# Successful Off Grid Solar Design

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**So You Think You Want to Go Off Grid?**

The common question asked by the uninitiated, without providing any other significant details, is “What will it cost to take my house (cabin, cottage, etc.) off grid?”

There is no pat answer to the question. From my own experience of living off grid for more than 5 years, my advice is to think very carefully about your willingness to adapt your energy consuming behavior to the variables of being dependent on sun, wind and in some cases moving water for your energy needs rather than being connected to a seemingly endless supply of grid electricity created by burning the remains of dinosaurs and their ancient habitat (oil and coal) or the fission of radioactive materials that leave waste with a nasty half-life of 50,000 years or more.

Even the best designed off grid system will experience variables that will require occasional behavior modification whether you like it or not. Sticker shock typically occurs for those who want things to be off grid and just like they have always been. Things are not going to be like they have always been. Reliability of the grid as evidenced by the recent events in India that left 600 million people without electricity is an insight into our energy future.

This being said, as far as I can tell, unless you are a Wall Street robber baron or a banker with friends at the Federal Reserve and Treasury Department, there is no better return on investment in today’s uncertain times than being your own power company. Grid power is not going to get any cheaper as fossil fuel supplies decline. The US solar tax credit and other local incentives help to defray initial investment. Your future cost of electricity is now known, with the main future expense being the replacement of batteries which you can cover through a monthly sinking fund contribution to your savings account that will be significantly less than your current utility bills.

**Success is in the DETAILS!**

The success of an off grid solar system design begins with details. The size of an off grid solar electric system depends on the amount of power that is required (measured in watts), the amount of time it is used (measured in hours)and the amount of energy available from the sun in available in the location where the system will be installed (measured in solar insolation (sun) hours per day).

As a prospective off grid solar system owner and user, you have control of the first two of these variables. The third variable depends on your location and the weather.

**Conservation Saves the Day**

Conservation plays a highly important role in keeping down the cost of an off grid solar system. The use of energy efficient appliances and lighting, as well as non-electric alternatives wherever possible, can significantly reduce the size and cost of the system.

There are very few exceptions where conservation is less cost effective than the alternative. Anything that you can operate on low voltage direct current (DC) rather than 115 or 230 volt alternating current

(AC) will make a big difference.  230 volt single phase AC in parts of the world that use 115 volts requires two inverters to make the two legs of 115 that make 230 single phase.

**Cooking, Heating, & 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 off grid 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, natural gas and wood are 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 plus for cooling-the largest amount of solar energy is usually available when the temperature is the highest.

Low voltage ceiling fans, ventilating fans and whole house fans do a remarkable job of creating comfort during both warm and cool weather.  We have lived off grid for over 5 years without air conditioning. The ceiling fan over the bed works wonders.  Ceiling fans running on low speed circulate heat from the wood stove during the heating seasons.

**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 110 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, a home will not be dark if the inverter fails and the lights are powered directly by the battery. In addition to conventional-size medium-base low voltage bulbs, the user can choose from a large selection of DC LED lights, which have 3 to 6 times the light output per watt of power used compared with incandescent types.

Halogen bulbs are 30% more efficient and actually seem almost twice as bright as similar wattage incandescents given the spectrum of light they produce. High quality LED lights are available for 12 and 24 volt systems.

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 LED 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 with the inverter.

AC light dimmers will only function properly on AC power from inverters that have pure sine wave output.

**Refrigeration**

Natural gas or propane powered absorption refrigerators are a good choice in small systems if natural or bottled gas is available. Modem absorption refrigerators consume 5-10 gallons of LP gas per month. They also create heat, good in the winter, not so good in the summer. If an electric refrigerator will be used in a stand-alone system, it should be a high-efficiency type. Some high-efficiency conventional AC refrigerators use as little as 1200 watt-hours of electricity per day at a 70° average air temperature.

A comparably sized Sun Frost refrigerator/freezer uses half that amount of energy and the smallest SunDanzer refrigerator (without a freezer) uses less than 200 watt-hours per day. The higher cost of good quality DC refrigerators is made up by savings in the number of solar modules and batteries required to operate the alternatives.

