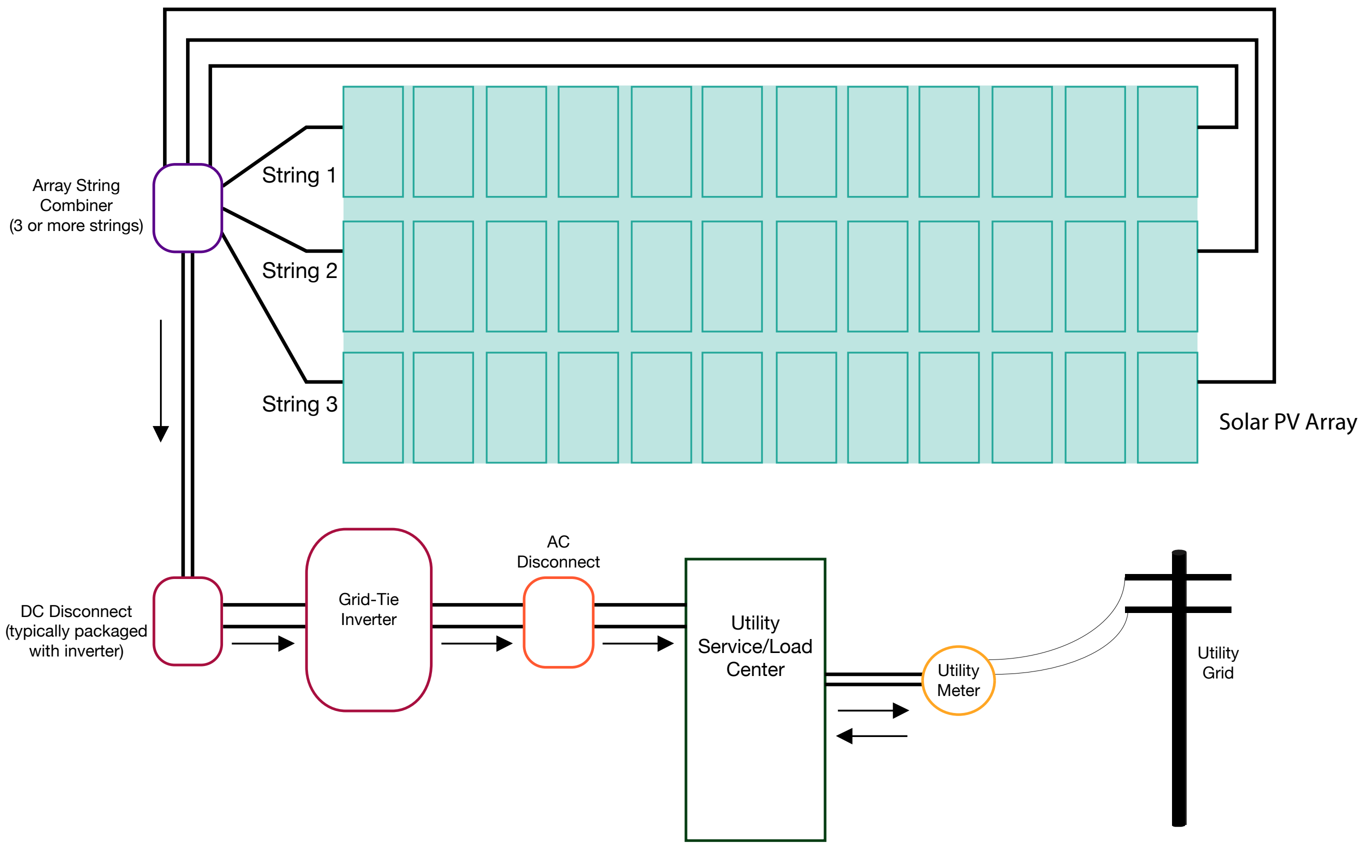
Utility Grid-Tie PV System Design

A grid-connected PV system consists of PV modules, output cables, a module mounting structure, AC and DC disconnect switches, inverter(s), grounding equipment, and a metering system, as shown in the diagram below. The Grid-Tie System Worksheet is designed to help contractors size a PV array to offset all of their client's electrical usage with the largest system that would be cost-effective to install. A smaller system can reduce part of the electric bill, and in locations with tiered or progressive rates, it may have a faster financial payback. Compare the worksheet result with the amount of space available to mount the PV array in order to get a rough idea of the maximum PV array size.

Below is a diagram of a typical batteryless grid-tie system (utility intertie). Many grid-tie inverters have built-in DC disconnect switches, while some have both a DC and an AC disconnect. Some models also contain a PV array string combiner so a separate one may not be necessary. Separate overcurrent protection for each series string of modules in a PV array (typically provided in the array combiner box) is required only if there are three or more series strings of modules connected to a single inverter input. Inverters with multiple MPPT input channels can have one or two series strings per channel without individual string fusing.



Worksheet: Grid-Tie PV System Design

Determine PV array size for a grid-connected system

______________ **Step 1: Determine the daily average electricity usage from the electric bills.**

This will be in kilowatt hours (kWh). Due to air conditioning, heating, and other seasonal usage, it is a good idea to add up all the bills for the year and then divide by 365 to find the average daily usage.

______________ **Step 2: Find the location's average peak sun-hours per day.**

See the maps on page 11 and/or the insolation map in the Reference section near the end of the catalog. For example, the average for Central California is 5 sun-hours.

______________ **Step 3: Calculate the system size (AC watts) needed to offset the average usage.**

Divide the 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 kW by 1000 to get AC watts.

______________ **Step 4: Calculate the number of PV modules required for this system.**

Divide the system AC watts in Step 4 by the watt rating of the modules to be used, and then divide by the inverter efficiency, usually 0.94 to 0.98, to get the total number of modules required. Round this number up to the next whole number of modules. For best results, use the module's PTC watt rating that is found on the California Energy Commission's Approved Equipment List (www.gosolarcalifornia.org/equipment) rather than the manufacturer's peak rating.

