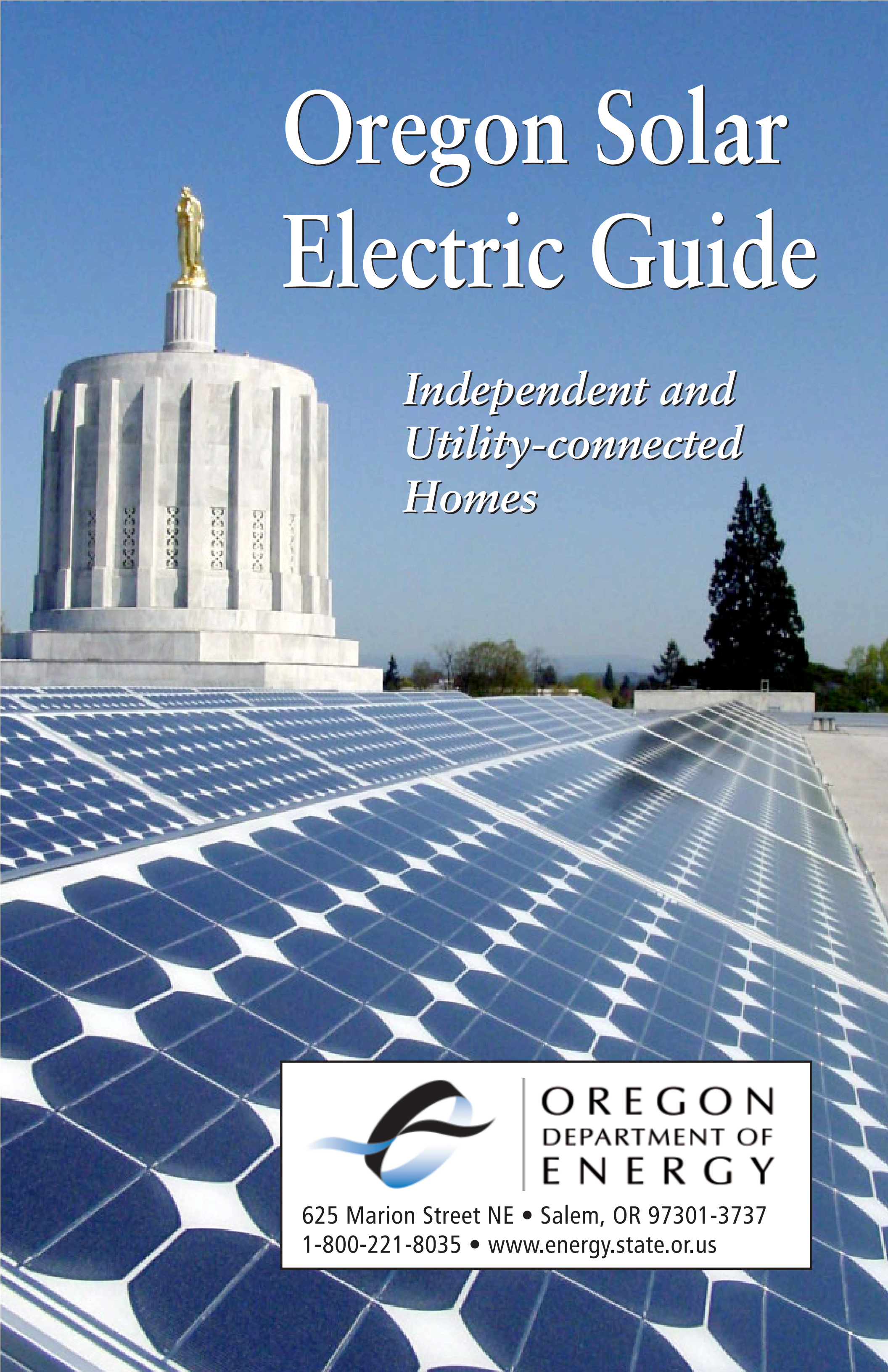

Oregon Solar Electric Guide

Independent and Utility-connected Homes

OREGON
DEPARTMENT OF
ENERGY

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Contents

Introduction

Solar electric power generated with "photovoltaics," or "PVs," is used in thousands of applications throughout the Northwest. These applications vary from road-side signs to high-mountain communications towers, and from hand-held calculators to entire ranches.

Say "PEE-VEE"

or

"Photo-vole-tay-ick"

This guide focuses on the use of solar electricity in homes and small businesses. It provides basic information about system components and what to expect when shopping for a solar electric system.

This is *not* a technical guide. For information on designing or installing a solar electric system, contact your local solar electric installer or consultant, or check the Web sites listed on page 41.

Figure 1 — Solar powered 1929 home in Salem

Photo courtesy of Cascade Solar Consulting

Figure 2 — Utility-independent solar electric home

Why do people buy solar electric systems?

People buy solar electric (PV) systems for a variety of reasons. Some want to be good stewards of the Earth's ecosystem by choosing a clean, renewable energy resource. Others believe that it makes more sense to invest their money in an energy-producing improvement to their property than to send their money off to a utility. Others seek the added security of a backup power system and consistently higher-quality power (more uniform voltage with less distortion). For homes located more than half a mile from existing electric utility power, a PV system generally costs less than running a generator or extending utility service to the property. Finally, some people just like the feeling of independence provided by a PV system.

You don't have to know quantum physics to understand the appeal of photovoltaics. PVs allow you to produce your own electricity with no noise, no air pollution and no moving parts while using a clean, renewable resource that comes free of charge to any location. A PV system will never run out of fuel, and it won't increase oil imports. It might not even contribute to the trade deficit, because many PV system components are manufactured in the United States.

For these and many other reasons, solar energy is widely considered the energy source of choice for the future, and Oregonians have a unique opportunity to take advantage of several statewide programs to help make it their energy choice.

How much does a PV system cost?

Solar electric power is expensive. If the up front cost of these systems are spread over 30 years, the cost of the electricity produced would be several times that of local NW utility power. Thus, if you already have utility power and your sole motivation for buying one electric power source over the other is cost — solar electric power is not for you. If your energy needs are where utility power is unavailable, solar electic power can be the cheapest option, since once the first cost is covered, the energy received is free.

Photo courtesy of Energy Smart Systems

Figure 3 — Solar in Beaverton

The good news is that the price of systems have dropped 1,700 percent over the past 40 years, and 50 percent over the past 10 years. Most PV modules come with a performance warranty of 25 years, making them the longest lasting energy generator known. They operate without moving parts, without generating pollution, without noise and with essentially no required maintenance. PV systems are modular, allowing you to start small and add on as your needs (or pocket book) grows.

For business and residential systems, financial incentives are available from the state and federal governments, and from some utilities.

In 2006, the typical cost of a grid-tied PV system ranged from $8-$9 per watt of direct current (DC). Off-grid or battery back-up systems range in price from $9 to $12 per watt DC.

How much energy is produced?

The amount of energy produced depends mostly on how large of a system is installed. Other impacts such as location and external shading must be included for a truly accurate estimate of the energy produced. A quick rule of thumb is that in the "cloudy" areas of Oregon, you can expect to generate about 1,000 kilowatt hours (kWh) for every 100 square feet of collector area you install. In the "sunny" areas of Oregon, this increases to about 1,250 kWh. Thus, if you pay seven cents per kWh, this would reduce your bill by $70 to $100 per year for each 100 square feet of collector area installed.

Does Oregon get enough sun for a PV system?

Yes. In fact, the Willamette Valley receives as much solar energy *annually* as the U.S. average — the same average as southern France. Eastern and Southern Oregon receive 20 to 30 percent more than the Willamette Valley — as much as or more than Florida.

