Utility Grid-Tie System Design

Budget, roof dimensions and other site-specific factors often call for custom system design. If you are planning to mount your array on a roof, decide which module best fits into the available roof space, taking into consideration obstructions such as chimneys, plumbing vents and skylights. See Solar Modules, page 18, for dimensions of modules. A grid-connected PV system consists of PV modules, output cables, module mounting structures, AC and DC disconnect switches, inverter(s), grounding equipment and a metering system. This worksheet will help you decide what size PV array would be required to eliminate your electric bill. This will be the largest system that would be cost-effective to install. A smaller system can reduce part of your bill, or eliminate higher cost electricity in locations that have progressively increasing rates as consumption increases. Use this information and the amount of available space to get a rough idea of your PV array size.

Grid-Tie PV Array Design Worksheet – Determine array size for your grid-connected system.

Step 1 Find your monthly average electricity usage from your electric bill. ______

This will be in kilowatt hours (kWh). Due to air conditioning, heating and other seasonal usage, it is a good idea to look at several bills. You can add the typical summer, fall, winter and spring bills and divide by four to find the average monthly usage.

Step 2 Find your daily average electricity use. ______

Divide the monthly average number of kWh use by 30 (days)

Step 3 Find your location's average peak sun hours per day. ______

See the maps on page 13, and/or the insolation map on page 208 For example, the average for California is 5 peak sun hours

Step 4 Calculate the system size (AC watts) to provide 100% of your electricity. ______

Divide your daily average electricity use by average sun hours per day. For example, if the daily average electricity use is 30 kWh, and the site is in California, system size would be: 30 kWh / 5 h = 6 kW AC. (Multiply kWh by 1000 to get AC watts.)

Step 5 Calculate the number of PV modules required for this system. ______

Divide the system AC watts in Step 4 by the CEC watt rating of the modules to be used, then divide by the inverter efficiency, usually 0.94, and you get the total number of modules required. (Round this number up)

Use table below (and on the next 2 pages) to determine array size/inverter combinations

This table shows inverter and module combinations for common modules used in grid connected systems. For a given inverter and module combination, the table displays the acceptable number of series strings of modules and the number of modules per string for temperatures between 14ºF and 104ºF. Where the inverter will support more than one string of modules, the table shows the number of modules that can be used with multiple strings. Sizing is accurate in locations where the maximum temperature is lower than 104ºF or the minimum temperature is higher than 14ºF. In locations where the minimum temperature is lower than 14ºF, the maximum number of modules per string may be lower.

In the table on the next page, the line labeled CEC watts is the expected output of the modules at normal operating temperature, in full sun. The approximate power output of a system in full sun will be the number of modules times the CEC rating of the modules times the inverter efficiency from second column on the table. Other factors, such as high or low temperature, shading, array orientation, roof pitch and dirt on the modules, will affect the system's actual output.

Inverter		CEC Efficiency	Module >	REC Solar AE-US		SCHOTT	SolarWorld	Evergreen
				REC215	REC225	POLY 220	SW230	ES-A-200
MFG	Model		CEC / Ratio >	187.2/0.871	196.2/0.872	193.9 / 0.881	204.4 / 0.889	180.7 / 0.904
				Recommended Number of Modules per String				
Schneider / Xantrex	GT 2.8	94.0%	one string	9 to 14	9 to 14	9 to 14	9 to 14	14 to 16
	GT 3.3	94.5%	one string	10 to 14	9 to 14	9 to 14	9 to 14	14 to 19
	GT 3.8	95.0%	one string	9 to 14	9 to 14	9 to 14	9 to 14	14 to 22
			two strings	9 to 10	9 to 10	9 to 10	9	
	GT 4.0	95.5%	one string	11 to 14	11 to 14	11 to 14	11 to 14	17 to 23
			two strings	11				
	GT 5.0	95.5%	one string	11 to 14	11 to 14	11 to 14	11 to 14	17 to 23
			two strings	11 to 13	11 to 13	11 to 13	11 to 13	

