DIY PV Installation & Passive Solar Sunroom
By Colin Croft

Brief overview
This article includes a discussion of a DIY installation of a grid-tied 5.4-kilowatt photovoltaic (PV) system using Enphase microinverters, as well as the conversion of a two-level sunroom into a passive solar heating space using a thermostat-controlled fan/vent system. I also discuss my limited experimentation with micro wind turbines (not for the faint of heart!), and the hardware and software I’ve used to monitor my energy consumption and generation.

Grid-tied 5.4-kilowatt PV system
I had installed an earlier grid-tied system in rural Banner County, in Wyrulec Company’s service area, and so that made the process easier the second time around.

I like the Enphase Microinverter system, due to ease of installation and the ability to build up a system over time. For those who can’t afford the up-front costs of a full PV system, microinverter-based systems allow do-it-yourselfers to add panels and microinverters over time, as their budgets allow. This strategy gives the frugal and patient do-it-yourselfer opportunities to look for sales on the microinverters and panels (eBay and Craigslist, for example), and to maximize their budgets, which is exactly what I did. Even with a modest initial investment, they will have the satisfaction of knowing they are generating some of their own renewable energy.

A microinverter-based system also has benefits in terms of potential shading issues, which was attractive to me, particularly during winter months (lower sun angle, meaning more tree shading issues, extended shadow profiles, and partial snow coverage).

I’ve used mostly Enphase M250s Microinverters, paired with panels in the 265- to 270-watt range. There is a fair amount of searchable discussions online about the “sweet spot” of panel size with the M250s, but I was also factoring in which panels I could find on sale or at a reasonable current price.
Panel mounting can end up being a considerable expense, and as a frugal do-it-yourselfer, I wanted to limit my costs there. For my rural Banner County installation, I had a wood frame, steel outbuilding I used for my solar install, simply bolting Unistrut through the metal roof to the framing underneath. The panels were bolted to the Unistrut with standard L-brackets and lock nuts--nothing fancy. The panels weathered several 80+mph western-Nebraska wind events with no issues. My wind turbines, however, did not fare the storms as well, as discussed below.

Roof-mounting solar panels on a residence, where we’re obviously concerned about leakage, is another matter. For our home, since we were having a roofing company replace our old shake shingles with a new composite/asphalt roof, after a fair amount of research, I decided to have the roofers install “E Mounts” by Quick Mount PV.

The local company was initially not very excited about doing this, as they had no experience with the product, but after showing them the installation materials, they got onboard. Obviously, making sure you or your roofing company properly bolts these mounts to the rafters or other structural roof member is critical. And you will need to do some planning on the kind of racking or mounting system you’ll be using, and the size of your solar panels so that you can plan the spacing and installation of the E Mounts accordingly.

Once the E Mounts were in place, I kept it simple and bolted on standard Unistrut to mount the panels. Here’s what this looked like after the first few panels were in place:

![Image of solar panels on roof]

I debated about the appropriate tilt the panels should have, but I ended up keeping them fairly flush with the slope of the roof, which was about 18.5 degrees from horizontal. Looking at estimated production values for my latitude (and keeping in mind my less-than-ideal roof orientation of 125 degrees rather than due south), about 35 degrees would have been an ideal year-round tilt or slope for a fixed mounted system. But the
difference in production, at least based on my calculations, was less than 5%, which I could easily make up for with an additional panel or two, all things considered.

A greater slope would have been advantageous for faster snow melt and slough-off, but in our neck of the woods wind is always an issue, and I wasn’t excited about the wind getting up “behind” that top row of panels. The top of the panels on the top row is bolted to some sections of heavy 6x6, which works out about right for maintaining stability.

The biggest challenge with this roof-mounted system was the height of the roof from the ground, and the difficulty of snow removal after storms. I’ve had decent luck with the Extreme Max Shingle-Saver 21’ Roof Snow Rake with a 24” Blade. There are several different types of snow rakes available.

After a storm, I can use the rake to remove around 2-3’ of snow from the bottom row of panels, which exposes their surface to the sun and quickly gets them generating power again. Usually it doesn’t take long for the snow on the higher panels to melt and slough off.

