

APPELL LIFE SCIENCES

York College of Pennsylvania



Image Courtesy of RLPS, Ltd.

Joshua Martz | Dr. Srebric | April 11, 2011

Outline

- PROJECT BACKGROUND
- EXISTING MECHANICAL SUMMARY
- DESIGN OBJECTIVES
- GROUND SOURCE HEAT PUMPS
 - CONSTRUCTION MANAGEMENT BREADTH
- CHILLED BEAMS
 - RUN-AROUND COIL SYSTEM
- SYSTEM COMPARISON
- ACKNOWLEDGEMENTS

Project Background

Project Team

Owner:	York College of Pennsylvania
Architect:	RLPS, Ltd.
CM:	Kinsley Construction
Structural:	Macintosh Engineering
Civil:	LSC Design, Inc.
MEP:	JDB Engineering

Project Information

Size:	102,000 SF
Location:	York, Pa
Cost:	\$16 million
Stories:	3/Basement
Construction Date:	January 2010-August 2011
Delivery Method:	D-B-B/CM gives GMP



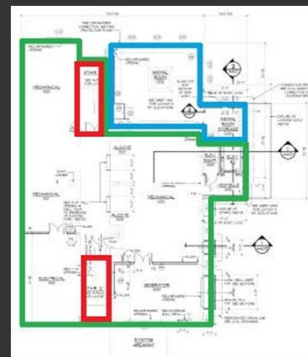
Site Plan

Outline

- PROJECT BACKGROUND
- EXISTING MECHANICAL SUMMARY
- DESIGN OBJECTIVES
- GROUND SOURCE HEAT PUMPS
 - CONSTRUCTION MANAGEMENT BREADTH
- CHILLED BEAMS
 - RUN-AROUND COIL SYSTEM
- SYSTEM COMPARISON
- ACKNOWLEDGEMENTS

Building Layout

- Classroom/Laboratory
- Mechanical/Electrical
- Office Spaces
- Stairs



Basement

Life Sciences Building



First Floor

Outline

- PROJECT BACKGROUND
- EXISTING MECHANICAL SUMMARY
- DESIGN OBJECTIVES
- GROUND SOURCE HEAT PUMPS
 - CONSTRUCTION MANAGEMENT BREADTH
- CHILLED BEAMS
 - RUN-AROUND COIL SYSTEM
- SYSTEM COMPARISON
- ACKNOWLEDGEMENTS

- Classroom/Laboratory
- Mechanical/Electrical
- Office Spaces
- Stairs

Building Layout



Second Floor

Life Sciences Building



Third Floor

Outline

- PROJECT BACKGROUND
- EXISTING MECHANICAL SUMMARY
- DESIGN OBJECTIVES
- GROUND SOURCE HEAT PUMPS
 - CONSTRUCTION MANAGEMENT BREADTH
- CHILLED BEAMS
 - RUN-AROUND COIL SYSTEM
- SYSTEM COMPARISON
- ACKNOWLEDGEMENTS

Building Layout

- Classroom/Laboratory
- Mechanical/Electrical
- Office Spaces
- Stairs
- Greenhouses

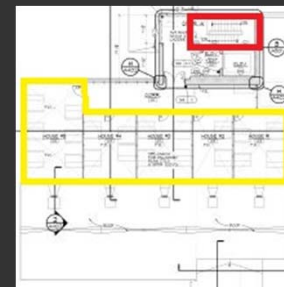


Basement

Greenhouse Building



First Floor



Second Floor

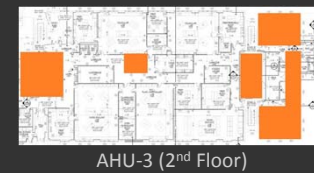
Outline

- PROJECT BACKGROUND
- EXISTING MECHANICAL SUMMARY
- DESIGN OBJECTIVES
- GROUND SOURCE HEAT PUMPS
 - CONSTRUCTION MANAGEMENT BREADTH
- CHILLED BEAMS
 - RUN-AROUND COIL SYSTEM
- SYSTEM COMPARISON
- ACKNOWLEDGEMENTS

Existing Mechanical Summary

- Mechanical Equipment Summary
 - 1 400 Ton Chiller
 - 3 Gas-fired Boilers
 - 2 Cooling Towers
 - Chilled/Hot/Condenser Water Pumps
 - 5 Air Handling Units
 - Fan Coil Units
 - VAV Boxes

