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Energy Modeling: The Proper Start To Commercial Design

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Introduction

- MEP Associates, LLC—
  - Started in 2002
  - Mechanical / Electrical & Civil Engineering Firm

- Office Locations—
  - Eau Claire, Wisconsin
  - Rochester & Eden Prairie, Minnesota
  - Norman, Oklahoma

- Specializing In—
  - Design of sustainable, energy efficient facilities and renewable technologies
  - Geothermal, Photovoltaic, Thermal Solar, Thermal Storage, etc.

- Hundreds of Geothermal Projects Completed
- Size of projects range from 15 to 10,000 ton systems

Overview

- Responsibilities of an Energy Engineer
- Energy Modeling
    - Energy Modeling Software
    - Energy Modeling Processes
- Why Energy Modeling & Geothermal
- Ground Loop Design
- Energy Performance (COP)
- Geothermal Project Site Conditions & Heat Exchanger Configurations
- Equipment Selections
- Example Projects on a Campus Scale

Responsibilities of an Energy Engineer

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Responsibilities of an Energy Engineer

- Energy Modeling and Feasibility Studies
  - Campus energy reduction (Cx)
  - HVAC upgrades and options
  - Life-cycle cost analysis

- ASHRAE/LEED Modeling
  - Federal tax deductions
    - EPACT 2005 – IRC Section 179D Energy Efficient Commercial Buildings
    - Model against ASHRAE baseline building

- LEED building certification
  - EAp2 credit prerequisite for LEED certification

What is Energy Modeling

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What is Energy Modeling

"Energy Modeling is a full year simulation of a building that focuses on energy consumption, utility bills and life cycle costs of various energy related items such as HVAC equipment, interior lighting, plug loads and domestic hot water."

Energy-Models.com

What is Energy Modeling

- Load Calculations
  - Heating and cooling loads
  - Equipment capacities
  - Air flow requirements
  - Supply temperatures
  - Compare/contrast HVAC options

- Energy Modeling
  - Predict monthly energy consumption
  - Estimate annual energy cost using client's rate structure
  - Determine life cycle payback for HVAC options
  - Design geothermal ground loop
  - Determine environmental impact

Energy Modeling Software

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Energy Modeling Software

- Widely Used Software Packages
  - Trane Trace 700
  - DOE 2.2 eQuest
  - Carrier HAP

- Analysis Capabilities
  - Load calculations
  - Energy modeling
  - Economic analysis

Energy Modeling Process

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Energy Modeling Process Overview

- Acquisition of Client Information

- Load Calculations

- Energy Modeling Inputs

- Energy Model Simulation

- Energy Model Calibration

- Creation of Alternative Systems

- Energy Model Results

- Energy Modeling for Commercial Design

Acquisition of Client Information

Acquisition of Client Information

- Architectural Drawings and Details
  - Building/room locations, dimensions and orientation
  - Construction types (roof, floor, wall and partition)
  - Fenestration and openings
- Mechanical Schedules
  - Equipment efficiencies and performance curves
  - EAT, LAT, EWT and LWT details
  - Ventilation and airflow requirements
  - Equipment motor size for sensible gain
- Internal Loads (Sensible Gains to Space)
  - Occupants, interior lighting, plug loads, ventilation and infiltration loads

Acquisition of Client Information

- Operational Schedules (Energy Model)
  - Occupancy
  - Interior lighting
  - Plug loads
  - Ventilation
  - Infiltration

Load Calculations

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Load Calculations

- Selection of Weather Data and Overrides
  - Bin data used to model ambient temperature
  - Temperature overrides account for seasonal temperature extremes
- Creation of Building Shell and Spaces
  - Apply architectural details to each room
  - Templates can be used to reduce work if many similar rooms exist
- Application of Internal Loads
  - Scheduled to contribute to worst case scenario
  - Internal loads applied during cooling hours and neglected during heating hours

Load Calculations

- Airflows, Ventilation and Infiltration
  - Scheduled to contribute to worst case scenario
  - Ventilation/Infiltration applied continuously at maximum design volumetric flow rate
  - Fan motors will account for some heat gain in supply/return airstreams
- Verification of Analysis Results
  - Check software output reports for accuracy (Trace)
    - System/Zone/Room checksums
    - Design heating/cooling capacity
    - Engineering checks

System Checksums

By MEP Associates

2- B FC-2 — **Fan Coil**

COOLING COIL PEAK / CLG SPACE PEAK

Cooling Coil Peak — Peaked at Time: Mo/Hr: 7 / 16; Outside Air: OADB/WB/HR: 89 / 72 / 91

Clg Space Peak — Mo/Hr: Sum of; OADB: Peaks

	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads						
Skylite Solar	0	0	0	0	0	0
Skylite Cond	0	0	0	0	0	0
Roof Cond	0	0	0	0	0	0
Glass Solar	69,053	0	69,053	13	155,824	41
Glass/Door Cond	14,439	0	14,439	3	1,729	0
Wall Cond	43,106	12,369	55,475	11	52,600	14
Partition/Door	0		0	0	0	0
Floor	0		0	0	0	0
Adjacent Floor	0	0	0	0	0	0
Infiltration	18,850		18,850	4	1,409	0
Sub Total ==>	145,448	12,369	157,817	30	211,562	55
Internal Loads						
Lights	39,358	9,839	49,197	9	52,212	14
People	46,323	0	46,323	9	39,413	10
Misc	39,420	0	39,420	8	63,077	16
Sub Total ==>	125,101	9,839	134,940	26	154,702	40
Ceiling Load	5,780	-5,780	0	0	5,574	1
Ventilation Load	0	0	175,202	34	0	0
Adj Air Trans Heat	0		0	0	0	0
Dehumid. Ov Sizing			0	0		
Ov/Undr Sizing	12,221		12,221	2	12,221	3
Exhaust Heat		-7,818	-7,818	-2		
Sup. Fan Heat			36,779	7		
Ret. Fan Heat		10,805	10,805	2		
Duct Heat Pkup		0	0	0		
Underflr Sup Ht Pkup			0	0		
Supply Air Leakage		0	0	0		
Grand Total ==>	288,549	19,416	519,946	100.00	384,059	100.00

HEATING COIL PEAK

Mo/Hr: Heating Design; OADB: 6

	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	0	0	0.00
Glass Solar	0	0	0.00
Glass/Door Cond	-68,939	-68,939	12.85
Wall Cond	-70,465	-90,924	16.95
Partition/Door	0	0	0.00
Floor	0	0	0.00
Adjacent Floor	0	0	0
Infiltration	-69,278	-69,278	12.92
Sub Total ==>	-208,682	-229,141	42.73
Internal Loads			
Lights	13,860	17,324	-3.23
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	13,860	17,324	-3.23
Ceiling Load	-4,338	0	0.00
Ventilation Load	0	-328,341	61.23
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	0	0	0.00
Exhaust Heat		3,876	-0.72
OA Preheat Diff.		0	0.00
RA Preheat Diff.		0	0.00
Additional Reheat		0	0.00
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-199,161	-536,281	100.00

TEMPERATURES

	Cooling	Heating
SADB	55.0	80.9
Ra Plenum	75.8	69.4
Return	76.4	69.4
Ret/OA	79.9	52.4
Fn MtrTD	0.2	0.0
Fn BldTD	0.4	0.0
Fn Frict	1.3	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	17,733	17,733
Terminal	17,733	17,733
Main Fan	17,733	17,733
Sec Fan	0	0
Nom Vent	4,738	4,738
AHU Vent	4,738	4,738
Infil	500	1,000
MinStop/Rh	0	0
Return	18,233	18,732
Exhaust	5,237	5,737
Rm Exh	0	0
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	26.7	26.7
cfm/ft²	0.81	0.81
cfm/ton	409.26	
ft²/ton	506.48	
Btu/hr-ft²	23.69	-24.89
No. People	237	

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB °F	Enter WB °F	Enter HR gr/lb	Leave DB °F	Leave WB °F	Leave HR gr/lb
Main Clg	43.3	520.0	387.6	17,733	81.8	64.2	64.6	55.0	54.4	64.1
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Opt Vent	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	43.3	520.0								

AREAS

	Gross Total	Glass ft²	Glass (%)
Floor	21,945		
Part	0		
Int Door	0		
ExFlr	0		
Roof	0	0	0
Wall	9,069	1,069	12
Ext Door	0	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-546.2	17,733	52.4	80.9
Aux Htg	0.0	0	0.0	0.0
Preheat	-12.3	17,733	52.4	53.1
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-546.2			

Project Name:

Dataset Name: 1512P1WCEP.TRC

TRACE® 700 v6.2.7 calculated at 02:35 PM on 01/05/2012

SYSTEM SUMMARY
DESIGN HEATING CAPACITIES
By MEP Associates

Alternative 1

System Coil Capacities

System Description	System Type	Main System Btu/h	Aux System Btu/h	Preheat Btu/h	Reheat Btu/h	Humid. Btu/h	Optional Vent Btu/h	Stg 1 Desic Regen Btu/h	Stg 2 Desic Regen Btu/h	Stg 1 Frost Prevention Btu/h	Stg 2 Frost Prevention Btu/h	Heating Totals Btu/h
CEP Building CV	Single Zone	-191,811	0	0	0	0	0	0	0	0	0	-191,811
2- VAV w/Reheat	Variable Volume Reheat (30% Min Flow Default)	-898,159	0	-952,956	0	0	0	0	0	0	0	-1,851,115
2- HAV HP	Fan Coil	-1,752,444	0	0	0	0	0	0	0	0	0	-1,752,444
2- B FC B	Fan Coil	-65,345	0	0	0	0	0	0	0	0	0	-65,345
2- B FC-1	Fan Coil	-611,385	0	0	0	0	0	0	0	0	0	-611,385
2- B FC-2	Fan Coil	-546,209	0	0	0	0	0	0	0	0	0	-546,209
2- B FC-3	Fan Coil	-716,841	0	0	0	0	0	0	0	0	0	-716,841
2- A FC B	Fan Coil	-63,714	0	0	0	0	0	0	0	0	0	-63,714
2- A FC-1	Fan Coil	-629,851	0	0	0	0	0	0	0	0	0	-629,851
2- A FC-2	Fan Coil	-541,098	0	0	0	0	0	0	0	0	0	-541,098
2- A FC-3	Fan Coil	-727,694	0	0	0	0	0	0	0	0	0	-727,694
2- C Fan Coil	Fan Coil	-1,734,045	0	0	0	0	0	0	0	0	0	-1,734,045
2- Kitchen MAU	Single Zone	-626,477	0	0	0	0	0	0	0	0	0	-626,477
Totals		**-9,105,074**	**0**	**-952,956**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**-10,058,030**

Building Plant Capacities

Plant	System	Peak Loads: Main Coil MBh	Preheat Coil MBh	Reheat Coil MBh	Humid. Coil MBh	Aux Coil MBh	Opt Vent Coil MBh	Misc Load MBh	Stg 1 Desic. Regen. MBh	Stg 2 Desic. Regen. MBh	Stg 1 Frost Prev. MBh	Stg 2 Frost Prev. MBh	Base Utility MBh	Absorption Load MBh
2- Supplimental Boiler		9,105	953	0	0	0	0	0	0	0	0	0	0	0
	CEP Building CV	192	0	0	0	0	0	0	0	0	0	0	0	0
	2- VAV w/Reheat	898	953	0	0	0	0	0	0	0	0	0	0	0
	2- HAV HP	1,752	0	0	0	0	0	0	0	0	0	0	0	0
	2- B FC B	65	0	0	0	0	0	0	0	0	0	0	0	0
	2- B FC-1	611	0	0	0	0	0	0	0	0	0	0	0	0
	2- B FC-2	546	0	0	0	0	0	0	0	0	0	0	0	0
	2- B FC-3	717	0	0	0	0	0	0	0	0	0	0	0	0
	2- A FC B	64	0	0	0	0	0	0	0	0	0	0	0	0
	2- A FC-1	630	0	0	0	0	0	0	0	0	0	0	0	0
	2- A FC-2	541	0	0	0	0	0	0	0	0	0	0	0	0
	2- A FC-3	728	0	0	0	0	0	0	0	0	0	0	0	0

SYSTEM SUMMARY

DESIGN COOLING CAPACITIES

By MEP Associates

Alternative 1

Building Airside Systems and Plant Capacities

		Peak Plant Loads								Block Plant Loads								
Plant	System	Main Coil ton	Aux Coil ton	Opt Vent Coil ton	Misc Load ton	Stg 1 Desic Cond ton	Stg 2 Desic Cond ton	Base Utility ton	Peak Total ton	Time Of Peak mo/hr	Main Coil ton	Aux Coil ton	Opt Vent Coil ton	Misc Load ton	Stg 1 Desic Cond ton	Stg 2 Desic Cond ton	Base Utility ton	Block Total ton
2- Chillers		738.0	0.0	0.0	0.0	0.0	0.0	0.0	738.0	8/17	574.2	0.0	0.0	0.0	0.0	0.0	0.0	574.2
	CEP Building CV	30.6	0.0	0.0	0.0	0.0	0.0	0.0	30.6	8/17	29.7	0.0	0.0	0.0	0.0	0.0	0.0	29.7
	2- VAV w/Reheat	147.0	0.0	0.0	0.0	0.0	0.0	0.0	147.0	8/17	130.0	0.0	0.0	0.0	0.0	0.0	0.0	130.0
	2- HAV HP	110.6	0.0	0.0	0.0	0.0	0.0	0.0	110.6	8/17	93.2	0.0	0.0	0.0	0.0	0.0	0.0	93.2
	2- B FC B	5.1	0.0	0.0	0.0	0.0	0.0	0.0	5.1	8/17	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.5
	2- B FC-1	42.4	0.0	0.0	0.0	0.0	0.0	0.0	42.4	8/17	25.5	0.0	0.0	0.0	0.0	0.0	0.0	25.5
	2- B FC-2	43.3	0.0	0.0	0.0	0.0	0.0	0.0	43.3	8/17	31.8	0.0	0.0	0.0	0.0	0.0	0.0	31.8
	2- B FC-3	62.9	0.0	0.0	0.0	0.0	0.0	0.0	62.9	8/17	52.9	0.0	0.0	0.0	0.0	0.0	0.0	52.9
	2- A FC B	4.6	0.0	0.0	0.0	0.0	0.0	0.0	4.6	8/17	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.5
	2- A FC-1	39.7	0.0	0.0	0.0	0.0	0.0	0.0	39.7	8/17	21.5	0.0	0.0	0.0	0.0	0.0	0.0	21.5
	2- A FC-2	38.7	0.0	0.0	0.0	0.0	0.0	0.0	38.7	8/17	26.8	0.0	0.0	0.0	0.0	0.0	0.0	26.8
	2- A FC-3	50.0	0.0	0.0	0.0	0.0	0.0	0.0	50.0	8/17	38.8	0.0	0.0	0.0	0.0	0.0	0.0	38.8
	2- C Fan Coil	149.0	0.0	0.0	0.0	0.0	0.0	0.0	149.0	8/17	119.2	0.0	0.0	0.0	0.0	0.0	0.0	119.2
	2- Kitchen MAU	14.2	0.0	0.0	0.0	0.0	0.0	0.0	14.2	8/17	3.7	0.0	0.0	0.0	0.0	0.0	0.0	3.7
Building totals		738.0	0.0	0.0	0.0	0.0	0.0	0.0	738.0		574.2	0.0	0.0	0.0	0.0	0.0	0.0	574.2

Building peak load is 738.0 tons.

Building maximum block load of 574.2 tons occurs in August at hour 17 based on system simulation.

ENGINEERING CHECKS

By MEP Associates

System	Zone	Room	Type	Floor Area ft²	COOLING % OA	COOLING cfm/ft²	COOLING cfm/ton	COOLING ft²/ton	COOLING Btu/hr·ft²	HEATING % OA	HEATING cfm/ft²	HEATING Btu/hr·ft²
Alternative 1												
	2- A 001-Mechanical Room		Zone	4,590	0.00	0.13	550.5	4,179.1	2.87	0.00	0.13	-2.83
	2- A 002-Storage		Zone	810	40.57	0.37	301.7	815.9	14.71	40.57	0.37	-18.37
	2- A 003-Storage		Zone	1,085	35.06	0.43	320.4	748.8	16.02	35.06	0.43	-19.61
	2- A 004-Corridor		Zone	690	53.21	0.19	240.0	1,276.9	9.40	53.21	0.19	-9.63
	2- A 005-Stairs		Zone	190	33.15	0.30	302.7	1,003.4	11.96	33.15	0.30	-13.43
	2- A 006a-Closet		Zone	40	59.11	0.25	254.5	1,002.9	11.97	59.11	0.25	-15.87
	2- A 006-Dorm		Zone	200	30.49	0.49	399.6	812.3	14.77	30.49	0.49	-20.99
	2- A 007a-Closet		Zone	10	59.05	0.25	254.6	1,002.4	11.97	59.05	0.25	-15.88
	2- A 008a-Closet		Zone	10	59.05	0.25	254.6	1,002.4	11.97	59.05	0.25	-15.88
	2- A 008-RR		Zone	65	0.00	0.12	445.4	3,789.8	3.17	0.00	0.12	0.00
	2- A 009-Kitchen		Zone	40	0.00	0.38	336.8	875.6	13.70	0.00	0.38	-5.43
2- A FC B			**System - Fan Coil**	**7,730**	**24.31**	**0.22**	**368.6**	**1,683.8**	**7.13**	**24.31**	**0.22**	**-8.24**
	2- A 101-Dorm		Zone	208	13.09	1.10	415.1	376.9	31.84	13.09	1.10	-34.65
	2- A 102-RA		Zone	100	18.59	0.81	402.2	498.5	24.07	18.59	0.81	-28.42
	2- A 103-Dorm		Zone	200	13.69	1.10	395.9	361.4	33.21	13.69	1.10	-34.91
	2- A 104-Corridor		Zone	30	48.86	0.20	261.5	1,277.8	9.39	48.86	0.20	-9.53
	2- A 105-Dorm		Zone	210	19.72	0.72	399.5	551.6	21.76	19.72	0.72	-25.80
	2- A 106-Dorm		Zone	200	22.90	0.66	357.5	545.6	21.99	22.90	0.66	-25.01
	2- A 107-RR		Zone	175	0.00	0.13	492.4	3,782.6	3.17	0.00	0.13	-0.35
	2- A 108-Dorm		Zone	210	19.72	0.72	399.5	551.6	21.76	19.72	0.72	-25.80
	2- A 109-Corridor		Zone	45	48.87	0.20	261.5	1,277.8	9.39	48.87	0.20	-9.53
	2- A 110-Dorm		Zone	200	22.90	0.66	357.5	545.6	21.99	22.90	0.66	-25.01
	2- A 111-Dorm		Zone	200	22.90	0.66	357.5	545.6	21.99	22.90	0.66	-25.01
	2- A 112-Corridor		Zone	260	36.98	0.27	298.8	1,104.9	10.86	36.98	0.27	-11.53
	2- A 113-RR		Zone	165	0.00	0.13	492.4	3,782.6	3.17	0.00	0.13	-0.35
	2- A 114-Corridor		Zone	215	48.87	0.20	261.5	1,277.9	9.39	48.87	0.20	-9.53
	2- A 115-Dorm		Zone	215	19.48	0.72	399.9	558.4	21.49	19.48	0.72	-25.49
	2- A 116a-RR		Zone	60	0.00	0.13	492.4	3,782.5	3.17	0.00	0.13	-0.35
	2- A 116-Corridor		Zone	345	48.87	0.20	260.4	1,272.4	9.43	48.87	0.20	-9.53
	2- A 117-Stairs		Zone	155	21.97	0.46	365.1	802.0	14.96	21.97	0.46	-17.09
	2- A 118-Dorm		Zone	200	23.42	0.64	398.5	622.0	19.29	23.42	0.64	-23.70
	2- A 119-Corridor		Zone	145	40.47	0.25	281.6	1,139.6	10.53	40.47	0.25	-12.40
	2- A 120-RR		Zone	215	0.00	0.13	492.4	3,782.6	3.17	0.00	0.13	-0.35
	2- A 121-Dorm		Zone	200	23.42	0.64	398.5	622.0	19.29	23.42	0.64	-23.70
	2- A 122-Dorm		Zone	200	13.42	1.12	422.8	378.4	31.71	13.42	1.12	-35.40
	2- A 123-Dorm		Zone	160	11.65	0.80	450.4	559.5	21.45	11.65	0.80	-24.53
	2- A 124-Corridor		Zone	45	48.87	0.20	261.5	1,277.8	9.39	48.87	0.20	-9.53
	2- A 125-Dorm		Zone	210	17.75	0.80	388.0	482.1	24.89	17.75	0.80	-27.88
	2- A 126-Corridor		Zone	130	48.87	0.20	261.5	1,277.9	9.39	48.87	0.20	-9.53

