

# THE BASICS OF ELECTRICITY

Before purchasing a photovoltaic system, it is a good idea to have a basic understanding of electricity. Simple familiarity with basic electrical terms and concepts will enable you to better understand your renewable energy system and use it with confidence.

The building blocks of an electrical vocabulary are voltage, amperage, resistance, watts and watt-hours. Electricity can simply be thought of as the flow of electrons (amperage) through a copper wire under electrical pressure (voltage) and is analogous to the flow of water through a pipe. If we think of copper wire in an electrical circuit as the pipe, then voltage is equivalent to pressure (psi) and amperage is equivalent to flow rate (gpm).

To continue with our electricity to water analogy, a battery stores energy much as a water tower stores water. Since a column of water 2.31 feet tall produces 1 psi at the base, the taller the water tower the higher the pressure you get at the base. As you can see from the picture to the right, the mushroom shape design of a water tower allows it to provide a large volume of water to end users at between 40-60 psi. Once drained below 40 psi which occurs near the neck of the tower, continued water usage will rapidly deplete the water supply at an ever decreasing pressure. Although a 12 volt battery is not physically shaped like a water tower, it has most of its stored electricity available between 12 volts to 12.7 volts. When drained below 12 volts, little amperage remains and the battery voltage will decrease rapidly.

In a simple system, a power source like a solar module provides the voltage which pushes the amperage through a conductor (wire) and on through a load that offers resistance to the current flow which in turn consumes power (watts). Power is measured in watts and is the product of voltage multiplied by amperage. Energy is power (watts) used over a given time frame (hours) and is measured in watt-hours or kilowatt-hours (1 kilowatt-hour equals 1000 watt-hours). For example, a 100 watt light left on for 10 hours each night will consume 1000 watt-hours or 1 kilowatt-hour of energy. A kilowatt-hour is the unit of energy measurement that the utility company bills you for each month. Electrical appliances are rated in terms of how many watts (or amps) they draw when turned on. To determine how much energy a particular appliance uses each day, you need to multiply the wattage by the number

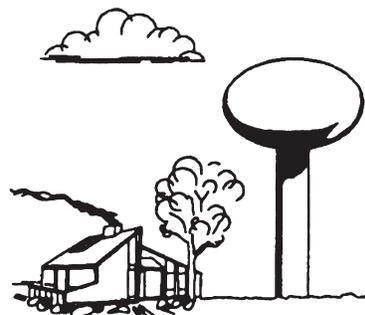
of hours used each day. See the load evaluation sheet on [page 12](#) for more information on electrical load calculations.

When wiring solar modules or batteries together in an renewable energy system, remember that connecting two of them in series (+ to -) doubles their voltage output, but keeps their amperage (or amp-hour capacity) the same. Connecting two of them in parallel (+ to +, - to -) doubles their amperage output (or amp-hour capacity), but keeps their voltage output the same. For example, most solar modules have a 12V nominal output so you would need to wire four of them in series (+ to -) to charge a 48V battery bank. The amperage output from these four solar modules in series is the same as that of a single solar module. Similarly, you would need to wire four 6V 350 amp-hour (AH) L-16 size batteries in series (+ to -) to configure them for 24V operation and then connect two strings of four batteries in parallel (+ to +, - to -) to obtain a 700 amp-hour capacity battery. See [Appendix F](#) for more information on battery wiring.

The discussion above of voltage and amperage leads to the subject of wire size. The amount of current that you can send through any electrical circuit depends on three things; the size or gauge (AWG) of the wire being used, the voltage of the system and the one way wire run distance. All wire (Cu and Al) has a listed resistance per 1000 feet with a larger gauge wire having a lower resistance value than a smaller one. The longer the distance and lower the voltage, the larger gauge wire you will need to use to minimize the voltage drop.

As a "rule of thumb", if your solar array consists of 4 or more, 60 watt or larger solar modules and is 50 feet or more away from the battery bank you should consider setting your system up at 24 or 48V instead of 12V. See the voltage drop tables in [Appendix B](#) at the back of the catalog for more information on wire sizing for 12, 24 or 48 VDC.

Many water towers are physically shaped like a mushroom. Electrically speaking, batteries are mushroom shaped as well. A tower designed to produce 50 p.s.i. for household pressure might be built like this.



| PSI | FEET | VOLTAGE |
|-----|------|---------|
| 60  | 139  | 12.70   |
| 50  | 115  | 12.57   |
| 40  | 92   | 12.43   |
| 30  | 69   | 12.30   |
| 20  | 46   | 12.17   |
| 10  | 23   | 12.03   |
| 0   | 0    | 11.90   |

# POWER CONSUMPTION TABLE

These figures are approximate representations. The actual power consumption of your appliances may vary substantially from these figures. Check the power tags, or better yet, measure the amperage draw with a clamp-on ammeter.

