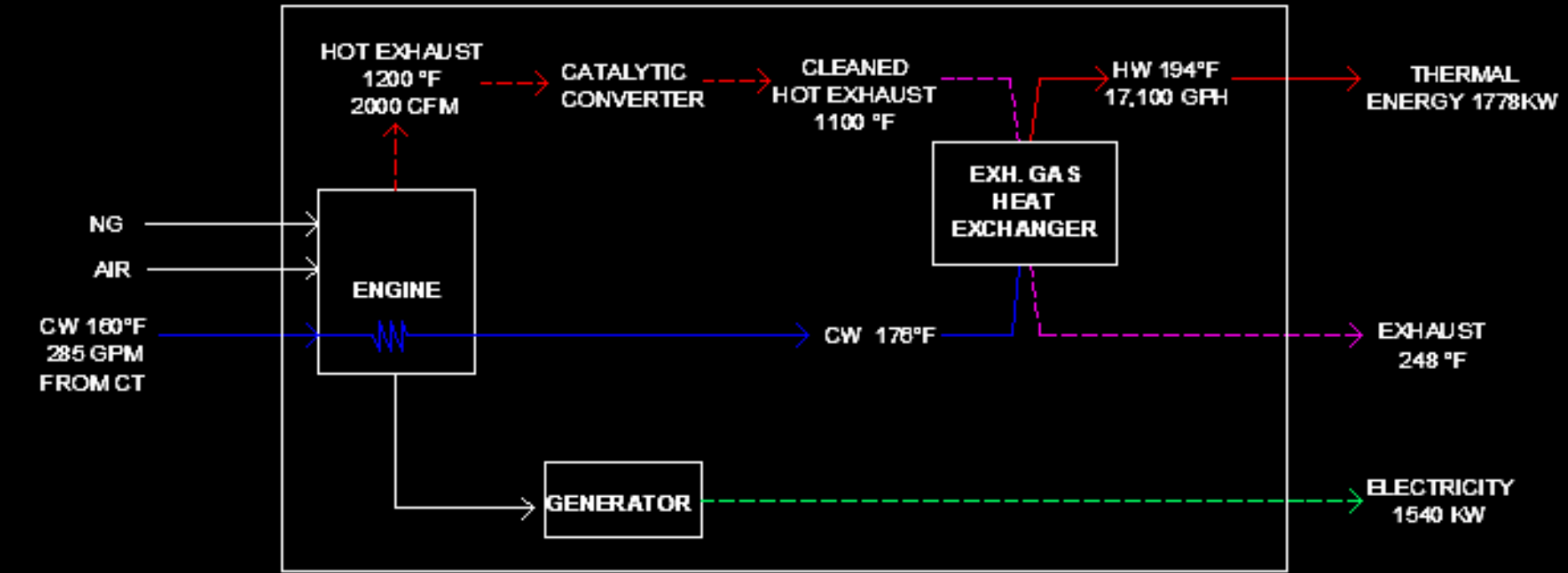
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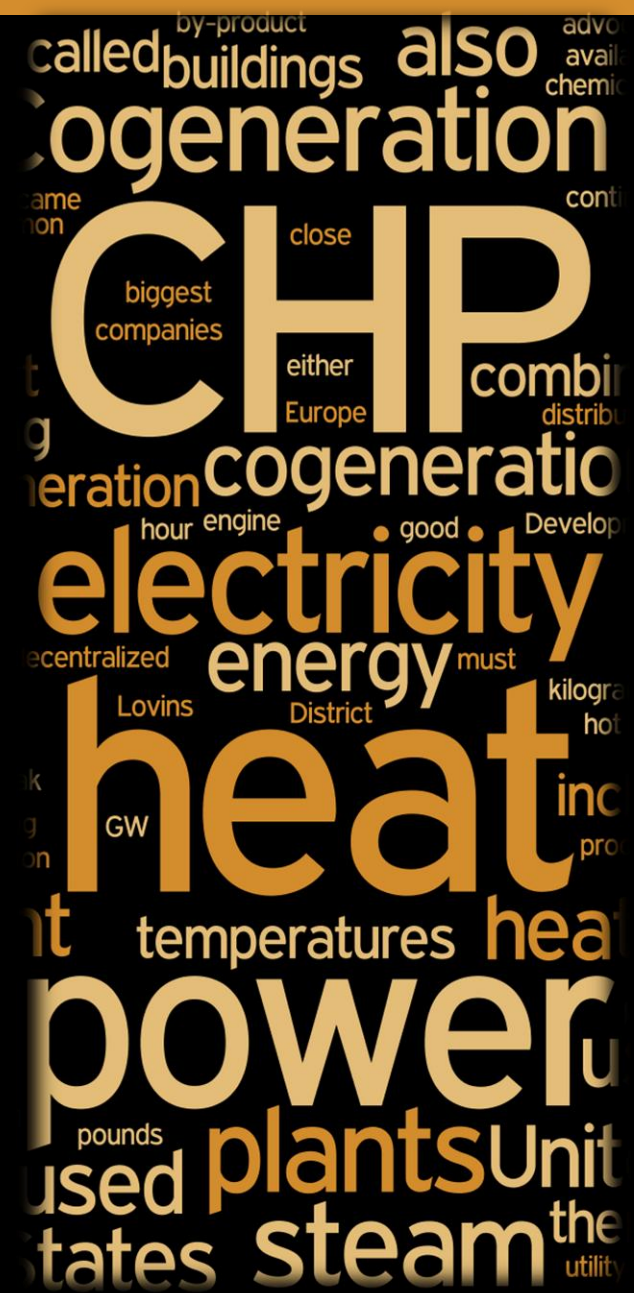
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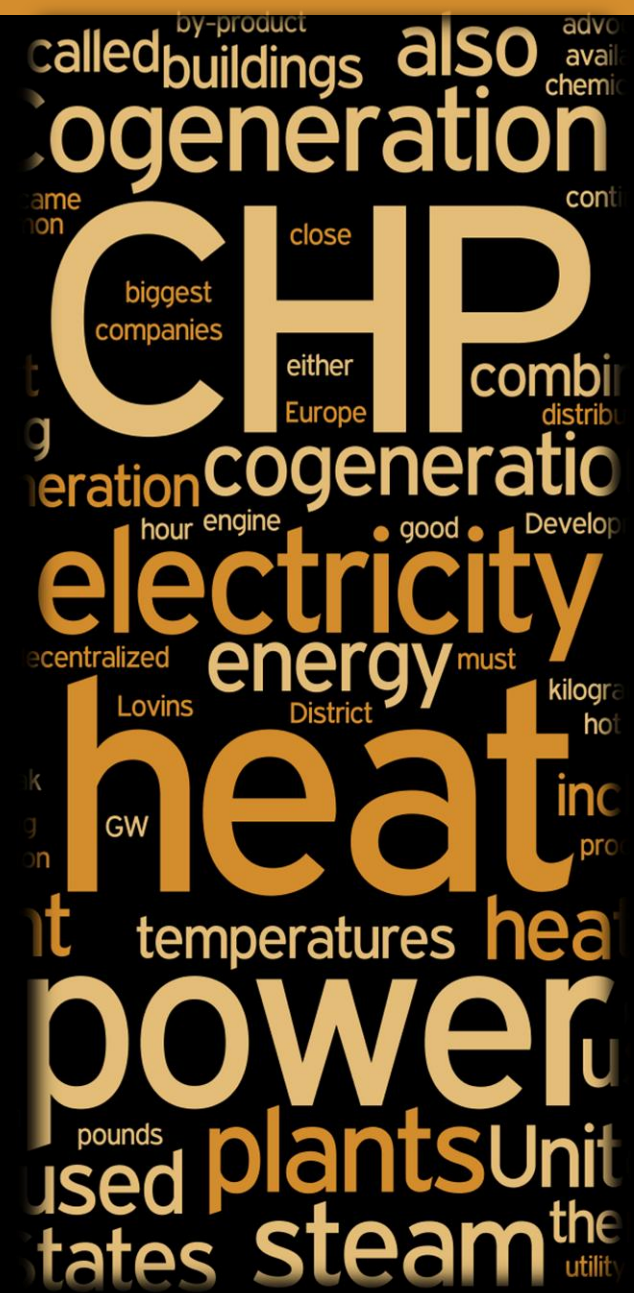
Heat Recovery	
Heat Recovery	6,068,314 Btu/hr
Heating Load	11,180,000 Btu/hr
Heat Recovery Basis Efficiency	60%

Energy Generation & Fuel Consumption	
Annual Electric Generation	13,490,400 kWh
Annual Thermal Generation	53,158 MMBtu
Annual Fuel Consumption	109,570 MMBtu

Revenue	
Electric Revenue	\$1,349,040
Thermal Revenue	\$401,346
Total Revenue	\$1,750,386

Expenses	
Fuel Expenses	\$827,254
O&M Costs	\$168,630
Standby Charge	\$55,440
Total Expenses	\$1,051,324

Saving	
Total Saving	\$699,062



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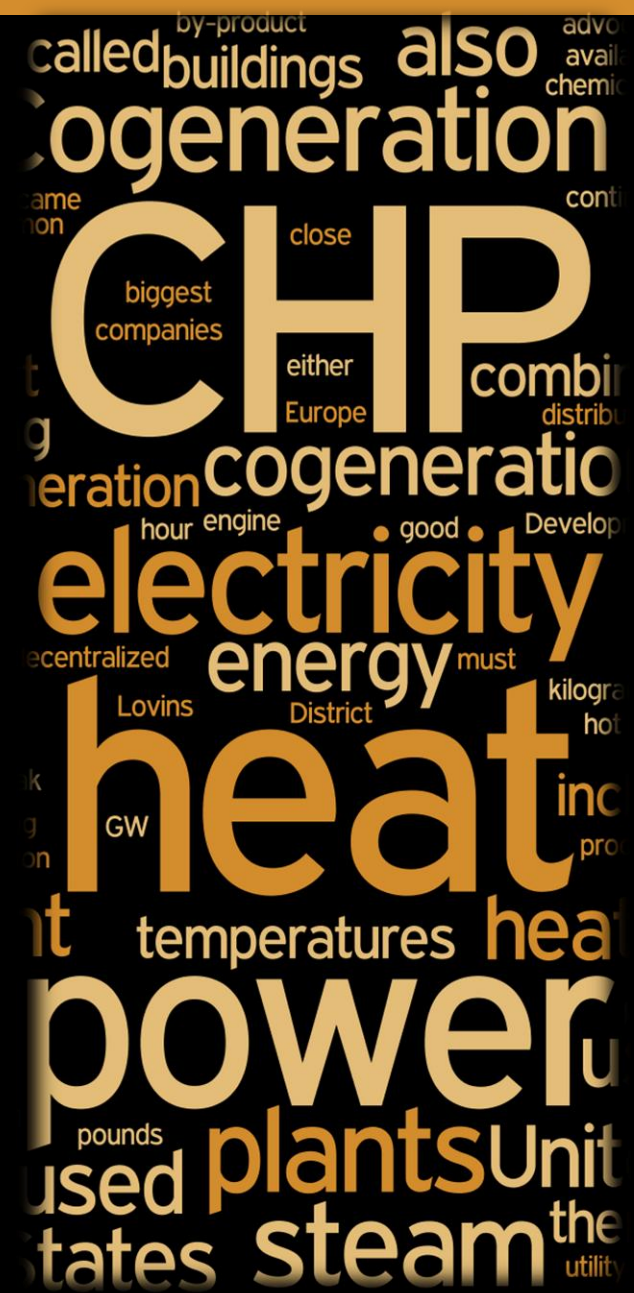
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Payback	
First Cost	\$2,310,000
Total Saving	\$699,062
Simple Payback	3.30 Yrs

