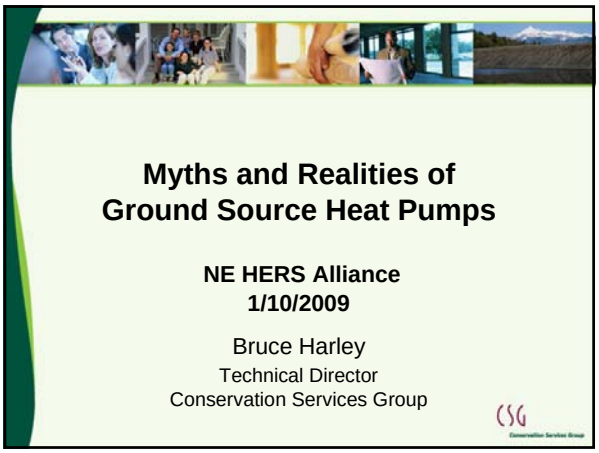


Myths and Realities of Ground Source Heat Pumps

NE HERS Alliance
1/10/2009

Bruce Harley
Technical Director
Conservation Services Group

Ground Source Heat ~~Pump~~

Geothermal Heating and Cooling

Geoexchange® System

Advantages of Geoexchange:

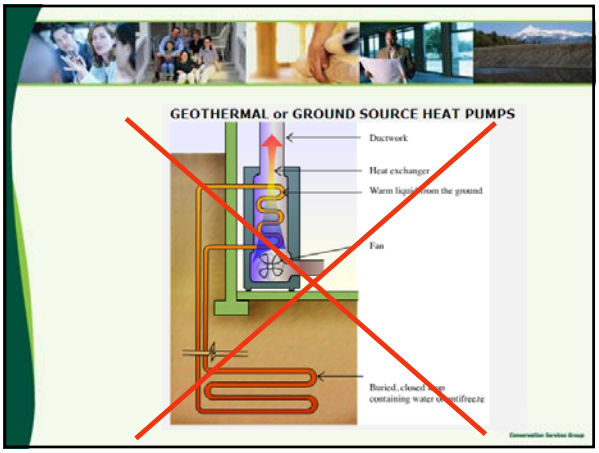
Nobody understands what it is or how it works

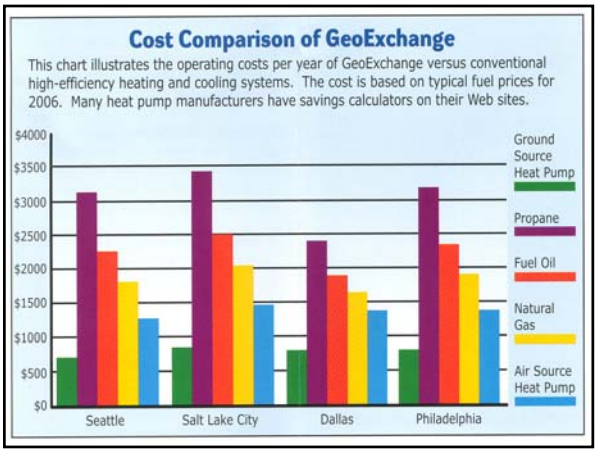
Quote from (new) CSG staff:

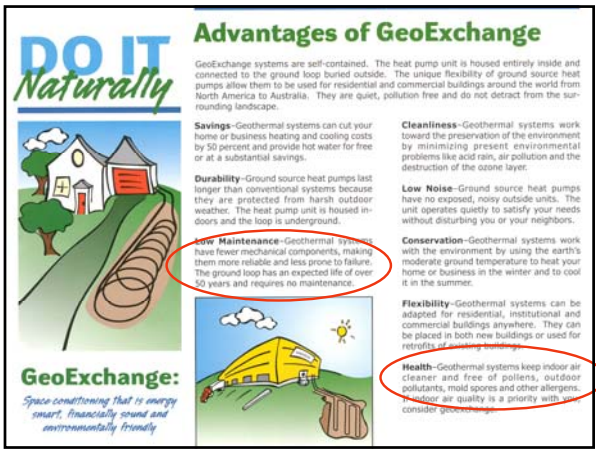
- The majority of my friends and family believe that Ground Source Heat Pumps and Geothermal Heating are two totally different things, the latter, of course, being the more "natural" and "environmentally responsible" choice…

Quote continued:

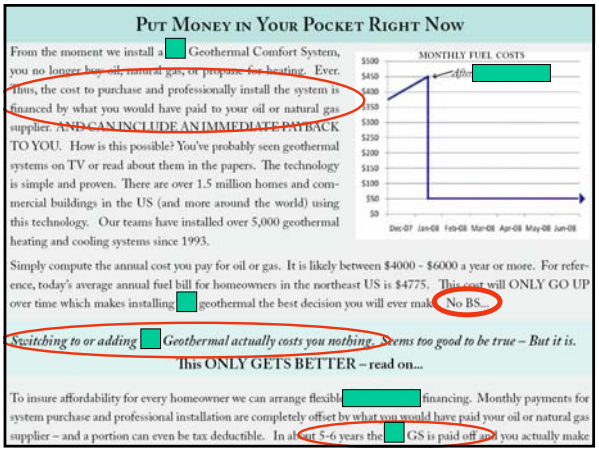
- …The prevailing belief among them is that with Geothermal heating all you have to do is flip a switch in your living room and heat emanates from the dirt -- unlimited "free heat" under everyone's house that is waiting to be "set free" by a couple of tubes and a bath fan.

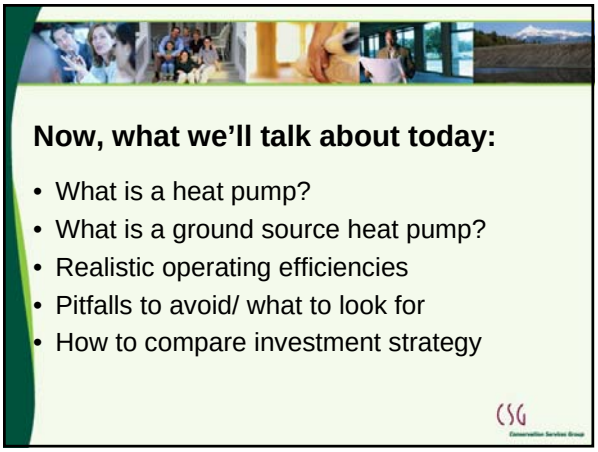


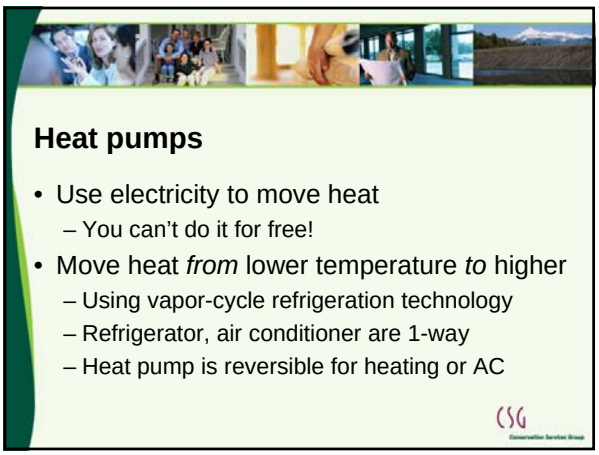


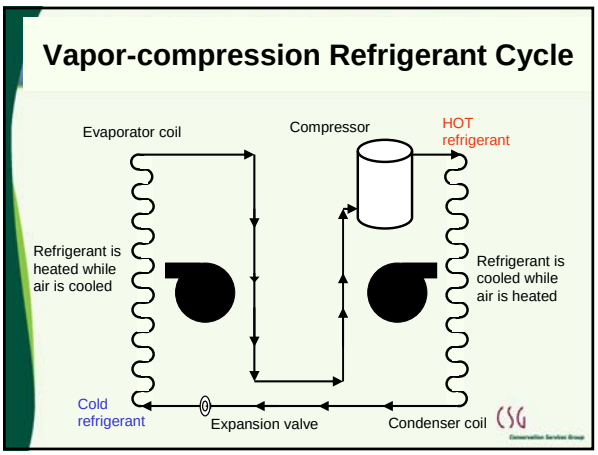

DO IT Naturally
Advantages of GeoExchange
GeoExchange systems are self-contained. The heat pump unit is housed entirely inside and connected to the ground loop buried outside. The unique flexibility of ground source heat pumps allow them to be used for residential and commercial buildings around the world from North America to Australia. They are quiet, pollution free and do not detract from the surrounding landscape.
Savings-Geothermal systems can cut your home or business heating and cooling costs by 50 percent and provide hot water for free or at a substantial savings.
Durability-Ground source heat pumps last longer than conventional systems because they are protected from harsh outdoor weather. The heat pump unit is housed indoors and the loop is underground.
Low Maintenance-Geothermal systems have fewer mechanical components, making them more reliable and less prone to failure. The ground loop has an expected life of over 50 years and requires no maintenance.
Cleanliness-Geothermal systems work toward the preservation of the environment by minimizing present environmental problems like acid rain, air pollution and the destruction of the ozone layer.
Low Noise-Ground source heat pumps have no exposed, noisy outside units. The unit operates quietly to satisfy your needs without disturbing you or your neighbors.
Conservation-Geothermal systems work with the environment by using the earth's moderate ground temperature to heat your home or business in the winter and to cool it in the summer.
Flexibility-Geothermal systems can be adapted for residential, institutional and commercial buildings anywhere. They can be placed in both new buildings or used for retrofits of existing buildings.
Health-Geothermal systems keep indoor air cleaner and free of pollens, outdoor pollutants, mold spores and other allergens. If indoor air quality is a priority with you, consider geoexchange.
GeoExchange:
Space conditioning that is energy smart, financially sound and environmentally friendly