Under cloudy conditions, photovoltaics produce 10 to 30 percent of their maximum output. However, because solar photovoltaics become less efficient when hot, our cooler climate helps make up for the cloudy days. With our cooler temperatures and longer summer days, a PV-powered stock-water pumping system in eastern Oregon will actually pump more water than an identical system in Phoenix, Arizona.

What happens at night?

For homes connected to an electric utility, the PV system provides some or all of your energy when the sun is shining. Any remaining electricity needs are automatically provided by your power company. For homes not connected to an electric utility, the PV system provides all your power. Such systems rely on batteries to store PV-generated energy for when the sun isn't shining, and small gas- or diesel-powered electric generators during extended cloudy periods. For direct water-pumping applications, the amount of water being pumped is proportional to how much sun is shining on the PV modules; therefore, unless connected to battery storage, no water is pumped at night.

Can I install a PV system myself?

Yes. However, you must have the skills and tools necessary to mount the modules on your roof or a pole-mounted tracking system and to perform basic electrical wiring. As a homeowner, you can "pull" the necessary permits yourself; however, you still must meet all building and electrical codes. Many systems today come as almost completely pre-assembled "panels" or "boxes," which greatly reduce the number of connections you need to make.

Lists of experienced Oregon solar contractors can be found on the following web sites:

- **www.oregon.gov/energy/renew/solar**
- **www.oregonseia.org**
- **www.energytrust.org**

Are financial incentives available in Oregon?

Yes! The state provides tax credits and low-cost loans. The federal government offers tax credits and accelerated depreciation. For more details, turn to the "Getting Help" section on page 38.

Solar Electric System Basics

Photovoltaics

PV technology converts sunlight directly into electricity. Electrons are excited by particles of light and driven toward

Photo courtesy of New Path Renewables

Figure 4 — One of Oregon's largest PV arrays in Bend

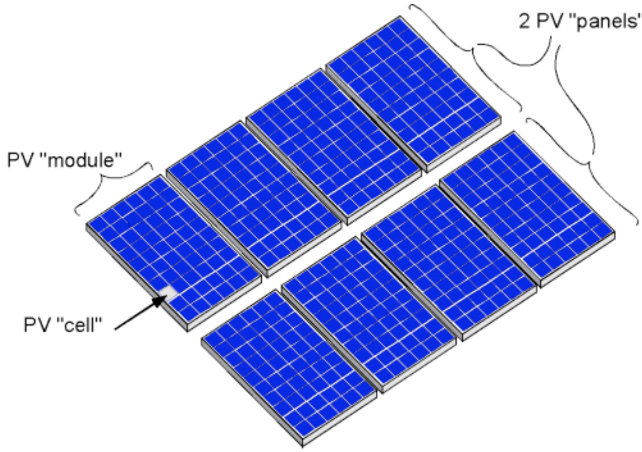


Figure 5 — A PV array is composed of one or more panels.

the surface of the PV cell by an electric field inherent in the semiconductor material of the PV cell. The more sunlight striking the PV cell, the more electricity produced.

The basic building block of PV technology is the solar "cell." PV cells are wired together and placed in a frame to form a PV "module." Modules are wired together in groups of similar voltage called "panels." The collection of one or more panels form the PV "array."

Modules come in different sizes and range from about 10 to 300 watts in power output. Peak output is the amount of power they deliver under conditions similar to a cloudless day. The wattages listed in catalogs are determined under "Standard Test Conditions" (STC). STC values are somewhat generous. Real world conditions typically result in 10 to 15 percent less energy produced under full sun.

A variety of materials and construction types are used to make photovoltaics. The most common types on the market today are crystalline-silicon, amorphous-silicon and thin-film photovoltaics. Crystalline-silicon PVs (both single- and poly-crystalline) are more efficient than amorphous-silicon PVs. However, amorphous-silicon PVs use less of the expensive silicon, and as a result may cost less for the same amount of power. Be aware that performance warranties offered by amorphous-silicon and thin-film photovoltaics manufacturers are currently shorter than those offered on crystalline-silicon

PVs, and because they have lower efficiencies, will require greater surface areas.

Solar energy basics

The first consideration is whether your property has good access to the sun. Good solar access means the sun's path from about 9 A.M. until 3 P.M. is unobscured by trees, roof gables, chimneys, buildings and other features of your home and the surrounding landscape. Even though an area is unshaded during one part of the day, it might be shaded during another. Such shading could substantially reduce the amount of electricity your system can produce.

Photo courtesy of Wind Stream Solar

Figure 6 — East- and west-facing collectors are okay if the roof slope is not too steep.

Make an initial solar access assessment of the site. Figure 7 shows how the sun moves across the sky at different times of the

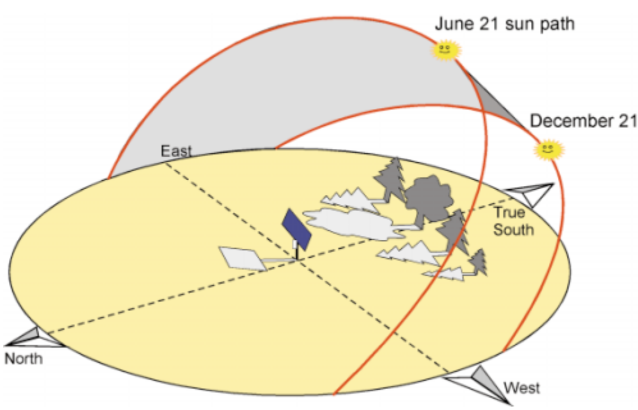
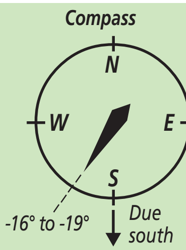


Figure 7 — The sun's path through the sky changes seasonally.

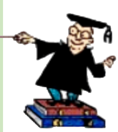
year. The sun is higher in the summer and lower in the winter. Remember that trees grow — a tree that seems small today could block your solar access in the future. If the site looks promising, your Solar contractor has the tools necessary to trace the sun's path at your location and determine more precisely the impact of shading from trees or other structures.

PV modules are very sensitive to shade. Unlike a solar water-heating panel, which can tolerate some shade, most brands of PV modules suffer dramatic losses in output when shaded by even a single branch of a leafless tree. A clearly defined shadow from a nearby object can actually make the shaded portion of the module draw power instead of producing it. Soft shading from a distant object such as a cloud or a tree causes a less dramatic reduction in power. In the fall, be sure to keep leaves off your array!

Mounting systems



True south is not the same as magnetic south. In Oregon, true south lies 16-19 degrees east of magnetic south, so adjust your compass accordingly.



Your PV system will generate the most energy when it is perpendicular to the sun's rays. The best way to

Photo courtesy of Cascade Solar Consulting

Figure 8 — Tracking pole mount

Figure 9 — Fixed roof mount

accomplish this is to mount the array on a tracking system that follows the sun as it moves across the sky. Because of our long summer days, a system with a tracking PV array will produce 25 to 35 percent more energy than a fixed array of the same size. However, the disadvantage of tracking arrays is that they require (minimal) maintenance and are unattractive on rooftops. Trackers are best used for applications such as summer water pumping, where making the best use of our longer summer days is more important than aesthetics.

A fixed mounting system remains pointed in one direction and can be aesthetically appealing when mounted flush to the roof. It also requires no maintenance. By adding a few extra modules to a fixed mounting system, you can get output equivalent to that of a tracking system.

Figure 10 — Fixed ground mount

A common question asked about fixed mounting systems is how the relative tilt (slope) and orientation (compass direction) affect performance. If you're trying to optimize wintertime performance, such as for an off-grid home, it's important to face the array toward true south and at about a 45-degree tilt. If you're trying to optimize annual performance, the orientation is much less important. An east- or west-facing array will result in only a 10- to 15-percent reduction in collected energy if the slope (tilt) of the array is low (10 to 30 degrees) compared to the best possible south-facing slope. For optimum annual performance, face the array in a southerly direction toward the area of the sky with the least shading.

