# The sensible, integrated photovoltaic energy system

*By Windy Dankoff*

The integrated photovoltaic system works as a whole which is greater than the sum of its parts. It contains subsystems that optimally work with each other and with your needs as they change through the seasons and the years. The integrated system is an attempt to combine multiple energy sources, storage, and usage systems for optimum economy. A well planned "whole system" can temper the feast or famine extremes of alternative energy and reduce or eliminate the need for a backup mechanical generator.

Integrated system design is very specific to **your** situation and climate. To get started on the right track follow these basic principles.

- 1. Recognize your essential needs.

Your need is not for electricity; it is for light, water, preserved food...electricity is **one** way to provide for these needs.

- 2. Minimize the steps of energy conversion.

Every time energy is gathered, converted, stored, transferred, or otherwise processed, a significant amount is lost. Consider the most direct approaches to meeting your needs.

- 3. Tie all systems together.

Make all systems function together as efficiently and as simply as possible.

- 4. Balance needs against solutions.

Use what we have when we need it.

The typical consumer's home is a model of disjointed energy practices. In summer, inefficient light bulbs and refrigerators generate hundreds of watts of waste heat, causing air conditioners to work overtime. In winter while cold abounds, refrigerators keep working hard to overcome the home's

added heat. Electricity used for heating consumes hundreds of times more energy than other uses. Purified, pressurized, quality drinking water is used to flush toilets and water the lawn. The alternative energy household does not have the "unlimited" energy supply that the utility line provides, and cannot afford such carelessness.

Applying principles 1 and 2, we utilize windows or skylight to let in daytime light, and we store vegetables in a cool pantry or root cellar. We can divert rainwater from the roof to a storage tank to supply garden and trees by gravity flow. We use direct solar heat to warm our home in winter and simple solar collectors to heat our water, with gas or wood fuel backup.

We use electricity for those functions that it can do best. Use battery direct DC power directly where feasible, rather than converting it all to AC through an inverter. If we must rely heavily on a gas generator, we use an efficient gas refrigerator, rather than converting the fuel's energy through an engine/generator to power an electric fridge.

Applying principles 3 and 4, we might use the sun for pumping irrigation water and/or refrigerating (high summer loads). The reduced demands in winter liberates plenty of energy for the extra winter lighting load. To make this possible, the pump and the home run off the same energy system.

There are endless variations to system design, with new possibilities opening as the technology advances. Assess your needs, read all you can on the subject, talk to PV users and dealers, and use your imagination!

## Utilizing excess energy

No matter how well balanced your system might be, there are many times when more energy is gathered than is immediately required. Your battery bank becomes fully charged and your voltage regulator will simply "waste off" excess energy.

**Fact:** an alternative energy system designed for year round use will produce excess energy **most of the time**.

A system providing mostly lights will produce lots of excess in the summer, when days are longer. A system providing irrigation water will produce excess in the winter. Your system must be designed to see you through worse than average conditions. The rest of the time, you have excess energy. Utilizing this excess energy may as much as **double** the effective value of your system.

## Overload diversion

The idea is to automatically switch excess energy to another load. A device that will use energy in an effective manner. Ideal overloads are those that incorporate a form of **storage**, such as:

- 1) second battery bank
- 2) water or preheater
- 3) water pumping into a storage tank
- 4) home ventilating or cooling, which uses excess solar power exactly when it is needed most.

**A second "reserve" battery bank** solves three problems by providing a place to dump excess energy, enough backup to reduce or eliminate the need for a backup generator, and a way to enlarge or replace your battery bank without discarding the old batteries. You should not combine batteries of different types or ages in the same set, so maybe you'd want to use an aging battery bank that has lost capacity or is too small for expanding needs as the "reserve" battery bank.

