A Consumer's Guide

Get Your Power from the Sun

U.S. Department of Energy

Energy Efficiency and Renewable Energy

Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

Contents

Cover photo: This PV system, integrated into an awning over the back porch of a home in California, generates electricity while shading the family's outdoor activities. (Courtesy of AstroPower/PIX12345)

Photo opposite: These PV modules are light and flexible, which makes them suitable for roofing shingles.

This Consumer's Guide is based on a state-specific guide written by Tom Starrs and Howard Wenger for the California Energy Commission, which was supported, in part, by the National Renewable Energy Laboratory in Golden, Colorado.

Get Your Power from the Sun

Are you thinking about buying a solar electric system for your home or business? If so, this booklet provides some basic information that can help you.

Solar electric systems, which are also called photovoltaic or PV systems, are reliable and pollution-free. They make use of a renewable source of energy—the sun. And PV systems for homes and businesses are becoming more affordable all the time.

PV works best in an energy-efficient building. So, adding insulation and energy-efficient lighting, appliances, and windows is a good idea, to reduce your home's overall electricity use before you install a PV system.

To make PV systems even more affordable, several states offer financial incentives through solar rebates and other programs. Some utilities have net metering programs, which further enhance the economics of PV. Net metering means that when your PV system generates more power than you need, the excess goes to the utility grid and the meter runs backward. This allows you to receive full retail value for the power that your PV system generates.

This booklet can guide you through the process of buying a solar electric system. It is not a technical guide to designing or installing a system—for that information, we recommend consulting an experienced PV system designer or supplier.

A PV system can be a substantial investment. As with any investment, careful planning will help you make the right decisions for your home or business.

Warren Gretz, NREL/PIX06283

Background

What is a solar electric or photovoltaic system?

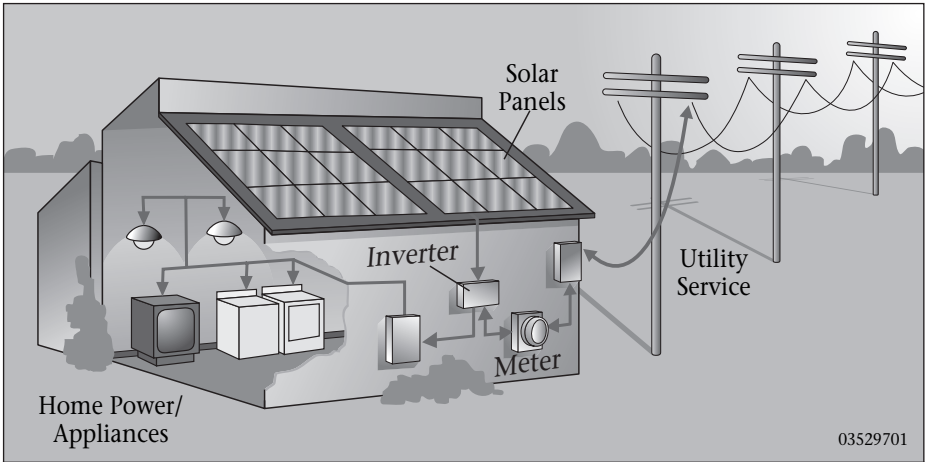
Photovoltaic (PV) systems convert sunlight directly to electricity. They work any time the sun is shining, but more electricity is produced when the sunlight is more intense and strikes the PV modules directly (as when rays of sunlight are perpendicular to the PV modules). Unlike solar thermal systems for heating water, PV does not use the sun's heat to make electricity. Instead, electrons freed by the interaction of sunlight with semiconductor materials in PV cells are captured in an electric current.

PV allows you to produce electricity—without noise or air pollution—from a clean, renewable resource. A PV system never runs out of fuel, and it won't increase U.S. oil imports. Many PV system components are manufactured right here in the United States. These characteristics could make PV technology the U.S. energy source of choice for the 21st century.

The basic building block of PV technology is the solar "cell." Multiple PV cells are connected to form a PV "module," the smallest PV component sold commercially. Modules range in power output from about 10 watts to 300 watts. A PV system connected or "tied" to the utility grid has these components:

- One or more PV modules, which are connected to an inverter
- The inverter, which converts the system's direct-current (DC) electricity to alternating current (AC)
- Batteries (optional) to provide energy storage or backup power in case of a power interruption or outage on the grid.

AC electricity is compatible with the utility grid. It powers our lights, appliances, computers, and televisions.



Residential grid-connected PV system

Special appliances that run directly on DC power are available, but they can be expensive.

Before you decide to buy a PV system, there are some things to consider:

First, PV produces power intermittently because it works only when the sun is shining. This is not a problem for PV systems connected to the utility grid, because any additional electricity required is automatically delivered to you by your utility. In the case of non-grid, or stand-alone, PV systems, batteries can be purchased to store energy for later use.

Second, if you live near existing power lines, PV-generated electricity is usually more expensive than conventional utility-supplied electricity. Although PV now costs less than 1% of what it did in the 1970s, the amortized price over the life of the system is still about 25 cents per kilowatt-hour. This is double to quadruple what most people pay for electricity from their utilities. A solar rebate program and net metering can help make PV more affordable, but they can't match today's price for utility electricity in most cases.

Finally, unlike the electricity you purchase monthly from a utility, PV power requires a high initial investment. This means that buying a PV system is like paying years of electric bills up front. Your monthly electric bills will go down, but the *initial* expense of PV may be significant. By financing your PV system, you can spread the cost over many years, and rebates can also lighten your financial load.

Are incentives available to help reduce the cost?

Yes, many states offer incentives. For specific information, call one of the contacts listed under "Getting Help" at the end of this booklet. Another excellent source is the National Database of State Incentives for Renewable Energy (DSIRE). Prepared by the North Carolina Solar Center, this database contains information on financial and regulatory incentives that promote renewable energy technologies.

Net Metering—In more than 35 states, customers who own PV systems can benefit from laws and regulations that require "net" electric meter reading. The customer is billed for the net electricity purchased from the utility over the entire billing period—that is, the difference between the electricity coming from the power grid and the electricity generated by the PV system. Through net metering, the customer obtains the full retail electricity rate—rather than the much lower wholesale rate—for kilowatt-hours of PV-produced electricity sent to the utility power grid. The benefits of net metering to consumers are especially significant in areas such as Hawaii and New York, which have high retail electric rates. Utilities also benefit because the solar-generated energy often coincides with their periods of "peak" demand for electricity.

Property and Sales Tax—Tax incentives may include a sales tax exemption on the PV system purchase, a property tax exemption, or state personal income-tax credits,

PV awnings such as this one in California provide both electricity and shade.

AstroPower/PIX12346

all of which provide an economic benefit to consumers by lowering high capital costs. The U.S. government also provides financial support for PV technology through a tax credit for commercial uses of solar energy. This energy investment credit provides businesses (but not individuals or utilities) with a 10% tax credit and 5-year accelerated depreciation for the cost of equipment used to generate solar electricity.

Buy-Down—Rebates and buy-downs, typically based on the rated power of the system, help to defray high capital costs and to create competitive, sustainable market growth. In the United States, the U.S. Department of Energy has been involved in a program known as TEAM-UP, or Technology Experience to Accelerate Markets in Utility Photovoltaics. Through this program, some 80 utilities in 40 states have installed more than 7 megawatts of grid-connected PV; supplier buy-downs and consumer rebates range between $2 and $4 per watt.

Residential Energy Rate—This is the average retail residential rate for energy from utilities, in cents per kilowatt-hour. Check your utility bill for your *actual* rate.

Investing in a PV system

Why should you buy a PV system?

People decide to buy PV systems for a variety of reasons. Some people want to help preserve the Earth's finite fossil-fuel resources and reduce air pollution. Others want to invest in an energy-producing improvement to their property. Some people like the security of reducing the amount of electricity they buy from their utility because it makes them less vulnerable to future price increases. And some people just appreciate the independence that a PV system provides.

If you plan to build a home away from an established utility service, inquire about the cost of installing a utility line. Often, the cost of extending conventional power to your residence is higher than the cost of a solar option.

Whatever your reason, solar energy is widely thought to be the energy source of choice for the future, and you may be able to take advantage of a state-sponsored program to help make it your energy choice for today and tomorrow.

Is your home or business a good place for a PV system?

Can you locate your system so it works well?

A well-designed PV system needs clear and unobstructed access to the sun's rays for most or all of the day, throughout the year. You can make an initial assessment yourself. If the location looks promising, your PV provider can determine whether your home or business can effectively use a PV system.