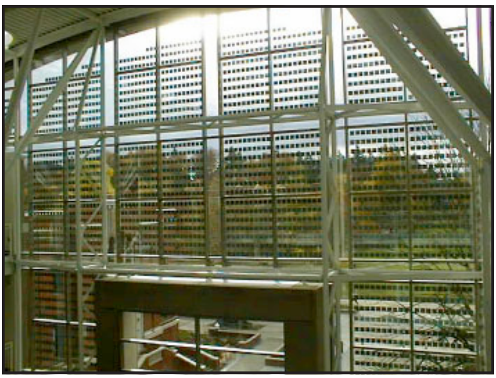


Figure 11 — University of Oregon's Lillis building shows PV cells integrated into vertical glass.

The space needed for your solar system is based on how much energy you wish to generate. Most residential systems require between 50 and 300 square feet of area. A rule of thumb is that a square foot of crystalline-silicon PV module area produces 10 watts of power in bright sunlight. For amorphous-silicon PV modules, you'll need roughly twice as much surface area. Thus, a 1,000-watt crystalline-silicon system requires about 100 square feet of roof area; a 1,000-watt amorphous-silicon system requires about 200 square feet.

For roof-mounted systems, keep in mind that some roof types are simpler and cheaper to work with than others. Typically, composition-shingle roofs are the easiest to work with and slate or tile roofs are the most difficult. In any case, an experienced solar installer should know how to work on all roof types and should use roofing techniques that eliminate any possibility of leaks. A roof mount also must provide several inches of clearance between the roof and the array, to allow air to cool the array and keep debris from collecting underneath it.

If your roof is older and needs to be replaced within the next 5 to 10 years, you should replace it at the same time you have the PV system installed. This will prevent having to remove and reinstall your PV system and will allow better integration of the roof mounts into your roof.

Figure 12 — Roof integrated thin-film modules

More innovative PV systems integrate PV cells into the roofing material (see figure 12), allowing the roof to collect energy while keeping the weather out. These and other building-integrated photovoltaic (BIPV) products are gradually reaching the market, and although they currently are more expensive, they might be worth asking your solar contractor about.

System life and maintenance

The operating life of components within different systems varies. The PV module is the most reliable component in any PV system. PV modules are engineered to withstand extreme temperatures, severe winds and impacts from one-inch diameter hail. PV modules have a life expectancy of 25 to 30 years, and manufacturers warrant them against power degradation for 10 to 25 years. PV modules require no care other than keeping them clear of snow, leaves and large bird droppings. Dust build-up is removed by rain.

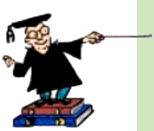
The electronic components (wires, fuses, charge controllers, inverters) used in solar electric systems generally come with two-year warranties and a life expectancy of 10 to 50 years. Tracking systems should be inspected regularly and should receive periodic maintenance. Inverters and other control equipment are essentially maintenance-free, but should be visually inspected per the manufacturer's recommendations.

For most batteries, you'll have to add water to the batteries every few months. Battery life expectancy ranges from 3 to 15 years, depending on individual system design and use.

Permit requirements

Some locations with homeowners' associations require you to gain approval from an architectural committee for a solar installation, to comply with "Covenants, Codes and Restrictions" (CC&Rs). You or your solar contractor might have to submit system plans to this committee and obtain approval from your neighbors before installing the system. Be sure you comply with CC&Rs before installing your PV system.

You'll also have to obtain various permits, in most cases from your city or county building department. You'll probably have to purchase a building permit, an electrical permit or both to legally begin installing a PV system. Typically, your solar contractor will take care of this task, rolling the price of the permits into the overall system price. However, in some cases your solar contractor might not know how much time or money will be involved in "pulling" a permit. Therefore, the permitting task might be priced on a "time and materials" basis, particularly when additional drawings or calculations must be provided to the permitting agency. In any case, make sure your solar contractor addresses the permitting costs and responsibilities at the outset.



PV Systems can produce a lot of power. Safety is important!

The Oregon Electrical Specialty code specifies requirements for installing a PV system. These requirements are based on the National Electrical Code (NEC) Article 690, which spells out requirements for designing and installing safe, reliable, code-compliant PV systems. If you're among the first in your community to install a grid-connected PV system, your local government might never have permitted one of these systems, and the building inspector might never have seen one. If this is the case, you and your solar contractor can speed the process by working closely and cooperatively with your local building officials to help educate them about the technology.

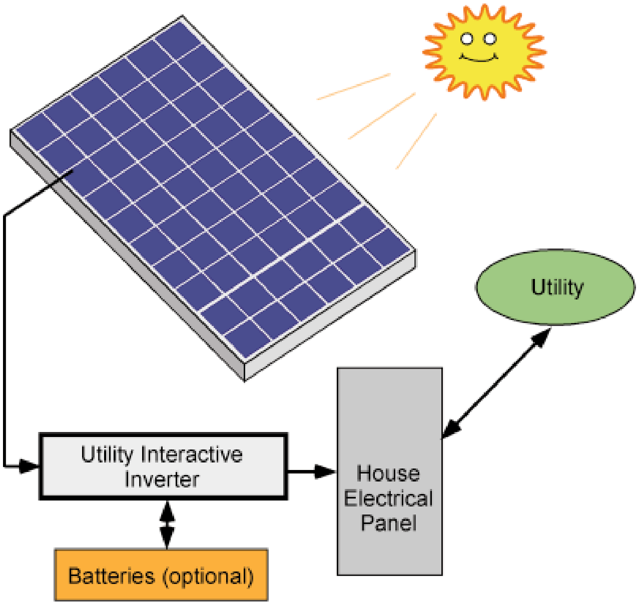


Figure 13 — Schematic of a utility-connected system

The size of your PV system is measured by the watts it produces under full sunlight. Table 1 (page 17) shows how many kilowatt-hours (kWh) are delivered by a 1,000-watt grid-connected system for several locations in Oregon, Washington and Idaho.

Utility-connected Solar Electric Systems

Utility-connected systems, sometimes called "grid-connected" systems, are for homes or commercial buildings that are connected to an electric utility. They are designed to provide a portion of the building's total electricity needs. These systems generate the same alternating current (AC) electricity provided by your utility and work interactively with utility power to maximize the output of your solar array. (See system diagram — figure 13)

The basics

Advances in solar power electronics make it relatively easy to connect a solar electric system to the utility. Energy generated by such a system is first used within your home, and surplus power is "pushed" onto your utility's wires. Under Oregon's new net-metering law, local utilities are required to allow you to "spin your meter backward" when using less electricity than your PV system produces (more on this later).

Figure 14 — Renewable solar energy on a Grants Pass home

A utility-connected system is composed of just two main components: the PV array and the utility-interactive inverter. A utility-interactive inverter is capable of both converting the DC power from the PV array to standard AC power and synchronizing that power with your utility's electricity.

Many systems are equipped with a battery and charge controller. This allows the system to provide backup power during utility power failures. Adding a battery will decrease the performance of your system 10 to 15 percent.

System sizing and annual output

Unlike a stand-alone solar electric system, a utility-connected system doesn't have to provide 100 percent of your daily energy needs. You can size the system according to your own desires and budget. When sizing your system, consider your budget, where your array can physically fit, what fraction of your energy you want from solar, and the availability of financial incentives.

The size of your system is typically described by the watts (power) that it can deliver under full sun. Some vendors may refer to DC watts, which the PV modules can produce under near ideal conditions. Table 1 shows how many kilowatt-hours (energy) are delivered for each watt (DC) installed.

If you want to find out how large a system you need to meet one-third of your household electricity, first find out your annual electricity use by multiplying your average daily energy use by 365 days. Next, divide this number by 3, then divide again by the appropriate value from Table 1 to get watts DC.

