Manoa Elementary School

Amanda Cronauer

Faculty Advisor: Dr. William Bahnfleth

14 April 2010

Presentation Overview

- Project Background
- Existing Mechanical Summary
- Design Objectives
- Alternative Descriptions
- Ground Source Heat Pumps
- Air Source Heat Pumps
- System Comparison
- Final Recommendations

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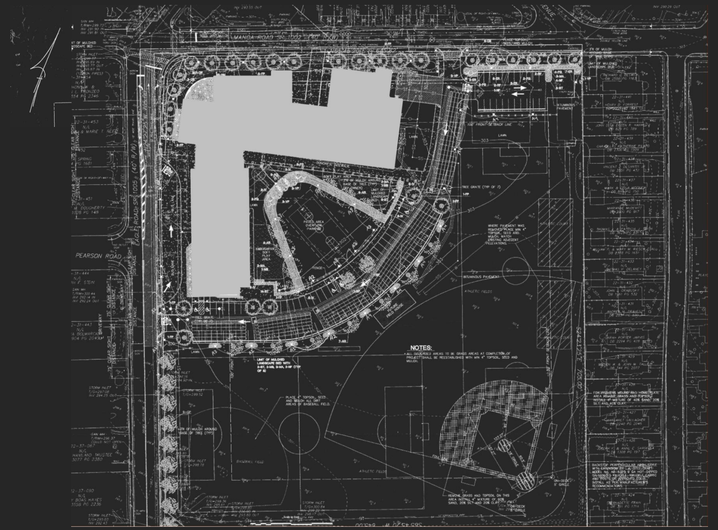
Project Background

Project Information:

Project Size:	85,355 sf
Location:	Havertown, PA
Cost:	$21.2 million
Stories:	Classroom [3], Administration [1]
Construction Dates:	May 2007-November 2008
Delivery Method:	Design-Bid-Build

Project Team:

Owner:	Haverford School District
Architect:	McKissick Associates Architects
General Contractor:	John S. McManus, Inc.
Structural Engineer:	Baker Ingram & Associates, Inc.
MEP Engineer:	H.F. Lenz Company



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Building Layout

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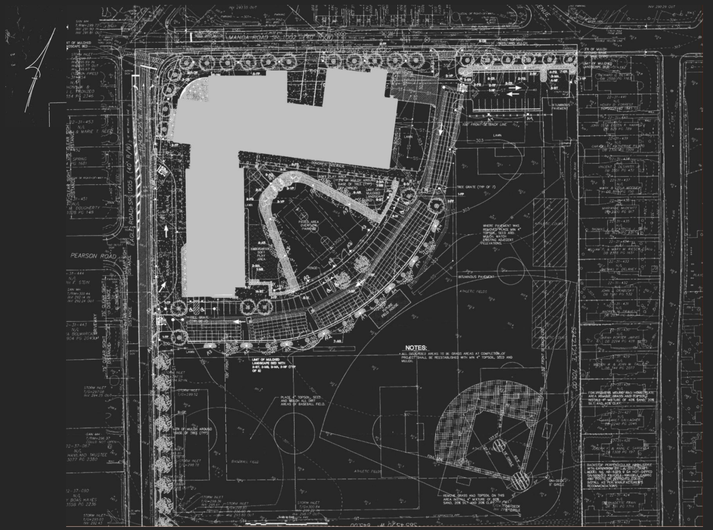

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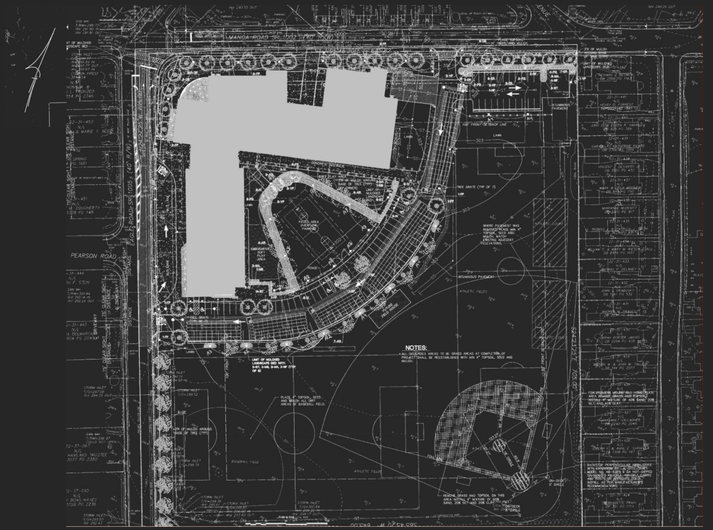