The orientation of your PV system (the compass direction that your system faces) affects its performance. In the United States, the sun is always in the southern half of the sky but is higher in the summer and lower in the winter. Usually, the best location for a PV system is a south-facing roof, but roofs that face east or west may also be acceptable. Flat roofs also work well for solar electric systems, because PV modules can be mounted flat on the roof facing the sky or bolted on frames tilted toward the south at an optimal angle. They can also be attached directly to the roof as “PV shingles.”

If a rooftop can't be used, your solar modules can also be placed on the ground, either on a fixed mount or a “tracking” mount that follows the sun to orient the PV modules. Other options (often used in multifamily or commercial applications) include mounting structures that create covered parking, or that provide shade as window awnings.

Is your site free from shading by trees, nearby buildings, or other obstructions?

To make the best use of your PV system, the PV modules must have a clear “view” of the sun for most or all of the day—unobstructed by trees, roof gables, chimneys, buildings, and other features of your home and the

surrounding landscape. Some potential sites for your PV system may be bright and sunny during certain times of the day, but shaded during other times. Such shading may substantially reduce the amount of electricity that your system will produce. To be eligible for some rebates, your system must be unshaded between certain hours during certain times of the year. Some states have laws that establish your right to protect your solar access through the creation of a "solar easement." Your PV provider can help you determine whether your site is suitable for a solar electric system.

Does your roof or property contain a large enough area for the PV system?

The amount of space that a PV system needs depends on the size of the system you purchase. Some residential systems require as little as 50 square feet (for a small "starter" system), but others could need as much as 1,000 square feet. Commercial systems are typically even larger. If your location limits the size of your system, you may want to install one that uses more efficient PV modules. Greater efficiency means that the module needs less surface area to convert sunlight into a given amount of electric power. PV modules are available in a range of types, and some offer more efficiency per square foot than others do (see table on the next page). Although the efficiency (percent of sunlight converted to electricity) varies with the different types of PV modules available today, higher efficiency modules typically cost more. System sizing, discussed later in this booklet, should also be discussed with your PV provider.

What kind of roof do you have, and what is its condition?

Some types of roofs are simpler and cheaper to work with, but a PV system can be installed on any type. Typically, roofs with composition shingles are the easiest to work with, and those with slate are the most difficult. In any case, an experienced solar installer will know how to work on all types and can use roofing techniques that eliminate any possibility of leaks. Ask your PV provider how the PV system affects your roof warranty.

If your roof is older and needs to be replaced in the near future, you may want to replace it at the time the PV system is installed to avoid the cost of removing and reinstalling your PV system. PV panels often can be integrated into the roof itself, and some modules are actually designed as three-tab shingles or raised-seam metal roof sections. One benefit of these systems is their ability to offset the cost of roof materials.

How big should your PV system be, and what features should it have?

To begin, consider what portion of your current electricity needs you would like your PV system to meet. For example, suppose that you would like to meet 50% of your electricity needs with your PV system. You could work with your PV provider to examine past electric bills and

determine the size of the PV system needed to achieve that goal.

You can contact your utility and request the total electricity usage, measured in kilowatt-hours, for your household or business over the past 12 months (or consult your electric bills if you save them). Ask your PV provider how much your new PV system will produce per year (also measured in kilowatt-hours) and compare that number to your annual electricity usage (called demand) to get an idea of how much you will save. In the next section, we'll provide more information on estimating how much you will save.

Some solar rebate programs are capped at a certain dollar amount. Therefore, a solar electric system that matches this cap maximizes the benefit of the solar rebate.

To qualify for net metering in some service territories, your PV system must have a peak generating capacity that is typically not more 10 kilowatts (10,000 watts), although this peak may differ from state to state. Also, utilities have different provisions for buying excess electricity produced by your system on an annual basis (see the section on net metering). Finally, customers eligible for net metering vary from utility to utility; for example, net metering could be allowed for residential customers only, commercial customers only, or both.

One optional feature to consider is a battery system to provide energy storage (for stand-alone systems) or backup power in case of a utility power outage (for grid-connected systems). Batteries add value to your system, but at an increased price.

As a rule, the cost per kilowatt-hour goes down as you increase the size of the system. For example, many inverters are sized for systems up to 5 kilowatts, so even if your PV array is smaller (say, 3 kilowatts), you may have to buy the same size of inverter. Labor costs for a small system may be nearly as much as those for a large system, so you are likely to get a better price for installing a 2-kilowatt system all at once, rather than installing 1 kilowatt each year for two years.

Roof Area Needed in Square Feet (shown in **Bold Type**)

PV Module Efficiency (%)	PV Capacity Rating (Watts)						
	100	250	500	1,000	2,000	4,000	10,000
4	**30**	**75**	**150**	**300**	**600**	**1,200**	**3,000**
8	**15**	**38**	**75**	**150**	**300**	**600**	**1,500**
12	**10**	**25**	**50**	**100**	**200**	**400**	**1,000**
16	**8**	**20**	**40**	**80**	**160**	**320**	**800**

For example, to generate 2,000 watts from a 12%-efficient system, you need 200 square feet of roof area.

How much will you save with your PV system?

The value of your PV system's electricity depends on how much you pay for electricity now and how much your utility will pay you for any excess power that you generate. If your utility offers net metering (and so pays the full retail price for your excess electricity), you and your utility will pay the same price for each other's electricity. You can use the calculation box on the next page to roughly estimate how much electricity your PV system will produce and how much that electricity will be worth. Actual energy production from your PV system will vary by up to 20% from these figures, depending on your geographic location, the angle and orientation of your system, the quality of the components, and the quality of the installation.

Also, you may not get full retail value for excess electricity produced by your system on an annual basis, even if your utility does offer net metering. Be sure to discuss these issues with your PV provider. Request a written estimate of the average annual energy production from the PV system. However, even if an estimate is accurate for an average year, actual electricity production will fluctuate from year to year because of natural variations in weather and climate.

If your utility does not offer net metering, you can still use the calculation box to determine the amount of electricity your system will produce. However, this is not as straightforward, because the excess electricity will not be worth as much as the electricity you actually use. You may earn only 2 cents per kilowatt-hour—or less than half the retail rate—for your excess power.

PV systems produce most of their electricity during the middle of the day, when residential electric loads tend to be small. If your utility does not offer net metering, you may want to size your system to avoid generating electricity significantly beyond your actual needs.

How much does a PV system cost?

No single answer applies in every case. But a solar rebate and other incentives can always reduce the cost. Your price depends on a number of factors, including whether your home is under construction and whether PV is integrated into the roof or mounted on top of an existing roof. The price also depends on the PV system rating, manufacturer, retailer, and installer.

The size of your system may be the most significant factor in any measurement of costs versus benefits. Small, single-PV-panel systems with built-in inverters that produce about 75 watts may cost around $900 installed, or $12 per watt. These small systems offset only a small fraction of your electricity bill. A 2-kilowatt system that meets nearly all the needs of a very energy-efficient home could cost $16,000 to $20,000 installed, or $8 to $10 per watt. At the high end, a 5-kilowatt system that completely meets the energy needs of many conventional

Calculating Electricity Bill Savings for a Net-Metered PV System

- Determine the system's size in kilowatts (kW). A reasonable range is from 1 to 5 kW. This value is the "kW of PV" input for the equations below.
- Based on your geographic location, select the energy production factor from the map below for the "kWh/kW-year" input for the equations.

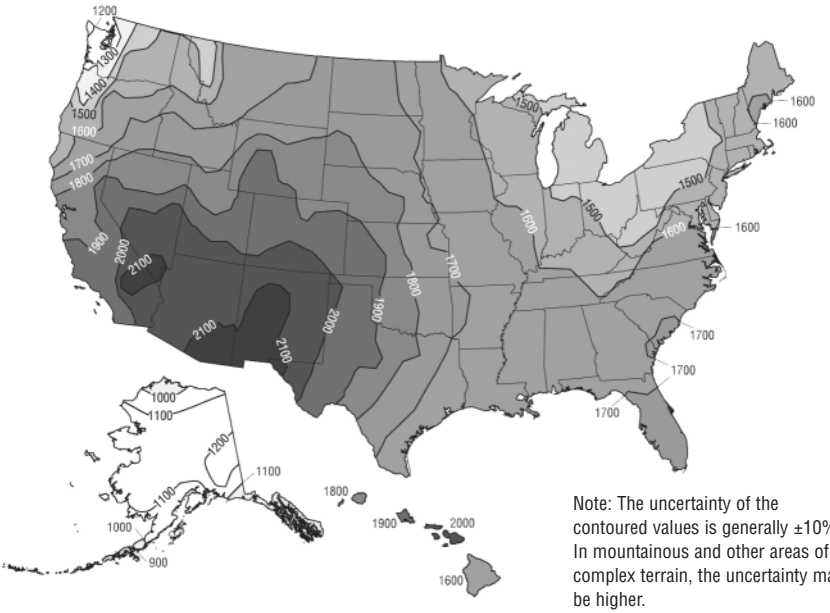
Energy from the PV system = (kW of PV) x (kWh/kW-year) = kWh/year

Divide this number by 12 if you want to determine your monthly energy reduction.