Inverter		CEC	Module >	REC Solar AE-US Series		SCHOTT	SolarWorld	Evergreen
				REC215	REC225	POLY 220	SW230	ES-A-200
MFG	Model	Efficiency	CEC / Ratio >	187.2/0.871	196.2/0.872	193.9 / 0.881	204.4 / 0.889	180.7 / 0.904
				Recommended Number of Modules per String				
SMA	SB700U	91.5%	one string					-
	SB2000HFUS	95.0%	one string	8 to 11	8 to 11	8 to 11	8 to 10	-
	SB2500HFUS	95.0%	one string	10 to 14	10 to 13	10 to 14	10 to 13	15
	SB3000HFUS	95.0%	one string	10 to 14	10 to 14	10 to 14	10 to 14	16 to 18
	SB3000US	95.5%	one string	10 to 12	9 to 12	9 to 12	9 to 12	14 to 18
	SB4000US	96.0%	one string	12 to 14	11 to 14	11 to 14	11 to 14	18 to 23
			two strings		11	11		
	SB5000US	95.5%	one string	12 to 14	11 to 14	11 to 14	11 to 14	18 to 23
			two strings	12 to 14	11 to 13	11 to 13	11 to 13	
	SB6000US	95.5%	one string	12 to 14	11 to 14	11 to 14	11 to 14	18 to 23
			two strings	12 to 14	11 to 14	11 to 14	11 to 14	18
			three strings		11	11		
	SB7000US	96.0%	one string	12 to 14	11 to 14	11 to 14	11 to 14	18 to 23
			two strings	12 to 14	11 to 14	11 to 14	11 to 14	18 to 21
			three strings	12 to 13	11 to 12	11 to 13	11 to 12	
	SB8000US	96.0%	one string	14	14	13 to 14	12 to 13	21 to 23
			two strings	14	14	13 to 14	12 to 13	21 to 23
			three strings	14	14	13 to 14	12 to 13	
PV Powered	PVP1100EVR	92.0%	one string	6	6	5 to 6	5 to 6	-
	PVP2000EVR	92.5%	one string	6 to 11	6 to 11	5 to 11	5 to 10	8 to 12
			two strings			5		
	PVP 2500	93.5%	one string	7 to 12	7 to 12	6 to 12	6 to 12	10 to 15
			two strings	7				
	PVP3000SVR	93.0%	one string	8 to 12	8 to 12	8 to 12	8 to 12	12 to 18
			two strings	8	8	8	8	
	PVP 3500	94.0%	one string	10 to 12	9 to 12	9 to 12	9 to 12	14 to 19
			two strings	10	9	9	9	
	PVP 4800	94.0%	one string	10 to 12	9 to 12	9 to 12	9 to 12	14 to 19
			two strings	10 to 12	9 to 12	9 to 12	9 to 12	14 to 15
	PVP 5200	94.5%	one string	11 to 12	11 to 12	11 to 12	11 to 12	17 to 19
			two strings	11 to 12	11 to 12	11 to 12	11 to 12	
Solectria	PVI1800	92.5%	one string	6 to 9	6 to 9	6 to 9	6 to 9	9 to 11
	PVI2500	93%	one string	6 to 9	6 to 9	6 to 9	6 to 9	9 to 15
			two strings	6 to 7	6	6		
	PVI3000	96.0%	one string	10 to 14	9 to 14	9 to 14	9 to 14	14 to 18
	PVI4000	96%	one string	10 to 14	9 to 14	9 to 14	9 to 14	14 to 23
			two strings	10 to 11	9 to 10	9 to 10	9 to 10	
	PVI5000	96%	one string	10 to 14	9 to 14	9 to 14	9 to 14	14 to 23
			two strings	10 to 14	9 to 13	9 to 13	9 to 13	14 to 15
	PVI5300	96%	one string	10 to 14	9 to 14	9 to 14	9 to 14	14 to 23
			two strings	10 to 14	9 to 14	9 to 14	9 to 14	14 to 16
			three strings	10	9	9	9	