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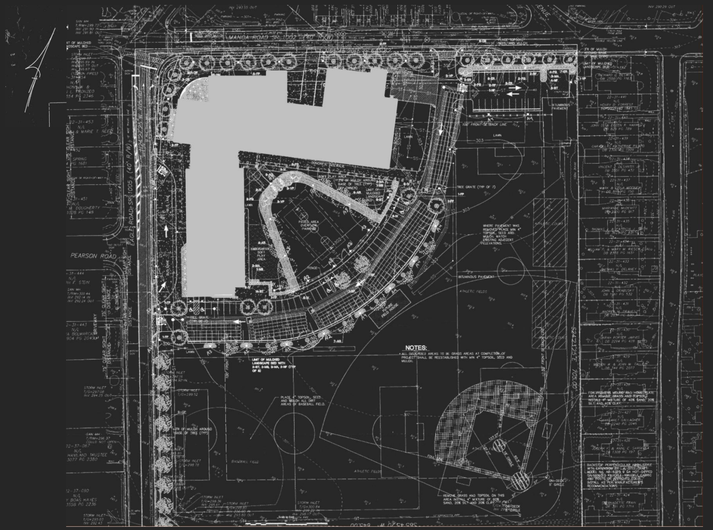

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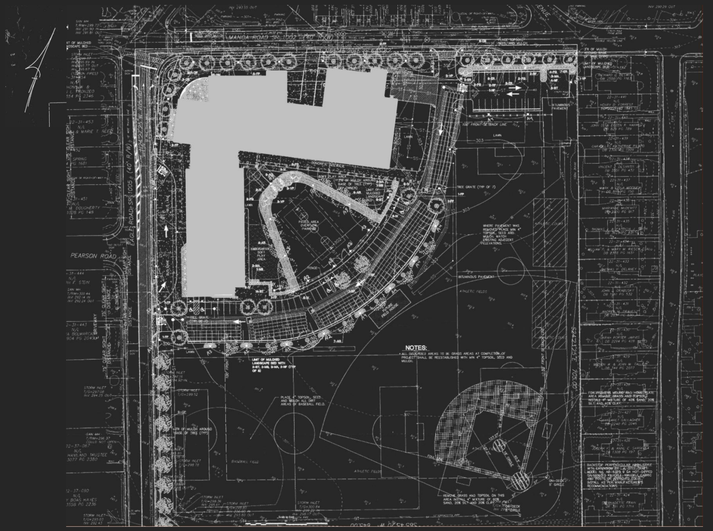

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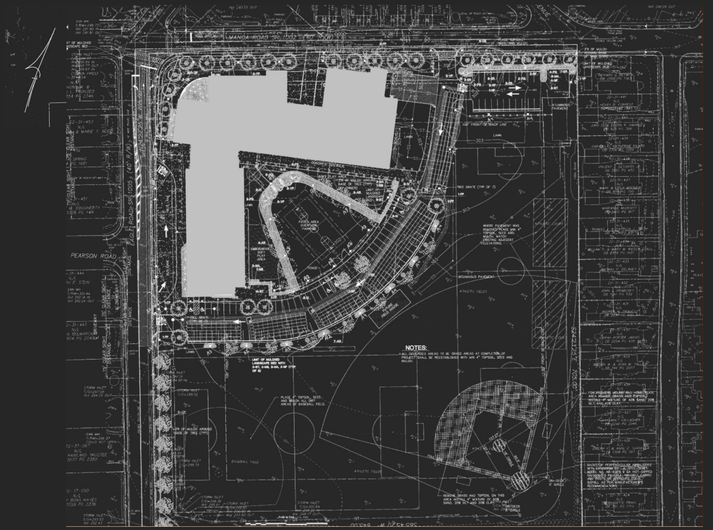

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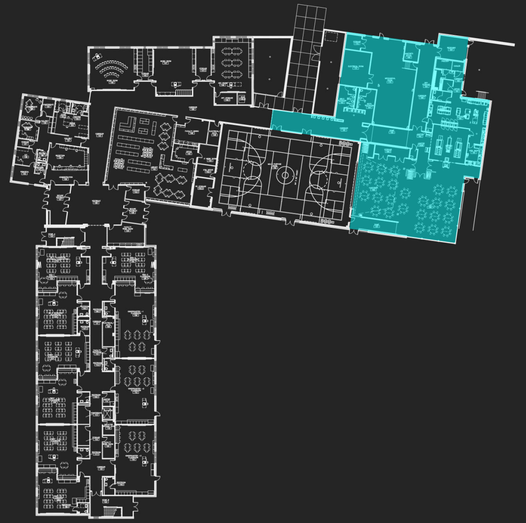