This might be a significant limitation in other areas of Nebraska, however. I was born and grew up in Omaha, and there is a considerable difference in sun and weather patterns on our end of the state compared to central and eastern Nebraska. Being able to access your panels after snow events could be much more important depending on your location’s typical snow and sun patterns. Obviously, folks with PV trackers aren’t in the same boat as those of us with fixed mounts, but for me and my location, I just wasn’t interested in the expense and aesthetic impact of trackers on my property.

Much of this discussion illustrates the wisdom of some patience and planning. It’s easy to get excited about installing PV or another renewable energy system, but taking the time to closely examine your site and doing the necessary research for the best equipment choices for that site is invaluable.

Closely examine your possible sites over many months throughout a calendar year, and at multiple times during a day. Do you have shading issues? How will snow removal and maintenance be accomplished? Are there any limitations on the wiring/grounding runs you will need to make? Do you have any potential code/zoning issues that need to be factored in?

Touching base with whoever will be doing your required inspection for grid-tying to the utility will help to answer any questions you may have. These are the kinds of issues/questions that are best addressed sooner rather than later, and will often point you in very different directions in terms of what PV system you end up installing.

The ability to monitor or track your PV system’s energy production via its optional “Envoy,” or Internet-connected Gateway, is good, but it is fairly limited compared to a more sophisticated system like SiteSage that I describe later on. It does provide decent notifications for individual panels/microinverter issues, and assuming you’ve correctly set up your array in the software, you can easily see where any individual problems lie, facilitating troubleshooting. I’ve only had one M250 microinverter fail in over 10 years of use, and it was promptly replaced under warranty by Enphase.

**Passive Solar Heating: Sunroom**

When we bought it, our 70s-era home had an attached sunroom (basically an enclosed patio) that was in rough shape. We renovated it, replacing the framing and windows with new tempered glass, double-pane (sealed and insulated) windows.
Again, pre-installation planning was critical for this do-it-yourself project, as well. I researched available glass panels and sizes first, confirmed availability and price for an economical choice, and then we built our framing around that size. All the glass panels are 76” x 34”.

The west-facing (front in the photo) and south-facing panels are 5/8” total thickness (2 panels + air/gas gap in between) with 1/8” glass thickness. The north-facing panels are 1” in total thickness with 3/16” glass thickness. All panels were installed with ¼” thick rubber spacers on bottom and 1/8” spacers along the sides (to allow for some expansion/contraction). Thick black butyl architectural tape, ½” W x 1/8” (CR Laurence Co.), was used for sealing around the panels, as well as silicone sealant on the outside seams.

NOTE: Two of these panels (west-facing bottom row, northwest corner and southwest corner) have already failed (seal compromised and some haze/condensate forming inside the panels), which I’m obviously not happy about.

The insulation advantages of using double-pane panels with a gas gap are obvious, but if the long-term durability isn’t there, that’s a concern. The original double-pane glass panels we replaced, which were likely installed in the late 1970s, were nearly all compromised, which resulted in hazy and dirty panels that could not be cleaned and really reduced the aesthetics and some sun penetration of the old sunroom.

Hopefully, I won’t see additional failures, but I guess what I’m saying is that folks considering a do-it-yourself project like this should seriously consider their options in terms of single-pane versus double-pane panels. Clearly there will be insulation/heat losses with single pane, but those need to be weighed against potential failure and replacement issues with the double-panes. I’m not sure if the problem is the temperature extremes in a sunroom like this, an issue with our installation, or what, but I just wanted to throw this issue out there for folks to consider.

But let’s talk about how this works: Obviously, you end up with a really nice sunroom that is perfect for lounging, exercising, reading and so on (last picture above). It heats up quickly, making for t-shirt temperatures by late mornings, even when the outdoor temperature is only in the 20s and 30s. If you have cats or other sun-loving pets, just try to keep them out of this space. It works so well that it must be vented
during warming months, which was why I installed the dual screened patio doors on both ends. Opening these up allows for excellent cross-ventilation to remove unneeded heat and keep that space usable on all but the hottest days. I also installed a ceiling/roof-mount vent fan, which pulls the warmest air pooling at the ceiling out and assists in ventilation.

You can see from the photo that this is a two-level sunspace. The home has three levels: a second floor, a main floor (which is the upper walk-out level of the sunroom) and a basement (the lower level of the sunroom leading to the patios). There are two large sliding patio doors connecting the home’s main floor with the walk-out level of the sunroom. And there is a basement door leading to the lower sunroom level. Opening that door, and one or more of the main-level patio doors, results in some passive heat exchange/convection.