Inverter		CEC Efficiency	Module >	REC Solar AE-US Series		SCHOTT	SolarWorld	Evergreen
				REC215	REC225	POLY 220	SW230	ES-A-200
MFG	Model		CEC / Ratio >	187.2/0.871	196.2/0.872	193.9 / 0.881	204.4 / 0.889	180.7 / 0.904
				Recommended Number of Modules per String				
Fronius	IG2000	93.5%	one string	7 to 11	7 to 11	7 to 12	7 to 11	11 to 12
	IG3000	94.0%	one string	7 to 12	7 to 12	7 to 12	7 to 12	11 to 16
			two strings	7	7	7	7	
	IG4000	94.0%	one string	7 to 12	7 to 12	7 to 12	7 to 12	11 to 19
			two strings	7 to 11	7 to 11	7 to 12	7 to 10	11 to 12
			three strings	7	7	7		
	IG5100	94.5%	one string	7 to 12	7 to 12	7 to 12	7 to 12	11 to 19
			two strings	7 to 12	7 to 12	7 to 12	7 to 12	11 to 15
			three strings	7 to 9	7 to 9	7 to 9	7 to 9	
			four strings	7	7			
	IG+3.0-1	95.5%	one string	11 to 14	11 to 14	10 to 14	10 to 14	16 to 17
	IG+3.8-1	95.5%	one string	11 to 14	11 to 14	10 to 14	10 to 14	16 to 22
	IG+5.0-1	95.5%	one string	11 to 14	11 to 14	10 to 14	10 to 14	16 to 23
			two strings	11 to 13	11 to 12	10 to 13	10 to 12	
	IG+6.0-1	96.0%	one string	11 to 14	11 to 14	10 to 14	10 to 14	16 to 23
			two strings	11 to 14	11 to 14	10 to 14	10 to 14	16 to 17
			three strings			10	10	
	IG+7.5-1	95.5%	one string	11 to 14	11 to 14	10 to 14	10 to 14	16 to 23
			two strings	11 to 14	11 to 14	10 to 14	10 to 14	16 to 21
			three strings	11 to 13	11 to 12	10 to 12	10 to 12	
	IG+10.0-1	95.5%	one string	11 to 14	11 to 14	10 to 14	10 to 14	16 to 23
			two strings	11 to 14	11 to 14	10 to 14	10 to 14	16 to 23
			three strings	11 to 14	11 to 14	10 to 14	10 to 14	16 to 19
			four strings	11 to 13	11 to 12	10 to 12	10 to 12	
	IG+11.4-1	96.0%	one string	11 to 14	11 to 14	10 to 14	10 to 14	16 to 23
	IG+11.4-3	95.5%	two strings	11 to 14	11 to 14	10 to 14	10 to 14	16 to 23
			three strings	11 to 14	11 to 14	10 to 14	10 to 14	16 to 21
			four strings	11 to 14	11 to 14	10 to 14	10 to 14	16
			five strings	11 to 12	11	10 to 11	10 to 11	
	IG+12.0-3 277v only	96%	one string	11 to 14	11 to 14	10 to 14	10 to 14	16 to 23
			two strings	11 to 14	11 to 14	10 to 14	10 to 14	16 to 23
			three strings	11 to 14	11 to 14	10 to 14	10 to 14	16 to 22
			four strings	11 to 14	11 to 14	10 to 14	10 to 14	16 to 17
			five strings	11 to 12	11 to 12	10 to 12	10 to 12	
			six strings				10	
KACO new energy	1501xi	94%	one string			6 to 8	6 to 8	9 to 10
	1502xi	95.5%	one string	6 to 9	6 to 8	6 to 9	6 to 8	9 to 10
	2502xi	95.5%	one string	10 to 13	9 to 13	9 to 13	9 to 12	15
	3502xi	95.5%	one string	10 to 14	9 to 14	9 to 14	9 to 14	14 to 21
			two strings		9	9	9	
	5002xi	95.5%	one string	10 to 14	9 to 14	9 to 14	9 to 14	14 to 22
			two strings	10 to 13	9 to 13	9 to 13	9 to 13	14 to 15

Grid-Tie with Battery Backup

Grid-tie systems with battery backup are configured differently and are much more complex than standard grid-tie systems without batteries. They need to be custom designed. If you need a backup system, consult with us to determine all the system components that you will need.

