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DOE Webinar – Residential Geothermal Heat Pump Retrofits

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DOE Webinar Series

Erin R. Anderson

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- Technology Options – Vertical vs. Horizontal
- Applications on Residences
- Costs
- Use & Availability – Certified Designers, & Installers
- Financing Options
- Key Information for RFPs
- Project QA/QC and Monitoring
- Tools & More Information on GHP

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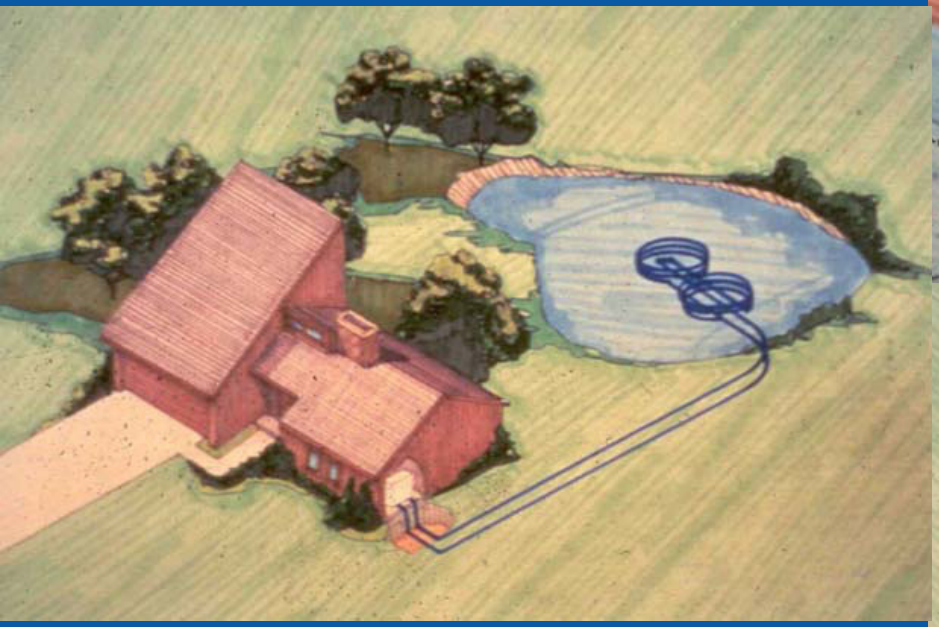
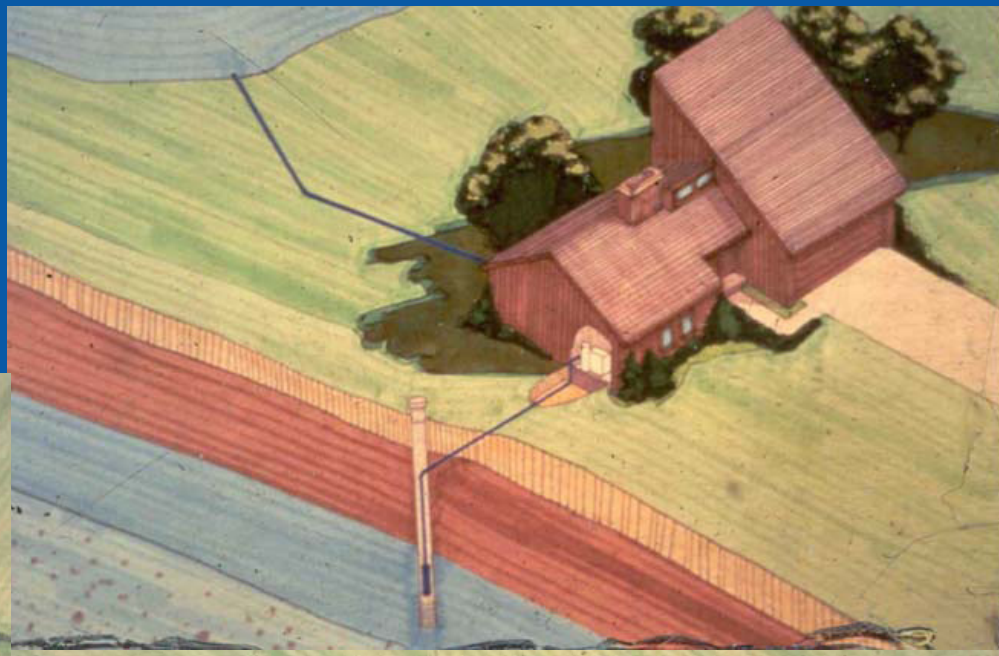
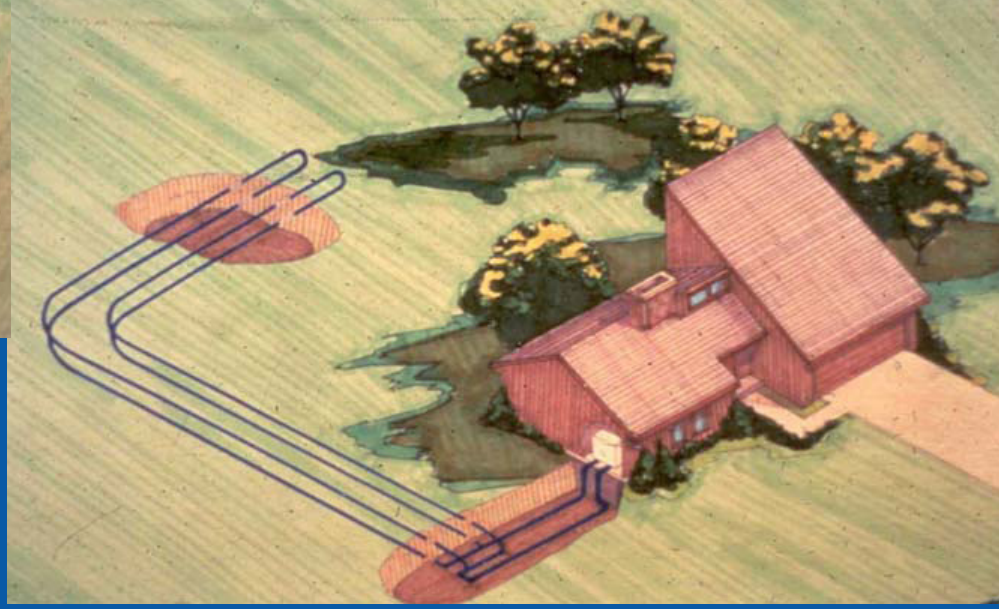
Technology Options







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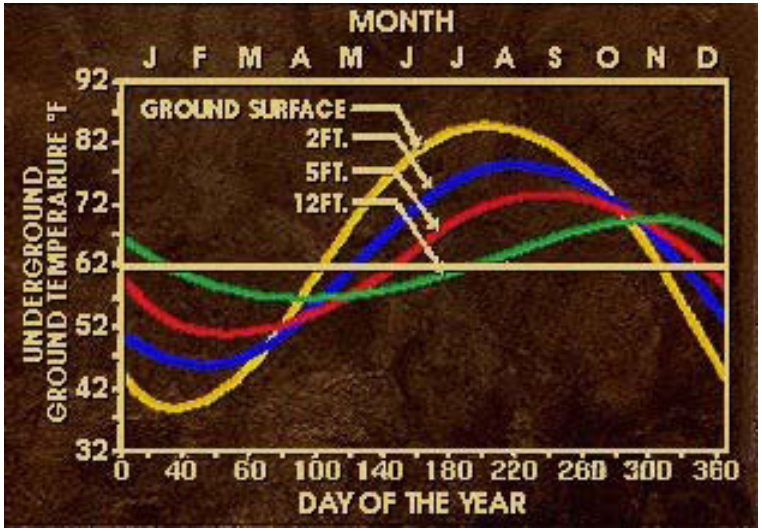
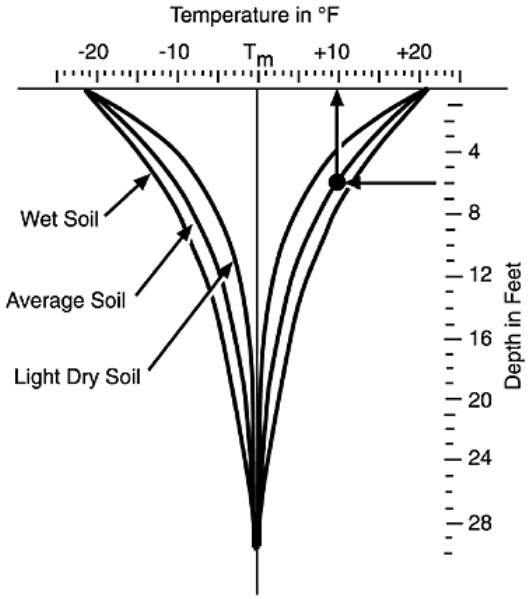
Geothermal Energy