The home, overall, has a pretty typical 70s-era open floor plan, with an open staircase connecting all three levels. Air flows from the open basement door into the sunroom, is heated and then exits through the open main-floor patio doors. This actually works pretty well, particularly with some ceiling fans on the main and second levels distributing the warmed air.

But such a technique obviously requires someone to be home to open or close those doors (haven’t trained the cats to do this yet!), and I wanted to automate the heat exchange to push more air/heat via some fans. To accomplish this, I installed dampers in both the basement door and in the wall, near the floor, on the main level, and installed an air stack on the upper sunroom level that would pull the warmest air from the sunroom ceiling via a fan, blowing it out into the main level of the house.

Since the sunroom is reasonably well-sealed, when the fan is running, this creates somewhat of a vacuum, resulting in the basement door vent being pulled open and drawing colder basement-level air into the sunroom/sunspace for warming. Here are some photos that, hopefully, will make this clearer:
10" Sinwan 254AP DC fan (12v DC x 1.9A = 23w)

Standard 8" single-wall chimney pipe

"Heat exchange" air intake (upper-level sunroom)

10" x 8" round pipe reducer

Double patio doors to main floor

Double patio doors to main floor of house
Heat exchanger "exhausting" sunroom/sunspace heat into main floor of home
Main floor-level air "exhaust"

- Standard single-wall 8" chimney pipe
- Classic foam/hinged/weighted "damper" helps reduce cold sunroom air from entering main floor when system not in use... pulls "open" when system in use...

Basement-level air "intake"
(view from "basement side")

- Air King BDD8R 8" Round Back Draught Damper
This system is fully automated, using a “smart home” automation system. I use SmartThings, but I assume you could do the same with other systems out there. A SmartThings SmartSense Multi Sensor reads the temperature inside the sunroom and is programmed to turn “on” and “off” the Z-wave plug-in appliance module that powers the DC fan at whatever temperatures you want. The appliance module also powers “open” and “closed” the Suncourt zone control damper, cutting off most of the cold air that would otherwise flow down the intake pipe into the house. I can also monitor the sunroom temperature and control the damper/fan via the SmartThings Mobile app.
Amazon’s Alexa voice-control system is integrating with more and more “smart home” systems, including SmartThings, which adds voice control to set your devices.

I’ve experimented a bit with different designs for secondary dampers for the room side. The crude foam disks, hinged at the top and weighted a bit at the bottom, work reasonably well, although you’re always going to get some cold air seepage with this kind of arrangement.

It’s difficult to quantify the heating performance and benefits of this system, since I created and installed it relatively soon after we moved into the house, and thus had no baseline for regular heating performance. However, I would estimate that I’m saving around 30-40% in heating costs using this setup.

As with a PV system, your results will be strongly correlated with your location’s average sunshine duration/hours per year. Here in western Nebraska, we enjoy more sun, particularly in the winter months, then I ever recall growing up in eastern Nebraska. But considering the many benefits of an attached sunroom beyond an air-exchange heating system, and the relatively modest costs of putting one in place, to me this seems like an idea well worth considering for many Nebraskans.

In addition to attached sunrooms, there are many other creative ideas out there for using the sun to heat air. Search “solar hot air collectors,” for example. For homes like mine that weren’t built with passive solar heating as part of their design, a solar heating retrofit such as an attached sunroom or solar hot air collectors are sensible alternatives.

**Monitoring residential energy consumption and production**

Renewable energy “nerds” can never have too much data! Early-on, I was very interested in monitoring my energy usage, and then monitoring or tracking my energy production once I started installing solar and wind projects.

One also reaps the benefits of the “mere measurement effect” in behavioral psychology, according to which an effort to measure some variable results in actual behavioral changes impacting that variable. In this context, merely making the effort to consciously measure energy consumption often results in changed behavior, reducing that consumption and creating a virtuous self-fulfilling prophecy of energy savings.

Accurate measurement of energy consumption is valuable even before any renewables are installed. When friends express excitement about installing a PV system, I give them a version of my lecture on “conservation first.”