Inverters for Grid-Tie with Battery Backup

OutBack makes G-Series inverters and switchgear, page 98, that can power loads up to 7.2 kW.

The Schneider Xantrex XW series of inverters, page 101, offers grid-tie inverters with battery backup capability in 6000-watt increments. Several can be stacked for 12kW or 18kW battery backup systems.

The SMA Sunny Island inverter, page 80, in conjunction with a Sunny Boy inverter and PV array, can be used to provide high-efficiency backup power in a grid-tied home or business. Backup systems up to 20kW can be configured using up to 4 Sunny Island inverters. SMA will soon have a way to expand this for systems up to 80kW

You can use the following steps to determine the dual-function inverter size and the battery capacity that your system will require. Follow steps 1-5 on the Grid-Tie PV Array Design Worksheet on page 7 to determine the size of the array required to provide the desired percentage of total power. Then calculate the inverter size and battery capacity needed using the worksheet below.

Worksheet: Inverter and Batteries for Grid-Tie w/ Backup System

Step 1 Find the power requirements (watts) for the appliances you need to power during a black-out. ______

Make a list of the loads and appliances that you absolutely need to power during an outage. Only list the essential items since the system size (and cost) will vary widely with power needed. The wattage of individual appliances can usually be found on the back of the appliance or in the owners manual. You can use a Kill-a-Watt meter for better measurements (page 141). If an appliance is rated in amps, multiply amps by the operating voltage (120 or 240) to find watts. Add up the wattage of all the items on your list that you need to run all at the same time to arrive at the total amount of watts. This is your “peak wattage” inverter requirement and will determine the size of the dual-function inverter that you will need.

Step 2 Decide the blackout duration you want to be prepared for. ______

Power outages last from a portion of an hour to a day (or more). Again, this decision will greatly affect the system size and cost, so it is more cost-effective to stay on the conservative side.

Step 3 Find the amount of stored power required. ______

Multiply the power requirements (in step 1) by duration in hours (in step 2). The result will be in watt-hours. For instance, if you need to power 1000 watts of appliances for 2 hours, you would need to have 2000 watt-hours (or 2 kWh) of stored power.

Step 4 Calculate the power storage needed. ______

Multiply the figure arrived at in step 3 by 1.7. In the example, 2 kWh X 1.7 = 3.4 kWh of stored power needed.

Step 5 Calculate battery capacity needed. ______

Divide the power storage requirement needed from step 4 by the DC voltage of the system (usually 48V, but sometimes 24V) to get battery amp-hour (Ah) capacity. See the battery section on page 146 for more information on batteries. Most backup systems use sealed batteries due to their greatly reduced maintenance requirements, and because they can be more easily placed in enclosed battery compartments.

Off-Grid System Sizing Information

The size of an off-grid solar electric system depends on the amount of power that is required (watts), the amount of time it is used (hours) and the amount of energy available from the sun in a particular area (sun-hours per day). The user has control of the first two variables, while the third depends on the location.

Conservation

Conservation plays an important role in keeping down the cost of a photovoltaic system. The use of energy-efficient appliances and lighting, as well as non-electric alternatives wherever possible, can make solar electricity a cost-competitive alternative to gasoline generators and, in some cases, utility power.

Cooking, Heating and Cooling

Conventional electric cooking, space heating and water heating equipment use a prohibitive amount of electricity. Electric ranges use 1500 watts or more per burner, so bottled propane or natural gas is a popular alternative to electricity for cooking. A microwave oven has about the same power draw, but since food cooks more quickly, the amount of kilowatt hours used may not be large. Propane, wood or solar-heated water are generally better alternatives for space heating. Good passive solar design and proper insulation can reduce the need for winter heating. Evaporative cooling is a more reasonable load than air conditioning and in locations with low humidity, the results are almost as good. One big plus for solar cooling: the largest amount of solar energy is available when the need for cooling is the greatest.