Select inverter(s) and determine string configuration

______________ **Step 5: Select the inverter/module combination from the table on the next page that is closest to the desired system size.**

The table on the next page shows inverter and module combinations for our most popular modules and grid-tie inverters with a 600 VDC maximum voltage limit. For a given inverter and module combination, the table displays the recommended number of series strings of modules and the number of modules per string for temperatures between 14°F and 104°F. 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 104°F and the minimum temperature is higher than 14°F. In locations where the minimum temperature is lower than 14°F, the maximum number of modules per string may be lower.

The line labeled "PTC" 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 multiplied by the watt rating of the modules and then multiplied by the inverter efficiency from the second column in the table. Other factors, such as high or low temperatures, shading, array orientation, roof pitch, and dirt on the modules, will affect the system's actual output.

	Inverter ↓	CEC % ↓	Module →	REC			Hanwha			Suniva		
				REC245	REC250	REC255	HSL-245TW	HSL-250TW	HSL-255TW	OPT260	OPT265	OPT270
			PTC →	217.3	221.9		220.5	225.1	227	232.8	235.7	240.3
Solar Edge	SE3000A-US	97.5	one string	8 to 15	8 to 15	8 to 14	8 to 15	8 to 15	8 to 14	8 to 14	8 to 14	8 to 13
	SE3800A-US		one string	8 to 19	8 to 19	8 to 18	8 to 19	8 to 19	8 to 18	8 to 18	8 to 17	8 to 17
	SE5000A-US		one string	8 to 21	8 to 20	8 to 20	8 to 21	8 to 20	8 to 20	8 to 20	8 to 19	8 to 19
			two strings	max 25	max 25	max 24	max 25	max 25	max 24	max 24	max 23	max 23
	SE6000A-US		one string	8 to 21	8 to 20	8 to 20	8 to 21	8 to 20	8 to 20	8 to 20	8 to 19	8 to 19
			two strings	max 30	max 30	max 290	max 30	max 30	max 290	max 28	max 28	max 27
Enphase	Enphase M215	96.0		1	1	1	1	1	1	1	--	--
Fronius	IG+ 3.0-1	95.5	one string	10 to 14	10 to 13	10 to 13	11 to 14	11 to 13	11 to 13	11 to 13	10 to 13	10 to 12
	IG+ 3.8-1	95.5	one string	10 to 14	10 to 14	10 to 14	11 to 14	11 to 14	11 to 14	11 to 14	10 to 14	10 to 13
	IG+ 5.0-1	95.5	one string	10 to 14	10 to 14	10 to 14	11 to 14	11 to 14	11 to 14	11 to 14	10 to 14	10 to 13
			two strings	10 to 11	10 to 11	10 to 11	11	11	11	11	10	10
	IG+ 6.0-1	96.0	one string	10 to 14	10 to 14	10 to 14	11 to 14	11 to 14	11 to 14	11 to 14	10 to 14	10 to 13
			two strings	10 to 14	10 to 13	10 to 13	11 to 14	11 to 13	11 to 13	11 to 13	10 to 13	10 to 12
	IG+ 7.5-1	95.5	one string	10 to 14	10 to 14	10 to 14	11 to 14	11 to 14	11 to 14	11 to 14	10 to 14	10 to 13
			two strings	10 to 14	10 to 14	10 to 14	11 to 14	11 to 14	11 to 14	11 to 14	10 to 14	10 to 13
			three strings	10 to 11	10 to 11	10 to 11	11	11	11	11	10	10
	IG+ 10.0-1	95.5	one string	10 to 14	10 to 14	10 to 14	11 to 14	11 to 14	11 to 14	11 to 14	10 to 14	10 to 13
			two strings	10 to 14	10 to 14	10 to 14	11 to 14	11 to 14	11 to 14	11 to 14	10 to 14	10 to 13
			three strings	10 to 14	10 to 14	10 to 14	11 to 14	11 to 14	11 to 14	11 to 14	10 to 14	10 to 13
			four strings	10 to 11	10 to 11	10 to 11	11	11	11	11	10	10
	IG+ 11.4-1	96.0	one string	10 to 14	10 to 14	10 to 14	11 to 14	11 to 14	11 to 14	11 to 14	10 to 14	10 to 13
			two strings	10 to 14	10 to 14	10 to 14	11 to 14	11 to 14	11 to 14	11 to 14	10 to 14	10 to 13
			three strings	10 to 14	10 to 14	10 to 14	11 to 14	11 to 14	11 to 14	11 to 14	10 to 14	10 to 13
			four strings	10 to 13	10 to 13	10 to 12	11 to 13	11 to 13	11 to 12	11 to 12	10 to 12	10 to 12

NOTE: Do not use 60-cell modules in strings of 14 or greater in locations with record low temperatures below 10°F (-12°C) as the string may exceed 600 VDC in these conditions. This does not apply to SolarEdge systems or Enphase inverters, which control voltage at the module level.