Energy Modeling Inputs

Engineering Future Focused Solutions
www.mepassociates.com

Energy Modeling Inputs

- Creation of Detailed Schedules
    - Define operation time of internal loads & ventilation
    - Mimic actual operation of the building

- Application of Percent Load
    - Internal loads fluctuate throughout the day
    - Percent load accounted for when creating model

Lights

TRACE® 700 Schedule Library

Lights - Office		Simulation type: Reduced year			
January - December	Cooling design to Weekday	Start time	End time	Percentage	Utilization
		Midnight	6 a.m.	0	
		6 a.m.	7 a.m.	10	
		7 a.m.	8 a.m.	50	
		8 a.m.	5 p.m.	100	
		5 p.m.	6 p.m.	50	
		6 p.m.	7 p.m.	10	
		7 p.m.	Midnight	0	
Heating Design		Start time	End time	Percentage	Utilization
		Midnight	Midnight	0	
January - December	Saturday to Sunday	Start time	End time	Percentage	Utilization
		Midnight	Midnight	0	

People

TRACE® 700 Schedule Library

People - Office Simulation type: Reduced year

		Start time	End time	Percentage	Utilization
January - December	Cooling design to Weekday	Midnight	7 a.m.	0	
		7 a.m.	8 a.m.	30	
		8 a.m.	5 p.m.	100	
		5 p.m.	6 p.m.	30	
		6 p.m.	7 p.m.	1	
		7 p.m.	Midnight	0	
Heating Design		Start time	End time	Percentage	Utilization
		Midnight	Midnight	0	
January - December	Saturday to Sunday	Start time	End time	Percentage	Utilization
		Midnight	Midnight	0	

Ventilation

TRACE® 700 Schedule Library

Vent - Office		Simulation type: Reduced year			
January - December	Cooling design to Weekday	Start time	End time	Percentage	Utilization
		Midnight	7 a.m.	0	
		7 a.m.	6 p.m.	100	
		6 p.m.	Midnight	0	
Heating Design		Start time	End time	Percentage	Utilization
		Midnight	Midnight	100	
January - December	Saturday to Sunday	Start time	End time	Percentage	Utilization
		Midnight	Midnight	0	

Energy Modeling Inputs

- Creation of Plants and Distribution Equipment
  - Input HVAC equipment performance curves
  - Apply electric consumption rates
  - Account for air side and hydronic distribution equipment

Energy Modeling Simulation

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Energy Model Simulation

- Selection of Simulation Hours
  - Reduced Year – Modified 8760 Analysis
    - Simulates building operation for typical weekday, Saturday and Sunday for each month of the year
    - Building load for each day type scaled to create hourly load profile
  - Full Year – 8760 Analysis
    - Requires standardized 8760 weather file for location
    - Simulation takes 4 to 5 times longer
    - Produces much more accurate hourly load profile

Energy Modeling Calibration

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Energy Model Calibration

- Existing Buildings
  - Compare against actual energy consumption
  - Average 2 to 3 years of building utility bills

- New Buildings
  - Compare against industry standards for similar buildings (BTU/SF)
  - Information sources include:
    - ASHRAE/LEED averages
    - Energy Star
  - Usually many client approved assumptions used to gauge the accuracy of the model

Energy Model Calibration

- Accuracy of the Model
  - Model revised until difference in annual/monthly energy consumption is within 5-10%
  - 5-10% difference in energy model will produce results that justify a HVAC recommendation
  - Models are revised using the following techniques:
    - Review software output reports for potential error
    - Review analysis assumptions with client
    - Review ventilation and infiltration rates and schedules
    - Review internal loads and associated schedules

BUILDING TEMPERATURE PROFILES

By MEP Associates

All hours - Alternative 1

System/Room Description	Unmet Clg Load Hours	---- Maximum---- Temp	Mo	Hr	Day	--- Number of Hours at each Temp Range (°F) --- >100°	100-95	95-90	90-85	85-80	80-75	75-70	70-65	65-60	60-55	55-50	< 50°	---- Minimum---- Temp	Mo	Hr	Day	Unmet Htg Load Hours
2- HAV 2nd Stair 3	0	75	5	10	Dsgn	0	0	0	0	0	0	5,261	3,499	0	0	0	0	69	1	15	Dsgn	0
2- HAV 2nd Stair 4	0	75	6	21	Wkdy	0	0	0	0	0	0	6,244	2,516	0	0	0	0	69	1	3	Wkdy	0
2- HAV 2nd Stair 5	0	75	4	13	Dsgn	0	0	0	0	0	0	6,125	2,635	0	0	0	0	69	1	6	Dsgn	0
2- HAV 3001 - Corridor	0	75	5	24	Mon	0	0	0	0	0	70	5,155	3,535	0	0	0	0	68	1	16	Mon	0
2- HAV 3002 - Elev Lobby	60	77	7	23	Dsgn	0	0	0	0	0	212	4,126	4,363	59	0	0	0	64	1	20	Dsgn	0
2- HAV 3003 - Corridor	0	75	5	24	Sun	0	0	0	0	0	140	5,060	3,560	0	0	0	0	68	1	14	Sun	0
2- HAV 3004 - Corridor	0	75	5	24	Mon	0	0	0	0	0	70	5,155	3,535	0	0	0	0	68	1	16	Mon	0
2- HAV 3005 - Corridor	0	75	6	24	Sun	0	0	0	0	0	140	5,011	3,609	0	0	0	0	69	1	16	Sun	0
2- HAV 301 - Dorm	0	75	8	19	Sat	0	0	0	0	0	0	6,052	2,100	608	0	0	0	64	1	13	Sat	0
2- HAV 302 - Dorm	0	75	6	20	Dsgn	0	0	0	0	0	0	5,549	2,467	744	0	0	0	64	1	19	Dsgn	0
2- HAV 303 - Dorm	0	75	1	19	Sun	0	0	0	0	0	0	6,838	1,778	144	0	0	0	64	1	11	Sun	0
2- HAV 304 - Dorm	0	75	6	20	Dsgn	0	0	0	0	0	0	5,549	2,467	744	0	0	0	64	1	19	Dsgn	0
2- HAV 305 - Dorm	0	75	1	19	Sun	0	0	0	0	0	0	6,838	1,778	144	0	0	0	64	1	11	Sun	0
2- HAV 306 - Dorm	0	75	6	20	Dsgn	0	0	0	0	0	0	5,549	2,467	744	0	0	0	64	1	19	Dsgn	0
2- HAV 307 - Dorm	0	75	4	17	Sat	0	0	0	0	0	0	6,664	1,820	276	0	0	0	64	1	24	Sat	0
2- HAV 308 - Dorm	0	75	6	21	Dsgn	0	0	0	0	0	0	5,619	2,397	744	0	0	0	64	1	19	Dsgn	0
2- HAV 309 - Dorm	0	75	4	17	Sat	0	0	0	0	0	0	6,688	1,810	262	0	0	0	64	1	11	Sat	0
2- HAV 310 - Toilet	0	75	6	24	Dsgn	0	0	0	0	0	52	5,188	3,520	0	0	0	0	69	1	7	Dsgn	0
2- HAV 311 - Dorm	0	75	4	17	Sat	0	0	0	0	0	0	6,688	1,810	262	0	0	0	64	1	11	Sat	0
2- HAV 313 - Dorm	0	75	4	17	Sat	0	0	0	0	0	0	6,688	1,810	262	0	0	0	64	1	11	Sat	0
2- HAV 315 - Dorm	0	75	4	17	Sat	0	0	0	0	0	0	6,688	1,810	262	0	0	0	64	1	11	Sat	0
2- HAV 317 - Dorm	0	75	4	17	Sat	0	0	0	0	0	0	6,664	1,820	276	0	0	0	64	1	24	Sat	0
2- HAV 319 - Dorm	0	75	1	19	Sun	0	0	0	0	0	0	6,838	1,778	144	0	0	0	64	1	11	Sun	0
2- HAV 319E - Elevator	0	75	5	24	Sun	0	0	0	0	0	140	5,060	3,560	0	0	0	0	68	1	14	Sun	0
2- HAV 320 - Linen	0	75	5	24	Sun	0	0	0	0	0	103	7,779	554	324	0	0	0	63	1	16	Sun	744
2- HAV 321 - Dorm	0	75	1	19	Sun	0	0	0	0	0	0	6,838	1,778	144	0	0	0	64	1	11	Sun	0
2- HAV 322 - Dorm	0	75	6	20	Dsgn	0	0	0	0	0	0	5,728	2,288	744	0	0	0	64	1	17	Dsgn	0
2- HAV 323 - Dorm	0	75	4	17	Wkdy	0	0	0	0	0	0	6,035	2,117	608	0	0	0	64	1	22	Wkdy	0
2- HAV 324 - Dorm	0	75	6	20	Dsgn	0	0	0	0	0	0	5,482	2,534	744	0	0	0	64	1	19	Dsgn	0
2- HAV 326 - Toilet	0	75	6	23	Sat	0	0	0	0	0	52	6,095	2,613	0	0	0	0	69	1	14	Sat	0
2- HAV 327 - Janitor	0	75	6	23	Sat	0	0	0	0	0	52	6,095	2,613	0	0	0	0	69	1	14	Sat	0
2- HAV 329 - Trash	0	75	5	24	Sun	0	0	0	0	0	103	7,779	554	324	0	0	0	63	1	16	Sun	744
2- HAV 330 - Dorm	0	75	4	17	Dsgn	0	0	0	0	0	0	5,883	2,133	744	0	0	0	64	1	24	Dsgn	0
2- HAV 331 - Dorm	0	75	4	14	Sat	0	0	0	0	0	0	5,500	2,516	744	0	0	0	64	1	12	Sat	0
2- HAV 332 - Dorm	0	75	4	17	Dsgn	0	0	0	0	0	0	5,844	2,172	744	0	0	0	64	1	24	Dsgn	0
2- HAV 333 - Dorm	0	75	4	14	Dsgn	0	0	0	0	0	0	5,519	2,497	744	0	0	0	64	1	24	Dsgn	0
2- HAV 334 - Dorm	0	75	4	17	Dsgn	0	0	0	0	0	0	5,861	2,155	744	0	0	0	64	1	24	Dsgn	0
2- HAV 335 - Dorm	0	75	4	14	Dsgn	0	0	0	0	0	0	5,519	2,497	744	0	0	0	64	1	24	Dsgn	0
2- HAV 336 - Dorm	0	75	4	18	Wkdy	0	0	0	0	0	0	5,858	2,158	744	0	0	0	64	1	17	Wkdy	0
2- HAV 337 - Dorm	0	75	4	15	Dsgn	0	0	0	0	0	0	5,488	2,528	744	0	0	0	64	1	24	Dsgn	0
2- HAV 338 - Dorm	0	75	4	17	Wkdy	0	0	0	0	0	0	5,886	2,130	744	0	0	0	64	1	17	Wkdy	0
2- HAV 339 - Dorm	0	75	4	15	Dsgn	0	0	0	0	0	0	5,519	2,497	744	0	0	0	64	1	23	Dsgn	0
2- HAV 340 - Kitchen	0	75	7	20	Sat	0	0	0	0	0	0	6,057	2,703	0	0	0	0	65	1	14	Sat	693
2- HAV 342 - Lounge	0	75	5	8	Dsgn	0	0	0	0	0	0	4,585	3,431	744	0	0	0	64	1	15	Dsgn	0
2- HAV 343 - Dorm	0	75	4	13	Wkdy	0	0	0	0	0	0	5,483	2,533	744	0	0	0	64	1	1	Wkdy	0
2- HAV 345 - Dorm	0	75	4	13	Wkdy	0	0	0	0	0	0	5,483	2,533	744	0	0	0	64	1	1	Wkdy	0
2- HAV 346 - Dorm	0	75	4	17	Wkdy	0	0	0	0	0	0	5,886	2,130	744	0	0	0	64	1	17	Wkdy	0

Project Name:
Dataset Name: 1512P1WCEP.TRC

TRACE® 700 v6.2.7 calculated at 02:35 PM on 01/05/2012

MONTHLY ENERGY CONSUMPTION

By MEP Associates

------- Monthly Energy Consumption -------

Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Alternative: 1	**Phase 1 with CEP Building**												
Electric													
On-Pk Cons. (kWh)	526,923	489,226	495,954	459,516	529,978	484,318	486,179	483,579	480,275	475,496	477,629	574,225	5,963,297
On-Pk Demand (kW)	1,025	1,161	1,046	1,071	1,194	1,089	1,007	1,006	1,170	1,112	1,020	1,167	1,194
Gas													
On-Pk Cons. (therms)	1	1	1	0	0	0	0	0	0	0	1	2	6
On-Pk Demand (therms/hr)	24	0	0	0	0	0	0	0	0	0	0	0	24
Water													
Cons. (1000gal)	39	33	32	25	4	2	1	2	10	23	31	38	239

Energy Consumption		
Building	65,823	Btu/(ft2-year)
Source	197,485	Btu/(ft2-year)
Floor Area	309,214	ft2

Environmental Impact Analysis	
CO_2	976,584,704 lbm/year
SO_2	6,777,334 gm/year
NOX	1,693,536 gm/year

EQUIPMENT ENERGY CONSUMPTION
By MEP Associates

Alternative: 1 Phase 1 with CEP Building

------- Monthly Consumption -------

Equipment - Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Lights													
Electric (kWh)	118,213.5	124,528.4	138,643.1	133,282.9	138,250.0	116,727.6	119,984.0	120,680.4	133,282.9	138,249.9	133,676.1	137,463.4	1,552,982.1
Peak (kW)	209.7	260.8	260.8	260.8	260.8	224.8	224.8	224.8	260.8	260.8	260.8	260.8	260.8
Misc. Ld													
Electric (kWh)	82,970.8	97,273.1	108,095.0	104,148.5	107,891.5	85,744.1	88,174.8	88,643.9	104,148.6	107,891.4	104,352.0	107,484.5	1,186,818.1
Peak (kW)	177.6	245.9	245.9	245.9	245.9	203.4	203.4	203.4	245.9	245.9	245.9	245.9	245.9
Cooling Coil Condensate													
Recoverable Water (1000gal)	0.1	0.1	0.2	0.6	15.5	24.4	37.4	21.8	3.9	0.2	0.3	0.1	104.6
Peak (1000gal/Hr)	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.1
<u>Cpl 1: 2- Chillers [Sum of dsn coil capacities=738.0 tons]</u>													
2- Screw Chiller 1 [Clg Nominal Capacity/F.L.Rate=250 tons / 154.2 kW] (Cooling Equipment - Cooling Mode)													
Electric (kWh)	4,489.7	5,416.0	8,010.5	24,813.7	71,907.7	74,914.7	66,737.3	64,388.0	51,102.6	31,861.8	9,734.0	5,071.2	418,447.1
Peak (kW)	56.7	63.2	81.9	208.9	304.4	308.9	214.5	198.6	293.7	239.3	89.2	45.1	308.9
2- Screw Chiller 1 [Htg Nominal Capacity/F.L.Rate=3,526 mbh / 264.9 kW] (Cooling Equipment - Heating Mode)													
Electric (kWh)	699.3	2,634.2	8,266.0	6,438.7	566.6	215.8	32.5	85.6	1,530.5	5,574.0	6,840.4	15,910.8	48,794.5
Peak (kW)	174.8	85.9	87.5	87.9	24.4	5.7	3.6	4.2	74.8	86.2	87.5	260.6	260.6
Cnst vol chill water pump (Misc Accessory Equipment)													
Electric (kWh)	7,397.4	6,681.5	7,397.4	7,158.7	7,397.4	7,158.8	7,397.4	7,397.4	7,158.7	7,397.4	7,158.8	7,397.4	87,098.1
Peak (kW)	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9
Cnst vol cnd water pump (Misc Accessory Equipment)													
Electric (kWh)	39.8	745.7	3,579.4	3,479.9	3,788.2	4,036.7	377.8	546.9	3,082.2	3,350.7	2,933.1	616.5	26,576.8
Peak (kW)	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9
Cntl panel & interlocks - 1 KW (Misc Accessory Equipment)													
Electric (kWh)	744.0	672.0	744.0	720.0	744.0	720.0	744.0	744.0	720.0	744.0	720.0	744.0	8,760.0
Peak (kW)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Var vol geothermal loop pump (Plant Geothermal Pump)													
Electric (kWh)	3,367.5	2,488.7	1,910.6	2,713.9	4,884.7	5,111.6	5,206.5	5,126.1	3,865.4	2,776.0	3,310.5	4,497.2	45,258.7
Peak (kW)	8.0	6.5	5.4	10.0	10.0	10.0	19.3	19.3	10.0	10.0	7.1	9.0	19.3

