Renewable heat from under your feet—
and with solar above, it's a system you'll love

(Chasing carbonless zero net energy at home)

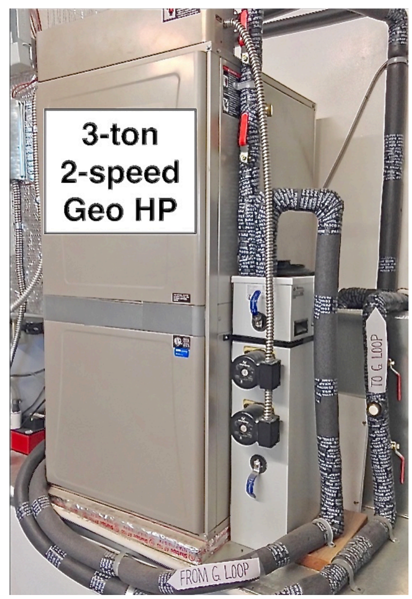
Bill Martin 2-28-21

I use a geothermal heat pump teamed with solar photovoltaic power at our house, completed in 2014. I've always chased the lowest possible utility bill and want to share how it was done with off-the-shelf technology. The biggest challenge in the northern Sierra is heating, not cooling, but our GHP (geo heat pump) can do both with efficiency that beats anything else.

Technology choices-

Any heat pump (including the air-source type I used in a 1977 house) works like a two-way version of your refrigerator or car's air conditioner. A refrigerant-compression cycle accesses and transfers heat from one place to another—it does not generate any heat itself.

You might ask why I wouldn't repeat the use of an air-source heat pump that was successful for me back in the 70s. Efficiency and operating cost is the answer. A GHP can provide more heating (or cooling) on less electric power than its air-based cousin. That's the definition of efficiency, "more using less." When it's working, an air-source unit is stuck with pulling heat **from** or rejecting heat **to** the air mass it is in contact with so it can satisfy a thermostat.



A GHP doesn't suffer like that. It pulls from or deposits to an underground resource that has a steady temperature profile better serving both heating and cooling. It doesn't do any defrosting (like an air-source unit must) and can make hot water whenever it's running, which is free during summer cooling. There's something else. While the air-source unit can only use air as it's transfer medium, it works only by *convection*. The GHP transfers better than that by *conduction,* using liquid that is many times as dense as air. To see what I mean, place your open hand above a hot mug of coffee. Now wrap your other hand around the mug with direct contact. Which one burns your palm?

A necessary ground loop-

An underground heat exchange loop of HDPE (high density polyethylene pipe) is necessary for a GHP to be fed circulated water. But how much pipe and how deep?

Since I live in a stream's alluvial fan at the bottom of a north facing canyon extending 3,000 feet above us, contact with vertical heat exchange bores to a depth of 200-feet would have likely been a struggle against cold snowmelt water for much of the heating season. So, I chose a horizontal loop.

Since the dominant thermal load on a house (heating, around here) decides the size (capacity) of the GHP, then, that dictates a minimum length of pipe and and a deployment method adequate to provide a fluid loop warm enough for satisfactory GHP performance.

During design, I armored the building envelope with more than code required insulation and very good windows. It is a large house of 3,265 square feet on a single floor, featuring R-50 ceilings, R-33 walls, and R-33 floors. Despite Quincy's winter design temperature being +10°F, I was able to choose a relatively small, 3-ton GHP to handle the load.

Our .6 acre lot provided adequate space to install ground loops surrounding the future house, and a Slinky® method was chosen using four trenches, each 7.5 feet deep, 4 feet wide, and 87 feet long. Each carries 800 feet of 3/4" HDPE pipe (3200') and two sets of headers (front and rear of the future house) run to the garage. This is a closed loop with 114 gallons of pumped fluid, round and round when the GHP runs. It takes 12 minutes for any unit of fluid to make the round trip to the end of any trench and back. However, if we owned land with "normal" soils, the quantity of buried pipe could have been far less.

When the *refrigerant Loop* inside the GHP is provided adequate fluid temperatures, we can be hopeful that the GHP will produce the expected quantity of heating or cooling that the inside building space requires. When that happens, we know that the system is not short looped, and we can expect long equipment life.

The two red thermometer readings from the entering (42.8) and leaving (37.7) loop water show a difference of 5.1°, which means this unit is working in Stage 2, its full capacity. What we look for in such a test is to see if during the run cycle, the two readings remain steady. That would mean that in the trip out to the underground heat exchanger and back there was a temperature recovery of 5.1 degrees, courtesy of dirt surrounding that heat exchanger.

When fluid temperatures like this reach the GHP's inside heat exchanger, a powerful bit of energy leverage (called phase change) is accomplished by evaporating liquid refrigerant to a vapor state that can then be squeezed by a compressor, boosting its temperature by up to 100°.

In summer, when cooling is desired, a reversing valve is activated by thermostat command. The direction of refrigerant flow now causes the energy of phase change to come from the ducted airstream of our house. The science of phase change in water isn't identical to refrigerant but to illustrate, you've got to add over 900 times the amount of heat to a pound of water at 212° to turn it into steam at 212° than is required for a one degree boost, anywhere between 32° and 212°.

As efficient as GHPs are, they still run on electricity, so we decided to make our own so we'd have a shot at being a **carbonless, zero net energy house**—consuming no more juice than we made each year. Of course, solar PV is the way that gets done.

Our all-electric house is connected to an electric utility by an NEM (net energy metered) connection that brings us unlimited power without having to use a battery system. It also lets us export unused electricity backward through the smart meter when we create more than we are using.

We pay about $11 per month for this connection but we offset it with previous credit from our generation of excess power. This helps us build an offset for those dark months where the solar is less effective and the days are short. Once a year (mid-November for us) we get a True-Up billing that summarizes the previous year. A consistent goal of Cost Zero has been achieved five out of the last six years and the consistently tough goal of Zero Net Energy was achieved twice. Greater cloudiness, more rain, and more snow (which can stick on our panels for up to 2 weeks) trims solar production. Those are factors we cannot control, and to hang out more panels to overcome them would be less cost effective.

TRUE-UP RESULTS

YEAR	KWH	RESULT
2015	-1,503	**BEST**
2016	952	
2017	2,608	**WORST**
2018	1,715	
2019	1,578	
2020	-35	**LATEST**

There's a nice synergy when using solar electricity with a geothermal heat pump. You can gather what you need from the sky above and from the dirt below on your own property.

Home is one of our favorite places to be, and I feel we've achieved automatic-thermostatic heating and cooling along with ***great comfort on the cheap***.

—Bill Martin

Martin is a long-time proponent of efficiency and green energy. He leads The California Geothermal Heat Pump Association, a non-profit trade group.