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SunRotor Model: SRP-4-150-24 (4 GPM, 24 VDC, 150' Maximum TDH)

Solar Water Pumping Basics

Where do solar pumping systems work?

Solar pumping systems work anywhere the sun shines. The majority of the continental U.S. enjoys plenty of sun to operate a pumping system economically.

The intensity of light varies greatly throughout the day. Morning and afternoon sunlight is less intense because it is entering the earth's atmosphere at a high angle and passing through a greater cross section of atmosphere, which reflects and absorbs a portion of the light.

We measure sun intensity in equivalent full sun hours. One hour of full sun is roughly equivalent to the sunlight on a clear summer day at noon.

The sunlight or insolation levels also vary seasonally. Fortunately, most needs for water correspond with the sunniest seasons of the year – spring, summer and fall.

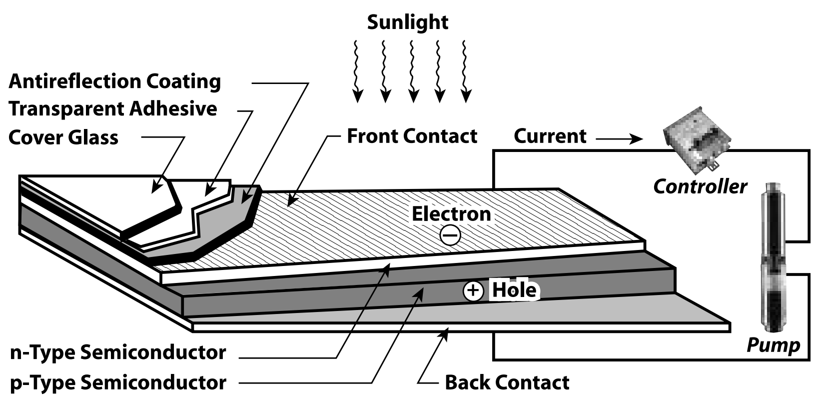
Small to medium solar electric pumping systems are easily portable. By mounting the solar system on an axle or trailer, a system can be moved from well to well. This increases the economic return of a system by increasing the seasons of use. It may also correspond with the rotation of grazing areas.

Solar power and water pumping are a natural. Generally, water is needed most when the sun shines its brightest. Solar modules generate maximum power in full sun conditions when we typically need larger quantities of water. Because of this "sun synchronous" matching, solar is an economical choice over windmills and engine driven generators for most locations where utility power is non-existent. Owners of solar water pumping systems enjoy a reliable power system that requires no fuel and very little attention.

How does the sun power a pump?

The photovoltaic effect produces a flow of electrons. Electrons are excited by particles of light and find the attached electrical circuit the easiest path to travel from one side of the solar cell to the other. Envision a piece of metal such as the side panel of a car. As it sits in the sun, the metal warms. This warming is caused by the exciting of electrons, bouncing back and forth, creating friction, and therefore, heat. The solar cell merely takes a percentage of these electrons and directs them to flow in a path. This flow of electrons is, by definition, electricity.

Photovoltaics or solar electric cells convert sunlight directly into electricity. This electricity is collected by the wiring in the module, then supplied to the DC pump controller and motor, which, in turn, pumps water whenever the sun shines. At night, or in heavy cloud conditions, electrical production and pumping ceases.



Economics of Solar Water Pumping

The economy and reliability of solar electric power make it an excellent choice for remote water pumping. Cattle ranchers in the Western U.S., Canada, Mexico, and Australia are enthusiastic solar pump users. Their water sources are spread over many miles of rangeland where power lines are few and refueling and maintenance costs are substantial.

If your water source is 1/3 mile or more from the powerline, solar is a favorable economic choice. This fact is reinforced by a number of Rural Electric Co-Operatives across the U.S. These Co-Ops actively advocate the use of solar pumps, as the cost to extend new lines is subsidized by other rate payers.

A solar pump minimizes future costs and uncertainties. The fuel is free. Moving parts are reduced to as few as one. A few spare parts can assure you many years of reliable water supply at near-zero operating costs.

SunRotor Solar Pump: Model SRP-6.0-150-36 (6 GPM, 36 VDC, 200' Maximum TDH)

Solar Power & Pump Co.
Elk City, OK
580-225-1704
1-866-246-7652

Fixed vs. Tracking Mount Structure

Fixed Mount structures are less expensive and tolerate higher wind loading. By fixing the modules due south, less water is pumped than a tracking system which orients the modules towards the sun as it arcs across the southern sky.

Tracking mount structures keep the modules at a 90 degree angle to the sun all day long. This provides more power to the pump over a longer period of the day, which produces 20 to 40 percent more water daily in the summertime.

Mounting Structures and Array Placement

Solar modules should be located in a sunny spot where no shading occurs. Even shadows from a tree limb, tall grass, or fence rails can substantially reduce power output.

For these reasons we typically mount the solar modules on a pole or ground mount above any obstacles. Remember the solar array can be placed some distance from the water source if shading is a problem. Wire size can be increased to compensate for longer cable runs and the associated voltage drop.

Water Storage – Efficient and Effective

Storing water in a good sized cistern or stock tank has many advantages. It is less expensive and more efficient than storing energy in batteries, giving your system a flywheel effect over cloudy days and letting the pump work at a slower continuous pace over the day. As a rule of thumb, the tank should be able to store 3 or 5 days worth of water. Generally speaking, animals, plants and humans use less water on cloudy days. Conversely, the sunniest days are when we consume the most water and when the solar modules are providing the pump with the most power.

Solar Trackers and Water Pumping – A Perfect Match

Trackers offer a great advantage when pumping water. Our passive single axis trackers are known for their excellent reliability and service life. They take no power from the system as they operate from the heat of the sun striking the frame members, causing freon to move from one cylinder to another. Our trackers come with a 10 year warranty and are highly recommended in all but the windiest locations. High winds can pull the array off the correct sun angle and will negatively affect power production if winds are consistent.

Why we don't Recommend Batteries in Water Pumping Systems

While batteries may seem like a good idea, they have a number of disadvantages in pumping systems. They reduce the efficiency of the overall system. The solar modules operating voltage is dictated by the battery bank and is reduced substantially from levels which are achieved by operating the pump directly. Batteries also require additional maintenance and under and over-charge protection circuitry which adds to the cost and complexity of a given system. For these reasons, only about five percent of solar pumping systems employ a battery bank.

Windmills: Yesterday's Answer to Remote Water Delivery

There are still thousands of windmill water pumping units standing in the western U.S. Regrettably, many are inoperable. These pumpers were very valuable for remote (off grid) sites, with the proper minimum wind conditions, when manpower was plentiful and cheap. Windmills, though potentially long lasting, need dedicated maintenance. The downhole leathers require inspection and high winds can cause mechanical damage to the blades. Parts for these mills are expensive and sometimes hard to find.

Solar water pumping systems have many advantages over windmill water pumpers. Though the initial cost of solar powered systems can be similar to that of a windmill (however, in many cases far less) the life time costs are much lower. Windmills must be used where there is a steady, constant wind for maximum results while solar pumps operate anywhere the sun shines. Solar pumping systems can be installed in less than a day by an individual or small crew and can be portable, while windmills (because of the need to erect a tower) can take a larger crew a much longer time to install. Windmills are secured to the ground and are stationary. Solar powered water pumping systems are the modern day upgraded version of the windmill which uses natural resources to deliver water in off grid locations.

Gas Fired Generators vs. Solar Energy

Generators are commonly used to provide power beyond the powerline. We have several economic studies concerning the economics of solar versus generators as a power choice. These studies consider all costs involved: modules, mounting structure, pumps, miscellaneous components, installation, operation, maintenance, yearly inspection, component replacement and salvage value. With this we can determine a life cycle cost and a present value. One such comparison was done by the Bureau of Land Management at Battle Mountain, Nevada specifically comparing solar water pumping systems. For one 3.8 gpm system with a 275 foot design head, the PV system cost only 64% as much over 20 years as the generator system did over only 10 years. This remote solar site is also used only 14% as many labor hours.

In 1989, Sandia National Laboratories noted that photovoltaic pumping systems in remote locations would often be cost effective compared to generators, even with 5 times the initial capital cost. Low end generators, which are initially inexpensive, require consistent maintenance and have a design life of approximately 1,500 hours. Small to medium sized solar pumping systems often initally cost less than a durable slow speed engine driven generator. Most larger pump systems initially cost more than generator systems, but tend to be far more economical in the end.

Solar Powered vs. Gas-Fired Generators and Windmills

SYSTEM TYPE	ADVANTAGES	DISADVANTAGES
Solar Electric Power System	• Low Maintenance • Clean • No fuel needed • Easy to install • Reliable long life • Unattended operation • Low recurrent costs • System is modular and can be matched closely to need	• Relatively high initial cost • Lower output in cloudy weather
Diesel (or Gas) Power Systems	• Moderate capital costs • Can be portable • Extensive experience available • Easy to install	• Needs maintenance and replacement • Maintenance often inadequate, reducing life • Fuel often expensive and supply intermittent • Noise, dirt and fume problem • Site visits necessary
Windmill	• Potentially long-lasting • Works well in windy site	• High maintenance • Costly repair • Difficult to find parts • Seasonal disadvantages • Need special tools for installation • Labor intensive • No wind, no power, no water

Rancher Concerns

Because of the low cattle prices of today, the cost of water is a prime concern for a rancher. Every dollar wasted on an inefficient water system is a dollar of profit out of the rancher's pocket. When faced with a need for a new water system or to repair an old system, the natural thought is to look at the lowest initial cost. But the lowest initial cost may not be the most cost effective. A smart rancher will not only look at the initial cost but will also consider the long term cost along with the reliability. If he is interested in higher profits he should take a look at his present water costs. He should then compare these costs to several alternative methods to determine the most cost effective one.