EQUIPMENT ENERGY CONSUMPTION
By MEP Associates

Alternative: 1 Phase 1 with CEP Building

------- Monthly Consumption -------

Equipment - Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Sys 2: 2- VAV w/Reheat													
90.1-04 Min VAV AF Centrifugal [DsnAirflow/F.L.Rate=78,437 cfm / 57.52 kW] (Main Clg Fan)													
Electric (kWh)	3,178.5	3,651.9	3,693.5	3,959.9	6,346.7	3,590.4	4,489.5	4,112.9	4,885.0	3,841.6	3,684.7	4,478.6	49,913.2
Peak (kW)	8.4	35.5	44.9	57.5	57.5	31.1	39.1	35.9	57.5	57.5	34.2	23.6	57.5
90.1-04 Min VAV AF Centrifugal [DsnAirflow/F.L.Rate=81,741 cfm / 29.97 kW] (Main Return Fan)													
Electric (kWh)	1,830.6	2,013.7	2,053.3	2,169.2	3,277.7	1,884.4	2,329.2	2,147.4	2,520.9	2,022.9	1,955.4	2,375.4	26,580.0
Peak (kW)	5.0	18.9	23.7	30.0	28.9	15.9	19.8	18.2	28.9	30.0	18.3	12.9	30.0
FC Centrifugal const vol [DsnAirflow/F.L.Rate=78,437 cfm / 20.98 kW] (System Exhaust Fan)													
Electric (kWh)	2,523.5	2,283.3	2,414.1	2,345.9	2,357.6	1,819.8	1,959.9	1,920.8	2,018.9	2,133.9	2,340.0	2,558.3	26,675.9
Peak (kW)	4.5	10.3	14.2	9.0	7.7	4.0	4.0	4.0	5.6	7.8	14.3	7.1	14.3
Sys 4: 2- B FC B													
FC Centrifugal const vol [DsnAirflow/F.L.Rate=1,872 cfm / 2.34 kW] (Main Clg Fan)													
Electric (kWh)	1,738.9	1,570.6	1,738.9	1,682.8	1,738.9	1,682.8	1,738.9	1,738.9	1,682.8	1,738.9	1,682.8	1,738.9	20,474.1
Peak (kW)	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3
FC Centrifugal const vol [DsnAirflow/F.L.Rate=1,888 cfm / 1.35 kW] (Main Return Fan)													
Electric (kWh)	998.8	901.4	998.1	965.5	996.3	963.8	995.7	995.9	963.7	996.1	964.3	996.6	11,736.1
Peak (kW)	1.4	1.4	1.4	1.4	1.3	1.3	1.3	1.3	1.3	1.4	1.4	1.4	1.4
Sys 5: 2- B FC-1													
FC Centrifugal const vol [DsnAirflow/F.L.Rate=13,643 cfm / 17.03 kW] (Main Clg Fan)													
Electric (kWh)	11,020.6	9,794.7	10,668.2	10,128.8	10,494.9	10,171.5	10,452.2	10,516.2	10,128.8	10,494.9	10,250.1	10,930.8	125,051.5
Peak (kW)	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0
FC Centrifugal const vol [DsnAirflow/F.L.Rate=14,533 cfm / 10.37 kW] (Main Return Fan)													
Electric (kWh)	6,712.6	5,921.5	6,453.1	6,108.0	6,251.7	6,034.4	6,197.0	6,237.6	6,008.8	6,239.5	6,115.2	6,537.0	74,816.3
Peak (kW)	10.4	10.4	10.4	10.4	10.1	10.1	10.1	10.1	10.1	10.4	10.4	10.4	10.4
Sys 6: 2- B FC-2													
FC Centrifugal const vol [DsnAirflow/F.L.Rate=17,732 cfm / 22.14 kW] (Main Clg Fan)													
Electric (kWh)	15,180.6	13,538.8	14,877.3	14,224.3	14,718.1	14,255.5	14,683.7	14,735.3	14,221.1	14,718.1	14,346.5	15,105.4	174,604.7
Peak (kW)	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1

Creation of Alternative Systems

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Creation of Alternative Systems

- Copy existing building model

- Adjust plant/system equipment, efficiencies, configuration, and operation as necessary

- Consider changes in sensible heat gain to spaces where equipment is altered

- Simulate model with alternative HVAC options

BUILDING COOL HEAT DEMAND

By MEP Associates

January	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	21.7	20.0	-535,856	1.4	-463,416	2.3	-443,866	2.3	-439,923	2.3	-424,738	2.3
2	20.1	18.5	-545,182	2.1	-484,303	2.3	-471,035	2.3	-466,411	2.3	-462,342	2.3
3	18.7	17.3	-542,956	2.2	-494,319	2.3	-481,314	2.3	-469,790	2.3	-477,401	2.3
4	17.6	16.2	-543,293	2.2	-502,891	2.3	-497,425	2.2	-495,747	2.2	-481,467	2.2
5	16.7	15.3	-545,016	2.2	-502,966	2.3	-500,431	2.3	-491,788	2.3	-499,218	2.3
6	16.2	14.8	-544,150	2.2	-508,173	2.3	-496,828	2.3	-506,793	2.3	-503,060	2.3
7	16.0	14.6	-548,120	2.2	-505,245	2.3	-511,561	2.2	-511,542	2.2	-499,541	2.2
8	16.5	15.5	-533,215	2.2	-443,163	2.3	-509,973	2.2	-498,976	2.2	-389,130	2.2
9	17.9	16.7	-620,245	2.2	-422,541	2.3	-465,898	2.3	-474,212	2.3	-417,390	2.3
10	20.1	18.8	-538,524	2.3	-436,961	2.3	-438,852	2.3	-436,908	2.3	-412,735	2.3
11	22.9	20.9	-467,277	2.3	-436,252	2.3	-401,135	2.3	-387,770	2.3	-402,077	2.3
12	25.8	23.2	-373,839	2.3	-396,424	2.3	-354,587	2.3	-365,050	2.3	-404,497	2.3
13	28.5	25.6	-329,151	2.3	-357,032	2.3	-333,027	2.3	-329,939	2.3	-381,240	2.3
14	30.7	27.3	-289,873	2.3	-333,464	2.3	-320,009	2.3	-305,384	2.3	-368,856	2.3
15	32.2	28.4	-285,527	2.3	-299,690	2.3	-299,184	2.3	-305,314	2.3	-347,270	2.3
16	32.7	28.9	-290,101	2.3	-299,321	2.3	-312,921	2.3	-308,576	2.3	-342,107	2.3
17	32.5	29.0	-299,173	2.3	-307,221	2.3	-318,599	2.3	-304,426	2.3	-341,741	2.3
18	31.9	28.6	-334,880	2.3	-328,599	2.3	-318,470	2.3	-325,587	2.3	-333,609	2.3
19	31.1	28.5	-376,241	2.3	-345,309	2.3	-335,822	2.3	-321,213	2.3	-346,336	2.3
20	29.9	27.4	-401,396	2.3	-359,663	2.3	-355,345	2.3	-353,552	2.3	-359,606	2.3
21	28.5	26.2	-423,795	2.2	-376,328	2.3	-359,386	2.3	-366,691	2.3	-376,157	2.3
22	26.9	24.7	-444,225	2.2	-391,642	2.3	-385,714	2.3	-372,718	2.3	-391,689	2.3
23	25.2	23.2	-463,929	2.2	-409,682	2.3	-401,451	2.3	-401,013	2.3	-410,000	2.3
24	23.4	21.6	-476,715	2.2	-428,218	2.3	-412,849	2.3	-418,567	2.3	-428,380	2.3

February	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	22.8	20.6	-473,805	2.2	-420,751	2.3	-405,310	2.3	-394,462	2.3	-403,716	2.3
2	20.9	19.2	-493,261	2.2	-432,817	2.3	-438,436	2.3	-430,380	2.3	-416,015	2.3
3	19.3	17.8	-507,000	2.2	-467,352	2.3	-460,180	2.3	-454,797	2.3	-450,787	2.3
4	17.9	16.6	-518,314	2.2	-478,746	2.3	-473,082	2.3	-456,600	2.3	-464,210	2.3
5	16.9	15.7	-521,285	2.2	-495,183	2.3	-481,024	2.3	-487,137	2.2	-475,819	2.2
6	16.2	15.1	-523,059	2.2	-498,887	2.2	-509,124	2.2	-506,466	2.2	-502,519	2.2
7	16.0	14.9	-508,834	2.2	-503,532	2.3	-504,348	2.3	-486,326	2.3	-494,780	2.3
8	16.6	15.6	-462,536	2.2	-415,537	2.3	-483,118	2.3	-487,073	2.3	-368,880	2.3
9	18.3	17.1	-451,913	2.2	-387,604	2.3	-461,224	2.3	-452,937	2.3	-405,925	2.3
10	20.9	19.0	-417,523	2.2	-400,297	2.3	-431,209	2.3	-417,202	2.3	-394,292	2.3
11	24.1	21.8	-351,943	2.3	-398,842	2.3	-377,011	2.3	-379,500	2.3	-372,813	2.3
12	27.5	24.4	-299,187	2.3	-353,389	2.3	-342,816	2.3	-340,338	2.3	-372,947	2.3
13	30.7	26.8	-271,169	2.3	-314,289	2.3	-311,331	2.3	-296,942	2.3	-326,793	2.3
14	33.4	28.7	-251,138	2.3	-293,248	2.3	-276,983	2.3	-282,585	2.3	-315,475	2.3
15	35.1	29.8	-247,297	2.3	-282,933	2.3	-273,262	2.3	-272,426	2.3	-314,029	2.3
16	35.7	29.8	-251,543	2.3	-279,826	2.3	-270,760	2.3	-259,492	2.3	-313,770	2.3
17	35.4	29.7	-244,768	2.3	-283,007	2.3	-270,407	2.3	-274,965	2.3	-315,422	2.3
18	34.8	29.5	-296,022	2.3	-299,602	2.3	-294,568	2.3	-290,338	2.3	-299,672	2.3
19	33.8	29.5	-336,479	2.3	-311,666	2.4	-298,977	2.4	-282,054	2.4	-311,723	2.4
20	32.4	28.6	-366,777	2.3	-325,560	2.3	-305,577	2.3	-310,914	2.3	-325,609	2.3
21	30.7	27.5	-392,446	2.2	-339,533	2.3	-328,480	2.3	-312,568	2.3	-339,531	2.3
22	28.9	26.0	-416,569	2.2	-356,631	2.3	-346,166	2.3	-347,523	2.3	-355,973	2.3
23	26.9	24.5	-437,151	2.2	-374,407	2.3	-352,002	2.3	-361,562	2.3	-372,983	2.3
24	24.8	22.6	-454,612	2.2	-393,277	2.3	-387,478	2.3	-374,181	2.3	-398,431	2.3

Energy Model Results

Energy Model Results

- Annual energy consumption for HVAC options

- Results can be used for further analysis
    - Geothermal Loop Field Design
        - Analysis produced accurate full year hourly load profile
        - Load profile describes rate and time at which BTUs are deposited/extracted from the ground
        - Consolidated in GT1 output file
        - GT1 file can be amended if necessary
        - Final GT1 file used in GLD software to design loop field
    - Economic Analysis
        - Life-Cycle Cost Analysis
        - Simple Payback
    - Environmental Analysis

Energy Modeling for Commercial Design

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Energy Modeling for Commercial Design

- Allows design to be tailored to individual client needs

- Allows engineers to predict energy consumption and cost savings for different HVAC solutions
    - Assists client in making informed decision on HVAC solutions

- Facilitates precise design of geothermal and thermal storage systems

Why is Energy Modeling Important to Commercial Geothermal Design?

Ground Loop Design

Ground Loop Design

- Utilize software to model ground loop heat exchanger.
    - Software inputs include:
        - Total heating /cooling BTU's for each month
        - The peak of each per month derived from energy model

- Equivalent cooling and heating hours are calculated from total loads and peaks.

- Output is total footage needed to satisfy loads and entering water temp to heat pumps.

- 10-20 year temperature model of how it (BTUs in/out) affects the earth.

Heating/Cooling BTUs

Average Block Loads - 09-06-16 14% North Plant

09-09-14 16% North Plant.zon

Monthly Load Data

Update

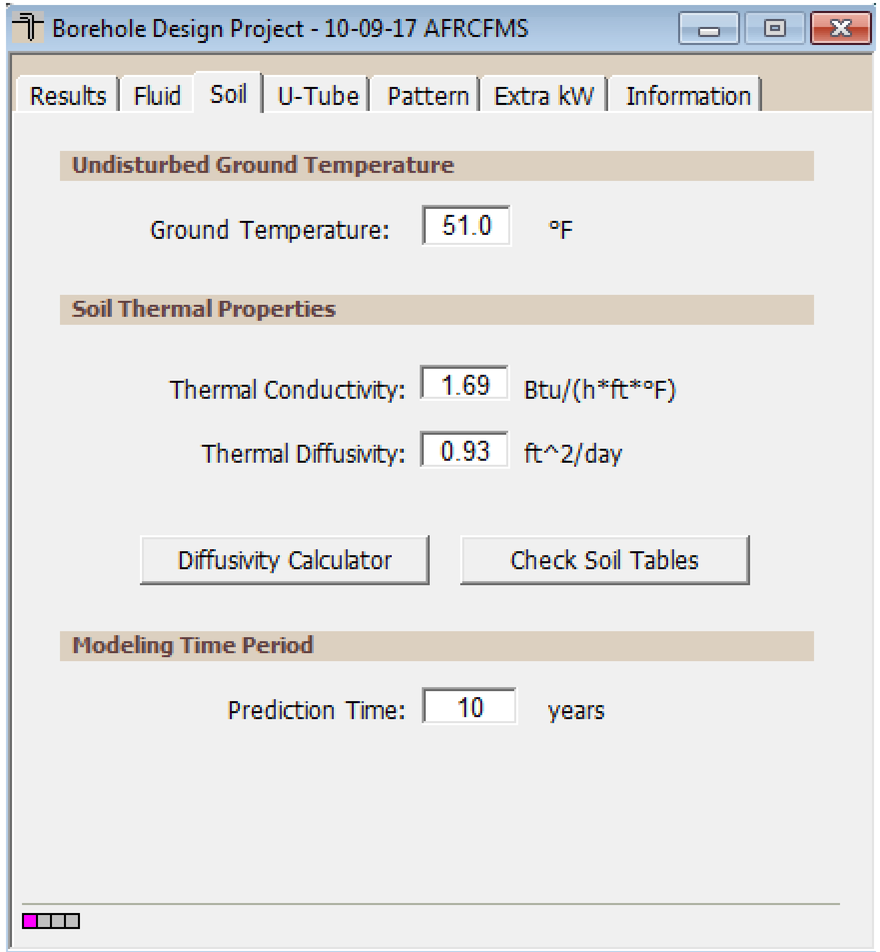
Cancel

	Cooling Total (kBtu)	Cooling Peak (kBtu/hr)	Heating Total (kBtu)	Heating Peak (kBtu/hr)
	0	0	0	0
January	42786	3668	5751782	21013
February	2982	912	4837255	18368
March	216886	7754	4447367	18428
April	822334	8214	2292996	12548
May	1574218	9883	851361	10834
June	3147679	9972	109630	5624
July	3696456	8184	769	902
August	3853897	9781	11256	2081
September	2167146	7568	59938	3532
October	1198711	8915	2050095	11856
November	327056	**7999**	3562598	13270
December	0	0	5583755	**17245**
Total:	17050151	**3.0** Hours at Peak	29558802	**3.0** Hours at Peak

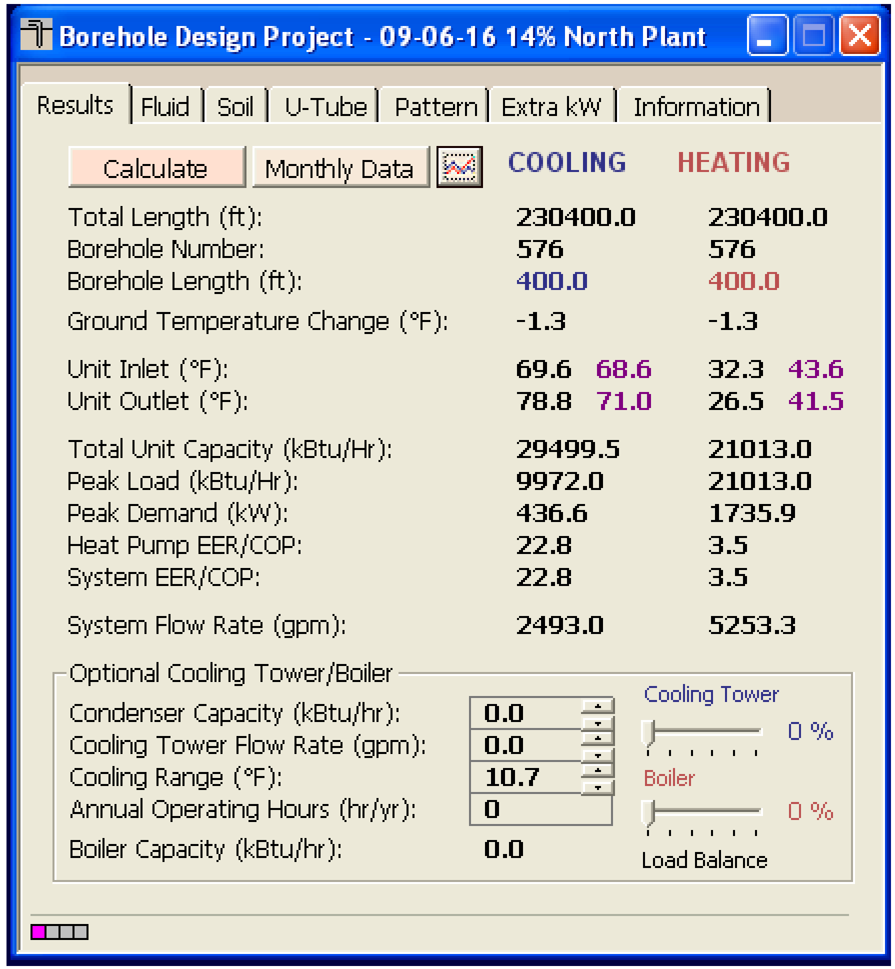
Flow Rate: **3.0** gpm/ton

Unit Inlet (°F): **69.6** **32.3**

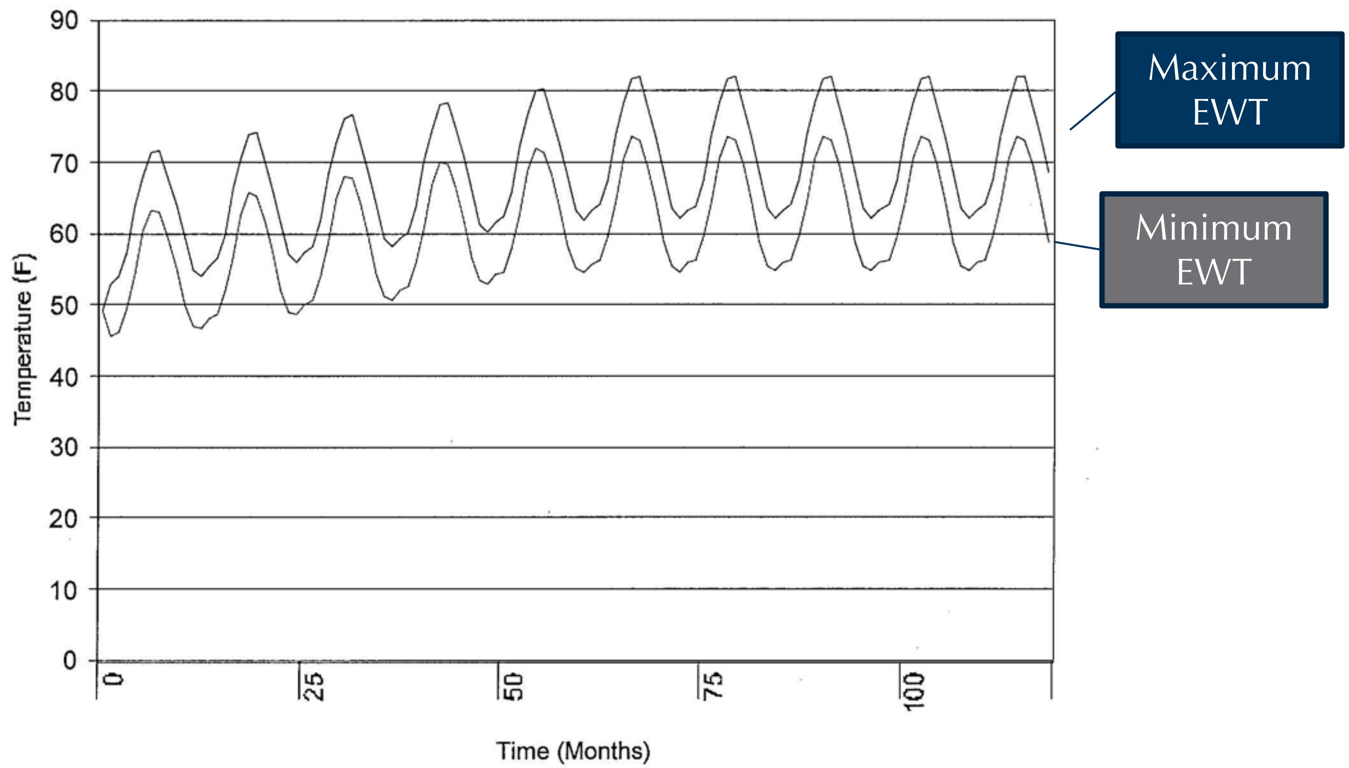
GLD Input


Borehole Design Project - 10-09-17 AFRCFMS
Results
Fluid
Soil
U-Tube
Pattern
Extra kW
Information
Undisturbed Ground Temperature
Ground Temperature:
51.0
°F
Soil Thermal Properties
Thermal Conductivity:
1.69
Btu/(h*ft*°F)
Thermal Diffusivity:
0.93
ft^2/day
Diffusivity Calculator
Check Soil Tables
Modeling Time Period
Prediction Time:
10
years