- Office Spaces
 - AHU-1 and AHU-3
 - VAV Boxes

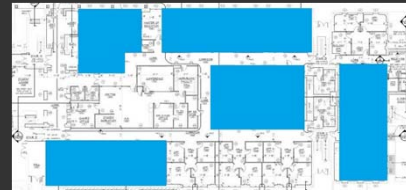


Outline

- PROJECT BACKGROUND
- EXISTING MECHANICAL SUMMARY
- DESIGN OBJECTIVES
- GROUND SOURCE HEAT PUMPS
 - CONSTRUCTION MANAGEMENT BREADTH
- CHILLED BEAMS
 - RUN-AROUND COIL SYSTEM
- SYSTEM COMPARISON
- ACKNOWLEDGEMENTS

Existing Mechanical Summary

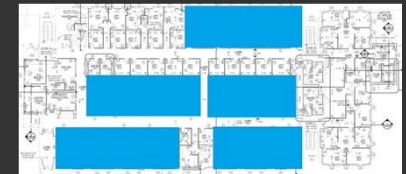
- Classroom/Laboratory Spaces
 - AHU-2, AHU-4, AHU-5
 - Pre-treated Outdoor Air
- Fan Coil Units



AHU-2 (1st Floor)



AHU-4 (2nd Floor)



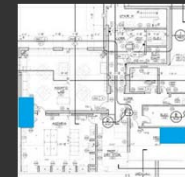
AHU-5 (3rd Floor)

Outline

- PROJECT BACKGROUND
- EXISTING MECHANICAL SUMMARY
- DESIGN OBJECTIVES
- GROUND SOURCE HEAT PUMPS
 - CONSTRUCTION MANAGEMENT BREADTH
- CHILLED BEAMS
 - RUN-AROUND COIL SYSTEM
- SYSTEM COMPARISON
- ACKNOWLEDGEMENTS

Existing Mechanical Summary

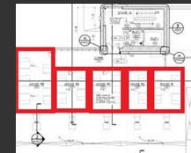
- Greenhouse Building
 - Labs
 - Fan Coil Units (Direct Outdoor Air)
 - Other Spaces
 - Direct Outdoor Air
 - Greenhouses
 - Evaporative Coolers, Natural Ventilation
 - Wall Insert Heaters/Horizontal Unit Heaters



Basement (FCUs)



1st Floor (FCUs)



2nd Floor (WIHs)

Outline

- PROJECT BACKGROUND
- EXISTING MECHANICAL SUMMARY
- DESIGN OBJECTIVES
- GROUND SOURCE HEAT PUMPS
 - CONSTRUCTION MANAGEMENT BREADTH
- CHILLED BEAMS
 - RUN-AROUND COIL SYSTEM
- SYSTEM COMPARISON
- ACKNOWLEDGEMENTS

Design Objectives

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

Outline

- PROJECT BACKGROUND
- EXISTING MECHANICAL SUMMARY
- DESIGN OBJECTIVES
- GROUND SOURCE HEAT PUMPS
 - CONSTRUCTION MANAGEMENT BREADTH
- CHILLED BEAMS
 - RUN-AROUND COIL SYSTEM
- SYSTEM COMPARISON
- ACKNOWLEDGEMENTS

Ground Source Heat Pumps

- Systems to be replaced:
 - Cooling:
 - Chiller
 - Cooling Towers
 - Chilled Water Pumps
 - Sump Tank
 - Heating:
 - Boilers
 - Hot Water Pumps

Outline

- PROJECT BACKGROUND
- EXISTING MECHANICAL SUMMARY
- DESIGN OBJECTIVES
- GROUND SOURCE HEAT PUMPS
 - CONSTRUCTION MANAGEMENT BREADTH
- CHILLED BEAMS
 - RUN-AROUND COIL SYSTEM
- SYSTEM COMPARISON
- ACKNOWLEDGEMENTS

Borehole Sizing

Cooling Length:

$$L_c = \frac{q_a * R_{ga} + (q_{lc} - 3.41W_c)(R_b + PLF_m * R_{gm} + R_{gd} * F_{sc})}{t_g - \frac{t_{wi} - t_{wo} - t_p}{2}}$$

