

# How to Size and Design a Photovoltaic (PV) Solar System for a Home, Casita, or Business

## THE AVERAGE HOUSE

There is no "average" household or "average family" in regard to sizing up a PV system. Every family is different. So designing a PV system requires special attention to each particular family or household usage patterns. Some families use appliances frequently, or work at home with office equipment and computers all day. Some have several children who like to watch many hours of television. Such a family may use as much as 10-20 KW hours per day. Other families, such as a moderate income family, or a retired couple, may just run a small refrigerator, a laptop or stereo, and a few lights on most days. A household like this could use as little as 5-10 KW daily.

Determining the correct size of a PV system for each household therefore requires that the family or household fill out a questionnaire. This questionnaire catalogs all family appliances, as well as the number of watts each appliance draws, and the number of hours that each appliance is used on an average day (or week). By calculating the average daily consumption pattern of a family, one can determine what size PV system each unique family requires in order to produce the number of kilowatts (KW) per day that meet that household's needs. The questionnaire will show whether a family needs 5 or 10 or 15 KW on a daily basis. (See PV electrical consumption questionnaire attached)

**HOW ELECTRIC POWER IS MEASURED:** Electricity is generally measured in kilowatt hours. When a utility company sends out electric bills, they charge customers by the number of kilowatt hours the customer pulls from the power lines as noted by the meter. All appliances have a per-hour watt rating. For example; a 100-watt bulb uses 100 watts per hour. So that ten 100-watt bulbs left on for one hour

would burn 1,000 watts, or one kilowatt (1KW). PV systems are also sized by the number of kilowatts produced; for example a one kilowatt (1 KW) system can produce 1,000 watts per hour

## **INTELLIGENT CONSUMPTION PATTERNS- HOW TO PICK AND USE YOUR APPLIANCES TO SAVE MONEY**

Solar San Miguel International has a mission of reducing energy consumption. We want our customers to be able to afford buying PV systems. Since PV components are fairly costly, our Company first tries to educate consumers how to reduce their consumption, by showing each family how to be efficient in their usage pattern.

It is extremely important for consumers, whether they are buying a PV systems or not, to know what power each appliance requires, and to plan their appliance purchases and electric load utilization accordingly. For example; an old, inefficient refrigerator can use up to 2,000 or even 3,000 watts per day (2-3 KW), while a new highly efficiency refrigerator can use as little as 700-1000 watts daily. Many consumers are surprised to find that a lap top computer only needs 20 watts per hour, while a desktop computer could use up to 200-300 watts per hour. Also it is useful to know that a large TV uses 250-300 watts per hour. Leaving a TV on all day will consume thousands of watts daily, as will a desk-top computer left on all day. It is also important to note that when a computer or TV screen is off, it is still drawing a lot of power in standby mode.

## **ELECTRIC APPLIANCES AND PV SYSTEMS**

Solar Panels produce direct current (DC). Most regular household appliances run on AC (alternating current). All wall outlets are AC. So in a house with regular AC appliances and outlets, an inverter is required to convert the DC produced by solar panels into AC. This inverter can be simple and inexpensive in small systems, or extremely complex. The inverter is often a major cost factor in larger PV systems, especially in household that require clean power supply for sensitive equipment such

as laser printers and remote phones, or systems that are designed to sell power back to the electric utility.

Some smaller super-efficient PV systems can run without inverters, directly sending electric energy (DC) from the panels to a battery bank, and using 12 volt DC to power all appliances. These 12 Volt systems do not need an inverter, but this means buying special 12 volt lights, a 12 volt refrigerator, and other 12 Volt appliances such as TVs. Regular 120 volt AC appliances are not an option if you take this route, but this may be an ideal inexpensive system for a small casita.

## APPLIANCES AND PV- HOW TO BE EFFICIENT

### REFRIGERATORS

Since refrigerators are most often the largest consumer of home energy, they require the most attention. Some PV households buy a gas refrigerator, or a super-efficient 12 Volt refrigerator, which can use as little as 200-500 watts per day. Though such refrigerators may cost \$1,000-1,500 dollars, a family that buys such a refrigerator will only require a small PV system. There are also highly efficient, super-insulated refrigerators that run on normal AC house current but use only a few hundred watts per day. Again these appliances are expensive, averaging \$1,200- \$2,000 dollars, but will save thousands of kilowatts over their lifetime of usage, and thereby reduce by thousands of dollars on the cost of PV components. There are now also commercially available medium sized refrigerators that are fairly inexpensive, and use only approximately 1000 to 1200 watts per day.

