The Need for Winter Energy Supplement

Steve Willey

Thermoelectric battery charging made up for the lack of sunlight on our photovoltaic modules this past winter. I tested a commercial Thermo-Electric-Generator (TEG) that uses propane for fuel. It generated about 750 watt-hours a day, which is one third of the electricity we need for our Backwoods Solar business and our home combined. In addition, I captured almost all the "waste" heat given off. By itself, this heat kept a room at 73 degrees, continuously through sub freezing weather outside.

Solar electric powered homes in northern climates face the problem of huge seasonal variations in sunshine. Summer days are nearly as long as in the desert southwest, but winter's days are short. In northern Idaho, where Elizabeth and I live, the December sunset comes at 4 PM. Northward to Canada and Alaska, the days are even shorter. Gray overcast and stretches of snow fall cancels the few remaining hours of sunshine for days, even weeks, at a time! That means a lot less battery charging power in the winter months, just when we spend our long evenings indoors with the lights on.

The standard solution is using an engine generator and a high current battery charger for quick charging and greatest fuel efficiency. This in turn requires large batteries that can accept a fast charge. There is always the noise and maintenance of reciprocating machinery, and an engine wastes its excess heat (unless it's water cooled and plumbed into radiators).

I was excited to be able to test a silent thermoelectric generator (called a TEG) with absolutely no moving parts. A TEG gives a slow steady charge to batteries 24 hours a day and simultaneously provides clean heat to the room it is in. This shows potential as an ideal balance for a solar power system's performance over the winter season, while keeping batteries warm, or even warming the home.

Above: Thermoelectric generation at Backwoods Solar Electric in Sandpoint, Idaho. Photo by Steve Willey

Thermoelectric generation is not a common power source, though the principle has been in industrial use for decades. A difference in temperature between a heated side and a cooled side of a thermocouple junction creates a small voltage. As with a solar module, many junctions are combined to get the voltage and amperes needed for battery charging. The temperature difference that drives the thermocouples can be created by concentrated solar energy, a wood fire, propane catalytic burners, or other fuels. The hot side is typically heated to 450 to 550 degrees F.

Testing a Wood Stove TEG

The first thermoelectric unit we tried was designed to operate from the heat of a wood stove. It was bolted directly onto the top plate of a Fisher wood stove, with cooling water circulated through a small tank on top to create the temperature difference across the thermocouple. This unit could produce a few amperes of battery charging and sounds like just the ticket for wintering in a wood heated cabin. However, the units manufactured for wood stove use have not been durable. The stove had to operate hotter than normal, over 500 degrees. Just one operation at 600 degrees or higher, or failure of cooling water, will destroy the silicon thermocouples. Even with a thermostatic draft vent on the stove, the temperature was not stable enough with typical wood fuel. Maybe a pellet stove… Eventually corrosion from cooling water and possibly some over temperature incidents deteriorated my $500 test unit.

Testing a Propane-Fired TEG

Propane heated thermoelectric generators have been tried and proven in remote locations such as remote railroad crossing signals, mountaintop TV/radio repeaters, offshore marine beacons, and oil pumping platforms. They have not been successfully marketed for remote home power systems. One or more catalytic burners apply accurately controlled heat to one side of the thermocouples. The other side of the thermocouples is cooled by large aluminum fins outside the machine's chassis in the surrounding air. The waste heat given off the fins is usually discarded or sometimes used to keep the equipment hut and batteries warm. TEGs need almost no maintenance. The units in production now are said to be very reliable industrial designs, but with industrial strength prices to match.

Elizabeth and I bought a Teledyne 2T4P propane fuel catalytic TEG to test through the past winter. My purpose was to experience the effect of this energy source on home battery charging when combined with photovoltaics, and also sense how much home heating could be produced as a byproduct.

The unit was delivered to us at the 1992 SEER gathering in Willits, California. It had a loose leaf notebook instruction manual, complete with setup, operation, and repair instructions. Although the instructions seemed to be a custom assembled assortment of pages to match the custom assembled TEG, they were very complete in most areas. Any questions that were not covered were answered satisfactorily by William Hall, marketing manager at Teledyne. There were a few tiny tools supplied to clean burner orifices and adjust air mixture.

The 2T4P model consists of four separate burners with thermocouples rated 9 Watts each, for 36 Watts total. It can generate about 3 Amperes battery charging, 12 to 15 Volt output, and is available also for 24 or 48 Volts. We lit the unit at the start of December and ran it continuously until warm weather and sunshine returned in March.

With the TEG located indoors, I wanted to see how effective it would be heating the room with clean dry heat from the thermocouple cooling fins. Two 3 Watt muffin fans were added to blow more air through the fins. The cooler the fins are kept, the more power is generated, and the more heat we extract for the room. About half the heat generated is available from the fins.

The other half of the generated heat passes out the exhaust pipe. Most TEGs are made for outside mounting, and the hot exhaust gases come out several small chimneys on top, one for each burner. Our unit, Teledyne model 2T4P, has optional internal manifold pipes to route exhaust from the four burners to a single exhaust pipe on one end. We installed the TEG on a concrete floor in our otherwise unheated solar product display room, and vented the exhaust through the wall to the outside. Like any propane heater, the exhaust contains a lot of water vapor. The manufacturer recommends insulating the exhaust pipe and keeping it short because the water vapor should escape as steam rather than condensing and freezing in the pipe. But instead of letting the heat escape, I added a cast iron radiator in the exhaust (see photograph). This gave us about twice as much heat as the fins alone would have produced. Sure enough, the radiator also condensed a gallon of water a day from the propane exhaust. We added drip holes at the bottom of the radiator and a catchment system so the liquid would neither run back into the TEG nor run out the exhaust pipe to freeze it shut, a common problem with TEGs.