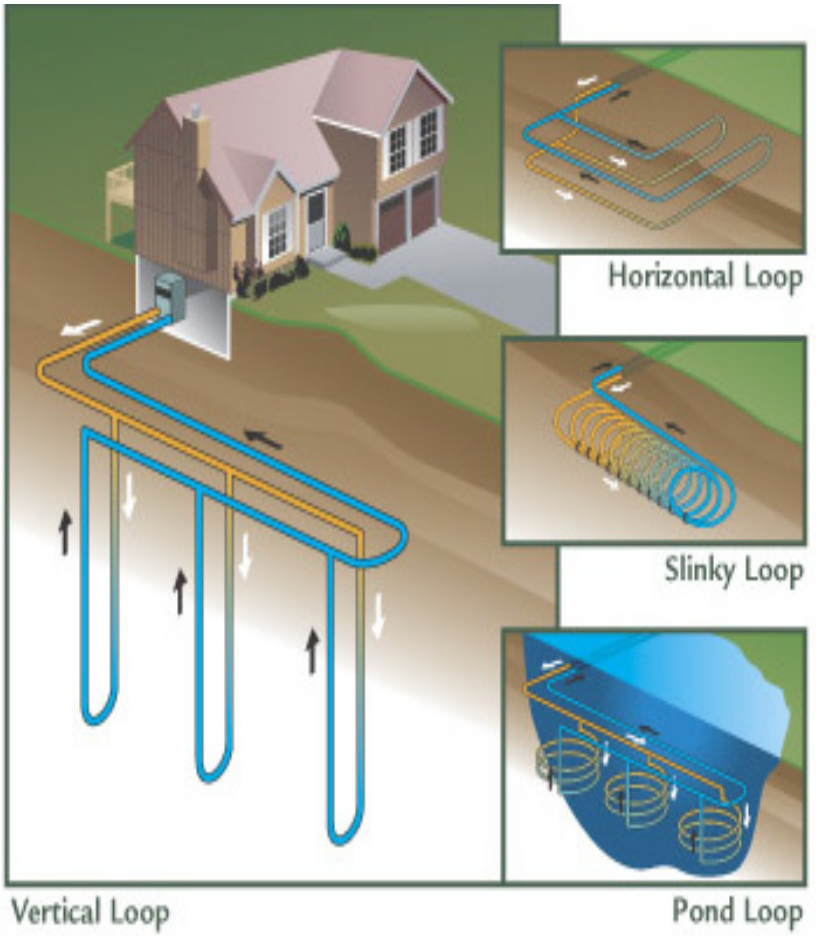
- Heat energy contained in the earth
- Shallow temperature fluctuate with the seasonal air temperatures
- Temperature become stable at depths of 30 ft and approach annual average air temps
- This is all true, absent a geothermal anomaly or high temperature gradient areas



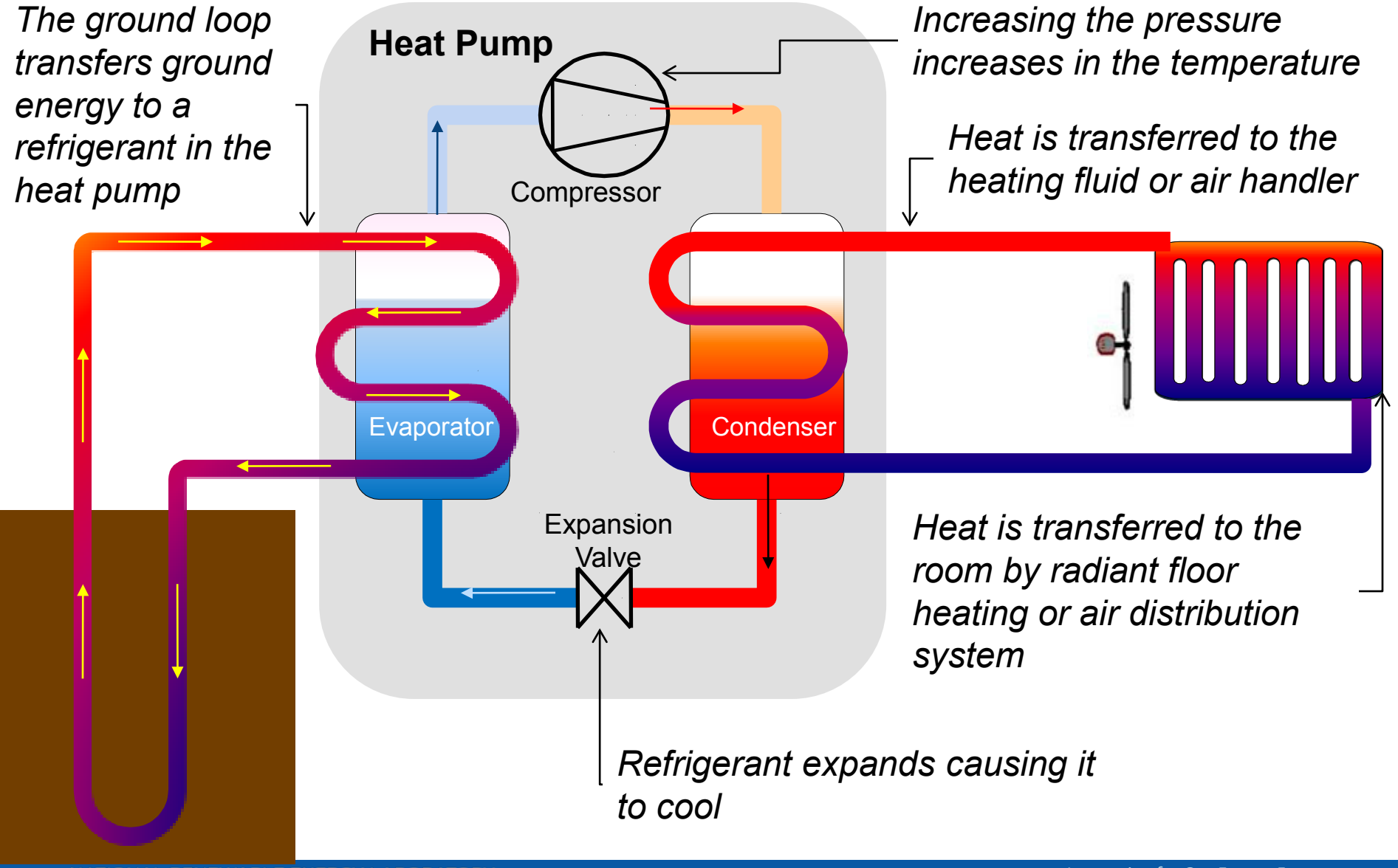


Geothermal Heat Pumps (GHP)

- Highly efficient method of providing heating and cooling
- Work by using ground temperature as a renewable resource for pumping heat in winter and rejecting heat in summer
- Cost effective
- Economic and environmental benefits