YOU CAN STOP BUYING OIL OR GAS TO HEAT YOUR HOME NOW!
No one needs to tell you the price of oil and natural gas is shooting through the roof. Just look at your last fuel bill. And both aren't going down, EVER. There are predictions for home heating oil to top $4 a gallon - THIS SEASON. Keeping up with your home heating bills isn't easy.
NY Monthly Average Home Heating Oil Prices
There is a solution. And best of all its "green"
Here's an opportunity to save money heating and cooling your home with a pure, renewable energy source you already own right in your backyard!
WHAT'S THE SECRET? THIS INCREDIBLE ENERGY SOURCE IS CALLED GEOTHERMAL
IT'S REAL - IT'S NOW - AND IT WORKS!
SUMMER OPERATION
Heat Energy is removed from the house (A/C mode) via the heat exchanger and sent into the ground.
In simple terms, the earth is a giant heat storage battery. Every minute of every day the sun heats the ground and the earth retains this heat. In the Northeast United States, a few feet below the surface, the earth is about 53 degrees Fahrenheit all the time. This constant heat is the source of clean, inexhaustible energy. And once tapped, it's yours free of charge. To tap and use this energy we're proud to offer the Geothermal Comfort System – a super-efficient, comfortable, reliable home heating and cooling system

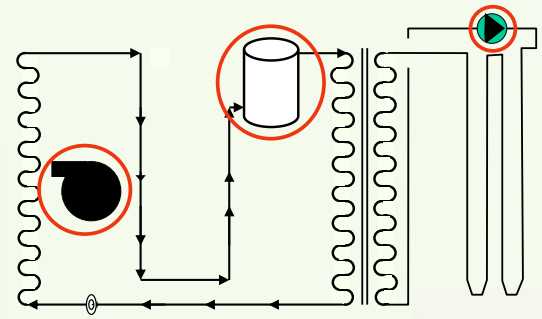

Put Money in Your Pocket Right Now
From the moment we install a Geothermal Comfort System, you no longer buy oil, natural gas, or propane for heating. Ever. Thus, the cost to purchase and professionally install the system is financed by what you would have paid to your oil or natural gas supplier. AND CAN INCLUDE AN IMMEDIATE PAYBACK TO YOU. How is this possible? You've probably seen geothermal systems on TV or read about them in the papers. The technology is simple and proven. There are over 1.5 million homes and commercial buildings in the US (and more around the world) using this technology. Our teams have installed over 5,000 geothermal heating and cooling systems since 1993.
MONTHLY FUEL COSTS
After
$500
$450
$400
$350
$300
$250
$200
$150
$100
$50
$0
Dec-07 Jan-08 Feb-08 Mar-08 Apr-08 May-08 Jun-08
Simply compute the annual cost you pay for oil or gas. It is likely between $4000 - $6000 a year or more. For reference, today's average annual fuel bill for homeowners in the northeast US is $4775. This cost will ONLY GO UP over time which makes installing geothermal the best decision you will ever make. No BS...
Switching to or adding Geothermal actually costs you nothing. Seems too good to be true – But it is.
This ONLY GETS BETTER – read on...
To insure affordability for every homeowner we can arrange flexible financing. Monthly payments for system purchase and professional installation are completely offset by what you would have paid your oil or natural gas supplier – and a portion can even be tax deductible. In about 5-6 years the GS is paid off and you actually make

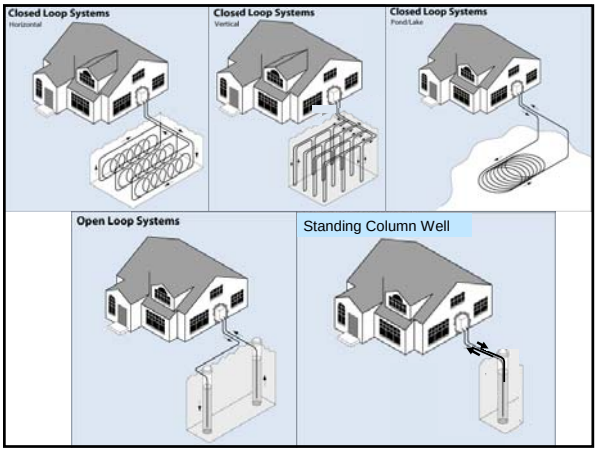

Now, what we'll talk about today:
• What is a heat pump?
• What is a ground source heat pump?
• Realistic operating efficiencies
• Pitfalls to avoid/ what to look for
• How to compare investment strategy
CSG


