

# Integration of Mechanical System Redesign

## Geothermal Heat Pump Redesign



## The New Learning Center

### Lutheran Theological Seminary at Philadelphia

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Architectural Engineering  
Mechanical Option  
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# Building Statistics

- Building Size

58,000 square feet

- Approximate Project Cost

\$14,880,000

- Delivery Method

Design-Bid-Build

- Construction Dates

March 2004 to February 2006



Top picture by GYA Architects, Inc.  
Bottom picture by Wes Lawson

# Building Statistics

- Owner

Lutheran Theological Seminary  
at Philadelphia

- Architect

GYA Architects, Inc.

- MEP Engineer

Paul H. Yeomans, Inc.

- Structural Engineer

O'Donnell & Naccarato, Inc.



Pictures by Wes Lawson

# Building Statistics

- Stone façade from original building
- Basement – Storage
- 1<sup>st</sup> Floor – Reception Hall, Lounges, and Kitchen
- 2<sup>nd</sup>, 3<sup>rd</sup> Floor – Classrooms and Offices



Top picture by GYA Architects, Inc.  
Bottom picture by Wes Lawson





# Presentation Outline



- Design Goals and Considerations
- Existing Systems
- Building Loads
- Mechanical Redesign
- Electrical Redesign
- CM Studies
- Conclusions
- Recommendations



# Design Goals and Considerations



- Feasible System
- Individual Occupant Comfort and Control
- Energy Efficient
- Low Cost
  - Operation Cost
  - Initial Cost
  - 20 Year Life Cycle Cost
- Low Site Emissions



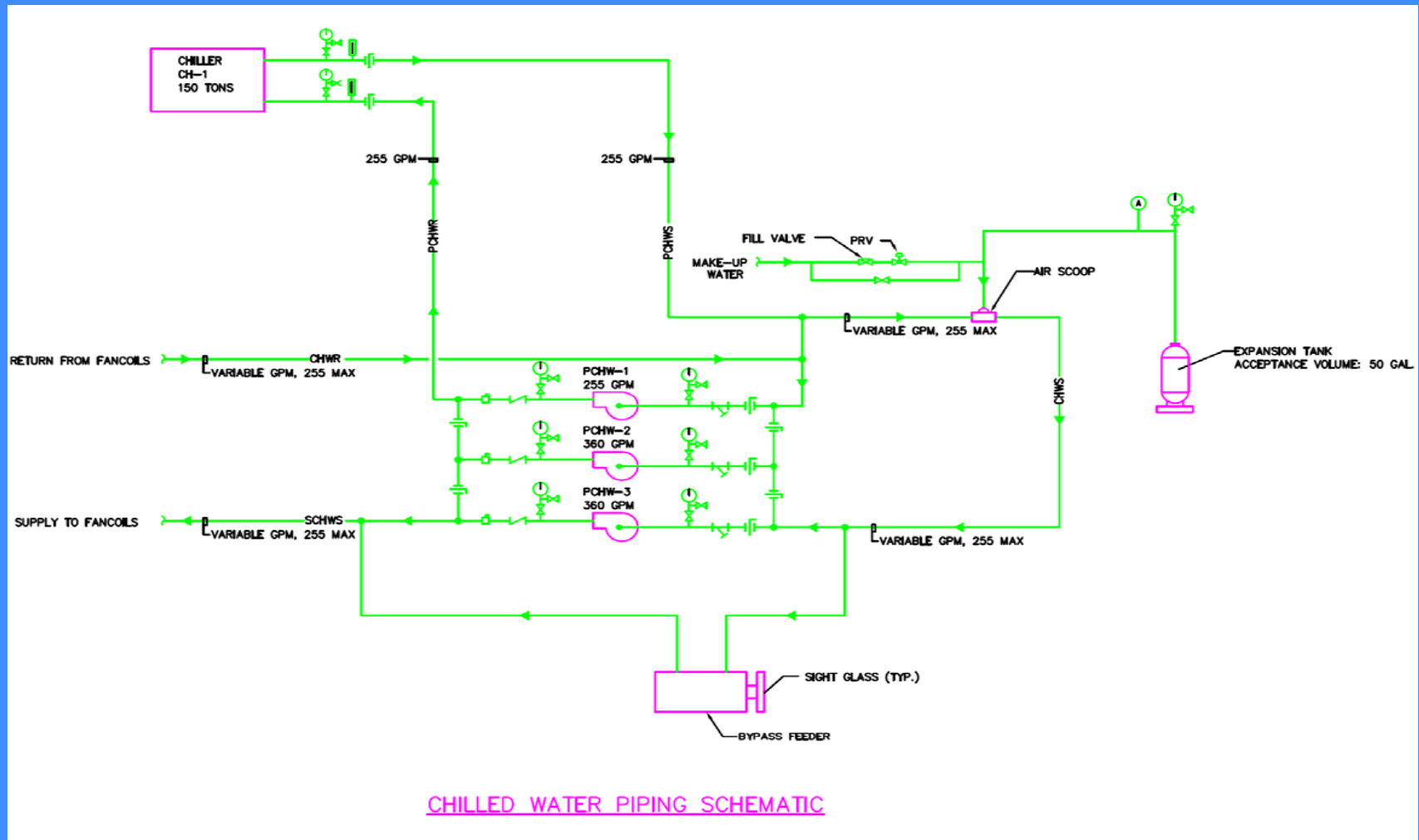
# Existing Mechanical System



- DOAS with Fan Coil Terminal Units
  - (3) Rooftop Units with Enthalpy Wheels
    - DX cooling with gas heat
  - Basement Supply Air Plenum
  - Air Cooled Chiller (150 tons)
  - (2) Gas Heat Boilers (1800 MBH each)
  - (66) Fan Coil Units