Multiply the hours used on the average day by the wattage listed below. This will give you the watt hours consumed per day, which you can then plug into the load evaluation form on the [next page](#).

Remember that some items, such as garage door openers, are used only for a fraction of an hour or minute per day. A 300 watt item used for 5 minutes per day will only consume 25 watt hours per day.

Where a range of numbers are given, the lower figure often denotes a technologically newer and more efficient model. The letters "NA" denote appliances which would normally be powered by non-electric sources in a PV powered home.

We strongly suggest that you invest in a true RMS digital multimeter if you are considering making your own power. Also helpful are clamp-on type ammeters. It actually makes sense to know where your power is being used, even if you are not producing it, and if you are, these meters are essential diagnostic tools.

| appliance           | watts     | appliance                  | watts    | appliance                | watts                |
|---------------------|-----------|----------------------------|----------|--------------------------|----------------------|
| Coffee Pot          | 200       | Garage door opener         | 350      | Compact fluorescent      |                      |
| Coffee Maker        | 800       | Ceiling fan                | 10-50    | Incandescent equivalents |                      |
| Toaster             | 800-1500  | Table fan                  | 10-25    | 40 watt equivalent       | 11                   |
| Popcorn Popper      | 250       | Electric blanket           | 200      | 60 watt equivalent       | 16                   |
| Blender             | 300       | Blow dryer                 | 1000     | 75 watt equivalent       | 20                   |
| Microwave           | 600-1500  | Shaver                     | 15       | 100 watt equivalent      | 30                   |
| Waffle Iron         | 1200      | Waterpik                   | 100      |                          |                      |
| Hot Plate           | 1200      | Well Pump (1/3-1 HP)       | 480-1200 | Electric mower           | 1500                 |
| Frying Pan          | 1200      |                            |          | Hedge trimmer            | 450                  |
|                     |           | Computer                   |          | Weed eater               | 500                  |
| Dishwasher          | 1200-1500 | Laptop                     | 20-50    | 1/4" drill               | 250                  |
| Sink waste disposal | 450       | PC                         | 80-150   | 1/2" drill               | 750                  |
|                     |           | Printer                    | 100      | 1" drill                 | 1000                 |
| Washing machine     |           | Typewriter                 | 80-200   | 9" disc sander           | 1200                 |
| Automatic           | 500       | Television                 |          | 3" belt sander           | 1000                 |
| Manual              | 300       | 25" color                  | 150      | 12" chain saw            | 1100                 |
| Vacuum cleaner      |           | 19" color                  | 70       | 14" band saw             | 1100                 |
| Upright             | 200-700   | 12" black and white        | 20       | 7-1/4" circular saw      | 900                  |
| Hand                | 100       | VCR                        | 40       | 8-1/4" circular saw      | 1400                 |
| Sewing machine      | 100       | CD player                  | 35       |                          |                      |
| Iron                | 1000      | Stereo                     | 10-30    | Refrigerator/Freezer     |                      |
|                     |           | Clock radio                | 1        | 20 cu. ft. (AC)          | 1411 watt-hours/day* |
| Clothes dryer       |           | AM/FM auto cassette player | 8        | 16 cu. ft. (AC)          | 1200 watt-hours/day* |
| Electric NA         | 4000      | Satellite dish             | 30       |                          |                      |
| Gas heated          | 300-400   | CB radio                   | 5        | Freezer                  |                      |
|                     |           | Electric clock             | 3        | 15 cu. ft. (Upright)     | 1240 watt-hours/day* |
| Heater              |           |                            |          | 15 cu. ft. (Chest)       | 1080 watt-hours/day* |
| Engine block NA     | 150-1000  | Radiotelephone             |          |                          |                      |
| Portable NA         | 1500      | Receive                    | 5        |                          |                      |
| Waterbed NA         | 400       | Transmit                   | 40-150   |                          |                      |
| Stock tank NA       | 100       |                            |          |                          |                      |
| Furnace blower      | 300-1000  | Lights:                    |          |                          |                      |
| Air conditioner NA  |           | 100 watt incandescent      | 100      |                          |                      |
| Room                | 1000      | 25 watt compact fluor.     | 28       |                          |                      |
| Central             | 2000-5000 | 50 watt DC incandescent    | 50       |                          |                      |
|                     |           | 40 watt DC halogen         | 40       |                          |                      |
|                     |           | 20 watt DC compact fluor.  | 22       |                          |                      |

Note: TV's, VCR's and other devices left plugged in, but not turned on, still draw power.

\* The daily energy values listed here are for the most efficient units in their class and the information was obtained from *Consumer Guide to Home Energy Savings* by Alex Wilson and John Morrill.