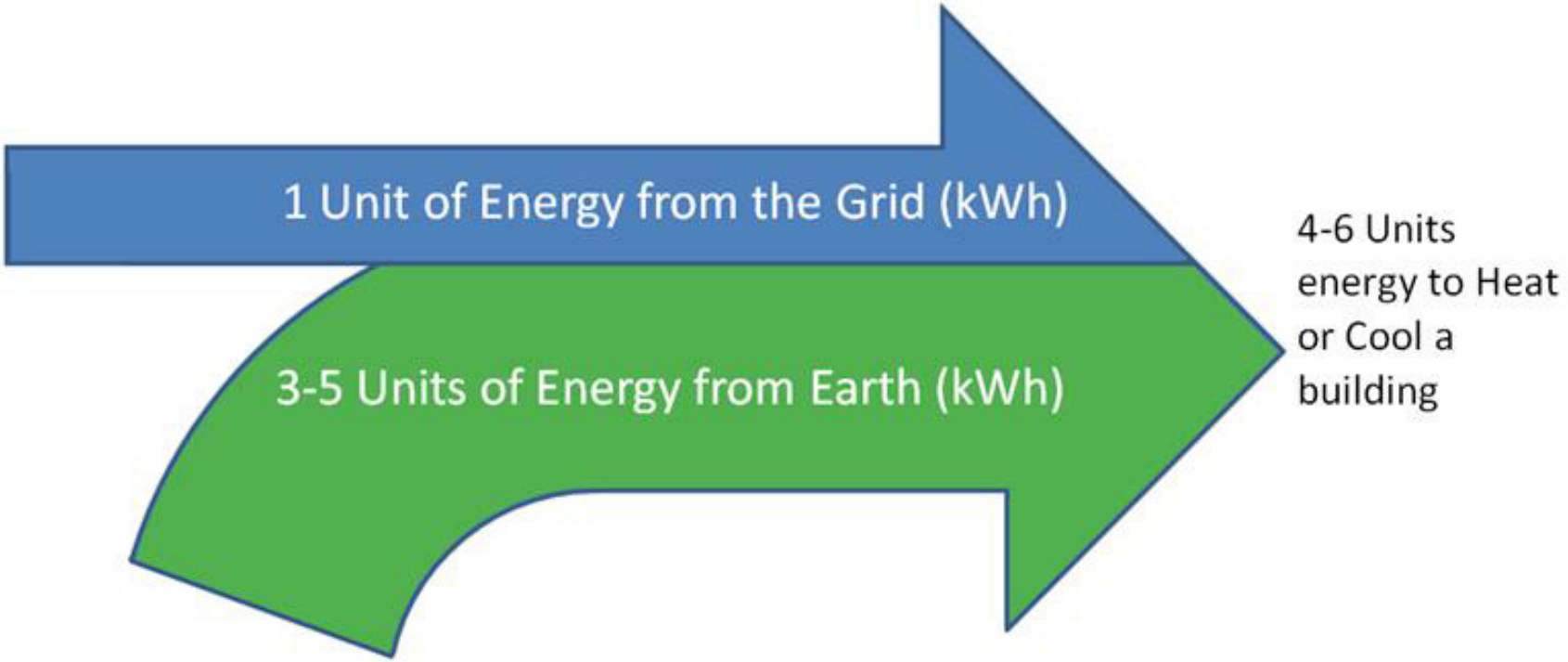


What is a Heat Pump & How Does it Work?



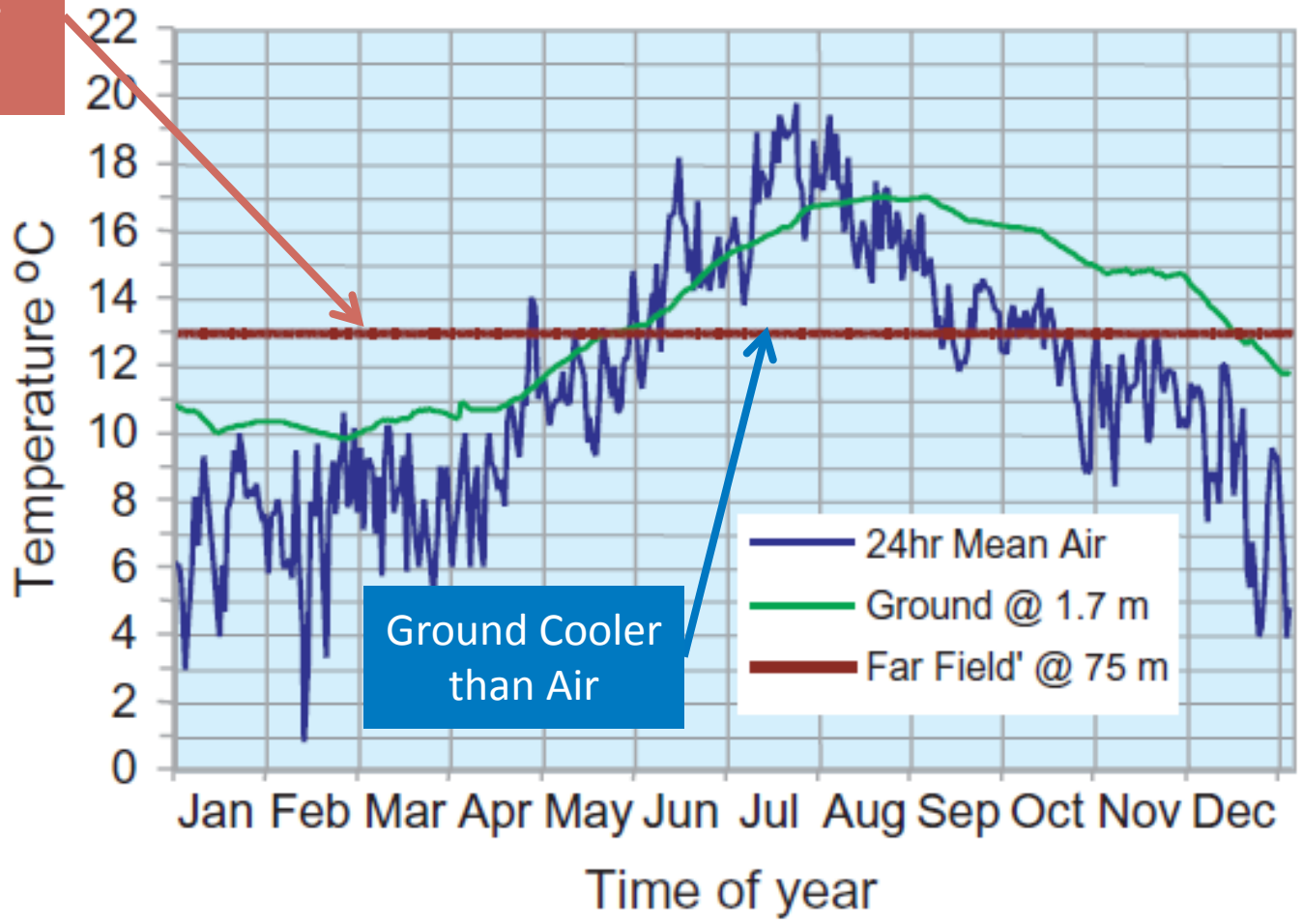
Geothermal Efficiency

- Use the green under your feet…as close to the money tree as you can get



Why is GHP useful and efficient?

Ground Warmer than Air

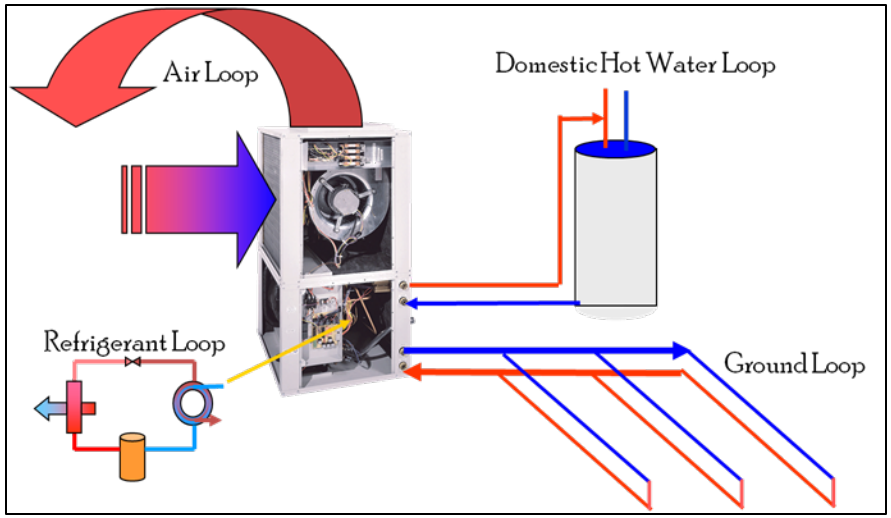


Types of Heat Pumps

- Characterized by medium used for the Heat Source & Heat Sink
  - Air to Air – Air Source Heat Pump
  - Water to Air – Water Source Heat Pump
  - Water to Water – Uses hydronic pipes through the building