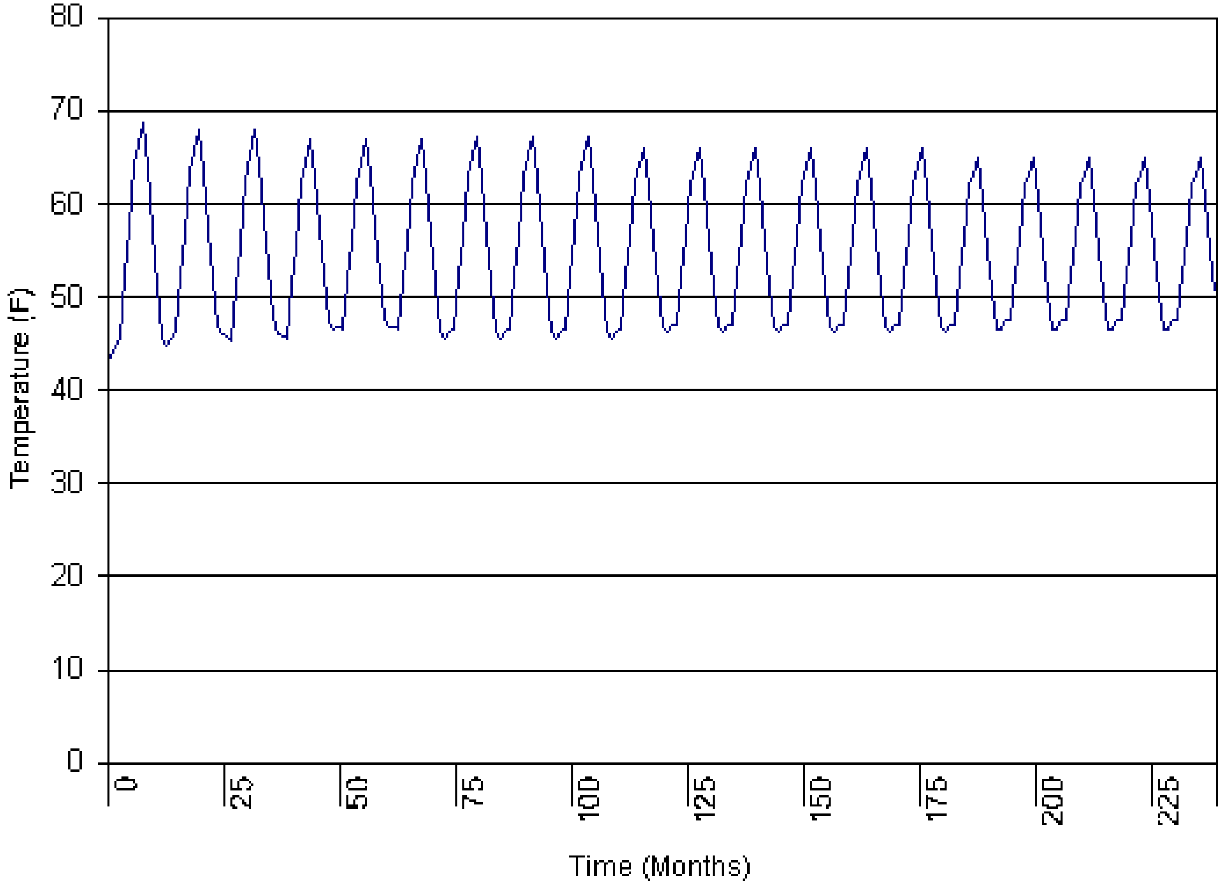
Software Example



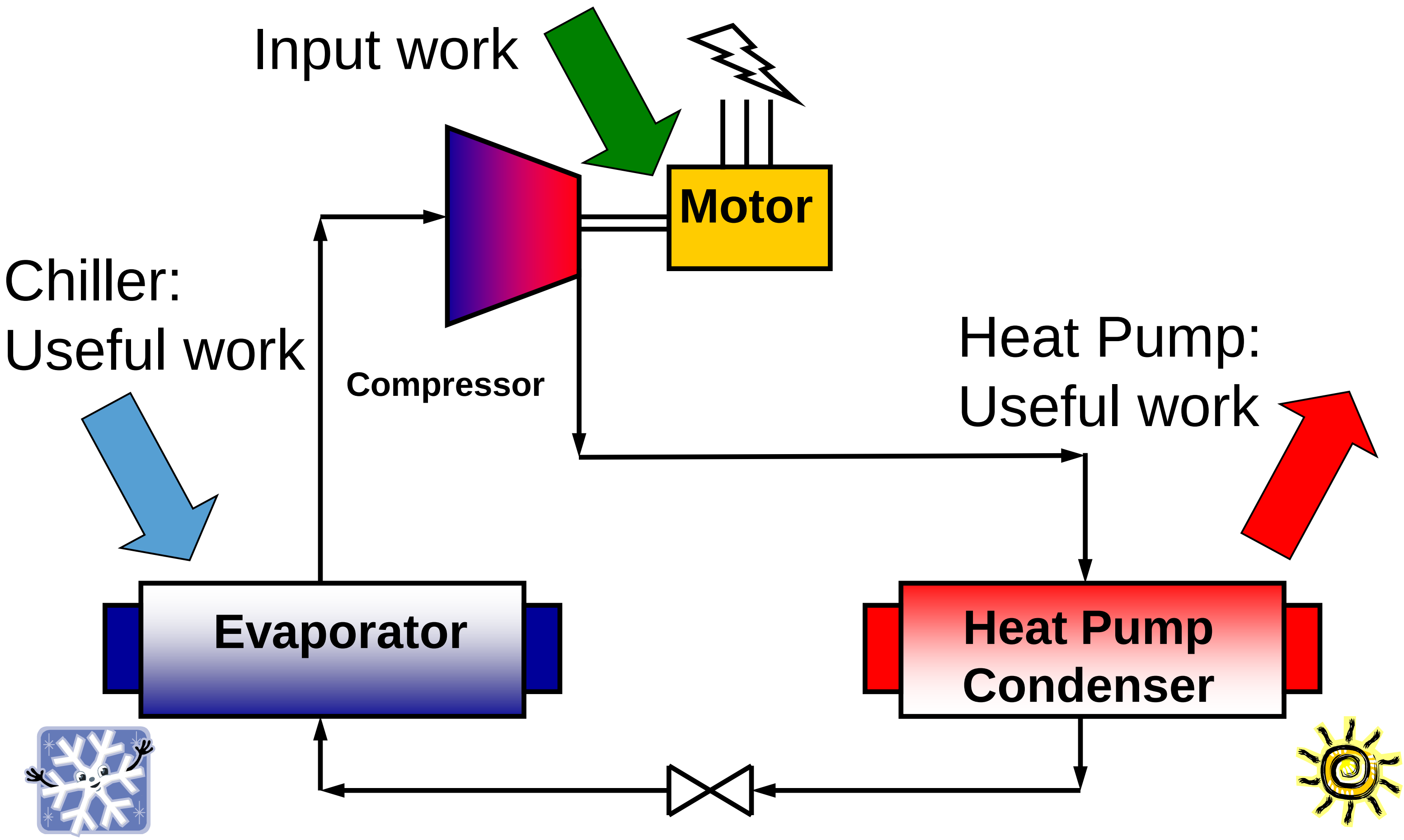
10 Year Ground Temperature Model



20 Year Ground Temperature Model



Performance Measurement

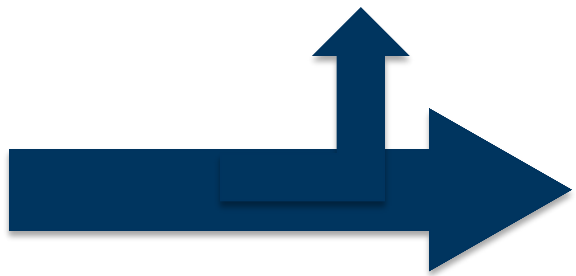


COP (Coefficient of Performance) = $\frac{\text{Useful work}}{\text{Input work}}$

