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.

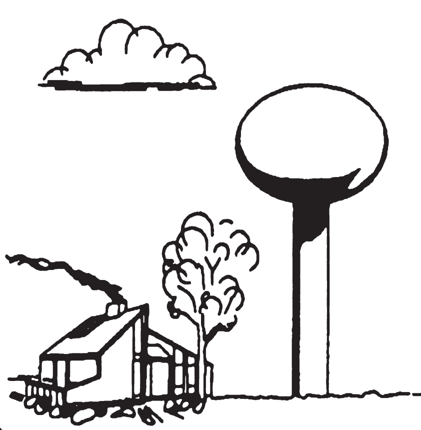
In a simple system, a power source like a solar module provides the voltage which pushes the amperage through a conductor (wire) and on through a load that offers resistance to the current flow which in turn consumes power (watts). Power is measured in watts and is the product of voltage multiplied by 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.

When wiring solar modules or batteries together in a 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.

Appliances	Watts	Appliances	Watts	Appliances	Watts
Coffee Pot	200	Garage door opener	350	Compact fluorescent	
Coffee Maker	800	Ceiling fan	10-50	Incandescent equivalents	
Toaster	800-1500	Table fan	10-50	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	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	30		
Iron	1000	Stereo	10-30	Refrigerator/Freezer	
		Clock radio	1	20 cu. ft. (AC)	1411 watt-
Clothes dryer		AM/FM Radio	8	16 cu. ft. (AC)	hours/day*
Electric NA	4000	Satellite dish	30		1200 watt-
Gas heated	300-400	CB Radio	5		hours/day*
		Electric Clock	3	Freezer	
Heater				15 cu. ft. (Upright)	1240 watt-
Engine block NA	150-1000	Radiotelephone		15 cu. ft. (Chest)	hours/day*
Portable NA	1500	Receive	5		1080 watt-
Waterbed NA	400	Transmit	40 150		hours/day*
Stock tank NA	100	Lights:			
Furnace blower	300-1000	100 watt incandescent	100		
Air conditioner NA		25 watt compact flour.	28		
Room	1000	50 watt DC incandescent	50		
Central	2000-5000	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.

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Solar Array Sizing Worksheet

Use the worksheet on the right to determine your solar requirements. We have included an example column and a column for your system.

1. Locate your site on the average yearly insolation map on page 6 and list the nearest figures.

2. Take your daily kwh load from your energy bill

3. Divide line 2 by line 1. This is the number of watts we need to generate per hour of full sun.

4. Find actual power produced by your selected module and enter. (rated amperage x battery voltage during charging). Example: Using KC130TM's, one module produces 7.1 amps. 13 volts is a common charging voltage for 12 volt systems. Actual power = amperage x charging voltage.

5. Divide line 3 by line 4. The result is the number of modules required for your system. When rounding this number, remember that sets of 2 modules are needed for a 24 volt system, sets of 4 for 48, etc.

	Example	Actual Figures
Step	yearly average	yearly average
1	5.0 sun hours per day	
2	100 watt-hours per day	
3	200 watts	
4	(7.1x13)=92.3i	
5	2.17	