Geothermal (aka Geoexchange) Heat Pump Installation Observations / Lessons Learned

On the road to living a more sustainable life style, our first priority was the installation of solar photovoltaic panels that generate electricity from sunlight. After the solar PV system was installed and operating in June of 2011, we were able to start Phase II – Geothermal Heating and Cooling. The Geothermal system became operational in Sept 2011. The following documents some of our observations and "Lessons Learned" during Phase II of our journey.

For more information about Geothermal (aka GeoExchange) systems, check out the U.S. Department of Energy website: Geothermal Heat Pumps (http://www.energysavers.gov/your_home/space_heating_cooling/index.cfm?mytopic=12640)

We became seriously interested in the geothermal heat exchange technology for home heating and cooling after talking with several suppliers at the 2011Home and Garden show in Denver, CO. It appeared from the representatives at the show that Water Furnace was one of the leading manufacturers of Geothermal Heat Pumps in the US. So using Water Furnace as a guide, we located several local contractors that sold the Water Furnace equipment and requested quotes from two contractors.

One contractor invited us to take a tour of his home where a Water Furnace geothermal system was installed and operating. He sent us a bid within a week for a 4 ton heating and cooling system that included two 300 foot deep "wells" for the closed vertical ground loop.

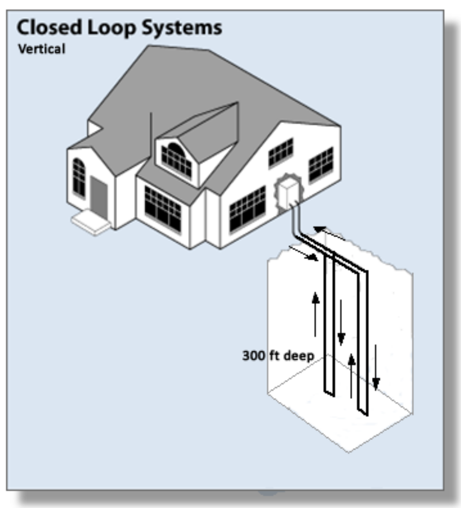
The second contractor came out to our home with sales brochures describing this same line of equipment. He sized and priced the system using his laptop computer. This contractor gave us an option of installing a horizontal ground loop in the back yard – it would have meant digging up ½ of the back yard and burying loops of black plastic pipe about 6-8 feet under the surface, but the cost would be $3000 cheaper.

We decided to go with a vertical ground loop to minimize the alteration to our yard.

As it turned out, when the bids came in, the first contractor's bid for a vertical ground loop was $3000 less than the bid for a vertical ground loop from the second contractor. We choose the lower bidder.

The installation of the Geothermal Heat Pump furnace consisted of two separate activities:

1. Geothermal (aka GeoExchange) Ground Loop Installation (in our front yard)
2. Heat Pump Furnace Installation (in the basement)



1. Geothermal (aka GeoExchange) Ground Loop Installation

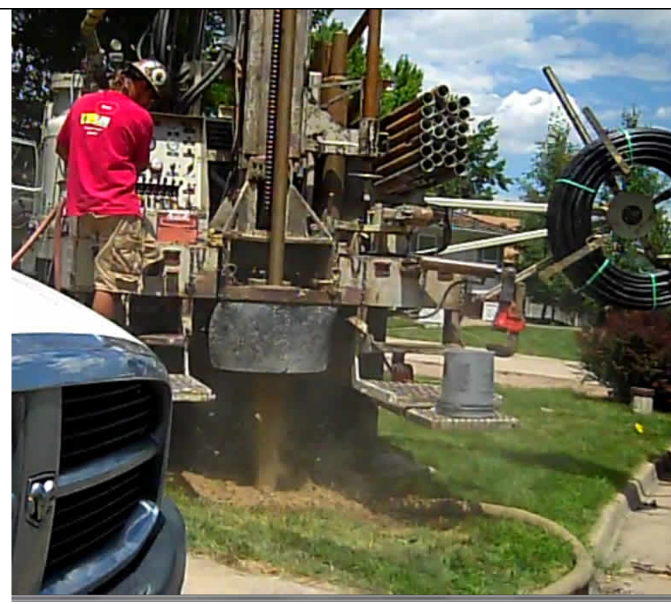
1.1. Geothermal Ground Loop Installation – Observations from 8/1/2011 to 8/2/2011

Day 1. The Can-America Drilling crew arrived around 12 noon on Monday and started drilling well # 1 near the street. The drilling went smoothly – they did encounter some water at 140 feet, but drilled to the 300 ft depth quite easily using a 5” diameter drill bit.