Heat pumps
• Use electricity to move heat
– You can't do it for free!
• Move heat *from* lower temperature *to* higher
– Using vapor-cycle refrigeration technology
– Refrigerator, air conditioner are 1-way
– Heat pump is reversible for heating or AC
CSG


Vapor-compression Refrigerant Cycle
Evaporator coil
Compressor
HOT refrigerant
Refrigerant is heated while air is cooled
Refrigerant is cooled while air is heated
Cold refrigerant
Expansion valve
Condenser coil
CSG

Ground Source Heat Pump





Air vs. Ground Source Heat Pumps

- Outdoor air source:
  - Hardest to heat (or cool) when most needed
  - Typically uses electric supplementary heat - $$
- Ground source:
  - Uses ground water, or circulates antifreeze through pipes in ground
  - Ground temperature is more stable seasonally

GSHP Pros … Cons

- Potentially more efficient
- Operating cost savings (?) (especially cooling)
- No outdoor unit
- No combustion in home

- High first cost
- More design issues
- More installation issues
- Less developed install/support infrastructure

Coefficient of Performance (heating):

$$COP = \frac{\text{Energy Delivered}}{\text{Energy Purchased}}$$

- *Some* of the heat is "free" – some you buy
- Air source *rated* at ~ 2.3 – 3.0
  - At 47F outdoors – mild conditions
- Ground source *rated* at ~ 3.2 – 4.5
  - *Different* ratings for ground loop/ground water
  - ARI/ISO rating doesn't tell the whole story…

RATED EFFICIENCY OF THE "*SYSTEM*"

Performance Data
ARI/ASHRAE/ISO 13256-1

ASHRAE/ARI/I

Model	Ground Water Heat Pump				Ground Loop Heat Pump			
	Cooling 59°F		Heating 50°F		Cooling 77°F		Heating 32°F	
	Capacity Btuh	EER Btuh/W	Capacity Btuh	COP	Capacity Btuh	EER Btuh/W	Capacity Btuh	COP
GSH/V015	15,600	23.9	12,900	4.1	14,900	18.5	11,200	3.8
GSH/V018	19,000	22.7	16,000	4.1	18,300	16.7	13,200	3.6
GSH/V024	26,500	21.2	23,500	4.0	26,000	17.1	19,200	3.6
GSH/V030	31,100	21.4	27,200	4.0	30,700	16.9	22,200	3.6
GSH/V036	36,000	20.7	32,900	4.0	35,800	16.4	26,700	3.4
GSH/V042	45,400	20.3	39,000	4.0	43,300	16.0	32,700	3.7
GSH/V048	49,000	19.9	43,300	4.0	48,900	16.4	36,900	3.7
GSH/V060	59,600	17.7	58,900	3.8	59,400	14.6	48,700	3.8
GSH/V070	70,000	16.8	62,900	3.8	67,100	13.4	53,400	3.6

EWT °F	GPM	°WPD		Cooling - EAT 80/67°F						Heating - EAT 70°F				
		PSI	FT	TC	SC	Sens/Tot Ratio	kW	HR	EER	HC	kW	HE	LAT	COP
20	12.0	7.6	17.6	Operation Not Recommended						31.4	2.95	21.3	88.2	3.12
30	6.0	2.5	5.8	55.5	38.9	0.70	2.00	62.3	27.7	35.7	2.98	25.5	90.7	3.51
	9.0	4.7	10.9	55.9	38.7	0.69	1.93	62.5	29.0	36.3	3.01	26.0	91.0	3.53
	12.0	7.4	17.1	56.4	38.5	0.68	1.85	62.7	30.5	36.9	3.04	26.5	91.4	3.56
40	6.0	2.4	5.6	53.9	38.2	0.71	2.30	61.7	23.5	40.2	3.[illegible]			
	9.0	4.6	10.6	54.3	38.0	0.70	2.21	61.8	24.6	41.0	3.[illegible]			
	12.0	7.2	16.6	54.7	37.8	0.69	2.12	61.9	25.8	41.9	3.11	31.3	94.2	3.95
50	6.0	2.3	5.4	52.3	37.5	0.72	2.59	61.1	20.2	44.7	3.15	33.9	95.9	4.15
	9.0	4.4	10.2	52.7	37.3	0.71	2.49	61.2	21.1	45.8	3.16	35.0	96.5	4.24
	12.0	7.0	16.1	53.0	37.1	0.70	2.40	61.2	22.1	46.8	3.17	36.0	97.1	4.33
60													98.2	4.40
													99.1	4.53
													100.1	4.66
													100.5	4.64
70	9.0													4.81
	12.0													4.97

3.64 @ 32F

RATED EFFICIENCY OF THE MACHINE ONLY (no fluid pump)

How can this be lower ???

