


## Ground Loop Design Version 2012

### GLD Training




# Welcome!

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VP – Thermal Dynamics, Inc.


**Daniel Bernstein**  
President - Gaia Geothermal, Inc.

- Presented by:
- Gaia Geothermal and Thermal Dynamics



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## Ground Loop Design Version 2012



### Course Overview

- How can GLD Software help you?**
- Brief introduction to GLD
- Why Use GLD Software?
- System Design Inputs and Their Impact
- How to use GLD
- What to Look For in a Good Design
- Practice!



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## Ground Loop Design Version 2012



### How Can GLD Help You?

- Easily design loop fields
- Easily select equipment
- Easily design piping
- Easily determine costs and savings
- Design a loop field in three minutes!




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## Ground Loop Design Version 2012

### What is GLD Software?

- **1997:** Version 1.0 – Training tool for engineers
- **2000:** Version 2.0 – Introduced at IGSHPA
- **2001:** Version 2.7 – Horizontal module release
- **2003:** Version 3.0 – Dongle-based license system
- **2005:** Version 4.0 – Development tool
- **2007:** Version 5.0 – Lund University model added
- **2008:** Version 5.0 – Residential Edition
- **2009:** Version 6.0 – Finance/Emissions Module
- **2010:** Version 7.0 – Piping/Pressure Drop Module
- **2012:** Version 7.5 – Grid Builder; G-Function Generator

Today: Used in over 54 countries,  
1000's of engineering customers world wide




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## Ground Loop Design Version 2012

### What is GLD Software?

Goal: To turn research advances into practical design tools


Developed in conjunction with:

- Oakridge National Lab
- University of Alabama
- Oklahoma State University
- Lund University, Sweden
- Oregon Institute of Technology- “GeoHeat Center”
- Major Heat Pump Companies- ClimateMaster
- Design and engineering firms



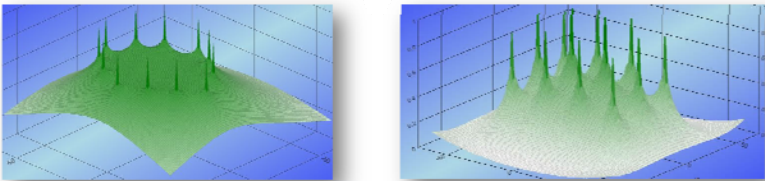

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### What is GLD Software?

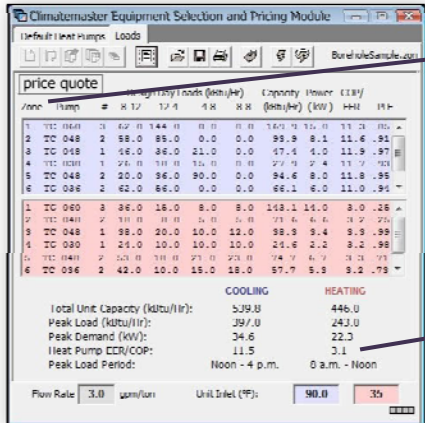
- GLD takes the mystery and complexity out of geothermal design and enables designer to:
  - Quickly match pumps to loads
  - Estimate loopfield size and drilling requirements
  - Estimate installation costs
  - Optimize the most cost effective design and piping layout
  - Avoid rule of thumb designs that can be too expensive to install
  - Perform a comprehensive lifecycle costing analysis



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### What is GLD Software?



Automatic pump selection across multiple zones

Dynamic pump performance calculations based on fluid temps/flow rates, etc.

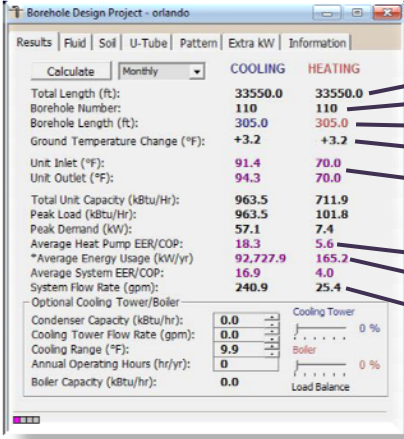
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Version 2012**

### What is Ground Loop Design Software?

- Basic Outputs include:



	COOLING	HEATING
Total Length (ft):	33550.0	33550.0
Borehole Number:	110	110
Borehole Length (ft):	305.0	305.0
Ground Temperature Change (°F):	+3.2	+3.2
Unit Inlet (°F):	91.4	70.0
Unit Outlet (°F):	94.3	70.0
Total Unit Capacity (kBtu/Hr):	963.5	711.9
Peak Load (kBtu/Hr):	963.5	101.8
Peak Demand (KW):	57.1	7.4
Average Heat Pump EER/COP:	18.3	5.6
*Average Energy Usage (kW/yr)	92,727.9	165.2
Average System EER/COP:	16.9	4.0
System Flow Rate (gpm):	240.9	25.4

Optional Cooling Tower/Boiler:

	Cooling Tower	Boiler
Condenser Capacity (kBtu/hr):	0.0	0.0
Cooling Tower Flow Rate (gpm):	0.0	0.0
Cooling Range (°F):	9.9	0.0
Annual Operating Hours (hr/yr):	0	0
Boiler Capacity (kBtu/hr):	0.0	0.0

Arrows from the screenshot point to the following outputs:

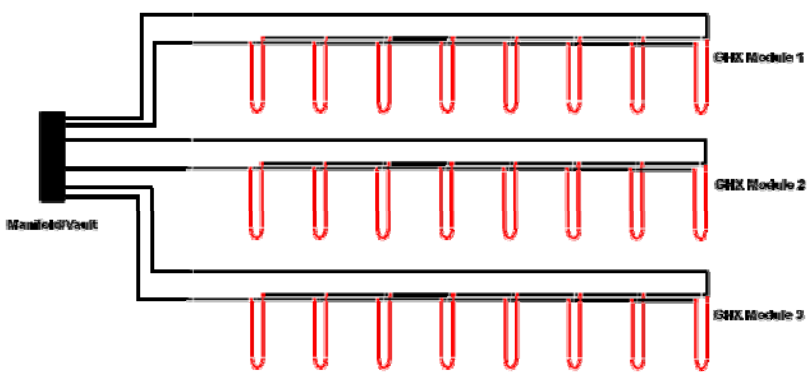
- Total Drilling
- Borehole Quantity
- Borehole Length
- Soil Temp Change
- Fluid Temperatures
- Pump Performance
- Energy Use
- Flow Rates

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### What is GLD Software?

GLD makes commercial piping design easy!



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### What is Ground Loop Design Software?


- More Advanced Outputs Include:

**Optimized Headers      GHX Module Pressure Drop      Balanced Flow Rates**

GHX Module - Supply-R...	2"	2"	45.57 gpm	45.57 gpm	4.93 ft/s	4.93 ft/s	27.4 ft. hd
U Circuit #01	1"	1"	5.74 gpm	5.74 gpm	2.03 ft/s	2.03 ft/s	13.7 ft. hd
GHX Header Section #01	2"	1"	39.83 gpm	5.74 gpm	4.31 ft/s	2.03 ft/s	0.0 ft. hd
U Circuit #02	1"	1"	5.68 gpm	5.68 gpm	2.01 ft/s	2.01 ft/s	13.3 ft. hd
GHX Header Section #02	2"	1 1/4"	34.15 gpm	11.43 gpm	3.69 ft/s	2.53 ft/s	0.0 ft. hd
U Circuit #03	1"	1"	5.67 gpm	5.67 gpm	2.00 ft/s	2.00 ft/s	13.2 ft. hd
GHX Header Section #03	2"	1 1/2"	28.48 gpm	17.09 gpm	3.08 ft/s	2.89 ft/s	0.0 ft. hd
U Circuit #04	1"	1"	5.69 gpm	5.69 gpm	2.01 ft/s	2.01 ft/s	13.3 ft. hd
GHX Header Section #04	2"	2"	22.79 gpm	22.79 gpm	2.47 ft/s	2.47 ft/s	0.0 ft. hd
U Circuit #05	1"	1"	5.69 gpm	5.69 gpm	2.01 ft/s	2.01 ft/s	13.3 ft. hd
GHX Header Section #05	1 1/2"	2"	17.09 gpm	28.48 gpm	2.89 ft/s	3.08 ft/s	0.0 ft. hd
U Circuit #06	1"	1"	5.67 gpm	5.67 gpm	2.00 ft/s	2.00 ft/s	13.2 ft. hd
GHX Header Section #06	1 1/4"	2"	11.43 gpm	34.15 gpm	2.53 ft/s	3.69 ft/s	0.0 ft. hd
U Circuit #07	1"	1"	5.68 gpm	5.68 gpm	2.01 ft/s	2.01 ft/s	13.3 ft. hd
GHX Header Section #07	1"	2"	5.74 gpm	39.83 gpm	2.03 ft/s	4.31 ft/s	0.0 ft. hd
U Circuit #08	1"	1"	5.74 gpm	5.74 gpm	2.03 ft/s	2.03 ft/s	13.7 ft. hd

**Fluid Velocities      Purge Pump Requirements      Flow State**

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### What is Ground Loop Design Software?