If you decide to install a vertical geothermal ground loop on your property, get mentally prepared for a drilling rig to show up in your yard. The strip of bare ground shows where we had stripped the sod between the locations of the two proposed "wells."

With the rig in place and erected, checkout proceeds

Last minute checks as drilling is about to begin



Drilling begins as high pressure water is forced into the drill pipe and out the lower end at the drill bit. The water is then forced back up the hole to emerge as a mud spray that impinges on the bottom of the platform (operator's knee level). The mud is then diverted by the black rubber shirt and falls back onto the ground around the hole. Notice the vacuum tube laying along the ground intended to vacuum up the emerging drilling mud.

After about an hour and half, the drill bit had penetrated to about 300 feet (using 15 of the 20 foot sections of drill pipe). The drill pipe/bit has been raised back out of the hole. Now it's just a matter of dealing with the drilling mud.

After the hole has been drilled, the boom is lowered - notice we provided some trees to make this a bit more challenging.

Before moving the drill rig, the 300 feet of double black plastic tubing is inserted down into the borehole from the spool to the right

The black plastic 1" tubing is now in place. About 20 feet of excess tubing remains on the spool.

The drilling was slowed significantly by the failure of the vacuum pump truck to handle the dirt / mud from the drilling process. The truck's vacuum system was not functioning properly that day. When set to high vacuum, there was virtually no vacuum generated, so the vacuum system was set to the lower range where it still functioned, but no very well. As a result, it required a lot of patience to slowly suck up the drilling mud/water that was being generated. But there was a significant quantity of drilling mud to remove. During the drilling, some overflowed into the street gutter that required significant clean-up all the way down to the corner of Jackson and Orchard.

After the borehole was completed, the drilling crew inserted the 1" black pipe. They had some difficulty at first but after about 20-30 feet was in the hole, the remainder did unroll easily and reach the bottom of the hole where it was l then staked / taped in place for the grouting process. The rig was then moved to the second hole. It was just after 3:00 pm by then and the crew decided to call it a day and try to get a better vacuum truck for the second hole.

Day 2. The crew of three returned around 9 am on Tuesday and began drilling Borehole #2. They had not been successful in getting a new vacuum truck so they decided to just vacuum the water and not the mud. They built a dirt barrier downstream at the street curb to prevent the water from reaching the street as it had the day before. By 10:35 am they had reached the 300 ft depth and proceeded to remove all the drill sections.

Hole # 2 was finished drilling around 10:35 am. The drill pipe was removed and the boom is being lowered. As indicated, there was a sea of mud that in this picture extends downhill to a temporary dirt dam at the street curb where the water is being sucked up by the hose from the vaccum truck.

Again the drilling crew had some difficulty getting the black tubing to enter the hole, but it seemed to be going well up to about half way when the black pipe got tangled in the spooling mechanism and came to an abrupt stop causing one side of the dual tubes to buckle around a member of the spooling device. They immediately freed the tubing from the spool cross member and attempted to straighten the buckled tube by using a clamping device at 90 degrees to the bend to remove the buckling. They then proceeded to resume lowering the black pipe into the hole. It was going down properly until the last 40 feet (260 feet was in the hole) when it stopped. They assume they had encountered water and filled the black pipe with water to offset the buoyancy. This procedure helped only slightly. There was obviously mud/sand/gravel at the bottom of the borehole they were trying to push the black plastic tubing through at that point.

The following was captured on video. They tried forcing the black pipe down the hole by hand - that worked for about 5 feet, but it required too much physical effort, so they raised the drilling rig back up, added a section of drilling pipe and lowered the drill pipe down to the hole, taped the black pipe to the steel drill pipe and used its weight to drive the black pipe further down. They had to be careful not to cause the two black pipes to buckle and were taping the black pipe to the steel pipe every three feet or so. This worked for another 5-10 feet when even the weight of the drilling pipe was insufficient to drive the black pipe further into the hole – there was still 25 feet of black pipe above ground. They cut off the remaining tubing and sealed it off by melting the ends shut and moved on to the grouting process.

