

New Castle Center for Delaware Hospice, Inc



Zachary Klixbull

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

Presentation Outline

Overview
Conditions
Evaluation
and Redesign
Mechanical Depth
and Breadth
Conclusion

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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

Presentation Outline

Overview
Conditions
Evaluation
and Redesign
at Depth
at Breadth
Conclusion

Building Statistics

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

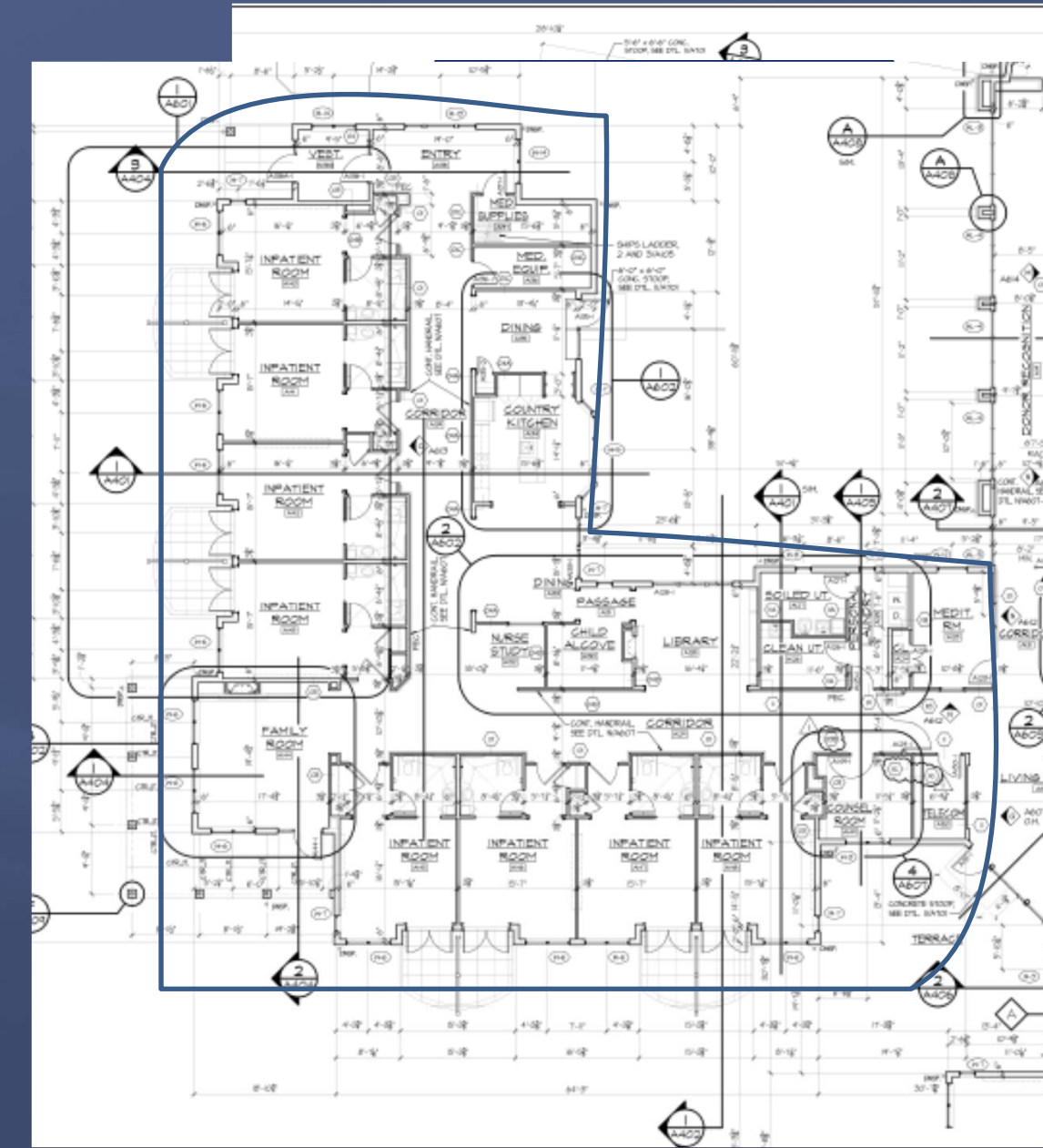
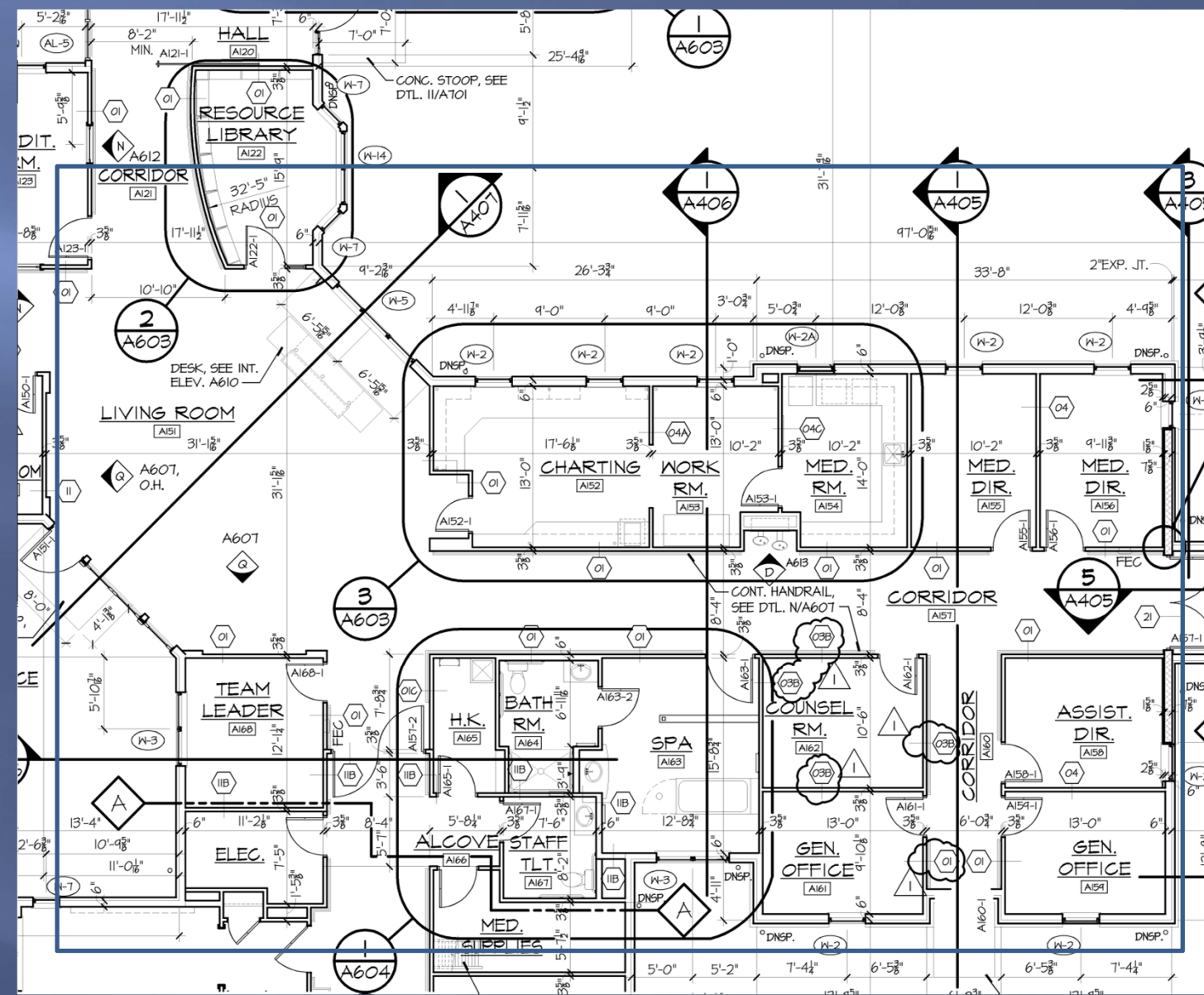
Dates of Construction

Construction Begins: August, 2011
Start Exterior Façade: January, 2012
Construction Complete: September, 2012

Presentation Outline

- Overview
- Conditions
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- and Redesign
- Technical Depth
- and Breadth
- Conclusion