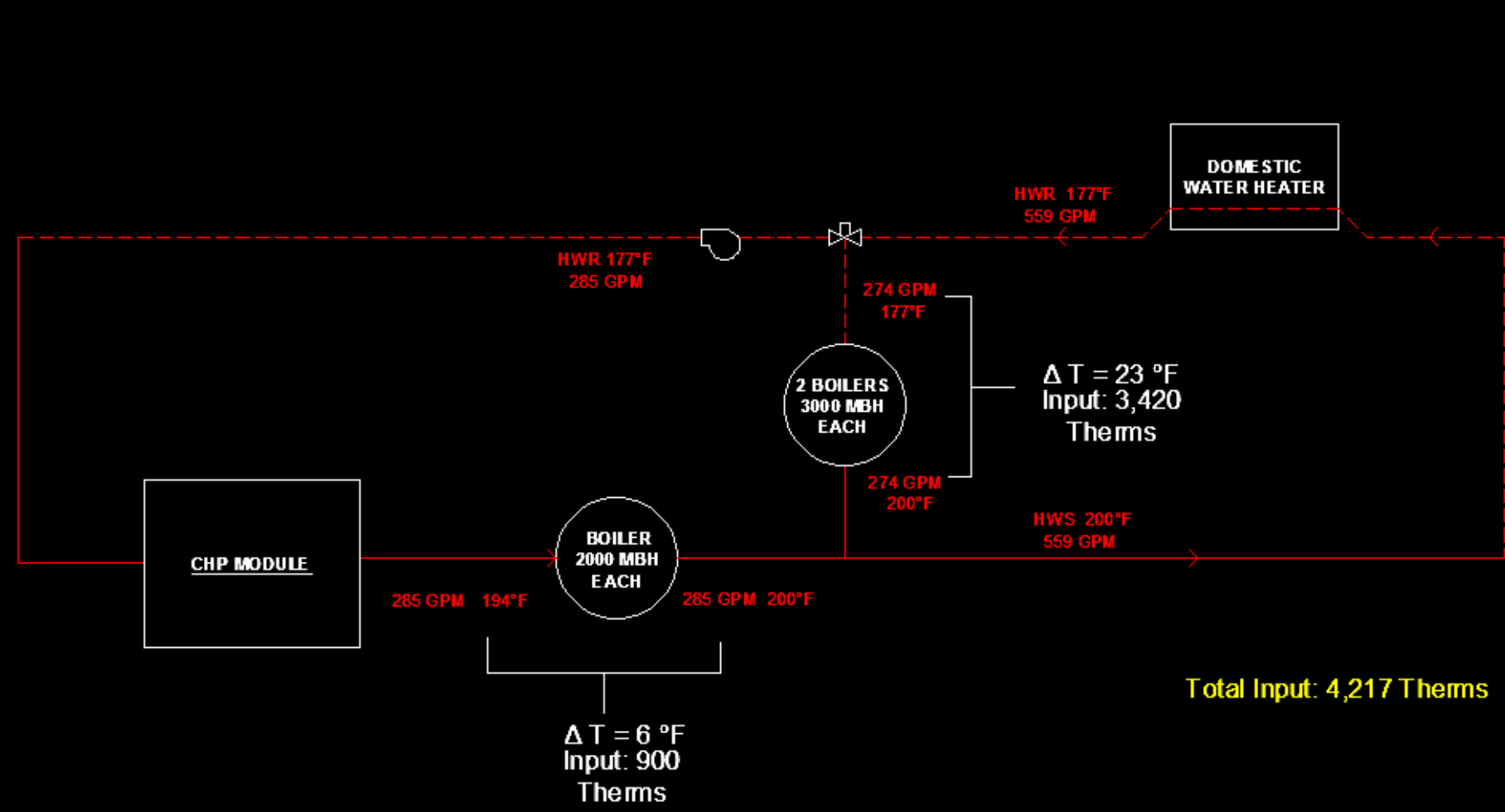
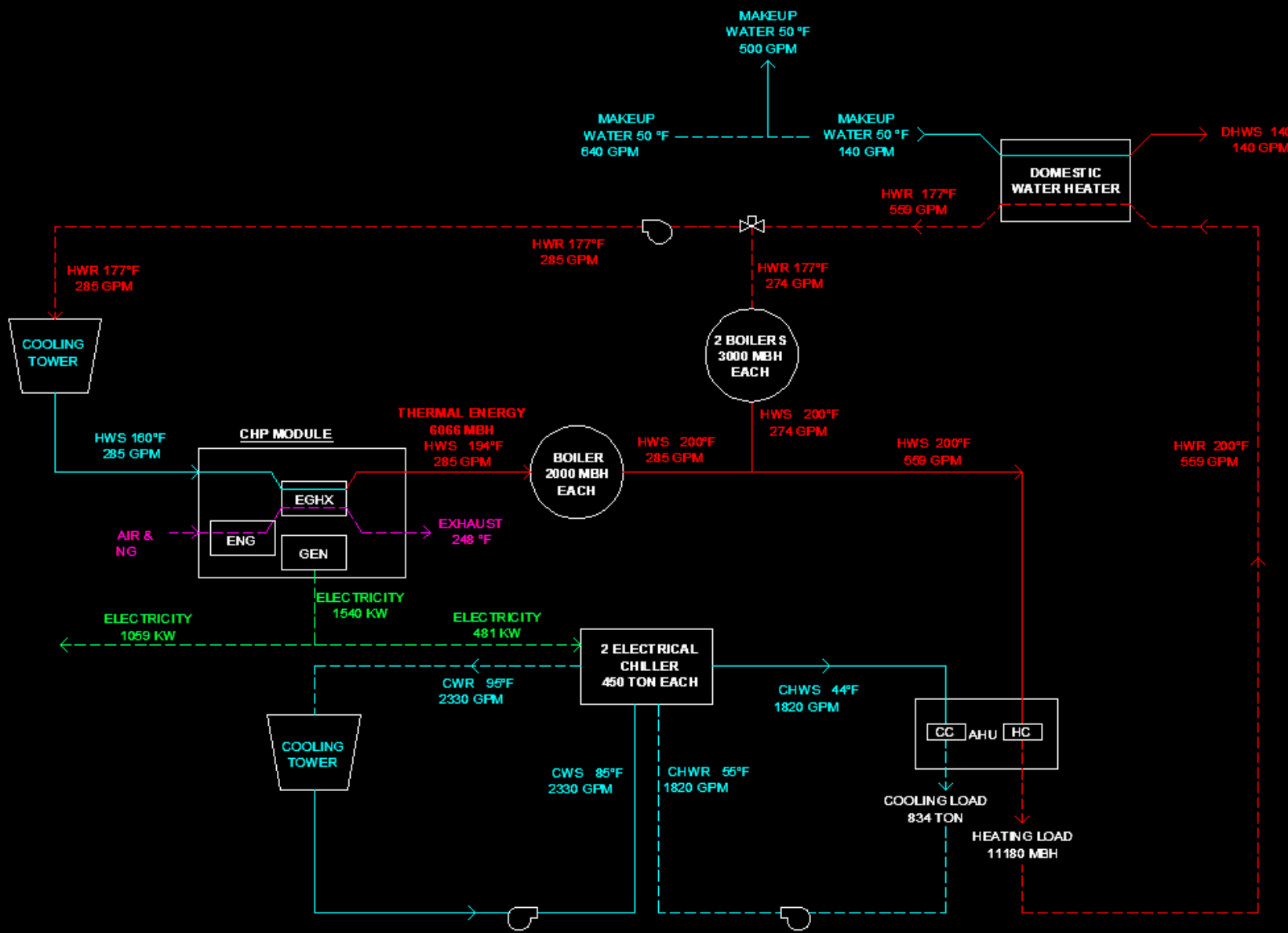
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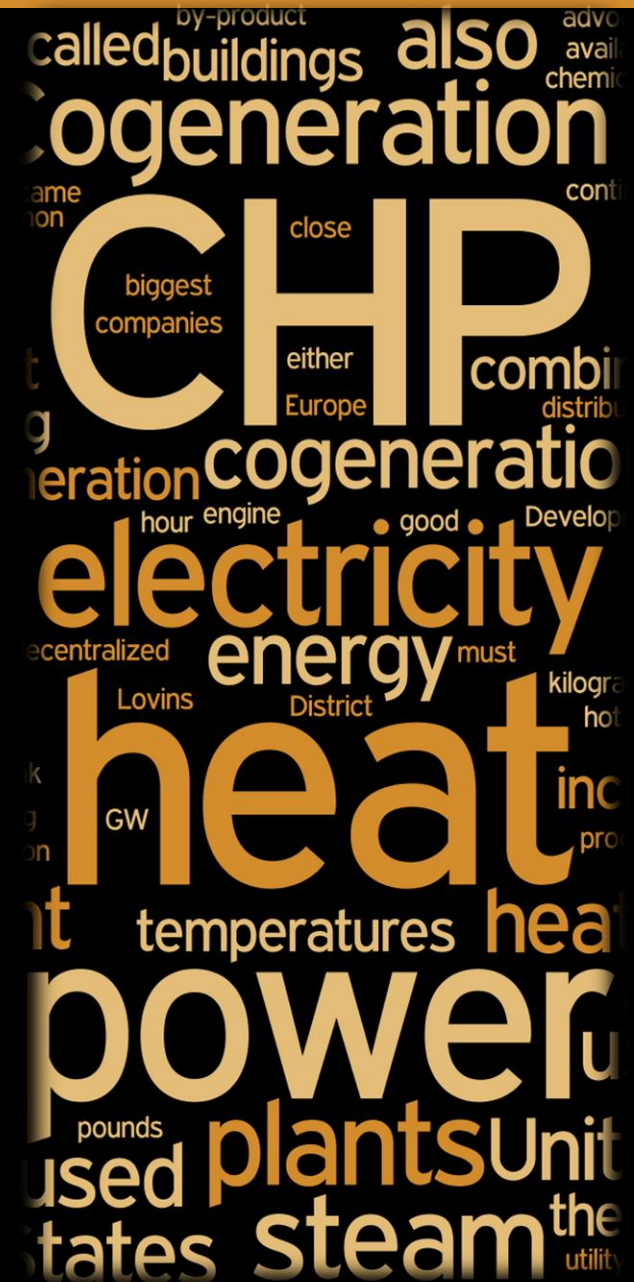
Expenses	
Fuel Expenses	\$827,254
O&M Costs	\$168,630
Standby Charge	\$55,440
Total Expenses	\$1,051,324

Saving	
Total Saving	\$699,062

called buildings also
 cogeneration
 CHP
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 plants
 steam

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 - CHP Module Simple Payback
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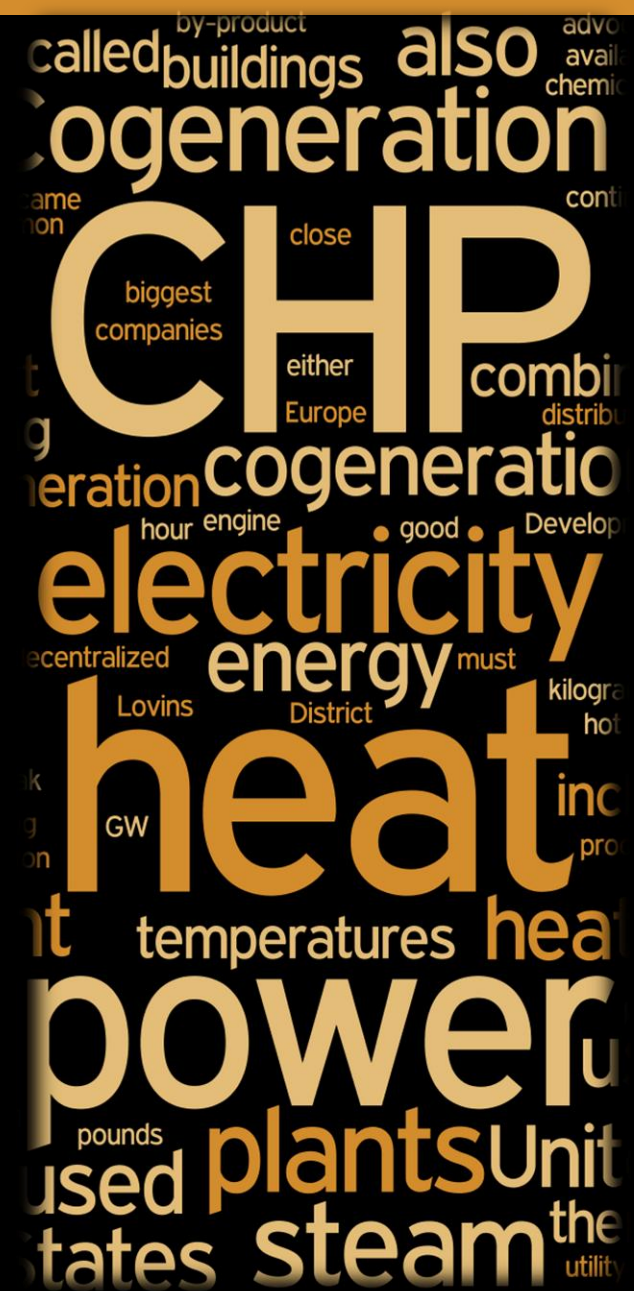