Designing a Solar Pumping System

There are many aspects of designing a solar pumping system. This guide provides the information to correctly select a pump, controller, sensors, solar array, wiring, and pipe. The process is broken down into the following steps:

STEP 1 - *Determining your basic amount of water required per day.*
STEP 2 - *Calculating the TOTAL DYNAMIC HEAD.*
STEP 3 - *Determining the solar resource for your location.*
STEP 4 - *Selecting the pump, controller, and solar array.*
STEP 5 - *Selecting the correct solar array mounting method.*
STEP 6 - *Selecting the right size pump cable and pipe.*
STEP 7 - *Using water level sensors and pump controls.*

[--]

STEP 1 - *Daily Water Requirement and Storage*

The size and cost of your system will depend on the amount of water required per day. AC pumping systems connected to a utility power grid are generally designed to run on demand with a specified flow rate. Unlike grid-tied systems, solar pumping systems are designed to provide a certain quantity of water per day. Water is pumped during sunlight hours and stored in a tank. The daily requirement is simply a total of all water required during a 24 hour period. This quantity is expressed in LITERS PER DAY or GALLONS PER DAY.

Tanks are used to store water for use during the night or periods of cloudy weather. Tanks are usually large enough to hold 3 to 5 days of daily water output.

If your application requires large amounts of water on a periodic basis, like watering a crop once a week, divide the weekly requirement by 7 to arrive at an average daily requirement. A system such as this should have a tank large enough to hold at least 1.5 times the weekly requirement.

Information about water needs is available from many sources. Government agencies can provide information for household and agricultural applications. Some guidelines for water uses and daily quantities are shown below. These are general guidelines only; actual values depend on many factors.

TABLE 1 – *TYPICAL WATER REQUIREMENTS*

USE	USAGE LITERS PER DAY	USAGE GALLONS PER DAY
EACH PERSON, FOR ALL PURPOSES	284	75
EACH MILKING COW	133	35
EACH COW/CALF PAIR	38 – 114	10 – 30
EACH HORSE, DRY COW, OR BEEF ANIMAL	38 – 76	10 – 20
EACH SHEEP	8	2
EACH HOG	15	4
100 CHICKENS	15	4

STEP 2 - *Calculating TOTAL DYNAMIC HEAD*

Total Dynamic Head, or TDH, is a very important factor in system design. TDH is the effective pressure the pump must operate against. TDH is expressed in METERS or FEET. TDH is the sum of 3 factors:

1. ***TOTAL VERTICAL LIFT***
   TOTAL VERTICAL LIFT is the sum of the STANDING WATER LEVEL, DRAWDOWN, and ELEVATION. The STANDING WATER LEVEL (SWL), measured in meters or feet, is the distance from the top of the well to the surface of the water in the well when no water is being pumped (see **FIGURE 1** on page 12). The STANDING WATER LEVEL water is also called the "static" (at rest) water level. The DRAWDOWN, measured in meters or feet, is the distance the standing water level lowers when water is pumped from the well. Depending on the well, the DRAWDOWN may be 1 to 20 meters (3 to 50 feet) or more. Slow flowing wells will have the greatest DRAWDOWN. The STANDING WATER LEVEL and DRAWDOWN can also be provided by the well drilling company or by testing the well. The DRAWDOWN is related to the flow rate of the pumping system; the greater the flow rate, the greater the DRAWDOWN.

NOTE: The sum of the STANDING WATER LEVEL and the DRAWDOWN is called the PUMPING LEVEL. ELEVATION to point of use, measured in meters or feet, is the vertical distance from the top of well to the point of use, such as the top of a storage tank.

2. ***FRICTION LOSS***
The FRICTION LOSS, measured in equivalent meters or feet, is the pressure required to overcome friction in the pipes from the pump to the point of use. The friction is based on: rate of flow, the length, diameter, and type of pipe, and also the number and type of pipe fittings used. The greater the flow, the greater the FRICTION LOSS. Tables are used to calculate friction loss.

3. ***TANK PRESSURE***
TANK PRESSURE, expressed in equivalent meters or feet of head, is the operating pressure of the storage tank. Solar pumping systems have very large tanks because no water is pumped at night or in very cloudy weather, pressurized tanks are rarely used in solar pumping systems. However, systems with battery power can be used to pump to pressurized tanks. For typical, non-pressurized systems, TANK PRESSURE equals zero.

TOTAL DYNAMIC HEAD = *TOTAL VERTICAL LIFT* + *FRICTION LOSS* + *TANK PRESSURE*

TOTAL VERTICAL LIFT
To calculate TOTAL DYNAMIC HEAD it is best to make a sketch like **FIGURE 1** on next page.

Calculate the TOTAL VERTICAL LIFT by adding the STANDING WATER LEVEL, the DRAWDOWN and the ELEVATION.

FRICTION LOSS
In most cases, calculating FRICTION LOSS can be simplified. If the system storage tank is located close to the well head, 10 meters (30 feet) or less, and the recommended pipe size is used, a simple rule can be used. Friction loss, in equivalent head, can be estimated at 5% of the TOTAL VERTICAL LIFT. This will allow for a few straight runs of pipe and a few fittings.

In cases where the tank is located far from the well, more than 10 meters (30 feet), more accurate calculations must be used for FRICTION LOSS. FRICTION LOSS is based on the size and length of the pipe, the number and type of fittings, and the FLOW RATE. Solar pumping systems, unless connected to a battery, pump only when the sun is shining on the solar array. Cloudy weather will also affect the flow rate. The flow rate varies over the course of the day with the peak flow occurring at midday. Because our system design is not complete (a pump and array have not been selected yet), the TOTAL DAILY OUTPUT can only be estimated. To estimate the flow rate, make a guess for the TOTAL DAILY OUTPUT and use the following equations:

US:
GPM (gallons per minute) = GPD (gallons per day) / 360

Metric:
LPM (liters per minute) = LPD (liters per day) / 360

Example:
DAILY REQUIREMENT = 3600 liters per day
FLOW RATE = 3600 / 360 = 10 liters per minute

Calculate the friction loss by adding the length of all piping in the system. Use TABLE 2 or 3 to express the friction loss from fittings in equivalent length of pipe. Add the total of fitting losses to pipe losses. Using the total equivalent length of pipe, and the flow rate, find the head loss in meters per meter of pipe, or feet per foot of pipe, from TABLE 4 or 5. Multiply this number by the total equivalent length of pipe. This number is the FRICTION LOSS in meters or feet of head.

When the system design is complete, use the actual DAILY OUTPUT of the chosen pump and array, recalculate the FLOW RATE, and review the FRICTION LOSS calculations. If necessary, recalculate the FRICTION LOSS and the TOTAL DYNAMIC HEAD and double-check your pump and array choice.

TANK PRESSURE
Tank pressure is specified from other system needs. When a pressurized tank is used, convert the cutoff pressure to meters or feet of head. If the water is allowed to flow free into an open or vented tank, the TANK PRESSURE is zero, use a value of zero when calculating TOTAL DYNAMIC HEAD. To convert pressure to equivalent head, use the following formulas:

US:
HEAD (in feet) = PRESSURE (psi) x 2.31

Metric:
HEAD (in meters) = PRESSURE (kPa) x 0.102

Example:
FIGURE 1 is a good example of how a system should be sketched to calculate TOTAL DYNAMIC HEAD. The worksheet on the following page can be used for the calculation. Practice the calculation using FIGURE 1). The TOTAL DYNAMIC HEAD for this system equals 92.852 feet.

WORKSHEET 1 - *TOTAL DYNAMIC HEAD*

CALCULATING TOTAL VERTICAL LIFT:

Standing water level LINE 1 ____________

Drawdown LINE 2 ____________

Elevation LINE 3 ____________

TOTAL VERTICAL LIFT (add lines 1 – 3) LINE 4 ____________

CALCULATING FRICTION LOSS:

Simplified method, tank close to well (see text):

FRICTION LOSS (multiply line 4 by 0.05) LINE 5 ____________

Calculated method, tank far from well (see text):

Total length of all pipes; add the length of all pipes.

________ + ________ + ________ + ________ = LINE 6 ____________

Equivalent length of fittings; add the equivalent length of all fittings (from TABLE 2 or 3).