What's going on?

- The old ARI 325/330 standards included a pumping allowance
- The new ARI/ASHRAE/ISO 13256-1 still includes a pumping allowance
- BUT it rates the unit at a blower external static pressure of **0 ESP**

And Pumping power?

- Only the pumping power required to overcome the *internal* resistance of the heat exchanger coil is included in the rating conditions.
- No allowance for external piping resistance
  - Or lift on open loop systems

Previous ratings under ARI 325 / 330:
(apparently otherwise identical product)

Model	Cooling 59°F		Heating 50°F		Cooling 77°F		Heating 32°F	
	Capacity Btuh	EER Btuh/W	Capacity Btuh	COP	Capacity Btuh	EER Btuh/W	Capacity Btuh	COP
GSH/V015	15,600	23.9	12,[illegible]	3.6	4.1	14,900	18.5	[illegible] 3.5	3.8
GSH/V018	19,000	22.7	16,[illegible]	3.6	4.1	18,300	16.7	[illegible] 3.3	3.6
GSH/V024	26,500	21.2	23,[illegible]	3.7	4.0	26,000	17.1	[illegible] 3.3	3.6
GSH/V030	31,100	21.4	27,[illegible]	3.5	4.0	30,700	16.9	[illegible] 3.3	3.6
GSH/V036	36,000	20.7	32,[illegible]	3.5	4.0	35,800	16.4	[illegible] 3.2	3.4
GSH/V042	45,400	20.3	39,[illegible]	3.7	4.0	43,300	16.0	[illegible] 3.3	3.7
GSH/V048	49,000	19.9	43,[illegible]	3.7	4.0	48,900	16.4	[illegible] 3.3	3.7
GSH/V060	59,600	17.7	58,[illegible]	3.5	3.6	59,400	14.6	[illegible] 3.2	3.8
GSH/V070	70,000	16.8	62,[illegible]	3.4	3.8	67,100	13.4	[illegible] 3.1	3.6

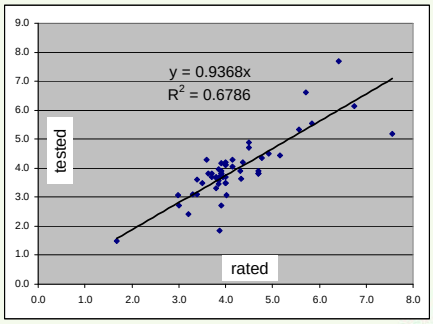
A Look at Tested Efficiencies

- 79 Systems measured in utility programs
  - 1998-2002
  - Not "problem" calls – did include 1 home with poorly designed valve system
  - *Compared with ARI 325/330 ratings*
  - One-time, steady state

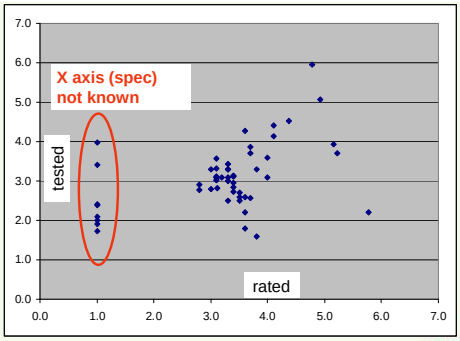
Machine Only		
Avg:	rated	tested
COP	3.9	3.7
EER	18.8	17.6

Heat pump only: COP spec/measured

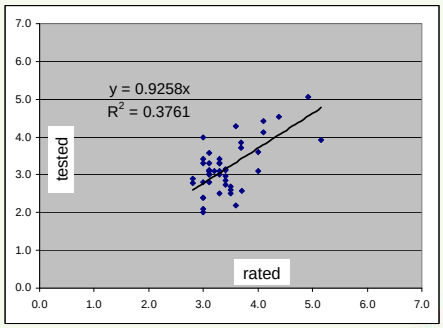
Note: COP values above ~3.5 = cooling tests