Example: A house in Eugene that uses 22 kWh per day would use 8,030 kWh per year. To provide one third of the annual electric energy, the system would need to provide 2,677 kWh per year. Assuming the array is not shaded, it would require approximately a 2,400-watt array. The result is how

Watts DC (input) are not the same as watts AC (output).

*Table 1 — Average annual energy output per DC watt installed**

Annual delivered energy (kWh per watts DC)

Location	Fixed	Tracking
North Coastal (Astoria)	1.02	1.30
South Coastal (North Bend)	1.25	1.63
Willamette Valley (Eugene, Portland)	1.14	1.52
South Western (Medford)	1.32	1.80
North Eastern (Pendleton)	1.30	1.81
Central (Bend)	1.42	1.99
South Eastern (Burns, K Falls)	1.39	1.92

*Array is facing due south with a slope between 25 and 45 degrees with no external shading from trees or buildings.

Figure 15 — A zero net energy home in northeast Portland

large the system will be, expressed in DC watts. Actual peak output of the array is expressed in AC watts, which is about 80 percent of DC watts.

Depending on your finances, you might choose to buy a 900-watt system this year and add another 900 watts in a few years. This is possible because of the scalable nature of PV arrays. However, because inverters come in discrete sizes, you might be better off buying one 1,800-watt inverter rather than two 900-watt units. The same goes for installation costs — it's cheaper to do it all at once. Buying a single large system will likely cost less time and money than the two increments. The larger the system, the less it costs per unit of energy delivered.

The amount of energy produced by your system is dependent on the amount of available sunlight and, to a lesser extent, the operating conditions of your batteries and inverter. Improper settings on these systems can have a significant impact on the amount of energy produced by the photovoltaics. If the system is not set properly, it could force the photovoltaics to operate at a suboptimal voltage.

Utility-interactive inverters

Once you've determined about how large a system you want, you'll need to select an inverter. Several inverter companies sell utility-interactive inverters. These inverters range in size from 700 to 25,000 watts. Options and features of inverters vary; consult with your local solar contractor to find out about options and features currently available.

Interactive utility inverters must meet UL-1741

Traditionally, inverters simply convert the DC electricity generated by PV arrays into the AC electricity used in our homes. More recently, inverters have evolved into remarkably sophisticated devices to manage and condition power. Utility-interactive inverters are designed to disconnect from the utility should an interruption occur in the utility power or its acceptable voltage and frequency operating range falls. These and other features prevent your system from sending power onto the utility wires when the utility staff are working on their wires. Make sure to use only inverters that are approved for utility interactive use. This provides maximum assurance for your utility that, in case of a power interruption, no power will flow onto the utility wires while a lineman is conducting repairs.

There are two types of utility-interactive inverters: those with batteries and those without batteries. For systems without batteries, when utility power fails, your electricity is automatically turned off even if you have plenty of sun on your PV system. When utility power

Figure 16 — Four solar-powered homes being built in Corvallis

fails in a system with batteries, the inverter still disconnects itself from the utility; however, power continues to your home from batteries and photovoltaic modules. Although battery backup power is attractive, such systems are more expensive, require occasional battery maintenance (depending on the battery) and are 5 to 15 percent less efficient.

Savings on your utility bill

Because PV systems have no fuel costs, you will see a reduction in your electric bill proportional to the size of your system. Use the following formula to estimate the dollar savings on your annual electric bill.

Table 2 — Savings on bill calculation

________________	x	_____________	=	_________________
solar for location (from Table 1)		*array size (DC watts)*		*annual output (kWh)*
________________	x	_____________	= $	_____________________
annual output (kWh)		*utility rate ($0.08/kWh ave.)*		*dollars saved per year*

Example: In an average year, a 2,000 watt (DC) array in Salem will produce 2,000 x 1.14 = 2,280 kWh, assuming no losses from poor tilt, orientation or shading. If the local electricity rate is 8 cents per kWh, it would save about $182 per year. This translates to about $7,300 over the first 30 years of operation assuming a 2 percent increase per year in utility rates.

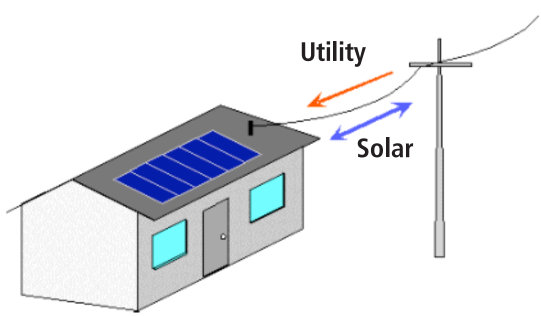


Figure 17 — Net metering

Figure 18 — With net metering, surplus power spins the meter backward.

Net metering

The 1999 Oregon Legislature passed a law requiring utilities to provide net metering. Net metering allows you to exchange any surplus energy produced by your PV system for utility energy used during periods when your PV system is not producing enough energy to meet your needs (e.g., at night). What this means is your electric meter spins backward when power is flowing from the building to the utility, and spins forward when electricity is flowing from the utility into the building. At the end of the month, you are billed only for net consumption — that is, the amount of electricity consumed, less the amount of electricity produced. The utility acts much the same as a battery, crediting your energy "account" for later use.

Example: During the middle of the day, your system produces three kilowatt-hours but the building uses only one kilowatt-hour. Thus, your "account" will be credited for two kilowatt-hours. Later that evening, you might use two additional kilowatt-hours and end up with a net zero balance — owing the utility nothing for that day.

Other important elements of the Oregon net metering law:

1) Daily surplus power generation is carried forward to the next day. However, on a monthly basis your utility may choose either to pay for any monthly surplus at the wholesale rate it pays for power or credit your account for

the next month. Some utilities pass the credit on to the next month, effectively allowing you to store up surplus credit during the summer for use in the winter when your demand is higher and available solar energy is less.

2) The utility may not charge any additional fees associated with being a net-metered system, nor may it charge for any meter changes associated with being net-metered (unless overruled by the public governing body).

3) The utility may not require you to pay for additional tests or purchase additional liability insurance, providing you meet the requirements established by the utility's governing body. If you're buying a PV system for your home, your standard homeowner's insurance policy usually is adequate to meet the utility's requirements (unless overruled by the public governing body).

4) The utility is not liable for acts or omissions of the customer-generator that cause loss or injury, including death to any third party.

5) Net metering applies only to solar, wind, hydro and fuel cells with not more than 25,000 watts of peak power output.

Figure 19 — Be your own electric company.

Obtaining an interconnection agreement

Interconnecting your PV system will require you to enter into an interconnection agreement with your local utility. Be sure to get a copy of your utility's net metering policy and its interconnection agreement before you purchase your system.

The interconnection agreement specifies the terms and conditions under which your system will be connected to the utility grid. It includes the technical requirements necessary to ensure safety, power quality, and other issues such as your obligation to obtain all necessary permits for the system, maintain the system in good working order, have the PV system insured and generally be responsible for its safe operation. The language in these contracts should be simple, straightforward and easy to understand. If you're unclear about your obligations under these agreements, contact the utility or your electrical service provider for clarification.

Recently tremendous progress has been made in developing nationally recognized standards for utility interconnection of PV systems. Although these standards are not necessarily binding on utilities, many utilities are adopting the standards rather than developing their own. The most important of these standards focus on inverters. Two of these standards are particularly relevant:

- Institute of Electrical and Electronic Engineers, Standard 929-2000: *Recommended Practice for Utility Interface of Photovoltaic Systems*. Institute of Electrical and Electronic Engineers, Inc., New York, NY
- 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 necessarily need to know about these standards, but your solar contractor and utility should. You are obligated to ensure that your solar contractor uses equipment that complies with the relevant standards and with article 690 of the National Electric Code, so be sure to discuss this issue.