Heating Length:

$$L_h = \frac{q_a * R_{ga} + (q_{lh} - 3.41W_h)(R_b + PLF_m * R_{gm} + R_{gd} * F_{sc})}{t_g - \frac{t_{wi} - t_{wo} - t_p}{2}}$$

Chapter 32: 2007 AHSRAE Handbook-HVAC Applications

Design Information

Cooling Design Information			
Entering Water Temperature (F)	Leaving Water Temperature (F)	Cooling Load (Btu/hr)	Borehole Length (ft)
75	85	1,594,800	14,801

Heating Design Information			
Entering Water Temperature (F)	Leaving Water Temperature (F)	Heating Load (Btu/hr)	Borehole Length (ft)
50	40	1,260,563	16,905

Outline

- PROJECT BACKGROUND
- EXISTING MECHANICAL SUMMARY
- DESIGN OBJECTIVES
- GROUND SOURCE HEAT PUMPS
 - CONSTRUCTION MANAGEMENT BREADTH
- CHILLED BEAMS
 - RUN-AROUND COIL SYSTEM
- SYSTEM COMPARISON
- ACKNOWLEDGEMENTS

Borehole Optimization

Assumptions:

Pipe: 1-1/4" High Density Polyethylene (HDPE)

- \$0.69/ft (40 ft lengths)
- Welding
 - \$4.79/weld
 - \$40.25/day per machine
- Grout:
 - Cooling: \$2,775
 - Heating: \$3,125

Earth Auger Data		
Length Feet	Daily Output Feet/day	Rental \$/week
$L_{\text{bore}} < 225$	1,800	12,190
$225 < L_{\text{bore}} < 325$	1,200	14,840
$L_{\text{bore}} > 325$	900	16,960

Cooling:

Drill A: Depths less than 225'									
Calculated Length	# Boreholes	Length per Bore	Actual Length	Drilling Cost	Pipe Cost	Welding Cost	Grouting Cost	Miscellaneous Cost	Total Cost
14,801	70	212	14,840	25,820	10,240	1,858	3,256	23,500	64,673

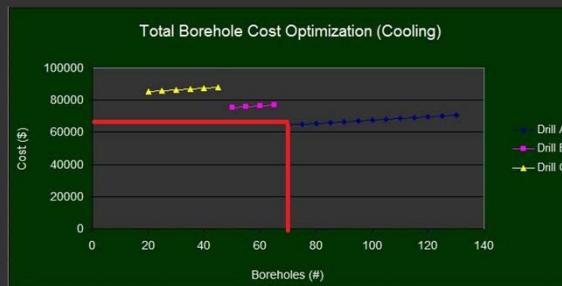
Heating:

Drill A: Depths less than 225'									
Calculated Length	# Boreholes	Length per Bore	Actual Length	Drilling Cost	Pipe Cost	Welding Cost	Grouting Cost	Miscellaneous Cost	Total Cost
16,905	80	212	16,960	25,820	11,702	2,111	3,720	24,500	67,854

Outline

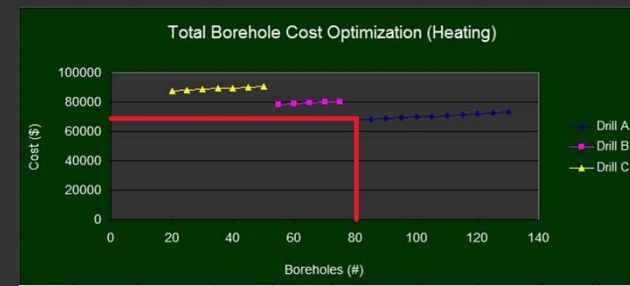
- ❑ PROJECT BACKGROUND
- ❑ EXISTING MECHANICAL SUMMARY
- ❑ DESIGN OBJECTIVES
- ❑ GROUND SOURCE HEAT PUMPS
 - ❑ CONSTRUCTION MANAGEMENT BREADTH
- ❑ CHILLED BEAMS
 - ❑ RUN-AROUND COIL SYSTEM
- ❑ SYSTEM COMPARISON
- ❑ ACKNOWLEDGEMENTS