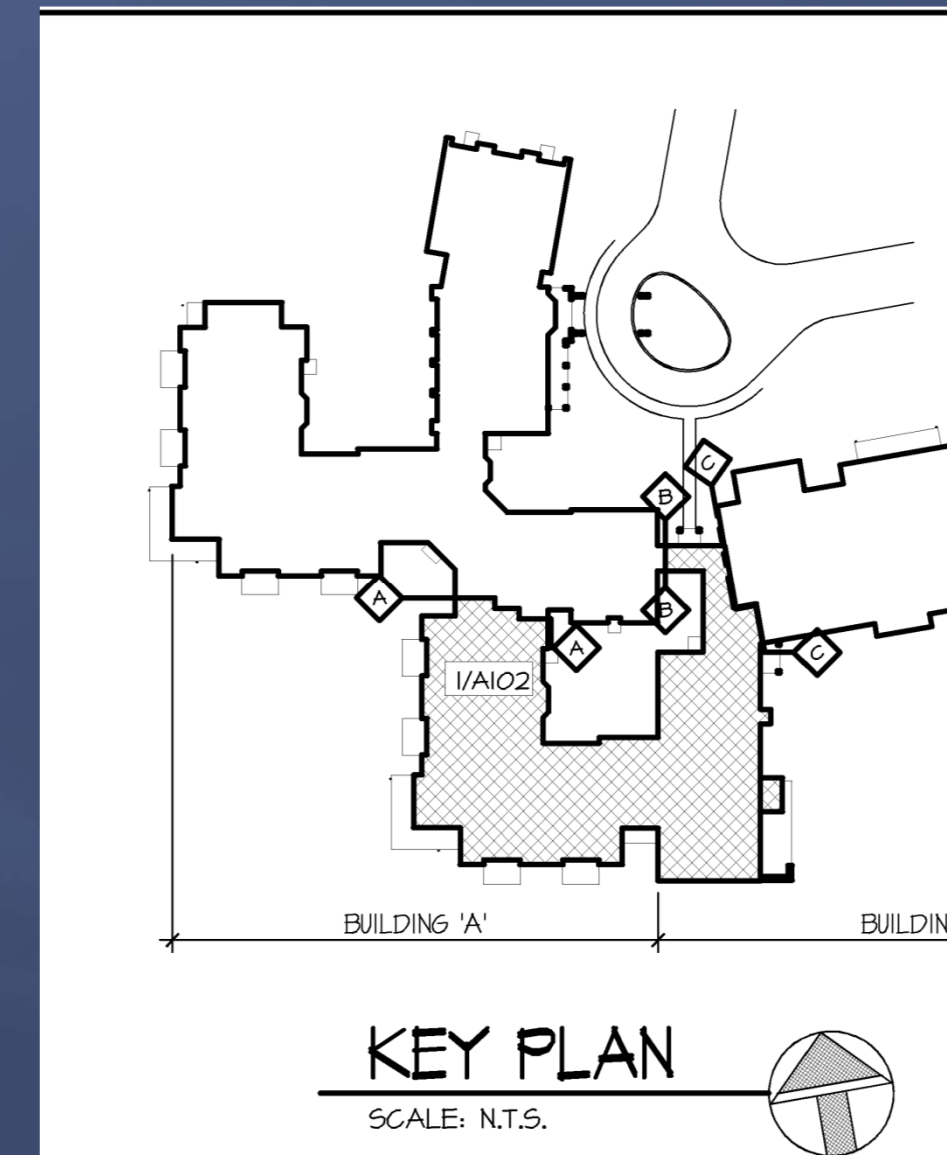
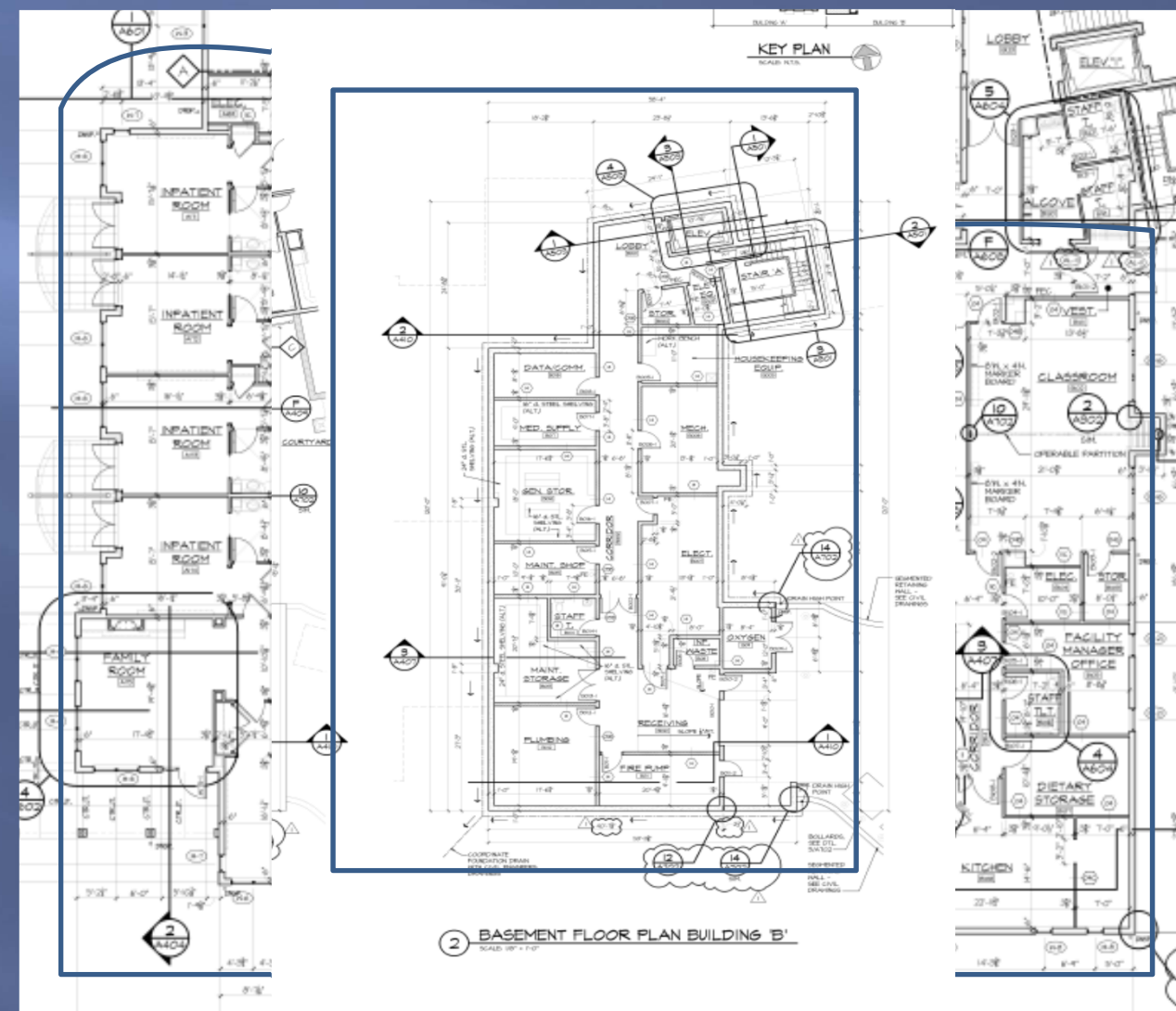
Zones



