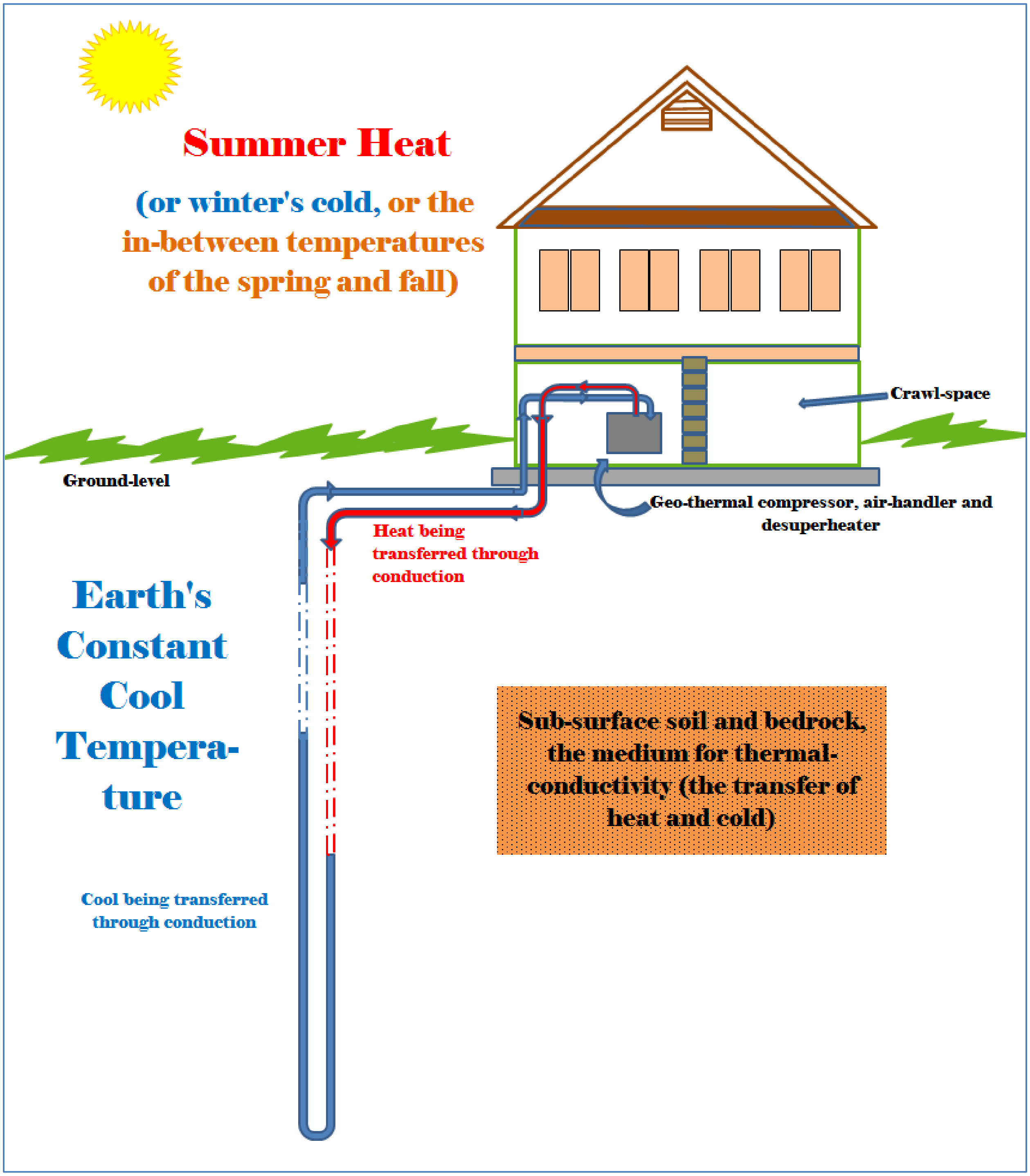
Woodlake's First Geothermal Heat-pump Installation

By David L. Faulkner, Natural Resource Economist, Woodlake Community Association (WCA) Board Member and Shelter Cove Resident, July, 2012



Summary Description: In this article I share our experience in exploring and ultimately deciding to invest in a geo-thermal heat-pump. Planning considerations are described as well as pre-installation economic expectations. Post-implementation performance is then presented followed by treatment of several topics that relate to energy efficiency, air quality and comfort. Lastly, a set of photographs are shared that depict the installation of the geo-system as well as encapsulation and insulation of our crawl-space. After more than two years of experience with our geo-system, we are completely satisfied.

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Acknowledgement

Thank you to my oldest son, Darren L. Faulkner, for providing review comments of numerous drafts of this document and for taking a majority of the photographs used herein.

Introduction/Background: In the fall of 2009 I began reading reviews of heating and air-conditioning systems (heating, ventilation and air-conditioning systems or HVAC) with the intent of eventually replacing our existing air-source heat-pump with a more efficient unit when ours quit working. The first unit we had lasted about 10 years and our second one was close to 10 years old so I wanted to educate myself on the options and plan for the replacement. I learned that air-source units typically last from 10-15 years depending on heating and cooling loads and how well they are maintained[1]. While surfing articles of interest on the world-wide web I discovered that geo-thermal heat-pumps are the most efficient heating and cooling systems according to the U.S. Department of Energy (DOE). They are the most efficient heating and cooling systems due to the fact that instead of using the air to exchange heat and cold they utilize the relatively constant temperature of the earth (about 60° Fahrenheit in the Richmond area) to exchange heat and cold from your house with the relative warmth of the earth in the winter and coolness in the summer[2]. 30-50% savings in annual energy costs are estimated to be typical of geo-thermal heat-pumps as compared to air-source heat-pumps. Even greater savings are possible if converting to a geo-thermal system from a more expensive fuel-based system.

In addition, geo-thermal units typically last much longer, 20-30 years (or even longer), as compared to the 10-15 years common for air-source units. Geo-thermal systems are significantly more expensive, but I also learned that the federal government has been promoting energy efficiency investments for many years including a significant tax credit for geo-thermal systems. There is a 30% federal tax credit (including labor and installation), with no upper limit, for consumers building new homes or replacing a HVAC system in an existing residence with a geo-thermal system (through December 31st, 2016)[3]. To qualify for the credit, geo-thermal heat pumps must be installed in a home you own and use as a residence (it does not have to be your main home) and rental units do not qualify.

I surfed the world-wide web and read on-line forums about the advantages and disadvantages of geo-thermal heat-pumps in the evenings and on weekends for a couple of months. As to be expected, there is a tremendous amount of on-line resources available, and I found the following web-sites http://www.igshpa.okstate.edu/ and http://www.geoexchange.org/ most helpful in addition to the DOE and EPA web-sites. The geo-thermal user forums on Geoexchange's site were especially helpful to be able to read testimonies on issues and concerns expressed by owners with actual experience. The questions of the interested also were helpful as some of the same questions occurred to me. Along the way, I also learned about **energy audits/reports**, **"desuperheaters"**, **energy and heat recovery ventilators (ERVs and HRVs)**, and **crawl-space encapsulation**. A summary table of air-source and geo-system components and the considerations to take into account when evaluating which system to purchase follows:

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[1] As with any mechanical device, preventive maintenance helps to get the most out of them in terms of their operating efficiency and longevity. Annual maintenance keeps system costs as low as possible by cleaning key components and oiling the moving parts; any parts that are failing or show signs of wearing out should get replaced. This requires a trained service technician, preferably one with experience who knows the technical details of your particular unit. Changing filters is also crucial for efficient performance.

[2] According to the U.S. Department of Energy "ground source heat pumps" (another name for geothermal) are the most efficient heating and cooling system technology available; go to www.eia.gov/neic/experts/heatcalc.xls "DOE Heating Fuel Comparison Calculator" an excel template with cost and efficiency information on all major systems; Also see the EPA's http://www.energysavers.gov/your_home/space_heating_cooling/index.cfm/mytopic=12330 for a wealth of geothermal information.

