INOVA Fairfax Hospital South Patient Tower

Falls Church, VA

Senior Thesis 2012

Mike Morder
Mechanical Option

Advisor: Dr. William Bahnfleth

INOVA South Patient Tower

- Introduction
- Depth 1: Central Chilled Water Plant
- Depth 2: Dedicated Heat Recovery Chiller
- Depth 3: Condensate Recovery
- Breadth 1: Two-Way Slab Reinforcing
- Breadth 2: Electrical
- Conclusion
- Acknowledgements
- Questions

INOVA South Patient Tower

- Introduction
  - South Patient Tower
  - Mechanical System
  - Design Objective
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Building Introduction

- Addition to Existing Patient Bed Tower
- Located in Falls Church, VA
- 236,000 SF
- Overall Cost: $76 Million
- Completion Expected in June 2012

Site Map

INOVA South Patient Tower

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Project Team

- Owner: INOVA Health System
- Architect: Wilmot/Sanz, Inc.
- General Contractor: Turner Construction
- Structural Engineer: Cagley & Associates
- MEP Engineer: RMF Engineering, Inc.
- Civil Engineer: Dewberry & Davis

Architectural Aspects

- Designed to Respect Existing Tower
- Natural Daylight Essential for Patient Rooms
- Focal Point – Atrium with Fountain at Entrance
- Pursuing LEED Silver

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Structural System

- Typical 29' x 29' Bays
- Reinforced Normal Weight Concrete
- Two-Way Slab with Drop Panels

Electrical System

- Two 2000 kVA Transformers
- 600 A Bus Ducts Provide Service Throughout Building
- 2000 kW Emergency Generator

INOVA South Patient Tower

Existing Mechanical System

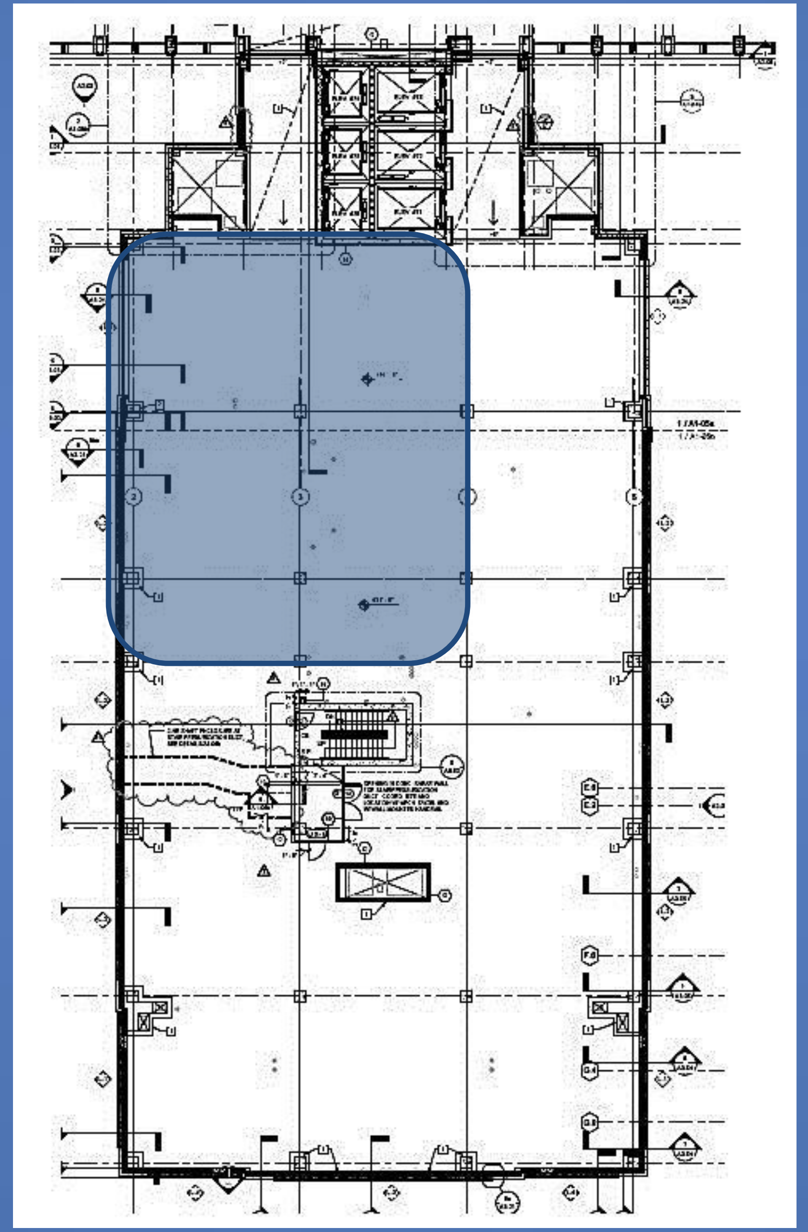
- Connected to Existing Campus Central Plant
- Steam System-
  - Domestic Hot Water Heating
  - Heat Exchangers Provide HHW
- Chilled Water System-
  - Supplies Cooling to AHUs
  - No Booster Pumps in Building
- Four (4) 20,000 CFM AHU
  - Majority of Bed Tower
- 10,000 CFM and 13,000 CFM AHU
  - Supply Cafeteria and Kitchen Hoods
- Baseboard Radiators (Hot Water)
- Constant Air Volume Terminal Units
  - Reheat Provided on Exterior Rooms

Design Objective

- Chilled Water Plant Optimization Study
- Chiller Design/ Layout
  - Centrifugal vs. Absorption
  - Primary Secondary vs. Variable Primary Flow
- Dedicated Heat Recovery Chiller
- Air-Handler Condensate Recovery System

- Best Selections = Most Economical
  - Most Energy Reduction
  - Lowest Emissions

Introduction



- Location: 5th Floor Mechanical Space
- Alternative 1: Purchased CHW and Steam
- Alternative 2: Centrifugal (Primary/Secondary)
- Alternative 3: Centrifugal (VPF)
- Alternative 4: Absorption (Primary/Secondary)
- Alternative 5: Absorption (VPF)

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Alternative 3: Centrifugal (VPF)

- Introduction
- Depth 1: Central Chilled Water Plant
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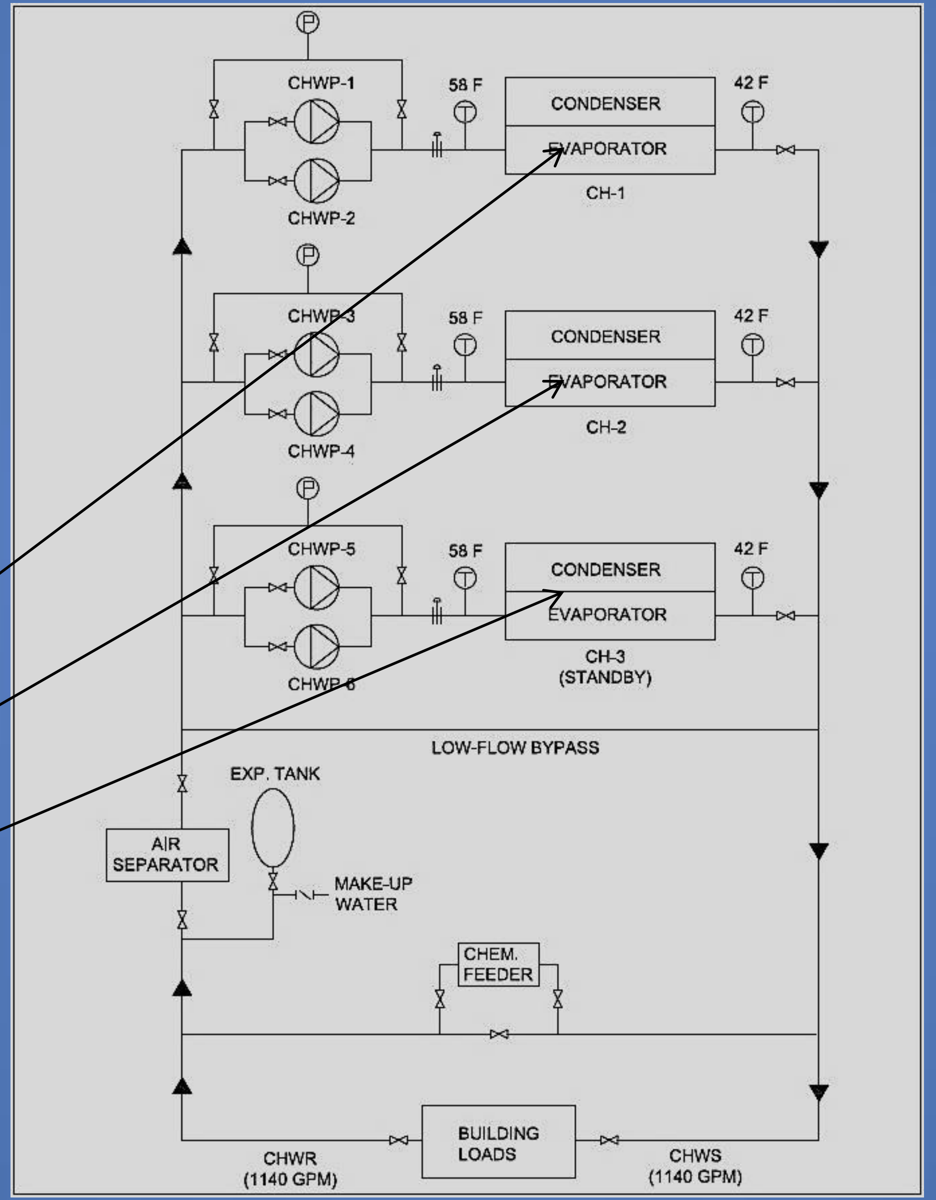
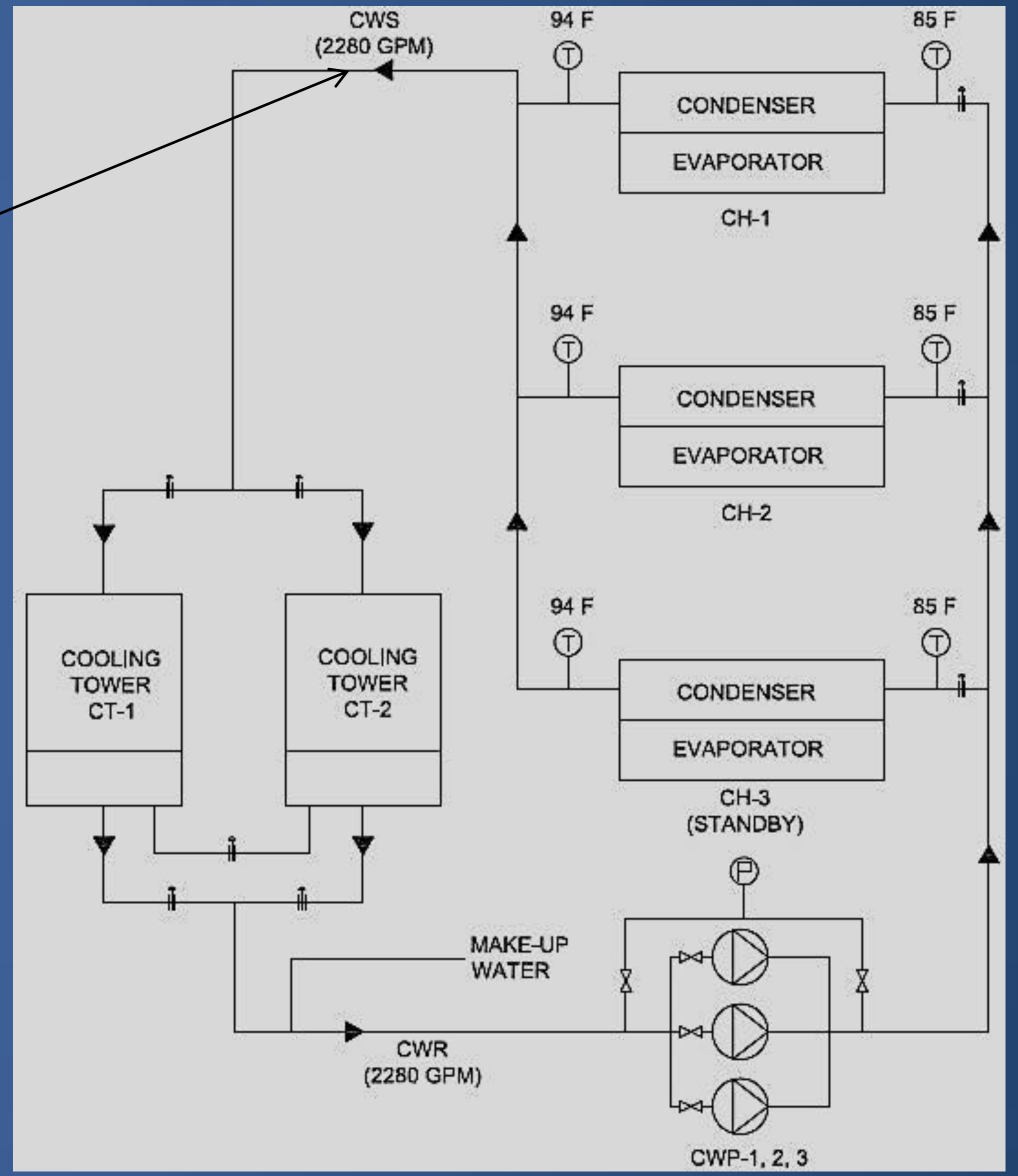
Centrifugal Chiller COP: 1.72



