RENEWABLE ENERGY

Electricity basics for renewable energy systems

FACT SHEET

BIOMASS

GEOTHERMAL

HYDROPOWER

SOLAR

WIND

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As a utility customer, you don't need to do anything but pay your monthly bill to get electricity. However, when you decide to install a renewable energy system to generate your own electricity, you become an energy producer as well as a consumer. To do this you'll need to be more familiar with the subject of electricity.

The general subject of electricity is far beyond the scope of this fact sheet. The purpose of this fact sheet is to present some basic electrical concepts and terminology to get you started toward buying a renewable energy system that works for you.

AMPS, VOLTS, OHMS AND WATTS

The basic function of electric generation systems is to create enough electrons (amps) at a high enough intensity (volts) to provide the electrical power (watts) you need.

Electricity is a flow of electrons through a wire. It's somewhat similar to water flowing through a garden hose. To determine the power available from water, you need to know the rate at which the water flows through the hose and the pressure that it is under. With electricity, the analogous terms are amps, which measure current, and volts, which measure electrical "pressure" or power.

The following equation relates amps and volts with a unit of electrical energy called the watt.

Energy (watts) = Current (amps) x Voltage (volts)

The **size** of the electrical service connected to a home or building is measured in amps. The most common is 100-amp service. The **voltage** of this service in a typical home is 120 volts. A commercial or industrial building might require 220-volt or 440-volt service. (High voltage service is needed to run motors more efficiently, for example.)

Electrical Resistance

Another basic electrical phenomenon is resistance. Resistance is measured in **ohms**. Current, voltage and resistance are related by Ohm's Law:

Voltage (volts) = Current (amps) x Resistance (ohms)

Creating resistance in an electric circuit is one important way we use electricity. Resistance is what produces the heat in a space heater and the light in a light bulb.

Inside an incandescent light bulb. An incandescent uses electrical resistance to make light. Current passes through a tungsten filament in a vacuum. The heat builds up and the filament begins to glow, producing a lot of heat and some light. Because more energy is transformed into heat than into light, incandescents are not very efficient.

Household wiring has very low resistance to minimize the loss of power in moving electricity from one place to another in the house. An electric space heater deliberately has a higher resistance so that electricity gets turned into heat.

ALTERNATING AND DIRECT CURRENT

The preceding description of electricity is somewhat simplified. It's based on the concept that electricity flows in one direction, like water through a garden hose. This is known as direct current (DC), and this is, in fact, the way electricity is produced by solar electric systems and some wind energy systems. It's also the kind of electricity delivered by batteries.

However, the electricity supplied by the utility to your home is delivered as alternating current (AC). With alternating current the electrons move in a wave pattern, changing direction 120 times per second (completing 60 cycles per second = a **frequency** of 60 Hertz).

Utilities produce AC electricity because it can be easily transformed from one voltage to another. Utilities transmit electricity through high voltage lines, then "step it down" at substations with transformers before it's delivered by low-voltage line to your house. This is more economical because less power is lost in long distance transmission when it travels at high voltage.

EFFICIENCY FIRST

Many electric loads can be reduced easily by using ENERGY STAR® appliances and lighting and by fuel switching (replacing electricity with gas, solar, or wood for hot water and home heating). By incorporating efficiency strategies, you can reduce electrical consumption 50 percent to 75 percent (i.e., from 5,000 to 2,500 kWh per year). This reduction would make possible a much smaller and more affordable renewable energy system.

POWER DOWN
Common home appliances that need lots of power

APPLIANCE	TYPICAL WATTAGE
Central air conditioning	2,300–6,500
Dishwasher	1,200
Electric clothes dryer	5,500
Electric space heating	2,000–10,000
Electric water heater (52 gallon)	4,500
Freezer	540–700
Hair dryer	1,500
Room air conditioner	500–1,500
Toaster	1,150

Off-grid homes probably would not have these appliances. Consider natural gas alternatives when possible, or do without and invest the money in your renewable energy system.

