New Castle Center for Delaware Hospice, Inc

Zachary Klixbull

Penn State University – Architectural Engineering
Mechanical Option
Advisor: Professor Bahnfleth

Presentation Outline

- g Overview
- conditions
- Evaluation
- d Redesign
- cal Depth
- l Breadth
- ion

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Building Statistics

Building Name:	DE Hospice – New
Location and site:	New Castle, DE
Building Owner:	Delaware Hospice
Occupancy type:	Medical
Size:	65,000 SF
Number of stories:	Two-story
Delivery method:	GMP, CM at risk

Building Statistics

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Project Team

Owner:	Delaware Hospice
Architect:	Reese, Lower, Patrick & Scoot
Construction Manager:	Skanska
Structural Engineer:	Macitosh Engineer
Mech./Elec./Plumbing Engineer:	Reese Engineering
Food Service Consultant:	JEM Associates
Interior Designer:	Reese, Lower, Patrick & Scoot
Landscape Architect:	Rummler Associates
Civil Engineer:	Landmark Engineering

Dates of Construction

Construction Begins: August, 2011

Start Exterior Façade: January, 2012

Construction Complete: September, 2012

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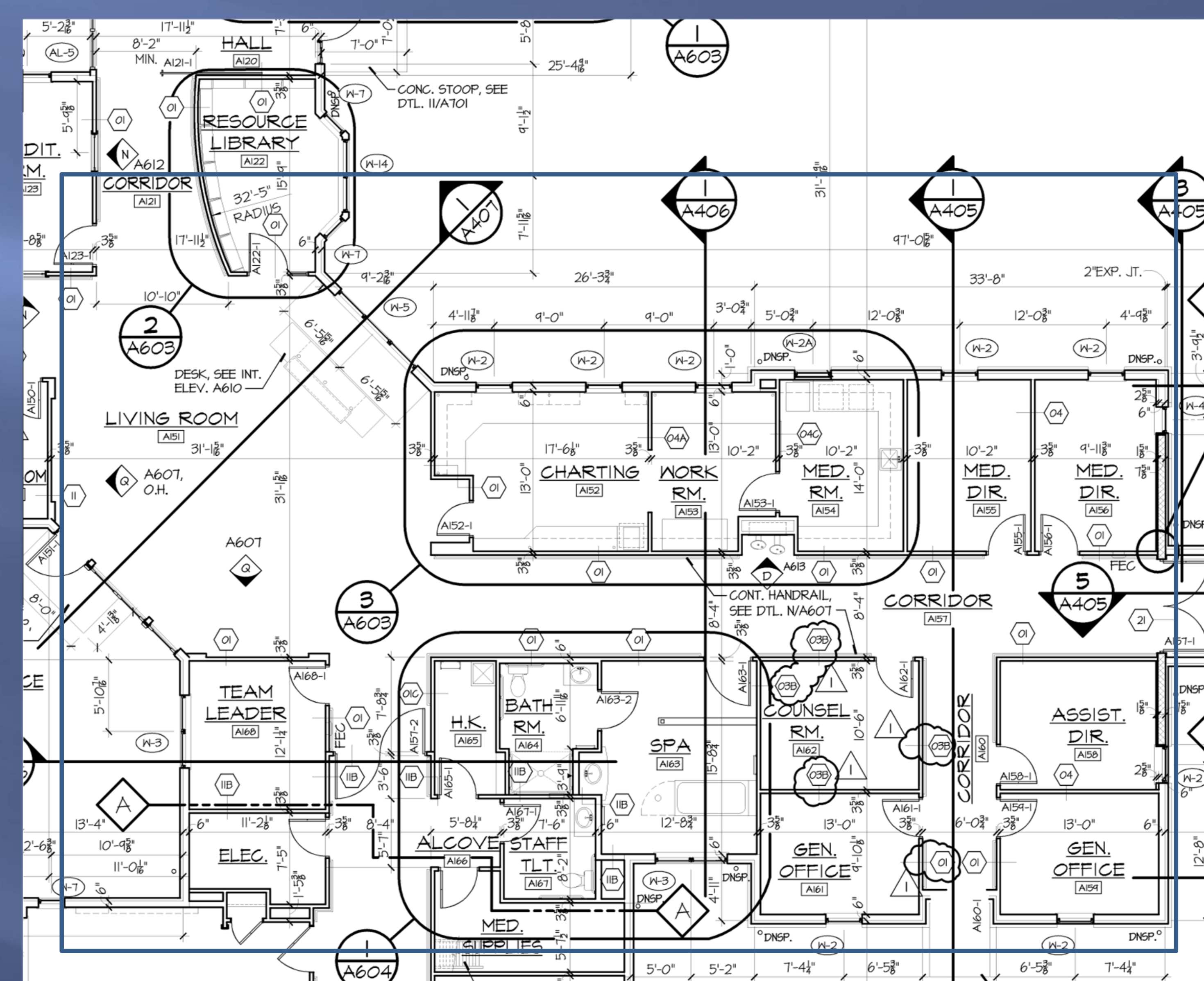
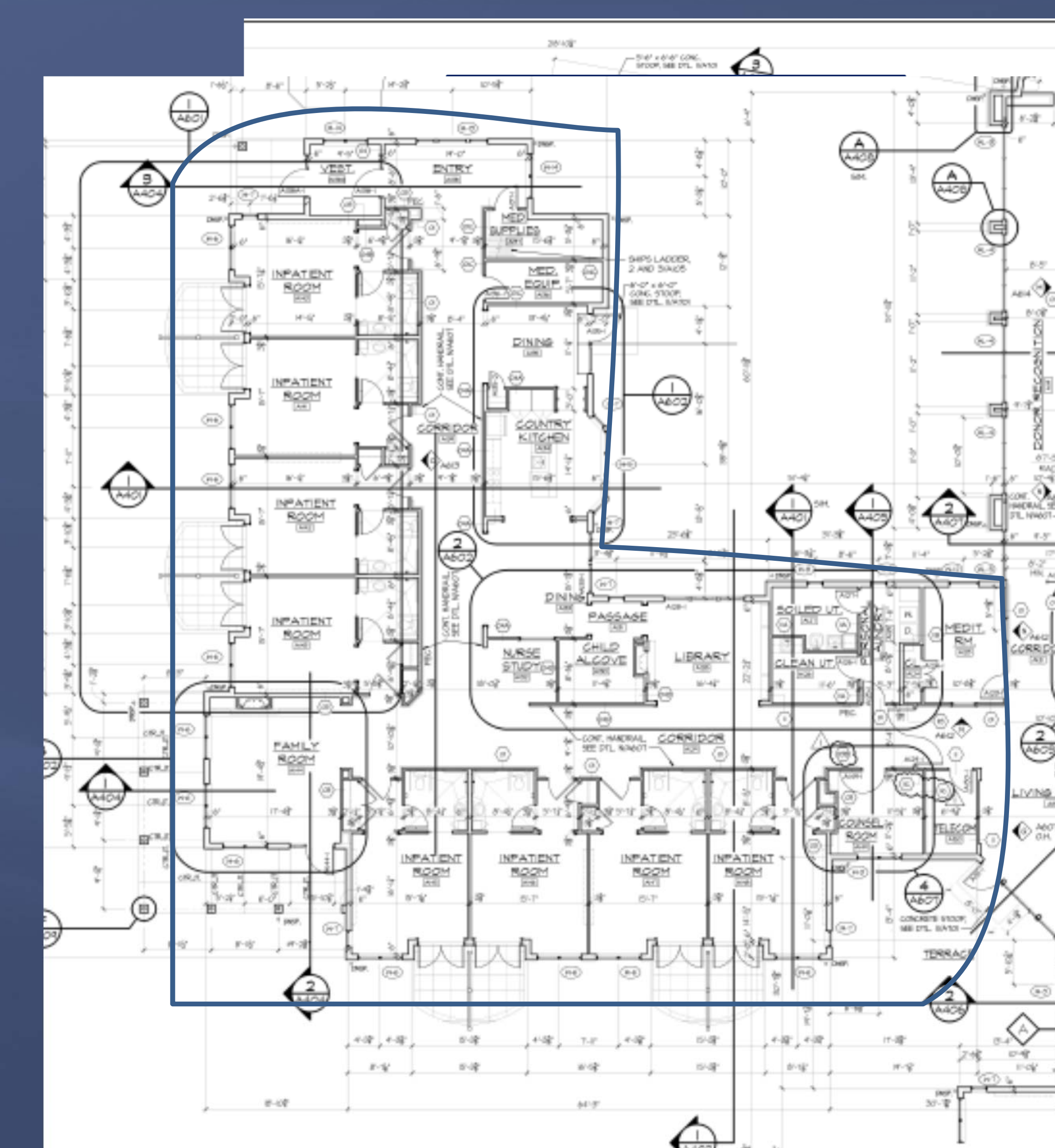
Zones