### LIGHTING

Lights are a large part of every family's electric bill. Please note that four incandescent 75 watt bulbs will use 300 watts per hour, while four compact fluorescent 15 watt bulbs will give the same light(or lumens), but burn only 60 watts per hour. And now the new 3-5 watt LED bulb technology can reduce that consumption to 20 watts per hour.(LED

stands for light-emitting diodes). It is also important to note that leaving just two or three incandescent bulbs outside the house on all night could burn up thousands of watts daily. It is always better to use compact fluorescent or LED bulbs particularly for lights that stay on for long periods.

### **ELECTRIC OVENS, TOASTERS AND MICROWAVES**

Appliances that heat with electricity usually draw a lot of power. An electric coffee maker uses 1,200 watts per hour, as does a microwave, or a toaster oven. An electric heater can also draw 1200 -1500 watts. But a microwave is only used for a few minutes a day, so it is an efficient appliance. On the other hand electric ovens, coffeemakers, and toasters will be used for longer durations, and suck a lot of power. If a family cannot afford a large PV system they need to avoid all electric heaters and ovens, and use only gas or a microwave to heat and cook.

### **STARTING SMALL- AFFORDABLE PHOTOVOLTAIC SYSTEMS**

A family can start small and build up towards a larger system with time, purchasing a PV system with only a few panels and one or two batteries, and then expanding later. To plan ahead for expansion the household merely has to plan on spending \$300- \$750 extra for a stronger charge controller and more powerful inverter that can allow for the possibility of expansion to more panels and batteries at a later date.

### **STORAGE BATTERIES AND NET METERING**

PV system costs can vary markedly depending on the amount of storage capacity needed (i.e.; the number of batteries), and this depends on the usage pattern of a household. Families need less storage batteries if they use their solar power more often during the day, for example; for water pumping, pool filter, laundry. Families that use most of their electricity at night need a larger battery bank.

## BASICS FACTS OF PV SYSTEM COMPONENTS

**SOLAR PANELS:** The primary components of a PV system are the solar panels, which produce DC current. Most often these are rated by the number of watts produced per hour in optimum sunshine. The most commonly used panels are now ranging from 150 to 190 watts per hour. In Mexico there is an average of 5-6 hours per day of optimum sunshine, so these panels usually produce approximately 700 to 1,000 watts (DC) per day. The main components of PV panels is purified silicon chips, which are essentially refined beach sand, one of the most common elements on earth. Purified silicon has a unique property of releasing electrons when bombarded by light photons, an energy component of sunlight. Sunlight landing on a panel thereby induces electricity to flow.

A series of panels coupled together is called a solar array. An array of six to nine panels is most often purchased by Solar San Miguel customers. These 1 KW to 1.5 KW arrays produce 6-9 KW of electricity per day. PV panels are usually priced per watt, and generally the retail cost of panels is approximately 6-10 dollars per watt depending on the size of the panel.

PV panels are extremely durable, often lasting for 40-50 years, and they often come with a 10-25 year warranty. Solar San Miguel imports the Evergreen Spruce brand 170-180 watt panels, manufactured in Massachusetts USA. Each panel produces approximately 7 amps at 25 volts (Volts x Amps equals Watts). We estimate each panel will provide an average 900-1000 watts daily. The Spruce panel is guaranteed by the factory to provide 100% output performance for 25 years. The panel will keep producing electricity after 25 years, for up to 50 years, but as the silicon deteriorates, the panel will provide perhaps 50%-95% of rated capacity as the PV panel ages.

There are also smaller panels available for camps or casitas that can only handle minimum loads like lights and radios. Small panels ranging from 5 watts to 80 watts are also available through our company.