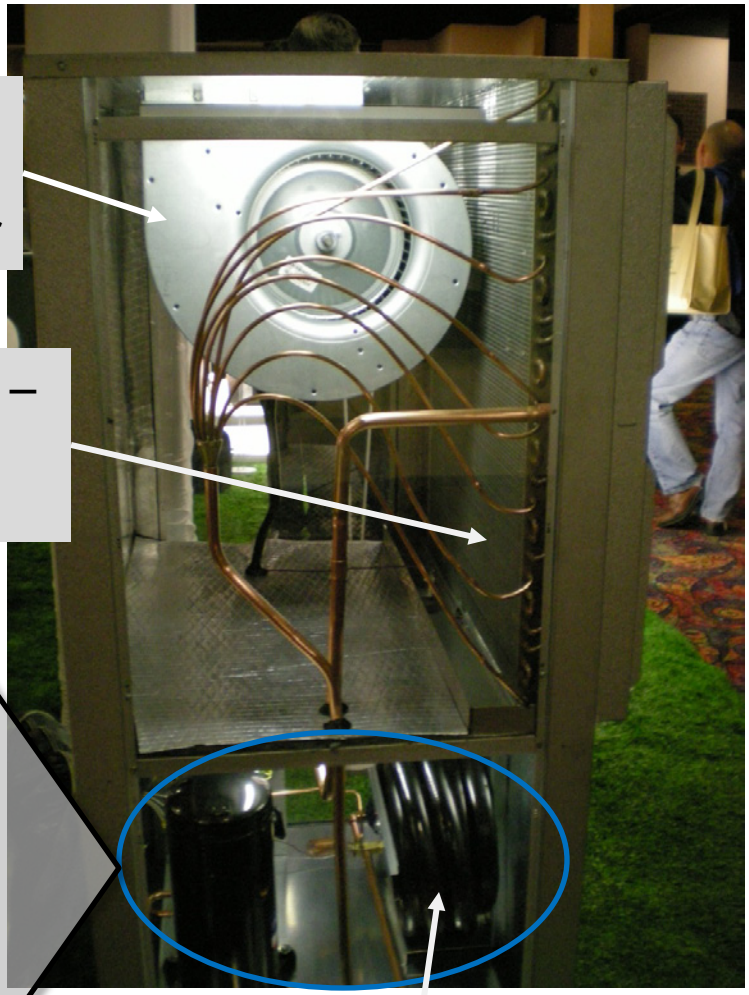
- Heats, Cools, & Produced Hot Water
  - Capacity is measured in tons, like AC units

GHP System & Components



Air Fan – circulates building air

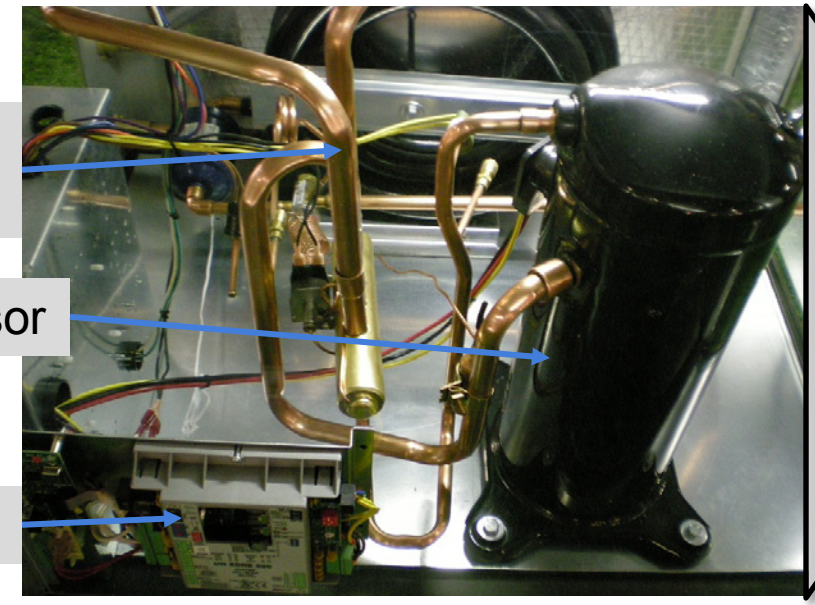
Air Coils – heats or cools air



Refrigerant Loop

Compressor

Controls



Ground Loop & Refrigerant Loop Connection

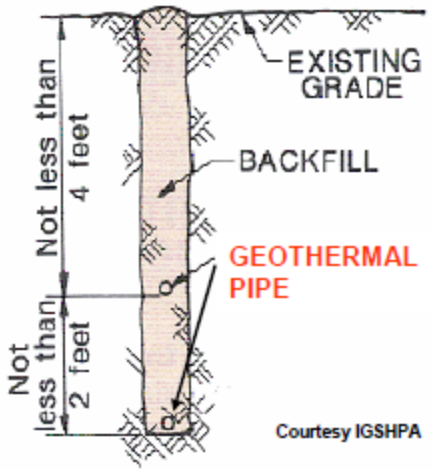
Types of Ground Heat Exchangers

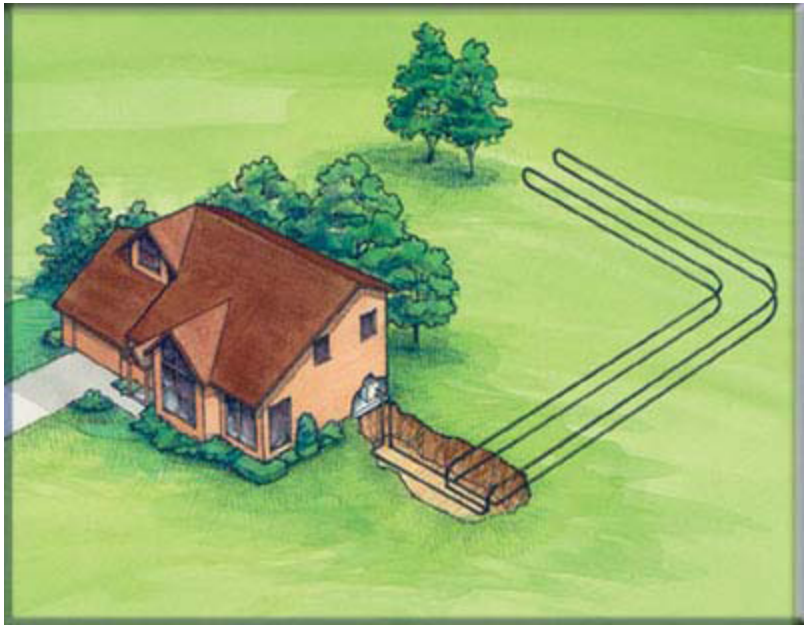
- Open Loop
  - Ground water from a well, river, or pond
  - Exchanges **Heat & Water** with the ground
  - Returns water to the ground

Closed Loop
  - Buried HDPE or copper (direct exchange) pipe
  - Circulates as secondary fluid (water or water/antifreeze mix or refrigerant with copper pipe)
  - Exchanges **Heat** with the ground
  - Configuration – depends on available space and installation costs

Horizontal Trench Loop

- Cost effective when land is plentiful
- Trench depth is 6 ft or more to go below frost line





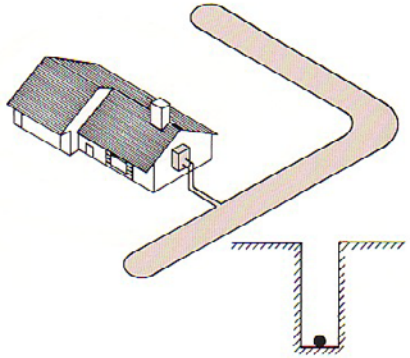
Rule of thumbs

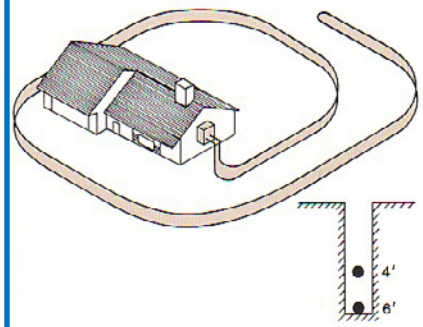
- Trench length – typically 300 ft
- Pipe length – out & back = 600 ft