[3] http://energystar.supportportal.com/ics/support/kbAnswer.asp?deptID=23018&task=knowledge&questionID=18016

Table 1. Geothermal vs. Air-Source Heat-pump Systems		
Consideration	**Air-Source**	**Geothermal**
Initial cost (purchase price and installation):	$3,000 - $20,000 depending on **model** (different models have different efficiency ratings with the most efficient having the highest initial cost, but lower operating costs) **and** depending on **size** (2-5 tons most common for residential models);	$10,000 - $32,000 depending on **model** (the most efficient have the highest initial cost, but lower operating costs), depending on **size** (2-5 tons most common for residential models), depending upon **type of thermal exchange loop** installed (vertical loops are the most efficient, but require a drilling rig and are more expensive; horizontal loops are less expensive, but a little less efficient) **and** depending upon the **geology** (soft sedimentary rock is easier and less expensive to drill into as compared to granite for example – Woodlake sits on top of sedimentary marine deposits that are easy/less costly to drill through);
Federal tax credit:	None currently available	30% of installed cost (no maximum);
Annual maintenance cost:	$60-$150 depending upon service provider and if you get just an inspection or full service;	$60-$150 depending upon service provider and if you get just an inspection or full service;
Use of air filters:	At in-house ductwork returns and/or at the air-handler;	At in-house ductwork returns and/or at the compressor/air-handler unit;
Cost of air filters:	From approx. $1-$65 each depending upon thickness and quality;	From approx. $1-$65 each depending upon thickness and quality (we use cheap ones at the returns and high quality filters at the unit);
Key components:	Compressor and heat-exchange fan; air-handler;	Combined compressor and air-handler in a single unit;
Location of key components:	Compressor and fan: outdoors; Air-handler: crawl-space or indoor somewhere (typically in a closet, garage, basement or attic);	The entire unit is typically either located in the crawl-space, garage, a utility room or basement;
Ease of installation	Usual installation is easy;	Installation of the heat-exchange loop can be very disruptive and messy in the short-term;
Exposure to outdoor elements:	The compressor and fan are completely exposed;	Entire unit is completely protected from the sun, wind, rain, temperature fluctuations that cause shrinking, swelling and frost heaves, acidic droppings from birds/other animals, etc.
Performance sensitive to air temperature?	Yes, don't perform best in extreme heat and cold, operating best between 50-85 degrees Fahrenheit;	No, only sensitive to the temperature of the earth which is relatively constant below 10ft. (horizontal loop systems are typically installed 5-8ft. deep);
Site limitations?	None	Vertical loops: sites with hard rock geology cost more to drill through, but have superior thermal-conductivity/heat exchange capacity; Horizontal loops: sites with deep sandy soils are inappropriate as they lack adequate thermal-conductivity;
Accessories:	Humidifiers, dehumidifiers	Humidifiers, dehumidifiers and desuperheaters
Expected useful life:	10-15 years (12 on average?)	20-30 years (25 on average?)

Pre-Investment Planning/Analysis: In order to fully evaluate each option and make a final decision, I developed an Excel spreadsheet to compare expected installation and operating costs for air-source vs. geo-thermal units. I assumed that the air-source alternative would have to be replaced every 12 years and the geo-thermal would last at least 24 years. Thus, in my analysis 2 air-source units would have to be purchased over the expected useful life of a geothermal unit. I used a 3-year average (2007-2009) from our Dominion Power utility bills for estimating annual and per unit ($/kWh) costs for electricity. I displayed several assumed scenarios for the expected cost savings achievable with a geo-system varying both years of expected useful life (20, 24, and 30 years) and percent energy saved per year (30%, 40% and 50%). I included the federal tax credit recognizing that we wouldn't benefit from it until the following year after we filed our taxes and received a refund. And I also included a 20% (not to exceed $2,000) rebate available at the time through the Virginia Department of Mines, Minerals and Energy[4]. This array of variables allowed for sensitivity analysis to determine how varying the base assumptions (useful lives, initial costs and operating costs, with both existing rates and higher projected costs for electricity assuming that they will go up over the next 24 years) affected analysis results.

I estimated the payback period for investing in a geo-thermal unit (compressor, air-handler and circulation loop) to range from 12 to 30 years based upon an assumed set of initial costs ranging from $20,000-$30,000 and a conservative 30% reduction in annual operating costs. I first used the low end of advertised operating cost savings because I wanted to be conservative and did not expect more. I had learned that the 30%-50% cost reduction range associated with geo-systems depends upon how energy efficient your existing house already is; the more efficient, the lower the savings; the less efficient the higher the savings (to a point). We had already made our home very energy efficient having installed a significant amount of added insulation in the attic, including an insulated cover over the access portal, storm doors on each of our three exterior doors and we also used 30+ tubes of latex caulk to seal inside and outside around our windows and doors and every joint and knot-hole on our cedar siding. I had also caulked around our indoor registers (air vents) and the joints where our exterior walls and ceilings meet. I expected our home to be very energy efficient and a home energy audit confirmed this in late December of 2009 (see more on home energy audits below). This perspective was further confirmed when I looked up national energy consumption data on the web site of the U.S. government's Energy Information Administration (see table below for the latest reported data from 2009).

Table 2. Our Household Energy Consumption as Compared to the Southern Region (Census Region) and National Averages[5]

Household	Average Annual Energy Consumption/Household			
	kWhr[6]	Million Btu	As a % of the South Region Average	As a % of the National Average
2007-2009 average for our home with 1,980sq.ft.	14,819	50.56	**65.0%**	**56.3%**
2009 average for our home with 1,980sq.ft.	14,966	51.07	**65.6%**	**56.9%**
2009 Average/household for the South region with between 1,500 and 1,999sq.ft.	22,801	77.8	100.0%	86.6%
2009 Average/household for the U.S. with between 1,500 and 1,999sq.ft.	26,318	89.8	115.4%	100.0%

[4] The DMME incentive was the result of the American Recovery and Reinvestment Act (also known as the Economic Stimulus Bill) signed into law by President Obama on February 17, 2009. This provision stimulated the economy through investments in domestic energy efficiency improvements.

[5] U.S. Energy Information Administration (EIA); http://www.eia.gov/consumption/residential/data/2009/#consumption-expenditures

[6] kWhr for our home and kWhr equivalent for the Southern region and national averages based upon 1kilowatt hour = 3,412Btus or 0.003412MillionBtu, given that many homes use more than electricity for power (fuel oil, natural gas, wood, etc.);

When deciding whether or not to invest in a geo-system, I had to first find out if the Woodlake Community Association (WCA) would allow a drilling rig to access our backyard via the trail in order to drill the vertical boring. Such rigs are the same as the ones used to drill potable water wells and they are large and very heavy. I presented what we wanted and why before a WCA Board meeting in December of 2009 and they approved my request subject to issuance of a permit and agreement to accept responsibility for any potential damages. In addition, they requested that I prepare an article for the WCA newsletter on how our geo-system investment worked out. I said that I would be glad to write an article, but wanted to wait until we had at least a full year's worth of electricity bills to be able to make a more complete assessment of system performance. 26 months have now passed since installation of our system was completed (March of 2010) and it has performed flawlessly.

We decided to go with investment in a geo-system in spite of the high cash-cost hurdle associated with the purchase price/installation for the following reasons: 1) expectation that a geo-system represents a long-term lower cost investment in a home comfort system that would also be less impacted by potential electricity increases in the future (lower risk/exposure to increasing prices in the future and higher prices would mean that the break-even point would be achieved sooner); 2) expectation for a system much less susceptible to performance problems due to temperature extremes (the earth's temperature below the surface is constant) and due to the unit being inside and protected from outside elements; 3) expectation for a much quieter system/higher quality of life at home; 4) appreciation for the intelligence designed into some models with two-stage compressors, variable-speed fans and "desuperheaters" for pre-heating of hot water using heat extracted from the house during cooling mode; and 5) I really liked the idea of using the heat and cooling potential of the earth;

Bid Solicitation, Evaluation and Contractor Selection: Once we decided to invest in a geo-system, I read information about the various manufacturers and settled upon a preferred manufacturer (Water Furnace). I contacted 7 companies who install their products and invited them to give us their sales pitch and prepare bids for a 3-ton high efficiency unit (Envision series). I scheduled appointments and interviewed the seven companies and received bids from six[7]. And based upon what I learned from the seven presentations/ interviews, I prepared a set of contract specifications. For example, I determined the exact model and tonnage to be provided (3-ton Water Furnace NDH 038 Envision with a variable speed blower and dual capacity compressor); that I wanted a non-pressurized pumping/circulation system (simpler than a pressurized circulation system); a "desuperheater" to pre-heat hot water, etc. I received 8 bids, including 2 geo-system bids from one company with two different efficiency levels, a geo-system bid and an air-source system bid from another company and the rest provided geo-thermal unit bids. The bids for the geo-systems (compressor, air-handler, desuperheater and ground-loop) ranged from $21,000 to $31,000. I evaluated all bids and then invited final offers from the two companies that I felt had made the best technical and people-skill impressions. I asked the

[7] The 7th company never provided a written bid even though they assured me that they would. In fact, I never heard from them again even though I tried to contact the sales representative to ask what had happened. I'm old fashioned and it is disappointing that someone's word is not always lived up to, but at a certain point you simply decide it is better that you don't hear from such companies and move on. One other company wanted to tell me what I wanted and tried to talk me out of a geothermal system. They did submit a geothermal bid, but also submitted an unsolicited air-source unit bid and were pushing it. Two of the companies only would submit a bid based upon boring in the front yard, but I didn't want to tear-up the front yard. Even though boring in the front yard would be the easiest set-up and presumably lower cost, compared to boring in the back yard, the bids from these 2 companies came in the highest. Also, two companies wanted to drill two borings in the back yard instead of a single set-up and drilling.

top two bidders for any final revisions to their initial bids, e.g., possible discounts for cash payment and leaving the rock dust in place instead of hauling it away (a 6inch x 500ft. boring creates about 3.6cubic yards of rock dust based upon πr^2h; left in place we saved $2,000), then received their final bids and awarded/signed a contract with Hungerford Heating and Cooling. Hungerford wasn't the least expensive nor the most expensive bidder, but they had the best offer overall. Their bid included one vertical loop, not two separate borings with each loop fused together. For me, the single 500ft. boring, instead of two or more borings, made more sense (fewer joints thermally fused together and 50 more ft. of length to assure adequate capacity).