- More Advanced Outputs Include:

**Optimized Headers      GHX Module Pressure Drop      Balanced Flow Rates**

U Circuit #01	1"	1"	4.54 gpm	4.54 gpm	2168	2168
U Circuit #02	1"	1"	4.49 gpm	4.49 gpm	2146	2146
U Circuit #03	1"	1"	4.48 gpm	4.48 gpm	2140	2140
U Circuit #04	1"	1"	4.50 gpm	4.50 gpm	2149	2149
U Circuit #05	1"	1"	4.50 gpm	4.50 gpm	2149	2149
U Circuit #06	1"	1"	4.48 gpm	4.48 gpm	2140	2140
U Circuit #07	1"	1"	4.49 gpm	4.49 gpm	2146	2146
U Circuit #08	1"	1"	4.54 gpm	4.54 gpm	2168	2168

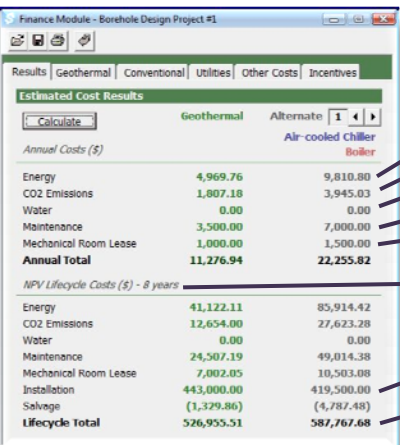
**Fluid Velocities      Purge Pump Requirements      Flow State**

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### What is Ground Loop Design Software?

- More Advanced Outputs Include:



Annual Costs (\$)	Geothermal	Alternate 1 Air-cooled Chiller
Energy	4,969.76	9,810.80
CO2 Emissions	1,807.18	3,945.03
Water	0.00	0.00
Maintenance	3,500.00	7,000.00
Mechanical Room Lease	1,000.00	1,500.00
<b>Annual Total</b>	<b>11,276.94</b>	<b>22,255.82</b>


  

NPV Lifecycle Costs (\$) - 8 years	Geothermal	Alternate 1 Air-cooled Chiller
Energy	41,122.11	85,914.42
CO2 Emissions	12,654.00	27,623.28
Water	0.00	0.00
Maintenance	24,507.19	49,014.38
Mechanical Room Lease	7,802.05	10,503.08
Installation	443,000.00	419,500.00
Salvage	(1,329.86)	(4,787.48)
<b>Lifecycle Total</b>	<b>526,955.51</b>	<b>587,767.68</b>

Labels pointing to the screenshot:

- Energy Costs
- CO2 Emissions
- Water Costs
- Maintenance Costs
- Value of Sq. Footage
- Lifecycle Costing
- Installation Costs
- NPV Calculations

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### Course Overview

- How can GLD Software help you?
- Brief introduction to GLD
- **Why Use GLD Software?**
- System Design Inputs and Their Impact
- How to use GLD
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- Practice!

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Ground Loop Design  
Version 2012

## Why Use GLD Software?

- To avoid risky “rule of thumb” designs
- To efficiently explore scenarios and quickly optimize designs
- To accurately balance installation cost/system performance tradeoffs
- To save your clients money
- To enhance your business success
- To save you time!



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Ground Loop Design  
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# Ground Loop Design Version 2012

## What is Ground Loop Design (GLD) Software?

- An advanced software suite that helps to properly size a closed loop ground heat exchanger by considering the interplay among:
  - Building Loads
  - Heat Pump Performance
  - Geological Conditions
  - Pressure Drop
  - Space and Drilling Limits
  - Operational Costs



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# Ground Loop Design Version 2012

## System Design Inputs and Their Impact

Modeling Time Period  
Entering Fluid Temperatures

COOLING TOWER/BOILER HYBRIDS

Ceiling-Mounted Units  
Console Units  
Vertical Units  
Mechanical Room

To/From Ground Loop

Undisturbed Ground Temperature

Thermal Conductivity

Grout Conductivity


Borehole Separation

or

Adapted From:  
Geo-Heat Center  
OIT

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**Ground Loop Design  
Version 2012**

## System Design Inputs and Their Impact


**Key Components:**

- Loads
- Entering Water Temperatures
- Pipe/Borehole Spacing
- Field Layout
- Ground Temperature
- Thermal Conductivity
- Grout Conductivity
- Modeling Time Period




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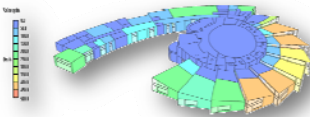
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**Ground Loop Design  
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## Loads: Residential vs Commercial

- Residential loads determined by climate/bin data
- Commercial loads determined by climate, structure and building use/internal gains/diversity
  - Oftentimes cooling dominated






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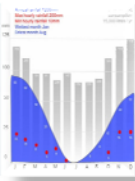
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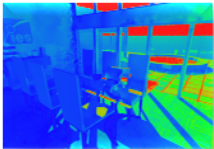
**Loads**

Loads are THE foundation of a geothermal system:

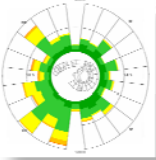
- Loads Overview
- Required Loads Data



Monthly Energy Output\*



Daylight contours



Climate Understanding

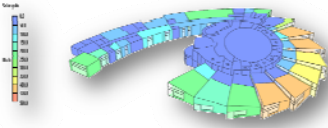
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**Ground Loop Design  
Version 2012**


**Loads: Overview**

A thorough understanding of the loads is essential for determining how much energy must be transferred to and from the ground. The designer must consider:

- Climate and Structure
- Energy Reclamation
- Internal gains (occupancy, electrical, process)
- Solar gains
- Energy loads
- Energy Balance



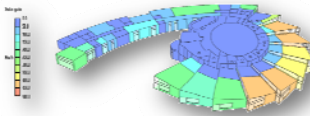
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## Ground Loop Design Version 2012

### Loads: Overview


- Conventional loads calculations require only the cooling load on the hottest day of summer when the building is fully occupied.
- Conventional loads calculations require only the heating load on the coldest night of the year
- With these two numbers, the building will have the “right” conventional equipment capacity





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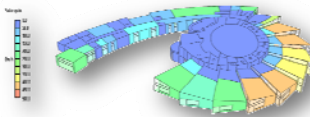
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## Ground Loop Design Version 2012

### Loads: Overview

- For a geothermal system to function, the design must guarantee that the equipment can utilize the ground all year round.
- Designing a geothermal system involves the design of a system and an energy source. The GHX must be the right size.
- If it is too big it costs too much. If it is too small it underperforms and gives geothermal technologies a bad reputation.
- More detailed loads data are required. They take more time to calculate and are more valuable. Designers should charge clients for these calculations.






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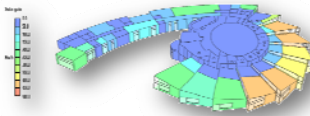





## Ground Loop Design Version 2012

### Loads: Overview

- We recommend advanced energy simulators such as Trane Trace, IES, eQuest and Carrier HAP.
- Standard mechanical equipment loads calculation tools do not provide the necessary loads data and should not be used.





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## Ground Loop Design Version 2012

### Loads: Overview

- Example: Church vs. Office





- Same peak load, same location, same geology
- Church used 2x a week
- Office used 12 hours a day, 5 days a week
- Office loopfield >> Church Loop



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### Loads: Required Loads Data

- Minimum (Design Day Method)
- Better (Monthly Simulation Method)
- Best (Hourly Simulation Method)




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**Ground Loop Design  
Version 2012**

### Loads: Required Loads Data

Minimum Required Loads Data (Design Day Method)

**Peak Loads** (btu/hr, kbtu/hr, kW)

**Annual Energy Loads** (total btu, total kbtu, kWh)

Annual energy loads are converted into Annual Equivalent Full Load Hours (AEFLH) by dividing:


**Annual Energy Load/Peak Load**



For example:

Peak Cooling: 1440kBtu/hr (~120 tons)

Annual Cooling Energy Load: 1,414,080kBtu

$AEFLH = 1,414,080 / 1440 = 982$  hours cooling



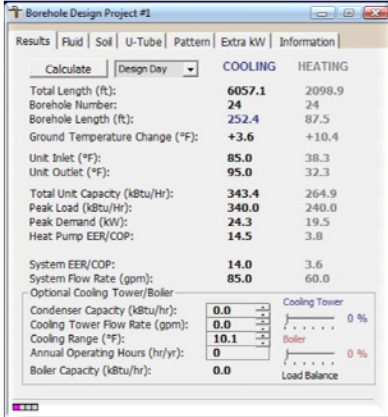
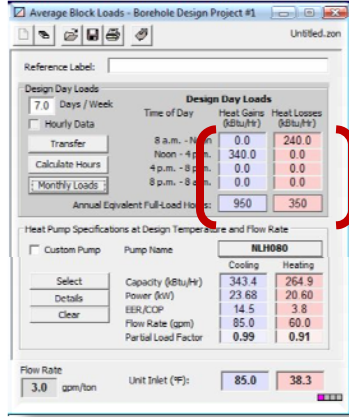

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**Ground Loop Design  
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### Loads: Required Loads Data

#### Minimum Required Loads Data

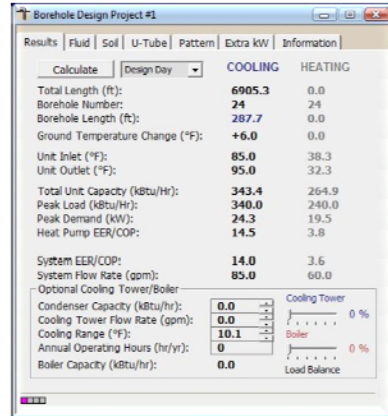
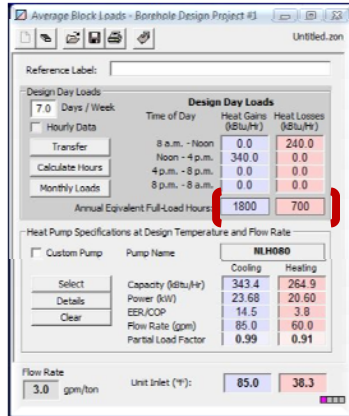



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**Ground Loop Design  
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### Loads: Required Loads Data

#### What happens if you guess the AEFLH?

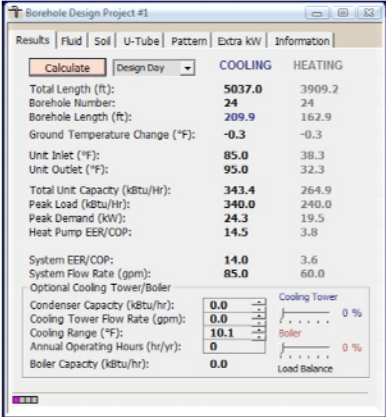
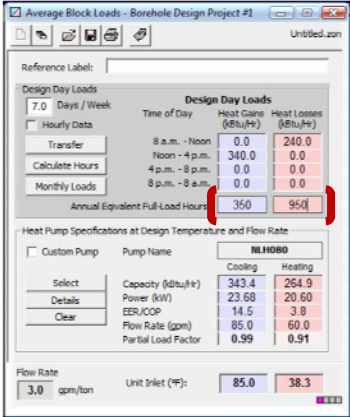



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**Ground Loop Design  
Version 2012**

### Loads: Required Loads Data

What happens if you guess the AEFLH?