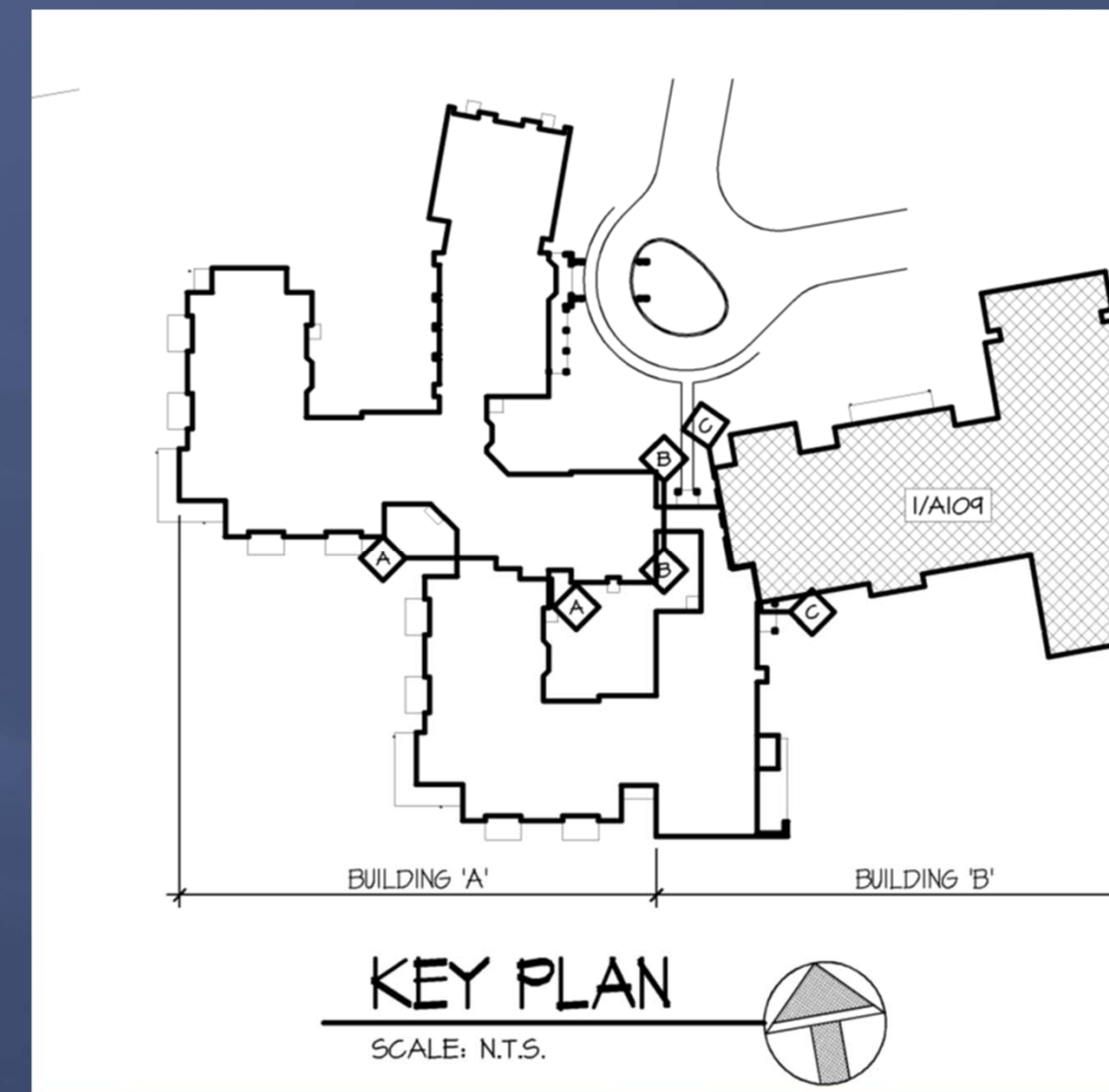
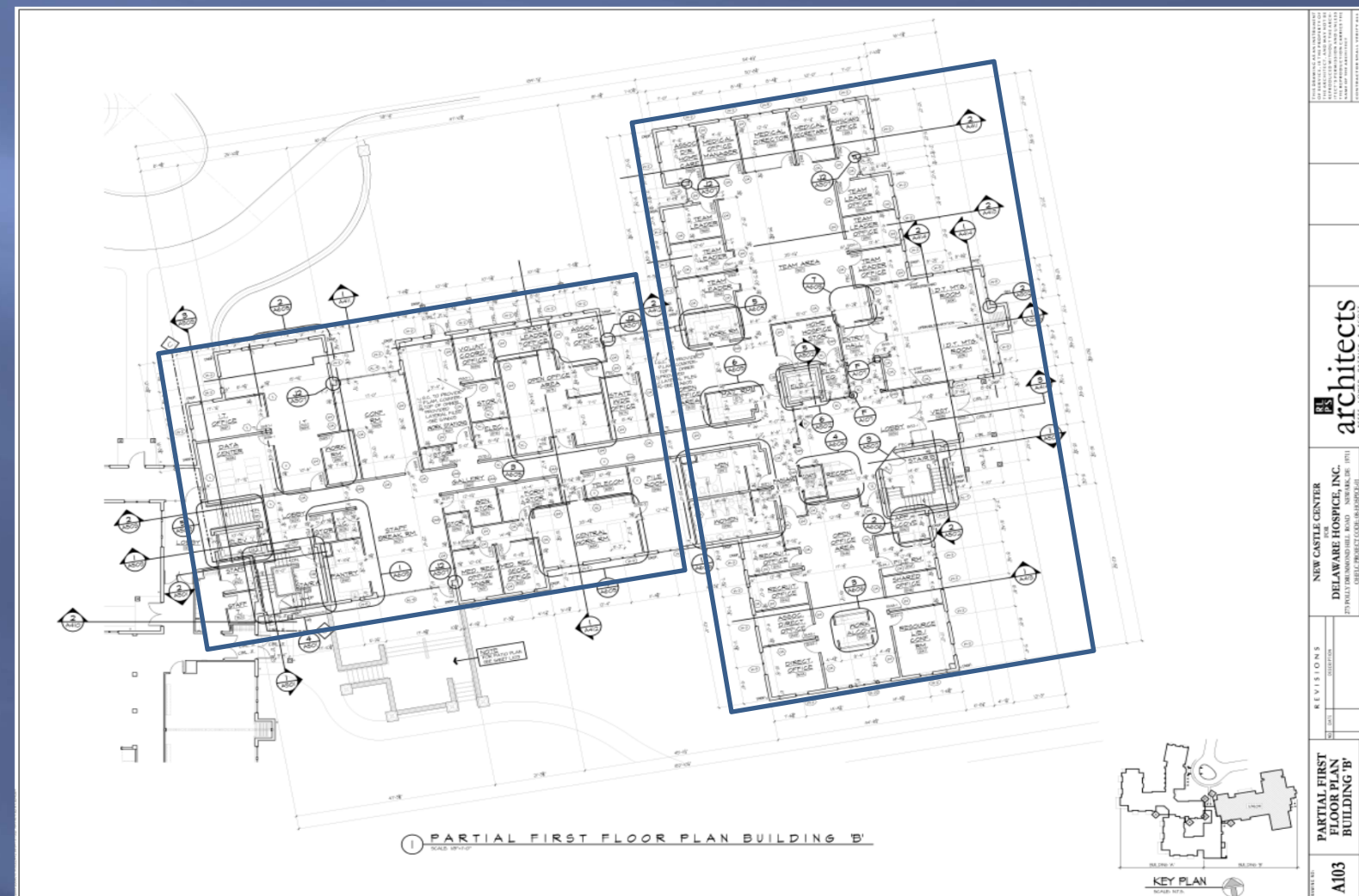
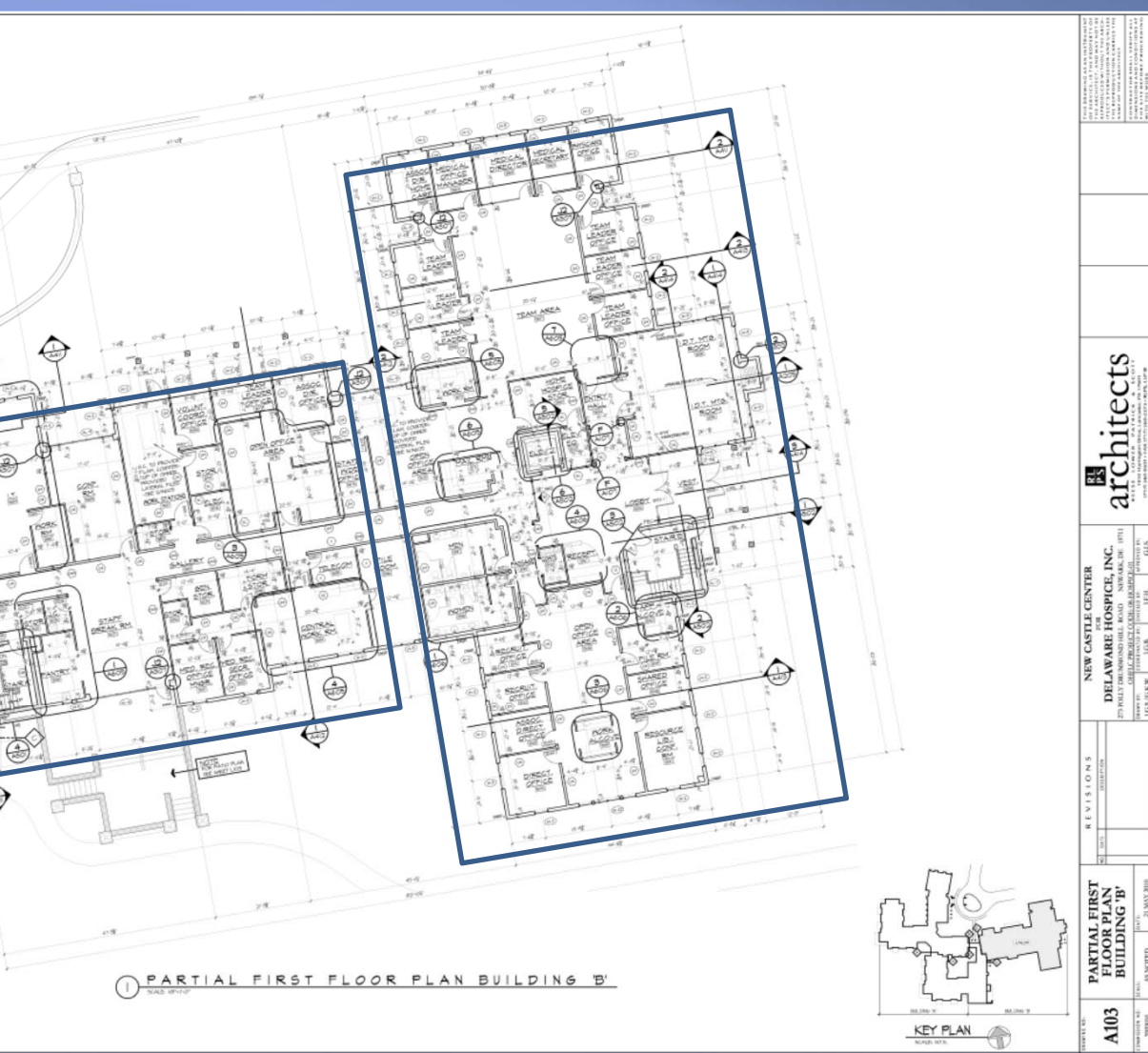
Presentation Outline

- Overview
- Conditions
- Evaluation
- and Redesign
- Technical Depth
- Final Breadth
- Conclusion

