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Solar Photovoltaic Advances: Home Grown Electricity and the Electric Utility Grid

What Are Solar Photovoltaics? Can I Really Grow My Own Electricity?

Solar photovoltaic (PV) panels convert a portion of sunlight into electricity. This electricity can be used directly to operate appliances such as water pumps and fans; can be stored in deep-cycle batteries for use after dark; and now, with recent technical advances, can be used to offset monthly electric utility bills. Photovoltaic panels come in a variety of sizes. For today's residential use, however, they are typically 2 ft. by 4 ft., generating 75 watts in full sun, and priced at $375 each.

In addition to PV panels and batteries, other equipment required for safety and processing are:

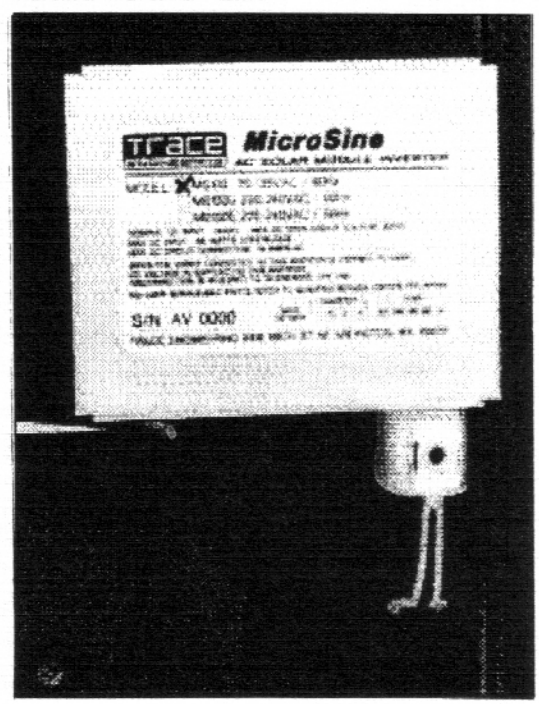
(1) appropriate **circuit breaker disconnects** for safety as defined by the 1999 National Electric Code.

(2) a **charge controller** to keep batteries from overcharging by disconnecting the PV panels from the batteries, or by rerouting excess electricity to a standby load like water or air heating elements, once the batteries become full.

(3) a **monitoring meter** to keep owners informed of the status of their solar PV system.

(4) an **inverter** to convert the low-voltage direct-current (DC) electricity generated by the solar PV panels (and stored in batteries) into high-voltage alternating-current (AC), used to run typical household appliances, and necessary for feeding electricity back to the utility grid.

There is now an option (the micro-sine inverter panel) which combines some of the above equipment right onto the rear surface of a solar PV panel, and displaces the need for batteries, and a charge controller for those of us connected to the electric utility grid. These PV panels, generating 100 watts in full sunshine, and priced at $850 each, are simply placed in sunlight after plugging into a standard household outlet. The electricity generated by the solar panel is processed (right on the rear of the panel) and matched to conform to the electricity flowing through the electric utility's grid. When the sun shines, the electricity used in the home is offset by the electricity generated from these specially designed PV panels. The advantage of this arrangement is the incredible simplicity of installation. Also the size of the system can be expanded at any time simply by acquiring another micro-sine inverter panel. The disadvantage of this arrangement, as opposed to an option that incorporates a battery bank, is that when the local utility grid goes out, so too does the electricity coming from the PV panel(s). This is necessary in order to protect crews working to repair utility lines from coming into contact with live wires.



Micro-sine inverter panel

Anyone can grow their own electricity from sunlight; however, not everyone may have a location with sufficient sunlight to make this worthwhile. A good rule of thumb is that if there is no place with enough sunlight to grow summer vegetables, than purchasing solar PV panels is likely to be a poor investment, unless you have a sunny rooftop. Take heart, your site may have other options for growing electricity, namely wind power or micro-hydro power.