Lighting

Lighting requires the most study since many options exist in type, size, voltage and placement. The type of lighting that is best for one system may not be right for another. The first decision is whether your lights will be run on low voltage direct current (DC) or conventional 120-volt alternating current (AC). In a small home, an RV, or a boat, low voltage DC lighting is often the best choice. DC wiring runs can be kept short, allowing the use of fairly small gauge wire. Since an inverter is not required, the system cost is lower. When an inverter is part of the system, and the lights are powered directly by the battery, a home will not be dark if the inverter fails. In addition to conventional-size medium-base low voltage bulbs, the user can choose from a large selection of DC fluorescent lights, which have 3 to 4 times the light output per watt of power used compared with incandescent types. High quality fluorescent lights are available for 12- and 24-volt systems. LED lighting is improving rapidly and already meets or beats the light output and efficiency of fluourescent lighting.

In a large installation or one with many lights, the use of an inverter to supply AC power for conventional lighting is cost-effective. AC compact fluorescent lights will save a tremendous amount of energy. It is a good idea to have a DC-powered light in the room where the inverter and batteries are in case there is a problem. AC light dimmers will only function properly on AC power from inverters that have pure sine wave output.

Refrigeration

Gas powered absorption refrigerators are a good choice in small systems if bottled gas is available. Modern absorption refrigerators consume 5-10 gallons of LP gas/month. If an electric refrigerator will be used in a standalone system, it should be a high-efficiency type. Some high-efficiency conventional AC refrigerators use as little as 1200 watt-hours of electricity/day at a 70º average air temperature. A comparably sized Sun Frost refrigerator/freezer uses half that amount of energy and a SunDanzer refrigerator (without a freezer) uses less than 100 watt-hours per day. The higher cost of good quality DC refrigerators is offset by savings in the number of solar modules and batteries required.

Major Appliances

Standard AC electric motors in washing machines, larger shop machinery and tools, swamp coolers, pumps, etc. (usually 1/4 to 3/4 horsepower) require a large inverter. Often, a 2000 watt or larger inverter will be required. These electric motors are sometimes hard to start on inverter power, they consume relatively large amounts of electricity, and they are very wasteful compared to high-efficiency motors, which use 50% to 75% less electricity. A standard washing machine uses between 300 and 500 watt-hours per load, but new front-loading models use less than 1/2 as much power. If the appliance is used more than a few hours per week, it is often cheaper to pay more for a high-efficiency appliance rather than make your electrical system larger to support a low-efficiency load. Vacuum cleaners usually consume 600 to 1,000 watts, depending on how powerful they are, about twice what a washer uses, but most vacuum cleaners will operate on inverters larger than 1,000 watts since they have low-surge motors.

Small Appliances

Many small appliances such as irons, toasters and hair dryers consume a very large amount of power when they are used but by their nature require very short or infrequent use periods. If the system inverter and batteries are large enough, they will be usable. Electronic equipment, such as stereos, televisions, VCRs and computers have a fairly small power draw. Many of these are available in low voltage DC as well as conventional AC versions. In general, DC models use less power than their AC counterparts.

Off-Grid Load Worksheet

Determine the total energy in amp-hours per day used by all the AC and DC loads in your system.

Calculate your AC loads

If there are no AC loads, skip to Step 5

1. List all AC loads, wattage and hours of use per week in the spaces provided. Multiply watts by hours/week to get AC watt-hours per week (WH/Wk). Add up all the watt hours per week to determine total AC watt-hours per week. Use a separate sheet of paper if you need to list more loads than the space below allows.

Description of AC loads run by inverter	watts	x	hours/week	=	watt-hours/week
	Total watt-hours/week				

NOTE: Wattage of appliances can usually be determined from tags on the back of the appliance or from the owner's manual. If an appliance is rated in amps, multiply amps by operating voltage (120 or 240) to find watts.

