ENERGY

Harvesting Energy from the Sun: Solar Photovoltaics

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Quick Facts...

Solar energy can generate all or a portion of a home's or business' electrical needs.

Colorado averages 5.5 hours of electrical-generating sun each day, 300+ days per year.

Numerous financial incentives are available to support solar energy investments.

Energy efficiency is the first step in the process.

Energy from the sun can be used to heat homes through passive solar design, solar hot water systems, solar space heating and electrical generation (photovoltaics or PV). It is a renewable energy source that does not contribute to greenhouse gasses. Compared to fossil fuel-generated electricity, each kilowatt of PV electricity annually offsets up to 16 kilograms of nitrogen oxides, 9 kilograms of sulfur dioxides, and 2,300 kilograms of carbon dioxide (CO_2) (www.eia.doe.gov/cneaf/electricity/page/co2_report/co2report.html).

How does it work?

Photovoltaic solar panels convert solar radiation (termed "insolation") into Direct Current (DC) electricity. When referring to electrical generation, insolation is described at watts per square meter. On a clear day, the total insolation is about 1000 watts per square meter. By measuring the insolation, the peak sun hours can be determined. Peak sun hours vary throughout the year and can be affected by the Earth's position relative to the sun, location of site (latitude), atmospheric conditions, and any obstructions at a given site (shade).

Photovoltaic solar systems typically contain several panels wired together (termed an array), electrical disconnects, overcurrent protection (circuit breakers or fuses), inverter, junction box, and other specialized equipment depending on application (grid-tied, off-grid, battery-backup). Your solar professional can assist with the pieces of equipment that are necessary for each application.

Electrical Terminology

There are several terms used in describing electricity that can be confusing for novices. A basic understanding of the common terms can be helpful when working with a professional solar designer/installer.

AC/DC – Alternating Current/Direct Current. PV solar cells produce DC electricity, while most household appliances operate on AC. In order for a home to utilize the electricity generated from a solar system, it must be converted from the DC-form to Alternating Current (AC). Direct current only allows electricity to flow in one direction, alternating current allows current to flow in the opposite direction at frequent intervals. The use of an electrical inverter converts DC electricity into AC. AC electricity is also utilized by utility companies and home wiring to alleviate the voltage loss from DC electricity.

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Electrical Load – A “load” is the demand for electricity. This can include lights, appliances, etc.

Voltage (V) – Voltage is the pressure that causes electrons to flow through a wire. This is similar to the force of water through a garden hose.

Amperage (A or I) – Amphere or amp is the unit of electrical current flowing through a wire. In the garden hose anology used previously, the amps would be the volume of water.

Watts (W) – Watts are the product of voltage and amperage (W = V x A). It is a measure of the rate of electricity used or produced. A kilowatt (kW) is equivalent to 1000 watts.

Energy usage – The amount of watts used for a given amount of time. This is often expressed as a watt-hour. If the garden hose example was filling buckets, it would be the number of buckets that would be filled during a given amount of time. Electrical demand can also be expressed as watt-hours (a 60 watt light bulb running for four hours will use 240 watt-hours of electricity). Utility companies measure electrical usage for customers in kilowatt-hours (1000 watt-hours).

A solar system used to power a home or business that does not have access to utility-provided electricity is termed an off-grid system.

Phantom loads – Some appliances will continue to draw energy even when turned off. For example, a television with a remote control or a microwave displaying the time of day will continue to draw energy to power those applications. Phantom loads should be reduced prior to investing in a solar energy system. In some cases, the use of a power-strip with a switch can eliminate phantom loads.

Grid-Tied vs. Off-Grid Systems

A solar system used to power a home or business that does not have access to utility-provided electricity is termed an ‘off-grid’ system. Solar panels provide power to a battery bank (series of batteries wired together) that store power for use when solar energy is not available (night or inclement weather). The battery bank is enclosed in a box to prevent gas escape or any potential battery acid spills. The bank is controlled by a charge controller that prevents over-charging of batteries and low voltage cutoff when batteries are trying to operate at too low of a charge (shortening battery life).

Solar systems that are connected to an existing electrical utility are called grid-tied systems.

Batteries typically used in PV solar systems are lead-acid batteries (liquid vented and sealed) and alkaline batteries (nickel-cadmium and nickel-iron). Most PV systems utilize lead-acid batteries (similar to those used in recreational vehicles, golf carts or marine applications) that are designed to handle frequent charging and discharging. Automotive batteries would not handle this ‘deep-cycling’ demanded of household electrical systems, as they are designed for large loads for short periods of time, with recharging happening quickly from the vehicle’s alternator.

Solar systems that are connected to an existing electrical utility are called ‘grid-tied’ systems. Grid-tied systems do not need to have batteries for storing energy. Instead, during periods of excess solar electricity generation, the electric meter turns backwards. When electrical demands are greater than electricity generated by the solar array, the power grid supplies this demand. The customer only pays for electricity used (net metering = total power used – solar power generated). The grid serves as the energy storage for the PV solar array. One drawback to this type of system is that electricity is not available if the grid power is interrupted. Net-metering requires acceptance from the utility provider, and net meters are installed by the electrical utility provider.

Grid-tied systems can incorporate a battery-backup system for critical electrical loads. These grid-tied, battery backup systems will provide power for backed-up electrical loads, but not for the general house in the event of a power failure. These types of systems can use a battery charger that can recharge the batteries from the power grid once the grid power is restored. This type of system may be useful in areas where grid power failure is frequent or reliable power is critical (vaccination storage, for example).