2280 GPM



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Alternative 5: Absorption (VPF)

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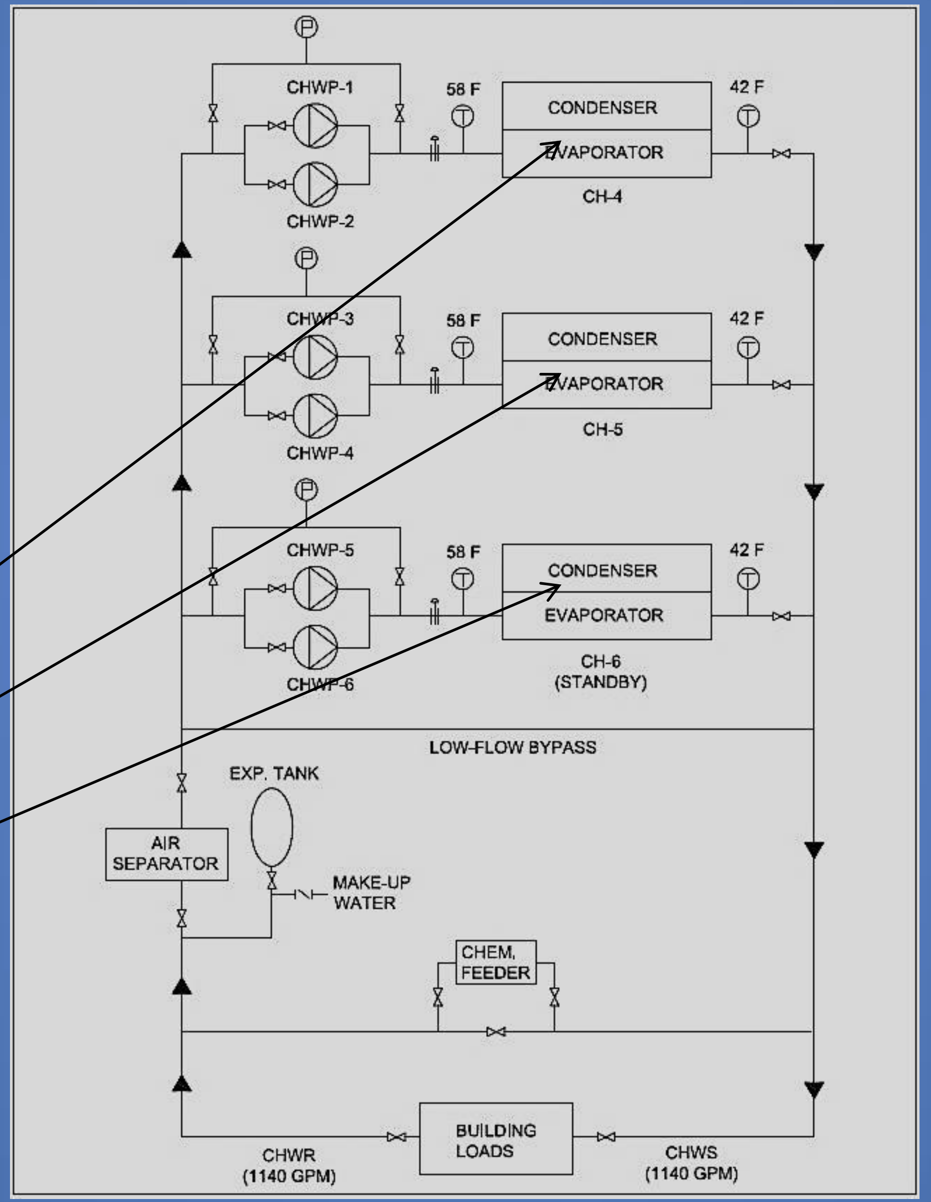
Absorption Chiller COP: 1.12



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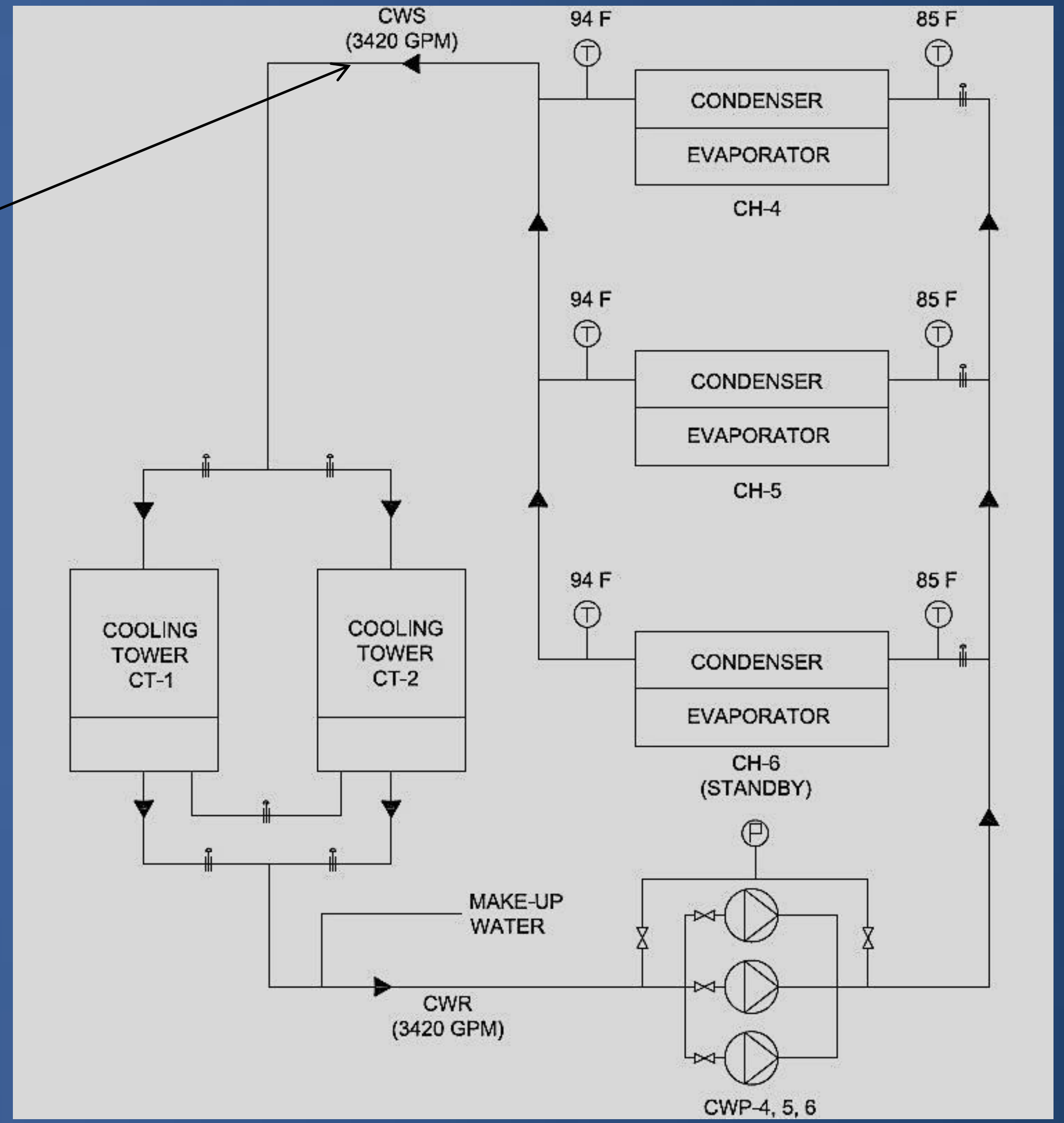

First Costs

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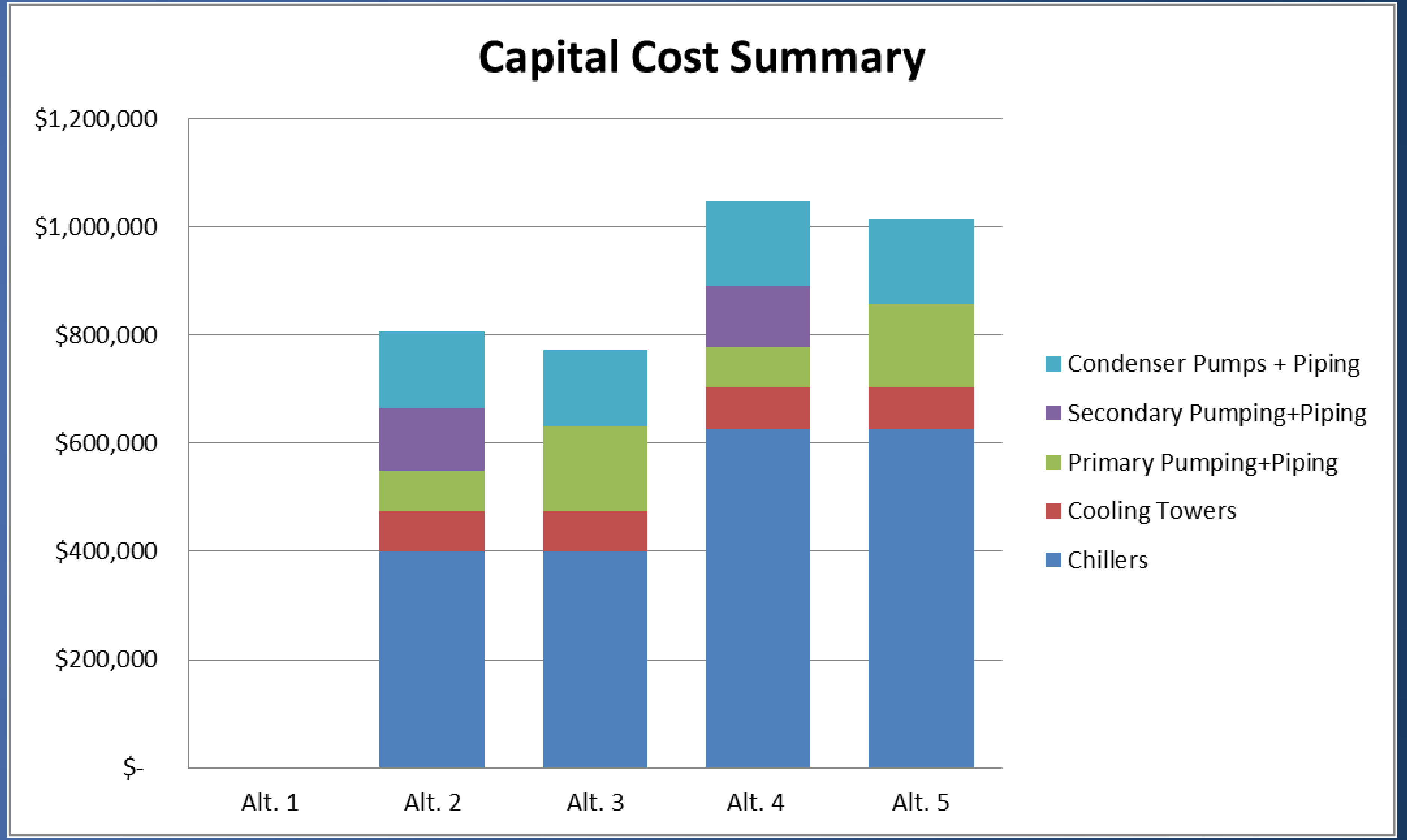
Unit Costs of Equipment

Equipment	Unit Cost
Pump (7.5 HP)	$ 4,070 / pump
Pump (15 HP)	$ 4,810 / pump
Pump (30 HP)	$ 8,440 / pump
Cooling Towers – Induced (Axial)	$ 38,220 / tower
Centrifugal Chillers	$ 350 / ton
Absorption Chillers	$ 550 / ton
Schedule 40 Piping (8”)	$ 203.15 / LF
Insulation	$ 25.33 / LF