Total system: COP spec/measured

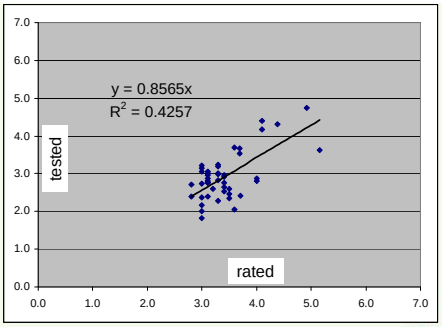


Total system: removed "problem" house and outliers



Total system: A*fter* adjusting for EWT

Entering temps: test conditions → ARI test conditions



System Efficiencies compared to ARI

Adjusted System Performance					
	Average	Rated	Tested	% of Rated	n
Closed loop @32F	COP	3.2	**2.9**	91%	19
	EER	14.5	**13.8**	95%	8
Open loop @40F	COP	3.4	**2.4**	71%	21
	EER	17.2	**11.6**	67%	3

What Interferes with Efficiency?

- All heat pumps:
  - Low air flow
  - Over or under on refrigerant charge
    - Affects cooling more than heating on TXV systems
  - Duct leaks (not reflected in above results)
  - *Under*sizing (in cold climate; also not reflected
    - Conservative sizing
    - Underestimating design load

What Interferes with GSHP Efficiency?

- **Water pumping power**
  - **Especially wells used for domestic water supply**
- Fan power of ECM blower (undersized ducts)
- *Neither of these are accounted for in ARI ratings*!
- **Ground loop sizing**
  - Undersized system
  - Ground loop design mistakes

Customer Expectations

- Customers may not be well informed about GSHP performance:
  - GSHP is not free energy
  - GSHP are not even cheap energy
    - Unless you are paying $0.06-0.10 per kWh
  - Much of the information that's on the internet is not true (Surprise!) or is biased
  - "Payback" should not be basis of decision

Improving GSHP Performance:

- Ensure careful design and installation
  - Adequate size (equipment & ground coupling)
  - Duct design (seal or move inside!)
  - Pumping (VFD pumps help w/ open loop (?)
- Start-up testing – actually read the meter
  - Confirm manuf's extended performance data
  - Include pump power!
- Turn off electric backup heat

Upgrade Building Shell First

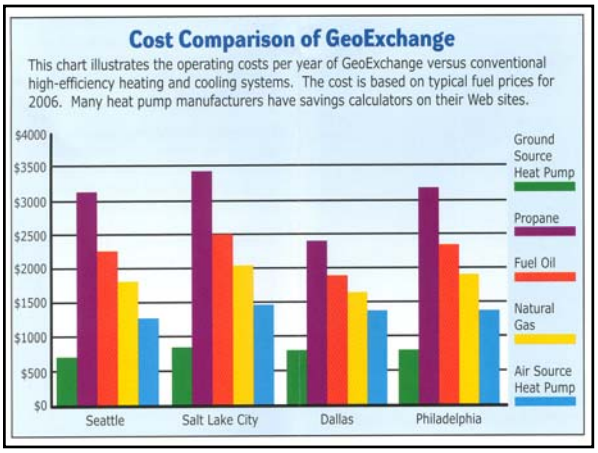
- Investment in GSHP is smaller if the load is reduced dramatically
- Take advantage of programs (ENERGY STAR) and tax credits to upgrade the shell and ducts
- Consider investing MORE in building enclosure efficiency vs GSHP

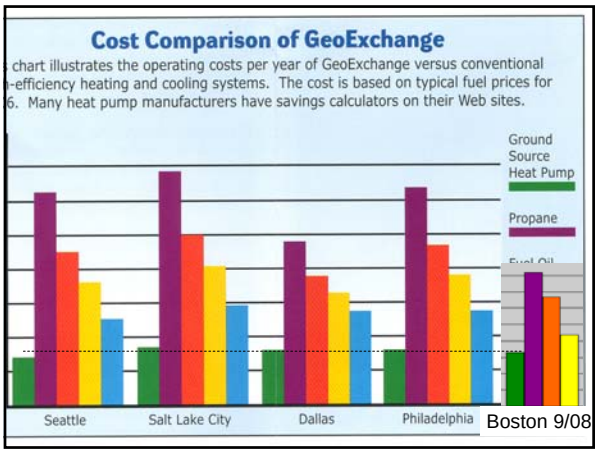
Another look: Price and Carbon

	Electric kWh	Nat Gas therm	Oil gallon	Propane gallon
Fuel rates	$ 0.17	$ 2.00	$ 4.00	$3.50
btu/unit	3,413	100,000	138,000	93,000
$/Million btu	$ 50	$ 20	$ 29	$ 38

Another look: Price and Carbon

	Electric kWh	Nat Gas therm	Oil gallon	Propane gallon
Fuel rates	$ 0.17	$ 2.00	$ 4.00	$3.50
btu/unit	3,413	100,000	138,000	93,000
$/Million btu	$ 50	$ 20	$ 29	$ 38
lb CO/Million btu	287	117	161	139
efficiency	300%	92%	87%	92%
$ / Mbtu load	$ 17	$ 22	$ 33	$ 41
lb CO/ Mbtu load	96	127	185	151