________ + ________ + ________ + ________ = LINE 7 ____________

Total equivalent length of pipe (add lines 6 & 7) LINE 8 ____________

TOTAL DAILY OUTPUT (estimated or actual) LINE 9 ____________

Flow rate (divide line 9 by 360) LINE 10 ____________

Friction loss per length (from TABLE 4 or 5; use next largest flow rate and actual pipe size) LINE 11 ____________

FRICTION LOSS (multiply line 8 & 11) LINE 12 ____________

CALCULATING TOTAL DYNAMIC HEAD:

TOTAL VERTICAL LIFT (enter line 4) LINE 13 ____________

TOTAL FRICTION LOSS (enter line 5 or 12, see text) LINE 14 ____________

TANK PRESSURE (in meters or feet of head) LINE 15 ____________

TOTAL DYNAMIC HEAD (add lines 13 – 15) LINE 16 ____________

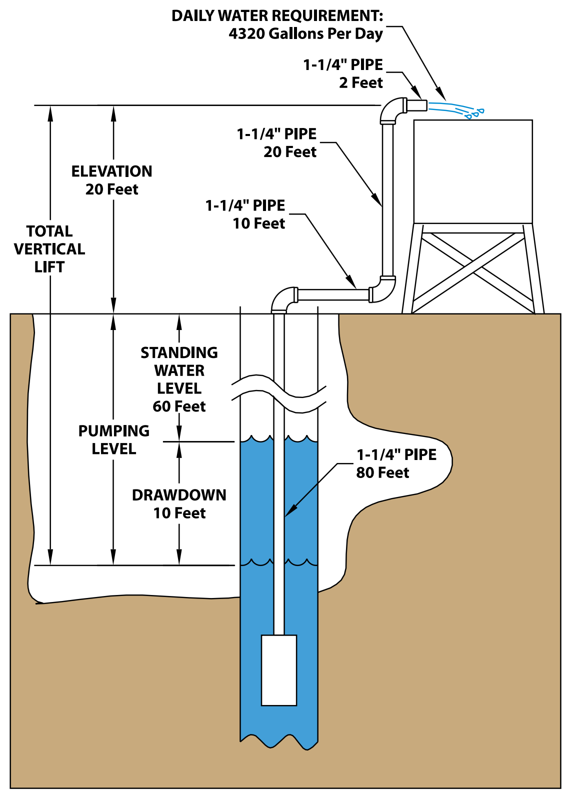


FIGURE 1

TABLE 2 - (METRIC) *FRICTION LOSS FOR FITTINGS IN EQUIVALENT METERS OF PIPE*

TYPE OF FITTING AND APPLICATION	NOMINAL SIZE OF PIPE FITTING (NPT)					
	1/2"	3/4"	1"	1 1/4"	1 1/2"	2"
	EQUIVALENT LENGTH OF PIPE (IN METERS)					
INSERT COUPLING	0.9	0.9	0.9	0.9	0.9	0.9
THREADED ADAPTER (PLASTIC TO THREAD)	0.9	0.9	0.9	0.9	0.9	0.9
90° STANDARD ELBOW	0.6	0.6	0.9	1.2	1.2	1.5
STANDARD TEE (STRAIGHT FLOW)	0.3	0.6	0.6	0.9	0.9	1.2
STANDARD TEE (90° FLOW)	1.2	1.5	1.8	2.1	2.4	3.3
GATE VALVE	0.3	0.3	0.3	0.3	0.6	0.6
SWING CHECK VALVE	1.5	2.1	2.7	3.7	4.0	5.2

TABLE 3 - (US) *FRICTION LOSS FOR FITTINGS IN EQUIVALENT FEET OF PIPE*

TYPE OF FITTING AND APPLICATION	NOMINAL SIZE OF PIPE FITTING (NPT)					
	1/2"	3/4"	1"	1 1/4"	1 1/2"	2"
	EQUIVALENT LENGTH OF PIPE (IN FEET)					
INSERT COUPLING	3	3	3	3	3	3
THREADED ADAPTER (PLASTIC TO THREAD)	3	3	3	3	3	3
90° STANDARD ELBOW	2	2	3	4	4	5
STANDARD TEE (STRAIGHT FLOW)	1	2	2	3	3	4
STANDARD TEE (90° FLOW)	4	5	6	7	8	11
GATE VALVE	1	1	1	1	2	2
SWING CHECK VALVE	5	7	9	12	13	17

TABLE 4 - (Metric) *FRICTION LOSS FOR SCH 40 PCV PIPE IN EQUIVALENT METERS*

FLOW IN LITERS PER MINUTE	NOMINAL PIPE SIZE LOSS IN METERS OF HEAD PER ONE METER OF PIPE					
	15.8 mm 1/2"	20.9 mm 3/4"	26.6 mm 1"	35.1 mm 1 1/4"	40.9 mm 1 1/2"	52.5 mm 2"
5	0.0058					
10	0.021	0.0053				
15	0.044	0.011				
20	0.076	0.019	0.0057			
25	0.11	0.029	0.0086			
30	0.16	0.041	0.012			
35	0.21	0.054	0.016			
40		0.069	0.021	0.0055		
45		0.086	0.026	0.0069		
50		0.1	0.031	0.0084		
60		0.14	0.043	0.012		
70		0.19	0.058	0.016	0.0073	
80			0.074	0.020	0.0093	
90			0.092	0.025	0.012	
100			0.11	0.030	0.014	0.0047
125			0.17	0.046	0.021	0.0071
150				0.064	0.030	0.010
175				0.085	0.040	0.013
200				0.11	0.051	0.017
225				0.14	0.064	0.021
250				0.17	0.077	0.026

TABLE 5 - (US) *FRICTION LOSS FOR SCH 40 PCV PIPE IN EQUIVALENT FEET*

FLOW IN GALLONS PER MINUTE	NOMINAL PIPE SIZE LOSS IN FEET OF HEAD PER ONE FOOT OF PIPE					
	1/2" 15.8 mm	3/4" 20.9 mm	1" 26.6 mm	1 1/4" 35.1 mm	1 1/2" 40.9 mm	2" 52.5 mm
2	0.041					
3	0.087	0.022				
4	0.148	0.037				
5	0.222	0.057	0.018			
6	0.312	0.08	0.025			
7	0.415	0.106	0.033			
8	0.53	0.135	0.042			
9	0.66	0.168	0.052			
10	0.805	0.204	0.063	0.017		
12		0.286	0.089	0.023		
14		0.38	0.118	0.031	0.014	
16		0.486	0.151	0.04	0.019	
20		0.605	0.228	0.06	0.028	
25			0.387	0.091	0.043	0.013
30				0.127	0.06	0.018
35				0.169	0.08	0.024
40				0.216	0.102	0.03
45				0.28	0.125	0.038
50					0.154	0.046
60					0.216	0.064
70					0.287	0.085

STEP 3 - *Determining Your Solar Resource*

The daily output of a solar pumping system varies with the amount of direct sunlight striking the surface of the solar modules. The more sunlight, the more water pumped. The amount of sunlight varies with weather, time of year, and location. You must know the amount of sunlight in your area before a proper system design can be completed. Also patterns of water usage vary. Some users require more water in summer while other users require the same amount of water in winter or summer. This manual contains "solar maps" that will aid you in determining you solar resource. These maps will provide you with a number called **S**un **H**ours **O**n **T**ilt, or **S.H.O.T.**, and a color that represents the amount of solar resource for your location and application.

The first step is to determine the pattern of water usage. If the application requires **a minimum amount of water each day**, the system should be designed to provide this amount of water with the least amount of sunlight. This generally occurs in winter. Solar maps, on the following pages, are provided for both December and June. Users requiring the same amount of water each day should use the December map in the northern hemisphere and the June map in the Southern hemisphere. Systems designed with these maps will provide the required water in winter when the least amount of sunlight or energy is available. They will also provide more water in summer.

If the application requires more water in the summer the system should be designed using the June map in the northern hemisphere and the December map in southern hemisphere. Systems designed with these maps will produce the water required in summer. These systems will produce less water in winter, and in some cases **may not** provide any water in the winter. These maps also assume that the solar array is fully exposed to sunlight during the entire day and is not shaded by trees or hills.

The angle the solar array is tilted toward the sun affects the energy produced. In order to produce the most energy the solar array must be pointed directly at the sun with the rays of sunlight falling perpendicular to the surface of the solar array. The S.H.O.T. maps provide the optimal angle the array should be tilted for maximum energy output during that season. In fact, these maps are only accurate when the array is mounted at the angle specified on the map. If the angle is changed, the water produced will decrease.

Users in tropical areas, between -23° and +23° of latitude, should examine both maps to determine the solar resource. Also the array tilt angle in these areas is a concern. Solar arrays in the tropics should not be mounted flat or at angles less than 15° despite the fact the sun may be directly overhead. Arrays mounted at low angles become covered with dirt and debris and lose energy output. Mounting at angles 15° or greater insures that rain and gravity will help keep the modules clean.