With the special micro-sine inverter panels anyone connected to the electric utility grid can grow their own electricity from sunlight **and** install it themselves. Should you choose to take this route it would still be quite beneficial to consult with an experienced PV installation contractor in your area, if available. These helpful folks know the ropes and should be familiar with your local building inspectors, should you choose to have a code approved system. They can be referred to for information about the logistics surrounding these types of installations in your area. If a local PV installer cannot be located, there are many books and magazines available (see references) to familiarize yourself, your codes enforcement department, and (should you choose to get permission from them) your local utility inspector .

What Steps Can I Take To Maximize the Effectiveness of My Electric Garden?

The suggestions for getting the most from a PV system are similar, and equally important, whether the system is utility grid-intertied in town, or is stand-alone in rural areas without utility electric service. Much of the information contained in Technical Paper 14, *Rural Solar Photovoltaic Use*, by Bob Fairchild is related to this topic, as is some of the information presented in Technical Paper 40, *The ASPI Solar Demonstration House*, self authored. These Technical Papers describe what is, and what is not, appropriate things to power from solar PV electricity. Namely, that it is too costly to generate heat (cooking, heating water or indoor air space) with solar PV electricity. For these applications, wood, gas, or the suns direct heat, are energy sources that make much more sense. Electric toasters and microwave ovens are O.K. when powered from family-sized solar systems since they are on only for short spurts.

Ideally, PV panels should be positioned where they never see a shadow except for fog, clouds, and when the sun goes down. At a bare minimum they need 4-6 hours a day void of potential shadows, preferably between 9:00 a.m. and 3:00 p.m. Even a power line casting a very small shadow on a PV panel can significantly reduce its overall output. It's unnerving to witness hard earned money squandered on PV panels mounted under tree cover or oriented in directions other than due south (due north for those living in the southern hemisphere). By the same token, it's frustrating to observe PV system owners trying to operate inefficient/inappropriate appliances and wondering why their battery bank doesn't appear to be charging up, or their monthly electric bill doesn't appear to be diminishing.

Solar PV panels should also be adjusted seasonally, so that they are oriented towards the sun as its path changes above the horizon. Alternatively, they could be mounted on a solar tracking mount, which automatically keeps the solar PV panels facing the sun as it moves across the sky. Solar tracking mounts tend to become cost effective only after the system has at least 6 PV panels (roughly 450 generating watts or about $2200 worth), or at least 3 micro-sine inverter panels (roughly 300 generating watts or about $2500 worth). Until the system gets that large, the extra electricity provided by the tracking mount versus manual seasonally adjusted mounts (roughly 30% annual increase depending on site conditions) can be acquired simply by purchasing another PV panel at less cost than the cost of the solar tracking mount.

From a human perspective the effectiveness of a solar PV system is only as good as its ability to meet our needs. When we boil right down to it, its not the amount of electricity generated by the system that's important, nor is it even the appliances that we are running. What we want and need is the function that those appliances provide. Benjamin Root, a frequent contributor to Home Power Magazine, has put it this way, "We want to read after dark, hear good music, and learn about what is happening in the world. We want water on demand and unspoiled food. We don't need the electricity like we don't need the drill. What we need is the hole."

A whole-house approach is necessary for the design of an effective solar PV system at a minimal cost. The first and most important step in designing a PV system is to analyze the loads or appliances that the system will operate. This is important for two reasons: (1) for accurately sizing the system such that the amount of electricity supplied by the PV panels matches the amount of electricity consumed by the components in the system and appliances running off the system; and (2) for observing whether the appliances powered by the system are appropriately efficient enough.

Solar PV systems are expensive. The savings in cost from purchasing standard appliances over efficient appliances rarely exceeds the cost of the added PV panels needed to run the less efficient appliances. Richard Perez, editor of Home Power Magazine, has put it this way, "Every watt [of energy] not used is a watt that doesn't have to be produced, processed, or stored. Every dollar spent for an efficient appliance saves three dollars in renewable energy system components."

O.K., But is it Even Legal for Me to Grow My Own Electricity While Hooked Onto the Utility Grid?