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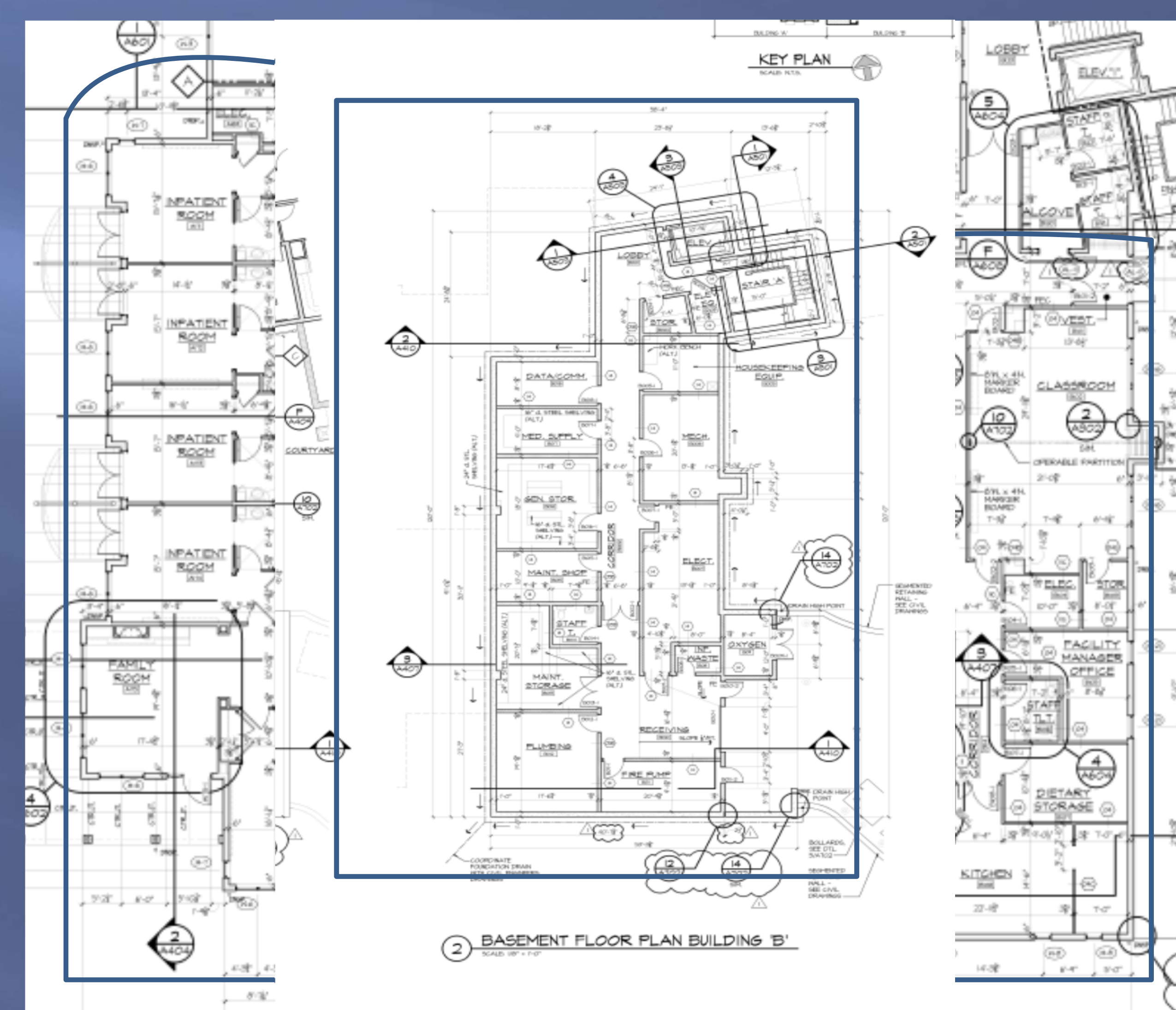
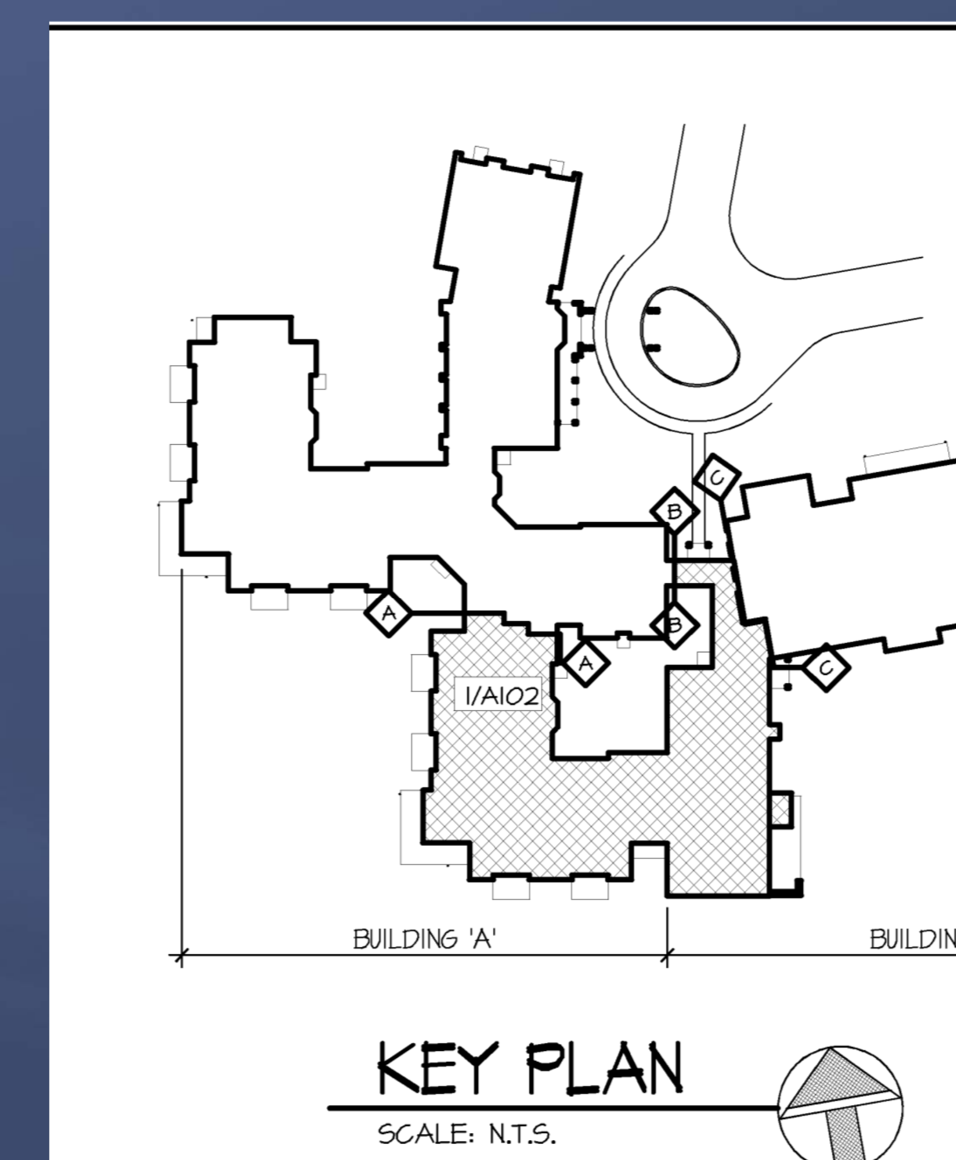
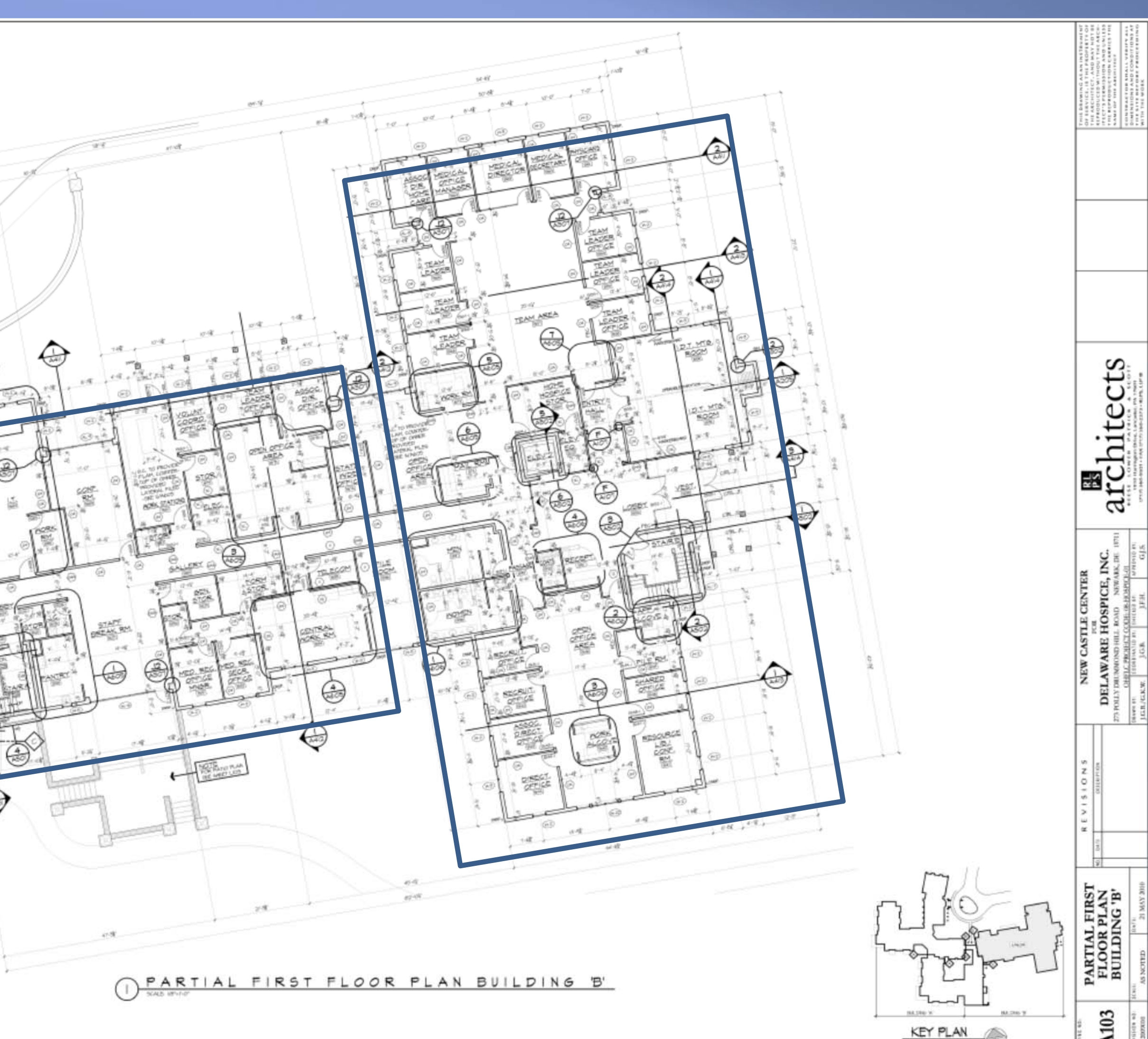
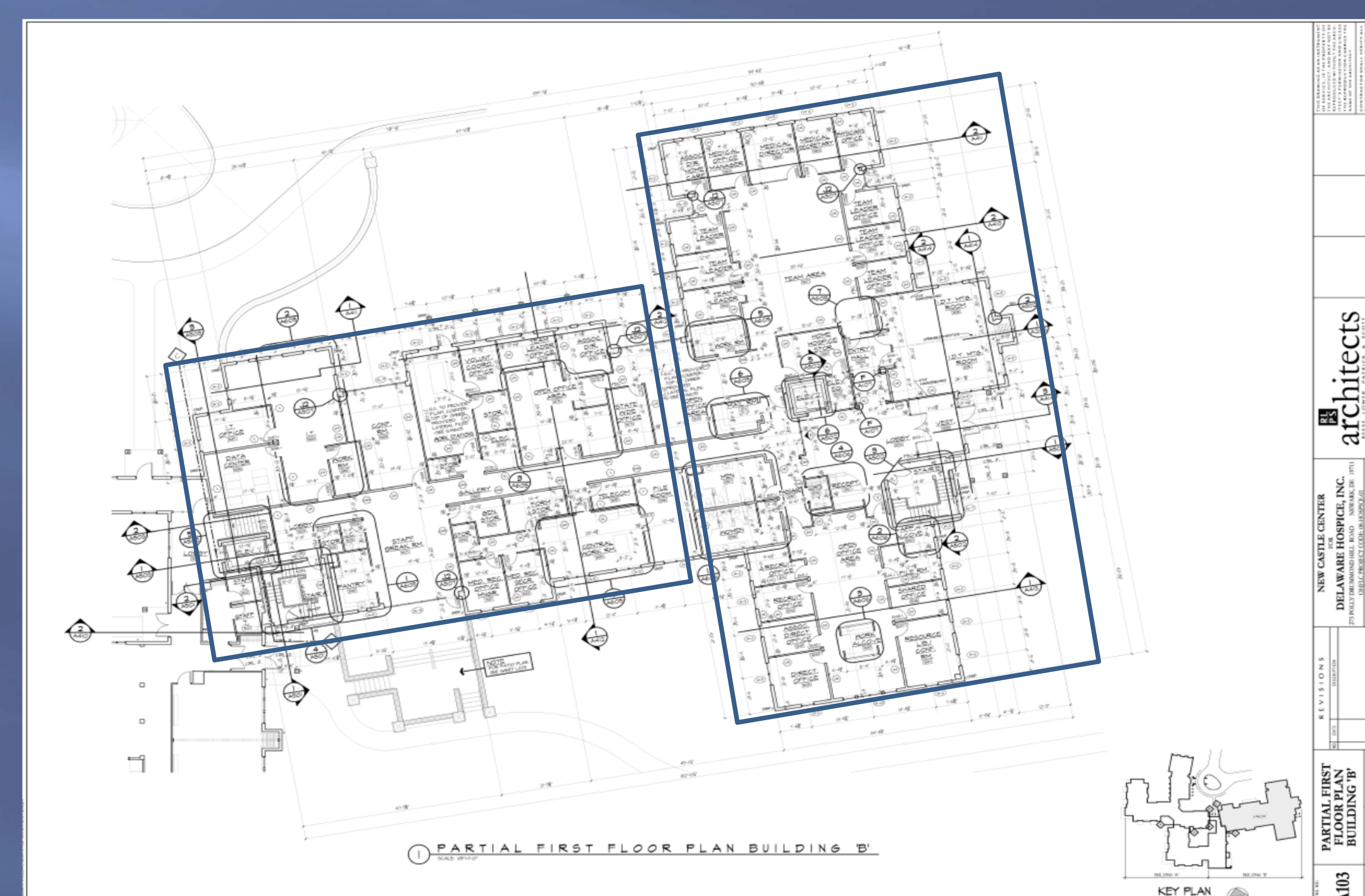