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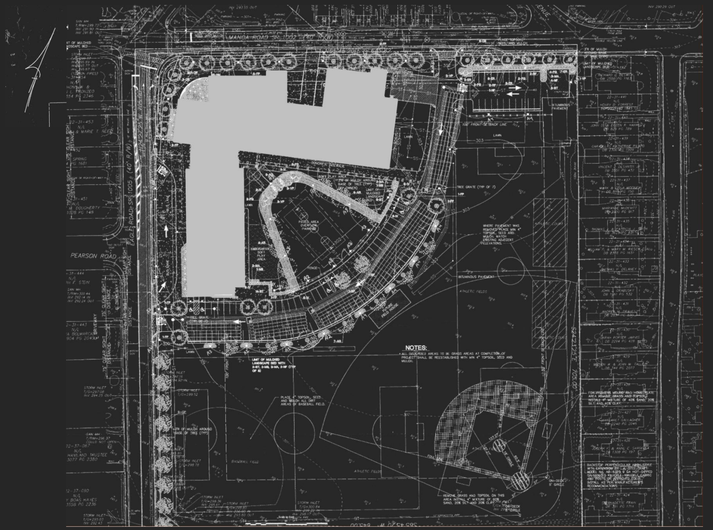

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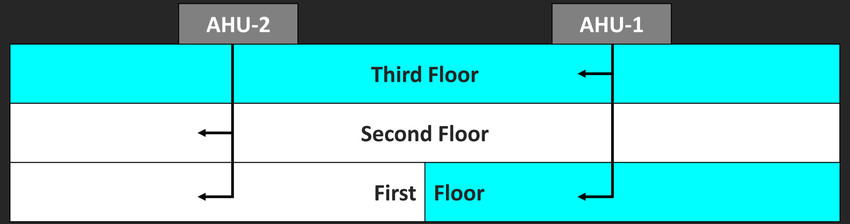
Existing Mechanical System

Classroom Wing:

- [2] Rooftop Variable Air Volume Units
- Direct Expansion Cooling
- Hot Water Perimeter Heating
- Energy Recovery Ventilators
- [2] Air Cooled Condensing Units



Administration Wing:

- Rooftop VAV Unit with Energy Recovery Ventilator [AHU-3]
- [2] Rooftop Constant Volume Units
- Direct Expansion Cooling
- Hot Water Heating
- [3] Air Cooled Condensing Units

Design Objectives

- Improve System Performance
  - Energy Consumption
  - Emissions
  - Total System Cost
- Comparison of Proposed System Performance

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Alternatives

Ground Source Heat Pumps:

[+] Decentralized System
[+] Higher System Efficiencies
[+] Lower Greenhouse Gas Emissions
[-] Increased Construction Costs
[-] Impact of Loop on Ecosystem

Dedicated Outdoor Air:

[+] Reduce Load on Heat Pumps
[+] Smaller
[-] Utilizes Electricity

Air Source Heat Pumps:

[+] Decentralized System
[+] Higher System Efficiencies
[+] Lower Greenhouse Gas Emissions
[+] No Extensive Excavation
[-] Utilizes Electricity

Vertical Loop Analysis

Systems to be Replaced:

- Series Fan Powered Boxes → Heat Pump
- Rooftop Air Handling Units → Dedicated Outdoor Air Unit

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Vertical Loop Analysis

Assumptions:

- Zoning
- Heat Pumps
- DOAS Units

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Vertical Loop Analysis

Loop Sizing:

- Cooling Length

$$L_C = \frac{q_c R_a + (q_{lc} - 3.41W_c)(R_b + PLF_m R_m + R_{gm} + R_{gd} F_{sc}}{t_g - \frac{t_{wi} - t_{wo}}{2} - t_p}$$

- Heating Length

$$L_C = \frac{q_c R_a + (q_{lc} - 3.41W_c)(R_b + PLF_m R_m + R_{gm} + R_{gd} F_{sc}}{t_g - \frac{t_{wi} - t_{wo}}{2} - t_p}$$

Vertical Loop Analysis

Loop Sizing:

Cooling Design Information			
Entering Water Temperature (°F)	Leaving Water Temperature (°F)	Cooling Load (MBH)	Total Borehole Length (feet)
75	85	1,434	23,959

Heating Design Information			
Entering Water Temperature (°F)	Leaving Water Temperature (°F)	Heating Load (MBH)	Total Borehole Length (feet)
45	35	1,153	25,052

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Vertical Loop Analysis

Loop Sizing:

Heating Design Information			
Entering Water Temperature (°F)	Leaving Water Temperature (°F)	Heating Load (MBH)	Total Borehole Length (feet)
45	35	1,153	**25,052**

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Vertical Loop Analysis

Goals:

- Meet Mechanical Load
- Minimize Construction Cost

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Vertical Loop Analysis

Assumptions:

- Piping → 1" High Density Polyethylene [HDPE]
  - $0.53 per linear foot
  - 40 foot lengths
  - $4.79 per weld
  - $40.25 per day for welding machine
- Grout→ Constant Price of $5,937 regardless
- Miscellaneous Site Costs → Specified by Number of Boreholes
- Borehole Driller