Source: Klaassen, Iowa Energy Center

Horizontal Layout Options

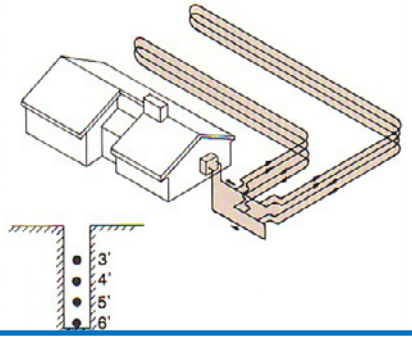
- Single flow path
- Large land area required
- Larger pipe diameters required to reduce friction loss
- Increased antifreeze fluid volume

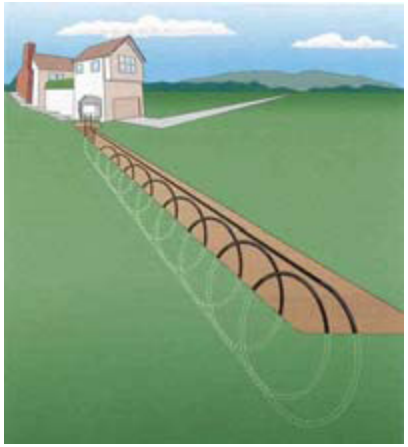




- Single flow path
- Shorter trench required than a single pipe system
- Larger pipe diameter than a parallel system

- Reduced trench length
- Parallel flow
- Deeper trench is generally required



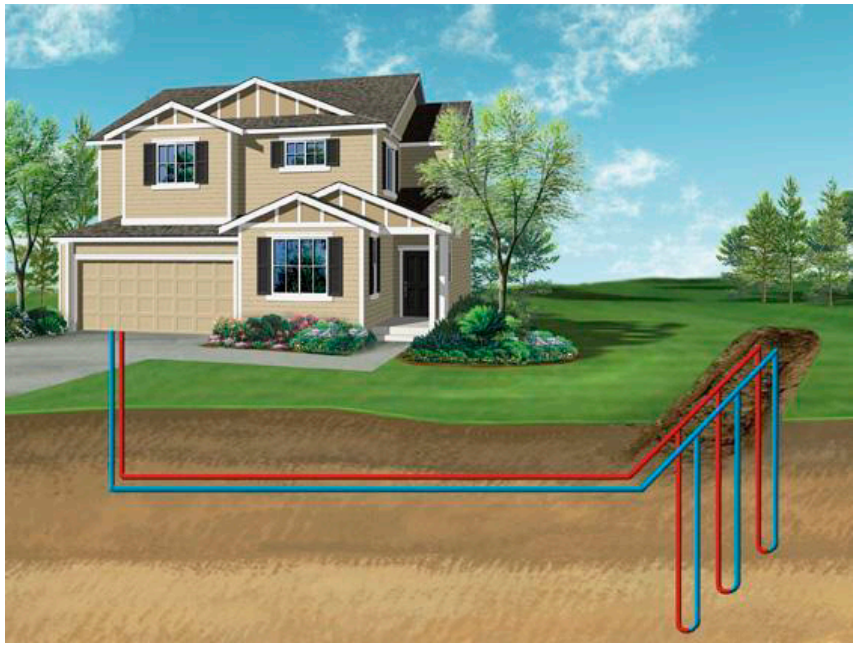


- More pipe area per trench length
- Horizontal or vertically installed

Source: IGSHPA

Vertical Ground Loop - Borehole

- Used in areas with land area restrictions
- Temperatures are typically more constant than horizontal
- Depths are usually 200-300 ft
- Pipe length 400-600 ft

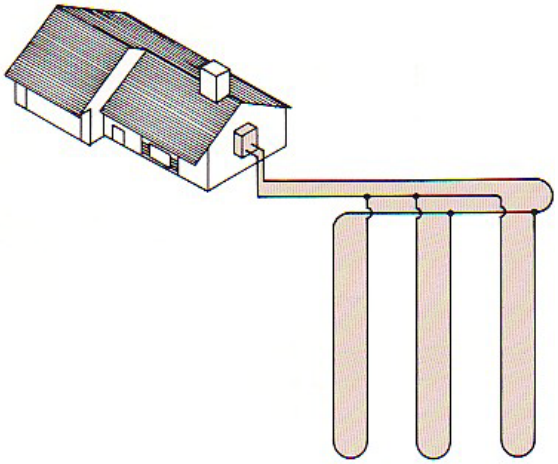


Rule Of Thumb:
1 ton for every 200-300 ft borehole

Vertical Configuration Options

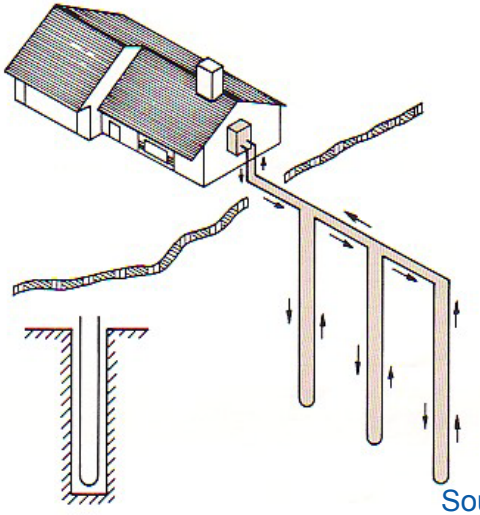
Parallel

- Small diameter pipe than series system
- Larger capacity heat exchanger can be designed
- ¾ and 1 inch pipe loops are common
- Bore hole depths can be increased in limited land areas



Series

- Larger pipe required for series system
- Large pipe difficult to handle
- Heat exchanger limited to about 3-tons because of pipe friction



Source: IGSHPA

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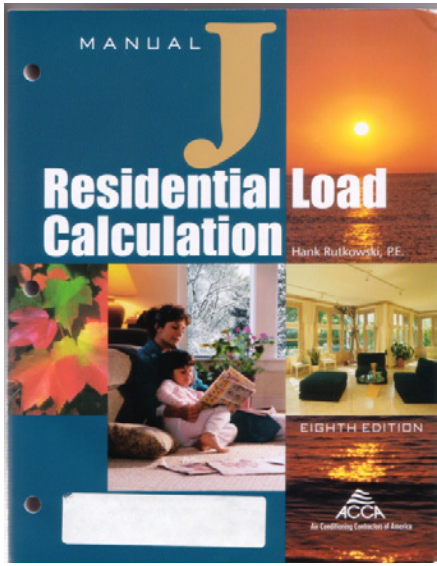
Applications on Residences

Process for Residential

- Determine the heating/cooling loads (Btuh)
- Select heat pump size
- Select indoor air/water distribution system
- Estimate the building's energy requirement
- Estimate the ground heat exchanger loads
  - Annual load
  - Design month's load



