WHAT'S THE PAYBACK FROM A SOLAR PHOTOVOLTAIC (PV) SYSTEM?

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You're heard it somewhere, if not from SEEDS: the prices for solar panels have fallen 80% since 2008[1]. So is investing in a solar electric system for your home the right thing to do? There are lots of reasons to want your own solar system (e.g. energy independence, reduced pollution, reducing your home's carbon footprint, etc.), but let's focus simply on the financials and explore the details of how to answer this question for yourself. There are five key parts to the question:

1. **Is my home a good location for solar?**
2. **What size PV system do I install?**
3. **How much will it cost?**
4. **How much money will I save?**
5. **And, is PV a good financial investment?**

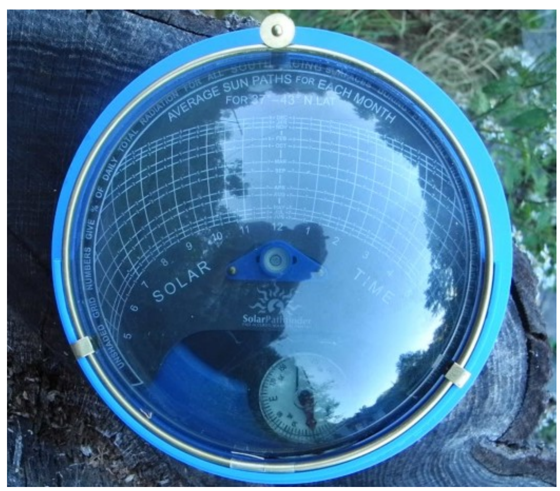
We will take each of these in turn. But first, let's clarify the type of system we will be discussing here. We are not talking about 'off-the-grid' battery backup systems, because batteries are expensive, toxic, and require a controlled environment with significant maintenance efforts. Rather, we will focus on the most common, grid-tied, battery-less, solar photovoltaic (PV) system. Nearly every home is already connected to the electric grid, and with Pennsylvania's net-metering regulations[2] the utility will act as a virtual battery for you, crediting you for any excess electricity your system produces. In effect, your electric meter will run backwards during the times when your PV system is producing more than your home is using (and the utility then gets to sell that to your neighbors). Of course, you must still pay the flat-monthly connection fees, taxes, etc. (currently from PPL this is a little less than $15 per month), as well as for any electricity that you consume that is greater than what your PV system generates in total during the year.

Is my home a good location for solar PV?

There are LOTS of factors here, but the biggest concerns are *orientation* and *shading*. In our area, the PV modules (as the panels are referred to in the industry) should be mounted so that they face directly south and at a tilt angle of approximately 25-45 degrees toward the horizon. The most common place to mount them is on a south-facing roof. If your roof is not facing directly solar south or is not at the optimum angle, some efficiency will be lost, but it still may be viable.

Also check to be certain any trees, utility wires, dormers, chimney, or satellite dish, etc. do not shade the array site between the hours of 9 a.m. and 4 p.m. It's best to be totally unshaded even in winter when the sun is lower in the sky. In cases where a roof mount is not possible, ground mounting in an unshaded area can be a good alternative.

If you have questions about the suitability of your site for solar, have an evaluation performed with an instrument called a **Solar Pathfinder**. At least three SEEDS volunteers have one of these tools and are glad to help other members in assessing possible sites (contact Jocelyn Cramer, our SEEDS Executive Director at jocelyn@seedsgroup.net). Professional solar installers will also have one of these, or a similar tool, and often include a free site evaluation as part of estimating the cost of a solar installation.



A Solar Pathfinder, showing too much morning shade!

What size PV system do I install?

Sizing a system is also something a professional installer can do with you. Your site may be physically limited by the available unshaded roof space (or ground area). Or, you could be limited by the overall amount of money you have to invest. For the optimum financial return, you want

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a system that produces no more than the electricity your home uses in a year. *Note: In PA during each April billing cycle, a utility pays for any excess kWhrs that its net-metered customers have collected. However, they don't pay at the full retail price that you'd pay to them; rather they pay out only at the "price-to-compare" rate, which does not include the per-kWhr distribution rate or certain taxes and fees.*

Now find your past electricity bills, or use your utility's website, and locate your home's total annual consumption in kWhrs. According to the US Energy Information Agency, the average Pennsylvania residence consumes 10,400 kWhrs[3]; so let's use the round number of 10,000 kWhrs for the rest of this example. To avoid over-sizing, we don't want your PV system annual production to exceed this amount.