Earth Auger Data		
Bore Length (feet)	Rent ($/day)	Output (feet/day)
< 225	12190	1800
225 ≤ Lbore ≤ 325	14840	1200
> 325	12190	900

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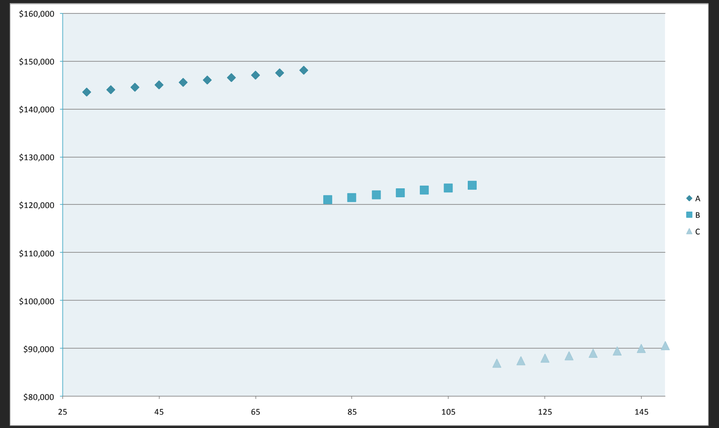
Vertical Loop Analysis

Results:



- **Vertical Loop Analysis**
  - Systems to be Replaced
  - Assumptions
  - Loop Sizing
  - **Loop Optimization [Construction Management Breadth]**
  - Results
- Horizontal Loop Analysis
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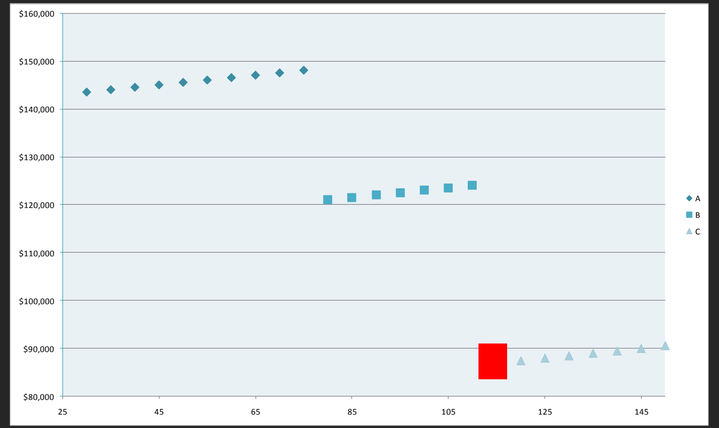

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  - Systems to be Replaced
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  - Loop Sizing
  - Results

Vertical Loop Analysis

Results:

- [115] Boreholes
- [218] feet per borehole
- $86,889 Total Installed Cost

Drill C: Depths Less than 225 feet													
Calculated Length	# Boreholes	Length per bore	Actual Length	Drilling			Pipe Cost	Welding			Grouting Cost	Miscellaneous Cost	Total Cost
				Days	Rental Weeks	Cost		Number	Rental Days	Cost			
25,052	115	218	25,070	14	3	$36,570	$13,287	627	2	$3,095	$5,937	$28,000	$86,889

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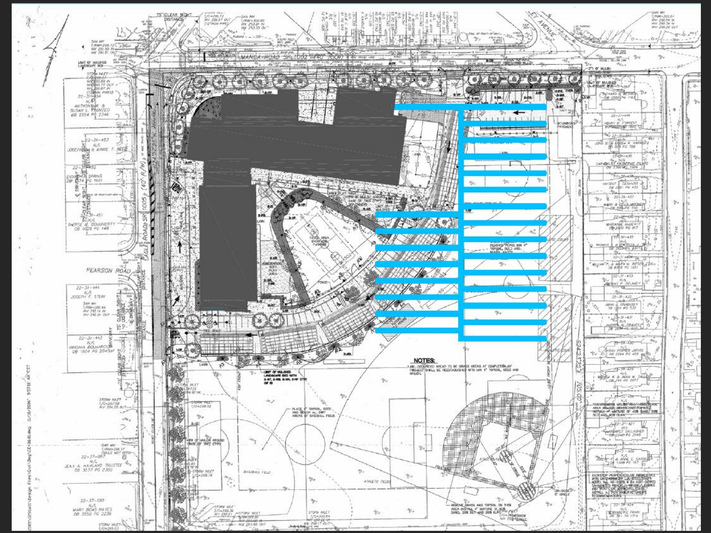