	
The black plastic is being inserted. On this hole, apparently material fell back into the bottom of the hole making it difficult to insert the last 25 feet of tubing. The tubing was taped to a section of drill pipe in an unsuccessful effort to drive it further down	As indicated, there is still about 25-30 feet of tubing remaining on the spool that could not be forced into the well. The remaining 25' was spliced in and placed at the bottom of the trench between the two wells to provide the required total length of tubing for a 4 ton geothermal ground loop.

The borehole is approximately 5 inches in diameter, the black plastic “U tube” of 1” diameter tubing leaves a significant amount of air gap between the tubing and the earth.   Air is not a good medium for transferring heat between the tubing and the earth, so a liquid clay grout is added to fill up the space and provide better thermal conductivity.   Bags of geothermal grout (Bentonite clay powder) were dumped into a mixing chamber on the grouting truck. Water was added and the mixture stirred to create this slurry that could be pumped into the boreholes and eliminate the air gaps between the tubing and the ground.   The grouting process took another 2 hours to fill the two boreholes. It seemed to go well although the system did get clogged and they had to stop and work on the equipment midway during the grouting of the second hole.

The operator of the grouting truck pours bags of thermal grout into the mixing chamber as they prepare a batch of grout (environmentally friendly bentonite clay).

The last step for the drilling crew is to "grout" the tubing. A bentonite clay / sand mixture is used as the grout to fill in the space around the tubing and provide a heat transfer path between the tubing and the ground. The orange pipe is inserted down the well to the bottom and the grout is injected – the orange hose is then slowly pulled upward as the hole fills with the grout – eventually the grout starts oozing out the top of the hole.

Summary – Geothermal Ground Loop Well Installation:

In general, the Geothermal drilling crew did a good job drilling the borehole, inserting the ground loop black plastic tubing and adding the grout around the tubing to establish a good thermal conduction path between the ground loop line and the earth.

We have one well down 300 feet with what appears to be a good insertion of the 1" black pipe and appropriate grouting. We have a second well down 275 feet. One of the 1" black tubes was inadvertently buckled/kinked midway in its length during installation, and the entire assembly stressed significantly in an attempt to drive it the last 25 feet (with 25 feet of pipe still remaining outside the well.) We can only assume that the extraordinary measures used to insert the black pipe did not cause further buckling down the well although none was observed above ground level – we did observe significant deflection but not to induce actual buckling. The 25 feet left outside the well had to be added to the manifold in the connecting trench to balance the two flow paths.

There was a significant amount of dirt/clay/shale/mud (3- 4 wheelbarrows) left above ground around the second well (the malfunctioning vacuum truck was unable to handle it). The trenching crew that came later removed this excess material because we did not have a convenient way to dispose of it. There was no way this amount of material could be combined with the material dug from the trench between the two boreholes so that all the dirt could be replaced and end up with a level surface that can be re-soded.

> The plastic pipe in well #2 should have been pressure tested to assure no leak was introduced when the black pipe was inadvertently kinked. It was not clear if the inadvertent buckling/kinking of one of the black pipes affected its local strength.

> In retrospect, I should have recommended that 1.5 x normal operating pressure by applied as a proof pressure that the 1" black plastic was not compromised to where it can cause a future failure in the ground loop. I would even have accepted a pressure test on a scrap piece of black pipe that had been buckled / kinked to where it was closed and then crimped to restore its shape. There was no pressure test to verify the integrity of the buckled tubing. The general contractor did however ask the Geothermal trenching contractor to conduct a simple test to assure the tubing was not completely buckled and would not flow water. Water did flow through the buckled line – demonstrating it was not completely blocked.

Clean-up at the drill site was good considering the malfunctioning vacuum truck. As a result there was significant material (3- 4 wheelbarrows) left behind by the drilling crew that the trenching crew later removed.

1.2 Ground Loop Manifold Installation – Observations 8/8/2011

A different crew was sent out by Can-America to finish the installation of the ground loop. This process involved installing larger diameter manifold tubing that connected the two ground loops. The manifold tubing then entered the basement. At my request, the contractor waited a week for the yard to dry out before returning with their backhoe / tractor. They first drilled two holes (~ 2 inches in diameter) through the concrete basement wall from the inside and then moved outside and began digging the trench from the basement wall back to each of the two wells. After the trench was in place, they proceeded to add the manifold tubing.