Energy bills savings = (kWh/year) x (Residential Rate)/ 100 = $/year saved

(Residential Rate in this above equation should be in dollars per kWh; for example, a rate of 10 cents per kWh is input as $0.10/kWh.)

For example, a 2-kW system in Denver, CO, at a residential energy rate of $0.07/kWh will save about $266 per year: 1,900 kWh/kW-year x $0.07/kWh x 2 kW = $266/year.



Note: The uncertainty of the contoured values is generally ±10%. In mountainous and other areas of complex terrain, the uncertainty may be higher.

homes can cost $30,000 to $40,000 installed, or $6 to $8 per watt. These prices are rough estimates; your costs depend on your system's configuration, your equipment options, and other factors. Your local PV providers can give you more accurate estimates or bids.

How can you finance the cost of your PV system?

When it comes to financing the cost of purchasing and installing your PV system, there are some special programs particular to financing solar and other renewable energy

Schott Applied Power Corp./PIX08808

This 20-kilowatt PV system produces electricity for the common areas of a shopping center in Cambridge, Massachusetts.

investments. But most of the options will be familiar to you.

The best way to finance PV systems for homes is through a mortgage loan. Mortgage financing options include your primary mortgage; a second mortgage, such as a U.S. Department of Housing and Urban Development (HUD) Title 1 loan; or a home-equity loan that is secured by your property. There are two advantages to mortgage financing. First, mortgage financing usually provides longer terms and lower interest rates than other loans, such as conventional bank loans. Second, the interest paid on a mortgage loan is generally deductible on your federal taxes (subject to certain conditions). If you buy the PV system for your home at the same time that you build, buy, or refinance the home, adding the cost of the PV system to your mortgage loan is likely to be relatively simple. It is also one way to avoid additional loan application forms and fees.

If mortgage financing is not available, look for other sources of financing, such as conventional bank loans. Seek the best possible combination of low rate and long term. This allows you to amortize your PV system as inexpensively as possible. Because your PV system is a long-term investment, the terms and conditions of your financing are likely to be the most important factor in determining the effective price of your PV-generated power.

PV systems for businesses are probably best financed through a company's existing sources of funds for capital purchases—such as Small Business Administration loans or conventional bank loans.

Selecting a PV provider

Who sells and installs PV systems?

In some areas, finding a PV provider can be as simple as picking up the telephone directory and looking under "Solar Energy Equipment and Systems—Dealers." However, many of the listings are solar water-heating companies and many companies might not be experienced in PV system design or installation. Similarly, many electrical contractors, although proficient in typical electrical contracting work, might not have expertise in PV or residential roof-mounting techniques. *How do you identify solar electric system providers?* Here are several suggestions.

- Check the Source Guide for renewable energy businesses (including PV) by name, product type, business type, and location: http://energy.sourceguides.com/index.shtml
- Contact the Solar Energy Industries Association (SEIA) at 202-628-7745 for a list of solar service providers.
- Contact your utility company to see which vendors it might recommend.
- Conduct a search on the Internet.

Reputable, professional contractors with experience in PV systems are the best choice for the actual installation.

How do you choose among PV providers?

Compile a list of prospective PV providers. (Those closest to you should have the lowest travel costs). Contact these providers and find out what products and services they offer. The following questions may give you a good sense of their capabilities:

Has the company installed grid-connected PV systems? If not, has it installed grid-independent (or stand-alone) PV systems?

Experience in installing grid-connected systems is valuable because some elements of the installation—particularly interconnection with the local utility—are unique to these systems. Because grid-connected systems are relatively uncommon, however, most contractors with PV experience have worked only on stand-alone systems. So, they have experience with all aspects of PV system installation *except* connection with the utility grid. However, a competent company with PV experience should not be eliminated just because it has not yet installed grid-connected PV. Experience with off-grid systems is valuable, because grid-independent systems are more technically complex than grid-tied systems.

How many years of experience does the company have installing PV systems?

This issue speaks for itself: A contractor who has been in business a long time probably understands how to work with customers and to compete effectively with other firms.

Is the company properly licensed?

PV systems should be installed by an appropriately licensed contractor. This usually means that either the installer or a subcontractor has an electrical contractor's license. Your State Electrical Board can tell you whether a contractor has a valid electrician's license. Local building departments might also require that the installer have a general contractor's license. Call the city or county you live in for additional information on licensing.

A solar rebate program may require that, in addition to being properly licensed, installers must demonstrate that they have special knowledge about installing PV systems. This special knowledge may be demonstrated in one of the following ways:

- Possession of a solar contractor specialty license, issued by a local building jurisdiction, that recognizes—through testing or other means—special knowledge of PV systems
- Certification in PV systems by a group such as the state chapter of SEIA
- A letter from the PV system manufacturer stating that the installer has the experience and training needed to install the system properly.

Does the company have any pending or active judgments or liens against it?

As with any project that requires a contractor, due diligence is recommended. Your state electrical board can tell you about any judgments or complaints against a state-licensed electrician. Consumers should call the city and county they live in for information on how to evaluate contractors. The Better Business Bureau is another source of information.

How do you choose among competing bids?

If you decide to get more than one bid for the installation of your PV system (always a good idea), make sure that all bids are made on the same basis. For example, a bid for a system mounted on the ground is usually very different from another bid for a rooftop system.

Similarly, some PV modules generate more electricity per square foot than others. Bids should clearly state the maximum generating capacity of the system (measured in watts or kilowatts). If possible, have the bids specify the system capacity in "AC watts" under a standard set of test conditions, or specify the output of the system at the inverter.

Also request an estimate of the amount of energy that the system will produce on an annual basis (measured in kilowatt-hours). Because the amount of energy depends on the amount of sunlight—which varies by location, season, and year to year—it's unlikely the contractor will quote a specific figure, but a range of ±20% is realistic. Bids also should include the total cost of getting the PV system up and running, including hardware, installation, connection to the grid, permitting, sales tax, and warranty.

Your warranty is a very important factor for evaluating bids. A solar rebate program may require that systems be covered by a two-year parts-and-labor written installation warranty, for example, in addition to any manufacturers' warranties on specific components. The installer may offer longer warranties. Also, ask yourself, "Will this company stand behind the full-system warranty for the next two years?"

Is the lowest price the "best deal"?

It might not be. You generally get what you pay for, and it's possible that a low price could be a sign of inexperience. Companies that plan to stay in business must charge enough for their products and services to cover their costs, plus a fair profit margin. Therefore, price should not be the only consideration, and quality should probably rank high on the list.

A home in the woods of New Hampshire had too much shade to use PV on the roof. The solution was installing a freestanding PV array.

Alan Ford/PIX09507

Before connecting a PV system to the grid

What should you know about permits?

If you live where a homeowners association must approve a solar electric system, you or your PV provider may need to submit your plans. You'll need approval before you begin installing your PV system. However, some state laws stipulate that you have the right to install a solar electric system on your home.

You will probably need to obtain permits from your city or county building department. These include a building permit, an electrical permit, or both. Typically, your PV provider will take care of this, rolling the price of the permits into the overall system price.

However, in some cases, your PV provider may not know how much time or money will be involved in "pulling" a permit. If so, this task may be priced on a time-and-materials basis, particularly if additional drawings or calculations must be provided to the permitting agency. In any case, make sure the permitting costs and responsibilities are addressed at the start with your PV provider before installation begins.

Code requirements for PV systems vary somewhat from one jurisdiction to the next, but most are based on the National Electrical Code (NEC). Article 690 in the NEC spells out requirements for designing and installing safe, reliable, code-compliant PV systems. Because most local requirements are based on the NEC, your building inspector is likely to rely on Article 690 for guidance in determining whether your PV system has been properly designed and installed. If you are one of the first people in your community to install a grid-connected PV system, your local building department may not have experience in approving one of these systems. If this is the case, you and your PV provider can speed the process by working closely with building officials to bring them up to speed on the technology.

What should you know about insurance?

For grid-connected PV systems, your electric utility will require that you enter into an interconnection agreement (see also the next section). Usually, these agreements set forth the minimum insurance requirements to keep in force. If you are buying a PV system for your home, your standard homeowner's insurance policy is usually adequate to meet the utility's requirements. However, if insurance coverage becomes an issue, contact one of the groups listed in the Getting Help section.

How do you get an interconnection agreement?

Connecting your PV system to the utility grid will require an interconnection agreement and a purchase and sale agreement. Federal law and some state public utility commission regulations require utilities to supply you with an interconnection agreement. Some utilities have developed

simplified, standardized interconnection agreements for small-scale PV systems.