Fossil Fuel Conventional Systems

10-20% of heat up the chimney

1 unit of purchased fossil fuel



80-90% of heat to the building

COP of Hot Water 0.8 – 0.95
COP of Steam 0.65 – 0.75

Electric Heat

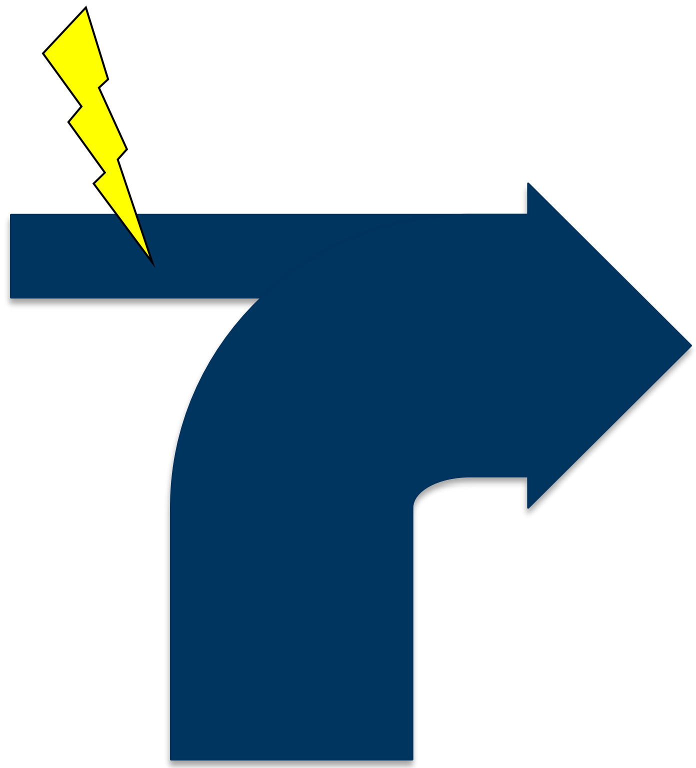
1 unit of purchased electricity

1 unit of heat to the building

COP of 1

Energy From The Earth

1 unit of purchased electricity

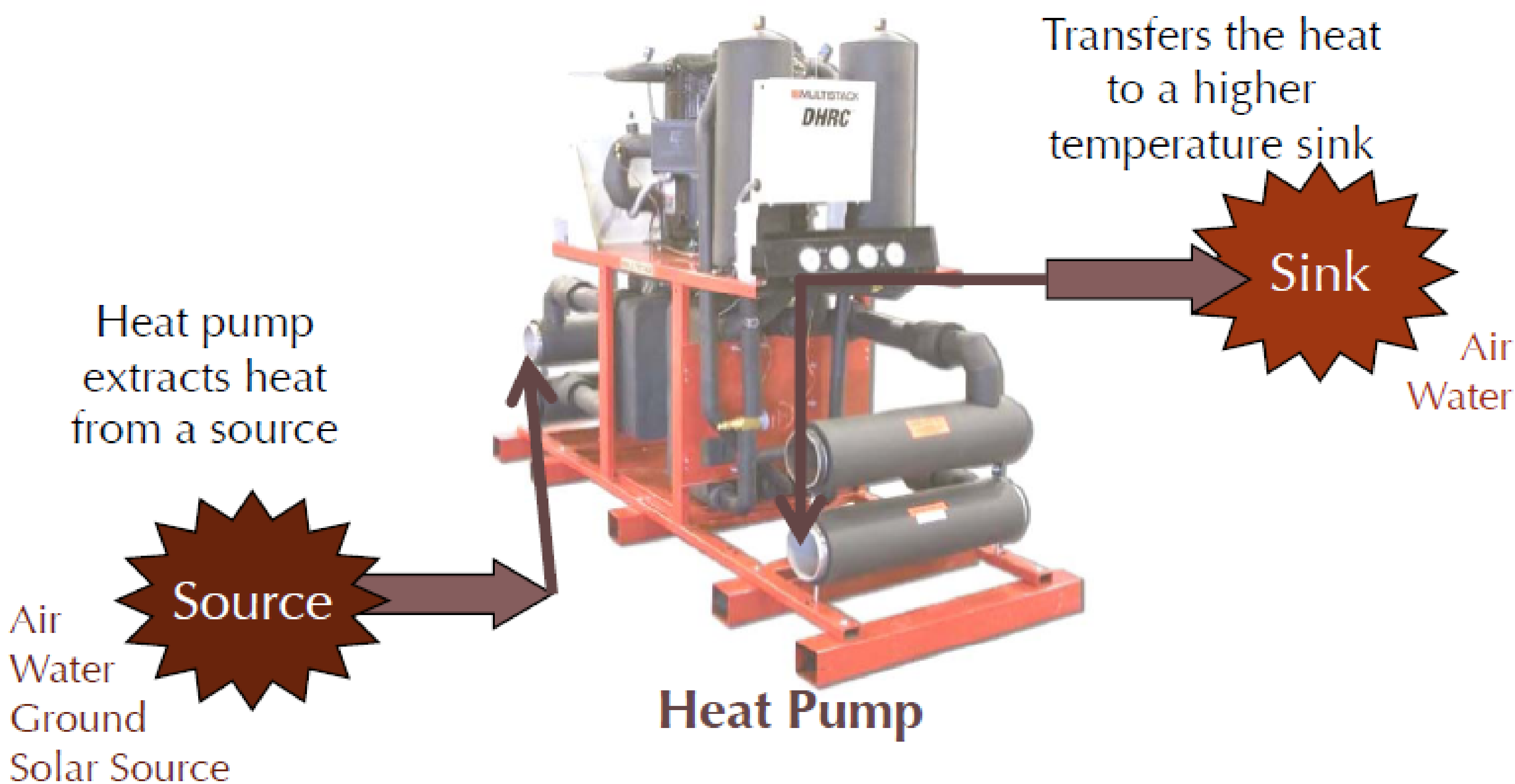


4.5 units of heat to the building

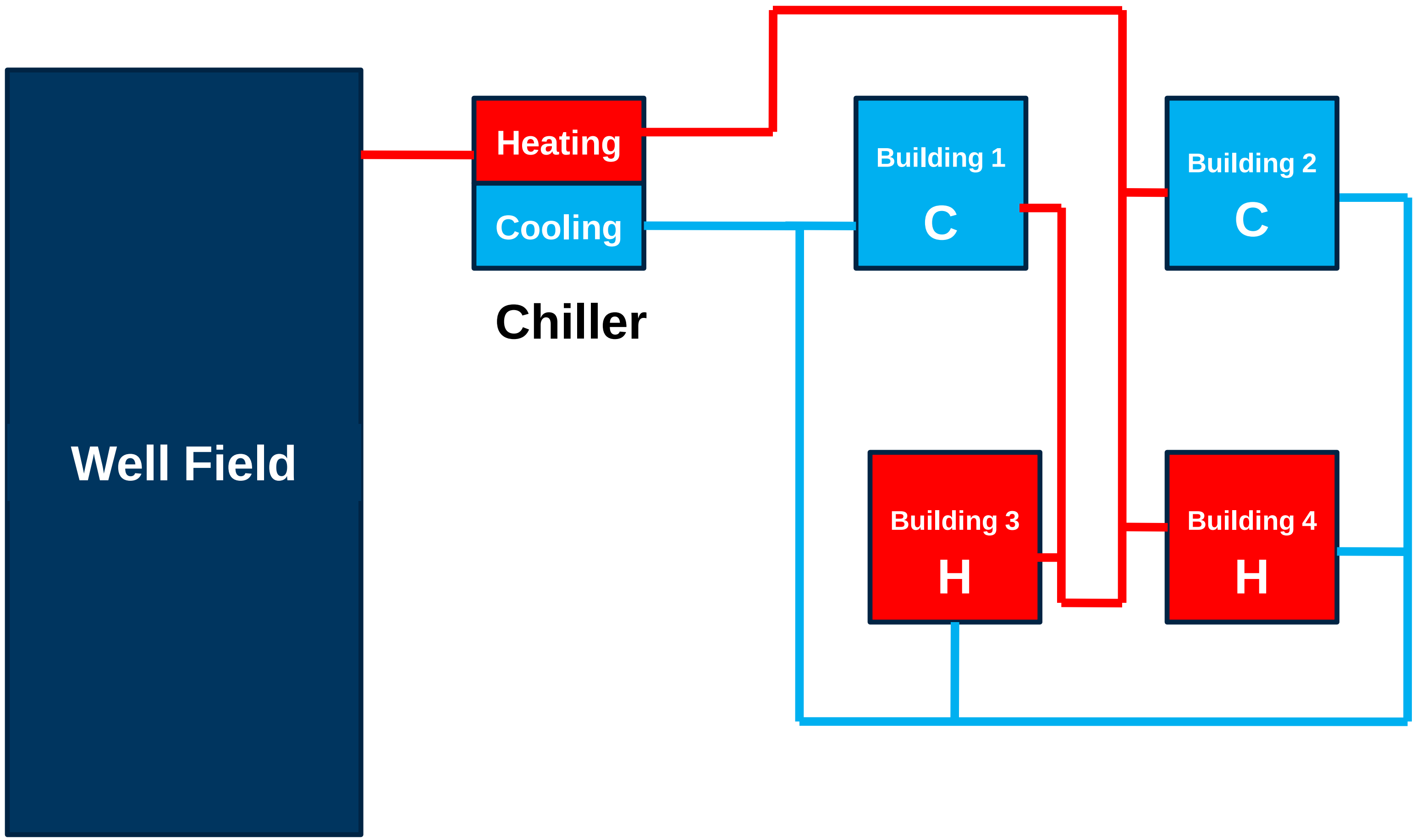
Plus 3.5 units of energy from the earth

Typical Geothermal Heat Pump

Heat Sources and Sinks

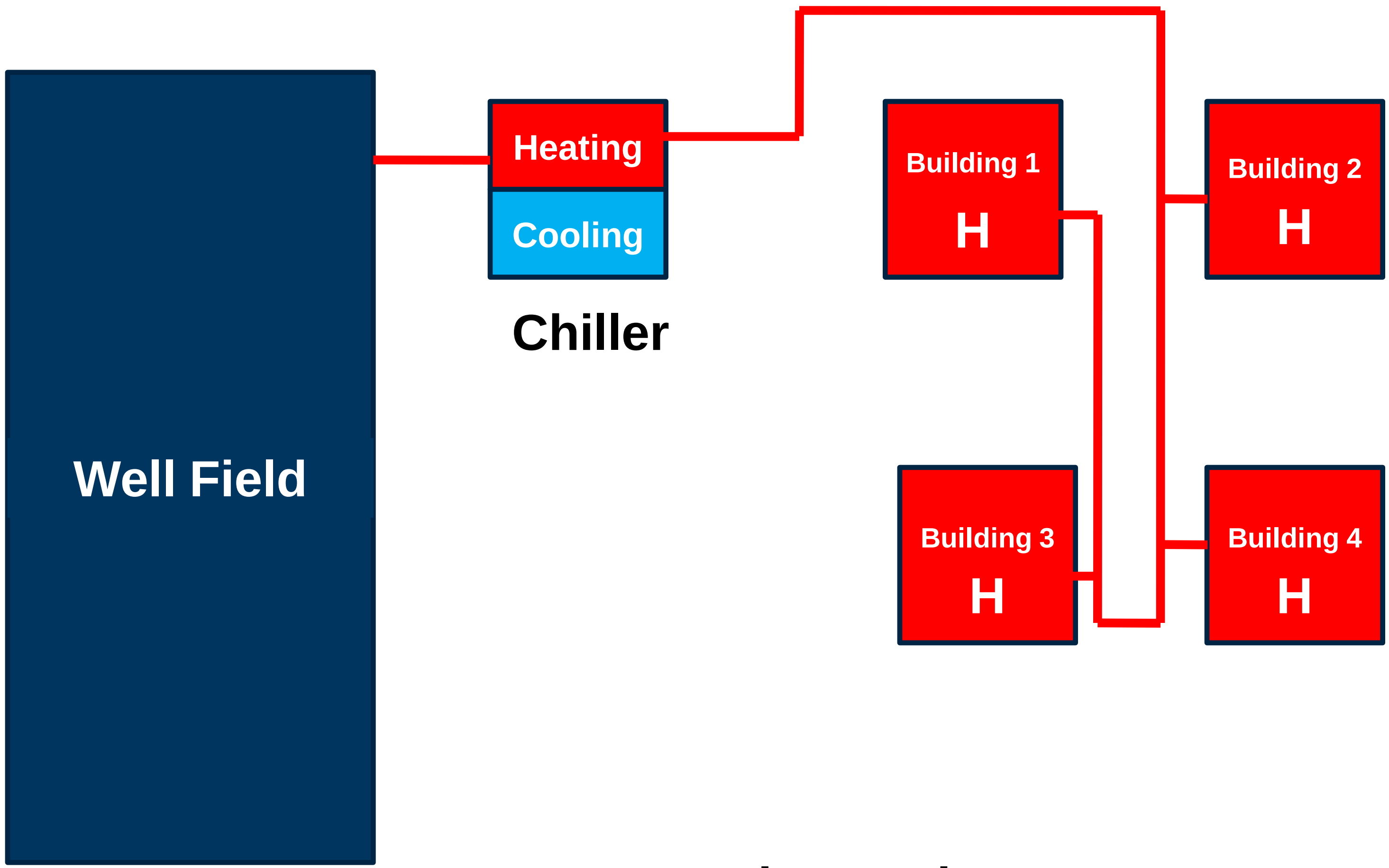


Central Energy Plan



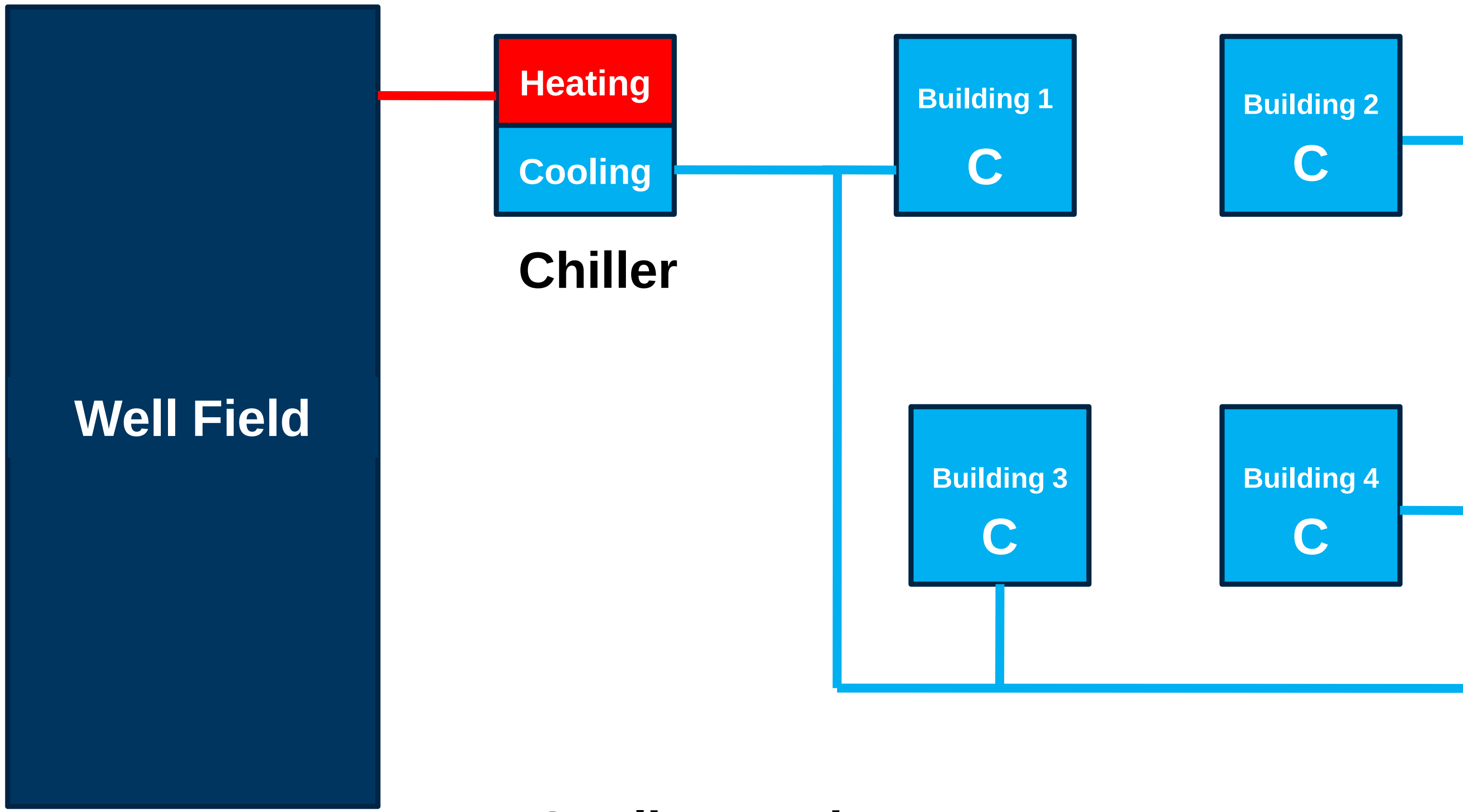
<u>Simultaneous Heating/Cooling</u>
COP = 10

Central Energy Plan



Heating Mode
COP = 3.4

Central Energy Plan



Cooling Mode

COP = 6.2 / EER 21.3 (Avg.)

Geothermal Project Site Conditions & Heat Exchanger Configurations

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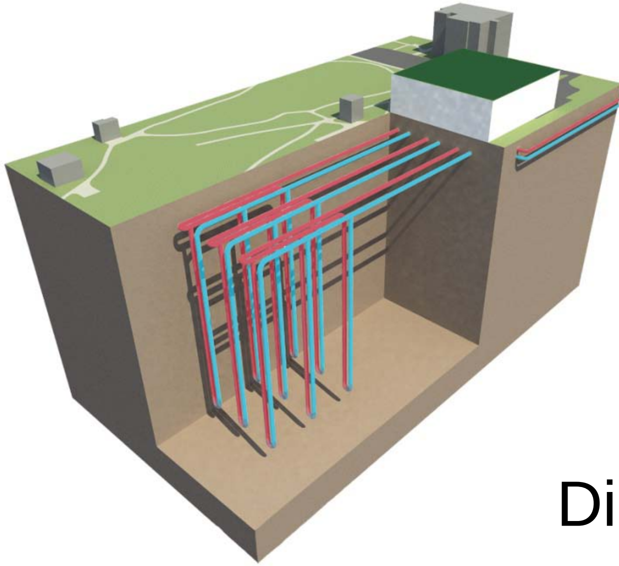
Geothermal Project Site Conditions

- Amount of land available influences type of well field.
  - Horizontal Open Trench
  - Horizontal Directional Bore
  - Vertical

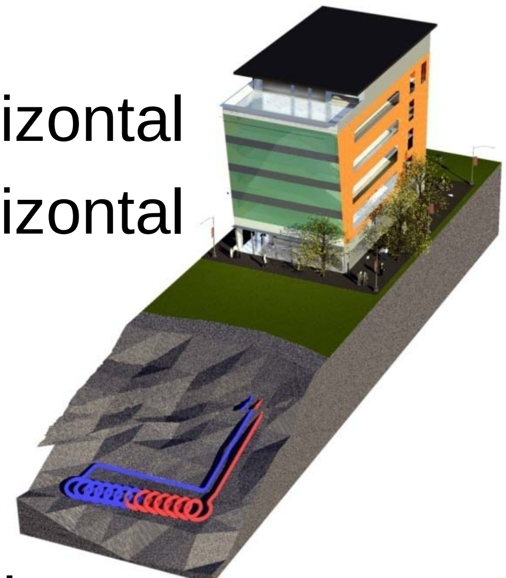
- Geological conditions dictate depth of vertical loop heat exchanger.

- Perform test well if system is greater than 50 tons.
  - Test well provides the following:
    - Site geological conditions
    - Conductivity
    - Diffusivity

Heat Exchanger Options



Vertical Heat Exchanger



Open Pit Horizontal

Directional Bore Horizontal

Closed Loop Pond/Lake

Open Loop Pond/Lake

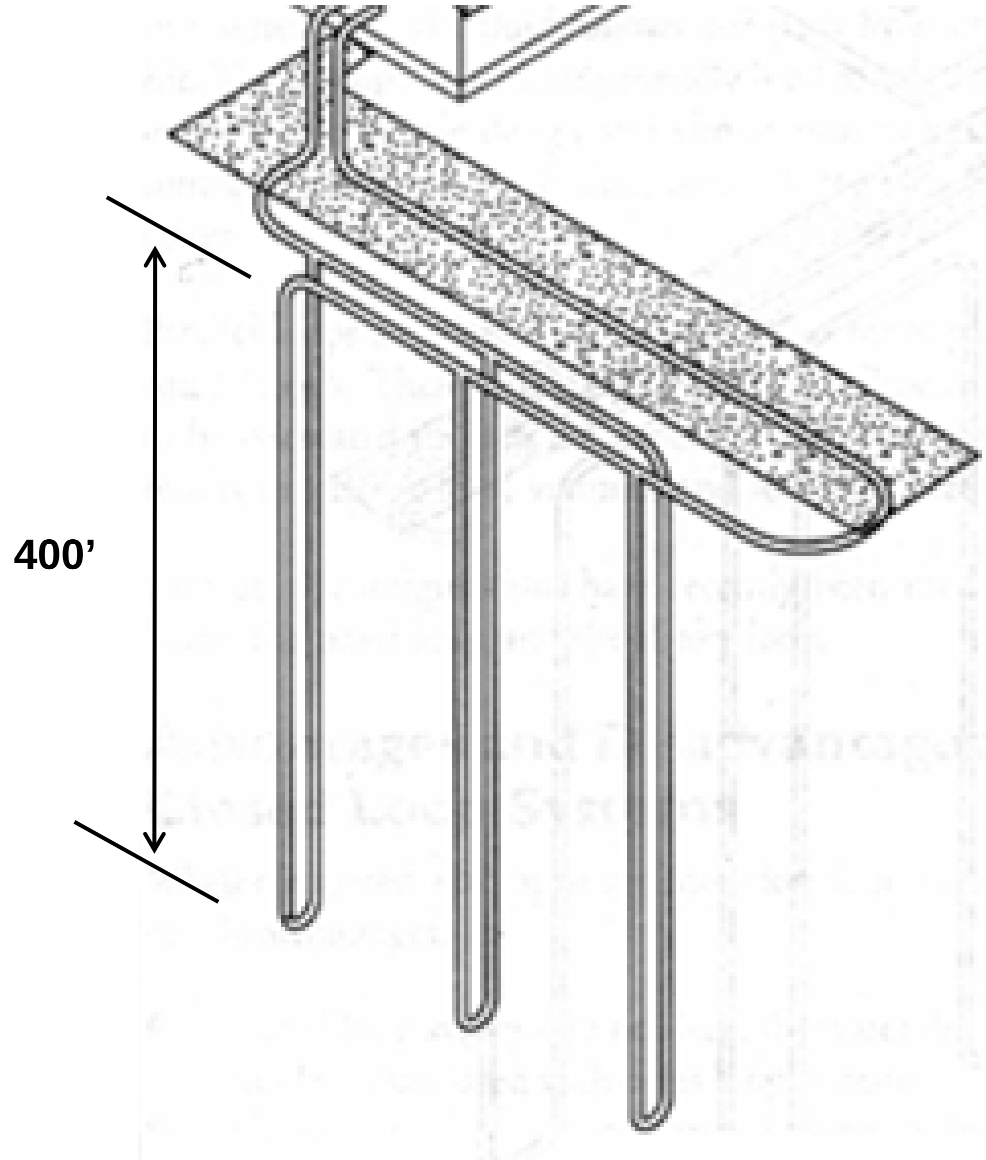
Loop Field Configurations

- Vertical Heat Exchanger
    - Horseshoe Reverse Return Pipe Layout
    - Straight Pipe Reverse Return

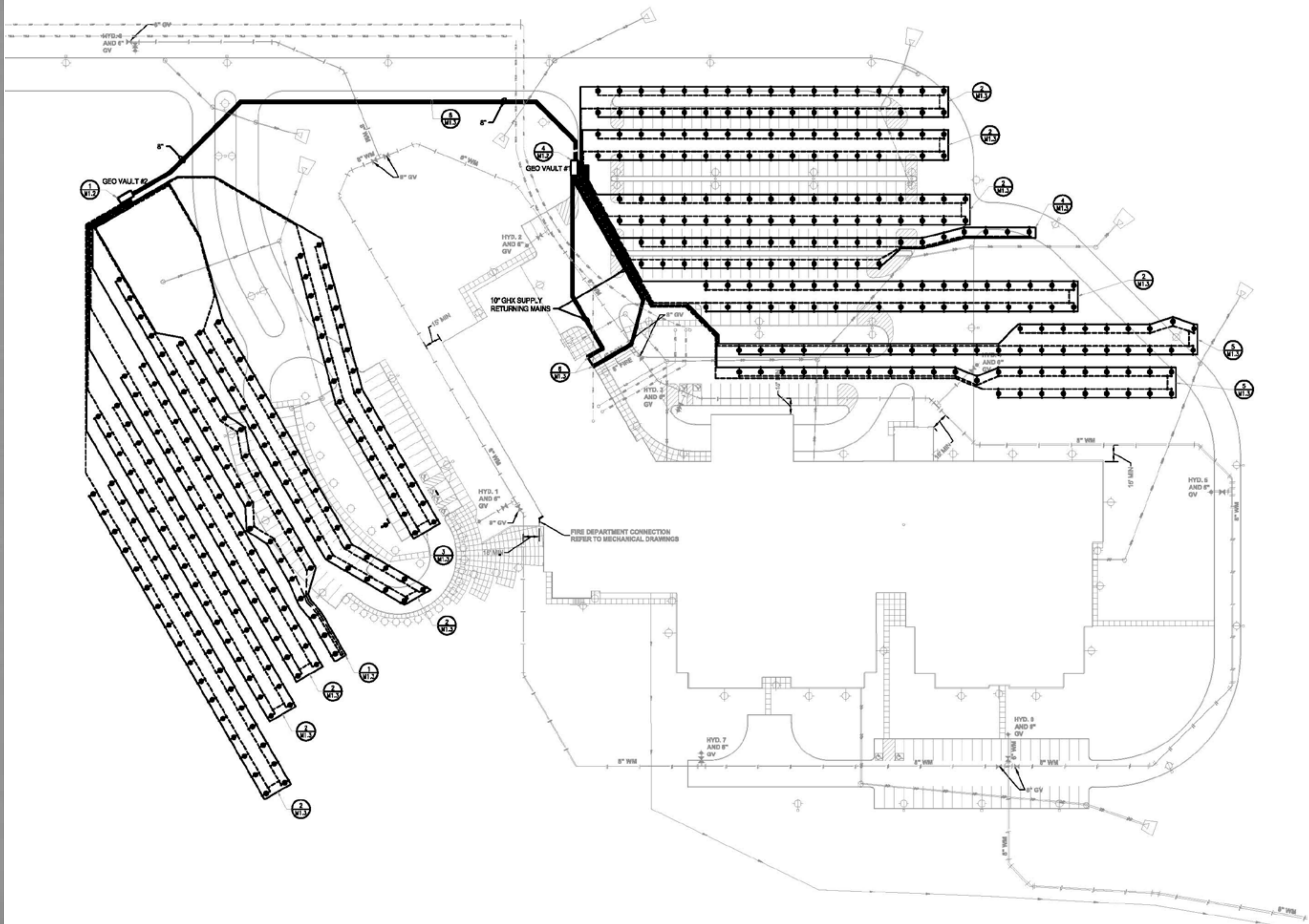
- Horizontal
    - Race Track
    - Slinky