2. Convert to DC watt-hours per week by multiplying line 1 by 1.15 to correct for inverter loss. ______________
3. Inverter DC input voltage; usually 12-, 24- or 48-volts. This is DC system voltage. ______________
4. Divide line 2 by line 3. This is total DC amp-hours per week used by AC loads. ______________

Calculate your DC loads

5. List all DC loads, wattage and hours of use per week in the spaces provided. Multiply watts by hours/week to get DC watt-hours per week (WH/Wk). Add up all the watt hours per week to determine total DC watt-hours per week.. ______________

Description of DC loads	watts	x	hours/week	=	watt-hours/week
	Total watt-hours / week				

6. DC system voltage. Usually 12, 24, or 48 volts. ______________
7. Find total amp-hours per week used by DC loads: divide total in line 5 by line 6. ______________
8. Enter total DC amp-hours per week used by AC loads from line 4. ______________
9. Add lines 7 and 8. This is total DC amp-hours per week used by all loads.

Calculate your amp-hours per day

10. Divide line 9 by 7 days. This is total average amp-hours per day that needs to be supplied by the battery. Enter this number on line 1 on the Number-of-Modules Worksheet on page 13, and on line 1 of the Battery Sizing Worksheet on page 149. ______________

Off-Grid Solar Array Sizing Worksheet

Use this worksheet to calculate the total number of solar modules required for your system if you are using a non-MPPT charge controller. If you are using an MPPT type charge controller, do steps 1-4 on this worksheet, then move to step 5 on the next page. Information on the different types of PV charge controllers can be found in the Charge Controller section, page 122.

To find average sun-hours per day in your area (line 3), check local weather data, look at the map below or find a city on page 207 that has similar weather to your location. If you want year- round autonomy, use the lower of the two figures. If you want 100% autonomy only in summer, use the higher figure. If you have a utility grid-tie system with net metering, use the yearly average figure. The peak amperage of the module you will be using can be found in the module specifications. You can also get close enough if you divide the module's rated wattage by the peak power point voltage, usually 17 to 17.5 for a 12-volt module or 34 to 35 volts for a 24-volt module.

Step 1 Total average amp-hours per day needed (line 10 of the Off-Grid Loads Worksheet, page 12) __________

Step 2 Multiply line 1 by 1.2 to compensate for loss from battery charge/discharge __________

Step 3 Average sun-hours per day in your area __________

Step 4 Divide line 2 by line 3. This is the total solar array amps required

If you are using a PWM charge controller, continue to Step 5 below.
If you are using an MPPT charge controller, go to step 5 on page 14

Step 5 Peak-power amps of solar module used. See module specifications __________

Step 6 Total number of solar modules in parallel required. Divide line 4 by 5 __________

Step 7 Round off to the next highest whole number __________

Step 8 Number of modules in each series string to provide DC battery voltage – see table below __________

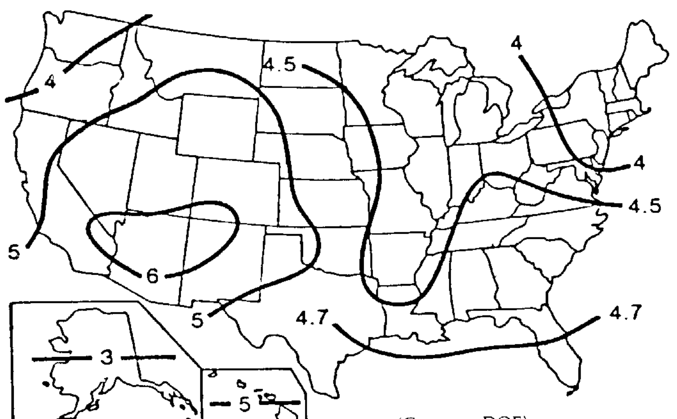
Step 9 Multiply line 7 by line 8 to get the total number of solar modules required. __________

Nominal System Voltage	Number of Series Connected Modules per String	
Volts	12V module	24V module
12	1	N/A
24	2	1
48	4	2

The maps below show sun-hours per day for the U.S.