Zones



Zones



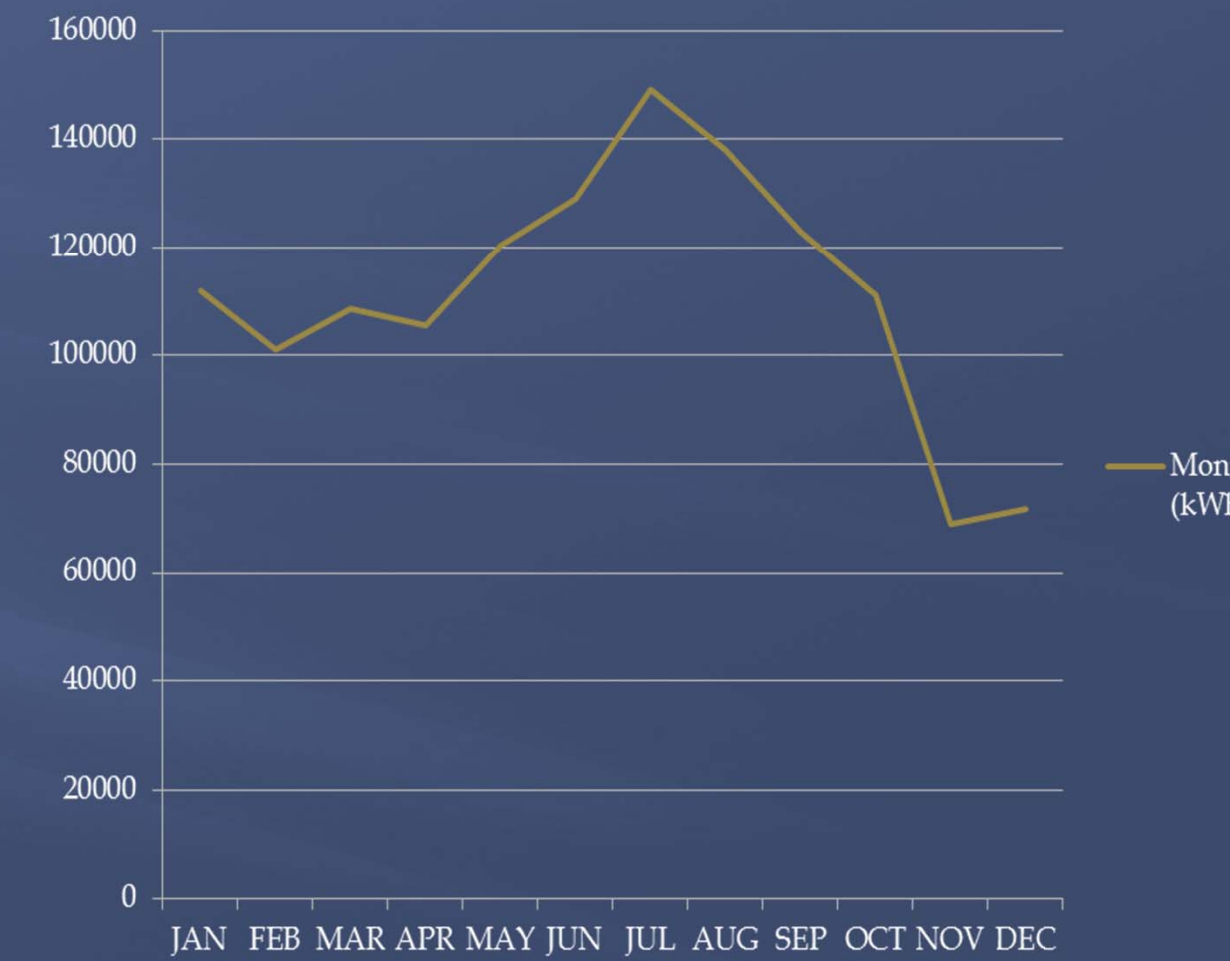
Presentation Outline

- Overview
- Existing conditions
- Evaluation
- and Redesign
- Technical Depth
- and Breadth
- of the
- Investment

Existing Conditions

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%

Monthly Energy Consumption (kWh)

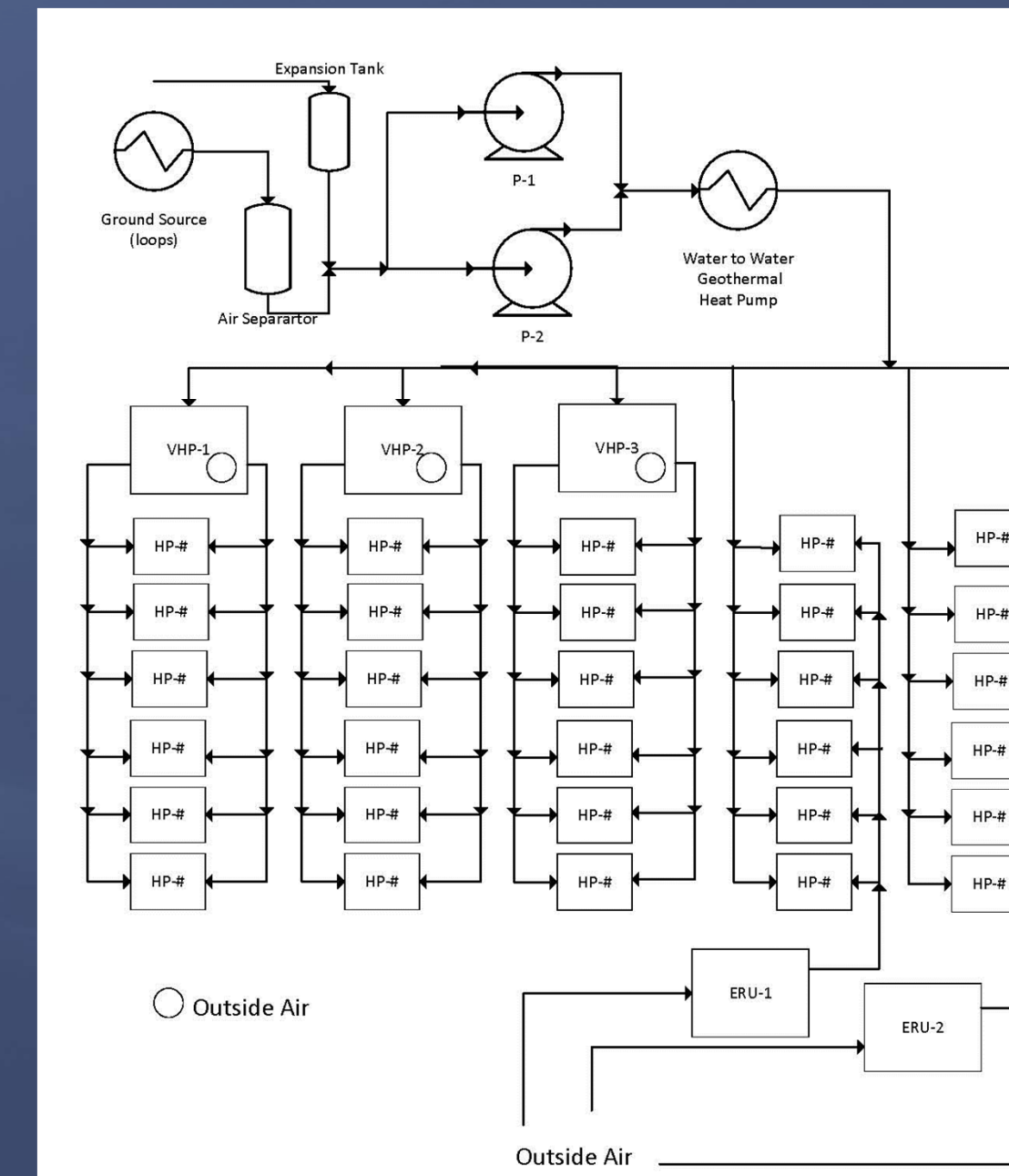
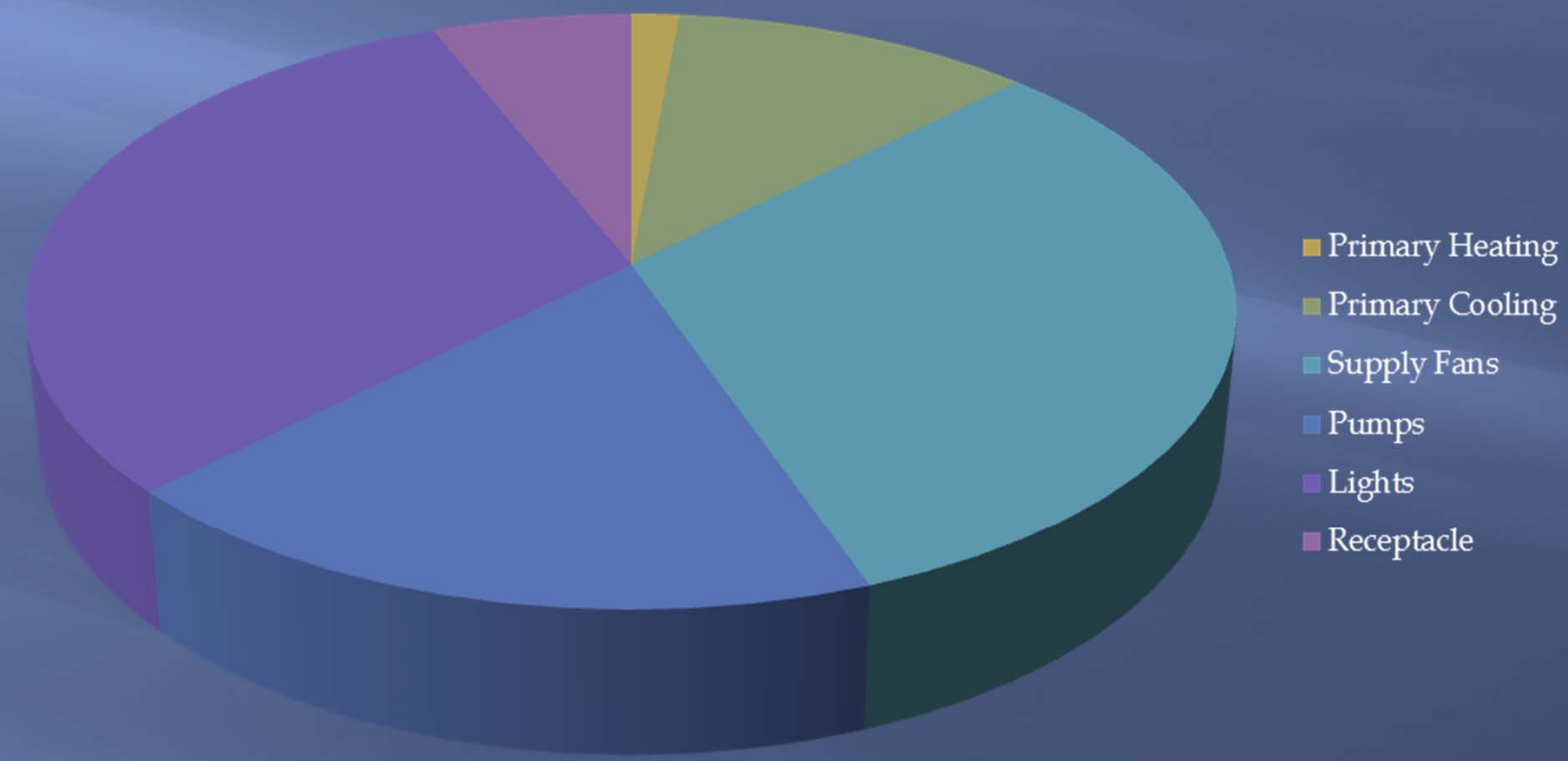