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		Annual Energy Generated		Annual Energy Consumption (Space Heating & Space Cooling)	
		Thermal (MMBtu)	Electricity (KWh)	Thermal (MMBtu)	Electricity (KWh)
Existing	Heating			103,091	-
	Cooling	-	-	-	4,204,800
Alternative 1	Heating			78,840	-
	Cooling	53,138	13,490,400	-	4,204,800

	Annual Net Saving				
	Thermal (MMBtu)	Electricity (KWh)	Thermal (\$)	Electricity (\$)	Total (\$)
Existing vs. Alternative 1	24,251	13,490,400	183,098	1,349,040	1,532,138



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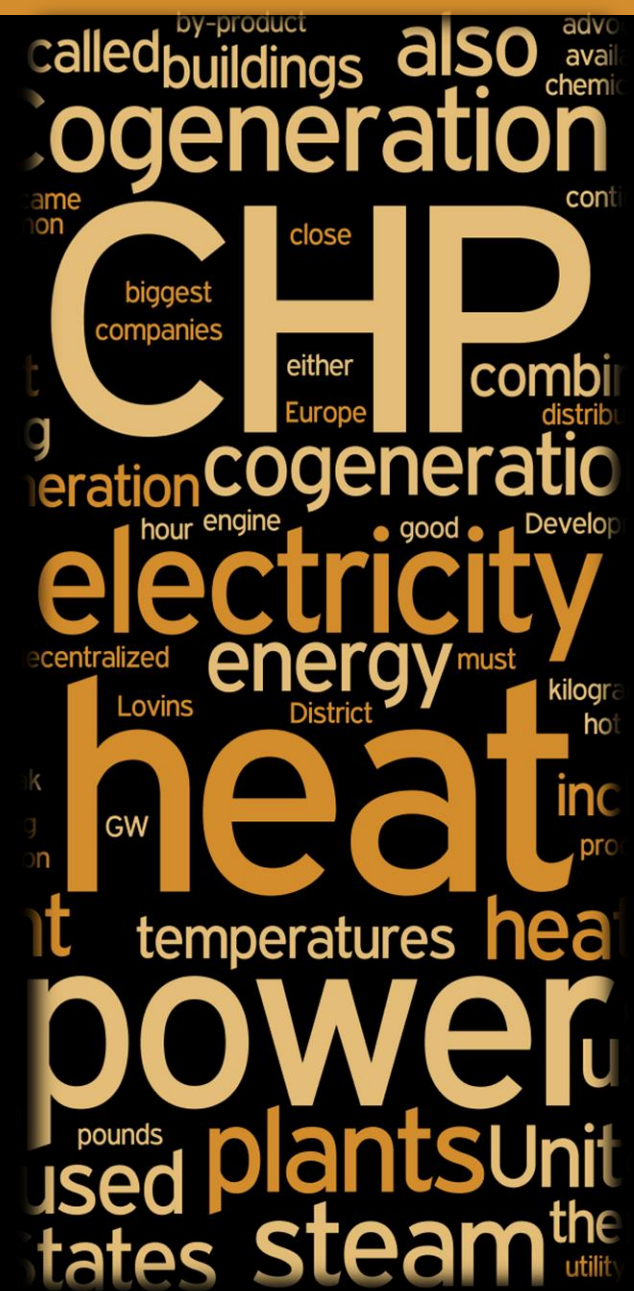
Combined Heat, Power and Cooling (CHPC) system

CHPC supplies energy in three forms:

- Electricity
- Heat
- Chilled water

Chiller Type	Heat Production (Brtu/kWh)		Absorber COP		Cooling Available (Tons/kW)	
	Min.	Max.	Min.	Max.	Min.	Max.
Single Effect	3,800	6,000	0.70	0.78	0.22	0.35
Double Effect	1,500	2,000	1.10	1.30	0.15	0.20

Absorption Chiller Selection	
Carrier 16JLR 47	
(Single Effect Lithium Bromide - Water Absorption Chiller)	
Cooling Capacity	450 Tons
Chilled Water Temp	54 / 44 F
Cooling Water Temp	85 / 95 F
Hot Water Temp	203 / 185 F
COP	0.7



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Combined Heat, Power and Cooling (CHPC) system

CHPC supplies energy in three forms:

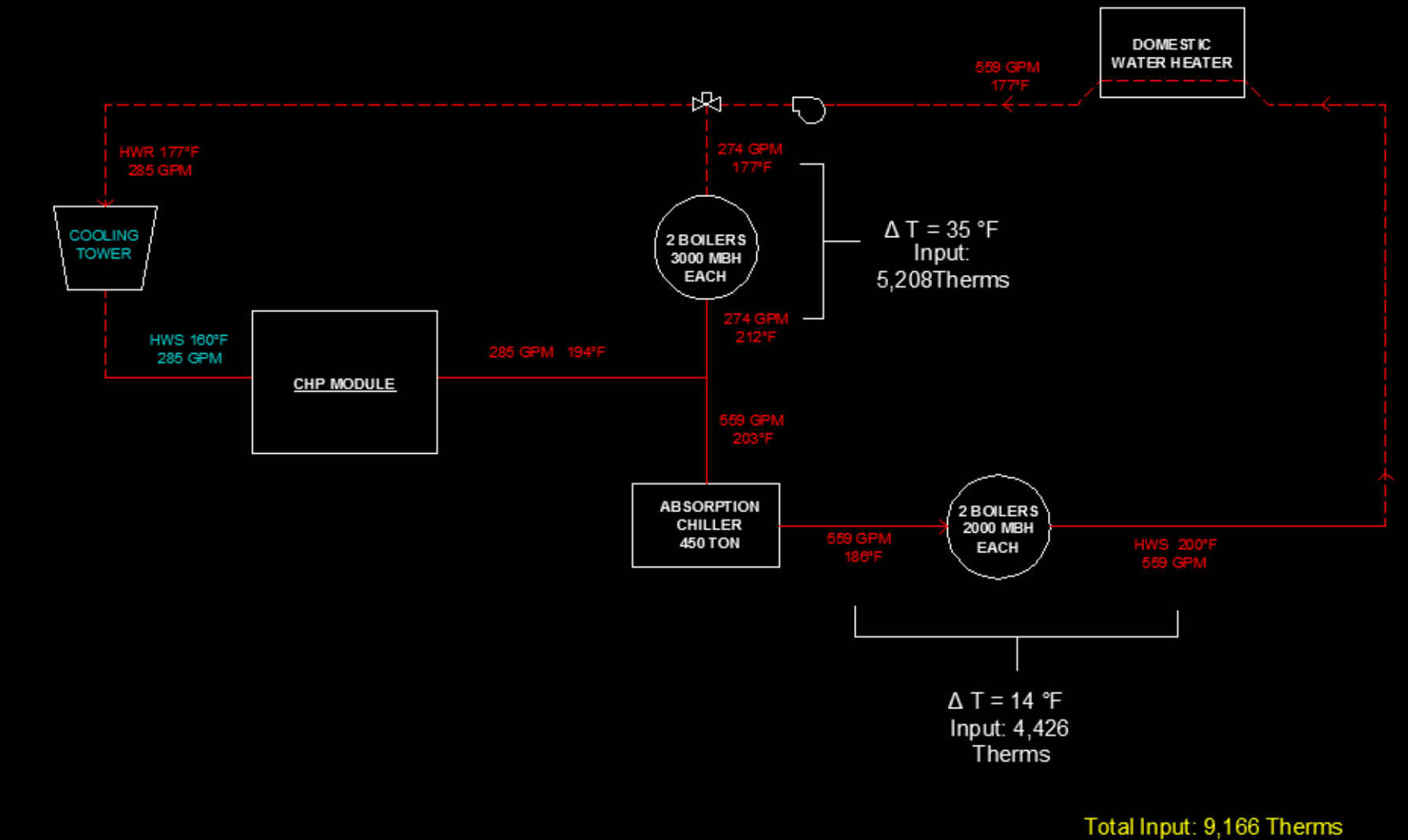
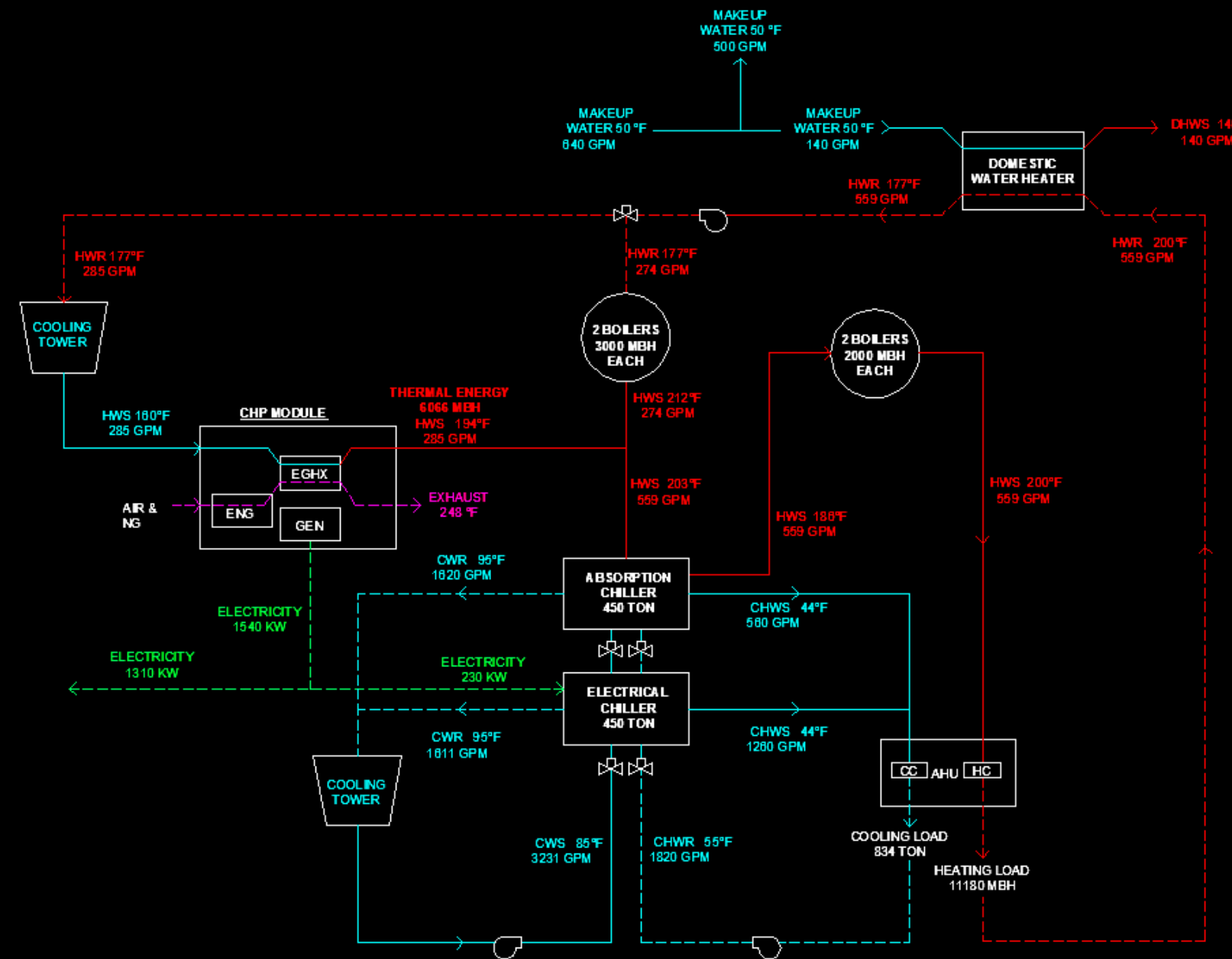
- Electricity
- Heat
- Chilled water