Horizontal loops[8] placed in trenches are simply covered with the excavated earth while vertical borings are backfilled with bentonite clay around the pipe to enhance the thermal-conductivity between the loop and the earth (you don't want air inside the loop nor around the installed pipe in the ground as both reduce heat/cool transfer and thereby system efficiency). For the 3 ton unit installed for us, a vertical boring of 500ft. was determined as necessary to assure adequate heat exchange for our home. Hungerford sub-contracted with Virginia Energy Services, Inc. to perform the drilling, install the circulation pump, water and antifreeze (typically methanol or methyl alcohol), and connect all lines to the Water Furnace unit. And by the way, the drilling rigs and process of drilling make a real mess of your yard; a significant quantity of ground rock and associated sediment come up (forced by water injected constantly into the hole to create the space for the loop) and this material has to either be collected and disposed of offsite or used onsite. We had the driller to simply leave the waste material in our yard. We used it to help level that part of our backyard, then bought 14cu.yds. of topsoil to place over it and reseeded.

Post-Installation Impressions: After installation, the first thing we noticed was how quiet the system is. We loved the quietness and gentleness of the system immediately. When it cycles on, it starts very quietly and gently, slowly builds up, reaches maximum air output, sustains this level for a while, then gently cycles down and turns off. The air exiting the registers in the summer feels cooler, to our subjective assessment, than what we had been used to and in the winter it definitely seems warm; warmer than what we had experienced with air-source units. Air source system discharge temperatures in the winter drop as the outside temperature drops eventually requiring electric resistance back-up heat to supplement the heat pump. Geo-systems have back-up heating strips as well, but in our experience so far they have not been needed. Also, in the summer, our geo-system removes so much humidity from the circulated air that our home simply feels a lot more comfortable. We also noticed how variations in outside air temperature did not stress it like the air-source systems we had previously owned. Indeed, we have never observed the system switch into the higher energy demand mode during very cold and very hot periods; not even during the record breaking heat we've experienced in June and July of this year nor during the week in July of 2010 when we had 105 degrees Fahrenheit exterior temperatures for 3 consecutive days (according to our thermometer). The geo-system cycles more frequently during really hot periods (and presumably extreme cold as well), but it has never had any trouble keeping the house comfortable in standard mode whatever the conditions outside have been.

Post-Installation Performance/Economic Assessment: Now that we have more than a full year's worth of electrical bills, I was able to evaluate how the recurrent operating costs for 2011 compare to three years of air-

8 Horizontal loops are significantly less expensive than vertical loops, but require more land. Their thermal-conductivity may not be quite as efficient as a vertical loop due to being closer to the surface, but certainly make sense if you have adequate land and don't have sandy soils because they don't conduct heat and cold as efficiently.

source system bills prior to our geo installation (2007-2009). I used 2011 for comparison because we experienced abnormally high power bills during January-March of 2010 due to having to use 6 space heaters, loaned to us by Hungerford, while waiting for the vertical loop to be installed. All of the installation work had been completed except for the drilling and loop work due to wet ground conditions that kept the heavy drill rig from accessing our back yard via the common property behind our home. The big drill rig was finally able to access the common property in mid-March and by the end of the month our project was completed.

For reference, our home has 1,980sq.ft. of finished space and is all electric, i.e., we depend completely upon electricity for heating, cooling, lighting, hot water, TV, etc. We have always set the thermostat to 68 degrees for heating and 77 degrees for cooling. Also, during the last 5.5 years we've typically had 3-6 persons in our home at any given time (holidays and vacations with less or more than the 3-6 person average depending on whether or not we had visitors or traveled away from home). So we assume that the demands on electricity have been fairly similar over the years. During the pre-geo system period we averaged $1,570 per year for electricity ($0.79/sq.ft. or $131/month) with the rate per Kwhr adjusted from $0.095/Kwhr, the average for 2007-2009, to $0.106/Kwhr, the average rate for 2011. We averaged $1,230 ($0.62/sq.ft. and $102/month) for electrical power in 2011. The $1,230 includes charges for the ERV we also installed which uses approximately $6.70/month or $80/year. Therefore, to make a more accurate direct comparison of air-source to geo-system I needed to add-in the expense of the ERV (verified with a kWt meter) to the air-source cost or subtract it from the geo-bids. With other minor adjustments (see Tables 1-5 below), the resulting change in electricity due to the geo-system for 2011 came out to $1,114 or $0.56/sq.ft. and $93/month. This represents a savings of $456/year ($38/month) or 29.1%; slightly less than the 30% reduction I had anticipated and assumed for the purpose of my pre-investment calculations to make a go or no-go decision.

Table 3. Power Use, Billing Rates, Change in Kilowatt-Hours and Total Annual Payments for Electricity (actual total payments/year and annual payments normalized using the 2011 rate/kWhr)

Item Description	Kilowatt hrs. used	Change in kWhrs used (%)	kWhrs. Used - Percent of Baseline '07-'09	Price per Kilo-watt-hr.	Annual Change in Price/ kWhr (% in-crease)	Total Annual Power Bill ($s/yr. paid for electri-city)	Annual Power Bills using 2011 rate ($0.106/ kWhr)	Change per year compared to '07-'09 base period ($)
2007	14,866	---	33.33%	$0.087	---	$1,300	$1,575	+$5
2008	14,625	-1.6%	33.33%	$0.094	+7.6%	$1,376	$1,549	-21
2009	14,966	+2.3%	33.33%	$0.104	+10.6%	$1,558	$1,585	+$15
2010[9]	16,999	---	---	$0.096	-7.7%	$1,634	$1,801	+$231
2011	11,608	**21.7%**	78.3%	$0.106	+10.4%	$1,230	$1,230	**-$340**
'07-'09 average	14,819	100%	100%	$0.095	+18.2%	$1,411	$1,570	---
% change from '07-'09 average to 2011 use	---	11,608/ 14,819 = **-21.7% (3,211)**	**---**	$0.1059/ $0.0952 = **+11.4%**	**---**	$1,230/ $1,411 = **-12.8% (-$181/yr & -$4,344 over 24 yr expected useful life)**	$1,230/ $1,570 = **-21.7% (-$340/yr & -$8,160 over 24 yr expected useful life)**	**-$340**

[9] I threw out the 2010 data due to wet ground conditions delaying the vertical boring and the remainder of work to complete our project. Due to this delay, for almost two full months from mid-January until mid-March, 2010 we had to use 6 space heaters to keep warm since our old system had been removed in anticipation of completing the boring and loop.

Table 4. Known Changes in Electrical Demand Between 2011 and the 2007-2009 Baseline Period (used to estimate change in energy use and the $ cost of electricity attributable to geo-system alone so as to compare "apples with apples")									
Item Description	**Amps**	**Volts**	**kWhrs /day**	**kWhrs /Year**	**$/ Month**	**$/ Year**	**% Re-duc-tion/ year**	**Cum-ulative % Re-duction /year**	**Cum-ulative $ Reduc-tion/ year**
ERV installed to improve air quality:	0.7	120	2.02	735.3	$6.50	$77.95	-4.97%	-4.97%	-$78
Condensate pump installed to serve the ERV (standby load 24hrs/day and pump-out of 20 seconds every 2hrs, 6months/year assumed):	0.1	115	0.28	100.7	$0.89	$10.67	-0.67%	-5.64%	-$89
	1.5	115	0.012	4.2	$0.04	$0.44	-0.04%	-5.68%	-$89
< $200 Dehumidifier installed to assure controlled, low humidity environment for air quality; used 6Xs/yr for 4 hrs. each time (after major storms and/or wet periods):	6.0	115	0.045	16.6	$0.15	$1.75	-0.11%	-5.79%	-$91
Increase in electricity use in 2011 due to increased weather related heat compared to '07-'09 baseline:	n/a	n/a	0.66	239.9	$2.12	$25.43	-1.62%	-7.4%	-$116
Geothermal heat-pump savings from Table 3. above:	---	---	---	---	$28.33	$340	-21.7%	-29.1%	**-$456**

Table 5. Other Changes in Electricity Use During Period of Evaluation that Affect Total Use, but Couldn't be Quantified						
	Calendar Year					
Item Description	**2007**	**2008**	**2009**	**2010**	**2011**	**Ex-pected Effect on Annual De-mand for Electri-city**
Average number of occupants in our household	4-6	3-6	3-6	3-6	3-6	Neutral ?
Changes in lighting from incandescent to more efficient compact fluorescent bulbs (CFLs)	Conversion continued	Conversion completed	Changed 3 light fixtures, 1 with a CFL & 2 with incandescent bulbs, to fixtures with 6 CFL bulbs each (an increase in tot. watts)	none	none	↑ by an un-known amount ?
20-year old water heater replaced	n/a	n/a	n/a	Replaced in March with a larger capacity (50 gallons vs. 40 gallons that the old one had)	In use	↑ by an un-known amount ?
Changes in other appliances	n/a	n/a	New washer and dryer bought in November (newer appliances should be more efficient and reduce energy use)	New refrig. bought in mid-Dec. (new should = more efficient energy use/cu.ft., but it is larger which = increased electrical demand overall due to larger total cu.ft. of capacity)	In use	Neutral ?