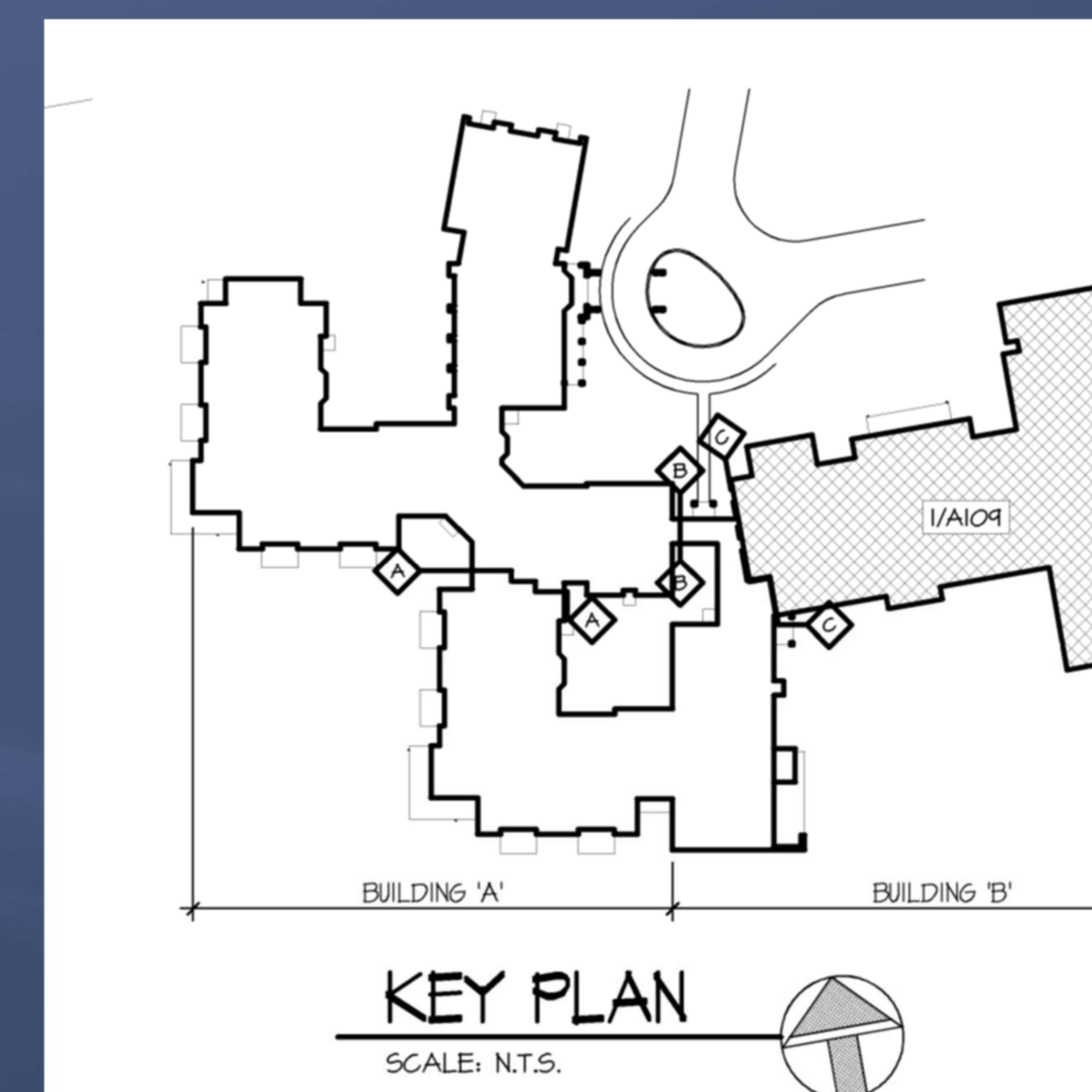
Zones



architects
PARTIAL FIRST FLOOR PLAN BUILDING 'B'



architects
PARTIAL FIRST FLOOR PLAN BUILDING 'B'



1/A109
BUILDING 'A'
BUILDING 'B'
KEY PLAN
SCALE: N.T.S.

Existing Conditions

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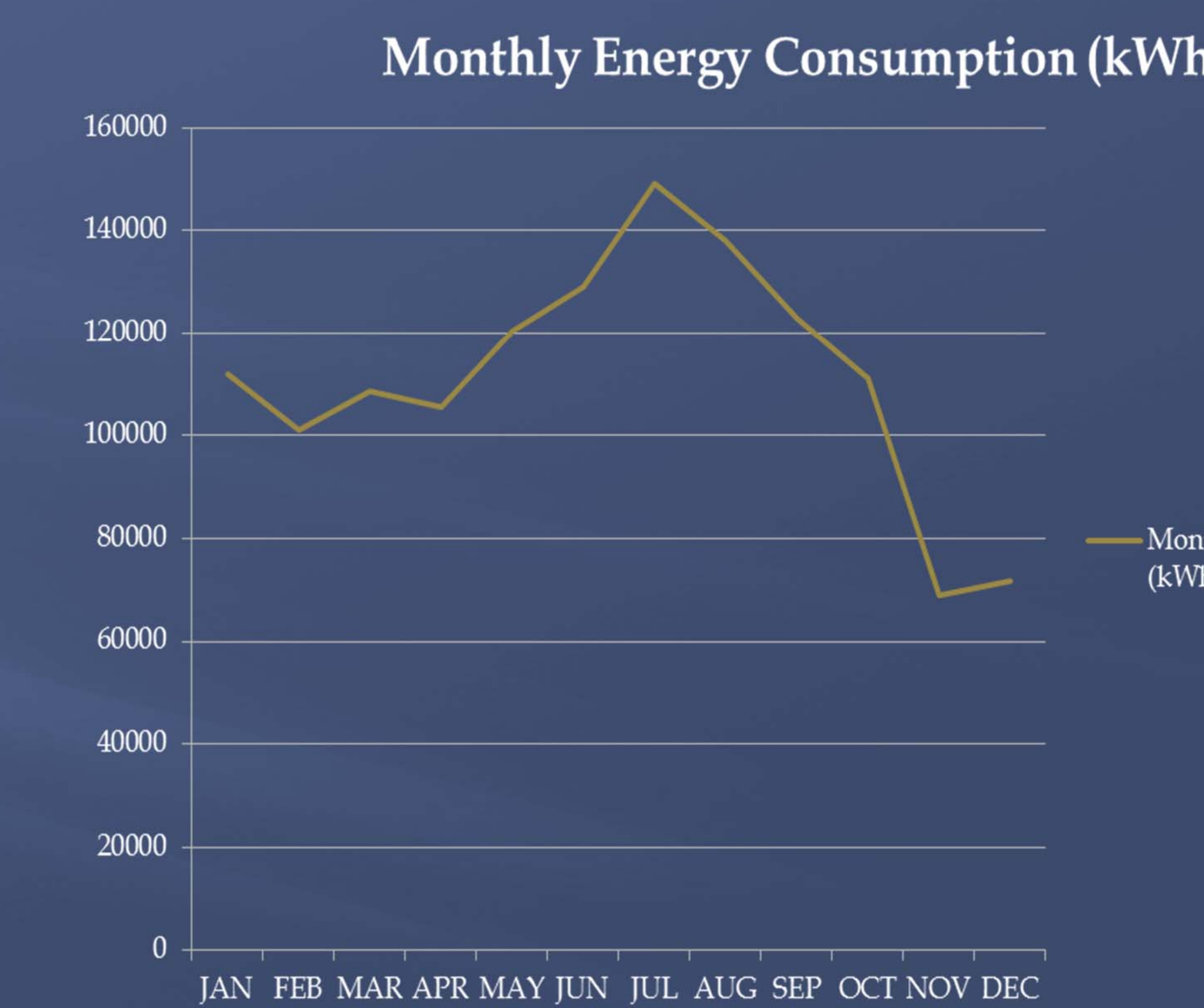
Annual Energy Consumption				
Load	Electricity (kWh)	Natural Gas (kWh)		Percent of Total Energy (%)
Heating		21,765		1.5%
Cooling	158,997			11.2%
Supply Fans	448,844			31.7%
Pumps	257,923			18.2%
Lighting	438,502			31%
Receptacle	88,126			6.2%



Systems Evalvation

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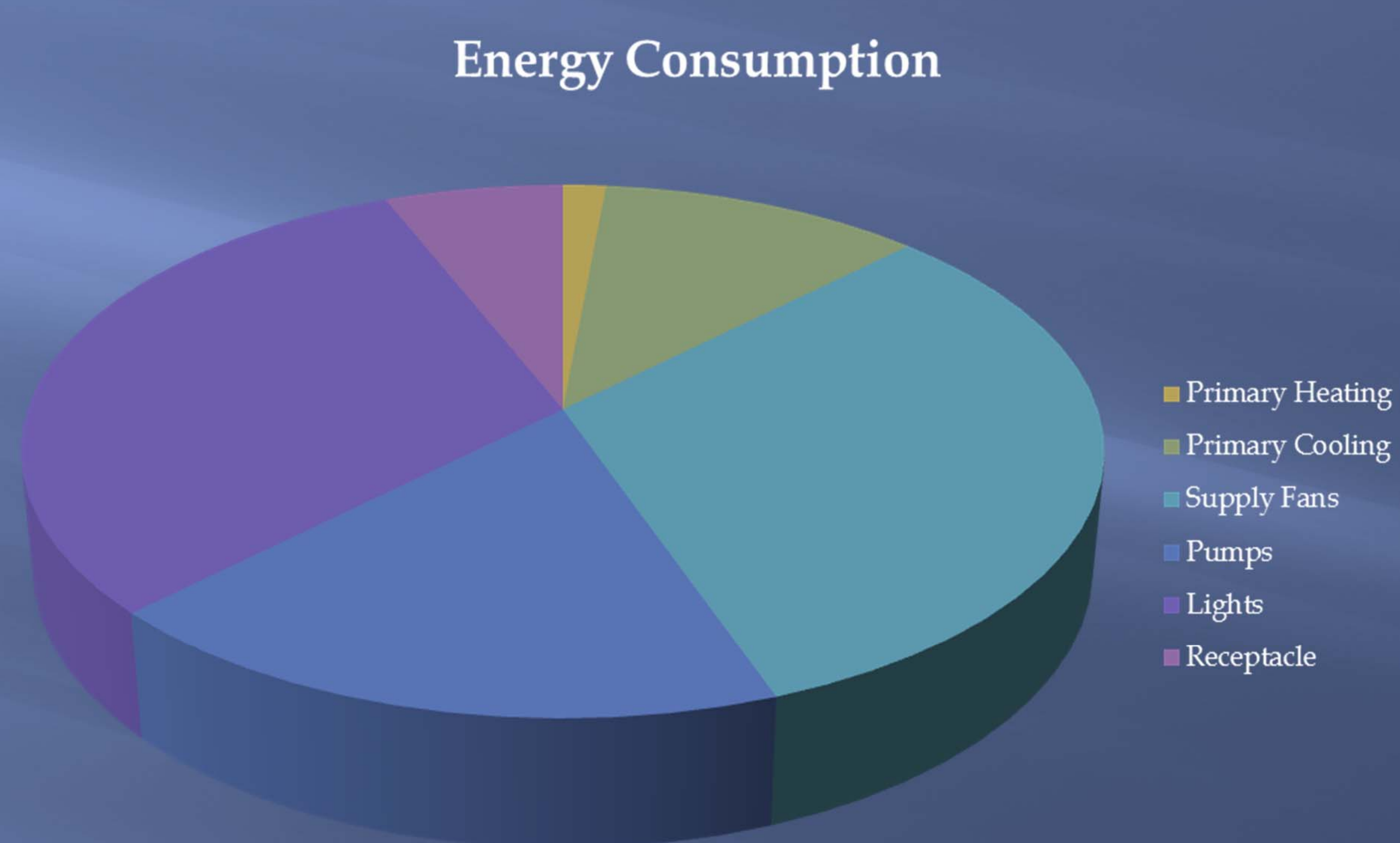