	Inverter ↓	CEC % ↓	Module →	REC			Hanwha			Suniva		
			Module →	REC245	REC250	REC255	HSL-245TW	HSL-250TW	HSL-255TW	OPT260	OPT265	OPT270
			PTC →	217.3	221.9		220.5	225.1	227	232.8	235.7	240.3
SMA	SB2000HFUS	97.0	one string	8 to 10	8 to 10	8 to 9	8 to 10	8 to 10	8 to 9	8 to 9	8 to 9	8 to 9
	SB2500HFUS	96.5	one string	10 to 12	10 to 12	10 to 12	10 to 12	10 to 12	10 to 12	10 to 12	10 to 11	10 to 11
	SB3000HFUS	96.5	one string	10 to 14	10 to 14	10 to 14	10 to 14	10 to 14	10 to 14	10 to 14	10 to 14	10 to 13
	SB3000TL	96.5	one string	6 to 14	6 to 14	6 to 14	6 to 14	6 to 14	6 to 14	6 to 14	6 to 14	6 to 13
			two strings	6 to 7	6 to 7	6 to 7	6 to 7	6 to 7	6 to 7	6 to 7	6 to 7	6
	SB4000TL	96.5	one string	6 to 14	6 to 14	6 to 14	6 to 14	6 to 14	6 to 14	6 to 14	6 to 14	6 to 13
			two strings	6 to 10	6 to 10	6 to 9	6 to 10	6 to 10	6 to 9	6 to 9	6 to 9	6 to 9
	SB5000TL	96.5	one string	6 to 14	6 to 14	6 to 14	6 to 14	6 to 14	6 to 14	6 to 14	6 to 14	6 to 13
			two strings	6 to 12	6 to 12	6 to 12	6 to 12	6 to 12	6 to 12	6 to 12	6 to 11	6 to 11
			three strings	6 to 8	6 to 8	6 to 8	6 to 8	6 to 8	6 to 8	6 to 8	6 to 7	6 to 7
	SB3000US	95.5	one string	9 to 12	9 to 12	9 to 12	10 to 11	9 to 11	9 to 11	9 to 11	9 to 11	9 to 11
	SB4000US	96.0	one string	11 to 14	11 to 14	11 to 14	12 to 14	12 to 14	12 to 14	12 to 14	11 to 14	11 to 13
	SB5000US	95.5	one string	11 to 14	11 to 14	11 to 14	12 to 14	12 to 14	12 to 14	12 to 14	11 to 14	11 to 13
			two strings	11 to 12	11 to 12	11 to 12	12	12	12	12	11	11
	SB6000US	95.5	one string	11 to 14	11 to 14	11 to 14	12 to 14	12 to 14	12 to 14	12 to 14	11 to 14	11 to 13
			two strings	11 to 14	11 to 14	11 to 14	12 to 14	12 to 14	12 to 14	12 to 14	11 to 14	11 to 13
	SB7000US	96.0	one string	11 to 14	11 to 14	11 to 14	12 to 14	12 to 14	12 to 14	12 to 14	11 to 14	11 to 13
			two strings	11 to 14	11 to 14	11 to 14	12 to 14	12 to 14	12 to 14	12 to 14	11 to 14	11 to 13
			three strings	11	11	11	--	--	--	--	--	--
	SB8000US	96.0	one string	13 to 14	13 to 14	13 to 14	14	14	14	14	13 to 14	13
			two strings	13 to 14	13 to 14	13 to 14	14	14	14	14	13 to 14	13
			three strings	13	13	13	--	--	--	--	--	--
Power-One	UNO-2.0-I-OUTD-S-US	95.5	string/max mods	4-10 / 10	4-10 / 10	4-9 / 9	4-10 / 10	4-10 / 10	4-9 / 9	4-9 / 9	4-9 / 9	4-9 / 9
	UNO-2.5-I-OUTD-S-US	96.0	string/max mods	4-12 / 12	4-12 / 12	4-12 / 12	4-12 / 12	4-12 / 12	4-12 / 12	4-12 / 12	4-11 / 11	4-11 / 11
	PVI-3.0-OUTD-S-US	96.0	string/max mods	4-14 / 15	4-14 / 15	4-14 / 14	5-14 / 15	5-14 / 15	5-14 / 14	4-14 / 14	4-14 / 14	4-13 / 13
	PVI-3.6-OUTD-S-US	96.0	string/max mods	4-14 / 18	4-14 / 18	4-14 / 17	5-14 / 18	5-14 / 18	5-14 / 17	4-14 / 17	4-14 / 17	4-13 / 16
	PVI-3.8-I-OUTD-S-US	96.5	string/max mods	6-12 / 19	6-12 / 19	6-12 / 18	6-12 / 19	6-12 / 19	6-12 / 18	6-12 / 18	6-12 / 17	6-12 / 17
	PVI-4.2-OUTD-S-US	96.0	string/max mods	4-14 / 21	4-14 / 21	4-14 / 20	5-14 / 21	5-14 / 21	5-14 / 20	4-14 / 20	4-14 / 19	4-13 / 19
	PVI-4.6-I-OUTD-S-US	96.5	string/max mods	6-12 / 23	6-12 / 23	6-12 / 22	6-12 / 23	6-12 / 23	6-12 / 22	6-12 / 22	6-12 / 21	6-12 / 21
	PVI-5000-OUTD-S-US	96.5	string/max mods	4-14 / 25	4-14 / 25	4-14 / 24	5-14 / 25	5-14 / 25	5-14 / 24	4-14 / 24	4-14 / 23	4-13 / 23
	PVI-6000-OUTD-S-US	96.5	string/max mods	4-14 / 30	4-14 / 30	4-14 / 29	5-14 / 30	5-14 / 30	5-14 / 29	4-14 / 28	4-14 / 28	4-13 / 27

NOTE: Do not use 60-cell modules in strings of 14 or greater in locations with record low temperatures below 10°F (-12°C) as the string may exceed 600 VDC in these conditions. This does not apply to SolarEdge systems or Enphase inverters, which control voltage at the module level.

