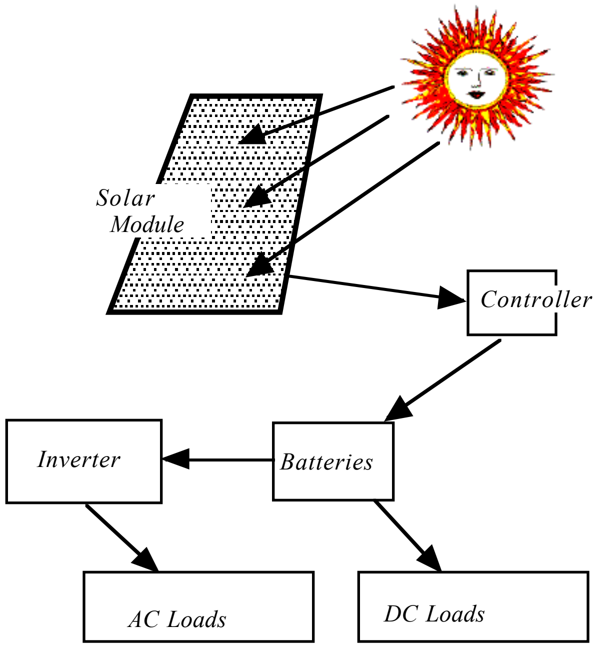
About Solar

The Basics of Solar Electricity Are Simple

The basics of how solar systems work can be seen in the diagram at right. The sun shines on solar modules that produce DC current. The current goes through a controller that regulates the amount of power that goes into the batteries. The batteries store DC power for use when needed. DC appliances run off energy straight from the batteries. You can choose to use AC appliances instead of DC—or in addition to DC—but the energy from the batteries must first be changed to AC voltage by an *inverter*.



Solar system design is not just about using the sun for electricity. It is about using this energy efficiently. Things as simple as window placement and flooring and window covering materials can affect how well your design will function. The ability to understand how energy is created, stored and used in your home is important. Many books are available on passive solar home design, and various statewide solar energy associations can be found on the Web along with the national solar energy association. Our New Mexico Solar Energy Association is located at: http://www.nmsea.org.

Energy conservation is the first area to consider. You will now be the power company as well as the power consumer. Your choices in appliances, lighting, cooking and heating will greatly affect the cost of your power plant. Use less power and you can buy a smaller power plant. *It really is simple.*

Developing an overall strategy for energy independence is the most important first step. Many people want to purchase equipment based on a budget. That is only part of the equation. It is better to make a plan of where you want to go with the money that you have to spend....and the money that you will want to spend later. The most economical step in going off-grid is to lower the amount of energy you use. You may be better off to start out with a new energy efficient stove, refrigerator and computer than to buy a small solar system that won't be able to run the inefficient appliances that you use now. Even if you purchase a grid-tied system to reduce your electric bill, you will realize a great savings with *energy efficiency,* even before you buy any solar equipment.

We've been doing solar energy systems for ten years and will be happy to help you design yours!

"What's the payback time on a solar electric system?"

	Car	Solar
Initial Cost	$20,000	$20,000
Gas & Maintenance per month	$250	$50
Insurance per month	$100	$0
Bill reduction per month	$0	$100
Depreciation	18% per yr.	5% per yr.
Life expectancy	5 yrs.	20 yrs.
Lifetime net cost	$41,000	$8,000

This may be the question we hear the most. In addition to the environmental, social and personal security benefits, the investment in solar does make economic sense. The chart at left compares a solar investment with another investment we are familiar with—the purchase of a new car.

When you finance a car purchase, because you pay interest up front, it takes 40 months of a 60 month note to actually own any equity in your car. That means that for almost 4 1/2 years you owe more than the car is worth. This chart uses a fixed gasoline cost for the life of a car, even though chances are gas prices will increase. Remember what you were paying for gas five years ago?

Solar electric systems have been shown to increase the value of a home by more than 85% of the system price or just about equal to the actual equipment cost! This chart uses a fixed electric company rate for the next 20 years to reflect the savings per month. Think you will be paying the same for electricity in the next five, ten or twenty years?

A Short Lesson in Electricity

Amps x Volts = Watts
Watts / Volts = Amps
Watts / Amps = Volts
Kw = 1,000 Watts

Electricity is the flow of electrons through a conductor like a wire. It's like the flow of water through a pipe.

To increase the flow of water through a pipe you need either a larger pipe or more pressure. The pressure in an electrical system is called voltage and is measured in volts. The higher the voltage in a system the more force behind it.

In a water pipe the size of the pipe also determines the rate of flow. The bigger the pipe the greater the flow. The amount of flow in electricity is called amperage, measured as amps or current.

