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.

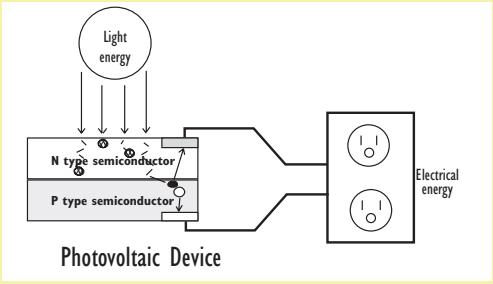
Depending on the solar resource availability and the home's electric energy consumption, a small solar electric system can lower electricity bills by 50 to 90 percent, prevent power interruptions and avoid the high costs of extending utility power lines to remote locations.

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

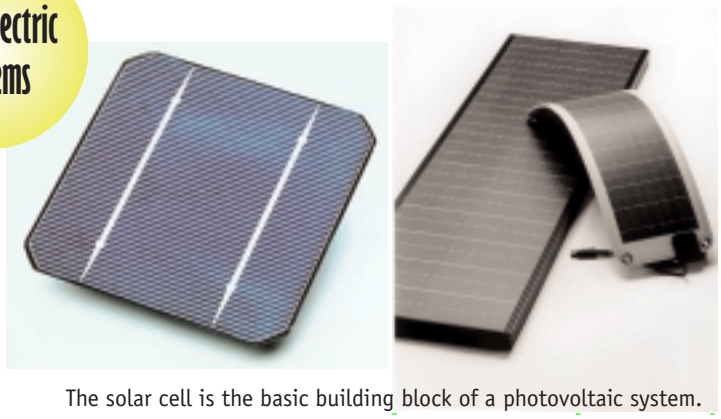
Increase solar energy usage by increasing energy efficiency

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

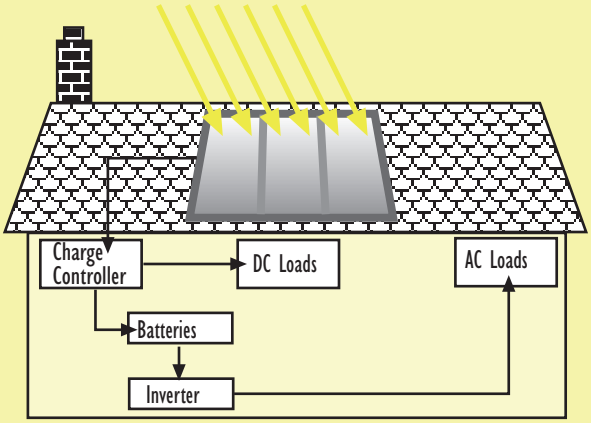
In grid-connected systems, the only additional equipment required is a power conditioning unit (inverter) and switching gear to disconnect the system from the grid in the event of a power outage. Batteries added to this configuration provide a power supply during power outage situations. Power conditioning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

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