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**Ground Loop Design  
Version 2012**

### Loads: Required Loads Data

Minimum Required Loads Data (Monthly Method)

**Peak Loads** (btu/hr, kbtu/hr, kW)

and

**Monthly total loads** (total btu, total kWh) for each month of the year for heating and cooling.

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**Ground Loop Design  
Version 2012**

### Loads: Required Loads Data

Required Loads Data (Monthly Simulation Method)

	Cooling		Heating	
	Total (kbtu)	Peak (kbtu/hr)	Total (kbtu)	Peak (kbtu/hr)
January	47	14	96676	758
February	62	11	73371	788
March	943	109	56079	747
April	3735	309	22355	603
May	46479	619	2811	251
June	89582	702	22	11
July	128982	756	0	0
August	106080	708	0	0
September	74392	650	213	56
October	27196	355	4639	435
November	409	27	36008	657
December	638	71	78607	811
<b>Total:</b>	<b>478545</b>	<b>3.0</b>	<b>370782</b>	<b>3.0</b>

Flow Rate: 3.0 gpm/ton    Unit Inlet (°F): 85.0    38.3

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**Ground Loop Design  
Version 2012**

### Loads: Required Loads Data

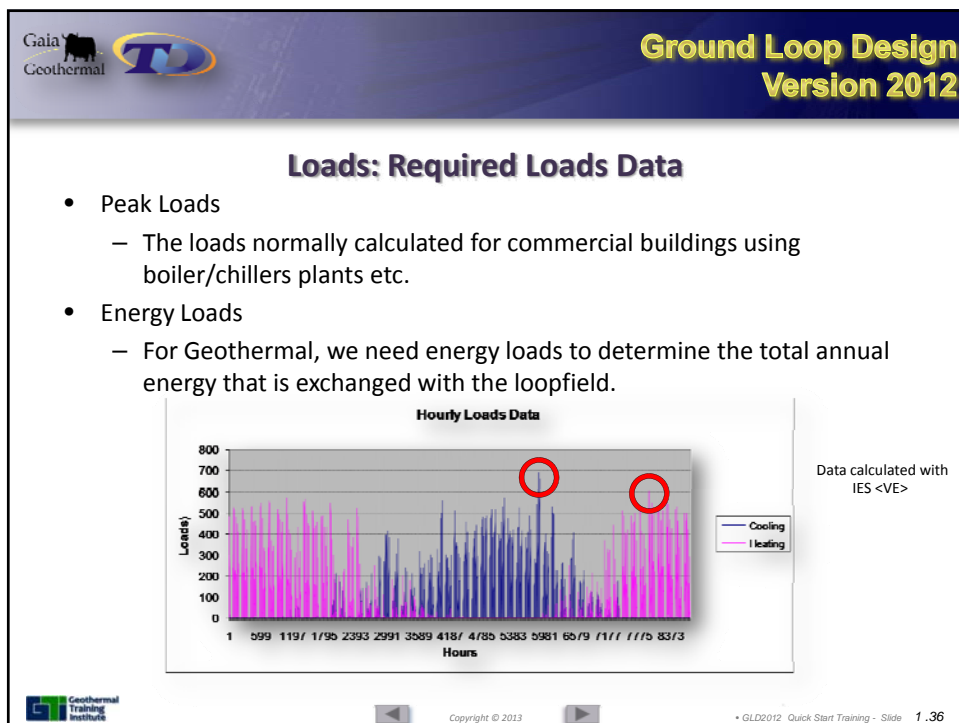
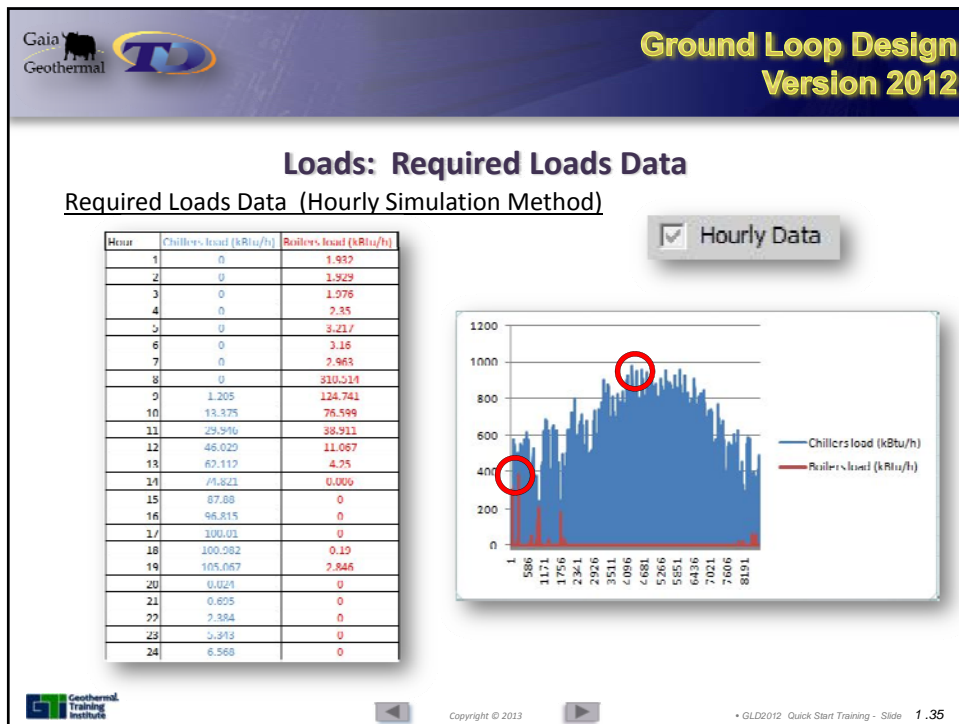
What can you do with Monthly Simulation Method Loads Data?


Predict the interplay of heating and cooling loads to estimate fluid temps over time, average COPs/EERs and annual power consumption.

For some loads profiles you can reduce your drilling based on the predicted thermal storage benefits arising from balanced loads.

	COOLING	HEATING
Total Length (ft):	14658.0	14658.0
Borehole Number:	60	60
Borehole Length (ft):	244.3	244.3
Ground Temperature Change (°F):	0.0	0.0
Peak Unit Inlet (°F):	80.5	45.5
Peak Unit Outlet (°F):	88.8	36.5
Total Unit Capacity (kbtu/Hr):	708.8	640.6
Peak Load (kbtu/Hr):	708.8	640.6
Peak Demand (kW):	10.0	9.2
Average Heat Pump EER/COP:	18.4	4.4
Avg. Annual Power (kWh):	25,974.2	24,671.4

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## Ground Loop Design Version 2012

### Loads: Required Loads Data

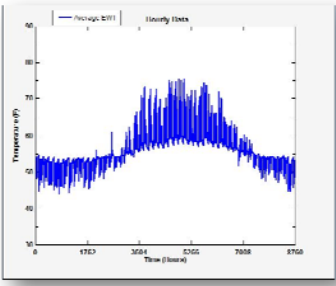
What can you do with Hourly Simulation Method Loads Data?


Predict the interplay of heating and cooling loads to estimate fluid temps over time, average COPs/EERs and annual power consumption.

For some loads profiles you can reduce your drilling based on the predicted thermal storage benefits arising from balanced loads.

Hourly simulations provide more detail than monthly simulations.


	COOLING	HEATING
Total Length (ft):	14640.0	14640.0
Borehole Number:	60	60
Borehole Length (ft):	244.0	244.0
Ground Temperature Change (°F):	0.0	0.0
Peak Inlet Inlet (°F):	75.6	43.9
Peak Inlet Outlet (°F):	85.4	38.2
Total Inlet Capacity (kBtu/Hr):	708.8	640.6
Peak Load (kBtu/Hr):	708.8	640.6
Peak Demand (kW):	42.7	50.2
Average Heat Pump EER/COP:	10.7	4.1
Avg. Annual Power (kWh):	25,571.1	26,516.0
System EER/COP:	16.5	3.7





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## Ground Loop Design Version 2012

### Loads: Software

- With loads programs, it is easy to have oversized loads
- Avoid oversized loads with geothermal design

With most commercial loads programs:


- the heat gain from the mechanical room is added to cooling load (for example, a chiller plant). This doesn't exist with geothermal systems.
- Lighting must be adjusted for scheduled use to avoid extra loads
- Eliminate any backup heat sources in the loads calculations
- Include energy recovery for outside air ventilation



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## Ground Loop Design Version 2012

### Loads: Reality Check

PEAK LOADS

New Construction Office Buildings:



- 20-30 btu/sq ft cooling
- Less for heating

Retrofit:

- 25-30 btu/sq ft cooling
- Heating may be as high


ANNUAL HOURS

Cooling annual loads over 2,000 hours = double check



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## Ground Loop Design Version 2012