✓ **AEE Solar was born in 1979**, long before grid-tie, when off-grid solar was the only form of domestic solar PV. So when it comes to off-grid know-how and equipment knowledge, **AEE Solar's experience, expertise, and product selection is unsurpassed.**

Grid-Tie with Battery Backup

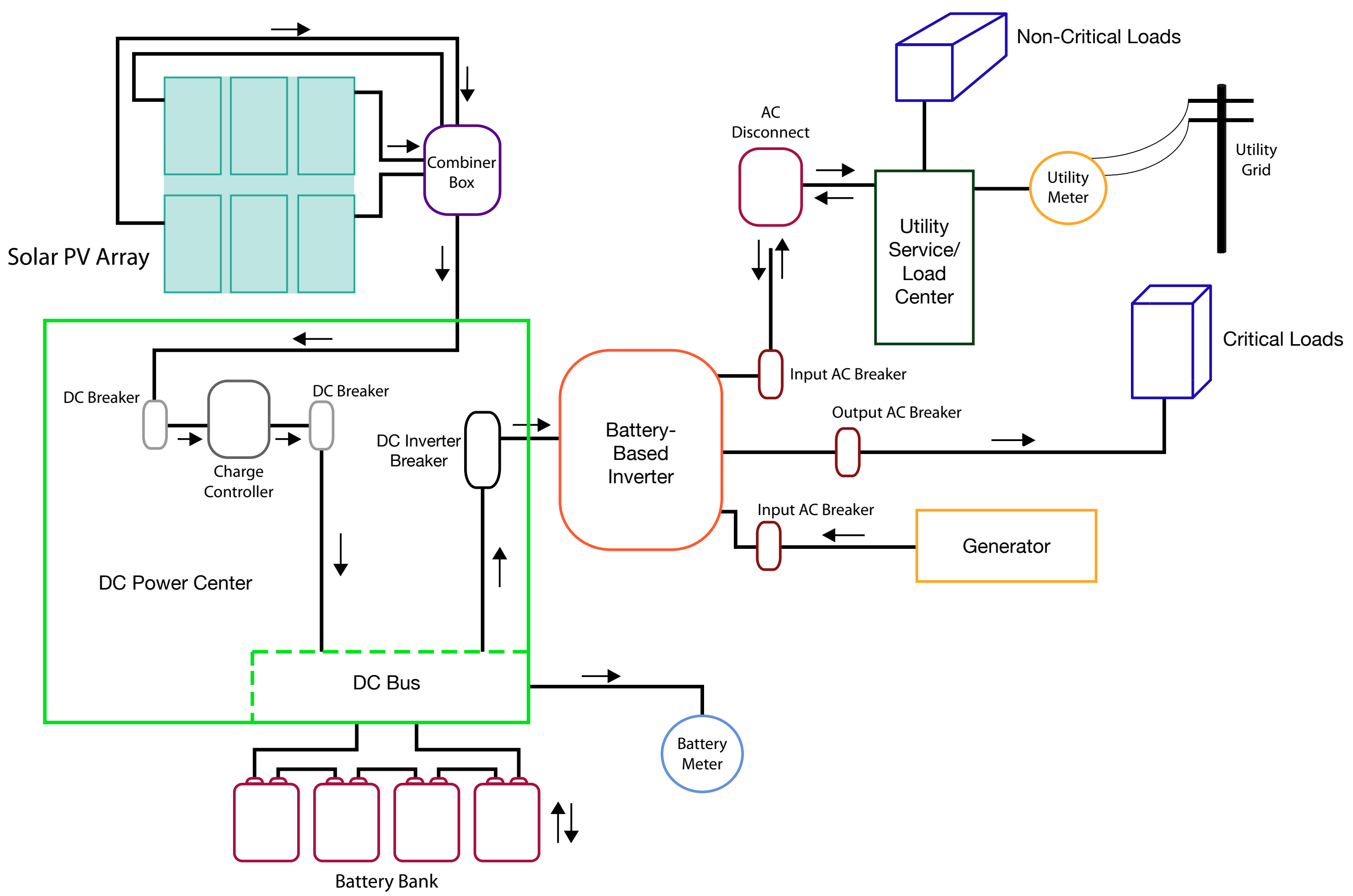
Many solar customers are unpleasantly surprised to learn that their batteryless grid-tie solar PV system will not power their home during a utility outage. In areas where blackouts and extended weather-related outages are more common, a battery backup system, like the one shown in the diagram below, can add value.

Sizing and designing a grid-tie system with battery backup is more complex than designing a batteryless system. They perform two separate functions: offsetting the power purchased from the electric utility (just like a standard batteryless system) and providing emergency backup power during utility outages. Both of these functions require separate design considerations and calculations.

The "grid-tie" part of the system is designed the same way as a batteryless grid-tie system is, using the average daily kWh power consumption and the yearly average peak sun-hours available where the PV array is located.

The "battery backup" part of the system is designed based on the power draw of the critical loads that need to operate during a grid outage, and how long the outage is expected to occur. These systems are generally designed to only run critical loads located in a separate sub-panel. They are not designed to power the whole house, although they can be designed to do so (at considerable extra cost).

Battery backup systems require specialized inverters and other components and must be carefully sized, so be sure to call AEE's Technical Support Team if you need help.



Inverters for Grid-Tie with Battery Backup

OutBack G-Series inverters and switchgear, as well as the new **Radian inverter**, can power loads individually from 2 to 8 kW and can be combined in a single system up to 80 kW. (See Battery-based Inverters and Power Systems)

The **Schneider Conext XW** series of inverters offers grid-tie inverters with battery backup capability in 4 kW, 4.5 kW, and 6 kW increments. Up to 4 units can be paralleled for battery backup systems up to 24 kW. (See Battery-based Inverters and Power Systems)

The **SMA Sunny Island** inverters, 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 can be configured with up to 24 kW single-phase output using up to 4 Sunny Island inverters or up to 72 kW of 3-phase output with up to 12 Sunny Island inverters and a Multi-Cluster Box. (See Battery-based Inverters and Power Systems)

Follow steps 1-5 on the Grid-Tie PV System Design Worksheet (on page 10) 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 with Backup System

Determine energy storage requirement for backup system

______________ **Step 1: Find the power requirements (watts) for the appliances that need power during a black-out.**

Make a list of the loads and appliances that need to power during an outage, such as refrigerators, safety lighting, etc. 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 owner's manual. 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 the list that may need to run simultaneously to arrive at the total amount of watts. This is the "peak wattage" inverter requirement and will determine the minimum size of the dual-function inverter that you will need. If the PV array is larger than the peak wattage, then skip steps 2 through 5 and size the inverter to the array as in a normal grid-tie system.

