# Designing Solar Energy Manual

**Jerry Gunning**

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**TOC**

## Introduction

Solar energy is the future of this planet's energy source. It is clean and exists in unlimited quantities wherever we turn. In fact, it doesn't involve using any kind of liquid. It is the purest energy source around. So what is solar energy? It is energy that comes from the sun's rays. Solar energy can be used for various reasons including heating a house, providing electricity, or desalination of seawater.

Solar energy can be used for so many different things. In fact, with today's new technology, solar energy is being used more than it has been in years past. Houses are made to accommodate solar energy. Cars are being built to work with solar energy. You even can cook your food with solar energy.

It was during the 1970s that solar energy came into its own. During 1977 the U.S. Department of Energy launched the Solar Energy Research Institute "National Renewable Energy laboratory" with the idea of getting companies to start producing products that used the sun as its power source. They believed very strongly that solar energy had a great potential for our country. Solar energy can help reduce our need for imported fuels, improve our air supply, and create jobs as new positions are created to deal with solar energy, including installation and maintenance. Once the federal government stepped in, it was during this time that solar energy production took off. This is why they allocated $40 million per year for solar energy

research. The Department of Energy was so focused on preserving our environment and supporting solar energy, they developed a clean, large-scale solar thermal technology that was referred to as concentrating solar power (CSP). This helped them focus on three main areas for solar technology: trough systems, dish/engine systems, and power towers. Solar power ability to deliver power as required, was what steered the government toward solar energy as the means of future energy sources.

As stated earlier, solar energy was the wise choice for alternative energy use, because it is clean and renewable. When we wash our clothes and hang them up to dry, we are in fact using the sun's rays to dry them. Plants use the sun's rays to make food. Even the human skin uses the sun's rays to produce vitamin D. Another reason that make solar energy the best choice is due in part to our environment. We need to reduce greenhouse gases to save our planet. Also, by using solar energy, it helps to strengthen the economy.

Regarding technologies that were developed, for use in solar energy construction, such technology created the likes of photovoltaic cells, concentrating solar power, and low temperature solar collectors, to name a few. Photovoltaic cells are used to convert sunlight to electricity and are made of semiconductors that consist of crystalline silicon. Some photovoltaic cells are formed from thin-film materials. If you couple this with reflective materials, this will focus the attention

on the sun's rays, which will shortly be converted into usable energy. There are many more devices that can absorb the sun's rays, but the above serve as examples and are most commonly used.

Solar energy is always available and will be for some time to come, as the sun will always shine its rays on our planet. So why not take advantage of this and use the energy the sun provides. We just need to use the right instruments to capture the sun's rays and convert those rays into energy. Also a need must exist for solar energy to be stored for future use.

The only problem that may exist for solar energy is the fact if the sky should be overcast one day, power may not be available. This is why a way to store the sun's rays is very important. Solar energy can provide us with a good energy source, as long as we can tap into it during times when the sun is not shining.

Solar energy is not going anywhere. With the price of solar parts dropping, solar energy will continue to be the main focus for homebuilders and the government alike. And with government grants and funds being provided for those using solar energy, why not take advantage of it and use solar energy.

## Chapter 1 – History of Solar Energy

Solar energy has been around ever since there was the sun and long before mankind first appeared on the earth. The existence of life on earth would not have been possible without solar energy from the sun. The cycle of night and day is determined by the earth's rotation in relation to the sun. Every aspect of our life is dependent on the existence of solar energy.

Every day we use solar energy in many ways, from providing warmth for our bodies to drying our laundry. Plant uses solar energy to make food that we in turn consume for nourishment. The rays of the sun heating the earth and causing thermal flows of air influence the weather. Water is evaporated into our atmosphere by the sun to support rainfall.

When the Industrial Revolution came around, fossil fuels were being used at an alarming rate. Because of this trend, scientists were in fear that the planet would run out, so engineers got together and studied ways around this. They wanted to come up with some form of renewable energy that would not pollute the planet.

After a lot of research, thought, and consideration, solar power was deemed the most appropriate method to use. Within 50 years, many techniques were developed to capture the

sunlight and solar radiation, and then use it to produce steam for many powered machines.

Although the technology to produce these systems that used solar power was developed, many was not implemented, being the world wanted to stay with fossil fuels, since these were the most dominate types of fuel sources of the day. Later in the 20th century, when the danger of running out of fossil fuels and the imminent destruction of the planet, due to pollution, was the primary focus of scientists, suddenly the focus changed again back to using solar energy. This is why many types of solar devices have been designed and implemented today.

**The First use of Solar Energy**

Lets take a trip back into history and follow the solar time line. According to information gathered from the US Department of Energy, the earliest recorded use of solar energy actually was back in the 7th Century B.C. when a magnifying glass was used to focus the sun's rays to make fire for various reasons and to burn ants. The Greeks and Romans used this same technique with mirrors in order to light torches.

During the 1st to the 4th Century A. D., Roman bathhouses were built with large south facing windows, which allowed the sun's rays in to warm the room. This idea of using windows to allow the sun's rays to enter rooms caught on fast, as sunrooms were built into houses and public buildings.

Back in 1200s A.D., ancestors of Pueblo people called Anasazi in North America lived in homes that were south-facing cliff dwellings. These dwellings were built facing the sun on purpose, just so the winter sun could shine through. Further down the line from 1767 to 1891, various countries took steps to create devices that used solar energy. It was in 1767 that Swiss scientist Horace de Saussure built the world's first solar collector. Sir John Herschel used it later in 1830s, during his expedition to South Africa.

It was back in the 1860s when the first use of solar power was recorded when Auguste Mouchout, a mathematics instructor at the Lyce de Tours, began his work in converting solar power into mechanical power. At that time coal was the primary resource used, and Auguste was concerned that continued use of it would eventually result in its demise. So he worked feverishly to come up with a way to take the pressure off of coal use. By the next year he received his first patent on a motor that ran on solar power. It was primitive in design, but he would continue to improve on it well in 1880. Thanks to Auguste, we have the framework for building solar power devices today.

Later in 1891, Baltimore inventor Clarence Kemp patented the first commercial solar water heater. Around 1908, William J. Bailley of the Carnegie Steel Company invented a solar

collector that had copper coils and an insulated box. In 1954, Daryl Chapin, Calvin Fuller, and Gerald Pearson develop the silicon photovoltaic cell at Bell Labs in the United States. A year later, Western Electric started selling commercial licenses for silicon photovoltaic technology. In the mid-1950s, Architect Frank Bridgers designed the first commercial office building that used solar water heating. This became the standard that was used later and even today.

In 1963, Sharp Corporation took the photovoltaic technology and improved on it, thereby producing a more practical silicon photovoltaic module. In the 1970s, Dr. Elliot Berman designed a solar cell that was less costly. This enabled the price to drop from $100 a watt to $20 a watt. It was right after the less expensive solar cell was invented that they became useful and was in fact used to power navigation warning lights and horns on offshore gas and oil rigs, lighthouses, railroad crossings, and many other solar applications.

In 1982 Australian Hans Tholstrup drives the first solar-powered car, the Quiet Achiever, almost 2,800 miles between Sydney and Perth in 20 days 10 days faster than the first gasoline-powered car to do so..

1986 The world's largest solar thermal facility is commissioned in Kramer Junction, California. The solar field contains rows of mirrors that concentrate the sun's energy onto a system of pipes circulating a heat transfer fluid.

The heat transfer fluid is used to produce steam, which powers a conventional turbine to generate electricity.

As the years went by, advances in technology allowed the creation of better devices that made solar energy even more practical and useful, considering the equipment used are more sophisticated and more efficient in collecting the sun’s rays and using it to power various applications.