The answer to this question is a resounding yes. The Public Utility Regulatory Act of 1978 (PURPA) legalizes selling back electricity to utility companies, at a wholesale rate. However, the bureaucratic challenge necessary to legalize a solar PV system on the grid, as well as the cost effectiveness of the system depends on four things:

(1) the state where the PV system is to be located.
(2) the experience that local inspectors have with utility-intertied PV systems.
(3) the experience/cooperativeness of the local electric utility company.
(4) the type of solar PV system application that is designed.

There are now 23 states (*Table 1*) in the U.S. that have laws requiring net metering. This means the electric utilities in those states are required to buy electricity generated from residences with small-scale renewable energy systems at the retail rate. For those growing electricity in these states, their electric meter either rolls forward when they are consuming more than their PV panels are generating, or rolls backwards when they are consuming less than their PV panels are generating. In these states, residences that consume the same amount of electricity that their PV system generates find their bill balances to zero. Most of the states net-metering laws limit the capacity which can be generated, and limit the retail rate to the balance used by the residence. In other words, if a residence generates more electricity in a billing cycle than it consumes, then the utility is allowed to buy this surplus at the wholesale avoided rate, which is often a small fraction of the retail rate.

In those states without net metering laws, the wholesale rate applies to anything that is fed into the electric grid. Most utilities in these states require two electric meters, one for keeping track of how much utility electricity is fed to the residence, and one for tracking the solar PV electricity fed to the utility each billing cycle. In order to break even and receive a bill balancing to $0, the residence quite often has to generate 4 times as much electricity than is consumed, since the wholesale avoided rates are often set by the utilities at 1/4th the retail rate.

The lack of experience local inspectors may have with solar PV systems can often present quite a challenge, albeit usually a beneficial one. Realize that in most regions (virtually anywhere in Appalachia) this will be trail-blazing work. Owners of these systems will be PV pioneers. In this scenario, experienced PV installation contractors can be relied on for complete plans to share with building inspectors. It may involve hours of phone calls and passing of equipment specification sheets, but it will be that much easier for the next household that wishes to go solar legitimately.

SUMMARY OF STATE "NET METERING" PROGRAMS (CURRENT)