It is important to know that nearly all PV modules sold in the US are tested and rated by one or more independent laboratories for their capacity to produce electricity. The ratings are in units of "watts$_{dc}$" or in other words, when there is full sunshine on the module it will produce its rated quantity of watts in direct current (DC) electricity. Most of the modules targeted for the residential market today come with a rating of between 230 and 340 watts$_{dc}$. For this example, we will use modules that are rated at 250 watts$_{dc}$, since these are likely to be among the least expensive. The next question is: how many PV modules do you need to generate 10,000 kWhr of electricity in a year?

Solar Photovoltaic (PV) Modules

Production will vary with weather, especially clouds and snowfall. But we have a simple rule of thumb based on experience from the local installers and existing system owners for an *average* system: For every one watt$_{dc}$ of rated capacity, a PV array in our area will generally yield approximately 1000 watt-hours, or one kWhr, of electricity annually. Alternatively for those so inclined, there is a web-based modeling tool called PVWatts[4] that takes into account decades of weather station and satellite monitoring across the country. PVWatts shows (see example on the last page) that for a *perfectly oriented and completely unshaded* PV system in Honesdale PA, every one watt$_{dc}$ of PV capacity will produce 1178 watt-hours (or 1.178 kWhrs) of electricity during an "average weather" year. If your site is more than 10-20% away from prefect, then you should use the PVWatts model to determine the appropriate yield factor for your situation/ location (see page 5 for how-to instructions).

So for the example house load of 10,000 kWhrs, when divided by our rule of thumb yield factor of 1000, that equals to 10,000 watts$_{dc}$, or 10 kW$_{dc}$, of PV capacity required to match the annual electricity consumption. Since each module produces 250 watts, we will therefore need 10000 ÷ 250 = 40 modules (round up, if needed). If we were to choose more efficient modules, then this number would be smaller (and the array would use a smaller space on your roof). But what matters to us is how this will affect the cost.

How much will the system cost?

For a definitive answer you'll want to get a quote from one or more solar installers. Every house and construction site is different with all kinds of potential issues that can increase (or sometimes decrease) the costs. Will the system be attached to the roof (and how), or be ground mounted? Will your system use US-made or imported components? How efficient and/or stylish will it be? DIY labor, or not? All these factors will affect the total cost of your system. Plus each town has different building permit and inspection fees that add to the total cost as well.

The PV modules are generally the largest cost element of a new system installation. While PV module prices have been dropping in recent years (due to additional factory capacity in Asia and in Europe), the rest of the system components (referred to as the "balance of system") and labor costs have not.

The second biggest cost element is the invertor. This is an electrical box that converts the DC power coming from the PV modules into the alternating current (AC) power that is used in your home and on the electrical grid. Invertor efficiency is important, and there are many different models and options as well. You could choose a single inverter, typically mounted near your electrical breaker box, or multiple micro-inverters that are typically mounted directly underneath each PV module. Generally,

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a single invertor will be less expensive with the larger number of modules you have. But, regardless of which type, the invertor(s) and other components must be sized correctly to the number and ratings of the PV modules.

5kW Grid-tied Inverter

Your installer will design and verify this as part of his/her job, or you can come to a SEEDS Solar PV DIY Forum to learn how. The key point is that the DC rating of a PV system drives many, if not most, of the costs of a professional installation. For this exercise, we'll use a local industry benchmark of $3.50 for each watt$_{dc}$, which is a rough average for a basic system installation cost over the past year in northeast PA. Or with a DIY installation, for just the non-premium materials cost, the benchmark is probably closer to $2 per watt$_{dc}$. So, for a professionally installed system with a rated capacity of 10,000 x $3.50 = $35,000 is the estimated total cost; or if you're handy and can do the labor and electrical connections yourself, approximately $20,000 in materials.

Now, $35,000 is a lot of money for any home improvement project. So first consider SEEDS' primary premise, that *energy conservation is a lot cheaper than installing solar*, AND the payback is much better. It's going to make more financial sense to invest first in good insulation, reduce air leakage (by improving the envelope), reduce water usage, replace inefficient appliances, and especially eliminate wasteful lighting and phantom electrical loads BEFORE investing in a solar PV system (see the SEEDS' home efficiency checklist[5] for suggested places to start). So get those projects done first, then re-estimate your reduced annual electrical consumption.

If, after conservation measures, your budget still can't afford this amount, a smaller system size will usually work to get started. There's no reason you can't add multiple PV systems on the same house over time, or in some PV system designs (especially with micro-inverters) you may be able to add to your system in stages. Plus, there are government incentive programs that can help make the investment more affordable.