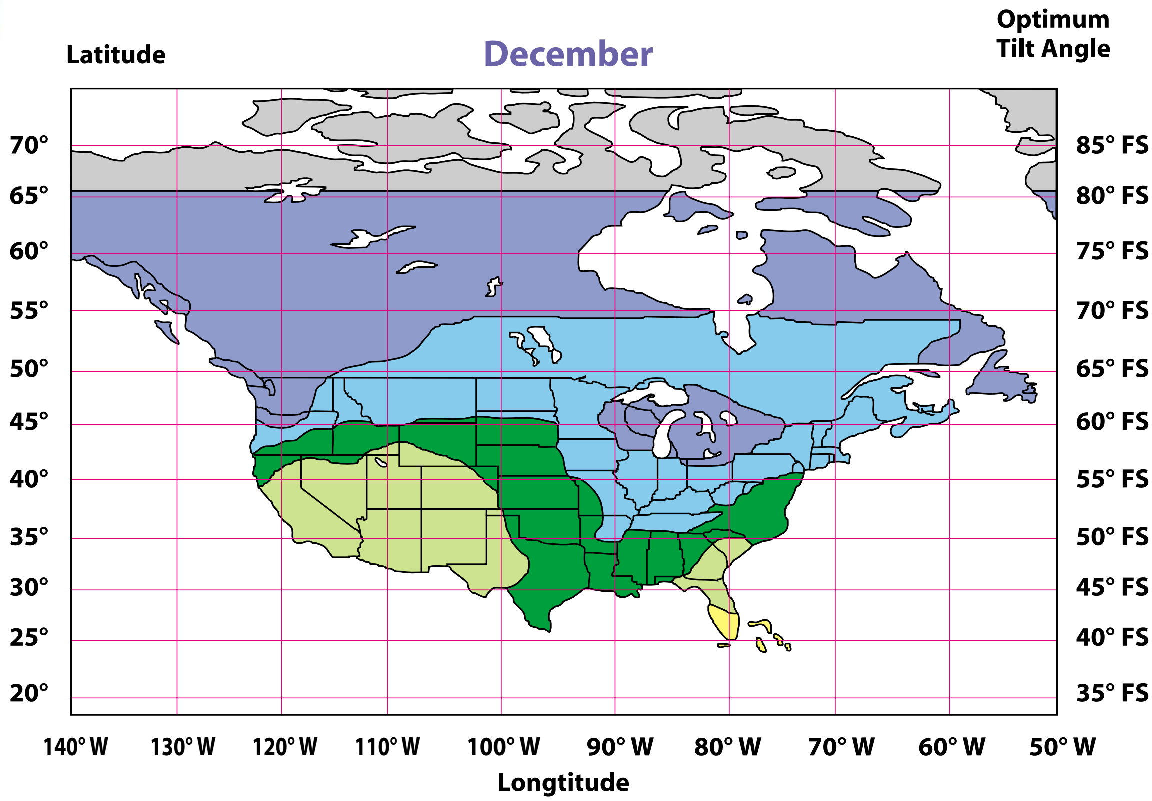
The solar array surface in the northern hemisphere should be pointed true south. Arrays in the southern hemisphere should be pointed true north. Arrays near the equator can be aimed north or south.

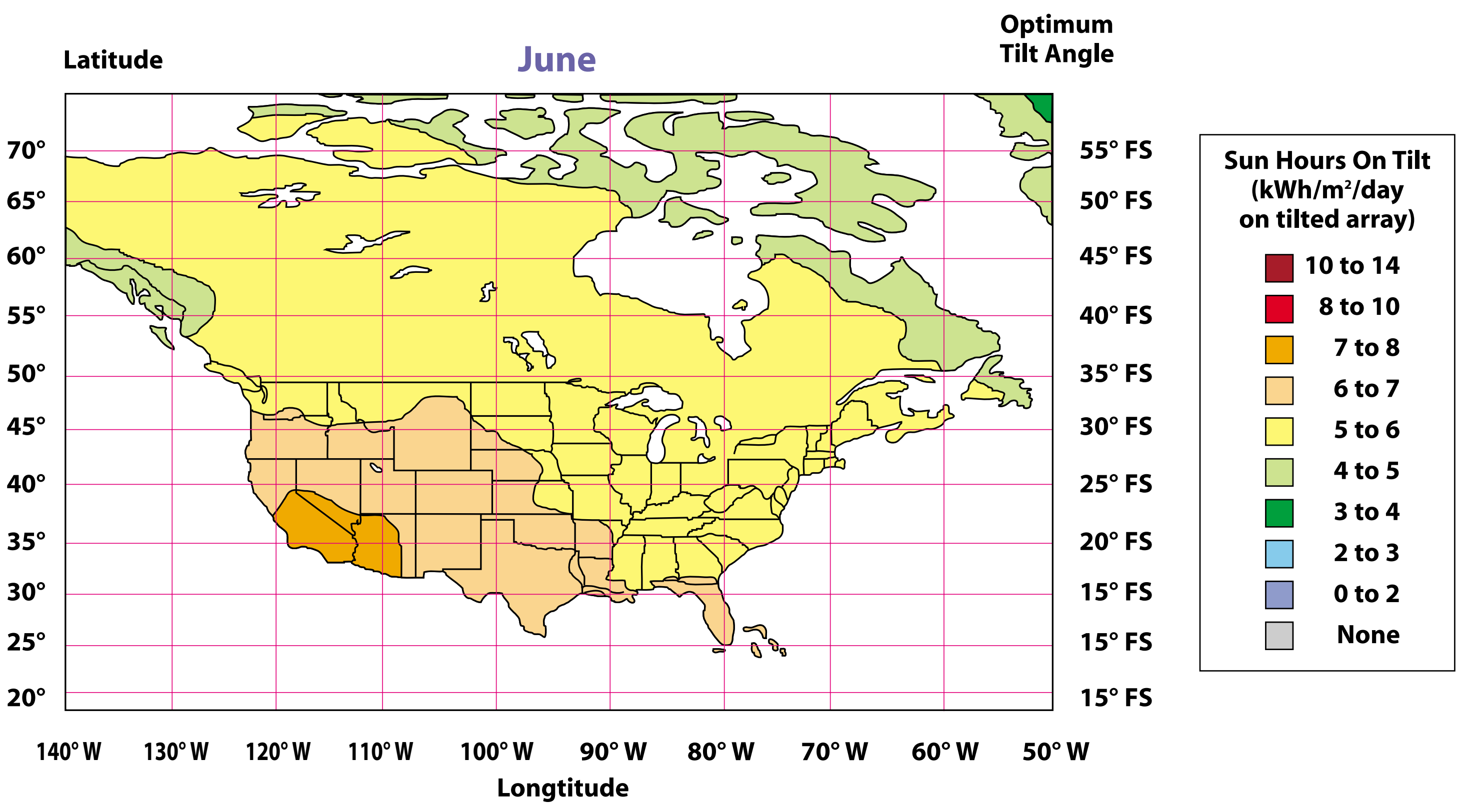
SUN HOURS ON TILT & TILT ANGLE

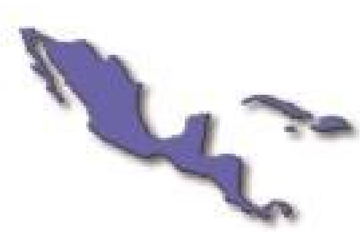
To determine the solar resource, follow these steps:

1. Decide whether to design the system for winter or summer.
2. Find your location on the maps, be sure to use the correct map for summer or winter. Remember the seasons are dependent on the hemisphere.
3. Read the color from the installation site on the map and use the legend to determine the **S.H.O.T.** value (kiloWatthours per meter squared per day on a tilted flat plate collector). This value is also known as "**S**un **H**ours **O**n **T**ilt". This value will be used to select the correct pump and array.
4. Use the scale on the right side of the maps to determine the optimum tilt angle for the solar array. "FS" means facing south and "FN" means facing north. See **FIGURE 2 - ARRAY TILT ANGLE** in **STEP 5 - ARRAY MOUNTING** to see how this angle is measured on the solar array.