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Energy

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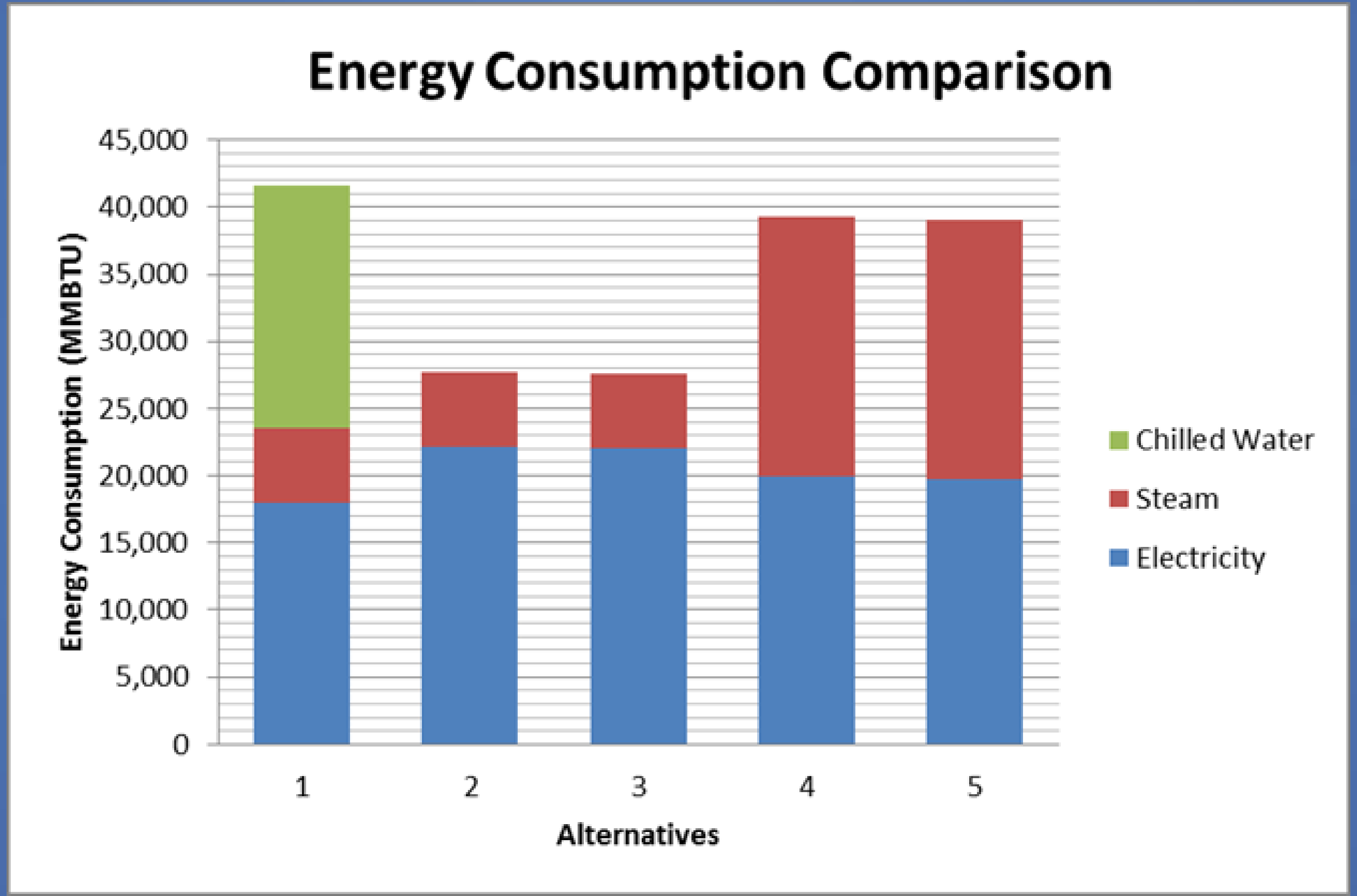

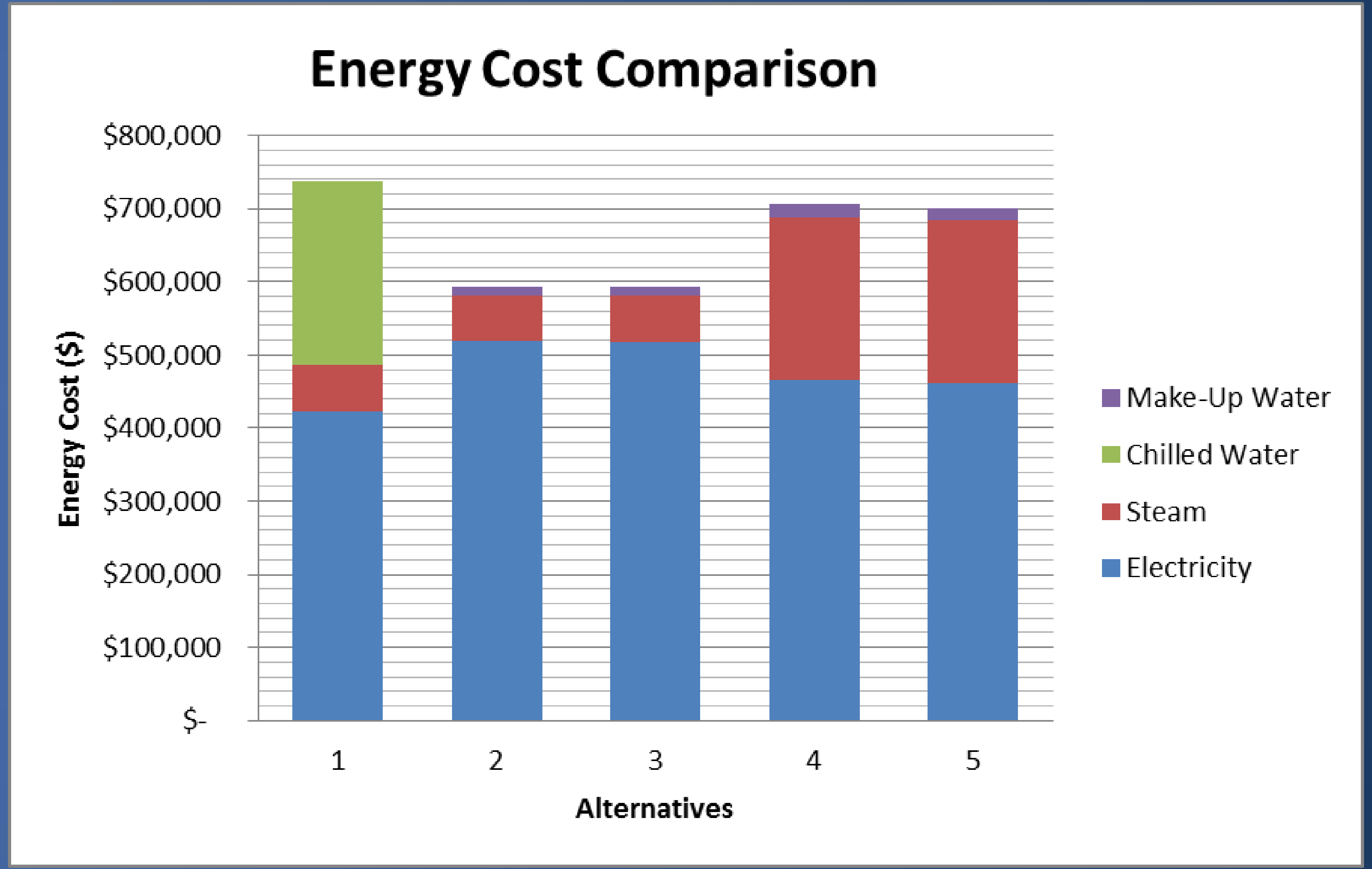

Emissions

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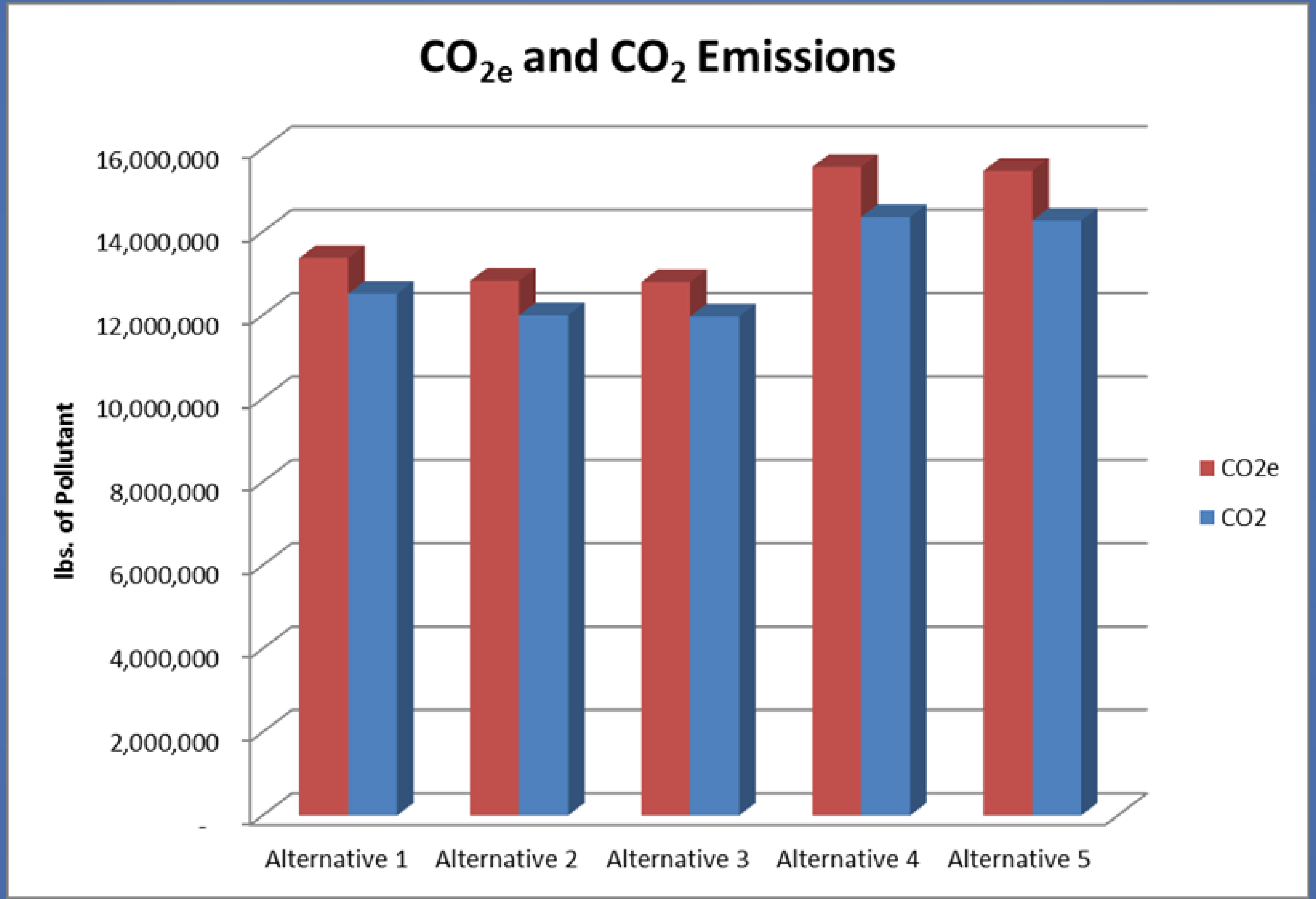