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 by the electric utility with which you entered into an interconnection agreement. The possibility exists that, as a result of these inspections, your solar contractor must make "corrections" to satisfy the inspector's requirements. Corrections are fairly common in the construction business, so don't be alarmed if they are requested of you and your solar contractor.

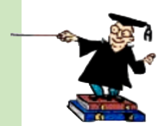
Photo courtesy of SolWest/EORenew

Figure 20 — Utility-independent home

Utility-independent Solar Electric Systems

Utility-independent, or "remote," solar electric systems provide electricity for places that are not connected to an electric utility. Photovoltaics have been used to power remote homes in the northwest for more than 20 years. Applications vary from simple systems that charge a trailer battery to complete home power systems that run everything from power tools to microwave ovens. This section covers the basics of what you need to get started; for more hands-on information and examples of remote solar homes, get a copy of *Home Power Magazine*.

Homes more than one-half mile from electric utility power should consider solar as a possible least-cost option.



When to consider a PV power system

The cost of extending a power line to a home depends on your local electric utility's line extension policy and the distance from the site to the existing electrical distribution lines. If the local utility has a generous line extension policy and the home site is close to existing distribution lines, a line extension might be your best option.

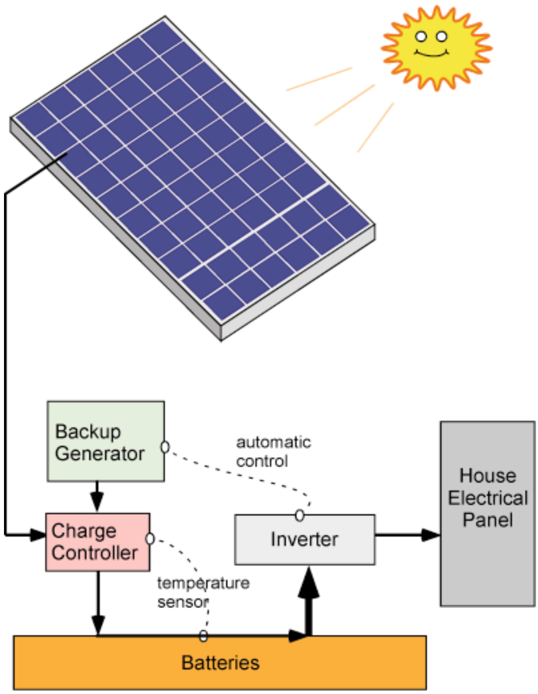
However, many electric utilities expect customers to pay the full cost of line construction. Utilities also are becoming reluctant to build power lines to small loads in remote locations even if the customer is willing to pay, because the utility must pay for expensive line maintenance once it's built.

Your local electric utility company can give you an estimate of the cost to extend a new line to a home site. With utility line construction costs typically ranging from $10,000 to $30,000 per mile, plus additional costs for maintenance, it might be to the utility's and your benefit to find an alternative source of power. Depending on your electricity requirements, a PV system could be the least-cost option, even when the nearest utility is no more than one-half mile away.

Photo courtesy of Solar Design & Construction

Figure 21 — Power panel with battery box

Solar electric homes are generally very energy efficient, but they don't necessarily require a change in lifestyle or standard of living. Unlike utility power, remote systems provide a limited amount of energy and have a fixed maximum power output. All remote systems rely on batteries to store energy for use when sunlight is insufficient, and most are equipped with small generators for backup electricity during extended cloudy periods.



PV array	A collection of PV modules sized to provide enough power to your system on a typical December day.
Charge controller	A voltage regulator designed to control the charging of your batteries to ensure maximum useful life.
Batteries	Deep-cycle batteries such as those used in RVs, golf carts or lift trucks. These are sized to provide you with three to five days of backup power.
Inverter	A power converter that transforms the DC power from your array and batteries into standard household AC power.
Backup generator	A small gasoline or propane generator used to recharge your batteries under extended periods of very poor sunlight conditions. This is optional but recommended, since it allows you to reduce the size of your battery bank.

Figure 22 — Schematic of a remote system (NOT a wiring diagram)

Another element of a remote home PV system is that space heating, water heating and cooking is done with either wood or gas. Using photovoltaics to power these systems would be very expensive. The best option is to use solar water heating and passive solar space heating to supplement conventional heating.

The four most common reasons why people choose a solar electric system for remote homes are:

- ☐ Increased reliability and power quality
- ☐ Quiet operation, compared to a gas or diesel generator
- ☐ Cheaper than a line extension
- ☐ Good environmental stewardship

The basics

Unlike utility power, a PV system provides a limited amount of energy and has a maximum power output. The amount of energy collected depends on the size of the array, and the maximum power output depends on the size of the inverter. Figure 22 shows a simplified schematic of a utility independent system.

System sizing

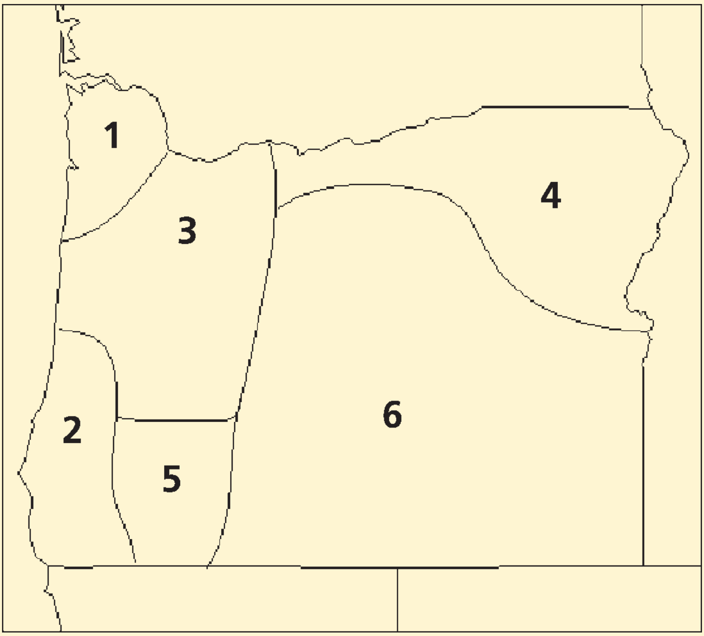
Properly sizing a utility-independent system is very important. We recommend that you consult with a solar contractor to assist you with this step. The goal is to determine a reasonable size for your system. Too large a system will leave you with surplus power in the summer; too small a system will force you to run your backup generator too much.

Before you call your solar contractor, determine how much energy you'll need. Start by adding up the average daily energy use for every piece of electric equipment you plan on using in the winter. Energy use is calculated by multiplying the equipment's power consumption (watts) by how long (hours) it is run on an average day. Because energy losses are different for alternating (AC) current than for direct current (DC) equipment, you'll need to keep these totals separate.

Once you've added up all your daily AC and DC energy use, you can estimate the size of the solar array by dividing this value by the number of equivalent full-sun hours for your

Table 3 — Solar energy in different climates, expressed in effective sun-hours

Hours of equivalent "full sun"



Zone	Sizing	Winter[1]	Annual[2]	Tracker[3]
1	2.1	1.8	3.6	4.6
2	2.6	2.5	4.4	5.7
3	2.4	1.7	4.1	5.4
4	2.7	2.1	4.7	6.5
5	2.8	2.0	4.9	6.7
6	2.9	2.9	5.1	7.1

Values are regional averages and may vary by 20% for your particular "micro-climate"

[1] *Winter sun hours are based on a collector tilted at lattitude+15 degrees.*

[2] *Annual values are based on collector tilted at latitude.*

[3] *Tracker values are annual values for a two-axis tracking array.*

location ("Sizing" column, Table 3, page 28). See Table 4 (page 29) for a sample load estimation. Table 5 (page 30) shows typical power consumption values for common household appliances.

