Myths and Realities of Ground Source Heat Pumps

NE HERS Alliance
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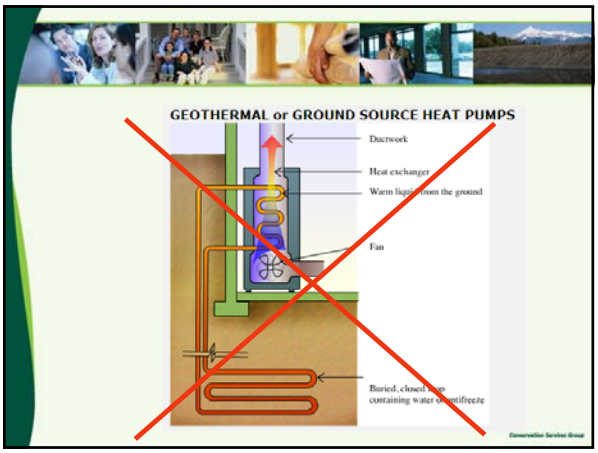
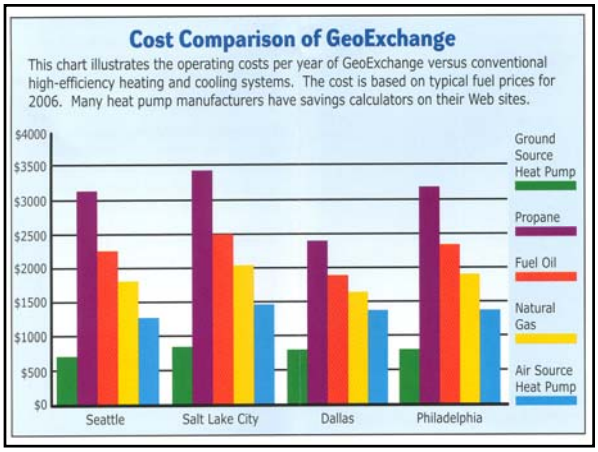
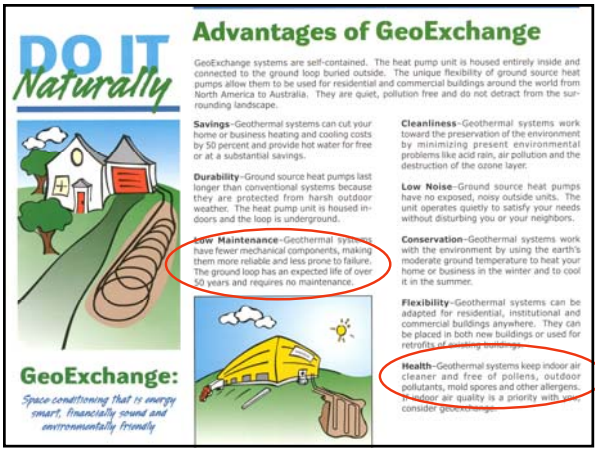
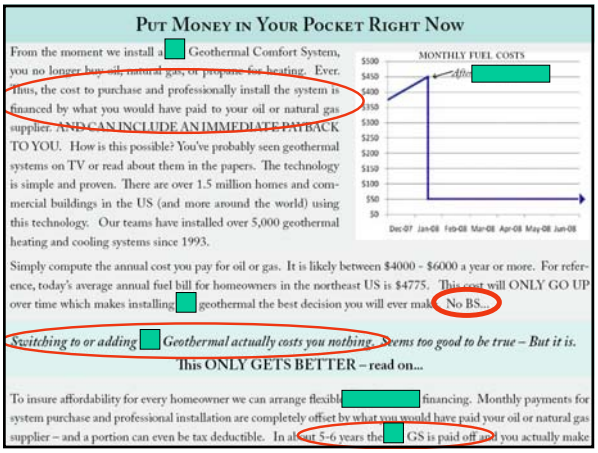


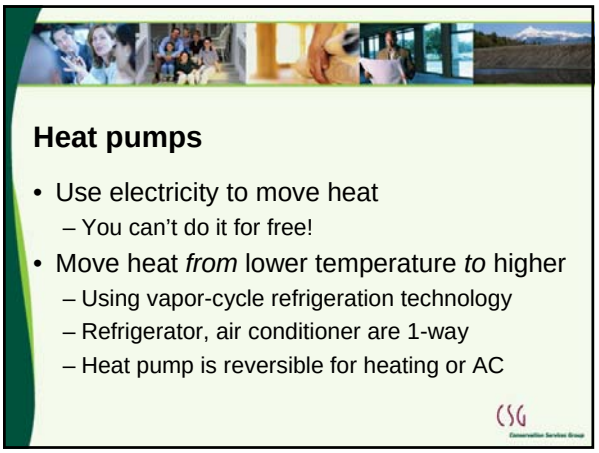






Now, what we'll talk about today:

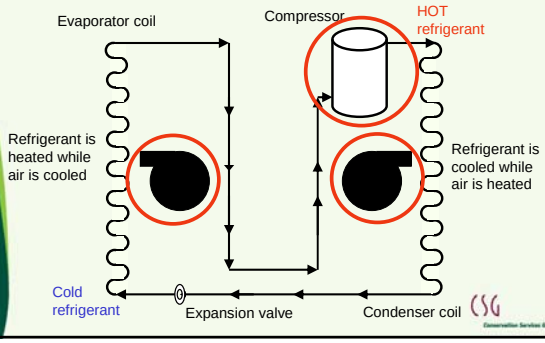
- What is a heat pump?
- What is a ground source heat pump?
- Published efficiency ratings (ISO 13256)
- Measured data on operating efficiencies
  - Past and current
- Cost and carbon