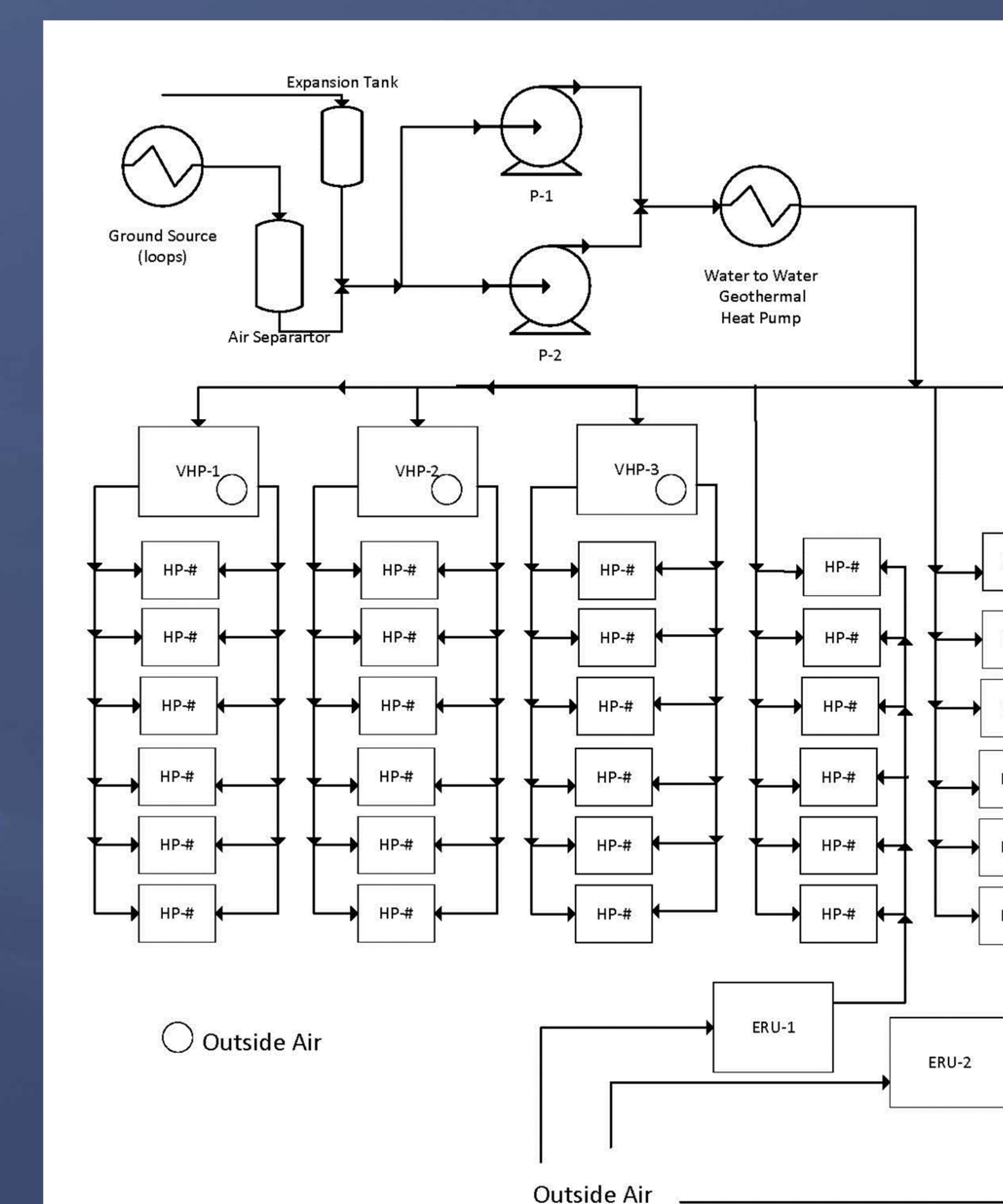

Hybrid Geothermal System

Geothermal Vertical Ground Loop Design

INPUT DATA

t-circuit heat loss factor	1.02	
esign Cooling block load	1060800	BTU
	88.4	Ton
esign heating block load	-266785.3	BTU
ermal Resistance of bore	0.4672897	BTU/(F*lbm)
ed ground temperature	57.2	F
enalty for interfernce of adjacent bore	0.7694444	
ure at heat pump inlet (cooling)	85	F
ure at heat pump outlet (cooling)	95	F
ature at heat pump inlet (Heating)	54	F
ure at heat pump outlet (Heating)	44	F
ut at design cooling load	14412.096	W
ut at design heating load	-1461.0934	W
oump correction factors		
Thermal diffusivity	1.38	FT^2/Day
Diameter of bore	0.5	ft
Time	3681	hr
G-factor	0.9	
ore separation distance	20	ft

Calculation

required bore length for cooling	-30489.454	ft
required bores @450 ft for cooling	-67.754342	
required bore length for heating	7836.7895	ft
required bores @ 450 ft for heating	17.415088	
Fo	81276.48	
effective thermal resistance of the ground, annual pulse	0.25	h*ft*F/Btu
effective thermal resistance of the ground, daily pulse	0.19	h*ft*F/Btu
effective thermal resistance of the ground, monthly pulse	0.31	h*ft*F/Btu
Part-load Factor during design month (cooling)	0.3207827	
Part-load Factor during design month (heating)	0.20996	
Net annual average heat transfer to the ground	362.30682	Btu/h
Ground Loop Heat Exchanger Length	-344.90332	ft/Ton
EER	14.07	
COP	4	
SEER	14.7735	

Calculation

required bore length for cooling	9057.9775
required bores @450 ft for cooling	20.128839
required bore length for heating	7836.7895
required bores @ 450 ft for heating	17.415088
Fo	81276.48
effective thermal resistance of the ground, annual pulse	0.25
effective thermal resistance of the ground, daily pulse	0.19
effective thermal resistance of the ground, monthly pulse	0.31
Part-load Factor during design month (cooling)	0.3207827
Part-load Factor during design month (heating)	0.20996
Net annual average heat transfer to the ground	362.30682
Ground Loop Heat Exchanger Length	102.46581
EER	14.07
COP	4
SEER	14.7735