Many wind energy systems produce what is known as “wild” or unpredictable AC power, where the frequency of the alternating current changes as the wind speed changes.

Inverters

Neither DC nor wild AC works with standard appliances. Some DC appliances are available but they typically are meant for recreational vehicles rather than homes or businesses. Both DC and wild AC power must go through an “inverter” that changes the power into standard AC.

Inverters are key components in renewable energy systems. Essentially, they create “high quality” power from the system. High quality power maintains a consistent wave pattern necessary for computers and other sensitive electronic equipment.

POWER AND ENERGY

The words “power” and “energy” sound interchangeable, but actually represent two different concepts. “Power” is used to refer to electricity in general or abstract terms, as in “the local power company,” or “do you have power in your cabin?” Technically, it is most commonly used to describe generation capacity or electrical load.

Generating plants typically are described in terms of the watts of power they produce. A coal-fired plant might produce 500 megawatts of power, a utility-scale wind turbine, 750 kilowatts, while a solar electric (PV) panel for recharging a computer battery might produce 25 watts of power.

Similarly, devices that use electricity, such as lights and appliances, are described in terms of their electrical load, which is the amount of power they draw when operating. **Rated power** can be used as a basis for comparison. For example, a 1,500-watt hair dryer draws 100 times as much power as a 15-watt clock radio.

When electric power is sold, it is measured in kilowatt hours of **energy**. Technically, energy is power used over time. It is the commodity sold by the electric utility. Your electric meter measures power as kilowatt hours (kWh) of energy and the power company sends a bill for that amount at their rate per kWh.

ELECTRICAL LOSSES

If you buy a one-kilowatt solar electric panel, will you really get one kilowatt of electricity under ideal conditions? Actually, you won’t. The energy output will be more like three-quarters of a kilowatt. That’s because renewable energy electrical systems lose power through the inverter, wires and batteries.

- **Inverters** experience electrical losses ranging from 5 percent to 15 percent. It pays to do research about a particular inverter’s internal losses before buying it.

- **Wire** losses typically are between 2 percent and 5 percent. The greater the distance between the wind turbine or solar panel and the electrical panel, and the thinner the wire, the greater the wire losses. Systems located at a distance from the electrical panel will need larger diameter wiring, which can get costly.
- **Battery** losses occur in the charging and discharging process. Losses can vary widely. Typically, they are smallest for grid-connected systems that include batteries for an uninterrupted power supply (UPS), and greatest for off-grid systems requiring significant amounts of storage. Battery losses range from a few percent to 30 percent.

CAPACITY VARIATIONS

The generating capacity of solar or wind systems can vary due to environmental factors. This capacity variation must be factored into the system's design.

Increased Panel Temperature

Solar electric panels gradually lose the ability to generate electricity as their temperature increases. Many solar panels have their back surfaces open to the air to keep them as cool as possible. Temperature losses for crystalline panels are about 14 percent. Temperature losses for thin-film panels are about 7 percent.

Change in Surface Area

Anything that reduces the sunlight reaching a solar panel will reduce power output. This includes snow, shading, dirt and a less-than-direct orientation to the sun. If located in full sun and kept clean of snow and dirt, "areas reductions" can be kept below 5 percent.

Panels mounted on a dual axis tracker, which keeps the panels perpendicular to the sun's rays, both vertically and horizontally, will generate 30 percent more power than a fixed array of panels.

Wind Speed

Wind speed and turbulence change the capacity of a turbine. Small increases in wind speed result in large changes in power output. A wind blowing at 10 mph will generate almost twice as much power as a wind blowing at 8 mph. Also, wind that blows evenly and smoothly will produce more energy than wind that is turbulent.

ENERGY MATH:
A hair dryer or a porch light—which costs more to run?

