

The Entropy Police

Geothermal heat pump design program

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Problem Statement

St. Gertrude's Monastery uses an antiquated coal-fired boiler; however, they want a more a reliable, economical, and environmentally friendly heat source. A cost-benefit analysis on alternative systems was conducted. The final system was then designed in a program with thermal analysis capabilities.

Client's Needs

- Cost benefit analysis comparison
- A system that costs less than \$750,000
- Environmentally friendly
- Building does not require cooling
- More reliable system
- Does not require changing heat delivery system

Objectives

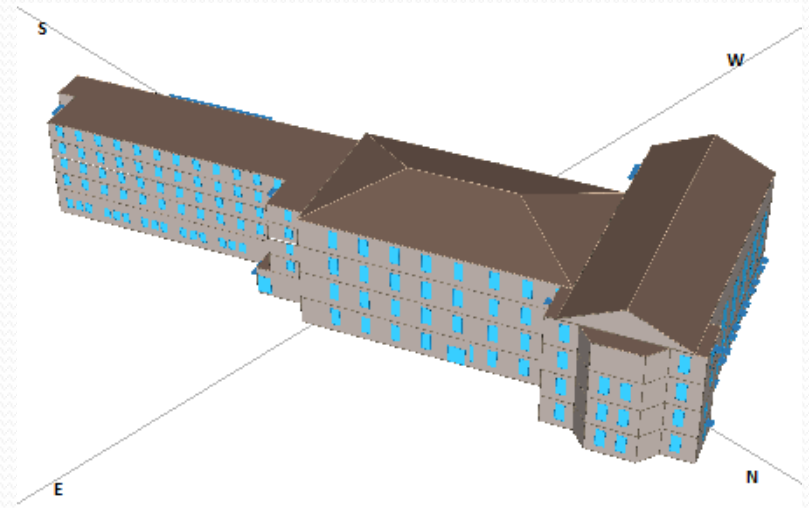
- Cost-benefit analysis comparison for:
 - Coal fire boiler
 - Geothermal
 - Biomass boiler
 - Electric boiler
 - Propane boiler
 - #2 heating oil
- Design a program in Engineering Equation Solver that:
 - Analyzes a geothermal system
 - Utilizes engineering economics to optimize pipe dimensions and flow
 - Has a simple user interface to allow easy design modifications

Table of Specifications

- Building square footage: 55,000 ft²
- Ground temperature 64° F
- Frost line approximately 18"
- Water going to radiator system needs to be at 120 °F

Building Heating Load

- 3 methods of calculation
 - Current fuel usage: 549 MBH
 - Hand Calculations: 594 MBH
 - eQUEST Model: 687 MBH
- Annual Heating Load (degree day method): 1435 MBtu



Cost-Benefit Analysis

	Coal	Geothermal	Biomass	Electric	Propane	#2 Fuel Oil
Fuel Cost (\$/MBTU)	13.52	8.37	18.67	35.17	34.81	37.72
Operation Cost (per year)	\$50,499	\$12,011	\$26,360	\$50,468	\$49,952	\$54,128
Maintenance Cost (per year)	\$24,501	\$1,000	\$24,500	\$0.00	\$2,000	\$2,000
Initial Cost (Including material and install costs)	\$0	\$277,000-\$700,000	\$53,375	\$36,600	\$52,975	\$64,350
Total Cost Over System Life Cycle (20 years)	\$1,500,000	\$537,220-\$960,220	\$1,070,575	\$1,045,960	\$1,092,015	\$1,186,910
Expected Life of Boiler/heat pump	n/a	20 years	20 years	20 years	25 years	22 years

Decision Matrix

Criteria	Weight	Coal	Geothermal	Biomass	Electric	Propane	#2 Fuel Oil
Initial Cost	5.00	5.00	1.00	4.00	3.00	3.00	3.00
Operating Cost	5.00	4.00	5.00	3.00	2.00	2.00	2.00
Ease of Use	4.00	2.00	5.00	1.00	5.00	4.00	3.00
Efficiency	3.00	2.00	5.00	3.00	5.00	3.00	3.00
Env. Impact	2.00	1.00	5.00	3.00	4.00	2.00	3.00
Fuel Availability	1.00	3.00	5.00	4.00	5.00	4.00	3.00
<u>Total</u>	-	<u>66.00</u>	<u>80.00</u>	<u>58.00</u>	<u>73.00</u>	<u>54.00</u>	<u>55.00</u>