As a result of these advances in technology, Home Depot began selling residential solar power systems in three stores in 2001. And in 2002, the largest solar power facility in the Northwest, a 38.7-kilowatt White Bluffs Solar Station was built and went online in Richland, Washington.

As you can see solar energy started many centuries ago but really only became popular within the last two centuries, and especially within the last 10 decades.

## Chapter 2 – Active Solar Space Heating

Converting to solar space heating in an existing home does offer some challenges, but they can be over come with careful planning. You learned in the chapter on “Passive Solar Home”, that passive solar space heating is achieved by taking advantage of sun’s warmth through design features, such as large south-facing windows, and materials in the floors or walls that absorb warmth during the day and release that warmth at night when it is needed most.

If you were planning to build a new house, then you would be all set. All you would need to do is have an architect design a passive solar house with all the attribute of solar energy. However in most cases we are talking about existing homes, so what do you do? Well I am happy to inform you that there are quite a number of good retrofit options available to a homeowner. The type of system you choose will depend on the system you are presently heating your home with.

**Hot water radiation Retrofits:** Retrofitting your hot water radiation (hydronic) system for solar energy could be relatively simple and inexpensive. This would involve sizing and selecting the correct collectors, a heat exchanger, shut off valves, control valve, piping and low voltage wiring. If you are starting from scratch, and lets assume you are also converting your domestic water heating to solar energy. This would be very cost effective,

as you would design the system to handle your hot water needs year round and your heating needs during the heating season.

This arrangement would allow you to use your existing hot water boiler for supplementary or back-up heat during low solar generating periods. This system would use a heat transfer fluid to transfer the heat from the collectors to a heat exchanger in a similar set up as described in the section on solar water heaters. The addition of controls and an automatic valve would allow the system to operate in the desired mode at all time.

This type of system is usually very cost effectives. Assuming that there is adequate space to mount collector and enough access to the sunlight. Here you are basically using your existing hydronic system and components. By adding the collectors and other components you can take advantage of the sun’s energy to supply most of your hot water and heating needs at a minimal installation cost. Now add any available government rebates or incentive and it does make lot of sense.

The only draw back is that you are still burning some fossil fuel whenever the boiler operate for back-up, The alternative to that would be to install a storage tank that would be used to store excess hot water for use when there are needs for supplementary heat. Unfortunately that would mean that your installation cost would increase and your payback period would be longer.

**Hot Air Heating System Retrofits**: Retrofitting solar heating to an existing hot air system, is very similar to what we discussed in the previous paragraph. The difference is, in this case we would install a hot water heating coil in the furnace or discharge ductwork of the hot air system. We would then use a pump to circulate the heat transfer fluid from the collectors through the heating coils. This process would transfer heat picked up by the collectors to the heating coils and the air being circulated through them by the furnace blower.

Again the existing furnace would be used to supply supplementary. This arrangement would be subjected to the same plus and drawbacks as in the previous paragraph. As stated before, there are other alternatives if you don't mind spending more.

Another thing to consider is this, what is the present condition of your furnace or hot water boiler? Is it close to the end of it's useful life? What is the energy rating? The answer to these questions will make a difference as to what would be the most cost effective way to go. If the existing system is inefficient and is close to the end of its useful life, then it may make sense to consider a complete "active solar space heating system" as explained below.

Active solar space-heating systems are similar to the solar hot water systems discussed in a previous chapter, they consist

of collectors, pumps, valves, controls, fans and piping to transfer and distribute the solar heat.

Active solar systems usually use an energy-storage system to provide heat when there is no sunlight. The most common types of active solar space-heating systems, usually works with either liquid or air as the heat-transfer medium in their collectors.

Both of these systems collect and absorb solar radiation, then transfer the solar heat directly to the interior space or to a storage system, from which the heat is distributed.

Liquid-based systems do this by heating water or a heat transfer fluid in a hydronic collector. Liquid systems are usually used when storage are included, they are well suited for radiant heating systems.

Air-based systems heat the air in an air collector. Air-based solar heating systems usually use an air-to-water heat exchanger to transfer heat to the domestic hot water system, making the system useful in the summertime. An auxiliary or backup system provides heat when storage is discharged.

**Sizing Your Active Solar Heating system -** Depends on factors such as the local climate, the type of the collector, the site, design, and heating needs of your house. It is generally accepted within the industry that, designing an active system to provide 40%–80% of the home's heating need, is most

economical. Anything below that would not be cost effective. Designing a system to provide 100% of your house heating needs although desirous is not very practical nor would it be cost effective.

One way to improve the cost effectiveness of your active solar system is to incorporate the heating of your domestic water in the design. Bearing in mind that, during the summer time the heating system would be otherwise idle. Proper insulation is also very important. The cost associated with adequate insulation on any heating system is small compared to the overall saving.

By using an active solar system to heat your home, you can see significant reduction in your energy cost. You will also be reducing the pollution from green house gases associated with the use of fossil fuel. If your local climate and sight location determine that solar would work for you, then by all means seriously start looking into installing a active solar heating system.

The resource section of this book is loaded with the information to get you started in the right direction.

## Chapter 3 – Passive Solar Homes

If you are considering building a new house or doing extensive renovation to an existing home, then it time to talk about “Designing Passive Solar Homes”. Your windows, walls, and floors can be design to collect, store, and distribute solar energy from the sun, in the form of heat in the winter, but reject solar heat in the summer. Unlike active solar systems, passive solar systems generally does not depend on mechanical devices to transfer heat, but rather it uses the structural materials.

The difference between a passive solar home and a conventional home is in the design. Passive solar designs are simple. This results in systems that are more reliable, cost less and have a longer lifetime. Because a passive system uses hardly any mechanical or electrical devices, there is not a lot of maintenance involved. It is more cost effective as the house is generally constructed using regular house building materials.

Other benefits of a passive solar house are, you will live in a quieter environment as there are less mechanical devices to create noise or vibrations. Since passive designs are incorporated into the house design it will last as long as the house does. The radiant heat generated from passive collecting surfaces are usually more comforting than the convection heat from traditional hot air or hot water systems.

An example of how a passive solar home design works is as follows:

First let us look at how heat moves and how heat can be stored for later use. Basically, heat moves from warmer materials to cooler ones until the temperature difference no longer exists. Passive solar home design distributes heat by using the following heat-movement and heat-storage systems:

- **Conduction:** This is the way heat moves through materials. Heat will cause molecules to vibrate extremely fast. The quick vibration will cause the molecule to hit another molecule, setting that one in motion. That one in turn hits another molecule, and so on. This is how energy is transferred through the material. You can tell this is happening by holding a spoon in a very hot cup of coffee or other liquid. Very soon you will feel the heat through the spoon to your hand. This is heat transference and is known as conduction.

- **Convection:** With convection the heart circulates through liquids or gases. If the fluid is warm, it becomes light and rises, but if the fluid is cold, it sinks. An example of that is when you go upstairs in your home. You will notice the upper levels are hotter than the lower levels. This is because the warmer air rises while the cold air sinks down to the lower level.

- **Radiation:** Radiated heat works by moving from warmer objects to cooler ones. There are two types of radiation relative to proper passive solar design: solar radiation and infrared radiation. As radiation strikes an object, it will be absorbed, reflected, or transmitted , depending on the material used. For example, opaque objects can absorb up to 40% to 95% solar radiation, depending on color of the object. Darker colors absorb more than lighter colors. This is why when solar colleting surfaces are usually the darker colors.

- **Infrared** radiation is when warmed surfaces radiate heat outwards toward the cooler surface. Your body heat is an example of this. If your body radiates heat to a cooler surface you lose that heat. This will cause your body temperature drop and may cause some discomfort.

