

# The Entropy Police

Geothermal heat pump design program and cost benefit analysis

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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.

# Client's Needs

- Cost benefit analysis comparison
- A system that would cost about \$750,000
- Environmentally friendly option preferred
- Building does not require cooling
- More reliable system
- Does not require changing heat delivery system

# Objectives

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

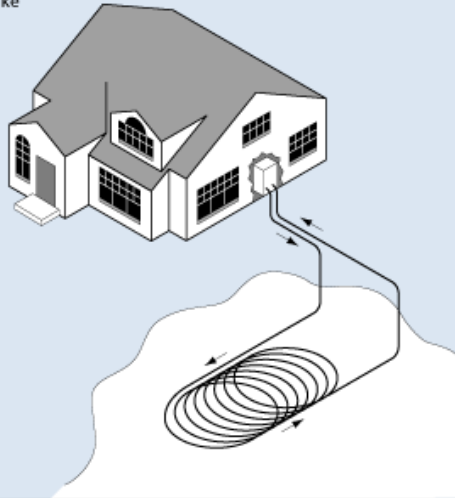
# Table of Specifications

- Maximum heating load per month is 261 MBtu.
- Yearly total is 921.7 MBtu.
- Building square footage: 49485 ft<sup>2</sup>.
- 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

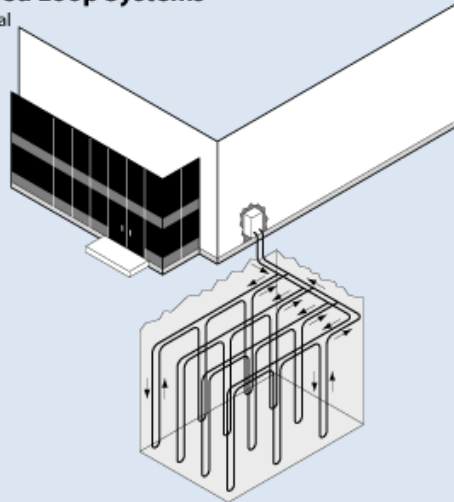
## Closed Loop Systems

Pond/Lake



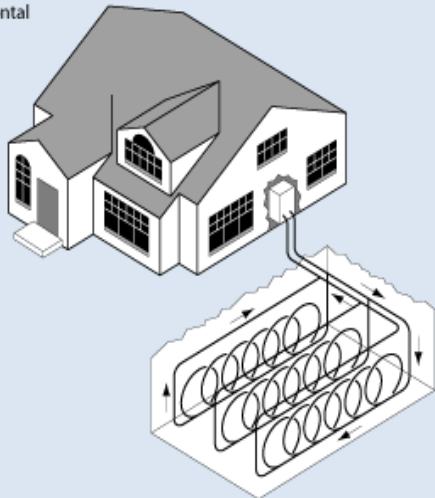
## Closed Loop Systems

Vertical

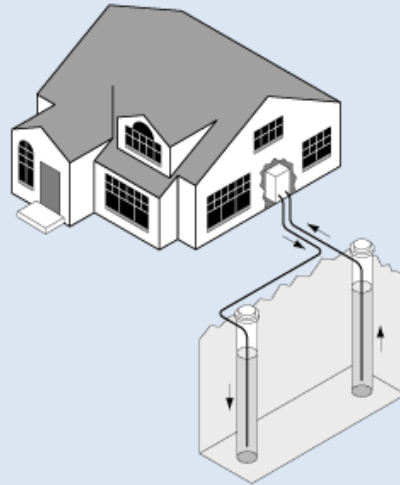


## Closed Loop Systems

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 based on utility costs:

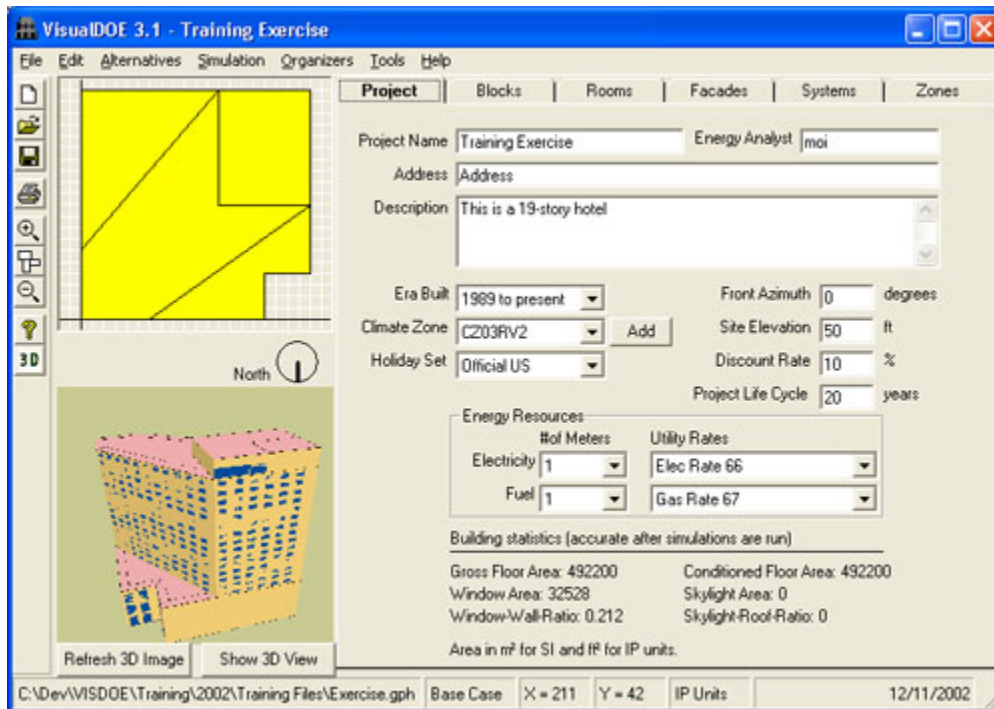
$m$  (mass flow rate - peak load) – 104.5 lbs/hr