______________ **Step 2: Define how long of an outage the system must accommodate.**

Power outages last from a few minutes to a day (or more). Again, this decision will greatly affect the system size and cost, so the length of time accommodated should be traded against the total loads supported. If the system needs to provide power for an indefinite period of time, use the array and battery bank sizing instructions for an off-grid system.

______________ **Step 3: Determine the amount of energy needed.**

Multiply the power requirements (in step 1) by duration in hours (in step 2). The result will be watt-hours. For example, powering a 350 W refrigerator, a 150 W computer, and a 500 W lighting system for 2 hours would require 2,000 watt-hours (or 2 kWh) of energy storage.

______________ **Step 4: Calculate the energy 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 energy storage is needed.

______________ **Step 5: Calculate battery capacity needed.**

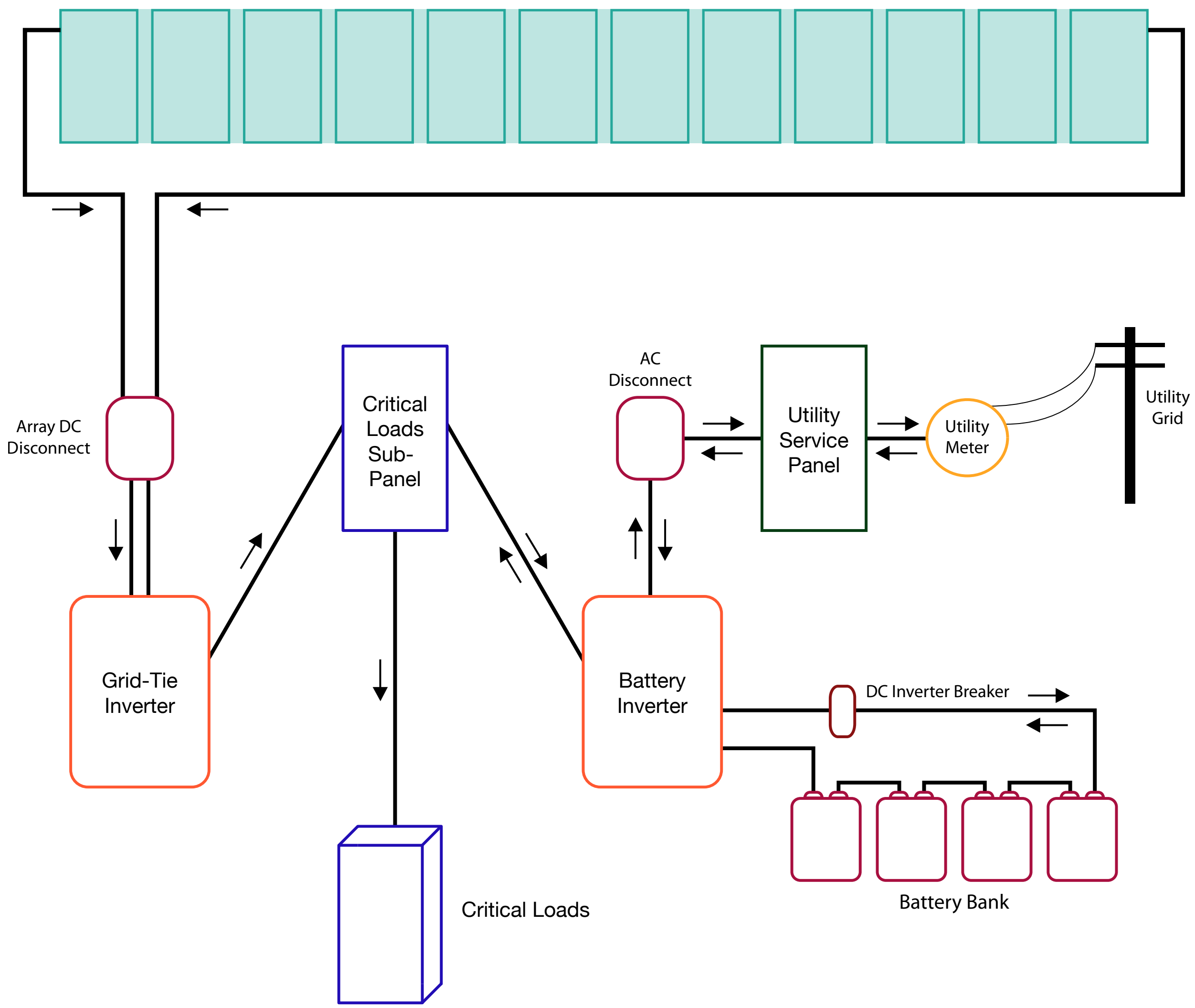
Divide the energy storage requirement from step 4 by the DC voltage of the system (usually 48 VDC, but sometimes 24 VDC) to get battery amp-hour (Ah) capacity. Most backup systems use sealed batteries due to their reduced maintenance requirements and because they can be more easily placed in enclosed battery compartments

AC-Coupled Systems

An AC-coupled power system is another form of battery-based system that can be used either in a grid-tie system with a battery backup application, or a completely off-grid system. Instead of using a battery charge controller with the PV array, these systems utilize standard grid-tie inverters that produce AC power (usually 240VAC), which can be "sold" to the utility grid when the grid is connected or can be used by a separate battery-based inverter to charge a battery bank during a grid outage.

Along with the standard batteryless grid-tie inverter, a second, bi-directional, battery-based inverter is used along with a battery bank to provide AC power during a grid outage. Both the AC output of the grid-tie inverter and the AC output of the battery inverter are connected in the critical-loads sub-panel. During normal operation when the grid is "up", the power from the PV array and grid-tie inverter just passes through the sub-panel and then through the built-in AC transfer switch located inside the battery inverter and on to the utility main panel. From there it is either consumed by house loads connected there or sold to the grid. If a grid outage occurs, the grid-tie inverter will automatically shut off. However, at the same time, the battery-based inverter will automatically switch off the grid connection and begin to power the loads in the critical loads panel from energy drawn from the battery bank. Since the grid-tie inverter is connected in this sub-panel, it detects the AC power from the battery inverter and, after a 5-minute delay, will turn back on. The power output from the array and grid-tie inverter will then be used directly by the critical loads connected to the sub-panel or will flow backward through the battery inverter to charge the batteries.