The interconnection agreement specifies the terms and conditions under which your system will be connected to the utility grid. These include your obligation to obtain permits and insurance, maintain the system in good working order, and operate it safely. The purchase and sale agreement specifies the metering arrangements, the payment for any excess generation, and any other related issues.

The language in these contracts should be simple, straightforward, and easy to understand. If you are unclear about your obligations under these agreements, contact the utility or your electrical service provider for clarification. If your questions are not answered adequately, contact one of the groups in the Getting Help section.

National standards for utility interconnection of PV systems are being adopted by many local utilities. The most important of these standards focuses on inverters. Traditionally, inverters simply converted the DC electricity generated by PV modules to the AC electricity we use in our homes. More recently, inverters have evolved into remarkably sophisticated devices to manage and condition power. Many new inverters contain all the protective relays, disconnects, and other components necessary to meet the most stringent national standards. Two of these standards are particularly relevant:

- Institute of Electrical and Electronic Engineers, *P929: Recommended Practice for Utility Interface of Photovoltaic Systems*. Institute of Electrical and Electronic Engineers, Inc., New York, NY (1998).
- Underwriters Laboratories, *UL Subject 1741: Standard for Static Inverters and Charge Controllers for Use in Photovoltaic Power Systems* (First Edition). Underwriters Laboratories, Inc., Northbrook, IL (December 1997).

You don't need to fully understand these standards, but your PV provider and utility should. It is your obligation to make sure that your PV provider uses equipment that complies with the relevant standards, however, so be sure to discuss this issue.

How do you get a net-metering agreement?

Some utilities offer customers with PV systems the option to net meter the excess power generated by the PV system. As noted, this means that when the PV system generates more power than the household can use, the utility pays the full retail price for this power in an even swap as the electric meter spins backward, and your PV power goes into the grid.

Net metering allows eligible customers with PV systems to connect to the grid with their existing single meter. Almost all standard utility meters can measure the flow of energy in either direction. The meter spins *forward* when electricity is flowing from the utility into the building and spins *backward* when power is flowing from the building to the utility.

For example, in one utility program, customers are billed monthly for the "net" energy consumed. If the customer's net consumption is negative in any month (i.e., the PV system produces more energy than the customer uses), the balance is credited to subsequent months. Once a year, on the anniversary of the effective date of the interconnection agreement, the utility pays the customer for any negative balance at its wholesale or "avoided cost" for energy, which may be quite small, perhaps less than 2 cents per kilowatt-hour.

Net metering allows customers to get more value from the energy they generate. It also simplifies both the metering process (by eliminating the need for a second meter) and the accounting process (by eliminating the need for monthly payments from your utility). Be sure to ask your utility about its policy regarding net metering.

Under the federal Public Utility Regulatory Policies Act (PURPA), utilities must allow you to interconnect your PV system. They must also buy any excess electricity you generate, beyond what you use in your home or business. If your utility does not offer net metering, it will probably require you to use two meters: one to measure the flow of electricity *into* the building, the other to measure the flow of electricity *out of* the building. If net metering is not available, the utility will pay you only a *wholesale* rate for your excess electricity. This provides a strong incentive to use all the electricity you generate so that it offsets electricity you would otherwise have to purchase at the higher *retail* rate. This may be a factor in how you optimize the system size, because you may want to limit generating excess electricity. Such a "dual metering" arrangement is the norm for industrial customers who generate their own power.

What should you know about utility and inspection sign-off?

After your new PV system is installed, it must be inspected and "signed off" by the local permitting agency (usually a building or electrical inspector) and most likely by the electric utility with which you entered into an interconnection agreement. Inspectors may require your PV provider to make corrections (which is fairly common in the construction business). A copy of the building permit showing the final inspection sign-off may be required to qualify for a solar rebate program.

What should you know about warranties?

Warranties are key to ensuring that your PV system will be repaired if something should malfunction during the warranty period. PV systems eligible for some solar rebate programs must carry a full (not "limited") two-year warranty, in addition to any manufacturers' warranties on specific components. This warranty should cover all parts and labor, including the cost of removing any defective component, shipping it to the manufacturer, and reinstalling the component after it is repaired or replaced. The rebate program's two-year warranty requirement supersedes any other warranty limitations. In other words, even if the manufacturer's warranty on a particular component is less than

two years, the system vendor must provide you with a two-year warranty. Similarly, even if the manufacturer's warranty is a limited warranty that does not include the cost of removing, shipping, and reinstalling defective components, the system vendor must cover these costs if the retailer/vendor also installed the system.

Be sure you know who is responsible for honoring the various warranties associated with your system—the installer, the dealer, or the manufacturer. The vendor should disclose the warranty responsibility of each party.

Know the financial arrangements, such as contractor's bonds, that ensure the warranty will be honored. (A warranty does not guarantee that the company will remain in business). Find out whom to contact if there is a problem. Under some solar rebate programs, vendors must provide documentation on system and component warranty coverage and claims procedures. To avoid any later misunderstandings, be sure to read the warranty carefully and review the terms and conditions with your retailer/vendor.

Getting Help

For more information on solar electric systems, please contact:

National Association of State Energy Officials (NASEO)
1414 Prince Street
Suite 200
Alexandria, Virginia 22314
Phone: 703-299-8800 • Fax: 703-299-6208
www.naseo.org/members/states.htm

Check the above Web site to find the contact for your state energy office, which typically promotes the development and use of renewable energy resources in your state. The office might offer technical assistance, sponsor workshops and forums, and provide general information to resident energy consumers on renewable energy resources and applications.

National Association of Regulatory and Utility Commissioners (NARUC)
1101 Vermont, N.W.
Suite 200
Washington, DC 20005
Phone: 202-898-2200 • Fax: 202-898-2213
www.naruc.org

This Web site has a listing of state Public Utility Commissions that you may contact.

Solar Energy Industries Association (SEIA)
1616 H Street, N.W., Suite 800
Washington, DC 20006
Phone: 202-628-7745 • Fax: 202-628-7779
www.seia.org

The Solar Energy Industries Association is the national trade association of the solar industry. Many states have a state chapter of the national SEIA organization, which can be found on SEIA's Web site.

Other helpful Web sites

Solar Energy Technologies Program: www.eere.energy.gov/solar

National Center for Photovoltaics: www.nrel.gov/ncpv

Million Solar Roofs: www.millionsolarroofs.com

Database of State Incentives for Renewable Energy (DSIRE): www.dsireusa.org

About the Office of Energy Efficiency and Renewable Energy

A Strong Energy Portfolio for a Strong America

Energy efficiency and clean, renewable energy will mean a stronger economy, a cleaner environment, and greater energy independence for America. By investing in technology breakthroughs today, our nation can look forward to a more resilient economy and secure future.

Far-reaching technology changes will be essential to America's energy future. Working with a wide array of state, community, industry, and university partners, the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy invests in a portfolio of energy technologies that will:

- Conserve energy in the residential, commercial, industrial, government, and transportation sectors
- Increase and diversify energy supply, with a focus on renewable domestic sources
- Upgrade our national energy infrastructure
- Facilitate the emergence of hydrogen technologies as vital new "energy carriers."

The Opportunities

Biomass Program—Using domestic, plant-derived resources to meet our fuel, power, and chemical needs
Building Technologies Program—Homes, schools, and businesses that use less energy, cost less to operate, and, ultimately, generate as much power as they use
Distributed Energy & Electric Reliability Program—A more reliable energy infrastructure and reduced need for new power plants
Federal Energy Management Program—Leading by example, saving energy and taxpayer dollars in federal facilities
FreedomCAR & Vehicle Technologies Program—Less dependence on foreign oil, and eventual transition to an emissions-free, petroleum-free vehicle
Geothermal Technologies Program—Tapping the Earth's energy to meet our heat and power needs
Hydrogen, Fuel Cells & Infrastructure Technologies Program—Paving the way toward a hydrogen economy and net-zero carbon energy future
Industrial Technologies Program—Boosting the productivity and competitiveness of U.S. industry through improvements in energy and environmental performance
Solar Energy Technology Program—Utilizing the sun's natural energy to generate electricity and provide water and space heating
Weatherization & Intergovernmental Program—Accelerating the use of today's best energy-efficient and renewable technologies in homes, communities, and businesses
Wind & Hydropower Technologies Program—Harnessing America's abundant natural resources for clean power generation

To learn more, visit www.eere.energy.gov

The National Renewable Energy Laboratory,
a DOE national laboratory, produced this Consumer's Guide for:

U.S. Department of Energy
Office of Energy Efficiency and Renewable Energy
1000 Independence Avenue, S.W.
Washington, D.C. 20585

December 2003 • DOE/GO-102003-1844

Small Solar Electric Systems: A Minnesota Guide

Can I use solar energy to power my home? More and more Minnesotans are asking themselves this question as people look for affordable, clean and reliable sources of electricity.

