

Geothermal heat pump design program and cost benefit analysis

The Entropy Police

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Problem Statement

St Gertrude's Monastery currently runs off of a coal-fired boiler; however, the sisters want to move to a more a reliable, economical, and environmentally friendly heat source. Currently, the sisters need a cost-benefit analysis on alternative systems, so that they may make an informed decision on how to proceed.

Objectives

- Cost-benefit analysis comparison for alternatives:
 - Coal fire boiler
 - Propane boiler
 - Electric boiler
 - Biomass boiler
 - Biodiesel boiler
- Develop an EES computer model
- Design optimized geothermal system

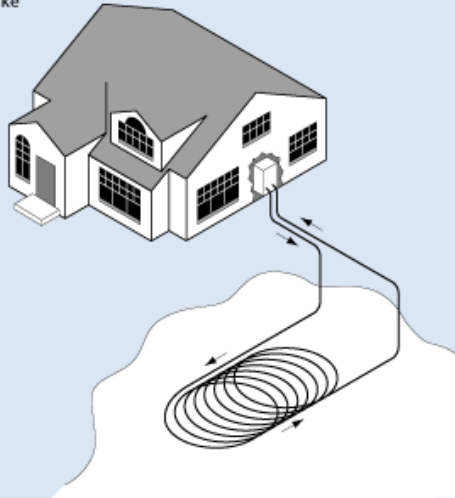
Table of Specifications

- Maximum heating load per month is 261 MBtu.
- Yearly total is 921.7 MBtu.
- Building square footage: 49485 ft².
- Ground temperature 64° F, water temperature 52° F.
- Frost line approximately 18”.
- Water going to radiator system needs to be at least 100° F.

Results of Project Learning to Date

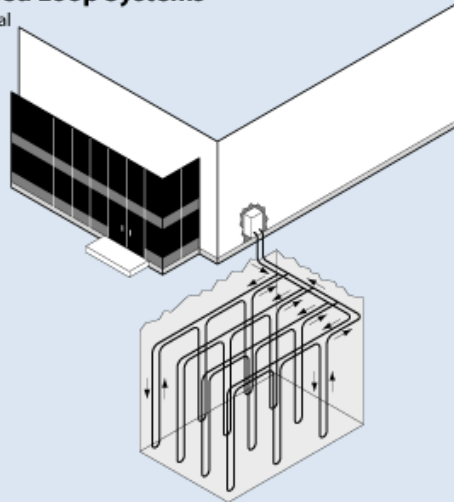
Closed Loop Systems

Pond/Lake



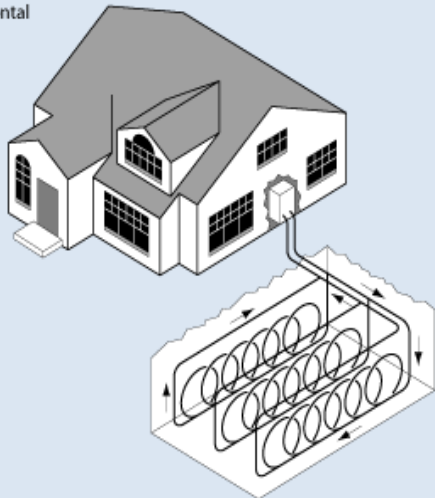
Closed Loop Systems

Vertical

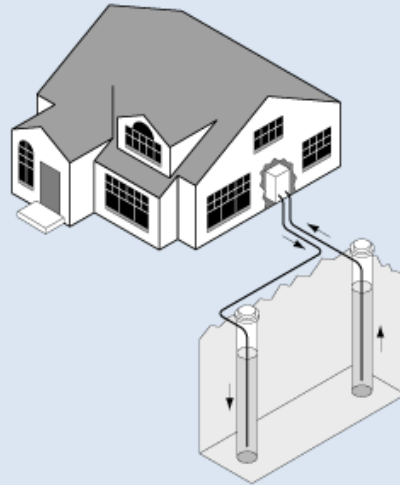


Closed Loop Systems

Horizontal



Open Loop Systems



Types of heat pump systems that are commonly used in industry.

Closed Loop

- Pond/lake
- Vertical
- Horizontal

Open Loop

- Each system has varying benefits and drawbacks, which is seen in pricing, space, and efficiency.

Pricing (lowest to highest)

- Open loop
- Pond/lake
- Horizontal
- Vertical

Heating Load

Reference Load

VisualDOE Tool

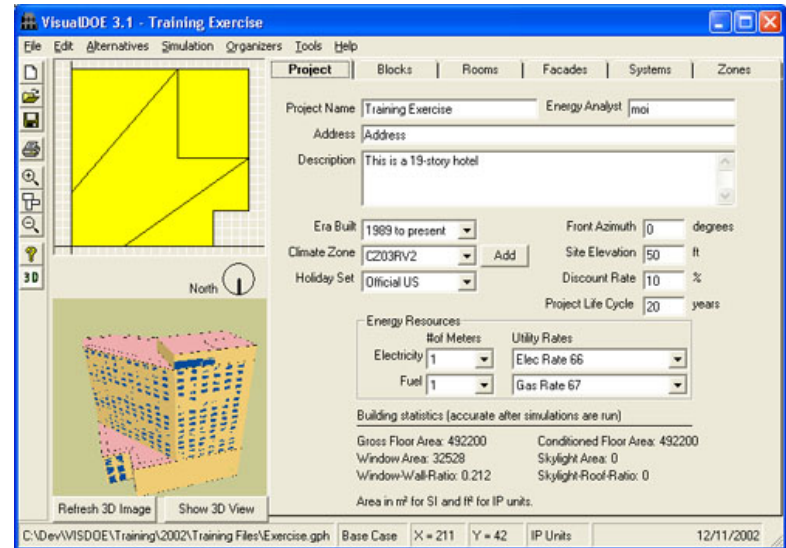
Reference load based on utility costs:

m (mass flow rate - peak load) – 104.5 lbs/hr

HHV (heating value) – 13840 Btu/lb

ϵ (boiler efficiency) – 75%

$$Q = m (HHV \times \epsilon) = 1.08 \text{ MBtu/hr}$$



System Data

	Coal	Biomass	Electric	Propane
Operation Cost (\$/MBTU)	8.00	9.09	34.22	24.82
Maintenance Cost	Working with vendors to determine cost			
Installation Cost				
Environmental Impact	Non-renewable	Renewable	Semi-renewable	Non-renewable
Emissions (lbs/MWh)	CO ₂ = 2,249 SO ₂ = 13 NO = 6	Carbon neutral	Low emission 50% hydro-electric 25% natural gas 25% other	Clean burning CO - Low

Geothermal

- Environmentally friendly
- Fairly sustainable
- High initial cost, low operating cost (65-70% less than traditional systems)
- Federal and state tax credits
- Single system for heating and cooling; in some cases hot water heating

System Summaries

- New systems must meet rules and regulations
- Electric and propane yield high costs comparatively
- Biomass, cheap and clean
 - Existing system can be converted
- Facility needed to house system?
- Geothermal analysis in progress

Time Line

- November 14th – Model of heating load
- December 31st – Cost benefit analysis
- April 1st – System model development and validation
- April 12th – Optimized system design
- April 24th – Final presentation and report
- May 2nd – Design Expo