- Pond
    - Matt
    - Slinky

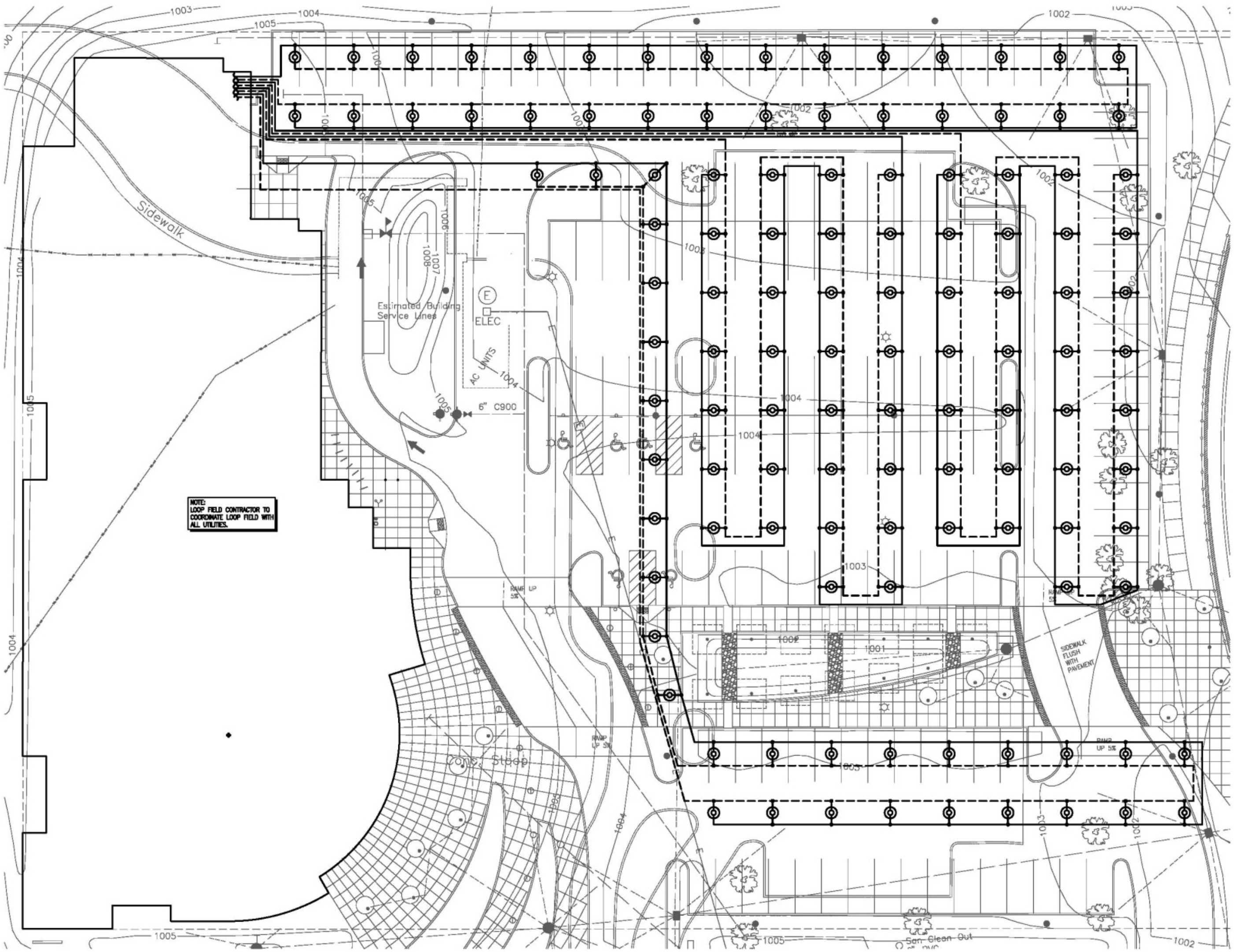
Vertical Well Field Diagram



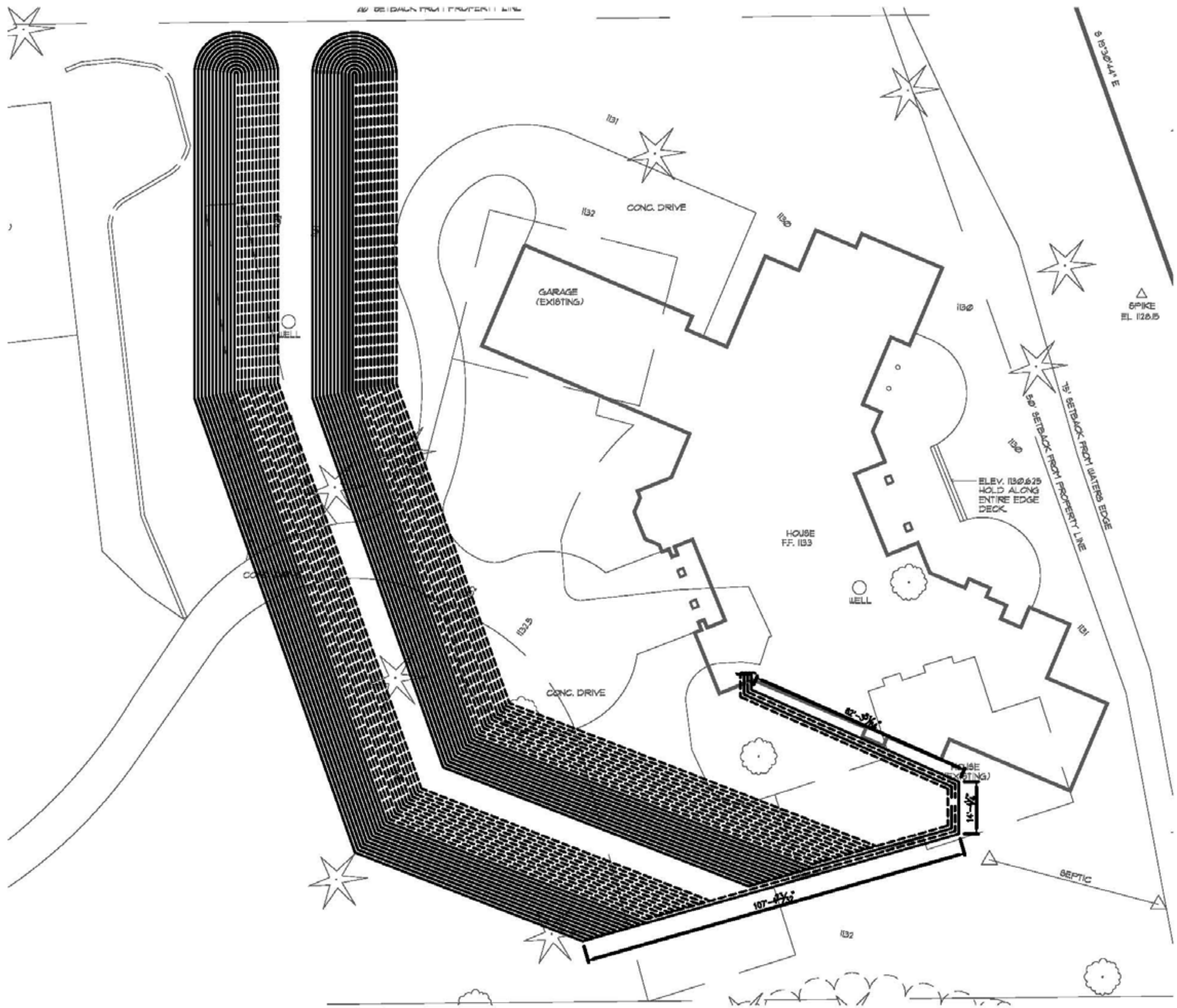
Horseshoe Reverse Return



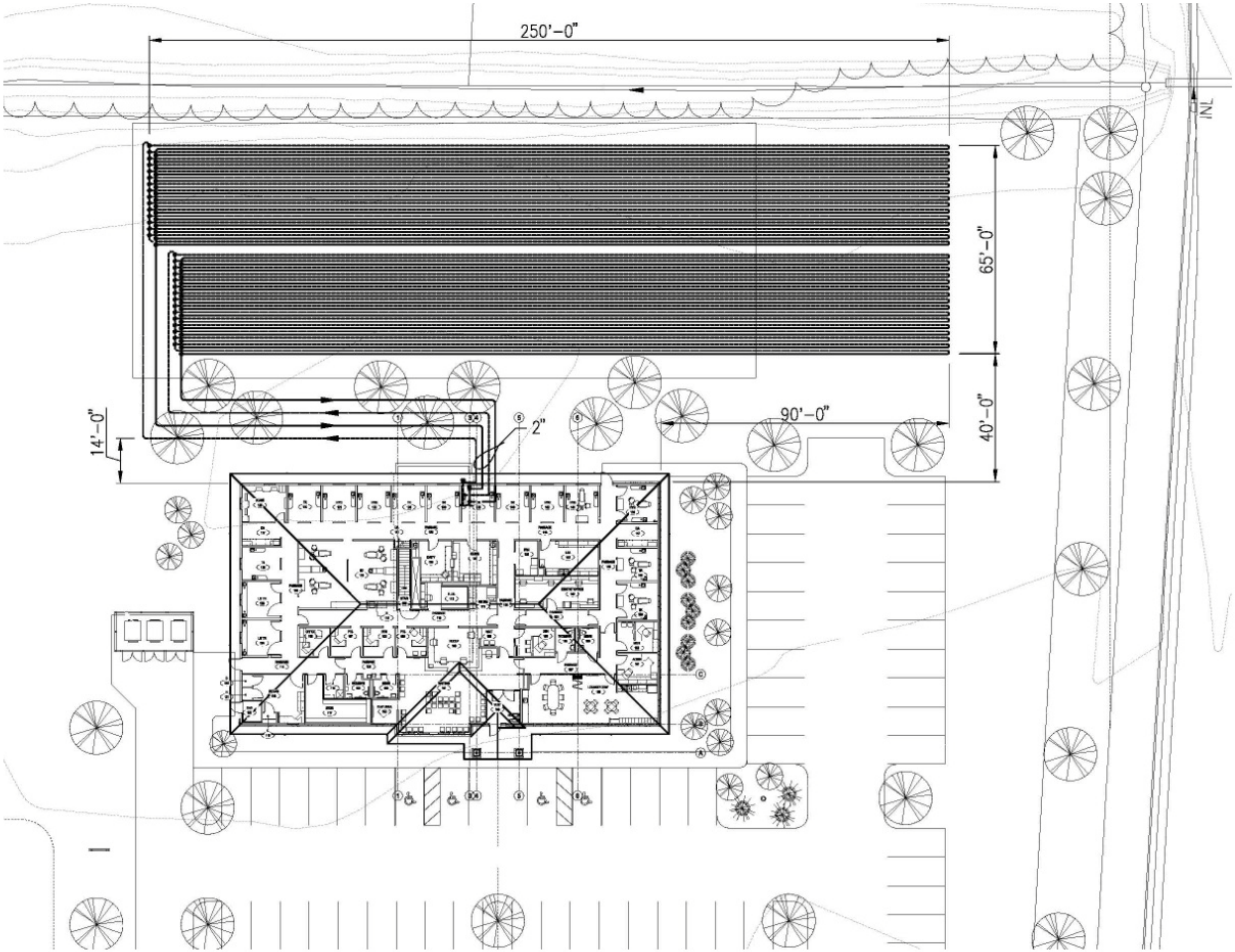
Horseshoe Reverse Return w/ No Vault



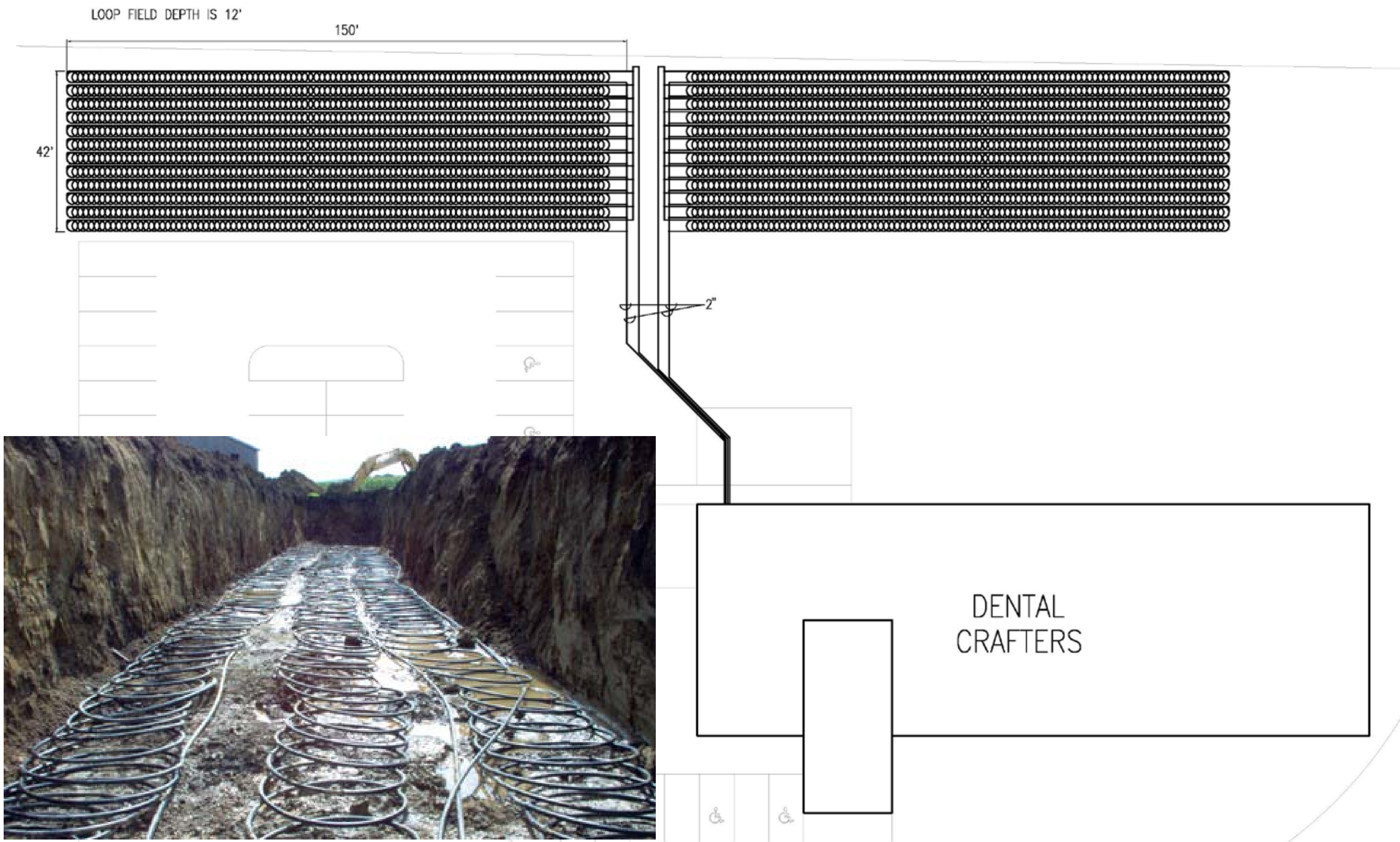
Race Track Horizontal Loop Field



Racetrack Horizontal Loop Field



Horizontal Slinky Loop Field

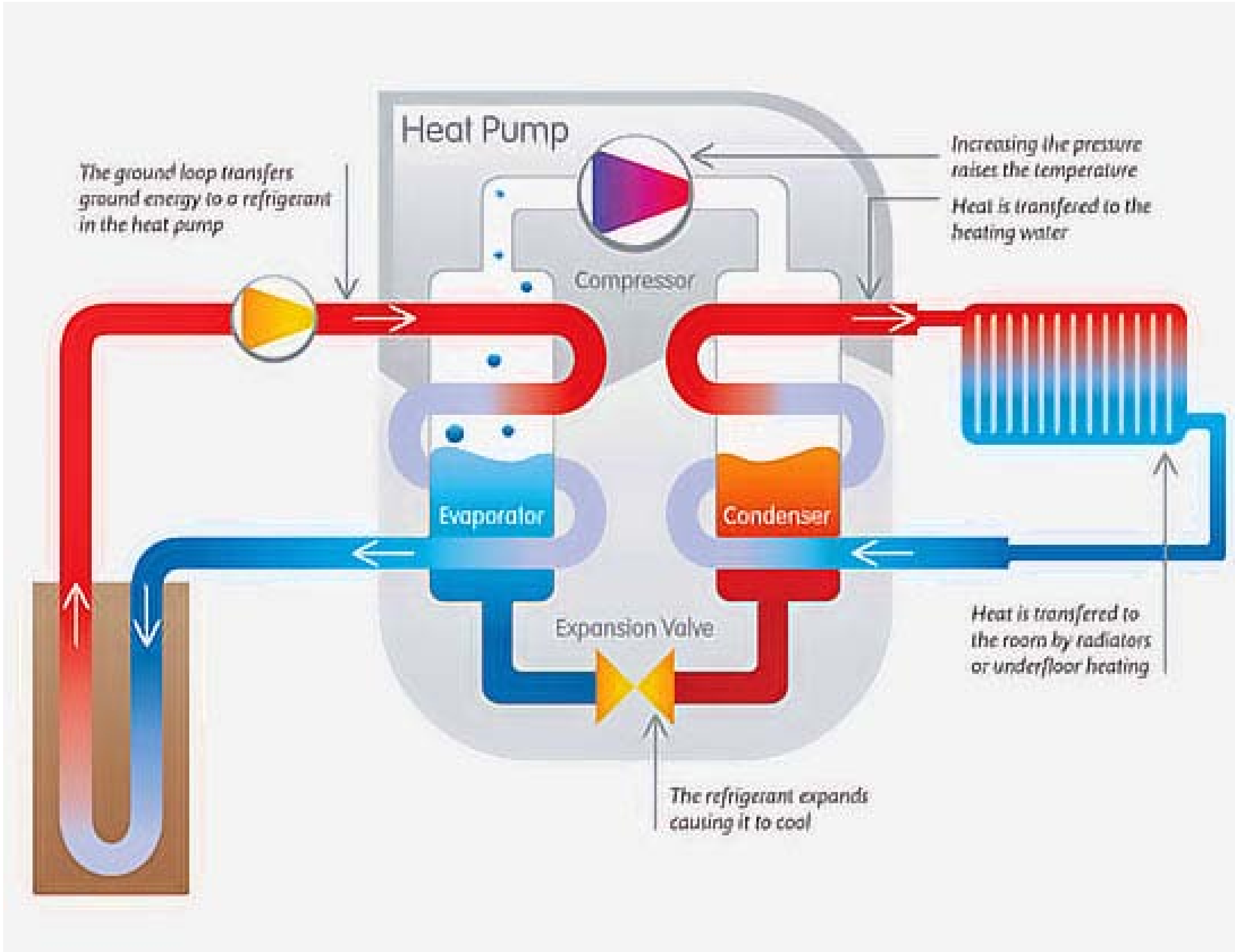


Equipment Selections

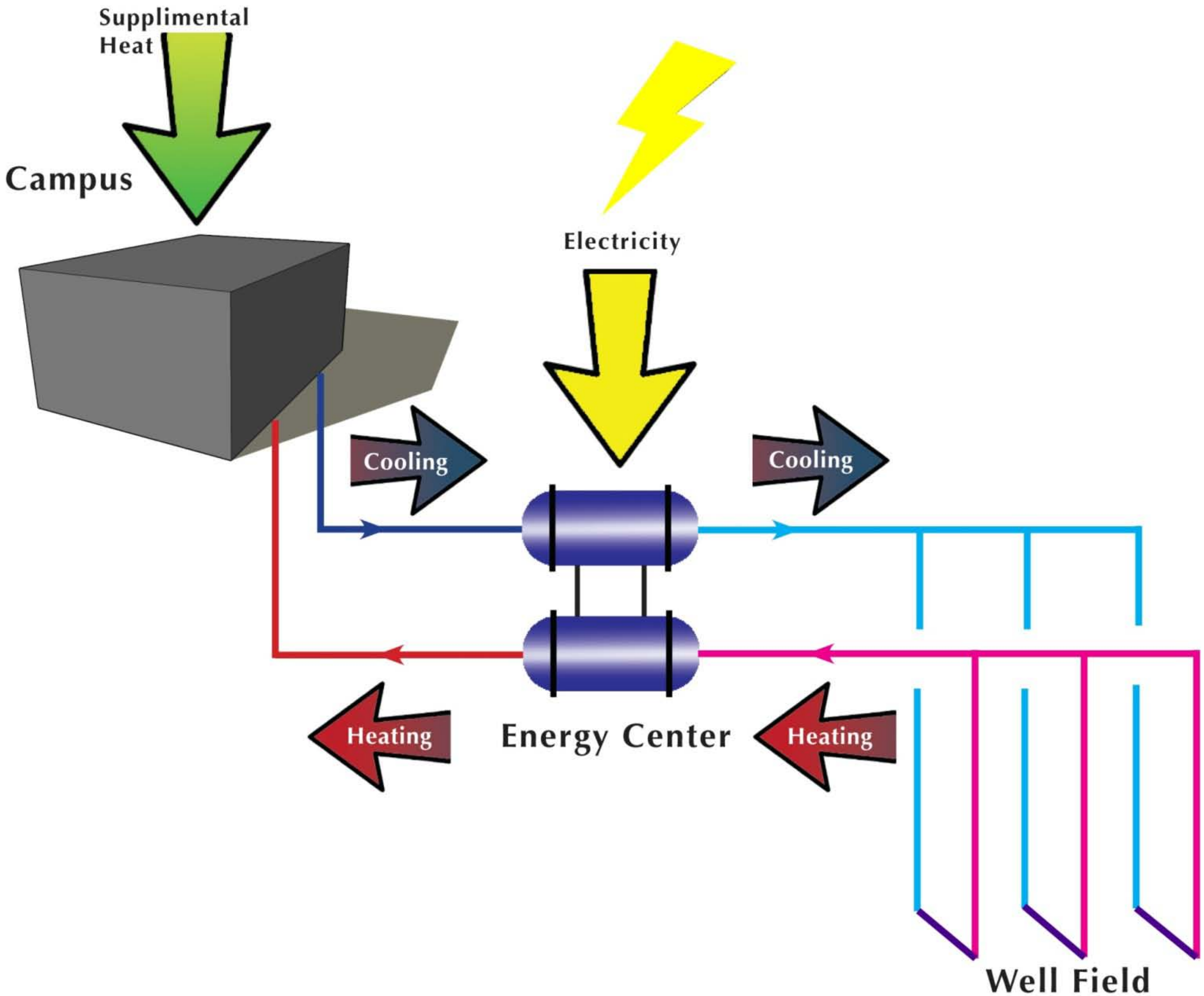
Equipment Selection

- Types of Systems
  - Water to Air Heat Pumps
    - Primary / Secondary
    - Primary
    - Dedicated Pump Packs
  - Water to Water Heat Pumps
    - Primary / Secondary Heating and Cooling
    - Primary / Secondary Heating and Cooling with Ice Storage

Air to Air Heat Pump



Water to Water Heat Pump



Glycol

- Use chemically treated water, if possible.

- When using glycol, check state & local regulations on the use of ethyl alcohol.

- Use propylene glycol, if ethyl alcohol is not permitted.

- Propylene glycol requires **20% minimum** to ensure no bacteria growth.

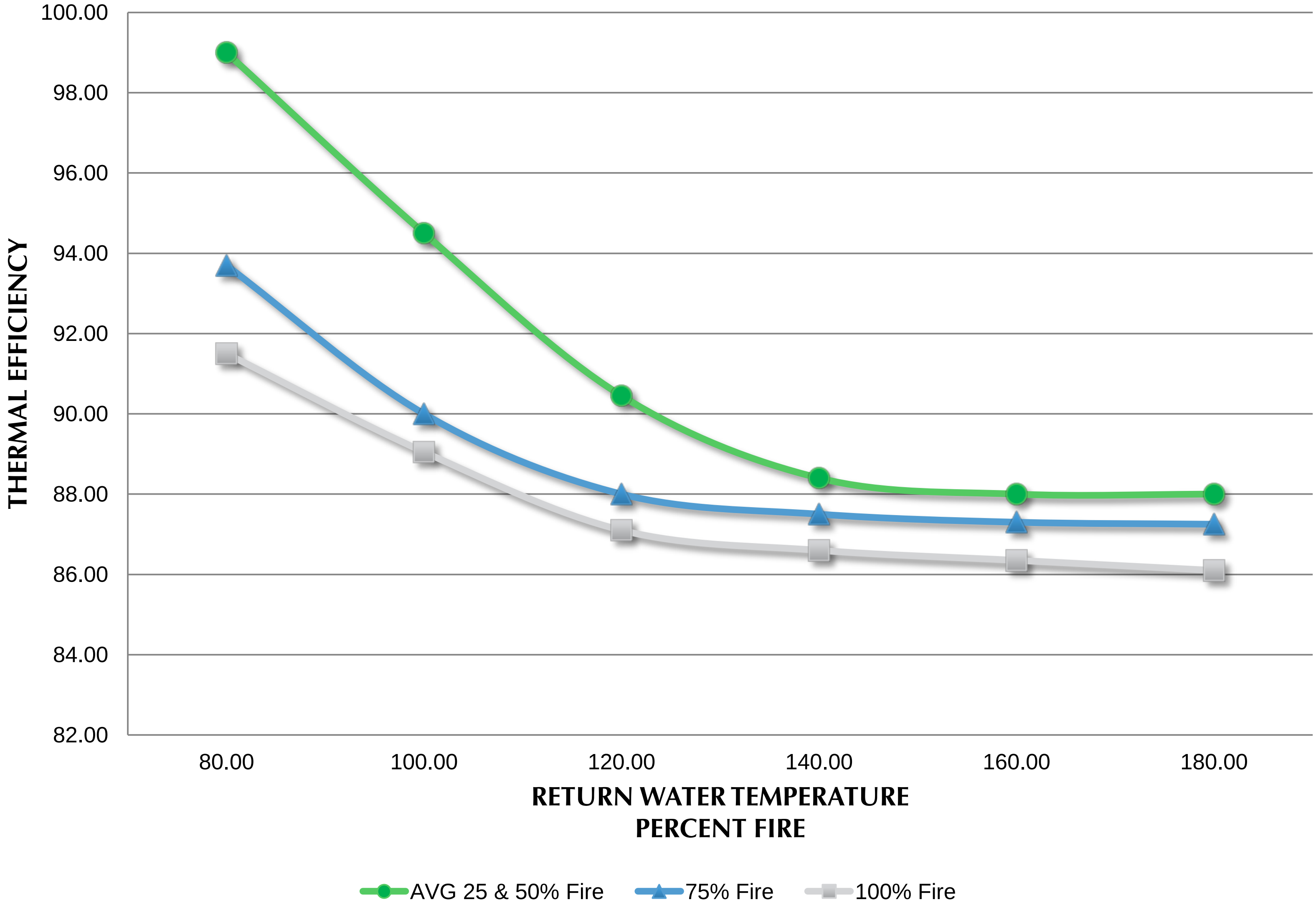
Low Water Temperature for Heating

- Select Water to Water Heat Pumps for a maximum of 120°.

- Select heating coils for a maximum 120° supply water temperature.

- In floor heat works well with 120°, there is no need for mix valves.

Boiler High Efficiency Curves



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Pressure Drop Calculations

PROJECT NUMBER/NAME:		
Total Flow Thru System:	75.4	GPM
Number of Circuits:	2	
	37.7	GPM/circuit
Number of Bores/Circuit:	12	
	3.14	GPM/bore

	COPPER		HDPE	
Pipe Size	Gal./ft	ID (in)	Gal./ft	ID (in)
0.75	0.0251	0.785	0.032	0.86
1	0.0429	1.025	0.047	1.075
1.25	0.066	1.265	0.075	1.358
1.5	0.093	1.505	0.099	1.554
2	0.161	1.985	0.154	1.943
2.5	0.248	2.465	-	-
3	0.354	2.945	0.335	2.864

OUTDOOR LOOP CALCULATIONS

Segment Name	Length of Pipe (ft)	Type of Pipe	GPM	SDR Rating	Pipe Dia (in)	Pipe ID (in)	Factor (HL/100')	Head Loss (ft water)	Volume (Gal./Ft Water)	Total Volume (Gal)
Manifold to bore 1	195	HDPE	37.7	11	2	1.943	3.5	6.825	0.154	30.036
B1 TO B2	20	HDPE	34.56	11	2	1.943	3.1	0.620	0.154	3.081
B2 TO B3	20	HDPE	31.42	11	2	1.943	2.5	0.500	0.154	3.081
B3 TO B4	20	HDPE	28.28	11	2	1.943	2.1	0.420	0.154	3.081
B4 TO B5	20	HDPE	25.13	11	2	1.943	1.7	0.340	0.154	3.081
B5 TO B6	20	HDPE	21.99	11	2	1.943	1.28	0.256	0.154	3.081
B6 TO B7	40	HDPE	18.85	11	1.5	1.554	2.88	1.152	0.099	3.941
B7 TO B8	20	HDPE	15.71	11	1.5	1.554	2.1	0.420	0.099	1.971
B8 TO B9	20	HDPE	12.57	11	1.25	1.358	2.6	0.520	0.075	1.505
B9 TO B10	20	HDPE	9.43	11	1.25	1.358	1.6	0.320	0.075	1.505
B10 TO B11	20	HDPE	6.28	11	1	1.075	2.3	0.460	0.047	0.942
B11 TO B12	20	HDPE	3.14	11	1	1.075	0.8	0.160	0.047	0.942
BORE 12 LOOP	220	HDPE	3.14	11	1	1.075	0.8	1.760	0.047	10.362
B12 TO MANIFOLD	175	HDPE	37.70	11	2	1.943	3.5	6.125	0.154	26.955
ADDITIONAL BORES (volume only)	2420	HDPE	-	11	1	1.075	-	-	0.047	113.982
									Total System Volume:	207.543

Total Loop Head Loss Calculations:	
Sub Total	19.9
Fittings (10% of piping)	2.0
TOTAL CALCULATED PRESSURE DROP	21.9
PG Multiplier	1.05