Minnesota has better solar resources than what most people may think. In fact, average annual resources in Minneapolis are comparable to solar resources in Jacksonville, Fla. Minnesota's solar energy can produce electricity when demand is highest—during the summer months. Solar electric systems will even produce electricity on cloudy days, although generation is significantly reduced.

Small solar electric systems can make a significant contribution to meeting energy needs. A small solar electric system may be a good choice if:

- trees, buildings, or other structures do not shade the installation location,
- there is adequate roof, wall or yard space to permit a collector assembly installation,
- the desired electrical output can be achieved,
- there are few personal financial barriers for on-grid homes or
- the home or cabin is located off-grid, away from power lines.

Most people are interested in solar energy because it is a nonpolluting source of power. Solar electric systems are one of the most flexible home-based renewable energy systems available. The system can be moved from one location to another with far greater ease than other renewable energy systems and can be added to over an extended period of time, a few solar panels at a time.

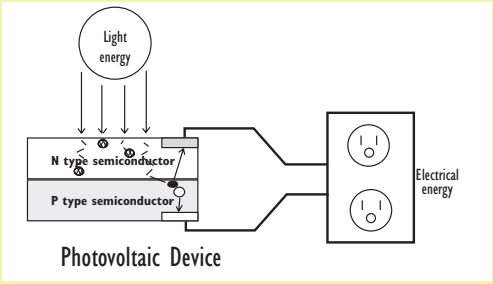
Depending on the solar resource availability and the home's electric energy consumption, a small solar electric system can lower electricity bills by 50 to 90 percent, prevent power interruptions and avoid the high costs of extending utility power lines to remote locations.

In small solar electric systems, PV cells are typically combined into panels that hold about 40 cells; multiple panels can be mounted together in an array that can measure up to several yards (meters) on a side. Panels come in sizes from a few watts to hundreds of watts—a small home system can use anywhere from 3 to 20 panels, depending on their size. Also available are solar roof shingles, which replace conventional roofing materials while providing electricity less expensively than standard solar panels.

The photovoltaic effect

French scientist Edmund Becquerel first reported the photovoltaic effect in 1839, when he observed a voltage between two electrodes in a beaker of electrolyte after the beaker was exposed to sunlight.

Solar electric or photovoltaic (PV) cells convert sunlight directly into electricity. PV cells are made of semi-conducting materials, similar to those used in computer chips. When exposed to sunlight, these materials absorb light energy and are "excited," causing electrons to flow through the material and produce electricity. This process of converting light (photons) to electricity (voltage) is called the photovoltaic effect.



Photovoltaic Device

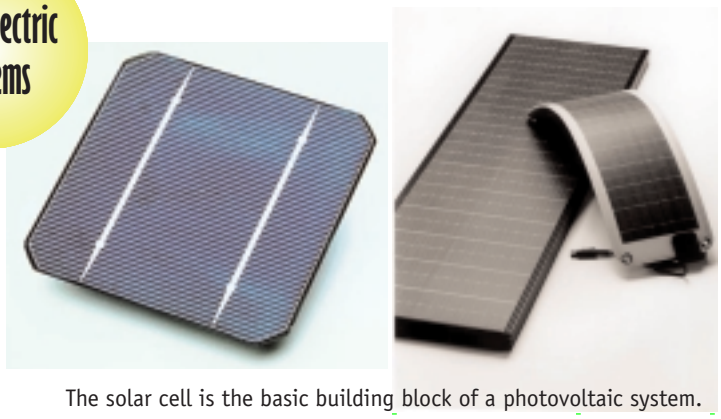
Increase solar energy usage by increasing energy efficiency

The amount of solar energy a home uses is determined more by the amount of electricity that is consumed rather than what is generated.

Pictured are two homes that use similar solar electric systems, both rated at 2.85 kilowatts, installed for $18,000 in 1996 under Xcel Energy's (then Northern States Power Company) Solar Advantage Program. The energy-efficient home receives about 71 percent of its energy from solar resources, compared to 38 percent for the average home.

The solar electric system for this home in Minnetonka, Minn., produced 2967 kilowatt-hours in 2001, meeting 71 percent of the home's electrical usage that year of 4192 kilowatt-hours. This energy-efficient home consumes about 50 percent less energy than the average home.

The solar electric system in this home in White Bear Lake, Minn., produced 2719 kilowatt hours in 2001, meeting 38 percent of the home's electrical usage that year of 7204 kilowatt-hours. The home is about average for electrical consumption.



The solar cell is the basic building block of a photovoltaic system. Individual cells can vary in size from about 1 cm (1/2 inch) to about 10 cm (4 inches) across. Although rigid panels (left) are more popular, flexible solar panels (right) offer the benefits of being lightweight, easily transportable, and they can be applied to smooth, curved surfaces. A potential drawback is that they have a lower output per square meter of surface area.

Start by increasing energy efficiency

Before choosing a solar electric system, reduce the home or business's energy consumption by increasing energy efficiency. Because energy efficiency is less expensive than energy production, increasing energy efficiency is more cost effective and will reduce the size and cost of the solar electric system that is needed. For example, replacing an older non-Energy Star refrigerator (pre-2001, when new efficiency standards were enacted) might cost $600, while trying to generate the electricity with a solar system may cost $2,000. Low power consumption always enhances a solar electric system's performance and investment.

To achieve maximum energy efficiency, take a whole-building approach. View the home or business as an energy system with interrelated parts, all of which work together to contribute to the efficiency of the system. From the insulation in the walls to the light bulbs in the fixtures, there are many ways to make a home or business more energy efficient:

- Reduce overall heating and cooling needs by up to 30 percent by investing just a few hundred dollars in proper insulation, caulking and weather-stripping products. See the Home Energy Guides "Home Insulation" and "Caulking and Weather-stripping."
- Save money and increase comfort by upgrading the heating, ventilation, and air-conditioning systems. Many new furnaces use only 20 percent of the electricity that standard furnaces use, especially those with variable-speed furnace fan motors, so shop wisely. See the Home Energy Guide "Home Heating."
- Replace the refrigerator and freezer with high efficiency models. Current refrigerator models

generally consume only 50 percent of the electricity used by a ten-year-old refrigerator. See the Home Energy Guide "Home Appliances."

- Replace all incandescent light bulbs with fluorescent and compact fluorescent light bulbs. Using fluorescent lighting can reduce lighting costs by up to 75 percent. See the Home Energy Guide "Home Lighting."
- When shopping for appliances, use the Energy Star® label as a minimum standard. Energy Star® appliances have been identified by the U.S. Environmental Protection Agency and U.S. Department of Energy as being the most energy-efficient products in their classes. For more information visit the web site www.energystar.gov

The "For More Information" section at the end of this guide lists additional resources about how to make homes and businesses energy efficient.

Making the decision

The following list can serve as a guide for deciding if a solar electric system is for you:

- the property has good solar resources,
- whether local zoning codes or covenants allow solar electric systems,
- long-term investments are a comfortable financial option,
- there is a commitment to decrease the impact on the environment, or
- the property is in a remote location that does not have easy access to utility lines.

Example: You are building a new home or remote cabin. The local utility will provide power, but at a cost of $20,000 for installation of power lines and poles. This cost could be avoided by installing a solar electric system and becoming your own utility. The utility costs may be amortized as part of the mortgage costs.

Before investing in a solar electric system, research potential obstacles. Some communities, for example, restrict the exterior appearance of homes in residentially zoned areas, although variances are often obtainable. Check the zoning restrictions by contacting the local building inspector, board of supervisors, or planning board. They can specify if a building permit is needed and provide a list of requirements. Condominium and townhouse developments may also restrict installations. An electrical permit is always required.

Most zoning and aesthetic concerns can be addressed by supplying objective data. For example, adding a solar electric system may defer the need for constructing additional power lines in the community. Many solar electric systems may be incorporated within a roof assembly or hidden by the roof or other sections of a building or plantings.

Determine solar resources

Does the sun shine often enough and long enough to make a small solar electric system economically worthwhile? The answer has more to do with the cost of the solar electric system than the amount of sun we receive. It is true that Arizona receives more sun than Minnesota (and that Minnesota receives more sunlight than New York), but the difference is small compared to the cost of the system—being in Arizona versus Minnesota may influence the decision but the costs will ultimately be the major factor. A discussion of solar resources is important, however.

Solar resource maps can be used to estimate the available solar resources. The Minnesota Department of Commerce has created a map by measuring solar insolation, which is the amount of radiation that penetrates the earth's atmosphere and actually reaches the ground.