Table 5. Other Changes in Electricity Use During Period of Evaluation that Affect Total Use, but Couldn't be Quantified (continued)						
	Calendar Year					Expected Effect on Annual Demand for Electricity
Item Description	2007	2008	2009	2010	2011	
Got rid of old cathode ray tube (CRT) TVs and replaced them with more efficient LCD and LED TVs	n/a	n/a	Purchased one large LCD TV and two small ones	Replaced small CRT TV	Replaced last sm. CRT TV	↓ by an unknown %?
Modification of ductwork to install a dedicated vent in the crawl space to provide conditioned, low humidity air to improve air quality and protect our geo-system investment; also creates positive air-pressure	n/a	n/a	n/a	Added vent represents 1/15th of total vents or 7% providing conditioned air to 1,980sq.ft. of crawl space; also has an electrical actuator that uses power (background load and full load every time the geo-system cycles on and off)	In use	↑ by 7%?, perhaps more except during the winter due to the stack effect
Encapsulation of crawl space and insulation of foundation walls	n/a	n/a	n/a	Begun in April, 2010	Completed in October, 2011	↓ by an unknown %?

The analysis presented in Tables 3. and 4., and the information presented in Table 5., demonstrate that precise determination of causality due to changes in electricity use is a complicated challenge. Exactly how much our electricity has been reduced by our geo-system alone is a question open to interpretation. It is also possible that I've made errors in some of the calculations of known changes. That said, I believe that the 29.1% reduction I've estimated is a reasonable approximation. The exact amount could be more, but I don't think that it would be less. Assuming that we continue to save on average $456/year on our power bills compared to the baseline years (2007-2009), I estimate the geo-system will break-even with what we would have spent on an air-source system in a little over 12 years (when the 2nd air-source unit is projected as needing to be purchased). I also calculated the net present value (NPV) for investing in the geo-system at $3,420 based upon a 24 year useful life and a 3% discount rate, i.e., I project that we will be $3,420 better off with a geo-system than we would be with an air-source unit.[10] By the way, during April-December of 2010 after completion of our geo-system, we averaged $100/month in electricity bills, close to the unadjusted average for 2011 at $102/month. And so far for 2012, we are averaging $102/month for January through July. And remember, these numbers are not

[10] It is important to note that the savings we have experienced are likely lower than what many others could realize due to the high efficiency we had already achieved with efficient casement windows and conservation measures (conservative thermostat settings, added insulation, storm doors, caulking etc.). One's savings are a function of how efficient your existing home and HVAC system are and what fuel (electricity, heating oil, propane, natural gas, wood, etc.) you currently use.

adjusted for the ERV, condensate pump, etc. that makes for a more accurate system to system comparison with air-source units. Therefore, it is clear that our geo-system has performed very consistently over the entire two plus years we've enjoyed it so far.

Table 6. Our Household Energy Consumption as Compared to the Southern Region (Census Region) and National Averages[11]

Household	Average Annual Energy Consumption/Household: kWhr[12]	Million Btu	As a % of the South Region Ave.	As a % of the National Ave.
2007-2009 average for our home with 1,980sq.ft.	14,819	50.56	65.0%	56.3%
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2009 Average/household for the U.S. with between 1,500 and 1,999sq.ft.	26,318	89.8	115.4%	100.0%

Table 7. Geo-System Economic Assumptions and Sensitivity Analysis Based Upon an Assumed 3% Interest Rate Used to Discount Future Costs and Cost Savings

Cost Savings (rebate, tax credit, what would have been expended for air-source heat-pumps and reduced electricity use) / Increased Costs

07-'09 Average Annual Total Cost for Electicity/Year: $1,570

Present Value (PV) of Expected Future Cost Savings (discounted annual operating costs by assumed percent saved per scenario and based upon the present value of an annuity formula) — Estimated Total Annual Savings on Electricity (%)

Initial Installation Cost range assumptions for Geo-sys.	Virginia Dept. of Mines, Minerals and Energy rebate[1/]	Present Value of Internal Revenue Service Tax Credit discounted 1 yr.[2/]	Source Replacement cost less IRS Tax credit discounted for one year[3/]	Net Cost excluding annual savings (initial cost-DMME rebate-IRS tax credit - air-source cost)[4/]	30.00% Est'd Savings/Yr: $471 — 20 yrs.	30.00% — 24 yrs.	30.00% — 30 yrs.	40.00% Est'd Savings/Yr: $628 — 20 yrs.	40.00% — 24 yrs.	40.00% — 30 yrs.	50.00% Est'd Savings/Yr: $785 — 20 yrs.	50.00% — 24 yrs.	50.00% — 30 yrs.	PV of Air-Source Replacement cost (after year 12 to match useful life of geo)[5/]	PV of costs for Condensate pump replacement assumed in years 10 and 20	Present Value of Geo-system circulation pump replacement cost in year 17
$20,000		$5,825		$6,377											$56 year 10	
$21,000		$6,117		$12,883												
$22,000		$6,408		$13,592											$42 year 20	
$23,000		$6,699		$14,301												
$24,000		$6,990		$15,010											Total Estimated PV $97	
$25,000	$2,000	$7,282	$5,798	$15,718	$7,007	$7,977	$9,232	$9,343	$10,636	$12,309	$11,679	$13,294	$15,386	$5,046		$726
$26,000		$7,573		$16,427												
$27,000		$7,864		$17,136												
$28,000		$8,155		$17,845												
$29,000		$8,447		$18,553												
$30,000		$8,738		$19,262												

Net Present Value Projections including all capital costs less: 1) what would have been expended for two air-source units (1 in year 1 and another that would have been installed at the end of year 12); 2) annual operating cost savings; 3) assumed added annual maintenance costs; and 4) expected replacement costs in the future for a condensate pump (in years 10 and 20) and the geo-circulation pump (in year 17)

Projected Net Present Value (black = positive net returns; red = negative net returns)

Initial Installation Cost range assumptions for Geo-sys.	based upon 30% annual savings — 20 yrs.	30% — 24 yrs.	30% — 30 yrs.	based upon 40% annual saving — 20 yrs.	40% — 24 yrs.	40% — 30 yrs.	based upon 50% annual savings — 20 yrs.	50% — 24 yrs.	50% — 30 yrs.
$20,000	$4,853	$5,822	$7,077	$7,189	$8,481	$10,155	$9,524	$11,140	$13,232
$21,000	$4,144	$5,114	$6,369	$6,480	$7,772	$9,446	$8,816	$10,431	$12,523
$22,000	$3,435	$4,405	$5,660	$5,771	$7,064	$8,737	$8,107	$9,723	$11,814
$23,000	$2,727	$3,696	$4,951	$5,062	$6,355	$8,028	$7,398	$9,014	$11,106
$24,000	$2,018	$2,987	$4,242	$4,354	$5,646	$7,320	$6,689	$8,305	$10,397
$25,000	$1,309	$2,279	$3,534	$3,645	$4,937	$6,611	$5,981	$7,596	$9,688
$26,000	$600	$1,570	$2,825	$2,936	$4,229	$5,902	$5,272	$6,888	$8,980
$27,000	-$108	$861	$2,116	$2,228	$3,520	$5,194	$4,563	$6,179	$8,271
$28,000	-$817	$152	$1,408	$1,519	$2,811	$4,485	$3,855	$5,470	$7,562
$29,000	-$1,526	-$556	$699	$810	$2,103	$3,776	$3,146	$4,761	$6,853
$30,000	-$2,234	-$1,265	-$10	$101	$1,394	$3,067	$2,437	$4,053	$6,145

1/ DMME rebates at the time of our investment were equal to 20% of installed cost not to exceed $2,000 and were paid in the same year as the geo-installation (year 1);

2/ IRS tax credit for high efficiency geo-systems (30% of installed cost with no maximum) occurs in year 2 of the period of evaluation given that taxes are filed and credits accrue the year following eligible expenditures are made;

3/ To account for what would have been spent for an air-source unit (compressor and air-handler) anyway: air-source unit purchase price in year 1 - discounted IRS tax credit for high efficiency air-source systems (20% of installed cost not to exceed $1,500) occurs in year 2 of the period of evaluation given that taxes are filed and credits accrue the year following eligible expenditures are made; Note: tax credits for high efficiency air-source units expired in 2010;