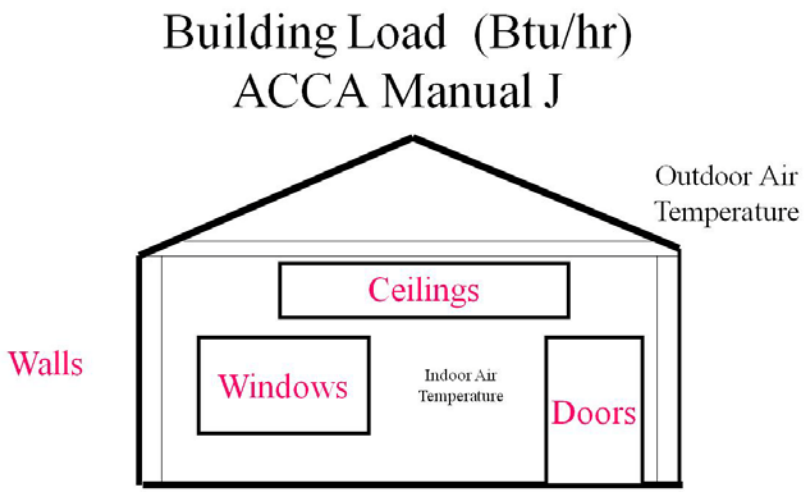


TABLE 3.3: Energy Calculation by the Bin Method: Ground-Source Heat Pump

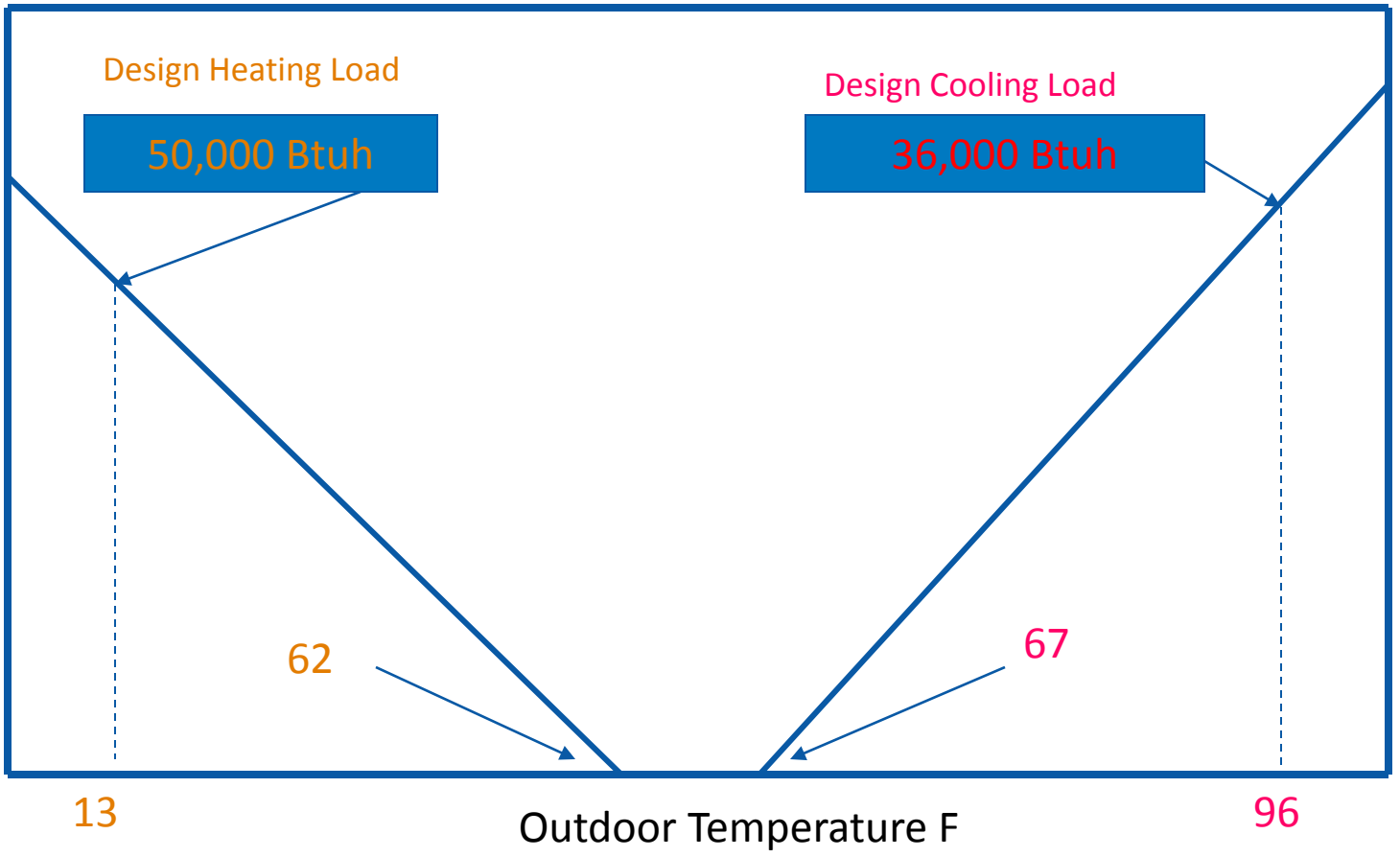
Residence in Stillwater, Oklahoma

Bin Temp-°F 1	Bin Hours 2	Bldg. Load Btu/hr 3	EWT F 3A	Unit Cap. Btu/hr 4	Theo. Run Time-% 5 3/4	Partial Load Fac. 6	Actual Run Time-% 7 5/6	Unit Input kW 8	Elec. Res.-KW 8A	Unit Input kWh 9 2x7(8+8A)	Ener. Cost $/kWh 10	Ener. Cost $ 11 9x10
112	1	55,862.16	100.0	30,596.04	1.00	1.00	1.00	3.27		3.27	0.075	0.25
107	13	49,655.26	96.4	31,253.94	1.00	1.00	1.00	3.20		41.66	0.075	3.12
102	69	43,448.36	92.7	31,911.84	1.00	1.00	1.00	3.14		216.58	0.075	16.24
97	185	37,241.46	89.1	32,569.74	1.00	1.00	1.00	3.07		568.51	0.075	42.64
92	309	31,034.56	85.4	33,227.64	0.93	0.98	0.95	3.01		881.47	0.075	66.18
87	420	24,827.66	81.7	33,885.54	0.73	0.93	0.79	2.94		969.99	0.075	72.75
82	565	18,620.76	78.1	34,543.44	0.54	0.88	0.61	2.88		989.90	0.075	74.24
77	731	12,413.86	74.4	35,201.34	0.35	0.84	0.42	2.81		864.22	0.075	64.82
72	800	6,206.96	70.8	35,859.24	0.17	0.79	0.22	2.74		479.01	0.075	35.93
67	712	0.00	67.1	36,517.14	0.00	0.75	0.00	2.68		0.00	0.075	0.00
62	678	0.00	62.8	39,997.8	0.00	0.75	0.00	3.23	0.00	0.00	0.050	0.00
57	654	5,102.00	60.8	39,114.5	0.13	0.78	0.17	3.18	0.00	347.09	0.050	17.35
52	625	10,204.00	58.8	38,231.1	0.27	0.82	0.33	3.14	0.00	640.85	0.050	32.04
47	631	15,306.00	56.8	37,347.8	0.41	0.85	0.48	3.09	0.00	937.66	0.050	46.88
42	622	20,408.00	54.9	36,464.5	0.56	0.89	0.63	3.04	0.00	1,190.86	0.050	59.54
37	568	25,510.00	52.9	35,581.2	0.72	0.93	0.77	3.00	0.00	1,313.69	0.050	65.68
32	495	30,612.00	50.9	34,697.8	0.88	0.97	0.91	2.95	0.00	1,327.83	0.050	66.39
27	311	35,714.00	48.9	33,814.5	1.00	1.00	1.00	2.90	0.56	1,076.39	0.050	53.82
22	184	40,816.00	46.9	32,931.2	1.00	1.00	1.00	2.86	2.31	951.03	0.050	47.55
17	101	45,918.00	44.9	32,047.9	1.00	1.00	1.00	2.81	4.07	694.49	0.050	34.72
12	49	51,020.00	43.0	31,164.5	1.00	1.00	1.00	2.76	5.82	420.60	0.050	21.03
7	14	56,122.00	41.0	30,281.2	1.00	1.00	1.00	2.72	7.57	144.08	0.050	7.20
2	5	61,224.00	39.0	29,397.9	1.00	1.00	1.00	2.67	9.33	59.99	0.050	3.00
-3	1	66,326.00	37.0	28,514.6	1.00	1.00	1.00	2.62	11.08	13.71	0.050	0.69

TOTAL COOLING COST: 376.17
TOTAL HEATING COST: 455.91

T-4.8

Building Heating and Cooling Load Profile



Free Hot Water

- Domestic Water Heating Applications
  - Desuperheater to heat domestic water
    - Cooling Season = Free Water Heating
    - Heating Season = High COP water heating
  - Water to water heat pumps preheat Domestic Water at COP of 3.0 to 5.0