Chiller Type	Heat Production (Brtu/kWh)		Absorber COP		Cooling Available (Tons/kW)	
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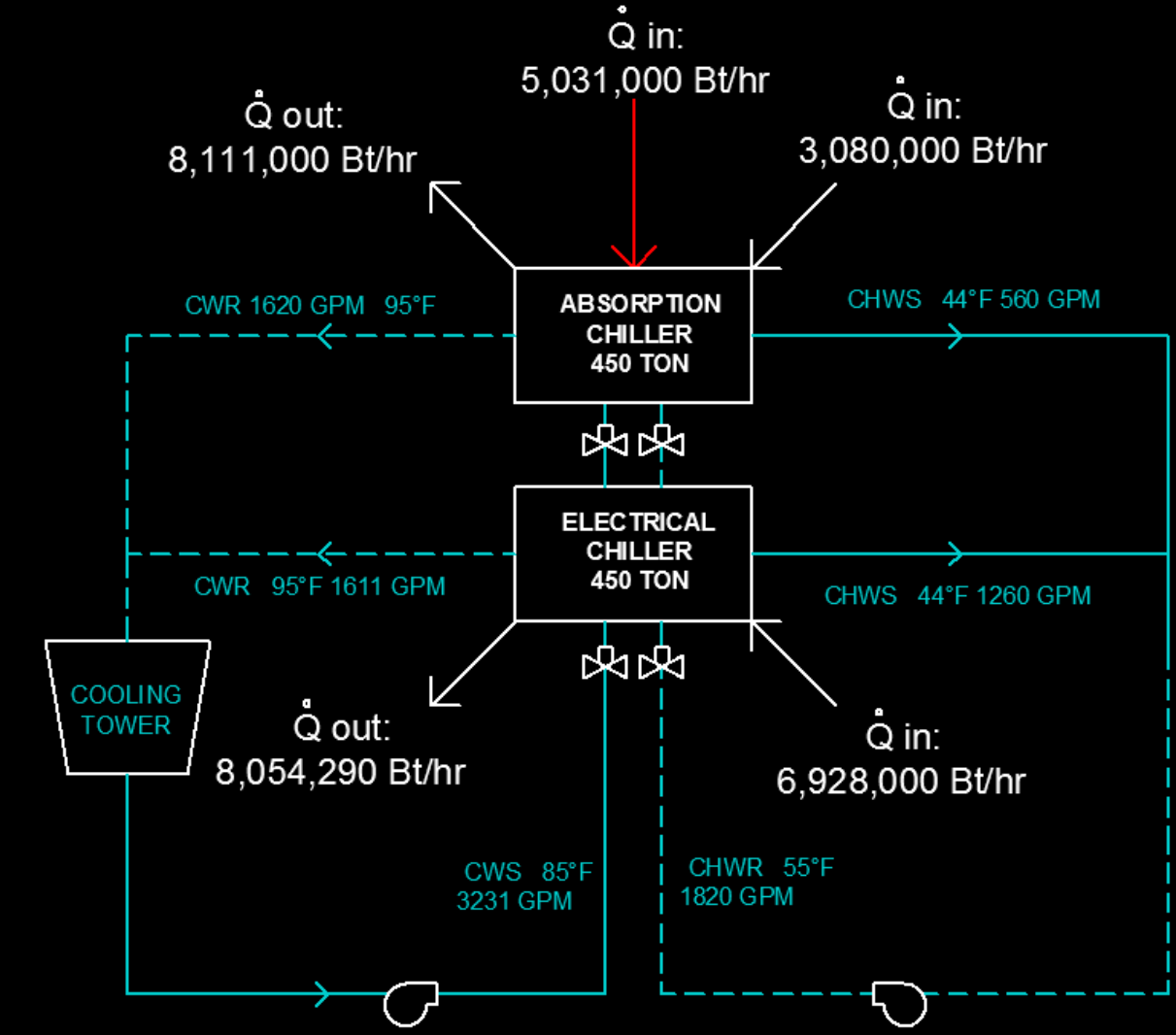
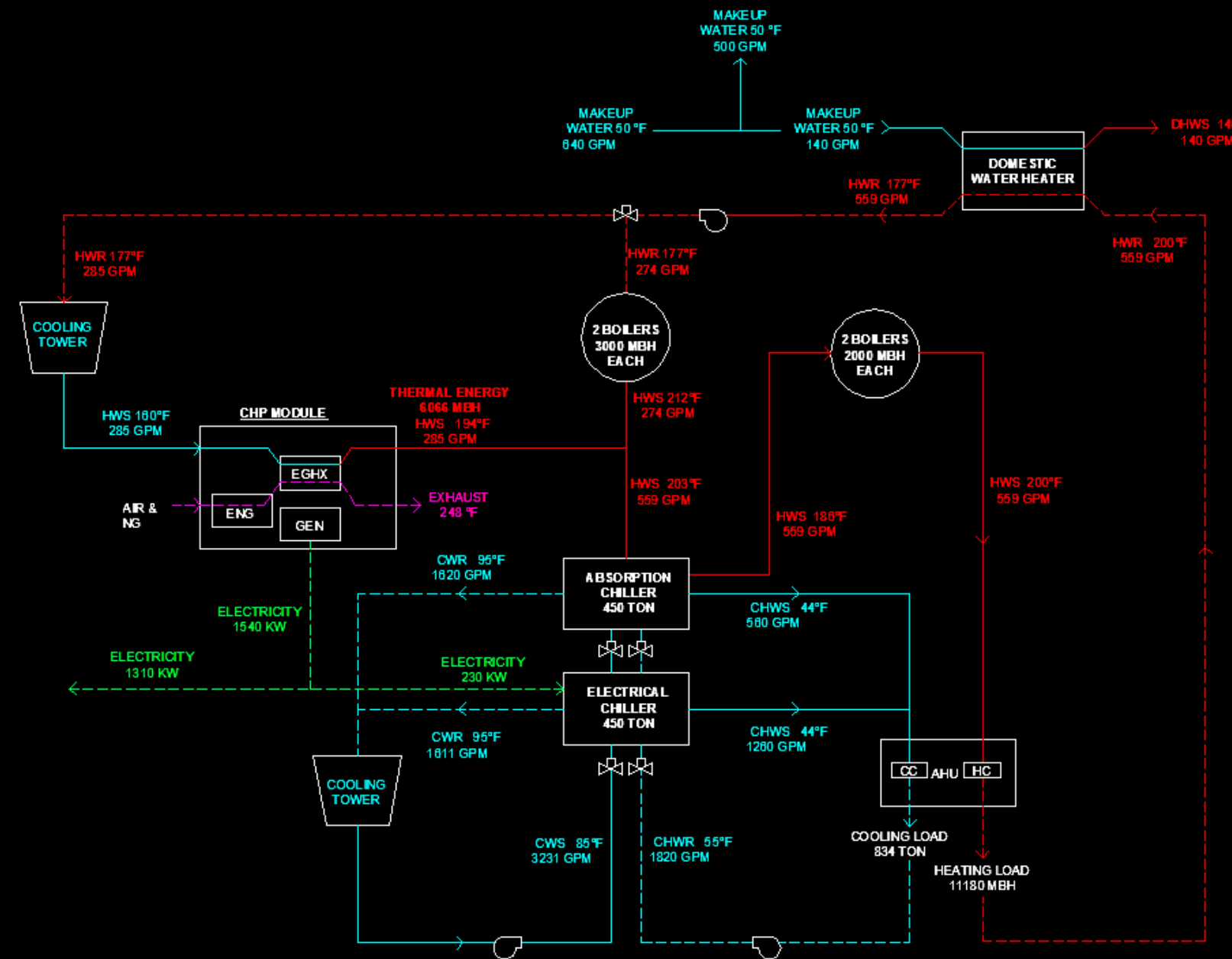
called buildings also available
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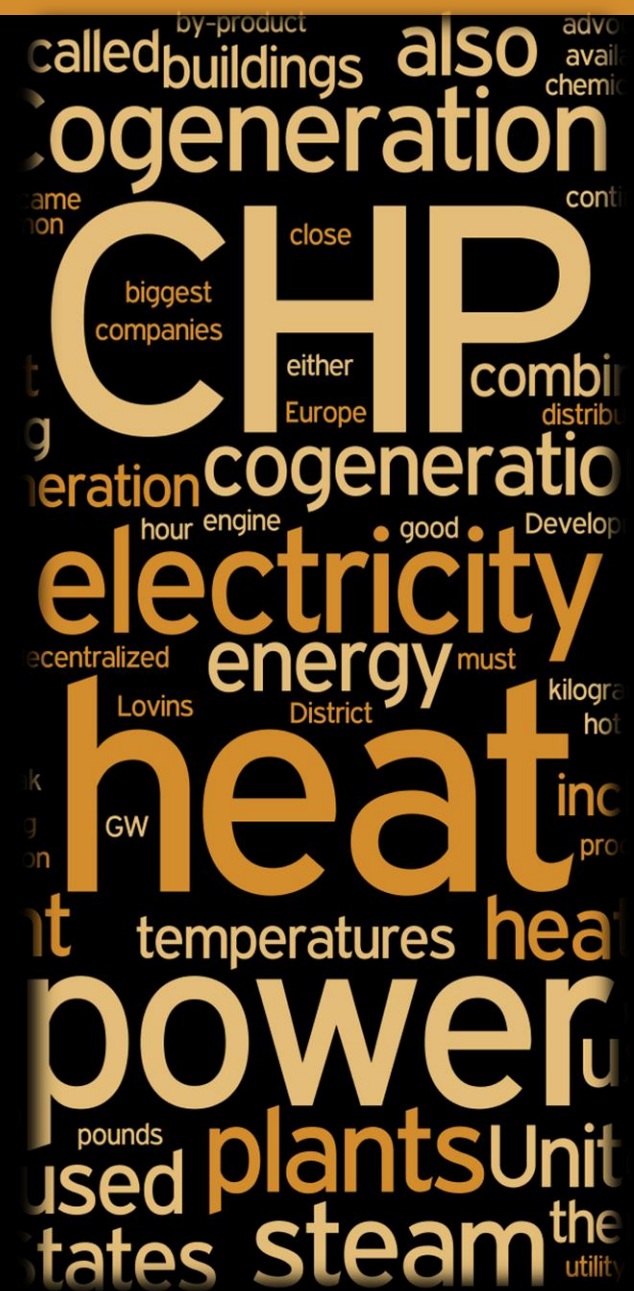