The SMA Sunny Island battery inverters are designed to work with SMA Sunny Boy inverters (not HFUS) and will communicate with each other to control the battery charging process. Other brands of battery-based inverters, such as OutBack, Schneider XW, and Magnum MS models can be used with most grid-tie inverters in an AC-coupled system; however, they have no built-in way to control battery charging. A relay can be placed in the AC connection to the grid-tie inverter, controlled by a battery voltage activated switch (such as the AUX relay built into many inverters) to disconnect the grid-tie inverter when the battery voltage rises to the full-charge voltage, ending the charge cycle. Alternatively, a diversion controller, connected to the battery, can be used with a diversion load to consume the excess power and keep the batteries from being overcharged.



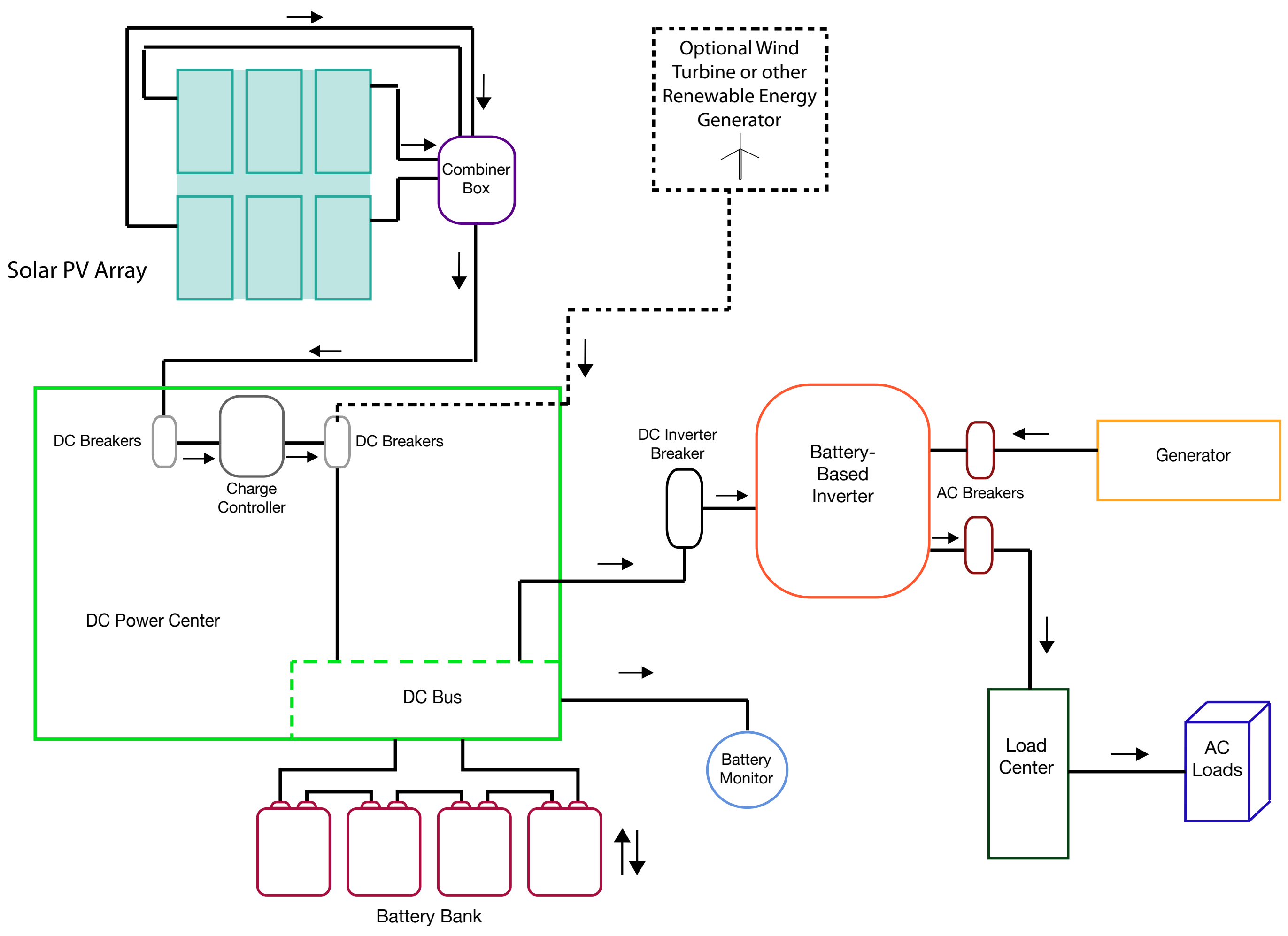
Off-Grid System Sizing Information

Off-grid solar PV systems, like the one shown in the diagram below, are one of the most economical ways to provide electricity in the absence of an electrical power grid. Off-grid systems are useful for remote homes and cabins, RVs and boats, and even for industrial applications like remote telemetry, cathodic protection, and telecommunications.

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).

Off-grid power systems are designed differently than grid-tie systems. With a batteryless grid-tie system, calculations for system sizing are based on the yearly average peak sun-hours available at the site, and are used to offset the yearly power consumption drawn from the utility grid. With an off-grid system design, the calculations are usually based on the peak sun-hour figures for the darkest month of the year in order to provide sufficient on-site power year-round. However, in locations where it is not practical to install a renewable energy power system that will provide 100% autonomy during the darkest time of the year, a generator can be used to help run loads and to charge the battery bank if the renewable energy sources are unable to keep up with power consumption.