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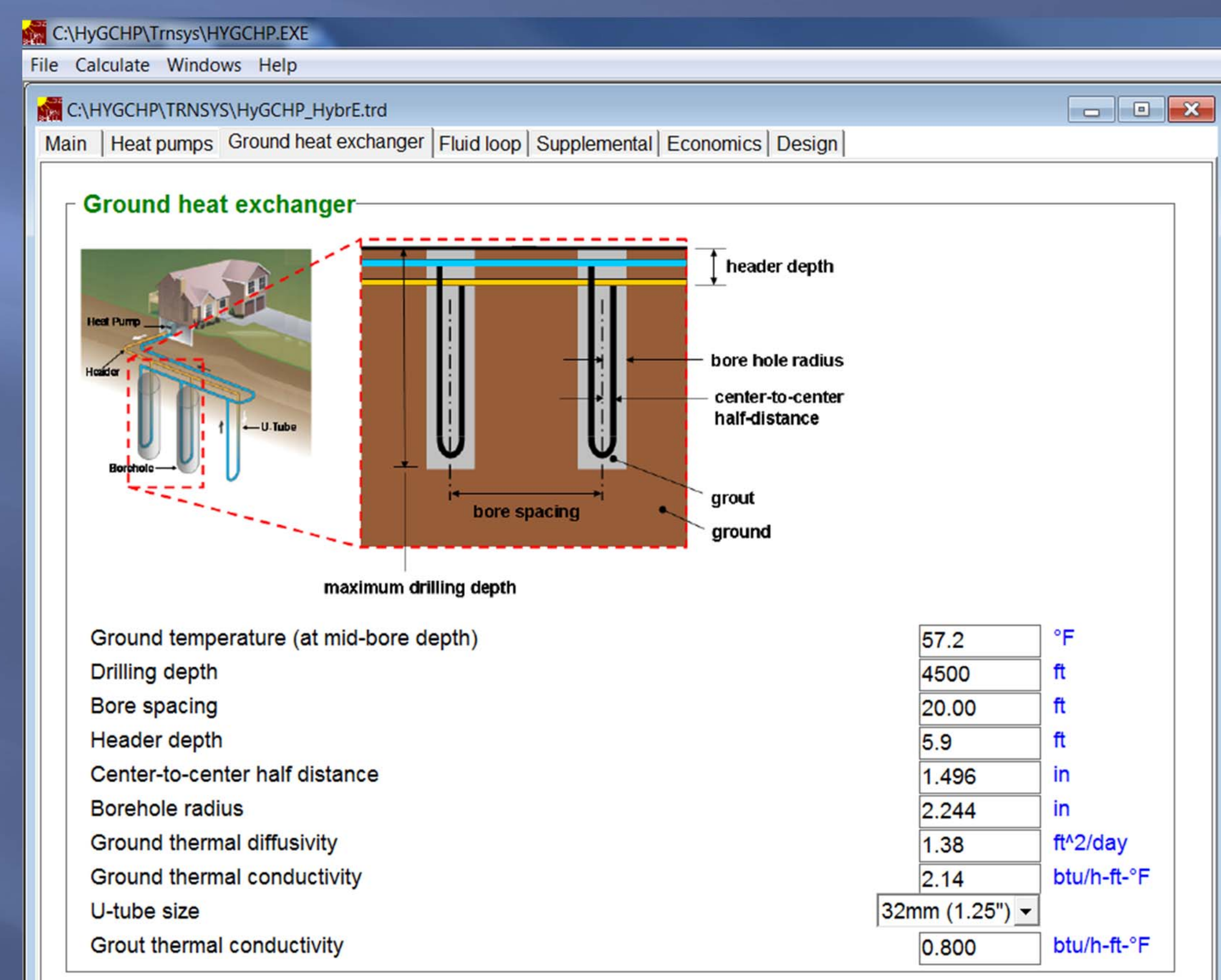
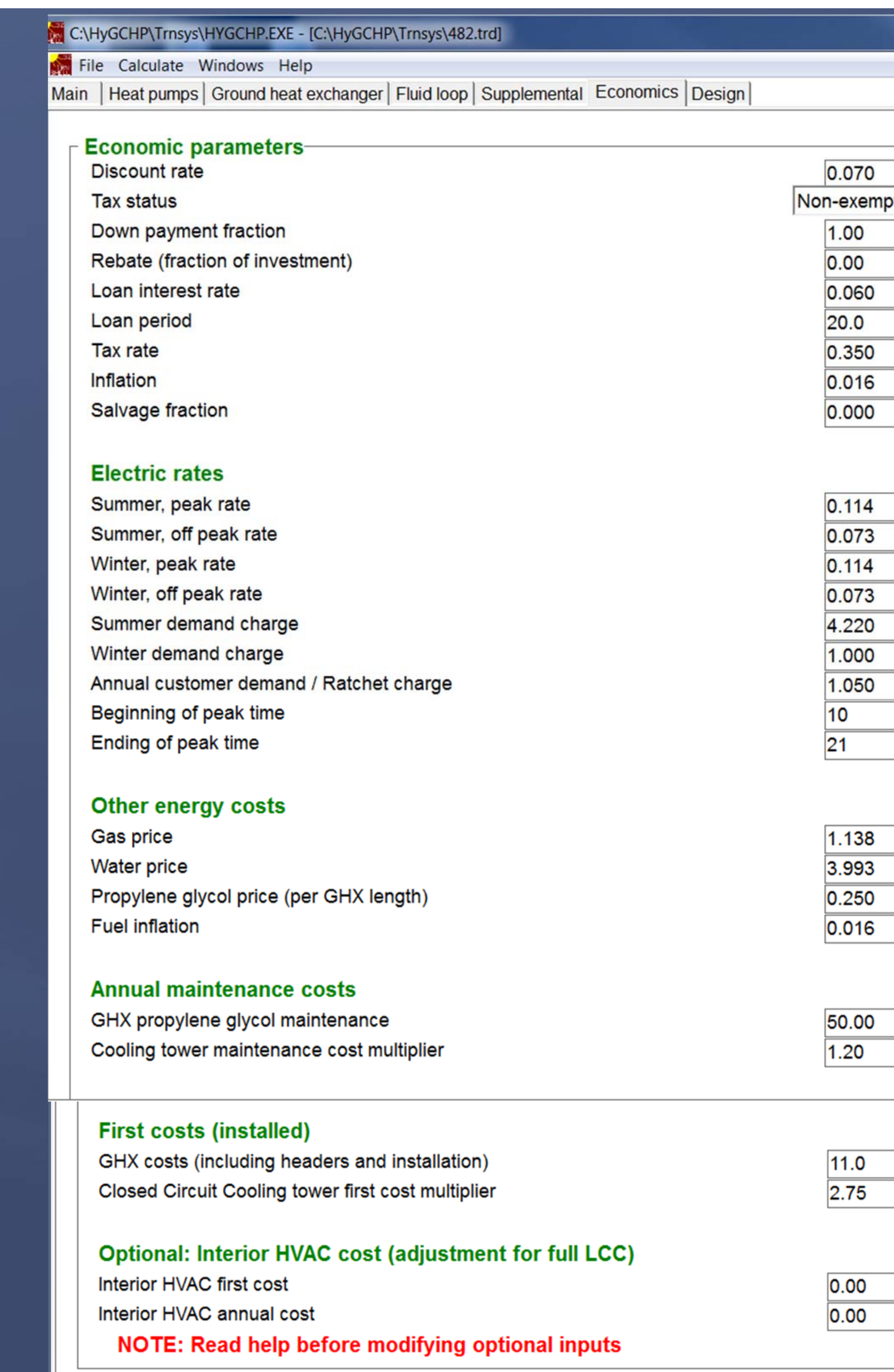




601.4 k$
455.74 k$
455.62 k$
195.47 k$
14.5 k$
10.74 k$
0 k$
0 k$
385316.8 kWh
716697.5 kWh
168619.3 kWh
0 kWh
0 kWh
0 kWh

Hybrid Geothermal System

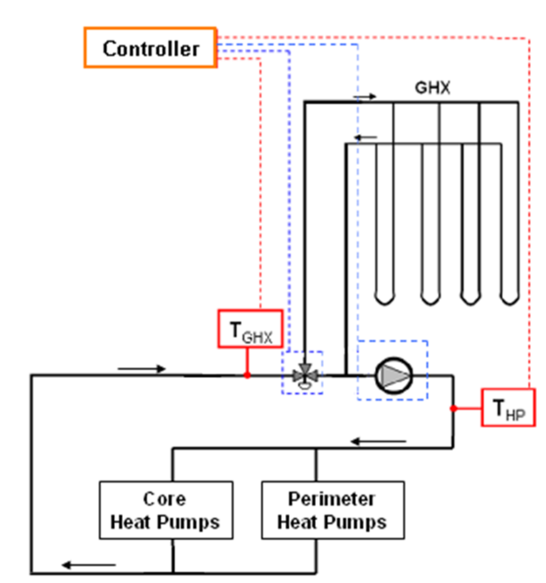
Other Data	
Min. heat pump Tin	53.9 °F
Max. heat pump Tin	81.7 °F
Avg. annual ground temp chang	1.3 D°F
GHX max. flow	271.4 gpm
Temperature violations	0 hours
Design Parameters	
GHX length	40500 ft
GHX cooling setpoint (TC2)	35 °F
GHX heating setpoint (TH2)	59 °F
Tower setpoint	N/A
Tower high speed	N/A
Cooling tower size	N/A
Boiler size	N/A

A. Run Single Simulation (required inputs)

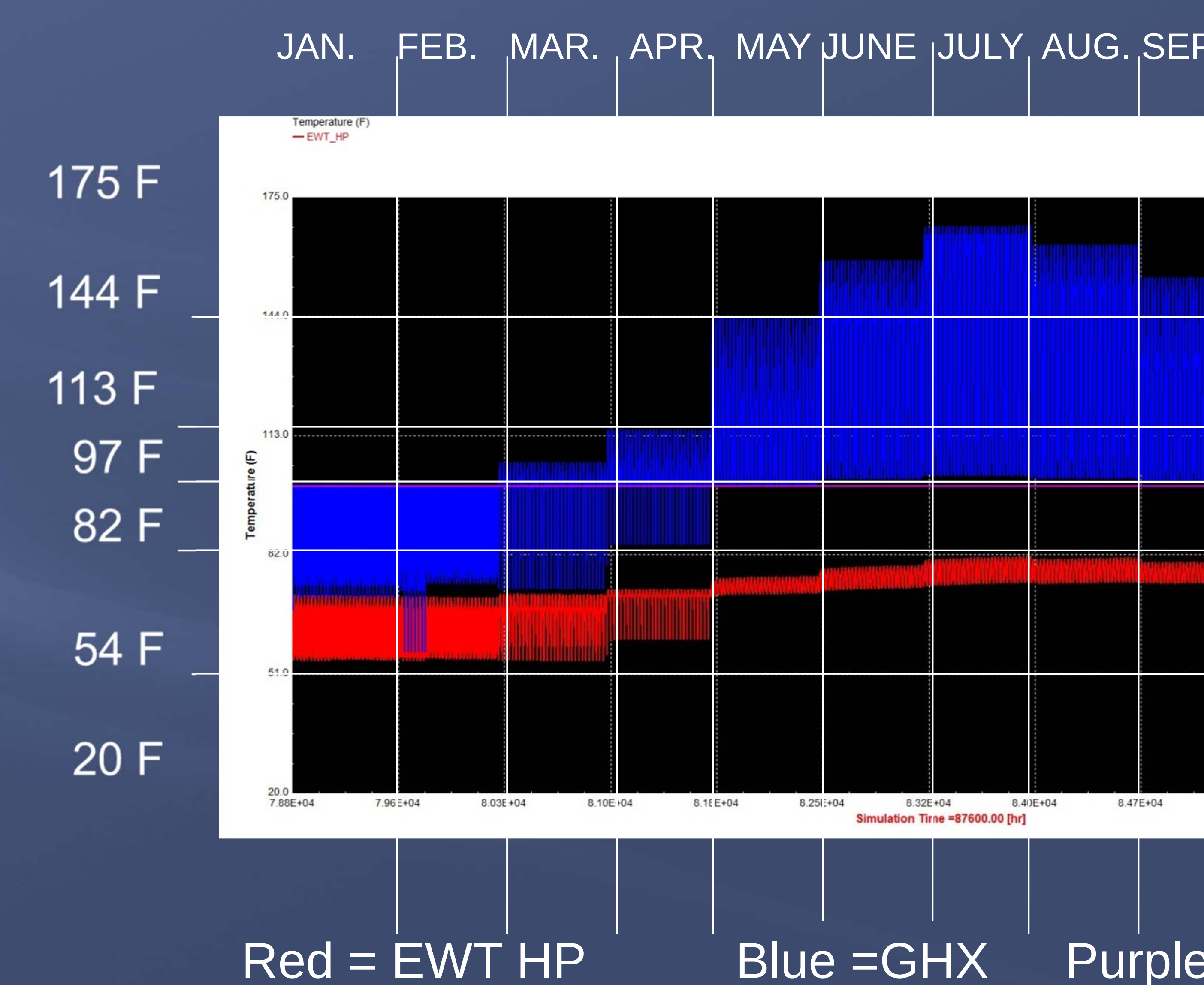
Total length 40500 ft

TC2 35 °F

Show real-time temperature/heat plot Yes (slows simulation!)