Presentation Outline

- Overview
- conditions
- Evaluation
- and Redesign
- Technical Depth
- and Breadth
- of the
- Investigation

Systems Evaluation

Energy Consumption



Hybrid Geothermal System

Geothermal Vertical Ground Loop Design

INPUT DATA	
duct-circuit heat loss factor	1.02
Design Cooling block load	1060800 BTU
	88.4 Ton
Design heating block load	-266785.3 BTU
Thermal Resistance of bore	0.4672897 BTU/(F*lbm)
Desired ground temperature	57.2 F
Penalty for interference of adjacent bore	0.7694444
Temperature at heat pump inlet (cooling)	85 F
Temperature at heat pump outlet (cooling)	95 F
Temperature at heat pump inlet (Heating)	54 F
Temperature at heat pump outlet (Heating)	44 F
Output at design cooling load	14412.096 W
Output at design heating load	-1461.0934 W
Pump correction factors	
Thermal diffusivity	1.38 FT ² /Day
Diameter of bore	0.5 ft
Time	3681 hr
G-factor	0.9
Bore 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

Hybrid Geothermal System

Presentation Outline

- Overview
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- Cal Depth
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Main Heat pumps Ground heat exchanger Fluid loop Supplemental Economics Design

Ground heat exchanger

Ground temperature (at mid-bore depth)	57.2	°F
Drilling depth	4500	ft
Bore spacing	20.00	ft
Header depth	5.9	ft
Center-to-center half distance	1.496	in
Borehole radius	2.244	in
Ground thermal diffusivity	1.38	ft ² /day
Ground thermal conductivity	2.14	btu/h-ft-°F
U-tube size	32mm (1.25")	
Grout thermal conductivity	0.800	btu/h-ft-°F

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Main Heat pumps Ground heat exchanger Fluid loop Supplemental Economics Design

Economic parameters

Discount rate	0.070
Tax status	Non-exempt
Down payment fraction	1.00
Rebate (fraction of investment)	0.00
Loan interest rate	0.060
Loan period	20.0
Tax rate	0.350
Inflation	0.016
Salvage fraction	0.000

Electric rates

Summer, peak rate	0.114
Summer, off peak rate	0.073
Winter, peak rate	0.114
Winter, off peak rate	0.073
Summer demand charge	4.220
Winter demand charge	1.000
Annual customer demand / Ratchet charge	1.050
Beginning of peak time	10
Ending of peak time	21

Other energy costs

Gas price	1.138
Water price	3.993
Propylene glycol price (per GHX length)	0.250
Fuel inflation	0.016

Annual maintenance costs

GHX propylene glycol maintenance	50.00
Cooling tower maintenance cost multiplier	1.20

First costs (installed)

GHX costs (including headers and installation)	11.0
Closed Circuit Cooling tower first cost multiplier	2.75

Optional: Interior HVAC cost (adjustment for full LCC)

Interior HVAC first cost	0.00
Interior HVAC annual cost	0.00

NOTE: Read help before modifying optional inputs

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

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

Hybrid Geothermal System

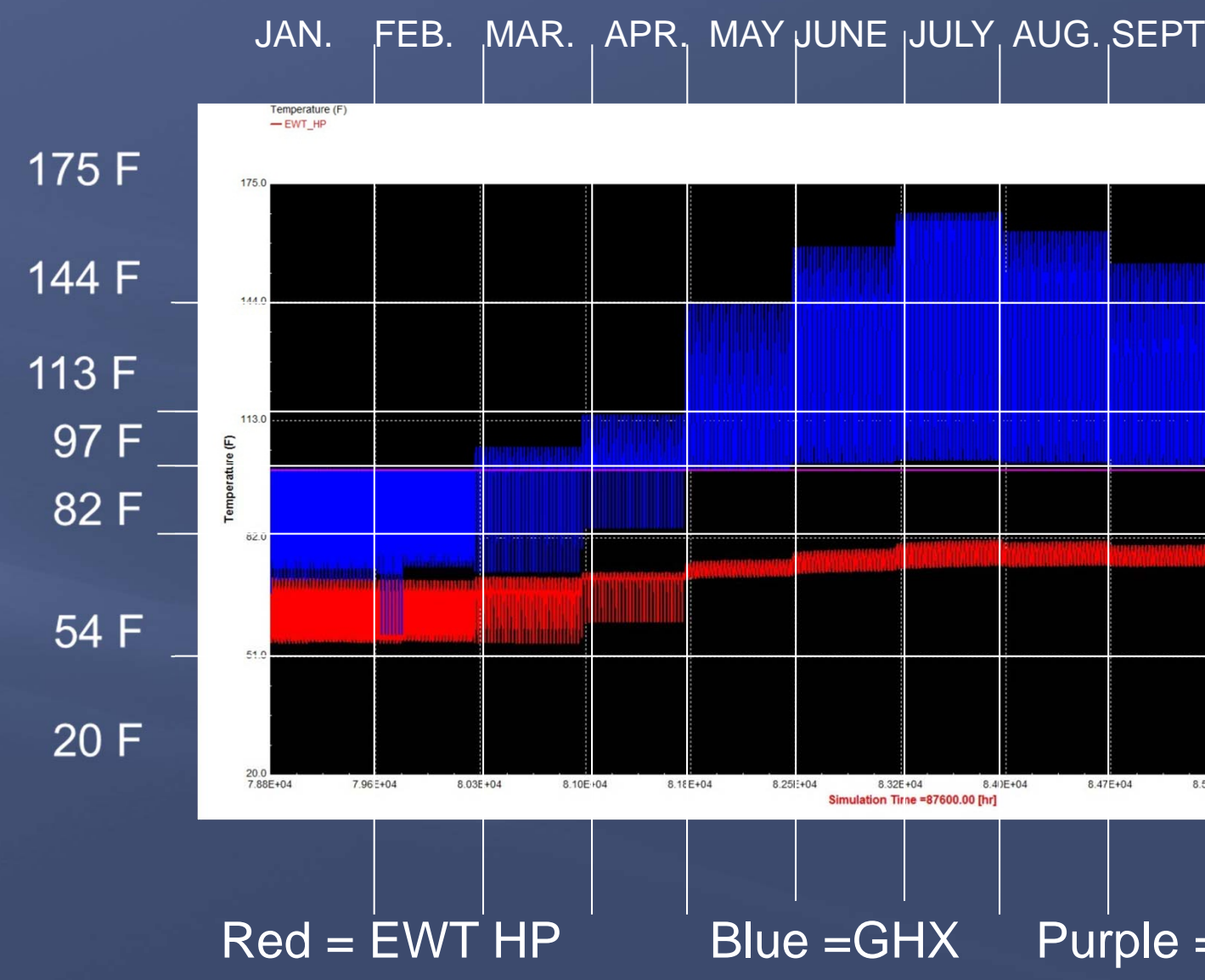
A. Run Single Simulation (required inputs)

Total length: ft

TC2: °F

Show real-time temperature/heat plot:

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).