The off-grid power system design is complex, and these systems require specialized inverters, charge controllers, and battery banks. Please contact the AEE Solar Technical Support Team if you need system design help.



Efficiency and Energy Conservation

The use of energy-efficient appliances and lighting, as well as non-electric alternatives, can make solar electricity a cost-competitive alternative to gasoline generators and, in some cases, utility power. Outlined below is information on typical energy consumption for various appliances and lighting.

Cooking, Heating and Cooling

Each burner on an electric range uses about 1,500 W, which is why bottled propane or natural gas is a popular alternative for cooking. A microwave oven has about the same power draw, but since food cooks more quickly in a microwave oven, the amount of kilowatt hours used is typically lower. Propane, wood or solar-heated water are generally better alternatives for space heating than electric baseboards. Good passive solar design and proper insulation can also reduce the need for winter heating. Evaporative cooling is a more reasonable load than air conditioning and in locations with low humidity, it's a great alternative.

Lighting

Lighting requires careful study since type, size, voltage and placement can all significantly impact the power required. In a small home, an RV, or a boat, low voltage DC lighting with LEDs 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. In a large installation or one with many lights, using an inverter to supply AC power for conventional lighting is often more cost-effective. AC compact fluorescent lights are common and efficient, but it is a good idea to have a DC-powered light in the room where the inverter and batteries are in case of an inverter fault. Also, AC light dimmers will only function properly on AC power from inverters that have sine wave output.

Refrigeration

Gas powered absorption refrigerators can work well in small systems if bottled gas is available. Modern absorption refrigerators consume 5-10 gallons of LP gas per month. If an electric refrigerator will be used in a standalone system, it should be a high-efficiency type. High-efficiency DC refrigerators are also available and can offer significant energy savings.

Major Appliances

Standard AC electric motors in washing machines, larger shop machinery and tools, swamp coolers, pumps, etc. (usually ¼ to ¾ horsepower) consume relatively large amounts of electricity and require a large inverter. Often, a 2,000 watt or larger inverter will be required. These electric motors can also be hard to start on inverter power, due to large surge loads at start-up, 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 ½ as much power. If the appliance is used more than a few hours per week, it is often more economical to pay more for a high-efficiency appliance rather than make the electrical system larger to support a low efficiency load. Vacuum cleaners usually consume 600 to 1,000 watts, depending on how powerful they are, but most vacuum cleaners will operate on inverters as small as 1,000 watts since they have low-surge motors.

Small Appliances

Many small appliances with heating elements such as irons, toasters and hair dryers consume a very large amount of power when they are used but, by their nature, require only short or infrequent use. With a sufficiently large system inverter and batteries, they will operate, but the user may need to schedule those activities with respect to the battery charging cycle – for example, ironing in the morning so that the PV system can recharge the battery bank during the day. Electronic equipment, such as stereos, televisions, VCRs and computers, draw less power than appliances with heating elements, but these loads can add up as well, so opt for more efficient models, such as an LCD TV instead of a plasma or CRT design.

Worksheet: Off-Grid Load

Determine the total amp-hours per day used by the AC and DC loads.

______ **Step 1:** List all AC loads, wattage and hours of use per week in the table below. (If there are no AC loads, skip to Step 5.)

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.

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 VAC) to find watts.

Calculate AC loads *(If there are no AC loads, skip to Step 5)*

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

______ **Step 2:** Convert to DC watt-hours per week by multiplying the result of Step 1 by 1.15 to correct for inverter loss.

______ **Step 3:** List the inverter DC input voltage; usually 12, 24 or 48 VDC. This is DC system voltage.

______ **Step 4:** Divide the DC Watt-hours per week by the DC system voltage to get the total DC amp-hours per week used by the AC loads.

______ **Step 5:** List all DC loads, wattage and hours of use per week in the table below. 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.

Calculate DC loads *(if applicable)*

Description of DC loads run by inverter	watts	x	hours/week	=	watt-hours/week
		x		=	
		x		=	
		x		=	
		x		=	
		x		=	
				Total watt-hours per week:	

______ **Step 6:** List DC system voltage. Usually 12, 24, or 48 VDC.

______ **Step 7:** Divide the total watt-hours per week by the DC system voltage to find total amp-hours per week used by DC loads.

______ **Step 8:** Add the total DC amp-hours per week used by AC loads from Step 4 to the amp-hours used by DC loads from Step 7 to get the total DC amp-hours per week used by all loads.

______ **Step 9:** Calculate your amp-hours per day. Divide the total DC amp-hours per week from Step 8 by 7 days to get the total average amp-hours per day that needs to be supplied by the battery.

You will need this number to begin sizing the PV array and battery bank. Note that the Solar Array Sizing Worksheet in this section, as well as the Battery Sizing Worksheet in the Batteries Section both begin with this number in their Step 1.

Worksheet: Off-Grid Solar Array Sizing

Determine how much current the solar array must produce to identify the total number of solar modules required for the system.

________ **Step 1:** List the total average amp-hours per day needed. Obtain this number from the Off-Grid Loads Worksheet on the previous page.

________ **Step 2:** Multiply the amp-hours per day needed by 1.2 to compensate for battery charge/discharge losses.

________ **Step 3:** List the average sun-hours per day in the system's area.

Check local weather data, look at the map below, or find a city on the Solar Insolation Table in the Reference Section that has similar latitude and 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.

________ **Step 4:** Divide the result of Step 2 by the average sun-hours per day from Step 3 to get the total solar array amps required.

Sizing Solar Arrays with PWM Charge Controllers

If you are planning a small low-cost system with a PWM charge controller, continue to Step 5 below. If you are planning a larger system with an MPPT charge controller, go to Step 5 in "Sizing Solar Arrays with MPPT Charge Controllers." Information on the different types of PV charge controllers can be found in the Charge Controller section.