State	Allowable Fuel Type	Allowable Customers	Allowable Capacity	Pricing Policy	Source of Authority	Enacted	Citation / Reference
Arizona	Renewables & cogeneration	All customer classes	≤ 100 kW	NEG(*) purchased at avoided cost	Arizona Corporations Commission	1981	Corp. Comm. Decision No. 52345
California	Solar and Wind	Residential and Small Commercial	≤ 10 kW	Net metering customers are billed annually; excess generation is "granted" to the utility	California Legislature	1998	Public Utilities Code § 2827
Colorado	All resources	All customers	≤ 10 kW	NEG carried over month-to-month	Public Service Company of Colorado	1994	Advice Letter 1265; Decision C96-901
Connecticut	Renewables & cogeneration	All customer classes	≤ 50 kW for cogeneration; ≤ 100 kW for renewables	NEG purchased at avoided cost	Department of Public Utility Control	1990	CPUCA No. 159
Idaho	Renewables & cogeneration	Residential and small commercial	≤ 100 kW	NEG purchased at avoided cost	Public Utilities Commission	1980	ID PUC Orders No. 16025 (1980); 26750 (1997)
Indiana	Renewables & cogeneration	All customer classes	≤ 1,000 kWh/month	No purchase of NEG; excess is "granted" to the utility.	Indiana Utility Regulatory Commission	1985	170 IN Admin Code § 4-4.1-7
Iowa	Renewables	All customer classes	No limit	NEG purchased at avoided cost	Iowa Legislature and Iowa Utilities Board	1983	Utilities Division Rules § 15.11(5)
Maine	Renewables & cogeneration	All customer classes	≤ 100 kW	NEG purchased at avoided cost	Public Utilities Commission	1987	Code Me. R. Ch. 36, § 1(A)(18) & (19), § 4(C)(4)
Maryland	Solar only	Residential only	≤ 80 kW	NEG carried over to following month; otherwise not specified	Maryland Legislature	1997	Art. 78, Sec. 54M
Massachusetts	Renewables & cogeneration	All customer classes	≤ 60 kW	NEG purchased at avoided cost	Massachusetts Legislature	1997	Mass. Gen. L. ch. 164, § 1G(g); Dept. of Tel. & Energy 97-111
Minnesota	Renewables & cogeneration	All customer classes	< 40 kW	NEG purchased at "average retail utility energy rate"	Minnesota Legislature	1983	Minn. Stat. § 261B.164(3)
Nevada	Solar and wind	All customer classes	≤ 10 kW	NEG purchased at avoided cost; annualization allowed	Nevada Legislature	1997	Nev. Rev. S. Ch. 704
New Hampshire	Solar, wind & hydro	All customer classes	≤ 25 kW	PUC may require 'netting' over 12-month period; retailing wheeling allowed for up to 3 customers	New Hampshire Legislature	1998	H.B. 485
New Mexico	Renewables, fuel cells, micro turbines	All customer classes	≤ 1,000 kW [as corrected]	NEG credited to following month; unused credit is granted to utility at end of 12-month period	Public Utility Commission	1998	NM PUC Order 2847 (11/30/98)
New York	Solar only	Residential only	≤ 10 kW	NEG credited to following month; unused credit is granted to utility at end of 12-month period	New York Legislature	1997	Public Service Law § 66-j
North Dakota	Renewables & cogeneration	All customer classes	≤ 100 kW	NEG purchased at avoided cost	Public Services Commission	1991	North Dakota Admin. Code § 69-09-07-09
Oklahoma	Renewables & cogeneration	All customer classes	≤ 100 kW and annual output ≤ 25,000 kWh	No purchase of NEG; excess is "granted" to the utility.	Corporations Commission	1990	Schedule QF-2
Pennsylvania	Renewables only	All customer classes	≤ 50 kW	NEG purchased at wholesale rate	Philadelphia Electric Company	<1996	PECO Rate R-S, Supp. 5 to PA Tariff PUC No. 2, Page 43A
Rhode Island	Renewables & cogeneration	All customer classes	≤ 25 kW for larger utilities; ≤ 15 kW for smaller utilities	NEG purchased at avoided cost	Public Utilities Commission	1985	Supplementary Decision and Order, Docket No. 1549
Texas	Renewables only	All customer classes	≤ 50 kW	NEG purchased at avoided cost	Public Utilities Commission	1986	PUC of Texas, Substantive Rules, § 23.66(f)(4)
Vermont	Solar, wind, fuel cells using renewable fuel, anaerobic digestion	Residential, commercial, and agricultural customers	≤ 15 kW, except ≤ 100 kW for anaerobic digesters	NEG carried over month-to-month; any residual NEG at end of year is "granted' to the utility	Vermont Legislature	1998	H. 605
Washington	Solar, wind and hydropower	All customer classes	≤ 25 kW	NEG credited to following month; unused credit is granted to utility at end of 12-month period	Washington Legislature	1998	House Bill 2773
Wisconsin	All Resource	All retail customers	≤ 20 kW	NEG purchased at retail rate for renewables, avoided cost for non-renewables	Public Services Commission	1993	Schedule PG-4

(*) "NEG" refers to the "net excess generation" of electricity by the customer-generator (i.e., generation exceeds consumption) during the billing period.

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SUMMARY OF STATE "NET METERING" PROGRAMS (PROPOSED)

State	Allowable Fuel Type	Allowable Customers	Allowable Capacity	Pricing Policy	Source of Authority	Proposed	Citation / Reference
Connecticut (enacted) [replaces existing rule after 1/1/2000]	Solar, wind, hydro, fuel cell, sustainable biomass	Residential only	No limit	Not specified	Connecticut Legislature	1998	Public Act 98-28
Illinois (pending)	Solar and wind	All retail customers	≤ 40 kW	NEG carried over month-to-month; any residual NEG at end of year is purchased at avoided cost	Illinois Legislature	1998	S.B. 1228
Maine (enacted) [replaces existing rule after 2/29/2000)	Renewables or other applicable technology [see 35-A MRSA § 3210(2)(C)]	All customer classes	≤ 100 kW	NEG carried over month-to-month; any residual NEG at end of 12-month period is eliminated w/o compensation	Public Utilities Commission	1998	Code Me. R. Ch. § 313 (1998); see also Order No. 98-621 (December 19, 1998).
Puerto Rico (pending)	Renewables only	Residential customers	≤ 50 kW	NEG carried over month-to-month; any residual NEG at end of year is purchased at avoided cost	Puerto Rico Legislature	1998	[TBD]