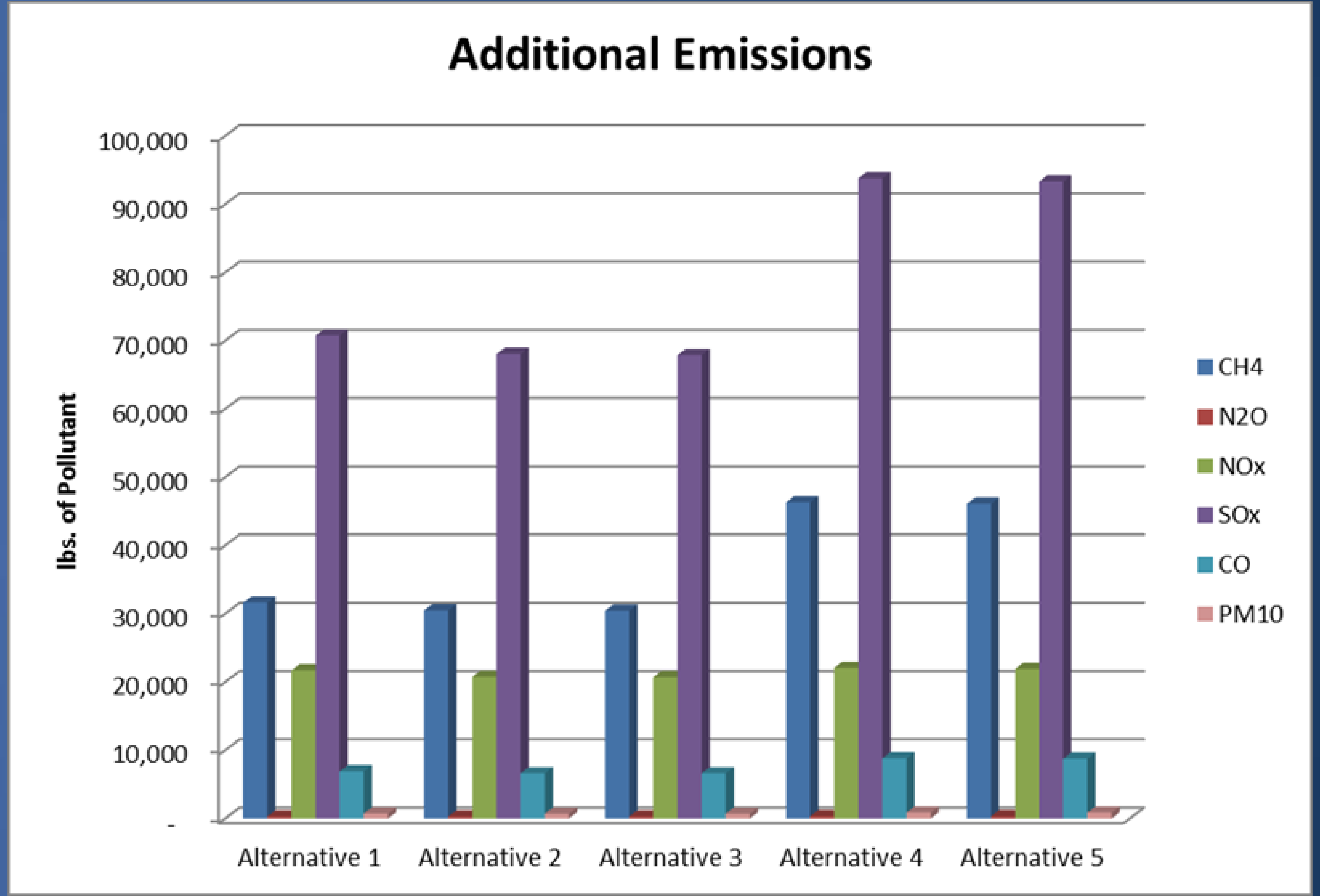

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Life-Cycle Cost Analysis

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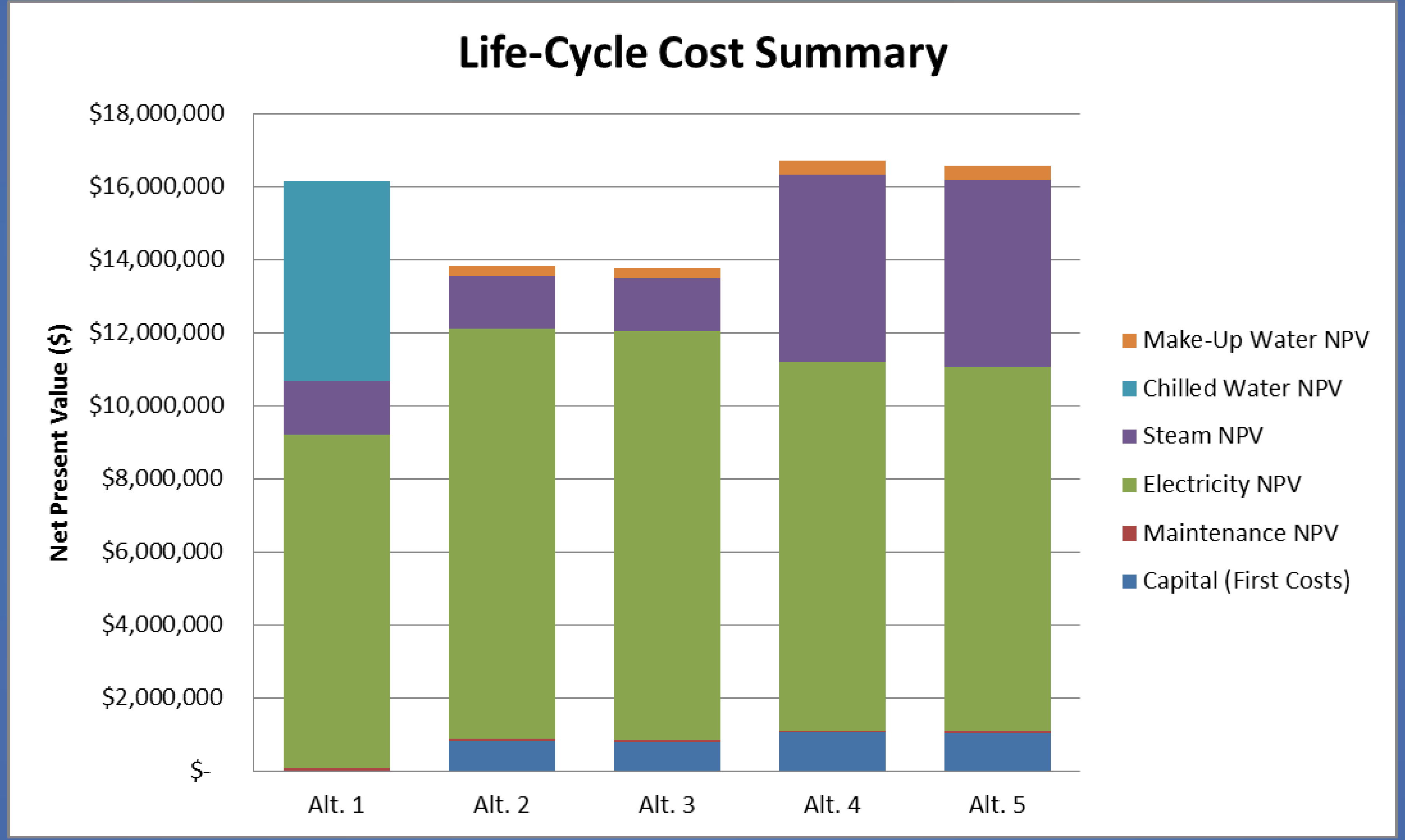


Payback Summary

	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5
Simple Payback	BASELINE	**5.6 yrs.**	**5.3 yrs.**	32.1 yrs.	26.9 yrs.
Discounted Payback	BASELINE	**7.0 yrs.**	**6.0 yrs.**	30+ yrs.	30+ yrs.

Alternative 3: Centrifugal Chillers (VPF)

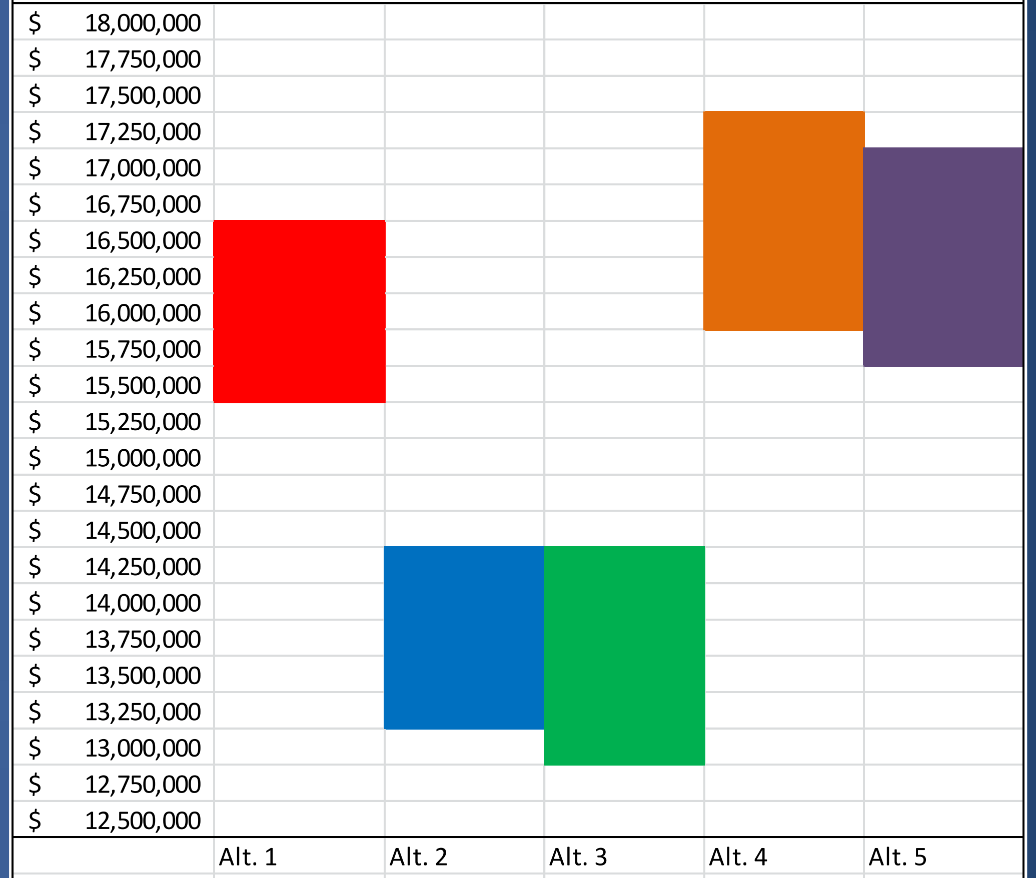
- Lowest Payback (Simple and Discounted)
- $2.4 Million Savings Compared to Current Design
- Lowest Energy and Emissions

Life-Cycle Cost Analysis

10% Capital Uncertainty, 10% Utility Price Uncertainty, 5% Discount, 5% Escalation

	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5
Low	$ 15,103,000	$ 12,782,000	$ 12,728,000	$ 15,631,000	$ 15,495,000
Mean	$ 16,154,184	$ 13,830,493	$ 13,768,082	$ 16,727,778	$ 16,588,395
High	$ 17,201,000	$ 14,889,000	$ 14,813,000	$ 17,835,000	$ 17,679,000

10% Capital Uncertainty, 5% Utility Price Uncertainty, 5% Discount, 5% Escalation



	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5
Low	$ 15,585,000	$ 13,257,000	$ 13,203,000	$ 16,126,000	$ 15,991,000
Mean	$ 16,154,221	$ 13,830,404	$ 13,768,144	$ 16,727,804	$ 16,588,362
High	$ 16,735,000	$ 14,402,000	$ 14,331,000	$ 17,324,000	$ 17,174,000

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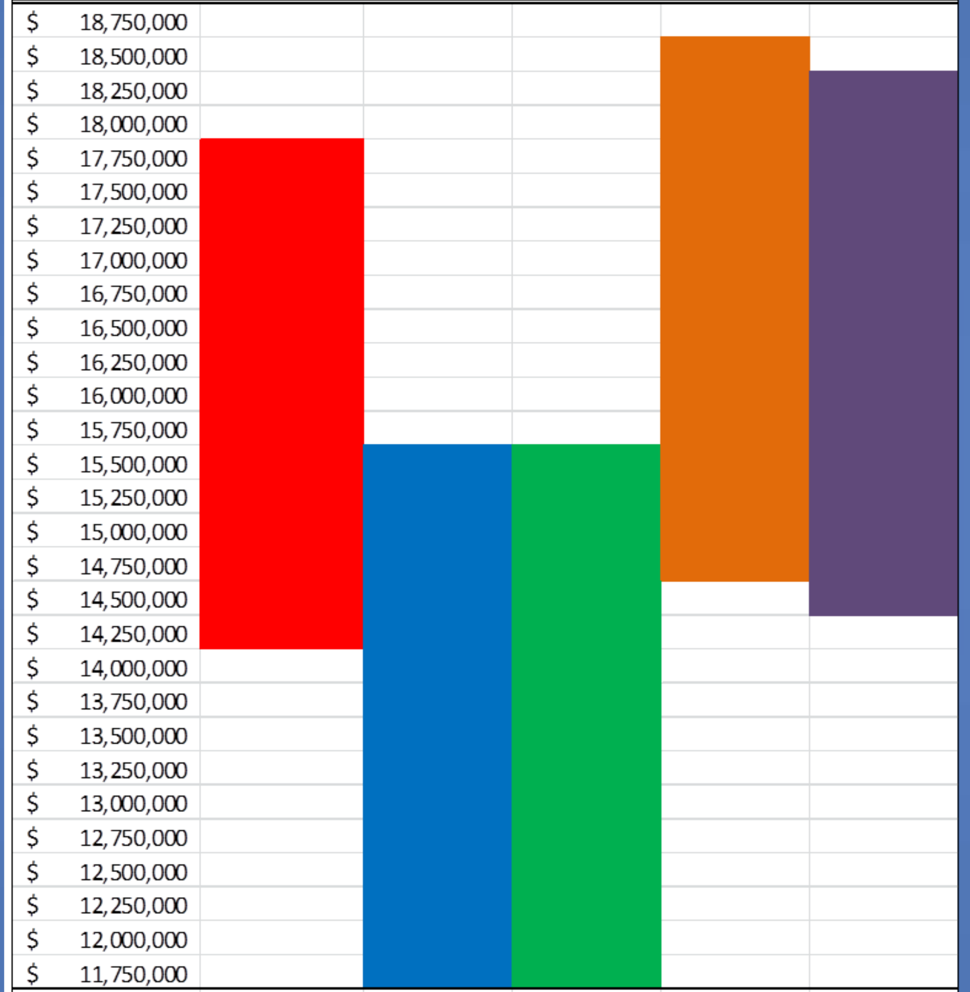

	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5
Low	$ 14,320,000	$11,940,000	$11,880,000	$14,790,000	$14,670,000
Mean	$ 16,156,153	$13,831,526	$13,769,701	$16,730,167	$16,589,993
High	$ 17,960,000	$15,730,000	$15,690,000	$18,690,000	$18,490,000

10% Capital Uncertainty, 5% Utility Price Uncertainty, 5% Discount, 5% Escalation

	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5
Low	$ 15,156,000	$12,815,000	$12,752,000	$15,694,000	$15,559,000
Mean	$ 16,156,241	$13,832,125	$13,769,813	$16,729,821	$16,590,196
High	$ 17,186,000	$14,858,000	$14,777,000	$17,794,000	$17,640,000