- A good transmitter of solar radiation is clear glass because it will transmit from 80% to 90% of solar radiation, but absorb infrared radiation. Once solar radiation is transmitted through glass and absorbed by the interior surfaces, it is then radiated back from the interior in the form of infrared radiation. The glass will then absorb the infrared heat trapping it in the home.

- **Thermal capacitance:** Thermal capacitance refers to the ability of materials to store heat. *Thermal mass*

refers to the materials that store heat. Thermal mass stores heat by changing its temperature, which can be done by storing heat from a warm room or by converting direct solar radiation into heat. The more thermal mass, the more heat can be stored for each degree rise in temperature. Masonry materials, like concrete, stones, brick, and tile, are commonly used as thermal mass in passive solar homes. Water has also been successfully used. (Source US Dept of Energy)

- Thermal capacitance is a term that describes the way materials store heat. This is also referred to as thermal mass. This process works by the material storing the heat, which changes the temperature of the material. It can do this by taking heat in a warm room and storing it, or by taking direct solar radiation and converting it into heat. Concrete, stone, brick, and tile are good materials to use for this because of their ability to absorb heat.

When designing your a passive solar home, you should incorporate these five elements of passive solar design.

- **Aperture:** This can be a large glass window. The material used has to allow sunlight to enter the building. Whatever aperture you use, it should be on a 30 degree angle of true south and should have direct

contact with the sun between 9 a.m. and 3 p.m. during the heating season.

- **Absorber:** The surface of your storage element must be hard and dark. This is because dark colors and hard surfaces absorb heat much better than light color soft surfaces do. This hard and dark surface must be in line of sight of the sun's rays to work.

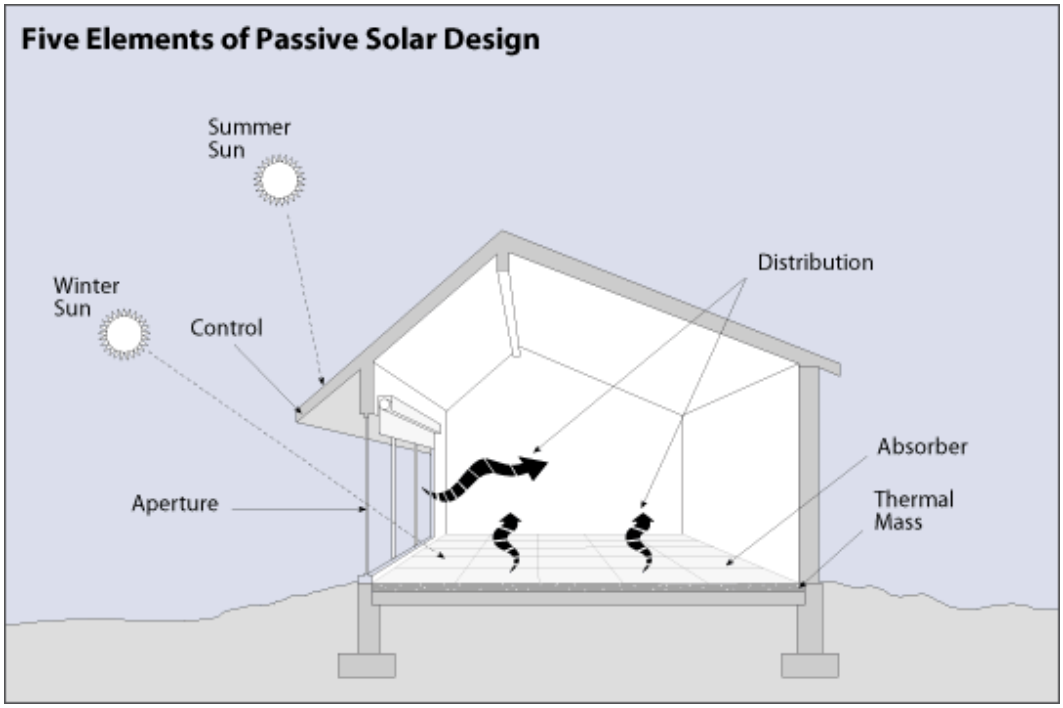
- **Thermal mass:** This was spoken about above. The main point here is the materials used must be able to retain or store the heat that is produced by the sun's rays. Although the thermal mass and absorber are usually made of the same material, the absorber is exposed to the sun's rays directly while the thermal mass sits below or behind the surface.

- **Distribution:** Every solar system must have a distribution system so heat can be circulated through the entire home. A passive system will use conduction, convection, and radiation to get the heat through the home. Of course, fans, ducts, and blowers may also assist in getting the heat transferred through the home.

- **Control:** In this situation roof overhangs can be used as a way to shade the aperture during summer so it doesn't collect the sun's rays. This keeps the heat out of the house, thereby allowing the home to remain cool. Other elements that may also be used to control heat

are electronic sensing devices such as a thermostat, operable vents and dampers, that can restrict heat flow when required.

To see all five elements in action and how the work, take a look at the image below:



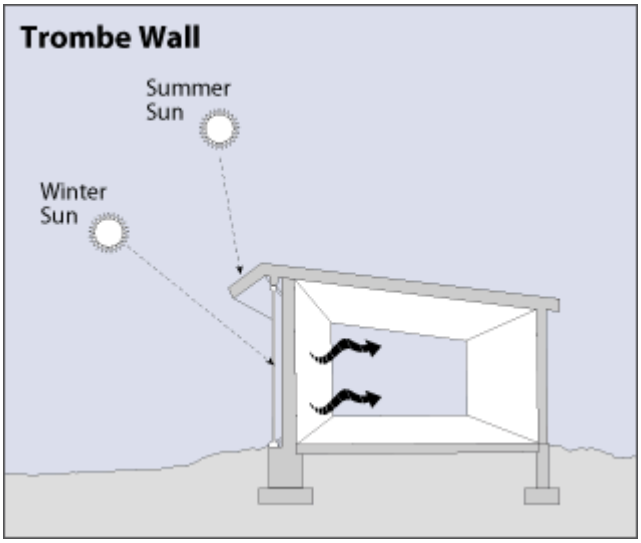

Other ways you can design your home is by the location where you install your windows and the glazing type used on the windows, the type of insulation you use, and the way air is sealed in your home, and any auxiliary heating and cooling systems you may want to install as back up sources.

To apply the above elements you can use three different passive solar design techniques:

- **Direct gain:** This is one of the simplest design techniques you can use. The sun's rays enter the house through the aperture (collector) which may be south-facing windows that have transparent or translucent glazing materials on the surface. The sun's rays strike the masonry floors or walls and absorb the heat. When the sun goes down the heat from the masonry materials releases the heat into the air.

- **Indirect gain:** With this technique a Trombe wall is used. With an indirect-gain technique, the thermal storage is between the south-facing windows and the living spaces. The wall itself consists of an 8-16 inch thick masonry wall. A single or double layer of glass is included that is about one inch from the wall's surface. The solar heat being absorbed by the wall's dark-colored outside surface is stored in the wall's thermal

Below is an example of a Trombe wall:




- **Isolated gain:** With isolated gain a sunspace is used. A sunspace is also referred to as a solar room or solarium. This room can be built as part of the house, if the house is being built for the first time, or can be installed as an addition to the home. Sunspaces are usually designed with vertical windows that have no glazing material on its surface. The thermal mass materials may consist of masonry floor, a masonry wall, or water containers.