Borehole Optimization



- ❑ 70 Boreholes
- ❑ 212 ft per Borehole
- ❑ \$64,673 Total Installation Cost

Results



- ❑ 80 Boreholes
- ❑ 212 ft per Borehole
- ❑ \$67,854 Total Installation Cost

Outline

- PROJECT BACKGROUND
- EXISTING MECHANICAL SUMMARY
- DESIGN OBJECTIVES
- GROUND SOURCE HEAT PUMPS
 - CONSTRUCTION MANAGEMENT BREADTH
- CHILLED BEAMS
 - RUN-AROUND COIL SYSTEM
- SYSTEM COMPARISON
- ACKNOWLEDGEMENTS

Life Cycle Cost

Cooling:

- 20 Year Equipment Lifetime
- \$246,673 First Cost
- \$58,330/year Energy Cost
- \$10,200/year Maintenance Cost
 - Based off \$0.10/SF
- Life Cycle Cost:
 - \$1,104,478

Heating:

- 20 Year Equipment Lifetime
- \$221,904 First Cost
- \$30,456/year Energy Cost
- \$10,200/year Maintenance Cost
 - Based off \$0.10/SF
- Life Cycle Cost:
 - \$724,799

Outline

- PROJECT BACKGROUND
- EXISTING MECHANICAL SUMMARY
- DESIGN OBJECTIVES
- GROUND SOURCE HEAT PUMPS
 - CONSTRUCTION MANAGEMENT BREADTH
- CHILLED BEAMS
 - RUN-AROUND COIL SYSTEM
- SYSTEM COMPARISON
- ACKNOWLEDGEMENTS

Borehole Layout

Cooling: (layout of pipes per AHU)



Heating: (layout of pipes per AHU)



Outline

- PROJECT BACKGROUND
- EXISTING MECHANICAL SUMMARY
- DESIGN OBJECTIVES
- GROUND SOURCE HEAT PUMPS
 - CONSTRUCTION MANAGEMENT BREADTH
- CHILLED BEAMS
 - RUN-AROUND COIL SYSTEM
- SYSTEM COMPARISON
- ACKNOWLEDGEMENTS

Pump Selection

- Ground Source Heat Pumps
 - Sized by sensible load required
- Circulation (Supply) Pumps
 - Sized by gpm required and head loss
 - 3 gpm/ton
 - Head loss calculated from longest run

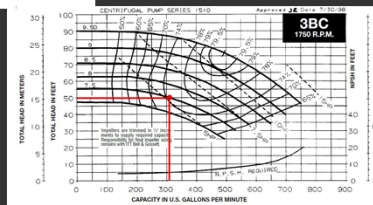
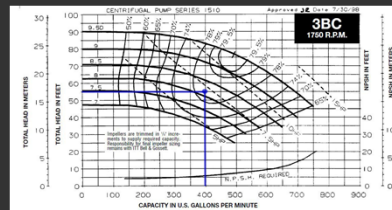
GSHP Cooling System Pumps			
Unit	AHU #	Manufacturer	Size
GCW180	Greenhouse	McQuay	15 tons
GCW180	AHU-1	McQuay	15 tons
GCW300	AHU-2	McQuay	25 tons
GCW300	AHU-3	McQuay	25 tons
GCW360	AHU-4	McQuay	30 tons
GCW360	AHU-5	McQuay	30 tons
Series 1510	Circ.	Bell&Gossett	400gpm/1750rpm

GSHP Heating System Pumps			
Unit	AHU #	Manufacturer	Size
GHW420	Greenhouse	McQuay	35 tons
GHW072	AHU-1	McQuay	6 tons
GHW240	AHU-2	McQuay	20 tons
GHW150	AHU-3	McQuay	12.5 tons
GHW300	AHU-4	McQuay	25 tons
GHW240	AHU-5	McQuay	20 tons
Series 1510	Circ.	Bell&Gossett	315gpm/1750rpm

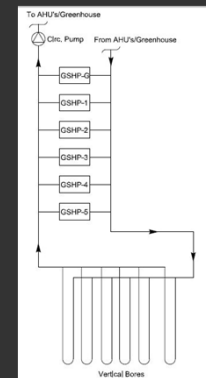
Outline

- PROJECT BACKGROUND
- EXISTING MECHANICAL SUMMARY
- DESIGN OBJECTIVES
- GROUND SOURCE HEAT PUMPS
 - CONSTRUCTION MANAGEMENT BREADTH
- CHILLED BEAMS
 - RUN-AROUND COIL SYSTEM
- SYSTEM COMPARISON
- ACKNOWLEDGEMENTS