**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. There are also battery powered low voltage vacuums that can now be purchased at places like Wal-Mart.

**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, VCR's 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.

**Standby Loads**

Electrical appliances and hardware that are “instant on” use electricity whether they are actually on or not.

**Looking Back in Time**

Before the electrification of North America and elsewhere, there were mechanical alternatives to most of the common appliances used today. Do you really need an appliance for every little thing in your kitchen and your life?

**Calculate Your Loads**

The last page of this document is a typical loads listing for conventional appliances. This is helpful but not as good as the real thing from your own situation. Details!

**Included in the ZIP file is an Excel workbook you can use to determine the total energy in watt-hours per day used by all the AC and DC loads in your system. Save a copy of the original and then use a copy to do your work. Send back the workbook and I will finish the calculations for you.**

**Calculate Your AC Loads**

If there are no AC loads, go to the DC loads section.

1. List all AC loads, amps, watts and hours of use per week in the spaces provided. Multiply watts by hours per day to get watt-hours per day. Add up all the watt hours to determine AC watt-hours per day. Insert more lines if you need to list more loads than the space allows.
2. **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.
3. Convert to DC watt-hours per week. Multiply the total AC watt-hours by 1.15 to correct for inverter loss.
4. Inverter DC input voltage; usually 12, 24 or 48 volts. This is DC system voltage. Usually, the bigger the system the higher the system voltage.
5. Divide the product of the watt-hours by the system voltage. This is total DC amp-hours per day used by the AC loads.

**Calculate Your DC Loads**

1. List all DC loads in the space provided. If you have no DC loads, skip this section.
2. DC system voltage. Usually 12, 24, or 48 volts. Usually, the bigger the system the higher the system voltage.
3. Find total watt-hours per week used by DC loads. Divide the total watt-hours by the system voltage.
4. Add the AC and DC loads; this is your total amp-hours per day for your system.

POWER CONSUMPTION:

Items listed by watts per hour unless otherwise stated. Remember that some items are used for shorter durations.

| | | | |
|---|---|---|---|
| Coffee Maker | 800 | Blow Dryer | 1000-1500 |
| Hot Water kettle | 1500 | Shaver | 15 |
| Toaster | 800-1500 | LTV 950 Ventilator | 66 |
| Blender | 300 | CPAP | 30-50 |
| Microwave | 600-1700 | Home Dialysis Machine (600 starting surge) | 100 |
| Hot Plate | 1200 | Oxygen Concentrator | 350 |
| Juicer | 85-1000 | Computer | 200-600 |
| Refrigerator/Freezer | 1500-2000/day | Laptop | 75- 100 |
| Freezer Conventional 14 cu Ft | 440 | Printer | 100-500 |
| Vacuum Cleaner | 200-1500 | Fax | 40 |
| Hand held vacuum | 100 | Cordless Phone | 50-150 |
| Iron | 1000 | TV 25' Color | 150+ |
| Table fan | 10-50 | TV 42' LCD | 210 |
| Fan | 100-200 | Xbox360 | 185 |
| Personal AC | 240 | DVD/ Radio/ CD | 25-100 each |
| Room AC | 1500 | Satellite/Internet | 30-85 |
| Garage Door Opener | 350+ | Clock radio | 10 |
| Alarm/ Security equipment | 150+ | Lights 100W equiv. CFL | 30 |
| High eff. Gas furnace | 250+ | Lights 100W Incandescent | 100 |
| Furnace Blower | 300-1000+ | Washing machine – automatic | 500 |
| Furnace (oil/forced air) | 250+ | Dishwasher | 1200-1500 |
| Hedge trimmer | 450 | 12" chain saw | 1100 |
| ¼' drill | 250 | 7 ¼" circular saw | 900 |
| 1" drill | 1000 | Aquariums | 300+ |
| 3" belt sander | 1000 | Water Pump (300gpd) | 3000+/day |

* NOTE: the watts listed by an appliance type are averages – makes/ models/ years made can drastically alter the watts used. Some appliances have a starting surge much higher than the watts they use to run.