FINAL ADJUSTED PRESSURE DROP	23.0

System Head Loss (ft.)	
Outdoor Loop HL	23.0
Inside Loop HL	20.4
Loops w/ Safety Factor (10%)	47.7
Heat Pump	12.0
Control Valve	2
Balancing Valve	4
Air Separator w/strainer	2
TOTAL HEAD:	67.7

System Volume (gal.)	
Inside Volume	166.0
Outside Volume (x2)	415.1
Air Separator	3.0
Volume Safety Factor (10%)	58.4
TOTAL VOLUME:	642.5

Static Pressure (ft.)	
Elevation above Press. Tanks:	20

Temperature Range (F)	
Max System Temp:	90.0
Minimum System Temp:	30.0
DELTA T:	60.0

Pressure Drop Calculations

INDOOR LOOP CALCULATIONS

Segment Name	Length of Pipe (ft)	Type of Pipe	GPM	TYPE	Pipe Dia (in)	Pipe ID (in)	Factor (HL/100')	Head Loss (ft water)	Volume (Gal./Ft Water)	Total Volume (Gal)
MANIFOLD TO HP-11 T.O.	45	CU	75.4	L	3	2.945	1.7	0.765	0.354	15.930
HP-11 TO HP-6 T.O.	28	CU	71.40	L	2.5	2.465	3.5	0.980	0.248	6.944
HP-6 TO HP-2 T.O.	48	CU	61.50	L	2.5	2.465	2.8	1.344	0.248	11.904
HP-2 TO HP-3 T.O.	19	CU	6.50	L	1	1.025	3.3	0.627	0.043	0.815
HP-3 TO HP-4 T.O.	46	CU	14.60	L	1.5	1.505	2.4	1.104	0.093	4.255
HP-4 TO HP-5 T.O.	25	CU	18.60	L	1.5	1.505	3.7	0.925	0.093	2.313
HP-5 TO HP-7 T.O.	31	CU	28.20	L	2	1.985	1.9	0.589	0.161	4.991
HP-7 TO HP-8 T.O.	76	CU	37.50	L	2	1.985	3.4	2.584	0.161	12.236
HP-8 TO HP-9 T.O.	21	CU	44.10	L	2.5	2.465	1.5	0.315	0.248	5.208
HP-9 TO HP-10 T.O.	51	CU	50.10	L	2.5	2.465	1.8	0.918	0.248	12.648
HP-10 TO HP-1 T.O.	19	CU	56.40	L	2.5	2.465	2.3	0.437	0.248	4.712
HP-1 TO HP-6 T.O.	33	CU	61.50	L	2.5	2.465	2.8	0.924	0.248	8.184
HP-6 TO HP-11 T.O.	21	CU	71.40	L	2.5	2.465	3.5	0.735	0.248	5.208
HP-11 TO MANIFOLD	40	CU	75.40	L	3	2.945	1.7	0.680	0.354	14.160
PIPING TO HEAT PUMPS (volume)	150	CU	-	L	1.25	1.265	-	-	0.066	9.825
RETURN PIPING (volume only)	290	CU	-	L	2	1.985	-	-	0.161	46.690
									Total System Volume:	166.023

Total Loop Head Loss Calculations:	
Sub Total	12.9
Fittings (50% of piping)	6.5
TOTAL CALCULATED PRESSURE DROP	19.4
PG Multiplier	1.05
FINAL ADJUSTED PRESSURE DROP	20.4

Example Projects on a Campus Scale

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Geothermal for Campus Systems

- Applying Geothermal Systems in a New Way

- Take Advantage of Campus Simultaneous Heating & Cooling Loads

- Potential to Eliminate Coal & Gas Fired Boilers

- Save Energy

- Reduce Carbon Emissions

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Geothermal for Campus Systems

- Campus Thermal Profile
    - GSF by Building
    - Capital Development Master Plan
    - Building Design Loads
        - Heating
        - Cooling
    - Three (3) Years of Monthly Energy Consumption and Peaks
        - Electrical
        - Cooling
        - Heating
- Site Conditions
    - Campus Utility Drawings
    - Potential Well Field Locations
- Hydraulic Modeling of the Campus
- Ground Loop Design
- Building Systems
    - Run Tests on HWS Temp vs. OAT

What System Works Best for Your Campus?

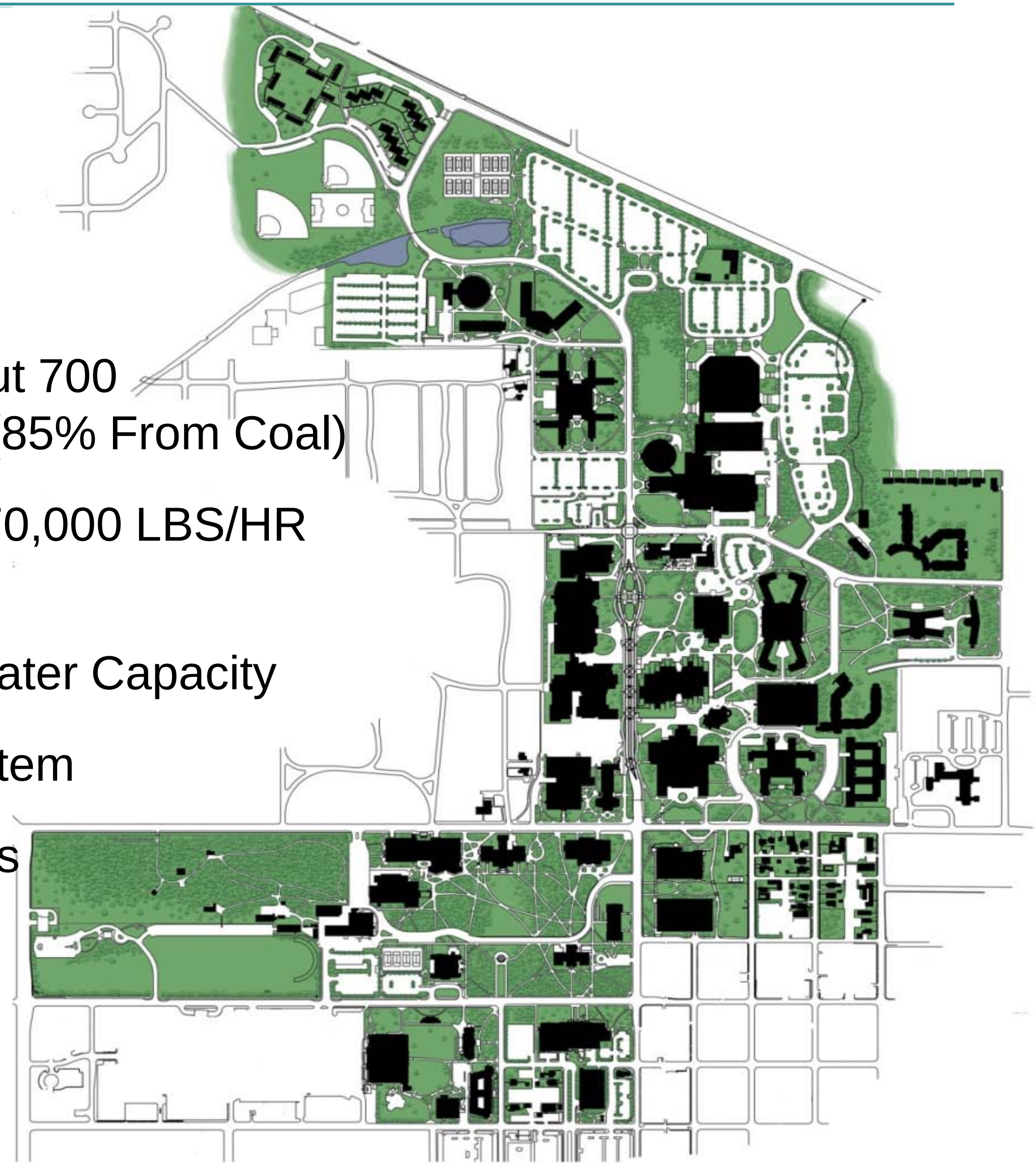
Identify Campus Thermal Profile

- Methods of identifying the campus thermal profile
  - Energy Model
    - Utilize Software
  - Utility Metering
    - Chiller/Heating Plant Metering
    - Building Level Metering