How much will I save in the future?

The good news is that there are currently federal and other incentive programs available that help homeowners to financially justify installing a PV system. We'll cover two such programs, but there may be other incentives available from the state or your local community, utility or even some installers. Commercial (including residential rental properties), non-profits and government entities in PA may have different programs available[6]. Visit http://dsireusa.org for a great summary of the renewable energy and efficiency incentives throughout the US. *Note: the PA Sunshine Grant program for residential and small businesses ran out of funding during 2013, and is now closed. We are hopeful that legislative efforts in Harrisburg may revive it at some point.*

1. **Federal Income Tax Credits**[7] – If you owe individual federal income taxes, you can claim a credit against those taxes (i.e. dollar for dollar reduction) of up to 30% of the costs you paid (not including DIY labor) for a solar system added to your primary residence through December 2016.

2. **Solar Renewable Energy Credits (SREC)** – The state of Pennsylvania requires investor-owned utilities to include a very small percentage of their electricity sold in PA to be generated by solar. The current requirement increases slightly each year to reach just 0.5% of their total "portfolio" in 2021. This is called a renewable portfolio standard (RPS), but the specific language used in PA is AEPS, or the alternative energy portfolio standard[8]. To meet this requirement, the utilities need to purchase "credits" (i.e. each credit being the right to claim one megawatt-hour of solar production for this purpose) from generators, including from residential PV systems! Previously an SREC might sell for as much as $250 and PV owners could sign multiple year advance supply contracts. However, due to some loopholes (e.g. generation outside of PA can qualify), the SREC market in PA has performed poorly and the current market price is only around $30 for each

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MWhr (after market commissions and income taxes), or about 3 cents per kWhr. The future market for SRECs may change, but let's assume for now this price will be constant in the future.

Both these programs will help with affordability. As with all such programs, the fine print matters, so investigate to ensure your system will fully qualify for these incentives, and be sure to shop around for the best SREC broker.

In addition to these programs, of course, you actually get to use the electricity produced by your PV system (or "bank it" via net-metering and use it later in the year) and therefore you avoid paying the utility for that amount of electricity each year. If you are currently paying 11.9 cents per kWhr (check those utility bills again), and you install a 10kW PV system in our area, your savings would then be \$0.119 x 10000 = \$1190 annually (average, depending on the weather). Of course this assumes electricity prices stay constant into the future. Yes, there is some chance of prices declining (as they did briefly in 2011 and 2012), but the most likely future scenario is for electricity prices to increase. The PA Public Utility Commission[9] reports that over the past 10 years average retail electricity prices in PA have risen by 3.3% annually (including inflation). If we assume this long-term trend continues (but removing inflation), then the electricity supplied from utilities could reasonably be priced 1.5% higher each year. And therefore your PV system's production (no fuel costs!) will be worth that much more in real savings to you!

Is PV a good financial investment?

Putting all these elements together, from a \$35,000 investment in PV, you can expect to receive back:

⇒ **\$10,500** in federal income tax credits in the first year (if you owe that much, or this can be carried over to future years),

⇒ **\$300** from selling SRECs each year, plus

⇒ **\$1190** in savings on electricity bills in the first year, and increasing 1.5% each year thereafter.

Using a spreadsheet (below), we calculate that the payback period for this investment will be just over 15 years, and have an internal rate of return of 4.5%. Yes, that's a long time, but the warranties on most PV modules and inverters are for 20 or 25 years, and they could keep producing for as long as 50 years (no moving parts!). Once the system is paid for, each and every year thereafter, the system will be returning a profit to you (as well as cutting carbon emissions and other pollutants over that whole interval). And, especially for those on a fixed budget, your price for this electricity won't be changing every few months. Even if you are not likely to own your home for that long, the investment can be recouped earlier from the increased value[10] of your house when you sell it.