HHV (heating value) – 13840 Btu/lb

$\varepsilon$  (boiler efficiency) – 75%

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

# Actual heating load – VisualDOE



VisualDOE 3.1 - Training Exercise

File Edit Alternatives Simulation Organizers Tools Help

Project Name: Training Exercise Energy Analyst: moi

Address: Address

Description: This is a 19-story hotel

Era Built: 1989 to present Front Azimuth: 0 degrees

Climate Zone: C203RV2 Site Elevation: 50 ft

Holiday Set: Official US Discount Rate: 10 %

Project Life Cycle: 20 years

Energy Resources:

#of Meters	Utility Rates
Electricity: 1	Elec Rate 66
Fuel: 1	Gas Rate 67

Building statistics (accurate after simulations are run)

Gross Floor Area: 492200	Conditioned Floor Area: 492200
Window Area: 32528	Skylight Area: 0
Window-Wall-Ratio: 0.212	Skylight-Roof-Ratio: 0

Area in m<sup>2</sup> for SI and IP for IP units.

Refresh 3D Image Show 3D View

C:\Dev\VISDOE\Training\2002\Training Files\Exercise.gph Base Case X = 211 Y = 42 IP Units 12/11/2002

Monthly Heating Load





# Coal

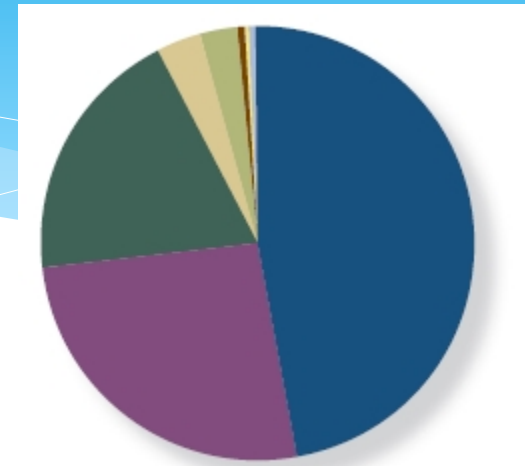
	Assessment		Comments
Operation Cost	\$2.63/Mbtu		Excluding transportation
Maintenance Cost	To be found from client		
Installation Cost	None		Already in place
Availability of fuel	Available		In use
Environmental Effects	Carbon additive, Acid rain		
Emissions	Carbon Dioxide	2,249 lbs/MWh	
	Sulfur Dioxide	13 lbs/MWh	
	Nitrogen Oxide	6 lbs/MWh	

# Biomass

	Assessment		Comments
<i>Operation Cost</i>	\$2.68/Mbtu		Including transportation
<i>Maintenance Cost</i>	To be found from vendors		About the same maintenance schedule as a coal boiler
<i>Installation Cost</i>	To be found from vendors		Possible retrofit
<i>Availability of fuel</i>	Available		Local saw mills
<i>Environmental Effects</i>	Carbon neutral		Does not use fossil fuels
<i>Emissions</i>	Can be carbon neutral	Less than coal	Does not use fossil fuels
	Sulfur Dioxide	Less than coal	
	Nitrogen Oxide	Less than coal	

# Electric

	<i>Assessment</i>	<i>Comments</i>
<i>Operation Cost</i>	\$24.91/MBtu	
<i>Maintenance Cost</i>	TBD	
<i>Installation Cost</i>	TBD	
<i>Availability of fuel</i>	Available	Avista
<i>Environmental Effects</i>	None	
<i>Emissions</i>	Varies	



Hydro	47.39 percent
Natural Gas	26.03 percent
Coal	19.09 percent
Waste	3.56 percent
Biomass	2.64 percent
Wind	0.65 percent
Cogeneration	0.24 percent
Nuclear*	0.24 percent
Landfill Gases*	0.11 percent
Petroleum	0.05 percent
Other	0.01 percent
Total:	100 percent

\* Avista doesn't own or operate landfill gas or nuclear generation facilities.

# Propane

	<i>Assessment</i>		<i>Comments</i>
<i>Operation Cost</i>	\$27.50/Mbtu		Excluding transportation
<i>Maintenance Cost</i>	To be determined from manufacturer		
<i>Installation Cost</i>	To be determined from manufacturer		Boiler and storage tank
<i>Availability of fuel</i>	Available, must be transported		Clearwater Power, Avista
<i>Environmental Effects</i>	Clean burning fuel		
<i>Emissions</i>	Carbon Dioxide	Less than coal	
	Sulfur Dioxide	Less than coal	
	Nitrogen Oxide	Less than coal	

# 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