The experience and level of cooperation held by electric utility companies varies greatly throughout the country. In more progressive states, some utility companies appear to realize the advantages (ie lower capital costs) of allowing decentralized renewable energy systems to feed their grid and offer incentives for those who would like to try growing their own. However, a large majority of utility companies are either highly unknowledgeable about the whole concept of utility-intertied residential PV systems, or they make it virtually impossible by requiring gold-plated safety disconnects and unwarranted multi-million dollar insurance policies before allowing connection.

What if I Don't Want My Power to go out when the Utility Grid goes down?

As stated earlier, the micro-sine inverter panels automatically stop producing power when the utility grid stops in order to assure safety of line workers. To continue having electricity when the grid does go down you could utilize either of the following two systems which incorporate batteries for backup power. This is only a general overview of these systems. Before you install a system be sure you know what you are doing. Electricity can kill. Read through the reference materials listed at the end of this paper. Contact a local photovoltaic installer with any questions or actual installation work if deemed necessary.

Utility Interface System

This type of solar PV system uses the electric grid as backup power only. No electricity is added to the utility grid. Electricity generated by the PV system is stored in a battery bank. If the batteries become low (during periods of extended overcast, or periods of heavy use), an automatic transfer switch changes the connection of the house loads from the low batteries to the utility grid. These transfer switches are often built right into inverters, and the switch generally takes no more than 32 milliseconds to complete, assuring that appliances like TV's or computers are not affected by the switch. When the batteries recover, the source is automatically switched back to them.

The advantage of this system above a stand-alone system is that it can have a lower initial cost and can be enlarged incrementally, requiring less and less use of utility power, until eventually the home can become totally independent of the utility grid.

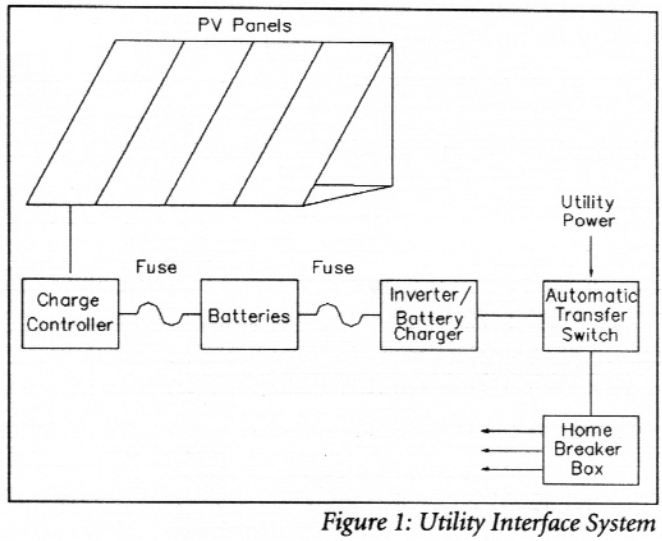

Figure 1: Utility Interface System

Utility Intertied System

This type of solar system sells electricity to the local utility company instead of storing the power in batteries (a small battery bank can be installed with a float charge to provide electricity during utility grid power outages). Utility companies often require two kWh meters (see Figure 2). One meter measures the power delivered to the utility grid as it is produced by the PV panels. A second meter is used to measure the power consumed by the loads in the house. This arrangement is often required especially in states without net metering, since the purchase rate the utility companies are willing to pay for small scale renewables is often far less than they are willing to sell for their dirty fossil fueled electricity.