Canada and USA Sun Hours On Tilt (S.H.O.T.) Maps

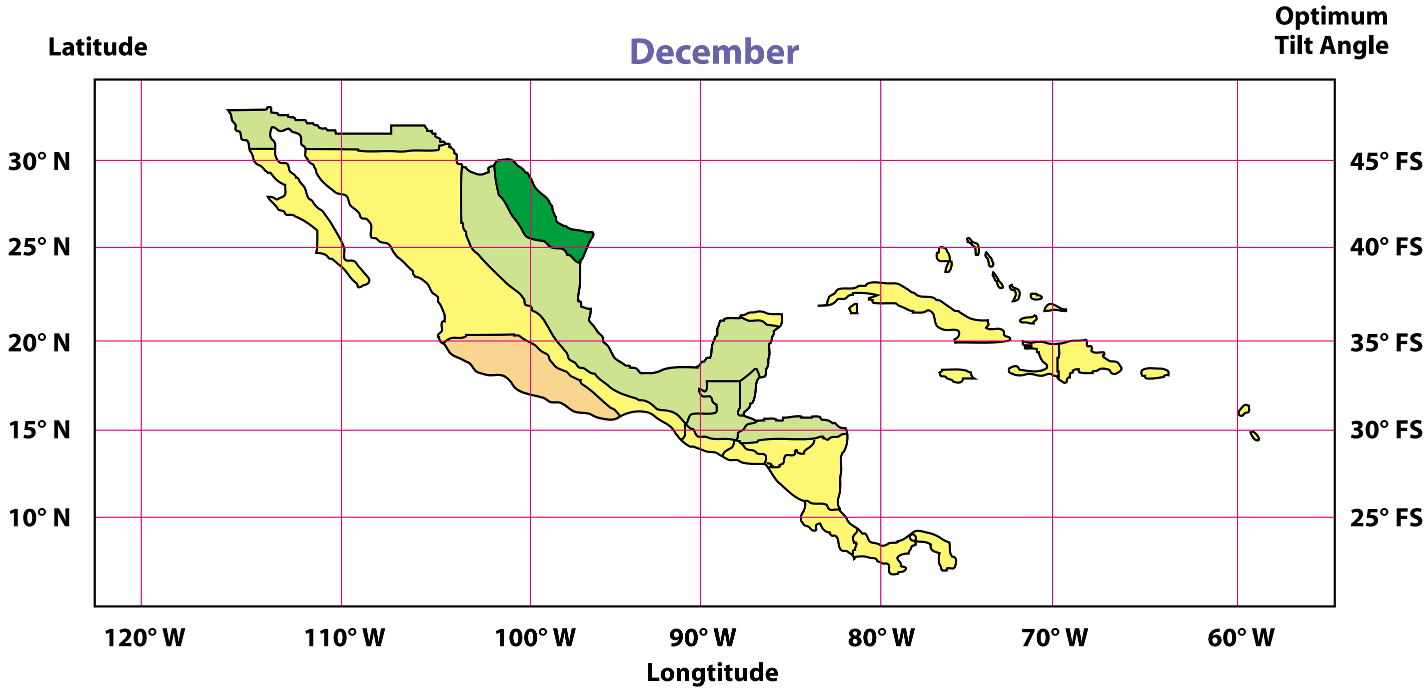




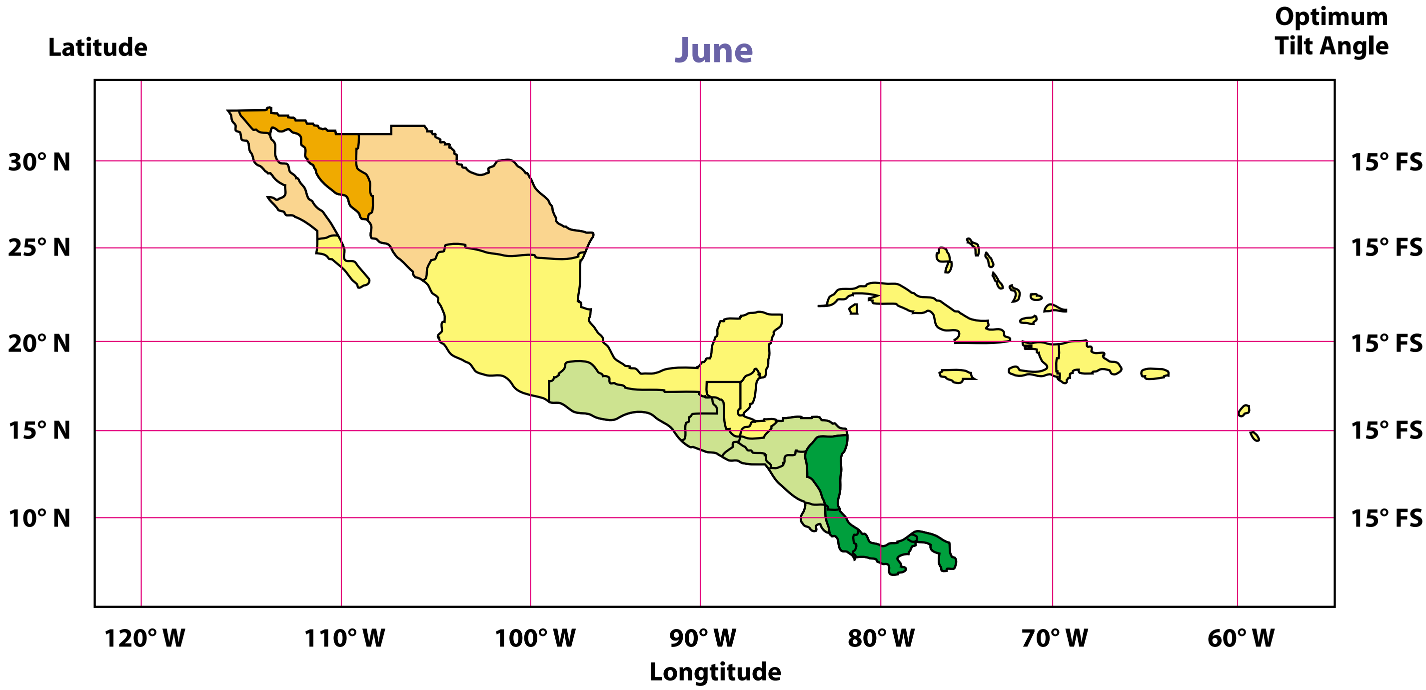


Mexico, Central America and Caribbean Nations Sun Hours On Tilt (S.H.O.T.) Maps

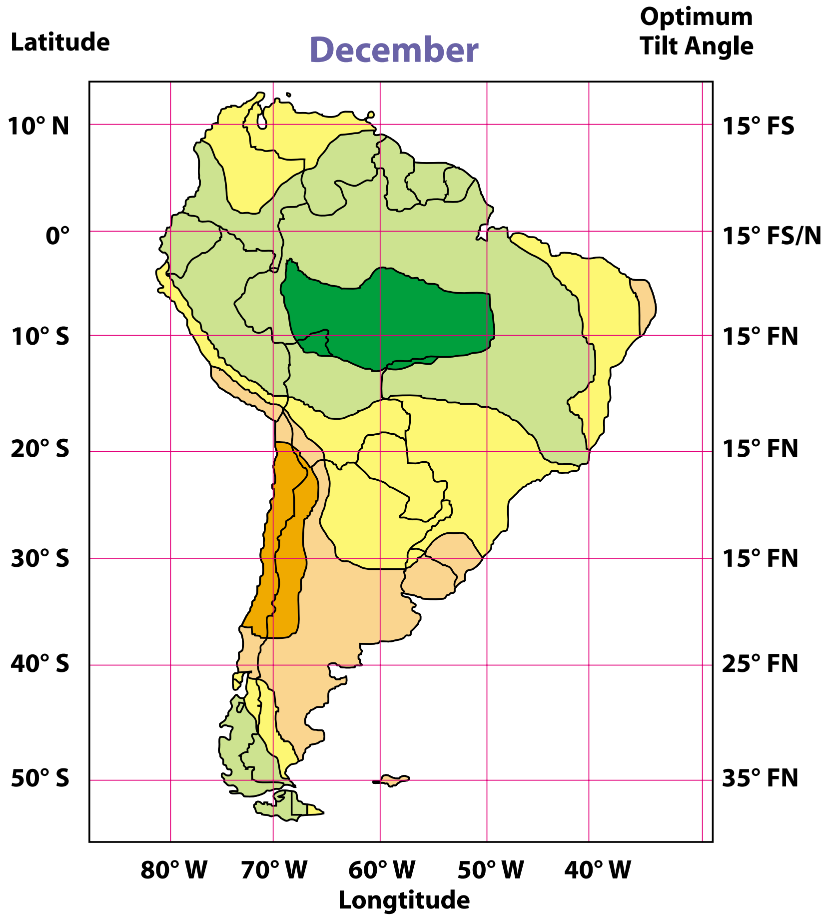
December

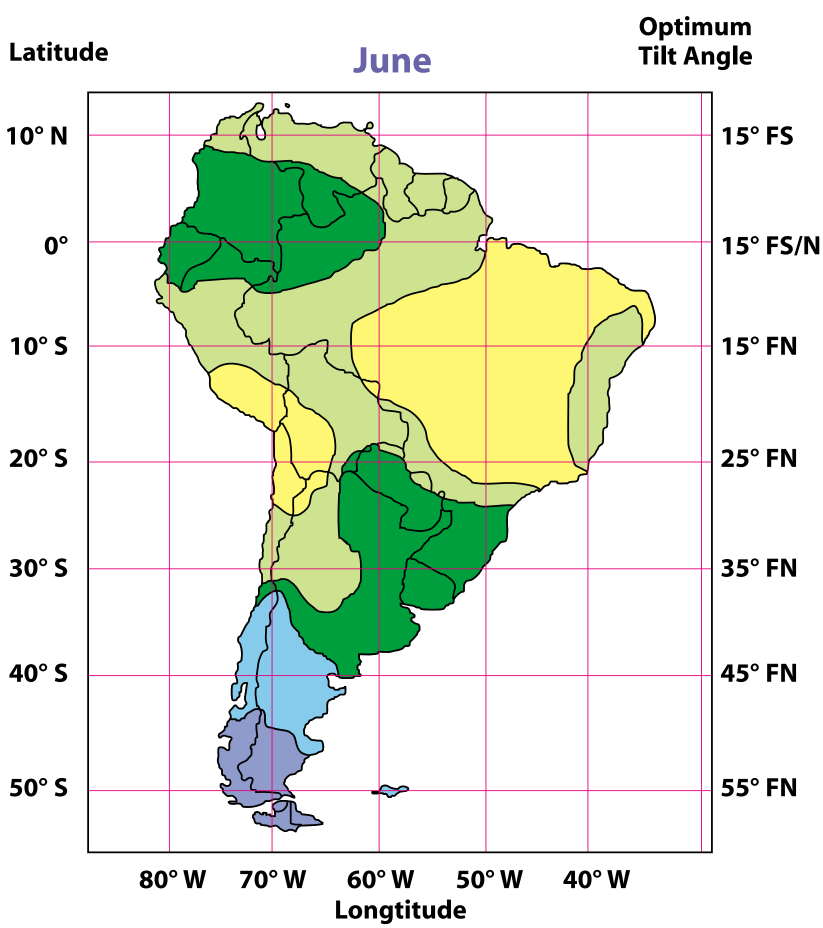


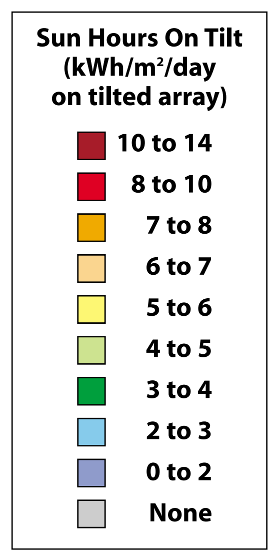
June



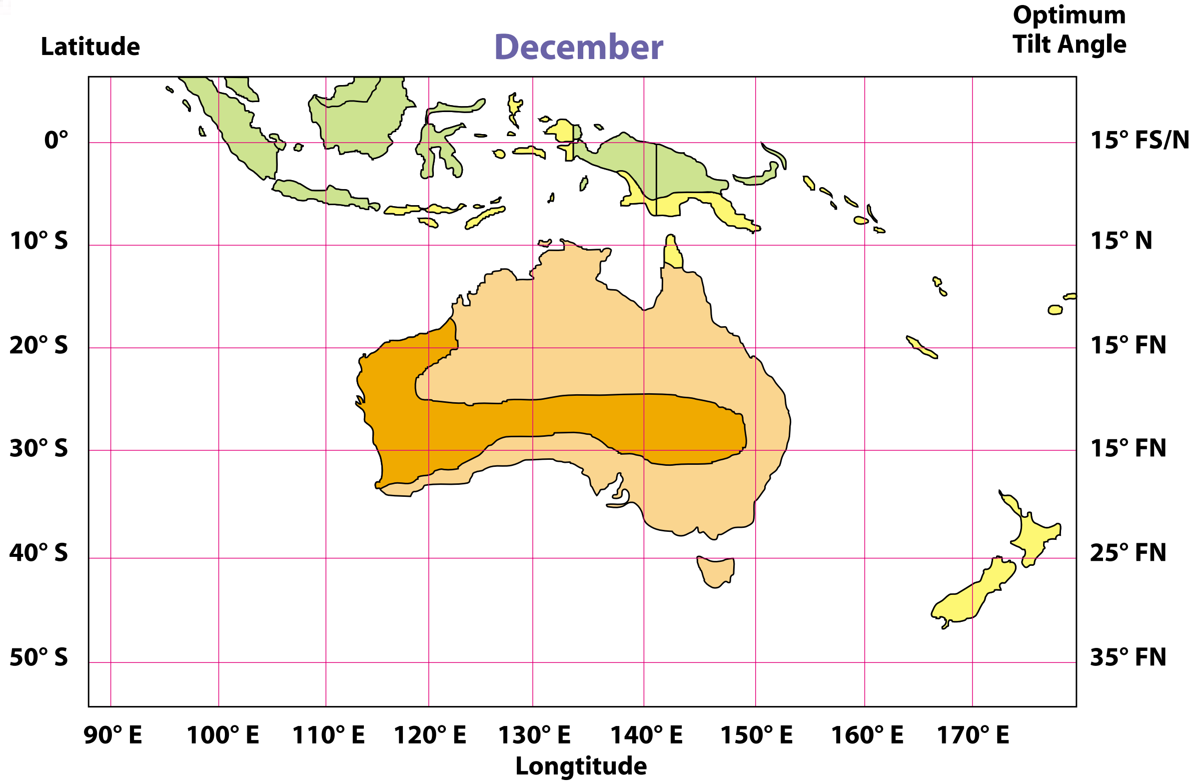
South America Sun Hours On Tilt (S.H.O.T.) Maps