4/ Present value of the net cost = purchase price - DMME rebate - IRS tax credit - - what would have been spent on an air-source unit in year 1 of the period of evaluation;

5/ To account for an assumed 2nd air-source unit needed to replace the first; purchased at the end of year 12, to provide an equal number of total years of service (24) as assumed/expected from a geo-system;

11 U.S. Energy Information Administration (EIA) data for 2009 (latest available) from: http://www.eia.gov/consumption/residential/data/2009/#consumption-expenditures

12 kWhr for our home and kWhr equivalent for the Southern region and National averages; based upon 1kilowatt hour = 3,412Btus or 0.003412MillionBtu, given that many homes use more than electricity for power (fuel oil, natural gas, wood, etc.);

I read many online testimonials from geo-system owners reporting the systems lasting beyond 25 years and these testimonials were just referring to the compressor and associated parts. The vertical loop portion of an investment in a geo-system can be expected to last 50-100 years or more. Therefore, whenever the compressor fails, only it will need to be replaced substantially lowering the cost of the next geo-system. If the compressor were to last for 30 years, we could expect a NPV of almost $4,400 over what we would have spent for an air-source system over the same period. It should be noted that I assumed the circulation pump would have to be replaced once within the period of evaluation (24 year useful life) and I assumed that it would cost $1,200 to replace. I also assumed that the condensate pump would need to be replaced twice over the 24 year useful life. Lastly, given how efficient our home already was before the geo-system was installed, the investment pays for itself without the DMME rebate over the 24 year expected useful life, but would not pay for itself without the IRS tax credit strictly based upon costs and projected cost savings. That said, qualitatively, we feel that we are enjoying a much higher level of comfort and quiet (peace) due to the geo-system. Added comfort and quiet are worth the added initial cost to us. The system clearly reduces our energy consumption significantly and delivers a much higher level of home comfort.

And FYI, our loop and circulation pump cost $9,800 or $15.80/linear ft. of boring (500ft.) and additional loop-line (120ft.) running under the house (over 40% of our total cost). We didn't have the yard space for a horizontal loop, but the high cost of the vertical loop begged the question of how would the economic numbers come out if we had the space? So I ran the economic analysis assuming the same system costs were made using a less expensive horizontal loop (assumed to cost $5,500 instead of $9,800; a savings of $4,300) and the break-even period was reduced from 12 years to only 3.6 years. The horizontal loop system scenario yielded a NPV of $6,230 over what an air-source system would cost during a comparable 24 year evaluation period. Indeed, the geo-system, assuming a horizontal loop, yielded a positive NPV with or without the IRS tax credit, but not without the DMME rebate and IRS tax credit unless a useful life of 30 years is realized (which is certainly not unheard of). I estimated that a 43% annual operating cost savings over 30 years would be required for our system to break-even without either the DMME rebate and IRS tax credit at current electricity rates. Regardless, the qualitative differences in system are worth the investment to us.

How Increasing Cost ($/kWhr electricity rate) Would Affect Payback: A 10% increase in the kWhr cost of electricity would result in a $157 increase in what our average annual cost of electricity would have been with our old air-source system. The same rate increase would increase our current average annual electricity bill with the geo-system by $114 or $43 less than for our air-source unit. Added savings of $43/year from lower power bills would translate into a total estimated savings of $946 over the remaining 22 years of expected useful life of our geo-unit. Our electricity rate/kWhr has increased by 23.3% since 2007 or about 3.9%/year on average.

Project Components: drilled loop; loop install into crawlspace or other location where your unit is located; installation of a pump to circulate the alcohol fluid in the loop; geo unit installation, metal duct connections and flex-duct installation as necessary; programmable thermostat; new returns and/or larger return capacity if advisable (if your existing return(s) are deemed undersized); and plumbing and electrical modifications as needed for your unit and desuperheater if added/connected to your hot water heater;

Key decisions to make when investing in a geothermal heat-pump:

1) what kind of geo-loop to install: vertical or horizontal loop;

2) pressurized (requires a trained technician to inspect fluid levels) or un-pressurized loop (can be inspected by the homeowner at any time); we went with an un-pressurized geo-fluid pumping system;

3) desuperheater or not to pre-heat water before it enters your hot water heater with heat removed from the house (requires plumbing modifications to connect to your water heater);

4) to invest in an Energy Recovery Ventilator (ERV – exchanges heat and cold while bringing in fresh air and also removes humidity), Heat Recovery Ventilator (HRV – exchanges heat and cold while bringing in fresh air) or none (this depends mainly on how tightly sealed and insulated your home is);[13]

5) front-yard, side-yard or backyard mess, i.e., where to locate your loop;

6) do you have enough air return with your existing return vents and ductwork (you can't have too much air return is often said as a general principle with respect to HVAC systems as more return reduces the pressure within the system to move/circulate conditioned air so your system doesn't have to work too hard);

7) if the unit is to be located in an un-encapsulated crawl-space, then it probably makes sense to add a budget estimate for encapsulation and get it done to protect your geo investment while it provides the comfort benefits discussed above; do this yourself or have it done after the geo install to avoid damage to the poly-liner;

8) filter options (how much air quality and protection of the unit do you want?); the cheap ones will remove large particulates, but the fine particles will go through them; more expensive filters will remove coarse and fine particles as well (we use cheap ones at the in-house returns to catch large particles and high quality MERV11 filters at the unit to capture fine particles);

9) do you have compressed fiberglass "ductboard" for your ductwork/air distribution and return system? If yes, then you might consider replacing it with metal ductwork as ductboard is fragile, can be damaged easily (it is a soft/weak material) and if it ever gets moisture in it, then mold can develop that can only be removed via disposal/replacement of the affected ductwork;

10) if you don't have a programmable, digital thermostat, then you could benefit from one/likely will get one with your new system; they allow for intelligent programming that allows your system to function more efficiently and better achieve the comfort levels you want;

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[13] Improvement suggestions: If you install an ERV or HRV, have a cut-off switch installed inside your house so you can turn it off in the spring and fall when you open the windows otherwise it will run 24 hours per day all of the time. We only turn it off to clean the 2 filters (one on the intake and one on the exhaust) once every six months and have to go under the house to access it. Also, instead of using condensation pumps to dispose of humidity removed from the circulating air, install collection trays and/or PVC pipeline so that gravity alone removes collected moisture.

Lastly, I want to give credit where credit is due. Hungerford's Dwight Altorelli, Sales Representative, worked with us every step of our project "holding our hands" by answering every question and there are a lot of questions that come to you on projects of this nature and scale. He also coordinated the work of Hungerford's install technicians as well as all sub-contractors (VA Energy Services, Curtis Drilling, Inc. and Curran Brothers Plumbing). Dwight was very professional, has excellent interpersonal skills and was a real pleasure to work with (a knowledgeable sales representative is invaluable when considering such a large and long-term investment). Hungerford's Mark Reeves and Andy Mullins were the main installation technicians who worked on our project and they also were very professional. We were and remain very pleased with Hungerford's performance now over two years after installation. Hungerford did everything they said they would and dealt with every concern that we had. Two hiccups occurred during our project: a pressurized circulation pump was mistakenly delivered to be installed even though we had decided upon a non-pressurized circulation pump and some of the install technicians initially left out of the set-up the bracket required for filters to clean circulating air at the unit. Dwight quickly got both issues straightened out. We want to publically express our sincere thanks to Hungerford for a job well done.

Additional Geothermal Heat-pump Resources: "Geoexchange at http://www.geoexchange.org/ ; University of Oklahoma sponsored "International Ground Source Heat Pump Association at http://www.igshpa.okstate.edu/ ; "Database of State Incentives for Renewables and Efficiency" at http://www.dsireusa.org/ ; "Advanced Energy" at http://www.crawlspaces.org/ ; "Building Science" at http://www.buildingscience.com/index_html ; "Green Building Talk" at http://www.greenbuildingtalk.com/ ; and "Green Building Advisor" at http://www.greenbuildingadvisor.com/

Home Energy Audits: Energy audits are on-site assessments to determine how well your home is insulated and how tight it is in terms of air, and therefore heat and cold, moving into and out of the living space. Home energy audits involve a trained technician making an assessment of your walls, ceilings, floors, doors, windows, skylights and installed insulation to determine how well each of these are resistant to heat transmission. When we got our audit done, the cost ranged from $250 to $300 depending upon the company supplying them and whether or not the home owner negotiates a better price by having already measured and documented data needed for the audit, e.g., number and size of windows, window orientation (north, south, etc.) and the width of eave overhangs (all of which affect heat gain and heat loss).

The audit technician measured the amount of leakage and infiltration of air through the building to determine: 1) how well your home retains heating and air-conditioning and therefore how efficient your home is; and 2) how often fresh air from outside cycles into and through your home via infiltration points and the "stack-effect" (hot air naturally rises) . The type of windows you have, e.g., casement windows are the most energy efficient, and the direction they face and their quality of construction and installation and the quality of seals around them as well as your doors greatly affects the energy performance of your home. Quality weather-stripping around windows and doors is crucial for achieving an efficient building "envelope". The goal of an audit is to assess your home's overall thermal performance and identify ways to improve your comfort and air quality and thereby maintain or improve human health.