  Here is a sample of a sunspace:

Courtesy Donald Aitken for the U.S. Department of Energy

When designing your passive solar home you need to keep in mind some facts. The thermal mass must be insulated from the outside temperature. If it is not insulated, the collected solar heat can drain away rapidly. Also to keep your summer climate inside your home comfortable, you need to include an overhang so as to block the sun's rays during the hottest days of the year. Care should be taken to calculate the proper overhand dimensions. Any wrong calculation could result in the overhang not blocking enough of the sun's rays.

As stated at the beginning of this chapter, you can beat apply the advantages of a passive solar home when you are first designing and building a new house. However this is not to say you can't do it with an existing home. Your exiting home can be retrofitted to take advantage of passively collecting and storing solar heat.

Building a passive solar home is the best way to go to save energy and to live in comfort all year round. You save not only on money, but you also help to conserve the environment by reducing the use of fossil fuels.

## Chapter 4 – Solar Electricity

Every single month you see it coming. You don't like it but it arrives, and usually at the time you least want it. When you look at it, you notice it keeps getting bigger. What am I talking about? Your dreaded electric bill. If you have had it with the electric company putting the screws to you with your electric rates, there is a solution. You can actually generate your own electricity and free yourself from the utility company.

There are substantial costs involved, but the end result is. You will be controlling you own energy cost, saving yourself money in the long run. You will also be contributing to a cleaner environment by decreasing our dependence on fossil fuels.

Generating your own electricity makes sense. Its an investment in your home that will pay for itself in energy savings. The system to generate electrical power for your home is known as Photovoltaic power (PV) – Solar electric energy. PV system produces electricity by absorbing sunlight into semiconductor materials through a process called the photoelectric effect.

PV power has lot of great qualities, It's noise free, pollution free, it's reliable, renewable and dependable. Using a PV system to power your home makes lots of sense for the environment and your pockets.  The good thing about using

solar power to create electricity is its available pretty much wherever you go in the world. As long as you have sunshine and the right equipment, you will always have electricity. Of course the type of system you design, develop, or purchase would depend on how much electricity you want to generate.

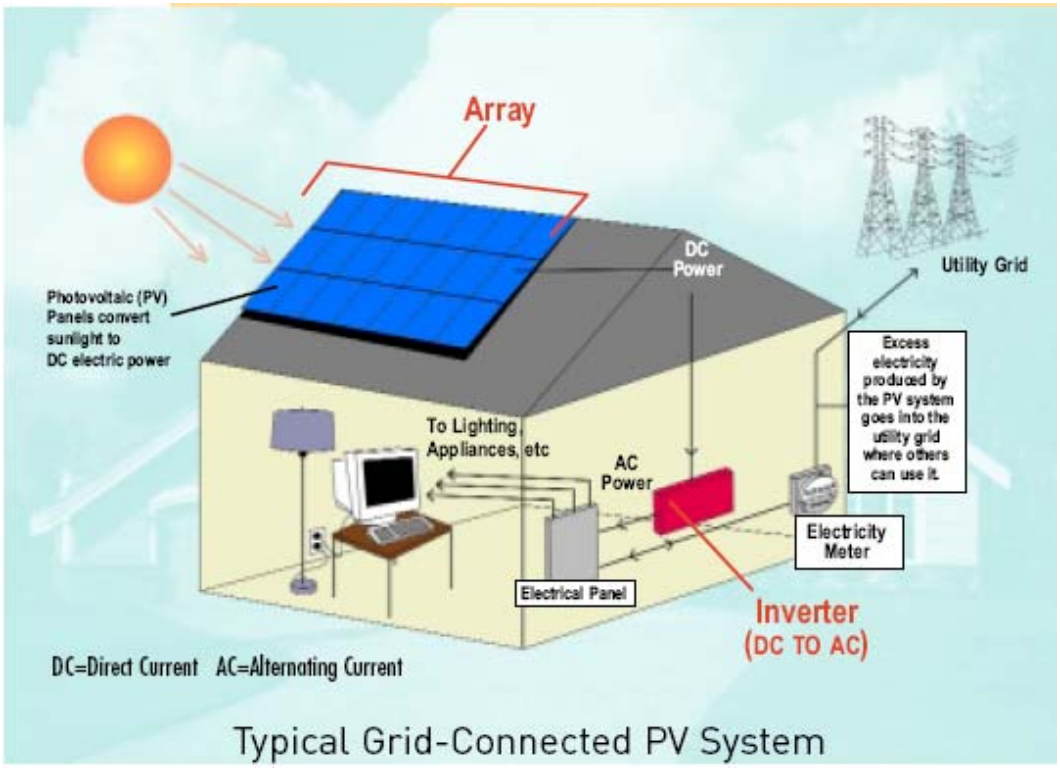
Of course, on the other side of the coin, if there really is a limited amount of sunshine in your neck of the woods, PV systems can still produce electricity on cloudy days, but not as much as on a sunny day. So site location is very important to consider when you want to convert to solar power for your home.

***Grid-Connected System:*** There are two commonly used PV systems. Grid-connected PV systems are connected to the utility grid and get back –up power when the PV system is not producing enough electricity, like at night or on badly overcast days. On sunny days when the system produces excess power, the utility will then purchase the excess through a Net Metering arrangement.

This usually a great arrangement for both sides, as this allows the homeowner to supply excess power to the utility during the day when demands are high and then have it credited back at night when the demand on the utility is lower.

A grid-connected system allows you to have back-up if you ever need to shut down your system for brief maintenance.

Here is an example of a grid-connected system:

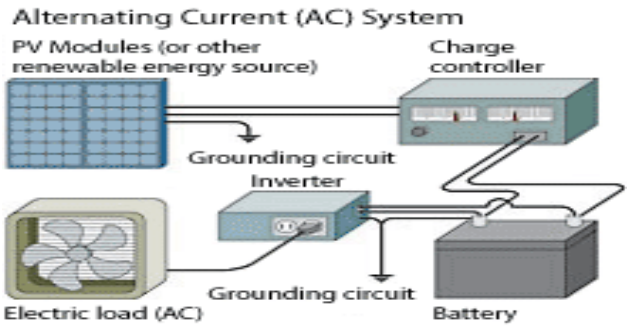



***Stand Alone (Off-Grid) System:*** The stand-alone off-grid systems are (as the name imply) are not connect to a utility grid, but instead uses a bank of storage batteries or a generator as back-up when there is not enough sunlight to generate electricity. In most cases, this kind of system is more expensive to install because of the additional costs of batteries or generators.

However a stand-alone system may make sense if you are in an isolated area, and where there is no utility grid. Other

application where stand-alone would make sense would be in situations where you can use a wind generator as a back –up.

Here is a layout of a stand-alone battery back-up system




***PV Basics:*** In order to better understand the process of generating solar electricity, let's go over the basics.

In the process PV technology convert sunlight into electricity throughout the day, enabling you to produce your own power for you home in an environmentally friendly way.

Solar cells, which are the heart of the PV system, are made of semiconductor material. When the sun's rays hits the materials, the rays are absorbed. This absorption turns into electrons. As the sun's rays enter the panels and gets absorbed, this forces the electrons that are already in place to move. This process of electrons moving out of the solar panels as the sun's rays are absorbed is referred to as the "photoelectric effect." When these electrons move, they travel

through wires that are built into the solar cell. This movement of electrons is what forms electrical current. Many PV systems are designed to work on sunny and cloudy days.

The basic PV or solar cell typically produces only a small amount of power. To produce more power, multiple solar cells are usually interconnected to form panels or modules. It takes an average of about 10-20 PV modules to provide enough power to electrify a house. This is because if one or two modules are used, they only produce about 12 to 24 volts.

This is enough to supply the battery, but the inverter would need a lot more power in order to do the conversion. If 10 PV modules were used, this would give about 120 volts DC (10PV modules x 12VDC = 120VDC). This in turn would allow the inverter to transform 120 volts DC to 120 volts AC.