Pump Curves



Pumping Schematic

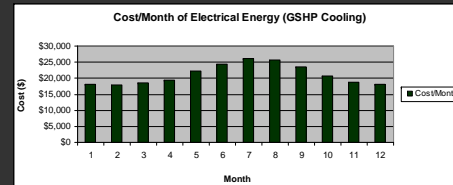
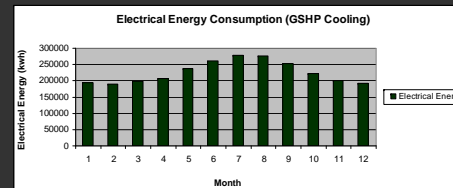


Outline

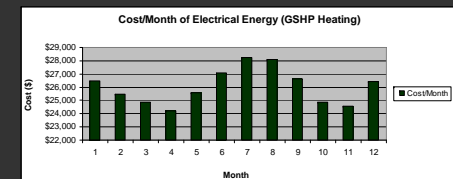
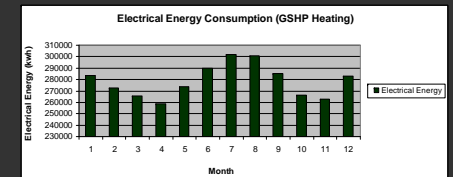
- PROJECT BACKGROUND
- EXISTING MECHANICAL SUMMARY
- DESIGN OBJECTIVES
- GROUND SOURCE HEAT PUMPS
 - CONSTRUCTION MANAGEMENT BREADTH
- CHILLED BEAMS
 - RUN-AROUND COIL SYSTEM
- SYSTEM COMPARISON
- ACKNOWLEDGEMENTS

Energy Usage and Cost

Cooling:



Heating:

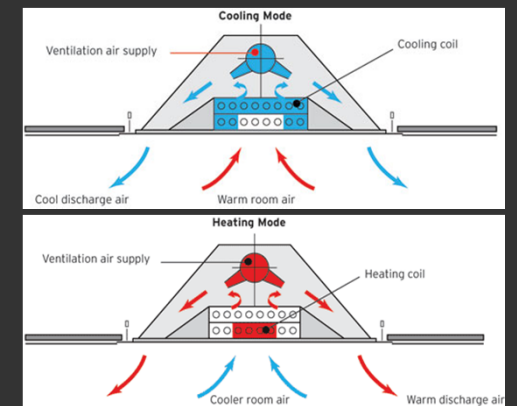


Outline

- ❑ PROJECT BACKGROUND
- ❑ EXISTING MECHANICAL SUMMARY
- ❑ DESIGN OBJECTIVES
- ❑ GROUND SOURCE HEAT PUMPS
 - ❑ CONSTRUCTION MANAGEMENT BREADTH
- ❑ CHILLED BEAMS
- ❑ RUN-AROUND COIL SYSTEM
- ❑ SYSTEM COMPARISON
- ❑ ACKNOWLEDGEMENTS

Chilled Beams

- ❑ Advantages
 - ❑ Low Operating Cost
 - ❑ High-Efficiency
 - ❑ Low Maintenance
 - ❑ Low Amount of Noise
 - ❑ Reduce Supply Air
- ❑ Disadvantages
 - ❑ Not Great at Heating Spaces/Supplementary Heating
 - ❑ Not Well Known Systems
 - ❑ Formation of Condensation on Unit



Outline

- PROJECT BACKGROUND
- EXISTING MECHANICAL SUMMARY
- DESIGN OBJECTIVES
- GROUND SOURCE HEAT PUMPS
 - CONSTRUCTION MANAGEMENT BREADTH
- CHILLED BEAMS**
 - RUN-AROUND COIL SYSTEM
- SYSTEM COMPARISON
- ACKNOWLEDGEMENTS

Energy Consumption

Chilled Beams vs. Fan Coil Units					
Chilled Beams			Fan Coil Units		
Tag	CFM	kwh Energy	Tag	CFM	kwh Energy
AHU-2	10,052	43,387	AHU-2	10,450	48,314
AHU-4	11,661	52,141	AHU-4	13,700	55,192
AHU-5	12,092	47,187	AHU-5	13,000	61,633
Total	33,805	142,715	Total	37,150	165,139
Differences	3,345	22,424			