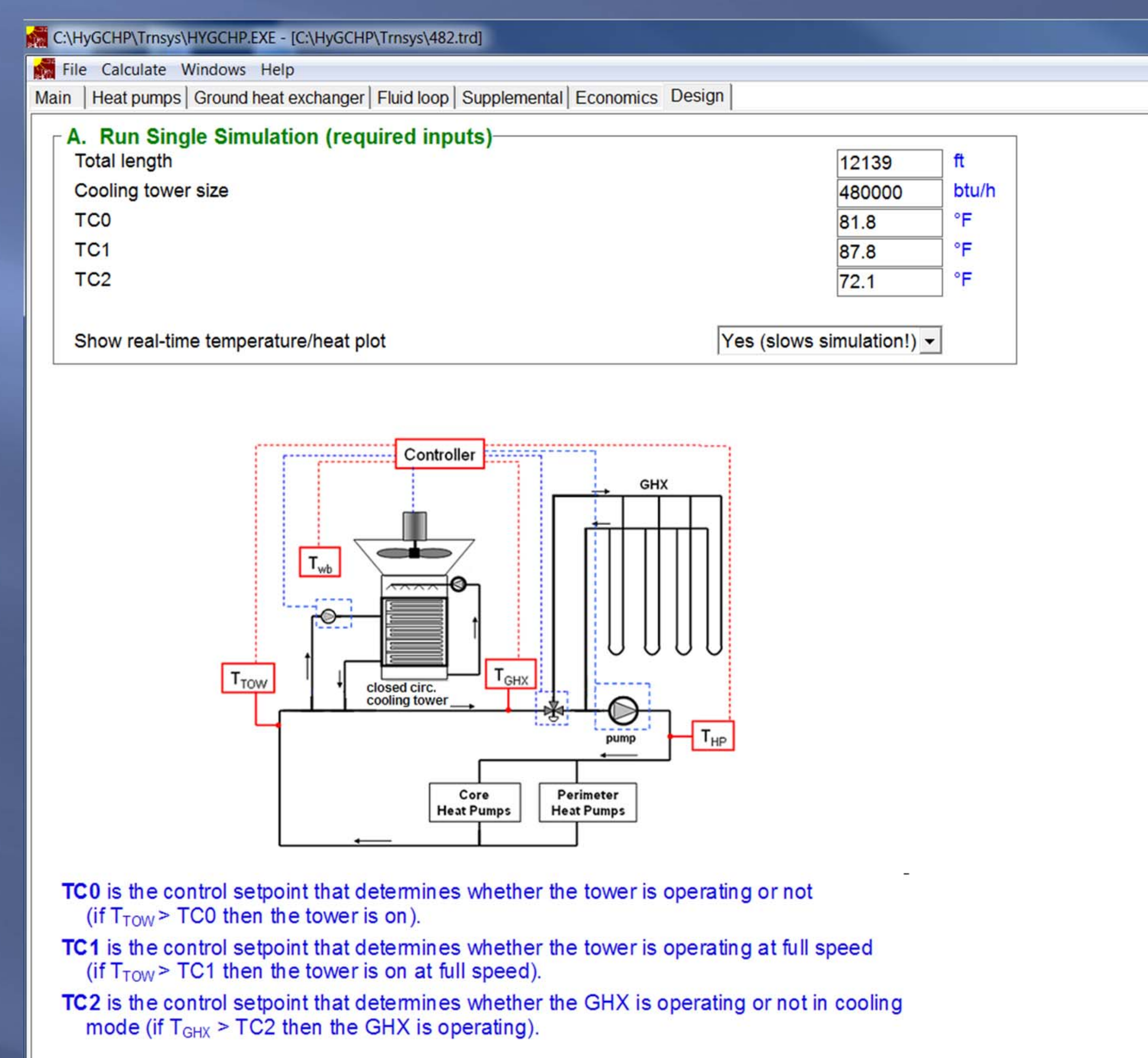
TC2 is the control setpoint that determines whether the GHX is operating or not in cooling mode (if T_{GHX} > TC2 then the GHX is operating).



Hybrid Geothermal System

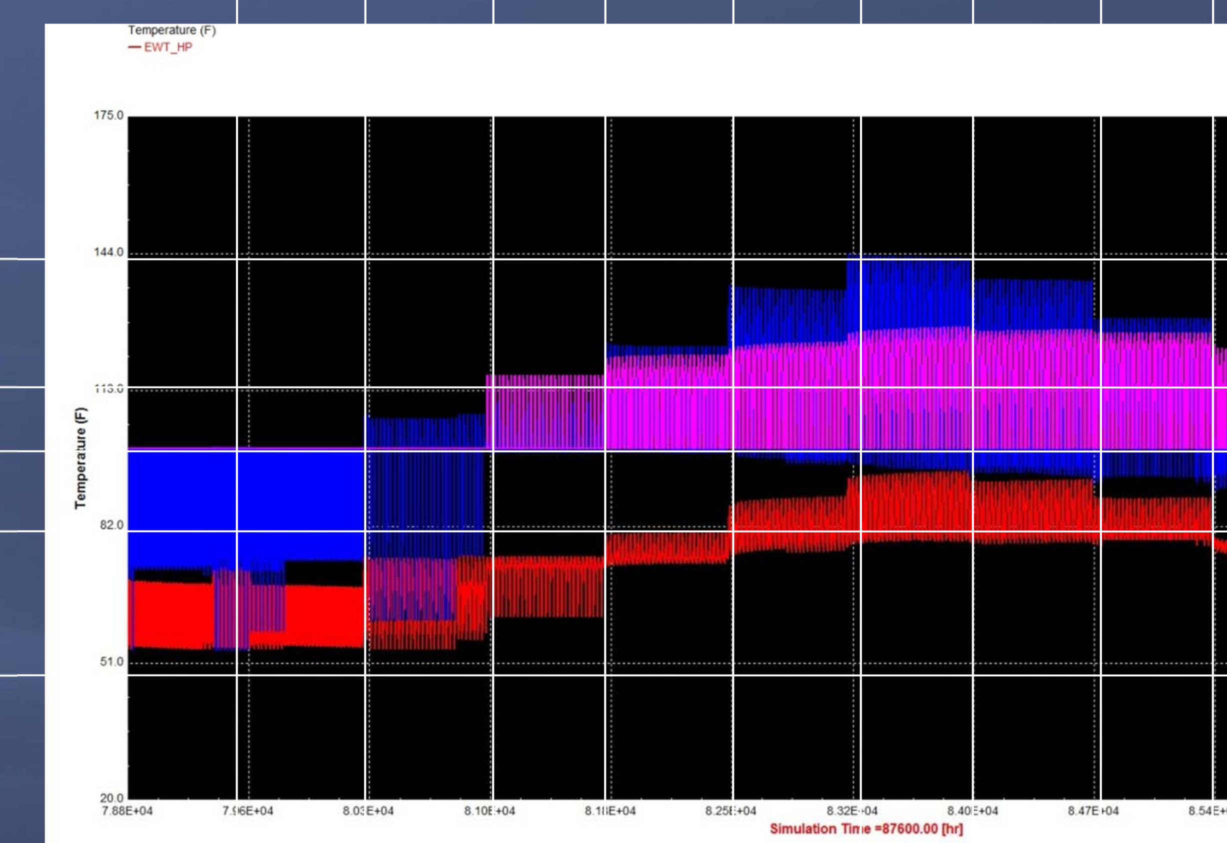
378.77	k$
164.21	k$
136.56	k$
240.31	k$
19.16	k$
8.11	k$
11.26	k$
0	k$
303608.5	kWh
922459.8	kWh
175677.5	kWh
180159.6	kWh
25311.5	kWh
0	kWh

Other Data		
Min. heat pump Tin	50.8	°F
Max. heat pump Tin	94.8	°F
Avg. annual ground temp chang	1.5	D°F
GHX max. flow	279.2	gpm
Temperature violations	0	hours
Optimal Design Parameters		
GHX length	12139	ft
GHX cooling setpoint (TC2)	72.1	°F
GHX heating setpoint (TH2)	58.8	°F
Tower setpoint (DT1)	49.8	D°F
Tower high speed (TC1)	87.8	°F
Cooling tower size	40	tons
Boiler size	N/A	



JAN. FEB. MAR. APR. MAY JUNE JULY AUG. SEPT

175 F
144 F
113 F
97 F
82 F
54 F
20 F



Red = EWT HP Blue =GHX Purple =

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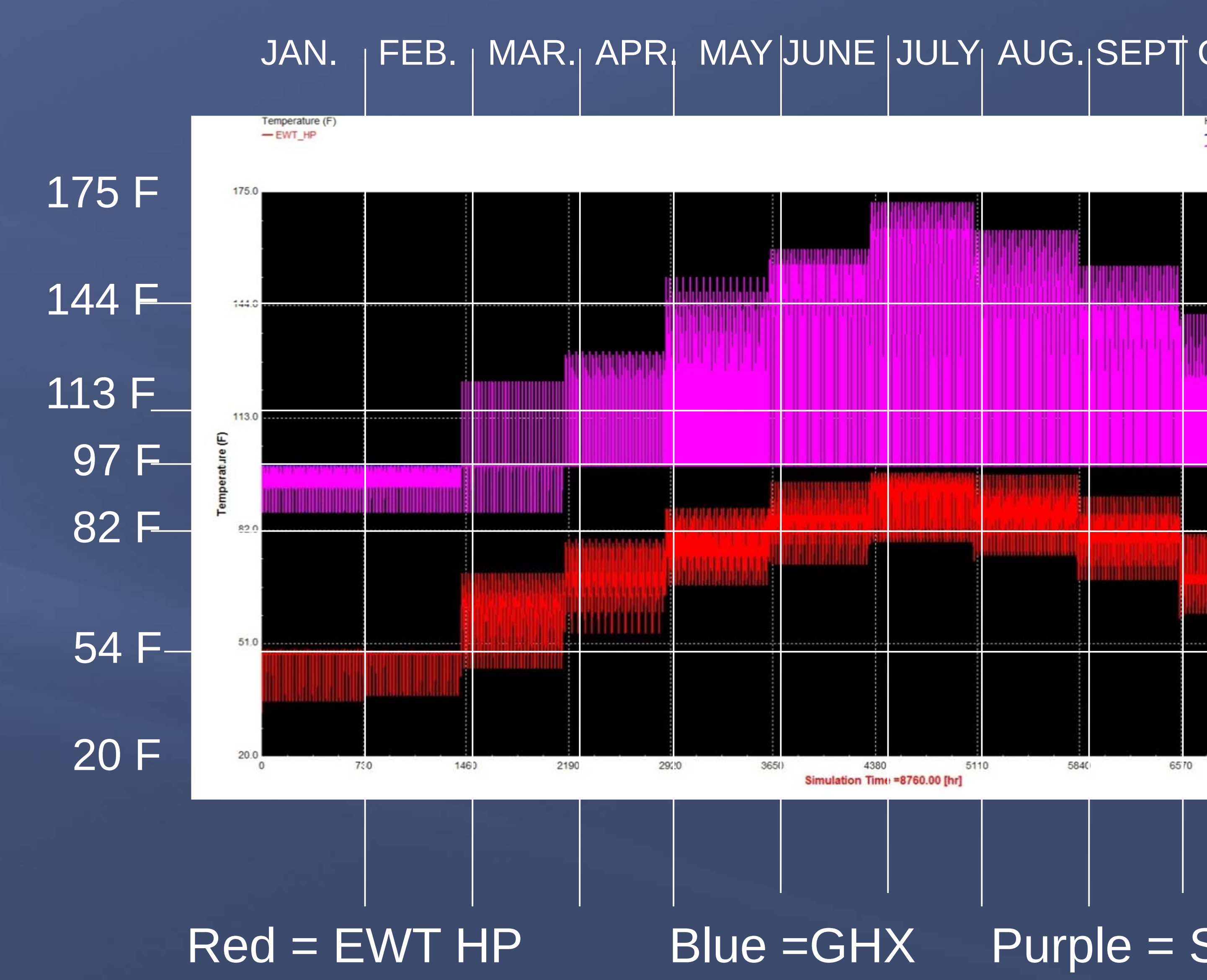
20-yr. Life Cycle Cost* (real $)	353.3	k$
Equipment Cost (nominal $)	59.2	k$
GHX cost	0	k$
Operating Costs, annual (nom. $)		
Electricity - consumption	28.22	k$
Electricity - demand	2.28	k$
Maintenance cost	1.82	k$
Water cost	2.58	k$
Gas cost	1.8	k$
Energy Consumption		
Total	317210.1	kWh
Heat pumps	201398.5	kWh
Pumping	19665.2	kWh
Cooling tower, fan	43912.6	kWh
Cooling tower, spray pump	5812	kWh
Boiler	46421.9	kWh

Other Data		
Min. heat pump Tin	35.2	°F
Max. heat pump Tin	97.8	°F
Avg. annual ground temp chang	N/A	
GHX max. flow	N/A	
Temperature violations	0	Hours
Optimal Design Parameters		
GHX length	N/A	
GHX cooling setpoint	N/A	
Boiler heating setpoint (TH1)	48.2	°F
Tower setpoint (DT1)	28.8	D°F
Tower high speed (TC1)	102.2	°F
Cooling tower size	92	tons
Boiler size	320	MBtu/hr