Solar resource mapping shows that a solar electric system would work well just about anywhere in Minnesota —although some areas of the state have slightly stronger solar resources than other areas of the state, there wasn't a broad range in strength of solar insolation statewide. The values range from 140 watts per square meter in the northern regions of the state up to 165 watts in the southwestern region.

To put the state's solar power into perspective, Minneapolis and Jacksonville, Fla. are nearly equal in terms of estimated annual solar energy production. Minneapolis has a greater summer solar resource than Jacksonville due to longer days and clearer skies, but a much lower winter solar resource. Although Minnesota's solar energy is intermittent, it does have the strongest solar resources when it is needed most—in the summer months when electrical demands for air conditioning are highest.

Local terrain and weather patterns may cause the solar resource at a specific site to differ considerably from these estimates, such as the palisade along the Lake Superior shoreline.

Select the best site

Unobstructed access to the sun for the collector surface is an absolute must for any solar electric system. Obstacles such as trees, houses, utility poles, branches, chimneys, and sheds need to be considered, as well as planning ahead for future obstructions such as new buildings

that are planned or trees that have not reached their full height. The system collectors need to be sited beyond all possible shadows of buildings and trees. Shadows at any time dramatically reduce the performance of solar electric systems and must be avoided to achieve good performance.

Whether the system is stand-alone or grid-connected, the length of the wire run between the system and the load (house, batteries, water pumps, etc.) needs to be taken into consideration. A substantial amount of electricity can be lost as a result of the wire resistance—the longer the wire run, the more electricity is lost. A larger wire reduces these losses but costs more; however, the closer the system to the building, the less this issue needs to be considered. Wire run losses are greater when using direct current (DC) instead of alternating current (AC). So, with a long wire run, it is advisable to consider converting DC to AC.

Select the proper size

The size of the solar electric system needed depends on the application—whether the system will provide supplemental power, back-up power, or power for the entire home or business.

The average home in Minnesota uses about 8,037 kWh per year, or about 670 kWh per month. However, the average energy-efficient home uses much less energy; for example, a home with a high efficiency fuel and electrically efficient air handler plus a natural gas or propane hot water heater can easily use only 3500 kWh per year.

To meet 100 percent of the home's annual energy demand of 8,037 kWh per year, an 8 kW solar electric system would be needed. A 1 kW system can provide about 1000 kWh annually, more or less depending on a specific site. The roof of a typical home can support a 2 to 3 kW solar electric system, so additional sites on the ground would be required. And this system would need to be kept free of snow for good year-round production.

The manufacturer will note the expected annual energy out-put of the system as a function of annual average solar energy available. Also check for the maximum electricity output that the system is designed to operate safely. Systems, including batteries, should have automatic overcharging components to prevent overcharging of batteries.

Solar electric systems used in residential applications can range in size from a few hundred watts to 10 kW depending on the desired amount of electricity. If the solar electric system is to supply energy for the whole house, establish an energy budget to help define the size of system that is needed. Solar electric system dealers can help size the system based on the home's electricity needs (see DOC brochure and list).

Small systems range in size from 20 watts to 1 kilowatt. The smaller (20-500 watt) systems are commonly used in a variety of applications such as charging batteries for recreational vehicles and sailboats as well as supplying power to remote cabins and lighting systems.

Smaller systems can also meet ongoing needs such as pumping water. Farmers and ranchers find that solar electric water pumps as well as solar electric fence systems are versatile tools for farm operations. Solar-electric pumping systems can be connected to the pump motor with an electric cable, permitting flexible installations.

Basic parts of a small solar electric system

Home solar electric systems are generally comprised of a collector or collectors, wiring, controllers, inverters and/or batteries and mounting brackets to optimize the exposure.

The solar electric panels need to be solidly mounted. Mounting racks must be engineered and installed to withstand the elements of wind, ice and snow. Panels can be mounted on the roof of a home, garage or shed or by themselves either on the ground or a pole.

Mounting solar electric systems on rooftops is one option, providing safe and easy access to adjust and service panels. Low angle roofs, such as the White Bear Lake installation mentioned earlier, might accumulate snow on the solar panels reducing electricity production by 2-3 percent annually. One can remove snow accumulation manually if this is considered a major issue.

Stationary mounted panels can also be adjustable, permitting solar electric panels to face the sun as near to perpendicular as possible. Many people adjust their panels two to four times a year, getting maximum exposure as the sun's path rises and falls over the passage of the seasons. The sun is much higher in the sky in the summer and lower in the winter. Solar panels mounted to the same angle as the location's latitude will produce the optimal annual electricity production without having to adjust these angles.

Solar electric panels may also be mounted on a tracking system, which will automatically adjust so that the PV panels face the sun throughout the day. Tracking systems can improve solar electric output by up to 30 percent.

Parts required in addition to the solar panels will depend on the application of the system and whether the system is grid-connected, stand-alone, or part of a hybrid system. Most suppliers can provide an all-inclusive package.

For a residential grid-connected application, the balance of system parts may include a controller, storage batteries (if back-up power is desired), a power conditioning unit (inverter), and wiring. Some solar electric systems will include controllers, inverters or other electrical devices. It is critical that all components be approved by a recognized testing agency, like Underwriters Laboratories (UL), to assure the component meets safety standards.

Equipment for stand-alone systems

A stand-alone or off-grid system, which is not connected to the utility grid, uses batteries to store excess generated power. This system can also be used in hours of darkness, power outages or during high demand. A charge controller is needed to prevent the batteries from overcharging. Deep-cycle batteries, such as those used for golf carts, can discharge and recharge 80 percent of their capacity hundreds of times, which makes them a good option for remote renewable energy systems. Automotive and other shallow-cycle batteries should not be used in renewable energy systems.

Small solar electric systems generate direct current (DC) electricity. In very small systems, such as those serving cabins or remote homes, DC appliances operate directly off the batteries. In conventional housing, most people want to use standard appliances that use alternating current (AC) so an inverter must be installed to convert DC electricity from the batteries to AC. Although the inverter slightly reduces the overall efficiency of the system, it allows the home to be wired for AC, a definite plus with financial lenders and future homebuyers.

For safety, batteries should be isolated from living areas and electronics because they contain battery acids and generate small amounts of flammable gas that need to be vented to the outside to prevent build-up. Lead-acid batteries also require protection from temperature extremes to avoid significant power loss.

Equipment for grid-connected systems

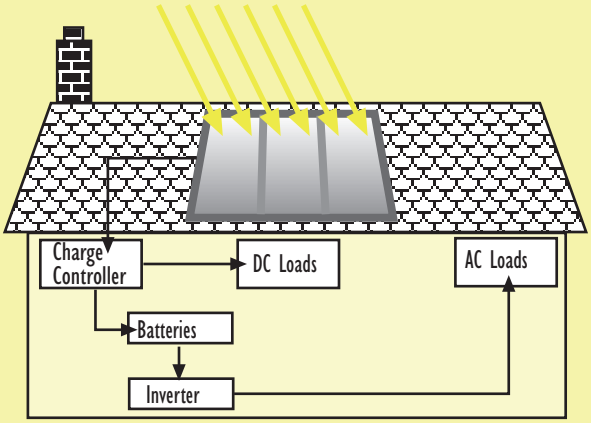
In grid-connected systems, the only additional equipment required is a power conditioning unit (inverter) and switching gear to disconnect the system from the grid in the event of a power outage. Batteries added to this configuration provide a power supply during power outage situations. Power conditioning equipment is needed to make solar electric system output electrically compatible with the utility grid.

Mounted and tracking solar electric panels

Stationary mounted panels can be adjustable, permitting the panels to face the sun as near to perpendicular as possible.

Solar electric panels may also be mounted on a tracking system, which will automatically adjust so that the PV panels face the sun throughout the day.

Basic Parts of a Small Solar Electric System



PV equipment exempt from state sales tax

To help boost the development of renewable energy generation, a photovoltaic device is now exempt from Minnesota state sales tax.

A photovoltaic device is defined as a solid-state electrical device, such as a solar module, that converts light directly into direct current electricity of voltage-current characteristics that are a function of the characteristics of the light source and the materials in and design of the device.

A "solar module" is a photovoltaic device that produces a specified power output under defined test conditions, usually composed of groups of solar cells connected in series, in parallel, or in series-parallel combinations.

The tax exemption is in effect for purchases made after July 31, 2001, and before August 1, 2005. For more information, the statute citation is: Minnesota Session Laws 2001, 1st Special Session, Chapter 5, Article 12, Sec. 44.

Questions about sales tax payments should be directed to the Minnesota Department of Revenue, Sales & Use Tax Hotline, at (651) 296-6181 or 1-800-657-3777.