Chilled Beam Amount

Chilled Beams per AHU			
	Capacity (BTU/hr)	Linear Feet	# Chilled Beams
AHU-2	407,137	407.1	68
AHU-4	476,759	476.8	79
AHU-5	469,223	469.2	78

Outline

- PROJECT BACKGROUND
- EXISTING MECHANICAL SUMMARY
- DESIGN OBJECTIVES
- GROUND SOURCE HEAT PUMPS
 - CONSTRUCTION MANAGEMENT BREADTH
- CHILLED BEAMS
 - RUN-AROUND COIL SYSTEM
- SYSTEM COMPARISON
- ACKNOWLEDGEMENTS

Life Cycle Cost

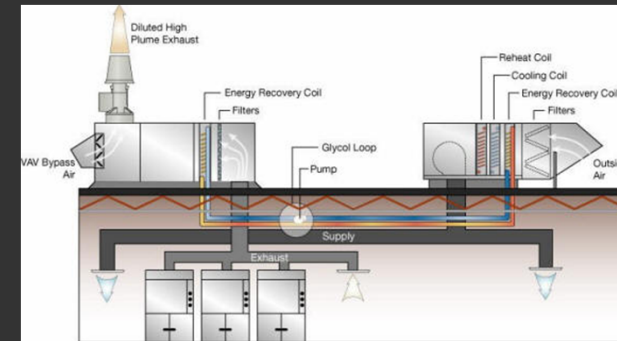
- 20 Year Equipment Lifetime
- \$297,686 First Cost
- \$13,344/year Energy Cost
- \$10,200/year Maintenance Cost
 - Based off \$0.10/SF
- Life Cycle Cost:
 - \$587,328

Outline

- ❑ PROJECT BACKGROUND
- ❑ EXISTING MECHANICAL SUMMARY
- ❑ DESIGN OBJECTIVES
- ❑ GROUND SOURCE HEAT PUMPS
 - ❑ CONSTRUCTION MANAGEMENT BREADTH
- ❑ CHILLED BEAMS
 - ❑ RUN-AROUND COIL SYSTEM
- ❑ SYSTEM COMPARISON
- ❑ ACKNOWLEDGEMENTS

Run-around Coil System

- ❑ Advantages
 - ❑ Airstreams not Adjacent
 - ❑ Relatively Space Efficient
 - ❑ Heating/Cooling Equipment Size Reduced
 - ❑ No Cross-contamination between Airstreams
- ❑ Disadvantages
 - ❑ Adds to First Cost
 - ❑ Adds pump, piping, expansion tank
 - ❑ Airstreams must be clean/Filtration Required



Outline

- PROJECT BACKGROUND
- EXISTING MECHANICAL SUMMARY
- DESIGN OBJECTIVES
- GROUND SOURCE HEAT PUMPS
 - CONSTRUCTION MANAGEMENT BREADTH
- CHILLED BEAMS
 - RUN-AROUND COIL SYSTEM
- SYSTEM COMPARISON
- ACKNOWLEDGEMENTS

Energy Consumption

Run-around Coil vs. Heat Wheel			
Run-around Coil		Heat Wheel	
	kwh Energy		kwh Energy
AHU-2	3,802	AHU-2	2,775
AHU-4	3,875	AHU-4	2,833
AHU-5	3,770	AHU-5	2,936
Total	11,447	Total	8,544
Differences	2,903		

Outline

- PROJECT BACKGROUND
- EXISTING MECHANICAL SUMMARY
- DESIGN OBJECTIVES
- GROUND SOURCE HEAT PUMPS
 - CONSTRUCTION MANAGEMENT BREADTH
- CHILLED BEAMS
 - RUN-AROUND COIL SYSTEM
- SYSTEM COMPARISON
- ACKNOWLEDGEMENTS

Ground Source Heat Pumps

Annual Energy Consumption GSHP Cooling				
Load	Electricity (kWh)	Natural Gas (kWh)	Total (kWh)	% of Total
Heating				
Gas-Fired		2637639	2637639	49%
Electric Heaters	190608		190608	4%
Cooling				
GSHP	623833		623833	12%
Auxiliary				
Supply Fans	207084		207084	4%
Pumps	487056		487056	9%
Lighting	703482		703482	13%
Receptacles	487998		487998	9%
		Total	5337700	100