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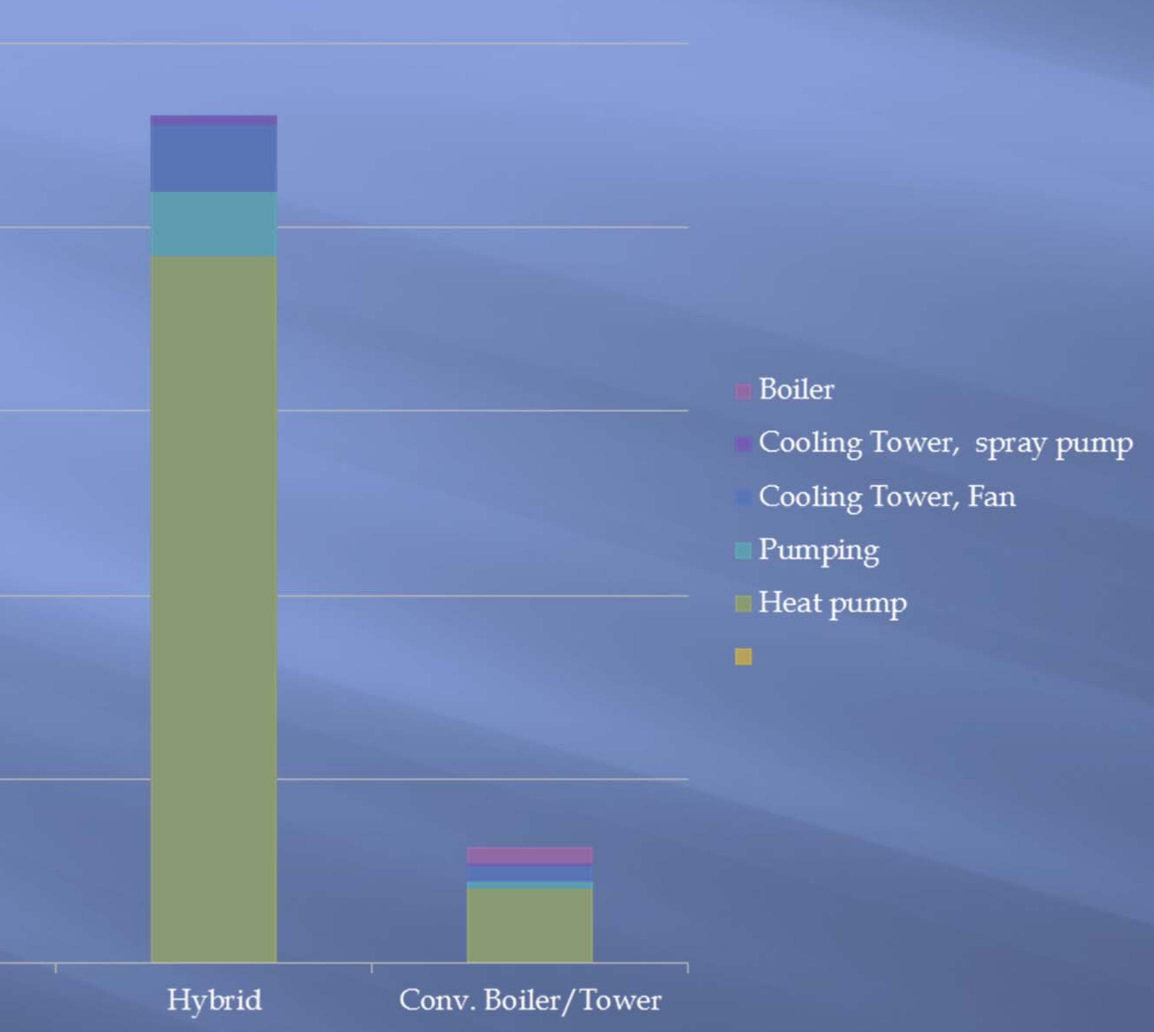