Modules are attached as panels on your roof or at ground level in racks to form a PV array. Some solar panels come in the form of roof tiles. These are known as integrated roof panels and are usually used on new homes or when roof replacement is coordinated with the solar installation.

PV arrays are usually installed in a fixed position facing south. In some more costly systems they are mounted on tracking devices that follows the sun as it travels. The sunlight shines on the solar panels, the panels produce direct current electricity (DC). This DC voltage is often around 12 volts. Some larger commercial systems produce 24 volts. The DC power

then enters the Inverter. (In stand-alone systems the DC power is stored in lead-acid batteries) These batteries in turn provide the power when needed.

The inverter then converts the DC volts to 120 volts AC to power the lights and appliances in the home.

***The Hardware***

Below I am providing you with a list of components associated with a solar generating system. Bear in mind that systems may vary depending on the application.

| Part | Description |
|---|---|
| | |
| Solar Panels | Solar panels (or PV panels) are components that are installed in groups of 1 to 12 panels on a solar mount. When connected in this way, they are also referred to as a solar array. |
| Charge Controller | A charge controller is also referred to as a charge regulator. This is a small wall mounted unit that receives the power from the solar panels and controls the flow to the battery. This also prevents the battery from being overcharged. |
| Batteries | Batteries are used in “stand alone system” to |

| | |
|---|---|
| | store energy for use in times of little or no sunlight. Like on cloudy days or at nights. |
| The Inverter | The inverter takes the DC current generated by the collectors and converts it into 120 Volts AC to be distributed throughout the house. |
| Meters | Meters are used to measure the amount of energy flowing through the system. On grid connected systems with "net metering arrangement" a bi-directional meter is used to measure both the energy you supply to the utility and the energy you receive.. |
| Power Center | The power center is your systems main control point and consist of: gauges, meters, DC circuit breakers, wiring connections, for batteries, inverter, solar and other sources. |
| | |
| | |

These components are used in one form or fashion in a solar electricity system.

**Advantages and Disadvantages of Using Solar Electricity**

Based on research, the average amount of energy the sun rays provide at noon time is about 1,000 watts per square meter. That is a lot of power the sun provides. We should tap into it. However, just as with everything we use on this planet, there are advantages and disadvantages to using solar electricity

**The advantages of using solar energy to electrify a home include the following**:

- Today photovoltaic manufactures are warranting their panels for a minimum of twenty years.
- Solar energy is quiet considering there are no moving parts.
- Solar energy  is non polluting, abundant and free.
- The payoff point - the point where the savings generated by the residential solar power system has paid for the installation cost - is between two and three years for an average installation.
- The PV system is virtually maintenance free. The only maintenance required would be to check on and replace worn out batteries that are part of the battery pack. (off grid systems)

- By using solar energy you are cutting back on the use of fossil fuel, thereby reducing the pollution of our and helping to make it safer for the generations to come.

**Just as there are advantages, there are also disadvantages.**

- These are: less electricity generated in the morning and evening than in the middle of the day.
- No electricity is produced at night or when it is overcast.
- When you install a PV system in your home, it becomes a permanent fixture of your property. So if you decide to sell the home, and move, the system will have to stay with the home.
- Certain kinds of weather conditions like hail and other falling objects can damage the solar panels to the point they no longer work and the entire system is down until they are replaced.
- There is a sizable investment for the solar energy installation, There are some tax incentives and rebates to help off set the installation cost, but there is a sizable investment that still needs to be made out of your pocket.
- Solar power does not work well powering devices that use an electric heating element such as an electric hot water heater.

As you can see, there are advantages and disadvantages to using solar power, but the advantages seem to outweigh the disadvantages. So if you can go for it, by all means do so.

## Chapter 5 – Solar Water Heating

Now let's look at one of the thermal application for solar energy. Heating domestic water is the second highest energy related cost in your household. A 80 gal. electric hot water tank in a household of four people will consume about 22 million BTUs per year. Without accounting for fuel cost increases this will cost approximately US $514.00 per year. As a homeowner, you probably are aware of the costs involved in having gas or electric water heaters. You see the results in your monthly bill. But what if you could cut costs and save a lot of money to boot.

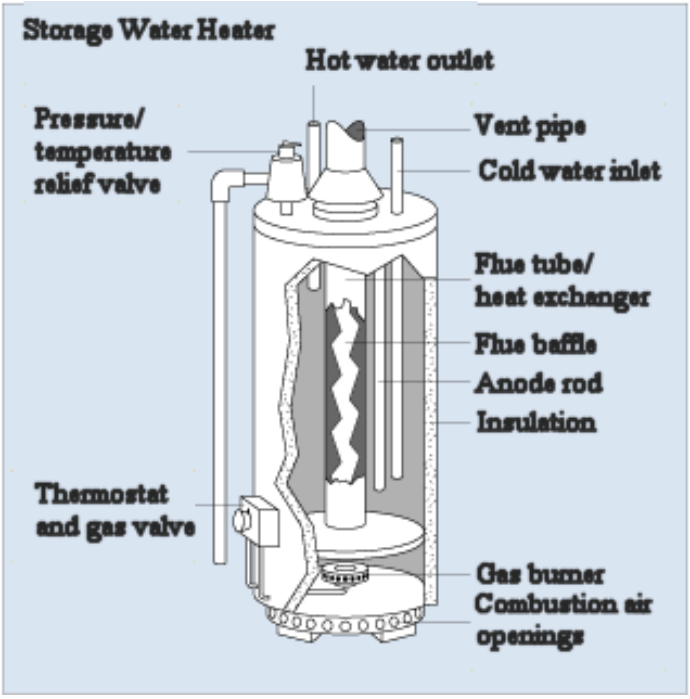
By switching to a solar water heating system you can drastically reduce your energy cost. This is one of the most cost effective applications of solar energy. According to the latest industry statistic, Initial return on investment is somewhere around 15 percent, tax-free, and increases each time gas and electricity prices climb. Most states have tax credits and other incentives that help to increase the bottom line even more.

Solar water heating can supply 50 to 60 percent of your daily hot water needs even in some of our cloudiest regions, and 80 percent or more in the sunnier areas. You are not only saving money, but you will also contributing to a cleaner and safer environment, by reducing the use of fossil fuel.

Another plus for switching to a solar water heater is, you are also providing in your home a safer environment. There is no chance of leakage from rusty gas lines, or broken water heaters.

At this point I'm going to cover the most common options for solar water heating and the basic principles of operation

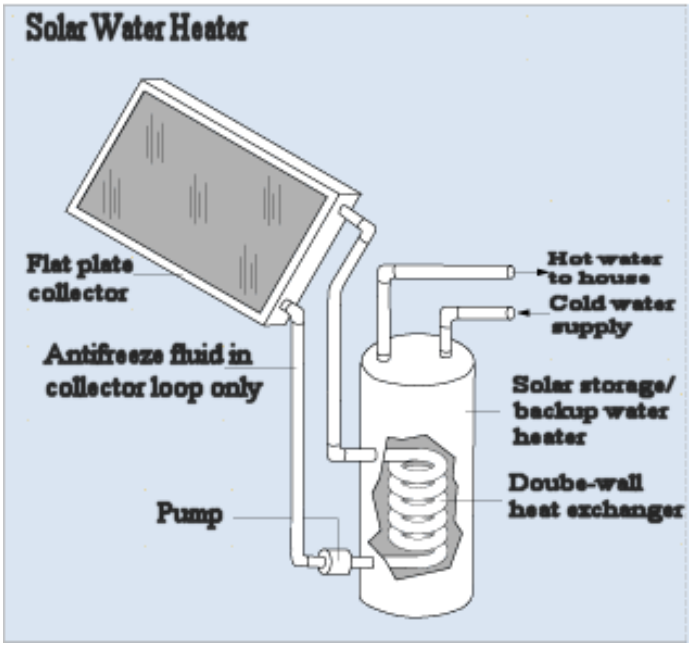
Obviously, solar water heaters are quite different from gas or electric water heaters. Here is an image of a conventional water heater:




Most solar water-heating systems for home consist of the following parts. (1) a solar collector (2) a storage tank (3) Piping (4) valves and (5) a pump (active systems only)

Solar water heaters use the sun to heat either water or a heat-transfer fluid in the collector. Heated water is then held in the storage tank ready for use. In some cases a conventional system provides additional heating as necessary. Solar water heaters are of two types: active and passive, the active system being the most common.