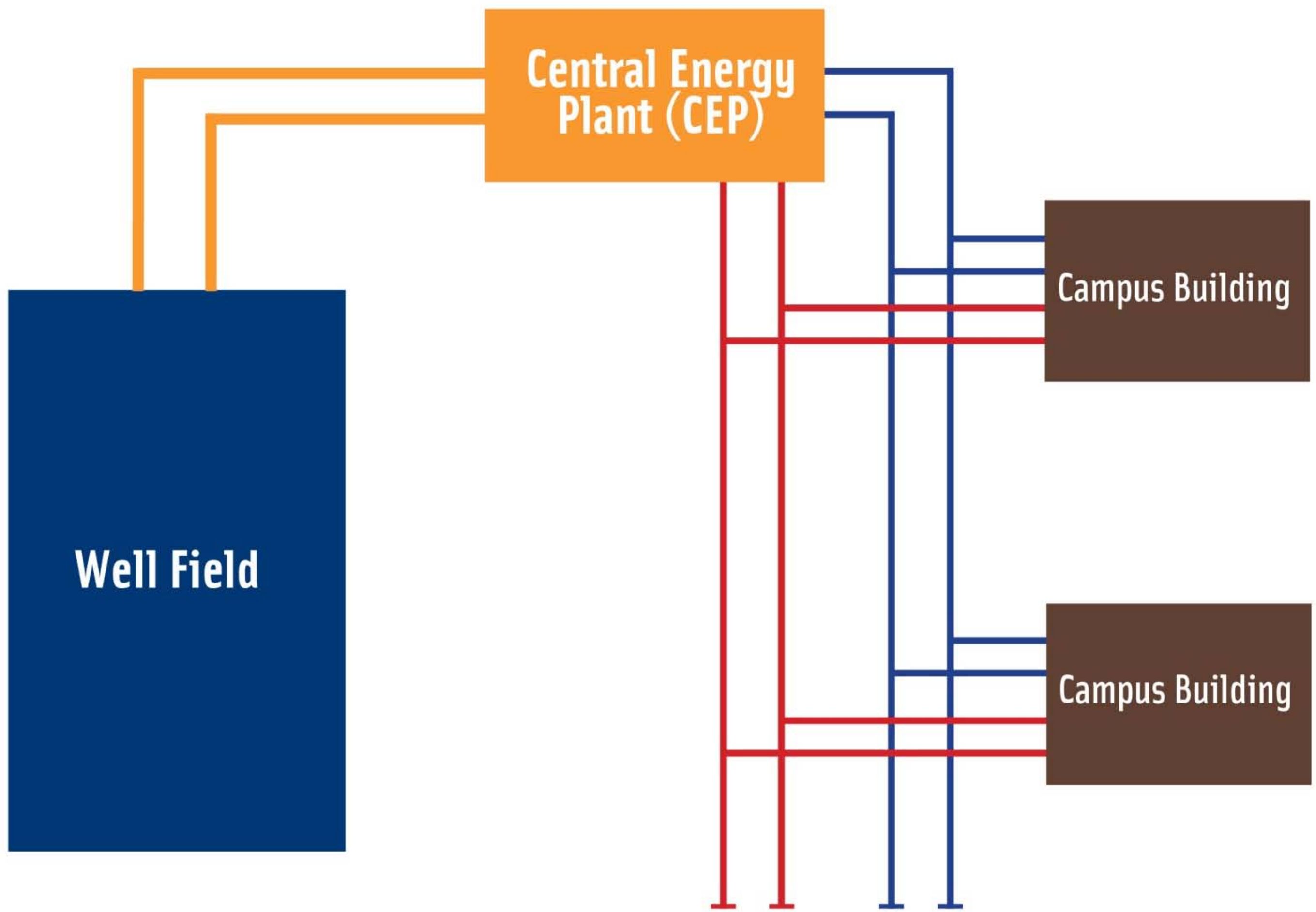
Ball State University; Muncie, IN

Ball State University Existing Systems

- 660 Acre Campus
- Four 25,000 PPH Coal Fire Boilers
- Three Gas/Oil Boilers
- Annually Produce About 700 Million Pounds Steam (85% From Coal)
- Winter Steam Peak: 170,000 LBS/HR at 150 Psi
- 10,000 Tons Chilled Water Capacity
- Steam Distribution System
- Five Centrifugal Chillers
- Chilled Water Distribution System

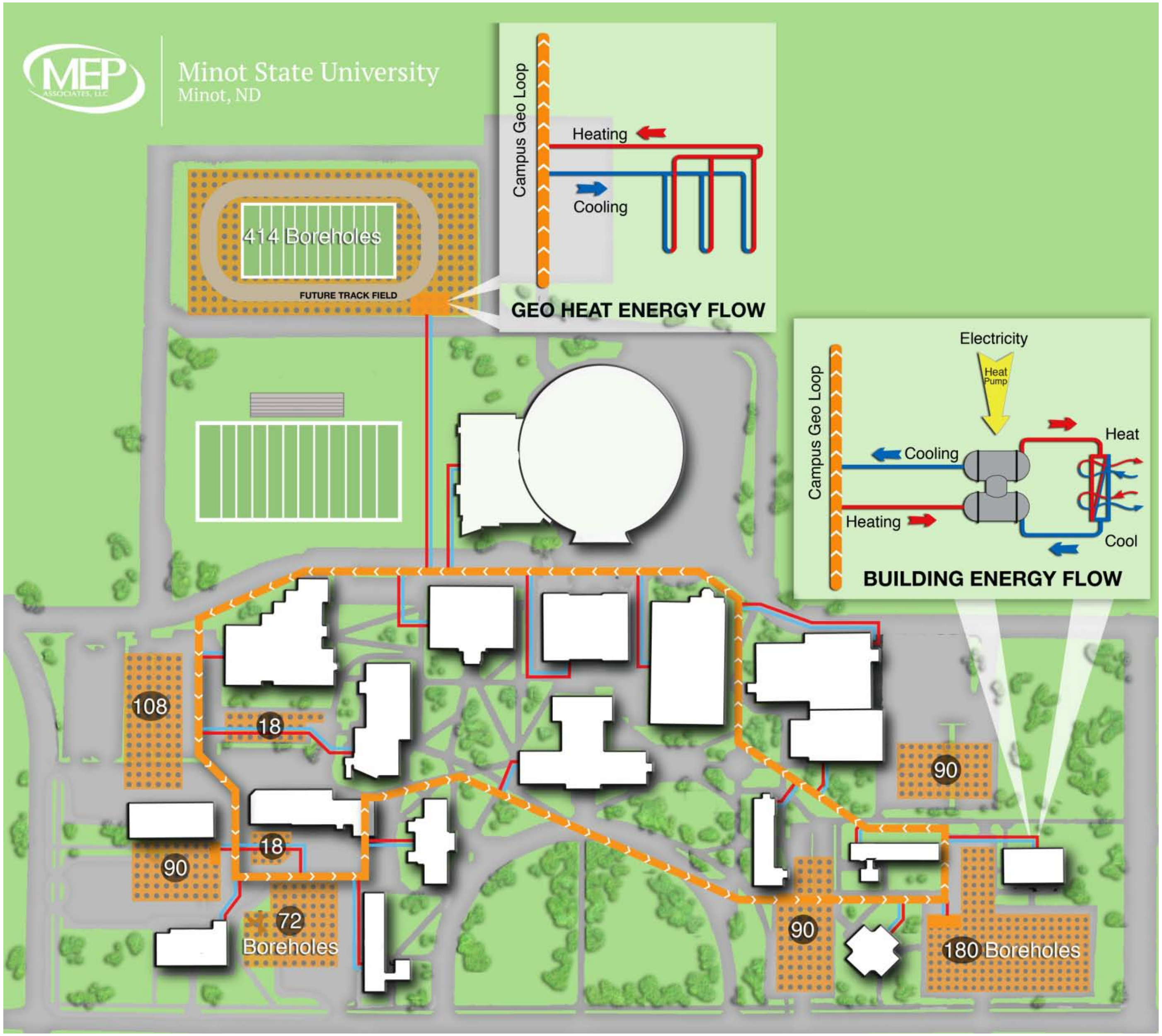


Four Pipe Distribution



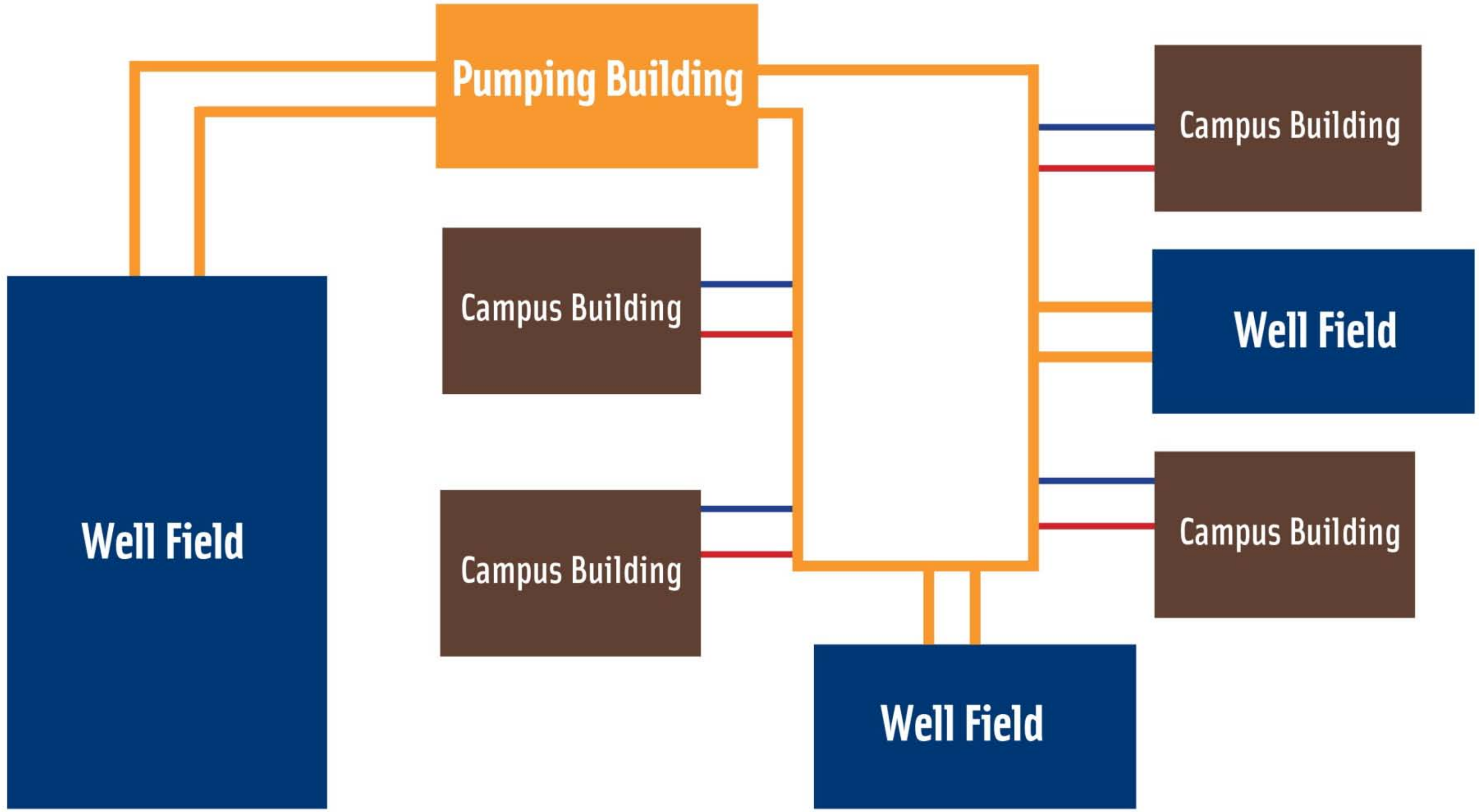
Minot State University; Minot, SD

- 1,196,000 GSF
- Seventeen (17) Buildings
- Steam Boiler Plant for Entire Campus
  - Three (3) Natural Gas Boilers
  - One (1) Coal-Fired Boiler
- Individual Building Cooling Systems

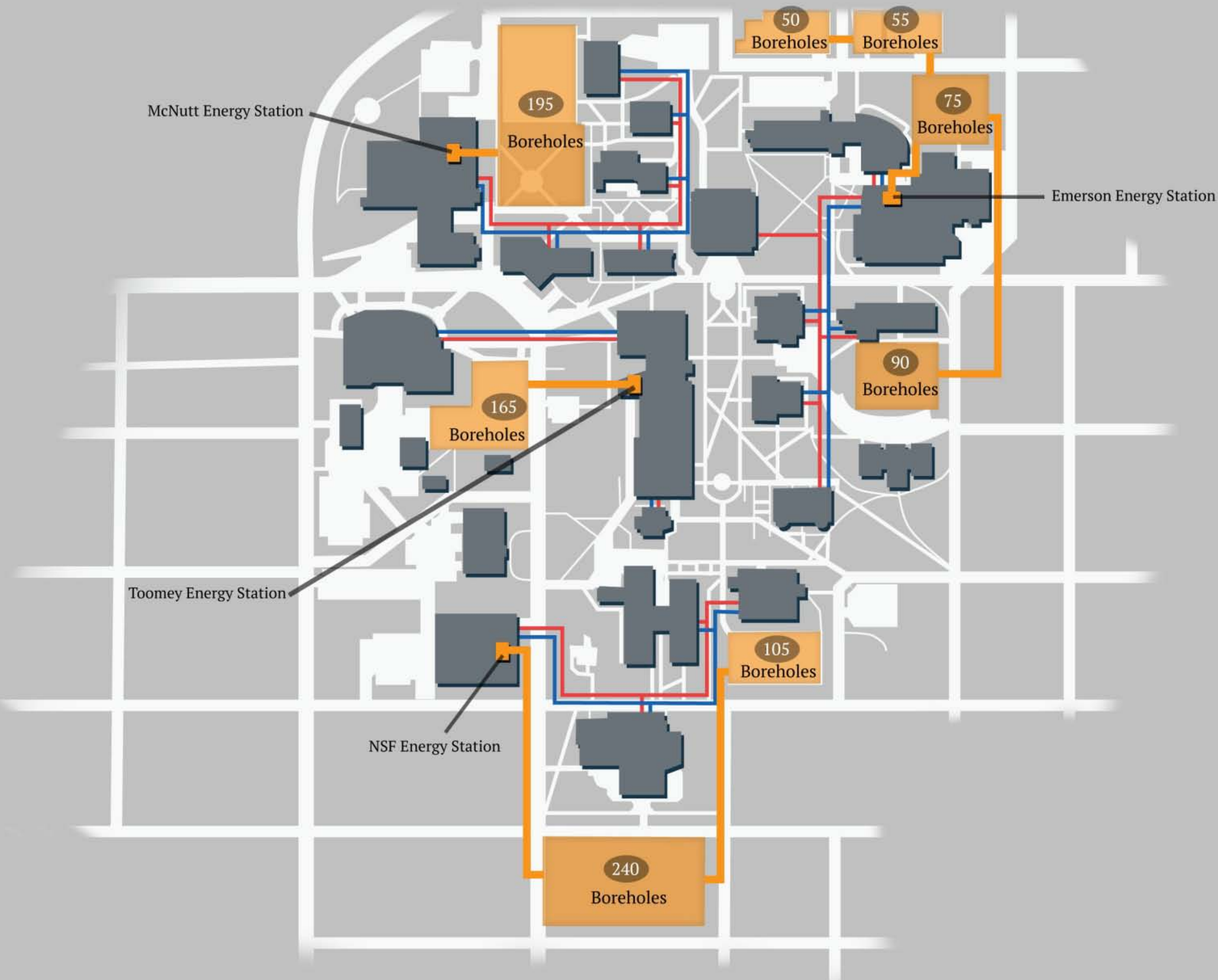


Minot State University
Minot, ND
414 Boreholes
FUTURE TRACK FIELD
Campus Geo Loop
Heating
Cooling
GEO HEAT ENERGY FLOW
Electricity
Heat Pump
Campus Geo Loop
Cooling
Heat
Heating
Cool
BUILDING ENERGY FLOW
108
18
18
90
72
Boreholes
90
90
180 Boreholes

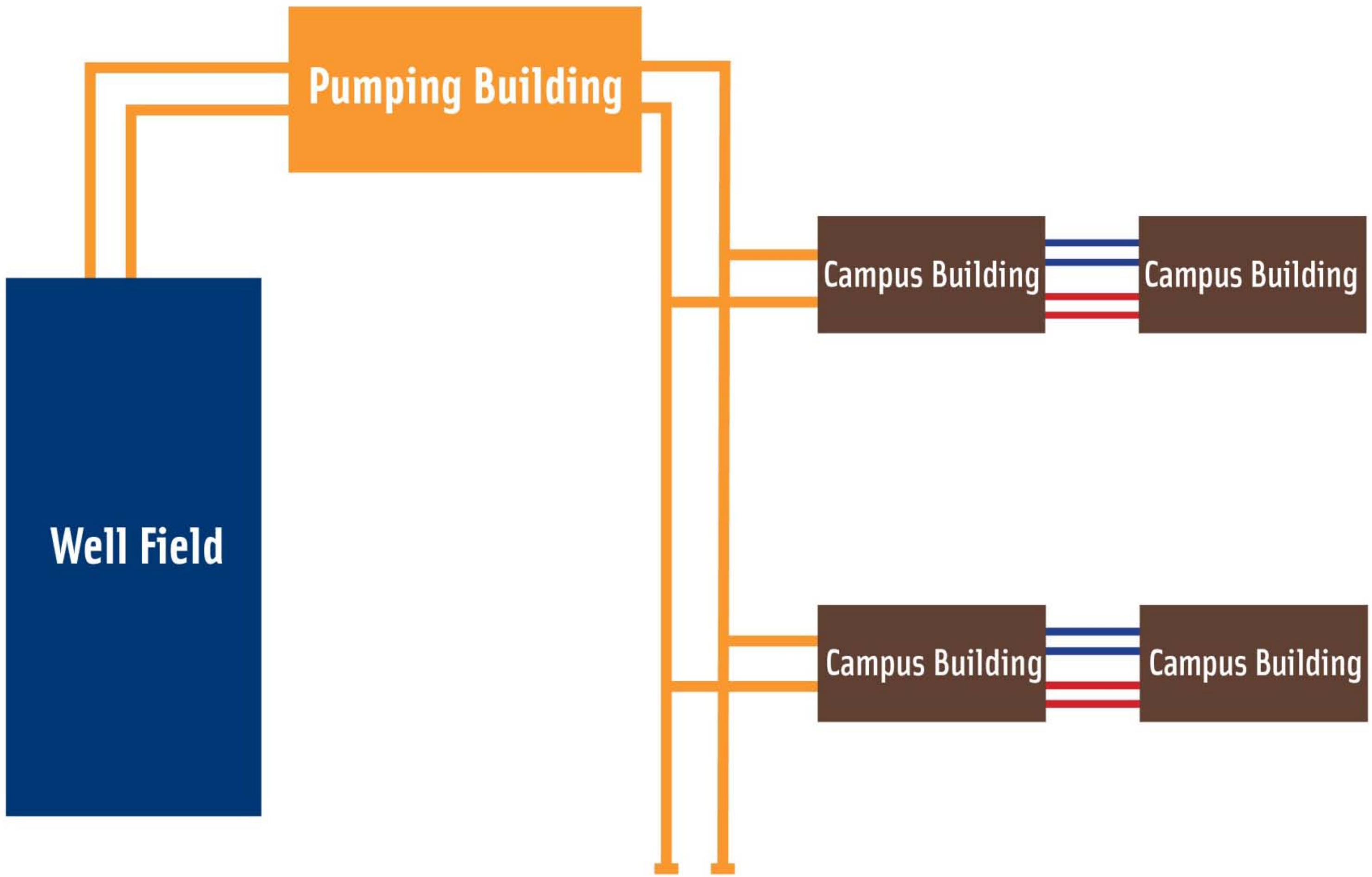
One Pipe Distribution



Missouri University of Science & Technology
Rolla, MO



Two Pipe Distribution



Questions?

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Thank You