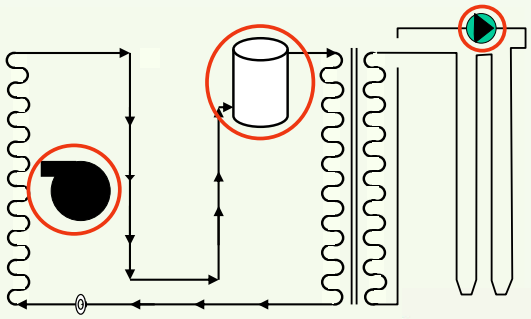
Heat pumps

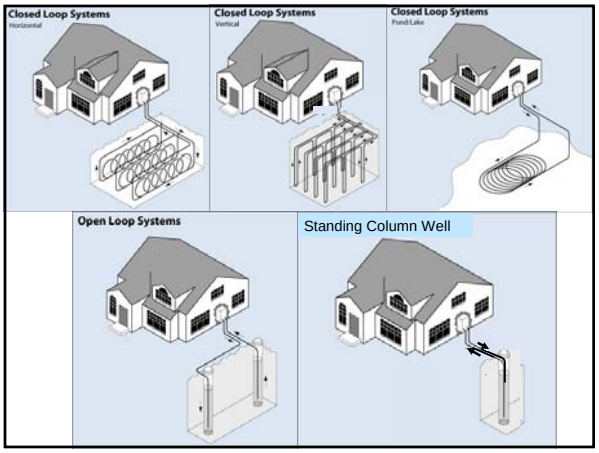
- Use electricity to move heat
  - You can't do it for free!
- Move heat *from* lower temperature *to* higher
  - Using vapor-cycle refrigeration technology
  - Refrigerator, air conditioner are 1-way
  - Heat pump is reversible for heating or AC

Vapor-compression Refrigerant Cycle



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	3.6	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

600 CFM Nominal (Rated) Airflow — Performance capacities shown in thousands of Btu

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

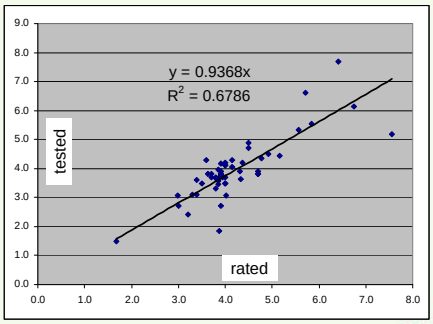
A Look at Tested Efficiencies

- 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

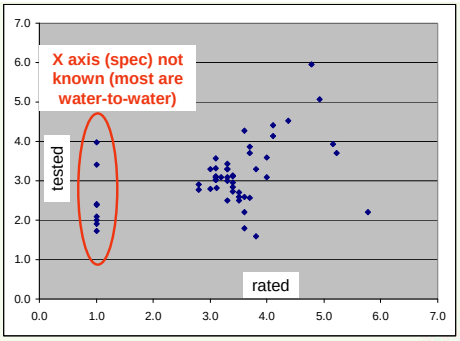
Machine Only		
Avg:	rated	tested
COP	3.9	3.7
EER	18.8	17.6

Heat pump only: COP spec/measured

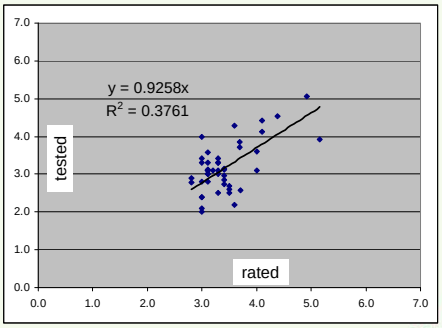
Note: COP values above ~3.5 = cooling tests



Total system: COP spec/measured

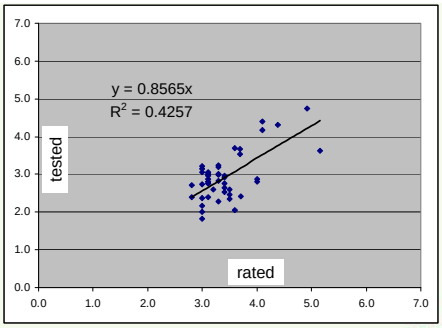


Total system: removed "problem" house and outliers



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 due to cost
    - Underestimating design load due to building flaws

What Interferes with GSHP Efficiency?

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

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

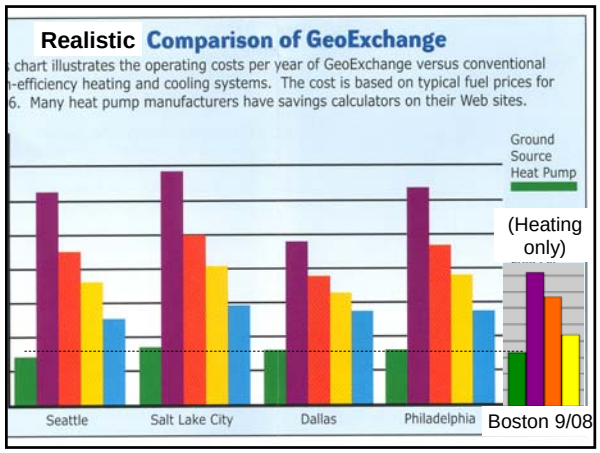
- Investment in GSHP is smaller if the load is reduced dramatically
- Take advantage of programs (ENERGY STAR) and tax credits to upgrade the shell and ducts
- Consider investing MORE in building enclosure efficiency vs GSHP

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



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

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