Boston 9/08

National comparison: price & carbon

	Electric kWh	Nat Gas therm	Oil gallon	Propane gallon
Fuel rates	$ 0.11	$ 1.50	$ 4.00	$3.50
btu/unit	3,413	100,000	138,000	93,000
$/Million btu	$ 50	$ 20	$ 29	$ 38
lb CO/Million btu	393	117	161	139
efficiency	300%	92%	87%	92%
$ / Mbtu load	$ 11	$ 16	$ 33	$ 41
lb CO/ Mbtu load	131	127	185	151

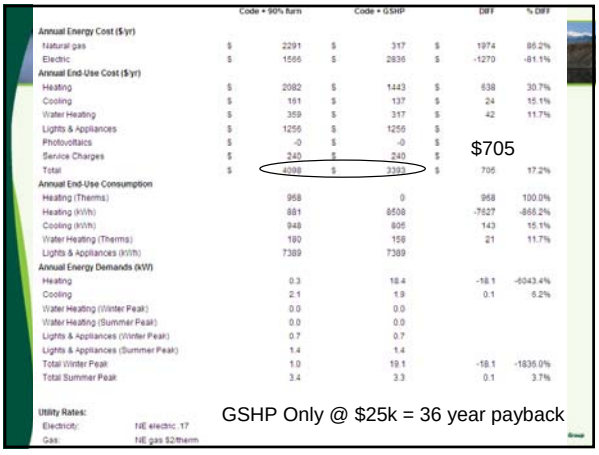
The math

- *Very* dependent on utility rates
- Initial GSHP cost vs. Shell upgrades
  - The building load will ALWAYS dictate the amount of energy you need to heat or cool
  - Reduce the load and you reduce dependency on the HVAC equipment, and reduce sensitivity to energy cost increases

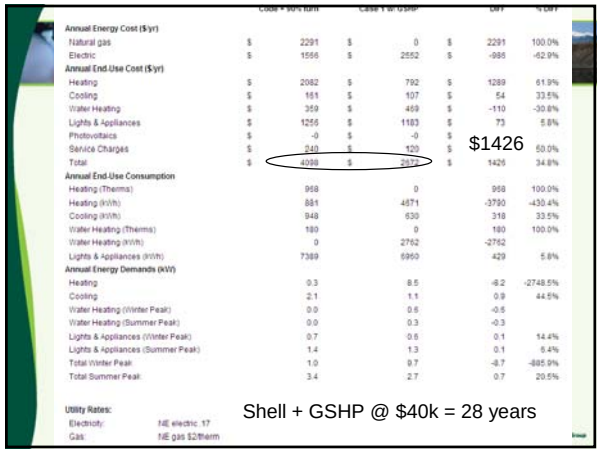
Modeled examples

Upstate NY home, 1950 sq ft

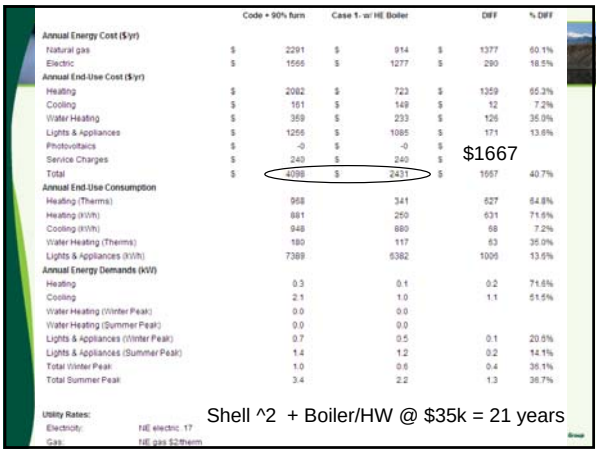
- Envelope load 70k btu/hour (code + 90%)
- Improve envelope to 29k btu/hr, then:
- GSHP (3.0) closed loop: + $15-25k
- Or: add 2" iso foam to walls/ceiling; 0.24 windows for similar cost