### Loads: Conclusion


- **Loads are really important!**
- **Calculate them accurately!**



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**Ground Loop Design  
Version 2012**



## Entering Water Temperatures

Flow Rate:  gpm/ton      Unit Inlet (°F):

- **Definition:**  
Entering Water Temperatures (EWTs)/Unit Inlet Temperatures are the temperatures coming into the heat pump from the ground source heat exchanger.
- **Range:**  
Cooling: 85-95 F (25-35 above ground temp)  
Heating: 30-40 F (15 below ground temp)
- **Impact**  
Heat Exchanger Length


Example 1



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**Ground Loop Design  
Version 2012**

## Borehole Spacing

Borehole Number:


Rows Across:



Rows Down:

Borehole Separation:  ft

- **Definition:**  
Center-to-center distance between adjacent boreholes
- **Range:**  
15 ft minimum, no maximum
- **Impact**  
more separation = less heat build-up in soil = less drilling  
less separation = more heat build-up in soil = more drilling


Example 1 (cooling dom)  
Example 2 (heating dom)



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## Ground Loop Design Version 2012

### Borehole Geometry

Borehole Number: **100**

Rows Across:

Rows Down:

Borehole Separation:  m


Borehole Number: **100**



Rows Across:

Rows Down:


Borehole Separation:  m

- **Definition:**  
Geometry of the loopfield
- **Range:**  
Depends on space
- **Impact**  
High Density Systems = More Drilling  
Low Density Systems = Less Drilling



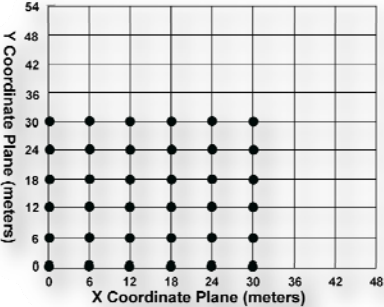



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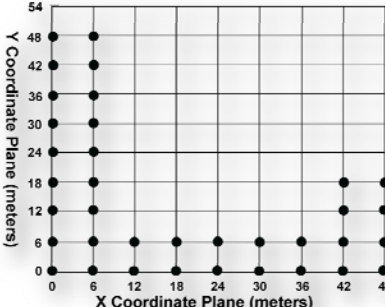


## Ground Loop Design Version 2012

### Borehole Geometry






36 boreholes x 437ft





36 boreholes x 406ft

~ 1,111 ft less drilling



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**Ground Loop Design  
Version 2012**



## Ground Temperature

Ground Temperature:  °F



- **Definition:**  
Subsurface undisturbed ground temperature
- **Range:**  
35F +/- to 68F +/-
- **Impact:**  
Maximize the Delta T between the Soil and EWTs to minimize drilling

Example 1




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**Ground Loop Design  
Version 2012**


## Thermal Conductivity



Thermal Conductivity:  Btu/(h\*ft\*°F)  
 Thermal Diffusivity:  ft<sup>2</sup>/day

- **Definition:**  
Ability of soil to transport heat
- **Range:**  
0.6 to 1.5 +
- **Impact:**  
higher conductivity = more efficient heat transfer = less drilling





Example 1




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## Ground Loop Design Version 2012

### Thermal Conductivity Testing


- What?
  - A test to determine the average thermal conductivity of the ground.
  - Usually for vertical systems. Can be performed for horizontal systems as well;
  - Measures:
    - Ground temperature (undisturbed)
    - Borehole Thermal Resistance
    - Conductivity (k)  
(how much heat flows through the soil)
- Why?
  - Allows you to design accurately
  - Test loop can be used in finished system





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## Ground Loop Design Version 2012

### Thermal Conductivity Testing

Perform a Thermal Conductivity (TC) test if the cost of the TC test is less than the cost difference between the best case and worst case design scenarios

For example: Difference in Soil Conductivity (SC)

- Drilling footage if SC is 0.80 Btu/(hr•ft.°F) – 3,500 Ft.
- Drilling footage if SC is 1.40 Btu/(hr•ft.°F) – 2,500 Ft.
- Drilling cost per vertical foot - \$12 / ft.
- Total cost difference - \$12,000
- Cost of TC test - \$7,500



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Gaia Geothermal Training Institute **Ground Loop Design Version 2012**

## Thermal Conductivity

**Thermal Conductivity Calculation Project**  
Project ID: None  
Import Data File: American\_Swedish\_Institute\_12.csv

Results | Basic | Flow | Diffusivity | Information

Calculate ☐ Save Calculated Graph Data

Calculation Interval  
Start: 12.0 hr End: 42.0 hr

Thermal Conductivity	1.60	Btu/(h·ft·°F)
Slope	2.95	
Average Heat Flux	17.4	W/ft
Average Power	5216.2	Watts
BH Thermal Resist (BTR)	0.31	h·ft²·°F/Btu
Thermal Diffusivity	1.23	ft²/day
Average Flow Rate	8.26	gpm

**Data Quality**

Power Standard Deviation	+/-	1.50	%
Power Variation	+/-	10.00	%
Temperature	+/-	5.00	%
Flow Rate	1/	1.00	%
Slope Stability	+/-	25.00	%
Water Flow Trend	+/-	20.00	%

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Gaia Geothermal Training Institute **Ground Loop Design Version 2012**

## Comprehensive, User-Friendly Report

• From GLD2012

**Ground Loop Design Thermal Conductivity Report - 3/7/2011**

Project Name: Swedish Institute Test Box  
Project Address: 2122 Brinkley Street  
City: Maple Plain State: MN Zip: 55129  
Designed By: Joe V. Gaudin  
Drawn By: Joe V. Gaudin  
BTR: 0.31  
TC Test Range: 200000  
Flow Rate: 8.26 gpm  
Address Line 1: 1234 Main Street  
Address Line 2:  
City: St. Paul State: MN Zip: 55101  
Phone: 612-555-1234  
Fax: 612-555-5678  
Email: jvg@gaia-geothermal.com

**Calculation Results**

Thermal Conductivity (Btu/ft·h·°F)	1.60
Thermal Diffusivity (ft²/day)	1.23
Average Heat Flux (W/ft)	17.4
Average Power (Watts)	5216.2
BH Thermal Resist (h·ft²·°F/Btu)	0.31
Flow Rate (gpm)	8.26
Water Flow Trend	Stable

**Standard Input Parameters**

Thermal Conductivity (Btu/ft·h·°F)	0.8
Thermal Diffusivity (ft²/day)	0.8
Average Heat Flux (W/ft)	17.4
Average Power (Watts)	5216.2
BH Thermal Resist (h·ft²·°F/Btu)	0.31
Flow Rate (gpm)	8.26


**Design Input Parameters**

Thermal Conductivity (Btu/ft·h·°F)	0.8
Thermal Diffusivity (ft²/day)	0.8
Average Heat Flux (W/ft)	17.4
Average Power (Watts)	5216.2
BH Thermal Resist (h·ft²·°F/Btu)	0.31
Flow Rate (gpm)	8.26

**Flow Rate Input Parameters**

Flow Rate (gpm)	8.26
-----------------	------

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**Ground Loop Design  
Version 2012**


## Grout Conductivity


Backfill (Grout) Information

Thermal Conductivity:  Btu/(h\*ft\*°F)


- **Definition:**  
Ability of grout to transport heat
- **Range:**  
varies
- **Impact**  
higher conductivity = more efficient heat transfer = less drilling

Example 1





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**Ground Loop Design  
Version 2012**

## Grout Conductivity


Backfill (Grout) Information


Thermal Conductivity:  Btu/(h\*ft\*°F)

100 borehole system


Grout Conductivity	Bore length	Total length	Cost (\$12/ft)
0.00	6039ft	603900ft	\$7,246,800
0.45	369ft	36900ft	\$442,800
0.57	350.3ft	35030ft	\$420,360
0.69	341ft	34100ft	\$409,200
0.79	335ft	33500ft	\$402,000
0.88	329ft	32900ft	\$394,800

Example 1





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**Ground Loop Design  
Version 2012**


## Modeling Time Period

Prediction Time:  years


- **Definition:**  
The length of time required for the ground temperature to stabilize
- **Range:**  
 Vertical system: 10-25 years  
 Horizontal system: 1-5 years  
 Pond system: N/A
- **Impact:**  
 Balanced systems, ground temperature stabilizes quickly  
 Unbalanced systems: required stabilization time increases

Example 1





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**Ground Loop Design  
Version 2012**


## Modeling Time Period


Prediction Time:  years

100 borehole system

Time	Bore length	Total length	Ground Temp Change
1 year	304.0 ft	30,400ft	0.9°F
3 years	311.5 ft	31,150ft	1.8°F
5 years	319.3 ft	31,930ft	2.2°F
10 years	329.0 ft	32,900ft	2.8°F
15 years	336.7 ft	33,670ft	3.2°F
25 years	344.1 ft	34,410ft	3.6°F
35 years	347.2 ft	34,720ft	3.8°F

Example 1





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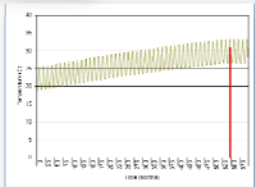
**Ground Loop Design  
Version 2012**

### Modeling Time Period

Prediction Time:  years

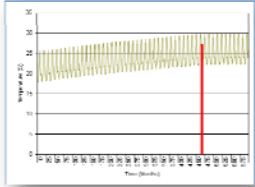
#### Unbalanced Load

Cooling Load	Heating Load
1,324 kBtu/2,222 hours	1,159 kBtu/1,333 hours



#### Balanced Load

Cooling Load	Heating Load
1,324 kBtu/2,222 hours	1,248 kBtu/2,205 hours



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**Ground Loop Design  
Version 2012**

### Course Overview

- How can GLD Software help you?
- Brief introduction to GLD
- Why Use GLD Software?
- System Design Inputs and Their Impact
- **How to use GLD**
- What to Look For in a Good Design
- Practice!