Here is an image of a solar water heater.




## Active Solar Water Heater

The active solar water heaters has pumps that circulate water and contain controls that monitor the entire system including the pump and angle of the collectors. There are two basic type of active systems.

- **Direct circulation system:** This type of solar water heater uses a pump to circulate water through the

collectors and into the home by way of the piping. These system should only be used in areas where there are very little chance of freezing

- **Indirect circulation system:** This system pumps non-freezing, heat-transfer fluid through a loop consisting of the collectors and a heat exchanger where the heat is transferred to the water being used in the home. This system is generally used in climates where there is a treat of freezing. This system should always have a pressure relief valve install as protection against overheating.

The two most common type of indirect circulation system used today are: (A) Anti-freeze system, where a food grade glycol is mixed with water (mixture ratio varies with design temp) to form the heat transfer fluid

(B) Drainback system, the is a type of indirect system that incorporate a reservoir tank inside the building, that allows the water in the collectors and piping to drain back into the reservoir whenever the circulating pump is stopped. These type of arrangement eliminates the possibility of freeze ups. However care must be taken that all piping and component are installed to slop the water back to the reservoir.

Storage tanks and reservoirs on all solar hot water system should be well insulated to prevent heat loss.

## Passive Solar water heaters

Passive solar water heaters(unlike active heaters) has no mechanical or moving parts, but instead rely on gravity and the tendency for water to naturally circulate as it is heated. Since they contain no mechanical parts, passive systems are usually, less expensive, needs less maintenance, and may even have a longer work life than active systems. The two most common types of passive systems are

- **Integral collector-storage passive system:** This system also known as a Batch heater works best in areas where the temperature rarely goes below freezing. This is usually a storage tank integrated into an insulated box that is covered with class and installed in the sun so as to face the south. The cold water is piped into the bottom of the tank and the hot water taken off the top. Because this is a passive system, this piping arrangement takes advantage of the natural heat flow. As the water is heated it expand and flows from the top of the tank. The cold water then rushes in through the bottom to take its place. Because the storage tank is outside, this type of system suffer

heat loss at nights or when the sun is not shinning and is usually not at peak efficiency in the mornings

- **Thermosyphon system: T**his system works on the principle of convection and is easily recognized as the collector is usually installed below the storage tank, This type of system is widely use around the world and is said to be the most popular worldwide. Open loop systems are used only in warmer climates and the portable water enters the collector at the bottom and rises to the tank as it is warmed by the sunlight. As the warm water rises the cold water naturally rushes in to take the place of the warm water and therefore create flow. In colder climate, indirect systems are generally used with a glycol mixture as freeze protection. In some cases the storage tank for this system is installed in the attic. However the storage tank must always be at a higher elevation than the collectors.

Whatever solar water heater you use, it is always wise to have a backup system. This backup system will provide hot water on days when the sky is overcast, and when hot water needs rise.

**<u>The collector comes in three different types:</u>**

- **Flat-plate collector:** Are generally a series of parallel copper tubes connected to a manifold at each end. This is then connected to a flat dark absorber plate, in a well

insulated and weatherproofed box and then covered with tempered glass.

    - **A glazed flat-plate collector –** This collector is insulated and waterproof box that contains a dark absorber plate under one or more glass or plastic covers.

    - **Unglazed flat-plate collector –** This collector is normally used for solar pool heating. The collector has a dark absorber plate that is made of metal or polymer, without a cover.

- **Integral collector-storage systems:** These are also known as ICS systems. These systems contain one or more black tanks or tubes in an insulated and glazed box. Cold water enters the solar collector first, where it is preheated. One heated, the water travels to the backup water heater where it is used. Systems like these can only be use in mild climate because there are exposed pipe that would freeze in cold weather.

- **Evacuated-tube solar collectors:** These collectors feature parallel rows of transparent glass tubes, with a glass outer tube, and a metal absorber tube that is attached to a fin. The fin coating help to absorbs solar energy and decreases radiated heat loss. Compared to flat plate, evacuated tubes are more efficient in cloudy weather. They also cost more, but like most things the

added efficiency does make it a better buy in the long run.

**Heat Exchangers**

Another component that plays an integral roll in solar water heaters are heat exchangers. Heat exchangers allow the transfer of heat from one fluid to another or from a fluid to air without them mixing. They are used in most close loop system to transfer the heat picked up from the collectors, by the heat transfer fluid to the portable water. In the heat exchanger the heat transfer fluid and the portable water flow counter to each other to maximize the heat transfer.

Heat exchangers are made of steel, copper, bronze, stainless steel, aluminum, or cast iron. In most application where water is involved , heat exchangers are usually made from copper or a copper alloy. Copper is used most since it is a good thermal conductor. Plus, it has good resistance to corrosion.

Most heat-transfer fluids use food grade antifreeze since antifreeze will not freeze at low temperatures. Food grade glycol is used to prevent cross contamination in case of a leak. Heat exchangers come in different types. Each one has its advantages and disadvantages. These three designs include:

- **Coil-in-tank:** This heat exchanger uses a coil of tubing that is inside the storage tank. The tubing can be single or double, depending on need. .

- **Shell-and-tube:** This heat exchanger is usually mounted somewhere outside of the storage tank. The heat exchanger contains two fluid loops that are separate from each other, but are contained in a case or shell. When the fluid flows, it is in direct opposite to each other when it goes through the heat exchanger. This way the most heat possible gets transferred. On the first loop, the fluid is heated by going through the inner tubes. On the second loop, the heat-transfer fluid flows between the shell and the tubes of water.

- **Tube-in-tube:** This type of heat exchanger is actually very efficient, for the tubes of water actually flow directly opposite of each other.

Care should be taken when selecting heat exchangers. All heat exchanger have a rated capacity. In order for any heat exchanger to be effective, it must be the right size. The following should be taken into consideration:

- Heat exchanger type
- The heat-transfer fluid
- The flow rate
- The inlet and outlet temperatures for every fluid used

When selecting a heat exchanger, the heat transfer rating will usually be listed on the exchanger.

## Heat-Transfer Fluid

Heat-transfer fluids are designed to take the heat from the solar collectors, through a heat exchanger to the water storage tanks.

According to the U.S. Department of Energy, when you select a heat-transfer fluid, you should consider the following:

- Coefficient of expansion – the fractional change in length (or sometimes in volume, when specified) of a material for a unit change in temperature
- Viscosity – resistance of a liquid to sheer forces (and hence to flow)
- Thermal capacity – the ability of matter to store heat
- Freezing point – the temperature below which a liquid turns into a solid
- Boiling point – the temperature at which a liquid boils
- Flash point – the lowest temperature at which the vapor above a liquid can be ignited in air.

This is why glycol is most widely used as a heat transfer fluid as it meets and in some case surpass above criteria's. It does not expand to rapidly when heated, it flows very easily, has a wide temperature tolerance, and have very high flash point.