Recall that one of the boreholes was down only 275 feet, so an additional 25 feet of tubing was to be added to both sides of well tubing and looped inside the bottom of the trench before connecting to the manifold tubing. Ideally, the end of the manifold lines coming from the house would have been placed exactly in the middle of the two wells, but for expediency, the actual junction was placed about 5 feet from the further well (to get to the middle, they would have had to splice on about 5 feet of 1" tubing to each well tubes that had been cut off before mating to the manifold – they did not. [Note: All connections of this black plastic tubing are made by melting the plastic with a special heater, so the joints are said to be stronger than the tubing itself.] So the manifold was effectively connected about 5 feet from the first well and about 15 feet from the second well (that was to have approximately 25 feet of tubing added – [unverified]). There is no way of knowing how balanced/unbalanced the flow from each of the two wells actually is.

Are you ready for some trenching?


The scene after a few hours of work with the backhoe

 Ready to start connecting the two ground loops together	 Manifold in place, soon to be tested for leaks and then the trench will be backfilled.

The trench was back filled by the contractor using the backhoe to pack the soil back in the trench, but there was a significant amount of soil left mounded above ground. After a day or so of deep watering (to where the dirt in the trench was nearly liquid all the way down to the bottom,) the mound did settle several inches but it was clear that another approach was needed before we could lay the original sod back down. So we decided to simply turn a portion of the trenched area into a mounded perennial plant/flower bed with a paver border that makes it appear this is what we intended to do all along. Perhaps in a year or so, the soil will have compacted and the flower bed will again be level with the rest of the yard, or not.

After a day or so of deep watering, it was clear we were still going to have a mound of dirt.

So we just turned the mound of dirt into a perennial plant/ flower bed.

Who would guess there are two 300’ deep geothermal boreholes with plastic tubing below the bed that allow our house to exchange energy with the earth and be heated and cooled sustainably year round?

The Geothermal crew finished installing the geothermal ground loop by filling it with a water-antifreeze (methanol) mixture, then pressurizing and sealing it off for the actual hookup by the Heat Pump Furnace crew.

Installing a geothermal system on an existing landscaped property is not for the faint-hearted. Generally geothermal ground loops are installed during the initial construction phase of a facility, so alteration of the site is not an issue – later landscaping will erase/cover any alteration caused by the drilling/trenching process. This of course is not the case when the system is installed as a retro fit to an existing heating /cooling system (as in our case). The use of a vacuum truck to remove the material that emerges from the wells is important – hopefully it works better than one used by Can-America. There is a tremendous amount of water used in the drilling process to remove the material from the hole. If this drilling mud is not removed as the drilling proceeds, the waste water will soak into the surrounding soil so the drilling rig may leave six inch or more deep ruts when the rig is moved (if it backs over the hole). If the rig can be removed going forward instead, there will be less alteration.

Although we did cut (and save) the existing sod from the areas where the actual wells and connecting trench would be located, the drilling rig and backhoe required a lot of area to move around. Because the ground removed during the trenching is significant, it must be placed on top of existing sod near the trench. When the soil is backfilled, it will be difficult to compact it sufficiently to return to a level surface over the trench.

As it turns out in Colorado, according to an inside source, there are only two major Geothermal contractors in the state who install these ground loops – and they are both based in Silma, CO. They realize they have a monopoly on the business, so we consumers might assume the cost of putting in a geothermal ground loop in Colorado is inflated from other regions of the country where there is significant competition. But in fairness, the well drilling rigs are very expensive and complicated pieces of equipment.