Installing a new PV system is fun, exciting, sexy...insulating your attic, not so much. However, it’s cheaper and more environmentally sound to reduce energy consumption first, rather than focusing on generating that energy with a PV system. Short of a full energy audit (not a bad idea if you can afford it), energy consumption monitoring is an effective way to evaluate your needs, make an effort to reduce those needs if possible, and then size/scale your PV system accordingly.

My first energy monitoring system was a TED (“The Energy Detective”) system. Initially you could monitor only two circuits with TED, and so I used it to monitor all my consumption, versus all my production. From skimming their website, it appears that they have increased the number of separately-monitorable circuits to 8, which certainly improves its usefulness and flexibility.
Most homes, however, have considerably more than 8 circuits, so if you want more precise/granular monitoring of individual circuits and even appliances/devices on their own breakers, you will need a more robust system.

I ended up paying considerably more for the SiteSage Residential system from PowerWise. There are many details on their website, but the bottom line for me, its ability to control up to 48 different circuits, as well as integrate other measuring options such as a water flow meter (I’m on a rural well system, was perfect for a “data nerd” like me.

The hardware runs about $650, plus a yearly software service fee of around $100. Their pricing and service/website access seems increasingly oriented towards businesses rather that residential or average consumers. And anyone who spends any amount of time learning about energy consumption, measuring a few devices, quickly learns which ones are consuming the most electricity, the average amount of that consumption, and so on.

After that initial learning curve, I’m not sure how useful SiteSage’s granularity is long-term. While I excitedly checked my SiteSage display in the months following its installation, I find myself rarely checking it now. I suspect at some point in the future I could live with a less-expensive system like TED, or perhaps even none at all. SiteSage does, however, allow you to set up notifications if your energy use (or even the incoming voltage itself) exceeds certain parameters, which certain users might find valuable.

The flow meter (installed inline on the incoming water line) consistently measures within about 5% of the usage/bills I receive from the well monitoring and billing service. Monitoring water usage can be a good way to detect leaks in lines, particularly for those with underground sprinklers, drip irrigation, etc.

More computer/software-savvy users might check out the energy monitoring system from Brultech. Their support/customer service was very responsive and helpful with my questions as I was researching my options. Ultimately, however, I decided against them based on the complexity of their system and my concerns over whether I could properly monitor it. The TED and SiteSage systems were much more “plug and play,” which I felt was a better fit for me.

**Micro wind turbines.** For several years while living at my rural Banner County home, I experimented with several micro wind turbines (turbines rated under 1.5 kilowatts). The turbines I bought were relatively-inexpensive Chinese-produced models from HYEnergy. I have no criticisms about the manufacturing quality of these turbines, but on balance wind has way too many potential concerns compared to solar. If your site is going to get occasional gusts over 50-60mph or so, you need to find a way to brake these turbines, or you will burn out the generators and/or blow your blades right off. Trust me…I went through 3 sets of blades and many small inverters.
People use batteries, big resistors and other methods for such braking, but if I were doing it again, I’d be sure to use some kind of mechanical furling system. (Video of a furling design sold by Windy Nation) that will “turn” the turbine/blades out of the direct wind in high wind conditions).

UPDATE March 2018: I see that Windy Nation’s website is no longer listing this product, or wind generators at all (although they are selling replacement blades!). This makes me wonder if others have encountered the issues I have with micro wind.

The bottom line for me was that all the hassles, failures and monitoring of my micro wind setup were nowhere close to justified, considering the power I produced compared to solar. For my location and low expenses for both my solar and wind setups, the $ cost per generated Kilowatt hour was easily 2-3 times higher with wind, and that’s before factoring in all the equipment failures and replacements (just over a few years, not the 15-20 lifespan of most PV panels).

Obviously if you’re in a specific situation, such as living off-grid or in an area with limited sunlight, then you may have no choice but to dive into wind. In that case I would recommend looking at a larger investment and a more stable, reliable approach than micro models.

For grid-tied users with decent solar resources, wind is just too uncertain and too much of a hassle...unless you’re just doing it for fun/hobby purposes. If you’re interested in taking a look at “micro” wind, one of the best resources is Larry Leamy of Leamy Electric, who has done a fair amount of work designing, installing and testing micro wind system in a typical residential or small business setting. If you read through the thread I’ve linked to, you’ll get a better idea of the complexity and challenges of micro wind compared to a typical “plug and play” PV system such as Enphase and other brands.
Best of luck with your own renewable energy project!

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