# Chilled Water Schematic

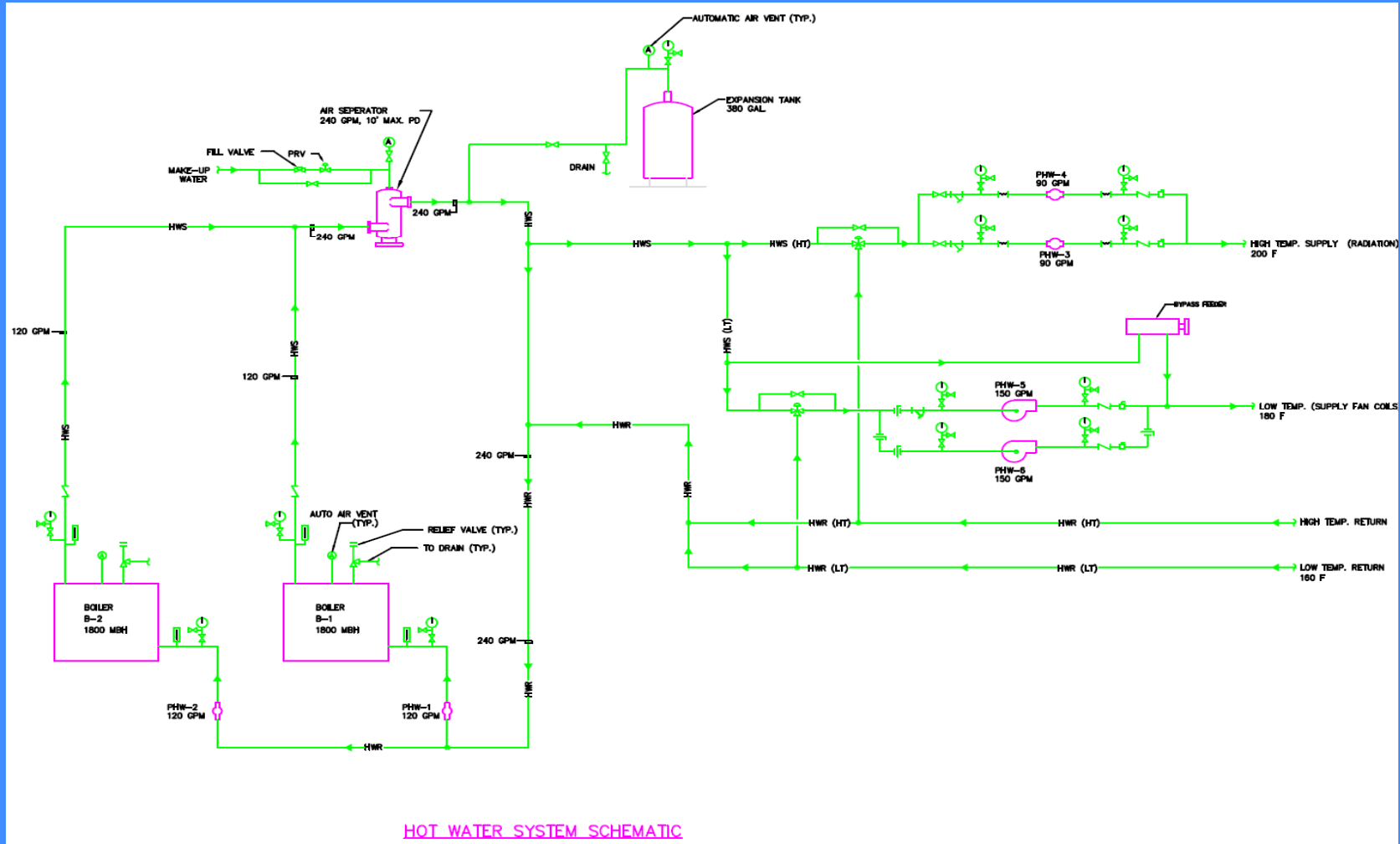


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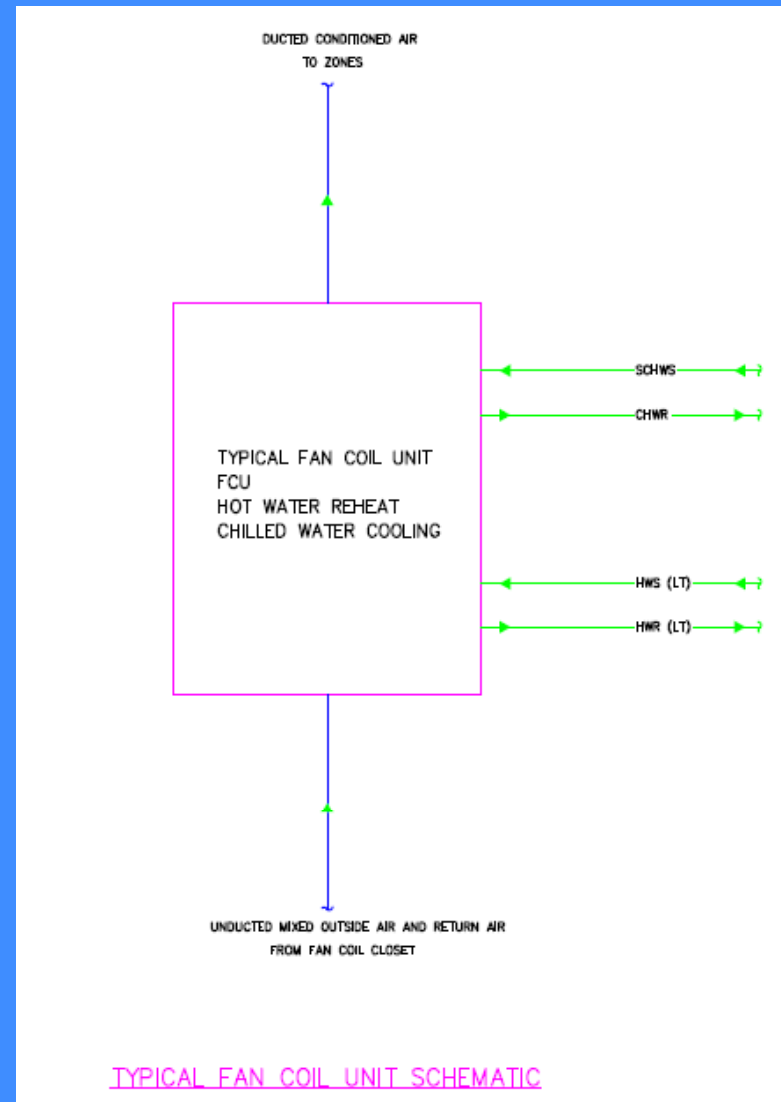
# Hot Water Schematic



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# Fan Coil Schematic





# Cooling Building Loads



- Original Design

- 150 tons for Fan Coil Units
- 62 tons of DX in Rooftop Units

- New Calculations

- 166 tons for building peak load
- All equipment on the same load source



# Heating Building Loads



- Original Design

- 150 tons for Fan Coil Units
- n+1 Boiler design
- 52.5 tons of gas heat in Rooftop Units

- New Calculations

- 125 tons for building peak load
- All equipment on the same load source



# Design Goals and Considerations



- Feasible System
- Individual Occupant Comfort and Control
- Energy Efficient
- Low Cost
  - Operation Cost
  - Initial Cost
  - 20 Year Life Cycle Cost
- Low Site Emissions





# Mechanical System Redesign Choice



## Why?

- Can be 100% OA system
- Terminal Heat Pumps can maintain individual control
- Energy Efficient
- Low Operation Cost
- Zero on site emissions



Image by WaterFurnace



## Electrical Questions ???



- Will the system size increase?
- Will additional power panels need to be added?
- Will the emergency power need to be increased?
- Will the units need to be circuited differently?



## CM Questions ???



- Will construction cost increase for the mechanical and electrical systems?
- Will construction time increase for the mechanical and electrical systems?
- Where will additional construction efforts take place?
- Will the redesign affect the on time delivery?



# Geothermal Alternative 1



- Geothermal Loop sized for heating load
  - 125 tons
- Cooling Tower sized for excess cooling load
  - 41 tons
- RTU-4 added