1.3 Lessons Learned. Areas Where the Geothermal Ground Loop Installation Process Might be Improved

1) The general contractor sized the required geothermal ground loop to be two 300 foot deep vertical boreholes for a "4 ton" heat pump furnace. I did not request to review the analysis that "sized" the system. As a result, I have no information about the performance "margin" built into the system. We simply expect the system to operate correctly (i.e. be able to heat and cool our home.)
2) As the black plastic tubing was inserted into one of the boreholes, an out of control spooling mechanism caused the tubing to become kinked. This seems like a bad thing to have happen, but the incident was not acknowledged, inspected, or even recorded by the driller. The tubing was not pressure tested (at say 1.5 times the operating pressure) to verify the kink placed in one of the lines during installation did not damage the integrity of the tubing.
3) The grouting process seemed to have few standards. There did not appear to be any consideration for those regions where the borehole encountered water during the drilling process. The actual grout mixture also seemed uncontrolled as far as the mixture of sand, grout and water is concerned. Our contractor appeared to use grout consisting mostly of bentonite clay in our boreholes.
4) The actual thermal conductivity of each borehole seems to be a rough guess based on observations during the drilling process – i.e. if the borehole went through a significant amount of shale versus fine clay, the effective thermal conductivity would be considered less. If the borehole penetrated aquifers, this would affect the heat transfer ability of the tubing – actually a section of tubing located in flowing water would have better heat transfer than a section in static soil. There was no actual quantitative measurement of the thermal conductivity/heat transfer capability of the installed ground loop.
5) Installation of the manifold for a multi-hole vertical closed ground loop is a key element for a balanced system. Based on what I observed, it was not apparent that the missing 50 feet of tubing was added into the circuit for the second well (unless it was covered up with dirt prior to my observation). As a result there may be a 5 % variation in the line length between the two wells – hence the flow resistance, flow rate and energy exchange between the two wells might be slightly off nominal, but probably nothing drastic.
6) The ground loop system does not include instrumentation required to evaluate the heat exchange effectiveness/efficiency of each of the two wells or even the ground loop system as a whole – it could very well be that the wells are not balanced and therefore their combined heat exchange capability is below the theoretical design levels. The addition of additional instrumentation (and or manifold tubing) results in a more expensive system, but one that would be easier to verify its actual performance and efficiency.
7) There was no confirmation of any leak rate or pressure change during the week or so the ground loop was locked up at an elevated pressure by the trenching crew.
8) There is no means of monitoring the ground loop operating pressure. The installer did indicate that if the system pressure decreases, the heat exchange/transfer rate is changed – in his terms, the ground loop "goes flat" and will have degraded heat exchange performance. The owner of the system has no way to evaluate the operating pressure and hence heat transfer performance of the ground loop – except in the event of a gross failure of heat pump. Annual maintenance that includes a pressure check is probably recommended.
9) The Geothermal contractor is "licensed" with the State. However, there is no city/state inspection associated with the geothermal ground loop, although the contractor does fill out a state form intended to quantify the parameters of the system. Basically, they come out, drill the boreholes, and install the plastic tubing then leave. If the general contractor is not monitoring the work constantly, there is no way to verify the Geothermal workmanship, except in the event of a gross failure of the ground loop after it is hooked up to the heat pump.

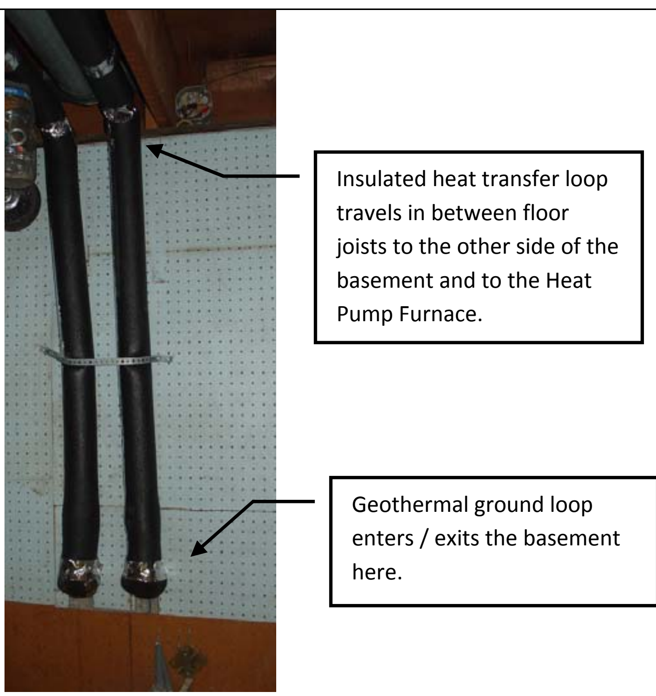
2. Heat Pump Furnace Installation

The heat pump plumbing crew arrived about one - two weeks later to finish the installation. The old gas-fired furnace / air conditioning unit was removed and replaced by the new heat pump furnace. The new unit consists of the following internal elements:

1) a blower assembly that pulls air through a heat exchange coil and then into the house ductwork,
2) the heat exchange coil that transfers energy between the air and the compressor fluid
3) a "desuperheater" – another heat exchange coil that allows preheating of hot water
4) the heat pump compressor
5) an auxiliary electric heater in the event the heat pump cannot keep up with the heat demand or is not functioning properly

Installation of the heat pump required two additional 220 volt circuits (one for the auxiliary electrical backup heater). Generally the modification to the existing air ducts is minimal – only a short custom made adapter from the cold air duct to the heat pump and one back to the hot air ducting is required.