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**Ground Loop Design  
Version 2012**

### GLD Methodology


- Step 1: Calculate loads with maximum accuracy
- Step 2: Import loads into the software
- Step 3: Select heat pumps
- Step 4: Vertical, Horizontal, Pond or Hybrid?
- Step 5: Input location-specific soil parameters
- Step 6: Design loopfield based on space constraints
- Step 7: Iterate and Optimize Design
- Step 8: Optimize design for PD/Purging
- Step 9: System economics/LEED Submittals





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**Ground Loop Design  
Version 2012**

### GLD Methodology

```


graph TD
    A[Optimize Loads] --> B[1) Import Loads]
    B --> C[2) Select Heat Pump (s)]
    C --> D[3) Design Heat Exchanger ↔ Piping Optimization]
    D --> E[4) Finance/CO2 Analysis]
  
```





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## Ground Loop Design Version 2012


### Sample GLD Project

- Input loads
- Select heat pump
- Set EWTs
- Design loop system
- Optimize




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## Ground Loop Design Version 2012

### What are we Trying to Accomplish?

- We want to design geothermal heat exchangers that are easily purged and perform well.
- We want a system that is easily purged so that we can get all the air bubbles out and ensure stable performance.
- We want a system that performs well so that the circulation pumps do not consume unnecessary energy.

Pump hp/100 tons of load	Efficiency
< 5	Excellent
5 – 7 ½	Good
7 ½ - 10	Ok
10-15	Poor
> 15	Bad




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**Ground Loop Design  
Version 2012**

### What are we Trying to Accomplish?

**A sample system:**

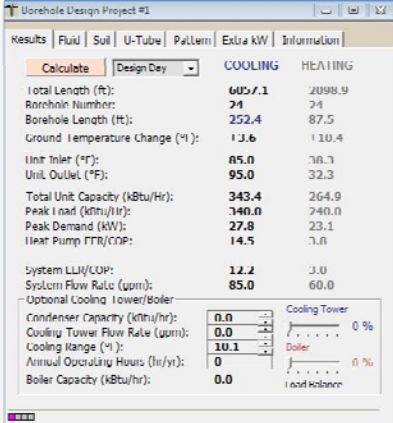
- 22,000kWh cooling
- 5,000 kWh heating

**Well Designed piping system:**

- 12 x 2 borefield
- 10 ft. hd @ 45gpm
- ~ 0.5 hp pump w/ 85% efficiency = 3,504 kWh
- Pump penalty = 11%

**Poorly Designed System:**

- 12 x 2 borefield
- 34 ft. hd @ 45 gpm
- ~ 1 hp pump w/ 85% efficiency = 7,884 kWh
- Pump penalty = 22%



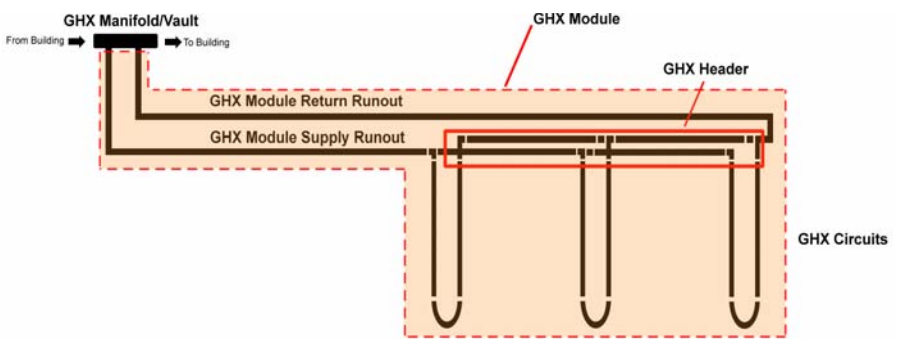
The screenshot shows the 'Ground Loop Design Project #1' window. The 'Results' tab is active, displaying a table of system parameters for both COOLING and HEATING modes. The 'Calculate' button is highlighted. The table includes fields for Total Length (ft), Borehole Number, Borehole Length (ft), Ground Temperature Change (°F), Unit Inlet (°F), Unit Outlet (°F), Total Unit Capacity (kBtu/Hr), Peak Load (kBtu/Hr), Peak Demand (kW), Heat Pump COP, System LHV/COP, System Flow Rate (gpm), and Optional Cooling Tower/Boiler. The 'Cooling Tower' section shows a Condenser Capacity of 0.0, Cooling Tower Flow Rate of 0.0, Cooling Range of 10.1, and Annual Operating Hours of 0. The 'Boiler' section shows a Boiler Capacity of 0.0.

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**Ground Loop Design  
Version 2012**


### Introduction to Nomenclature

• Standardized Nomenclature is critical to clear communication.



The diagram shows a schematic of a Ground Loop Design system. It starts with a 'GHX Manifold/Vault' on the left, with arrows indicating 'From Building' and 'To Building'. The manifold connects to a 'GHX Module'. The module has two main lines: 'GHX Module Return Runout' and 'GHX Module Supply Runout'. These lines lead to a 'GHX Header' which then branches into three 'GHX Circuits'. Each circuit is represented by a U-shaped line, indicating a loop. The entire system is enclosed in a dashed red box.


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Gaia Geothermal 


## Ground Loop Design Version 2012


### Introduction to Nomenclature

- **U-Tube:** An assembly of two lengths of HDPE pipe connected on one end with a molded, purpose built U-bend.



- **GHX:** Refers to a **g**round **h**eat **e**xchanger, and may include vertical, horizontal trenching, horizontal boring, pond or lake heat exchanger buried in the ground or submerged in a body of water.

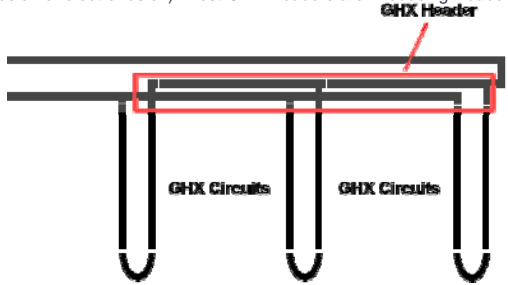
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Gaia Geothermal 


## Ground Loop Design Version 2012

### Introduction to Nomenclature

- **GHX Circuits:** HDPE pipe buried in the ground in horizontal or vertical orientation designed to transfer energy to and from the ground. Typically a number of GHX Circuits are fusion welded to a GHX Header that is in turn fusion welded to a Supply-Return Runout. Heat transfer fluid is circulated through the assembly to a building.
- **GHX Header:** Connection points between Supply-Return Runout piping and GHX Circuits. GHX Headers are buried in the ground adjacent to the GHX Field and are comprised of an assembly of fusion welded fittings and pipe. Fittings and pipe are manufactured using HDPE resin and are connected using heat fusion (butt fusion, socket fusion or electro-fusion). Most GHX Headers are "Reducing Headers"



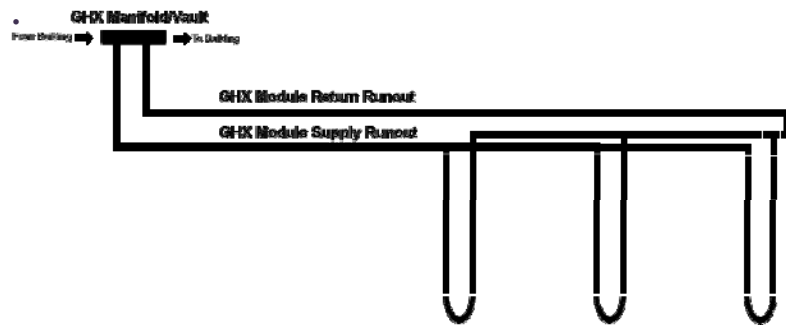
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Gaia Geothermal 

## Ground Loop Design Version 2012

### Introduction to Nomenclature

- **GHX Module Supply-Return Runout** : Supply-Return Runout refers to the high-density polyethylene (HDPE) piping installed to connect the GHX Circuit piping to the Pump House header. The Supply-Return Runout has both a supply pipe and a return pipe.



The diagram illustrates the GHX Module Supply-Return Runout. It shows a horizontal line representing the runout, with a vertical line branching off to the left. The vertical line is labeled 'GHX Module Return Runout' and the horizontal line is labeled 'GHX Module Supply Runout'. The runout is connected to a 'GHX Manifold/Vault' on the left, which has arrows indicating 'From Building' and 'To Building'. Three vertical lines branch off from the bottom of the runout, representing the GHX Circuits.

**GHX Manifold/Vault**  
From Building → To Building


**GHX Module Return Runout**

**GHX Module Supply Runout**

**GHX Circuits**

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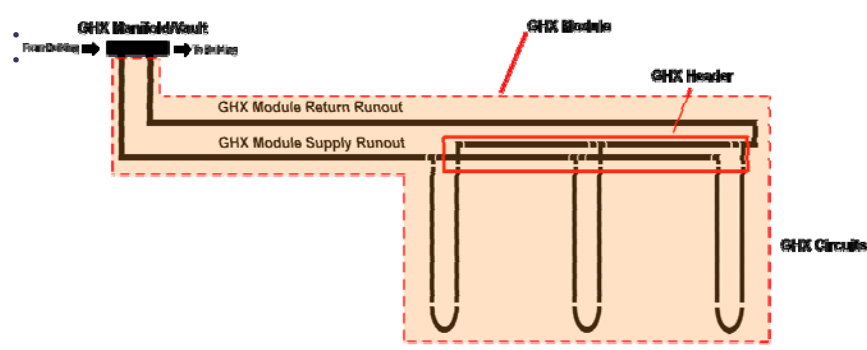
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Gaia Geothermal 

## Ground Loop Design Version 2012

### Introduction to Nomenclature

- **GHX Module**: Completed assembly of GHX components, including GHX Supply and Return Runouts, GHX header and GHX Circuits.