________ **Step 5:** Find the peak amperage of the module you will be using from its specifications or Data Sheet.

We provide the peak power current of our most popular modules in the Solar Module Section.

________ **Step 6:** Divide the total solar array amps required from Step 4 to get the total number of parallel strings of modules required. Round up to the nearest whole number.

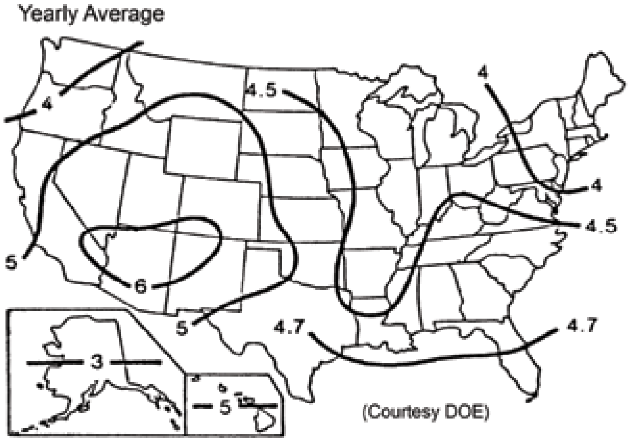
________ **Step 7:** Use the table below to determine the number of modules in each series string needed to provide DC battery voltage.

Note: Due to the industry shift to larger PV cells, 24 VDC solar modules may not be available from AEE.

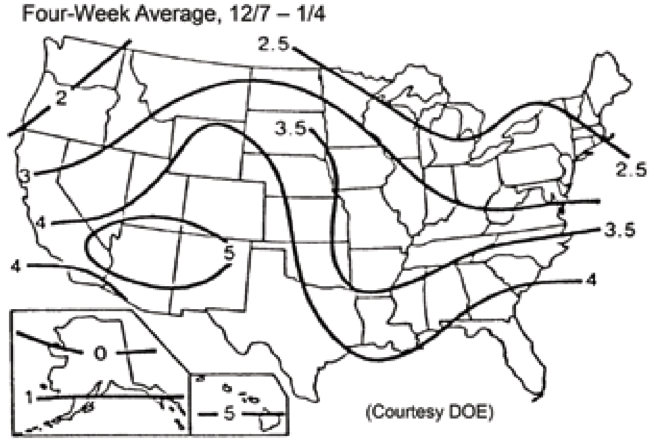
Nominal System Voltage	Number of Series Connected Modules per String	
Volts	12 V module	24 V module
12	1	--
24	2	1
48	4	2

________ **Step 8:** Multiply the number of strings from Step 6 by the number of modules per string from Step 7 to get the total number of solar modules required.

Yearly Average



Four-Week Average, 12/7 – 1/4



Average Sun-Hours per Day

Sizing Solar Arrays with MPPT Charge Controllers

Step 5: Note the total solar array amps required. Obtain this number from Step 4 of the Off-Grid Solar Array Sizing worksheet.

Step 6: Enter the average charging voltage. Use 13.5 VDC for 12 VDC systems; 27 VDC for 24 VDC systems; or 54 VDC for 48 VDC systems.

Step 7: Multiply the total solar array amps required from Step 5 by the average charging voltage from Step 6 to determine the total PV array wattage required.

Step 8: Enter the nameplate power (in watts) of the PV module you plan to use.

Step 9: Divide the total PV array wattage required from Step 7 by the module nameplate power from Step 8 to determine 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: Use the table below to determine the number of modules in each series string.

MPPT Charge Controller Sizing Table – Range of Modules in Series[1]						
Charge controller model	Max DC input voltage	Nominal battery voltage	Cell count of PV module used			
			36	54	60	72
OutBack FM 60 & 80 Schneider XW-MPPT150-60 Morningstar TriStar 45 & 60	150 VDC	12 V	1 to 5	1 to 3	1 to 3	1 or 2
		24 V	2 to 5	2 or 3	2 or 3	1 or 2
		48 V	4 or 5	3	3	2
MidNite Solar Classic 150	200 VDC	12 V	1 to 5	1 to 3	1 to 3	1 or 2
		24 V	2 to 6	2 to 4	2 or 3	1 to 3
		48 V	4 to 6	3 or 4	3	2 or 3
MidNite Solar Classic 200	250 VDC	12 V	1 to 7	1 to 5	1 to 4	1 to 3
		24 V	2 to 7	2 to 5	2 to 4	1 to 4
		48 V	4 to 8	3 to 6	3 to 5	2 to 4
MidNite Solar Classic 250	300 VDC	12 V	1 to 9	1 to 6	1 to 5	1 to 4
		24 V	2 to 9	2 to 6	2 to 5	1 to 4
		48 V	4 to 9	3 to 7	3 to 6	2 to 5
Schneider XW-MPPT600-80	600 VDC	24 V, 48 V	14 to 22	9 to 15	9 to 14	7 to 11

[1]Based on temp range of 14°F to 104°F. Adjustments may be needed in locations with temps outside this range.

Step 11: Divide the total number of modules from 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, increase or decrease the number of modules to obtain a whole number of series strings.

CAUTION: Decreasing the total number of modules may result in insufficient power production.

Step 12: Multiply the module nameplate power from Step 8 by the number of modules per string from Step 10 to determine the total wattage per string.

Step 13: Find the total number of chosen controllers needed.

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

Max Array Wattage per Controller Size								
Battery Voltage	Controller Rated Output Amps							
	15 A	30 A	45 A	50 A	60 A	75 A	80 A	95 A
12 V	200 W	400 W	560 W	650 W	750 W	900 W	1000 W	1150 W
24 V	400 W	800 W	1125 W	1300 W	1500 W	1800 W	2000 W	--
48 V	--	1600 W	2250 W	2600 W	3000 W	3600 W	4000 W	--

Step 14: Divide total number of strings from Step 11 by the number of strings per controller from Step 13. Round up to the nearest whole number.