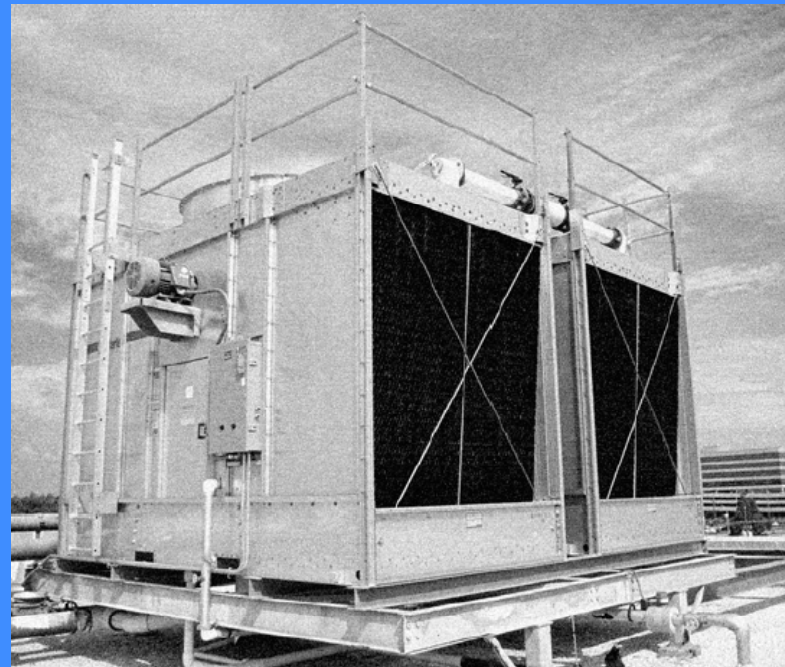
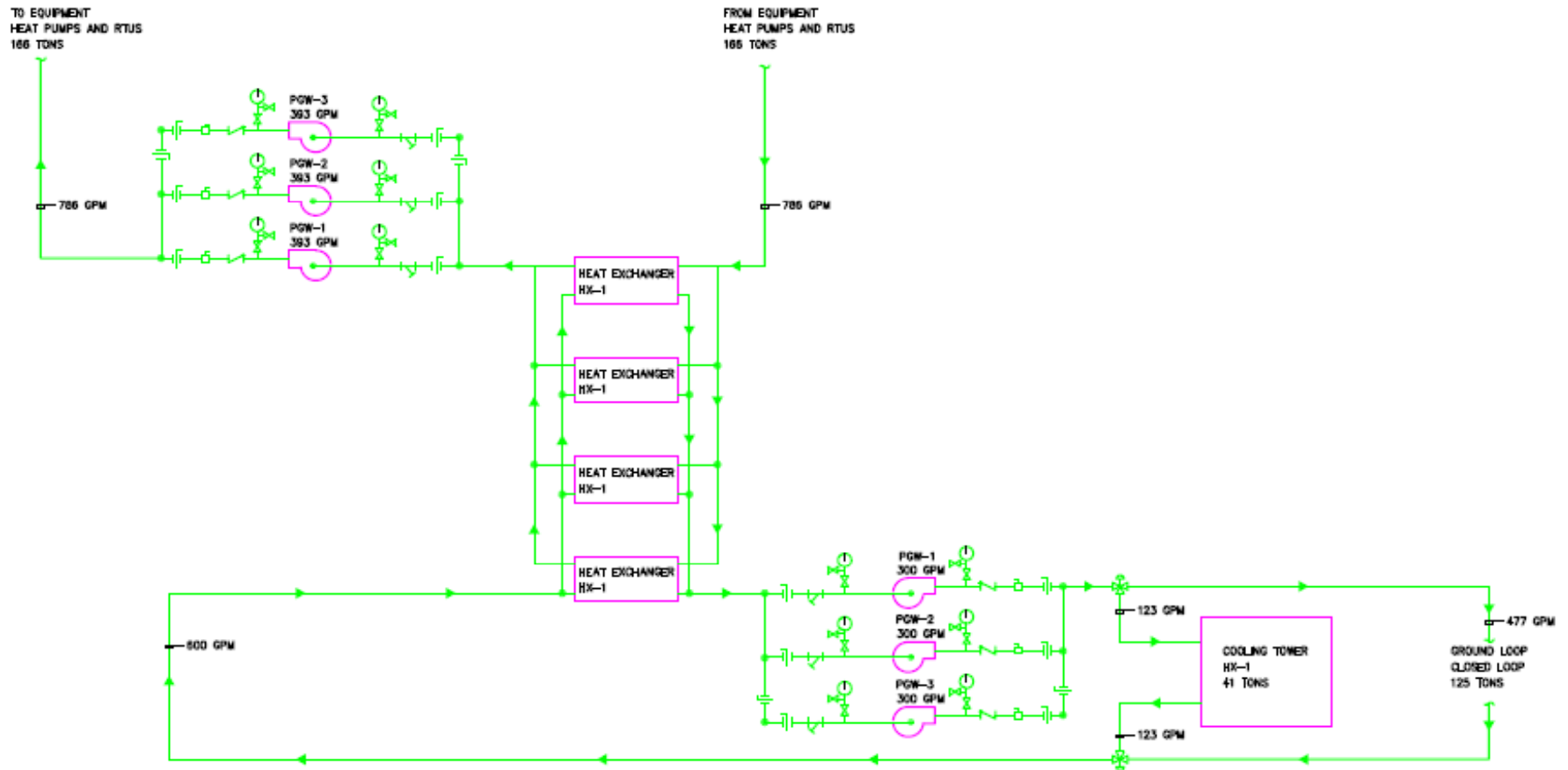


Image by Trane, Inc.