The diagram illustrates the GHX Module assembly. It shows a horizontal line representing the runout, with a vertical line branching off to the left. The vertical line is labeled 'GHX Module Return Runout' and the horizontal line is labeled 'GHX Module Supply Runout'. The runout is connected to a 'GHX Manifold/Vault' on the left, which has arrows indicating 'From Building' and 'To Building'. A red dashed box encloses the runout and the three vertical lines branching off from the bottom, which are labeled 'GHX Circuits'. The red dashed box is labeled 'GHX Module' and 'GHX Header'.

**GHX Manifold/Vault**  
From Building → To Building

**GHX Module Return Runout**

**GHX Module Supply Runout**


**GHX Module**

**GHX Header**

**GHX Circuits**

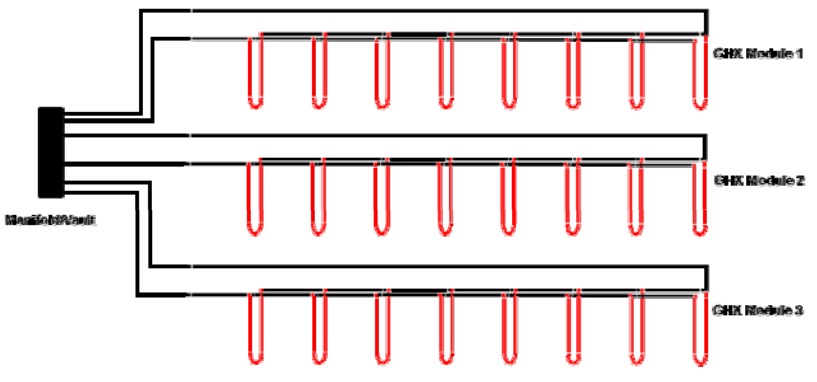
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Gaia Geothermal  **Ground Loop Design Version 2012**

### Introduction to Nomenclature


• **GHX Field:** Assembly of all GHX Modules connected to a single building or group of buildings via GHX Manifold(s)/Vault(s).



The diagram illustrates a GHX Field configuration. A central black vertical bar on the left is labeled "Manifold/Vault". Three horizontal lines branch out from this manifold to the right, each labeled "GHX Module 1", "GHX Module 2", and "GHX Module 3" respectively. From each module, eight vertical red lines (representing ground loops) extend downwards. The entire diagram is set against a white background with a blue header.

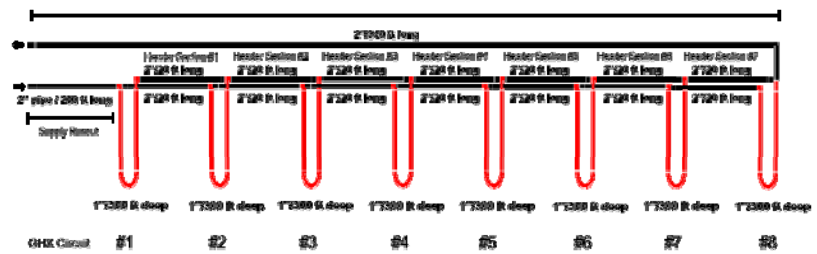
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Gaia Geothermal  **Ground Loop Design Version 2012**

### Purging Design: RR Systems


- You want to have a piping system that you can purge with available purge pumps.
- A 2 ft/sec fluid velocity throughout entire system is required to purge air effectively.
- Systems are purged with water and all calculations must be done with water.



The diagram shows a purging design for a RR system. A horizontal black line at the top is labeled "Purging Manifold". Below it, a series of eight vertical red lines (representing ground loops) extend downwards. Each loop is connected to a horizontal black line labeled "Header Section #1" through "#8". Below each header section, the text "2\" data-bbox="250 690 750 810"/>

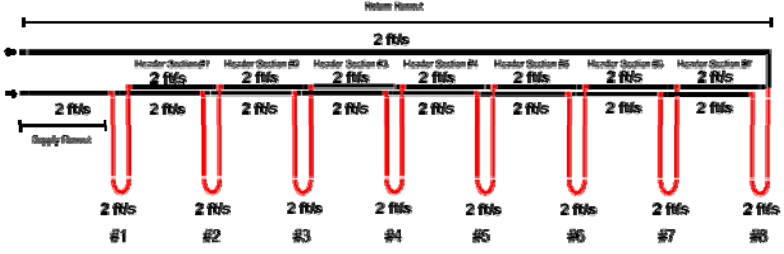
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Gaia Geothermal  **Ground Loop Design Version 2012**

### Purging Design: RR Systems

- You want to have a piping system that you can purge with available purge pumps.
- A 2 ft/sec fluid velocity throughout entire system is required to purge air effectively.
- Systems are purged with water and all calculations must be done with water.



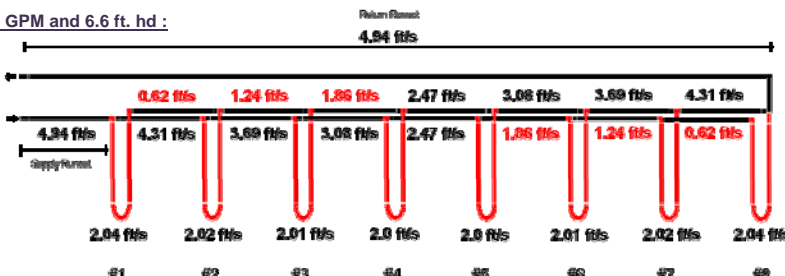
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Gaia Geothermal  **Ground Loop Design Version 2012**

### Purging Design: RR Systems


- You want to have a piping system that you can purge with available purge pumps.
- A 2 ft/sec fluid velocity throughout entire system is required to purge air effectively.
- Systems are purged with water and all calculations must be done with water.

45.32 GPM and 6.6 ft. hd :



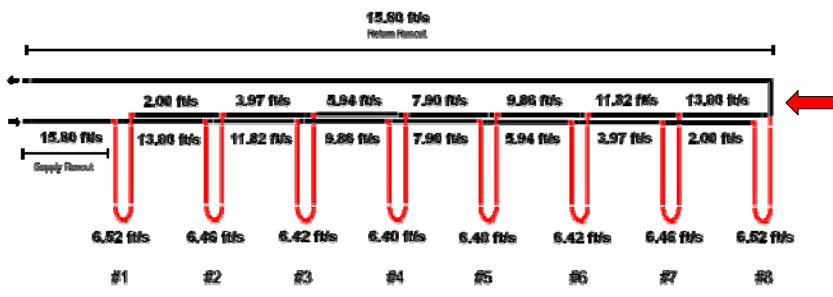
- The GHX circuits are being purged but the headering is not.

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Gaia Geothermal  **Ground Loop Design Version 2012**


### Purging Design: RR Systems

- Based on this configuration, to achieve 2 ft/s flow rates across the headering system requires:  
146 GPM and 345 ft. hd.



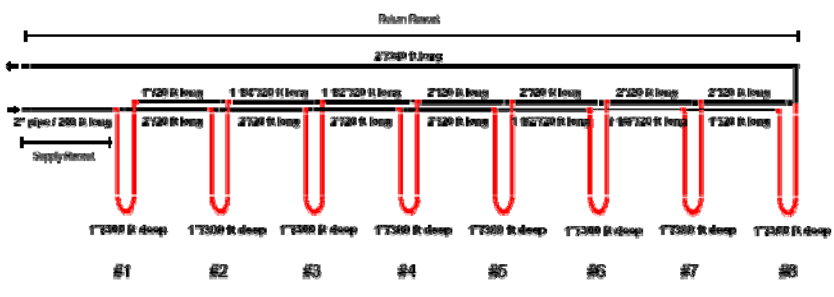
- This clearly is unreasonable and justifies the use of a reducing headering system.


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Gaia Geothermal  **Ground Loop Design Version 2012**

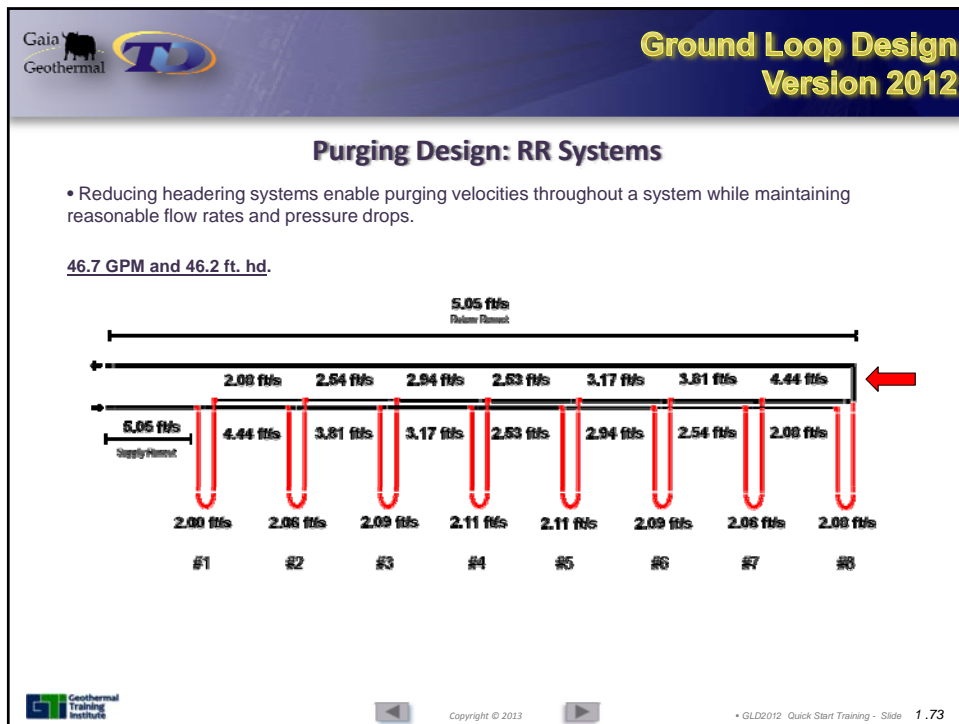
### Purging Design: RR Systems

- Reducing headering systems enable purging velocities throughout a system while maintaining reasonable flow rates and pressure drops.