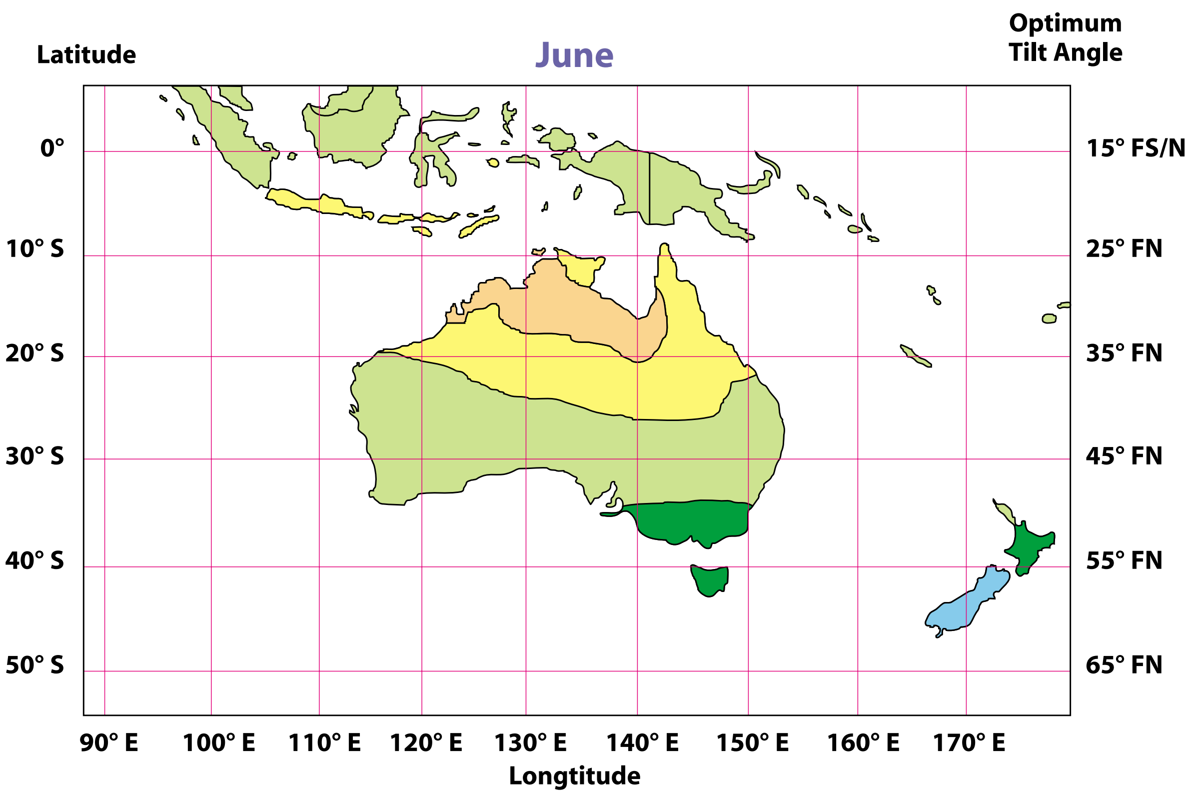




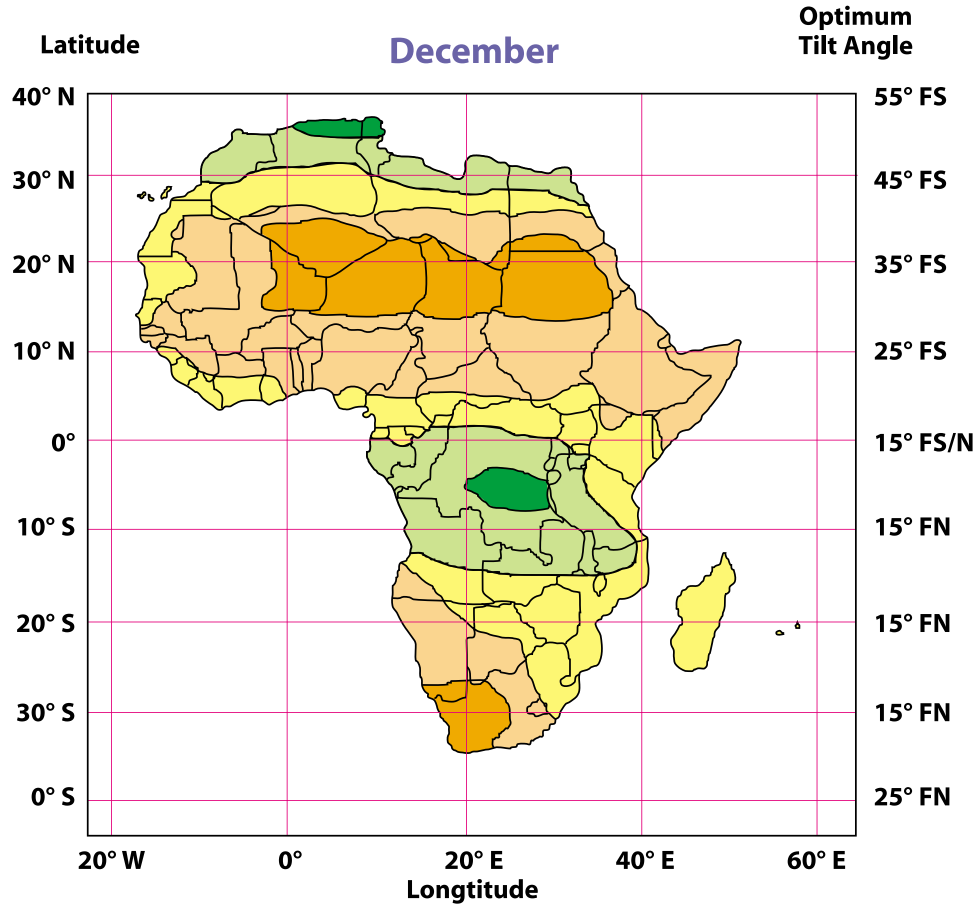


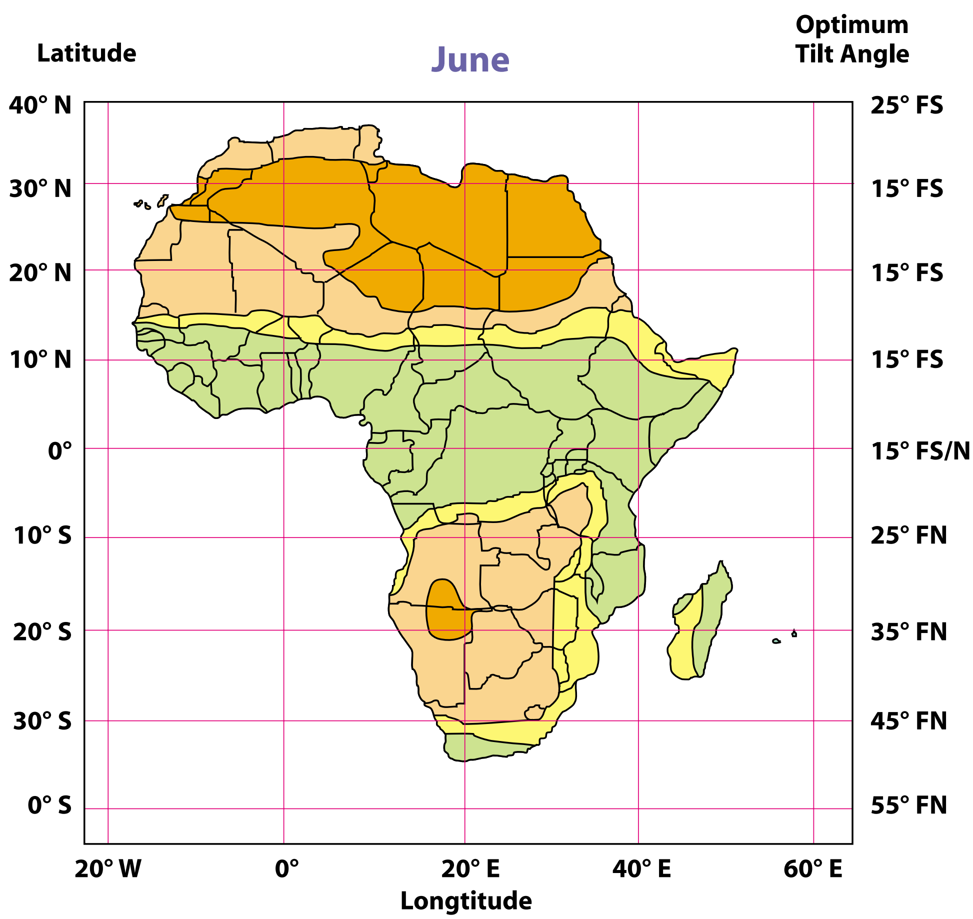
Australasia
Sun Hours On Tilt (S.H.O.T.)
Maps