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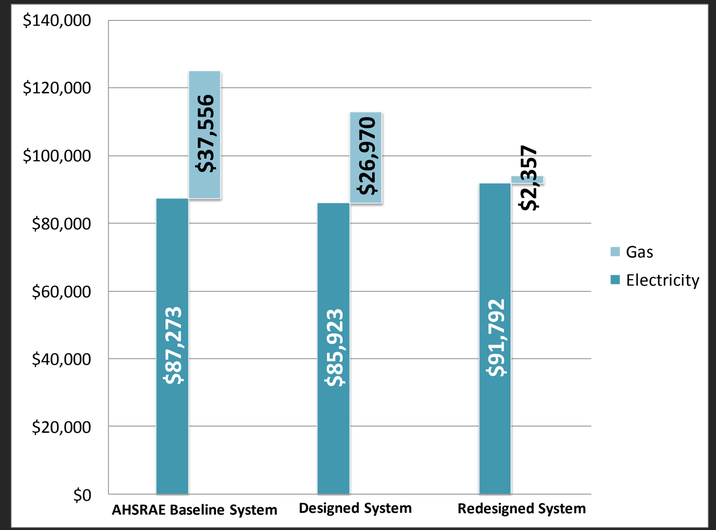

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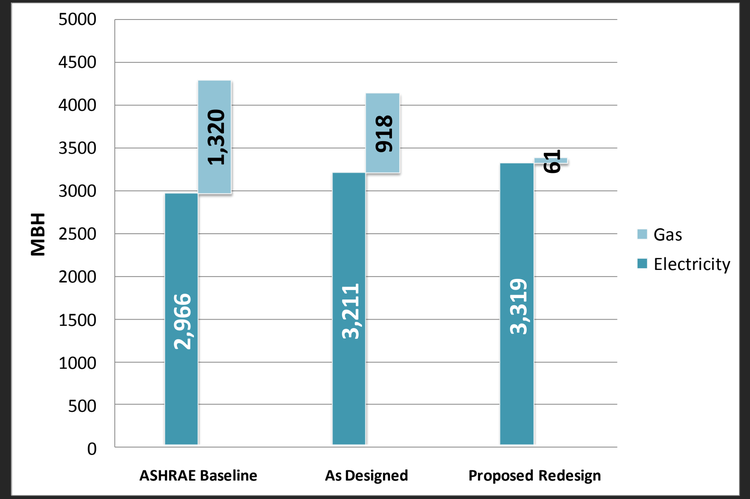
Vertical Loop Analysis



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Vertical Loop Analysis

System Energy Savings Comparison				
	Savings Over Baseline		Savings Over Designed	
	%	$	%	$
As Designed	9.56	11,936		
Redesign	24.58	30,680	19.91	18,744

25% Reduction = 7/19 LEED Points [EA Credit 1]

Greenhouse Gas Emission Data				
	CO2 (lbm/year)	NOX (lbm/year)	SOX (lbm/year)	Total Redesign Savings (lbm/year)
ASHRAE Baseline	2.02E+04	3.05E+01	1.64E+03	1.56E+04
As Designed	1.59E+04	2.47E+01	1.15E+03	1.08E+04
Redesign	6.15E+03	1.10E+01	1.03E+02	

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Vertical Loop Analysis

Simple Payback Period:

Design:
- [5] Rooftop AHU's =$280,000
- [5] ACCU's= $12,000
- Utility= $112,893

Redesign:
- [67] Heat Pumps= $420,050
- [5] DOAS Units= $82,042
- Vertical Loop= $86,889
- Utility=$94,129

Simple Payback Period: 10.76 years

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Vertical Loop Analysis

Simple Payback Period:

Design:

- [5] Rooftop AHU's =$280,000
- [5] ACCU's= $12,000
- Utility= $112,893
- Ductwork= $319,850

Redesign:

- [67] Heat Pumps= $420,050
- [5] DOAS Units= $82,042
- Vertical Loop= $86,889
- Ductwork= $74,531
- Utility= $94,129

Simple Payback Period: 1.2 years

- **Vertical Loop Analysis**
  - Systems to be Replaced
  - Assumptions
  - Loop Sizing
  - Loop Optimization
  - [Construction Management Breadth]
  - **Results**
- Horizontal Loop Analysis
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Horizontal Loop Analysis

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Systems to be Replaced:

- Series Fan Powered Boxes → Heat Pump
- Rooftop Air Handling Units → Dedicated Outdoor Air Unit

Horizontal Loop Analysis

Assumptions:

- Zoning
- Heat Pumps
- DOAS Units

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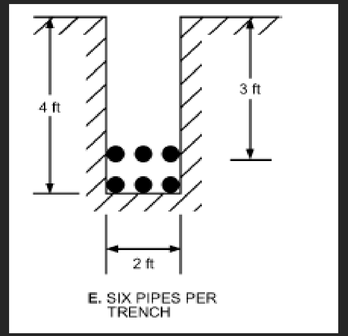
Horizontal Loop Analysis