Rebate program reduces PV costs

In an effort to spark development of solar energy, the Minnesota Department of Commerce State Energy Office is administering a rebate program that could pay up to 25 percent of installation costs for a photovoltaic system.

The program provides a rebate of $2,000 per kilowatt for 1 to 4 kilowatts of grid-connected systems. Applications must be made before the installation begins, and rebates will be issued once installation is completed and inspected.

An example of how the program will reduce installation costs: A person who installs a 2kW system, an estimated cost of $20,000, would get a rebate of $4,000.

The rebate program is funded by Xcel Energy's Renewable Development Fund, one of the requirements stemming from the 1994 Prairie Island Nuclear Power Plant legislation. During the four-year program, approximately $1 million will be spent to install 400 kilowatts of grid-connected photovoltaic systems.

For more information on the rebate program, email the Energy Information Center at energy.info@state.mn.us or call 651-296-5175 or 1-800-657-3710. Information is also available on the web site at www.commerce.state.mn.us.

The cost of solar electric systems

Solar energy becomes more cost effective as the cost of electricity increases. Although smaller electric systems cost less in initial outlay, they are proportionally more expensive.

A small solar electric system can cost anywhere from $3,000 to $35,000 installed, depending on size, application and service agreements with the manufacturer. According to the American Solar Energy Association, the average cost for a typical home solar electric system is approximately $10 per watt (installed).

Although solar electric systems involve a significant initial investment, they can be competitive with conventional energy sources when considering a lifetime of reduced or avoided utility costs.

The length of the payback period—the time before the savings resulting from the system equals the cost of the system itself—depends on several factors including:

- the system selected,
- tax benefits or exemptions,
- potential rebates,
- production credits from the state and federal governments,
- electricity cost in the area, and
- how the solar electric system is used.

Things to consider when purchasing a solar electric system

As with any major purchase, shop comparatively for a solar electric system and get at least three bids. Review product literature from several manufacturers and read product reviews in trade magazines.

Narrow the field to a few companies and do more research to be sure they are recognized solar energy businesses and that parts and service will be available when needed. Ask for references of past customers with similar installations and contact the Better Business Bureau to check the company's integrity. Ask other system owners about performance, reliability, maintenance and repair requirements and whether the system is meeting their expectations. Also, find out the length of the warranty and what is included. The state electrical code requires that a solar electric system be inspected before activated.

For more information see the publication "Choosing a Renewable Energy Contractor," available from the Minnesota Department of Commerce Energy Information Center.

Installation and maintenance

Many manufacturers and dealers also offer installation and maintenance services. A list of installers may be available from the manufacturer, the local utility or the phone book. The Department of Commerce State Energy Office also maintains a list of dealers and installers, but does not endorse or recommend specific companies.

A credible installer will provide many services such as obtaining necessary permits. As a general rule the Department of Commerce State Energy Office recommends installation by a trained licensed electrical contractor or licensed electrical professional.

Choosing to self-install

Some people elect to install the systems themselves. When deciding to self-install, first consider the following questions:

- Can you install the panel mounting system on roof or yard?
- Do you know the difference between AC and DC wiring?
- Do you know enough about electricity to safely wire the system?
- Do you know how to safely handle and install batteries?

If the answer is no to any of the above questions, the system should probably be installed by a system integrator or installer, including a licensed electrician or licensed electrical contractor.

Although small solar energy systems are very simple devices, they do require some maintenance. If you do not have the expertise to maintain the system, an installer may provide a service and maintenance program.

Bolts and electrical connections should be checked and tightened if necessary. The mounting components should be checked for corrosion and for proper angle tension. With proper installation and maintenance, the system should last up to 30 years or longer.

Grid-connected systems

Small solar electric energy systems connected to the local utility's electricity distribution system and are called grid-connected systems. A grid-connected solar electric system can reduce consumption of utility-supplied electricity for lighting, appliances and other uses. If the solar electric system cannot deliver the full amount of energy needed, the utility makes up the difference. When the solar electric system produces more electricity than the household requires, the excess is sent or sold to the utility (see sidebar on Net Metering).

Grid-connected systems can be practical if the following conditions exist:

- Utility-supplied electricity is expensive (about 10 to 15 cents per kilowatt-hour) or the net cost of the system is reduced by a rebate.
- The cost and requirements for connecting the solar electric system to the grid are not prohibitively expensive.
- There are good incentives for the sale of excess electricity or for the purchase of solar-generated electricity. (Average retail rate of the utility combined with any other production incentive)

Federal regulations (specifically, the Public Utility Regulatory Policies Act of 1978, or PURPA) require utilities to connect with and purchase power from small solar electric energy systems. However, contact the utility before connecting to their distribution lines to address any power quality and safety concerns. The utility can provide a list of requirements for connecting a solar electric system to the grid. The American Solar Energy Association is another good source for information on utility interconnection requirements.

Net Metering

A net metering program allows the electric meters of customers with generating facilities to turn backwards—and send electricity back into the grid—when a customer's generator produces more energy than is used. Net metering allows customers to offset their electricity consumption over the entire billing period, not just instantaneously. This offset enables customers with generating facilities to receive retail prices for the excess electricity they generate.

Safety Requirements

Whether or not the solar electric system is connected to the utility grid, the installation and operation of the solar electric system is subject to the State Electrical Code.

The state's principal concern is with the safety of the system, so code requirements emphasize proper wiring and installation and the use of components that have been certified for fire and electrical safety by approved testing laboratories, such as Underwriters Laboratories (UL).

Electrical code requirements are based on the current National Electrical Code (NEC), which is published by the National Fire Protection Association. Solar electric energy installations are governed by the NEC.

If the solar electric system is connected to the local utility grid, then the utility also has legitimate concerns about safety and power quality that need to be

addressed. The utility's principal concern is that a customer's solar electric system automatically stops delivering any electricity to its power lines during a power outage. Otherwise, line workers and the public, thinking that the line is "dead," might not take normal precautions and might be hurt or even killed by the power supplied from a private electric system.

Another concern among utilities is that the power from a small solar electric system needs to synchronize properly with the utility grid and match the utility's own power in terms of voltage, frequency and power quality.

Interconnection Requirements

Most utilities and other electricity providers require customers with private energy systems to sign a formal agreement before allowing customers to interconnect to the utility grid. The terms and conditions in these agreements must be reviewed and approved by state regulatory authorities.

Insurance

In Minnesota, net metering rules allow utilities to require owners of renewable energy electric generation systems that are connected to the utility's grid to maintain $300,000 in liability insurance. This is generally found as part of a Homeowners Insurance Policy or may be added to that policy. An insurance agent or company can provide a statement of coverage to give to the utility. Utilities consider these requirements as necessary to protect them from liability for facilities they do not own and have no control over. In the 21 years since utilities have been required to allow small solar systems to interconnect with the grid there has never been a liability claim relating to electrical safety. Each utility decides whether to require insurance.

Indemnification

An indemnity is an agreement between two parties in which one party agrees to secure the other party against loss or damage arising from some act or some assumed responsibility. In the context of customer-owned generating facilities, utilities often want customers to indemnify them for any potential liability arising from the operation of the customer's generating facility.

Although the basic principle is sound—utilities should not be held responsible for property damage or personal injury attributable to someone else—indemnity provisions should not favor the utility but should be fair to both parties. Look for language that says, "each party shall indemnify the other . . ." rather than "the customers shall indemnify the utility . . ."

Utility customer charges

Customer charges can take a variety of forms, including interconnection charges, metering charges and standby charges, among others. Do not hesitate to question any charges that seem inappropriate. Federal law (Public Utility Regulatory Policies Act of 1978, or PURPA, Section 210) prohibits utilities from assessing discriminatory charges to customers who have their own generation facilities.

Hybrid Systems

Hybrid wind and solar energy systems can provide reliable off-grid power for homes, farms or even entire communities (a co-housing project, for example) that are located far from the nearest utility lines. According to many renewable energy experts, a "hybrid" system that combines wind and solar electric technologies offers several advantages over either system alone.

In Minnesota, wind speeds are low in the summer when the sun shines brightest and longest. Conversely, the wind is strong in the winter when there is less sunlight available. Because the peak operating times for wind and solar electric systems occur at different times of the day and year, hybrid systems are more likely to continually produce power when needed.

When neither the wind turbine nor the solar modules are producing electricity, most hybrid systems provide power through batteries and/or a small auxiliary backup engine-generator powered by conventional fuels, such as gasoline, diesel or even biodiesel. If the batteries run low, the engine-generator can provide power and recharge the batteries.

Adding an engine-generator makes the system more complex, but modern electronic controllers can operate these systems automatically. An engine-generator can also reduce the size of the other components needed for the system. Keep in mind that storage capacity must be large enough to supply electrical needs during non-charging periods. Battery banks are typically sized to supply the electric load for three to four days without sun, wind or recharging.