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Costs

First Costs

- Generally, the geothermal system cost inside the building is less than or equal to conventional systems
- The incremental cost over a conventional system is in the Geothermal Heat Exchanger (aka. ground loop)
- Manage the installed costs
  - Reduce heating/cooling loads
    - Efficient building envelopes
  - TC (thermal conductivity) test as applicable for project size
  - Organize & minimize geothermal system piping

Cost of Installation

- Installed cost – ground loops
  - Ground coupled – horizontal: $1,100/ton
  - Ground coupled – slinky: $1,300/ton
  - Ground coupled – vertical: $1,500/ton
  - Ground water (3 ton, w/o well): $950/ton
- Water-to-air heat pump units
  - 8.8 kW (2.5 tons): $2,750 ($1,100/ton)
  - 10.5 kW (3.0 tons): $3,000 ($1,000/ton)
  - 14.1 kW (4.0 tons): $3,600 ($900/ton)
- Substantial variations possible

Ref: Kavanaugh & Gilbreath (1995), and Rafferty (2008)

Estimations on Installed Costs

	2008 Mature Market Est. from Graph	2008 Immature Market
	$ per Ton	
ASHP	$2,000	$4,000
Gas w/AC	$1,967	$3,933
Ground Water	$3,333	$6,667
Horizontal	$3,933	$7,867
Slinky	$4,033	$8,067
Vertical	$4,300	$8,600

Estimates includes both inside (ductwork, heat pump unit, controls etc) and outside (ground loop, piping, excavation and/or drilling)

Source: Kevin Rafferty, 2008 - "An Information Survival Kit For The Prospective Geothermal Heat Pump Owner"

Savings

- Average Energy savings: 31% to 71%
- Average Cost savings ($): 18% to 54%
- Heating efficiencies 50 to 70% higher than other heating systems
- Cooling efficiencies 20 to 40% higher than available air conditioners

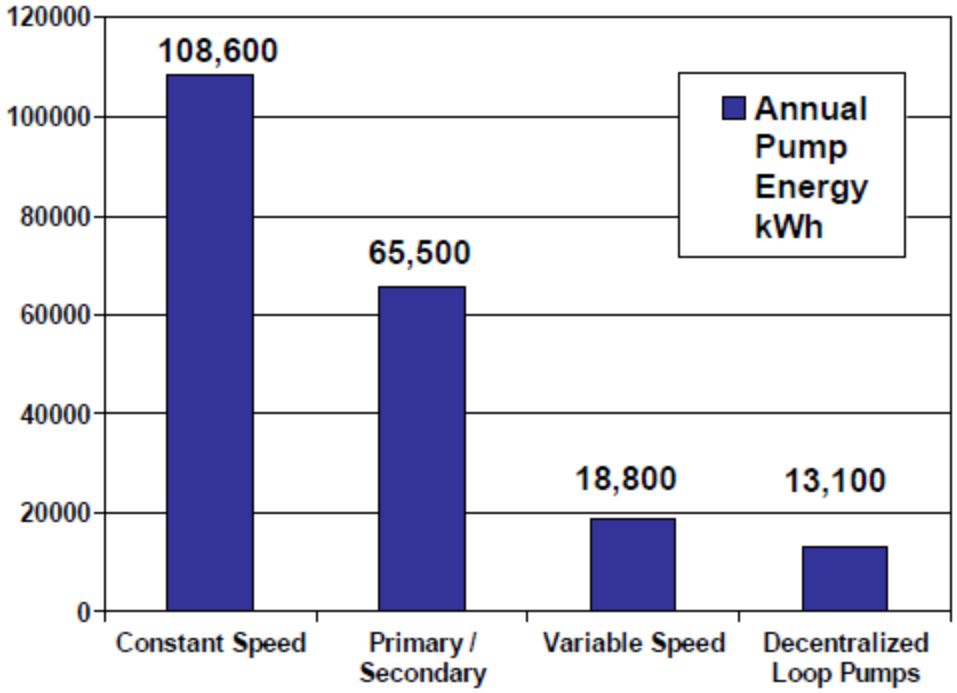
Savings in Energy Costs in USA Compared to GHP ($ per Btu or kWh)

- 4x for electric resistance
- 3x for propane
- 2x for ASHP
- 2x for fuel oil
- 2x for natural gas

Sources: Geo-Heat Center, http://geoheat.oit.edu/pdf/hp1.pdf, IGSHPA

Operational & Maintenance Costs

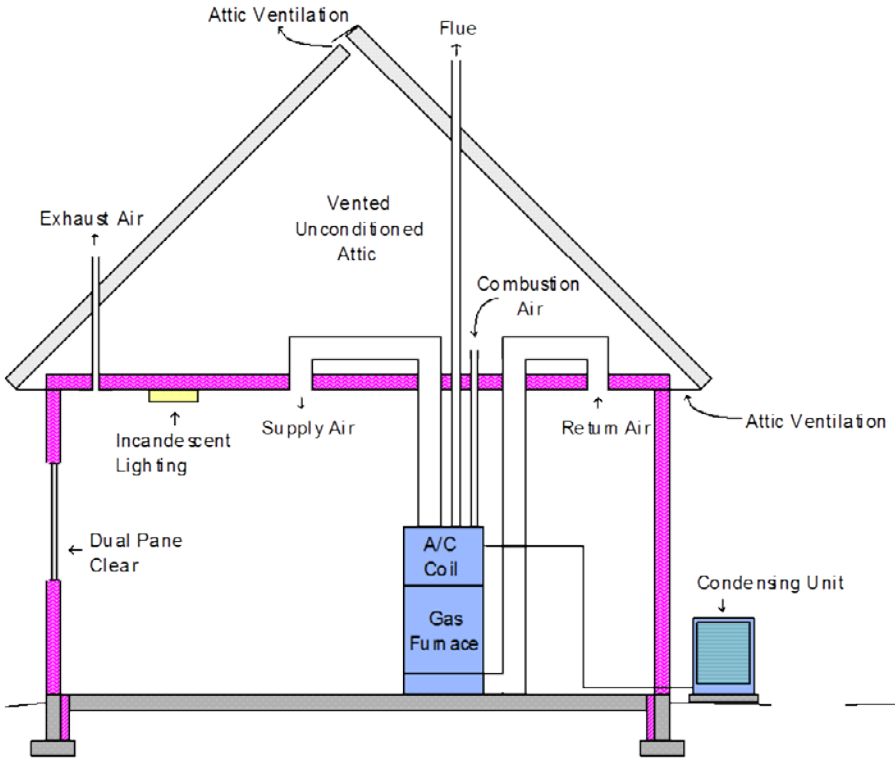
- Make sure circulating pumps are sized correctly
  - Oversized pumps are energy hogs



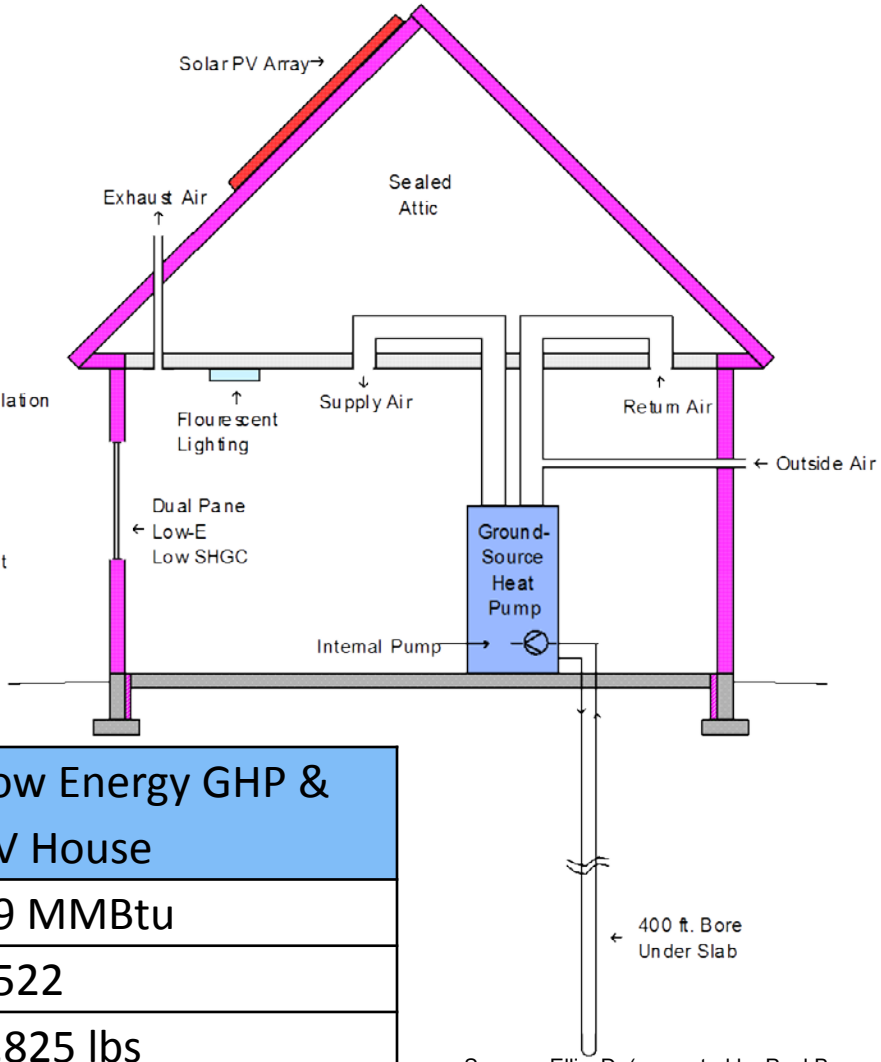
Source: Kavanaugh, K & McInerny, S, "Energy Use of Pumping Options for GSHP"