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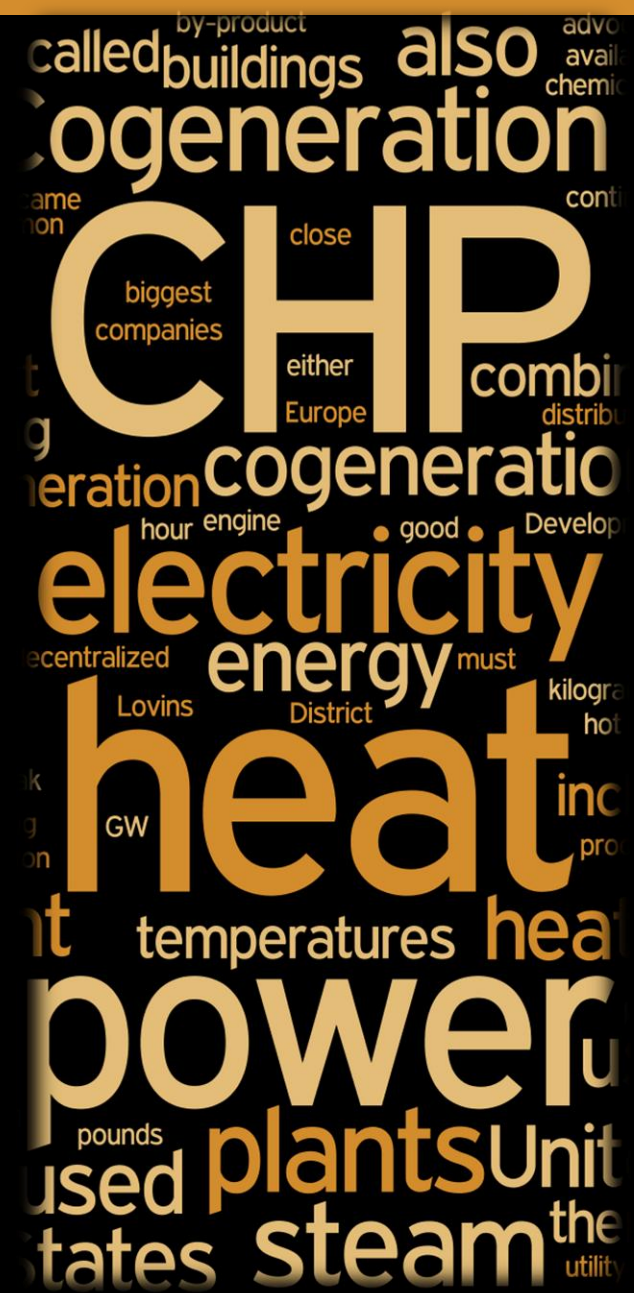
Total Input: 330 KW



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		Annual Energy Generated		Annual Energy Consumption (Space Heating & Space Cooling)	
		Thermal (MMBtu)	Electricity (KWh)	Thermal (MMBtu)	Electricity (KWh)
Existing	Heating	-	-	103,091.37	-
	Cooling	-	-	-	4,204,800
Alternative 2	Heating	53,138	13,490,400	80,296.93	-
	Cooling			-	2,890,800

	Annual Net Saving				
	Thermal (MMBtu)	Electricity (KWh)	Thermal (\$)	Electricity (\$)	Total (\$)
Existing vs. Alternative 2	22,794	14,804,400	172,098	1,480,440	1,652,538



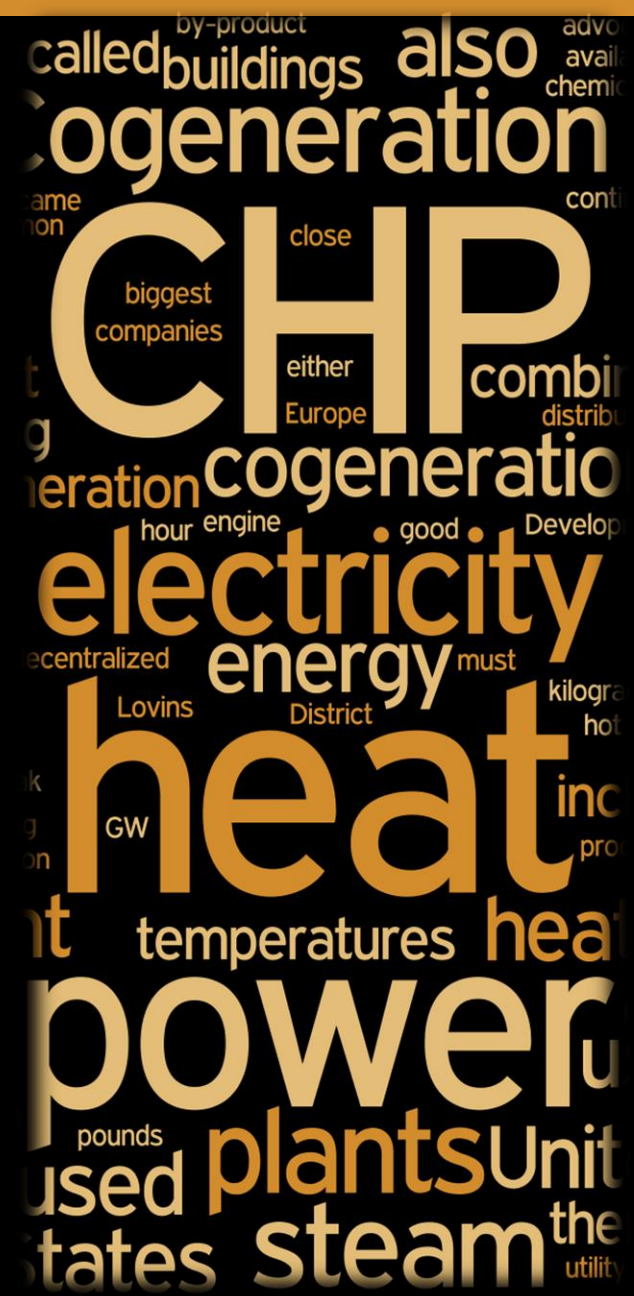
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	Annual Net Saving				
	Thermal (MMBtu)	Electricity (KWh)	Thermal (\$)	Electricity (\$)	Total (\$)
Existing vs. Alternative1	24,251	13,490,400	183,098	1,349,040	1,532,138
Existing vs. Alternative2	22,794	14,804,400	172,098	1,480,440	1,652,538
Alternative2 vs. Alternative 1	(1,457)	1,314,000	(11,000)	131,400	120,400

First Cost	Existing	Alternative 1	Alternative 2
Boilers	\$2,280,000	\$1,387,000	\$1,900,000
Electric Chiller	\$304,000	\$304,000	\$152,000
Absorption Chiller	\$0	\$0	\$180,000
Pumps	\$400,000	\$400,000	\$400,000
Total	\$2,984,000	\$2,091,000	\$2,632,000
Saving On First Cost	\$0	\$893,000	\$352,000

Alternative 1: More Saving on First Cost

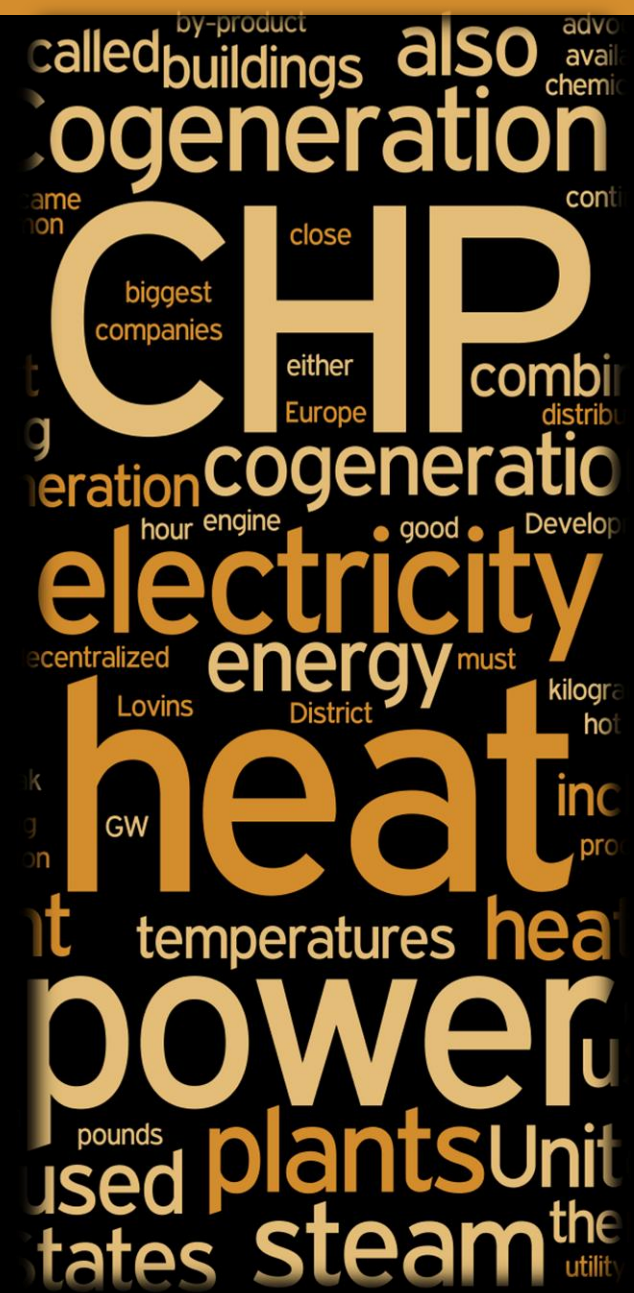
Alternative 2: More Saving on Annual Energy Consumption



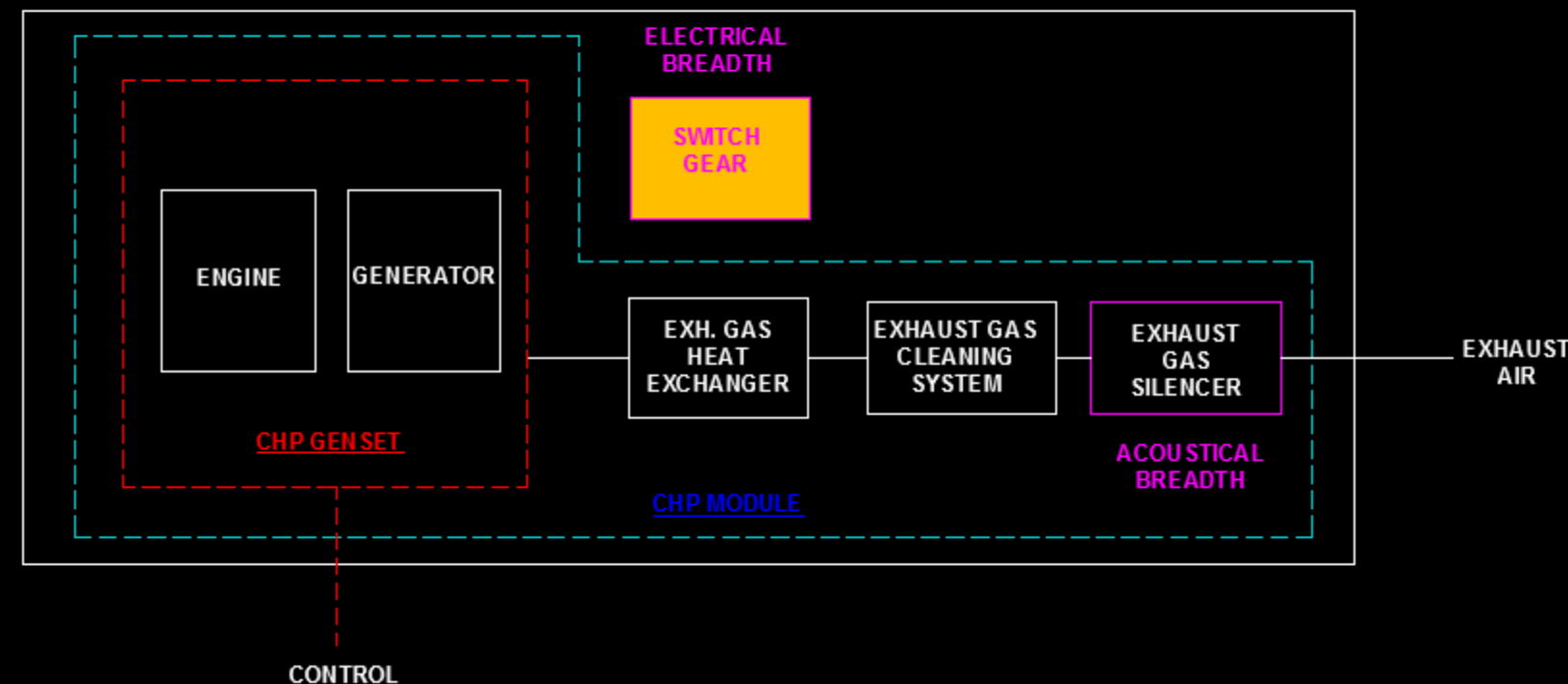
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Annual Emissions Analysis - Alternative 1		
	Emissions/Fuel Reduction	Percent Reduction
NOx (tons/year)	(4.452)	(0.469)
SO2 (tons/year)	22.205	0.998
CO2 (tons/year)	4,369	0.362
CH4 (tons/year)	0.090	0.384
N2O (tons/year)	0.122	0.894
Total GHGs (CO2e tons/year)	4,408	0.364
Carbon (metric tons/year)	1,080	0.362
Fuel Consumption (MMBtu/year)	22,298	0.145
Number of Cars Removed	765	