Equivalent full-sun hours describe how long it would take to deliver the daily average energy if the sun stayed directly overhead on a cloudless day and your collector was tilted perpendicular to the sun's rays. Despite the fact that these conditions rarely happen, it allows an apples-to-apples comparison of different climates and simplifies calculating the energy your system will provide.

Design your system so that it can grow with your future needs.

Table 4 — Load calculation for off-grid system

Example load calculation — medium-sized home

AC Appliances (120/240 Volt)	Num.	x	Watts	x	Average hrs/day	=	Ave. Daily Energy Use
Coffee maker	1	x	600	x	0.2	=	120
60 W lamp	2	x	60	x	3.0	=	360
16 W fluor. lamp	6	x	16	x	3.0	=	288
Dish washer	1	x	1,200	x	0.5	=	600
Microwave	1	x	900	x	0.1	=	90
Stereo	1	x	60	x	2.0	=	120
27" Color TV	1	x	250	x	1.0	=	250
VCR	1	x	40	x	1.0	=	40
Clock	1	x	10	x	24	=	240
Circulation fan	1	x	100	x	1.25	=	125
Clothes washer	1	x	430	x	0.5	=	215
Miscellaneous (vacuum, blender, etc)	few	x	some	x	a little	=	100
		x		x		=	
		x		x		=	
AC Load							2,548

DC Appliances (12/24/48 volt)	Num.	x	Watts	x	Average hrs/day	=	Ave. Daily Energy Use
Refrigerator (16 c.f. Sunfrost)	1	x	120	x	10	=	1,200
Well Pump	1	x	100	x	4	=	400
DC Load							1,800

Adjusted AC Energy =	AC Load	2,548	x	1.6	=	4,077
Adjusted DC Energy =	DC Load	1,800	x	1.4	=	2,520
Total Estimated Energy Needed (add above two values) =						**6,597**

Notice that the "Sizing" column in Table 3 does not correspond to the amount of sun during any particular month. Using this value will ensure that your system won't be significantly oversized during the summer, while keeping wintertime backup charging to a minimum. You might be able to get by with an even smaller system than determined by using the Sizing column. However, doing so will require you to reduce your normal energy use during the winter.

Table 5 — Power consumption of typical appliances

Typical power use of appliances

Appliance	Watts	Appliance	Watts
Blender	300	Computer	
Coffee maker (0.2)	600	Desktop	150
Toaster	800–1,500	Laptop	40
Deep fryer	1,400	Inkjet printer	100
Microwave	600–1,500	Monitor — 17"	150
Waffle iron	1,200		
Frying pan	1,200	TV — 20" color	150
Mixer	100	TV — 27" color	250
Slow cooker	200	VCR	40
		CD player	35
Dish washer — standard	1,200	Stereo	80
Sink waste disposal	450	CB radio	10
		Electric clock	10
Refrigerator (12)			
24 c.f. w/ice maker	250	Lights — compact fluorescent	
20 c.f. energy efficient	150	Incandescent equivalent	
16 c.f. SunFrost DC	120	40-watt equiv.	11
		60-watt equiv.	16
Clothes washer (1)	350	75-watt equiv.	20
Clothes dryer — electric	2,200	100-watt equiv.	28
Clothes dryer — gas	350		
		Electric mower	1,500
Garage door opener	350	Hedge trimmer or weed eater	450
Ceiling fan	85	3/8" drill	300
Table fan	50	Drill press	1,000
Electric blanket	800	Belt sander	1,200
Blow dryer	1,200	Electric chain saw	1,100
Shaver	20	Circular saw	1,400
Clothes iron	1,000		
Vacuum cleaner	200–700	Furnace blower	300–1,000
		Air conditioner — room	1,200
		Air conditioner — central	4,500
		Water heater — electric (2.2)	4,500

Note: numbers in parentheses are typical daily hours of operation

Efficiency and phantom loads

Although estimating your daily energy use is tedious, it'll give you an idea of where you can improve your home's electric efficiency. In the above example, replacing your clock with a battery-powered digital one and the two incandescent lamps with fluorescent lamps would reduce your daily energy use by 504 watt-hours. For a home in Redmond, this translates to needing two less PV modules saving you about $1,000.

Using readily available technology, you can reduce your electric energy consumption to one-third that of a typical home. Appliances should be selected for efficiency. Fluorescent lights are preferred over incandescents because they use a quarter of the energy. Refrigerators, dishwashers, water pumps and small loads that are run all day should be carefully selected. The extra $400 you spend on a highly efficient refrigerator will substantially reduce the amount you'll have to spend on your PV system. And most importantly, all space heating, water heating and cooking should be done with wood or gas (propane).

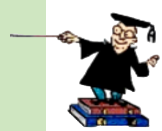
Another important thing to watch out for is "phantom loads." A phantom load is an electric device that continues to draw power even though the device is not "on." A good example of this is a VCR or a stereo. Even though it might not be in use, a small light or clock is running and drawing power. This might seem insignificant, but because it's running 24 hours a day, seven days a week, it can drain a noticeable amount of power from your batteries. To prevent phantom loads from draining your batteries, make sure the appliances you buy draw no power without your approval.

Power:

$$\text{watts} = \text{volts} \times \text{amps}$$

Energy:

$$\text{kWh} = \frac{\text{watts} \times \text{hours}}{1{,}000}$$



Inverter and backup power

Most remote homes today use inverters to transform the DC power of a PV array and batteries into standard household AC power. This is not to say that all your energy use will or should be in AC form. Inverters generally impose an "efficiency penalty" of 10 to 15 percent. Thus, you may get better performance running some loads directly on DC power. Your solar contractor can help you determine if this would be a good strategy. The most common loads run with DC power are pumps and refrigerators.

Once you've totaled all your energy consumption, your solar contractor can help you determine how many PV modules you'll need and the size of your inverter and battery backup system. An inverter for a remote system doesn't require the sophisticated electronics necessary to synchronize the power with a utility's power. It doesn't even have to be in the form of a pure sine wave. Inverters that produce "modified square wave" AC power are acceptable (Figure 23). The up side of these inverters is that they will save you a considerable amount of money. The down side is that some appliances such as motors, AC refrigerators, clothes washers and microwave ovens run hotter and sometimes noisier when powered by a modified square-wave inverter.

Another nice feature offered by many home-power inverters is the ability to start up a small generator when you've either been using too much energy or the skies have been dark for an extended period. A backup generator allows you to size your battery backup reasonably. If you sized your battery storage to get you through the worst possible week of the worst winter, it would not only be *enormous* but would have higher losses and require an even larger PV array to maintain it at full charge. The generator you choose need not be designed to run continuously, since it will be used only to carry you through those very dark weeks of winter or to "top off" your batteries. The generator does need to be large enough to both "bulk" charge your batteries and power your home's key electric needs at the same time. Buy a **quality** generator that has remote turn-on function so the inverter can automatically start the generator when the batteries get too low.

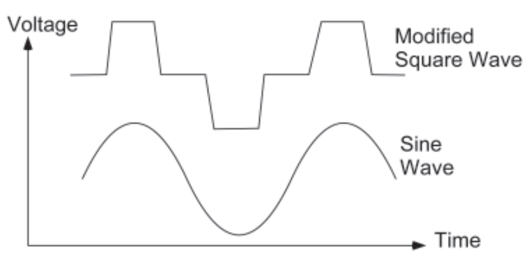


Figure 23 —Wave shapes

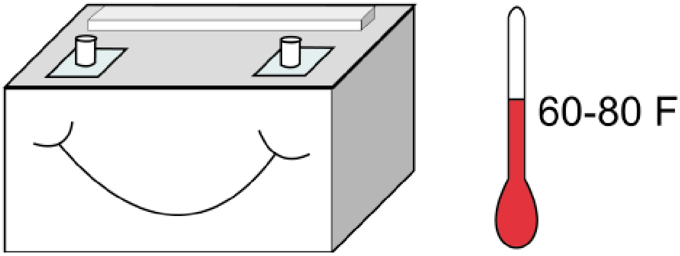


Figure 24 — A happy battery is warm, dry, clean and well ventilated.