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

Hybrid Geothermal System

A. Run Single Simulation (required inputs)

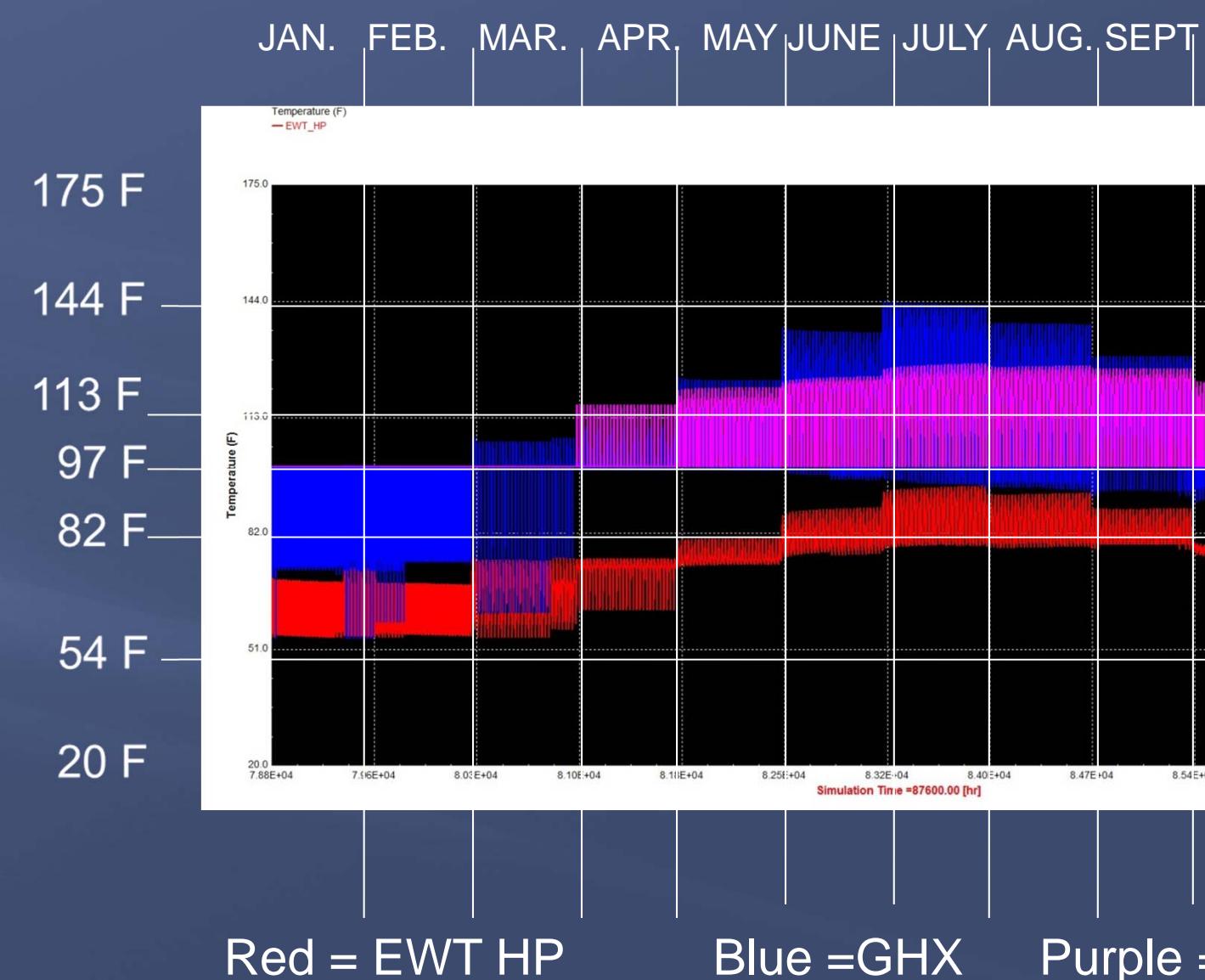
Total length	12139	ft
Cooling tower size	480000	btu/h
TC0	81.8	°F
TC1	87.8	°F
TC2	72.1	°F

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

TC0 is the control setpoint that determines whether the tower is operating or not (if $T_{TOW} > TC0$ then the tower is on).

TC1 is the control setpoint that determines whether the tower is operating at full speed (if $T_{TOW} > TC1$ then the tower is on at full speed).

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).