**Overload water heating** can contribute a saving of fuel in the AE home, although it has serious limitations. To understand this limitation, consider that a typical (rapid heating) AC electric water heater of 40-gallon capacity draws 9000 watts, while the average home AE system has only a few hundred watts to dump intermittently! If you have a solar thermal water heating system, you will already have hot water by the time your PV system is ready to dump. If not, an ordinary electric water heater can be refitted with low voltage heating elements to supply more or less warm water for direct use or preheated water to save gas. Or a gas heater can be fitted with an electric element to save gas. A 150-watt (12 amps at 12.5 volts) heating element will heat one gallon of water from 55 to 125 degrees F. in 1.25 hours. This is a useful amount of heat. Excess energy is **free**—we might as well use it!

**Water storage for irrigation** has enormous potential for making the most of solar power, especially because the most water is required when there is the most sun! It is ideal to store at least a two week supply of water. When your storage tank fills, allow it to overflow to some trees; the ground stores water/energy too! Use drip irrigation, mulching etc. to minimize evaporation losses.

**House or attic ventilation or cooling** is a perfect way to "blow off" excess summertime solar power during hot weather.

## Control of overload energy

This need not be complex. The simplest "human regulator" is simply a voltmeter, a switch, and you. When you see or anticipate your battery voltage approaching 15 volts (12V system), you flip the switch. The switch transfers all or most of your array to your alternate load or turns your well pump or cooler on. When your voltage drops to 12.5 or so, then there is no longer excess energy so you flip the switch back to the normal full charge position. A control system can do this automatically for you, switching automatically as clouds come and go, appliances turn on and off, etc. If your control system does not have overload diversion, it may be added without altering existing controls.

By the way, PV modules run cooler when they are connected and working (energy is being removed from them). Modules that are disconnected by regulation that does not use their excess energy actually get a little hotter. The decades may reveal that modules that are used constantly last longer than those that are often disconnected!

## "Growing" a system

Many people cannot afford, or do not need, to buy a complete energy system all at once. You may be constructing your homestead gradually, expanding your energy system as your enterprises or your family expand. A system designed for growth from the start will be integrated with your needs and will save you a lot of money when the time comes to expand. Balance these suggestions against your budget limitations.

**Rule: build a heavy infrastructure:** This refers to the parts of the system that form its foundation and are difficult to enlarge later.

**Wire sizing:** If you are burying wire from your PV array, or concealing it in walls, use large enough, heavy gauge, wire to carry sufficient current for your future, enlarged array (or put your wire in oversized conduit so that more, or larger wire may be added easily). Add a "pull me" rope to conduits so that more wires can be added later.

**AC distribution:** When you wire a new house, distribute AC power lines to receptacle boxes in every room even if you don't plan to make extensive use of AC power. Inverters will keep improving and getting cheaper. Consider who may live in your home years from now. Future generations or prospective buyers may not accept the limitations you have imposed on them. Hallways tangled with extension cords are **not** a good option! Nor is ripping walls open to add wiring, or adding lots of surface conduit. You may leave unused receptacle boxes unwired until ready for use.

**Array support:** It may cost only a little more to buy or build an array frame or tracker of twice the capacity that you need initially. Future expansion will be easy, less expensive, and better looking.

**Battery bank:** When you connect new batteries to old ones you are inviting problems. Oversize your battery bank and avoid using its full capacity until you expand your array. Or, leave enough space in your battery area for a second, larger bank of batteries to be installed next to your old set.

**Consider a 24-volt system:** 12 volts is a vehicle standard. It is still ideal for a modest home system that does not need to run large motors or inverters and does not have long runs. But, a 24-volt system is more efficient and economical for larger systems and for small systems designed to grow. A dual 24/12 volt system need not be complex or costly.

**Note:** Fortunately, there is no strict need for compatibility among PV modules, old and new; different types and power ratings may be mixed into your array.

A photovoltaic system is unique in that its "generator" is composed of small modules and can be expanded over time. This is one of the many factors that make PV power the most liberating energy technology ever developed. Make the most of it by employing integrated system techniques and designing for future needs.

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