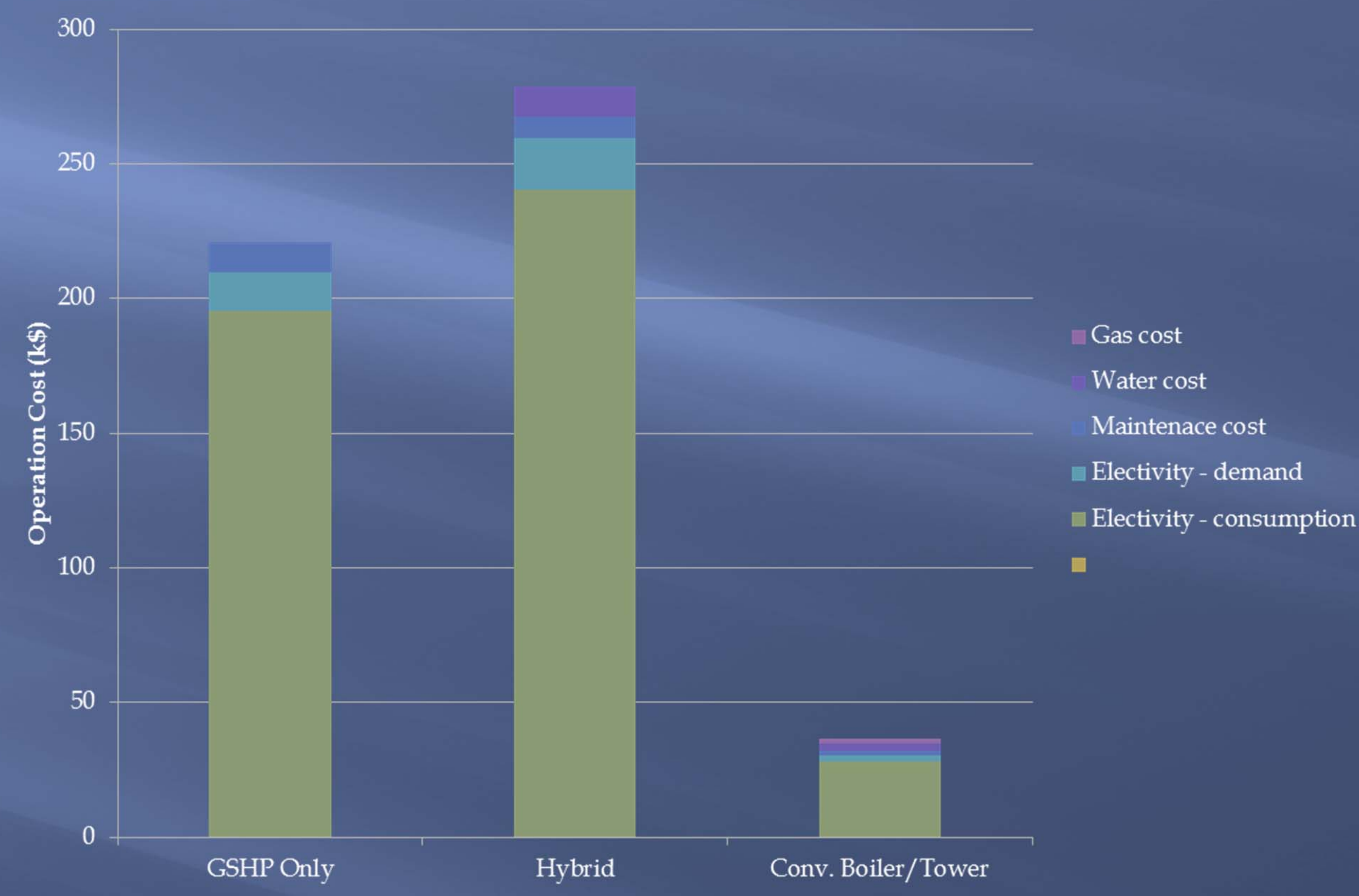

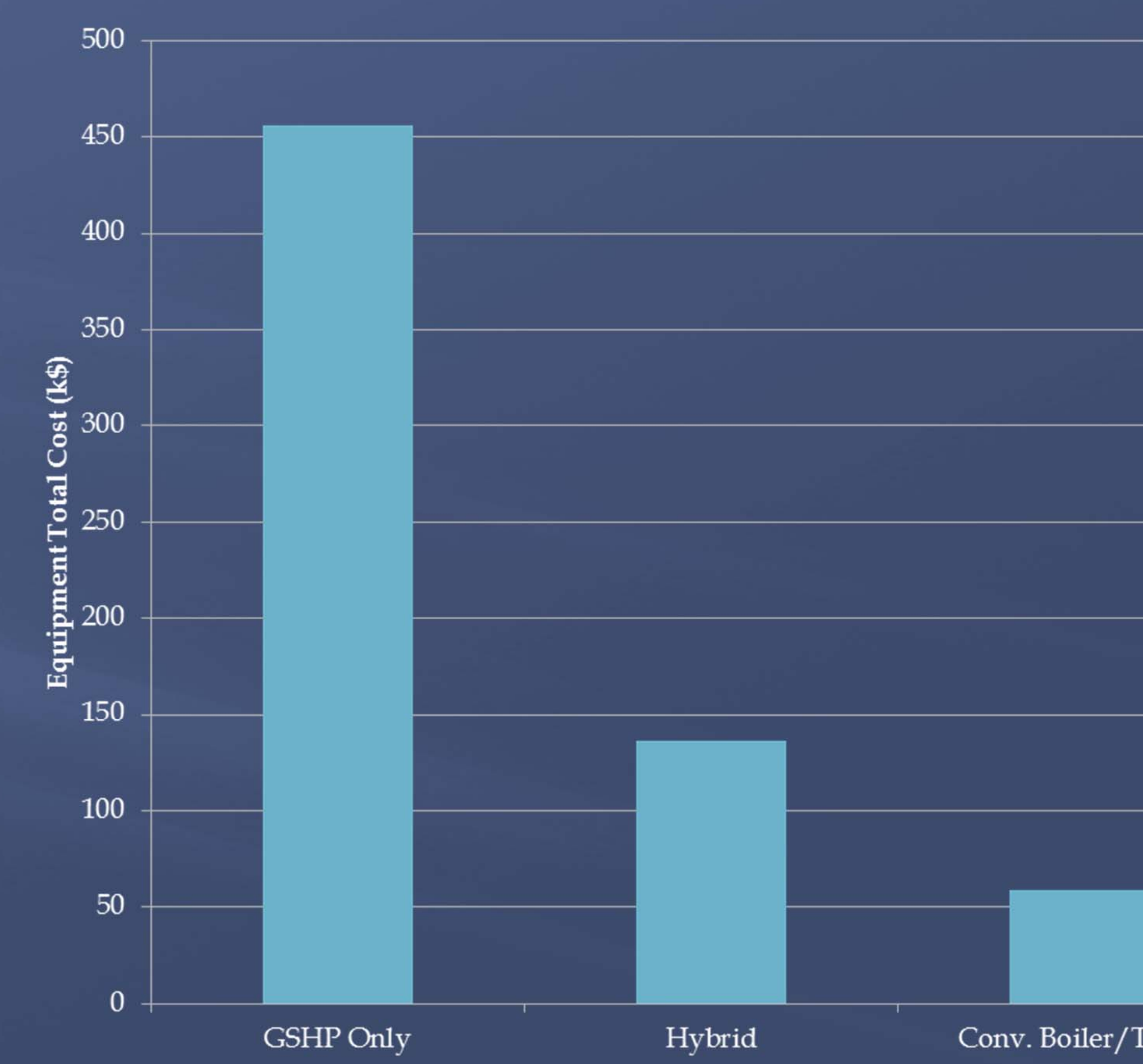

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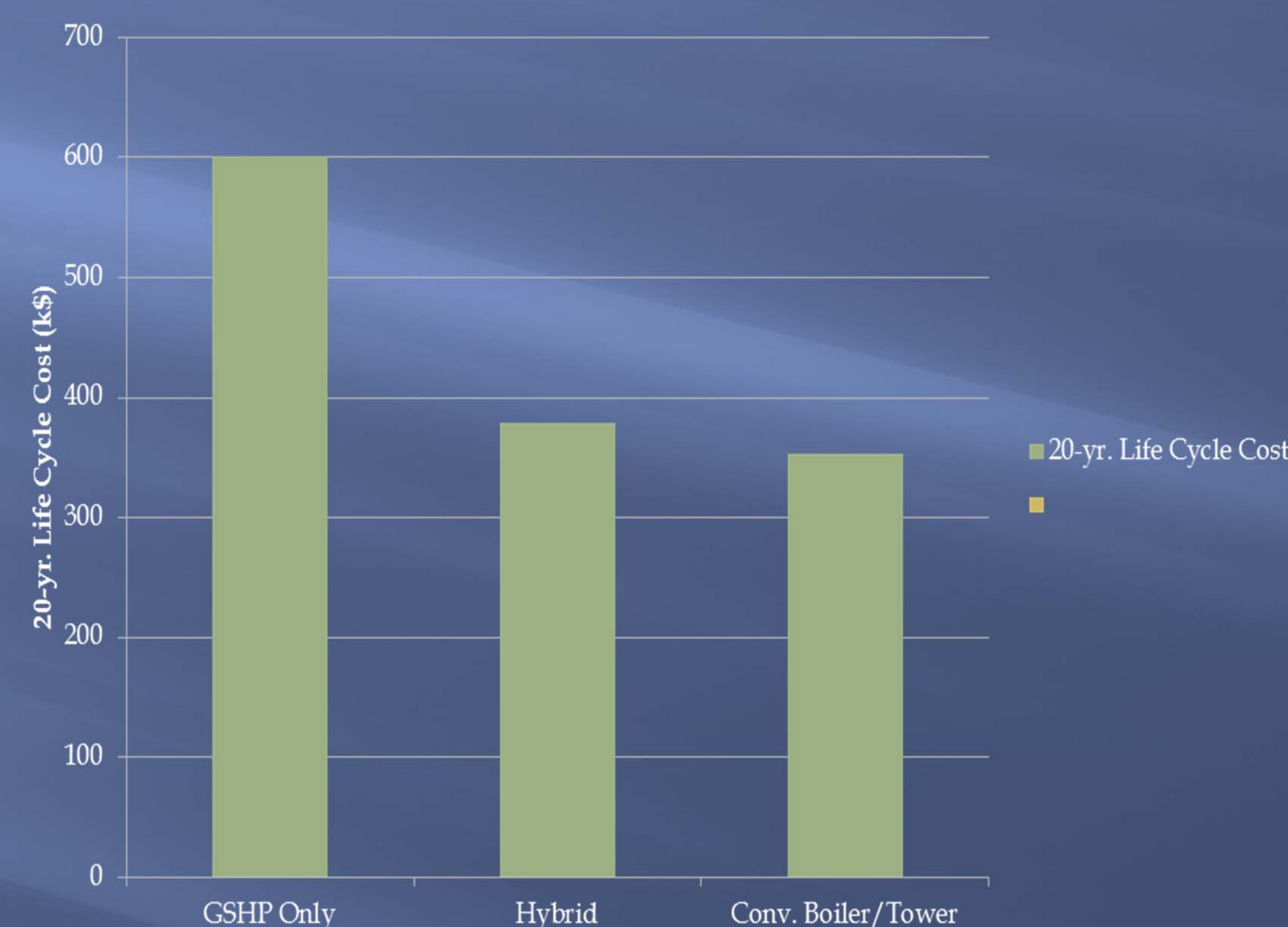

Other Data	GSHP Onl
Number of boreholes in ground heat exchanger	90 @ 450
Average annual ground temp. change (F)	1
Max. fluids temperature entering heat pumps (F)	81
Min. fluids temperature entering heat pumps (F)	53
GHX max. flow (gpm)	271

Electrical Breadth

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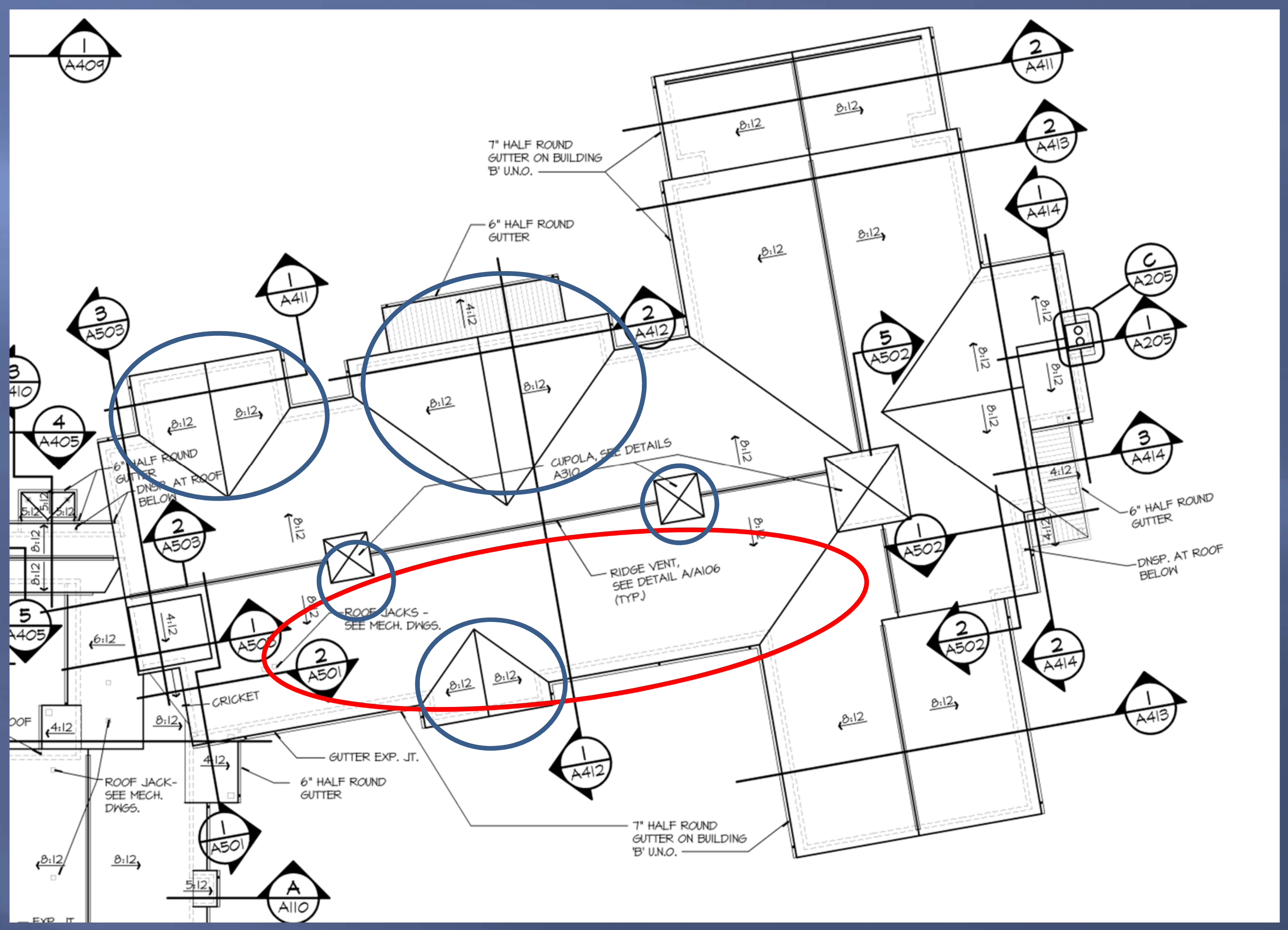

Electrical

3360 sq. ft.

2175 Watts @ 1587 sq. ft.

$191,475 investment, $134,028 after rebat

$4,059 annual savings

33.04 years pay back period

Conclusion

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In conclusion on my research of ground so heat pump or hybrid geothermal for DE Hospice, I find that hybrid geothermal is a great choice for a more green design with a lower first cost. If ground source heat pump can be afforded it would be better to choice them in the long run. With only saving $53, a year, it would only take just over six year annual savings to make up for the $319,18 equipment cost.

Reference

brid Ground-Source Heat Pump Installations: Experiences, d Tools.” Energy Center of Wisconsin. June 30, 2011

andbook: HVAC Applications.” 2007. American Society of ation, and Air-Conditioning Engineers

Simple Approaches to Energy Efficiency: Optimal Air, Geothermal” ASHRAE Journal July (2006): pp. 44-50

d Geothermal Heat Pump for Beachfront Hotel” ASHRAE 06): pp. 49-55

augh and Kevin Rafferty. “Ground-Source Heat Pumps: rmal System for Commercial and Institutional Buildings” ociety of Heating, Refrigeration, and Air-Conditioning

Appendix

$$L_c = \frac{q_a \cdot R_{ga} + [q_{lc} - 3.142 \cdot W_c] \cdot [R_p + PLF_m \cdot R_{gm} + R_{gd} \cdot F_{sc}]}{t_g - \left[\frac{t_{wi} - t_{wo}}{2}\right] - t_p}$$

F_{sc}= *short circuit heat loss factor*
L_c= *required bore length for cooling, ft*
q_a= *net annual average heat transfer to ground, Btu/h*
q_{lc}= *building design cooling block load, Btu/h*
R_{ga}= *effective thermal resistance of ground (annual pulse), h-ft-°F/Btu*
R_{gd}= *effective thermal resistance of ground (daily pulse) , h-ft-°F/Btu*
R_{gm}= *effective thermal resistance of ground (monthly pulse) , h-ft-°F/Btu*
R_p= *thermal resistance of pipe and borehole, h-ft-°F/Btu*
t_g= *undistributed ground temperature, °F*
t_p= *temperature penalty for interference of adjacent bores, °F*
t_{wi}= *liquid temperature at heat pump inlet, °F*
t_{wo}= *liquid temperature at heat pump at outlet, °F*
W_c= *power input at design cooling load, Btu/h*
PLF_m= *part load factor during design month*

$$F_{of} = \frac{4 \cdot \alpha \cdot \tau_f}{d_p^{\,2}} \qquad R_{ga} = \frac{G_f \ldots}{\ldots}$$

$$F_{o1} = \frac{4 \cdot \alpha \cdot [\tau_f - \tau_1]}{d_p^{\,2}} \qquad R_{gm} = \frac{G_1 \ldots}{\ldots}$$

$$F_{o2} = \frac{4 \cdot \alpha \cdot [\tau_f - \tau_2]}{d_p^{\,2}} \qquad R_{gd} = \frac{G_2 \ldots}{k_g}$$

F_{of} = *Fouriers number for* τ_f
F_{o1} = *Fouriers number for* τ_1
F_{o2} = *Fouriers number for* τ_2
α = *Thermal diffusivity of the ground,* m^2*/day*
d_p= *Outside diameter of pipe, ft*
k_g= *Thermal conductivity of the ground, Btu /h-ft-°F*

Questions?