# Geothermal Alternative 1







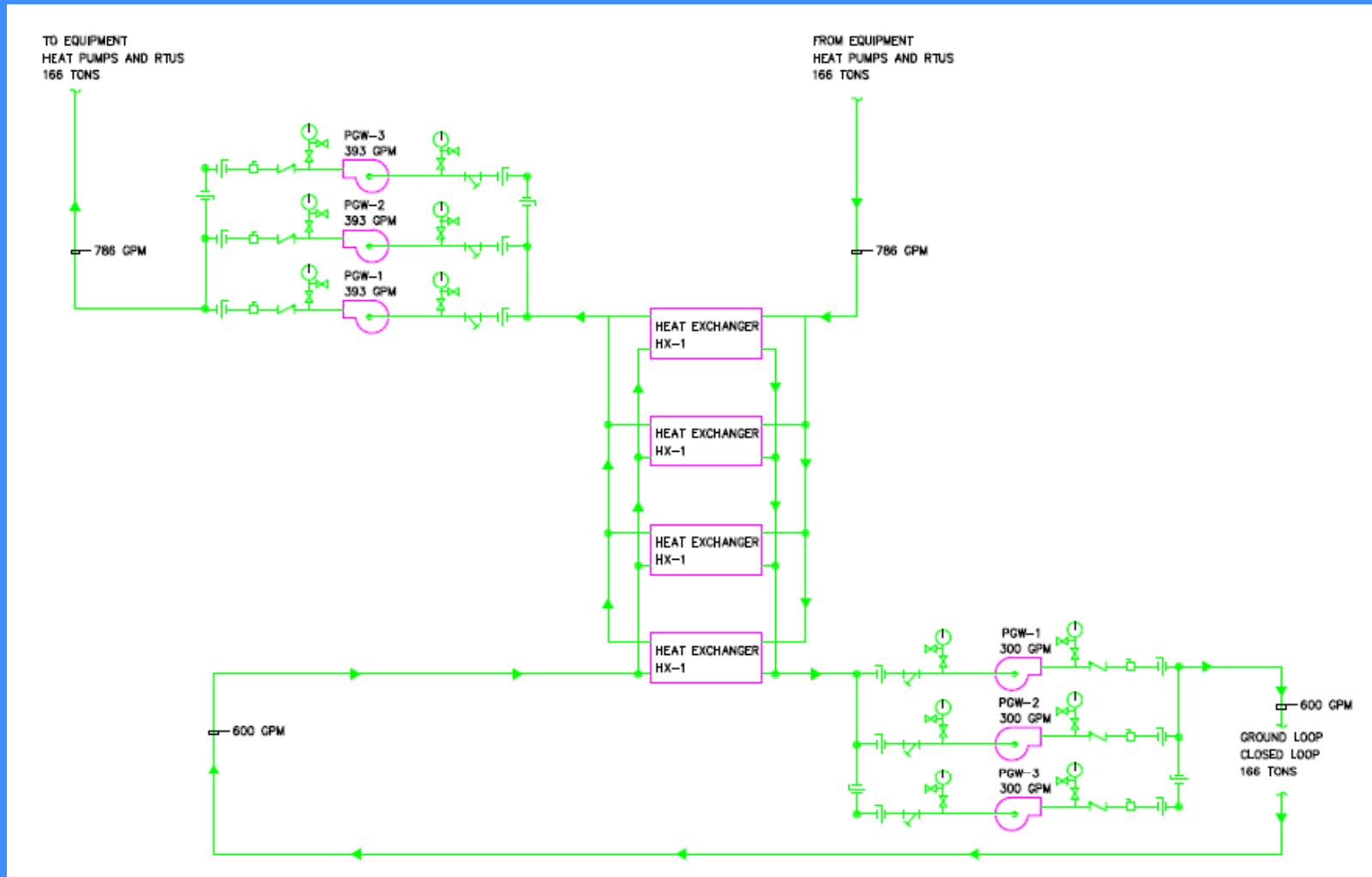
## Geothermal Alternative 2



- Geothermal Loop sized for Highest Capacity
  - 166 tons
- Cooling is not supplemented by a Cooling Tower
  - Extra capacity in loop for heating conditions
- RTU-4 added