Since room air for combustion is drawn into the stock TEG chassis through a screen on its bottom, we fabricated an intake manifold to go under the chassis. A dryer vent hose connects the manifold to a second 2 inch pipe through the wall. Then intake and exhaust were entirely outside the building and isolated from inside air. These units have no safety gas shut off devices like those used on residential gas appliances, and we didn't want any chance of raw gas pouring out into the room.

Operation and Performance

Our 40 Watt TEG could produce full output of 3.5 Amperes, at 12 to 15 Volts battery charging. After the wood stove TEG experience, we chose to run it at a conservative 3 Amps by adjusting the gas pressure a little lower. An adjustable regulator and gas pressure gauge is built in the control panel for setting the temperature of operation. This gave us enough power to run the fans with a balance of 2.5 Amperes charging the battery 24 hours a day. The operating voltage was usually at 12.5 to 13 Volts but at times solar charging raised the battery voltage to 14.5 Volts. The TEG still maintained at least a 2 Ampere charge rate at the raised voltages, and could have been adjusted higher to compensate if we had desired. Overall, after ½ amp is deducted to run the fans, this gave 75 Amp-hours a day at 12.5 Volts, or 750 Watt-hours per day. That is over 20 kiloWatt-hours a month.

Propane gas is connected at full tank pressure to the built in regulator. (You cannot just tie in to existing home appliance low pressure gas lines). We set up a separate 20 gallon cylinder to supply the TEG so we would know exactly how much fuel it was using. Gas consumption was right at 10 gallons a week. At $1 per gallon that is about $10 for 5+ kiloWatt-hours each week, or $2 per kiloWatt-hour. This is hardly free energy.

But wait. If the heat released is efficiently captured and added to heating of the house, the whole cost picture changes. We are burning this propane to heat the house, as we might need to do anyway. How much heat does it produce? I don't have equipment to directly measure the BTU output, but subjectively the warm air produced felt like perhaps a 750 watt electric heater feels. It did heat an otherwise unheated corner room, about 12 x 20 feet with an outside entrance door, to 73 degrees when outside temperature ranged from zero to 25 degrees. Next winter we will relocate the TEG elsewhere, and in its place we will install a propane wall heater to compare TEG fuel consumption with a conventional heating appliance. I expect the fuel consumption will be very close to the same for heat alone. If so, the TEG electricity could then be considered free.

The TEG had no maintenance requirements other than the chore of lighting it each time the gas cylinder was changed. There are four burners, all inaccessible to a match. You separate the exhaust pipe from the unit, turn the gas on and cover the exhaust pipe. After 20 seconds remove the cover and apply a lit match. A flame shoots out almost a foot, then zips down the throat of the TEG to the innards. A test jack is provided to connect a digital test meter to built-in temperature sensors (just another thermocouple) in each burner, with a switch to select the burner monitored. If some burners do not show increased temperature, repeat the match trick again till all four burners show heat. Then the exhaust pipe is reconnected and within minutes the ammeter begins to show battery charging.

Options
Output voltage regulators, and automatic spark ignition that will start and stop the heater on demand of your battery voltage alarm are optional features for easier use. For our monitored testing, we decided on the manually (match) lit unit, with no voltage regulator. It simply operates full time during those four winter months. Because our 12 volt battery bank is rated 2000 Ampere-hours, the 3 Amp rate of charge will not raise our battery voltage enough to operate an automatic charge control. Overcharge damage is not likely.

Benefits
Besides heating the room all winter, our batteries remained within 20% of full charge through those winter months. Never was I surprised with the 50% deep discharge that usually sneaks up when there is no solar charge for three weeks of snowy weather. Extensive generator running for remedial charge was eliminated. We did continue our practice of running the generator when we did laundry in the winter, but never just for supplemental charging even in our sunless December and January. And it really is *silent* in operation. Other than the fans, which are optional, there really is nothing to be heard.

Equipment Cost
Ah yes, you have been waiting for the catch and here it certainly is! This 36 Watt TEG with the custom exhaust manifolds cost over $4000. For that I could have bought a lot of solar modules plus a propane heater too. In most places that would be the only sane choice. Only in areas with weeks of overcast and snowfall without a sunny break does a TEG look appealing at current prices. Smaller models are available that produce 18 Watts and 9 Watts, and larger models are sized up to 90 Watts for prices from $2800 to over $8000.

Durability
With no moving parts there is potential for long trouble free service. There are instructions and parts available to replace the thermocouples, and the catalytic burners. There is little else inside these two foot long metal boxes that might need replacement. I did talk to one communications technician from Alaska who said they had experienced a lot of trouble with their TEG, which was installed out in the weather. Other industrial users report good luck, and we had entirely consistent performance here so far with just four months operating time. I am told the U.S. Forest service cleans their TEGs annually and replaces them after 4 to 6 years of continuous service. That would represent 16 to 24 years of service three months per year.

Applications
I feel TEGs have great potential in northern residences and particularly coastal Canada and Alaska where sunlight may not be available for several months a year. I also see potential use in travel trailers and motor homes where the heat and power generated would be ideal for long stays anywhere in snowy climates. Solar equipped full time "snowbird" RVers must migrate to the south for rooftop PV systems to operate in winter.

However the TEG industry has a little more work to do before these units can be marketed to the public. They need the usual gas safety devices to cut the flow of gas if any burner should become extinguished. They need factory manifolding for safe and complete outside venting, with provision for condensation draining. They need a regulator that accepts the standard low pressure regulated propane used by other appliances. And most important, they need pricing more in line with the value of the hardware provided.

Access

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