Annual Emissions Analysis - Alternative 2		
	Emissions/Fuel Reduction	Percent Reduction
NOx (tons/year)	1.317	0.086
SO2 (tons/year)	40.830	0.999
CO2 (tons/year)	9,350	0.548
CH4 (tons/year)	0.191	0.568
N2O (tons/year)	0.227	0.940
Total GHGs (CO2e tons/year)	9,425	0.550
Carbon (metric tons/year)	2,312	0.548
Fuel Consumption (MMBtu/year)	63,561	0.326
Number of Cars Removed	1,637	



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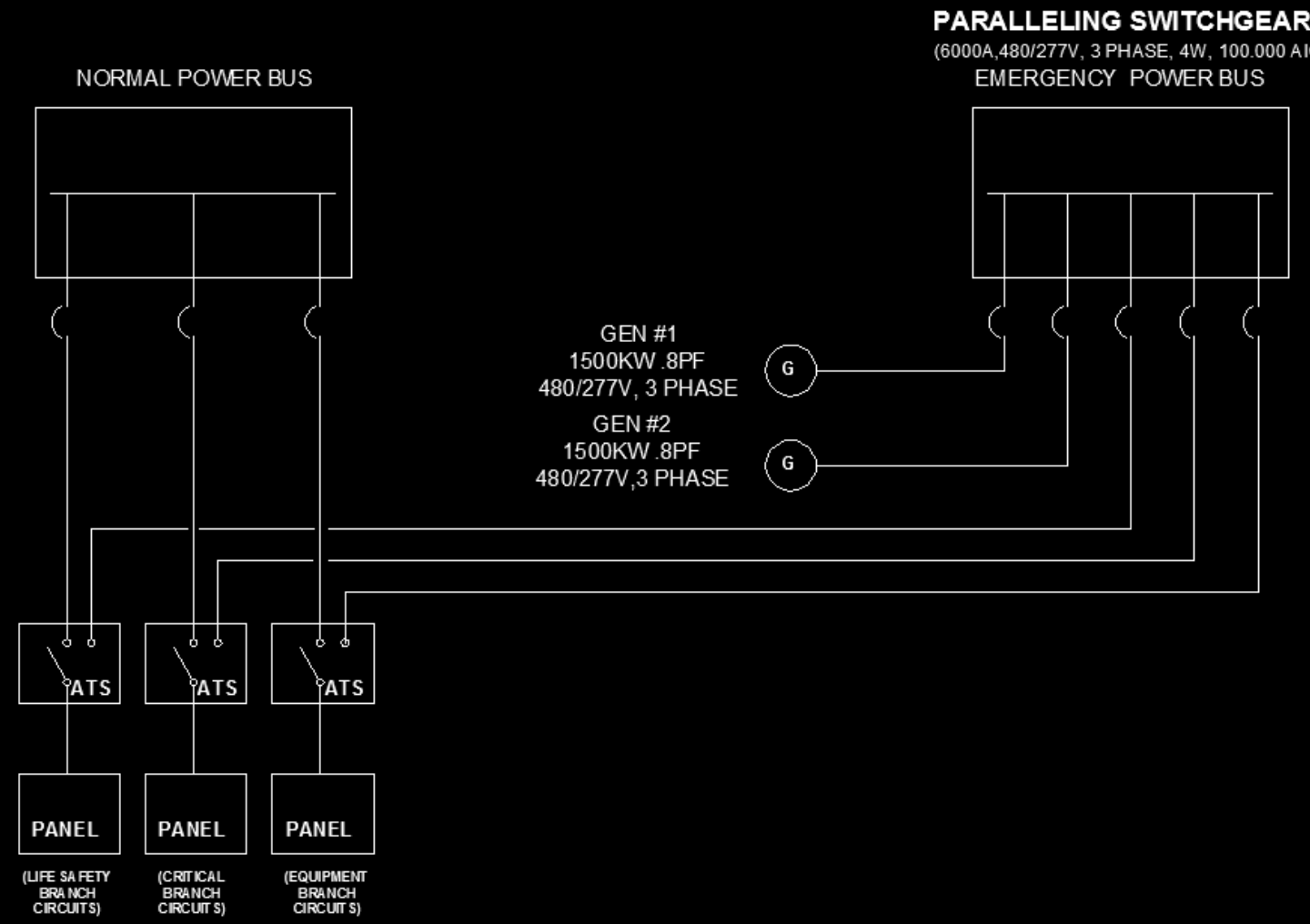
Replacing existing emergency generator with CHP generator

NEC 517.31 and NFPA 99 3-4.3.1

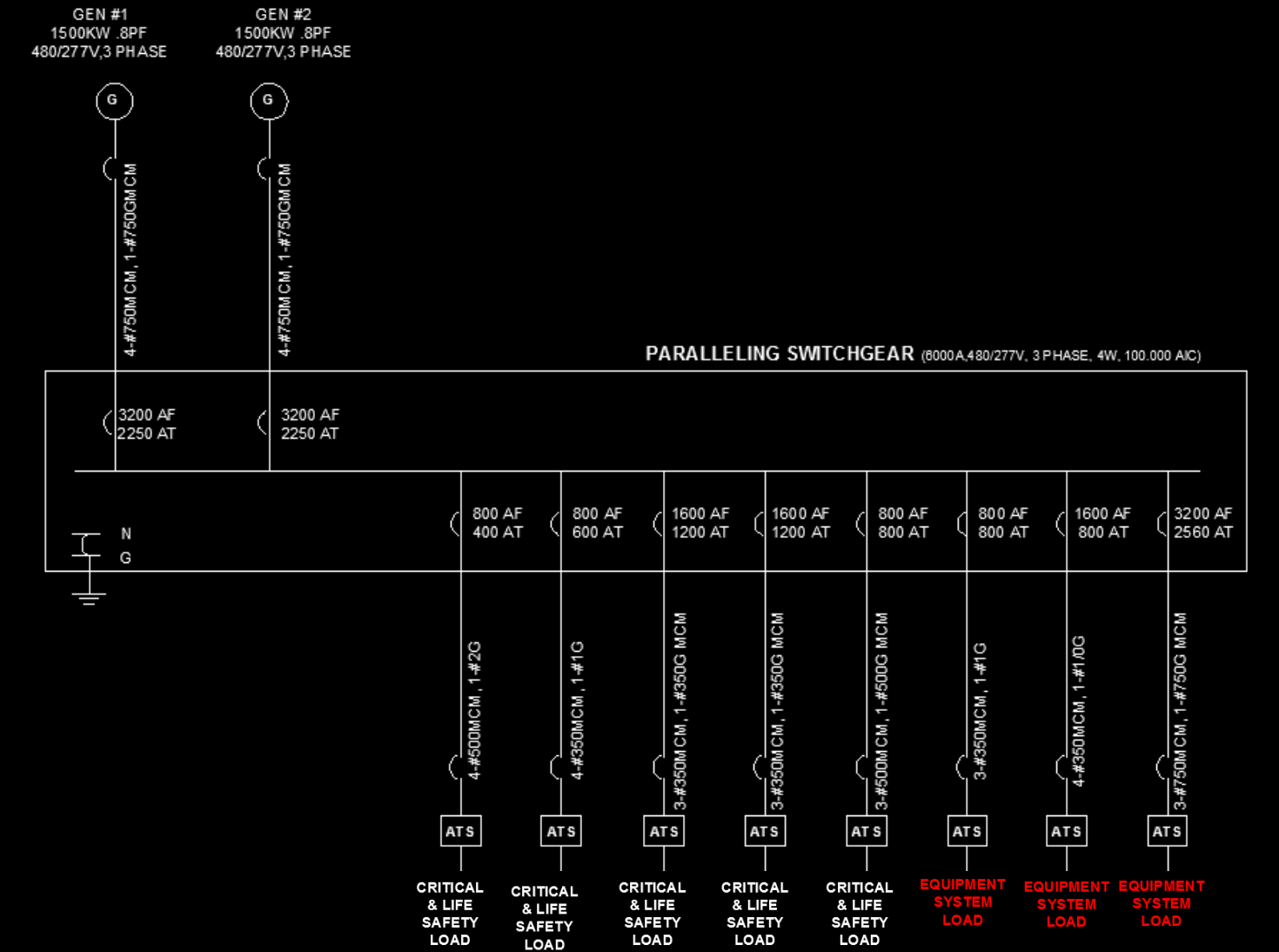
Emergency generator Startup time (Healthcare facility) < 10 s
CHP system cannot serve for the life safety load & critical load.

called buildings also available
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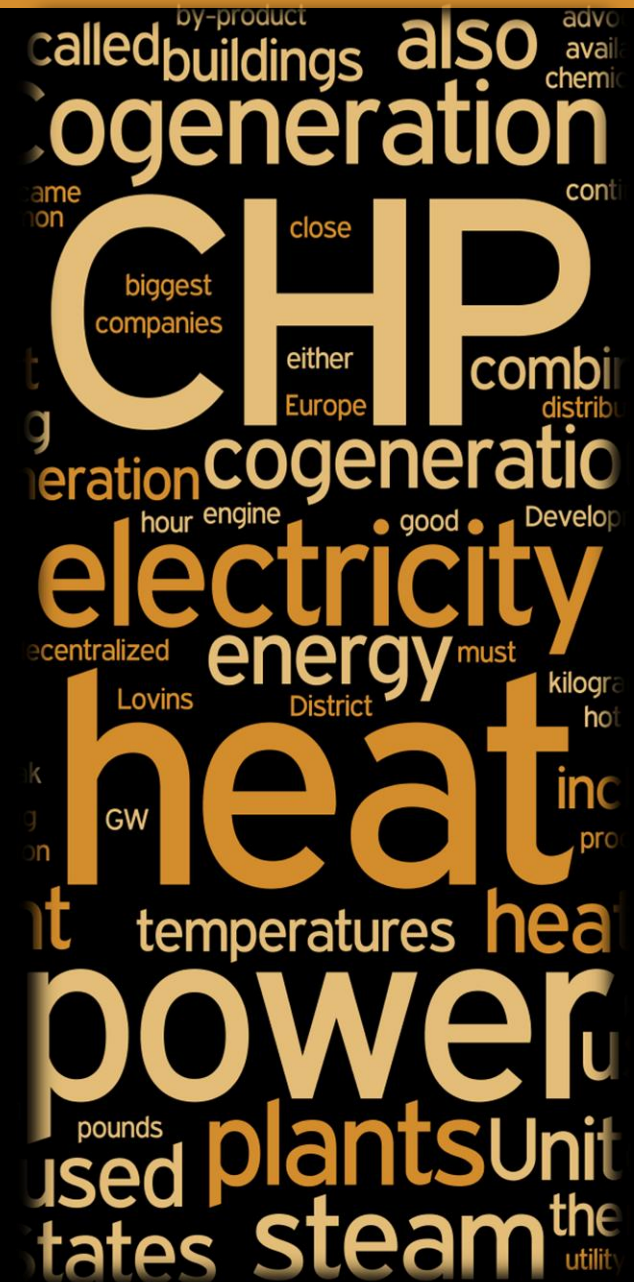
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SIMPLIFIED ELECTRICAL SYSTEM - EXISTING