Africa Sun Hours On Tilt (S.H.O.T.) Maps

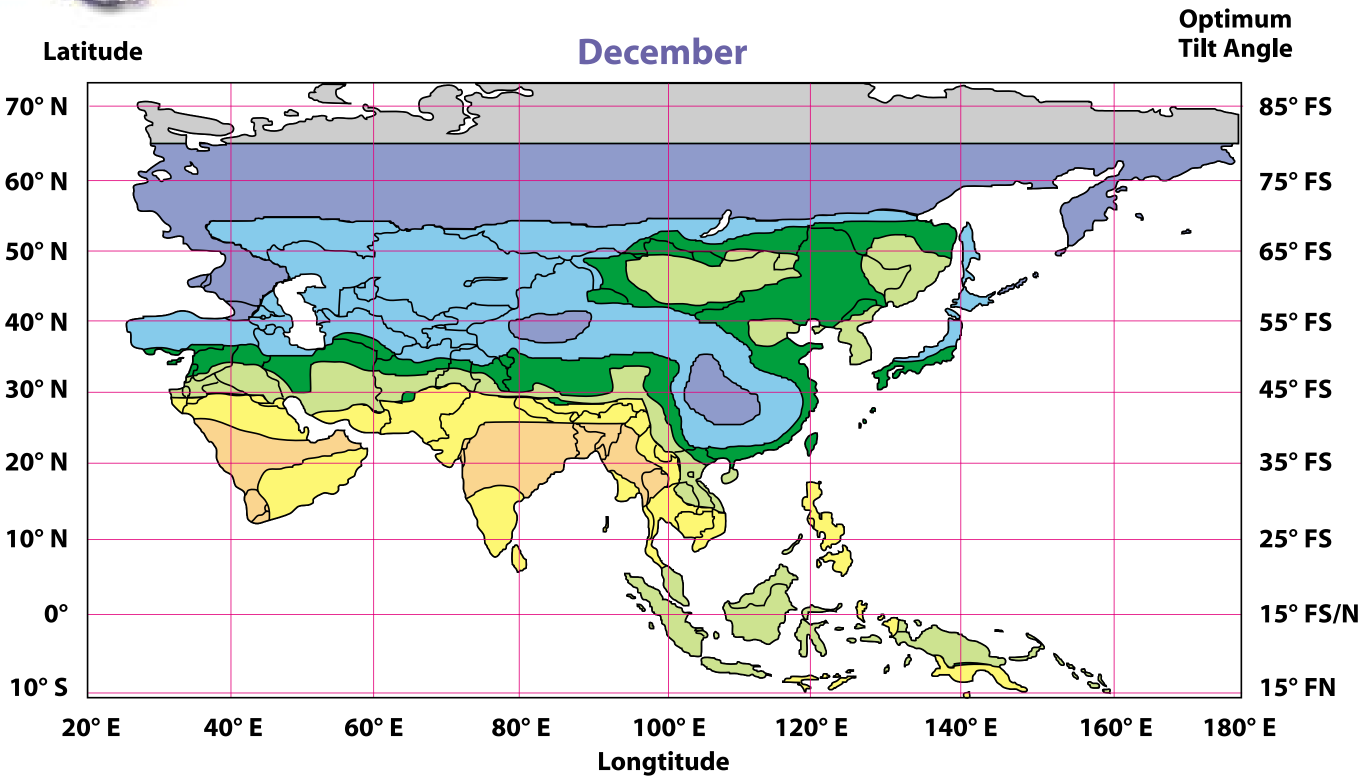


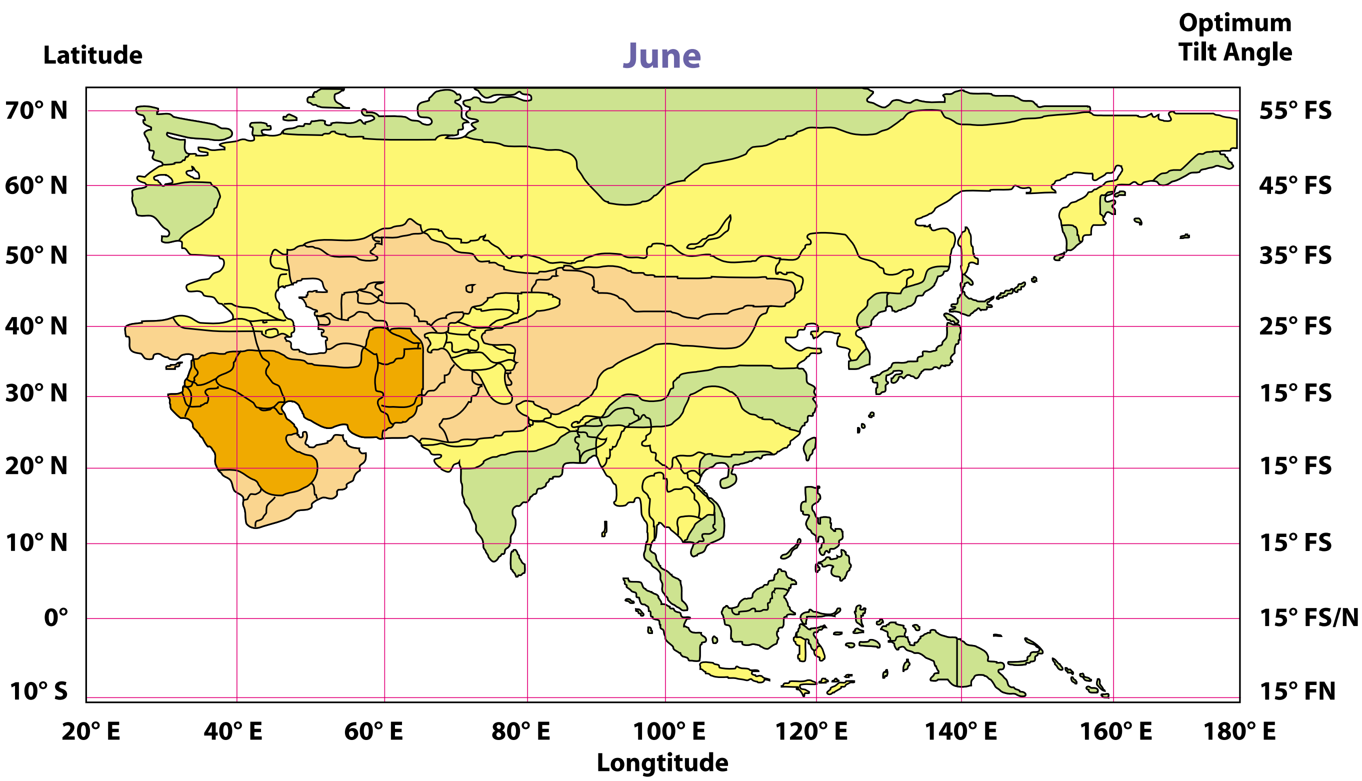


Sun Hours On Tilt (kWh/m²/day on tilted array)