Habitat for Humanity Project – Hope Crossing, OK

Standard Gas House



Low Energy GHP + PV House



	Standard Gas House	Low Energy GHP & PV House
Energy Use	95 MMBtu	19 MMBtu
Energy Cost	$1,739	$522
CO_2 Emissions	25,460 lbs	9,825 lbs

Source: Ellis, D. (presented by Paul Bony 2010, April 19), ClimateMaster

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Use & Availability – Certified Designers & Installers

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Feel Confident with the Team

- Find certified contractors, designers, & installers:

IGSHPA

GEO

- Call around to University's in the area who might do research on GHP and find out who are the best contractors
- Get firms that understand the critical importance of designing a GHP system that fits the building use and loads

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Financing Options

Help with the Costs

- ESCOs - Energy Services Company
  - Successful with Fort Polk
  - Energy Saving Performance Contract (ESPC)
- Utility Negotiations
  - Reduce rates due to reduction of summertime peak loads with GHP
- Utility & Tax Incentives
  - DSIRE - http://www.dsireusa.org/

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Key Information for RFPs

Things you should have in an RFP

1. All contractors, installers, designers, & drillers must be IGSHPA certified
2. Require a minimum number of previous successful GHP projects in your area and references
3. Contact the bidders previous clients
4. Costs
    1. What are the actual performance savings of previous projects
    2. Clearly state how you want the GHP components broken down – NO LUMP SUM Contracts

Project Specifications

- GHP General Specifications – by Oak Ridge Lab
  - http://www.ornl.gov/~webworks/cpr/v823/rpt/107119.pdf

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Project QA/QC and Monitoring

QA/QC

- Get GHP Smart…Fast
- Know the processes and what to look for
- If you get qualified owners rep, make sure that they are IGSHPA certified or have worked on several successful GHP projects.

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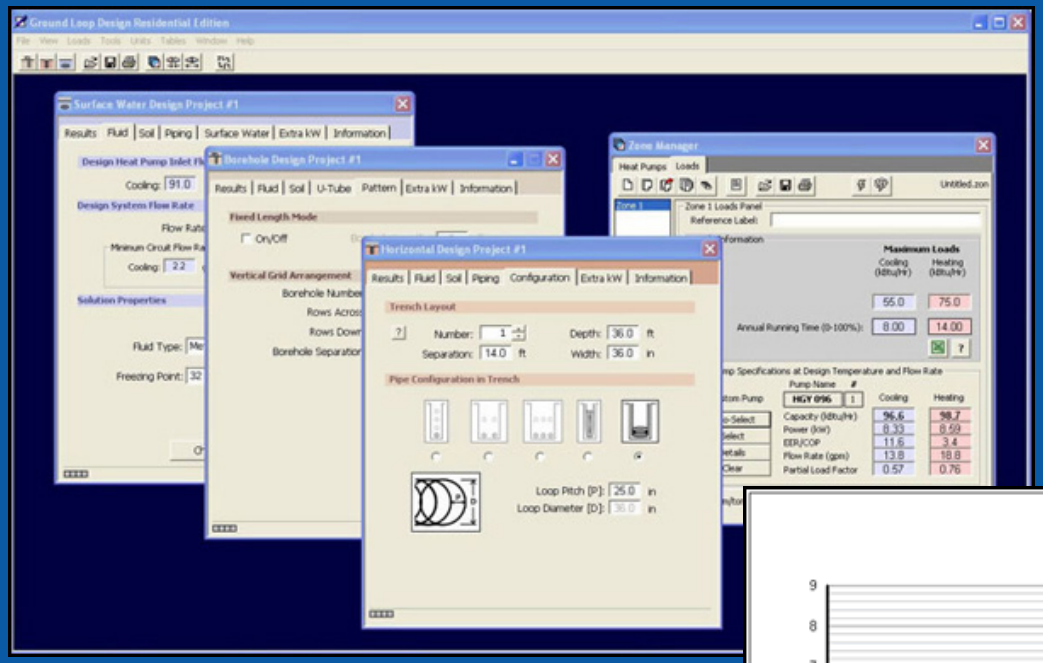
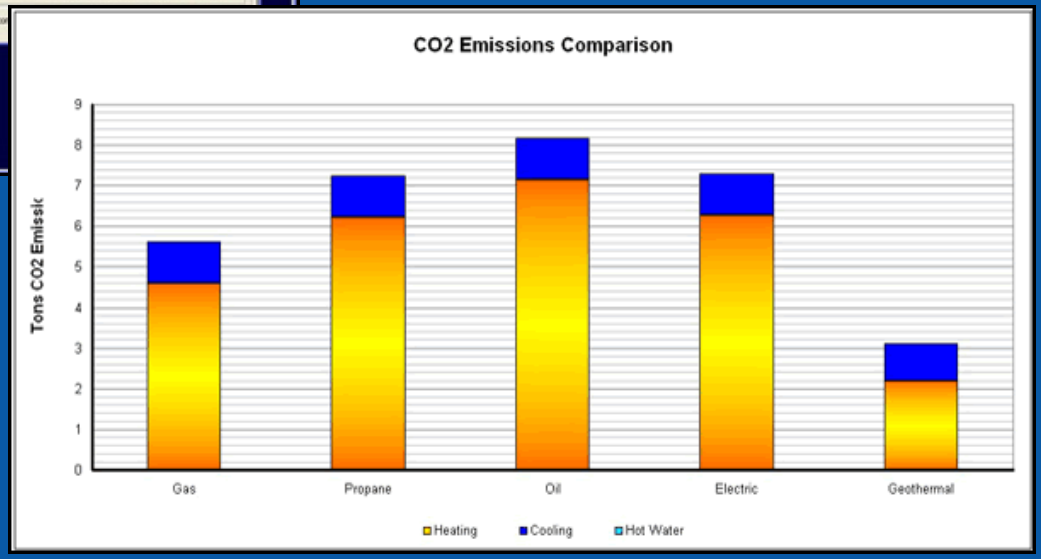
Tools & More Information on GHP





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Software & Certified Installer Directories

Software

- RETScreen
  - http://www.retscreen.net/ang/g_ground.php
- GeoKISS
  - http://www.geokiss.com/gsoftware.htm
- Gaia Geothermal
  - http://www.gaiageo.com/

Industry Directory

- IGSHPA
  - http://www.igshpa.okstate.edu/directory/directory.asp
- GEO
  - http://www.geoexchange.org/find-a-pro/geothermal-heat-pump-directory.html

More Information

- Geo-Heat Center
  - http://geoheat.oit.edu/techpap.htm#heatpump
- GROUND-MED
  - http://www.groundmed.eu/
- Geothermal Surviver Kit - Rafferty
  - http://www.heatspring.com/downloads/intro/GeothermalSurvivalKit.pdf