**INVERTERS:** Solar Panels produce direct current (DC). Most regular household appliances run on AC (alternating current). All wall outlets are 120 Volts AC, or 240 Volts AC. So in a house with regular AC appliances and outlets, an inverter is required to convert the DC produced by solar panels into AC. This inverter can be simple and inexpensive in small systems, or extremely complex. Good inverters that produce clean AC power for large home systems are expensive, and can cost as much as \$3,000. But such inverters are critical for homes with equipment such as laser printers or sensitive electronic equipment.

Low cost inverters are available for as little as \$80 dollars, but can only run a few AC lights and a radio. Inverters capable of running refrigerators, lights, radios and TVs generally run at least \$200-\$300 dollars, and may cost \$800-1,200 for moderate sized PV systems.

For larger systems Solar San Miguel imports Outback Power System inverters, made in Washington State, USA. These are of top quality, and one of the highest rated inverters in production today. We also import rugged, low cost Xantrex DR inverters for smaller to medium systems. These DR inverters have been tested in the Caribbean and many third world countries for 10 years. They come highly recommended for use in damp sea-shore or jungle locations.

**BATTERIES:** Solar systems require deep cycle batteries that can be charged with power produced by the PV array during the day, and discharged at night to power lights and appliances. Regular car batteries are not designed for this type of usage, and will die very quickly if discharged often. That is why deep-cycle marine-type batteries are used for PV systems. The number of batteries is determined by the amount of power produced that needs to be stored. Most household use the majority of power at night so that most of the power produced during the

day needs to be stored. But if a lot power is used during the day, for example for well pumping, than less storage capacity is needed.

Most often Solar San Miguel customers buy large deep cycle wet-cell batteries (often used in golf carts) that can each store and safely discharge approximately 1000 watts per day. We also carry maintenance free (dry) gel-cell batteries. Average cost of such deep-cycle batteries is approximately \$250-\$350 dollars.

**CHARGE CONTROLLERS:** A charge controller is an important part of a solar system, and every PV system must have one. This electronic component is essentially a battery charger, but in larger systems it can also be a computer that maximizes the power coming from the solar panels. It can improve efficiency by sending power directly from the PV array to appliances. Small charge controllers may cost \$75 dollars, but large controllers cost up to \$650 dollars for the complex, larger systems. For medium to large systems we import Outback M60, the top-rated charge controller in the PV industry.

**NET-METERING:** A sophisticated charge controller can sell power to the utility in a process called net-metering. Net metering is essentially selling power to the utility grid during the day, and buying it back at night. Advanced charge controllers have the capacity to read grid voltage, and raise the PV voltage in the system higher, thereby causing a reverse flow of electricity out to the utility line. This reversal also causes the meter on the house to spin backwards. Such a sell-back feature essentially allows for the utility to be used as the storage bank for surplus power produced during the day, and thereby reducing drastically the cost and maintenance of batteries in a PV system. Mexico has already passed a law instituting net-metering, and CFE implementation is due to take effect this coming year.

## PHOTOVOLTAIC SYSTEM COSTS

One can easily see that by merely changing the refrigerator, using laptop computers and compact fluorescent or LED bulbs, and avoiding electric heaters and ovens, a family can drastically reduce consumption/usage pattern by thousands of watts per day. This could be as much as a 30%-60% reduction if the family is willing to change their usage pattern. But just changing the refrigerator and lights can save 25%-30% of the energy bill.

Since each large PV solar panel costs on average \$1,000, and can produce approximately 1,000 watts per day, a family that is willing to reduce and conserve their energy usage may save thousands of dollars on the initial cost of a PV system, reducing the number of panels and batteries required. So that 3000 watts less consumption daily, can avoid \$3000 in PV panels cost alone. Below are some ballpark average costs for PV systems:

### SYSTEM TYPE A

#### DC 12 VOLT MINI SYSTEM FOR CASITA

Using 12 Volt 80-130 watt panels, 12 volt compact fluorescent or LED bulbs, and a small 12 Volt TV or stereo, this DC system without inverter can cost as little as \$700-\$900 dollars . But if a 12 Volt refrigerator is added, more panels may be needed, and the cost could be as high as \$1,250-\$2,500 dollars The cost depends on the size of the refrigerator and how many lights and other appliances are used.