Assumptions:

- Sizing Method Applicable
- Horizontal, 6-Pipe Coil
- Ground Temperature



E. SIX PIPES PER TRENCH

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Horizontal Loop Analysis

Results:

[150] foot per ton loop recommended

[17,925] feet of length required

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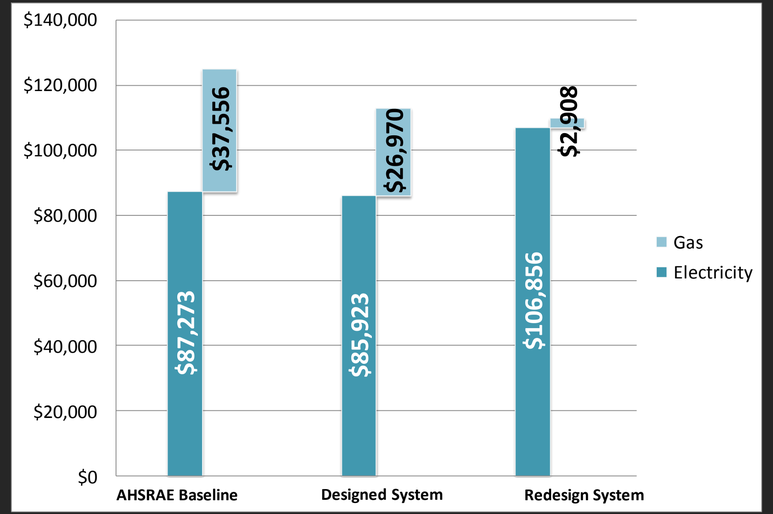
Horizontal Loop Analysis



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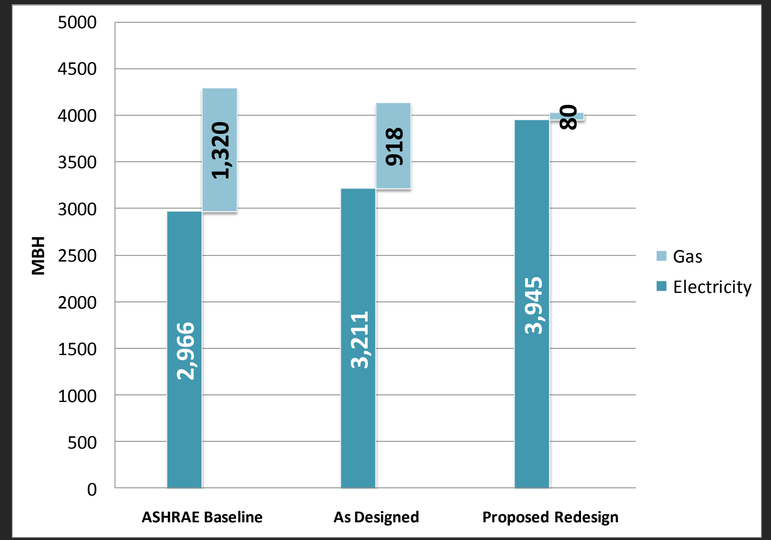
Horizontal Loop Analysis



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Horizontal Loop Analysis

System Energy Savings Comparison				
	Savings Over Baseline		Savings Over Designed	
	%	$	%	$
As Designed	9.56	11,936		
Redesign	12.07	15,065	2.85	3,129

12% Reduction = 1/19 LEED Point [EA Credit 1]

Greenhouse Gas Emission Data				
	CO2 (lbm/year)	NOX (lbm/year)	SOX (lbm/year)	Total Redesign Savings (lbm/year)
ASHRAE Baseline	2.02E+04	3.05E+01	1.64E+03	1.43E+04
As Designed	1.59E+04	2.47E+01	1.15E+03	9.55E+03
Redesign	7.40E+03	1.31E+01	1.31E+02	

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Horizontal Loop Analysis

Simple Payback Period:

Design:

- [5] Rooftop AHU's =$280,000
- [5] ACCU's= $12,000
- Utility= $112,893
- Ductwork= $319,850

Redesign:

- [67] Heat Pumps= $420,050
- [5] DOAS Units= $82,042
- Horizontal Loop= $76,898
- Ductwork= $74,531
- Utility= $109,764

Simple Payback Period: 0.95 years

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Air Source Heat Pumps

Systems to be Replaced:

- Series Fan Powered Boxes → Heat Pump
- Rooftop Air Handling Units → Dedicated Outdoor Air Unit

Air Source Heat Pumps

Assumptions:

- Zoning
- Heat Pumps
- DOAS Units

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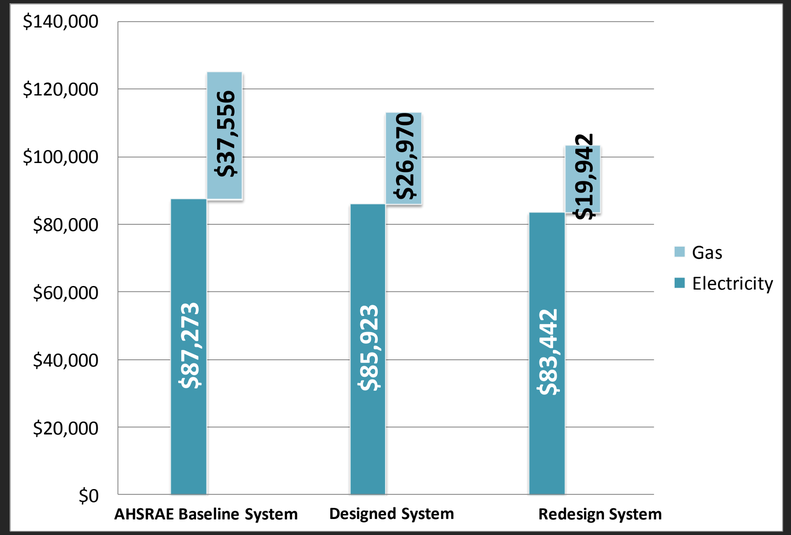

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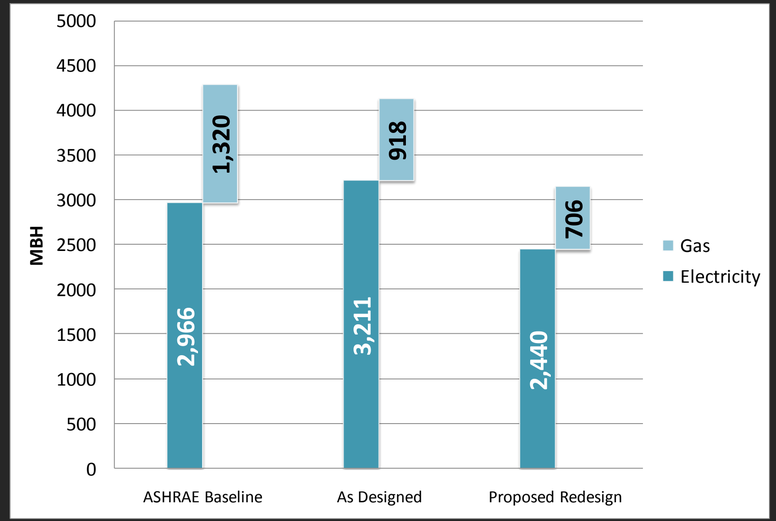

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Air Source Heat Pumps

System Energy Savings Comparison				
	Savings Over Baseline		Savings Over Designed	
	%	$	%	$
As Designed	9.56	11,936		
Redesign	17.18	21,445	9.20	9,509

17% Reduction = 3/19 LEED Points [EA Credit 1]

Greenhouse Gas Emission Data				
	CO2 (lbm/year)	NOX (lbm/year)	SOX (lbm/year)	Total Redesign Savings (lbm/year)
ASHRAE Baseline	2.02E+04	3.05E+01	1.64E+03	8.75E+03
As Designed	1.59E+04	2.47E+01	1.15E+03	4.00E+03
Redesign	1.22E+04	1.89E+01	8.82E+02	

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Air Source Heat Pumps

Simple Payback Period:

Design:
- [5] Rooftop AHU's =$280,000
- [5] ACCU's= $12,000
- Utility= $112,893
- Ductwork= $319,850

Redesign:
- [67] Heat Pumps= $211,403
- [5] DOAS Units= $83,042
- Ductwork= $74,531
- Utility= $103,384

Simple Payback Period: 0.65 years

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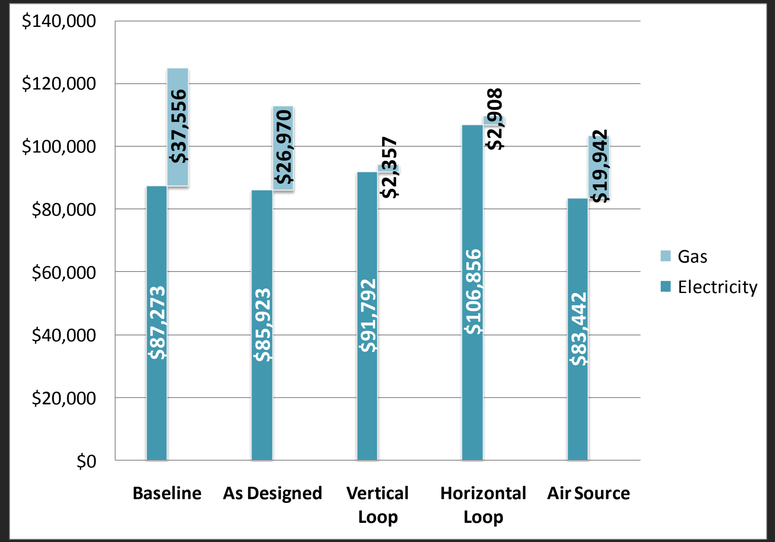