When an appliance has a high power rating it doesn't necessarily mean the appliance uses more energy. It depends on how much the appliance is used.

Let's compare a hair dryer rated at 1,500 watts, with a 60-watt light bulb. The hair dryer is used every day for 10 minutes. The light bulb is lit 8 hours per night as a security measure. Let's assume the utility rate is $.08 per kilowatt hour.

Kilowatt hours = (watts x hours) / 1,000

Hair dryer

1. Hair dryer uses 1,500 watts, 10 minutes per day for 30 days (1 month)
2. Hours = 10 minutes per day x 30 days = 300 minutes = 5 hours
3. Kilowatt hours = 1,500 watts x 5 hours = 7,500 watt-hours = 7.5 kWh
4. Dollars = 7.5kWh x $.08 per kWh = $.60 per month to operate the hair dryer

Porch light

1. Porch light uses 60 watts, 8 hours per day for 30 days (1 month)
2. Hours = 8 hours per day x 30 days = 240 hours
3. Kilowatt hours = 60 watts X 240 hours = 14,400 watt-hours = 14.4 kWh
4. Dollars = 14.4 kWh x $.08 per kWh = $1.15 to operate the porch light

The hair dryer draws 25 times more power than the light bulb (1,500 watts vs. 60 watts) but uses half as much energy each month (7.5 kWh vs. 14.4 kWh). If you have a renewable energy home, you can power the light bulb but probably not the hair dryer, even though the hair dryer uses far less energy per month.

A well-designed renewable energy home is also energy efficient. This home generates electricity using a wind turbine and solar electric panels. Energy efficient appliances and daylighting keep power loads low so that the renewable energy systems can provide most of the electricity. Heating is partially provided by a wood burning, masonry fireplace. Good construction techniques, including high insulation levels and air sealing, help keep the heat inside.

ENERGY UNITS:
Watts, kilowatts, and kilowatt hours

Kilowatt (kW)—A unit of 1,000 watts. A kW is the standard unit for expressing the size of a solar electric or wind turbine system, or the size of an electrical load.

1 Kilowatt (kW) = 1,000 watts
1 Megawatt (mW) = 1,000,000 watts

Kilowatt hour (kWh)—A unit of 1,000 watt-hours. A kWh is the standard unit for energy, expressed as kilowatts of electricity used over time. The utility's rates are expressed as cents per kilowatt hour.

Kilowatt hours = (watts X hours) / 1000

Example: 2,000 watts for four hours: (2,000 X 4) / 1,000 = 8 kWh

LEARN MORE:

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Contact Focus on Energy to learn more about renewable energy choices. We have fact sheets and case studies featuring solar water heating, solar electricity, passive solar design and wind turbines. Renewable energy incentives also are available.

Focus on Energy also has information on Wisconsin ENERGY STAR Homes®. Wisconsin ENERGY STAR Homes can assist builders and buyers with selecting appropriate levels of insulation, noting common air sealing issues and completing site visits during construction to ensure these details are implemented. Visit focusonenergy.com or call 800.762.7077 for more information.

The Not So Big House: A Blueprint for the Way We Live
Sarah Susanka and Kira Obolensky, 1998, Taunton Press. The goal of this book is to help readers create a smaller home that better serves their lifestyle, personality and values.

energystar.gov
The ENERGY STAR Web site offers information on high quality energy efficient appliances that will help make your energy efficient, renewable home a reality.

There Are No Electrons: Electronics for Earthlings.
Kenn Amdahl. Broomfield, Colorado: Clearwater Publishing Company. 1991. An entertaining introduction to electricity concepts.

Focus on Energy is a public-private partnership offering energy information and services to energy utility customers throughout Wisconsin. The goals of this program are to encourage energy efficiency and use of renewable energy, enhance the environment, and ensure the future supply of energy for Wisconsin. For information about the Focus on Energy services and programs, call 800.762.7077 or visit focusonenergy.com.

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