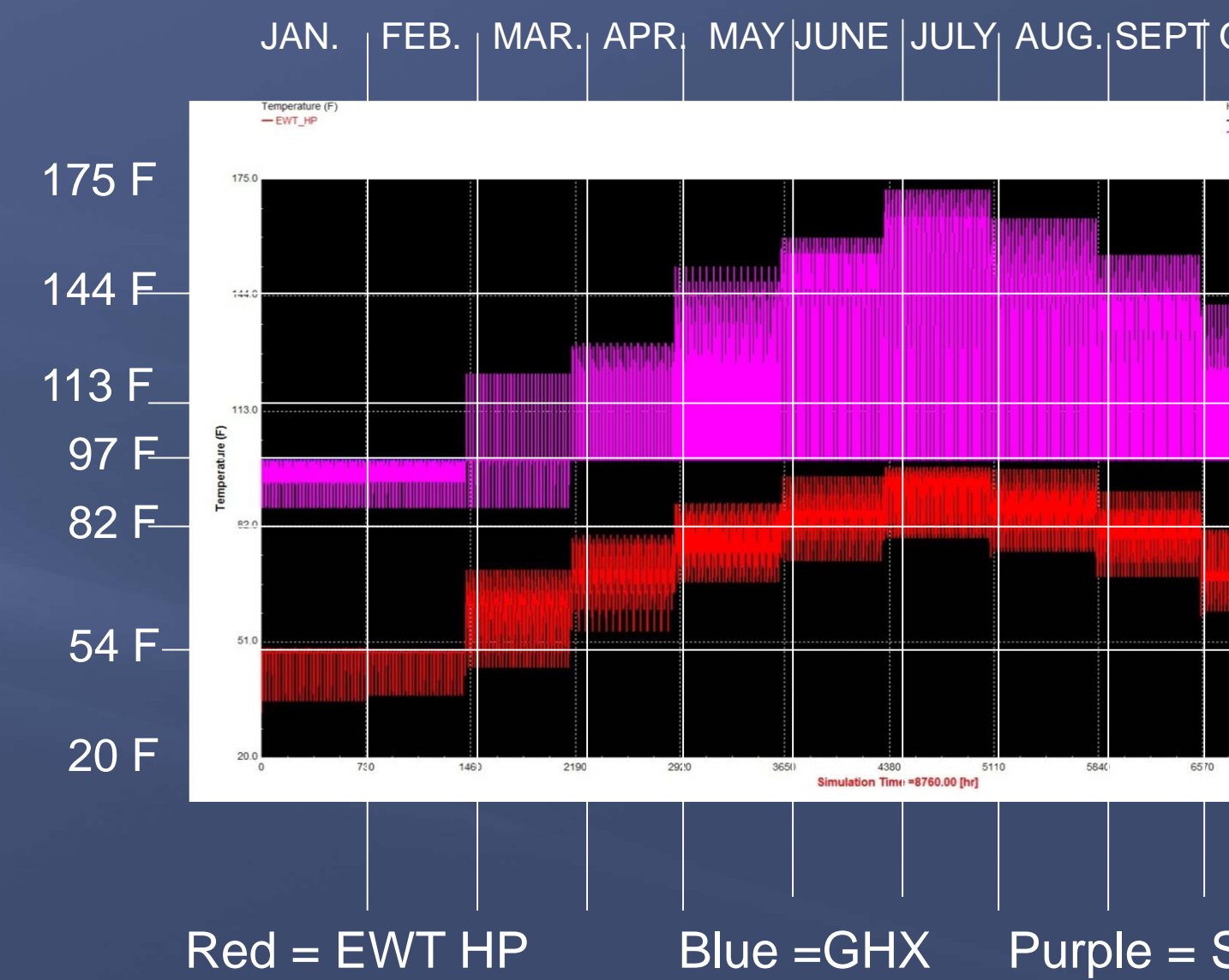
Hybrid Geothermal System

Presentation Outline

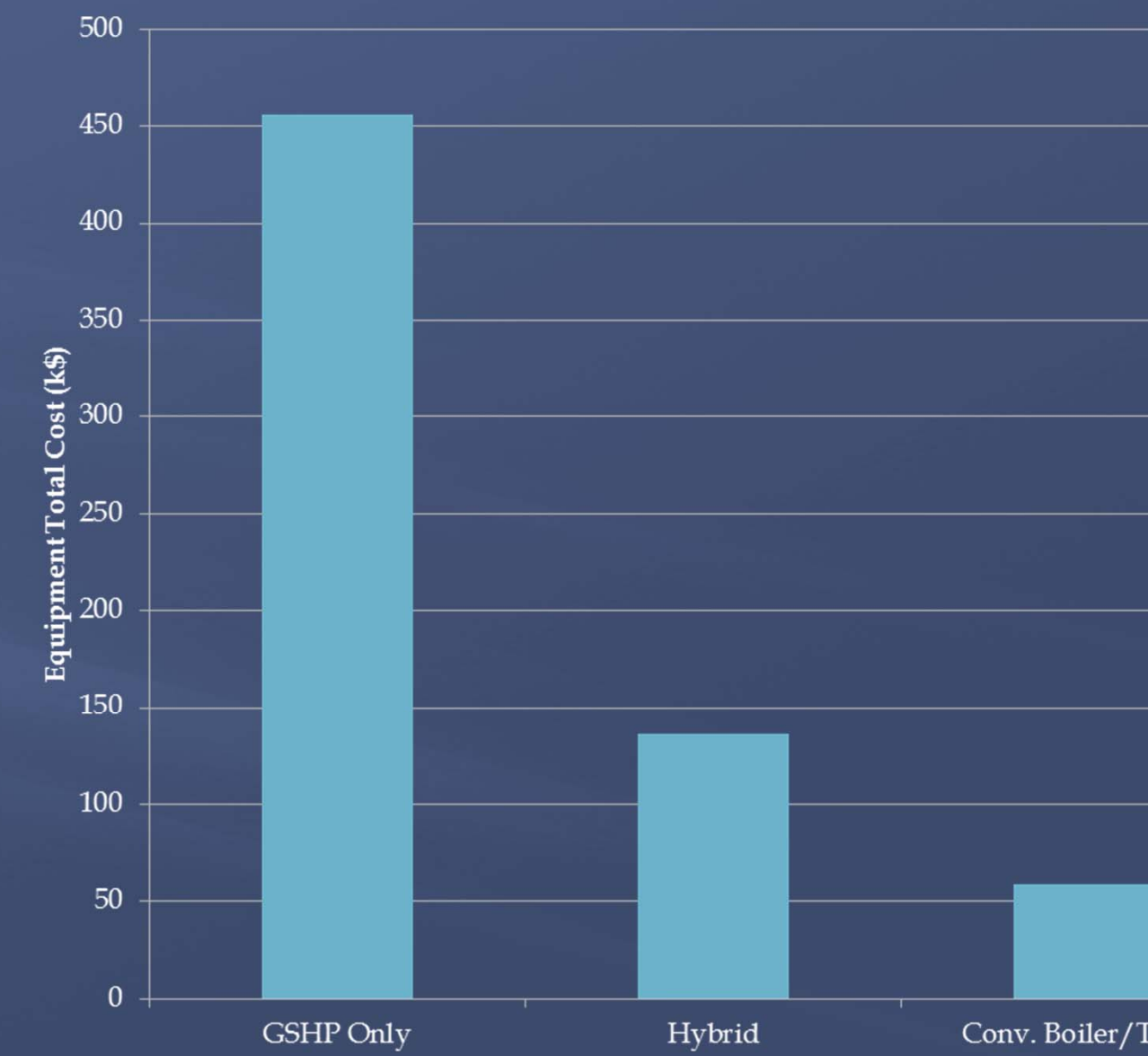
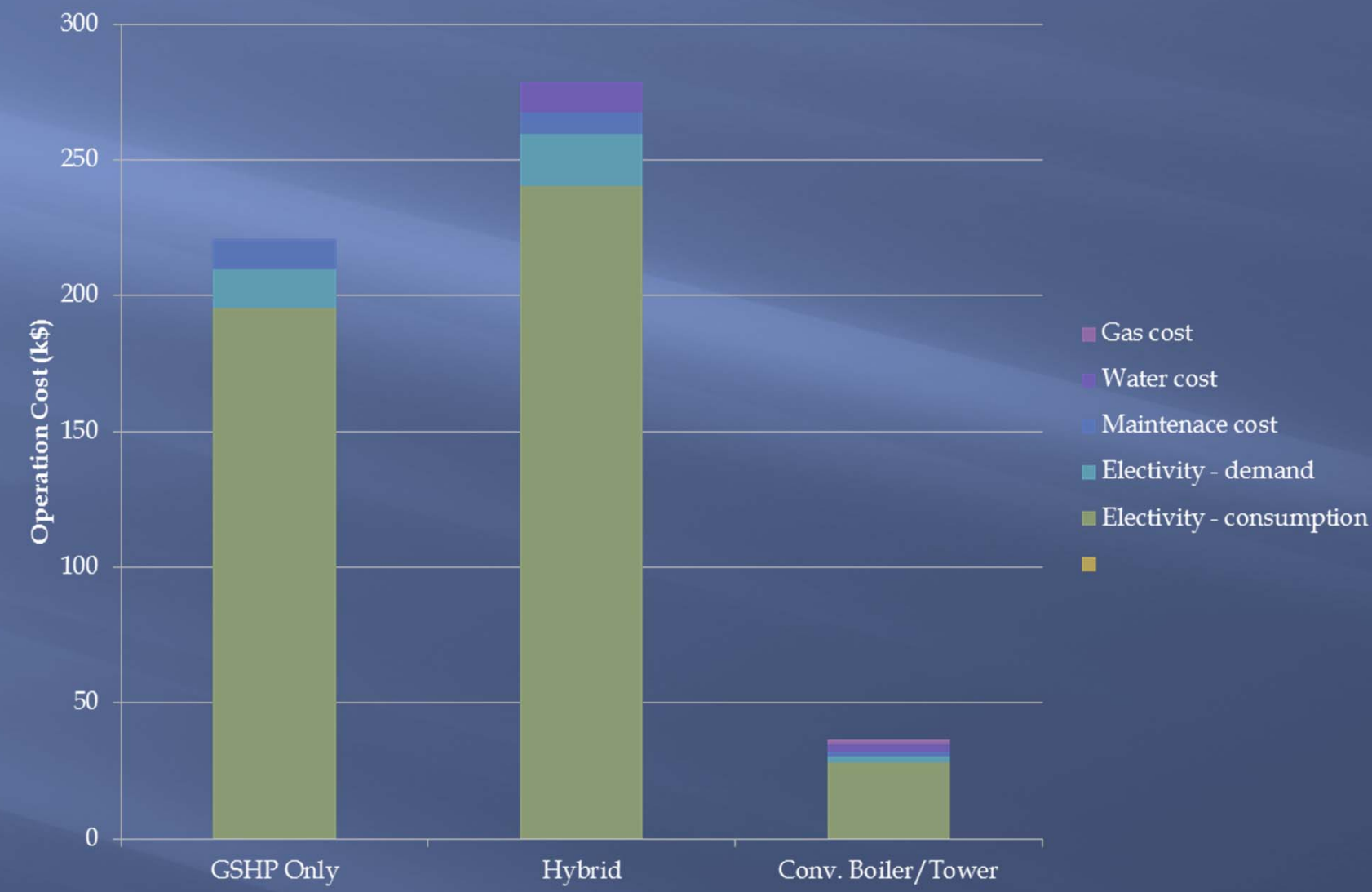
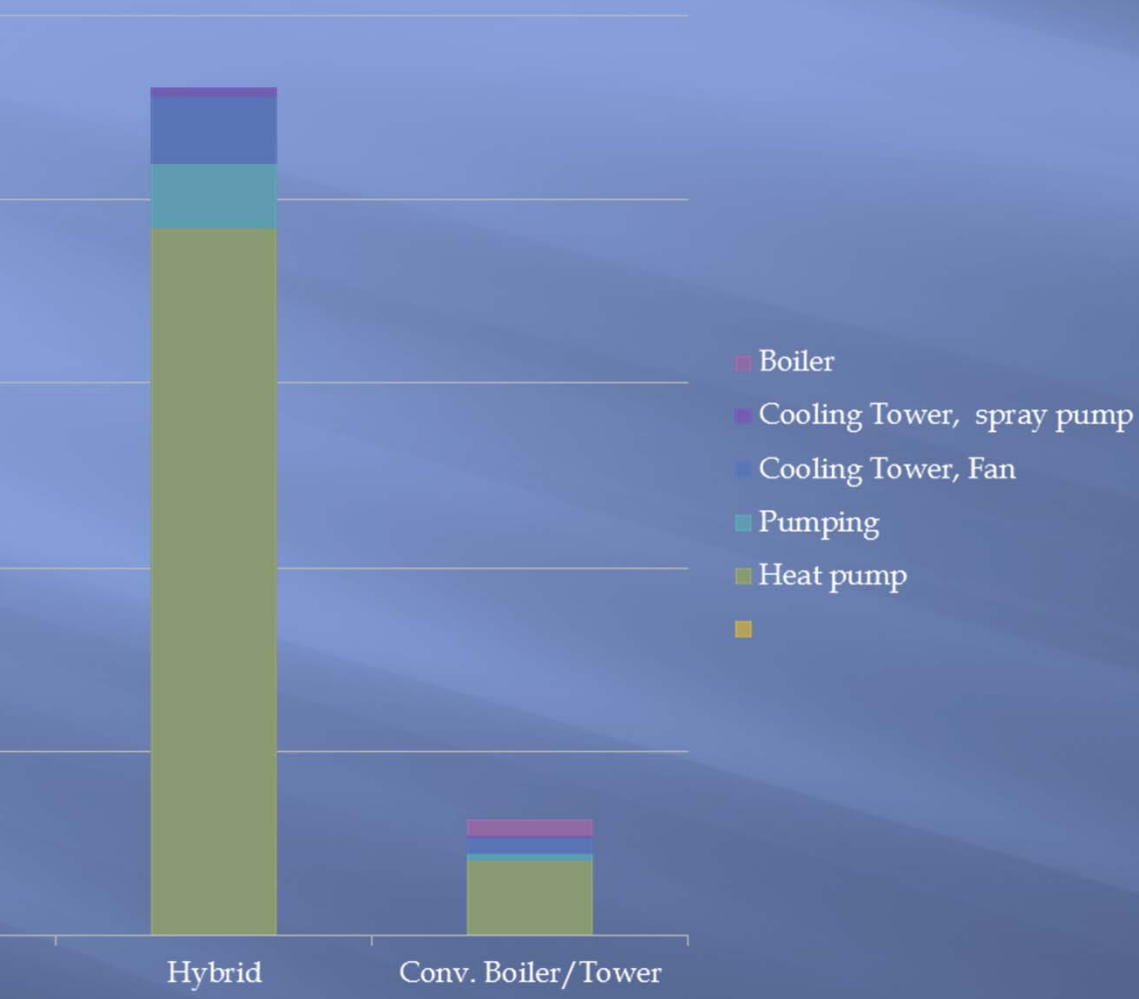
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20-yr. Life Cycle Cost* (real \$)	353.3 k\$
Equipment Cost (nominal \$)	
GHX cost	59.2 k\$
Operating Costs, annual (nom. \$)	
Electricity - consumption	28.22 k\$
Electricity - demand	2.28 k\$
Maintenance cost	1.82 k\$
Water cost	2.58 k\$
Gas cost	1.8 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