Batteries

Batteries come in a variety of different configurations and styles that are capable of storing tremendous amounts of energy. Unsealed, deep-cycle, lead-acid batteries are used most commonly because they offer the best storage per dollar. Automobile batteries should never be used, because they're designed for quick, infrequent discharges and won't last long if deeply discharged. Your solar contractor can help you sort out the various trade-offs between different batteries and issues such as maintenance, temperature, ventilation, storage capacity, discharge rate, physical size and voltage configuration.

Batteries typically are sized to provide three to five days of power under "no-sun" conditions. A lead-acid battery about the size of a large truck battery (some are much larger) will hold about one kilowatt-hour. Thus, if your home uses five kilowatt-hours per day (5 kWh), you would need about 20 batteries (5 kWh x 4 days of backup/1 kWh per battery = 20 batteries).

Because batteries wear out, it's important to protect your investment. Your charge controller provides day-to-day battery protection. This electronic device can be set so that your PV array doesn't overcharge the batteries, and so that your batteries don't become too discharged. Unsealed batteries require that you check their water level every few months to prevent hydrogen gas buildup. Batteries should be kept at between 60 and 80 degrees Fahrenheit for optimal performance. To ensure longevity, most batteries should **never** be discharged more than 50 percent.

Charge controllers

Charge controllers are voltage regulators designed to control the charging of your batteries to ensure maximum useful life. Power flowing from your solar array must not be allowed to flow directly into your batteries. The charge controller ensures that the energy is added to the battery at a rate that doesn't harm the battery. If the battery is already fully charged, the charge controller prevents overcharging. Most charge controllers also can be used to disconnect circuits when voltage gets too low, thus protecting your battery from being overly discharged.

Figure 25 — Solar contractor David Parker gets thumbs up from Kettle Foods in Salem.

Selecting a Solar Contractor

Oregon is home to a number of reputable contractors with experience installing PV systems. In some locations, finding a solar contractor can be as simple as picking up the telephone directory and looking under "Solar Energy Equipment and Systems — Dealers." However, many of those listings are for companies experienced in solar water-heating system installations; they might be inexperienced in PV system design and installation. Similarly, many electrical contractors, although highly proficient in typical electrical contracting work, might not have expertise in working with PV systems or with roof-mounting techniques.

A good place to start is to contact the Oregon Department of Energy, The Oregon Solar Energy Industry Association, or the Energy Trust of Oregon. Be aware, however, that contractor lists do not guarantee contractor performance. It's up to you to carefully select whom you hire.

How do I choose among solar contractors?

Whether you use our list or compile one of your own, the next step is to narrow it down by calling the solar contractors and asking questions. When contacting any company, consider its location relative to yours. If you can locate a solar contractor who is relatively close to where the system will be installed and who meets the other criteria outlined below, it'll be easier to work with them rather than with a company located farther away. When contacting companies, you might ask some of the following:

What kind of solar experience does the contractor have?

Because installing solar electric systems requires a range of expertise, you should ask how many installations the contractor has completed for your particular type of system (utility interactive, utility independent, remote pumping and even solar water heating). If you're interested in a utility-interactive system, try to find a contractor who has performed interconnections with your local utility.

Although utility-interconnected systems are different from remote systems, a competent contractor with PV experience should not be eliminated just because they haven't installed utility-interactive PV systems in the past. In fact, previous experience with remote systems is valuable because utility-independent systems are more technically complicated than utility-interactive systems. The bottom line, however, is that a competent contractor will be able to work on both on-grid and off-grid systems in a professional manner. In addition, many contractors got their start doing solar water heating system installations. Although quite different from PV systems, they both require expertise in roof attachment and solar resource assessment. Experienced solar water heating contractors know how to mount arrays without causing leaks in your roof and how to make maximum use of the sun for your particular site.

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

This issue speaks for itself: A company or contractor that has been in business a long time has demonstrated the ability to work with customers and to compete effectively with other firms.

Is the company properly licensed/certified?

First of all, make sure the contractor is properly licensed and bonded with the state Contractor's Board (503-378-4621). Second, verify that the installer is licensed as either a limited renewable energy technician (LRT) or a journeyman electrician (JE). Both are electrical licenses. The LRT license is limited to renewable energy systems below 25,000 watts. The journeyman electrician is a broader license that requires more general experience with electrical systems. Unlike a limited renewable energy technician, however, a journeyman electrician may or may not have expertise with solar electric systems – so be sure to ask.

How do I obtain and choose among competing bids?

If you have decided to get more than one bid for the installation of your PV system, you should take steps to ensure that all of the bids you receive are made on the same criteria. As an example, comparing a bid for a system that would be mounted on the ground versus another bid where the system would be mounted on a roof would be like comparing apples with oranges. Similarly, there are different types of PV panels, some of which generate more electricity per square foot than others.

Bids should clearly state the peak generating capacity of the system under full sunlight (measured in watts or kilowatts). Also, you should obtain an estimate of the amount of energy 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 from season to season and year to year as well as geographically, it's unrealistic to expect a specific figure; a range of ±20 percent is more 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*.

System warranty. A good standard to use when considering the length and terms of PV system warranties is two years for labor, five years on the power electronics and 20+ years on the solar modules. When the system is professionally installed rather than self-installed, the warranty also should include the labor of removing and reinstalling any defective components, and shipping costs.

Check references. As with hiring any contractor, be sure to call several references provided by the contractor. Ask previous customers if they would hire the contractor again, what they would have done differently, and to describe the contractor's limitations and strengths.

Is the lowest price the best deal?

It might not be. Ultimately, you, the purchaser, must decide how much you wish to pay for your PV system. However, remember that a solar contractor is a contracting business just like any other type of contractor, with overhead and other operating expenses that must be covered. Companies that plan to stay in business must charge a price for their products and services that is adequate to cover their costs plus a fair profit margin. If you let price be your only consideration, you ultimately might wish that you had based your purchase decision on other factors as well.

Verifying and accepting the installation

If you're hiring a professional to do the installation, ask them to verify that it delivers what they said it would. To do this, you'll have to take a power reading on a sunny day when there is no cloud cover. The system should deliver what the contractor claimed it would when the sun is striking perpendicular to the collector. If the sun is striking at an angle less than perpendicular to the collector surface, then performance must be derated by the cosine of the angle between the sunlight and the perpendicular to the collector surface.

Before accepting the completed installation, make sure you understand the controls and any maintenance requirements it has. This includes learning:

- ☐ Where not to touch
- ☐ How to read the current status of the system
- ☐ How much energy is being produced
- ☐ The batteries' state of charge
- ☐ What maintenance is required of the batteries
- ☐ What to do in case of utility power disruption
- ☐ How to disconnect the system

Getting Help

State tax credits

Oregon offers tax credits and low-interest loans for both residences and businesses installing PV systems. Program details can be found at www.oregon.gov/energy.

Residential energy tax credits are based on installed watts. The amount of the credit is based on $3 per watt up to $6,000 or 50 percent of the cost of the system, whichever is less. The maximum amount claimed in any one year is $1,500, therefore it can take up to 4 years to claim a $6,000 tax credit. You are allowed to take up to 5 years to claim the entire credit amount. This is a one-time credit per system. The system must be verified by a technician that has been certified by the Oregon Department of Energy. Homeowner installations are allowed, but must be verified by either the Oregon Department of Energy or a certified technician.