Electrical "power" is a combination of the pressure, or **VOLTAGE** times the flow, or **AMPERAGE**. This combination is called the **WATT** or **WATTS**. This is generally the unit of power that we use in assessing electrical systems. It functions as a common denominator for different voltages and amperages. For example:

5 amps at 24 Volts = 120 Watts (Amps x Volts = Watts)
or
1,500 watts / 120 Volts = 12.5 amps (Watts/ Volts = Amps)

One watt that is powered for one hour is called one **WATT HOUR.** 1,000 watts use for one hour is a **KILOWATT HOUR.**

These formulas help us figure out how much solar power it will take to run our loads:

A 4 amp motor running for 1/2 hr. at 120 volts uses 240 watts.
4(amps) x 120(volts)=480 watts / 2 (1/2 hr.) = 240 Watt hrs.

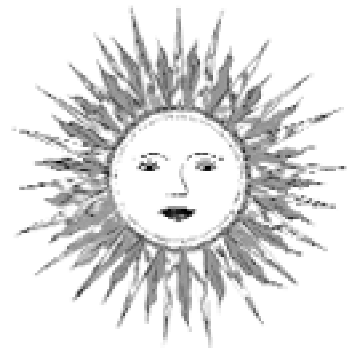
A 100 watt solar panel produces 100 watt hours per full solar hour. It would take about 2 1/2 hours for that solar panel to run the motor for 1/2 hour. This is a simplistic example because there are various inefficiencies in solar electric systems, but this is a good "rule of thumb".

Should you wire your electrical system for AC or DC?

To design your system you need to decide what voltage you will use. Most off-grid homes use a combination. In our home most loads, including lighting, are AC and run off the inverter. This catalog is published on a MacIntosh computer powered by the sun. Only our phone system and our pumps are 12 VDC. In the event of an inverter failure we still have phone and water.

If you have a small system, then DC is a simpler and less expensive way to go because there is no need for an inverter. But if you plan to use appliances that you already own (stereo, TV, tools etc.) you will need an inverter. Since AC appliances, light bulbs and tools are more readily available and generally less expensive you may want to run most things AC. Just remember that if your inverter goes down so does everything that relies on it. Fortunately, inverters are very sturdy and long lasting.

Some people are concerned about the magnetic field that AC wiring creates in their homes. There are possible health hazards related to this phenomenon. If you are concerned, then don't put AC wires in the walls by your bed where you spend the most time in your house.



12 Volt, 24 Volt, 48 Volt... What?

Now you have to decide what your DC system voltage will be; 12, 24, or 48 volts? It used to be simple because every one used DC light bulbs and appliances like car stereos. But now inverter systems have become so sophisticated and reliable, that people are choosing to power their entire house or shop with 120 volts AC. Our house is almost all AC.

You may want to have DC for your water pressurizing pump and communications if you are beyond phone lines and have to rely on cell or radio phones. And you may want a DC light in the room or building that houses your inverter in case it shuts down and you have to go in to inspect it.

Using 12 volts DC allows you to use straight battery power for a lot of things. Anything that will run in a car or RV will run off 12 volts, so there are many choices. Remember that the lower the system voltage, the more power (voltage) loss there is on long wire runs.

With a 24 or 48 volt system you can still invert to 120 AC and put your solar panels farther away from the house and use small (less expensive) wire to get there. However there are a couple of things to remember. There are only a few 24 volt appliances and almost no 48 volt appliances. There are voltage converters that can be used sparingly like a 12 volt phone run off a 24 volt system. With a 24 volt system you have to buy solar panels in groups of two and 6 volt batteries in groups of four (4 panels and 8 batteries for a 48 volt system). Most of our systems are 24 VDC.

Whatever size system you choose, the AC end of it is easy. Your electrician can wire the house just like a "normal" house (see phantom load suggestions below) and simply get the AC from the inverter instead of the grid.

Phantom Loads

Don't pay for electricity that you aren't using. Phantom loads are the electricity that appliances use when they are turned OFF! That's right... The light on your stereo or TV that shines when they are off means that as much as 50% of their "on" power is being used while they are "off" so that they can come on "instantly". I tested my stereo, TV and VCR when they were off and found that they were using 42 watts per hour! That's 1,008 watts per day to be "off"!

Common phantom loads are: TV, VCR, clocks on appliances, computer systems. Plug these loads into "power strips" and turn the strips off when the appliances are not being used. If you are building a new house, get your electrician to put in a wall switch that turns power on and off to these appliances. It's a simple and inexpensive way to conserve electricity, even if you are ON the grid.