	Electricity		SRECs	Capital Cost	Annual	Net	Payback
	$/kWh	Savings	Income	& Tax Credits	Income+Cost	Investment	Period
start				$ (35,000)	$ (35,000)		
YE2014	$ 0.119	$ 1,190	$ 300	$ 10,500	$ 11,990	$ (23,010)	1
2015	$ 0.121	$ 1,208	$ 300		$ 1,508	$ (21,502)	2
2016	$ 0.123	$ 1,226	$ 300		$ 1,526	$ (19,976)	3
2017	$ 0.124	$ 1,244	$ 300		$ 1,544	$ (18,432)	4
2018	$ 0.126	$ 1,263	$ 300		$ 1,563	$ (16,869)	5
2019	$ 0.128	$ 1,282	$ 300		$ 1,582	$ (15,287)	6
2020	$ 0.130	$ 1,301	$ 300		$ 1,601	$ (13,686)	7
2021	$ 0.132	$ 1,321	$ 300		$ 1,621	$ (12,065)	8
2022	$ 0.134	$ 1,341	$ 300		$ 1,641	$ (10,424)	9
2023	$ 0.136	$ 1,361	$ 300		$ 1,661	$ (8,764)	10
2024	$ 0.138	$ 1,381	$ 300		$ 1,681	$ (7,083)	11
2025	$ 0.140	$ 1,402	$ 300		$ 1,702	$ (5,381)	12
2026	$ 0.142	$ 1,423	$ 300		$ 1,723	$ (3,658)	13
2027	$ 0.144	$ 1,444	$ 300		$ 1,744	$ (1,914)	14
2028	$ 0.147	$ 1,466	$ 300		$ 1,766	$ (148)	15
2029	$ 0.149	$ 1,488	$ 300		$ 1,788	$ 1,640	16
2030	$ 0.151	$ 1,510	$ 300		$ 1,810	$ 3,450	17
2031	$ 0.153	$ 1,533	$ 300		$ 1,833	$ 5,282	18
2032	$ 0.156	$ 1,556	$ 300		$ 1,856	$ 7,138	19
2033	$ 0.158	$ 1,579	$ 300		$ 1,879	$ 9,017	20
2034	$ 0.160	$ 1,603	$ 300		$ 1,903	$ 10,920	21
2035	$ 0.163	$ 1,627	$ 300		$ 1,927	$ 12,847	22
2036	$ 0.165	$ 1,651	$ 300		$ 1,951	$ 14,798	23
2037	$ 0.168	$ 1,676	$ 300		$ 1,976	$ 16,774	24
2038	$ 0.168	$ 1,676	$ 300		$ 1,976	$ 18,750	25
sum=		$ 35,750	$ 7,500	irr=	4.50%		

Conclusion

A return of 4.5% may not be what you could get from Wall Street, but then you won't be taking nearly as much risk with this investment. And this rate of return is far better than the current interest rates on a bank account or new CD, and is roughly the same average return as from recent 10-year US Treasury bonds[11]. We think solar is a good investment in northeast PA, but as with any investment, you will need to make your own decision specific to your situation. At SEEDS, "education" is literally our middle name, so we hope this discussion has helped you learn more about the economics of solar PV.

Please send any questions or comments on this topic you may have to jack@seedsgroup.net.

USING PVWATTS TO MODEL PV PRODUCTION:

The National Renewable Energy Lab (NREL) provides an excellent online modeling tool to estimate the AC kilowatt-hours (kWhr) produced by solar photovoltaic (PV) systems. Go to http://pvwatts.nrel.gov and enter your zip code in the "**Get started**" box at the top of the page, then press the "**GO>>**" button. The next page will ask you to select a "data source" for your area. This is for historical weather data needed to determine the average amount of sunshine that will hit your PV modules. For Honesdale PA, the default data source is a National Weather Service measurement site in Wilkes Barre that is nearly 30 miles away. Click on the "**Change**" button, and in the pop-up window select the nearest possible site instead. *Note: the 'SolarAnywhere' data source is used in the example below, but requires you to first prove you're human by entering the text you see in an abstract image (rather than being a web-bot trying to extract their proprietary data).* Press the "**Select**" button to close the pop-up, and then the "**Go to system info**" arrow in the right margin.

The next page asks you for five specific details about your system site. Each already has a default value, but you'll need to change at least a couple of them.

⇒ For "DC System Size (kW)", enter just "1" for this exercise. You can come back later if you wish to change it.

⇒ For "Array Type", use the pull down menu. Active tracking is not cost effective anymore, so you'll most likely want to select either the "Fixed (roof mount)" or "Fixed (open rack)" option. The latter is appropriate for ground mounts.

⇒ For "DC-to-AC Derate Factor" the default is 0.77. This default is sufficient, unless you have shade on this location at any point during the year, or you're planning to use extra-efficient (and more expensive) modules or inverters. Optionally, look at the comprehensive "Derate Calc." pop-up window if you'd like to further explore how aspects of the design can make a PV system more or less efficient.