# Geothermal Alternative 2

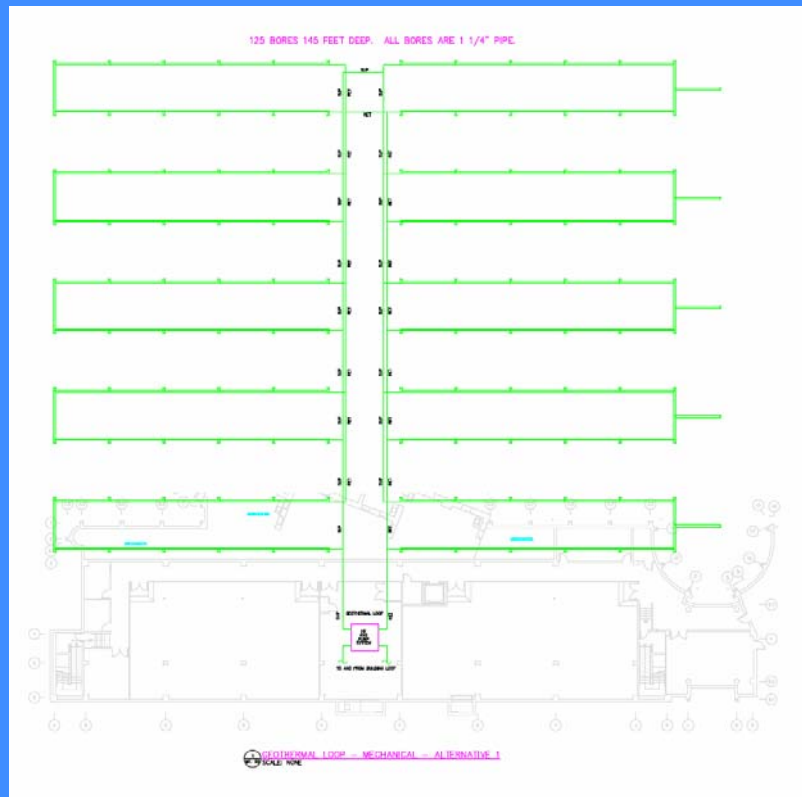




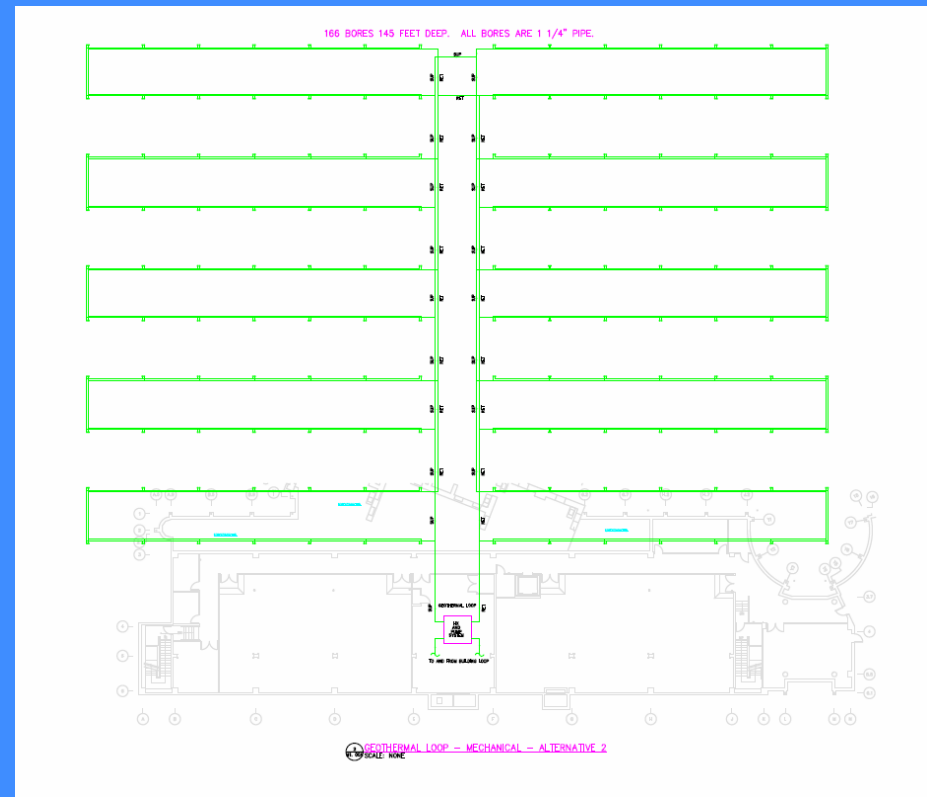
# Geothermal Alternative Bore Comparison



## Alternative 1



## Alternative 2





# Operation Energy Consumption



Source	Original Fan Coil Design		Alternative 1		Alternative 2	
	Total Energy kWh/yr	% of Total Energy	Total Energy kWh/yr	% of Total Energy	Total Energy kWh/yr	% of Total Energy
Boiler and accessories	312,554	45.9%	-	0.0%	-	0.0%
Heat Pump Heating	-	0.0%	165,505	29.8%	166,403	29.1%
Chiller and accessories	38,814	5.7%	-	0.0%	-	0.0%
Heat Pump Cooling	-	0.0%	57,205	10.3%	57,183	10.0%
Cooling Tower	-	0.0%	1,666	0.3%	-	0.0%
Fans	210,412	30.9%	108,855	19.6%	109,792	19.2%
Pumps	12,257	1.8%	76,088	13.7%	92,065	16.1%
Lighting	146,623	21.5%	146,623	26.3%	146,623	25.7%
<b>Total Energy Consumption</b>	<b>680,945</b>	<b>100.0%</b>	<b>555,385</b>	<b>100.0%</b>	<b>571,832</b>	<b>100.0%</b>
<b>Total Cost per Year</b>	<b>\$88,523</b>		<b>\$72,200</b>		<b>\$74,338</b>	

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# Emissions



	Fan Coil Design	Alternative 1	Alternative 2
	Emissions	Emissions	Emissions
Pollutant	lbm / year	lbm / year	lbm / year
CO <sub>2</sub>	1,001,358	766,431	789,128
SO <sub>x</sub>	4,315	4,188	4,312
NO <sub>x</sub>	2,942	2,466	2,539
Particulates	367	0	0