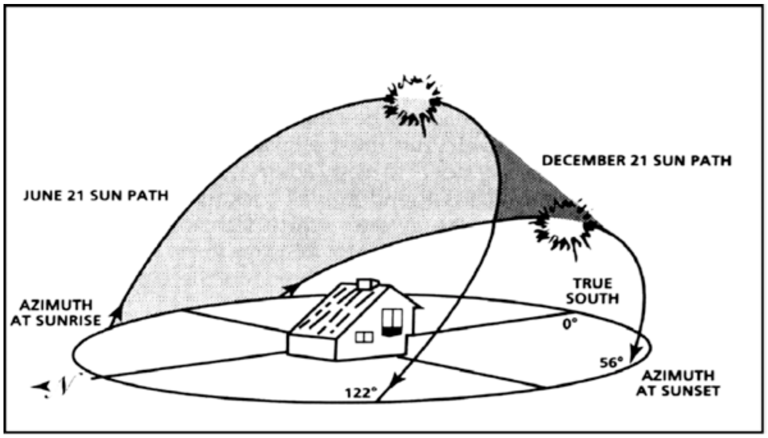
The numbers 110 volts, 117 volts and 120 volts AC all refer to household current in the USA. We use the number 120 to do the math.

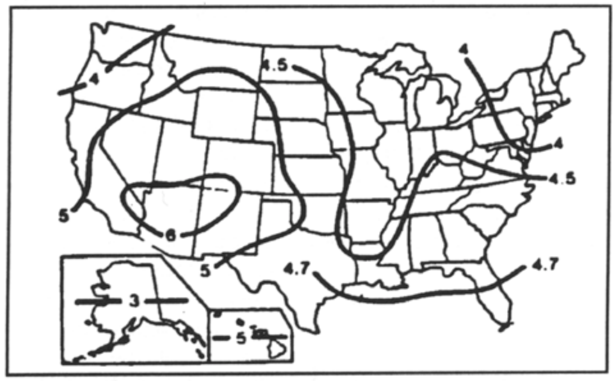
Planning and Sizing a Solar Electric System

The two most important factors in planning a solar electric system are the amount of sunlight that you have, or insolation, and your daily power consumption, or loads.

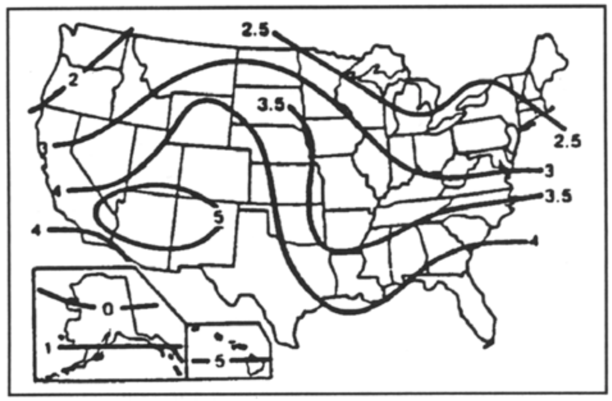
Power Consumption

The easiest way to calculate your power consumption is to look at your electric bills from the last several months. This will tell you how much you use in Kilowatt hrs. Each Kilowatt hr. is 1,000 watts for one hour. WOW! That's a lot! But it may include loads that solar will not efficiently power like electric stoves or heating. If you plan to use solar electricity you may need to make some changes in your choice of appliances and even in the way that you live.





Average Sun Hours Year-Round



Sun Hours per Day Dec-Jan

Wattage Requirements for Common Appliances per Hour

Description	Use	Description	Use
		Kitchen Appliances	
22 cu ft auto defrost refrigerator	490	Dishwasher	1500
Equator 375 efficient AC refrigerator	90	Trash compactor	1500
Sunfrost DC refrigerator	60	Can opener	100
(refs. run approx. 10hrs. per day)		Microwave	750
		Exhaust fan	50
AC Jet pump, 165 gal. per day	500	Coffee pot	1200
DC house pump 1-2 hrs. per day	60	Food processor	1200
		Toaster	1200
TV (25" color)	130	Gas stove (glow bar)	200
TV (19" color)	60	Office	
Satellite system	45	Computer & Monitor	140
VCR	30	Typewriter	200
Laser disc	30	Sewing machine	150
Stereo	15	Hygiene	
CB system (DC)	10	Hair dryer	1500
Cellular phone (DC)	10 - 24	Whirlpool bath	750
		Misc	
Mini-Florescent light bulb	22	Electric blanket	250
Electric clock	10	Garage door opener	300
Clock radio	10	Ozone air cleaner	40
Iron	1500	Tools	
Clothes washer	450	2 hp. table saw	2250
Staber efficient washer	250	Grinder	600
Gas dryer	250	Drill	300

Insolation

Insolation is sunlight intensity that is measured in equivalent full sun hours. One hour of 100% sunshine on a solar panel or array equals one full sun hour. Even though the sun is up for 12 hours a day, all of those hours are not considered full sun hours. There are two reasons for this: the sun in the morning and late afternoon is shining through more atmosphere than at mid-day. Also in the early and late times of day, the angle of the sun is too sharp relative to the surface of your solar panels. Panels are more able to use light that is closer to perpendicular to their surface. That is a large part of what makes trackers attractive because they hold your array closer to perpendicular throughout the day, thus increasing the usable output of the sun.