PARALLELING SWITCHGEAR DISTRIBUTION DIAGRAM - EXISTING



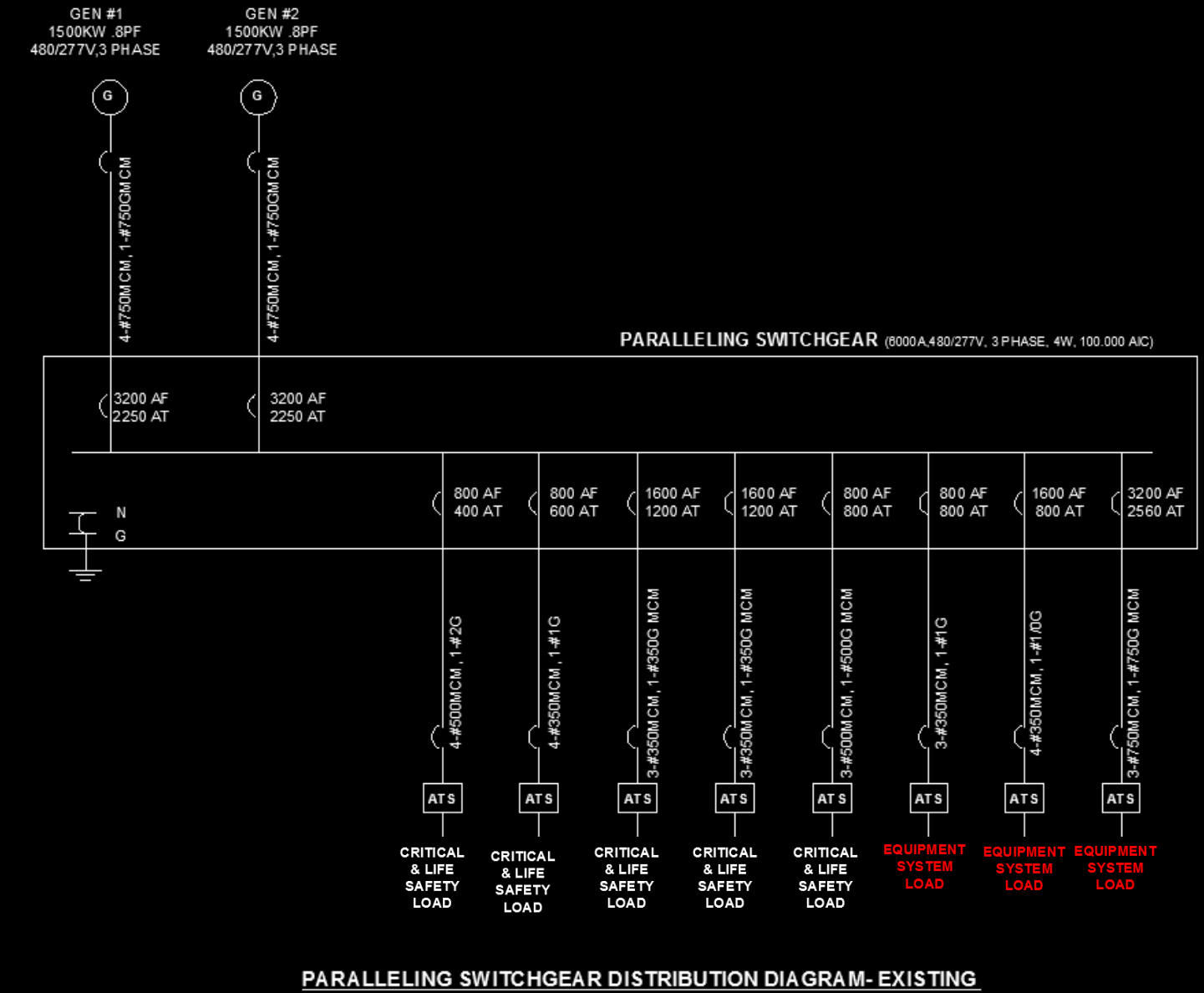
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	Percentage (%)
Critical & Life Safety	50.2
Equipment System	49.8
Total	100

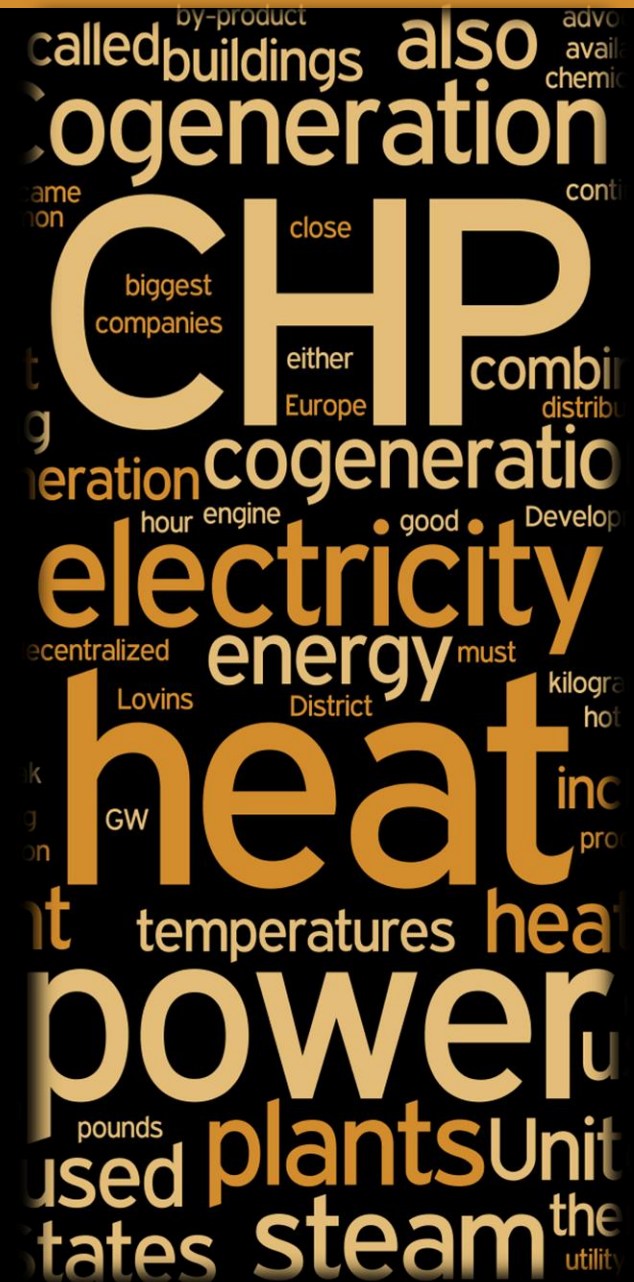
Each of existing emergency generators serves 50% of total emergency load.

Gen #1 is big enough to serve as the life safety load and critical load.

Gen #2 will be replaced by the CHP generator.



PARALLELING SWITCHGEAR DISTRIBUTION DIAGRAM- EXISTING



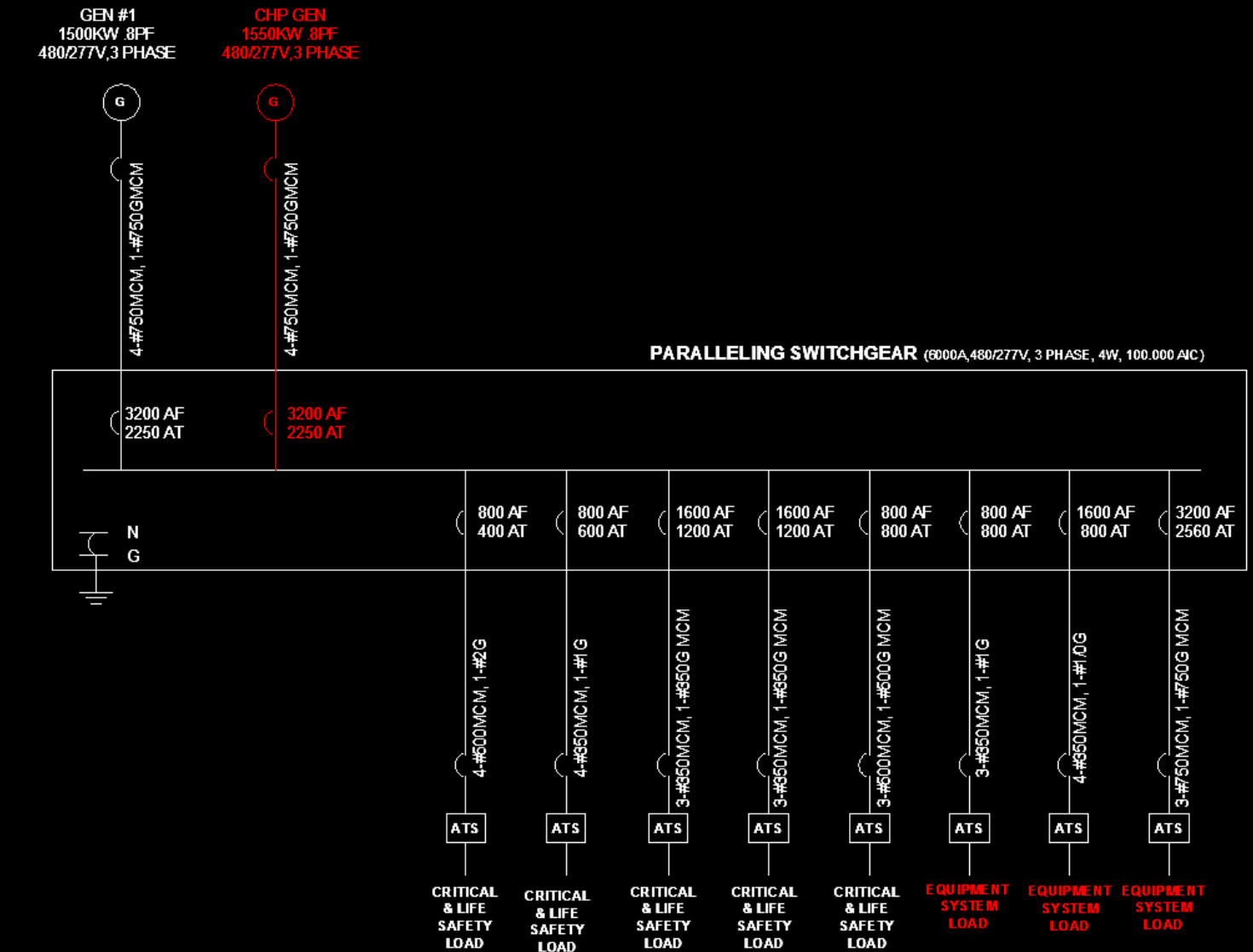
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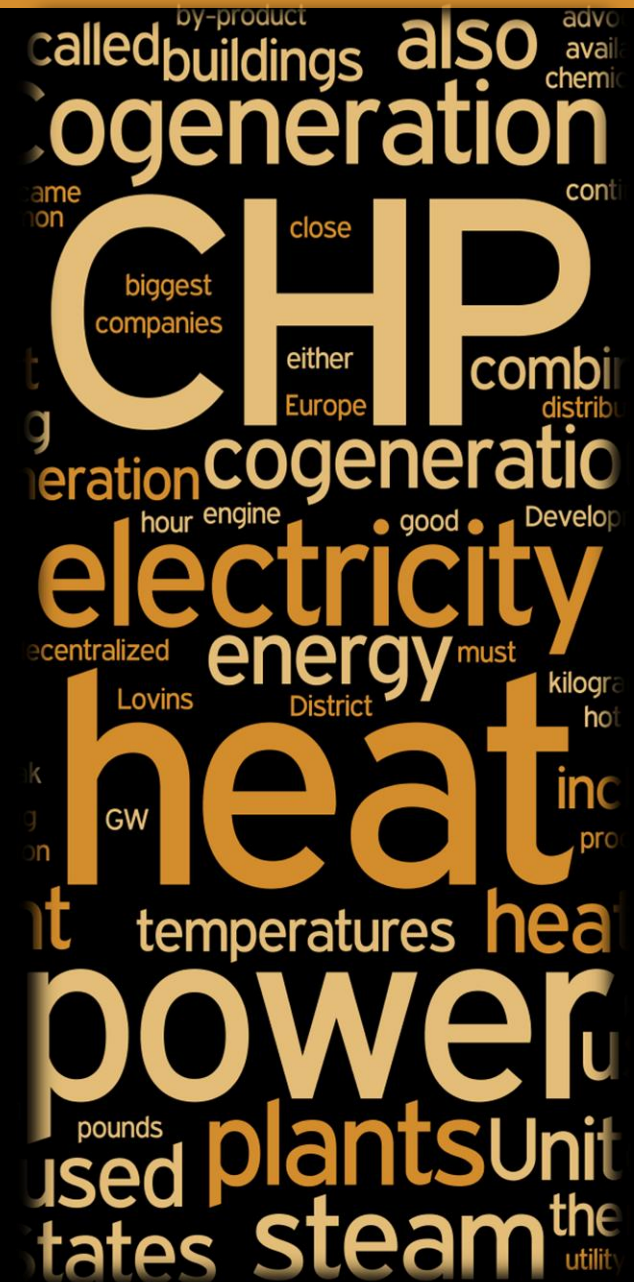
	Percentage (%)
Critical & Life Safety	50.2
Equipment System	49.8
Total	100

Each of existing emergency generators serves 50% of total emergency load.