Annual Energy Consumption GSHP Heating				
Load	Electricity (kWh)	Natural Gas (kWh)	Total (kWh)	% of Total
Heating				
GSHP	326723		326723	6%
Cooling				
Chiller	1991808		1991808	36%
Cooling Tower	727097		727097	13%
Condenser Pump	56390		56390	1%
Auxiliary				
Supply Fans	207084		207084	4%
Pumps	1249056		1249056	22%
Lighting	703482		703482	12%
Receptacles	487998		487998	8%
		Total	5748638	100

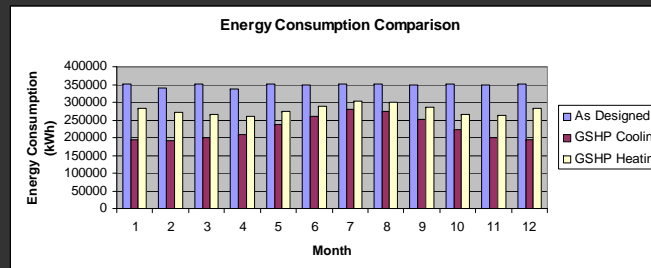
As Designed

Annual Energy Consumption				
Load	Electricity (kWh)	Natural Gas (kWh)	Total (kWh)	% of Total
Heating				
Gas-Fired		2637639	2637639	31
Electric Heaters	190608		190608	2
Cooling				
Chiller	1991808		1991808	23
Cooling Tower	727097		727097	8
Condenser Pump	56390		56390	1
Auxiliary				
Supply Fans	221632		221632	3
Pumps	1573235		1573235	18
Lighting	703482		703482	8
Receptacles	487998		487998	6
		Total	8389889	100

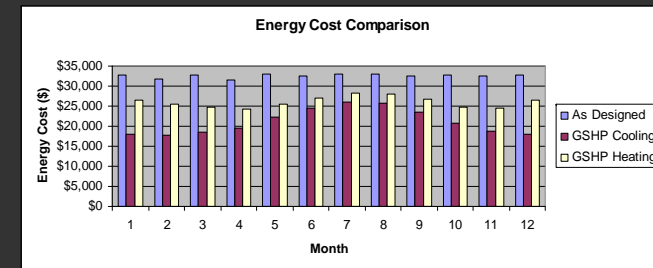
Outline

- PROJECT BACKGROUND
- EXISTING MECHANICAL SUMMARY
- DESIGN OBJECTIVES
- GROUND SOURCE HEAT PUMPS
 - CONSTRUCTION MANAGEMENT BREADTH
- CHILLED BEAMS
 - RUN-AROUND COIL SYSTEM
- SYSTEM COMPARISON
- ACKNOWLEDGEMENTS

Energy Consumption/Month



Energy Cost/Month



Outline

- PROJECT BACKGROUND
- EXISTING MECHANICAL SUMMARY
- DESIGN OBJECTIVES
- GROUND SOURCE HEAT PUMPS
 - CONSTRUCTION MANAGEMENT BREADTH
- CHILLED BEAMS
 - RUN-AROUND COIL SYSTEM
- SYSTEM COMPARISON
- ACKNOWLEDGEMENTS

Annual Energy Cost Savings

- GSHP Cooling
 - Savings: \$137,495/year
 - Includes Chilled Beams
- GSHP Heating
 - Savings: \$78,436/year
 - Includes Chilled Beams

Simple Payback

Simple Payback			
	Initial Cost	Annual Energy Savings	Years
GSHP Cooling/ Chilled Beams	\$544,359	\$137,495	3.96
GSHP Heating/ Chilled Beams	\$519,590	\$78,436	6.62

Outline

- PROJECT BACKGROUND
- EXISTING MECHANICAL SUMMARY
- DESIGN OBJECTIVES
- GROUND SOURCE HEAT PUMPS
 - CONSTRUCTION MANAGEMENT BREADTH
- CHILLED BEAMS
 - RUN-AROUND COIL SYSTEM
- SYSTEM COMPARISON
- ACKNOWLEDGEMENTS

Annual Emissions

GSHP Cooling:

Emission Factors for Delivered Electricity			
Pollutant (lb)	Factors (lb of pollutant/kWh)	Electricity (kWh/year)	Emissions (lb of pollutant/year)
CO _{2e}	1.55	2700061	4185094.6
CO ₂	1.48	2700061	3966090.3
CH ₄	0.0027	2700061	7290.2
N ₂ O	0.0000322	2700061	86.9
NO _x	0.00291	2700061	7857.2
SO _x	0.00888	2700061	23976.5
CO	0.000601	2700061	1622.7
THMOC	0.0000546	2700061	147.4
Lead	0.00000117	2700061	0.3
Mercury	0.00000027	2700061	0.1
PM10	0.0000714	2700061	192.8
Solid Waste	0.178	2700061	480610.9

Emission Factors for On-Site Combustion			
Pollutant (lb)	Factors (lb of pollutant/1000 ft ³)	Natural Gas (1000 ft ³ /year)	Emissions (lb of pollutant/year)
CO _{2e}	123	8763	1077849.000
CO ₂	122	8763	1069086.000
CH ₄	0.0025	8763	21.908
N ₂ O	0.0025	8763	21.908
NO _x	0.111	8763	972.693
SO _x	0.00632	8763	5.538
CO	0.0033	8763	817.588
THMOC	0.00613	8763	53.717
Lead	0.0000005	8763	0.004
Mercury	0.00000026	8763	0.002
PM10	0.0084	8763	73.609

As Designed:

Emission Factors for Delivered Electricity			
Pollutant (lb)	Factors (lb of pollutant/kWh)	Electricity (kWh/year)	Emissions (lb of pollutant/year)
CO _{2e}	1.55	5952250	9229875.5
CO ₂	1.48	5952250	8809330.0
CH ₄	0.0027	5952250	16071.1
N ₂ O	0.0000322	5952250	191.7
NO _x	0.00291	5952250	17321.0
SO _x	0.00888	5952250	52856.0
CO	0.000601	5952250	3577.3
THMOC	0.0000546	5952250	325.0
Lead	0.00000117	5952250	0.7
Mercury	0.00000027	5952250	0.2
PM10	0.0000714	5952250	425.0
Solid Waste	0.178	5952250	1059500.5

Emission Factors for On-Site Combustion			
Pollutant (lb)	Factors (lb of pollutant/1000 ft ³)	Natural Gas (1000 ft ³ /year)	Emissions (lb of pollutant/year)
CO _{2e}	123	8763	1077849.000
CO ₂	122	8763	1069086.000
CH ₄	0.0025	8763	21.908
N ₂ O	0.0025	8763	21.908
NO _x	0.111	8763	972.693
SO _x	0.00632	8763	5.538
CO	0.0033	8763	817.588
THMOC	0.00613	8763	53.717
Lead	0.0000005	8763	0.004
Mercury	0.00000026	8763	0.002
PM10	0.0084	8763	73.609

Outline

- PROJECT BACKGROUND
- EXISTING MECHANICAL SUMMARY
- DESIGN OBJECTIVES
- GROUND SOURCE HEAT PUMPS
 - CONSTRUCTION MANAGEMENT BREADTH
- CHILLED BEAMS
 - RUN-AROUND COIL SYSTEM
- SYSTEM COMPARISON
- ACKNOWLEDGEMENTS

Final Recommendations

- Energy Consumption and Cost Savings
 - Cooling GSHP System
- Lowest First Cost
 - Heating GSHP System
- Lowest Emissions
 - Cooling GSHP System
- Chilled Beams vs. Fan Coil Units
 - Chilled Beams
- Run-around Coil vs. Heat Wheel
 - Heat Wheel

Outline

- PROJECT BACKGROUND
- EXISTING MECHANICAL SUMMARY
- DESIGN OBJECTIVES
- GROUND SOURCE HEAT PUMPS
 - CONSTRUCTION MANAGEMENT BREADTH
- CHILLED BEAMS
 - RUN-AROUND COIL SYSTEM
- SYSTEM COMPARISON
- ACKNOWLEDGEMENTS

Acknowledgements

- Penn State University AE Faculty and Staff
- Dr. Srebric, Thesis Advisor
- Thomas Leary, P.E.; JDB Engineering
- Family and Friends

QUESTIONS?



Image Courtesy of RLPS, Ltd.

Joshua Martz | Dr. Srebric | April 11, 2011