An audit also involves a "blower-door test" to determine how air-tight your home is (see: http://en.wikipedia.org/wiki/Blower_door for more details), thermal-imaging scans that reveal where hot and cold spots are and infiltration/exfiltration (movement of air in and out) testing with a smoke stick (a device that produces fake smoke that moves towards/where leaks exist). Chris Barrett of Atlantic Heating and Cooling conducted our energy audit and did an excellent job. The resulting report findings directly affected our decision to install an energy recovery ventilator to enhance the performance of our geo-unit and in-home air quality.

ERVs and HRVs: ERVs and HRVs also are types of auxiliary heat-exchange mechanisms in addition to the main loop and desuperheaters, but they can be added to any HVAC system not just geo-thermal. As the ventilation portion of their names imply they provide fresh air ventilation into the house and stale inside air is exhausted to the outside. Incoming air passes through an air filter and a heat exchange core (large surface area baffle made of a thermal-conductive material) where the temperature of incoming air is equalized (as closely as possible) with inside air, i.e., already cooled, air-conditioned inside air is used to cool incoming hot air when in cooling mode and heated inside air is used to warm-up cold outside air during heating mode before it enters your living space. In this way, an exchange of heat or cool takes place and less energy is needed to condition the incoming fresh air.

HRVs transfer heat from the outgoing air to incoming air during the winter and perform the reverse in the summer. ERVs perform the same heat transfer and have the added functionality of transferring moisture to incoming air in the winter and dehumidify incoming air during cooling in the hot times of the year. Less humid air in the summer is more comfortable to most individuals. And air with more humidity than the cold external air in the winter is also more comfortable to most people. The fresh air provided by either ERVs or HRVs also makes for higher air quality. They consist of an intake, air filter, heat-exchange core, motor and blower and duct work; condensation during the summer is also removed. Both systems connect to existing ductwork and although they run 24hrs./day, they function with little electricity; less than a single 60watt light bulb burning 24hrs./day. We chose an ERV to enhance geo-system system performance, air quality (cleaner air) and comfort (lower humidity) and connected the exhaust ducts to our bathroom vents to help remove humidity from the moisture laden air created by bathing/showering. This arrangement reduces fogging and we are very pleased with the effects on our subjective senses of comfort. Lower humidity air in the summer is much more comfortable to us. How much humidity the geo-unit removes vs. the ERV is an open question. At a minimum they are working together to reduce humidity and our subjective assessment is that we are enjoying the best air quality we have ever experienced.

Desuperheaters: Desuperheaters are a type of auxiliary heat-exchange system that can be added to a geothermal unit in addition to the main closed-loop. Desuperheaters transfer heat from the house during cooling mode to water before it enters the water heater. In this way, the water entering the hot water heater is pre-heated which reduces the energy needed to complete heating the water. The heat transferred to the water heater also reduces the amount of heat that needs to be transferred to the earth via the main loop; thus these two features complement each other. They have an added cost, but reduce the heat the geo-thermal loop has to dissipate during cooling mode and have the added benefit of making water heating more efficient/less costly as well. There is quite a lot of debate about whether or not an insulated pre-heater water storage tank is needed in-line between the desuperheater and your hot water heater tank. The argument for a storage tank is: Desuperheaters have minimal capacity to treat and store heated water and are not capable of supplying hot water instantaneously. The compressors don't run 100% of the time and your hot water heaters typically need to re-fill themselves in the mornings and at night when most people bathe. This may or may not coincide with when your geo-system and desuperheater are running. So the reasoning is that a pre-heater storage tank is necessary for the desuperheater to dump heated water into. In this configuration the desuperheater functions when heat is available from the compressor's hot gas temperature that occurs while the compressor is running and the heated water discharges into the storage tank and from there into the hot water heater. Supposedly, this maximizes the beneficial effects of a desuperheater. The added storage tank does incrementally increase the cost of your system. We included a desuperheater with our geo-system, but without an added storage tank. I don’t doubt that we are getting some benefit from it, but I’m not sure if we are getting all that is possible.

Crawl-Space Encapsulation (closed crawl-space): Crawl-space encapsulation is a relatively new concept derived from developments in building design and construction science that determined that vented crawl-spaces (typical in home construction since about World War II) don’t make good sense for the health and longevity of any home and its occupants. Nor do they make sense from an energy efficiency perspective (more on this below). Encapsulation involves use of a heavy fiber-reinforced polyethylene liner and waterproof tape to completely cover the ground, foundation walls and all foundation piers so that the liner acts as a barrier to moisture. The liner can also help impede radon gas movement up and into homes where this toxic natural gas is a concern (fortunately, radon gas is not a major concern in Woodlake).

Prior to World War II, homes were typically built on piers that elevated structures from contact with the ground. This allowed air to circulate underneath structures year round and circulating air minimizes build-up and persistence of humidity on the rim and floor joists and sub-flooring. Vented crawl-spaces came into normal construction practice after World War II based upon the idea that the foundation looked better and would perform just as well as historic buildings did on foundation piers alone (they also keep dogs and kids from playing under the house and minimized access to wild critters). It took a while, but building science finally determined, with repeatable empirical data, that vented crawl-spaces contribute to humidity, mold and mildew in these spaces which in turn rots wood, provides ideal moist conditions for termites and increases allergy problems in the inhabitants through the stack effect carrying mold and mildew into the living space.

The basic reason vented crawl-spaces increase humidity is a function of temperature differences, relative humidity differences and dew point temperatures of the inside and outside environments. During the summer crawl-spaces are cooler than the outside air. Warm outside air holds more moisture than cool air and when it enters the crawl-space through vents, it cools down. Cooling down reduces the ability of the air to hold moisture and condensation under the house results. Condensation can build up and this creates conditions that allow mold and termites to flourish.

Condensation of moisture is not a concern usually in the winter as cold air can’t hold much moisture compared to warm air and usually keeps vented crawl-spaces dry during the winter (if the vents are open). However, cold air in the crawl-space during the winter creates another concern: it decreases the effectiveness of heating and drives up heating system costs. Specifically, ductwork in crawl spaces exposed to cold air in the winter, allows heat to escape either through leaks or radiation. In addition, homes that lack floor insulation permit heat from the first floor to radiate downward into the crawl space even if the ductwork is insulated. In summary, homes with floor and wall insulation in the crawl spaces use less energy all year long and when you add a moisture barrier with encapsulation, you get a more efficient, more enduring and healthier home environment. Between 10% and 15% savings in home energy costs are reported for insulated and encapsulated crawl spaces.

A wealth of technical information on encapsulation is available at Advanced Energy's http://www.crawlspaces.org/ website. See "Closed Crawl Spaces: A Quick Reference for the Southeast" there as well as numerous other references on this topic including "Closed Crawl Spaces: Top Performers Nationwide" available at http://www.advancedenergy.org/buildings/knowledge_library/crawl_spaces/pdfs/Closed%20Crawl%20Spaces.pdf , and "Moisture Performance of Closed Crawlspaces and their Impact on Home Cooling and Heating Energy in the Southeastern U.S." available at: http://www.advancedenergy.org/buildings/knowledge_library/crawl_spaces/pdfs/Moisture%20Performance%20of%20Closed%20Crawl%20Spaces.pdf and "Moisture Solution Becomes Efficiency Bonanza in Southeastern United States" at: http://www.advancedenergy.org/buildings/knowledge_library/crawl_spaces/pdfs/Moisture%20Solution%20Becomes%20Efficiency%20Bonanza.pdf .

Encapsulation Effects on Air Quality: Moisture in the crawl space permits mold and mildew to develop. Mold and mildew are types of fungi that break down organic matter such as wooden floor joists and sub-flooring. The presence of mold in the crawl space translates into poorer living space air quality due to opportunities for the reproductive spores to migrate into your living space. They can migrate into your living space, to a lesser or greater extent, due to the basic nature of your house due to: 1) how well sealed your HVAC ducts are; 2) the "stack effect" (warm air rises and pulls air from lower levels upward); 3) the influence of outside wind; 4) whether or not you have any powered attic fans that can increase the stack effect; and 5) how well your first floor is sealed from the crawl space. All of this matters because air quality suffers when the presence of mold spores increases. Many of us suffer from allergies and encapsulation is an excellent means of improving air quality in your home by preventing environmental allergens from migrating into your living space. See http://www.atsdr.cdc.gov/csem/asthma/docs/asthma.pdf for a Center for Disease Control paper entitled "Environmental Triggers of Asthma – Case Studies in Environmental Medicine" for an excellent treatment of allergens in built environments. It doesn't deal explicitly with encapsulation, but covers a large number of the issues and concerns related allergens.