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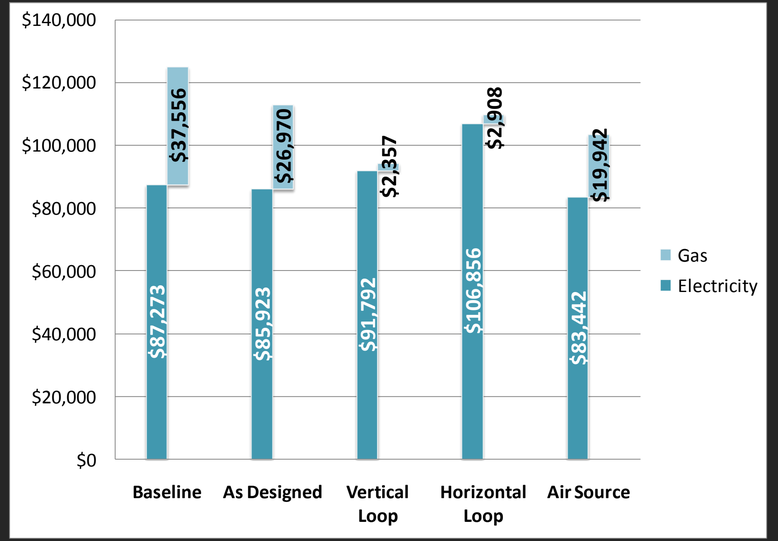

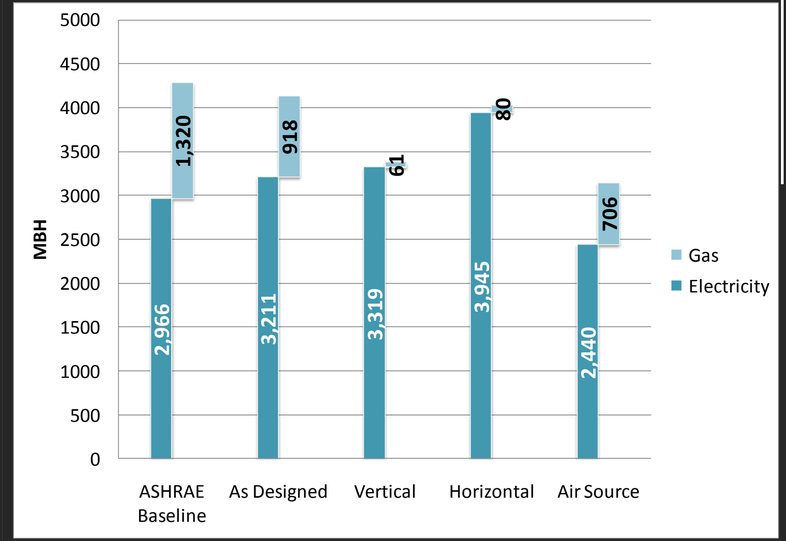

System Comparison

Greenhouse Gas Emission Data				
	CO2 (lbm/year)	NOX (lbm/year)	SOX (lbm/year)	Total Emissions (lbm/year)
ASHRAE Baseline	2.02E+04	3.05E+01	1.64E+03	2.18E+04
As Designed	1.59E+04	2.47E+01	1.15E+03	1.71E+04
Vertical Loop	6.15E+03	1.10E+01	1.03E+02	6.26E+03
Horizontal Loop	7.40E+03	1.31E+01	1.31E+02	7.54E+03
Air Source	1.22E+04	1.89E+01	8.82E+02	1.31E+04

Simple Payback Period:

- Vertical Loop GSHP = [1.2] years
- Horizontal Loop GSHP = [0.95] years
- Air Source Heat Pump= [0.65] years

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Final Recommendations

Emissions and Fuel Consumption:

- Vertical Ground Source Heat Pump

Lowest First Cost:

- Air Source Heat Pump

Fastest Potential Payback:

- Air Source Heat Pump

LEED Points:

- Vertical Ground Source Heat Pump

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Special Thanks To:

- Paul Cronauer, H.F. Lenz Contact
- Verne McKissick, McKissick Architects Contact
- Dr. Bahnfleth, Faculty Advisor
- Penn State Architectural Engineering Mechanical Faculty
- Family and Friends for all their support
- Fellow AE Students
- Jonah, moral support

Questions

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