Dedicated Heat Recovery Chiller

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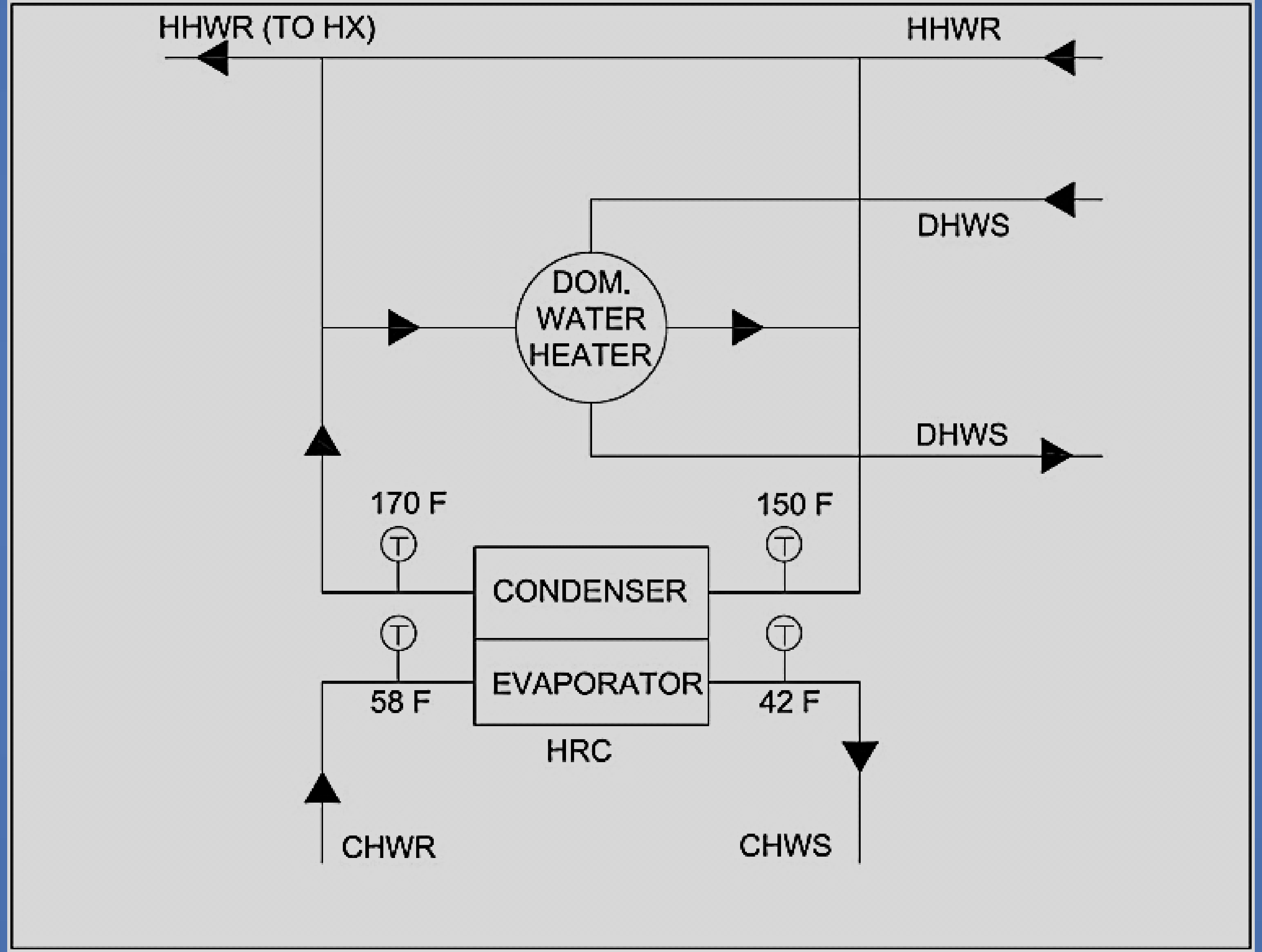

Heat Recovery Chiller Operating Conditions

Module	Chilled Water		Heat Rejection		Cooling EER	Heatin g COP
	EWT (F)	LWT (F)	EWT (F)	LWT (F)		
25 ton	58	42	150	170	3.7	2.1
32 ton	58	42	150	170	3.8	2.1

Unit Cost

	Cost / Unit
Heat Recovery Chiller	$ 600 / ton

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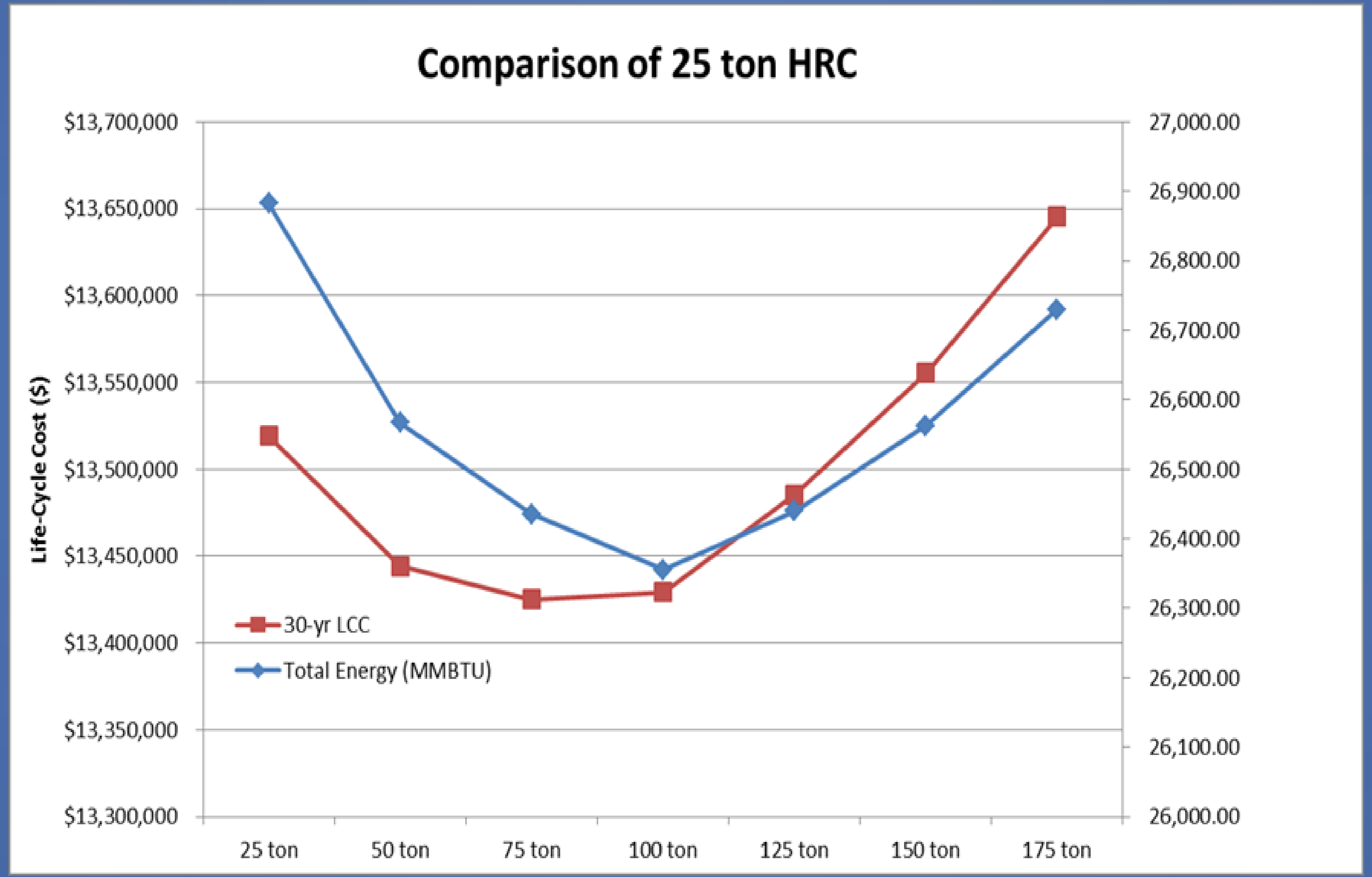

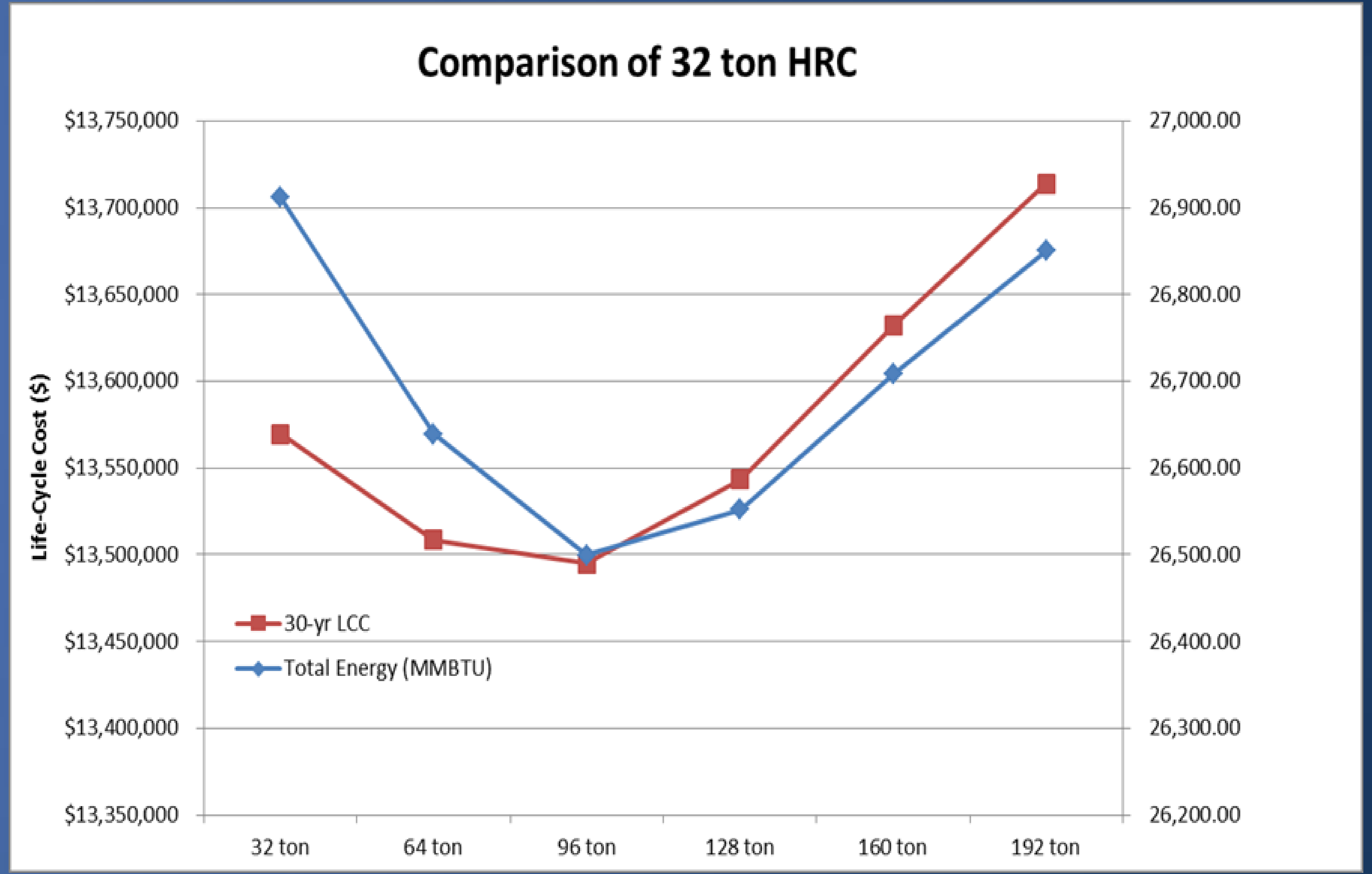

INOVA South Patient Tower   Dedicated Heat Recovery Chiller

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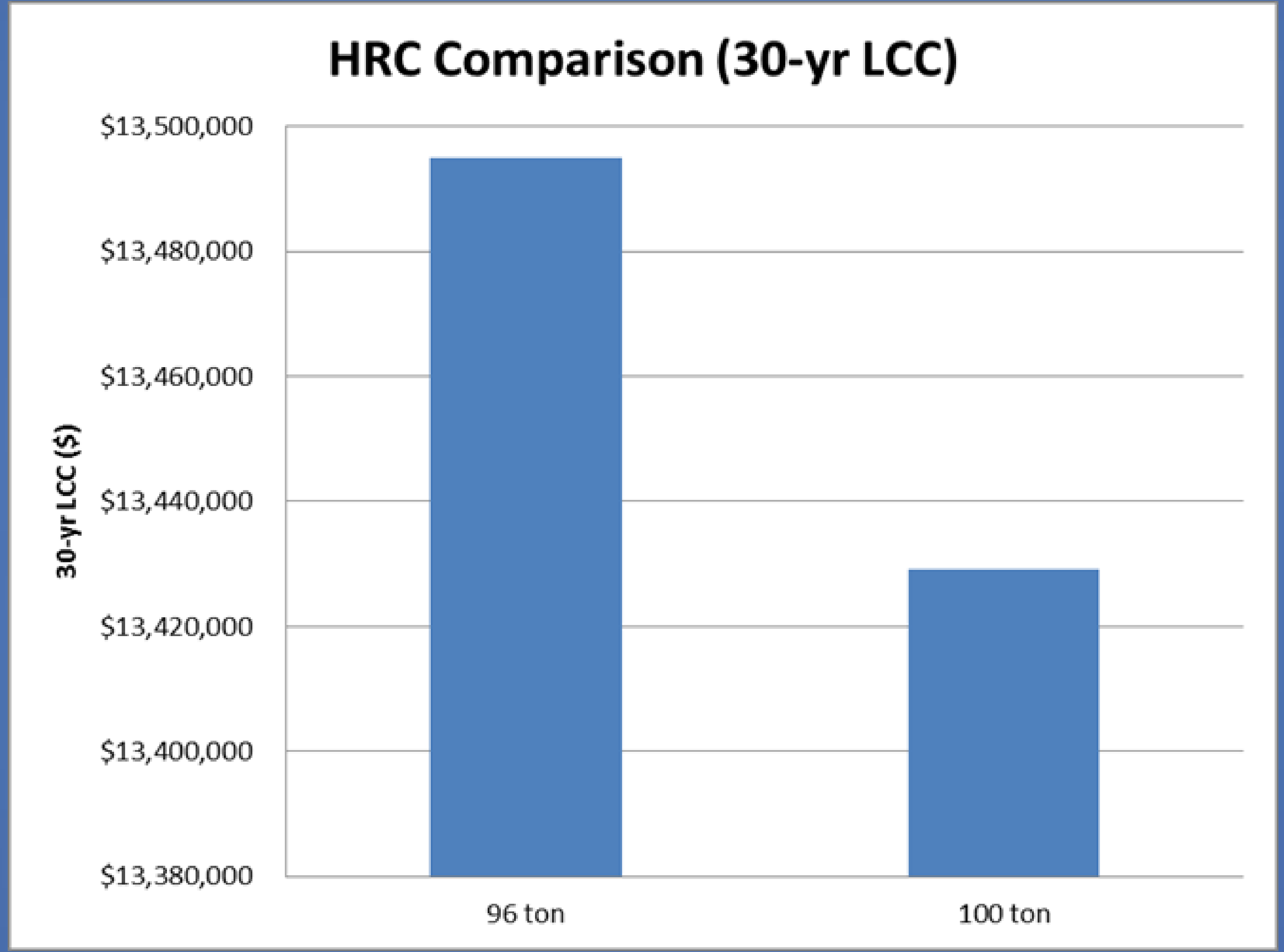