An off-grid hybrid system may be practical if:

- the location has an average annual wind speed of at least 9-mph (4.0 m/s),
- the location has unobstructed sunlight,
- a grid connection is not available or can only be made through an expensive extension; the cost of running a power line to a remote site to connect with the utility grid can be prohibitive, ranging from $15,000 to more than $50,000 per mile,

depending on terrain,
- there is a personal desire for energy independence from the utility,
- there is a personal desire to generate clean power; and/or
- a backup power supply is needed in the event of power outages.

Conclusion

Solar electricity for a home or business is one of several energy options in Minnesota. Energy can be generated to meet all or part of the demand, or become a net generator and potentially sell extra power to the local utility. Deciding whether a solar electric system is feasible depends on many factors; for best results, conduct careful research and make some economic decisions before proceeding with plans.

This off-grid home near Red Wing, Minn., combines wind and solar power. On the roof are five solar thermal collectors for space heating and domestic hot water needs, and two skylights provide day lighting and passive solar heat of the upstairs. A PV panel array will be installed on a pole-mounted tracker in summer, 2003. Annual production data for the home, completed in 2002, is not available yet. The home exceeds the energy code by 50 percent and incorporates energy-efficient and environmentally sustainable features. An ethanol-fueled generator provides back-up power to the home.

Glossary of Terms

Ampacity—The current, in amperes, that a conductor can carry continuously under the conditions of use without exceeding its temperature rating.

Ampere-hour—A unit for the quantity of electricity obtained by integrating current flow in amperes over the time in hours for its flow; used as a measure of battery capacity.

Converter—A device the converts direct current (DC) to alternating current (AC). Also called an inverter.

Grid—The utility distribution system that connects electricity generators to electricity users.

Inverter—A device the converts direct current (DC) to alternating current (AC). Also called a converter

W—watt, a measure of power for electrical current equal to 3.4 Btu's

kW—Kilowatt, a measure of power for electrical current (one thousand watts).

kWh—Kilowatt-hour, a measure of energy equal to the use of one kilowatt in one hour.

MW—Megawatt, a measure of power (one million watts).

O&M Costs—Operation and maintenance costs.

PUC—Public Utility Commission, a state agency which regulates utilities.

PURPA—Public Utility Regulatory Policies Act (1978), 16 U.S.C. § 2601.18 CFR § 292 that refers to small generator utility connection rules.

Rated output capacity—The maximum output power of a solar electric panel operating in sunlight of 1000 W/m2 .

For More Information

Books

The Solar Electric House: A Design Manual for Home-Scale Photovoltaic Power Systems This book helps homeowners decide if photovoltaics are for them, how to choose the right system and determine if they want to install it themselves. By Steven J. Strong with William G. Scheller, Sustainability Press, 1987 (revised 1991), 276 pages, $21.95, ISBN 0-9637383-2-1.

Solar Electric Independent Home Meant to educate and spread the use of PV, this book was written specifically for the PV homeowner or the potential PV homeowner. Chapters on system sizing, appliances, home wiring, system installation, lighting protection and the National Electrical Code, explain how to use a PV system for greatest efficiency. By Paul Jeffrey Fowler, revised 1993, 200 pages, 25 photos, 75 CAD diagrams, $16.95, ISBN 1-879523-01-9.

The New Independent Home: People and Houses that Harvest the Sun, Wind and Water The Independent Home has become a best seller. Profiles solar homesteaders whose experiments and innovations have opened the possibility of solar living for the rest of us. By Michael Potts, Chelsea Green Publishing, 1993 (revised 2000) 416 pages, illus., color photos, $30.

Government Agencies

The Energy Information Center at the Minnesota Department of Commerce State Energy Office provides energy efficiency and renewable energy information to consumers. The Home Energy Guide series offers simple but detailed information about improving energy efficiency in the home. Many publications are available about renewable energy resources. Experts are also available to answer individual questions by phone or email. For more information visit the Department of Commerce web page at: www.commerce.state.mn.us, e-mail at: energy.info@state.mn.us, or call: 651-296-5175 or 1-800-657-3710 (Minnesota only).

Energy Savers Tips on Saving Energy and Money at Home A homeowner's guide for saving energy and reducing utility bills. Available free from U.S. Department of Energy's Energy Efficiency and Renewable Energy Clearinghouse (EREC), P.O. Box 3048, Merrifield, VA 22116. Phone: (800) 363-3732. Web site: http://www.eren.doe.gov/consumerinfo/energy_savers.

Energy Efficiency and Renewable Energy Clearinghouse P.O. Box 3048, Merrifield, VA 22116. Phone: 1-800-DOE-EREC (363-3732). Web site: http://www/eren.doe.gov.

National Climatic Data Center Federal Building 151 Patton Avenue, Asheville, NC, 28801-5001. Phone: (828) 271-4800. Web site: http://www.ncdc.noaa.gov.

U.S. Department of Commerce, National Technical Information Service 5285 Port Royal Road, Springfield, VA 22161. Phone: (800) 553-6847. Web site: http://www.ntis.gov/ordering.htm.

Non-Government Organizations

American Solar Energy Society 2400 Central Avenue, Suite. G-1 Boulder, CO 80301 Phone: 303-443-3130. Email: ases@ases.org. Web site: http://www.ases.org.

Interstate Renewable Energy Council, P.O. Box 1156, Latham, NY 12110-1156. Phone: 518-458-6059. Email: info@irecusa.org. Web site: http://www.irecusa.org/index.html.

Midwest Renewable Energy Association (MREA) A nonprofit network for sharing ideas, resources, and information with individuals, businesses and communities to promote a sustainable future through renewable energy and energy efficiency. Host of the annual Renewable Energy and Sustainable Living Fair. This three-day festival is the world's largest venue to learn about renewable energy, energy efficiency, and sustainable energy systems. The Fair offers more than 100 workshops presented by experts from across the US and working demonstrations of renewable energy and energy efficiency technologies. 7558 Deer Road, Custer, WI 54423 Phone: 715-592-6595. Email: info@the-mrea.org. Web site: www.the-mrea.org.

Minnesota Renewable Energy Society (MRES) Established in 1978, MRES is a locally-based, non- profit organization committed to developing awareness and use of renewable energy sources across Minnesota. 1916 2nd Ave South, Minneapolis, MN 55403-3927. Phone: 612-872-3285. Web site: http://freenet.msp.mn.us/org/mres/

Solar Electric Power Association (SEPA) A collaboration of utilities, energy service providers and the photovoltaic industry working together to create and encourage commercial use of new solar electric power. 1800 M Street, N.W., Suite 300 Washington, DC 20036-5802. Phone: (202) 857-0898. Email: SolarElectricPower@ttcorp.com. Web site: http://www.solarelectricpower.org/

Periodicals

Solar Today An award-winning bimonthly magazine that covers all solar technologies, from photovoltaics to climate-responsive buildings to wind power. Regular topics include building case studies, energy policy and community-scale projects. Published by the American Solar Energy Society. 2400 Central Ave., G-1, Boulder, CO 80301. Phone: 303-443-3130. Web site: http://www.ases.org.

Home Power Magazine The definitive magazine for the homemade power enthusiast, published bimonthly. PO Box 520, Ashland, OR 97520 Phone: (800) 707-6586. Web site: http://www.homepower.com.

Web Sites

Minnesota Department of Commerce, State Energy Office, Energy Information Center

A Minnesota clearinghouse for energy efficiency and renewable energy information and resources within Minnesota. E-mail: energy.info@state.mn.us. Web site: www.commerce.state.mn.us

The American Solar Energy Society (ASES) Provides answers to frequently asked questions and information on all aspects of solar energy. Web site: http://www.ases.org

Database of State Incentives for Renewable Energy A comprehensive source of information on state, local, utility and selected federal incentives that promote renewable energy. A project of the Interstate Renewable Energy Council (IREC) http://www.dsireusa.org/

Green Power Network Net Metering Web Site. Net metering programs are now available in 30 states. http://www.eren.doe.gov/greenpower/netmetering

Solar Energy for Homeowners Offers things to consider before investing in a small solar energy system and also basic information about the systems. http://www.eren.doe.gov

National Renewable Energy Laboratory The U.S. Department of Energy's premier laboratory for renewable energy research & development and a lead lab for energy efficiency research and design. http://www.nrel.gov

This solar-powered lighting system is owned and operated by the Minnesota Department of Natural Resources and provides lighting at a remote public access point.

This publication is adapted from "Small Wind Energy Systems" produced for the U.S. Department of Energy by the National Renewable Energy Laboratory, a DOE Laboratory. DOE/GO-102001-1293 ay 2001