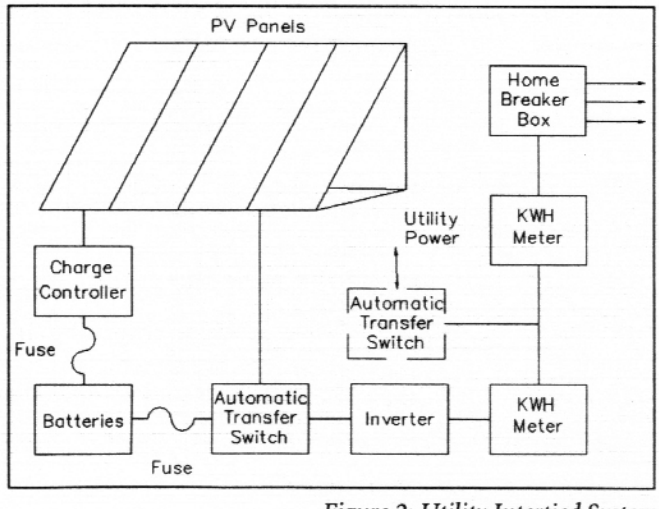

Figure 2: Utility Intertied System

Do I Really Have to Inform My Local Utility Company?

Perhaps you don't wish to be a local trailblazer when it comes to legally backfeeding the electric utility grid. Perhaps you live in a state where no efforts have been made towards net billing. Jumping through the local utility's regulatory hoops may not be something your interested in. Many people across the country feel this way and are simply not informing their utility company that their electric meter may at times run backwards. This isn't to imply that these are unsafe systems. These are safe systems, wired to code, and often times have been inspected by code enforcement officers.

This has become such a phenomenon that there is even a name for it, "guerrilla solar". It is a response to utility companies' hold on their monopolies and their profits, since they are generally willing to pay, for renewables, only a tiny fraction of what they charge for their dirty power. Utility companies feel comfortable with the idea of centralized power. Only they can make it, and we can only buy it. Solar guerrilla's have a better idea, using solar energy, wind energy, and micro-hydro power to energize their homes and to share that energy with their neighbors through the utility's electric lines. Renewable energy resources are nonpolluting and sustainable. Renewable energy is inherently decentralized and freely distributed to everyone daily. Remember that the sun is more powerful than any utility company. If your electric company does not like the idea of transforming from a monopolistic supplier of electricity to a service-oriented company, then guerrilla solar can be your response.

REFERENCES

Home Power 6/yr $22.50, PO Box 520, Ashland, OR 97520 • 800-707-6585 • www.homepower.com • hp@homepower.org

"Who Owns the Sun? People, Politics, and the Struggle for a Solar Economy", Daniel M. Berman and John T. O'Connor, Forward by Ralph Nader • ISBN 1-890132-08-x

"Independent Energy Guide. Electrical Power for Home, Boat, and RV", Kevin Jeffrey • ISBN 0-9644112-0-2

"The New Solar Electric Home. The Photovoltaic How-To Handbook", Joel Davidson

"Alternative Energy Sourcebook, 10th Edition," Real Goods, 555 Leslie Street, Ukiah, CA 95482-5507 • 800-762-7325 • FAX: 707-468-9486 • www.realgoods.com

"The Solar Powered Home", video tape with Rob Roy, 84 minutes (available from ASPI, 50 Lair Street, Mt. Vernon, KY 40456 • 606-256-0077 • www.kih.net/aspi)

SOURCES

Alternative Energy Engineering, PO Box 339, Redway, CA 95560-0339 • 800-777-6609 • www.alt-energy.com (solar electric equipment)

EKAT, 150 Gravel Lick Branch Rd, Dreyfus, KY 40385 • 606-986-6146 (solar electric equipment and installer)

Joshua Bills, PO Box 543, Berea, KY 40403 • 606-986-3736 • josh@blsurveying.com (solar electric equipment and installer)

Sunelco, PO Box 1499, Hamilton, Montana 59840-1499 • 800-338-6844 • www.sunelco.com • sunelco@montana.com (solar electric equipment)

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