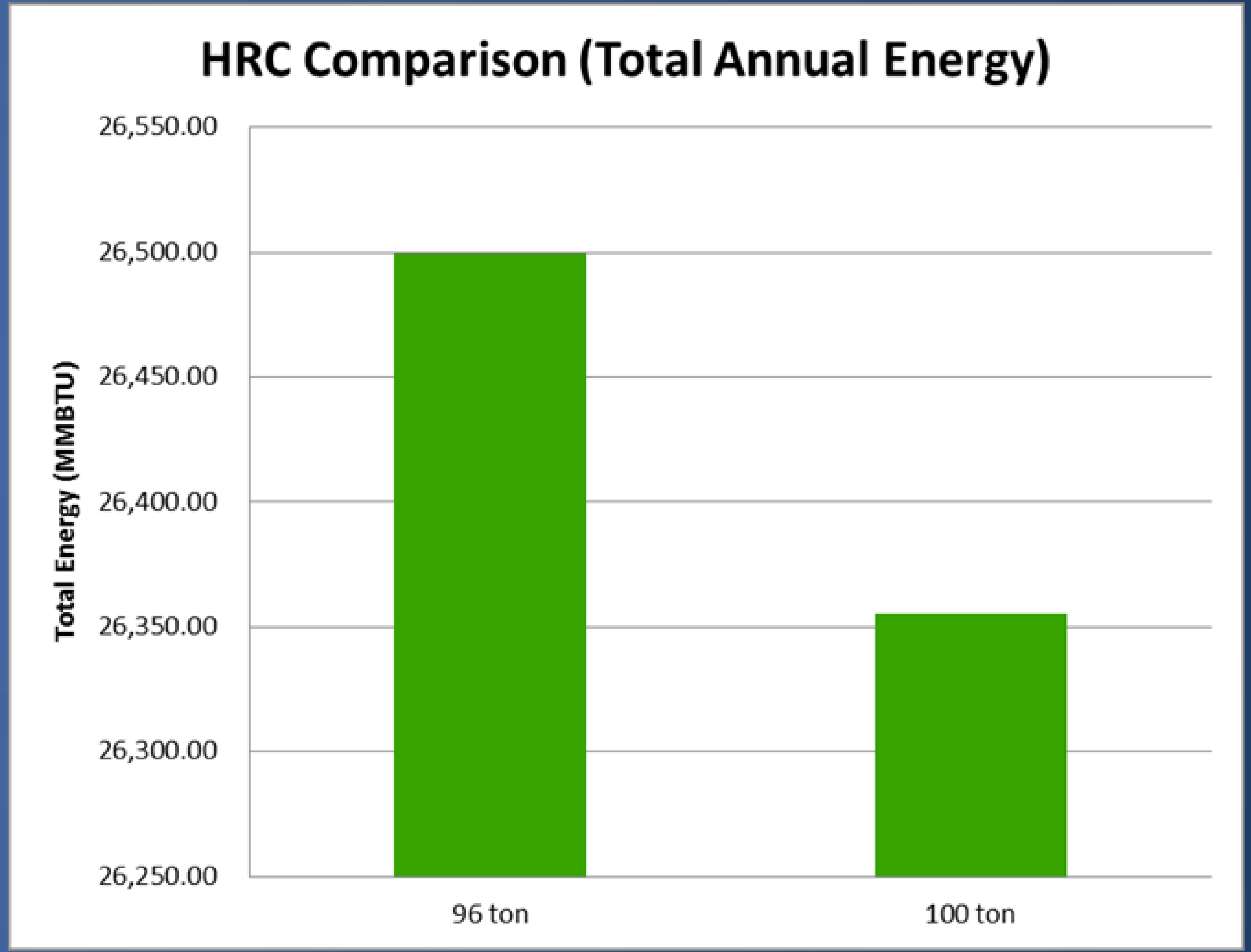

Condensate Recovery System

$$Condensate\left(\frac{lbs.}{hr}\right) = CFM * \rho_{air} * 60\frac{min}{hr} * \Delta w$$

Where:

CFM = Airflow over Coil
ρ_{air} = density of air
Δw = difference in humidity ratios across cooling coil

	January	February	March	April	May	June
Condensate (1000 gal.)	1.1	0.8	8.6	7.5	53.9	128.0
	July	August	September	October	November	December
Condensate (1000 gal.)	203.9	161.1	86.4	4.7	6.8	1.8

Example Monthly Calculation (July)

Hour	OADB	OAWB	MADB	MAWB	Clg (Tons)
1	73.3	66.8	73.3	66.8	405.5
2	72.0	66.0	72.0	66.0	379.5
3	71.0	65.6	71.0	65.6	365.5

CFM	Entering HR	Leaving HR	Condensate
85,191.5	0.01257	0.006189	2375.0
79,745.5	0.0123	0.006189	2129.1
76,789.2	0.01224	0.006189	2030.1

INOVA South Patient Tower — Condensate Recovery System

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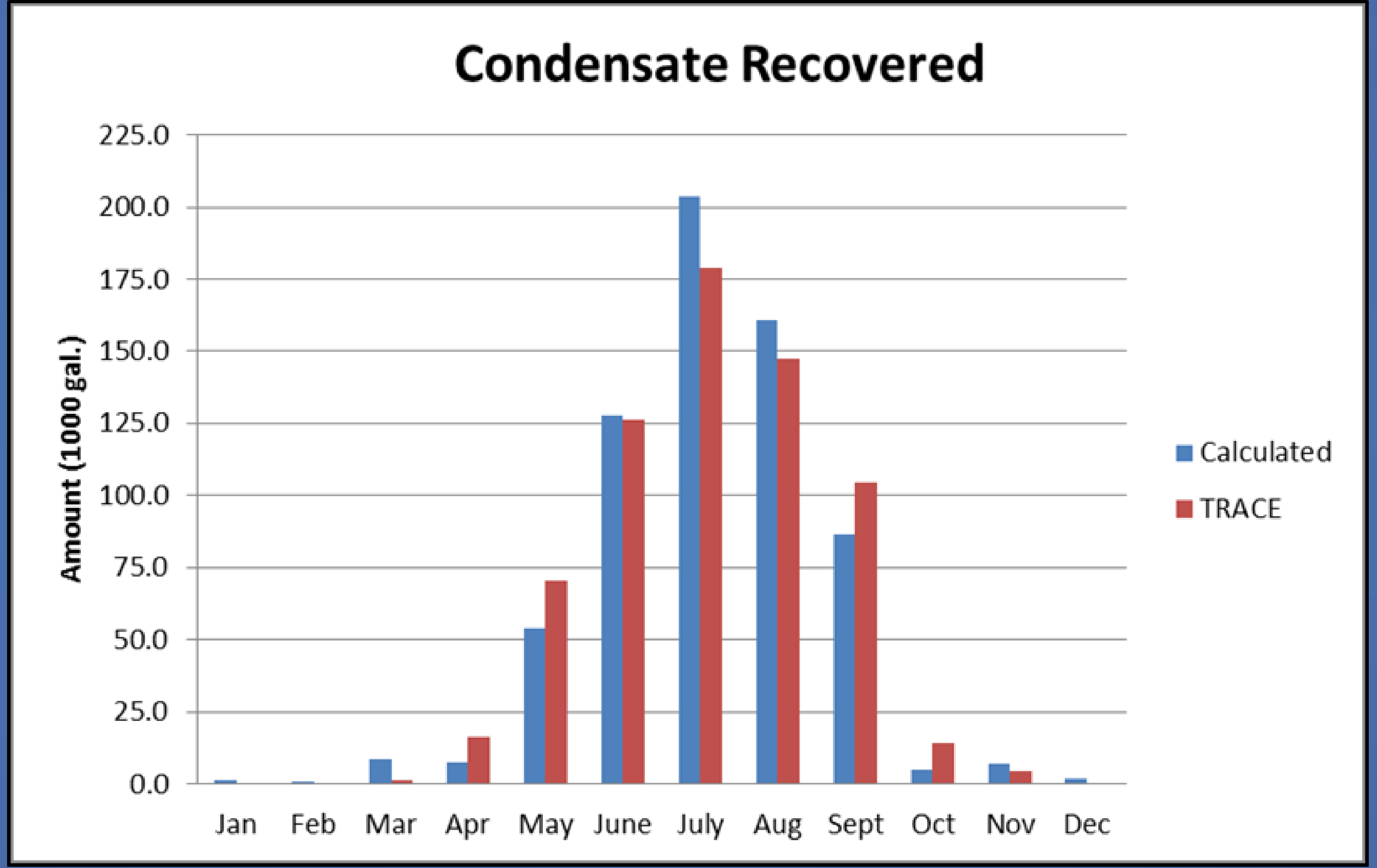

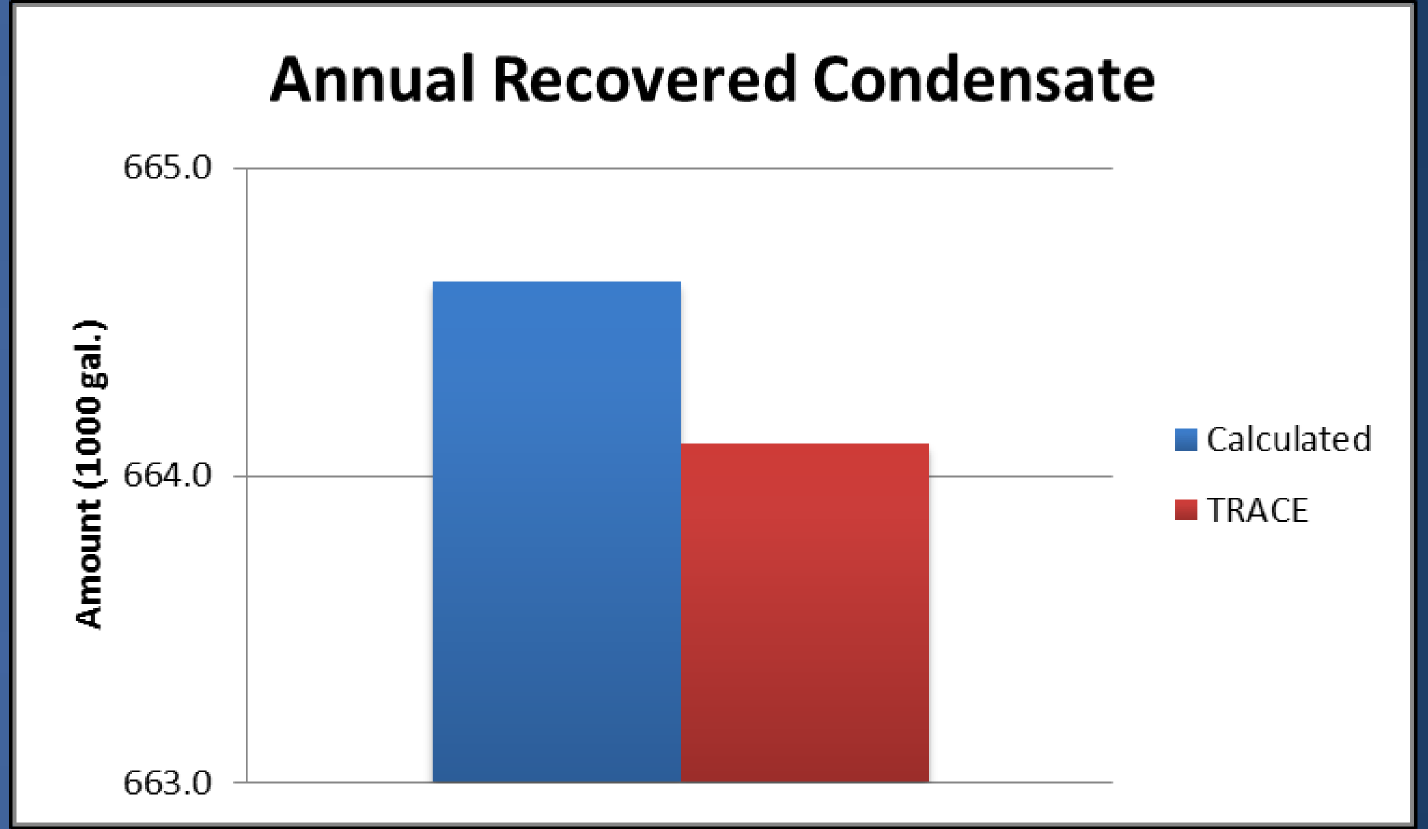

	Amount (1000 gal.)	Annual Cost
Water (Make-Up)	4,891	$ 10,565
Reduced Make-Up	4,226	$ 9,129
Savings	14 %	14 %