There are many heat-transfer fluids in use. The most common ones are:

- **Water:** Water is another form that can be used as a heat-transfer fluid. It is nontoxic and inexpensive. Water is very easy to pump. The drawbacks to using water are that it can boil and freeze. Plus, it can corrode pipes and ducks.

- **Glycol/water mixtures:** Many solar water heating systems use a certain amount of glycol and water together. You'll find glycol mixtures ratios at 50/50 or 60/40. You may even find ethylene and propylene glycol used. This is also known as antifreeze. Ethylene glycol is very toxic and should only be used in a double-walled, closed-loop system. The reason being if it leaked out into the water supply, it could cause major contamination.

- **Hydrocarbon oils:** Hydrocarbon oils have a high viscosity and lower specific heat than water. The bad part is that if you use the fluid it requires more energy to pump. But on the plus side is the fluid is cheap.

- **Silicones:** Silicones are good to use in solar water heating systems because they have a low freezing point and very high boiling point, plus they last a long time. The downside to silicone is it requires more energy to pump, and leak easily.

So! Are you are ready to select your solar water heating system yet? Before you do, let me take you through the steps and point out some very important things you need to consider. Solar water heating systems cost a bit more to purchase and install than regular water heating systems. However, if you are upgrading your existing system to solar power for the long-term, then you will end up saving a lot of money. The amount you save will depends on a few things, like: The amount of hot water you use, how well was your system designed, was it sized right and your geographical location.

If you happen to have a house that is being built from scratch, you will want to install a solar water heating system, before you finish with construction of your home. Plus, you will benefit from tax savings and government grants that will be available to you.

Another factor to consider when you are thinking about installing a solar water heater is the location of your home. If your home is shaded by trees, or other houses that prevents the sunlight reaching your collectors, then you may not be able to generate enough hot water for you needs. However, if the sunlight exposure is good, then you are in good shape..

You also need to consider what size system you will need. You will have to know the total collector area and the storage volume you'll need to meet your hot water needs. Here are some generally accepted rules of thumb from the folks at AAA

Solar in Albuquerque for solar thermal collector sizing based on your climatic region.

- In the Sunbelt, use 1 square foot (0.09 m2) of collector per 2 gallons (7.6 l) of tank capacity (daily household usage).
- In the Southeast and mountain states, use 1 square foot of collector per 1.5 gallons (5.7 l) of tank capacity.
- In the Midwest and Atlantic states, use 1 square foot of collector per 1.0 gallon (3.8 l) of tank capacity.
- In New England and the Northwest, use 1 square foot of collector per 0.75 gallon (2.8 l) of tank capacity

By using the above rules of thumb, you can easily figure out your collector needs, using a formula of 20 gallons per person per day for the average household.

Your next step is to, check with your local building codes, zoning office, and any other rules or regulations, to see what kind of permits you will need before you get started.

Once your solar water heating system has been installed, it will usually last for at least 15 to 20 years, very little maintenance will need to be done to it. If, when you install the system, there are some electrical or electronic components that are installed with the solar water heating system; your system will need maintenance every 3-5 years.

## Chapter 6 – Solar Pool Heating

Heating your swimming pool if you have one, can be another big hit in the wallet. as it is usually another source of high energy related cost, If you are heating your pool with an electric heater, a heat pump or gas fired heater. You can help lower your expenses each month by switching to a solar swimming pool heater. You may even be able to enjoy your swimming pool year round, especially if your pool is built in the ground.

Solar swimming pool heaters are cost competitive with gas and heat pump pool heaters. And they are fairly easy to install and relatively inexpensive.

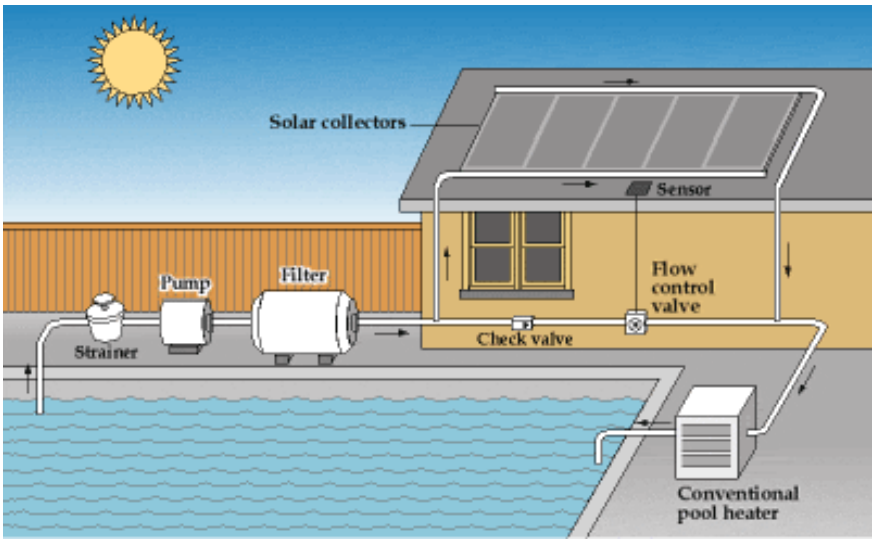
The basic components for putting together a pool heater is very similar to the components for a water heater as (covered in the chapter on solar water heater) the three main additions are shown below.

- **Filter**: A filter removes takes any incoming debris before the water gets pumped through the collector. Thereby protecting the collector from becoming clogged with debris picked up from the pool.

- **Pump**: The pump works by circulating the water into and out of the filter, through the collector, and back to the pool.

- **Flow control valve**: The flow control valve is an automatic or manual device that diverts pool water through the solar collector.

The image below is an example of a solar pool heater system in place:




Solar pool water heating systems work by taking pool water, pump it through the filter, through the solar collector, where it is heated, and then return the heated water to the pool. If you happen to live in very hot climates, you can actually use the solar collectors to cool the pool. You do this by allowing the water to circulate through the collector at night.

Some solar pool heaters have control valves and sensors that work automatically to divert water through the collector when the collector's temperature reaches a level that is higher than the pool temperature. If the collector temperature equaled

the pool temperature, the control valve would change the water direction so the flow goes back to the pool.

With any heated pool, one of the most effective things you can do to save pool heating costs and reduce greenhouse gas is to install a good pool cover. You would be surprised at how great a savings you will realize by this relatively inexpensive addition to your pool.

As with the solar water heaters collectors are one of the main components of a solar pool heater. Collectors for pools come in various makes and types and can be made of different materials. The type of collector you select for your pool maybe determined by the climate you live in, If the climate you live in is warm most of the year, you may want to select an unglazed collector system.

Unglazed collectors don’t have a glass covering and are generally made of rubber or plastic treated with an ultraviolet (UV) light inhibitor to increase durability and prevent premature cracking. Because of the materials that they are made of, unglazed collectors are very flexible and relatively inexpensive. In colder climate where you plan to drain down your pool in the winter, the less expensive unglazed collectors, would be your ideal choice.

Systems using glazed collector are usually more expensive because they are made of copper tubing on an aluminum plate and have an iron-tempered glass covering. However they do

have some advantages over the unglazed collectors. Glazed collectors are more efficient at absorbing solar energy on days when there are less sunlight, This makes them a better choice in year round systems using heat exchangers and heat transfer fluids. If you are planning to use your pool year round consider including freeze protection whether you use glazed or unglazed systems

Solar swimming pool heaters are the best way to go if you want to save on money year round. You can sure cut down on your water, electric, and gas, depending on your energy source. After your initial investment, you'll find you will recoup that money with five years of installation. So buying and installing solar pool water heater makes a lot of sense.