The heat pump installation crew demonstrated good workmanship. The electrician who installed two new circuits, the "tin man" who custom made new sheet metal adapters between the new furnace and existing ductwork, and the plumber who installed the new pre-heat water tank and connected the ground loop to the furnace all appeared to work together efficiently. The system was hooked up and operating within two days. The following photos illustrate their work.



Geothermal ground loop enters basement about 4 feet above the floor. Outside, it's about 5-6 feet below the surface – well below the frost line.

The heat exchange loop comes down from the ceiling into a flow control / valve assembly before connecting to the heat pump furnace.

The new Heat Pump Furnace replaces the original natural gas burning furnace. Because the GeoExchange technology does not burn any fuel (fossil or bio), there is no need for an exhaust flue / chimney. So much for Santa Claus, sorry kids.

The Heat Pump system also preheats/heats water – a second preheat tank was tucked behind the primary electric hot water tank.

The Heat Pump Furnace assembly is much like a gas-fired furnace in that it uses the same cold and hot air ductwork, and a fan/blower to circulate cold and hot throughout the house. This photo with the furnace cover removed, shows the blower assembly where air from the "cold air" register enters on the left side and exits through the "hot air" plenum at the top of the photo.

A closer look shows that the "cold air" is pulled through a heat exchange radiator by the blower assembly. The radiator temperature is controlled by the heat pump compressor – notice there are three layers of small black coils looping around the raditor. The fluid circulating in these small tubes is either hot or cold depending on how the heat pump is being driven – i.e. whether the house is being heated or cooled.

 The compressor for the heat pump is directly below the blower assembly.	 The ground loop coils are positioned just below the heat pump compressor (inside the styrofoam) for heat exchange with heat pump. No combustion anywhere – just the circulation of fluids that allow the house to exchange energy with earth – sustainably. No fossil fuel is consumed; zero emissions into the atmosphere.

2.1 Heat Pump Furnace Installation Lessons Learned.

1) Verify what you are actually buying when you review the contractors quote. When they delivered the new heat pump furnace, I was initially shocked. All along I had insisted on a “made in the U.S.” product and assumed that I was buying a Water Furnace brand heat pump. Although the contract did not specify a brand or a model number, just that it was a “4 ton” rated unit, it was the only equipment shown to me during the tour / pre-proposal phase. Quite frankly, I felt like the victim of a bait and switch scam. I quickly got on the internet and began researching the supplier of the equipment that was just delivered and fortunately concluded that their product was of good quality and it too was made in the U.S. According to the specifications available, the unit I now had in the basement, that was not yet hook up, was actually more efficient than the comparable Water Furnace option. So I calmed down, but still felt this could have been handled better by the contractor.

2) When the ground loop is opened to connect to the heat pump furnace there will be some water/methanol mixture spilled – it has a very distinct smell that will fill the house for a day until it evaporates.

3) Without any additional instrumentation on the heat pump assembly, it is not possible to monitor the ground loop or heat pump performance. Of course most people would have no need to monitor flow rates or evaluate the energy used to circulate the water in the ground loop or assess the efficiency of the “desupersaturator” (to determine the efficiency of the water preheat system), etc.

Conclusion.

Are we happy to no longer be using fossil energy for heating our home and providing hot water? **Ecstatic!**

The Geothermal/GeoExchange heat pump system appears to work properly in both cooling and heating modes (despite the perceived areas for improvement mentioned above). The physics and technology are well verified and definitely in the direction of sustainability. Your only concern is proper "sizing" of your system and workmanship.

The solar PV panels on the roof are providing all the electrical power required to operate the geothermal heat pump (as well as our lights and other appliances) so our home is powered solely from the Sun's energy.

We have yet to see how the system performs over an entire year and whether or not we have enough solar panels when the winter days are shorter and the sun is lower in the southern sky.

With this phase of our sustainability conversion process complete, we can now turn our attention to finding a plug-in electric vehicle that replaces the red object in our driveway – we may have to add a few more panels, but there is plenty of roof area left.

Send comments/ questions to: mahetrick@msn.com