Gen #1 is big enough to serve as the life safety load and critical load.

Gen #2 will be replaced by the CHP generator.

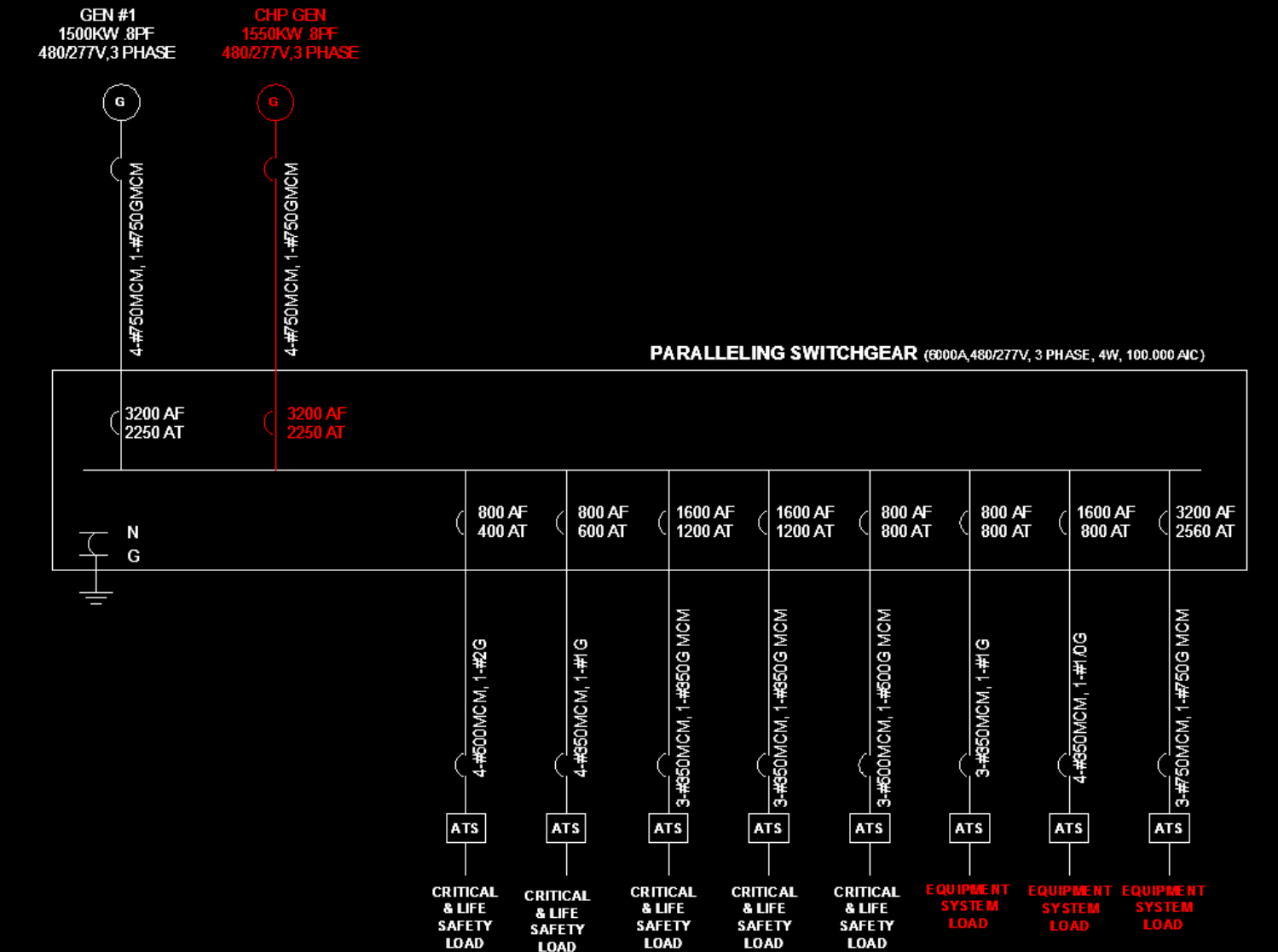


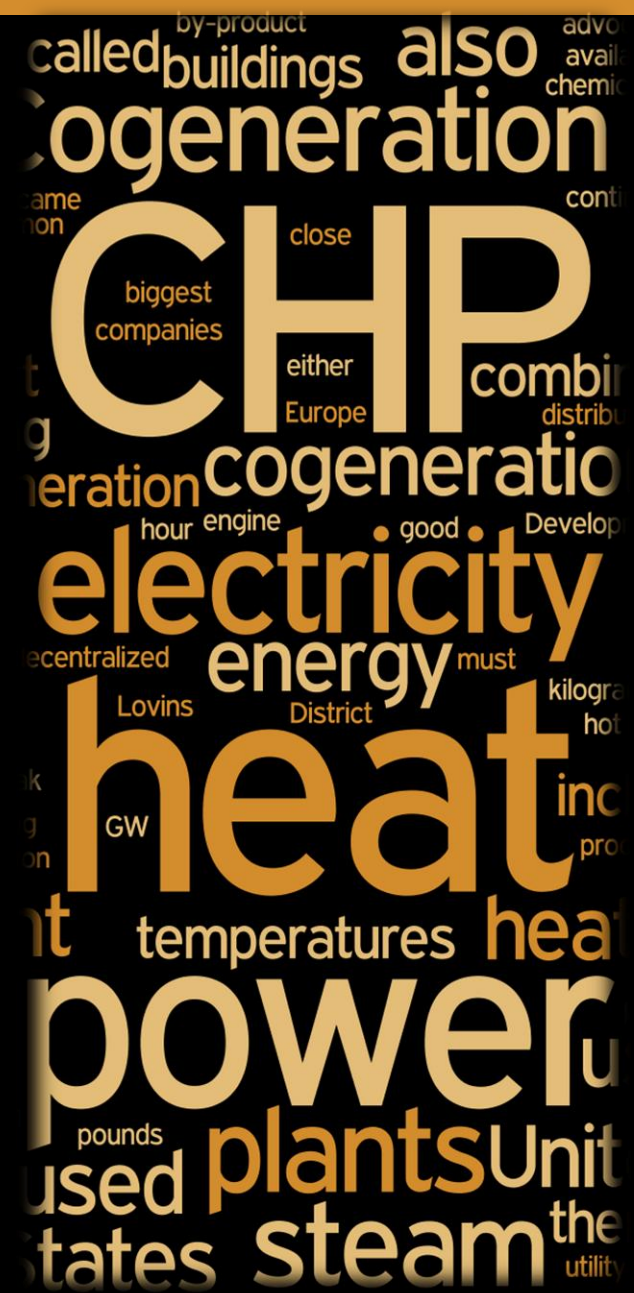


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Sizing Conductors		
Electrical Output	1,540	KW
Power Factor	0.90	
Voltage	480	V
Amps	1,667	A
Over Current Protection (115%)	1,917	A
Up sized: 4 set of # 750 MCM, 1 set of #750 G MCM		

NEC 445.13. Over Current Protection For Generator : 115%





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	Alternative 1	Alternative 2
Net Saving (\$)	1,532,138	1,652,538

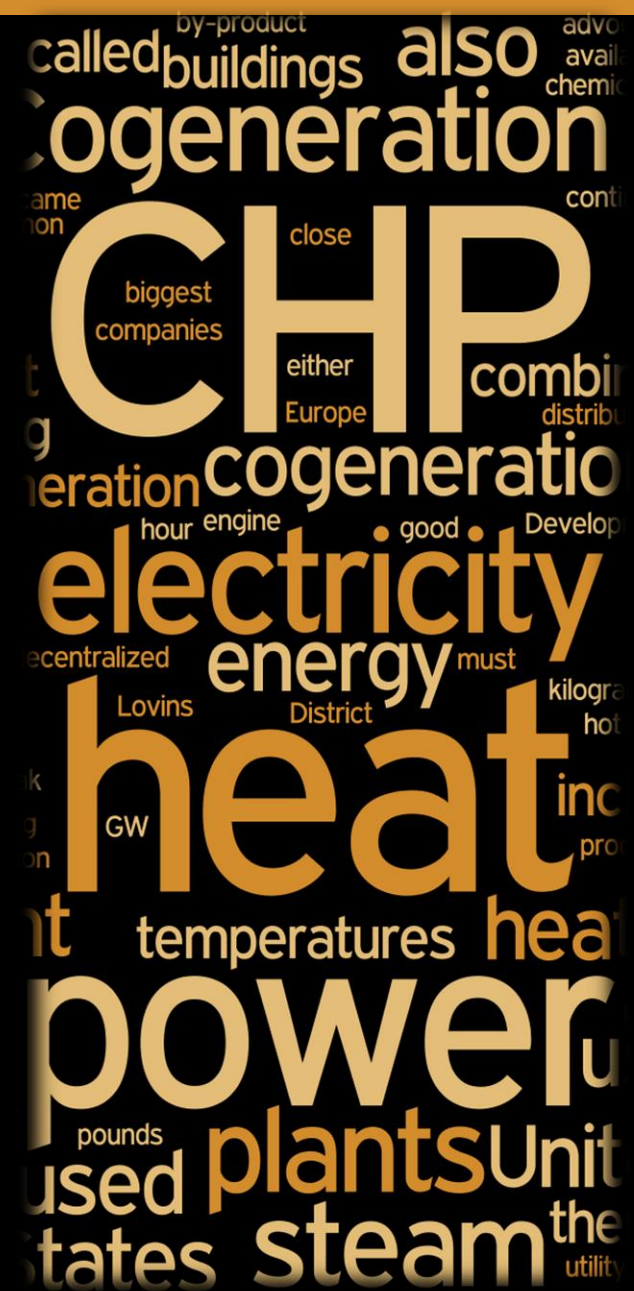
Primary Goal:

- Reduce energy consumption

	Alternative 1	Alternative 2
	Percent Reduction	
Carbon (metric tons/year)	36%	55%
Fuel Consumption (MMBtu/year)	14%	33%

Secondary Goal:

- Cut back on emissions



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Questions?



Special Thanks to:

- James D. Freihaut, PhD – Professor of AE Dept.
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- Jason Wilson – Scheeser Buckley Mayfield LLC
- Josh Roehm – Scheeser Buckley Mayfield LLC