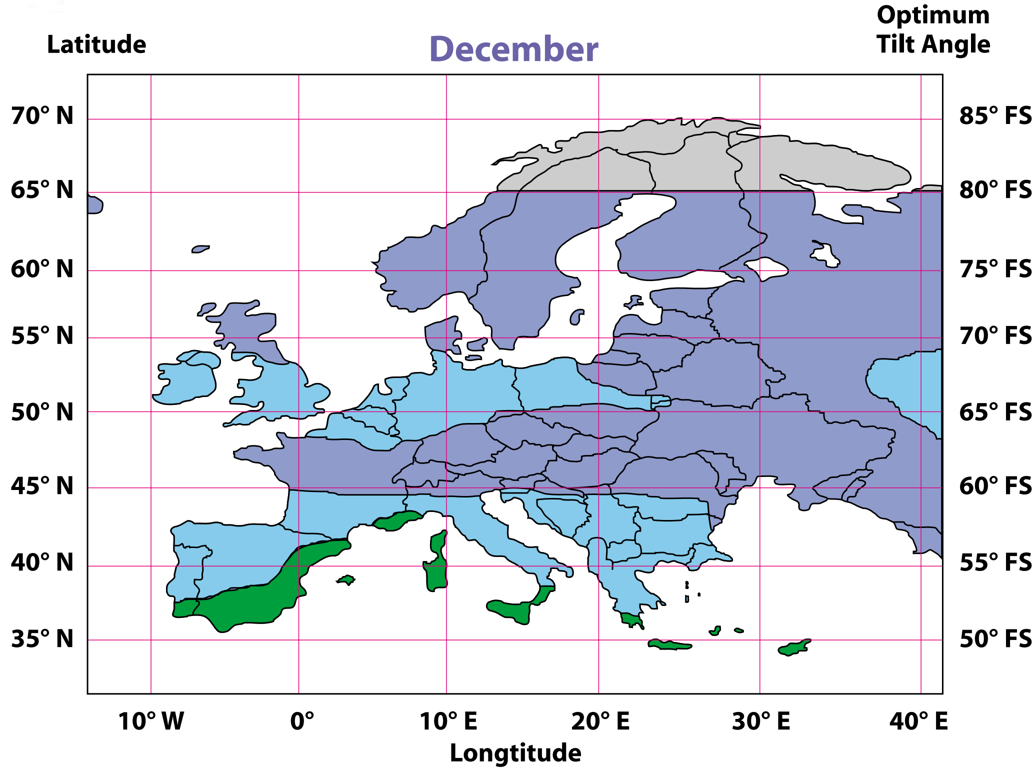
- 10 to 14
- 8 to 10
- 7 to 8
- 6 to 7
- 5 to 6
- 4 to 5
- 3 to 4
- 2 to 3
- 0 to 2
- None

Asia
Sun Hours On Tilt (S.H.O.T.) Maps



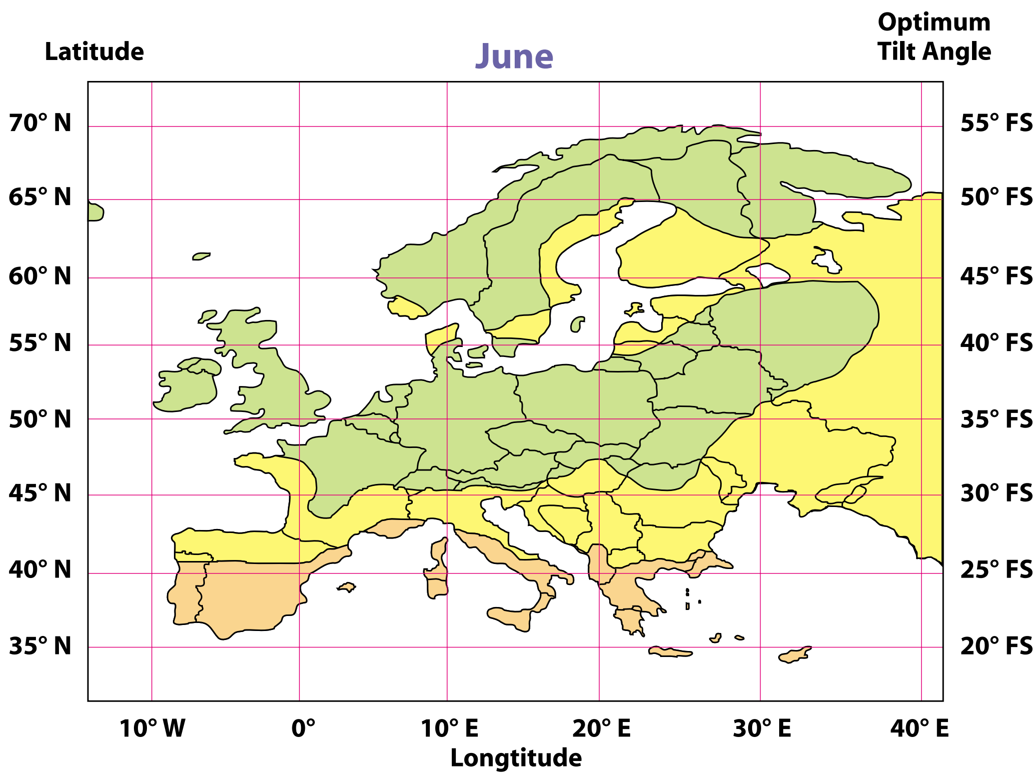


Europe
Sun Hours On Tilt (S.H.O.T.) Maps



Sun Hours On Tilt (kWh/m²/day on tilted array)

- 10 to 14
- 8 to 10
- 7 to 8
- 6 to 7
- 5 to 6
- 4 to 5
- 3 to 4
- 2 to 3
- 0 to 2
- None



Glossary

AC – Alternating current. Electrical energy which reverses its direction at regular intervals, typically 60 Hertz.

Ampere or amp – Electric current is measured in amperes or amps.

Array – A group of solar electric modules connected together.

Battery Bank – A group of batteries wired together to store power in a solar electric system. Allows power to be stored at night, on cloudy days, or to use more power than the array can produce at one time.

Centrifugal Pump – A pump which utilizes rotating impellers to accelerate water upward.

Controller – Converts power from the solar array in a certain voltage-current configuration to a voltage-current configuration more efficiently utilized by the pump.

Current – The rate of flow of an electric charge. Current is measured in amps.

Current Booster – A function of the controller which converts a given voltage and current output from the array to a more useful configuration to the pump typically providing more current but nearly equivalent power.

Diaphragm Pump – A positive displacement pump which utilizes a cam shaft to cause piston displacement. A flexible elastomer (diaphragm) acts as a sealing mechanism in the piston and cam assembly.

DC – Direct current. Electrical energy flowing in one direction and of substantially constant value.

Drawdown – The distance the standing water level lowers when water is pumped from the well at a given rate.

Elevation – Vertical distance from the ground to the input level of a tank or storage means.

Flow Rate – Volume of water provided per second, minute, hour, or day.

FN – Facing North.

Friction Loss – Pressure loss due to the resistance to flow of water in a pipe.

FS – Facing South.

GPM – Gallons per minute.

Ground Mount – A fixed array mounting method for solar modules which has multiple connections to earth.

Inverter – An appliance used to convert independent DC power into AC power.

Kilowatt or kW – One thousand Watts. *(See Watts)*

Line Loss –Power loss across a length of wire. Copper wire, depending on its size, has a specified resistance per foot. Wire is then adequately sized to meet a specified line loss (typically 3-5%).

LPM – Liters per minute.

Module – Modular solar electric charger; the term is used interchangeably with solar electric panel.

Mounting Angle – Angle of array measured from horizontal.

Parallel Wiring – A system of wiring, for solar electric modules or batteries, which increases amperage. Parallel wiring is "+ to +" (positive to positive) and "- to –" (negative to negative).

Photovoltaic – Converting light into electricity. Photo means "light," voltaic means "electric". Often referred to as "PV" for short. More commonly referred to as "solar electric."

Glossary (cont'd)

Pole Mount – A stationary pole top array mounting method.

PSI – Pounds per square inch.

Sand Shroud – An apparatus which "shrouds" the pump (using a collar and section of large diameter pipe) to ensure input water enters the pump from below so that sand and sediment is no longer entrained in the input water.

Series Wiring – A system of wiring, for solar electric modules or batteries, which increases voltage. Series wiring is "+ to –" (positive to negative).

Solar Cell – The smallest basic solar electric device, which generates electricity when exposed to light. Typical solar modules are comprised of 36 solar cells wired in series.

Solar Electric – The preferred term used to describe something which uses sunlight to produce electricity. Photovoltaic is the more technical term.

Standing Water Level – The distance from the top of the well to the surface of the water in the well when no water is being pumped.

Sun Hours On Tilt (S.H.O.T.) – Number of sun hours at a given angle from horizontal.

System Grounding – A means of electrically connecting a photovoltaic system to ground.

Tank Pressure – For pressurized systems, pressure of tank in psi or kpa.

Total Dynamic Head – A means of expressing the load of a pumping system at a given flow in terms of its equivalent vertical column of water (i.e. vertical lift and friction converted to vertical lift).

Total Vertical Lift – The sum of standing water level, drawdown, and elevation.

Tracker – An array mounting method which passively rotates with the sun in order to extract more power early and late in the day.

True Maximum Power Point Tracking – A feature of the pump controller which ensures the solar array operates at its maximum power point.

Voltage or Volts – Voltage is the amount of electrical pressure that causes electricity to flow in the power line. If electricity were water, voltage would measure the amount of pressure at the faucet.

Watts – A watt is a measurement of total electrical power. Volts X Amps = Watts.

Watt Hour – The quantity of electrical energy used or produced when one Watt is used for one hour.

Solar Power & Pump Co.

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