The small DC system requires only a low cost charge controller and one or two 12 Volt deep-cycle batteries, along with one or two panels. Such a system would be expandable simply by adding more 12 volt PV panels, and more storage batteries. But remember, there is no room in this configuration for regular AC appliances. And it does not include the cost of the refrigerator. For a system with an efficient mini-fridge, a one-panel, one battery system is a possibility at a cost of approximately

\$1,250 dollars. With two panels and two batteries the cost jumps to over \$2,000. (Once again, this does not include the cost of the fridge).

## **SYSTEM TYPE B**

### **SMALL 120 VOLT AC SYSTEM FOR CASITA OR SMALL HOUSE**

A small system, with an inexpensive AC inverter, may cost as little as \$1,200 dollars, while a slightly larger system can cost up to \$4,000, depending on whether your load is 1 KW or 3 KW per day. By using a small efficient AC refrigerator, compact fluorescent or LED bulbs, laptops, and small TVs or stereos, a 120 volt system can be quite affordable to the average family. And such a system may be expanded easily if the original equipment has been purchased with growth in mind. Remember that a bigger refrigerator and more appliances will require more panels, and more batteries. So while a small system that will support 1,000 watts daily usage can be purchased for less than \$2,000 dollars, a household that requires over 2,000 watts per day (2KW) would need a system that can cost as much as \$3,000-\$4,000 dollars,

## **SYSTEM TYPE C**

### **SMALL-MEDIUM-SIZED PV SYSTEMS FOR SMALL HOUSE**

A system that produces 3000 watts (3KW) daily (usually three large panels) costs approximately \$4,000-\$6,000 dollars, depending on the cost of inverter, number of batteries, and sophistication of the charge controller. This size system can run all household appliances, with perhaps the exception of sensitive laser printers (this depends on which inverter is part of the package). But a household must be careful not to run too many appliances at once, and to be careful not to drain the batteries. At this level planning for expansion is often cost effective, so the inverter and the charge controller should be sized up to allow for additional batteries and panels.

## **SYSTEM TYPE D**

### **LARGE 120 VOLT PV SYSTEM FOR MID-SIZED HOUSEHOLD**

Larger PV systems that can produce from 5,000 to 10,000 watts per day (5-10 KW), will cost as much as \$12,000 to \$20,000 dollars.

These larger PV systems are for medium to large households, and for families who do not wish to change their lifestyle markedly. Many large PV households are grid-tied, meaning they buy some power from the utility while also producing PV power for a majority of their needs. Being grid tied-means a family can start with a smaller system, and build it to supply a greater percentage of their power needs over time. The inverters and charge controllers can handle up to 15 KW per day. These systems can also sell power to the grid.

### **SYSTEM TYPE E**

#### **LARGE 120-240 VOLT SYSTEMS FOR HIGH USAGE HOUSE**

For large households with high usage patterns, or for home offices with lots of equipment, a large PV array and control system may be necessary. Sometimes a well pump is 240 volts. With a second inverter and sometimes an additional charge controller, such systems can supply 240 Volts for large pumps and heavy duty appliances such as dryers. 120-240 Volt PV systems, supplying 10-15 KW per day, may average in cost between \$20,000-\$30,000 dollars.

### **SYSTEM TYPE E-X**

#### **COMMERCIAL PV INSTALLATION**

Large commercial installations for hotels, housing complexes, and commercial buildings, may need 20-50KW per day, and 240 Volts. Solar San Miguel has installed a 6 KW a system at Casa Chorro, a B&B located near the Parque Juarez. The system has 33 Evergreen 180 watt panels, and uses two Outback inverters and two Outback charge controllers. The system supplies 240 Volts and has produced an average of 30 kilowatts daily (30KW) since installation. PV systems of this size can cost \$40,000 to \$100,000 dollars. Large installations can be calculated at approximately \$10-\$12 dollars per watt (so a 6,000 watt system would be \$60,000 to \$72,000 dollars.)

The Federal Government of Mexico has passed a business tax law that essentially allows for 100% depreciation of all solar equipment in the first year after installation. For a profitable company paying taxes to Hacienda, this is essentially a large subsidy that mitigates the initial cost of PV installation to profitable commercial enterprises.