# Initial Cost of Mechanical Equipment



- Cost of Differing Mechanical Equipment
- Highest Cost Equipment
  - Fan Coil Design: Chiller, 2 Boilers
  - Alternative 1: Heat Exchanger, Heat Pumps, RTU-4
  - Alternative 2: Heat Exchanger, Heat Pumps, RTU-4

	Fan Coil Design	Alternative 1	Alternative 2
Cost	\$389,175	\$376,175	\$368,425



# Electrical Redesign

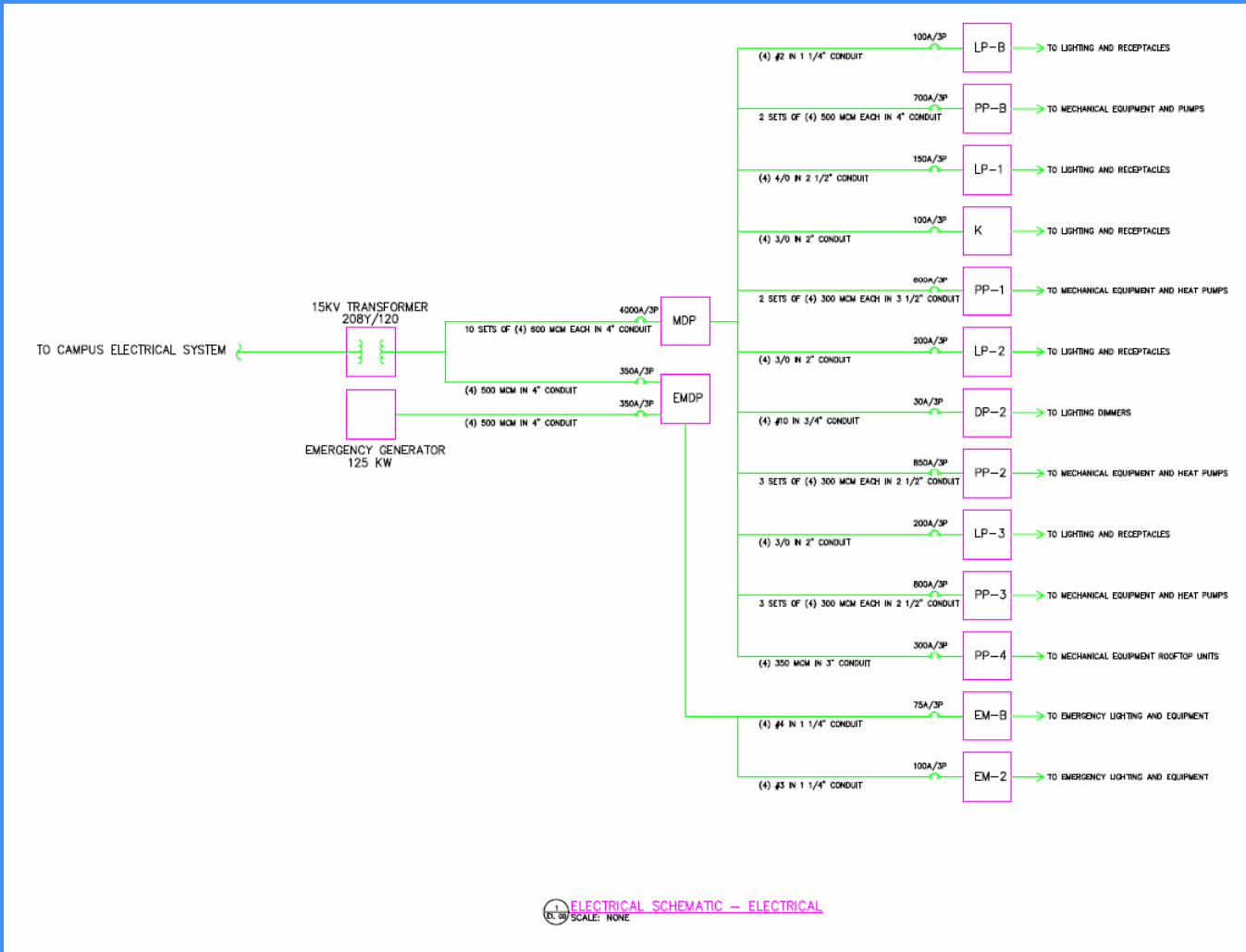


## Answering Questions

- System increased from 690 to 823 kVA (20%)
- Increased from 4 to 5 power panels
- No increase in emergency power system
- One circuit per Heat Pump instead of multiple Fan Coils on a single circuit



# Electrical Redesign



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# Electrical Power Cost



	Fan Coil Design	Alternative 1	Alternative 2
Cost	\$134,089	\$260,962	\$260,962
Cost / SF	\$2.31	\$4.50	\$4.50