Advanced Energy also has available on its website a report prepared by Duke University professors for the U.S. Department of Housing and Urban Development entitled "Assessing Allergens and Asthma Triggers in the Home Environment: a Study of the Southeastern United States". It is available at: http://www.advancedenergy.org/buildings/knowledge_library/crawl_spaces/pdfs/Final%20Report%20HUD%20Duke%20University.pdf . Section 5.1.4 "Role of Crawlspace" on pages 84 and 85 makes the following four bulleted points regarding crawlspaces and allergens:

- "Crawlspaces can have a strong influence on indoor air quality."
- "The temperature and humidity levels in crawlspaces generally provide an excellent environment for fungal growth."
- "Human, animal, and weather-related disturbances of the crawlspace may stir up fungal spores, thus facilitating their transmission into the home environment."
- "Transmission may occur through leaks between the home and the crawlspace, as well as via the HVAC system."

Encapsulated crawl spaces minimize favorable conditions for allergens to develop and also reduce their opportunities to migrate into living space. For these reasons as well as the home energy implications, I sought bids from 3 companies that encapsulate crawl spaces and also insulate foundation walls and underneath first floors. The quotes I received were for $4,755, $6,823 and $6,942. The lowest bid included a 6milimeter (mm) polyethylene vapor barrier on the ground and wrapped around foundation piers and sealed/attached to the foundation walls, closing/insulation of the existing vents and access doors, 1 inch of rigid polyurethane spray foam (R-5) on the foundation walls and rim joists, and a remote thermostat and relative humidity monitoring system. The rim joists are the floor joists that rim the exterior of your house and are exposed to the external elements of nature. The $6,823 quote included a vapor barrier of unspecified thickness to be installed over the ground and wrapped around foundation piers and sealed to the foundation walls, closing of all existing vents, new insulated access doors and installation of a drainage system in a low spot. The most costly bid at $6,942 offered to do the least: a vapor barrier of unspecified thickness to be installed over the ground and wrapped around foundation piers and sealed to the foundation walls, a moldicide to be sprayed on the floor joists and for $1,700 extra, a “highly recommended” dehumidifier which would have taken the total quote to $8,642. The lowest bid seemed to offer the most value, but only included a 6 mm poly-liner while all the forums and other information sources I’ve read indicated that a 12mm thick liner is preferable for encapsulation and a minimum of 10mm should be used. A 12mm thick or greater liner with fiber re-enforcement is recommended so that the liner can stand up to humans walking around on top of it.

Long story, short: my son and I bought the needed materials and encapsulated our crawl space for less than $2,000. The $2,000 included the addition of relatively expensive recycled plastic bottle insulation on the foundation walls (I can’t stand fiberglass insulation). We installed R-13 insulation on the east, north and west facing foundation walls and R-19 on the exposed southern foundation wall as well as the westerner and northern foundation walls that support the projection of our living space that is our sunroom. For less than $2,000 in materials and our labor, we were able to create a scrawl space that is clean, dry and comfortable year-round. It protects our investment in the geothermal heat-pump and has contributed to air quality that is the best we have ever enjoyed (our subjective assessment). It was a lot of hard work and took us from April of 2010 after the installation of our geo-system was completed until early October of 2011 to complete the work. We worked mostly on weekends, and sometimes in the evenings after work (when I had the energy). I didn’t keep track of how many hours it took, but it was a big job, was often very strenuous and in cramped spaces. Such an endeavor is certainly not a DIY project for the faint of heart, but with patience and perseverance do-it-yourselfers can get it done. Lastly, I would not recommend such a project be attempted by one individual. Many of the tasks involved in this project require at least two sets of hands.

Materials Required for Encapsulation and Insulation of the Crawl Space:

1) Aluminum flashing to cut pieces to fit inside of each existing foundation vent to act as a barrier to sunlight;

2) Cans of spray foam insulation to seal and insulate the existing vents (sprayed onto the aluminum flashing pieces to prevent air movement) and any other pathways for air to migrate into the crawl space or into the living space;

3) Marking crayons or some other type of marker to mark where the liner will stop (3 inches from the top of the foundation wall recommended so that the wall can still be inspected for termites);

4) "Crusher-run" fine gravel or sand if your crawl-space doesn't already have such a material as a structure improving base over the bare soil;

5) Fiber-re-enforced polyethylene liner of at least 10-12mm thickness;

6) Water-proof tape to seal all of the seams where pieces of the liner overlap;

7) Two-sided butyl rubber tape to help attach liner to the foundation walls and piers;

8) Plastic foundation pins, a.k.a. Christmas tree ratchet fasteners to assure the liner adheres to the foundation walls and piers (the 5/16" diameter x 1-1/8" long fasteners are inserted into 5/16" holes drilled with a hammer drill and masonry bits; they are installed every 18" - 24");

9) Treated lumber to cut 5/8s" x 1.25" "furring-strips" to attach to the foundation walls so the insulation can be attached to the walls and to attach/hang the insulation from the first layer of furring strips;

10) Construction adhesive to permanently attach furring strips to the foundation walls;

11) Concrete screws to help assure that the furring strips stay attached to the foundation walls;

12) Mastic duct sealant to paint all tape seams and help assure that they are water-proof;

13) Either spray on or batting insulation (we bought R-13 and R-19 "Soft-touch" polyester insulation made from recycled plastic bottles with no associated VOCs or off-gassing from Dow Chemical);

Tools Required for Encapsulation and Insulation of the Crawl Space:

1) Rigid steel garden rake to clean ground of construction debris/other materials that could puncture the liner;

2) Cordless hammer drill;

3) Cordless drill;

4) 5/16s masonry bits (you will wear out several);

5) Drill bits for pre-drilling wood furring strips to receive wood screws without splitting;

6) Clamps (to hold the furring strips in place until the construction adhesive cures and the masonry screws are in place;

7) Table saw to rip furring strips into the needed dimensions;

8) Miter saw to cut furring strips to the needed lengths;
9) Metal snips to cut aluminum flashing into vent insert pieces;

10) Box cutters/other tool such as heavy duty scissors to cut butyl tape and large-mouth (long) scissors to cut insulation into needed lengths;

11) 25ft. tape measurer or longer;

12) Screwdrivers to hand tighten some of the screws used where you can't get a cordless screwdriver;

Historic Weather Data from the U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA):

Table 8. Richmond's Recent Weather History from National Oceanic and Atmospheric Administration (NOAA) Data

Month	2007-2009 mean tempera-tures	2007-'09 Depar-ture from Normal ('71-'00)	2011 mean tempera-tures	2011 Depar-ture from Normal ('071-'00)	% Difference (2011/2007-2009 averages)	% Difference (2011/1971-2000 – 30yr. long-term averages)	Difference between 2011 & 2007-2009 period	Difference between 2011 & 1971-2000 period
January	39.6	3.2	34.4	-2.0	86.87%	94.51%	-13.13%	-5.49%
February	40.4	0.9	44.8	5.3	110.89%	113.42%	10.89%	13.42%
March	49.8	2.1	48.7	1.0	97.79%	102.10%	-2.21%	2.10%
April	58.5	1.4	61.8	4.7	105.64%	108.23%	5.64%	8.23%
May	67.1	1.7	69.1	3.7	103.03%	105.66%	3.03%	5.66%
June	76.8	3.3	76.0	2.5	99.00%	103.40%	-1.00%	3.40%
July	78.3	0.4	82.0	2.7	104.77%	105.26%	4.77%	5.26%
August	79.2	2.9	79.0	1.5	99.79%	103.54%	-0.21%	3.54%
September	71.5	1.7	72.6	2.0	101.54%	104.01%	1.54%	4.01%
October	61.6	3.3	59.4	1.1	96.48%	101.89%	-3.52%	1.89%
November	50.5	1.5	53.5	3.1	106.01%	109.18%	6.01%	9.18%
December	42.6	2.2	46.3	5.3	108.60%	114.60%	8.60%	14.60%
Annual	**59.7**	**2.1**	**60.6**	**2.7**	**101.62%**	**105.27%**	**1.62%**	**5.27%**

This data is part of NOAA's "Quality Controlled Local Climatological Data" specifically for Richmond's Byrd International Airport. The data indicates that the 2007-2009 period before our geo-system was installed experienced average temperatures that were 2.1 degrees warmer than the historic averages for the 1971-2000 period. 2010 and 2011 were 2.3 and 2.7 degrees warmer than the historic average as well. Therefore, the savings realized with our geo-thermal system would have been even larger if the current warming trend had not occurred (1.62% greater compared to the 2007-2009 period and 5.27% greater compared to the average temperatures experienced during the 30 year period from 1971-2000). So far average monthly temperatures for 2012 are running 3.6 degrees above the 1971-2000 averages and 1.5 degrees above the 2007-2009 base period of my analysis.