INOVA South Patient Tower

Depth Conclusions

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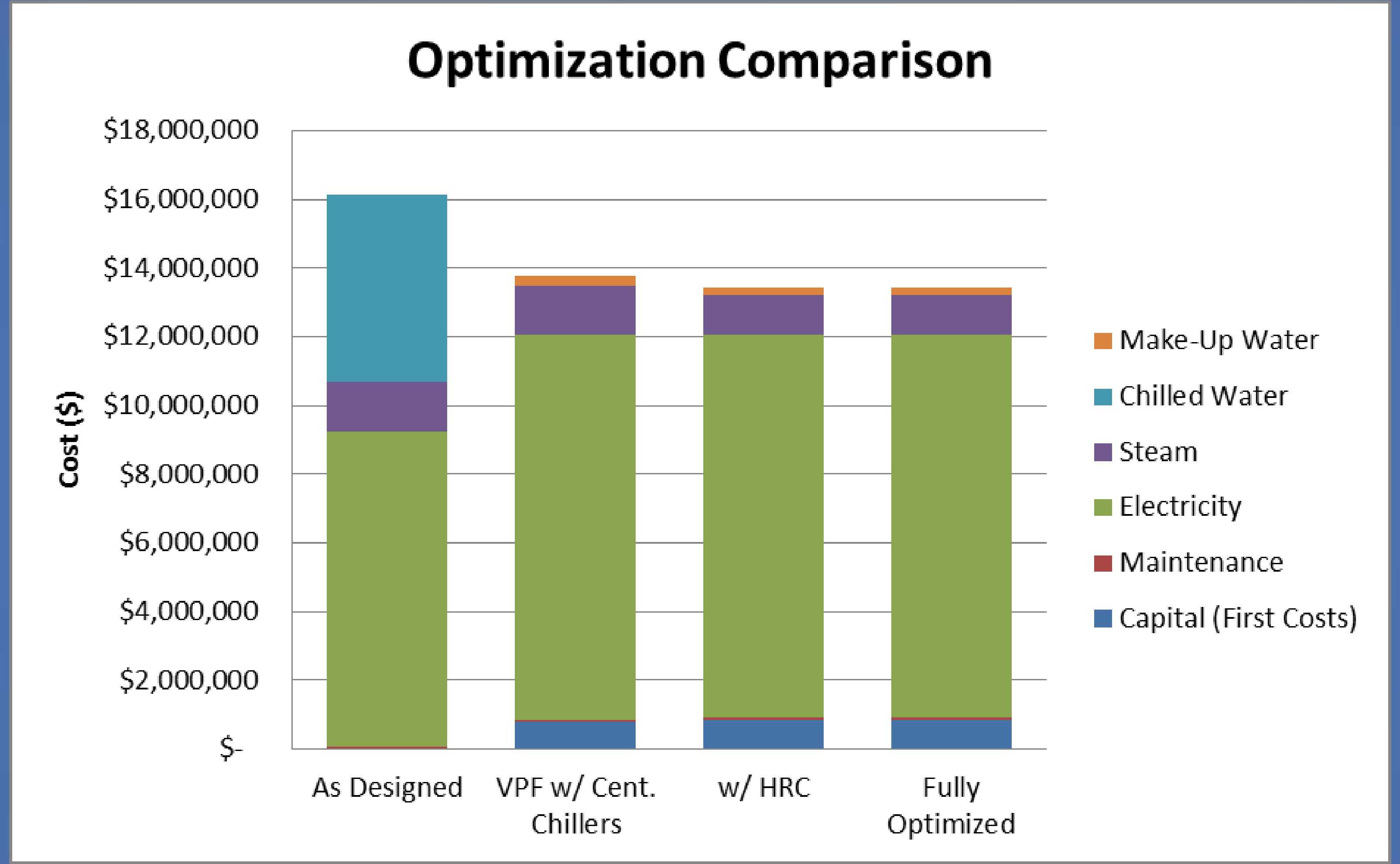
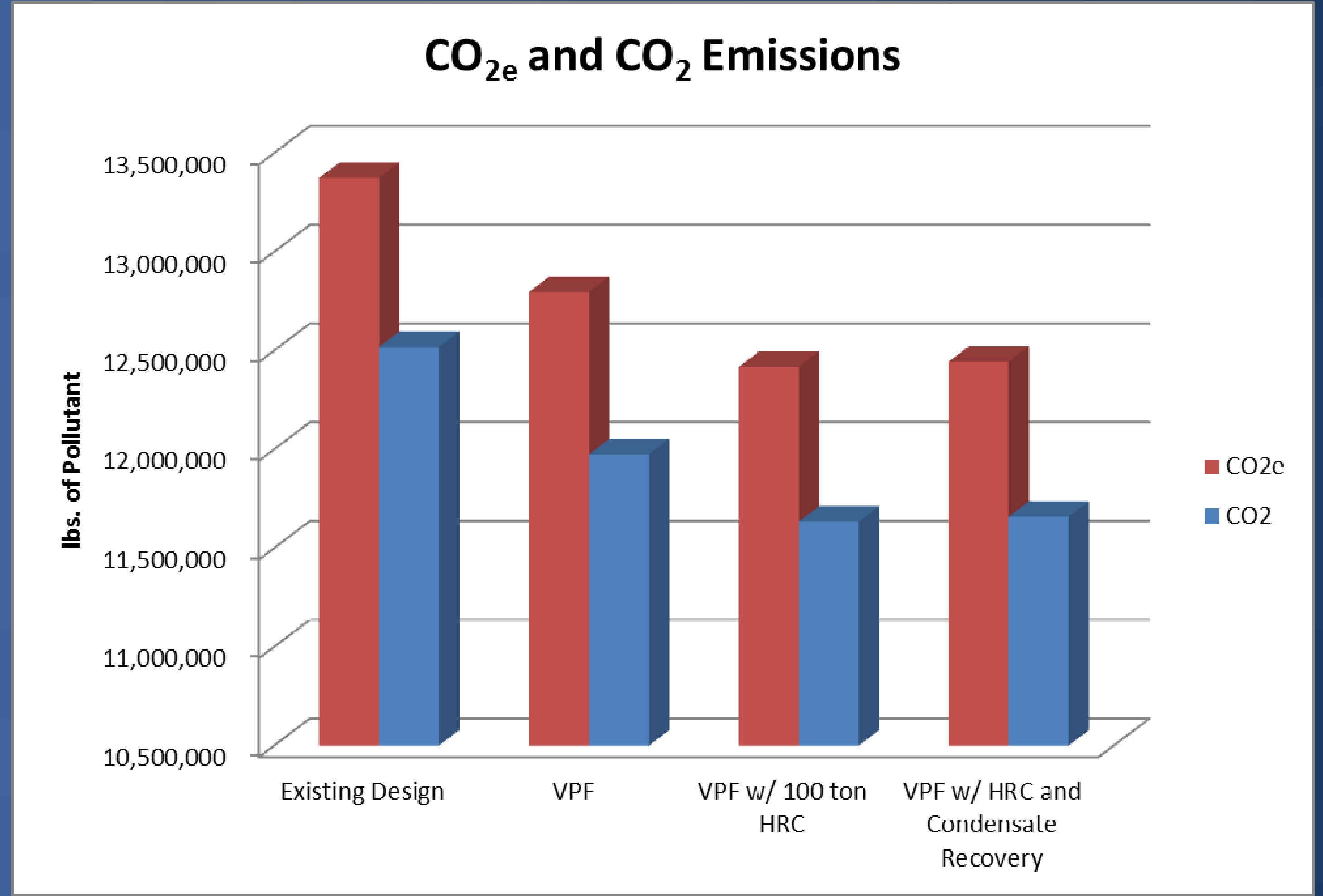
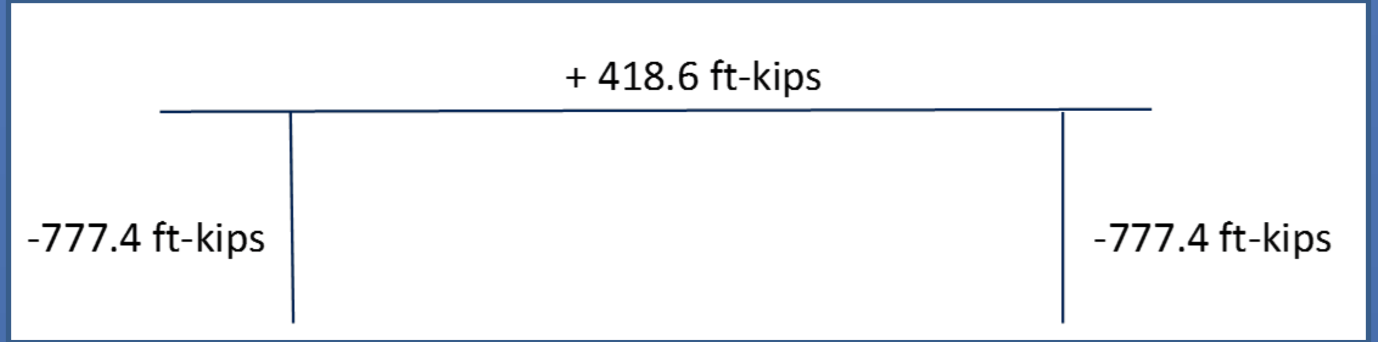


SPB: BASE 5.3 5.2 5.1



Structural Breadth

Equipment	Amount	Weight/Unit	Total Weight (lbs)
Centrifugal Chillers	3	22,173 lb /each	66,519
Heat Recovery Chiller	4	2,000 lb / 25 ton	8,000
Pumps	9	200 lbs / each	1,800
Piping	300 ft	36.32 lb / ft	10,896
Water	-	19.66 lb / ft	
Steel Pipe (8")	-	16.66 lb / ft	
Total			87,215
Distributed Load	Area =	3,364 ft^2	25.9 lb / ft^2



Assuming #6 Bars	Middle Strip		Column Strip	
	Neg. Moment	Pos. Moment	Neg. Moment	Pos. Moment
Moment (M_U)	-194.3	+ 167.4	-583.1	+251.2
Width Column Strip	174"	174"	174"	174"
Effective Depth	9.375"	9.375"	14.25"	9.375"
$M_N = M_U / \phi$	-215.94	+186	-647.9	+279.1
R = (Mn x 12000) / bd^2	169.4	145.95	220.04	219
ρ (Table A-3)*	0.0033	0.0033	0.0039	0.0039
A_s = ρbd	5.383 in^2	5.383 in^2	9.67 in^2	6.362 in^2
$A_{s,min}$ = 0.0018bt	3.289 in^2	3.289 in^2	3.289 in^2	3.289 in^2
N = (larger 7 or 8) / 0.44	13	13	22	15
N_{min} = width / (2t)	9	9	9	9

Structural Breadth

Column Strip:

Negative Moment:	0 bars (Design OK)
Positive Moment:	(10) #6 bars / bay

Middle Strip:

Negative Moment:	(6) #5 bars / bay
Positive Moment:	(8) #5 bars / bay

Size	lb/ft	Amount	Length (ft)	Total Weight (lb.)
# 6	1.502	40	14.5	871.2
# 5	1.043	56	14.5	846.9
TOTAL				**1718.1**

Structural Additional Cost:

$ 0.76 / lb X 1718.1 lb = $ 1,305.76

INOVA South Patient Tower

Electrical Breadth

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- Breadth 1: Two-Way Slab Reinforcing
- **Breadth 2: Electrical**
  - **Equipment Sizing**
- Conclusion
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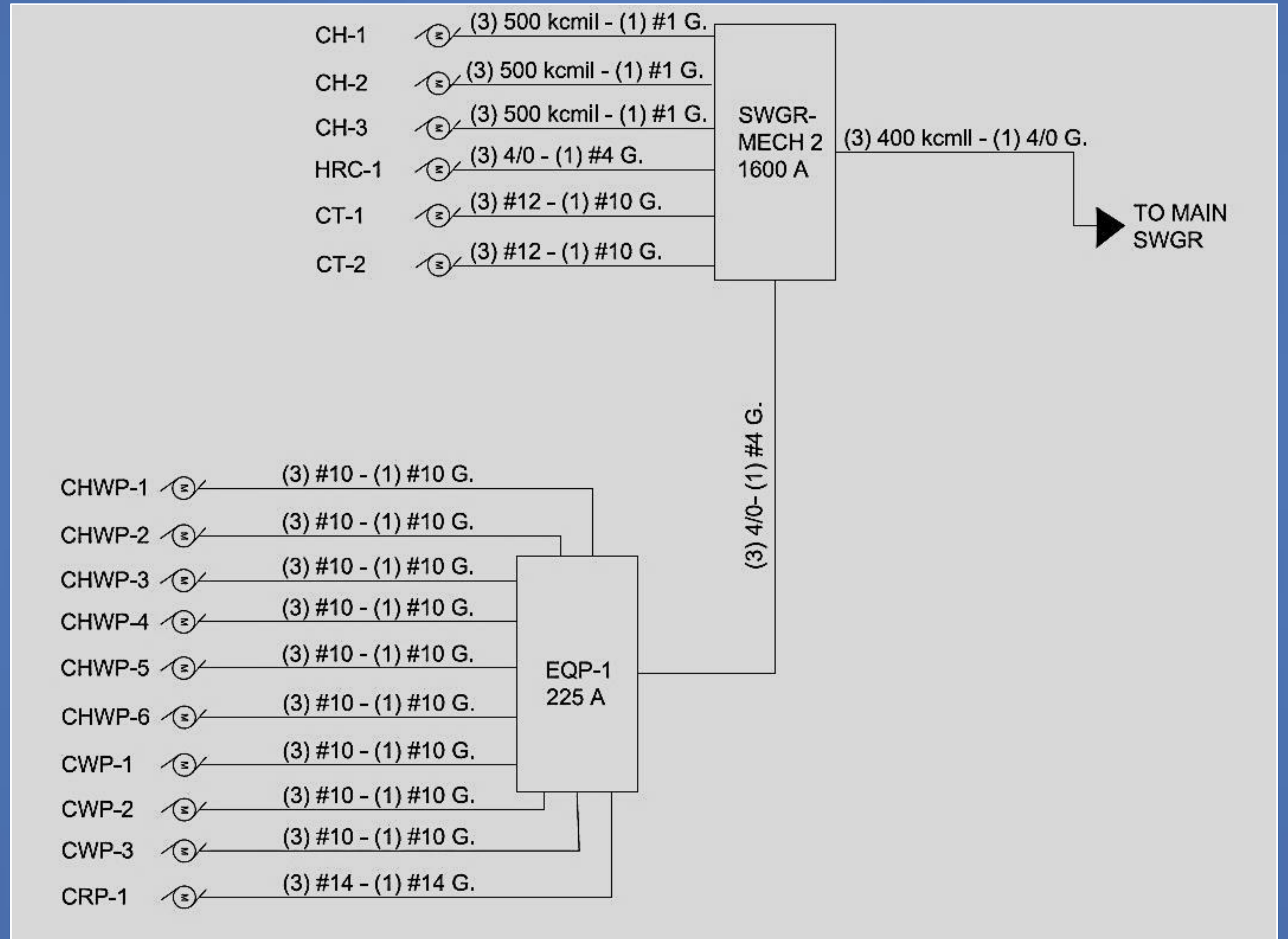

ELECTRICAL ONE-LINE

Equipment	Cost
1600 A Switchboard	$ 3,450
225 A Panelboard	$ 1,090
Motor Starters	$ 5,751
Wire	$ 17,650
Conduit	$ 7,501
Circuit Breakers	$ 38,047

Electrical Additional Cost: $ 73,489

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Conclusion

- Centrifugal Chillers with VPF
  - Dedicated Heat Recovery Chiller
  - Condensate Recovery
- Savings: $ 2.729 million over 30 year life
- Simple Payback: 5.1 years

- Additional Structural / Electrical Costs Included
- Savings: $ 2.655 million over 30 year life
- Simple Payback: 5.6 years

MAE Course Relation

- AE 557- Centralized Cooling
  - Chilled Water Plant Design / Study
- AE 558- Centralized Heating
  - Life-Cycle Cost Analysis
  - Utility Costs

Acknowledgements

Dr. William Bahnfleth	Faculty Advisor, Penn State University
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Tony McGhee	Account Executive, Johnson Controls Inc.

All my fellow AE peers, friends and family for their support throughout the thesis process.

THANKS ALL OF YOU!

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THANK YOU

QUESTIONS?

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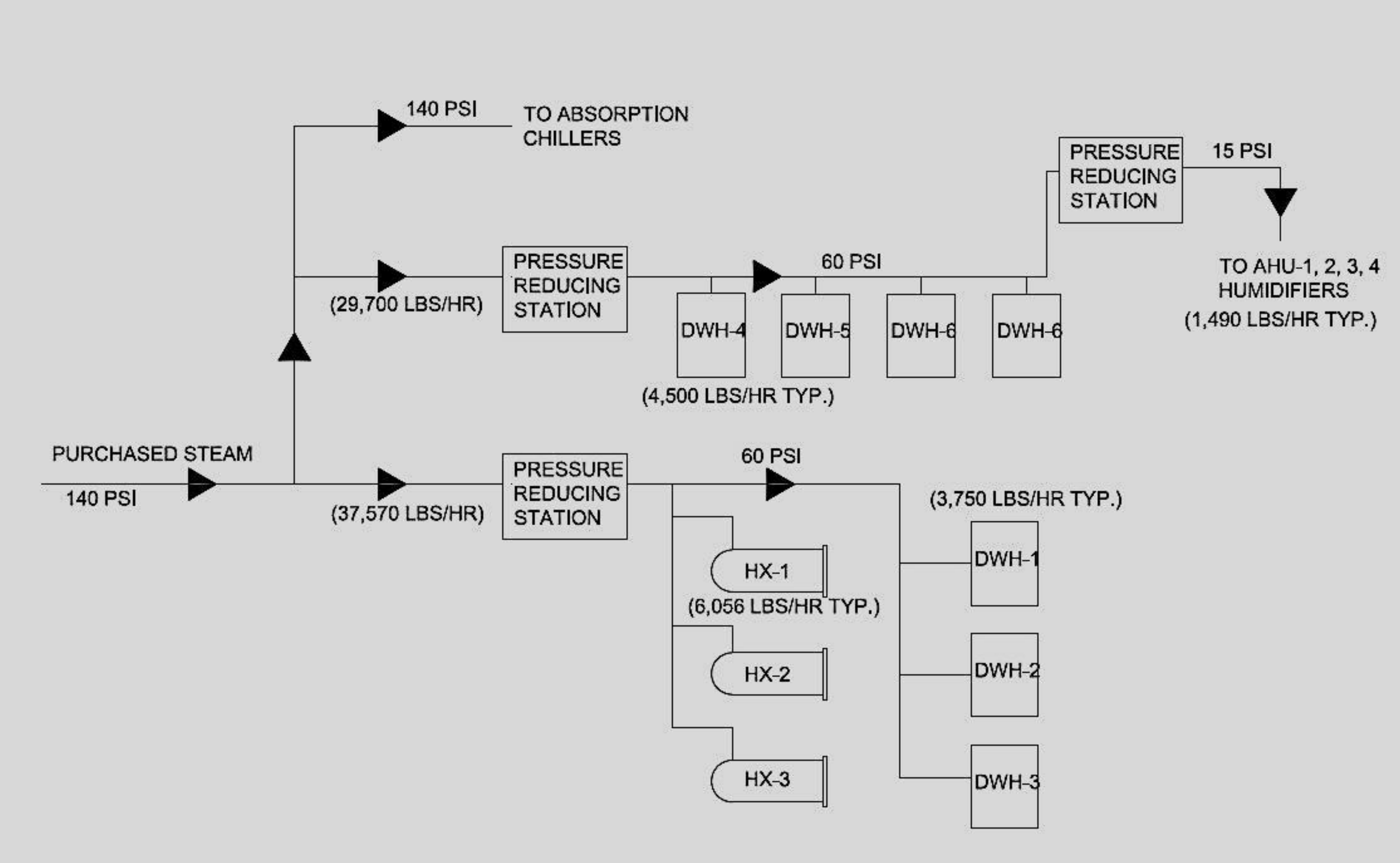

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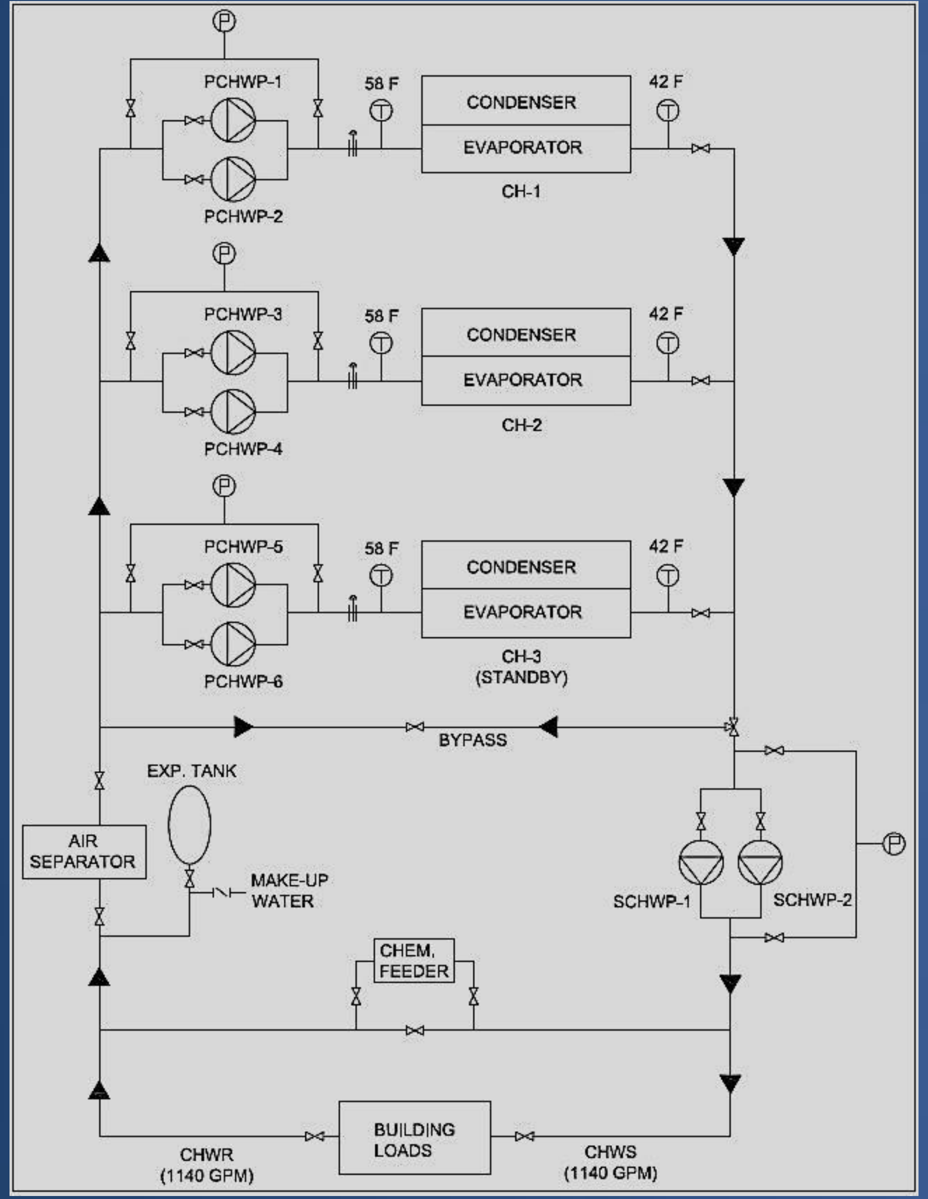

Equipment	HP	FLA	Volts	KVA	PF	KW	OCP	Wire Size	Conduit Size	Motor Starter
CHWP-1	15	21	480	17.4	0.9	15.7	50	(3) #10 - (1) #10 G.	3/4"	1
CHWP-2	15	21	480	17.4	0.9	15.7	50	(3) #10 - (1) #10 G.	3/4"	1
CHWP-3	15	21	480	17.4	0.9	15.7	50	(3) #10 - (1) #10 G.	3/4"	1
CHWP-4	15	21	480	17.4	0.9	15.7	50	(3) #10 - (1) #10 G.	3/4"	1
CHWP-5	15	21	480	17.4	0.9	15.7	50	(3) #10 - (1) #10 G.	3/4"	1
CHWP-6	15	21	480	17.4	0.9	15.7	50	(3) #10 - (1) #10 G.	3/4"	1
CWP-1	15	21	480	17.4	0.9	15.7	50	(3) #10 - (1) #10 G.	3/4"	1
CWP-2	15	21	480	17.4	0.9	15.7	50	(3) #10 - (1) #10 G.	3/4"	1
CWP-3	15	21	480	17.4	0.9	15.7	50	(3) #10 - (1) #10 G.	3/4"	1
CH-1	-	294	480	244.1	0.88	214.8	600	(3) 500 kcmil - (1) #1 G.	3"	N/A
CH-2	-	294	480	244.1	0.88	214.8	600	(3) 500 kcmil - (1) #1 G.	3"	N/A
CH-3	-	294	480	244.1	0.88	214.8	600	(3) 500 kcmil - (1) #1 G.	3"	N/A
HRC-1	-	184	480	152.8	0.8	122.2	450	(3) 4/0 - (1) #4 G.	2-1/2"	N/A
CT-1	10	14	480	11.6	0.9	10.5	30	(3) #12 - (1) #10 G.	1/2"	0
CT-2	10	14	480	11.6	0.9	10.5	30	(3) #12 - (1) #10 G.	1/2"	0
CRP-1	3	4.8	480	4.0	0.85	3.4	15	(3) #14 - (1) #14 G.	1/2"	00