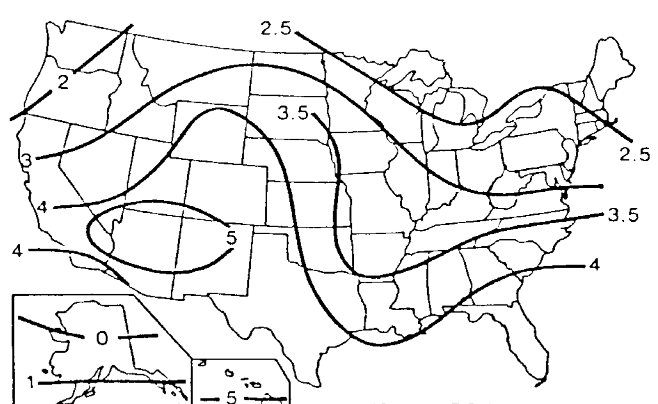
See a larger version of the USA map on page 208.

Yearly Average



(Courtesy DOE)

Four-Week Average, 12/7–1/4



(Courtesy DOE)

Solar Array Sizing Worksheet for use with MPPT Charge Controllers

Begin on page 13, steps 1 - 4 before starting on this page.

Step 5 Total solar array amps required from Step 4 of module worksheet for standard controllers. ________

Step 6 Enter average changing voltage: use 13.5V for 12V systems; use 27V for 24V systems; use 54V for 48V systems. ________

Step 7 Multiply Step 5 result by Step 6 result. This is the total PV array wattage required. ________

Step 8 Enter the peak power wattage of the chosen PV module. (Use the module's Peak Power wattage at STC.) ________

Step 9 Divide the wattage on Step 7 by the wattage on Step 8. **This is the total number of modules needed**. Round up to the nearest whole number. (NOTE: this number may need to be adjusted in Step 11.) ________

Step 10 Number of modules in each series string. See table below, and add number here. ________

Table for 150VDC maximum controllers. (For controllers with other max voltages, see controller instructions.)				
Module		Nominal battery voltage		
Type	# of cells	12V	24V	48V
REC220, SCHOTT 220, SolarWorld 230	60	1 to 3	2 or 3	3
SolarWorld 175	72	1 to 2	1 to 2	2
Mitsubishi UD185MF5, Kyocera 200	54	1 to 3*	2 to 3*	3*
Evergreen ES-A and ES-C and other 12V nominal modules	36	1 to 5	3 to 5	4 to 5
12V nominal modules w/ Apollo 200V controller	36	2 to 5	3 to 5	5

*In climates that never have freezing temperatures below 10°F, four Mitsubishi 185UD5 modules may be used in series

Step 11 Divide the number of total modules in Step 9 by the number of modules per series string from Step 10. This is the total number of array series strings. If this is not a whole number, either increase or decrease the number of modules in Step 9 to obtain a whole number of series strings. CAUTION: decreasing the total number of modules may result in insufficient power production. ________

Step 12 Determine wattage of each series string. Multiply module wattage from Step 8 by number of modules per string on Step 10. This is the total wattage per string. ________

Step 13 Determine number of module strings per controller. Divide appropriate wattage figure from the chart below by the wattage per string from Step 12. Round down to a whole number. This is the total number of module strings per controller. If you have more module strings (from Step 11) than can be handled by the chosen controller, either use a larger controller, or use multiple controllers. ________

Step 14 Divide total number of strings from Step 11 by the number of strings per controller from Step 13. Round up to a whole number. This is the total number of chosen controllers needed. ________

Maximum watts that can be used with an MPPT controller			
Controller amp rating	System nominal battery voltage		
	12V	24V	48V
15A	200W	400W	800W
30A	400W	800W	1600W
50A	650W	1300W	2600W
60A	750W	1500W	3000W
80A	1000W	2000W	4000W