Summary and Conclusions: After many evening and weekend hours of reading/studying our options for replacement of our air-source system, we decided to go with investment in a geo-system in spite of the high cash-cost hurdle associated with the purchase price/installation based upon the following general considerations:

Table 9. System Features Comparison						
Type System	**Installation Cost**	**Annual Operating Cost**	**Maintenance Cost**	**Eventual Replacement Cost**	**Expected Useful Life**	**Life-cycle Cost**
Geo-thermal heat-pump	High	Lowest	Low	Moderate	Very Long	Lowest Life-Cycle Cost
Air-source heat-pump	Moderate	Moderate	Low in early years – Moderate in later years	Moderate	Medium	Moderate
Combination Systems: Air-source unit for cooling and Combustion system for heating	High-Very High depending on whether or not you have to install a storage tank underground, e.g., for heating fuel or propane, or if you have to pay for a supply pipeline installed for natural gas and how long it has to be	Moderate depending upon heating fuel source markets	Moderate-High	Moderate for each system = High together	Medium for Air-source, Long for Combustion	Moderate for Air-source and Moderate to High/Very High for Combustion systems depending upon installation requirements and heating fuel source markets

In addition, we chose geo-thermal for the following specific reasons: 1) expectation that a geo-system represents a long-term lower cost investment in a home comfort system that would also be less impacted by potential electricity increases in the future (lower risk/exposure to increasing prices and indeed the higher future electricity prices rise, the sooner the break-even point would be achieved, etc.); 2) expectation for a system much less susceptible to performance problems due to temperature extremes (the earth's temperature down deep is constant) and due to the unit being inside and protected from outside elements; 3) expectation for a much quieter system/higher quality of life at home; 4) appreciation for the intelligence designed into the system with respect to the two-stage compressor, variable-speed fan, "desuperheater" pre-heating of hot water using heat extracted from the house during the summer and the prospects of enjoying low humidity air in the summer; and 5) I really liked the idea of using the heat and cooling potential of the earth; Now after over two years of experience, our decision on all of these counts, has proven to be completely satisfying.

Not having an outdoor unit creates a little added space in the backyard and eliminates the risks associated with vandals and thieves possibly ever messing with it and tree limbs possibly falling on it in stormy weather. Having it located under the house also eliminates performance issues associated with weather related temperature extremes outside. In addition, the unit is simply so much quieter than an air-source system given that a noisy fan for thermal transfer is not needed. Having the compressor, air-handler and thermal-exchange features all located together makes for a more intelligent and energy efficient system; one that also happens to remove an amazing amount of humidity from the air. Lastly, the air quality we now enjoy is unsurpassed in our experience; indeed the air quality is fantastic. I'm typing these final words on July 8th, 2012 as it is 103°F outside (one of several days in a row over 100°F and we feel very comfortable and contented in our home. The bottom-line is our home comfort system delivers clean, cool air in cooling mode and warm, clean air in heating mode; much cooler and warmer to our subjective senses than our air-source experiences of the past. It would have been preferable to see a higher level of efficiency achieved, but overall we are very satisfied.

According to the U.S. Energy Information Administration (EIA), the average annual cost of energy in the U.S. in 2009 (the latest data available) for homes comparable in size to our was $2,088 ($1.24/sq.ft.) and $2,164 ($1.20/sq.ft.) for homes in the Southern Region. The U.S. average in 2011 dollars, adjusted for inflation using the Consumer Price Index, equaled $2,197 ($1.30/sq.ft.) and the Southern Region average cost in 2011 dollars equaled $2,277 ($1.26/sq.ft.). Our total annual cost of electricity for 2011 was $1,230 ($0.62.sq.ft.) or 56% of the national and 54% of the Southern Region's average annual costs. Between having the most efficient type of windows (casement), the conservation measures we had already implemented and our geo-thermal heat-pump, we have a highly efficient home and heating and cooling system that provides a very satisfying level of comfort. Our system performance expectations with respect to comfort, quiet/peacefulness and air quality have been fully met. We are very thankful for having made this investment instead of buying another air-source unit. Investment in a geo-thermal unit is a long-term investment and don't forget that if you have the space, a horizontal loop system is significantly less costly than the vertical loop we had to install. Also, if you are contemplating building a new home, then investing in a geo-thermal system makes even more sense as you can build in the geo-system as a marginal added cost of your mortgage. Hopefully, our system will perform as expected over the next 22 years or even more. We fully expect that it will last a long time and enthusiastically endorse geo-thermal heat-pumps. If you can get over the initial cash-cost hurdle by using cash on-hand, a home improvement loan or a home equity line of credit, then we highly recommend geo-thermal heat-pumps.

Midlothian, VA, July, 2012

Photographs of Our Geo-thermal Heat-pump Project and Encapsulation of the Crawlspace:

Photo 1: Drilling rig employees laying down steel sheets and plywood to guard against damage from the rig's weight/tires;

Photo 2: More steel sheeting and plywood laid in place before the drill rig accesses the trail/ common property;

Photo 3: The drill rig backed into place in our back yard in preparation to begin drilling;

Photo 4: Another view of the drill rig maneurvered into place for drilling;

Photo 5: Drill rig preparations; the operator is picking up the first 20ft. section of drilling pipe;

Photo 6: Full view of the rig positioned to begin drilling;

Photo 7: View of the rotary drill bit and a support truck loaded with 20ft. sections of PVC casing to line part of the boring;

Photo 8: Close-up of one of the rotary drill bits; and stock of 20ft. drill pipe sections;

Photo: 9: Rotary bit positioned to begin drilling;

Photo: 10: The first 20ft. section of PVC casing being inserted down the boring;

Photo: 11: Bales of straw and silt-fencing placed to capture run-off from the site;

Photo: 12: Coiled-up 500ft. + long geo-loop rolled to the site;

Photo: 13: Quite a lot of ground water came up during the drilling;

Photo: 14: Another view of the geo-loop, all 500+ ft. of it ready to be inserted down the boring;

Photo 15: View looking south towards the drilling rig set-up with our "Guest House" (storage shed) to the left of the truck;

Photo: 15: View of Woodlake Community Association issued access permit;

Photo: 16: The drilling crew inserting the "U-bend" formed end of the geo-loop into the boring (attached to a heavy piece of rebar to help pull the end to the bottom);

Photo: 17: Unrolling and shoving the loop into the boring;

Photo: 18: Drilling crew inserting the last several feet of the geo-loop;

Photo: 19: Bags of bentonite clay on top of a service truck that accompanied the drilling rig; the hopper on the right is used to mix the clay powder with water before pumping it into the boring;

Photo: 20: Drill site after completion with the loop sticking up with the ends taped off until it can be connected

Photo: 21: Virginia Energy Services (sub-contractor) beginning to excavate so the vertical loop (green tape on ends) can be connected to the already installed section of pipe in the crawl space (red tape on ends in the lower right-hand corner);

Photo: 22: Thermally fusing a connecting piece onto the vertical loop

Photo: 23: Here's a close-up of the iron used to thermally fusing loop pieces together;

Photo: 24: Fusing complete; now to fill the trench with soil;

Photo: 25: Placing detectable magnetic tape over each line of loop so Miss Utility can find it if/when needed;

Photo: 26: Close-up of the magnetic tape label;

Photo: 27: One more close-up of the magnetic tape label;

Photo: 28: Our back yard after the addition of 14 tons of topsoil, lime, some fescue seed and mulch;

Photo: 29: The common property adjacent to our back yard and along the trail after we raked, seeded and mulched;

Photo: 30: View of our back yard looking west after our work is done. Betty and I are seated on a bale of straw, tired but thankful and contented. We installed the 16" high (WCA approved) retaining wall to level our sloping back yard. We just didn't order the topsoil until after the drilling so the wall would serve as a trap for the rock dust and ground water.

Photo: 31: Here's the completed Water Furnace Envision NDH-038 geothermal unit in our crawl space;

Photo: 32: And here is the "Geo-Pulse Flow Center" (fluid circulation pump);

Photo: 33: Close-up of the dedicated vent in our crawl space; note actuator on the left-hand side that opens and closes the vent when the unit turns on and off;

Photo: 34: Close-up of the Honeywell Energy Recovery Ventilator (ERV);

Photo: 35: Close-up of encapsulation with insulation; note 3" space of viewable foundation wall for termite inspection, black mastic sealant over poly-liner joint and 2-sided butyl rubber tape used to hold insulation until a 2nd furring strip can be installed to permanently hold insulation;

Photo: 36: Same image pulled back to view full length of foundation wall; note furring strip of wood over the insulation on the left;

Photo: 37: A view of the poly-liner and furring strip holding it up before insulation is installed;

Photo: 38: A close-up of the same section of liner and furring strip before the insulation is hung; We used a 12mil polyethylene liner sourced from Americover, Inc.(see www.americover.com)

Photo: 39: A view of encapsulation of our crawl space with wrapped piers and insulated walls; also note the low-cost dehumidifier we bought and installed (condensation gravity feeds down PVC pipe that passes through the foundation wall where our old air-source unit's copper pipe used to pass;

Photo: 40: Another view of the encapsulation and insulation job my oldest son and I did; note the geo-loop lines (in and out) that emerge from the crawl space floor and run along the floor joists;