⇒ For "Tilt (deg)" the default will be the same as the latitude of your location, e.g. 41.6 degrees for Honesdale, as this is generally the most efficient *year-round* tilt angle to mount the array from the horizon toward the sky. If you're using a roof mount, you'll likely want them flush to the roof (to avoid extra wind loads) and therefore need to replace this with the angle of your roof. If you're using a ground mount, the best angle locally for *total annual* production from a net-metered system is roughly 30 degrees (i.e. around here we have fewer clouds during summer, so we lower the tilt angle by 10-12 degrees to take advantage of that).

⇒ For "Azimuth (deg)" you will need to enter the direction the array will be facing. Best would be exactly solar (not magnetic) south, or 180 degrees (which is the default). For a ground mount, you can probably make that align perfectly, but for roof mounts you'll need to estimate which direction the roof surface faces. With some experience you can do this most easily via Google Earth or other web-based mapping application with satellite/aerial imagery of your house. Those maps are already oriented with solar south at the bottom of the page. If you're using a magnetic compass, see the sidebar.

Now press the "**Go to Results**" arrow in the right margin. The number we are most interested in from this page (see next page) is in the large bold font at the very top of the page (and in orange font on the last row of the table, labelled "Annual", and in the "AC Energy (kWh)" column). For our Honesdale example, this is 1178 kWhrs when using the most optimum values. What this means is that for each 1000 (or 1k) rated watts$_{dc}$ of totally unshaded PV modules installed in Honesdale, we can expect to produce 1178 kWhrs of electricity in an average weather year. Or, in other words, the expected yield factor is 1178 watt-hours for each watt$_{dc}$ of capacity.

Note: the last column of the PVWatts result uses an assumed value for the average price of electricity (e.g. for Honesdale it is using just 9¢ per kWhr), but that's a much lower price than we see on our homes' bills. Therefore the dollar value shown for the 1178 kWhrs is $111, but our actual savings would be higher than that.

USING PVWATTS TO MODEL PV PRODUCTION: (CONTINUED)

RESULTS **1,178 kWh per Year**

Month	Solar Radiation (kWh / m² / day)	AC Energy (kWh)	Energy Value ($)
January	2.84	70	7
February	3.70	82	8
March	4.55	109	10
April	5.35	121	11
May	5.41	121	11
June	5.25	112	11
July	5.79	125	12
August	5.54	120	11
September	4.99	107	10
October	3.87	88	8
November	2.72	60	6
December	2.58	63	6
Annual	4.38	1,178	$ 111

Location and Station Identification	
Requested Location	honesdale pa
Weather Data Source	SolarAnywhere from Clean Power Research
Latitude	41.55° N
Longitude	75.25° W
PV System Specifications *(Residential)*	
DC Rating	1 kW
DC to AC Derate Factor	0.77
Array Type	Fixed (open rack)
Array Tilt	30°
Array Azimuth	180°

Magnetic South is NOT True South

Got your compass? When using a magnetic compass, remember to correct for the magnetic declination caused by the fact that the Earth's magnetic field is not aligned with its axis of rotation. Currently (and it changes on the order of 0.1 degree each year) this means in northeast PA that magnetic north is approximately 12.5 degrees west of 'true north.' Or, more appropriately for solar work, that magnetic south points 12.5 degrees east of true or solar south. A smartphone compass app can also work, but check to ensure it displays solar, or true north verses magnetic north as a traditional compass would.

For more information on this topic, see http://www.ngdc.noaa.gov/geomag-web/.

References:

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2. http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=PA03R&re=0&ee=0
3. http://www.eia.gov/consumption/residential/reports/2009/state_briefs/pdf/pa.pdf
4. http://pvwatts.nrel.gov/
5. http://seedsgroup.net/resources/home-energy-efficiency-checklist/
6. http://dsireusa.org/incentives/index.cfm?state=PA&re=0&ee=0&spv=0&st=0&srp=1
7. For more information, see http://www.irs.gov/pub/irs-pdf/f5695.pdf
8. http://dsireusa.org/incentives/incentive.cfm?Incentive_Code=PA06R&re=0&ee=0
9. http://www.puc.state.pa.us/General/publications_reports/pdf/EPO_2013.pdf
10. See http://cleantechnica.com/2013/12/17/study-shows-rooftop-solar-adds-thousands-to-home-resale-values/, regarding Lawrence Berkeley National Laboratory study.
11. http://pages.stern.nyu.edu/~adamodar/New_Home_Page/datafile/histretSP.html