Sizing your Solar System

To size an off-grid system, you will first need to "inventory" your electrical demands or loads.

Choosing the size of a system needed depends on the type of system. Grid-tied systems are easier to size, as a customer can choose to offset part or all of their electrical usage. Off-grid systems need to provide all of the electrical demands, plus a 'buffer' for periods of inclement weather (termed autonomy). Many off-grid systems utilize a hybrid system with a backup generator, but relying on this type of electrical generation is expensive and noisy. Hybrid systems can also utilize other renewable energy sources such as wind turbines as a secondary source of electrical generation.

To size an off-grid system, you will first need to inventory your electrical demands or loads. The simple act of turning on the light switch or starting the microwave draws electrical demands that need to be accounted for. Typically, the load estimation will account for all electrical loads present (lights, appliances, etc.), the amount of time each day the appliance is used, and the number of days each week the appliance is used (weekend cabins do not use electricity every day, but have higher demands when occupied). An example of a Load Estimation Worksheet may be found at www.ext.colostate.edu/energy/solar.html. By adding up the electrical load needs, inserting an autonomy factor, accounting for design inefficiencies (batteries can be 80 percent efficient, inverters can be 90 percent efficient), and any voltage drop due to long wire runs, a system designer can determine the size of system necessary for off-grid applications.

To size a grid-tied system, electrical customers can add up their total electrical usage for the year (available on their utility bills), and divide by 365 days per year. This daily electrical usage (kWH) is then divided by the average solar resource (insolation) in their area. In Colorado, an average insolation factor is 5.5 hours per day. The result is the amount of kWatts needed in a solar array (not accounting for design inefficiencies).

For example: A Colorado home had a total of 8002 kWH of energy usage for a year (example 08/2009).

- 8002kWH/365 days = 21.92 kWH/Day
- 21.92 kWH/Day ÷ 5.5 = 3.985 kW = 4000W PV System
- 4000W ÷ .90 inverter efficiency = 4444W system = 4500W system
- 4500W X $9.50/W installed price = $42,750
- Federal Incentive (30%) = $12,825
- Utility Company incentive ($3.50/W) = $15,750
- Net Cost ($42,750 - $12,825 - $15,750) = $14,175**

***For illustrative purposes only, based in Salida, CO using average insolation data. Local costs and rebates may vary.*

There also are interactive calculators available for on-grid applications. Please visit www.ext.colostate.edu/energy/solar.html for links to several calculators. These calculators can give examples of costs for a system and applicable financial incentives.

Sticker Shock?

For many electrical users, realizing the expense associated with their current habits and appliances is sobering. As with any clean energy technology, often the best investment of dollars is on the demand side rather than the supply side of the electrical equation. Something as simple as purchasing a more-efficient refrigerator and installing compact florescent light bulbs can lower the size of the PV array and related wire sizing, battery bank, etc. and lower the cost of the solar system. Often, conducting a home energy audit by a qualified professional will help evaluate where money can be invested in energy efficiency. Having the most energy-efficient home is the starting point of any clean energy technology investment.

Purchasing the total electrical needs for the next 20 or so years can be daunting. Fortunately, numerous electrical utility companies offer financial incentives for grid-tied applications. Recent federal legislation removed limits on photovoltaic system installations, paying for 30 percent of the project provided the system is placed in service prior to December 31, 2016. Several state incentives may also be applicable to your situation and location. There may also be local incentives available from local governments (rebate of local sales tax, for example). Check with your local building department, municipality or CSU Extension office for more information.

Between these financial incentives, many systems have been subsidized at 40 to 50 percent of the total project cost. To pay for the balance of the system, many homeowners have turned to home equity-type financing instruments. Clean energy upgrades can provide value to a home, and it is important to visit with your tax and financing professionals prior to engaging in a clean energy investment.

Selecting a Solar Energy Designer/Installer

As demand for solar energy continues to rise, so will contractors willing to meet that demand. As with any business, evaluation of contractors is important when investing in clean energy technologies. Because solar arrays can produce large quantities of electricity, only qualified professionals should install PV systems.

Obtain several quotes prior to selecting a contractor. Inquire about what is included in the quoted price. Some contractors will include related electrical work performed by a licensed electrician, others may not. Work completed 'downstream' of the inverter must be performed by a licensed electrician to insure compliance with National Electrical Code (NEC) and local building codes.

Finally, check with your solar professional about whether they will complete required paperwork for cost-sharing from utility companies or if this is the responsibility of the customer. Typically the utility-based incentives will be paid after the installation is complete and the net meter is installed. Check with your contractor about whether they will finance the utility payment and other payment schedule details.

Inquire about any warranties offered by the contractors and equipment manufacturers. PV panels have long useful lives, so it is not unusual to see power-output warranties of 20 to 25 years. Batteries and other components will have much shorter warranty coverage. As with most warranties, mistreatment of components will often void warranties, another reason to utilize experienced professionals.

Ask for references and any certifications they may have. You will be investing several thousand dollars into equipment and labor. Solar professionals should be able to provide numerous references and details about their experience and training. They may also be members of local business groups, chambers of commerce, etc.

The North American Board of Certified Energy Practitioners (NABCEP) offers a credentialing program for clean energy professionals. NABCEP certified professionals have completed educational requirements and practical, hands-on experience to be certified by this professional association. This type of certification may be of value to a clean energy customer, but should only be one part of the selection process. Several quality solar professionals are available that are not necessarily NABCEP-certified.

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