## Chapter 7 – To Self-Install or Not

One of the most often asked question by homeowners is can I do it myself or do I need a contractor. To be quite honest with you, there is no easy answer to that question. It is said that, one should never answer a question with another question, however in this case I must take an exception to the rule. Your answers to some pertinent questions should help you to decide what's right for you.

1. **What is your skill level?**
   Only you would know the answer to this question, as to whether you are mechanical or technical person, or how good are you with your hands, and what DIY projects that you have completed in the past. Depending on your expertise there are some solar conversion projects that can be successfully accomplished by DIY.

2. **What level of solar conversion are you thinking of?**
   Some solar projects like converting your domestic water heater will require less technical skill than say converting your electric service to a PV system.

3. **What does your municipal codes say?**
   This can be most important factor in determining if you can DIY. Some municipal code requires that any plumbing, piping, structural or electrical work, have to be done by a licensed professional. That's why it always a good idea to

check with your code enforcement department before planning any projects.

4. **Will you be covered by your homeowner's insurance?** This can be another showstopper. Always check you homeowner's policy before attempting any project, even if you plan to hire a contractor. This action could save you lots of surprises and headaches.

After doing all the above homework you feel comfortable that you can handle the project, then by all means proceed. You could achieve a very high level of satisfaction and save yourself a bundle while you're at it. The resource section of this manual is loaded with information and contacts for acquiring all you will need for your project.

If on the other hand you decided that it will be a bit much for you, then follow the guide to selecting a contractor for you projects.

One of the differences between doing the installation yourself and having a contractor do it involves cost. If you did the installation yourself, you would not have to fork out all that money to pay a contractor. You would only need to purchase the equipment and components, as well as any tools you may need. The amount of savings you would realize would depend on the project itself.

## Looking For A Solar Contractor

As stated above, if you have the time to do the installation yourself and are good with your hands, you may want to invest in doing so. However, if you are not good with your hands or you do not have the time, perhaps hiring a contractor would be the best way to go.

You have to realize that contractors do not just install components. They help design a plan as to how each part and component will work together to accomplish what is necessary for the entire system to work. They will analyze your present home construction and provide tips and techniques that will not only help you in the short term but the long term as well.

Solar contractors can help you determine what type of solar system will serve your needs best. Based on your budget and the site ability to generate solar energy. He can advice you on whether you need a solar thermal system or if you maybe a candidate for a solar electric system. You may be able to have both systems installed. You can talk to the contractor about these ideas and decide what is best for you.

In order to find a solar contractor, you can look in the resource section of this manual, or you can go to the Yellow pages and look up one there. Your best bet however is to check with your state DOE to see if they have a list of registered and licensed solar contractors in the state where you live. They usually keep a list of them. The biggest concern is to make sure

the contractor is fully licensed, reliable, dependable, and has a lot of references. You will need to check them out first before you hire them to make sure they are on the up-and-up.

When you do contact contractors, you need to ask them many questions about what they do. You need to find out if they do their own system analysis or do they hire an outside firm to do that. How long have they been installing solar products? Obviously, you want someone thoroughly experienced in this area. Ask what solar equipment have they installed? Do they install solar electricity, solar pool heaters, solar water heaters, and other solar systems? If they do, you are in good shape. If they don't this means you may have to hire more than one contractor, especially if you want more than one type of system installed.

Talking about licenses, does the contractor also have certain certifications? If they install certain components from one or two manufacturers, find out if they have certifications from those manufacturers to install that equipment. By having a certification, it means they are knowledgeable and well equipped to handle the work. Find out if there are any pending judgments against them. See if there are any lawsuits pending. This could be a telltale sign that they are not professional if they do have negative feedbacks.

The best way to get a good deal is to ask around. Find out from several contractors and see what the bid range is. Ask

someone who already had a solar system installed, which contractor they used and what was their experience. That may be your ticket to hiring the best. If you find someone who had a solar system installed, ask what their experience was like and if the company did an excellent job. This information may help you decide on whom you will choose for the job.

The old adage is you get what you pay for. So be careful, be aware, and scrutinize. This is the way to get the best deal possible and know you won’t get shafted.

## Chapter 8 – The Legal Stuff

As with anything you do to your home, you have to take care of those legal requirements that get in the way. Such things as codes, covenants, and restrictions have to be examined. The county, city, or state where you live has certain requirements that have to be met for any kind of installation or modification to take place in or on a home. This is to take care of health and safety requirements as well as zoning laws.

The first step in the process is to submit a permit to the town or city where you live, to let them know what you are planning to do. By doing this, they will have a record of your project, so if there are any complaints, the town or city can answer those complaints fairly and amicably. If the town or city accepts your permit, you can begin the work. You may even have to submit actual plans of what you are going to do. Some towns, cities, or counties require a set of plans first so they can check to see if there may be some hazards involved or not.

Certain installations to a home could interfere with the next door neighbor, especially if the improvements center around landscaping changes. Before you do work of any kind, contact your town zoning board, and inspection office to find out what paperwork or permits you will need. You wouldn’t want to start the installation and find out you broke the law and get fined for doing something illegal.

If you are going to install a solar electricity system, you will need electrical and structural permits, since these areas will be involved. The most common permit you'll need for your PV system is an electrical permit. Photovoltaic systems are included in the National Electrical Code in Article 690.

If you do the work yourself, you will need all the permits and licenses before you do anything. However, if you hire a contractor to do the work for you, your contractor will be familiar with this and ensure you have the proper permit before work commences.

As for your solar electrical system, in order to be connected to the utility grid, you must follow interconnection standards as set out in Institute of Electrical and Electronic Engineers (IEEE) 929-2000 (www.ieee.org) and your states Public Service Commission's Standard Interconnection Requirements  It is vital that you inform your utility as early as possible that you will be installing a grid-connected PV system and adhere to their rules exactly.

Your PV installer should be familiar with entering into an interconnection agreement with your utility. Also, since you will be working with the grid, you will need to establish a contract with the utility. This contract includes important system information and shows that you understand your responsibilities in running and maintaining your system. Normally, the contract will be finalized once the utility confirms that the equipment has

been installed properly and that all requirements have been met.

The most important part of the installation process is to have insurance in place. You must have a homeowner's policy to cover accidents or injuries that should occur during installation. This is especially true if you hire a contractor to do the work.

Another factor to consider when working with a solar electrical installation is that you will need to complete a net metering agreement with the utility for residential systems of 10kW or less. Interconnecting a photovoltaic system to the utility grid requires an interconnection agreement as well as a sale and purchase agreement, or a net metering agreement with your local utility. Your contractor and utility company will be able to go through this with you in more detail.

After all work is completed, your contractor will take your system through a series of tests to make sure everything is working correctly. They will hand you a copy of the evaluation. Keep it with your records. Also part of your system you need to keep is your owner's manual, copies of any plan drawings, and instructions for any future maintenance.

The last step in the process is the inspection. After your system is fully installed and tested, it should be inspected by the local building and electrical inspector. Your utility may inspect it as well. It is important to have these inspections because they may identify problems that may exist.

## Summary

There is no doubt solar energy is here and will be around for many years to come. As more people become knowledgeable about solar energy, more people will get involved in it. And as the demand for it increases, eventually the price for components will come down.

Solar energy not only helps the consumer save money, but it also helps the environment, considering no fossil fuels are being consumed. For this reason, any new home construction that takes place, it is advantageous to have the new homes constructed with solar energy in mind. This will help the homeowner with not only costs savings, but the government will provide the homeowner with tax credits and other incentives.

Take advantage of solar energy because in the end it will not only be a money saver, but it will also help protect the environment. And think about it, the sun is always shining, so you'll have solar energy around for years to come.

## Bonus

## Solar Resources