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**Ground Loop Design  
Version 2012**

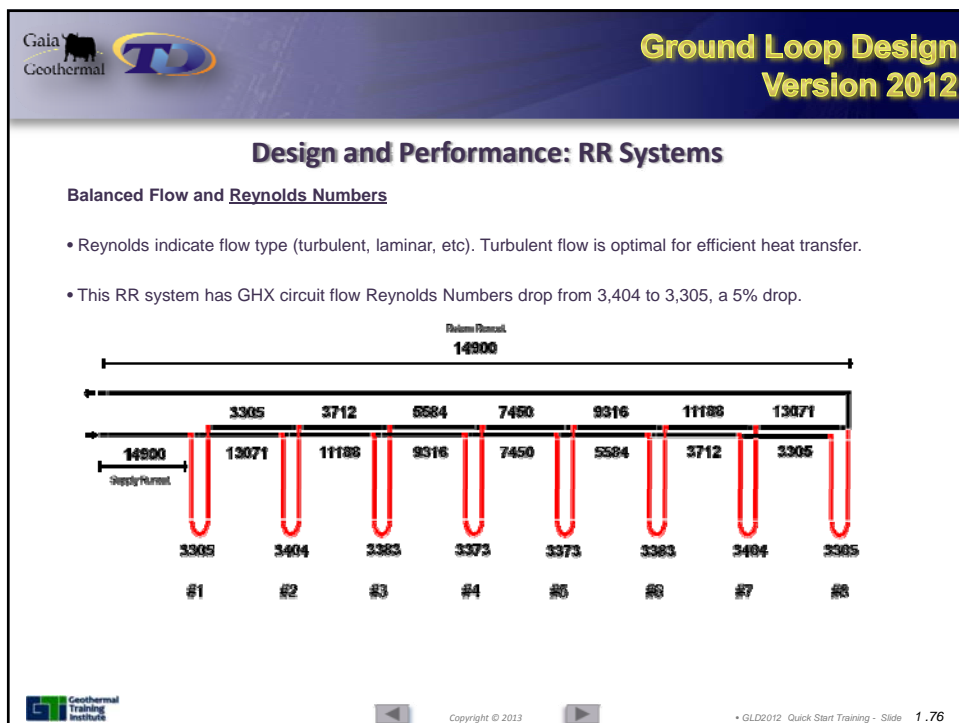
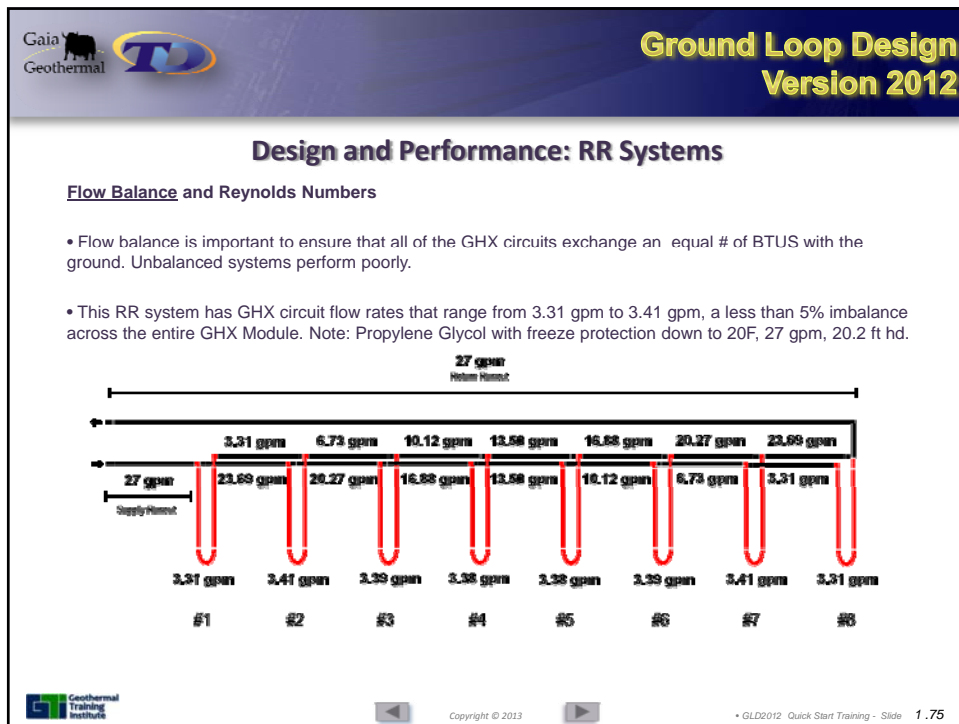
### Purging Design: RR Systems



- Other Reducing Header Options:

Header Section	Example	Velocity (ft/s)	Design Option 1	Velocity (ft/s)	Design Option 2	Velocity (ft/s)
Runout	2"/2"	5.05 / 5.05	2"/2"	2.34 / 2.34	2"/2"	2.69 / 2.69
1	2"/1"	4.44 / 2.00	2"/1"	2.06 / 2.00	2"/1"	2.37 / 2.29
2	2"/1 1/4"	3.81 / 2.54	2"/1 1/4"	3.84 / 2.56	2"/2"	2.03 / 2.93
3	2"/1 1/2"	3.17 / 2.94	2"/2"	3.20 / 2.96	2"/2"	3.67 / 2.18
4	2"/2"	2.53 / 2.53	2"/2"	2.55 / 2.55	2"/2"	2.92 / 2.92
5	1 1/2"/2"	2.94 / 3.17	2"/2"	2.96 / 3.20	2"/2"	2.18 / 3.67
6	1 1/4"/2"	2.54 / 3.81	1 1/2"/2"	2.56 / 3.84	2"/2"	2.93 / 2.03
7	1"/2"	2.00 / 4.44	1"/2"	2.00 / 2.06	1"/2"	2.29 / 2.37
Flow Rate		46.7 gpm		49.5 gpm		71.9 gpm
PD		37.6 ft. hd.		42.5 ft. hd		84 ft. hd.

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## Ground Loop Design Version 2012


### The Finance/Lifecycle Costing Module



Lifecycle costing is a standard investment analysis methodology that counts present and future costs and savings in today's dollar terms (known as net present value, or NPV, analysis).

Future costs and savings are converted into today's dollar terms using the discount rate, which is typically the inflation rate.



Typically, the commercial real estate sector likes to see NPV analysis that has a investment payback of approximately  $\leq 8$  years.

To do a full NPV analysis on a geothermal system requires the designer to take into account "hard" and "soft" costs for a geothermal system and one or more conventional systems.



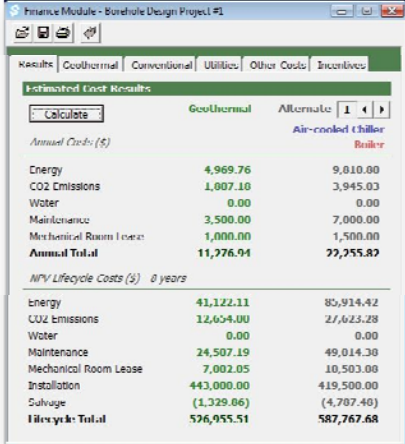

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## Ground Loop Design Version 2012

### The Finance/Lifecycle Costing Module




Estimated Cost Results		
	Geothermal	Alternative 1 Air-cooled Chiller
<b>Annual Costs (\$)</b>		
Energy	4,969.76	9,810.00
CO2 Emissions	1,007.10	3,945.03
Water	0.00	0.00
Maintenance	3,500.00	7,000.00
Mechanical Room Lease	1,000.00	1,500.00
<b>Annual Total</b>	<b>11,276.94</b>	<b>22,255.82</b>
<b>NPV Lifecycle Costs (\$) @ 8 years</b>		
Energy	41,122.11	80,914.42
CO2 Emissions	12,654.00	27,623.28
Water	0.00	0.00
Maintenance	24,507.19	49,014.30
Mechanical Room Lease	7,002.05	10,503.00
Installation	443,000.00	419,500.00
Salvage	(1,329.06)	(4,707.40)
<b>Lifecycle Total</b>	<b>526,955.51</b>	<b>587,767.68</b>




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## The Finance/Lifecycle Costing Module

**Hard Costs**


- Installation Costs - installation costs per square foot.
- Energy Consumption (kWh) costs



**Soft Costs**

- CO<sub>2</sub> emissions costs
- Opportunity costs related to mechanical room size
- Maintenance costs
- Water consumption costs


**Incentives**

- Federal/National
- State/Provincial




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## The Finance/Lifecycle Costing Module

**Hard Costs: Installation**

System Type	Cost per Square Ft Installed
Geothermal Vertical	\$16 to \$21
Geothermal Horizontal	\$13 to \$17
Geothermal Surface Water	\$13 to \$16
Geothermal Vertical/Hybrid	\$14 to \$18
VAV- Water Cooled w/boiler	\$16 to \$19
VAV- Air Cooled w/boiler	\$14 to \$18
Fan Coil WCC w/ boiler	\$12 to \$16
Rooftop Gas/Electric	\$10 to \$16