GSHP Only @ $25k = 36 year payback

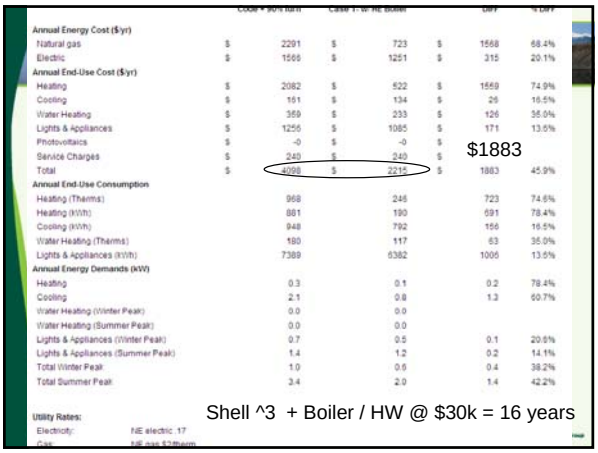


Shell + GSHP @ $40k = 28 years



	Code + 90% furn	Case 1- w/ HE Boiler	DIFF	% DIFF
Annual Energy Cost ($/yr)				
Natural gas	$ 2291	$ 914	$ 1377	60.1%
Electric	$ 1566	$ 1277	$ 290	18.5%
Annual End-Use Cost ($/yr)				
Heating	$ 2082	$ 723	$ 1359	65.3%
Cooling	$ 161	$ 149	$ 12	7.2%
Water Heating	$ 369	$ 233	$ 126	35.0%
Lights & Appliances	$ 1256	$ 1085	$ 171	13.6%
Photovoltaics	$ -0	$ -0	$	
Service Charges	$ 240	$ 240	$ 1667	40.7%
Total	$ 4098	$ 2431		
Annual End-Use Consumption				
Heating (Therms)	968	341	627	64.8%
Heating (kWh)	881	250	631	71.6%
Cooling (kWh)	948	880	68	7.2%
Water Heating (Therms)	180	117	63	35.0%
Lights & Appliances (kWh)	7389	6382	1006	13.6%
Annual Energy Demands (kW)				
Heating	0.3	0.1	0.2	71.6%
Cooling	2.1	1.0	1.1	51.5%
Water Heating (Winter Peak)	0.0	0.0		
Water Heating (Summer Peak)	0.0	0.0		
Lights & Appliances (Winter Peak)	0.7	0.5	0.1	20.6%
Lights & Appliances (Summer Peak)	1.4	1.2	0.2	14.1%
Total Winter Peak	1.0	0.6	0.4	36.1%
Total Summer Peak	3.4	2.2	1.3	36.7%
Utility Rates:				
Electricity:	NE electric 17			
Gas:	NE gas $2/therm			

Shell ^2 + Boiler/HW @ $35k = 21 years



Annual Energy Cost ($/yr)				
Natural gas	$ 2291	$ 723	$ 1568	68.4%
Electric	$ 1566	$ 1251	$ 315	20.1%
Annual End-Use Cost ($/yr)				
Heating	$ 2082	$ 522	$ 1559	74.9%
Cooling	$ 161	$ 134	$ 26	16.5%
Water Heating	$ 369	$ 233	$ 126	35.0%
Lights & Appliances	$ 1256	$ 1085	$ 171	13.6%
Photovoltaics	$ -0	$ -0	$	
Service Charges	$ 240	$ 240	$ 1883	45.9%
Total	$ 4098	$ 2215		
Annual End-Use Consumption				
Heating (Therms)	968	246	723	74.6%
Heating (kWh)	881	190	691	78.4%
Cooling (kWh)	948	792	156	16.5%
Water Heating (Therms)	180	117	63	35.0%
Lights & Appliances (kWh)	7389	6382	1006	13.6%
Annual Energy Demands (kW)				
Heating	0.3	0.1	0.2	78.4%
Cooling	2.1	0.8	1.3	60.7%
Water Heating (Winter Peak)	0.0	0.0		
Water Heating (Summer Peak)	0.0	0.0		
Lights & Appliances (Winter Peak)	0.7	0.5	0.1	20.6%
Lights & Appliances (Summer Peak)	1.4	1.2	0.2	14.1%
Total Winter Peak	1.0	0.6	0.4	38.2%
Total Summer Peak	3.4	2.0	1.4	42.2%
Utility Rates:				
Electricity:	NE electric 17			
Gas:	NE gas $2/therm			

$1667

$1883

Shell ^3 + Boiler / HW @ $30k = 16 years

Estimated Carbon Impact:

	Base	Base+ GSHP	Shell + GSHP	Shell^2+ boiler	Shell^3+ boiler
Gas	117.8	0	0	43.5	36.9
Elect	3.2	47.5	27.5	10.7	2.7
Net CO x1,000 lb	**14.7**	**13.6**	**7.9**	**8.2**	**5.1**

Conclusions….

- GSHP is not a slam dunk…
  … you have to do the analysis
- MUST account for fan and pump power
- Tested systems under ARI 325/330 were ~10-30% less efficient than those ratings
- AND: ISO ratings overstate efficiencies by an additional 11% compared to old ARI