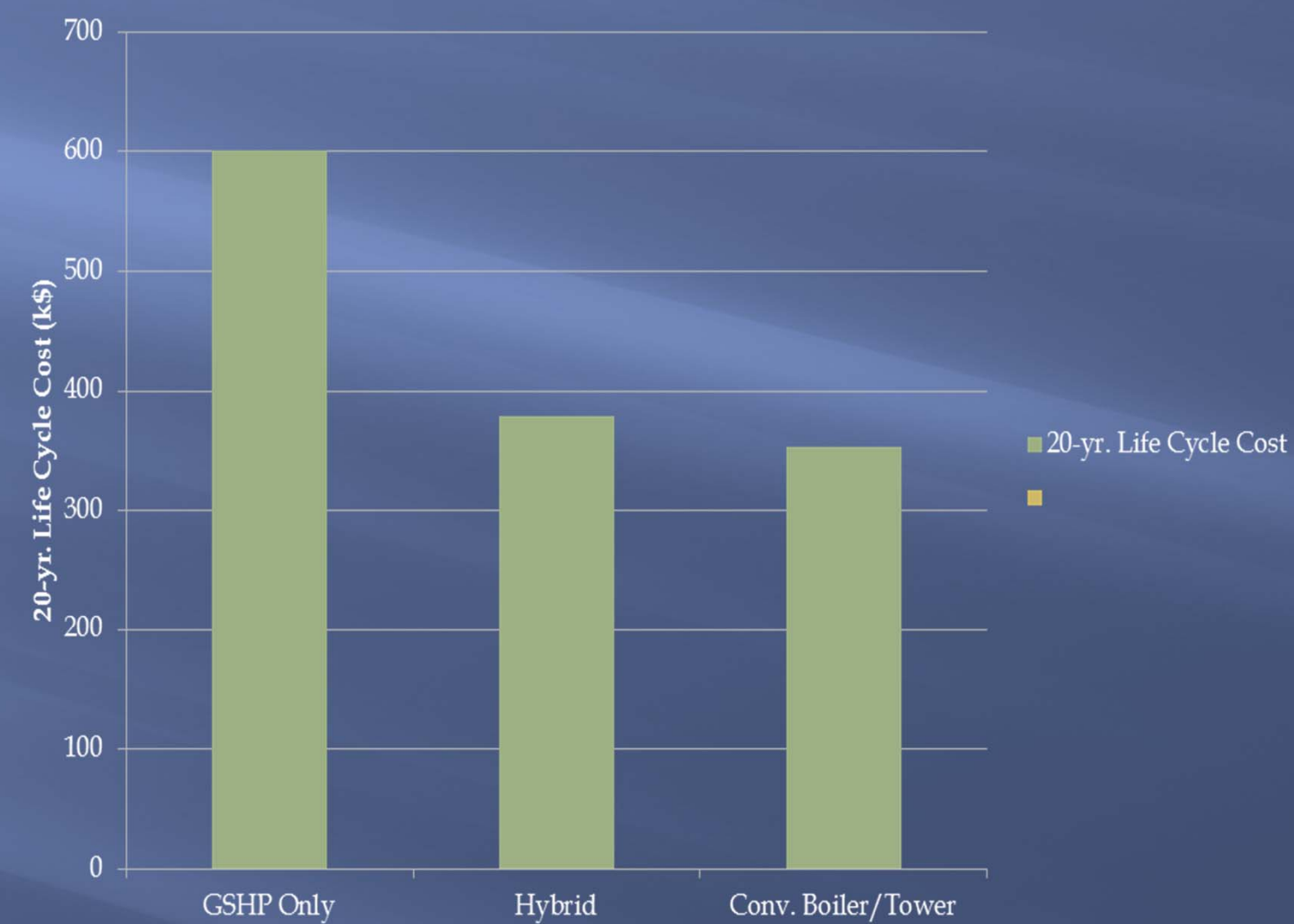
Hybrid Geothermal System



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Hybrid Geothermal System

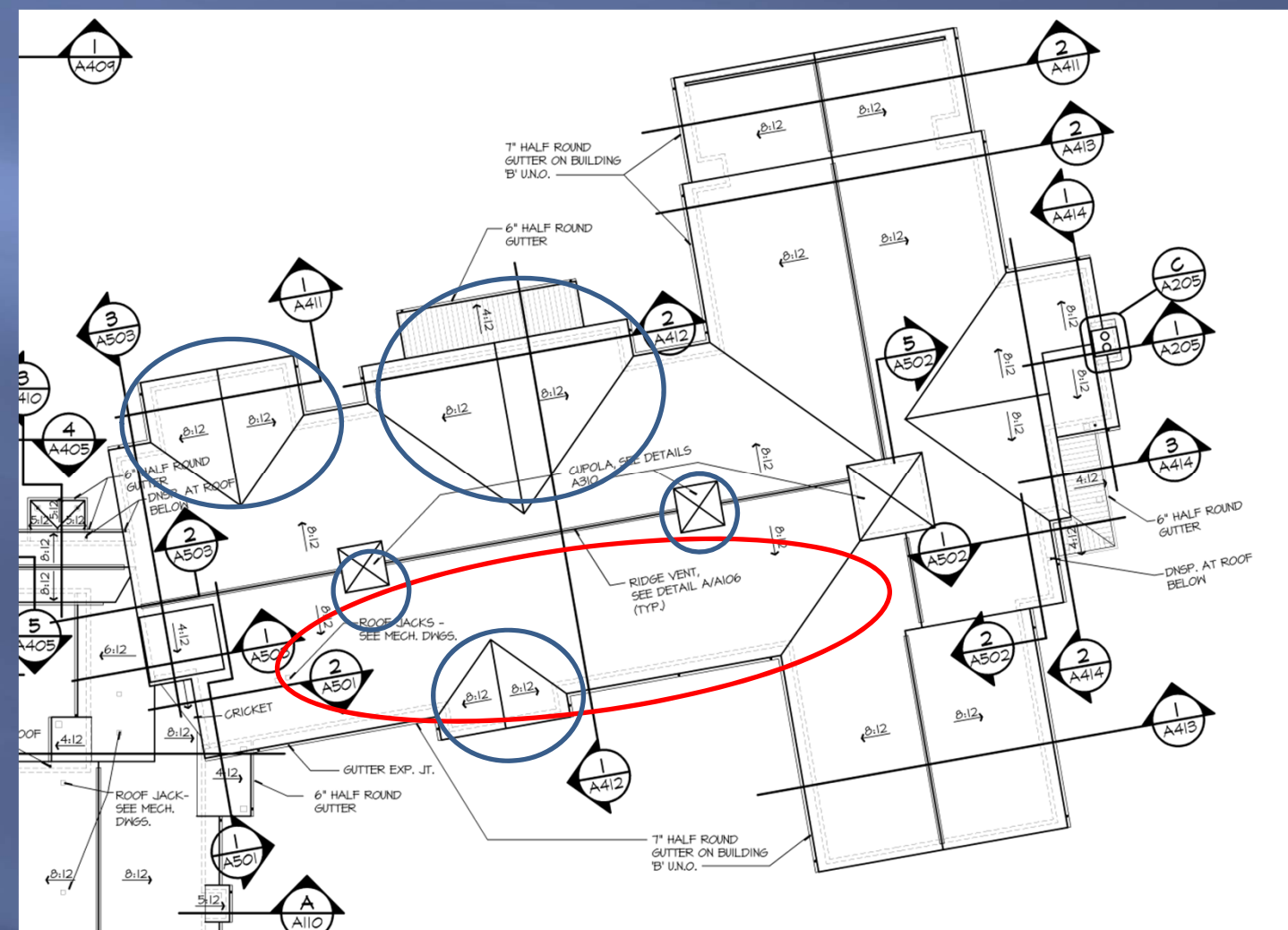


Other Data	GSHP Only
Number of boreholes in ground heat exchanger	90 @ 450
Average annual ground temp. change (F)	1
Max. fluids temperature entering heat pumps (F)	81
Min. fluids temperature entering heat pumps (F)	53
GHX max. flow (gpm)	271

Presentation Outline

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Electrical Breadth



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

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Conclusion



In conclusion on my research of ground source 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 choose them in the long run. With only saving \$53,000 a year, it would only take just over six years of annual savings to make up for the \$319,180 equipment cost.

Reference

Hybrid Ground-Source Heat Pump Installations: Experiences, Challenges, and Tools.” Energy Center of Wisconsin. June 30, 2011

Handbook: HVAC Applications.” 2007. American Society of Heating, Refrigeration, and Air-Conditioning Engineers

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

Design of a Ground Source Heat Pump for Beachfront Hotel” ASHRAE Transactions (2006): pp. 49-55

Laugh and Kevin Rafferty. “Ground-Source Heat Pumps: A Geothermal System for Commercial and Institutional Buildings” ASHRAE Transactions (2006): pp. 49-55

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

$$F_{of} = \frac{4 \cdot \alpha \cdot \tau_f}{d_p^2}$$

$$R_{ga} = \frac{G_f}{k_g}$$

$$F_{o1} = \frac{4 \cdot \alpha \cdot [\tau_f - \tau_1]}{d_p^2}$$

$$R_{gm} = \frac{G_1}{k_g}$$

$$F_{o2} = \frac{4 \cdot \alpha \cdot [\tau_f - \tau_2]}{d_p^2}$$

$$R_{gd} = \frac{G_2}{k_g}$$

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?