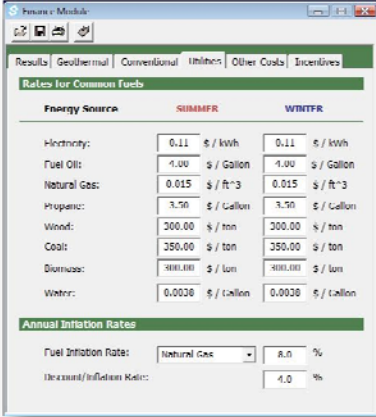

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## The Finance/Lifecycle Costing Module

**Hard Costs: Energy**



Energy Source	SUMMER	WINTER
Electricity:	0.11 \$ / kWh	0.11 \$ / kWh
Fuel Oil:	4.00 \$ / Gallon	4.00 \$ / Gallon
Natural Gas:	0.015 \$ / ft <sup>3</sup>	0.015 \$ / ft <sup>3</sup>
Propane:	3.50 \$ / Gallon	3.50 \$ / Gallon
Wood:	300.00 \$ / ton	300.00 \$ / ton
Coal:	350.00 \$ / ton	350.00 \$ / ton
Biomass:	400.00 \$ / ton	400.00 \$ / ton
Water:	0.0020 \$ / gallon	0.0020 \$ / gallon

**Annual Inflation Rates**

Fuel Inflation Rate:  8.0 %


Discount/Inflation Rate:  %

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## The Finance/Lifecycle Costing Module

**Soft Costs: CO<sub>2</sub>**



**Emissions Costs**

CO2 Emission Rate:  lbs / kWh

CO2 Emissions Cost:  \$ / ton

Effective Inflation Delay:  yr

Region/State	CO <sub>2</sub> Emission Factors			CH <sub>4</sub> lbs/MWh	N <sub>2</sub> O lbs/MWh
	lbs/kWh	short tons/MWh	metric tons/MWh		
New England	0.98	0.491	0.440	0.0207	0.0140
Connecticut	0.91	0.471	0.427	0.0174	0.0120
Maine	0.85	0.428	0.388	0.0166	0.0110
Massachusetts	1.28	0.639	0.579	0.0174	0.0129
New Hampshire	0.68	0.341	0.310	0.0172	0.0141
Rhode Island	1.06	0.520	0.477	0.0068	0.0047
Vermont	0.03	0.014	0.013	0.0090	0.0039
Mid Atlantic	1.04	0.520	0.471	0.0093	0.0140
New Jersey	0.71	0.353	0.320	0.0077	0.0079
New York	0.86	0.429	0.389	0.0081	0.0089
Pennsylvania	1.20	0.592	0.544	0.0107	0.0203
East North Central	1.63	0.816	0.740	0.0133	0.0267
Illinois	1.16	0.582	0.528	0.0092	0.0180
Indiana	2.08	1.040	0.942	0.0143	0.0373
Michigan	1.58	0.790	0.717	0.0140	0.0250
Ohio	1.80	0.900	0.817	0.0130	0.0236
Wisconsin	1.61	0.821	0.746	0.0138	0.0250

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### The Finance/Lifecycle Costing Module

**Soft Costs: Mechanical Room Size**

- In some cases, the geothermal system will have a smaller footprint than a conventional system.
- For new construction, this means construction costs savings
- For retrofits, this means space available for other uses = savings

**System Details**

	COOLING	HEATING
Eqv Full Load Hours:	0 hr	0 hr
Equipment Type:	Air-cooled Chiller	Boiler
Power Source:	Electricity	Electricity
Installed Capacity:	0.0 kWh/hr	0.0 kWh/hr
Efficiency:	0.0 EER	0.0 %
Extra Power:	0.0 kW	0.0 kW
Mech. Install Area:	400 ft <sup>2</sup>	400 ft <sup>2</sup>
Water Usage Rate:	0.00 gpm/ton	0.00 gpm/ton

**Primary Geothermal      Hybrid Component**

	COOLING	HEATING
Eqv Full Load Hours:	0 hr	0 hr
Peak Capacity:	0.0 kWh/hr	0.0 kWh/hr
Average Heat Pump Efficiency:	0.0 EER	0.0 COP
Circulation Pump Input Power:	0.0 kW	0.0 kW
Circ. Pump Power:	0.0 hp	0.0 hp
Motor Efficiency:	0.0 %	0.0 %
Additional Power:	0.0 kW	0.0 kW
Mech. Room Installation Area:	600 ft <sup>2</sup>	

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### The Finance/Lifecycle Costing Module

**Soft Costs: Maintenance Costs**

System Type	Cost per Square Ft per year
Geothermal Vertical	\$0.09 to \$0.11
VAV- Air Cooled Chiller w/ gas boiler	\$0.10 to \$0.14
VAV- Water Cooled Chiller w/boiler	\$0.18 to \$0.20
Cooling tower systems	\$0.50 or more

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## The Finance/Lifecycle Costing Module



**Soft Costs: Water Consumption Costs**

- Cooling towers consume 2 gpm/ton.
- A 300 ton system will use 600 gpm
- Water can cost \$2.50/hour of cooling



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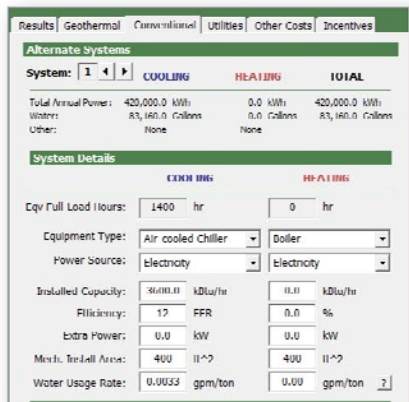




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## The Finance/Lifecycle Costing Module

**Soft Costs: Water Consumption Costs**


- Cooling towers consume 2 gpm/ton.
- A 300 ton system will use 600 gpm
- Water can cost \$2.50/hour of cooling





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## The Finance/Lifecycle Costing Module


### Incentives

- Commercial Incentives
- Residential Incentives

**Tax Incentives**


Investment Tax Credit:	10	%
Fixed Tax Credit:	0.00	\$ / Project





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## Challenges of Using Design Software

- Garbage In/Garbage Out
- Need to know the site-specific information
- Need to Understand Relationships Between Design Parameters
  - GLD is an excellent training tool!






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Course Overview

- How can GLD Software help you?
- Brief introduction to GLD
- Why Use GLD Software?
- System Design Inputs and Their Impact
- How to use GLD
- **What to Look For in a Good Design**
- Practice!



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What to Look For in a Good Design

- Reasonable Loads
- Appropriately selected heat pump(s)
- Appropriate flow rates/EWTs
- Accurate soil temperatures/TC values
- Appropriate Borehole Spacing for land area
- Stable soil temperatures over many years (vertical systems)
- Appropriate pipe selection to minimize PD




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Ground Loop Design  
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Course Overview

- How can GLD Software help you?
- Brief introduction to GLD
- Why Use GLD Software?
- System Design Inputs and Their Impact
- How to use GLD
- What to Look For in a Good Design
- **Practice!**

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Designing with GLD

- Vertical Systems
- Horizontal Systems
- Surface Water Systems



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Gaia Geothermal  **Ground Loop Design Version 2012**

### Vertical Design Project

**Known design variables:**

- Thermal Conductivity – 1.75 Btu/(hr \* ft \* °F) for a 275' boring
- Thermal Diffusivity – 1.25 ft<sup>2</sup> / day
- Ground Temperature – 49.5 °F
- Loads File – Heavycooling.GT1





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Gaia Geothermal  **Ground Loop Design Version 2012**

### Designing Horizontal Systems



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## Ground Loop Design Version 2012

### Horizontal Design Project



**Known design variables:**

- Site selected for directional drilling for minimal site impact
- Thermal Conductivity – 1.00 Btu/(hr \* ft \* °F) for a 400' boring
- Thermal Diffusivity – 0.95 ft<sup>2</sup> / day
- Ground Temperature – 51.0 °F
- Loads File – Heavycooling.GT1  
(Same as Vertical)



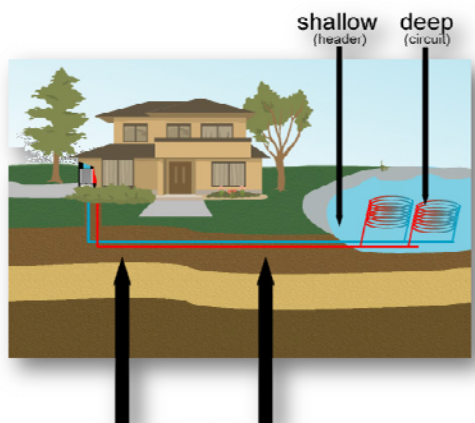

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## Ground Loop Design Version 2012

### Ponds




Horizontal Section




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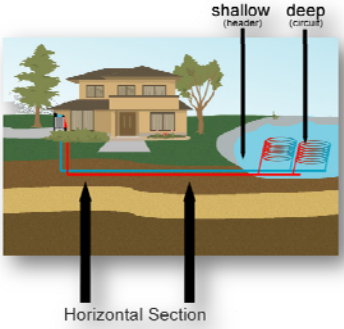
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## Ground Loop Design Version 2012

### Ponds


- Building Loads
- Capacity of body of water
- Pond Temperatures
- Soil Properties
- Pipe Size
- Pressure Drop Calculations
  - Turbulent flow essential
- Note: No Annual/Duration loads with ponds!





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## Ground Loop Design Version 2012



### Pond Module Method

- Step 1: Enter Loads/Pond Temps
- Step 2: Choose pipe style and size
- Step 3: Check the minimum allowable flow rate for turbulent flow
- Step 4: Choose a layout
- Step 5: Enter head loss for pipe and header
- Step 6: Calculate
- Step 7: Modify the parallel loops to balance turbulent flow and reduce pump power.




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## GLD Software



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