Business energy tax credits are based on additional cost over the alternative nonrenewable energy system. The state offers a 35 percent tax credit of the incremental cost of the system. The tax credit is applied over five years — 10 percent each of the first two years and 5 percent each of the subsequent three years. To be eligible for this tax credit, *you must submit an application prior to committing financially to the project.* Once the project is approved, the Department of Energy

Photo courtesy of Solar Energy Solutions

Figure 26 — Tax credits are available for both PV and solar water heating systems.

issues pre-certification. Once the project is completed and documentation of the final costs is submitted, the Department of Energy issues certification for the tax credit amount.

SELP loans are available for both residential and commercial applications. The loan rate is about one point above the current rate for Oregon State tax-exempt bonds. The finance period is generally 15 years. The State requires that these be low-risk loans; therefore, financial equity in your home or business solvency is required. For more information, contact the Oregon Department of Energy.

Federal Incentives

Federal incentives are available for both residences and businesses. Thirty- percent tax credits up to $2,000 are available for residential systems through 2007. Thirty- percent tax credits without size limit are available for businesses through 2007. Businesses may also qualify for the use of accelerated depreciation allowances.

Utility Incentives

Customers of PGE and PacifiCorp can receive discounts for PV systems purchased through participating solar contractors. Contact the Energy Trust at (503) 493-8888 or www.energytrust.org for more information.

Customers of publicly owned utilities (e.g. Eugene Water and Electric Board, Central Electric Co-op, City of Ashland) may also be eligible for incentives. The Bonneville Power Administration allows these utilities a discount if they invest in conservation and renewable energy. Your utility may use this discount to offer incentives for solar, so be sure to call them before beginning a project.

Other Incentives

The Northwest Solar Cooperative has teamed with the Bonneville Environmental Foundation (BEF) to launch Solar Starters, a unique program that allows participating small-scale PV installations to sell the "environmental benefits" produced by their solar electric system. The Northwest Solar Cooperative pays 10 cents per kWh for every kWh produced. (This is in addition to the energy saved on your utility bill.) Systems are eligible for 5 years and annual payments begin to accrue as soon as a contract is signed and the solar system starts generating energy. Contact Doug Boleyn (503) 655-1617 for more details.

Financing

There is nothing magical about financing the cost of purchasing and installing your PV system. Although there are some special programs available for financing solar and other renewable energy investments, most of the options will be familiar to you.

There are four common ways to finance a system: home mortgage, unsecured bank loan, state Energy Loan Program loan, or incentive program financing.

The home mortgage is perhaps the most appealing (although not available for businesses), because the interest paid on the loan is exempt from federal taxes. Financing a solar electric system with a home mortgage can take the form of a second mortgage, a line of credit, or a total home refinancing. An unsecured bank loan is generally available to people with good credit rating. Contact your local lending institution for more details.

The state Energy Loan Program (SELP) loan is available through the Oregon Department of Energy (call 1-800-221-8035). The finance period is generally 15 years. A SELP loan is based on state bonds sold for energy efficiency and renewable energy and may have a very competitive rate, however small loans may not be competitive with other lending institutions because of the required application fee. In addition, the loan must be secured, typically with equity in your house or business.

Several utility incentive programs offer financing options. Customers in PGE or PacifiCorp service territories should contact the Energy Trust of Oregon (**www.energytrust.org**) or 503-493-8888. Eugene Water and Electric Board customers should call 541-484-1125 and ask about incentives and financing options for solar energy projects.

Programs and Organizations

University of Oregon Solar Radiation Laboratory

For information about the solar energy resource for your area, contact Dr. Frank Vignola of the University of Oregon, 541-346-4745.

Solar Energy Association of Oregon (SEA of O)

SEA of O is a nonprofit chapter of the American Solar Energy Association. SEA of O provides public education and outreach about the benefits and uses of solar energy for space heating, water heating and electricity generation. 503-231-5662

Oregon Department of Energy
www.oregon.gov/energy

Oregon Solar Energy Industries Association:
www.oregonseia.org

Solar Energy Association of Oregon:
www.solaror.org

Figure 27 — This home in Grants Pass sold for an extra $8,000 because of the solar array.

Home Power Magazine:
www.homepower.com

Sandia National Laboratory:
www.sandia.gov/pv

US DOE PV Program:
http://www.eren.doe.gov/pv/

University of Oregon Solar Monitoring Lab:
http://solardat.uoregon.edu/

Oregon Solar Electric Consumers Guide — September 2006 Edition
Christopher Dymond, Oregon Department of Energy

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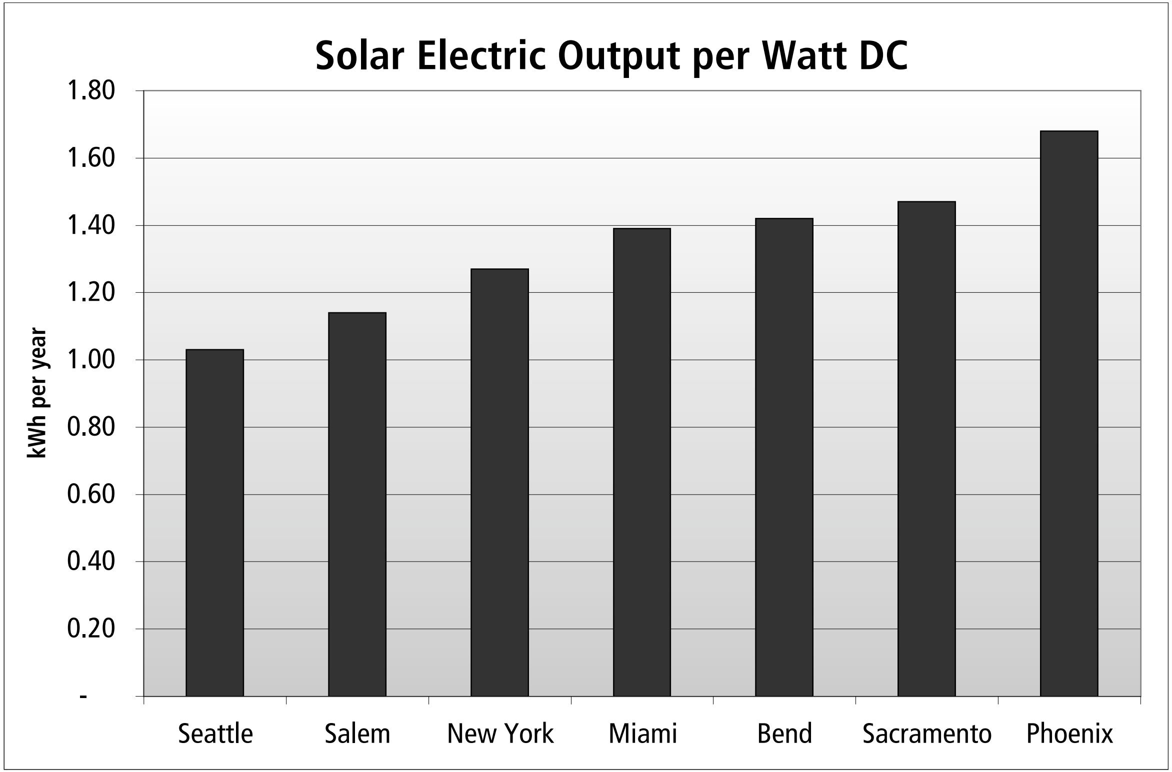
Figure 28



Solar Electric Output per Watt DC
kWh per year
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
-
Seattle
Salem
New York
Miami
Bend
Sacramento
Phoenix

Generate your own electricity from the sun!

Photo courtesy of Cascade Solar Consulting

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