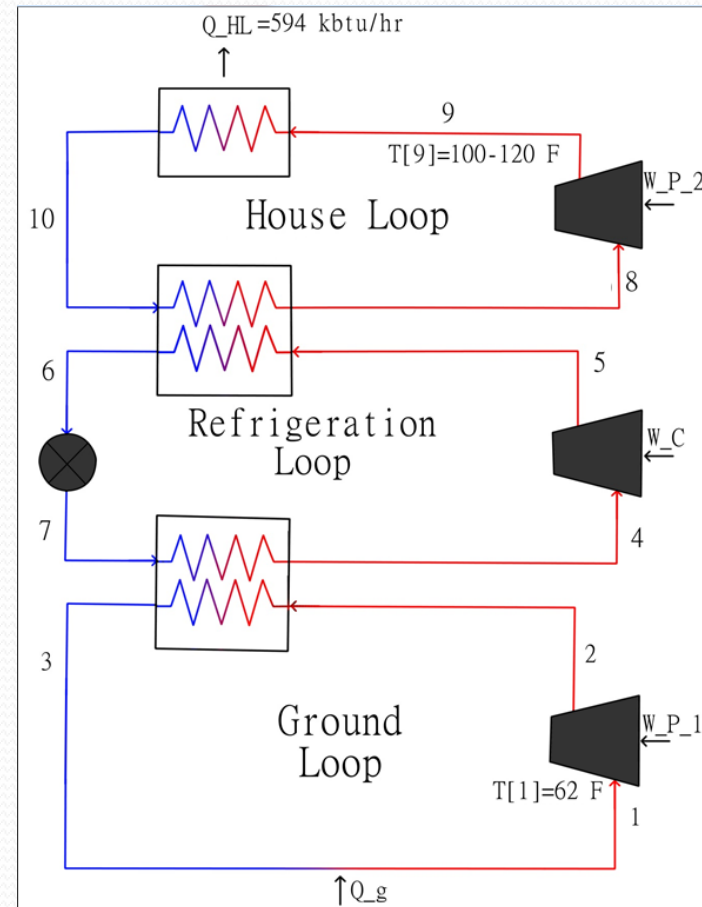
Geothermal Heat Pump

- Environmentally friendly
- Sustainable
- High initial cost, low operating cost
- Single system for heating and cooling; in some cases hot water heating

Geothermal System

Components

1. Heat Exchangers
2. Pump/Compressor
3. Pipes and Fittings
4. Valve
5. Working Fluid



Geothermal Modeling

- EES allows convenient analysis with built-in thermodynamic properties.
- Performs unit analysis
- Simple user interfaces

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{-----Modeling-----}  
"First Law of Thermodynamics"  
"! Ground Loop"  
  Q_dot_gr*convert(KBtu,Btu) = W_dot_p_ground*convert(hp,Btu/hr) + Q_dot_ground*convert(KBtu,Btu)  
  W_dot_p_ground*eta_p_1 = m_dot_1*(h[2] - h[1])*convert(btu/hr,hp)  
  Q_dot_ground = ((k_pipe*A_pipe*(T[1] - T[3]))/s)*convert(Btu,kBtu)  
  Q_dot_ground = m_dot_1*(h[1] - h[3])*convert(Btu,kBtu)  
"! Vapor Compression Refrigerator Loop"  
  Q_dot_rh = Q_dot_gr + W_dot_c*convert(hp,kBtu/hr)  
  W_dot_c*convert(hp,Btu/hr)*eta_c = m_dot_2*(h[5] - h[4])  
"! House Heating Loop"  
  Q_dot_H = m_dot_3*(h[9] - h[10])*convert(btu,kbtu)  
  W_dot_p_2*eta_p_2 = m_dot_3*(h[9] - h[8])*convert(btu/hr,hp)  
  Q_dot_rh*convert(kBtu,Btu) + W_dot_p_2*convert(hp,Btu/hr) = Q_dot_H*convert(KBtu,Btu)
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Thank You