# Construction Time



- Time of Differing Mechanical and Electrical Construction
- Highest Labor Time
  - Fan Coil Design: Chiller, Boilers, Building Piping
  - Alternative 1: Heat Pumps, Geothermal Ground Piping
  - Alternative 2: Heat Pumps, Geothermal Ground Piping

Hours	Fan Coil Design	Alternative 1	Alternative 2
Mechanical	1468	1530	1557
Electrical	297	1086	1086
Total	1765	2616	2643



# Construction Cost



- Cost of Differing Mechanical and Electrical Construction
- Highest Construction Equipment Cost
  - Fan Coil Design: 500 MCM feeder wires
  - Alternative 1: 600 MCM feeder wires, transformer
  - Alternative 2: 600 MCM feeder wires, transformer

Cost	Fan Coil Design	Alternative 1	Alternative 2
Mechanical	\$186,819	\$368,622	\$448,441
Electrical	\$33,679	\$85,517	\$85,517
Total	\$220,498	\$454,139	\$533,958





# Total Life Cycle Cost



Cost	Fan Coil Design	Alternative 1	Alternative 2
Total Initial Cost	\$710,083	\$1,005,759	\$1,077,828
Yearly Operation Cost	\$88,523	\$72,200	\$74,338
20 Year Life Cycle	\$2,480,543	\$2,449,759	\$2,564,588
Savings		\$30,784	-\$84,045



# Total Life Cycle Cost



- Energy Policy Act of 2005
  - 16 2/3% energy reduction qualifies for tax deductions
  - \$0.60 per square foot
- Saves an extra \$6,960 per year
- 20 Year life cycle
  - Alternative 1: \$170,000 saved**
  - Alternative 2: \$55,150 saved**



# Geothermal Alternatives



- Alternative 1 is the clear selection because:
  - Lower Initial Cost
  - Lower Operation Cost
  - Lower Life Cycle Cost
  - Lower Construction Time
  - Lower Emissions
  - Equivalent Individual Occupant Control
  - Will have less affect on the Earth temperature due to cooling tower



# Alternative 1 vs. Existing System



- Alternative 1 advantages:
  - Lower Operation Cost
  - Air Handling Unit for Basement
  - Lower 20 Year Life Cycle Cost by \$170,000
  - Lower Emissions
- Fan Coil System Advantages:
  - Lower Initial Cost by \$300,000
  - Lower Construction Time



# Personal Recommendation



- Alternative 1  
Geothermal Heat Pump  
System

- System Operation
- Life Cycle Cost
- Operation Cost

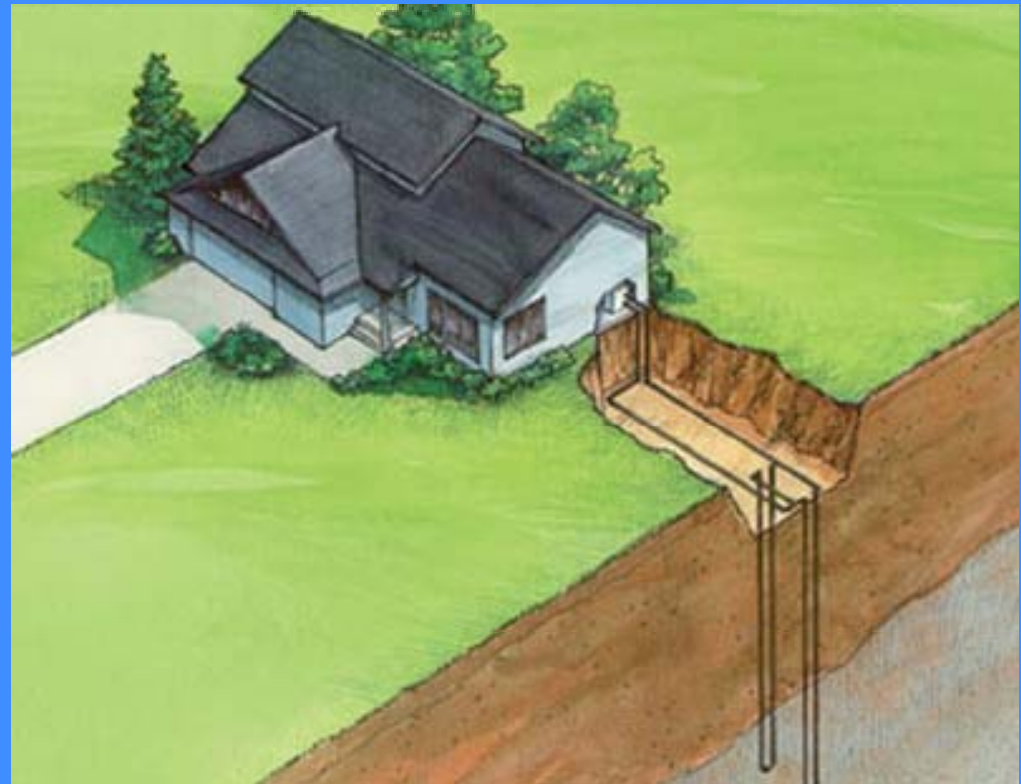


Image by WaterFurnace



# Questions?



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