The most productive hours of sunshine for solar electricity are from 9 am to 3 pm. In some parts of the United States these may be the only hours of sunlight in the winter. So we use both the average full sun hours and the winter full sun hours to help in designing systems. Look at the charts above to see how much sunlight you can expect in your area.

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Load Evaluation Chart

Use the following chart to understand your total electrical use. Note which loads are AC and which are DC. This, along with the largest AC load number, will help you pick an inverter that will power your loads. Don't forget to include anticipated loads that you would like to use in the future like power tools or a washing machine.

Remember to move loads like clothes drying, cooking and water heating to other energy sources. Hang your clothes on the line, cook with a solar cooker, heat your water with a solar water heater. Propane gas is not solar but, if you have access to it, it can be far less expensive than electricity for these problematic loads.

This estimate does not have to be EXACTLY accurate. However, the closer you get, the better you will be able to design your solar system. And, of course, you can call us for free help. It makes it easier if you have done your homework and have these numbers to help us help you.

Appliance	AC	DC	Qty.		Wattage (V x A) Mult. * 1.5 for AC		Hours per Day		Days per Week	Divide By 7	"="	Avg. Watt Hrs. per Day
				x		x		x		/7		
				x		x		x		/7		
				x		x		x		/7		
				x		x		x		/7		
				x		x		x		/7		
				x		x		x		/7		
				x		x		x		/7		
				x		x		x		/7		
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				x		x		x		/7		
				x		x		x		/7		

Largest AC Load in Watts:		Total AC Wattage Used At One Time:		Total Watt Hrs. Per Day:
Total Watt Hrs. Per Day:	÷	System Loss Factor: *	=	Actual Watt Hrs. Per Day:
	÷	.8	=	

* Use .8 as your system loss factor. There are inefficiencies and losses in solar systems and batteries.

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System Worksheet

Worksheet for Sizing Your Solar Array

Use this page to determine you solar array and battery needs. We have included examples. Call if you need help.

1. Locate your site on the Sun Hours per Day maps on page 5 and list the nearest figures for both winter and yearly average.

2. Take the daily corrected total loads in watt hours from your Load Evaluation Chart (page 6)

3. Divide line 2 by line 1. this is the number of watt hours you need to generate per hour of full sun.

4. Find the actual power produced by your selected PV panel and enter here (rated amperage x battery voltage during charging). Example: Using a UniSolar US 64, one panel produces 3.9 amps. 13 volts is a common charging voltage for a 12 volt system. Actual power = amperage x charging voltage. Write the result in line 5.

5. Divide line 3 by 5. The result is the number of panels required for your system. when rounding this number, remember that groups of 2 panels are needed for a 24 volt system and groups of 4 for a 48 volt system.

Example

	Winter	Yearly Average	Winter	Yearly Average
1.	2.5	5.0		
2.	1,000	1,000		
3.	400	200		
4.	3.9 x	16.5		
5.	64	64		
6.	6.25	3.125		

Notice from the example that during winter almost twice the number of panels are required if there is only half as much available sunlight. In northerly climates this is often aggravated by a larger wintertime demand for more lights.

Worksheet for Battery Sizing

1. Determine total watt hours per day required from your Load Evaluation Chart (page 6)

2. Determine days of storage required. This is the greatest number of cloudy days in a row expected (3 to 7 is common for houses).

3. Multiply line 1 by line 2.

4. Figure planned depth of discharge. 80% is the maximum for lead acid batteries, 50% is common for optimum longevity of you batteries. Divide line 3 by a factor of .8 or .5 respectively.

5. De-rate your battery for low temperatures by multiplying line 4 by 1.2

6. Find the watt hour capacity of your selected battery. This is the voltage times the amp hour capacity. Example: Interstate deep cycle = 6 volts x 220 amp hours.

7. Divide line 5 by line 6. The result is the number of batteries required.

8. Round the number up to fit the system voltage. Example: a 24 volt system requires groups of 2 batteries when using 12 volt batteries or groups of 4 batteries when using 6 volt batteries.

Example

1,000	
4	
4,000	
8,000	
9,600	
1,320	
7.2	
8	

Notice: The battery bank amperage should normally be at least 5 times the hourly amperage draw of the largest appliance or 5 times the highest hourly amperage output of the battery charger in your inverter.